SOXS WG1 - Solar System Bodies

The evolution and origins of transient Solar system populations

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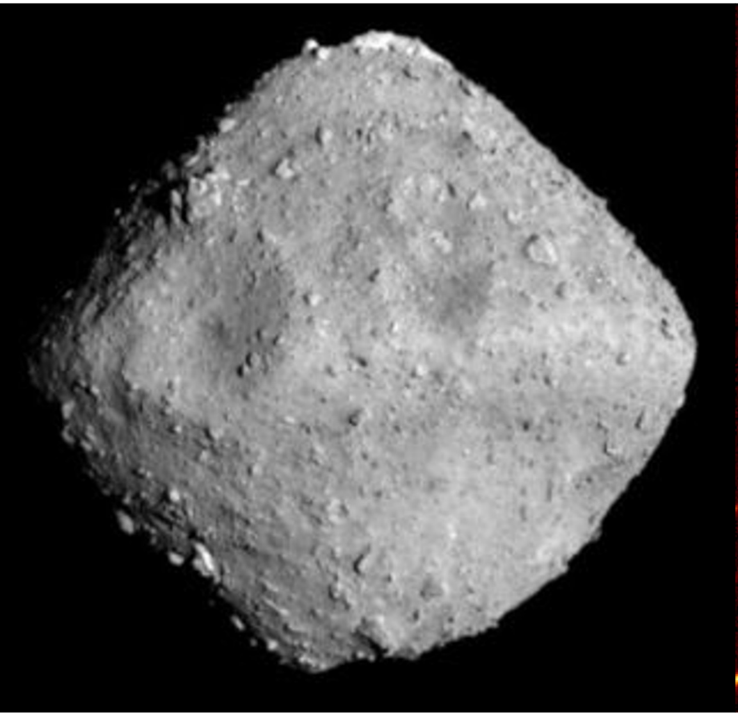
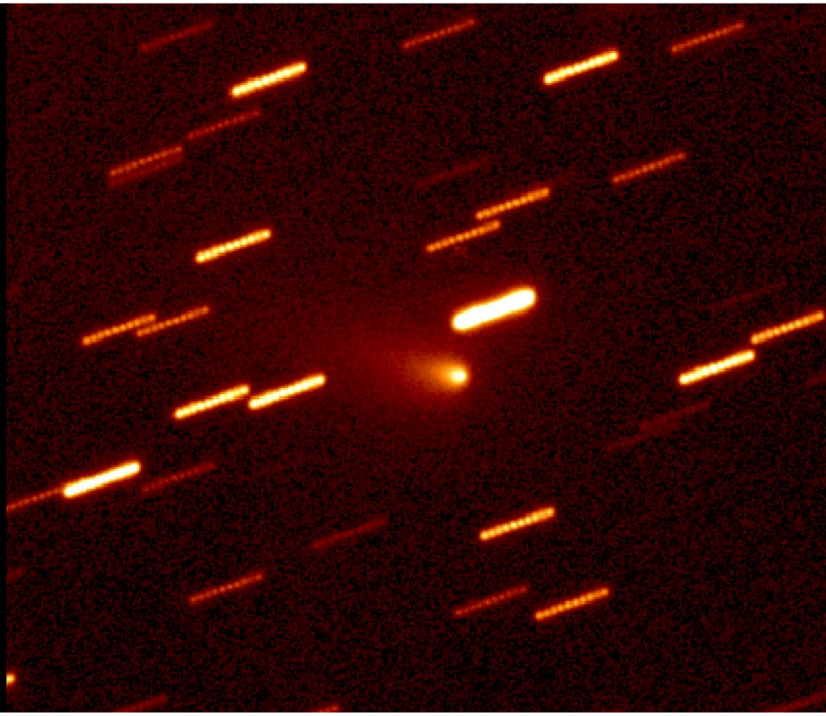
SOXS WG1 - Solar System Bodies

The overall goal is to study current-day transient populations of the Solar system, and test models of the evolutionary history.

1. Near-Earth Objects
2. Cometary Bodies
3. Fast Response Transients (Mission targets, IOs, active bodies)

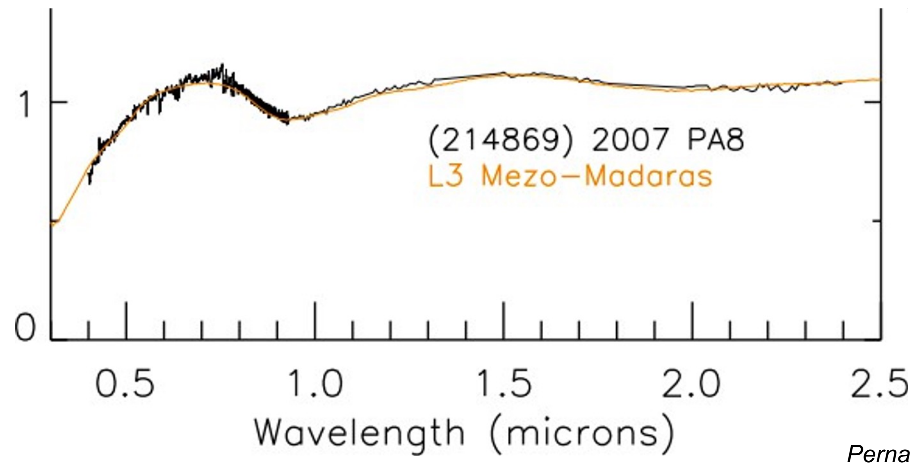




SOXS WG1 - Solar System Bodies

<u>Why SOXS?</u>

OPT/NIR spectroscopy is fundamental for measuring compositions and mineralogy of asteroids.

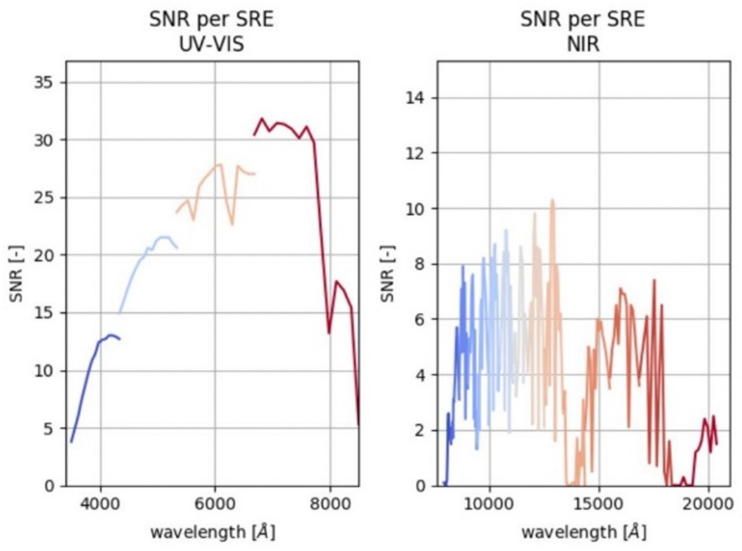


Perna et al. 2016

Asteroid spectra contain solid-state absorption bands from ~0.4 - 2.0 um, giving compositions.

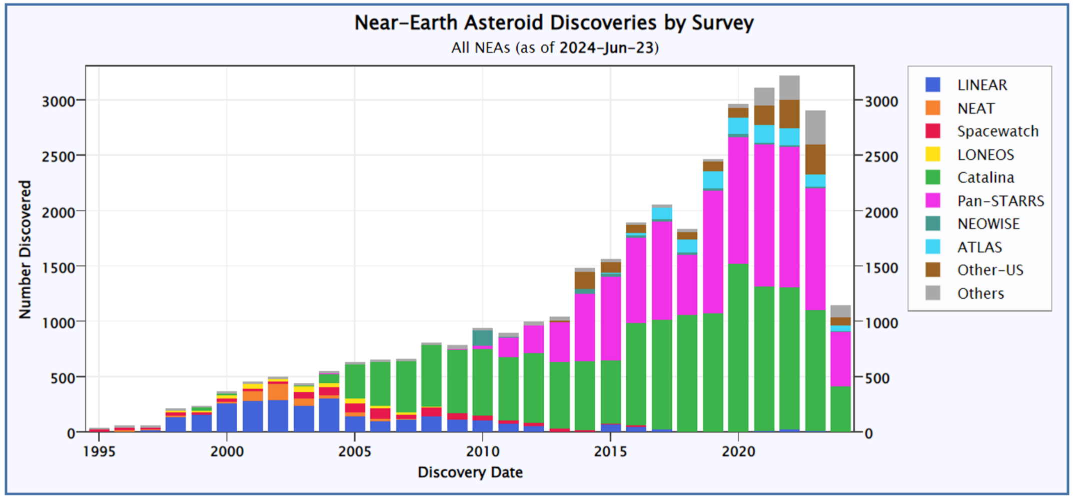
Cometary spectra contain resolvable gas emission from ~0.4 - 1.0 um, plus dust grain scattering up to 2um.

SOXS is the <u>perfect</u> instrument for Solar system spectroscopy.



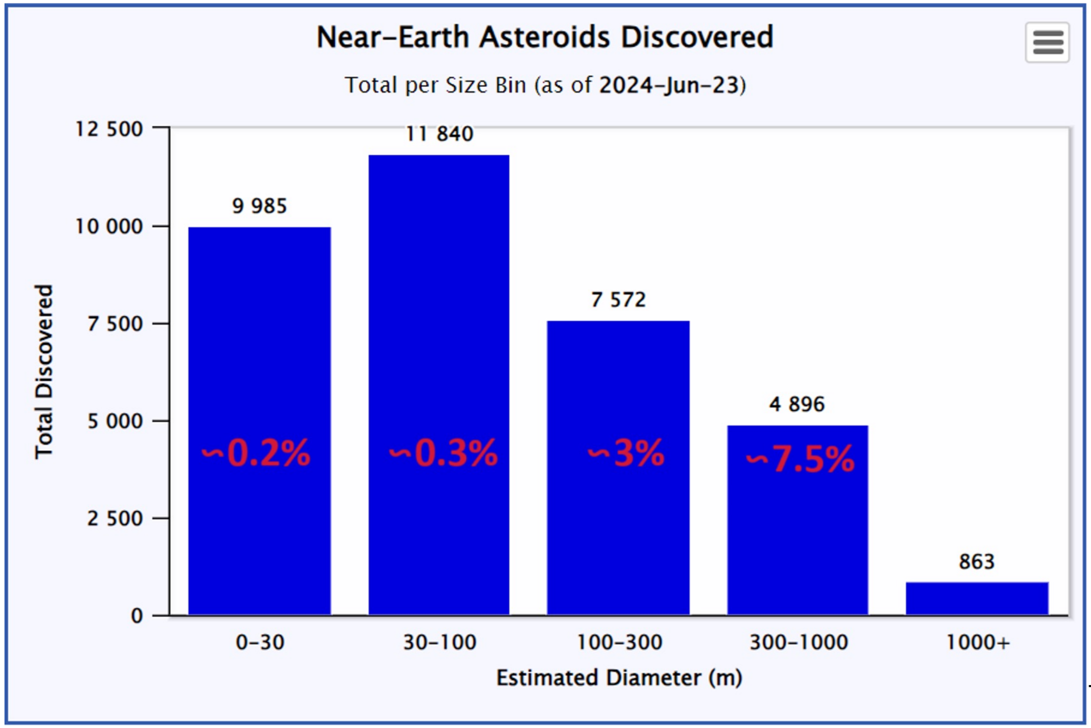
V=20
Texp=1hr

1. Near-Earth Objects
Understanding the transient population



<u>Current discovery rate ~8 per day.</u>

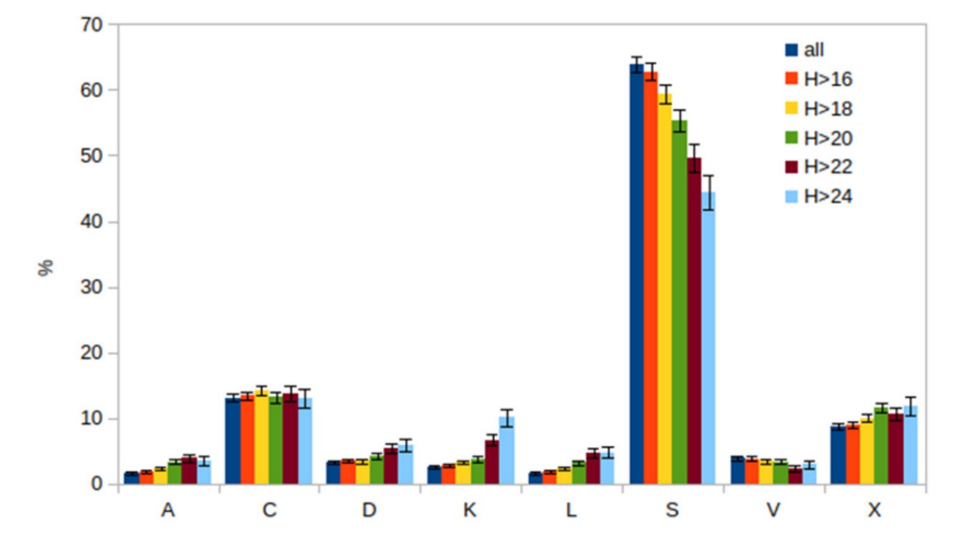
Incoming new facilities (Vera Rubin, ZTF, FLYEYE…) will significantly increase this rate.



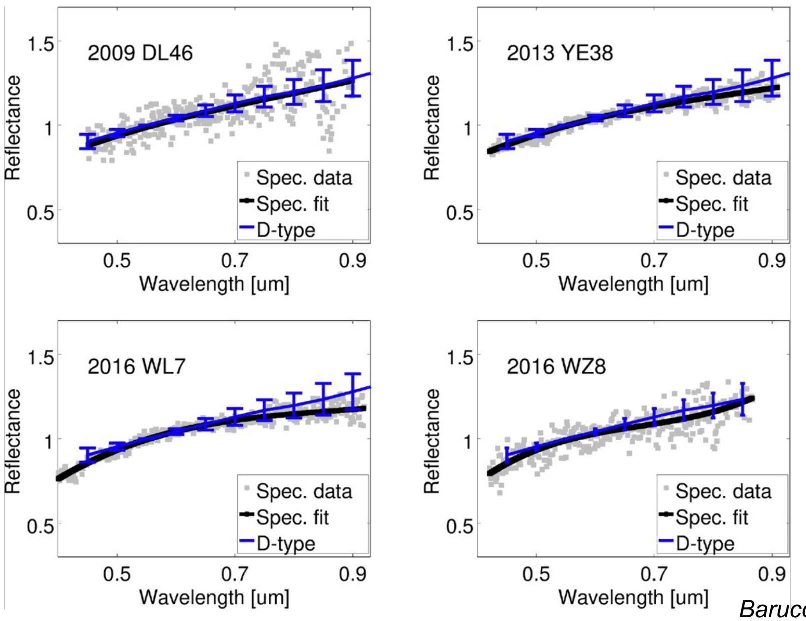
Majority of current discoveries at diameters < 300m.

- Compositions of the large population (> 1 km) well known from spectroscopy/photometry.
- poorly understood at < 100m

1. Near-Earth Objects
Understanding the transient population



Ieva et al. 2020



Barucci et al. 2018

Majority of NEOs are silicate or volatile-rich carbonaceous asteroids.

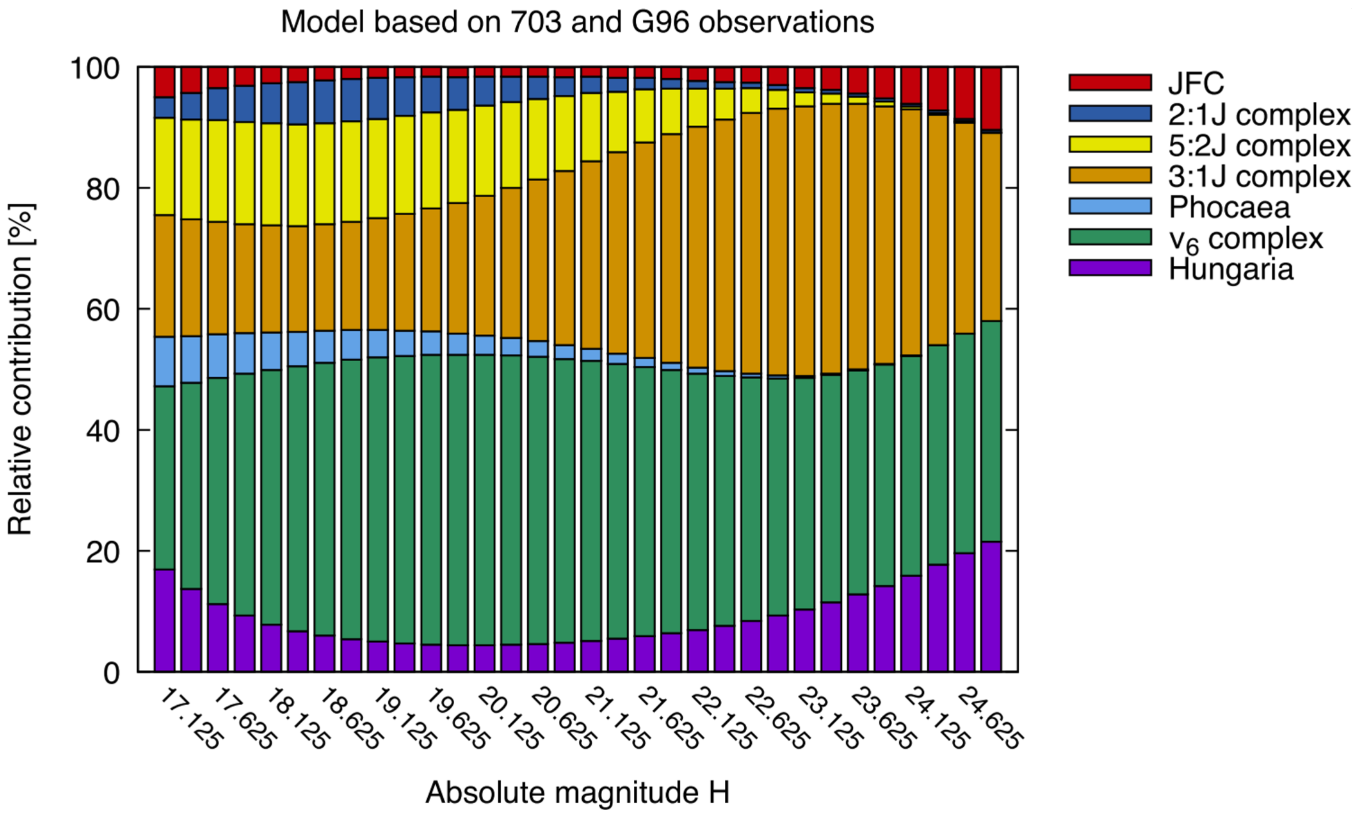
Recent studies (Perna+ 2018, Ieva+ 2020) indicate strong compositional variations as a function of size.

May be due to size-dependant source regions or loss of more primitive objects due to solar heating/ disruption.

There appear to be an significant numbers of low-albedo “primitive” asteroids from the outer-belt or inert comet nuclei.

Small number statistics prevent accurate constraints on dynamical models of delivery.

1. Near-Earth Objects
Understanding the transient population



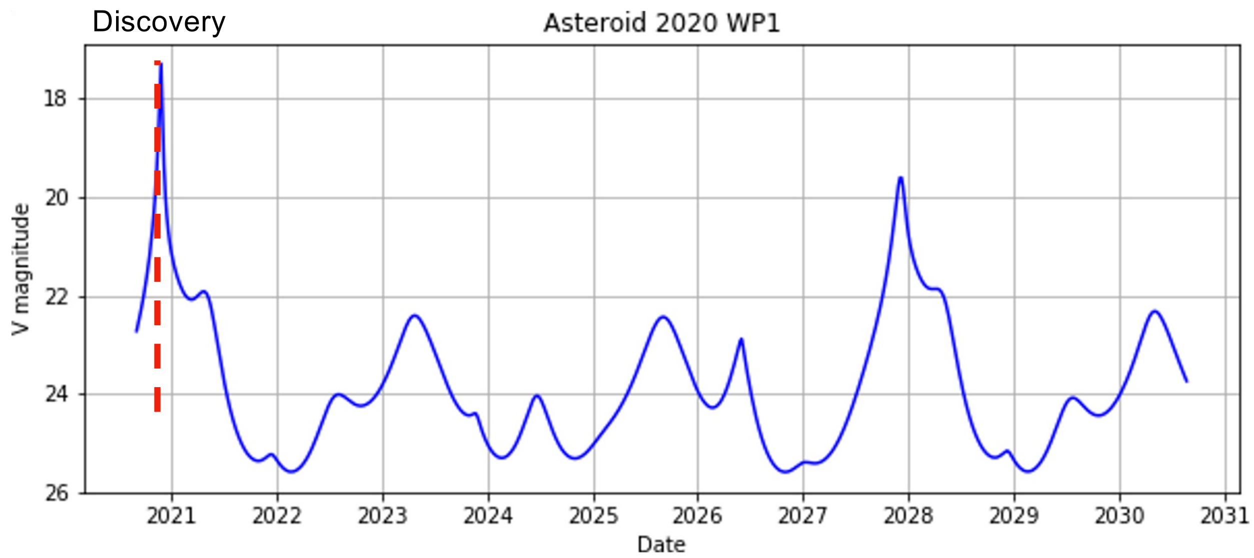
Granvik et al. 2018

Current models predict fraction of NEOs from source regions as a function of size.

Different source regions have different compositions, allowing model testing.

1. Near-Earth Objects
Understanding the transient population

For current-discovered NEOs, optimal spectroscopy window is at apparition.

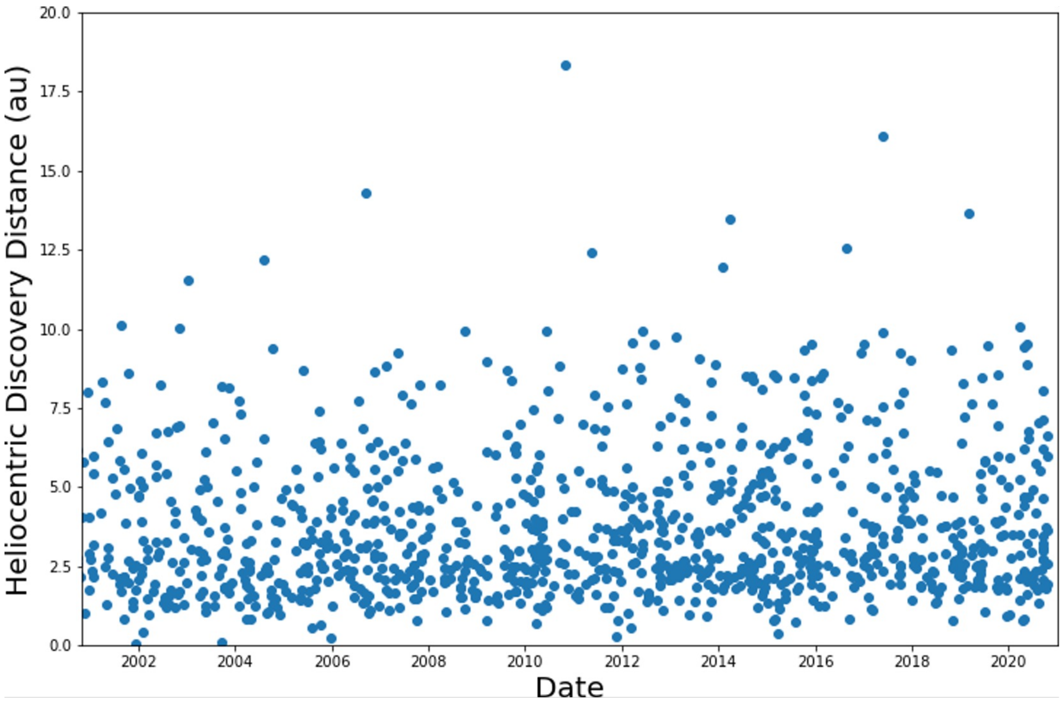


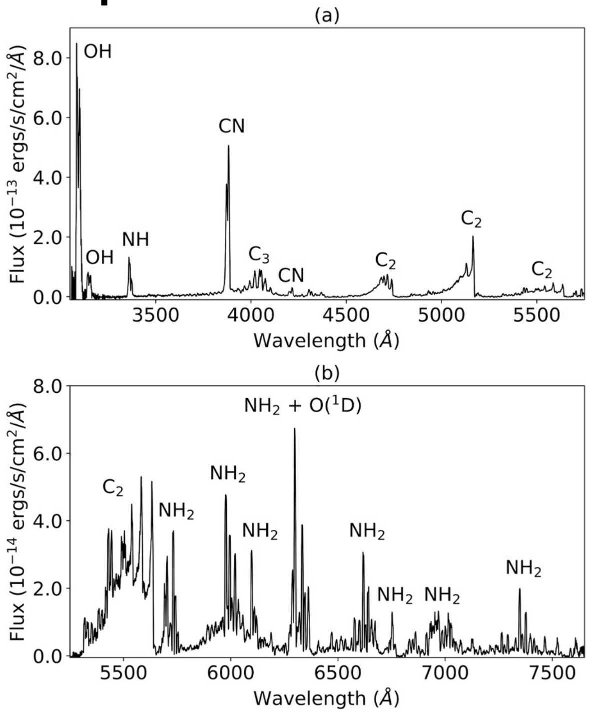
Science Goals:
Spectroscopy of recently-discovered NEOs with 10m – 300m to constrain composition of small NEO population, compare with models and population at ≥ 500 m.

Compositions of Potentially Hazardous Objects: Diameter ≥ 140m, minimum distance ≤ 0.05 au. Direct sampling of largest threat population.

Triggering Criteria: V≤ 20, 3-σ orbital uncertainty ≤ 1.5 arcmin, D≤ 300m

2. Cometary Bodies
Evolution and intrinsic compositions



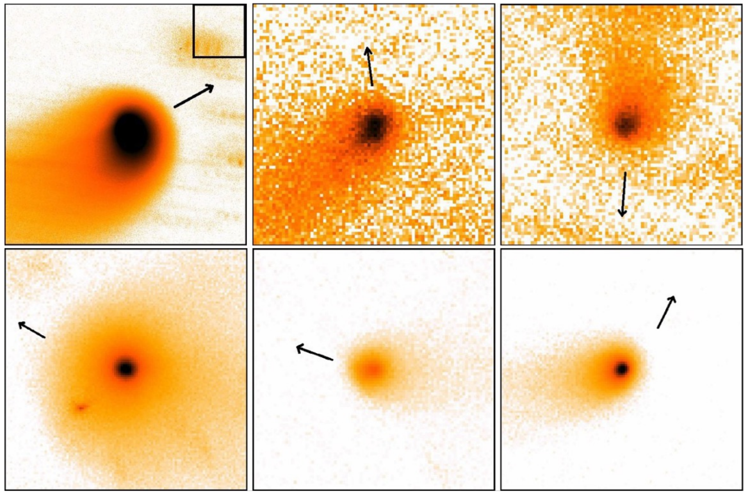


Hyland et al. 2019

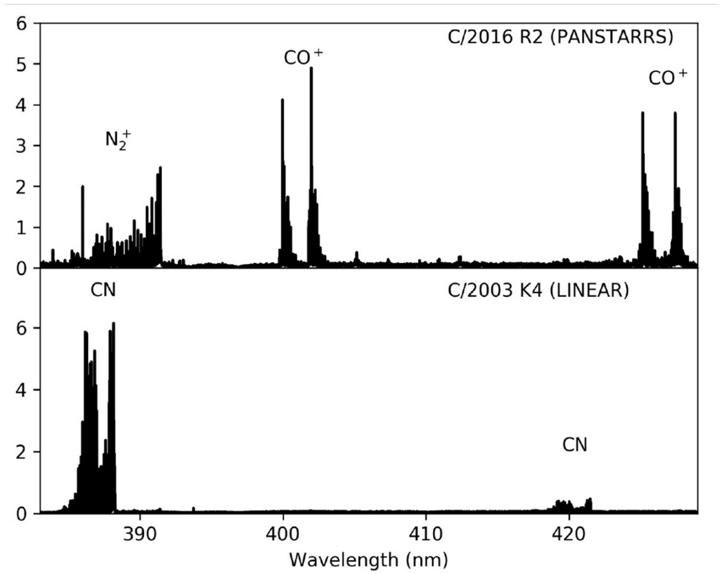
<u>Comet discovery rate ~50 per year, ~ 10–15 at distances > 5 au</u>.

Almost all spectroscopic studies of active objects occur within 3 au, where H_2O sublimation dominates.

2. Cometary Bodies
Evolution and intrinsic compositions



Mazzotta Epifani et al. 2014



Opitom et al. 2017

Photometry and imaging clearly shows activity at 5 – 10 au, where CO/CO_2 should dominate activity.

Comets such as C/2020 R2 show CO-dominated activity, but can lack of other species such as HCN.

The temporal evolution of gas species and dust grain properties is highly uncertain.

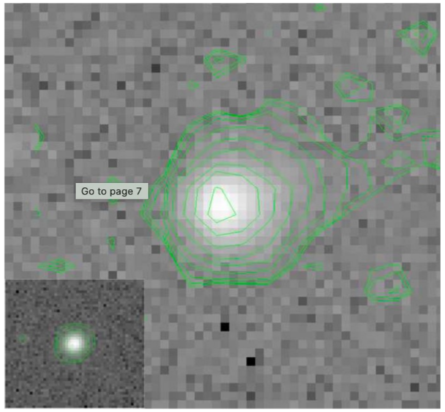
Science Goals:
Spectroscopic evolution of a selection of comets moving in from >5 au to inner solar system. (Time taken to move from 10 au to 1 au is ~3 years).

(a) Measure evolution of gas abundances from initial week activity to H_2O-dominate sublimation.
(b) Measure dust grain evolution including search for ice absorption features at 1.5um, 1.65 um.

Triggering Criteria: V≤ 20, 3-σ orbital uncertainty ≤ 1.5 arcmin
Initial heliocentric distance > 5 au
Perihelion distance < 3 au

2. Cometary Bodies
Evolution and intrinsic compositions

523676 (2013 UL10)



Mazzotta Epifani et al. 2018

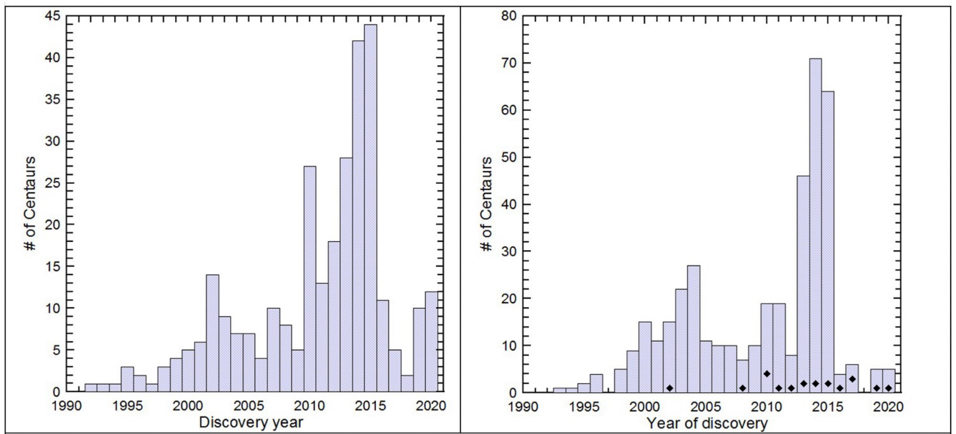
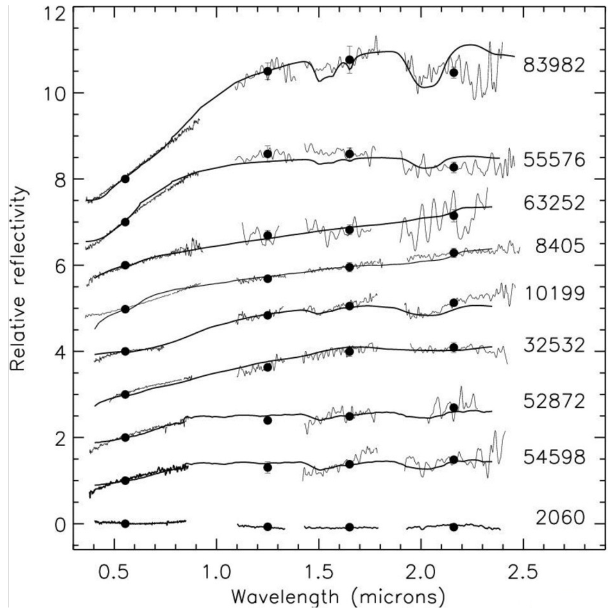


Figure 3 – Discovery rate for Centaurs (left) and TNOs (right) since the first discovery (1977 and 1993, respectively). For TNOs, black dots represent the high-I members ($i \geq 70°$)

Barucci & Peixinho 2006



TNO/Centaur discovery rate will jump when the Vera Rubin starts!

Centaurs, between Jupiter and Neptune, are a transitional population from Trans Neptunian Objects (TNOs) evolving into Jupiter Family Comets (JFCs). Some are active and show outbursts, explosive release of material. Inert centaurs allow probing of surfaces containing volatiles and organic-rich surfaces.

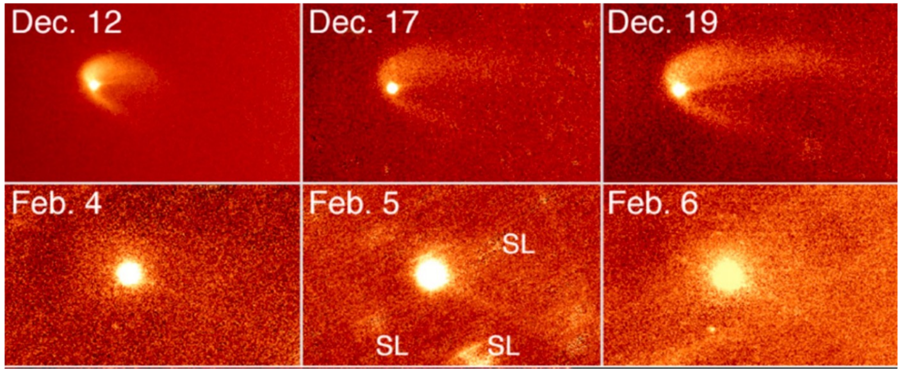
Science Goals for Centaurs:
Spectroscopy of new active/outbursting centaurs to search for gas emission and measure (volatile-rich) dust properties.

TNOs provide the origin of the JFCs seen in the inner Solar system. Last 10 years have seen discovery of high-inclination/retrograde TNOs, possibly originating in the Oort Cloud. May represent samples from inner Oort Cloud.

Science Goals for classification program:
Spectroscopy of hydrated minerals and ices on new bright Centaurs/high-i TNOs revealing surface ices and potential links to cometary populations.

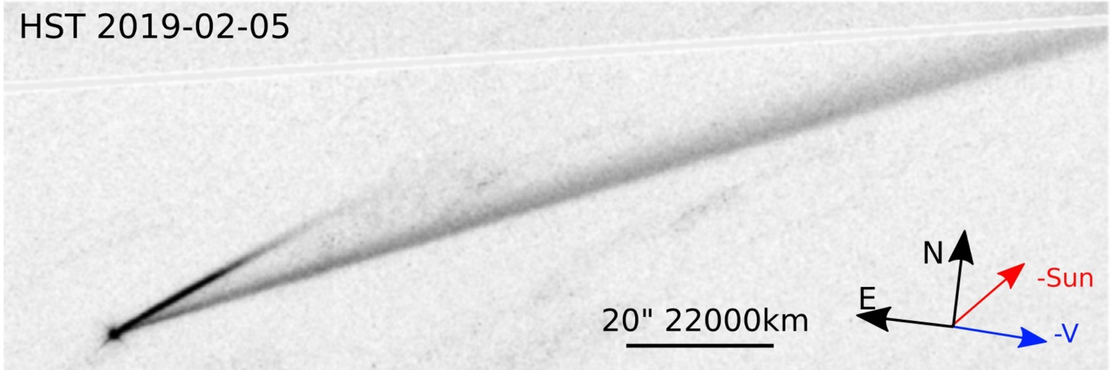
3. ToO - Fast Response Transients
Active Asteroids

Asteroid Collision - (596) Sheila



Ishiguru et al. 2011

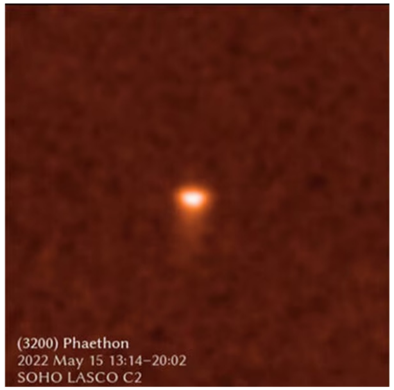
Asteroid Rotation Breakup - (6478) Gault



~1 Active asteroid discovered per year to date.

Kleyna et al. 2019

?????? - (3200) Phaethon



May be caused by several mechanisms (e.g. collision, rotational disruption or sublimation of sub-surface ices). *But do not know physical mechanism at discovery.*

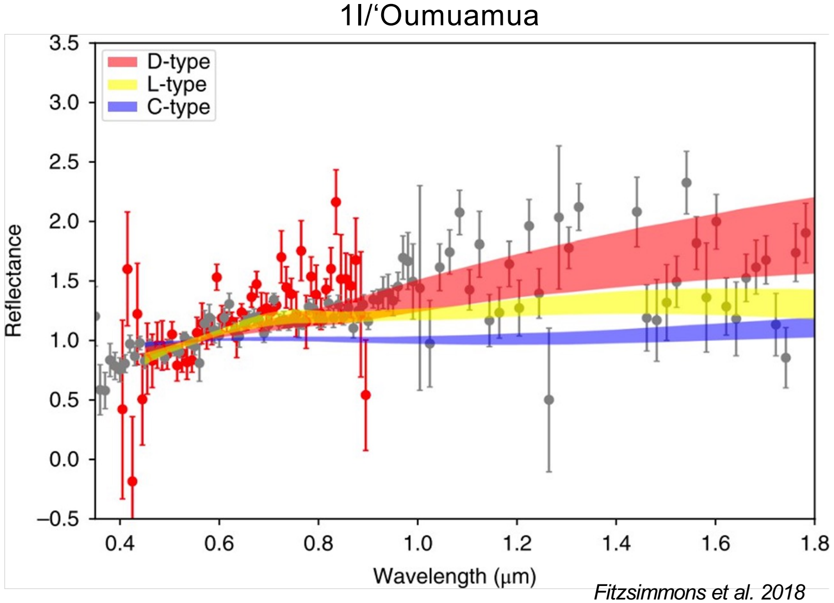
Science Goals:

Search for gas emission → prove sublimation hypothesis.

Measure reflectance spectrum → constrain grain size distribution/mineralogy.

Trigger Criteria: Detection of ejecta/coma in the object + comet trigger

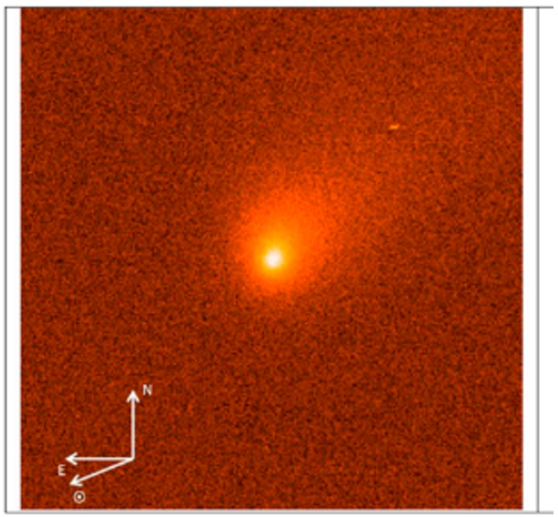
3. ToO - Fast Response Transients
Interstellar Objects



Fitzsimmons et al. 2018

1I/'Oumaumua - Earth-approaching orbit, perihelion 0.25 au. Inert, gas sublimation inferred. Surface reflectance properties matched carbon/volatile-rich asteroids (eg. D-type).

2I/Borisov - distant orbit, perihelion 2.01 au
Active cometary object, CO dominated outgassing, gas abundances showed strong time-evolution.



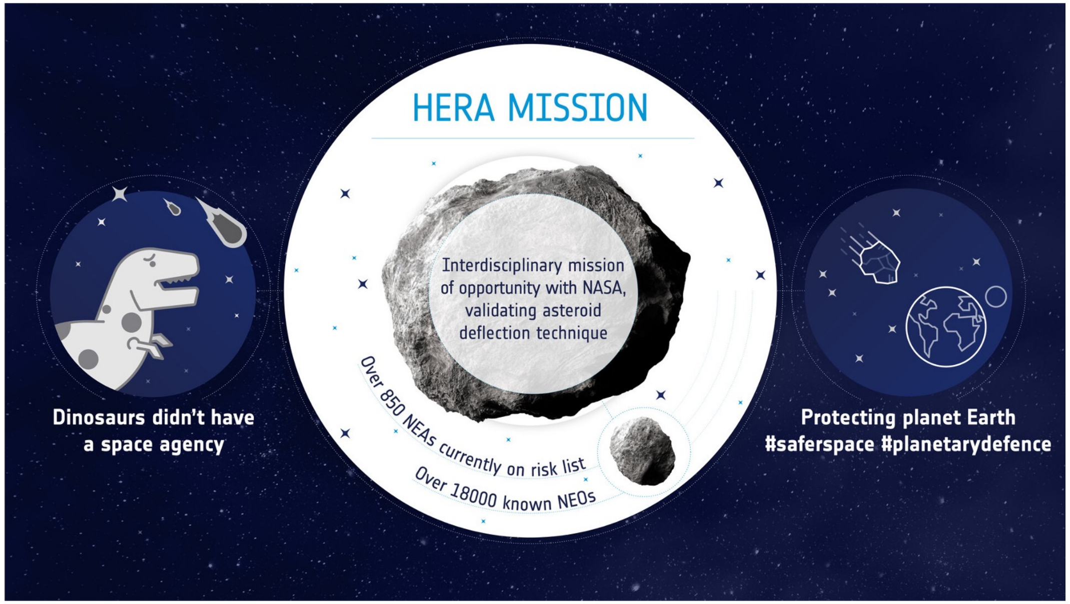
Mazzotta Epifani et al. 2021

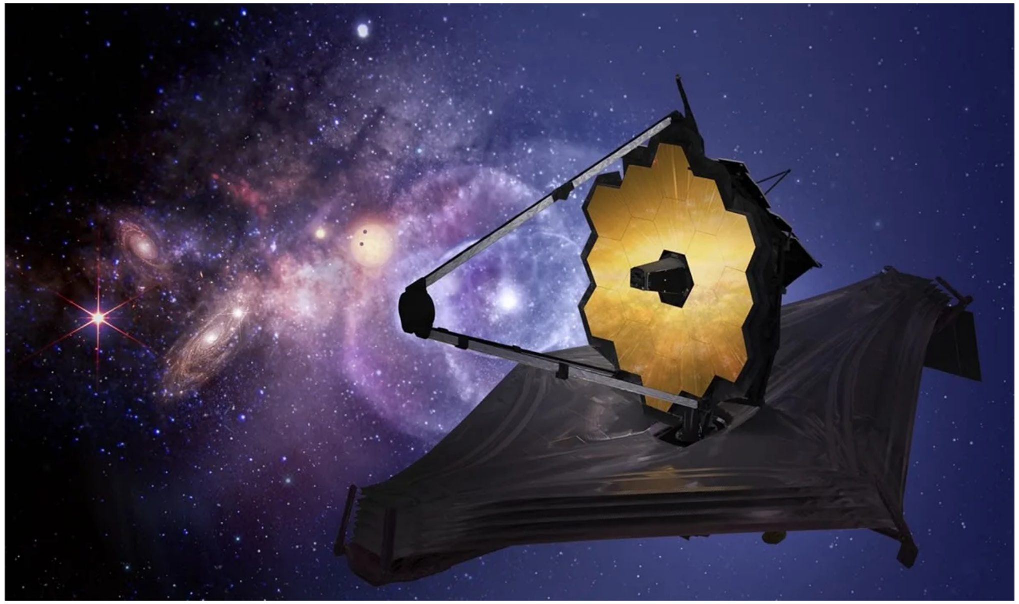
<u>Vera Rubin Observatory may discover ~1-10 IOs per year.</u>

Science Goals:
Search for gas emission, compare compositions with Solar-system populations.

Trigger Criteria: e > 1 at 3-σ

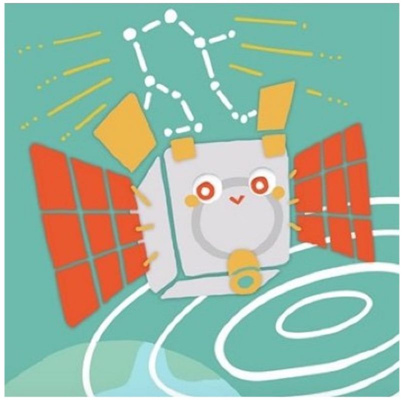
3. ToO - Fast Response Transients
Mission targets

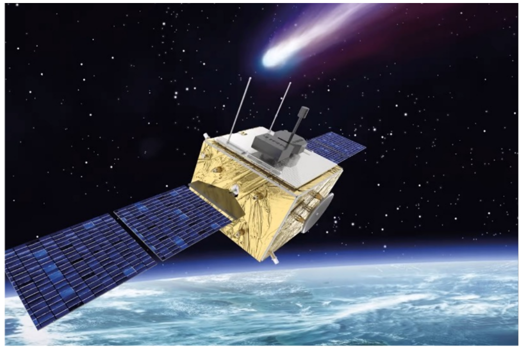




Hera

Didymos + Dimorphos
+ Flyby target (NEOs)





JWST
?

Destiny+

Phaethon
(NEO)

Comet Interceptor

To be discovered
(Comets)

Time estimate per Nation

VERY ROUGH

National share (hr/yr)

hr	WG1	WG2	WG3	WG4	WG5 flat	WG6	WG7	WG8	WG9	WG10	WG11	WG12	TOT	Avail
ITALY	100	271	270	70	40	58	100	100	18		71	40	1038	380
WEIZ				10				120					130	185
QUB	25					150		10			12		197	62
FINL	20		32	10	40	13	20	10	6	20			181	54
MAS					40			40	8	100			188	46
TAU						28				140			168	30
NBI					40						3		43	15

Italy 70%, QUB 15%, Finland 15%

Nationality subject interest

1. NEOs - Italy 80%, Finland 20%
2. Cometary Bodies - UK 30%, Italy 70%,
3. Fast response Targets - Finland 33%, UK 33%, Italy 33%

CAVEAT: very preliminary

Potential Breakdown/Estimate

1. NEOs: 8 nights/year
2. Cometary Bodies: 4 nights/year comets + 3 nights/year active centaurs+classification.
3. Fast Response Transients + Mission Targets: 3 nights/year