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NIRPS: Near-Infrared Planet Searcher to join HARPS on the ESO 3.6-m telescope

François Bouchy (1), René Doyon (2), Francesco Pepe (1), François Wildi (1), Nicolas Blind (1), Etienne Artigau (2), Lison Malon (2), and the NIRPS team[1]

(1) Département d'Astronomie, Université de Genève, Chemin des Maillettes 51, 1290 Versoix, Switzerland (francois.bouchy@unige.ch)

(2) Institut de Recherche sur les Exoplanètes (IREx), Département de Physique, Université de Montréal, C.P. 6128, Succ. Centre-Ville, Montréal, QC, H3C 3J7, Canada

Abstract

The Near-InfraRed Planet Searcher (NIRPS[1]) is a new ultra-stable infrared (*YJH*) spectrograph that will be installed on ESO 3.6-m Telescope in La Silla, Chile. Aiming to achieve a precision of 1 m s^{-1}, NIRPS is designed to find rocky planets orbiting M dwarfs, and will operate together with HARPS. Here we describe the NIRPS science cases and present its main technical characteristics.

1. La Silla - Paranal Observatory: a hub for extrasolar planet research

Our knowledge of the frequency and architecture of planetary systems and their nature has been revolutionized in the last two decades thanks to various detection techniques providing complementary measurements. Observational efforts were undertaken with ground- and space-based facilities, notably radial velocity (RV) surveys using high-precision spectrographs and transit surveys. The forthcoming space armada, initiated by the launch of TESS in 2018, CHEOPS and JWST in 2020, and PLATO in 2026, will only spark a new revolution in the field of extrasolar planets if it is complemented by efficient ground-based facilities. The LaSilla-Paranal Observatory has a key role to play as it already hosts prime ground-based planet-finding facilities like HARPS, ESPRESSO, SPHERE, TRAPPIST, and NGTS. NIRPS will enable complementary precise RV measurements in the nIR with a precision of 1 m s^{-1}, specifically targeting the detection of low-mass planets around the coolest stars.

2. M dwarfs: a shortcut to habitability and life

While the detection of an Earth analogue around a Sun-like star requires a precision of better than 10 cm s^{-1}, M dwarfs offer a more accessible and attractive means of achieving the above goals. The amplitude of the RV signal scales with $M^{-2/3}$, where M is the stellar mass. In addition, thanks to their much lower luminosity, the habitable zone of M dwarfs is typically 10 times closer than in the case of Sun-like stars. These combined effects imply that for a star of spectral type mid-M with an Earth-mass planet receiving an Earth-like insolation, the RV signal is on the order of 1 m s^{-1} and therefore detectable with state-of-the-art RV spectrographs. As M dwarfs are cool and emit most of their flux in the nIR, one needs to obtain RV measurements in this domain to reach the highest possible precision.

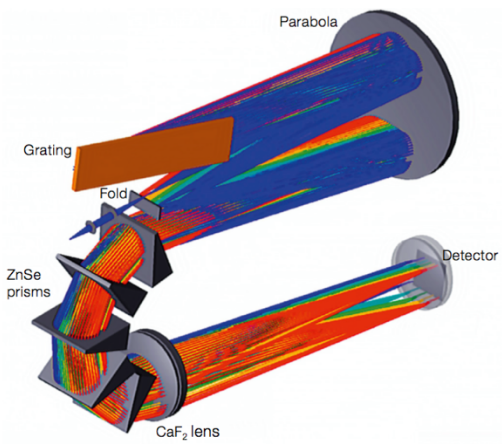
NIRPS has been designed to explore the exciting prospects offered by the M dwarfs, focusing on three main science cases:
- High-precision RV survey of M dwarfs
- Mass (and density) measurements of planetary candidates orbiting M dwarfs from transit surveys
- Atmospheric characterization via transmission spectroscopy

[1] *The NIRPS consortium is jointly led by Université de Montréal and Université de Genève and includes partners from Brazil (UFRN), France (IPAG, LAM), Portugal (Universidade de Porto and Universidade de Lisboa), Spain (IAC), Switzerland (University of Bern) and Canada (Université Laval, McGill University, Herzberg Institute of Astrophysics, Royal Military College of Canada, York University, University of Toronto, University of Western Ontario, University of British Columbia).*

3. Specifications, overall design and expected performance

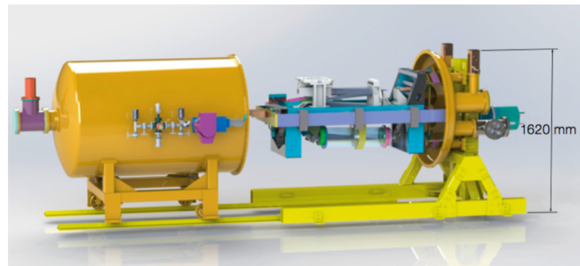
To achieve its science goals, NIRPS will operate in the *Y*-, *J*- and *H*-bands with continuous coverage from 0.97 to 1.8 µm. It will ensure high radial velocity precision and high spectral fidelity corresponding to 1 m s^{-1} in less than 30 min for an M3 star with $H = 9$. Its spectral resolution will be 100,000 to best exploit the spectral content. It will be operated simultaneously with HARPS without degrading the HARPS performance.

NIRPS is part of a new generation of adaptive optics (AO) fiber-fed spectrographs. NIRPS will use a 0.4-arcsecond multi-mode fiber, half that required for a seeing-limited instrument, allowing a spectrograph design that is half as big as that of HARPS, while meeting the requirements for high throughput and high spectral resolution. A 0.9-arcsecond fiber will be used for fainter targets and degraded seeing conditions.



The entire optical design is oriented to maximize high spectral resolution, long-term spectral stability and overall throughput. Light exiting from both object and calibration fiber links is collimated by a parabolic mirror used in triple pass and is relayed to an R4 echelle grating. The diffracted collimated beam is focused by the parabola on a flat mirror that folds the beam back to the parabola. The cross dispersion is done with a series of five refractive ZnSe prisms that rotate the beam by 180°. A four-lens refractive camera focuses the beam on a Hawaii 4RG 4096 × 4096 infrared detector. The instrument covers the 0.97 to 1.81 µm domain on 69 spectral orders with a 1 km s^{-1} pixel sampling at a resolution of 100,000 (HAM) or 75,000 (HEM). The global throughput of the spectrograph alone is estimated to be 30% at 0.97µm and 45% at1.81µm.

The spectrograph is installed inside a cylindrical cryostat (1.12-m diameter, 3.37-m long) maintained at an operating temperature of 80 K with a stability of 1 mK and an operating pressure of 10^{-5} mbar.



The HARPS and NIRPS spectrographs can be operated individually or jointly. The default operation mode will see both instruments operating simultaneously, except for high-fidelity polarimetric observations with HARPSpol.

4. Summary and Conclusions

In return for the manpower effort and financial contributions of the consortium to design, build, maintain and operate NIRPS for five years, ESO will grant the consortium a period of Guaranteed Time Observation (GTO) corresponding to 40% of the 3.6-m Telescope time, leaving ample time for community-driven science topics. In order to be in phase with future space missions such as TESS, CHEOPS, JWST and PLATO, NIRPS is being developed on a fast track; its first light is scheduled for the first quarter of 2020.