Scheduler and Survey Strategy

Peter Yoachim

University of Washington

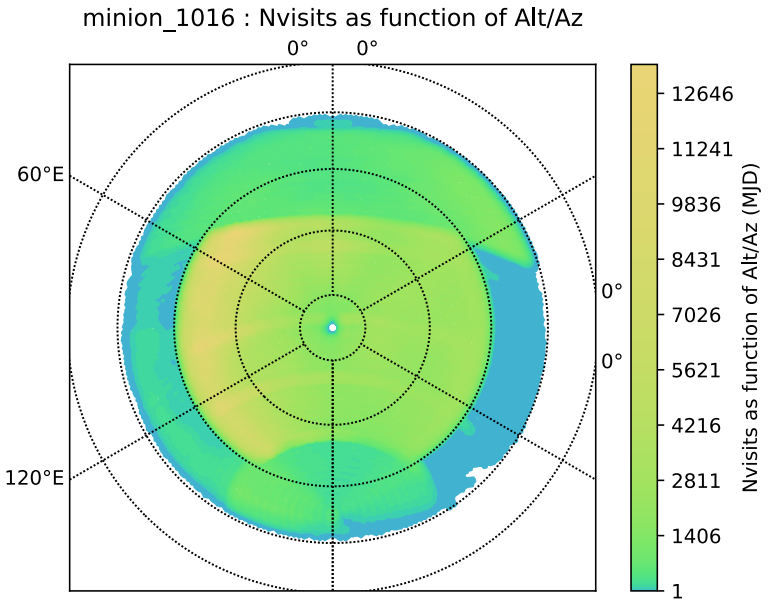
Ways folks try to schedule telescopes

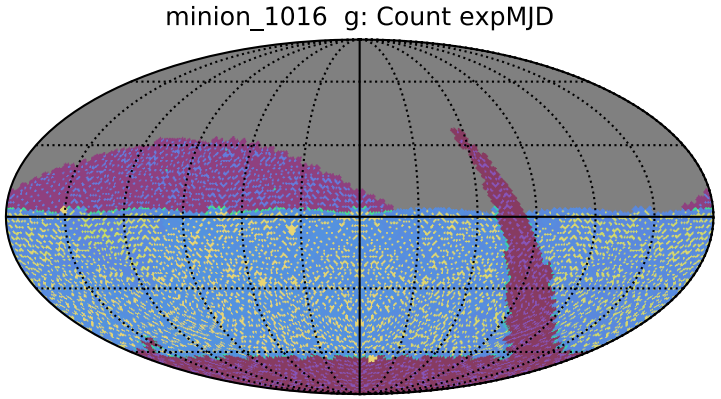
- Have proposals that list observations to be done, ranked by a TAC
  - Can manually select programs to execute (most observatories)
  - Use a greedy algorithm to select observations on the fly (previous OpSim)
  - Optimize the schedule using Integer Programming (ZTF, LCOGT)
- Just scan the sky in a set pattern (AltSched, Rothchild et al 2019)
- Make a configurable/trainable AI that picks what to observe
  - Markov Decision Process (Naghib et al 2019)

Opsim circa 2017

- Meets SRD
- Survey footprint adjustable

- Unstable behavior and often collapses to airmass limit
- No spatial dithering
- Tough to modify proposals, debug behavior

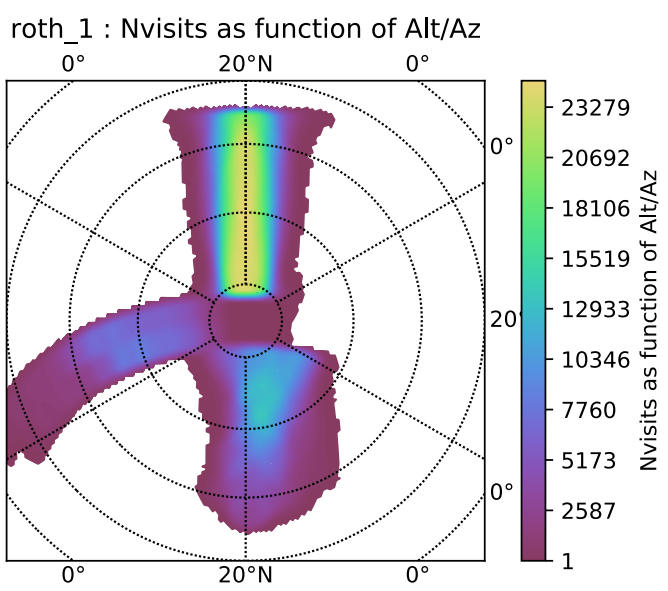


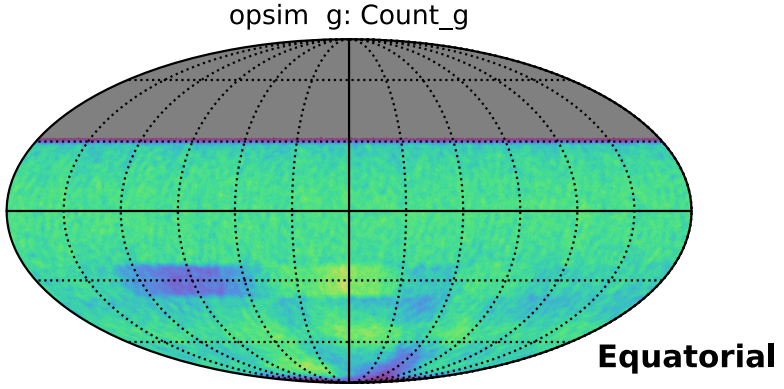


Rothchild et al, AltSched 2017

- Very fast to run
- Effective dithers
- Well sampled light curves

- No recovery from weather/downtime
- Points at the moon sometimes
- Tough to modify, can't really change survey footprint

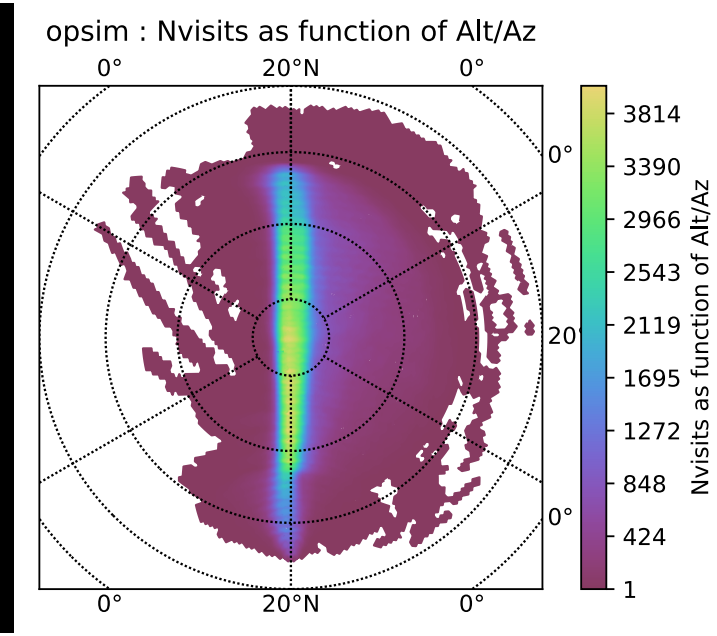


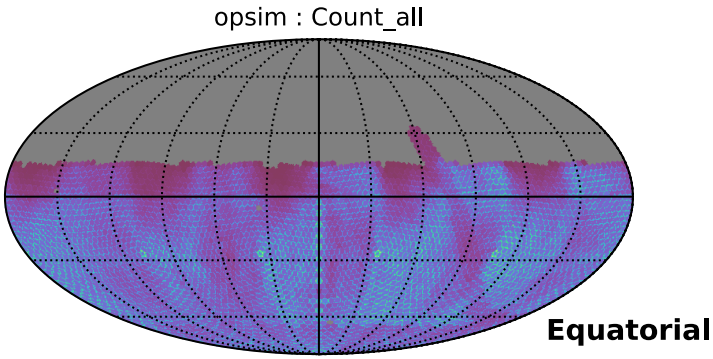


Naghib et al, Feature Based Scheduler 2017

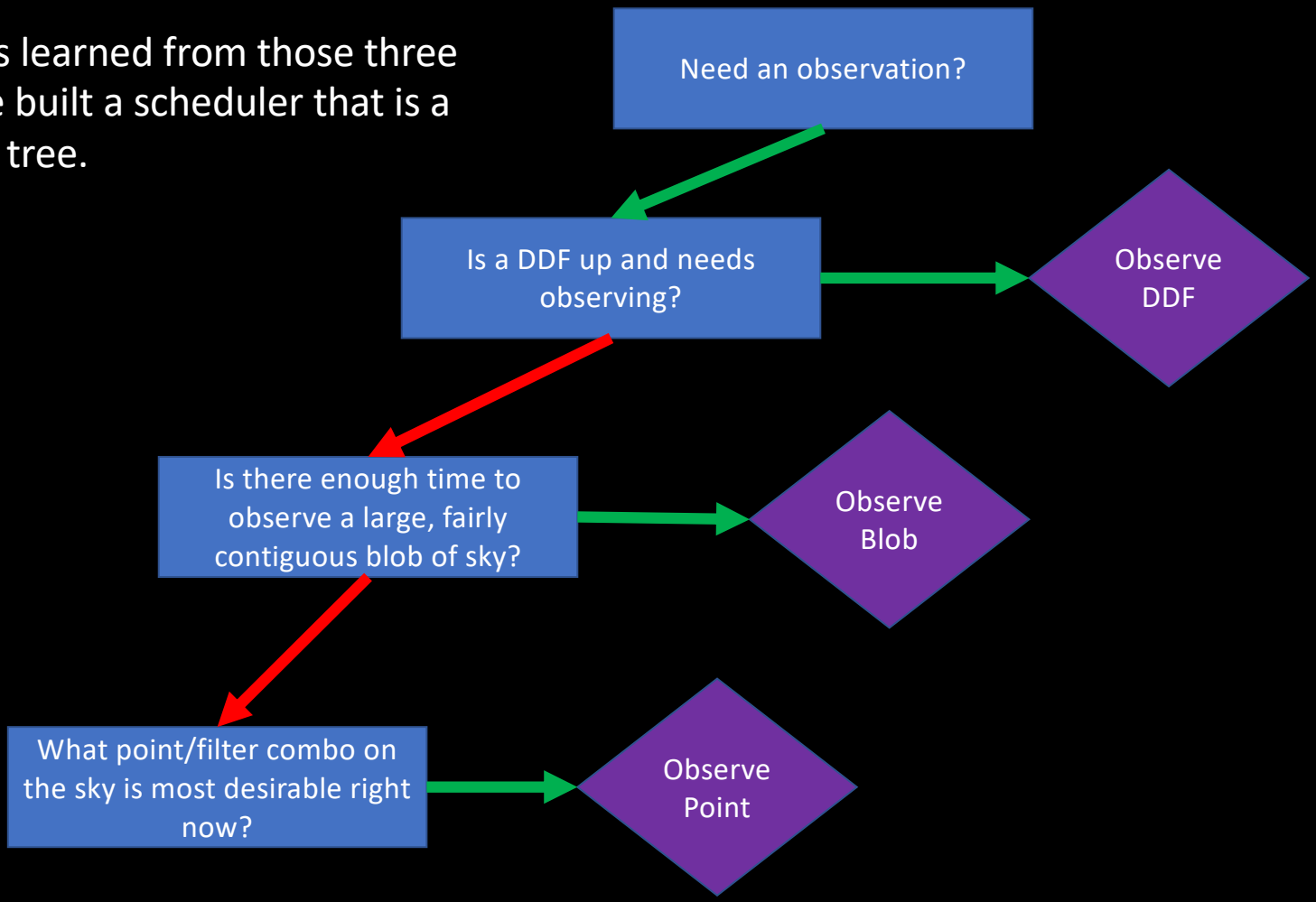
- Shows promise on balancing conditions and survey footprint

- No dithering
- Observing at zenith
- Not modular code





Taking the lessons learned from those three schedulers, we've built a scheduler that is a modular decision tree.



The Markov Decision Process how we pick non-DDF observations

Features i.e. the current state (MJD, Skybrightness map, Observing history)

Basis Functions

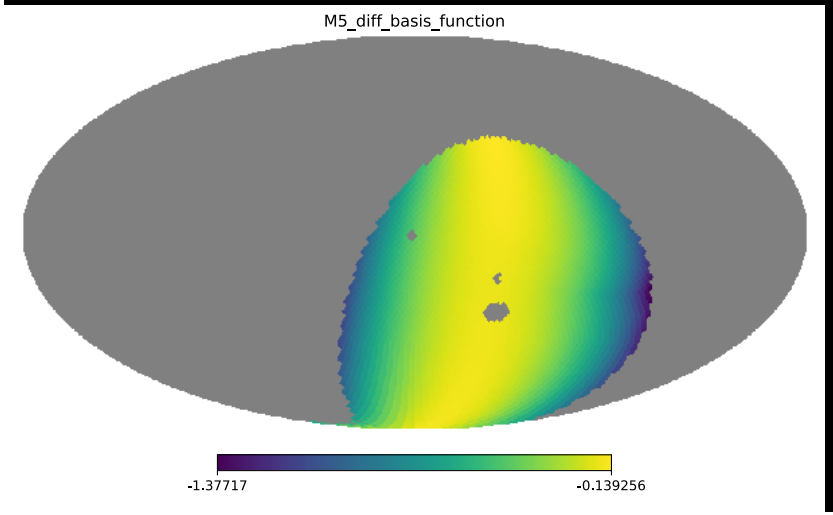
Reward Function (linear combo of Basis Functions)

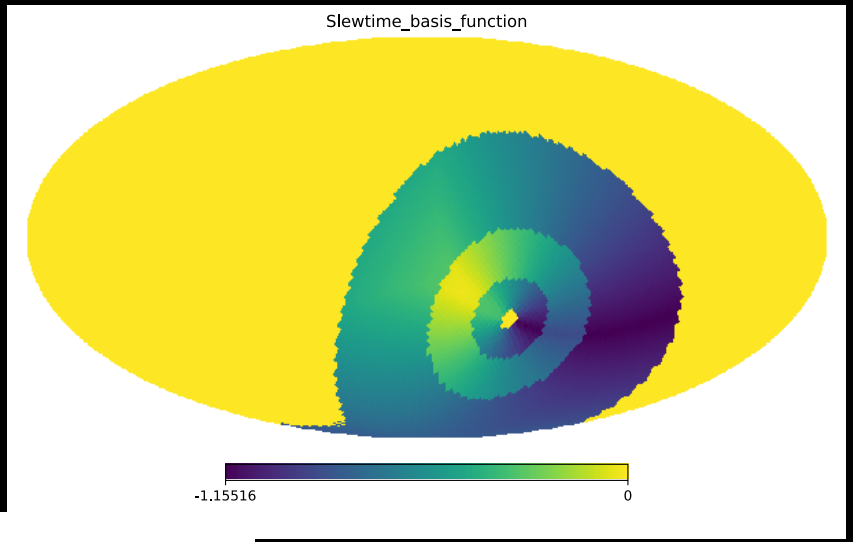
Decision Function

Basis functions

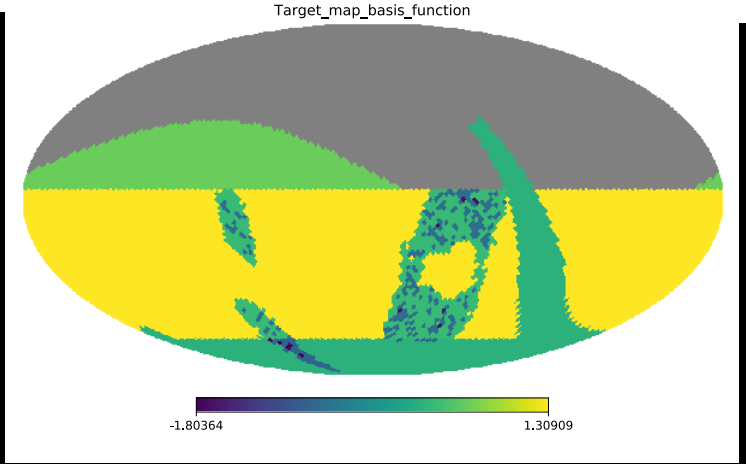
- Calculated on nside=32 HEALpix grid (1.8 degree resolution)
- Slewtime
- Survey progress (normalized) minus desired footprint
- Point source 5-sigma limiting depth (from skybrightness, airmass, seeing, filter) MINUS 5-sigma depth in dark time on the meridian. This is, how many magnitudes of penalty is it to observe a spot now versus waiting for it to be optimal conditions. Works great for making spatial selection and filter selection (currently assuming 1-mag of depth in one filter is worth the same as a mag of depth in another).

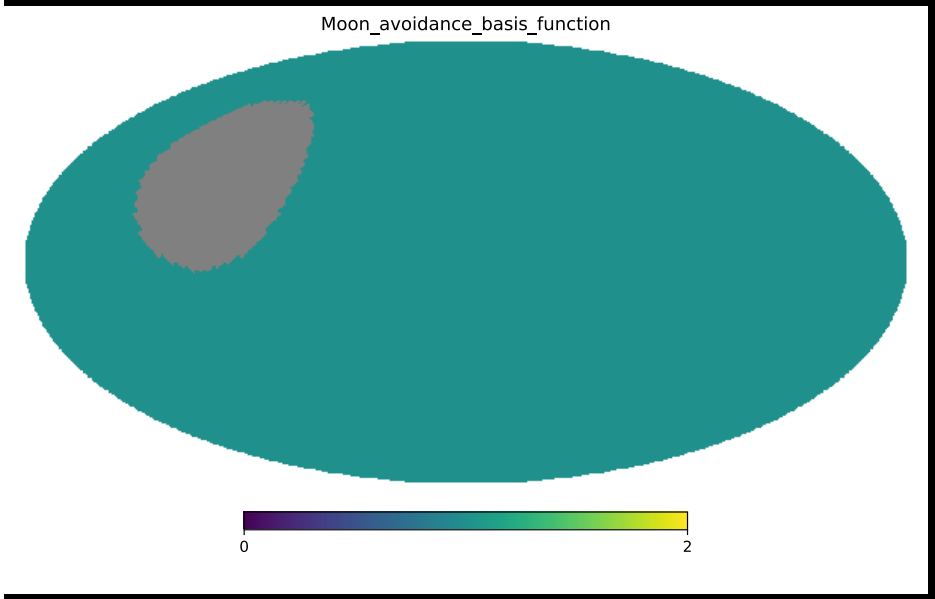
The Basis functions

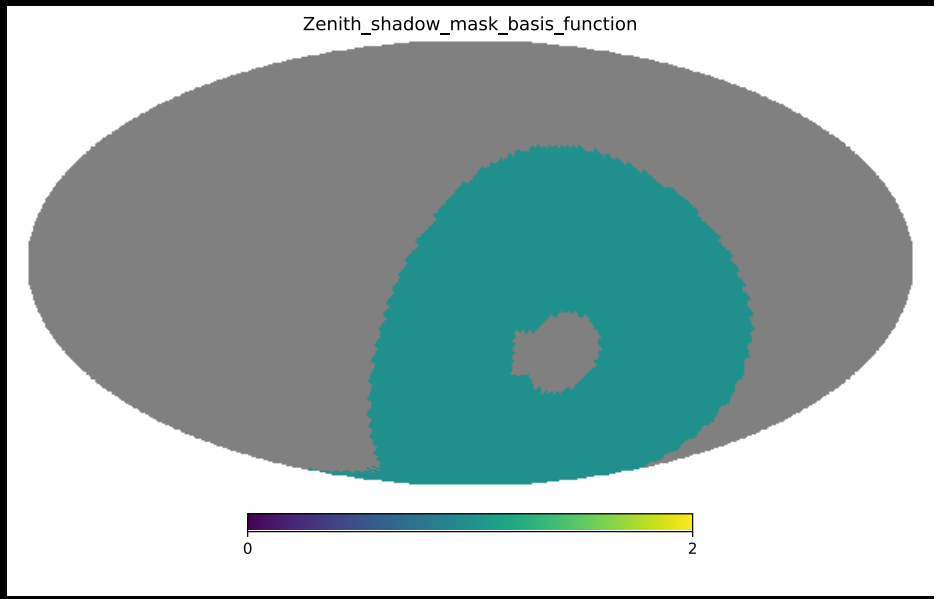




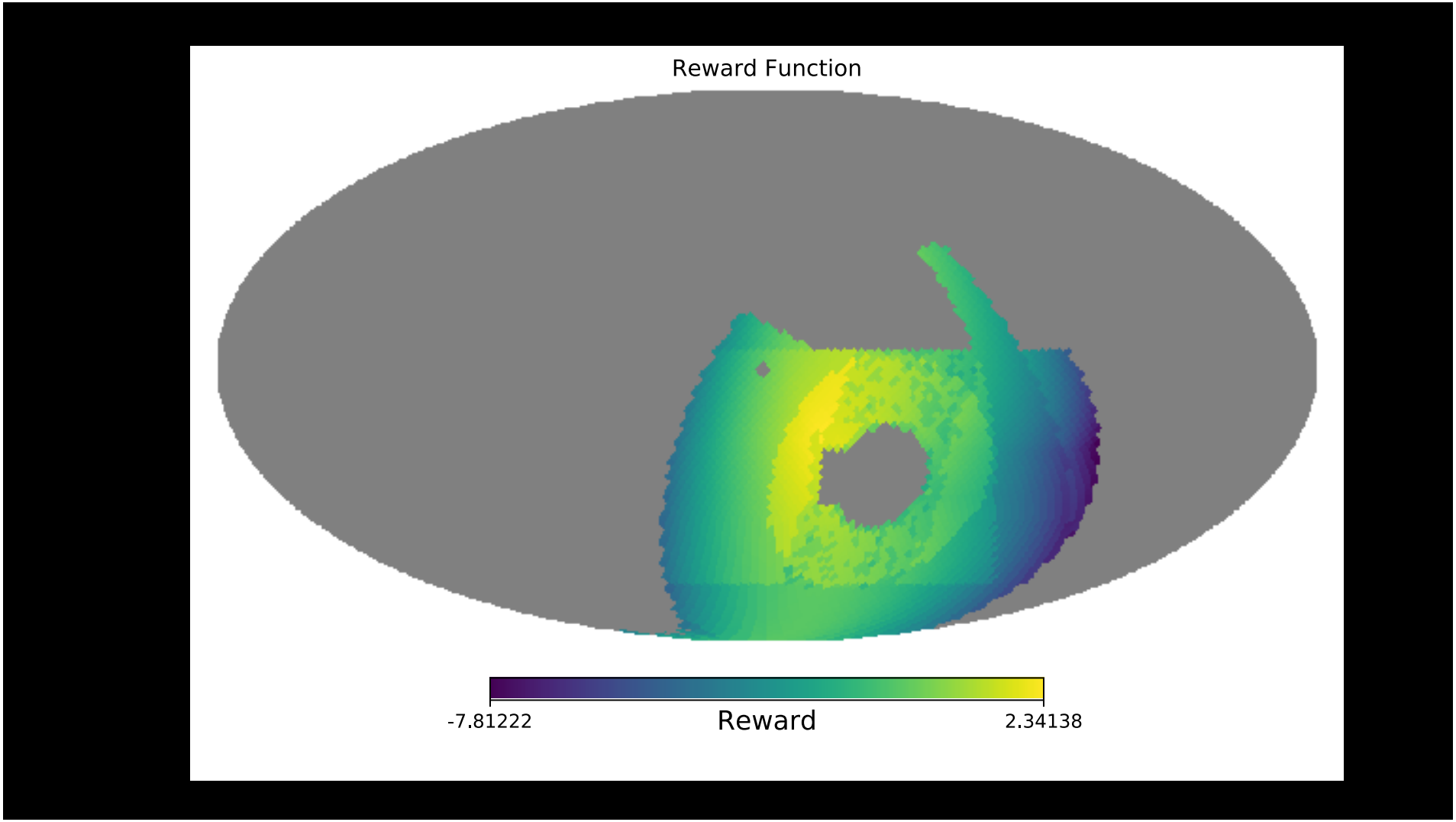
R-band basis functions, paused a few days into survey

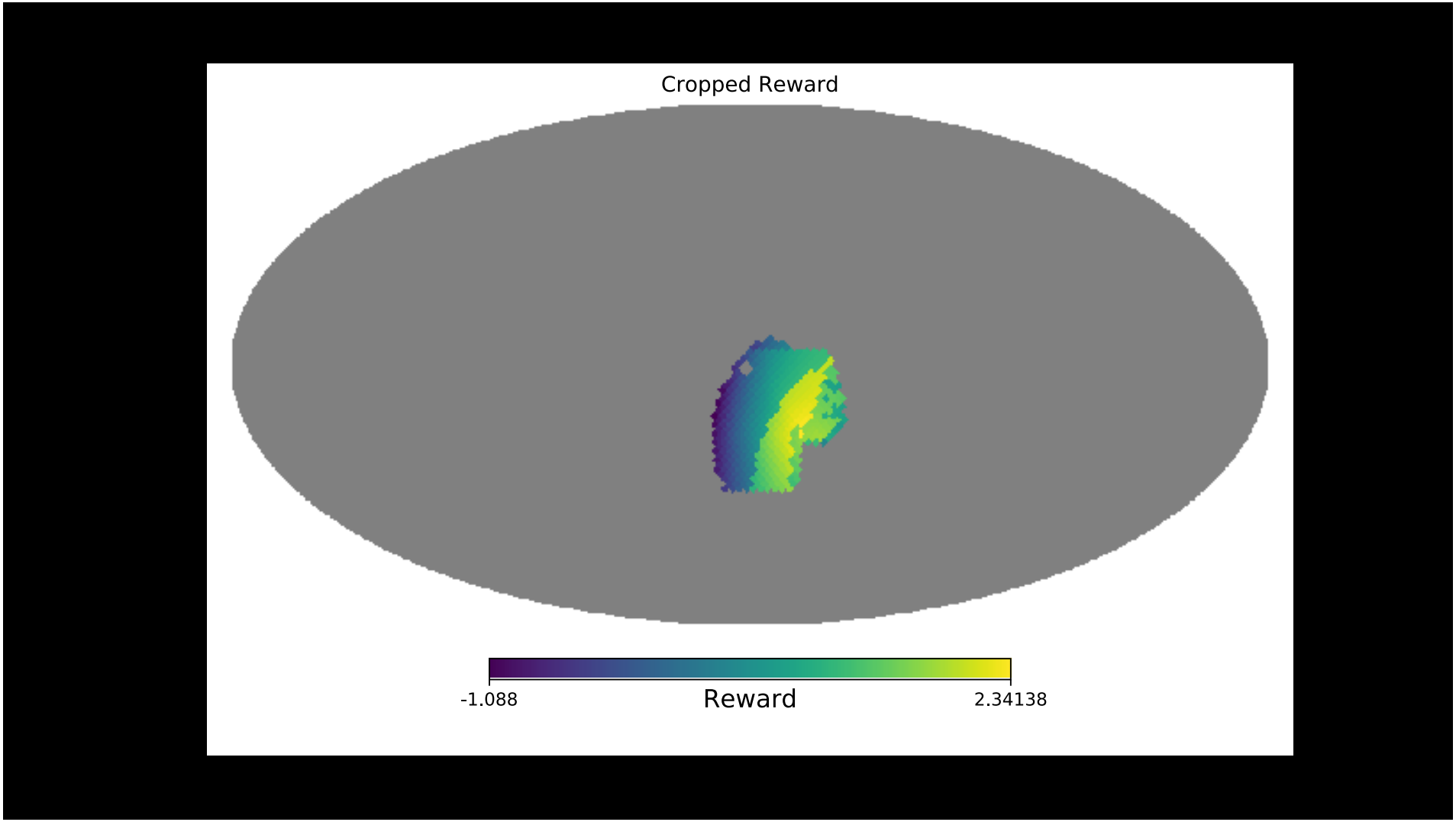


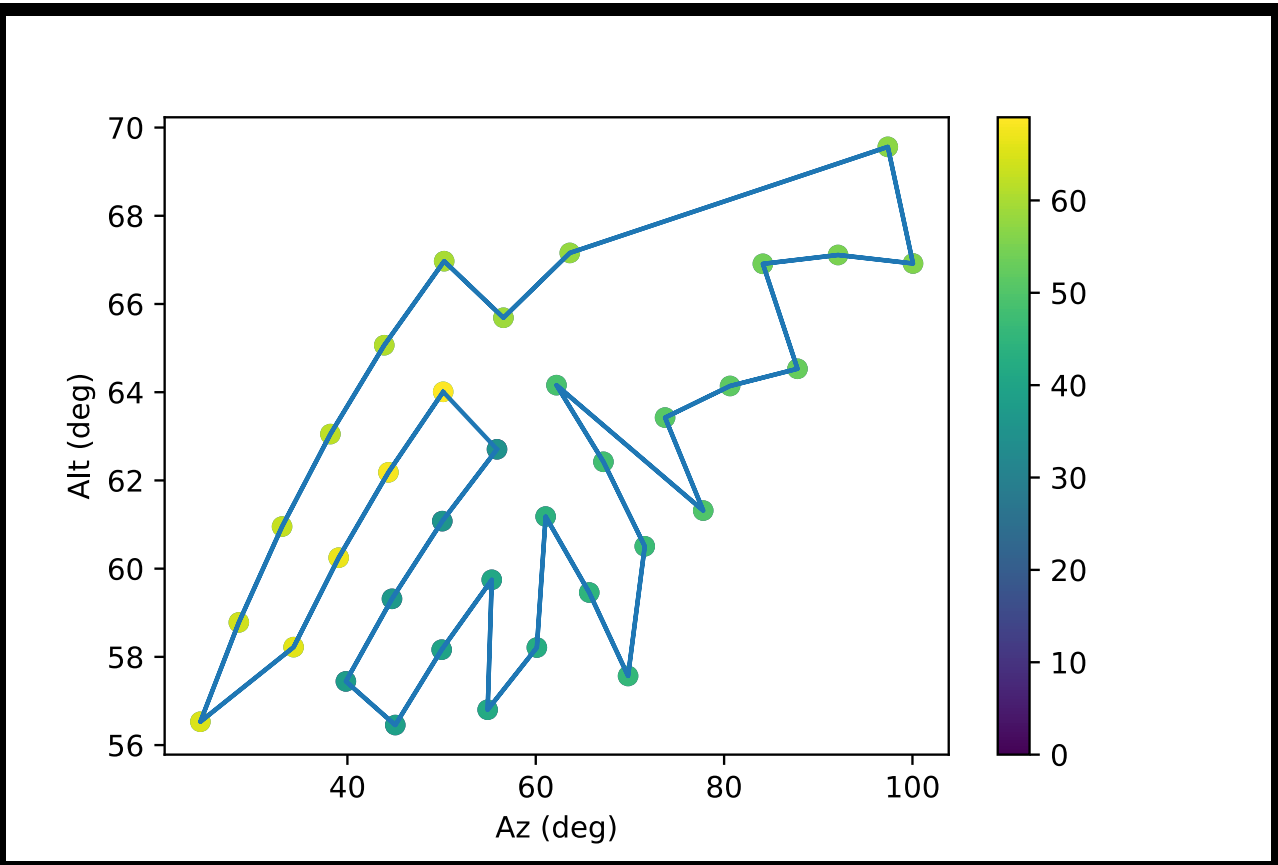




Moon and zenith mask basis functions


Reward Function
-7.81222
Reward
2.34138

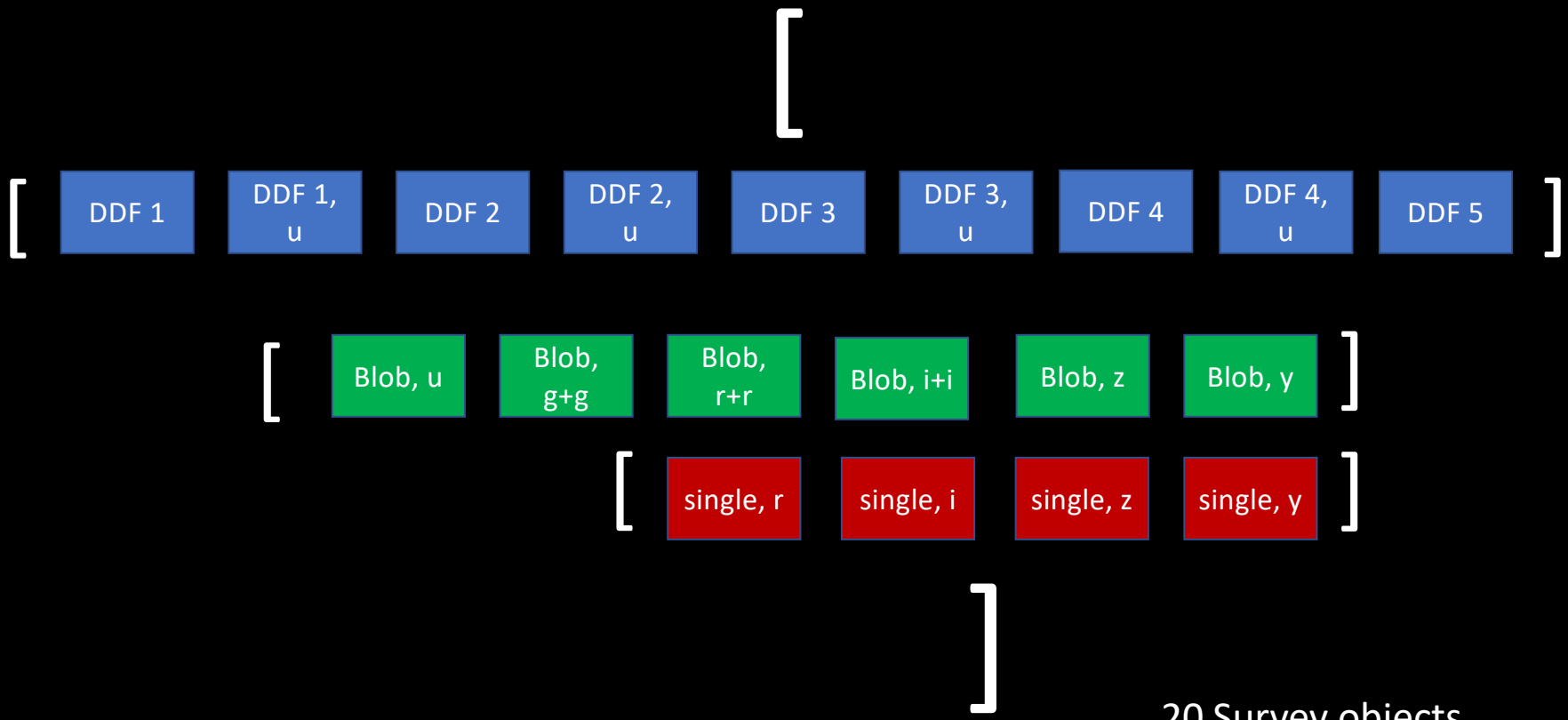

Cropped Reward
-1.088
Reward
2.34138



HEALpix to pointing mapping randomized each night.
Project to plane and solve traveling salesman
List of observations get rotator angle set, then added to the queue

Slew time
Image
Depth
Desired
Footprint

Our “scheduler” is a modular object oriented decision tree

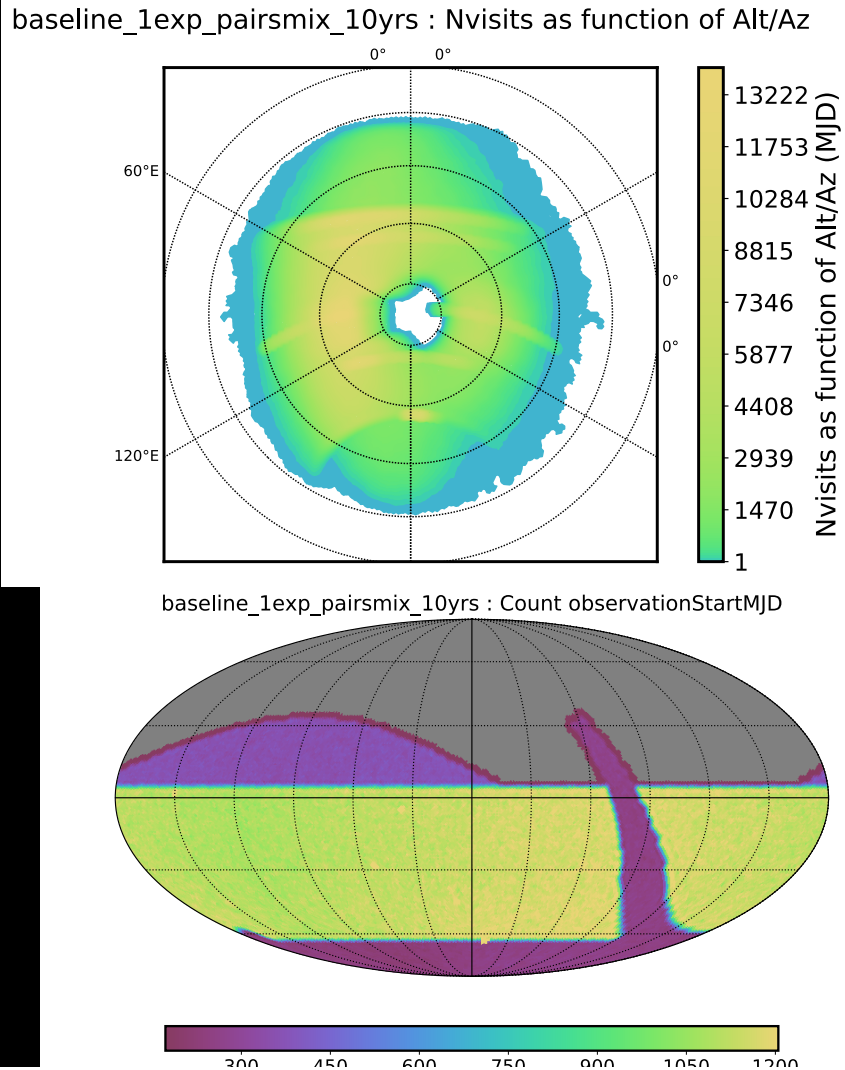


20 Survey objects

New Baseline

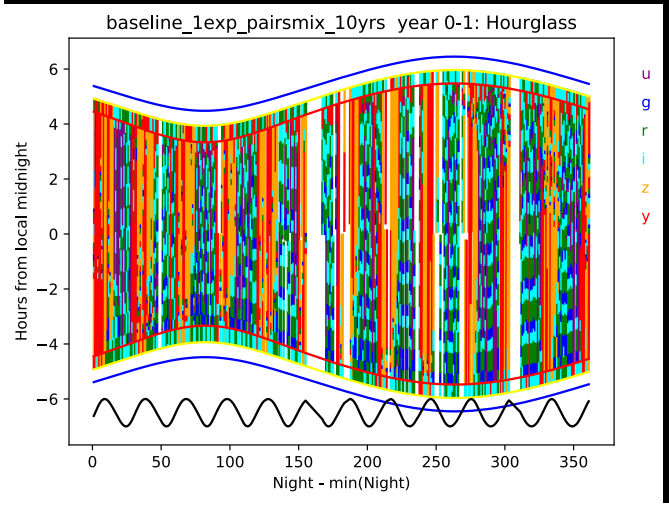
- Can set arbitrary survey footprint
- Spatial dithering
- Observations near meridian (but avoids moon and zenith)
- Object oriented python, so easy to modify behavior
- Small number of free parameters to train to optimize behavior

- No fixed sky tessellation (i.e., no fields)
- No master list of observations to execute
- No “global” optimization (this is a trained AI)
- No config file, build scheduler object with ~200 lines of python

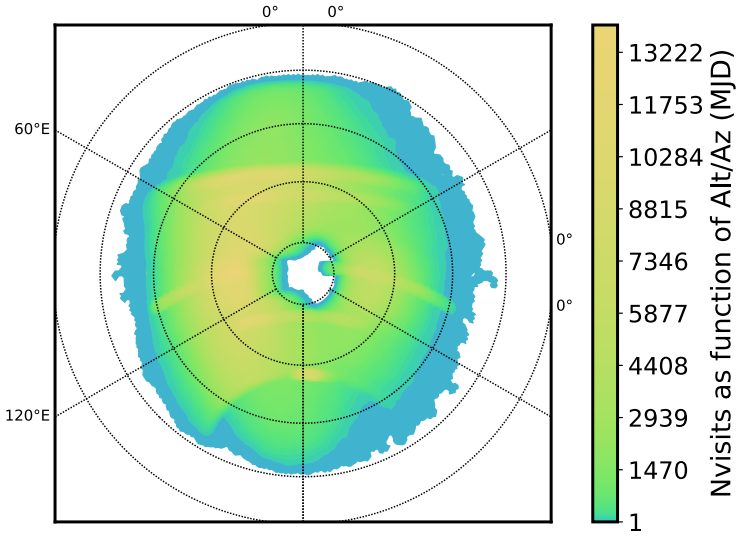


- Properly dithered final footprint
- Observations at reasonable hour angles
- Red filters in bright time
- No pointing at moon, no pointing at zenith
- Open shutter fractions 71-80% (max would be ~84% with no filter changes)

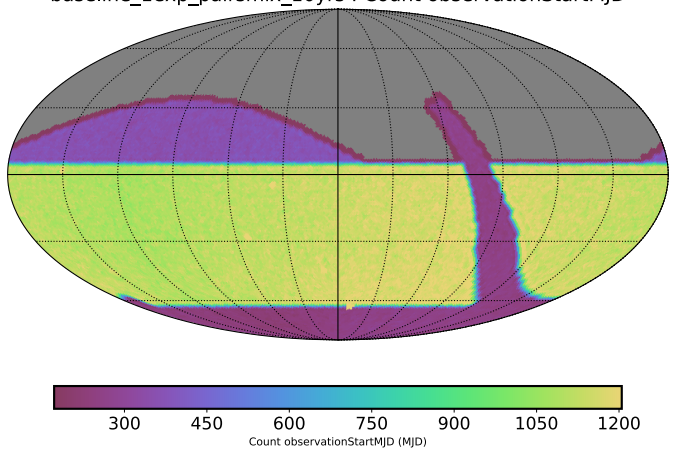
The scheduler is (finally) not doing anything obviously wrong



baseline_1exp_pairsmix_10yrs : Nvisits as function of Alt/Az

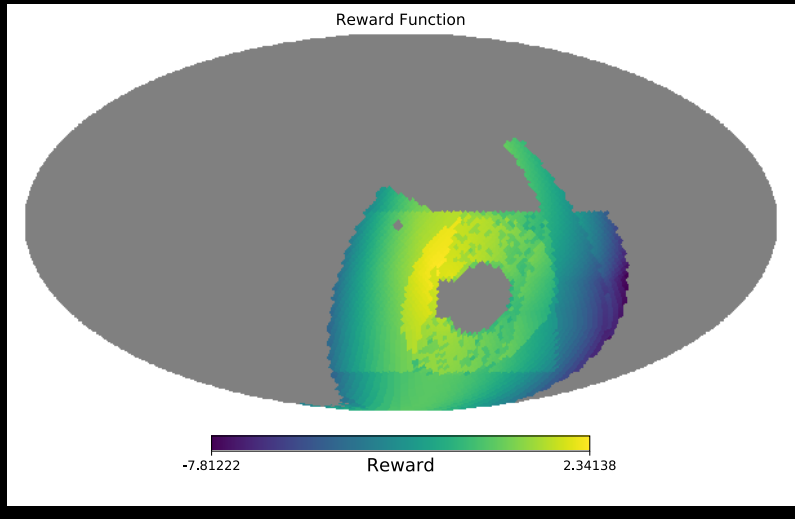


baseline_1exp_pairsmix_10yrs : Count observationStartMJD

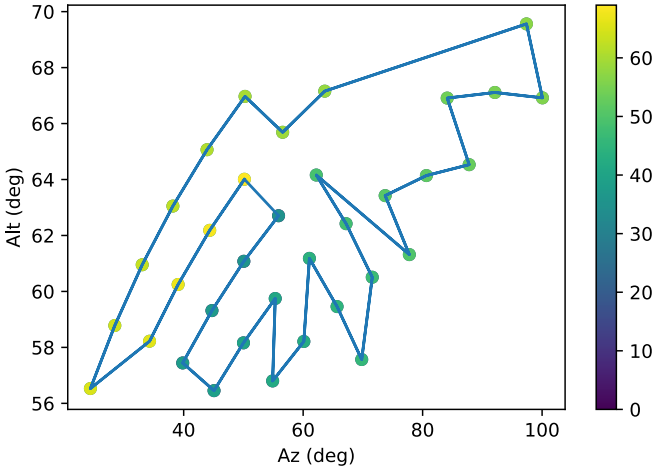


We are leveraging

- The reward function changes slowly
- No one has demanded high-precision temporal scheduling on observations (observations should be paired, but with 15-30 minute gaps).
- No strong temporal constraint on when DDFs get observed



If we wanted to spend most of the time doing DDF-like observations, it would probably be better to use integer programming for scheduling. Now we have ~1 DDF sequence per night, so little to no penalty treating them as interrupts.



Stuff we did the SAC asked for

- Pairs in same or different filters
- 1x30 or 2x15 visits
- Footprint variations (9 different ones)
- Presto color (g+i+pause+g)
- Vary u-band filter loading
- 1s or 5s exposure sky coverage
- Rolling cadences (13 variations)
- Dithered DDF (spatial)
- DESC DDF
- Target of opportunity
- Stability tests

Bonus Experiments

- Pathological footprint
- Variable exposure time
- AltSched like behavior
- Camera rotator dithering
- Smarter rolling cadence

Still in the queue

- AGN DDF
- Akari and WFIRST/Euclid DDF experiments
- Bulge and low galactic latitude variations
- LMC/SMC mini-surveys
- Twilight NEO survey
- Twilight DCR
- Mini-surveys in the North
- Season extension (not super well defined)
- Anti-alias timing (tough to do, is it really a problem?)

Issues

- Fixed optimistic weather downtime, we now match SOAR and Gemini South
- DDF logic probably too strict, v1.2 released runs couldn't catch up when they fell behind (e.g., downtime during season). Mostly fixed, can re-run DDF experiments in next version release
- Probably need to enforce full sky coverage every year (for difference imaging templates and ubercal)
- Add bright planet avoidance (explicitly)
- Soften moon avoidance limit?

Post on Community discussing the new runs:
https://community.lsst.org/t/july-2019-update/3760
or
http://ls.st/xsb

"Why didn't you simulate what we wanted?"

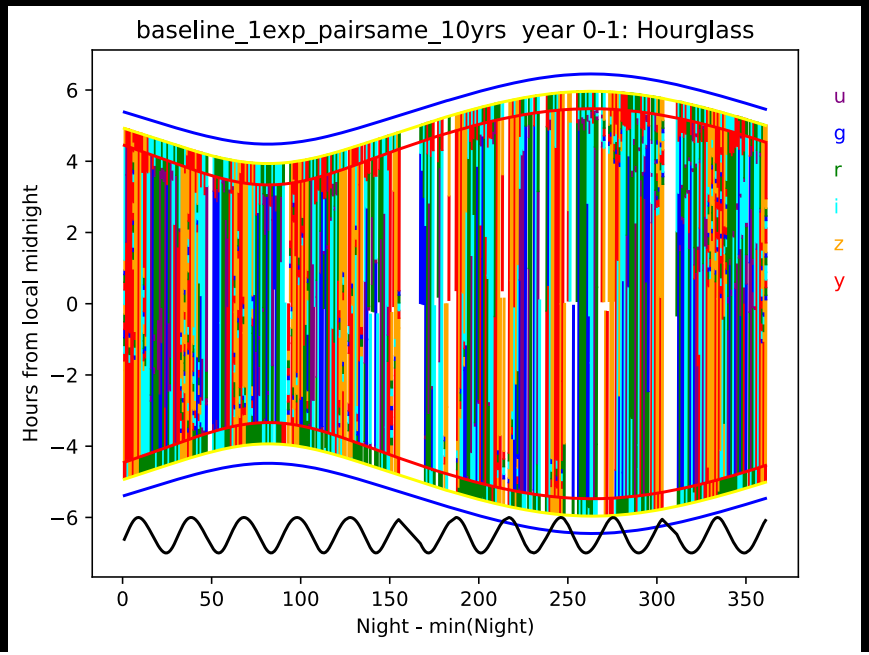
- White Paper → SAC → people writing code
- Took artistic liberties to ensure simulation could still meet SRD, or just to make it faster to code
- Some white paper ideas are easier to put in the Markov Decision Process framework than others
- We made 87 sims and still aren't through the list, there hasn't been time to check that simulations are exact matches to what was requested

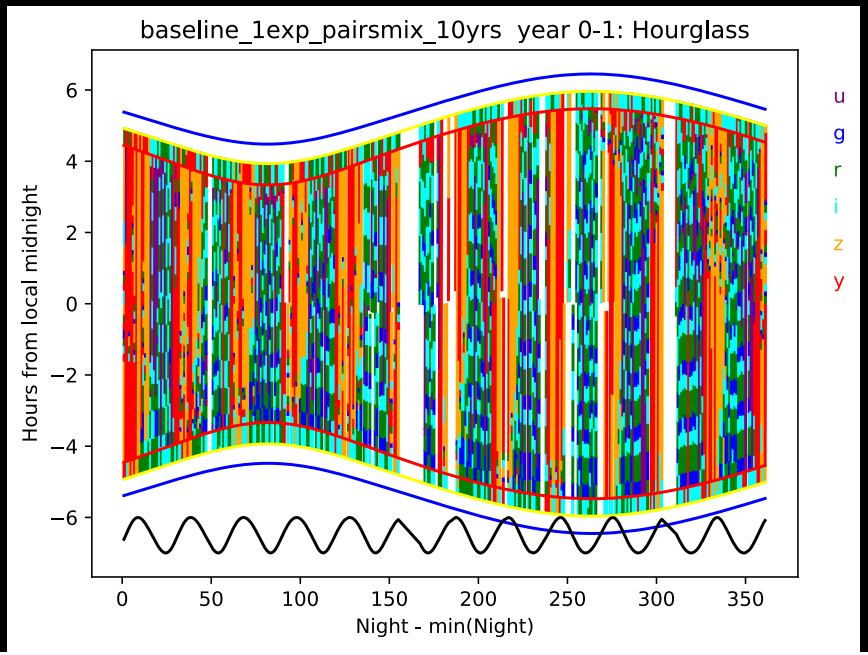
Please look at what we have released, and give us feedback on how it looks, we can make more iterations

Baseline-like sims

- 1x30s snaps in a visit
- 2x15s snaps in a visit
- g+g, r+r, i+i pairs
- g+r, r+i, i+z pairs

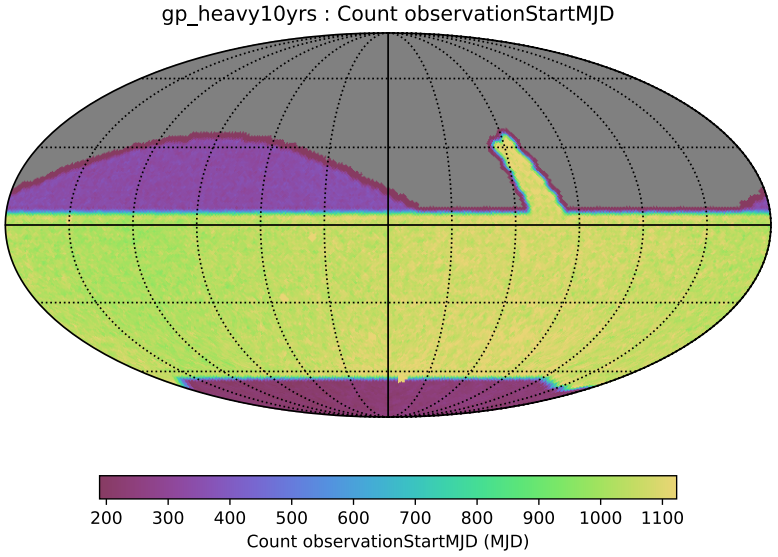
1x30s snap, mixed filter pairs as the "baseline" behavior for the rest of the simulations



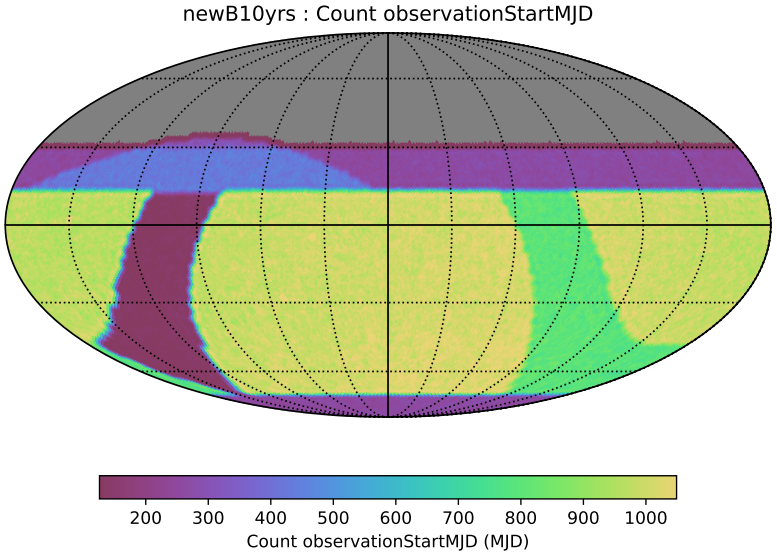


Footprints

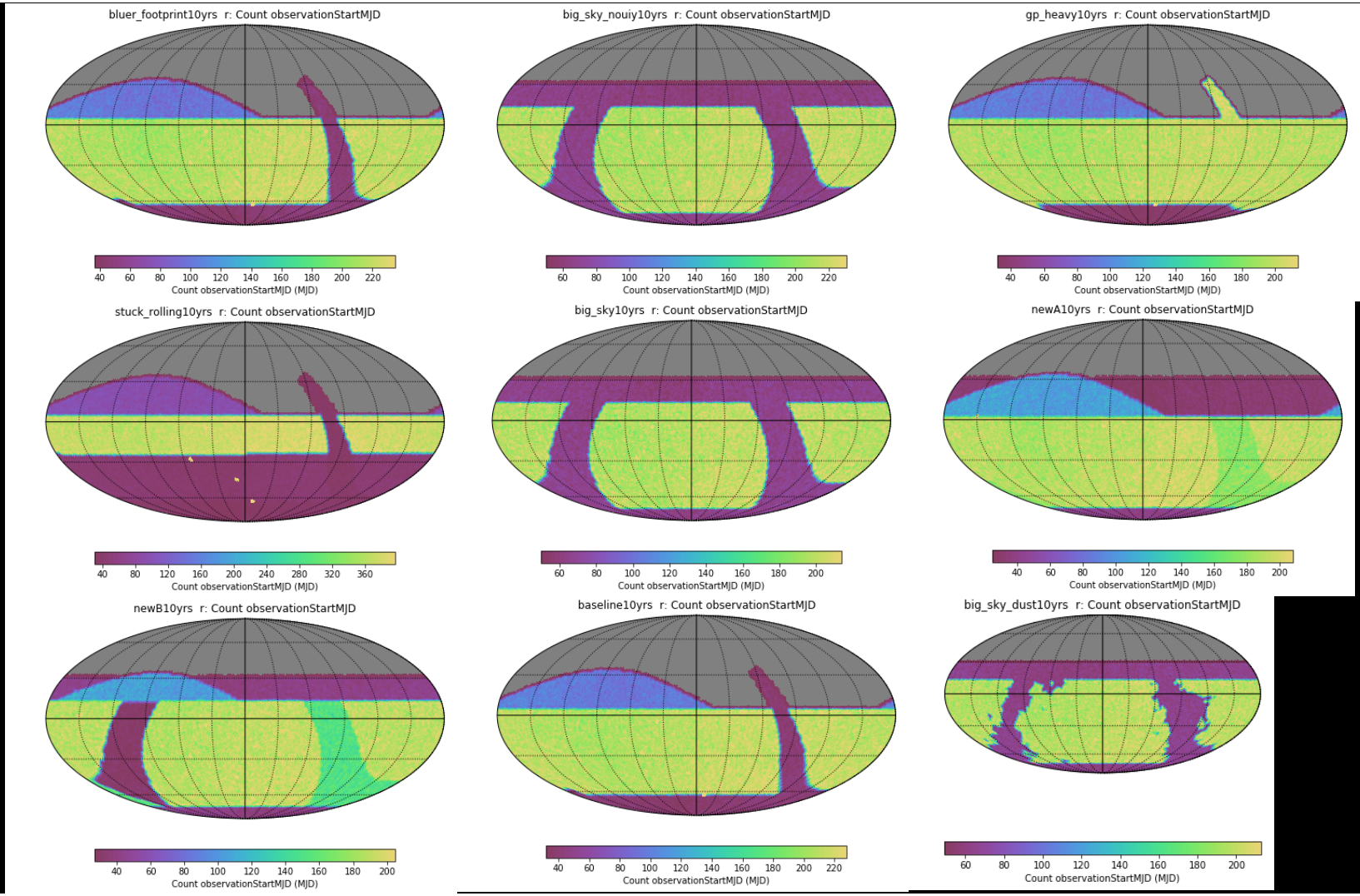
- 8 different survey footprints



Galactic Plane like WFD

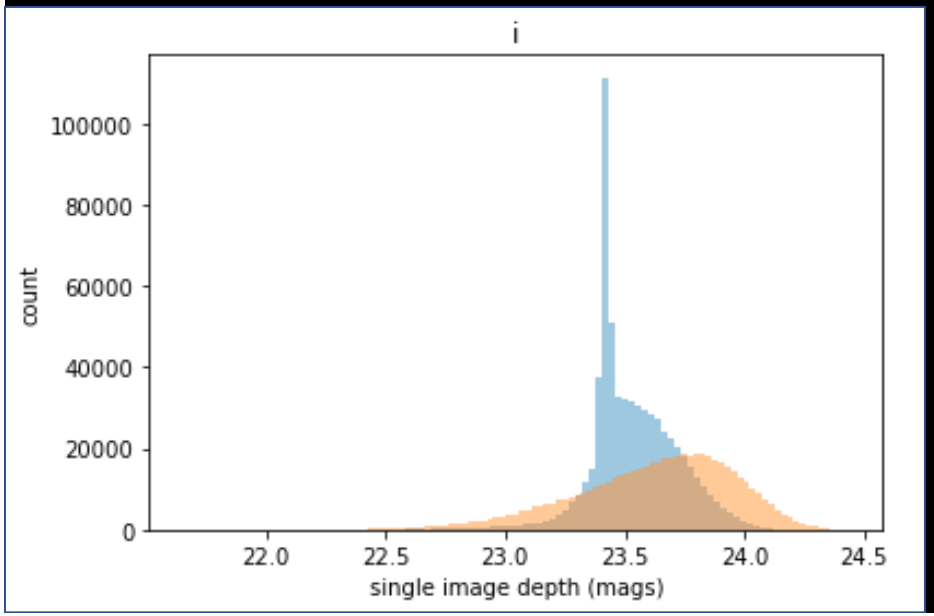


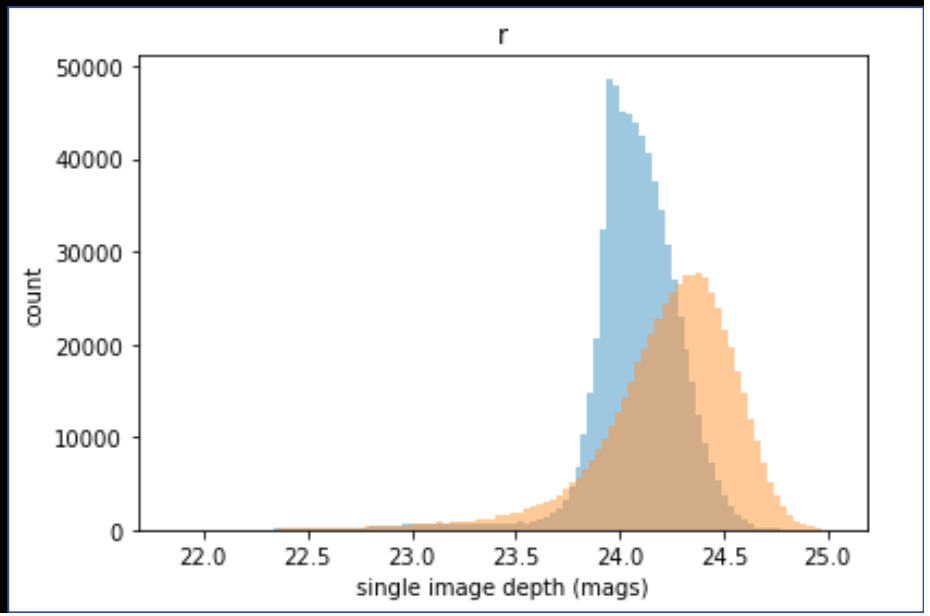
Decrease Galactic anti-center, extend WFD, cover all of north


bluer_footprint10yrs r: Count observationStartMJD
40 60 80 100 120 140 160 180 200 220
Count observationStartMJD (MJD)
big_sky_nouiy10yrs r: Count observationStartMJD
60 80 100 120 140 160 180 200 220
Count observationStartMJD (MJD)
gp_heavy10yrs r: Count observationStartMJD
40 60 80 100 120 140 160 180 200
Count observationStartMJD (MJD)
stuck_rolling10yrs r: Count observationStartMJD
40 80 120 160 200 240 280 320 360
Count observationStartMJD (MJD)
big_sky10yrs r: Count observationStartMJD
60 80 100 120 140 160 180 200
Count observationStartMJD (MJD)
newA10yrs r: Count observationStartMJD
40 60 80 100 120 140 160 180 200
Count observationStartMJD (MJD)
newB10yrs r: Count observationStartMJD
40 60 80 100 120 140 160 180 200
Count observationStartMJD (MJD)
baseline10yrs r: Count observationStartMJD
40 60 80 100 120 140 160 180 200 220
Count observationStartMJD (MJD)
big_sky_dust10yrs r: Count observationStartMJD
60 80 100 120 140 160 180 200
Count observationStartMJD (MJD)

Variable Exposure Time
(Not recommended by SAC, but I'd already done it)
Adjust exposure time between 20 and 100s to get specified depth on every visit.

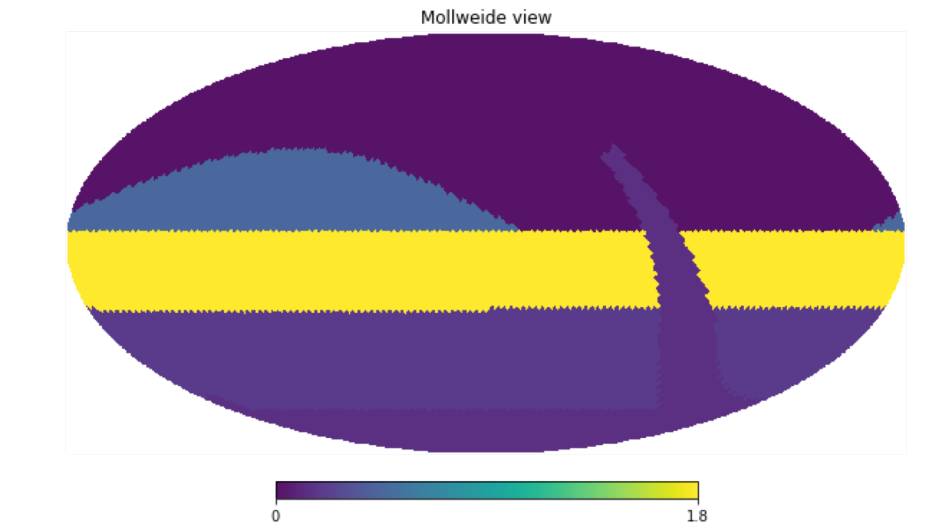
Images are shallower, but you get more of them. 2.9 million observations instead of 2.5, lose ~0.1 mag of final coadded depth.



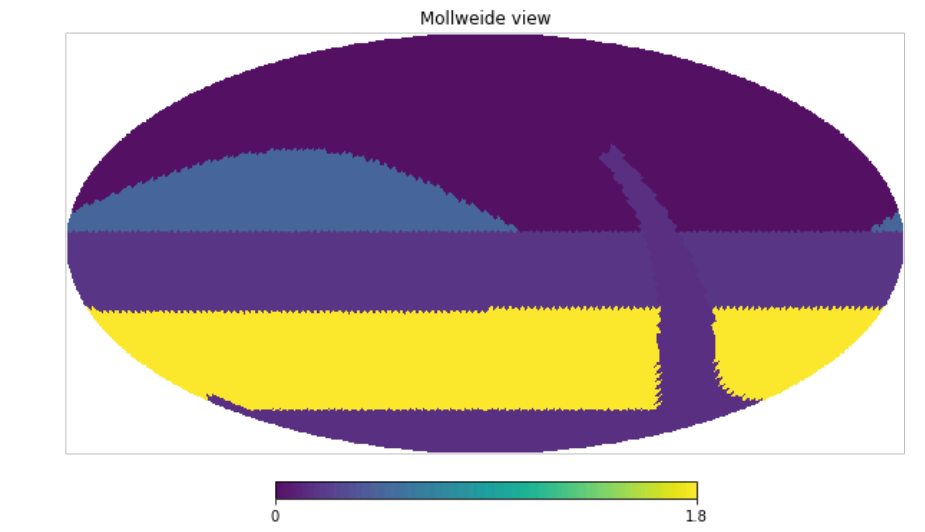


Rolling Cadence

Even Years



Odd Years



We've run 13 different rolling variants

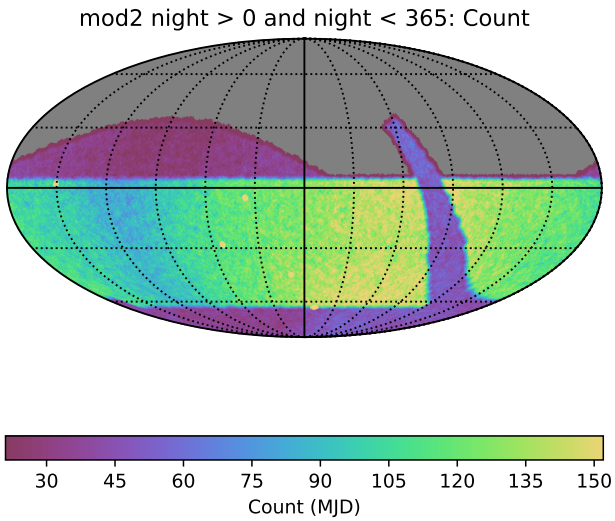
- 2,3,5,6,10 dec bands
- On/off maps and scrolling for full seasons
- 5, 10, 20% scale-down factors

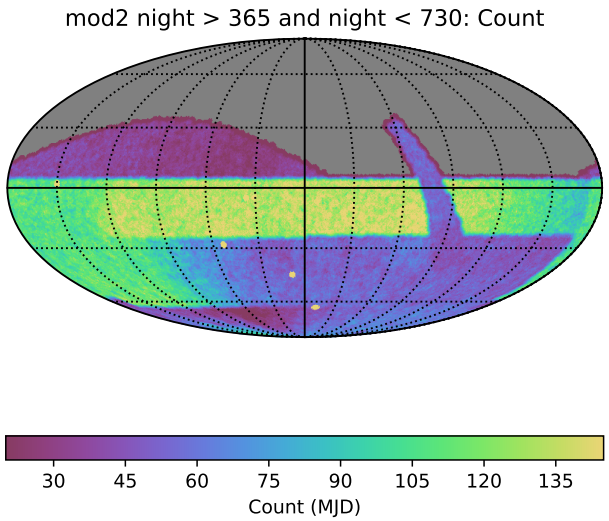
Rolling Cadence

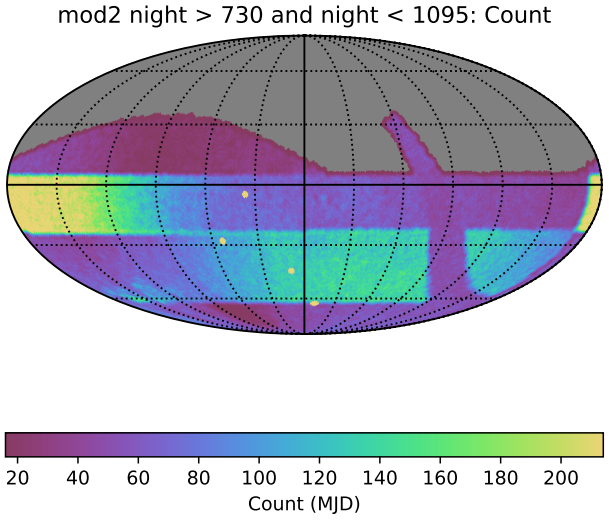
Start off normal, then divide WFD in half and alternate emphasis on north and south

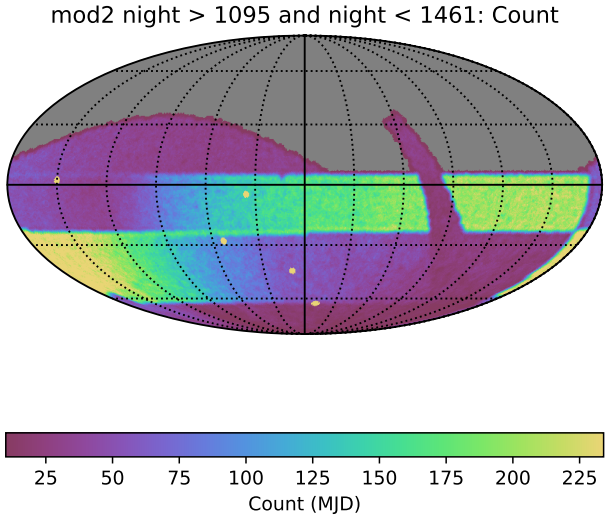
Year 1 like baseline, WFD gets 120 observations/yr

Rolling, get 25 or 215 observations per year

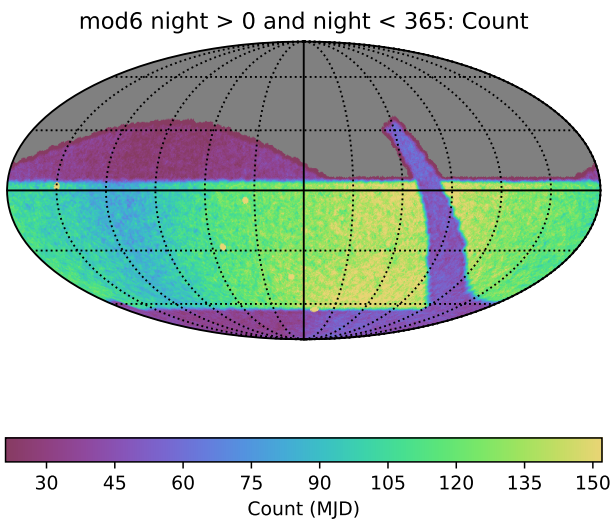


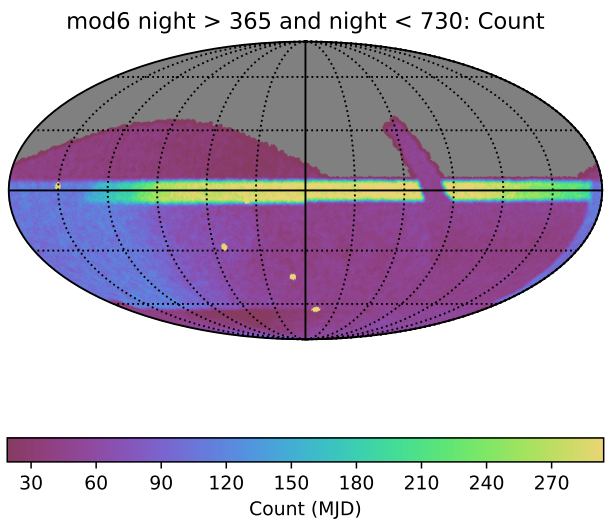


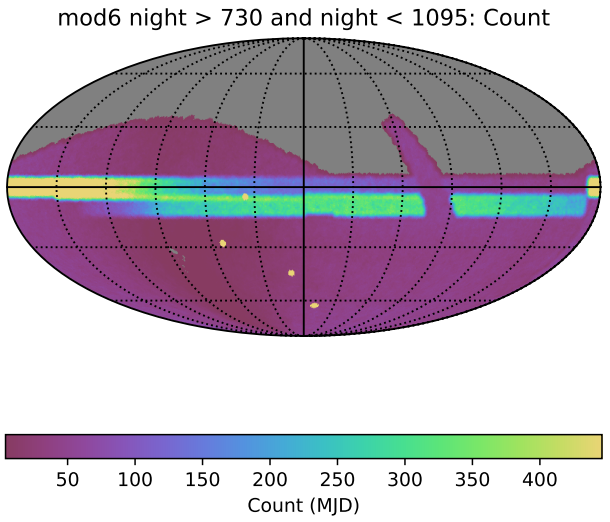


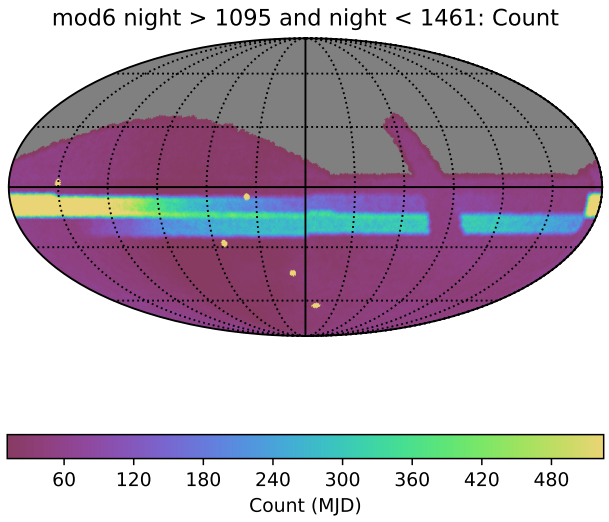


Can get extreme and have 6 declination stripes. 450+ observations in a season! (then 400 more observations spread over 9 years)









Short exposures

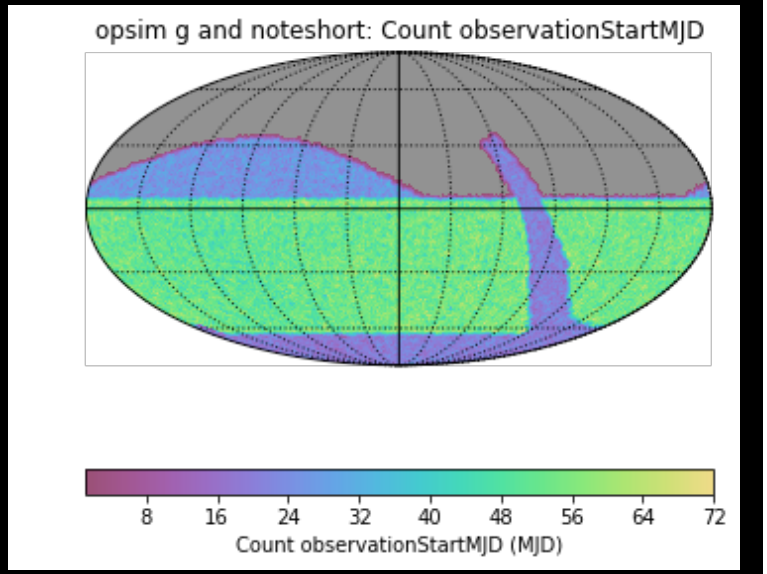
- Mixing in 2s or 5s exposures

Twilight time

- Taking 1s exposures in twilight

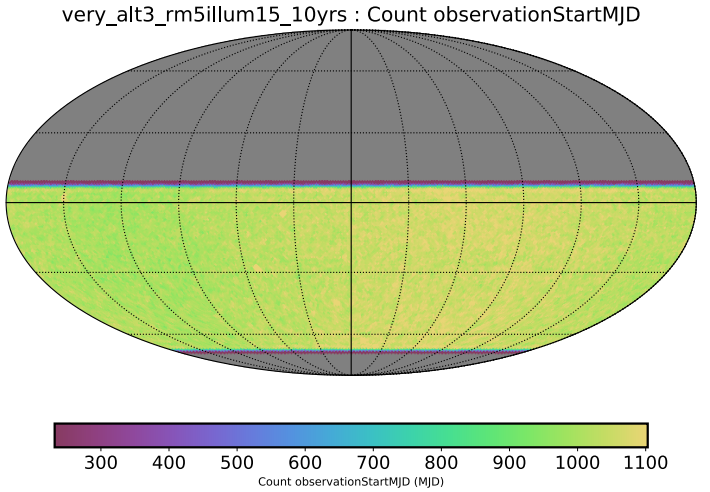
Filter Loading

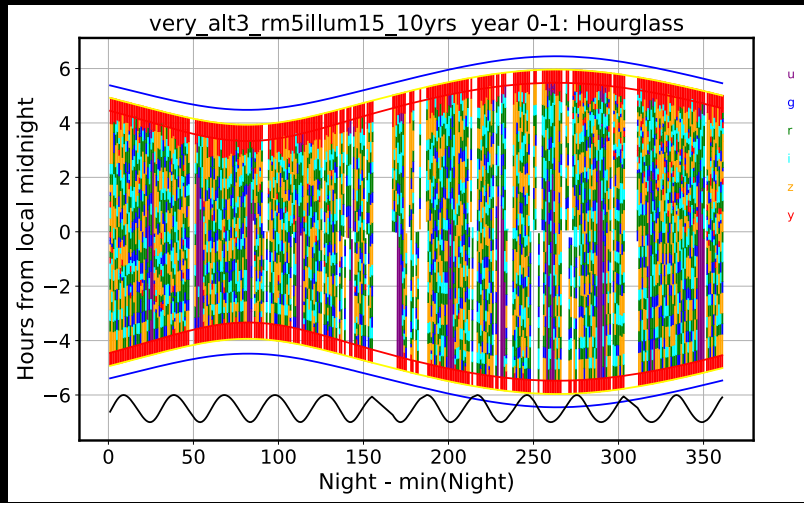
- Vary when u and z get swapped out of the camera

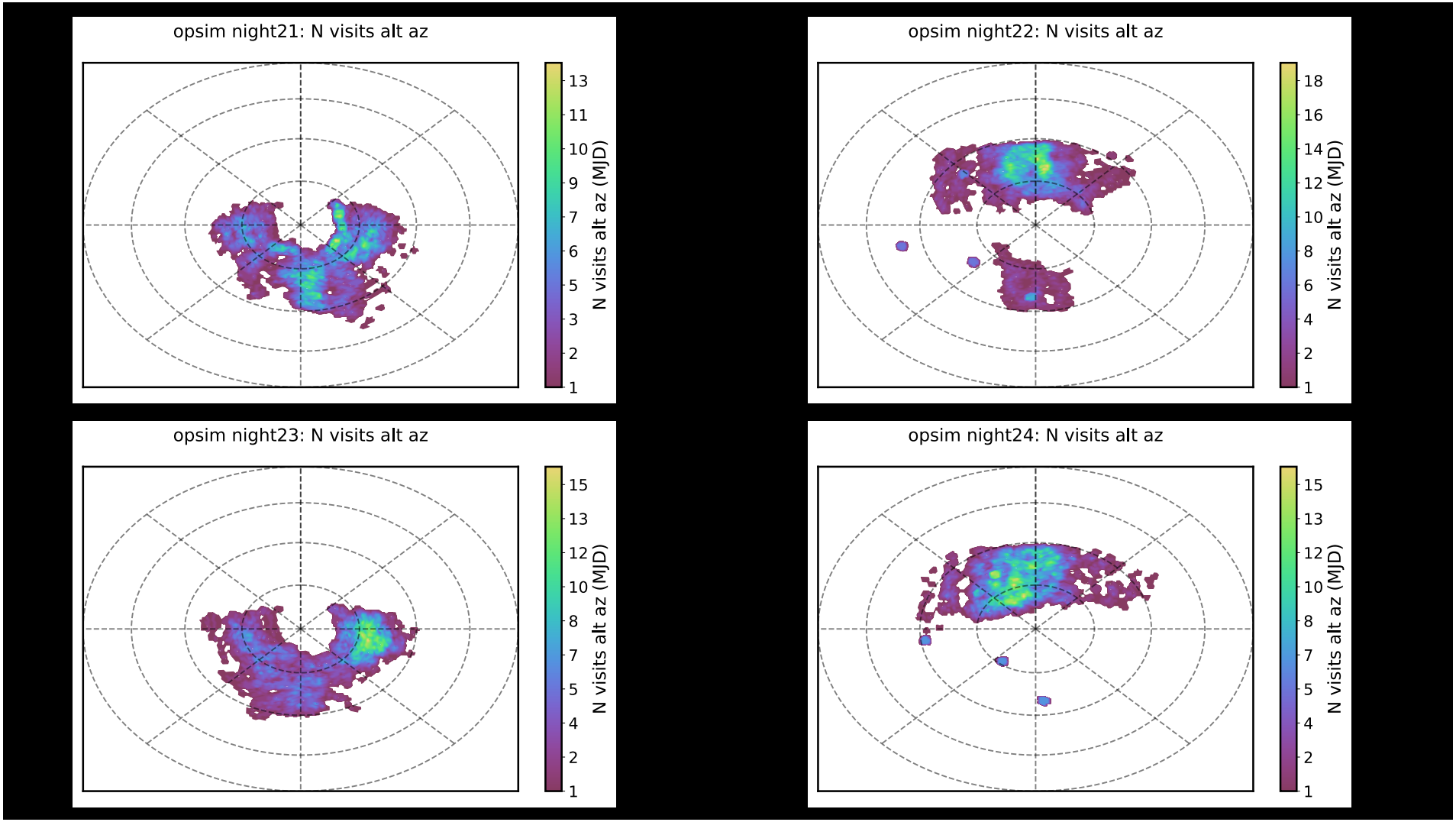


Alt-Sched like

- Y-band in twilight
- Blue filters in bright time
- Alternate north and south each night

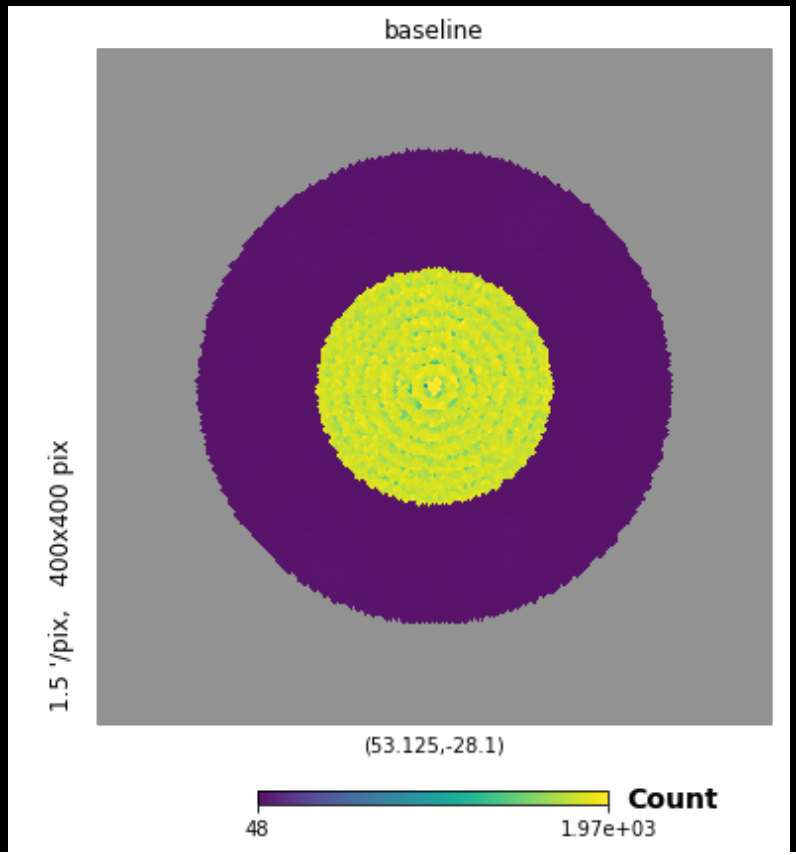


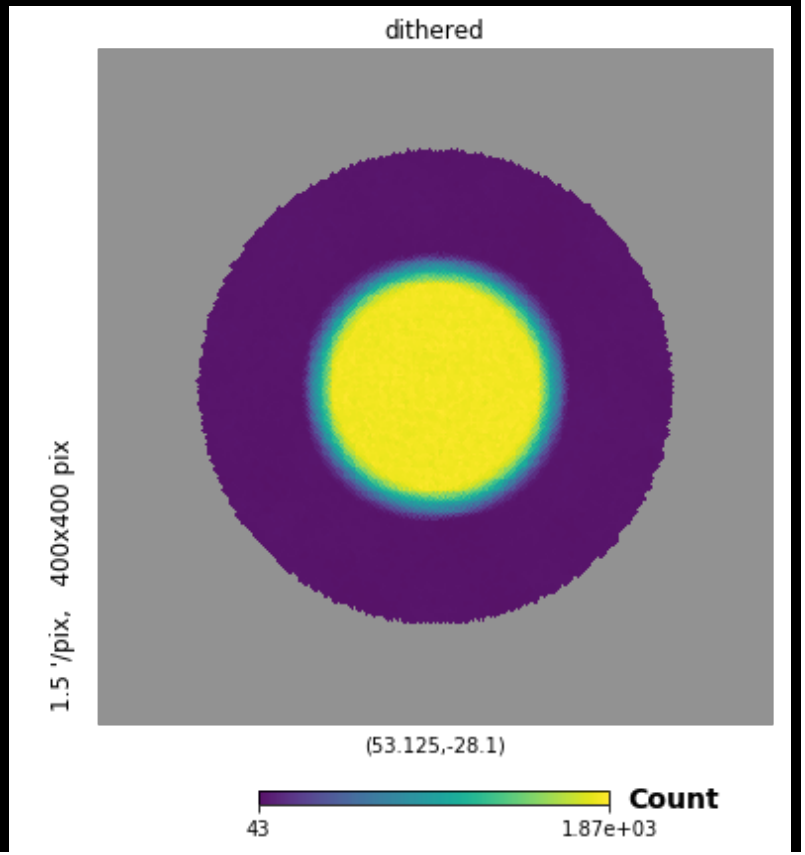



opsim night21: N visits alt az
N visits alt az (MJD)
13
11
10
9
7
6
5
3
2
1
opsim night22: N visits alt az
N visits alt az (MJD)
18
16
14
12
10
8
6
4
2
1
opsim night23: N visits alt az
N visits alt az (MJD)
15
13
12
10
8
7
5
4
2
1
opsim night24: N visits alt az
N visits alt az (MJD)
15
13
12
10
8
7
5
4
2
1

DDF

- Spatial Dithering
- DESC suggested cadence

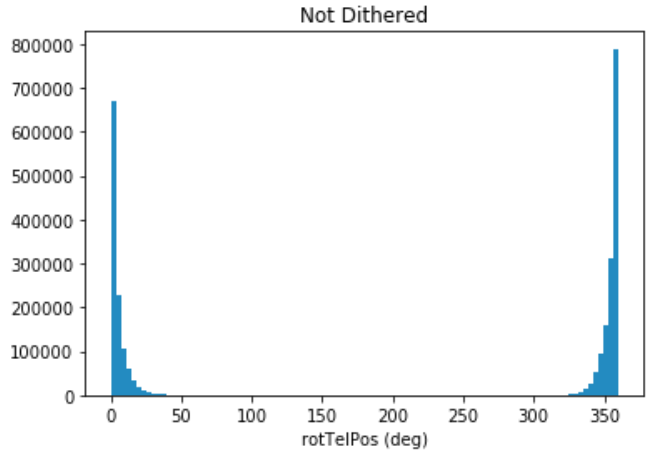


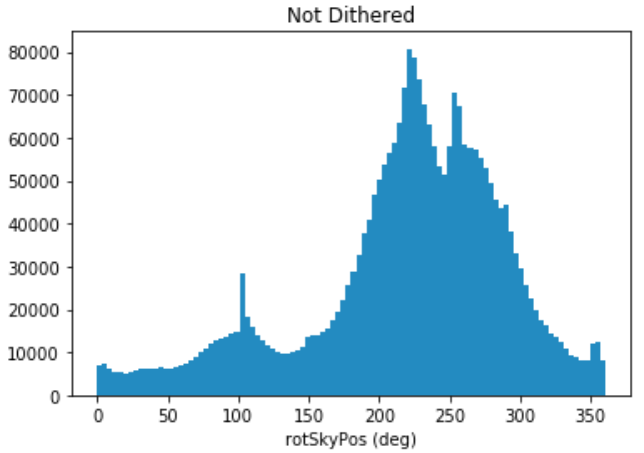


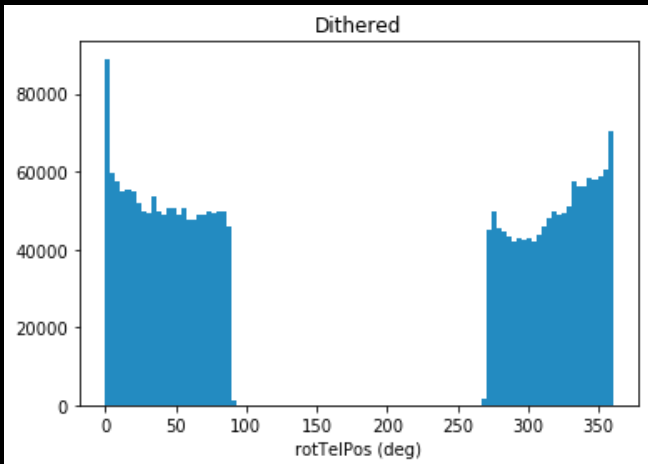
Rotator Angle

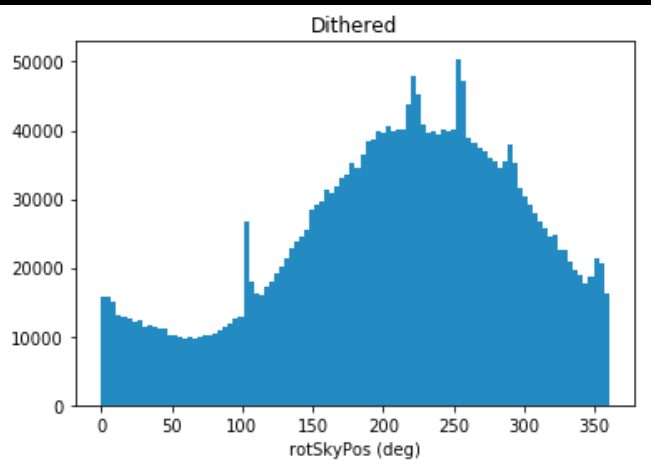
Baseline keeps the camera-telescope angle near zero.

Can select a telescope angle per night to randomize orientation



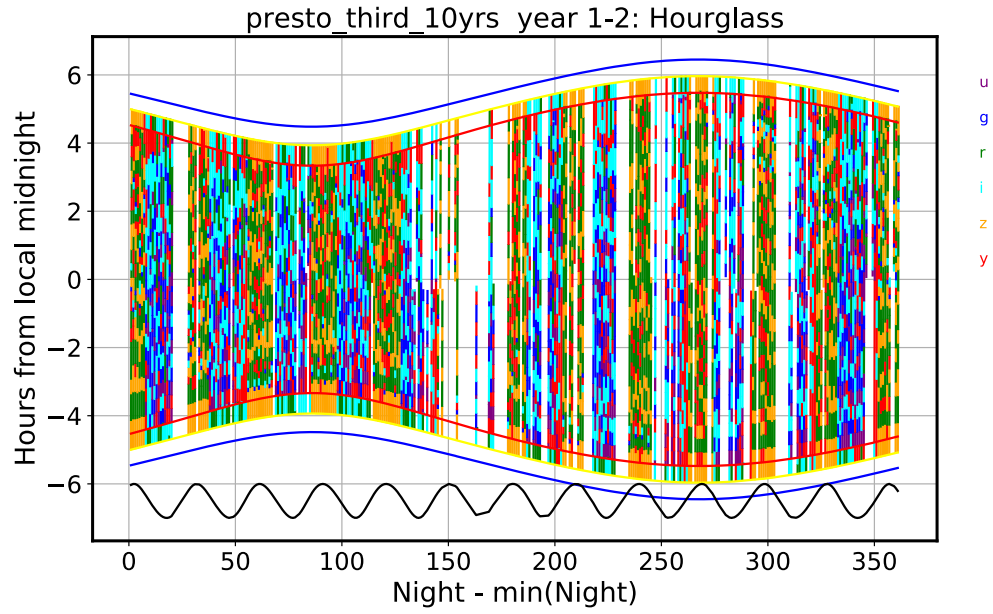


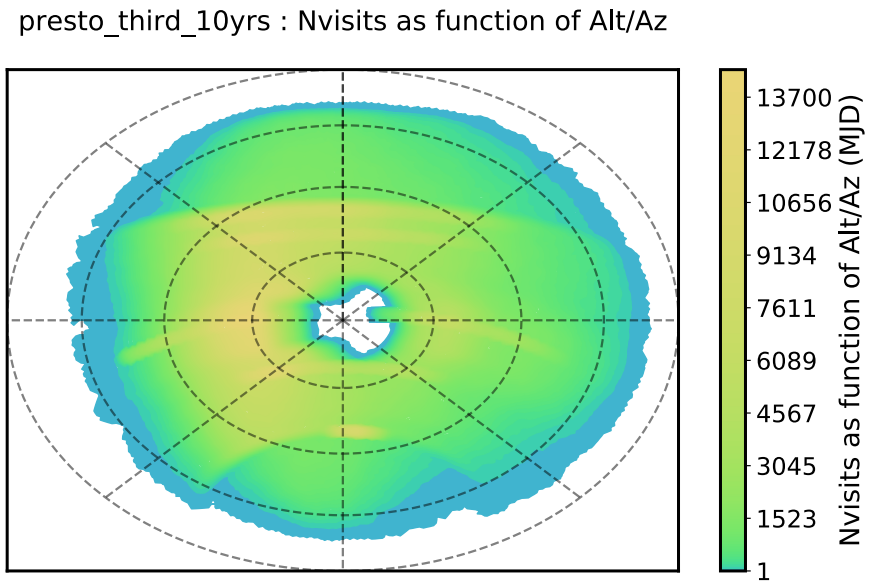




Presto color

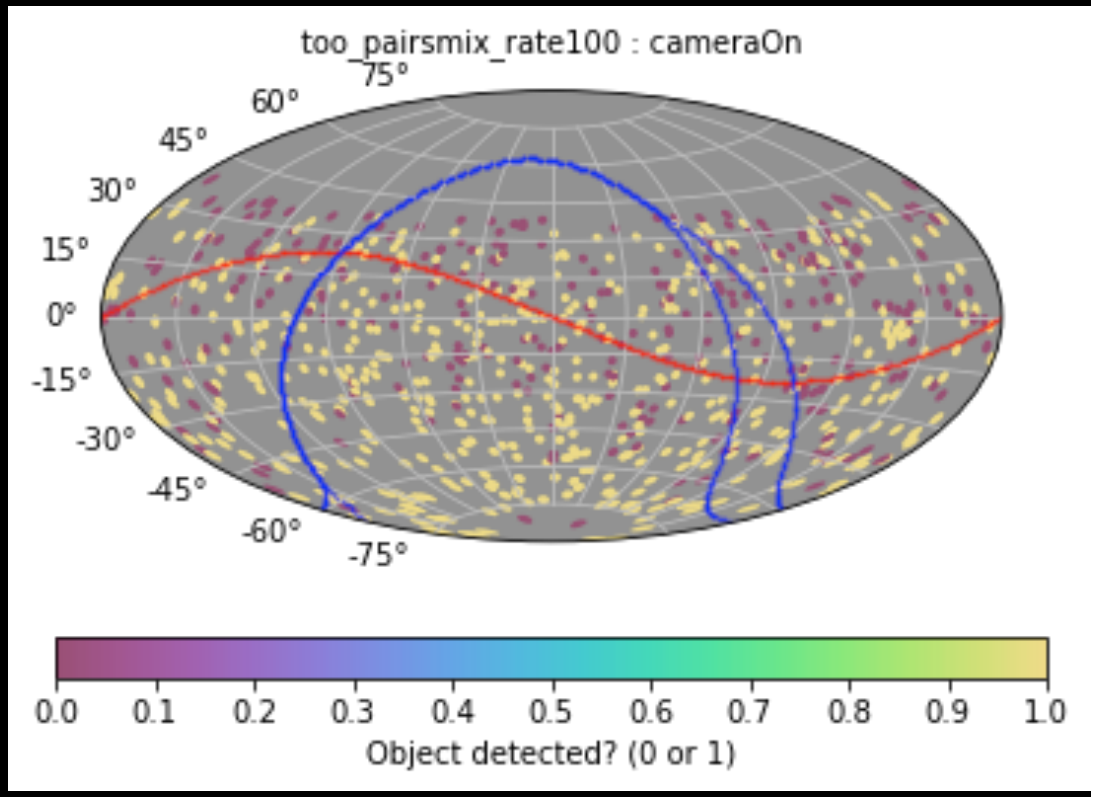
- g+i…40-120min later+g
- r+z…+r





Target of Opportunity

- 1, 10, 50, 100 alerts per year
- Usually able to detect ~55% of ToOs



Post on Community discussing the new runs:
https://community.lsst.org/t/july-2019-update/3760
or
http://ls.st/xsb