 DOI: 10.18727/0722-6691/5234

Report on the ESO Workshop

20th Anniversary of Science Exploration with UVES

held online, 21–22 October 2020

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The UltraViolet-Visual Echelle Spectrograph (UVES) was first offered to the ESO community in 2000. A workhorse covering a vast range of topics from Solar System objects to cosmology, it quickly became one of the most productive instruments at Paranal. For the 20th anniversary of UVES's entering into service, over 100 astronomers from across the world convened in a virtual workshop to celebrate the instrument's achievements and to reframe its role, in a profoundly changed instrumental and scientific landscape, as it enters its 3rd decade of operation at the Very Large Telescope (VLT).

Motivations

UVES was originally designed as a highly configurable, multi-purpose instrument able to cover most, if not all, science cases for high-resolution optical spectroscopy. Over the years it proved a stable, reliable instrument with very little downtime and excellent operational efficiency. Its class-leading light-gathering efficiency, extensive wavelength coverage and reliable automatic reduction pipeline have made UVES the most productive ESO instrument (in terms of published papers, see Figure 1) during most of its lifetime.

However, in the 20 years since UVES began observing at Paranal, both the needs of the science community and the technologies deployed by UVES's competitors have, obviously, evolved. At ESO, the ultra-stable Echelle SPectrograph for Rocky Planet and Stable Spectroscopic Observations (ESPRESSO) has comparable limiting magnitude in the red and offers superior resolution, while being inefficient in the blue and renouncing the spatial resolution offered by the UVES slit. The X-shooter spectrograph has for many years offered superior efficiency and simultaneous spectral coverage, at the cost of resolution. Even higher efficiency, but at lower resolution and in a narrow UV range, will be offered by the Cassegrain U-Band Efficient Spectrograph (CUBES). In addition, forthcoming high-multiplex facilities such as the 4-metre Multi-Object Spectroscopic Telescope (4MOST) and the Multi-Object Optical and Near-infrared Spectrograph (MOONS) will screen enormous numbers of targets, but at the expense of signal-to-noise, spectral coverage and resolution: this will put pressure on UVES (and similar "workhorses" such as X-shooter and the FOcal Reducer and low-dispersion Spectrograph [FORS]) to follow up a constant stream of high-interest targets.

Outside ESO, among UVES's competitors are the HIgh Resolution Echelle Spectrometer (HIRES) at the Keck I telescope and the High Dispersion Spectrograph (HDS) at the Subaru Telescope, whose performances are largely comparable to that of UVES, while the Cosmic Origins Spectrograph (COS) on the Hubble Space Telescope exploits that telescope's exceptional spatial resolution and ability to observe in the far-UV, but reaches only intermediate resolutions (R ~ 20 000).

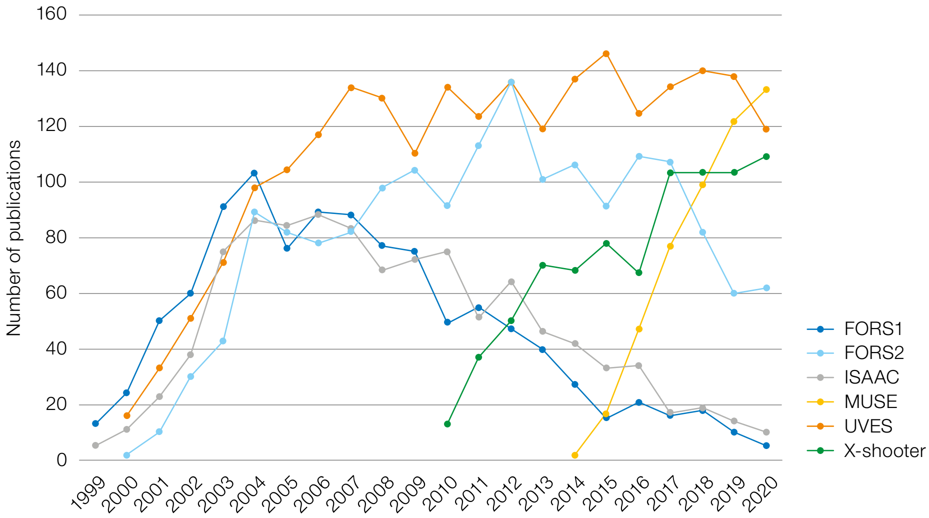

Figure 1. Publication statistics for some of VLT's instruments. UVES is on average the most productive instrument.

At the same time, UVES is projected to remain in operation for the foreseeable future, and will thus require significant hardware upgrades both to fight component obsolescence and to maintain, and perhaps upgrade, its performance to meet the current needs of the community. These considerations defined the core purpose of the workshop: to survey the long list of fields where UVES has been and still is a crucial instrument, and to define which of its capabilities make it competitive and what could be improved to better meet the challenges of the decade(s) to come.

Workshop organisation

The workshop was originally foreseen as a 1-day event to be held (in person) at ESO's headquarters in Garching, Germany, but owing to the COVID-19 pandemic it was re-scoped into a virtual meeting using Microsoft Teams and reformatted into two ~ 3-hour sessions. Care was taken to choose times of day that facilitated world-wide participation, particularly from ESO Member States and partner and host countries, which spread across time-zones from + 10 hours (the east coast of Australia) to –4 hours (Chile).

Given the broad range of fields UVES is used for, and the limited length of the workshop, the 13 speakers and 4 panelists were all invited.

Figure 2. Building and installing UVES. Left: November 1998, in the integration hall in Garching. The image was taken by Bob Fosbury and shows, from right to left, Gianni Zamorani, Sandro D’Odorico, Lukas Labhardt, Yannick Mellier, Tim de Zeuw, Max Pettini, Hans Kjeldsen. Upper and lower right: in Paranal during integration and commissioning in September 1999. For details of these images, see D’Odorico (2000).

The online format proved very successful and attracted around 200 registered participants from all over the world, up to 120 of whom were connected at any given time.

Sessions were recorded and the videos of each presentation have been made available via YouTube[1]. The PDF versions of each presentation have been uploaded to Zenodo[2]. The videos and PDFs are also available via the workshop website[3].

Each day’s presentations were followed by a round-table session, led by two panelists — different people on each day — and chaired by ESO’s VLT Programme Scientist Bruno Leibundgut.

Summary of talks and discussions

After a warm welcome from ESO Director General Xavier Barcons, the original project manager, Sandro D’Odorico, recapped the evolution of the UVES project from its inception in 1986. As per the VLT instrumentation programme, the original plan was to build two UVES instruments with different specifications. These were subsequently consolidated into a single instrument, which was shipped to Paranal in 1999 and fully commissioned by January 2000 (Figure 2). Manufacturing the large échelle gratings and the fluorite glasses for the blue-arm camera were the most significant technical challenges. D’Odorico also noted that the high quality of UVES, a 100%-internal ESO project, was instrumental in giving ESO the prestige and authority to subsequently review the work of instrument partners.

Johan Kosmalski detailed the optical design of UVES, and the choices and innovations (such as the design of the collimator optics) that made it such an efficient instrument. He also described an early design for an updated blue-arm configuration that would permit capture of the whole blue wavelength range in a single shot by reducing cross-dispersion — whilst still allowing an approximately eight-arcsecond slit length — and building a new blue camera with an increased field of view. Newer optics and an improved detector would increase the blue-arm efficiency by an estimated 50%.

The first of the talks on scientific achievements with UVES was given by Emmanuel Jehin, who described the impact of UVES on Solar System, and in particular cometary, science. UVES has been instrumental in the study of long organic molecules released by comets and their dissociation by solar radiation as they move along the cometary tail.

Else Starkenburg described the important contribution of UVES to the study of Local Group dwarf galaxies, and Milky Way streams. This important field grew dramatically during the lifetime of the instrument, which was ideally suited to provide crucial data on their stars’ chemistry, thanks to its high efficiency, large telescope diameter and southern hemisphere placement.

Laura Magrini covered the role of UVES in the study of the disc of the Milky Way and its open clusters. Here UVES saw a broad range of uses, covering H II regions, low- and high-mass stars, exoplanet host characterisation, studies of nucleosynthesis, chemical clocks, and the formation and evolution of the disc. Again, the large spectral coverage, flexibility and high resolution were crucial in this field.

John Pritchard presented a brief history of UVES from the operational point of view and an overview of key performance-related statistics, the most striking of which is possibly the approximately four years of cumulative open-shutter time achieved over the 20-year lifetime of the instrument (to date).

Michael Murphy summarised the important contribution made by UVES to the search for cosmological variability of the fundamental constants α (the fine structure constant) and μ (the proton/electron mass ratio): these two fundamental physical quantities are not derived from any other deeper physical principle, and as such they are only *assumed* to be constant across the lifetime of the Universe. However, this can be tested observationally since they subtly affect atomic and molecular lines superimposed at high redshift over the spectra of bright quasars. The availability of VLT-UVES (and Keck-HIRES) in the early 2000s improved on the precision of previous measurements by a factor of about 10. Highly stable instruments like ESPRESSO have since replaced UVES in the measurement of α, but μ can only be studied in the extreme blue part of the spectrum and remains within reach of only blue-sensitive spectrographs like UVES.

Pasquier Noterdaeme addressed the role of UVES in the study of molecular absorption systems in quasar sightlines: the evolution of molecular gas over the lifetime of the Universe is crucial, since it is the fuel for star formation in galaxies. Before UVES, only a handful of H_2 detections had been achieved, but the high resolution of UVES down to the atmospheric cutoff was crucial, and to this day about 60% of detections have been made from UVES observations.

Valentina D'Odorico described the contribution of UVES to the study of deuterium abundances. Deuterium is a crucial baryometer, whose abundance in high-redshift absorption systems is fundamental to constraining Big Bang nucleosynthesis. It is, however, a highly challenging measurement that requires high efficiency in the extreme blue: to date, deuterium has been measured in roughly 20 absorption systems.

Norbert Christlieb summarised the studies exploiting UVES in the field of low-metallicity, ancient stellar populations. The properties of the first generation of stars, long disappeared, are imprinted in the low-mass, second-generation stars they enriched chemically. These elusive objects are thus extremely precious for understanding the early phases of the Universe. Together with this, UVES crucially contributed to all topics related to old stars, such as Na-O anticorrelation in globular clusters and heavy element nucleosynthesis. Here again, the blue sensitivity of UVES, coupled with its high resolution, was, and still is, crucial.

Annalisa De Cia presented the contribution of UVES to the study of transients, such as novae, supernovae and gamma-ray bursts (GRBs), objects that present the opportunity to study both the source itself and the absorption systems along its line of sight. The challenge of course is that these objects are unexpected, rare and faint, and they fade quickly, necessitating a prompt response. UVES contributed to studying the evolution of SN1987A's rings over a period of seven years (from first-light to 2007; a spectrum of SN1987A was in fact used for the workshop poster and logo). UVES provided evidence for Luminous Blue Variables as supernovae type IIn progenitors, and evidence of ^{7}Be, and hence Li, production in novae, a key piece in the puzzle of Li production at high metallicity. UVES was also instrumental in the study of GRBs, producing the first high-resolution spectrum of a GRB. In this field, the availability of Target of Opportunity and Rapid Response Mode (RRM) observing schemes on UVES was crucial. It was remarked how RRM on UVES is now becoming even more powerful: X-shooter has been moved to Unit Telescope 3 (UT3), removing potential trigger conflicts, and the new RRM implementation now permits changing focus from another instrument to UVES, greatly increasing the likelihood that the trigger will be activated.

Finally, Magda Arnaboldi and Isabelle Percheron described the availability of science-ready one-dimensional UVES spectra in the ESO Science Archive Facility. UVES was the first instrument for which this service was introduced, in 2013, beginning with a subset of slit data. In subsequent releases, image slicer data were added and some issues resolved, and finally in 2020 the whole 20 years of science data were reprocessed homogeneously. Perhaps more importantly, stacked, reduced spectra for multi-exposure observing blocks were added then, as well as improved calibration. A total of roughly 100 000 primary reduced spectra, and 35 000 stacked spectra are now available (and these numbers are growing)[4].

Discussions, and plans for the future of UVES

One of the main purposes of the workshop was to collect feedback and suggestions about which UVES capabilities and characteristics are most important, and how to enhance them in the years to come so as to maintain UVES as a competitive facility in the instrumental landscape. For this reason, each speaker was asked to include a final slide on this topic. In addition, at the end of each day roughly 45 minutes were dedicated to two discussion sessions, during which four panelists (Amelia Bayo and Lorenzo Monaco on the first day, Sebastian Lopez and Sandra Savaglio on the second day), collected these suggestions and added their own in a brief presentation, after which the floor was opened to the participants for discussion. The main suggestions put forward can be summarised as follows:

- Maintain and improve blue-arm performance: the capability of UVES to observe down to the atmospheric cutoff at 300 nm, coupled with its high resolution, was deemed crucial for many science cases, such as studies of the variation of fundamental constants, high-redshift deuterium and molecular absorption, abundance analysis in low-metallicity stars, and beryllium and heavy-element abundances. This point was strongly stressed, since there is no existing or foreseen replacement for this UVES capability: ESPRESSO does not reach the bluest part of the visible spectrum, while X-shooter and CUBES lack the resolution needed to disentangle the highly crowded line systems frequently encountered in the blue. Plans

towards a "single shot" blue arm with improved efficiency were very positively received.
- **Improve the quality and reliability of wavelength calibration:** the stability and repeatability of wavelength calibration are considered less than optimal, particularly in the blue. This is an issue that was also identified as being pertinent to fighting obsolescence: the currently available ThAr lamps are less than optimal for calibrating the large UVES spectral coverage. The implementation of an ESPRESSO-like Fabry-Perot (FP) calibration source was discussed, since it has the potential to provide a highly regular wavelength reference across the whole range. Since UVES has limited stability requirements, the FP-drift calibration could be performed with a simple ThAr reference.
- **UVES as a follow-up machine:** several speakers emphasised the need for spectroscopy to follow up observations with forthcoming massive survey facilities such as ESO's 4MOST and MOONS and the WHT Enhanced Area Velocity Explorer (WEAVE) at the William Herschel Telescope. 4MOST, for instance, will produce spectroscopy for millions of sources over a 5-year timeframe, potentially detecting thousands of targets every year that will need to be followed up with higher resolution, larger/different spectral coverage, or higher signal-to-noise ratio. Concerns were expressed that the current operational paradigm for Paranal instruments (UVES is clearly not the only instrument that will be requested for these follow-ups) might not be ready to handle the large number of requests from survey consortia.
- **CUBES-UVES fibre link:** the forthcoming CUBES spectrograph will cover the 300–400 nm range with much higher efficiency but lower resolution than UVES (the CUBES resolution is foreseen to be about 20 000), but it will not cover the rest of the visible range. There was strong support for installing CUBES at the UT2 Cassegrain focus and connecting it to UVES via a fibre link similar to the one used with the Fibre Large Array Multi-Element Spectrograph (FLAMES), observing simultaneously with both spectrographs — to produce UVES spectra with $R \sim 47\,000$.
- **Long-slit spectroscopy:** it was noted that while many forthcoming instruments reflect a strong focus on the advantages of fibre-fed spectrographs, there are nonetheless certain science cases which require a long slit such as UVES has.

Based on the lively discussion and clear ideas about possible futures for UVES the workshop was a real success. It is evident that the instrument is considered highly relevant and competitive in its current form, but also that clear support — along with readily identifiable science cases — exists for a number of possible hardware upgrades. This input will prove invaluable in defining any possible future upgrade project.

Demographics

The scientific organising committee sought fair representation from the community. The committee itself was 50% male and 50% female, the local organising committee being 60% male. 46% of the speakers were female, as were 50% of the panelists. Otherwise, we did not request gender information during registration, so we don't have statistics on the attendees. The workshop was well attended with registered participants from 30 countries (see Figure 3); of particular note was a strong contingent from India.

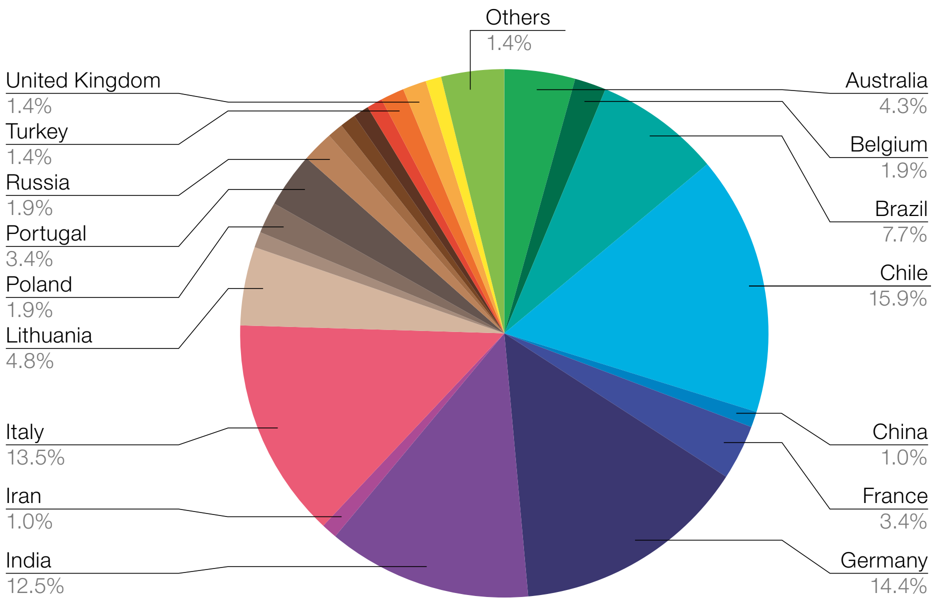

Figure 3. Registrants by country of affiliation.

Acknowledgements

We wish to warmly thank the workshop speakers, panelists, and Bruno Leibundgut as chair of the discussion sessions, for their help and the wealth of ideas they all brought forward. We also wish to thank ESO Director General Xavier Barçons for his warm message of welcome, and ESO's IT support, together with Paulina Jiron, Nelma Silva and Veronique Ziegler for logistical support.

References

D'Odorico, S. 2000, The Messenger, 99, 2

Links

1. Workshop Youtube playlist: https://www.youtube.com/playlist?list=PLDNJqjce4cUzFGinXDWtlZeOT-BWpolaFW
2. Workshop presentations: https://zenodo.org/communities/uves2020
3. Workshop programme: https://www.eso.org/sci/meetings/2020/uves2020/program.html
4. Access to science-ready UVES spectra at the ESO Science Archive Facility: http://archive.eso.org/wdb/wdb/adp/phase3_spectral/form?collection_name=UVES