Rubin Observatory Science Performance

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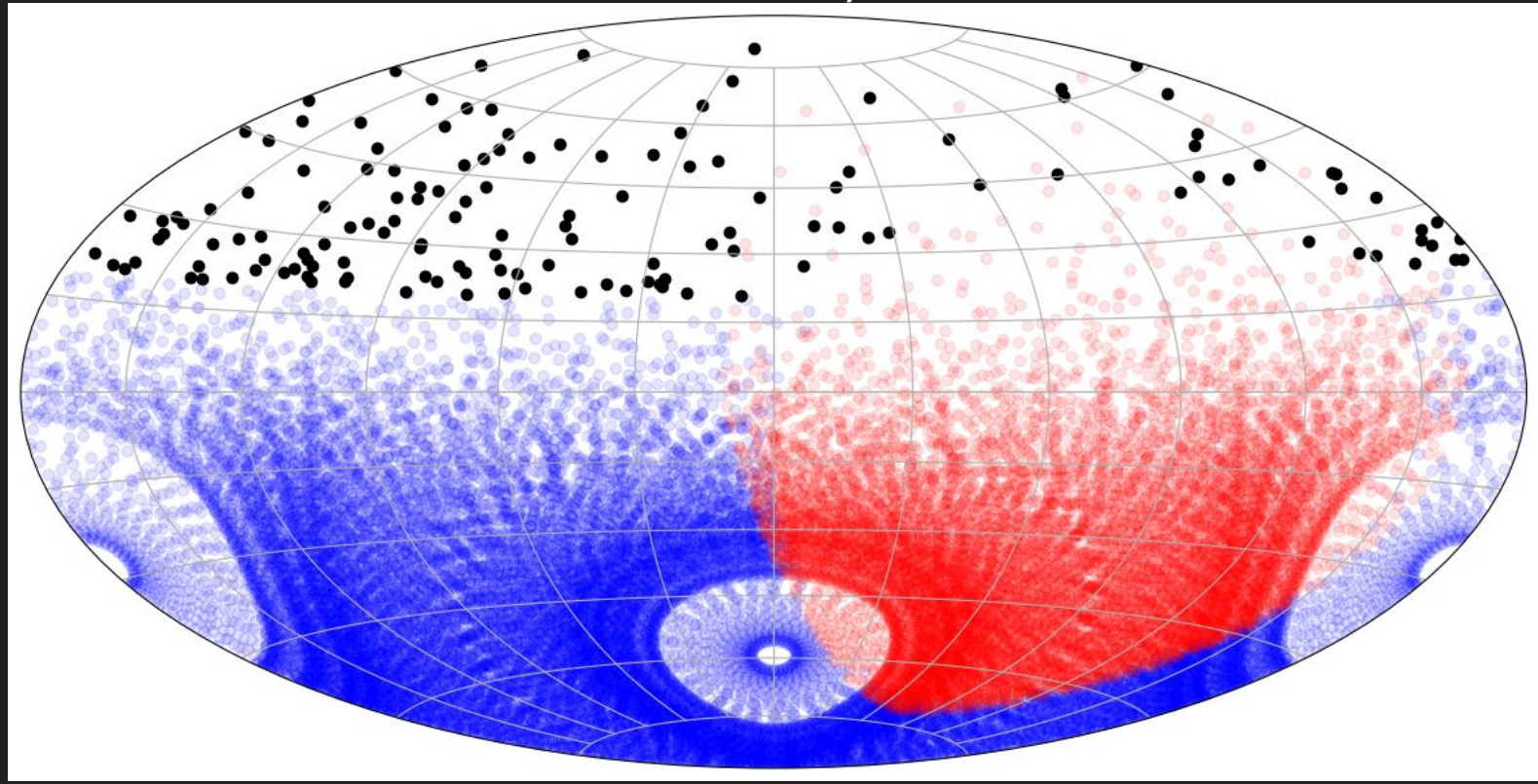
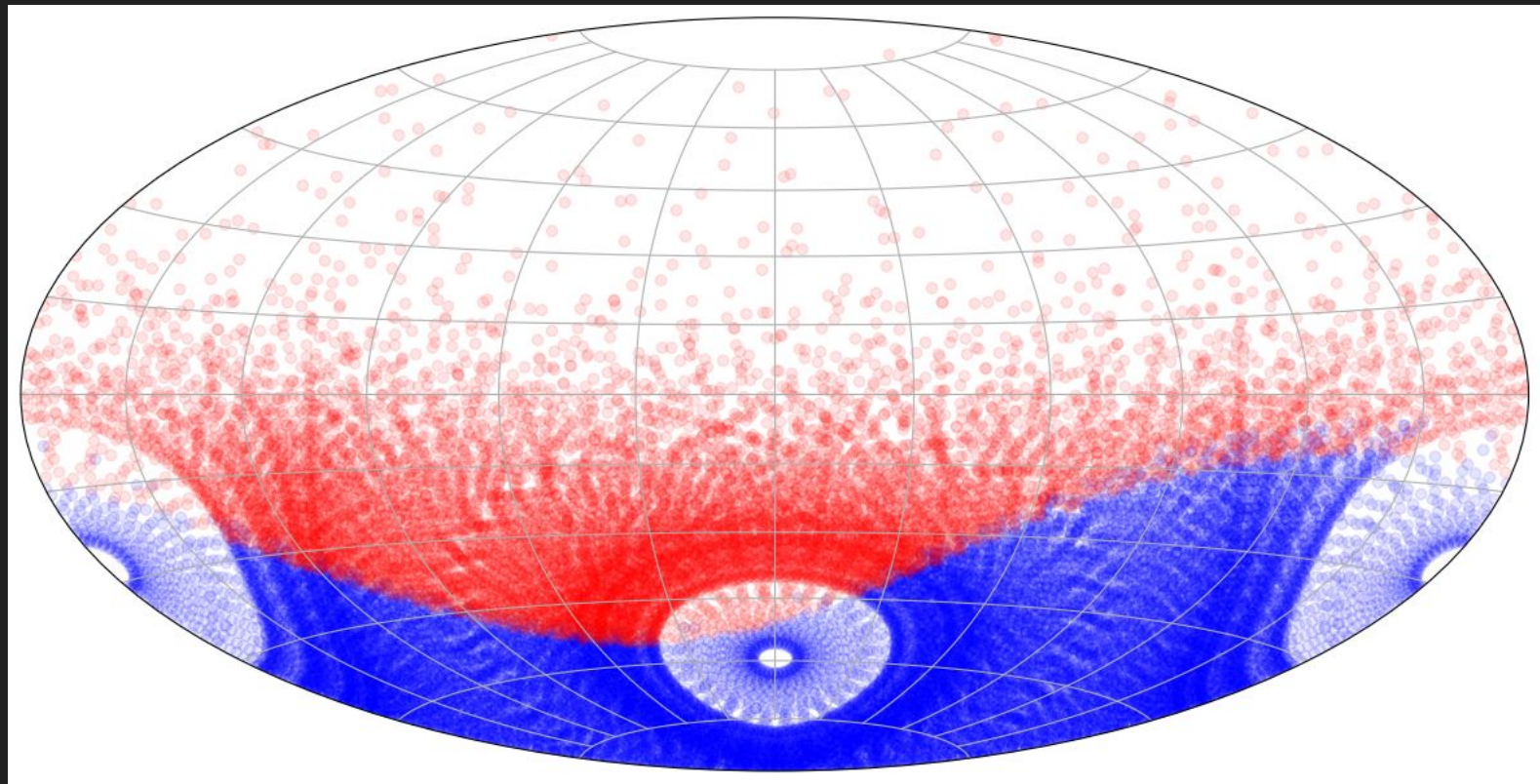
Astro 597A, Jan 2023

Thing I forgot last time, satellite mega constellations. 30k Starlink satellites (black are above horizon and illuminated)



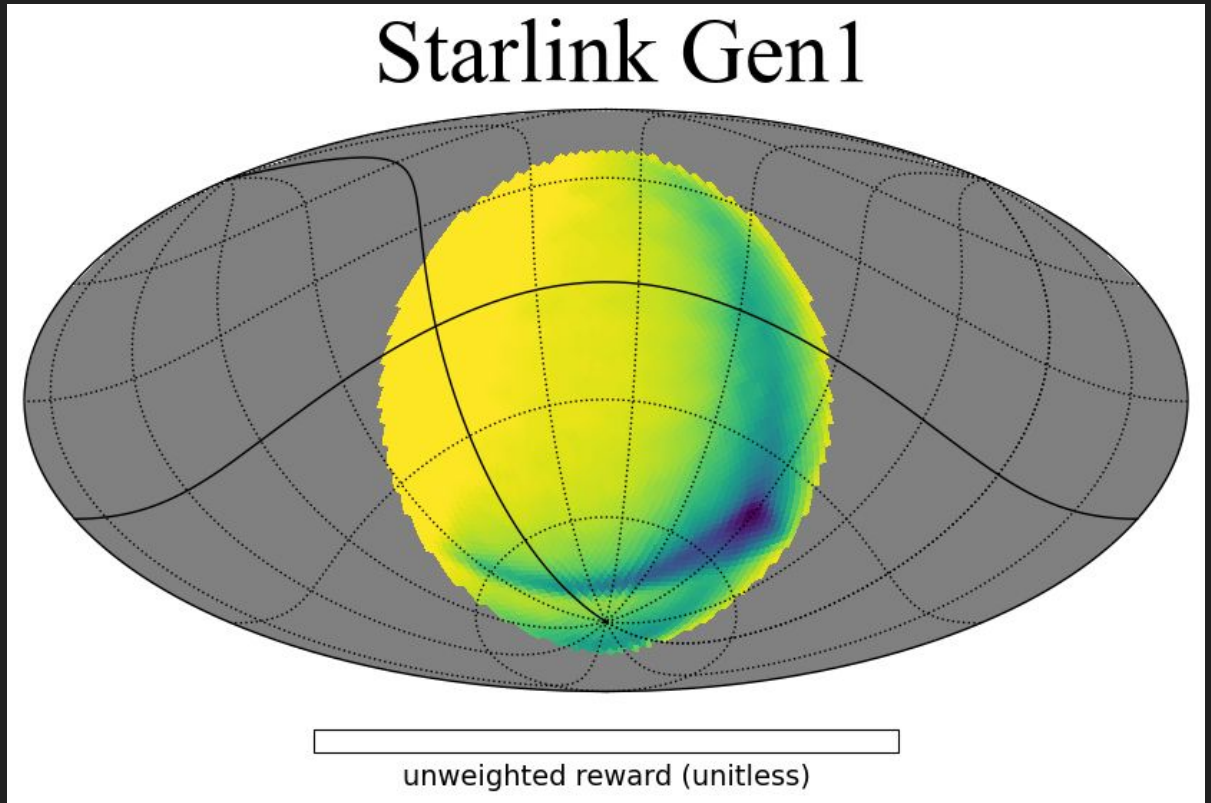
Later in the night, everything is in shadow, so no problem



We can make a prediction of where satellites will be, add that as a new basis function and give it negative weight

Final result is, yes, we can avoid many streaks, but the loss of depth and increased slew time means it's probably not worth dodging

Hu et al, 2022



Last time

- Talked about how Rubin observes
- Rules of thumb that are mostly about maximizing signal to noise ratio get converted to basis functions so we can balance telescope behavior
- Scheduler simulation generates observations

This time:

- How can we calculate how well we “do science”

General problem

Given ~2 million observations, how well can you do a science?

This has proven to be a surprisingly difficult problem for a lot of our science collaborations!

Some examples

- How well can we measure astrometry on a fiducial object
- What fraction of transients do we recover?
- Solar System objects!

Proper Motion

- Define a fiducial star (maybe 24th mag with a flat SED)
- Calculate the SNR each time the star is observed
- Calculate the centroid error each time it's observed
- *If there are no degeneracies in an astrometric* fit, the uncertainty in the proper motion is the same as the uncertainty in the slope of a fitted line

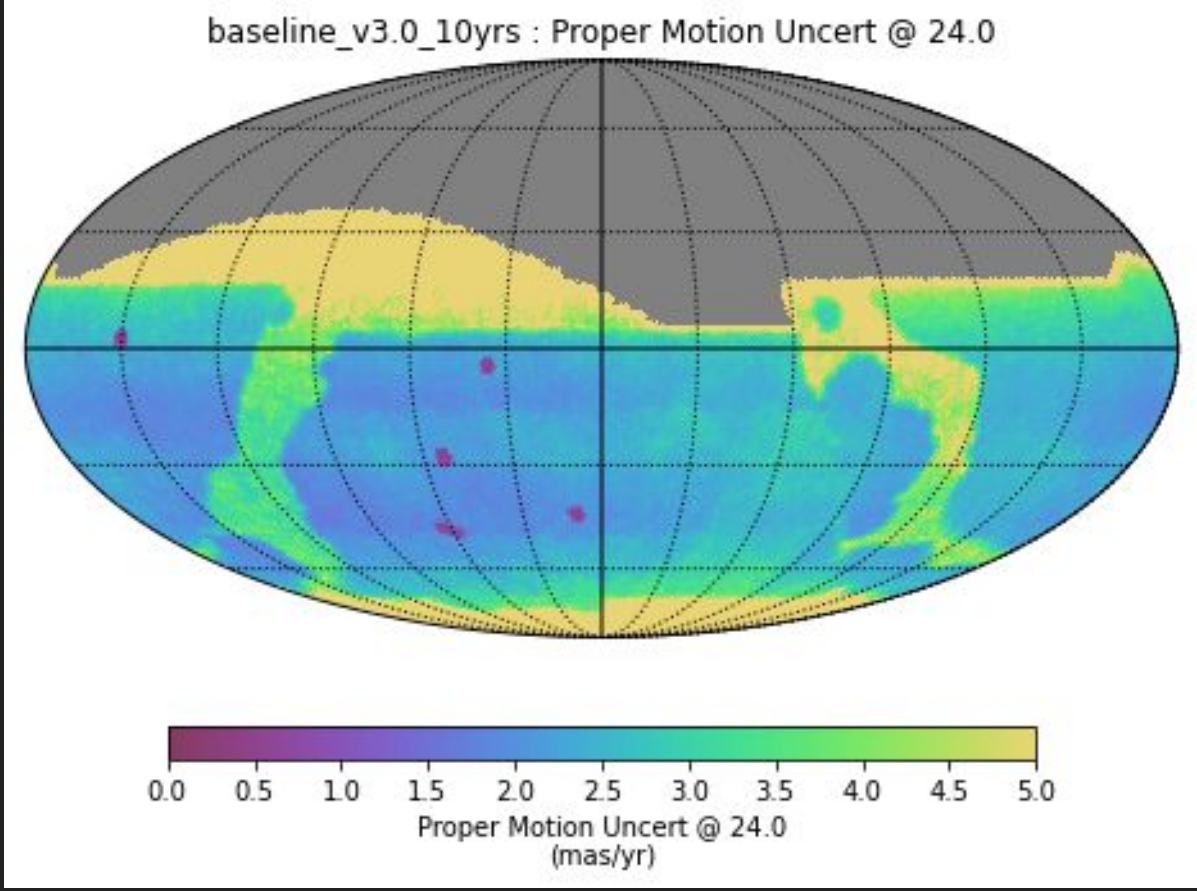
$$SNR = 5 * 10^{-0.4(m-m_5)}$$

$$\sigma = \frac{\theta_{FWHM}}{SNR}$$

$$\sigma_{pm} = \frac{\sum \frac{1}{\sigma^2}}{\sum \frac{1}{\sigma^2} * \sum \frac{t^2}{\sigma^2} - \sum \frac{t}{\sigma^2}^2}$$

MAF:

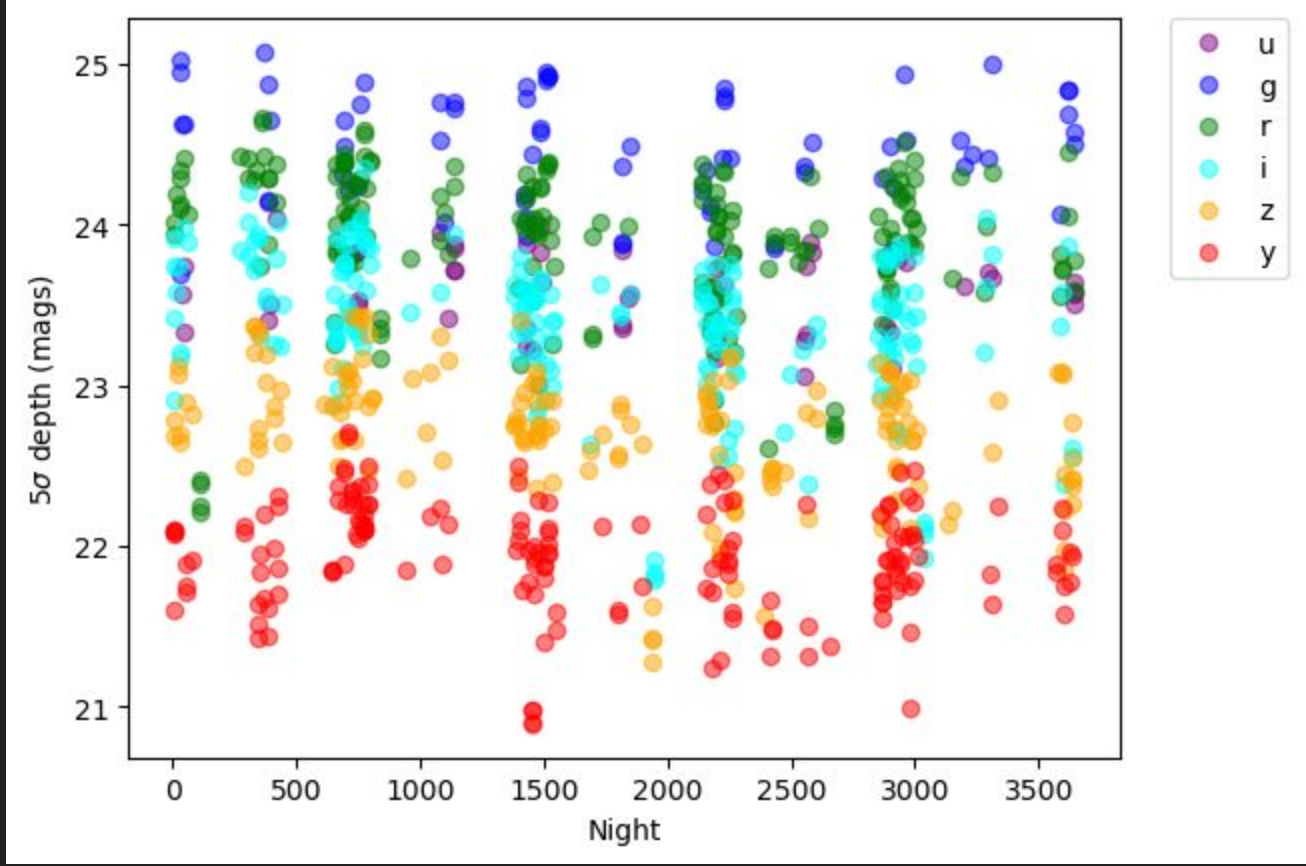
- Loops over HEALpix centers
- Finds overlapping observations
- Passes those observations to your metric code and records the result



A nice metric, but now one can extend it, say, compute the volume of space you could detect stellar streams astrometrically

Here's how a typical spot in the WFD gets observed.

Can anyone explain the outliers?

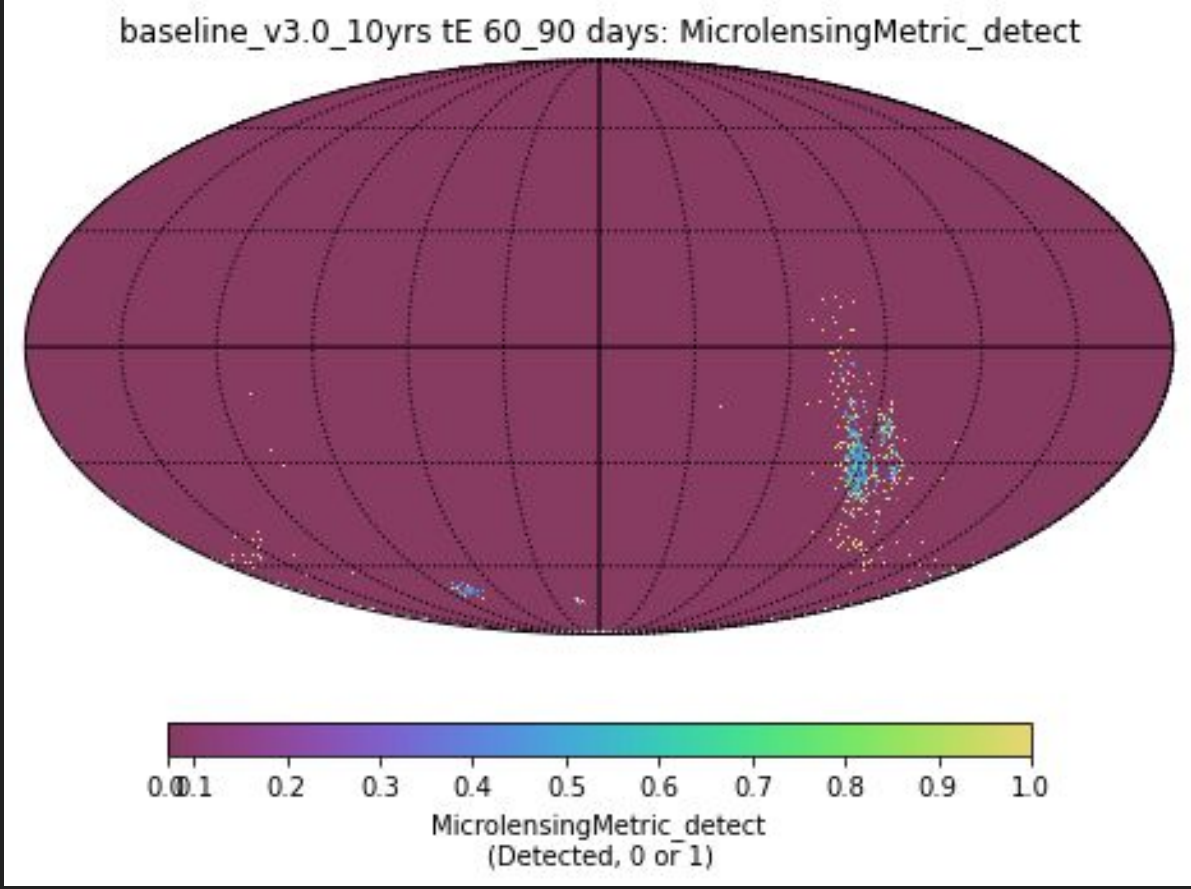


Microlensing

- Let’s define a population of events
- Distribute them properly on the sky
- Define some detection criteria

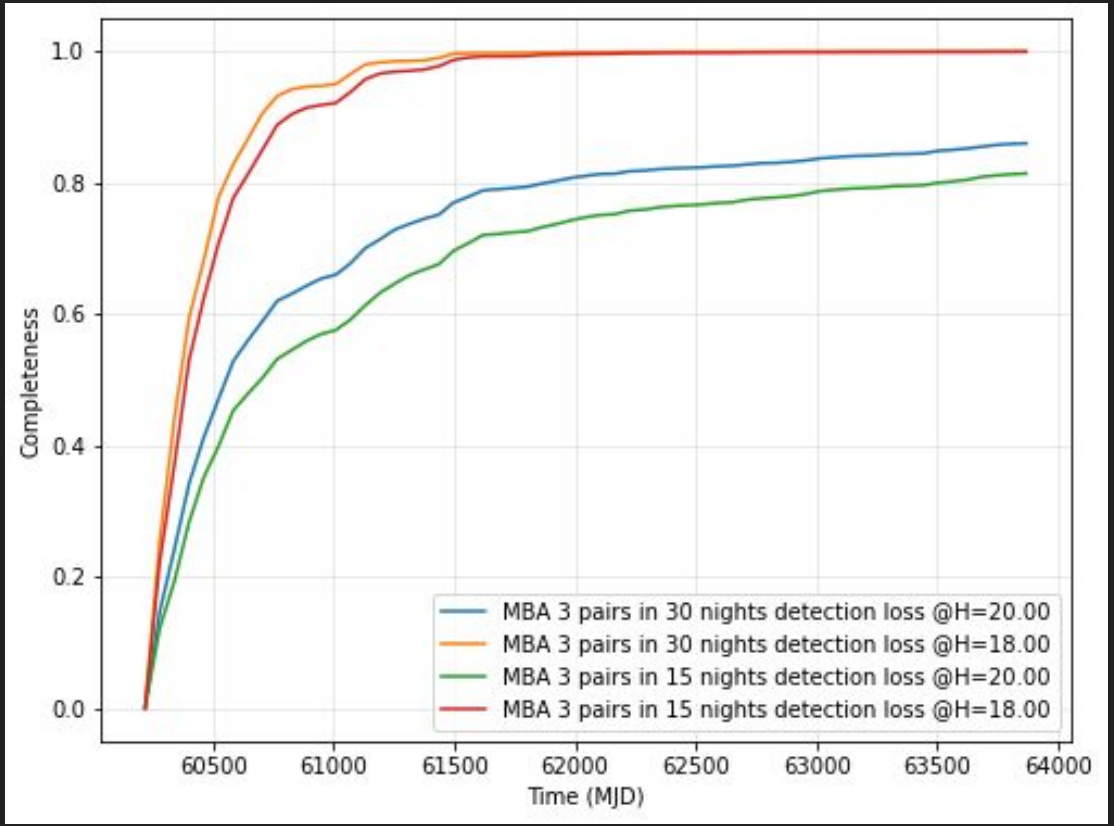
MAF

- Now we loop over each event
- Generate the light curve
- See if it passes the detection criteria



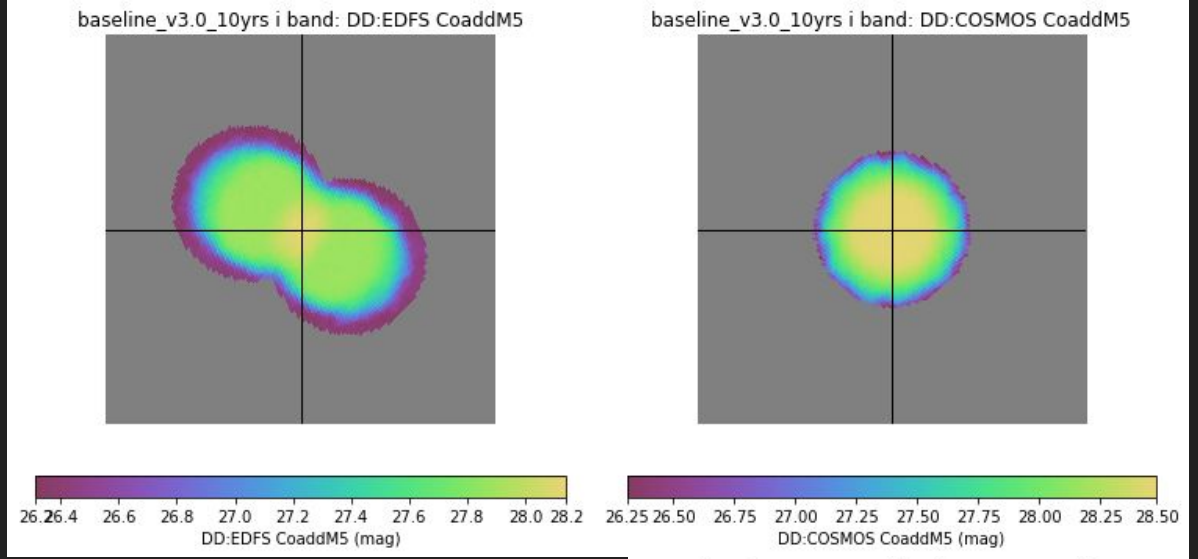
Solar system

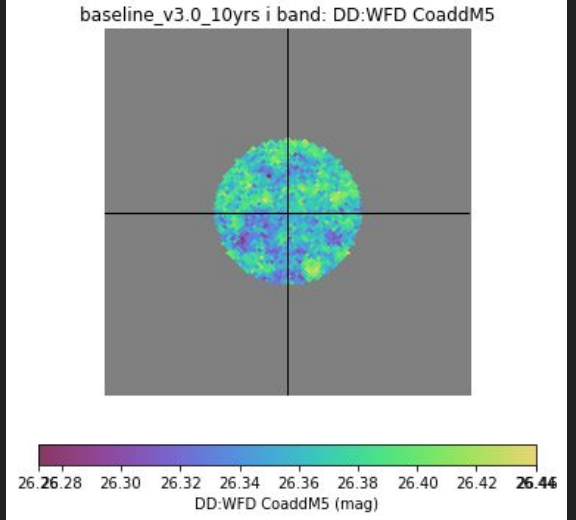
- Extra step, we take a population of orbits (typically 5-10k), propagate them, check which ones overlap observations
- Then we can check recovery



DDFs

- Can have MAF run on a subset of HEALpix
- Or have your transient events concentrated in the sky at the DDF





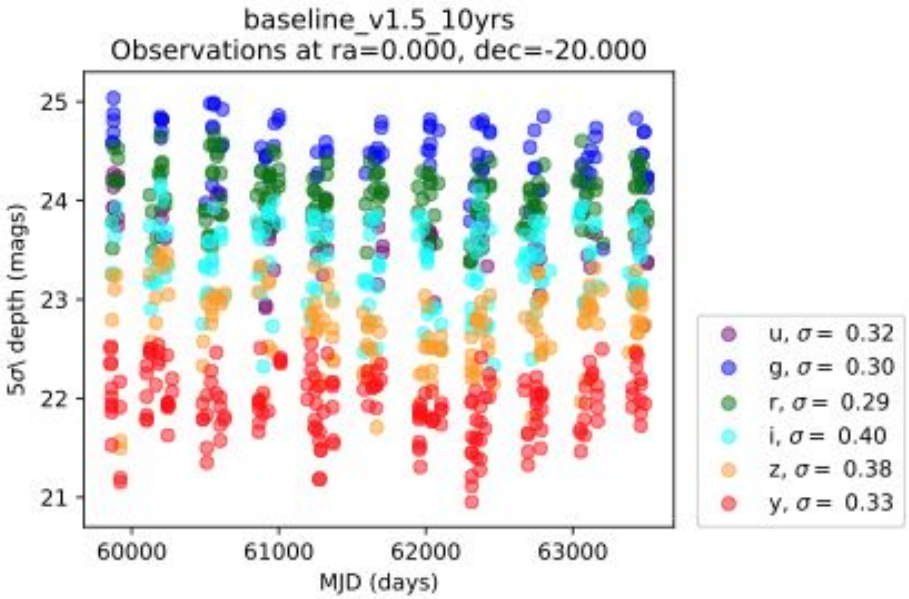
Implementation minutiae

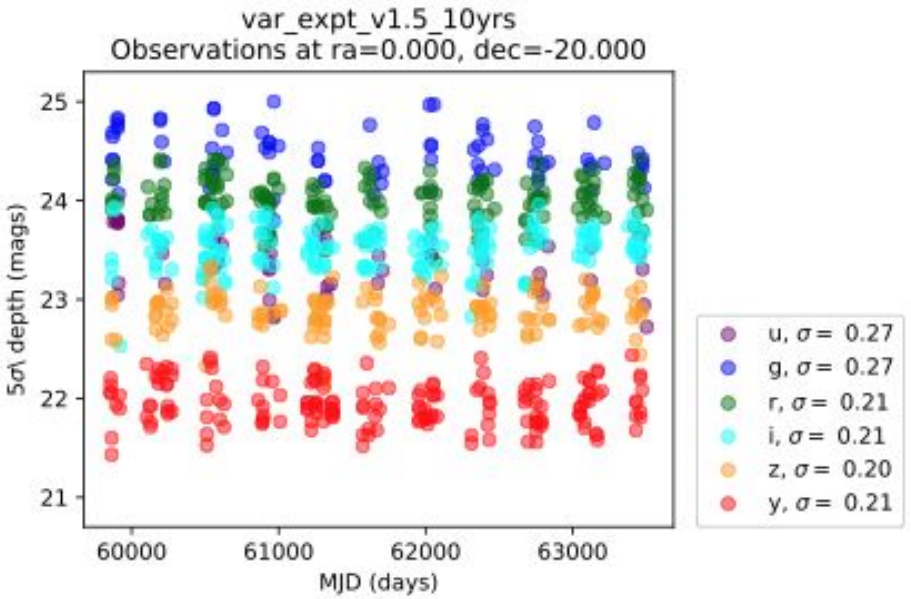
- In the scheduler, we take an observation, find what HEALpix centers it overlaps, and add it to a map
- MAF, we start at a HEALpix (or transient event) center, find all the overlapping observations, then compute something

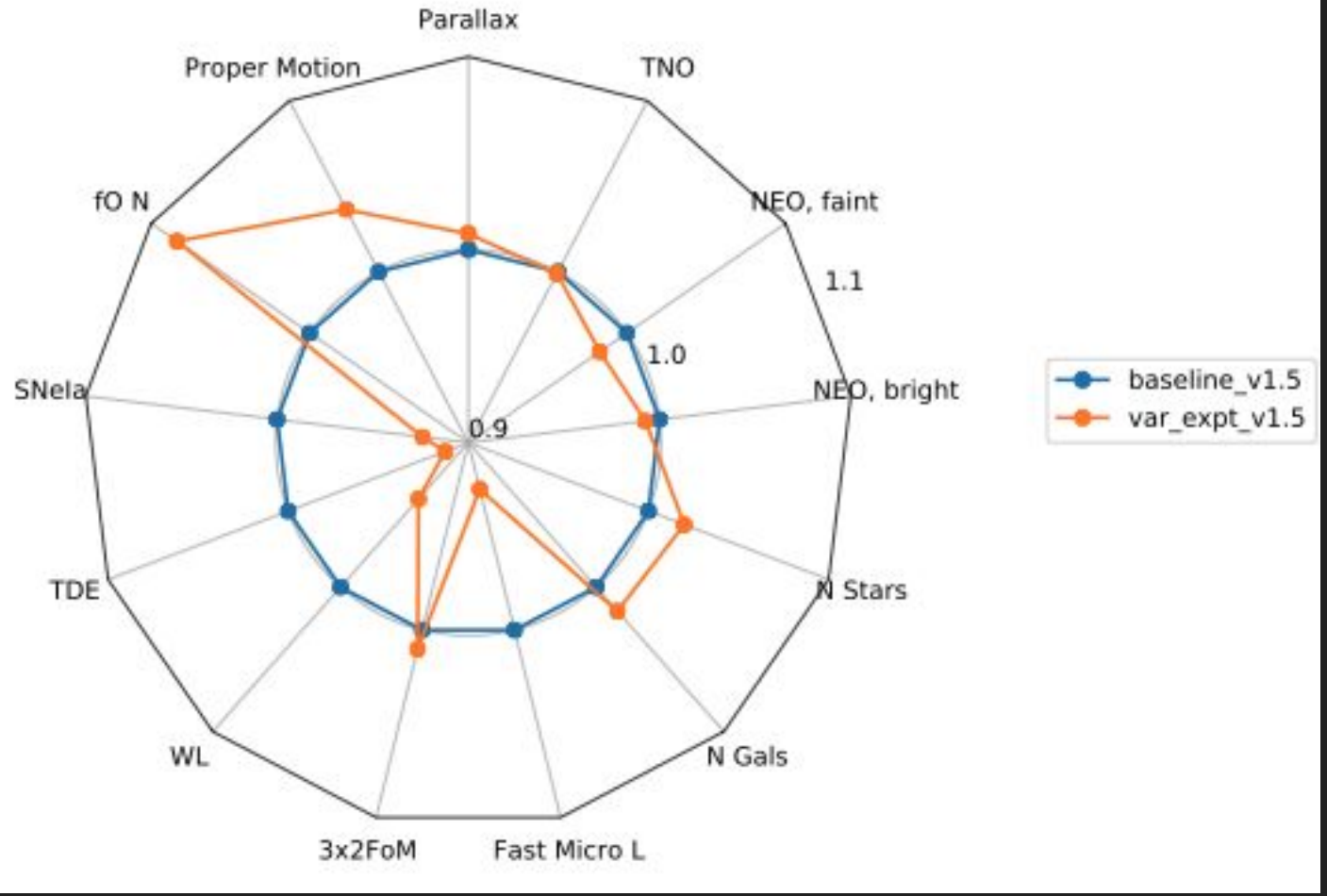
Choice between looping over N HEALpix or M observations. Depends on length of survey and desired map resolution which way is more painful.

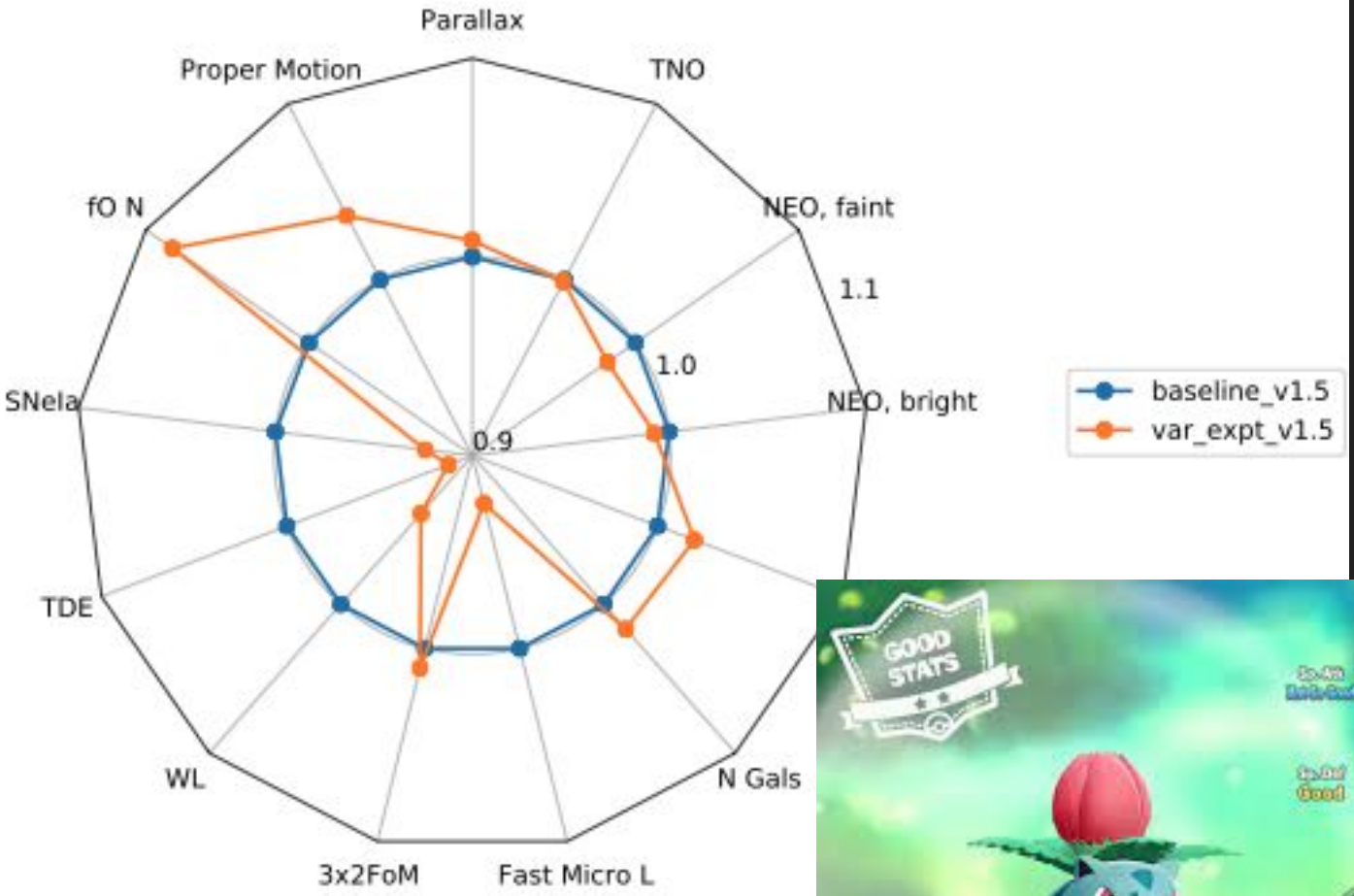
We can take lots of science metrics and see how changing survey strategy impacts things

Example, use dynamic variable exposure times






Parallax
TNO
NEO, faint
1.1
1.0
NEO, bright
0.9
N Stars
N Gals
Fast Micro L
3x2FoM
WL
TDE
SNeIa
fO N
Proper Motion
baseline_v1.5
var_expt_v1.5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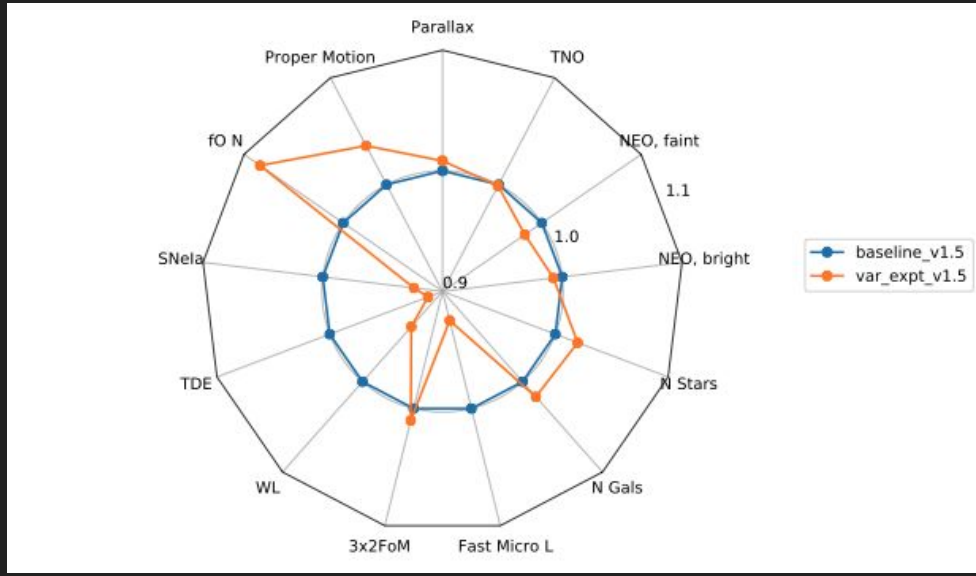
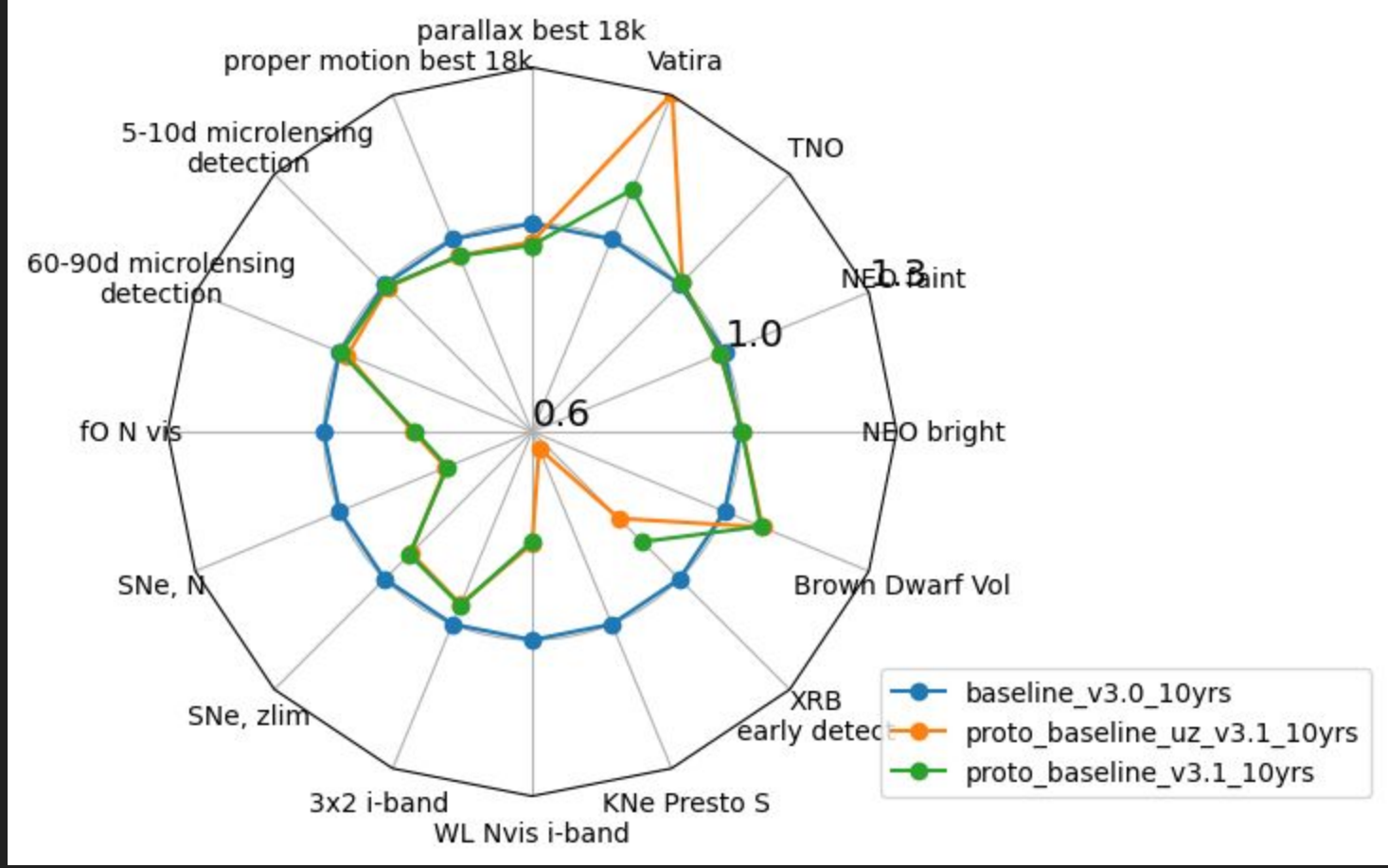
fO N
Proper Motion
0.9
baseline_v1.5
var_expt_v1.5

GOOD STATS
HP
Good
Good
Good
Good
Ivysaur
Lv. 23

One must be careful with these!

- Can end up shot noise limited (say we go from 10 Vatira objects to 13, is that really 30% better?)
- Many metrics are for a single filter, so can be deceptive
- Make sure direction is right (more objects, deeper magnitude, lower error)





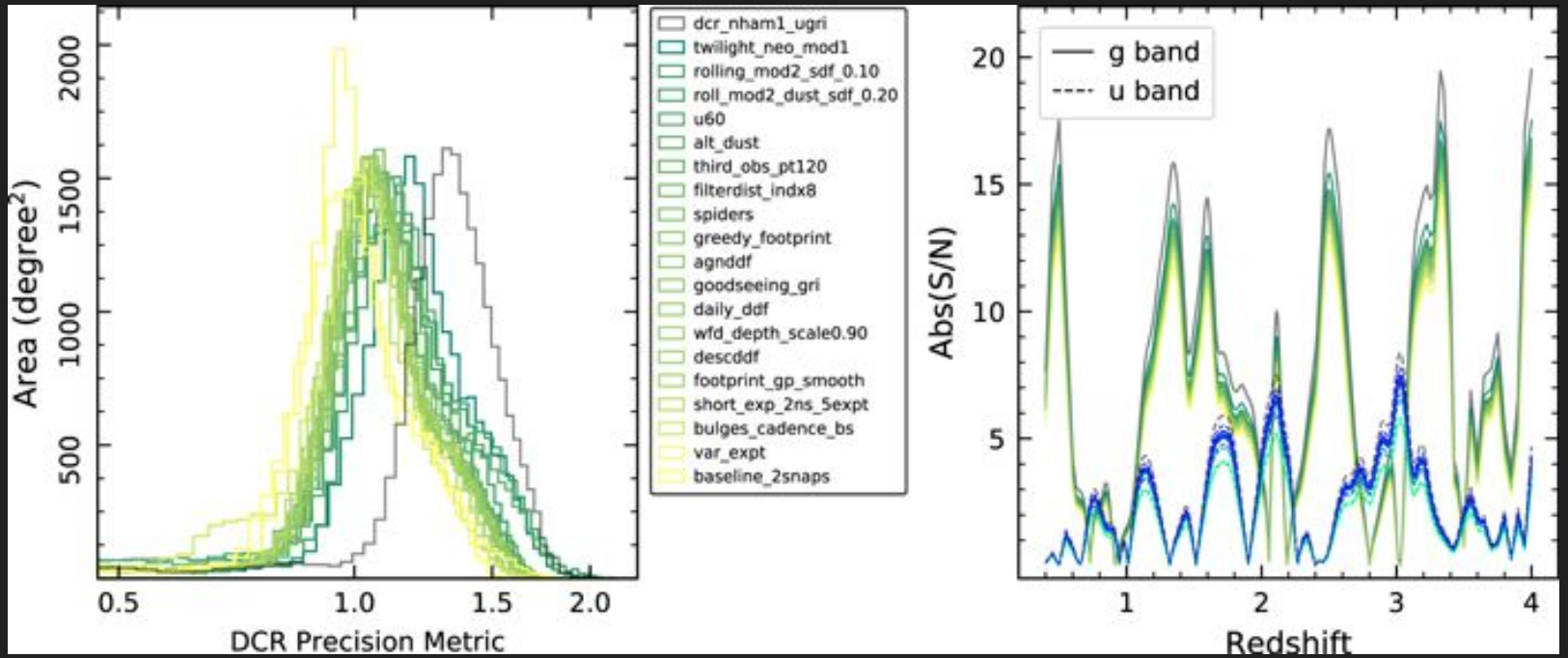
Here's one I made yesterday. It was supposed to be a very subtle change, but there are huge differences. Footprint changed due to a missed closed parentheses.

Some metrics we could use if anyone wants to write them

- How well can we measure the shape of galaxies?
  - Need to consider systematic errors, so how well we rotate the camera to different positions
- What volume do we probe in the Local Group for dwarf galaxies?
  - We have a dwarf galaxy metric, but needs to get converted to measure volume
- How well can we identify interstellar asteroids?
  - Need to generate a population of hyperbolic orbits!
- DDFs! Really need to optimize the DDF strategy
- Still need a simple photo-z metric

RNAAS

- Great place to publish if you write a metric



Yu et al, 2020

Lots of simulations and MAF output online

http://astro-lsst-01.astro.washington.edu:8080/

List of all Opsim Runs

Run List | Metrics List | All Results | Multi Color | Summary Stats

Run Name	Group	Maf Comment	Run Comment	SQLite File
baseline_v2.0_10yrs	baseline	Metadata+	baseline	baseline_v2.0_10yrs.db
baseline_v2.0_10yrs	baseline	Glance	baseline	baseline_v2.0_10yrs.db
baseline_v2.0_10yrs	baseline	Science	baseline	baseline_v2.0_10yrs.db
baseline_v2.0_10yrs	baseline	DD metrics	baseline	baseline_v2.0_10yrs.db
baseline_v2.0_10yrs	baseline	SSO	baseline	baseline_v2.0_10yrs.db
bluer_indx0_v2.0_10yrs	bluer	Metadata+	bluer indx0	bluer_indx0_v2.0_10yrs.db
bluer_indx0_v2.0_10yrs	bluer	Glance	bluer indx0	bluer_indx0_v2.0_10yrs.db
bluer_indx0_v2.0_10yrs	bluer	Science	bluer indx0	bluer_indx0_v2.0_10yrs.db
bluer_indx0_v2.0_10yrs	bluer	DD metrics	bluer indx0	bluer_indx0_v2.0_10yrs.db
bluer_indx0_v2.0_10yrs	bluer	SSO	bluer indx0	bluer_indx0_v2.0_10yrs.db
bluer_indx1_v2.0_10yrs	bluer	Metadata+	bluer indx1	bluer_indx1_v2.0_10yrs.db
bluer_indx1_v2.0_10yrs	bluer	Glance	bluer indx1	bluer_indx1_v2.0_10yrs.db
bluer_indx1_v2.0_10yrs	bluer	Science	bluer indx1	bluer_indx1_v2.0_10yrs.db
bluer_indx1_v2.0_10yrs	bluer	DD metrics	bluer indx1	bluer_indx1_v2.0_10yrs.db
bluer_indx1_v2.0_10yrs	bluer	SSO	bluer indx1	bluer_indx1_v2.0_10yrs.db
ddf_frac_ddf_per0.6_v2.0_10yrs	ddf	Metadata+	ddf frac ddf per0.6	ddf_frac_ddf_per0.6_v2.0_10yrs.d
ddf_frac_ddf_per0.6_v2.0_10yrs	ddf	Glance	ddf frac ddf per0.6	ddf_frac_ddf_per0.6_v2.0_10yrs.d
ddf_frac_ddf_per0.6_v2.0_10yrs	ddf	Science	ddf frac ddf	ddf_frac_ddf_per0.6_v2.0_10yrs.d

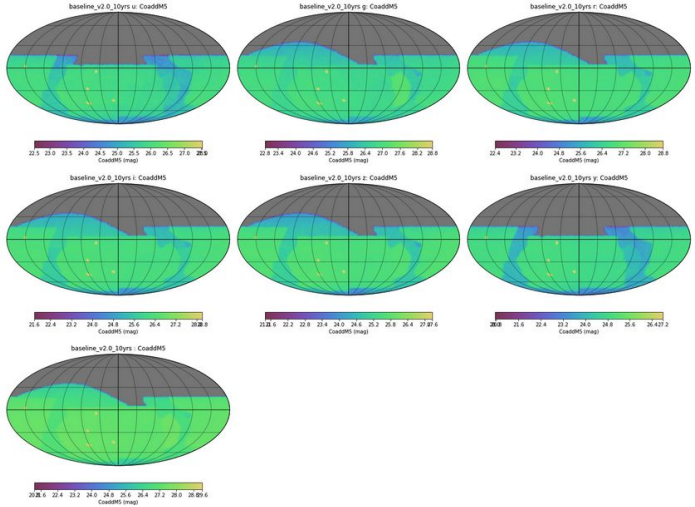
OpSim Run: baseline_v2.0_10yrs

Run List | Metrics List | All Results | Multi Color | Summary Stats

1. Basic Maps
   NULL
2. Basic Stats
   Count Stats
   NULL
   Percent stats
   Saturation
3. DDF
4. Hourglass
   Year 1
   Year 10
   Year 2
   Year 3
   Year 4
   Year 5
   Year 6
   Year 7
   Year 8
   Year 9
5. Pointing Efficency
   NULL
6. Roll Check
   NULL
7. SRD
   FO metrics
8. Science
   Astrometry
   Solar System
9. Slew
   Slew Basics

Basic Maps : NULL

CoaddM5



Some quick start notebooks:
https://ls.st/bs1

There's lots of stuff in
https://github.com/lsst/rubin_sim_notebooks
(but it can be kind of a lot to find what you're looking for)

Text