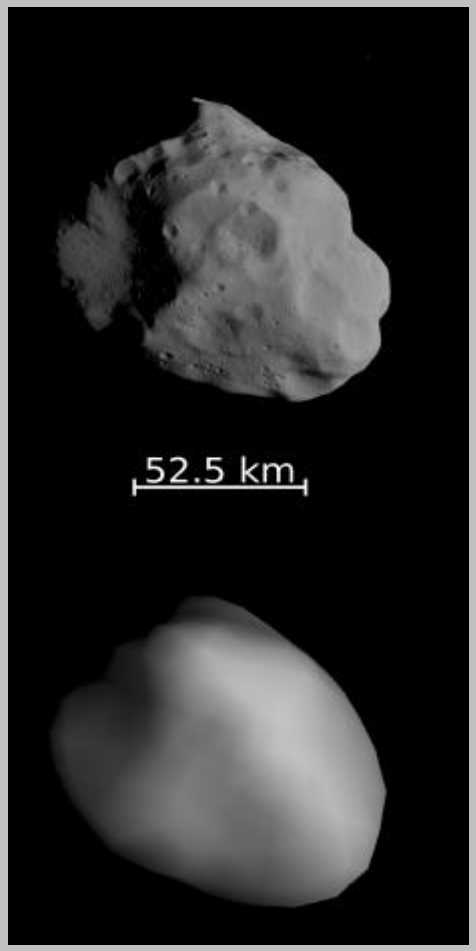
The 1-m telescope at Pic du Midi: a collaborative science program in the course of a long history of the observatory.

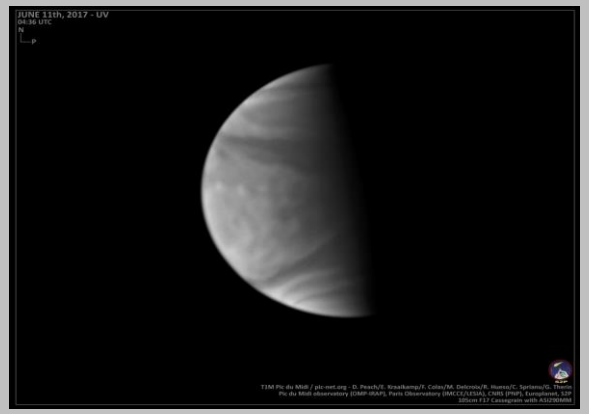
F. Colas, A. Klotz, D. Darson J. Dubouil - Firenze 2024

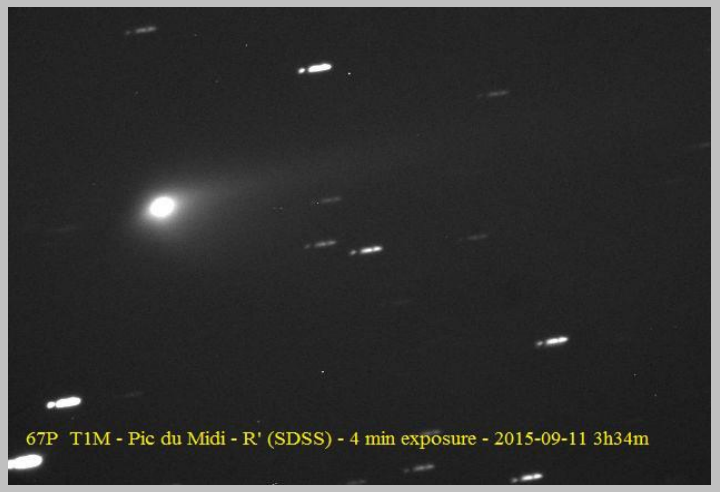
INTERNATIONAL CHIANTI TOPICS FOCUS WORKSHOPS

the swiss knife for astronomy ! Flexible telescope used on alerts

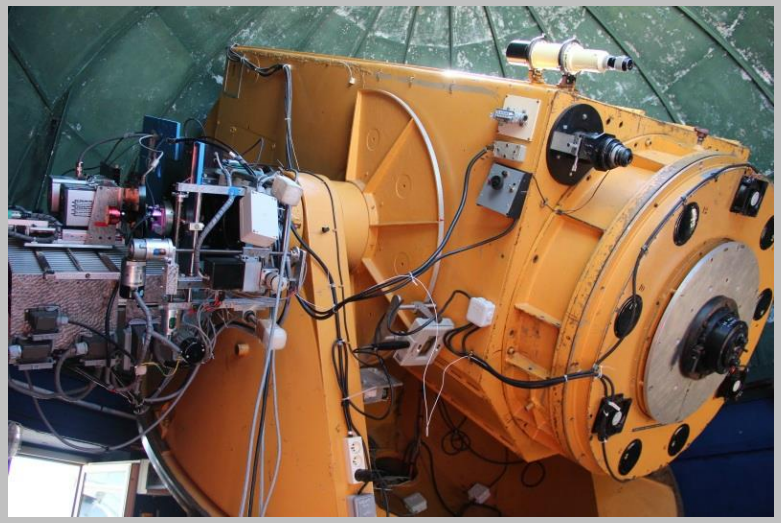


Lutetia



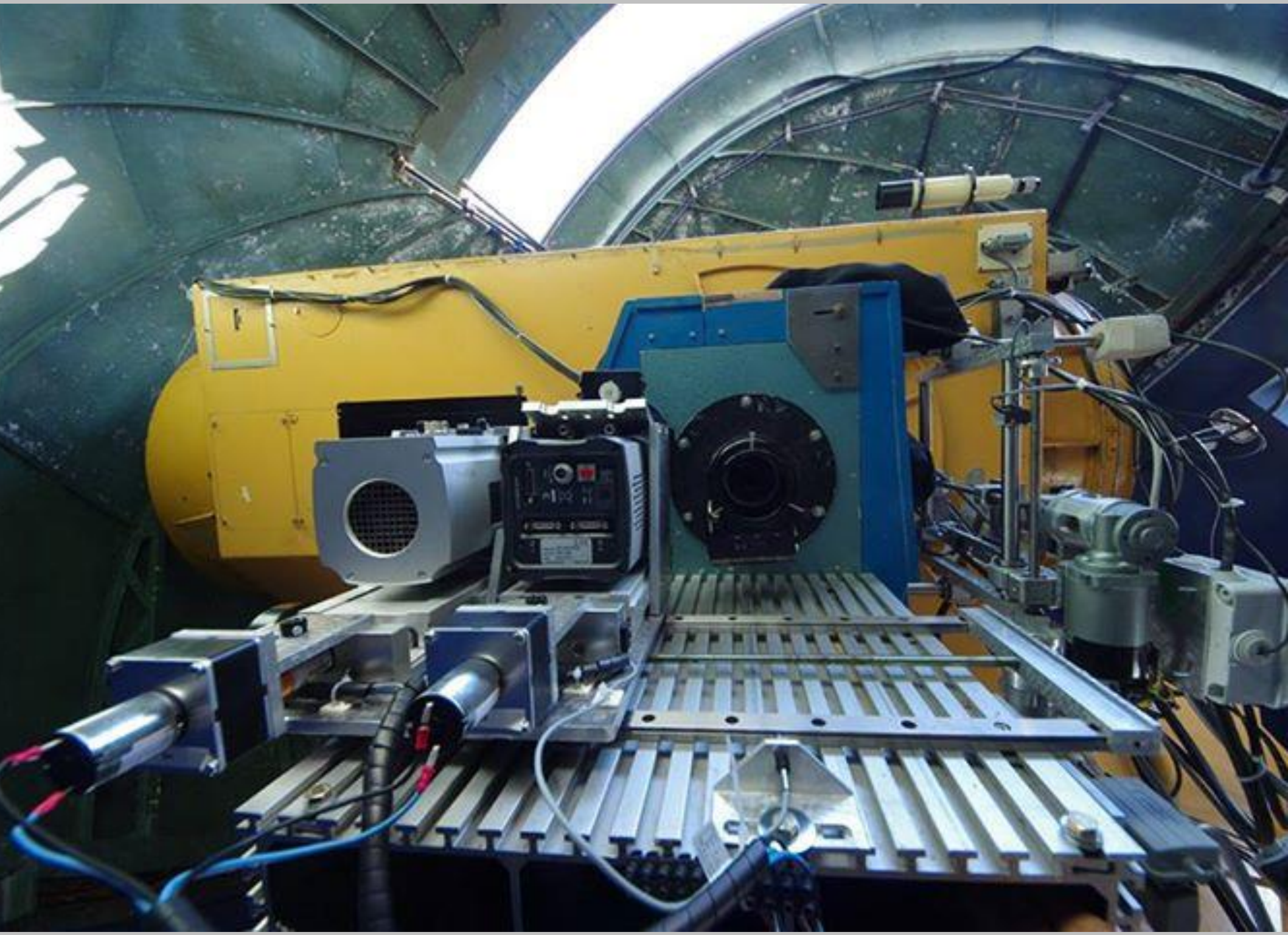


67P/Tchouriumov-Guérassimenko

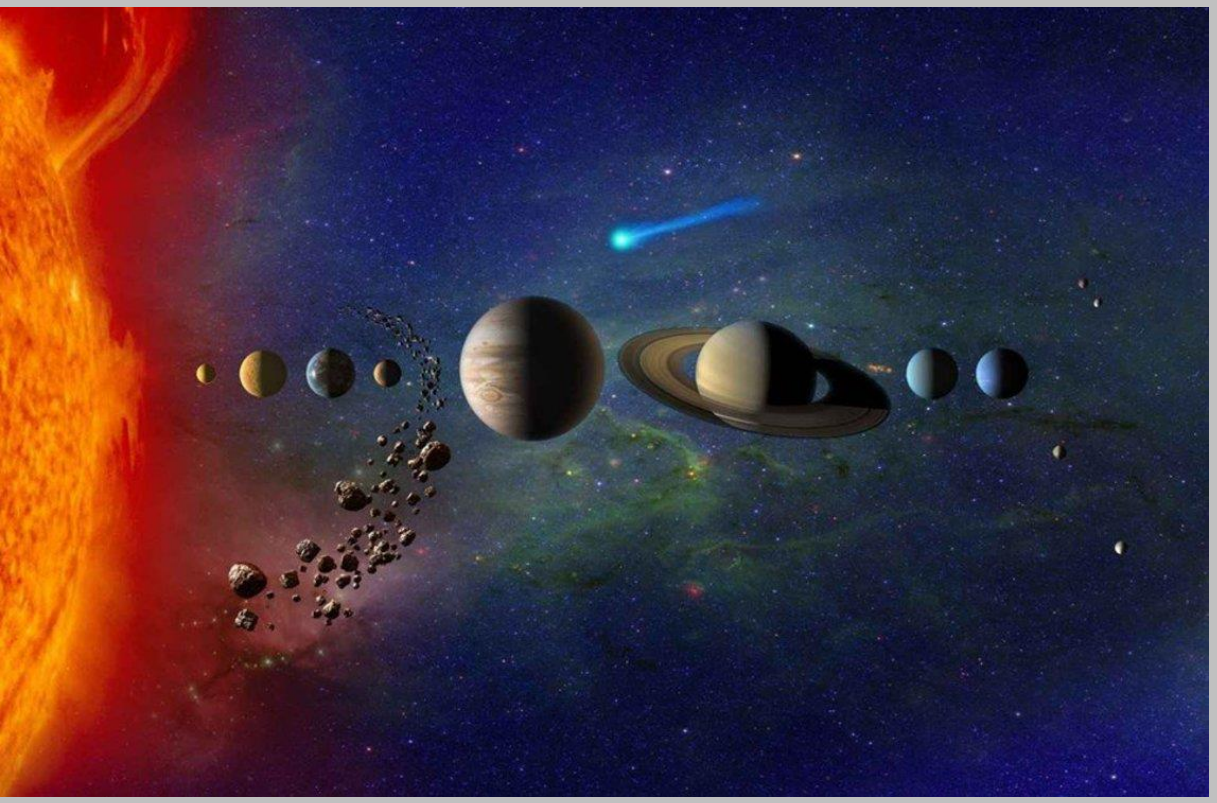


The “Station de Planétologie des Pyrénées” (S2P), Pic du Midi observatory


CNRS Images
Station de Planétologie des Pyrénées



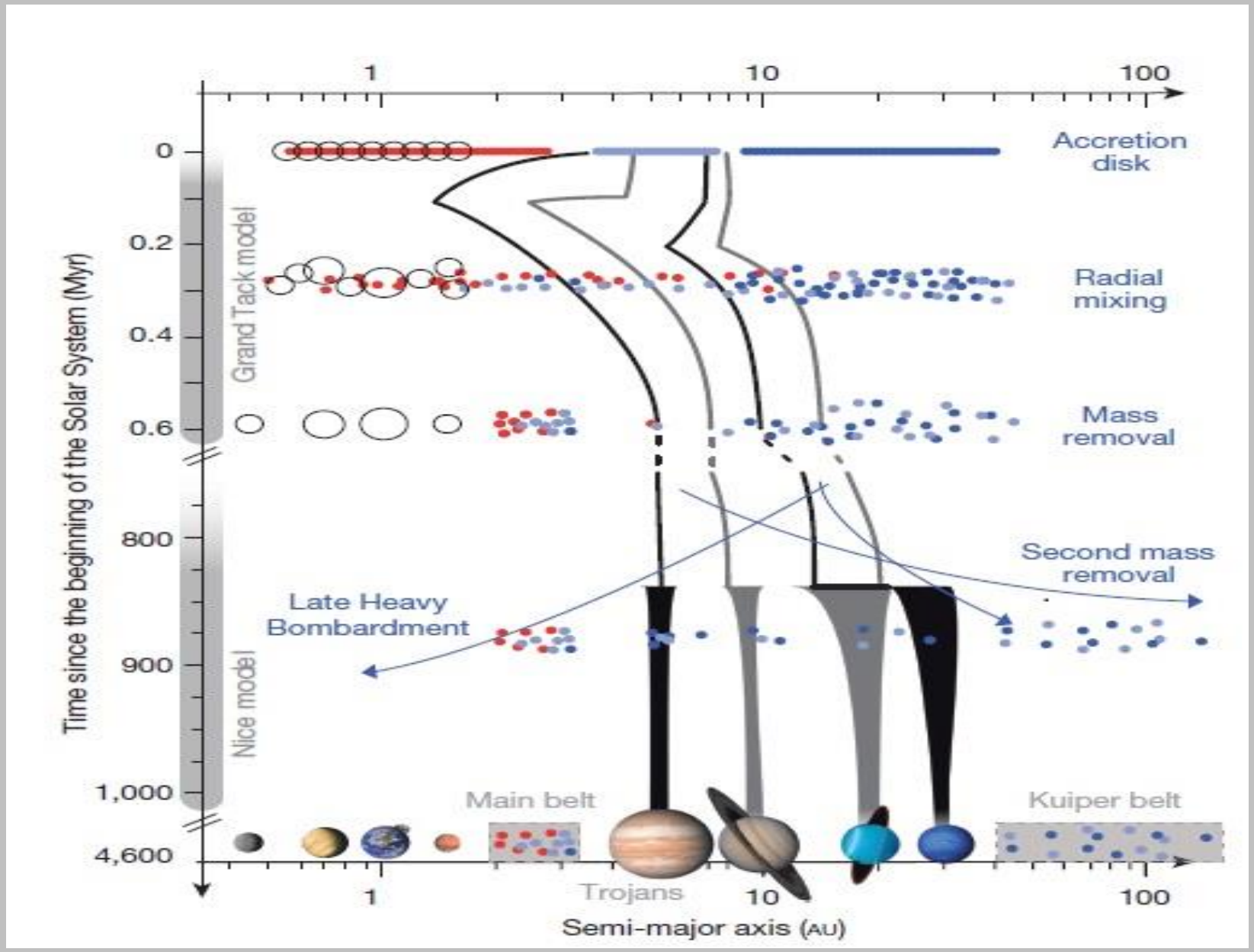
Caracterize Interplanetary matter



The study of interplanetary matter is fundamental for our understanding of the Solar System
Solar System:
Formation (meteorites)
Evolution (impact flows on Earth and other planets)
Impact risks
...

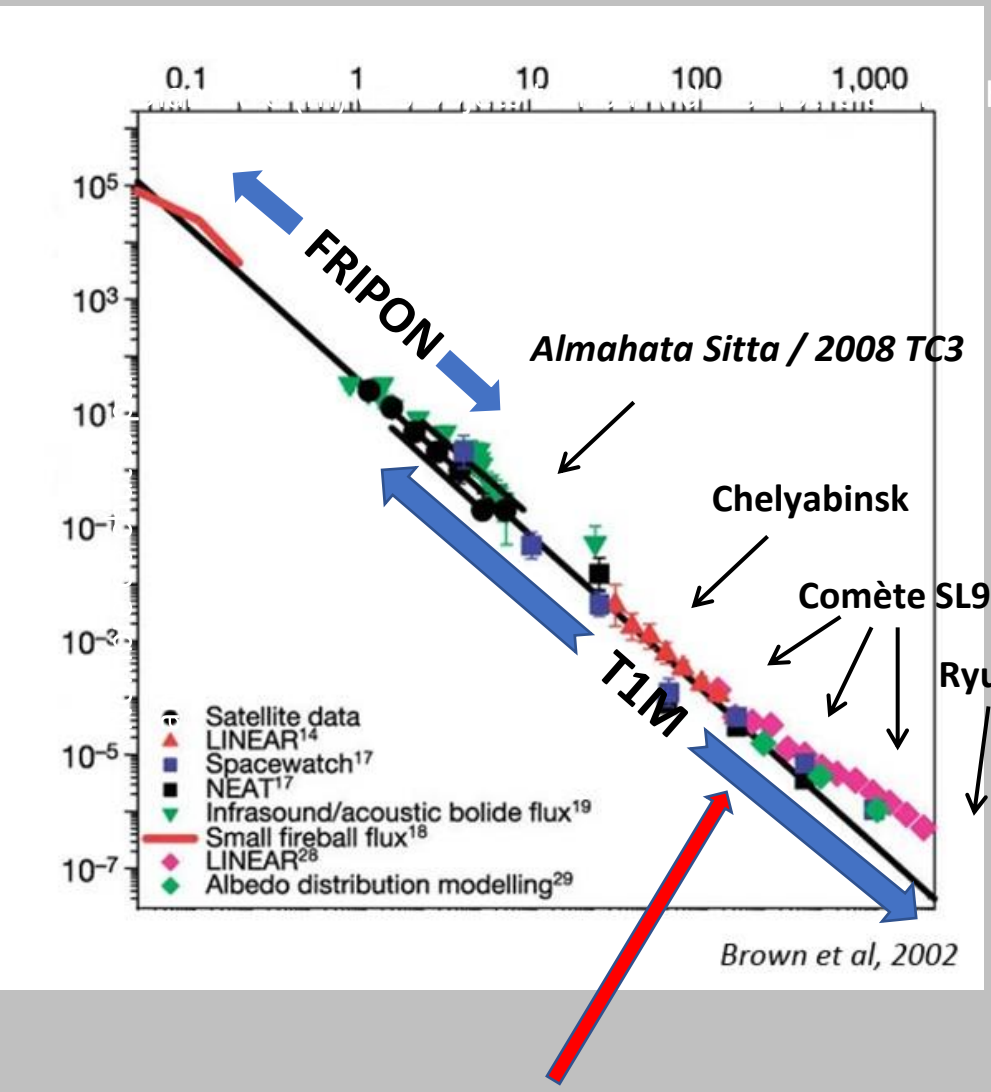
nterplanetary matter covers a large number of objects from micron dust to 1000 km asteroids

Evolution du système solaire



Migration of planets = mixing of matter **(Nice model !)** *B.Carry F DeMeo*

The small bodies of the System at Pic du Midi



hère

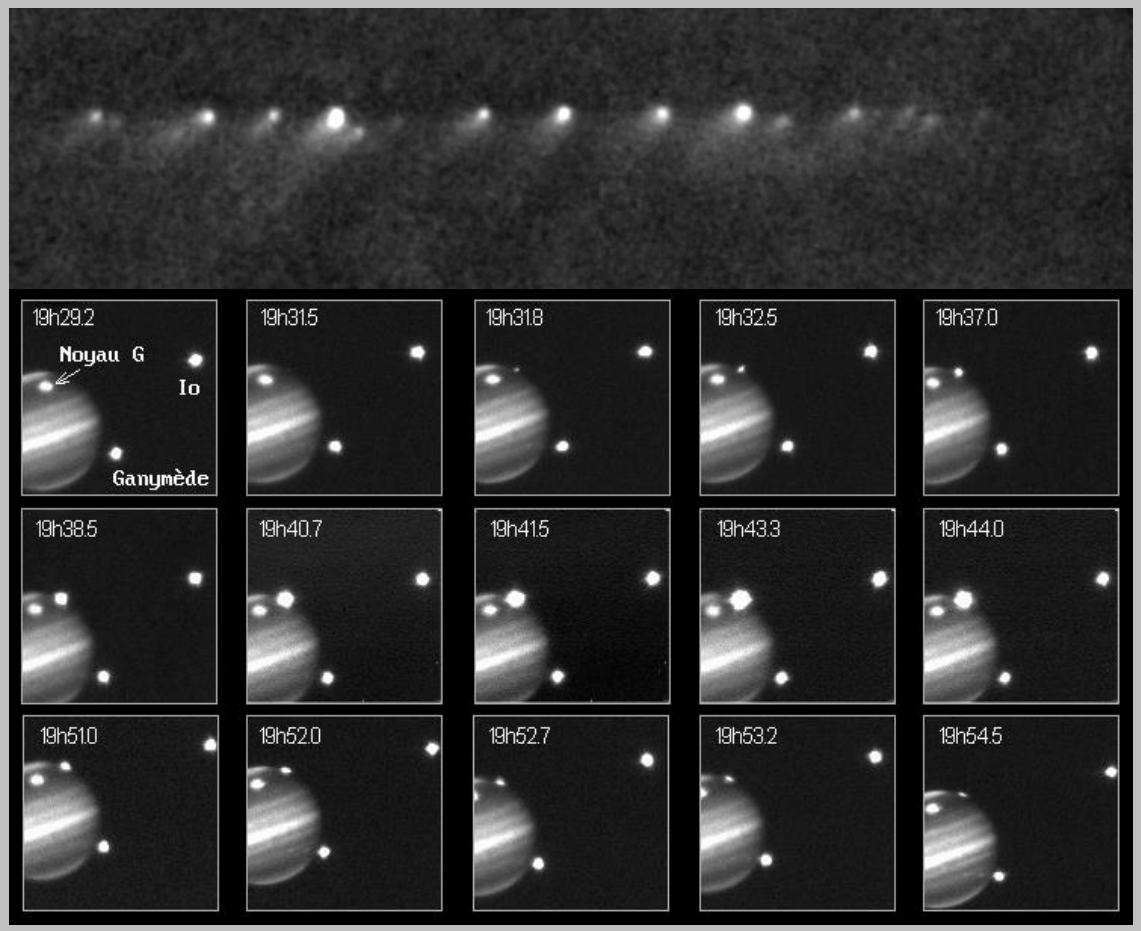
LSST exhaustive detection limit ~ 150 m

Statistics on falling objects in the Earth's atmosphere

FRIPON : from one centimeter to one meter : missing link between dust (zodiacal light and shooting stars) and asteroids (telescopes and impacts on giant planets)

- FRIPON 1 cm => 1 m
- Almahata Sitta (3 m, asteroid discovered before its fall)
- Chelyabink (17 m, every 200 years?)
- Comet SL9 (50-300 m, falls every 100 years?)
- Benou (500 m, space mission Osiris-Rex)

Observation of interplanetary matter



From 5 m to 500 m

nterplanetary "rocks" :
Impacts on Jupiter

After the fall of the comet Shoemaker Levy 9 in 1994, 6 collisions with Jupiter were observed

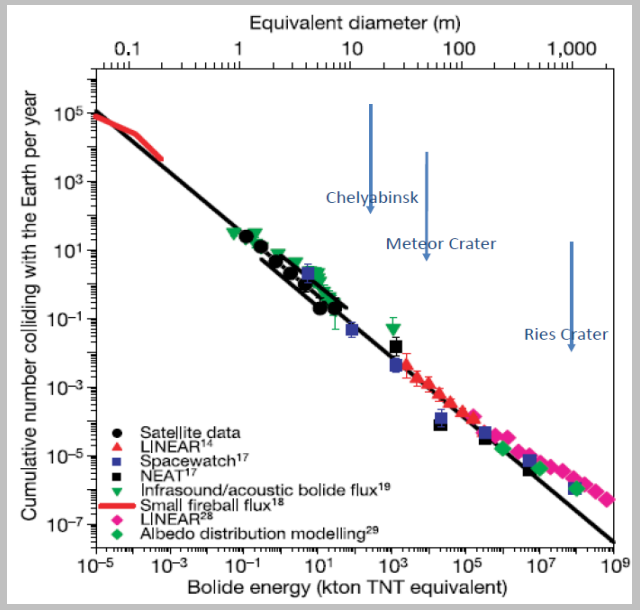
1 event per year ?

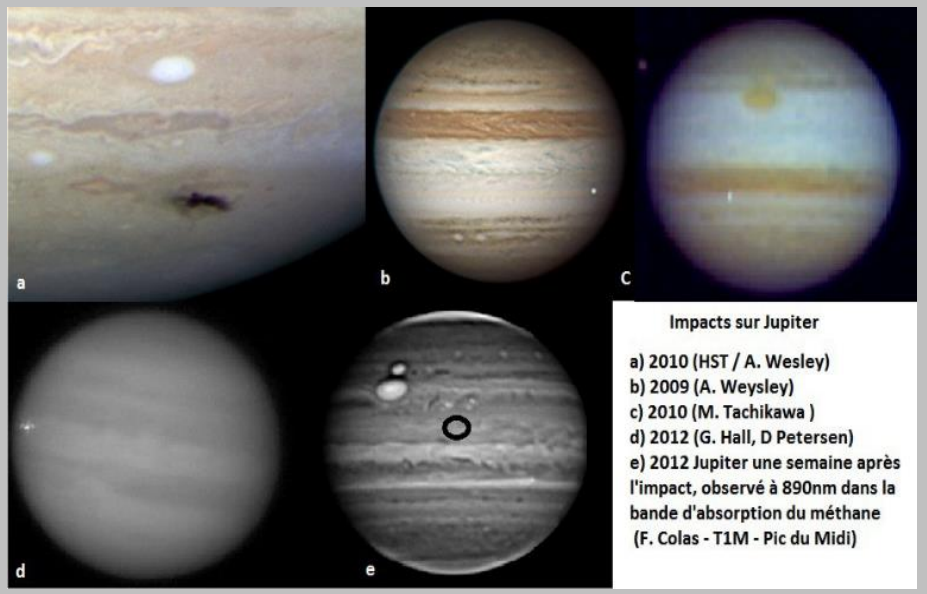
Comets and asteroids

Fall of the cometShoemaker Levy - 9
Pre-impact images
Impact of the H nucleus on July 18, 1994

(Pic du Midi Observatory, F. Colas et al)

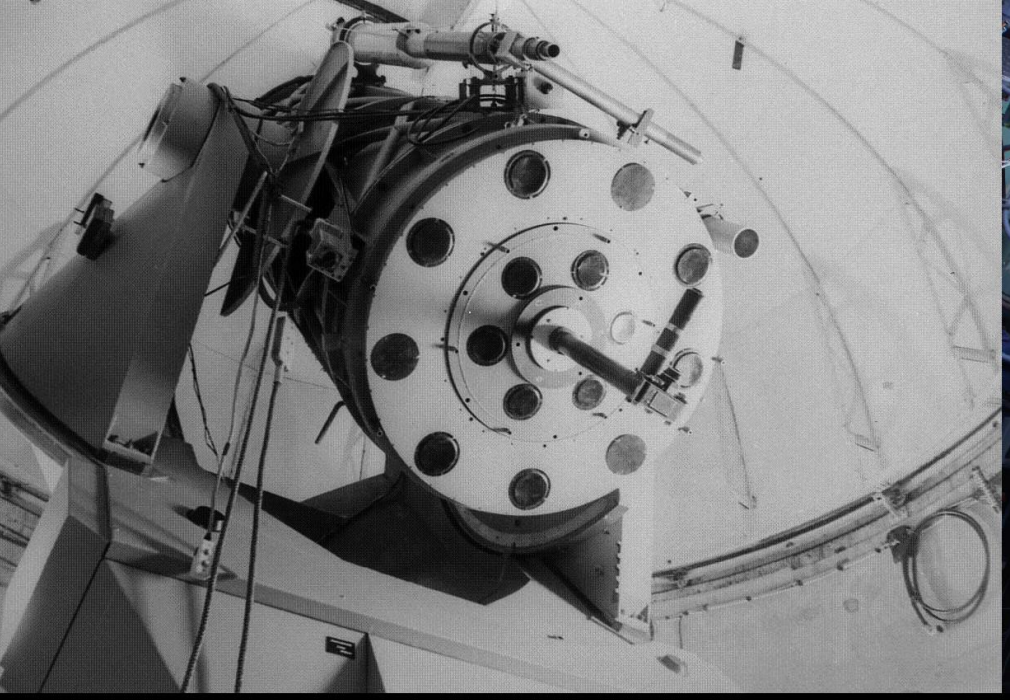
Observation of interplanetary matter program "**Lucky Planet**"

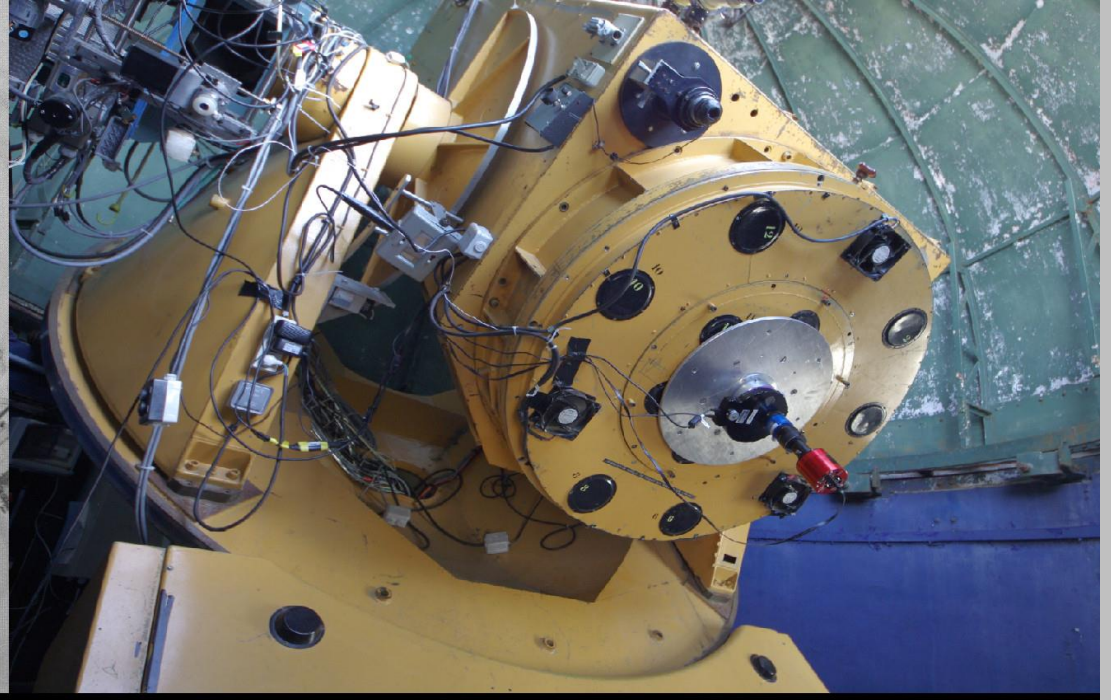




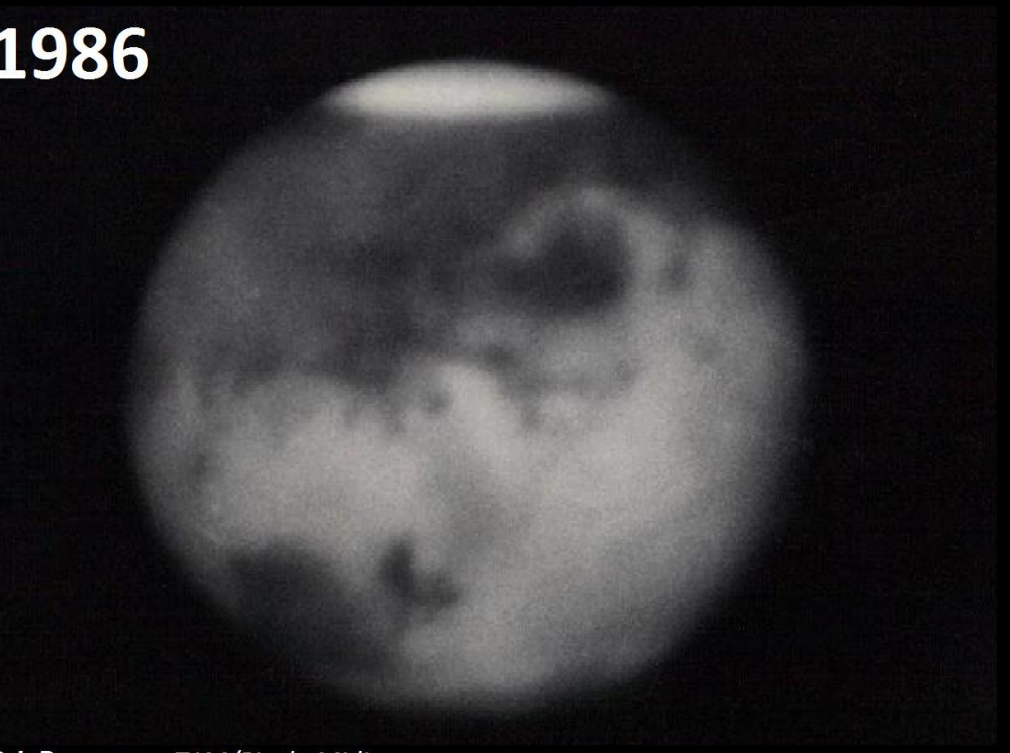
"Flux d'impacts dans le système solaire et datation des surfaces"

Mission "JUNO" :
Jupiter follow-up



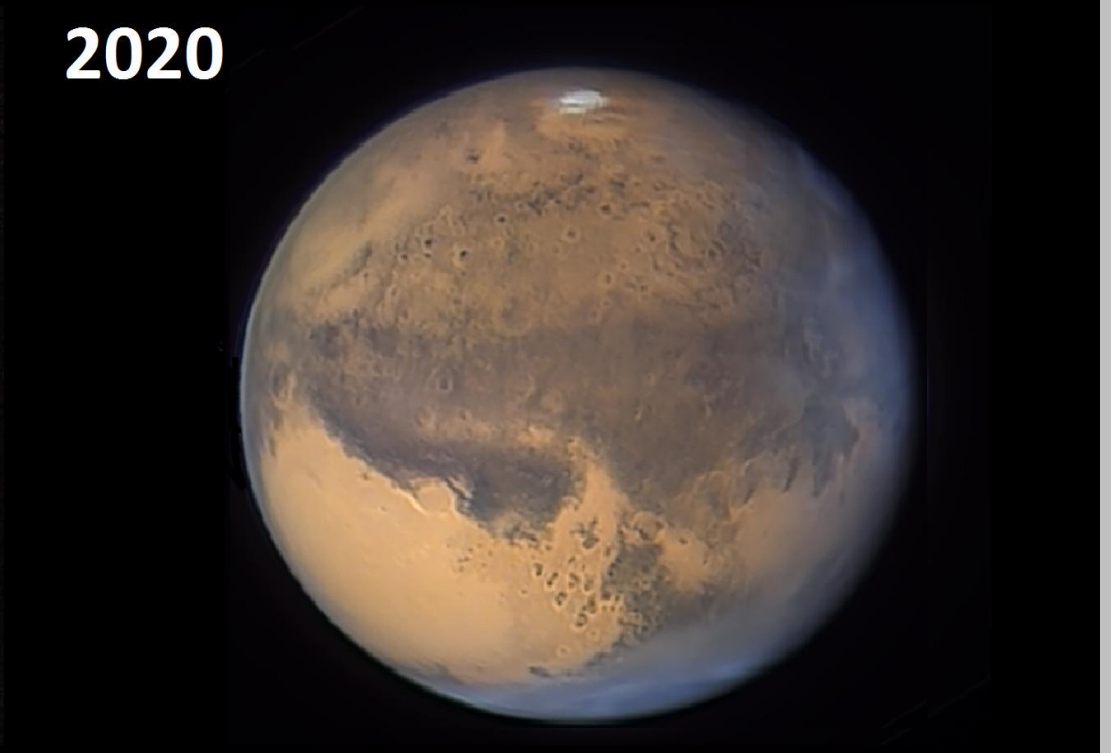


1986



© J. Dragesco *T1M/Pic du Midi*

2020



@ F. Colas, T. Legault, J.L. Dauvergne *S2P/IMCCE/OMP*

JEAN DRAGESCO
FACULTÉ des Sciences
BP 117
BUTARE
RWANDA

15-VII-86 — 23h07m U.T.

$\omega = 67°6$ — $d = 22''9$

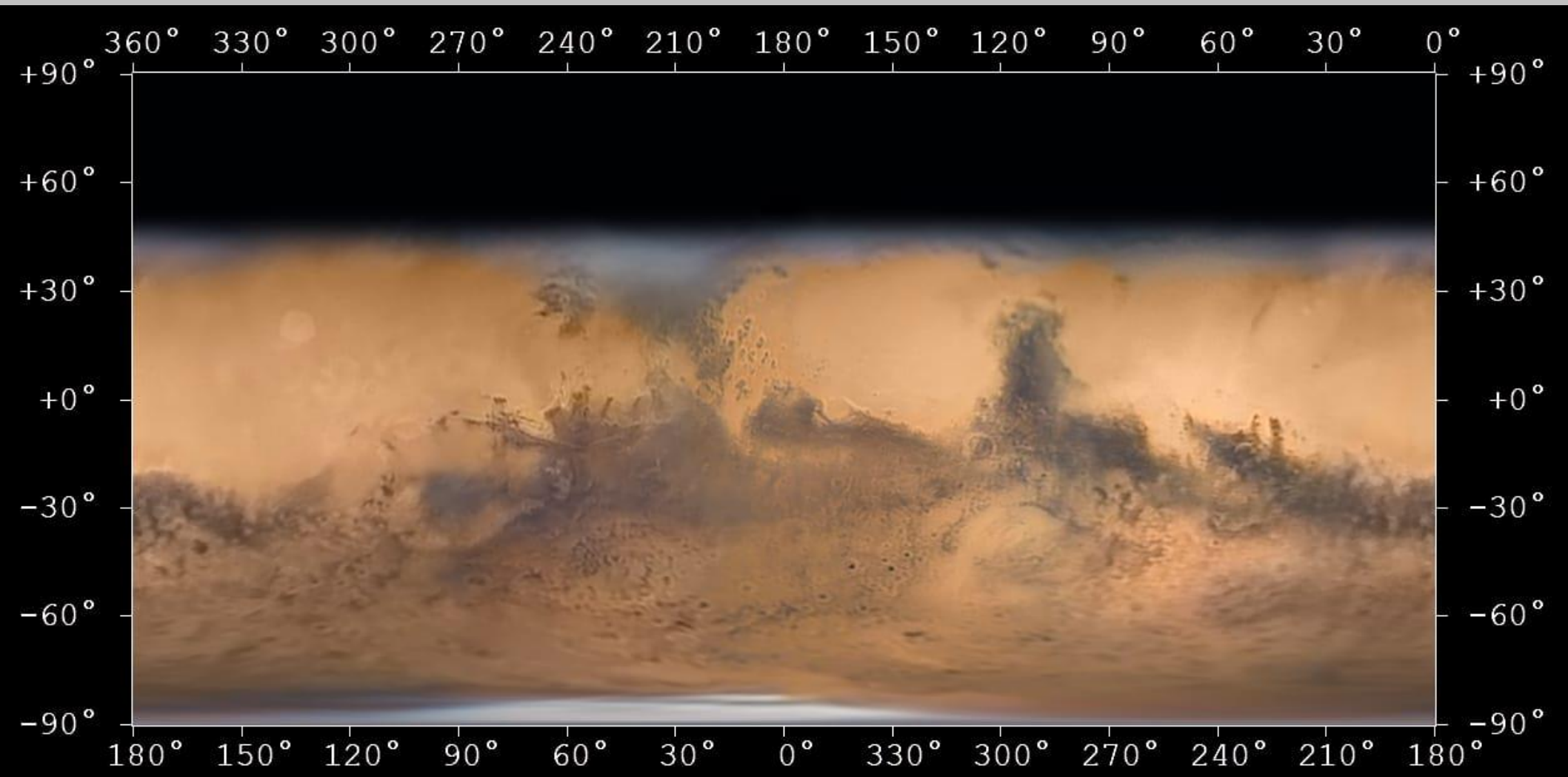
Tél. : 106 cm — $F/D = 52$

Filtre : W29 — 24x15

1/2 sec — HC-110 (1/15).

Pic-du-Midi

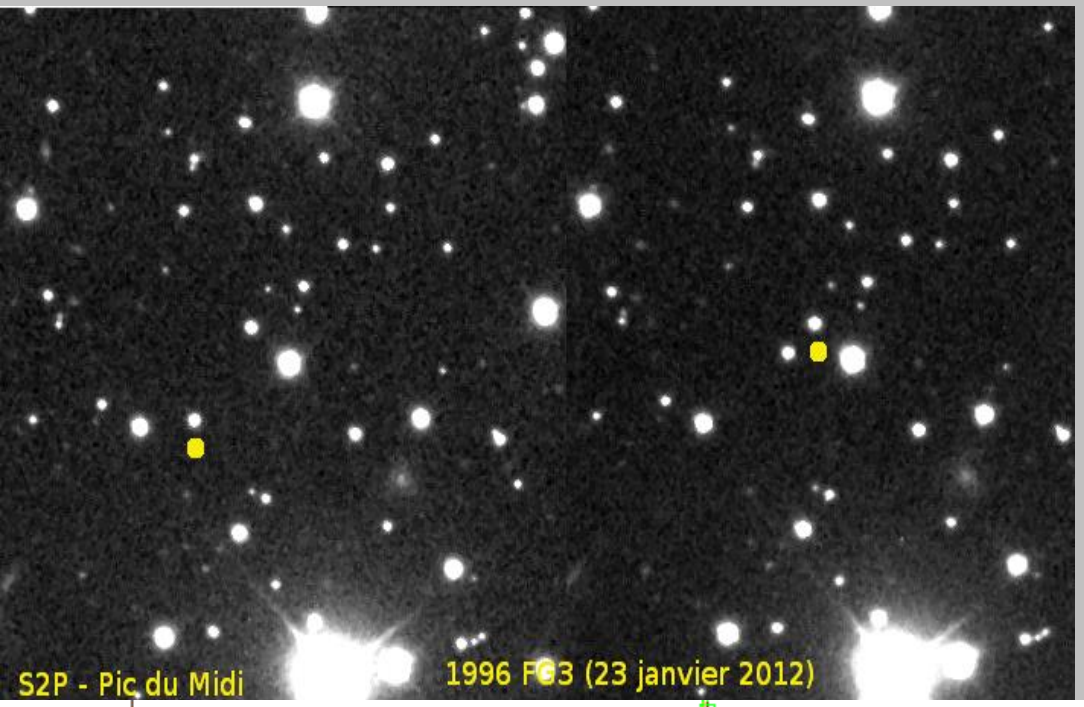
Il semblerait que cette photo soit l'une des meilleures jamais réussies, à partir d'un observatoire terrestre. Il y a une infinité de fins détails, certains jamais encore photographiés. Pouvoir séparateur = env : 0,3". !



Opposition of Mars - 2020

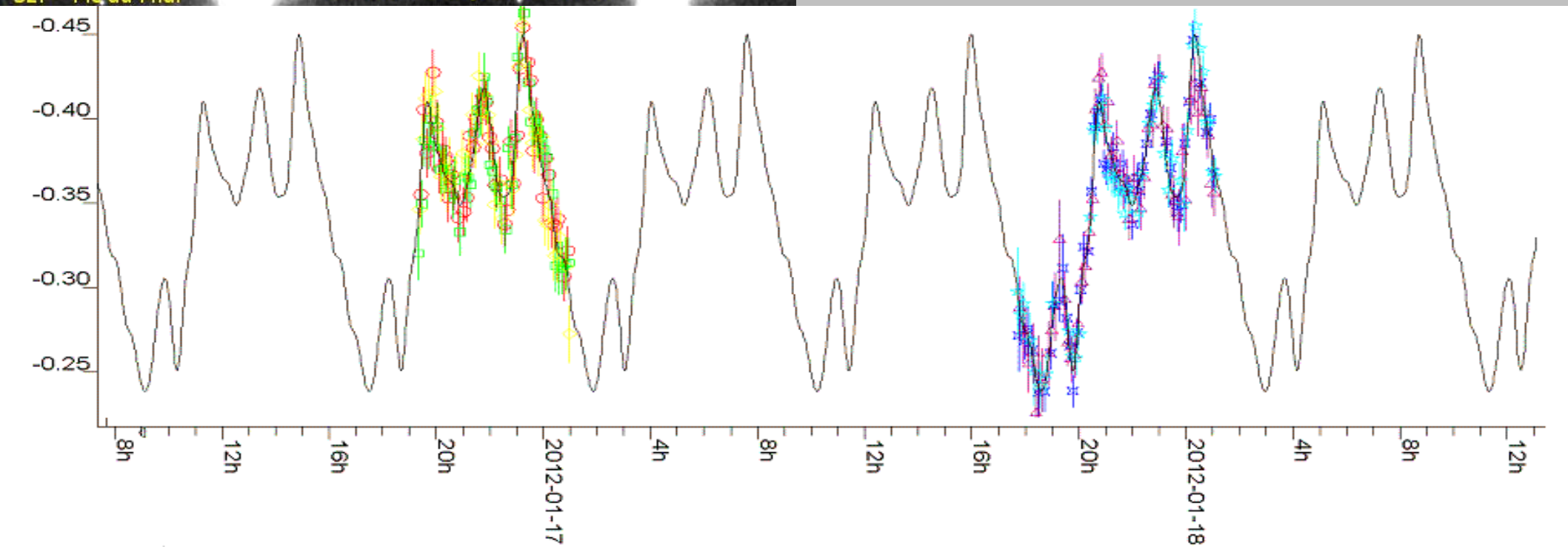
Pic du Midi - 1 Meter Telescope
Planetocentric latitudes
Equirectangular projection

Photometric telescope



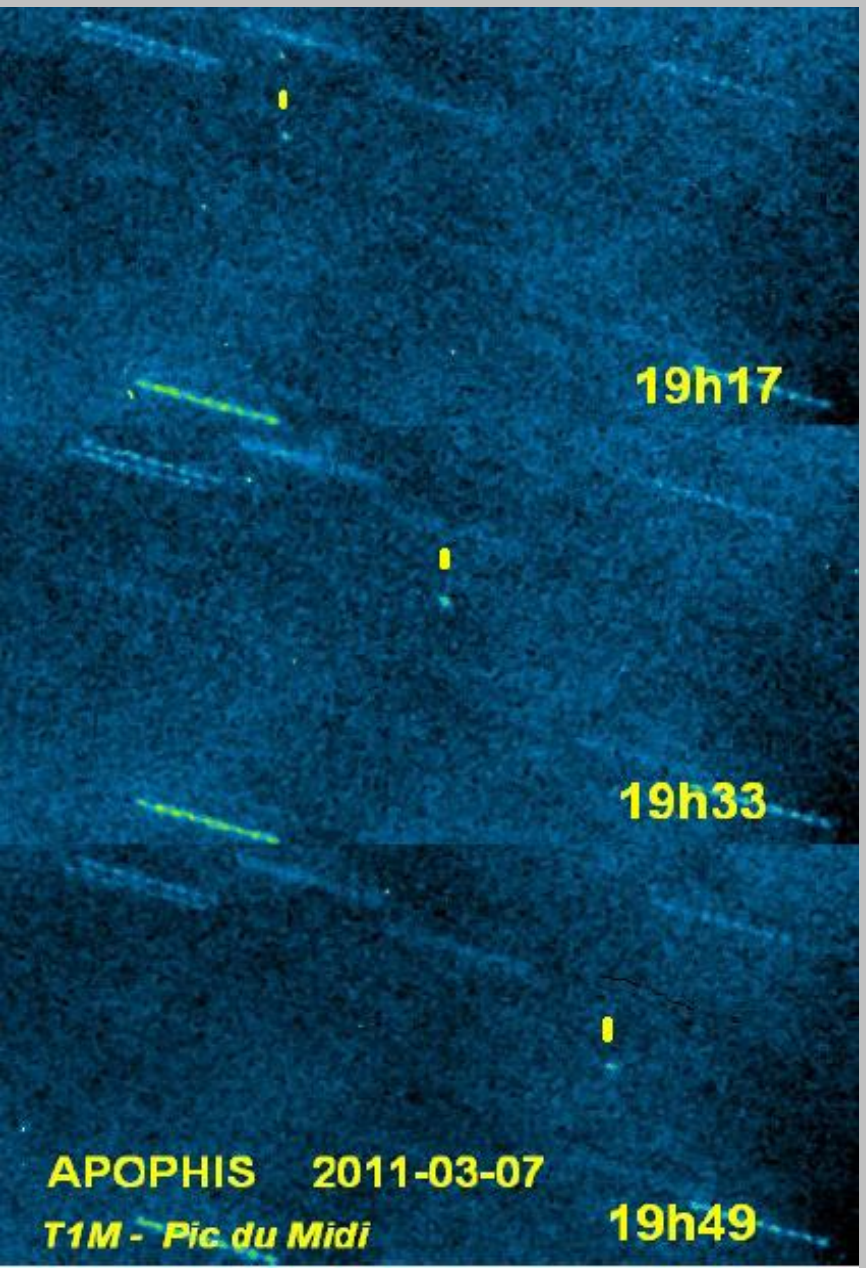
996 FG3 (Marco Polo-R target)

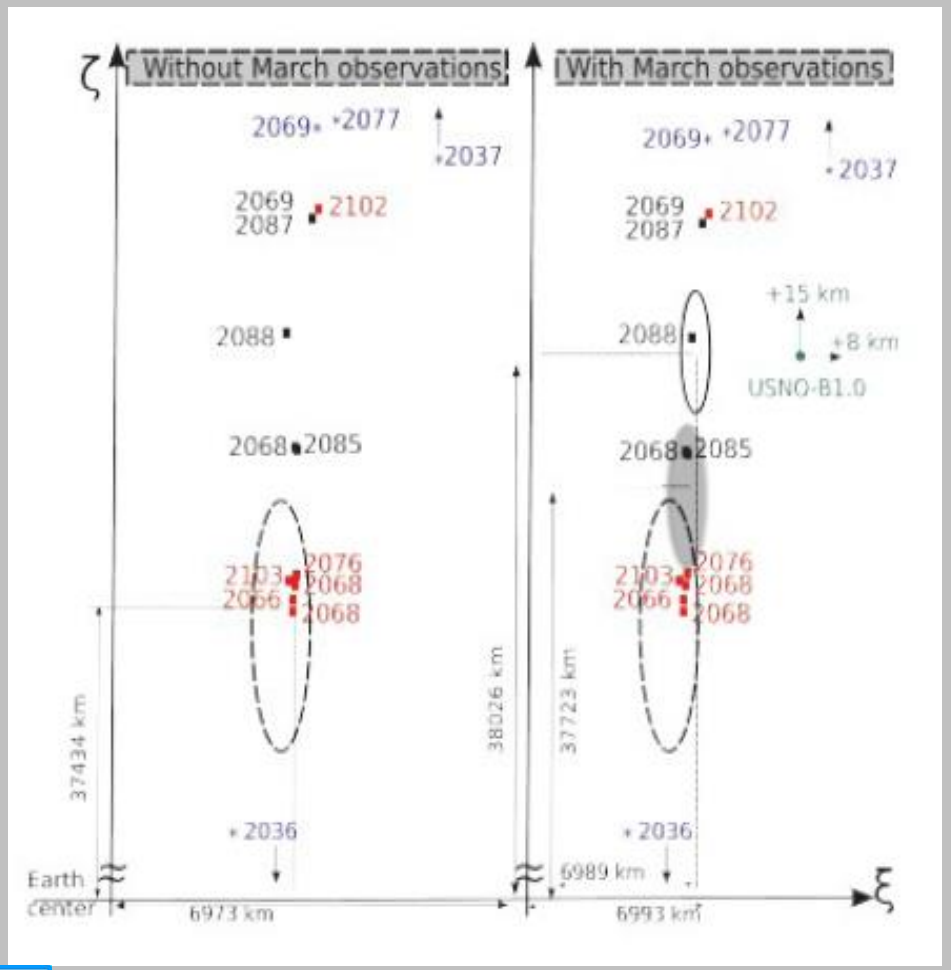
- Spectral and optical properties
- Astrometry



Astrometric telescope

Near Earth Object
(99942 Apophis)



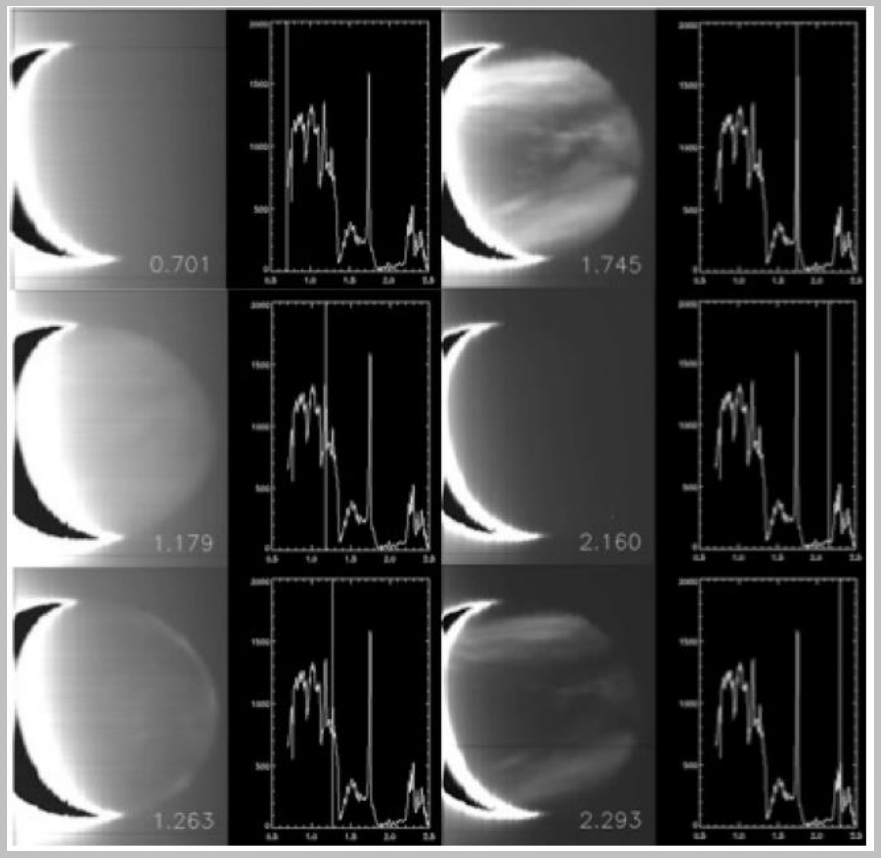


Thèse D. Bancelin (2011)

"Key holes"

Program EURONEAR

Venus atmosphere



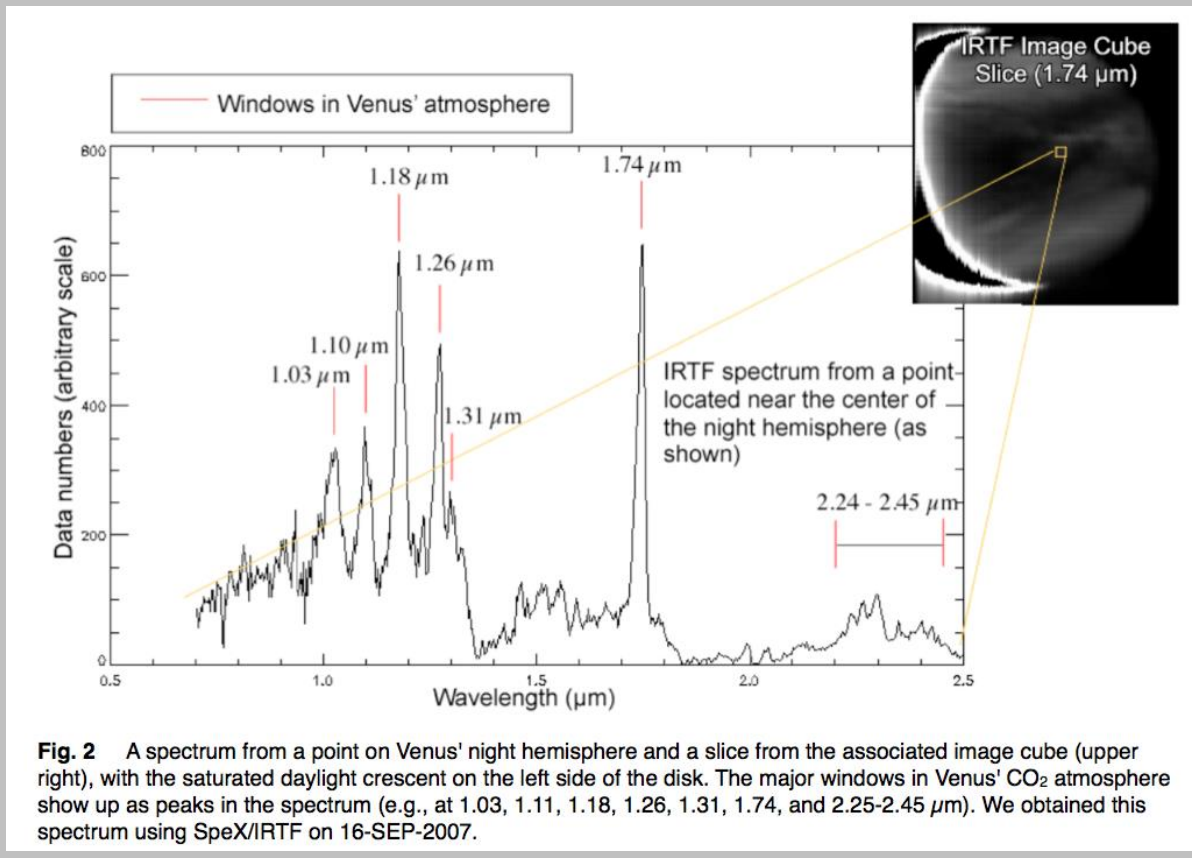
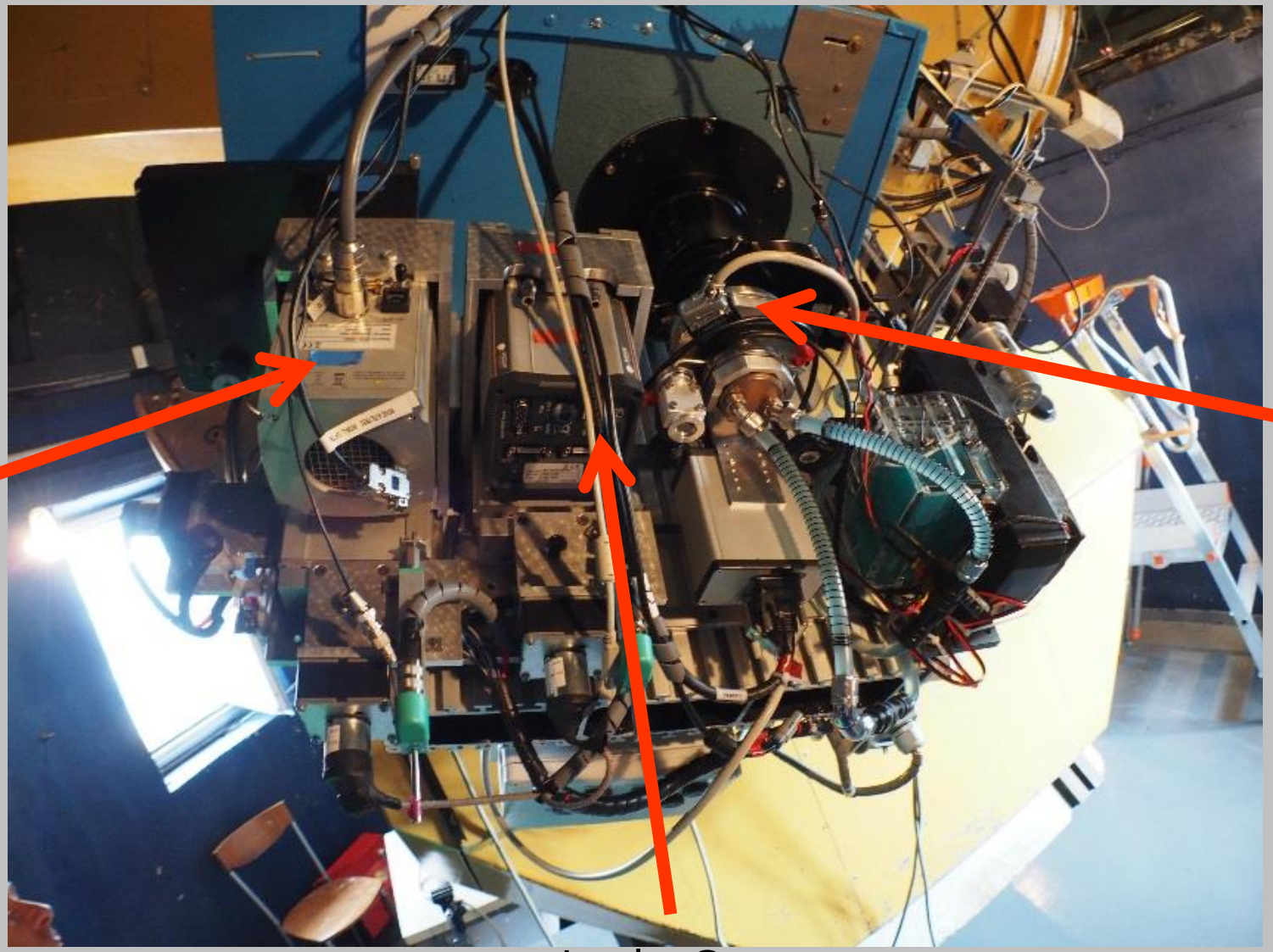


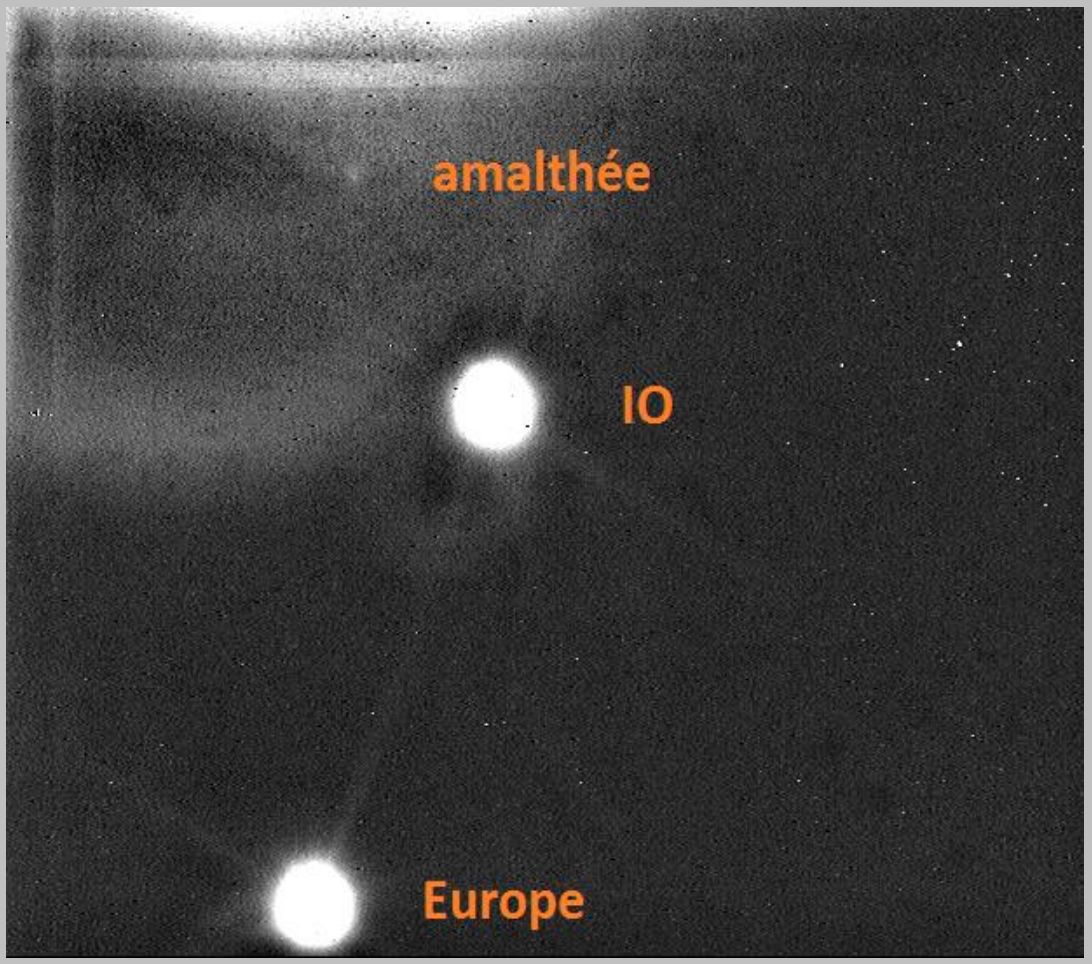
Fig. 2 A spectrum from a point on Venus' night hemisphere and a slice from the associated image cube (upper right), with the saturated daylight crescent on the left side of the disk. The major windows in Venus' CO_2 atmosphere show up as peaks in the spectrum (e.g., at 1.03, 1.11, 1.18, 1.26, 1.31, 1.74, and 2.25-2.45 μm). We obtained this spectrum using SpeX/IRTF on 16-SEP-2007.

ESA mission to Venus : EnVision

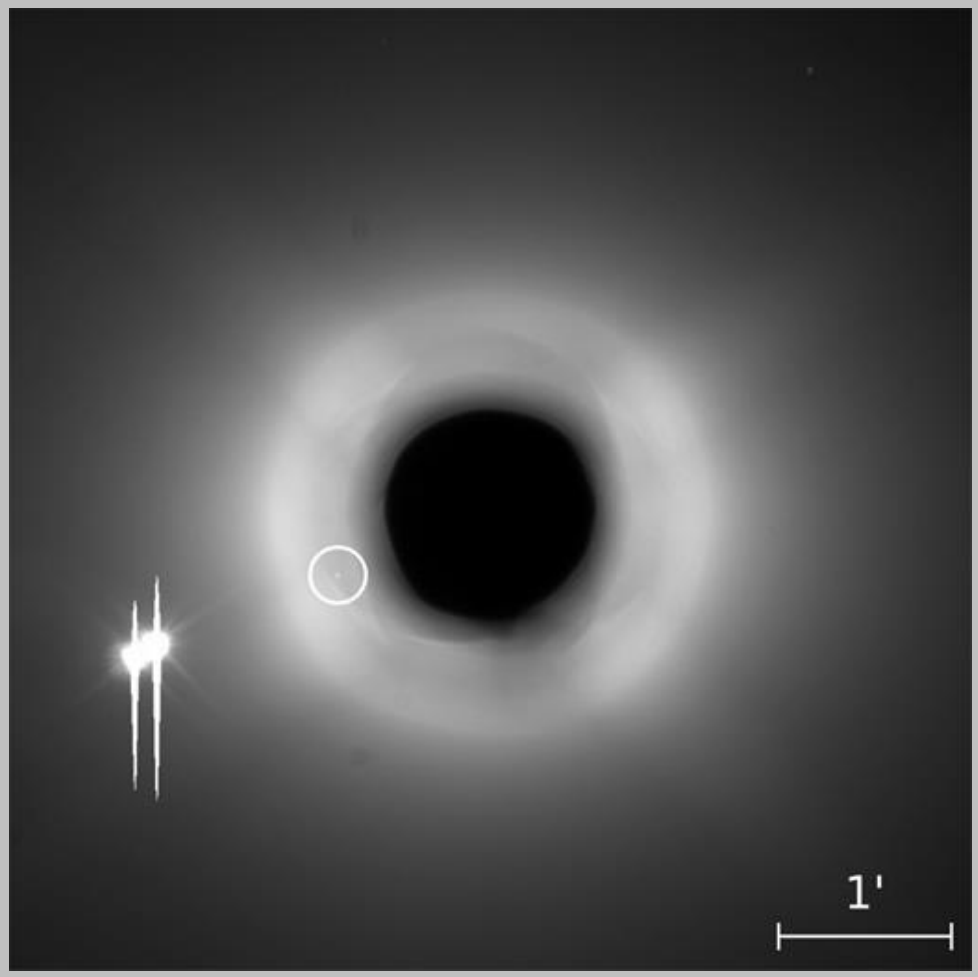
T1M – Pic du Midi
the swiss knife for astronomy !
For solar system objets and others ;-)
Flexible telescope used on alerts



EPARADISE



CCD E2V
(pico cam)



Sur les images « normales » CCD, il est impossible d'obtenir des positions d'Amathée en même temps que celles de satellites Galiléens.

APPLICATION CASE : ASTRONOMY PIC DU MIDI

JUPITER

Filter J, Jupiter in Linear (CTIA) response stack of 40 exposure of 5s each with NDRO readout noise reduction

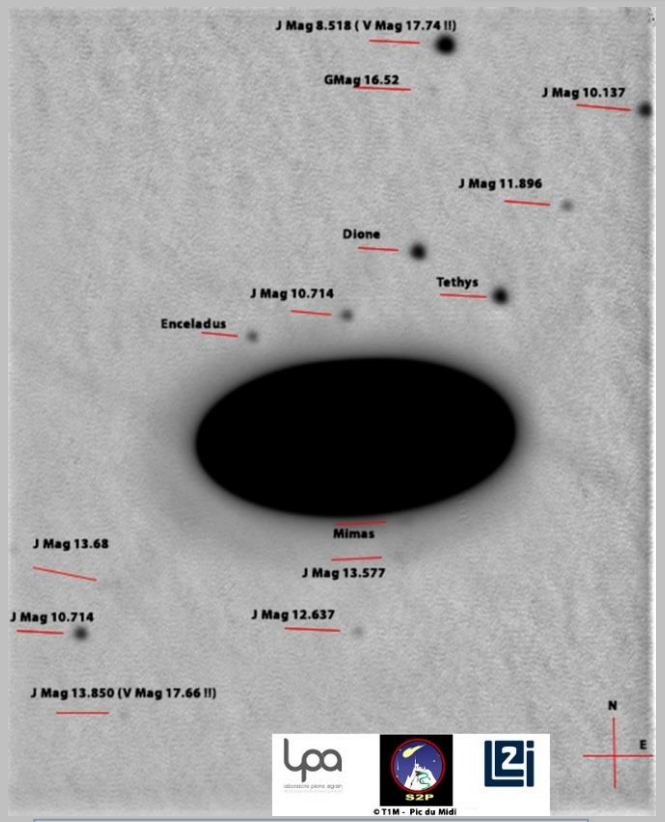
Filter J, Jupiter in Linear-Log response stack of 80 exposure of 2s each with NDRO readout noise reduction

APPLICATION CASE : ASTRONOMY PIC DU MIDI

SATURNE

Stack of 40 exposure of 10s each. No NDRO, just one classical read at the end of each 10s exposure. Log an Lin response on each exposure.

Filter J, Stack of 40 exposures of 10s. (Log and Lin response mixed on each)
11/07 22H55 UT



Same image, inverted, with display levels fully stretched : here lowest J magnitude is 13.85

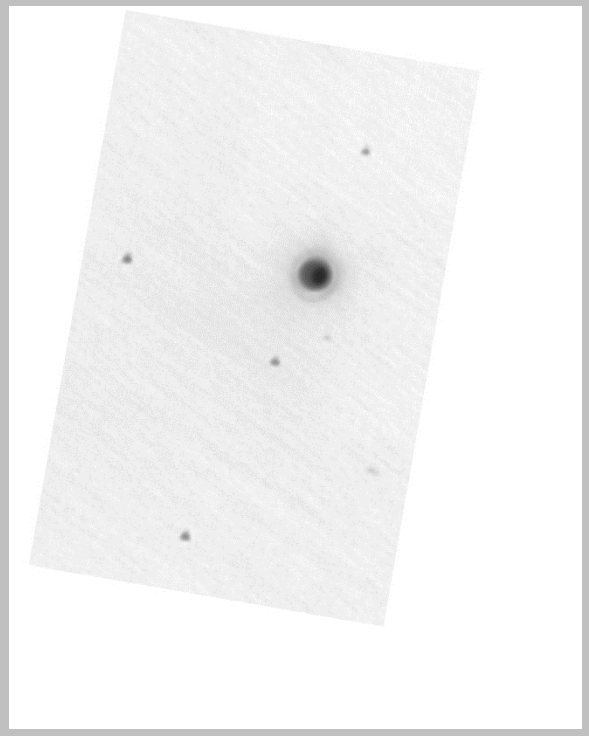
Stack of 40 exposure of 10s each. No NDRO, just one classical read at the end of each 10s exposure. Log and Lin response mixed on each exposure.

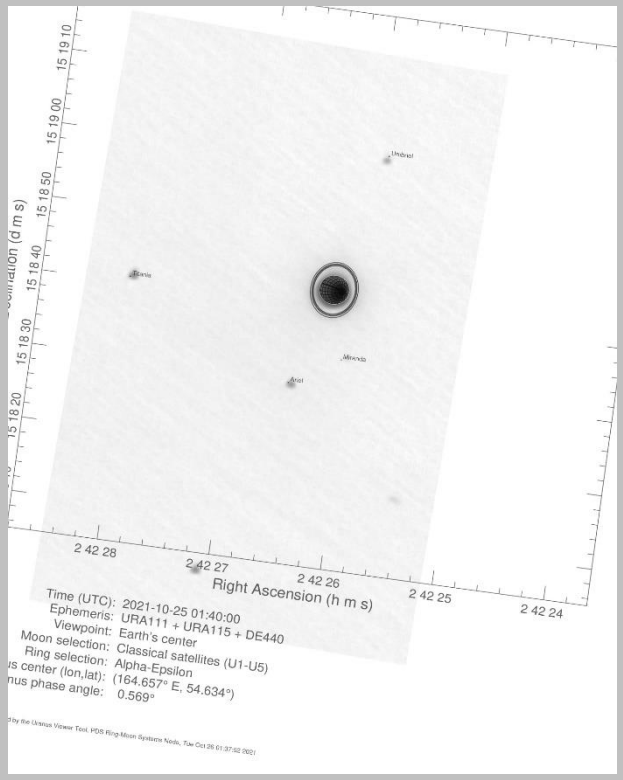
© T1M - Pic du Midi

APPLICATION CASE : ASTRONOMY PIC DU MIDI

Filter J, Uranus (CTIA) NDRO readout noise reduction, stack of 500 exposure of 600m. 24 October 2021. We can see satellites, pole clouds, and rings !

Uranus





Same image, inverted, and surimpose with position of Uranus satellites and rings ... rings confirmation!

CIAO at Pic du Midi

C ompact

I nnovative

A daptive

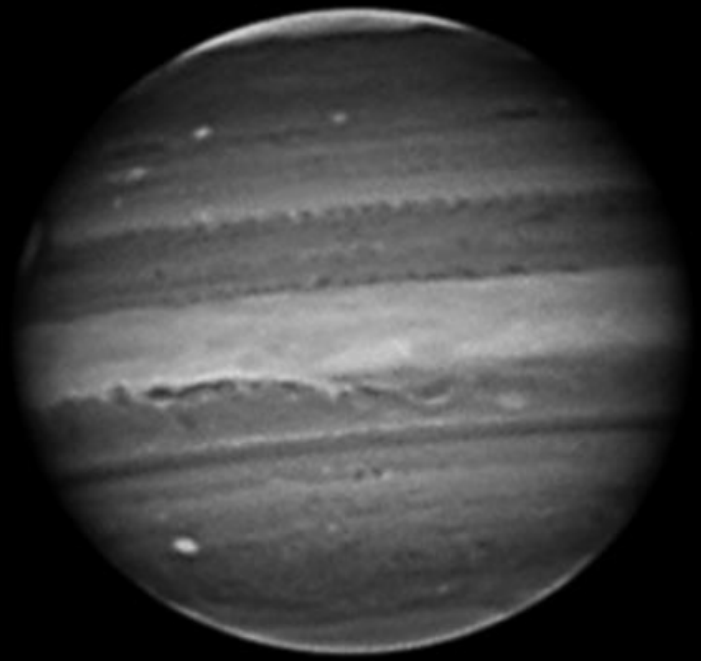
O ptics

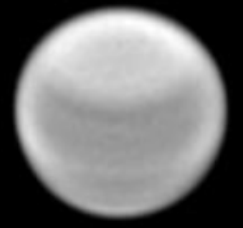
Goals of the device

- The first goal at Pic du Midi is to have a device equivalent to an **active** optic in order to compensate the optical and mechanical deformations of the instrument

This point is often the main weakness of telescopes from 0,4 to 2 m

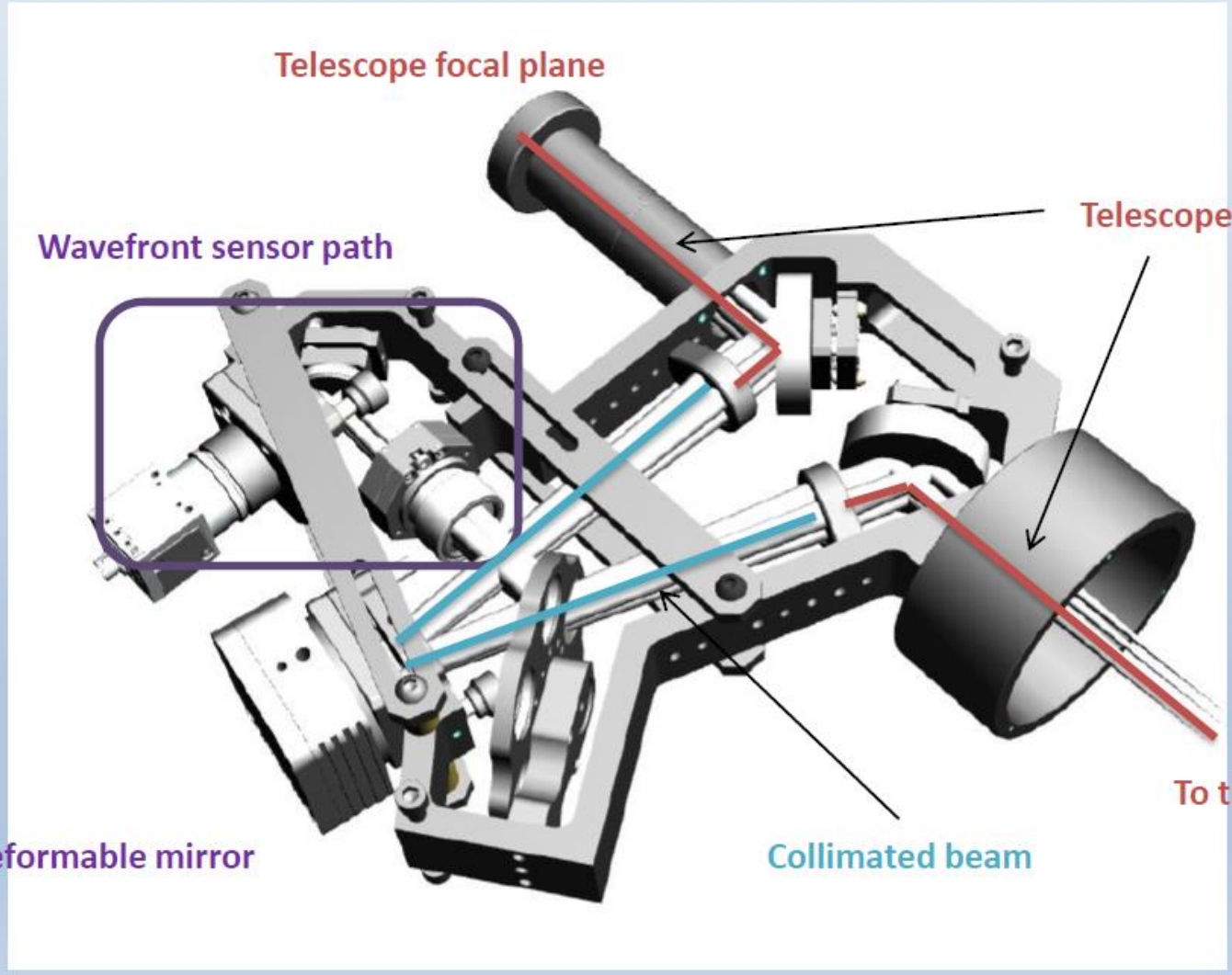
- The second goal is adaptive mode that will be particulary interesting for Uranus, and CH4 images of Jupiter and Saturn





5°
Derotation 4 x 15 mn

CIAO


Telescope focal plane
Telescope f#
Wavefront sensor path
To the scientific camera
Deformable mirror
Collimated beam

CIAO

The wavefront sensor

- Shack-Hartmann 12x12 microlenses
- 1.2kHz
- 20 nm rms accuracy at 5000 photons per microlens

The deformable mirror

- Monomorph piezo-electric with 40 actuators
- > 1kHz
- > 10 mm diameter
- < 15 nm rms WFE accuracy for low orders
- > 5µm PtV of curavture and astigmatism

CIAO

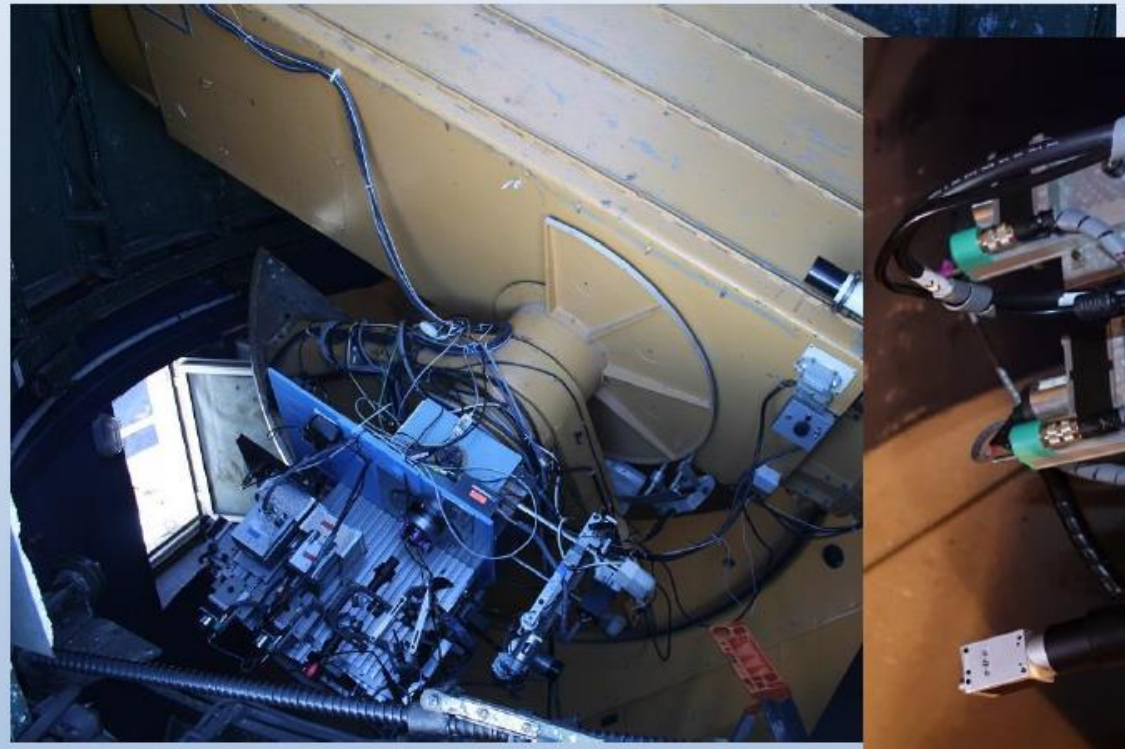
Spec

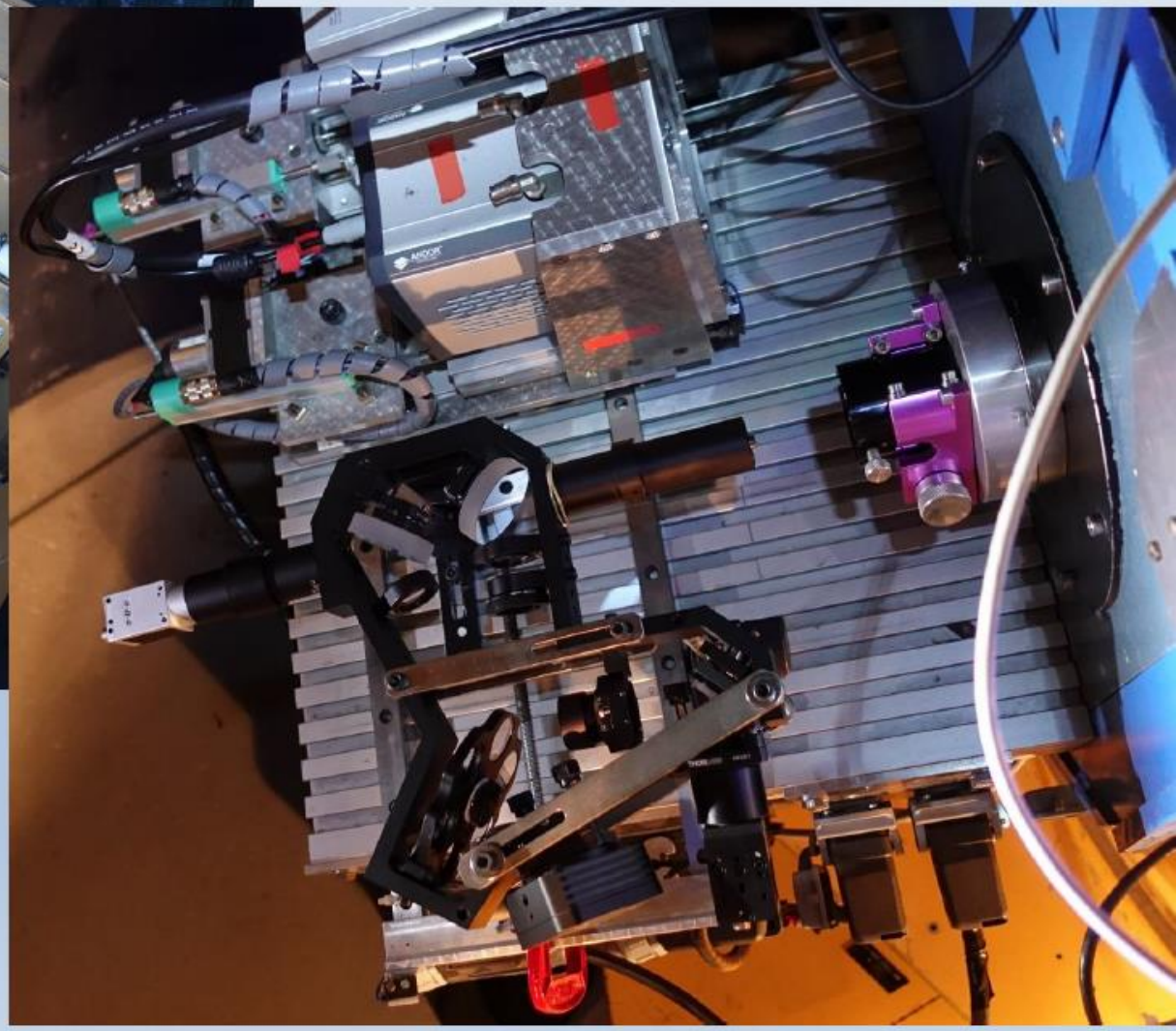
- The design work in the range of f/10 to f/17
- Field : 8x8 mm at f/17
- 2'' or 3'' standard adaptation
- Rejection Bandwidth : up to 100 Hz

(magnitude 5 with a 1 meter telescope)

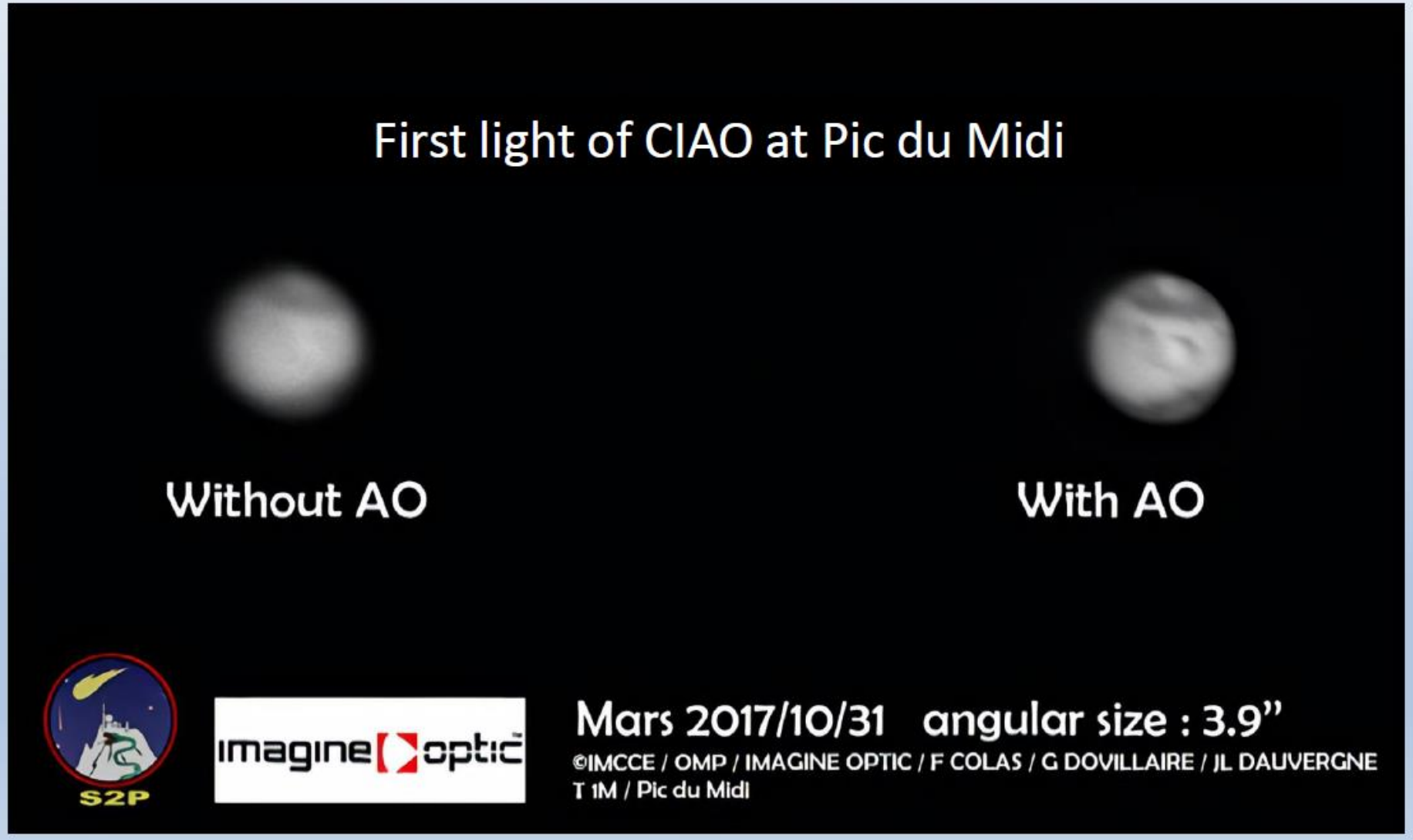
- Strehl = 0,8 between 0,4 to 0,7µm
- Easy access to the WFS and the DM
- The dichroic glass can be easely changed
- Field mask for extended targets

CIAO's First light run, october 2017

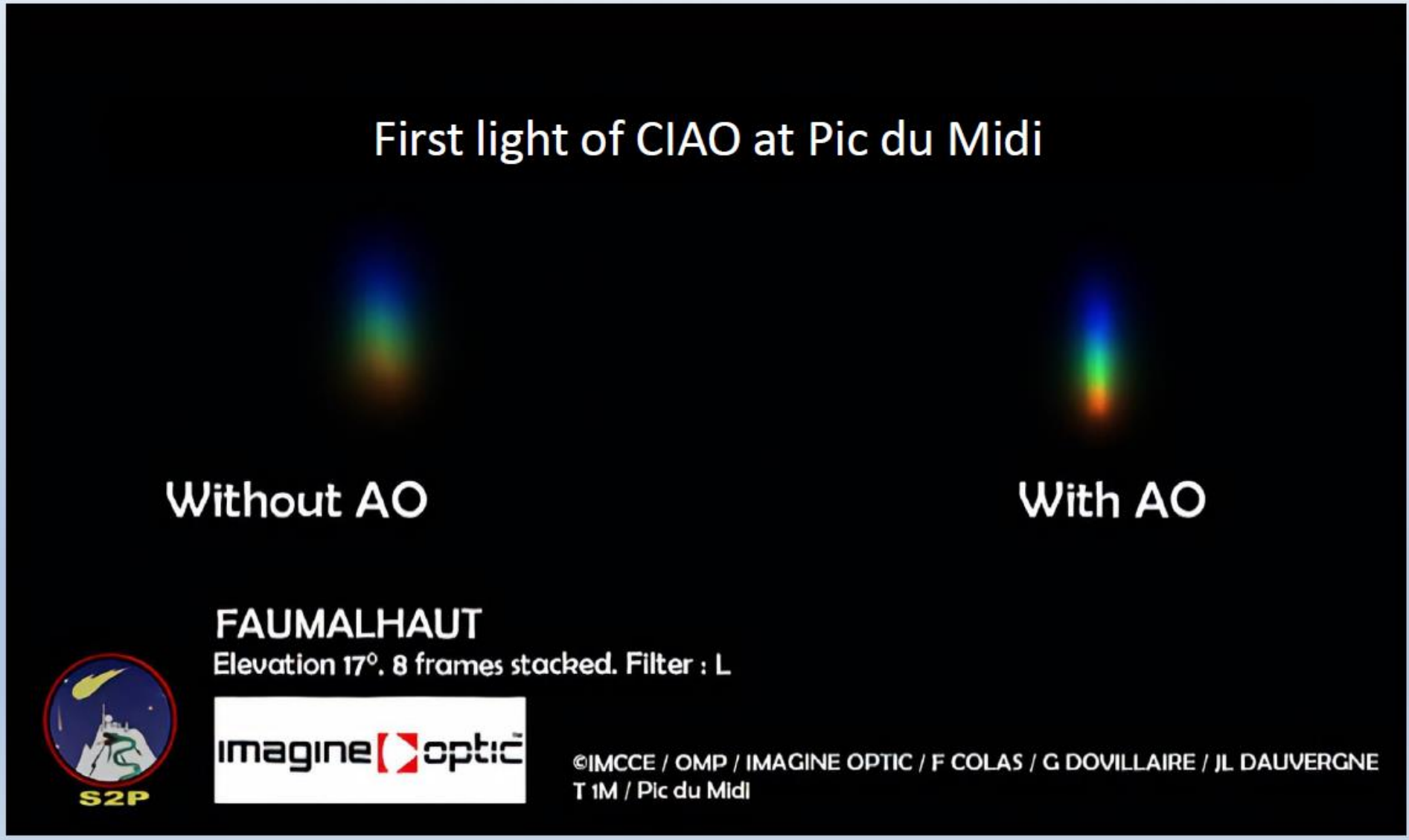




CIAO

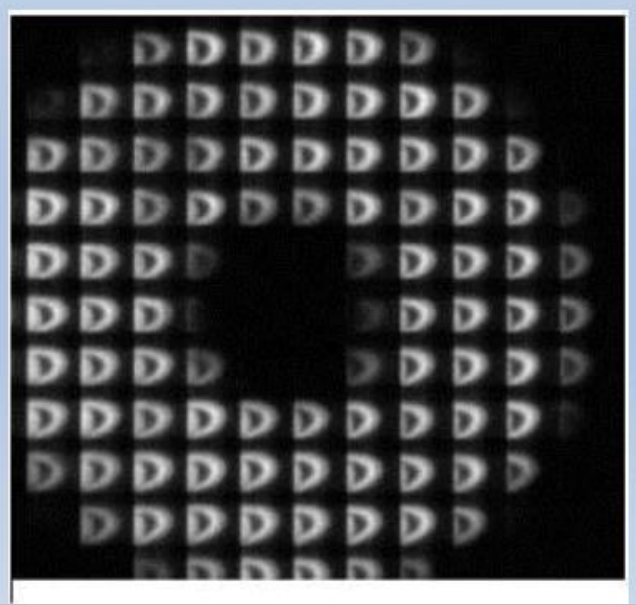

First light of CIAO at Pic du Midi
Without AO
With AO
S2P
Mars 2017/10/31 angular size : 3.9”
©IMCCE / OMP / IMAGINE OPTIC / F COLAS / G DOVILLAIRE / JL DAUVERGNE
T 1M / Pic du Midi

CIAO


First light of CIAO at Pic du Midi
Without AO
With AO
FAUMALHAUT
Elevation 17°. 8 frames stacked. Filter : L
S2P
©IMCCE / OMP / IMAGINE OPTIC / F COLAS / G DOVILLAIRE / JL DAUVERGNE
T 1M / Pic du Midi

July 2018 run

- We add an atmospheric refraction corrector
- We change the optical configuration to get less micro lenses and to enhance sensitivity
- We test the extended object mode



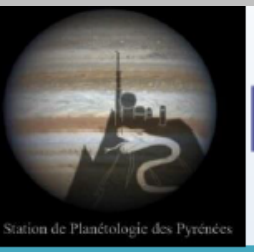
shack **hartmann** with extended object

July 2018 run

- Active optic mode, most of the “amateur” telescope are not well aligned

Lucky Imaging, with active optic and réfraction corrector

First order Zernike polynomials fit



l'Observatoire de Paris

imagine optic™

Conclusion

- We managed to build an **adaptive optics system** dedicated to **high resolution imaging of planets**
- We used on the shelf components to reduce the cost of the system for the end user
- The system allows correcting the air turbulence but also the residual of static aberrations coming from the telescope (thermal, gravity…)
- It enhance image but do not make miracle !

What's next ?

- **Increase the sensitivity** to be able to use fainter targets as a guide star
- Modify the software to include specific features in tilt correction (in case of issues in telescope pointing stability)
- Add software feature to allow **fine focus correction by the deformable mirror.**
- Add a internal source to allow a system calibration even if the system is connected to the telescope.
- Enhance extended source mode

T1M – Pic du Midi

Versatile instrument (Swiss knife for solar system studies and beyond !)
Open to a large community

- Long exposure CCD camera : Astrometry and Photometry (TN0, NEO, asteroids, comets, GRB, GW..)
- sCMOS short pose camera :
- Fast photometry (occultation, NEO)
- Lucky imaging (giant planets)
- SIRIS SWIR camera: near satellites, giant planets, GRB, GW..
- Adaptive optics :
- - Satellites
- Giant planets
- .....

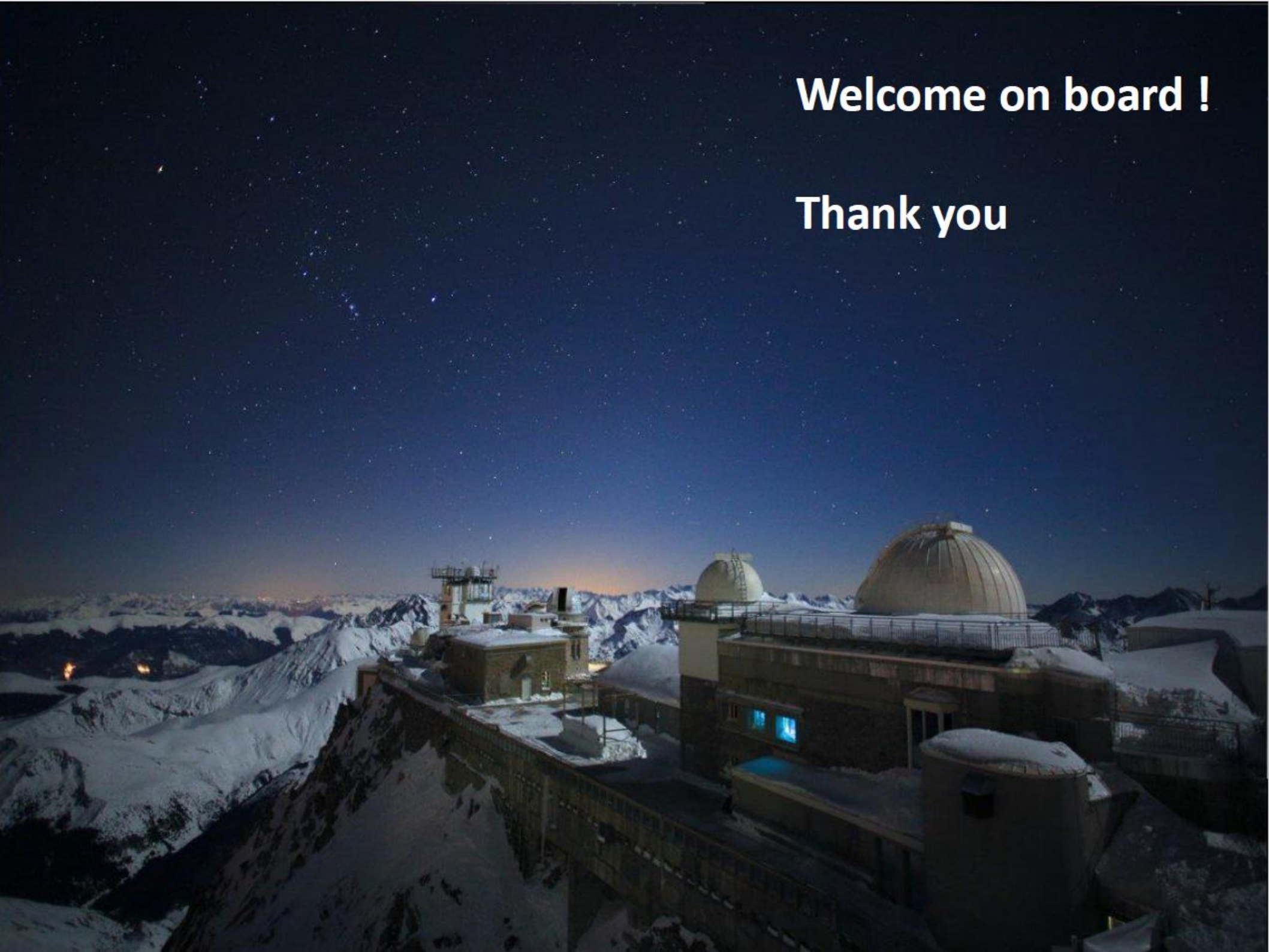
Publications : 6 to 7 articles per year for the last 10 years
Mode of operation : small team, flexible use

https://t1m.omp.eu/

2024: news rooms for 30 persons

Possibility to organise schools and workshop

1 m, 0,6 m telescopes available ans also small instruments !


Welcome on board !
Thank you