LOCNES

LOw Cost NIR Extended Solar telescope

Lorenzo Cabona

INAF- Padova

on behalf of the LOCNES TEAM

Claudi R., Pace E., Ghedina A., Liu S.J., Stefani S. , Tozzi A., D'Orazi V., Rainer M., Guglielmino S., Harutyunyan A., Berilli F., Lanza A.F., and *Di Fabrizio L.*

6th Chianti Topics - Firenze

26-29/2/2024

Telescopio
Nazionale
Galileo

La Palma, 1996

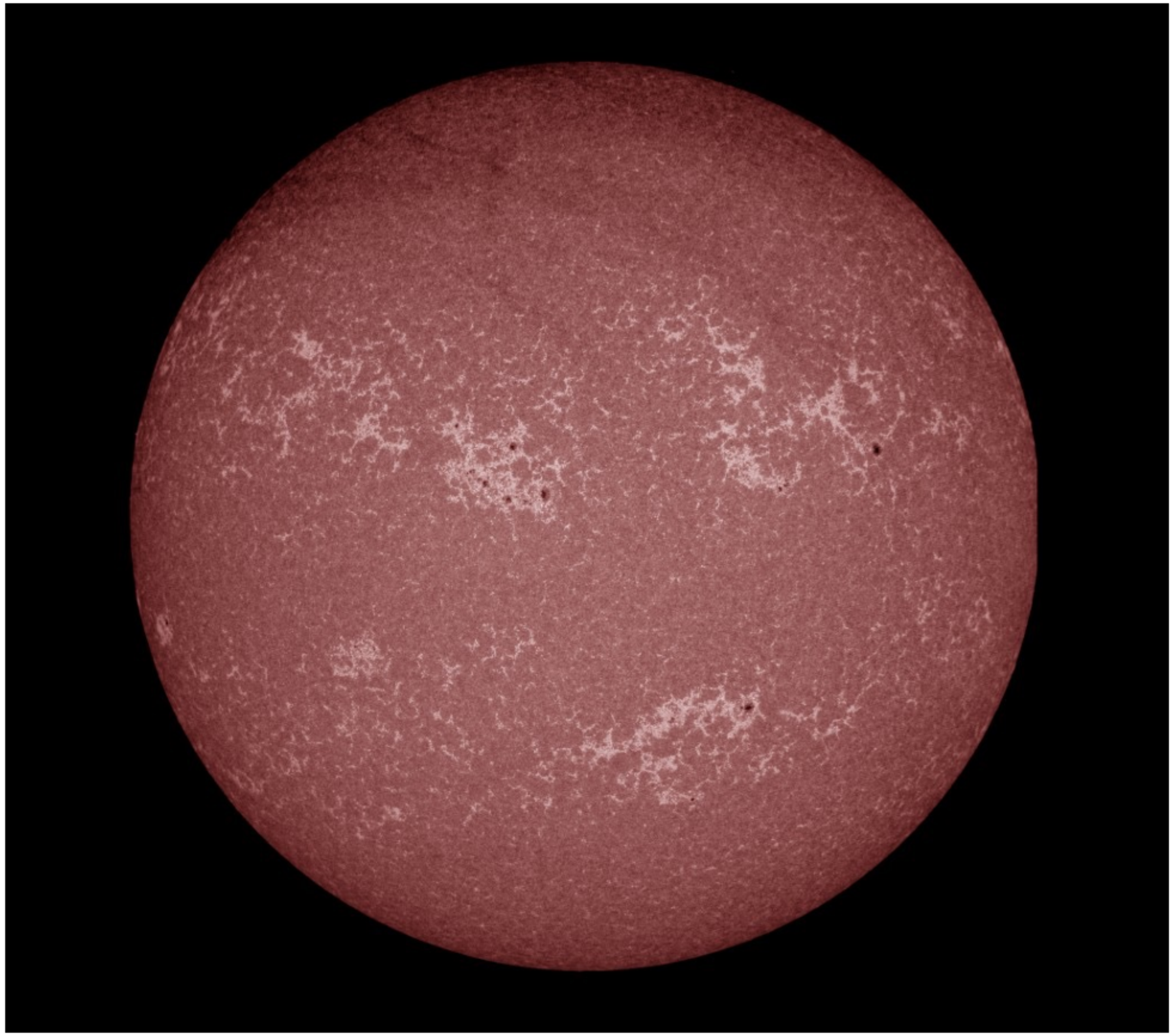
D=3.6m, RC, F/11
Active Optics

What is LOCNES?

LOCNES is a small, 2-inch, solar telescope installed at the TNG (Telescopio Nazionale Galileo). It feeds the NIR spectrograph GIANO-B through a 40-m patch of optical fibers with the light of the Sun.

LOCNES has been designed to obtain high signal-to-noise ratio spectra of the Sun-as-a-star with an accurate wavelength calibration through molecular-band cells.

The LOCNES telescope



SDO AIA 1600 channel

Why observe the Sun-as-a-star?

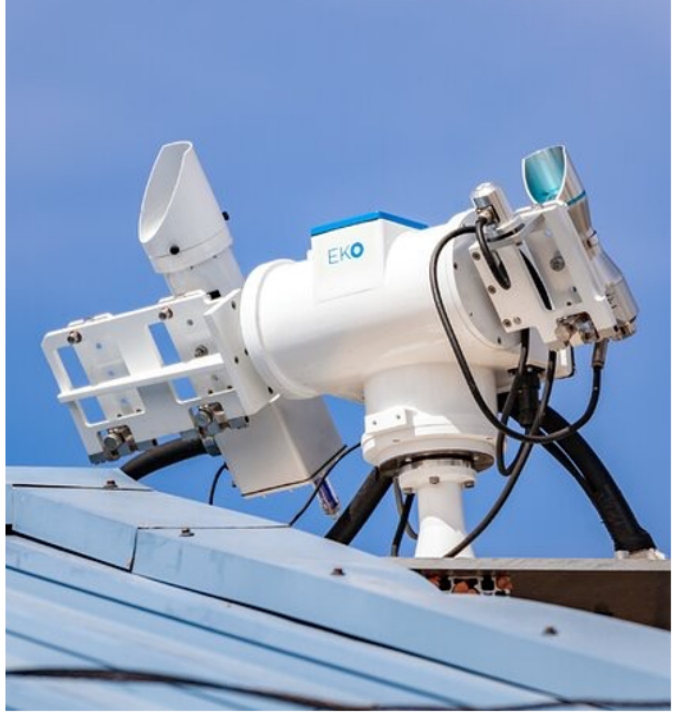
Observing the Sun-as-a-star means collect solar spectra as if it were any other star, without any spatial information.

The flux of the entire Solar disk is mixed using an integrating sphere and sent to the spectrometer through one optical fiber.

This approach of observing the Sun-as-a-star allows us to directly correlate any change in surface inhomogeneities observed by solar satellites like the Solar Dynamics Observatory with variations in the full disk Radial Velocity data.

Main goals and complementary objectives

- Study the *variation of the NIR spectra* of the Sun-as-a-star due to its magnetic activity.
- Study the impact of solar acoustic oscillations, convection, and magnetic activity on the measurements of the Radial Velocity of the Sun-as-a-star from the optical to the NIR.
- Improving the ability to detect and characterize exoplanets with orbits periods ranging between few days to weeks.



The Sun-as-a-star instruments

- LCST: Low-Cost Solar Telescope at TNG

feeding HARPS-N spectrograph (0.38-0.69um; R=115000).

- HELIOS at 3.6m of ESO Feeding:

- HARPS (0.38-0.69um; R=115000)
- NIRPS (0.97-1.81 μm R=80000).

- LOST at 4.3-m Lowell Observatory

feeding the EXPRES spectrograph (0.38-0.68um; R=115000).

- NEID at the WIYN Telescope

(380-930 nm; R=90,000)

- MAROON-X at Gemini north Telescope

(500-920nm; R=80,000)

- PEPSI at LBT

(383 nm to 914 nm; R=43-120-250K)

- ABORAS at HARPS-3 Isaac Newton Telescope (INT)

380–690 nm (polarimetric Solar Telescope)

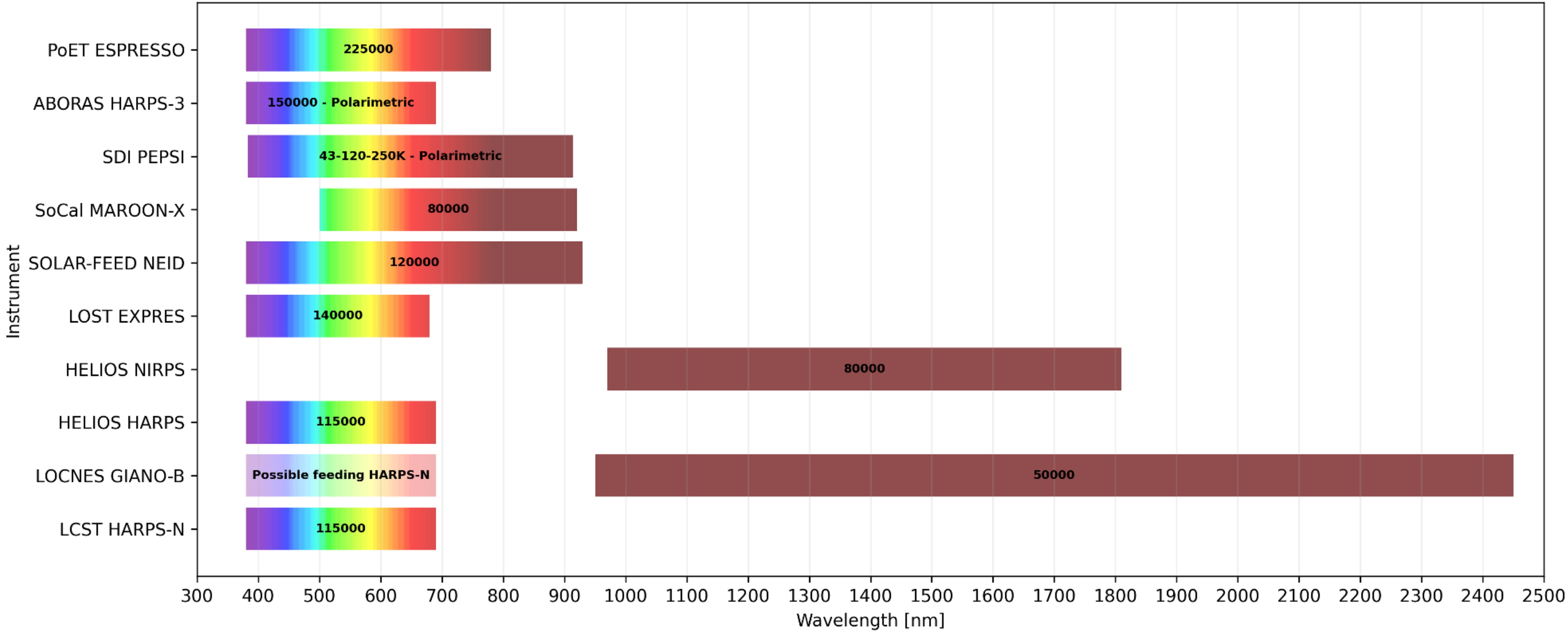
- PoET at VLT feeding the ESPRESSO spectrograph

380-780 nm; R=225000.

- LOCNES (LOw Cost NIR Extended Solar telescope) TNG

feeding GIANO-B spectrograph (0.9 to 2.5um; R=50000)

The Sun-as-a-star instruments



The Instrument

The LOCNES solar telescope at TNG is a simple instrument built from off-the-shelf components.

The telescope, all the electronics, and a webcam are positioned inside a custom dome, located on the south face of the TNG dome, close to the pre-existing LCST solar telescope.

The telescope

The telescope is constituted by a plano-convex lens with a diameter of 50.8 mm and a focal distance of f=200 mm.

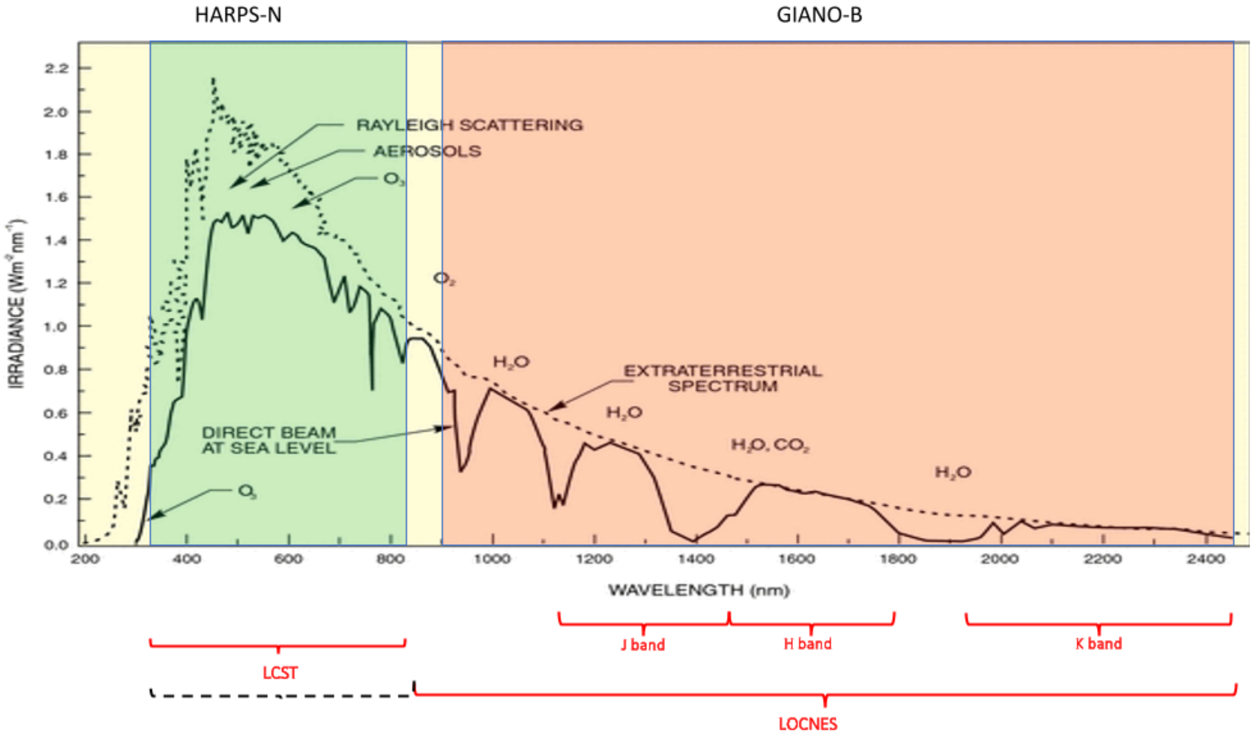
The lens feeds one integrating sphere that is positioned at the focal distance of the lens.

A guide camera attached to the telescope frame ensures proper alignment, keeping the 2 mm solar image cantered on a 6 mm input aperture.

The fiber link

From the integrating sphere two patches of optical fibers feed with the scrambled light of the Sun the TNG spectrographs.

- The fiber to GIANO-B is a series of two 20 m long ZBLAN fibers with 200 μm diameter.
- A 40-meter LOW-OH fiber that is already installed could be used to transmit light to HARPS-N.

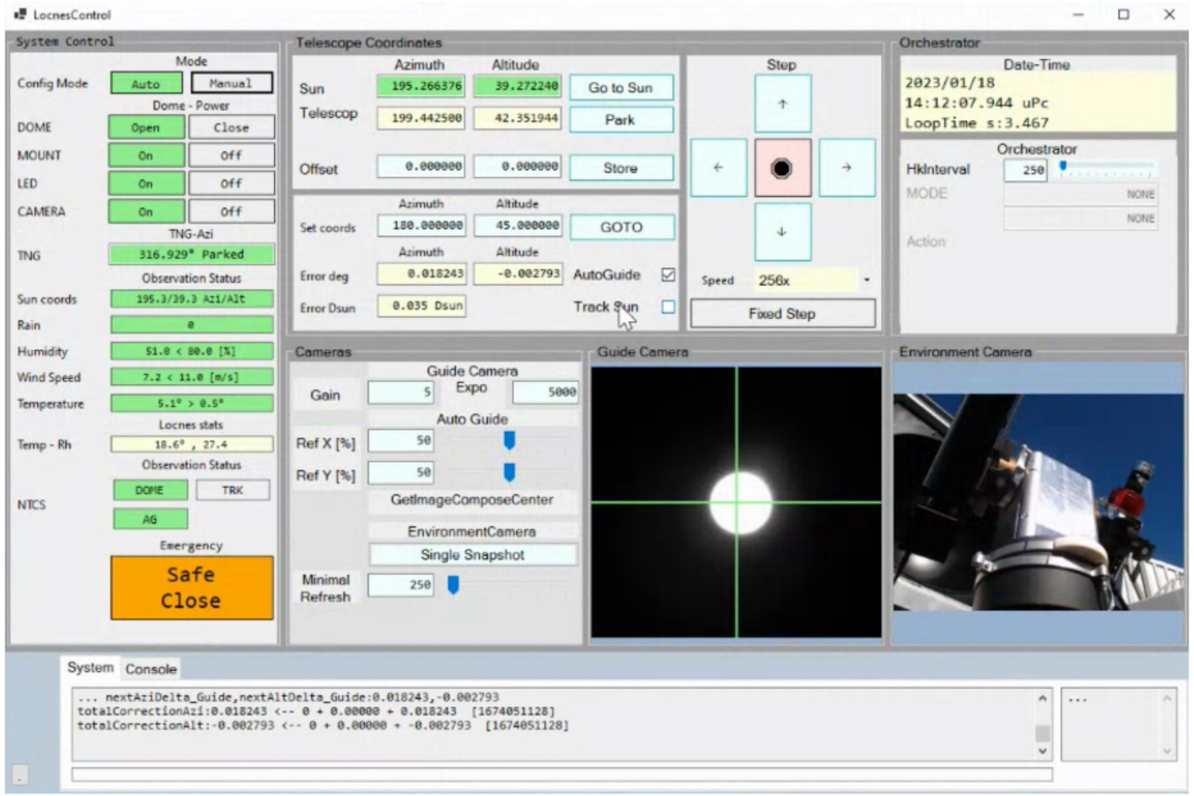


LOCNES frequency interval capability

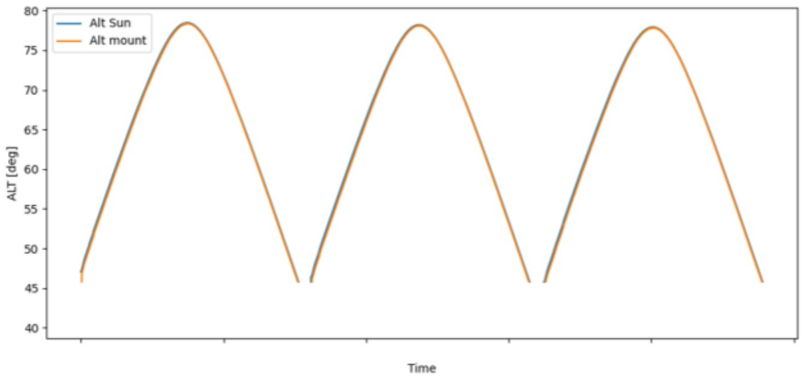
The control software

The LOCNES control system is developed in c# based on the framework .NET 6, but internally it also uses Python 3 (e.g: coordinates maths, sun recognition, alert management ....).

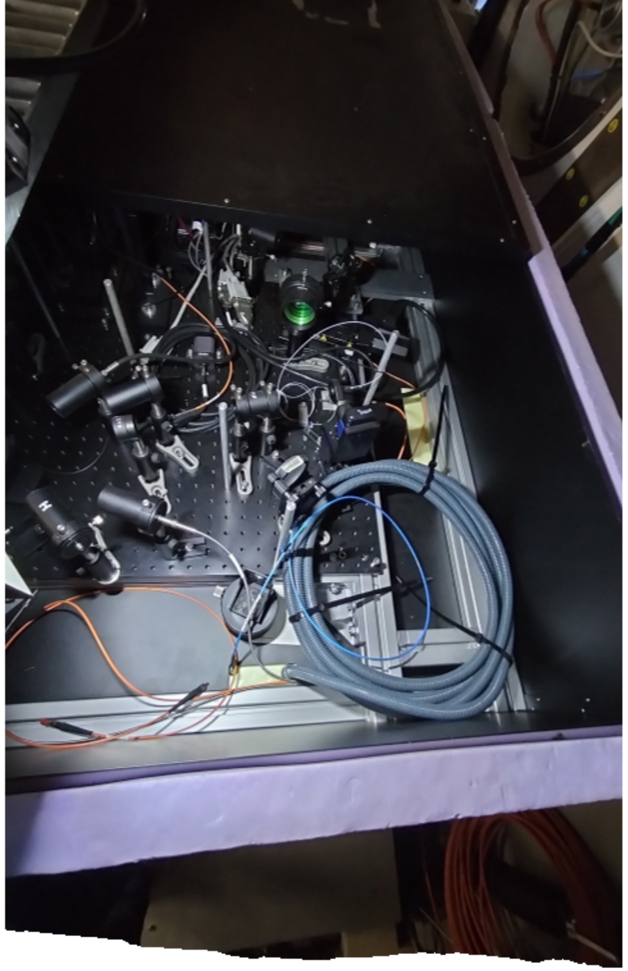
It has been designed to ensure operation in both manual and fully automated modes, interacting with the other subsystems and the weather station of the TNG.

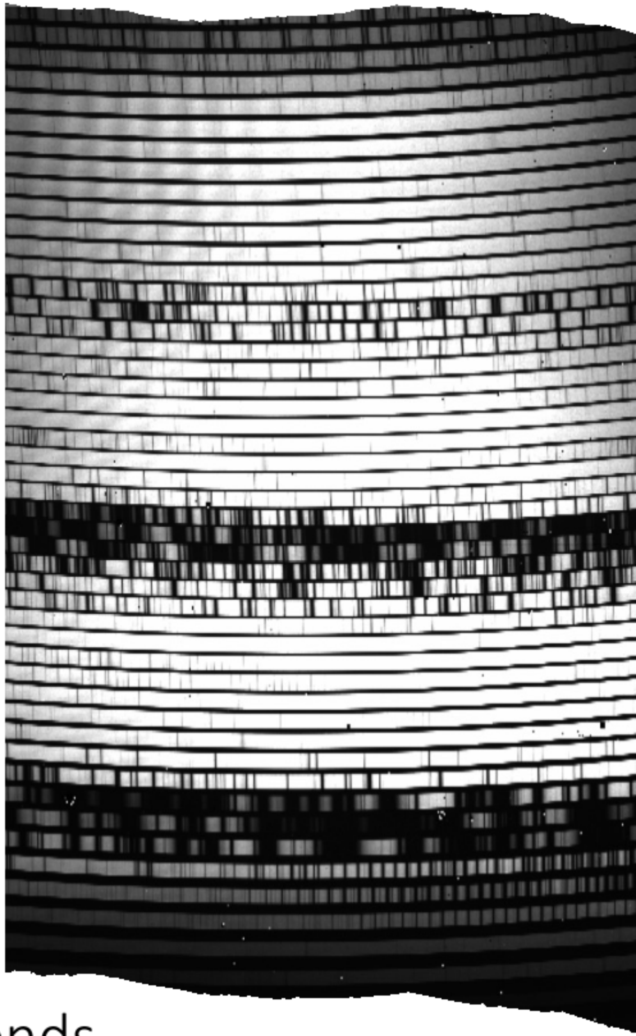


The GUI of the LOCNES control software



An example of three days of automatic operation, software automatic Sun tracking.



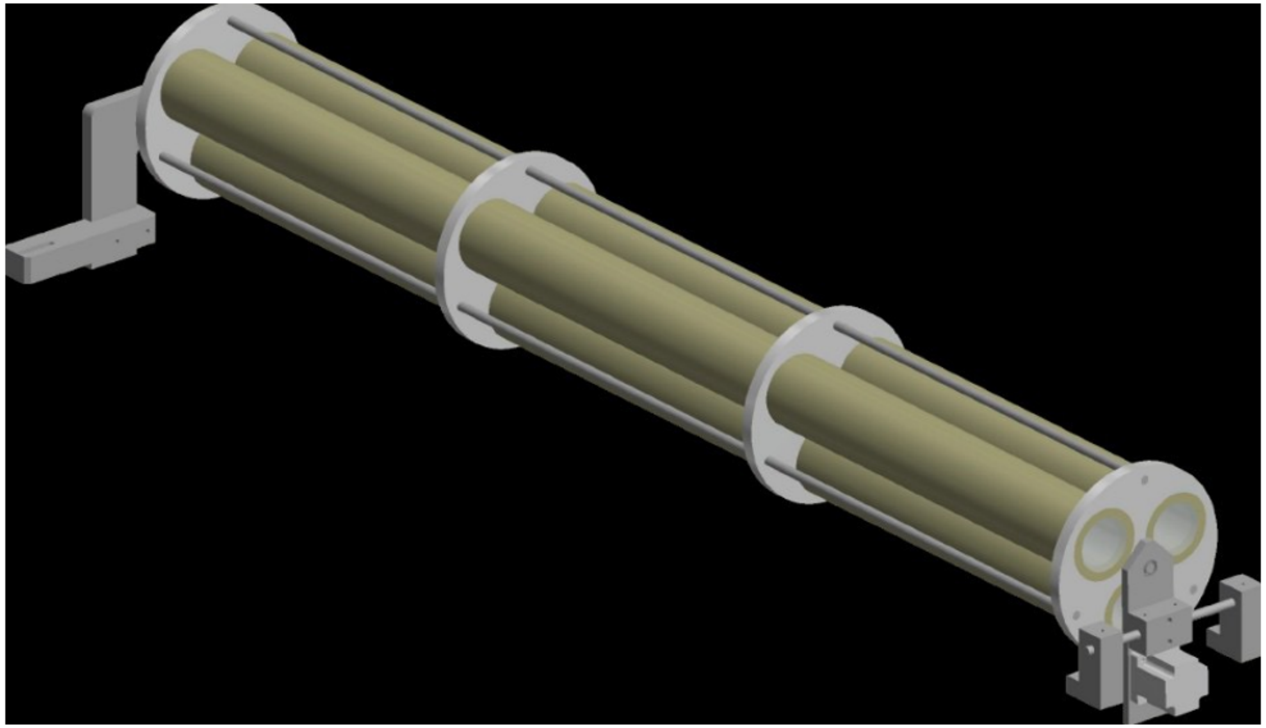
The solar telescope has a high throughput, enabling exposures as 30 seconds.

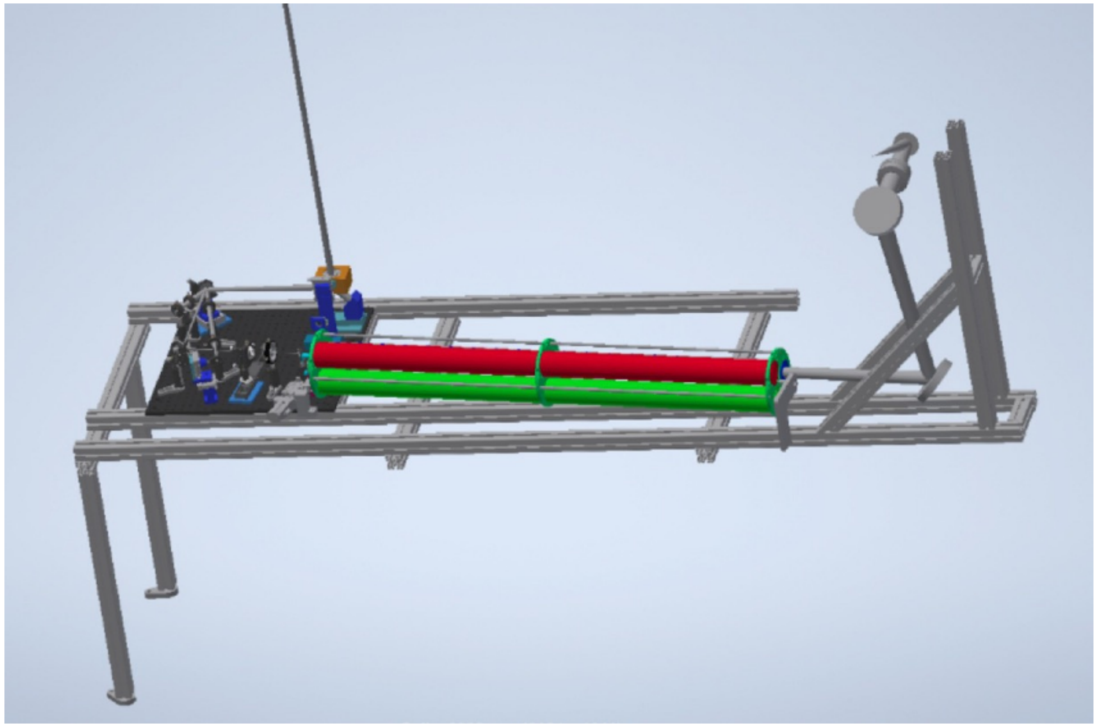
In this mode, the Sun’s five-minute oscillation signal is easily observable.

This may prove valuable for asteroseismology studies and testing different exposure times and observing strategies to mitigate the impact of oscillation and granulation jitter.

The absorbing cells

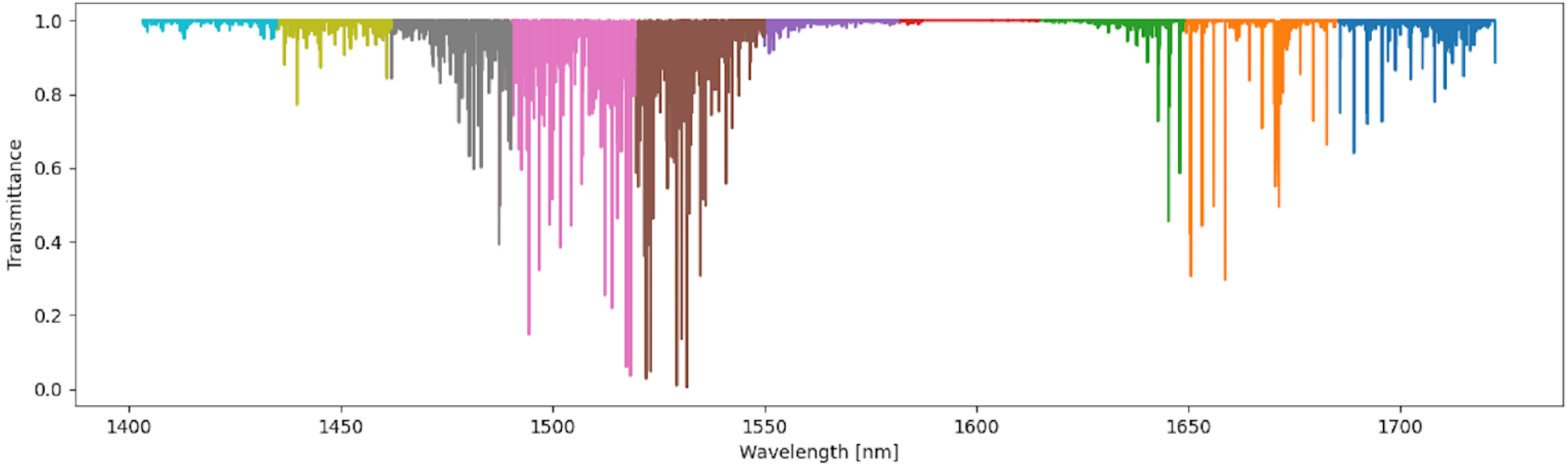
GIANO-B has been equipped with NIR absorbing cells in order to have an inertial inner reference for high precision radial velocity measurements. The cells was mounted on a revolver inside the pre-slit optics to be able to put the absorbing cell into the optical path towards the GIANO-B slit.



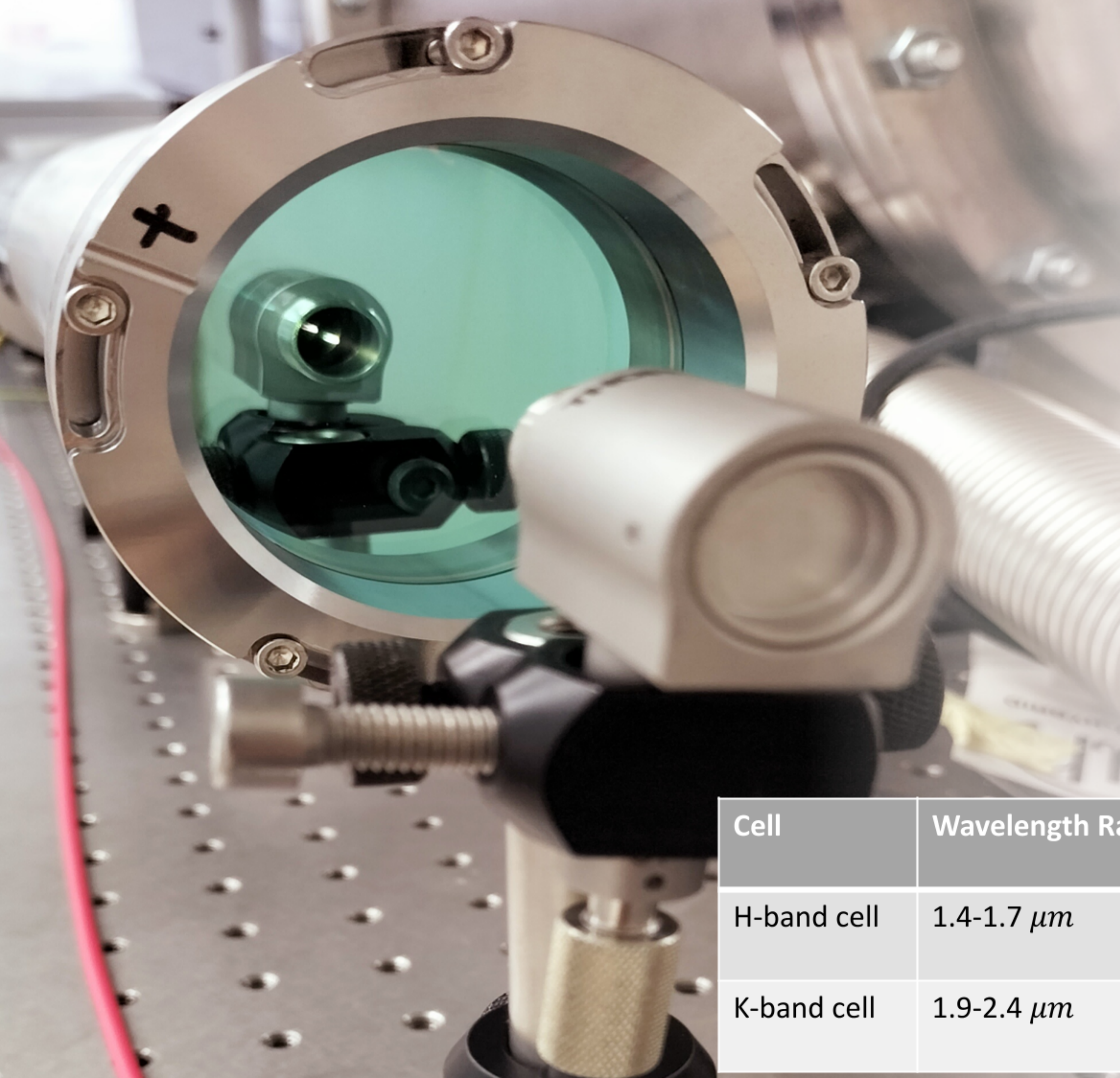


The absorbing cells

A spectrum of the gas mixture present into one of the absorbing cell could be over-imposed on the stellar spectrum.



The measured absorption of H-cell (90 mbar CH_4 and 60 mbar C_2H_2). The different order of the GIANO-B echelle are highlighted with different colours.



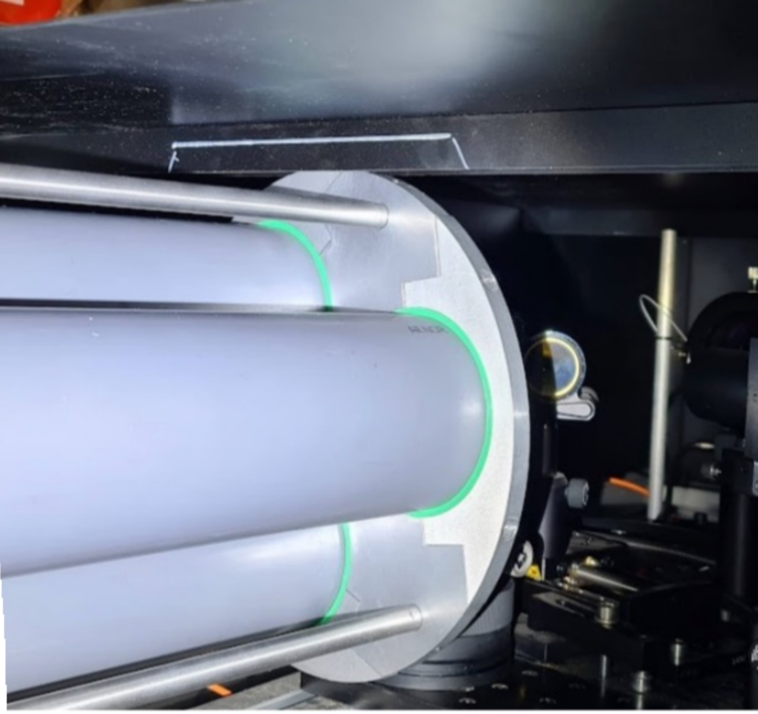
The absorbing cells

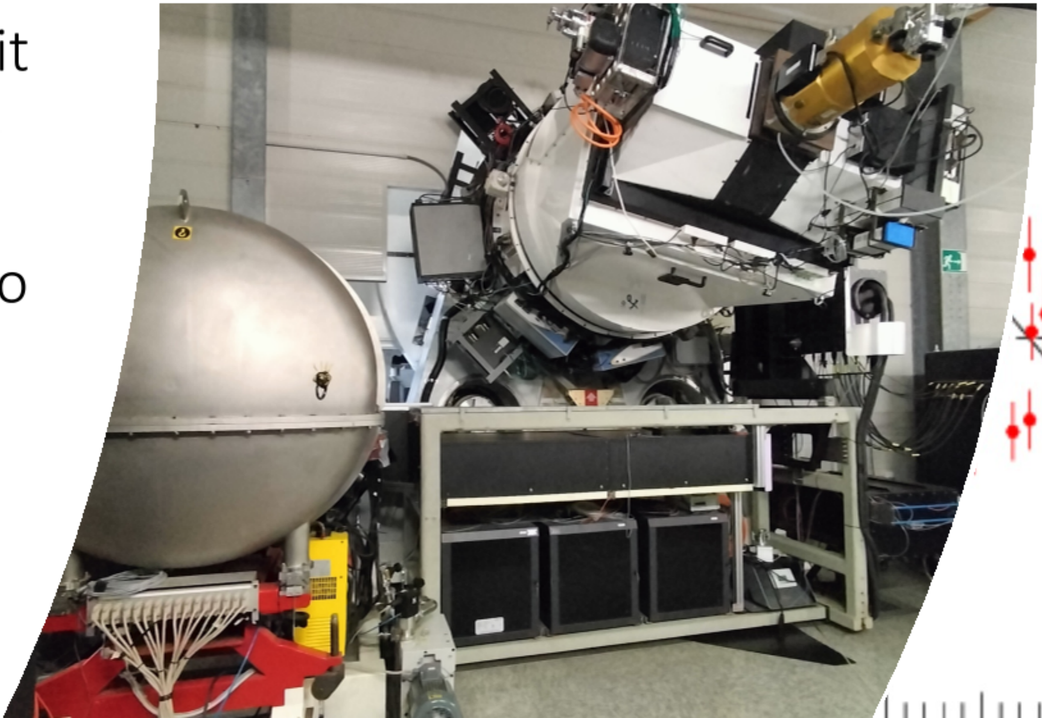
The design of the GIANO cells was obtained optimizing: the absorption path length, the species of gas and the individual pressures.

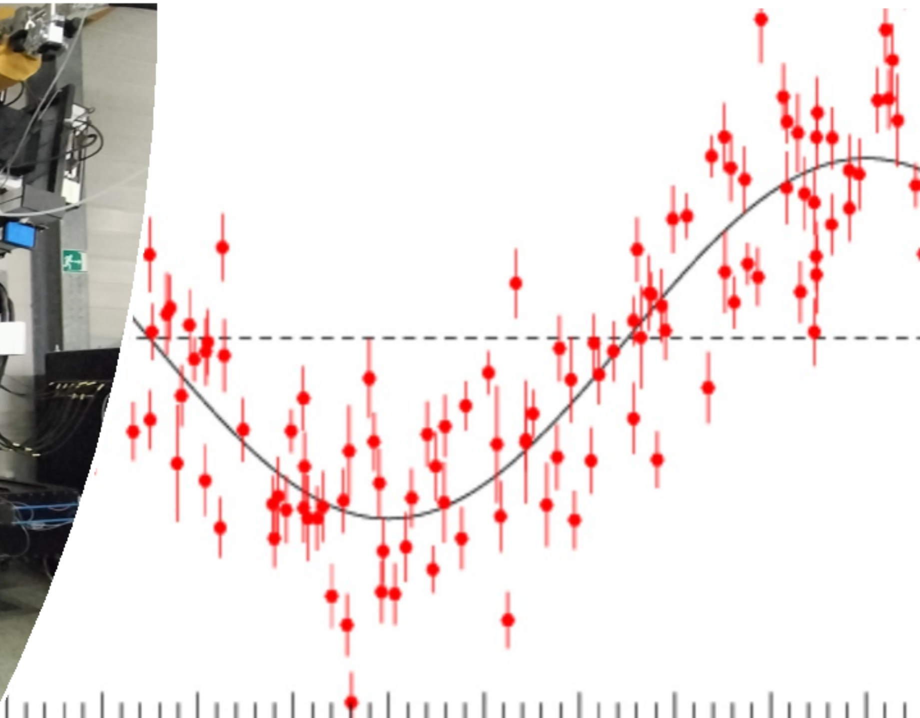
This to obtain the desired line-width, and the feature richness and depth, leading to the attainable radial velocity limit of the cell.

Cell	Wavelength Range	sRV @SNR 200 per band	Fill properties
H-band cell	1.4-1.7 μm	4 m/s	Methane 90mb +/- 5mb Acetylene 60mb +/- 5mb
K-band cell	1.9-2.4 μm	3 m/s	Ammonia 10mb +/- 5mb Methane 50mb +/- 5mb

Making use of the absorbing cell, the value of the radial velocity of the target is so evaluated by fit the composite spectrum by a synthetic reconstruction of it using the cell spectrum, the instrumental profile of GIANO-B and a high signal to noise spectrum of the star alone.

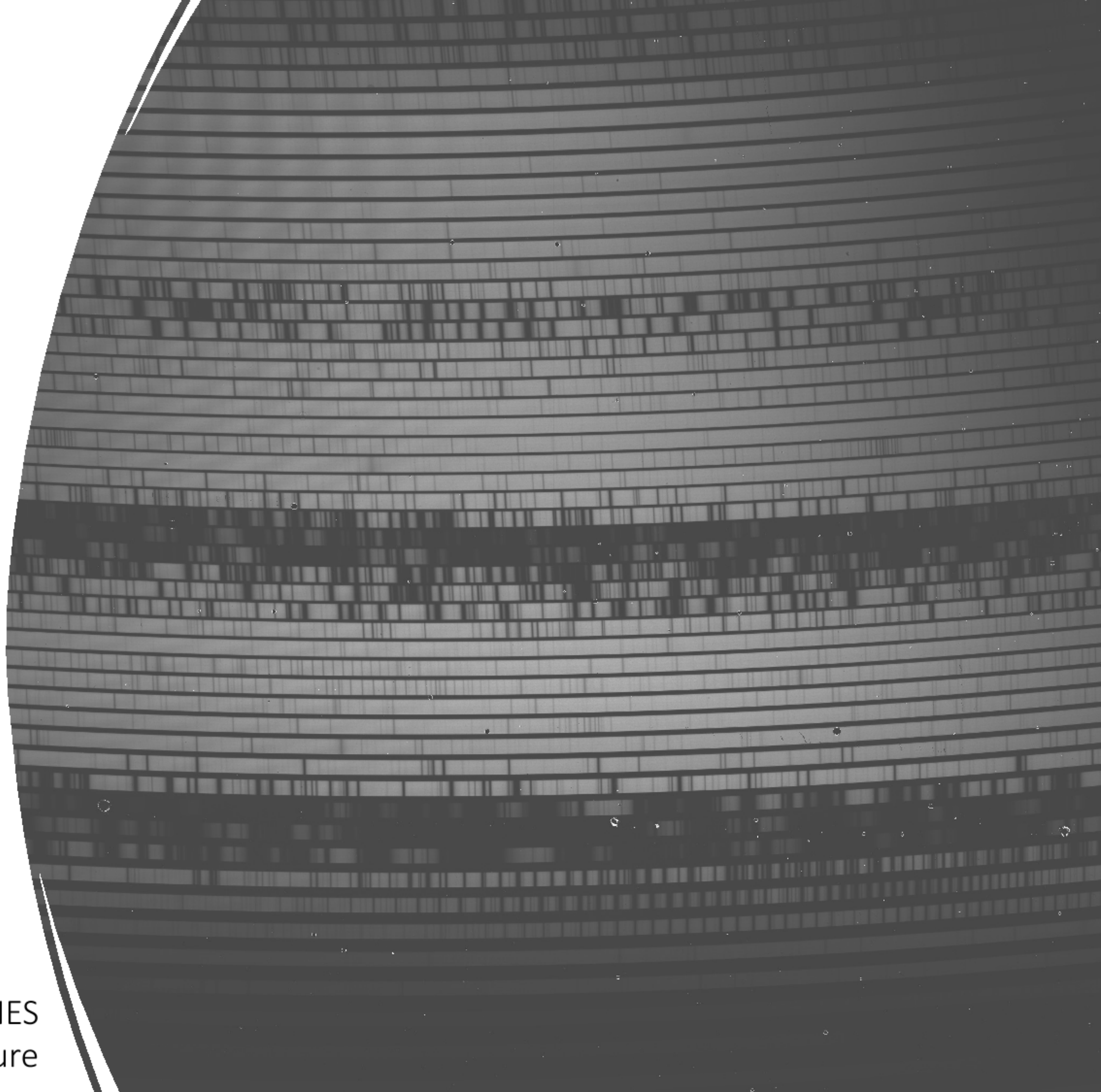






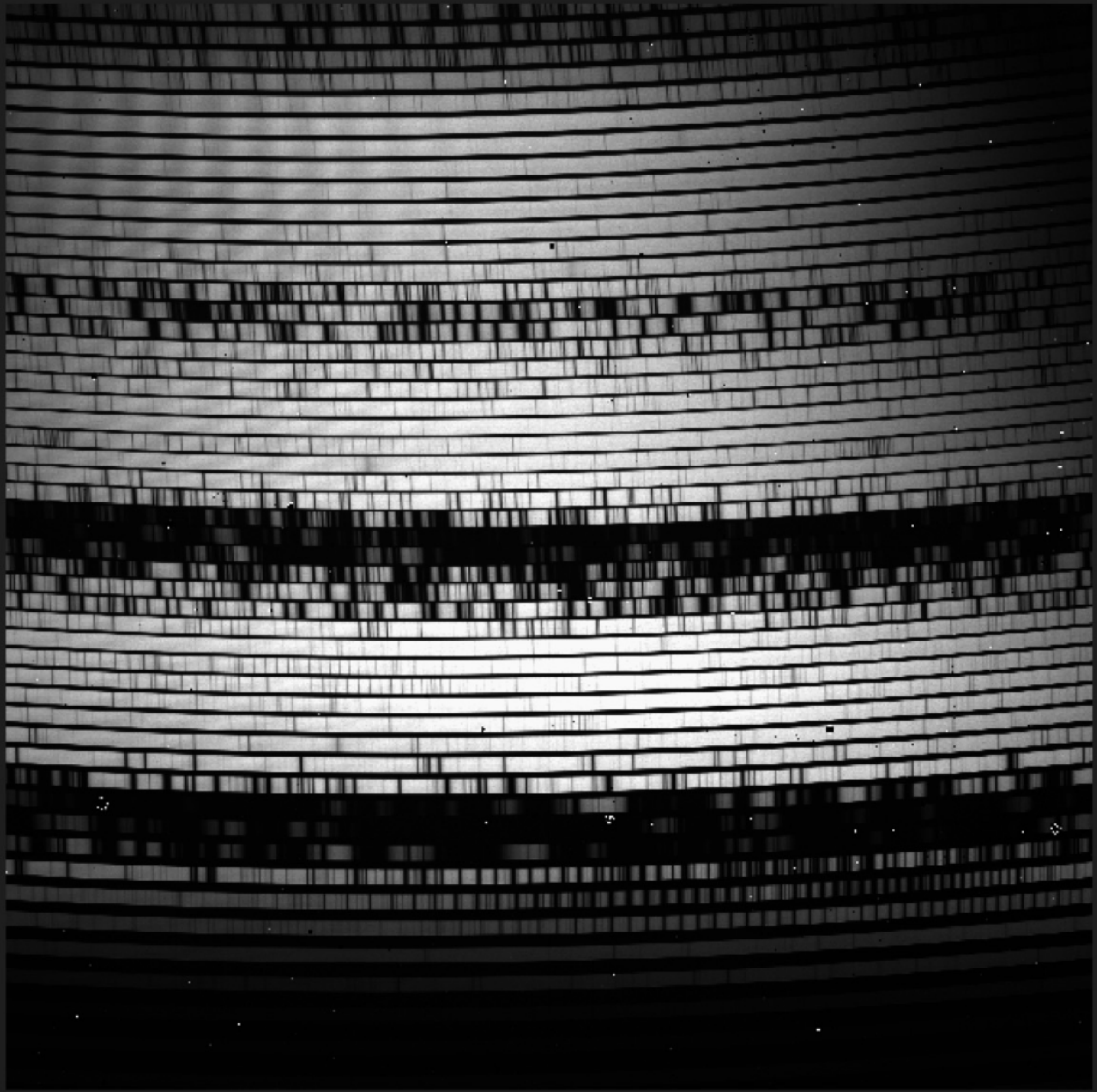
Commissioning

- 11 May 2023: first scientific light
- 20-21-22 June: replaced the ZBLAN fibres

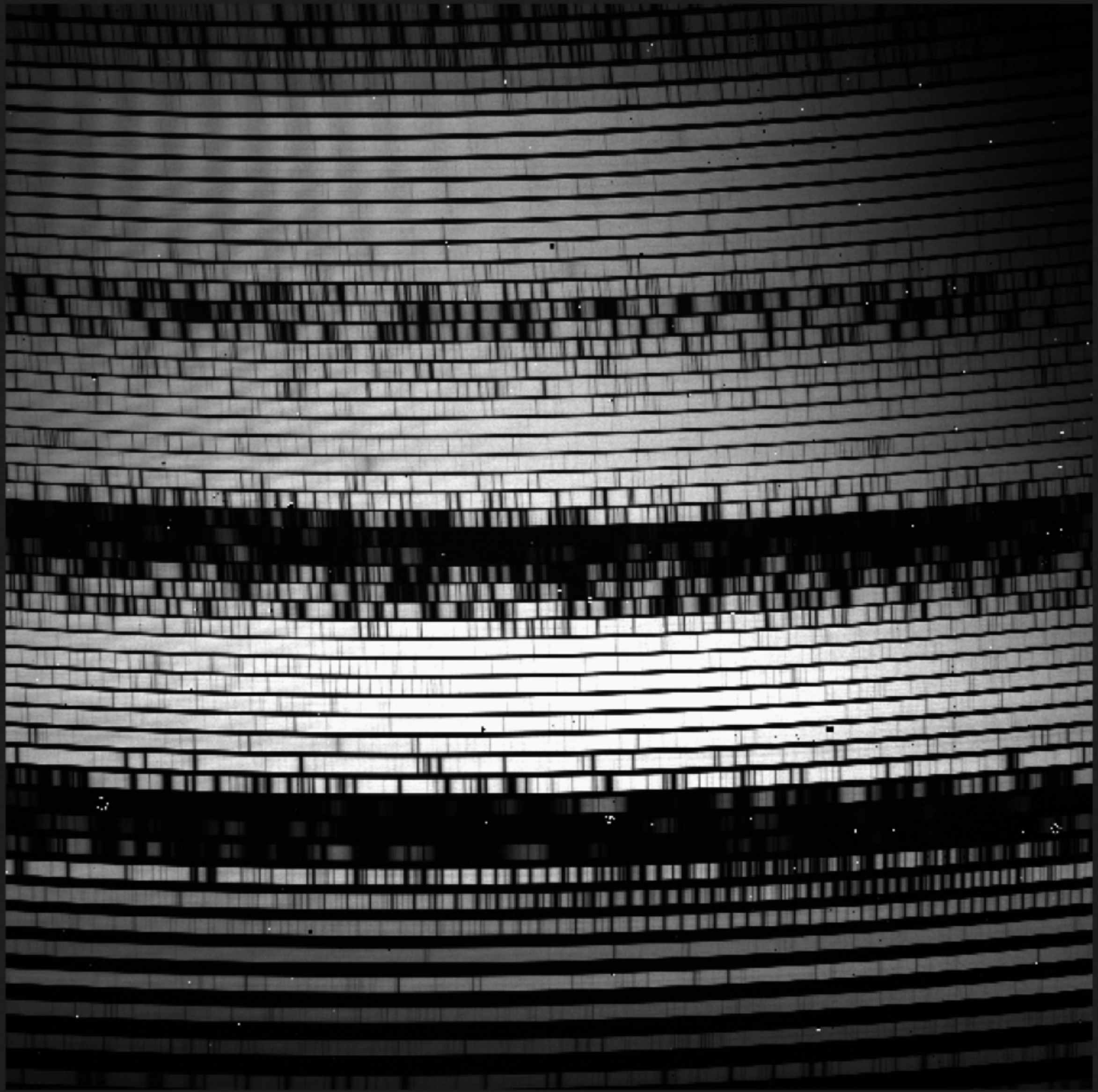


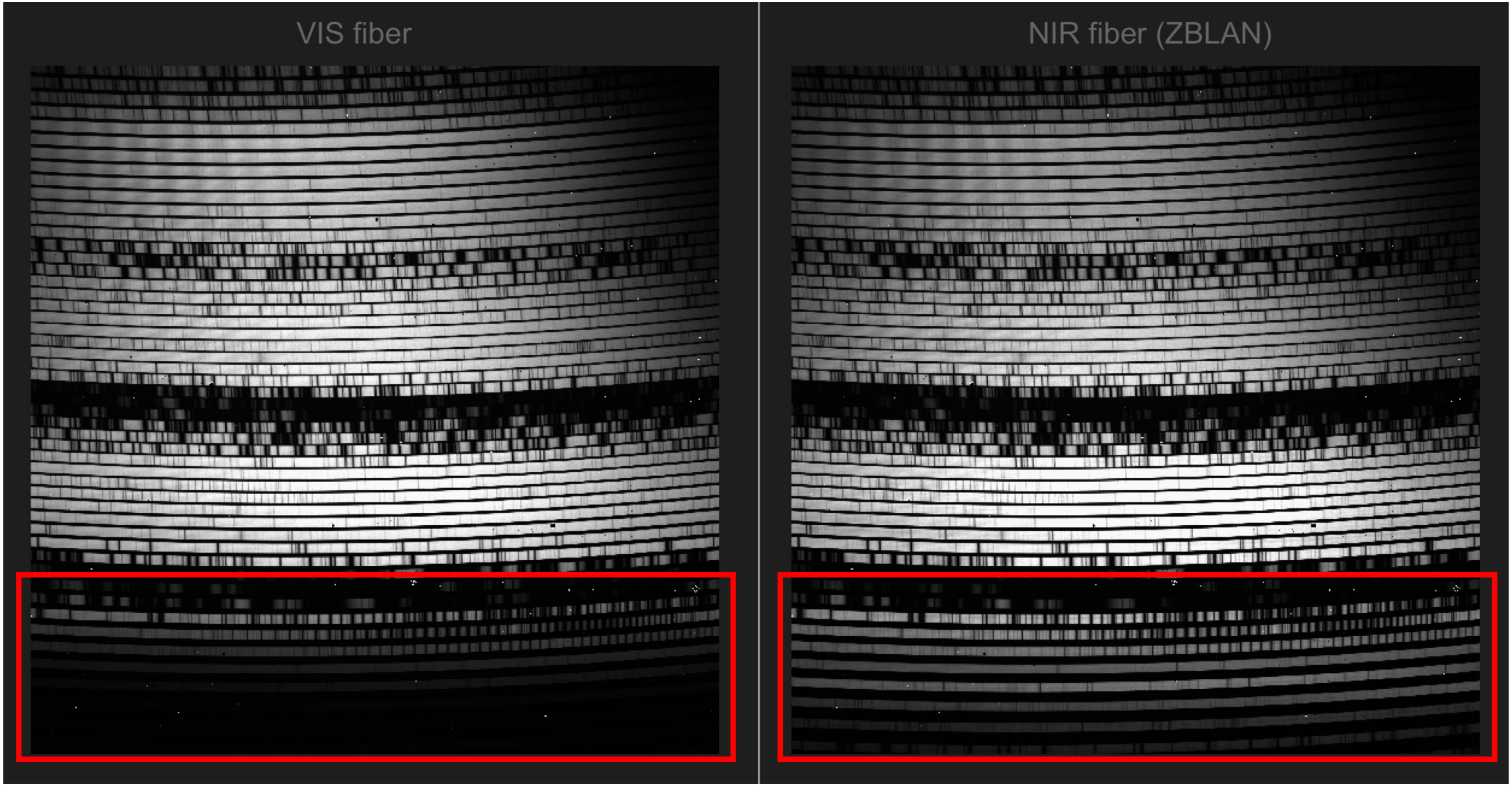
First spectrum of the Sun acquired with LOCNES
30 sec exposure

VIS fiber



NIR fiber (ZBLAN)



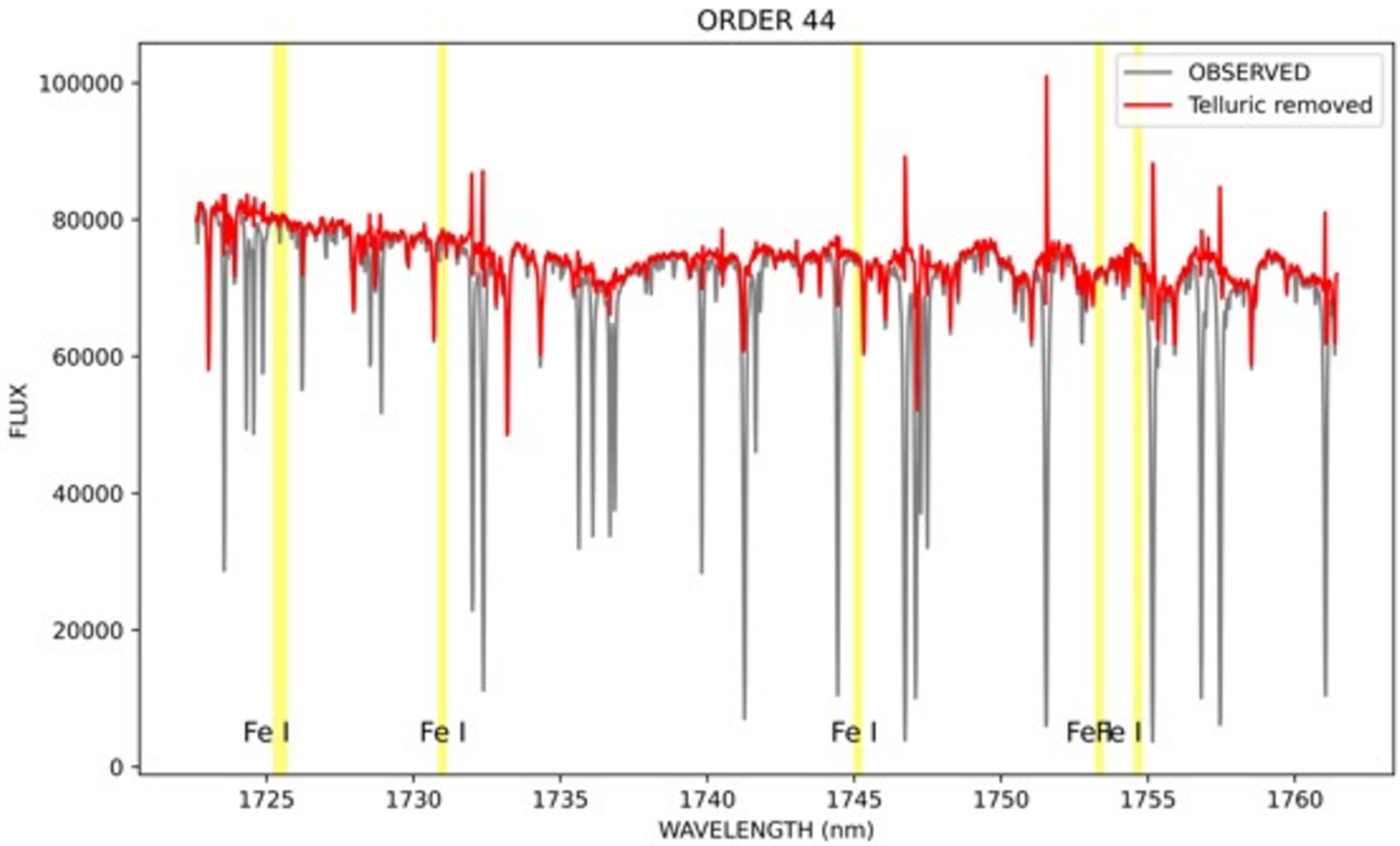

VIS fiber
NIR fiber (ZBLAN)

First results

Using ESO Molecfit software, we can correct the acquired spectra for atmospheric absorption features (telluric absorption).

Molecfit. A. Smette at al. 2015 A&A 576, A77

The absorption lines of the iron (in the case shown in the right figure) are used for the astrophysical determination of transition probability *log(gf)*.

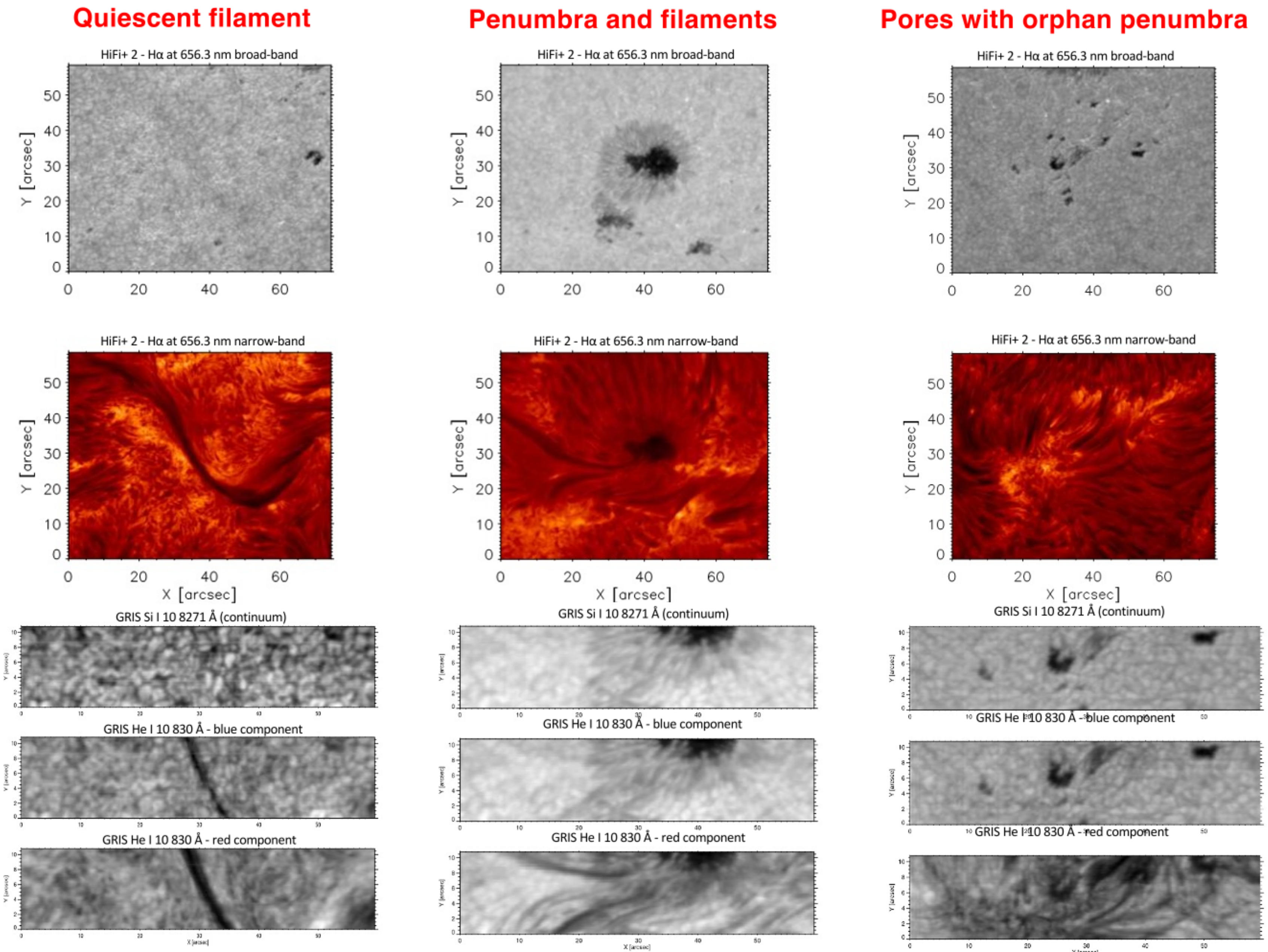


The 44th order of the echellogram of GIANO-B
where some of the iron absorption lines can be observed.
The SNR in this order is about 280 (per pixel)
Data were preliminary analysed by: Monica Rainer, Valentina *D'Orazi, and Harutyunyan Avet.*

Simultaneous observational campaign with the GREGOR telescope

(31 July-09 August 2023)

- 10-day observing campaign at GREGOR Solar Telescope in Tenerife, Spain.
- Instruments:
  HiFI+ fast imaging
  GRIS full Stokes spectropolarimetry.
- Science topics: small-scale energy release phenomena, flares, filaments, penumbral formation, penumbral jets.
- Highlights of the observations will be presented tomorrow at SOLARNET-S3 by Lezzi and Ferrente.



Some highlights from 09/08/2023 observations

Next steps

- Begin daily fully automatic acquisition of Sun spectra (in the coming weeks).
- Characterization of absorption cells and their installation in the GIANO-B pre-slit.
- Development of an automatic pipeline for data reduction and precision Radial Velocity measurement.
- Improve and speed up the correction of the Telluric absorption, mitigate the effects of Fringing and Modal Noise.

Thank You
for your attention!