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Report on the ESO Workshop

The VLT in 2030

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This four-day workshop offered a forum to discuss the scientific future of the VLT and VLTI. Overview talks of some of the main scientific topics for the next decade were followed by presentations on the most important facilities operating in 2030. Several instrument concepts and ideas were presented which would signifantly enhance the current VLT and VLTI capabilities. The workshop discussions are the basis for the plans for the VLT after 2025.

Introduction

The VLT/I ranks amongst the most productive and most visible astronomical facilities worldwide. As the world's premier ground-based facility, it provides a powerful suite of visible and infrared instruments, including unique capabilities like coherent and incoherent combinations of the four 8-metre Unit Telescopes (UTs) and a multi-laser-guided adaptive optics (AO) system. In combination with the Atacama Large Millimeter/submillimeter Array (ALMA), VLT/I provides comprehensive coverage of the electromagnetic spectrum from the ultraviolet and visible through the infrared to submillimetre wavelengths for the European astronomical community and its partners.

With the advent of ESO's Extremely Large Telescope (ELT), the VLT and VLTI will take on a new role. They will continue to serve a large community and provide unique data. The VLT's and VLTI's unique capabilities are due to the versatile instrumentation on the four 8-metre telescopes, the spatial resolution achievable by interferometry with baselines of over 100 metres, access to ultraviolet/blue and optical wavelengths (including support from adaptive optics) and the flexible operations model. The telescopes and instruments have been maintained at peak performance and new capabilities continuously developed over the past two decades. An ongoing programme to avoid hardware and software obsolescence ensures that the facility can be operated for many years to come. A dedicated instrumentation programme is in place for the coming decade.

Workshop structure

How do we make sure that the future of the VLT and VLTI remains science driven? The workshop was designed to address this question by charting some of the most exciting current research topics into the next decade and deriving the necessary capabilities based on discussions throughout the workshop programme. The workshop was attended by about 130 participants. Two approaches were followed. First, the workshop participants heard reviews of five central research topics: cosmology, galaxy and black hole evolution, resolved stellar populations, star and planet formation, and the Solar System. In the second part, facilities that are due to be operating in the second half of the next decade were presented. These include ALMA, the next generation of ELTs, European Space Agency (ESA) space-based observatories, the James Webb Space Telescope (JWST), the Large Synoptic Survey Telescope (LSST), the Cherenkov Telescope Array (CTA) and the Square Kilometre Array (SKA). The ESO status, in particular the current VLT and VLTI setup (instrumentation, operations, calibrations, surveys) was also laid out. This was followed by contributed presentations on science cases and potential new VLT instruments. All sessions had ample time set aside for discussions. The workshop programme is available online[1].

ESO Director General Xavier Barcons opened the workshop and gave an overview of the current ESO situation and plans. He stressed that ESO's ELT is central to the organisation's efforts in the coming years and cautioned the audience that VLT developments would need to proceed within the available resources. Within that envelope there is stable funding for Paranal instrumentation developments and Paranal operations (the ELT will eventually be integrated into this operational paradigm). This implies that there will not be a new generation of VLT and VLTI instruments, rather a steady, albeit limited, flow of new instruments in the coming decade.

Five major topics were chosen for broad summaries and forward looks into the next decade. It is always difficult to predict the future, but the five reviewers did an excellent job. Matthew Colless (Australian National University, Canberra) reviewed the current and future plans in cosmology. He restricted himself to the determination of cosmological parameters and astrophysical contributions to fundamental physics but excluded topics like galaxy formation and evolution. In the realm of multi-object spectroscopic facilities he acknowledged the significant potential of the 4-metre Multi-Object Spectroscopic Telescope (4MOST); he also pointed out that other projects, for example, the Dark Energy Spectroscopic Instrument (DESI) at the National Optical Astronomy Observatory (NOAO), are more advanced and will begin observations sooner. Versatile facilities like the VLT will become very important, should a deviation from the currently favoured Λ-Cold Dark Matter (ΛCDM) model be discovered. He noted the important contributions to the study of strong gravity by the VLT and the VLTI. It was pointed out during the discussion that the VLT has played critical roles in addressing some of the most fundamental cosmological problems, for example, providing crucial spectroscopy for supernova cosmology projects and to probe the variation in fundamental constants such as the fine-structure constant. Looking to 2030, he felt that other facilities such as Euclid would become significantly more important for cosmology than the VLT.

Linda Tacconi (Max Planck Institute for Extraterrestrial Physics [MPE], Garching) presented the current status of the very wide field of galaxies and black holes. Resolved properties, like rotation curves or velocity dispersions, will gain in importance to the understanding of the dynamics of early galaxies. She emphasised the strength of integral-field spectroscopy for such studies and how well the VLT already caters to this type of research (for example, the Spectrograph for INtegral Field Observations in the Near Infrared [SINFONI], the Multi Unit Spectroscopic Explorer [MUSE], and the *K*-band Multi Object Spectrograph [KMOS]). Several of

the planned instrument developments will be extremely helpful for this field (the Enhanced Resolution Imager and Spectrograph [ERIS], and the MCAO-Assisted Visible Imager and Spectrograph [MAVIS]), and for some other studies presented during the workshop. Of course, a better understanding of individual supermassive black holes is critical and GRAVITY, the AO-assisted, two-object, multiple beam-combiner on the VLTI, represents a breakthrough in this respect. Linda Tacconi emphasised the importance of very high angular resolution observations of active galactic nuclei (AGN) as probes of galaxy evolution over cosmological times.

The ESA space observatory Gaia has fundamentally changed our view of the Milky Way, its various components and the dynamics of Local Group galaxies. Eline Tolstoy (Kapteyn Institute Groningen) presented the many open questions stemming from the analysis of Gaia data. Follow-up spectroscopy will be extremely important to complementing the positional information with radial velocities and abundances of the stars to be provided by massive surveys with ground-based facilities. A most important aspect is covering the ultraviolet for the study of the nucleosynthesis of heavy elements. 4MOST already dedicates a large fraction of its observing time to Gaia follow-up. Other instruments of interest are the Fibre Large Array Multi Element Spectrograph (FLAMES) and the Multi-Object Optical and Near-infrared Spectrograph (MOONS). But there remains a gap in respect of fainter stars and the need for higher spectral resolution to better constrain the stellar parameters and abundances with a potential future VLT multi-object high-resolution spectrograph.

Our knowledge of planet formation continues to develop rapidly. Anne-Marie Lagrange (Institut de planétologie et d’astrophysique de Grenoble, IPAG) reviewed the current situation; many protoplanetary disks are known but the number of directly imaged planets remains small. Clearly, sensitivity and higher angular resolution are key for this field. The ELTs (and JWST) will be major players, but there remain various capabilities which the VLT and VLTI can offer. An upgraded Spectro-Polarimetric High-contrast Exoplanet REsearch instrument (SPHERE) and an optical AO system, like MAVIS, would be beneficial. The importance of coronagraphy was stressed. The VLTI with GRAVITY and the Multi AperTure mid-Infrared SpectroScopic Experiment (MATISSE) is just beginning to tackle exoplanets, and better characterisations of planetary atmospheres can be expected. Transit measurements and follow-up observations of PLATO targets clearly represent another exciting research theme waiting to be explored.

The importance of the VLT for Solar System objects was described by Heike Rauer (DLR, Berlin). The VLT provides both the versatility and stability needed for regular and continuous observations of Solar System objects. While space missions will always provide more detailed views, they are mostly limited to short periods (of the order of years). Ground-based observatories can provide steady observations and long-term coverage. They can also yield larger statistical samples for asteroids, comets and trans-Neptunian objects. Special and unforeseen events on timescales that prevent satellite missions, for example the Shoemaker-Levy 9 impact on Jupiter, will heavily rely on ground-based observations. Synergetic observations to complement future planetary missions, like the JUpiter ICy moons Explorer (JUICE) or Europa Clipper, will enhance the science return of these space missions. The best angular resolution is clearly an asset for observations of Solar System bodies.

Summary talks on existing and future facilities set the stage for synergies and complementarity. Ciska Kemper (ESO) presented some science results based on the synergy between ALMA and VLT data and described the ALMA2030 Development Roadmap. The ELTs will be the flagship ground-based near-infrared observatories and their strengths were outlined by Michele Cirasuolo (ESO). The exciting ESA programme for the coming decade was detailed by Fabio Favata (ESA). The JWST launch is planned in early 2021 and Gillian Wright (UK Astronomy Technology Centre [UKATC], Edinburgh) described its scientific plans and capabilities. With a 10-year planned lifetime, the JWST and VLT will complement each other for many projects.

Starting in 2022, the LSST will provide many variable objects, which will need dedicated follow-up observations. The VLT and many 4-metre telescopes will be prime facilities for the required spectroscopy, as outlined by Pierre Astier (Laboratoire de physique nucléaire et de hautes énergies [LPNHE], Paris). The planning for the best usage of the various telescopes has already begun. Pierre also presented an interesting connection with gravitational wave observations, suggesting that the LSST could find many optical counterparts. The Cherenkov Telescope Array (CTA) is under construction and its status and plans were presented by Werner Hofmann (Max-Planck-Institut für Kernphysik [MPIK], Heidelberg). It will be exciting to search for optical counterparts of the many ultra-high-energy sources CTA will discover. Anna Bonaldi (Square Kilometre Array Organisation) introduced the SKA. It will be interesting to combine the radio detections with optical sources. Sofia Randich (Istituto Nazionale di Astrofisica [INAF], Arcetri) summarised the Gaia-ESO survey. She underscored the importance of high spectral resolution and blue efficiency for stellar abundance work. A summary of the findings of the Public Survey Panel after its scientific review of the completed and ongoing ESO public surveys in May 2019 was delivered by Bruno Leibundgut (ESO).

Several talks provided background information on the current VLT/I situation. The instrumentation planning for the VLTI (Antoine Mérand, ESO) and the VLT (Bruno Leibundgut, ESO) were followed by presentations on data flow operations (Michael Sterzik, ESO), Paranal operations (Steffen Mieske, ESO) and calibration plans and issues (Alain Smette, ESO). New ideas include atmospheric forecasting to allow planning of observations in more detail, or at least implementing “now-casting” to obtain a full understanding of the current status for real-time scheduling. A move away from standard stars to physical atmosphere models for calibration of the atmosphere was also presented.

Lively discussions followed these sessions. The importance of adequate preparation for LSST transient follow-up was stressed several times. The complementarity of JWST infrared imaging and

Figure 1. Workshop participants enjoy a break in front of the ESO Supernova Planetarium & Visitor Centre.

low-resolution spectroscopy with ground-based infrared high-resolution spectroscopy was highlighted, although this will probably be more in synergy with the ELTs than with the VLT. In general, better coordination between ground- and space-based observatories was urged. The programmatic aspects of VLT and VLTI instrumentation were presented by Luca Pasquini (ESO) setting the framework for the 21 contributed talks outlining science cases and concepts of new instruments. Individual presentations on the science plans of MOONS (Michele Cirasuolo, ESO), MAVIS (Richard McDermid, Macquarie University Sydney) and an ultraviolet spectrograph (Chris Evans, UKATC Edinburgh) started off this part of the programme. Several new and exciting instrument ideas on different scales were presented, which will further enhance the VLT and VLTI capabilities.

The workshop programme provides an overview of the newly proposed projects and their science cases and we refer the reader to that list for a summary. There were also 16 posters[2] on display, as not all requested talks could be accommodated in the workshop programme. It is too early to discuss any of these proposals, suggestions and ideas in detail. However, some trends can already be discerned. There are a few concepts for instruments with a wide range of astrophysical applications. Others cater to more specific science cases or have a relatively narrow science focus. The workshop finished with an extensive discussion. Because of the different levels of detail in the science cases and instrument concepts, a wide range of opinions and positions was voiced. The workshop closed with a summary by Denis Mourard (chair of the Scientific Technical Committee [STC], Observatoire de la Côte d'Azur [OCA]); he outlined a first categorisation of the different topics, which will be the basis for future discussions.

Demographics

The Science Organising Committee was composed of one Council and four STC members as well as relevant ESO staff. Its gender distribution was 4 female and 7 male members. Among the invited speakers 8 out of 20 were women (4 out of the 5 reviews). However, among the 45 submitted contributions only one was by a woman and there were 24 women among the 130 participants. While this gender ratio reflects that of the instrumentation community, we hope that these stark statistics act as a wake-up call to ESO instrument builders. On the timescales explored by this meeting, positive action to ensure more inclusion in our community can and should be undertaken.

Outlook

The workshop successfully laid out the scientific landscape and explored the interests of the community regarding VLT/I developments. The enthusiasm displayed by the community presentations on the scientific potential and the ideas for new instrumentation was obvious. It has become clear that the VLT/I will remain a facility that can serve many different interests and science applications. This versatility should be maintained as far as possible. At the same time, VLT/I operations may open up to more specific experiments or projects, for example through visiting instruments. The planning of the future VLT instrumentation complement needs to account for the existing (and aging) instrumentation; some instruments may not be maintainable at reasonable cost for another decade. A summary of the concepts presented at the workshop together with a first scientific assessment will be prepared for the next STC meeting in October for further discussion. A concrete plan for VLT and VLTI after 2025 will be prepared by the Programme Scientists and presented for recommendation to the STC in April 2020. With the long-term planning in hand, the next instrumentation studies can start to be fully operational some time during the second half of the coming decade.

Acknowledgements

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Links

[1] Workshop programme: https://www.eso.org/sci/meetings/2019/VLT2030/program.html
[2] Workshop poster papers: https://www.eso.org/sci/meetings/2019/VLT2030/posters.html