DP 0.3 Introduction

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What is DP0.3?

- Data set containing simulated catalogs from the first year of operations as well as the full 10yr survey (roughly a billion total measurements)
    - Data products mimic what will be delivered by the real survey (SSObjects, diaSource, MPCORB tables) and uses a prototype of the daily processing pipeline
    - Note: catalogs only - no simulated images!
- Simulations use v3.0 cadence
- Astrometric and photometric errors match expectations as a function of magnitude
- Simulated linking matches design goals (95% completeness under many conditions)
- Same database system as will be used during operations

Schematics of the processing for DP0.3

- Inputs: Orbital elements (heliocentric), absolute magnitudes and colors (*griz* only) for Solar System populations
- Ephemeris generation: on-sky position as a function of time (using ObjectsInField) for each LSST exposure/visit
- Simulation of detection properties: apparent magnitudes + error, astrometric scatter due to shot noise, camera footprint (using sorcha - formerly SurveySimPP)
- Linking simulation following survey design goals: 95% probability of discovery for an object given every combination of tracklets (using difi)
- Simple absolute magnitude and phase coefficient estimates for all sources
- Outputs: catalogs of individual detections, objects, absolute magnitudes and orbital properties

Sorcha

- Formerly called SurveySimPP, Sorcha is the Solar System survey simulator for LSST
  - Sorcha's job is to, given a set of object parameters (orbits, absolute magnitudes, colors, lightcurve properties, cometary activity, …), simulate Rubin's detections and measurements.
- Sorcha is undergoing active development - but is now a mature software package
  - When we generated DP0.3, it took us years of compute (weeks of time) to produce this catalog. Now it can be done in a day! (Awesome work by the LINCC team)
- https://github.com/dirac-institute/sorcha

Simulated linking (by J. Moeyens)

difi: “Did I Find It?”. Python code that was designed to answer two questions:

- **What should an idealized linking algorithm find in these labelled observations?**
- Given these linkages found, how did my linking algorithm perform?

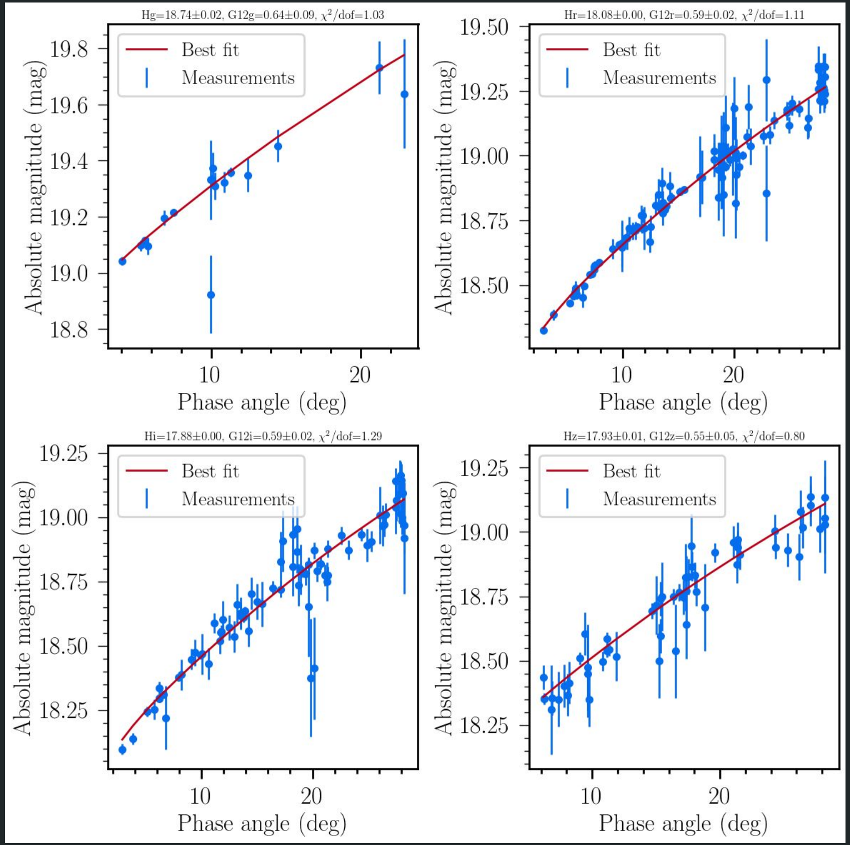
Tracklet-metric:

- 2 observations on at least 3 unique nights within a 15 day window
- Tracklets must be astrometrically separated by more than 1 arcsecond
- Consecutive detections cannot be separated by more than 90 minutes
- Each discovery opportunity (each set of three tracklets) has a 95% chance of being successfully linked

https://github.com/moeyensj/difi

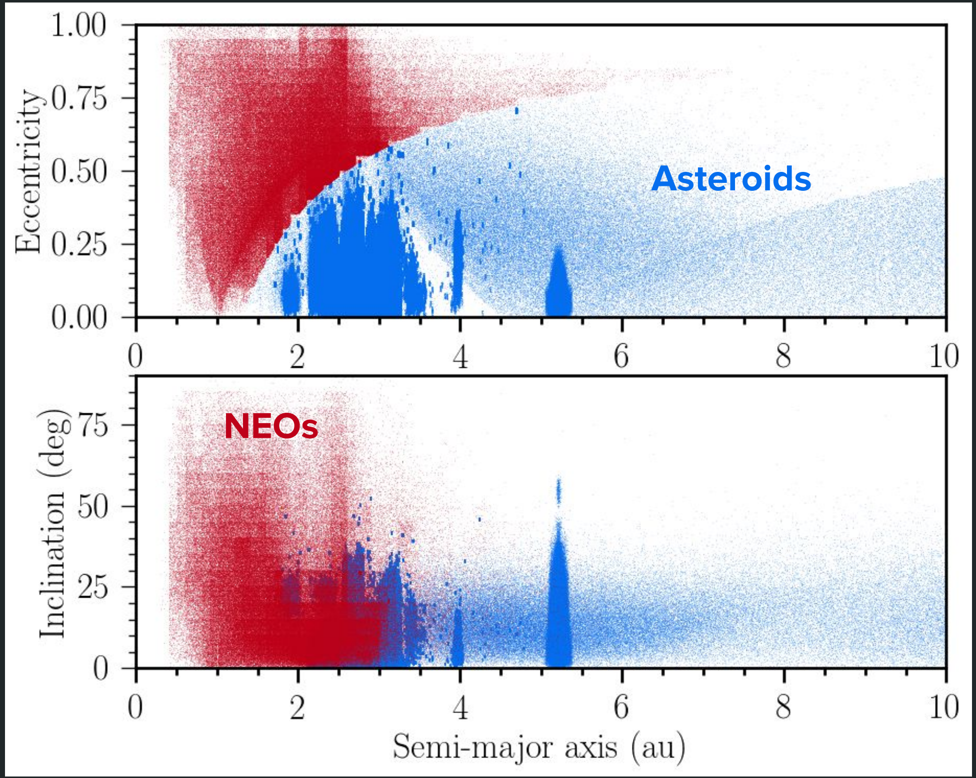
Daily data processing pipeline

- Will be run daily by the survey and deliver survey products for all linked objects:
  - Orbit fits (currently using openorb)
  - Absolute magnitudes (HG12 system) per band
  - Matched to MPCORB catalog (that is, will have MPC identifiers for all objects)
- Left: example of a randomly chosen object



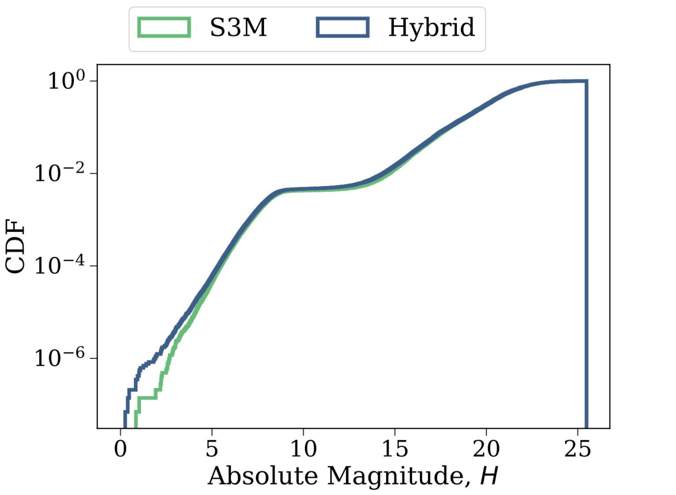
Source populations: inner Solar System

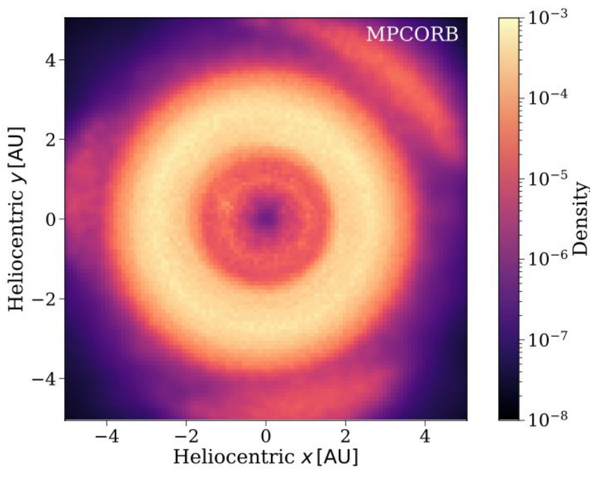
- Pan-STARRS Synthetic Solar System model (S3M, [Grav et al 2011 - PASP, Vol 123, 902, 423]):
  - Includes NEOs, the asteroid belt, Centaurs, and trans-Neptunian objects
- Right: source population for NEOs and asteroids

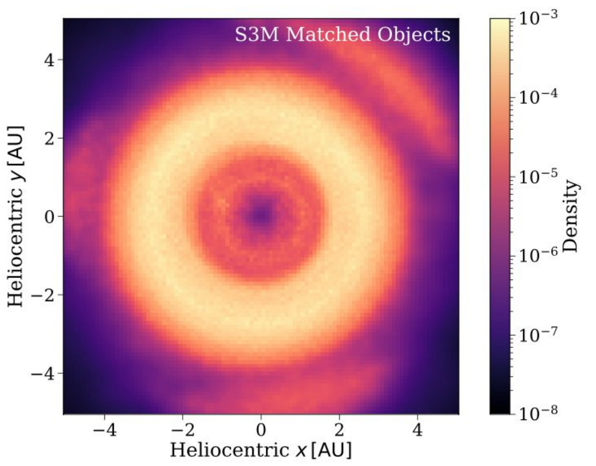


Hybrid catalog (by T. Wagg)

- To avoid overestimating discovery rates in the bright/near complete regime, objects from S3M are replaced by their most similar real counterparts in the source population







Outer Solar System

- S3M broadly reproduces main structures in the trans-Neptunian region
- Population of long period comets by Kelley, Nesvorny, Vokroulicky
  - Two realizations, restricted to closer than 5 au and 20 au, respectively

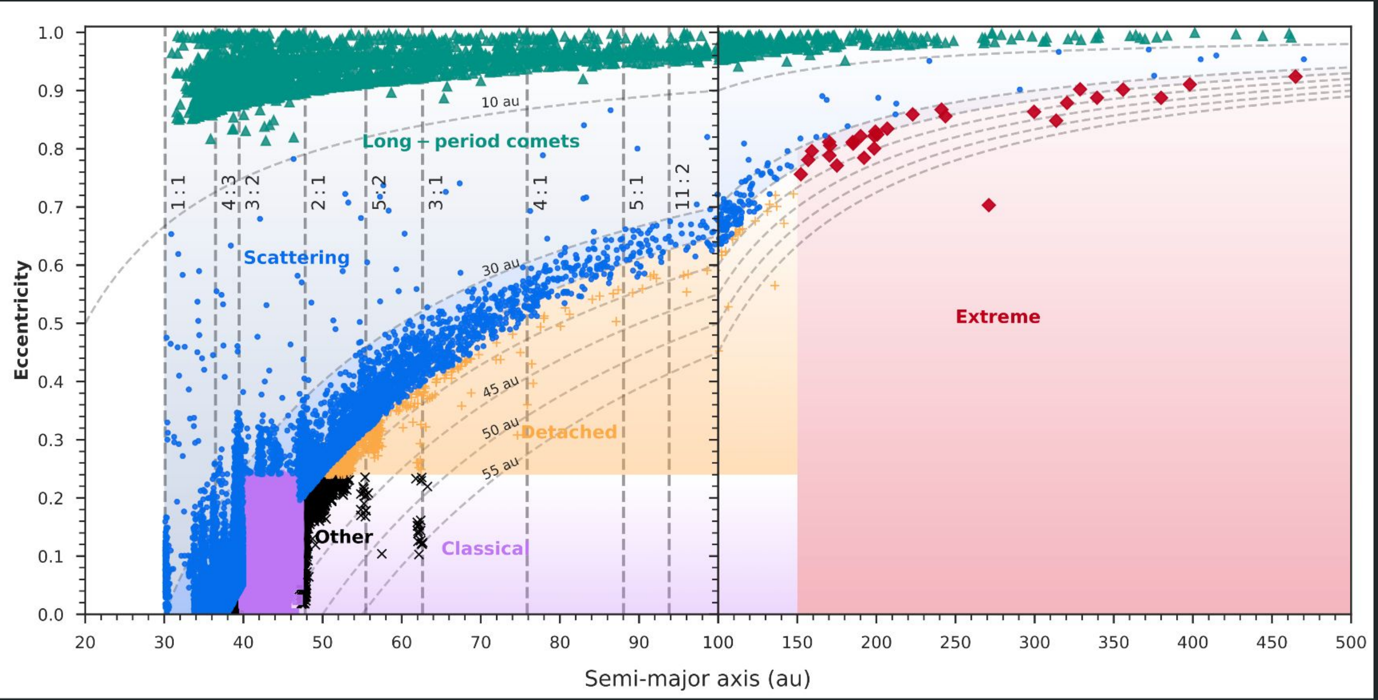
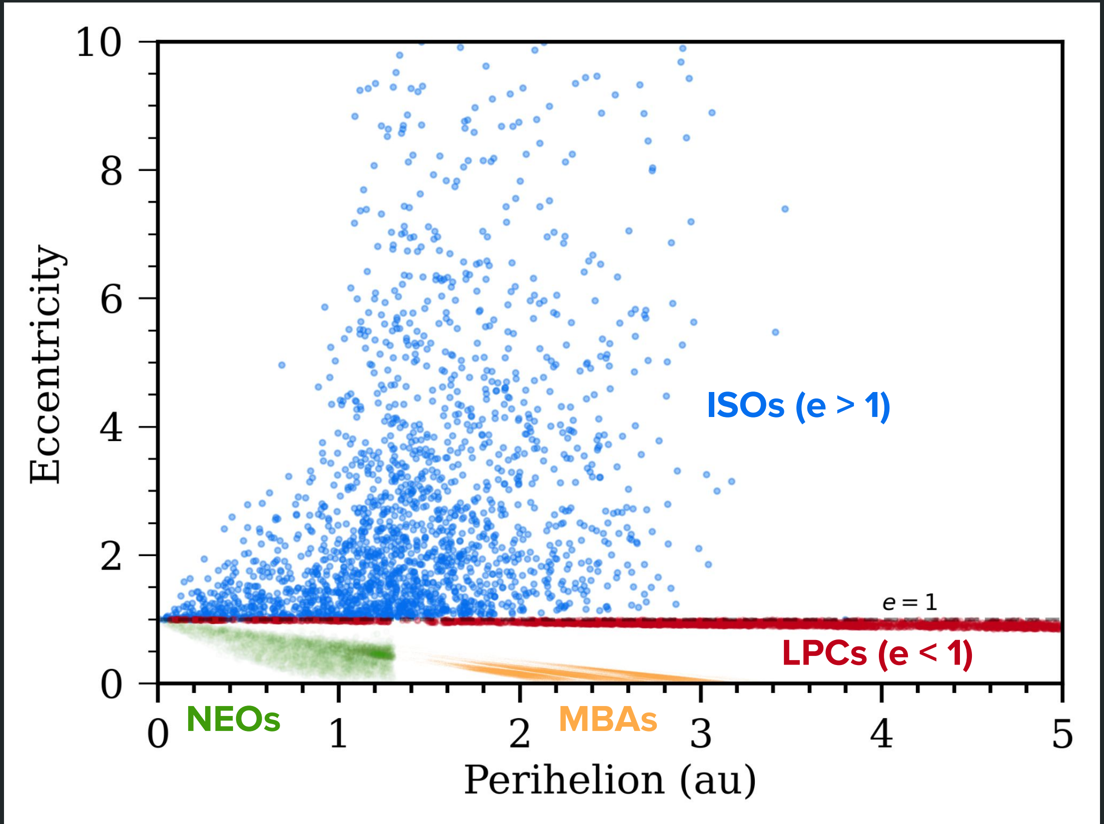


Figure credits: Andrés Plazas Malagón (next delegate talk!)

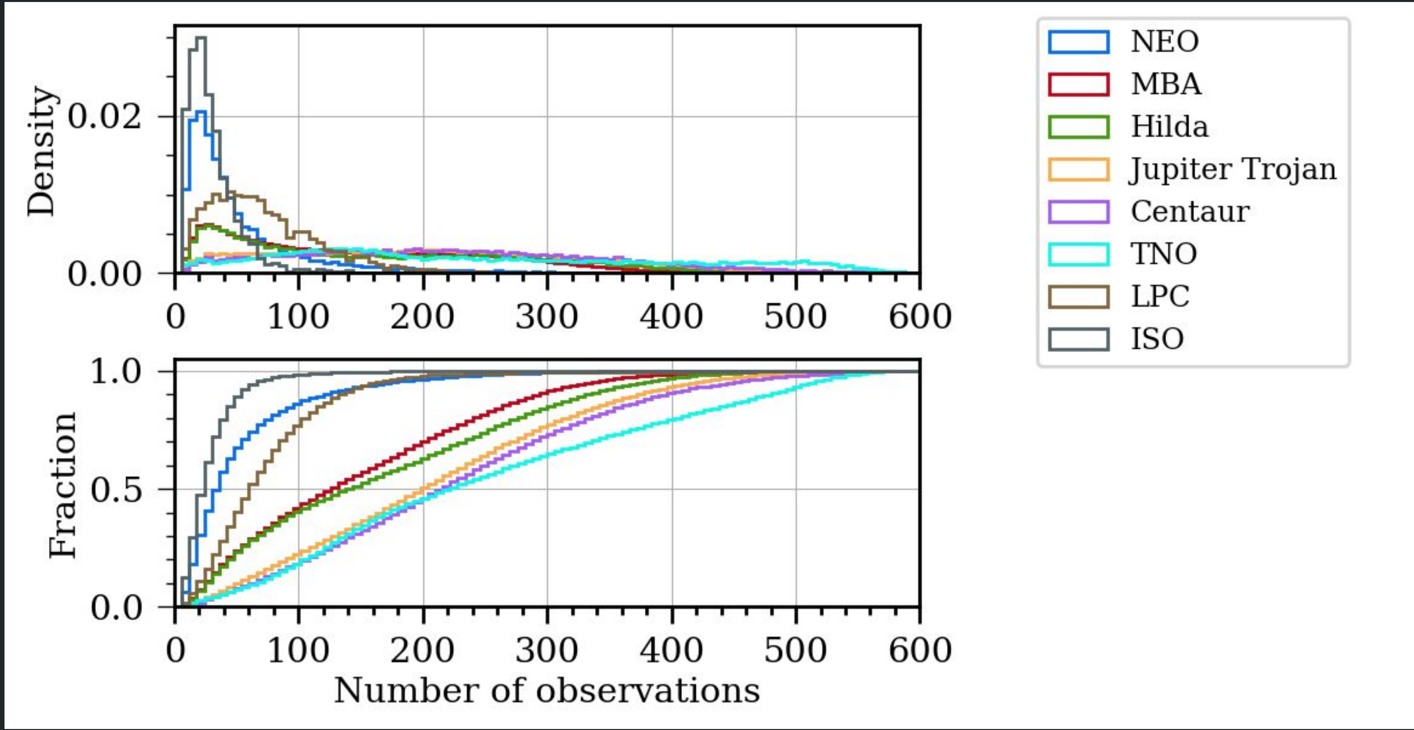
Interstellar objects et al

- In addition to long period comets, we also have a population of interstellar objects
    - Note: both LPCs and ISOs are **not** normalized, so the number of “discoveries” is not at the same order of magnitude as expected from the survey
- Easter egg: population of spaceships with NEO and ISO-like orbits (but with an extra impulse)



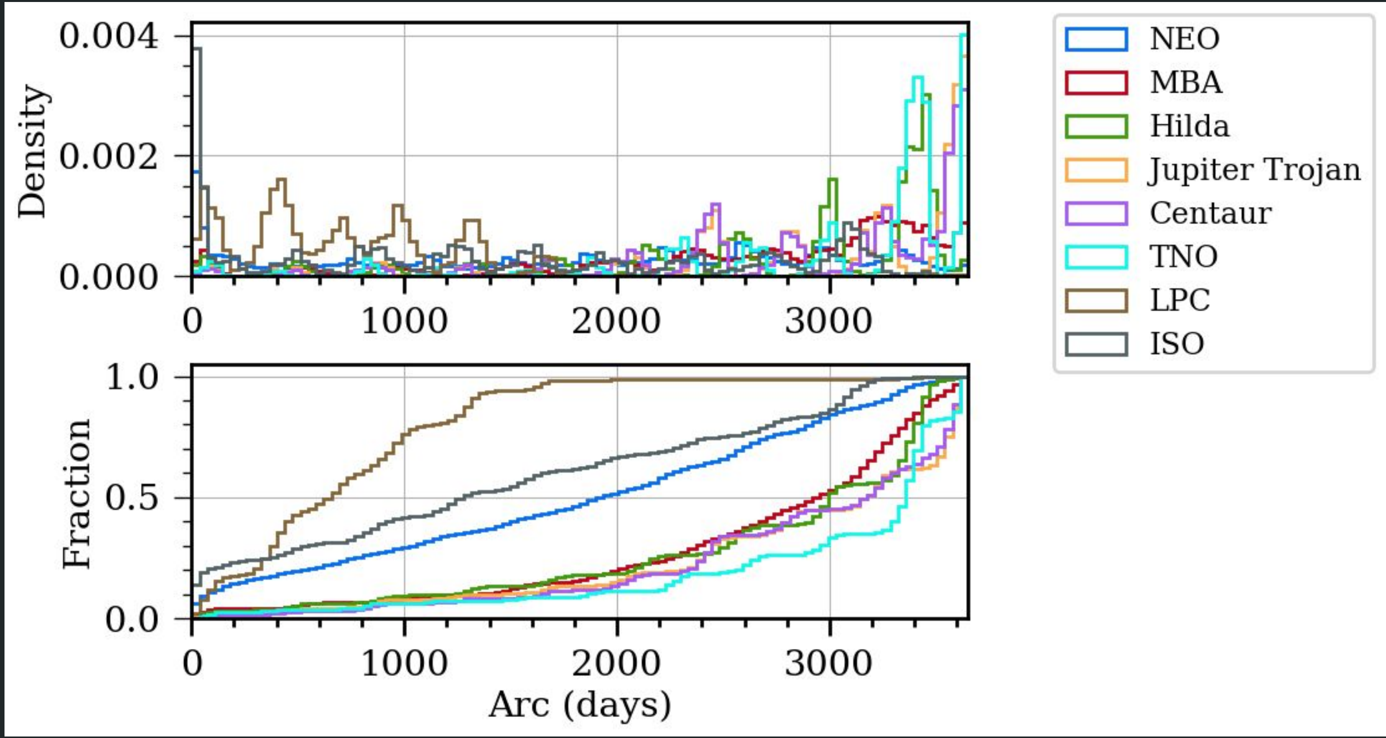
Number of observations per population

- How many observations will the typical object have?
- Depends on perihelion: more distant objects have more observations, on average (unsurprisingly)



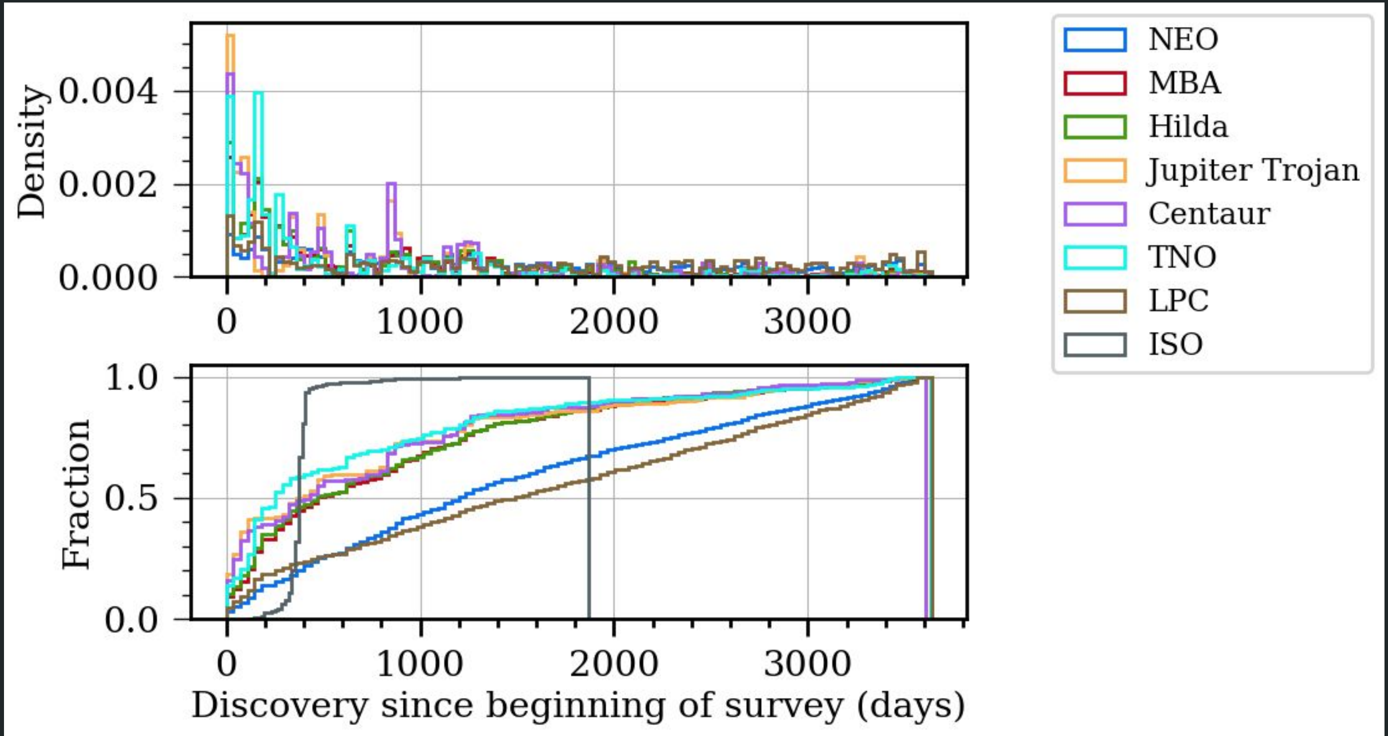
Similarly, the orbital arcs...

- You can see the same structure in the length of the orbital arcs for each population: more distant = longer arc
- Note: at a fixed distance, the longer the arc, the higher the quality of the orbit fits



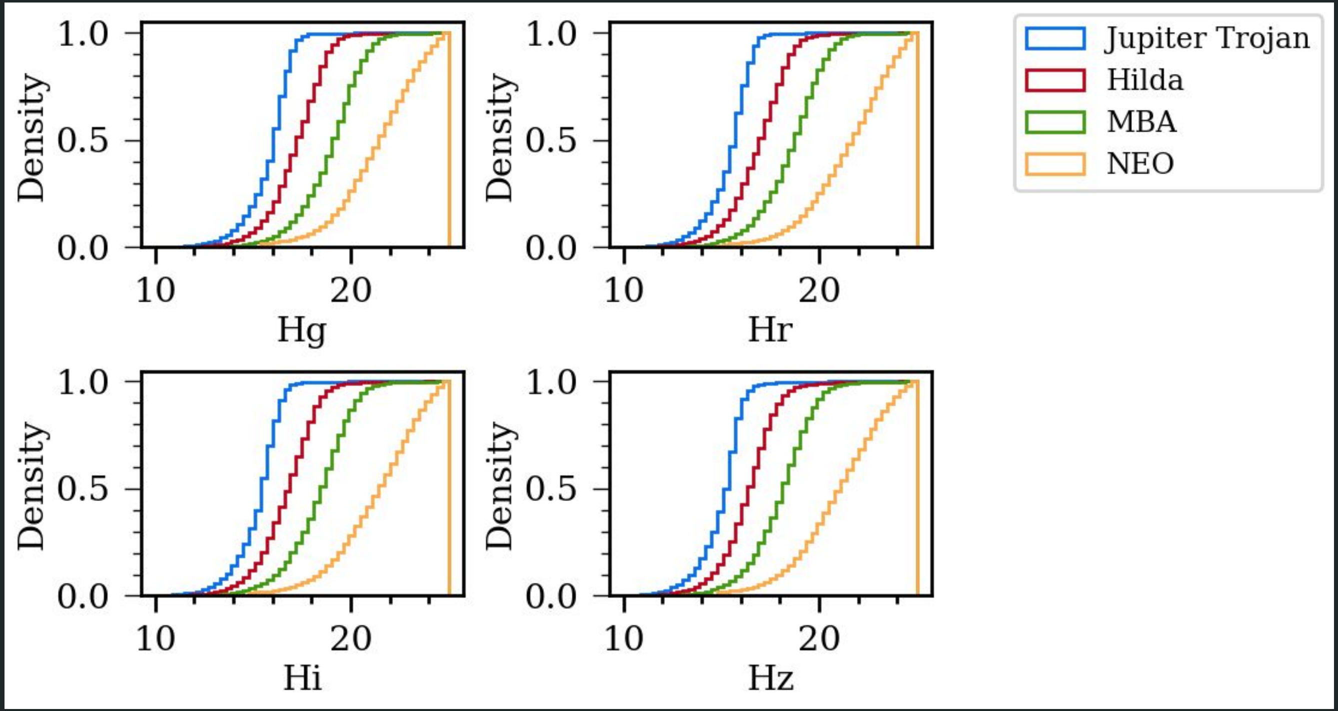
Same story once again: elapsed time until object discovery

- Another way of thinking about this: when are the objects discovered?
  - Note: this is the survival function of the previous histogram
- Answer: for the less eccentric populations, >50% of objects are discovered during year 1
- Constant flux of NEOs and LPCs as the survey progresses
  - Simulated ISOs have roughly the same time of perihelion passage, or they would show the same structure



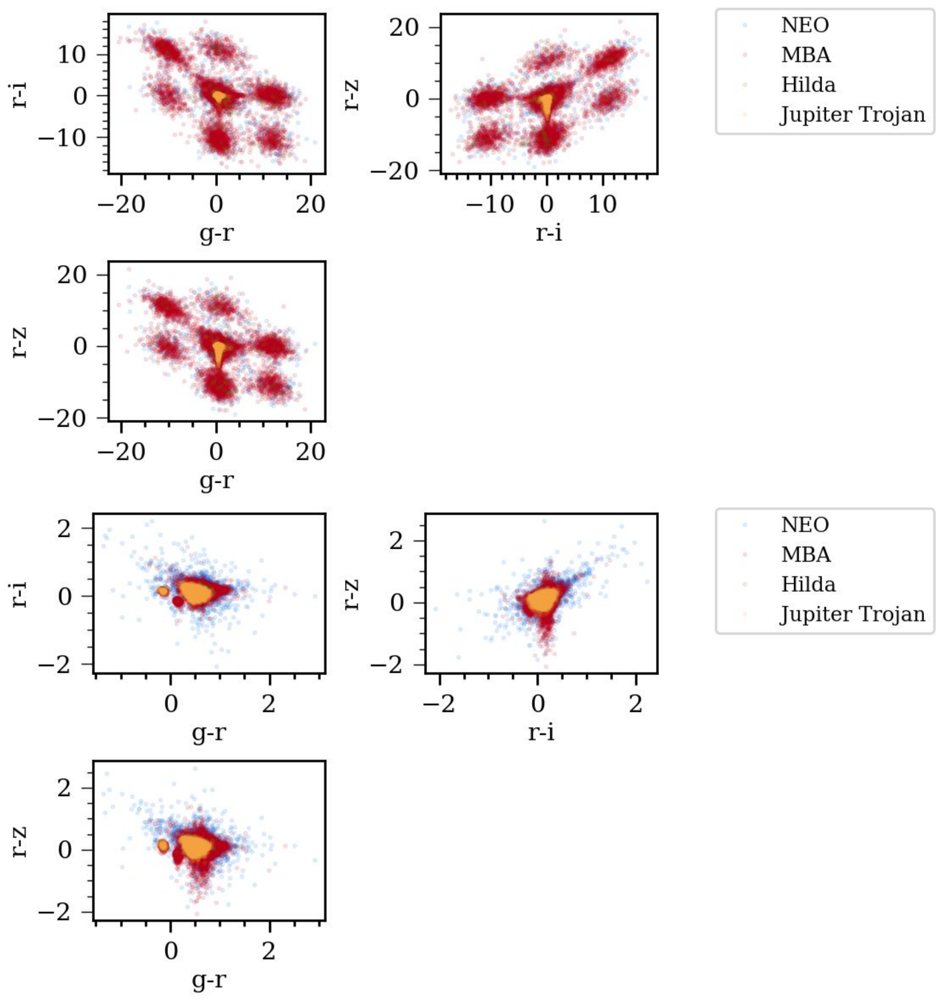
Absolute magnitudes

- Detail: prototype photometry pipeline for absolute magnitude vs phase pipeline currently only handles objects with significant phase coverage (eg ignoring TNOs) - solution is not stable otherwise



Colors

- Assuming that, for bands b and b', Hb and Hb' are well measured, we can take a look at the color b - b' = Hb - Hb'
- Without selecting on S/N for the objects, color structure looks super weird!
  - We believe these are due to a previously unnoticed bug in the survey simulation software
- When we select on S/N, things look more sane



Known issues

- Bad color classes
  - Two classes, no variance.
  - ~0.2 mag too dim across the board (V-r = 0)
  - Don’t represent outer solar system well
- No u, y bands
- Issue with trailed magnitudes leading to very dim detections
- Camera footprint awkward
- ISOs all pass at similar times, no H distribution (all bright)