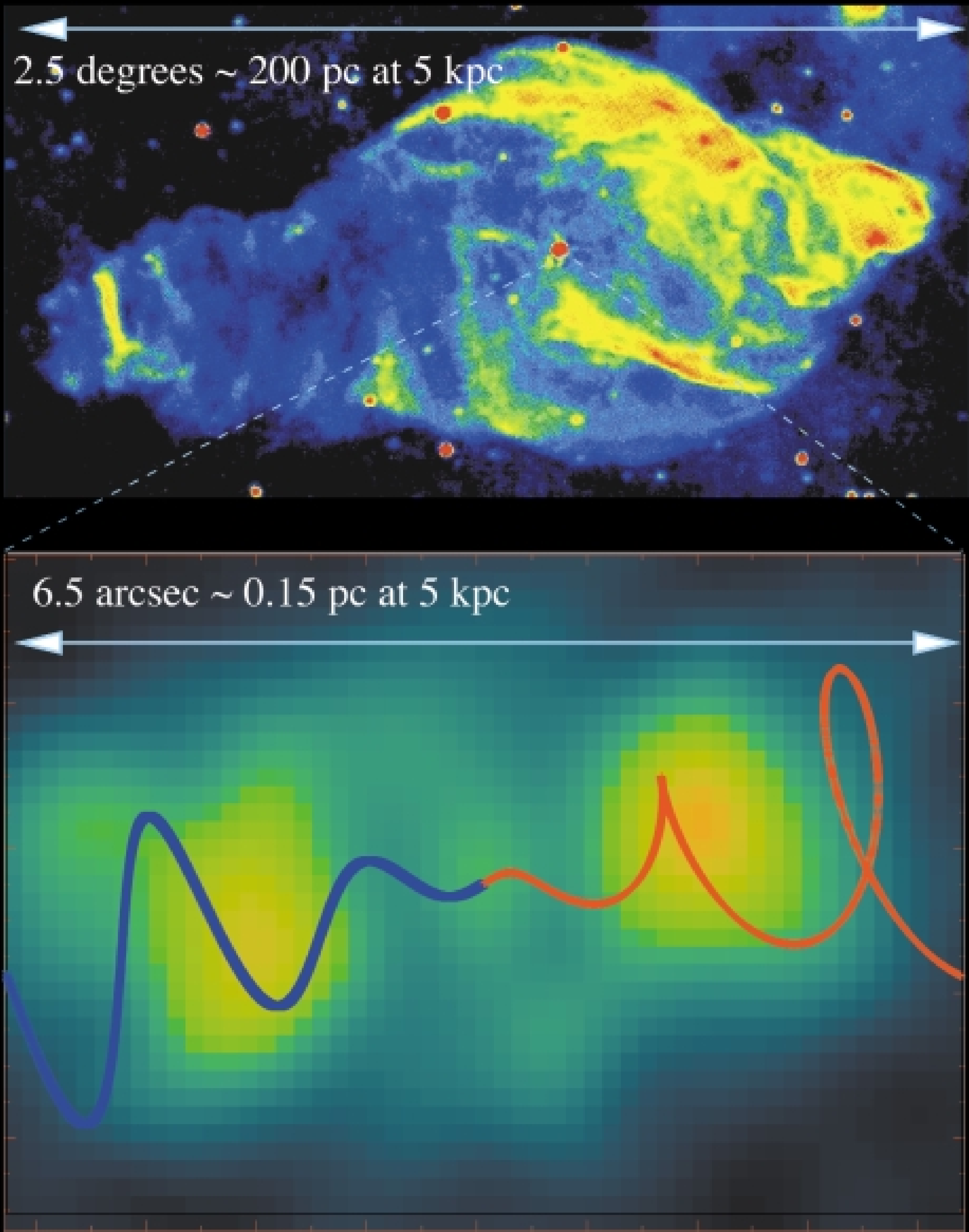
NOVA Report



2001 - 2002

Illustration on the front cover:

Discovery of arcsec-scale relativistic X-ray jets from two X-ray binaries in observations with Chandra. Migliari, Fender and Méndez reported in Science (2002) X-ray imaging spectroscopy of SS 433 which revealed X-ray lobes within three arcseconds of the core, and with very strong, Doppler-shifted lines of highly ionized iron in their spectra. This is the first evidence for the re-heating of atomic nuclei in a relativistic jet. The lower panel shows arcsec-scale X-ray jets from SS 433 deep within the large-scale W50 nebula (top panel, made available courtesy of Dubner et al, Astron. J. 116, 1842). The jets in SS 433 precess with a well-known period of 164-days. The blue and red curves in the lower panel indicate the expected projection onto the sky of the jets, precisely coincident with the extended X-ray emission.

Illustration on the back cover:

Photograph of the MID-infrared Interferometer (MIDI) hardware designed and built at ASTRON. This instrument is a two-element beam combiner for the ESO VLT Interferometer. The MIDI project (NL co-PI Waters) is a collaboration between Germany, the Netherlands and France, led by the Max Planck Institut für Astronomie in Heidelberg. The Netherlands contributed to MIDI through financial support from NOVA to allow ASTRON to design and build the cold optical bench, and through the NOVA-ESO VLTI Expertise Center (NEVEC) to design and construct the instrument control and analysis software. MIDI is the first NOVA instrumentation project for which hardware and software delivery is completed. In December 2002 first astronomical signals were received with MIDI on the VLT Interferometer at Paranal, Chile. The figure shows the cold bench optics. The layout is very compact in order to fit the cryogenically cooled hardware in a small cryostat (not shown in the picture). The (25 cm diameter) black slotted disc is the filter wheel. Most components (including the reflective optics) were fabricated out of Al 6061-T651 aluminium alloy and thermally treated for stress-release after all mechanical work. This procedure allowed for alignment of the optics unit in the laboratory at room temperature, using visible light. After cooldown to 40 K, the alignment was still within tolerance. For the MIDI operating wavelength at 10 μm, this procedure proved a perfectly acceptable approach.

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2001 - 2002

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NOVA is a federation of the astronomical institutes at the universities of
Amsterdam, Groningen, Leiden, Nijmegen and Utrecht, legally represented by the University of Groningen.

Table of contents

1. Introduction

In 1997 the Dutch government initiated a ten-year research program, the so-called ‘In Depth Strategy’ to identify and stimulate national focus points of excellent scientific research, which also train outstanding young scientists. To meet the selection criteria, such focus points were compared with the best foreign institutes in their field of research. The Netherlands Organization for Scientific Research (NWO) selected six such National Research Combinations from 34 proposals covering all academic disciplines. The Netherlands Research School for Astronomy, NOVA, was ranked highest among the six, and received an initial grant from the Minister of Education, Culture and Science of 21 M€ in order to carry out its proposed innovative research program entitled ‘The Life-Cycle of Stars and Galaxies’.

The NOVA program had a vigorous start in 1999, with a budget profile that ramped up to full strength by 2002. The current report describes activities in 2001 and 2002. This period saw many new appointments on the permanent and temporary research and technical staff. By late 2002 NOVA funds nearly 25% of the research and technical positions at the participating universities, as well as an active workshop and visitor program which now also supports joint colloquia. The ambitious instrumentation program is now in full swing, with the first NOVA supported instrument MIDI already delivered to the ESO Paranal Observatory in Chile, and all the other projects on track.

Highlights include:

– A total of 35 PhD degrees in astronomy awarded at the five NOVA institutions, with cum laudes for Hony and Vlemmings.
– A large variety of new astrophysical results which are summarized in §3 of this report.
– Detection of ‘first fringes’ with MIDI and the VLT Interferometer.
– Official signing ceremony for the OmegaCam contract between NOVA-ESO-MPE, and the extension of the NOVA-ESO ALMA contract, both in Groningen.
– Several appointments on NOVA overlap positions: Pols (UU), Quirrenbach (UL), and internal promotions to such positions for Waters (UvA) and Sackett (RuG).
– Many awards and honors for NOVA researchers, including election to the Royal Academy of Arts and Sciences (KNAW) for van Dishoeck and van der Klis, election to the National Academy of Sciences of the United States for van Dishoeck, award of the French-Netherlands Descartes-Huygens prize to de Zeeuw, and of the Descartes 2002 prize of the European Union for outstanding scientific progress through European collaboration to the European Gamma Ray Burst Consortium led by van den Heuvel.
– NWO awarded a ‘vernieuwingsimpuls grant’ to Ehrenfreund, a VIDI grant to Groot, and a VICI grant to Quirrenbach.
– NWO also awarded 5.7 M€ to a NOVA led-consortium (PI’s van Dishoeck and Waters) including ASTRON and TNO-TPD to build a key component for the Mid InfraRed Instrument (MIRI) on the James Webb Space Telescope.
– Selection of NOVA as an EU Marie Curie Training Site, of the NOVA-led AstroWise Consortium as an RTD Network, and of the Amsterdam-led Gamma Ray Burst Consortium as another RTD Network.
– The University of Nijmegen (KUN) appointed Kuijpers and Groot to lead a graduate program in astronomy. Membership of KUN in NOVA was approved in 2002 during the re-recognition procedure carried out every five years by the KNAW. The legal representation (penvoerderschap) of NOVA rotated from UvA to RuG in 2002.
– Completion of the NCA-NOVA-NWO strategic plan for astronomy entitled “Astronomy in the Netherlands, strategy for 2001-2010”.

The NOVA program has significantly increased the research output of Dutch astronomy, has led to an instrumentation program that is focused strongly on ESO (flankerend beleid), and also enhances the already well-established NOVA graduate education in astronomy.

2. Mission Statement and Research Program

NOVA is a federation of the astronomical institutes of the universities of Amsterdam, Groningen, Leiden and Utrecht, officially recognized by the Royal Dutch Academy of Sciences in 1992. In 2002 the University of Nijmegen (KUN) joined the federation after reopening their Department of Astrophysics with its own PhD program in 2001. When NOVA was founded as an inter-university collaboration, it was agreed that its legal representation ('penvoerderschap') should rotate between the participating universities. Accordingly, Leiden University (UL) was 'penvoerder' in the 1992-1996 period, and the University of Amsterdam (UvA) was 'penvoerder' for the following five years ending on 1st September 2002. From that date onwards NOVA is legally represented by the University of Groningen (RuG), for a term of five years.

2.1. NOVA's Mission

NOVA's mission is to carry out frontline astronomical research in the Netherlands, and to train young astronomers at the highest international level. All graduate astronomy education in the Netherlands is concentrated in NOVA.

2.2. The NOVA program: The life-cycle of Stars and Galaxies

Stars form in galaxies from interstellar material, and at the end of their lives return chemically-enriched material to the interstellar medium from which new generations of stars and planets form. The most massive and luminous stars evolve fastest, and leave neutron stars and black holes. This life cycle causes evolution in the stellar population of a galaxy as a whole. Recent technological advances make it possible to observe this evolution all the way back to epochs when the Universe was less than 4% of its present age. The goal of the NOVA Program is to unravel the history of star formation in the Universe, and so to understand the life cycle of stars and galaxies. This requires full knowledge of astronomy and astrophysics, and state-of-the-art observations.

The NOVA research program concentrates on the following three areas:

– Formation and evolution of galaxies: from high redshift to the present
– Birth and death of stars: the life-cycle of gas and dust
– Final stages of stellar evolution: physics of neutron stars and black holes

The research is carried out in three interuniversity networks, each led by 4-6 key researchers with international reputations.

The NOVA instrumentation program is carried out in collaboration with the NWO institutes ASTRON and SRON, and institutions abroad. The aim is to strengthen the technical expertise at the universities, and to develop and construct new instrumentation for the ESO Very Large Telescope, the ESO-VLT Interferometer (VLTI), the VLT Survey Telescope (VST), the Atacama Large Millimeter Array (ALMA), the Westerbork Synthesis Radio Telescope (WSRT), and for the Sackler Laboratory for Astrophysics (SLA).

The entire program enables NOVA researchers to obtain a rich harvest of results from the unique ground-based and space-based facilities which are becoming available during this decade, and will allow NOVA to maintain and strengthen its status as an international top center for research and education in astronomy.

In October 2001 the Nederlands Comité Astronomie (NCA), NOVA and the Council for Physical Sciences of the national funding agency NWO published a strategic plan for Dutch astronomy entitled 'Astronomy in the Netherlands: strategy for 2001-2010'. The report concluded that it is essential that the research and instrumentation development programs at the universities carried out by NOVA on the one hand, and the major instrumental development and technical R&D initiatives at the NWO institutes ASTRON and SRON on the other hand, are fully complementary, well-coordinated, and have sufficient critical mass. The report demonstrated that astronomers in the Netherlands have chosen to make a few major investments in well-selected new initiatives rather than taking part in many projects in a ratio of gross national product of the partners.

3. Progress reports from the research networks

This chapter summarizes the research highlights of the three research networks. More information can be found in the annual reports of the university astronomical institutes.

3.1. Formation and evolution of galaxies: from high redshift to the present

The study of galaxy formation and evolution continues unabated. Within the NOVA institutes these issues are addressed via a range of techniques, and by studying objects as close as our own Galaxy, and as distant as look back times of 95% of the age of the universe. This overview is by no means exhaustive, but rather illustrates the variety of studies of galaxy formation and evolution carried out in the NOVA institutes.

3.1.1. Proper motions in the Galactic Bulge

Combining archival HST images with new data, Kuijken measured proper motion distributions in several low-extinction windows towards the galactic bulge. The measurements (some 30,000 stars with proper motions accurate to 20 km s^{-1} at 8 kpc distance) provide detailed kinematic maps along the 3 sightlines on the minor axis investigated so far, and show the velocity gradient consistent with bulge rotation, population/kinematic correlations, and allow a clean sample of bulge stars to be defined, free of contamination by foreground disk stars. The resulting color-magnitude diagram is completely consistent with a single, old population without blue stragglers. This work is being extended to fields off the minor axis, with the aim to understand the gravitational potential, mass, pattern rotation, stellar population and orbital makeup of the Galactic bar.

3.1.1.2. A ghostly ring around the Galaxy

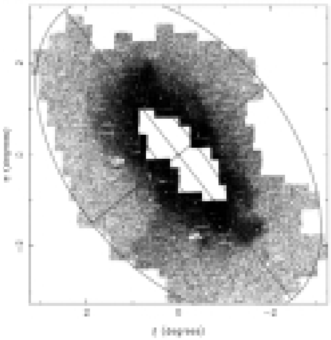
Using the wide-field camera at the INT on La Palma, Ferguson (NOVA postdoc) and collaborators have uncovered what may be a giant ring of stars surrounding the Milky Way disk. A concentration of distant stars had previously been seen in Sloan Survey images, but the new data suggest that this is part of a rather thick, ring-like structure that encircles the whole Galactic disk. It is currently unclear what might have caused this structure: possibilities include the remnants of an ancient warp, or a shredded satellite galaxy. The structure may contain as much as a billion solar masses of stars. This result adds to the growing evidence that the outskirts of galaxies contain fine dynamical structure.

3.1.2. Nearby galaxies

3.1.2.1. Andromeda (M31)

Ferguson has been working on several projects concerning the formation and evolution of our nearest large companion galaxy, M31. Along with Johnson (ESO, Chile) and Tanvir (Hertfordshire), she has analyzed all deep HST/WFPC2 pointings towards M31 that are publicly available in the HST archive. These data are being used to construct color-magnitude diagrams (CMDs) of unprecedented depth (for an external spiral) at various locations in the outer disk and halo, facilitating study of the red giant branch, red clump, horizontal branch and luminous main sequence stars. Quantitative and comparative analysis of the CMDs provides constraints on the star formation and assembly history of the galaxy, as well as the stellar metallicity gradient at large radii. An intriguing first result is the finding of a significant mean age (≥8 Gyr) and a moderately high metallicity for stars in M31's far outer disk - an observation which suggests the highest angular momentum regions of disks were in place fairly early on, contrary to some theories which suggest disk galaxy formation is suppressed until relatively recent epochs ($z \leq 1$).

Along with Irwin (Cambridge), Ibata (Strasbourg), Lewis (Sydney) and Tanvir, Ferguson carried out a wide-field panoramic imaging survey of M31 using the Wide Field Camera on the INT. They have now surveyed a region of ~26 square degrees centered on M31, extending out to a ~55 kpc along the major axis (see Fig. 1). Due to its contiguous nature, this is the first survey capable of making uninterrupted study of the properties of the luminous giant population across M31, allowing local density enhancements to be distinguished from both large-scale structure and foreground contamination. A first result is the discovery of a giant stellar stream located near to, but offset from, the southern minor axis of M31. The stream is of very low surface brightness (V ~ 30 mag/arcsec^2) and extends out to at least a radial distance of 40 kpc; it is most likely due to the tidal interaction between M31 and its peculiar dwarf companion M32. A substantial HST allocation (~47 orbits with ACS and WFPC2) was awarded in Cycle 11 to conduct a more extensive study of the stellar populations at large radii in M31 (including those associated with the tidal stream). Future spectroscopic follow-up observations with WHT and Gemini are being planned.



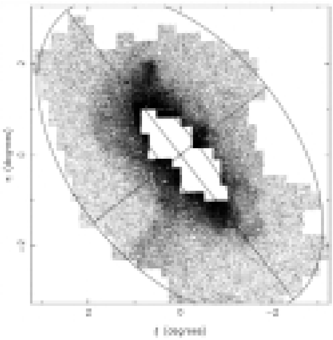


Fig. 1: Substructure in the halo of M31, as traced by the giant star distribution. Top: the surface density of blue RGB stars across the 25 deg² survey area. The outer ellipse indicates the current spatial extent of the survey, whereas the inner ellipse represents an inclined disk with i = 77.5; the optical disk of M31 lies well within this boundary. The dwarf companions M32 and NGC 205 lie at (0°, -04) and (-05, 04), respectively. Much substructure is seen at large radii, including the giant stellar stream and stellar over-densities at both extremes of the major axis. No corrections have been made for foreground or background contamination. Bottom: same as (left), except showing the surface density of red RGB stars. Note the lower Galactic foreground contamination on this map. Comparison with the projection in the top figure clearly indicates that the morphology of the substructure varies as a function of color.

3.1.2.2. **Luminosity function of HI selected galaxies**

Zwaan (Melbourne), Sprayberry (Keck Observatory) and Briggs analyzed the B-band optical luminosity function and surface brightness distribution of HI selected galaxies from a blind HI survey. The total luminosity function of the HI selected sample is flat, with Schechter parameters M* = $-19.38^{+1.02}_{-0.62}$ + 5 log *h* mag and $\alpha = -1.03^{+0.25}_{-0.15}$, in good agreement with results of optically selected late-type galaxies. Bivariate distribution functions of several galaxy parameters show that the HI density in the local Universe is more widely spread over galaxies of different size, central surface brightness, and luminosity than is the optical luminosity density. The number density of very low surface brightness (> 24.0 mag/arcsec^2) gas-rich galaxies is considerably lower than that found in optical surveys designed to detect dim galaxies. This suggests that only a part of the population of LSB galaxies is gas rich and that the rest must be gas poor. However, an important conclusion is that this gas-poor population must be cosmologically insignificant in baryon content. The contribution of gas-rich LSB galaxies (> 23.0 mag/arcsec^2) to the local cosmological gas and luminosity density is modest (18^{+6}_{-5} and 5^{+2}_{-2} percent respectively); their contribution to Ω_{matter} is not well-determined, but probably <11%. These values are in excellent agreement with the low redshift results from the Hubble Deep Field.

3.1.2.3. **Dynamical modeling and central black hole masses**

Cappellari (NOVA postdoc), Verolme, Verdoes Kleijn, Franx and de Zeeuw completed the construction of dynamical models for the stellar and gas kinematics of the elliptical galaxy NGC1459, as obtained from an HST/STIS spectrum and groundbased long-slit spectra. They estimated the mass in the counter-rotating stellar disk, and found that the mass of the super massive black hole (BH) at the center of this galaxy, as derived from gaseous measurements, is an order of magnitude lower than the BH mass obtained by modeling the groundbased and HST stellar kinematics. This is one of the first cases in which a BH mass was determined independently with observations of both stellar and gas kinematics. The BH mass discrepancy indicates the urgent need for further work before the correlation and the scatter between the BH mass and other galaxy global parameters can be interpreted reliably.

Verdoes Kleijn, de Zeeuw, Noel-Storr, Carollo, van Gorkom (all three Columbia University New York), Baum and van der Marel (STScI Baltimore) continued their analysis of an HST/STIS spectroscopic follow-up survey of the nuclear emission-gas for a complete sample of UGC FR I radio galaxies. These observations were primarily aimed at determining central black hole masses and constraining the ionization mechanism of the gas. Verdoes Kleijn and collaborators determined an upper-limit to the central black hole (BH) mass for one case, NGC 4335. The inferred mass upper-limit falls below the BH mass central velocity dispersion relation. This suggests that either the relation is not as tight as previously thought or the commonly used gas dynamical models are not adequate for a reliable BH mass determination.

3.1.2.4. The Planetary Nebulae Spectrograph: kinematics in the halos of early-type galaxies

July 2001 saw the commissioning of the PN.S, an instrument designed specifically for the kinematic study of the outskirts of galaxies using planetary nebulae (PNe) as tracers, on the WHT at La Palma. Kuijken, Douglas and Romanowsky are members of the Australian/Italian/Dutch/British consortium (Freeman, PI) that funded, designed and built the instrument. Over a 10′ field of view this instrument maps nearby galaxies through a narrow-band O[III] filter in order to survey for PNe. Rather than taking narrow-band images, which would reveal the location but not the redshift of the PNe, the PN.S splits the beam and disperses the light into two opposite directions, yielding two narrow-band slitless spectrograms of the field. A PN shows up as a compact source in these spectrograms, and its location in the pair of opposite-dispersion images can be solved for the (undispersed) sky position, and the radial velocity of the PN. Thus a single observation combines the detection and radial velocity measurement of a large sample of PNe. The sensitivity of the PN.S at the WHT is such that several hundred nebulae can be measured in galaxies as far as the Virgo cluster in a single night, enough to define the velocity dispersion of the stellar population in these galaxies out to 5 effective radii.

Four observing runs with the instrument took place in 2001 and 2002, providing the first maps of the stellar dynamics of a sample of round elliptical galaxies. Once the sample is complete, fundamental quantities such as the total angular momentum content, the degree of substructure, and the dark matter halo profiles of elliptical galaxies can be studied in detail. Also a survey of the disk of M31 was completed in late 2002, which will give a complete dynamical picture of the old stellar disk of our nearest neighbor.

3.1.2.5. SAURON: integral-field kinematics in the central regions of galaxies

The SAURON instrument is a panoramic integral-field spectrograph for the WHT on La Palma. It was built by a collaboration of groups from Leiden (de Zeeuw), Lyon (Bacon) and Oxford (Davies), and is designed specifically for the kinematic mapping of the stars and gas in the inner regions of bright nearby galaxies (out to ~1 effective radius). It is used for a multi-year program to measure the kinematics and line strength distributions for a representative sample of 72 nearby early-type galaxies (ellipticals, lenticulars, and Sa bulges, in clusters and in the field). Data are now in hand for a complete sample of 70 objects. The SAURON observations of the representative sample are being complemented with high spatial resolution observations of the nuclei.

Early-type galaxies turn out to have a very rich internal structure, which is beautifully revealed in the kinematic and line strength maps. These show significant deviations from axisymmetric kinematics, including minor axis rotation and decoupled cores, as well as extended s-shaped emission-line gas distributions, and a variety of stellar population properties. Detailed modeling of the data sets is a large and complex task. A first application was to M32: combining the SAURON data with HST observations allowed measurement of the central black hole mass, and also of the inclination and hence the intrinsic shape of this galaxy. Models constructed for other galaxies in the sample (NGC2974, NGC 4365, NGC4473, NGC821) have been used to distinguish different kinematic populations, to refine black hole mass estimates, determine M/L ratios, and measure triaxiality.

3.1.2.6. Coma cluster survey in optical and 21cm line

Beijersbergen, van der Hulst, Hoekstra (Cita, Toronto) and van Dokkum (Caltech) finished their analysis of the Coma cluster. An INT WFC multicolor mosaic covering a 5.2º area was used to determine statistical luminosity functions as a function of projected position in the cluster and revealed a population of small, star bursting galaxies at the periphery of the cluster. Analysis of a sample of 583 spectroscopically confirmed cluster members, using morphological classifications by van Dokkum revealed that the velocity distribution of spiral galaxies is not-relaxed indicating that this component of the cluster is not in virial equilibrium. Other indications to this effect are the increase in the scatter of the color-magnitude relations of elliptical and S0 galaxies towards larger cluster radii. A large, blind HI study performed with the WSRT revealed 24 galaxies of which 14 are new HI detections and for 11 cluster membership is established for the first time. The velocity distribution of the galaxies detected in HI indicates that also this population is not virially relaxed.

3.1.2.7. Anomalous HI kinematics in spirals

Boomsma, Oosterloo, Sancisi and van der Hulst have continued their study of the vertical structure and kinematics of HI gas in spiral galaxies. An increasing number of galaxies have been identified with a substantial amount of HI gas exhibiting anomalous kinematics compared to the normal galactic rotation. Special attention is given to the analysis of sensitive HI observations of the nearby almost face-on spiral galaxy NGC 6946.These are a dramatic improvement compared to the previous HI study of Kamphuis (PhD thesis, 1993) who found the first evidence for HI with anomalous velocities, presumably driven out of the disk by the massive star formation activity. The new data show a wealth of HI structures, varying from HI holes, both in the inner and in the outer disk of NGC 6946 to various high velocity gas features, some very localized, some extended, resembling large gas streamers. The goal is to make a proper inventory of all phenomena observed in HI and relate these to the star formation activity in the disk.

3.1.2.8. Mass distribution in early-type disk galaxies

Noordermeer, van der Hulst, van Albada, Sancisi, and Swaters (JHU) continued their study of the mass distribution in early type (S0 - Sab) disk galaxies. Most of the 25 galaxies studied thus far have an HI rotation curve that rises steeply in the central regions, and then declines significantly in the outer parts. The stellar disk needs to be quite massive in order to explain the decline of the rotation velocities in the outer parts. This is in contrast with late type disks, whose rotation curves can be fitted with dark matter haloes only. Additional long-slit Hα spectra have been obtained to resolve the steep rise of the rotation curve in the central regions, where beam smearing complicates an unambiguous analysis of the HI data. These will be important for constraining the dark matter contribution in the inner parts of these early type galaxy disks.

3.1.2.9. Star formation in interacting galaxies

The star formation rate in interacting galaxies is considerably higher than in non-interacting galaxies. Lamers, Bastian (NOVA PhD) and collaborators have studied the star formation in the interacting galaxy M51, which had a close encounter with its companion NGC 5194 about 3×10^8 years ago. With a new and accurate method for the determination of ages, masses and extinction of star clusters, based on WFPC2-photometry obtained with HST, they found a huge starburst of 4×10^7 stars with an age of ~300 Myr in the nucleus of M51. This starburst is obviously triggered by the interaction with the companion galaxy during close encounter. The nucleus is surrounded by a bulge that is dominated by very old stars age >5 Gyr. The inner spiral arms, at a distance of 1 to 3 kpc from the nucleus, do not show evidence for enhanced star formation during the close encounter. However, several dozens of bright blue point sources were found within the bulge. A study of their spectral energy distribution shows that these are young and very massive stars with ages up to about 20 Myr. Contrary to young massive stars in our Galaxy, these stars seem to be formed outside stellar clusters. It is suggested that the stars are formed from hot clouds that had inefficient cooling because the CO molecules were destroyed by the intense radiation from the nearby starburst in the nucleus. If this explanation is correct the ongoing process of star formation near the nucleus of M51 may resemble the star formation in the early Universe.

3.1.3. High-redshift galaxies and evolution

3.1.3.1. High-redshift lensed "baby galaxy" behind A2218

In collaboration with Ellis and Santos (Caltech) and Kneib (Toulouse), Kuijken surveyed some of the best-known strong lensing clusters for highly magnified, distant star-forming galaxies with the Keck telescope. A very interesting object was discovered: a doubly imaged z = 5.56 source whose spectrum displayed only a single, narrow emission line at 800 nm. The combination of the spectrum and the lensing model make the identification of the line as Lyman-α at redshift 5.56 unambiguous. The source is magnified 33 times by the cluster lensing effect, and is only barely visible on deep HST images. Without the lensing it is questionable whether it could even be detected with JWST. The lack of any continuum in the spectrum indicates that this is a very young object: spectral modeling suggests a source forming stars at a rate of about 1 $M_\odot$ yr^{-1}, and only 1 million years old. The implied low stellar mass, of the order of 10^6 $M_\odot$ is consistent with expectations for the first galaxies to form in favored hierarchical formation scenarios.

This object represents a unique combination of high redshift and intrinsic faintness. It opens up the possibility to study small galaxies at the time when they first formed in great numbers. The work continues: more lensing clusters are being surveyed in the same way, in order to establish the frequency of this kind of source and to study their properties.

3.1.3.2. Imaging Ly-α emission line gas at z>3

Reuland, Röttgering, Miley and van Breugel (LLNL, UC) obtained extremely deep narrow-band images centered at the Ly-α emission line of three z>3 radio galaxies. The Ly-α emitting gas extends over a region of more than 100 kpc. While most of the bright, central emission is due to ionization by starburst and radio jets, the cone-shaped, filamentary features resemble those of nearby active galactic nuclei (AGN; Seyferts, radio galaxies) and ultraluminous infrared galaxies indicating that they may exhibit huge starburst superwinds. The spherically symmetric, low surface-brightness emission

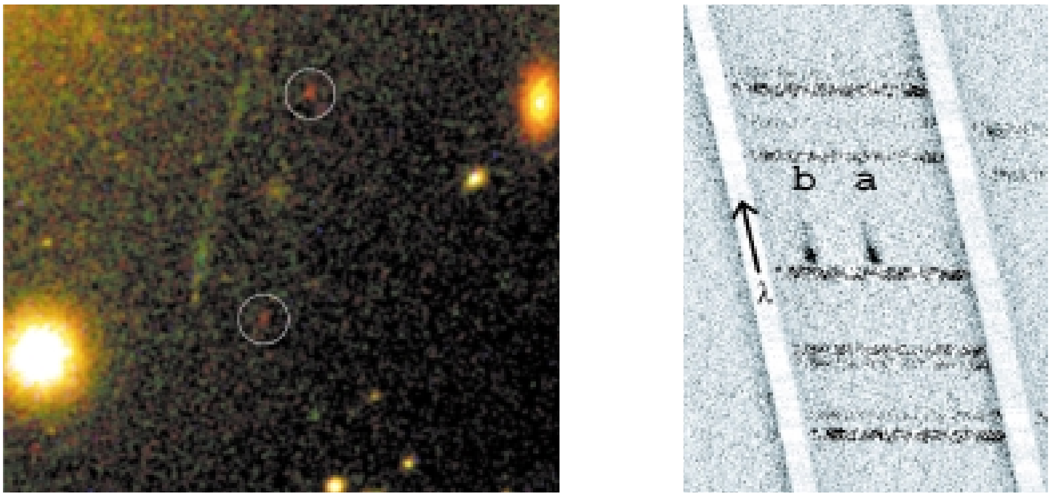


Fig. 2: Discovery of a high-redshift (z=5.58) low-mass star forming galaxy behind the strong lensing cluster Abell 2218, identified in a blind spectroscopic survey of strongly lensed areas on the sky. Left: the pair of images of the lensed source, as seen in a HST image of the cluster. Right: confirmation with Keck/ESI, showing identical spectra consisting of a single asymmetric emission line. Combined with the constraints from the lensing, the line identification as Ly-α is unambiguous.

extends to very large (>100 kpc) radii. This may be primordial gas that is still falling towards the central object.

3.1.3.3. Lyman Break Galaxies in a z=4.1 protocluster

Miley, Venemans (NOVA PhD) and collaborators have studied a clustering of objects near the z=4.1 radio galaxy TN J1338-1942, which represents the most distant structure of objects known. It consists of 21 VLT-spectroscopically confirmed Ly-α emitters, first identified as part of a narrow-band imaging program on the VLT of fields surrounding radio galaxies to identify such emitters. All distant radio galaxies that were observed in this program have yielded such substantial galaxy over densities.

TN J1338-1942 has long been a target of the ACS GTO team, and was observed within a few months of ACS first light on-board HST. All 12 confirmed Ly-α emitters in the ACS field showed up as g-dropouts, and all were spatially resolved. The ACS observations further show that the population of all the g-dropouts in the field is anomalously high in this region (by a factor of 4-6) and that it is clustered around the radio galaxy. This implies the presence of a further 50 Lyman-break proto-cluster member candidates, and is additional evidence that TN J1338-1942 is member of a proto-cluster at z=4.1.

3.1.3.4. Evolution of early-type galaxies

Van Dokkum and Franx analyzed the evolution of early-type galaxies in clusters and in the field. It is usually assumed that the evolution of these galaxies is very simple, but on the other hand evidence has accumulated which shows that these galaxies were transformed from later types quite recently. Such morphological transformations have a strong effect on the interpretation of the data on distant galaxies, as the set of early-type galaxies at high redshift is a special subset of all progenitors of early-type galaxies at low redshift: they are preferentially the older ones. As a result the apparent evolution of early-type galaxies is artificially slow. Van Dokkum and Franx showed that the small scatter in the Fundamental Plane, and color magnitude relation at low redshift puts a strong constraint on the bias that is caused by this morphological evolution, and as a result the corrections on the previous estimates of the formation redshifts are not very large. The best-fit mean formation redshift of early-type galaxies in clusters is 2 ± 0.3 for models with $\Omega_M = 0.3$ and $\Omega_\Lambda = 0.7$. Van de Ven (NOVA PhD) extended the analysis of the Fundamental Plane (FP) of lensing galaxies with redshifts up to z~1. In this project, together with van Dokkum and Franx, the FP, a tight relation between structural parameters and the velocity dispersion, is being used as a probe of the evolution of these field early-type galaxies. The mass-to-light ratio M/L evolution that follows from the FP provides a very strong constraint on the epoch of star formation of the galaxies, and hence on their formation history. The preliminary results show that the field galaxies have a larger spread in the stellar population ages than the cluster galaxies. Some of them follow the young-age prediction from the hierarchical models, but about half of the lens galaxies have the same old stellar population as cluster galaxies.

3.1.3.5. Ultra-deep ISAAC near-IR observations of Hubble Deep Field South

Rudnick, Franx and Labbé, analyzed infrared VLT imaging of the Hubble Deep Field South, deriving photometric redshifts as well as the luminosities in the redshifted optical U, B and V bands. They found an excess of bright galaxies with $L_B > 5x10^{10}h^{-2}L_{\odot,B}$: local B-band luminosity functions predict 0.1 galaxies in the redshift range 2<z<3.5, but they found 9! Luminosity evolution in the B-band by a factor of 2.4-3.2 can explain the discrepancy. Confirmation of the photometric redshifts is, however, desirable to verify these results.

Labbé and Franx fully reduced and analyzed the ultra-deep near-infrared imaging of the Hubble Deep Field South: the first of two fields in the Faint InfraRed Extragalactic Survey (FIRES) imaged with ISAAC on the VLT. The data were collected in about 100 hours under the best seeing conditions; they constitute the deepest ground-based infrared observations to date, and form the deepest Ks-band in any field (see Fig. 3). The depth of the current survey allowed determination of the spectral energy distributions of high-redshift galaxies with unprecedented accuracy, essential to a proper understanding of their stellar populations. Labbé and Franx constructed a Ks-limited multicolor catalog, selecting high-z galaxies from their rest-frame optical light. They found a wide variety of morphologies: some galaxies are large in the rest-frame optical, where the rest-frame optical light is more concentrated compared to the rest-frame UV light, as in nearby normal spirals. They also found a new population of optically faint galaxies at photometric redshifts 2<z<4 with very red near-infrared colors (Js–Ks>2.3), that would be missed completely by the standard U-dropout criteria. These galaxies are generally compact and many show pronounced breaks in the observed near-infrared, identified as the Balmer/400 nm break. They may contribute substantially to the total stellar mass density at redshifts z~3. Overall, the results demonstrated the necessity of extending optical observations to near-infrared wavelengths for a more complete census of the early universe.

3.2. Birth and death of stars: the life-cycle of gas and dust

The aim of the research of Network 2 is to study the origin and evolution of stars and planetary systems. The main tracers are the gases and dust particles

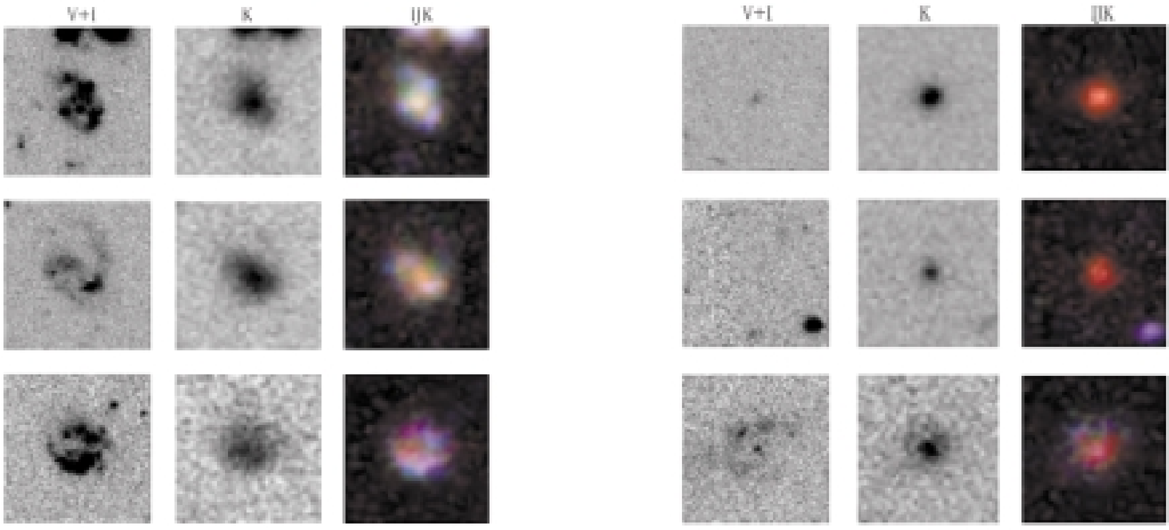


Fig. 3: Results from the FIRES project, an ultra-deep imaging in J,H,K with the VLT of the Hubble Deep Field South. In each panel, images of some of the galaxies are shown as they appear in different colors: visual V+I (HST - 0.55 + 0.81 μm; left), near-infrared Ks (VLT - 2.16 μm; middle), and optical-to-infrared I,J,K-color composites (HST+VLT; right).The left panel shows three very red galaxies, all at large distances.The upper two have compact shapes, whereas the galaxy at the bottom is comparable in size to the Milky Way. Red galaxies like these that were found in the present survey are a major constituent of the Universe at high redshift.The three galaxies in the right panel are equally distant but are bluer and their images are also extended.There are indications of star formation in some knots in the rudimentary spiral arms.The large galaxies represent a class never before seen at this large distance and they look surprisingly similar to giant spiral galaxies like our Milky Way.

that are expelled into the interstellar medium through the winds from late-type stars and are incorporated into star-forming regions and eventually new solar systems, thereby undergoing physical and chemical modifications. The projects involve a combination of observations, mostly at infrared and submillimeter wavelengths, theoretical modeling and laboratory astrophysics (see section 5.7). In 2001-2002, much of the research was still driven by the rich harvest of results from the Infrared Space Observatory (ISO) but with a shift toward exploitation of new facilities, in particular the ESO-VLT. All NOVA-funded positions have been filled, and the PhD students are entering their most productive phase. Two of the senior postdocs/staff appointed in the network, Ehrenfreund and Spaans, have obtained permanent staff positions at Dutch universities, and Ehrenfreund received an NWO 'Impulse for Renewal grant' to start her own astrobiology group.

In the following, a brief summary of scientific highlights is given, focussing on those projects which involve a direct collaboration between Groningen, Amsterdam and Leiden. Regular network meetings have been held every six months.

3.2.1. Chemical modeling of interstellar clouds

3.2.1.1. Formation of H_2: from high redshifts to the present

Molecular hydrogen is the most abundant molecule in the universe and plays a fundamental role in the interstellar medium. Theoretical arguments indicate that most H_2 must be formed on the surfaces of interstellar solid material by recombination of atomic hydrogen. Cazaux (NOVA PhD) and Tielens developed a new model to understand H_2 formation which includes the following processes: a hydrogen atom stuck on a grain surface can be either strongly bound (through chemisorption) or weakly bound (through physisorption), and can travel from site to site by diffusion and tunneling. This model has been tested against existing laboratory experiments, and subsequently extended to astrophysical conditions, where it can explain H_2 formation up to grain temperatures of the order of 100 K.

Cazaux and Spaans applied the results of this model to the high redshift universe. They found that a range of physical parameters influences the H_2 formation rate, in particular the dust and gas temperature, but less the dust surface composition. The relative importance of H_2 formation on dust grains compared with gas phase formation through the H^- route was studied. This ratio depends on the dust abundance, the electron abundance, and also on the relative strength of the far-UV (extra-)galactic radiation field. For a cosmological evolution of the star formation rate and a dust density consistent with the 'Madau plot', a positive feedback effect on the H_2 abundance due to dust grains can occur as early as a redshift of z~3-5.

3.2.1.2. Grain surface chemistry in dense clouds

The ISO-SWS spectra of massive protostars studied in Leiden and Groningen show a composition with distinct water-rich and inert components containing a variety of carbon-bearing species, many of which must be formed on the surfaces of dust grains. Keane (NOVA postdoc) and Tielens developed an accretion-limited model for this chemistry. The model is centered on key hydrogenation and oxidation reactions: H + CO, H + H_2CO and O + CO. The results show that the distribution of the accreting oxygen among O and O_2 controls the CO/CO_2 ratio, but whether the O + CO or OH + CO route dominates CO_2 formation is not clear. The models best approximate the observed ice mantle composition for densities of 10^4-10^5 cm^{-3}, where the accretion time scale becomes comparable to the free-fall time scale. The deuteration of various molecules has also been studied within this model.

3.2.2. Deeply embedded low-mass protostars

3.2.2.1. Chemical survey of low-mass protostars

Jørgensen (NOVA PhD), Schöier, van Dishoeck and Tielens, together with Ceccarelli (Bordeaux) and Maret (CESR, Paris), initiated a large JCMT and IRAM 30-m survey for submillimeter emission lines from a sample of low-mass protostars. The physical structure of the envelopes around these deeply embedded objects was established using radiative transfer modeling of SCUBA dust continuum observations. No significant difference in the power-law structure was found for the youngest class 0 sources (ages few 10^4 yr) compared with the more revealed class I cases (ages few 10^5 yr). The resulting temperature and density distributions formed the starting point for modeling the chemical properties of the envelopes. CO was found to be heavily depleted in the class 0 objects, suggesting that this species evaporates above 20 K, the sublimation temperature of pure CO ice. Subsequent studies focused on HCO^+, HCN, HNC and CN, as well as their isotopes and deuterated species. Clear signatures of evaporation and subsequent gas-phase chemistry are found with increasing temperature (i.e., evolution), with the CO and HCO^+ abundances closely related. The degree of deuterium fractionation for HCO^+ shows an anti-correlation with that of HCN, which provides constraints on the temperature dependence of gas-phase fractionation processes.

3.2.2.2. **Do low-mass protostars have hot cores?**

Schöier, Jørgensen and van Dishoeck completed their reanalysis of the submillimeter data of the IRAS 16293-2422 class 0 low-mass protobinary object. Using the temperature and density profile derived from SCUBA submillimeter continuum data, quantitative estimates of various molecular abundances and possible changes with radius were made. Molecules such as H_2CO, CH_3OH, SO, SO_2 and OCS show a drastic increase in their abundances in the warm (>100 K) and dense (10^6-10^7 cm^{-3}) inner region. The location at which this increase occurs is consistent with the radius at which ices are expected to thermally evaporate off the grains, indicative of the 'hot cores' also seen around massive protostars. However, the ices may also be liberated due to grain-grain collisions in turbulent shear zones where the outflow interacts with the envelope.

To investigate this issue, high angular resolution H_2CO and continuum interferometry observations at 1 mm have been carried out at OVRO (see Fig. 4). Modeling of the continuum suggests that the binary has cleared most of the material in the inner envelope, out to the binary separation. The H_2CO emission is dominated by compact dense and hot (T>150 K) gas close to the positions of the protostars. The velocity structure indicates large scale rotation roughly perpendicular to the CO outflow. In contrast, a similar study of the low-mass protostar L1448-mm shows high-resolution H_2CO emission with a velocity pattern consistent with the outflow direction.

Another approach was taken by Cazaux (NOVA PhD) and Tielens, in collaboration with Castets and Ceccarelli (Grenoble). Evaporated molecules such as CH_3OH can initiate a rich chemistry in the warm gas leading to complex organic species, but until now such complex molecules have only been detected in hot cores around high-mass protostars. Deep searches with the IRAM 30 m telescope reveal some organic acids and nitriles toward IRAS 16293-2422. This indicates that hot core chemistry can also occur around low-mass protostars, in spite of the much shorter time scales.

3.2.2.3. **VLT-ISAAC 3-5 μm survey of low- and intermediate mass YSO's**

Pontoppidan (NOVA PhD), van Dishoeck, Thi, Tielens and Schutte, in collaboration with Dartois and d'Hendecourt (IAS, Paris) finished their large ESO VLT-ISAAC program to observe ices and gas around a large sample of low-mass young stellar

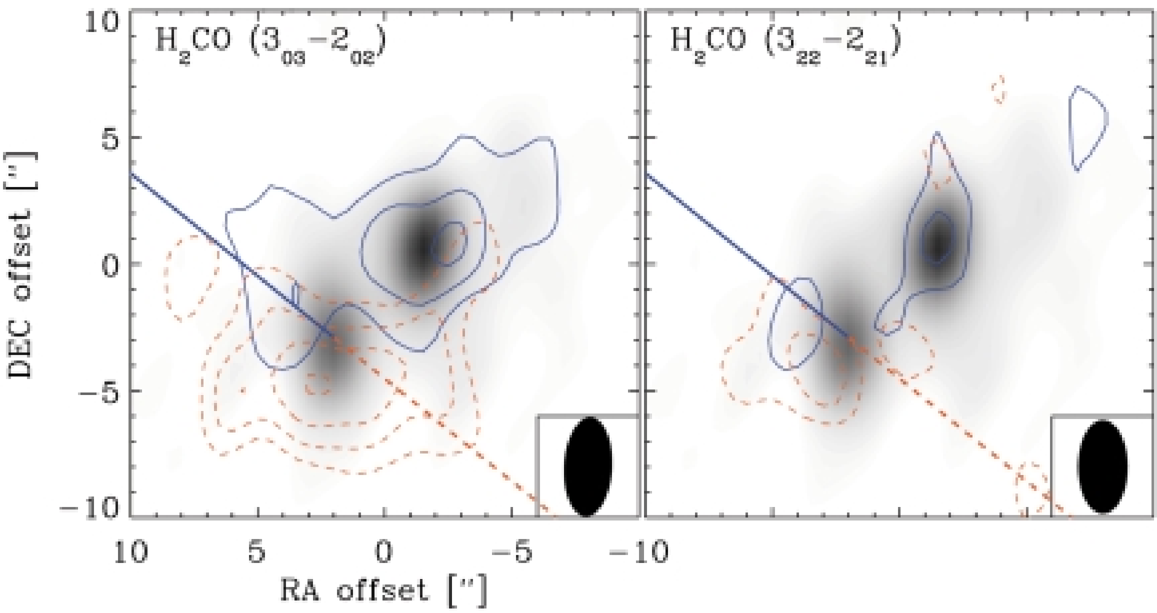


Fig. 4: OVRO interferometer maps of H_2CO emission (contours) overlaid on the 1.37 mm continuum emission (greyscale) from the protobinary low-mass object IRAS 16293-2422. The H_2CO emission has been separated into a blue (4-7 km s^{-1}; solid lines) and a red (1-4 km s^{-1}; dashed lines) part. The velocity pattern is seen to be consistent with a rotating disk or envelope, perpendicular to the direction of the large scale CO outflow (Schöier, Jørgensen et al.).

objects (YSO's) in nearby star-forming regions at unprecedented S/N and spectral resolution. In total, spectra of about 50 sources were obtained covering the 3-5 μm atmospheric windows with resolving powers up to $\lambda/\delta\lambda \sim 10^4$. The goal of the project is to search for broad absorption features from ices (CO, H_2O, OCN^-, CH_3OH, ...) and for CO gas through its ro-vibrational transitions around 4.7μm. Most of the targets are low- and intermediate mass protostars, to complement previous ISO-SWS studies on high-mass YSOs.

Together with Fraser (NOVA postdoc), Pontoppidan focused on the analysis of the 4.67 μm CO ice bands toward 36 sources. Using a phenomenological decomposition of the band as well as a simple physical model, it is shown that the CO ice has the same fundamental structure along all lines of sight: surprisingly, all CO ice bands can be fitted excellently using only 3 linear parameters. This result has important consequences for the understanding of the formation and structure of interstellar ice mantles. It is concluded that the observations show evidence for irregularly-shaped grains and that most interstellar CO ice exists in a nearly pure form, i.e., mixed with less than 10% other molecular species.

As part of the above VLT survey, Pontoppidan and Dartois have detected the presence of abundant solid methanol toward three low-mass young stars in the Serpens and Chamaeleon star-forming clouds. These are the first detections of solid methanol reported toward low-mass young stars. The inferred abundances of 15-25% compared to water ice are as high as those found toward some high-mass YSO's. This result is of great importance to the ongoing discussion on the formation mechanism of methanol and its role in hot-core chemistry, which previously assumed that solid methanol is only found in high abundances near massive young stars.

Most sources have strong absorption of ices in the 3-5 μm spectra, with gas-phase CO present in many cases. Surprisingly, however, the embedded source GSS30 IRS1 in the Ophiuchus core shows a large number of bright ro-vibrational emission lines from ^{12}CO and ^{13}CO. Pontoppidan, together with Schöier, analyzed these lines and found that the emission must originate in a reservoir with 10-100 Earth masses of thermalized gas at a well-determined single temperature of ~5-15 K. Although not conclusive, evidence suggests that the gas is associated with an accretion shock in the disk rather than an outflow.

3.2.3. High-mass protostellar envelopes

3.2.3.1. Interplay between gas and ices

Keane, Boonman, Tielens and van Dishoeck have detected for the first time the ν_2 ro-vibrational band of gaseous SO_2 around 7.3 μm in absorption toward a sample of deeply embedded massive protostars using the ISO-SWS. The derived excitation temperatures of $T_{ex} \sim 200$-700 K indicate an origin in the warm gas of the inner envelope close to the protostar. The SO_2 abundances are high ($\sim 10^{-7}$) and very similar toward the different sources, suggesting that the SO_2 formation has saturated. The low spectral resolution of the data ($\lambda/\delta\lambda \sim 1500$) makes it difficult to rule out an origin in shocks. Therefore, Braakman (student UvA), Boonman, van Dishoeck and van der Tak (MPIfR) analyzed submillimeter spectra of sulfur-bearing species toward the same sources. The line widths are only a few km s^{-1} and the abundance ratios SO/SO_2, SO/CS do not agree with predictions from shock models. Thus it is concluded that shocks do not play a dominant role in these sources, in contrast to what is seen in Orion-KL.

Boonman and van Dishoeck, in collaboration with Lahuis (SRON) and Doty (Denison University), also analyzed ISO-SWS spectra of gas-phase CO_2 around 15 μm toward deeply embedded massive protostars. The excitation temperature and the gas/solid ratio increase with the temperature of the warm gas, in agreement with other evolutionary tracers. The low CO_2 abundance of only 10^{-8} for gas at 100-300 K is unexpected, however, because of the high abundance of solid CO_2, which can evaporate at ~100 K. The favored explanation is destruction of CO_2 following evaporation by a shock in the past, combined with freeze-out in the coldest part at $T<100$ K.

Boonman, van Dishoeck, Doty and collaborators also modeled H_2O spectra between 5 and 540 μm toward 6 deeply embedded massive protostars obtained with the ISO-SWS and LWS and with the Submillimeter Wave Astronomy Satellite (SWAS). Detailed radiative transfer modeling in combination with different physical/chemical scenarios shows that ice evaporation in the warm inner envelope and freeze-out in the cold outer part are important for most sources. Shocks do not seem to contribute significantly to the observed emission, in contrast with the case for Orion. Predictions for H_2O lines to be observed with the Herschel Space Observatory were made.

Van Dishoeck wrote a review paper on a comparison of the chemical changes during star formation between low- and high-mass YSO's. The chemical characteristics are in both cases dominated by freeze-out in the cold outer part of the envelope and evaporation of ices in the warm inner part. Both sets of objects have a similar power-law envelope structure with evidence for abundance jumps up to factors of 10^3 in the inner envelope for certain molecules. Potential differences include (i) the hot core chemistry, with complex organic molecules so far detected only for high-mass YSO's; (ii) the high level of deuterium fractionation seen only in low-mass YSO's; (iii) the effects of internal or external UV and X-rays; (iv) the relative importance of shocks versus thermal heating of the envelope; and (v) the importance of geometrical effects.

3.2.3.2. Mid-infrared spectra of dusty galaxies

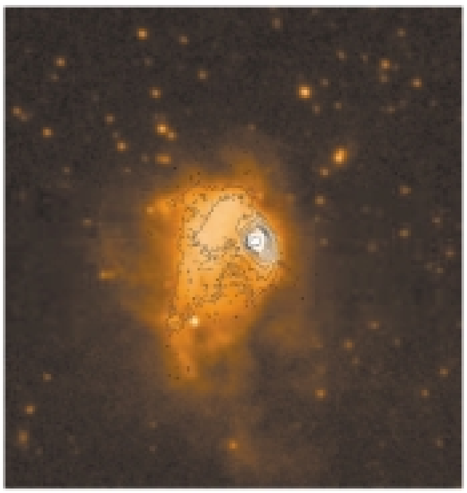
Many of the spectral features seen in the spectra of Galactic massive protostars are also present in mid-infrared spectra of dusty galactic nuclei. Spoon, Keane, Tielens and collaborators analyzed ISO data of a sample of external galaxies. The 6-8 μm water ice absorption is detected in 18 out of 103 galaxies, while other galaxies also show weak to strong PAH emission. Ice bands are present in most of the ULIRGs, whereas it is weak or absent in the large majority of Seyferts and starburst galaxies. This result is consistent with the presence of larger quantities of molecular material in ULIRGs as opposed to other galaxy types. The spectral variation from PAH emission to absorbed continuum emission near 8 μm shows strong similarities with Galactic star-forming clouds. This suggests an evolutionary sequence from strongly obscured beginnings of star formation (and AGN activity) to a less enshrouded stage of advanced star formation (and AGN activity), as the PAHs get stronger and the broad 8 μm feature weakens.

3.2.4. Very young massive stars

3.2.4.1. The stellar content of UC HII regions

Bik (NOVA PhD), Kaper and others studied the stellar content of ultracompact HII (UC HII) regions, that are believed to be the sites of recent massive star formation. The high extinction towards UC HII regions requires observations at infrared wavelengths. Using the ESO NTT and VLT, a near-IR imaging and spectroscopy survey of southern UC HII regions was conducted (see Fig. 5). This lead to the identification of very massive O stars, as well as a population of emission line objects whose nature is not yet clear. It is possible that these stars are surrounded by remnants of the material from which they were formed. Follow-up observations at mid-IR and radio wavelengths are planned.

The nature of the enigmatic object NGC 2024 IRS2 has long been a mystery. Lenorzer, Bik and others studied the infrared spectrum of the star and showed that it is behind a large amount of obscuring dust, which is however not physically associated with the star. At a distance of about 400 pc, and assuming an early B spectral type, there must still be a substantial IR excess, showing that the star has ample circumstellar material. The properties of



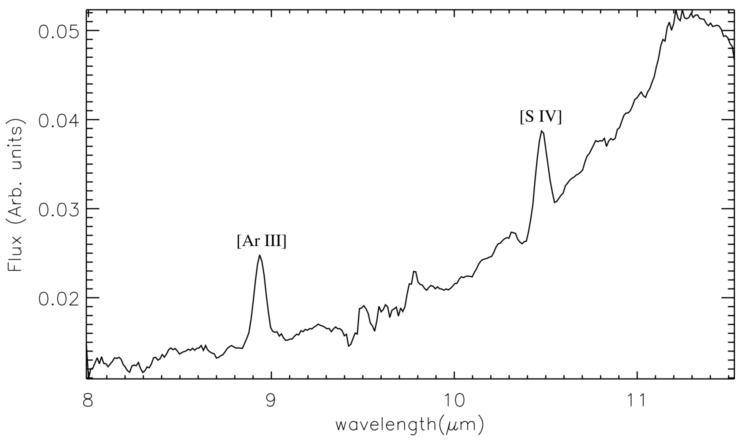


Fig. 5: Left: Br-gamma (2.166 μm) image (1′ x 1′) of the UC HII region IRAS 15411-5352, with overlayed 11.7 μm TIMMI2 contours. Even at 11.7 μm the central source is still a point source, suggesting the presence of hot circumstellar matter very close to the central star. Right: TIMMI2 N-band spectrum of the central source of IRAS 15411-5352. Forbidden lines of a high excitation level are visible suggesting a hot underlying ionizing source.

NGC 2024 IRS2 may be similar to those of the emission line objects found by Bik and Kaper in UC HII regions.

3.2.5. Disks around pre-main sequence stars

3.2.5.1. Disks around intermediate mass young stars

Van Boekel (NOVA PhD), Waters and others have studied the spatial distribution and composition of disks surrounding intermediate mass pre-main-sequence stars, so-called Herbig Ae/Be stars. The mid-IR 10-20 μm emission from Herbig Ae/Be stars originates from the inner (few AU) regions of the accretion disk that surrounds these stars. For the first time, a correlation could be established between the strength of the 10 μm silicate band and its shape. Strong bands are dominated by small amorphous silicate grains, while weaker bands show a flat-topped band dominated by larger grains. Often, these weaker bands also show evidence for crystalline silicates, that are likely (but not always) due to thermal annealing of amorphous silicates. The emission could be spatially resolved in two cases, in particular the Polycyclic Aromatic Hydrocarbon (PAH) emission traces the disk to distances of the order of 100 to 200 AU.

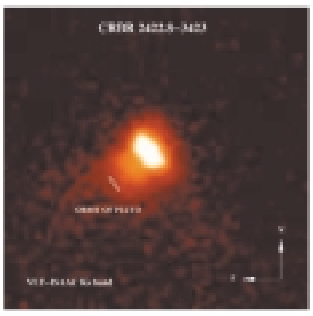
Van Boekel, Dullemond (MPA) and Dominik investigated the feasibility of constraining the inner disk structure using future observations with the mid-infrared instrument MIDI for VLTI (see § 5.3). In particular the question was addressed what the accuracy and phase angle coverage of observations must be for the clear detection of an asymmetry. These studies were then used to define the guaranteed observing program of the MIDI consortium, which will be executed starting spring 2003.

3.2.5.2. Identification of FeS grains in protoplanetary disks

Sulphur is depleted in cold dense molecular clouds with embedded young stellar objects, indicating that most of it probably resides in solid grains. Iron sulphide grains are the main sulphur species in cometary dust particles, but there has been no direct evidence for FeS in astronomical sources. Hony, Waters, in collaboration with Keller (NASA, Texas) and others, have succeeded in measuring laboratory infrared spectra of FeS grains from primitive meteorites, as well as from pyrrhotite ($[Fe, Ni]_{1-x}S$) grains in interplanetary dust, which show a broad FeS feature centered at 23.5 μm. A similar broad feature is seen in the ISO-SWS infrared spectra of young stellar objects, implying that FeS grains are an important but previously unrecognized component of circumstellar dust. The feature had previously been attributed to FeO. The observed astronomical line strengths are generally consistent with the depletion of sulphur from the gas phase, and with the average Galactic sulphur/silicon abundance ratio.

3.2.5.3. Gas-phase molecules and ices in disks

Thi, van Zadelhoff and van Dishoeck performed a JCMT and IRAM 30 m search for gas-phase molecules such as CO, ^{13}CO, HCO^+, CN, HCN, and H_2CO in disks around two T-Tauri and two Herbig Ae stars. Line ratios indicate that the emission arises from dense (10^6-10^8 cm^{-3}) and moderately warm (T~20-30 K) intermediate height regions of the disk atmosphere between the midplane and the upper layer, in accordance with predictions from models of the chemistry in disks (see below). The abundances of most species are lower than in the envelope around the solar-mass protostar IRAS 16293-2422 (see section 3.2.2.2) due to freeze-out and photodissociation. CN is strongly detected in all disks, and the CN/HCN abundance ratio toward the Herbig Ae stars is even higher than that found in galactic photon-dominated regions. A deuterated molecule, DCO^+, is detected for the first time in a



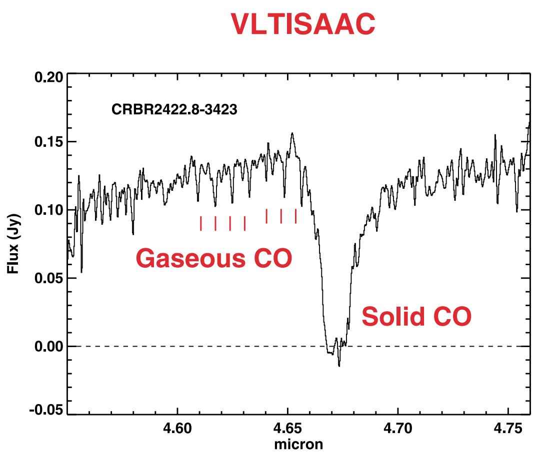


Fig. 6: Right: VLT-ISAAC M-band spectrum toward the edge-on disk CRBR2422.8-3423, showing the very deep solid CO absorption together with gas-phase CO lines. Left: VLT 2 μm image of the same object (from Thi, Pontoppidan, van Dishoeck et al.).

disk. The high inferred DCO^+/HCO^+ ratio of ~0.035 toward TW Hya is consistent with models of the deuterium fractionation in disks which include strong depletion of CO.

Thi, Pontoppidan, van Dishoeck and others also obtained the first direct evidence for significant CO freeze-out in a circumstellar disk. The edge-on object CRBR2422.8-3423 was observed at 4.5-4.8 μm with VLT-ISAAC at R~10^4 (see Fig. 6). The spectrum shows the deepest solid CO absorption ever observed. Absorption by foreground cloud material likely accounts for only a small fraction of the total solid CO. Gas-phase ro-vibrational CO absorption lines are also detected with a mean temperature of 50±10 K. The average gas/solid CO ratio is ~1 along the line of sight. For an estimated inclination of 20° ± 5°, the solid CO absorption originates mostly in the cold, shielded outer part of the flaring disk.

Van Zadelhoff, together with Aikawa (Kobe), Hogerheijde (Steward Observatory) and van Dishoeck, finished their calculations of the abundances in disks around pre-main sequence stars using a full-2D UV continuum radiative transfer code to calculate the dissociation rates of molecular species. Most of the emission was found to originate from a warm intermediate layer where the temperatures are high enough to prevent freeze-out onto grains and where ultraviolet photons induce an active chemistry. The effects of different stellar spectra (cool 4000 K blackbody versus star with excess UV radiation) were also investigated.

Kamp, van Zadelhoff and van Dishoeck computed the line emission for various species for tenuous disks such as those around β Pictoris and Vega and made predictions of line intensities for future facilities such as APEX, Herschel-HIFI and ALMA.

3.2.6. Large organic molecules in space

3.2.6.1. The rich spectrum of interstellar PAHs

The most prominent features in the mid-infrared spectra of most astrophysical objects, including distant galaxies, are due to Polycyclic Aromatic Hydrocarbons (PAHs). Tielens, together with Peeters, Hony, van Kerkhoven and others, analyzed the ISO-SWS spectra of a large sample of reflection nebulae, HII regions, YSO's, evolved stars and galaxies. The most striking aspect of the features in the 3-12 μm region is their extreme variability. All features shift in peak position from source to source, show different profiles and each seems to be composed of several subfeatures. Nevertheless, the spectra can be roughly categorized in three classes, as illustrated in Fig. 7. Comparison with laboratory spectra and theoretical calculations has allowed some of the features to be assigned to either pure PAHs, substituted (i.e. containing N or O) PAHs and PAHs containing some 5-ring structures. The observed variations

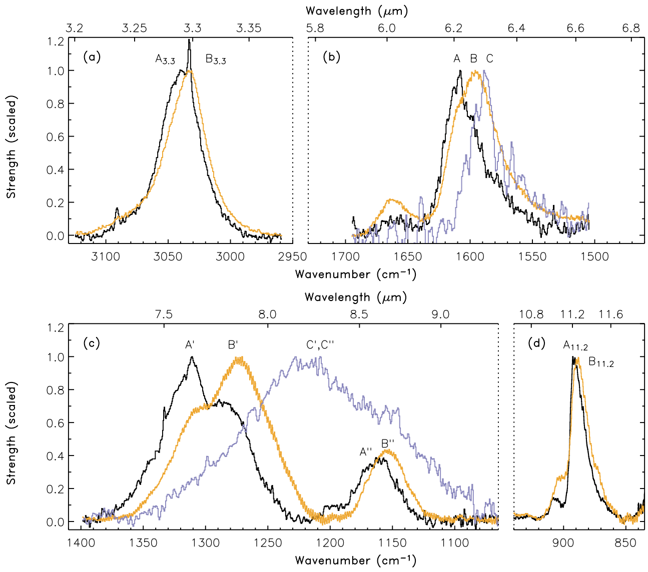


Fig 7: An overview of the observed variations in the profiles of the 3-12 μm PAH emission features. The spectra in each panel are scaled independently so that the peak intensity equals 1. For each feature, the observed profiles have been grouped in different classes depending on their peak position and profile. For all features, class A peaks at the shortest wavelengths while B and C shift progressively to longer wavelengths. Analysis of this classification shows that sources which are class A for the 6.2 μm band are also class A for the 7.7 as well as for the 3.3 and 11.3 μm bands. Globally, the same holds for the other classes. These observed variations imply variations in the physical and chemical characteristics of the population of PAHs responsible for the emission. The observed spectral classes correspond to definite astronomical types of sources. Class A sources are invariably sources which involve interstellar material illuminated by an nearby massive star (material associated with an HII region or reflection nebula). Class B and C sources involved circumstellar material illuminated by a old star (post-AGB object or planetary nebula) or a young stellar object (Herbig AeBe star). It is likely therefore that the observed spectral variations trace the chemical modification of the PAH family over the course of their lifecycle from the place where PAHs are formed - the environment of late type stars injecting material into the ISM - to the harsh conditions of the ISM with strong shocks and energetic photons and back again to the conditions associated with planet-forming disks. (Peeters, Tielens and co-workers).

in the emission bands are thought to be linked to the local physical conditions such as processing by intense UV radiation and shock waves.

3.2.6.2. Diffuse interstellar bands in the Magellanic Clouds

In an effort to provide more insight into the carriers of the mysterious diffuse interstellar bands (DIBs), Ehrenfreund (NOVA) and collaborators observed at unprecedented S/N and spectral resolution optical absorption spectra toward reddened stars in the Magellanic Clouds with the ESO-VLT. This led to the first detection of DIBs in the Small Magellanic Cloud and clear variations of DIB features toward several targets in the Large Magellanic Cloud. The differences of DIBs in the Clouds compared with Galactic targets may be governed by different chemical processes in low-metallicity regions combined with local environmental conditions. This work is now continued by Cox (NOVA PhD) in collaboration with Ehrenfreund, Kaper and Spaans.

3.2.7. Astrobiology

Stimulated by a 'Impulse for Renewal' grant of NWO, Ehrenfreund established the first Astrobiology group in the Netherlands. Together with Ruiterkamp and collaborators, laboratory UV-visual-NIR absorption spectra were measured of a representative set of large PAHs that have also been selected for a long duration exposure experiment on the International Space Station (ISS). PAHs with sizes up to 600 amu, including 5-ring species and PAHs containing heteroatoms, were synthesized. The spectra were also compared to astronomical DIB spectra. Ruiterkamp finalized the sample design for the BIOPAN/PHOTON 2002 orbit flight, which was supposed to hold a sub sample of PAHs, but this experiment was unfortunately lost when the rocket exploded at launch in October 2002.

Ten Kate and Ruiterkamp, with support from ESTEC, refurbished the Mars simulation chamber at ESTEC to study the behavior of complex organic molecules in Martian soil analogs, exposed to simulated Martian atmospheres, UV radiation, oxydizing agents and effects of thermal cycling. These experiments are in preparation for, and support of, the Exobiology Multi-User Facility and data to be obtained from Beagle 2.

Peeters investigated the photo stability of nucleobases (such as adenine) under simulated space conditions. These species appear to be more stable against UV radiation compared with the amino acids studied previously by Ehrenfreund and collaborators.

3.2.8. Evolved stars

3.2.8.1. Crystalline silicates and ices

One of the main surprises of the ISO mission was the detection of crystalline silicates in a variety of sources. Molster, Waters, Tielens and others finished a series of papers on oxygen-rich Asymptotic Giant Branch (AGB) stars in which an exhaustive inventory of these bands is made: besides the broad 10 and 18 μm bands due to amorphous silicates at least 49 narrow bands due to crystalline material are found. Comparison with laboratory data suggests that both olivines ($Mg_{2x}Fe_{2-2x}SiO_4$) and pyroxenes ($Mg_xFe_{1-x}SiO_3$) are present, with x close to 1, i.e. the minerals are very Mg-rich and Fe-poor. This composition is similar to that seen in disks surrounding young stars and in the solar system comet Hale-Bopp. There is a natural division into objects that show a disk-like geometry (strong crystalline silicate bands), and objects whose dust shell is characteristic of an outflow (weak crystalline silicate bands). This difference must be related to the composition or grain shapes of the dust particles. The spectra were modeled using a simple dust radiative transfer method. Crystalline silicates are on average colder than amorphous silicates.

Dijkstra (NOVA PhD), Dominik and Waters are continuing these studies using mid-infrared ISO spectra combined with ground-based images taken with the TIMMI2 camera at the ESO 3.6 m telescope. The ISO spectrum of the post-AGB star IRAS16342-3814 shows absorption bands of crystalline silicates to a wavelength of about 40 μm, and evidence for 43 μm crystalline water ice absorption. This makes this object the reddest one observed with ISO spectrometers. The mass loss rate must have been of the order of 10^{-3} $M_\odot$ yr^{-1}. Mid-infrared imaging shows that the emission is bipolar, and even at 10 μm the equatorial torus is still highly optically thick.

Dijkstra and Dominik constructed a model for the formation of crystalline water ice in the outflows of oxygen-rich AGB stars. They studied the conditions necessary for the formation of both crystalline and amorphous water ice, and calculated predicted ice growth rates as functions of mass loss rate. Only rather high mass loss rates (typically a few times 10^{-5} $M_\odot$ yr^{-1} result in conditions that are favorable for the formation of water ice, in agreement with the observations.

3.2.8.2. Detection of carbonates

The infrared spectra of planetary nebulae are dominated by thermal emission from dust that was ejected when the star was still on the AGB. The composition of the dust as well as the geometry can be used to trace the very last mass loss of the star, just before it left the AGB. An emission band at 92 µm was noted in the ISO spectra of two rather similar planetary nebulae, but has long eluded identification. A comparison with laboratory spectra of carbonates with different chemical composition by Kemper, Waters and others has shown that the carbonate calcite ($CaCO_3$) provides an excellent match to the observed 92 µm emission band. In addition, evidence for the presence of dolomite ($CaMg(CO_3)_2$), which has a strong resonance near 65 µm, was found. The amount of calcite and dolomite required to explain the strength of the emission band does not violate the cosmic abundance of Ca. The formation mechanism of the carbonates is not clear. Gas-phase condensation involving CaO and CO_2 is possible, but more exotic formation mechanisms, operating at low temperature and involving the reactions of Ca atoms with CO_2 ice, may also be responsible.

3.2.8.3. The 30 µm feature in carbon-rich AGB stars

Hony, Waters, Tielens and others detected the 30 µm feature in a wide variety of late-type sources: low mass loss carbon stars, extreme carbon-stars, post-AGB objects and planetary nebulae. The spectra show variations in the wavelength and width of the extracted profiles of the feature, which were modeled using magnesium sulfide (MgS) dust grains with a temperature different from the continuum temperature. The systematic change in peak positions can be explained by cooling of MgS grains as the star evolves off the AGB. In several sources a residual emission excess at 26 µm can also be fitted using MgS grains but with a different grain shape distribution. No evidence for rapid destruction of MgS during the planetary nebula phase is found, suggesting that the MgS may survive to be incorporated in the ISM.

3.2.8.4. AGB stars as probe for mass distribution of the Milky Way

AGB stars are excellent tracers of the Galactic structure and kinematics, because they are bright in the infrared and thus observable in Galactic directions with high extinction. Their envelopes often harbor masers which reveal the line-of-sight velocity of the star to within a few km s^{-1}. Many AGB stars were identified in the inner Galaxy at 7 and 15 µm with ISOCAM, which had a sensitivity two orders of magnitude deeper than IRAS and a resolution at least ten times better. Messineo (NOVA PhD), in collaboration with Habing, Omont (IAP) and others, continued to work on finalizing the point source catalogue from the ISOGAL survey, which contains over 100,000 objects. In particular, a photometric calibration analysis was performed and the completeness was studied with simulation of artificial stars. In collaboration with Ortiz and others, ~100 OH maser sources were identified with ISOGAL sources within one degree from the Galactic Center. In addition, a 86 GHz (v = 1, J = 2 - 1) SiO maser line survey was performed with the IRAM 30 m telescope of a sub sample of ISOGAL and MSX sources to measure radial velocities. SiO maser emission was detected in 271 sources, doubling the number of maser line-of-sight velocities known toward the inner Galaxy. Compared with the OH/IR stars, the 86 GHz SiO maser emitters are more numerous and they are mostly well-understood Mira variables. The newly obtained longitude-velocity diagram clearly reveals a stellar nuclear disk component (see Fig. 8).

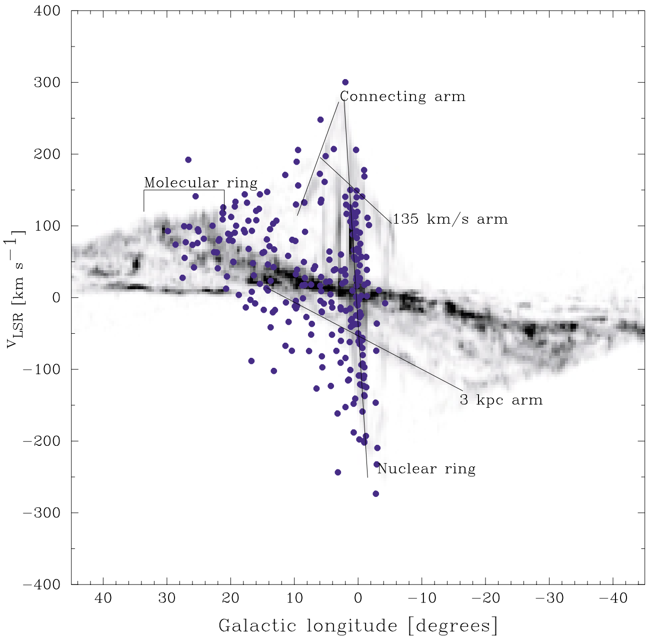


Fig. 8: Stellar velocity versus Galactic longitude diagram overlayed on grayscale CO data. The SiO 86 GHz maser positions are shown as dots (from Messineo, Habing et al.).

3.3. Final stages of stellar evolution: physics of neutron stars and black holes

The aim of NOVA Network 3 is to study the physics of neutron stars and black holes, including processes related to their formation such as supernovae and Gamma Ray Bursts. These are objects of fundamental physical importance. Neutron stars contain the densest form of bulk matter known, whose equation of state is as yet undetermined. Gravity near neutron stars and black holes is sufficiently strong that general relativistic effects dominate the dynamics rather than providing small corrections to the classical laws of motion; in this extreme regime the theory of relativity has not been tested yet. Network 3 concentrates on the astrophysics, formation and evolution of compact objects and their host systems by (1) direct observation of neutron stars and black holes and the processes around them, in particular of radio pulsars, X-ray binary systems and gamma-ray bursts, (2) population studies, and (3) theoretical work on formation and evolution of compact objects and host systems as well as on physical processes near them.

3.3.1. Gamma ray bursts, shocks and particles

3.3.1.1. Observational studies

Since the death of Jan van Paradijs in 1999 gamma-ray burst (GRB) research is led by van den Heuvel, Kaper and Wijers. Wijers was appointed on 1 July 2002 to succeed van Paradijs. Van den Heuvel coordinates the European Gamma Ray Collaboration at ESO (GRACE), a consortium of 5 European and 2 US groups. The collaboration has been successful in obtaining considerable VLT time, including an ESO Large Program, and has been responsible for over 70% of all GRB afterglow identifications and redshift measurements so far. In addition to ESO telescopes it uses the NOT and the ING Telescopes on La Palma, the HST, as well as telescopes on Hawaii, in India, Australia and South Africa. GRACE was the first to measure optical polarization variations of an afterglow (2002) and also measured the largest GRB redshift so far (z=4.50 of GRB 000131). An Amsterdam-led group of GRB observers and theoreticians from seven countries was awarded in 2002 a four-year EU Research and Training Network grant of 1.73 M€ for collaborative GRB research. In 2002 the Amsterdam-led European GRB collaboration was awarded the 0.5 M€ Descartes prize of the European Commission for outstanding scientific progress through European collaboration.

A redshift of z=1.61 was measured by Vreeswijk and collaborators for the very faint (28 magn in V) host galaxy of GRB 990510 using the interstellar absorption lines of the host visible in the spectrum of the GRB afterglow. This showed that GRBs provide an excellent way for measuring redshifts of very faint and distant galaxies, for which measurement of a redshift is otherwise impossible.

Vreeswijk and collaborators derived a high star formation rate (SFR = 35 $M_\odot\,yr^{-1}$) in the host galaxy of GRB 990712 (z=0.4), and in several other GRB host galaxies. This confirms the suspicion that GRB hosts are very actively star forming galaxies. As part of this work, Vreeswijk confirmed his earlier suggestion that the continuum radio flux of hosts is an excellent indicator for the SFR.

Using WHT observations Salamanca found that the host galaxy of GRB 010222 is the strongest damped Ly-α galaxy known. Salamanca and Wijers observed shells with velocity differences of 3500 km s^{-1} in the spectra of the host galaxy of GRB 021004 (redshift z= 2.33). This is a new phenomenon, not seen in any other GRB afterglow so far.

Rol and co-workers observed with the VLT considerable polarization variations on a timescale of hours in the early afterglow of GRB020813.

3.3.1.2. Theoretical studies

Achterberg and Wiersma (NOVA PhD) showed that the magnetised ultra-relativistic shocks believed to cause GRB afterglows in almost all cases can be considered as ‘perpendicular shocks’, where the magnetic field in the propagation direction can be neglected. They derived approximate Rankine-Hugoniot jump conditions by showing that shock compression decreases with increasing field strength. Kuijpers and Papadopoulos (Thessaloniki) considered the excitation of low-frequency magneto-hydrodynamic waves by gravitational waves, and found that fast magneto-sonic waves can grow but that Alfvén waves do not grow to first order in the metric perturbation. Moortgat (NOVA PhD) and Kuijpers found that the growth rate of magneto-sonic waves in an electron-positron wind from a binary merger is larger than was found by Papadopoulos et al. This mechanism may play a role in GRB events where the progenitor system is a merging neutron star binary.

3.3.2. X-ray binaries

3.3.2.1. Neutron stars and black holes

3.3.2.1.1. *X-ray pulsars*

Work continued on the first accreting millisecond pulsar, SAX J1808.4-3658, discovered in 1998 by Wijnands and van der Klis with NASA’s Rossi X-ray Timing Explorer (RXTE) in the outburst of a transient X-ray source first identified by in ‘t Zand (NOVA postdoc) and collaborators using BeppoSAX. By the end of 2002 this object had already been mentioned in more than 150 articles in refereed journals. Three more accreting millisecond pulsars have since been found with RXTE, so SAX J1808.4-3658 was indeed the first of a new class of accreting neutron stars. In October 2002, the long awaited outburst of the source observable with

RXTE finally occurred. RXTE cleared most of its scheduled observations from the timeline and observed the entire 6 week outburst, the first 4 weeks interrupting the observations effectively only when the source could not be observed due to Earth occultations, obtaining the best covered X-ray transient outburst ever. There was intense interest in these observations as it was expected that they might allow for the first time to observe the quasi-periodic phenomena known to occur in weakly magnetic neutron stars in an object with a known spin rate (the pulse frequency of 401 Hz), providing strong tests of models. Everything that was hoped for was indeed discovered in this outburst, and more: burst oscillations at 401 Hz confirming the suspected link of this phenomenon with neutron star spin, kilohertz quasi-periodic oscillations separated by about 200 Hz falsifying one of the main proposed classes of models for that phenomenon (beat frequency models), but suggesting another spin-disk interaction, perhaps involving a strong-field relativistic effect, as well as a completely new phenomenon, which seems best interpreted as a quasi-periodic sideband to the pulse frequency and might be related to Lense-Thirring precession. Analysis of these results by Wijnands (St Andrews), van der Klis, and Chakrabarty and Morgan (MIT) is in progress.

Jonker and van der Klis discovered 0.59 s X-ray pulsations from the low-mass X-ray binary 2A1822-371. The long pulse period, in the second rather than in the millisecond range was a surprise, because the object is thought to be in an old system (more than a 10^8 yrs) where accretion should have suppressed the magnetic field and spun up the star. Director's Discretionary Time follow up observations with the VLT to measure the neutron star mass provided another surprise: a low mass, less than the canonical 1.4 $M_{\odot}$, is allowed by the data, whereas a long period of accretion should have made the mass larger than that value.

3.3.2.1.2. *Black holes*

A broad Fe K-α emission line was discovered in the transient black hole system XTE J1650-500 by Miller (MIT), van der Klis and collaborators using XMM-Newton. The line is best modeled with emission from an accretion disk around a Kerr black hole spinning at nearly the maximum rate allowed by general relativity. Some of the enormous energy of the black hole spin is fed back into the disk in this model, and makes its inner edge light up in X-rays. This result is one of the first examples of direct spectroscopic observations interpretable in terms of relativistic motion near a compact object in an X-ray binary; much further spectroscopic work on such systems is needed to establish whether such interpretations are correct.

Simultaneous twin high-frequency QPOs at frequencies of 180 and 270 Hz, i.e., in an approximate 2:3 frequency ratio, were discovered by Miller, van der Klis and co-workers. Kluzniak and Abramowicz recently conjectured that such QPOs could be related to resonances occurring in an accretion disk at radii where the general relativistic azimuthal and radial orbital frequencies have small integer ratios. That these frequencies are different at all is due to relativity: in classical mechanics they are the same. That they would be different by as much as 50% is only possible in the strongest of gravitational fields, very close to a black hole (or a neutron star).

The defining characteristic that observationally distinguishes an accreting black hole candidate from an accreting neutron star is its mass. For this reason, mass determinations are a central issue in black hole studies. Two new dynamical black hole masses were determined by optical spectroscopic observations by Orosz, van der Klis et al. In the superluminal jet source SAX J1819.3-2525 (V4641 SgR) a black hole with a mass of 8.7-11.7$M_{\odot}$ was found. In the system XTE J1550-564 (where also the twin QPOs were found) a lower limit on the compact object mass was determined of 7.4 ± 0.7 $M_{\odot}$, indicating that this object, too, is definitely a black hole and not a neutron star.

3.3.2.1.3. *Low magnetic field neutron stars*

Cottam (Goddard), Paerels (Columbia) and Méndez reported in Nature the discovery of the first spectroscopic evidence of the gravitational redshift

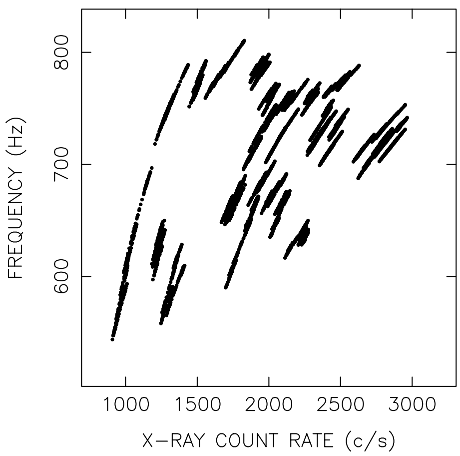


Fig. 9: Parallel lines as calculated with the model for the quasi-periodic oscillations.

from a neutron star surface, by the identification of atmospheric Fe and O absorption lines during 28 X-ray bursts in EXO 0748-676. The redshift, z=0.35, is consistent with canonical neutron star models and excludes some of the more exotic possibilities.

The activity in the area of the quasi-periodic oscillations (QPOs) continued to be very high thanks to the unabating stream of data from the RXTE satellite. The first quantitative, albeit phenomenological, explanation by van der Klis for the enigmatic phenomenon of the 'parallel lines' in the quasi-periodic oscillation (QPO) frequency vs. X-ray flux diagram is still valid. The inner radius of the accretion disk is assumed to be determined by the local photon to matter ratio. If part of the X-ray luminosity responds 'sluggishly' to the variations in the amount of matter, the (numerical) model produces parallel lines remarkably similar to those observed (see Fig. 9).

Yu and van der Klis found that, contrary to the usual situation, kiloHertz QPO frequency decreases when the X-ray flux increases if this increase is due to increased nuclear burning on the neutron star surface instead of to increased accretion through the accretion disk. This is a rather spectacular confirmation of what is predicted in the sonic point model of Miller, Lamb and Psaltis in which the QPOs arise at the inner disk edge, whose radius is determined by the Poynting-Robertson effect.

Van Straaten, van der Klis, di Salvo (NOVA postdoc) and co-workers identified a number of frequencies in the X-ray flux variations that correlate in an almost identical way in different sources with very different luminosities, suggesting that they represent a fundamental set of physical oscillations of an accretion disk relatively independent of the amount of matter in the disk. While most frequencies vary together, one feature seems to keep an approximately constant frequency between 100 and 200 Hz. Similarly constant-frequency oscillation features are seen in black hole candidates (see also Miller's work reported on in section 3.3.2.1.2) and are suspected to reflect the (constant) properties of the warped space-time around the compact object rather than any (time variable) disk configuration property dependent on instantaneous mass accretion rate.

The first example of incommensurability between kiloHertz QPO and burst oscillation frequencies where the former exceeds the latter was found with RXTE in the source 4U 1636-53 by Jonker, Méndez and van der Klis. Previously, beat-frequency models had been proposed where these frequencies should be commensurate, then observations showed cases where burst frequencies were too high, upon which a modified model had been proposed to accommodate this, but not the opposite case as found in 4U 1636-53.

3.3.2.2 Jets

Fender established that all black hole binaries have the same radio properties when in the low/hard state, and that these properties can be most readily interpreted as a consequence of a powerful, self-absorbed outflow. In a detailed study of more than one hundred simultaneous radio and X-ray observations of the 'microquasar' GRS 1915+105, Klein-Wolt, Fender, van der Klis et al. established an unambiguous connection between 'hard' X-ray states with durations as short as minutes and the transient formation of radio jets.

Spurred on by these and related works, and the unprecedented broadband spectral coverage possible for the low/hard state black hole transient XTE J1118+480, Markoff, Falcke (Bonn) and Fender developed a broadband jet model for the low/hard X-ray state in which, surprisingly, it turned out that the X-ray power law may in fact be optically thin synchrotron emission. Support for this interpretation, a radical alternative to the standard Comptonisation models, came in the observations of Corbel and Fender who found a break in the near infrared spectrum of the black hole binary GX 339-4 which is entirely consistent with optically thin synchrotron emission extending through the X-ray band.

Fender and Kuulkers compiled all previous radio and X-ray observations of X-ray binary transients and found both a correlation between accretion and jet power and, unexpectedly, that black hole binaries are more 'radio loud' than neutron star binaries.

Perhaps the highlight observational results were the discovery of arcsec-scale relativistic X-ray jets from two X-ray binaries in observations with the orbiting Chandra observatory. Migliari, Fender and Méndez reported in Science X-ray imaging spectroscopy of SS 433 (front cover of this report) which revealed X-ray lobes within three arcseconds of the core, and with very strong, Doppler-shifted lines of highly ionised iron in their spectra. This is the first evidence for the re-heating of atomic nuclei in a relativistic jet. Corbel, Fender et al. also in Science reported moving X-ray jets from the black hole binary XTE J1550-564 (see Fig. 10), probably associated with a major outburst four years earlier in 1998. These spectacular observations constitute the first ever proper motions in X-rays from a jet, and pro-

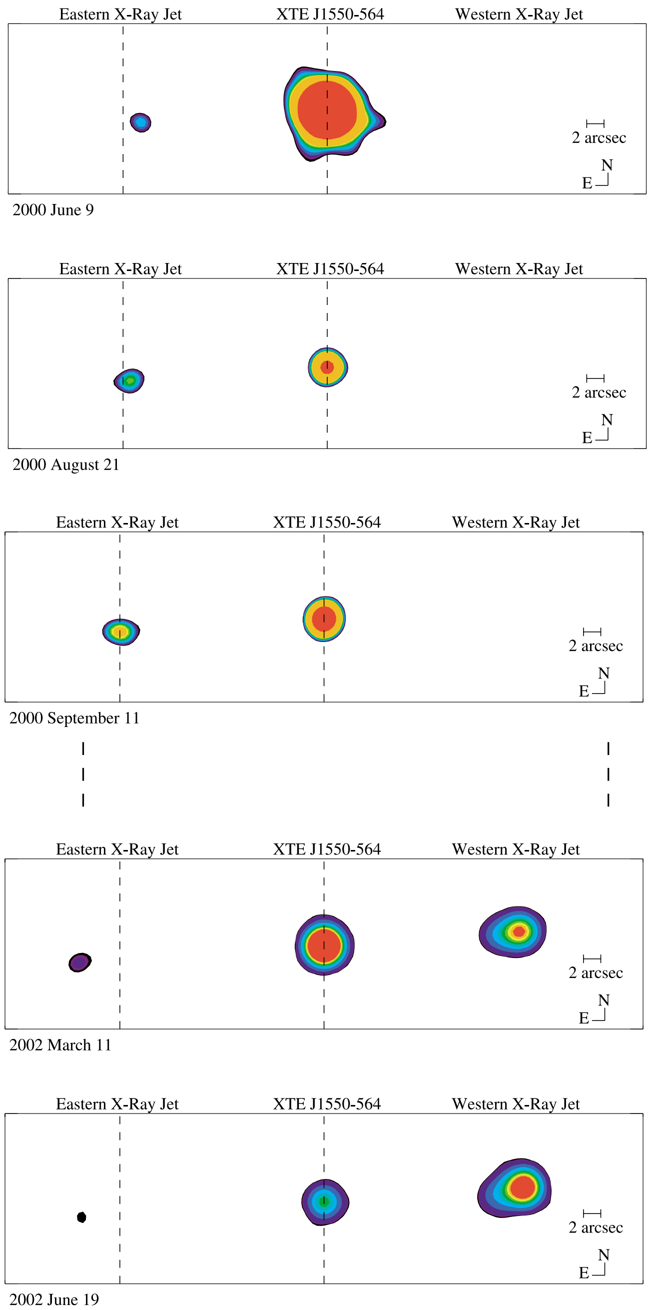


Fig. 10: Moving X-ray jets from the black hole transient XTE J1550-564. Multiple Chandra observations reveal two-sided, decelerating, X-ray jets, converting their kinetic energy into (shock-)acceleration of particles in the ISM. These are the first ever proper motions in X-rays from a jet, and the broadband radio through X-ray spectrum provides strong evidence for synchrotron X-rays associated with a galactic binary.

vide strong evidence for synchrotron X-rays associated with a galactic binary.

Di Salvo (NOVA postdoc) and co-workers continued their work on hard X-ray spectral tails in neutron stars. With BeppoSAX they detected an exceptionally hard spectral component above 30 keV in GX 349+2, with no evidence of a high energy cut-off up to ~100 keV. A general trend is emerging from this work, namely that the hard component is weaker at higher accretion rates. The neutron star spectra seem quite similar to spectra observed from black holes, so the same mechanism may operate in both, implying it does not depend on the presence or absence of an event horizon. They propose that like in the black holes, the high energy electrons responsible for the hard tails in these neutron stars might be associated with a jet.

3.3.2.3. Populations and evolution

3.3.2.3.1 *Galactic populations*

The Wide Field Cameras of the BeppoSAX satellite observed the galactic center region during several weeks every year in April and October. Using these data, Verbunt, in 't Zand (NOVA postdoc), Heise, Kuulkers and Cornelisse discovered two new classes of X-ray sources: (i) short-lived (a week), relatively faint (<0.1 Eddington) transients, strongly concentrated towards the center of the Galaxy, almost all of which are bursters, and thus neutron stars, whereas ordinary transients usually are black holes, and (ii) sources which are detected only during an X-ray burst and whose persistent flux from Chandra observations is 6 or 7 orders of magnitude below the Eddington limit. They concluded that the population of neutron star binaries in our galaxy may be dominated by, perhaps as many as 4000, quiescent systems. The total number of known X-ray burst sources was increased from 40 to 60 by this work. In Serpens X-1 a superburst was found after which ordinary bursts were suppressed for 5 weeks, in agreement with the theoretical expectation that the superburst heats the neutron-star atmosphere so much that nuclear burning becomes continuous.

3.3.2.3.2. *Star clusters*

Verbunt and van der Klis collaborated with Pooley and Lewin (MIT) and Homer and Anderson (Seattle) on Chandra and HST observations of X-ray sources in globular clusters. These are now uncovering the populations of low-mass X-ray binaries, cataclysmic variables and magnetically active close binaries in globular clusters, for the first time. In the case of NGC6752, HST observations allowed the identification of 12 of the 19 X-ray sources, most with cataclysmic variables. This is the most complete combined X-ray and optical study of a globular cluster so far, and shows that cataclysmic variables, long predicted but not found up to now, are indeed present in sizable numbers. NGC6440 is too obscured by foreground matter to obtain useful optical HST observations, but the X-ray properties - in particular luminosity and spectra - allowed classification of four (among 24) sources as low-mass X-ray binaries in which the neutron star accretes at a low rate. This classification was confirmed in a spectacular fashion when one of these sources went into outburst as a soft X-ray transient, as confirmed in a target of opportunity Chandra observation. Of the remaining X-ray sources most are likely cataclysmic variables, but in any case much larger numbers of low-mass X-ray binaries apparently exist in globular clusters than hitherto expected.

In 2001 a NWO Computational Science grant was awarded to van den Heuvel and Sloot (UvA Computer Science) for starting a program for combined dynamical and stellar (including binary) evolution of dense star clusters, making use of the ultra-fast GRAPE computers. The project started early in 2002 with the appointment of Portegies Zwart on a prestigious Royal Academy fellowship, and the appointments of postdoc Sipior and PhD student Gualandris. This group completed the first dynamical and stellar evolution computation of a cluster of 64,000 stars. They found that during the early evolution of massive star clusters, very massive stars, up to 800 $M_{\odot}$, can be formed by the collisions of single stars and binaries. This may lead to the formation of intermediate mass black holes, with masses between 100 and 1000 $M_{\odot}$ in young massive star clusters such as observed in starburst galaxies like the Antennae Galaxies and M82. Another result was the demonstration that the black hole claimed to be present in the center of the globular cluster M15 on the basis of radial velocity studies, can also be explained by the presence of a large number of neutron stars and white dwarfs.

3.3.2.3.3. *Stellar and binary evolution*

Pols (NOVA overlap) investigated the evolution of helium stars (the naked cores of massive stars), and in particular the effect of Wolf-Rayet mass-loss rates on the evolution. The reduced mass loss rates implied by recent Wolf-Rayet wind models were found to produce final pre-supernova masses in much better agreement with observed black holes in binaries. In collaboration with Petrovic and Langer he also investigated the radii attained by massive helium star models. Such helium stars were found to have an extended, very low-mass and low-density halo surrounding the stellar core. The appearance of this halo is related to an opacity peak at 200,000 K. The extended halo is not present in low-metallicity models or in models with a sufficiently high mass-loss rate.

Nelemans, in collaboration with Verbunt, Portegies Zwart and Yungelson (Moscow) carried out detailed population synthesis calculations for predicting the formation rates of detached and semi-detached (AM CVn) double white dwarf binaries. The obtained formation rates lead to an expected Supernova Ia rate of order 0.003 per year. In view of future LISA observations, Nelemans, Portegies Zwart and Yungelson calculated the theoretically predicted strength and frequency distribution of gravitational waves produced by the population of double degenerate binaries in the Galaxy. This shows that LISA is expected to observe the gravitational radiation signals of tens of thousands of close binaries in the Galaxy.

Savonije and Witte continued studies of tidal circularization and synchronization of close binaries by means of resonance locking of pulsational modes and obtained completely novel results. In the resonances, dissipation turns out to be very strong and the timescales for circularization and synchronization are very much shortened. They found that taking this effect into account (where the systems evolve through many resonance modes) the tidal timescales are very much shorter than obtained in classical treatments of tidal dissipation.

Dewi and Pols studied the evolution of binaries containing a helium star and a neutron star. Such systems are remnants of Be/X-ray binaries after evolving through a common-envelope phase, and are an intermediate stage in the evolution towards double neutron stars. By calculating detailed evolution models, mass transfer from the helium star to its neutron-star companion was followed. Such a mass transfer phase was found to be crucial in the formation of close double neutron stars like PSR 1913+16 and PSR 1534+12. In addition, Dewi and Pols found that under certain conditions a second common envelope phase can occur, producing double neutron stars in very tight orbits. Such systems merge within 1 Myr, and are therefore very unlikely ever to be observed, but their merger events give rise to bursts of gravitational wave radiation, and possibly to short-duration gamma-ray bursts. This new population can significantly enhance the merger rate of double neutron stars.

To investigate stars of which initial masses produce black holes in close binary systems, Langer (NOVA overlap) together with Fryer (Los Alamos), Heger (Chicago) and Wellstein (Potsdam) modeled the evolution of a 60 $M_{\odot}$ + 34 $M_{\odot}$ close binary from zero age until the first supernova and beyond. They found that, for six different models with different assumption on the uncertain stellar wind mass loss in the Wolf-Rayet phase of the 60 $M_{\odot}$ star after the major mass transfer phase, its mass at collapse can be in the range from 3-11 $M_{\odot}$. All six models have been followed through iron core collapse and bounce, with strong supernova explosions $E_{kin} > 10^{51}$ erg found for the lower final masses and direct collapse of the star into a black hole only for the largest final mass. Correspondingly, the final compact object masses, which were computed by following the supernova evolution and fall back of material for a time scale of about one year, were found to be in the range 1.2 to 11 $M_{\odot}$. These results imply that so called Case B evolution for black hole binary progenitors can not be excluded, but the production of gamma-ray bursts - which could only occur during direct black hole formation - from the initially more massive star in Case A or Case B binaries appears unlikely.

Close binaries consisting of a main sequence star and a white dwarf are considered as candidates for Type Ia supernova progenitors. Langer together with Deutschmann and Wellstein (Potsdam) and Höflich (Austin) performed self consistent calculations of the time dependence of the structure of the main sequence star, the mass transfer rate, and the orbit by means of a binary stellar evolution program. They obtained, for the first time, a complete picture of the time evolution of the mass transfer rate in such systems. In contrast to results based on simple estimates of the mass transfer rate in systems of the considered type, their results allowed for the possibility that even systems with rather small initial white dwarf masses (~0.7 $M_{\odot}$) may produce Type Ia supernovae, which then might originate from very rapidly rotating white dwarfs. The calculations were performed for two different metallicities, Z=0.02 and Z=0.001. It was found that for systems with the lower metallicity, the mass transfer rates are on average five times larger than in comparable system at solar metallicity. This was found to lead to a systematic shift of the supernova Ia progenitor population, with the possibility to induce a metallicity dependence of the supernova explosion. This metallicity dependences further implied a significant drop of the Type Ia supernova rate towards low metallicity.

3.3.3. Radio pulsars

3.3.3.1. Pulsations

Stappers et al. continued the successful new pulsar timing program with WSRT/PuMa. The observations set new standards in timing precision, especially at low frequencies. Over the current three year baseline a timing accuracy of better than 600 nanoseconds was reached for the rapid pulsars PSR J1713+0747 and PSR B1937+21. The observations of the bright nearby MSP J1012+5307 (< 1μs) and the double neutron star binary pulsar J1518+4904 (~4 μs) are the most accurate currently available. Using the high spectral resolution capabilities only afforded by PuMa, observations of the steep spectrum MSPs PSR J0034-0534 and J0218+4232 at 92 cm are also providing the most accurate timing solutions known. While this program is still in its relative infancy compared with other timing programs, thanks to these steps forward in timing precision it becomes possible to measure proper motions, and to derive parallaxes – or obtain upper limits to it – for MSPs. This will allow a better understanding of pulsar velocities, and a study of the pulsar luminosity function as well as of their binary companions. Some MSPs, for example PSR J1012+5307 and J1713+0747, are likely suitable as members of a pulsar timing array. This array will, via the gravitational wave background, provide constraints on inflationary models of the universe and galaxy evolution scenarios. Observations of binary pulsars will also test general relativity and binary evolution theory.

Ramachandran, Rankin (NOVA visitor), Stappers, van Leeuwen and Kouwenhoven in their continuing study of the drifting subpulses of pulsars resolved a 30 year old dispute over the nature of polarization of radiation from PSR B0809+74. The very high quality PuMa observations clearly show the earlier claim that subpulses remember their polarization state as they drift, to be wrong. The correct explanation of the observations involves the existence of orthogonal polarization modes in the pulsar signal, of which previous workers were unaware.

Edwards (NOVA postdoc) and Stappers developed a new approach to the analysis of drifting subpulses involving two-dimensional Fourier transforms. The technique offers much better sensitivity than older methods, thereby significantly increasing the number of pulsars for which this important phenomenon can be observed. Considered within this framework the carousel model for pulsar emission makes specific quantitative predictions, which relate to geometric factors that have remained largely unexamined to date. The strong tests offered

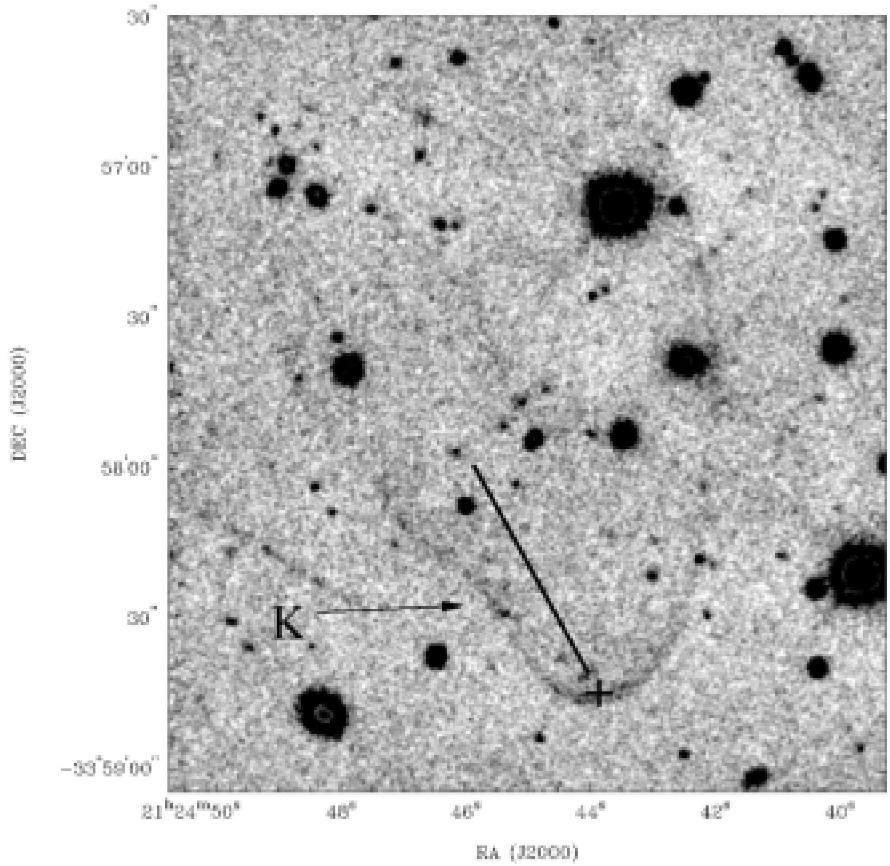


Fig. 11: Hα image of the nebula surrounding PSR J2124-3358 detected with the NTT. The plus sign marks the position of the pulsar, while the straight line indicates the pulsar's direction of motion in its local standard of rest. The length of the line is equal to the distance traveled by the pulsar in 1000 yr. A kink in the bow shock is labeled with a "K"; the filament immediately to the north of the K is most likely not related to the pulsar.

by the new technique should therefore play an important role in evaluating this commonly accepted but fairly weakly verified model. Application of the new technique to PuMa data is in progress.

Another significant development was the establishment of the multi-frequency observations (MFO) collaboration. This international group was formally set up in May 2002 during a NOVA sponsored meeting in Amsterdam organized by Ramachandran, Rankin and Stappers to combine the radio frequency coverage provided by up to 7 observatories in 7 different countries. These observatories are used to enable simultaneous multi-frequency pulsar observations to be made of single pulses from bright pulsars over an unprecedented frequency range from 25 MHz to 2.3 GHz. These observations will revolutionize studies of pulse morphology, pulsar spectra, pulsar polarization, drifting subpulses and nulling, all of which will enable us to better understand the problem of the pulsar emission mechanism which has remained a mystery since the discovery of pulsars.

The theory of the high-energy emission of radio pulsars was challenged by the detection of gamma-ray pulses of the recycled pulsar PSR J0218+4232. Chandra observations performed by Kuiper, Hermsen, Verbunt et al. provided the absolute phases of the X-ray pulsations. Since the gamma-ray pulse profile, determined earlier from CGRO observations, shows its peaks at the same phases, the gamma-ray detection is now secure.

3.3.3.2. Pulsar wind nebulae

Stappers and collaborators discovered two new Hα pulsar wind nebulae (PWN). One is associated with the slow pulsar B0740-28 and the other with the nearby millisecond pulsar J2124-3358 (see Fig. 11). In both cases the characteristic bow-shock morphology implies a direction of motion consistent with the previously measured velocity vector for the pulsar, but complex morphologies challenge models of the interaction of pulsars with the interstellar medium. Complex combinations of interstellar medium parameters such as bulk flow, density gradients and possibly an anisotropic pulsar wind are required to explain the observed morphology.

Stappers, van der Klis and collaborators reported in Science the discovery of the first ever X-ray nebula associated with a millisecond pulsar, the so-called Black Widow pulsar PSR B1957+20. This is the second fastest pulsar known. A very low-mass companion star orbits around it and is gradually ablated by the pulsar wind. The X-ray emission consists of a point source at the pulsar and a narrow feature of length 16 arcseconds trailing its motion. The tail shows for the first time that like the young pulsars, the millisecond pulsars, which have much weaker magnetic fields, also power relativistic winds. The combination of an X-ray nebula, corresponding to the termination shock of the pulsar wind, and the Hα bow-shock of the wind with the interstellar medium, has never before been seen and with deeper observations can provide unique constraints on the nature of pulsar winds.

Van der Swaluw and Wu (Toronto) applied the hydrodynamical theory for the behavior of pulsar-driven nebulae inside a supernova remnant to devise a diagnostic that allows one to estimate the spin period of the pulsar at birth from the ratio of PWN to supernova remnant.

Gallant and Tuffs (Heidelberg) studied the synchrotron emission of a number of young pulsar-powered supernova remnants with ISO. In the remnant 0540-69.3 in the Large Magellanic Cloud, almost a 'twin' of the well-known Crab nebula in our own Galaxy, the IR emission seems to be a transition between the X-ray and radio spectra. In the Crab nebula the same population of electrons responsible for the intense radio emission seems to generate the infrared emission, but their distribution is steeper due to the energy loss that they incur in the process.

Kuijpers considered the generation of a fast equatorial pulsar wind, and the conversion of the electromagnetic (Poynting) energy flux into a wind of fast particles. He found that this conversion takes place when the ideal plasma can no longer maintain a force-free wind due to a lack of charge carriers (so-called 'current starvation'), at a distance of $0.5M^{\gamma}$ light cylinder radii (M is the multiplicity of the pair plasma, γ the Lorentz factor at the base of the pair wind). At that point, a huge voltage drop develops along the magnetic field direction as the condition of ideal magneto hydrodynamics breaks down. The associated electric fields accelerate the wind particles, the currents dissipate, and the outer magnetic field pattern slips with respect to the inner field structure. The energy conversion is a case of generalized magnetic reconnection.

4. PhD's in astronomy awarded in 2001 - 2002

In 2001 a total of 15 PhD's in astronomy were awarded in the Netherlands, and another 20 were awarded in 2002. The table below lists all PhD's in astronomy over 2001-2002 specified for each university.

Name	PhD date	Funding	Promotor	Thesis title
UvA				
J. Homan	14-03-2001	UvA	van den Heuvel	X-ray timing studies of low-mass X-ray binaries
G.A. Nelemans	28-03-2001	UvA, NWO	van den Heuvel, Verbunt	White dwarfs, black holes and neutron stars in close binaries
D. McDavid	29-05-2001	Foreign	van den Heuvel co: Henrichs	Polarimetry of early emission line stars
B. Deufel	06-07-2001	Foreign	Spruit	On the origin of the hard X-ray spectra of neutron stars and black holes
L. Voûte	09-10-2001	Private	van den Heuvel	The many shapes of giant pulses
P. Jonker	19-10-2001	UvA	van der Klis	Probing low-mass X-ray binaries with X-ray timing
J. Bouwman	25-09-2001	NWO, PIONIER	Waters, Hovenier	The processing and evolution of dust in Herbig Ae/Be systems
M.G. Witte	12-12-2001	UvA	van den Heuvel	Tidal evolution of eccentric binaries
J. Cami	10-06-2002	UvA	de Jong, Waters	Molecular gas and dust around evolved stars
G. Drenkhahn	11-06-2002	Foreign	Spruit, van der Klis	Magnetically powered gamma-ray bursts
P. Vreeswijk	12-06-2002	UvA, NWO	van den Heuvel, Kaper	Gamma-ray burst afterglows and the nature of their host galaxies
F. Kemper	04-09-2002	UvA	van den Heuvel, Tielens, Waters	Mass loss and dust formation around oxygen-rich evolved stars
C. Neiner	23-10-2002	Foreign, UvA	Acker, van den Heuvel, co: Hubert, Henrichs	Pulsation, rotation, wind and magnetic field in early B-type stars
S. Hony	25-10-2002	UvA	Tielens, Waters	Infrared light on the composition of the dust surrounding carbon-rich stars
RuG				
D.Y.A. Setia Gunawan	05-06-2001	RuG	de Bruyn	Colliding winds in Wolf-Rayet binaries
I. Garcia-Ruiz	26-11-2001	NWO	Kuijken, Sancisi	Warps in disk galaxies
J.V. Keane	08-02-2002	RuG	Tielens	Origin and evolution of ices around massive young stars
I.M. van Bemmel	06-05-2002	RuG	Tielens, Barthel	Dust and gas in extra-galactic radio sources
R. Vermeij	16-09-2002	RuG	van der Hulst	The physical structure of Magellanic Cloud H II regions
N.L. Martin-Hernandez	13-12-2002	RuG	Tielens	The galactic metallicity gradient, infrared and radio studies of H II regions
E. Peeters	13-12-2002	SRON	van der Hulst	The galaxy population in the Coma Cluster
UL				
M.R. Cioni	20-09-2001	UL	Habing co: Loup	AGB stars and other red giants in the Magellanic Clouds
Y. Simis	10-10-2001	UL	Icke	Mass loss modulation in dust forming stellar winds
W-F. Thi	13-02-2002	UL	van Dishoeck	Gas and dust around young low-mass stars: from envelopes to disks
T. Thomas	06-03-2002	UL	de Zeeuw co: Katgert	The influence of cluster environment on galaxies
G.A. Verdoes Kleijn	06-03-2002	Foreign, UL	de Zeeuw co: Baum (STScI)	The centers of nearby radio-loud galaxies

Name	PhD date	Funding	Promotor	Thesis title
UL				
V. de Heij	01-05-2002	UL	Burton co: Braun	Compact high-velocity clouds
G-J. van Zadelhoff	15-05-2002	UL	van Dishoeck	Shaping disks
W. Vlemmings	14-11-2002	NWO	Habing	Circumstellar maser properties through VLBI observations
M. Haverkorn	18-12-2002	NWO	Miley, de Bruyn co: Katgert	WSRT Polarimetric Imaging of the warm ISM
UU				
E. van der Swaluw	06-06-2001	UU	Achterberg	Supernova remnants, pulsar wind nebulae and their interaction
M.C. van den Berg	21-03-2001	NWO	Verbunt	Optical studies of X-ray sources in the old open cluster M 67
W.J.M. de Wit	19-11-2001	SRON	Lamers, Beaulieu	Pre-main sequence candidate stars in the Magellanic Clouds XIE-124W
L.M. Kuiper	08-02-2002	SRON	Verbunt, Hermsen	High-energy radiation from spin-down powered pulsars
J.M. Krijger	09-10-2002	NWO	Kuijpers	Structure and dynamics of the solar chromosphere

5. Instrumentation Program

5.1. ALMA high-frequency mixer development

ALMA, planned as a three-way project between Europe, North America, and Japan during 2001, reverted back to a two partner project (Europe and North America) in early 2002. Japan was unable to join at that point, and Europe and North America decided to proceed. Japan may be able to join at a later stage, increasing the scope of the project. In 2002 both remaining partners provided final approval for the full funding of the project (550 M€, 50% Europe and 50% North America). The project turned into the construction phase during Summer 2002 with the creation of a joint European - North American ALMA project office, and started the recruitment of an international project director, project manager, project scientist, and project engineer. The full 64 antenna (sub)millimeter array at the 5000m altitude Chajnantor highlands in Chile is expected to be completed in late 2011. First scientific use of the ALMA mini-array (6-8 telescopes) is aimed for by the second half of 2007.

The present two-way baseline project contains four receiver bands. One of them is the ALMA Band-9 (600-720 GHz) receiver for which NOVA is responsible to carry out the design and development work. Van Dishoeck continued as member and chair (in 2001) of the international ALMA science advisory committee. At the request of the ESO DG, she stepped in to become the interim European ALMA project scientist in Spring 2002 for about one year.

5.1.1. NOVA - ALMA project

The NOVA - ALMA project aims to develop a high sensitivity 600-720 GHz (Band-9) prototype mixer and receiver for ALMA. It is a collaboration between the mixer team located at SRON-Groningen and the SIS device experts at the Technical University Delft (TUD). There is a close interaction with the Herschel-HIFI team at SRON-Groningen, led by de Graauw.

During 2001-2002 the project team designed, fabricated, and measured a few prototype mixers, made a conceptual receiver design, and developed the capability of series fabrication in collaboration with local industry. Two mixer designs were pursued: a waveguide design, and a quasi-optical design. Both designs provide good sensitivity.

5.1.2. Waveguide design

The waveguide (WG) mixer uses a waveguide/horn combination to couple the incoming radiation into the Superconductor-Isolator-Superconductor (SIS) tunnel junction which is located on a very thin quartz substrate (2 mm x 0.08 mm x 0.04 mm) across the main waveguide. The main waveguide dimensions are also exceptionally small (0.4 mm x 0.1 mm) and should be machined with very tight tolerances. The main advantages of a WG mixer is that it has become a classical design solution and therefore its properties, design approach and radiation pattern are well known from lower frequency work. The horn and the backpiece are aligned with respect to each other radially by means of a ring and angularly by means of two pole pieces which also serve as magnetic flux conductors to create a magnetic field across the SIS junction for Josephson noise suppression. A prototype of this mixer design has been produced and tested successfully (see Fig. 12).

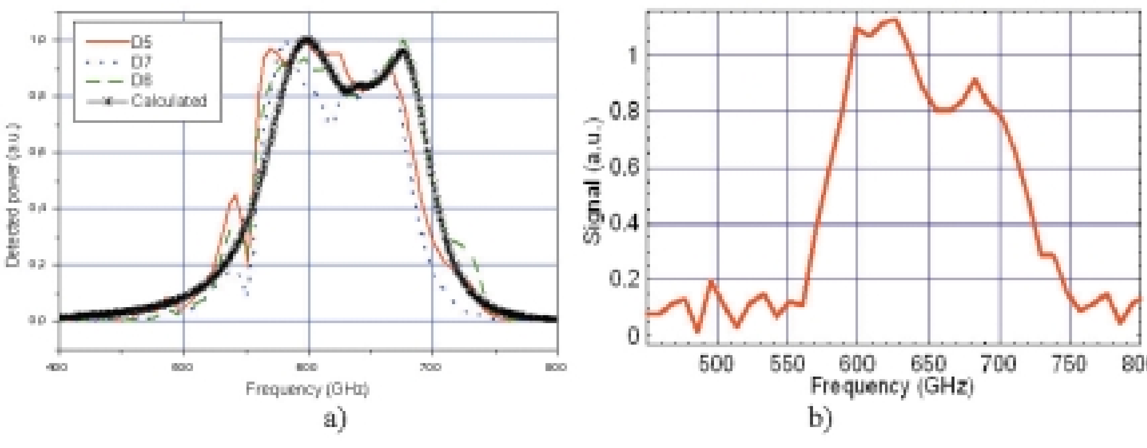


Fig. 12. a) Measured direct response of three different waveguide mixers of similar design and the calculated response. b) The measured mixer direct response curve.

The SIS junction together with the integrated tuning structures, RF transformer and filtering are defined with high precision by using photolithographic techniques. In the mixer production process at DIMES Nb/SiO/Nb tuning strip lines and Nb-AlOx-Nb SIS junction technology are currently used. The electromagnetic structure is calculated and optimized using the 3D electromagnetic solver of the Microwave Studio software package. A time-domain method is used which gives enough accuracy to do a general RF design. The noise temperature of the mixer was evaluated. The results show that the prototype receiver cartridge is able to cover the full ALMA Band-9 frequency range (602-720 GHz) with noise temperatures in agreement with the project specifications (< 147 K for 80% of the band, and < 224 K for the entire band).

5.1.3. Quasi-optical design

The quasi-optical (QO) mixer uses an elliptical lens made from silicon and an on-chip planar antenna to couple the radiation to an SIS junction. The lens diameter is usually of order of 10 mm. The mixer chip is made of silicon and has dimensions of 3 mm x 3 mm x 0.2 mm. The antenna is incorporated on the chip during the SIS junction production process using a photolithographic technique. Making such a mixer does not require very tight mechanical tolerances and handling of exceptionally small elements. The main uncertainty for the QO mixer is its radiation pattern. Additional development work on the QO mixer specifications is required before full confidence is obtained that this solution can be applied for the ALMA Band-9 receiver.

5.1.4. IF band extension to 4-12 GHz

The results achieved on the prototype show that the ALMA Band-9 specifications are met for a 4-8 GHz IF band. Subsequently an additional development program was started to extend the band up to 12 GHz as demanded by the science requirements. There are two possible technical solutions for a IF bandwidth extension: (1) development of a 4-12 GHz cryogenically cooled isolator or (2) integration of the mixer and the amplifier. Both options require a change of the mixer design to decrease the parasitic impedances at the IF. This sets an additional limitation for the construction of the SIS mixer. Initial work shows the net result might be that the continuum sensitivity of the receiver, utilizing the 8 GHz wide IF band could be comparable to (or even worse than) the sensitivity of the 4 GHz IF bandwidth system, and that the spectral line sensitivity could be even better for the narrow IF band system. Clearly, further study on the technical implementation is needed.

5.1.5. Preparation for series production

One of the challenges of the current WG mixer design is the feasibility of series production. To investigate this, a collaboration was set up with a company specialized in fine-mechanical machining, Witec B.V. (Ter Apel, The Netherlands), to fabricate mixer backpieces and diagonal horns on their CNC milling machines with as little human intervention as possible. Because self-alignment of the different parts of the mixer structure is a central requirement of the design, special attention was paid to the accurate positioning of the backshort cavity with respect to the reference circle, as well as to the depth of the stamped cavity, which plays a large role in tuning the frequency band of the receiver. After a few iterations during which the tooling was perfected, all important alignments had converged to within an accuracy of ~10 μm, which is sufficient to provide good mixer performance, while the machining time had dropped to the order of hours per backpiece (as compared to several days of manual fabrication).

5.1.6. Optics and overall cartridge design status

The optical design of the Band-9 receiver cartridge was done in close cooperation with the ALMA optics group. The main design conditions are: cartridge diameter of 170 mm; quasi-optical LO insertion scheme, dual polarization; no focusing optics between secondary and cartridge input; all optics should be placed on the Band-9 cartridge. The design concept includes frequency-independent coupling and distortion compensation using a pair of elliptical mirrors. Alignment tolerances for the mirror displacement on the order of 30 μm were estimated. The required accuracy is possible to achieve with modern machining techniques. The current design approach is to ensure alignment by design and accurate machining without the need of manual adjustments. A preliminary optical design was worked out to make sure that all optics fit inside the cartridge. Physical optics calculations were done in collaboration with MRAO to verify the optical layout.

5.1.7. ESO contracts

In December 2000, an agreement between NOVA and ESO was signed for the prototype design study for the ALMA Band-9 receiver cartridge. This document specifies the NOVA work package during the ALMA phase-1 period (1999-2001), including staff contributions (both in Groningen and Delft), task descriptions, and deliverables from NOVA to ESO. ESO contributed 225 k€ in cash to NOVA for the work of Wild as European Receiver Team Manager for the period 1 May 1999 to 31 December 2001.

In March and June 2002, respectively, NOVA and ESO signed two amendments to the abovementioned agreement covering the period 1 January to 31 December 2002. Through the amendments, ESO contributed an additional amount of 214 k€ in cash to the NOVA-ALMA project for salary (28 k€) and material costs (186 k€). In addition, ESO reimbursed 24 k€ for part of the salary of Wild, acting as European Receiver Team Manager for the period 1 January - 30 April 2002.

On 11 October 2002, a NOVA-led consortium of NOVA-SRON-DIMES submitted a proposal to ESO to carry out the work package for the design, construction and verification of the ALMA Band-9 prototype receiver cartridge in response to an ESO Call for Proposals issued in August that year. On 5 November 2002 Baryshev, Boland and Wild met with the ESO ad-hoc proposal review committee, and with ESO contract officers to present the proposal and to clarify questions. Ultimo 2002 it became clear that ESO is prepared to grant the proposal valued at 1.7 M€.

5.1.8. Staff changes

Meijer started his PhD project on SIS junctions in Delft on 1st April 2001. This position is jointly funded by NOVA and TUD. On 10 October 2001 Gerlofsma joined the project team in Groningen as project technician for a 3-year period to carry out laboratory measurements (mixer parameters and junction qualifications).
Wild stepped down as European Receiver Team Manager effective 1 May 2002 and took up the position of HIFI signal chain manager at SRON. Since May 2002, Wild continued for 20% of his time as project manager of the NOVA-ALMA Band-9 project. However, due to his new commitments in the HIFI project, Wild also stepped down as NOVA-ALMA project manager on 31 December 2002. Starting 1st January 2003 Baryshev was appointment as NOVA-ALMA part-time (50%) project manager continuing his task as project scientist for the remaining time.

5.2. Dutch Open Telescope (DOT)

The DOT at the Observatorio del Roque de los Muchachos on La Palma is an innovative optical telescope for high-resolution imaging of the solar atmosphere. It successfully achieves diffraction-limited image quality (0.2 arcsec angular resolution at the 45 cm diameter of the primary mirror) due to the combination of the excellent site, the open construction, and post-detection image restoration through speckle reconstruction.

The DOT has inspired new open-telescope projects worldwide: the German GREGOR 1.5 m telescope for Tenerife (funded; first light around 2005), the 1.6 m New Solar Telescope for Big Bear Solar Observatory (being proposed), the Indian MAST 1 m telescope for Udaipur Solar Observatory (proposed), and the planned large US Advanced Technology Solar Telescope 4 m telescope (site selection started, first light around 2010).

In the spring of 2001, a high-level DOT Evaluation Committee (three leading observatory directors from abroad) reported very favorably on the DOT efforts and results in the previous DOT funding period (1998-2001). Following their advice, a new three-year DOT funding period was agreed on at the end of 2001 by Utrecht University, NWO, and NOVA, with additional support coming from the EU (after a successful bid to continue the Utrecht-led European Solar Magnetometry Network from the Fourth Framework TMR into the Fifth Framework RTN program), NATO, INTAS, SOZOU, and the Pieter Langerhuizen Lambertuszoon Fonds.
The major activities during 2001-2002 were the start of DOT science, with the first DOT papers published both by Utrecht authors (4 papers) and by DOT data users elsewhere (6 papers), the installation of a multi-pipeline speckle image acquisition system, and the design, construction and partial installation of a tomographic multi-wavelength system.

The international success of the initial DOT movies led to an early decision to apply speckle reconstruction consistently in all DOT observing. An elaborate five-camera and five-computer speckle image acquisition system, with dual optical fiber links between the telescope and the control room in the Swedish telescope building, was designed and built by IGF (Utrecht University workshop), and installed at the telescope during 2001. It collects and stores as much as 360 Gbyte of speckle data per observing day. The DOT science efforts addressed photospheric magnetism using G-band image sequences. The G band, a molecular CH band around 430.5 nm wavelength, is particularly suited for high-resolution studies of the intricate structure and dynamics of the magnetic fields on the solar surface. The studies concentrated on the magnetic fine structure of sunspot penumbrae, oscillations in sunspot umbrae, and the dynamical topology of the tiny bright points that mark magnetic fluxtubes outside active regions. The latter are studied best by subtraction of G-band and simultaneous continuum data, a technique which became feasible after the installation of the second wavelength channel (see Fig. 13). In the meantime, such simultaneity has also been achieved in dual G band plus Ca II resonance-line observing, with the latter line sampling the solar atmosphere about 500 km higher up. The resulting image sequences are presently coming out of the speckle processing and exhibit spectacular sharpness compared to all previous Ca II data in solar physics.

Sampling the solar atmosphere at high resolution in tomographical fashion at different heights simultaneously is the key strategy for DOT science and represents a unique niche in worldwide solar physics. The design for six-wavelength tomography optics and the corresponding mechanical support structures was completed in 2002. Splitting the beam into multiple very different wavelengths without loss of diffraction-limited resolution and mounting the necessary optics trains in robust fashion near the DOT focus (besides the incoming beam) is far from trivial, but satisfactory optomechanical solutions have been found. Extensive optics testing at ASTRON ensures that diffraction-limited image quality is indeed reached at each wavelength. The second channel (blue continuum) was installed late in 2001.The third and fourth channel (Ca II and red continuum) are ready for mounting. The Hα channel (high chromosphere) and the Ba II channel (Dopplergrams) will follow soon.

Another optomechanical effort was the realization of a real-time focus monitor, needed to keep the DOT in precise focus while the mechanical structure expands in the course of the day. This was successfully implemented through phase-diverse imaging using the original DOT video registration system. A beam splitter produces two out of focus images, one behind and one before the exact focus; contrast balancing of the two images at video speed furnishes a precise way to locate exact focus (at the intermediate position). A parallel effort concerns speedup of the speckle processing, which becomes a major pipeline bottleneck with the increase of wavelengths and cameras. Student de Wijn devoted his 2001-2002 computational physics research project to successfully implement and test a parallel version of the speckle code after porting it to C. It created the possibility of dramatic performance improvement through massive parallellization, for which funding is presently sought. De Wijn is now a graduate student in the DOT team.

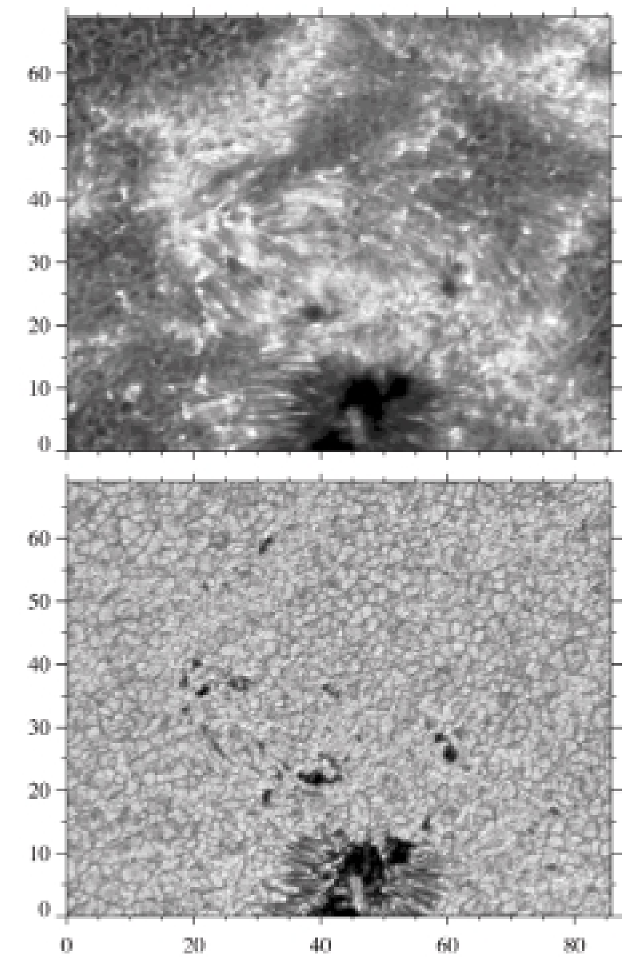


Fig. 13: First tomographic images from the DOT, taken in December 2002. Image scales in arcsec. Lower: G band image, sampling the deep photosphere.The superb angular resolution resolves the tiny magnetic elements in the intergranular lanes (bright dots). Upper: synchronously taken Ca II H image, sampling the low chromosphere, about 700 km higher.The active region shows penumbral extensions and field alignments. Elsewhere, the magnetic elements combine into a bright chromospheric network.The dark areas display convective overshoot and acoustic wave patterns.

5.3. MID-infrared Interferometer (MIDI)

MIDI is a two-element beam combiner for the ESO VLT Interferometer (VLTI). MIDI was built by a German/Dutch/French consortium led by the Max-Planck-Institut für Astronomie (MPIA) in Heidelberg, with PI Leinert. The Netherlands contributed to MIDI through financial support from NOVA in partnership with ASTRON. The NOVA team (NL PI Waters) contributed to MIDI in two main areas: (a) the optical and mechanical design, and construction, of the cold optical bench (ASTRON, Dwingeloo), and (b) design and implementation of instrument control and analysis software (NEVEC, Leiden).

The MIDI instrument is designed to operate in the thermal infrared. The light of two telescopes (either the 8.2m UTs or the 1.8m Auxiliary Telescopes, ATs) is passed to an arrangement of warm optics, including a small instrumental delay line which allows scanning a limited optical path difference to find the fringes. The two beams then enter the cold optical bench whose optical elements are cooled to 40 K, while the detector is at a temperature of 4-8 K. The entire cold optical bench is surrounded by radiation shields and placed in a cryostat.

Beam combination is done close to the pupil and the detection of the interferometric signal is done in the image plane. This allows efficient baffling against the high thermal background and is less sensitive to strong variations in pixel gains of thermal infrared detector arrays.

ASTRON designed and manufactured the cold optics at the heart of the instrument. The two beams coming from the VLTI delay lines are re-imaged, spatially filtered, combined, dispersed and imaged onto the detector. The rest of the instrument, warm optics, cryostat, cooling system, detector unit and electronics, is produced by MPIA. The instrument control and data analysis software is being developed jointly by MPIA, NEVEC (Leiden) and Observatoire de Paris (Meudon). The start of the project was when the Conceptual Design Review was passed successfully in December 1998, though MPIA had been working since 1997 on the concept of MIDI. MIDI has successfully passed its hardware Final Design Review (FDR) in 2000, and its software FDR in 2001, respectively.

5.3.1. Cold optics hardware

By November 2001, the instrument was fully integrated at the MPIA and first fringes were obtained using a laboratory light source. This was followed by a long period of detailed tests and optimization of the instrument hardware, which continued until September 2002. This period was also used to test instrument control software as well as the near-real-time software analysis system, developed under supervision of Jaffe (Leiden Observatory/NEVEC). Regular meetings with the ESO instrument scientist and software engineers were held to monitor progress. The MIDI team managed to meet the schedule and preliminary acceptance Europe was achieved during a meeting on September 2002 in Heidelberg. Thereafter some further work on alignment of the cold optics was required at MPIA. This resulted in an alignment that has approximately 97% overlap in both the image and pupil planes for the smallest 70 μm) pinhole. Some extra adjustments to the alignment were started at the end of September 2002 but there was insufficient time to complete the changes before the system was shipped to Chile. The first cool-down at Paranal was successful with no problems recorded for the cold optics. The MIDI team carried out the Assembly, Verification, and Integration (AIV) work as planned, and at some point was even several days ahead of schedule. First light was obtained early December, and first fringes with the test siderostats some 10 days later. This was followed by first fringes on the large UTs, on 15 December 2002. A press release by ESO was issued to mark this happy event.

5.3.2. Software

Development of the "Near Real Time System" (developed by de Jong and Jaffe at NEVEC) resulted in the detection of the first fringes from MIDI in the laboratory at Heidelberg on 30 October 2001, illustrated in Fig.14. The FDR for MIDI software was passed on 9-10 April 2001 and Preliminary Acceptance Europe (PAE) was passed on 10 September 2002. The development of software to facilitate the operating procedures (Bakker and Jaffe) progressed substantially during 2001 and 2002. The MIDI pipeline (the off-line reduction software) is written by Meisner. The AIV of MIDI at Paranal was successfully passed in December 2002.

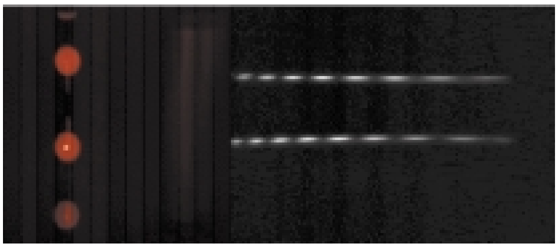


Fig. 14: MIDI first fringes in the laboratory at Heidelberg obtained with a laser on 30 October 2001. On the left one sees three bright circles resulting form the thermal background of two arms of the interferometer.These spots correspond to the two interferometric channels and one photometric channels (the other photometric channel is not visible in this figure).Within the middle bright spot there is a bright pixel: the interferometric signal of the laser. On the right the intensity of the interferometric signal with optical path length modulation. It shows the successive minima and maxima corresponding to constructive and destructive interference of the signal for the two interferometric channels.

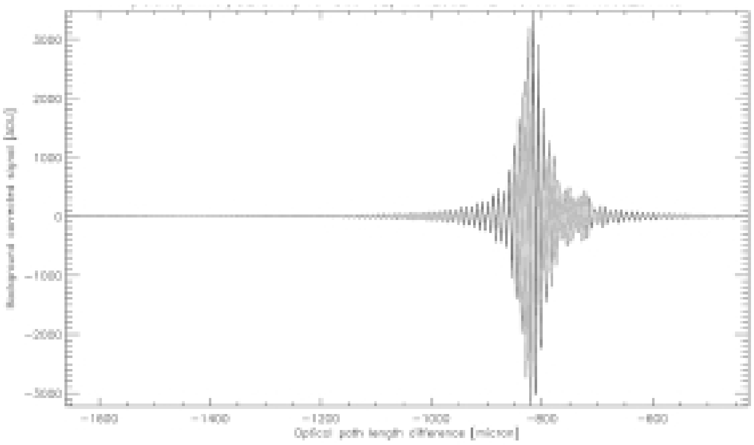


Fig. 15: MIDI first fringe of a science source, Epsilon Carina, on 15 December 2002 with UT1 and UT3. The signal of a filtered fringe is presented at -820 micron optical path length between the two beams of the interferometer. This position corresponds to a net optical path difference of zero, leading to constructive interference of the signal. This fringe marks the beginning of the era of 10 micron interferometry in Europe.

5.3.3. MIDI science

In 2001, the MIDI guaranteed time observing program was finalized and submitted to ESO. In total the program fills 30 interferometric nights with the UTs and over 100 using the ATs. The science program roughly divides into three main themes, focusing on young stars, evolved stars and active galactic nuclei. Most of the evolved star program will be executed using the ATs. As preparation for the observations, simulations of individual objects as they will be observed with MIDI were performed, and on the basis of such simulations observing strategies are being defined. The MIDI science team met in October 2002 to further detail the observations to be carried out in the Guaranteed Time Observing (GTO) program. At the end of September 2002, abstracts and target lists for the first planned GTO run in June 2003 were submitted to ESO. During the AIV period in November-December 2002, some objects that are also in the MIDI GTO target list were observed and fringes were successfully recorded. These data are now being analyzed by the MIDI team to assess the performance of the instrument.

Work also continued on obtaining a list of reliable calibrators. Several observing runs at ESO and at the South African Southern Observatory provided spectra and photometry of some 500 candidate calibrators. Optical photometry of some 100 stars in the Geneva system was collected by the Institute for Astronomy, Leuven University, using the Leuven Mercator telescope on La Palma. These data will be merged with literature data to construct full spectral energy distributions and will then be used to obtain estimates on the angular size of the calibrators. In collaboration with the ESO VLTI team measurements of the angular size of MIDI calibrators is planned in the near-IR, using the VLTI test camera VINCI.

5.4. NOVA-ESO VLTI Expertise Center (NEVEC)

The NOVA-ESO VLTI Expertise Center (NEVEC) for the ESO VLT Interferometer (VLTI) is an expertise center in optical/infrared interferometry funded by NOVA as a joint venture with ESO. The objectives of NEVEC are:

- development of instrument modeling, data reduction and calibration techniques for VLTI, concentrating on optimizing VLTI for studies of faint objects;
- accumulation of expertise relevant for a second-generation VLTI instrument;
- provision of education in VLTI.

5.4.1. NEVEC activities

Over the 1999-2002 period, NEVEC devoted 7.4 staff-years to MIDI software development and an additional 7.4 staff-years to ESO specific tasks (VLTI/VINCI commissioning, VLTI calibrators, the pre-PRIMA project, the pre-GENIE project), and 9.8 staff-years on science, educational activities, interfaces and overall management.

Below the most important NEVEC projects in 2001 and 2002 are summarized.

5.4.2. MIDI

NEVEC staff made significant contributions to the software development for and commissioning of MIDI (see section 5.3 for a description of activities and results).

5.4.3. VLTI/VINCI commissioning

The first interferometric instrument for the VLTI, the 2-way beam combiner operating at 2 µm, the VLTI Interferometer Commissioning Instrument (VINCI), saw first fringes on a celestial object on 17 March 2001 with the siderostats and on 29 October 2001 with the VLT unit telescopes. NEVEC staff made a significant contribution to the VINCI commissioning: Percheron, Jaffe, and Cotton participated in the commissioning at Paranal, while Meisner and Le Poole analyzed data at Leiden. Measurements with VINCI gave an angular size for the star Alpha Hydrae of 9.29±0.17 milli-arcseconds (with a 16 meter baseline on the siderostats), and for Achernar 1.92±0.05 milli-arcseconds (with a 102 meter baseline on the unit telescopes ANTU and MELIPAL).

5.4.4. Defining calibrators for VLTI

Percheron and Richichi (ESO) started a program to measure and build a self-consistent database of VLTI calibrators. In any interferometer there is a loss of contrast in the instrument. The instrumental 'transfer function' can only be measured if a set of calibrators with known angular size is available. There are a few stars whose angular diameters are known sufficiently accurately to suffice as VLTI calibrators, since no instrument can measure these diameters other than an interferometer. Some data is available from lunar occultation and speckle interferometry. NEVEC and ESO have started a joint project to build a database of calibrators with self-consistent angular diameters. The French VLTI/AMBER team will soon contribute to this effort.

5.4.5. Preparation and calibrators for PRIMA

The Phase Referenced Imaging and Micro-arcsecond Astrometry (PRIMA) is a phase-referencing instrument being developed for VLTI. By studying objects close to bright reference stars, PRIMA will extend interferometry to faint targets and make possible a broad range of new fundamental astrophysics based on high-resolution astrometry and imaging. To optimally exploit PRIMA, preparatory surveys for suitable reference objects and scientific targets are essential. Röttgering and Le Poole have therefore started a project to search for faint science objects close to bright reference sources to be used as targets for PRIMA.

5.4.6. The pre-GENIE project

The pre-GENIE project intends to study potential 'show stoppers' for current and future VLTI instruments. Potential 'show stoppers' for MIDI could be fluctuations in the thermal background, while a potential show stopper for external fringe tracker (e.g. by FINITO or PRIMA) could be the fluctuations of the relative humidity in the VLTI infrastructure leading to differential dispersion between the reference and science channel. To quantity these fluctuations an informal international consortium was set up (Heidelberg, Meudon, NEVEC, ESO, ESA) intending to measure these fluctuations. Additional humidity sensors will be purchased, calibrated and tested in Leiden, and installed at the VLTI. NEVEC wrote the calibration plan, and will conduct the analysis of the experimental results.

5.4.7. Educational activities

A workshop on 'Imaging with the VLTI' was organized on 11 October 2001 by NEVEC in close collaboration with TNO/TPD to bring together all those involved in optical interferometry in the Netherlands. On 10 and 11 January 2002 a 'strategy day on optical interferometry' and a NEVEC retreat took place at Noordwijkerhout. During this meeting the initiative was taken to develop a national strategic plan on interferometry and the decision was taken to concentrate further NEVEC activities on PRIMA. From 6 to 8 June 2002 an international workshop on the VLTI instrument GENIE (a ground based demonstrator for DARWIN) was held in Leiden and organized by NEVEC. In total 82 scientist and engineers participated.

5.4.8. Space interferometry

d'Arcio, le Poole, Röttgering and den Herder (SRON) performed a conceptual study for the forthcoming IRSI/DARWIN space mission. Emphasis was on development of techniques for co-phasing and wide-field imaging. Various activities were carried out in collaboration with the Technical Physics Department of the Technical University at Delft led by Braat and the optics group of the space- engineering department of TNO/TPD. This work includes an investigation on phase shifting for nulling interferometers, and conceptual studies for SMART3, a precursor mission to DARWIN. Röttgering, in his role as IRSI-DARWIN science team member, organized several meetings to explore possible collaborative projects involving the synergy between VLTI and space interferometry, including a workshop to bring together the various groups involved in optical interferometry in the Netherlands under the umbrella of an informal working group, the Dutch Joint Aperture Synthesis Team (DJAST). Participating institutes are NEVEC, Leiden Observatory, SRON, TNO/TPD, Fokker Space, ESA, TU Delft, TNO/FEL, SRON and NIVR .

5.4.9. **Staff**

In Leiden the following staff members contribute to the NEVEC activities: NOVA funded NEVEC staff: Bakker (project manager), de Jong (scientific programmer), Meisner (technical astronomer) and Percheron (technical astronomer); and several tenured staff astronomers: Jaffe (PI of MIDI software development), Le Poole (project scientist), Miley (PI till September 2002), Quirrenbach (PI from September 2002) and Röttgering. External funded NEVEC staff at Leiden include d'Arcio (SRON funded postdoc), Heijligers (PhD, partly funded by Fokker Space), and Gori (PhD, funded by TNO/TPD). During 2001 and 2002, guests and temporary staff working within NEVEC included Cotton (NRAO), Hartmann (Cygnus consultancy) and Eiroa (Madrid). In Amsterdam Waters and van Boekel (PhD, jointly funded by NOVA and ESO) made contributions to NEVEC.

5.4.10. **Oversight of Dutch VLTI activities**

Dutch participation in VLTI is being guided by a national steering committee that meets once per year, consisting of de Graauw (SRON-Groningen), Jaffe (Leiden), Rutten (Utrecht), le Poole (Leiden), Miley, (Leiden - Chair), Noordam (ASTRON), Röttgering (Leiden), Pel (Groningen), Schilizzi (JIVE) and Waters (Amsterdam). Miley and Waters are the Dutch members of the Quadripartite VLTI Implementation Committee (CNRS, MPI, ESO, and NOVA).

5.5. OmegaCAM

5.5.1. The OmegaCAM project

OmegaCAM is the wide-field camera for the VLT Survey Telescope (VST). Its focal plane contains a 1x1 degree, fully corrected field of view, tiled with 32 2048x4096-pixel CCD detectors for a total of about 16000 x 16000 pixels - a quarter of a gigapixel. The camera and telescope are designed specifically for good image quality, and the detector array will sample the excellent seeing on Paranal well with 0.2 arcsec per pixel. The total cost of the instrument is of the order of 6 M€. NOVA leads the project, and contributes about 1/3 of the funding.

OmegaCAM and the VST are expected to have an operational lifetime of at least 10 years. By way of payment for the instrument, ESO will grant guaranteed observing time: for NOVA this will be about 4 weeks of VST time per year, over the lifetime of the instrument. Towards the end of the development phase of the project, a data center, OmegaCen will enable the Dutch user community to work with the

Fig 16: Parts of the OmegaCAM cooling system at the ESO workshop before integration. From left to right: inner liquid nitrogen tank, cryostat vessel, and heat exchanger.

OmegaCAM data as efficiently as possible. Facilities for processing raw data into calibrated images, and for extracting and measuring sources from these images, are being designed.

Scientific use of OmegaCAM will include simultaneous monitoring of millions of stars for variations in brightness, which can be caused by gravitational microlensing, occultation by faint companions (perhaps planets), intrinsic variability or transients such as distant supernovae or gamma-ray bursts. Tracking object positions over a timescale of years allows faint nearby stars to be recognized through their motion on the sky. Measurement of the systematic alignments of distant galaxies, caused by gravitational lensing, will map the intervening mass distribution in galaxy clusters. Multi-filter observations will allow photometric redshift determinations for distant galaxies, which form the basis for deep mapping projects with spectrographs on the larger telescopes.

2001 saw the completion of the design phase of the project with a successfully-passed Final Design Review at ESO in the fall. Manufacture was since started, and at the end of 2002 is in very advanced state (housing structure completed, filters on order, shutter unit completed, prototype filter exchange mechanism under test, etc). At ESO construction of the detector system is also advanced, though it has incurred significant delay: all CCDs are in house and have been tested at a purpose-built testbench (with significant support from NOVA staff), the cryostat components are mostly in place, readout electronics are being assembled. Delivery of the complete detector system is foreseen for end of 2003, at which point integrated system tests can start in Munich. The final system should be ready for shipping to Paranal in the first half of 2004.

In March 2002, a public presentation of the project was held at the university of Groningen, to mark the formal signing of an Agreement between ESO, NOVA the Ludwig-Maximilians-Universität München, and the Osservatorio Astronomico di Padova concerning the OmegaCAM project. The instrument, its scientific use, and the technical challenges posed by the tremendous data rate it produces, were presented and received quite some attention in the national press.

5.5.2. ASTRO-WISE

Meanwhile the preparation for the very high data rates to be expected from the instrument (10s of Tbytes per year) is underway. This particularly challenging task is led by a NOVA team in Groningen and Leiden. A network of data centers spread throughout ESO member countries is planned, which will operate a common system dubbed ASTRO-WISE. It will be centered around a modern federated database containing raw data, processed data, calibration data and recipes. A large funding request to the European Commission for development work related to ASTRO-WISE was successful (EU grant of 1.5 M€), and the 4-year project formally started in 2002. Software tools are being developed which allow for (semi-)automatic calibration of the images, combination of exposures, extraction of sources, and measurement of source properties. The integrated approach to the data reduction and data archiving is intended to make it as straightforward as possible for individual users or small groups to handle the huge volumes of OmegaCAM data without getting bogged down in tedious data management. The result will be a precursor to a true Virtual Observatory, a goal being worked towards on many fronts world-wide.

5.6. Pulsar Machine (PuMa-2)

Work on all four modules which make up the PuMa-II project has continued apace during 2001-2002. The external data handling solution for PuMa of Module 1 has continued to work extremely well over this period. The hardware for the change over to the new faster workstations for PuMa to enable 100 Mbit ethernet capabilities and an expanded disk suite was installed. Initial tests revealed that there were some problems with the disk array being used, these have now been circumvented. Nearly all PuMa observation configurations have now been enabled in the new system and successful pulsar observations have been carried out. These observations have shown how the functionality and observational capabilities (which up until now have often been disk space limited) will be greatly enhanced. Implementation of the final two configurations is expected to occur early in 2003.

The coherent dedispersion module, Module 2 of the project, was completed during the period 2001-2002. To enable it to be used by as wide a community as possible the code has been ported to operate under Linux, HPUX and True-64 Unix. Module 2 has been extensively used for two projects by Stappers and collaborators studying the so-called giant pulses from both the Crab pulsar and the fastest pulsar known PSR B1937+21. Module 2 is in part intended as a pilot project for the final, full bandwidth baseband recording and coherent dedispersion module, named Module 4. Based on Module 2 experience, late in 2001 the decision was made to use general purpose processors (GPP) for Module 4. This decision was based on three main considerations, (i) the continued rapid advance in GPP speeds and the even more rapid decrease in the price of hard disks, (ii) the expected simpler conversion of the software developed in Module 2 to a multi-processor GPP platform than to the alternative digital signal processor (DSP) platform and lastly (iii) the combined hard disk/GPP solution providing scope for more science to be obtained (through offline reprocessing) from a single data set than a fully real-time DSP solution.

The choice was made for the preferred de-accelerator hardware for Module 3 in the first half of 2001 and the full Compaq ES40 machine was delivered in the fall of 2001. The ES40 in combination with a fiber channel RAID array with 0.5 Terabytes of data and 8 GBytes of RAM was chosen. This package was chosen to facilitate the two different de-acceleration algorithms which are implemented under this architecture to vastly improve the sensitivity in searches for binary millisecond pulsars. In both cases the important considerations were very large shareable memory, high input-output rates for both hard disks and the memory, and multiple processors. Problems with connectivity associated with the initial placement of the machine at SARA meant that there was a five month delay before it was placed on the experimental network at the FNWI Faculty at the University of Amsterdam. This final location proved to be greatly beneficial through enabling extremely high data transfer rates and ease of access. Both the software implementing the standard 'constant acceleration' method and that which implements the new 'partial coherence recovery technique' (PCRT) were installed in the machine late in 2002. The core software for both was prepared by, respectively, Edwards (NOVA post-doc) and Jouteux (NOVA PhD). This module is now complete and heavy use is planned for it in the coming years.

The specific architecture of the machine has also enabled a number of other large PuMa-related projects not involving deacceleration to make use of it. A recent project by Smits, Stappers, Macquart, Ramachandran and Kuijpers has combined all of the so-far completed resources of the PuMa II project. It aimed to test a recent claim of the detection of coherence, which is thought to be present in pulsar emission, by analyzing coherently dedispersed data of very bright pulsars. The data were obtained using the PuMa system in its baseband recording mode and analyzed using the coherent dedispersion method/Module 2. Subsequently simulations of the influence of interstellar scintillation on such data and the presence of coherence were carried out using the Module 3 hardware greatly reducing the timescale on which this could be achieved as compared to using other resources. In an unrelated effort, the Module 3 hardware was used to enable analysis of WSRT HI data of the whole of M31 by Braun which could not have been achieved on any other available computer due to the memory requirements.

5.7. Sackler Laboratory for Astrophysics

The activities in the Raymond & Beverly Sackler Laboratory consisted of two elements: continued experiments with the existing high-vacuum equipment in support of new observational data, and construction of two new ultra-high vacuum set-ups, SURFRESIDE and CRYOPAD. The research is closely linked with that of Network 2 described in section 3.2.

On 17 September 2001, a one-day international symposium 'From interstellar dust to comets: a journey through space and time' was organized in Leiden in honor of the 80th birthday of the founding father of the Leiden laboratory, J. Mayo Greenberg, who sadly passed away later that year. The symposium was attended by more than 50 scientists.

5.7.1. Research summary

5.7.1.1. Amino acids and other complex organics in irradiated interstellar ice analogs

Muñoz-Caro and Schutte (NOVA overlap), in collaboration with Meierhenrich (CNRS, Orleans), succeeded to produce amino acids in simulated interstellar conditions. Amino acids are the essential components of living organisms on Earth, but the proposed mechanisms for their spontaneous generation have been unable to account for their presence in Earth's early history. The delivery of extraterrestrial organic compounds has been suggested as an alternative (albeit hotly debated) route. By means of gas chromatography-mass spectrometry, 16 amino acids were detected in the room-temperature residue of an interstellar ice analogue consisting of H_2O, CO, CO_2, CH_3OH, and NH_3 ice at T~12 K which was subjected to hard UV-irradiation at high vacuum pressure. The chiral amino acids showed enantiomeric separation. Pyrroles, furanes and amines were also found, and evidence for the presence of carboxylic acid salts and the formation of hexamethylenetetramine (HMT) at room temperature was presented for the first time. Mixtures containing sulfur (initially as H_2S ice) showed that sulfur-polymerization is efficient. All products were confirmed by ^{13}C-labelling of the ice. Some of the amino acids produced in these experiments are also present in carbonaceous chondrites whereas other species could exist in comets. A detailed quantitative infrared analysis of the complex organic refractory material was also performed and the effects of the most relevant free parameters, such as ice composition, UV dose, photon energy, and temperature have been investigated.

5.7.1.2. Ions in interstellar ices

Keane, Schutte and Tielens investigated the origin of the weak absorption bands at 6.3, 7.2 and 7.4 µm in the ISO-SWS spectrum of the embedded high mass young stellar object W 33A. Comparison with laboratory data shows that HCOOH gives a good fit to the 7.2 µm feature, while the 6.3 and 7.4 µm bands are well matched by the corresponding molecular ion, $HCOO^-$. HCOOH ice was previously suggested by Schutte based on features at 5.8 µm, and is the heaviest molecule that has been observed directly in interstellar ices. The presence of $HCOO^-$ confirms that acid-base reactions are an essential factor in interstellar ice chemistry.

Van Broekhuizen (NOVA PhD) and Schutte finished their laboratory simulations of the formation of OCN^- in interstellar ices. This ion, which can be probed through its vibrational stretching mode at 4.62 µm, has been observed towards a large number of mostly high-mass protostars. Several pathways were investigated involving either UV photolysis or thermal processing of relevant ice mixtures. Photolysis of CO with NH_3 is too inefficient to account for the high observed abundances, but photolysis of

CH_3OH with NH_3 showed an unexpectedly high OCN^- production rate. Thermal processing of mixtures involving HNCO can also meet the observational constraints.

5.7.1.3. **Stringent upper limit to the solid NH_3 abundance**

Taban (visiting student Romania), Schutte and Pontoppidan (NOVA PhD) analyzed the ESO-VLT near-infrared spectrum of the high mass embedded protostar W 33A. The aim was to search for the 2.21 µm overtone feature of solid NH_3 and the 2.27 µm band of solid CH_3OH. The abundance of solid NH_3 has been a hotly debated subject: tentative detections of the 9.1 µm umbrella mode indicate a high abundance of 15% with respect to H_2O ice, while the weakness of the ammonium hydrate feature gives estimates of less than 5%. The advent of 8 m class telescopes allows for the first time meaningful observations of the weak near-IR features of ice components. The absence of the 2.21 µm NH_3 band in the W 33A spectrum gives an upper limit of less than 5%, derived from comparison with relevant laboratory spectra. The 2.27 µm CH_3OH feature was positively identified and its derived abundance is very similar to values inferred earlier from mid-IR features, demonstrating the feasibility of probing ices by near-IR spectroscopy.

5.7.1.4. **Spectroscopy of CO on astrophysical surfaces and ices**

Bisschop (student UU) and Fraser (NOVA postdoc) investigated the behavior of CO ices on a number of astrophysical grain analogs, including HAC (hydrogenated amorphous carbon), CsI and zeolites. They found that at high spectral resolution, the CO-ice band can be deconvolved into at least 2 and occasionally 3 components, in keeping with recent observational findings of Pontoppidan et al. CO can be easily trapped in any hydrogen-bonding ice system, but the final desorption temperature of the CO depends intrinsically on the interplay between the crystallization and desorption behavior of the trapping matrix. The behavior of CO on an acidic ice, HCOOH, was studied in detail. In an effort to understand a new solid state feature observed by Pontoppidan et al. at 2175 cm^{-1}, Bisschop and Fraser investigated direct gas-grain interactions on naturally occurring zeolites. CO was observed to chemisorb at 2175 cm^{-1} with the band strength increasing at lower temperatures, providing a tentative explanation of this band.

5.7.1.5. **Formation of solid CO_2**

Fraser, in collaboration with Ruiterkamp and Tielens, studied the chemical reactions that may lead to CO_2 production under interstellar conditions. Ruiterkamp focused on those reactions which may occur in regions where UV photon-induced chemistry dominates. Under these conditions, the reaction between H_2O and CO is now known to progress via a diffusion-limited reaction between CO and OH radicals. Fraser focused on photon dominated reactions in the absence of H_2O, and also looked at the direct reaction between CO and O atoms. Tielens built models of both systems, to reproduce the laboratory findings.

5.7.1.6. **Physics-chemistry of ices in space**

Fraser and Ehrenfreund were part of an ESA Topical Team to study physical and chemical aspects of ices in space. In collaboration with a number of colleagues from around Europe, the topical team started to investigate how ice studies in microgravity (using parabolic flights, the International Space Station (ISS) and Drop Tower Experiments) can be used to enhance our understanding of cometary, interstellar and atmospheric ices. As part of this team, Fraser worked on the development of a new instrument / experiment, to fly on the ISS in 2005. The ICAPS experiment (Interactions of Cosmic and Atmospheric Particle Systems) is designed to study physical parameters of particle systems under long duration microgravity conditions. The experiment addresses problems in particle aggregation, icing of dust and light scattering effects.

5.7.2. **Construction of new equipment**

5.7.2.1. **SURFRESIDE**

Fraser, together with van Broekhuizen, Schutte, van Dishoeck and de Kuyper (technical workshop), made significant progress on the construction of SURFRESIDE, the Surface Reaction Simulation Device. SURFRESIDE is designed to study atom-

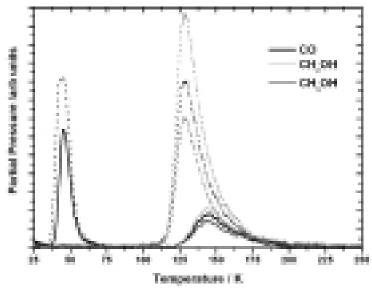


Fig. 17: First scientific results from SURFRESIDE. A mixture of CO and CH_3OH is deposited on the cold substrate and gradually heated. The CO is found to desorb at two different temperatures: one peak occurs around 50 K (due to CO surface desorption) and one peak around 130 K (due to CO trapped in CH_3OH ice). Such data are important as input to models of the CO freeze-out and desorption in protostellar regions and disks.

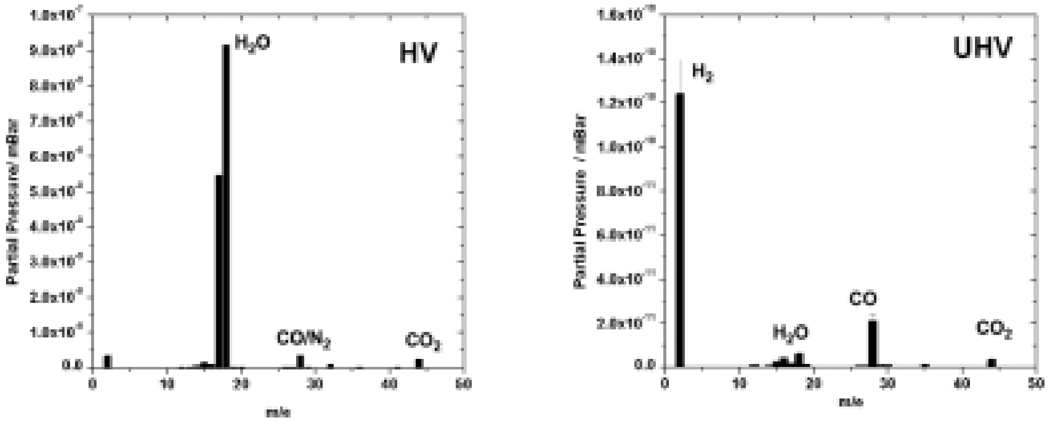


Fig. 18: High-Vacuum (HV, left) versus Ultra-High Vacuum (UHV, right) conditions. At HV conditions of ~10^{-7} Torr, the pressure is dominated by H_2O, which contaminates the experiments. Under UHV conditions of <10^{-10} Torr such as reached now in SURFRESIDE and CRYOPAD, H_2 is the dominant component, and H_2O and CO are minor fractions.
The experiment was tested using simple ice systems, specifically to investigate the trapping of molecular species such as CO with no or very small permanent dipole moments within ices that are or are not capable of hydrogen bonding. First results using temperature programmed desorption to study the desorption kinetics of CO when trapped in CH_3OH showed that CO can become trapped in the CH_3OH matrix until the CH_3OH ice itself undergoes a phase change (see Fig. 18). This behavior is similar to that of the CO-H_2O system studied previously by Fraser and collaborators. The data also indicate that CO can be released from the ice surface at much higher temperatures than was previously assumed, relating to the binding energy between CO and CH_3OH being greater than that between CO and CO. The implications of these findings will be implemented in the models and observational interpretations of the molecular astrophysics group.

molecule, molecule-molecule and radical-molecule chemical reactions occurring at the surface or in the bulk of interstellar ice grain mimics under pseudo-interstellar conditions, and reached pressures of better than $1x10^{-10}$ Torr as standard. When cooling is applied, this can drop to $5\text{-}6x10^{-11}$ Torr, well below the original specifications and ideally suited for surface chemistry studies under interstellar conditions. The experiment was set-up for experimental use, with the exception of the atomic beam part. The FT-RAIRS (Fourier Transform Reflection Absorption InfraRed Spectroscopy) system was aligned, a method for calculating ice porosities and thicknesses using non-normal incidence of a He-Ne laser has been finalized, and heating ramps and temperature control for temperature programmed desorption experiments has been established.

5.7.2.2. CRYOPAD

Van Broekhuizen and Schutte, together with Fraser, de Kuiper, Benning and van As (technical workshop) and with advice from Fraser, finalized the design and most of the assembly of the new Cryogenic Photoproduct Analysis Device. CRYOPAD is specifically designed to simulate the formation of volatile complex organic molecules from interstellar ice by solid state chemistry in 'hot cores' such as found around massive protostars. The processes to be studied include processing by ultraviolet radiation and by heating. Ultra high vacuum conditions of the entire assembly were reached in late 2002, with first experiments ready to start in early 2003. Desorption products and surface reactions will be simultaneously detected by quadrupole mass spectrometry.

5.8. SINFONI

SINFONI (SINgle Faint Object Near-infrared Investigation) is a collaboration between ESO, MPE and NOVA. It consists of a cryogenic near-infrared (JHK-band) integral field spectrograph (SPIFFI) developed by MPE (PI. Thatte) fed by an adaptive optics unit developed by ESO. First light of SINFONI at UT4 (Yepun) of the VLT will be in 2004. This telescope will be equipped with a laser guide star system (LGS) in mid-2004, so that from very early on essentially the whole Paranal sky will be available to SINFONI with diffraction-limited resolution and full spectral multiplexing.

5.8.1. Key features of SINFONI

The combination of adaptive optics and integral field spectroscopy in the near-infrared (where adaptive optics performs best) is very powerful. SINFONI allows fully spectrally multiplexed imaging at a spatial resolution equal to the HST optical resolution (3 times better in both dimensions in K-band) and vastly more sensitive in K-band. In contrast to most other integral field spectrographs, SINFONI is cryogenic and thus allows full K-band capability. This makes SINFONI a very powerful instrument for all branches of near-infrared astronomy. It will deliver data that cannot be obtained with other instrumentation, either by direct detection or interferometry.

5.8.2. NOVA role in SINFONI

The NOVA contributions consist of the following four parts:

5.8.2.1. SINFONI 2K camera and detector

NOVA has a key role in producing the spectrograph camera and detector for SINFONI. While originally conceived with a 1024^2 detector, implementing a 2048^2 detector will greatly enhance SINFONI's science performance. This modification to the original SINFONI design requires (in addition to procurement of a 2048^2 detector and associated electronics by ESO, and related software modifications) the development of a new spectrograph camera. An agreement between NOVA, ESO and MPE was signed in 2002, where the details of the collaboration are defined. The development and production of the camera is the responsibility of NOVA, in addition to a financial contribution to the procurement of the detector. The camera workpackage has been subcontracted by NOVA to ASTRON. Principal technical challenge of this camera is the fact that very large (17 cm diameter) lenses are involved, and that some of the lens materials (e.g., CaF_2) are very difficult to handle. A particular difficulty is the fact that during cooldown to operating temperature, the lenses do not shrink as much as the lens mounts. Hence a lens mount had to be developed that compensates for the difference in coefficient of thermal expansion. The camera workpackage (see Fig. 19) successfully passed its Preliminary Design Review in September 2002, and Final Design Review is scheduled for March 2003. Delivery of the camera to MPE for implementation in the SINFONI spectrograph is foreseen for the summer of 2003.

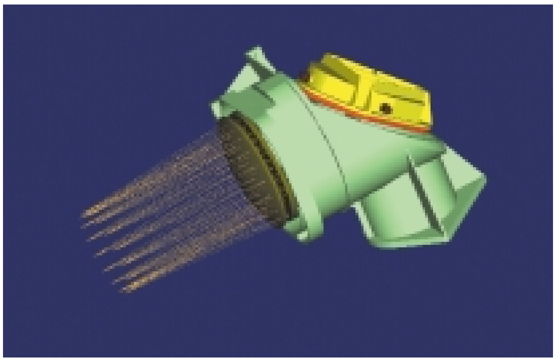


Fig. 19: CAD drawing of the SINFONI 2K camera.

5.8.2.2. Performance of laser guide star system adaptive optics

NOVA is developing a number of software components for SINFONI. Two of these components are related to adaptive optics and have a wider range of applicability than just SINFONI. This concerns the development and use of a simulation tool that analyses the performance of adaptive optics in the case of a laser guide star system. This tool takes into account the effects that are present with laser guide star adaptive optics but not with natural guide star adaptive optics. These effects include the upward travel of the laser beam through the turbulent atmosphere (affecting tip-tilt sensitivity), the cone effect (laser spot is not seen through the same column of air as the science target), the size of the laser spot (not a point source), the fact that the laser spot is not at infinity, etc. This workpackage is being carried out in Leiden by Brown (funded by NOVA from the SINFONI budget). By late 2002, the simulation tool was nearly finished. Further steps will include runs specifically tuned for SINFONI which will then be fed into the SINFONI performance model.

5.8.2.3. Adaptive optics point spread function reconstruction

The second NOVA-supplied software component is a package for reconstruction of the adaptive optics corrected point-spread-function based on the wavefront sensor data. The package will be able to handle three different wavefront sensor principles: the curvature sensor (as used in SINFONI), the Shack-Hartmann sensor (as used in NAOS-Conica) and the pyramid sensor (as used in MAD, the Multiconjugate Adaptive optics Demonstrator, currently under development at ESO). This workpackage is being carried out at ASTRON, under contract with NOVA, by Glazenborg (curvature and Shack-Hartmann sensors) and Rigal (pyramid sensor). B_γ late 2002 the reconstruction tool for the curvature sensor (which is needed for SINFONI) was essentially finished.

5.8.2.4. SINFONI performance analysis and commissioning

Finally, NOVA will supply manpower for assisting with SINFONI commissioning at Paranal and performance validation in Garching. Development of a SINFONI exposure time calculator (including the full effects of adaptive optics, as supplied by other NOVA-SINFONI work packages) will form part of the workpackage, which will start in 2003.

5.8.3. Scientific utilization of SINFONI

SINFONI is a mainstream instrument, catering to a large fraction of the NOVA scientific community. Therefore the use of guaranteed time will be coordinated by a NOVA-wide science team including astronomers from all NOVA institutes, and presently consisting of van der Werf (NOVA-PI for SINFONI, chair of the Science Team), Brown, Franx, van der Hulst, Kaper, Katgert, Lamers, Pel, Tolstoy and de Zeeuw. The science team will oversee all scientific aspects of the NOVA involvement in SINFONI. This will include establishing procedures for arriving at a coherent program for the Dutch guaranteed VLT time resulting from this project. In addition, the science team will provide input on the scientific specifications of instrument, requirements for software, etc. The amount of guaranteed time will be 19 nights.

5.8.4. Staff

Staff associated with SINFONI is located in Leiden and at ASTRON. At Leiden these are van der Werf (PI, project manager), Brown (laser guide star simulations), van Starkenburg (NOVA PhD, scientific utilization), Mengel (postdoc, now at ESO, SINFONI performance analysis), de Zeeuw, Katgert, Franx, Bakker (management team). Key personnel at ASTRON are: Pragt (2K camera project manager), Schoenmakers (optical design), Kroes (mechanical design), Elswijk (optical testing), Kragt (mechanical analysis), Glazenborg (PSF reconstruction) and Rigal (PSF reconstruction). The national SINFONI science team (listed above) consists of researchers from all NOVA institutes.

5.8.5. Strategic role of SINFONI

With the present computer power and deformable mirror and wavefront sensor techniques, rapid wavefront fluctuations can be analysed and corrected in real-time, producing at last seeing-limited data from ground-based telescopes. This technique has developed extremely rapidly. While 10 years ago adaptive optics was still something relatively exotic, it is now a mainstream, common-user technique. It is to be expected that in the near future all major telescopes will be equipped with common-user adaptive optics systems, and laser guide star systems to provide full sky coverage. These developments are so fast that adaptive optics forms an integral part (and not just an add-on) of the concept of new telescopes such as extremely large telescopes (30-100-m diameter), which will be equipped with multi-conjugate adaptive optics (MCAO) systems, which use more than one reference star, providing correction over a large field of view. Here the challenges are enormous: deformable mirrors with a large number of actuators, special-purpose detectors and novel correction algorithms (using Kalman filtering and the like) are required. The NOVA-SINFONI program builds up cutting-edge expertise in this very rapidly developing field, and play a significant role in the development path towards advanced adaptive optics on a future extremely large telescope.

In addition, integral field techniques are the state of the art in astronomical spectroscopy. The NOVA-SINFONI program builds on existing expertise in the Netherlands (heritage from SAURON and OASIS) and enhances this, but also looks ahead towards the future, where massive integral field spectrographs may become the first instruments on a new generation of extremely large telescopes. The SINFONI project thus solidly anchors adaptive optics and integral field spectroscopy in the astronomical community in the Netherlands as modern common-user techniques, and looks ahead towards the newest instrumental developments in optical and near-infrared astronomical observing.

5.9. MIRI

In late 2011, NASA and ESA will launch the successor to the Hubble Space Telescope (HST), the James Webb Space Telescope (JWST). The JWST is a passively cooled telescope that will be in a Sun-Earth Lagrange 2 Halo orbit. It will have a 6m primary mirror with diffraction-limited performance for $\lambda > 2$ μm with three scientific instruments: a 0.6 - 5 μm near-IR camera, a near-IR multi-object spectrometer (1 - 5 μm), and the Mid-InfraRed Instrument MIRI. JWST will have unprecedented sensitivity in the infrared, and will allow astronomers to study the birth of stars and planetary systems and probe the distant universe at an epoch when the first generation of stars were born.

MIRI will be three orders of magnitude more sensitive than any ground-based telescope in the 5 - 28 μm range, a large part of which (> 50 %) will be completely blocked by atmospheric features from the ground. Compared with SIRTF (the 85 cm NASA Space Infrared Telescope Facility to be launched in 2003), MIRI will have more than an order of magnitude increase in sensitivity and spatial resolution. Moreover, SIRTF will have only very low resolution spectroscopy $R= \lambda \backslash \Delta\lambda = 50 - 100$ in the important 5 - 10 μm range, and only R = 600 in the 10 - 38 μm range. Thus, MIRI will revolutionize the science to be performed in this poorly explored wavelength range.

In Summer 2001, NOVA astronomers van Dishoeck and Waters, together with Pel, de Graauw, Tielens, van der Werf and Quirrenbach, put forward a NOVA-led proposal for NWO-Groot funding for Dutch participation in MIRI, in particular the spectrometer part of the instrument. In summer 2002, NWO granted 5.765 M€ for this project, which together with a commitment of 1.5 M€ from NOVA and in-kind contributions from the universities brings the total budget to ~ 9 M€.

MIRI will be designed and built by a joint US/European consortium. Both partners contribute about equally, with the US having the overall lead. The scientific oversight occurs through the MIRI science team, led by George Rieke and containing 5 members from each continent. The PI for the European consortium, consisting of ~10 countries, is Gillian Wright (UK-ATC). The Dutch contribution is led by NOVA, with ASTRON and TPD as sub-contractors of NOVA. SRON has a consultancy role, and will provide support in the area of space qualified design, and PA/QA.

Since December 2001, the Dutch team has participated intensively in the phase A study of MIRI, especially in the design of the spectrometer part. In the baseline design, the spectrometer has four channels and four separate integral field units (IFUs) with a field of view of about 4"x4" and slices ranging from 0.2 - 0.6" each. A grating provides a spectral resolving power $\lambda\backslash\Delta\lambda$ of 1500 - 4000. The signal is recorded on two 1000x1000 pixel detectors. Three separate exposures are needed for full spectral coverage. The current design, in which instrument scientist Pel has played a major role, is described in detail in the phase A MIRI consortium study report, which was presented to ESA in September 2002. The phase A milestone was passed successfully. Phase B will start in mid-2003.

5.10. Light Scattering

Solid material or dust is ubiquitous in our solar system, and in interstellar space. The scattering properties of dust are an important diagnostic tool which contains essential information about the nature of the grains, such as composition, size and shape of the solid particles. Because numerical techniques alone are not adequate to simulate efficiently light scattering by particles with realistic shapes and internal structures, light scattering experiments are essential to determine the scattering properties of real particles. Such laboratory measurements were performed with the Light Scattering Experiment (LSE) in Amsterdam. LSE is a collaboration between the FOM-Institute AMOLF, UvA and NOVA. The apparatus is designed to measure the full (that is polarization resolved) scattering matrix of small particles, covering a scattering angle range from about 3° (near forward scattering) to about 174° (near backward scattering).

The LSE was moved from the VU to the AMOLF in February of 2001, where it was installed and several improvements to the hardware and software were made. In 2002 an elaborate measurements program was started, involving both atmospherically and astrophysically relevant samples including (1) measurements on seven volcanic ashes samples (collaboration with NASA), (2) two differently colored clay samples, and (3) Martian analog samples.

5.10.1. Martian analogs

The scattering matrix as a function of the scattering angle was measured at 633 nm for two Martian analog samples. One sample (provided by the NASA Ames Research Center) consists of palagonite material and has been used in previous Mars related research. The measured scattering matrix will be used to study Martian aerosols including their polarization. The other Martian analog sample (provided by Kharkov University, Ukraine) consists of hematite particles. Fig. 20 presents preliminary results for the palagonite and hematite samples. The data show the so called scattering function and the degree of linear polarization of the scattered light, when the light incident on airborne randomly oriented particles is unpolarized, as a function of the scattering angle. The figure shows that the two dust samples have quite different scattering patterns. The palagonite particles present a scattering function and a degree of linear polarization that are quite similar to those of terrestrial mineral aerosol particles. They have a scattering function that ranges over almost three orders of magnitude for the angles covered in the measurements, being strongly peaked towards smaller angles. The scattering function has a rather flat side-scattering and backscattering behavior. In contrast, the hematite scattering function is much less peaked at small angles and ranges over a little more than one order of magnitude for the angles covered. The degree of linear polarization of the palagonite sample shows a characteristic bell shape, and a negative branch for large scattering angles. Again, the hematite shows a quite different pattern, i.e., a rather low double maximum and no negative branch. The main cause of the differences in the scattering patterns of the micron-sized palagonite and hematite particles is probably the large difference in refractive index at visible wavelengths. From these considerable differences in scattering behavior between these two Martian analogs, it may be expected that their presence in the Martian atmosphere will have a sub-

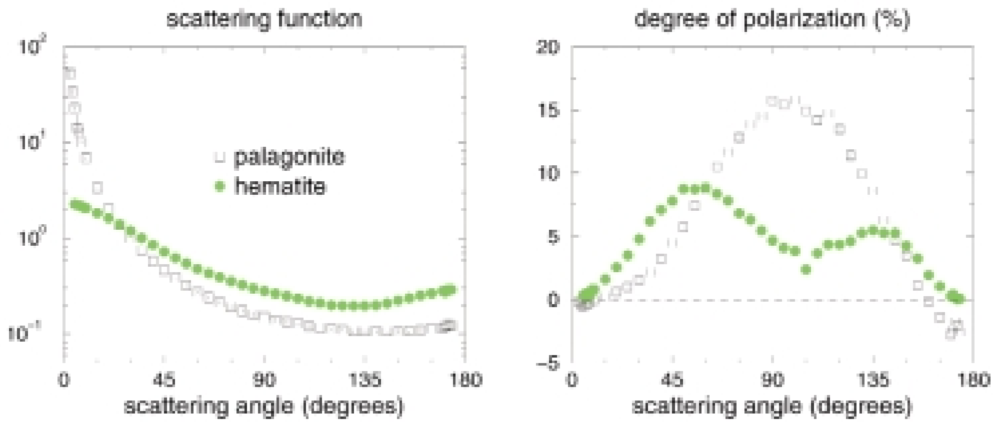


Fig. 20: Measurements of the scattering function and the degree of linear polarization as functions of the scattering angle for randomly oriented micron-sized dust particles of the Martian analogs palagonite and hematite at a wavelength 632.8 nm.The scattering function is normalized to unity at 30°. Experimental errors are shown by error bars or within the size of the symbols.

stantially different effect on the Martian weather and climate.

5.10.2. Cosmic dust analogs

Forsterite is known to occur widely in comets and around stars. Three cosmic dust analog forsterite samples were provided by Brucato (from the group of Colangeli, Naples). These samples are unique not just because of their composition but also because of their very well separated size distributions. Usually, small particles tend to stick to larger particles which makes it highly complicated to investigate the separate effect of larger particles on light scattering. In the astrophysical laboratory in Naples a sedimentation and washing technique was used in which the small particles are almost completely removed from the larger particles. Therefore, the measurements of the scattering matrices of these samples, performed at 633 nm, give a better insight in the effect of particle size on light scattering by these irregular particles than was ever possible before.

The discovery of exo-planets opens the exciting possibility to apply expertise on planetary atmospheres to those of exo-planets. Model calculations show that hot Jupiters may have 'clouds' consisting of olivines and other mineral particles. A large variety in atmospheric structure and composition is expected for giant as well as terrestrial exo-planets. Light scattering experiments are essential to properly interpret the brightness and polarization of solar system planetary atmospheres as well as exoplanetary observations. Stam has started to apply laboratory light scattering measurements to exoplanetary atmosphere models.

In collaboration with the group of Shkuratov (Ukraine), light scattering measurements were performed for dust on surfaces using the samples described above. For these samples both measurements of single light scattering as airborne particles and reflection of the same particles on surfaces are available. This provided insight in the origin of the phenomenon of 'negative polarization' observed for asteroids and planetary regoliths.

Min, Hovenier and de Koter carried out a theoretical study of the scattering and thermal infrared properties of small particles, in particular the effects of size and shape distributions on infrared spectral distributions. By careful analysis of different numerical techniques to calculate the absorption cross-section for randomly oriented particles of a given size and shape distribution, they were able to find accurate solutions for a wide range of parameters. These calculations were compared with infrared spectra of proto-planetary disks and to the infrared spectrum of the comet Hale-Bopp.

Liu, Mishchenko, Hovenier, Volten and Muñoz (visitor from University of Granada) studied ways to extrapolate the experimental phase function for quartz aerosols from 5° to 0° using the known refractive index, Mie theory and diffraction theory. Such an extrapolation makes it possible to employ the measurements for radiative transfer models.

5.11. NL involvement in studies for 2nd generation VLT instruments

In December 2001 ESO issued a call for proposals requesting proposals for 2nd generation VLT instruments with capabilities in the following areas:

1. cryogenic multi-object spectrometer in the 1-2.4 μm range (KMOS);
2. wide-field 3D optical spectrometer (now named MUSE);
3. medium resolution wide-band (0.32-2.4 μm)

spectrometer (X-shooter);
4. high-contrast, adaptive optics assisted, imager (planet finder).

Dutch groups are active partners in international consortia in competition for three of above mentioned instrument proposals: MUSE (single proposal in that field), X-shooter (single proposal in that field), and planet finder (two competing proposals, NL is partner in the CHEOPS consortium).

Phase-A studies for KMOS and X-shooter will be received by the ESO-SPC in the fall of 2003, and final decisions on these instruments by the ESO Council are expected by December 2003. MUSE and CHEOPS are expected to complete their phase-A studies in 2004, with final decisions by the ESO Council in late 2004.

Below a description is given of the projects with a Dutch involvement. NOVA seed funding is provided to carry out technical R&D and design studies, and to contribute to the phase-A work.

5.11.1. MUSE

MUSE (Multi Unit Spectroscopic Explorer) is a panoramic integral-field spectrograph for the wavelength range 0.5-1.0 µm with a 1′x1′ field of view, providing 90,000 simultaneous spectra with a spatial resolution between 0″.05 and 0″.2. An adaptive optics system will provide improved image quality so that MUSE is uniquely suited to study distant and nearby galaxies. The F-NL-UK-G-Swiss consortium (PI Bacon, Lyon) is developing innovative AO concepts, optimized for correction over a wide field-of-view and for operation at short wavelengths. The AO activity is led by the Leiden Group, with active participation of the Durham and ESO adaptive optics groups. Extensive simulation software is being used to compute accurate point-spread-functions which are input for realistic simulations of the expected instrument performance. NOVA PI is de Zeeuw.

5.11.2. CHEOPS

CHEOPS aims at the direct detection of faint planetary companions in the vicinity of bright stars, using high order AO in combination with polarimetric and spectral differencing techniques. The instrument is a dual conjugate AO system, aiming for very high Strehl ratios, restricting to 7-11 magnitude stars, and using the star itself as the phase reference, feeding a near-IR integral-field spectrograph plus a visible-light polarimeter. Detection feasibility is focussed on young, contracting planets (not the old hot-Jupiters where contrast is much lower). Longer-term objectives are the diagnostics of planetary atmospheres, including polarization signatures. Science case includes circumstellar matter (debris disks, etc). The project is a collaboration between MPIA (PI), Padua, ETH Zürich and NOVA. The Dutch contribution to the project is twofold: (1) Waters, Stam and Dominik perform physical studies of planetary atmospheres to determine scattering and thermal infrared emission properties of exo-planetary atmospheres; Quirrenbach and Stuik (NOVA postdoc) analyze the AO characteristics of spatial sampling and correction, temporal sampling and correction, scintillation, wavefront sensor cross talk and aliasing, AO closed-loop error propagation, wavefront sensor phase estimator, anisoplanatism, and overall tilt compensation performance. NOVA PI is Waters.

5.11.3. X-shooter

X-shooter is a very high efficiency medium-resolution spectrograph which covers the range 300-1900 nm in a single exposure; R=10,000 (max); >20 % efficiency targeted, with the objective of being a highly competitive instrument of choice; at Cassegrain at VLT (allows spectropolarimetry). The NL/DK/I/ESO consortium is one of the two groups selected by ESO to perform a feasibility study, to be completed in March 2003. The scientific motivation has a very broad scope, serving a large user community. The main NOVA scientific driver for this instrument is the study of the physical origin of gamma-ray bursts and the nature of their host galaxies, to study faint brown dwarfs, to identify the progenitors of Type Ia supernovae, to quantify the properties of high-z (lensed) galaxies, and to probe the structure of the intergalactic medium.

This project involves new, young, permanent staff at UvA (Kaper) and KUN (Groot) in instrumentation, in line with the overall NOVA strategy. Much of the technical work for X-shooter is carried out at ASTRON (near-IR arm, and overall integration), KUN (cryogenic enclosure), and UvA (data reduction software). NOVA PI is Kaper.

6. Personnel funded by NOVA

The tables in this chapter listed all research and technical support staff whose employment was - partially - funded through the NOVA program in 2001and 2002.

NOVA funded Astronomical Research

Project	Title	Project leader	Univ	Researcher	Yrs	Start	End	Remarks
Network #1								
10.10.1.01	Radio galaxies at high redshift	Miley	UL	Drs. Bram Venemans	4.0	Oct 1, 2000		
10.10.1.02	Gas through the galaxy formation epoch	de Bruyn	RuG	Dr. Nissim Kanekar	2.0	Mar 1, 2002		
10.10.1.03.1	Mass distribution of galaxies from weak lensing	Kuijken	RuG	Drs. Fabrice Christen	2.0	Sep 12, 2000	Sep 12, 2002	a
10.10.1.03.2	Mass distribution of galaxies from weak lensing	Franx	UL	Drs. Arjen van der Wel	2.0	Sep 1, 2001		a
10.10.1.04	Nuclei of elliptical galaxies	de Zeeuw/ Jaffe/Kuijken	UL	Drs. Davor Krajnovic	4,0	Sep 1, 2000		
10.10.1.05	Structure and evolution of elliptical galaxies	de Zeeuw/Franx	UL	Drs. Glenn van de Ven	2.0	Oct 1, 2001		a
10.10.1.06	Triggered star formation in nearby mergers	Lamers/Icke	UU	Drs. Nathan Bastian	4.0	Mar 1, 2001		
10.10.1.07	Galaxy formation and evolution	Kuijken	RuG	Dr. Annette Ferguson	3.0	Dec 1, 2000		
10.10.1.08.1	Network postdoc position	Miley	UL	Dr. Richard Wilman	1.0	Mar 1, 2001	Mar 1, 2002	b
10.10.1.08.2	Network postdoc position	De Zeeuw	UL	Dr. Yannick Copin	0.1	Mar 1, 2001	Apr 1, 2001	b
10.10.1.09	Network postdoc position	Kuijken	RuG	Dr. Andrew Cole	2.0	Sep 23, 2002		
10.10.1.10	Network postdoc position	Lamers	UU	Dr. Amina Helmi	1.2	Jul 1, 2002	Sep 1, 2003	d
10.10.1.11	Triggered star formation in interacting galaxies	Lamers	UU	Drs. Mark Gieles	1.0	Nov 1, 2002		
10.10.1.12	Network postdoc position	Miley	UL	Dr. Tracy Webb	2.0	Sep 1, 2002		
Network #2								
10.10.2.01	Interaction of Young Stellar Objects with their environment	Tielens	RuG	Drs. Stephanie Cazaux	4.0	Nov 1, 1999		
10.10.2.02	Studies of complex organic molecules	van Dishoeck	UL	Dr. Pascale Ehrenfreund	2.0	Jul 1, 1999	Jul 1, 2001	d
10.10.2.03	Structure and formation of circumstellar disks	van Dishoeck	UL	Drs. Jes Jørgensen	4.0	Nov 1, 2000		
10.10.2.04	Formation of the most massive stars in the Galaxy	Kaper/Waters	UvA	Drs. Arjan Bik	4.0	May 1, 2000		
10.10.2.05.1	Evolution of gas/dust ratio in circumstellar disks	van Dishoeck	UL	Drs. Klaus Pontoppidan	4.0	Nov 1, 2000		
10.10.2.06	Solid-state features in circumstellar disks	Waters	UvA	Drs. Roy van Boekel (50%)	4.0	May 1, 2000		c
10.10.2.08	Physics and chemistry of AGB outflows	Tielens	RuG	Dr. Marco Spaans	2.0	Sep 1, 2000	Sep 1, 2002	d
10.10.2.09	Radiative transfer models of atmospheres of evolved stars	Waters	UvA	Drs. Rien Dijkstra	4.0	Jul 1, 2000		
10.10.2.10	Stellar population studies of AGB stars	Habing	UL	Drs. Maria Messineo	4.0	Nov 1, 1999		
10.10.2.11	Search for large carbonaceous molecules in space	Ehrenfreund/ Kaper/ Spaans	UL	Drs. Nick Cox	2.0	May 1, 2002		
10.10.2.13.1	Deuterium fractionation in regions of star formation	Tielens	RuG	Dr. Jacquie Keane	0.3	Mar 1, 2002	May 15, 2002	
Network #3								
10.10.3.02	Radio pulsar studies using PuMa on the WSRT	Van der Klis	UvA	Drs. Stephane Jouteux	1.9	Oct 1, 1999	Sept 1, 2001	
10.10.3.02	Radio pulsar studies using PuMa on the WSRT	Van der Klis	UvA	Drs. Patrick Weltevreden	4.1	Dec 1, 2002		
10.10.3.03.1	Evolution of neutron stars	Verbunt	UU	Drs. Marc van der Sluys	4.0	Sep 1, 2001		
10.10.3.03.2	Evolution of neutron stars	Verbunt	UU	Dr. Jerry Orosz	0.2	Jul 1, 2002	Sep 1, 2002	
10.10.3.04.1	Neutron stars & black holes	Van der Klis	UvA	Drs. Andrea Tiengo	0.9	Jan 15, 2002	Dec 15, 2002	
10.10.3.04.2	Neutron stars & black holes	van der Klis	UvA	Dr. Tiziana di Salvo	2.0	Mar 1, 2002		
10.10.3.05	Massive X-ray binaries with XMM-Newton, Chandra and VLT	van den Heuvel	UvA	Drs. Arjen van der Meer	4.0	Dec 1, 2000		
10.10.3.06	Physics of ultra-relativistic shocks	Achterberg	UU	Drs. Jorrit Wiersma	4.0	Feb 1, 2001		
10.10.3.07	Pulsar wind & pulsar emission	Achterberg/ Kuijpers	UU	Dr. Sushan Konar	2.0	Jun 1, 2002		
10.10.3.08	Binary population synthesis	Verbunt/ van den Heuvel	UU	Dr. Jean in 't Zand	2.8	Sep 1, 2002		
10.10.3.9	Jets from neutron stars in X-ray binaries	Fender	UvA	Drs. Elena Gallo	4.0	Sep 1, 2001		

Project	Title	Project leader	Univ	Researcher	Yrs	Start	End	Remarks
Miscellaneous projects								
10.50.02	Postdoc NOVA Director	De Zeeuw	UL	Dr. Michele Cappellari	3.5	Mar 1, 2001		e
10.50.03	PhD student NOVA Chair	Van den Heuvel/ Henrichs	UvA	Drs. Roald Schnerr	1.3	Dec 1, 2002		
10.50.04	Research stimulation at KUN (Nijmegen)	Kuijpers	KUN	Drs. Joachim Moortgat	3.0	Jan 1, 2002		
Overlap appointments		**Overlap with**						
10.20.3.01	Laboratory astrophysics	Baas	UL	Dr. Willem Schutte 50%	3.3	Jan 1, 1999		
10.20.4.01	Evolution of massive stars	Kuperus	UU	Prof. Norbert Langer	4.8	Jan 1, 2000		
10.20.2.01	Evolution of galaxies	Van Albada	RuG	Prof. Penny Sackett	0.8	Apr 1, 2001	Dec 31, 2001	
10.20.1.01	Birth and death of stars	Van den Heuvel	UvA	Prof. Rens Waters	4.5	Jan 1, 2001		
10.20.3.02	Optical-infrared instrumentation	Miley	UL	Prof. Andreas Quirrenbach	2.8	Sep 1, 2002		
10.20.4.02	Infrared-radio astronomy	Nieuwenhuizen	UU	Dr. Onno Pols	4.5	Sep 1, 2001		

Remarks

a. Additional 2 years funding is guaranteed by the university.
b. NOVA funding is additional to an EU grant.
c. Additional 2 years funding through ESO PhD fellowship.
d. Received permanent university staff position after end of NOVA funding.
e. NOVA funding is additional to an ESA fellowship.

Instrumentation Program

Project/job description	Project leader	Inst	Researcher	Yrs	Start	End
ALMA R&D mixers						
Project manager	van Dishoeck	RuG	Dr. Wolfgang Wild	3.1	May 1, 1999	Jun 1, 2002
Project manager	van Dishoeck	SRON	Dr. Wolfgang Wild (20%)	0.6	Jun 1, 2002	Dec 31, 2002
Mixer scientist	Wild	RuG	Dr. Andrey Baryshev	5.2	Nov 15, 1999	
Receiver physicist	Wild	RuG	Dr. Ronald Hesper	4.3	Sep 1, 2000	
Technical support	Wild	RuG	Gerrit Gerlofsma	3.3	Oct 10, 2001	
Junction scientist	Klapwijk	TuD	Dr. Tony Zijlstra (50%)	4.4	Sep 1, 2000	
Junction engineer	Klapwijk	TuD	Mark Zuiddam (50%)	4.4	Sep 1, 2000	
Technical PhD student	Klapwijk	TuD	F.E. Meijer (50%)	4.0	Apr 1, 2001	
NEVEC						
Technical astronomer	Miley/Quirrenbach	UL	Dr. Isabelle Percheron	3.4	Sep 1, 1999	Feb 1, 2003
Technical astronomer	Miley/Quirrenbach	UL	Dr. Jeff Meisner	4.0	Sep 1, 1999	
Physicist/project manager	Miley/Quirrenbach	UL	Dr. Eric Bakker	4.3	Oct 1, 2000	
Software engineer	Miley/Quirrenbach	UL	Dr. Jeroen de Jong (50%)	5.0	Feb 1st, 2000	
OmegaCam						
Calibration software scientist	Kuijken	RuG	Dr. Edwin Valentijn	5.8	Apr 1, 1999	
Programmer calibration software	Kuijken	RuG	Danny Boxhoorn	5.8	Apr 1, 1999	
Programmer database and pipeline software	Deul	UL	Dr. Roeland Rengelink	5.3	Oct 1, 1999	
PuMa						
Science postdoc	Van der Klis	UvA	Dr. Russell Edwards	3.0	Apr 1, 2001	
Sackler Laboratory for Astrophysics						
Technical PhD student	van Dishoeck	UL	Drs. Fleur van Broekhuizen	4.0	Oct 1, 2000	
Postdoc	van Dishoeck	UL	Dr. Helen Fraser	3.3	May 1, 2000	
Postdoc	van Dishoeck	UL	Dr. Pascale Ehrenfreund	1.0	July 1, 2001	
SINFONI						
WP1: PSF reconstruction	Van der Werf	ASTRON	Annelie Glazenborg	2.0	Apr 1, 2002	
WP2: AO performance simulation	Van der Werf	UL	Dr. Antony Brown	3.6	Apr 1, 2001	
Emission line studies of high-z galaxies	Van der Werf	UL	Drs. Lottie van Starkenburg	3.0	Sep 1, 2002	
Seed funding projects						
AO for MUSE and CHEOPS	Quirrenbach	UL	Dr. Remco Stuik	1.0	Dec 1, 2002	

7. Workshops & Visitors

The NOVA workshops & visitors program enables researchers to invite foreign experts to the Netherlands for collaborative projects.

7.1. Workshops in 2001-2002

The table below lists the workshops which received financial support from NOVA. The table is followed by a description of each meeting. In addition the university astronomical departments in Amsterdam, Groningen, Leiden and Utrecht received NOVA funding up to 3400 € per institute per year to strengthen the local colloquium program through inviting more foreign speakers. A common approach is to co-ordinate the colloquium programs in various places in such a way that foreign speakers visit two or more institutes during their stay in the Netherlands.

	Organizer	Subject	Location	Duration In days	Start 2001
W-16	Tielens	Interstellar silicates	UL/Lorentz	5	17/04/01
W-17	Icke	Dutch astrophysics day	UL/Lorentz	2	01/03/01
W-18	vd Heuvel, Kaper	From X-ray binaries to GRBs	UvA	3	06/06/01
W-19	Schutte	From interstellar dust to comets	UL	1	17/09/01
W-20	Tielens	HIFI/Herschel science workshop	UL/Lorentz	4	16/10/01
W-21	van Woerden	NVWS centenary celebration	Netherlands	1	22/09/01
W-23	Miley, Katgert	Variety is the spice of life	UL	2	29/11/01
					2002
W-22	van der Kruit	Evolution of galaxies	RuG	1	19/03/02
W-24	Röttgering	XMM - large scale structure survey	UL/Lorentz	3	08/01/02
W-25	Fender	Circular polarization from relativistic jets	UvA	3	17/07/02
W-26	Mellema	Dutch astrophysics days	UL/Lorentz	2	13/04/02
W-27	Jarvis, Röttgering	High redshift radio galaxies	UL/Lorentz	5	11/11/02
W-28	Katgert	Oort workshop on astronomical surveys	UL	2	17/06/02
W-30	van der Klis	Pulsar emission physics	UvA	3	27/05/02
W-31	Lamers	Teachers day on astronomy	UU	1	25/11/02
W-32	Portegies Zwart	MODEST-2 workshop	UvA	5	16/12/02
W-33	Romers	Astrophysics symposium Delft	TU Delft	1	03/12/02

W-16: Interstellar silicates

This workshop brought together 37 scientists from 9 different countries. The aim of the meeting was to bring together scientists involved in all aspects of studies of interstellar silicates. The central theme throughout this meeting was to confront laboratory studies and theory with the most recent observations as obtained with the Short Wavelength Spectrometer (SWS) on board of the Infrared Space Observatory (ISO). SWS provided for the first time a complete inventory of interstellar dust and the interpretation and analysis of this data has dramatically altered our understanding of the origin and evolution of the dusty universe. The participants of the workshop reviewed the widespread occurrence of crystalline silicates in regions around protostars, newly formed from interstellar material, and stars in the latest stages of their evolution which return much of their mass to the interstellar medium.

W-17: Dutch Astrophysics Days 2001

Icke initiated an annual 2-days meeting focussing on theoretical astrophysical research carried out in the Netherlands. The Dutch Astrophysics Days want to be a forum to exchange ideas, inform each other about ongoing research, to hold brainstorm sessions about outstanding theoretical challenges, and have a 'free software swap'. The meeting, held on 1-2 March 2001, was attended by about 20 participants.

W-18: From X-ray binaries to Gamma-Ray Bursts

The program of this memorial symposium concentrated on a number of themes, to which Jan van Paradijs made valuable contributions: (1) black holes in binary systems; (2) neutron stars and their formation events; (3) white dwarfs in binary systems, and (4) various aspects of gamma-ray bursts.

In the last decades our understanding of neutron stars and black holes has improved dramatically driven by the wealth of data produced by spaceborn and ground-based telescopes. Jan van Paradijs made major scientific contributions to the study of compact stars in X-ray binaries, and in establishing the places of origin and the physical properties of gamma-ray bursts. 125 astronomers attended this symposium held at Amsterdam (6-8 June 2001) to honor their colleague and friend. The program also gave room to discuss recent results, such as the discovery of a massive 14 $M_\odot$ black hole in the close binary system GRB 1915+16), new developments in the area of quasi-periodic oscillations (in disks around neutron stars in low mass x-ray binaries), and the latest news in the field of gamma-ray bursts.

W-19: From interstellar dust to comets

The symposium featured 11 international speakers, giving presentations on subjects covering the entire life cycle of interstellar dust up to its incorporation in comets. Apart from review talks, new developments were discussed. These discussions were exceptional for their constructive and open, exploratory character. This symposium, held to celebrate Mayo Greenberg's 80th birthday, was an excellent meeting among scientists and friends in many aspects, where the warm personal contact made a fruitful and relaxed scientific exchange possible.

W-20: HIFI/Herschel science workshops

Herschel is ESA's fourth cornerstone science mission to be launched in 2007. It will study the universe in the far-infrared and submillimeter part of the spectrum. SRON is the PI institute for the heterodyne instrument, HIFI. The purpose of this workshop was to specify the observing program to be carried out during the guaranteed observing time for the HIFI consortium. The meeting, held on 16-19 October 2001, was attended by 32 participants from 10 countries involved in HIFI. The guaranteed time observing program will cover the following science areas: star formation, stellar evolution, interstellar medium and extragalactic observations.

W-21: NVWS centenary celebration

On 22 September 2001 the Dutch amateur astronomical society 'Nederlandse Verening voor Weeren Sterrenkunde (NVWS) celebrated its 100th anniversary in Ede with a one day symposium on 'Evolution of the universe'. About 350 members and guests attended the meeting. Queen Beatrix of the Netherlands was one of the honorary guests. Invited speakers included Kuijken (formation and evolution of galaxies), and van Dishoeck (birth and evolution of stars, planets, and life).

W-22: Tjeerd van Albada emeritus Symposium 'evolution of galaxies from high redshift to the present'

On the occasion of Tjeerd van Albada's 65th birthday one symposium and two workshops were held in Groningen. The symposium, held on 19 March 2002, on the evolution of galaxies from high redshifts to the present, attended by 80 participants, was concluded with Van Albada's farewell lecture. Several speakers addressed observational studies of stellar populations in nearby galaxies, evolution of the Fundamental Plane and the mass-to-light ratio of elliptical galaxies, as well as computational work on formation and evolution of structure in the universe, and dynamics of spiral and elliptical galaxies.

Van de Weygaert organized the workshop 'tracing the emergence of structure in the universe' held on 14-15 March 2002 with 23 speakers and 40 participants. The second workshop titled 'The evolution of the Local Group' was organized by Tolstoy and Ferguson. This meeting on 20 March had 11 speakers and 40 participants.

W-23: Harry van der Laan emeritus symposium 'variety is the spice for life'

A two day symposium was held on 29-30 November 2001 on the occasion of the 65th birthday of Harry van der Laan. The first day of the symposium was dedicated to current astronomical research with addresses by several colleagues, especially from places that Harry has been closely involved with, such as Leiden, Cambridge, and Dwingeloo. On the second day, van der Laan's policy and managerial interests were addressed in a session on 'other challenges in astronomy, science and society'.

W-24: XMM - large scale structure survey

The consortium that carries out the XMM-LSS survey met at the Lorentz Center in Leiden on 8-10 January 2002. Each of the participating institutes was present with a small delegation. A wide area survey is carried out with XMM-Newton with the aim of mapping the large scale structure (LSS) of the universe up to a redshift of z~1 as traced by clusters and quasars: the XMM-LSS survey. This X-ray survey is done in parallel with an extensive follow-up program of radio, optical and IR observations, making use of state-of-the-art observational facilities. In this meeting the first results from the XMM survey were discussed. Other topics of the meeting included: (1) the status of the observing and funding proposals submitted, (2) activities of the working groups and of the general organization, (3) review and discussion of the methods used for reduction of the X-ray data, (4) planning of further XMM-Newton, optical and radio observations, (5) collaboration with SIRTF survey SWIRE.

W25: Circular polarization from relativistic jets

On 17-19 July 2002 Fender organized a workshop at the Astronomical Institute 'Anton Pannekoek', UvA, on the subject of 'Circular polarization from relativistic jet sources'. The meeting addressed both observations and techniques as well as theoretical interpretation of this phenomena, which holds the tantalizing promise of distinguishing between baryonic (e-:p+) or 'antimatter' (e-:e+) jets from active galactic nuclei and micro-quasars. The workshop attracted 35 attendees from around the world, and was a great success. The proceedings, to be published by Kluwer (editors Fender and Macquart), are expected to appear in 2003.

W-26: Dutch Astrophysics Day 2002

The second Dutch Astrophysics day (see W-17 for the first one) was organized by Mellema on 3-4 April 2002. There were 22 participants from all university astronomical institutes in the Netherlands, as well as from the FOM Institute for Plasma Physics at Rijnhuizen. The program reflected the wide interest of the Dutch astrophysical community. Some time was scheduled for discussion on collaboration and contacts between the different theoretical groups.

W-27: High redshift radio galaxies

About 50 participants from Australia, Canada, France, Germany, the Netherlands, UK and the USA attended this workshop held in the Lorentz Center in Leiden on 11-15 November 2002. The meeting showed that the understanding of radio galaxies has made huge steps forward over the last 3-5 years. Studies on wider cosmological questions, like the ability to trace large scale structure in the universe, became feasible using radio galaxies as beacons. Another example is the ability to probe the masses of black holes in powerful galactic nuclei. New simulations were also presented in which the structure of radio sources could be explained.

W-28: Oort workshop on 'astronomical surveys'

At the initiative of the Oort hoogleraar 2002, Prof. J.E. Gunn (Princeton University), one of the initiators of the Sloan Digital Sky Survey (SDSS), a workshop on 'astronomical surveys' was held in Leiden on 17-18 June 2002. Results and progress reports from several survey programs, like 2dF, SDSS, Canadian Galactic Plane survey, and Lyman-break galaxies, were discussed together with new instrumental concepts like GMOS, VIMOS, ACS, Virtual Observatory, OmegaCAM, LOFAR and GAIA.

W-30: Pulsar emission physics

In this meeting, held in Amsterdam on 27-29 May, 2002, the first results from a joint European pulsar observing program were discussed and assessed. From January 2002 onwards, six major observatories - WSRT (NL), Effelsberg (Ger) Jodrell Bank (UK), Kalyazin (Russia), PRAO (Russia) and UTR-2 (Ukraine) -carried out high precision polarimetric observations simultaneously at different frequencies ranging from 35 MHz to 5 GHz. 30 pulsars were carefully selected and observed. The prime aim of the study is to construct a detailed library of high-quality polarimetric observations at a wide range of frequencies to unravel the physical mechanism that produces the radio emission from pulsars. The meeting was a good mixture of talks based on recent high quality observational results, and new insights into the physics of the problem of pulsar emission mechanism and the propagation effects in the pulsar magnetosphere. Some time was devoted to technical issues concerning a common data library, such as data formats, polarization calibration, flux calibration, and time alignment of observations between all the observatories taking part in this observing program.

W-31: Teachers day on astronomy

On 25 November 2002 about 130 high school teachers in physics and mathematics attended a one day educational program, held in Utrecht, to update their knowledge on astronomy. The course was organized by the NOVA Minnaert Committee, and the NOVA-NCA Education Committee. In the morning three lectures were given on our Solar system dealing with formation, evolution, life on other planets, and greenhouse processes. In the afternoon six parallel workshops were held to develop school programs using expertise from various disciplines varying from astronomy, physics, chemistry to biology. Presentations given by the lecturers and programs developed during the afternoon were collected and copied on CD-rom to be distributed among the participants and to be mailed to high schools in the Netherlands.

W-32: MODEST-2 workshop

MOdeling DEnse STellar systems (MODEST) aims to bring a number of experts from the fields of stellar dynamics and stellar evolution together, to discuss and coordinate efforts toward realistic simulations of star clusters. This workshop, organized by Portegies Zwart and Hut (IAS, Princeton) attracted some 30 participants from various fields of astronomy and computational science. Speakers outlined how their work fits in the MODEST collaboration, what the most relevant issues are for their area, or what they had accomplished since the previous MODEST meeting in the Summer of 2002. Furthermore, the present and future of the MODEST collaboration was discussed and further workshops and meetings planned (up to MODEST-7 in August 2005).

W-33: Astrophysics symposium at Technical University Delft

As part of the celebration of its 14th lustrum the 'Vereniging voor Technische Physica' at the Technical University in Delft organized a one-day symposium on astrophysics on 3 December 2002. The meeting exposed students in technical physics to recent discoveries and challenging new developments in astronomy.

7.2. Visitors in 2001 - 2002

The table in this section lists the foreign visitors who received financial support from NOVA to visit the Netherlands for collaborative projects with NOVA researchers. The table is followed by a description of each activity.

	Host	Visitors	Location	Duration	Start 2001
V-13	Van den Heuvel	Prof.dr. J. Rankin	UvA	5 m	01/02/01
V-14	Langer	Dr. D. Lennon	UU	1 m	01/05/01
V-15	Van der Klis	Dr. A. Lommen	UvA	2 w	18/01/01
V-16	Fender	Dr. H. Falcke, Dr. S. Markoff	UvA	2 d	01/03/01
V-17	Röttgering	Dr. W. de Vries	ASTRON	3 m	01/04/01
V-18	Fender	Dr. R. Hynes	UvA	1 w	02/05/01
V-19	Barthel	Dr. C. Dullemond	RuG	4 d	23/05/01
V-20	van den Heuvel	Dr. L. Yungelson	UvA	1 m	09/05/01
V-21	Fender	Drs. C. Brocksopp	UvA	9 d	05/06/01
V-22	de Bruyn	Dr. J. Dennett-Thorpe	RuG	2 m	15/06/01
V-23	Röttgering	Dr. A. Cohen	UL	1 m	10/06/01
V-24	Fender	Drs. G. McCormick	UvA	4 w	01/09/01
V-25	Lamers	Dr. T. Nugis	UU	1 m	01/09/01
V-27	van Albada	Dr. R. Swaters	RuG	1 w	03/09/01
V-28	Habing	Dr. P. Whitelock	UL	1 w	16/09/01
V-29	Henrichs	Dr. S. Jankov	UvA	1 m	19/09/01
V-30	Tolstoy	Dr. A. Cole	RuG/UL	1 w	20/09/01
V-31	Franx	Dr. C. Papovich	UL	4 d	21/02/01
V-32	Fender	Dr. S. Markoff	UvA	6 d	05/11/01
V-33	de Koter	Dr. J.S. Vink	UvA	1 w	17/10/01
V-34	van den Heuvel	Dr. L. Yungelson	UvA	2 m	13/12/01
					2002
V-36	Portegies Zwart	Dr. D. Pooley	UvA	1 m	28/05/02
V-37	Portegies Zwart	Dr. M. Fellhauer	UvA	2 d	16/05/02
V-38	van der Klis	Dr. P. Reig	UvA	8 d	18/05/02
V-39	van den Heuvel	Dr. L. Yungelson	UvA	6 w	11/10/02
V-40	de Zeeuw	Prof. K. Gebhardt	UL	1 w	01/08/02
V-42	de Zeeuw	Prof. H. Morrison, Dr. P. Harding	UL	1 m	18/06/02
V-44	Waters	Dr. S. Kurtz	UvA	8 d	01/11/02
V-46	Portegies Zwart	Prof.dr. S. McMillan	UvA	1 w	22/09/02
V-47	Fender	Dr. T. Maccarone	UvA	1 w	01/11/02

V-13: Visit of Prof. J. Rankin

The aim of Rankin's (University of Vermont, USA) visit was to strengthen the calibration of pulsar polarization measurements using the WSRT and the PuMa pulsar-backend. She collaborated with various scientists at the Anton Pannekoek Astronomical Institute, which proved most valuable and stimulating for the pulsar research in the Netherlands. This visit stimulated an international observing program for pulsars reported about in W30 (section 7.1). She completed several papers on the emission mechanism and geometry for the pulsar B0809+74, together with van Leeuwen, Stappers and Ramachandran, and on an empirical theory on pulsar emission describing the spectral behavior of conal beam radii and emission heights, together with Mitra (MPIfR, Bonn).

V-14: Visit of Dr. D. Lennon

Lennon (ING, La Palma) collaborated with Langer (NOVA overlap) to analyze published results on the carbon and nitrogen abundances in B-type stars. Evidence was found for what appears to be a bi-model behavior of the carbon to nitrogen abundance ratio in the sample. These observational data were compared with Langer's stellar evolution models which include rotational mixing that might explain these results. An alternative scenario that binarity might play a role can't be ruled out, at least for some systems. Exchange of observational and theoretical information further showed that the distribution of rotational velocities in the B-star sample was a feature that had been largely ignored in all interpretations of these results.

V-15: Visit of Dr. A. Lommen

Lommen (University of California at Berkeley, USA) collaborated with Stappers and Ramachandran in a search for shape-changes in PSR J1713+0747 by comparing data from both WSRT and the Arecibo Telescope. Such changes have been observed in PSR J1022+1001 and the issue is whether or not they are present in all millisecond pulsars such as these. If detected, the shape-changes would explain some of the observed pulse arrival time jitter seen in PSR J1713+0747. No significant pulse-shape changes were detected, but the collaboration is continuing between Stappers and Lommen in other respects as Lommen visited the University of Amsterdam for 11 months in 2002 as a Canadian funded NRC postdoctoral fellow.

V-16: Visit of Dr. H. Falcke and Dr. S. Markoff

Falcke and Markoff (both MPIfR, Bonn) worked with Fender to complete a paper on the theoretical interpretation of hard X-rays from accreting black holes as arising directly from relativistic jets. Pursuing this line of investigation they were able to fit the entire broadband spectrum of one black hole X-ray binary source, XTE J1118+480, over eleven decades in energy (far more comprehensive than any other attempted modeling of spectral states in galactic X-ray binaries). The next step in their collaboration is an attempt to model other similar spectra as jet-dominated systems to test the applicability of the model which, if correct, will have far-reaching consequences for our understanding of accretion around black holes.

V-17: Visit of Dr. W. de Vries

de Vries (Livermore National Laboratory, USA) visited Dwingeloo and Leiden to collaborate with Morganti, Vermeulen, Röttgering, Jarvis and Wilman (NOVA postdoc) to reduce WSRT data for the Bootes Field (16x12 hours observations at 20 cm). Combined with deep surveys with the NOAO-4m, SIRTF, VLA at 90 cm for the vast majority of 5000 radio sources their photometric redshift will be determined, as well as galaxy type, level of star formation activity, (cluster?-) environment and dust content. This will allow for decisive studies of the radio spectral index properties and the evolution of the optical/IR spectral energy distributions, including the K - z diagram, of low luminosity radio galaxies out to high redshifts without steep spectrum radio selection. Study of even higher redshift/luminosity radio sources will allow to define the evolution of the radio luminosity function at $z \approx 4$ and to constrain the currently much disputed redshift cut-off.

V-18: Visit of Dr. R. Hynes

Hynes (University of Southampton, UK) visited Fender and O'Brien in Amsterdam to jointly model HST and RXTE timing data on the enigmatic black hole binary XTE J1118+480. These simultaneous data allow the measurement of an X-ray flare and its delayed echo in the ultraviolet, and hence probe the binary geometry using the light travel delays. This field of 'echo mapping' is one in which O'Brien is an expert and his code to model the predicted delays made it possible to test which geometries can account for the observed ultraviolet response. The most obvious model in which the echoes come from the accretion disc around the black hole was eliminated, a result that was not expected before the visit. Other possibilities were explored. These included delayed ultraviolet emission from the jet which is likely formed in this system.

V-19: Visit of Dr. C. Dullemond

Dullemond (MPA - München) visited the Kapteyn Institute to collaborate with PhD student van Bemmel and Barthel to model dust tori around cores of active galactic nuclei. Dullemond's numerical code for dust disks around young stars was used and adapted for the new circumstances.

V-20, V-34 and V39: Visit of Dr. L. Yungelson

Yungelson (Russian Academy of Science), an expert on (double) star evolution and the formation of compact objects, visited Amsterdam three times in 2001-2002 to work on joint projects with van den Heuvel, Portegies Zwart, and PhD students Nelemans and Dewi. In one of the projects gravitational wave signals were calculated for a population of compact binaries in our Galaxy. It was shown that at frequencies below 2 mHz the double white dwarf population forms an unresolved background for the low-frequency gravitational wave detector LISA. Above this limit some few thousand double white dwarfs and few tens of binaries containing neutron stars will be resolved. Of the resolved double white dwarfs ~500 have a total mass above the Chandrasekhar limit. The visits resulted in a number of joint publications.

V-21: Visit of Drs. C. Brocksopp

Brocksopp (John Moores University, Liverpool, UK) collaborated with Rob Fender on multi-wavelength observations of the black hole X-ray binaries. A thesis chapter on the radio orbital modulation of Cyg X-1 was written. For the source XTE J1748-288 new radio data were discussed and similarities with the previously studied XTE J1859+226 were found. The joint work on GS 1354-64 (paper published) and XTE J1859+226 (paper submitted) has led to two follow-up papers.

V-22: Visit of Dr. J. Dennett-Thorpe

Dennett-Thorpe (UK) collaborated with de Bruyn to complete two papers on the scintillating quasar J1819+3845. During the last two years they collected unique observational results using the WSRT on the causes of extremely fast interstellar scintillation. This project combines elements of high-temperature AGN physics with anisotropic turbulence theory of very local (about 10-20 pc) fast-moving plasma and has excited specialists around the world.

V-23: Visit of Dr. A. Cohen

Cohen (Naval Research Laboratory, Washington, USA) worked with Röttgering on the low frequency radio counterpart to the XMM-Newton large Scale Structure Survey. Over 200 radio sources at both 325 MHz and 74 MHz were observed to study the evolution of radio sources. A paper was written on this subject. Future comparison of these data to upcoming X-ray and optical images of the same regions will shed light on the nature of the environments in which cosmological radio sources form. This will result in further joint publications and observing proposals. Cohen also participated in various discussions on LOFAR.

V-24: Visit of Dr. G. McCormick

McCormick (Jodrell Bank, UK) worked with Fender on the interpretation of an extensive radio data set of the galactic jet source SS 433. The specific aim was to measure in detail how the circularly polarized component of the emission varies with the angle of the jets to the line of sight. Together they visited ASTRON to work with de Bruyn on the reduction and analysis of the obtained WSRT data.

V-25: Visit of Dr. T. Nugis

Nugis (Tartu Observatory, Estonia) is a specialist in radiative transfer and the structure of winds of Wolf-Rayet (WR) stars. He visited Utrecht to work with Lamers on an explanation of the high mass loss rates of WR stars by radiation driven 'optically thick' stellar winds. Similar models were already proposed for Novae-winds, but were not properly developed for WR winds.

V-27: Visit of Dr. R. Swaters

Swaters (Johns Hopkins University, Baltimore, USA) collaborated with van Albada and other members of the WHISP team to prepare the publication of the WSRT 21 cm line data. The WHISP project aims to study the kinematics and HI distribution in near low surface brightness galaxies.

V-28: Visit of Dr. P. Whitelock

Whitelock (SAAO, Cape Town, South Africa) visited Leiden to discuss with Habing and Messineo (NOVA PhD student) various options to proceed with further studies of Asymptotic Giant Branch stars, especially those that are found in the Magellanic Clouds. The discussions were fruitful and helped to specify better the goals for the PhD research project of Messineo.

V-29: Visit of Dr. S. Jankov

Jankov (University of Beograd, Serbia), an expert on the analysis of spectra of pulsating massive stars, collaborated with Henrichs and Neiner to understand the σ Ori data obtained during the MUSICOS 1998 observational campaign. The data consisted of 249 high signal to noise ratio and high-resolution spectra taken with 8 telescopes. In particular, the He

I 4471, 4713, 4921, 5876, 6678, CII 4267, Mg II 4481 and Si III 4553 Å lines have been analyzed. This work resulted in a substantial contribution to Neiner's PhD thesis on pulsation, rotation, wind and magnetic field in early B-type stars pulsating Be stars.

V-30: Visit of Dr. A. Cole

Cole (Univ. of Massachusetts, USA) visited Groningen to collaborate with Tolstoy to finish a paper on deep HST imaging of the galaxy IC 1613. Aim of the joint project is to study the history of star formation in this object.

V-31: Visit of Dr. C. Papovich

Dr. Papovich visited Leiden Observatory to work with Franx and other staff members on HST data recently obtained with the Advanced Camera for Surveys.

V-32: Visit of Dr. S. Markoff

Markoff (MPIfR) visited Fender in Amsterdam to continue their collaboration on the interpretation of jets in X-ray binaries. They developed a broadband jet model for the low/hard X-ray state in which it turned out that the X-ray power law may in fact be optically thin synchrotron emission. In order to develop the model further, and to gain a better insight into model parameters, the model needs to be applied to as many sources as possible. This will be much easier if the model were represented as either an analytic or table format. During this visit such models were completed to enable other collaborators to apply the model to more data sets.

V-33: visit of Dr. J.S. Vink

Vink (Imperial College, London) visited de Koter (UvA) to continue their ongoing collaboration to predict the mass loss behavior of Luminous Blue Variable stars. Their approach is to predict mass loss rates by radiation pressure on ionic lines using a Monte Carlo formalism to describe the radiation process. This approach allows to describe mass loss rates as function of stellar parameters like effective temperature, elemental abundance, and stellar mass.

V-36: Visit of Dr. D. Pooley

Pooley visited Portegies Zwart to continue their joint project on the origin of bright X-ray point sources in the Galactic star cluster NGC 3603. In a paper on a similar cluster (R136) in the LMC, Portegies Zwart, Pooley and Lewin predicted that NGC 3603 would contain a large number of bright X-ray sources. During the visit recent Chandra data on NGC 3603 was analyzed. The study revealed that the X-ray emission was resolved into dozens of discrete point sources. Optical data from the HST archive and infrared VLT observations were used to identify the nature of each of the discrete sources. They concluded that NGC 3603 is almost identical to the LMC cluster R136, with the exception that the former is not perturbed by the external field of the Galaxy.

V-37: Visit of Dr. M. Fellhauer

The dynamics of various astrophysical systems is influenced by dynamical friction. In particular recent observations of young star clusters near the Galactic center (within the inner pc), a place much too hostile to form these objects, give rise to the question, how efficient dynamical friction can drag these objects, which have formed outside the center, to the place they are located now within their short lifetime. Fellhauer (Institut für Theoretische Physik und Astrophysik, Kiel) worked with Portegies Zwart and collaborators to determine the exact Coulomb Logarithm for the Galactic Center to apply the result into the dynamical friction formula first developed by Chandrasekhar.

V-38: Visit of Dr. P. Reig

The purpose of the visit of Reig (University of Crete) was to perform X-ray data analysis on the low-mass X-ray binary Aquila X-1 as part of a collaborative project between Amsterdam, Utrecht and the University of Crete. Previously Reig and van der Klis had shown that Aquila X-1 is an atoll source. However, recently it was suggested that the classification of LMXB as Atoll and Z sources is a selection effect due to incomplete sampling. Special software developed at the UvA was applied to public RXTE observations to investigate the true nature of Aquila X-1.

V-40: Visit of Dr. K. Gebhardt

Gebhardt (University of Texas at Austin) visited Leiden to discuss recent work on black hole masses derived for a number of nearby galaxies. Observational results obtained by Gebhardt's group were compared with results from dynamical modeling calculations carried out in de Zeeuw's group, with specific attention to the robustness of the inferred black hole masses and the inferred internal orbital structure for galaxies and for globular clusters.

V-41: Invited speakers for the National Astronomers Conference

This NOVA grant was to invite Mayor (University of Geneva) and Leibundgut (ESO) to give review talks at the Dutch National Astronomers Conference.

V-42: Visit of Prof. H. Morrison and Dr. P. Harding

Morrison and Harding (both Case Western University, USA) spent a month of their sabbatical leave in Leiden to discuss issues on the formation, structure and evolution of the Galaxy, with emphasis on the galactic halo. Morrison is the PI of the so-called Spaghetti Collaboration which carries out significant survey of halo substructure, and contains Mateo, Freeman, Helmi and others as team members. They also visited the Kapteyn Institute and the Astronomical Institute at Utrecht (to work with Helmi).

V-44: Visit of Dr. S. Kurtz

Kurtz (IA-UNAM, Mexico) visited Amsterdam to discuss issues relating to the formation of massive stars with Waters and his group. The idea was to bring together observers studying massive star forming regions in the near-IR and in the radio. Observations at these very different wavelength regions give complementary information and can be used to probe the early evolution of massive stars. A collaboration was planned to use the VLA and VISIR to study of hyper-compact HII regions.

V-46: Visit of Dr. S. McMillan

McMillan (Drexel University, Philadelphia, USA) collaborated with Portegies Zwart to study the inspiral and internal evolution of dense star clusters near the Galactic center. These clusters sink toward the center due to dynamical friction with the stellar background, and may go into core collapse before being disrupted by the Galactic tidal field. If a cluster reaches core collapse before disruption, its dense core, which has become rich in massive stars, may survive to reach close to the Galactic center. When it eventually dissolves, the cluster deposits a disproportionate number of massive stars in the innermost parsec of the Galactic nucleus. Their numerical results show that only star clusters with initial masses ~10^5 $M_\odot$ can reach the Galactic center from an initial distance of ~60 pc within one initial relaxation time or a few million years, whichever is smaller.

V-47: Visit of Dr. T. Maccarone

Maccarone (SISSA, Italy) visited Fender to work on the disc-jet coupling in X-ray binaries and its possible relation to the same property in active galactic nuclei.

8. NOVA Information Center (NIC)

Popularization of astronomy is an excellent vehicle for stimulating interest in the natural sciences in general, which is of great importance at a time when the interest in university studies in some of these disciplines is declining. In the second and third year of NICs existence, various long term projects conceived during the first year, 2000, came to fruition. All target groups (the media, school students, the general public, astronomers) show increasing awareness of these outreach activities. NICs efforts in 2001-2002 were more or less evenly divided between producing multimedia material, press releases to the media and organizing special events.

NIC staff (1.1 fte) remained unchanged: Jaspers (0.6 fte) and Visser (0.5 fte). Actual working time available, however, slightly decreased in 2002 when Visser started to make use of an arrangement for seniors to reduce their real working hours.

8.1. Special events

NIC co-organized or participated in the following outreach-events:

- VISIR/MIDI media-presentation, Dwingeloo, with ASTRON (April 2001);
- VLT contest, for school students, in collaboration with the amateur astronomical society in the Netherlands KNVWS (Koninklijke Nederlandse Vereniging voor Weer- en Sterrenkunde), and sponsored by KLM and Algemeen Dagblad (August 2001); Marcel Haas won 2 hours VLT time to observe two globular clusters (M22 and NGC6441) containing a planetary nebula. This event received major publicity in newspapers and on TV;
- Life in the Universe, school competition about extraterrestrial life, in collaboration with ESO and financially supported by NWO (October 2001);
- Wide Angle on the Universe, Groningen, a media presentation on OmegaCAM, Astro-Wise and ALMA, in collaboration with the Kapteyn-institute (March 2002);
- Nederlandse Astronomen Conferentie 2002. 'Focussing on Infinity', conference talk and plenary discussion on outreach and public relations, Lunteren (May 2002);
- Teachers' conference, Utrecht, in collaboration with NAC, to develop educational material on astronomy for general science teachers (November 2002);
- Beta-festival, at NEMO in Amsterdam, in collaboration with the public relations department of the University of Amsterdam. Master classes for talented school students (December 2002).

8.2. Astronomical press service & Astro-newsletter

Press releases to the media via the NIC electronic news service named 'Astronomische Persdienst, AP' became more frequent in 2001, concurrent with an increasing stream of information from within the Dutch astronomical community. Through this channel NIC informed the media 11 times in 2001, 19 times in 2002 (not counting simple 'forwards' from KNVWS, ASTRON and SRON). Some press releases were issued in close consultation with outreach offices of ESO and other international organizations when appropriate.
In a number of cases the press releases received prime media attention, for instance at national TV stations and national newspapers (VPRO Noorderlicht and many other national media on the VLT-contest, RTL-news on 'baby-galaxies').
Starting in June 2002, NIC set up an Astro-newsletter (by email) for general science teachers at secondary schools, keeping them up to date about relevant astronomical and outreach events. At the end of 2002 it had close to a hundred subscribers.

8.3. Web site and CD-rom

Construction of the NIC web site www.astronomy.nl, which started in 2000, was essentially completed by the end of 2001. It features an overview of Dutch astronomy (especially the NOVA research program) for the general public, astronomical news, 'Ask a question' service by e-mail, upcoming events and a 'Tour of the Universe'. The Tour is a highly visual, popular scientific introduction to modern astronomy, loosely based on the 'powers of ten' principle.

In 2002 this Tour was put on CD-rom, with substantial extra material (newspaper articles and lectures on astronomy). 3000 copies were made for distribution to schools, teachers and as hand-outs at special events. Stichting Weten co-financed 50% of the 'Tour'.
The NIC web site attracts an increasing number of visitors, from typically 750/month in 2000, 1,000/month in 2001 to 3000/month in 2002. Each 'session' in the statistics is counted as one visitor; typical number of 'hits' increased from ~10,000 to ~30,000 per month.

8.4. Promotion/education material

NIC assisted in producing the educational folder for general science (Algemene Natuurwetenschap, ANW) teachers at secondary schools. A portable NOVA display (2x3 m, 12 exchangeable panels) was designed and constructed, and is now routinely used as 'eye-catcher' at numerous public events.

A full color poster (80x50 cm, 3000 copies) was designed, produced and distributed to schools for promoting the web site and the Tour of the Universe.
A Cosmic Roulette was designed and constructed. It is a hands-on 'pin ball' machine that allows children (if not adults) to send comets and near earth asteroids into the solar system. Even when not yet fully operational (at the 'Open Day' of the Leiden Observatory during the national Science Week) it proved irresistible for 2- to 12-year olds.

8.5. Other activities

NIC was involved in the following ad-hoc activities:
Design, lay-out, last correction and printing of the NCA-NOVA-NWO strategic plan for astronomy entitled 'Astronomy in the Netherlands' (October 2001);
Consultancy and support for the SRON-exhibition 'Wat een ruimte', held at the Utrecht University Museum to mark the 40^{th} anniversary of SRON (June 2002);
Workshop for astronomy-students at the University of Amsterdam on 'journalism and science outreach as a career-opportunity';
Arranging a display of meteorites at the universities of Amsterdam and Leiden at the occasion of the National Science Week (October 2002);
Contribution to the GENIE/DARWIN workshop (June 2002, Leiden) and redesigning the NEVEC-web site;
Representation of NOVA (large display and various outreach materials) at the 5th anniversary of the Science Museum NEMO in Amsterdam (June 2002), at the 2002 KNVWS-symposium in Groningen, at the NVON teachers' conference in Amsterdam (March 2002), and at the NAC 2001 in Dalfsen.

9. Organization

9.1. Board

Prof.dr. E.P.J. van den Heuvel (chair)	UvA	
Prof.dr. P.C. van der Kruit (vice-chair)	RuG	
Prof.dr. A. Achterberg	UU, till March 2002	
Prof.dr. F. Verbunt	UU, since March 2002	
Prof.dr. G.K. Miley	UL	
Prof.dr. J. Kuijpers	KUN, since September 2002	
Prof.dr. H.R. Butcher (observer)	ASTRON	
Prof.dr. J.A.M. Bleeker (observer)	SRON	
Prof.dr. H.J. Habing (observer)	NCA	

9.2. International Advisory Board

Prof.dr. J.N. Bahcall (chair)	IAS, Princeton, USA
Prof.dr. R. Ekers	ATNF, Epping, Australia
Prof.dr. K.C. Freeman	ANU, Canberra, Australia
Prof.dr. M.J. Rees	IoA, Cambridge, UK
Prof.dr. F. Shu	National Tsing Hua university, Taiwan
Prof.dr. R. Sunyaev	MPA, Garching, Germany

9.3. Key Researchers

Prof.dr. A. Achterberg	UU
Prof.dr. F. Briggs	RuG, till May 2002
Prof.dr. E.F. van Dishoeck	UL
Prof.dr. M. Franx	UL
Prof.dr. H.J. Habing	UL, till December 2002
Prof.dr. M. van der Klis	UvA
Prof.dr. K. Kuijken	UL
Prof.dr. H.J.G.L.M. Lamers	UU
Prof.dr. N. Langer	UU
Prof.dr. G.K. Miley	UL
Prof.dr. A.G.G.M. Tielens	RuG/SRON
Prof.dr. F. Verbunt	UU
Prof.dr. L.B.F.M. Waters	UvA

9.4. Coordinators research networks

Prof.dr. K.H. Kuijken	UL	Network 1
Prof.dr. E.F. van Dishoeck	UL	Network 2
Prof.dr. M. van der Klis	UvA	Network 3

9.5. Instrument Principal Investigators

Dr. W. Wild	RuG/SRON	ALMA mixer till Dec 2002
Drs. A. Baryshev	RuG	ALMA mixer since Dec 2002
Dr. R.J. Rutten	UU	DOT
Prof.dr. L.B.F.M. Waters	UvA	MIDI
Prof.dr. G.K. Miley	UL	NEVEC till September 2002
Prof.dr. A. Quirrenbach	UL	NEVEC, since September 2002
Prof.dr. K.H. Kuijken	UL/RuG	OmegaCAM
Prof.dr. M. van der Klis	UvA	PuMa-2
Dr. P.P. van der Werf	UL	SINFONI
Prof.dr. E.F. van Dishoeck	UL	Sackler Lab
Prof.dr. E.F. van Dishoeck	UL	MIRI
Prof.dr. L.B.F.M. Waters	UvA	MIRI

9.6. Instrument Steering Committee

Prof.dr. M.A.C. Perryman (chair)	ESA/UL
Ir. A. van Ardenne	ASTRON
Prof.dr. M. Franx	UL
Dr. M.W.M. de Graauw	SRON
Dr. P. Groot	KUN, since July 2002
Prof.dr. M. van der Klis	UvA
Prof.dr. K. Kuijken	UL, since July 2002
Prof.dr. G. Monnet	ESO
Dr. J.W. Pel	RuG
Prof.dr. A. Quirrenbach	UL, since September 2002
Dr. R.J. Rutten	UU
Dr. R.G.M. Rutten	ING, La Palma, Spain
Dr. E. Tolstoy	RuG, since July 2002

9.7. Phase-2 Instrumentation Advisory Committee

Members of the Instrument Steering Committee plus

Dr. R. Fender	UvA
Prof.dr. H.J. Habing	UL
Prof.dr. J.M. van der Hulst	RuG
Dr. A. de Koter	UvA
Dr. P.P. van der Werf	UL
Dr. J. in 't Zand	SRON

9.8. Education Committee

Dr. P.D. Barthel (chair)	RuG
Dr. G.J. Savonije	UvA
Prof.dr. V. Icke	UL
Prof.dr. J. Kuijpers (secretary)	KUN
Dr. R.J. Rutten	UL
Dr. H.J. van Langevelde	JIVE
Drs. E.K. Verolme	UL, PhD student
Drs. C. Dijkstra	UvA, PhD student
G. Janssen	UU, student
L. Vermaas	RuG, student

9.9. Minnaert Committee

Prof.dr. H.J.G.L.M. Lamers (chair)	UU
Dr. P.D. Barthel	RuG
Prof.dr. V. Icke	UL
Dr. A. de Koter	UvA
Dr. P. Groot	KUN

9.10. NOVA Information Center (NIC)

A. Jaspers	NOVA
Jac. Visser	UvA/NOVA

9.11. Office

Prof.dr. P.T. de Zeeuw (director)	UL
Dr. W. Boland (deputy director)	NOVA
R.T.A. Witmer (finance and control)	UL
M.A. Zaal (management assistant)	NOVA

10. Financial report 2001 - 2002

In €	2001	2002
ASTRONOMICAL RESEARCH		
Overlap Appointments	**440**	**449**
Research Funding		
Network Galaxy Formation & Evolution	297	442
Network Birth & Death of stars	348	346
Network Final Stages of Stellar Evolution	113	309
Other research	61	37
Workshop and Visitors	29	55
Total Research Funding	**848**	**1189**
TOTAL ASTRONOMICAL RESEARCH	**1288**	**1638**
INSTRUMENTATION		
ALMA mixer development	452	398
DOT	42	42
VLTI (MIDI, NEVEC)	249	532
OmegaCam	417	450
PUMA - 2	339	76
Sackler Laboratory for Astrophysics	257	301
SINFONI	55	199
New Initiatives	0	61
TOTAL INSTRUMENTATION	**1811**	**2057**
OVERHEAD		
NOVA Office	85	154
Outreach	37	90
TOTAL OVERHEAD	**122**	**244**
TOTAL EXPENDITURE	**3221**	**3938**
TOTAL GRANT	**3409**	**4260**
EXTERNAL FUNDING	**225**	**303**
PREFINANCING/REPAYMENT	**– 412**	**– 624**

11. List of abbreviations

A&A	Astronomy and Astrophysics (European journal)
ACS	Advanced Camera for Surveys on HST
AGB	Asymptotic Giant Branch
AGN	Active Galactic Nuclei
AIV	Assembly, Integration and Verification
ALMA	Atacama Large Millimeter Array
AMBER	Astronomical Multiple Beam Recombiner
ANU	Australian National University
ANW	Algemene Natuurwetenschappen
AO	Adaptive Optics
APEX	ALMA Pathfinder EXperiment
ASTRON	Stichting Astronomisch Onderzoek in Nederland (Netherlands Foundation for Research in Astronomy)
ASTRO-WISE	Astronomical Wide-field Imaging System for Europe
AT	Auxiliary Telescope
ATNF	Australia Telescope National Facility
AU	Astronomical Unit
BH	Black Hole
Caltech	California Institute of Technology
CCD	Charge-Coupled Device
CITA	Canadian Institute for Theoretical Astrophysics
CMD	Color Magnitude Diagram
CNRS	Centre National de la Recherche Scientifique
CRYOPAD	Cryogenic Photoproduct Analysis Device
DIB	Diffuse Interstellar Band
DIMES	Delft Institute of Microelectronics and Submicron Technology
DJAST	Dutch Joint Aperture Syntheses Team
DOT	Dutch Open Telescope
DSP	Digital signal processor
ESA	European Space Agency
ESO	European Southern Observatory
ESTEC	European Space Research & Technology Center
FDR	Final Design Review
FIRES	Faint InfraRed Extragalactic Survey
FNWI	UvA Fac. voor Natuurkunde, Wiskunde en Informatie
FP	Fundamental plane
GAIA	ESA's cornerstone 6 mission
GENIE	Ground based demonstrator for DARWIN on the VLTI
GHz	GigaHerz
GMOS	Gemini Multi Object Spectrograph
GPP	General Purpose Processors
GRACE	European Gamma Ray Collaboration at ESO
GRAPE	Special purpose computer
GRB	Gamma-Ray Burst
GREGOR	Open Solar Telescope on Tenerife
GTO	Guaranteed Time Observing
HI	Hydrogen 21 cm line
HIFI	Heterodyne Instrument for the Far-Infrared for HSO
HSO	Herschel Space Observatory, ESA's cornerstone 4 mission
HST	Hubble Space Telescope
IAP	Institut d' Astrophysique, Paris
IAS	Institute for Advanced Study, Princeton
ICAPS	Interactions of Cosmic and Atmospheric Particle Systems
IF	Intermediate Frequency
ING	Isaac Newton Group (of the Roque de los Muchachos Observatory on La Palma)

INT	Isaac Newton Telescope (part of ING)
IoA	Institute of Astronomy, University of Cambridge, UK
IRAM	Institut de RadioAstronomie Millimetrique
IRAS	InfraRed Astronomical Satellite
IRSI/Darwin	Infrared Space Interferometer
ISAAC	Infrared Spectrometer And Array Camera
ISM	Interstellar Medium
ISO	Infrared Space Observatory
ISOCAM	Infrared Space Observatory - Infrared Array Camera
ISOGAL	Mid Infrared Survey of the Inner Galaxy with ISO
ISS	International Space Station
JCMT	James Clerk Maxwell Telescope (on Mauna Kea, Hawaii)
JHU	Johns Hopkins University
JIVE	Joint Institute for VLBI in Europe
JWST	James Webb Space Telescope, successor of HST
KNAW	Koninklijke Nederlandse Academie van Wetenschappen (Royal Academy of Arts and Sciences)
KUN	Katholieke Universiteit Nijmegen (Catholic University Nijmegen)
LGS	Laser Guide Star
LISA	Laser Interferometer Space Antenna
LLNL	Lawrence Livermore National Laboratories
LOFAR	LOw Frequency ARray, proposal for giant radio telescope
LSS	Large Scale Structure
LWS	Long Wavelength Spectrometer
MAD	Multiconjugate Adaptive optics Demonstrator
MCAO	Multi-conjugate adaptive optics
MFO	Multi frequency observations
MIDI	Mid-Infrared Interferometry Instrument for ESO's VLTI
MIRI	Mid-InfraRed Instrument for the JWST
MIT	Massachusetts Institute of Technology
MODEST	Modeling Dense Stellar Systems
MPA	Max Planck Institut für Astrophysik (Garching)
MPE	Max Planck Institut für Extra Terrestrische Physik (Garching)
MPI	Max Planck Institut
MPIA	Max Planck Institut für Astronomie (Heidelberg)
MPIfR	Max Planck Institut für Radioastronomie (Bonn)
MRAO	Mullard Radio Astronomy Observatory, Cambridge UK
NAOS-Conica	Nasmyth Adaptive Optics System - Near Infrared Imager and Spectrograph (VLT)
NASA	National Aeronautics and Space Administration (USA)
NATO	North Atlantic Treaty Organization
NCA	Nederlands Comité Astronomie
NEVEC	NOVA-ESO VLTI Expertise Center
NGST	Next Generation Space Telescope, now JWST
NIC	Nova Information Center
NIR	Near InfraRed
NIVR	Nederlands Instituut voor Vliegtuigontwikkeling en Ruimtevaart (Netherlands Agency for Aerospace Programmes)
NOT	Nordic Optical Telescope, La Palma
NOVA	Nederlandse Onderzoekschool Voor Astronomie (Netherlands Research School for Astronomy)
NRAO	National Radio Astronomy Observatory (USA)
NRC	National Research Council, Canada
NTT	(ESO) New Technology Telescope

NWO	Nederlandse organisatie voor Wetenschappelijk Onderzoek (Netherlands Organization for Scientific Research)
OASIS	Integral Field Spectrograph for the WHT
OCW	(Ministerie van) Onderwijs, Cultuur en Wetenschappen (Ministry for Education, Culture and Science)
OmegaCAM	Wide-field camera for the VLT Survey Telescope
OmegaCen	OmegaCAM data center
OVRO	Owens Valley Radio Observatory, California, USA
PAH	Polycyclic Aromatic Hydrocarbon
PCRT	Partial Coherence Recovery Technique
PI	Principal Investigator
PNS	Planetary Nebula Spectrograph
PRAO	Pushchino Radio Astronomy Observatory (Russia)
PRIMA	Phase Referenced Imaging and Micro-arcsecond Astrometry
PSF	Point Spread Function
PuMa	PUlsar MAchine (for the WSRT)
PWNe	Pulsar Wind Nebulae
QO	Quasi Optical
QPO	Quasi Periodic Oscillation
R&D	Research and Development
RuG	Rijksuniversiteit Groningen (University of Groningen)
RXTE	Rossi X-ray Timing Explorer
SARA	Computing and Networking Services based at the University of Amsterdam
SAURON	Spectrographic Areal Unit for Research on Optical Nebulae
SAX	Satellite per Astronomia in Raggi X
SCUBA	Submillimeter Common User Bolometer Array (on JCMT)
SDSS	Sloan Digital Sky Survey
SFR	Star Formation Rate
SINFONI	Single Faint Object Near-infrared Investigation
SIRTF	Space InfraRed Telescope Facility
SIS	Superconductor-Insulator-Superconductor
SISSA	International School for Advanced Studies, Trieste, Italy
SPIFFI	Spectrometer for Infrared Faint Field Imaging (VLT)
SRON	Stichting Ruimte-Onderzoek Nederland (Space Research Organization in the Netherlands)
STIS	Space Telescope Imaging Spectrograph
STScI	Space Telescope Science Institute
SURFRESIDE	Surface Reaction Simulation Device
SWAS	Submillimeter Wave Astronomy Satellite
SWIRE	The SIRTF Wide area InfraRed Extragalactic Survey
SWS	Short Wavelength Spectrometer
TIMMI2	ESO's Thermal Infrared Multimode Instrument on the 3.6 m telescope at La Silla, Chile
TMR	Training and Mobility of Researchers
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Research Institute for Applied Physics)
TNO-TPD	TNO - Technisch Fysische Dienst (Institute for Applied Physics and Technology)
TUD	Technische Universiteit Delft (Technical University Delft)
UC	University of California
UCSD	University of California at San Diego
UL	Universiteit Leiden (Leiden University)
ULIRGs	Ultra-luminous Infrared Galaxies
UTs	Unit Telescopes of VLT
UU	Universiteit Utrecht (Utrecht University)
UV	Ultra Violet
UvA	Universiteit van Amsterdam (University of Amsterdam)
VIMOS	VIsible MultiObject Spectrograph on VLT
VINCI	VLT INterferometer Commissioning Instrument
VISIR	VLT Imager and Spectrometer for the mid-Infrared
VLA	Very Large Array (USA)
VLT	Very Large Telescope (ESO)
VLTI	Very Large Telescope Interferometer (ESO)
VST	VLT Survey Telescope
WG	Wave Guide
WHISP	WSRT HI survey of irregular and SPiral galaxies
WHT	William Herschel Telescope (part of ING)
WSRT	Westerbork Synthesis Radio Telescope
YSOs	Young Stellar Objects
XMM	X-ray Multi-mirror spectroscopy Mission