# Comet Interceptor (ESA-JAXA) and EnVision (ESA-NASA): new missions, new science

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# It's time to explore Venus

## EnVision (ESA)

- 5th mission in the M-class programme of ESA's scientific programme.
- Exploration of planet Venus from the interior to the upper layers of the atmosphere.
- Instrumentation carefully selected to address:
  - Why the Earth and Venus followed such a different evolutionary paths?
  - Is Venus still geologically active?
  - Past conditions related to hosting life (ocean?)
  - Context for other planetary systems with terrestrial planets in them.

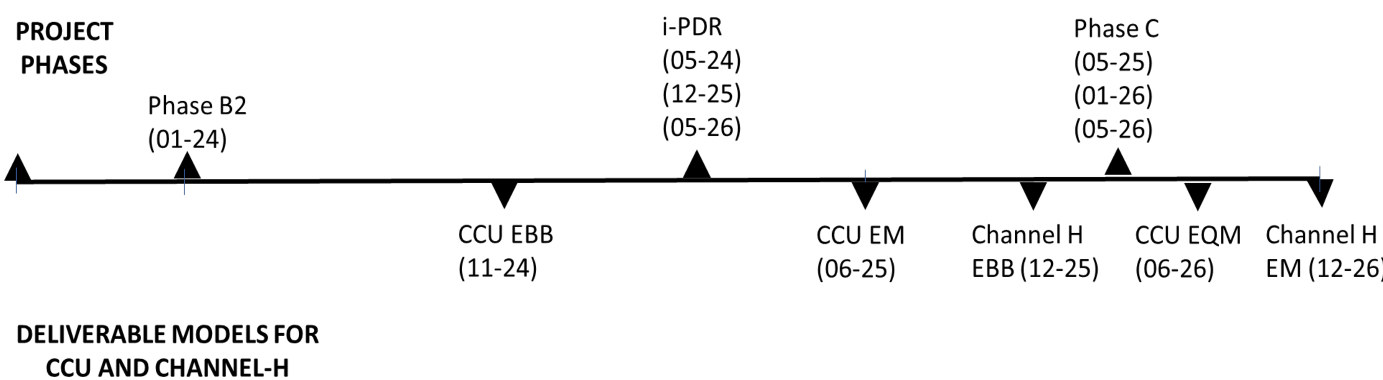
## VERITAS (NASA)

- Explore the interior and surface of the planet to
  - Determine the composition and origin of the terrains,
  - Ascertain the nature of volcanism (steady or catastrophic),
  - Measure the tectonics, size and state of the core,
  - Know if there are tectonic processes,
  - Detect hints of volcanism, etc

# EnVision (ESA)

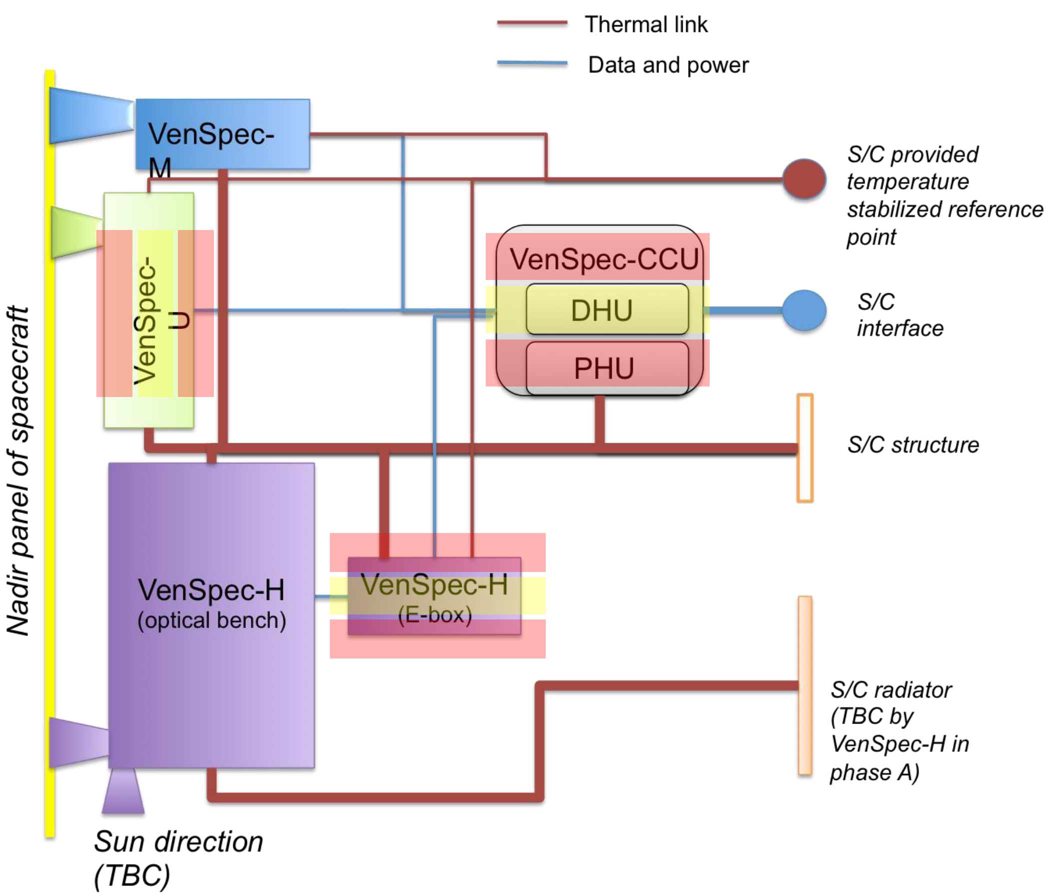
- Launch by Ariane 6.
- First window in 2031, with other possible options in 2032 and 2033.
- 15 months to reach the planet –> 16 months to achieve orbit circularisation through aerobraking.
- 92-mins orbit, quasi-polar with an altitude of between 220 km and 540 km.

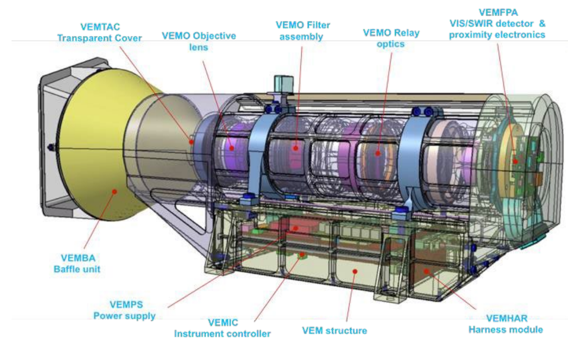
- VenSAR (30 m/pix and 10 m/pix)
- SAR: first instrument to probe the subsurface of Venus mapping its vertical structure
- Radio Science Experiment and radio occultation experiment.
- **VenSpec suite**: spectrometers in UV (VenSpec-U, gas and particulate absorber at the cloud tops) and IR (VenSpec-H, nadir viewing, night and day-side observations), and a spectrometer-IR mapper (VenSpec-M) enabled to study the water vapour in the atmosphere.



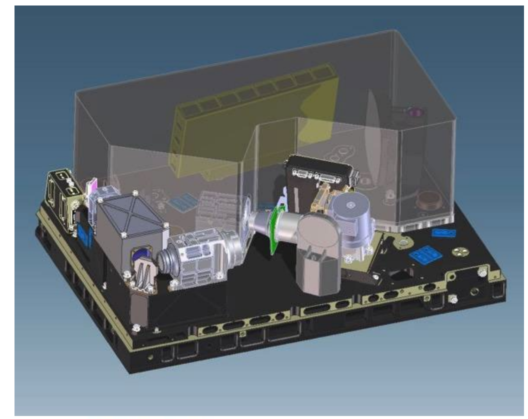
# VenSpec suite

Complex set of 3 complex instruments

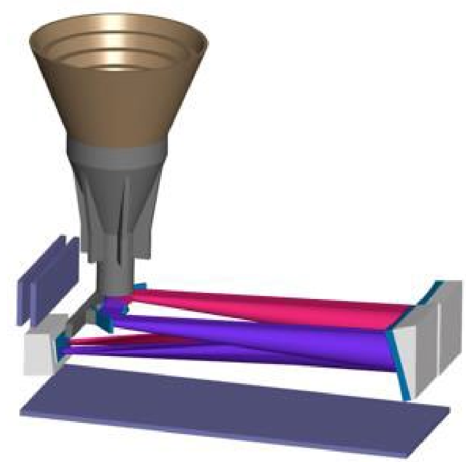



VenSpec-M



VenSpec-H



VenSpec-U

Power supply unit for VenSpec CCU (Central Control Unit), VenSpec-H and VenSpec-U are detailed by Jaime Jiménez et al.

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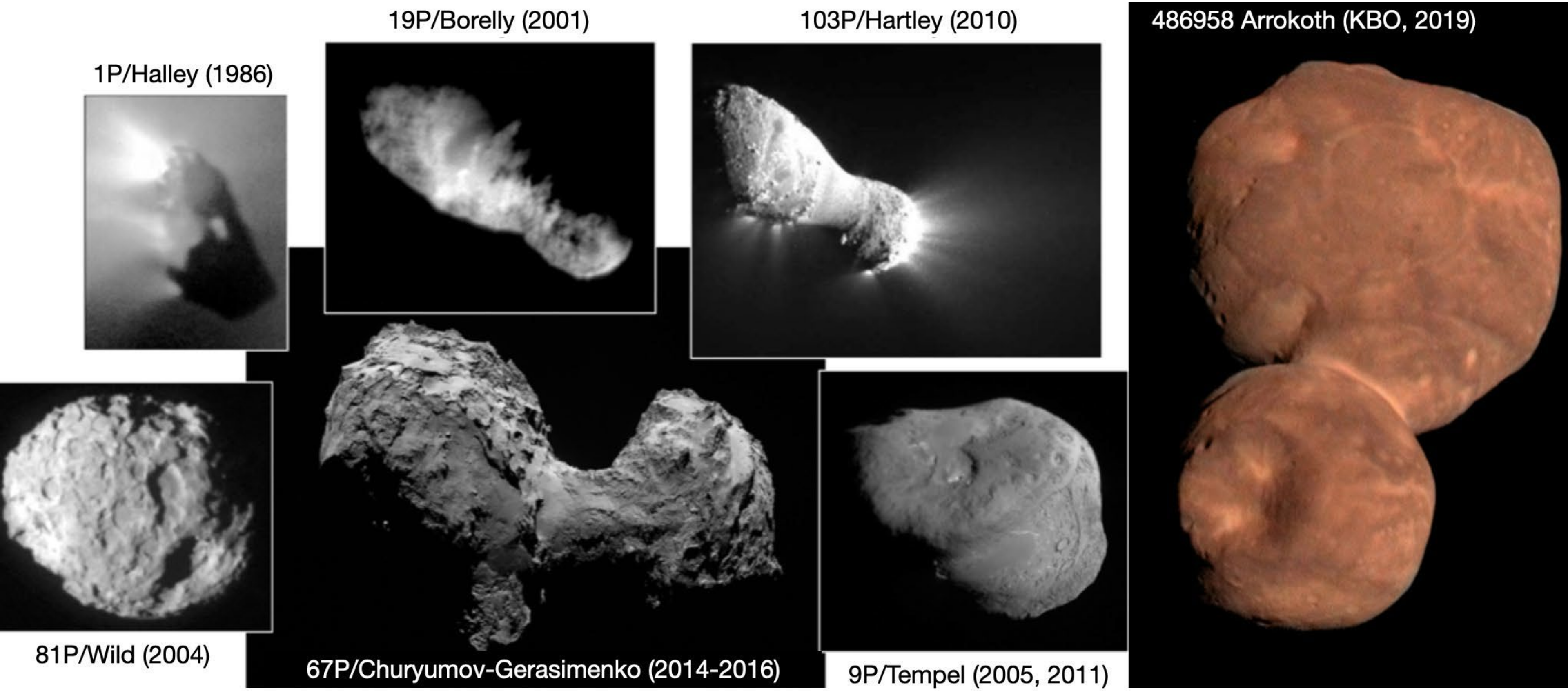
# It's time to catch a pristine comet
# or
# an interstellar planetesimal

- **Comet Interceptor** is a mission proposed to ESA in response to its July 2018 F-class call for modest-sized missions.
- Maximum cost to ESA at completion: €150M, but launch cost and science instruments not included in this sum.
- Constraints: 850-900kg maximum wet mass; launch in 2029 with the Ariel exoplanet observatory mission; delivery to Sun-Earth L2.

- All previous comet missions have been to objects that have passed the Sun many times.
- Targets were relatively evolved, with thick dust mantles.
- A dynamically-new comet (DNC) is one that is probably nearing the Sun for the first time.
- A mission to a DNC would encounter a pristine comet, with surface ices as first laid down at the Solar System's formation.
- An interstellar visitor is not ruled out.

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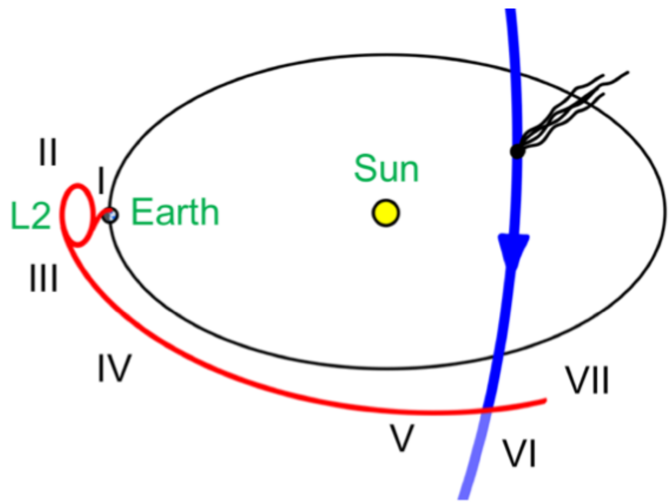
# Mission Profile

- Mission 'parked' at L2 after launch with Ariel, waits for new target discovery by Vera Rubin Telescope or other ground-based survey (2-3 years)
- Short cruise and fast flyby near 1 AU
- Mothership with remote sensing payload, distant 'safe' flyby (few 1000km)
- Released subspacecraft take instruments on different trajectories through coma, including much closer to nucleus

**Mission Phases**

| | |
|---|---|
| I | Launch & delivery to L2 |
| II | Station-keeping at L2 |
| III | Departure from L2 |
| IV | Cruise and instrument commissioning |

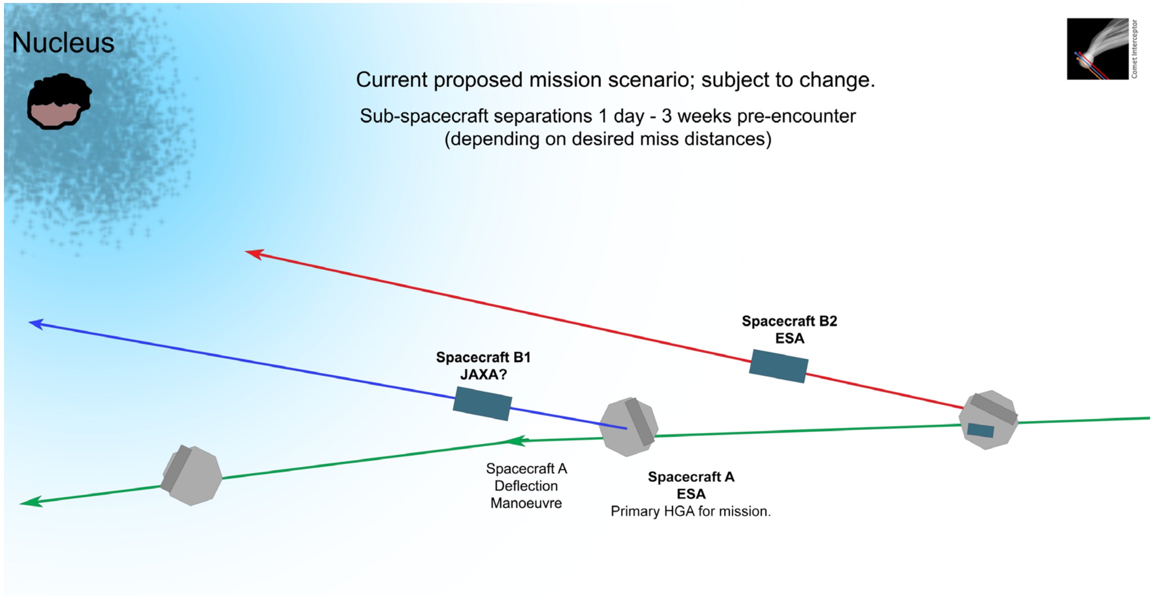



| | |
|---|---|
| V | Separation of spacecraft elements |
| VI | Target Encounter |
| VII | Data playback and solar wind studies, if possible |

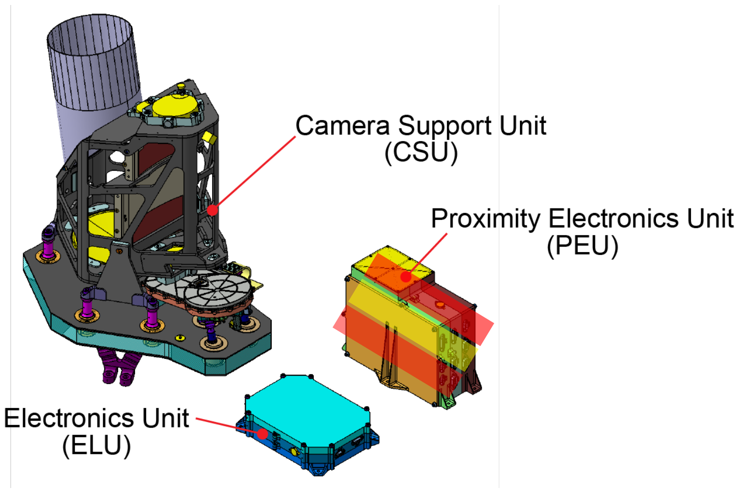
Not to scale

# New Science

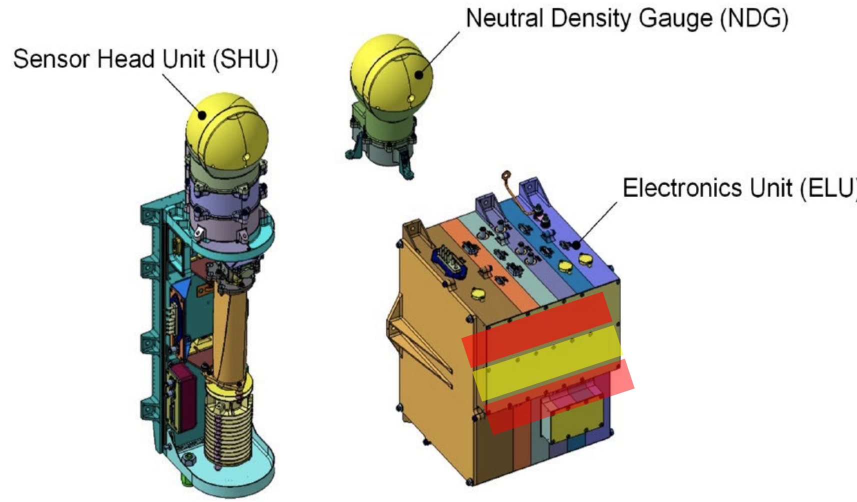
- **Multi-point measurements** of cometary environment, including plasma: separation of spatial and temporal effects.
- **Energetic Neutral Atoms**: first observations of solar wind-neutral charge exchange processes at a comet
- **Multiple views of cometary nucleus:** views from three spacecraft reveal 3D structure of nucleus and coma from a single flyby
- **Entire Visible Sky**: EnVisS
- Panchromatic and polarimetric mapper
- All-sky view of dust, including polarimetry.




| Spacecraft | Instrument | Description |
|---|---|---|
| A ESA | CoCa | Visible/NIR Imager |
| | MANIaC | Mass spectrometer |
| | MIRMIS | Thermal IR spectral imager |
| A ESA / B2 ESA | DFP | Dust, Fields and Plasma (similar in A and B2) |
| B2 ESA | EnVisS | All-sky visible imager and polarimeter |
| | OPIC | Visible/NIR Imager |
| B1 JAXA | HI | Lyman-alpha Hydrogen imager |
| | PS | Plasma Suite |
| | WAC | Wide Angle Camera |



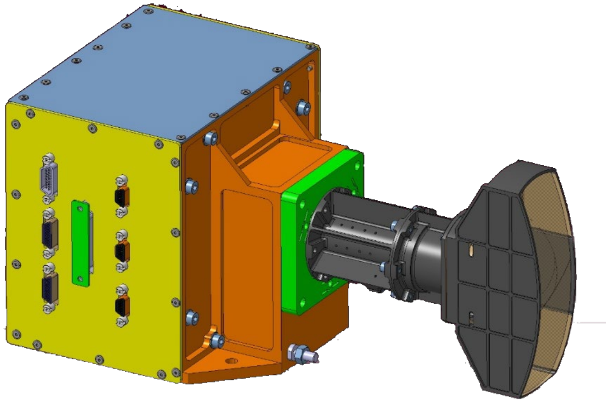

CoCa (Comet Camera) led by CH with contributions from BE, DE, ES and HU




MANiaC led by CH with contributions from AU, ES, FR and PL

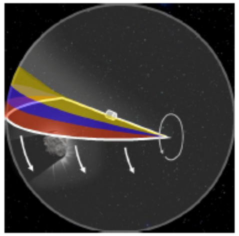
| | |
|---|---|
| Instrument pixel scale | 8 µrad/px |
| Field of View | 0.69° x 0.92° |
| Detector | CIS115 Back-side illuminated CMOS image sensor |
| Pixels | 1504 x 2000 |
| Pixel size | 7 x 7 um |
| Exposure times | 220 µs (fly-by) to 15 min (identification), rolling shutter |
| Imaging rate multi-colour | ≥ 1 frame per second |
| Imaging rate single colour | ≥ 2 frames per second |
| Filters | 475 nm (Δλ=150 nm) BLU<br>675 nm (Δλ=100 nm) ORG<br>775 nm (Δλ=100 nm) RED<br>900 nm (Δλ=150 nm) NIR |
| Mass | 13.5 kg (3 units) |
| Power | 19 W average |
| Volume | CSU: 350 x 460 x 550 $mm^3$; PEU: 210 x 160 x 70 $mm^3$; ELU: 120 x 240 x 180 $mm^3$ |
| Data I/F | Spacewire |
| Instrument memory (holding science data) | 2 x 128Gbit |
| Max data volume | 128Gbit uncompressed |

SHU and the NDG contain antechambers for the thermalization of the incoming gas.
NDG: density range of $10^{-6}$ to $10^{-14}$ mbar
SHU is designed for a mass resolution of m/Δm > 800 for mass/charge > 40 Da/e-

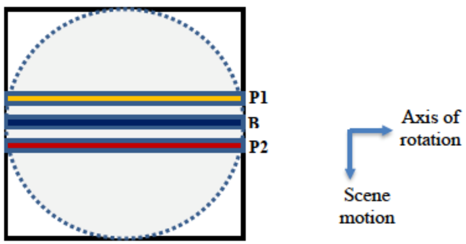


| | |
|---|---|
| Wavelength coverage | 550-800 nm<br>1 broad band filter (B) and 2 polarimetric filters (P1 and P2) |
| Instrument FoV | 180°x45° (fixed)<br>180°x360° (dynamic) |
| Entrance aperture (F#) | 1.23 mm (2.8) |
| Detector | CMOS 2kx2k 5.5-micron px size |
| Scale factor | 0.1°/px |
| MTF | >70% @ 45 lp/mm |
| Distortion and telecentricity | <8% (f-theta distortion law) and <4° (at the FoV edges) |

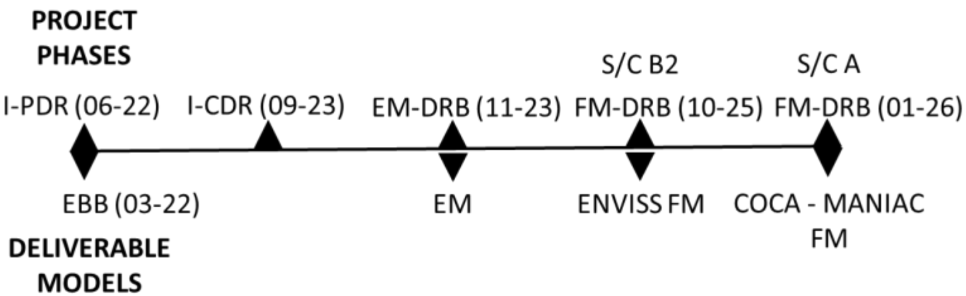
EnVisS (Entire Visible Sky) led by IT with PSU and DHU (shared with OPIC) from ES

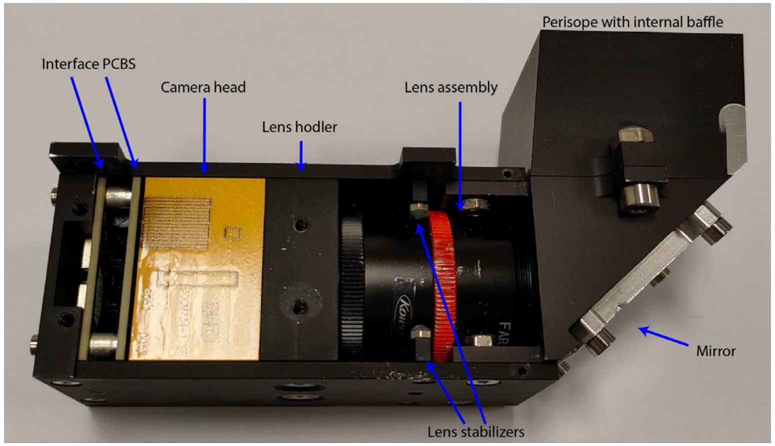


(a)




(b)

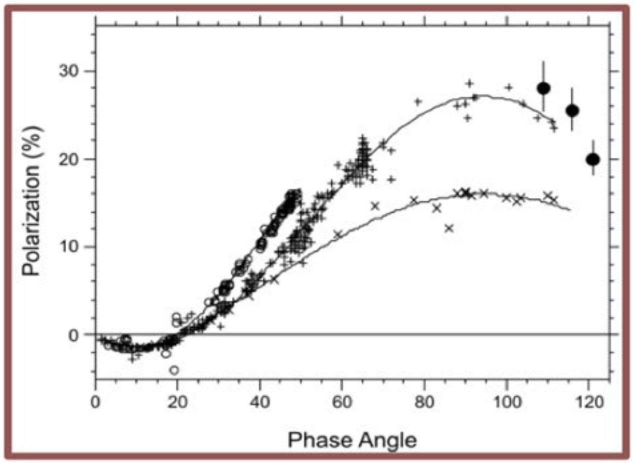


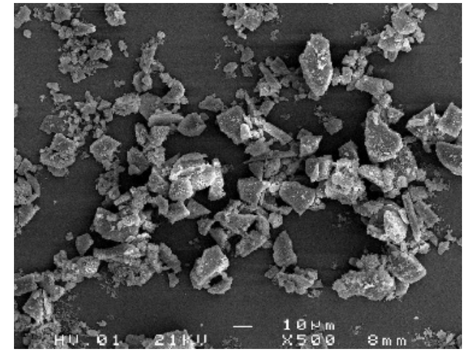

OPIC (Optical Periscope Imager for Comets) led by EE with contributions from ES (DHU shared with EnVisS) and FI

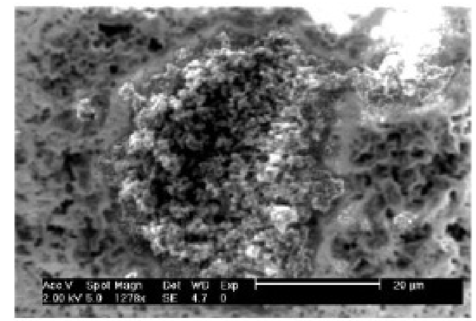
# Polarimetry of Comets

COMETS




**Bell-Shape**



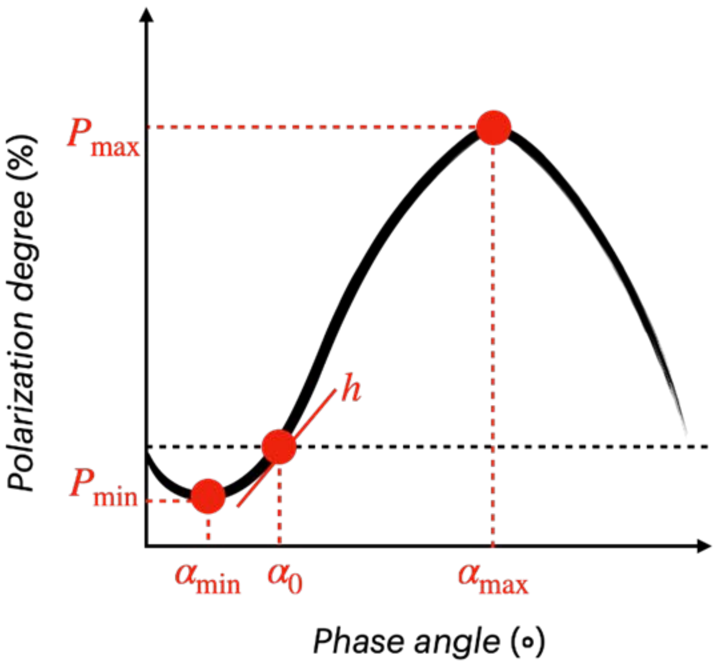


micron-sized particles

Observational data from **Database of Comet Polarimetry** (Kiselev et al. 2005)

# EnVisS: All-sky polarization curve

For scattered light from irregular dust aggregates,




- Typical polarimetric phase curves of cometary dust displays a bell-shaped curve, which can be described by the **six parameters**.
- Dependent on the microphysical and compositional properties of dust aggregates.

| Negative branch ($\alpha \lesssim 22°$) | Positive branch ($\alpha > 25°$) |
|---|---|
| sensitive to the microstructure (and secondarily to the composition) | sensitive to the composition and porosity |

Kwon et al 2021: 10μm silicate emission ⟺ $P_{max}$

*Unlike remote observations, CI can cover both branches (nearly) simultaneously!*

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