Interstellar Disparity: N- vs O-bearing molecules

25/08/25-29/08/25 Lorentz Center@Omega

Scientific Report

This workshop aimed at bringing together scientists from diverse backgrounds and areas of expertise, ranging from theoretical and experimental chemistry to observational astronomy (galactic and extragalactic) and astrochemical modeling, to tackle one of the longstanding question in astronomy: the origin of the observed dichotomy between nitrogen and oxygen bearing species.

Complex organic molecules (>5 atoms) are of particular interest in astrochemistry, as they are thought to be building blocks for Life. Yet, despite their numerous observations in galactic and extragalactic regions, their formation pathways are still highly debated or unknown, and represent one of the main challenges in astrochemistry. More puzzling is the discovery of spatial disparity between O- and N-bearing complex molecules, observed at high angular resolution. This disparity can be seen in various environments, from galactic star-forming regions to the interstellar medium of external galaxies. This dichotomy may arise from differences in the species chemistry, in variations of physical conditions or by the influence of external feedback, but to date, there is no satisfactory explanation, probably due to gaps in our understanding of how these species are formed in the interstellar medium. Four main topics have been addressed in the workshop: (i) where this dichotomy has been observed, ii) the role of the carboxyl (-COOH) group, iii) the fate of the cyanides (-CN), and (iv) the role of the environment.
Overall, the workshop aimed to enhance the communication between different expertise areas, foster new collaboration channels between galactic and extragalactic astronomers, and merge the collective knowledge of the astronomical, experimental, and theoretical chemistry communities.
We believe our main goals were achieved, and most of our short-term outcomes were fulfilled.

1. We successfully brought together a diverse group of scientists who were able to exchange ideas and perspectives across their respective fields. The program included ample time for open discussion, naturally guided by the overview talks in each session. This helped establish a common basis on top of which to build further dialogue.
2. The breakout sessions were particularly effective. We collected a list of open questions from the invited speakers and assigned them to the different groups. Each group was diverse, bringing together participants with complementary expertise. The results of the discussions were then presented in plenary sessions to gather feedback and work toward a general consensus.

Furthermore, we have kicked off other long-term outcomes we aim to keep working on:

1. We have fostered connections across disciplines and initiated the writing of a **community white paper** to consolidate insights from observers, modelers, and chemists on this chemical dichotomy. This paper

will provide a concise review of the current state of the field, highlight the main outcomes of the workshop, and outline future research directions.
2. We identified robust points in our current understanding, as well as specific open questions that can be addressed in the near future and serve as groundwork for subsequent workshops.
3. We also strengthened ties between the galactic and extragalactic communities by identifying common chemical features to be tested and explored in future studies.

Building on these outcomes, one of the main scientific advances of the workshop was the realisation that the observed chemical dichotomy is not strictly linked to N- versus O-bearing species, but it is instead molecule-dependent and/or related to observational biases. This perspective changes how we interpret existing data and provides a clear guide to design future studies.
Discussions were key to figuring out future avenues: chemical models should be made openly available, with careful documentation and a transparent treatment of input parameters. Similarly, well-curated reaction networks are necessary. A mismatch between models and observations should not be seen as a failure, but as a chance to challenge and expand our current understanding of chemistry. When it comes to laboratory and computational studies, selecting which molecule to investigate next in laboratory and computational studies is crucial, given the cost of such work, and this choice should be guided by both observations and models. On the observational side, minimising biases is essential, either by carrying out new targeted observational campaigns or by revisiting archival data hunting for overlooked clues.

Organization
The workshop contained review talks (1hr), poster sessions (30min), break-out room sessions (1h30) and plenary discussions (1h). Every day, there were one or two review talks followed by 15min questions/discussions. During the poster sessions, the presenters of each poster had a 5 min presentation followed by 3 min questions. We chose this set-up to enhance the visibility of posters, which are usually not getting enough attention during conferences. Then, during the break-out sessions, we split into three groups. Each group had a set of questions to address. Each group had to prepare a summary of their discussion, and all summaries were then discussed during the plenary session at the end of the day. An online participation in the workshop was also possible, and the online participants have been actively engaged in the discussions. In total, we had 35 participants, among whom 5 were online. Within the participants (excluding the organisers), 54 are early- to mid-career and 60% identify as women.This format was very effective, sparking a lot of discussions among the participants.

Finally, we, as organisers, and the participants as well, are very satisfied with the workshop and its outcome.-We would like to thank the Lorentz Center, and in particular Giel van Butselaar, for the excellent organisation, and NOVA for granting us some additional funding, so as to make this successful workshop possible.

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