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The ESO Summer Research Programme 2019

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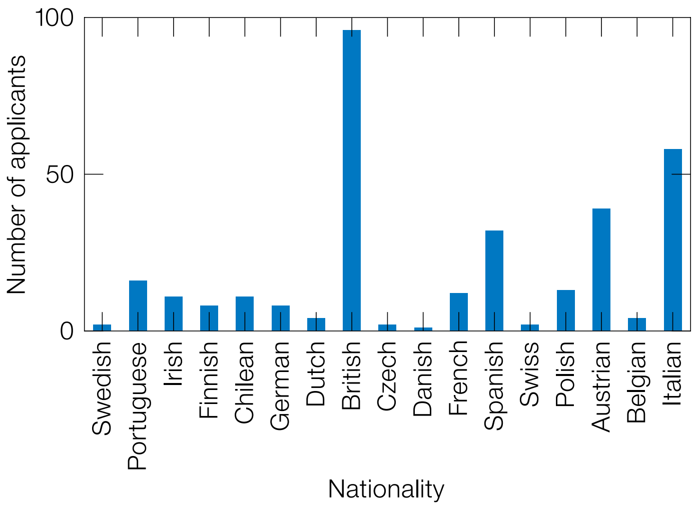

Figure 1. Distribution of the nationalities of the applicants for the first ESO Summer Research Programme.

For the first time ever, a summer research programme was organised at ESO Garching. Seven students, enrolled in universities all around the world, were selected from more than 300 applicants. They each spent six weeks from June to August 2019 carrying out a scientific project under the supervision of teams of ESO Fellows and postdocs, while engaging in the scientific life of ESO. The students carried out research in different fields of astronomy, from comets to high-redshift galaxies and from pulsating stars to protoplanetary discs. In this report we present the programme and describe the main outcomes of the projects.

Motivation and organisation

Summer studentship programmes for undergraduate students are becoming the preferred way for an enterprising student to gain their first research experience; these programmes can last from a few weeks to months at top-class international universities or research centres. Such programmes have a wide range of benefits to students and hosts alike. The ESO Fellows in Garching identified this as an opportunity that had been missing at Garching until now and decided to organise a six-week-long Summer Research Programme at ESO for up to seven university students.

A proposal was submitted by the Garching ESO Fellows requesting funds from the Director for Science to cover travel costs and to provide a basic stipend to cover lodging and living expenses for the students. The proposal was accepted and ESO Fellows, with the support of ESO administrative assistants, organised the first-ever ESO Summer Research Programme. This involved booking ESO apartments and office space, setting up the website[1], organising the application process and the selection of students, planning and delivering a lecture series and, most importantly, designing and leading the research projects.

The response from the community was incredible. More than 300 valid applications were received from university students in most Member States, from our Host Country Chile, and from ESO's strategic partner, Australia (Figure 1). Participants were selected by first distributing the applications amongst all potential supervisors for an initial ranking, followed by a final selection by a committee comprising three fellows, one student and one staff member. The final list included seven students — four females and three males — from seven different countries. After a short video interview all seven students accepted the offer.

Programme overview

The programme started with a workshop, open to all ESO staff, on 1 July 2019. At this workshop the seven research projects were introduced by the advisors, and the students introduced themselves. An introduction to ESO was delivered by the head of the ESO User Support Department Marina Rejkuba, and the Director General greeted all participants from the control room of the La Silla Observatory (he was visiting La Silla for the total solar eclipse at the time).

The students were each working on their own research project, with the supervision of one or more ESO Fellows, for the duration of the programme (Figures 2 & 3). The schedule in the first three weeks also consisted of a set of eight lectures on astronomical topics, a visit to the ESO Supernova including a planetarium show, and a telecon with Anita Zanella (an ESO Fellow observing at Paranal). The final three weeks were mainly focused on the research projects, but with an additional two lectures and one visit to the Extremely Large Telescope (ELT) primary mirror test stand. Most of these additional activities and lectures were organised following an explicit request from the students who had expressed enthusiasm about the first set of lectures. Throughout the duration of the programme the students were among the most active attendees of scientific activities at ESO Headquarters, including talks, science coffees, and informal meetings.

Figure 2. Student Tania Machado with her supervisor Chris Harrison.

Figure 3. ESO Summer Research Programme student Aisha Bachmann with supervisors Jeremy Fensch and Remco van der Burg.

The last days were all focused on the preparation of the most thrilling event for the students: their 15-minute presentation to be given in front of ESO staff, students and fellows during the final workshop in the old ESO auditorium. This event was very well attended by ESO personnel (Figure 4) and showcased the great science that the students were able to achieve during this relatively short programme; some examples are described in the next section.

Students and their research projects

Understanding the formation mechanism of galaxies at their extremes

Advisors: Remco van der Burg & Jérémy Fensch
Student: Aisha Bachmann (German), University Bochum, Germany

One of the most surprising recent results in the field of galaxy formation is the discovery of a significant population of ultra-diffuse galaxies (UDGs) in local galaxy clusters. These are galaxies of the size of the Milky Way, but with a stellar mass similar to dwarf galaxies. Theorists are proposing models that can produce such galaxies in simulations; these generally invoke tidal heating scenarios arising from interactions with neighbouring galaxies, or outflows coming from the galaxies themselves. To distinguish amongst these different scenarios it is important to study the abundance of UDGs as a function of cosmic epoch. This is a very challenging task because only the Hubble Space Telescope (HST) can spatially resolve UDGs at high redshift, and cosmological surface brightness dimming makes them extremely difficult to detect.

Aisha looked for UDGs, at redshifts beyond 1, in the deepest cluster images that were ever taken with the HST. She wrote a detection algorithm and tested it on mock galaxies that she inserted into the data; she then used the algorithm to search for real UDG candidates. Finally, Aisha identified which UDGs, among the candidates she found, are cluster members rather than projections along the line of sight by statistically comparing her detections with those of a reference field. Her preliminary results look extremely interesting and Aisha aims to finalise them during the next months and write up her findings in a publication.

Comet evolution from the Kuiper Belt to a dormant comet in the near-Earth asteroid population

Advisors: Rosita Kokotanekova
Student: Abbie Donaldson (UK & Ireland), University of St Andrews, UK

This project focused on analysing photometric observations of the comet 169P/NEAT taken between February and June 2019 with the FOcal Reducer/low dispersion Spectrograph 2 (FORS2) on the Very Large Telescope (VLT) and with the Wide Field Camera (WFC) on the Isaac Newton Telescope (INT) on La Palma. Since the comet was observed close to aphelion and was therefore inactive, the photomet-

Figure 4. One of the research students, Matthew Wilkinson, presents his research to fellow participants and ESO staff.

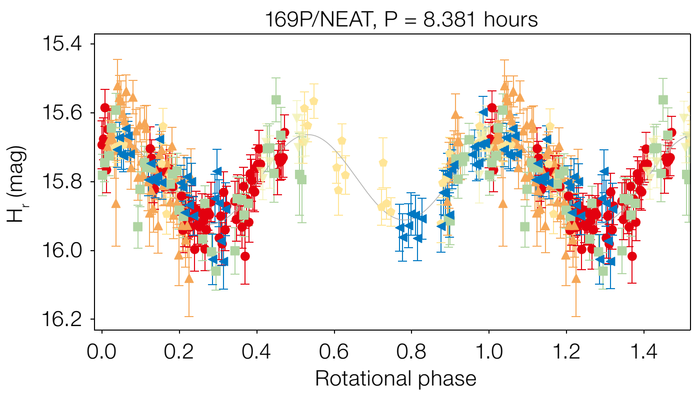

Figure 5. Rotational light curve of comet 169P/NEAT derived from INT/WFC data. The different symbols correspond to data taken during each of the six observing epochs between February and May 2019.

ric observations could be used to extract the brightness variation of the nucleus due to rotation and change of geometry. Abbie derived the rotational light curve of 169P/NEAT using the most likely rotation period of 8.381 hours (Figure 5) and constrained the comet's albedo and the slope of the phase function. Abbie's results will be included in a publication comparing the surface properties of two of the darkest Jupiter-family comets, 169P/NEAT and 162P/Siding Spring with other comets and asteroids.

Preparing for the Extremely Large Telescope: how will high-redshift star-forming galaxies appear with HARMONI?

Advisors: Anita Zanella & Chris Harrison
Student: Tania Machado (Portugese), Technico Lisbon, Portugal

The ELT, with its 39-metre diameter primary mirror, will have the angular resolution and light gathering power to revolutionise our understanding in many astrophysical fields. This project is in preparation for the use of the High Angular Resolution Monolithic Optical and Near-infrared Integral-field spectrograph (HARMONI), a first-generation ELT integral-field spectrograph, to spatially resolve the interstellar medium of high-redshift (z ~ 2–5) galaxies and to measure the physical processes occurring on scales of individual star-forming regions. Tania created simulated HARMONI datacubes of how galaxies at z ~ 2–3 will appear when observed with different observing strategies and observing conditions. The most important result from Tania's work was that our ability to extract key physical properties from the simulated data was limited by applying standard analysis techniques and not limited by the data quality. Work is now required to optimise the techniques before the arrival of the exquisite HARMONI data. Tania has a strong interest in keeping in contact with her advisors and with ESO to continue this work and she hopes to show her results at the conference "Spectroscopy with HARMONI at the ELT" to be held in Oxford in September 2020.

Caught in the act: witnessing the formation of the most massive galaxy clusters across the cosmic time

Advisors: Chian-Chou Chen (T. C.) & Fabrizio Arrigoni Battaia,
Student: Marta Nowotka (Polish), Colorado College, USA

In the hierarchical model of structure formation, the most massive galaxies often form through merging processes within the highest density peaks, known as protoclusters. Identifying these protoclusters and characterising their properties is key to reaching a full understanding of galaxy formation. Recently, new prime candidates for signposts of massive protoclusters have been discovered: they are enormous (> 200 kpc) Lyman-α nebulae (ELAN) which host multiple active galactic nuclei and are surrounded by over-densities of Lyman-α emitters.

To better understand their formation history, Marta developed complex Python algorithms to analyze SCUBA-2 850-micron data and found evidence of dust-obscured star formation around one ELAN. This is an exciting result and we expect it to be published in high-impact journals. Marta will continue to work on the project by investigating similar data sets in other ELAN fields, as well as enjoying a trip to Hawai'i to carry out observing runs at the James Clerk Maxwell Telescope (JCMT) on Maunakea.

Modulated variability: a new window into stellar pulsations

Advisors: Richard I. Anderson
Student: Samuel Ward (UK), University of Durham, UK

What causes the variability patterns of classical Cepheid variable stars to change over time? More and more modulated variability is being discovered among Cepheids, yet its origin remains elusive, and the properties of the modulation challenge the classical paradigm of Cepheids as other well-understood, more simple, variable stars.

Samuel analysed an 8-year-long set of high-resolution optical spectra of a bright Cepheid to unravel the nature and cause of the star's modulated variability. He created his own method for modeling spectral line profiles using multiple components and used it to trace the changes in complex line profiles over time. Additionally, he investigated how different atmospheric layers move at different velocities. Samuel found compelling evidence that the observed modulated line splitting is most likely caused by non-radial pulsation modes, rather than by atmospheric shock related to the dominant pulsation mode, as previously proposed.

Dark matter content of galaxies from globular cluster kinematics

Advisors: Prashin Jethwa & Laura Watkins
Student: Matthew Wilkinson (Australian), University of Queensland, Australia

How well can we measure the amount of dark matter in a galaxy? This was the central question of this project, and its answer will have important consequences for our understanding of cosmology and galaxy formation. Questions about dark matter certainly motivated our pool of potential students, with 115 eager applicants for this project. Out of this talented pool, we selected Matthew, who tested the accuracy of calculations of galactic dark matter content.

Matthew tested calculations which use observations of globular clusters — dense, bright clusters containing tens of thousands of stars. This very same calculation had recently been applied to observations in the Milky Way, so testing its accuracy is of real, present importance. To do this test, Matthew applied the calculation to simulations and compared the results to the correct answer known from the simulations. The results suggest that the calculation may be underestimating the amount of dark matter in galaxies. This is a tentative result and confirming it would require more tests. Prashin and Laura remain in touch with Matthew and are enthusiastically supporting him as he applies for PhD positions in astronomy.

Testing disc evolution with ALMA surveys of CO emission

Advisors: Stefano Facchini, Anna Miotello & Carlo Manara
Student: Francesco Zagaria (Italian), University of Pavia, Italy

How protoplanetary discs evolve is a long-standing question. How they evolve determines the planet formation potential of discs and is a key ingredient in any planet formation model. The two main theoretical paradigms describe disc evolution as driven by viscosity, or by magnetically supported winds. The two lead to different predictions about the evolution of gas disc radii, with the former predicting that the disc radii should expand. In this project, Francesco tested the viscous scenarios by comparing statistical properties of CO fluxes measured by ALMA for the disc populations of Lupus and Upper Sco, two star-forming regions spanning ages between 2 and 10 Myr. Francesco developed a code aimed at reproducing the observed CO fluxes within the viscous evolution framework, with interesting results. While the model reproduces the statistical properties of individual star forming regions well, it is not able to fit all of the star forming regions simultaneously. This suggests either that the viscous evolution scenario has to be revisited, or that the two star forming regions had different initial conditions in their disc mass and radius distributions. The results are presented in a draft paper that will be submitted soon.

Feedback and future programmes

We asked students to give feedback on the programme, and the responses were extremely positive (Figure 6). Interviews carried out with the students are presented in the ESOBlog[2] and highlight how much they enjoyed their research experience and the programme overall.

The great success of the programme has not been overlooked by the ESO Director of Science and by ESO management and we are pleased to report that funding has been secured to run the programme again in the summer of 2020. This is great news for many, including future potential applicants who have already started to inquire about the deadline for applications. How this programme continues will depend on the efforts of many, and its expansion to include more ESO staff, including Fellows in Santiago and/or other ESO departments, is very much encouraged.

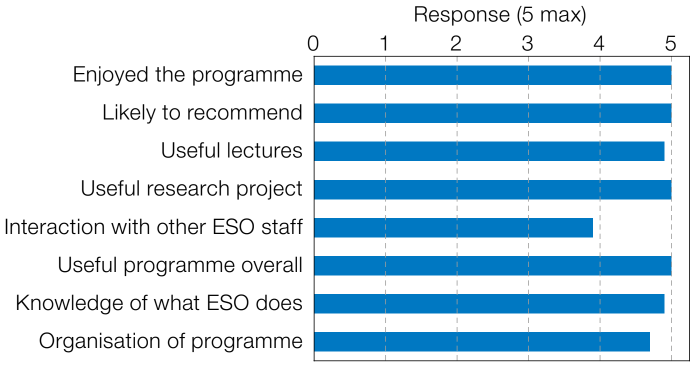

Figure 6. Average results from the feedback given by students at the end of the programme; 5 is the most positive score.

Acknowledgements

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Links

[1] ESO summer research programme website: http://eso.org/summerresearch/
[2] ESOBlog entry *Meet Our 2019 Summer Research Programme Students*: https://www.eso.org/public/blog/from-comets-to-cosmology/

ESO/S. Otarola

The ALMA array on the Chajnantor Plateau from October 2019.