Observing the Sun as a star to characterize the impact of stellar activity on ARIEL observations

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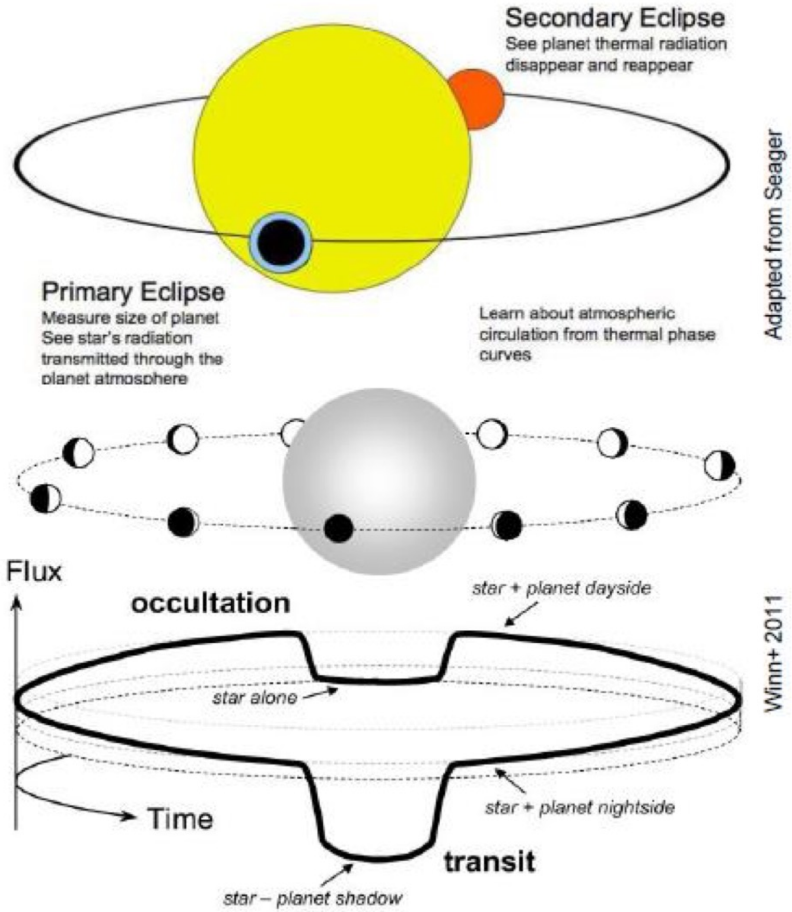
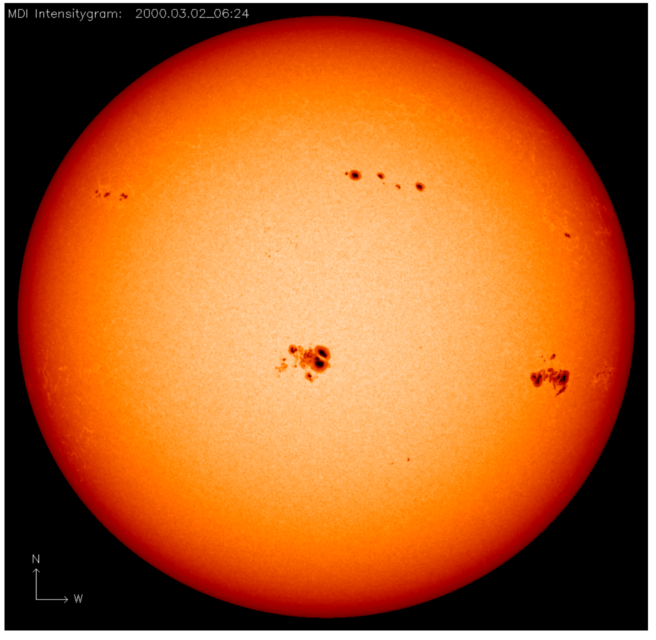
Planetary atmospheres

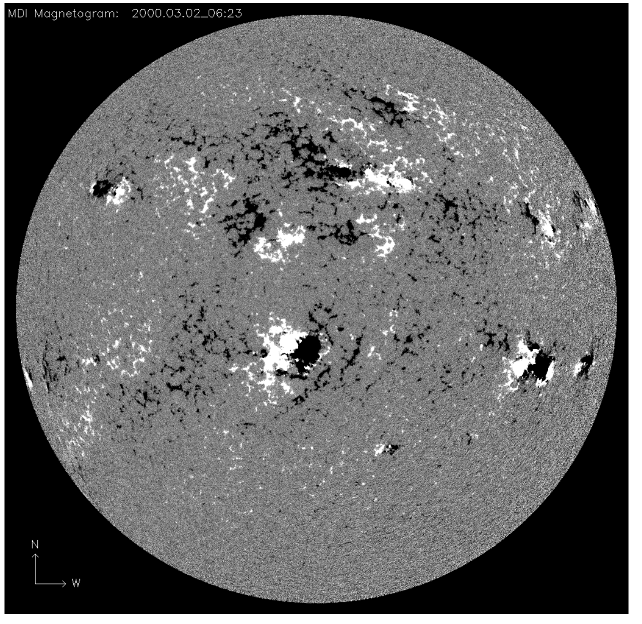


- Observing the spectrum of a planetary atmosphere implies that the stellar spectrum should be stable at least at the 10-100 ppm level during the collection of the data;
- For a single transit observation, the timescale of data collection is of the order of 5-15 hours (full transit duration + baseline);
- If N successive transit spectra are to be summed up, the data collection timescale is NP_{orb} ~ tens of days;
- The Sun can be used to study the phenomena that affect the stellar background spectrum on those collection timescales.

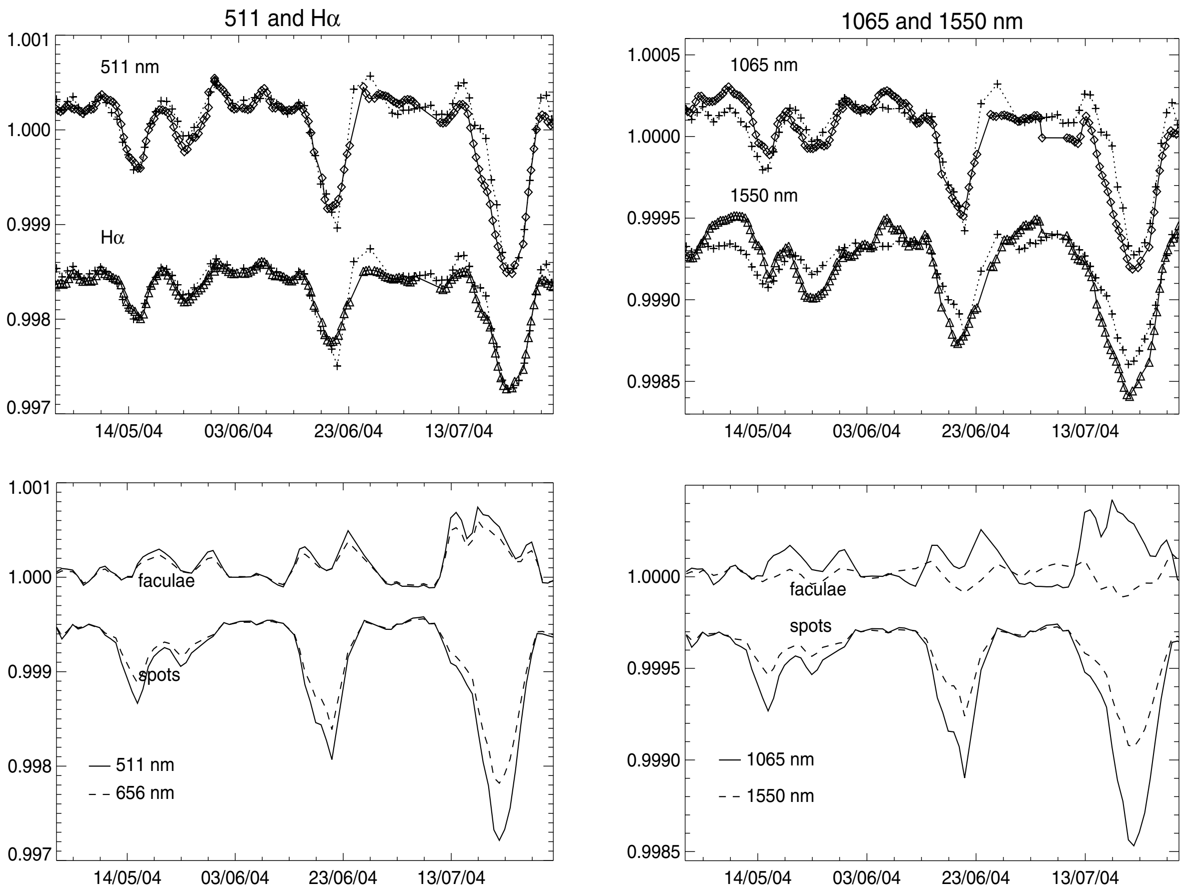
Solar activity

- In the Sun we can study stellar activity in detail, thanks to the spatial and time resolution (down to 50-100 km and a fraction of a second, respectively);
- In the photosphere, the features associated with magnetic fields are sunspots, faculae, and the network.





Variation of Solar Spectral Irradiances



In the NIR, the amplitude of the variations is reduced due to the lower contrast.

At 2400 nm, the reduction is by a factor of ~ 3-4 with respect to 511 nm, that is the relative variations are typically between 100 and 500 ppm.

(Unruh et al. 2008)

An example case: CO lines in the Sun

Wavenumber = 4296 cm^{-1} corresponds to λ = 2327.7 nm

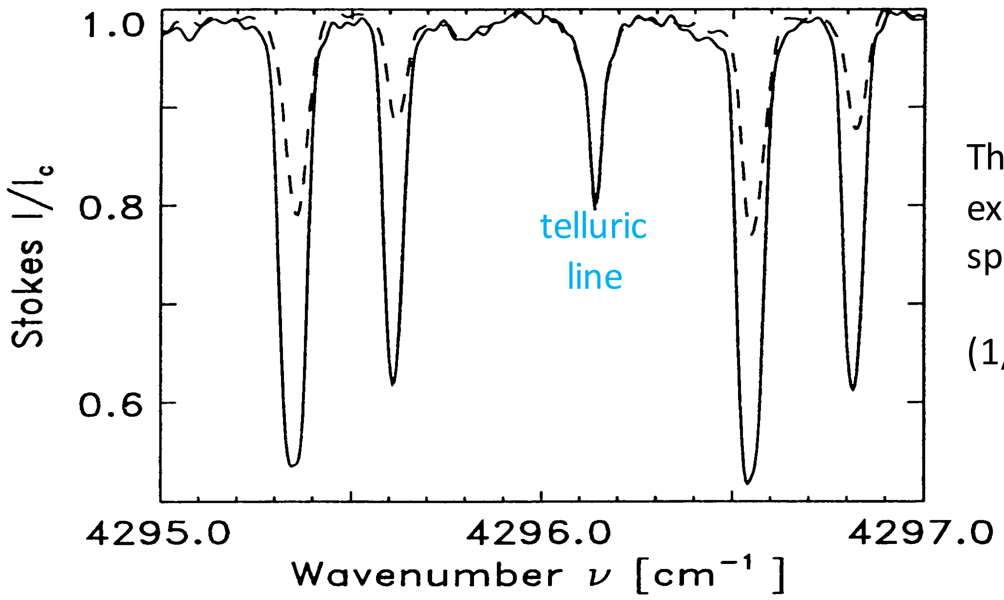


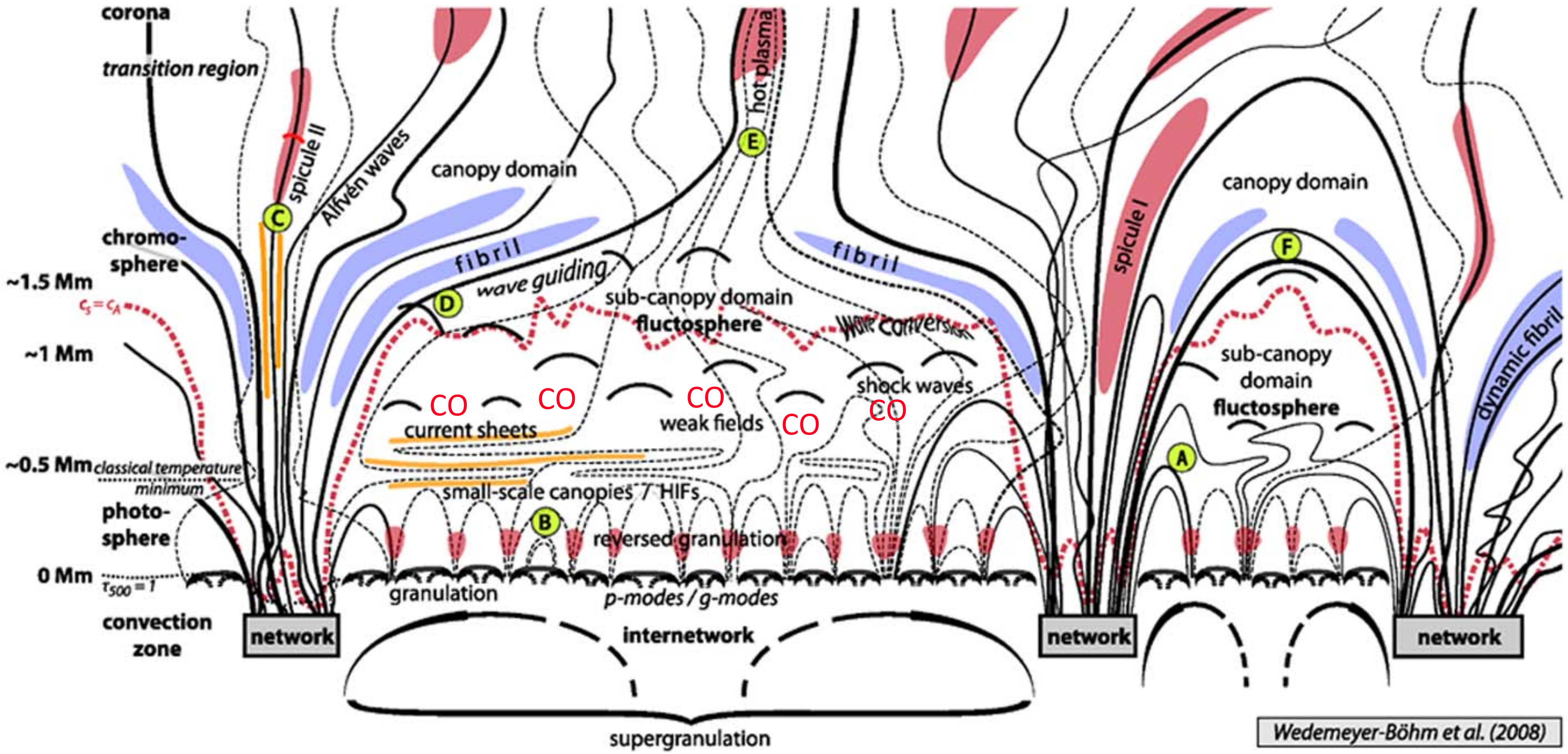
Fig. 9. CO first overtone vibration-rotation band lines observed in an umbra (solid) and in a plage (dashed). The wavenumber scale has been used to facilitate comparison with the data published by Ayres (1978)

Rüedi et al (1995)

The maximum *temperature-dependent effect* of activity expected on the disc-integrated low-resolution ($R \approx 300$) spectrum of CO at 2400 nm is given approximately by:

$(1/5) \times 0.25 \times (\Delta F_{2.4} / F_{2.4}) \approx 0.05 \times (8 \times 10^{-4}) = 4 \times 10^{-5} = 40$ ppm

A rough sketch of the quiet Sun atmosphere



(Wedemeyer-Bohm et al. 2009; Ayres 2016)

Observing the Sun as a star

- To fully exploit the exquisite precision of space-borne spectra acquired by *ARIEL*, we need to correct for the effects of stellar activity on timescales from a few hours to tens of days;

- The Sun can be the best template to understand stellar activity;

- We have a large body of spatially resolved optical and NIR data (cf. Penn 2014), but very few observations of the Sun as a star;

- Therefore, we devised a system to obtain spectra of *the Sun as a star from the optical to the NIR*;

- This lead to the development of *LOCNES: LOw Cost NIR Extended Solar telescope.*

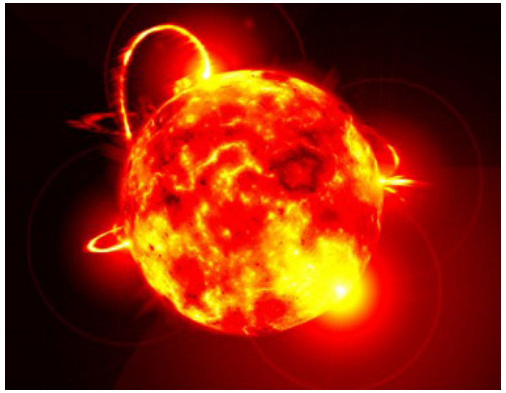
The LOCNES Team

- P.I. & P.M.: Riccardo Claudi (INAF – Astronomical Observatory of Padova)
- Co-P.I. & S.E.: Adriano Ghedina (INAF – Fundacion Galileo Galilei)
- Co-P.I. & AIV Manager: Emanuele Pace (Physics and Astronomy Department of Firenze University).
- Anna Maria Di Giorgio (INAF – IASP) and Scigè John Liu (INAF – IASP): Instrument Control Software.
- Andrea Tozzi (Astrophysical Observatory of Arcetri) and Lorenzo Gallorini (Master Thesis, Physics and Astronomy department of Firenze University): test on Optical Fibers
- Ilaria Carleo (Physics and Astronomy Department of Padova University & INAF – Astronomical Observatory of Padova): Radial Velocities
- Scientific Board: Antonino Francesco Lanza (INAF- Astrophysical Observatory of Catania); Giuseppina Micela (INAF Astrophysical Observatory of Palermo); Emilio Molinari (INAF Astronomical Observatory of Cagliari); Ennio Poretti (INAF- Fondacion Galileo Galilei & INAF- Astronomical Observatory of Brera); David Phillips (*Harvard-Smithsonian Center for Astrophysics, Cambridge*).

Science cases

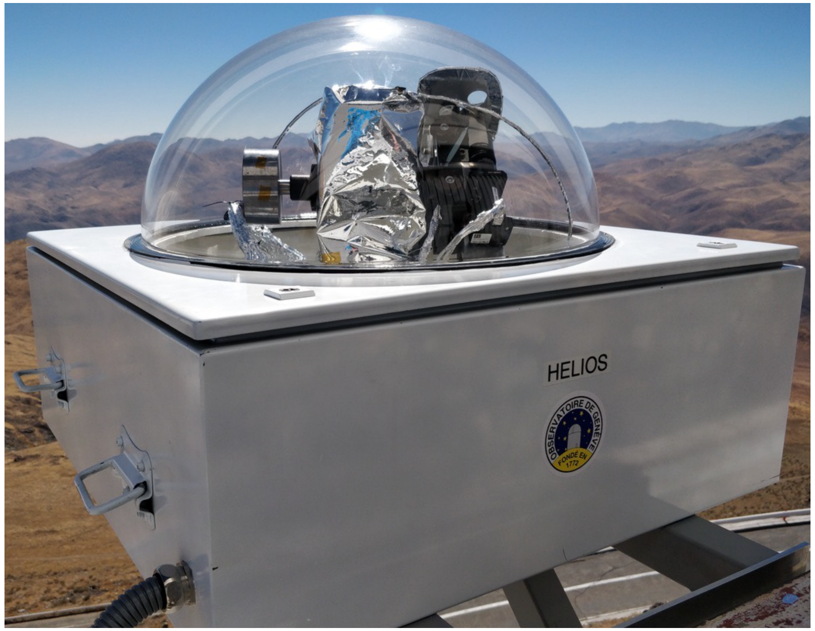
- Study the impact of solar acoustic oscillations, convection, and magnetic activity on the measurements of the *radial velocity* of the Sun as a star from the optical to the NIR;

- Study the *variation of the optical and NIR spectra* of the Sun as a star due to its magnetic activity.

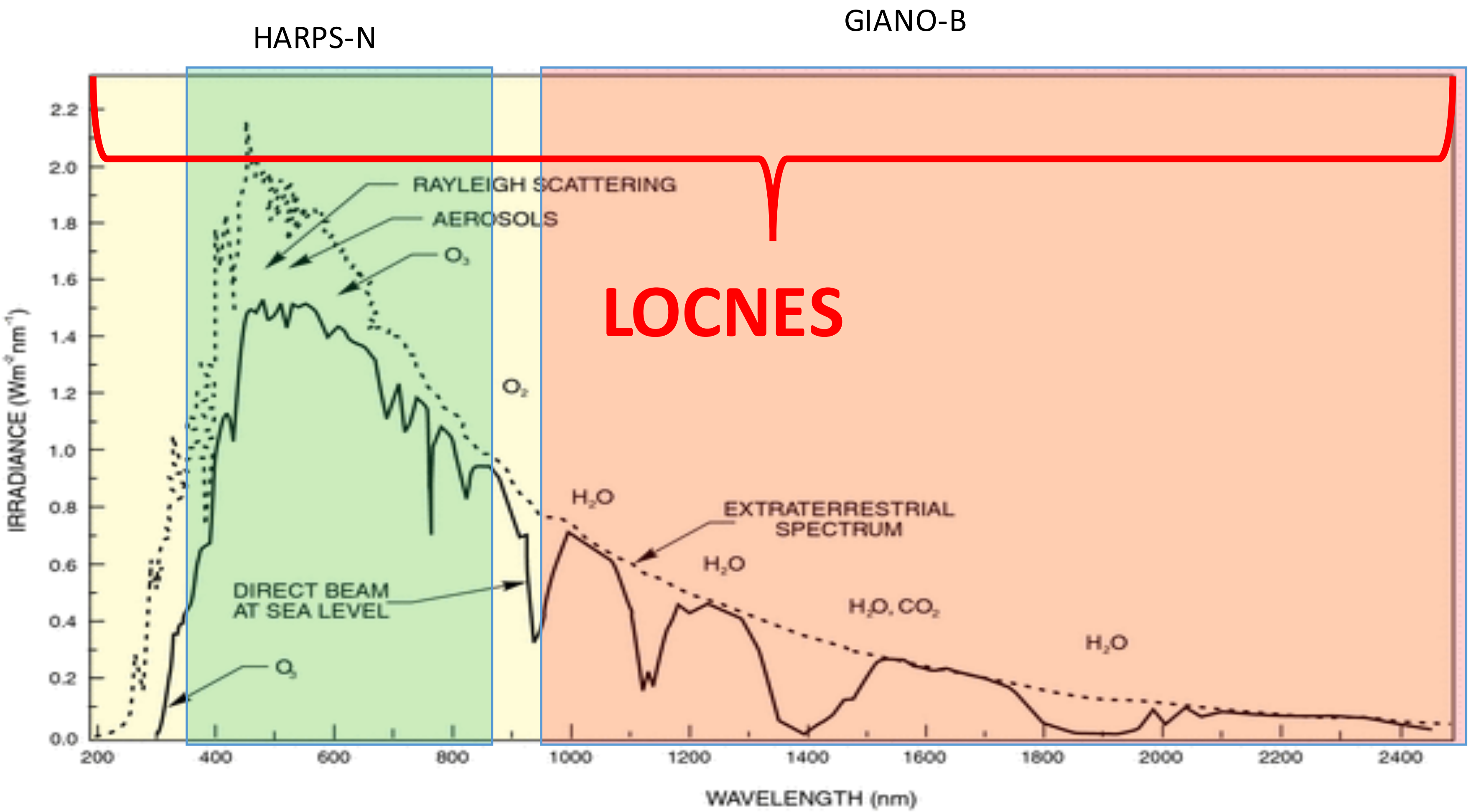


What Already Exists

North Hemisphere:
LCST @ TNG

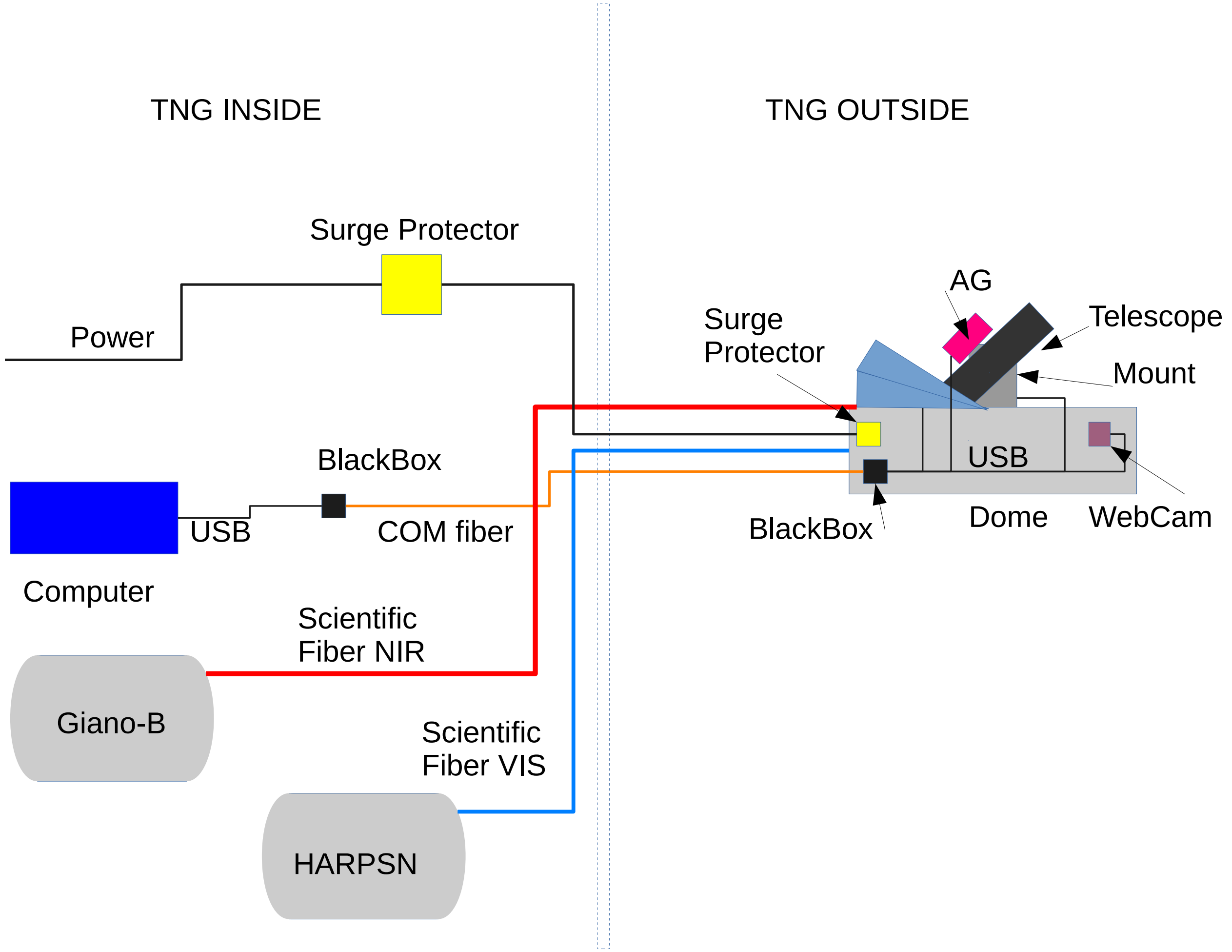


South Hemisphere:
HELIOS @ ESO 3.6m

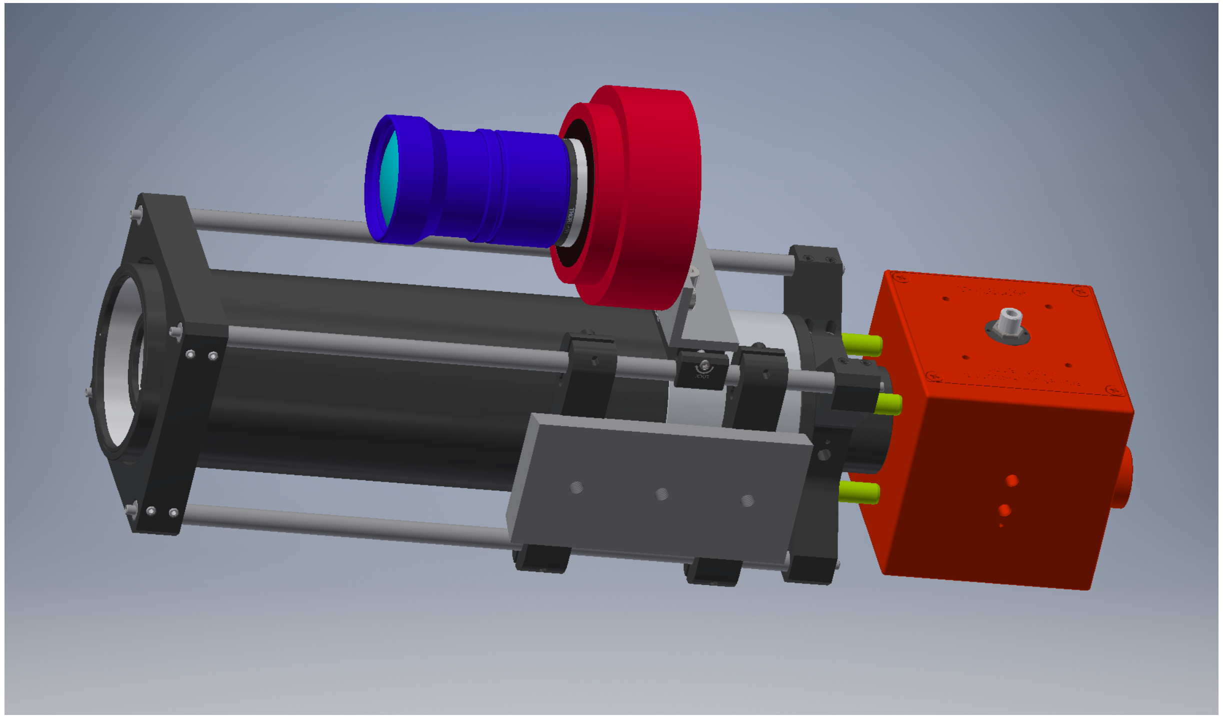


The simultaneous acquisition of the HARPS-N optical spectrum and the GIANO-B NIR spectrum is made possible thanks to the use of fibers feeding the two spectrographs with the light collected by LOCNES.

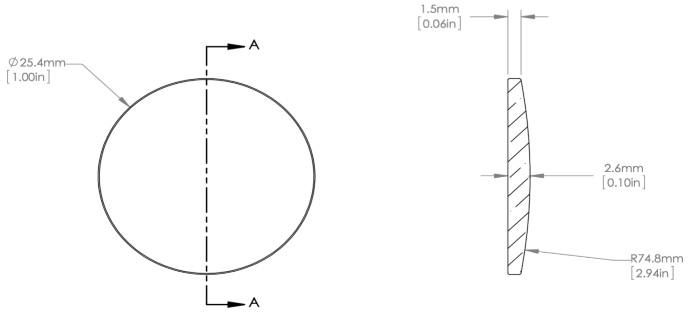
LOCNES Scheme



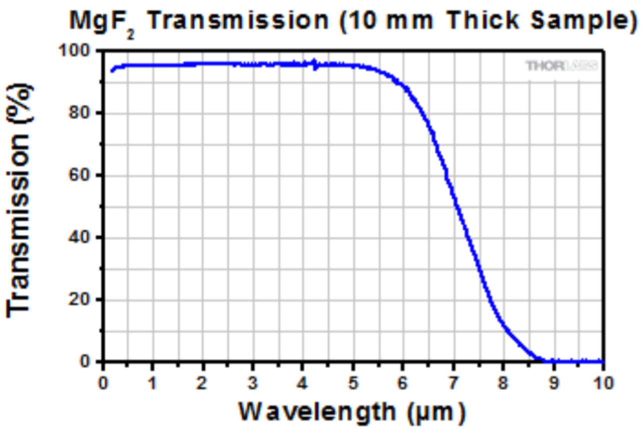
LOCNES: The Telescope



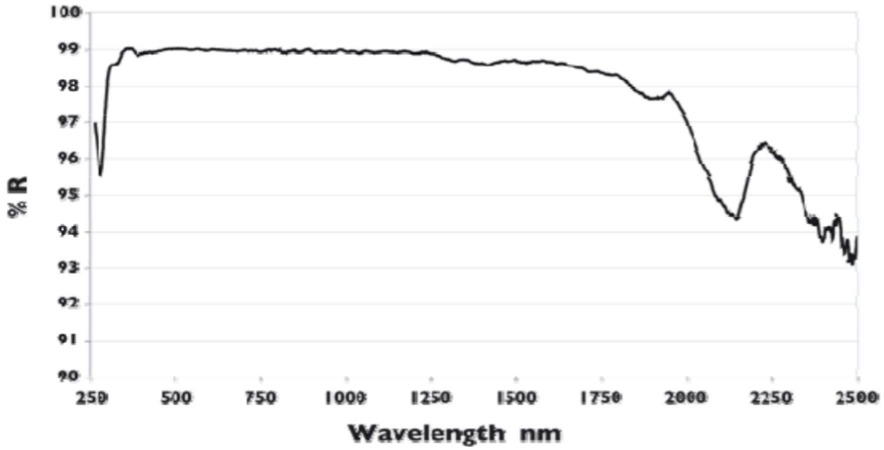
The telescope main components



ThorLABS 6007 Lens: 25.4 mm aperture; f=200 mm



Labs IS200 series 61X61X65 mm



The Guide Camera

CMOSAR0130 CS 1280X960
Pixel size 3.75 µm
Image/s 60

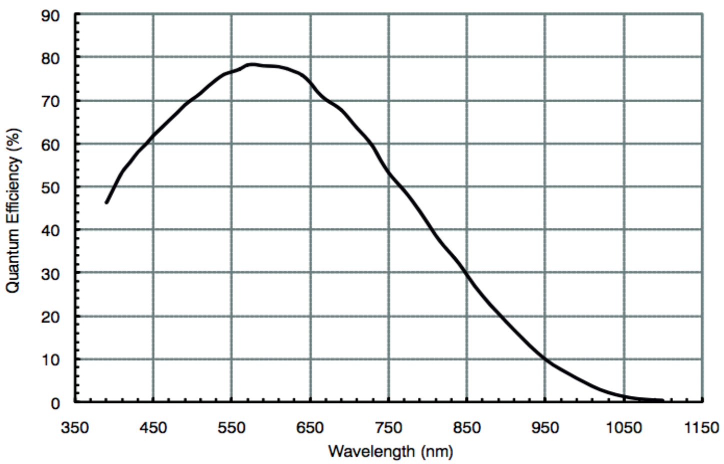
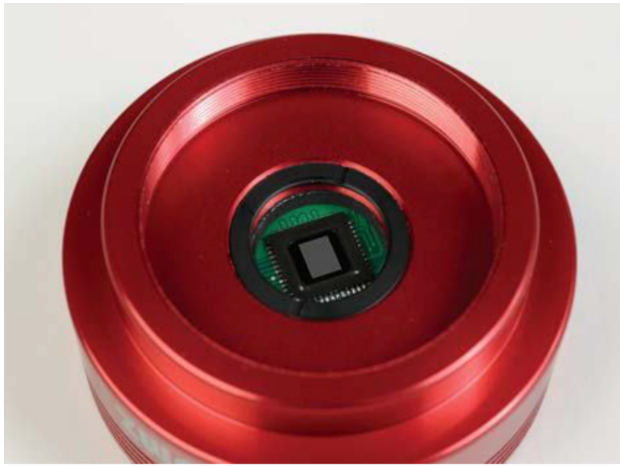


Figure 26. Quantum Efficiency – Monochrome Sensor

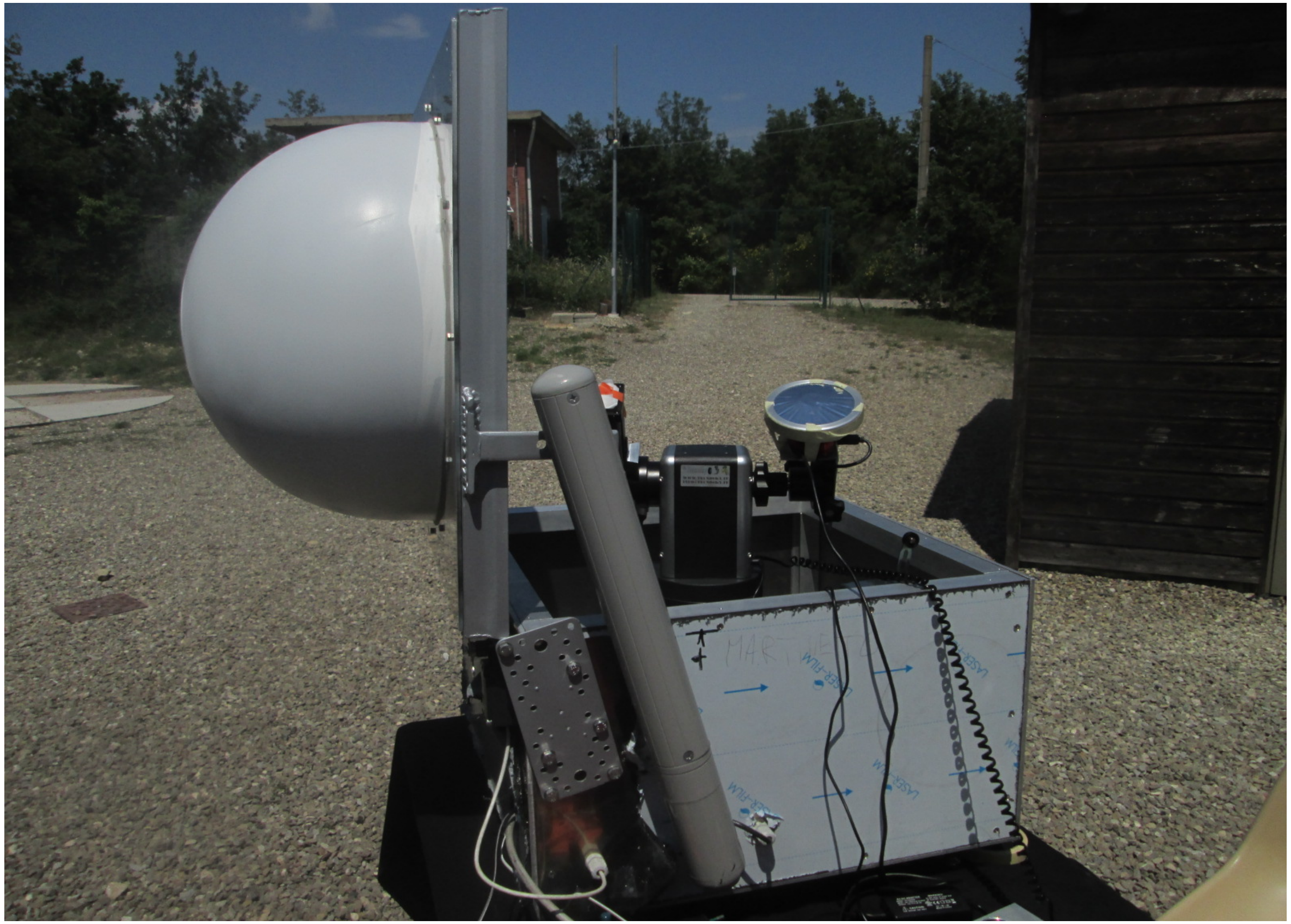


LOCNES: The Mount

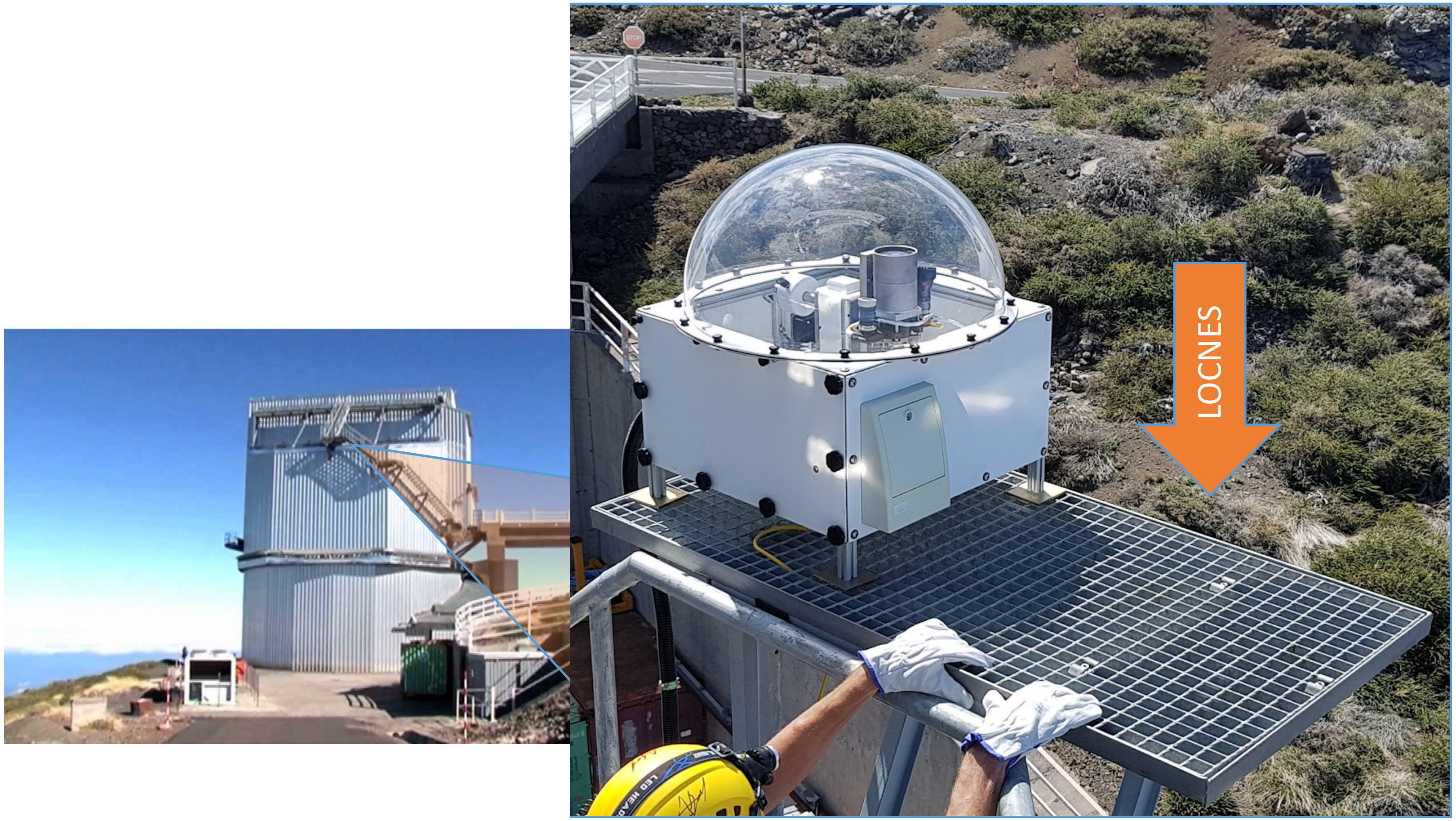
Mount	AltAzimuth Mount
Body Materials	Die-cast Aluminum
System	GoToNova®
Primary Payload	33 lb
Secondary Payload	10 lb
Mount Weight	13 lb (including CW shaft and battery)
Gear	Aluminum worm wheel/Brass worm gear
Motor	128X microstep stepper motor
Transmission	Sychronous belt
Resolution	0.1 arc second
Tracking	Automatic
Tracking Rate	celestial, solar, lunar and user defined
Hand controller	Go2Nova® 8407 with over 212,000 object database
Slew Speed	1x, 2×,8×,16x, 64×,128x, 256×,512x and MAX(~10º/sec, 2400X)
GPS	32-channel GPS
Sensors	Position and angular detection
Level indicator	Yes
Dovetail Saddle	6" Losmandy/Vixen dual saddle Optional secondary Vixen saddle
Counterweight	10 lb
Battery	Built-in rechargeable Li-ion battery (11.1V, 4.4AH)
Battery Running Time	10 hour at 20ºC
Battery Charger	100-240V AC input /12.6V DC 2000mA output (Included)
Wireless Control	Yes, full control via built-in WIFI adapter
Firmware Upgrade	Yes, via serial port
Computer Control	Yes. PC via ASCOM and Mac/Tablet/SmartPhone via WIFI
Tripod	2" stainless steel tripod
Warranty	Two year limited warranty for mount 90 day limited for battery

LOCNES: The Dome...a transparent one?

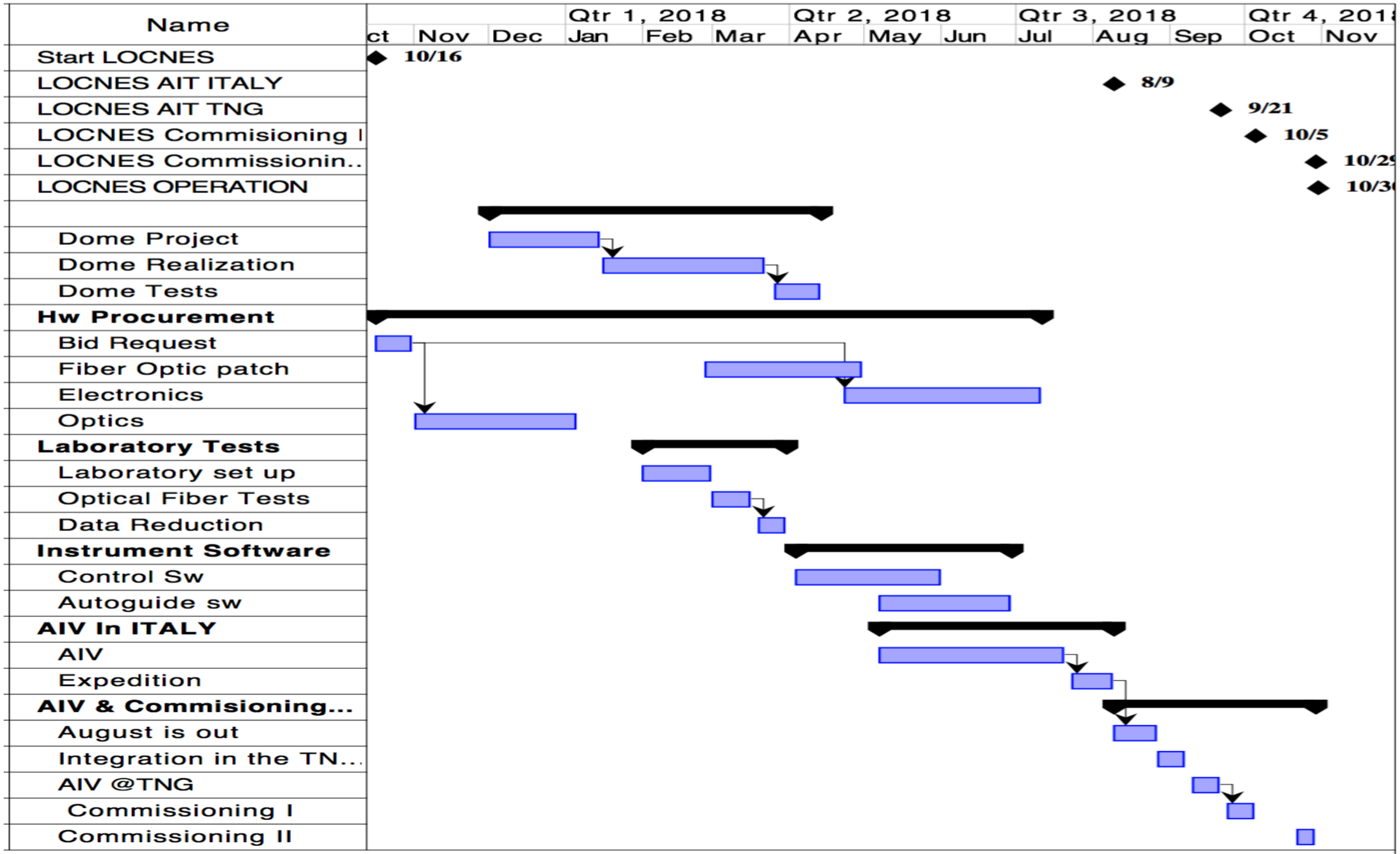
LOCNES: The Dome



Where LOCNES will be mounted?



Schedule



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Qtr 1, 2018
Qtr 2, 2018
Qtr 3, 2018
Qtr 4, 201
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Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Start LOCNES
10/16
LOCNES AIT ITALY
8/9
LOCNES AIT TNG
9/21
LOCNES Commisioning I
10/5
LOCNES Commissionin...
10/2
LOCNES OPERATION
10/3
Dome Project
Dome Realization
Dome Tests
Hw Procurement
Bid Request
Fiber Optic patch
Electronics
Optics
Laboratory Tests
Laboratory set up
Optical Fiber Tests
Data Reduction
Instrument Software
Control Sw
Autoguide sw
AIV In ITALY
AIV
Expedition
AIV & Commisioning...
August is out
Integration in the TN...
AIV @TNG
Commissioning I
Commissioning II

Conclusions

- *LOCNES* in conjuction with *HARPS-N* and *GIANO-B* will allow us to characterize the variability of the solar spectrum from the visible (400-800 nm, R = 115 000) to the NIR (950-2400 nm, R = 50 000) *observing the Sun as a star*;

- A variety of time scales will be accessible from less than 1 minute to years (cf. LCST in operation since 2015);

- The Sun will be observed starting from the current activity minimum to the maximum of the next 11-yr cycle and hopefully beyond;

- We expect to contribute to *ARIEL* by a better understanding of the impact of stellar activity on optical and NIR disc-integrated spectra.

Thank you for your attention

Additional slides

Spectrum of a planetary atmosphere