Near Earth Objects: Surveys, characterization, contamination

Presented to National Academy of Sciences – Committee on Planetary Protection

2 December 2021

David E. Trilling (Northern Arizona University)

Brief outline

Introduction to Near Earth Objects (NEOs)

Finding NEOs

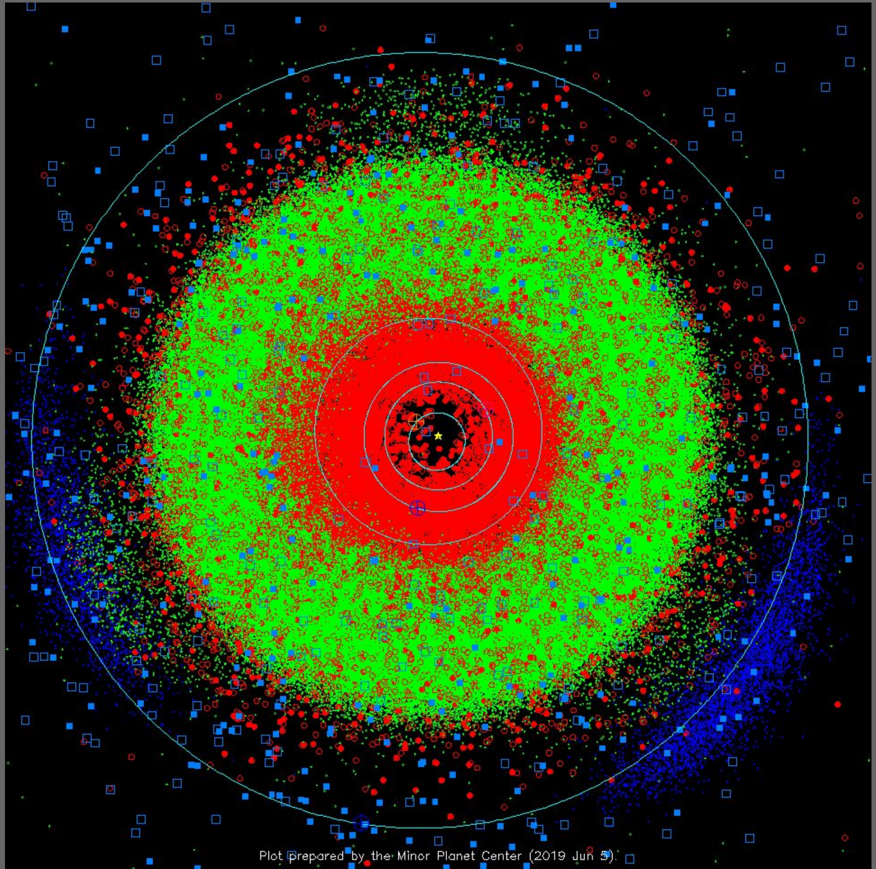
Characterizing NEOs

Impact of contaminating a small number of NEOs

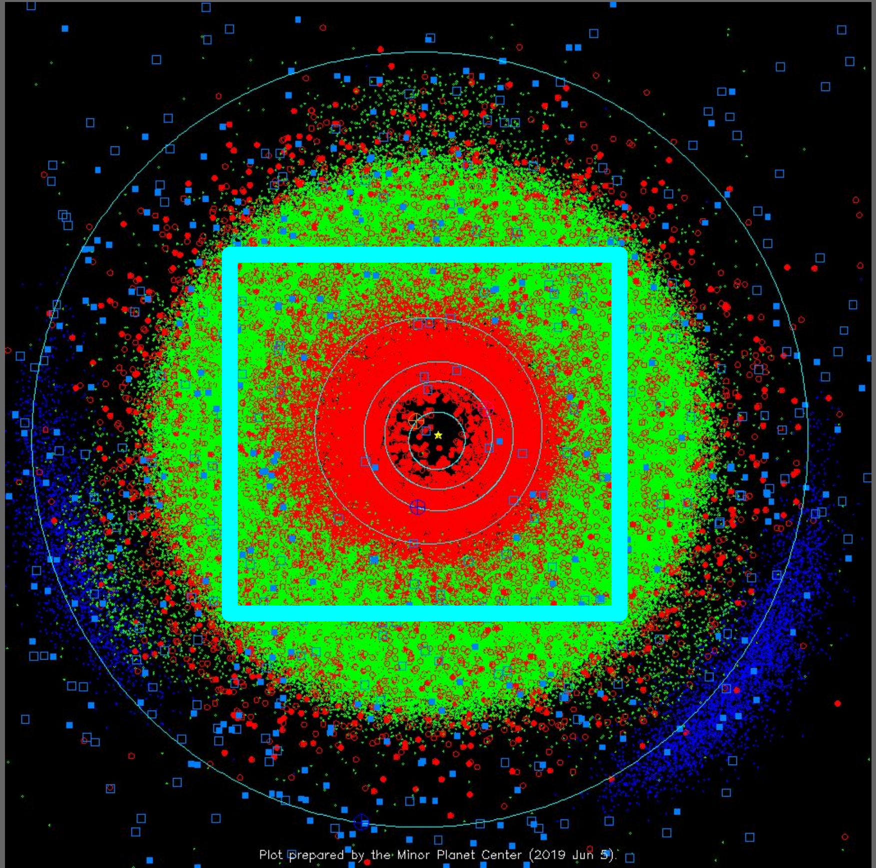
Specific questions from Statement of Task

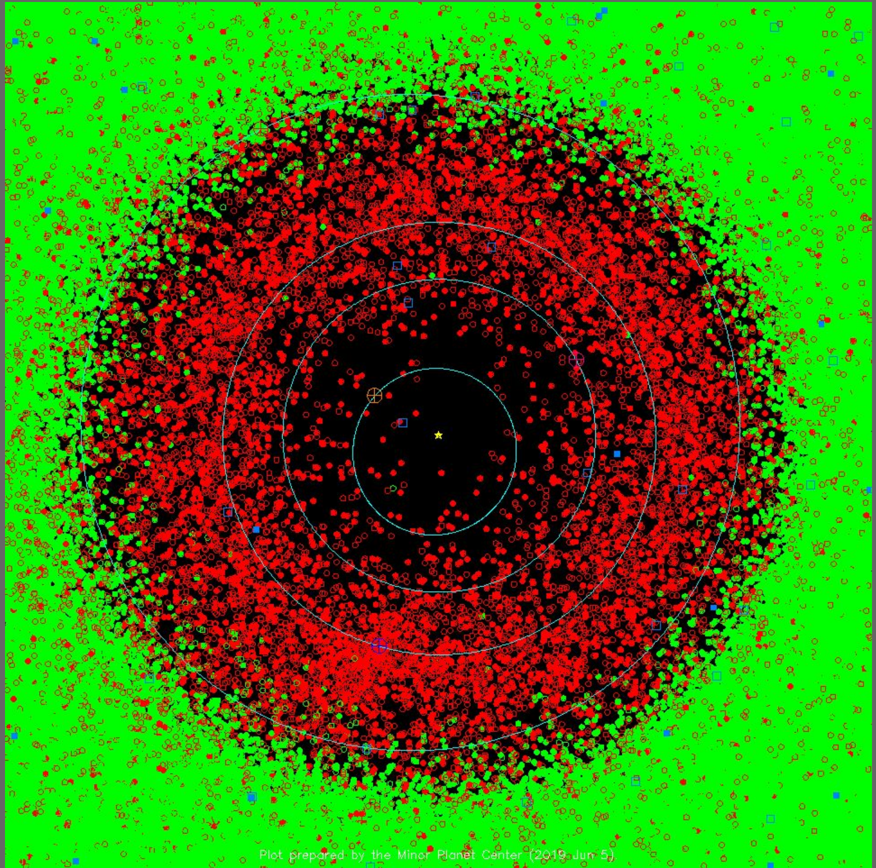
Introduction to Near Earth Objects (NEOs)

Introduction to Near Earth Objects (NEOs)



Introduction to Near Earth Objects (NEOs)

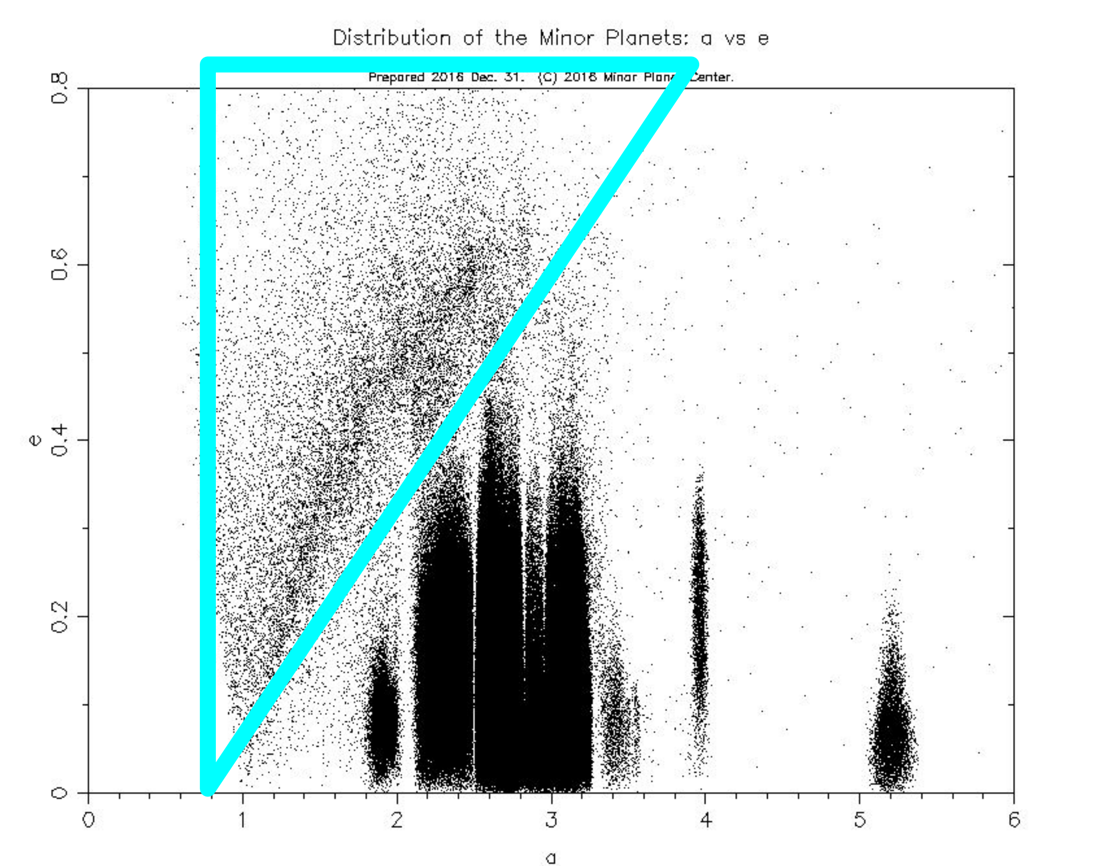




Introduction to Near Earth Objects (NEOs)

NEO definition:

Perihelion less than 1.3 au



Introduction to Near Earth Objects (NEOs)

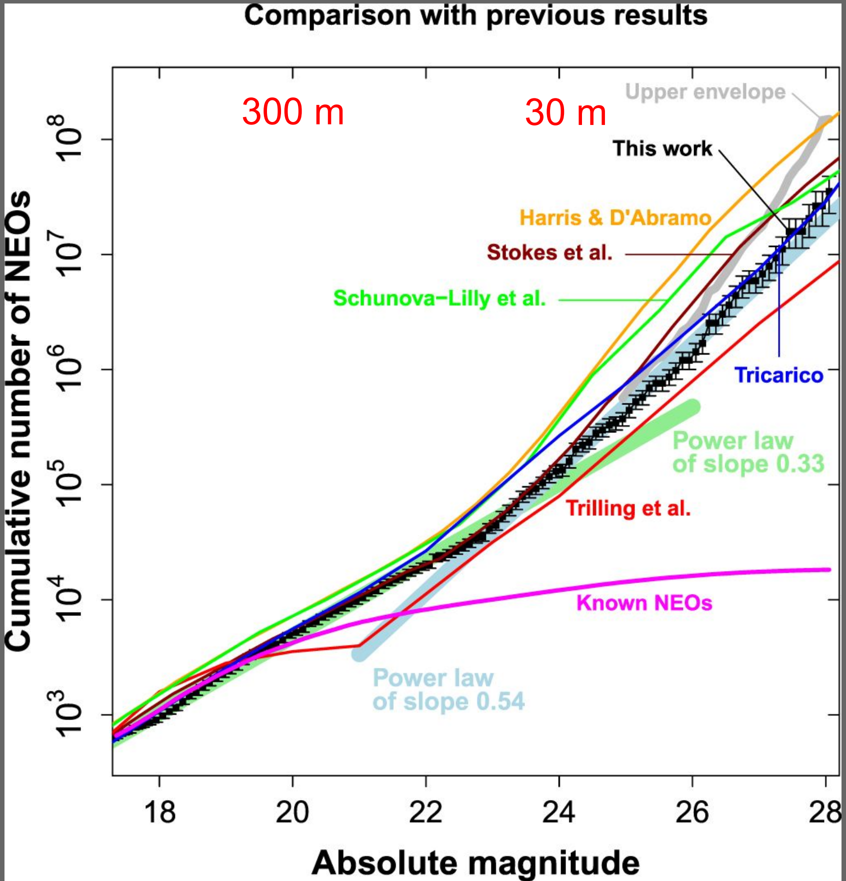
There are 27,651 known NEOs to date

Predictions:

NEOs > 1 km: 1000

NEOs > 100 m: 50,000

NEOs > 10 m: 10^7



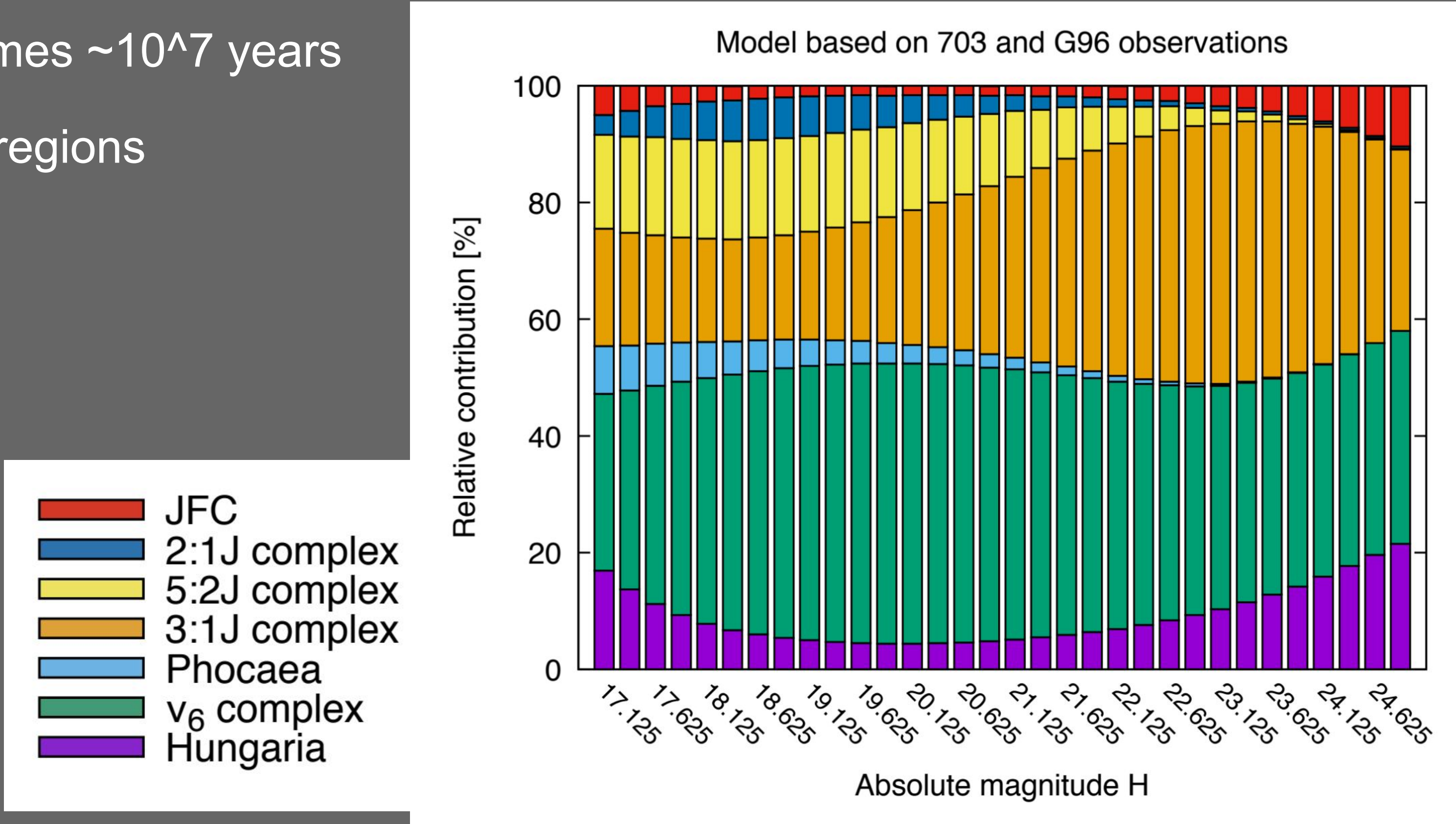
Heinze et al. 2021

Introduction to Near Earth Objects (NEOs)

Granvik et al. 2018

Dynamical lifetimes ~10^7 years

Various source regions



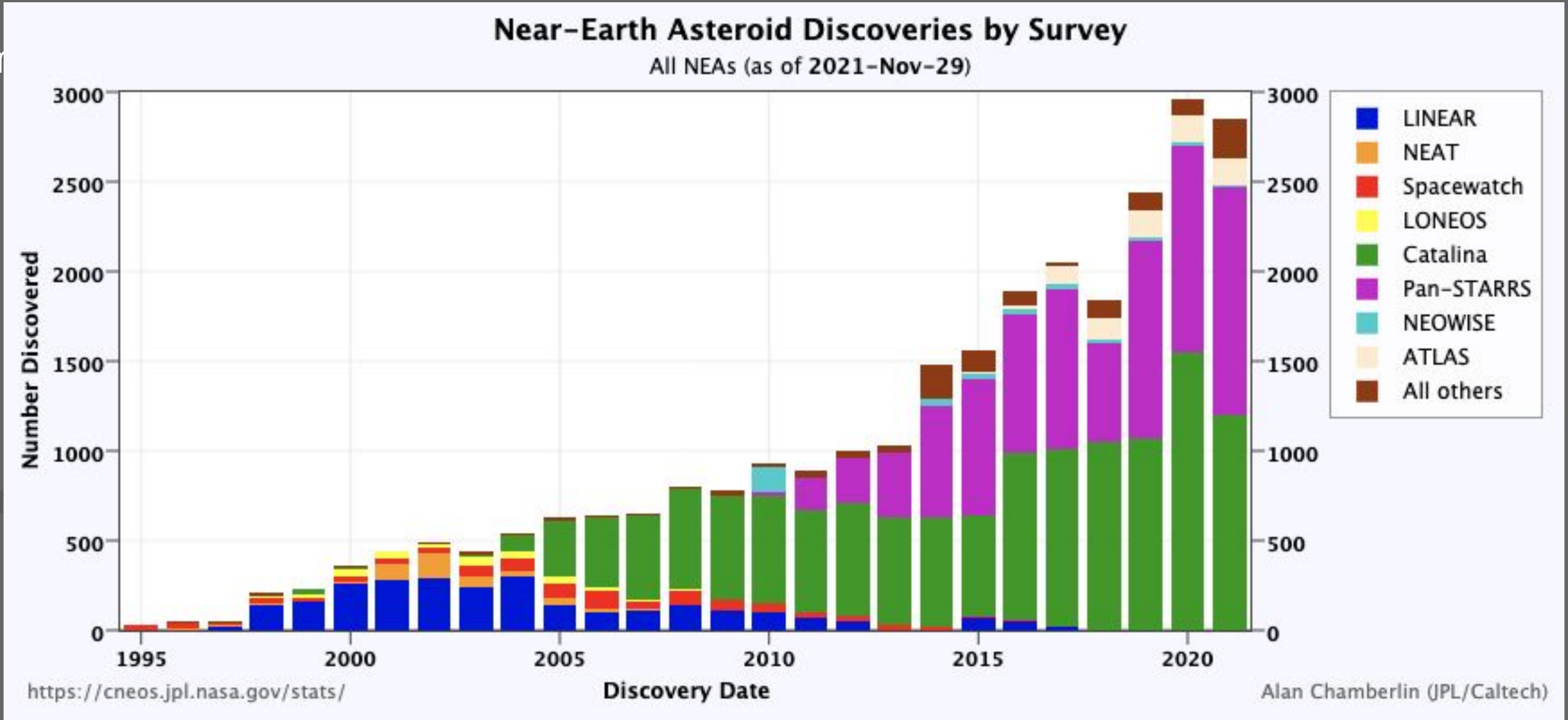
Finding NEOs

Finding NEOs

Almost all NEOs are discovered by dedicated sky surveys

Finding NEOs

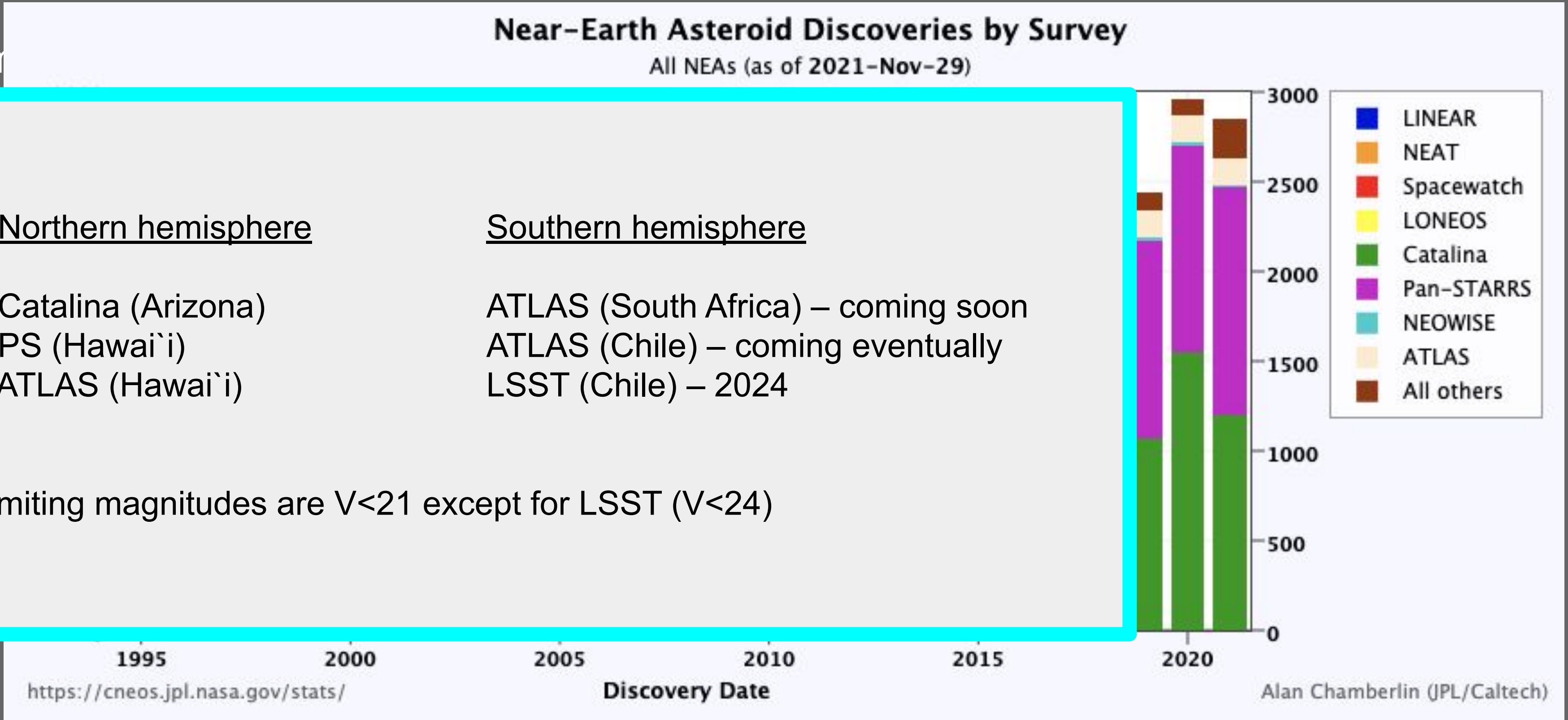
Alm



Su

Finding NEOs

Alm

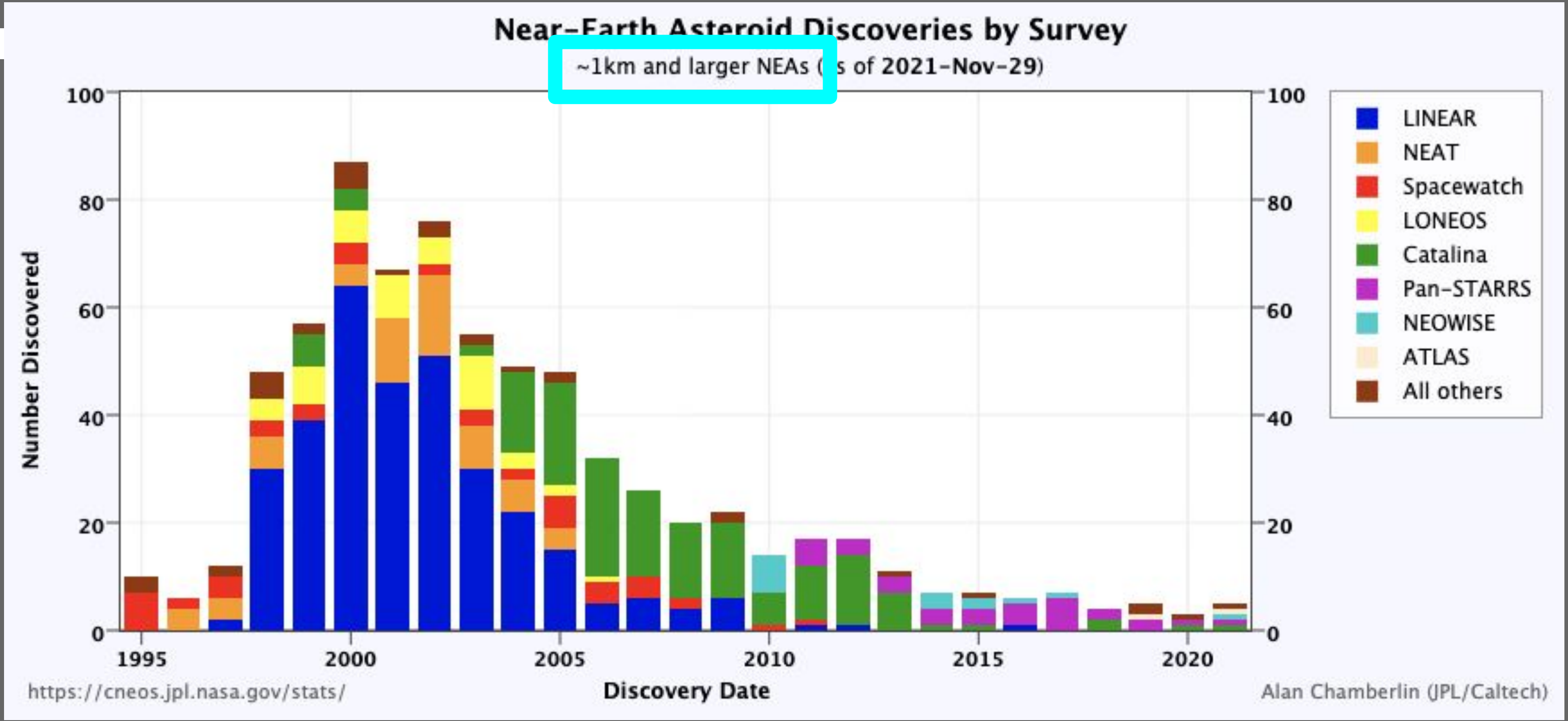


Northern hemisphere	Southern hemisphere
Catalina (Arizona)	ATLAS (South Africa) – coming soon
PS (Hawai`i)	ATLAS (Chile) – coming eventually
ATLAS (Hawai`i)	LSST (Chile) – 2024

Limiting magnitudes are V<21 except for LSST (V<24)

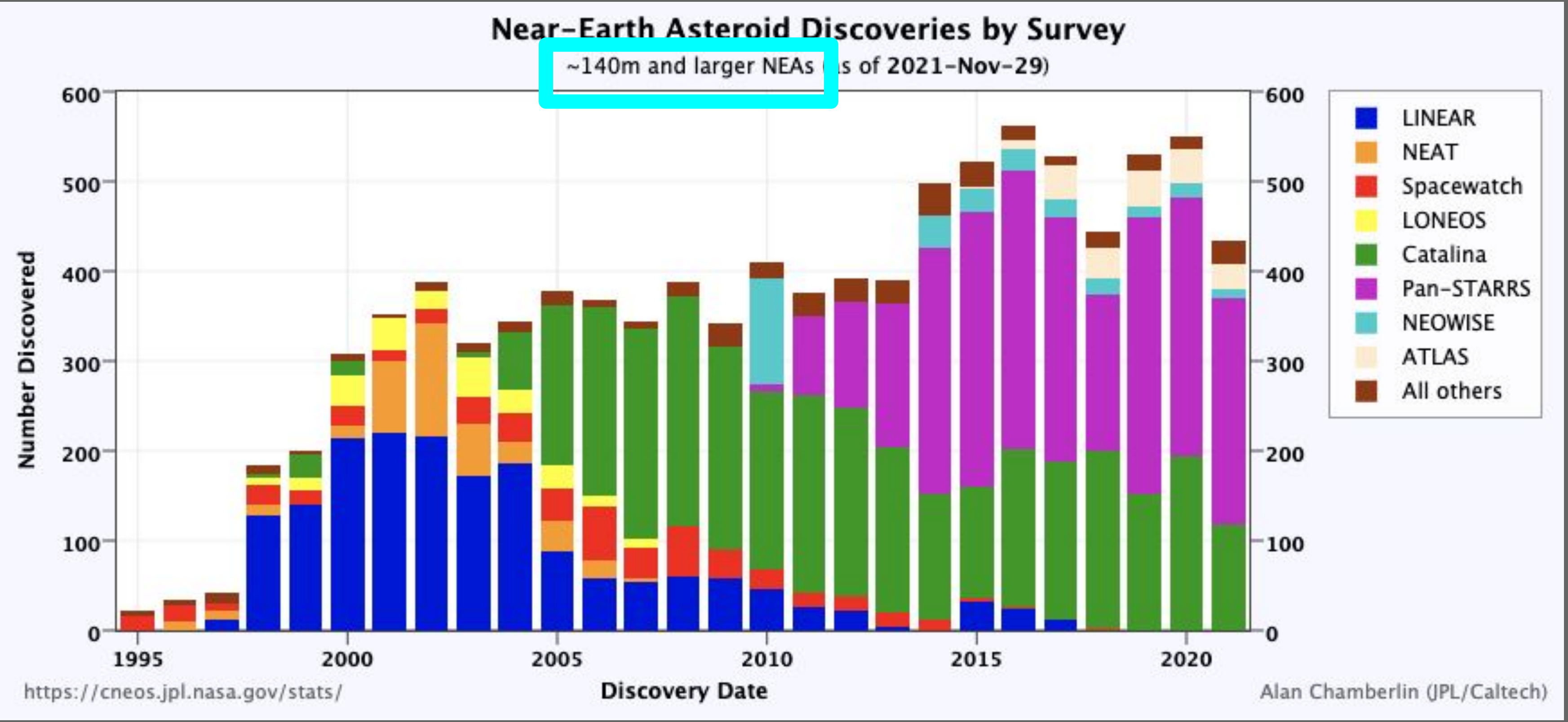
Finding NEOs

Al



Finding NEOs

Alr



Finding NEOs

Preliminary orbits can be determined

[In many but not all cases, orbits later refined by further observations]

Finding NEOs

Preliminary orbits can be determined

[In many but not all cases, orbits later refined by further observations]

Look ahead: The Legacy Survey of Space and Time (LSST), to be carried out with the 8.4 meter Vera C. Rubin Observatory.

Some 100,000 NEOs will be discovered. In general, recovery, orbit refinement, and characterization only possible with LSST, since these objects are so faint ($V<24$)

Finding NEOs

What discovery surveys don’t tell us:

Composition

Size

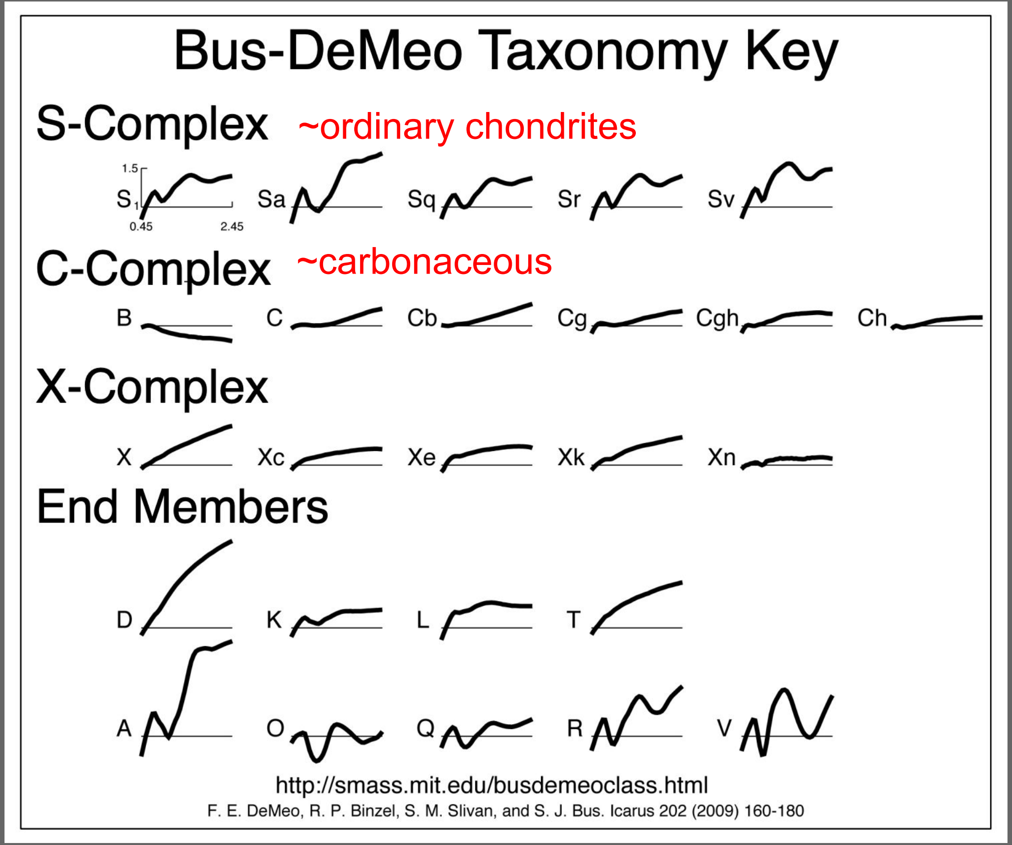
Shape

Other properties (regolith, internal structure, moons, etc. etc.)

Characterizing NEOs

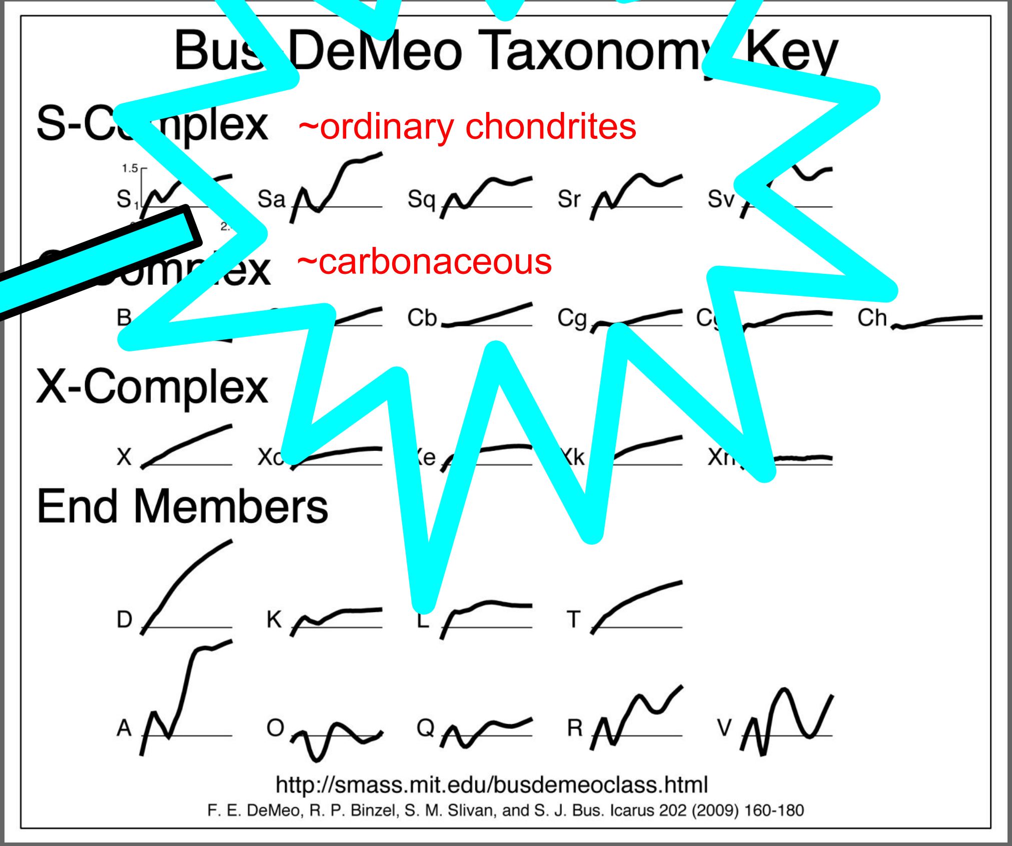
Characterizing NEOs (1) – Spectroscopy/composition

Spectroscopy implies composition



Characterizing NEOs (1) – Spectroscopy composition

Spectroscopy implies composition



We know the compositions by comparing asteroid spectra to meteorite spectra and compositions.

This is the most important tool for thinking about planetary protection.

Carbonaceous here means likely to include organic compounds and water.

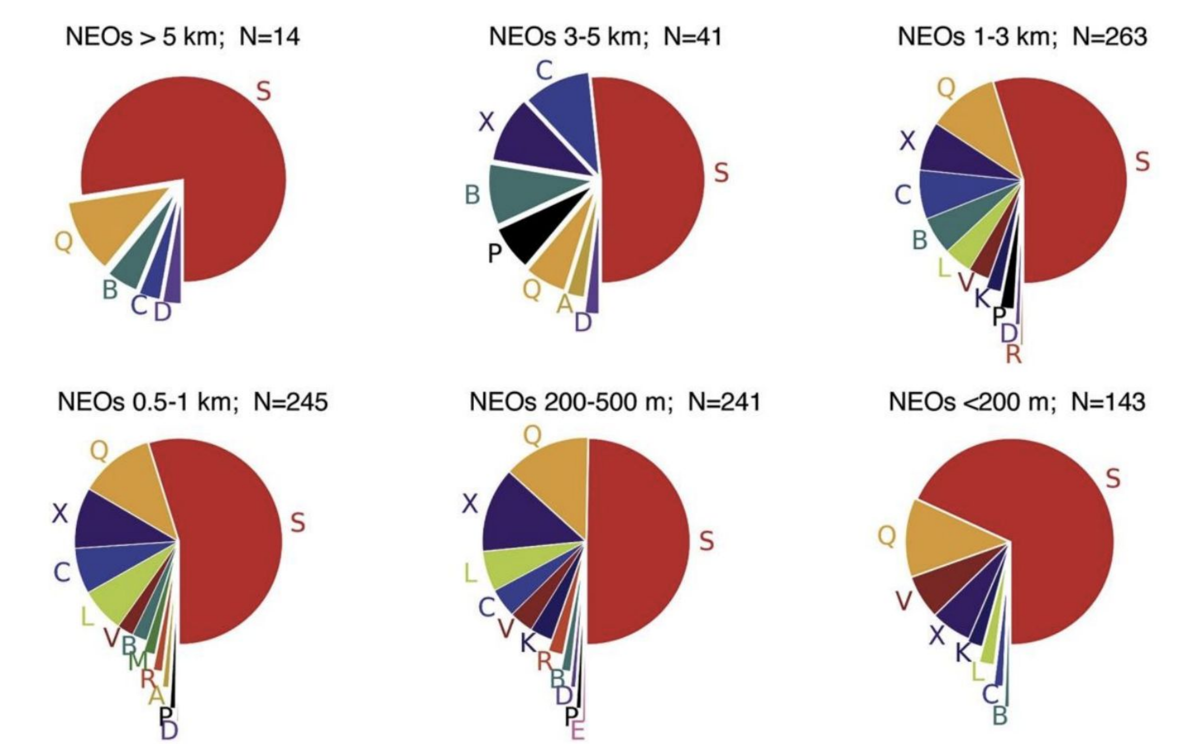
Characterizing NEOs (1) – Spectroscopy/composition

Spectroscopy implies composition

Largest current survey:

MITHNEOS (>1000 NEOs)

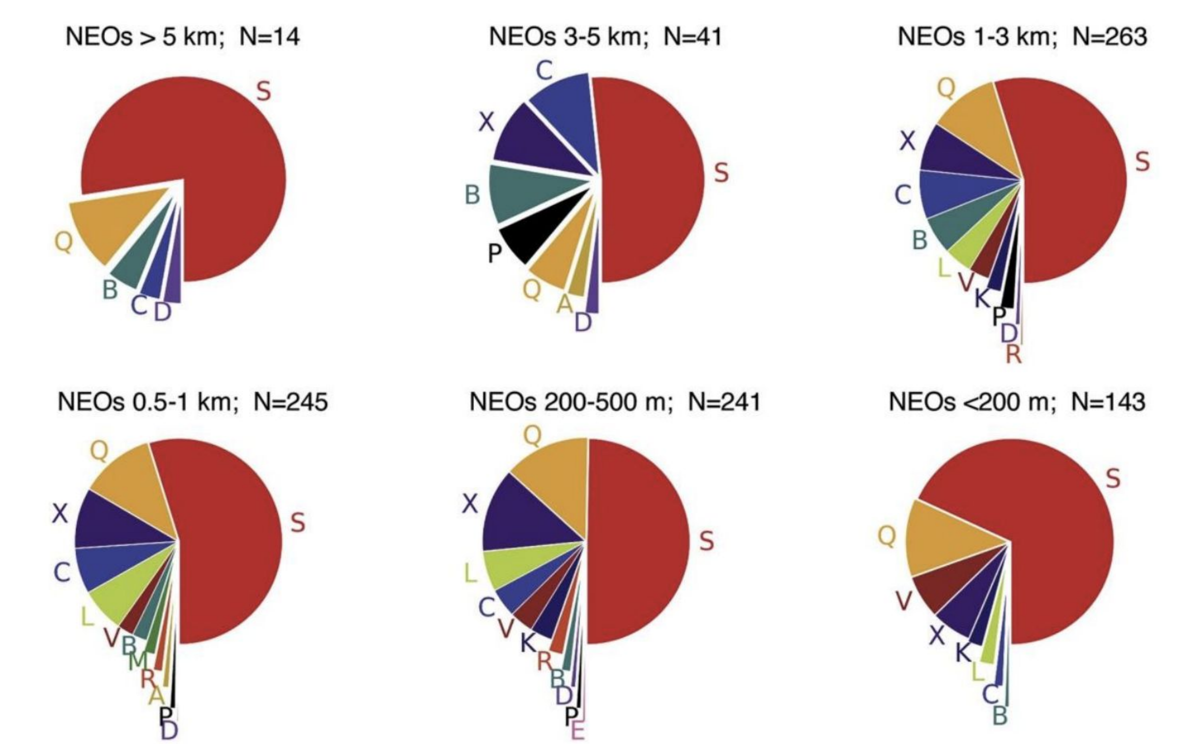
Binzel et al. 2019



Characterizing NEOs (1) – Spectroscopy/composition

Spectroscopy implies composition

Binzel et al. 2019



Largest current survey:

MITHNEOS (>1000 NEOs)

Other significant surveys:

MANOS (small, low delta v)

Moskovitz et al. (>200)

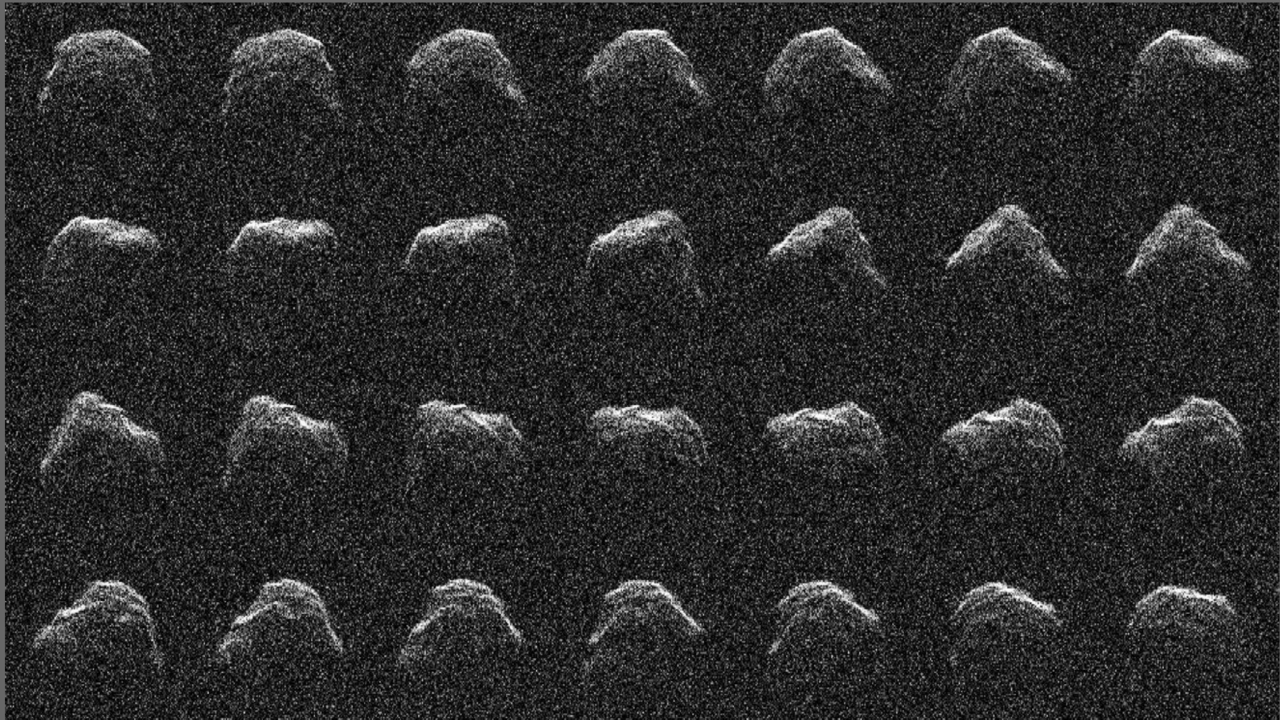
UKIRT (spectrophotometry)

Trilling et al. (>400)

Characterizing NEOs (2) – Size

Direct measurements: radar (1000 NEOs over several decades)

JPL



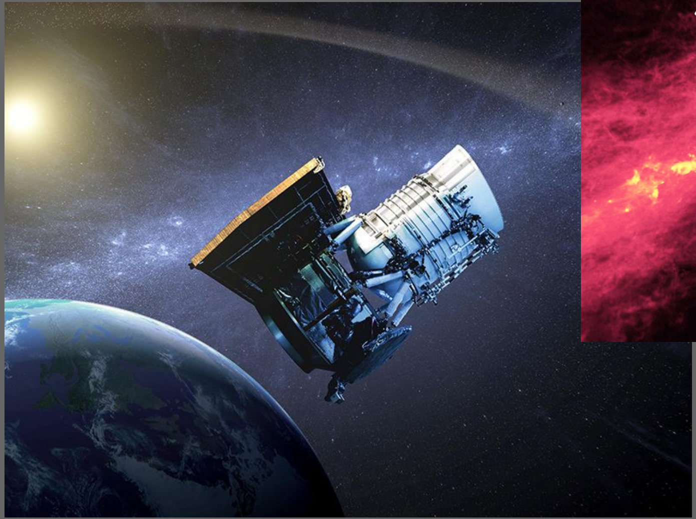
Characterizing NEOs (2) – Size

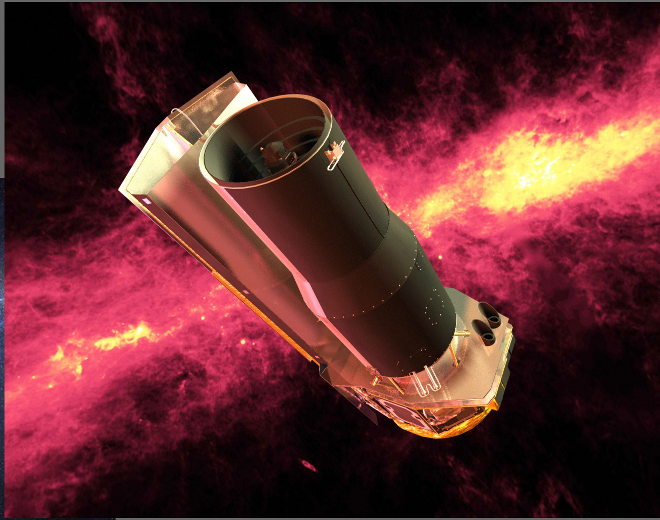
Direct measurements: radar (1000 NEOs over several decades)

Space-based infrared:

NEOWISE (~2000), Spitzer (~2000)

NASA





Characterizing NEOs (2) – Size

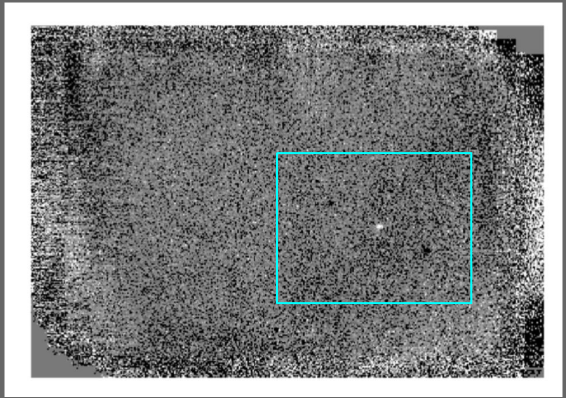
Direct measurements: radar (1000 NEOs over several decad

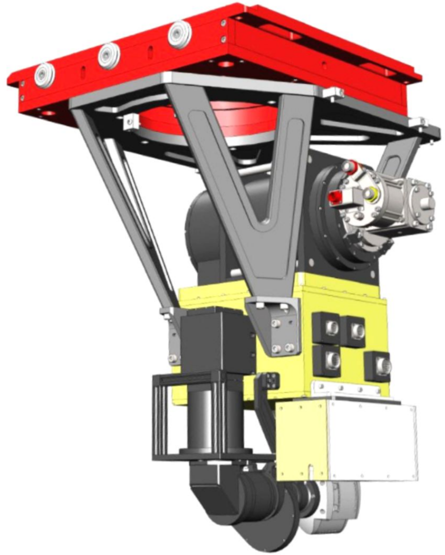
Space-based infrared:

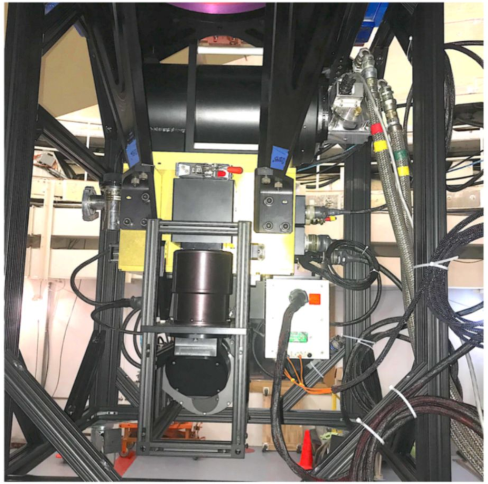
NEOWISE (~2000), Spitzer (~2000)

Ground-based infrared:

IRTF/MIRSI (~hundreds/year)





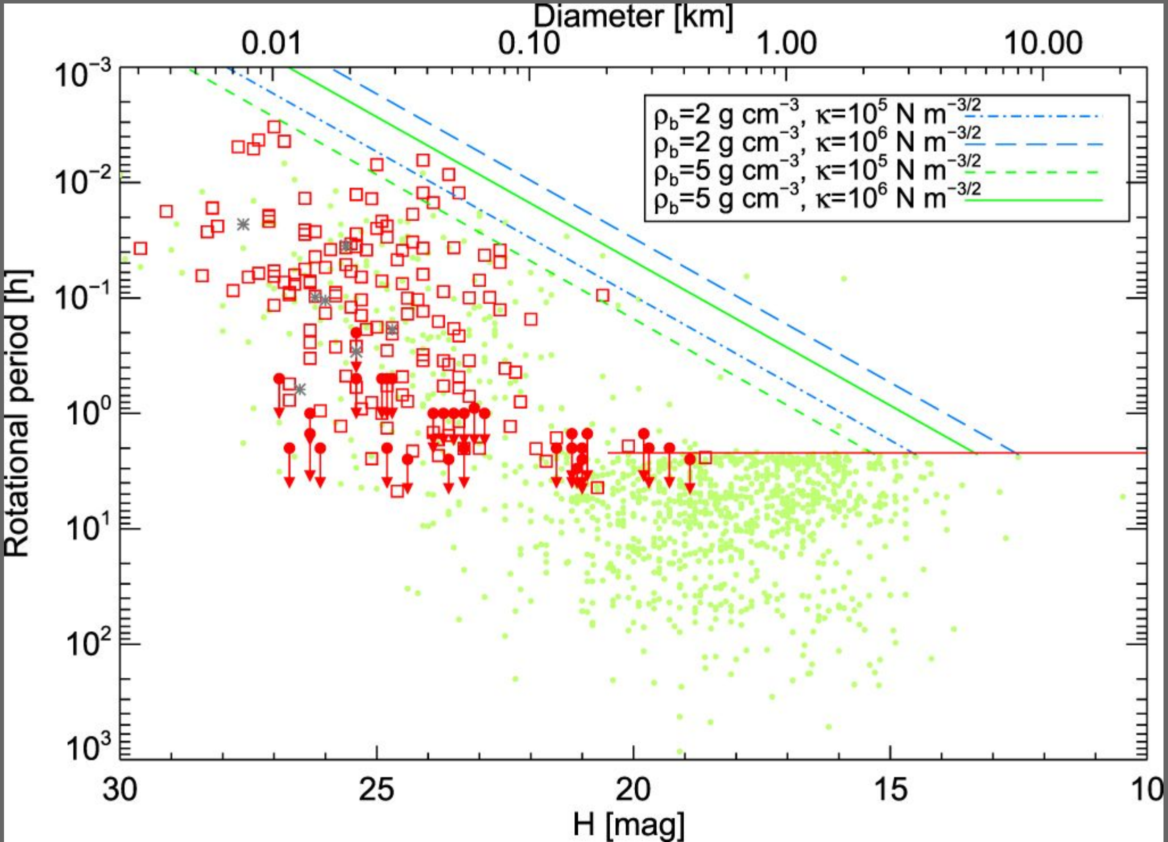


Characterizing NEOs (3) – Shape

Thirouin et al. 2018

Individual lightcurves:

shape, strength



Characterizing NEOs (3) – Shape

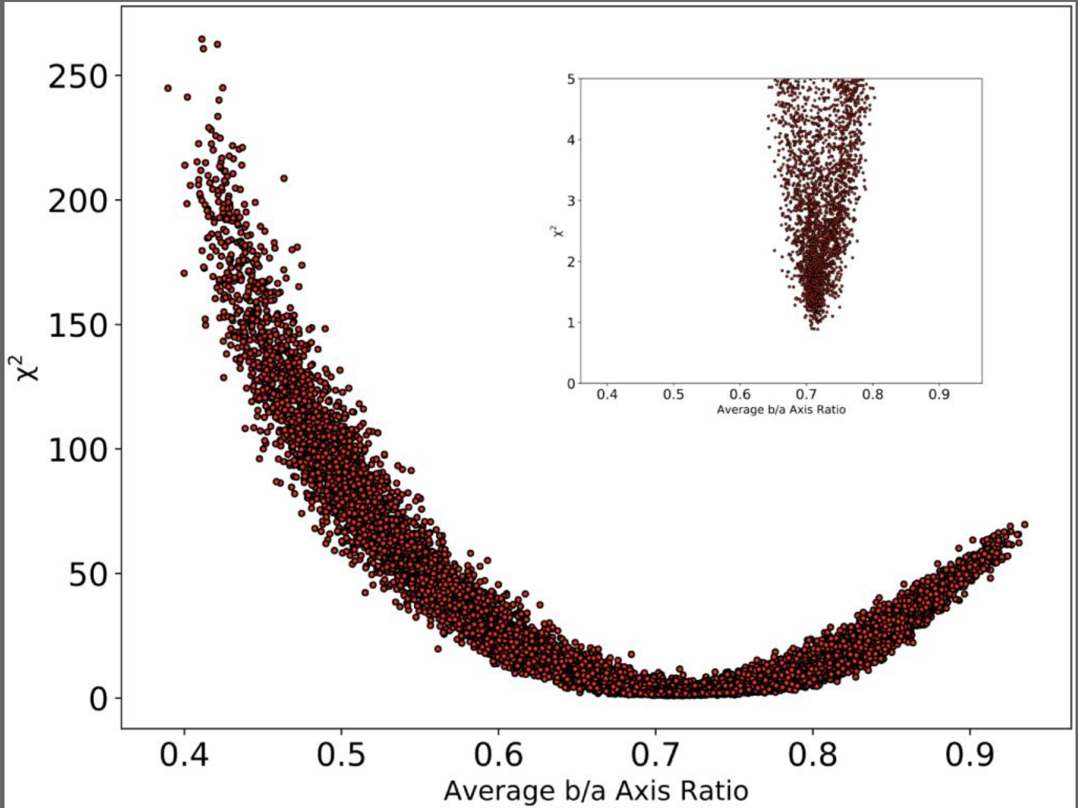
McNeill et al. 2019

Individual lightcurves:

shape, strength

Partial lightcurves for many NEOs:

Average shape of NEOs



Characterizing NEOs (4) – Individual objects

High resolution imaging

Searches for activity

Thermal inertia, porosity

Measuring Yarkovsky effect (density determination)

Surface heterogeneity

Spacecraft visits: Eros, Itokawa, Bennu, Ryugu (extremely detailed information)

Impact of contaminating a small number of NEOs

Impact of contaminating a small number of NEOs

In general, this is probably fine!

There are many thousands of known NEOs, and probably one million NEOs larger than 10 meters.

Impact of contaminating a small number of NEOs

In general, this is probably fine!

There are many thousands of known NEOs, and probably one million NEOs larger than 10 meters.

BUT:

The properties that make a specific NEO interesting for spacecraft exploration might also make it interesting for implications related to the origin of life.

Impact of contaminating a small number of NEOs

In general, this is probably fine!

There are many thousands of known NEOs, and probably one million NEOs larger than 10 meters.

BUT:

The properties that make a specific NEO interesting for spacecraft exploration might also make it interesting for implications related to the origin of life.

Example:

A spacecraft target might be carbonaceous (primitive), with a source region that implies the presence of water+organics. Now worry about contamination!

Specific questions from Statement of Task

Specific questions from Statement of Task (1)

(1) Are NEOs “sufficiently numerous … that the contamination of one object in the population would reasonably be expected to have no tangible effect on the potential for scientific investigation using other objects in the population?”

Answer: Yes. Note “using other objects” in this question. Contaminating any given object almost certainly has no effect on studying other objects.

Specific questions from Statement of Task (2)

(2) For NEOs, “is it appropriate to categorize all missions to objects ... as planetary protection Category I?”

[Category 1: “a target body which is not of direct interest for understanding the process of chemical evolution or the origin of life. No protection of such bodies is warranted and no planetary protection requirements are imposed by this policy.”]

Answer: No, because of the phrase “all missions” in this question. (See example from three slides back.)

Specific questions from Statement of Task (3)

(3) If "new information indicates that [NEOs are] sufficiently inhomogeneous with regard to planetary protection to warrant reassessment, what protocols should be followed in order to revise the defining parameter ranges and corresponding planetary protection categories?"

Answer: I'm not sure what this question means. Suggestion: Some (categories of) NEOs may be intrinsically interesting for astrobiology and therefore planetary protection, and others not. Most NEOs are rocky, unremarkable. Some NEOs are primitive and more intriguing. Different categories for different bodies, or different (sub)populations?

Thank you