NIRPS IS JOINING HARPS TO EXTEND HIGH PRECISION SPECTROSCOPY TO THE NEAR INFRARED

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Abstract. NIRPS (Near-InfraRed Planet Searcher) is an ultra-stable near-infrared spectrograph being installed on ESO's 3.6m telescope at La Silla Observatory, Chile. Its first light happened in May 2022. NIRPS uses an adaptive optics system to efficiently couple the telescope beam into a 0.4 arcsec multi-mode fiber. The instrument covers the range 0.97-1.81 μm with a spectral resolution of 80,000. NIRPS will be operated in tandem with HARPS allowing to cover simultaneously the spectral range 0.38-1.81 μm. The main scientific objectives of the NIRPS consortium will focus on the detection and characterization of exoplanets and their atmosphere. The HARPS+NIRPS combination will also play a key role in high resolution spectroscopic analysis, in the study of stellar activity, in the resolution of binary systems, and in the study of late M dwarfs and young stars. In addition, HARPS+NIRPS will also allow the daily monitoring of the Sun via the HELIOS solar telescope in order to study the Sun as a star. We present here the main characteristics of the instrument, its performances obtained in laboratory as well as the first tests on sky.

Keywords: Planetary systems – Techniques: radial velocity – Stars : low-mass – Planets and satellites: detection

1 Description of the instrument

NIRPS is a new near-infrared spectrograph that covers the Y, J, and H bands with a spectral resolution of 80,000 (Bouchy et al. 2017). A new grating is currently being installed to push the resolution up to 100,000. The instrument is extremely stable and aims to reach an accuracy of 1 m/s. It will work in tandem with HARPS (Mayor et al. 2003), which is also installed on the 3.6 meter ESO telescope, to cover the visible to near infrared range.

NIRPS is composed of 4 subsystems (see Fig. 1.): the front-end attached to the telescope (including the adaptive optics system), the fiber link that allows carrying the light coming from the telescope through the front-end to the spectrograph, the cryogenic spectrograph and the calibration unit similar to the one of ESPRESSO. The calibration unit is composed of two Uranium-Neon Hollow cathode lamps for wavelength calibration, a Tungsten lamp for spectral order geometry and spectral flat-field, a Fabry-Perot cavity for wavelength solution and instrumental drift monitoring and 2 fiber-coupled laser diodes for AO calibration. It is a compact instrument with a train of 5 refractive prisms which rotate the light beam by 180 degrees.

Two modes are available depending on the magnitude of the star: the High Accuracy (HA) mode with a fiber that has a conjugate size of 0.4 arcsec on the sky, and the High Efficiency (HE) mode. This mode uses target fiber which conjugate size is 0.9 arcsec on the sky. In the NIRPS fiber link, the image of the fiber will be sliced in two halves at a pupil level feeding a rectangular fiber. This enables to keep a high resolution for the HE mode. The spectral resolution measured with the present grating is 82000 in HA and 75000 in HE. The Fiber Link includes several provisions to scramble the light in addition to its obvious function of guiding the

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light from the telescope to the spectrograph through optical fibers. The purpose of the light scrambling is to stabilize the position of the photo-center of the light to a tiny fraction of the fiber diameter.

You can find some pictures of the different parts of the NIRPS instrument in Fig. 2.

The instrument has recently done its 5th commissioning in June 2022, which was its first commissioning with the complete instrument. The first 4 commissionings were dedicated to the Front-End, AO system and fiber train but without the spectrograph. During this commissioning at La Silla, we measured an absolute Fabry-Perot drift over 2h with a dispersion of only 9 cm/s confirming the stability of the instrument. A first light has been done just before this last commissioning by taking advantage of a technical night of the 3.6m on May 17 and some stars were observed.

We expect to start the observations of the GTO early 2023 with 3 main programs oriented towards exoplanets: a first program for the blind search of planets around M dwarfs, a second one measuring the masses of planets detected in transit in particular by the TESS mission and the last one for the characterization of atmospheres. The instrument will be open to the community next year in P111.

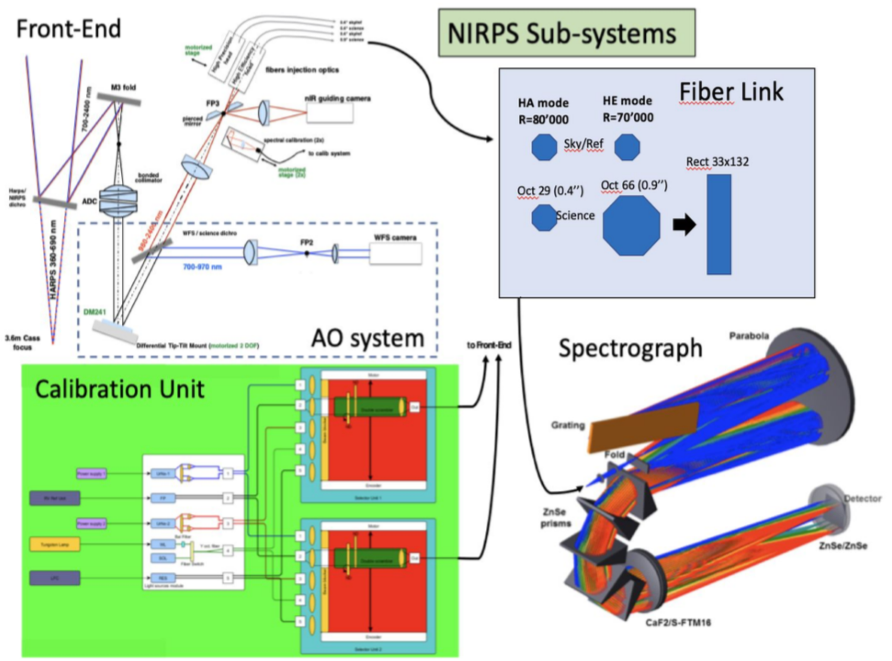

Fig. 1. NIRPS and its different subsystems: the Front-End, the Calibration Unit, the Fiber Link and the Spectrograph.

2 Science interests for stellar physics

NIRPS will be a valuable resource in the field of exoplanets but also in the stellar physics domain for multiple reasons.

2.1 Spectral range coverage

NIRPS will operate in conjunction with HARPS on the ESO's 3.6m telescope, which will allow us to obtain observations in a spectral band that covers the visible to near-infrared. Combining the two spectrographs, we obtain a 5 octave coverage with HARPS ranging from 378 to 691 nm and NIRPS from 971 to 1875 nm.

An example of application taking advantage of this large spectral coverage is the study of spots on the surface of a star which will have a different signature in the visible spectrum and in the IR spectrum. Indeed, the presence of spots on the surface of the star induces a radial velocity signal due to the temperature difference between the spot and the stellar photosphere and to the stellar rotation. The radial velocity signatures induced by stellar activity are expected to be weaker in near-IR observations, because the flux contrast between the stellar photosphere and the spots is weaker (Klein 2020).

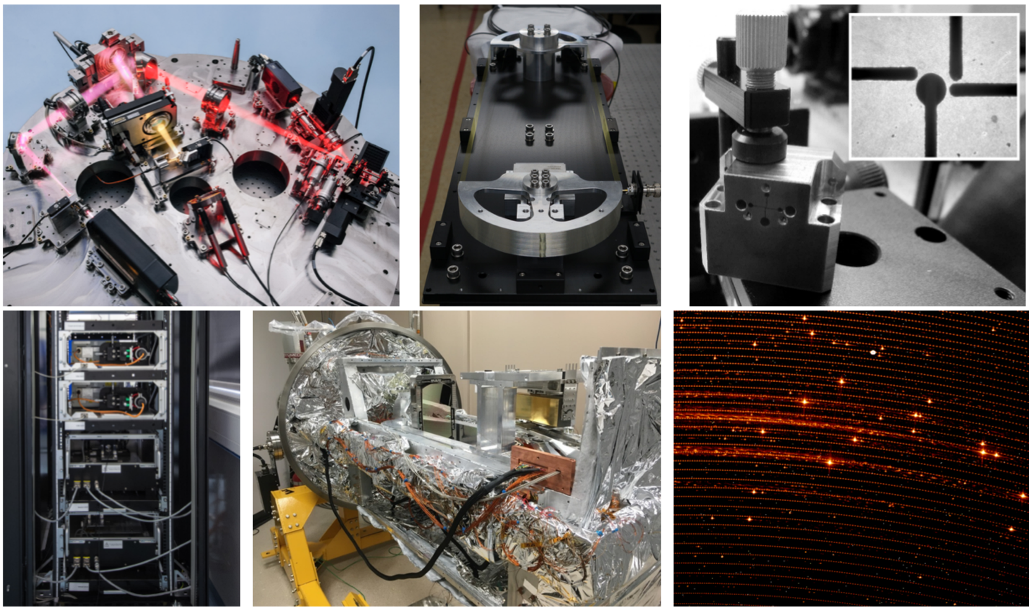

Fig. 2. Upper Left: Picture of the NIRPS Front-End including the deformable mirror and wave front sensor of the AO system, the atmospheric dispersion corrector, and the nIR guiding camera. **Upper Middle:** Picture of the stretcher which allows to reduce the modal noise produced by the fibers. **Upper Right:** Zoom of the entrance of the spectrograph of the 4 different fibers. **Bottom Left:** Picture of the calibration unit. **Bottom Middle:** Picture of the open spectrograph. **Bottom Right:** Raw frame of the Uranium + Fabry-Perot lamp on the H4RG detector.

The visible/near-IR comparison allows to distinguish a planetary signal from stellar activity (Huélamo et al. 2008). A very good example is AD Leo (Carmona et al. in prep), where obtaining near-IR data showed that the radial velocity signal is chromatic and thus does not come from a planet but rather from the star itself.

2.2 Specific spectroscopic features at high spectral resolution

A second important aspect of NIRPS is that it will be able to observe certain spectroscopic features at high spectral resolution. In addition to what was already possible to detect with HARPS in the visible, such as the Calcium line, the H alpha line and many others, with NIRPS we will have the possibility to resolve the Helium triplet and the Paschen beta line which are sensitive to the modulations of the stellar activity and which are located in a region of the spectrum little contaminated by the Earth atmosphere (Moutou et al. 2020). We will also be able to measure the magnetic field with the Zeeman broadening effect using iron lines (Reiners & Basri 2008).

2.3 Adaptive optics imaging capability

One of the most important aspects that differentiates NIRPS from other spectrographs is its adaptive optics system that will allow us, for example, to resolve binary systems. Adaptive optics is a technique that corrects for the effects of atmospheric turbulence, which cause stars to twinkle. When the AO loop is closed and the adaptive optics are working, we can resolve stars separated by 0.3 arcsec.

2.4 Observing the Sun with HELIOS

NIRPS will also be connected to HELIOS to observe the Sun as a star everyday. The goal of HELIOS is to obtain very high precision spectra of the Sun on a daily basis. This allows to learn things about the Sun itself, in particular to improve our knowledge of stellar activity, but also to improve techniques for detecting exoplanets. HELIOS consists of a lens that focuses the light from the Sun onto an integrating sphere. The light comes out of the sphere through an optical fiber connected to HARPS and NIRPS. The whole installation is enclosed in a strong and waterproof box covered with a plexiglass dome. The overlap between HARPS-N located in the Canary Islands and HELIOS in La Silla will allow a continuous observation of the Sun of about 12 hours to monitor chromospheric variations, as well as spots on the surface of the Sun. The first spectrum of the Sun was recently taken by combining HELIOS with NIRPS and is shown in Fig. 3.

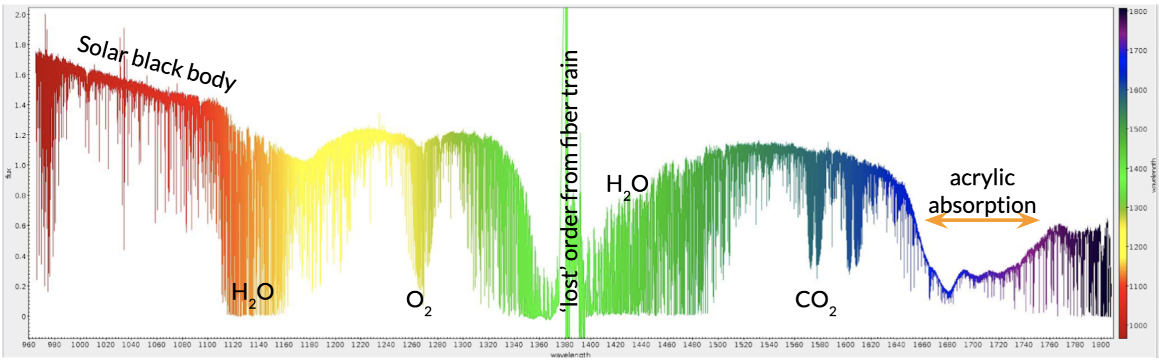

Fig. 3. Solar spectrum taken on 2022-05-17 using HELIOS and NIRPS. The acrylic absorption comes form the plexiglass dome of HELIOS.

3 Conclusions

An important part of the telescope time will be dedicated to the detection of exoplanets around low mass stars, active stars and young stars. But there remains time available for other types of programs. We have seen that NIRPS will be very useful to resolve some important spectral lines for the study of stellar activity. Its adaptive optics system will allow to identify stellar companions not resolved before. And finally, we will be able to observe the Sun as a star in the visible and near infrared by combining HARPS and NIRPS.

NIRPS is completely installed in La Silla, its first light has taken place and we already have taken spectra for a few stars like Barnard's star and Proxima Centauri. In the coming months, there will be additional commissioning time in order to test the new echelle grating which should improve the resolution, to optimize the AO scanning mode to minimize modal noise and finally the addition of a Laser Frequency Comb (LFC) is planned by the end of the year to improve the wavelength solution of the instrument. The NIRPS instrument will be opened to the community in P111 (April 2023).

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