Rubin Observatory

LSST Survey Strategy and Solar System Metrics

Lynne Jones

Rubin Obs LSST SSSC Sprint | Everywhere! | June 16, 2020

- "LSST Feature Based Scheduler, Cadence Decisions Overview, and Solar System Metrics”

- How we’re generating simulated pointing histories for Rubin Observatory’s Legacy Survey of Space and Time

- What is the SCOC and what will it do?

- Solar system metrics!
  - What are we tracking? What populations are we using?
  - What does this show so far?
  - What do you do next?

How we are generating simulated pointing histories

- Realistic weather (seeing and cloud databases from nearby observatories)
- Realistic downtime (scheduled + unscheduled)
- High fidelity sky brightness model (based on ESO model + twilight)

- Scheduling software — “Feature Based Scheduler” (FBS)
- FBS combines different basis functions (the five-sigma depth across the sky in each filter, the slew time, the number of visits acquired at each point compared to how we want visits distributed [‘target map’], etc) to decide where to point the telescope
- Using these basis functions, there are multiple algorithms in use for scheduling visits depending on goals and conditions:
  - Scripted surveys (deep drilling fields, ToO observations, 2nd visit of a pair/triple ….)
  - Blob surveys (schedule sets of visits that cover a small region of sky, which can be repeated in approximately 20-30 minutes for pairs or more)
  - Greedy surveys (what’s the simple/greedy/easy best thing to do next, if the weather conditions are changing? - twilight)

How we are generating simulated pointing histories

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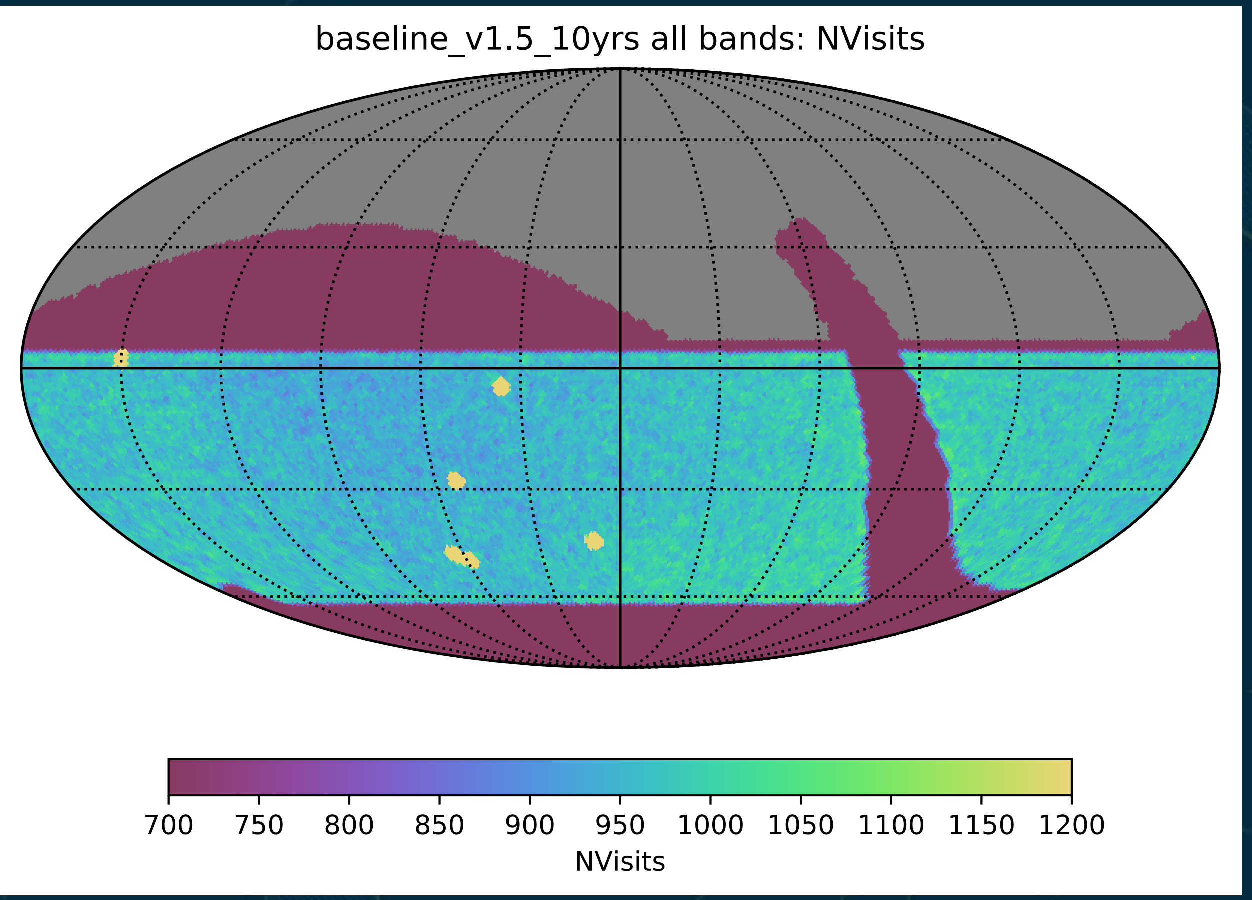
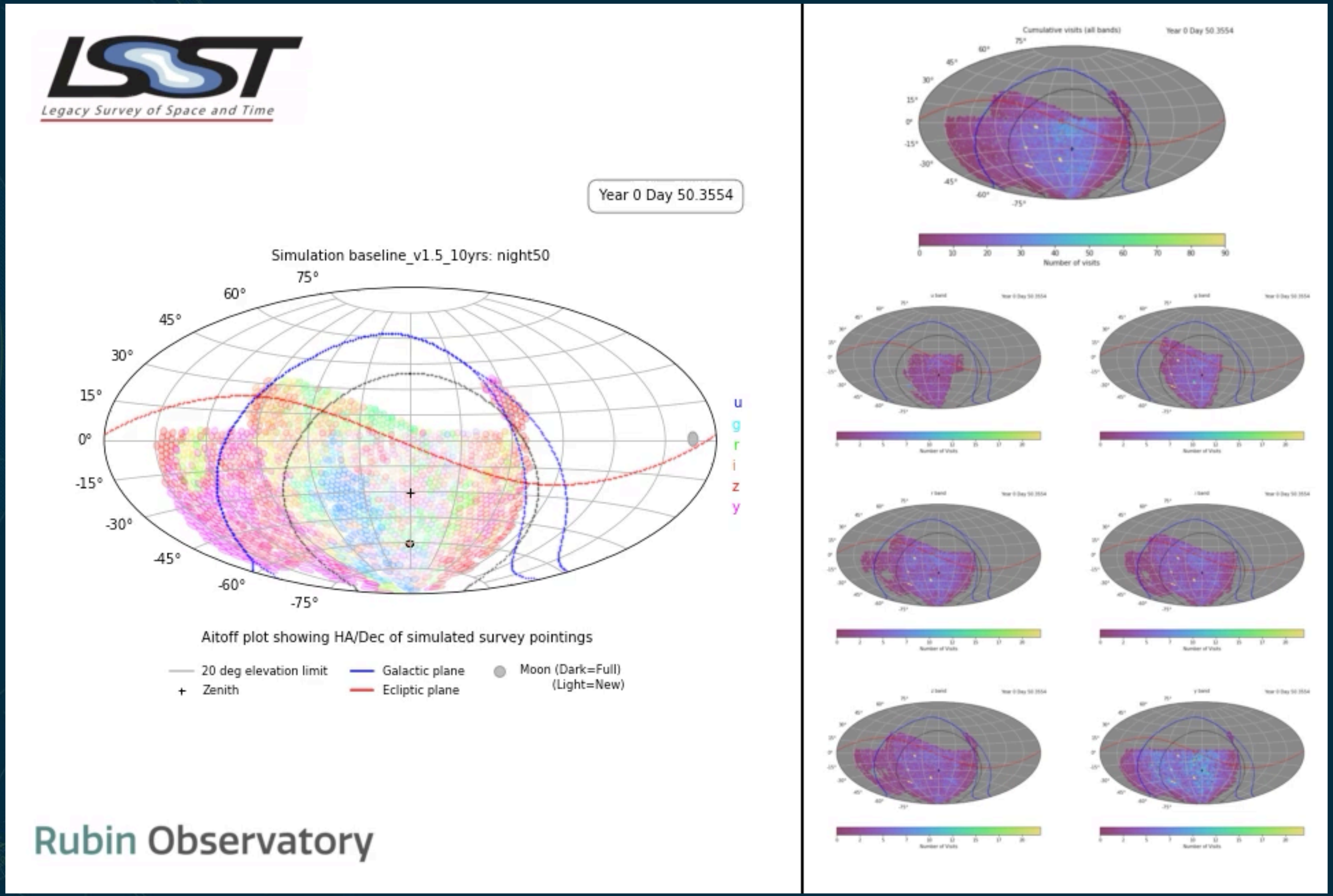


Example
baseline_v1.5_10yrs



See the movie again on community.lsst.org (Science / Survey Strategy section) (https://ls.st/mov15)!

How we are generating simulated pointing histories

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- What kind of surveys are we simulating?
  - Using inputs from white papers and SAC response
  - Footprint variations - like WFD footprint location + galactic bulge coverage
  - Intra-night scheduling variations - same/mixed filters, pairs, triples
  - rolling cadence options - 2/3/6 bands, better scheduling of how rolling happens
  - twilight NEO cadences
  - u band options - timing for filter mount/unmount, how u is paired with other filters
  - DDF variations - DESC & AGN, Euclid S as 5th field, better scheduling in general
  - DCR high-airmass visits, adding short exposures, ensuring good seeing visits
  - … and others.
- More information on each of the 'families' of simulations to investigate these effects are included in each of the FBS release announcements on community.lsst.org
  - https://community.lsst.org/c/sci/survey-strategy

What is the SCOC and what will it do? (Cadence Decision Making Process)

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- SCOC = Survey Cadence Optimization Committee
- Committee representing the astronomical community, to provide recommendations on the survey strategy. Make recommendations on strategy to Operations Director.
- Composed of community members, with broad Science Collaboration representation, but also charged with representing and communicating with the community at large.
- SCOC membership* and charge (from latest newsletter)
  - https://www.lsst.org/content/charge-survey-cadence-optimization-committee-scoc

POTENTIAL (LIKELY?) SCHEDULE	
Survey Strategy report from project to SCOC	Released @ PCW 2020
Community workshop	Early 2021
SCOC report on initial strategy (for community comment)	Late 2021
Simulation of initial strategy	Early 2022
Community workshop	Summer 2022
Simulation of final strategy	Late 2022
Start of Rubin Obs LSST Operations	Not earlier than early 2023

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Solar System Metrics!

- Current standard metrics
  - Discovery rate as a function of time and H magnitude, with different discovery criteria (3 nights with 2 pairs per night, within 15 nights as 'baseline') == completeness
  - Number of observations (per object, as a function of H)
  - Observation arc length (per object, as a function of H)
  - Likelihood of being able to detect activity as a function of length of activity
  - Likelihood of being able to measure 1/2/3/4 colors or do lightcurve inversion [Inner Objects WG]
  - Likelihood of being able to measure 1/2/3/4/5 colors [Outer objects WG]
- Applied to 5K objects from each population (orbits cloned over H range)
  - NEO (Granvik model) [C & S types]
  - MBA (S3M model) [C & S types]
  - Trojan (S3M model) [C type]
  - TNO (CFEPS L7 model) [TNO sed]
  - See https://github.com/lsst-sssc/SSSC_test_populations_gitlfs

Metric example: baseline_v1.5_10yrs

- Let's do a walkthrough of what gets put up online …
- http://astro-lsst-01.astro.washington.edu:8081/allMetricResults?runId=20#Discovery (https://ls.st/gin)
- See a subset of the 'discovery' metrics (we calculate more .. but de-cluttering for these outputs) .. Cumulative completeness + differential completeness + completeness over time, for each population, using 3 nights with 2 pairs per night, over either a 15 or 30 night window.
  - We do also calculate what happens to discovery with different SNR requirements, different window requirements, different pair/triple/Nnights requirements. These outputs are available in the data on the Jupyterhub on epyc (for SSSC).
- Characterization metrics:
  - NObs + ObsArc (note that the values plotted are the mean/median/X percentiles across the whole population at each H value)
  - Fractions of each population with possibility of calculating colors/light curve inversion
  - Chance of detecting activity (again, as fraction of population) for each population

A Few Survey Strategy Experiment Results

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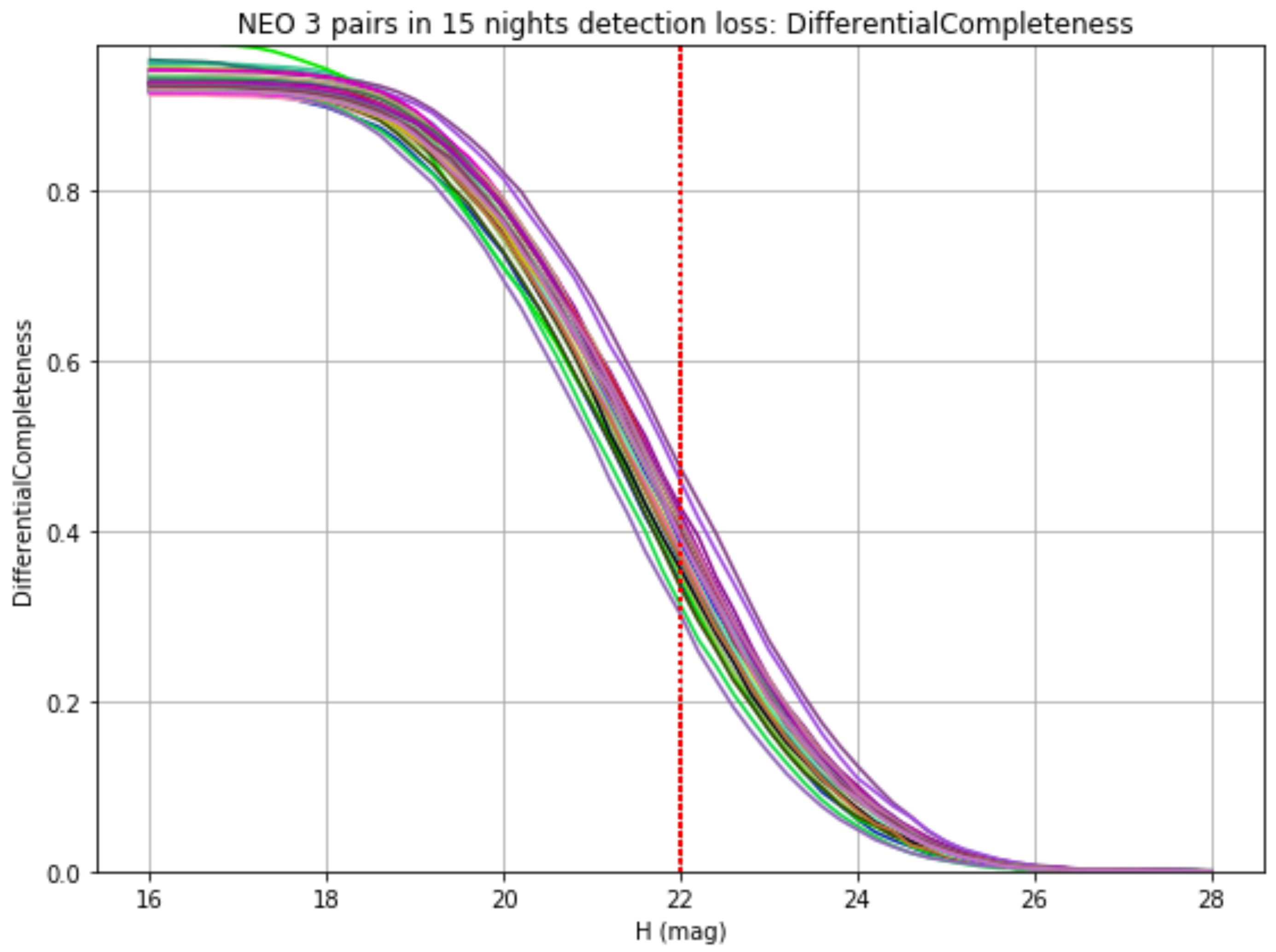
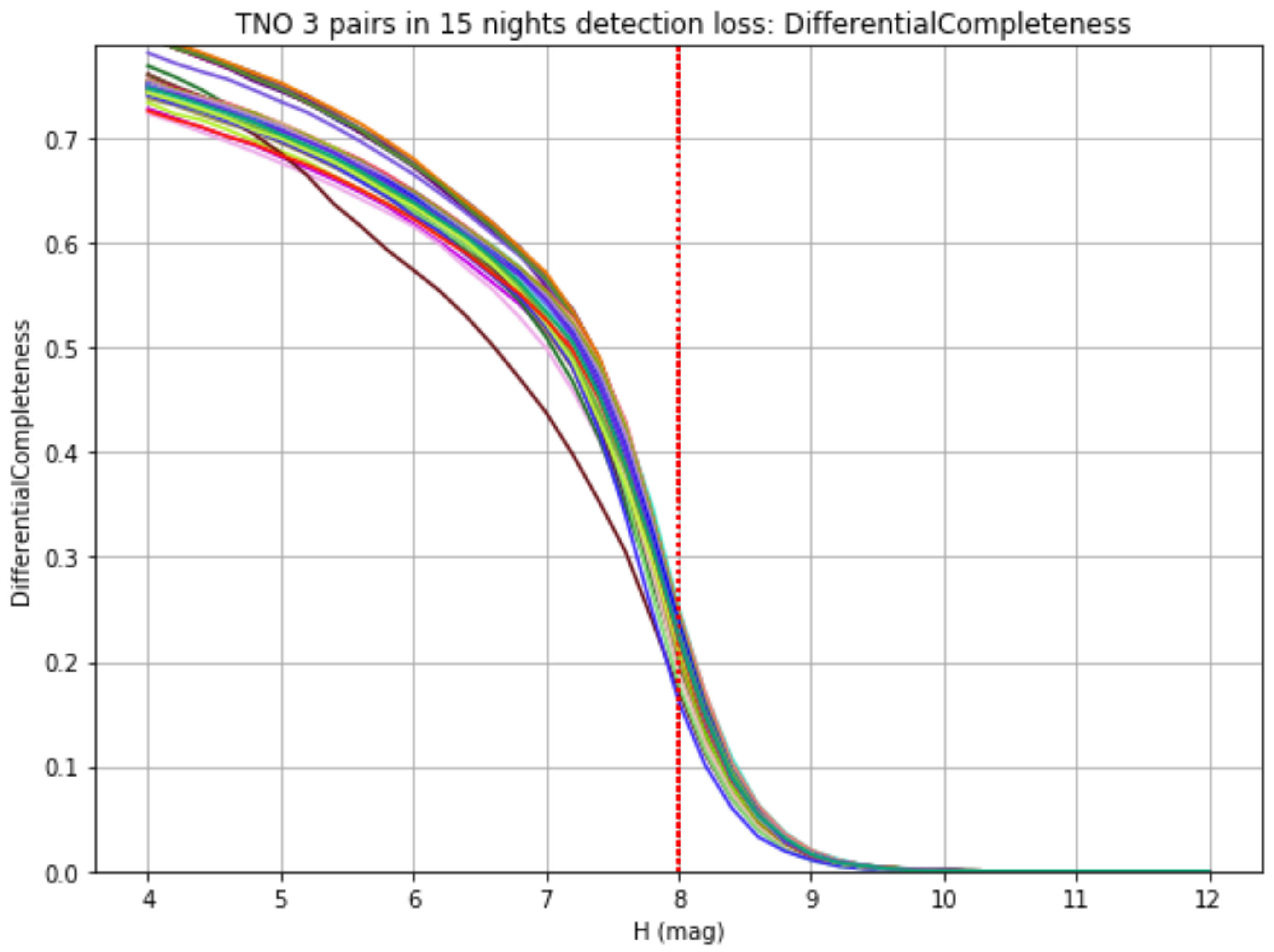
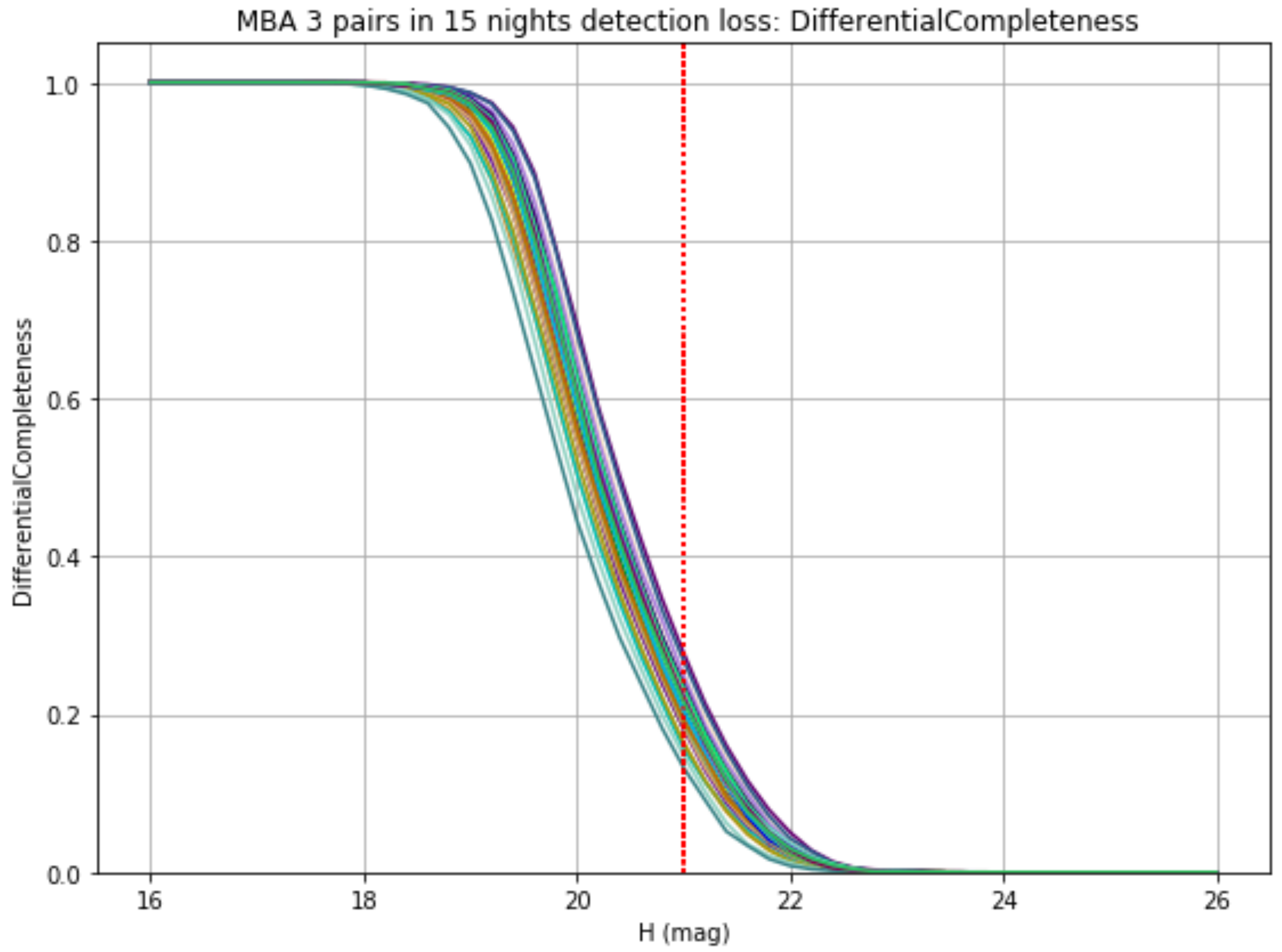
- Simulation releases to compare include FBS 1.4 and FBS 1.5 (and if needed .. you can reach back further to FBS 1.3, etc. — but you can also just ask us to run something again)
  - FBS 1.4 because some experiments didn’t repeat in 1.5, but results should generally only be compared within a release, not across
  - In FBS 1.5, a new method is used to choose fields within each blob, which increases the number of contiguous fields observed
  - Caveats: If a family of simulations exists in the 1.5 release, prefer that version. If you find significant differences between 1.4 and 1.5, ask.

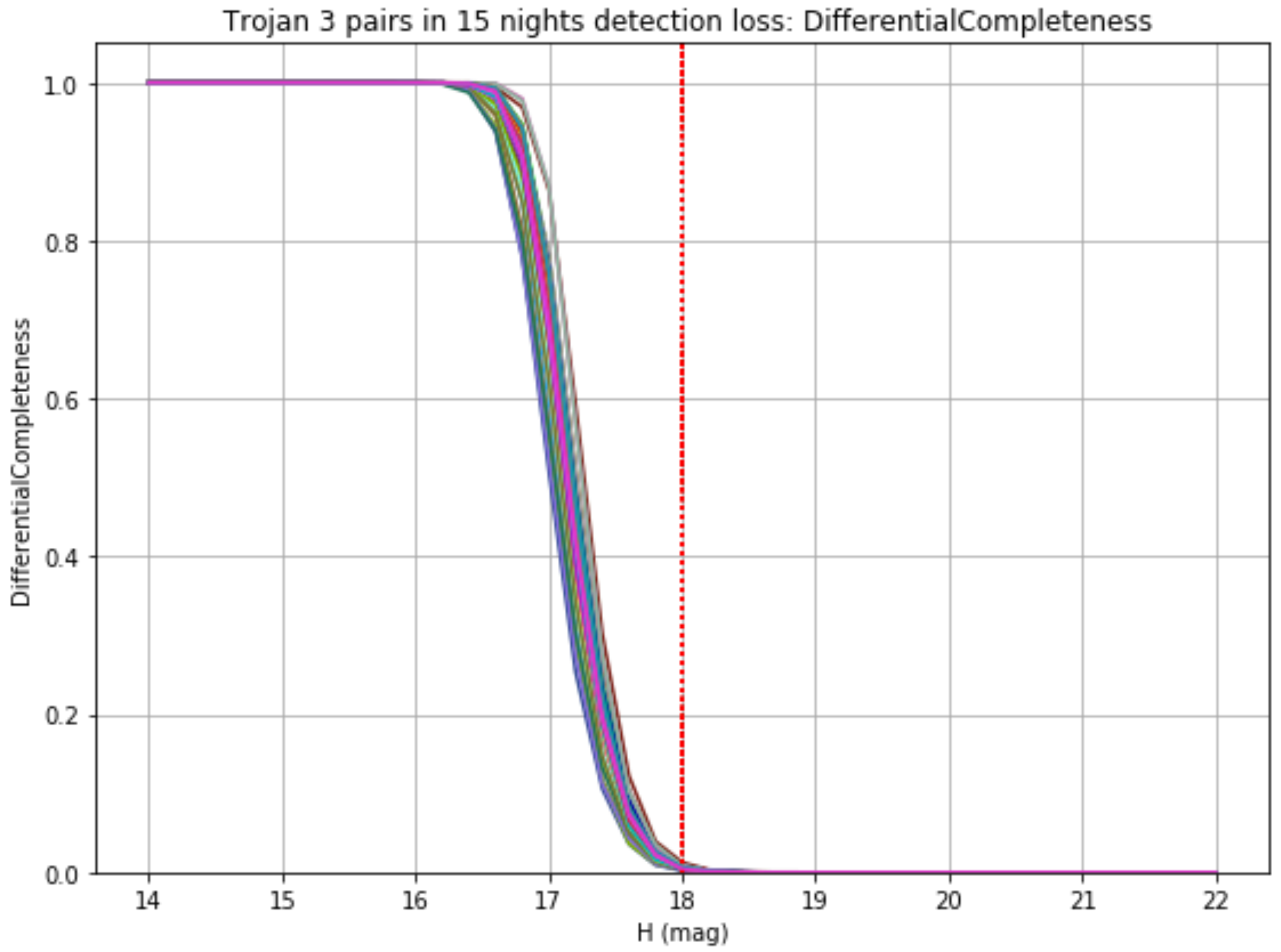
- Discovery is a high priority - so let’s start with that.

Discovery across ALL of 1.4 runs, all populations

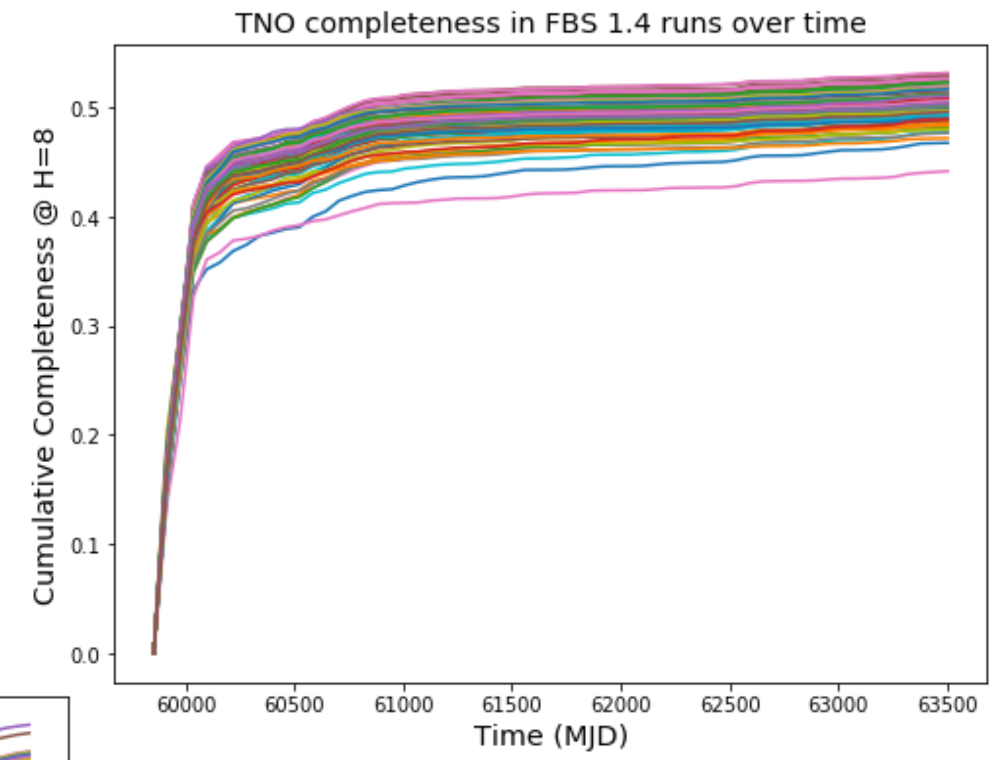


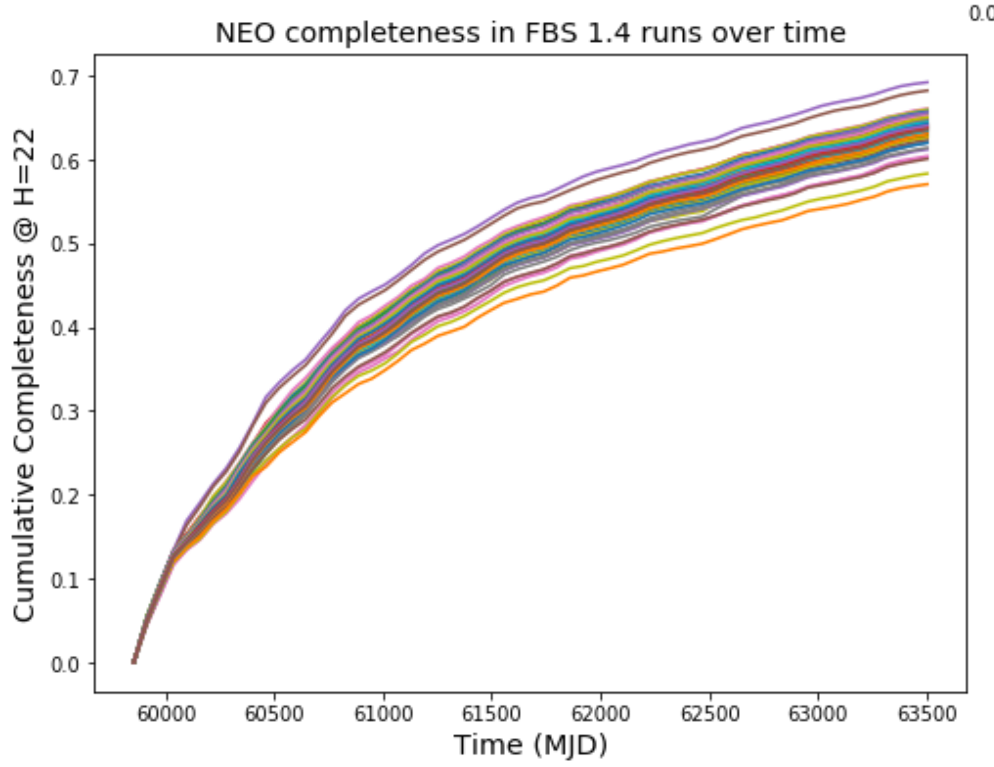






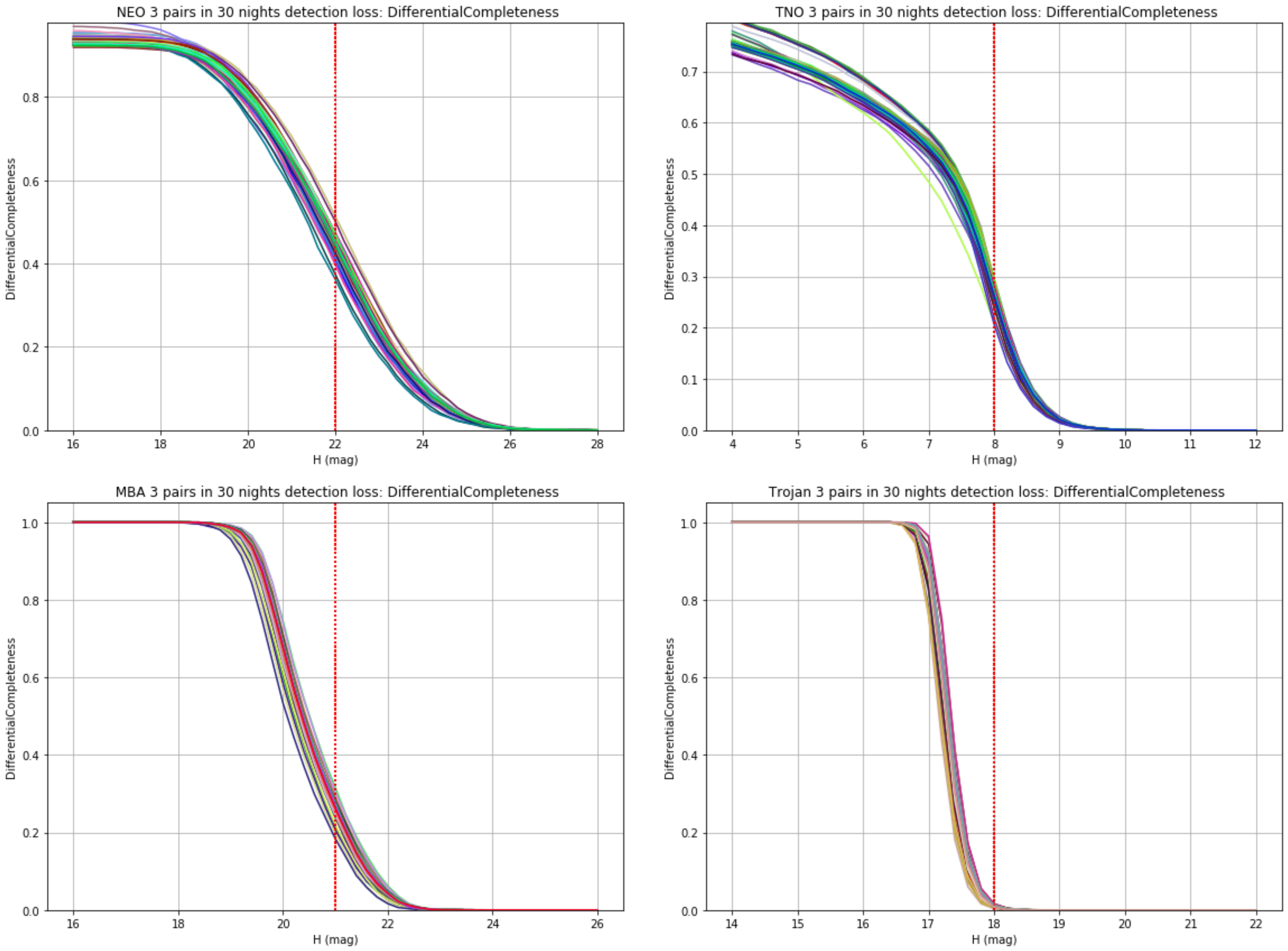
Takeaways:
This is helpful to see that no simulation completely breaks things, and no simulation is overwhelmingly better. But we do see differences!





We can also look at completeness over time; looks like it tracks overall completeness

Discovery across ALL of 1.4 runs, all populations

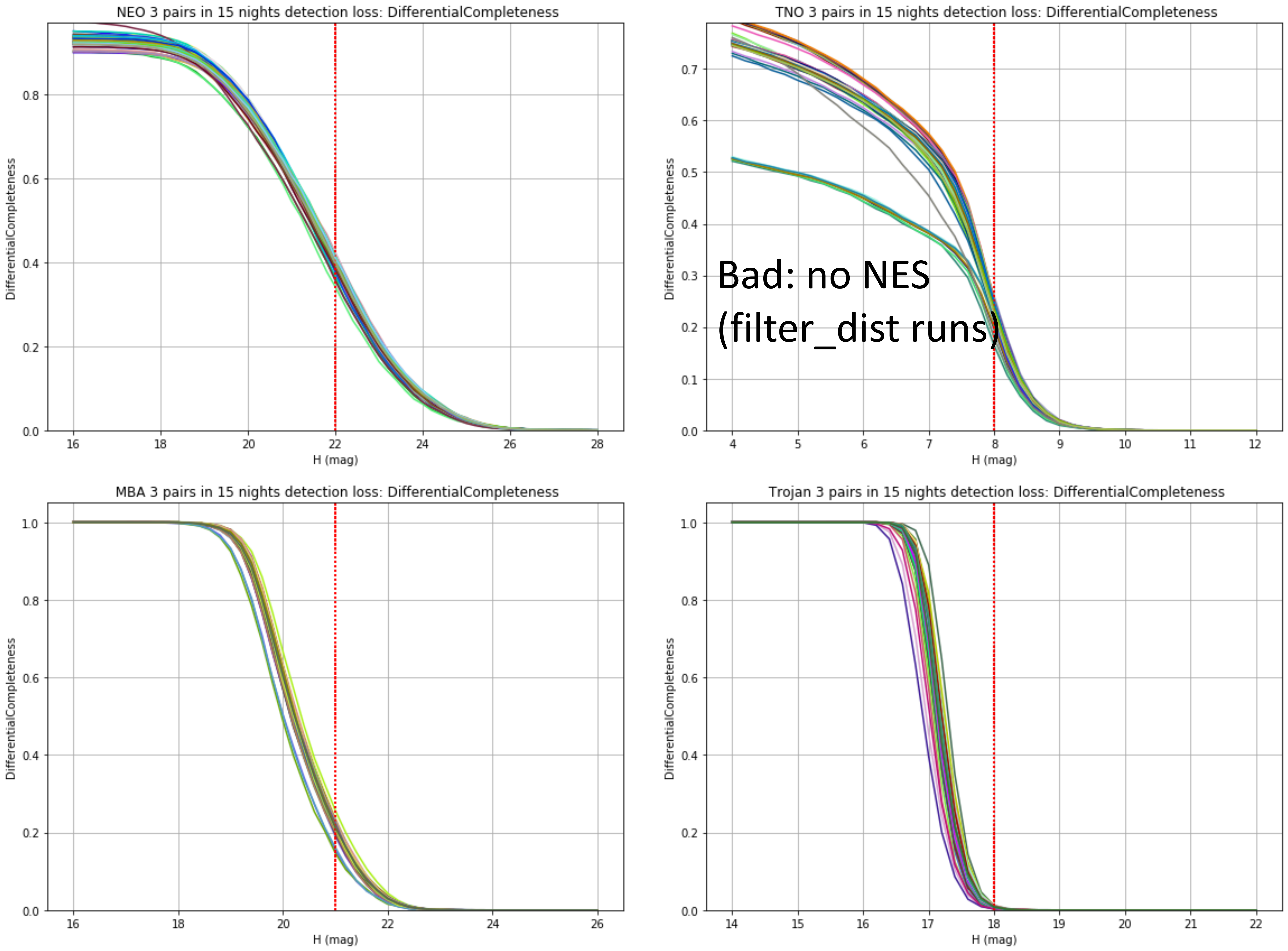


Takeaways:
This is helpful to see that no simulation in 1.4 completely breaks things, and no simulation is overwhelmingly better. But we do see differences!

Also, more relaxed discovery criteria make differences between the simulations smaller.

Also, that to find small trends between runs, we will have to pull out completeness values at particular H points .. and probably look at the ‘big’/small H end AND somewhere near a midpoint.

Discovery across ALL of 1.5 runs, all populations



Throwing the FBS 1.5 simulations into the mix … mostly similar — but not for TNOs! (and primarily near bright end).

* the runs with the poor TNO discovery are runs where there was no NES coverage (‘filter_dist`) .. intended to look at the filter distribution, for photo-z, they had some other effects. This family of sims was new in 1.5.

Don’t forget characterization (FBS 1.4 comparisons)

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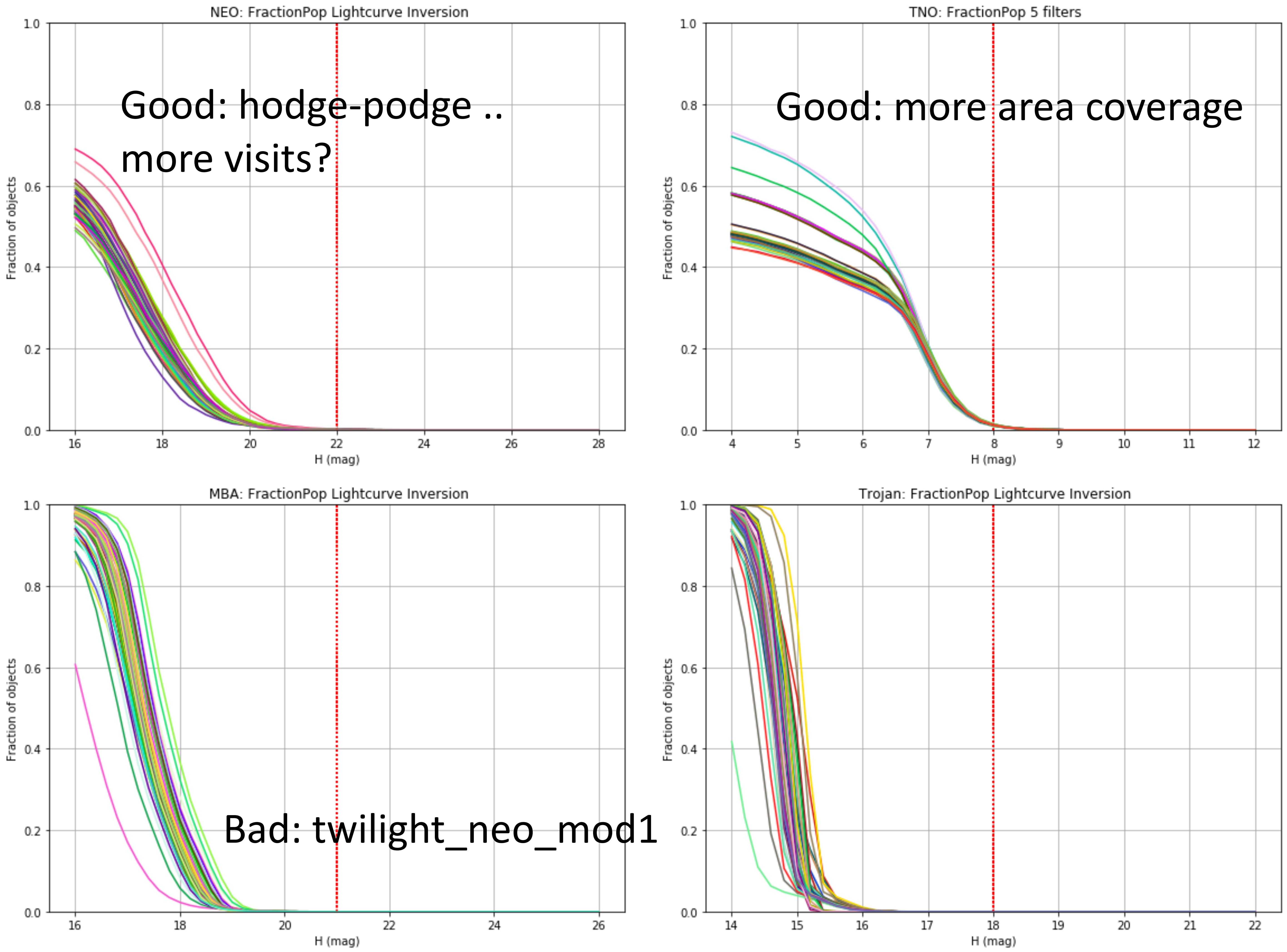

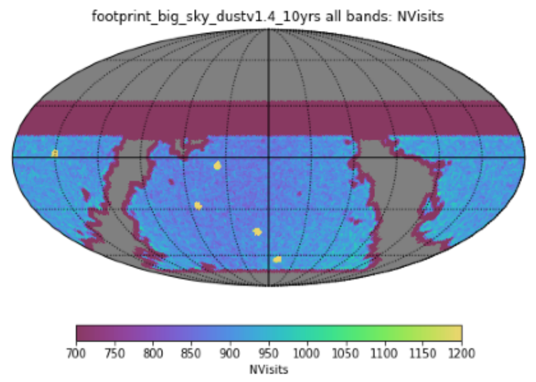

Analysis - a possible approach

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- Look for differences in summary metrics at particular H values — small H and mid-range H
  - Completeness with (two? one?) discovery criteria
  - Fraction of population for light curve inversion
  - Fraction of population with various colors
  - Weight towards completeness, with tie-breakers based on characterization? Or more balance between these?
  - By using just the numbers at given H values for the summary metric results, it simplifies making these comparisons - a big DataFrame
- Look for trends across families, to be able to place those trends into context
  - What tends to work better, what is bad?
- Write summaries of the effects of these variations and how they impact science
  - What changes are good/bad/neutral?

- This would be wonderful, consolidated, SC-validated, input for the SCOC! Enables a ranking of simulations plus the reasons for that ranking.

Hopefully useful links

Simulation Links

- FBS 1.4 announcement https://community.lsst.org/t/fbs-1-4-release-january-2020-update-fbs-1-4-runs/4006
- FBS 1.5 announcement https://community.lsst.org/t/fbs-1-5-release-may-update-bonus-fbs-1-5-release/4139

- FBS 1.4 databases https://epyc.astro.washington.edu/~lynnej/opsim_downloads/fbs_1.4/
- FBS 1.5 databases https://epyc.astro.washington.edu/~lynnej/opsim_downloads/fbs_1.5/

- FBS 1.4 MAF outputs http://astro-lsst-01.astro.washington.edu:8082/
- FBS 1.4 MAF outputs http://astro-lsst-01.astro.washington.edu:8081/

- The databases, simulations of the observations, and MAF outputs are available on the epyc SSSC Jupyterhub (common/NEW)

Code Links

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- Feature Based Scheduler code: https://github.com/lsst/sims_featureScheduler
  - This requires many supporting packages from LSST - install them all with 'lsst_sims' (see instructions here https://confluence.lsstcorp.org/display/SIM/Catalogs+and+MAF or just use the jupyterhub environments)

- Configurations for FBS 1.4 and 1.5 simulations
  - https://github.com/lsst-sims/sims_featureScheduler_runs1.4
  - https://github.com/lsst-sims/sims_featureScheduler_runs1.5

- Metrics Analysis Framework code: https://github.com/lsst/sims_maf
  - (also has lots of LSST requirements, also part of lsst_sims)

Appendix

Using a small orbit sample to represent the full population

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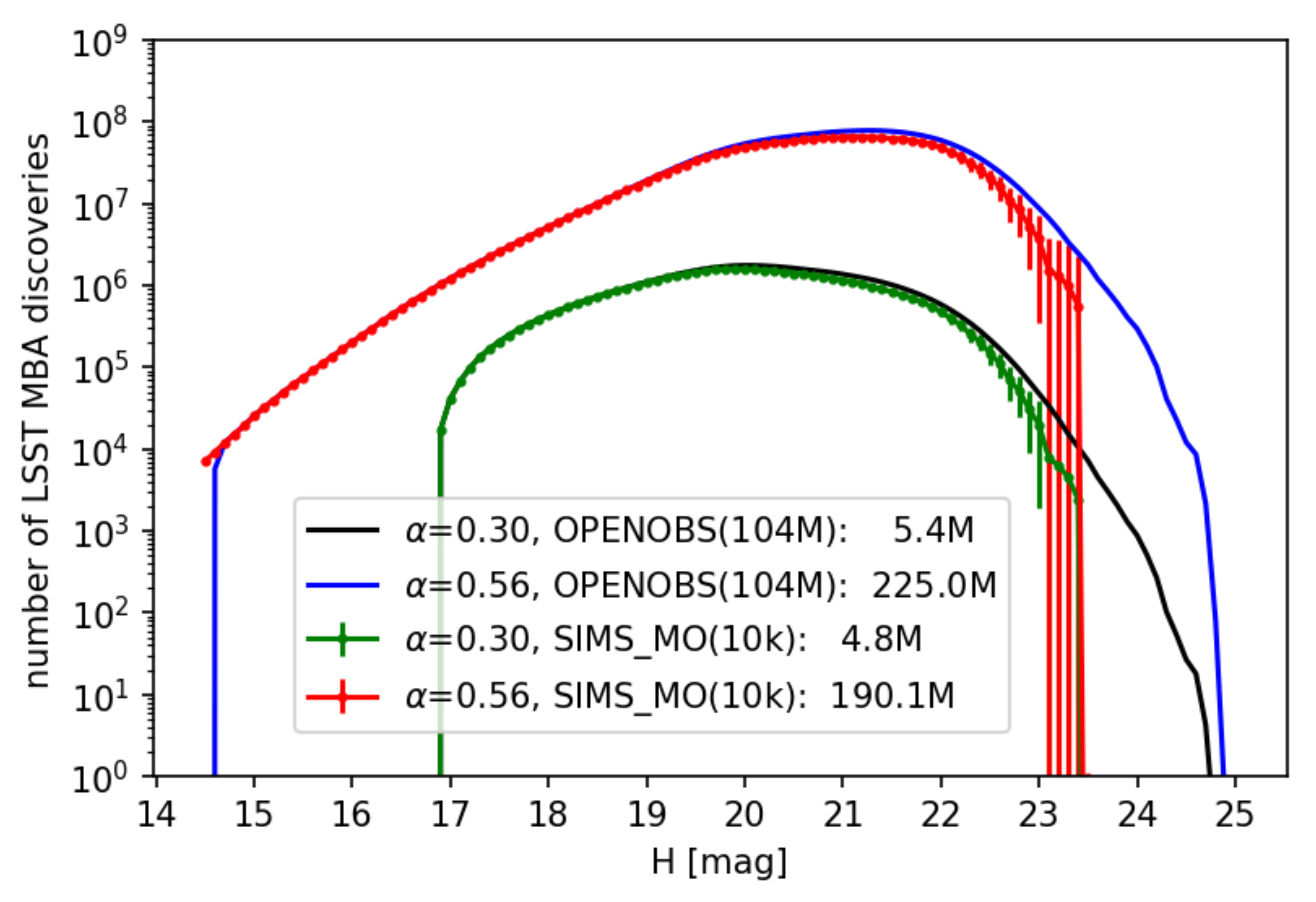
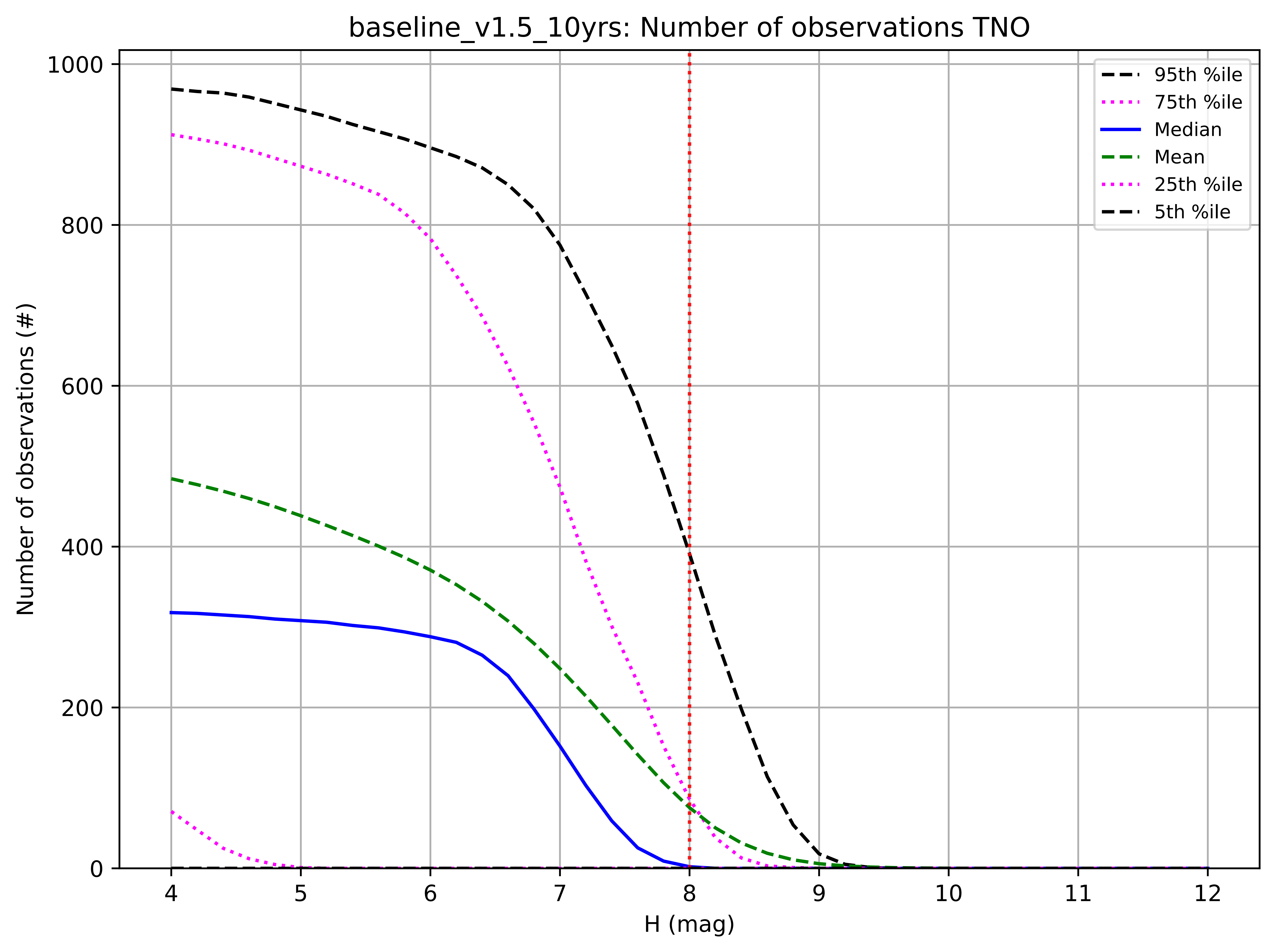
- Typically, we use 5k objects in MAF metrics, then clone each orbit over a range of H values [then evaluate the metric using the resulting *different* observed magnitudes at each H]
- This does not include N(H)
  - (necessary though, if you want total N)
- Pretty accurate when compared to full population
- Good to remember sample size and errors



Example: calculating the number of discoveries expected as a function of H, using both a large and small sample of the population. Results from 10k similar to results from 104M, until statistical error range increases at large H. (Eggl, DMTN-109).

Close-up of NObs metric plot



The 'mean' often crosses the other percentile lines, so is a bit messy (and indicates that we have unusual distributions).

But these plots (NObs and ObsArc) are intended to show the variation across the population for these basic stats .. here, 5% of the big TNOs have close to 0 observations, while 5% have over 950. The median number of observations at the bright end is about 300.

From the ObsArc plot for the same run, I see the median arc length is about 3500 nights, or 9.5 years .. or about 30 observations per year, most likely. Meanwhile, 25% of the bigger TNOs (about 100?) could have closer to 100 observations per year.