SPIP at TBL, the faithfull companion of the SPIRou Spectropolarimeter at CFHT

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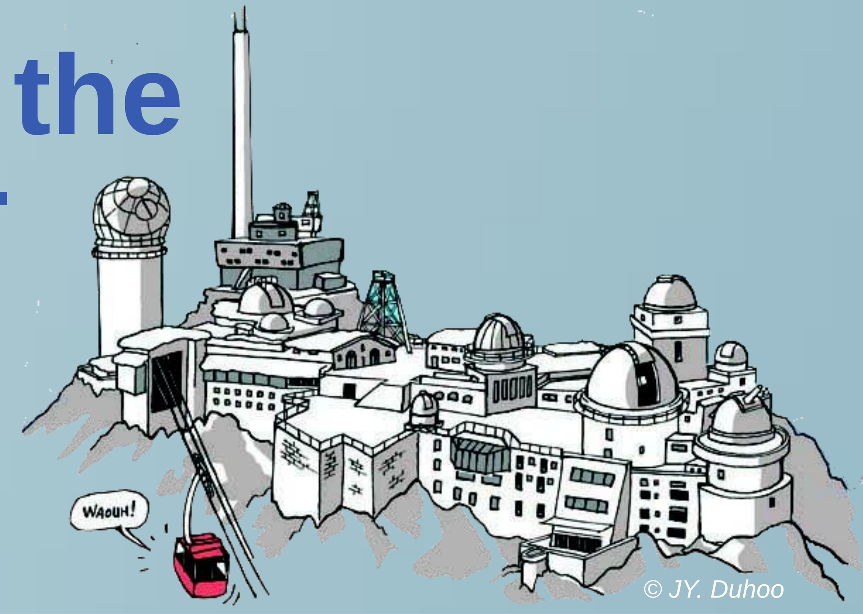

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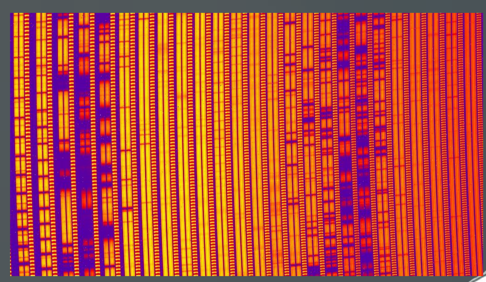
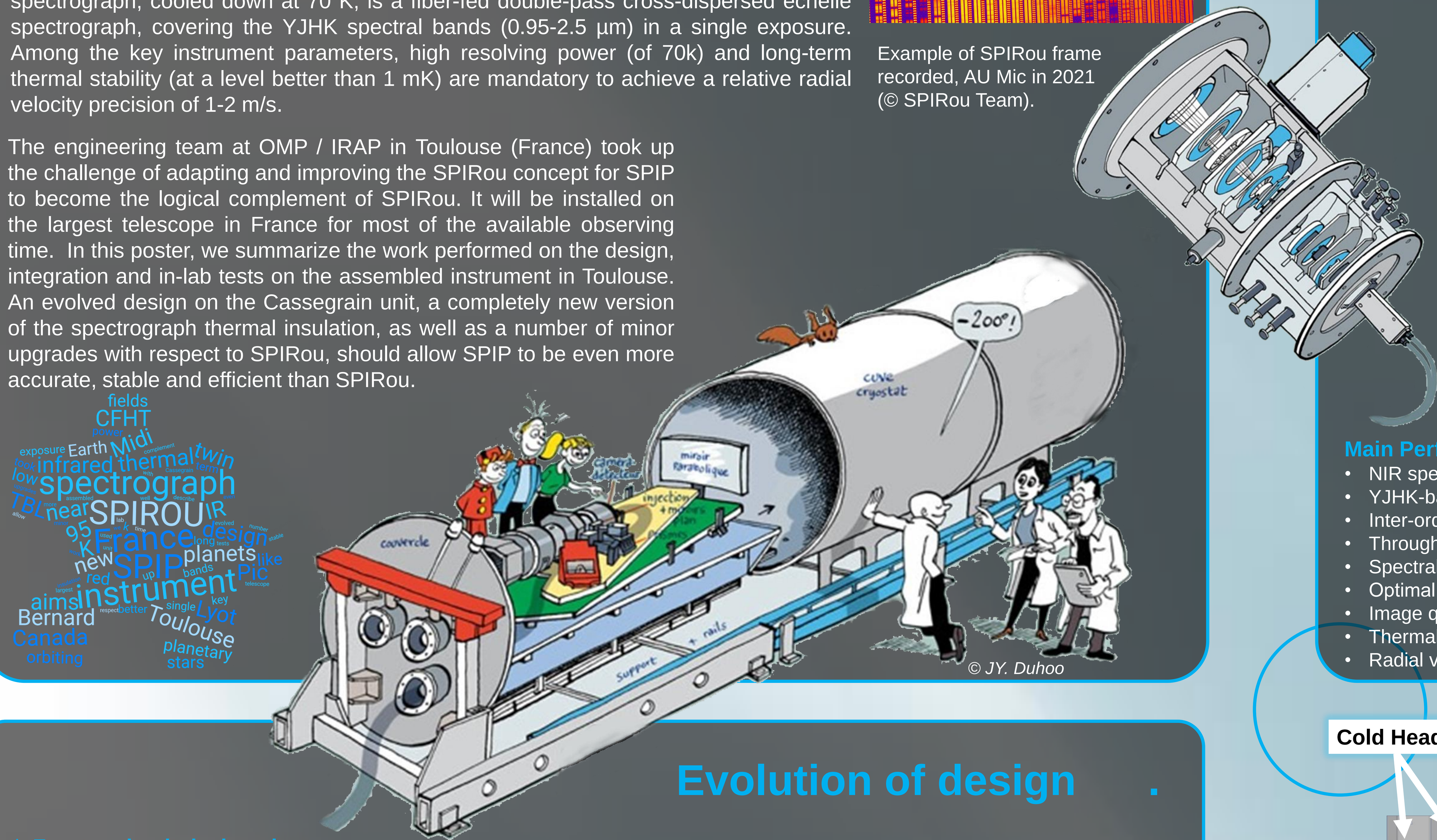
Introduction

SPIP is a near infrared (nIR) echelle spectropolarimeter and a high-precision velocimeter for the 2-m Telescope Bernard Lyot (TBL – Pic du Midi, France), a twin version of SPIRou, mounted at the 3.6-m Canada France Hawaii Telescope (CFHT - Maunakea, Hawaii). This new generation instrument aims at detecting planetary worlds and Earth-like planets orbiting nearby red dwarfs, and at studying the impact of stellar magnetic fields on the formation of low-mass stars and their planets. The cryogenic spectrograph, cooled down at 70 K, is a fiber-fed double-pass cross-dispersed echelle spectrograph, covering the YJHK spectral bands (0.95-2.5 µm) in a single exposure. Among the key instrument parameters, high resolving power (of 70k) and long-term thermal stability (at a level better than 1 mK) are mandatory to achieve a relative radial velocity precision of 1-2 m/s.



Example of SPIRou frame recorded, AU Mic in 2021 (© SPIRou Team).

The engineering team at OMP / IRAP in Toulouse (France) took up the challenge of adapting and improving the SPIRou concept for SPIP to become the logical complement of SPIRou. It will be installed on the largest telescope in France for most of the available observing time. In this poster, we summarize the work performed on the design, integration and in-lab tests on the assembled instrument in Toulouse. An evolved design on the Cassegrain unit, a completely new version of the spectrograph thermal insulation, as well as a number of minor upgrades with respect to SPIRou, should allow SPIP to be even more accurate, stable and efficient than SPIRou.



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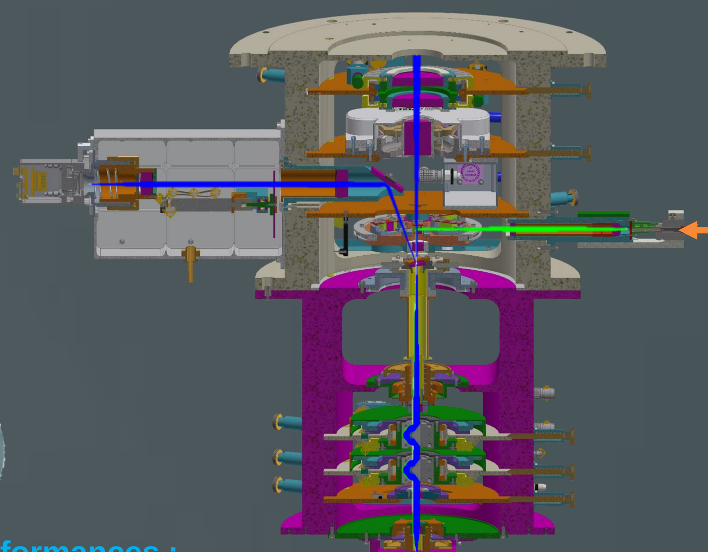
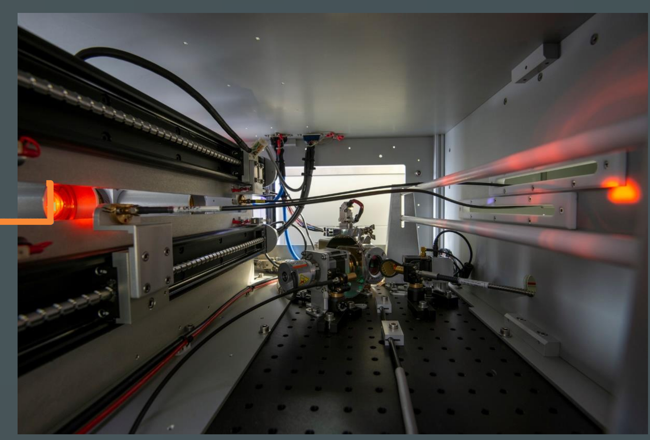
Instrument Concept

In brief, SPIP instrument essentially consists into four main sub-systems, the Frontend-Cassegrain and the Backend-Spectrograph, interconnected by Fiber links, and associated with a Calibration /Radial Velocity Reference module.

❖ **Front end unit is composed by :**

- an injection/calibration module attached to the Cassegrain focal plane of the telescope (Atmospheric Dispersion Corrector , Image Stabilization Unit)
- an achromatic polarimeter (two Fresnel rhomb retarders)
- calibration sources (radial velocity reference module & calibration lamps)





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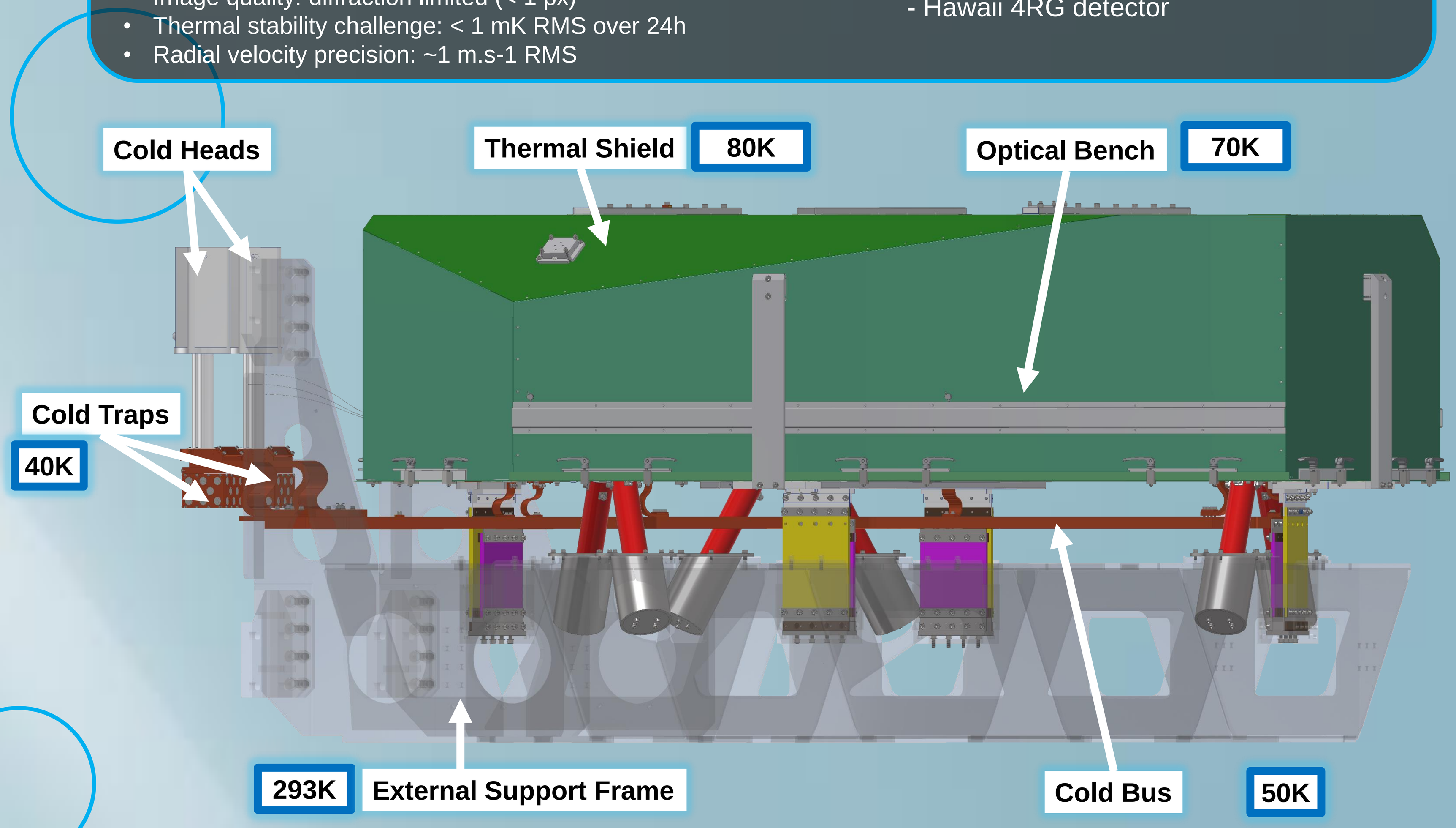
Main Performances :

- NIR spectral range: 0.95 – 2.5 µm in a single exposure
- YJHK-bands, 47 orders min. (#78 to #32), no gap
- Inter-order background: 1-2 %, overall domain
- Throughput: 10-15 % at 2.1 µm (K-band)
- Spectral resolution: 70 ± 5K
- Optimal focus: < 5 µm
- Image quality: diffraction limited (< 1 px)
- Thermal stability challenge: < 1 mK RMS over 24h
- Radial velocity precision: ~1 m.s-1 RMS

❖ **Back end unit is composed by :**

- fiber link & image slicer
- parabolic mirror
- double pass cross disperser prisms
- an echelle grating
- fully dioptric camera
- Hawaii 4RG detector



Evolution of design

❖ **Front end unit design changes :**

- beam aperture @ TBL/Cassegrain focus f/25 (CFHT: f/8)
- optics focal reducer, ISU, ADC, viewing & calibration channels
- mechanical changes in fiber output unit connectors E2000 (FC for SPIRou)

❖ **Backend unit is essentially a cryogenic spectrograph unit :**

- installed at ground level (only place large and strong enough to fit cryogenic dewar)
- clean & thermally stable environment
- anti-vibrations system added
- science fiber link elongated (~45m needed to link Cassegrain unit to ground level)
- pupil slicer improved

Inside the vacuum vessel, the radiative insulation is performed by Multi Layer Insulation (MLI) at different levels of temperature regulation. MLI is installed all around cold bus (brown) and thermal shield (green) elements.
Indeed, the main insulation contributor acts between the vacuum chamber wall and the thermal shield, where temperature has to drop down from external temperature (293K) to setpoint temperature (80K). A 40 layers MLI is used on top of thermal shield to achieve this level of insulation and a 10 layers MLI enclosed the cold elements to avoid losses.

Pictures of spectrograph optical alignement in OMP/IRAP clean room.

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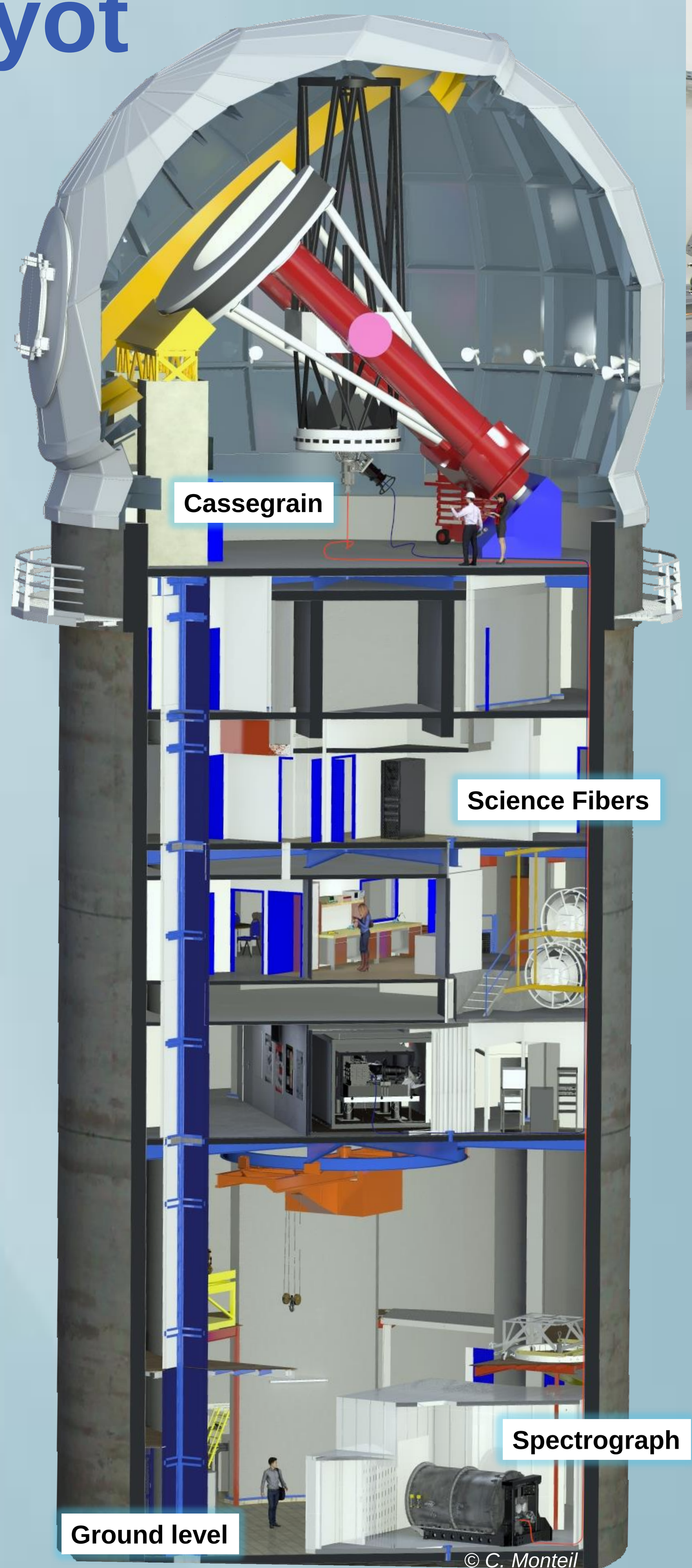
Telescope Bernard Lyot

(TBL, Pic du Midi 2877m, France)



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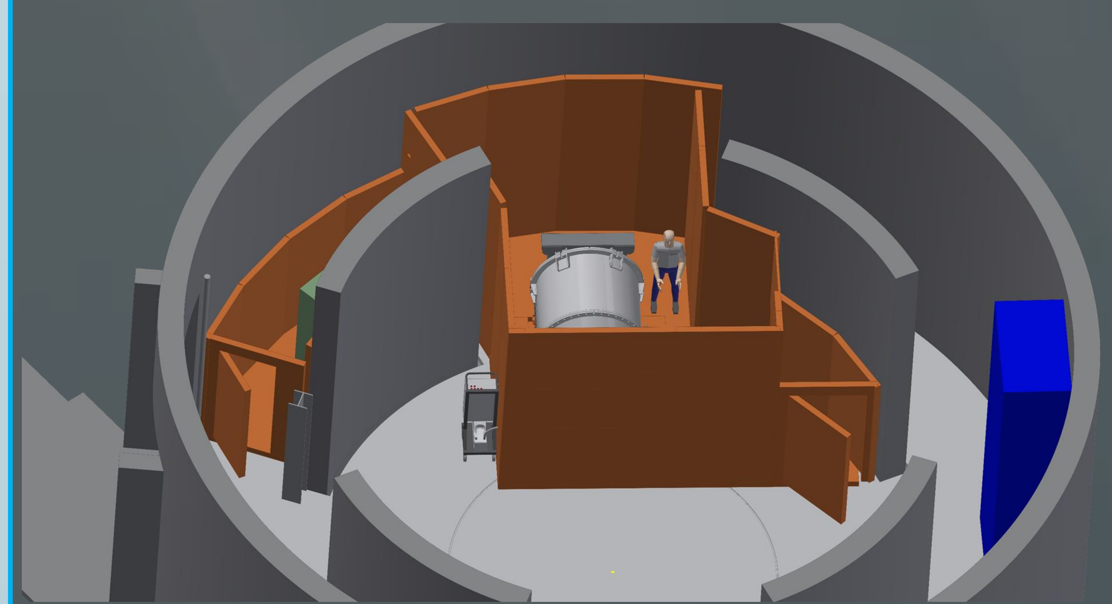
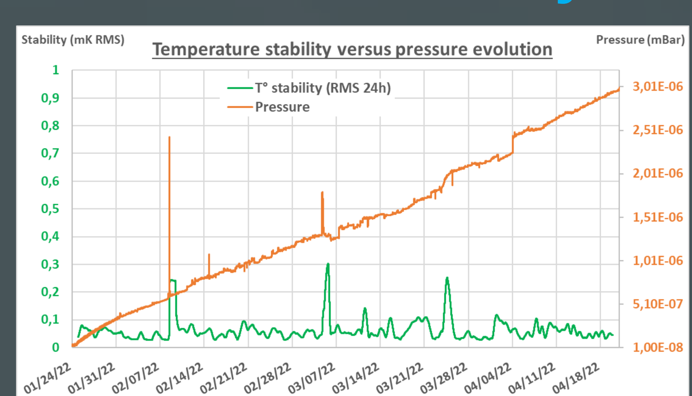
Instrument Chamber

The main purpose of this installation is to provide an appropriate environment in terms of cleanliness, temperature and hygrometry, for two modules of the SPIP instrument (the spectrograph and the calibration unit including Fabry-Perot) on ground level of the Bernard Lyot Telescope tower located on the site of the Pic du Midi de Bigorre at altitude 2877 m.

- Cleanliness: ISO8
- Temperature: 5°c +/- 0.5
- Controlled hygrometry to stay above the dew point

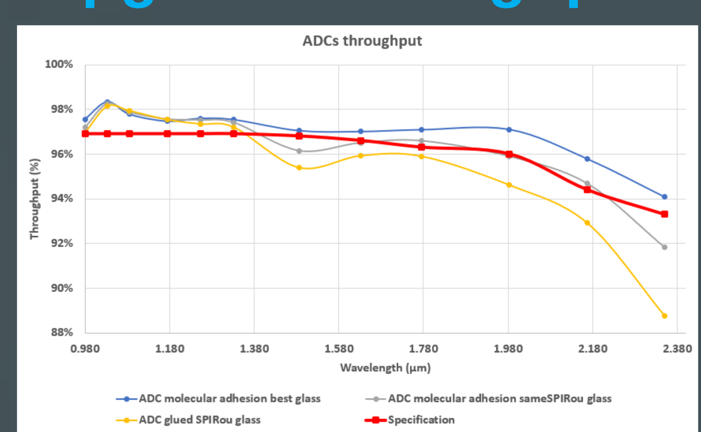


Thermal Stability



After 3 months without pumping, the pressure rose to around 3e^{-6} mbar, without having any effect on the stability, which remained below 0.05mK RMS on 24 hours throughout the cycle (except during sudden rises of pressure for several hours during failure tests of cryocoolers without even going above 1mK RMS).

Upgrade Throughput



The ADC module, which is made up of two glued prisms for SPIRou, has been molecularly joined and each of the prisms has been reduced in thickness. The curve above shows that the gain in transmission should be between grey and blue curves, compared to the SPIRou version, in yellow.

Conclusion & perspectives

- Final acceptance tests planned during 2023 A.
- Instrument integration on site at TBL 2023 B.
- First Light 2023 B.

Improvement of the telescope bonette at TBL (VISION project). It will allow the use of the two instruments Néo-Narval (0.370 to 1.000 µm) and SPIP (0.950 to 2.500 µm) simultaneously.

Planned for 2023 A.

More Informations

An international collaboration

❖ **France / Switzerland / Canada** IRAP / OMP, LAM / OHP (France), Obs. de Genève (Switzerland) UdeM & ULaval (Canada)
❖ **Worldwide science group :** ~ 85 persons from Europe / Canada / Brazil / USA & Australia

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