# Rapid reconnaissance missions based on ESA's Comet Interceptor

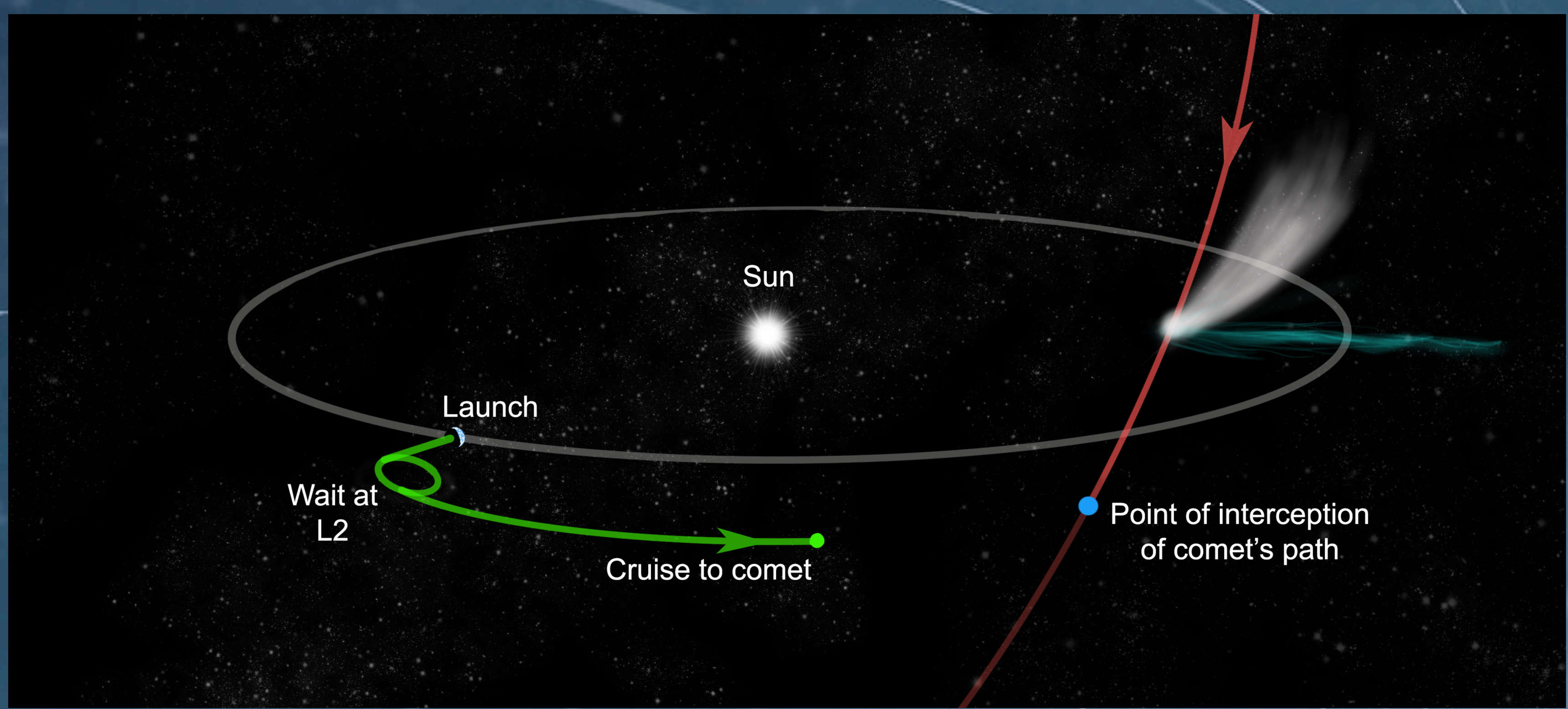

C. Snodgrass[1], G. H. Jones[2], and C. Tubiana[3]

[1]University of Edinburgh, UK; [2]Mullard Space Science Laboratory, University College London, UK;
[3]INAF - Istituto di Astrofisica e Planetologia Spaziali, Rome, Italy


## Comet Interceptor: A mission to a pristine comet

- All previous comet missions have been to objects that have passed the Sun many times
- Targets were relatively evolved, with thick coatings of dust on their surfaces
- A mission to a comet that is approaching the Sun for the first time would encounter a **pristine** object, with surface ices as first laid down at the Solar System's formation

- To do this, Comet Interceptor must be planned and launched *before* its target comet is discovered, as the warning time is likely to be only a few years
- The mission will launch in 2029, with the ESA Ariel space telescope
- It will be 'parked' in orbit around the Sun-Earth L2 point
- Once a suitable target is discovered, the spacecraft will have a short cruise to a fast flyby



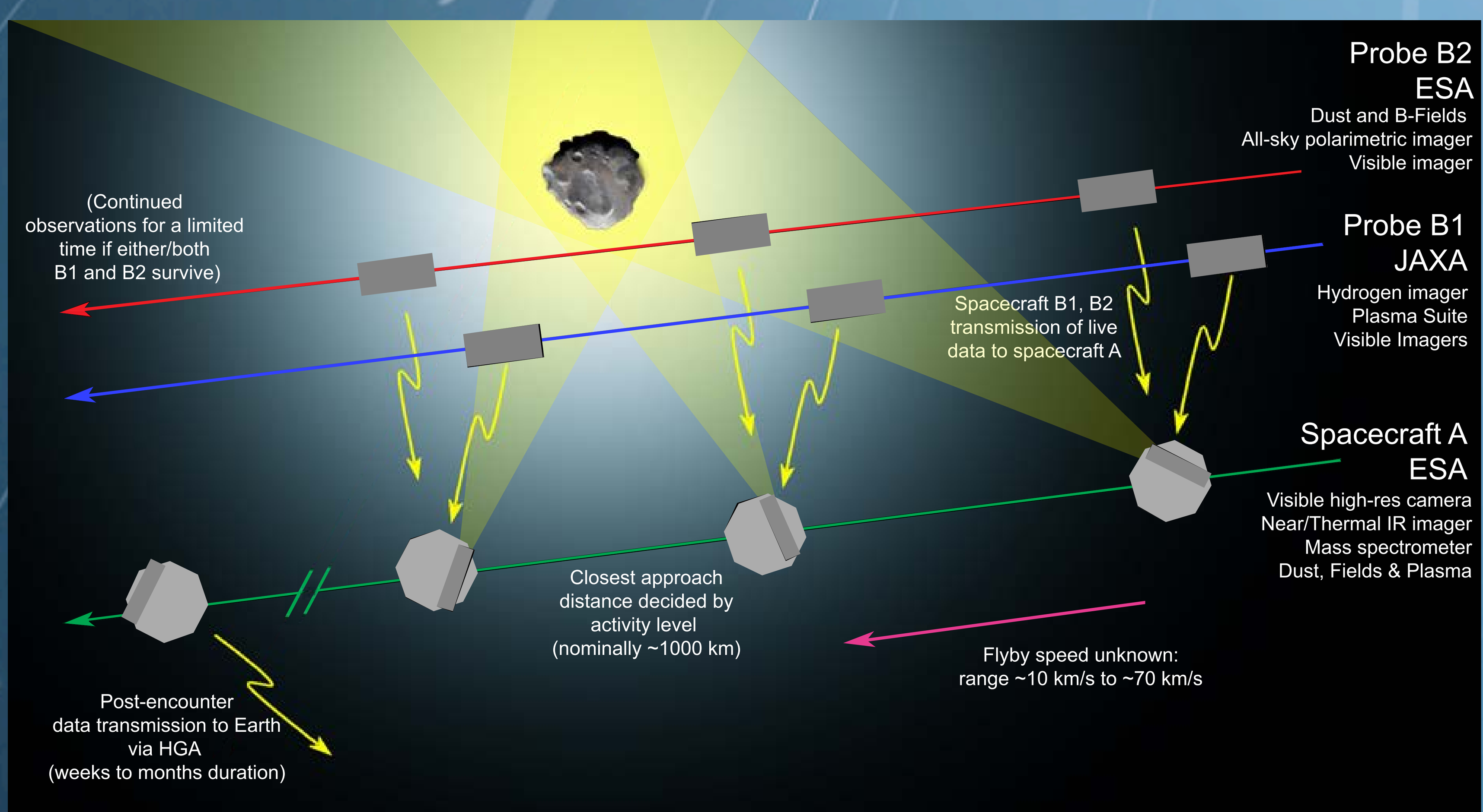

## Multiple Spacecraft Architecture

- Comet Interceptor has three spacecraft, to make multi-point measurements
  - 3D sampling, separates time and space variations in a cometary coma
  - Separating safe / distant measurements and high risk / high gain close approaches

- **A: main spacecraft (ESA)**
  - Passes sunward of comet at ~1000 km ('safe' distance)
  - Data relay for other spacecraft
  - Propulsion + communication
  - Core payload to ensure results even if other spacecraft fail

- **Probe B1 (contributed by JAXA)**
  - Targeted to pass through inner coma
  - In-situ sampling, nucleus and inner coma imaging
  - 3 axis stabilised

- **Probe B2 (ESA)**
  - Targeted closest to nucleus
  - 'Expendable' probe designed to get as close as possible
  - Dust detector and magnetometer, whole coma polarimetric imaging
  - Spin stabilised, no active control




## Rapid Reconnaissance for Planetary Defence

- A Comet Interceptor type mission concept could be used to get a rapid first look at any potentially hazardous asteroid
- A spacecraft waiting in space could return resolved asteroid images within a few years of discovery, depending on trajectory requirements
- This would be much quicker than a dedicated mission could be planned, built and launched – crucial if pre-impact warning time is less than a decade
- Resolved images could give strong indications about the size, shape and bulk structure of the asteroid (rubble pile or not), and surface boulder size distributions, all of which would influence any deflection attempt
- Additional information could be returned from a MIRMIS-like infrared instrument, on composition and thermal properties
- A planetary defence (asteroid) optimised version can be a lot simpler than Comet Interceptor: single spacecraft, no *in situ* instruments or dust shields
- Mission concept is inherently flexible on launch opportunities, and can take advantage of rideshares to any suitable 'parking' orbit
- Trade offs to be considered on small, cheap, short-lived (CubeSat?) probes versus more capable and robust spacecraft designed for longer waits

## Intercepting an unknown target

- A key trade is on fuel mass (and therefore $\Delta v$ capability) versus payload
- Comet Interceptor has a 6 year limit on whole mission lifetime (launch, waiting, transfer cruise, comet encounter, data downlink) due to cost cap
- Comet encounter must be near ecliptic, between 0.9 and 1.2 au from the Sun
- Increasing distance from Earth within this region can be achieved with either more fuel or longer cruise time (given an early enough comet discovery)

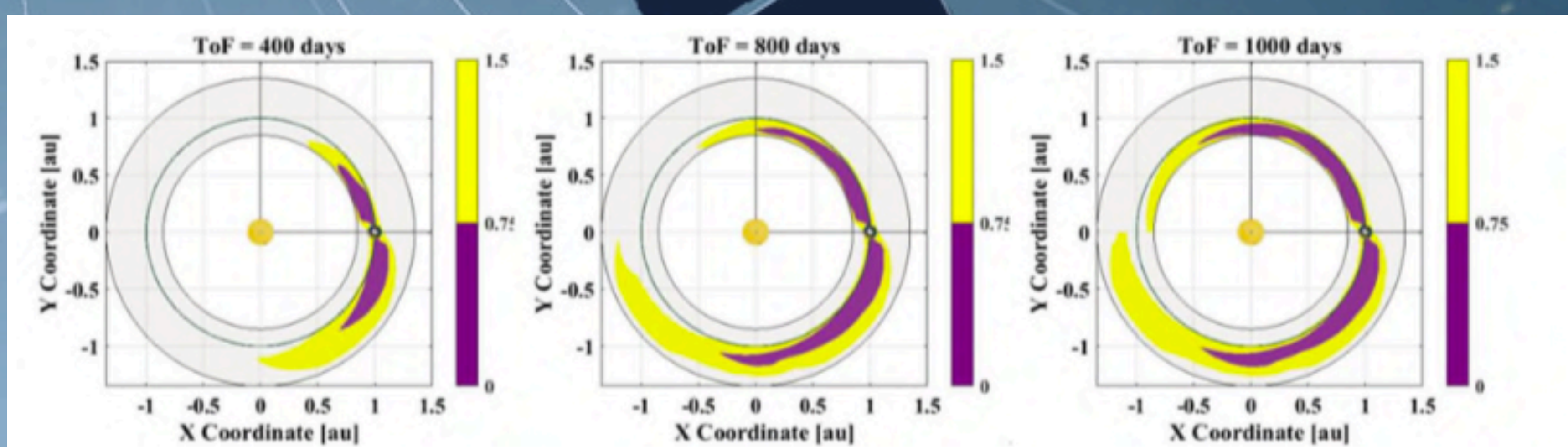



Figure 5: Accessible regions for chemical propulsion. The color map represent the $\Delta v$ budget in km/s

- Detailed analysis by Sánchez et al 2021 [Acta Astronautica 188:265] shows accessible regions in Earth-rotating frame for different $\Delta v$ and cruise length

## Comet Interceptor Payload

Figure 3: CaSSIS instrument on ESA ExoMars TGO, on which CI CoCa is based [Uni Bern].

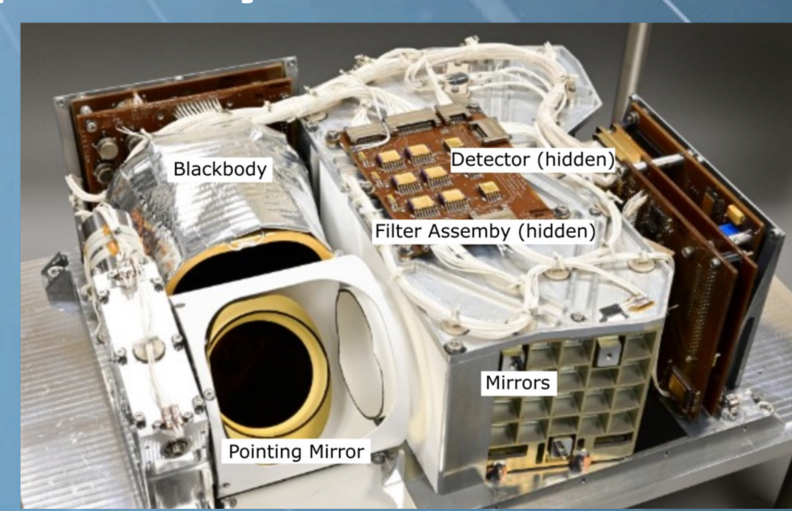



Figure 4: The Lunar Thermal Mapper instrument, similar to the thermal infrared channel of MIRMIS [University of Oxford].

- Mix of cameras and in situ sensors to measure structure, composition and dynamical behavior of the comet, and its interaction with the solar wind

| Spacecraft | Instrument | Description |
|---|---|---|
| A ESA | CoCa | Visible high resolution camera |
| | MIRMIS | Near to Thermal IR spectral imager |
| | MANiaC | Mass spectrometer |
| A / B2 | DFP | Dust, Fields & Plasma (sensors on A and B2) |
| B2 ESA | EnVisS | All-sky polarimetric imager |
| | OPIC | Visible imager |
| B1 JAXA | HI | Lyman-alpha Hydrogen imager |
| | PS | Plasma Suite |
| | NAC/WAC | Narrow & Wide Angle Cameras |

For an asteroid mission, the most important instruments will be high resolution cameras for size and structure, and infrared (including thermal IR) remote sensing for composition and surface properties

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