SOXS WG1 - Solar System Bodies

The evolution and origins of
transient Solar system populations

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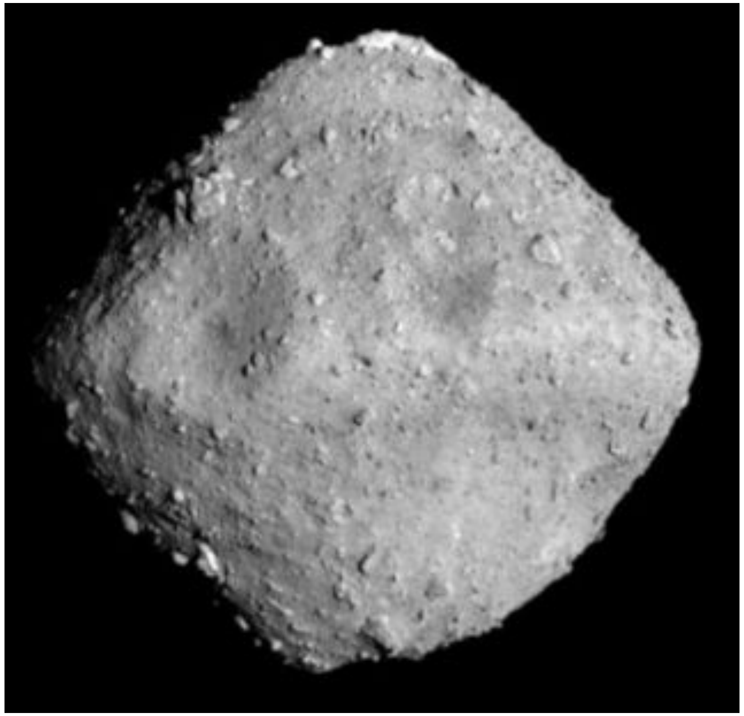
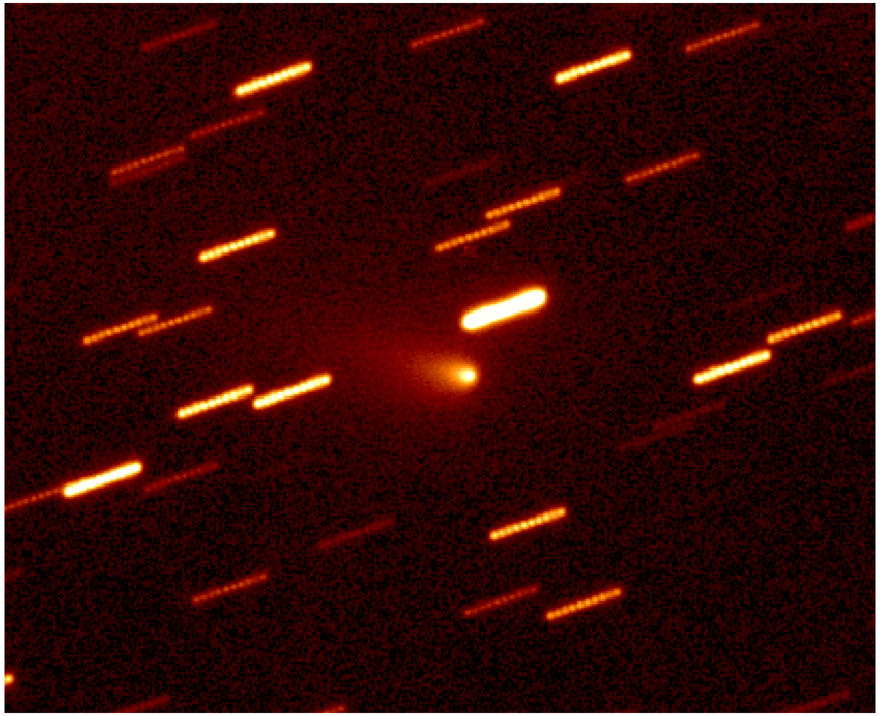
SOXS WG1 - Solar System Bodies

Overall aims are 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. Selected Targets including Fast Response Transients





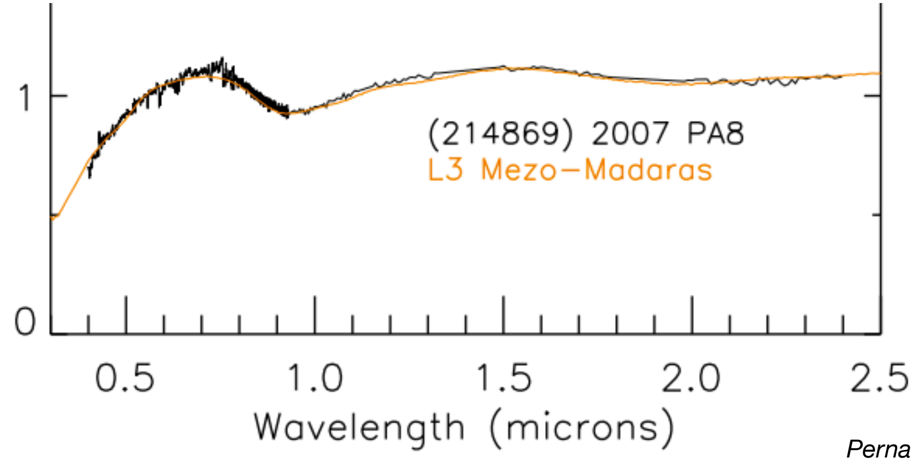
SOXS WG1 - Solar System Bodies

Why SOXS?

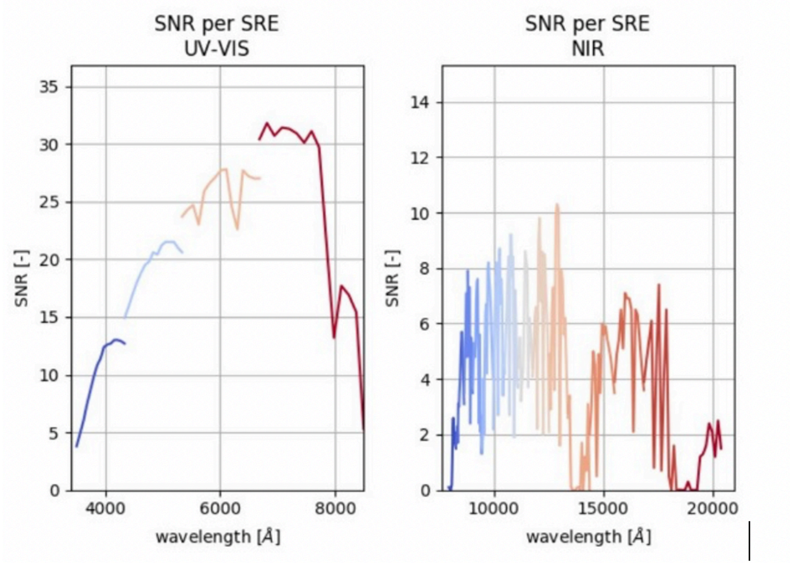
Asteroid/icy body spectra contain solid-state absorption bands from ~0.4 - 2.0 um, giving compositions.

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

SOXS is the “perfect” instrument for Solar system spectroscopy.

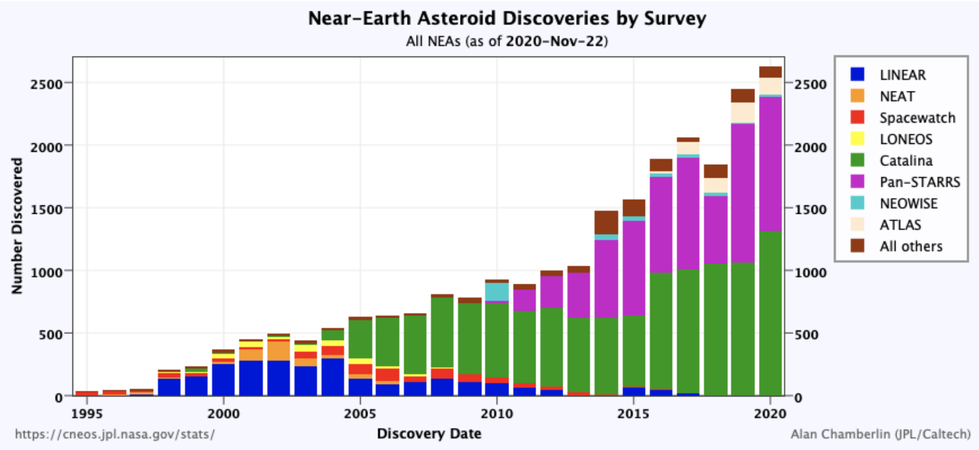


Perna et al. 2016



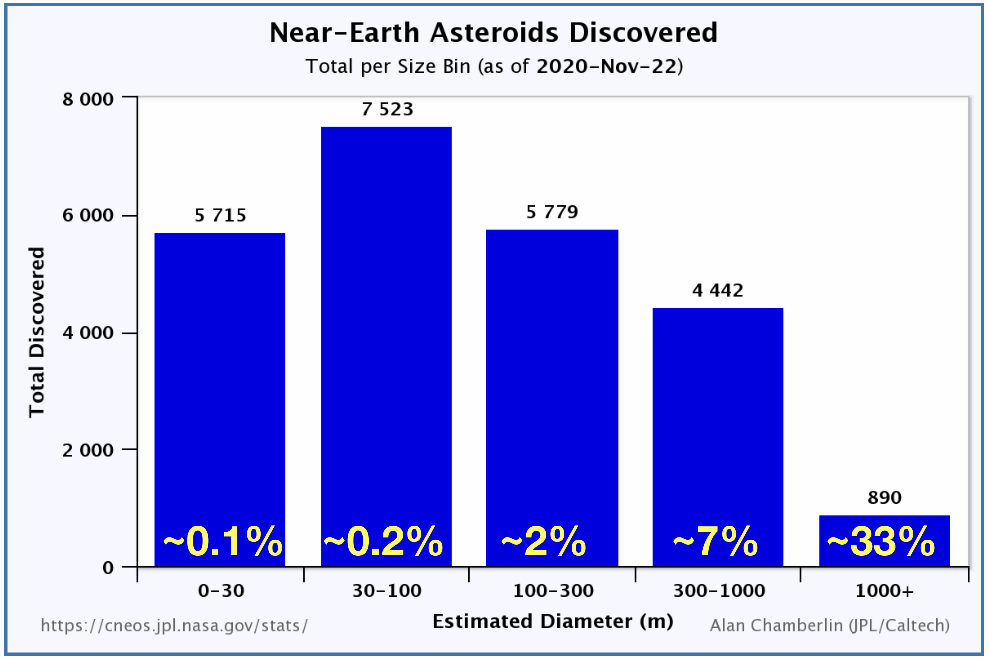
V=20
Texp=1hr

1. Near-Earth Objects
Understanding the transient population



Current discovery rate ~8 per day.

Incoming new facilities (LSST, ATLAS) will significantly increase this rate.

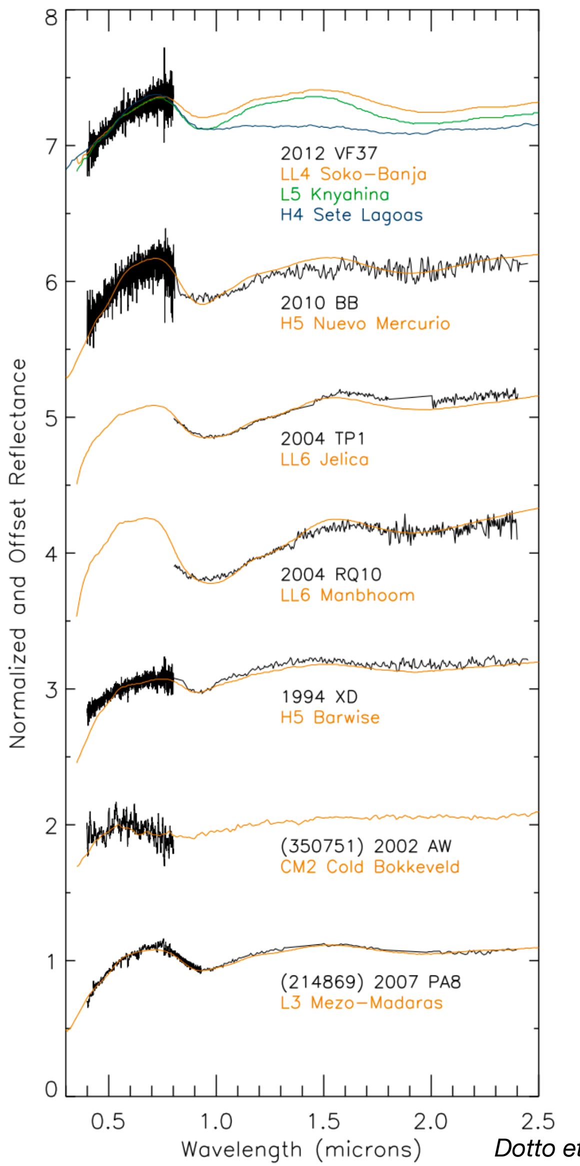


Majority of current discoveries at diameters < 500m.

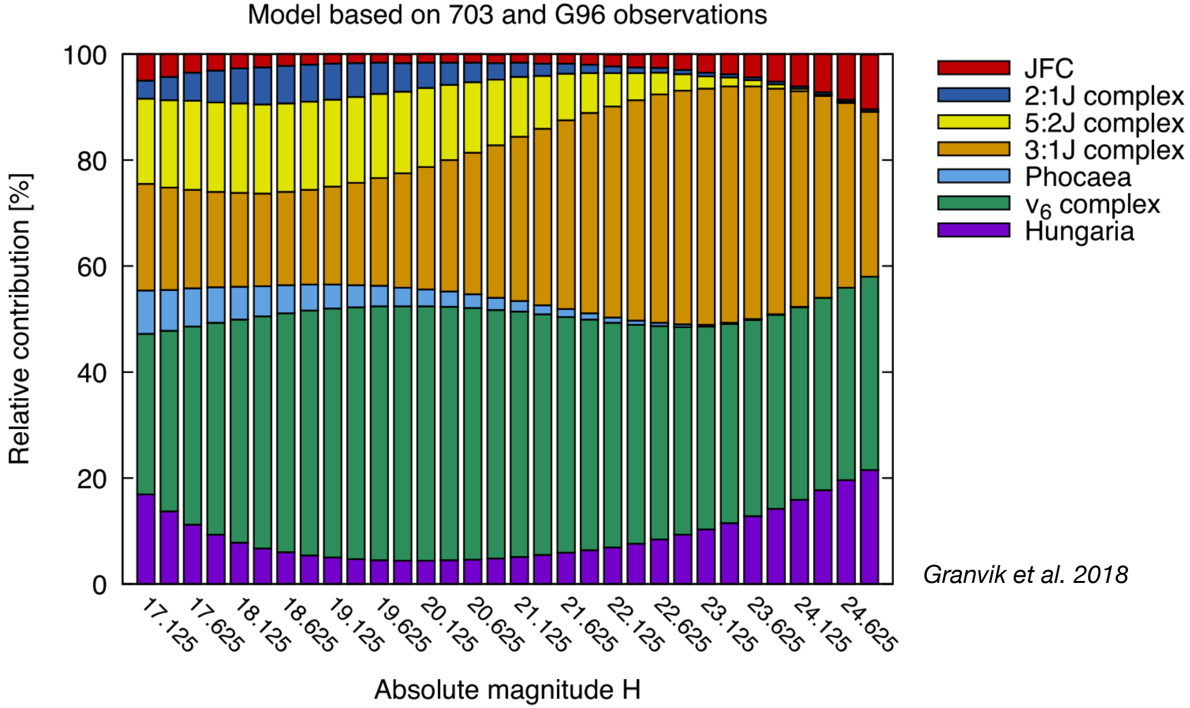
Compositions of the large population well known from spectroscopy/photometry, very poorly understood at

Physical/compositional knowledge uncertain poor at diameters <100m

1. Near-Earth Objects
Understanding the transient population



Dotto et al. 2015



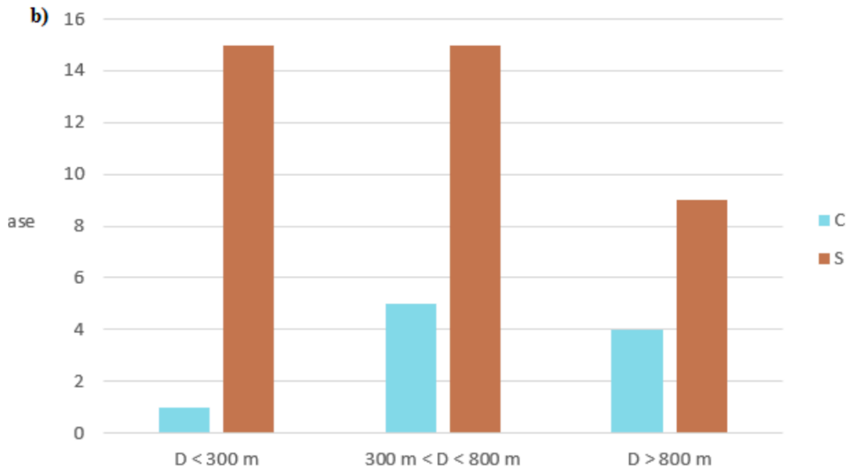
Granvik et al. 2018

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

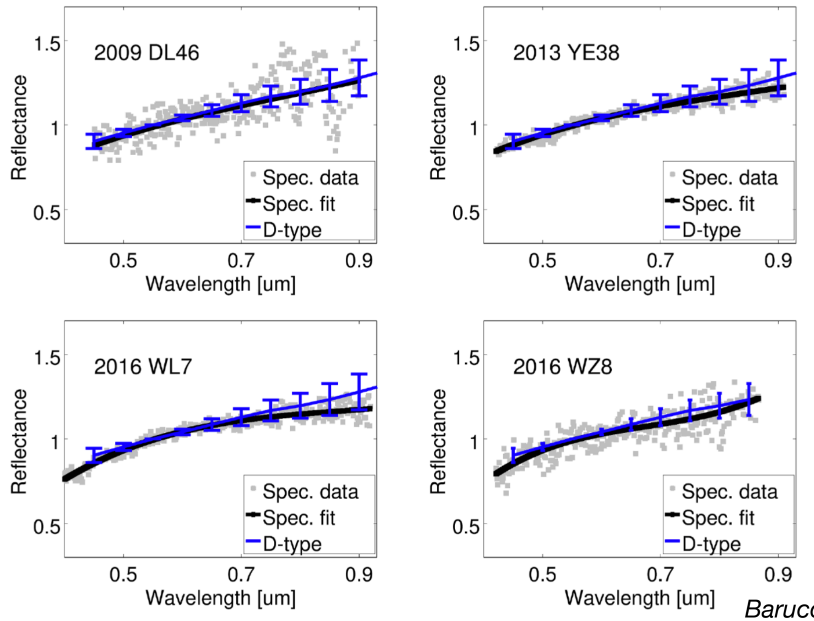
Current models predict fraction of NEOs from source regions as a function of size.

Different source regions have different compositions, allowing model testing.

1. Near-Earth Objects
Understanding the transient population



Ieva et al. 2018



Barucci et al. 2018

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

Recent studies indicate strong compositional variations as a function of size.

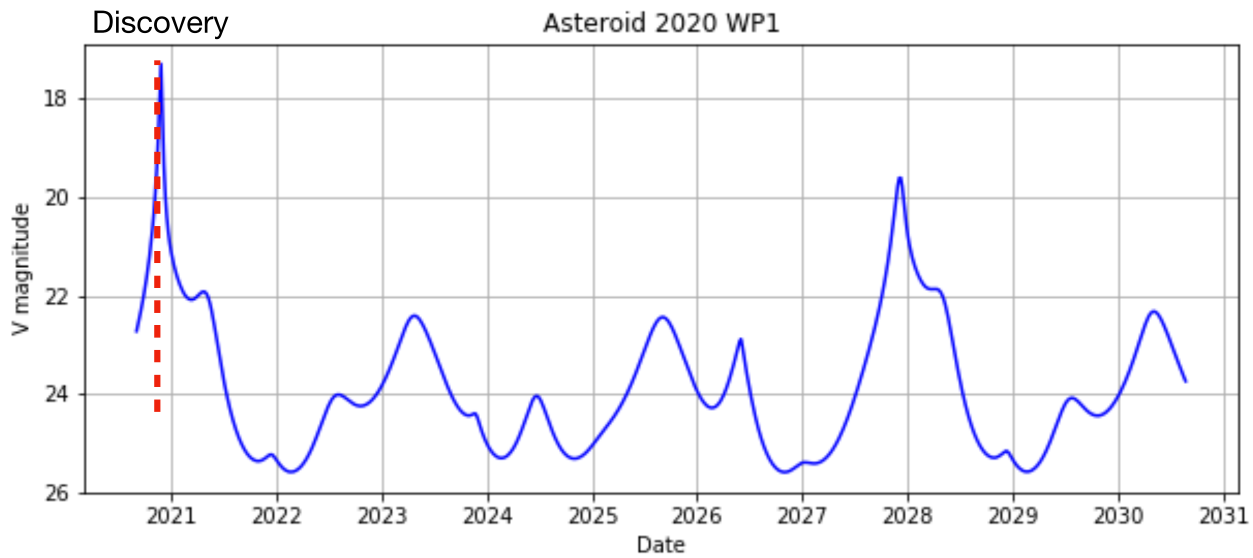
May be due to size-dependant source regions or loss of more primitive objects due to solar heating/ disruption.

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

For small NEOs, optimal spectroscopy window is discovery apparition.

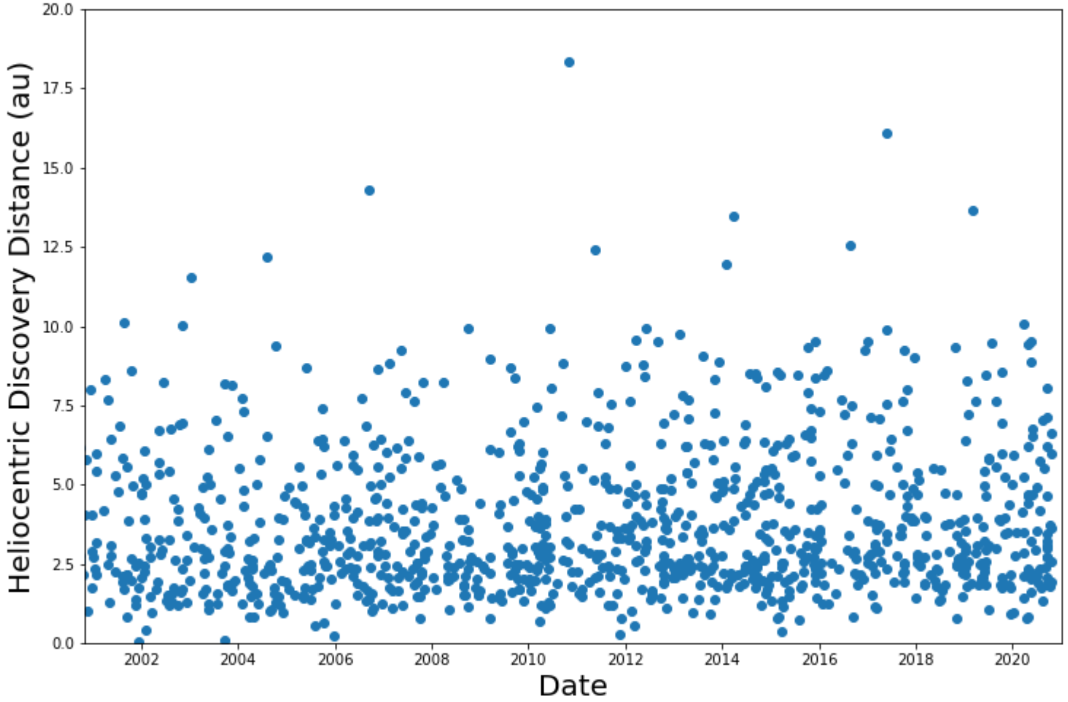


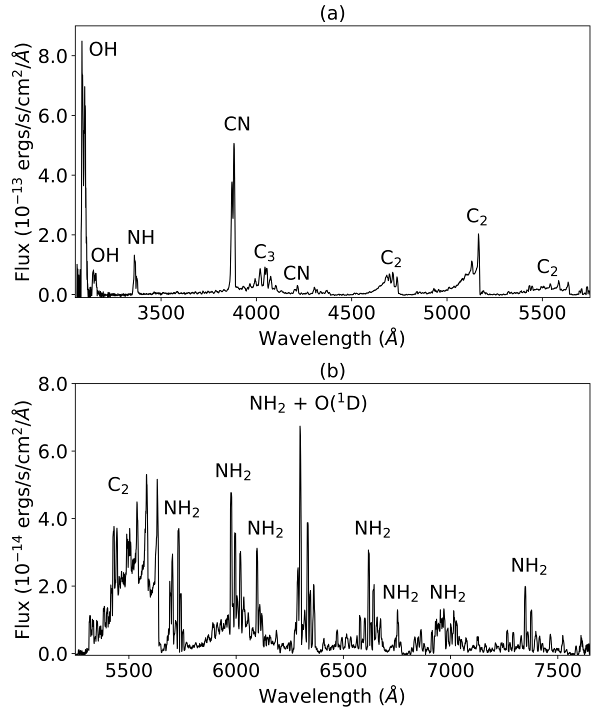
Science Goals:
Spectroscopy of NEOs with 10m – 300m to constrain composition of small NEO population, compare with models and population at $\geq$ 500 m.

Compositions of Potentially Hazardous Objects: Diameter $\geq$ 140m, minimum distance $\leq$ 0.05 au. Direct sampling of largest threat population.

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

2. Cometary Bodies
Evolution and intrinsic compositions





Hyland et al. 2019

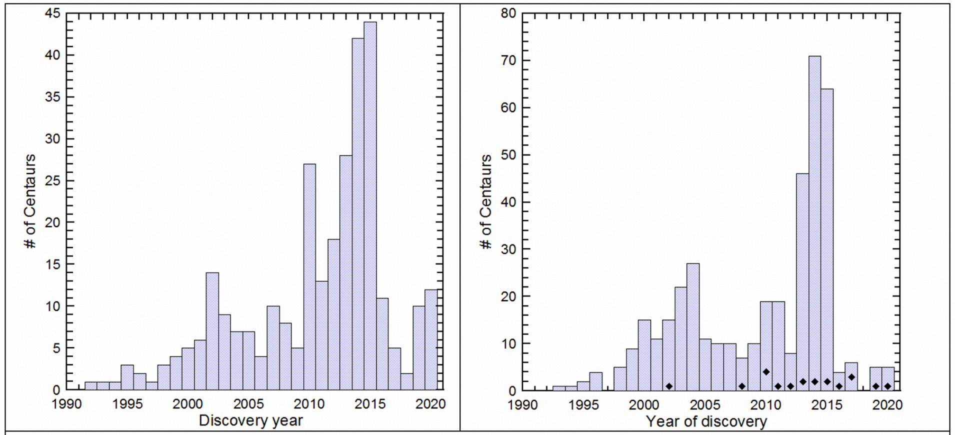


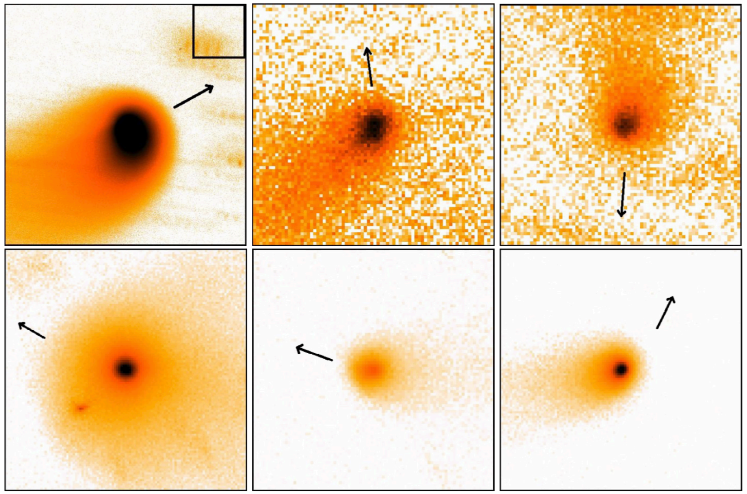
Figure 3 – Discovery rate for Centaurs (left) and TNOs (right) since the first discovery (1977 and 1993, respectively). For TNOs, black dots represent the high-I members ($i \geq 70°$)

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

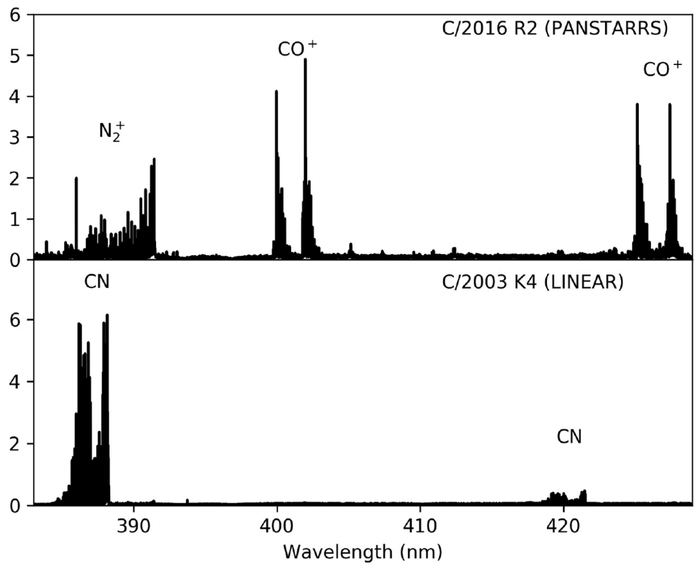
TNO/Centaur discovery rate strongly variable, will jump when the LSST starts!

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.

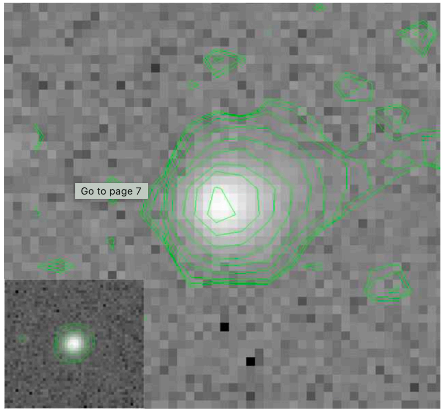
Science Goals:
Spectroscopic evolution of a selection of comets moving in from >5 au to inner solar system. (Time taken to move from 10 au to 1 au is ~3 years).

(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$\lesssim$ 20, 3-σ orbital uncertainty $\lesssim$ 1.5 arcmin
Initial heliocentric distance > 5 au
Perihelion distance < 3 au

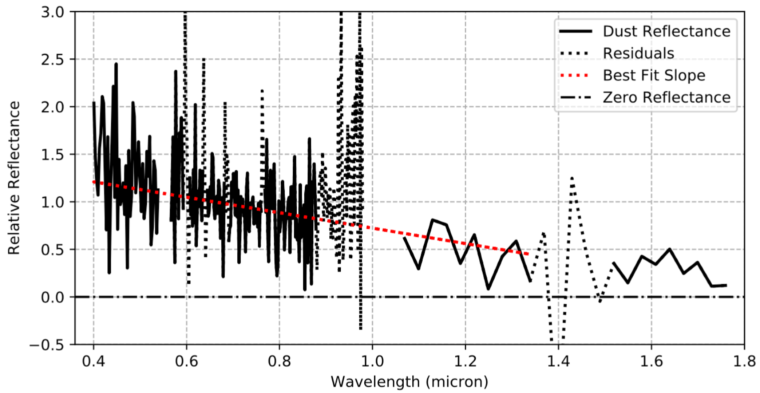
2. Cometary Bodies
Evolution and intrinsic compositions

523676 (2013 UL10)

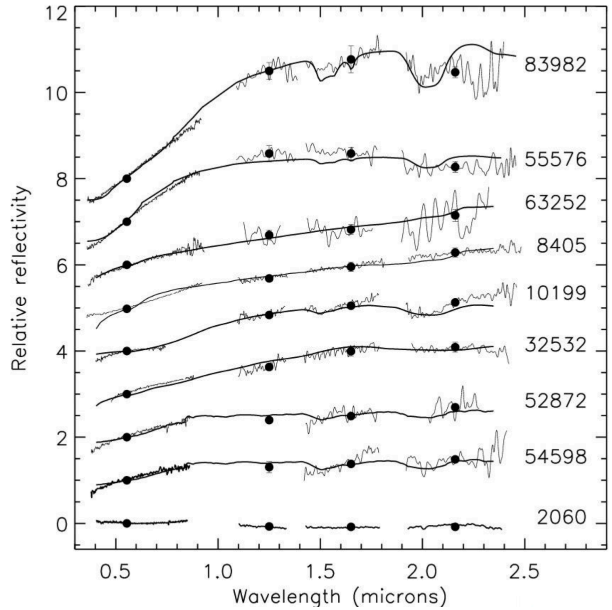


Mazzotta Epifani et al. 2018

174P/Echeclus



Seccull et al. 2019



TNOs provide the origin of the Jupiter Family Comets seen in the inner Solar system.

Centaurs between Jupiter and Neptune are the transitional population of TNOs evolving into comets. Some are active and show outbursts, explosive release of material.

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

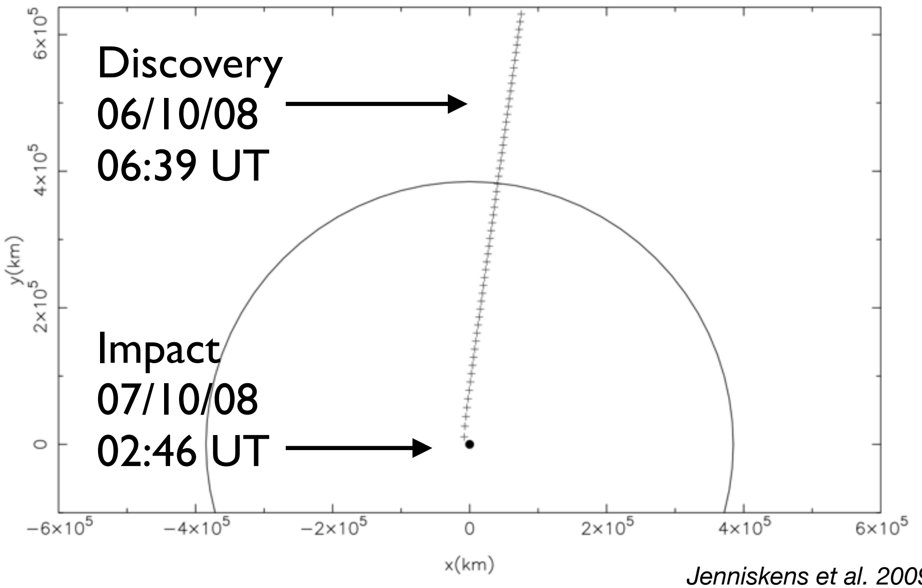
Last 10 years have seen discovery of high-inclination/retrograde TNOs, possibly originating in Oort Cloud. May represent samples from inner Oort Cloud.

Inert centaurs allow probing of surfaces containing in volatiles and organic-rich surfaces, before evolving into Jupiter-Family Comets or being ejected as ISOs.

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

3. Specific targets - Fast Response Transients
Impactors, Minimoons

2008 TC3



Jenniskens et al. 2009

2020 CD3

Fedorets et al. 2020

4 small NEOs discovered on impact trajectories. Only 2008 TC3 had spectroscopy, photometry obtained.

Spectroscopy gives mineralogy/albedo - size, density.

Allows modelling of atmospheric entry, comparison with recovered meteorites.

Trigger Criteria: Impact Probability > 1% + NEO trigger

2 small NEO minimoons discovered, temporary captures in Earth-Moon system

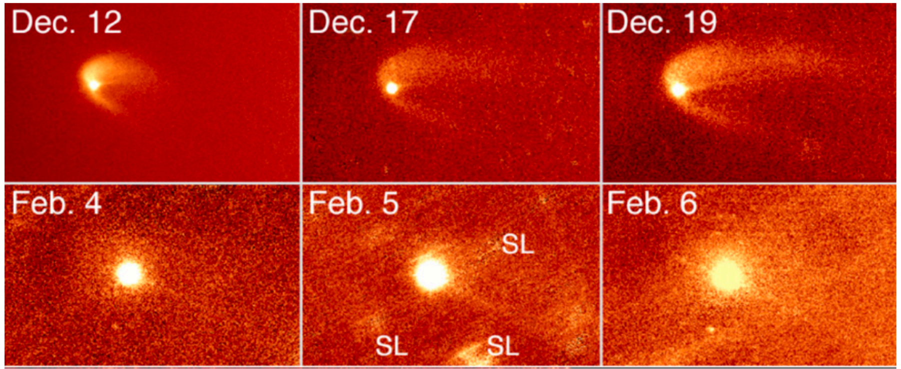
Potentially easy objects to reach with missions (NHATS), targets for exploitation.

1-10 discovered per year via LSST.

Trigger Criteria: Geocentric orbit + NEO trigger

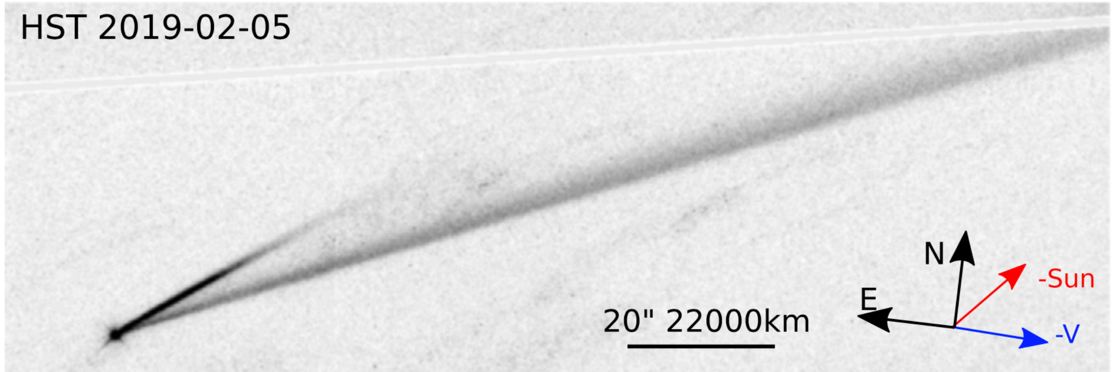
3. Specific targets - Fast Response Transients
Active Asteroids

Asteroid Collision - (596) Sheila



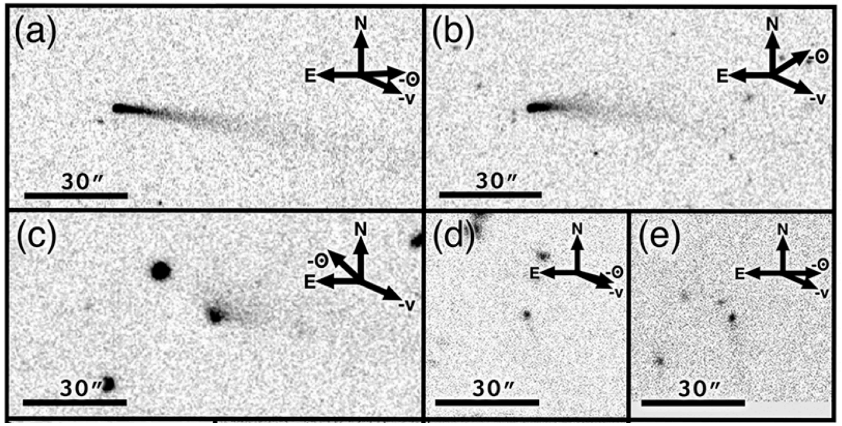
Ishiguru et al. 2011

Asteroid Rotation Breakup - Gault



~1 Active asteroid discovered per year to date. *Kleyna et al. 2019*

Main Belt Comet — 313P/Gibbs



Hsieh et al. 2015

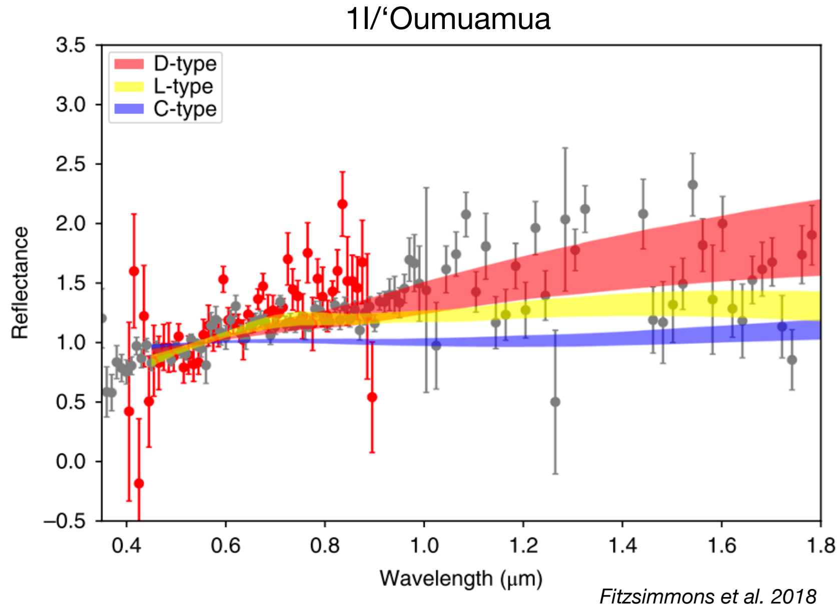
May be caused by collision, rotational disruption or sublimation of sub-surface ices. *But do not know physical mechanism at discovery.*

Science Goals:
Search for gas emission - prove sublimation hypothesis.

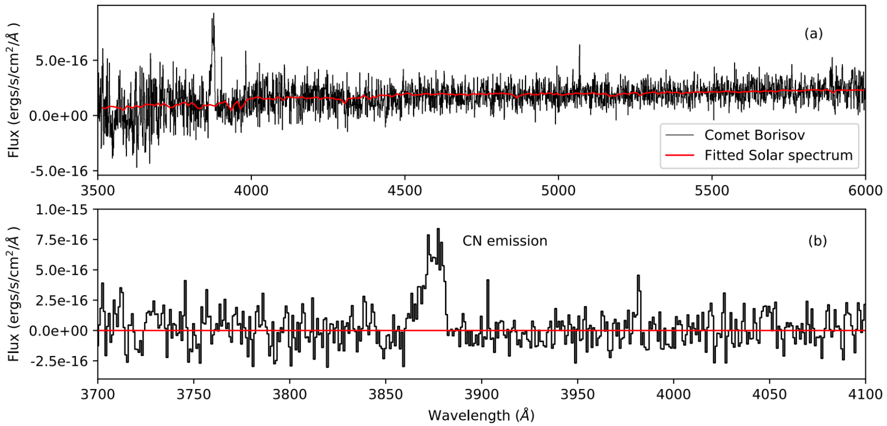
Measure dust reflectance spectrum, constrain grain size distribution/mineralogy.

Trigger Criteria: Detection of ejecta/coma in main-belt object + comet trigger

3. Specific targets - Fast Response Transients
Interstellar Objects



Fitzsimmons et al. 2018



Fitzsimmons et al. 2019

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

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

Rubin Observatory may discover ~1-10 ISOs per year.

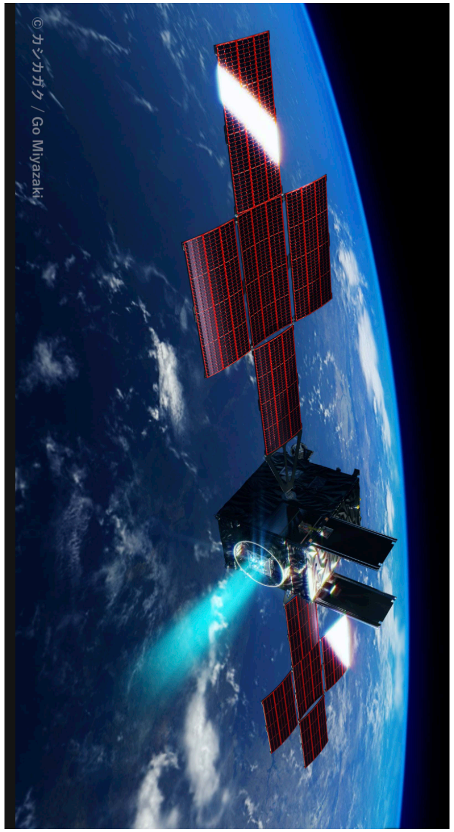
Science Goals:
Search for gas emission, compare compositions with Solar-system populations.

Trigger Criteria: e > 1 at 3-σ

3. Specific targets - missions
DART/LICIACube/Hera, Destiny+, Comet Interceptor, JWST

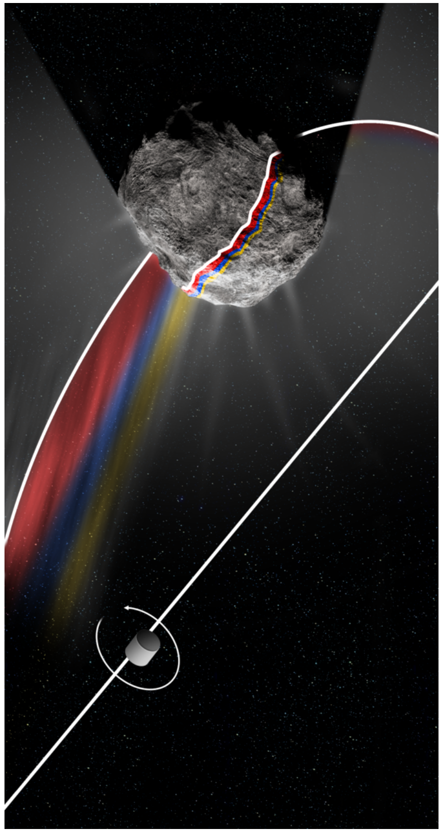
DART/LiciaCUBE/Hera

Didymos + Dimorphous
+ Flyby target (NEOs)



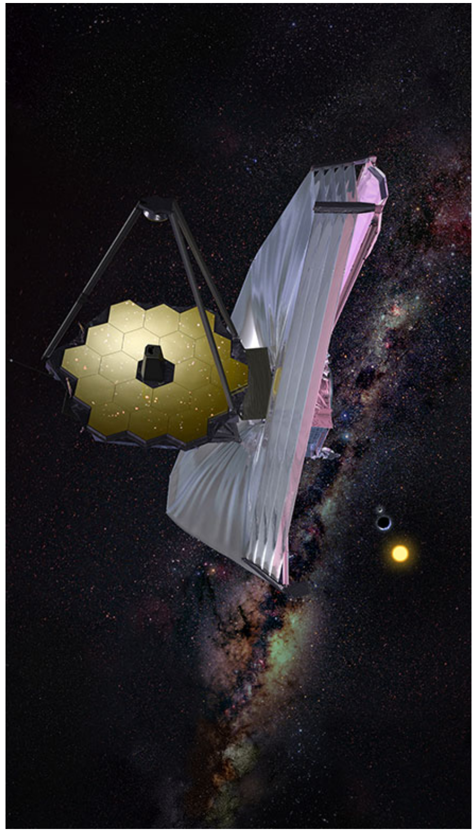
Destiny+

Phaethon
(NEOs)



Comet Interceptor

To be discovered
(Comets)



JWST?

Initial Time Breakdown/Estimate

1. NEOs: 7 nights/year
2. Cometary Bodies: 4 nights/year comets + 3 nights/year active centaurs+classification.
3. Fast Response Targets+Mission Targets: 3 nights/year

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%

Time estimate per Nation

Italy ~70%, UK ~15%, Finland ~15%

Still To Do

- **Finish Consolidating Science Cases**
- **Agree on Selection/Triggering Criteria**
- **Fully calculate time requirements**