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TELESCOPE BERNARD LYOT BEYOND NARVAL: NEO-NARVAL AND SPIP

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Abstract. The present communication describes two instruments proposed for Telescope Bernard Lyot...

Keywords: instrumentation, spectropolarimeter, Infrared, exoplanet formation, stellar magnetism

1 Introduction

The Pic du midi 2-m Telescope Bernard Lyot (TBL; 15 technical, 5 science staff) is a National Facility run by Observatoire Midi-Pyrnes (Univ. Toulouse, CNRS). Major upgrades of TBL large equipments (driving motors, dome, cooling plants, hydraulic systems) have been done in the past 5 years securing operations of the telescope until 2030. Since 2009, TBL offers 240 nights/year is full service mode to French and European (via OPTICON) communities. TBL has been housing the spectropolarimeter Narval since 2007 on a science case focussing on stellar magnetism accross the H-R diagram. The dedication of TBL to Narval has produced a highly efffective science return, and numerous pionneering studies on stellar magnetism (cf contributions in these proceedings, Users meeting session). Narval has now been used for 8 years under high pressure (> 2) with no sign of stalling for the coming years. In order to stimulate thinking on future instrumentation, TBL Science Council made a call for ideas in 2012. Two projects were proposed on complementary science cases. Neo-Narval (PI T. Boehm, IRAP) for the study of evolved stars and planets, SPIP (PI J.F. Donati, IRAP, co-PI G. HEBRARD, IAP) for the study of young planetary systems and the discovery of exo-earths. The 2014 INSU AA prospective fully supports the development of Neo-Narval and supports SPIP with recommendations of carefully phasing that development with other IR spectropolarimetric projects. The 2 instruments are briefly presented in sections 2 and 3.

2 Study of evolved systems: Neo-Narval

2.1 Neo-Narval Science Case

Neo-Narval science case* is around three main topics. The first topic is the study of evolved stars and planetary systems. In particular, more and more hot Jupiters are known to spiral in towards their host stars. Direct measurements of planet engulment will be at graps of Neo-Narval. Physics of evolved sub-giant to giant phases, and the fate and impact of magnetic fields at those phases will be probed. The second topics is a continuation of Narval science case on stellar magnetism studies accross the HR diagram where much needs to be done still to understand evolution on magnetic activity over years. And finally, Neo-Narval will be a unique instrument to study magnetic jitter in stars, and its impact on exoplanet detections.

2.2 Neo-Narval Overview

In order to achieve the proposed science goals, the science requirements are to reach a velocimetry stability of $<$3m/s, to perform polarimetry analyses in Stokes QUV over the visible spectrum 0.370-1μm at a resolution > 50000.

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*full science case at `http://www.tbl.obs-mip.fr/INSTRUMENTATION2/neonarval`.

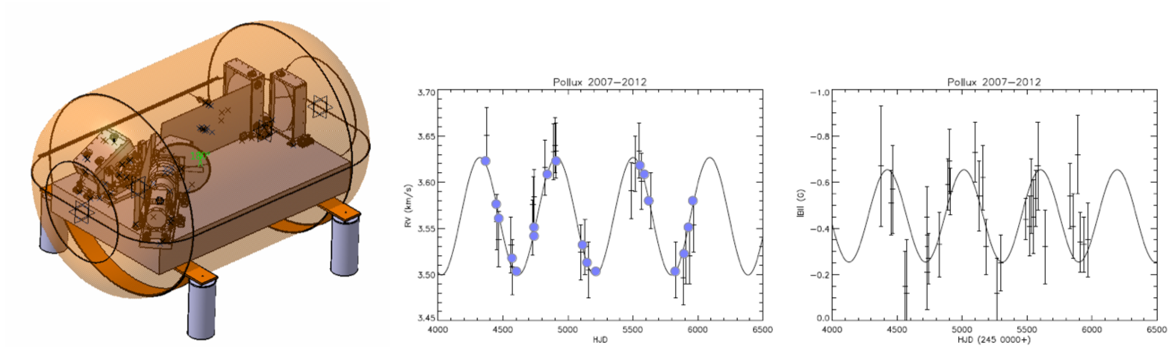

Fig. 1. Left: One design for Neo-Narval **Right:** Expected velocimetry improvement (filled circle) compared to existing Narval sensitivity, and magnetic jitter analysis on Pollux (cf science case).

Reaching the science requirements is possible using Narval with careful technical upgrades on the existing instrument. Those improvments are routinely implemented in SOPHIE, HARPS and other stabilized spectrographs around the world by teams who accepted to share their expertise with Neo-Narval technical team. Specifically one needs to stabilize the refraction index to 10^{-6} within the diffractive (grating) and refractive (crossdispersing prisms) optics of the spectrograph. One can show that stabilizing spectrograph temperature to 0.01K and volume V to $\rho_{gas}\Delta V/V < 10^{-6}$ will do, where ρ_{gas} is the enclosure gas density in bar. In turn, that can be achieved using isobaric and isothermal enclosures for the spectrograph, octogonal fiber injection for pupil stabilisation, and a realtime wavelength calibration (and velocimetry-optimized reduction pipeline). Additional upgrades will be necessary on Narval science camera (faster electronics, lower noise, Deeply depleted E2V chips) and on the polarimeter rhomboedra coders to improvment the instrument operation robustness and efficiency.

2.3 Neo-Narval implementation plan

The total budget (without human ressources) of the project is 500,000 euros. The technical team composed by IRAP, OMP, and TBL, with the expertise support of SOPHIE and HARPS teams. Neo-Narval is expected to have its first light in 2017. Funding is now secured from local sources (CPER 2015-2020). The current calendar proposes to finalize the enclosure designs in 2015, upgrade the camera, injection and polarimeter in 2015, start building an enclosure prototype in 2016-2017, for a final integration at the end 2017. A major constraint for Neo-Narval implementation is that Narval will observe continuously over 2015-2017, hence any upgrade to Neo-Narval shall have a minimal impact on TBL/Narval operations. TBL team, responsible of the integration, has a known expertise in phasing upgrades with minimal impact on observations.

3 Planet formation and young exo-Earth finder: SPIP

3.1 SPIP Science Case

SPIP science case[†] is challenging and clearly supports the future of Pic du midi beyond 2020. Being a copy of SPIRou (CFHT), SPIP covers the same topics over the brightest end of SPIRou targets. Namely, SPIP is build to explore new planetary systems close to the sun, and in particular exo-Earths orbiting the habitable zone around M dwarfs. A second hot topic probed by SPIP will be the formation of stars and their planetary systems. Models show that magnetic fields are paramount in young protoplanetary disks. Depending on their strength, magnetic field can seed or suppress planetoid formation. SPIP/SPIRou will be the first instruments able to gather observations of magnetic field in young protoplanetary systems. Finally, SPIP will perform detailled studies of evolved fully convective systems.

[†]full science case at `http://www.tbl.obs-mip.fr/INSTRUMENTATION2/spip`.

3.2 SPIP Overview

Science requirements of SPIP can be summarized as follows. A complete and simultaneous wavelength coverage of 0.98-2.35 μm (Y to K bands). A spectral resolution of 75000, a radial velocity precision of 1m/s. SPIP must perform a polarimetry analysis in all Stokes parameters QUV over the full spectral range (achromatic). It is expected to reach a sensitivity of S/N$\sim$100 per pixel of 2.3 km/s @ H=9.5.

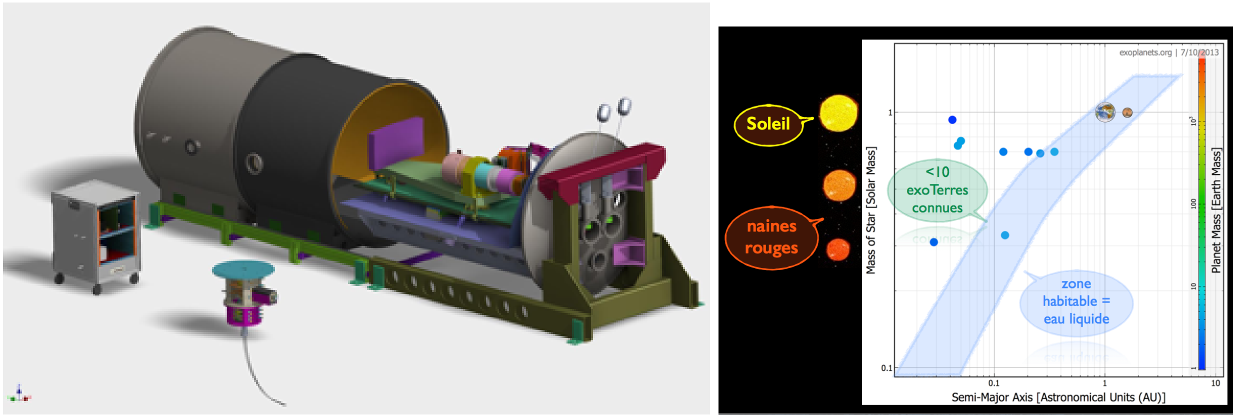

Fig. 2. Left: SPIP mechanical design **Right:** SPIP is expected to probe young planetary systems around young M stars

Contrary to Neo-Narval, reaching such requirements for SPIP required the development of a completely new instrumental concept now finalized for SPIRou, including a redesigned polarimeter and Cassegrain module using a high efficiency IR guiding camera, fluoride optical fibers connecting polarimeter and spectrograph, a new design for the image slicer, a spectrograph fully enclosed in a cryocooled vessel (operating Temperature 80 K, stabilized to mK) based on HARPS / Sophie. SPIP is expected to be an exact copy of SPIRou excepting for the entrance collimator adapted to TBL focal ratio and seeing.

3.3 SPIP implementation plan

SPIP budget is 4.5 million euros (hardware only). The budget for SPIP is not yet secured, and will probably shift from the current CPER to the next one (2021-2026), which makes full sense in terms of phasing Narval $\rightarrow$ Neo-Narval $\rightarrow$ SPIP. This shift also harmoniously fits the current technical schedule and commitments of OMP/IRAP technical teams. Duplication of an existing instrument is at grasp of TBL team, the previous experience with Narval has been fully successful. The success of SPIP integration will depend heavily on the support of SPIRou team. The human ressources will come from TBL, OMP and IRAP SPIRou team. Current first light for SPIP is now expected in 2022.

4 Conclusions

Thanks to the commitment of CNRS/INSU and Université de Toulouse to support funding and staff to TBL at Pic du midi, French astronomers still have access to a state-of-the-art facility. The proposed new instrumentation, a funded Neo-Narval and to-be-funded SPIP warrant a bright future for TBL over the coming decade. In addition to their own science cases, both instruments will play a strong role in support to space-based missions (GAIAI, TESS, CHEOPS, PLATO) and ground-based large facilities (ALMA, NOEMA, LOFAR, SKA). In addition to science, TBL offers a unique opportunity for training young astronomers in astronomical observations and service observing on a top-level observing facility.

References

Neo-Narval Science case, Boehm, T. et al., 2014, `http://www.tbl.obs-mip.fr/INSTRUMENTATION2/neonarval`

SPIP Science case, Donati, J.F. and Hebrard G., 2012, `http://www.tbl.obs-mip.fr/INSTRUMENTATION2/spip`