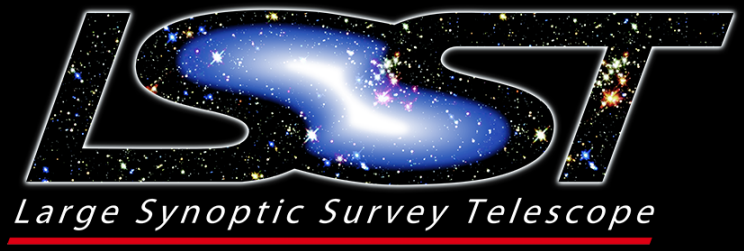


the need for the North Ecliptic Spur survey

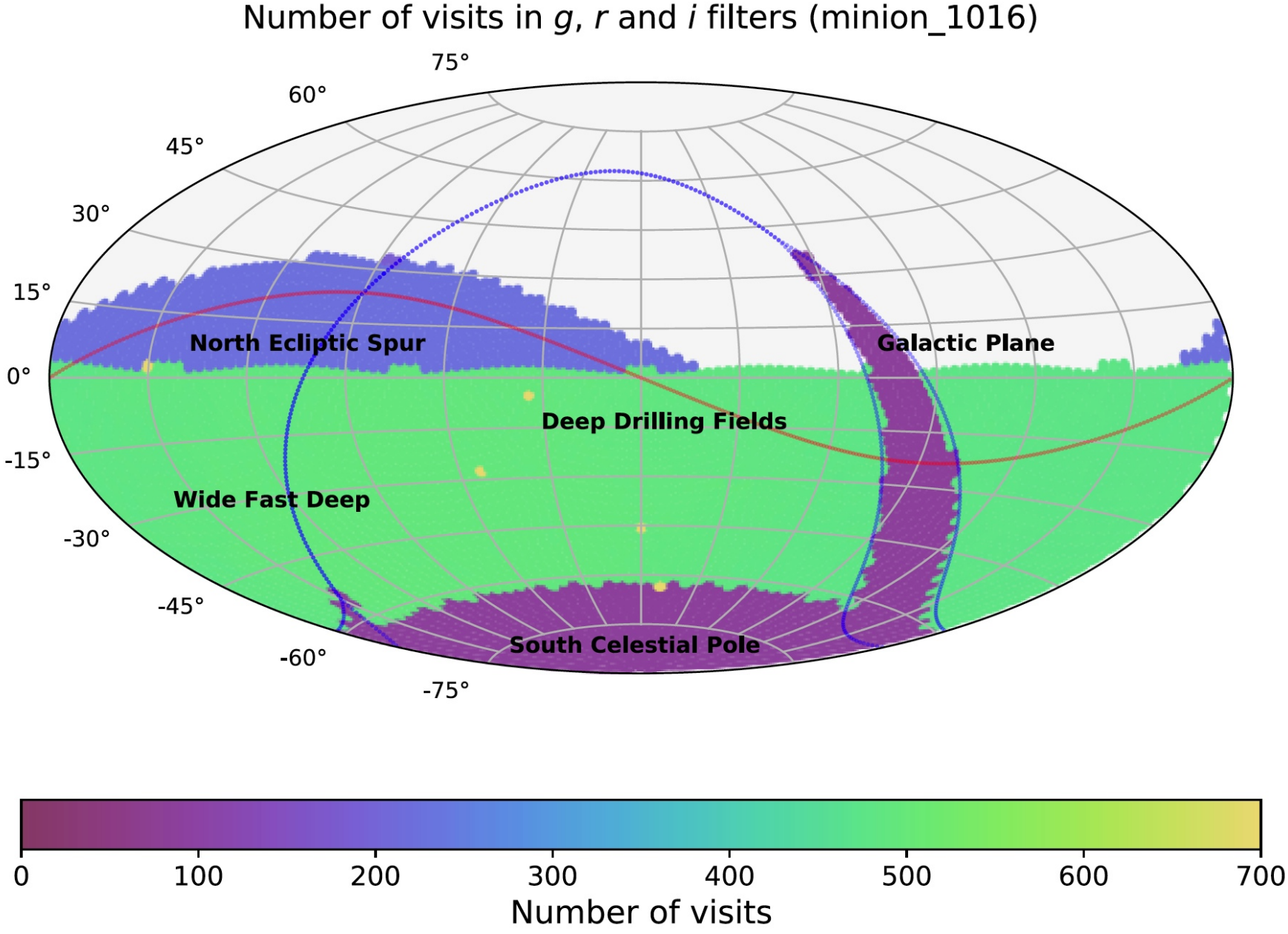
Michele Bannister

@astrokiwi

what is the North Ecliptic Spur?

critical science cases:

- asteroid activity
- distant resonant populations
- a planet! maybe?

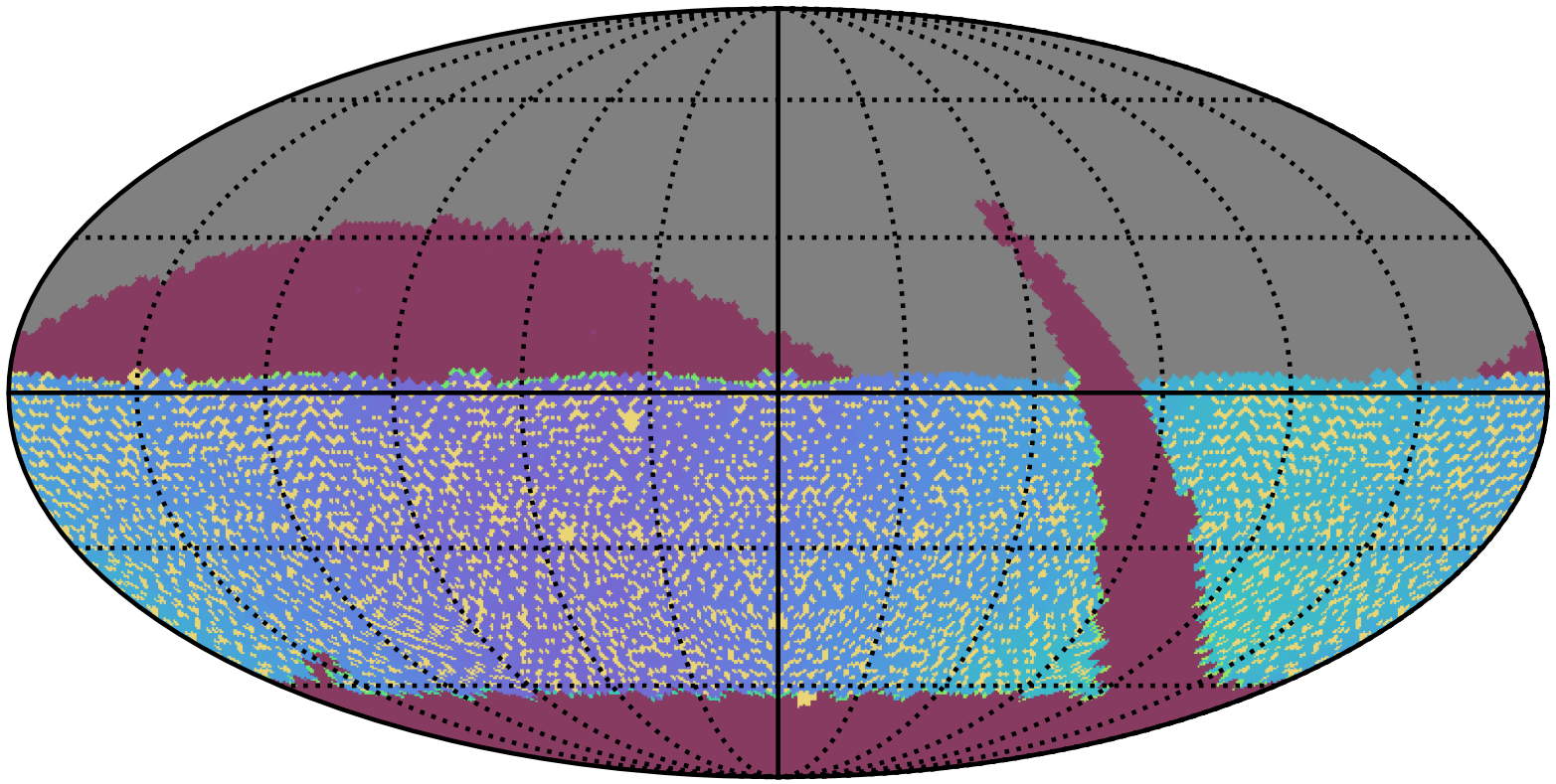

Number of visits in g, r and i filters (minion_1016)
75°
60°
45°
30°
15°
0°
-15°
-30°
-45°
-60°
-75°
North Ecliptic Spur
Galactic Plane
Deep Drilling Fields
Wide Fast Deep
South Celestial Pole
0
100
200
300
400
500
600
700
Number of visits

L. Jones

for the Solar System

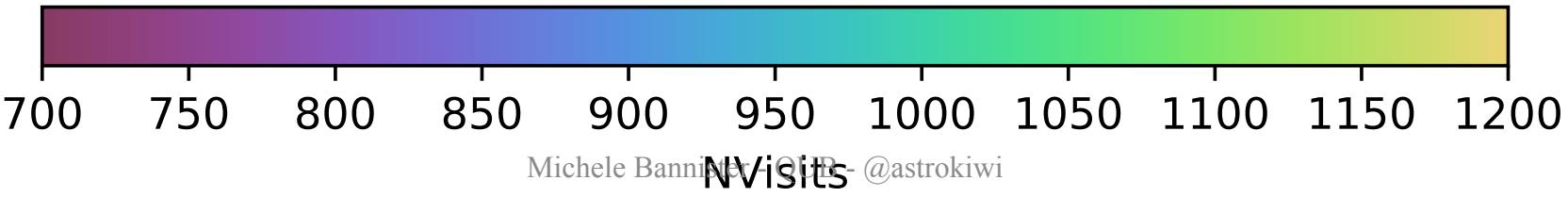
we have the potential

to survey the entire population



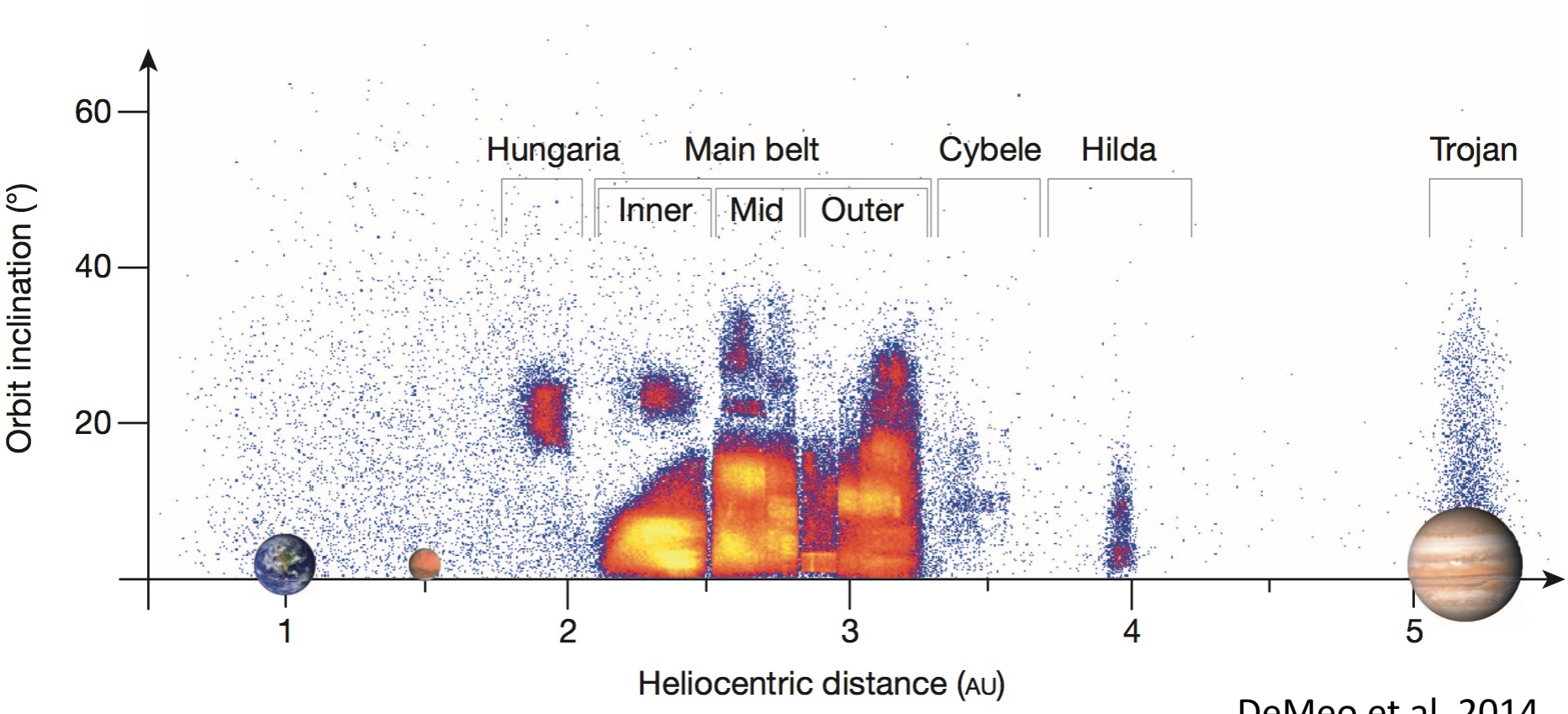
cadence: 2018A

Cost: about 5% of all survey time



active asteroids

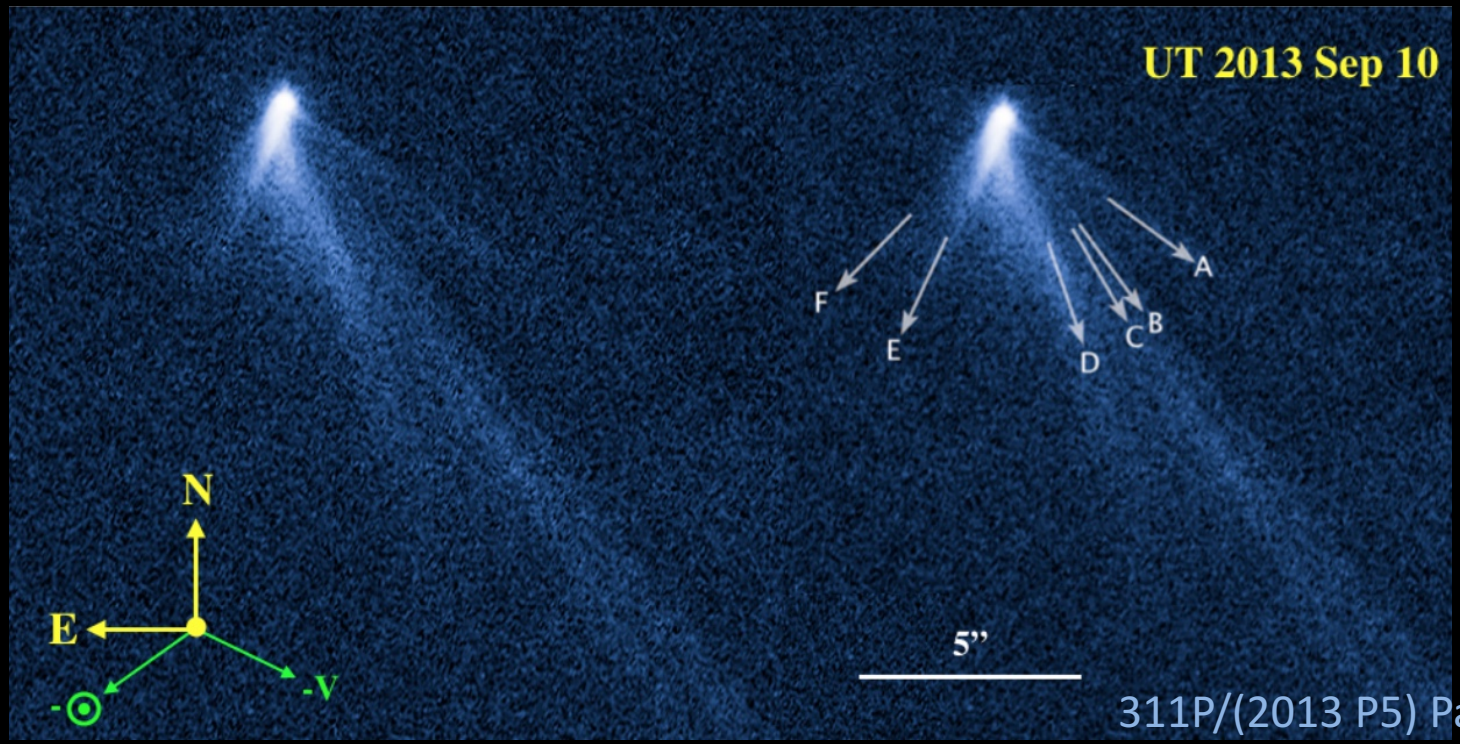
active asteroids
provide insight into
collisions, volatiles in the main belt



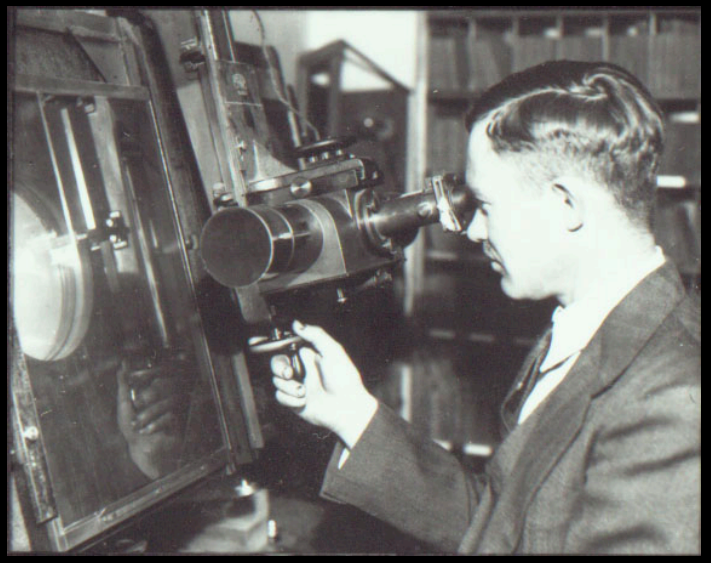
DeMeo et al. 2014

active asteroids

- one to a few events/year
- longitudinal events for main-belt comets
- full ecliptic coverage is critical

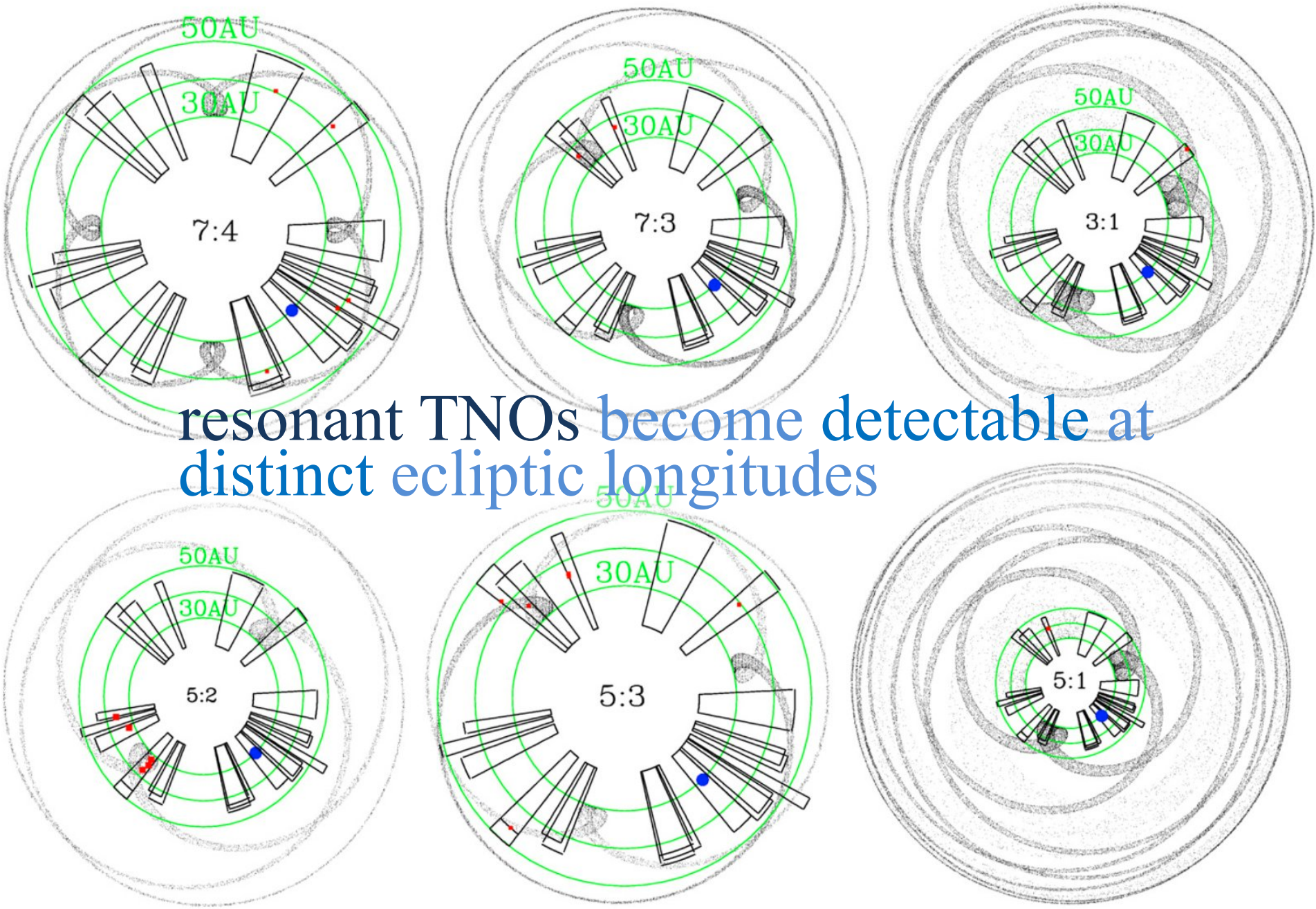


311P/(2013 P5) PanSTARRS
Jewitt et al. 2013, 2018



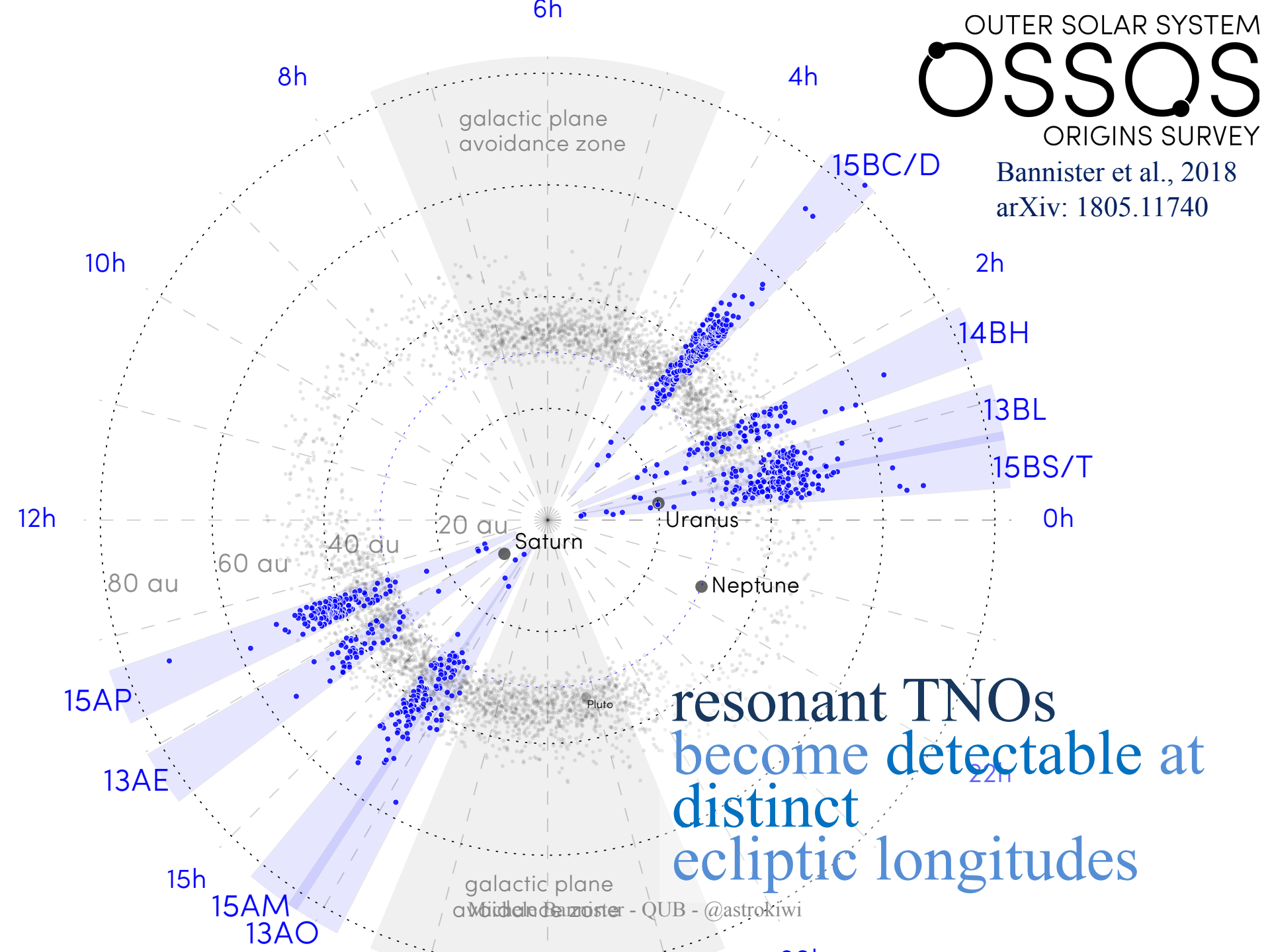
Observer: Clyde Tombaugh

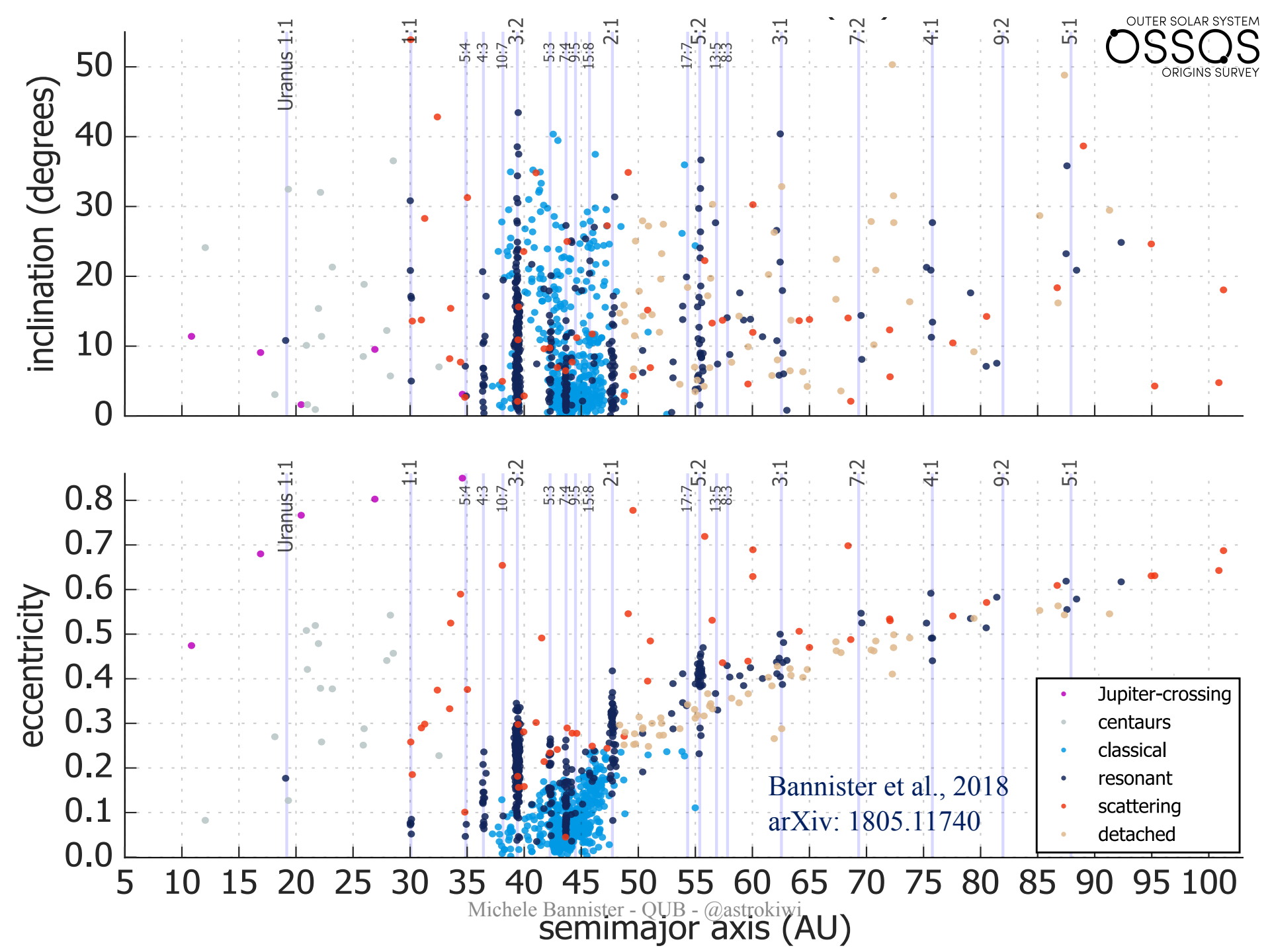
the distant minor planets
resonant populations

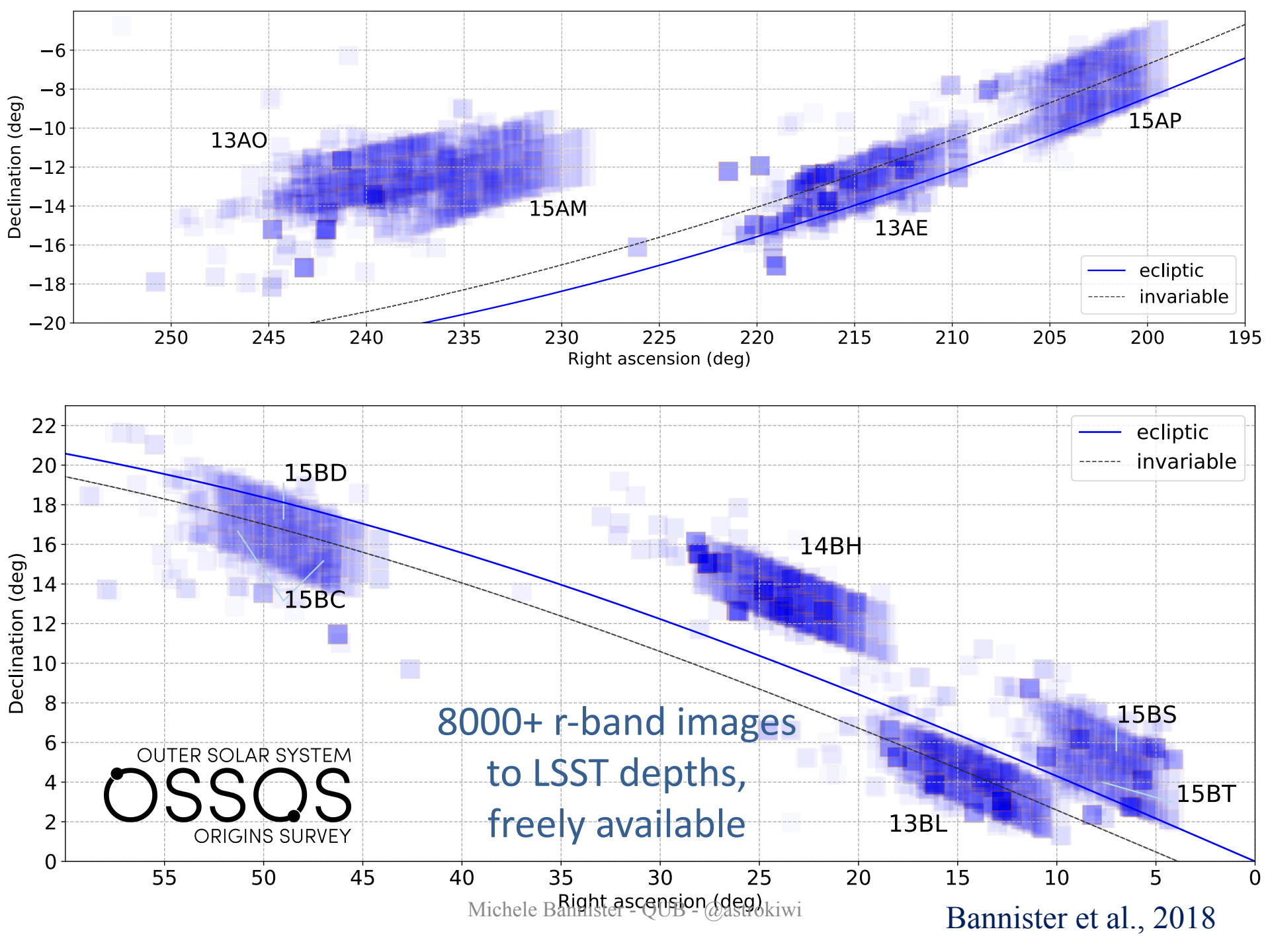


resonant TNOs become detectable at distinct ecliptic longitudes

Gladman et al. 2012


OUTER SOLAR SYSTEM
OSSOS
ORIGINS SURVEY
Bannister et al., 2018
arXiv: 1805.11740
6h
8h
4h
10h
2h
12h
0h
22h
15h
galactic plane
avoidance zone
galactic plane
avoidance zone
15BC/D
14BH
13BL
15BS/T
15AP
13AE
15AM
13AO
20 au
40 au
60 au
80 au
Saturn
Uranus
Neptune
Pluto
resonant TNOs
become detectable at
distinct
ecliptic longitudes
Michele Bannister - QUB - @astrokiwi


OUTER SOLAR SYSTEM
OSSOS
ORIGINS SURVEY
inclination (degrees)
eccentricity
semimajor axis (AU)
Uranus 1:1
1:1
5:4
4:3
10:7
3:2
5:3
7:4
9:5
15:8
2:1
17:7
5:2
13:5
8:3
3:1
7:2
4:1
9:2
5:1
Jupiter-crossing
centaurs
classical
resonant
scattering
detached
Bannister et al., 2018
arXiv: 1805.11740
Michele Bannister - QUB - @astrokiwi


13AO
15AM
13AE
15AP
ecliptic
invariable
Declination (deg)
Right ascension (deg)
15BD
15BC
14BH
15BS
15BT
13BL
8000+ r-band images
to LSST depths,
freely available
OUTER SOLAR SYSTEM
OSSOS
ORIGINS SURVEY
Michele Bannister - QUB - @astrokiwi
Bannister et al., 2018

Knowing what we don't see is equally important

Discovery bias:

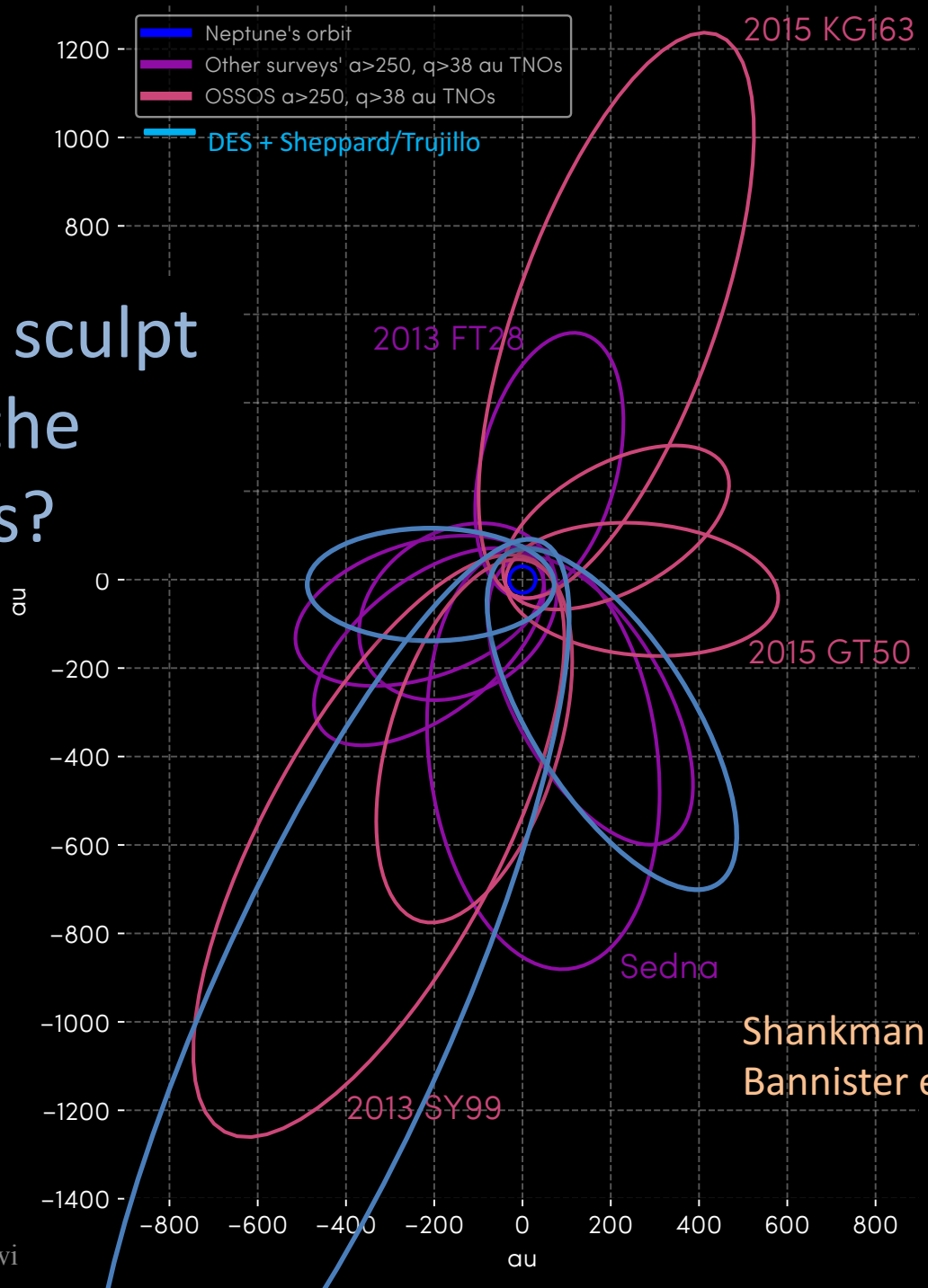
- single epochs will vary in depth
- sky coverage is not the whole sky
  - we need the North Ecliptic Spur to happen!

Tracking (ephemeris) bias:

- unusual orbits are harder to link & can be lost
  - expect the first 1-2 years to be a little patchy

a distant planet?

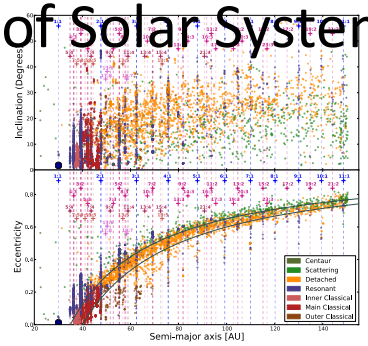
does a planet sculpt the orbits of the extreme TNOs?



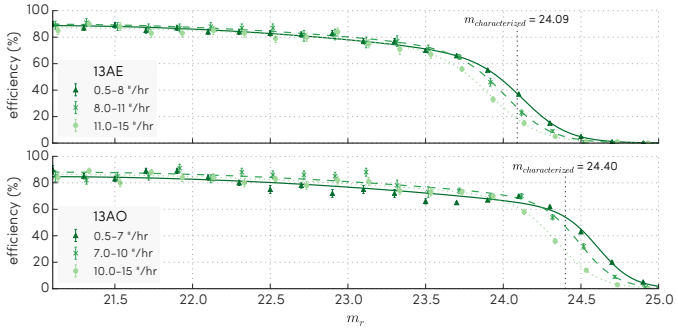
Shankman et al. 2017
Bannister et al. 2018

A solid framework to **test** dynamical ideas

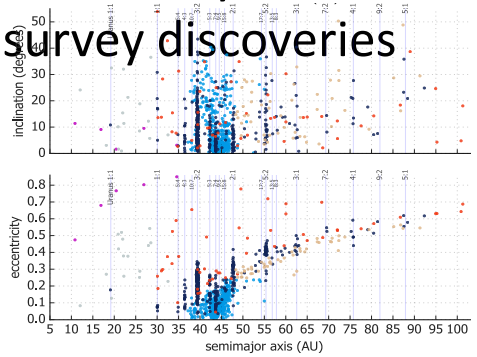
1. Create a model distribution of Solar System orbits



2. Use a Survey Simulator to "observe" your model via precisely calibrated detection sensitivities

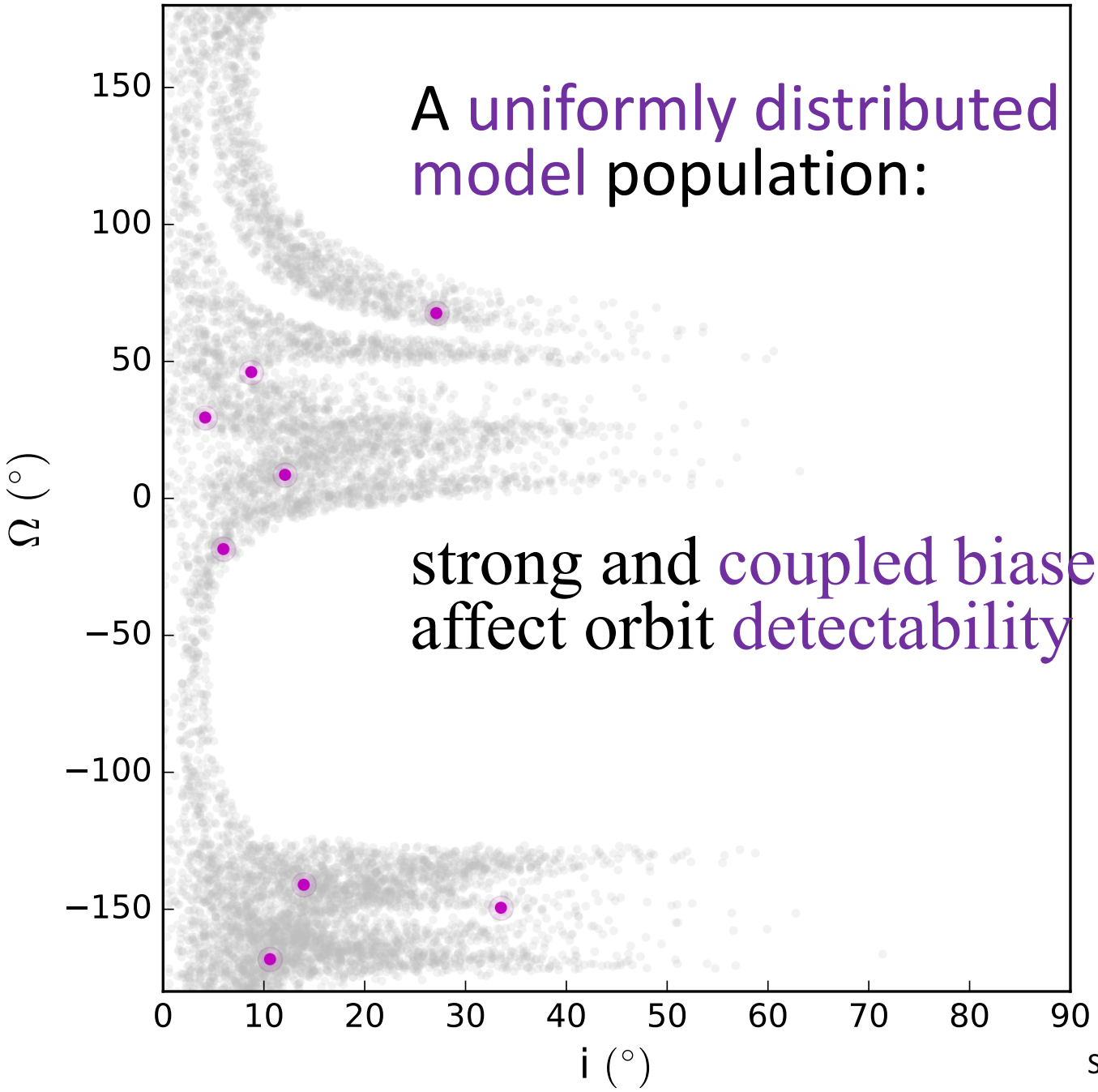


3. Choose your statistical test: compare what's detectable in your model to the survey discoveries



https://github.com/OSSOS/SurveySimulator

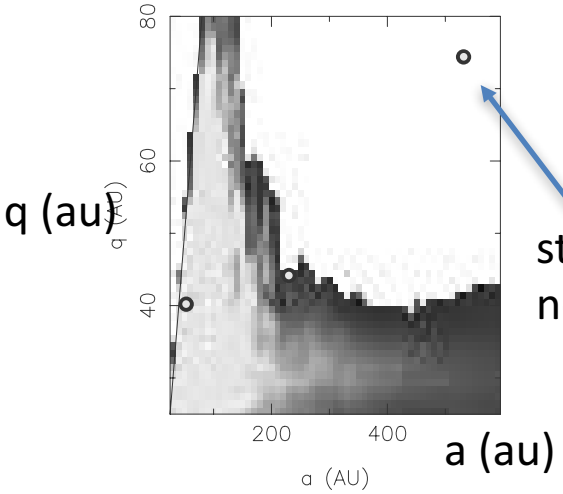
OUTER SOLAR SYSTEM
OSSOS
ORIGINS SURVEY



Shankman et al., 2017
arXiv:1706.05348

How to make the strangely distant TNOs?

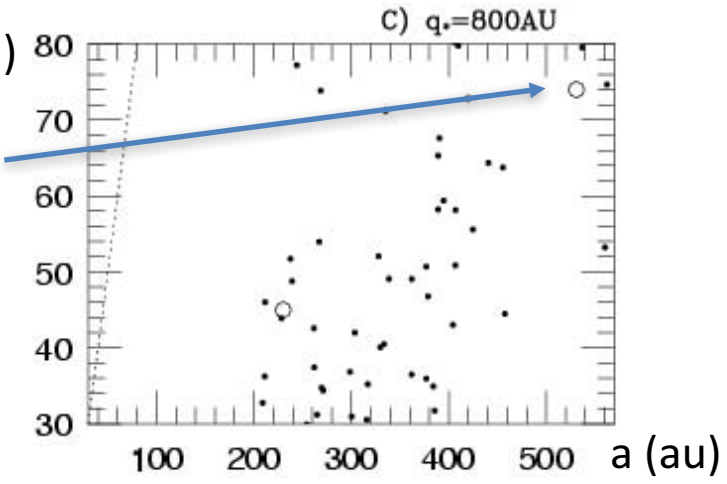
- an extra planet? (Gladman et al. 2002, Brown et al. 2004, Gomes et al. 2006)
  - a rogue: once orbiting, gone now (Gladman & Chan 2006)
  - present-day planet? (Brown 2004, Gomes et al. 2006, Soares & Gomes 2013, Sheppard & Trujillo 2014, Batygin & Brown 2016, half the community in 2016-2017)
- capture from another star's system? ((Kenyon & Bromley 2004; Jílková et al. 2015)
- a stellar flyby? (Kenyon & Bromley 2004; Morbidelli & Levison 2004, Kaib et al. 2009)
- perturbations in the Sun's birth cluster? (Brasser et al. 2012, Brasser & Schwamb 2014)
- self-gravitation in the planetesimal disk (Madigan & McCourt 2016)
- diffusion from the inner Oort cloud? (Bannister et al. 2017)



stirred disk:
no Sedna

Morbidelli & Levison, 2004

passing star:
makes Sedna



Conclusions

We need the North Ecliptic Spur survey.

- ensure good coverage of active asteroids
- only way to map most distant minor planets!
- mitigate many observing biases on TNOs
- confirm:
  - how Neptune migrated
  - the creation of detached orbits: an unseen planet?