

Report on the ESO Workshop

Preparing for 4MOST – A Community Workshop Introducing ESO’s Next-Generation Spectroscopic Survey Facility

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The 4-metre Multi-Object Spectroscopic Telescope (4MOST) is a state-of-the-art, high-multiplex, fibre-fed, optical spectroscopic survey facility currently under construction for ESO’s 4-metre Visible and Infrared Survey Telescope for Astronomy (VISTA). During the first five years of operation 4MOST will be used to execute a comprehensive programme of both Galactic and extragalactic Public Surveys, and 30% of the observing time during this period will be available to the community. The purpose of this workshop was to prepare the ESO community for this exciting scientific opportunity.

ESO has a long history in survey astronomy, dating all the way back to its original mission. A new chapter will be added to this history by the advent of 4MOST, a spectroscopic survey facility featuring a field of view large enough to survey a large fraction of the southern sky in a few years, and a multiplex of 2400 fibres enabling surveys of tens of millions of objects (de Jong et al., 2019). 4MOST will spectroscopically complement a number of current and future facilities, including Gaia, eROSITA and Euclid, and will address a wide range of science areas, from the structure of the Milky Way to cosmology.

To enable its science goals, 4MOST was specifically designed as a facility for executing large surveys. Hence, for a period of at least five years, VISTA will be dedicated exclusively to observations with 4MOST, and the 4MOST facility will in turn be dedicated entirely to a comprehensive, five-year programme of both Galactic and extragalactic surveys. 70% of the observing time during this five-year period will be awarded to the 4MOST Consortium in return for delivering and operating the facility. This time will be spent on a set of 10 distinct yet interlocking surveys, collectively known as Consortium Surveys. The other 30% of the

observing time will be available to the ESO community to conduct additional surveys. Regardless of their provenance, however, all 4MOST surveys will be ESO Public Surveys.

The process of selecting the Community Surveys will be initiated by a Call for Letters of Intent for Public Spectroscopic Surveys, to be issued by ESO by the end of 2019. The workshop reported on here was jointly organised by ESO and the 4MOST Consortium to prepare the broader ESO community for this exciting scientific opportunity, to help potential Principal Investigators (PIs) respond successfully to the Call, and to foster scientific collaborations between the community and the 4MOST Consortium.

Specifically, the goals of the workshop were: (i) to provide the ESO community with up-to-date information regarding the 4MOST facility, its capabilities, survey strategy, data reduction and science pipelines, the 4MOST Consortium’s scientific plans, and the application and selection processes for 4MOST Community Surveys; (ii) to provide the ESO community with an opportunity to present their scientific ideas for 4MOST Community Surveys; and (iii) to provide a platform for discussion, networking and collaboration between potential Community Survey PIs and the 4MOST Consortium, and to explore complementarities between Consortium Surveys and potential Community Surveys.

To prime the workshop, the 4MOST Consortium had published a series of 13 articles in the March 2019 issue of *The Messenger*¹ (i.e., two months before the workshop), describing the facility, its operations, the survey strategy, and each of the 10 Consortium Surveys.

Broadly speaking, the presentations at the workshop fell into three categories, which are described in the following sections.

Providing information about 4MOST to the community

The seven presentations in the first category essentially provided the community participants in the workshop with “techni-

cal” information about 4MOST. These presentations largely corresponded to the articles by de Jong et al. (2019), Walcher et al. (2019) and Guiglion et al. (2019) in the above-mentioned 4MOST issue of *The Messenger*, and all of the information presented is also available on the 4MOST website². The 4MOST PI, Roelof de Jong, presented an overview of the 4MOST project and the technical characteristics and capabilities of the facility. In a separate presentation he also laid out the constraints and principles of the survey strategy.

Jakob Walcher provided a very lucid, high-level account of the complex 4MOST operations scheme. This was a particularly important talk because several aspects of this scheme, including the role of the 4MOST Consortium in operations, and the concepts of a shared focal plane and participating and non-participating Community Surveys, are new to the world of ESO operations and were thus unfamiliar even to experienced ESO users. This talk was further complemented by Nic Walton’s presentation on 4MOST data reduction and scientific analysis pipelines, and data products. Sofia Feltzing and Joe Liske explained the concept of the 4MOST Science Team in some depth, i.e., the organisational entity within which all of the Consortium and participating Community Surveys work together to plan, execute and exploit the 4MOST survey programme. Finally, Vincenzo Mainieri, the ESO 4MOST Project Scientist, detailed the process by which ESO will select the Community Surveys.

The second category comprised 10 presentations, one for each Consortium Survey, in which the 4MOST Consortium laid out its scientific plans. Briefly, the Consortium Surveys consist of: four surveys complementing Gaia and targeting the bulge/disc and halo components of the Milky Way at low and high spectral resolutions, respectively; a survey of the Magellanic Clouds; two surveys following up galaxy clusters and active galactic nuclei (AGN) detected by the X-ray telescope e-ROSITA, respectively; a galaxy evolution survey; a cosmology survey; and, finally, a survey dedicated to the follow-up of extragalactic transients.



ESO/M. Zamani

Figure 1. Participants at the Preparing for 4MOST workshop outside ESO headquarters.

Each of the talks in this category presented the survey’s scientific context, specific goals, currently planned survey area and target selection, and its data quality requirements. The goal of these talks was to provide potential Community Survey PIs with enough information to decide whether the scientific questions they had in mind (i) are already addressed explicitly by the Consortium, (ii) can be addressed with the Consortium Surveys’ data (all of which will be made public), or (iii) require a new survey. Since the Consortium Surveys were already succinctly described in the above-mentioned 4MOST issue of the Messenger we will not discuss these talks further here.

Community proposals: Galactic science

The third category consisted of 16 presentations in which members of the community presented their science cases for Community Surveys. Eight of these were concerned with Galactic science, and a recurring theme among them was that 4MOST’s wide field of view is singularly well suited to studying stellar clusters, associations, star-forming complexes and their larger scale environment. Sara Lucatello and Antonella Vallenari jointly proposed complementing the chemodynamical studies of field stars by the Consortium Surveys with a commensurate effort to understand the formation of stellar clusters, their evolution, and their relation with the field population by

conducting a comprehensive survey of 120 globular and 1500 open clusters.

Meanwhile, Henri Boffin argued the case specifically for observing young stellar clusters in order to unravel their connected formation histories in large complexes. Similarly, Nicholas Wright outlined a survey of high- and low-mass young stars and ionised nebulae across several massive star-forming complexes to extend our view of star formation and early stellar evolution beyond the most nearby and most clustered stellar systems to the entirety of such star-forming complexes. This limitation on our current view of star formation also motivated Germano Sacco to propose an unbiased survey of all pre-main sequence and upper main sequence stars within 500 pc. Pre-main sequence stars were also on Giacomo Beccari’s mind, but in the context of protoplanetary discs, and he discussed how 4MOST data of such stars in young starburst clusters could add chemical and kinematic information to existing $H\alpha$, Gaia and WISE data to comprehensively understand disc fractions and lifetimes.

Moving away from clusters and star formation, Carme Gallart addressed the formation history of the Milky Way by discussing age distributions (derived from Gaia colour-magnitude diagrams) of geometrically defined halo and disc samples and proposed a similar analysis for samples defined by abundances and kinematics using 4MOST. Tommaso Marchetti made an interesting case for a 4MOST survey of thousands of candidate hypervelocity stars identified from Gaia data in order to obtain their radial veloci-

ties and chemical compositions. A full characterisation of this high velocity population would allow us to trace the Galactic potential and constrain the environment of the Galactic centre, whence these stars were ejected. Finally, Giampaolo Piotto discussed the crucial role of 4MOST in characterising the target sample of the PLATO mission.

Community proposals: extragalactic science

Kicking off the extragalactic part of the community talks, Hans Böhringer put forward a proposal for a 4MOST redshift survey of candidate members of galaxy clusters in the redshift range 0.4–0.8, selected initially from KiDS and VIKING, and later from Euclid. He argued that this survey would support the main Euclid cluster science by extending the cluster sample below a redshift of 0.8 (where Euclid’s own infrared spectroscopy is ineffective) and calibrating the Euclid cluster selection function and cluster masses with high precision. On the topic of AGN, Gandhi Poshak described his efforts to construct a complete sample of AGN within 250 Mpc, which 4MOST could support by providing spectroscopic follow-up of infrared- and X-ray-selected candidates.

Moving on to the domain of galaxies, Arjen van der Wel summarised some results from the recently completed VLT survey Large Early Galaxy Astrophysics Census (LEGA-C) and shared his thoughts on the possibility of complementing the Consortium’s galaxy redshift survey (Wide-Area VISTA Extragalactic

Survey — WAVES) with an intermediate redshift, high-S/N extension, thus allowing stellar populations, star formation histories and kinematics to be derived with the same precision as in the local Universe. Along the same lines, Amata Mercurio presented her proposal for a southern (i.e., 4MOST) extension of the high-S/N Stellar Populations at intermediate redshifts Survey (StePS) which will be carried out with WEAVE, a wide-field multi-object and multi-IFU facility on the William Herschel Telescope. The distinguishing feature of StePS-South would be its synergy with WAVES, i.e., the combination of deep spectroscopy and detailed environmental information.

Another type of synergy — that between 4MOST and MeerKAT — was discussed by Kenneth Duncan. He described the wealth of information that could be derived from the combination of 4MOST spectroscopy with radio continuum and HI data from the deep extragalactic MeerKAT surveys MeerKAT International GigaHertz Tiered Extragalactic Exploration (MIGHTEE) and Looking at the Distant Universe with the MeerKAT Array (LADUMA). This would include, *inter alia*, the star formation history of the Universe, the evolution of the cosmic HI density, and the fundamental relations between galactic HI content and star formation, stellar mass, and environment. Lingyu Wang then proposed a multi-purpose 110-square-degree redshift survey of 0.5 million intermediate redshift galaxies in Stripe 82, a region covered by a wealth of multi-wavelength data, with the primary aims of constraining the nature of dark matter and dark energy, and tracing galaxy and AGN evolution over the redshift range 0.2–0.6. Turning to the low-redshift Universe, Edward Taylor reported on the forthcoming Taipan survey and proceeded to make the case for a complete hemispheric 4MOST redshift survey of 5.5 million galaxies out to a redshift of 0.1 to study the baryon lifecycle of galaxies as a function of mass and environment, and to map out the large-scale density and velocity fields. Finally, Dominik Bomans highlighted the ability of 4MOST to identify relatively large samples of rare galaxies by focusing on the case of extreme emission-line galaxies.

The presentations from the three categories above were interspersed with one another and spread throughout the programme³. Also, each day of the workshop included two question and discussion sessions to provide the opportunity for participants to clarify any remaining issues, and to jointly discuss the connections between the scientific ideas presented by the community and the Consortium's plans.

Conclusions

The workshop was a resounding success. As was expected, the community identified a number of exciting scientific themes, ranging from protoplanetary discs to galaxy evolution and cosmology, that can be addressed with 4MOST in addition to the science cases proposed by the Consortium. Many of the community speakers stressed the complementarity between their science goals and those of the Consortium Surveys, thus reinforcing the vision that the scientific value of the 4MOST survey programme as a whole is larger than the sum of its constituent parts. Furthermore, of the ~90 workshop participants in total, about 55 were from the community. Considering that this workshop was mostly aimed at potential PIs of Community Surveys, we believe that the turnout, as well as the wide range of science cases presented, demonstrated the strong interest within the community in the large-scale survey capabilities provided by 4MOST. In turn, the organisers received feedback from community participants indicating that the Consortium and ESO had done a good job of providing relevant information to the participants.

Demographics

Although the Scientific Organising Committee considered gender balance while putting together the programme, this was not easy to achieve owing to the special nature of this workshop. Of the total sample of 33 speakers only 8 (24%) were women. This was due to only 1 out of 7 speakers in the first category above being female, reflecting a dearth of women in leadership positions in the 4MOST project, and only 4 out of 16

(25%) talks contributed by the community being delivered by women. The latter ratio was unfortunately slightly lower than the ratio of 7:24 (29%) among the requested talks, but the SOC agreed that the three submissions by women that were not selected did not sufficiently address the goals of the workshop. In the second category (i.e., science presentations by the Consortium) the gender balance was slightly better; while the female fraction should have been 40% in this category according to the initial planning, it became 30% owing to the late arrival of one of the female speakers. This percentage is still representative of the 31% of Consortium Survey PIs who are women. Full gender parity was achieved among the session chairs.

In terms of academic age, the speaker roster was heavily biased towards senior people, with only three postdocs and one PhD student among the speakers. We attribute this again to the special nature of this workshop, where the Consortium was represented by senior figures of the 4MOST project and the Consortium Surveys; similarly, the community was represented by potential leaders of Community Surveys. Such positions tend to require long-term employment stability, i.e., permanently employed staff.

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References

- de Jong, R. S. et al. 2019, *The Messenger*, 175, 3
- Guiglion, G. et al. 2019, *The Messenger*, 175, 17
- Walcher, C. J. et al. 2019, *The Messenger*, 175, 12

Links

- ¹ Link to 4MOST Messenger issue: <https://www.eso.org/sci/publications/messenger/toc.html?v=175&m=Mar&y=19>
- ² Link to 4MOST website: <https://www.4most.eu>
- ³ Link to workshop programme: <https://www.eso.org/sci/meetings/2019/4MOST/program.html>
The workshop programme contains links to videos and PDFs of all presentations, as well as videos of the discussion sessions.