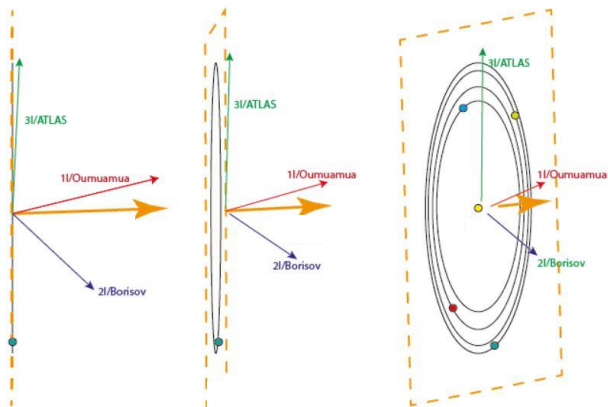


The interstellar comet 3I/ATLAS as seen by JANUS on board the JUICE spacecraft

E. Mazzotta Epifani¹, C. Tubiana², L.M. Lara³, L. Agostini¹, L. Penasa⁴, J.L. Rizos³, R. Hueso⁵,
F. Moreno³, A. Lucchetti⁴, F. Tosi¹, E. Dotto¹, M. Pajola⁴, I. Bertini⁶, S. Fornasier⁷, A. Aboudan⁸,
M. Aye⁹, E. Kersten¹⁰, K.-D. Matz¹⁰, R. Politi², F. Trauthan⁶, A. Zinzi¹¹, R. Evill¹², A. Diez¹²,
I. Belgacem¹³, J.M. Castro Marin³, V. Della Corte¹⁴, S. Hviid¹⁰, T. Roatsch¹⁰, N. Schmitz¹⁰, M. Patel¹⁵,
M. Read¹⁵, K. Stefanov¹⁵, G. Portyankina¹⁰, P. Palumbo²
& the JANUS team

¹INAF – OAR (Osservatorio Astronomico di Roma), Via Frascati 33, 00040 Monte Porzio Catone (Roma), Italy

The ISO 3I/ATLAS

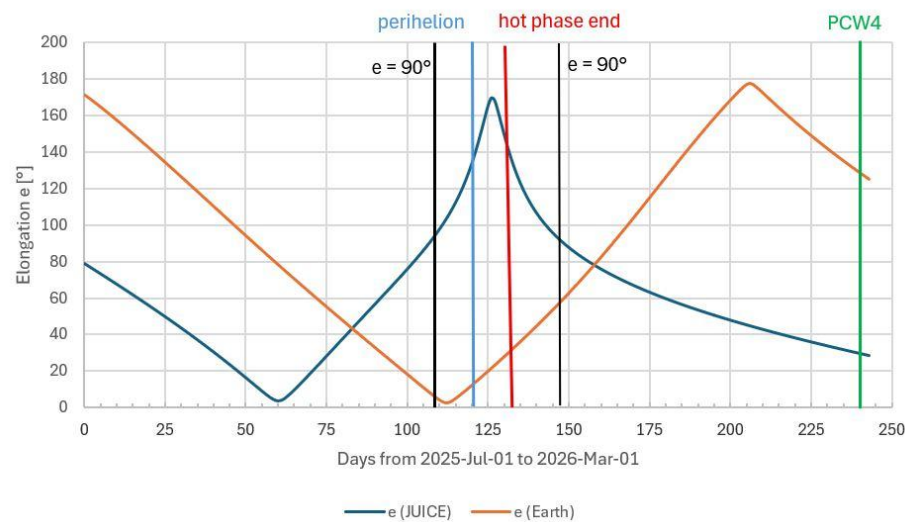


Credit: P. Panunzi

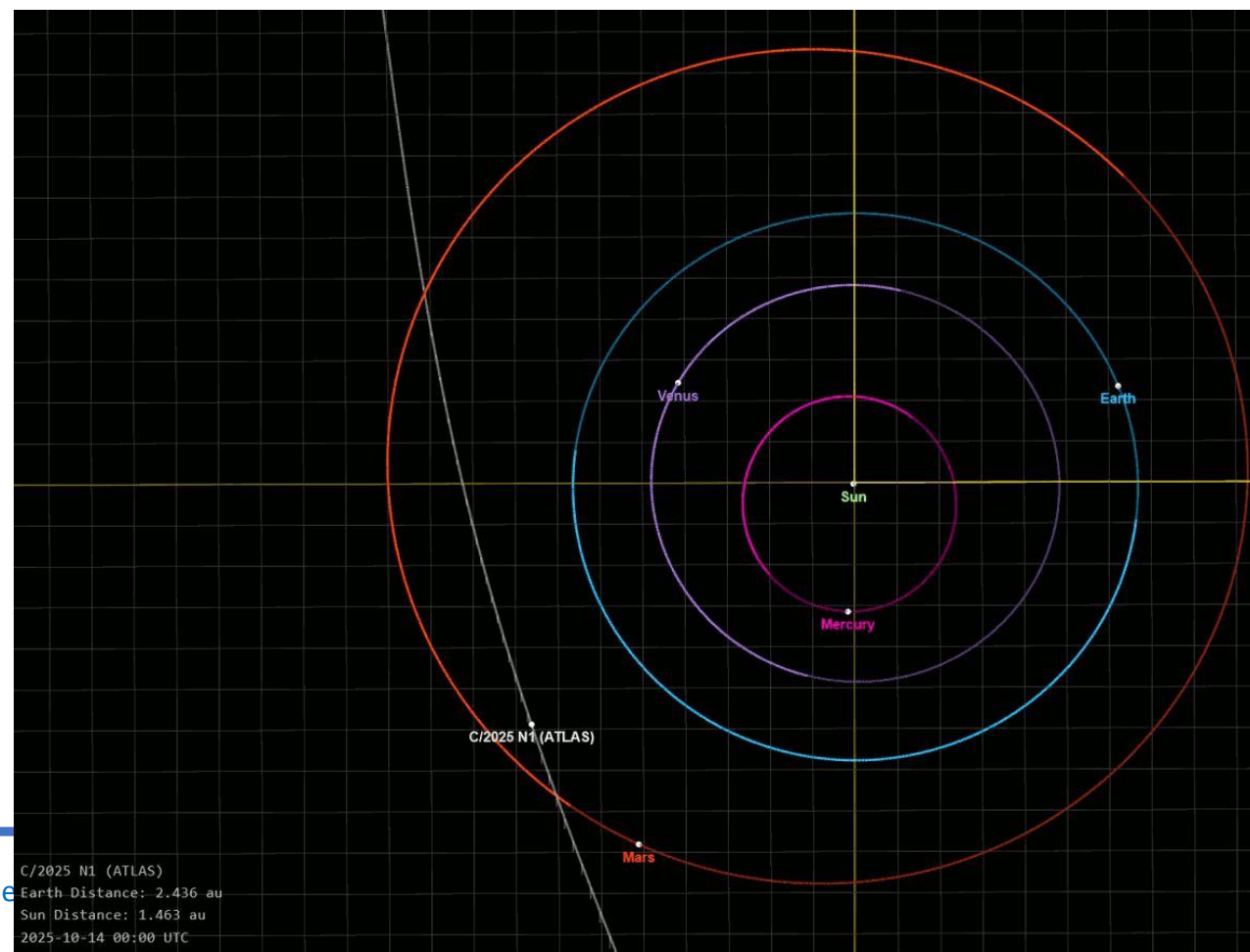
Perihelion passage (29 Oct. 2025)

$r_q = 1.36$ au and $e = 12.1^\circ$:

not observable by ground-based telescopes



- Discovered in July 2025, inbound, at $r_h \sim 4.5$ au (during JUICE cruise to the Jovian system)
- Target of an impressive observational campaign since the discovery, both from ground-based and space-born telescopes, observatories and other instruments



bodies and technologie

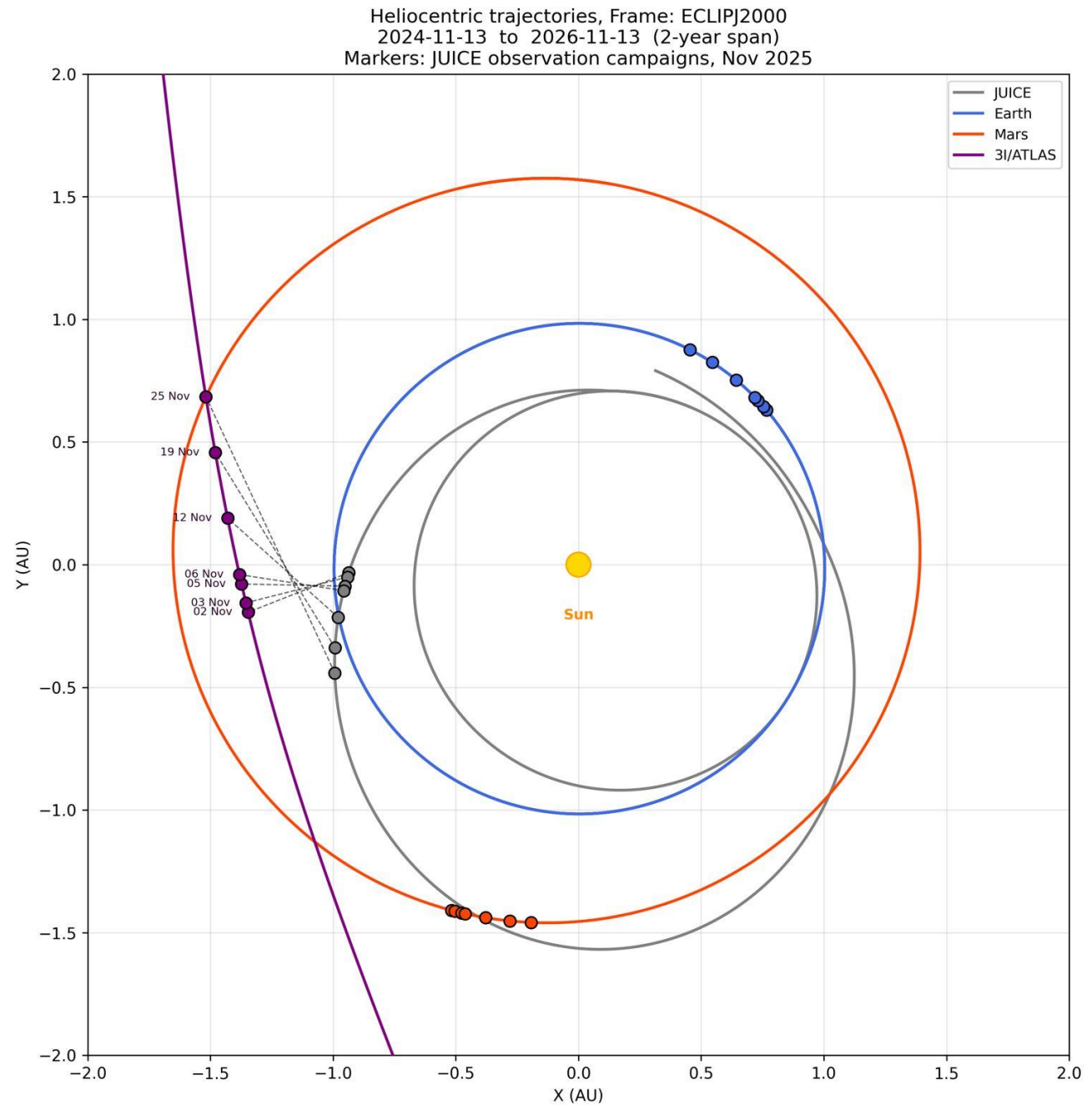
C/2025 N1 (ATLAS)
Earth Distance: 2.436 au
Sun Distance: 1.463 au
2025-10-14 00:00 UTC

The ISO 3I/ATLAS

- JUICE observation campaign: over 3 weeks after perihelion (Oct-Nov 2025)
- 3I/ATLAS – JUICE distance: 0.42 – 1.24 au
- different observing epochs

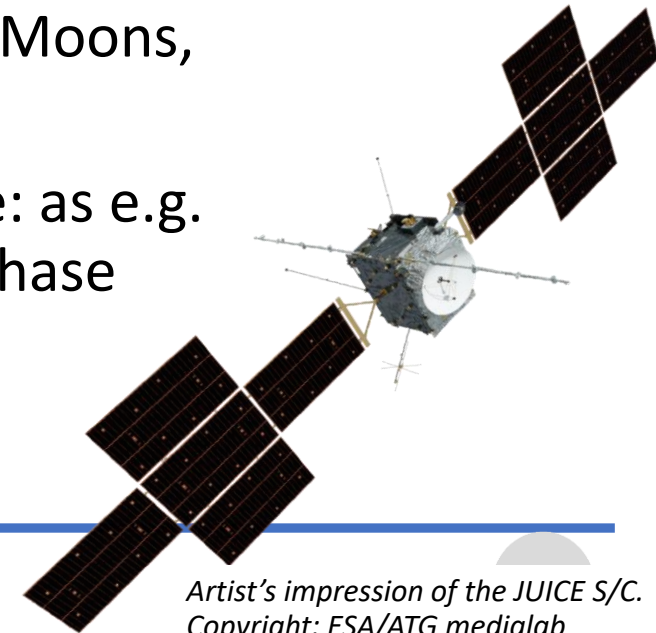
Perihelion passage (29 Oct. 2025)

$r_q = 1.36$ au and $e = 12.1^\circ$:
well accessible from JUICE



The ESA JUICE (JUperiter ICy Explorer) mission

- First ESA L-class mission, launched on 14 April 2023
- En-route to the Jovian system
- Main mission goal: in-depth characterisation of the Jovian system
- Payload: 10 remote sensing, geophysical and in-situ instruments designed to globally characterise Jupiter, its Moons, and their environment
- «Target of Opportunity» science: as e.g. comet 3I/ATLAS, during cruise phase



The JANUS camera onboard JUICE

Scientific camera system

PI: P. Palumbo

CoPI: G. Portyankina

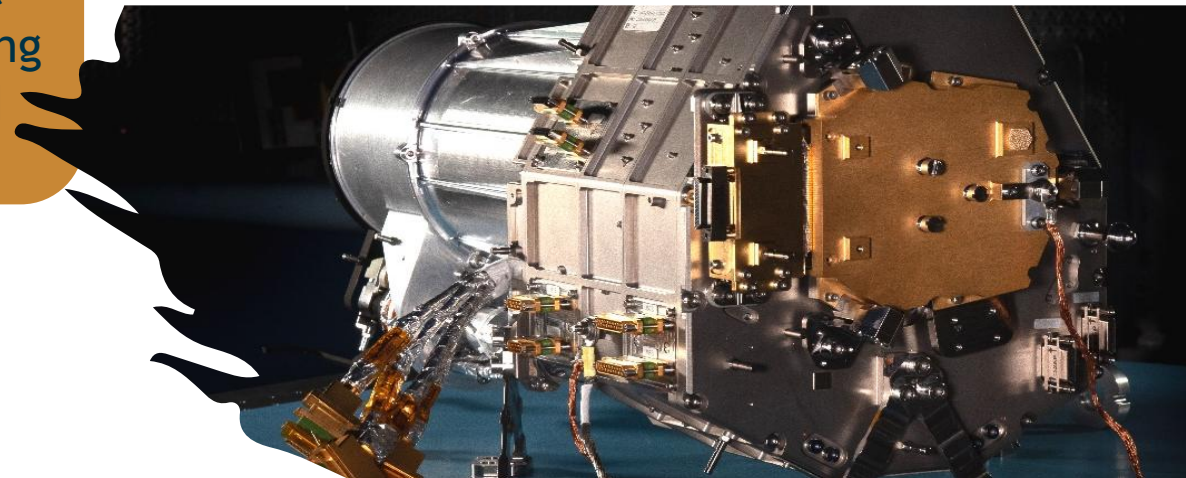
Characterize **Ganymede**, **Callisto**, and **Europa** as planetary bodies, including their potential habitability, with special focus on Ganymede

Characterize and study the physical properties of other satellites of the Jupiter system, including **Io**, the **irregular**, and **inner satellites**

Study and monitor the external layers (down to the troposphere) of **Jupiter's atmosphere**

Perform a physical characterization of the **ring system**

Study the **exospheres** of the Galilean satellites with special emphasis on **Io** and **Europa**



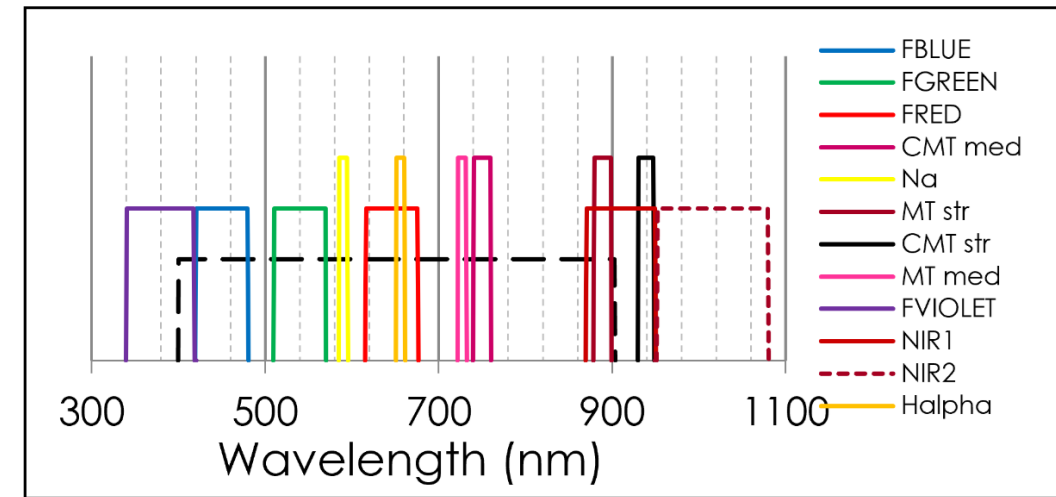
The JANUS camera onboard JUICE

Scientific camera system

PI: P. Palumbo

CoPI: G. Portyankina

- Aperture: 116 mm
- Focal length: 467 mm
- FOV = $1.29^\circ \times 1.72^\circ$ (along track x across track)
[Swath of 15 km from 500 km and 3×10^4 km from 10^6 km]
- Teledyne-e2v CMOS detector with 1504×2000 pixels
- iFOV: $15 \mu\text{rad}/\text{pix}$
- Resolution: 7.5 m/pix at 500 km, 3 m/pix at 200 km, 15 km/pix at 10^6 km
- **13 filters covering the wavelength range 340 – 1080 nm (near UV, Visible, Near IR)**

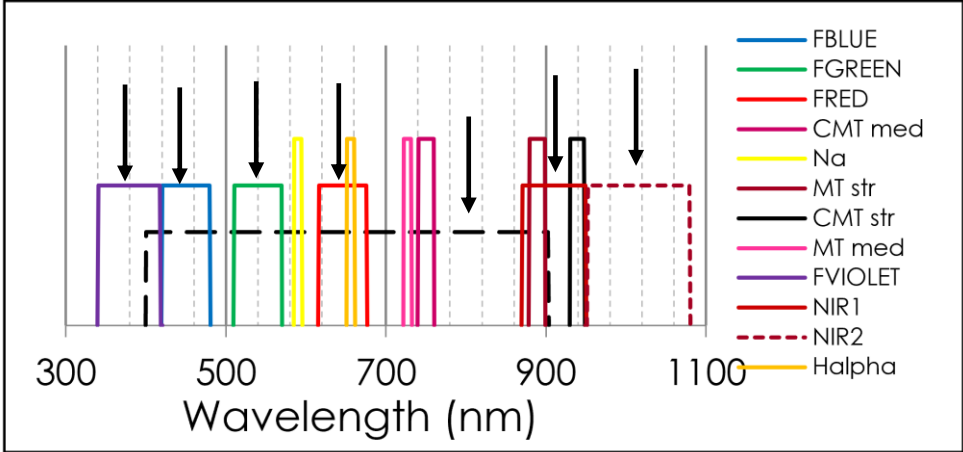


F1	PAN	650/500	Panchromatic (clear) – monochromatic imaging
F2	BLUE	450/60	Blue – satellite colours
F3	GREEN	540/60	Green, background for Na – satellite colours
F4	RED	646/60	Red, background for H α – satellite colours
F5	CMT medium	750/20	Continuum for medium methane band, geology, oxygen
F6	Na	590/10	Sodium D-lines in exospheres
F7	MT strong	889/20	Strong methane band
F8	CMT strong	940/20	Continuum for strong methane band, Fe $^{2+}$ on satellites
F9	MT medium	727/10	Medium methane band
F10	Violet	380/80	UV slope
F11	NIR 1	910/80	Fe $^{2+}$, Io lava spots
F12	NIR 2	1015/130	Fe $^{2+}$, Io lava spots – GALA laser altimeter footprint
F13	H α	656/10	H α -line for aurorae and lightning

The JANUS campaign at comet 3I/ATLAS

123 images in 5 observing slots, using 7 filters, with t_{exp} from 1 to 120 sec with sequence of images with increasing exposure times (e.g. F1: 1 s, 5 s, 15 s, 30 s, 60 s, 120 s, allowing spectral coverage in the range 340-1080 nm

Date	r [au]	$d_{S/C}$ [au]	α [°] (JUICE)	# images	Filters	
5 Nov. 2025	1.38	0.43	8.5	28	F1 (650), F10 (380), F4 (646), F11 (910)	PAN + Violet, Red, near-IR
6 Nov. 2025	1.38	0.44	12.4	28	F1 (650), F2 (450), F3 (540), F12 (1015)	PAN + Blue, Green, near-IR
12 Nov. 2025	1.44	0.6	34.4	18	F1 (650), F10 (380), F4 (646), F11 (910)	PAN + Violet, Red, near-IR
19 Nov. 2025	1.55	0.93	41.3	18	F1 (650), F10 (380), F4 (646), F11 (910)	PAN + Violet, Red, near-IR
25 Nov. 2025	1.67	1.24	40.7	31	F1 (650), F2 (450), F3 (540), F4 (646), F11 (910)	PAN + Blue, Green, Red, near-IR

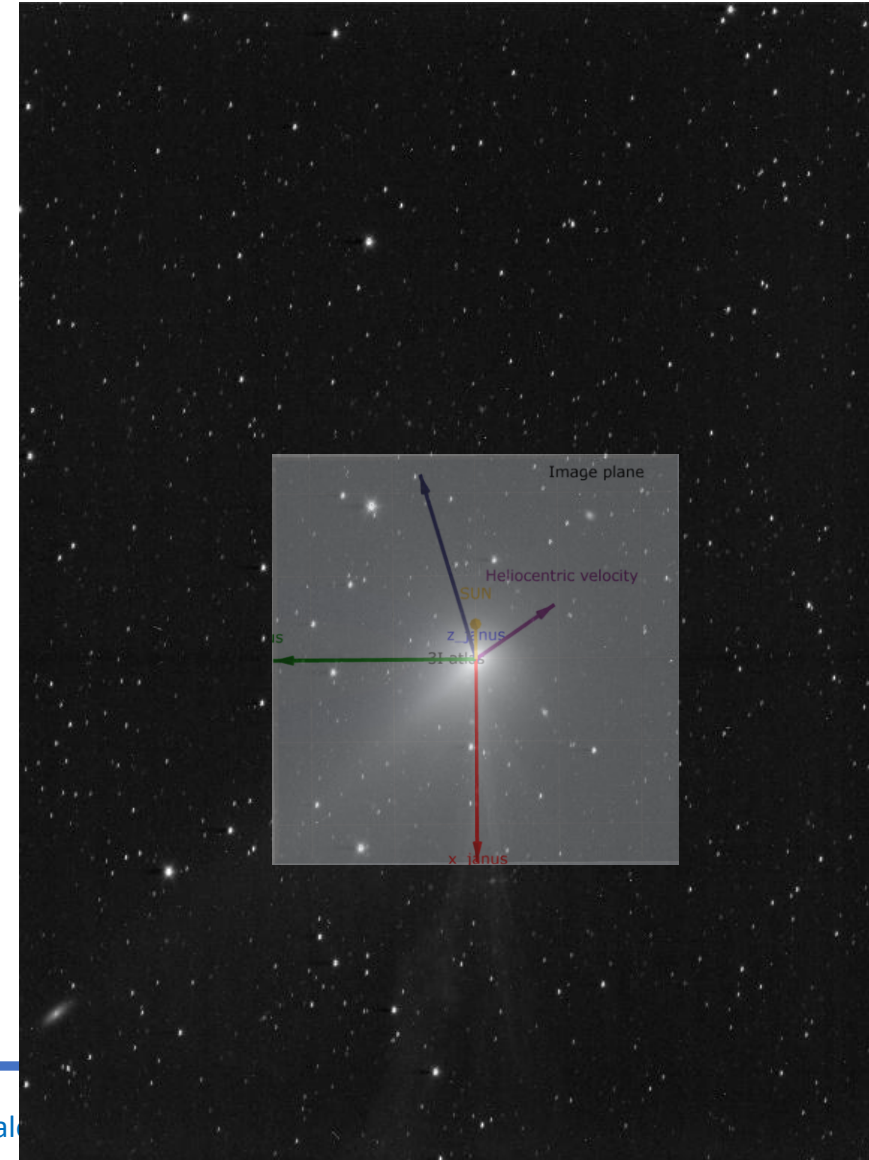


The JANUS campaign at comet 3I/ATLAS

Example of image in the **PAN filter (F01)** acquired on **5, 6, 12, 19 and 25 November 2025**.

Projected image vertical size: 1.93 million km.

- x_janus
- y_janus
- z_janus
- SUN
- Heliocentric velocity
- Celestial North

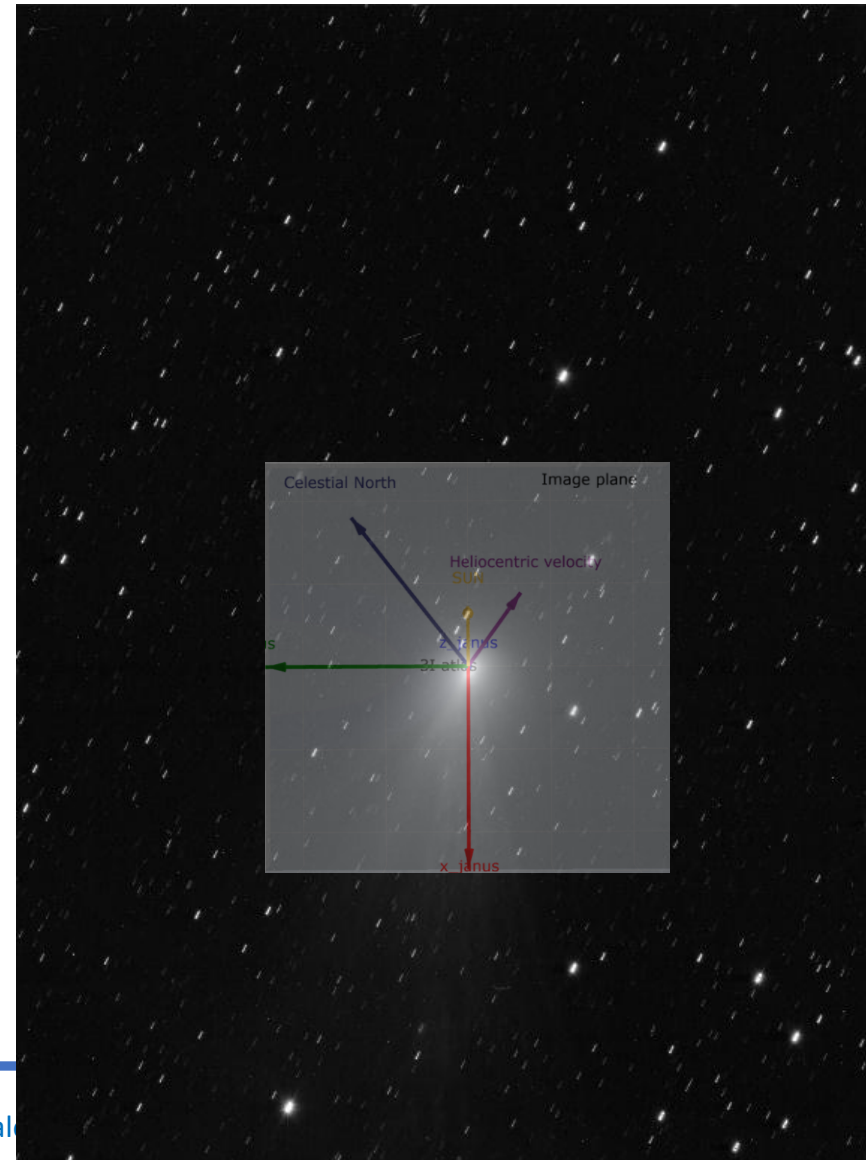


The JANUS campaign at comet 3I/ATLAS

Example of image in the **PAN filter (F01)** acquired on 5, **6**, 12, 19 and 25 November 2025.

Projected image vertical size: 1.97 million km.

- x_janus
- y_janus
- z_janus
- SUN
- Heliocentric velocity
- Celestial North

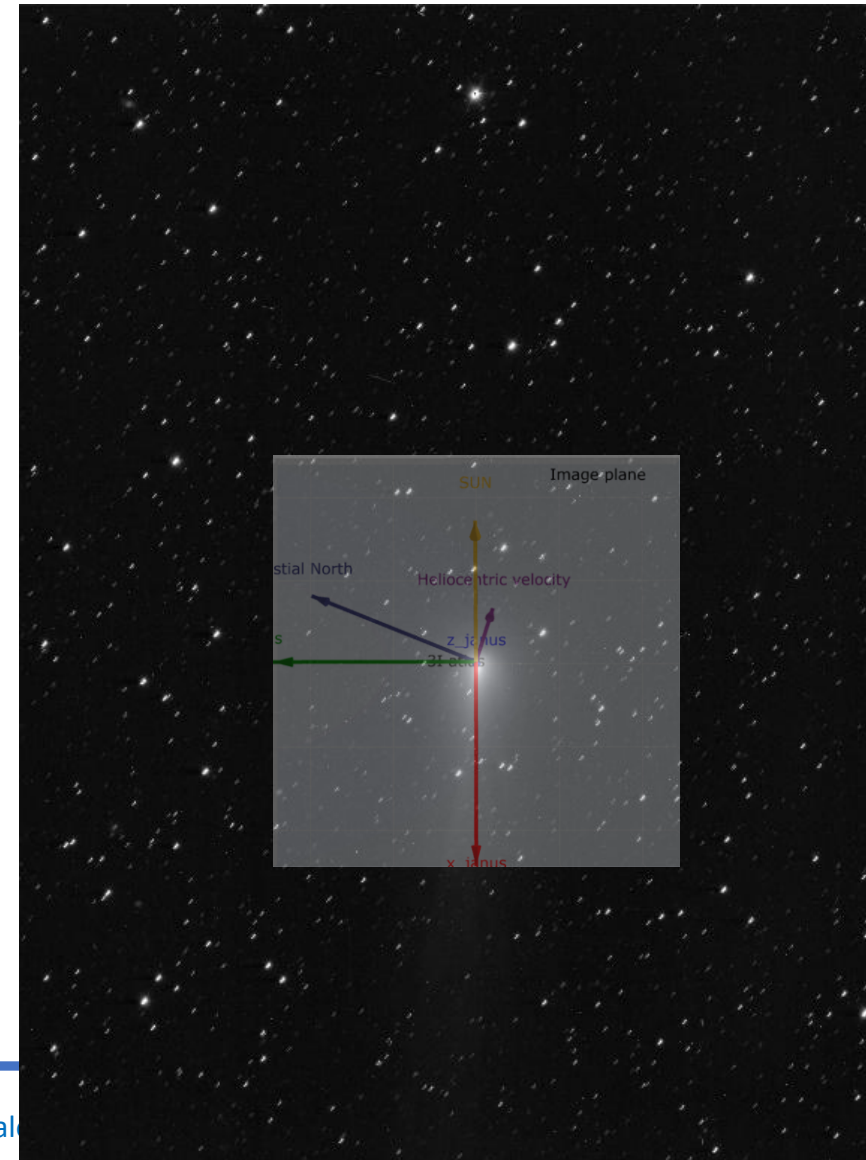


The JANUS campaign at comet 3I/ATLAS

Example of image in the **PAN filter (F01)** acquired on 5, 6, **12**, 19 and 25 November 2025.

Projected image vertical size: 2.69 million km.

- x_janus
- y_janus
- z_janus
- SUN
- Heliocentric velocity
- Celestial North

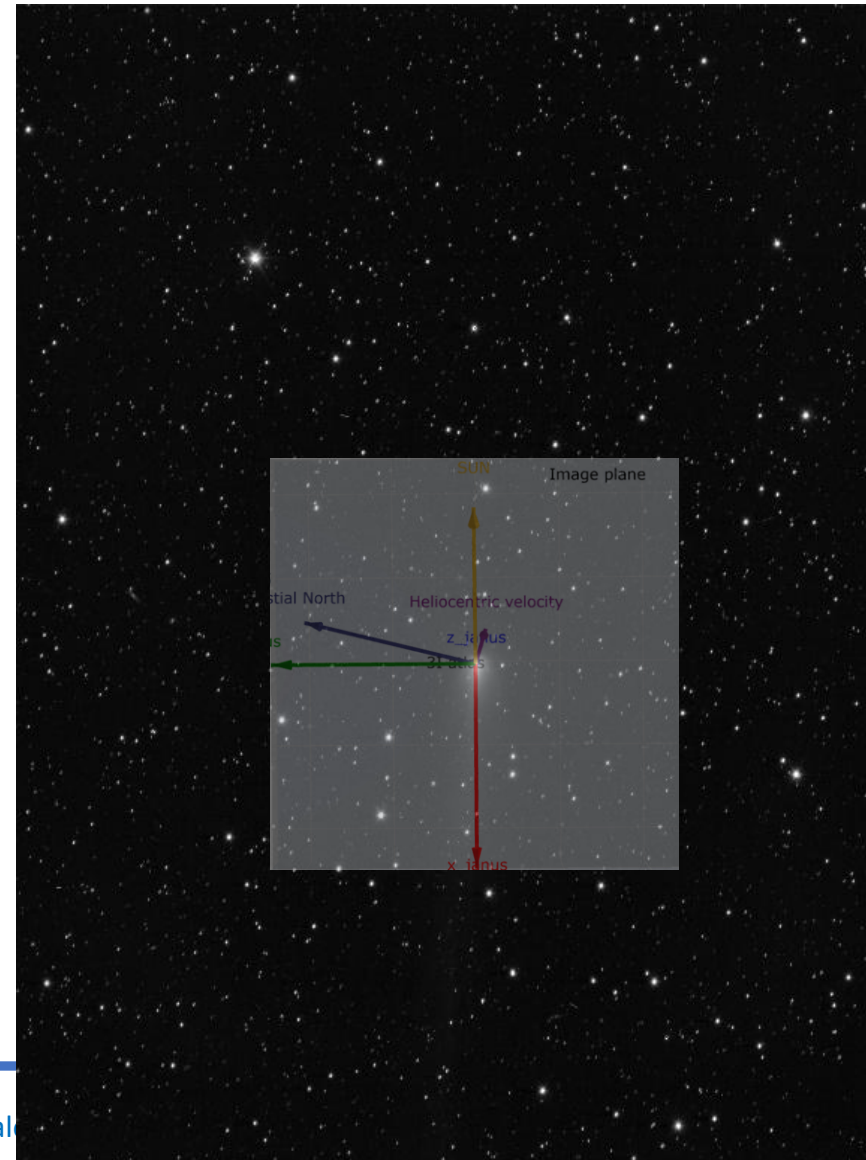


The JANUS campaign at comet 3I/ATLAS

Example of image in the **PAN filter (F01)** acquired on 5, 6, 12, **19** and 25 November 2025.

Projected image vertical size: 4.17 million km.

- x_janus
- y_janus
- z_janus
- SUN
- Heliocentric velocity
- Celestial North

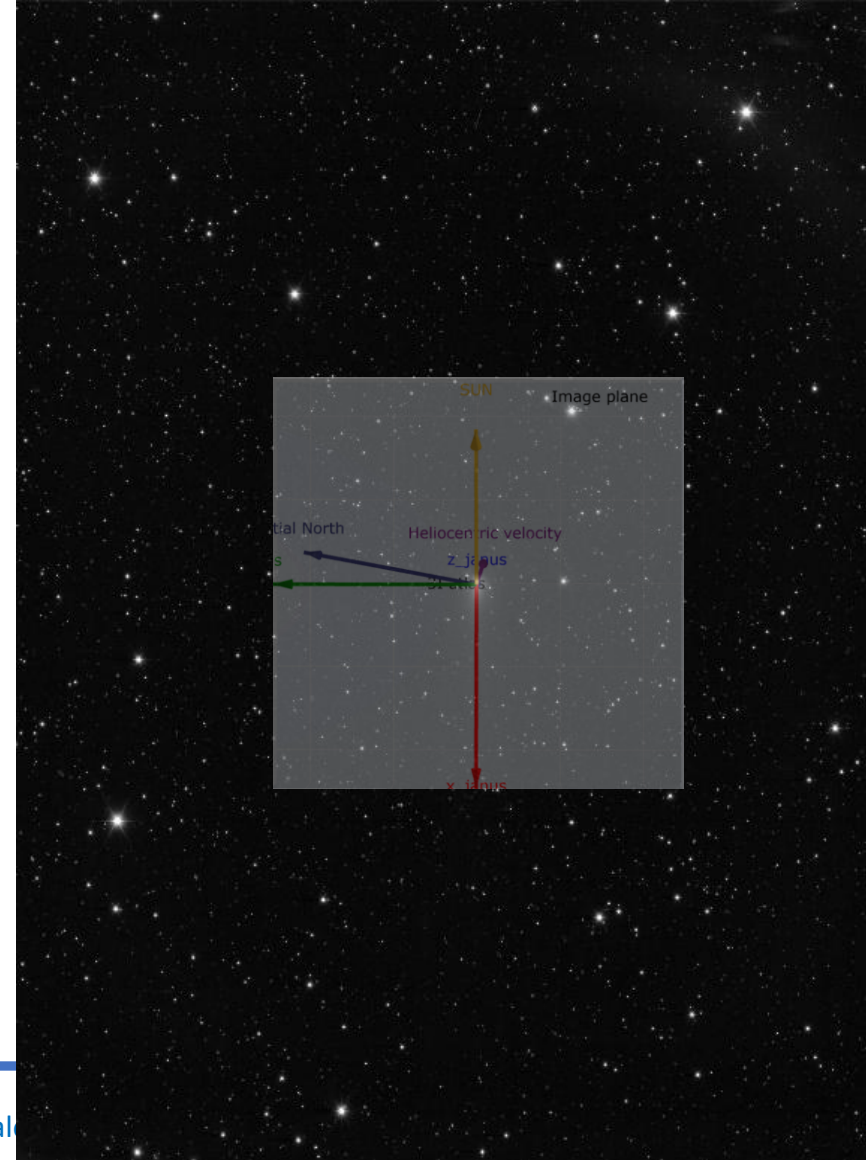


The JANUS campaign at comet 3I/ATLAS

Example of image in the **PAN filter (F01)** acquired on 5, 6, 12, 19 and **25** November 2025.

Projected image vertical size: 5.57 million km.

- x_janus
- y_janus
- z_janus
- SUN
- Heliocentric velocity
- Celestial North



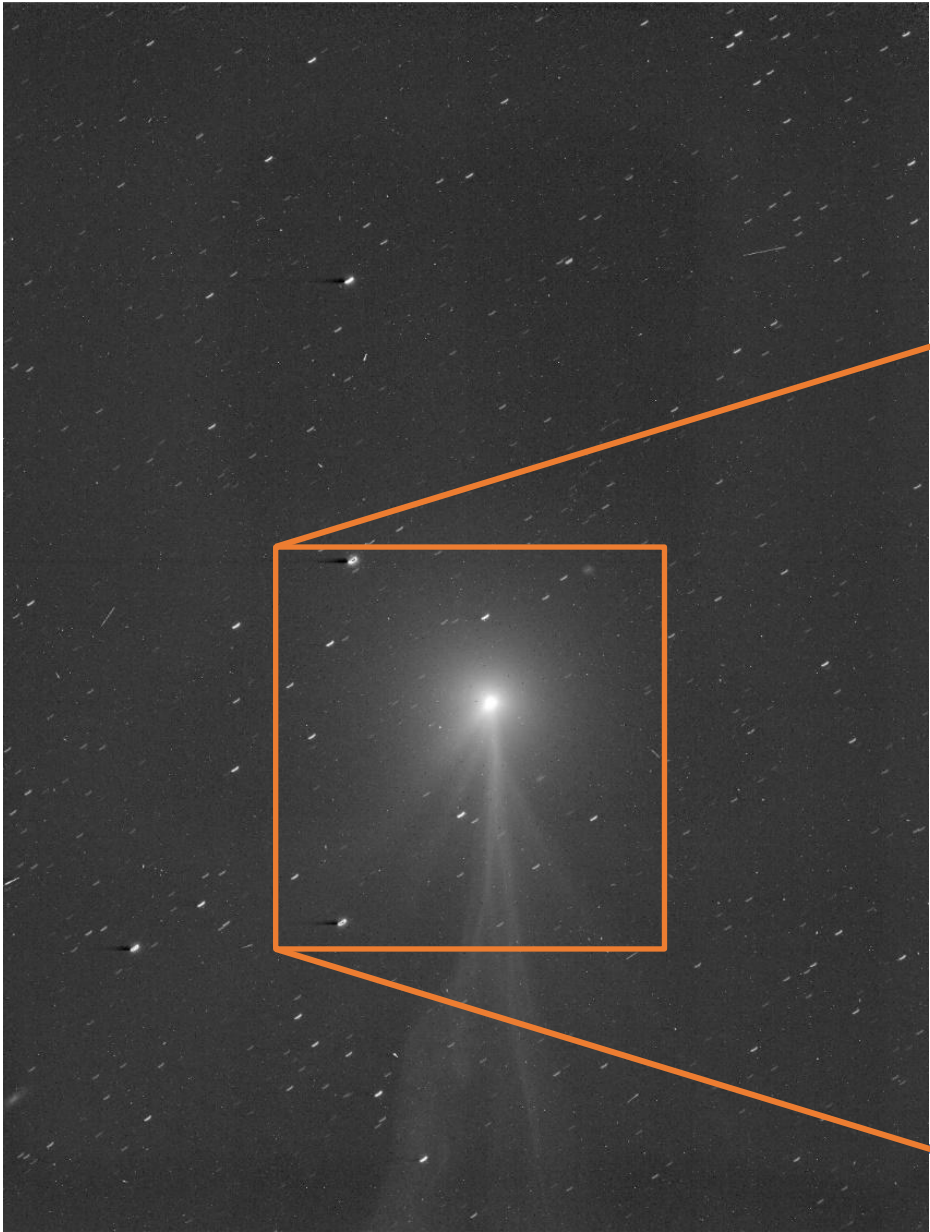
The JANUS campaign at comet 3I/ATLAS

Example of images in the **Violet filter (F10)** acquired on **5, 12, and 25** November 2025.

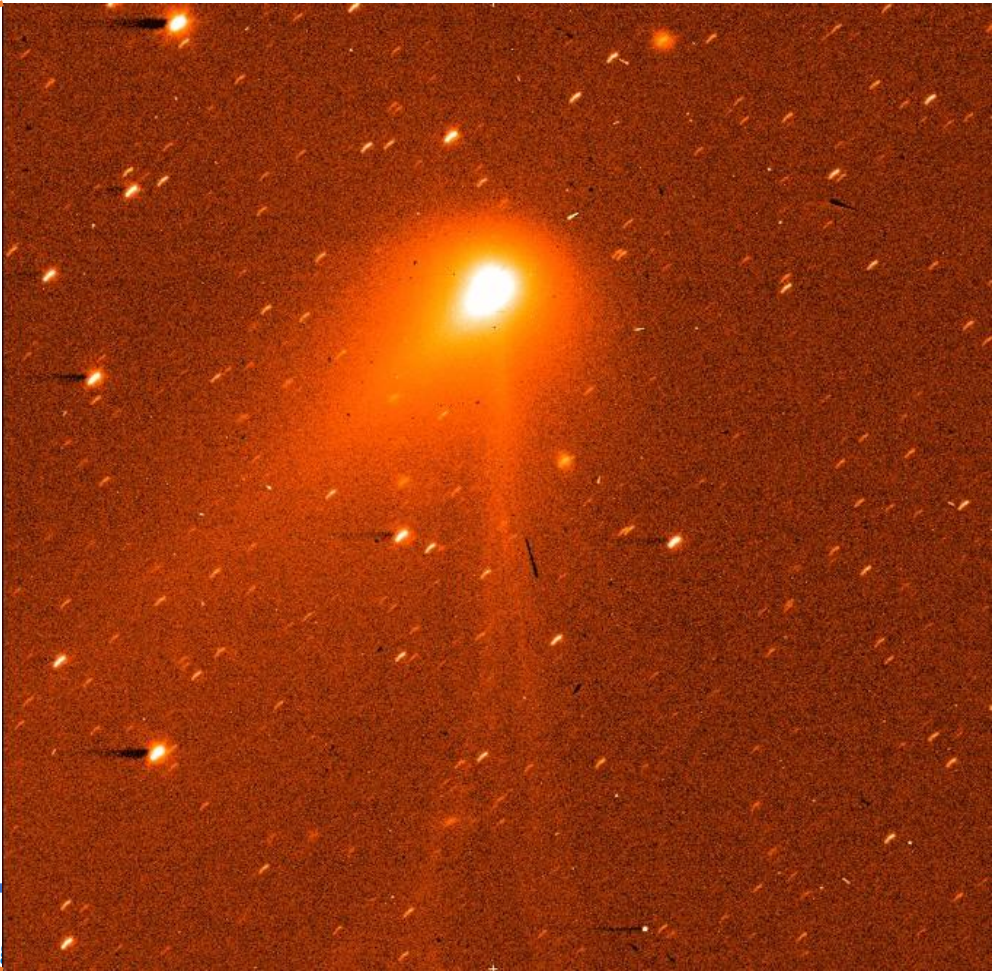
Projected image vertical size: 1.93, 4.17, and 5.57 million km, respectively



The JANUS campaign at comet 3I/ATLAS



janus_par_sc_0815610318_0023_04_20251104t224341_0020__1.0	
Session	815610318, 2025-11-05
Filter	F04 ($\lambda_{central}$: 646 nm, $\Delta\lambda$: 60 nm)
Exposure time	90 s
Projected (sub) FOV	7.50 x 7.5 [10^5 km]



janus_par_sc_0815610318_0019_10_20251104t223836_0020__1.0	
Session	815610318, 2025-11-05
Filter	F10 ($\lambda_{central}$: 380 nm, $\Delta\lambda$: 80 nm)
Exposure time	112 s
Projected (sub) FOV	7.50 x 7.5 [10^5 km]

The JANUS campaign at comet 3I/ATLAS



PAN and colour images and sequences are being used for both *technical* and *scientific* exploitation:

- Application of the **calibration** pipeline (counts → scientific measurement unit, + further calibration steps to add more “classical” astronomical calibration – magnitudes etc.)
- **Correction** to recover a (known) artifact (Signal Deviation Baseline Shift) affecting much illuminated rows
- Investigation of **pointing stability** and of **tracking quality**, through a point-to-point image analysis
- Investigation of **saturation** and **recovery of saturated pixels** (for long exposure images), through a point-to-point image analysis
- **Morphological analysis** on selected images, for dust coma (PAN and RED filters), through “classical” enhancement techniques
- **Dust environment analysis**, through standard «classical» $Af\rho$ parameter
- **Color maps** through multicolour analysis
- Investigation of the **interaction with solar plasma**, through combined solar activity – UV filters analysis (cfr paper by Porter et al., *in press*, «Interstellar Object 3I/ATLAS as Observed by NASA PUNCH», describing 3I/ATLAS’ observations by PUNCH heliospheric explorer mission in September-November 2025)

The JANUS campaign at comet 3I/ATLAS

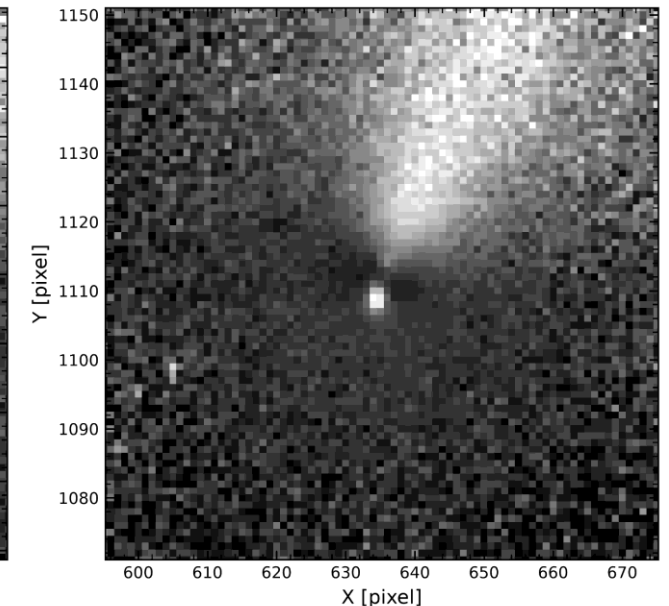
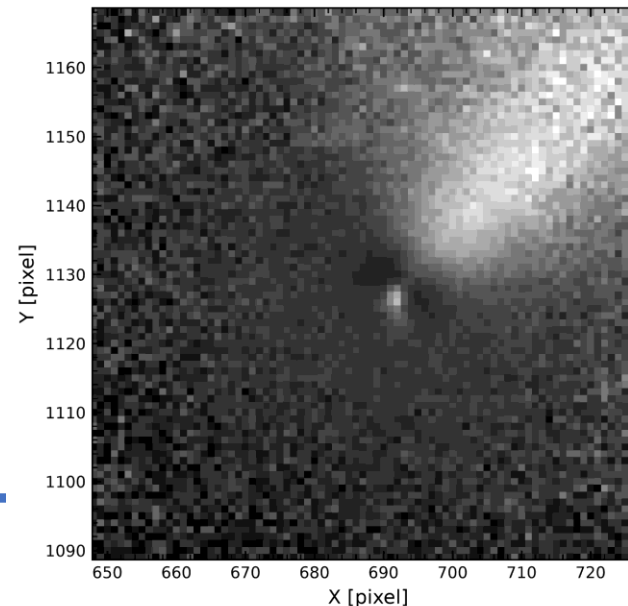
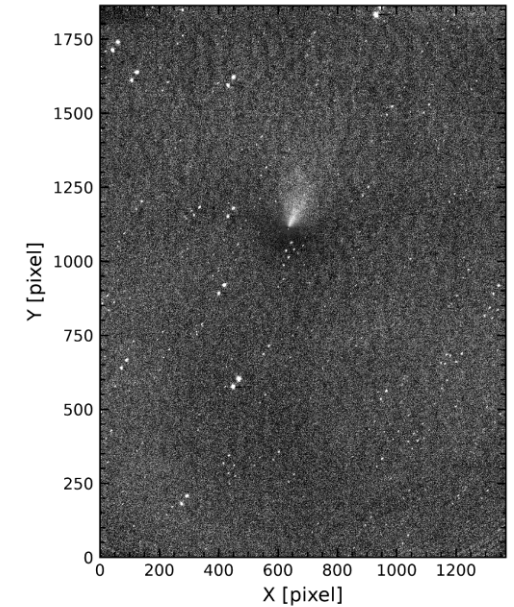
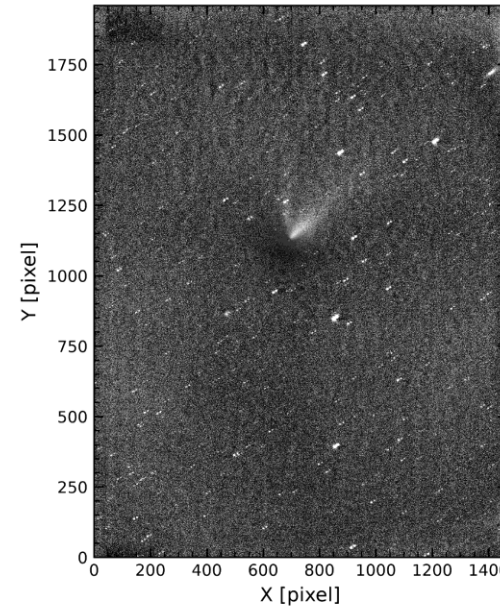


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The JANUS campaign at comet 3I/ATLAS – morphological analysis

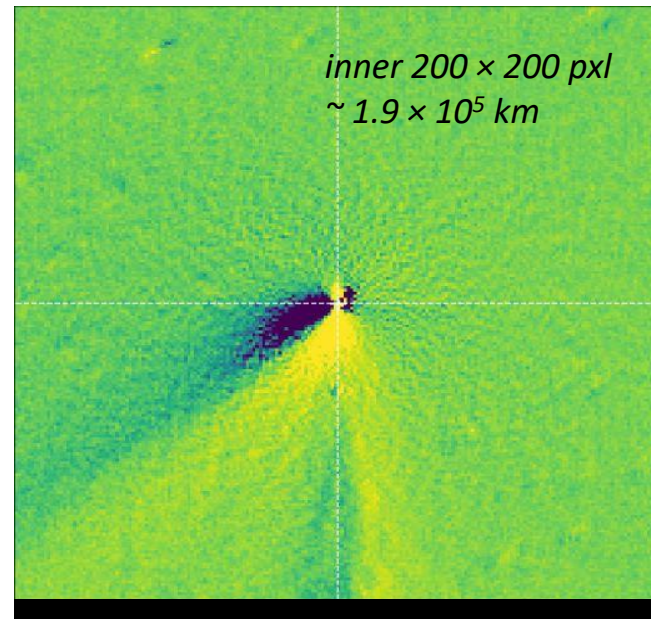
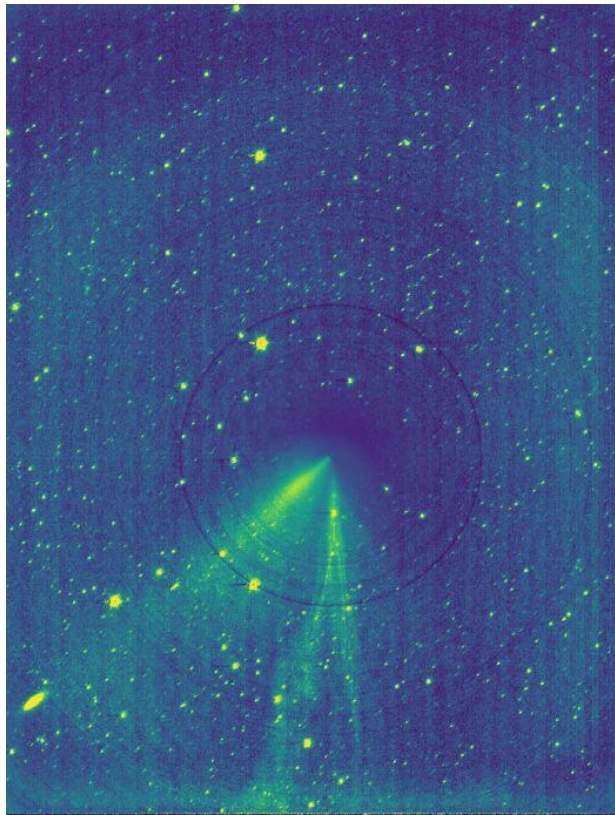
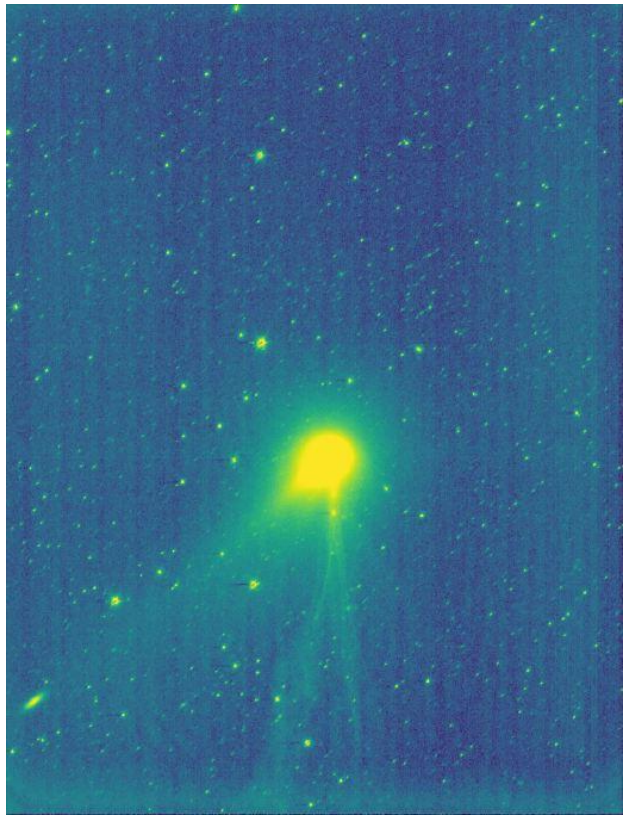
- We aim to study the coma morphology and its variations during the observing window
- We are applying some techniques (e.g. azimuthal median, Laplace filtering, ...) to enhance the structures in the dust coma
- Epoch: 2025-11-05 and 2025-11-06
- Stack of F01 ($\lambda_{central}$: 650 nm) images
- Division by Azimuthal median



hints of presence of a discrete active high-latitude source on the sunlit side

The JANUS campaign at comet 3I/ATLAS – morphological analysis

- We aim to study the coma morphology and its variations during the observing window
- We are applying some techniques (e.g. azimuthal median, Laplace filtering, ...) to enhance the structures in the dust coma

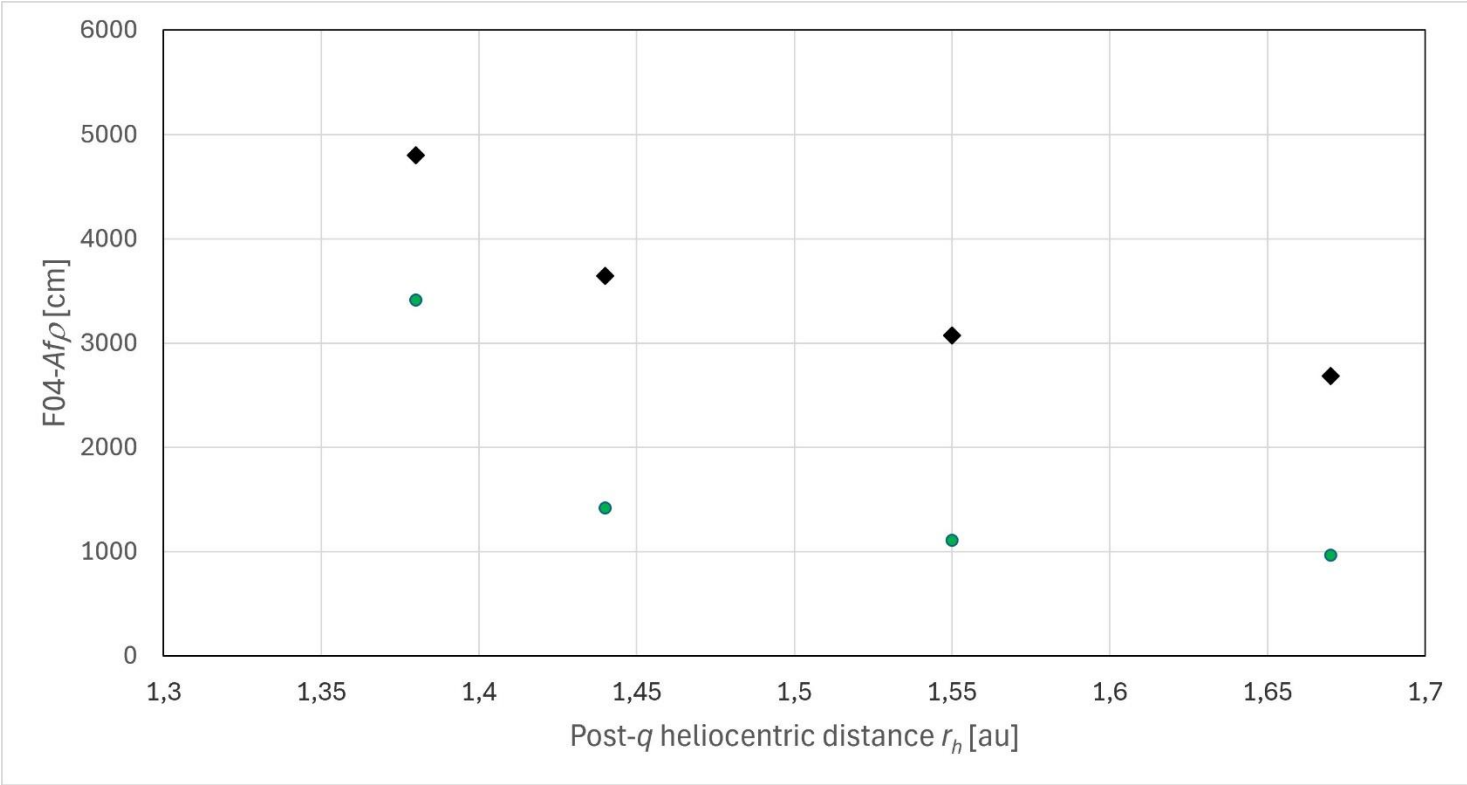


hints of presence of a discrete active high-latitude source on the sunlit side

5 Nov. 2025 – example of modified Larson–Sekanina rotational gradient filter (Larson & Sekanina 1984)

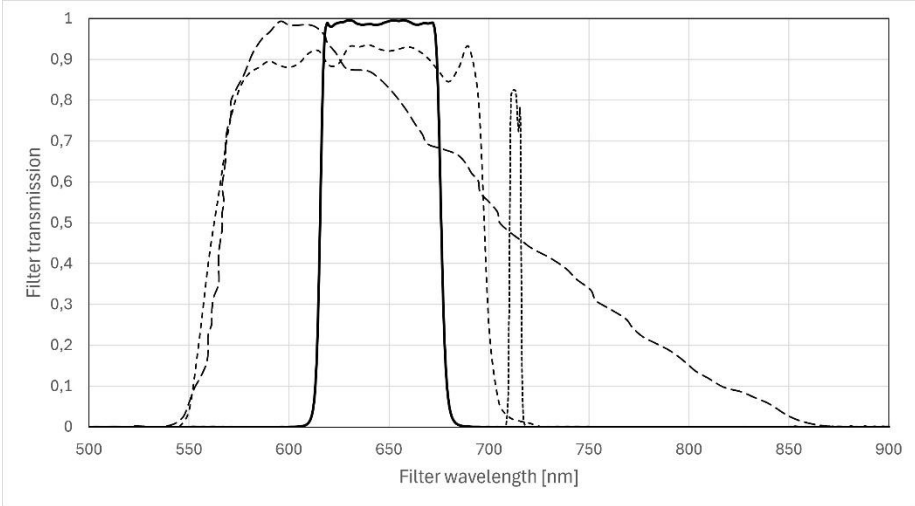
The JANUS campaign at comet 3I/ATLAS – dust environment

$Af\rho$ obtained from F04 (RED) images in aperture of $\rho \sim 10^4$ projected km and also corrected for the phase angle



Need of a further proper spectral correction?

Obs. slot	$Af\rho$ [cm]	$A(0^\circ)f\rho$ [cm]
5 November 2025	3414 ± 177	4803 ± 249
12 November 2025	1421	3651
19 November 2025	1107 ± 14	3072 ± 40
25 November 2025	967 ± 10	2683 ± 27

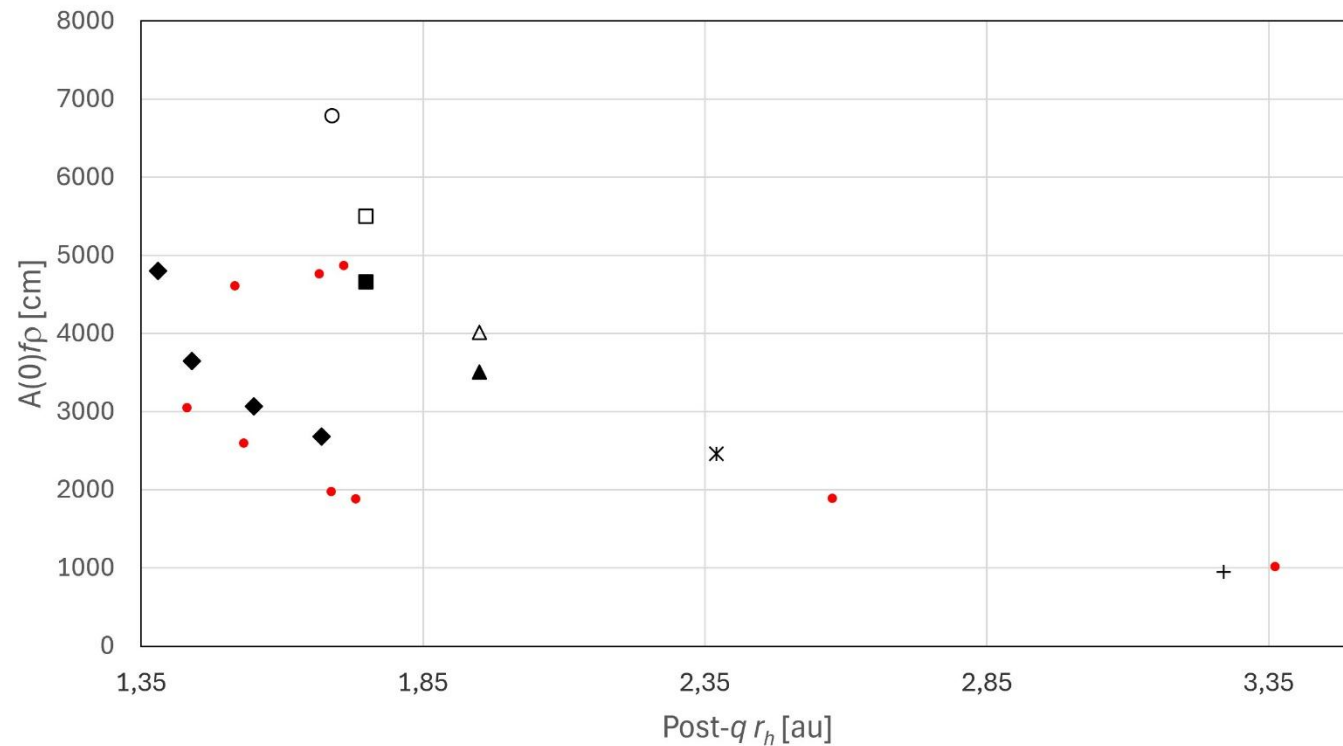


The JANUS F04 (RED) filter is poorly “comparable” with many photometric red filters that have been used in ground-based post- q observations of 3I/ATLAS (e.g. TRAPPIST-R, TRAPPIST-RC, Gemini r-band...)



The JANUS campaign at comet 3I/ATLAS – dust environment

$Af\rho$ obtained from F04 (RED) images in aperture of $\rho \sim 10^4$ projected km and also corrected for the phase angle

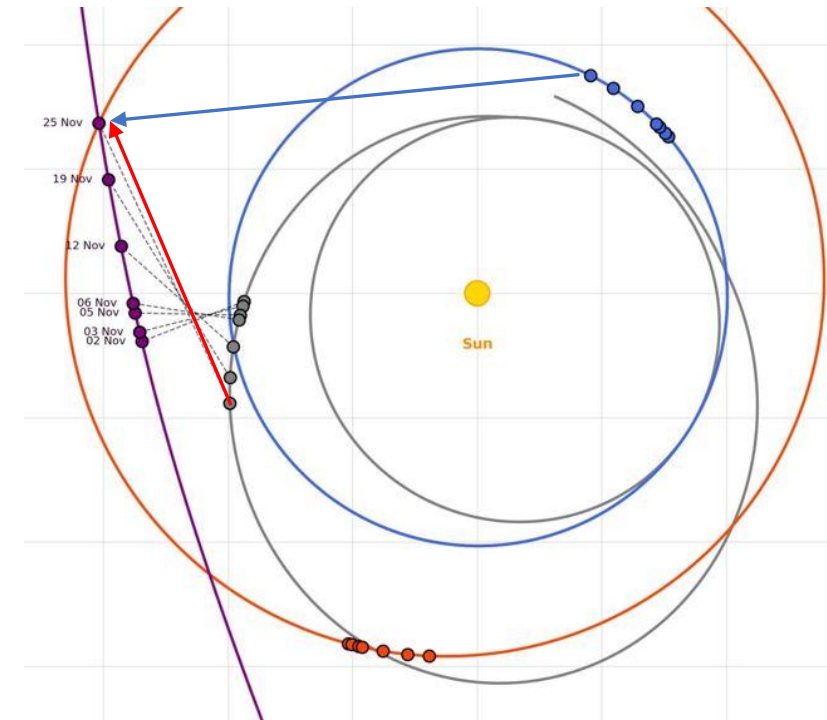


open circle: Gemini r-band (Bolin et al. 2025b); filled and empty squares: TRAPPIST-N R-band and RC-band, respectively (Jehin et al. 2025a); filled and empty triangles: TRAPPIST-N R-band and RC-band, respectively (Jehin et al. 2025b); asterisk: Gemini r-band (Bolin et al. 2026a); cross: Gemini r-band (Bolin et al. 2026b); red dots: values obtained with small telescopes and tabulated in the LESIA DataBase.)



Dust coma modelisation to account for coma anisotropy

Different (JANUS vs onground) “view” wrt the comet orbital plane (different dust column): observing viewpoint matters on the $Af\rho$ for anisotropic dust emission

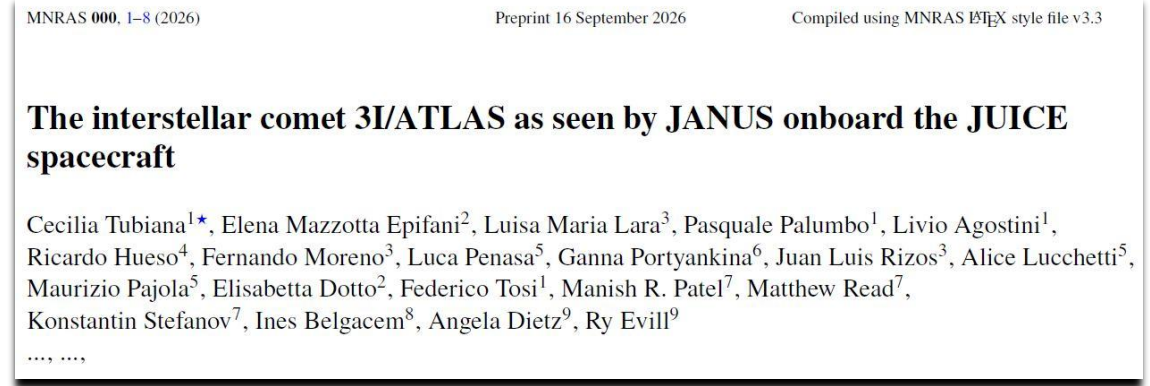


The JANUS campaign at comet 3I/ATLAS

Even if JANUS has not been designed to observe comets and interstellar objects this observing campaign has provided very valuable data which are helping to:
study the behaviour of the object around perihelion
optimise the knowledge of instrument and system

- A «general paper» presently in preparation (final draft is in completion) to be submitted soon

Data are available internally (within the JANUS team); we only ask to coordinate activities following a publication plan that foresees a FIRST GENERAL PUBLICATION (to present data and work to make them scientifically usable)



- Further “specific papers” are already foreseen in the near future, on specific scientific issues:
 - Detailed dust coma modelling
 - Color maps
 - Interaction with solar plasma

The interstellar comet 3I/ATLAS as seen by JANUS on board the JUICE spacecraft

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N. Schmitz¹⁰, M. Patel¹⁵, M. Read¹⁵, K. Stefanov¹⁵, G. Portyankina¹⁰, P. Palumbo²
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²INAF – IAPS (Istituto di Astrofisica e Planetologia Spaziali), Via Fosso del Cavaliere 100, 00133 Roma, Italy

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⁴INAF – OAPd (Osservatorio Astronomico di Padova), Vicolo Osservatorio 5, 35122 Padova, Italy

⁵Escuela de Ingeniería de Bilbao, Univ. del País Vasco, UPV/EHU, Plaza Ingeniero Torres Quevedo 1, 48013 Bilbao, Spain

⁶Dip. di Scienze e Tecnologie, Università degli Studi di Napoli “Parthenope”, Centro Direzionale - isola C4, 80143, Napoli, Italy

⁷LESIA, Paris Observatory, CNRS, Univ. PSL, Univ. Paris Cité, Sorbonne Univ., 5 place Jules Janssen, 92195 Meudon, France

⁸Università di Padova - CISAS Giuseppe Colombo, via Venezia 15, 35131 Padova, Italy

⁹Freie Universität Berlin, Inst. for Geosciences, Malteser-Straße 74-100, 12249 Berlin, Germany

¹⁰German Aerospace Center (DLR), Institute of Planetary Research, Rutherford-Straße 2, 12489 Berlin, Germany

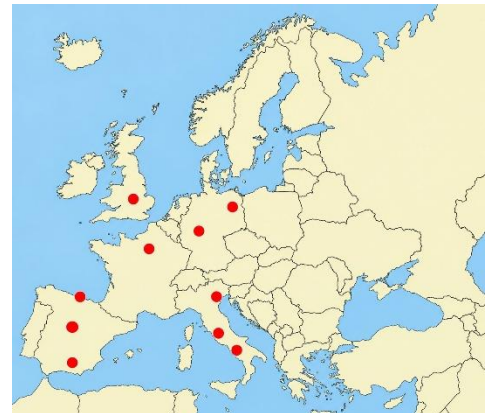
¹¹ASI – Agenzia Spaziale Italiana, Via del Politecnico, 00133, Roma, Italy

¹²ESOC, Robert-Bosch-Straße 5, 64293 Darmstadt, Germany

¹³ESAC, Camino Bajo del Castillo, s/n, 28692 Villafranca del Castillo, Madrid, Spain

¹⁴INAF – OACN (Osservatorio Astronomico di Capodimonte), Salita Moiariello 16, 80131, Napoli, Italy

¹⁵School of Physical Sciences, The Open University, Milton Keynes, MK7 6AA, UK

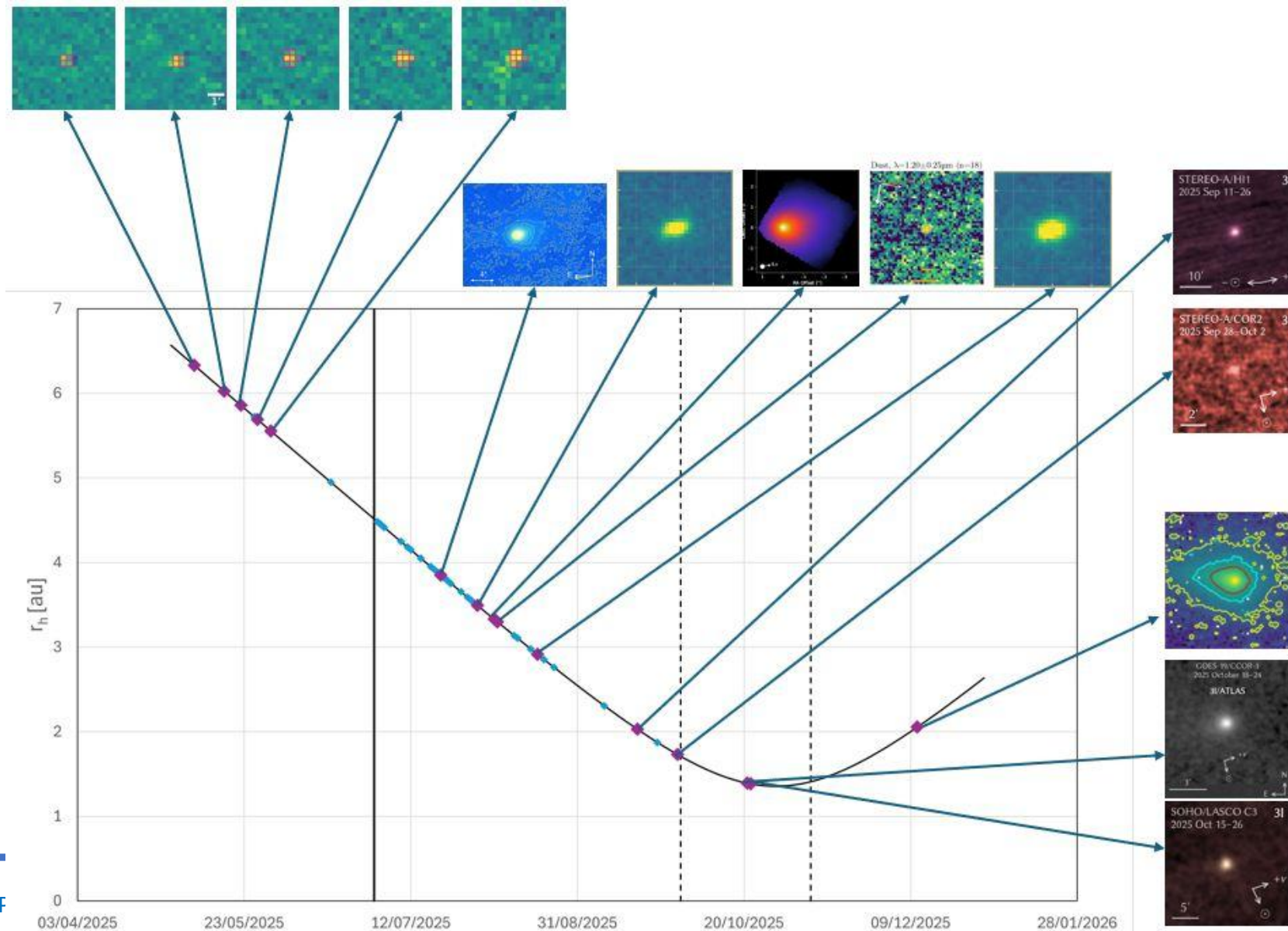






The ISO 3I/ATLAS

- Observed by space-born telescopes and instruments also during the “blindness” ground-based period



The JANUS campaign at comet 3I/ATLAS – dust environment

Different (JANUS vs onground) “view” wrt the comet orbital plane (different dust column): observing viewpoint **DOES MATTER** on the $Af\rho$ for **anisotropic dust emission**

