VISION 2025

NETHERLANDS RESEARCH SCHOOL FOR ASTRONOMY

Leadership in Global Astronomy

NOVA Vision 2025

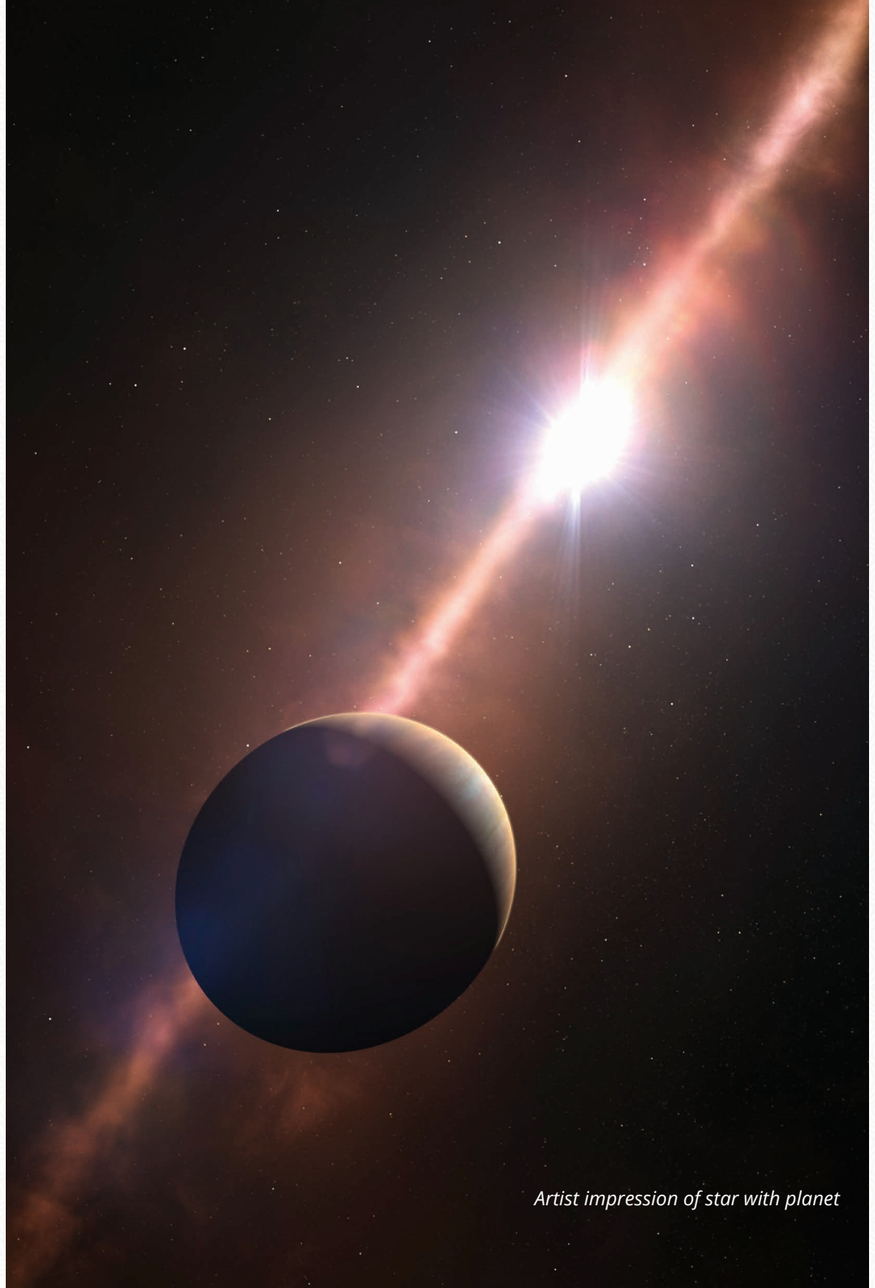
NOVA (the Netherlands Research School for Astronomy) is the alliance of the four university astronomy institutes in the Netherlands, at the University of Amsterdam, University of Groningen, Leiden University and Radboud University.

Universiteit van Amsterdam

rijksuniversiteit groningen

Universiteit Leiden

Radboud Universiteit



Artist impression of star with planet

Top Astronomy = Top Talent + Top Instrumentation

Summary

The Netherlands Research School for Astronomy, NOVA, coordinates Dutch university research, instrumentation, PhD education and outreach activities in a coherent national program.

NOVA is of the highest international quality, rated 'exemplary' by recent international reviews. NOVA's goals for 2025 are to ensure a globally leading role in the next generation of astronomical discoveries and facilities, in particular related to the Extremely Large Telescope of the European Southern Observatory, and to create an environment that attracts the most talented students and keeps the best astronomers in the Netherlands. Its combined multidisciplinary research and instrumentation program will maximize Dutch scientific exploitation of new world-class observatories and capitalize on the investments made by the Dutch government. Because time scales for astronomical projects are long, typically 15-25 yr, NOVA needs to be able to carry out strategic planning and make long-term commitments to international partners. Its program therefore requires financial stability.

NOVA works closely with high-tech industry to develop new technologies and to stimulate spin-offs that benefit societal challenges. It trains PhD students in a wide variety of high-level skills, nurtures talent, engages children in the natural sciences, and enthusiastically shares new discoveries about our Universe with the general public. NOVA serves as a pilot for a new type of national institute that enables university participation in flagship international projects with a 'lean and mean' organization.

Optical image of the Ophiuchus star-forming region

1. Astronomy

Astronomy is a unique discipline that combines top science, cutting-edge technology and education, while inspiring and exciting the general public. Discoveries in astronomy continue at an amazing pace. Close to home, a surprising variety of planets circling nearby stars have been found, with characteristics very different from those in our own Solar System. The dusty birthplaces of stars and planets, and perhaps even life itself, are being revealed with new facilities. Mergers of dying stars may be at the origin of some of the most powerful explosions in the Universe. Galaxies, including our own Milky Way, have been found to host black holes with masses millions times that of the Sun. Galaxies are now detected at the edge of the visible Universe from where radiation took 13 billion years to reach the Earth.Remarkably, visible objects comprise only 5% of the Universe, with the remaining 95% consisting of mysterious dark matter and dark energy that leave no directly observable trace and whose nature is not understood.

Astronomers study phenomena involving gigantic scales of length and mass (the entire Universe), huge densities (neutron stars), enormous gravitational fields (black holes), ultra-high vacuums (interstellar space), and immense energies and intense fluxes of particles and radiation (gamma-ray bursts and supernovae). The desire and curiosity to understand our fascinating Universe is shared between astronomers and the general public, and astronomy presents an excellent vehicle to enhance appreciation for the natural sciences and technology in children and students [1].

Because astronomical signals are extremely weak, astronomy is a driver for the development of advanced technology, such as the most sensitive detectors for electro-magnetic radiation and the fastest computers processing big data streams. Strong national and international collaboration allows the construction of large telescopes and satellites that lead to exciting discoveries. NOVA, the Netherlands Research School for Astronomy, coordinates Dutch university research, instrumentation, education and outreach into a coherent program and is the Dutch link to the European Southern Observatory (ESO), co-founded by the Netherlands.

This document presents the longer-term vision for NOVA. It complements the 2011-2020 national Strategic Plan for Astronomy in the Netherlands [2] and also addresses broader issues than frontline academic research. It highlights the importance of astronomy in education at all ages and stresses the close ties of astronomy with industry and technology, as well as its contributions to global societal challenges.

NOVA Quality

NOVA is of the highest international quality, comparable to that of top US and UK universities (Harvard, Princeton, Cambridge). Its instrumentation program is of the same scope as that of a Max Planck Institute.

Objective measures of the NOVA quality include:

- Excellent and exemplary status in consecutive top-research school evaluations
- High-profile staff, including six Spinoza prize laureates, three KNAW Academy professors, nine ERC-Advanced Grants and one ERC-Synergy Grant
- Top quality PhD students, with the Netherlands ranked number one in the number of US postdoctoral prize-fellowship recipients (per capita).

ESO and E-ELT

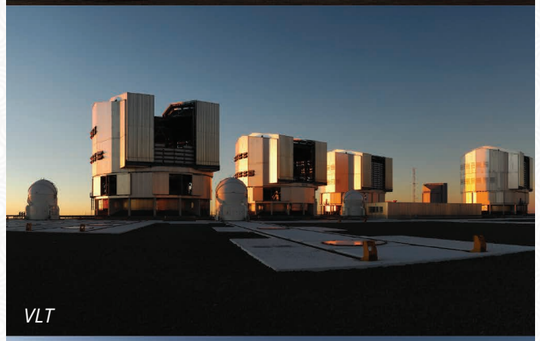
The European Southern Observatory, ESO, is an intergovernmental organization of 16 countries, currently led by a Dutch Director General. It builds and operates the most advanced ground-based telescopes in the world, located in Chile, with headquarters in Germany. Its facilities include the Very Large Telescope, the European share in the Atacama Large Millimeter Array (ALMA), and the future European Extremely Large Telescope (E-ELT), which is under construction with first light expected in 2024 [3]. ESO telescopes are a feat of high-tech engineering, combining state-of-the-art technology and the need to operate in a remote, hostile high altitude desert environment.

The E-ELT with its 39-meter main mirror will be the most powerful telescope in the world. It will allow scientific breakthroughs in virtually all areas of astronomy, from our own solar system to the edge of the Universe. Specifically, the E-ELT will allow the discovery and characterization of Earth-like exoplanets, one of the main areas of future Dutch research. In addition, the E-ELT will be key for probing the physics of the Universe at the time when the first stars were formed, studying the nature of the mysterious dark energy, and for reconstructing the formation history of nearby galaxies by resolving them into individual stars.

The NOVA instrumentation program contributes significantly to the E-ELT in a 20 year plan: NOVA has the prestigious role of Principal Investigator for the mid-infrared imager and spectrometer METIS and is involved in an additional 3 out of 7 foreseen E-ELT instruments. Dutch industry is directly involved in the E-ELT infrastructure and is an essential partner in the NOVA instrumentation program.

La Silla Observatory

ALMA



VLT

E-ELT artist impression

2. NOVA and the link with ESO

NOVA is the alliance of the four university astronomy institutes in the Netherlands: in Amsterdam, Groningen, Leiden and Nijmegen. NOVA's mission is excellence in astronomical research and education according to the highest international standards. To achieve its mission, NOVA designs and builds frontline instrumentation, in particular for ESO, thereby maximizing the scientific return and impact of major telescopes for a relatively modest investment. Internationally NOVA is unparalleled: no other country has managed to combine all of its university astronomy research into a single national program.

NOVA has chosen three research areas to focus on, combined in the coherent and collaborative program 'The life cycle of stars and galaxies: from the dawn of time to the present'. These are

- Origin and evolution of galaxies from high redshift to the present
- Formation and evolution of stars and planetary systems
- Astrophysics in extreme conditions

NOVA has developed from a fledgling collaboration at its start in 1992, to an internationally recognized and accepted research alliance and leading provider for ESO instrumentation. NOVA has demonstrated the strength and resilience of a university alliance. It has built up an excellent reputation for on-time, on-budget and within-specification delivery of first rate instruments.

NOVA funding from the top-research grant provided by the Ministry of Education, Culture and Science (OCW) amounts to 5 M€/yr. NOVA operates on a yearly budget of 9 M€ excluding the university institutes budgets. The external revenues are primarily for the instrumentation program. The universities and NOVA together fund 50% of the staff positions for research and instrumentation (see p.22). The other half is funded through external grants obtained from national and international competitive programs.

NOVA is the national home base of ESO. For ground-based astronomy, ESO has grown into the world's premier astronomical organization, with the most powerful telescopes that are a testimony to precision engineering (see page 6). The Dutch share of ESO is funded directly by the government, but the instruments attached to the telescopes are the responsibility of individual ESO member states. NOVA's role is to co-steer the scientific definition, design and realization of instrumentation for the ESO telescopes, and to ensure that scientific exploitation by the Dutch user community is of the highest quality. In brief: NOVA maximizes international impact through national coordination. Typical timescales for instrumentation projects from conception to first light are 15-25 years. As this is well beyond typical 5-year funding cycles, long-term stable funding is essential. In this international function NOVA transcends the traditional definition of a top research school.

NOVA and National Strategic Planning

The access to, and development of instruments for, the multi-wavelength and multi-messenger observational facilities is enabled by NOVA, the NWO institutes ASTRON [4] and SRON [5], and the NWO division of Physical Sciences (NWO-EW) [6]. OCW provides the annual contributions to ESO and the science program of ESA. All partners have complementary roles; the many joint appointments of research staff create an effective conduit for communication and (technical) training of students.

Efficient coordination between these organizations and its member scientists led to the 2011-2020 national Strategic Plan which describes the unified national ambitions. Continuation and long-term stable funding of NOVA is identified as the highest priority in the Strategic Plan.

The Dutch astronomical program is strongly aligned with the European strategic roadmap ASTRONET, where NOVA astronomers played a central role in its definition. It is also an integral part of the theme 'Van elementaire deeltjes tot heelal' in the KNAW 2011 'Nationale Wetenschapsagenda'.

3. Worldwide trends for 2025

In 2025 astronomical research will be radically different from what it is today. State-of-the- art research equipment has increased in scale, complexity and cost, requiring larger research and instrumentation groups to design, build and operate them. Further technological advances will have made possible tremendous breakthroughs in several areas, and major new telescopes are being constructed now that will be operational by 2025, in particular the E-ELT.

Astronomy as a science will also continue to change: stronger interdisciplinary links with chemistry, particle physics, biology, geology and computer science will further broaden the field. The Universe is the ultimate laboratory where extreme conditions exist that cannot be recreated on Earth. Technological advances in computer storage and processing will allow time-lapse 'movies' of the entire sky, opening up the full study of all visible objects in the Universe. Handling the real-time information flow and developing exascale database techniques are one example of such an interdisciplinary topic. Observations are no longer limited to detection of photons (light), but will include other messengers such as cosmic rays and neutrinos. Gravitational waves are expected to be detected in the coming decade and will start an entirely new interdisciplinary field.

Globally, the field will expand by the entry of new countries who recognize that investing in astronomy has many benefits: it is an excellent way for capacity building, to develop high-tech skills in industry, and to educate and attract students in the natural sciences and engineering. In this way 'system-level' researchers will be trained that are capable of addressing societal challenges and problems of high complexity.

New astronomical discoveries will continue to impact society at large. They will inspire artists and students alike, and continue to change the way we view ourselves, our origins and our future.

The challenge for the Netherlands is to maintain its global leadership as a small community in a larger world, both in terms of the quality of its science and its ability to steer new facilities. The way to achieve this is through continuing to intensify national and international collaboration, and by creating a vibrant community above the critical mass that is able to attract and keep the best talent in an environment where research and technological opportunities go hand-in-hand. NOVA is poised to make this happen.

NOVA NUMBERS

52 + 4

52 years ago ESO was founded by five member countries, among which the Netherlands. Over these years 4 out of 7 Directors General have been Dutch.

Numbers of NOVA researchers	
Scientific staff	64
Postdocs	72
PhD students	157
Instrumentalists	46
Total	**339**

Numbers of NOVA researchers at the university astronomical institutes and NOVA staff working on instrumentation for 2013.

4. Goals for 2025

NOVA's main goal is to steer and lead astronomy worldwide in its three main science areas, enabled by revolutionary new facilities that will become operational by 2025, and thereby strengthen its status as one of the world's premier research and education combinations in astronomy. The key element of NOVA's strategy is to build instrumentation for new facilities, in particular to be Principal Investigator of one of the first three instruments on the E-ELT, whose construction has recently been approved and funded.

The main action needed to achieve this goal is that NOVA obtains permanent status and financial stability to carry out its integrated research and instrumentation program, which is critically contingent on strategic planning and being able to make long-term international commitments. NOVA thereby serves as a pilot for a new type of university alliance that enables national participation in flagship international projects.

Specific targets of the NOVA 2025 program are:

1. NOVA has a vibrant and interdisciplinary scientific community that carries out science according to the highest standards, and is able to attract and keep the best talent worldwide.
2. NOVA continues to build state-of-the-art instruments to enable its front-line research. It drives the development of the technological breakthroughs needed to reach the challenging astronomical specifications, in close collaboration with industry.
3. NOVA's innovative technologies and methodologies lead to spin-offs which benefit industry and contribute in a unique way to the knowledge economy and societal challenges.
4. NOVA's educational program is in the top five of PhD astronomy programs in the world.
5. NOVA's outreach program inspires and excites a large part of Dutch society, and is an example for similar programs in other disciplines.

Actions required to achieve these goals include:

- NOVA achieves a balanced and diverse distribution of staff in terms of age, disciplines, gender, nationalities and minorities.
- NOVA strengthens and formalizes its interdisciplinary and international collaborations, as well as its relations with industry. It actively promotes societal applications of its innovations.
- The PhD program attracts top students from around the world, remains a 4-year research-oriented track, and also prepares students for careers outside of astronomy.
- NOVA ensures that astronomy is implemented in the national curriculum at primary and secondary schools, and thereby attracts children and students into the natural sciences.

"Thanks to the orders of magnitude jumps in sensitivity and sharpness with ALMA, JWST and E-ELT, we will be able to zoom into the planet-forming zones of disks around young stars for the first time and finally address age-old questions about our origin. How are planets like Jupiter and Earth formed, and how unique is the architecture of our solar system? How and where are water and organic molecules made that form the basis for pre-biotic material and eventually life? Are they common?"

-- Ewine van Dishoeck

"In the coming 10 years, we will be able to address three big questions in cosmology: the nature of dark energy, the nature of dark matter, and the assembly of galaxies. We can study how galaxies like the Milky Way are formed, from the birth of the universe to the current day. The new telescopes ALMA, JWST, E-ELT and EUCLID will allow astronomers to look back in time and study the physical processes in the universe when it was still very young, only a few hundred million years after the Big Bang."

-- Marijn Franx

"The cores of neutron stars reach densities far higher than anything we can achieve on Earth, conditions where we expect to form exotica including stable states of strange quark matter and quantum superfluids. Over the next 10 years neutron star astronomers will begin to make profound discoveries about the nature of dense matter, in regimes that cannot be reached by laboratories like CERN."

-- Anna Watts

"In the next ten years we will make a picture of the event horizon of a black hole - measuring the most extreme deformation of space and time ever possible. This will allow us to probe the fabric of space and time in the most fundamental manner."

-- Heino Falcke

"The new E-ELT will make it possible to find and characterize planets like Earth orbiting our neighboring stars for the first time. What we will find? No idea! That is the thrill of scientific exploration."

-- Ignas Snellen

"By 2025, with ESA's Gaia mission and new ground-based follow-up instruments, we will have a completely new view of our home galaxy, the Milky Way. We will have determined its origin by finding and characterizing its building blocks, in some sense this is like reconstructing its genealogy tree. These data will also allow us to map the distribution of mass in the Milky Way and pin down the nature of the mysterious dark matter."

-- Amina Helmi

The NOVA Program

Top Astronomy = Top Talent + Top Instrumentation

HST image of part of the Carina nebula

A1. NOVA Research

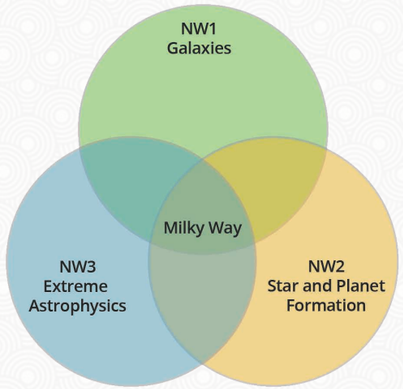
The NOVA research program 'The Life Cycle of Stars and Galaxies' consists of three interconnected research lines addressing the most important questions in present-day astrophysics:

- ***Network 1: Origin and evolution of galaxies from high redshift to the present.*** How do galaxies form and evolve, and how can they be used as tracers of the evolution of the Universe and its (dark) constituents? For the 2025 era, NOVA envisions a globally leading role in the areas of the formation of our Milky Way Galaxy, the very first galaxies in the Universe (the epoch of reionization and 'first light'), and dark energy, the mysterious component causing the accelerated expansion of the Universe.

- ***Network 2: Formation and evolution of stars and planetary systems.*** How are new solar systems formed from tenuous clouds of gas and dust? What is the chemical composition of the planet-forming material? Are there signs of biogenic molecules in exoplanet atmospheres? For the 2025 era, NOVA envisions having a leading role in the field of extrasolar planet formation and characterization, in particular geared towards understanding the building blocks of life and the uniqueness of our own Earth and solar system.

- ***Network 3: Astrophysics in extreme conditions.*** The highest temperatures, densities and energies are encountered in objects with the strongest gravitational potentials: neutron stars and black holes. How do these objects form and evolve? By 2025, NOVA envisions co-leading the direct imaging of the horizon of the supermassive black hole in the center of our own Milky Way Galaxy and those in the nearest galaxies, and in the study of transient phenomena as messengers of physics in extreme environments, including the study of objects that create detectable gravitational waves.

These three science areas are organized in national networks, led by top-researchers across the NOVA member universities. There are also strong cross-network collaborations. The networks are highly dynamic and open: a great strength of the NOVA program is its ability to adapt its research program quickly to new developments.



NOVA NUMBERS

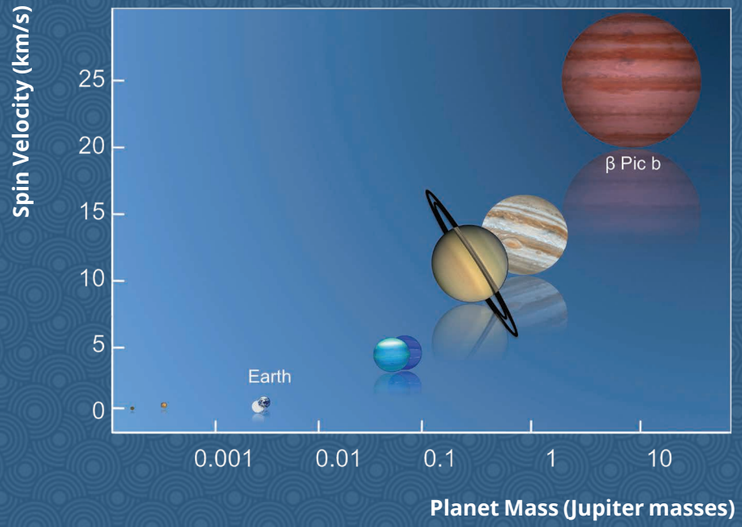
6+9

Number of Spinoza Prize and ERC- Advanced Grant winners in Dutch astronomy

Science Highlights

Network 1 - Galaxies

The deepest image of the universe obtained with the Hubble Space Telescope revealing the earliest known galaxies appearing at an epoch when the Universe was only 5% percent of its present age. This discovery points to unexpectedly rapid formation of galaxies just a few hundred million years after the Big Bang (Bouwens et al. 2011, Nature).

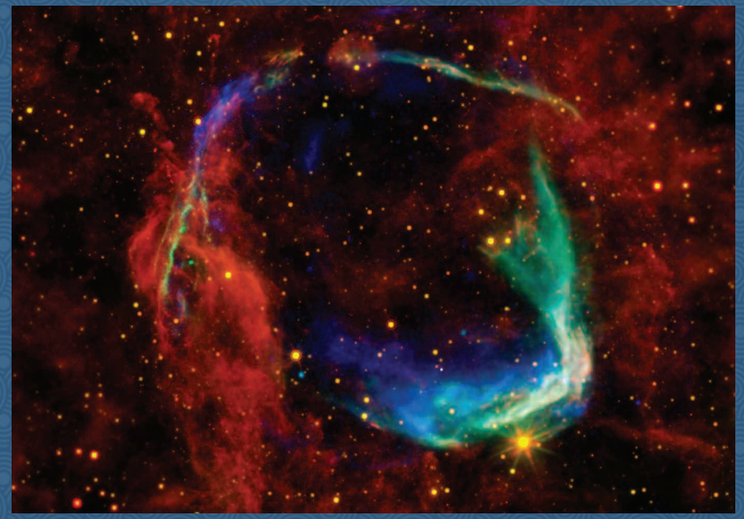


Network 2 - Star formation & Planets

First determination of the length of a day on an exoplanet. The rotation rate of Beta Pictoris b has been found to have a day that lasts only eight hours, much shorter than any planet in the Solar System (Snellen et al. 2014, Nature).

Network 3 - Compact Objects

X-ray (blue/green) + infrared image (red/yellow) of supernova remnant RCW 86 in which elementary particles are accelerated to enormous energies (Broersen et al. 2014). When such a cosmic ray hits the Earth, it triggers a shower of new particles which give off radio emission that is detected by the LOFAR radio telescope (Buitink et al 2014).



NOVA Instrumentation

X-Shooter instrument on ESO's Very Large Telescope. NOVA built the near infrared spectrometer. The privileged access to, and in-depth knowledge of, the instrument led to highly visible research of astronomers in the Netherlands.

A2. NOVA Instrumentation Program

Astronomy is driven forward by new technologies in combination with bright ideas, new insights and theories. NOVA is the national lead for instrumentation at the ESO telescopes. The success of European astronomy depends critically on ESO and the national institutes working closely together to design and construct instruments. NOVA has two technical groups - the Optical-Infrared and Submillimeter groups - and both have now been designated 'preferred supplier' of ESO instrumentation. NOVA has (co-)led or been involved in 7 out of 18 VLT instruments, 2 out of 8 ALMA receivers, and 4 out of the 8 feasibility studies for E-ELT instruments, even though the Netherlands contributes only 5% of the ESO budget. NOVA has built up a strong reputation for delivering instruments that are within-specification, on-time and within-budget.

The benefits of the close involvement of NOVA astronomers in instrumentation are evident: astronomers define the functionality of these instruments and steer their science capabilities to Dutch interests. They remain involved throughout the complete instrument-building cycle. Through guaranteed time, NOVA astronomers are among the first to obtain science results, thus reaping the hottest early science harvest and obtaining a scientific head-start. Co-leading or being part of the instrument team is key to doing modern frontline astronomy.

For 2025 NOVA envisions that it will be, at any given time, PI on at least one ESO instrument including the METIS instrument for the E-ELT (see page 17). The NOVA instrumentation program also invests in smaller-scale instrumentation and R&D projects where new concepts and technologies will be developed, implemented and matured before being applied at the largest telescopes.

NOVA NUMBERS

9

The number of ESO instruments NOVA has delivered (7) or is presently working on (2) in collaboration with international partners. In total ESO and its member states have built 27 instruments over a period of 52 years.

Knowledge enabling for industry

Astronomical instrumentation and facilities provide a strong opportunity for Dutch industry because of their scale and required precision. The E-ELT, the various ESA space missions, and the planned SKA radio telescope are all billion-Euro infrastructure projects where Dutch industry can profit. To ensure a proper interaction and information flow between ESO projects and Dutch industry, a stable home base organization is required which provides this liaison function: NOVA.

Astronomical instruments operate at the limit of what is technologically possible, and push industry beyond their current capabilities. As such, astronomy is a 'knowledge-enabler'. Industry is driven by astronomy to develop new innovative techniques and procedures, which later can be turned into profitable industry-to-industry contracts. Astronomical techniques are always at the very beginning of the innovation chain. An investment in astronomical instrumentation is therefore an investment in common-day products of 20-30 years into the future. Examples include WIFI, CCD and CMOS cameras. The basic principles behind these current-day technologies were developed for astronomy in the 1980's and 1990's. As such, astronomical instrumentation research naturally fits with the national top sectors of High Tech Systems and Materials (HTSM), in particular the roadmaps on Advanced Instrumentation and Information and Communication Technology (ICT).

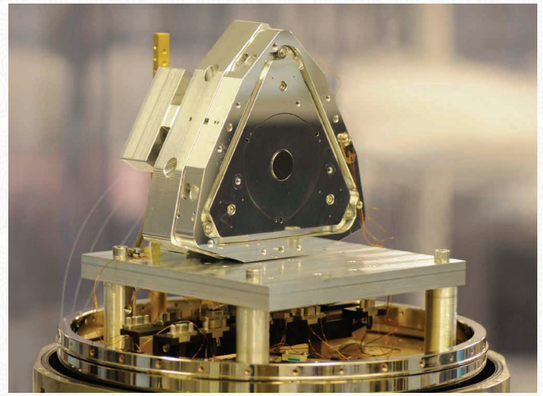
Gabby Kroes wins engineering prize 2014 at Hannover Messe

NOVA instrument steering committee reviewing project progress

High precision instruments require ultra-clean conditions

E-ELT and METIS

METIS, the mid-infrared imager and spectrograph, will be one of the first three instruments on the E-ELT, with first light around 2026. Combining the light gathering power of the E-ELT with high resolution spectroscopy and the sharpest infrared images ever, METIS will be uniquely capable to explore exciting new science areas, including the discovery and characterization of extra-solar planets, from gas giants such as Jupiter down to rocky planets that are only a few times more massive than Earth. Based on the long and successful track record of infrared instruments in the Netherlands, NOVA is leading the METIS consortium of seven international institutes in seven countries, ensuring that the capabilities are well matched to Dutch interests. Building an instrument for the E-ELT and leading it as PI is a significant step upward in scale, scope and responsibility compared with what NOVA has done so far. The project has a total budget of approximately 40 M€, and is being done in close collaboration between NOVA, industrial partners (VDL-ETG, JPE), knowledge institutes (TNO, SRON) and international partners.



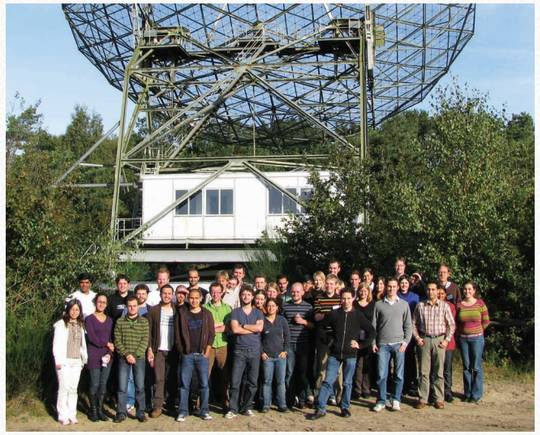
METIS chopper, a key technical development to rapidly switch between source and sky to suppress noise.

A3. NOVA Education

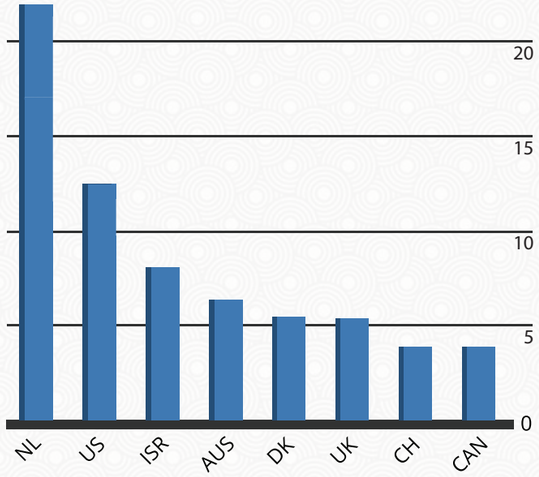
Research and education are closely interwoven. NOVA is the national graduate school in astronomy. The philosophy of the NOVA PhD program is that of a master-apprentice model, where a number of PhD students work in close collaboration with a staff member and (often) a post-doctoral researcher in an integrated team. Training is provided in 1st-year and 3rd-year national 'schools' as well as in specialized courses in 'soft skills' (e.g. presentation skills, scientific writing, and effective communication) at the universities. NOVA has developed an intensive PhD progress monitoring program that is a key factor in achieving a high PhD graduation fraction (>90%) as well as a median PhD period of 4.3 yrs. The success of the NOVA PhD program is evidenced by the high number of prize post-doctoral fellowships that PhD students trained in the Netherlands obtain abroad, exceeding even in absolute numbers that of large countries such as the UK and Germany.

In the coming decade, NOVA will extend its activities within the MSc program from national coordination to attracting foreign talent to the Netherlands at an early stage. Early talent scouting at the MSc level is essential to ensure a high quality PhD program, where about 50% of the students are from abroad, showcasing the ability of astronomy to be a 'brain-gainer'.

NOVA has also strived to provide an appropriate level of astronomy education at the secondary and primary school level as part of its outreach program. For 2025 it will double its efforts to foster the fascination for the natural sciences at a young age (5-10), and to sustain this fascination throughout secondary education. For primary schools, NOVA will focus on educating teachers as well as showcasing astronomy through activities such as the three mobile planetaria and educational apps and games. At secondary school level (ages 12-18) it will incorporate modern astronomy into the physics and chemistry education programs.



The NOVA school in front of the Dwingeloo radio telescope.



Countries where PhD was obtained for US postdoctoral prize fellowships over the last ten years, normalized per capita.

Societal Impact of Astronomy

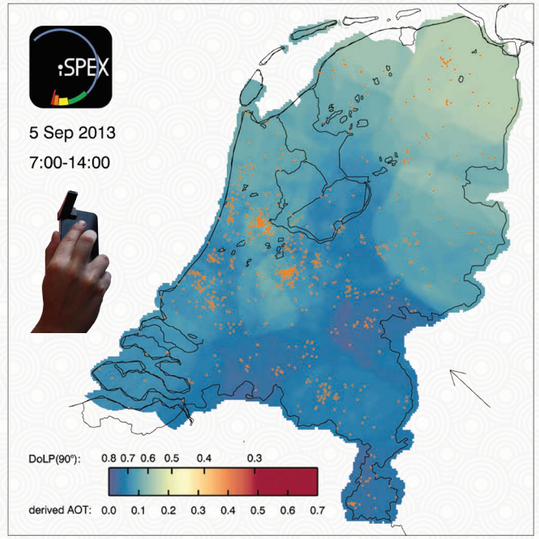
Astronomy has played an important role in the development of the human race. The ability to predict the motions of the Sun and stars were decisive factors in the emergence of agriculture, time keeping and navigation in the earliest civilizations. The quest to explore the Universe and to determine our place among the billions of stars and galaxies continues to appeal to our deepest cultural and philosophical yearnings.

Present day societal challenges also benefit from developments in astronomical research. Instrumental techniques and algorithms find their way into medical, ICT and environmental research. Adaptive-optics laser eye surgery, traffic flow simulations, in-field animal recognition, measuring atmospheric pollution levels, skin cancer diagnosis techniques and WIFI beam-forming are only a few examples of astronomy-developed techniques. Large scale challenges such as global climate change, energy production and understanding life itself benefit from having a different perspective as provided by astronomical studies of the atmospheres of other planets, both within and outside our Solar System, and of the nuclear fusion processes that occur in stellar cores. If Earth proves to be unique as a habitable planet, this may boost our willingness to preserve our planet and view life itself as a precious commodity. At the same time, proving that we are not alone will have an equally fundamental impact on sociology, philosophy, the arts, and all major religions.

Human Capital Development

Astronomy-trained students are required to think at 'system-level'. Astronomical research questions are never isolated table-top experiments, but take place in diverse, distant and uncontrolled environments. Students are required to handle highly complex research questions and collaborations: they need to develop scenarios, cope with the practical limitations of real data, develop algorithms for handling data imperfections, plan further observations to test models, and carry out numerical simulations of such diverse matters as the magnetic fields and gas flows near black holes and the complex motions of trillions of stars within galaxies. This forces students to think on how to handle problems with a high level of complexity, and how to solve them using a wide range of tools, often in collaboration with people from different technical backgrounds. Working in international teams also hones communication skills, cultural exchanges and an awareness of cultural diversity.

This combination of skills makes astronomy students attractive to a wide range of sectors in society, varying from consultancy firms to ministries, ICT, industrial labs, and banks. Astronomy is therefore a human capital developer whose impact exceeds that of cutting-edge research alone. The excellence of NOVA also attracts the best talent from all over the world, for example to a PhD or Postdoc position in the Netherlands. Subsequently, they often stay in the Netherlands, providing an influx of knowledge-workers.



Map of aerosols above the Netherlands measured with iSPEX on smartphones in a community program. iSPEX is a spin-off from innovative astronomical instrumentation to measure polarized light. It received the 2012 Dutch Academische Jaarprijs.

A4. NOVA Outreach and Public Education

The general public is highly fascinated by astronomy. Big questions such as ‘How did the Universe come into existence?’, ‘Are we alone?’, ‘What is a black hole?’, ‘Where does it end?’ are asked time and time again. The broad public interest is also evidenced by the presence of the Artis Planetarium, Omniversum, Infoversum and a large section of the NEMO Science center dedicated to astronomy. From its start, NOVA has established the ‘NOVA Information Center’ (NIC) to act as a channel to publicize research results and engage the general public in astronomy developments. This has been tremendously successful, among others through regular press releases, the astronomie.nl website, and the mobile planetarium (reaching more than 100,000 children in five years). For 2025, the vision for the NIC is to have a multi-tiered strategy targeting audiences at various levels, to be strongly engaged in secondary education, and to facilitate primary school teachers’ education.

NOVA NUMBERS

1.3 million

Number of people watching the TV program ‘Heel Nederland kijkt Sterren’ in November 2014

Knappe kunst

Een techniek van astronomen om heel verre planeten te onderzoeken gebruiken ontwerpers nu voor een namaakregenboog.

‘Rainbow Station’ heet hun k
genboog, die elke dag een pa
nuten geprojecteerd zal wor
Maar compleet nep is hij ook
niet. Het is bijvoorbeeld niet
woon een geprojecteerde fot
een regenboog.
Echte regenbogen ontstaan
dat zonnestralen binnen reg
druppels gespiegeld worden
zoallicht bestaat uit meerder

Uitzonderlijke foto van planetenvorming

ALMA-telescoop Materieschijf rond jonge ster HL Tauri is in beeld gebracht met enorme telescoop in Chili

Door Eddy Echternach

AMSTERDAM. Astronomen hebben een spectaculaire foto gemaakt van een planetenstelsel in wording. De opname, gebaseerd op gegevens van de ALMA-telescoop in het noorden van Chili, toont de materieschijf rond de jonge ster HL Tauri. De ster staat zo’n 450 lichtjaar van de aarde.

De afwisseling van heldere en donkere ringen in deze schijf wijst erop dat het daarin aanwezige gas en stof bezig is om samen te klonteren. Daarbij zijn vrijwel zeker al objecten van planeetformaat ontstaan.

Het is niet voor het eerst dat de ‘protoplanetaire’ schijf rond een ster is gefotografeerd. Maar de nieuwe ALMA-opname is wel verreweg de scherpste tot nu toe.

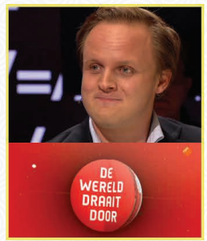
De uitzonderlijke scherpte van de opname is te danken aan de enorme omvang van de telescoop, die uit 66 afzonderlijke, deels verplaatsbare schotelantennes bestaat. Bij het maken van de opname van HL Tauri bedroeg de grootste afstand tussen de schotels vijftien kilometer – bijna het maximaal haalbare.

In de huidige configuratie zijn de opnamen van ALMA scherper dan de foto’s die met de Hubble-ruimtetelescoop worden gemaakt. Daarbij komt dat ALMA de hemel op submillimeter-golflengten bekijkt – een golflengtegebied waarin dwars door het vele stof in de omgeving van jonge sterren heen kan worden gekeken.

Sterren ontstaan uit wolken van gas en fijn stof, die onder invloed van hun eigen zwaartekracht samentrekken.

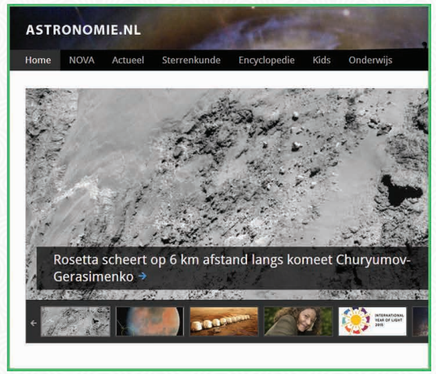
Dit is geen tekening, maar een foto van de stofwolk om de jonge ster HL Tauri.

Daarbij ontst
heet gas, wa
acties op gaa
een ster als o
ren.
Het gas er
van een ster
uiteindelijk i
linge botsing
in die schijf
deeltjes ter g
grind ontsta
ring resulter
tolden, kom
nesten.
Geschat w
miljoen jaar
we waarnem
planetaire v
ler gaat: de
niet ouder d

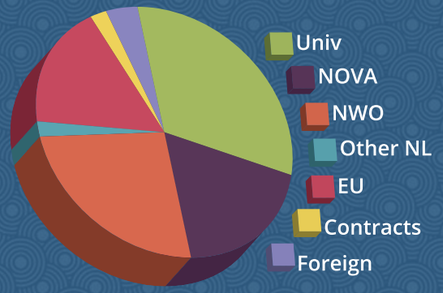


OUTREACH

Jonge Nederlandse sterrenkundigen gaan terug in tijd met Amerikaanse supertelescoop

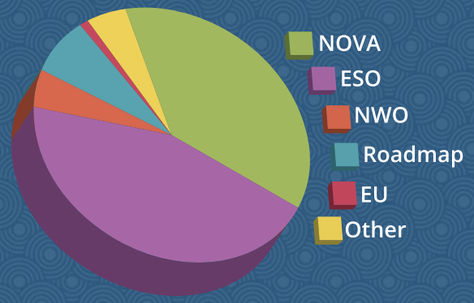


Facts and Figures



Origin of funding for research staff and instrumentation positions

The expenditure on NOVA and university research staff and instrumentation positions amounted to 21.1 M€ in 2013. This covers the staff numbers as listed on page 7. The universities contributed 31% of the funding, NOVA 20%, NWO 24%, other organizations in the Netherlands 3%, European Union 17%, contract research 2% and other foreign 3%.



Origin funding NOVA instrumentation

For the period 2009-2013 the NOVA expenditure on instrumentation. amounted to 24.5 M€. NOVA provided 37% of the funding. The external revenues came from ESO (44%), grants from NWO (5%), from the national Roadmap program for large-scale research facilities (8%), European Union (1%) and Other (6%).

NOVA contributions to ESO instruments

- Beam combiner for MIDI, the first VLT Interferometer instrument (2002)
- The near-infrared camera for SINFONI, the near-infrared integral field spectrometer exploiting Adaptive Optics at the VLT (2004)
- Data reduction software for the OmegaCam camera for the VLT Survey Telescope (2005)
- The near-infrared spectroscopic arm for X-Shooter, the first VLT second generation instrument (2009)
- The Band-9 receivers for ALMA (2011, see figure)
- The ASSIST tower for testing the innovative deformable secondary mirror for the VLT required for the Adaptive Optics observations with the Multi Unit Spectroscopic Explorer (MUSE) on the VLT (2011).
- The polarimeter instrument for SPHERE-Zimpol, the VLT instrument optimized to characterize atmospheres of exoplanets (2013)

References

[1] Astronomy for the Developing World, strategic plan 2010-2020, IAU; www.iau.org

[2] Strategic Plan for Astronomy in the Netherlands 2011-2020; www.nova-astronomy.nl/PPR.php

[3] European Southern Observatory; www. eso.org

[4] ASTRON; www.astron.nl

[5] SRON; www.sron.nl

[6] NWO Physical Sciences; www.nwo.nl/ew

Photo credits: ESO, ESA, NASA and NOVA

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Abbreviations

ALMA: Atacama Large Millimeter/submillimeter Array

ASTRON: Netherlands Institute for Radio Astronomy

E-ELT: European Extremely Large Telescope

ESA: European Space Agency

ESO: European Southern Observatory

EUCLID: ESA mission to map the geometry of the dark Universe

HST: Hubble Space Telescope (NASA)

JWST: James Webb Space Telescope (NASA successor of HST)

NOVA: Netherlands Research School for Astronomy

SRON: Netherlands Institute for Space Research

VLT: ESO's Very Large Telescope

Back cover: Computer simulation of the formation of structure in the Universe (Schaye et al. 2015).