What we do (not) know about TNOs

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What am I going to talk about?

Ideas

What we do know

What we do not know

End

Ideas

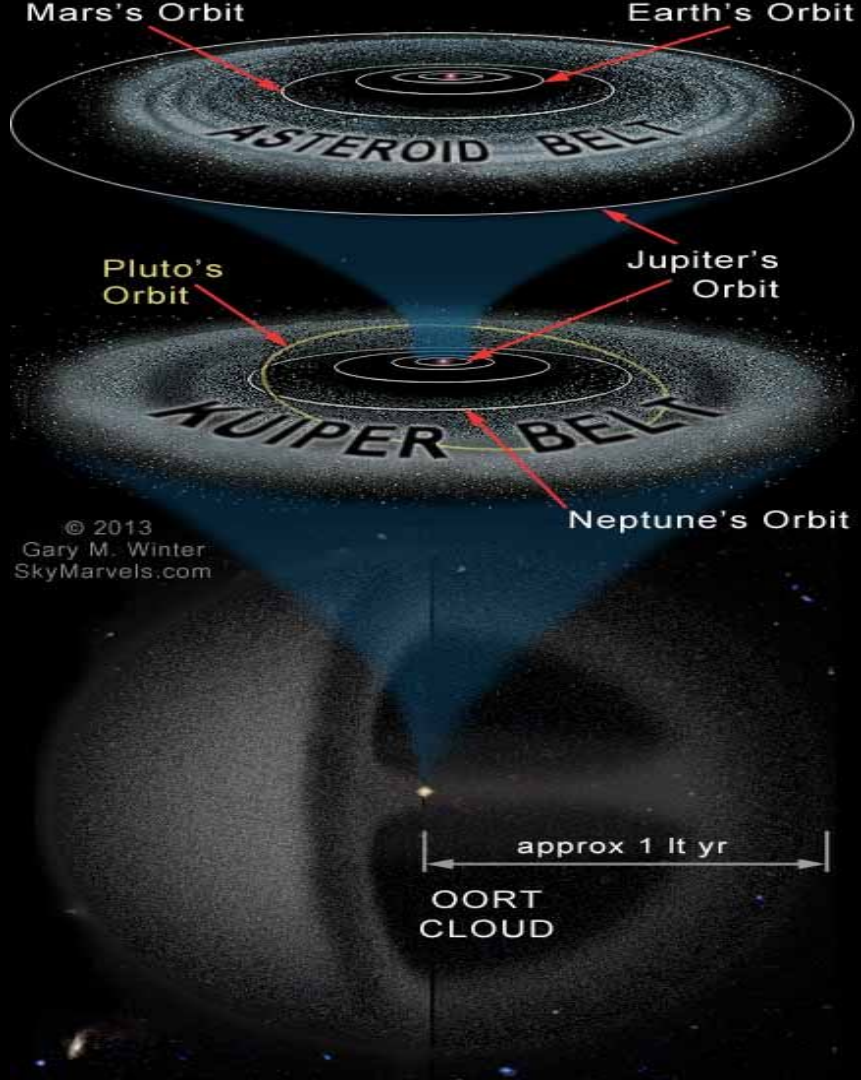
What are the trans-Neptunian objects?

Ideas

What are the trans-Neptunian objects?

They’re the most primitive objects in the Solar System

4 yep... different page, no animation here


Mars's Orbit
Earth's Orbit
ASTEROID BELT
Pluto's Orbit
Jupiter's Orbit
KUIPER BELT
Neptune's Orbit
© 2013
Gary M. Winter
SkyMarvels.com
approx 1 lt yr
OORT CLOUD

Once upon a time

1801	(1) Ceres
1930	Pluto
1930	Leonard
1949	Edgeworth
1951	Kuiper
1979	(2060) Chiron
1980	Fernández
1992	(15769) 1992 QB1
2006	Pluto
2016	IX planet (?)

6... no, really, it is many

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Today about 2,000 known objects

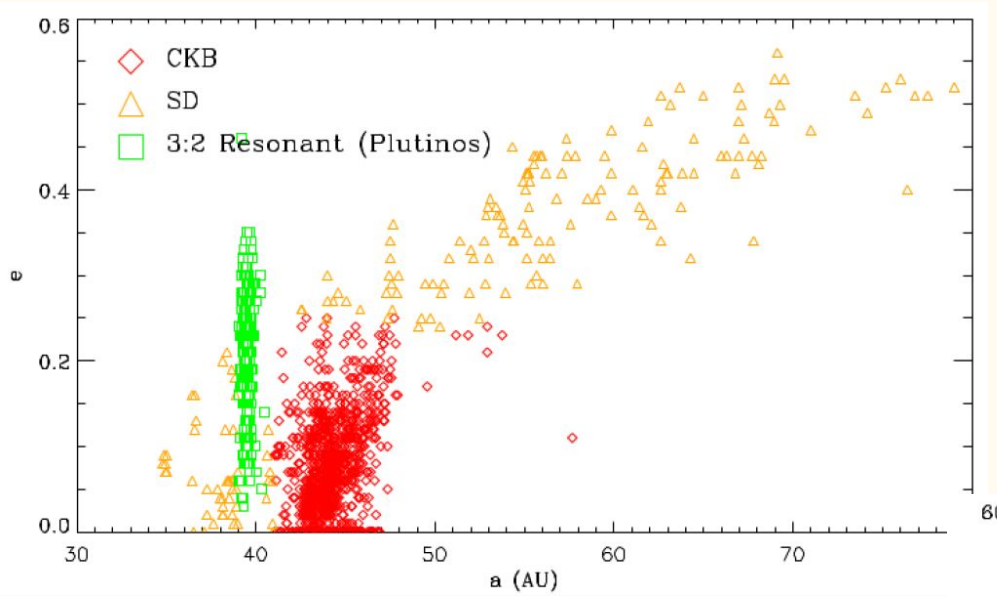
(of a several millions expected with sizes $>$ 1 km)

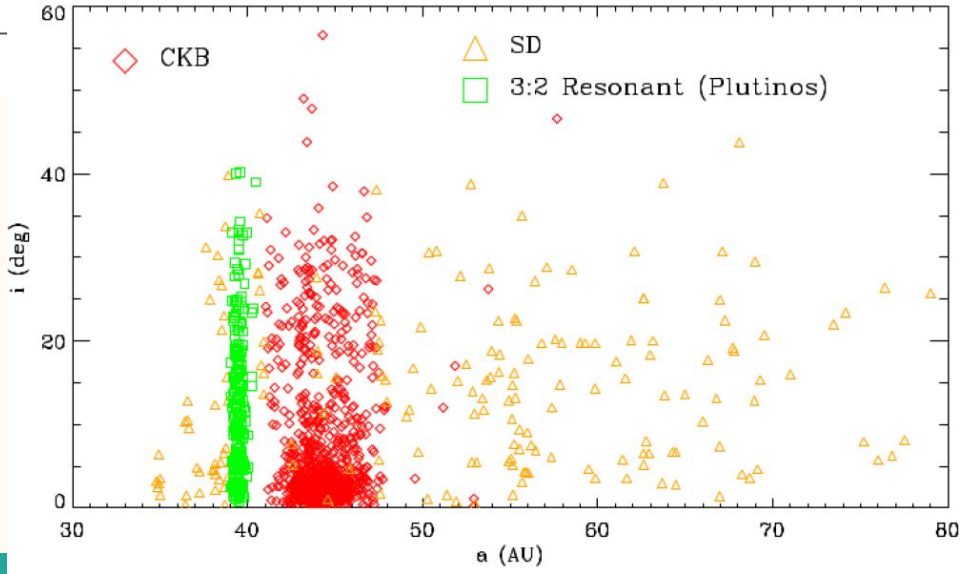
We … knew?

Belt with low dynamical and physical excitation

→ low eccentricities and inclinations

→ homogeneous distribution of properties





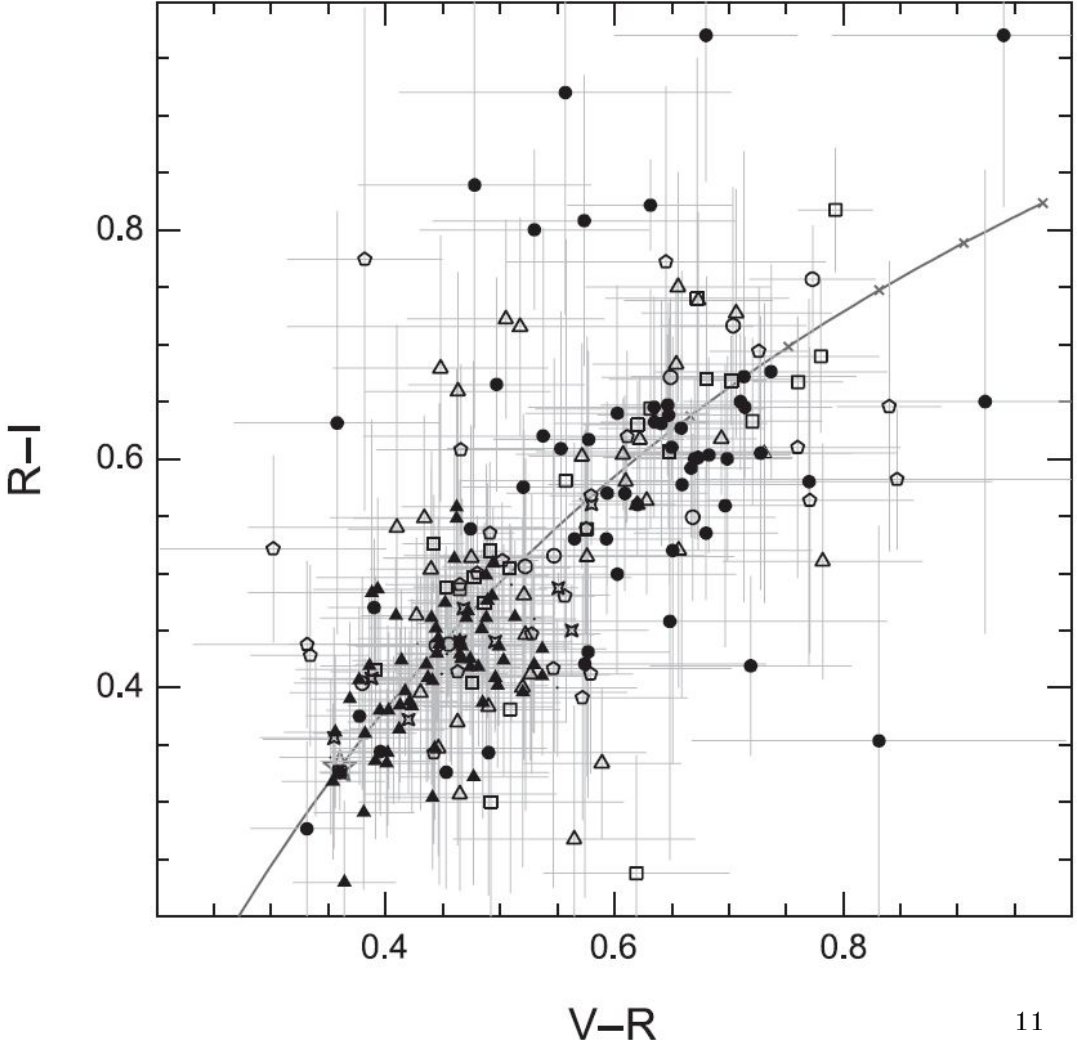
(Courtesy M.C. Ayala-Loera, data from MPC)

What do we know?

What do we know?

Distant “small” objects

→ Large dispersion of colors



Doressoundiram et al. (2008)

What else do we know?

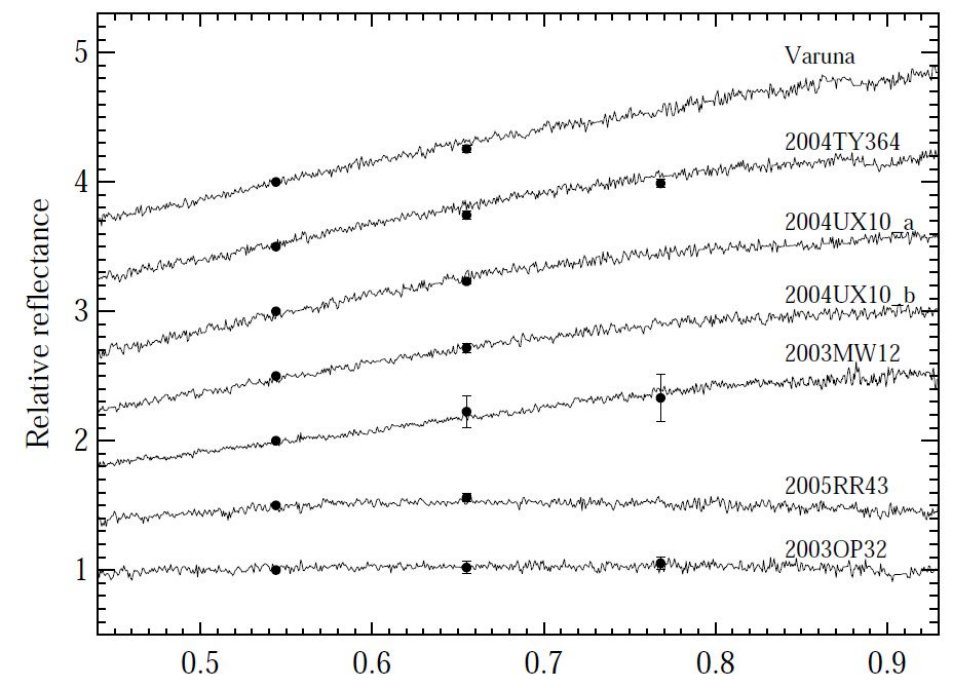
Distant “small” objects

→ Ices

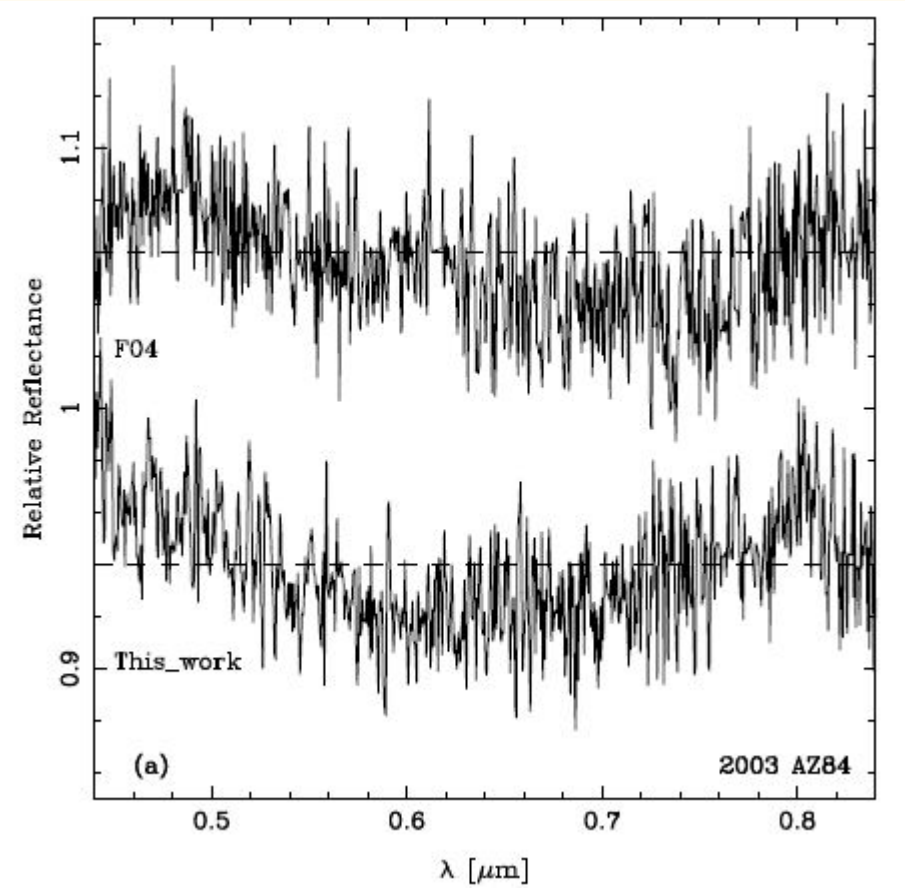
→ Organics

→ Silicates

VIS spectroscopy

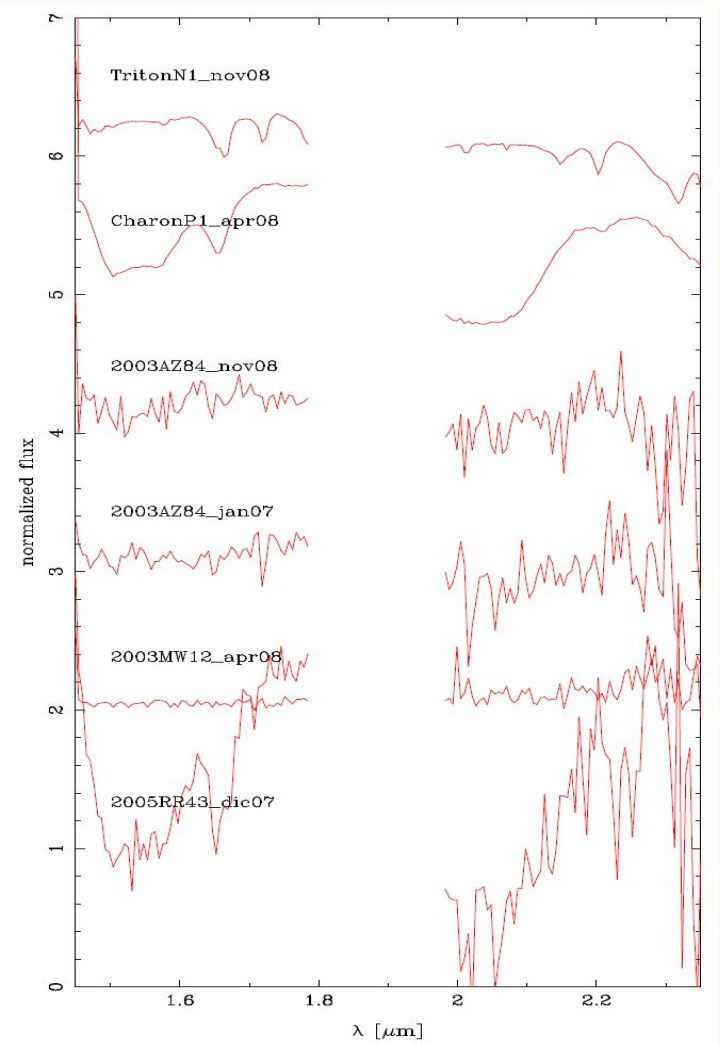


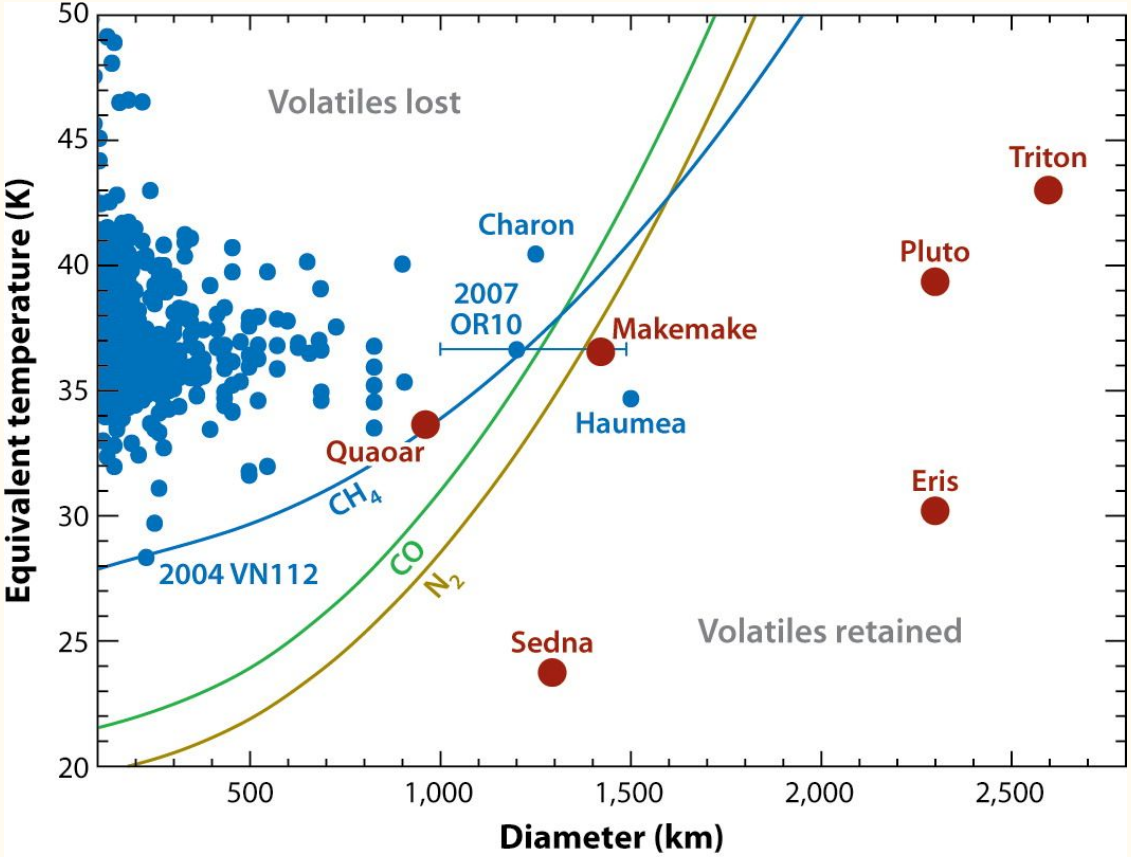
Fornasier et al. (2009)



Alvarez-Candal et al. (2008)

NIR spectroscopy





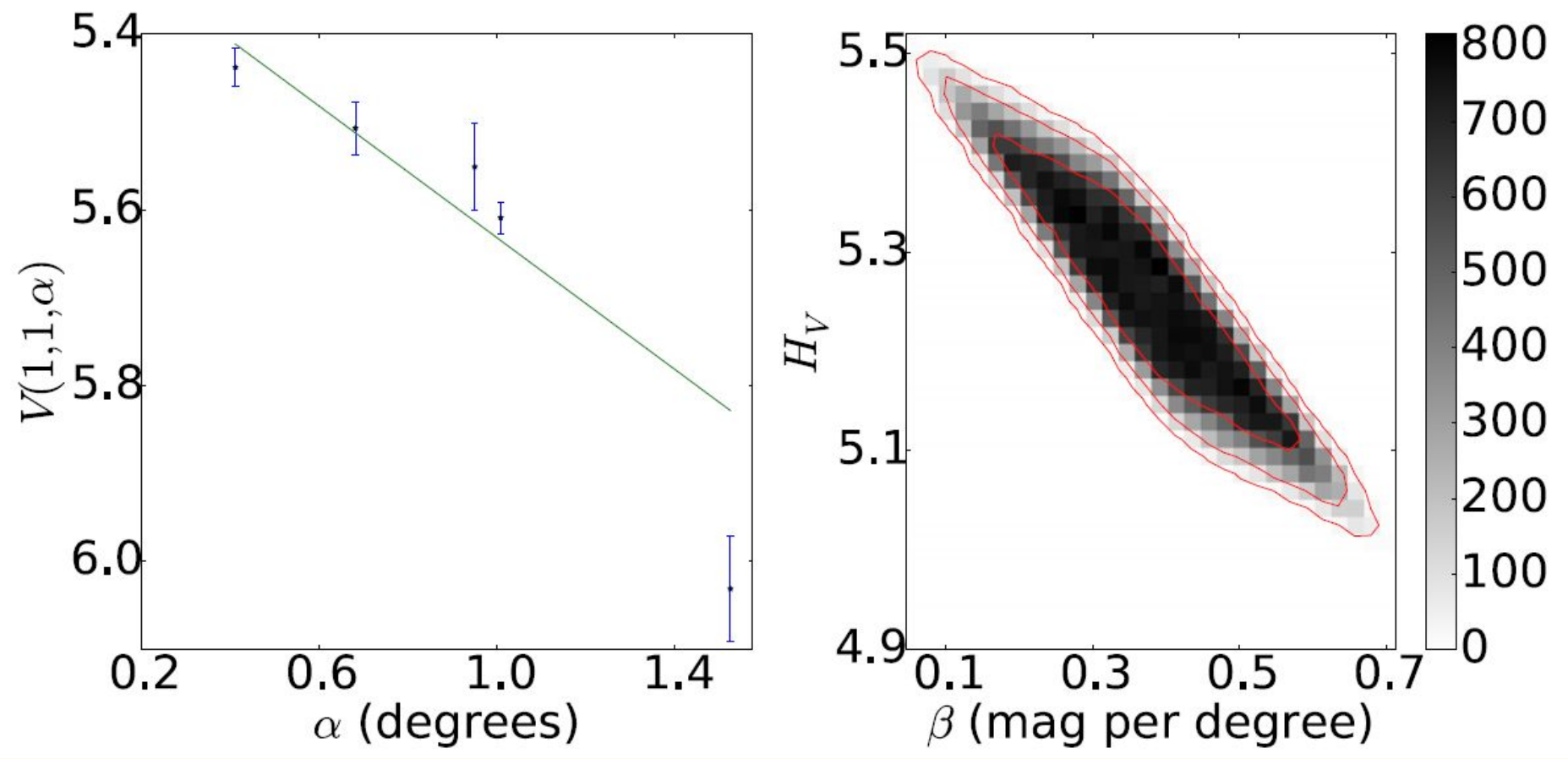
Brown ME. 2012.
Annu. Rev. Earth Planet. Sci. 40:467–94

What else do we know?

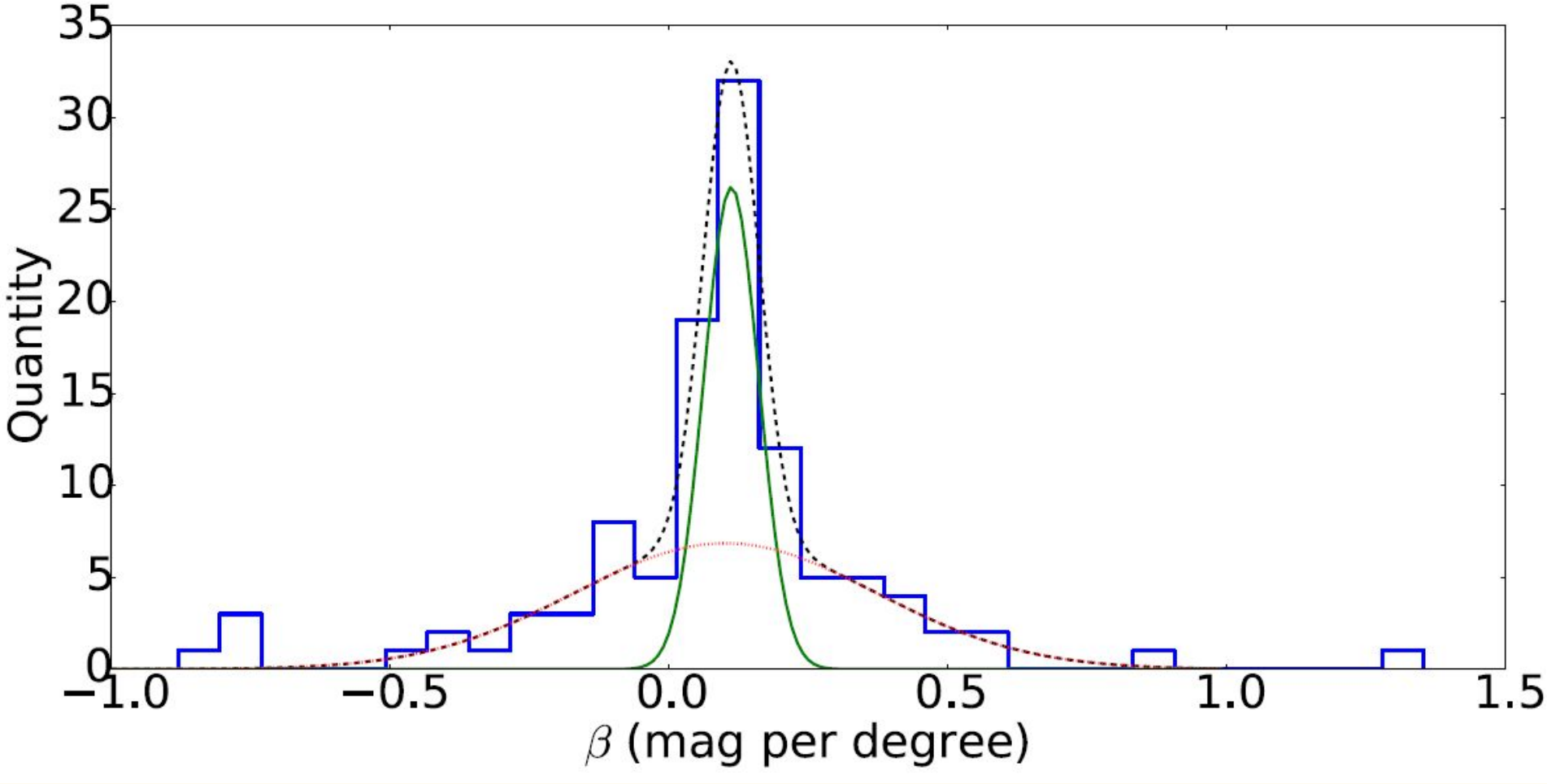
Some information about sizes

→ Absolute magnitudes

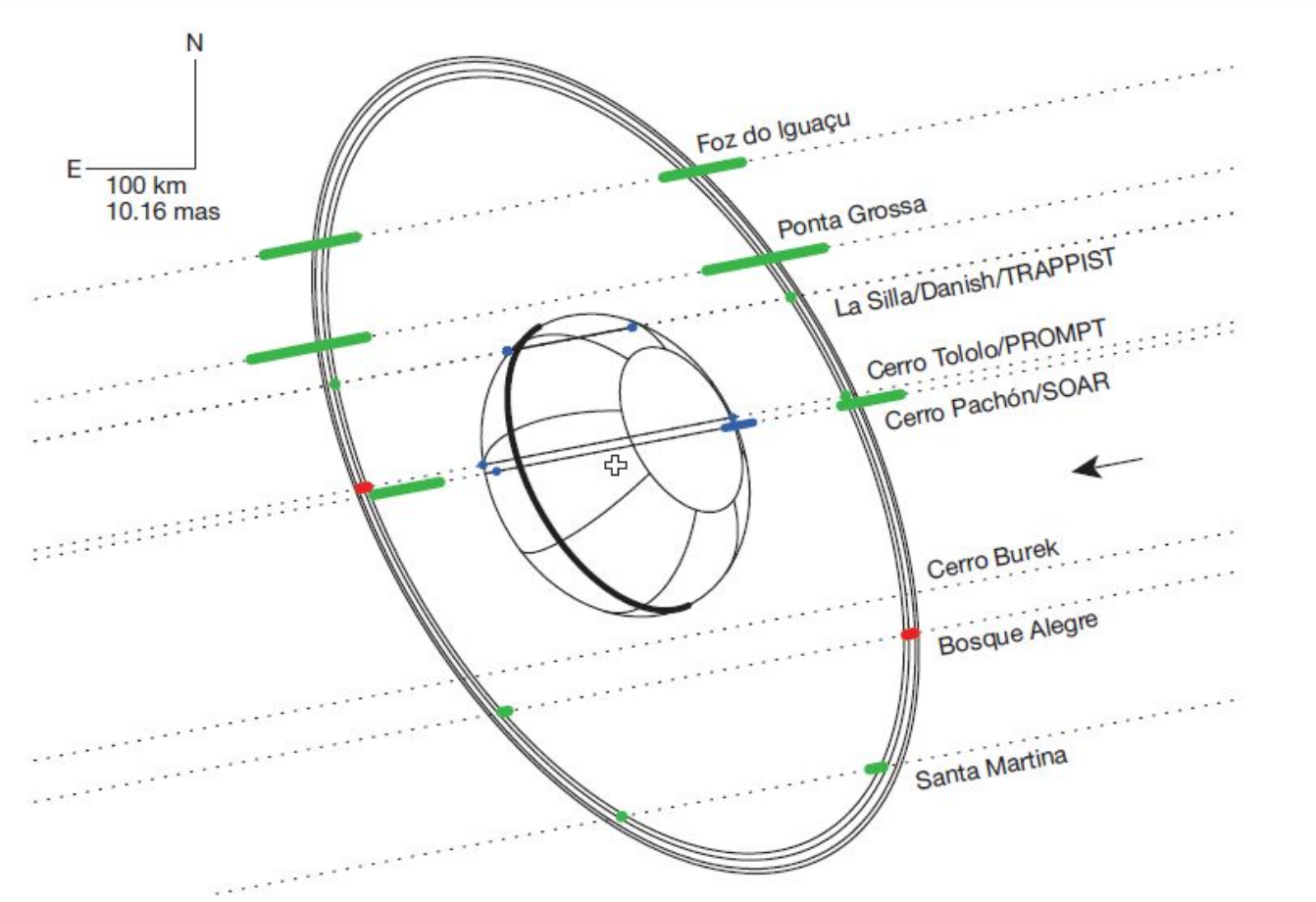
→ Stellar occultations



1996 TL66 - Alvarez-Candal et al. (2016)



Alvarez-Candal et al. (2016)



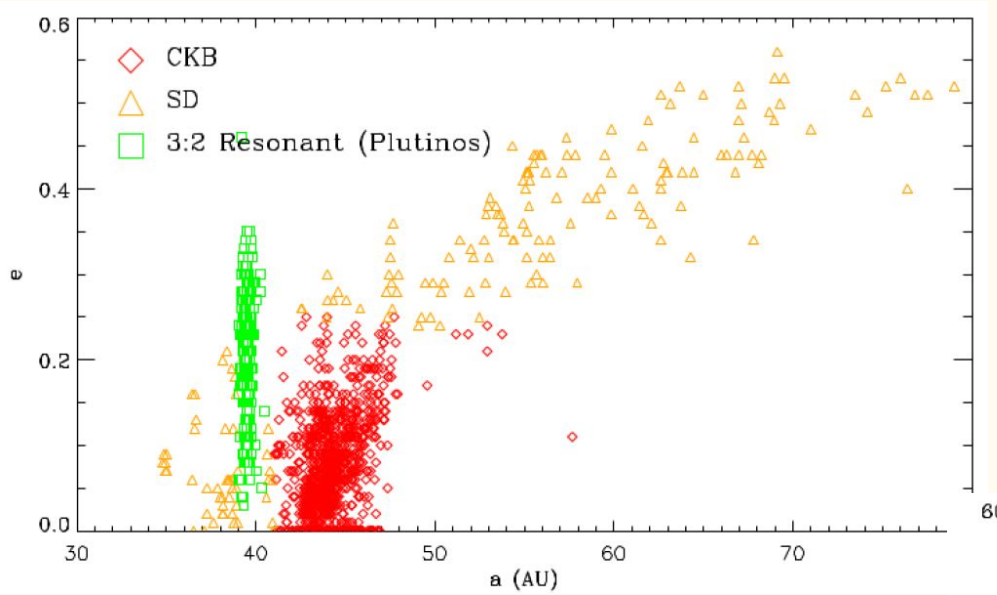
Chariklo - Braga-Ribas et al. (2014)

What else do we know?

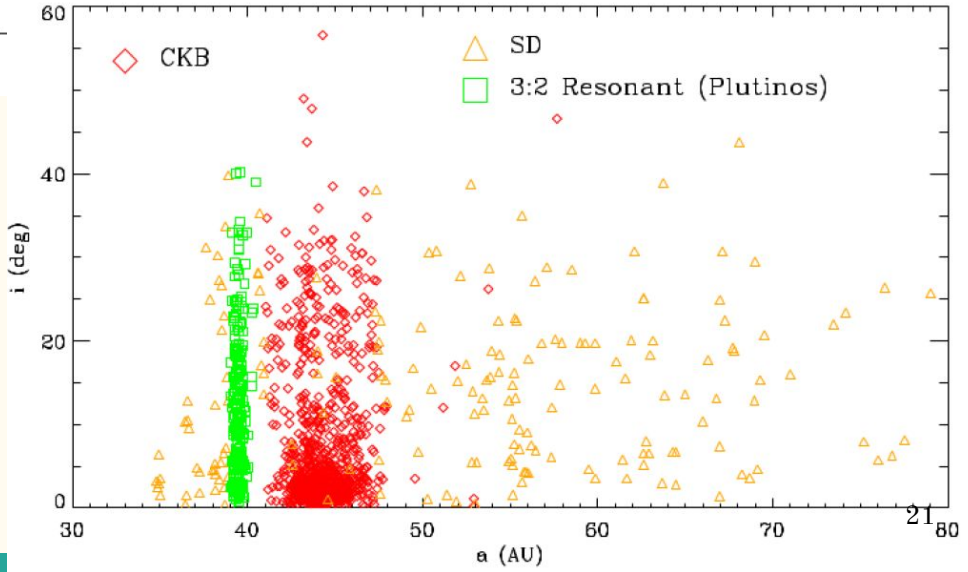
The belt shows

→ an unexpectedly high level of dynamical excitation

→ some quite weird spatial distribution of objects



(same plots again)



Planetary Migration by Fernández and Ip (1984)

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Resonant Population → Resonant Sweeping by Malhotra (1994)

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Classical Population of TNOs → Resonant Sweeping 2.0 by Gomes (2003)

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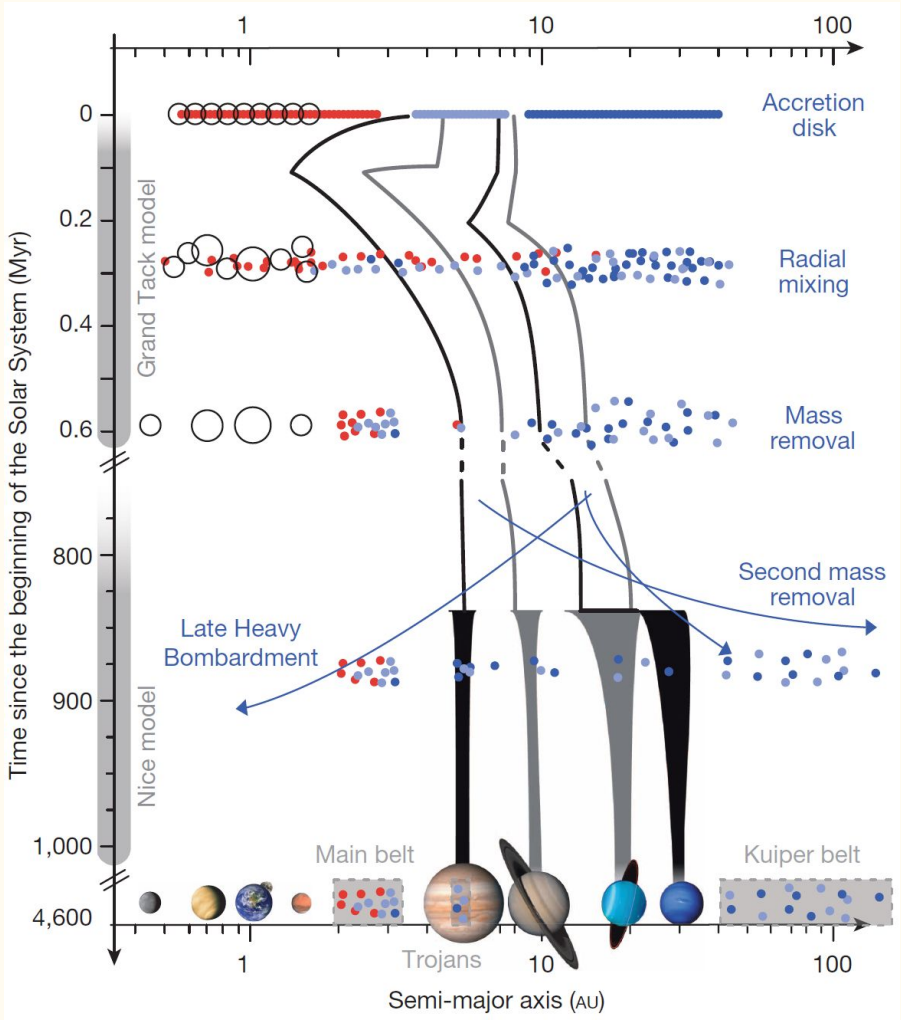
Classical Population of TNOs → Resonant Sweeping 2.0 by Gomes (2003)

End of Classical Belt → Neptune's migration by Gomes et al (2004)



Grand Tack

(Walsh et al. 2011)

Nice model

(Tsiganis et al. 2005 + other papers)

DeMeo and Carry (2014)

What we do not know?

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→ Sizes (D< 100-ish km)

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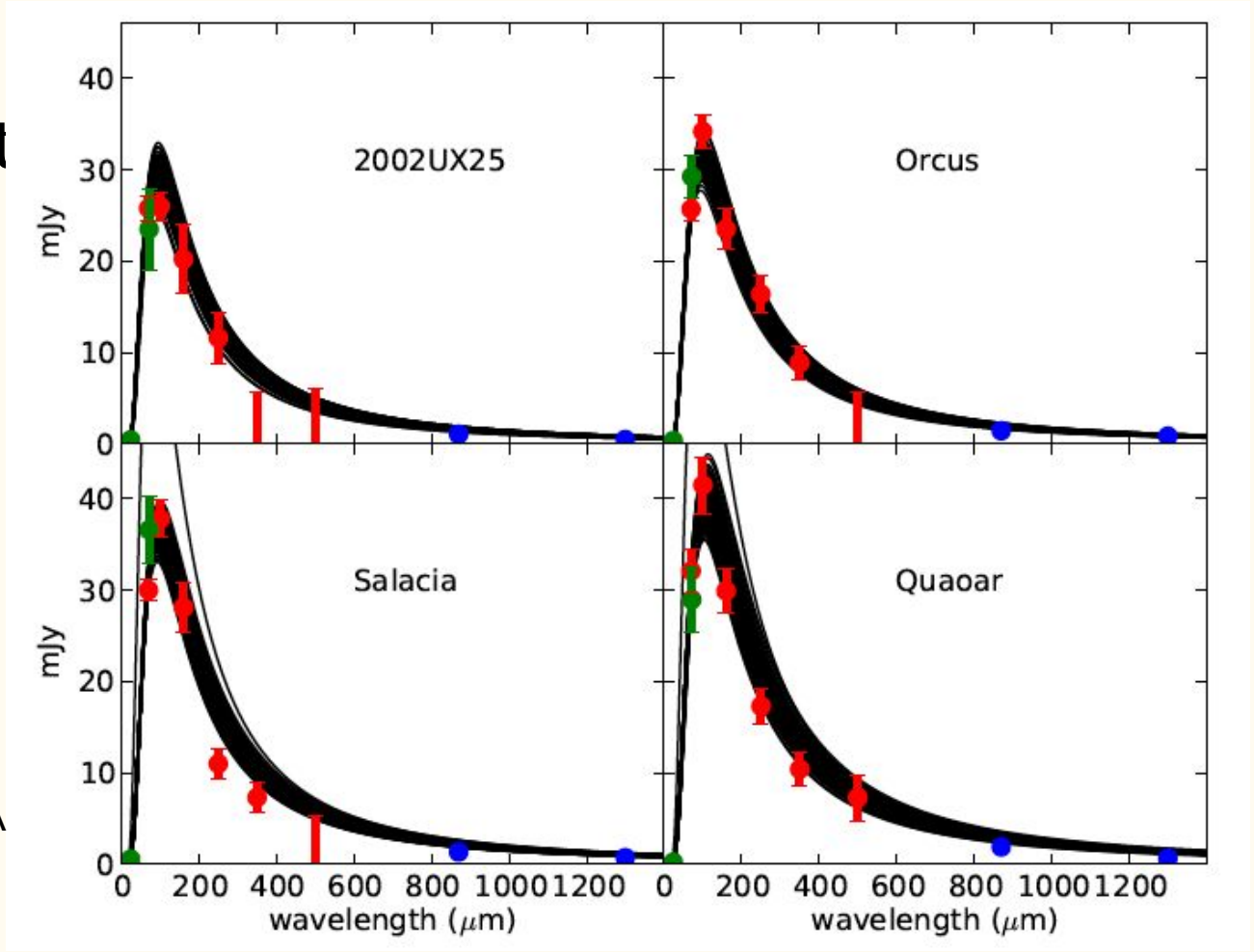
"TNOs" are cool (a Key Project of the Herschel Space Telescope)

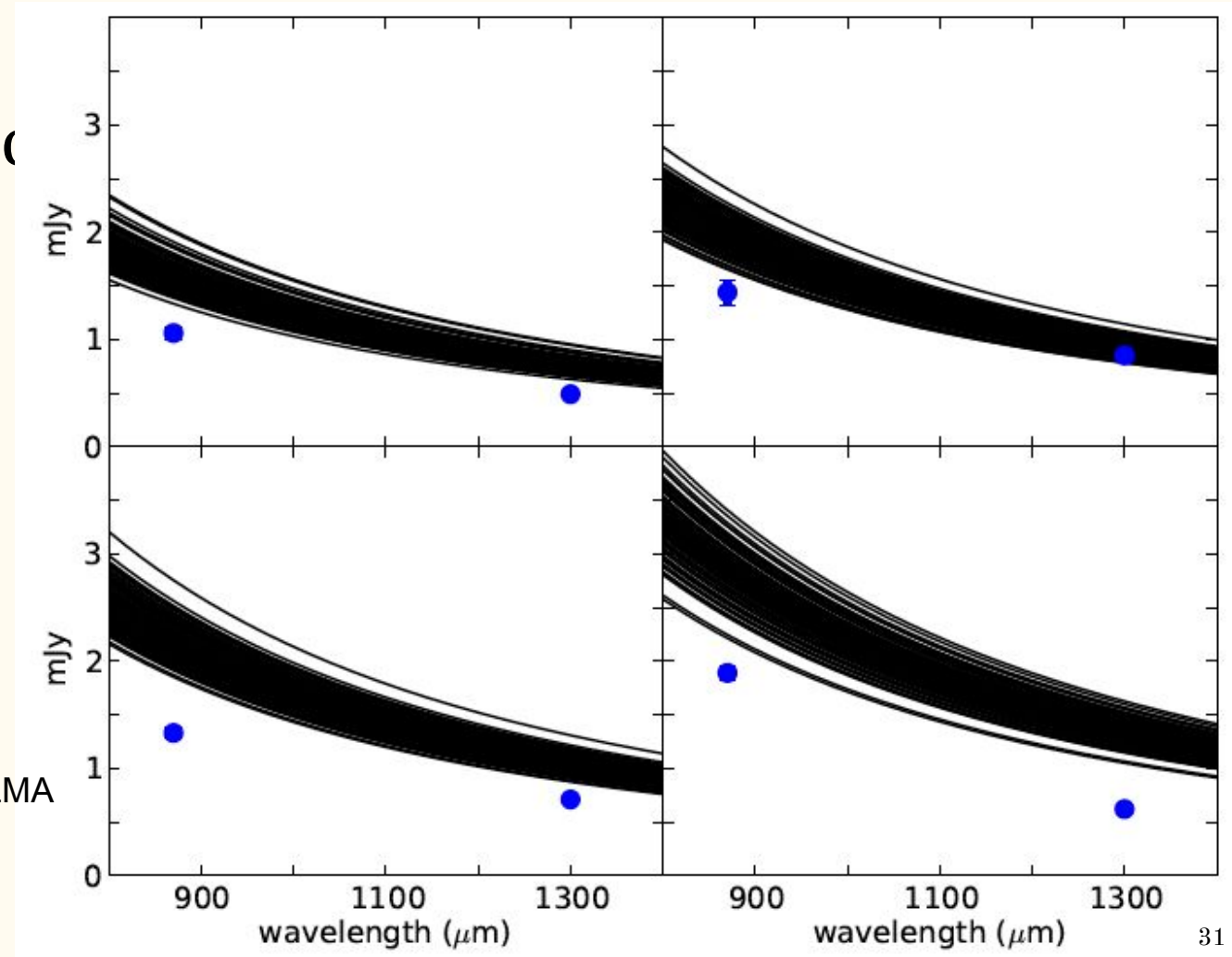
over 100 objects (few > 10 km, some > 50 km, mostly > 100 km)

What we do not



Brown and Butler (2017) ALMA

What we do n



Brown and Butler (2017) ALMA

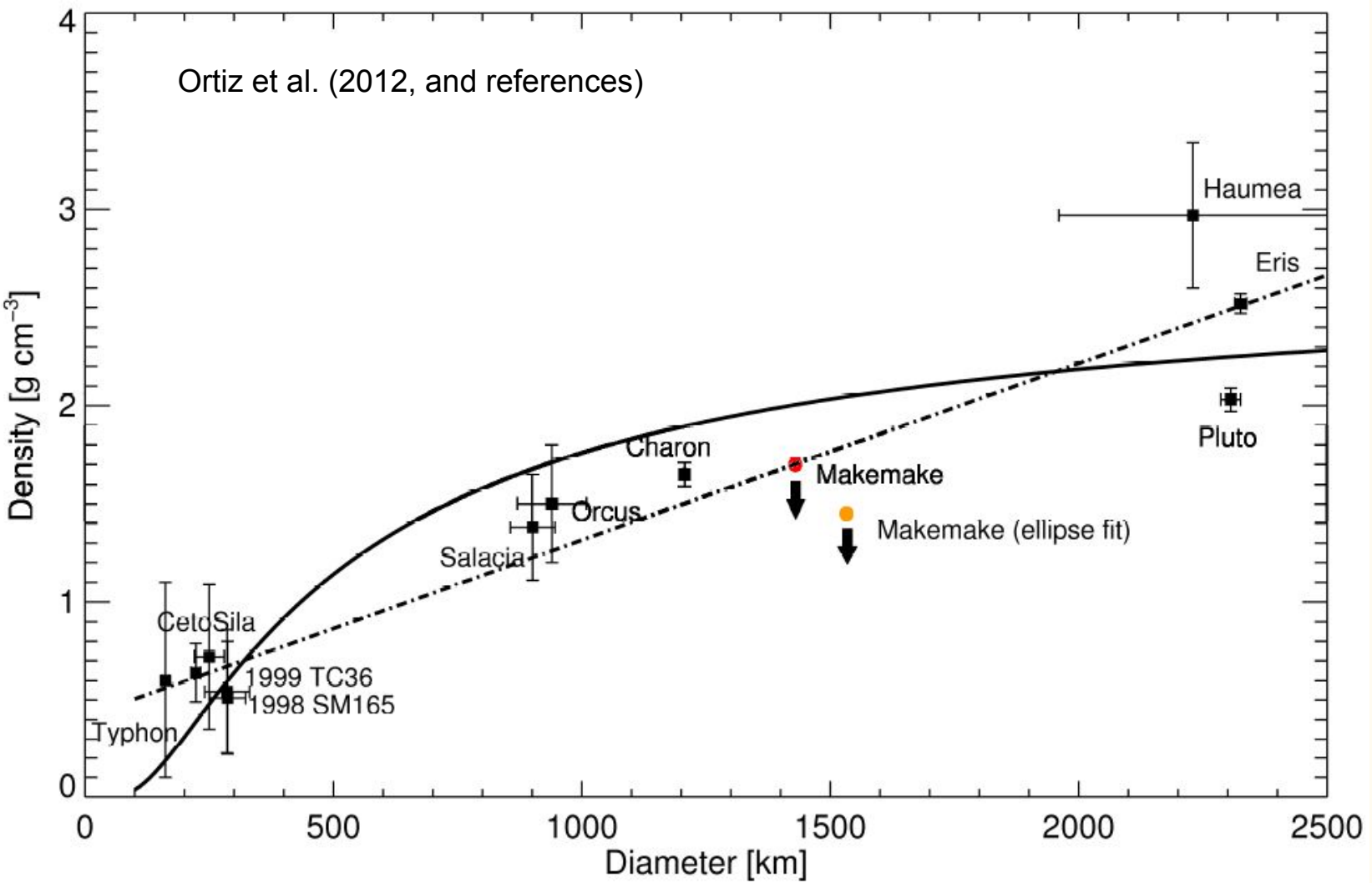
What we do not know?

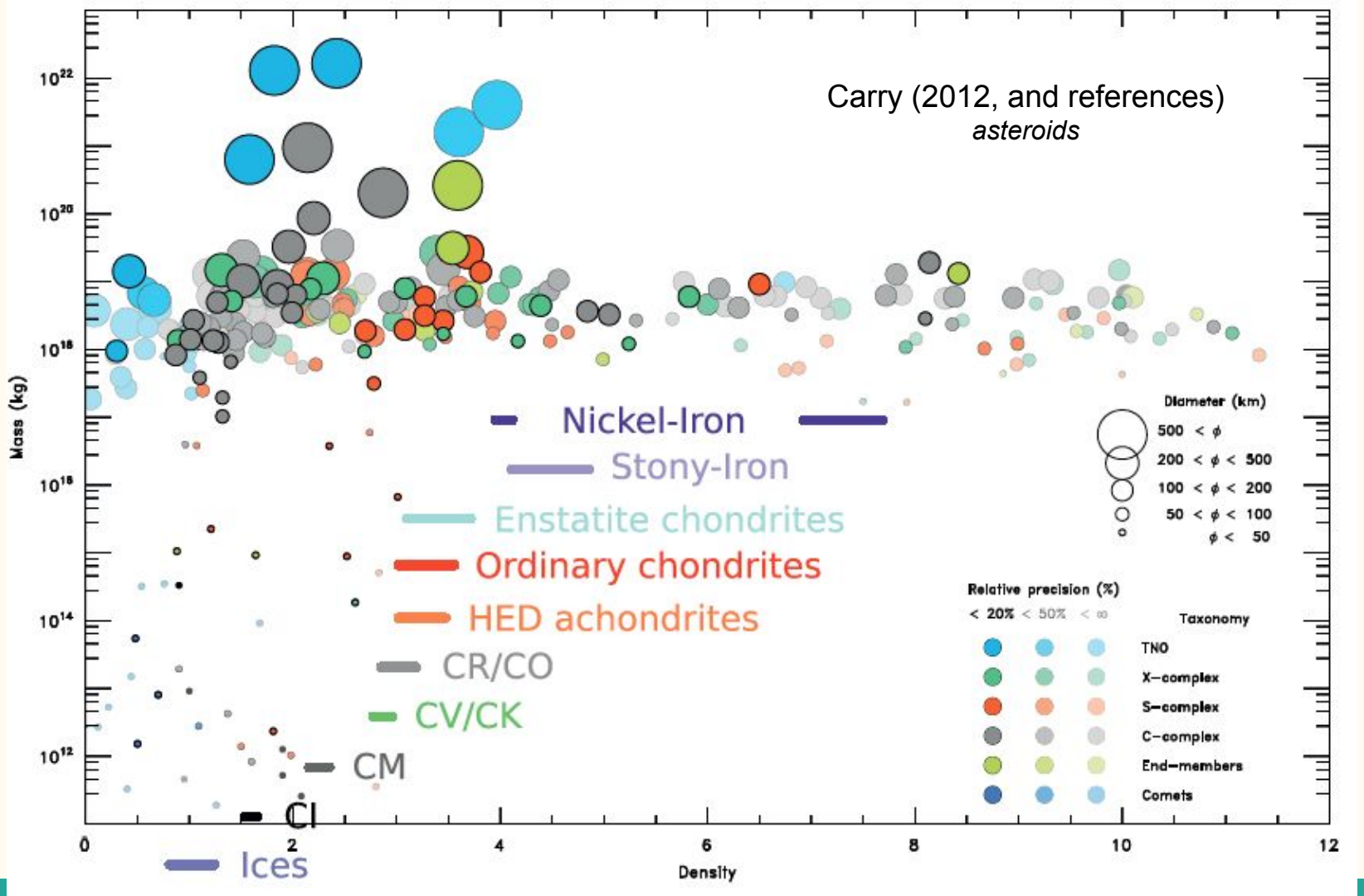
Densities (!)

What we do not know?

Densities (!)

We know nothing about the TNO internal structure


Ortiz et al. (2012, and references)
Density [g cm^{-3}]
Diameter [km]
0
1
2
3
4
0
500
1000
1500
2000
2500
Haumea
Eris
Pluto
Charon
Makemake
Makemake (ellipse fit)
Orcus
Salacia
CelestaSila
1999 TC36
1998 SM165
Typhon

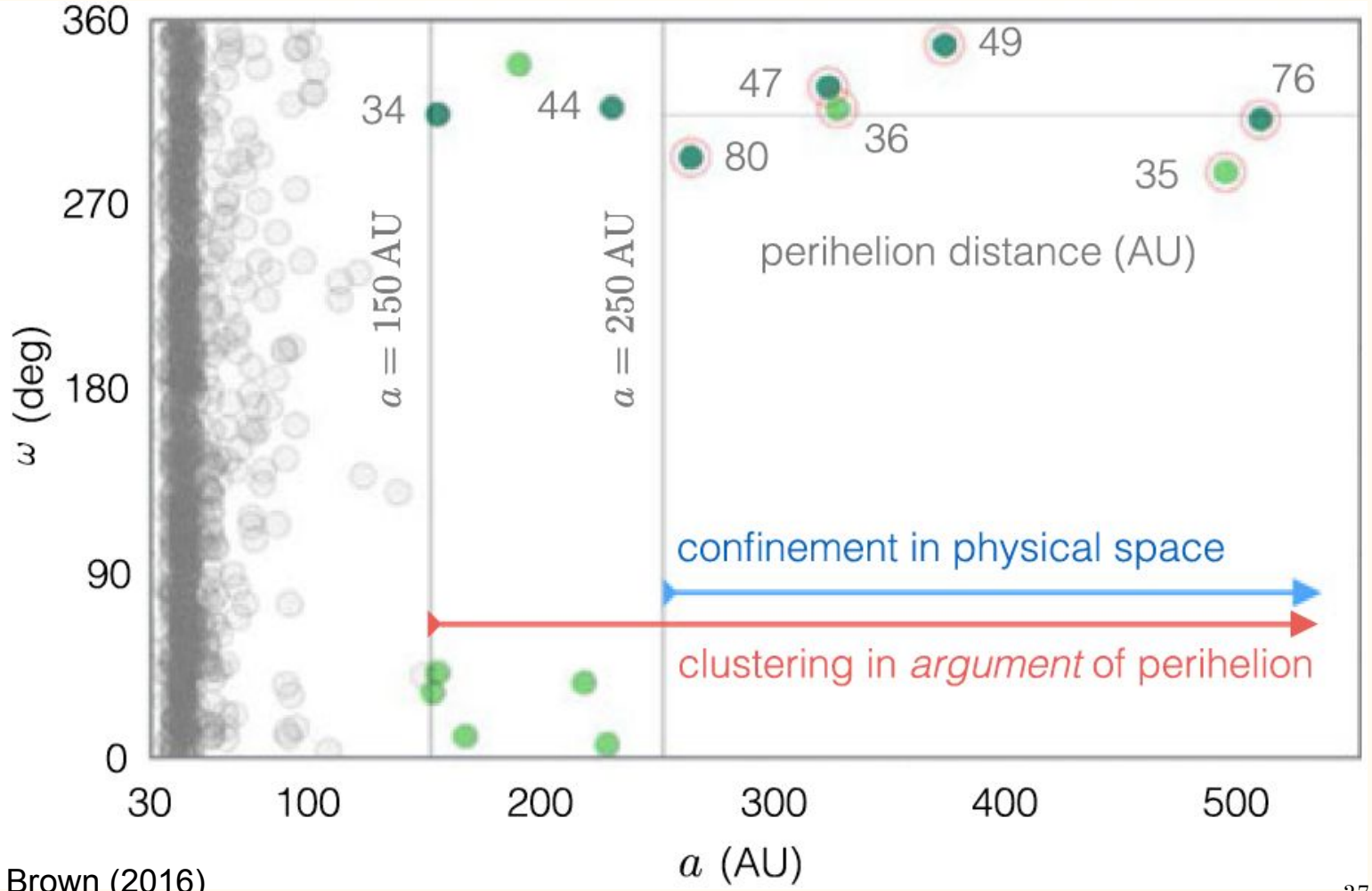

Carry (2012, and references)
asteroids
Mass (kg)
Density
Nickel-Iron
Stony-Iron
Enstatite chondrites
Ordinary chondrites
HED achondrites
CR/CO
CV/CK
CM
CI
Ices
Diameter (km)
500 < ϕ
200 < ϕ < 500
100 < ϕ < 200
50 < ϕ < 100
ϕ < 50
Relative precision (%)
< 20% < 50% < ∞
Taxonomy
TNO
X-complex
S-complex
C-complex
End-members
Comets

What we do not know?

→ Large surveys in the south did not discover any bright (big) TNO

(Rabinowitz et al. 2012)

→ Are there more "large" objects over there?



Batygin and Brown (2016)

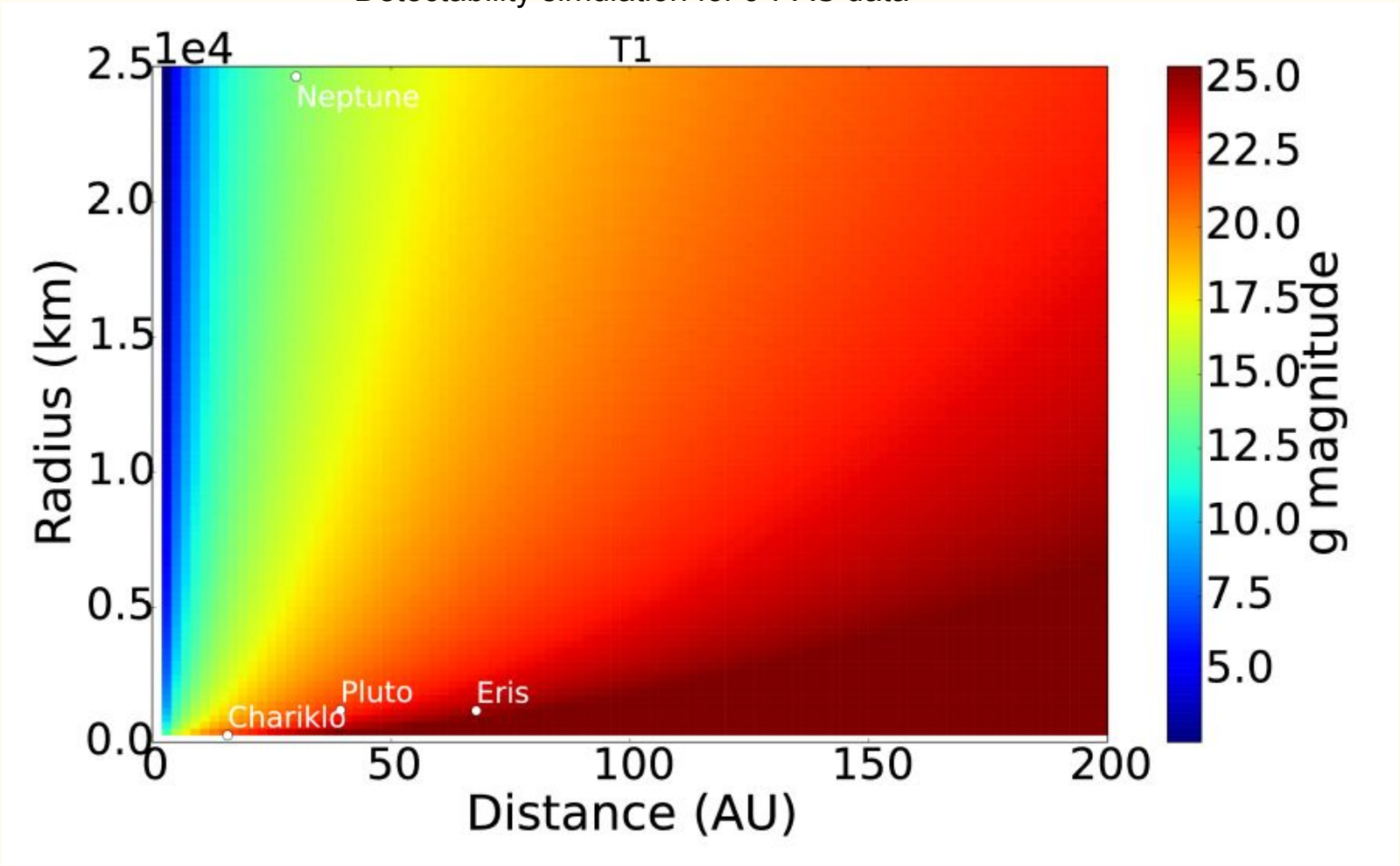
What we do not know?

Are there more "large" objects over there?

Maybe... → Dynamics

Observationally, nothing yet

Detectability simulation for J-PAS data



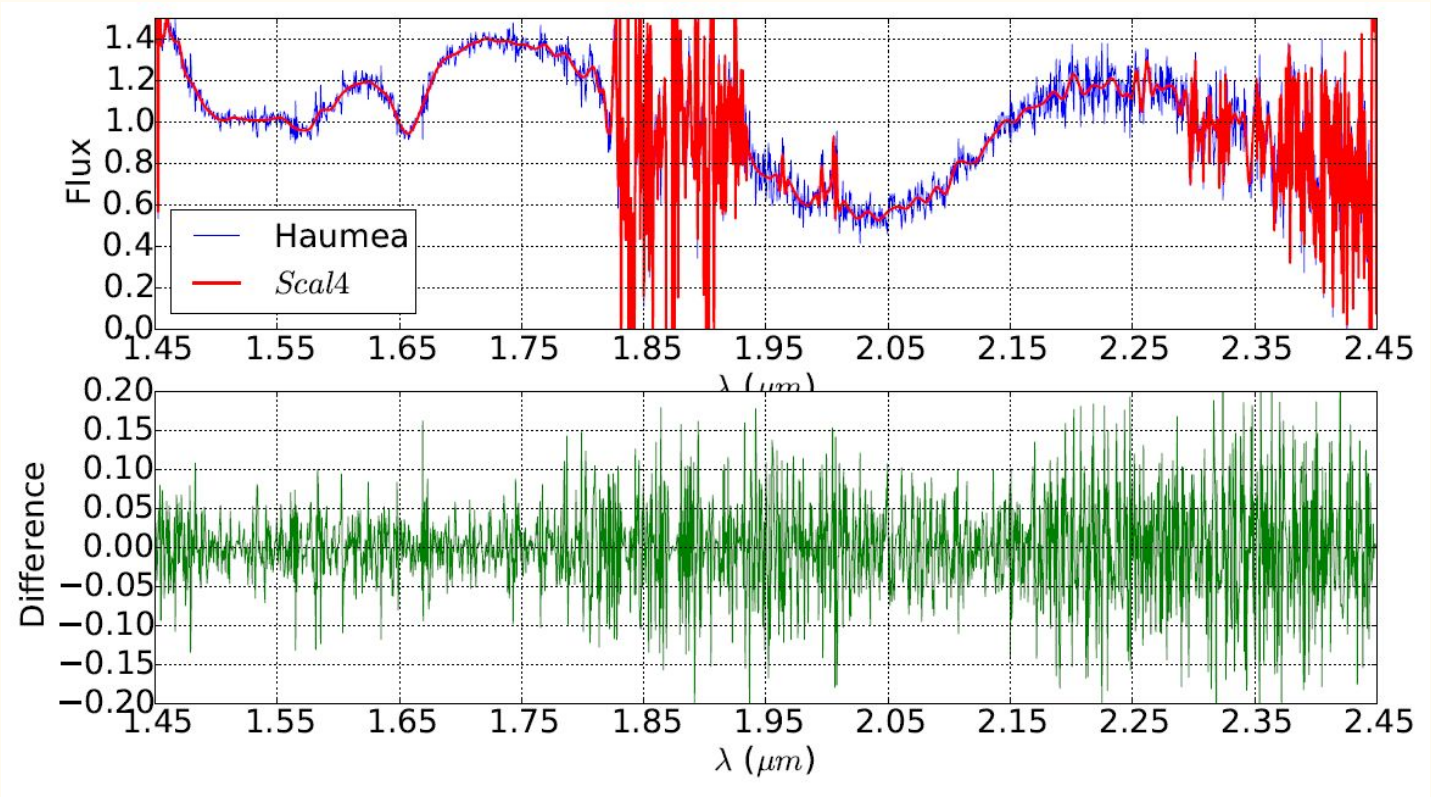
What we do not know?

Composition and surface characteristics

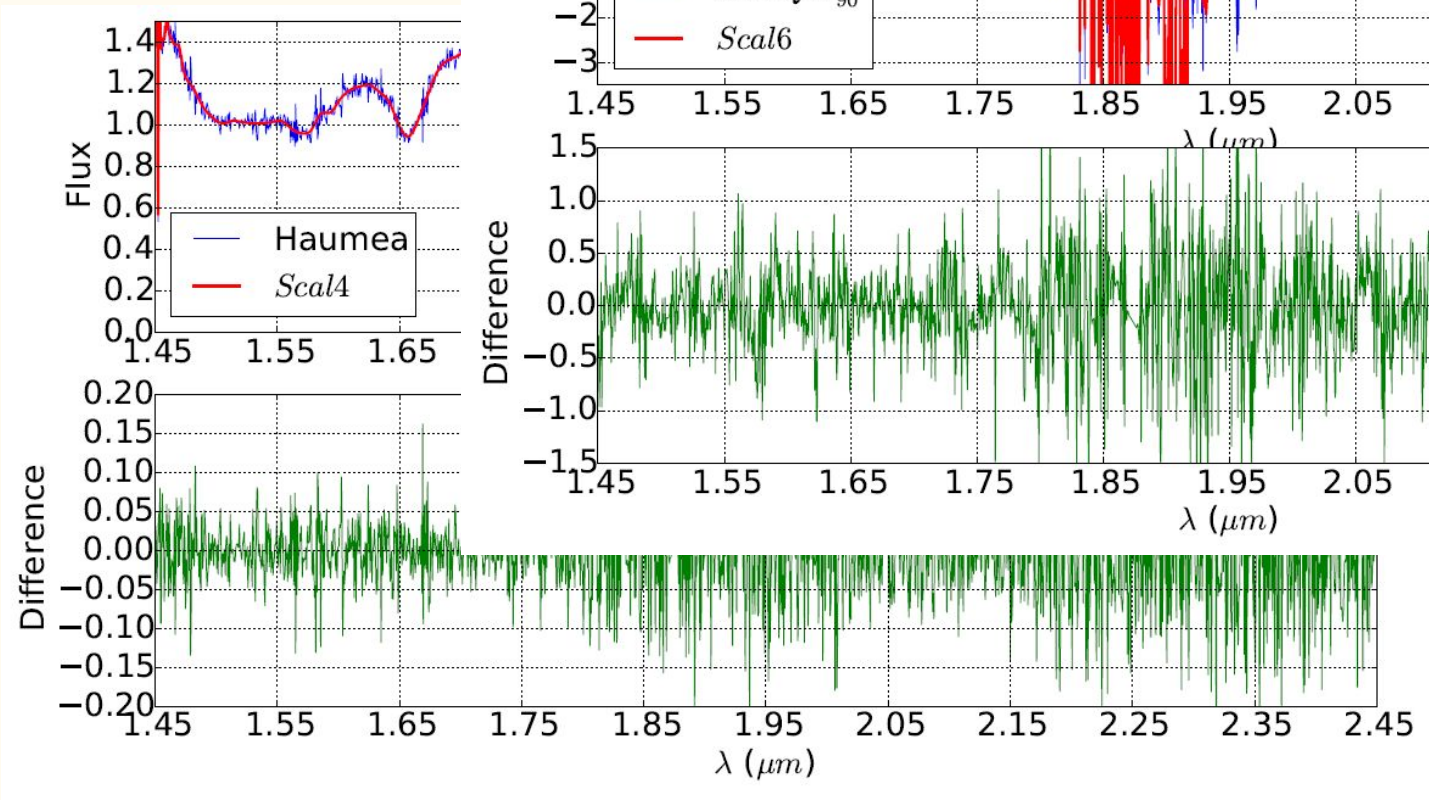
→ we see some ices, a touch of silicates and organic material

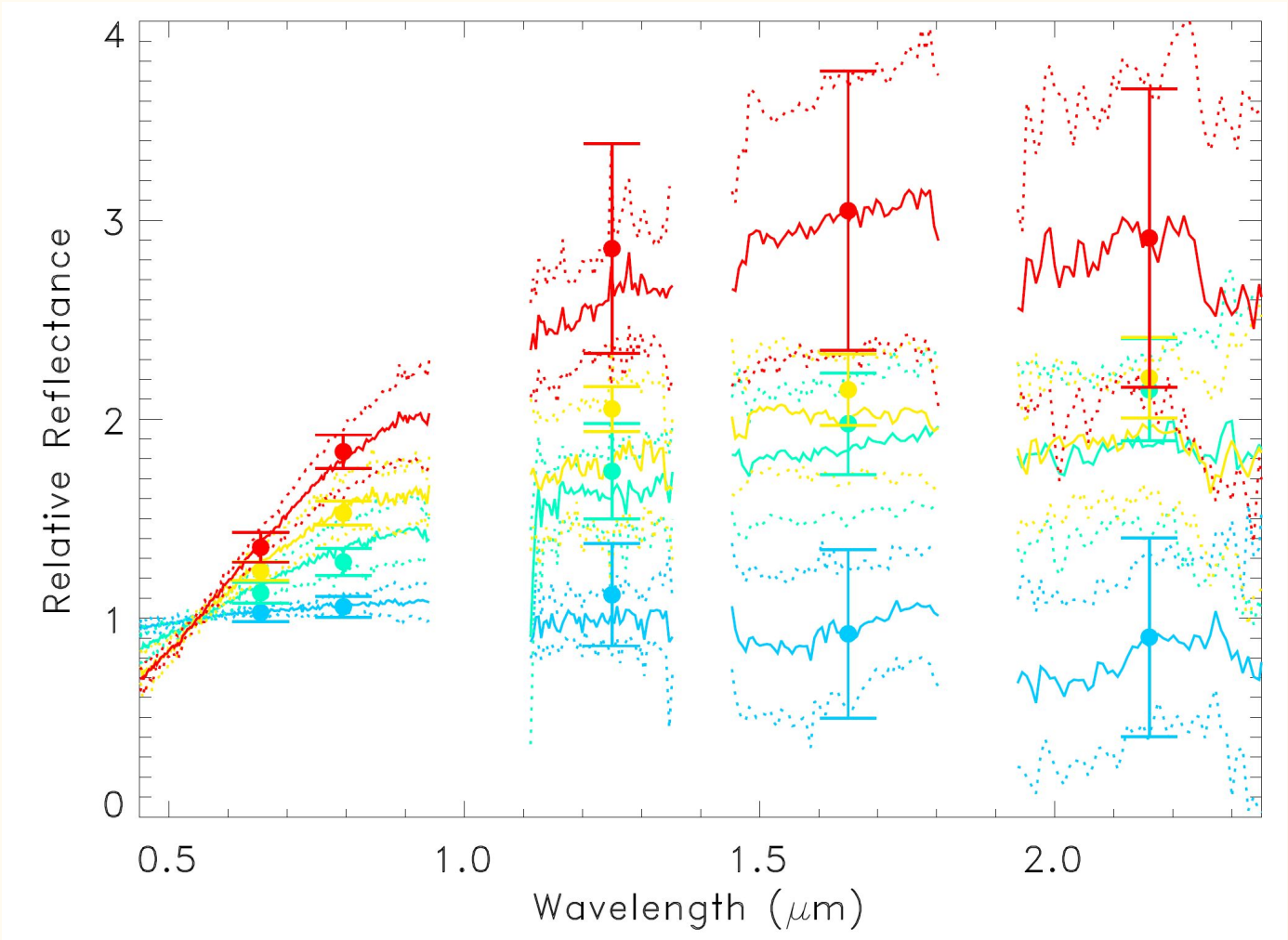
Mostly for large objects

Souza-Feliciano et al (in prep.)



Souza-Feliciano et al (i





Merlin et al. (submitted)

What do we need?

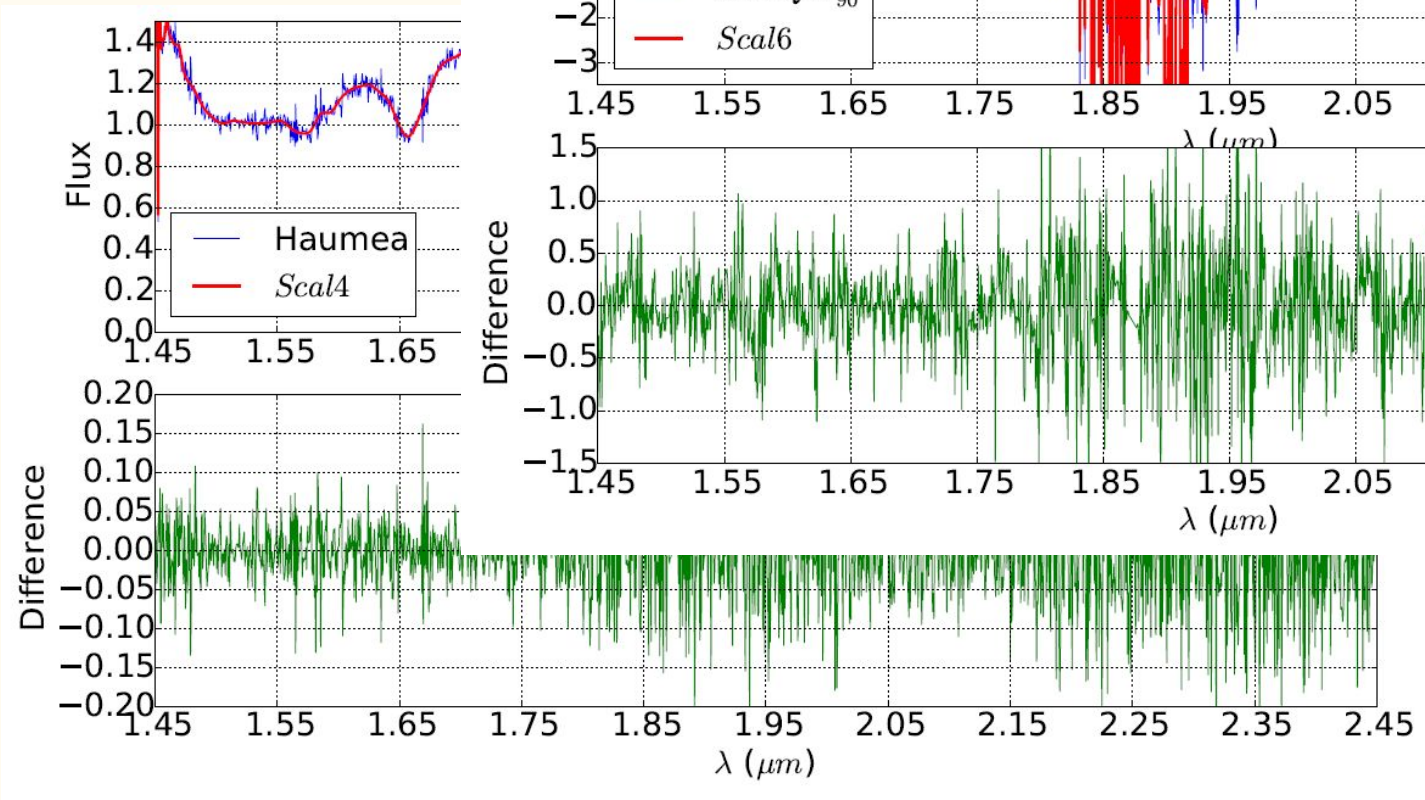
the answer to the life, the universe, and everything

What do we need?

→ make the most of the data we already have

(which is quite a lot)

Souza-Feliciano et al (in prep.)



More data?

Simultaneous imaging → smaller TNOs

- Visible filters (SLOAN + Custom made)
- Throw in a sprinkle of NIR (Y,J,H,Ks)

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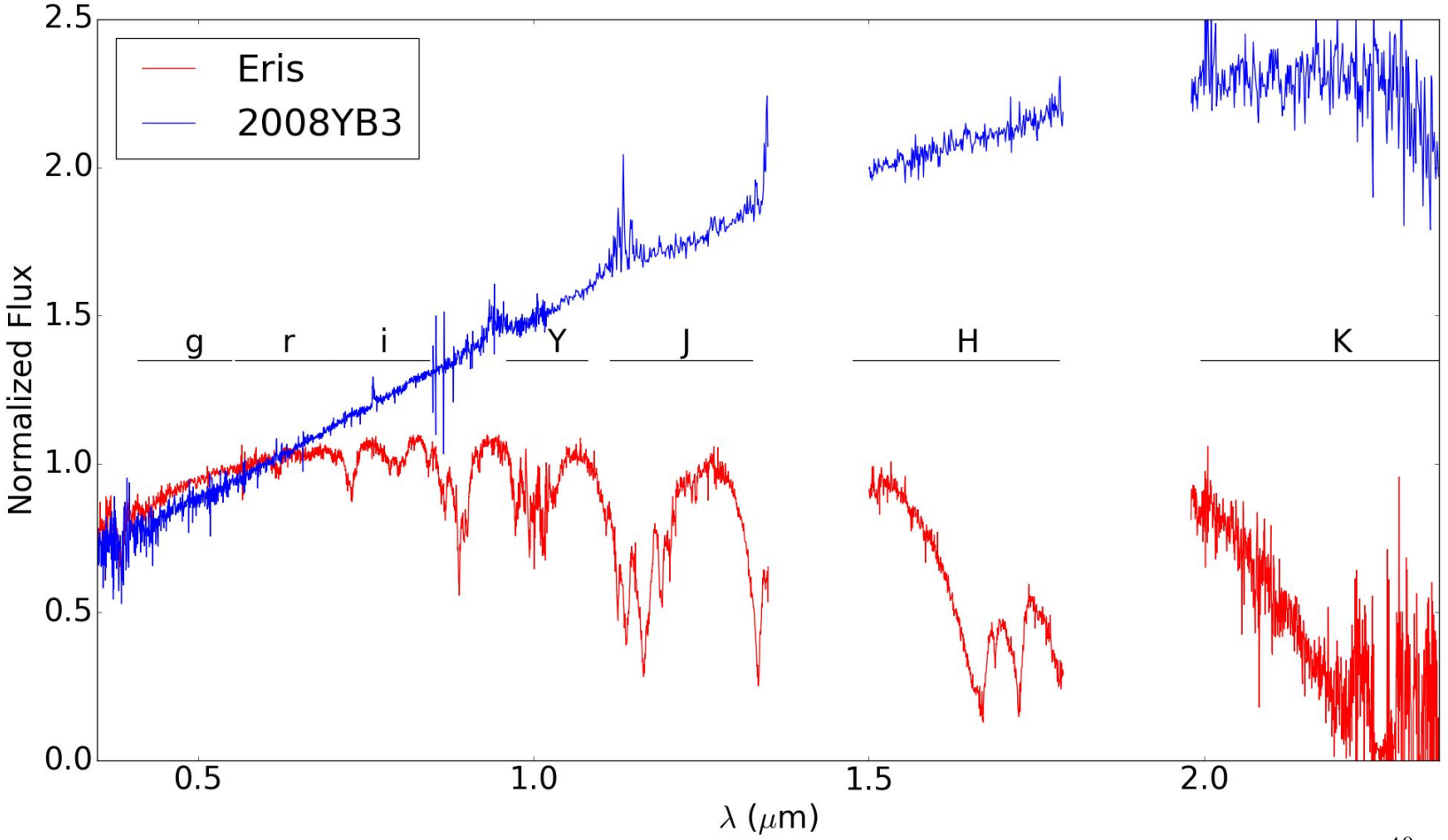
Simultaneous spectroscopy → increase database

- Vis + NIR



49 cool figure!

What else?

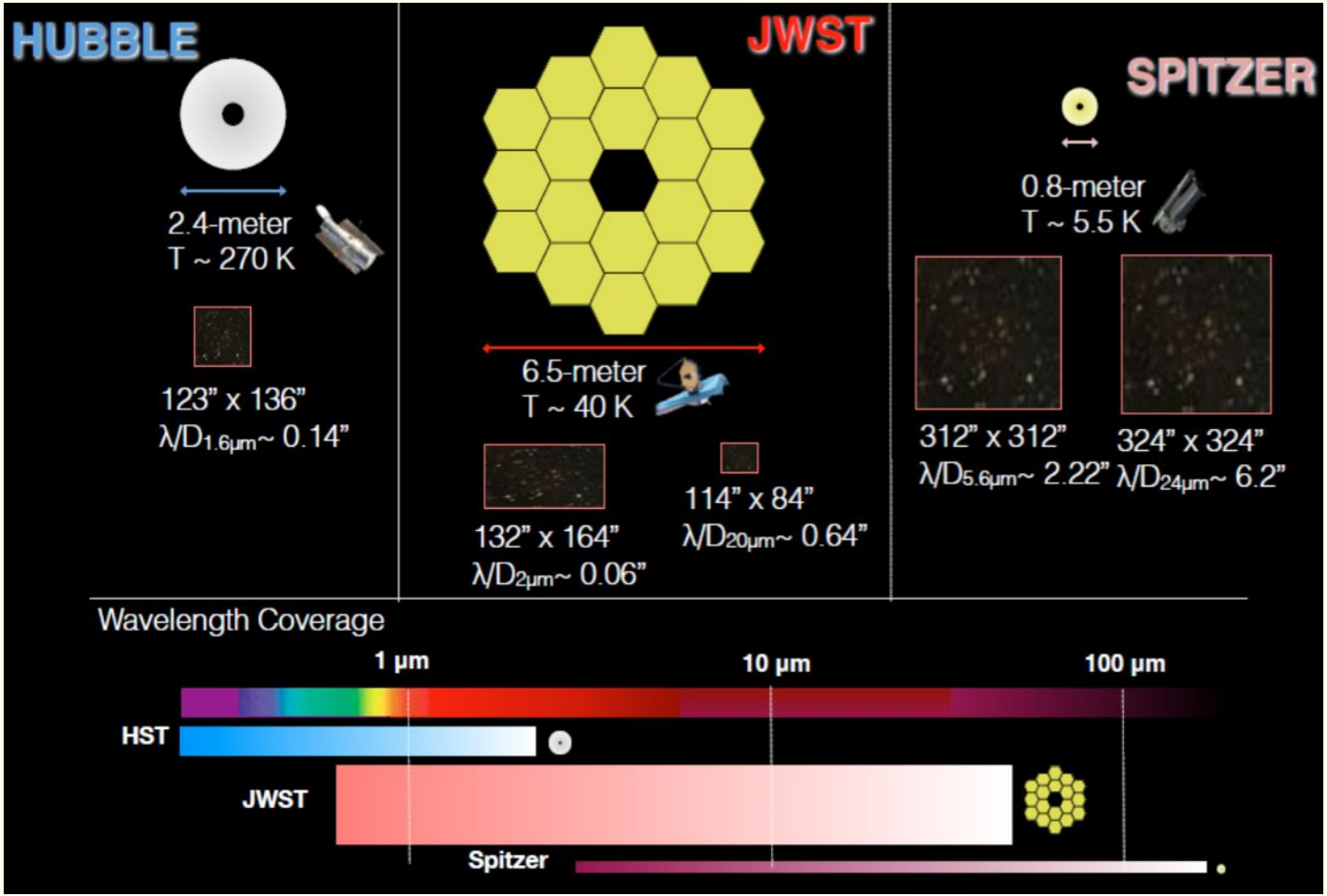
New facilities

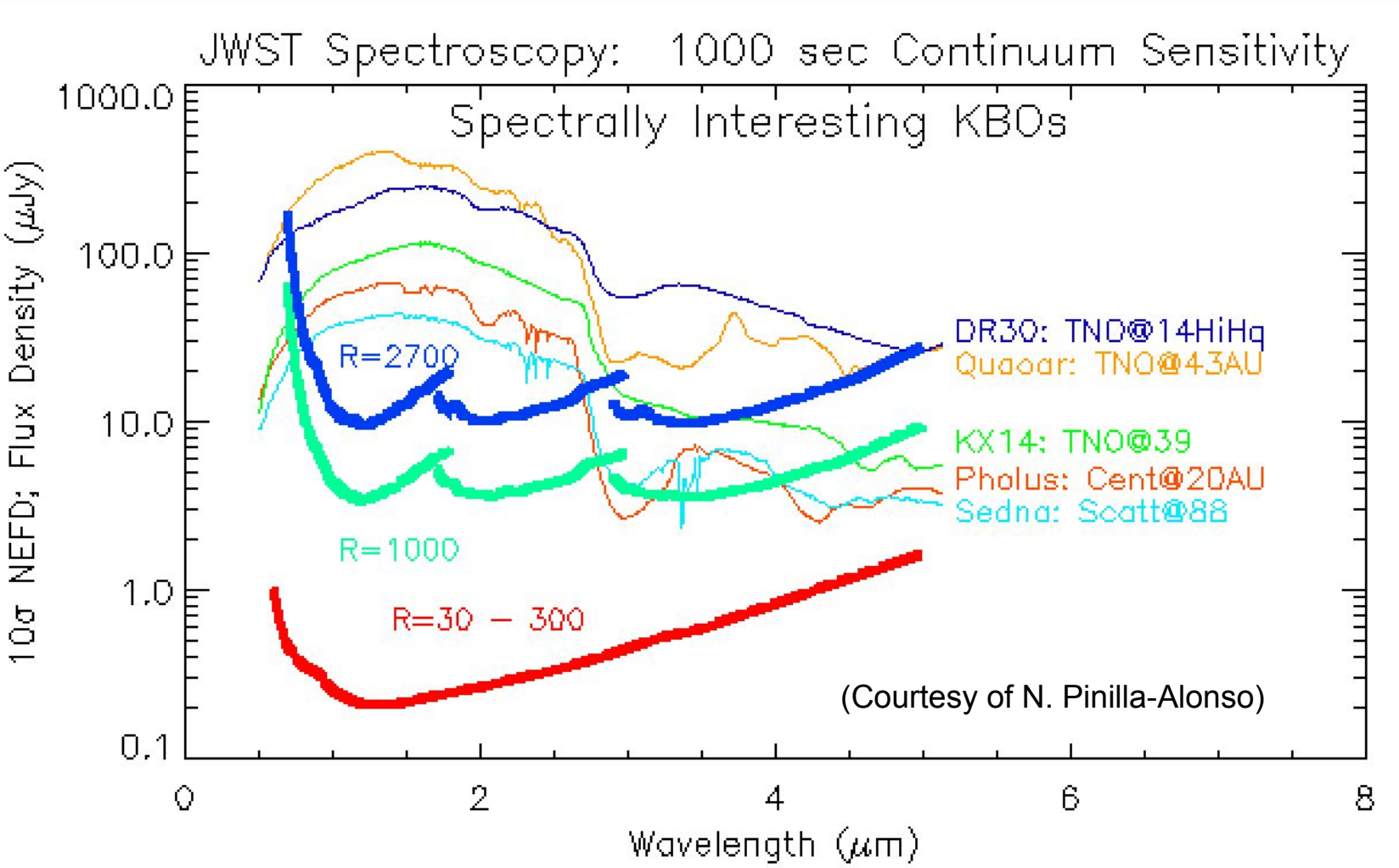
What else?

JWST

Launch 2018

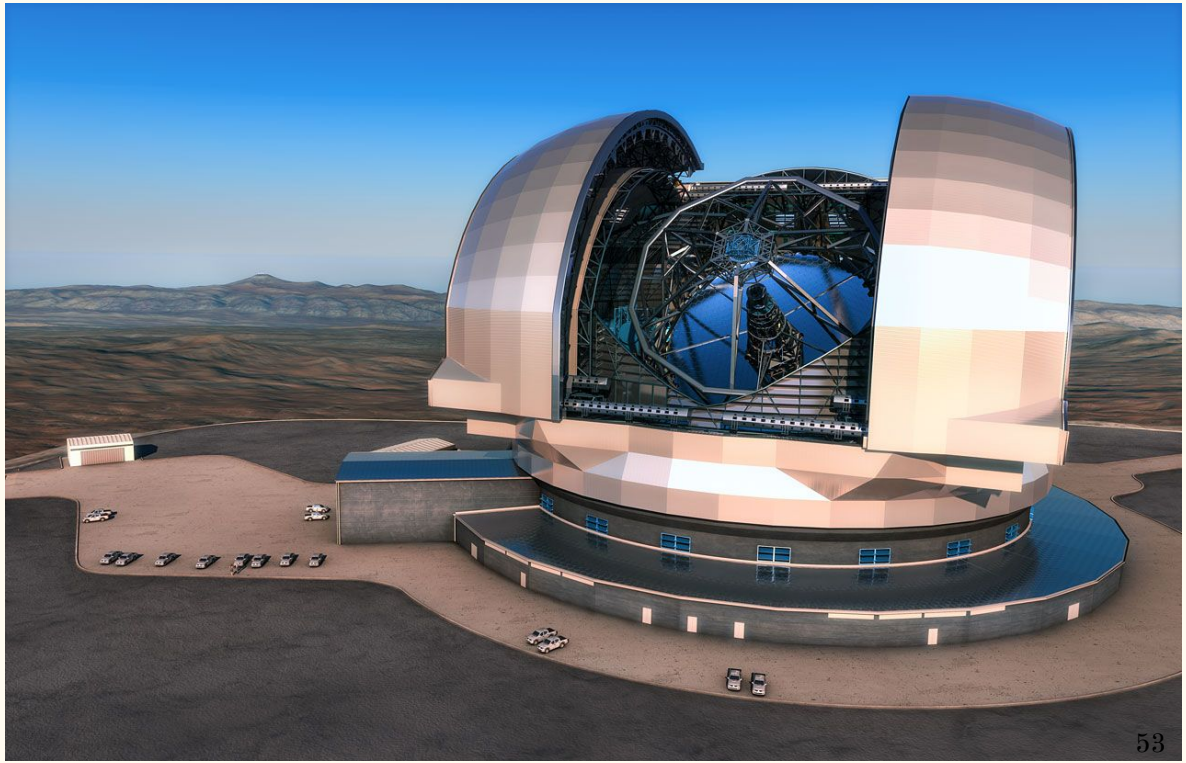
4 instruments




JWST Spectroscopy: 1000 sec Continuum Sensitivity
Spectrally Interesting KBOs
1000.0
100.0
10.0
1.0
0.1
10σ NEFD; Flux Density (μJy)
0
2
4
6
8
Wavelength (μm)
R=2700
R=1000
R=30 – 300
DR30: TNO@14HiHq
Quaoar: TNO@43AU
KX14: TNO@39
Pholus: Cent@20AU
Sedna: Scatt@88
(Courtesy of N. Pinilla-Alonso)

More data?

Extremely Large Telescopes



(www.eso.org)

Finishing...

We have a paradigm : Grand Tack + Nice model

... and in spite of many, it seems to work

We have a fair idea about surface compositions

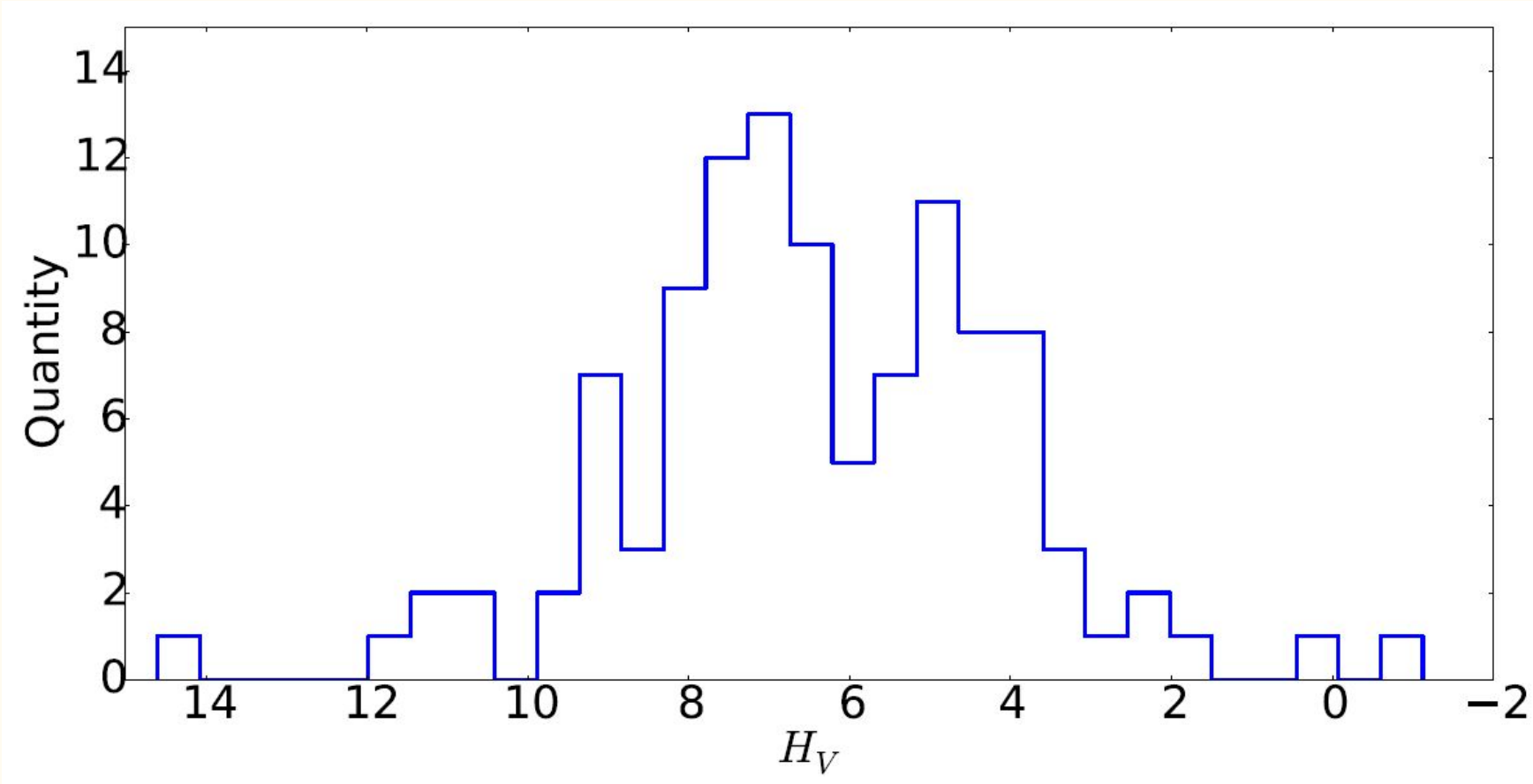
... but for the large objects

Finishing...

Understand the TNO population

→ understand how the Solar System formed

¡Gracias!



Alvarez-Candal et al. (2016)