Identification of Targets for ESA's Comet Interceptor Mission

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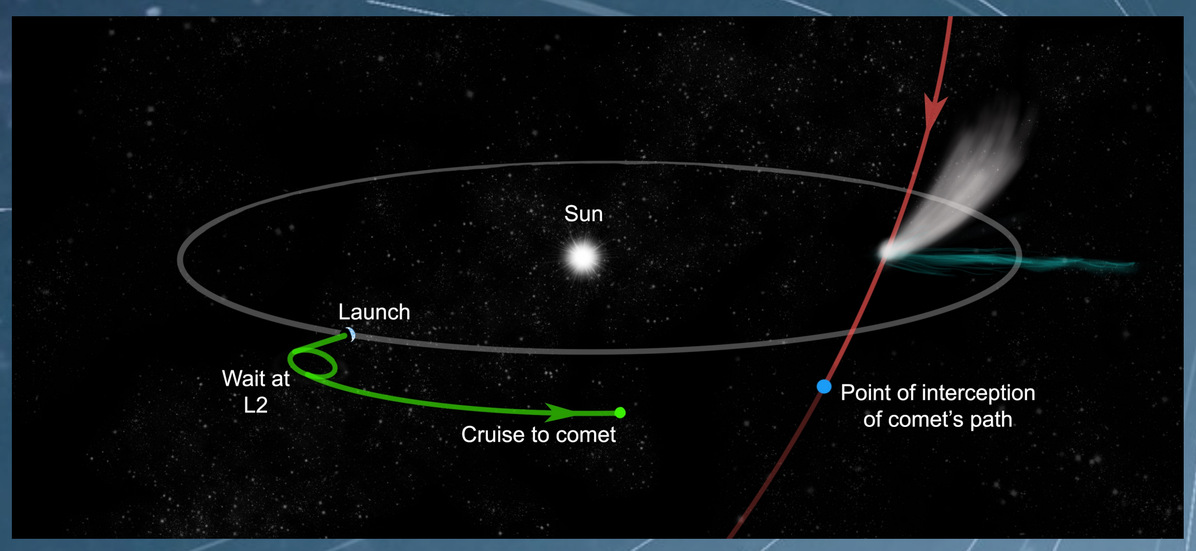
Comet Interceptor: A mission to a pristine comet

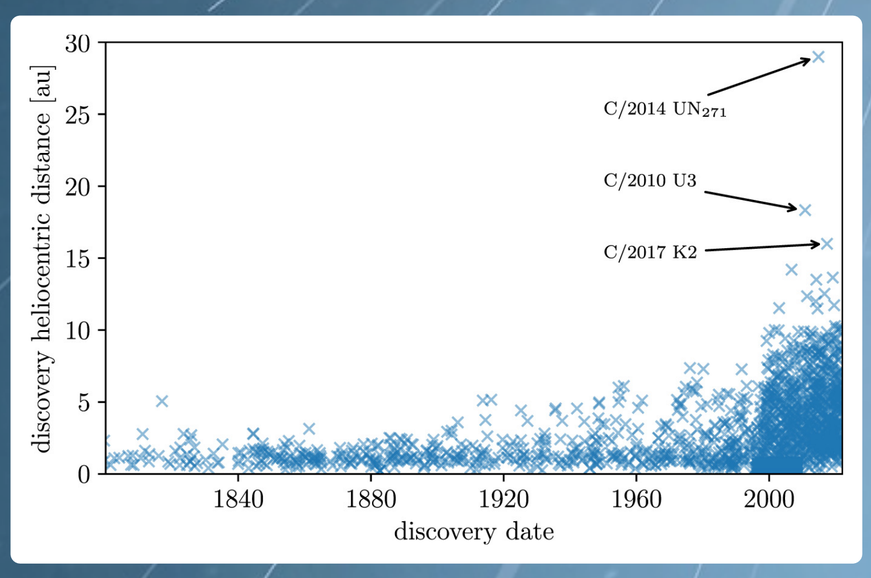
- All previous missions have been to comets that passed the Sun many times
- Targets were relatively evolved, with thick coatings of dust on their surfaces
- A mission to a comet that is approaching the Sun for the first time would encounter a **pristine** object

- 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 target is found, the spacecraft will have a short cruise to a fast flyby



Distant comet discovery

- We need a minimum 1-3 year warning time between discovery and encounter date, depending on distance from Earth at encounter
- This implies discovery at a distance beyond 5 au, and ideally beyond 10 au
- Discoveries at these distances are becoming more common in the era of modern sky surveys, and are expected to increase further with LSST



Discovery distance of comets. From Lister et al. 2022 [PSJ 3, 173]

Simulating LSST comet discoveries

- To assess what typical warning times will be with LSST, we need to simulate comet discoveries with the survey
- We will use the new LSST survey simulator software* to generate synthetic Long Period Comet observations based on a range of inputs:
  - Orbit model (Wiegert & Tremaine 1999 [Icarus 137, 84])
  - Nucleus size distribution: each comet randomly selected based on latest Long Period Comet size distribution (Boe et al 2019 [Icarus 333, 252])
  - Activity model/brightening law: the largest source of uncertainty comes from the assumptions made about where activity starts and at what rate comets brighten as they approach the Sun. Ongoing studies of distant cometary activity will inform the choice of parameters used
  - Colour, albedo, phase function: these will have relatively little effect on LSST discoveries

* https://github.com/dirac-institute/survey_simulator_post_processing

Intercepting an unknown target

- A key trade is on fuel mass (and therefore Δv 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)

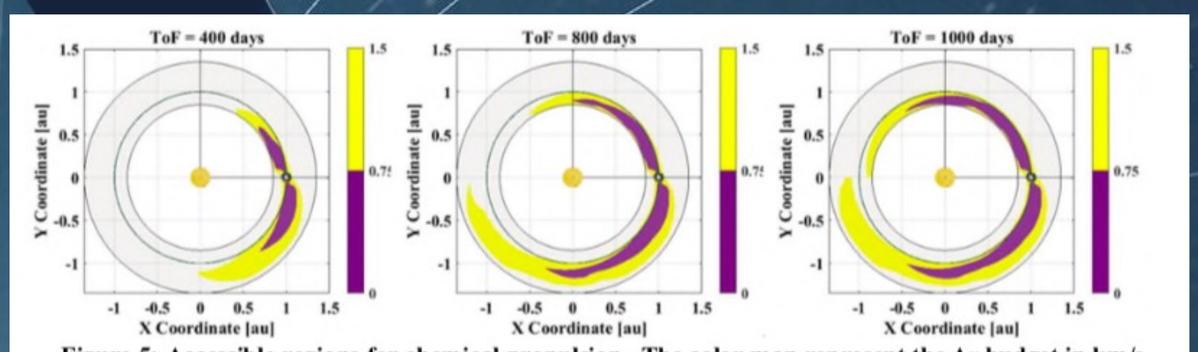
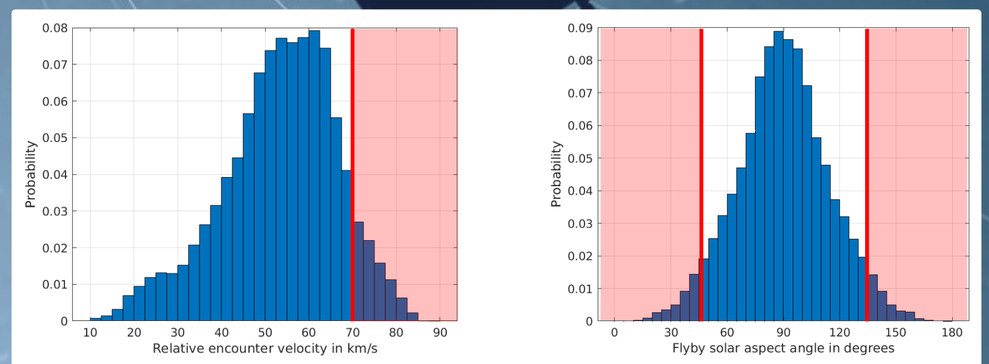


Figure 5: Accessible regions for chemical propulsion. The color map represent the Δv budget in km/s

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

- Limits on relative velocity, activity level, and solar aspect angle of the spacecraft during the fly-by also constrain the choice of possible comets
- These are to enable design of dust shields and power systems, and remove relatively few possible targets (red shaded areas in the distributions below)



a) Relative velocity b) Fly-by solar aspect angle

- Upper limit to activity level, for nominal 1000 km fly-by of main spacecraft, defined by 'Halley-like' case. Combined with max velocity gives a Giotto-like encounter, and therefore similar shielding required
- Details of dust model used to assess risks and for mission planning, shield and instrument design, etc., are given by Marschall et al 2022 [A&A 666, A151]

Target Identification activities

- The Target Identification Working Group carries out the following activities:
  - Coordination of study of comets to better understand likely behaviour
    - E.g., improving knowledge about distant activity, evolution of activity inbound between approximately 10 and 1 au
    - Group members associated with LOOK project, and observational programmes at VLT, SOAR, TNG, INT etc.
  - Simulation of survey performance to predict likely discovery rate
    - Simulation work described in box to the left
    - Group members also active in LSST SSSC, including in defining inputs on survey cadence (Schwamb et al 2023 [ApJS 266, 22])
  - Monitoring of new comet discoveries, and assessment of possible targets
    - Including preliminary assessment of whether newly discovered comets would be reachable or not, coordinating follow up observations, and orbit refinement
    - Identification of 'virtual' targets that would have been possible if already in space now; practicing procedures for real targets
  - Prioritisation between different targets
    - Including consideration of backup targets (known short period comets) in case no suitable new comet is found