Comet Interceptor Mission: Estonian OPIC as the Eyes Towards an Ancient World

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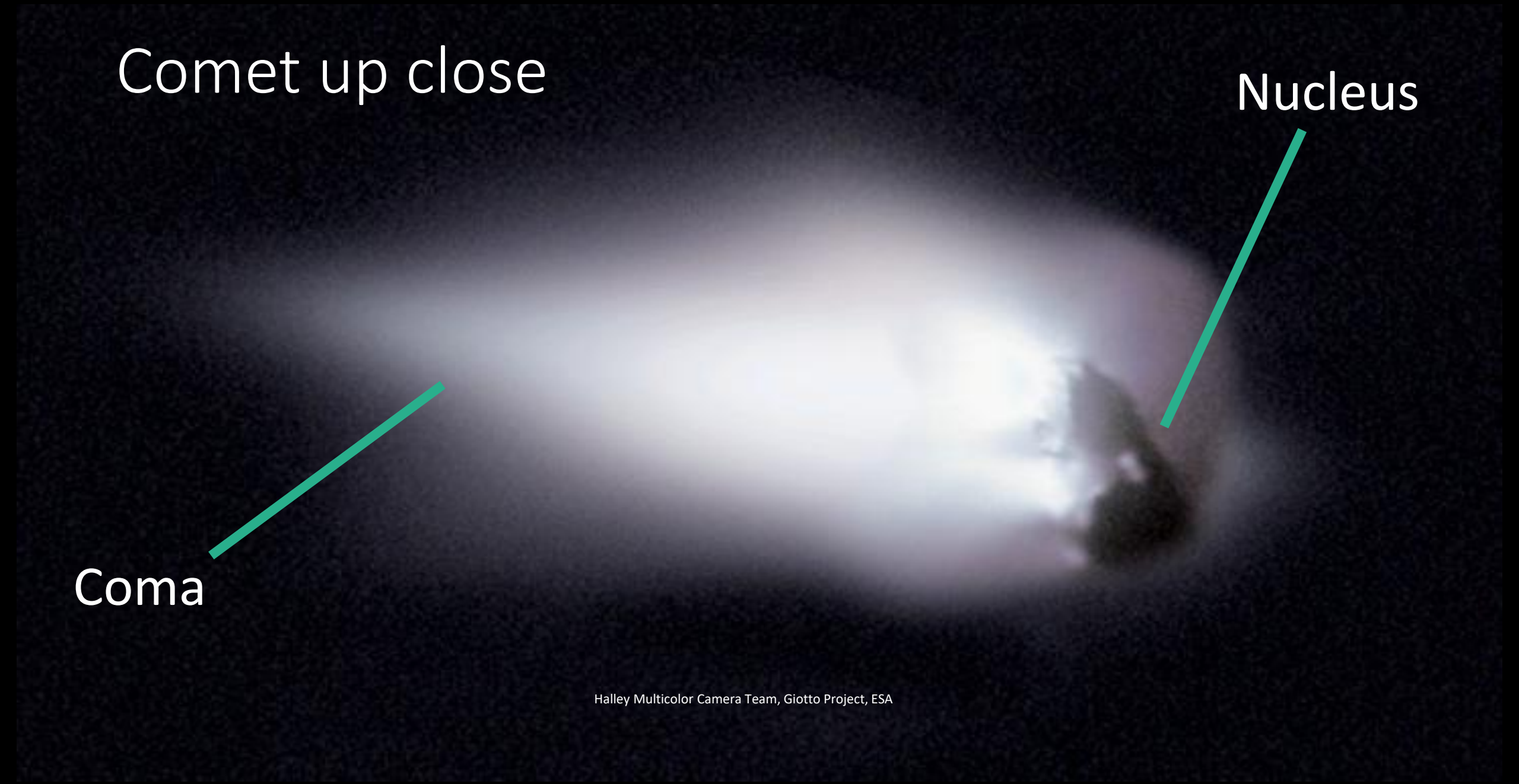
Comets

- Comets are leftovers from Solar system formation
  - A snapshot of chemical composition from there
- Consist of dusts and ices
- When comet approaches the Sun, it starts to evaporate
- Sometimes the dust and gas tails are visible from Earth's surface with a naked eye

Comet P/Halley as taken March 8, 1986 by W. Liller, Easter Island, part of the International Halley Watch (IHW) Large Scale Phenomena Network.

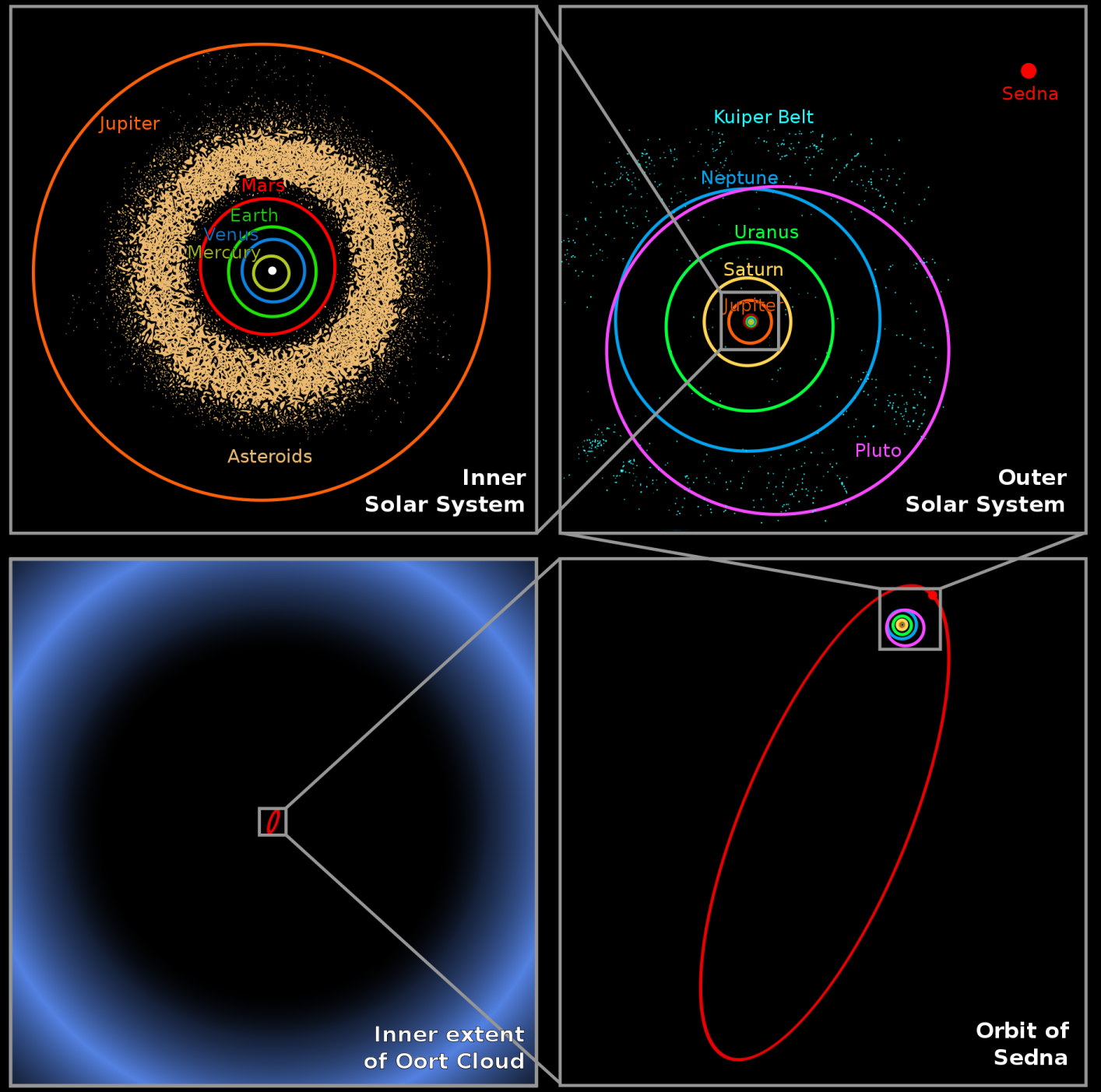
Comet up close



Halley Multicolor Camera Team, Giotto Project, ESA

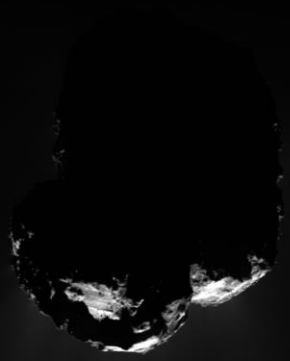
Comets normally reside in Öpik-Oort cloud

- Large set of icy bodes at the edge of the Solar system
- Very low temperatures, work as “time capsules”
- Occasionally, some comets are perturbed to move closer to the Sun



Rosetta and 67P/Churyumov–Gerasimenko

- Best studied comet up close is 67P/Churyumov–Gerasimenko
- ESA Rosetta spacecraft orbited this
- Philae lander landed in 2014



SA/Rosetta/MPS for OSIRIS Team
MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

Justin Cowart

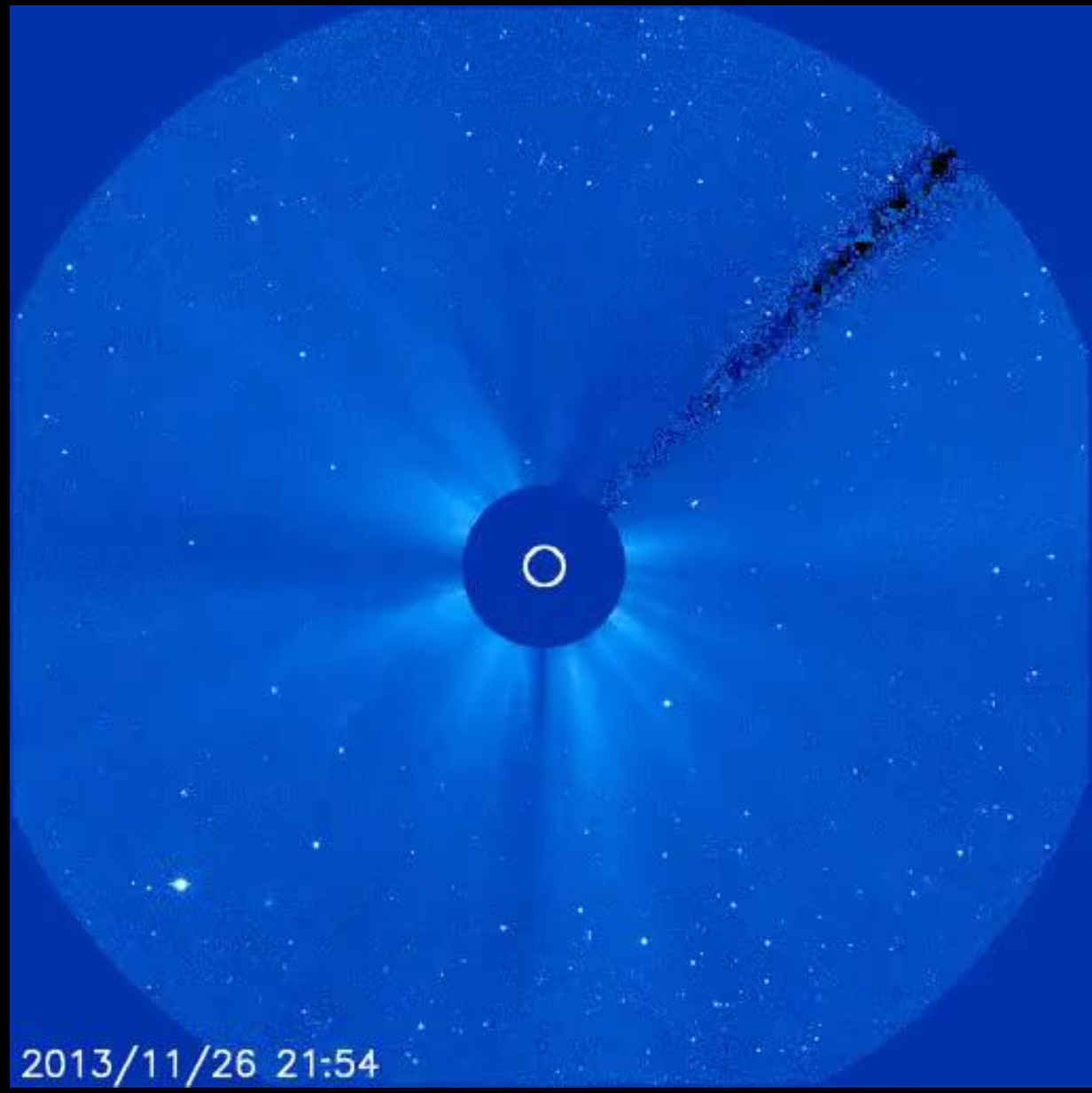
Surface erosion

- Passing near the Sun erodes the surface
- No longer representative of original conditions
- Problem with Rosetta mission
- Solution
  - Dynamically new comets

Credit: ESA.

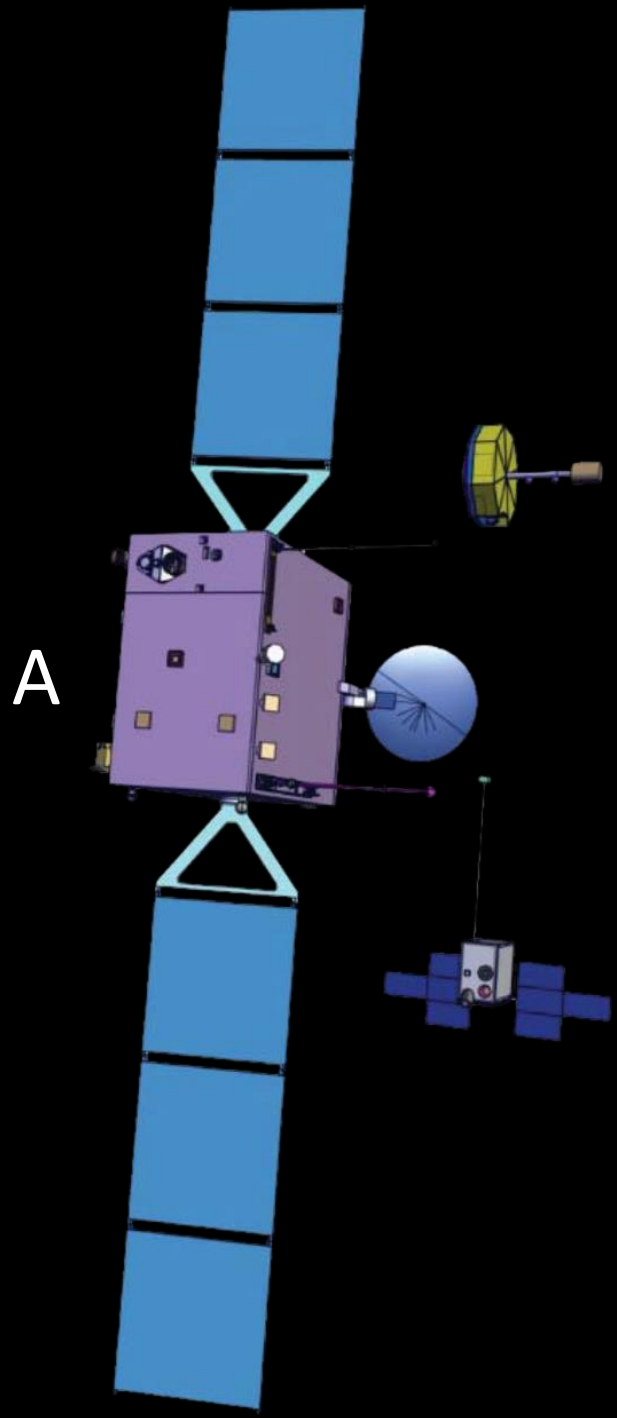
Dynamically new comet

- Occasionally still comets pass the Sun for the first time
- A potential example of this is ISON comet in 2013 that probably originated from the Öpik-Oort cloud and flew past the Sun



Comet Interceptor

- Mission to intercept a dynamically new comet
- Consists of three spacecraft
  - A from ESA
  - B1 from JAXA
  - B2 from ESA



Instruments

Comet Camera (CoCa) (A)
Nicolas Thomas, Univ. Bern, Switzerland, CoCa Lead Scientist

Dust, Fields, Plasma (DFP) (A and B2)
Hanna Rothkaehl, Center of Space Research (CBK), Warsaw, Poland, DFP Lead Scientist

Mass Analyzer for Neutrals in a Coma (MANiaC) (A)
Martin Rubin, Univ. Bern, Switzerland, MANIaC Lead Scientist

Modular InfraRed Molecules and Ices Sensor (MIRMIS) (A)
Neil Bowles, Univ. Oxford, UK, MIRMIS Lead Scientist

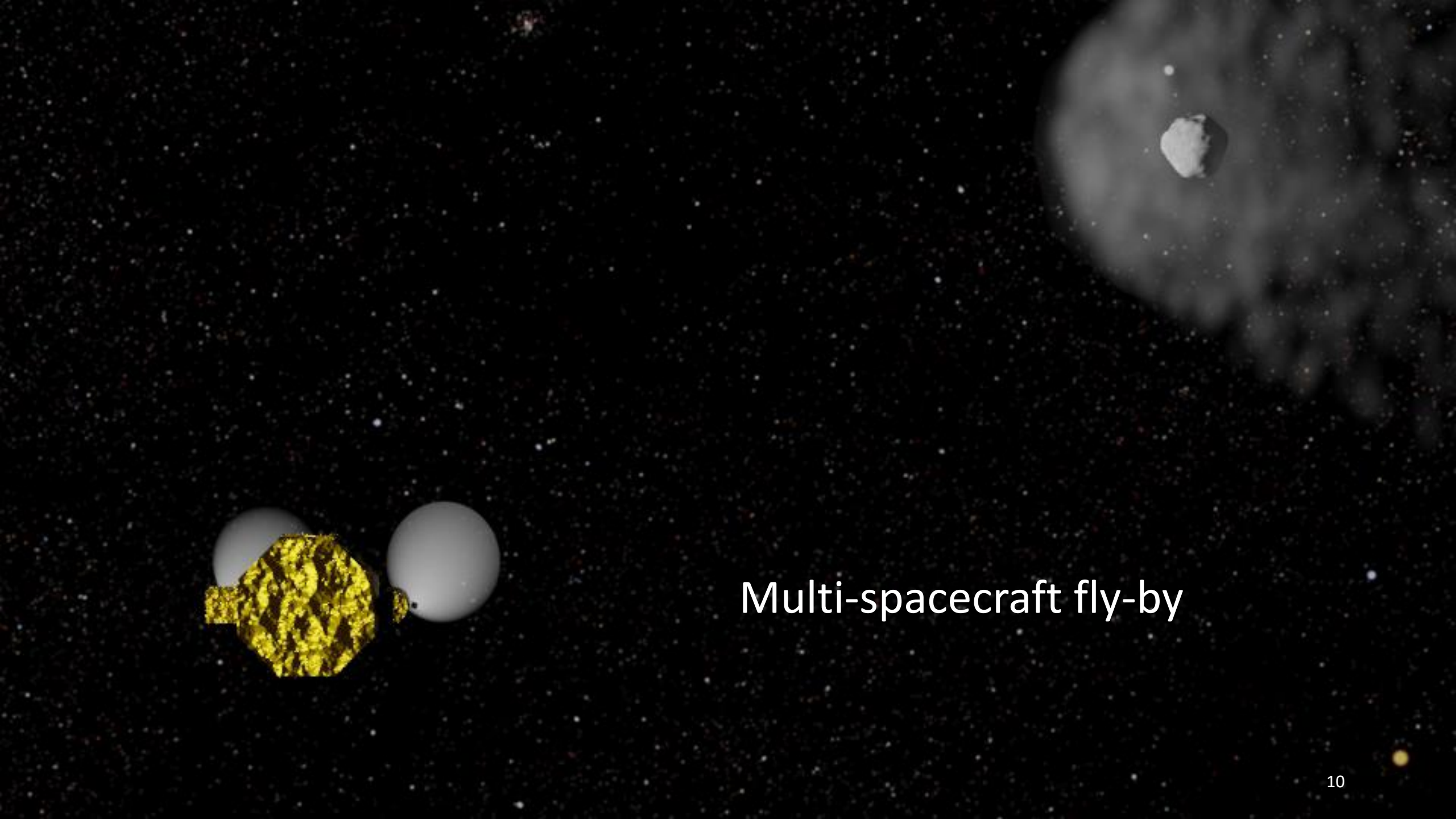
Hydrogen Imager (HI) (B1)
Kazuo Yoshioka, Univ. of Tokyo, Japan, HI Lead Scientist

Narrow Angle Camera/Wide Angle Camera (NAC/WAC) (B1)
Naoya Sakatani, JAXA, JapanNAC/WAC Lead Scientist

Plasma Suite (PS) (B1)
Satoshi Kasahara, University of Tokyo, Japan, PS Lead Scientist

Entire Visible Sky (EnVisS) (B2)
Vania Da Deppo, CNR-IFN, Padova, Italy, EnVisS Lead Scientist

Optical Periscope Imager for Comets (OPIC) (B2)
Mihkel Pajusalu, Univ. of Tartu, Estonia, OPIC Lead Scientist



Multi-spacecraft fly-by

T-6.67 seconds

Main spacecraft to nucleus distance=1370 km

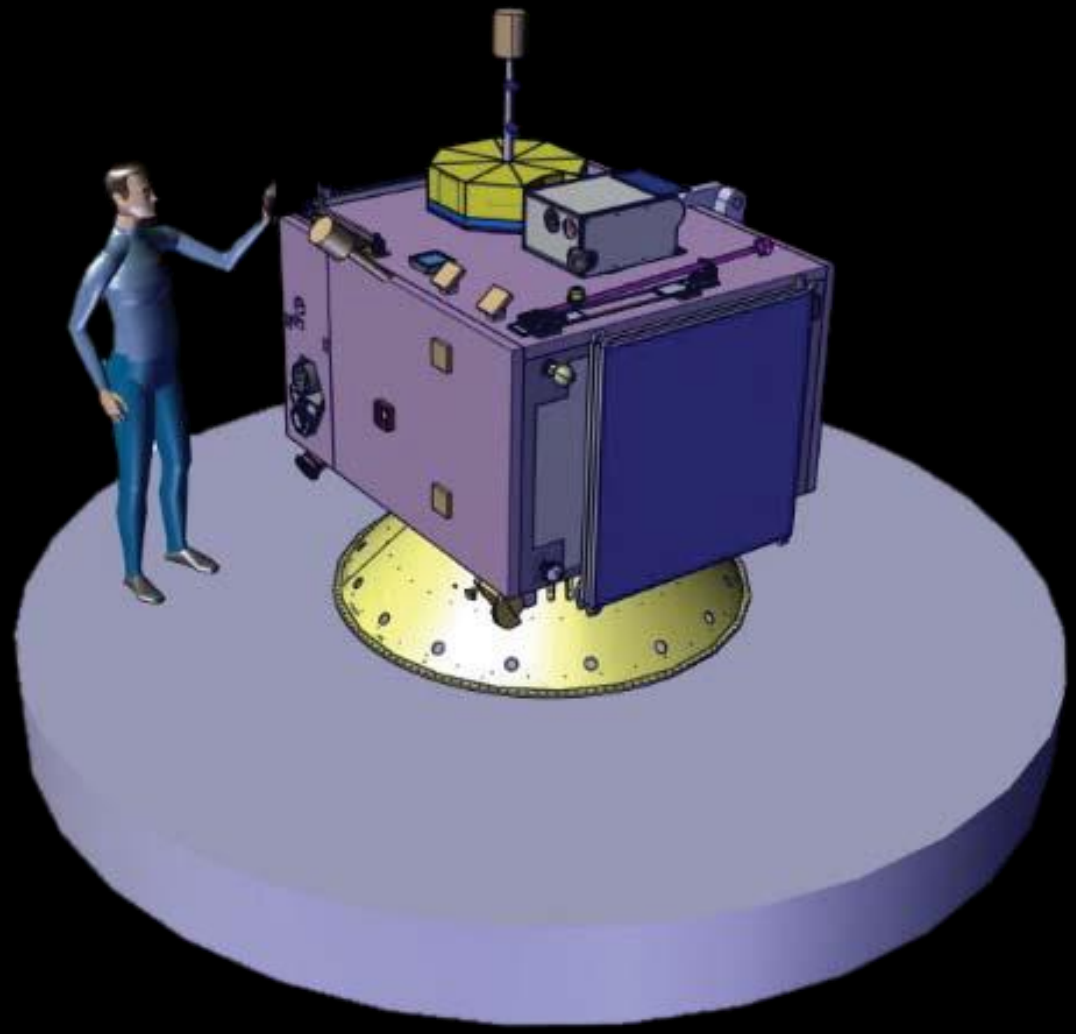
OPIC to nucleus distance=672 km

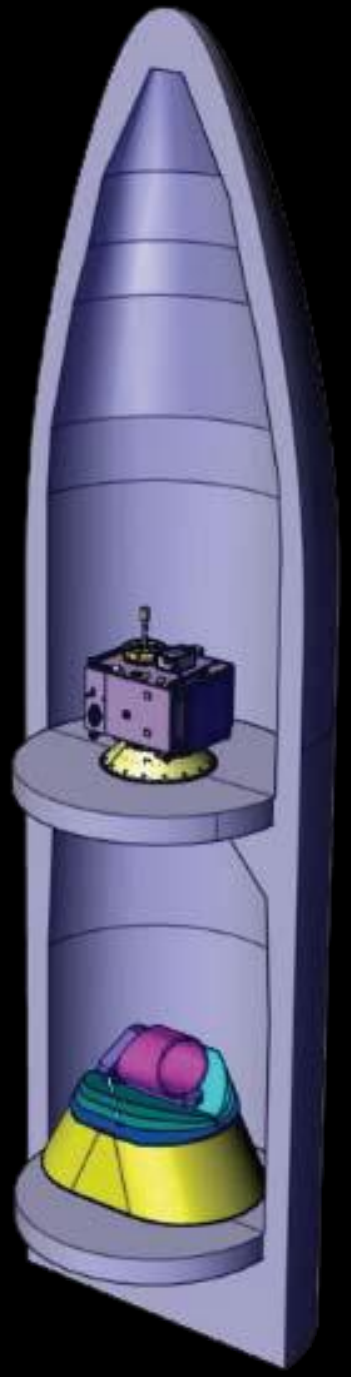
Main spacecraft

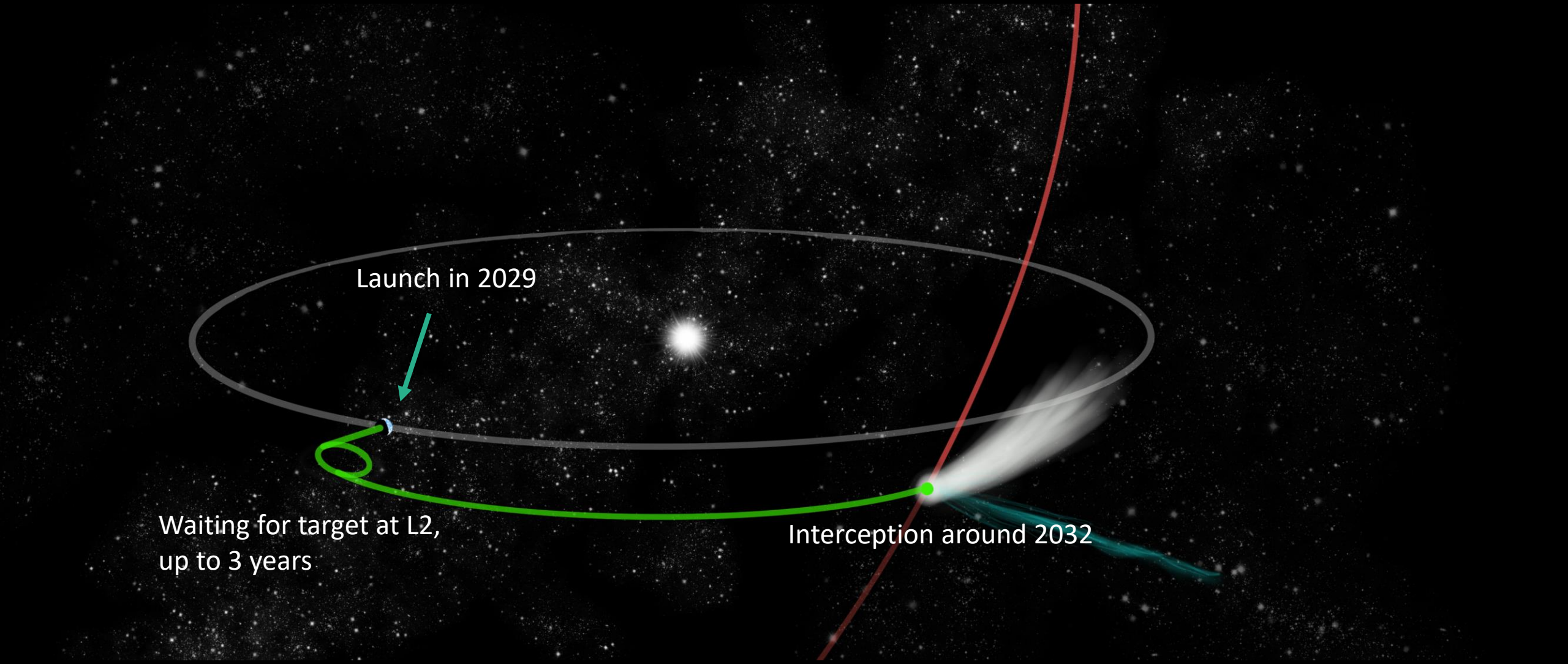
OPIC (Estonian contribution, blue dot) on close approach spacecraft

00:12,77

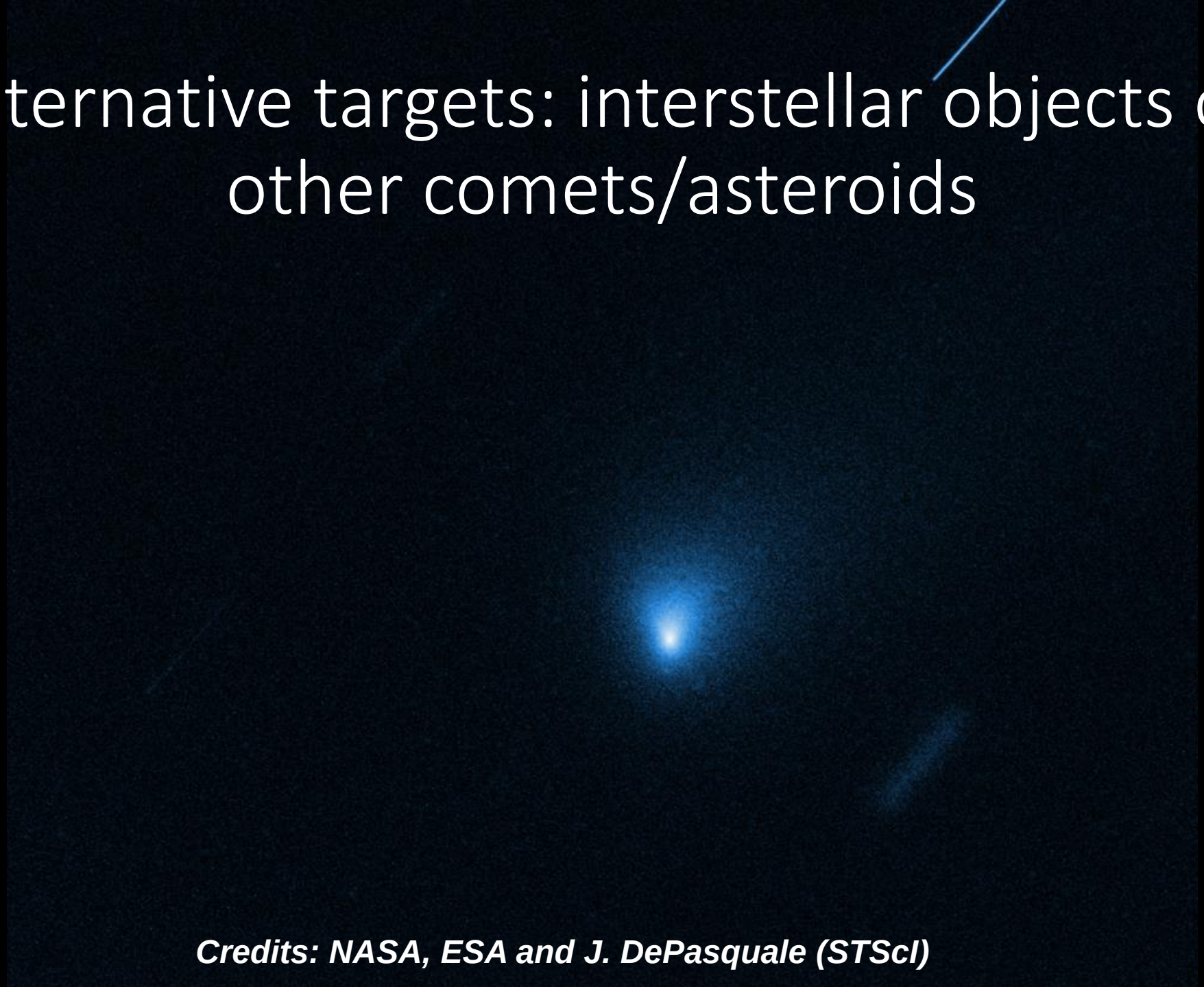
To be launched with ARIEL in 2029






Launch in 2029
Waiting for target at L2,
up to 3 years
Interception around 2032

Alternative targets: interstellar objects or other comets/asteroids

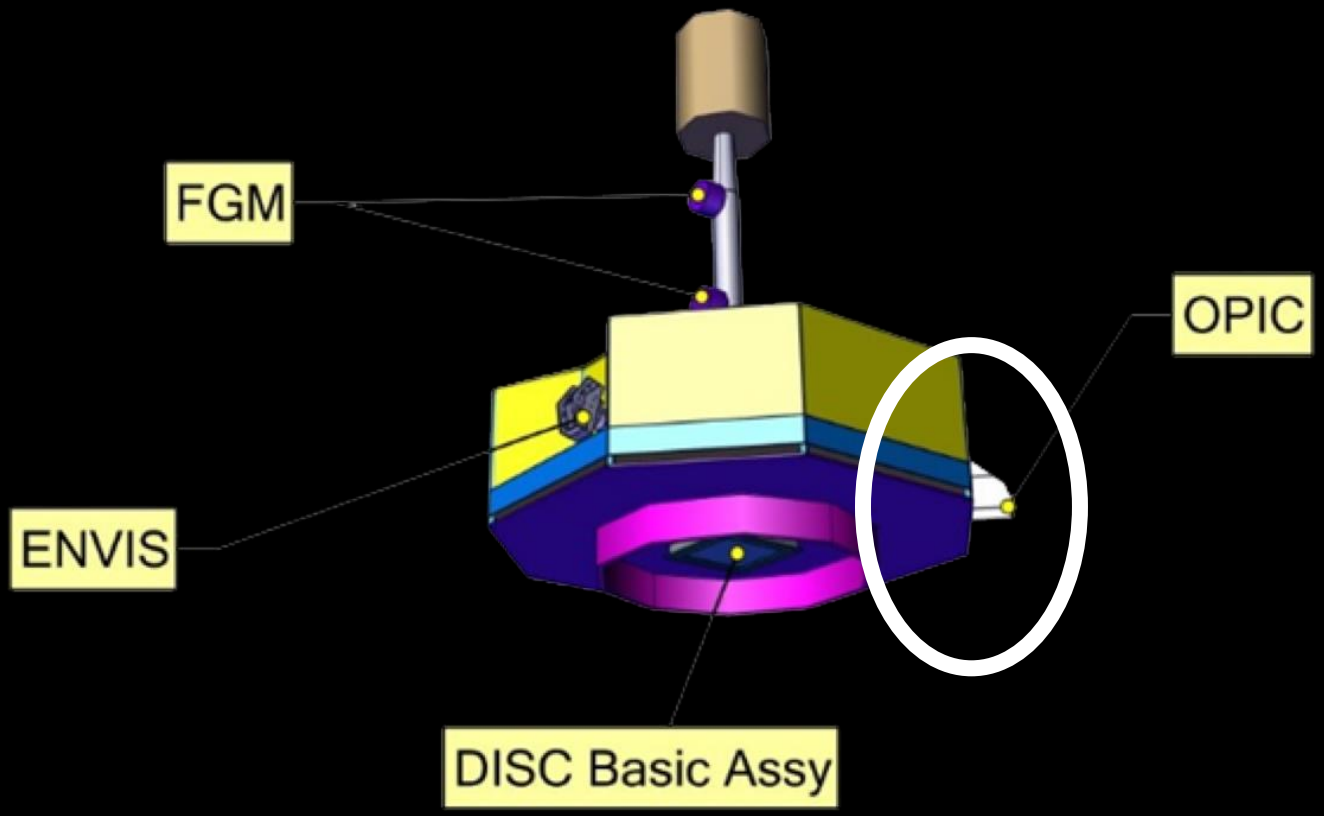


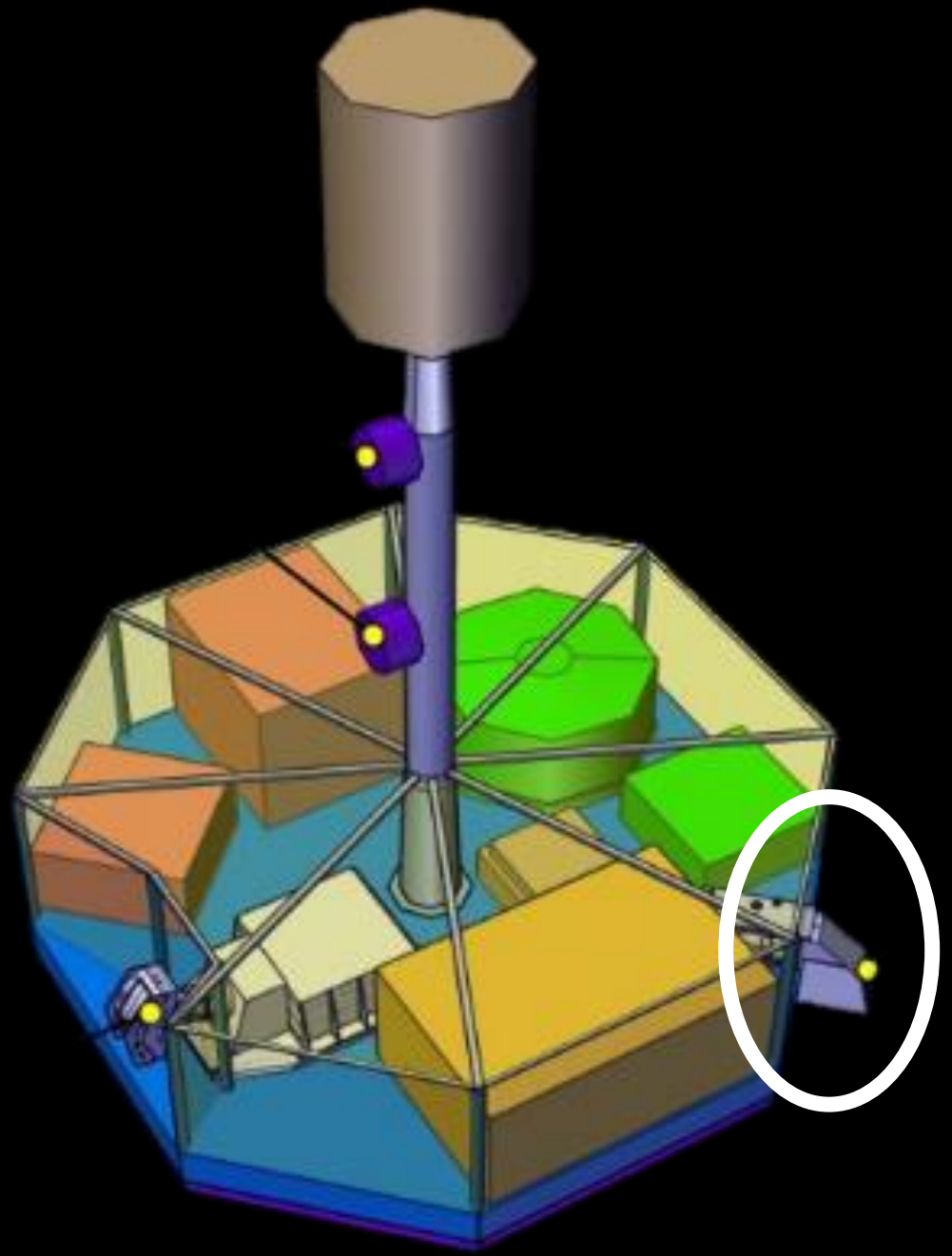
Credits: NASA, ESA and J. DePasquale (STScI)

Our participation

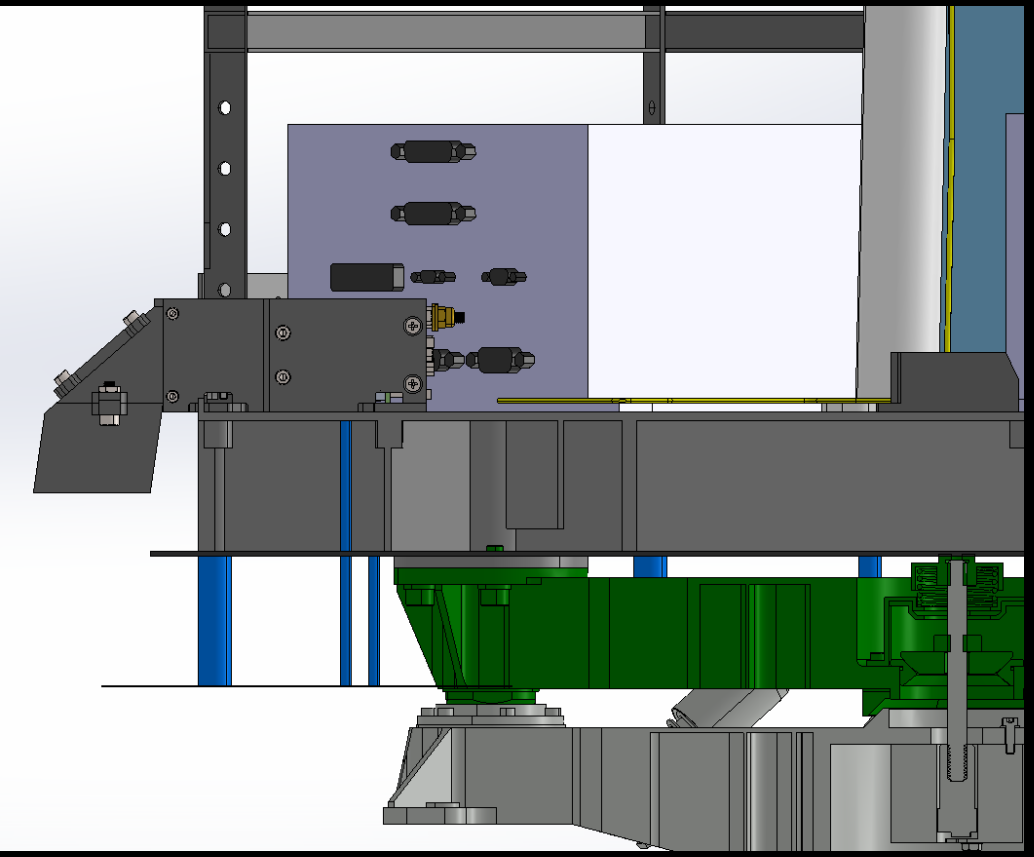
- This is the first Estonian full participation in an ESA science mission
  - First piece of hardware properly developed according to ECSS
- We have been a part of the consortium since 2018
  - We were discussing before the F-class mission call opened
  - Wrote part of the original Comet Interceptor proposal
- Mission got selected in 2019
- Mission got adopted in 2022
- Estonia is building Optical Periscopic Imager for Comets (OPIC)
  - Originally OPtical Imager for Comets
- PRODEX funding from May 2023
- Also part of CI Executive, CI Operations Planning and CI SWT

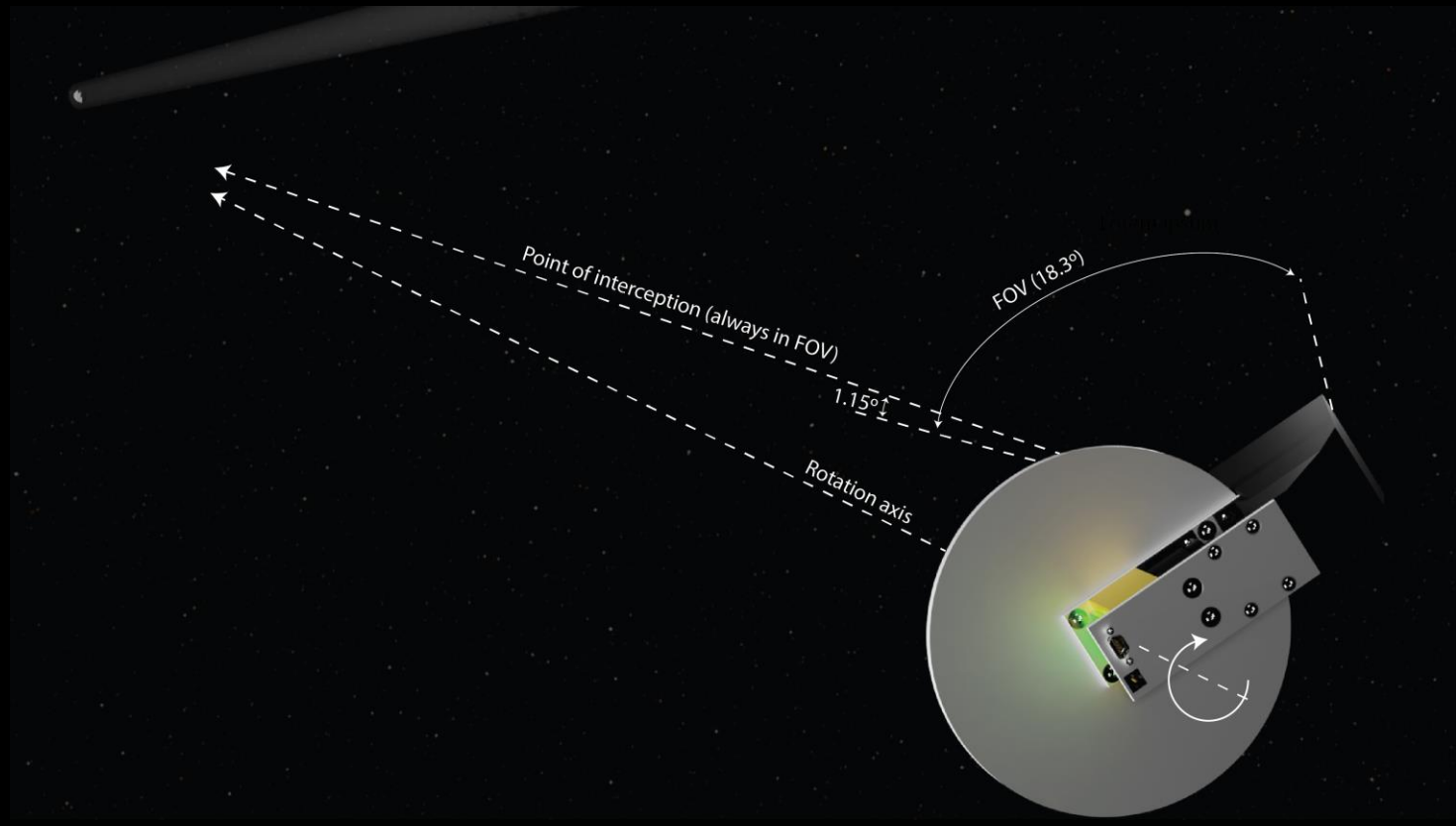
B2 probe





Placement and viewing geometry

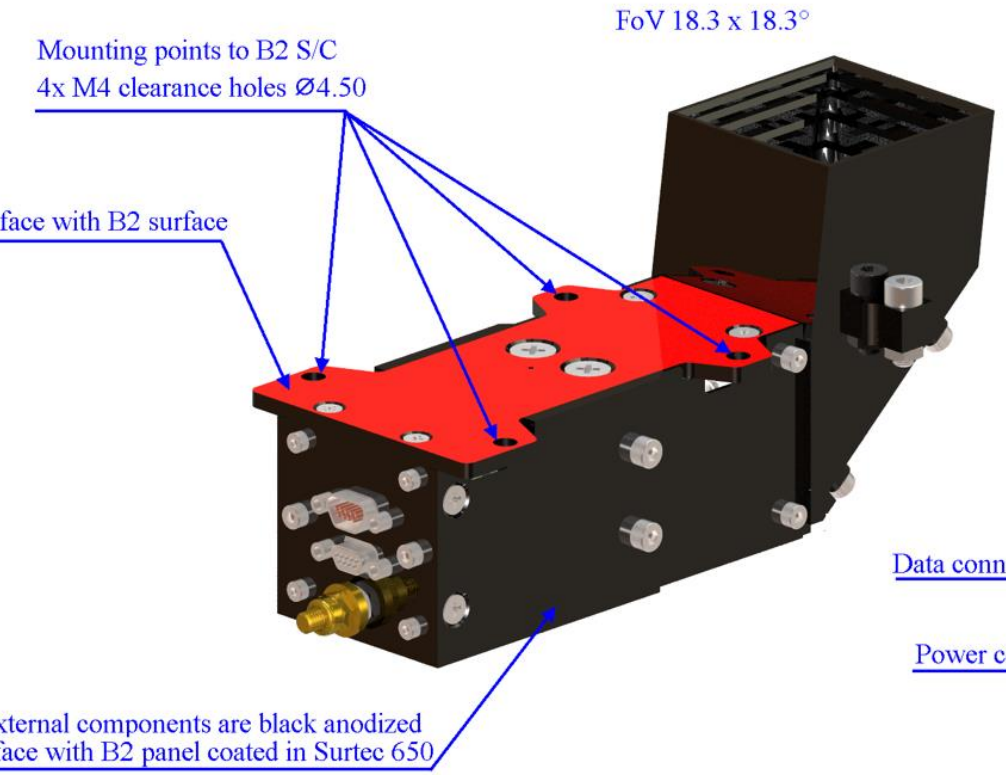




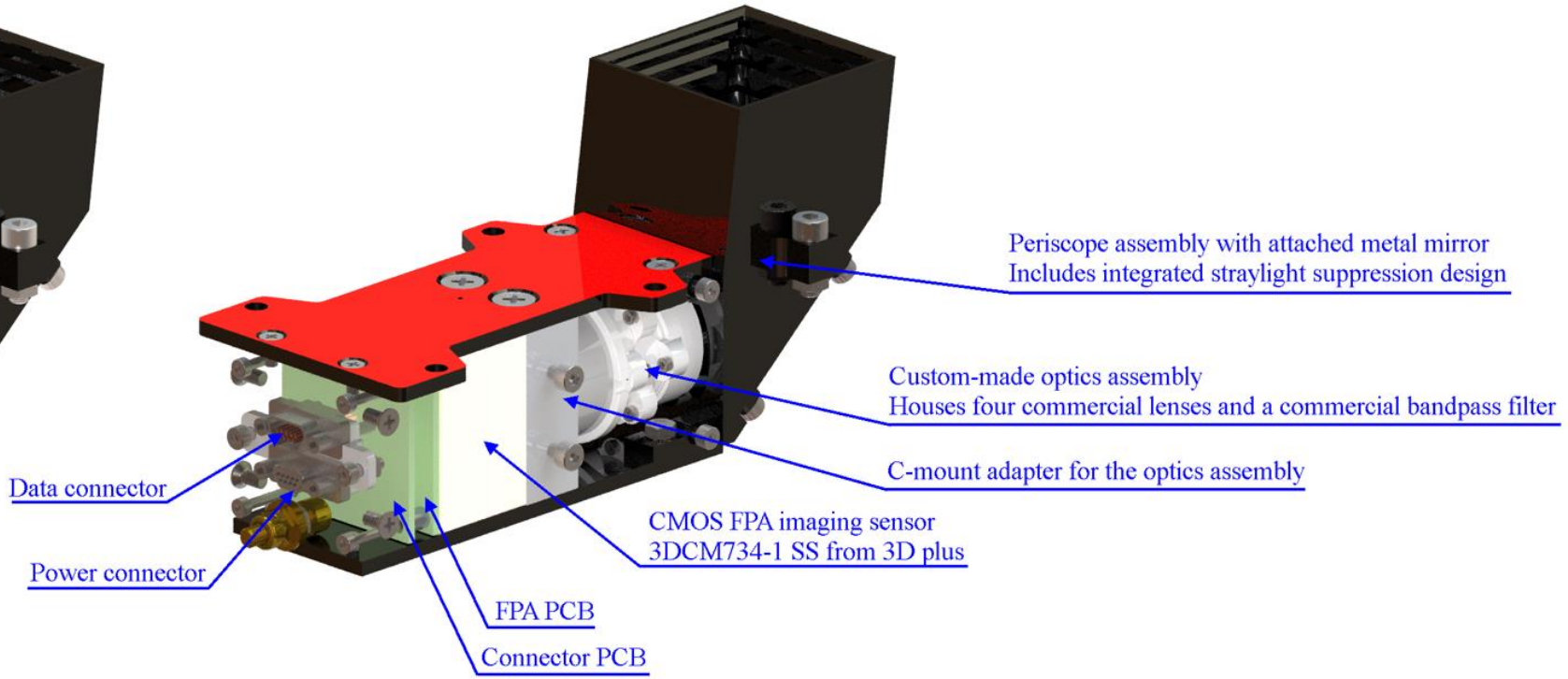
OPIC core team at Tartu Observatory

1. Dr. Mihkel Pajusalu (ILS)
2. Sten Salumets (Project Manager)
3. Merli Pärl (Project Manager)
4. Dr. Tuomas Henrik Kahanpää (PA/QA)
5. Karlis Luksis (FPGA developer)
6. Artiom Nikolajev (Mechanical and Simulations Engineer)
7. Ric Dengel (FPGA development and mission simulations, PhD student)
8. Herman Proosa (Testing Engineer)
9. Karin Kruuse (Testing Engineer)
10. Joosep Kivastik (Optical Engineer, Junior Researcher, PhD student)
11. Aditya Savio Paul (Junior Researcher, PhD student)

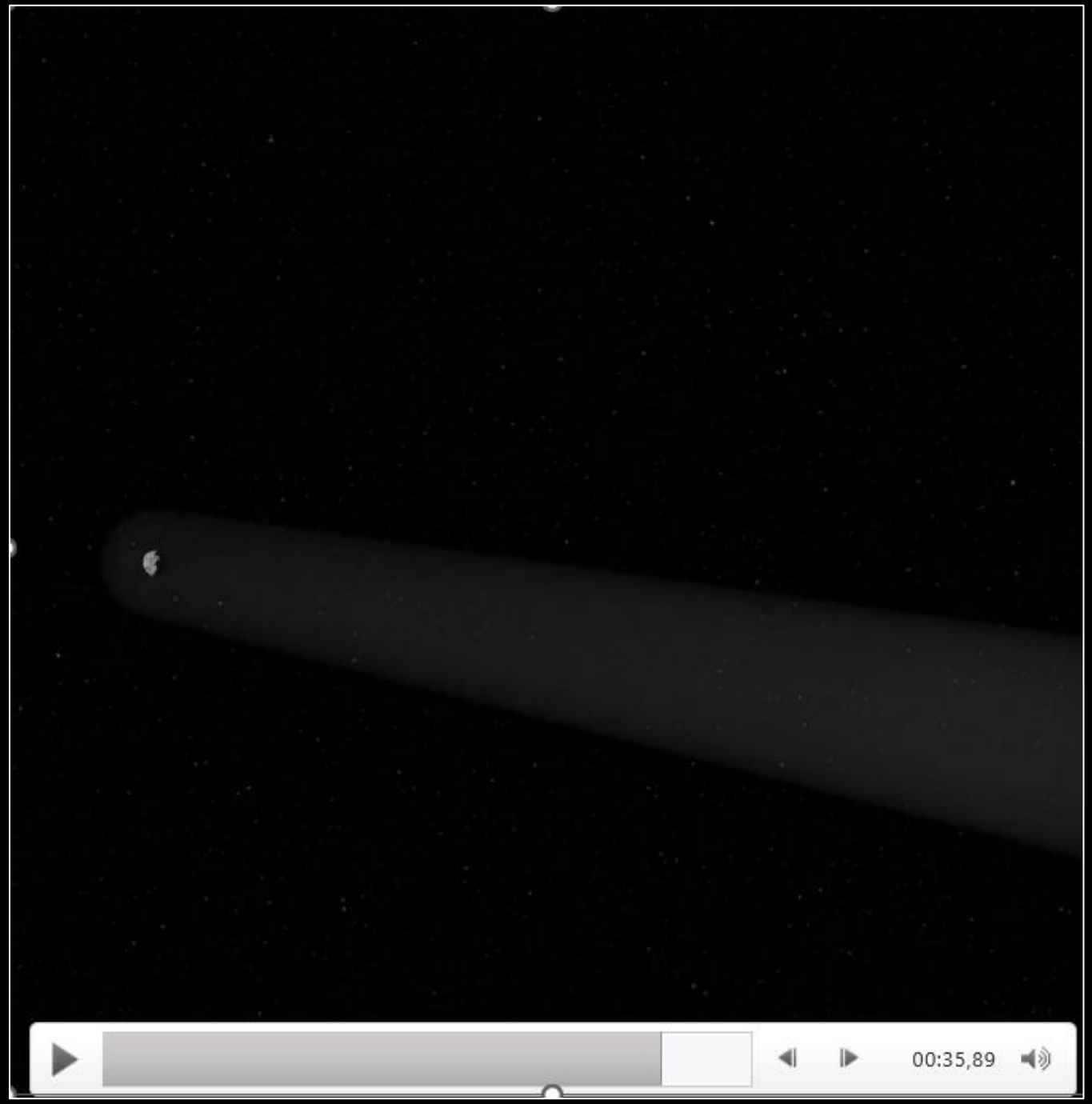
Fully enclosed instrument



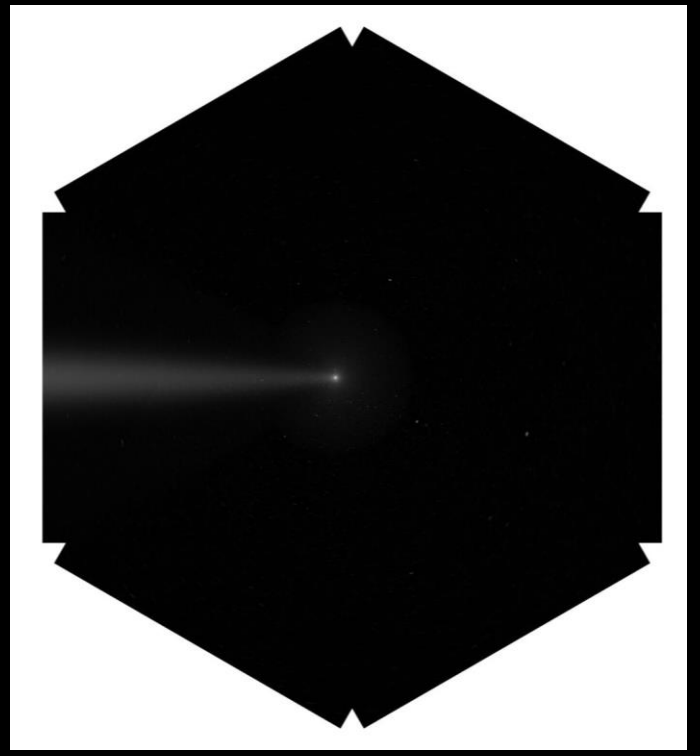
View of instrument internals



Illustrative view from camera to show relevant effects (unrealistic relative intensities)



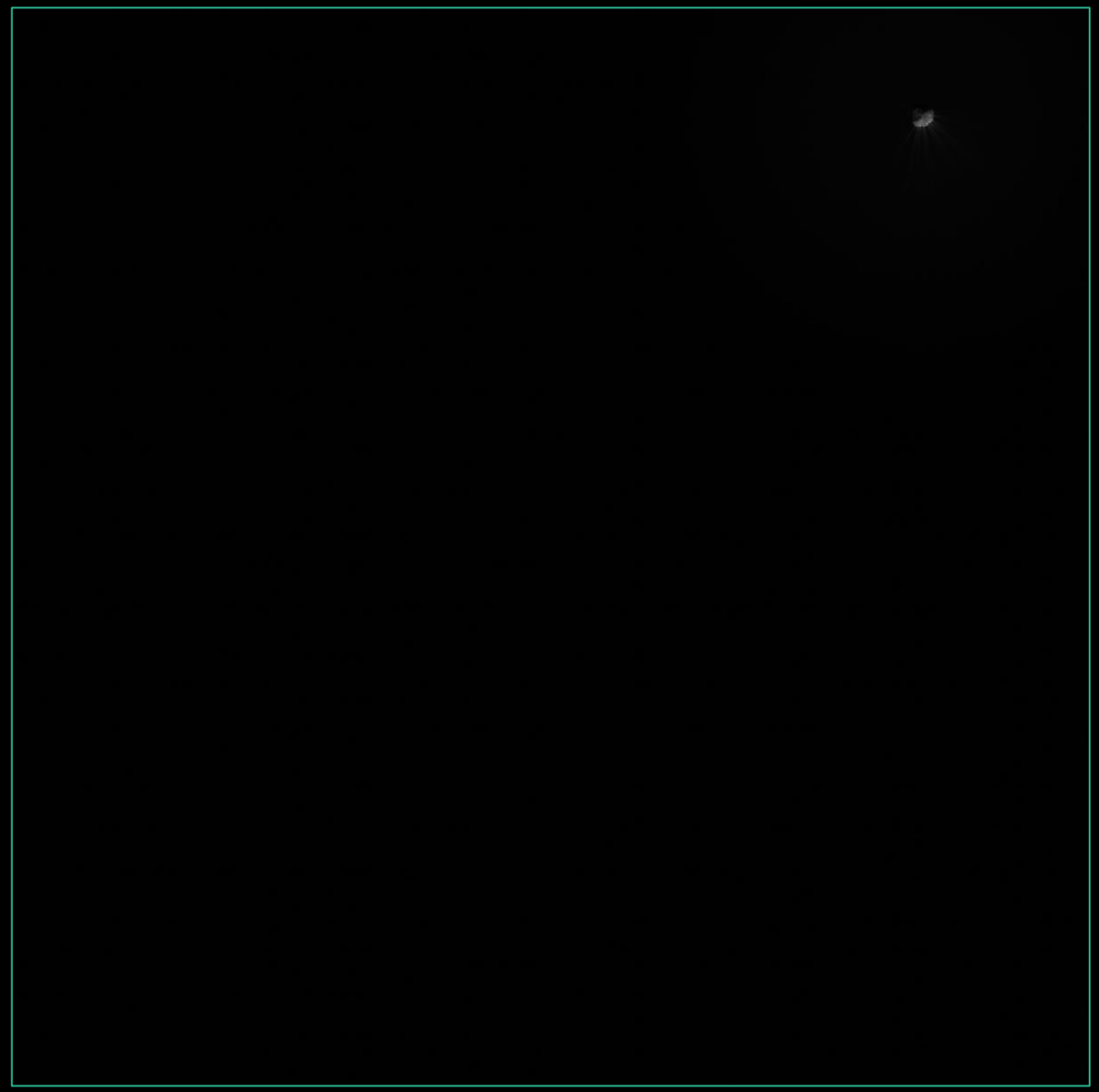
Science data type 1: Full frame long distance images



6 images for full scan
images could be used to constrain EnVisS

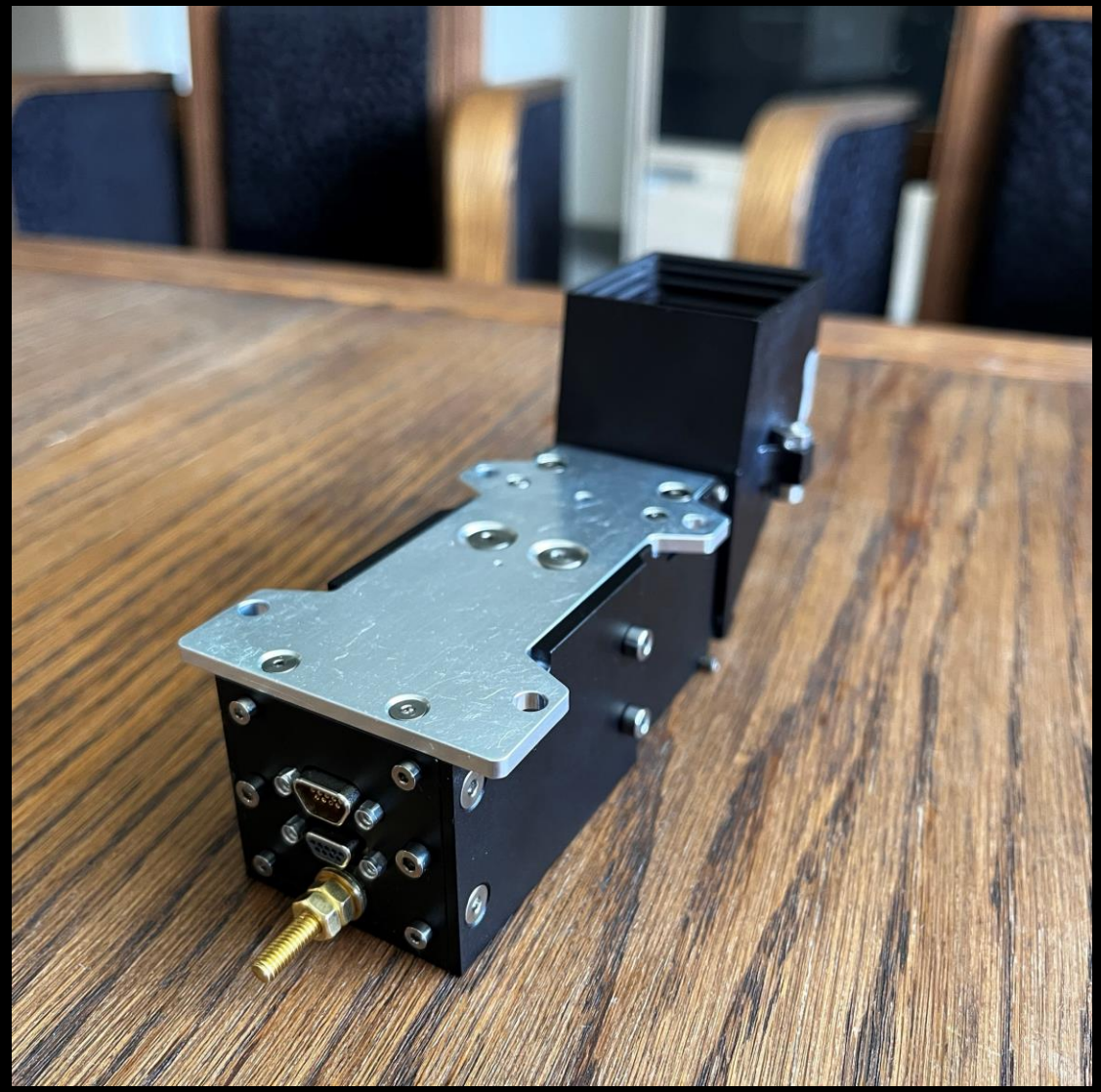
Full frame monochrome images
Can be combined with EnVisS for full sky image
For looking at the large scale structure of coma and changes in it
Plan is to combine them on ground to avoid misalignment errors

Type 2: auto-cropped

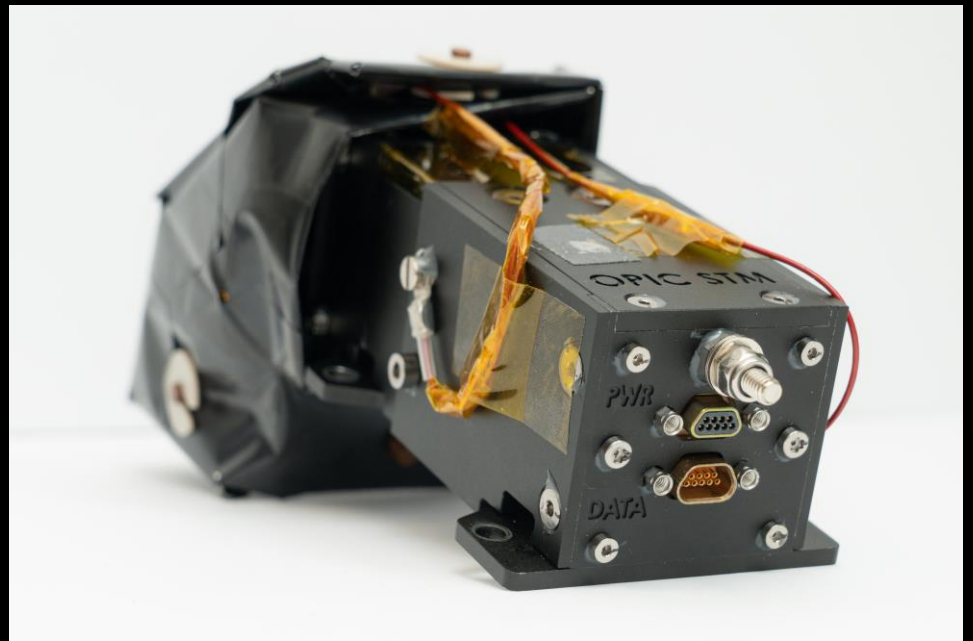


IMPRIO core developed by Bitlake Technologies

OPIC EM2 was built and tested



EMF and STM delivery due in February




Huomio!
työpiste-
kohtaiset
ohjeet
Käytettävä
kuulon-
suojaimia
Käytettävä
suojalaseja
PR1 (7)

Radiation testing in ESTEC Co-60 facility

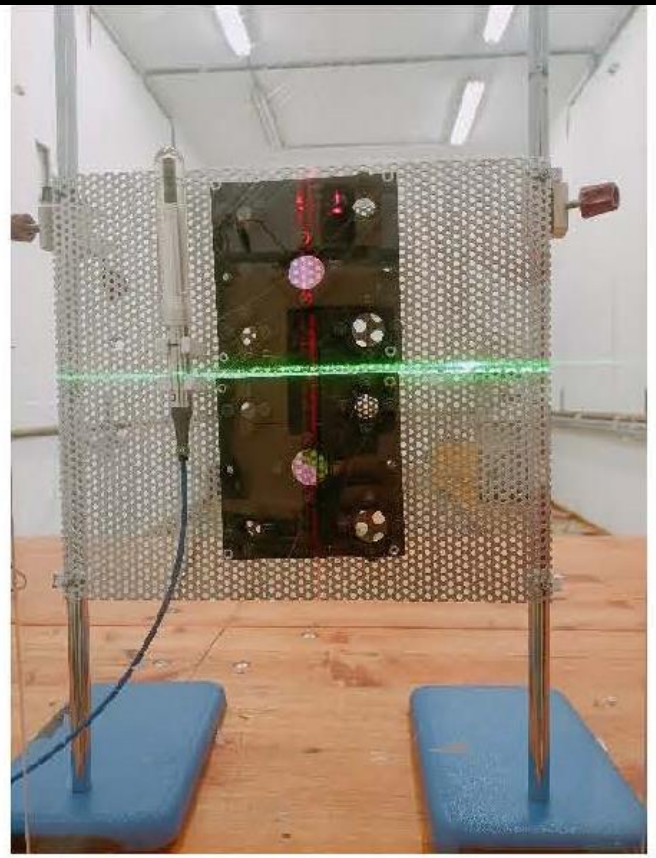
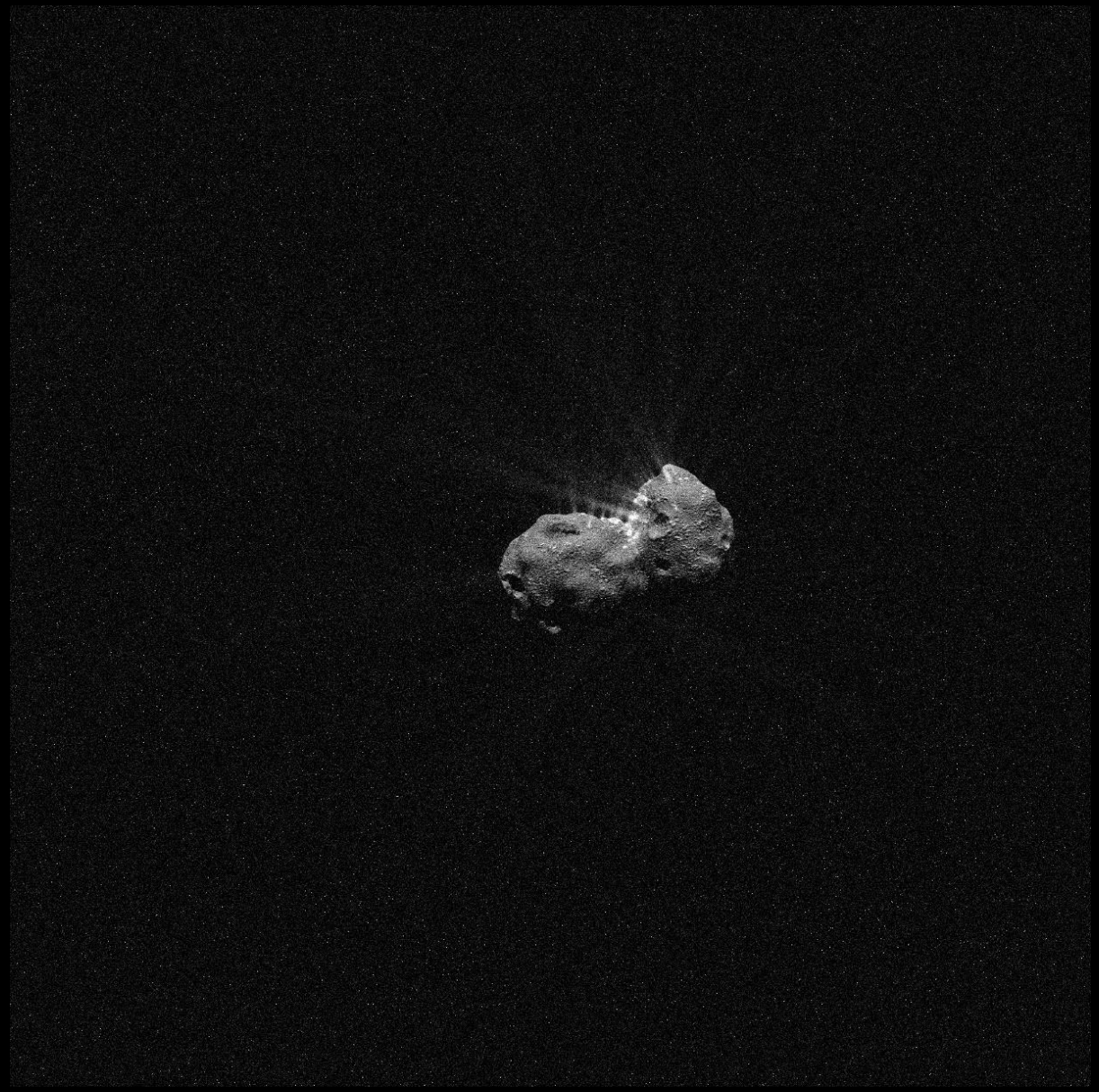


Figure 3: Picture of the setup installation in Run 1. Overall view on the left, front view on the right.

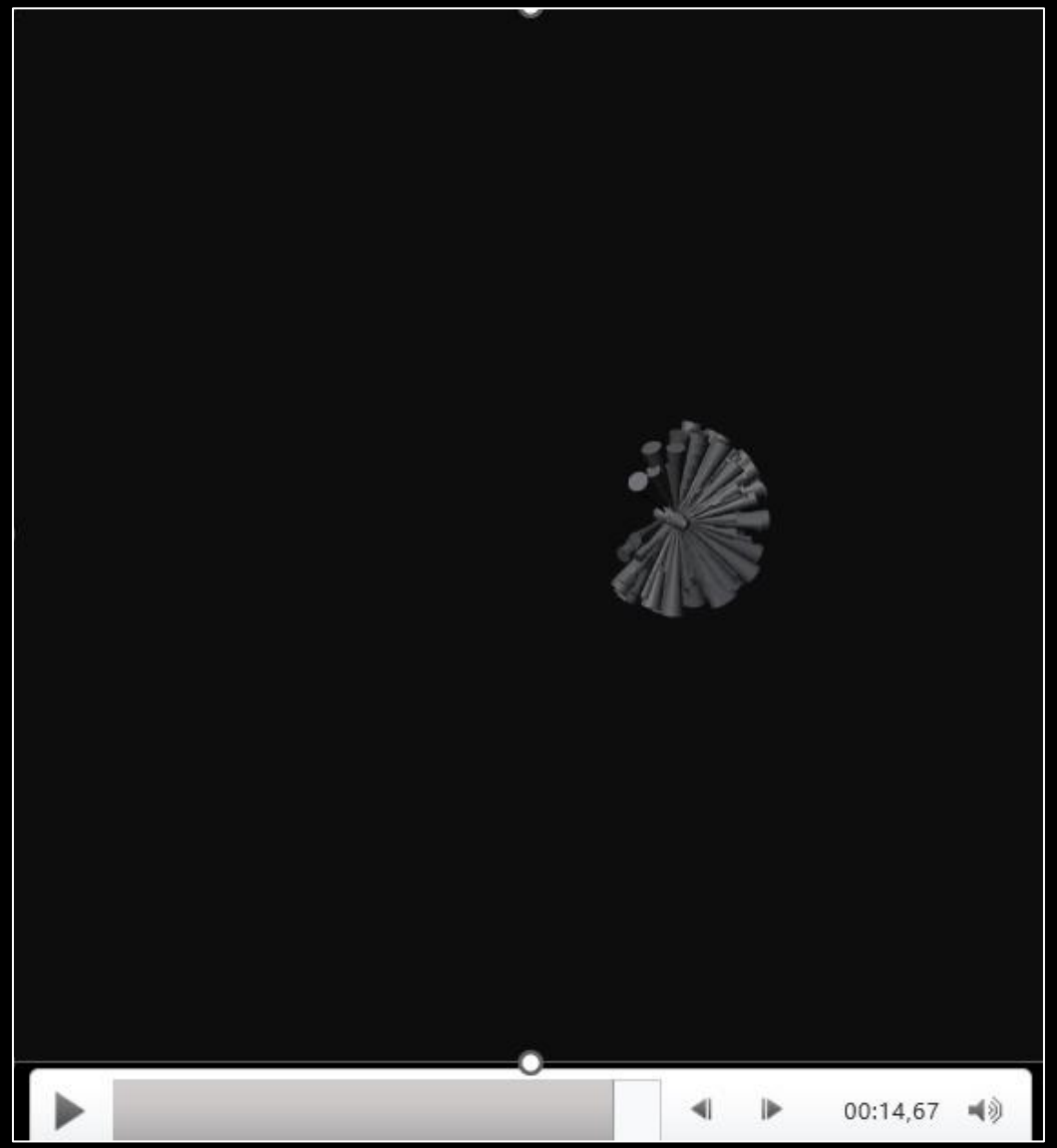
Simulations

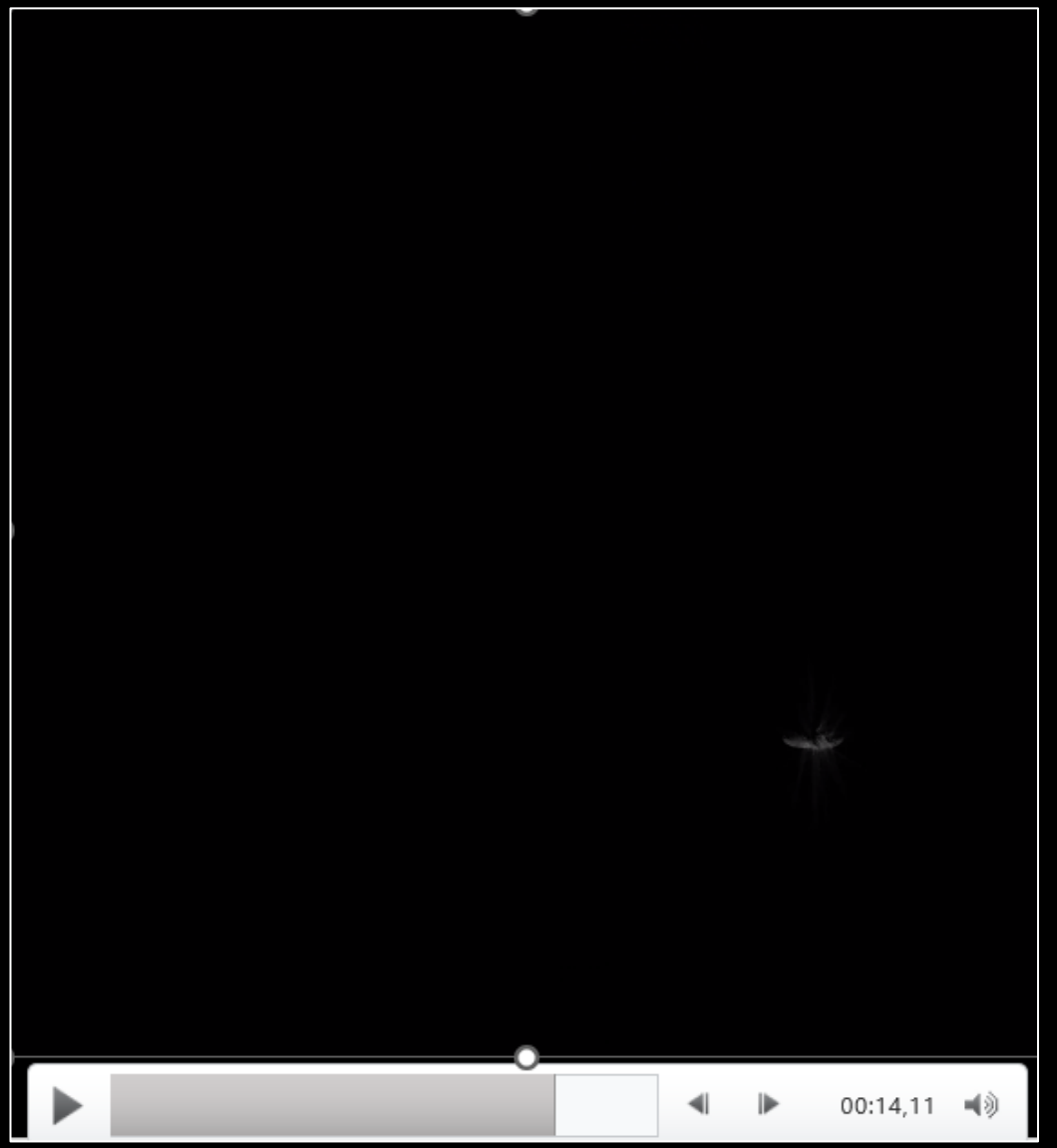
- New simulation pipeline being built
  - Based on Blender, but many improvements compared to previous SISPO
  - Developed under OSIP LEVERAGING HIGH RELIABILITY LOW LATENCY MACHINE LEARNING FOR IMAGING DURING VERY FAST AUTONOMOUS FLY-BY MISSIONS Activity number: 4000141651 by Ric Dengel
- Generates also segmentation masks
- Can add noises
- General approach: simulating, comparing with reference imagery and adjusting to match



Simulated image, noise is overestimated

New animations





Physical testing (same optics, same sensor)

Related projects

- ESA IIS for Bitlake Technologies in Latvia
- ESA OSIP LEVERAGING HIGH RELIABILITY LOW LATENCY MACHINE LEARNING FOR IMAGING DURING VERY FAST AUTONOMOUS FLY-BY MISSIONS Activity number: 4000141651 by Ric Dengel
- Industrial contract for PRODEX, starts January 2024

Future and timeline

- January 2024: OPIC manufacturing partner kick-off
- February 2024: EFM and STM delivery
- First quarter 2024, QM and FM production begins
- 2024 second half QM test campaign
- 2025 first half FM test campaign
- 2025 second half FM delivery
- 2026 beginning QAR
- 2026-2035 support for instrument operations and science

Conclusion

- OPIC development is progressing
- Flight model production begins this year
- Launch planned in 2029
- Fly-by around 2032
- Mission end around 2035 (last follow-up activities)