Report on the ESO Workshop

Six Years of FLAMES Operations

held at ESO Headquarters, Garching, Germany 1–3 December 2008

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A significant fraction of the community of users of the VLT multi-fibre spectrograph facility, FLAMES, gathered at ESO Headquarters in December 2008 to present scientific highlights, after six years of FLAMES operations. This proved to be a great opportunity to review the scientific impact that FLAMES has had on different fields of astrophysical research and for ESO to assess the current and future needs of FLAMES users. We report on the two and a half day meeting, during which all participants openly discussed their experience with FLAMES and shared their expertise.

The Fibre Large Array Multi Element Spectrograph — or simply FLAMES — recently completed six years of successful operations attached to the Very Large Telescope (VLT) Nasmyth A focus of Kueyen, at the La Silla Paranal Observatory.

The combination of an extended field of view with many and varied fibres (a total length of 1.6 km if stretched from end to end!) and set-ups has made FLAMES a unique facility in ground-based astronomy. Thanks to its versatility, FLAMES can be used in many different astronomical applications. Extrasolar planet-hunting, chemical abundances of stellar groups (globular, open clusters, Galactic streams, Local Group galaxies, etc.), kinematics and dark matter, planetary nebulae, the interstellar medium and stellar evolution are only some examples of the science cases that have been targeted with FLAMES.

We thought it was time to celebrate and to review the performance of FLAMES during these six years of operations. Following the successful experience inaugurated with UVES almost six years ago, the FLAMES community was invited to participate in an informal workshop held at ESO Headquarters from 1–3 December, 2008.

It was a great pleasure to see that almost all of the teams who had so far made use of FLAMES attended the workshop. The participants were asked to present their scientific results and to add one slide describing the pros and cons of using FLAMES to carry out their science. These points were collected and used in the final open discussion (see below). In addition, a few more technical talks were presented by members of the community and the FLAMES Instrument and Operations Team (IOT) presented some statistics concerning the use of FLAMES. During these six years of operations, about 9000 science frames have been taken (with an average of 100 objects per image!), the equivalent of 400 nights of VLT time in total. This corresponds to about 25% of the time available on Kueyen and is close to the fraction of UT2 time requested at proposal submission (roughly one third per UT2 instrument).

Science highlights

All participants were invited to give a talk in one of the five different sessions, namely, star formation and planets, chemical evolution of the Milky Way and streams, external galaxies, kinematics and dark matter, and stellar evolution. Each session began with an introductory review talk. All presentations are available online[1]. Many of the talks described samples of stars in the hundreds to thousands, emphasising the huge multiplex gain obtained in using FLAMES over single-slit instruments.

A few subjectively selected highlights demonstrate the range of scientific ideas and prospects presented during the workshop; the high quality of the science presentations is of course not limited to those cited in this article.

The combination of a photometric transit with the measurement of radial velocity allows the actual mass and radius of extrasolar planets to be derived. Transit candidates yielded by surveys like OGLE or CoRoT are full of impostors (i.e., different configurations can produce a light curve similar to the one observed in a genuine planetary transit). Dominique Naef and Francois Bouchy showed how FLAMES contributed to cleaning up the list of impostors for transit candidates and to deriving radial velocity curves for the very faint OGLE transit planets. Richard Jackson described a search for planets and/or binary companions in very low mass stars and brown dwarfs in which he concluded that the binarity fraction appears to be lower in these objects than for higher mass stars.

Age is one of the fundamental parameters in astrophysics. The Lithium Depletion Boundary (LDB), i.e., the position in the colour-magnitude diagram that separates low mass stars with and without detected lithium, is a function of age and is thought to be almost model-independent. Rob Jeffries showed an example of how FLAMES can be used to determine the LDB of the faint members of NGC 2547 based on the observations of the Li 670.8-nm line. His approach could be extended to a handful of clusters that would then constitute benchmarks for gauging theoretical isochrones.

The study of the Milky Way (MW) Bulge was reviewed by Alvio Renzini, who presented evidence for the very rapid formation of the Bulge. Moreover, Bulge stars seem to be chemically different from the stars in dwarf spheroidal galaxies. Although the origin of the Bulge has not been fully understood, Renzini qualified the FLAMES contribution as a "quantum jump" in this direction. Simone Zaggia presented results of FLAMES observations in the direction of the Chandra Deep Field South where they found more stars than expected beyond 20 kpc and even one star at 165 kpc. Vanessa Hill reviewed the state of our knowledge of chemical evolution in dwarf spheroidal (dSph) galaxies and the LMC. Each of the LMC, Sagittarius, Fornax, Sculptor and Carina galaxies shows a distinct chemical evolutionary track. There is

some evidence that the abundance pattern in metal-poor stars is indistinguishable everywhere, although dSph galaxies appear to lack the most metal-poor stars (Fe/H < –3) found in the MW halo.

Chris Evans and Christophe Martayan presented observations of early-type stars in the Magellanic Clouds. In the large programme (LP) described by Evans it was found that rotational mixing is not as dominant as previously thought, with both Martayan and Evans finding that low metallicity stars spin faster. However, a remaining open question is whether the birthplace of a star (in a bound cluster for example) is as important as its initial metallicity in determining the rotational parameters. Jonathan Smoker used archive data from this LP to investigate the small-scale structure of high velocity clouds towards the Magellanic system and found variations in Ca II equivalent width of a factor of 10 over a few arcminutes. In another study concerning the gas, Yiannis Tsamis and Alena Zwansig described the use of ARGUS to map planetary nebulae and protoplanetary discs in emission lines at high spatial and spectral resolution to determine the physical properties and chemical abundances of these objects.

Katrin Jordi and colleagues used FLAMES to look into the velocity dispersion of Palomar 14. They concluded that their results tend to favour more classical Newtonian mechanics rather than the MOND predictions. In an invited review, Gerry Gilmore described the use of FLAMES to observe the dynamics of dwarf spheroidals (supporting flat inner-mass profiles) and how FLAMES has been used to resolve the spatial scales of the first enrichment and reionisation. Thousands of stars have already been observed, although many targets still exist for study.

Andreas Korn put forward evidence for the need to include atmospheric diffusion to correctly explain lithium depletion in metal-poor stars. Indeed, if atmospheric diffusion is taken into account, the observed Li abundances in NGC 6397 can be reconciled with the cosmic microwave background and Big Bang nucleosynthesis predictions.

Finally, on the extragalatic front, Francois Hammer reviewed the results on the morphological and kinematical study of galaxies at $z \sim 0.6$ using the deployable Integral Field Units (IFUs). The preliminary conclusions suggest that spiral galaxies are more frequent by a factor of two at the present day than at $z \sim 0.6$ (70% versus 33%). In contrast, the rate of peculiar, compact or mergers drops from 44% at $z \sim 0.6$ to about 3% at $z = 0$, whereas the fraction of luminous infrared galaxies drops from 20% at $z \sim 0.6$ to 0.5% at $z = 0$. This work is ongoing, with the final aim being to understand the origin of the present-day spirals.

Technical talks

The morning of the last day was filled with more technically-driven talks on data reduction, analysis tools, possible (new) applications and upgrades for FLAMES.

In his talk on IFU data reduction, Christer Sandin presented his open software, used to reduce IFU and ARGUS data, and drew attention to the need to properly account for differential atmospheric refraction correctly when analysing IFU images. Giuseppina Battaglia described the sky subtraction method developed by Mike Irwin and applied by her team in the chemical study of the dSph galaxies.

The MATISSE package has been developed by the Nice Observatory team to analyse stellar spectra to be collected by the GAIA mission. A demonstration of the enormous potential of the use of MATISSE to treat FLAMES data was given by Alejandra Recio-Blanco. Fredric Royer showed a web-based tool designed to query the FLAMES GTO science-ready data obtained by the Observatoire de Paris.

Luca Pasquini showed the potential of a very interesting FLAMES IFU application to observe simultaneously the photometric and spectroscopic transit of a giant planet in front of its host star. An investigatory study is ongoing. If validated, this type of observation could help to improve mass and radius determination of extrasolar planets. It may also provide spin-orbit inclination and indications of additional (unseen) low-mass companions by studying variations of the transit time.

Closing the technical session, Francoise Roques proposed a future upgrade of FLAMES, aimed at using its large field of view to carry out fast photometry of a large area of the sky. A dedicated workshop on ESO Spectroscopic Surveys[2] will take place in March 2009 at ESO Headquarters in Garching to discuss the future of survey instruments such as FLAMES.

Open discussion

The open discussion was moderated by Luca Pasquini, who made the initial point that, in such a complex instrument, with many different modes and used in many different applications, the users are quite often the experts. Therefore, the exchange of experience, tools, etc. with ESO staff and within the community itself is desirable, and indeed necessary, to improve the data quality provided to the users by ESO.

During the workshop, it became clear that most FLAMES users do not reduce their data with the ESO pipeline software. Rather, a large fraction still uses the Geneva Baseline Data Reduction Software (BLDRS) that was the only data reduction software available at the very beginning of FLAMES operations. During the open discussion, ESO representatives reported that the ESO GIRAFFE pipeline software is now mature, robust, and produces science-ready data, especially when used interactively. Users are therefore encouraged to download the package[3] and to use it for their own data reduction. Workshop participants mentioned that the Geneva BLDRS offers some automated tools to extract further information from the GIRAFFE spectra (e.g., radial velocities, for all science and simultaneous calibration fibres). Representatives of the ESO FLAMES IOT took note of these remarks and will investigate

solutions, for example improvement of relevant algorithms or adaption of the products of the ESO pipeline to interface to relevant data analysis packages.

A number of other technical issues were brought to the attention of the ESO staff attending the Workshop, including:

– differences in equivalent widths between FLAMES/UVES and FLAMES/GIRAFFE spectra of the same objects;

– typical shifts in the cross-dispersion direction between the science and morning flats should be quantified and reported in the User Manual;

– the accuracy of sky subtraction should be quantified and reported in the User Manual;

– the need for a new set of solar spectra taken with the new CCD at all settings.

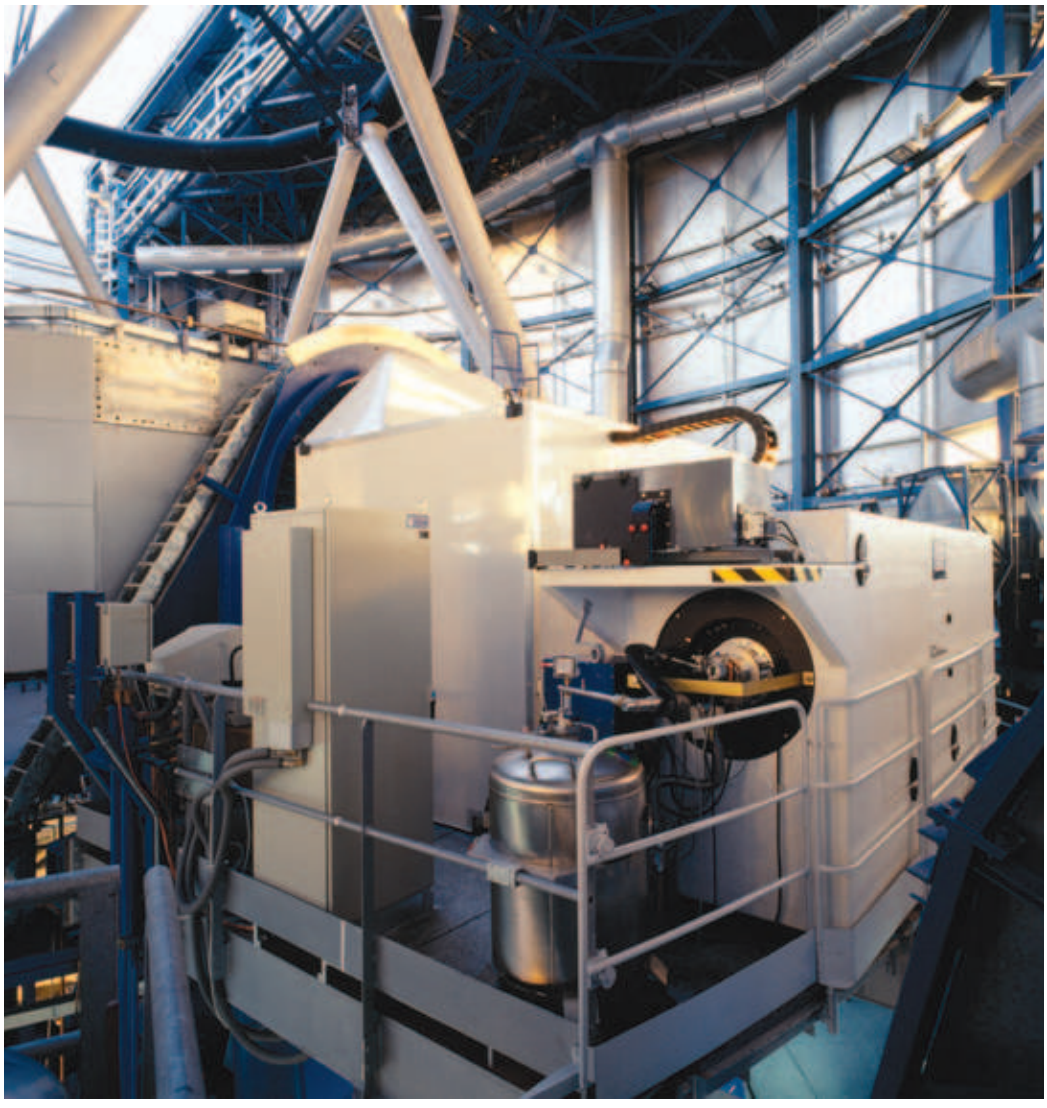
These and other points that were raised during the Workshop will be discussed within the FLAMES IOT for further follow-up. The results of these investigations will be disseminated by means of the FLAMES webpages[4] and related documents.

Acknowledgment

We would like to thank all participants for their willingness and good spirit in sharing results and experiences during the three days of the workshop. For us, the ESO staff present, it was a wonderful experience to share the room with a large fraction of the community of FLAMES users. Finally, we would like to thank the Director General Discretionary Fund programme for funding this informal workshop.

Notes

[1] http://www.eso.org/sci/facilities/paranal/instruments/flames/doc/FLAMES_6th_Anniversary/FLAMES_6th_Anniversary.html
[2] http://www.eso.org/sci/meetings/ssw2009/index.html
[3] http://www.eso.org/pipelines
[4] http://www.eso.org/sci/facilities/paranal/instruments/flames/news.htm



The FLAMES facility mounted at the Nasmyth A platform of VLT UT2, Kueyen.