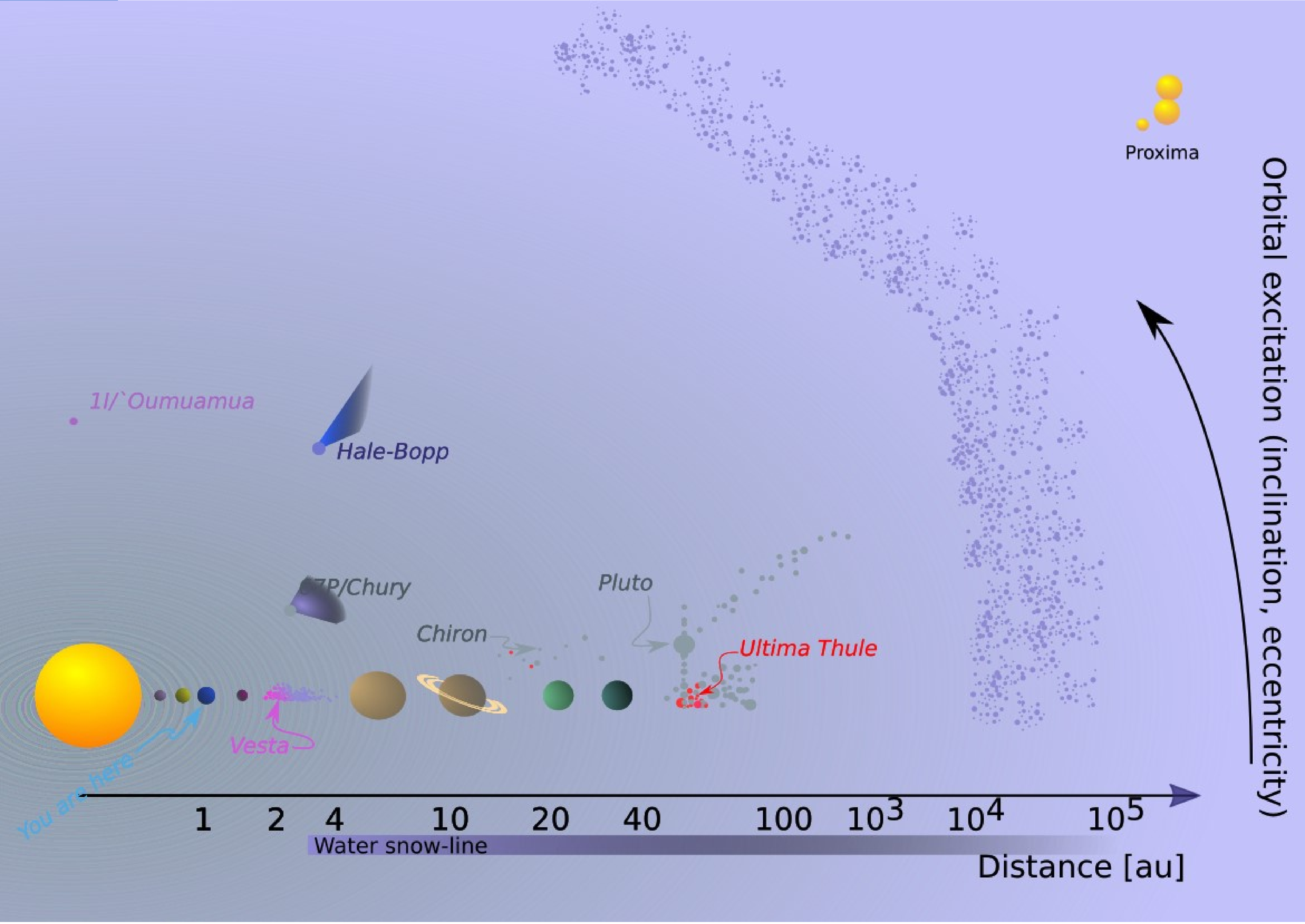
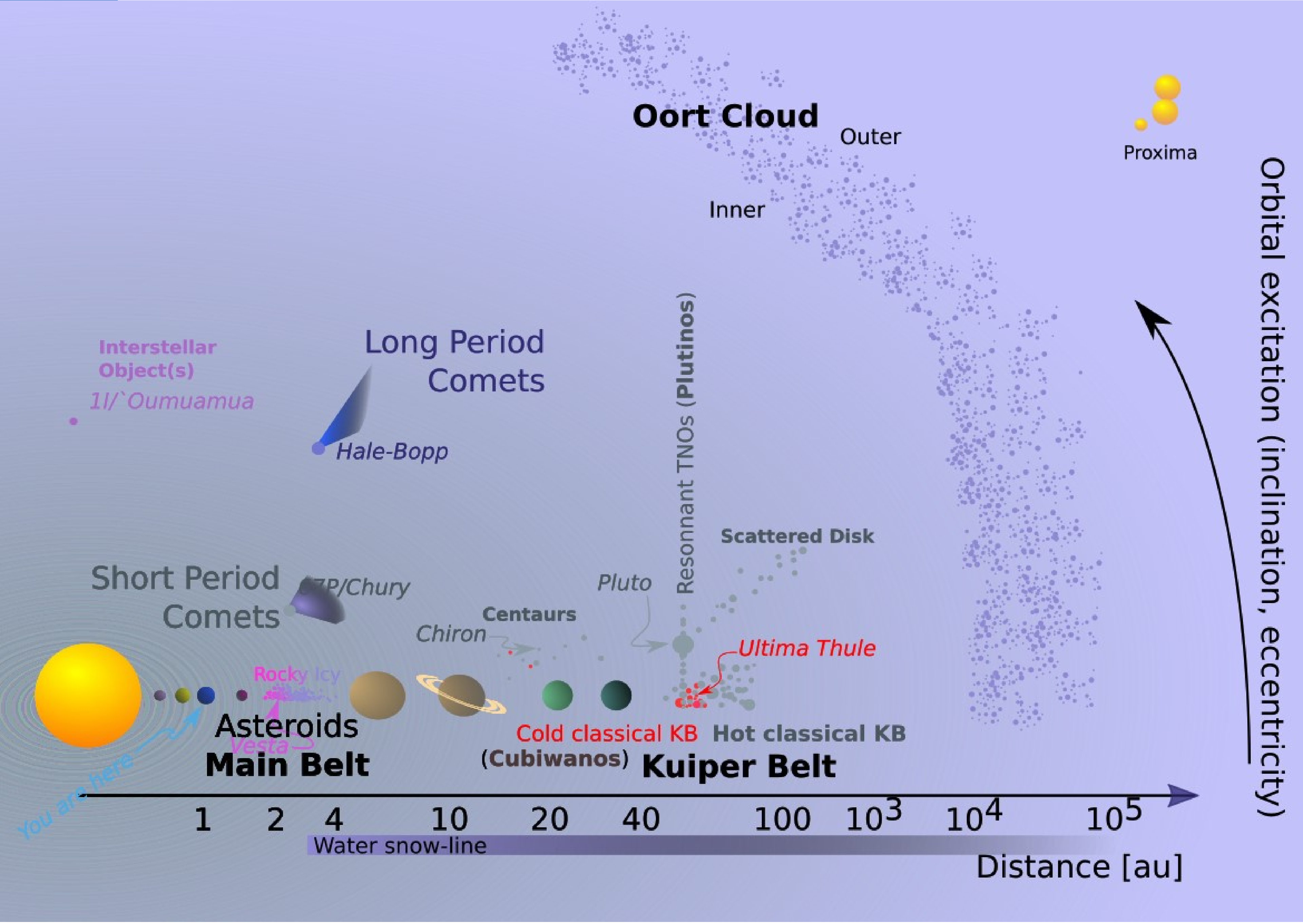
Minor Bodies in our Solar System, as seen by FORS

Olivier Hainaut | ESO | Public


Proxima
Orbital excitation (inclination, eccentricity)
1I/`Oumuamua
Hale-Bopp
67P/Chury
Pluto
Chiron
Ultima Thule
Vesta
You are here
1
2
4
10
20
40
100
10^3
10^4
10^5
Water snow-line
Distance [au]


Oort Cloud
Outer
Inner
Proxima
Orbital excitation (inclination, eccentricity)
Interstellar Object(s)
1I/`Oumuamua
Long Period Comets
Hale-Bopp
Resonnant TNOs (Plutinos)
Scattered Disk
Short Period Comets
67P/Chury
Pluto
Centaurs
Chiron
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Rocky Icy
Asteroids
Vesta
Main Belt
Cold classical KB
(Cubiwanos)
Hot classical KB
Kuiper Belt
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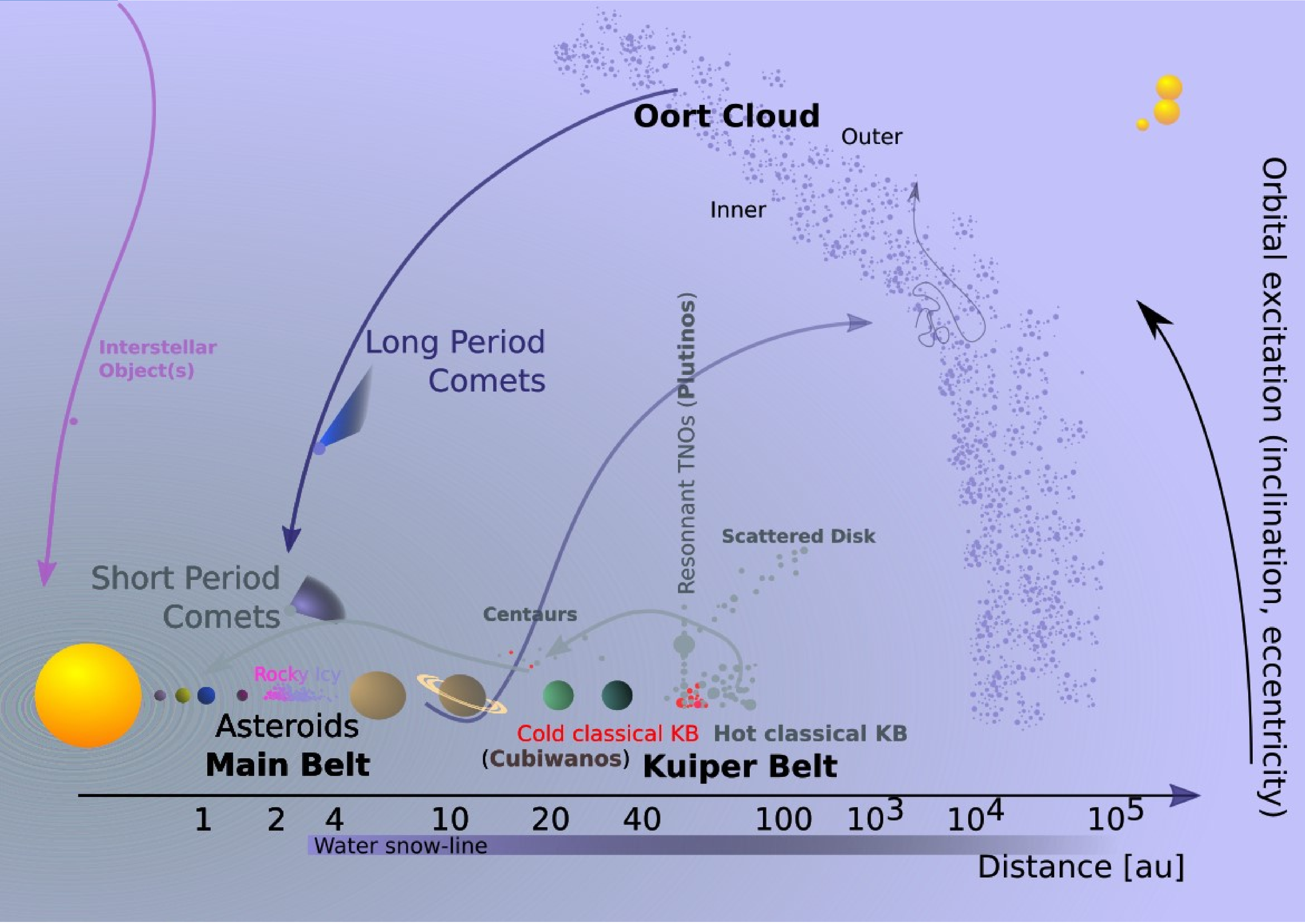
Oort Cloud
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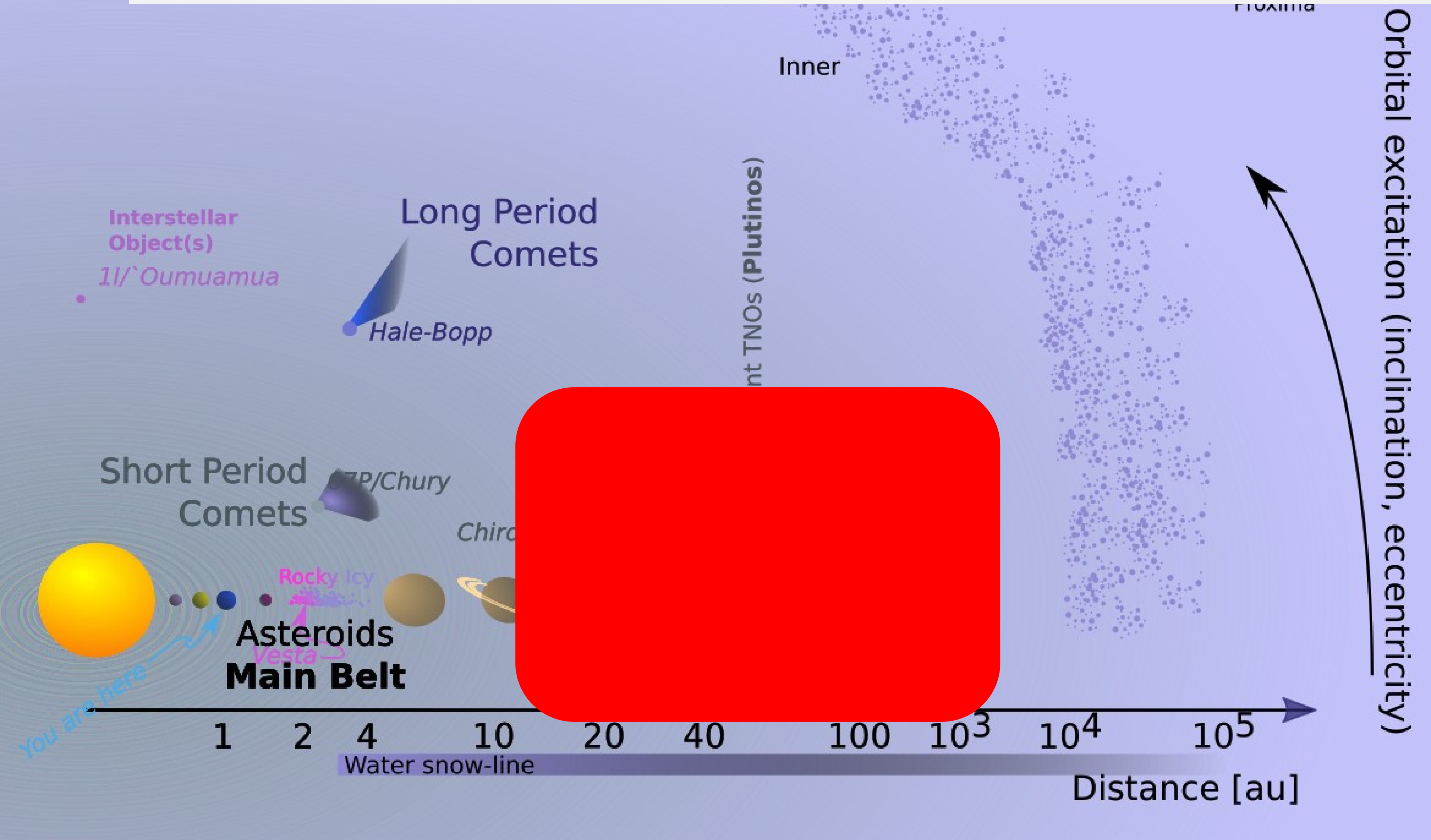
1 2 4 10 20 40 100 10^3 10^4 10^5
Water snow-line
Distance [au]

TNO population

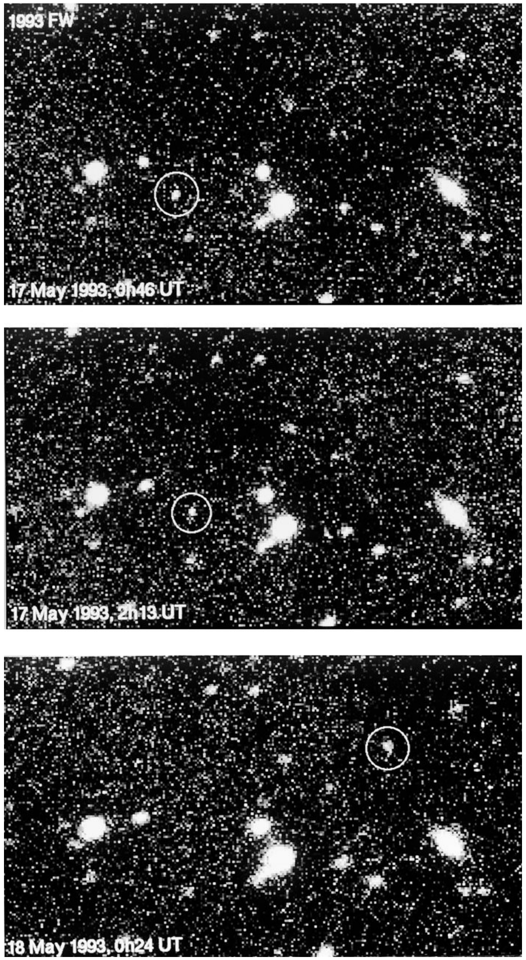


TNO population

- First TNO (after Pluto): 1992 QB1, Hawai`i
- Second one: 1993 FW
- By 2000: 100 = a population
- Today: 2000 objects

➔ ESO large program for the characterization of the TNOs

➔ 2d ESO large program for the characterization of the TNOs



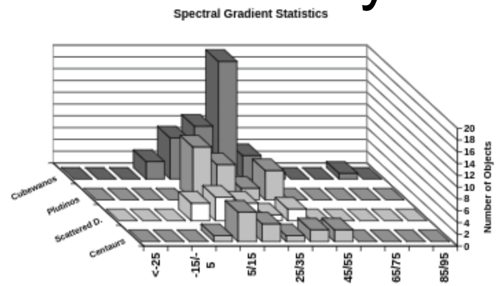
1993 FW | eso9305

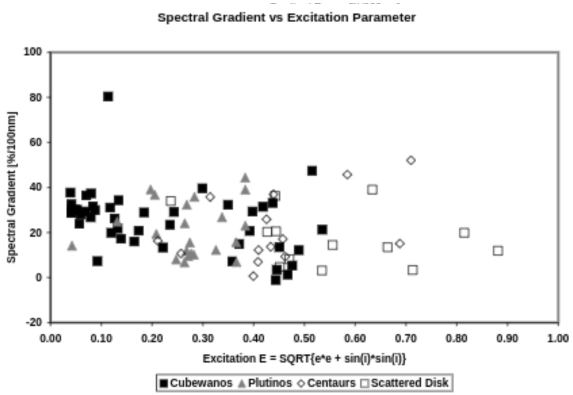
TNO LP1 and LP2

- 2001A&A...380..347D - **BVRI Photometry of 27 Kuiper Belt Objects with ESO/Very Large Telescope -** Delsanti, A. C.; Boehnhardt, H.; Barrera, L. et al.
- 2002A&A...395..297B - **ESO large program on physical studies of Transneptunian Objects and Centaurs:** Visible photometry - First results -Boehnhardt, H.; Delsanti, A.; Barucci, A. et al.
- 2004A&A...421..353F - **ESO Large Program on physical studies of Trans-Neptunian objects and Centaurs:** Final results of the visible spectrophotometric observations - Fornasier, S.; Doressoundiram, A.; Tozzi, G. P.et al.
- 2004A&A...417.1145D - **Simultaneous visible-near IR photometric study of Kuiper Belt Object surfaces with the ESO/Very Large Telescopes -** Delsanti, A.; Hainaut, O.; Jourdeuil, E. et al.
- 2010A&A...510A..53P - **Colors and taxonomy of Centaurs and trans-Neptunian objects** - Perna, D.; Barucci, M. A.; Fornasier, S. et al.
- 2008A&A...487..741A - **Visible spectroscopy of the new ESO large program on trans-Neptunian objects and Centaurs.** Part 1 - Alvarez-Candal, A.; Fornasier, S.; Barucci, M. A. et al
- 2009A&A...493..283D **- Visible and near-infrared colors of Transneptunian objects and Centaurs from the second ESO large program -** DeMeo, F. E.; Fornasier, S.; Barucci, M. A. et al
- 2009A&A...508..457F - **Visible spectroscopy of the new ESO large programme on trans-Neptunian objects and Centaurs: final results -** Fornasier, S.; Barucci, M. A.; de Bergh, C. et al
- Etc....

TNO population

- Beginnings
  - Photometry

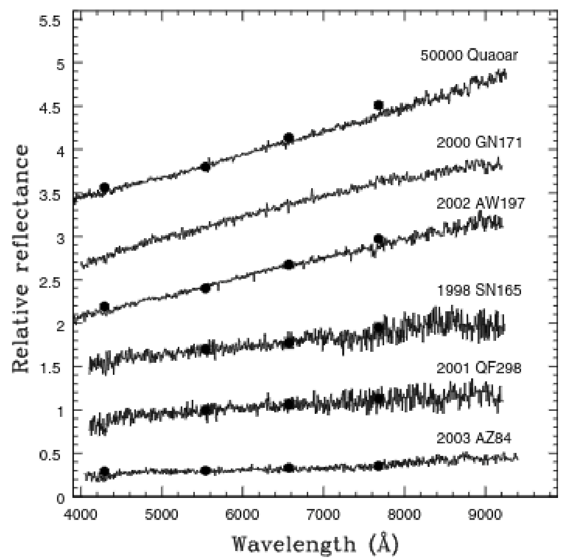




Boehnhardt+ 2002A&A...395..297B

Delsanti+ 2004A&A...417.1145D
Perna+ 2001A&A...380..347D

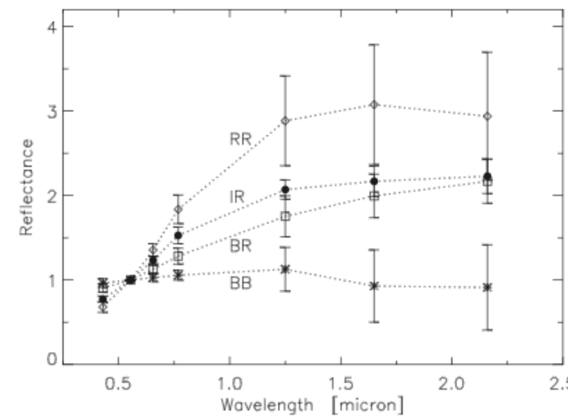
  - Spectroscopy



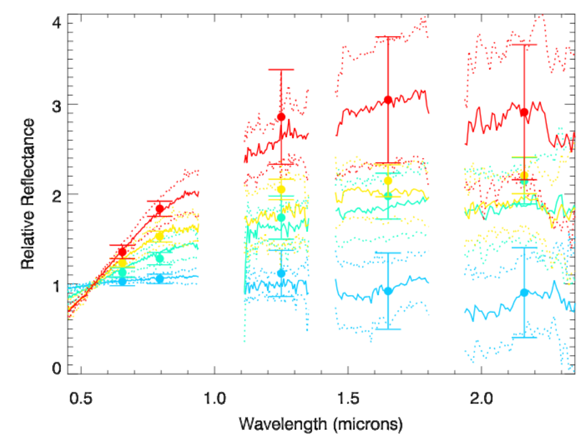
Fornasier+ 2004A&A...421..353F

Alvarez-Candal+ 2008A&A...487..741A
Fornasier+ 2009A&A...508..457F

  - Taxonomy



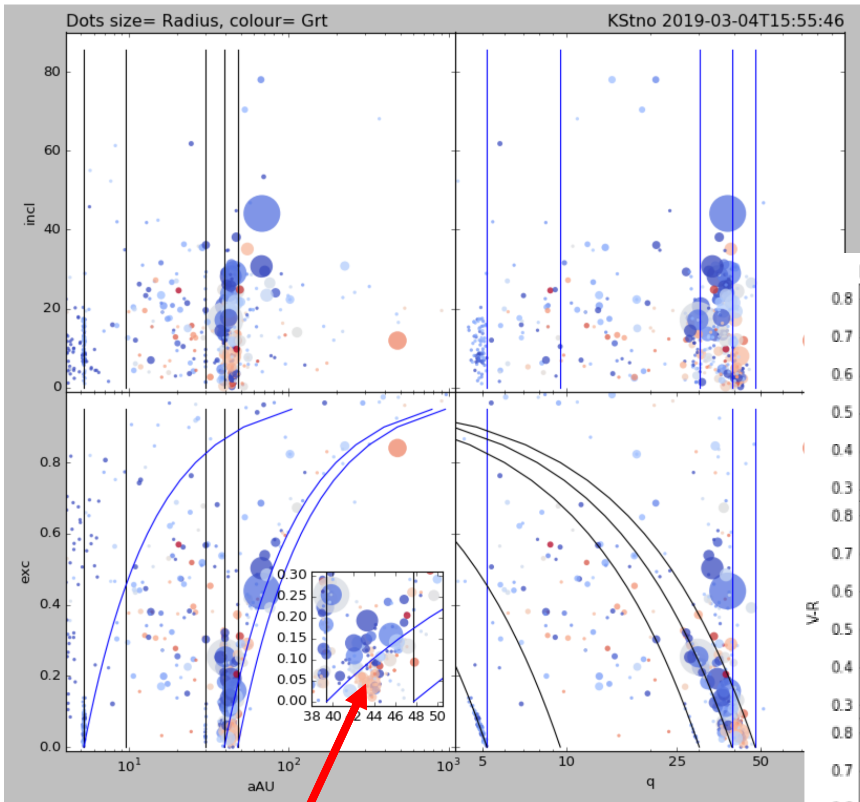
Perna+ 2010A&A...510A..53P



Merlin+ 2017A&A...604A..86M

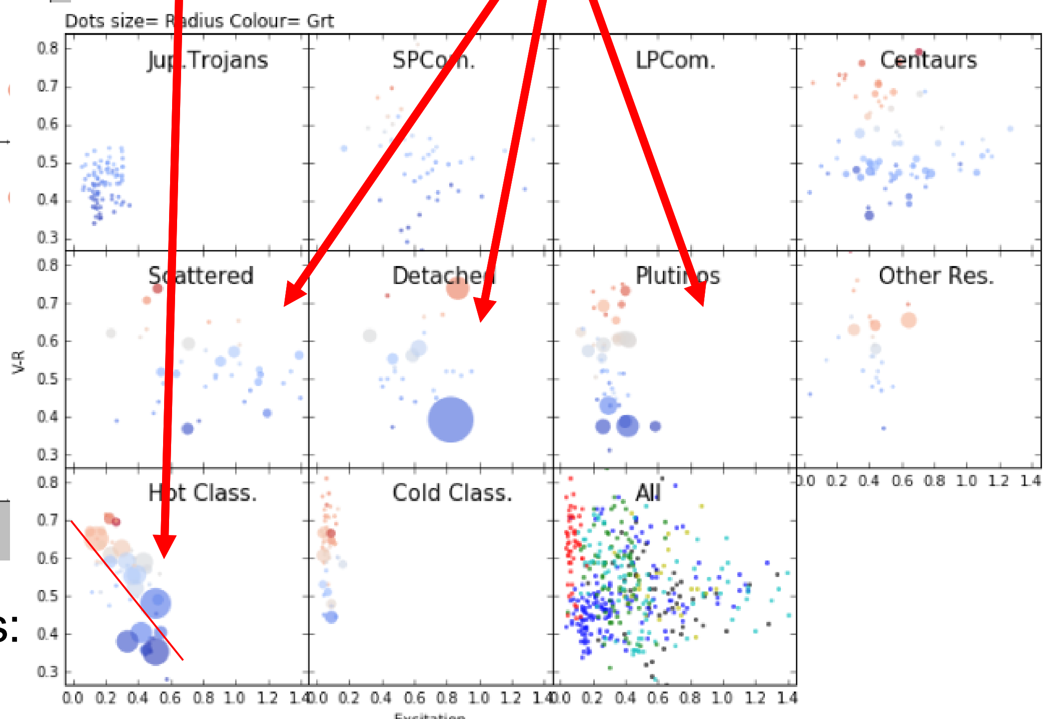
TNO population

- Physical understanding of the population as a whole



A trend with orbital excitation

3 populations with the same origin



A primordial population of red bodies: Cold Classical TNOs

Hainaut+ 2012A&26A...546A.115H

TNO population

- Physical understanding sub-populations
  Ultra-wide TNO binaries

  "We find that gravitational collapse binary formation models produce an orbital distribution similar to that currently observed, which along with a confluence of other factors supports **formation of the cold Classical Kuiper Belt in situ through relatively rapid gravitational collapse** rather than slow hierarchical accretion."

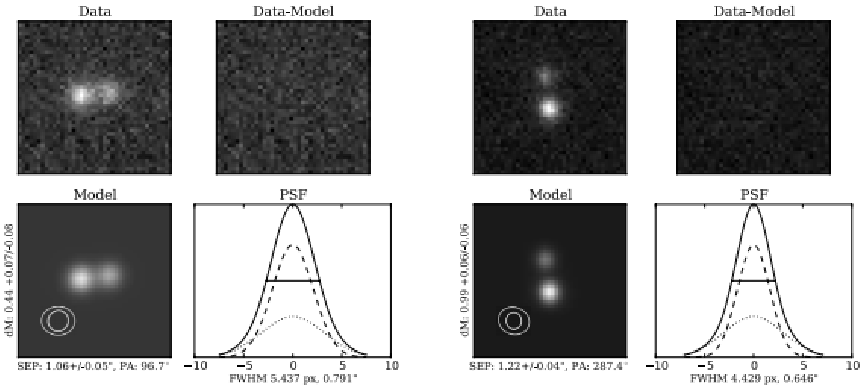
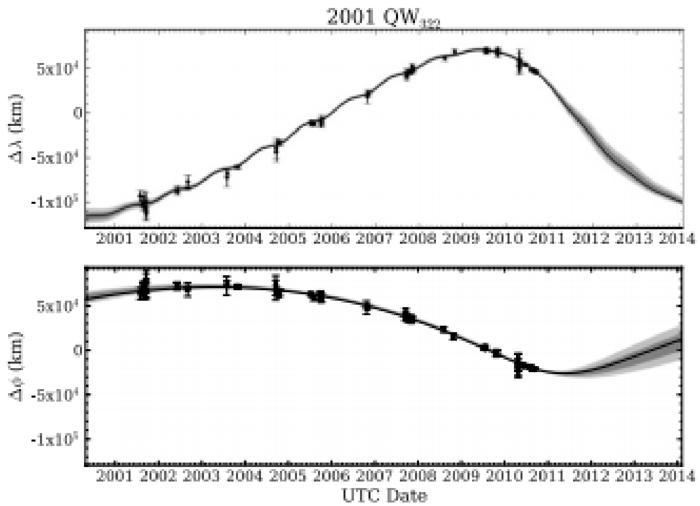


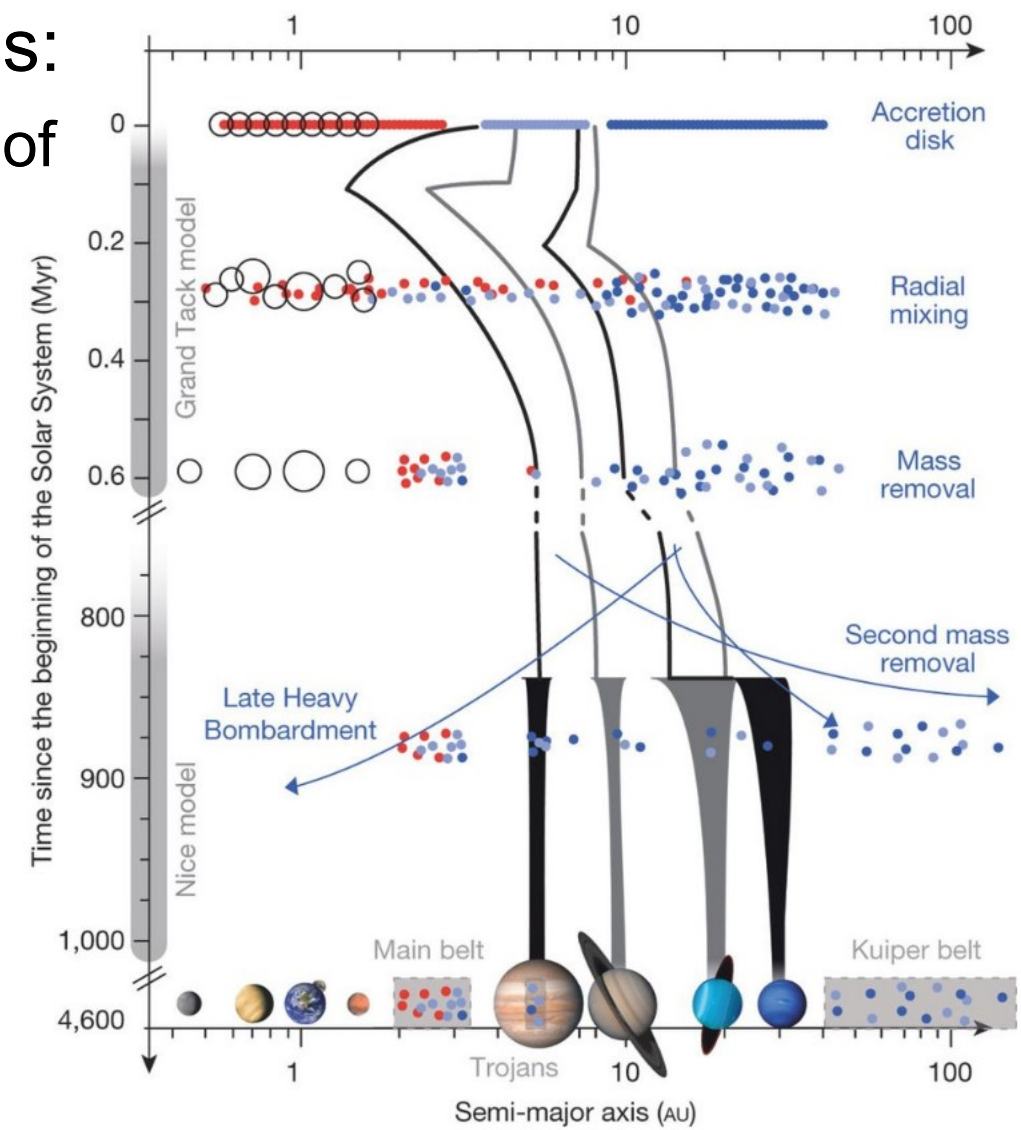
Figure 2. Same as Figure 1, but for CFEPS binaries 2006 BR$_{284}$ (left) and 2006 JZ$_{81}$ (right).



Parker+ 2011ApJ...743....1P

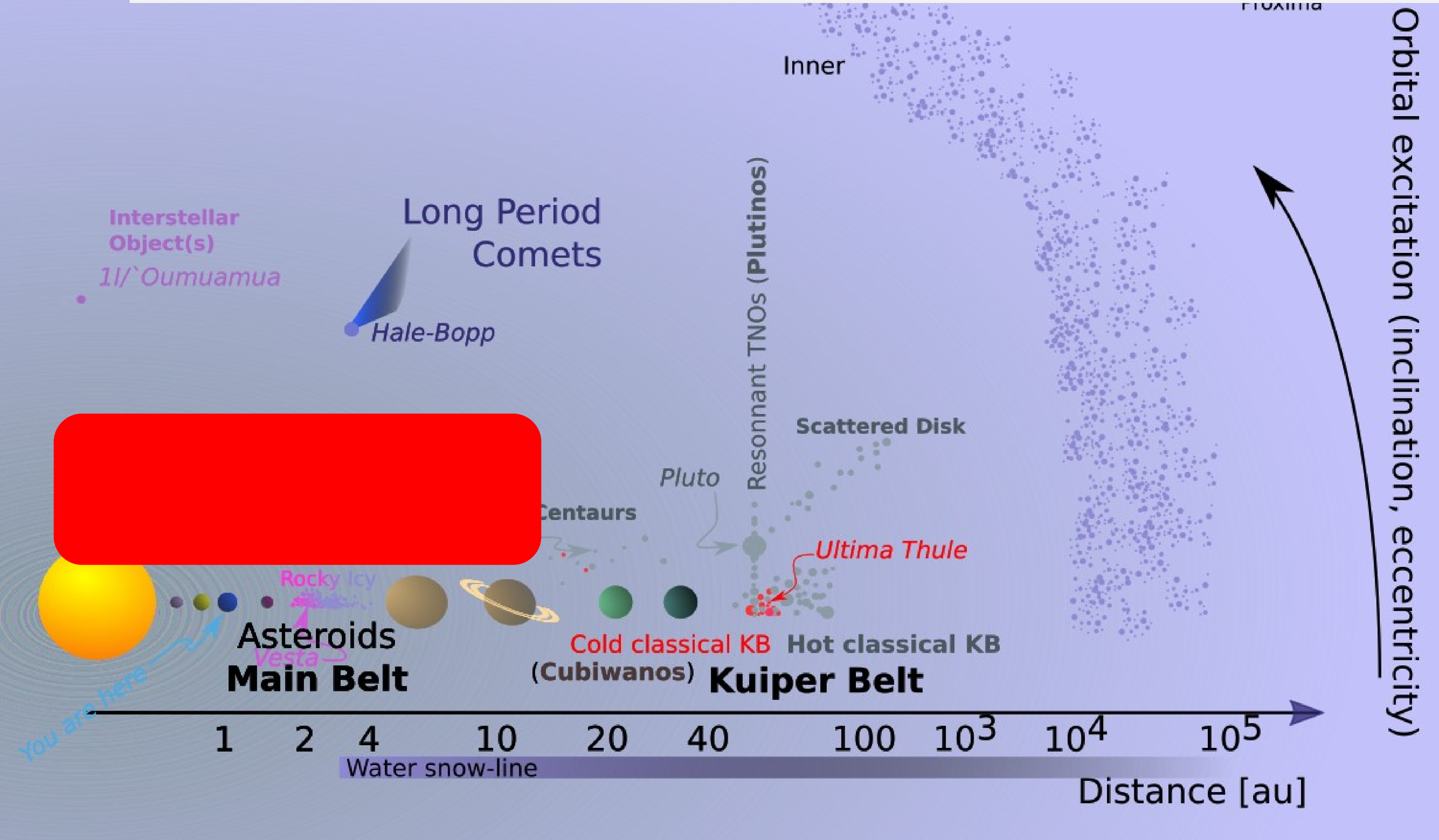
TNO population

- Constrain other fields:
  - dynamical evolution of early Solar System,
  - planet migration,
  - architecture of the Asteroid Belt,
  - exoplanet system architecture…



DeMeo & Cary 2014 Nature 505, 629

Comets



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Kuiper Belt
1 2 4 10 20 40 100 10^3 10^4 10^5
Water snow-line
Distance [au]
Orbital excitation (inclination, eccentricity)

Comets Population

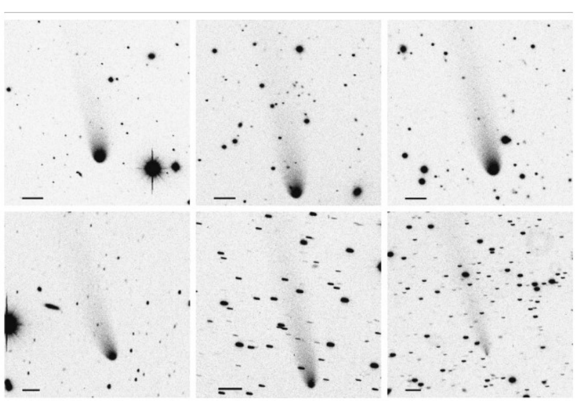
- Cometary Activity at large heliocentric distances:

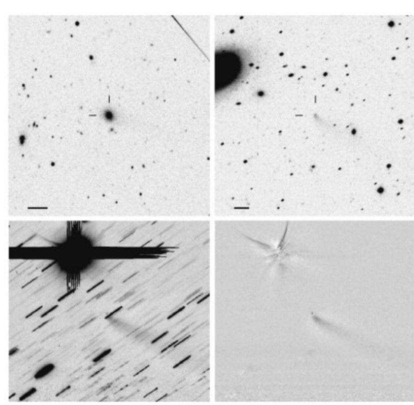
Start/end of activity (FORS!)

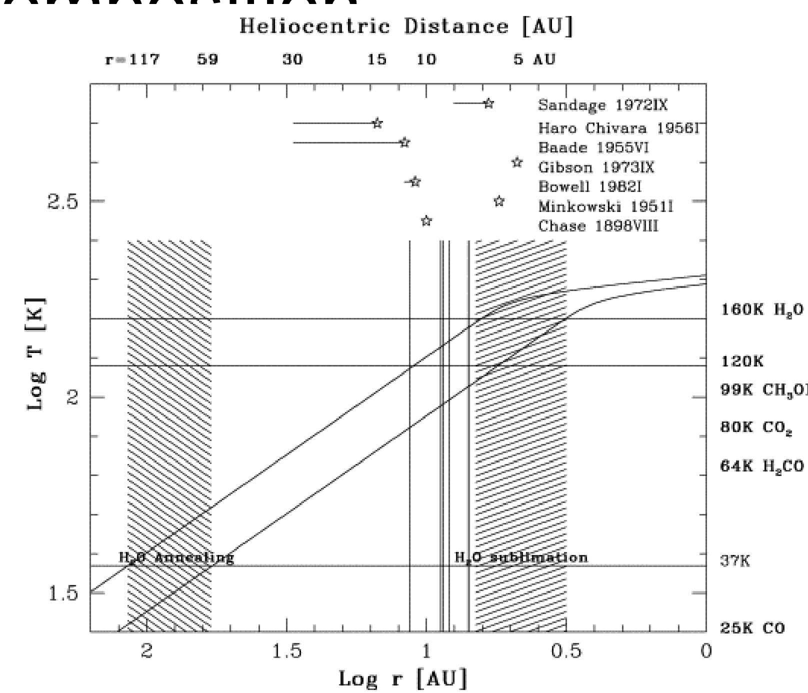
Thermal models

==> activity processes and composition

Meech+ 2009Icar..201..719M

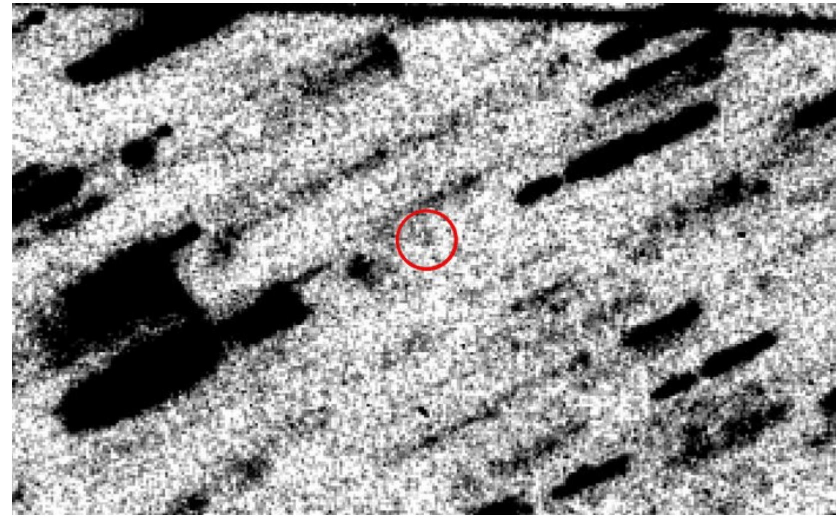






Comet Highlight

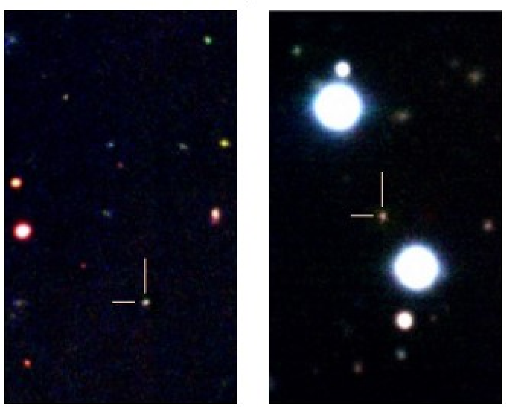
- 1P/Halley
  - FORS1 + FORS2 + VIMOS, 32ks
  - V= 28.2, r= 28.1 au

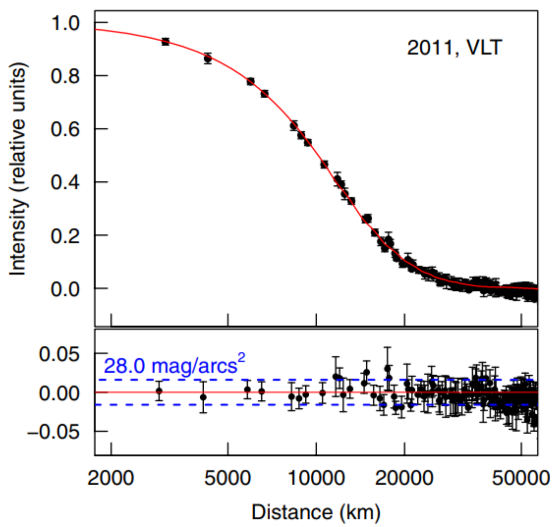


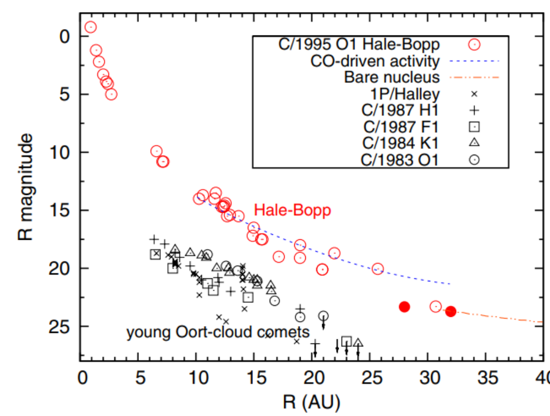
eso0328

- C/Hale-Bopp's nucleus
  - r=37km, 8% albedo increased <- re-depositoin of icy grains

2011, VLT







Szabo+ 2012ApJ...761....8S

Comets / Space Mission

- EPOXI and 103P/Hartley 2
  - Snodgrass, Meech, Hainaut 2010A&A...516L...9S The nucleus of 103P/Hartley 2, target of the EPOXI mission
- Deep Impact / Stardust-NExT and 9P/Tempel 1
  - Meech+ 2011Icar..213..323M Deep Impact, Stardust-NExT and the behavior of Comet 9P/Tempel 1 from 1997 to 2010
  - Weiler+ 2007Icar..190..423W The gas production of Comet 9P/Tempel 1 around the Deep Impact date
- Rosetta and 67P/Chury
  - Tubiana+ 2008A&A...490..377T - Comet 67P/Churyumov-Gerasimenko at a large heliocentric distance
  - Agarwal+ 2010Icar..207..992A - The dust trail of Comet 67P/Churyumov-Gerasimenko between 2004 and 2006
  - Tubiana+ 2011A&A...527A - 67P/Churyumov-Gerasimenko at large heliocentric distance
  - Tozzi+ 2011A&A...531A..54T - Evolution of the dust coma in comet 67P/Churyumov-Gerasimenko before the 2009 perihelion
  - Vincent+ 2013A&A...549A.121V - Spin and activity of comet 67P/Churyumov-Gerasimenko
  - Snodgrass+ 2016A&A...588A..80S - Distant activity of 67P/Churyumov-Gerasimenko in 2014: Ground-based results during the Rosetta pre-landing phase
  - Moreno+ 2016A&A...587A - The dust environment of comet 67P/Churyumov-Gerasimenko from Rosetta OSIRIS and VLT observations in the 4.5 to 2.9 AU heliocentric distance range inbound
  - Stinson, Bagnulo, Tozzi 2016A&A...594A.110S - Polarimetry of comets 67P/Churyumov-Gerasimenko, 74P/Smirnova-Chernykh, and 152P/Helin-Lawrence
  - Moreno+ 2017MNRAS.469S.186M - The dust environment of comet 67P/Churyumov-Gerasimenko: results from Monte Carlo dust tail modelling applied to a large ground-based observation data set
  - Opitom+ 2017MNRAS.469S.222O - Ground-based monitoring of comet 67P/Churyumov-Gerasimenko gas activity throughout the Rosetta mission

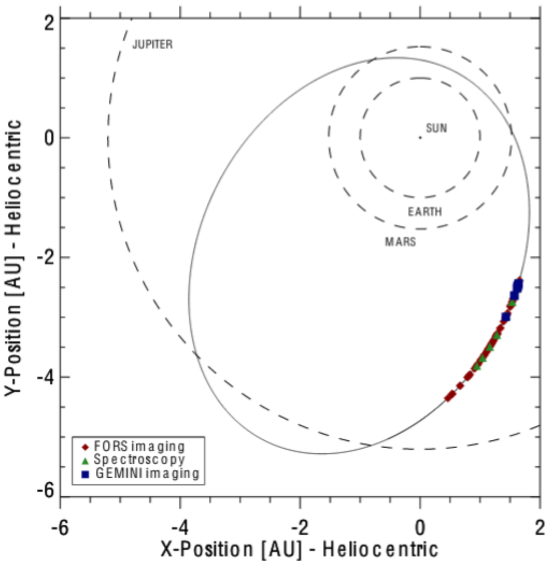
Comets / Space Missions

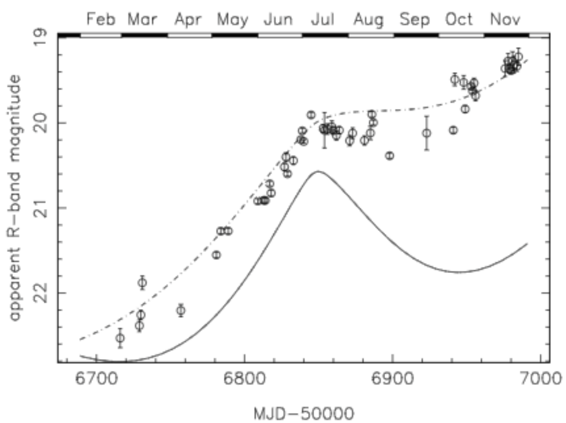
- 67P/Chury: pre-Rosetta:

Characterization of

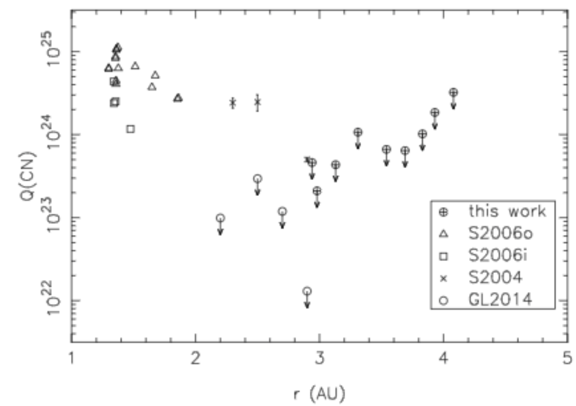
- The nucleus,
- The activity profile, dust properties
- Gas production rates

→ prepared Rosetta's strategy





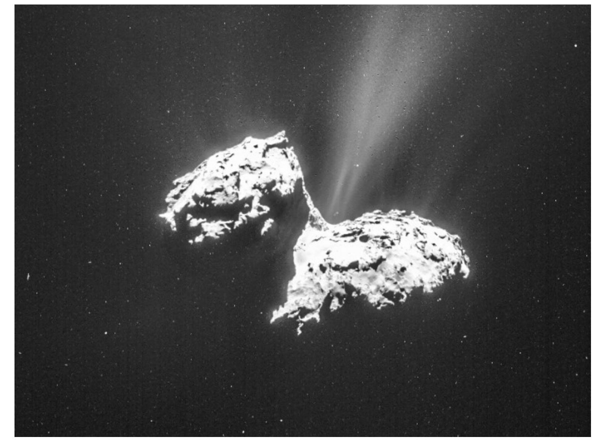
Photometry: activity profile
Snodgrass+ 2016A&A...588A..80S

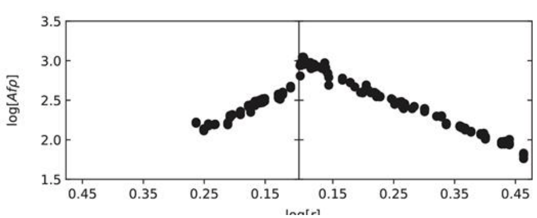


Spectro: gas production rates
Snodgrass+ 2016A&A...588A..80S

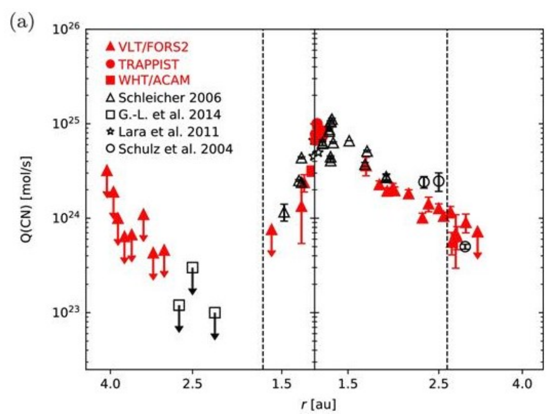
Comets / Space Missions

- 67P/Chury during Rosetta:
  - Gives context
    - Spatial (different scales)
    - Temporal (seasonal effects)
  - Link with other comets
    - (observed only from the Ground)



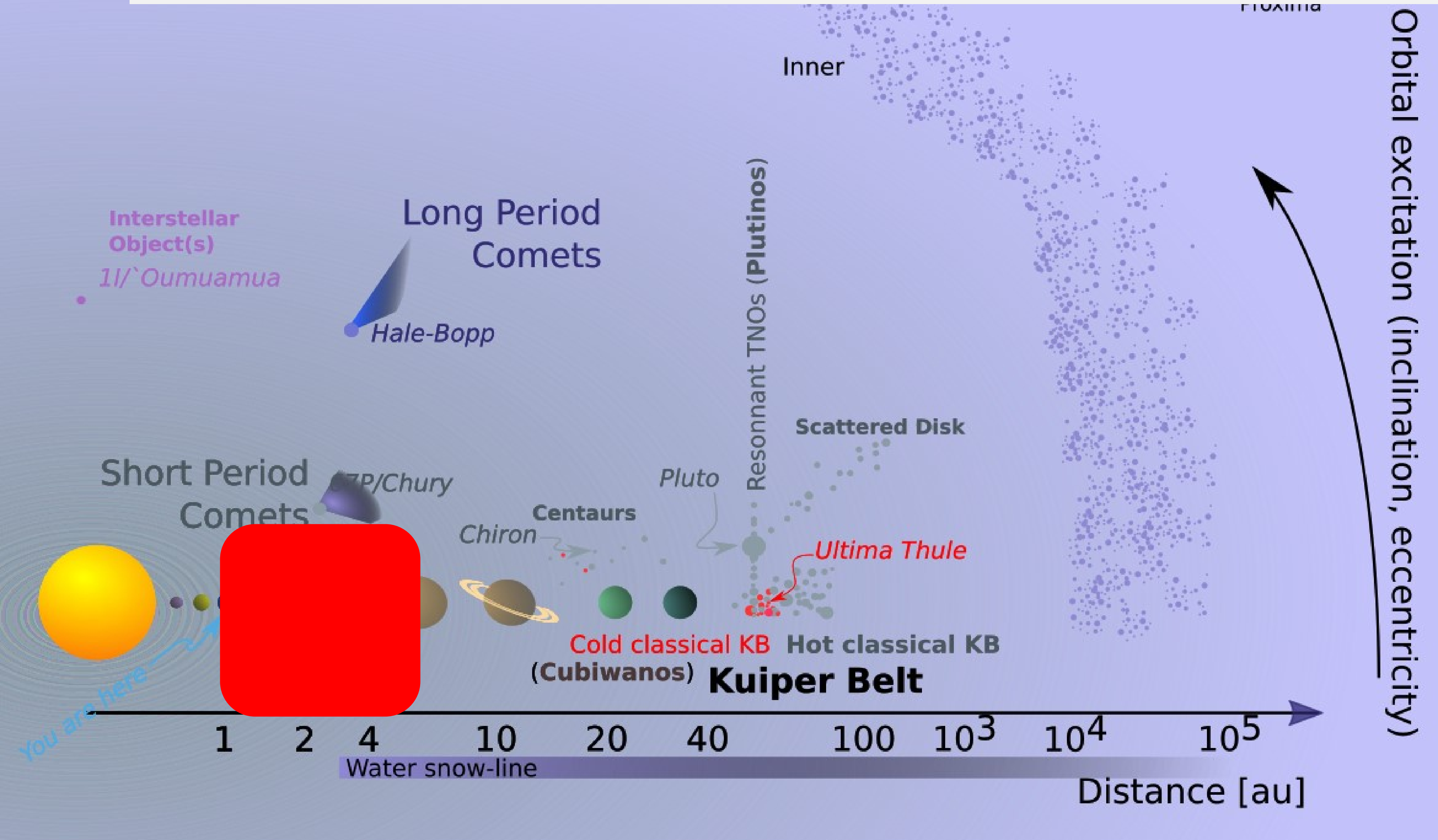


Dust production during Rosetta
Opitom+ 2017MNRAS.469S.222O



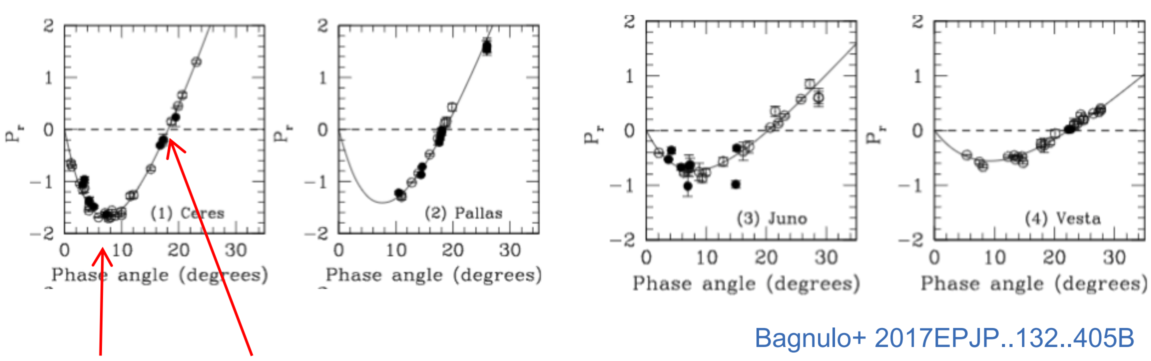
Gas production during Rosetta
Opitom+ 2017MNRAS.469S.222O

Asteroids & Polarimetry



FORS & Polarization

- Boehnhardt+ 2008A&A...489.1337B
  Photometry and polarimetry of the nucleus of comet 2P/Encke
- Cellino+ 2014MNRAS.439L..75C
  A successful search for hidden Barbarians in the Watsonia asteroid family.
- Bagnulo+ 2015MNRAS.446L..11B
  Linear spectropolarimetry: a new diagnostic tool for the classification and characterization of asteroids.
- Bagnulo+ 2016A&A...585A.122B
  Broadband linear polarization of Jupiter Trojans
- Bagnulo+ 2017EPJP..132..405B
  Polarimetry of small bodies and satellites of our Solar System

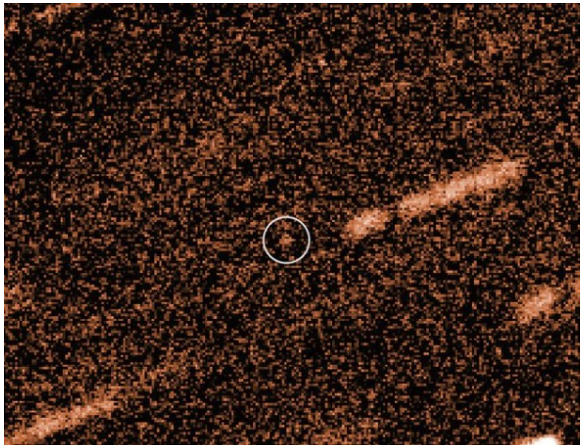


Bagnulo+ 2017EPJP..132..405B

NEO prevention

ESO
in collaboration with ESA Planetary Defence Office,
in the context of the International Asteroid Warning Network,
in UN-Committee for the Peaceful Use of Outer Space:

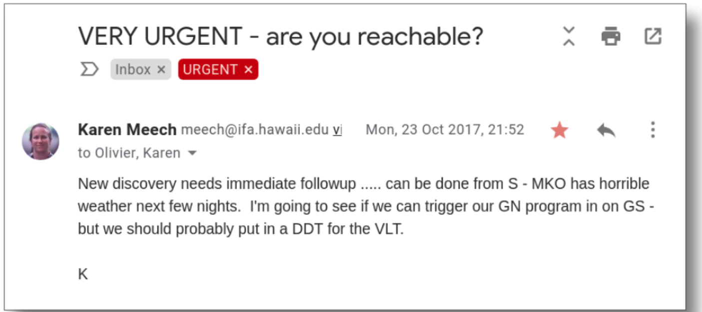
- Recover / refine the orbit of threatening NEOs that are too faint for NEO facilities (up to 12h/semester)
- Characterize an upcoming impactor to prepare mitigation.



2009 FD, mag=26.5, threat decreased 10x
ESO ann14004

1I/`Oumuamua

- ESO DDT
  - 2017-oct-19 Discovery @ PS1
  - 2017-oct-22 Hyperbolic orbit
  - 2017-oct-23 Alert
  - 2017-oct-24 DDT submitted
  - 2017-oct-24 evening: FORS is observing



VERY URGENT - are you reachable?

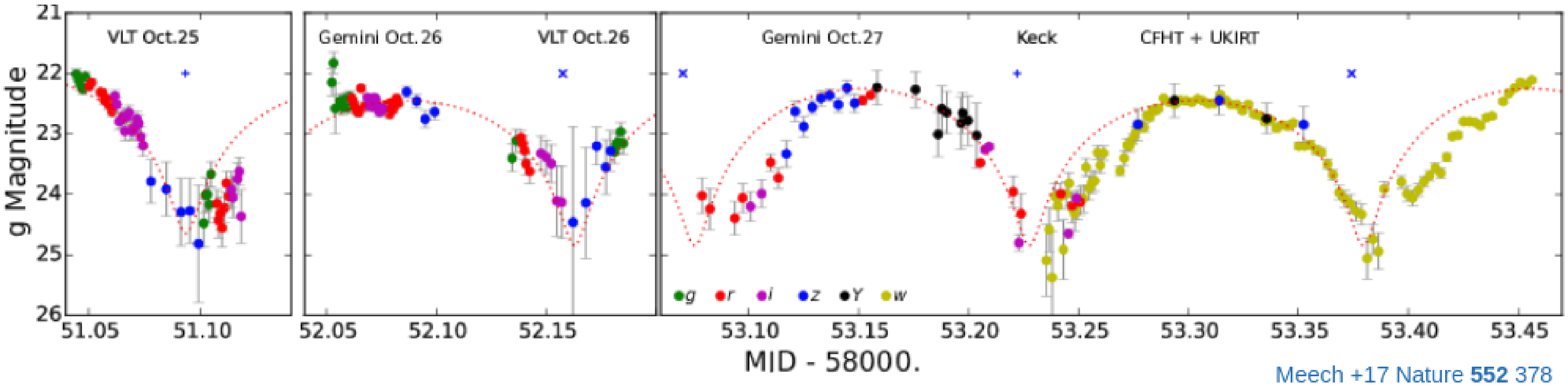
Inbox × URGENT ×

Karen Meech meech@ifa.hawaii.edu Mon, 23 Oct 2017, 21:52

to Olivier, Karen

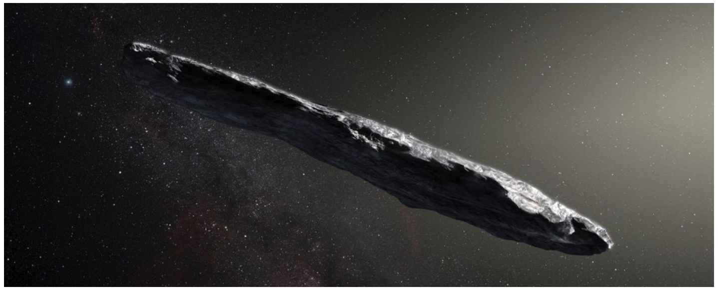
New discovery needs immediate followup ..... can be done from S - MKO has horrible weather next few nights. I'm going to see if we can trigger our GN program in on GS - but we should probably put in a DDT for the VLT.

K



Meech +17 Nature **552** 378

- First interstellar object
  - Huge elongation ~10:1
  - Colours are ~comet-like
  - Non-gravitational forces are comet-like
  - Many questions; 5 papers (2 Nature) out of this DDT



FORS

- **Significant contribution to population studies**
  - **TNOs**
  - **Comets**
  - **Main-Belt Comets and Active Asteroids**
- **Strong support to Space Missions**
  - **Rosetta @ 67P**
  - **Deep Impact @ 9P/T1**
- **A series of unique/ record/ special object characterized**
- **Special mention:**
  - **Versatility well adapted to Solar System objects**
  - **Power of polarimetry**
  - **Super DDT tool**

➔ When can we get FORS+ ?