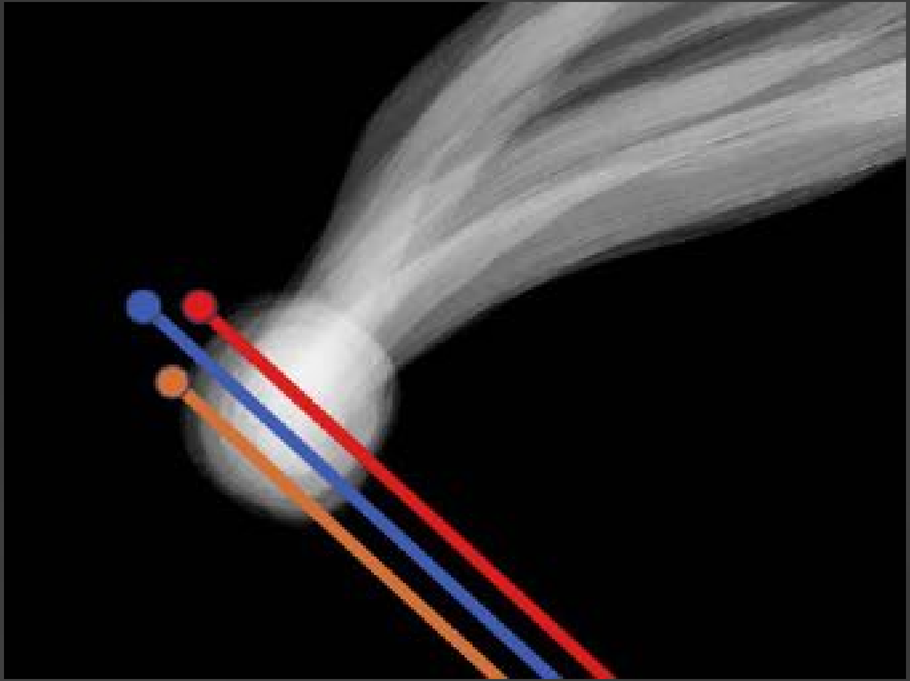
Comet Interceptor

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



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and

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OVERVIEW

- What are Dynamically New Comets (DNCs)
- *Comet Interceptor* space mission
- Ground-based observations waiting for *Comet Interceptor*

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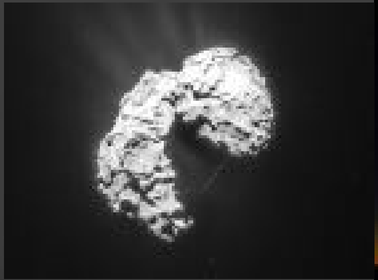
What are comets

- 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

Comet Interceptor

- 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

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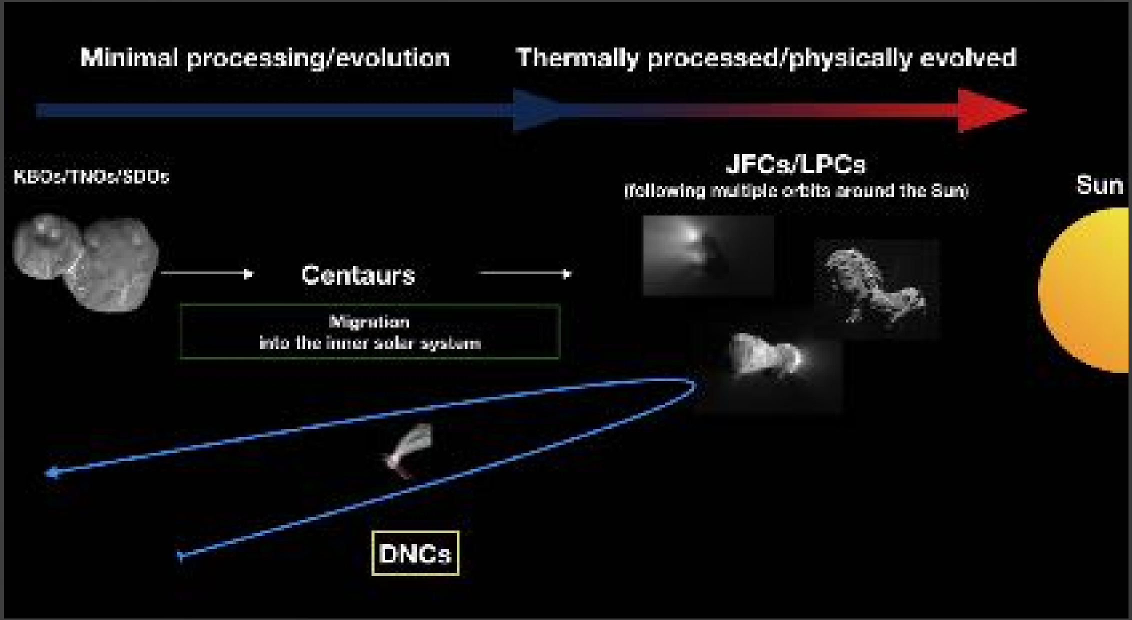
Dynamically New Comets: why

- 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



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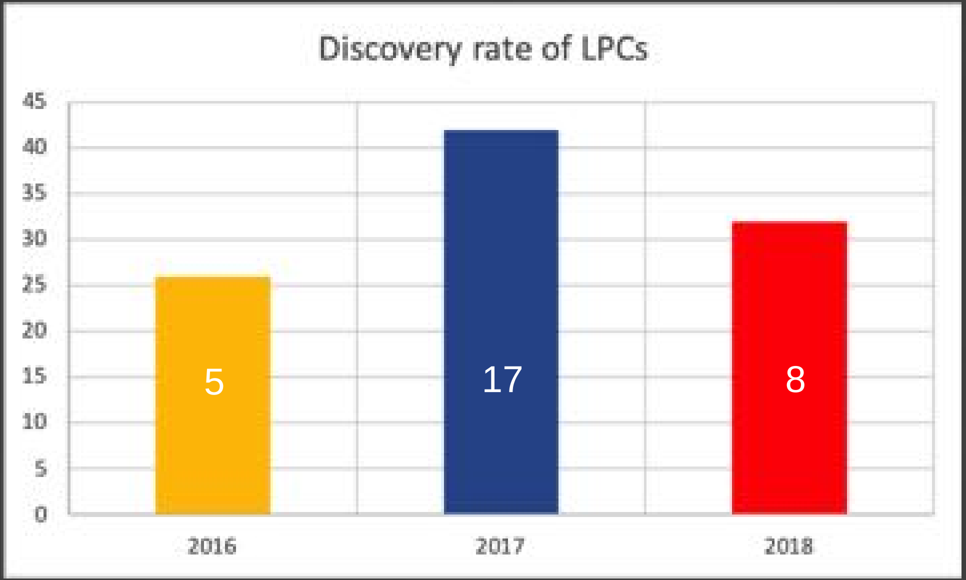
Dynamically New Comets: statistics



- 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

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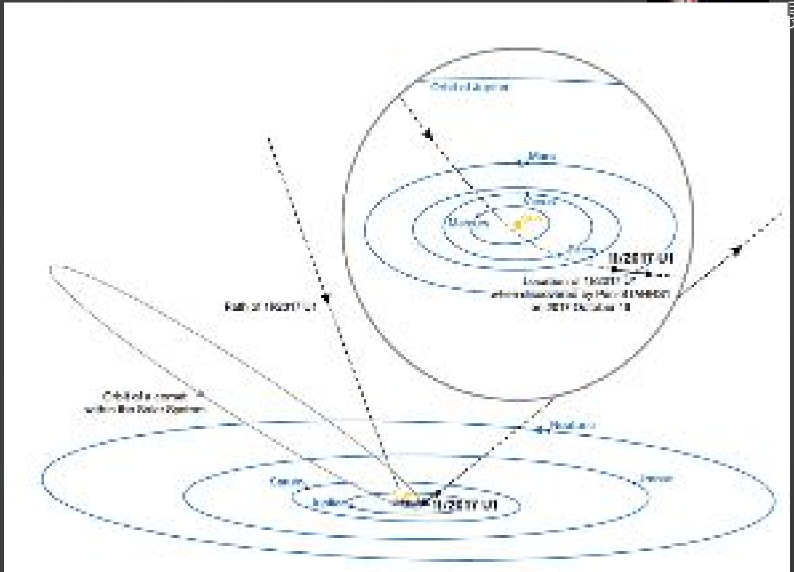
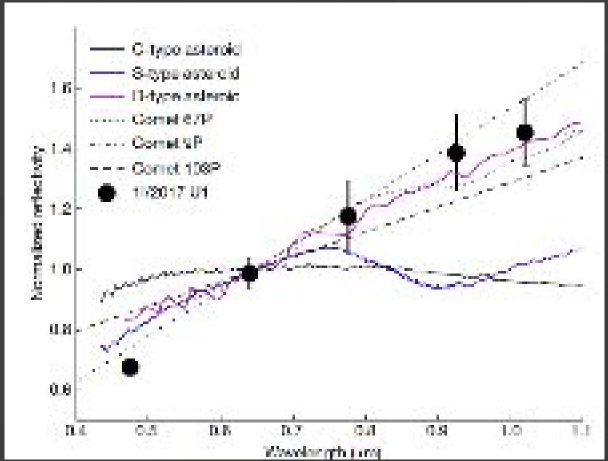
Examples from interstellar space: 1I/Oumuamua

- 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

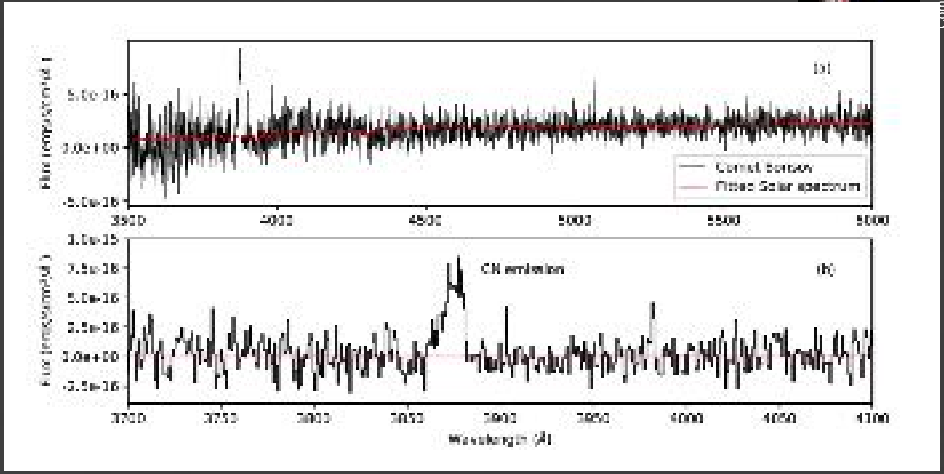




Its presence in the Solar System implies underestimation of number densities of interstellar objects, based on the assumption that they all were cometary like.

Examples from interstellar space: 2I/Borisov

Hubble image (Credits: NASA, ESA, D. Jewitt,/UCLA)



CN emission clearly observed

O emission (indicative of H_2O emission)

- C 2019 Q4 2I/Borisov was discovered on 30th August 2019 before perihelion
- Activity visible at the time of discovery (at 2.94 AU)
- $Q(CN)=4x10^{24}\ s^{-1}$ and $Q(C_2)< 4x10^{24}\ s^{-1}$, consistent with gas abundance rations in SS comets
- Estimated mean diameter of 0.7-3.3 km

Comet Interceptor

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


Comet Interceptor

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

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

Comet Interceptor

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

LSST Project/NSF/AURA

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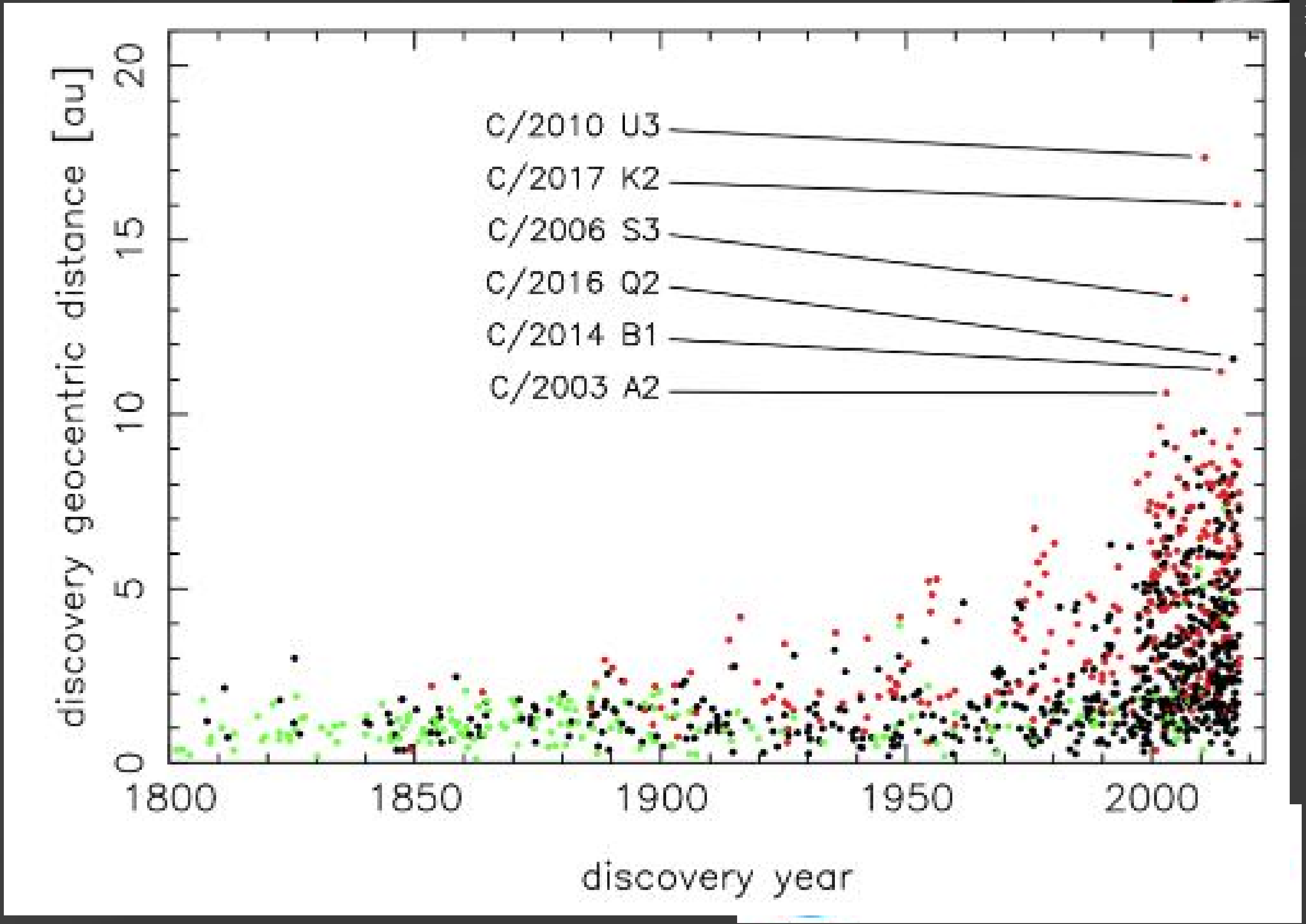
Discovery of DNCs

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*

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.

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New Science

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

Comet Interceptor

Multi-point measurements of cometary environment, including plasma

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

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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

Comet Interceptor

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

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TNG proposal (PI La Forgia)

Comet Interceptor

INAF – TIME ALLOCATION COMMITTEE

Application for observing time **Category: C**

Period AOT37 (April 2018 – September 2018)

1. Title

Visible and near-IR spectroscopy of different dynamical c

2. Abstract

Taxonomic classification of comets based on their volati
different depending on their formation zone (A'Hearn et
System formation models (Brasser and Morbidelli, 2013)
before being scattered to the various reservoirs from whi
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, C_2, C_3,
C_2). Water production rate will be estimated through O(
investigated and dust to gas ratios will be derived using b
This will result in an extensive characterization of come
test the recent dynamical models and help in understandi
evolutionary.

11. List of targets (note that the absence of a proper object list and information may weaken the proposal)

Name	α	δ	Epoch	Mag.	Time	Additional Information
C/2016 R2	04 30 23.70	+37 33 18.5	J2000	V15.4	2200	best obs date: 01/04/2018, dyn. new
62P	13 59 31.61	+05 35 12.3	J2000	V16.2	2700	best obs date: 15/04/2018, JFC
C/2015 O1	14 52 45.75	+54 53 43.7	J2000	V15.8	15600	best obs date: 15/04/2018, dyn. new
C/2016 N6	07 48 30.93	+60 03 07.6	J2000	V15.4	11000	best obs date: 28/04/2018, dyn. new
P/2013 CU129	08 35 39.49	+33 16 17.2	J2000	V17.8	6300	best obs date: 28/04/2018, JFC, NEO
C/2016 M1	19 42 17.39	-08 31 13.3	J2000	V14.3	5600	best obs date: 28/04/2018, dyn. new
C/2016 N4	08 14 24.40	+83 22 23.2	J2000	V18.1	7200	best obs date: 08/05/2018, dyn. new
P/2010 H2	16 09 06.04	-18 58 28.9	J2000	V15.3	2400	best obs date: 08/05/2018, JFC
C/2017 M4	18 24 10.31	+46 25 58.22	J2000	V18.3	30600	best obs date: 08/06/2018, hyperbolic
37P	23 39 15.43	-00 04 04.2	J2000	V15.5	2400	best obs date: 10/07/2018, JFC
C/2017 S3	01 37 50.65	+58 18 19.0	J2000	V16.1	1500	best obs date: 10/07/2018, hyperbolic
C/2015 V1	00 31 44.57	-26 26 46.1	J2000	V16.9	3600	best obs date: 17/08/2018, hyperbolic
48P	22 41 08.15	-24 38 04.9	J2000	V14.6	1400	best obs date: 17/08/2018, JFC
29P	23 11 43.16	+01 24 37.2	J2000	V16.0	2700	best obs date: 17/08/2018, JFC
64P	00 07 39.84	+14 54 10.9	J2000	V15.3	1900	best obs date: 17/08/2018, JFC
164P	09 04 29.22	+21 51 59.1	J2000	V17.5	3600	best obs date: 23/09/2018, JFC
21P	06 33 16.78	+11 26 07.8	J2000	V10.3	12	best obs date: 23/09/2018, JFC, NEO
60P	07 34 28.84	+22 05 05.5	J2000	V18.2	7200	best obs date: 23/09/2018, JFC
171P	04 39 10.87	-06 19 24.7	J2000	V18.5	7200	best obs date: 23/09/2018, JFC
69P	03 56 36.27	-08 25 35.1	J2000	V16.3	2700	best obs date: 23/09/2018, JFC
38P	05 36 44.39	+10 37 40.1	J2000	V15.9	3600	best obs date: 23/09/2018, Halley type
123P	08 41 41.16	+29 59 16.4	J2000	V17.4	6300	best obs date: 29/09/2018, JFC
46P	01 52 38.29	-25 40 55.1	J2000	V15.9	2700	best obs date: 29/09/2018, JFC, NEO
78P	21 19 53.73	-07 48 05.1	J2000	V14.7	1400	best obs date: 29/09/2018, JFC

ESO proposal (PI La Forgia)

Comet Interceptor

European Organisation for Astronomical Re

OBSERVING PROGRAMMES OFFICE • Karl-Schwarzschild-Straße 2 • D-85748 Garching bei

APPLICATION FOR OBSERVING TIME

Important Notice:

By submitting this proposal, the PI takes full responsibility for the content o names of CoIs and the agreement to act according to the ESO policy and

1. Title

Visible and near-IR spectroscopy of different dynamical classes of c

2. Abstract / Total Time Requested

Total Amount of Time: 0 nights VM, 23.1 hours SM

Taxonomic classification of comets based on their volatile chemical co depending on their formation zone (A'Hearn et al., 1995; Fink, 200 models (Brasser and Morbidelli, 2013) suggest that comets formed al to the various reservoirs. Our aim is to observe 21 comets, of variou (JFC), Encke type, Halley type, hyperbolic etc.) in the full UVB - VIS their heterogeneities. Volatile composition will be studied through visible (OH, CN, C_2, C_3, NH_2, O(^{1}D)) and NIR emission features (CN, C_2 and H_2O). 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.

11. List of targets proposed in this programme

Run	Target/Field	α(J2000)	δ(J2000)	ToT	Mag.	Diam.	Additional info	Reference star
A	60P	11 22 03.16	+03 42 36.3	1.0	17.3		01/04,JFC	
A	120P	11 03 16.29	+20 04 54.8	0.67	15.2		01/04,JFC	
A	C/2016 N6	05 33 45.40	-20 10 02.4	0.67	16.6		01/04,new	
A	C/2014 B1	11 31 35.64	+09 44 31.3	1.0	17.6		01/04,hyperbolic	
A	P/2014 C1	11 56 17.01	+02 37 29.7	1.5	18.6		01/04,Encke	
A	C/2016 M1	04 31 09.34	-48 56 11.0	0.67	15.9		01/04,new	
B	C/2017 M4	16 01 11.70	-30 51 16.0	0.67	15.3		12/05,hyperbolic	
B	78P	15 36 25.77	-15 48 53.2	1.0	17.4		12/05,Encke	
B	C/2018 A6	07 24 52.30	-53 25 59.7	1.0	17.7		12/05,Halley	
C	C/2018 F4	11 03 05.48	-55 11 51.0	1.0	18.0		10/06,hyperbolic	
C	C/2018 K13	16 49 10.46	-40 50 35.6	1.0	17.5		10/06,new	
D	209P	10 58 01.48	+12 12 07.9	1.0	17.7		26/06,JFC-NEO	
D	P/2010 H2	21 01 48.80	-32 44 34.7	0.67	16.8		26/06,JFC	
E	108P	03 35 39.41	+20 35 00.9	1.0	17.6		07/08,JFC	
E	C/2017 B3	00 14 02.76	-46 01 50.4	0.67	16.3		07/08,hyperbolic	
F	29P	00 50 38.23	+10 07 12.7	0.67	16.6		17/09,JFC	
F	101P	23 47 23.47	-00 02 07.9	1.0	17.1		17/09,JFC	
F	260P	02 41 19.87	+31 50 05.7	0.67	16.0		17/09,JFC	
F	C/2018 N2	02 15 07.90	+28 31 43.9	0.3	14.0		17/09,new	
F	C/2017 T2	05 31 03.77	+25 14 53.2	0.67	15.0		17/09,new	
F	68P	17 57 07.25	-12 17 04.0	1.0	17.5		17/09,JFC	

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ESO proposal (PI Snodgrass)

Comet Interceptor

European Organisation for Astronomical Research in the Southern Hemisphere

Observing Programmes Office • Karl-Schwarzschild-Strasse 2 • D-85748 Garching bei München • email: opo@eso.org • Tel. +49 89 3200 6473

Cycle: Cycle P105

Type: Normal

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. 60s, 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 emission 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.

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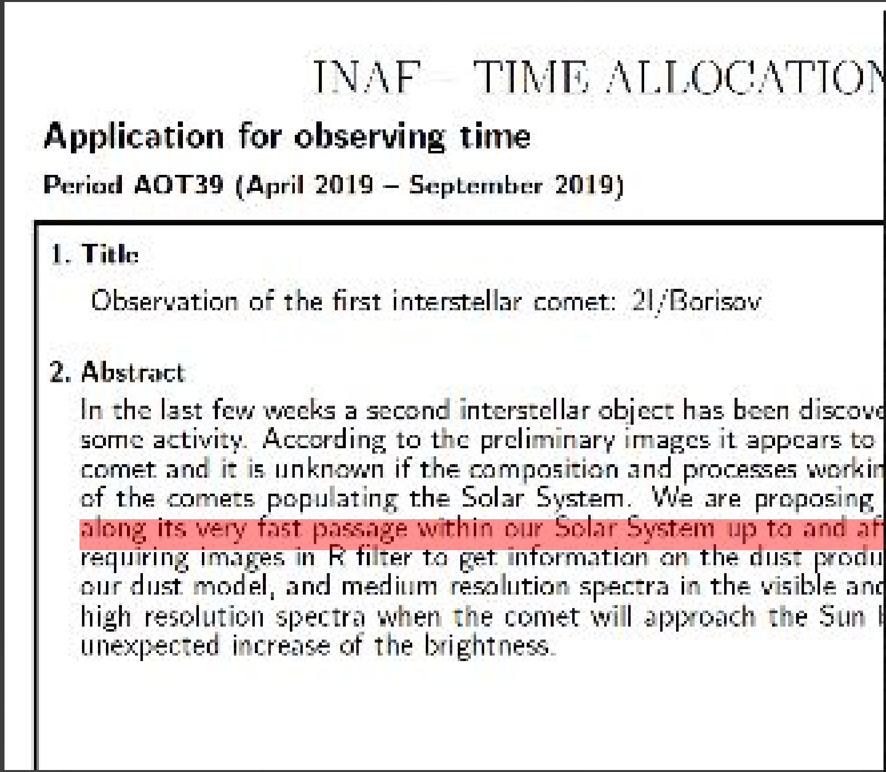
TNG DDT proposal (PI Cremonese)



INAF – TIME ALLOCATION

Application for observing time

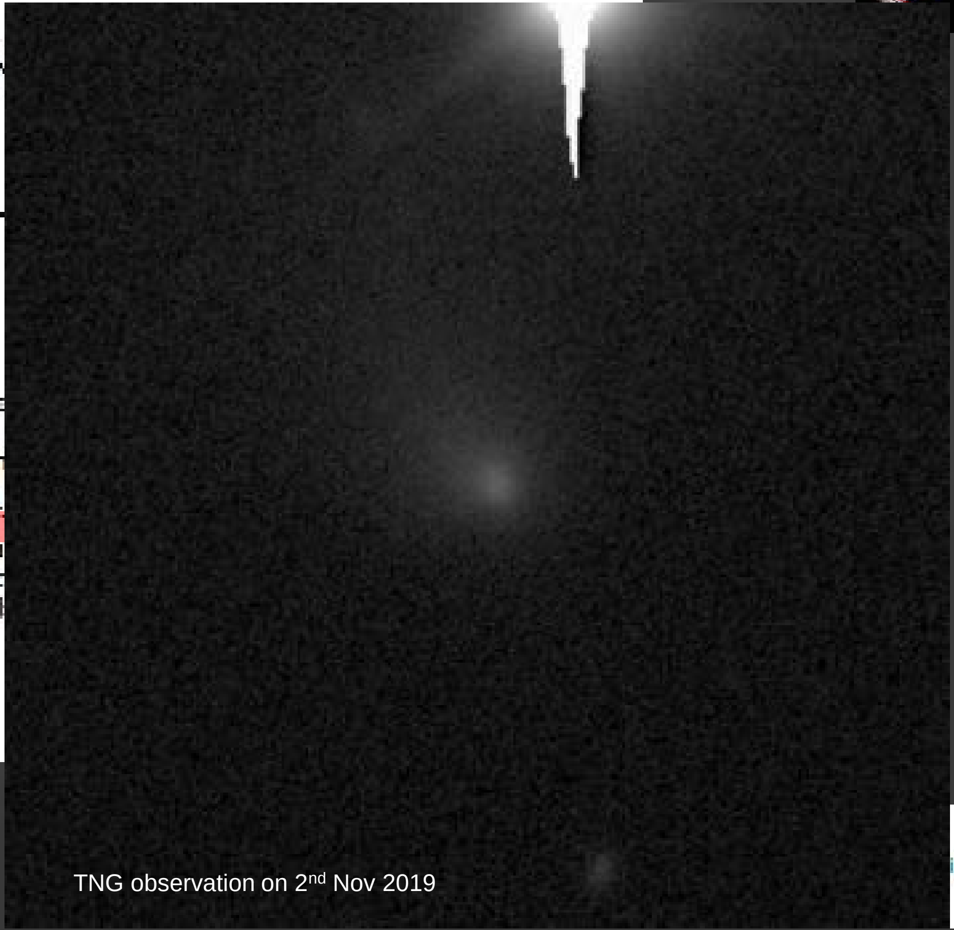
Period AOT39 (April 2019 – September 2019)

1. Title

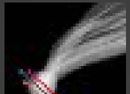
Observation of the first interstellar comet: 2I/Borisov

2. Abstract

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



TNG observation on 2nd Nov 2019



Comet Interceptor

Summary


Comet Interceptor

- 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*

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thank you