CAFE: Calar Alto Fiber-fed Echelle spectrograph

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Figure 1: An external view of FOCES, the current high-resolution spectrograph of the 2.2m, that is intended to be copied. In the view, it is visible the input of the two fibers, the external cover that isolate the optical table, and the external CCD.

1 Instrument Description

CAFE is a new Echelle scpectrograph for the 2.2m at Calar Alto that will replace the actually operating one, FOCES. In many respects, CAFETEROS will be very similar to FOCES, with some small improvements.
FOCES is an echelle spectrograph, fed by a 100 μm optical fiber, mounted at the Cassegrain focus of the 2.2m at Calar Alto. Figure 1 shows an external view of the instrument. The spectrograph itself follows a white-pupil design collimated with two off-axis parabolic mirrors. The 15 cm beam leaving the 31.6 lines/mm R2 echelle is refocussed in the vicinity of a small folding mirror. Behind this mirror, there is an intermediate slit which allows efficient removal of scattered light. The cross-dispersion is achieved with a tandem prism mounting, and the beam imaged with an f=3 transmission camera onto a field centered on a 15μm 2048^2 Loral CCD. Two of these main components are visible in Figure 2.
The echelle image covers the visible spectral region from 380 to 750 nm displayed in 70 spectral orders with full spectral coverage. Spectral orders are separated by 20 pixels in the blue and by 10 pixels in the red. The maximum spectral resolution is R = $\lambda/\Delta\lambda$= 40600 with a 2 pixel resolution element; unvignetted resolution as defined by the fibre alone would be obtained at R = 18000. Replacing the CCD by a 2048^2 chip with 15μm pixel diameter and taking into account light losses from a reduced entrance slit width a full 2 pixel resolution of R = 65000 is obtained.
FOCES was constructed by the Institute for Astronomy and Astrophysics of the Munich University (PI:T.Gehren), and it has been under operations at Calar Alto since 1998. It has been recently requested to turn back to Munich, and therefore it will not be offered since September 2009. In many senses this instrument it is very similar to FEROS, that

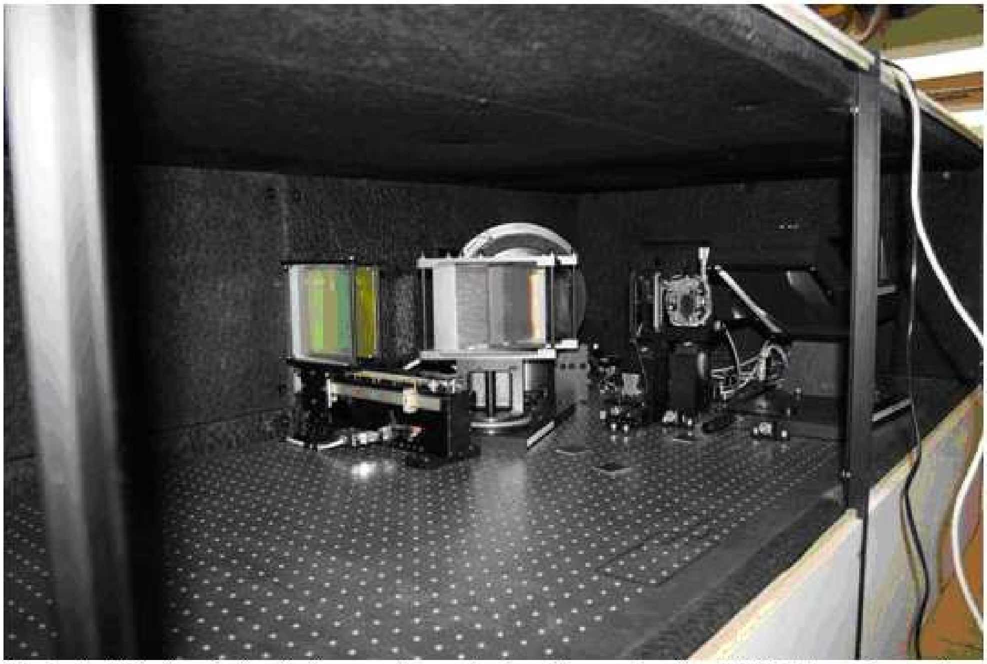

Figure 2: An internal view of FOCES, where it is visible two of their main components, the diffraction grating, inclined 65^o degrees, to the right size of the image, and the two coupled grisms, to separate the orders, to the left size of the image.

was operative at the 1.5m Danish telescope, and now it is at 2.2m telescope at ESO. Figure 3 shows the optical layout of FOCES, with the main components highlighted. As it can be seeing in Kaufer (1997) and Korn (2002), FOCES and FEROS share the basic design, components, and performance. The major advantage of the FOCES design is that the order tilt for normalization is much more homogeneous.
The basic idea is to replace it with a very similar instrument, taking the opportunity to include some basic improvements from problems that are know well understood in the original design, and that will increase the efficiency in about a 10% (F.Grupp, private communications). Apart from the desing, there are some developments, like the camera, that has to be re-built, since the former provider do not produce that products anymore (Zeiss). In a similar way, we expect that the use of new materials will increase slightly the efficiency (in particular, the fibers), and reduce the cost (many of the components are now industrial standards).

2 Science Justification

FOCES is basically the bright-time instrument of the 2.2m, and therefore, it is mounted about a 30% of the time, producing a similar fraction of the articles produced by the telescope. Therefore, there is a variety of science projects (and groups) that make use of this instrument. We list here the abstracts of some of the requested proposals on the last semesters, which represent the projects that could not be performed with-out this kind of instruments.

- **Searching planets in circumstellar disks around T Tauri stars:** We propose to continue our radial velocity search for planets around young stars (1-100

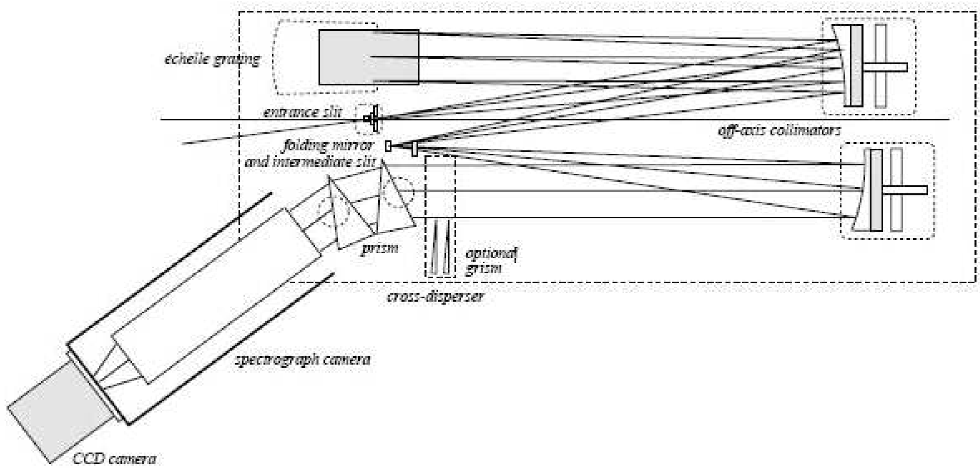

Figure 3: Optical layout of the FOCES spectrograph with entrance slit, echelle grating, folding mirror, prism/grim cross-disperser and camera. Most of these components will be similar in the new instrument.

Myr) with disks. As shown by our discovery of the first planet orbiting a very young (8-10 Myr) TTauri-like star with a circumstellar disk (TW Hya) [8], it is possible to detect short-period giant planets around young stars. Detections of planets around such stars are crucial to put observational constraints on planet formation timescales and theories and reveal the relation between circumstellar disks and planets. We want to continue our work and propose to use FOCES to carry on a systematic radial velocity search for planets around young (1-100 Myr) stars in the northern hemisphere. This survey is the northern complement to our on-going FEROS survey. *P.Weise (MPIA), R.Launhardt, J.Setiawan, Th. Henning, A.Mueller*

- **Complementary simultaneous observations for COROT:** CoRoT will observe two new fields, one in summer (May-Jul.) and one next winter (Nov.- Jan.). As up to now, it will have need of ground-based observations to achieve its science goals, i.e., to map the stellar interior by observing the pulsations of stars in low- (with photometry from space) and high-degree modes (with spectroscopy from the ground). These observations are starting to yield interesting results, some of which will be shown here. With this proposal, we intend to continue a very successful program to gather multi-site spectroscopy of pulsating stars simultaneously with CoRoT. *P.J.Amado and the COROT collaboration. (IAA)*

- **Accurate physical properties of low-mass eclipsing binary stars:** Current theoretical stellar evolutionary models are incapable of matching the observed properties of 0.3 - 1.0 MB stars. They predict radii which are up to 15% too small, and Teffs which are correspondingly too high. There is evidence that some of this discrepancy may be due to increased magnetic activity, which causes a profusion of starspots and thus inflated radii. High-quality measurements of the physical properties of low-mass stars are needed to help understand this discrepancy. We are undertaking a project to measure accurate masses, radii and Teffs of a set of low-mass detached eclipsing binary systems. We are currently obtaining high-precision light curves using our own small telescopes. Here we apply for FOCES time to obtain the phase-resolved spectroscopy needed to complete the analysis of each system. *J.Southworth (U.Warwick), B.T.Gaensicke, D.Boyd, P.Lampens, P. van Cauteren.*

- **Physical parameters of pulsating pre-main sequence stars:** With space missions (MOST, COROT, KEPLER and those to come) working like a catalyst, asteroseismology is entering a new era. One of the topics among the most exciting in this area is that of pulsating pre-main sequence stars, for which very little is known and the scientific potential is enormous. One of the first steps towards the understanding of these objects is to obtain physical parameters with enough precision for the asteroseismologic models to work. This is the first time that a systematic spectroscopic study of this type of objects will be conducted . *D. Diaz-Fraile (IAA), P.J.Amado, E.Rodriguez*

- **Extra-solar planets - characteristics of the parent stars:** Accurate radial-velocity measurements of numerous bright nearby stars have continuously uncovered more than two hundred extra-solar planets within the last few years. The light of the host stars of these planets is however as well a basic source for e.g. their ages, their metal-enrichment levels, and likewise a constraint to the planetary masses. To achieve this piece of information we aim at high-resolution, high signal-to-noise spectroscopy, along with model atmosphere analysis techniques, stellar interior calculations, and the precise Hipparcos astrometry. Of particular importance will be to find out whether host stars of extra-solar planets are indeed fairly metal-rich, or instead only subject to selection effects. *K. Fuhrmann (ING, La Palma), et al.*

Basically, this kind of instruments is used for astroseismology studies, pulsing stars, search for extrasolar planets, and the study of the mass of binary stars. The absence of this instrument will produce an important hole in the schedule, and will reduce the science productivity of scientific groups settled at the MPIA and the IAA. There is no other available instruments with these requirements in the north hemisphere in 2m-class telescopes, for European astronomers. The other similar instrument in the northern hemisphere, FIES[1], at the NOT telescope, very similar also to FEROS and FOCES, it is not accesible to German astronomers, and has a much reduced fraction of time for Spanish ones.
Another important point to take into account it is that the strategic plan of the observatory includes the development of a high-resolution optical & near-infrared spectrograph for the 3.5m (HRS), due to a decision by the Science Advisor Committee (SAC). Although conceptually this instrument is similar to FOCES or the upgrade proposed here, its proposed resolution (R$\sim$100000) it is much larger, it is expected to cover a much wider wavelength range (including the NIR), and its sensitivity will be much higher. In this regards, this instrument it is much similar to HARPS ([Rupprecht et al.(2004)]). However, since they share the main basic science cases (with a reduced scope for the proposed instrument), and a similar technique, the proposed instrument will be a fundamental mid-stone to train astronomers, perform pilot studies, and develop techniques for the future use of HRS.

3 Upgrades

As indicated before, some of the components of FOCES, like the camera, cannot be acquired actually, since the providers do not exist anymore. On the other hand, some

[1] http://www.phys.au.dk/~srf/FIES/

different aspects of the original desing has been demonstrated not to be optimal, and in recent revisions it has been identified that simple changes in the design can increase the performance significantly, without an appreciable increase in the cost.
In addition, we propose to perform a simple, and basic upgrade in the instrument, that will allow it to perform self-calibration. The instrument is equipped with two entrance fibers, with the basic propose to obtain simultaneous spectra of the science object and the adjacent sky. This capability of the original design can be used to obtain simultaneous calibration spectra from the ThAr lamps (included in FOCES) or from a iodine cell (to be developed). These upgrades will be easily performed by modifying slightly the telescope module.
The main changes will be:

- Having the Echelle moved by micrometer screw instead of step motor. As common 2k CCDs allow the whole spectral range to be taken there is no obvious need for moving the spectrum around after commissioning.
- A similar change for the Prisms. They can be aligned by hand and it could safe effort and money (step motors, controllers...) by simplifying this part.
- The slit unit will have a remote controller. Almost all misalignments and bad mistakes related to FOCES happened when people adjusted the slit. There are some commercial (Newport) components to built a simple remote controller with a reduce effort and cost.
- It has been identified a problem with the coupling system in FOCES. By adding a slightly more complex coupling optics, on the spectrograph side, it could be possibly improve throughput by 10-20%. This is just an option that should be done in addition to a copy of the "old" coupling, not to risk the development. Buying commercial components, from LINOS microbench, this module should cost less than 10000 Euros.
- There should be some modifications in the telescope module. After the use that the Munich group require from this module (Grupp, private communications), they will get it back to Calar Alto. We will require to adapt it to include an iodine calibration unit, and to allow for a second positioning system for the calibration mirror, to allow the second fiber to get light from the ThAr calibration lamp, for self-calibration. The current experiments with HARPS[2], demonstrate that the use of any of both systems is accurate, although the second one produce slightly better results. We have in house the knowledge to produce an iodine lamp, with a reduced cost (U.Thiele, diploma thesis was about this calibration systems).
- A more sophisticated fiber shaker. This unit it is required to reduce the internal speckle in the fibers, and it is actually a very experimental version.
- To isolate and stabilize thermally the instrument, buy building a thermal controlled room to allocate the instrument. To control the temperature has been demonstrate to increase the efficiency of the instrument, in particular the stability of the resolution. This development will be a fundamental pilot study for the development of HRS, where this kind of rooms will be a basic requirement.

All these upgrades should be done without a fundamental increase of the cost of the instrument, as a basic requirement

[2]http://www.eso.org/sci/facilities/lasilla/instruments/harps/inst/scimodes.html

4 Working plan, budget and status of the project

The idea is to have a new version of FOCES working in the telescope at the end of 2010. It is due to this reason that we have adopted the most simple solution, that it is to copy most of the components from the existing instrument. To speed-up the process, we have started a basic, informal, collaboration with the group that has developed the original instrument, and that are currently developing new similar instruments for other observatories (Grupp, private communications), although it is our willing that this instrument is developed completely by CAHA personal, although not affecting their actual duties.

The basis of this collaboration is that the FOCES-group will share the new designs and help the developers with their previous extensive experience with the instrument. On exchange, they want to participate in the commissioning of the instrument and the calibration stages, and to keep the ownership of the designs. This agreement will grant the validity of the final design, and speed-up the development.

Since the problem generated by the moving of FOCES to Munich was already known about one year ago, it was created a working group at Calar Alto, integrated by S.F.Sanchez, J.Aceituno and U.Thiele, to study the problem and the possible solutions. A basic budget of the cost of the instrument was done on the basis of the original cost of FOCES ($\sim$350000 German marks of 1998, Th.Gehren, private communications), and the current cost of some of the components, based on exploratory requests to some providers for optical components. As a result of this study, it was found that it will be possible to develop the instrument with $\sim$400 k Euros, if it was done using the workshops at Calar Alto, and paying for the extra work that it will be required, by the developers.

A basic requirement of this project is that it will not produce any cost to Calar Alto and to its partners. Therefore, in order to provide us with the required funds it was requested in March of 2008 two projects, one to the Ministery of Innovation and Science, within the program of *Mejora y Acceso de ICTS* (projects to help large science and technological infrastructures, like CAHA), and another to the local government of the *Junta de Andalucia*. Until now (February 2009), we got a positive answer from the Ministery of Innovation of Science, which has granted us with 112500 Euros, a $\sim$25% of the required funds, that has already arrived to our account, and more is expected in 2010. We are still waiting for the final decision of the *Junta de Andalucia*. We are also in touch with the National Commission of Astronomy to get additional funds through the *Acciones Complementarias* program.

So far, we need to expend the already obtained money by June 2009, if we want to get additional funds on the next years. This imposes strong limitations to its use, and it will basically be expended in the acquisition of some of the main components, like the grims, the fold-mirrors, and/or the grating. All together, they will cost $\sim$100 k euros.

The working plan will expand through 2009 and 2010, and it can be outlined by the following scheme:

- Obtain the additional funds required to perform the project. We are currently waiting for the response of the local government to know how much money it still needed to cover the budget. The requests should be done before the end of March 2009.

- Obtain the final design by the Munich Observatory (F.Grupp, as contact person). We will have a first meeting at the end of February 2009. The different components that has not been changed in the modified design will be identified. A review system will be settle, taking into account that we are not developing a new instrument, but just modifying slightly an already working system. The review will be performed by an external reviewer (most probably a single one, to speed up the process).

- Request the main components of the instrument that has not changed in the modified design. It is needed to do that request before the end of March in order to full-fill the requirements of the Ministery of Science, and justify the costs by June 2009.
- Start to mount the optical components that we acquire along this year (along 2009).
- Develop the electronic components to control the motorized systems (along 2009).

The working plan for 2010 will depend on when we got the final funds to develop the instrument, and when we will obtain all the required components. It is important to note here that a considerable amount of work has already be done to identify that components that we can use from FOCES, like the telescope module, the fibers (although if we have additional funds they will be replaced), or to identify other components that can be used from the spare parts already available at the observatory (like the optical bench).

Acknowledgement

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