# Evaluating the LSST Observing Strategy: Metrics

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LSST 2019 PCW

Aug 14, 2019

# Current Status

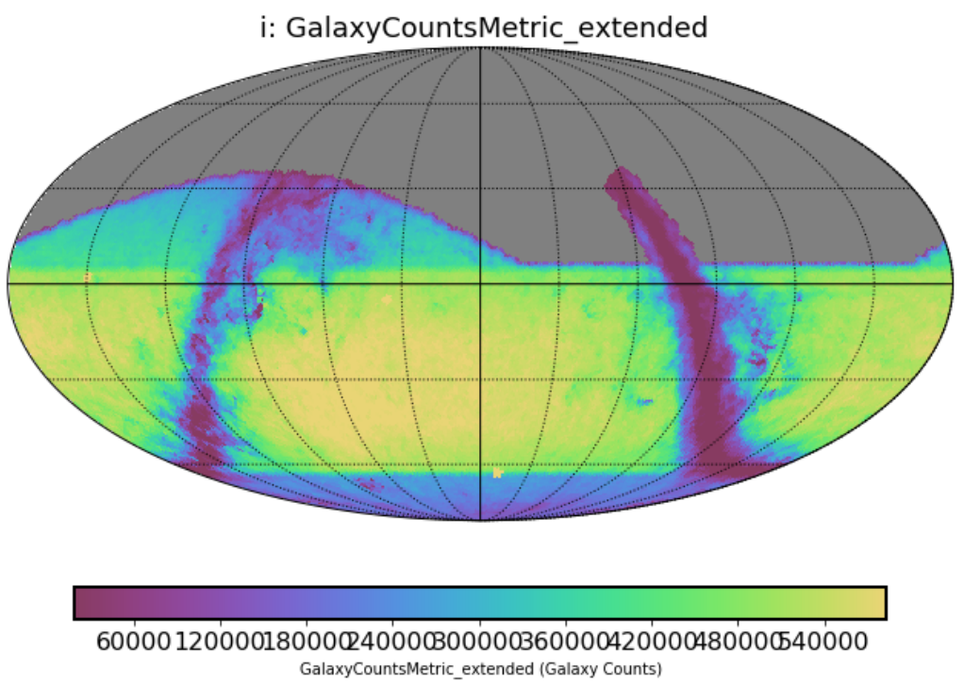
- WP Nov 2018 / SAC guidelines May 2019 / Simulations..
  - See July2019 update on community with more information on FBS 1.2 set of runs
  - https://community.lsst.org/t/july-2019-update/3760 (http://ls.st/xsb)
- Not complete, but getting better understanding of what metrics are telling us and what will need to go into report to the SCOC
- Will be releasing more runs and also writeups describing interpretation and comparisons of various runs
- So let's talk about metrics!

# Key Metrics

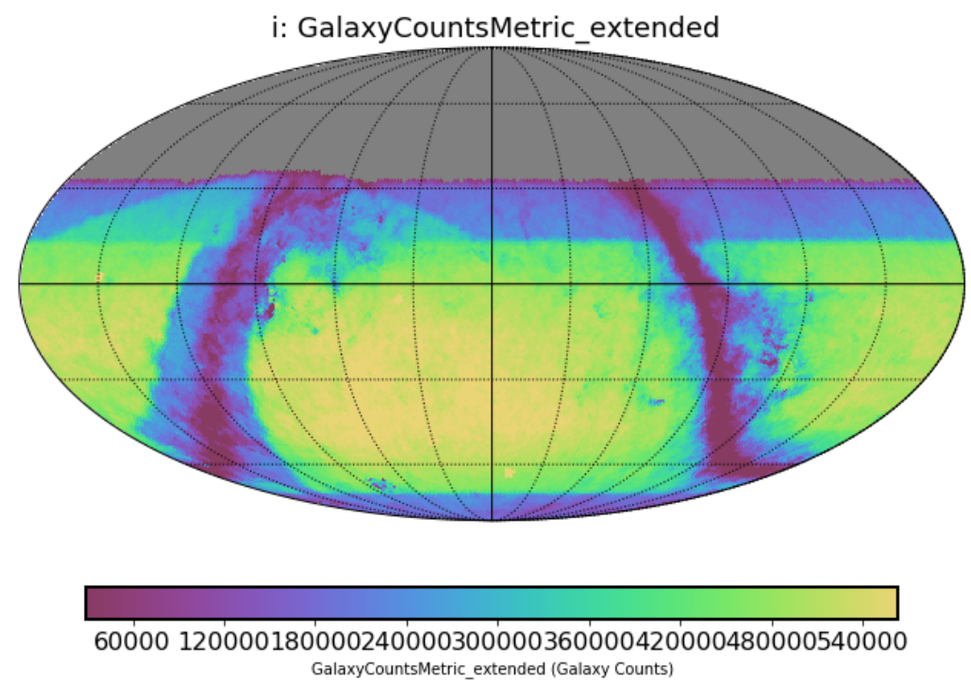
- Galaxy counts
- Transient recovery
- Astrometry (parallax, proper motion)
- Solar system metrics
- What are we missing?

# Galaxy Counts

- Galaxy Count Metric (credit Humna Awan)
- Calculate number of galaxies available for LSS studies



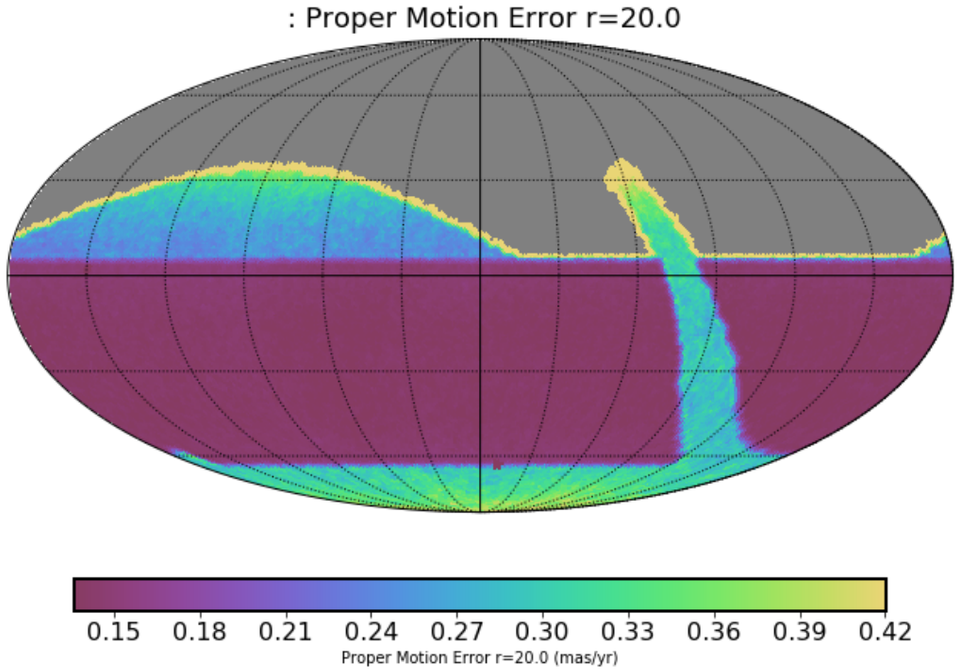

Baseline WFD:
10.8 billion galaxies



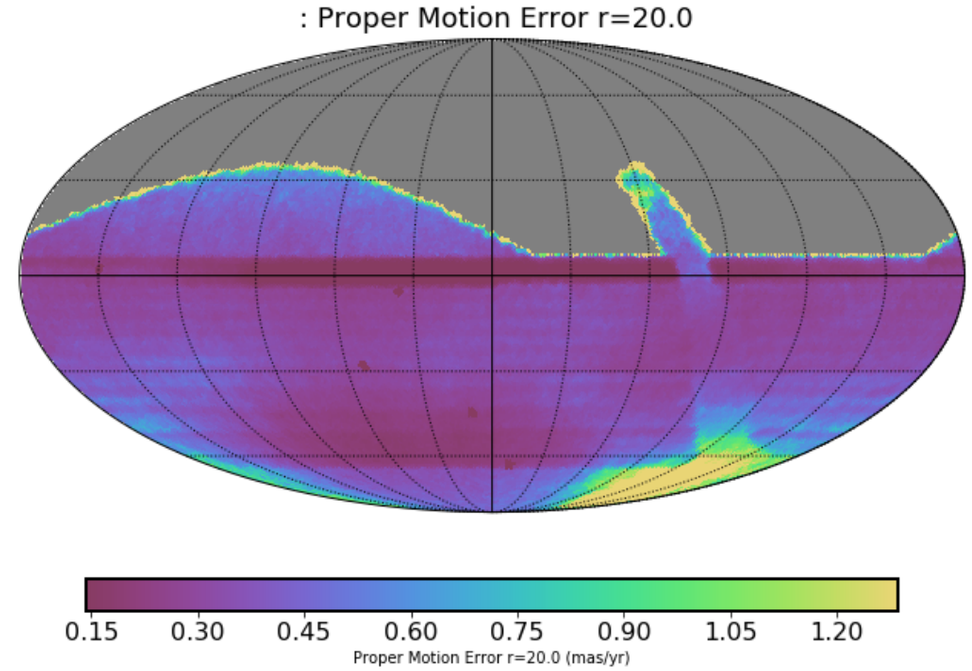

newB footprint WFD:
10.6 billion galaxies

# Astrometry (Parallax and Proper Motion)

## Uncertainty in the proper motion of an r=20 star




Baseline WFD median:
0.14 mas



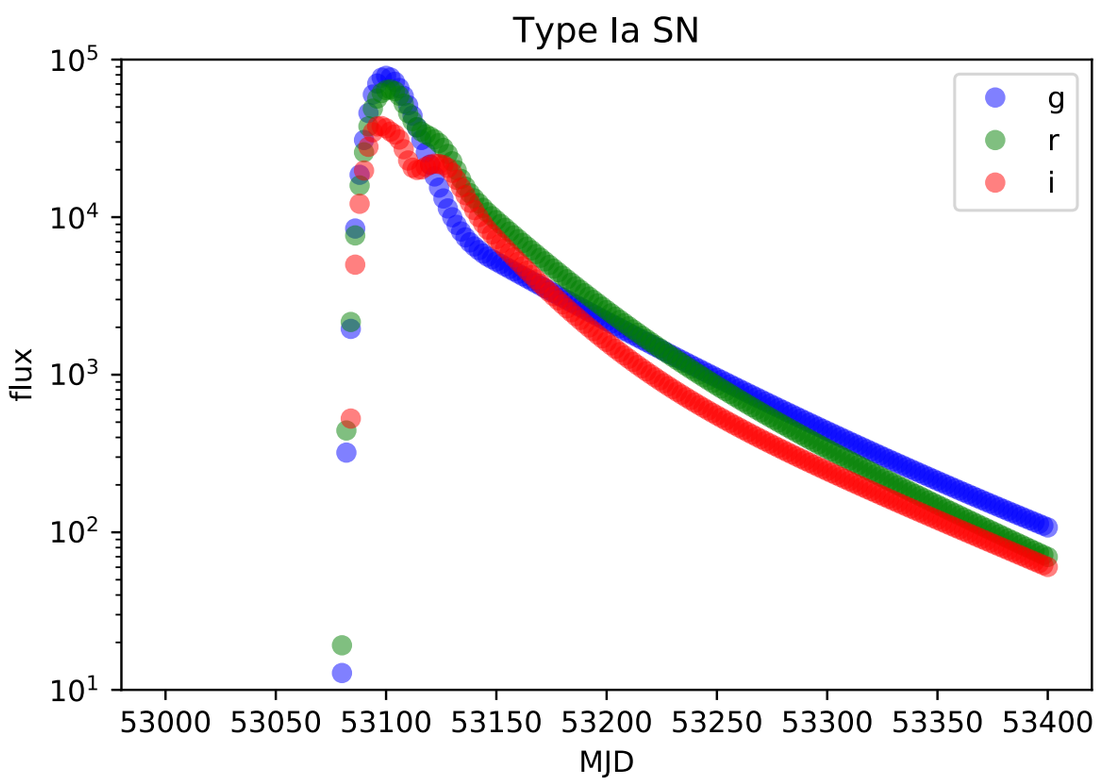

simple_roll_mod10_sdf0.20 WFD :
0.30 mas

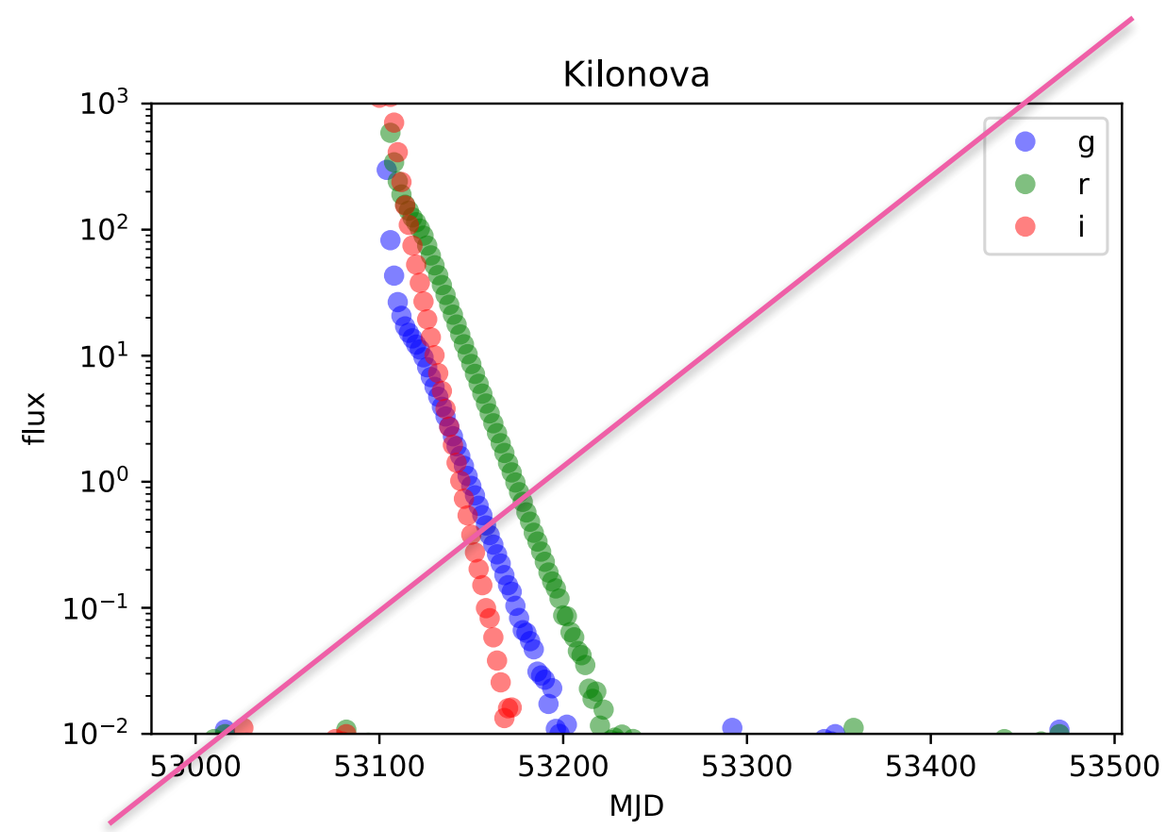
If there is no covariance, the proper motion uncertainty only depends on when observations happen and the centroiding errors.
If we do a very aggressive rolling cadence, proper motion error blows up.

# Transient Metrics

- Transient metrics: generate population of transients using (PLAsTiCC) light curves, distribute over sky & time, use MAF to test recovery rate

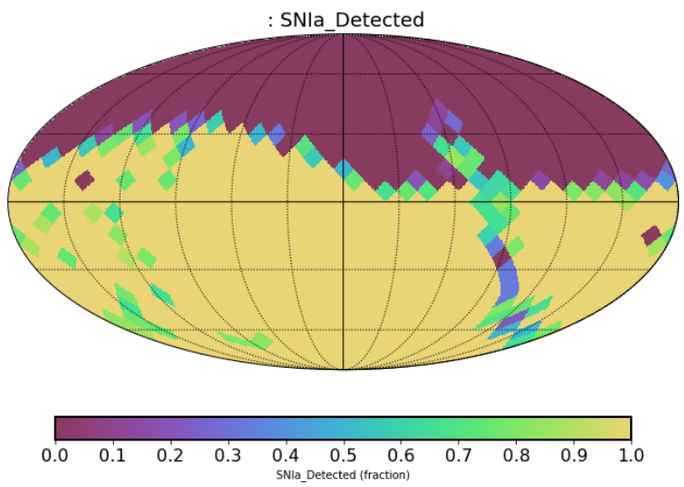
**"Pre-peak"** criteria: Measure a color before peak, and a rise slope in at least 1 filter
**"Well sampled"**: Divide LC into 10 bins, demand 5 have observations (any filters). I would love a better criteria!



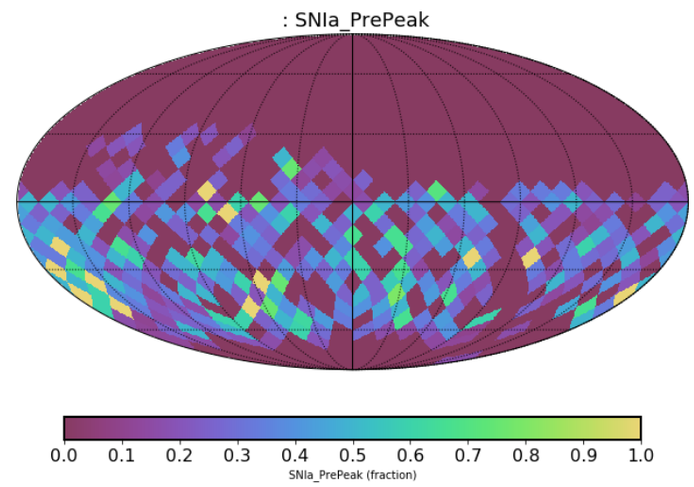



# Intra-night visits FBS 1.2 runs

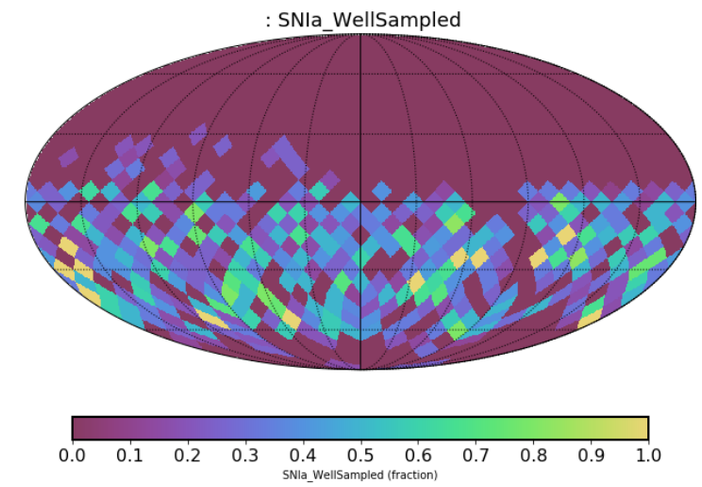
## 4k Type Ia SNe



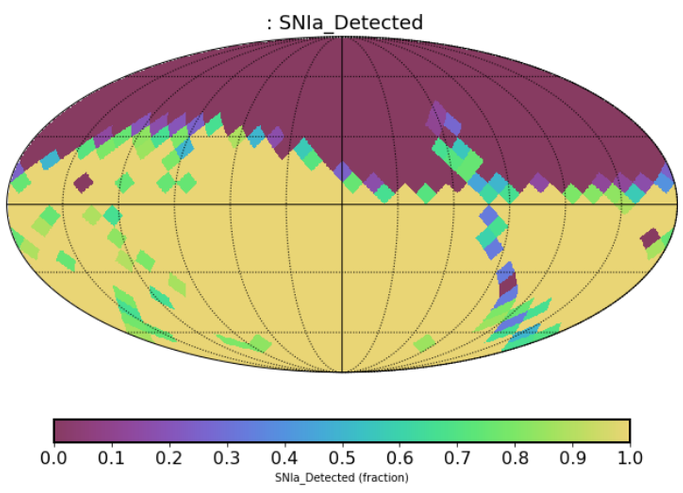

Pairs mixed 62% detected




15% measured pre-peak




17% “well-sampled”

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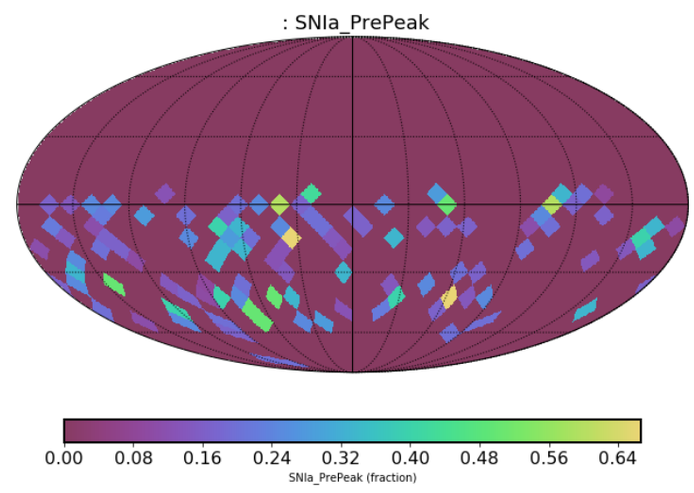
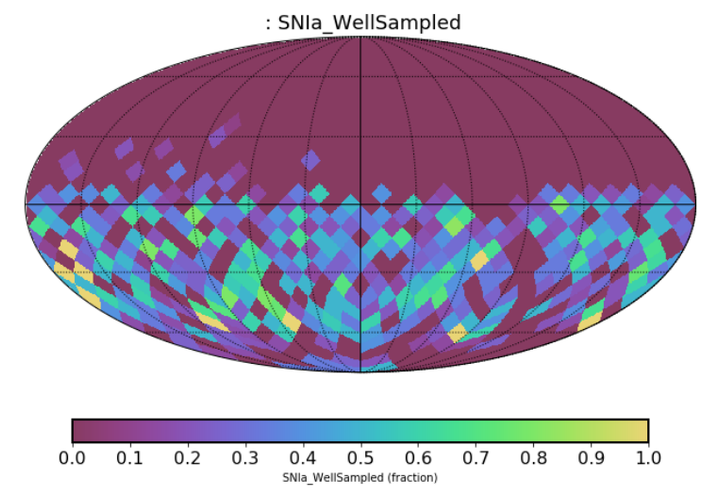



3% measured pre-peak



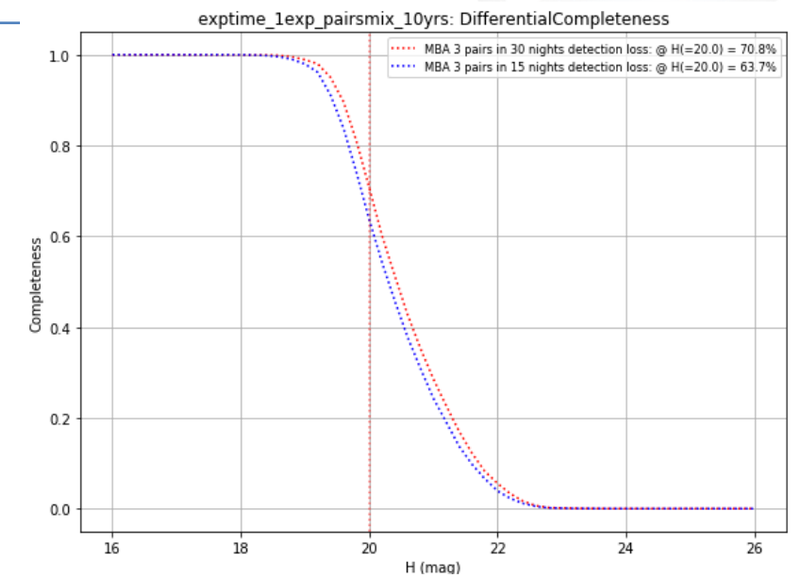

16% “well-sampled”

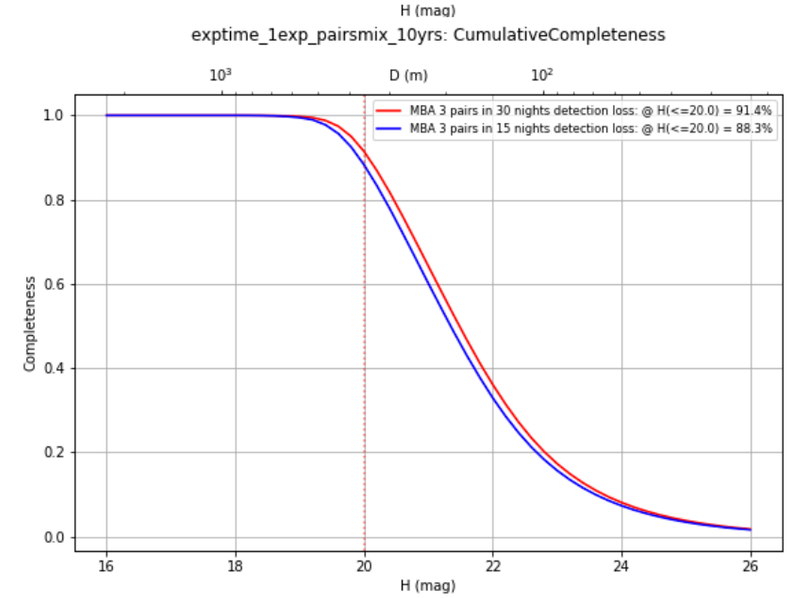
# Solar system metrics

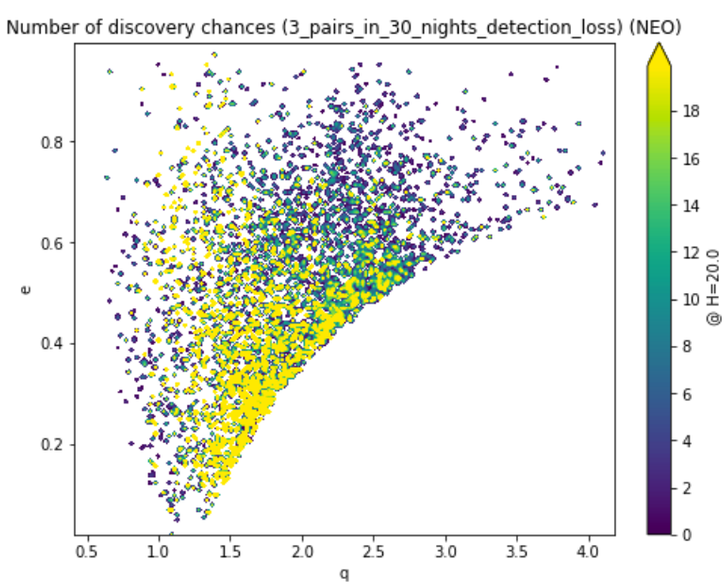
- To calculate metrics, first need to generate simulated observations of the objects
  - NEO (Granvik), MBA (S3M), Trojan (S3M), TNO (CFEPS L7)
  - + sims_movingObjects
  - https://github.com/lsst-sssc/SSSC_test_populations_gitlfs

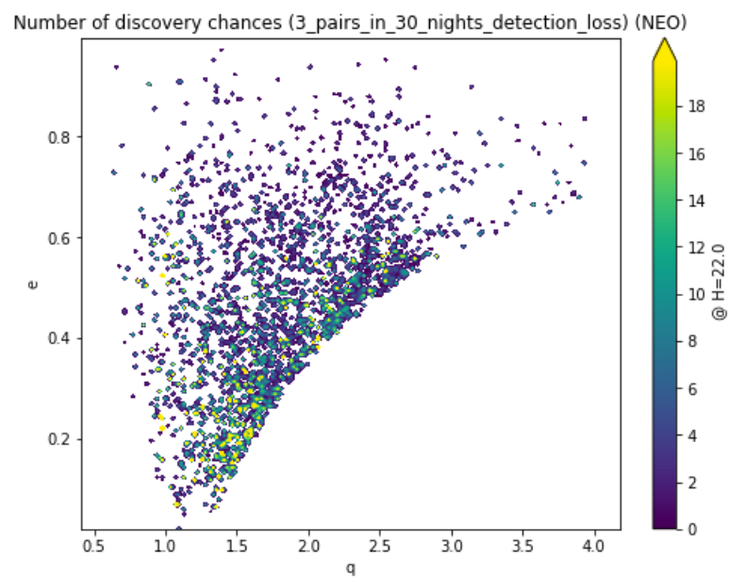
# Solar system metrics

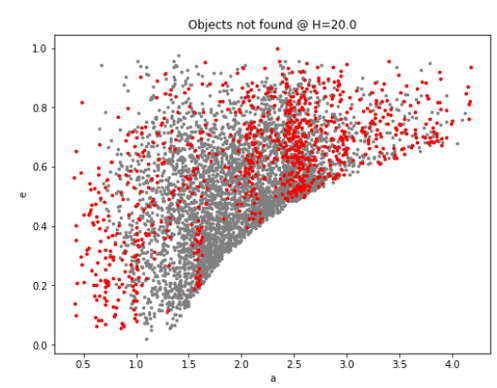
- Discovery metrics (as previously)
  - 3 pairs in 15 nights
  - 3 pairs in 30 nights **
  - .. 3 pairs in 12 nights, 20 nights
  - .. 4 pairs in 20 nights, 3 triplets in 30
  - .. Single detection, single pair
  - .. 3x15 & 3x30 @ SNR=3,4,5.
  - HighVelocity (trailing) pair



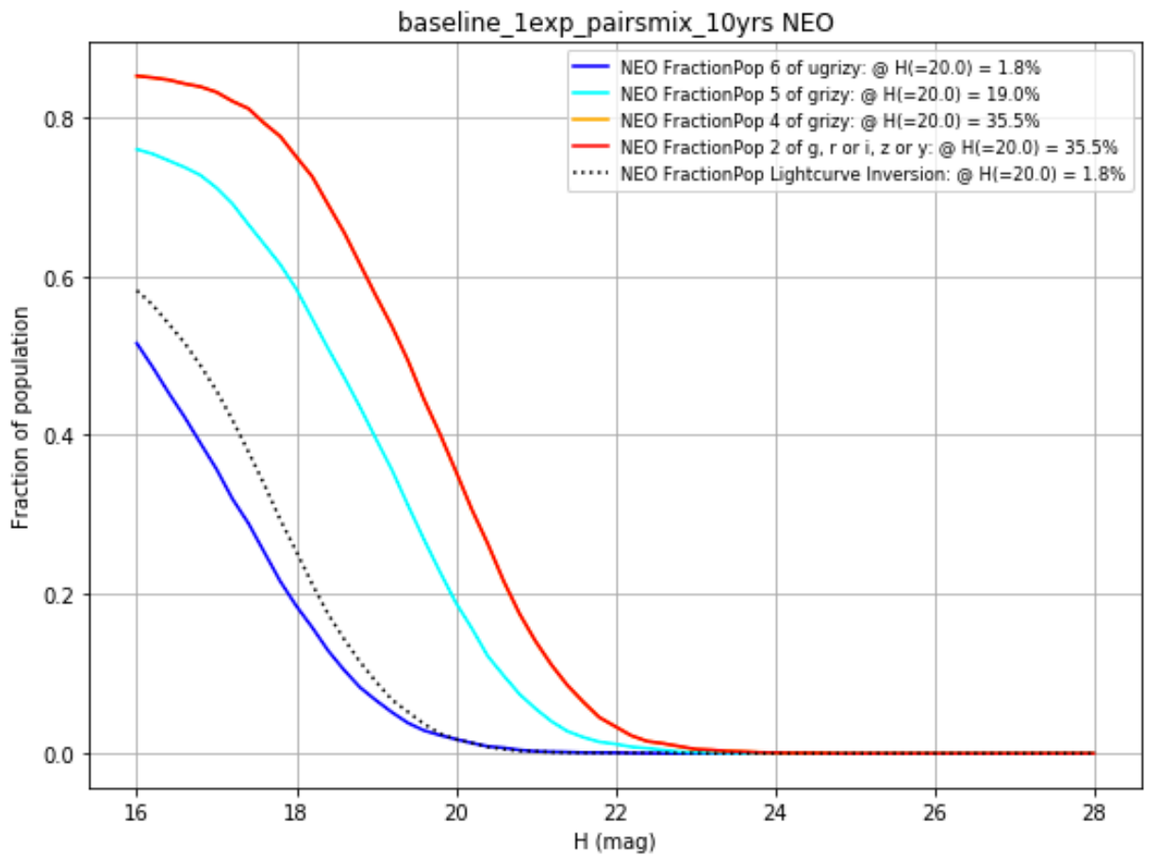



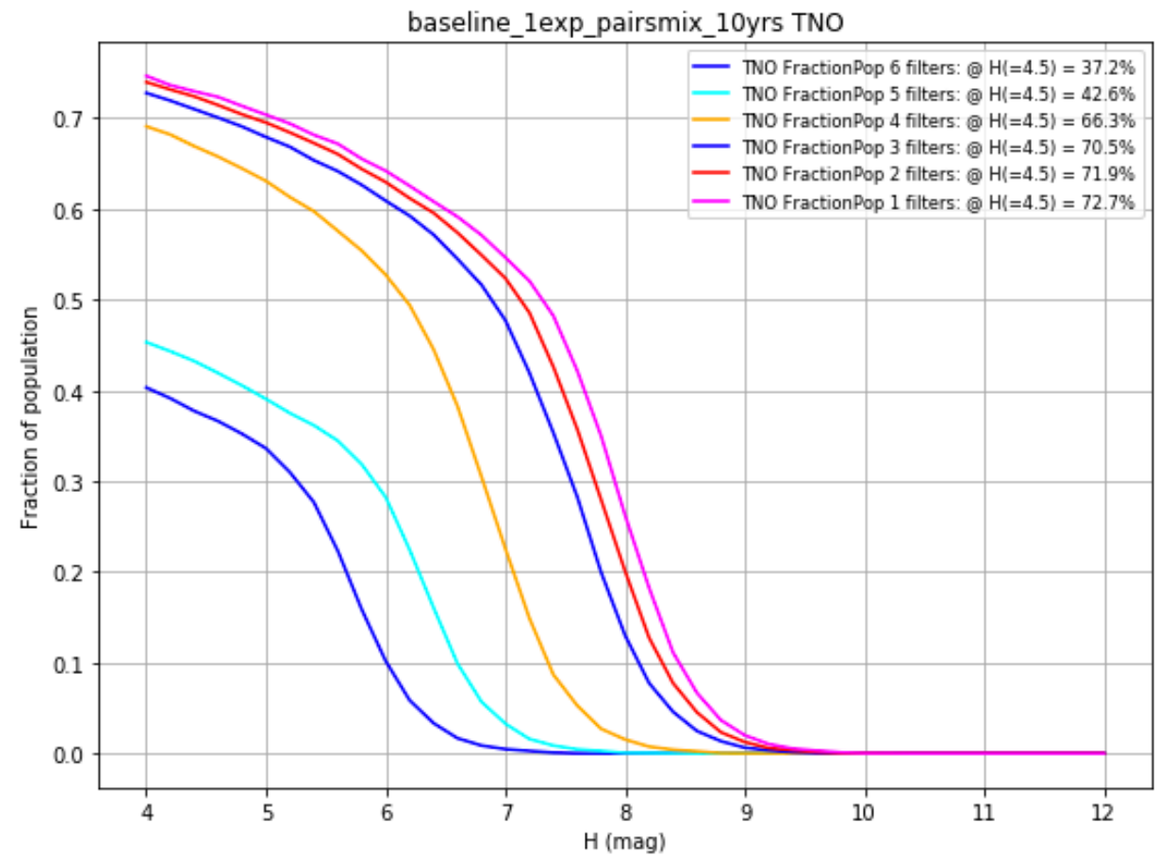



# Solar system metrics

- Characterization metrics (as previously)
  - “Chance of detecting activity”
    - Bin time (or mean anomaly) over survey (or orbit) and build histogram of visits - what fraction of bins received a visit?
  - Inner solar system
    - Lightcurve inversion (updated metric)
    - Color determination (10+ SNR-weighted observations)
      - g + ([r or i] OR [z or y] (2 colors)
      - 4 of grizy
      - 5 of grizy **
      - 6 of ugrizy
  - Outer solar system
    - Lightcurve/Color in 1, 2, 3, 4, 5 ** or 6 filters (30+ obs in first filter, 20+ in secondary)

# Solar system metrics



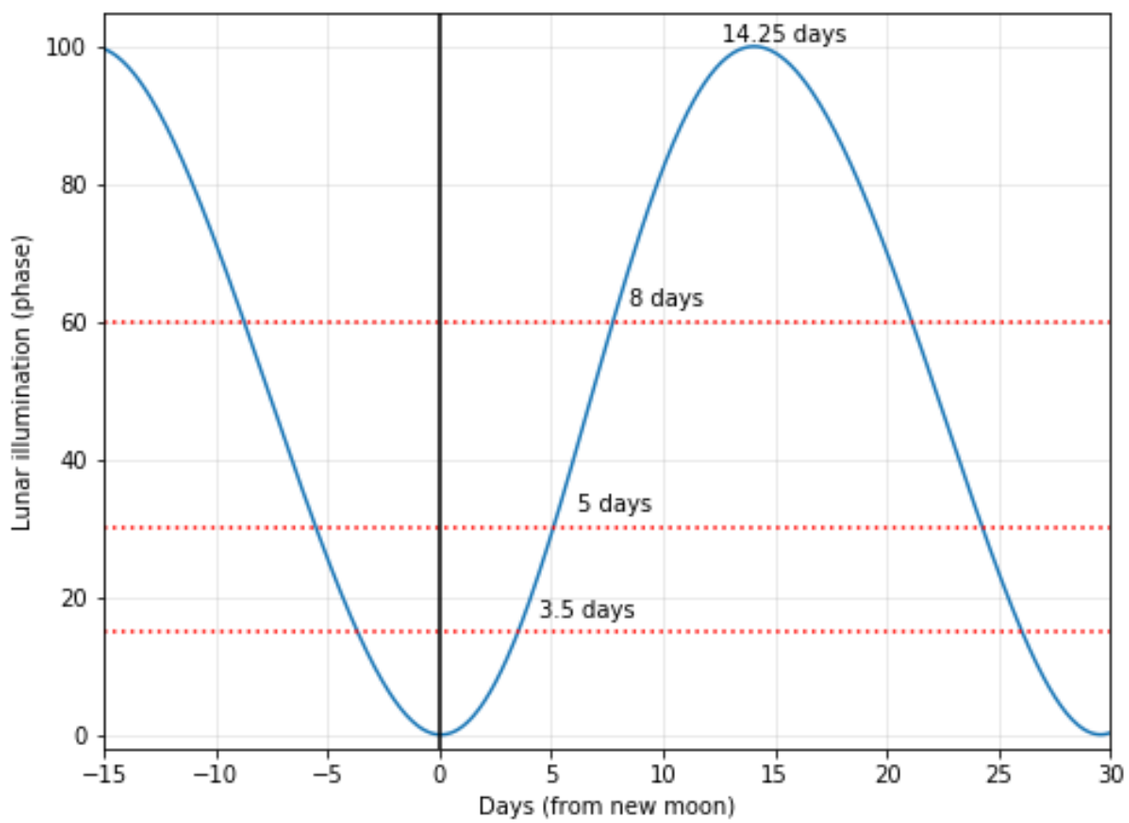

Online at
http://astro-lsst-01.astro.washington.edu:8081
.. will also find a link for downloading full outputs if interest

# Analysis

- u band filter swap
- baseline - pairs of visits
- WFD footprint
- rolling cadence

# u band filter switch FBS 1.2 runs

- Limit u band to within +/-2 nights of new moon




Effect on DD

| | Illum 15 | Illum 30 | Illum 60 |
|---|---|---|---|
| DD:u,290 | 726 | 1295 | 2079 |
| DD:u,COSMOS | 1421 | 2590 | 3206 |
| DD:u,ECDFS | 1714 | 3178 | 3327 |
| DD:u,ELAISS1 | 1092 | 2079 | 3281 |
| DD:u,XMM-LSS | 1211 | 2247 | 3265 |

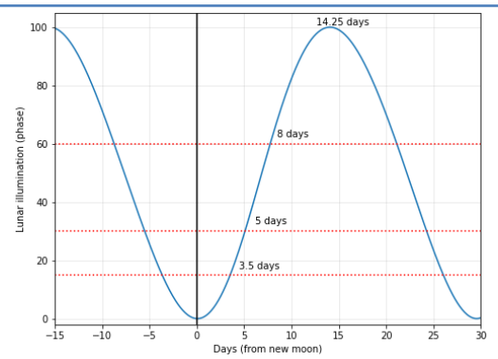
Visits

| | Illum 15 | Illum 30 | Illum 60 |
|---|---|---|---|
| DD:u,290 | 27.106095 | 27.408551 | 27.653017 |
| DD:u,COSMOS | 27.397545 | 27.724804 | 27.815033 |
| DD:u,ECDFS | 27.560829 | 27.912816 | 27.898625 |
| DD:u,ELAISS1 | 27.434422 | 27.808381 | 28.052296 |
| DD:u,XMM-LSS | 27.383279 | 27.724085 | 27.915011 |

Coadd m5

Bugfix (in 1.3): +0.2 to u band mag

# u band filter switch FBS 1.2 runs



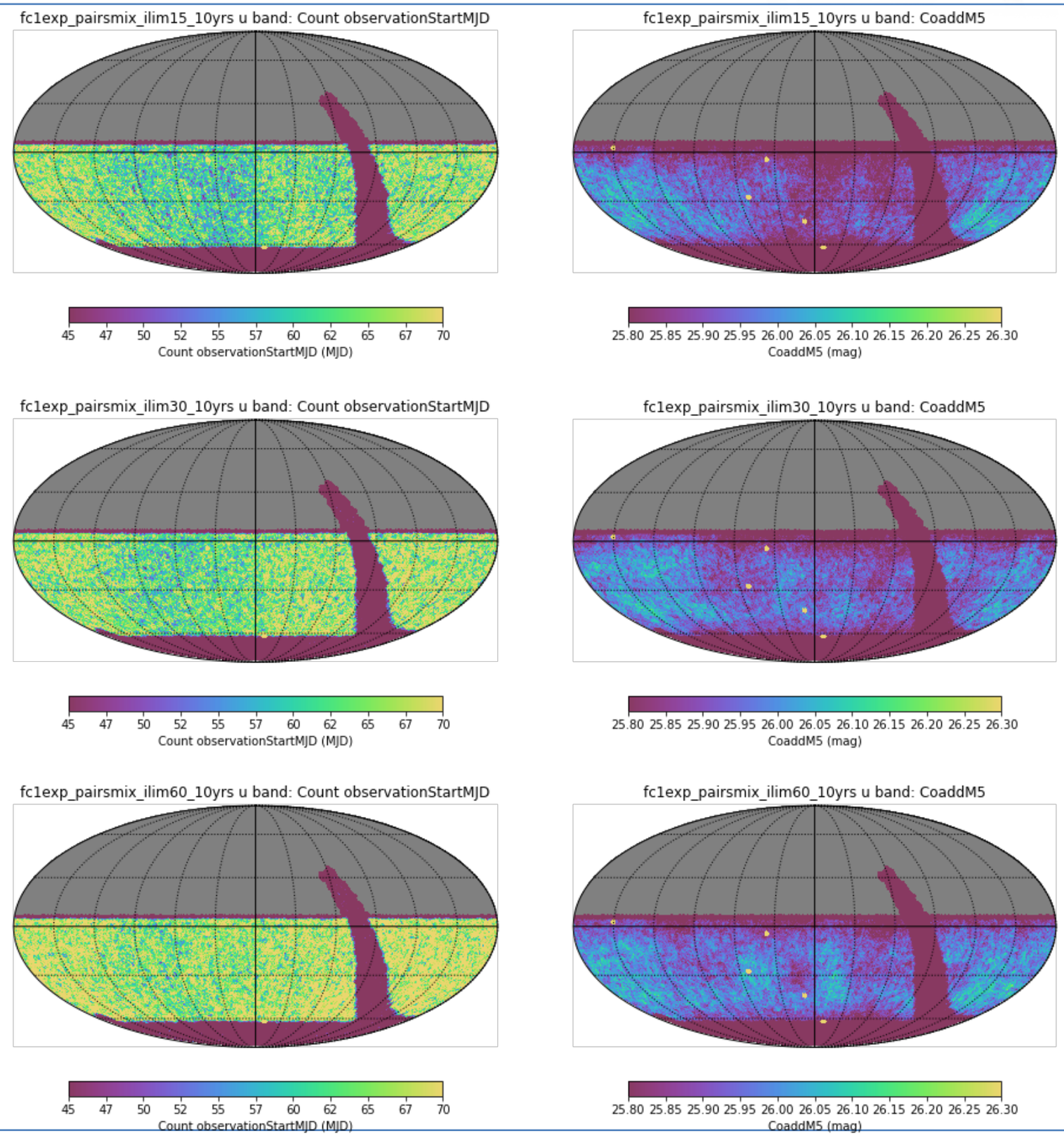

## Visits

| | Illum 15 | Illum 30 | Illum 60 |
|---|---|---|---|
| **Min** | 1.000000 | 1.000000 | 1.000000 |
| **25th%ile** | 54.000000 | 55.000000 | 58.000000 |
| **Mean** | 59.386335 | 62.798245 | 66.956338 |
| **Median** | 62.000000 | 63.000000 | 66.000000 |
| **75th%ile** | 67.000000 | 68.000000 | 71.000000 |
| **Max** | 1788.000000 | 3251.000000 | 3402.000000 |

## CoaddM5

| | Illum 15 | Illum 30 | Illum 60 |
|---|---|---|---|
| **Min** | 22.181656 | 22.318727 | 22.004103 |
| **25th%ile** | 25.728216 | 25.764568 | 25.787233 |
| **Mean** | 25.753742 | 25.783810 | 25.803447 |
| **Median** | 25.867756 | 25.900715 | 25.919637 |
| **75th%ile** | 25.948631 | 25.968181 | 25.986368 |
| **Max** | 27.592408 | 27.928824 | 28.064792 |

Bugfix (in 1.3): +0.2 to u band mag



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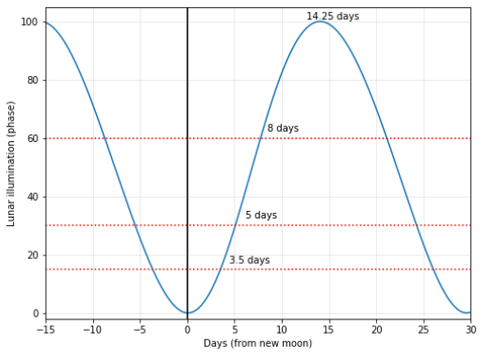
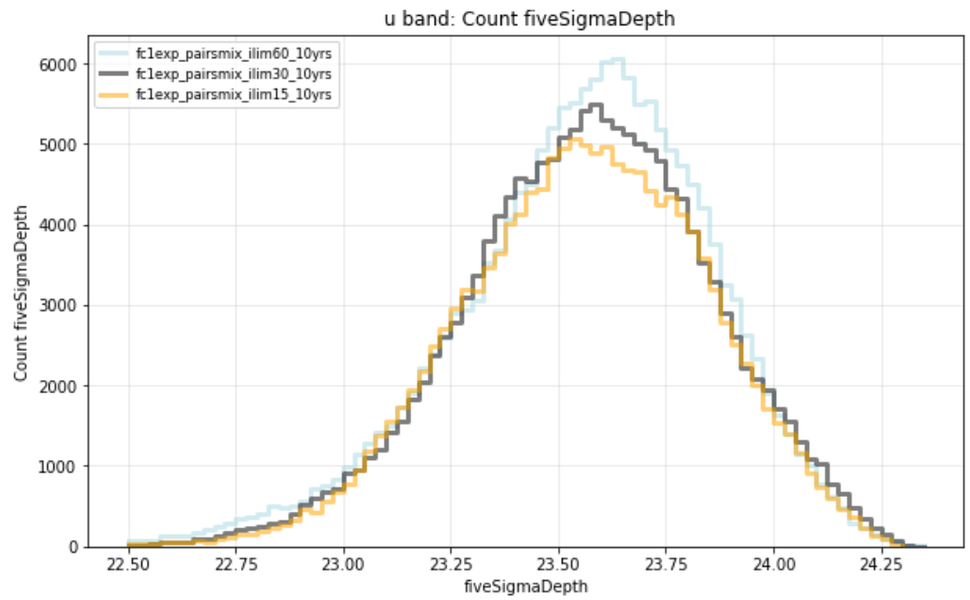
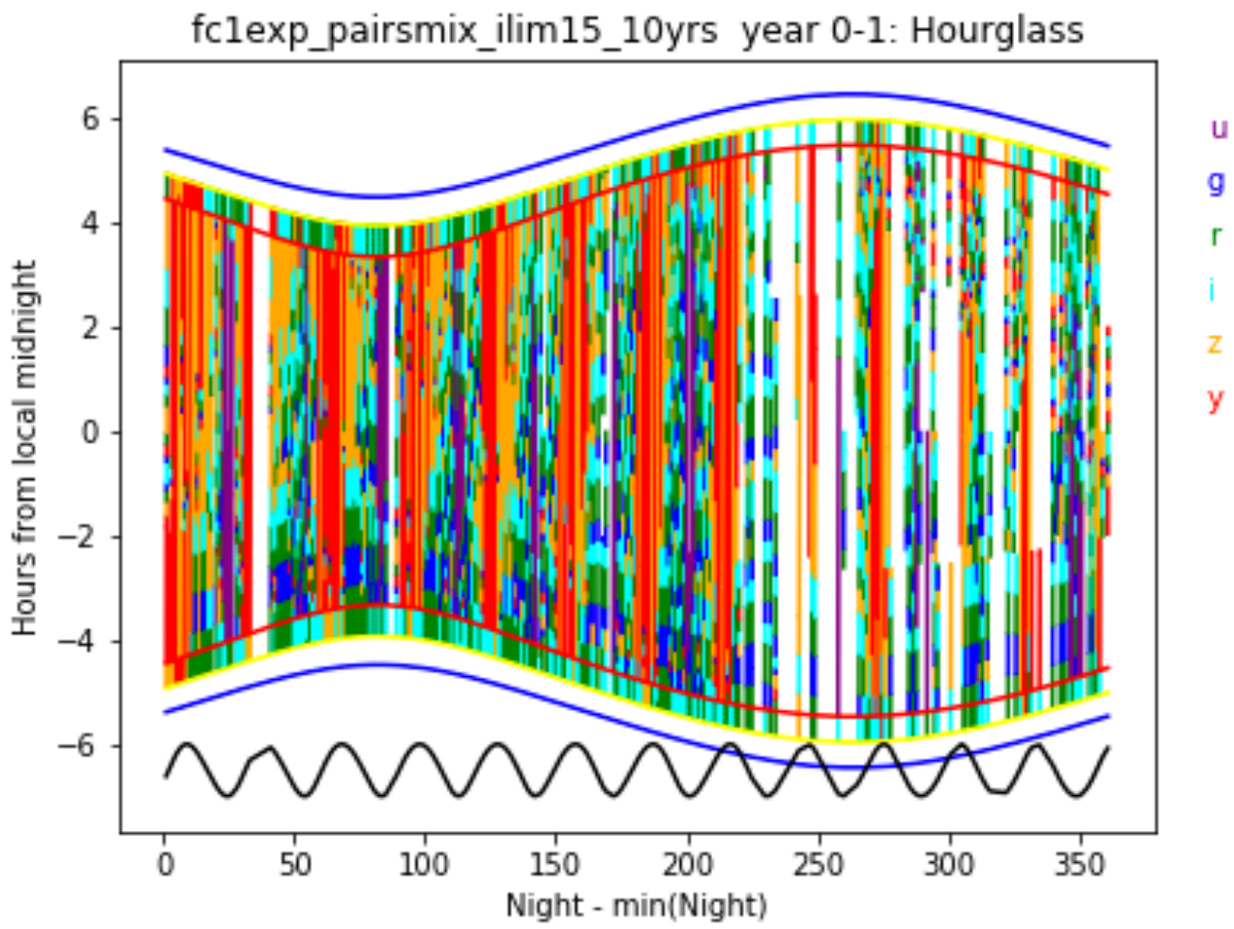
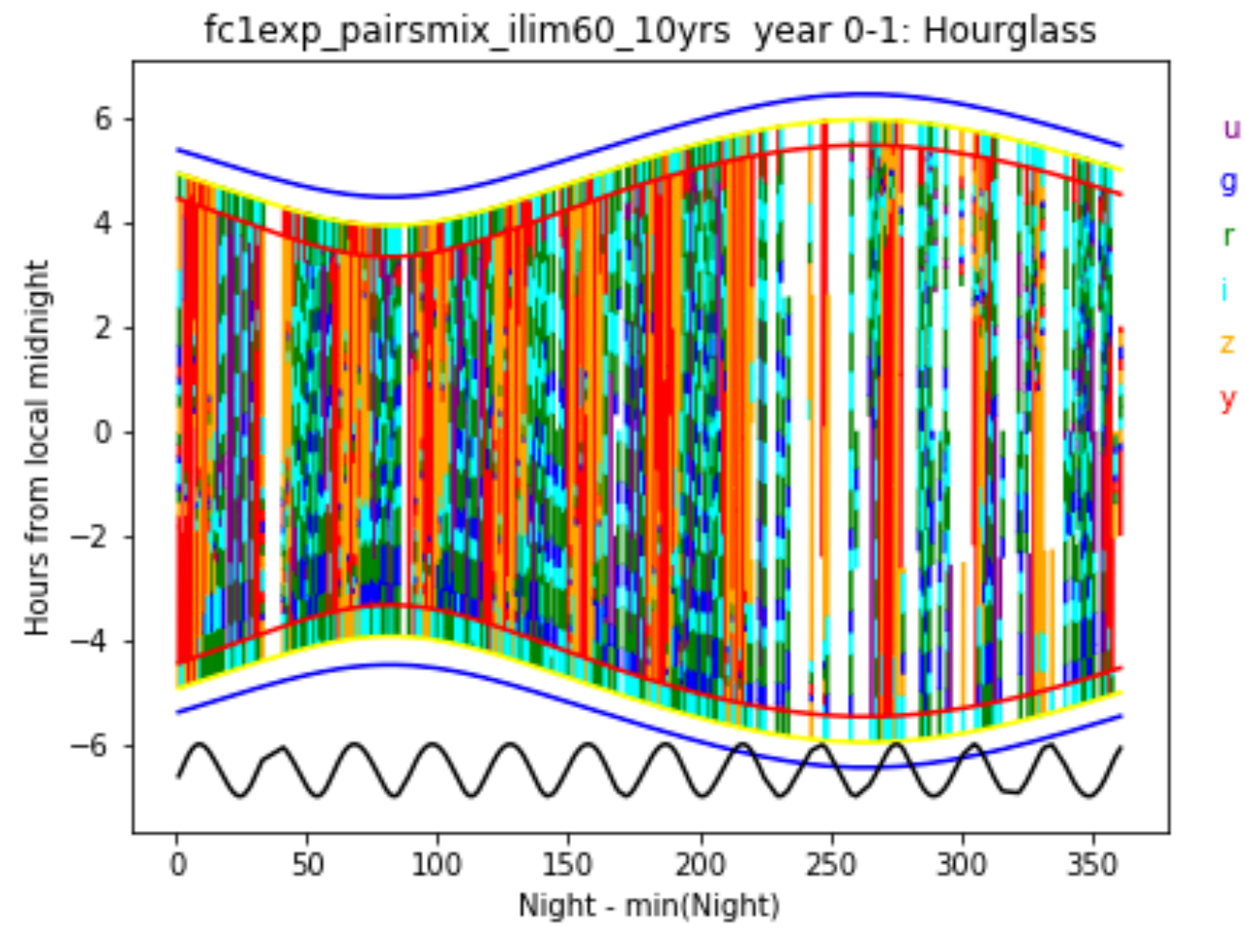


# Analysis

- u band switch
- Motivation for limiting the time u band available comes from DESC/get best u band depth
- Limiting u band availability restricts potential WFD u band depth
- We get u band under good circumstances almost all of the time (even if it's not "new moon")

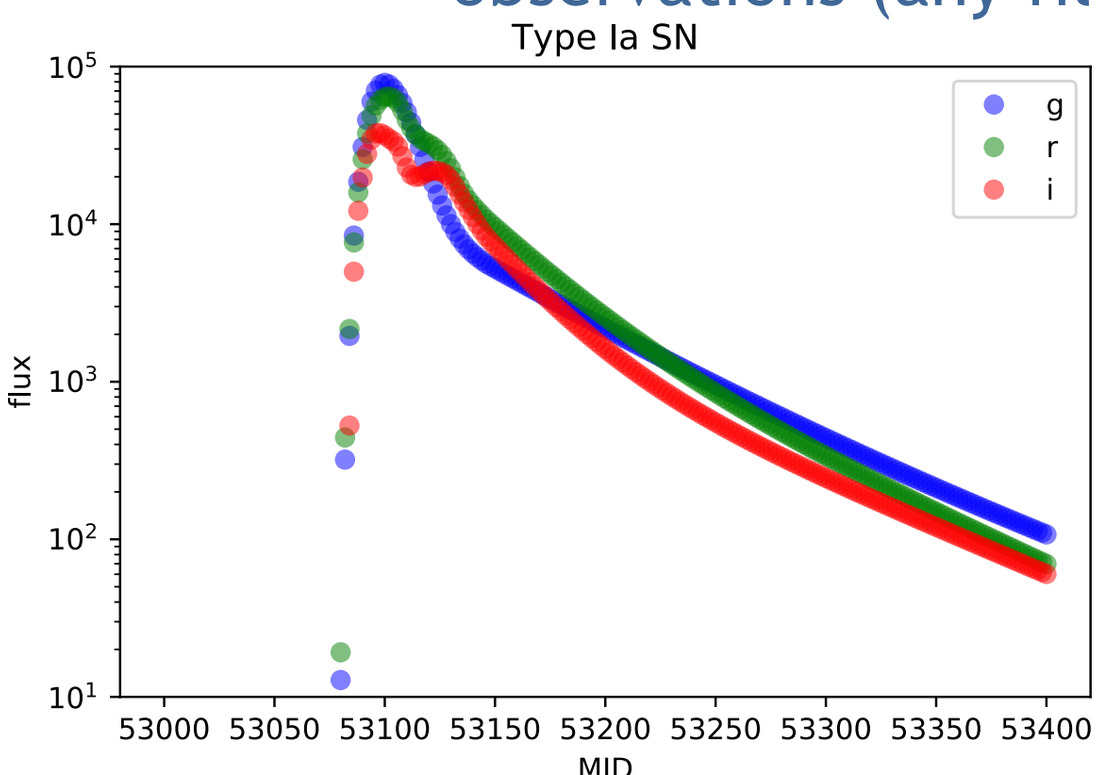
- Re-run with even more emphasis on u during dark time?
  - Look at longer exposures in u band? (& there will be improvement with bugfix in FBS 1.3 too)

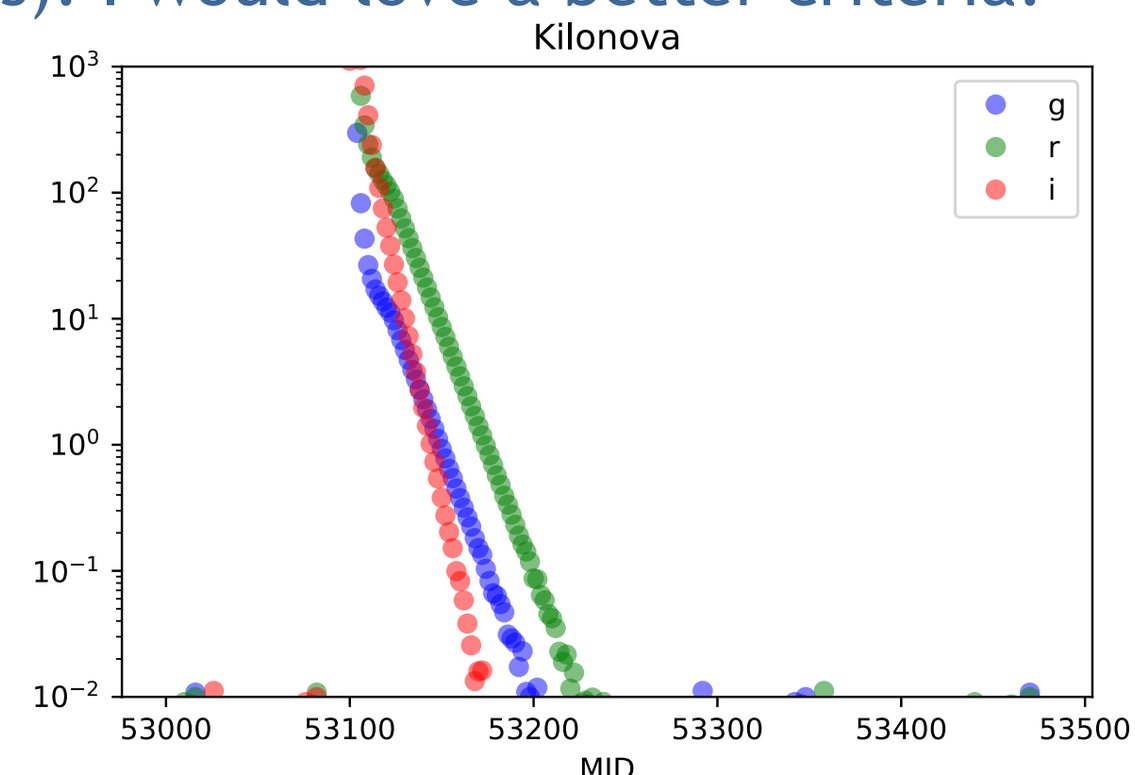
# Intra-night visits FBS 1.2 runs

- Filters for pairs (same, mix, presto)

- Transient metrics: generate population of transients using (PLAsTiCC) light curves, distribute over sky & time, use MAF to test recovery rate

  **"Pre-peak"** criteria: Measure a color before peak, and a rise slope in at least 1 filter
  **"Well sampled"**: Divide LC into 10 bins, demand 5 have observations (any filters). I would love a better criteria!



# Intra-night visits FBS 1.2 runs

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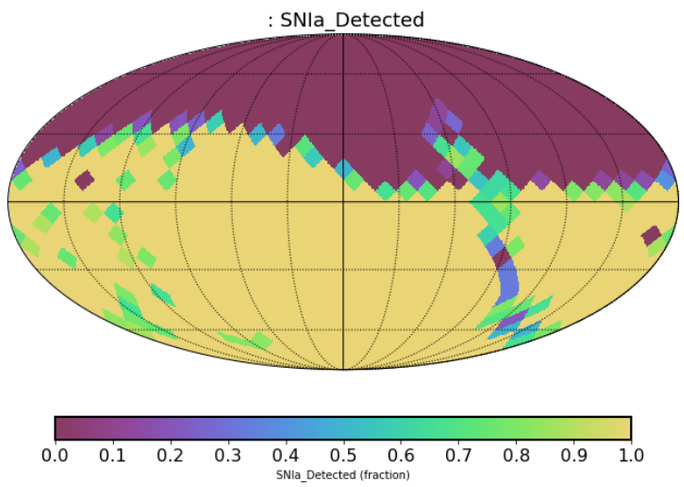


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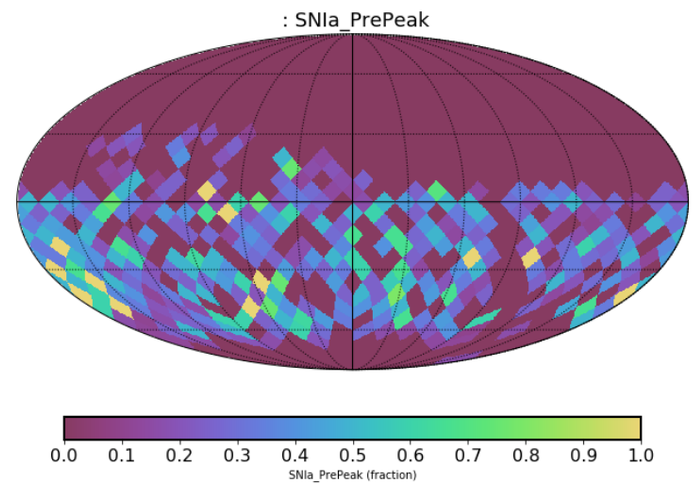
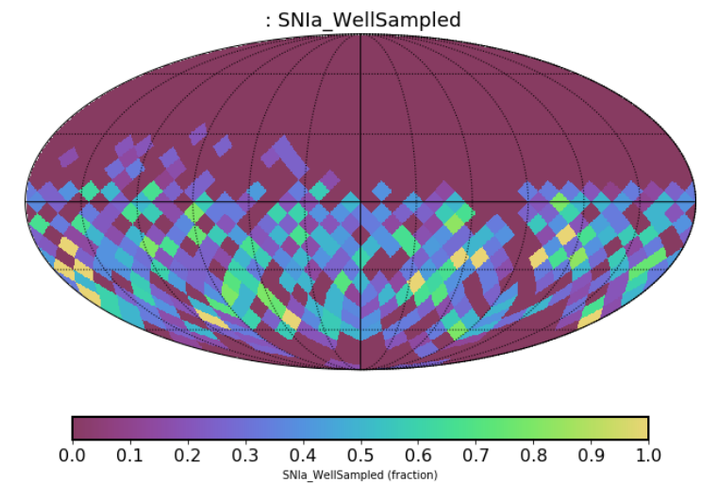
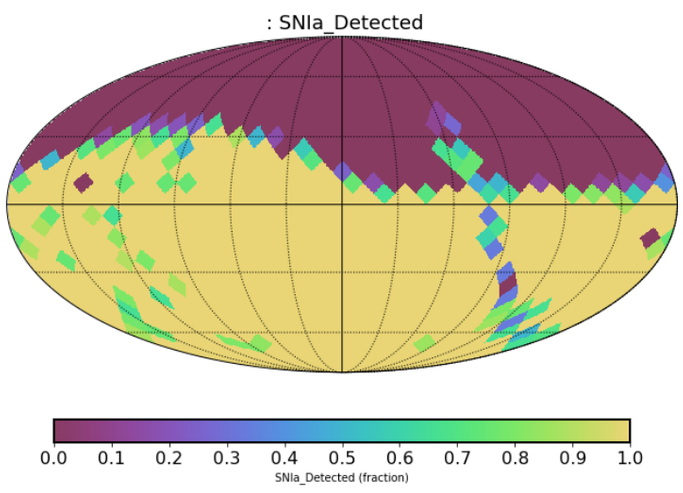



15% measured pre-peak




17% “well-sampled”

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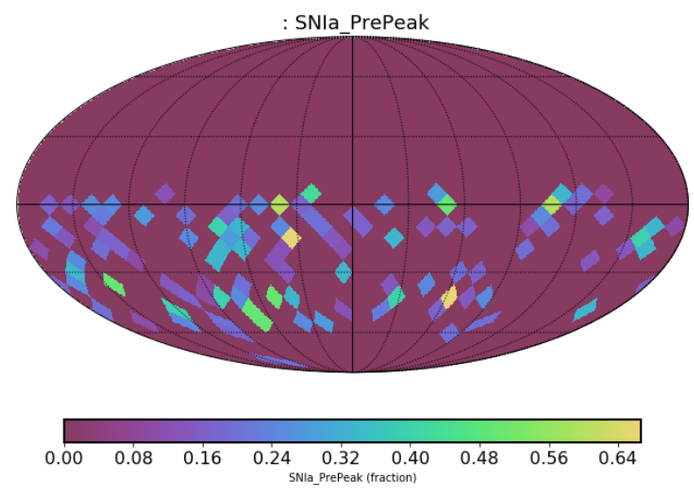
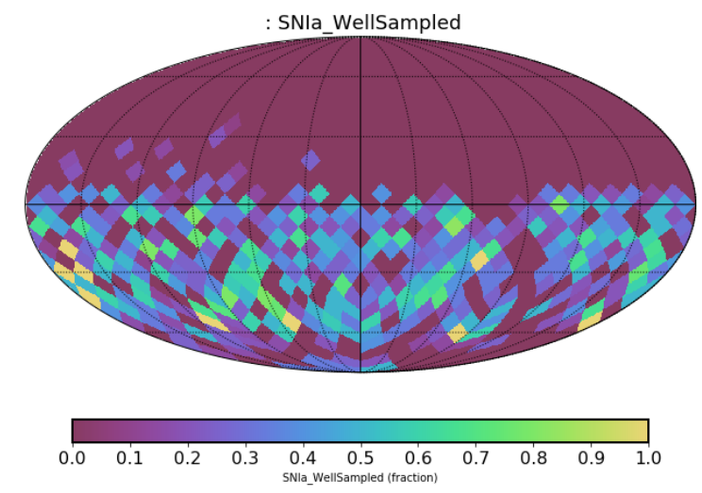



3% measured pre-peak

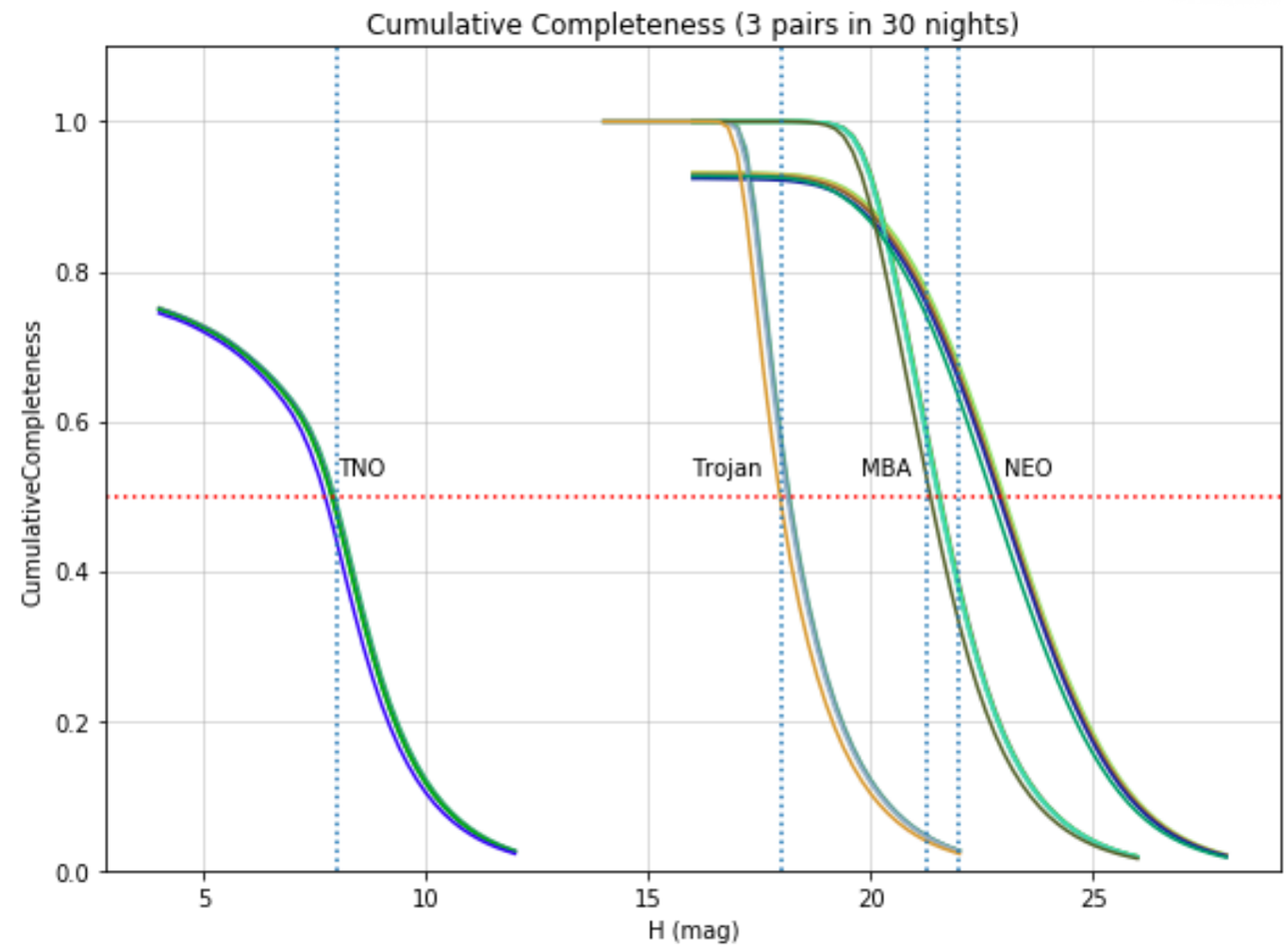



16% “well-sampled”

# Intra-night visits FBS 1.2 runs

Mixing filters for pairs does have a cost to SSOs.

Set up some small % of visits to be same filters?




| | NEO H=22 | MBA H=21.25 | Trojan H=18 | TNO H=7.5 |
|---|---|---|---|---|
| baseline_1exp_pairsame_10yrs | 67.3 | 59.2 | 57.5 | 57.7 |
| baseline_1exp_pairsmix_10yrs | 66.5 | 58.7 | 56.6 | 57.0 |
| baseline_2exp_pairsame_10yrs | 66.0 | 58.2 | 56.3 | 56.9 |
| baseline_2exp_pairsmix_10yrs | 65.2 | 57.8 | 55.0 | 56.6 |
| presto_third_10yrs | 62.9 | 52.7 | 48.4 | 54.3 |

~1% mixing pairs

~2% mix pairs + 2x15s

~5-6% presto_third

# Analysis

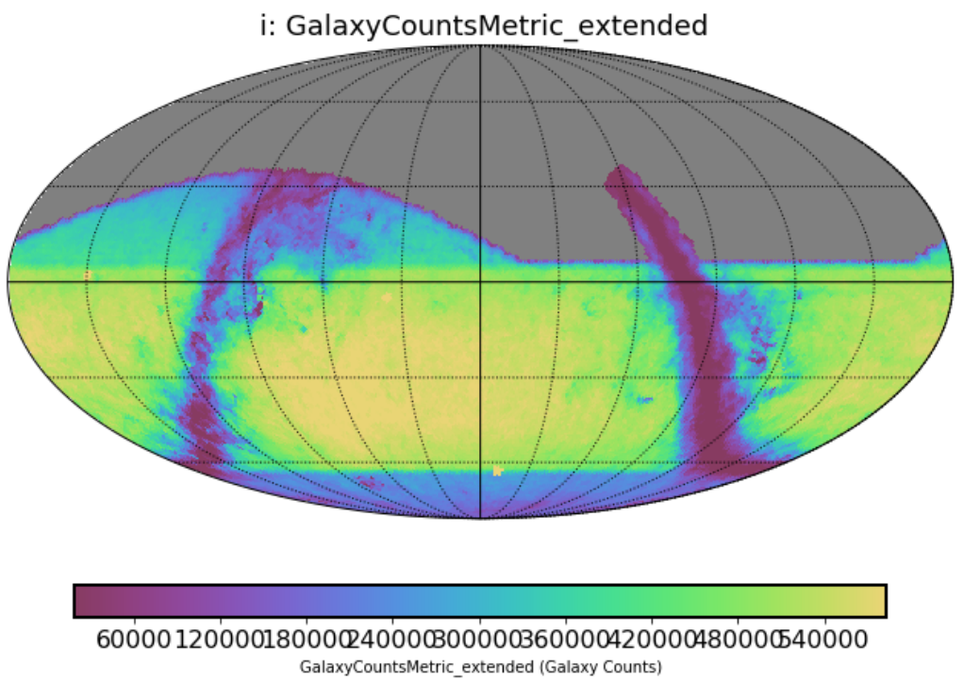
- Motivation for pairs in different filters comes from characterizing (slowly) changing transients
- Increases pre-peak sampling of SNIa (3% - 15%)
- Pushback comes from worry that SSOs will be harder to discover - there is some impact on SSO discovery, particularly with presto_third in its current form.
- Additional pushback that changing filters is less efficient - ~2% penalty
- Add some small % of visits in same-filter, try to rework presto_third

| | Nvisits |
|---|---|
| baseline_1exp_nopairs_10yrs | 100.8 |
| baseline_1exp_pairsame_10yrs | 100.0 |
| baseline_1exp_pairsmix_10yrs | 97.9 |
| baseline_2exp_pairsame_10yrs | 92.4 |
| baseline_2exp_pairsmix_10yrs | 90.5 |

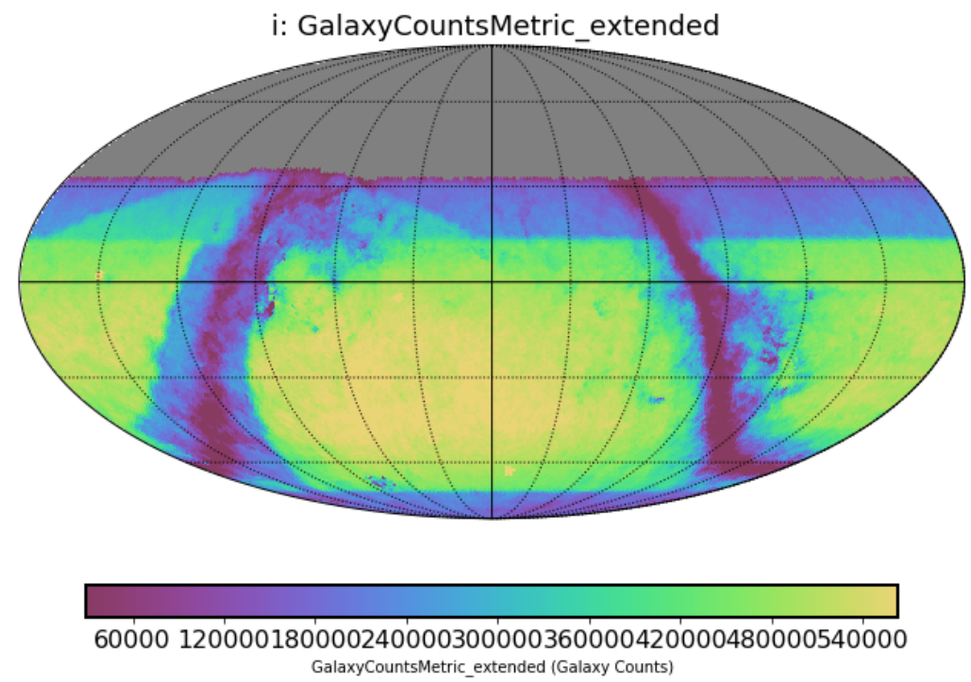
# WFD footprint FBS 1.2 runs

- ‘WFD footprint’

- Galaxy Count Metric (credit Humna Awan)
- Calculate number of galaxies available for LSS studies




Baseline WFD:
10.8 billion galaxies

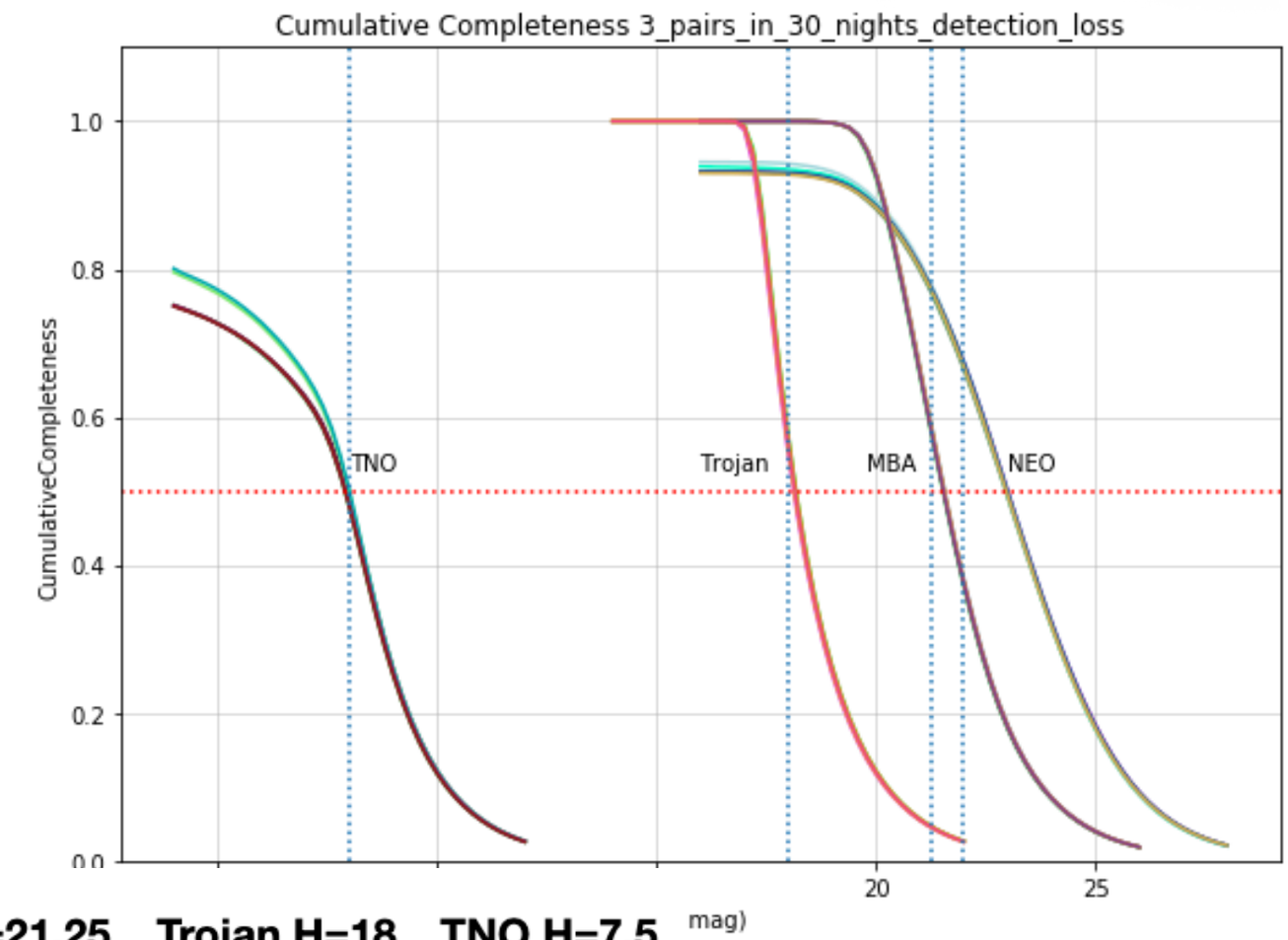



newB footprint WFD:
10.6 billion galaxies

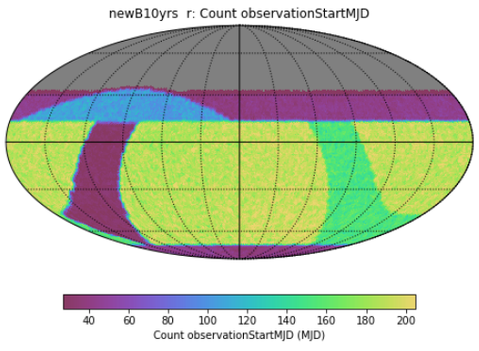
# WFD footprint FBS 1.2 runs

– ‘WFD footprint’

More coverage in the north improves discovery of TNOs.




| | NEO H=22 | MBA H=21.25 | Trojan H=18 | TNO H=7.5 |
|---|---|---|---|---|
| baseline_1exp_pairsame_10yrs | 67.3 | 59.2 | 57.5 | 57.7 |
| baseline_1exp_pairsmix_10yrs | 66.5 | 58.7 | 56.6 | 57.0 |
| newA10yrs | 67.0 | 58.0 | 54.9 | 59.5 |
| newB10yrs | 67.1 | 58.6 | 55.9 | 60.0 |
| bluer_footprint10yrs | 67.5 | 59.0 | 57.5 | 57.2 |
| gp_heavy10yrs | 66.8 | 58.5 | 56.1 | 57.1 |

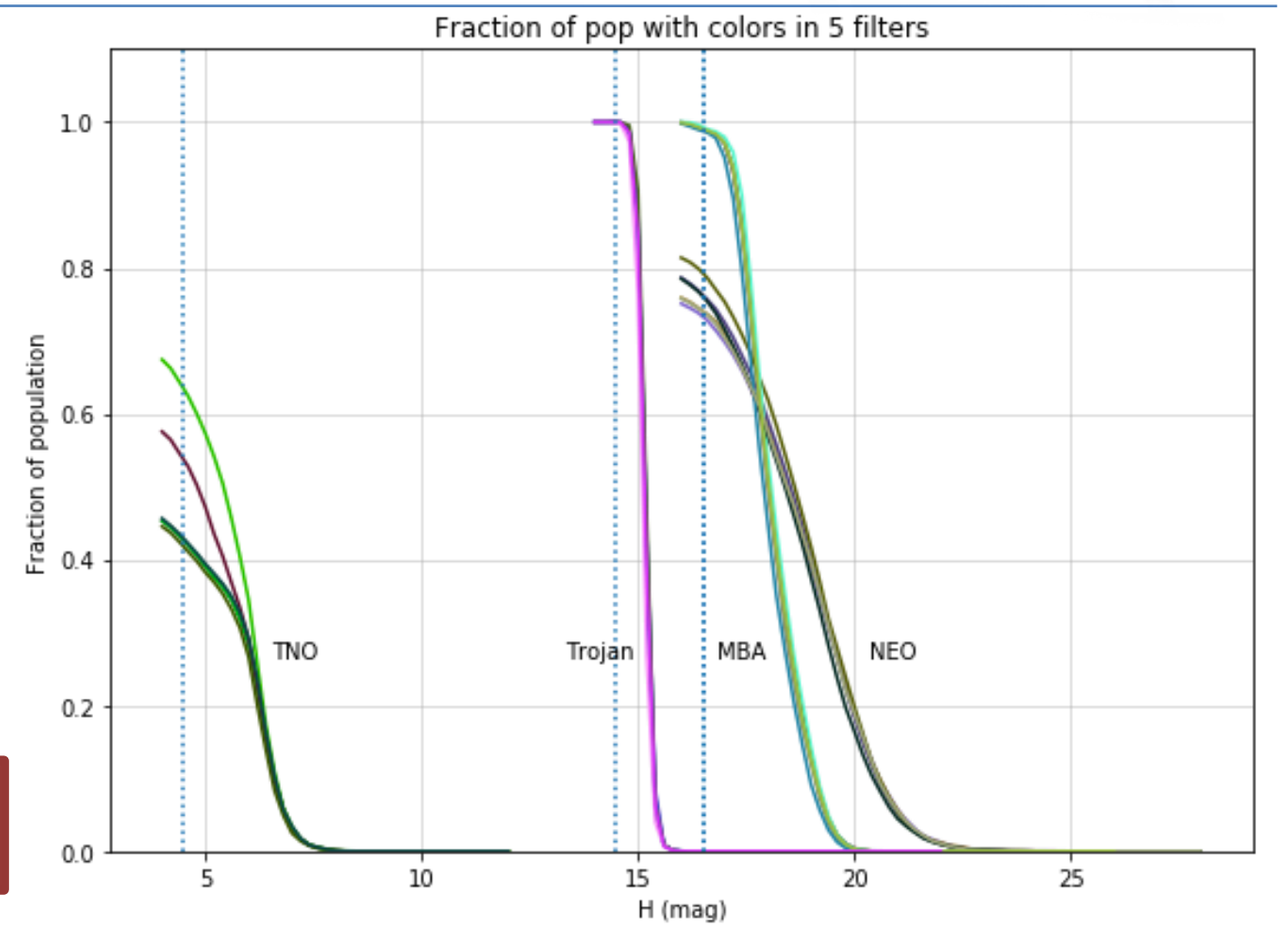


# WFD footprint FBS 1.2 runs

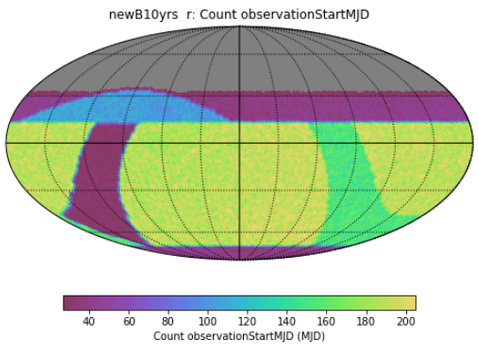
– ‘WFD footprint’

More coverage in the north improves characterization of TNOs AND NEOs.

Need to add MBC & resonant TNO




| | NEO H=16.5 | MBA H=16.5 | Trojan H=14.5 | TNO H=4.5 |
|---|---|---|---|---|
| baseline_1exp_pairsame_10yrs | 73.3 | 98.9 | 100.0 | 42.6 |
| baseline_1exp_pairsmix_10yrs | 74.1 | 99.0 | 100.0 | 42.6 |
| newA10yrs | 76.3 | 99.1 | 100.0 | 53.7 |
| newB10yrs | 79.3 | 99.3 | 100.0 | 63.4 |
| bluer_footprint10yrs | 76.1 | 98.8 | 99.9 | 41.8 |
| gp_heavy10yrs | 74.0 | 99.0 | 100.0 | 42.9 |



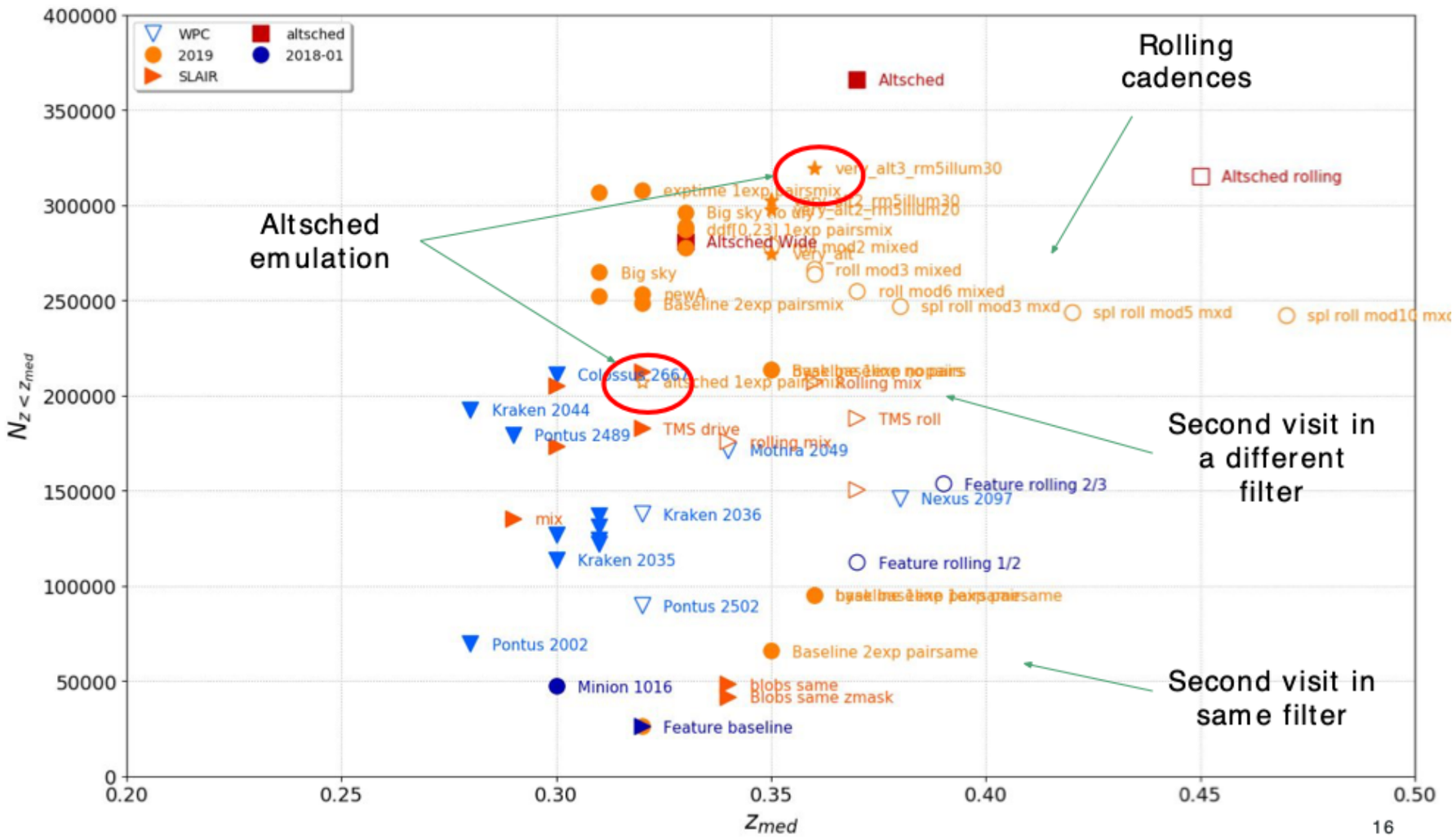
# Analysis

- Footprint
- Motivated first by DESC desire for more galaxies
- Galaxy counts don’t show clear improvement
- Some motivation from mini-surveys (NES, Euclid, DESI)
- Some improvement for SSOs (discovery and characterization) if WFD footprint extended north

- Return to DESC for clarification on metrics
- Redo footprint with E(B-V) cut exactly (done)
- Redo footprint with 90% WFD and with 825 visits .. look at options to increase visits in N/S (counter poor seeing)

# Rolling cadence FBS 1.2 runs

– ‘rolling cadence variations’



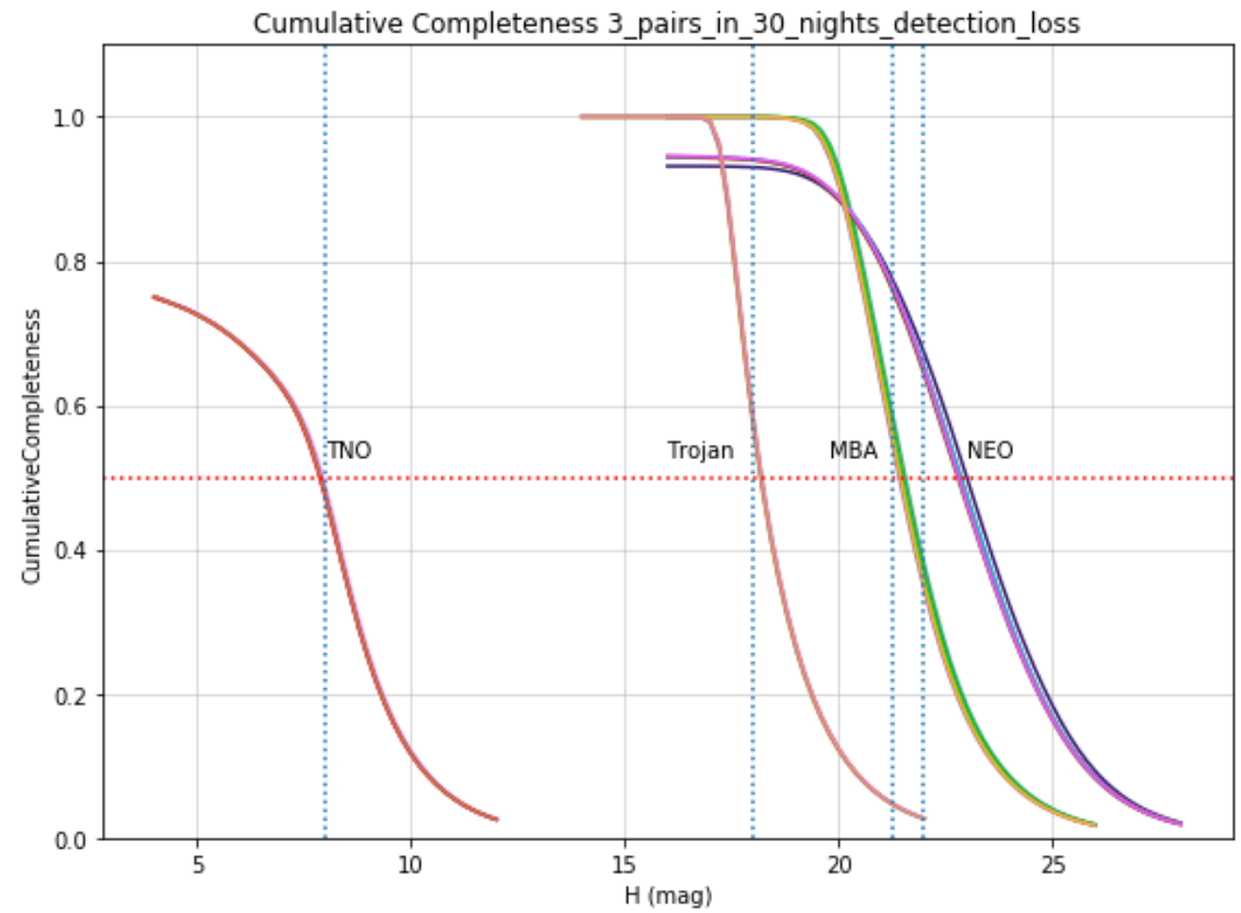

SNe group has been running more intensive analysis and giving feedback on sims

From Nicolas Regnault

# Rolling cadence FBS 1.2 runs

– ‘rolling cadence variations’

Rolling cadence has some impact on discovery of NEO and MBAs. Have not tested MBCs yet or looked into potential orbital element distribution changes.

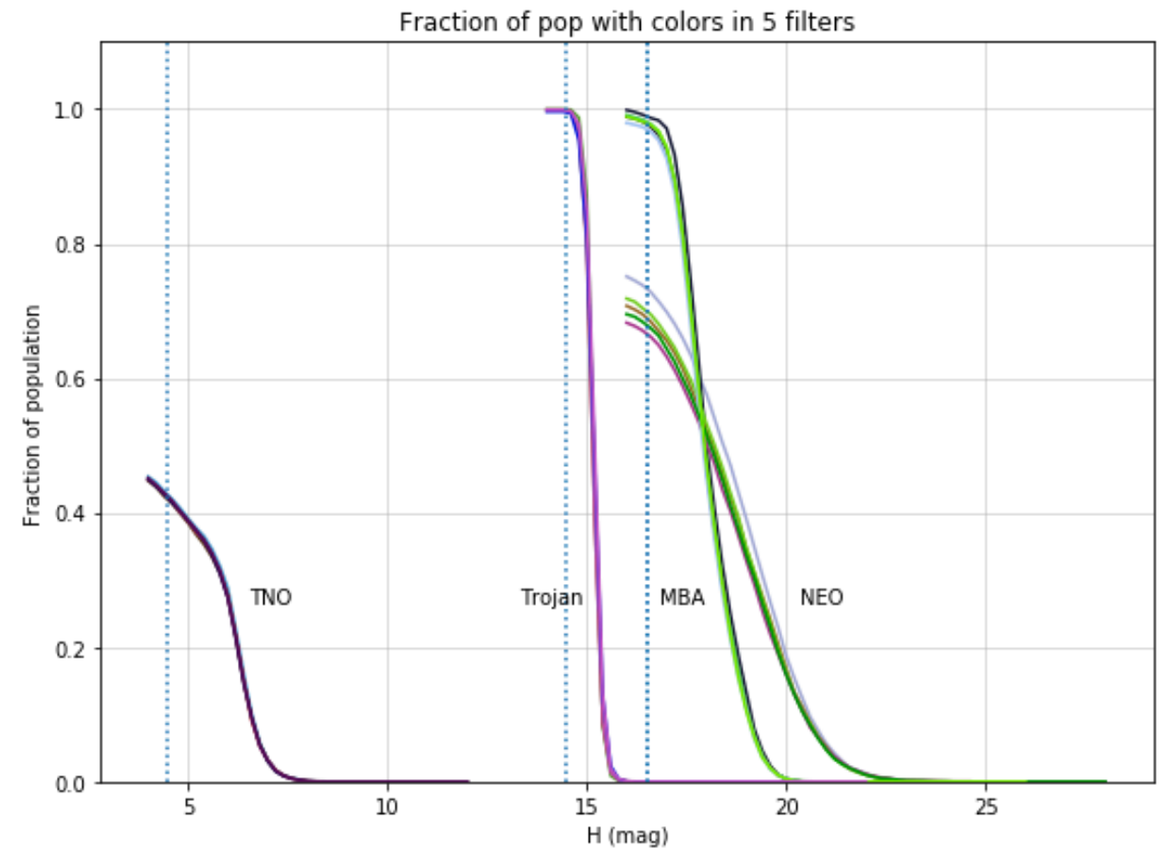



| | NEO H=22 | MBA H=21.25 | Trojan H=18 | TNO H=7.5 |
|---|---|---|---|---|
| baseline_1exp_pairsame_10yrs | 67.3 | 59.2 | 57.5 | 57.7 |
| roll_mod2_sdf0.05mixed_10yrs | 65.3 | 57.0 | 58.2 | 56.9 |
| roll_mod2_sdf0.20mixed_10yrs | 65.3 | 57.1 | 57.3 | 56.7 |
| roll_mod3_sdf0.05mixed_10yrs | 64.3 | 55.0 | 58.5 | 56.5 |
| roll_mod3_sdf0.20mixed_10yrs | 64.9 | 55.9 | 58.7 | 56.8 |

~2-3% losses for NEOs and MBAs, slightly better with higher background visits

# Rolling cadence FBS 1.2 runs

– ‘rolling cadence variations’

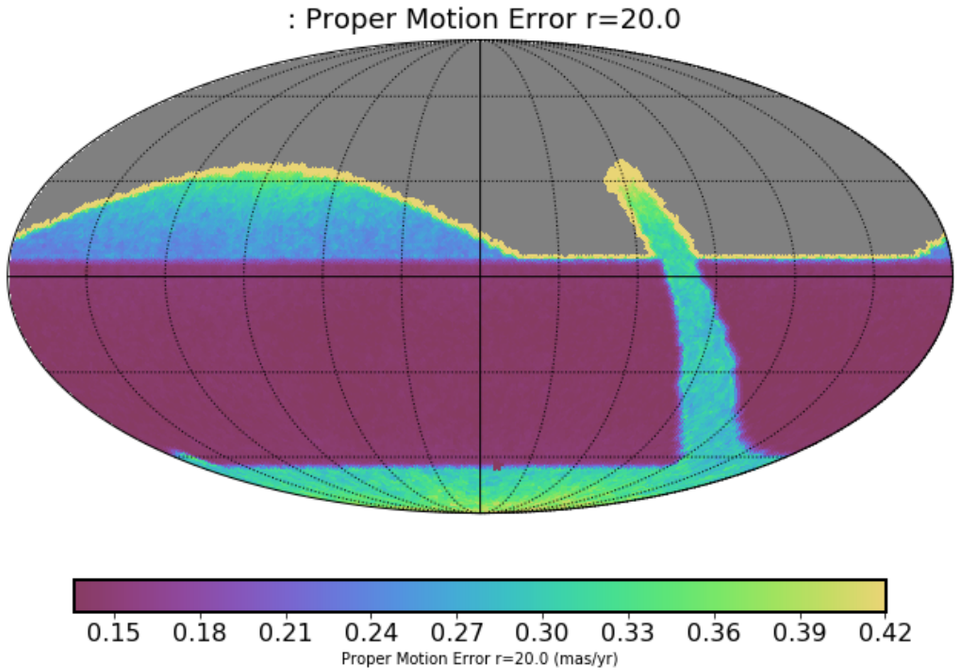



| | NEO H=16.5 | MBA H=16.5 | Trojan H=14.5 | TNO H=4.5 |
|---|---|---|---|---|
| baseline_1exp_pairsame_10yrs | 73.3 | 98.9 | 100.0 | 42.6 |
| roll_mod2_sdf0.05mixed_10yrs | 68.9 | 97.7 | 99.8 | 41.9 |
| roll_mod2_sdf0.20mixed_10yrs | 69.9 | 98.1 | 99.8 | 42.2 |
| roll_mod3_sdf0.05mixed_10yrs | 66.6 | 97.0 | 99.5 | 42.1 |
| roll_mod3_sdf0.20mixed_10yrs | 67.9 | 97.9 | 99.8 | 42.3 |

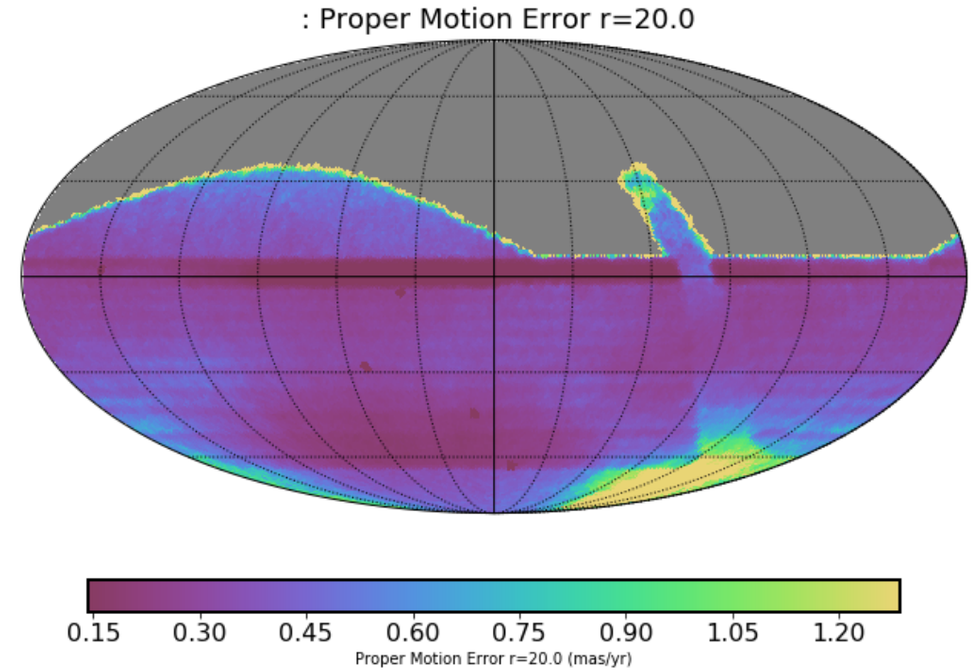
~4-7% fewer NEOs obtaining measurement of grizy colors

# Rolling cadence FBS 1.2 runs

## Uncertainty in the proper motion of an r=20 star




Baseline WFD median:
0.14 mas




simple_roll_mod10_sdf0.20 WFD :
0.30 mas

If there is no covariance, the proper motion uncertainty only depends on when observations happen and the centroiding errors.
If we do a very aggressive rolling cadence, proper motion error blows up. Need full sky coverage in year 1 and 10 to keep proper motion errors low.

# Analysis

- Rolling cadence
- Motivated by desire to increase cadence for WFD observations (better discovery for transients)
  - Rolling cadence does better for SN discovery, but doing pairs in mixed filters is largest improvement
- Has some negative impact on discovery and characterization of inner solar system (NEO, MBA) objects
  - Check wider range of rolling cadence runs
  - Run simulations with higher background rate?
- Likely to need full-sky coverage each year for difference imaging templates & calibration

- Likely we're missing some metrics sensitive to rolling cadence variations