Dynamically new comets investigation in view of the ESA *Comet Interceptor* mission

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OVERVIEW

What are Dynamically New Comets (DNCs)

*Comet Interceptor* space mission

Ground-based observations waiting for *Comet Interceptor*
What are comets

- Cometary nuclei as aggregates of smaller icy planetesimal brought together at low velocity in a random fashion
- Composed of ices (50%), silicates (25%), organic refractory material (25%), carbonaceous molecules (few %)
- Evidence of a coma

- LPC : P > 200 yr
- SPC : P< 200 yr (Halley-type: 20 < P < 200 yr, JFC: P < 20 yr)

- Tisserand parameter (interaction with Jupiter)
Dynamically New Comets: definition

- Objects coming from the Oort cloud or potentially from interstellar space

- Objects with a semimajor axis larger than 10000 AU (or >25000 AU, according to a more restrictive definition - see Dybczynski, 2007)

- Visiting our planetary system for the first time

- Influenced by the invisible matter in the Galaxy and/or individual stars passing close to the Sun

- Estimated to be the 40% of LPCs
Dynamically New Comets: why

- The most pristine material of our Solar System
- Insight of Solar System formation and evolution
- Totally unexplored objects (no information on size and albedo)
- Comparison with other known SPCs (JFC, HTC) and LPCs
Dynamically New Comets: statistics

- Through g-b surveys like SOHO, LINEAR, PanSTARRS
- More than 2150 LPCs are known (from MPC)
- DNCs might be bright even when very far from the Sun because of coma activity due to CO and CO$_2$
Comet Interceptor

Examples from interstellar space: 1I/Oumuamua

- 1I/2017 U1 Oumuamua entered our Solar System in 2017 (discovered on 19th October 2017)
- Elongated shape: length 10-times its width
- Mean diameter of 102 m (assuming an albedo of 0.04)
- No cometary activity – but non-gravitational acceleration possibly due to some activity (not observed from ground)
- Spectral properties compatible with comets or organic-rich asteroids of the SS

Its presence in the Solar System implies underestimation of number densities of interstellar objects, based on the assumption that they all were cometary like.
Examples from interstellar space: 2I/Borisov

- C 2019 Q4 2I/Borisov was discovered on 30\textsuperscript{th} August 2019 before perihelion
- Activity visible at the time of discovery (at 2.94 AU)
- $Q(\text{CN})=4\times10^{24} \text{ s}^{-1}$ and $Q(\text{C}_2)< 4\times10^{24} \text{ s}^{-1}$, consistent with gas abundance ratios in SS comets
- Estimated mean diameter of 0.7-3.3 km

CN emission clearly observed

O emission (indicative of H$_2$O emission)
Comet Interceptor is a mission targeting a dynamically-new comet, or an interstellar object.

Why?

- All previous comet missions have been to SPCs, objects that have passed the Sun many times
- Targets were relatively evolved, with thick coatings of dust on their surfaces
- 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
- Study of ISO will enable elemental abundances in other solar systems to be measured and planetary formation theories to be tested
Comet Interceptor is a mission targeting a dynamically-new comet, or an interstellar object.

How?

• The only way to encounter a DNC is to discover it inbound with enough warning to direct a spacecraft to it.

• The likelihood of this happening will soon be greatly increased by LSST – the Large Synoptic Survey Telescope:
  • LSST might not increase the number of DNCs found every year, but will increase the distance at which they’re discovered inbound.
  • LSST will likely find one accessible ISO in ~10 years (non-negligible chance of a suitable target within 2-3 years).

• Comet Interceptor spacecraft can wait in dynamically-stable location L2 until the target is found.
Discovery of DNCs

Discovery date and distance of LPCs. Recent advances in survey technology mean that we are now discovering comets beyond 10 AU from the Earth (and Sun), years in advance of perihelion. LSST will be even more powerful than current surveys. (from Krolikowska & Dybczinski 2019)
New Science with Comet Interceptor

- Characterize for the first time, a dynamically-new comet or interstellar object, including its surface composition, shape, and structure, the composition of its gas coma. A unique, multi-point ‘snapshot’ measurement of the comet- solar wind interaction region is to be obtained, complementing single spacecraft observations made at other comets.

- 3 s/c not in the same Sun-comet plane to sample the 3D structure of the coma

- Additional science will include multi-point studies of the solar wind pre- and post-encounter over gradually-changing separation distances.
New Science

**Multi-point measurements** of cometary environment, including plasma

**Energetic Neutral Atoms**: first observations of solar wind-neutral charge exchange processes at a comet

**Entire Visible Sky** (EnVisS): Multispectral and polarimetric mapper
   All-sky view of dust, including polarimetry, neutral gas, and ion features
Comet Interceptor Mission Profile

- Target discovered by a ground-based observatory (2-3 yr from launch for a target identification)

- Possible backup targets identified:

  73P: JFC

  26P: JFC, second target of Giotto. No images available
Ground-Based observations

- PanSTARRS and ATLAS surveys
- Proposal at TNG (AOT37, PI La Forgia)
- Proposal at ESO (Cycle 103A, PI La Forgia)
- Proposal at ESO submitted (PI Snodgrass) for photometry and mid-res spectroscopy
- DDT proposal at TNG (PI Cremonese)
- Proposal in preparation at TNG (PI Lazzarin)
- Proposal at Asiago (PI Lazzarin) for photometry
1. Title

Visible and near-IR spectroscopy of different dynamical

2. Abstract

Taxonomic classification of comets based on their volatiles different depending on their formation zone (A’Hearn et al., System formation models (Brasser and Morbidelli, 2013)) before being scattered to the various reservoirs from which observable. Our aim is to observe 24 comets, of various type, hyperbolic etc.) in the VIS+NIR spectral range in composition will be studied through visible (CN, C₂, C₃, C₄). Water production rate will be estimated through O₁. This will result in an extensive characterization of comets to test the recent dynamical models and help in understanding evolutionary.
**ESO proposal (PI La Forgia)**

**European Organisation for Astronomical Research**

**APPLICATION FOR OBSERVING TIME**

**Important Notice:**

By submitting this proposal, the PI takes full responsibility for the correctness of the dates and the agreement to act according to the ESO policy and rules.

1. **Title**
   
   Visible and near-IR spectroscopy of different dynamical classes of comets

2. **Abstract / Total Time Requested**

   Total Amount of Time: 0 nights VM, 23.1 hours 5M

   Taxonomic classification of comets based on their volatile chemical composition and their formation zone (A'Hearn et al., 1995; Fink, 2000 models (Brasser and Morbidelli, 2013) suggest that comets formed all over the various reservoirs. Our aim is to observe 21 comets, of various (JFC), Encke type, Holley type, hyperbolic etc. in the full H, BV, VIS, and IR. Their heterogeneities, volatile composition will be studied through visible (OH, CN, C2, C3, NH3, O3D) and NIR emission features (CN, C2, and H2O). This will result in an extensive characterization of comets of various dynamical classes, and will allow to test the recent dynamical models and help in understanding if the observed heterogeneities are primordial or evolutionary.
Time Justification

Justification of the telescope time, including technical and seeing overheads. Please discuss each run.

We anticipate one or two new comet discoveries at distances beyond 10 au in any given semester, based on the discovery rate in recent years from surveys such as ATLAS, Pan STARRS etc.

Run A: Monthly imaging of new comet(s). In the most optimistic case, two new comets would be found in the first month, requiring 12 visits in total in the semester. This is unlikely; we request up to 8 visits as a reasonable maximum. Each visit requires a series of R-band images, each of which will be relatively short to enable good astrometry of a moving target and the field stars (e.g. 50s, to be adapted based on the rate of motion and brightness of the actual comet). These frames will be stacked to give a single high S/N image for assessing the dust production and coma morphology, with a total exposure time of approx 500s, sufficient for the expected brightness of the comet (around V=21, near the limits of current surveys). Each visit, including overheads, will take 20 minutes. We request a total of 160 minutes for this run.

Run B: Spectroscopy of new comet(s). Based on our previous experience, low resolution spectroscopy with FORS can make sensitive searches for gas emissions in faint comets in one hour OBs (two 1500s exposures + overheads). We request two visits, enabling spectra on two comets or, if a suitable target is discovered early in the semester, two spectra months apart to begin to follow the long-term evolution of a single comet.

Runs C and D target the already discovered distant comet C/2019 E3 beyond 10 au. The visibility of the comet means we ask for 5 imaging visits and 1 spectroscopic visit this semester: exposure times etc are the same as for runs A+B.
Comet Interceptor

Application for observing time
Period AOT39 (April 2019 – September 2019)

1. Title:
Observation of the first interstellar comet: 2I/Borisov

2. Abstract:
In the last few weeks a second interstellar object has been discovered, some activity. According to the preliminary images it appears to be a comet and it is unknown if the composition and processes working on the comets populating the Solar System. We are proposing to observe along its very fast passage within our Solar System up to and after perihelion, requiring images in R filter to get information on the dust production and our dust model, and medium resolution spectra in the visible and high resolution spectra when the comet will approach the Sun and unexpected increase of the brightness.

TNG observation on 2nd Nov 2019
DNCs allow one investigating the primordial, possibly unprocessed, material of the Solar System

Interstellar objects seem to be quite numerous. Their properties are common to SS comets

GB can widely improve our knowledge on DNCs and ISO, thanks also to the refinement of observing techniques

GB are important to have an insight of the largest number of comets, in view of *Comet Interceptor*
thank you