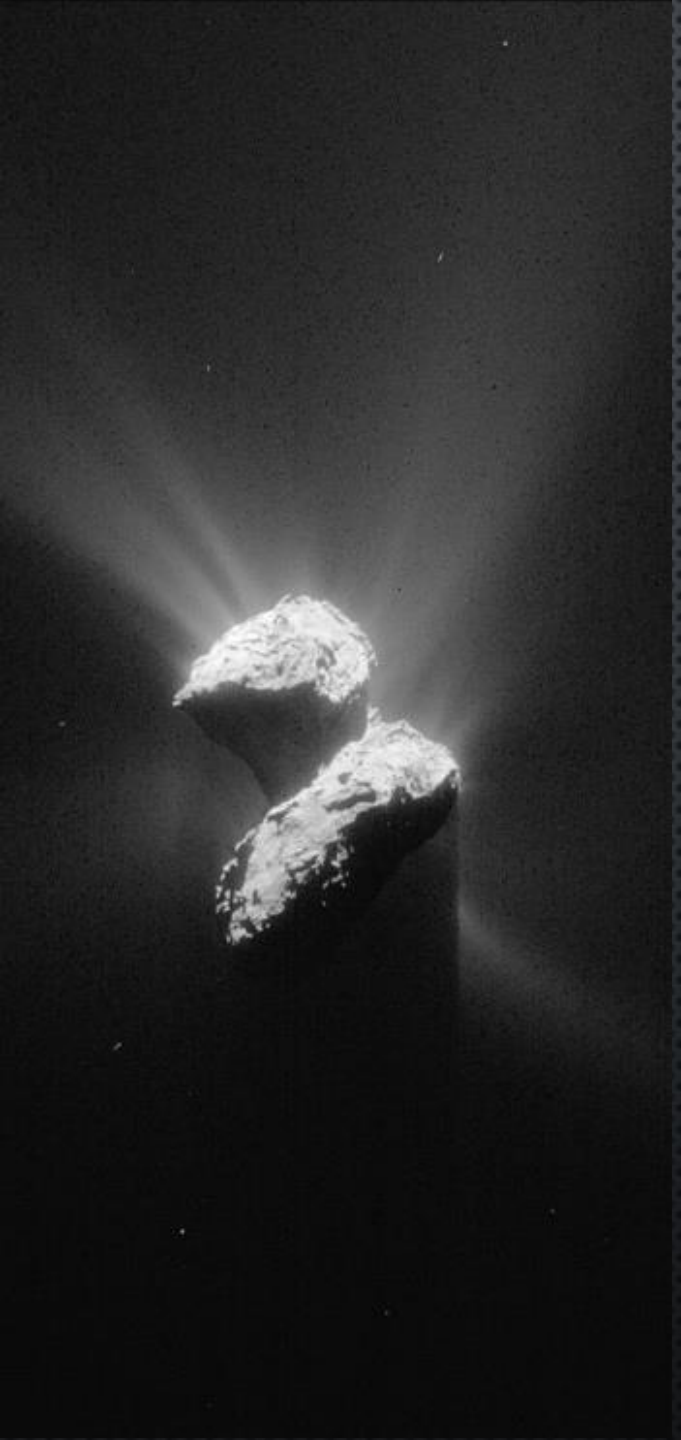
COMET INTERCEPTOR

Vincenzo Della Corte

on behalf of italian comet interceptor team

RSN3 27/05/2021



Comet Interceptor is a mission targeting a long-period comet, preferably dynamically-new, or an interstellar object.

Why?

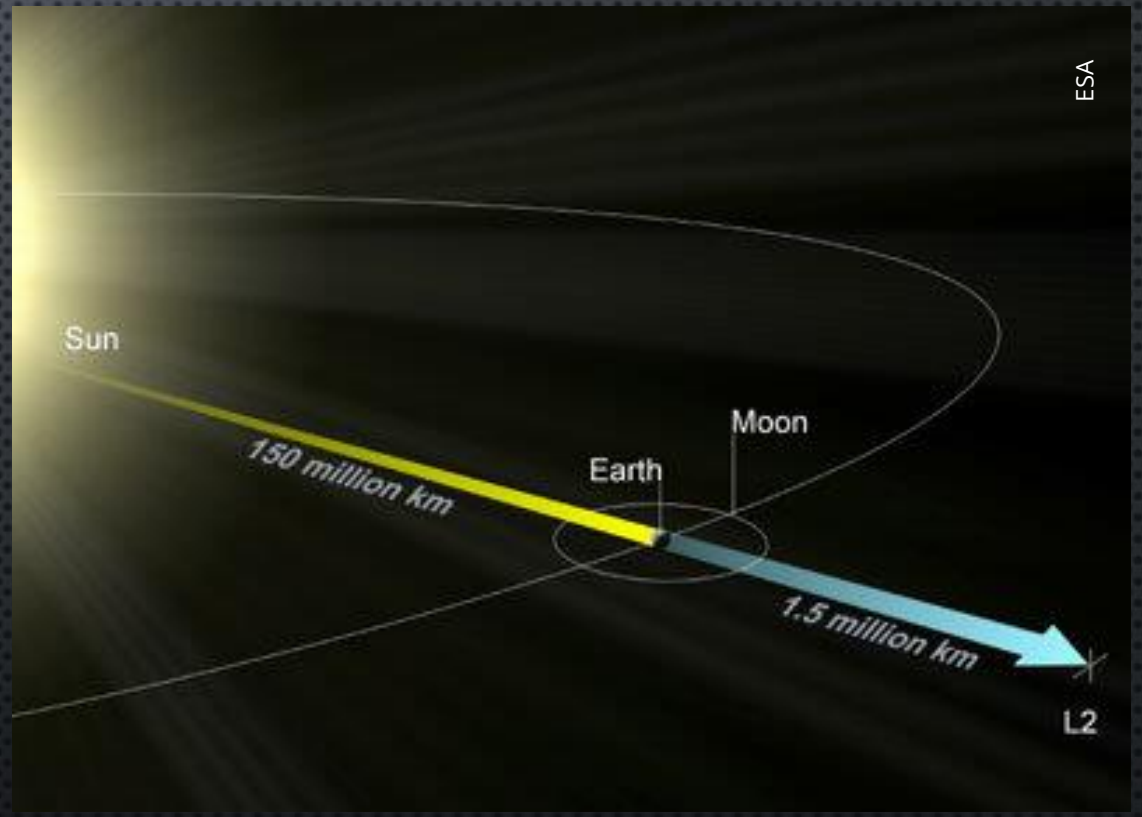
- All previous comet missions have been to objects that have passed the Sun many times
- Those comets have changed over time, and are covered in a thick layer of dust
- A dynamically-new comet is one that is probably nearing the Sun for the first time
- These are **pristine**

How?

- The only way to encounter a long period comet is to find one inbound very early
- The upcoming Vera Rubin Observatory (formerly LSST) will increase the **distance** at which comets are discovered inbound
- Even with advance warning, still not enough time to plan and build a spacecraft

SOLUTION: WE WAIT, IN SPACE

- We build a spacecraft that can cope with all kinds of comets
- We launch it to a stable 'parking' location in space
- We can respond rapidly to new discoveries - departure from parking location 6-12 months after target discovery



ESA F-class call

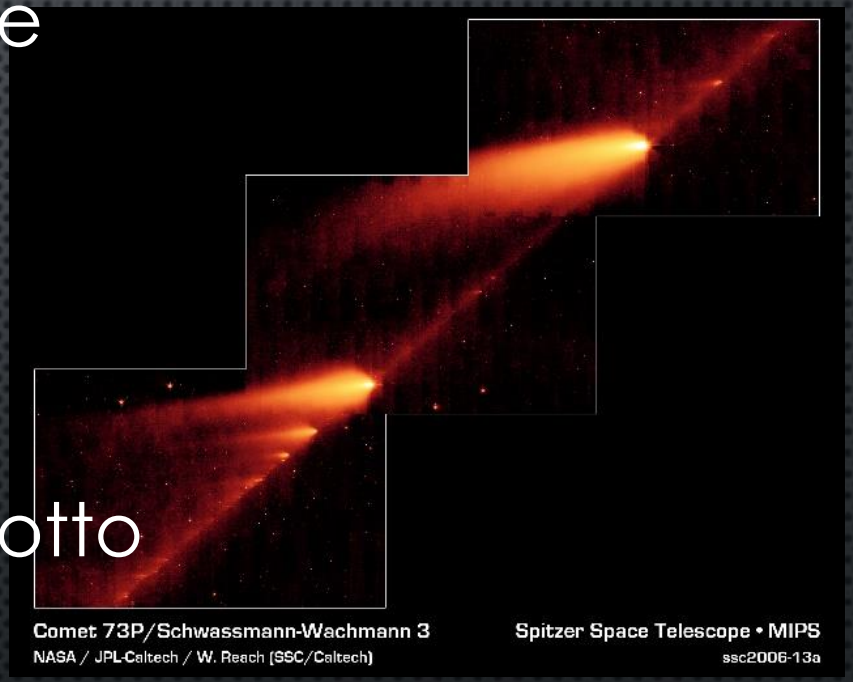
- In July 2018, F-class mission call announced.
- Maximum cost to ESA at completion, excluding launch: €150M.
- ESA member states and other collaborating agencies generally fund instruments and the science teams.
- Shared launch with Ariel exoplanet telescope, to Sun-Earth L2 point, in 2029

Challenges

- We may encounter comets at > 70 km/s
- We can't predict our path through the comet
- Cost limit means that entire mission should be < 5 years in duration

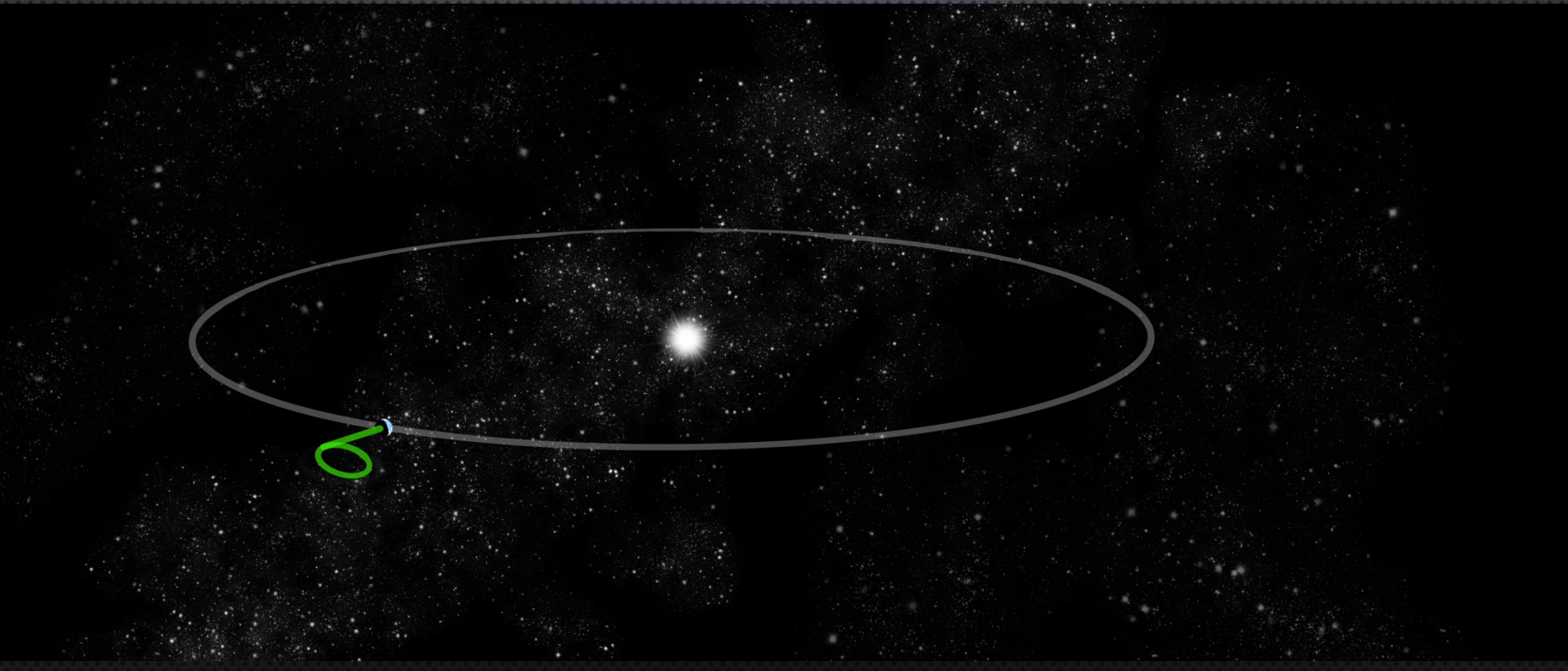
Solutions

- Limited radio link to Earth at encounter
- Dust shielding equivalent to that used on Giotto
- Wait at L2 limited to ~3 years
- Backup short period comet targets

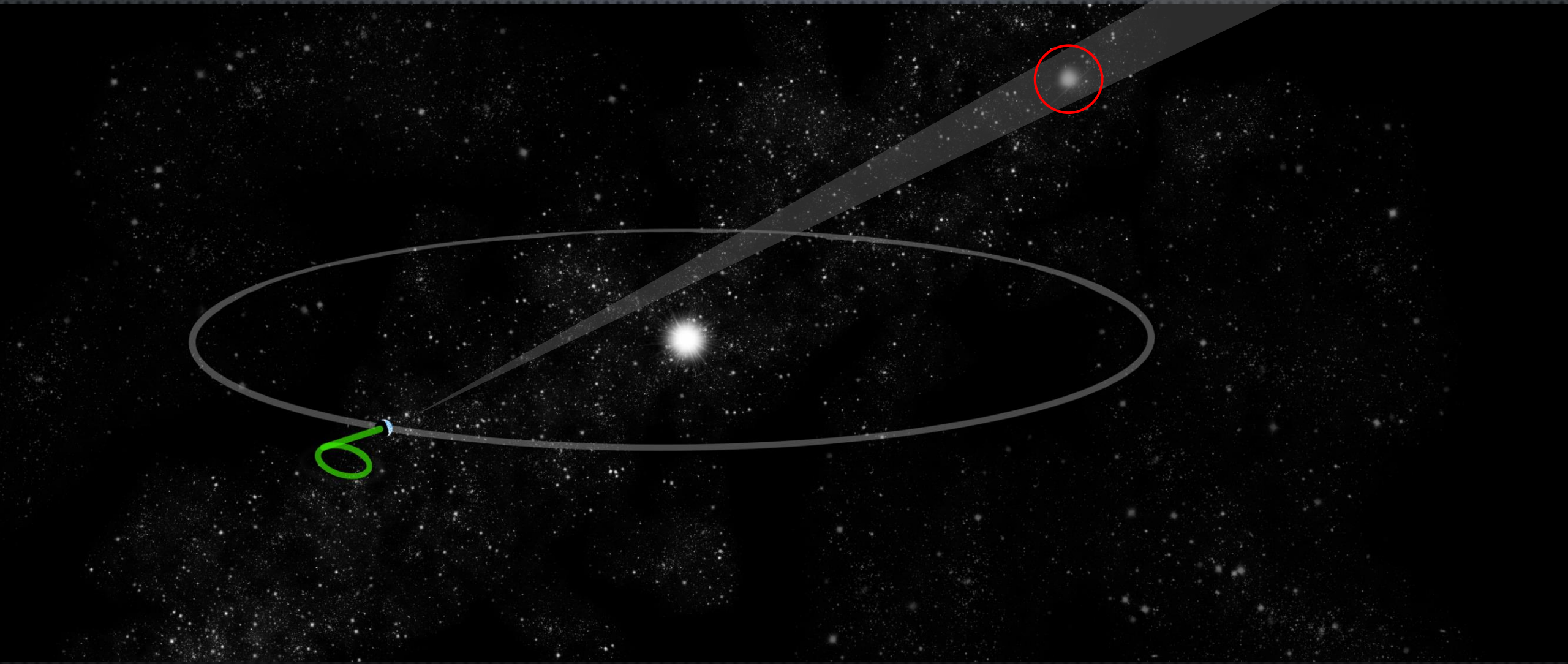


A mission to short period comet will carry out new science: not repeat of previous missions.

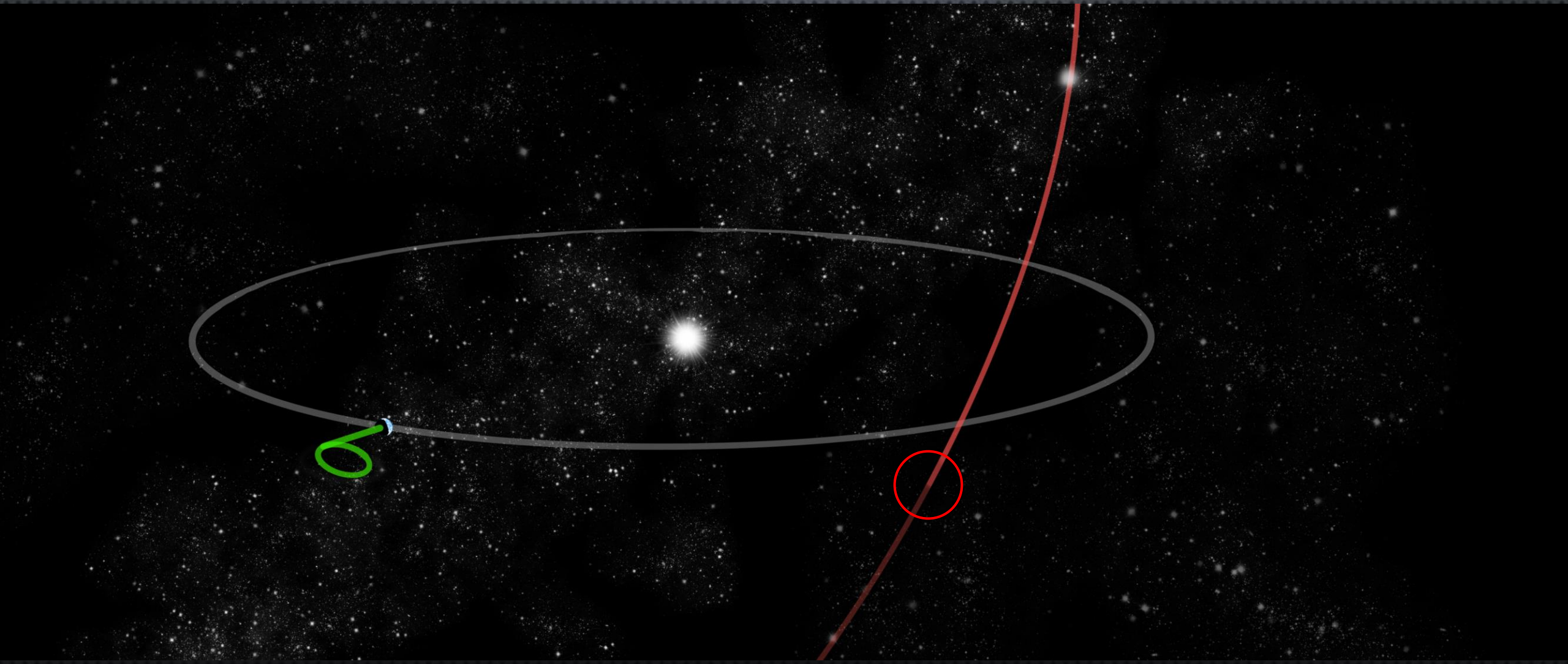
- Mission ‘parked’ at stable Lagrange point L2 after launch with Ariel
- Waits for up to 2-3 years for new target discovery
- Short cruise and fast flyby of target comet near Earth’s distance from the Sun; encounter has to take place close to the ecliptic – the plane of Earth’s orbit



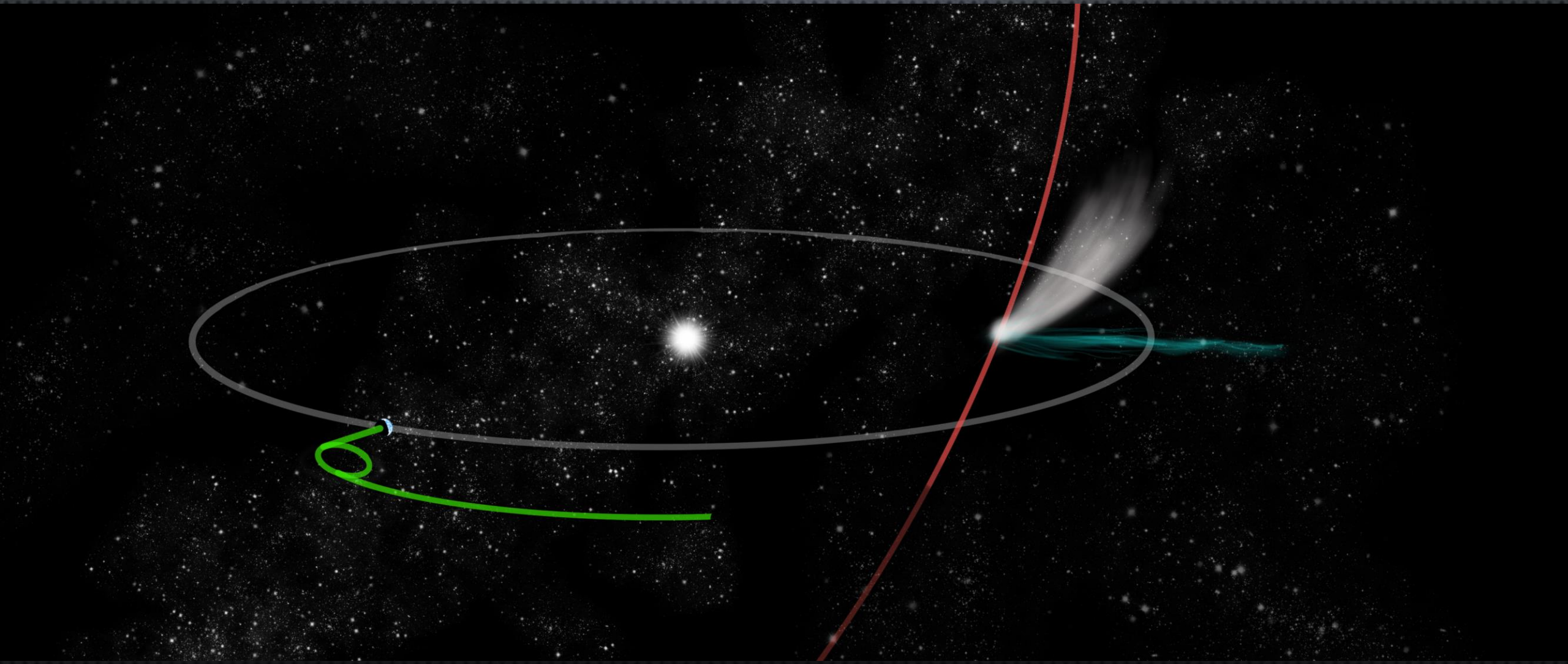
- TARGET DISCOVERED BY A GROUND-BASED OBSERVATORY



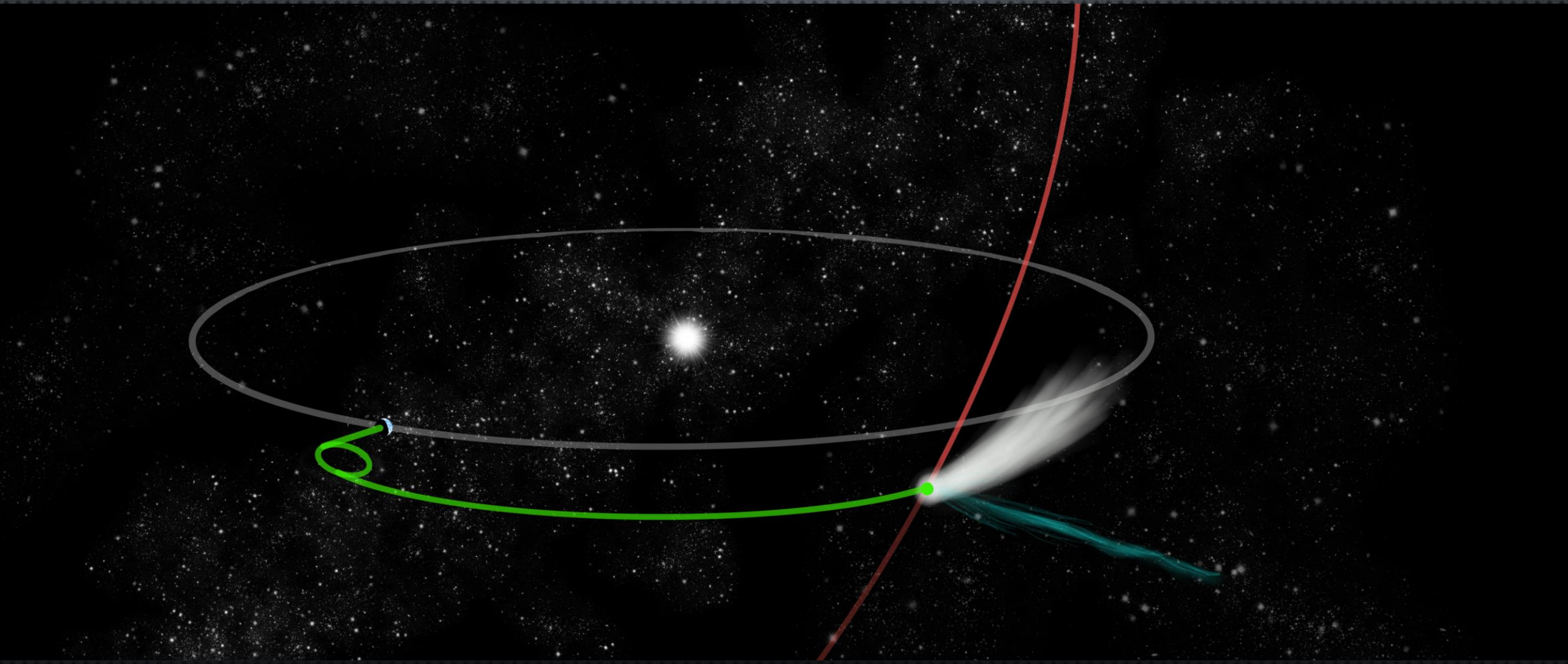
- Orbit computed and ecliptic crossing point predicted



- Comet Interceptor leaves L2 to intercept comet's path



- Encounter with comet close to the ecliptic plane



A Multi-Spacecraft Mission

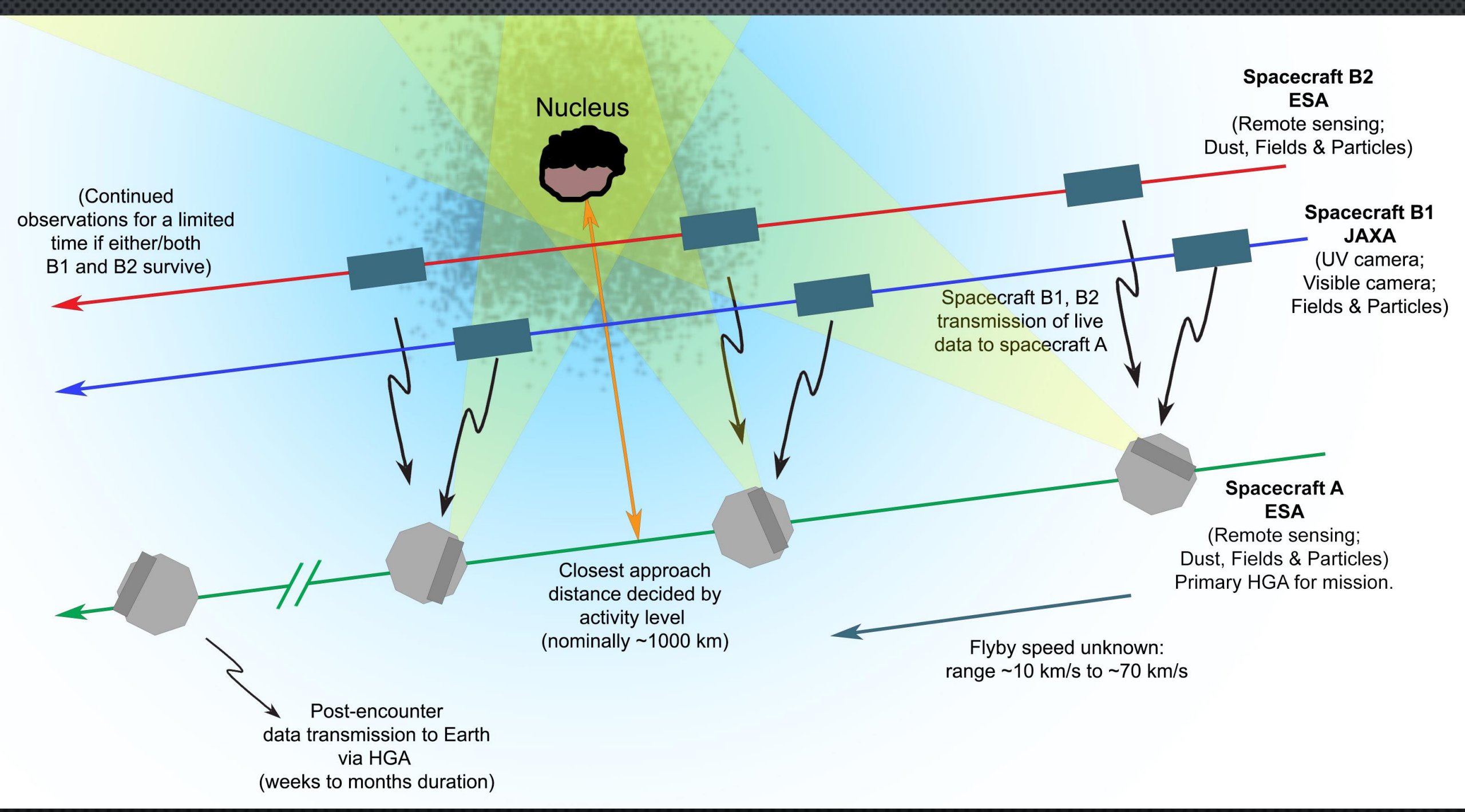
- A: main spacecraft

safe / distant measurements

- B1: inner coma

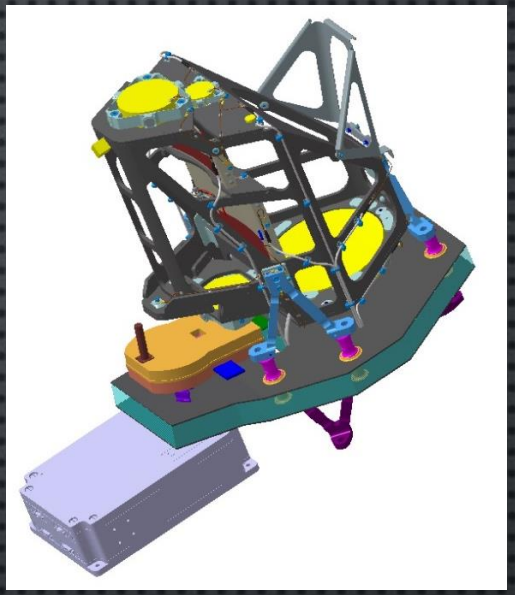
- B2: nucleus + coma

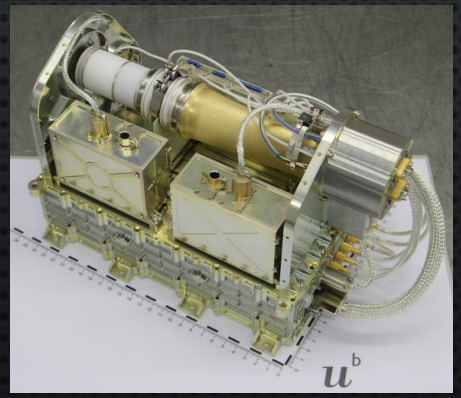
higher risk / high gain
closer approaches
to nucleus

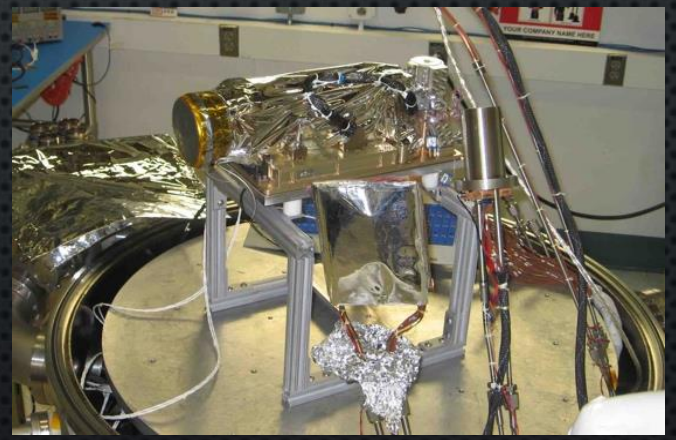

Nucleus
Spacecraft B2
ESA
(Remote sensing;
Dust, Fields & Particles)
(Continued
observations for a limited
time if either/both
B1 and B2 survive)
Spacecraft B1
JAXA
(UV camera;
Visible camera;
Fields & Particles)
Spacecraft B1, B2
transmission of live
data to spacecraft A
Spacecraft A
ESA
(Remote sensing;
Dust, Fields & Particles)
Primary HGA for mission.
Closest approach
distance decided by
activity level
(nominally ~1000 km)
Flyby speed unknown:
range ~10 km/s to ~70 km/s
Post-encounter
data transmission to Earth
via HGA
(weeks to months duration)

PAYLOAD - A

- CoCa – visible camera, based on ExoMars TGO CaSSIS
  - Flight spare of CaSSIS, with filter wheel added
- MANIaC – mass spectrometer
  - Rosina heritage
- MIRMIS – IR camera
- Dust, Field, and Plasma (DFP) package
  - DISC – dust impact sensor (IT-INAF)
  - COMPLIMENT – plasma + E-field
  - FGM – magnetometers
  - LEES – electrons
  - SCIENA – ions & energetic neutrals

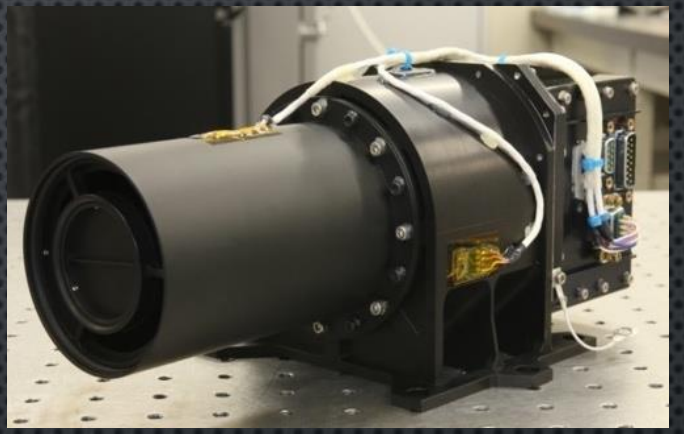




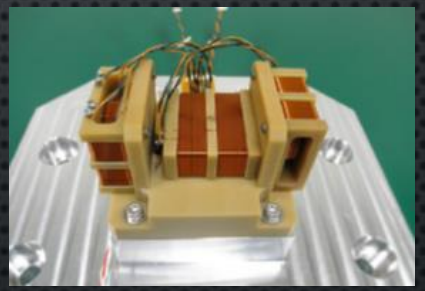


PAYLOAD – B1 (JAXA)

- Hydrogen Imager – FUV camera
  - Hydrogen maps via Ly-α, water production rate. Re-flight of PROCYON/LAICA



- Plasma suite (BepiColombo heritage)
  - MAG – magnetometer
  - ICA – ion mass spec (time of flight)



- Wide Angle Camera
  - 30-60°, monochrome camera
- Narrow Angle Camera
  - Few metre resolution at closest approach, for 0.25s

PAYLOAD – B2

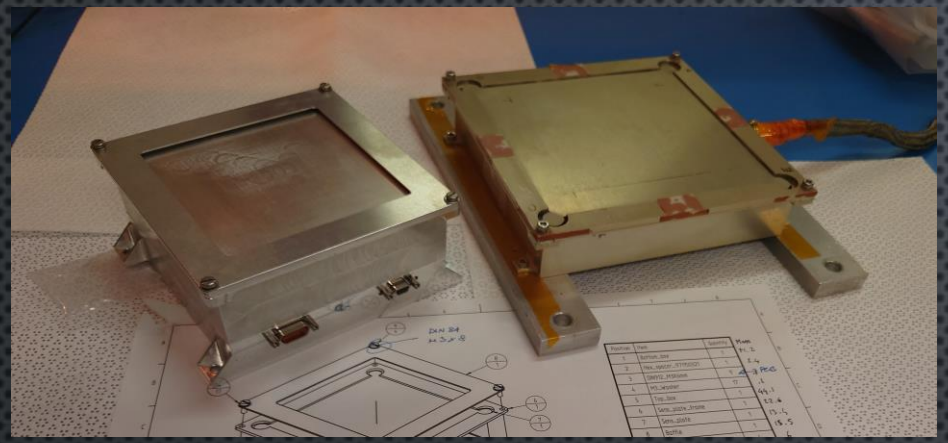
- EnVisS – coma mapping camera (IT-CNR& IT-INAF)
  - Broadband and polarimetric imaging filters, ~180deg stripe, scans whole sky

- OPIC – forward looking camera
  - Monochromatic visible camera

- DFP – B
  - DISC – dust impact sensor (IT-INAF)

  - FGM – magnetometers

DISC instrument concept



- DISC direct heritage from Impact Sensor fo GIADA Instrument
- Sensing element : thin aluminum plate equipped with PZT
- A dust particle impacting the aluminum plate generates acoustic waves that propagate in the diaphragm till the PZTs
- From Signals of PZT momentum of impacting particles can be retrieved

The design concept of Impact Sensor tuned for low speed impacts <100m/s is applicable to Hyper Velocity Impacts:

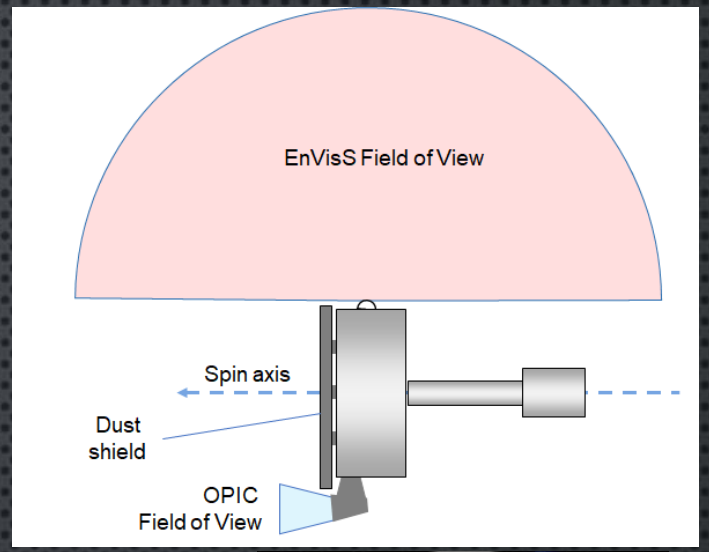
- Far from impact point on plate (few mms) mechanical behaviour of sensing element is the same that in case of low speed impacts

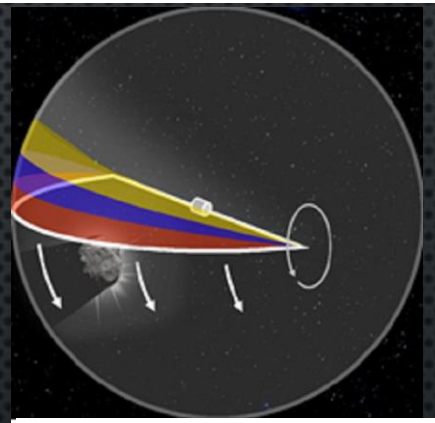
During the close encounter DISC sensor will:

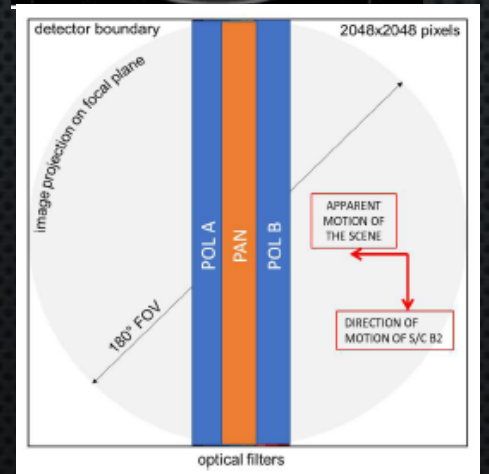
- determine the dust mass distribution for particles with mass in the range 10^{-15} – 10^{-8} kg, corresponding to particle sizes from about 200 micron down to 1 micron, depending on S/Cs flyby speeds;
- count of dust particles with mass >10^{-8} kg;
- characterize dust impacts in terms of duration from which we will constraint particles density/structure;
- characterize sensing surface damages (possible after flyby using internal sensor calibrator)

EnVisS instrument concept

- Push-frame imager, facilitated by the spacecraft's spin; a fisheye optical head allows a 180° across-track field of view.
- 360° B2 spacecraft rotation allows EnVisS to image almost the entire visible sky.
- Filters mounted in front of the detector - broad band and polarisers – allowing broadband and polarimetric imaging of the target coma.
- No moving parts; keeps the instrument compact and simple.
- No pointing requirements relative to the nucleus; sunward or antisunward passage past nucleus equally valuable.

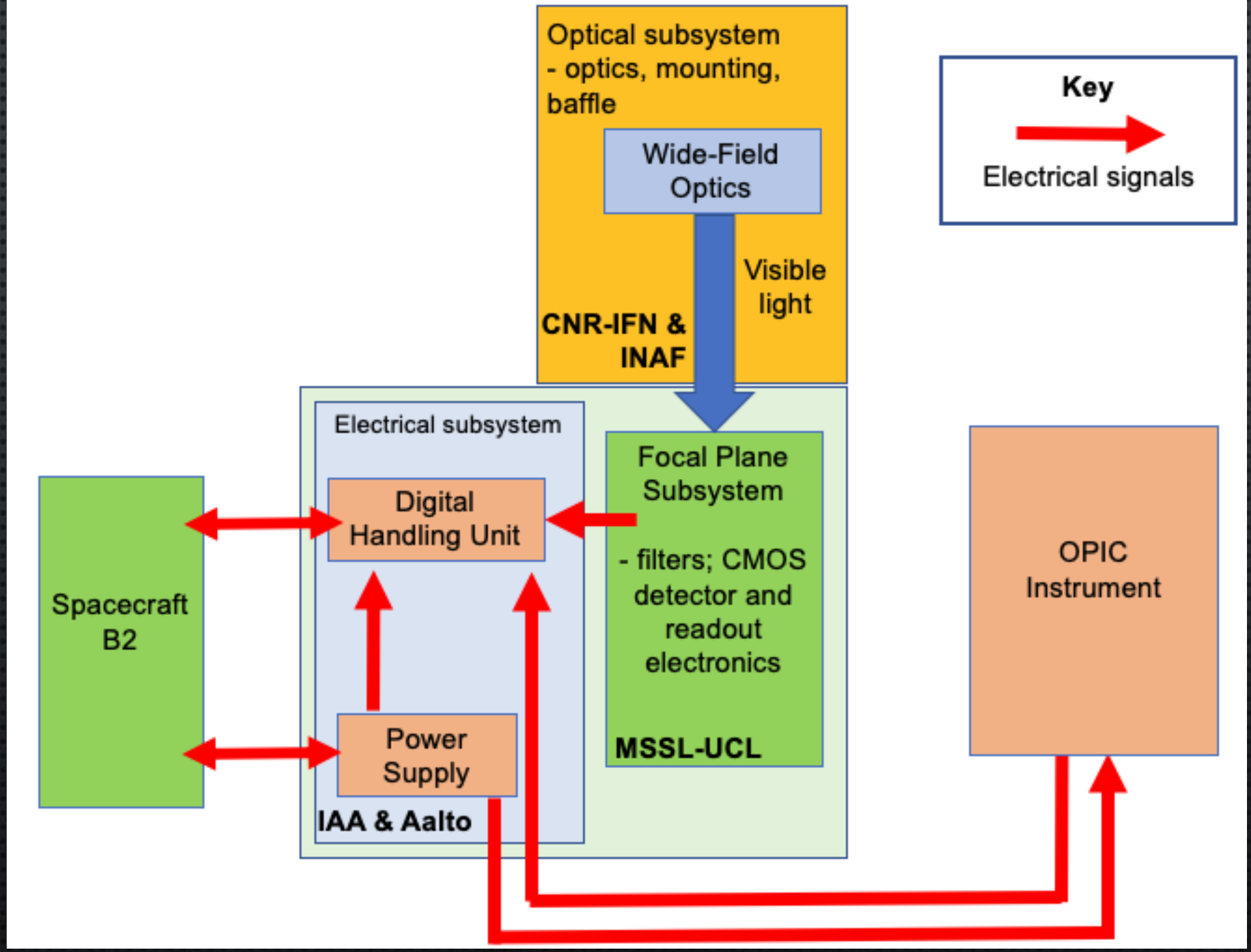






three broad band filters are foreseen at present. They are:
- one broadband filter positioned to be centered on the detector;
- two polarimetric filters with polarization angles -/+ 60° (POLA and POLB).

Due to scientific requirements and technical instrument constraints, the wavelength range for all the filter strips has been selected to be 550-800 nm.


Optical subsystem
- optics, mounting, baffle
Wide-Field Optics
Visible light
CNR-IFN & INAF
Key
Electrical signals
Electrical subsystem
Digital Handling Unit
Power Supply
IAA & Aalto
Focal Plane Subsystem
- filters; CMOS detector and readout electronics
MSSL-UCL
Spacecraft B2
OPIC Instrument

TEAM/LEADERSHIP

Italian Scientific Team INAF :

INAF-IAPS
Vincenzo Della Corte (DISC PI)
Cecilia Tubiana (Resp delle Op. Scientifiche CI)
Maria Teresa Capria (Co-I)
Vladimir Zakharov (Co-I)
Giovanna Rinaldi (Ass.)
Andrea Longobardo (Ass.)
Alessandra Migliorini (Ass.)

INAF-OAPD
Claudio Pernechele (resp dis. ottiche EnVisS).

INAF-OAT
Stavro Ivanovski (Ass.)
Marco Fulle (Ass.)

INAF-OAS
Alberto Buzzoni (Ass.)
Albino Carbognani (Ass.)

INAF-OAR
Elena Mazzotta (Ass.)

Univ. di Napoli Parthenope:

Alessandra Rotundi : National co-PI
Laura Inno: Co-I and part of Vera Rubin Observatory Legacy Survey of Space and Time (LSST), italian ref. Point of "Solar System Science team";
Ivano Bertini : Co-I (coord. Observation from ground)
Federico di Paolo (Ass.)
AliceMaria Piccirillo (Ass.)
Fiorangela La Forgia (Co-I)

CNR-IFN:

Vania Da Deppo (EnVisS resp/Co-PI)
Paola Zuppella (Ass)

Univ. di Padova:

Monica Lazzarin (Ass)

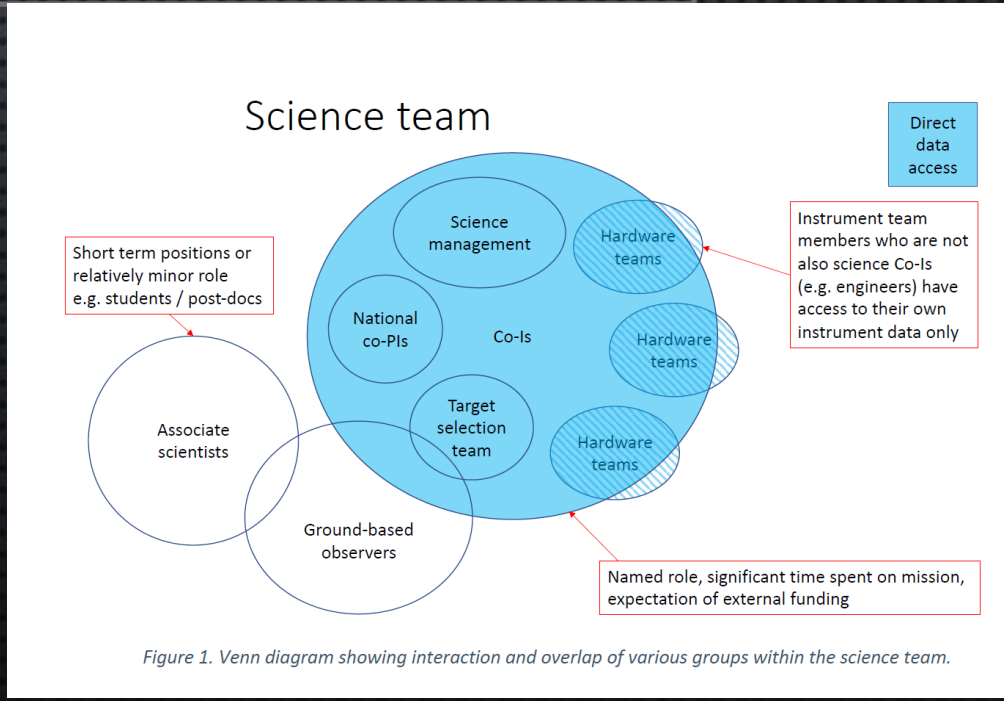


Figure 1. Venn diagram showing interaction and overlap of various groups within the science team.

PROSPETTIVE /PROGRAMMAZIONE

Milestone	Planning
Start of P/L phase A/B	Jan-20
Start of industrial phase A/B	Sep-20
Instruments PRRs completed by	*Q4-20*
Instruments SRRs completed by	*Q2-21*
End of Phase A/B1 (S-SRR)	Q3-21
Instruments PDRs completed by	*Q2-22*
End of Phase B2 (S-PDR)	Q2-22
Prime contractor selection	Q3-22
Start of phase C/D/E	Jan-23
Instruments CDRs completed by	*Q3-23*
Instruments EMs & S(T)Ms DRB	***1st February 2024 (TBC)***
End of S(T)M & EM campaigns	Sep-24
S-CDR	Q4-24
Probe B2 platform ready	Q4-25
Probe B2 instrument FMs DRB	***1st October 2025 (TBC)***
S/C A platform ready	Q1-26
Probe B2 integration & functional tests	Q1-26
Payload QARs completed by	*Q1-26*
S/C A instrument FMs DRB	***2nd February 2026 (TBC)***
Delivery of integrated B1 and B2	Q2-26
Start of S/C integration & funct. tests	Q2-26
End of S/C integration & funct. tests	Q4-26
Start of the ETC at satellite level	Q1-27
S-QAR	Q4-27
Launch readiness (including 6 month margin)	2028

Teams involved in the HW responsibilities are following the timeline of the mission. In these weeks the I-SRRs both for in-situ instruments and remote sensing are on-going
The review will close by the end of June.

Team involved in ground observations in support of target definition are preparing proposals of observations and data anlyses

Activities related to LSST have been presented during RSN5 sessions in the frame of the LSST project.

Next months will be used for the development of instruments:

- To increase TRL up to 5 (EnVisS)
- To demonstrate instrument performances in High Velocity Impact by means of tests (DISC)

FONDI

A partire dalla selezione della missione il progetto ha ricevuto il finanziamento da parte di ASI per lo sviluppo degli strumenti con responsabilità italiana, tramite un accordo ASI-INAF con partecipazione del CNR-IFN di Padova e dell'Università degli Studi di Napoli "Parthenope"

Stima inviluppo complessivo intera attività (k€):	2500
Stima inviluppo complessivo per la parte di attività INAF (k€):	1000
Stima fondi acquisiti da INAF fino al 2020 (k€):	150

Un supporto specifico per lo studio delle prestazioni di DISC agli impatti iperveloci è in fase di stipula con ESA confinanziamento complessivo 220k€.

Criticità/Competenze da acquisire

Nell’ambito del programma Comet Interceptor sono presenti diversi ruoli di responsabilità rivestiti dal personale INAF:

- Tra questi, c’è il ruolo di “Mission Science Operation Manager”, un ruolo di gestione ad alto livello. Questo ruoleo è rivestito da personale non staff dell’INAF-IAPS (“assegnista di ricerca Senior”).
- L'interpretazione dei dati di una missione cometaria non può prescindere dalla capacità di modellazione dell'ambiente di polvere, queste capacità sono al momento presenti all'interno del team, ma in parte con personale non staff INAF.
- Per lo sviluppo di DISC è prevista un’intensa campagna di misura, durante la fase di sviluppo, e la responsabilità della calibrazione, nella fase di realizzazione del modello da volo. Per svolgere questa attività è necessaria una figura dedicata, che possa seguire: la calibrazione e la successiva analisi e modellazione dei dati.
- Nel prosieguo dello sviluppo dello strumento EnVisS è necessario acquisire una figura dedicata alla correzione delle distorsioni ottiche, critica per l’interpretazione dei dati.