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P. Molaro, R. Pallavicini, I. Porceddu (ITAL Consortium).

References

Avila, G. Guinouard, I., Jocou, L., Guillon, F., Balsamo, F. 2002, in *Instrument Design and Performance for Optical/Infrared Ground-Based Telescopes* Proc. *SPIE* **4841** (in press).

Blecha, A., North, P., Cayatte, V., Royer, F., Simond, G. 2000, Proc. *SPIE* Vol. **4008**, p. 467.

D'Odorico, S. et al. 2000, *Proc. SPIE* Vol. **4005**, p. 121.

Gillingham, P., Miziarski, S., Klauser, U. 2000, Proc. *SPIE* Vol. **4008**, p. 914.

Gillingham P.R., Popovic D., Waller L.G., Farrell T.J. 2002, in *Instrument Design and Performance for Optical/Infrared Ground-Based Telescopes*, Proc. *SPIE* **4841** (in press).

Hammer, F., Hill, V., Cayatte, V. 1999, *Journal des Astronomes Français*, **60**, 19.

Jocou, I. et al. 2000, Proc. *SPIE* Vol. **4008**, p. 475.

Mulas, G., Modigliani, A., Porceddu, I., Damiani, F. 2002, in *Instrument Design and Performance for Optical/Infrared Ground-Based Telescopes,* Proc. *SPIE* **4841** (in press).

Pancino, E. et al. 2002: *ApJ* **568**, L101.

Pasquini, L. et al. 2000, Proc. *SPIE* Vol. **4008**, p. 129.

Pasquini , L. et al. 2002, in *Instrument Design and Performances for Optical/Infrared Ground-Based Telescopes,* Proc. *SPIE* **4841** (in press).

Royer, F., Blecha, A., North, P., Simond, G., Baratchart, S., Cayatte, V., Chemin, L., Palsa, R. 2002, in *Astronomical Data Analysis II,* Proc *SPIE* **4847** (in press).

HARPS: ESO's Coming Planet Searcher

Chasing Exoplanets with the La Silla 3.6-m Telescope

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Introduction

An extensive review of past, present and future research on extrasolar planets is given in the article "Extrasolar Planets" by N. Santos et al. in the present issue of *The Messenger*. Here we want to mention only that the search for extrasolar planets and the interpretation of the scientific results have evolved in recent years into one of the most exciting and dynamic research topics in modern astronomy.

As a consequence, ESO decided to have a dedicated spectrograph built to be installed at the La Silla 3.6-m telescope. An Announcement of Opportunity was issued in 1998 and a consortium chosen for the realization of the project which consists of Observatoire de Haute Provence (F), Physikalisches

Institut der Universität Bern (CH) and Service d'Aéronomie du CNRS (F) under the leadership of the Observatoire de Genève (CH) where the Principal Investigator and the Project Office are located. Further contributions come from ESO-La Silla and ESO Headquarters (Garching). The agreement was finally signed in August 2000.

According to this agreement, the HARPS Consortium bears the cost for the spectrograph and all its components whereas ESO provides the Cassegrain Fibre Adapter, the fibre link, the dedicated HARPS room in the telescope building and the complete detector system. In return, the HARPS Consortium will be granted 100 HARPS observing nights per year for a period of 5 years after successful Provisional Acceptance in Chile. HARPS will of

course also be offered to the astronomical community like any other ESO instrument.

The Radial Velocity Method: Error Sources

A description of the radial velocity method for the detection of extrasolar planets in general and of the CORALIE spectrograph installed at the Swiss Leonhard Euler Telescope at La Silla in particular was given by Queloz & Mayor (2001); it describes the technique applied also with HARPS and the spectrograph which is its direct ancestor. An instrument like CORALIE achieves an accuracy in radial velocity determination of about 3 m/s, and with this accuracy planets down to a minimum mass of about one third the mass of Saturn

have been discovered. For HARPS an accuracy of 1 m/s RMS is specified. To achieve this goal, we have to analyse the limitations that are encountered by a spectrograph in order to overcome them.

Photon noise

The contribution of photon noise to the radial-velocity (RV) measurement error can be expressed, according to Hatzes & Cochran (1992), by the generic formula

$$\sigma_{RV} \propto S^{-0.5} \cdot \lambda\lambda^{-0.5} \cdot R^{-1.5}. \qquad (1)$$

The measurement precision is proportional to the square root of the flux S and the wavelength range $\lambda\lambda$ of the spectrograph. It should be mentioned that in practice it is not the wavelength range that determines the precision, but rather the number of spectral lines and their depth, since the information on RV is contained in the stellar absorption lines. Nevertheless, the formula tells us that we must maximize the amount of light entering the spectrograph. This goal can be reached by increasing the spectral range, maximizing the optical efficiency of the instrument, and, of course, by using the largest telescope available.

The UVES-like optical design as well as the choice of the optical components make HARPS an efficient spectrograph. However, this is not sufficient to get a precise RV spectrograph, since,

again according to formula (1), higher precision is obtained when the spectral resolution R is increased. Unfortunately, telescope diameter D, spectral resolution R, and fibre diameter ϕ (projected on the sky) are not independent, but linked by the formula

$$R_{\max} = \frac{2 \cdot \tan\beta \cdot h}{\varphi \cdot D}, \qquad (2)$$

where h is the diameter of the collimated beam on the echelle grating and $\tan\beta$ is the tangent of the echelle grating angle. In other words, if we want to increase the spectral resolution we have to increase the collimated beam diameter, or restrict the field of view ϕ and consequently decrease the slit efficiency.

A trade-off therefore had to be made between spectrograph size, spectral resolution, and slit efficiency. Our solution consists in building an instrument using the largest monolithic echelle grating available to date (a 837×208 mm grating developed for UVES) and to balance spectral resolution against slit efficiency. The compromise led to a spectral resolution of $R = 93,000$ which in most cases is sufficient to resolve the stellar absorption lines. Going beyond would not reduce the photon noise but only increase slit losses. At the selected resolution the fibre covers 1 arcsec on the sky. The resulting slit losses are about 50% on average. It should be recalled however that the goal was to optimize the instrument for RV precision, which is proportional to $R^{1.5}$ but only proportional to the square root of S. Thus, a fibre twice as large would collect twice the amount of light, but would also reduce the spectral resolution by a factor of 2. The resulting RV precision would be reduced by a factor 2.

Instrumental errors

If we want to detect RV variations of 1 ms^{-1} we must be able to detect changes in the stellar absorption line position which are

Figure 1: The finished HARPS Cassegrain Fibre Adapter ready to be shipped from La Silla to Geneva for system tests.

smaller than 1/1000 of a CCD pixel. A temperature variation by 1°C or the change of atmospheric pressure by 1 mbar would already produce effects of the order of 100 ms^{-1}! We have therefore decided to act on different fronts:

• Stabilize the spectrograph environment. HARPS is installed in vacuum to remove effects caused by varying ambient pressure. In addition, the temperature of the whole instrument is actively controlled.

• Simplify the opto-mechanical design, avoid any moving or movable components, design a robust spectrograph.

• Use a spectral reference to track residual instrumental drifts.

Since it is impossible to avoid drifts of 10 nm on the instrument, the spectral reference is mandatory. On HARPS we will have the possibility of using either a ThAr spectral lamp in simultaneous reference mode, or an iodine absorption cell in self-calibrating mode. Both techniques attain to date similar performance at the level of about 3 ms^{-1}. The main mode of HARPS will be the ThAr simultaneous reference, since it allows to cover a spectral range 3 times larger than with the iodine cell, which in addition absorbs about 50% of the light. The efficiency is thus 6 times higher using the ThAr simultaneous reference mode.

Often, stability of the instrumental profile (IP) is associated with the RV precision of an instrument. In practice, both spectral reference methods allow to avoid errors produced by internal IP variations. It is however true that the ThAr simultaneous reference technique does not account for variations of the slit illumination. This technique works therefore only if combined with a fibre feed and with an image scrambler, whose sole function is to "scramble" the light entering the fibre at the telescope. The goal is to avoid a change in spectrograph illumination when the position of the star on the fibre entrance changes. We estimate that the residual effects are of the order of 0.25 ms^{-1} and can thus be neglected. It is worth mentioning that good telescope guiding and high spectral resolution reduce these kinds of error sources even further.

External errors

We should not forget that RV measurements may be influenced by error sources related neither to the instrument nor to the telescope. Any of those can produce RV errors of the order of several ms^{-1} if not correctly accounted for. Without going into detail, we mention the following:

• Atmospheric absorption lines which vary in relative position and intensity compared to the stellar spectrum
• Atmospheric dispersion

• Sunlight reflected by the moon and superimposed on the stellar spectrum

• Stellar companions close to the target star may contaminate its spectrum, depending on seeing conditions

• Stellar jitter, intrinsic variability of the star

HARPS: The Implementation

The La Silla 3.6-m telescope

As already mentioned, ESO decided early on to install HARPS at the La Silla 3.6-m telescope. This telescope recently underwent a major overhaul and was retrofitted with a new control system based on the VLT software and data flow. These improvements, together with the obvious fact that a 4-m-class telescope is ideal in providing the large number of photons required for high signal-to-noise ratio spectra, make this telescope a superb complement to our new instrument.

The HARPS Cassegrain Fibre Adapter (HCFA)

To connect the fibre link (see below) to the telescope, the La Silla Engineering Department designed and manufactured a new fibre adapter for the Cassegrain focus. The HCFA fulfils a number of functions: It allows the remotely controlled exchange of the fibres for HARPS and the CES and provides both fibre feeds with an atmospheric dispersion compensator (ADC) and the possibility to use the telescope's guide camera for guiding on the respective fibre entrance. For HARPS, there is also a neutral density filter and a feed for the calibration fibre which carries the light from a separate calibration unit (see below). This is a crucial part of the calibration concept of HARPS (described in Queloz & Mayor 2001). As a unique feature, HARPS will offer the observer two options for precise wavelength calibration: the default Thorium-Argon method and the use of the Iodine absorption cell. This Iodine cell is also mounted in the HCFA and can be moved in and out of the telescope beam under remote control. Figure 1 shows the finished HCFA.

Calibration unit

The HARPS calibration unit provides the instrument with light for wavelength and flatfield calibration. For this purpose it contains a set of hollow-cathode Thorium-Argon and halogen lamps which can be remotely switched on and off. A motorized exchange mechanism allows to position the calibration fibre in front of any desired lamp. The calibration fibre pair connects the calibration unit, which is located next to the air-conditioned HARPS enclosure in the coudé west room, with the fibre adapter at the Cassegrain focus.

Figure 2: The closed HARPS vacuum vessel in the Geneva integration laboratory.

Fibre links, image scramblers

Strictly speaking HARPS is a distributed system, and one of the most important components connecting its various parts is the observation fibre link. Its purpose is to feed the spectrograph down in the telescope building with (a) the star light collected at the Cassegrain focus and with (b) either the ThAr spectrum for the simultaneous calibration or with light from the night sky for better sky subtraction. For HARPS we chose two 70μm fibres (type FVP made by Polymicro), corresponding to 1 arc-second on the sky, and put it in a "shower tube" made of sturdy steel mesh for mechanical protection. The total length of the fibres from the Cassegrain focus to the spectrograph entrance (by way of the declination bearing, telescope fork, northern telescope mount bearing and into the coudé west room) is 38 metres.

To minimize focal ratio degradation, the light is coupled into the object and reference fibres by means of two micro lens doublets per fibre. By projecting the image on the fibre input end, the telescope pupil is at infinity. This design combines an excellent image quality with easy, uncritical alignment.

A double image scrambler is located at the entrance of the object/reference fibres into the vacuum vessel of the spectrograph. In combination with the fibre feed, it serves to stabilize the spectrograph illumination: the object may move at the fibre entrance due to guiding errors or seeing, but the intensity distribution at the fibre exit, i.e. the spectrograph entrance, will not change. In addition the scrambler serves as the feed-through for the fibres into the vacuum and it also

houses, on the atmosphere side, the exposure shutter.

The light is finally led to the spectrograph entrance inside the vacuum vessel by means of two short (2-metre) pieces of fibre. The coupling to the spectrograph is again achieved by a pair of doublet microlenses per fibre.

The second fibre link leads, as mentioned before, from the calibration unit in the coudé west room up to the Cassegrain focus. It is therefore also about 38 metres long, consisting of a pair of 300μm core diameter fibres (type FVP made by Polymicro).

Vacuum vessel with spectrograph

The vacuum vessel has the purpose of protecting the spectrograph proper from temperature variations and from the effects of refractive index variations of air. This vessel has a volume of approximately 2 m^3. It is evacuated by means of a turbo molecular pump before the start of operations; we expect to repeat the regeneration of the vacuum about once or twice per month.

Since the long-term stability of the spectrograph is of paramount importance for the success of the exoplanet search, the vacuum should be broken as seldom as possible. For this reason there are no moving functions inside the vacuum except the focussing mechanism of the camera. This will however be adjusted and locked before the vessel is finally closed. Figure 2 shows the closed vessel in the Geneva integration hall.

The spectrograph itself is a cross dispersed echelle spectrograph, very similar to UVES at the VLT. It is a white pupil design with the grism cross disperser placed in the white pupil. The

Figure 3: The open HARPS vacuum vessel. The back side of the echelle grating is visible on top of the optical bench as well as the rail system used for moving the large parts of the vessel.

is thus 4096^2 pixels (15 μm square) of which a field of 62.7×61.4 mm is actually used at a sampling of 4 pixels per spectral element. The performance of the chips is summarized in Table 2.

As HARPS is a stationary instrument, its detectors are cooled by a continuous-flow cryostat (CFC) of the current ESO standard design. A special feature of the HARPS cryostat is however the fact that the detector head (visible on the left in Fig. 4) is mounted to the spectrograph bench inside the vacuum vessel, with the actual CFC outside. Both are connected by a stainless steel bellows which protects the detector high vacuum (10^{-6} mbar) from the mere "emptiness" (10^{-2} mbar) of the spectrograph vessel. The detector head window also serves as field lens of the camera optics.

As a consequence of this configuration, all cables connecting the detector head to the FIERA controller have to pass through vacuum feed troughs.

Thermal enclosure

In order to keep the spectrograph temperature as constant as possible it was decided to put the vacuum vessel in an additional thermal enclosure. This is a well insulated room on the coudé floor of the 3.6-m telescope building which is itself already temperature stabilized. Based on preliminary measurements we expect to keep the temperature variations of the spectrograph

echelle grating, a copy of the UVES mosaic, is operated in quasi-Littrow condition. An f/2.1 parabolic mirror serves as collimator and is used in triple pass. A dioptric camera images the cross-dispersed spectra (one each from the object and reference fibres) side by side onto a mosaic of two $2k \times 4k$ EEV CCDs. 68 orders cover a spectral range from 380–690 nm. At a spectral resolution RS of 90,000, determined by the fibre diameter, a spectral resolution element is sampled by 4 pixels. All optical components are mounted on a stainless steel optical bench. The optical parameters are listed in Table 1.

Procurement of the optics turned out to be the most demanding of all. The first company charged with the production of the cross disperser grism failed to deliver and a new contract had to be negotiated with another supplier. The collimator mirror also failed to materialize, both within schedule and with acceptable quality. The mirror which was finally delivered had to be re-polished by another company to meet our requirements.

In order to improve the observing efficiency by always applying the correct exposure time (according to the selected signal-to-noise ratio SNR) we fitted an exposure meter, again following the example of UVES. Two photon counters are used to separately measure the light coming from the object and ref-erence fibres which is reflected off the gap on the echelle between the two gratings comprising the mosaic.

Detector system

HARPS employs a mosaic of two EEV type 44-82 CCDs (nicknamed *Jasmin* and *Linda*). The spectral format
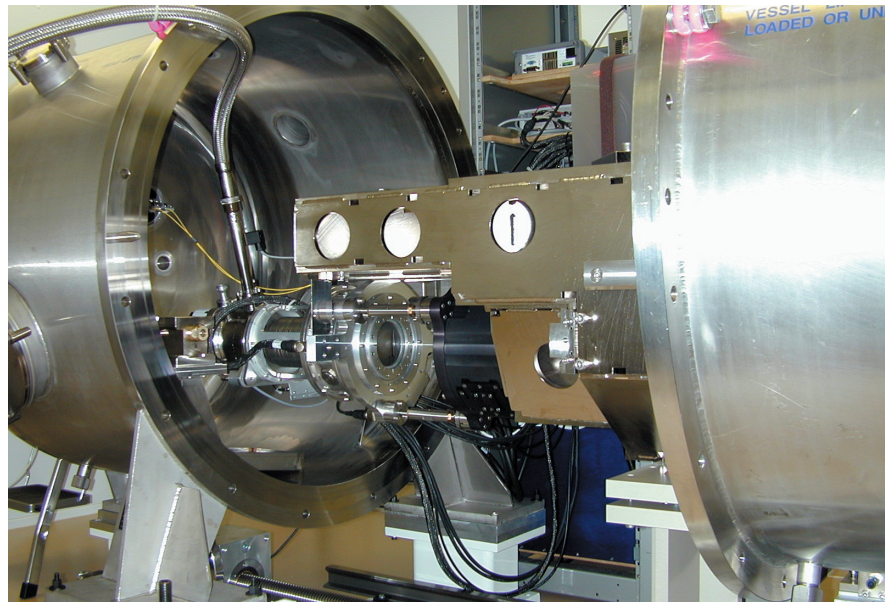

Figure 4: The figure shows the CCD detector system mounted below the spectrograph bench. Visible are also the field lens and a holder which still connects the head and the CFC. In the final configuration the CFC will be mounted outside the vacuum vessel.

Table 1 Summary of the HARPS spectrograph optics.

System	2 fibres (1″ dia.), spectral range 380–690 nm, collimated beam diameter 208 mm
Echelle	R4, 31.6 gr/mm, blaze angle 75°, mosaic 2×1 on Zerodur monolith $840 \times 214 \times 125$ mm, efficiency > 65% in the visible
Cross disperser	FK5 grism, 257.17 gr/mm blazed at 480 nm, $240 \times 230 \times 50$mm, T = 73% (av)
Collimator	Zerodur, f = 1560 mm, used diameter 730 mm, triple pass
Camera	All dioptric, 6 elements in 6 groups, f = 728 mm, f/3.3, T > 85%

Table 2: Properties of the HARPS detector system.

DQE	82–85% peak, 70% minimum
Read-out noise	~ 3e⁻ at 50 kpx/sec (2 ports/chip)
CTE	0.999999 (horizontal+vertical) at 166 kpx/sec
Cosmetics	Science grade (grade 1)
Read-out modes	50 kpx/sec and 625 kpx/sec, one or two ports per chip

bench inside the vacuum vessel (the only place that really matters) below 0.1K, ideally at 0.01K!

Performance

The instrument

Recently we have completed the integration of HARPS at the Geneva Observatory. Tests of the complete spectrograph have been carried out, and the spectroscopic characteristics verified. The spectral format recorded corresponds well to the calculated values. All the orders – except order 115 which falls between the two CCDs – could be localized and extracted using a tungsten flat-field lamp (Fig. 5), while the wavelength calibration was done using the ThAr spectral lamp. In Figure 6 we show a small segment of the extracted and wavelength-calibrated ThAr spectrum. About 3500 spectral lines covering a large intensity range could be detected and identified. From the spectrum shown, which was recorded during an exposure of 7 s, we estimate that the internal photon noise on the radial velocity is only 10 cm s⁻¹. This represents a large gain compared to CORALIE, in part due to the higher optical efficiency of the spectrograph, but mainly due to the higher spectral resolution. Indeed, the Gaussian fit of a single ThAr line indicates a spectral resolution of $R = 98,000$, which is about 5% higher than expected.

As mentioned above, HARPS is equipped with an iodine cell for the self-calibration mode. We have recorded a spectrum of our iodine cell by sending the white light of the tungsten lamp through it. The extracted and wavelength-calibrated spectrum is shown in Figure 7. The intensity of the continuum varies strongly across the echelle order because of the blaze re-

sponse of the grating. The angle of the echelle grating was not centred correctly at that time thus delivering an asymmetric blaze response. This was corrected later by tilting the echelle grating physically by 0.25°.

The total efficiency of the instrument has not yet been determined. This measurement will be done during Commissioning using a reference star. Nevertheless, the optical components were measured individually. Table 3 summarizes the expected optical efficiency of HARPS derived from these measurements. From this, and based on data recorded with the CORALIE instrument at La Silla (see Queloz &

Mayor (2001)), we have estimated the RV precision of HARPS as a function of stellar magnitude (see their Fig. 14). The total RV efficiency of HARPS is thus about 75 times higher than that of CORALIE. This extraordinary RV efficiency will offer exciting new possibilities in other research fields, for example in asteroseismology.

Operations

Often neglected, observational efficiency also plays an important role. In fact, searching for exoplanets requires that many measurements per object are carried out. Telescope time must therefore be used efficiently.

From the beginning, strong emphasis was put on efficient operations scenarios to optimize the yield from an observing run. Most important is certainly the adoption of the VLT Data Flow System, from the preparation of Observation Blocks with P2PP through the use of BOB at the telescope to the imple-
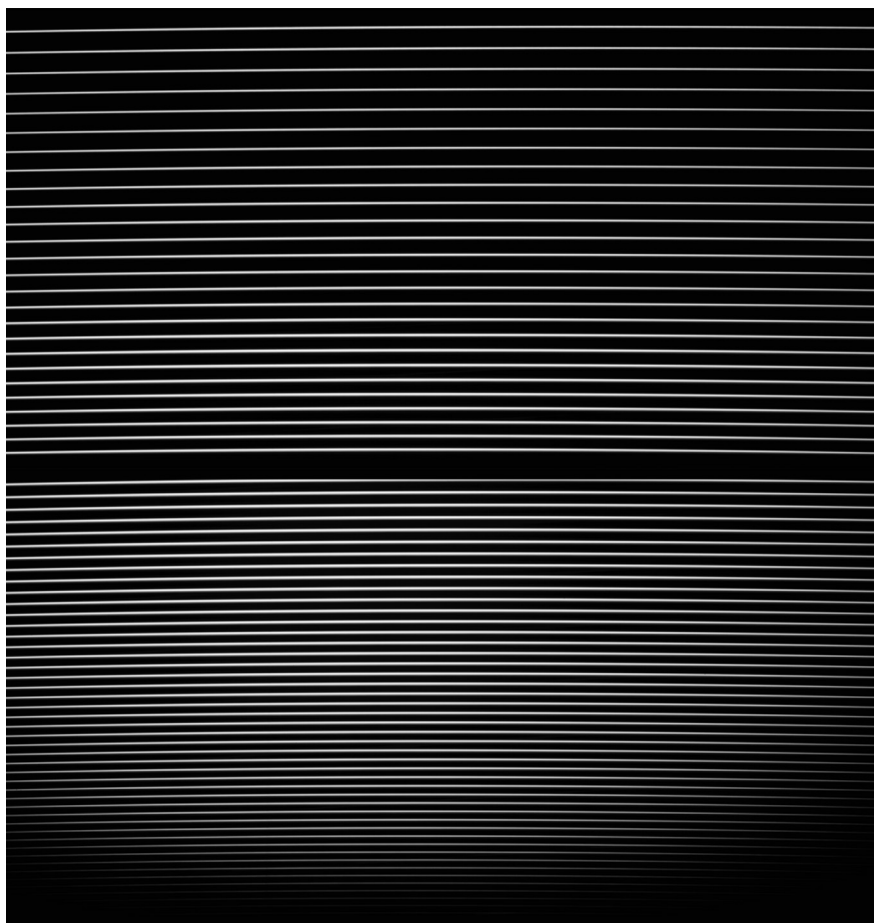

Figure 5: Spectral flat-field of HARPS using the tungsten lamp. Only one fibre (object) is illuminated for the localization of the orders.

Table 3: Optical efficiency of HARPS.

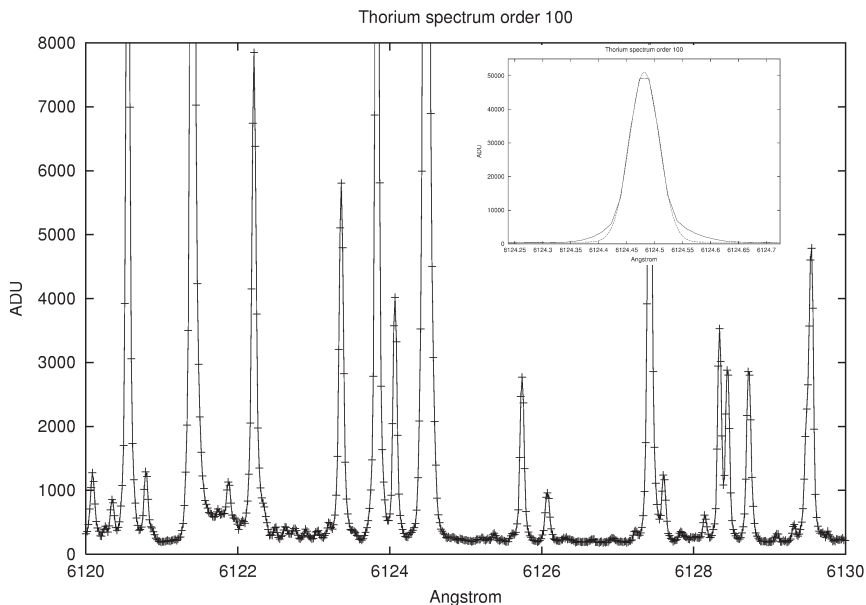| Wavelength	380 nm	400 nm	450 nm	500 nm	550 nm	600 nm	650 nm	690 nm
Tel. + atm.	44%	47%	54%	57%	59%	59%	61%	63%
"Slit"	46%	47%	48%	49%	50%	50%	51%	52%
Instrument	8%	11%	15%	15%	17%	17%	15%	12%
CCD	65%	78%	85%	85%	81%	79%	76%	72%
Total	1.0%	1.9%	3.2%	3.5%	4.0%	3.9%	3.4%	2.9%

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Figure 6: Segment of the extracted ThAr spectrum. In the small window one single line is shown. The FWHM of the superimposed Gaussian (dashed line) corresponds to a spectral resolution of R = 98,000.
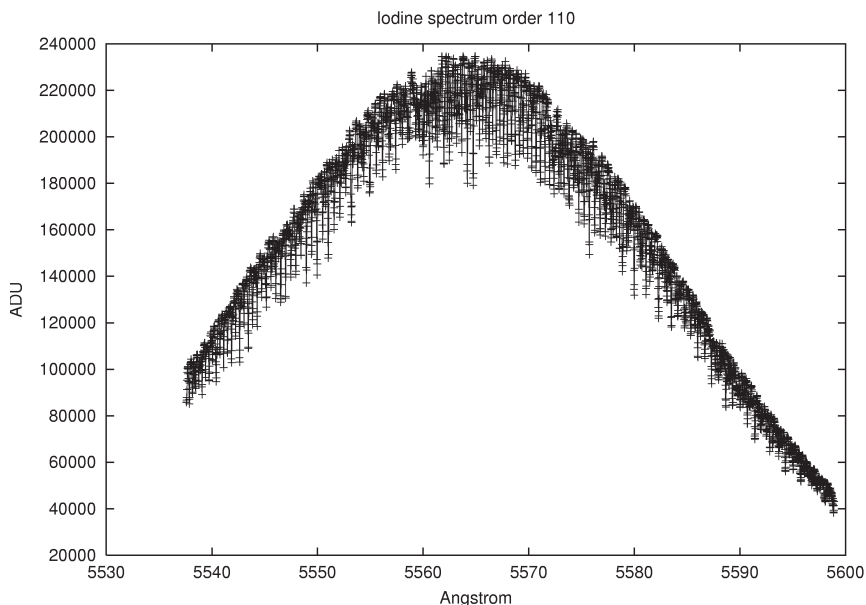

Figure 7: Portion of the extracted and wavelength-calibrated iodine spectrum. The intensity variation across the echelle order is caused by the blaze response of the grating.

mentation of a full online data reduction pipeline. A sophisticated software tool will support the observer during the run: it will allow online calculation of the exposure time (based on the brightness of the star, the actual brightness of the night sky, the seeing and the desired SNR) and enable him to optimize during the night the short-term scheduling of observations of targets in a pre-prepared object catalogue.

All raw data are then stored in the local archive. In addition, observations in the high-precision ThAr mode are automatically reduced in near real time by a pipeline running on a dedicated workstation: at the end of the night the observer will have available all final radial velocities, ready for publication! All data can be immediately written to DVD-ROM and are also archived in the central Garching science archive.

Outlook

The HARPS project is now close to completion. Following the initial Announcement of Opportunity in 1998 were the project kick-off in February 2000, optics Final Design Review (FDR) in April 2000, Preliminary Design Review in July 2000, FDR in March 2001, and software FDR in July 2001. HARPS is currently undergoing extended system tests at Geneva Observatory (see Pepe et al. 2002). As soon as these are finished, we will perform Preliminary Acceptance (Europe), scheduled for December 2002. After the transport to La Silla and the subsequent re-integration and functional tests we plan to have First Light in February 2003, followed by two commissioning runs of 2 weeks duration each. HARPS should then be available to the ESO astronomical community from Period 72 on. At the specified performance, it will be a marvellous radial velocity machine which will among others serve to strengthen the leading role European astronomers play in the new and exciting field of extrasolar planet research.

References

Hatzes, A., Cochran, W. in *Proceedings ESO Workshop on High-Resolution Spectroscopy with the VLT*, M. Ulrich, ed., ESO, (ESO Garching), 1992

Santos, N. et al.: this *Messenger*.

Pepe, F. et al., "Performance Verification of HARPS – First Laboratory Results", in *Astronomical Telescopes and Instrumentation 2002: Ground-based Telescopes and Instrumentation,* Proc. SPIE Vol. **4841**, (2002, in print).

Queloz, D., Mayor, M. 2001, From CORALIE to HARPS, *The Messenger,* **105**, 1–7.

Table 4. The main HARPS industrial contractors.

Vacuum vessel	APCO Technology (CH)
Optical bench	Deshors Ets. (F), Acrodur (F)
Crossdisperser grism	Cybernetix (F), Thermo RGL (USA)
Echelle grating	Thermo RGL (USA)
Camera, collimator	SESO (F), SAGEM (F)
Coatings	SAGEM (F), Gretag TFP (CH)
Optical fibres	SEDI (F)
Iodine cell	Hellma (D), Physikalisch-Technische Bundesanstalt (D)