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Report on the ESO Workshop

QUESO: Submillimetre/Millimetre/Centimetre *Q* & *U* (and *V*)

held at ESO Headquarters, Garching, Germany, 25–27 October 2017

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Polarised emission encodes essential physical information about many components of the Universe, ranging from dust grains and magnetic fields in molecular clouds, protoplanetary discs and evolved stars, through to the formation and propagation of relativistic outflows in Active Galactic Nuclei, and to the effects of inflation and primordial gravitational waves on Cosmic Microwave Background (CMB) anisotropies. The aim of this workshop was to bring together current and future ALMA users, observatory calibration experts and software developers from a broad range of research fields making use of polarimetric techniques in the frequency range between approximately 5 and 1000 GHz. This range was deliberately restricted in order to focus attention on common problems and to promote cross-fertilisation between different subject areas. The meeting provided an opportunity for the polarimetric community to develop collaborations, understand the latest technological developments and decide on common priorities for the future.

Observing centimetre- or millimetre-wave polarised radiation at very high angular resolutions and sensitivities typically involves the use of interferometric techniques. Modern instruments can now enable full polarisation imaging at unprecedented sensitivity over wide instantaneous bandwidths. Polarisation observations have become routine at the Karl G. Jansky Very Large Array (JVLA) as well as other modern observational facilities in the centimetre, millimetre, and submillimetre bands, and they will increasingly become important for the Atacama Large Millimeter/submillimeter Array (ALMA). It is particularly exciting to note that ALMA's excellent site will allow interferometric polarisation observations to be made at frequencies approaching 1 THz for the first time.

Figure 1. Participants at the QUESO Workshop photographed in front of the ESO Library.

The meeting began with two extended presentations by George Moellenbrock and Ivan Marti-Vidal on polarimetric techniques for high-frequency interferometry. These presentations summarised the techniques of interferometric polarimetry, data calibration and interpretation, and novel algorithms developed for the new generation of interferometers. Synthesis instrumental polarisation calibration fundamentals for both linear (ALMA) and circular (JVLA) feed bases were reviewed, with special attention paid to practical problems affecting modern instruments.

A major theme of the meeting was the unique role of polarimetric observations in constraining the magnetic fields in regions of star formation at high mass — by Heshou Zhang, Katherine Pattle, Archana Soam and Thushara Pillai — and at low mass — by Anaelle Maury, Maud Galametz and Valeska Valdivia. Massive filaments are magnetised and the magnetic field may be as important as turbulence and gravity. Different methods for estimating the field strength (the Chandrasekhar-Fermi method and Zeeman splitting) are valid in different regimes and therefore difficult to cross-check. Polarimetric observations may potentially bring new insights into important micro-physics, such as the efficiency of grain alignment by magnetic fields, anisotropic radiation fields and molecular gas flows. Further studies would then enable more robust investigations of magnetohydrodynamic effects such as magnetic braking.

Polarimetry also complements total-intensity imaging of protoplanetary disks. From the fitting of ALMA polarimetric data from 0.87 to 3 mm in the archetypal disc around HL tau, Akimasa Kataoka infers that the grain sizes are much smaller than those derived from the total intensity spectrum alone, with important implications for planet formation.

Liz Humphreys and Helmut Wiesemeyer outlined how strong masers (SiO, H_2O and OH) are observed in cool evolved stars. The maser emission can display a high degree of circular and linear polarisation, revealing information about the magnetic field strength and morphology, which are dynamically important in the circumstellar envelopes, and which fall off with radius as expected for a toroidal geometry. Magnetic fields may also drive the shapes of the AGB stars to highly axisymmetric/aspherical planetary nebulae.

The meeting also covered extragalactic applications. The measurement of Faraday rotation at millimetre wavelengths in the cores of AGN is emerging as an important probe of the accretion rate, following early work on the Galactic Centre. Detections were presented for M87 and 3C273 by Keichi Asada and Talvikki Hovatta, and Hiroshi Nagai noted that the non-

detection in Centaurus A may be a consequence of orientation.

An old problem, relevant to both AGN jets and star formation, is how to distinguish between vector-ordered and disordered but anisotropic field topologies, as both are capable of producing high degrees of polarisation. Carole Mundell considered both topologies in her discussion of AGN and gamma-ray burst sources. Monica Orienti pointed out that the degree of field ordering may also help to distinguish between particle acceleration mechanisms, for example in hot spots of radio galaxies.

Although the main theme of the workshop was interferometric imaging of polarisation, observations of the CMB with bolometric arrays were also discussed by Sean Bryan. There are well-known and exciting applications of CMB observations, including the potential detection of cosmological B-modes, but also a number of synergies, both observational (polarised point sources, foreground subtraction) and technical (improved lens materials for millimetre-wave receivers).

The meeting served a valuable purpose by identifying priorities for future developments in instrumentation. In rough order of importance, these were agreed to be:
- Very accurate circular polarisation calibration in continuum and line (Zeeman effect).
- Improved efficiency of polarisation calibration, avoiding the need for large parallactic angle rotation during an observation.
- Wider frequency coverage (for example, extending polarisation observations to the ALMA Bands 8–10).
- Lower systematics for measurement of linear polarisation, both to measure polarisation fractions < 0.1 % in protoplanetary discs and to achieve high dynamic range for total intensity.
- Polarisation calibration over the primary beam, for example using Mueller matrix methods. This is essential for ALMA polarisation mosaics.

All of the presentations are linked on the meeting website[1] and are available through the SAO/NASA Astrophysics Data System database.

Demographics

There were 62 registered participants at the workshop (Figure 1), three quarters of these coming from European institutions. One-third of all participants were women, and a similar fraction were early-career researchers, i.e., Masters and Doctoral students or junior postdoctoral scientists.

Acknowledgements

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Links

[1] QUESO Programme: https://www.eso.org/sci/meetings/2017/QUESO2017/program.html

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Report on the MOSAIC Science Colloquium

Spectroscopic Surveys with the ELT: A Gigantic Step into the Deep Universe

held at the Toledo Congress Centre, Toledo, Spain, 17–19 October 2017

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The Phase A design of MOSAIC, a powerful multi-object spectrograph intended for ESO's Extremely Large Telescope, concluded in late 2017. With the design complete, a three-day workshop was held last October in Toledo to discuss the breakthrough spectroscopic surveys that MOSAIC can deliver across a broad range of contemporary astronomy.

ESO's Extremely Large Telescope (ELT) will be the world's largest optical/infrared facility for at least a generation. It will have an immense collecting area, equivalent to gathering together all the current large telescopes in use today. Multi-object spectroscopy (MOS) will be a key capability of the ELT, able to harness its unprecedented sensitivity to deliver unrivalled surveys of the Universe. The MOSAIC design combines high-multiplex near-infrared and visible spectroscopy, together with adaptive optics (AO) spectroscopy in the near infrared that exploits the fantastic angular resolution of the ELT across a large field of view.

The workshop opened with the latest news on the ELT project from the ELT Programme Scientist, Michele Cirasuolo, and with overviews of the scientific motivations and technical design of MOSAIC, which were presented by François Hammer and Myriam Rodrigues. These were followed by talks that helped set the scene of the broader landscape in the