Preliminary Results from CLASSY:

Lots of little cold classicals, and maybe a distant TNO

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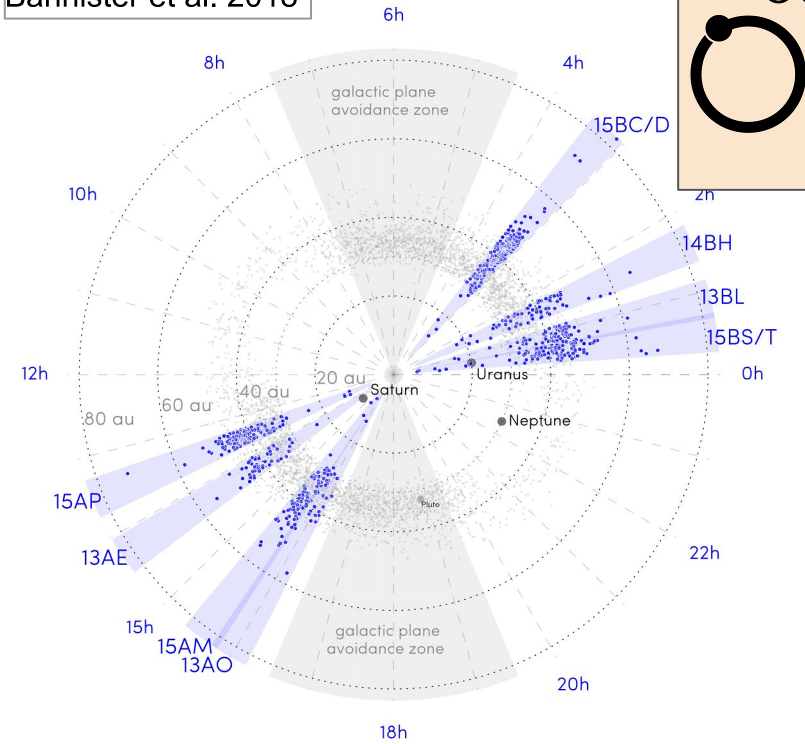
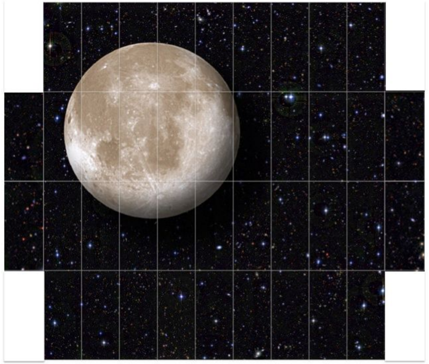
Christa Van Laerhoven (RASC)
Kat Volk (PSI)
Shiang-Yu Wang (ASIAA)

Bannister et al. 2018



OUTER SOLAR SYSTEM
OSSOS
ORIGINS SURVEY

1 square degree FOV



- Both surveys build on the framework of OSSOS/CFEPS (early 2000s-now).
- Using Megacam on CFHT, queue-observing
- CLASSY will be “well-characterized”: we know all our biases and can account for them in simulations. Currently in **preliminary** data reduction stage

OUTER SOLAR SYSTEM
OSSOS
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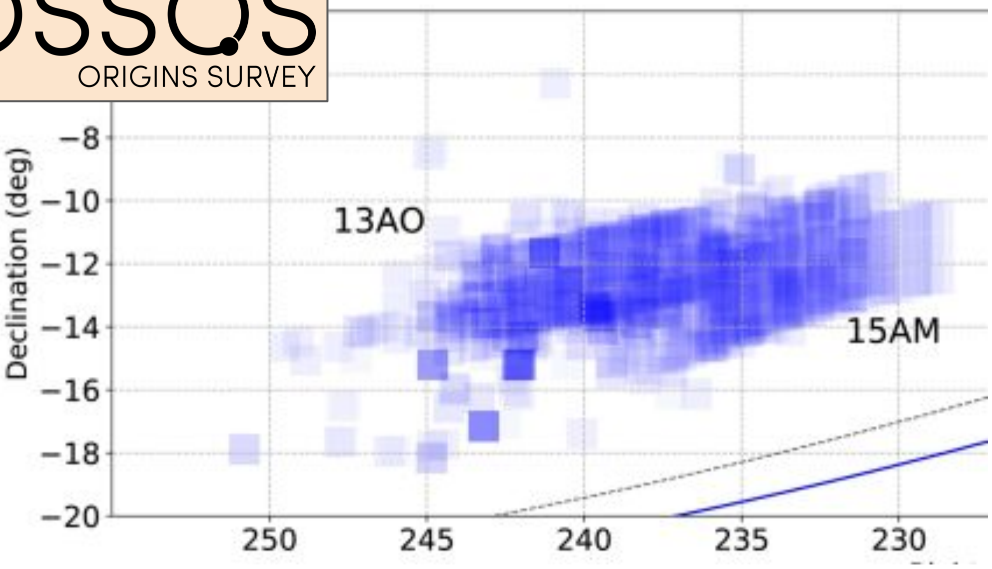
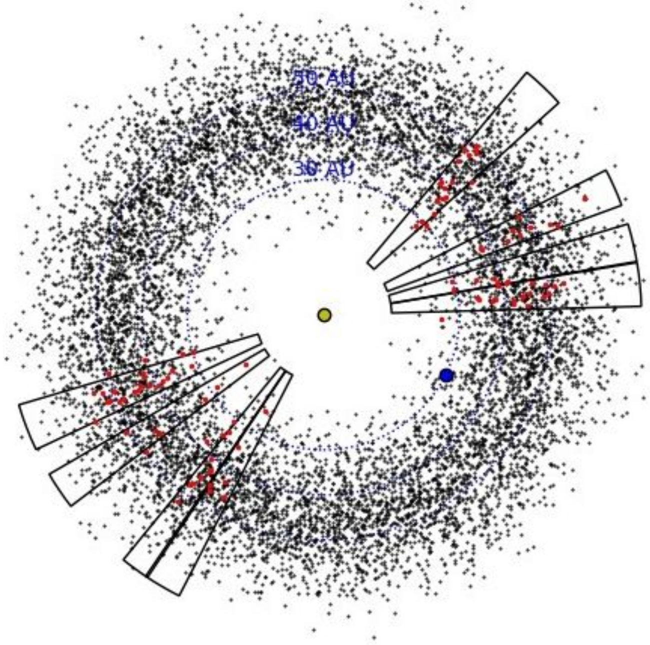
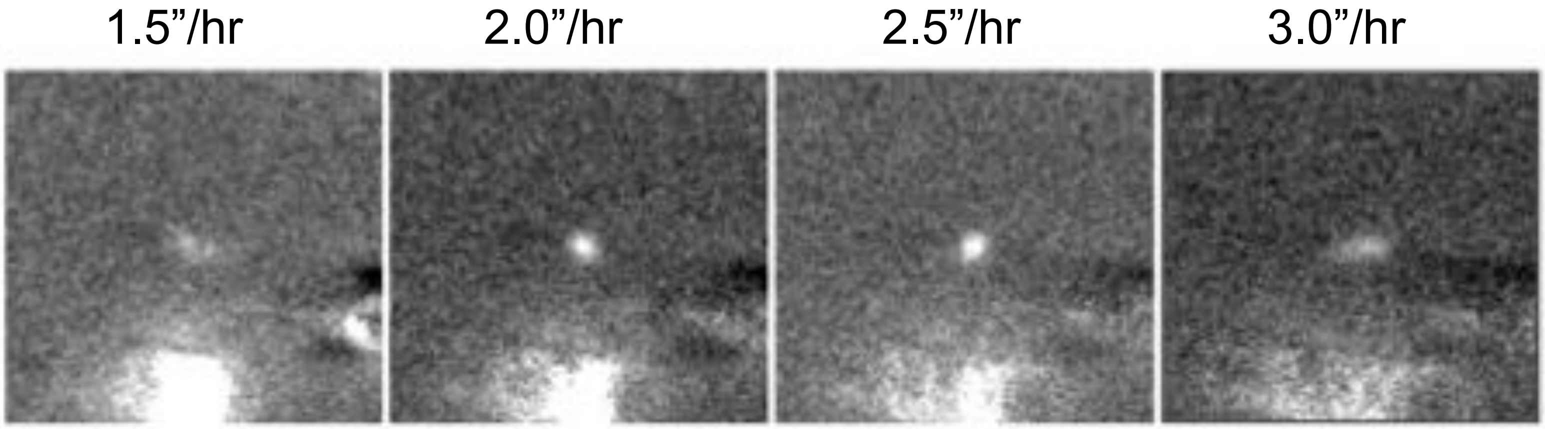




Each survey block has a known magnitude limit, sky coverage, date of observation, detection efficiency, and tracking efficiency.

This lets us **debias** our measurements - how many TNOs with what size distribution in each subpopulation are required to match our detections in orbital elements and magnitude?

CLASSY = deeper OSSOS



By shifting and stacking observations taken over the course of ~3-5 hours on CFHT, we should be able to go to much deeper magnitude limits

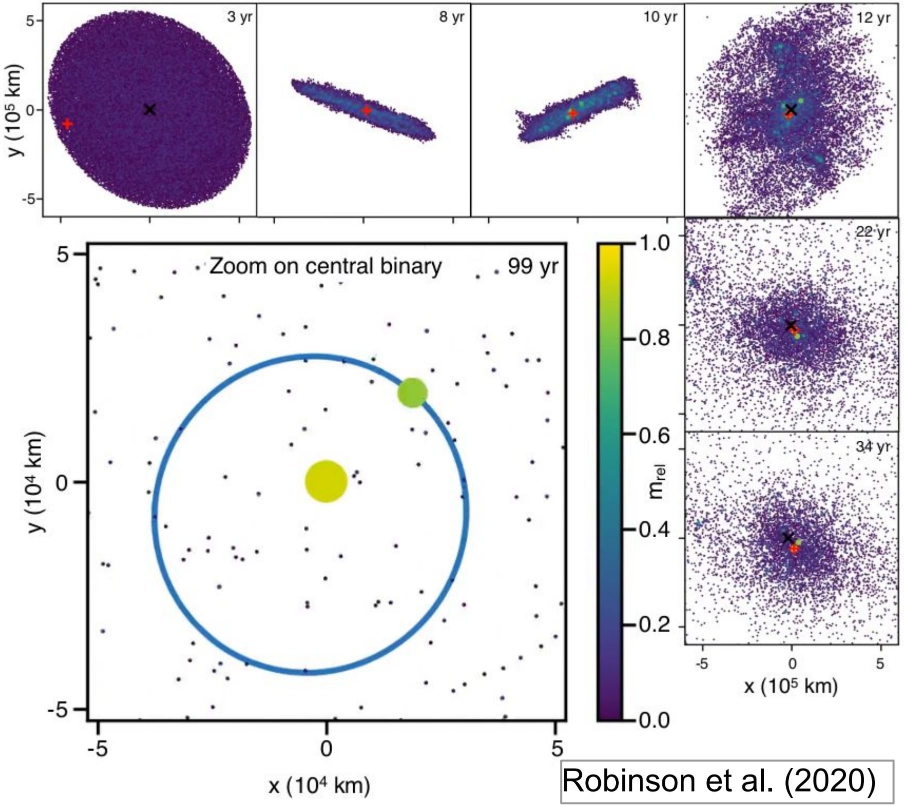
Goal: find **smaller** and **more distant** TNOs

CLASSY science goal #1:
Cold Classical size distribution

Predict we'll detect ~400 cold classical TNOs

Cold classicals so far are consistent with pebble collapse simulations

What does the size distribution of the smaller pieces look like?



Robinson et al. (2020)

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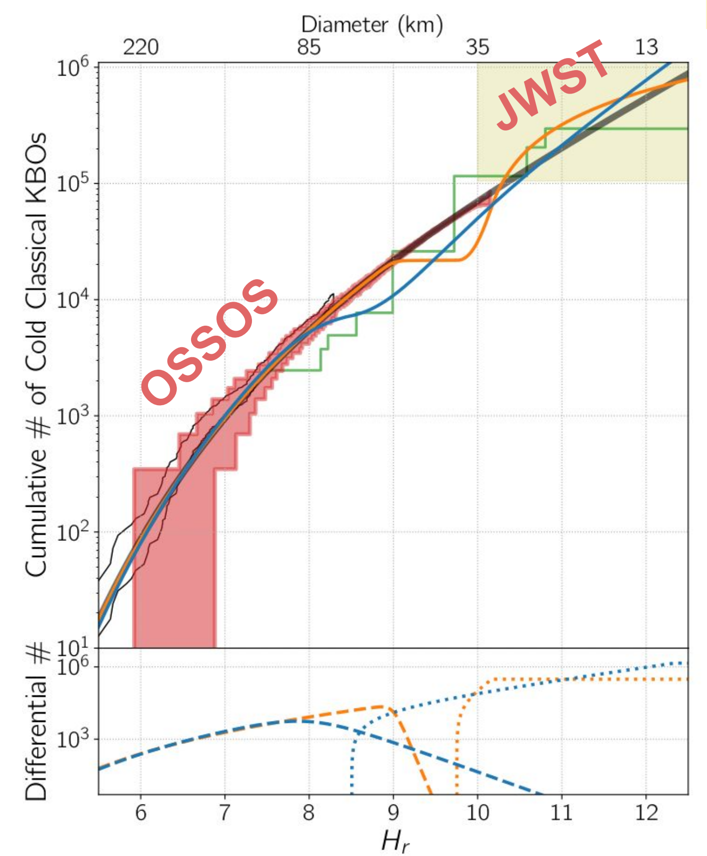

Based on Kavelaars et al. (2021)

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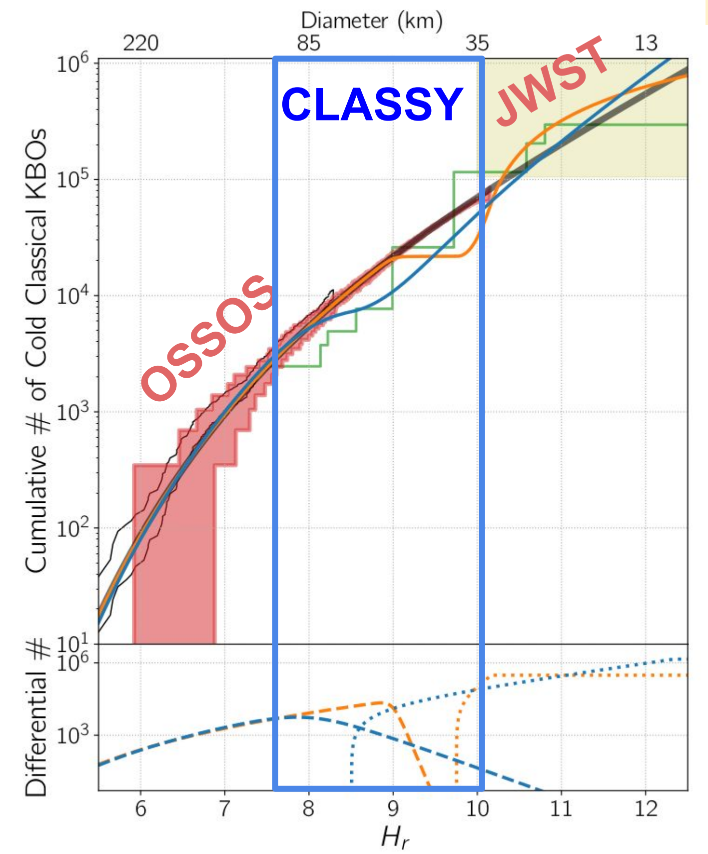


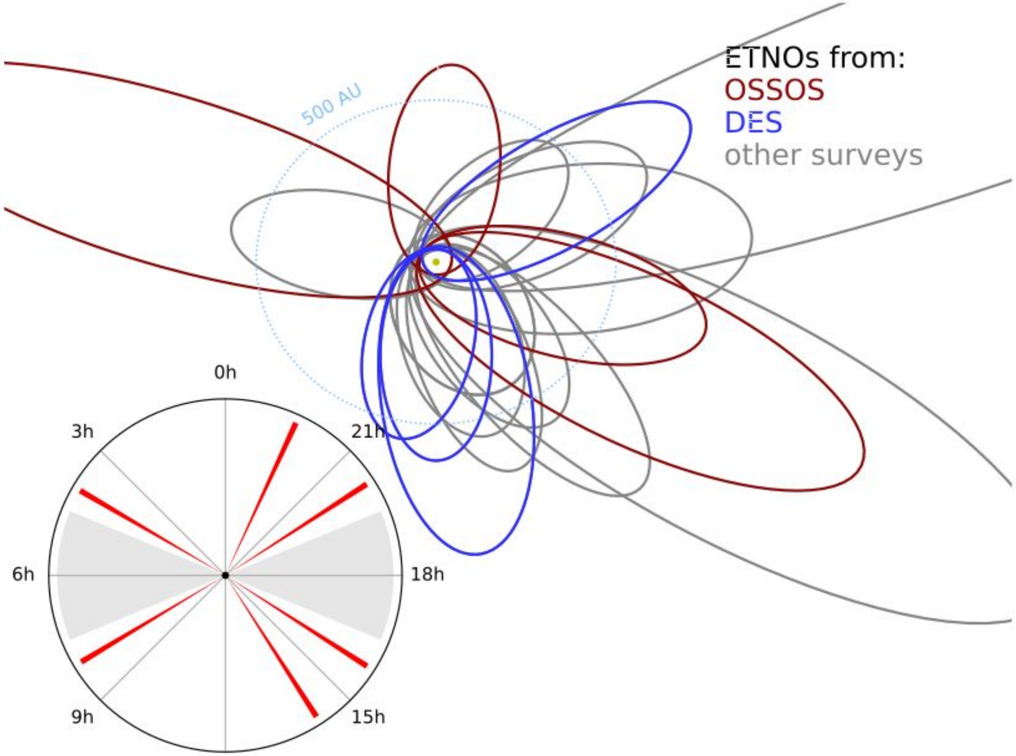
Based on Kavelaars et al. (2021)

CLASSY science goal #2:
Find distant TNOs all around Solar System

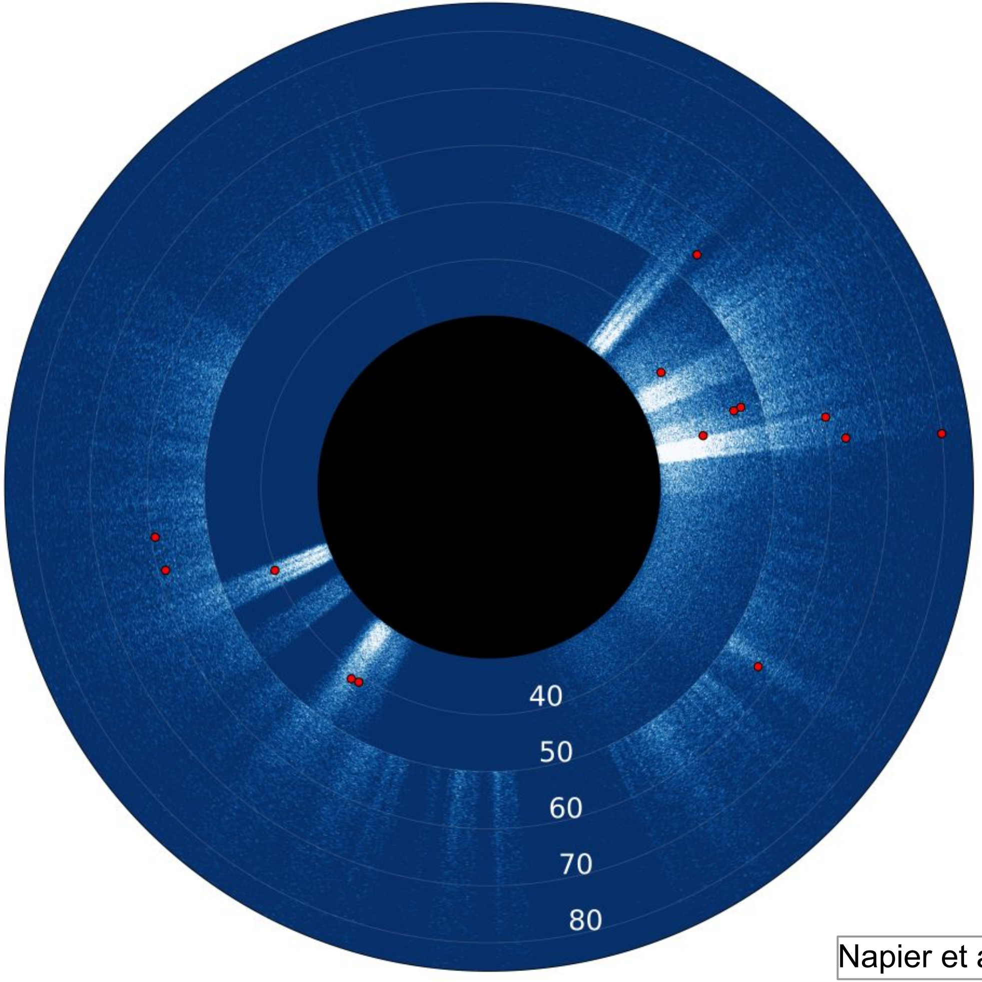
Fairly equally spaced discovery blocks around ecliptic

Each block has similar depths, will (hopefully!) have similar tracking fractions

Could find a few ETNOs per pointing. Any patterns in the distribution?



You find high-q TNOs where you look for them.



Weather, Milky Way, telescope pressure all effect what parts of sky have been searched effectively

Napier et al. (2021)

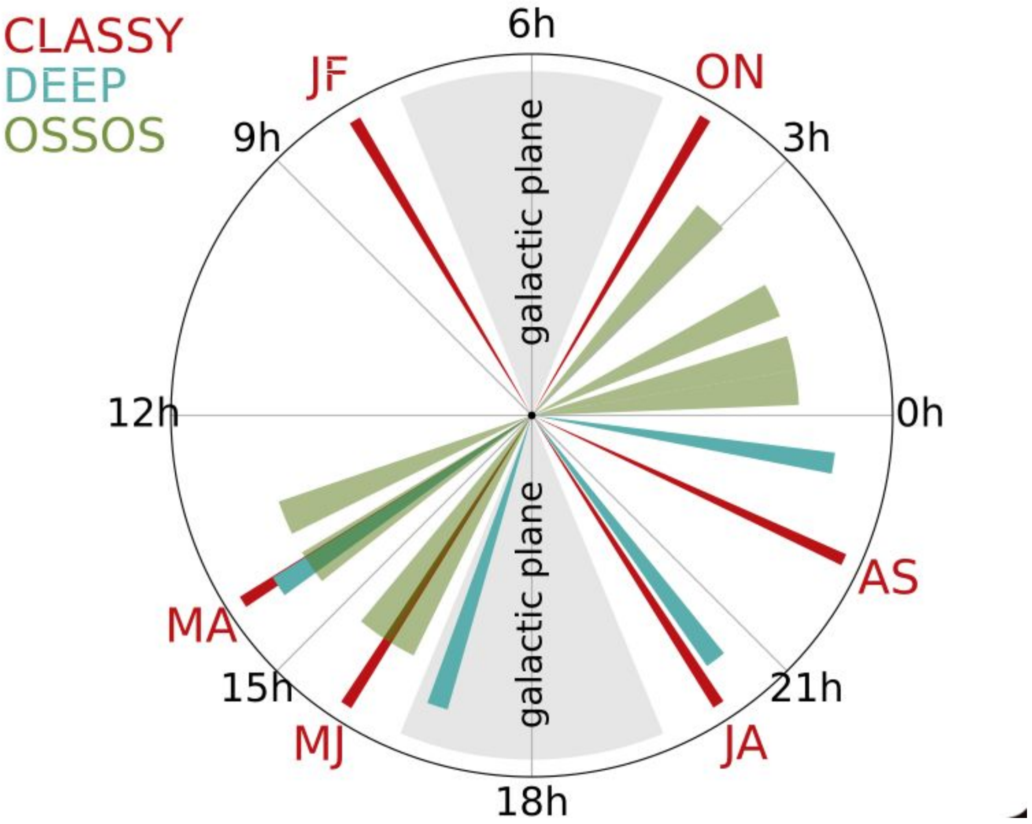
CLASSY's strategy: look in all directions (except the Milky Way).

Complement rather than duplicate DEEP (tiny bit of overlap with 1 OSSOS block, maybe one DEEP block, good sanity check!)

Will require a bit of luck to have excellent observing conditions in winter on Maunakea, but so far so good!

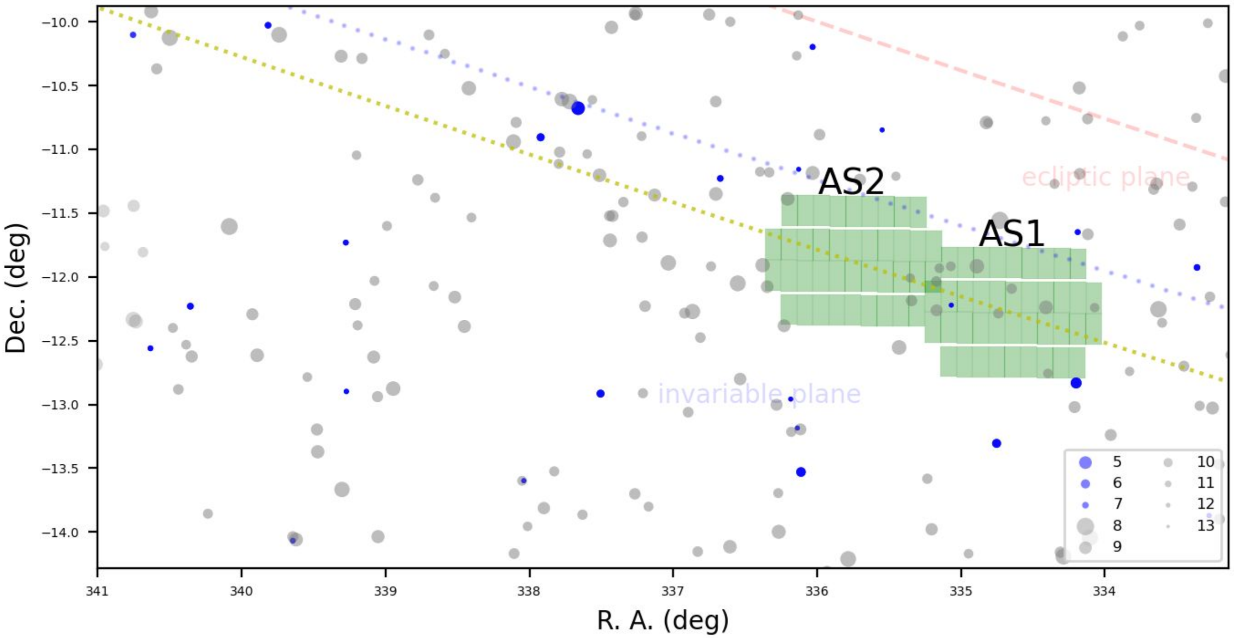
Observing started Aug 2022

Discovery sets all successful!



CLASSY discovery strategy

Highest density of TNOs will not be on the ecliptic plane, or the invariable plane, but on the “forced plane” (Huang, Gladman, & Volk 2022) - varies with distance and longitude



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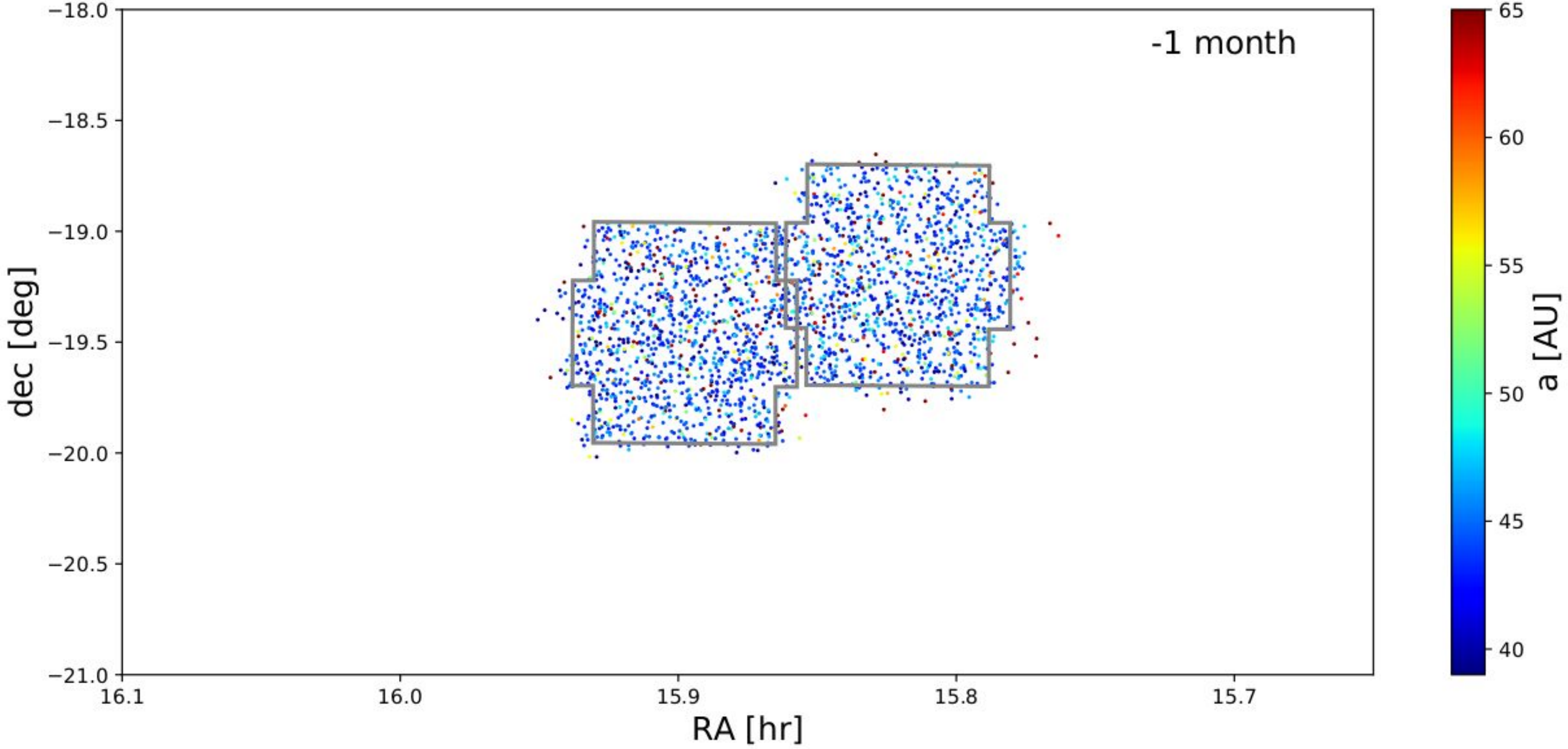

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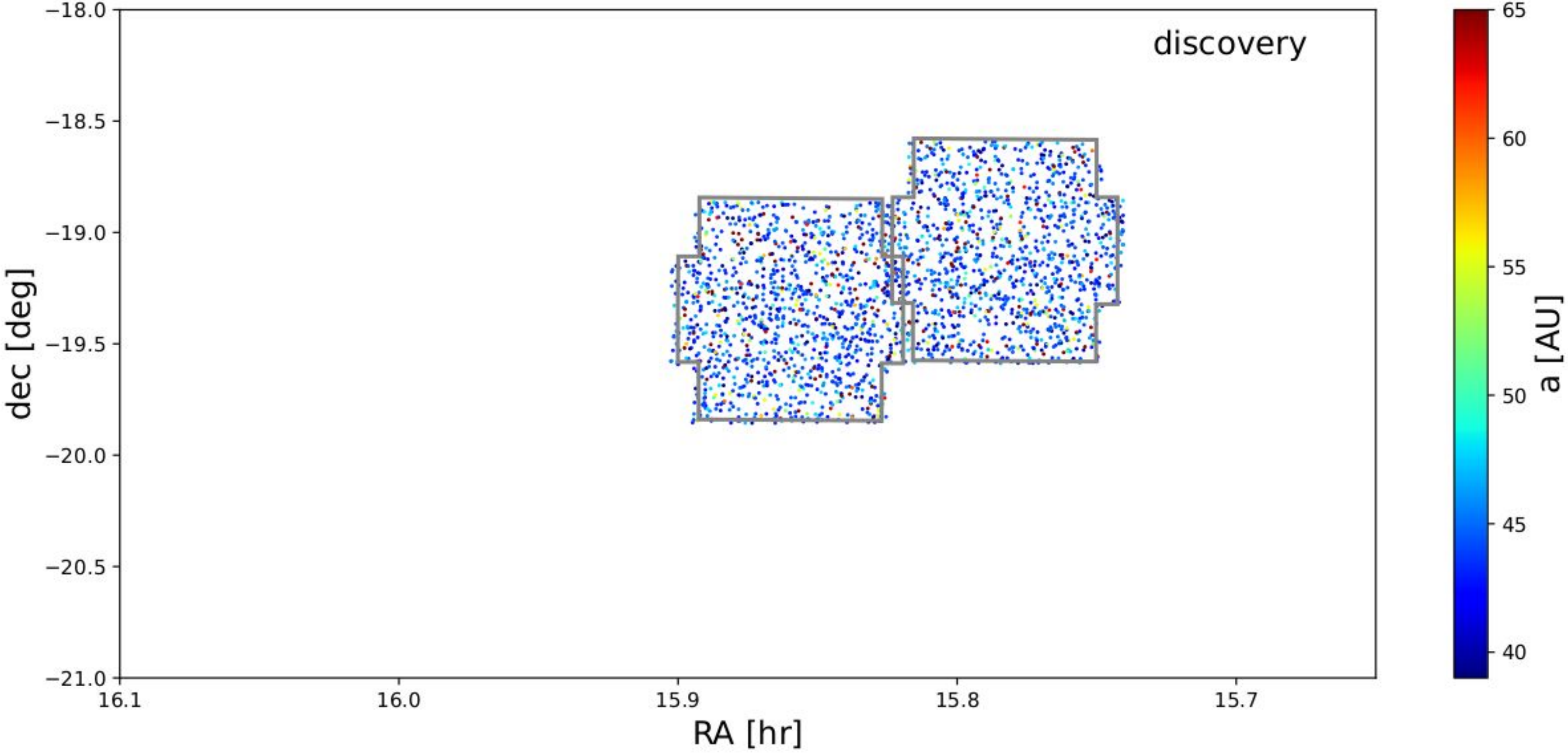
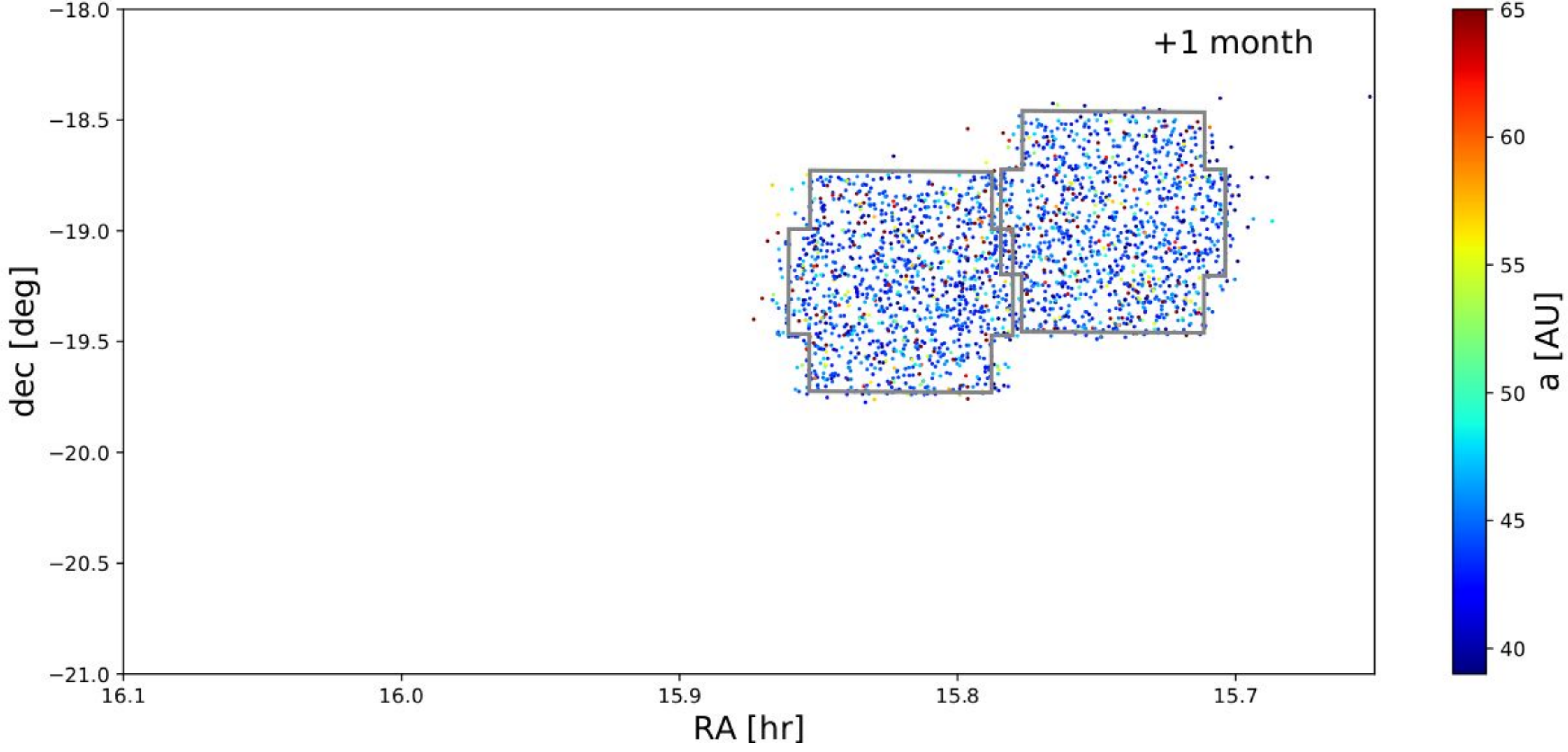


CLASSY discovery strategy



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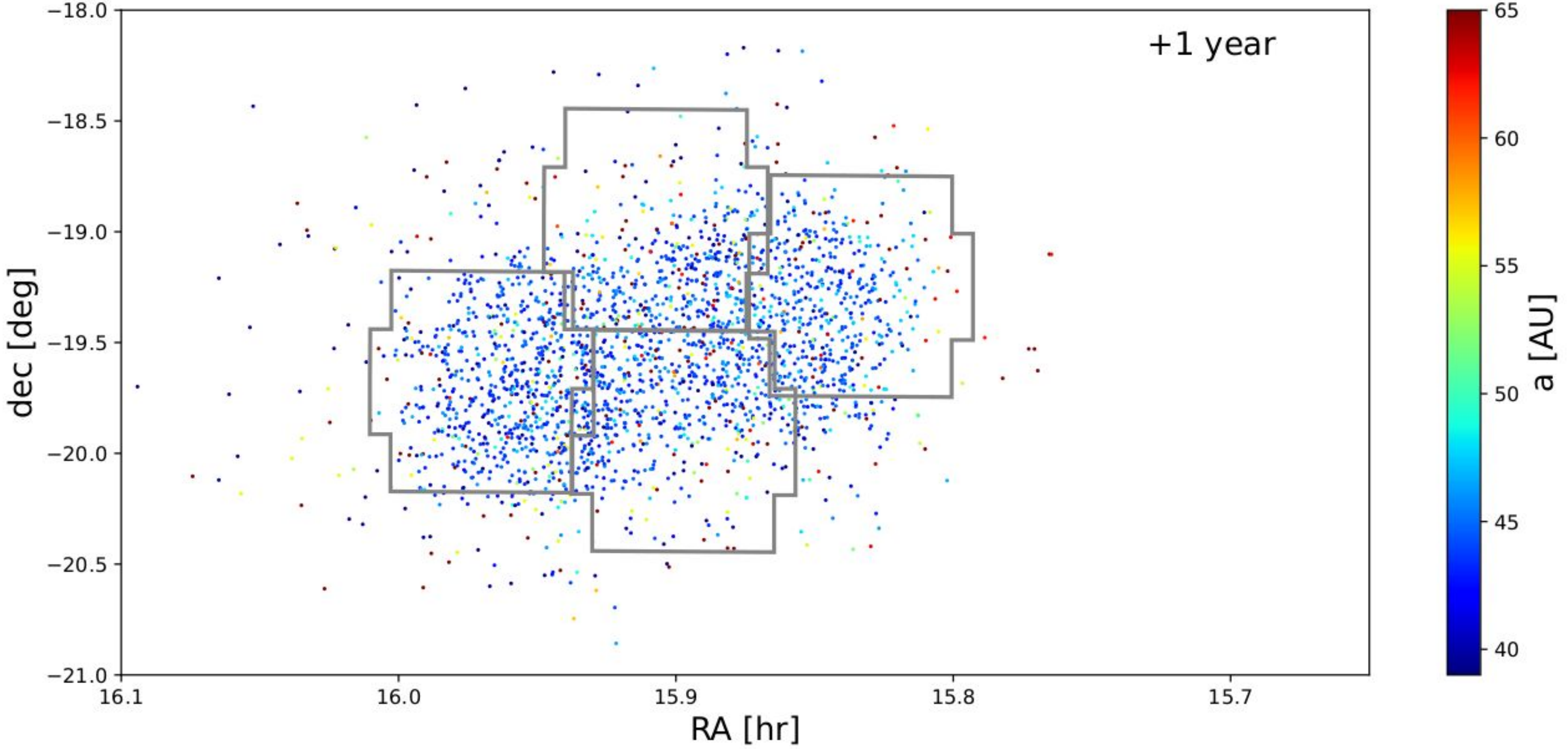

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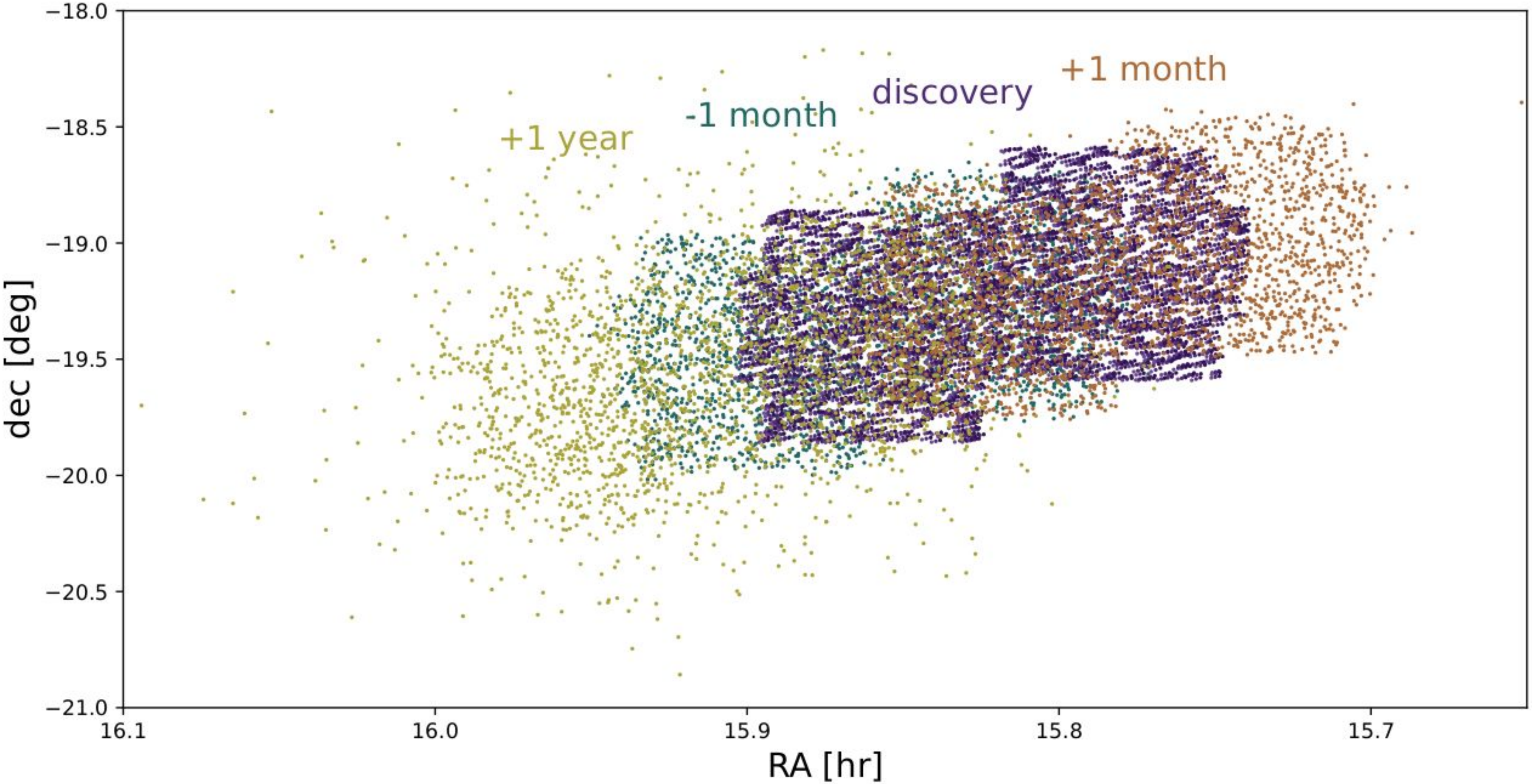

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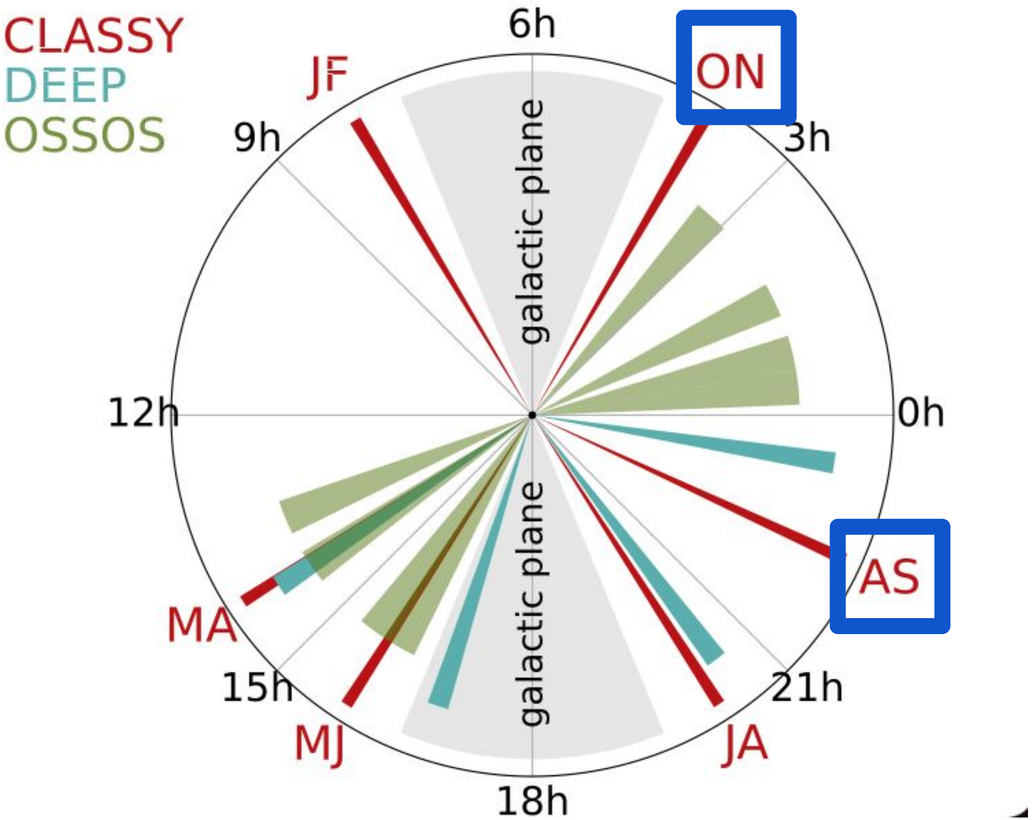
"+1 year follow-ups" in progress:



The pipeline

Based on New Horizons DKBO search

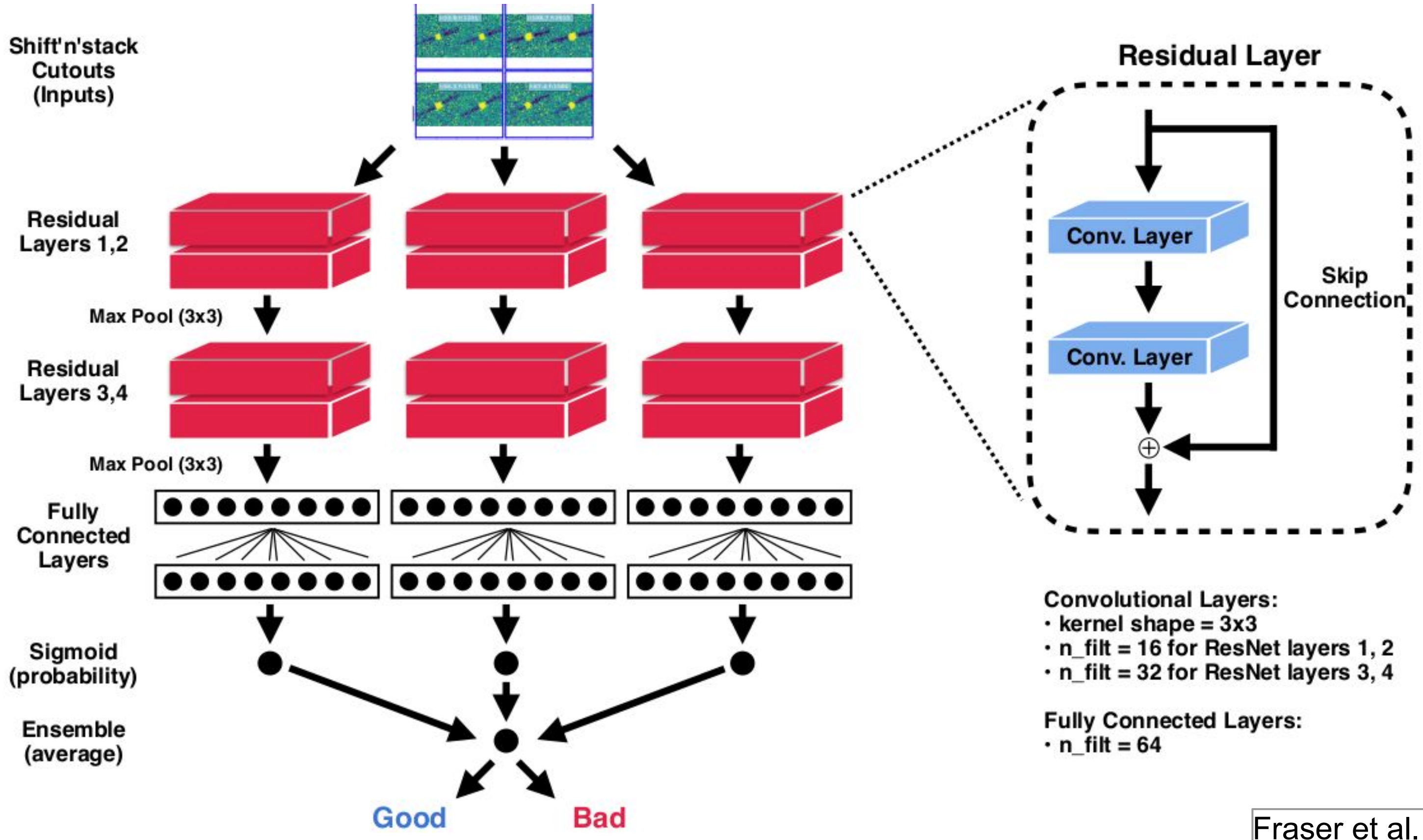
Nightly:

- CADC Megapipe for photometric and astrometric calibrations (Gwyn 2008)
- TRailed Image Photometry in Python (TRIPPY) for artificial source implantation (Fraser et al. 2016)
- LSST pipeline (v19) for image subtraction
- KBmod for shift and stack detections (Whidden et al. 2019)
- ResNet for good/bad source rejection (New Horizons DKBO search)
- Human vetting to clean up rare obvious garbage sources
- Repeat 1-6 for randomized-time implanted sources

Discovery Lunation:

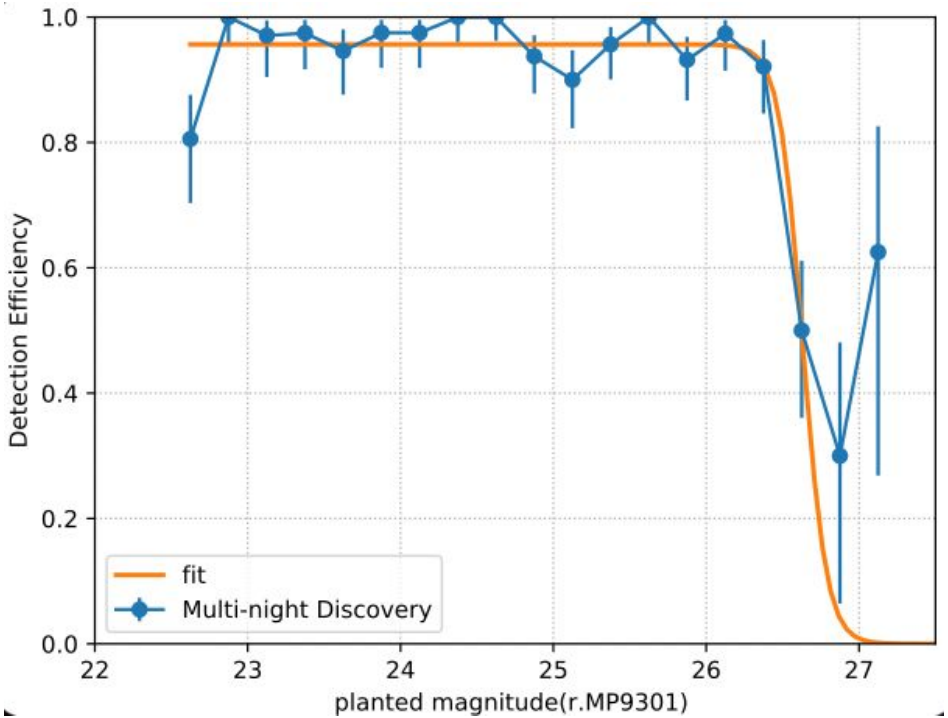
- Source grouping

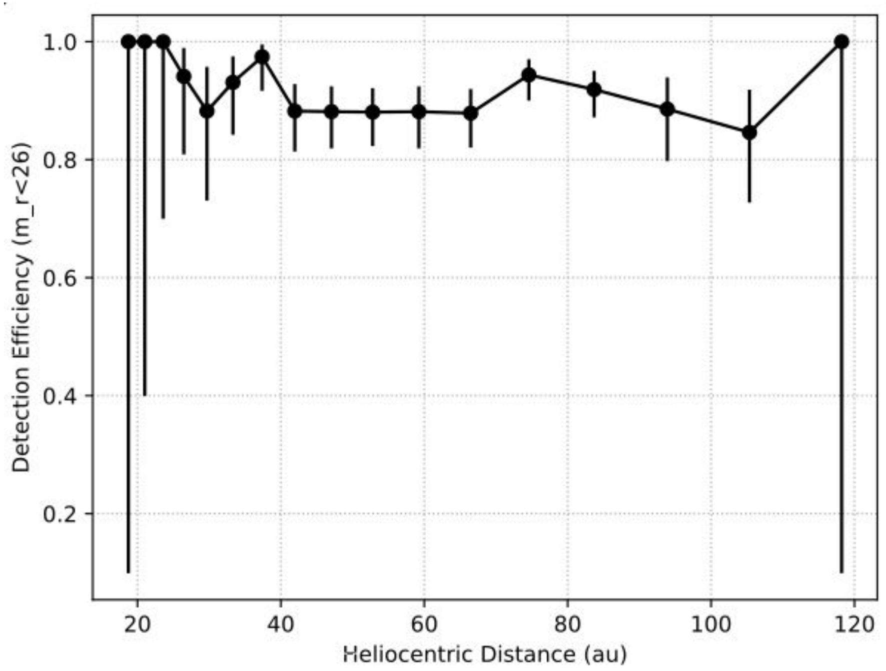
The Residual Network



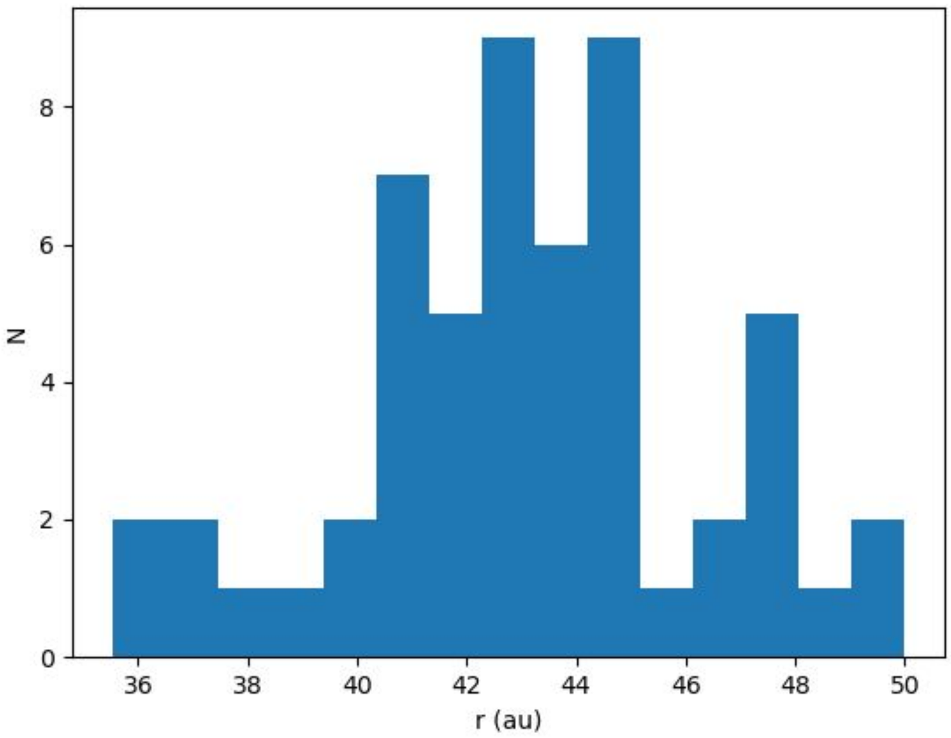
Fraser et al. in prep.

Initial detection efficiencies





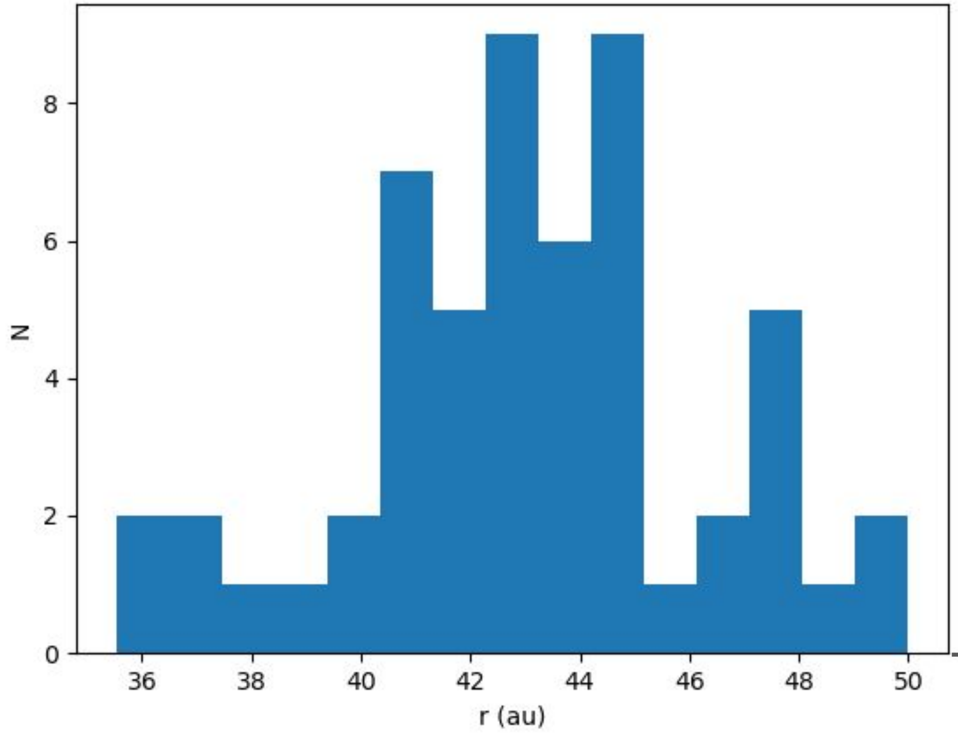
PRELIMINARY discoveries for AS1 pointing



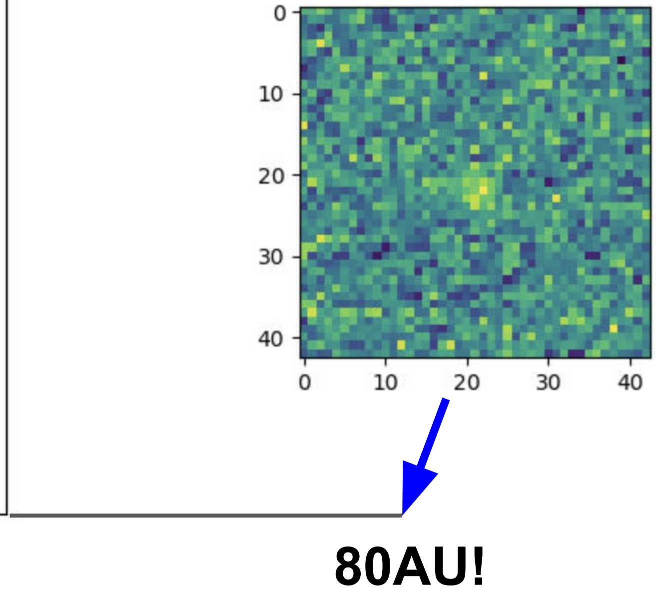
From discovery triplets

Now in the process of linking to +1 month and -1 month

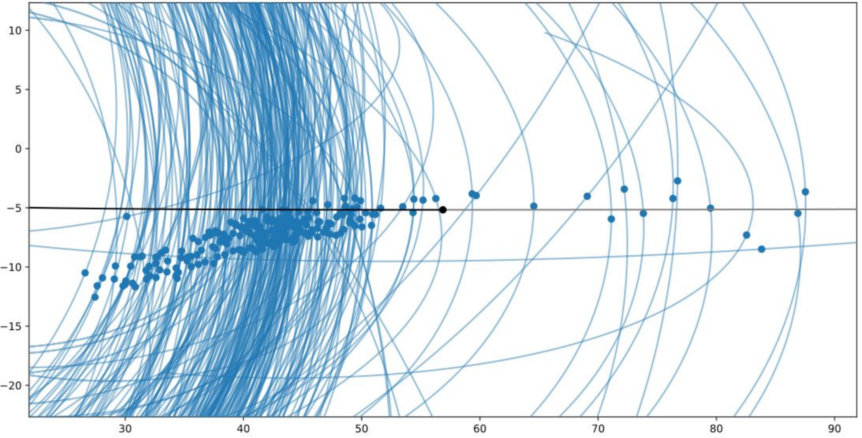
PRELIMINARY discoveries for AS1 pointing



Very preliminary from single-night shift-n-stack (one night with EXCELLENT seeing)

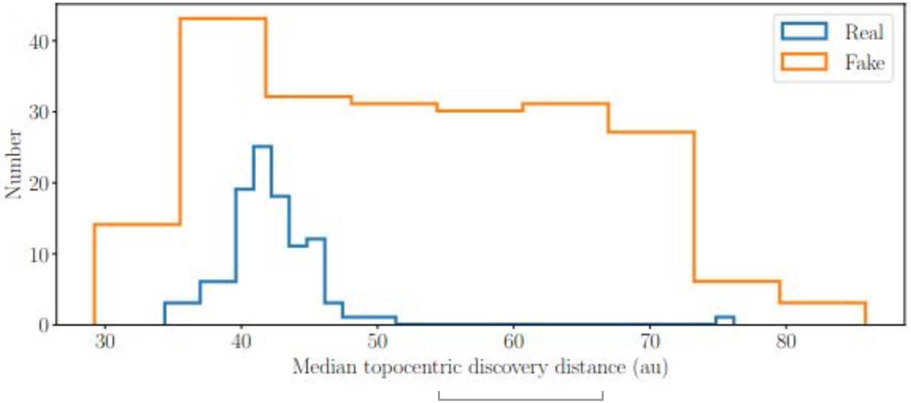


Previous deep TNO search data



S. Porter

NH distant TNO search

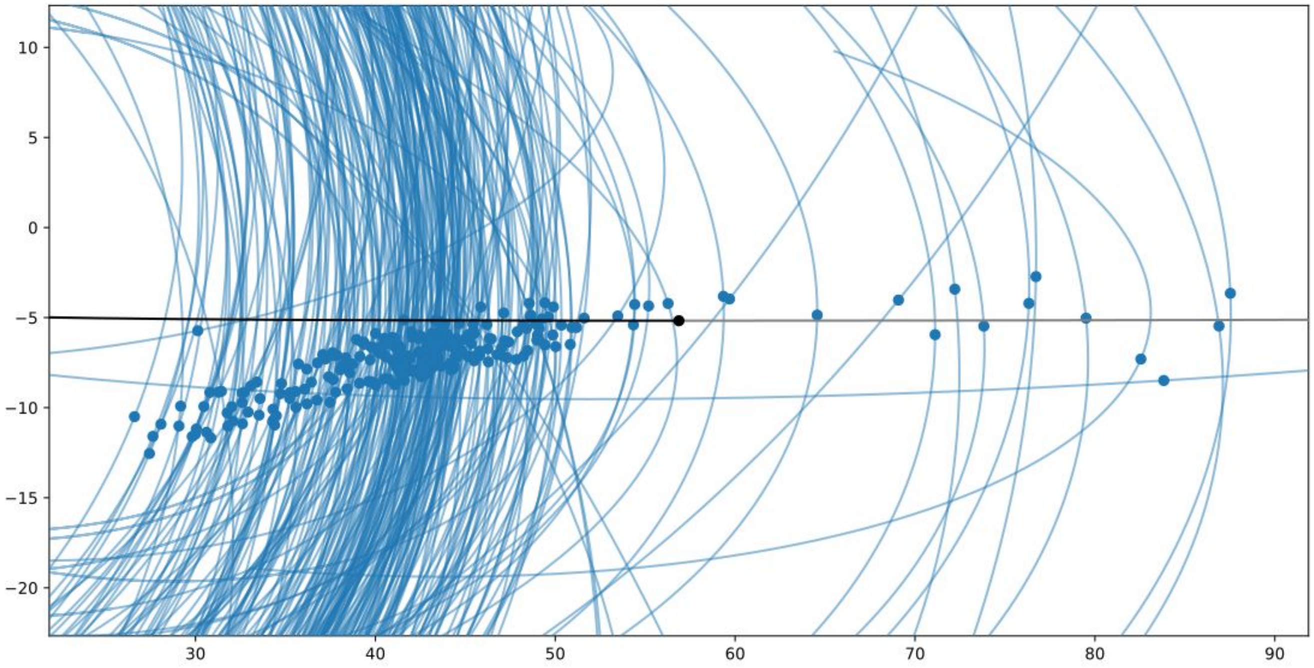


Smotherman et al. 2023

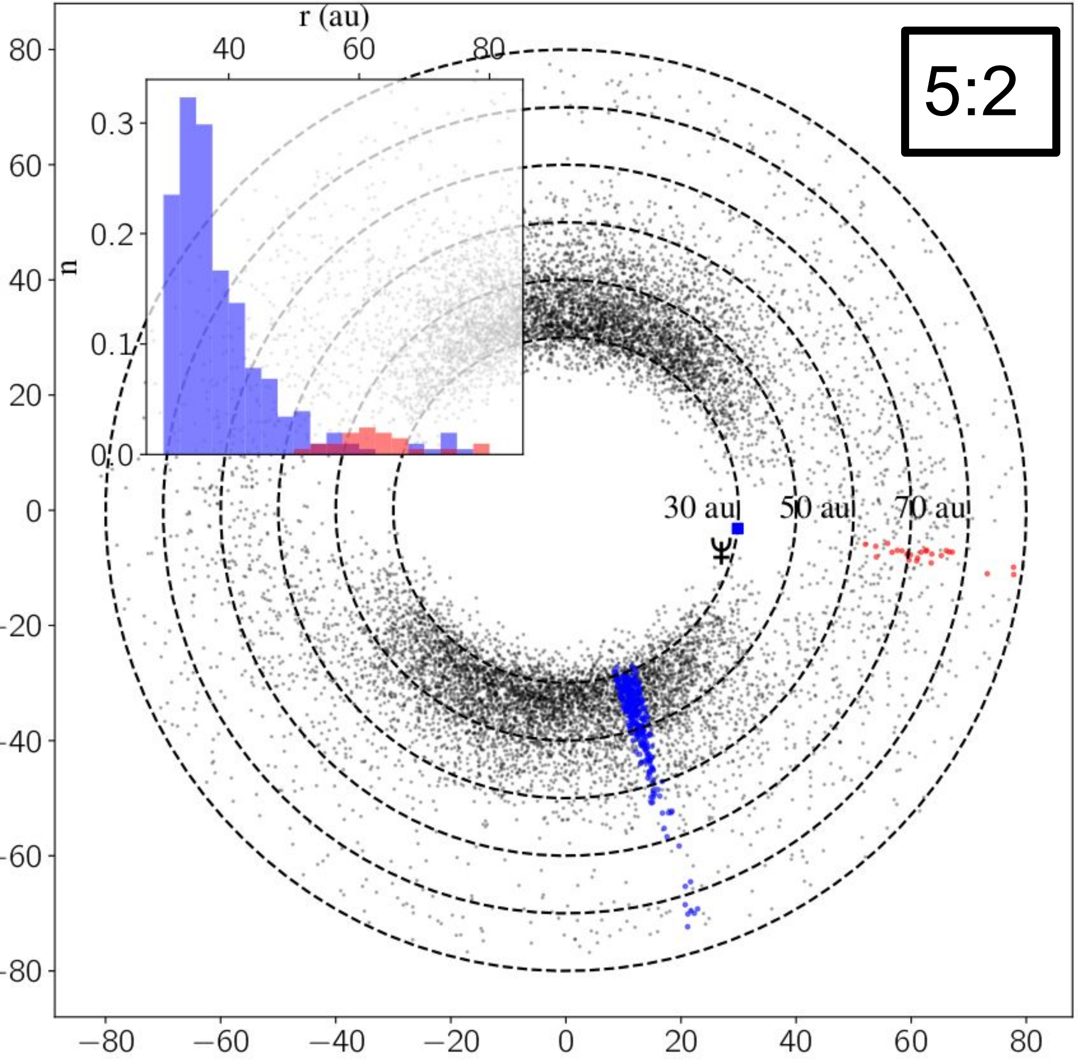
DEEP Survey

What does this mean if real?

Lots of distant TNOs! What are their orbits?



S. Porter



The distant resonant populations might be able to account for the distant detections

Fraser et al. in prep.

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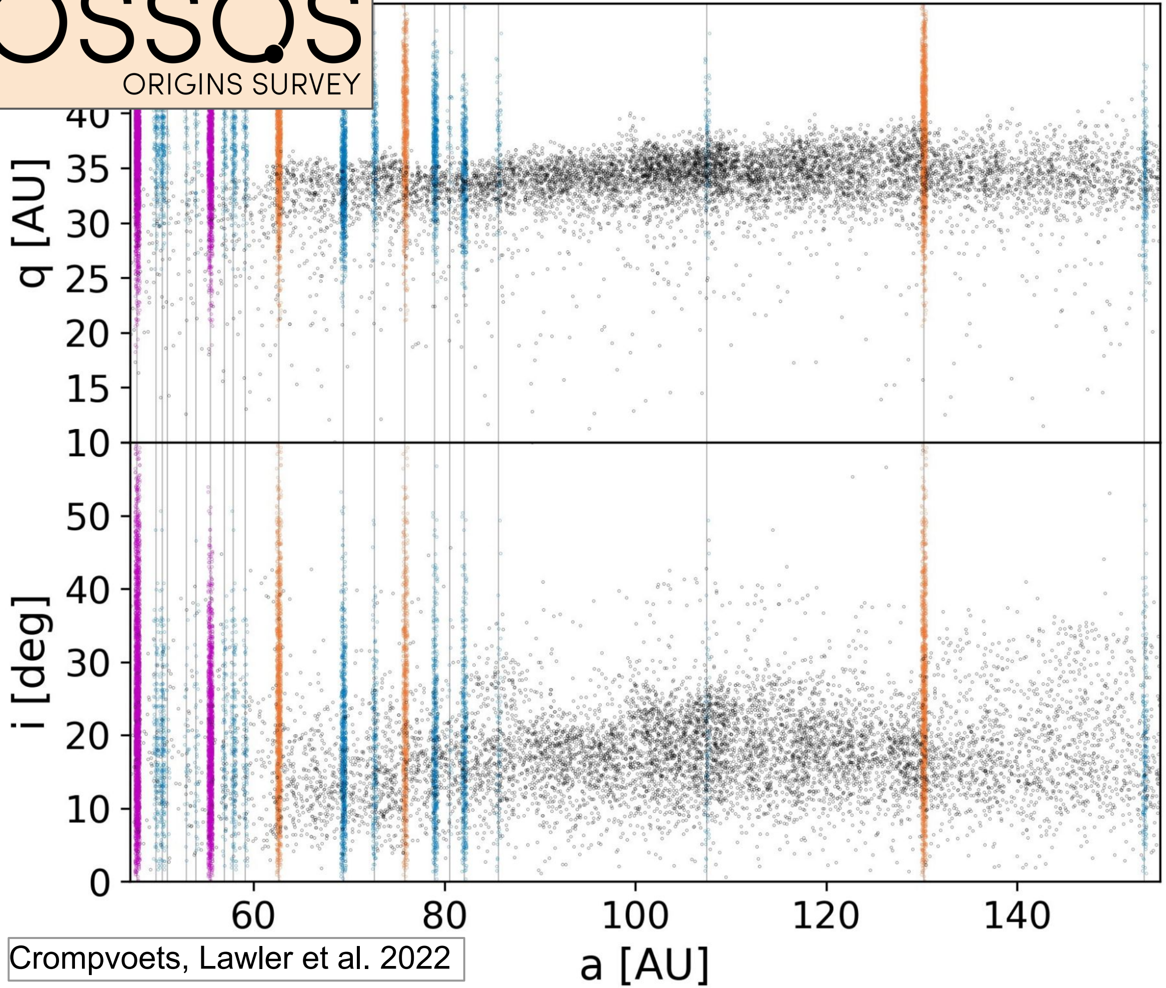


Crompvoets, Lawler et al. 2022

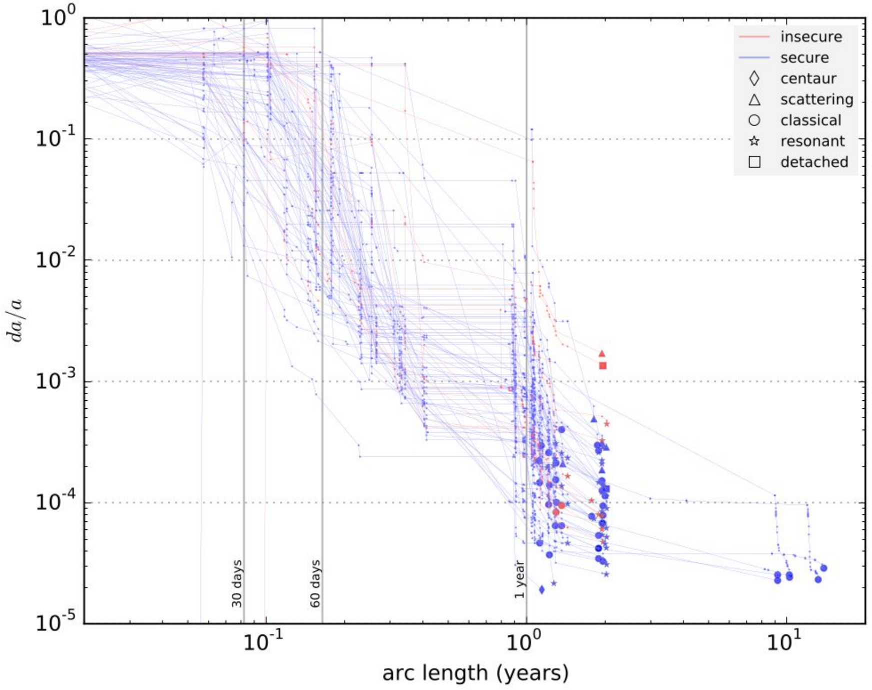
Debiased populations

Resonance	Semimajor axis [AU]	Number of detections	q_c [AU]	q_w [AU]	σ_i [°]	Median Population ($H_r < 8.66$)
3:1	62.5	12	36	3	20	17000^{+11000}_{-8000}
4:1	75.7	5	38	3	20	13000^{+15000}_{-8000}
5:1	87.9	3	38	4	25	11000^{+19000}_{-8000}
9:1	130.0	2	40	4	25	18000^{+39000}_{-15000}
5:2[a]	55.3	29	39	5	17	6600^{+4100}_{-3000}
7:2	69.3	2	34	3	14.5	2300^{+5400}_{-1900}
9:2	81.9	1	34	3	14.5	1100^{+6000}_{-1100}
23:2	153.1	1	34	3	14.5	4000^{+15000}_{-4000}
7:3	52.9	1	37.5	3	14.5	3000^{+5000}_{-2300}
8:3	57.8	2	37.5	3	14.5	2300^{+5000}_{-2000}
10:3	67.1	1	37.5	3	14.5	1400^{+6000}_{-1400}
11:4	59.0	2	37.5	3.5	25	3900^{+9000}_{-3400}
15:4	72.5	2	37.5	3.5	25	2600^{+12000}_{-2500}
17:4	78.8	1	37.5	3.5	25	3100^{+12000}_{-3000}
27:4	107.3	1	37.5	3.5	25	5000^{+23000}_{-4800}
11:5	50.8	2	38	4	20	2100^{+4900}_{-1800}
12:5	53.9	2	38	4	20	2400^{+5600}_{-2000}
13:5	56.8	3	38	4	20	1200^{+4800}_{-1200}
24:5	85.5	1	38	4	20	2500^{+11000}_{-2400}
13:6	50.3	5	37.5	3.5	14.5	1700^{+4300}_{-1400}
23:6	73.6	1	37.5	3.5	14.5	1800^{+7400}_{-1800}
17:8	49.7	2	37.5	3.5	14.5	700^{+3100}_{-700}
35:8	80.4	1	37.5	3.5	14.5	2600^{+11000}_{-2500}
TOTAL						$110{,}000^{+240{,}000}_{-82{,}000}$

~Same population in distant resonances as in the entire scattering or main classical belt. (With big uncertainty!)

We should find between 2-12 distant TNOs in CLASSY

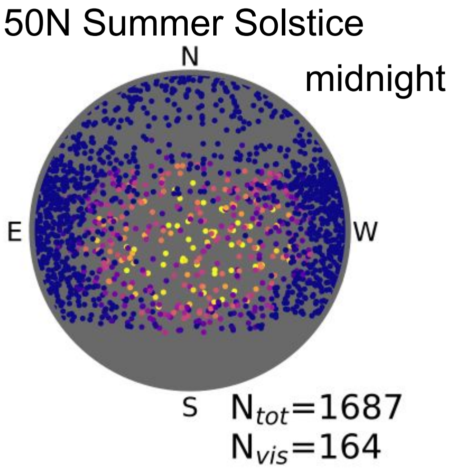
If we do as good at job at follow-up as OSSOS, should know if these distant objects are near-resonant at 1 year, could possibly diagnose resonances with 1 more year of follow-up astrometry



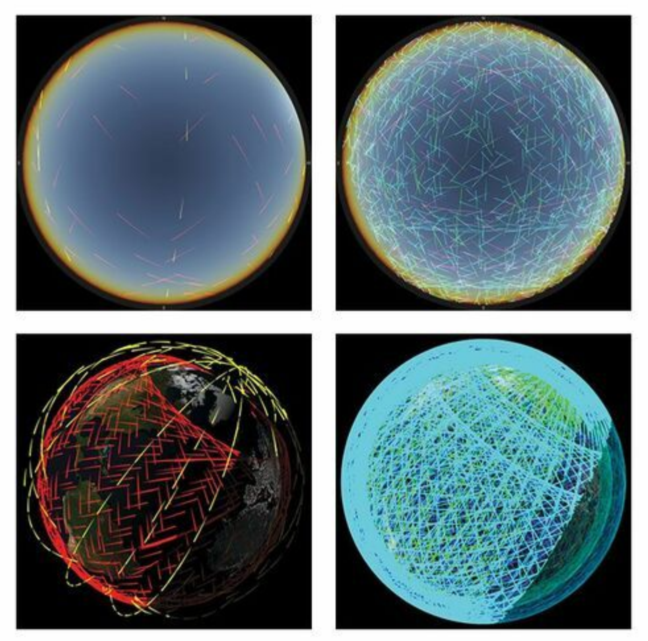
Bannister et al. 2016

…but future TNO observations (as well as all of observational astronomy) could be severely hampered by megaconstellations of bright satellites, like Starlink.

Please help fight for regulation! Tell people what's happening to the sky, talk to your gov't reps, and get outside to a dark site to enjoy the sky yourself - it's changing right now



Lawler, Boley & Rein 2022



Starlink: 4,968 (34k planned)
OneWeb: 634 (7k planned)
Kuiper: 2 (3k planned)
Others: 1,000,000 filed

IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference: cps.iau.org

AAS COMPASSE committee

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