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Report on the ESO workshop

Coordinated Surveys of the Southern Sky

held at ESO Headquarters, Garching, Germany and online, 27 February – 3 March 2023

Martin Zwaan[1]
Anna Bonaldi[2]

[1] ESO
[2] SKA Observatory, Jodrell Bank, Macclesfield, UK

How can two major organisations dedicated to ground-based astronomy work together to maximise the science impact of their astronomical surveys? This was the topic for the Coordinated Surveys of the Southern Sky symposium, jointly organised by ESO and the Square Kilometre Array Observatory between 27 February and 3 March 2023. The aims of the symposium were to raise awareness across the respective communities of survey capabilities and to build liaisons in preparation for synergetic surveys, as well as for multi-wavelength follow-up programmes.

Introduction

More than 200 participants gathered, in person at ESO's headquarters and online, between 27 February and 3 March 2023, for the Coordinated Surveys of the Southern Sky symposium, jointly organised by ESO and the Square Kilometre Array Observatory (SKAO). The aim of the symposium was to plan how to get the most from surveys conducted by both organisations' facilities. To achieve this, the symposium had sessions focusing on planned surveys and current and upcoming survey facilities, including SKA pathfinder and precursor instruments as well as the SKA, and ESO's optical, near-infrared and millimetre facilities. In addition, ample time was reserved for more focused discussion sessions to create opportunities to discuss in more detail the ideas of synergies, make plans and create connections between the communities.

The SKA project originated from the desire the study neutral hydrogen emission from the earliest galaxies, requiring a collecting area of unprecedented size. Since then, the design of the SKA has evolved, and it will be able to also explore new frontiers in galaxy evolution and cosmology, cosmic magnetism, the laws of gravity, time-domain astrophysics, extra-terrestrial life — and the unknown[1]. The SKAO, currently under construction, will consist of two instruments: the SKA Low, in Western Australia, observing in the 50–350 MHz frequency range, and the SKA Mid, in South Africa, with frequency bands in the 350 MHz to 15.4 GHz range. The SKAO is scheduled to begin science operations after the end of construction in 2028. The science programme for the SKAO will be determined through competitive calls for time allocation proposals from the scientific community. It is foreseen that the majority of the telescope time will go towards Key Science Projects: large observational programs, running for several years. In addition to the SKA itself, several currently operational SKA precursors and pathfinder facilities (MeerKAT, ASKAP, LOFAR, and MWA) were covered in detail at the symposium.

On the ESO side, comprehensive overviews of ESO's current facilities were presented at the symposium. Emphasis was put on upcoming instrumentation that is of particular interest for synergetic survey observations. The new Multi-Object Optical and Near-infrared Spectrograph (MOONS) currently under construction for the Very Large Telescope (VLT) will provide exquisite spectroscopic capabilities across the 0.64–1.8 µm wavelength range using 1000 fibres with individual robotic positioners. The 4-metre Multi-Object Spectroscopic Telescope is a wide-field spectroscopic survey facility that is under

Figure 1. Workshop participants attending in person at ESO's headquarters.

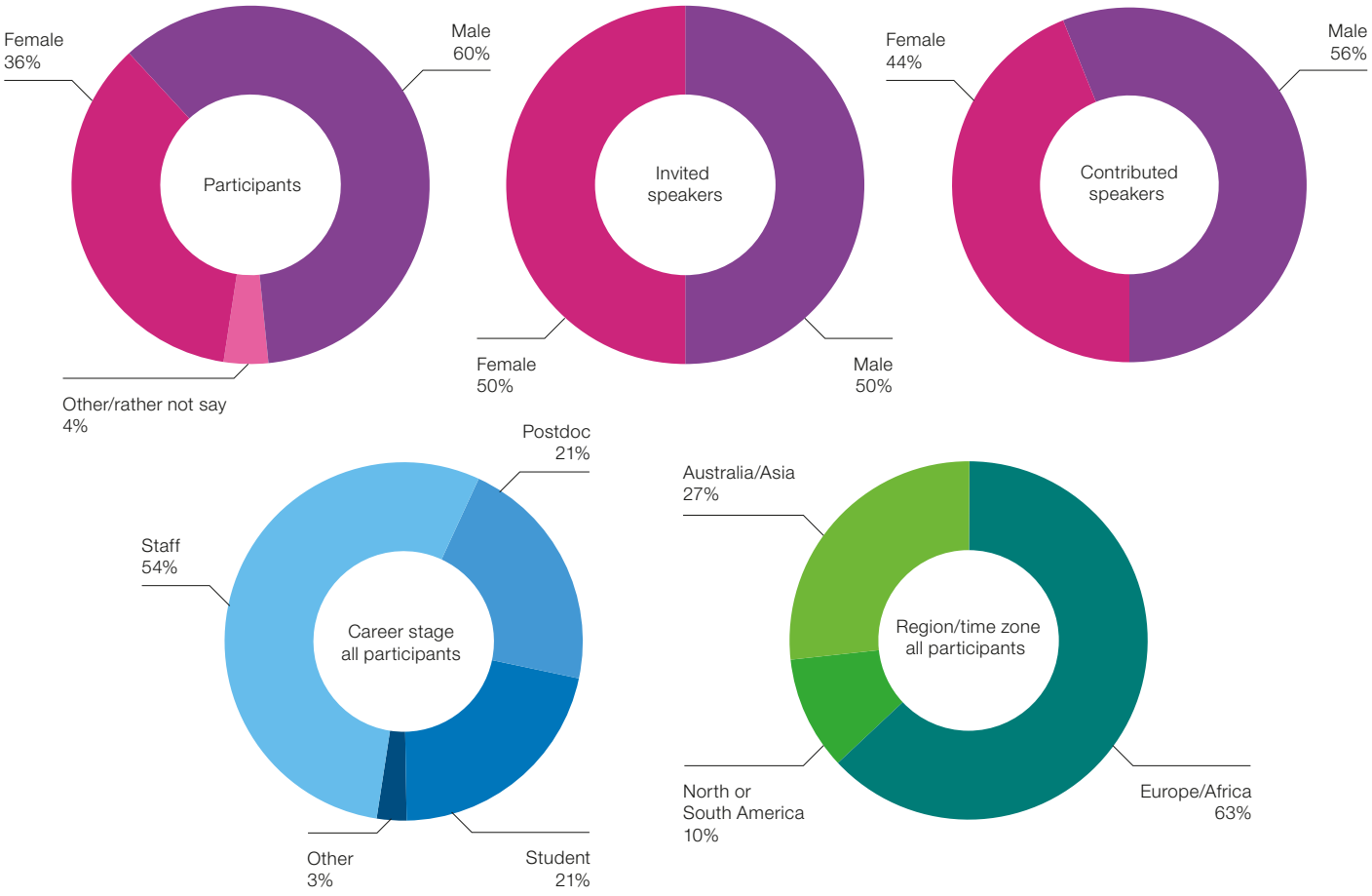

Figure 2. Demographics of workshop participants.

development for the Visible and Infrared Survey Telescope for Astronomy (VISTA) and which will be able to simultaneously obtain spectra of around 2400 objects distributed over a hexagonal field of view of 4.2 square degrees. Finally, MOSAIC will be a cutting-edge multi-object spectrograph that will use the widest possible field of view provided by ESO's Extremely Large Telescope (ELT). Another important facility for possible SKA synergies is the Atacama Large Millimeter/submillimeter Array (ALMA), which, despite its limited field of view, provides a unique view of gas and dust across the Universe, fitting quite naturally alongside deep radio observations.

Throughout the symposium, contributed presentations showcased examples of the scientific synergetic use of the above-mentioned facilities. These presentations, in addition to invited talks, addressed four intertwined themes spread over four days: 1) science within the Milky Way galaxy and our own Solar System; 2) transients and time-domain science; 3) galaxy evolution; and 4) the epoch of reionisation, cosmology and the high-redshift Universe. Following the main symposium, two half-days were reserved for more focused workshops, organised by science theme. The purpose of these workshops was to synergise the ideas presented at the symposium, forge synergies between different teams and develop plans for collaborative surveys and cross-facility follow-up programmes.

Synergies per science area

The Galaxy

The Galactic centre provides an excellent example of where multiwavelength observations are essential to capitalise on the power of the current and next generation of telescopes. The Galactic centre has already been targeted extensively with, for example, ALMA and the VLT(Interferometer), and future observations with these facilities in concert with the SKA will provide a wealth of information on its structure, the formation history, star formation etc. Other potential opportunities for synergetic science in the Galaxy include grain growth in protoplanetary discs or the physics of young stellar objects, where joint wide-field observations with MOONS and the SKA could target hundreds of objects, which then could be combined with pointed ALMA observations. Unidentified radio sources were underscored as another example, where wide-field optical follow-up with, for example, 4MOST, would assist identification.

Transients and time-domain

The SKA and its pathfinders are opening up new avenues into real-time discovery of transient events, as well as the potential to access previously inaccessible timescales. The SKA could serve as a transient discovery machine for, for instance, Fast Radio Bursts, providing targets for follow-up with ESO facilities. Multi-wavelength follow-up is critical for the characterisation of astrophysical transients and should cover a range of timescales. Immediate response times are important for reverse shocks in gamma-ray bursts, and longer timescales are needed to study source evolution with light curves, as well as for redshift measurements of extragalactic transient sources. The instruments needed for this work encompass most of ESO's facilities, providing wide-field deep imaging, spectroscopy, and high angular resolution, as well as similar capabilities on SKA's facilities including the high-time-resolution mode.

Galaxies and galaxy evolution

The discussions around this theme highlighted the importance of running optical spectroscopy surveys ahead of SKA surveys. This would avoid the need for long spectroscopic follow-up campaigns, and the availability of spectroscopic data would allow, for example, HI 21-cm stacking of the radio data. In particular, the importance of 4MOST surveys supporting SKA redshift survey campaigns was emphasised, as well as integral field unit and ALMA deep fields, which in tandem with SKA deep observations, will provide a full census of molecular, atomic and ionised gas at kiloparsec-scale spatial resolution. Joint galaxy evolution studies would benefit from a tiered approach to the identification of survey fields, ranging from a few to several thousand square degrees.

Epoch of reionisation, cosmology and high redshift

Similar arguments hold for this science area. In particular, near-infrared spectroscopy over large fields offered by MOONS and MOSAIC will provide large samples of galaxies at high redshift, which, cross-correlated with low-frequency SKA surveys, give a unique insight into galaxies at the time of cosmic reionisation. Similar synergies would enable intensity mapping used for measuring the three-dimensional structure of the early Universe. For cosmological surveys, obvious synergies exist between the 4MOST and SKA wide-field surveys.

Concluding remarks

Participants were deeply engaged in suggesting and discussing synergetic science over the course of the symposium. The examples given above are merely the beginning of what science and which coordinated observations will be possible. Those ideas will be consolidated over the next months into a publication that will be a point of reference for collaborations going forward.

To prepare optimally for future joint surveys between SKAO and ESO facilities, several points related to policy and organisation were touched upon which will require further discussion. For example, participants addressed the possibility of exploring coordinated time allocation processes to optimise the efficiency of telescope scheduling and as a means to forge collaborations early on. In addition, coordinated archival capabilities were highlighted as an area where much common effort would be beneficial. Existing Virtual Observatory infrastructure efforts and precursor datasets should be used to train and prepare for SKA datasets. Note that existing survey teams are doing a lot of preparatory work that should be built on for future infrastructure.

The workshop took place at ESO's Headquarters in Garching, and allowed virtual as well as in-person participation. The Scientific Organising Committee (SOC) was composed of Anna Bonaldi (SKAO, co-chair), Martin Zwaan (ESO, co-chair), Barbara Catinella (ICRAR/UWA), Michele Cirasuolo (ESO), Pratika Dayal (Groningen), Miroslava Dessauges (Geneva), Jan Forbrich (Hertfordshire), Jochen Liske (Hamburg), Celine Peroux (ESO), Elaine Sadler (Sydney) and Patrick Woudt (Cape Town). In total 276 participants registered for the symposium, at any time approximately 90 people attended in person, others participated online and numbers varied depending on the geographical location of the participants. The organisers ensured a balanced distribution of gender, seniority and geographical origin of the SOC members, the invited speakers, and the workshop leads (see Figure 2).

Acknowledgements

Many thanks to the Local Organising Committee, which consisted of Alžběta Opištilová, Ellen Leitinger, Ivanna Langan, Martin Zwaan, Nelma Silva, and Simon Weng. In addition, we thank the SOC, and especially also the discussion leads of the various workshops: Mario Santo, Anna Bonaldi, Shari Breen, Rainer Schoedel, Matthew Colless, Isabella Prandoni, Ben Stappers, and Patrick Woudt.

Links

[1] SKA Science Book: https://www.dropbox.com/scl/fi/t5fuudtu1zqr6flswcbgn/SKA-Astophysics-Vol1.pdf?rlkey=4gg5vk7fngi0n9w6ft59sldnf&e=1&dl=0z