

Report on the ESO workshop

Two in a Million — The Interplay Between Binaries and Star Clusters

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A substantial fraction of cosmic star formation happens in star clusters, and the binary populations therein are shaped by interactions amongst themselves and with other cluster stars. The intricate interplay of star clusters and the binary stars they host was the topic of this workshop, which brought together about 150 scientists working on four cornerstones of modern astrophysics: star formation, stellar evolution, cluster dynamics, and gravitational waves. As well as invited reviews and contributed talks, the scientific programme offered breakout sessions focused on various practical skills linked to the workshop theme. Informal poster-viewing sessions concluded the session days and offered the opportunity for extended discussions about recent results as well as future instruments.

Rationale

Each binary in a star cluster will evolve through a multitude of interactions with other cluster members. These interactions strongly alter the primordial populations via binary disruption, flyby and exchange interactions, or the Kozai-Lidov mechanism (Kozai, 1962; Lidov, 1962), and result in systems that are endemic to clusters such as dynamically-formed binary black holes or low-mass stars orbiting degenerate companions. The detection and characterisation of the latter hold crucial information about the kick velocities resulting from supernova explosions, a major unknown limiting our capabilities to understand the growing number of gravitational wave detections.

Remarkably, star clusters also provide a unique window through which to study a multitude of phenomena linked to binary stars in a controlled environment, since the ages, metallicities, and masses of cluster members are usually well known. Given that, star clusters play a key role in improving our understanding of post-



Figure 1. Conference photo in front of the ESO Supernova Planetarium & Visitor Centre.

interaction products, like blue stragglers, stripped stars, or classical Be stars. Different formation mechanisms for these objects make predictions that can best be tested in clusters, such as the stellar-merger or mass-transfer scenarios proposed for blue straggler formation.

Binary stars also have a crucial impact on the evolution of clusters, and act as reservoirs that balance the energy budget of their hosts, closely linking the lifetime of a cluster to its binary population. Binaries reverse and moderate the core collapse of long-lived clusters, while few-body interactions involving binaries efficiently eject cluster members from their hosts. Some of the open questions in our understanding of cluster evolution, like the origin of the bimodal spin distributions found in young open clusters or the multiple-populations phenomenon observed in old globular clusters, have been linked to binary stars.

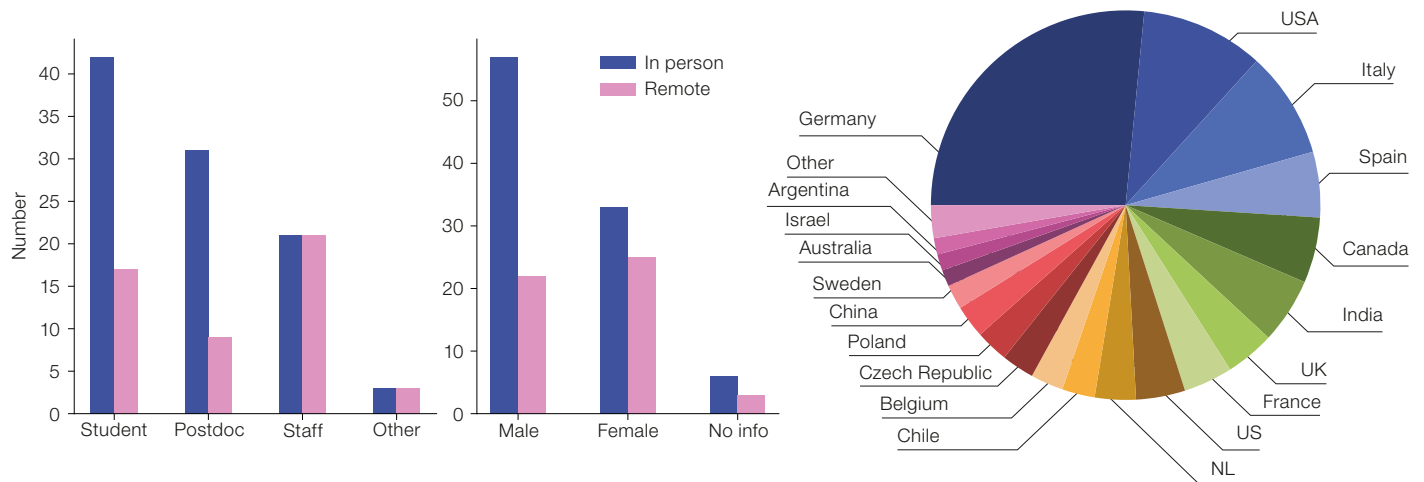
The current Very Large Telescope (VLT) instrumentation, particularly the Fibre Large Array Multi Element Spectrograph (FLAMES) and the Multi Unit Spectroscopic Explorer (MUSE), has allowed significant advances in our understanding of how binary evolution impacts star clusters and vice versa. The workshop offered an opportunity to review these successes and to plan ahead for new and upcoming instruments, like the Enhanced Resolution Imager and Spectrograph (ERIS) and the Multi-Object Optical and Near-infrared Spectrograph (MOONS) on the VLT, or ESO's Extremely

Large Telescope (ELT) with its ground-breaking set of instruments, which will significantly boost our ability to study stellar populations in clusters.

Programme

The scientific talks during the week were structured according to the four scientific pillars on which the workshop rested¹. Following the typical evolutionary sequence, the programme started on Monday with sessions on star and cluster formation, while Tuesday was largely dedicated to the binary populations in young star clusters. After the sessions on interacting binary stars on Tuesday afternoon and Wednesday, Thursday was dedicated to ancient globular clusters and their binaries, before the workshop concluded on Friday with a series of talks presenting new results on the possible star–cluster links of binary black hole mergers detected via gravitational waves, both from an observational and a theoretical point of view. Additionally, each day featured one talk about instrumentation, presenting either current instrumentation such as LIGO/VIRGO/KAGRA gravitational wave detectors, introducing new instruments such as VLT/MOONS, or highlighting the capabilities of the ELT.

Recurring themes throughout the week included the strong dependency of multiplicity properties on stellar mass, the



importance of interaction products in explaining the colour-magnitude diagrams of young star clusters, the power of the Gaia spacecraft in studying binaries in nearby star clusters as well as run-away stars, and the necessity of detailed comparisons between models and observations to understand the binary populations inside star clusters. For further details, we refer the interested reader to the presentation slides, made available by the workshop participants on Zenodo².

In addition to the invited and contributed talks, two slots for breakout sessions were included in the programme and took place on Tuesday and Thursday afternoon. Those were filled by the participants themselves with interactive sessions, more in-depth discussions, and hands-on tutorials covering many different skills. Those included, for example, a hands-on session about machine learning and its application to star clusters, a discussion session about potential new instruments for the VLT, the status of ELT instrumentation, and ideas for new telescopes beyond the ELT, as well as a career-planning session particularly targeting junior scientists, in which more senior scientists offered tips, tricks and experiences on how to navigate through an academic career.

Two poster sessions were organised in the evenings, with typical Bavarian refreshments, which enabled participants to inspect and discuss the posters and to interact in a more informal setting.

Demographics

Overall, almost 150 scientists participated in the conference, of whom roughly two thirds attended in person, the remainder joining online. In addition to bringing together scientists from different research fields, the Scientific Organising Committee (SOC) and the Local Organising Committee (LOC) sought fair representation from the communities in all possible aspects. In particular, the conference targeted early-career scientists, who could for example apply for travel support. As shown in Figure 2, the overall participation of early-career scientists was high, with almost 70% of all participants being either students or postdocs. A majority of those attended the conference in person.

While the ratio between male and female participants was roughly 60/40, the ratio between male and female speakers was approximately 50/50. When selecting the invited talks, the SOC strove to have a similar number of female and male speakers, and to achieve fair distribution between senior and junior speakers.

Overall, there were participants from 22 different countries from five different continents. The fractions of participants coming from individual countries can be seen in the right panel of Figure 2.

Outlook

All in all, the conference was a great success, fulfilling the goal of bringing together scientists from many different

Figure 2. Demographic distributions of the career stage (left) and gender (middle) of the participants, split up into in-person (blue) and remote (pink) participants. Right: Overview of the home countries of all participants.

communities and providing a platform for the exchange of recent findings and new ideas, in particular for the younger generation. During the conference summary, which was prepared and presented by a group of PhD students who volunteered for this task³, it was suggested that a ‘Three in a million’ conference be hosted at ESO in 10 years from now — a promising idea that will hopefully be seized on by one of our younger colleagues.

Acknowledgements

We would like to thank all participants, in person and remote, for their active participation in the conference, which was crucial in making it so interesting and diverse. We would further like to thank our SOC and LOC members for their active and energetic support. A special thanks goes to Denisa Tako for her endless help and support with the organisational aspects of the conference.

References

- Kozai, Y. 1962, *AJ*, 67, 591
Lidov, M. L. 1962, *Planetary & Space Science*, 9, 719

Links

- ¹ Workshop programme: <https://www.eso.org/sci/meetings/2023/binaries/programme.html>
² Presentation slides on Zenodo: <https://zenodo.org/communities/binaries2023?q=&l=list&p=1&s=10&sort=newest>
³ Conference summary: <https://zenodo.org/records/10372015>