LSST Scheduler
Status and Future Plans

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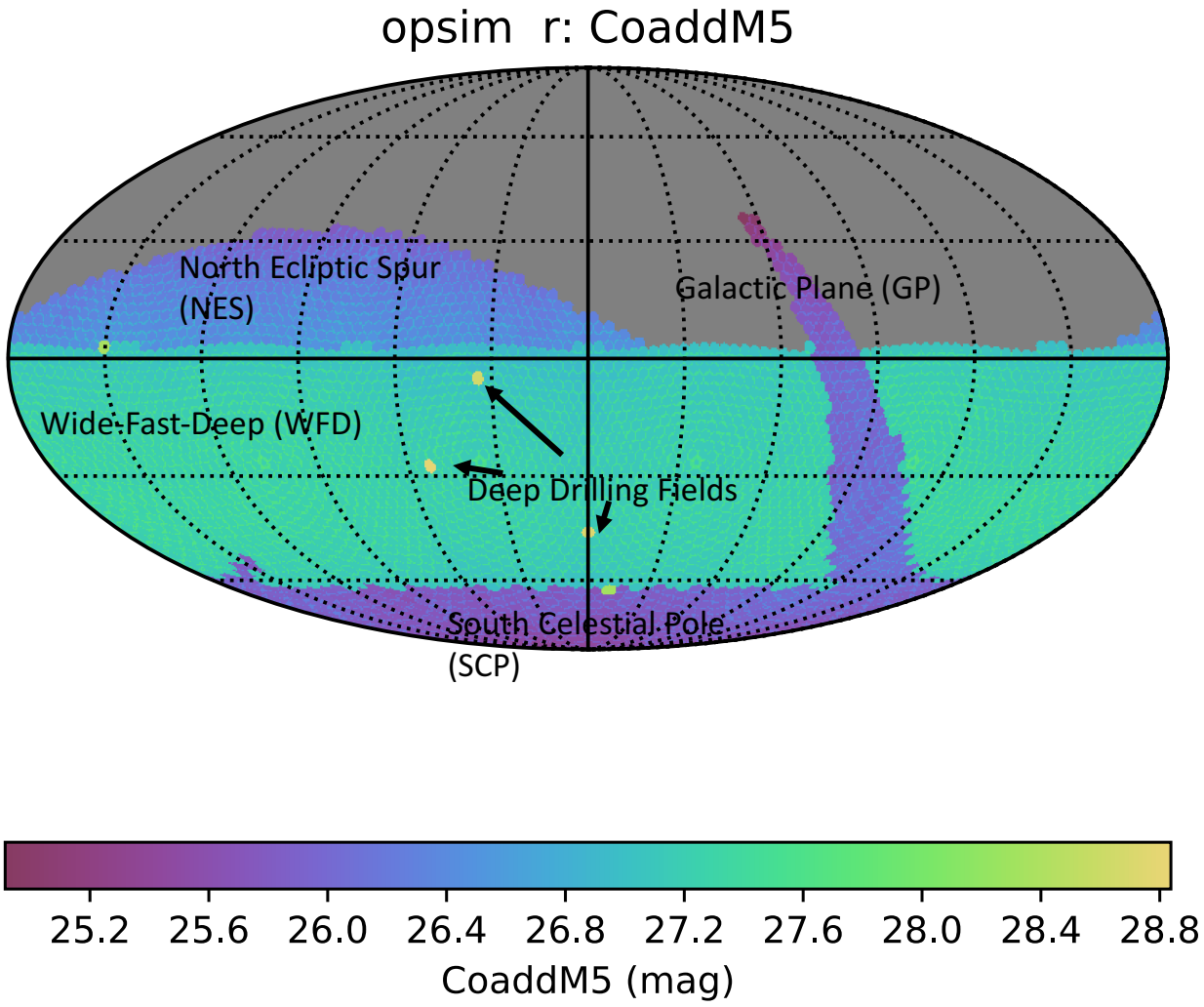
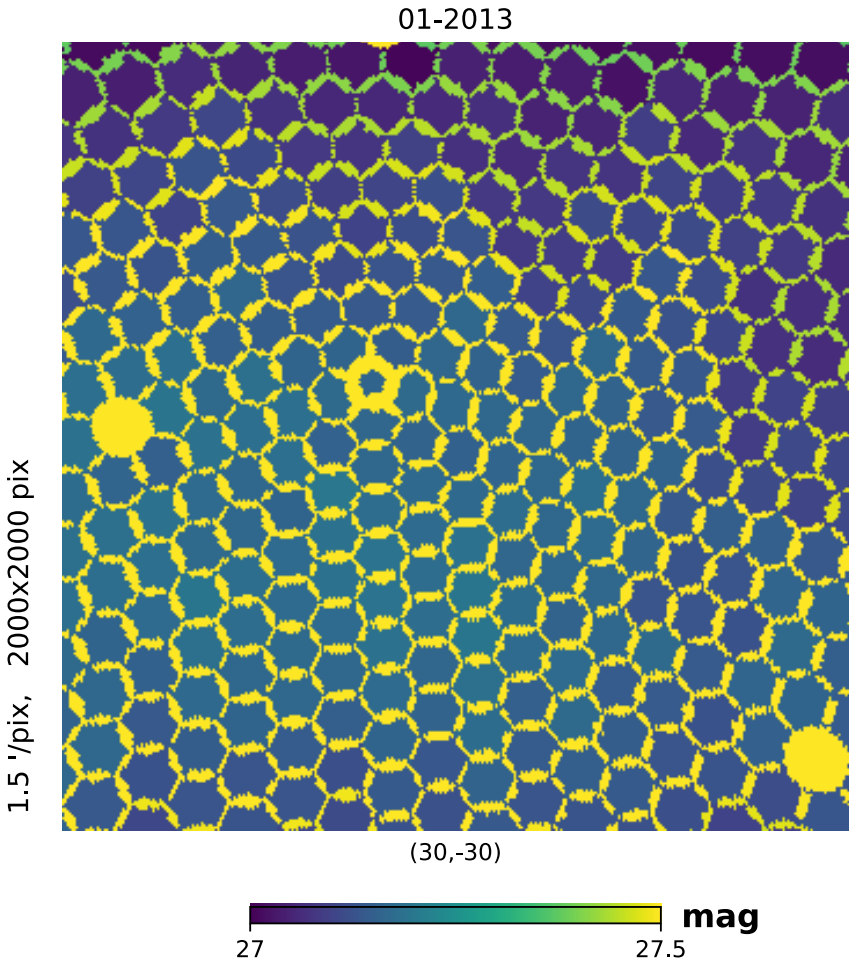
Old proposal based scheduler

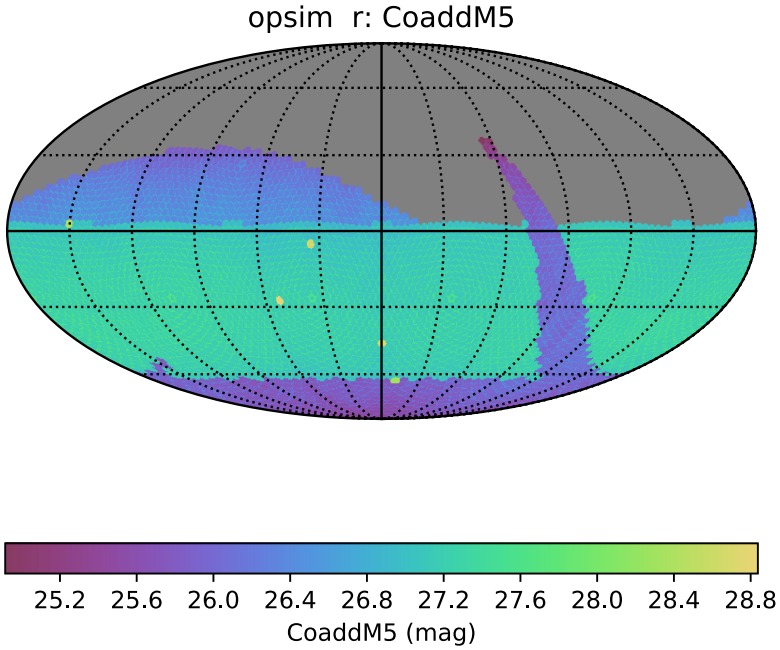
Simulating the motion of the dome and telescope, using realistic weather logs, scheduled and unscheduled downtime, seeing model, sky brightness model, etc.

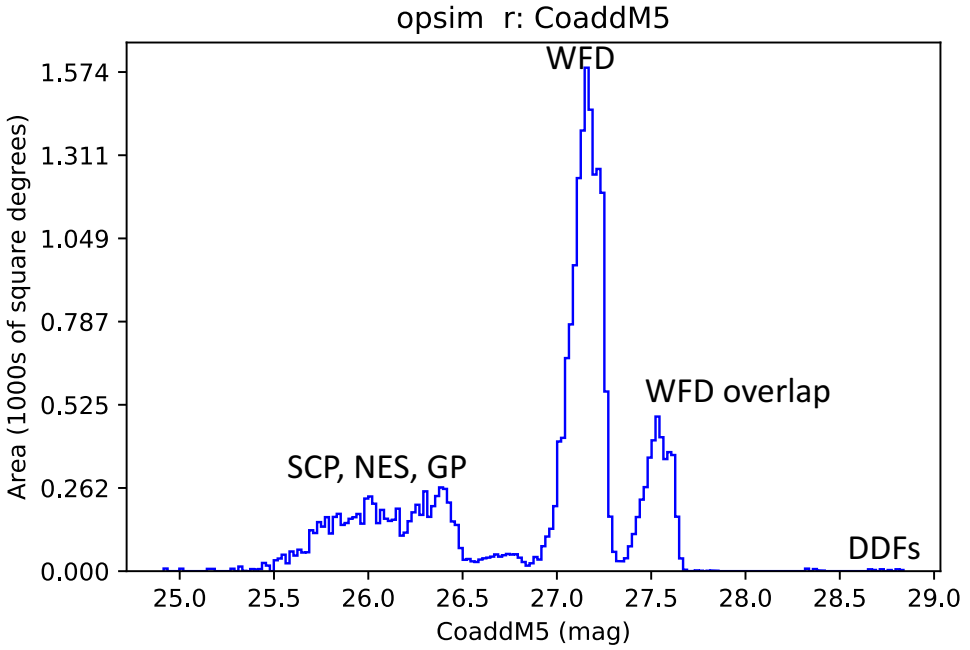


Fixed fields mean overlap areas get over-observed

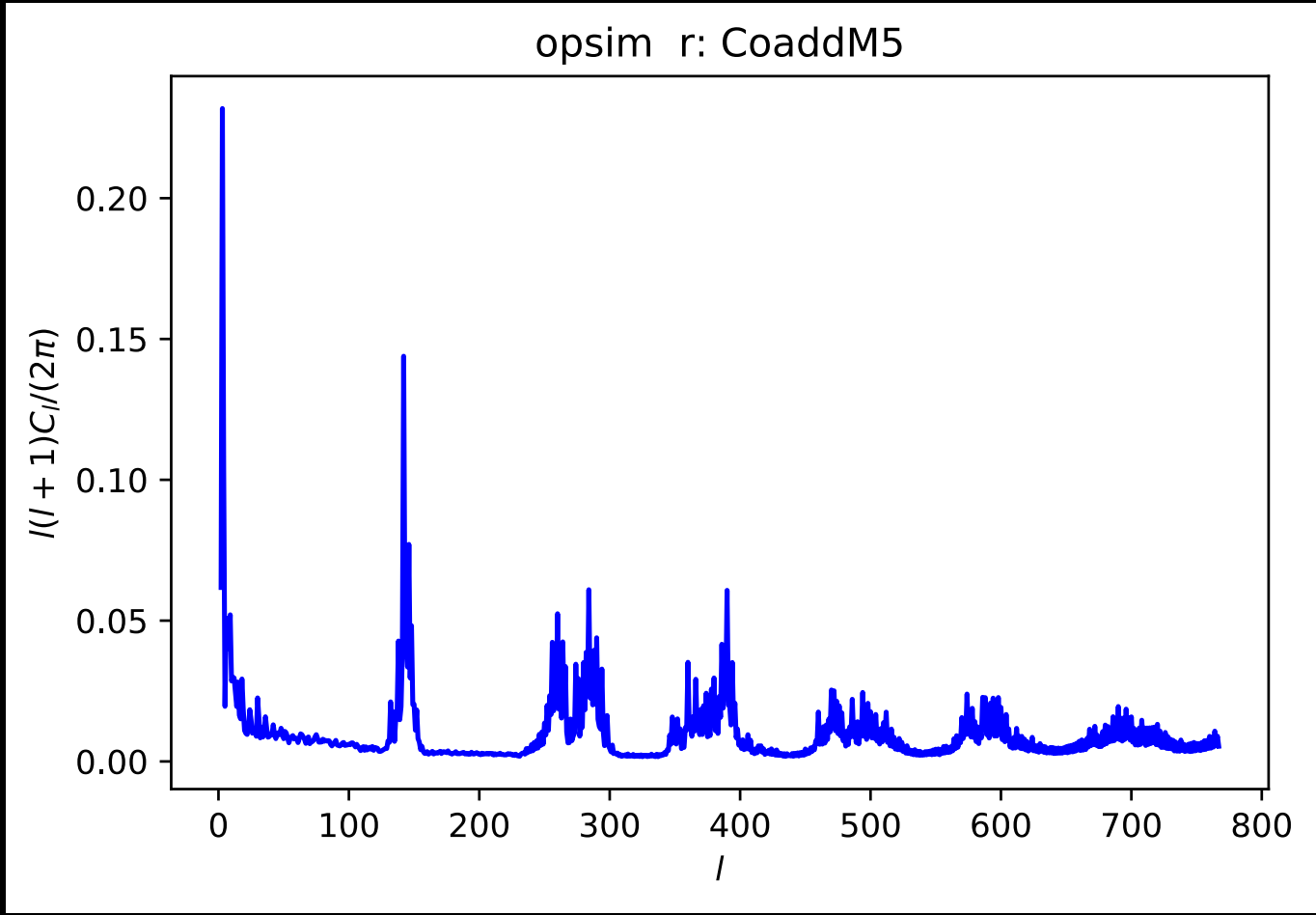


Old proposal based scheduler



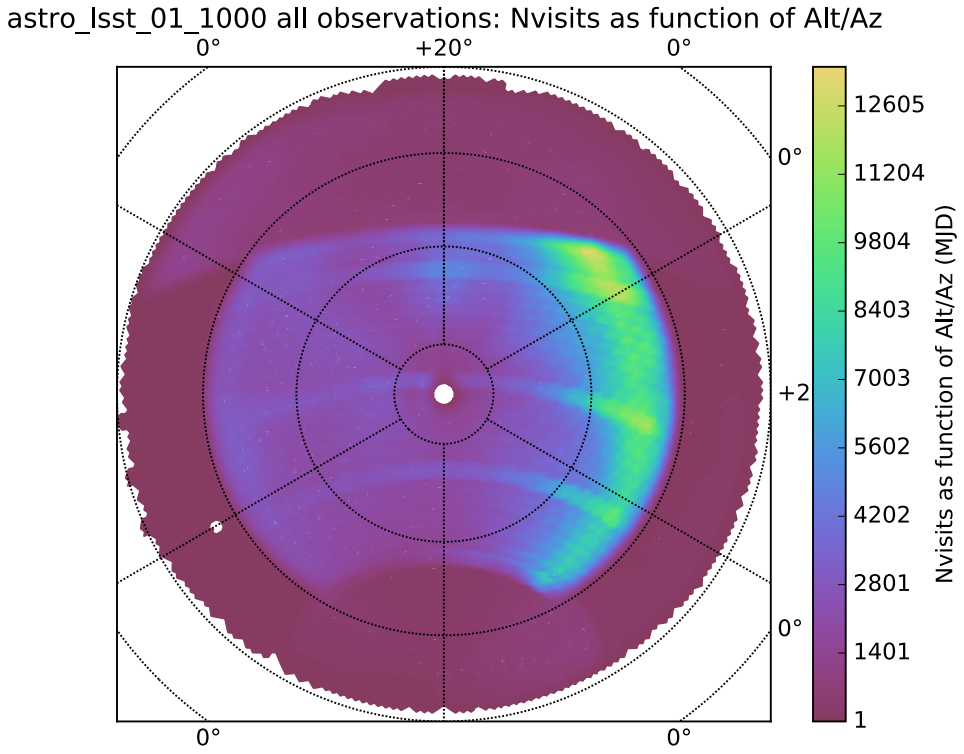


Overlap region creates a spike in the power spectrum at ~1 degree



Before, we had a “Proposal Based” scheduler.

- Write down all the observations we want (125 visits of Field 23 in r, 90 visits of field 36 in y, …)
- Pick the “best” observation from remaining list at any given time
- Mostly minimizing slew time

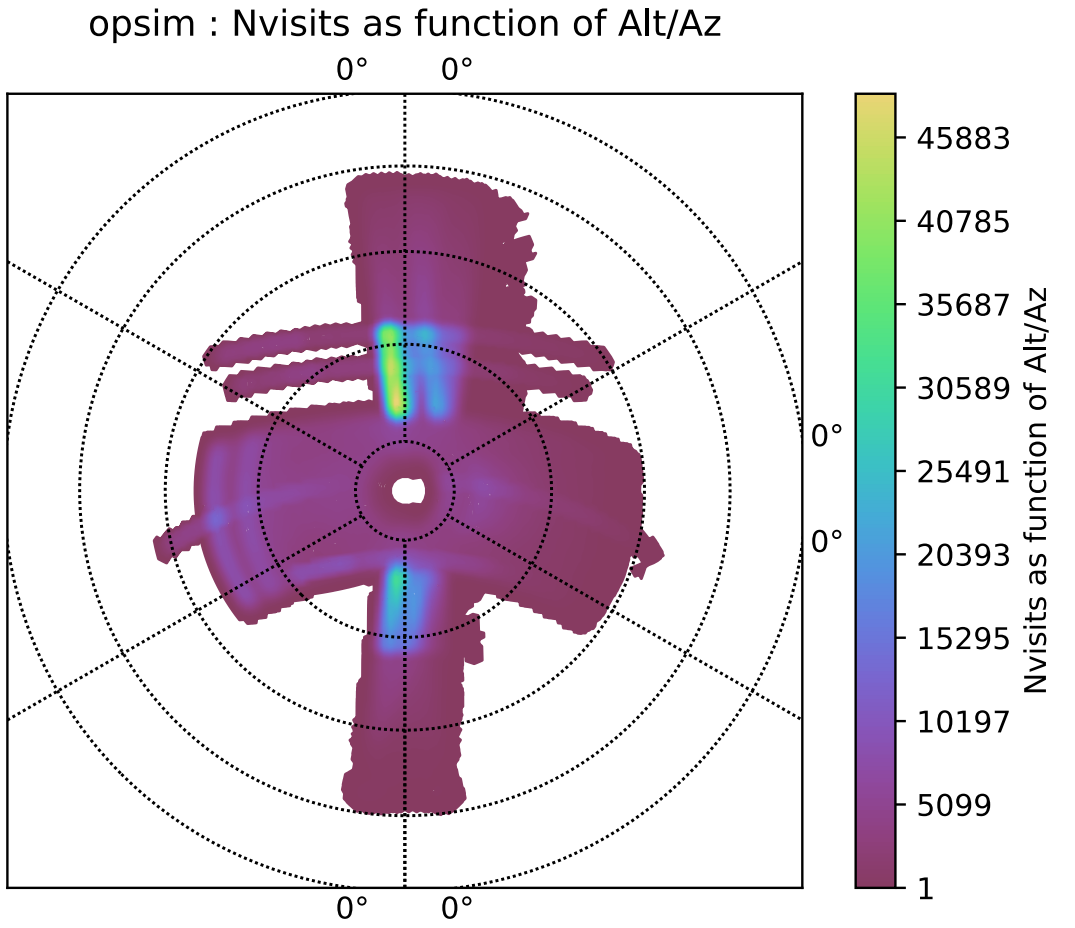


Alt,az distribution for the old scheduler. To minimize slew time, it tends to go to hit the airmass limit and raster in azimuth.

Now, with Markovian Feature Based framework

- Track progress at high resolution (HEALpixels, nside=32, 1.8 degree resolution, 12,288 pixels)
- Compute a reward function for which HEALpixel is most desirable at any given time

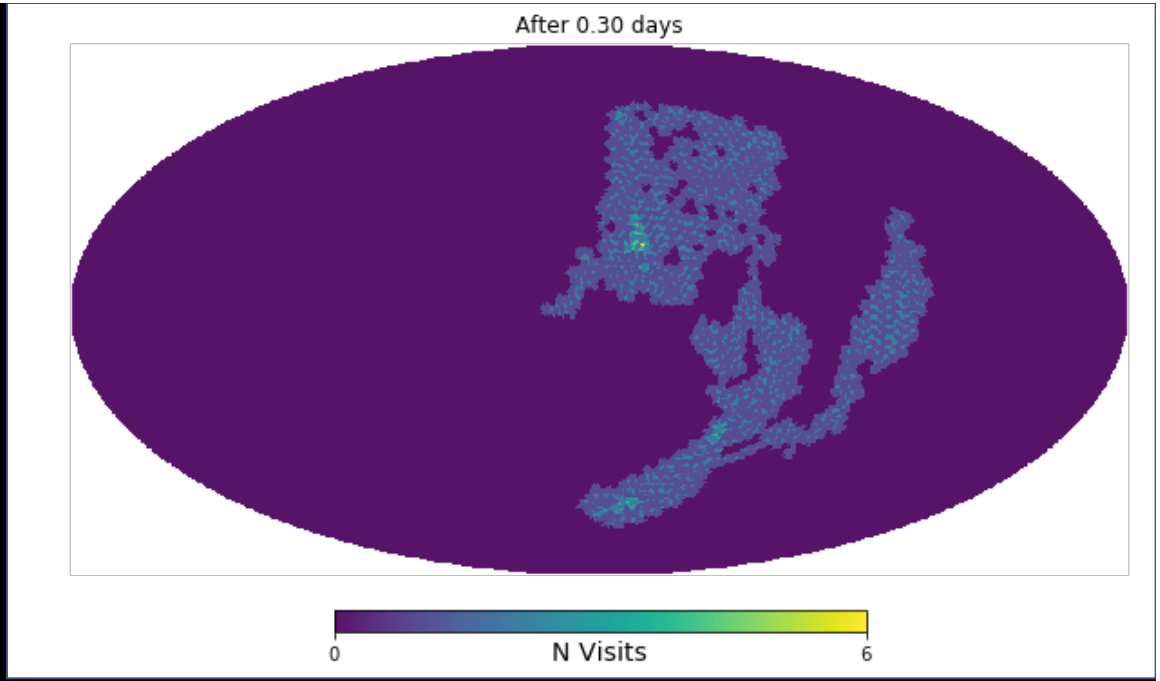
Lots of the work done my Elahe Naghib (Operations Research, Princeton) and Daniel Rothchild (CS, Berkeley)



How do we pick what to observe?

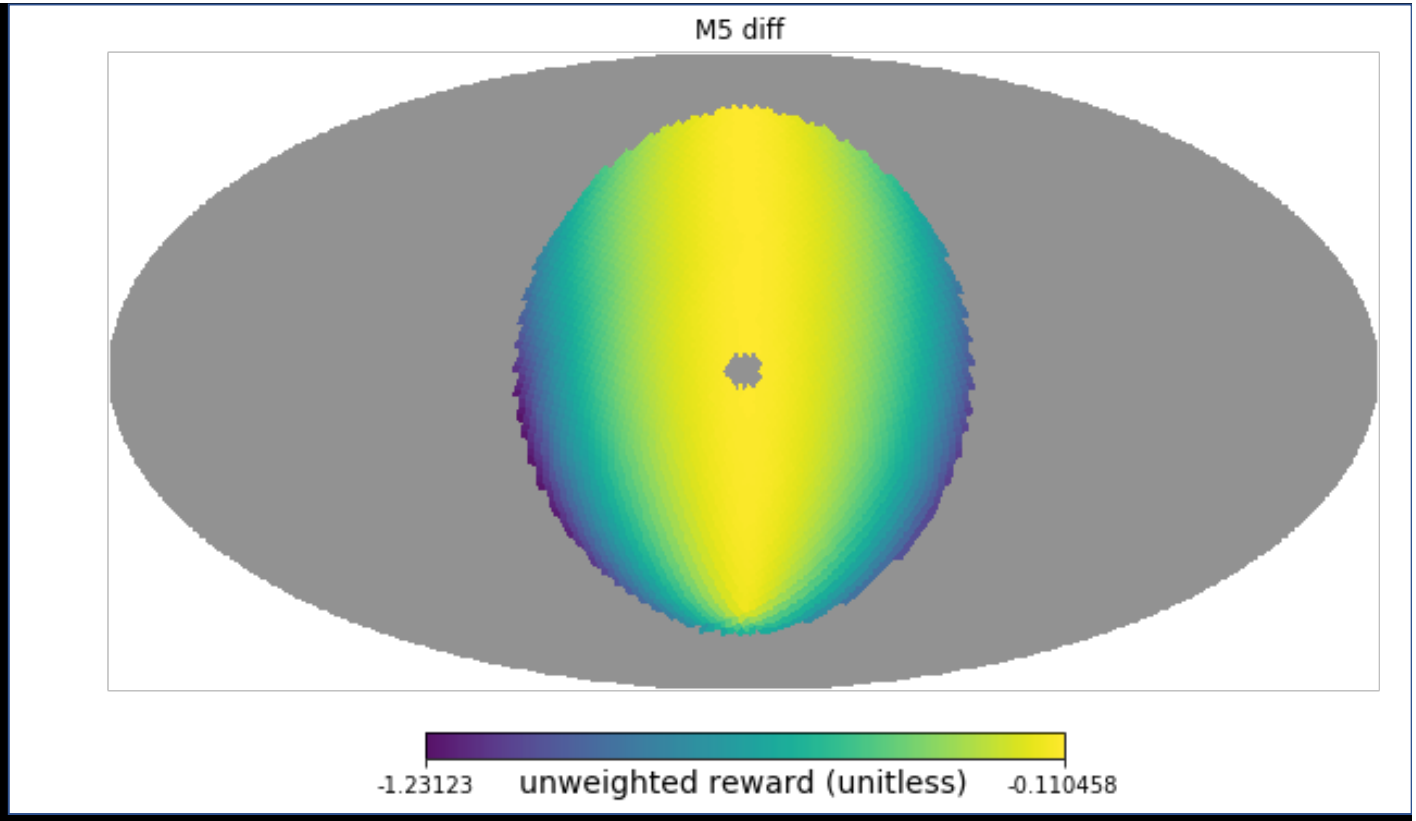
1. What has the least depth degradation (compared to dark time on the meridian)?
2. What area has fallen behind?
3. What's the shortest slewtime?
4. What filter are we in?
5. Mask out bad regions in alt,az space

This let's us pick which healpixel we would most like to observe. To decide where to actually point the telescope, we randomize the tessellation every night (so there is a changing nightly mapping of HEALpix to RA,dec telescope pointing).



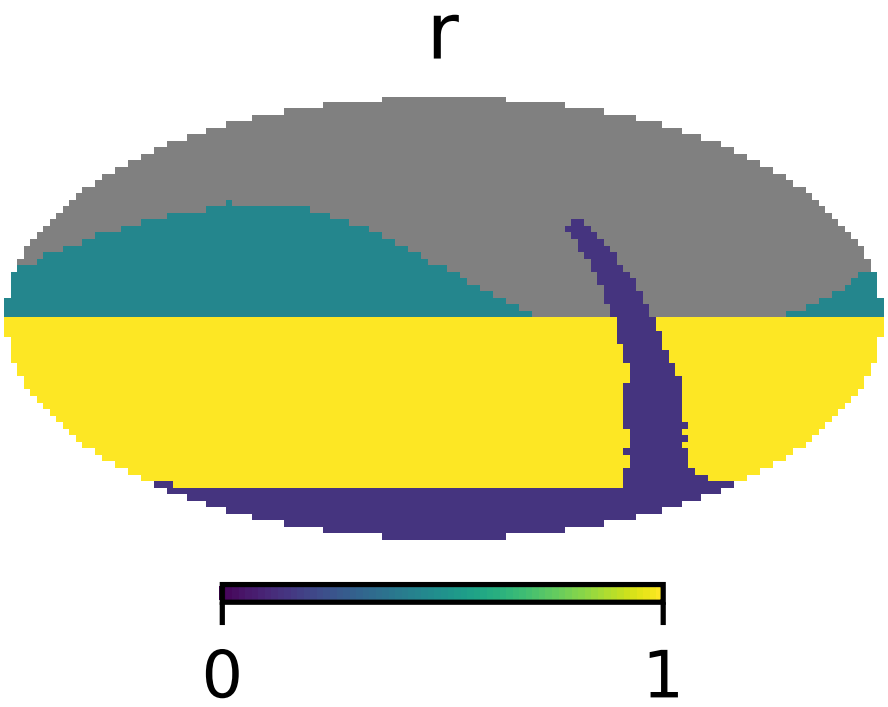
Example r-band only survey

5-sigma limiting depth Compared to meridian dark time, using model sky brightness, airmass, and seeing

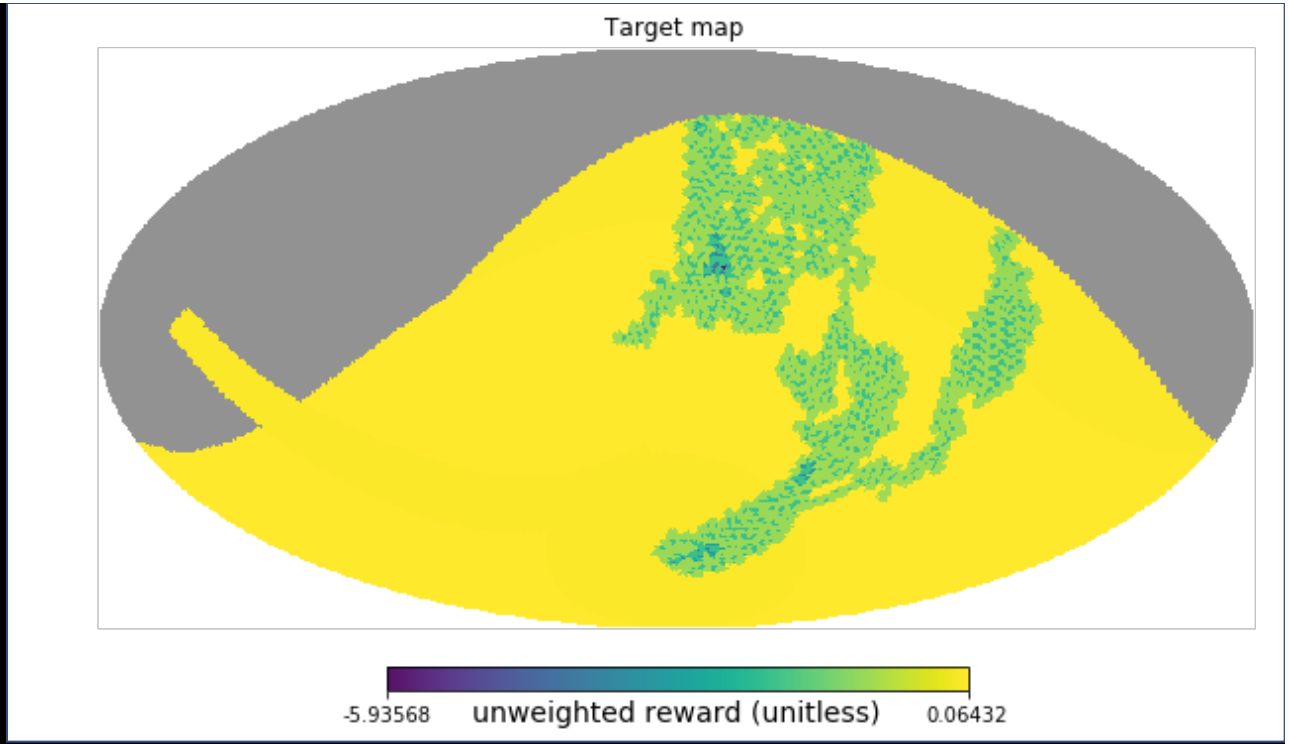


Target goal map, where regions are defined in terms of the **ratios**.
WFD = 1
NES = 0.46
SCP = 0.15
GP = 0.15

(No running out of observations, can make a map per filter)

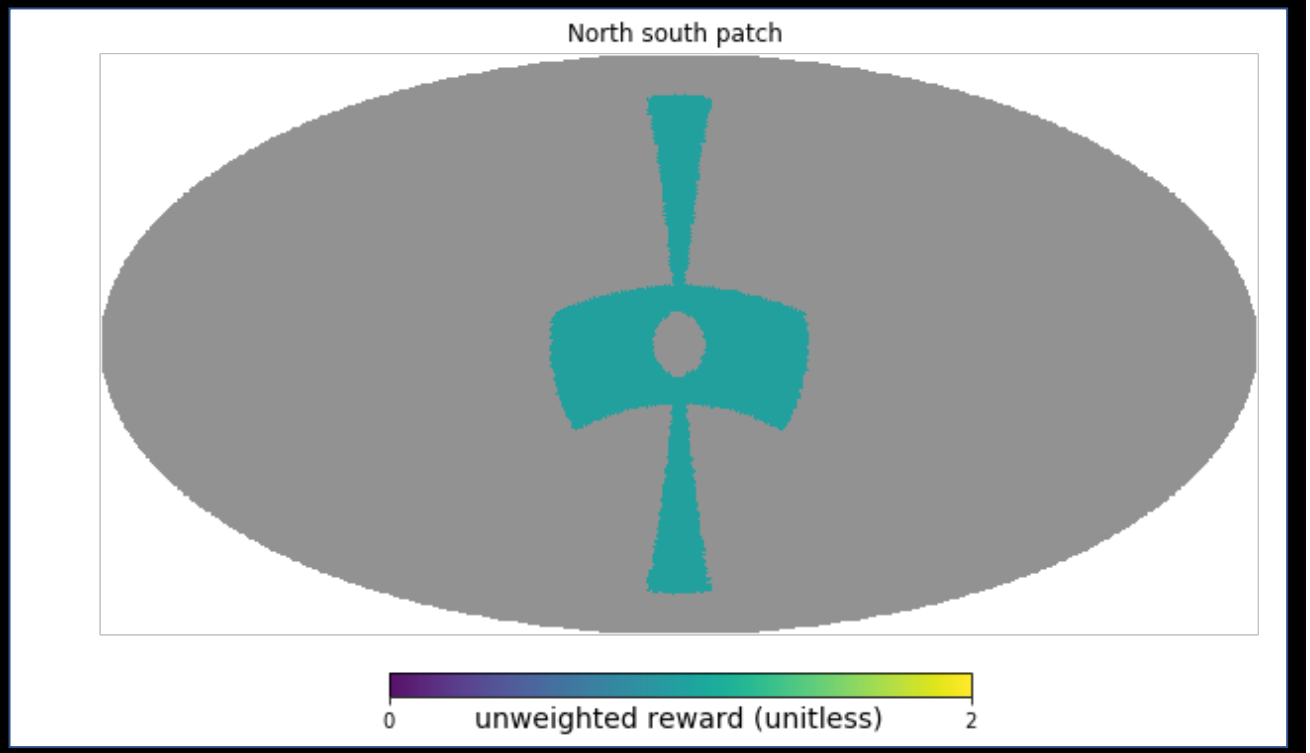


Combine the target goal map with the map of completed observations to generate a map of how far behind HEALpixels are



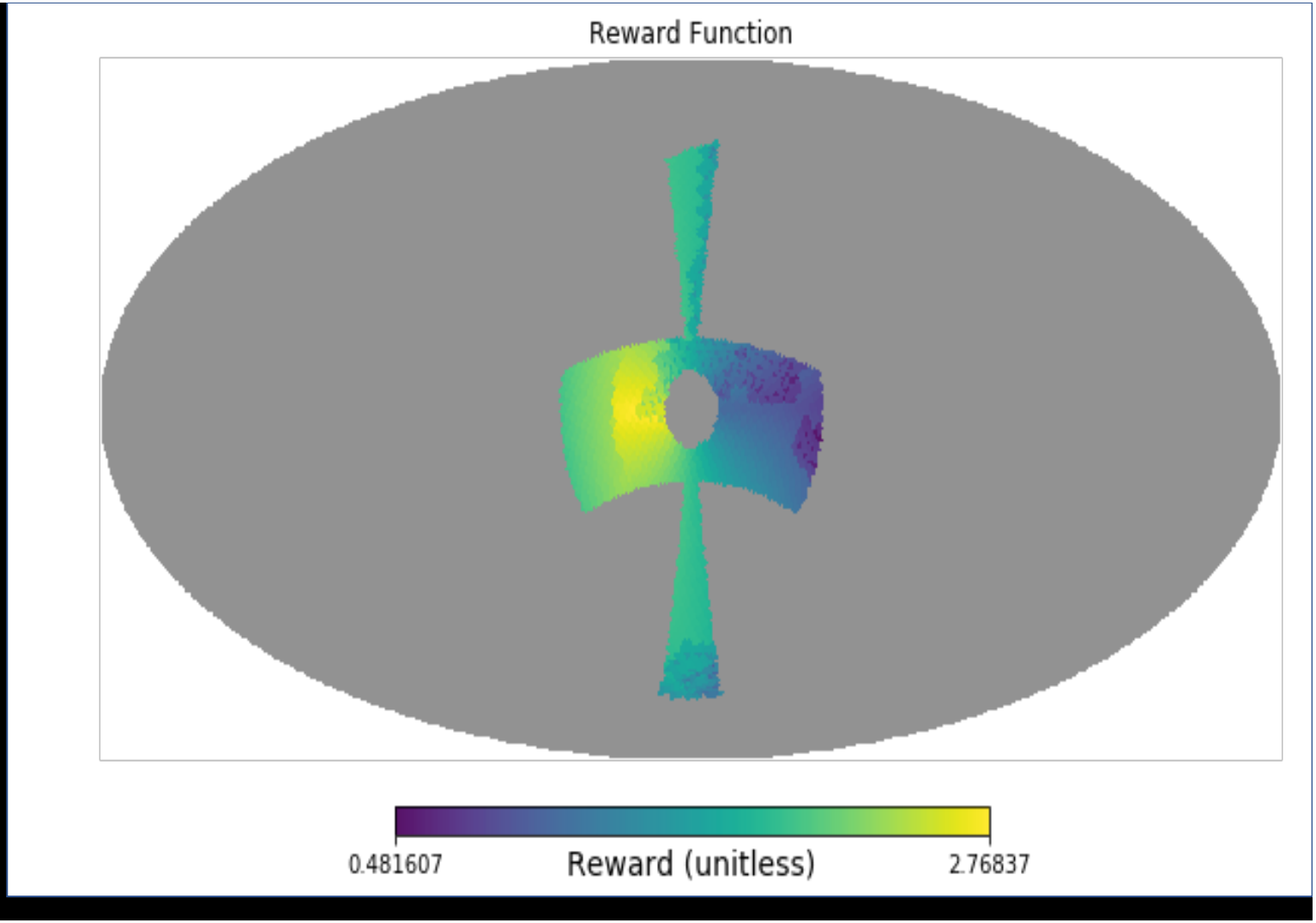
Time to slew to any HEALpixels

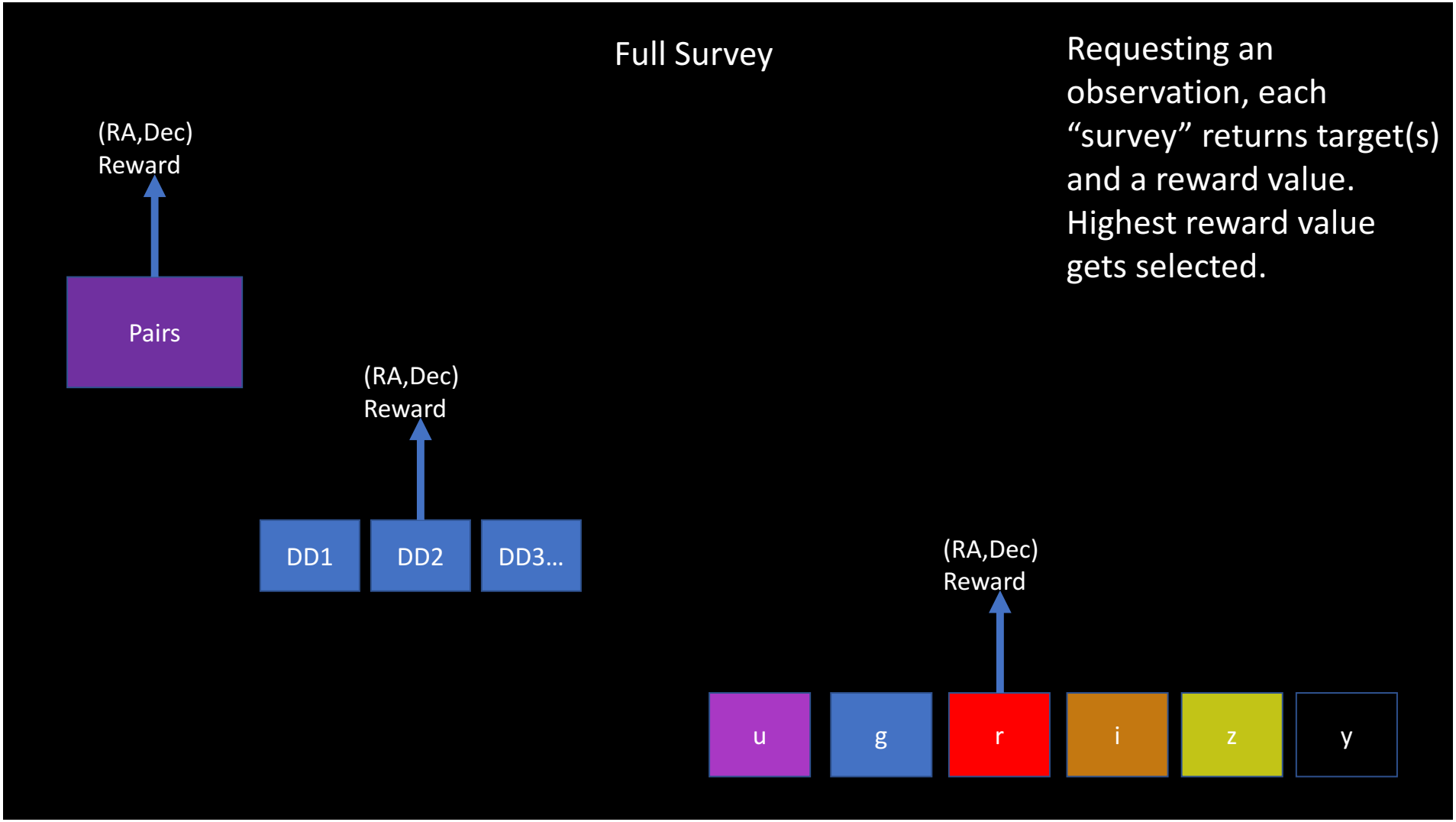
Mask in alt,az space to prevent getting stuck near zenith or airmass limit



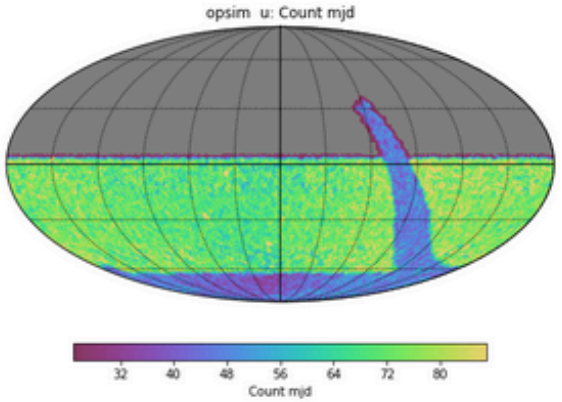
Final reward function is a linear combination of the basis functions.

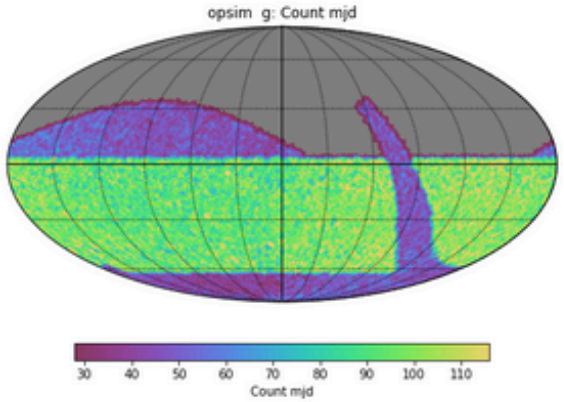
Single filter survey only has 3* free parameters!

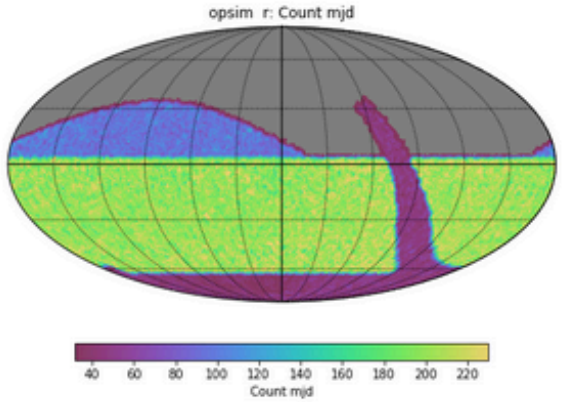


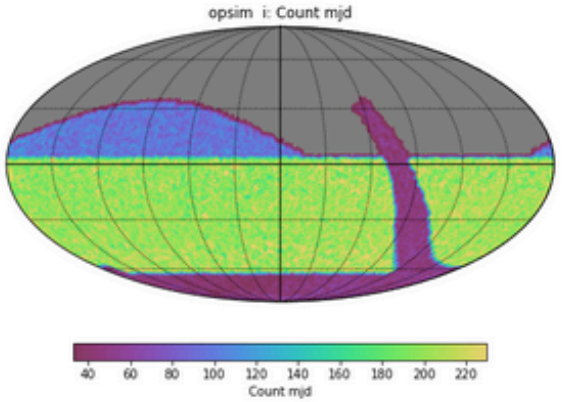

Full Survey
Requesting an observation, each "survey" returns target(s) and a reward value. Highest reward value gets selected.
(RA,Dec)
Reward
Pairs
(RA,Dec)
Reward
DD1
DD2
DD3…
(RA,Dec)
Reward
u
g
r
i
z
y

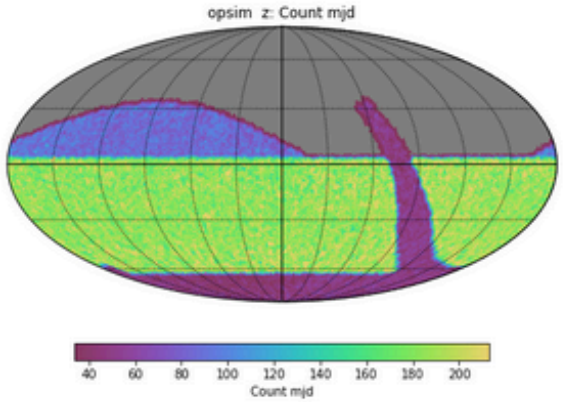
Number of observations in each filter

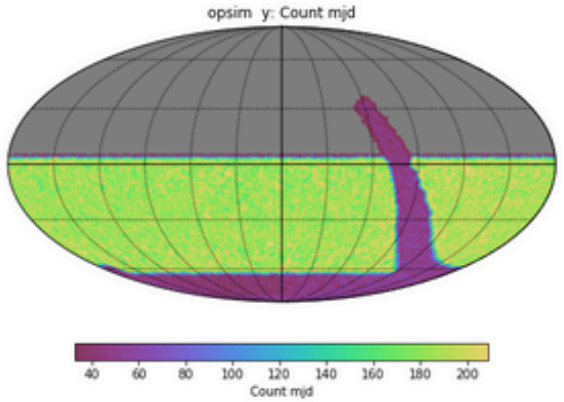




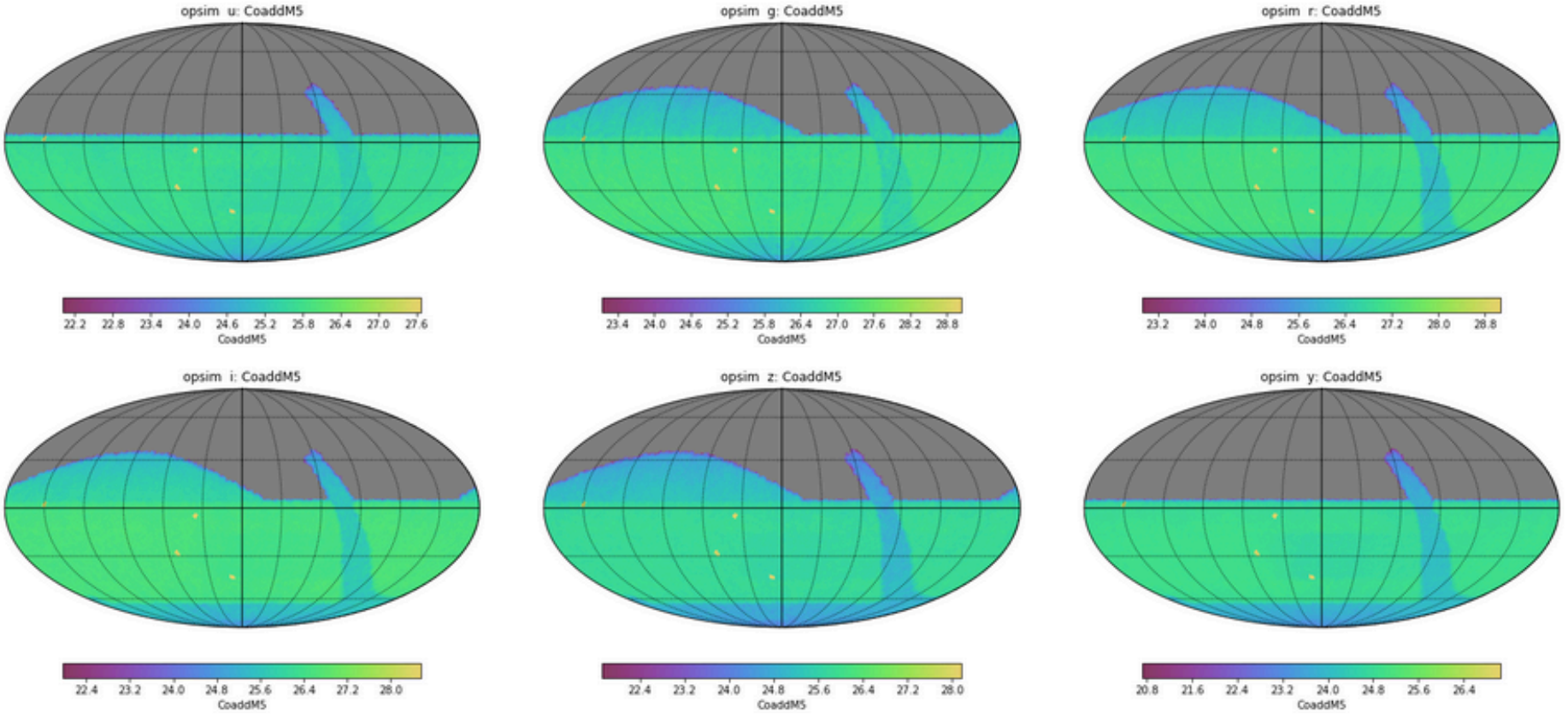




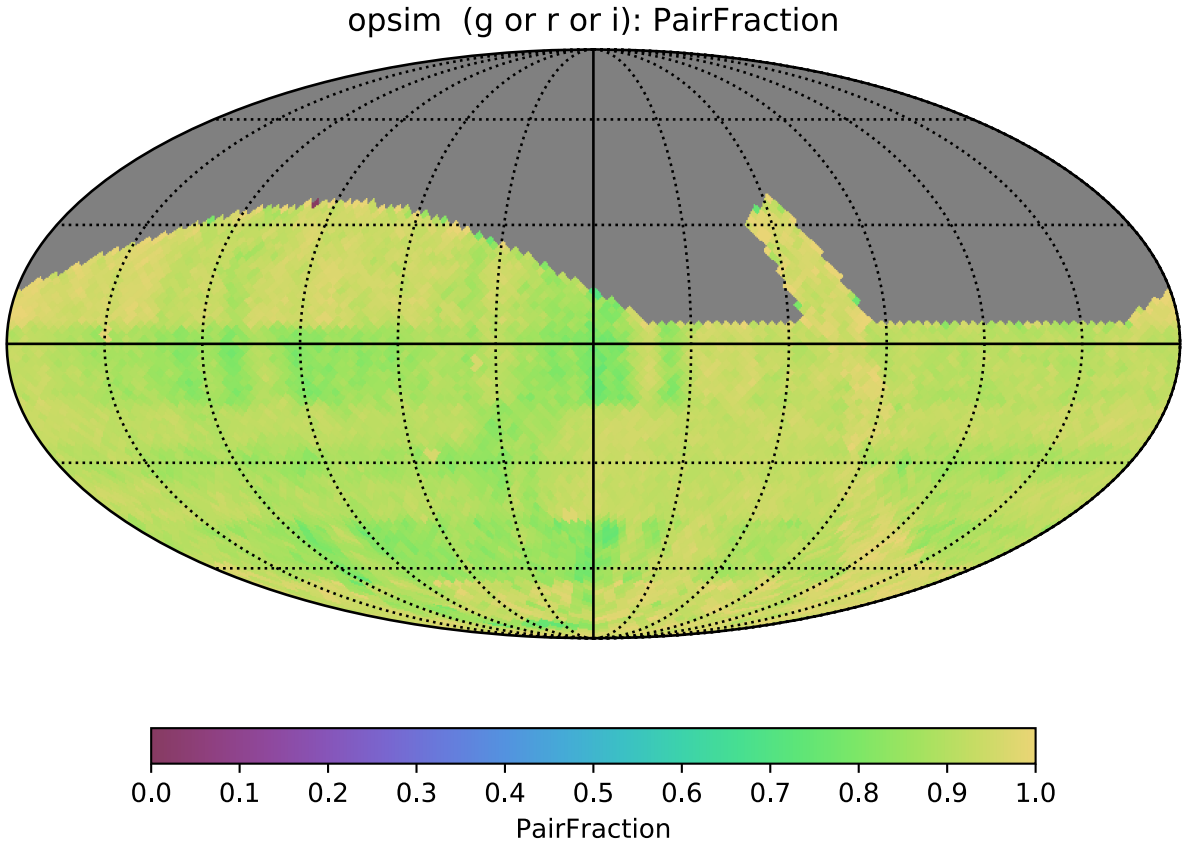




Coadded Depth

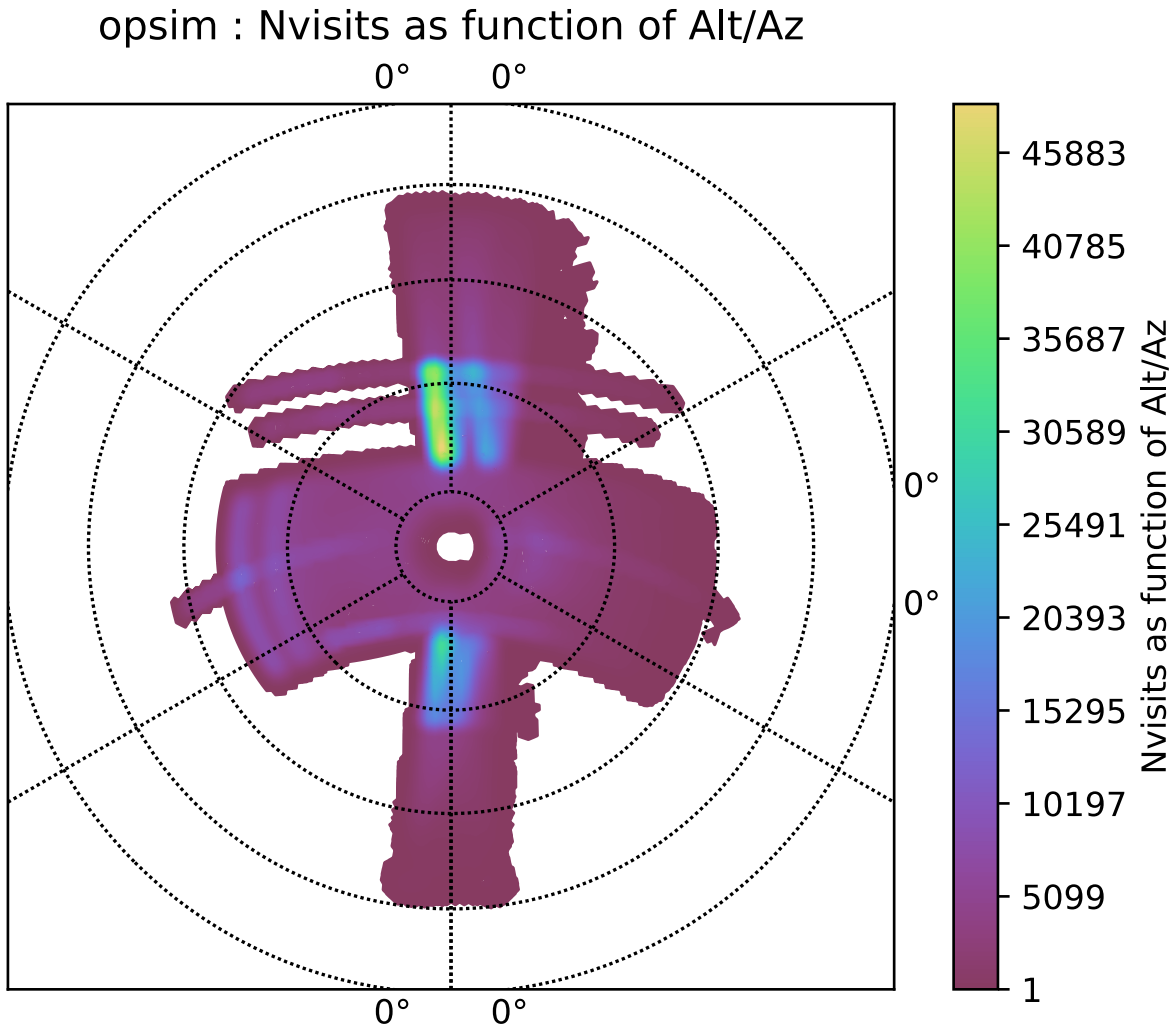


Fraction of observations that are in a pair that can be used for solar system object detection (peak around 90%)



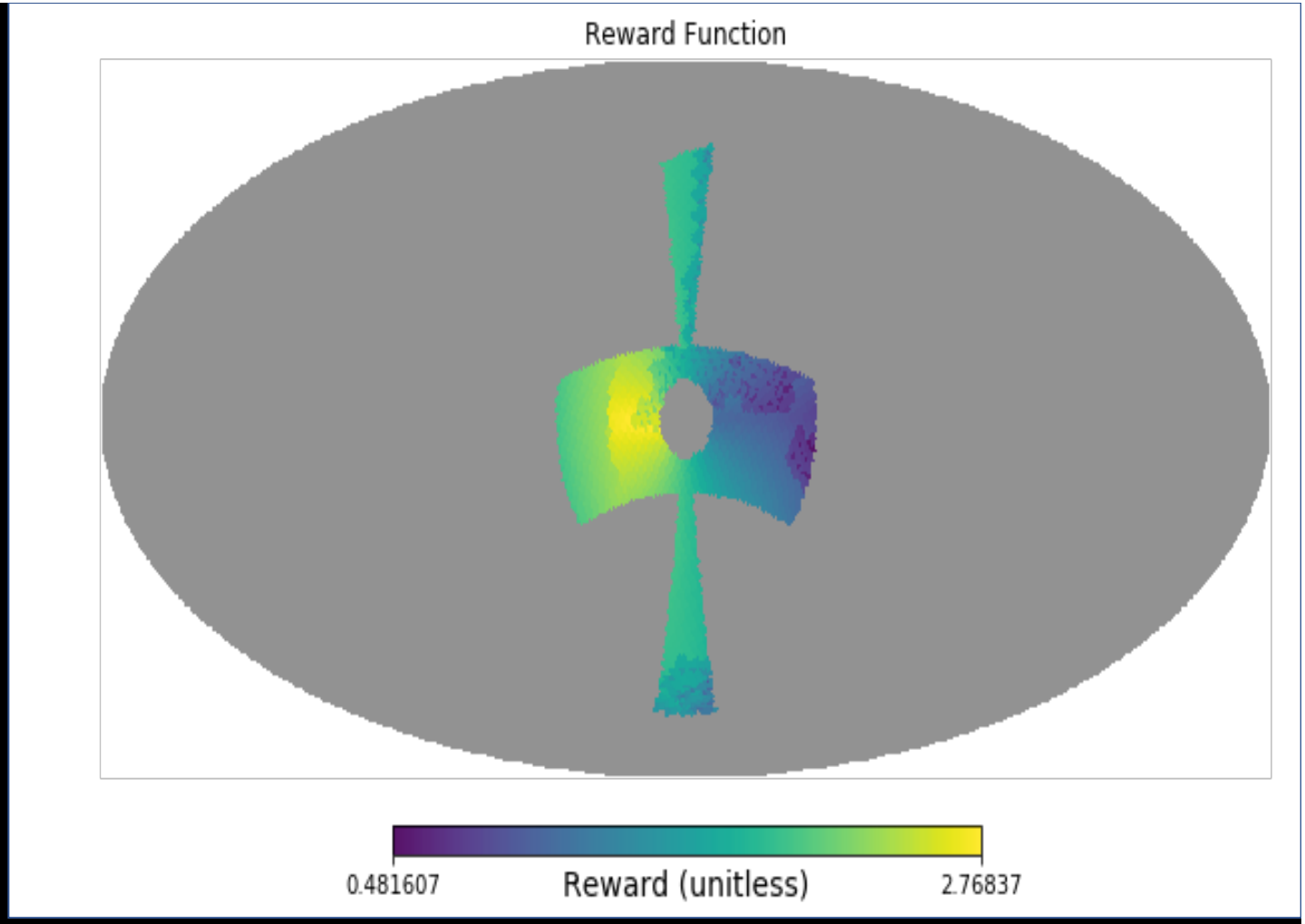
Shutter open 76% of possible time. (82% would be the maximum with no filter changes and minimum slew times)

Observing mostly near meridian.

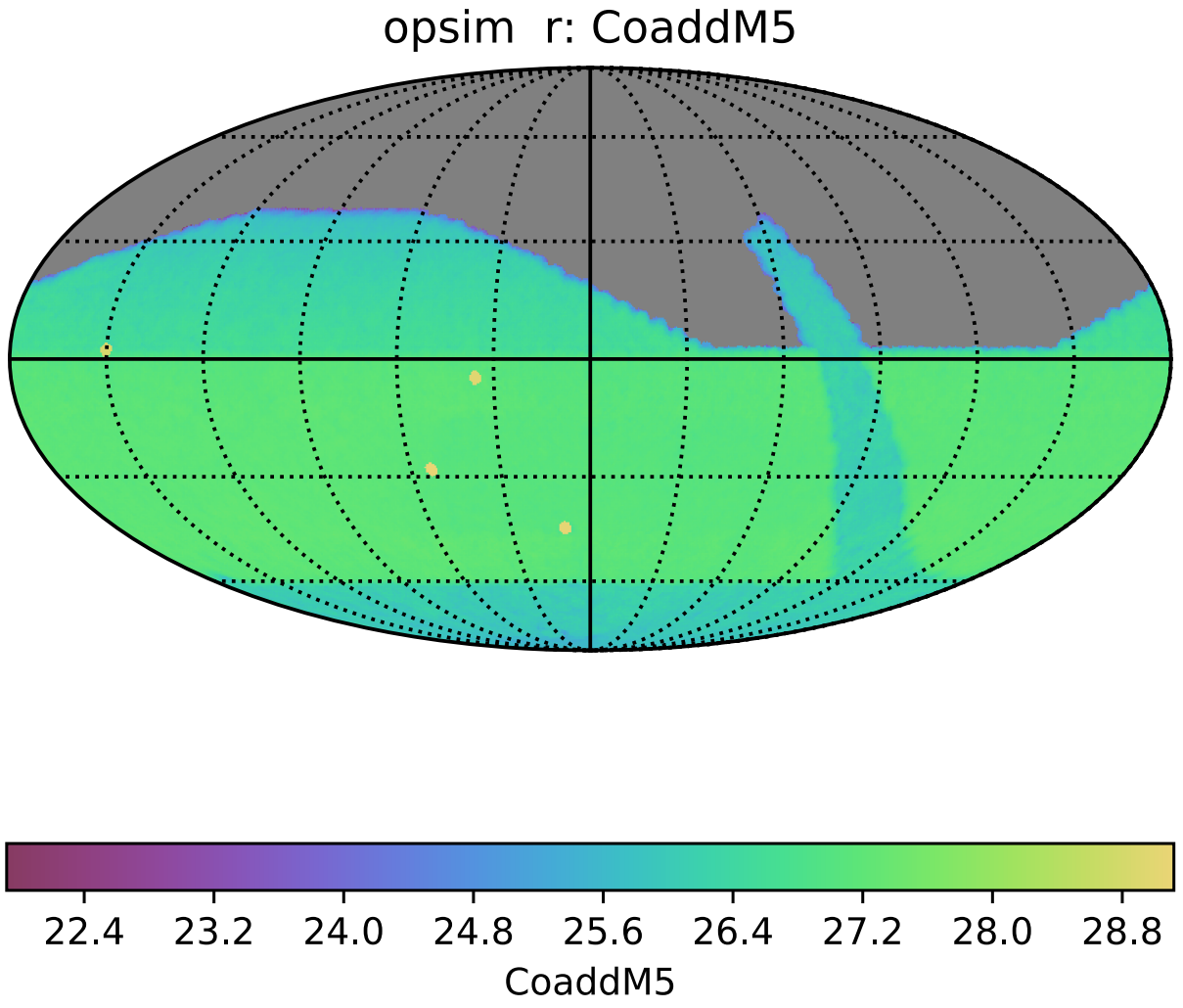


The reward function shows the best HEALpixel to observe.

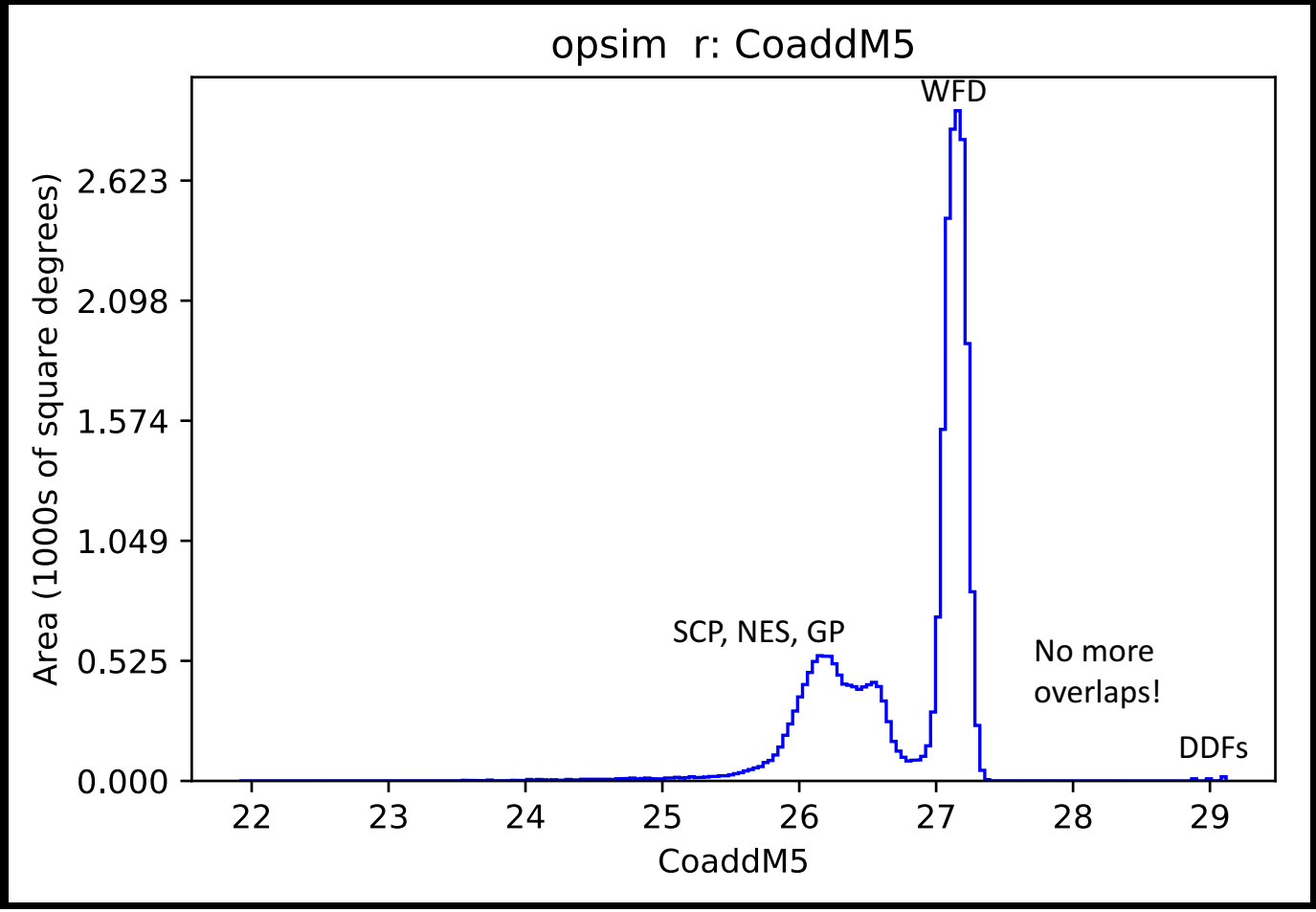
Each night, we randomly rotate the tessellation and create a new mapping of HEALpix to pointings



No more over-exposed overlap regions

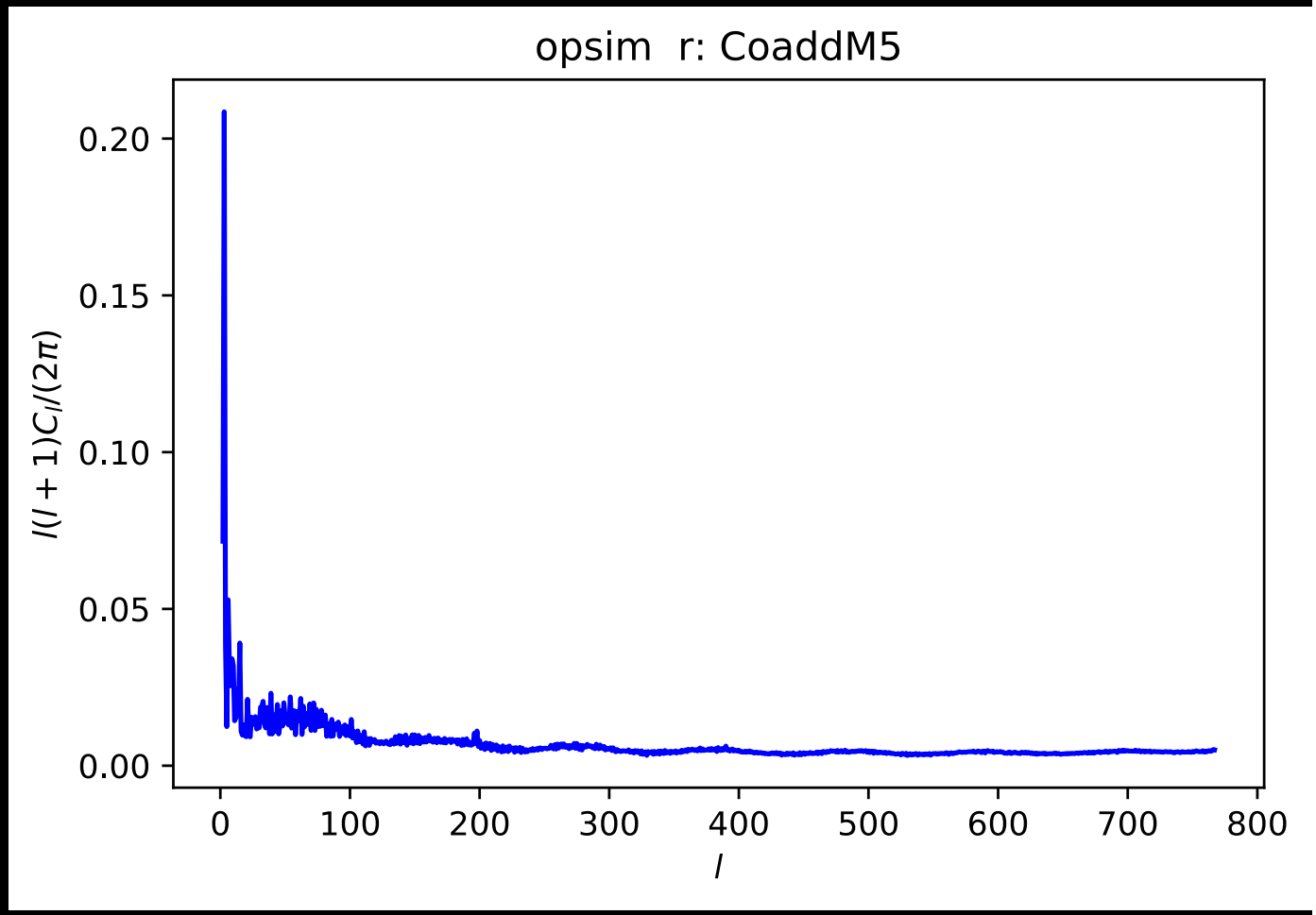


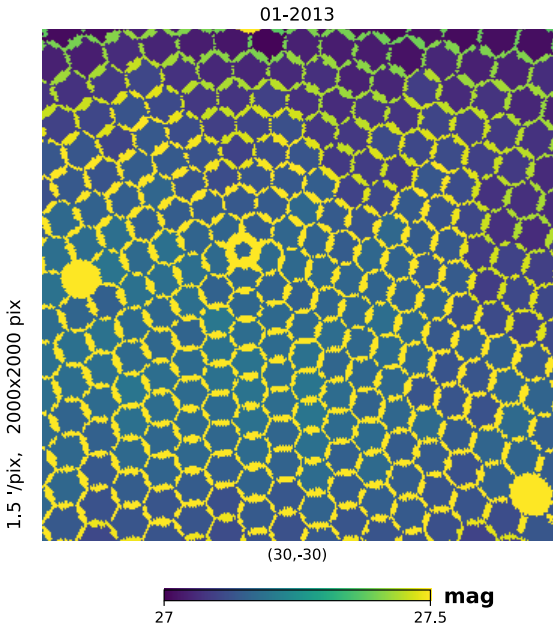
Feature based scheduler

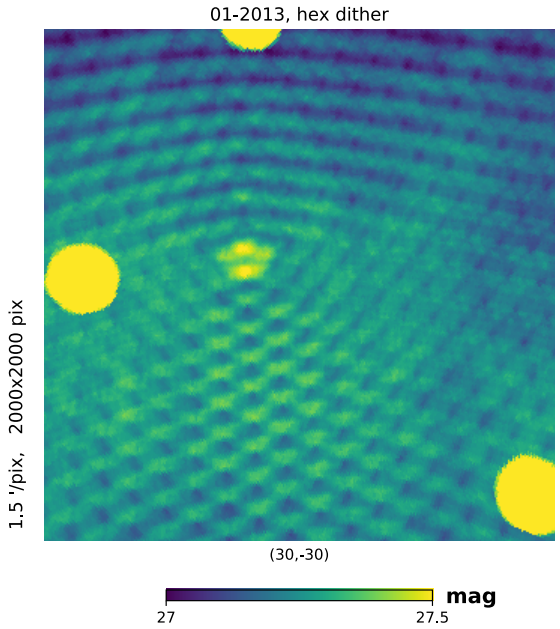


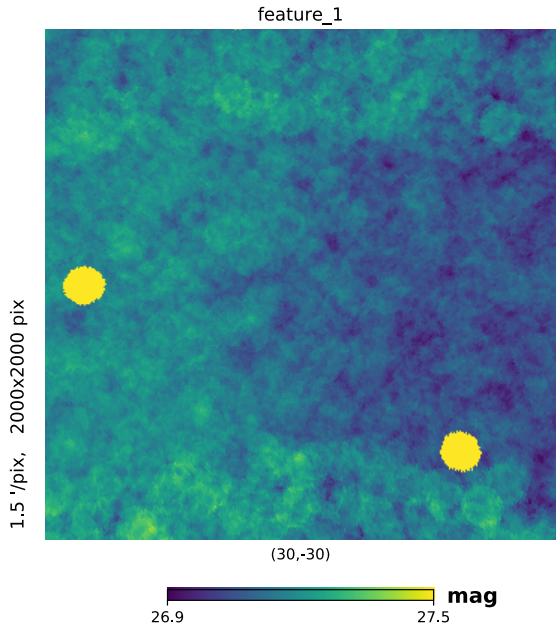
Feature based scheduler.

No more giant power spike at 1 degree (l=180)







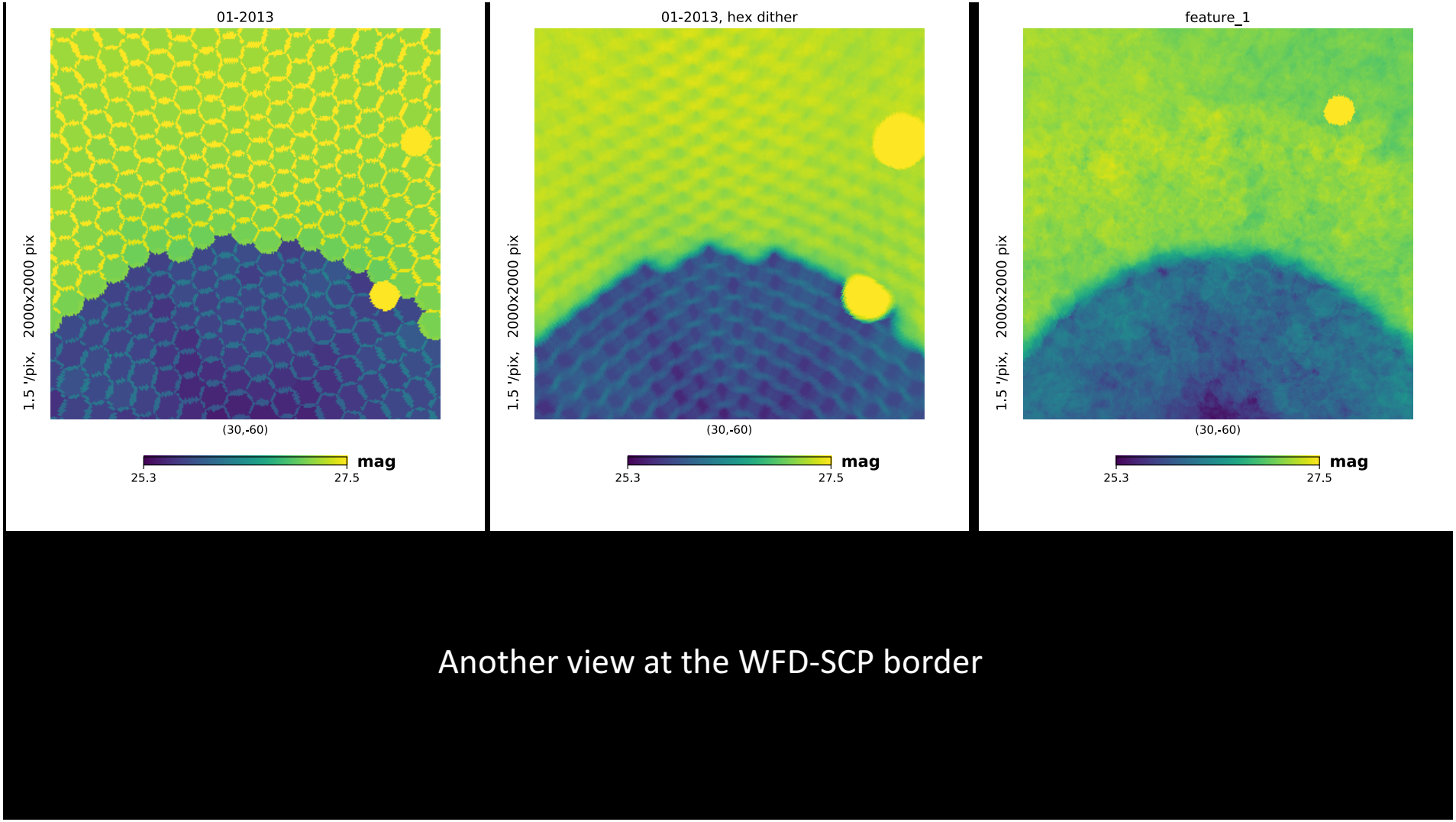


Undithered

Sub field dithers

Feature Based scheduler

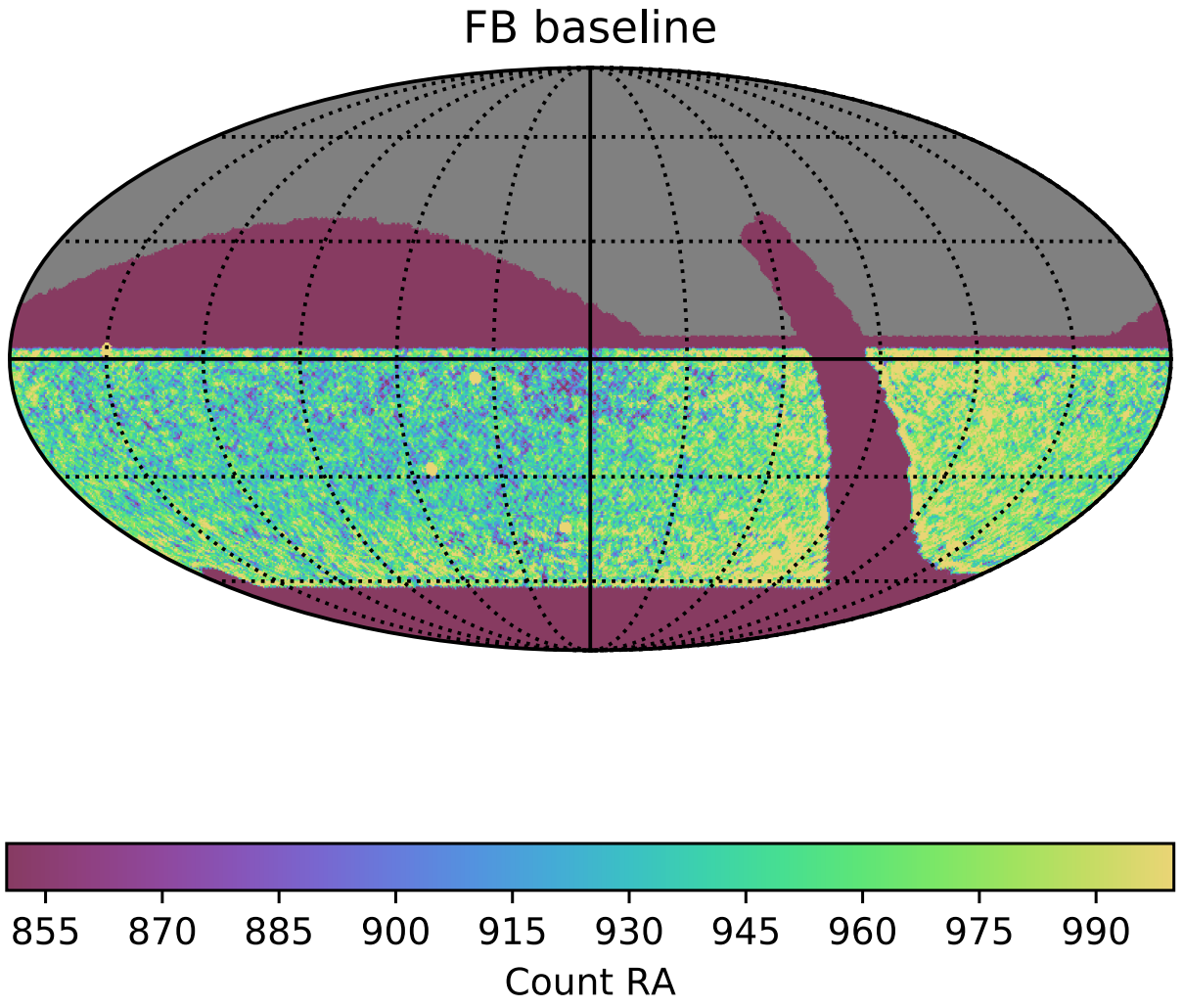
So far, we have only tried to keep the number of visits even. We could try to keep coadded depth even.



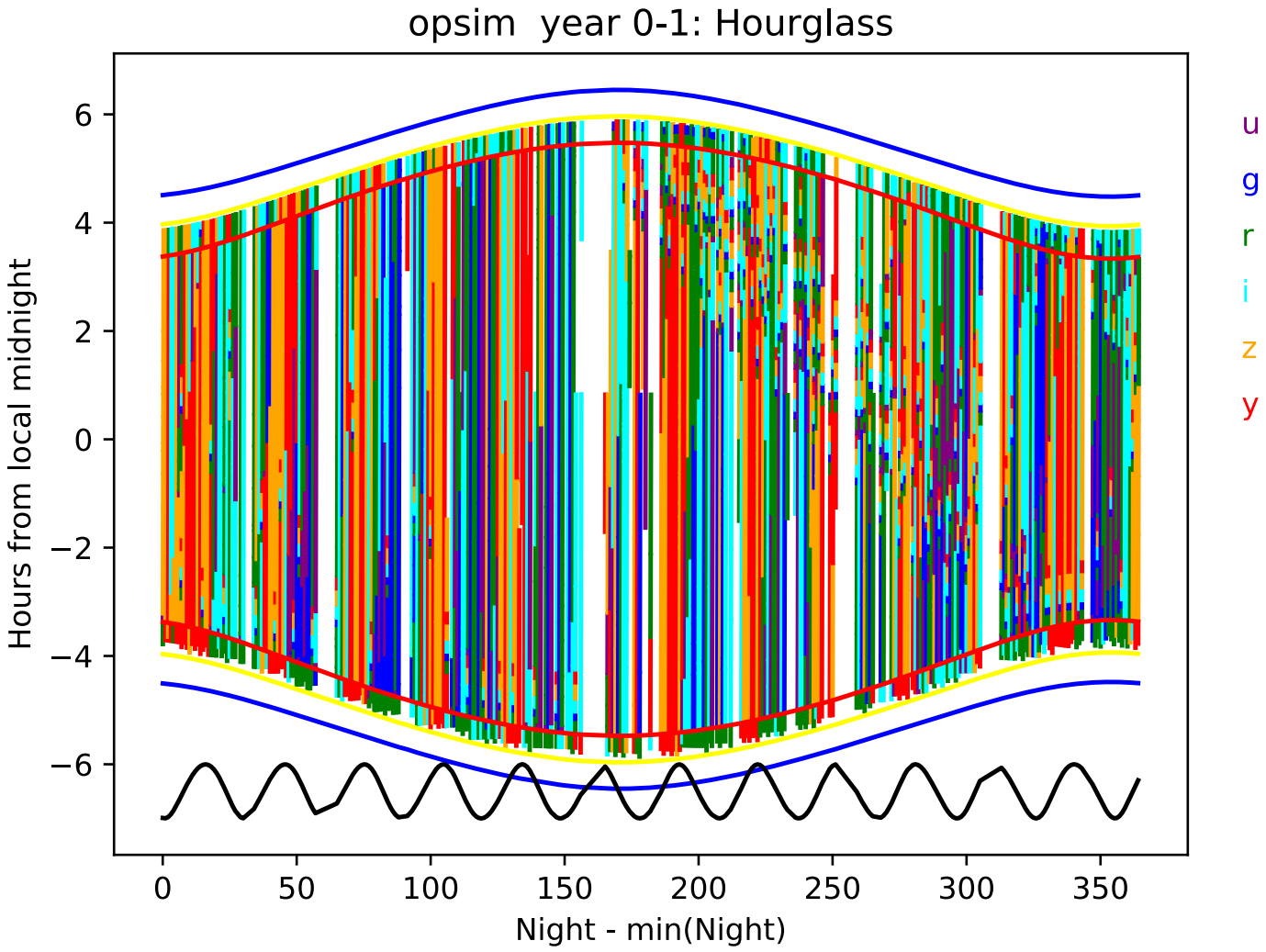
Another view at the WFD-SCP border

We are a little under-subscribed in winter, little over-subscribed in summer.

May want to adjust WFD area a bit to compensate. Make sure we don't pile-up DD fields too much in RA.

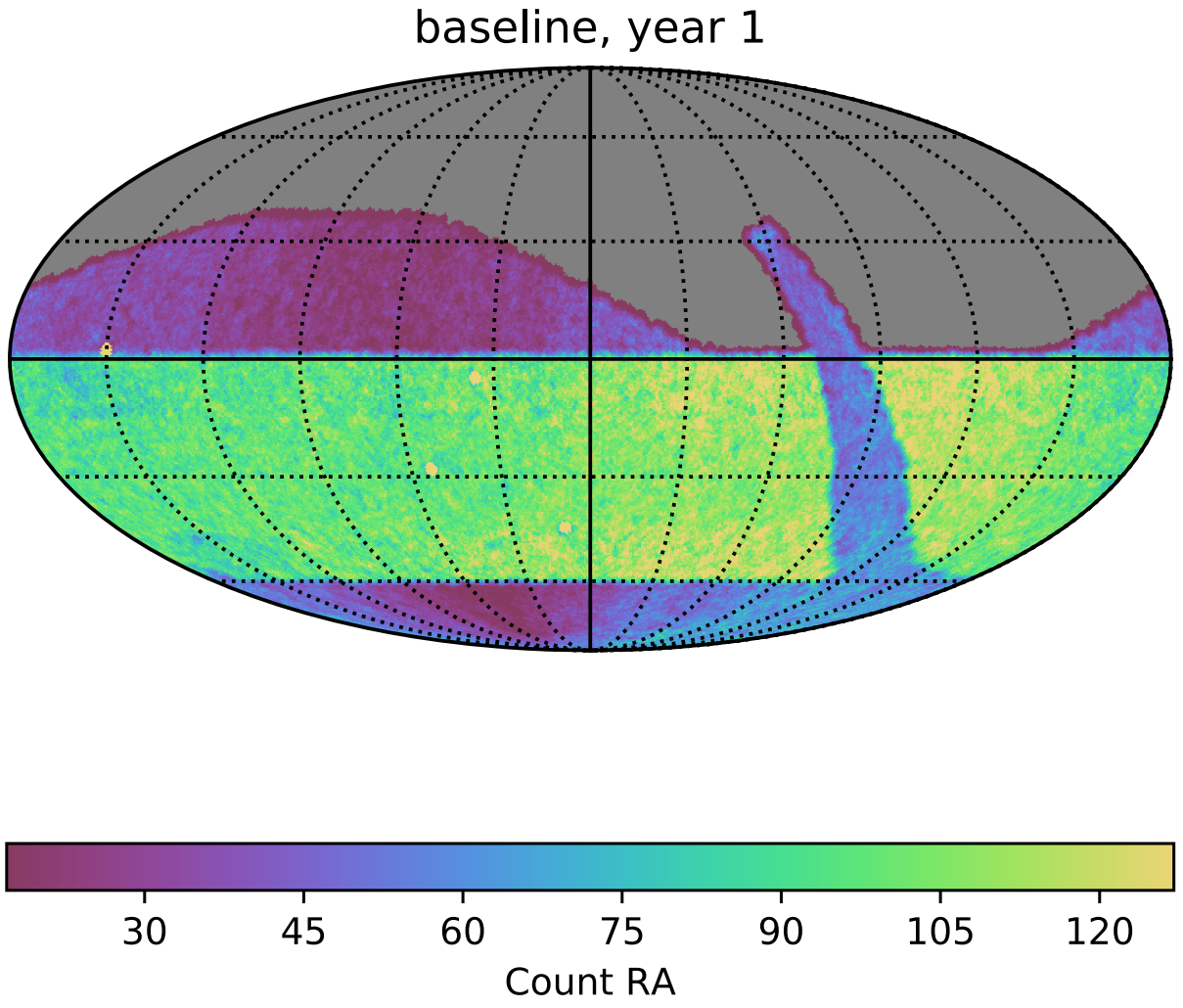


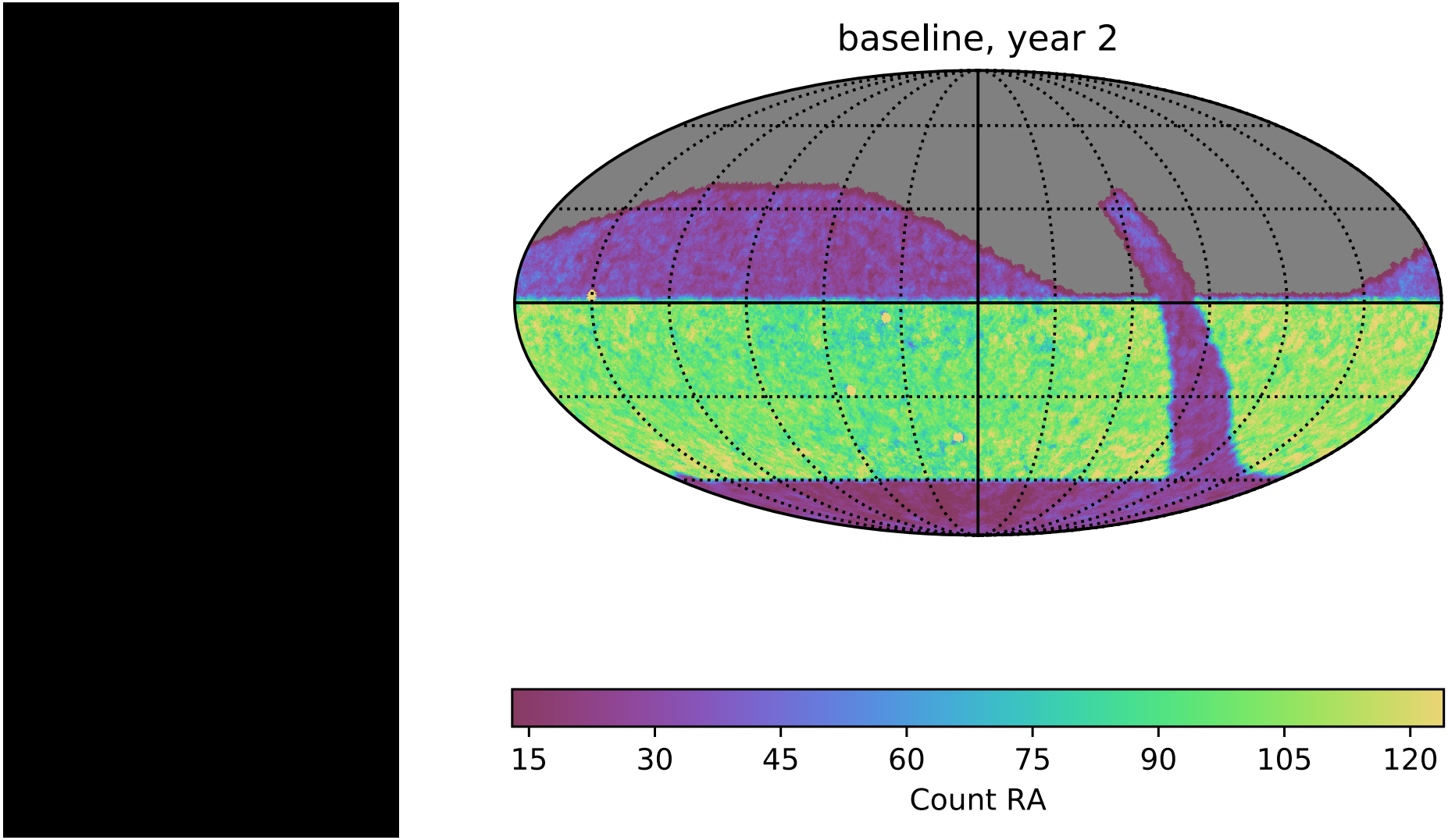
Filter choice currently gets driven largely by lunar phase. So we get several days of red followed by days of blue.

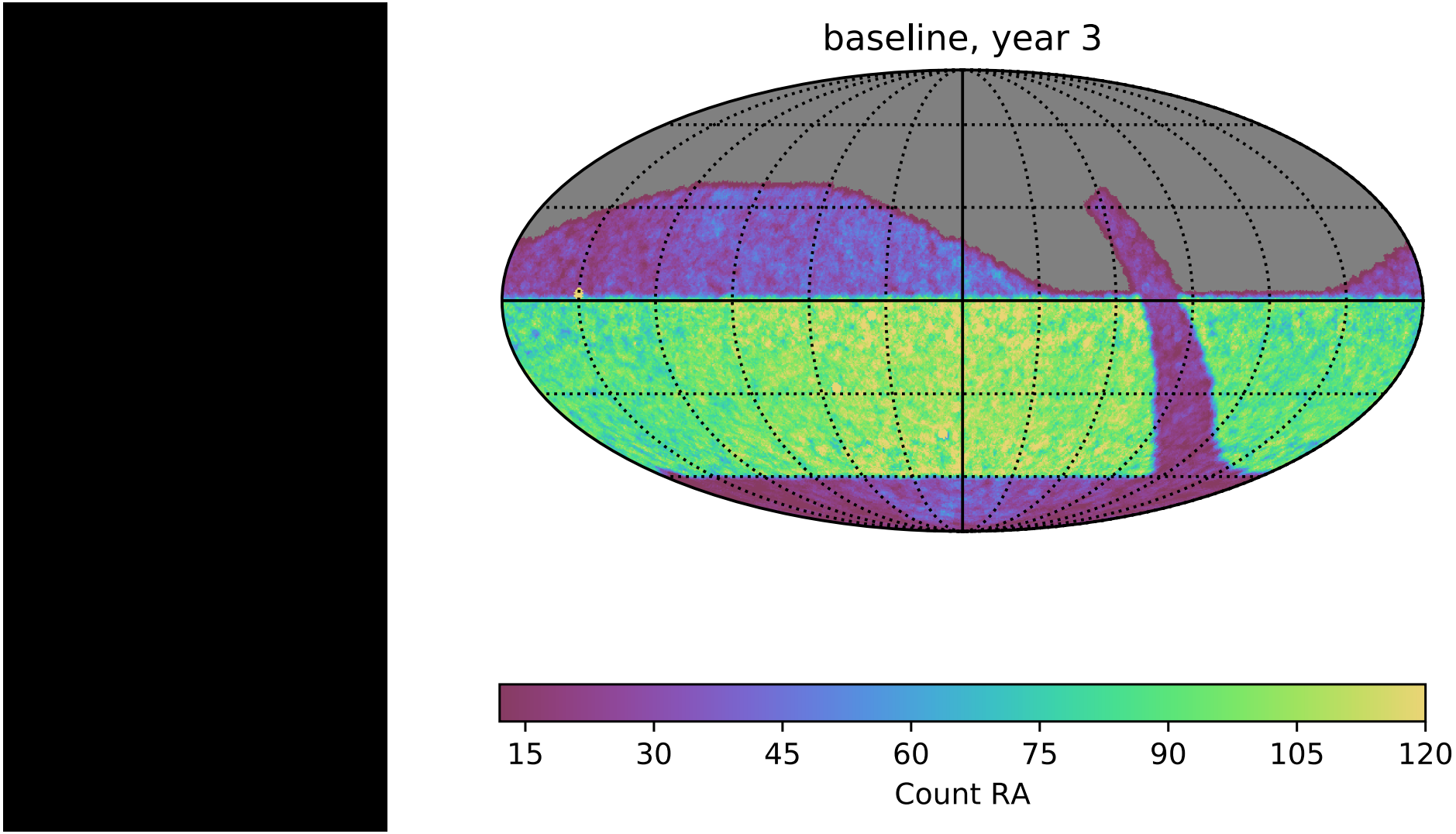


Some initial experiments in rolling cadence
(proof of concept, I did these in a day)

WFD~90-100
observations/yr

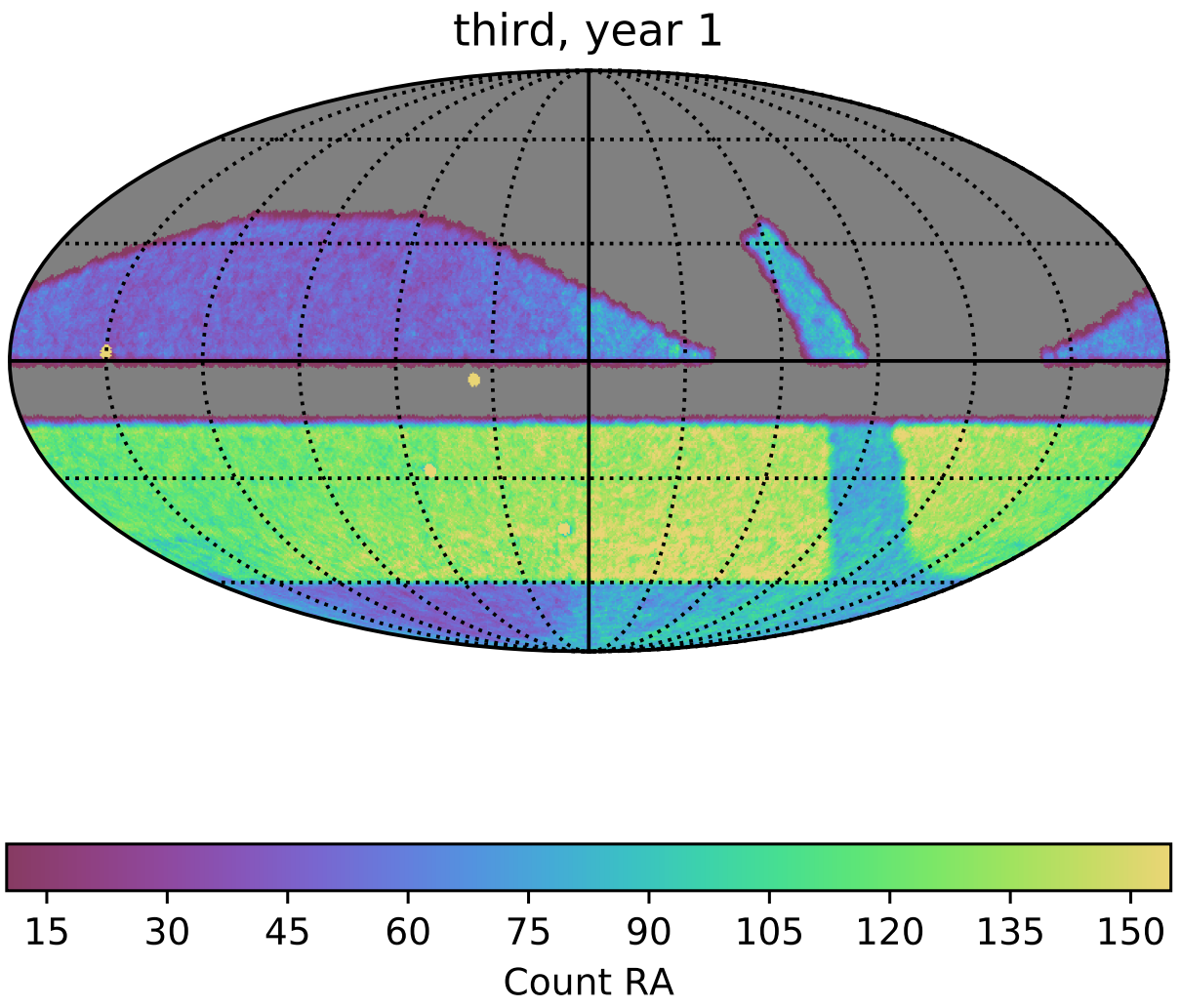


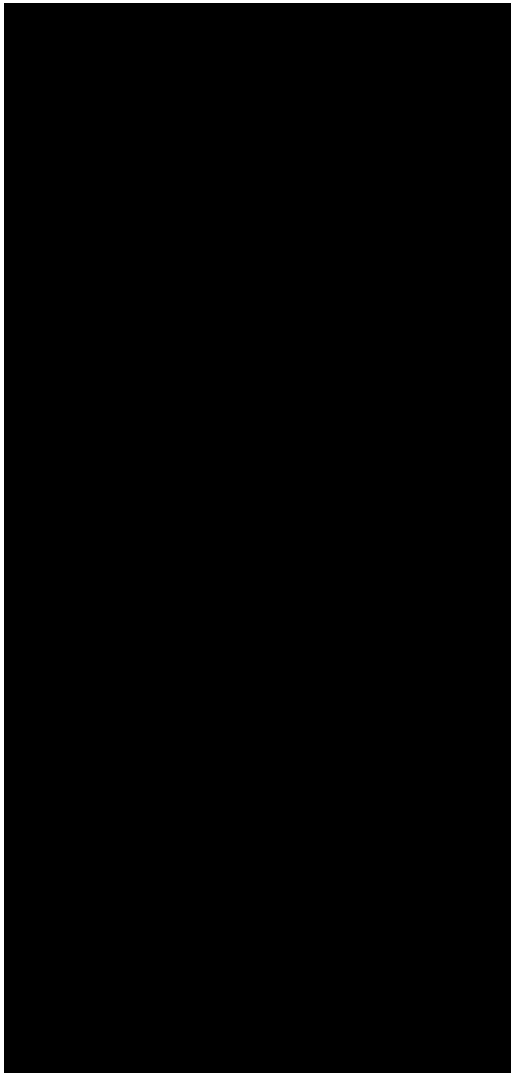

baseline, year 2
15
30
45
60
75
90
105
120
Count RA

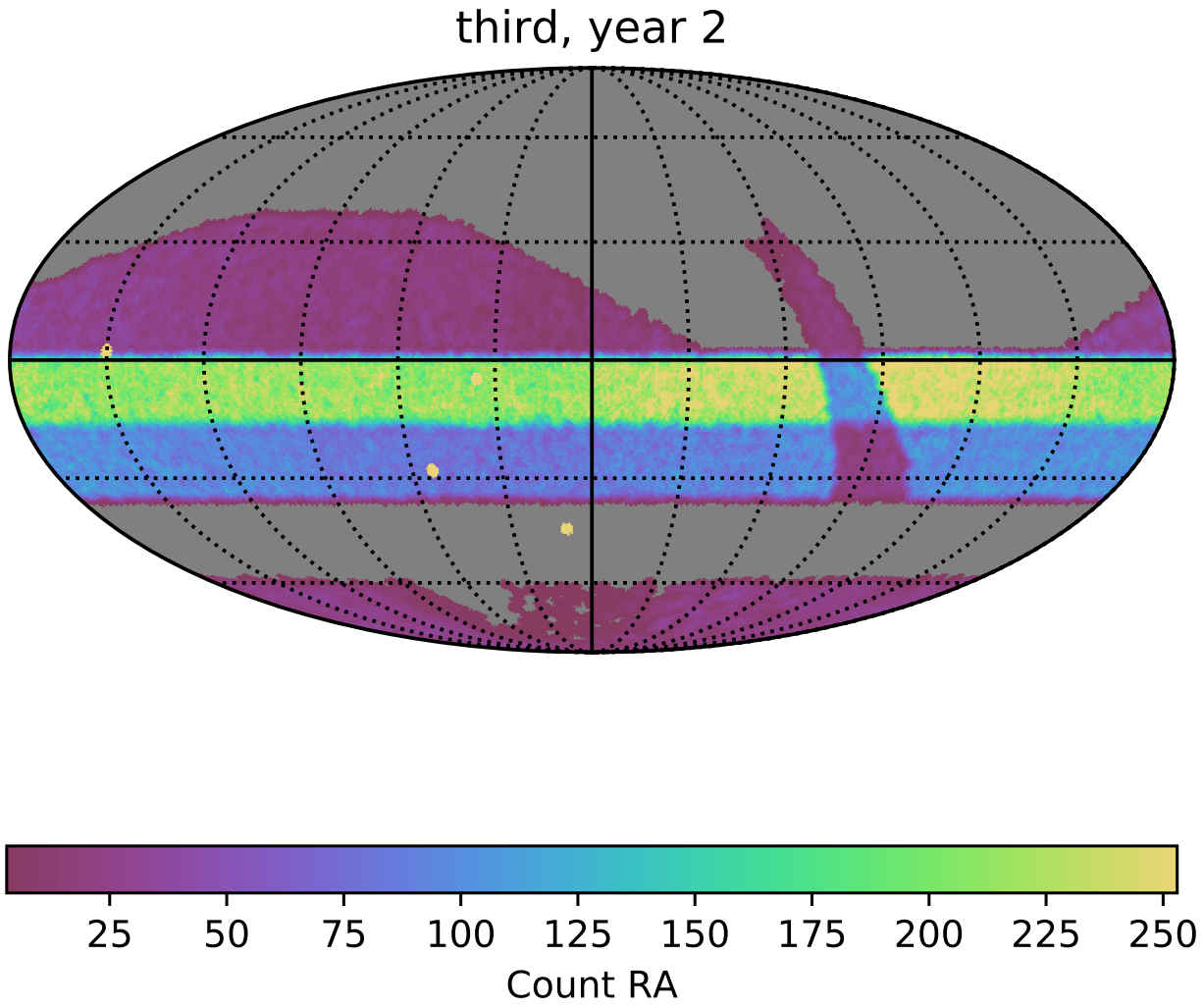

baseline, year 3
15
30
45
60
75
90
105
120
Count RA

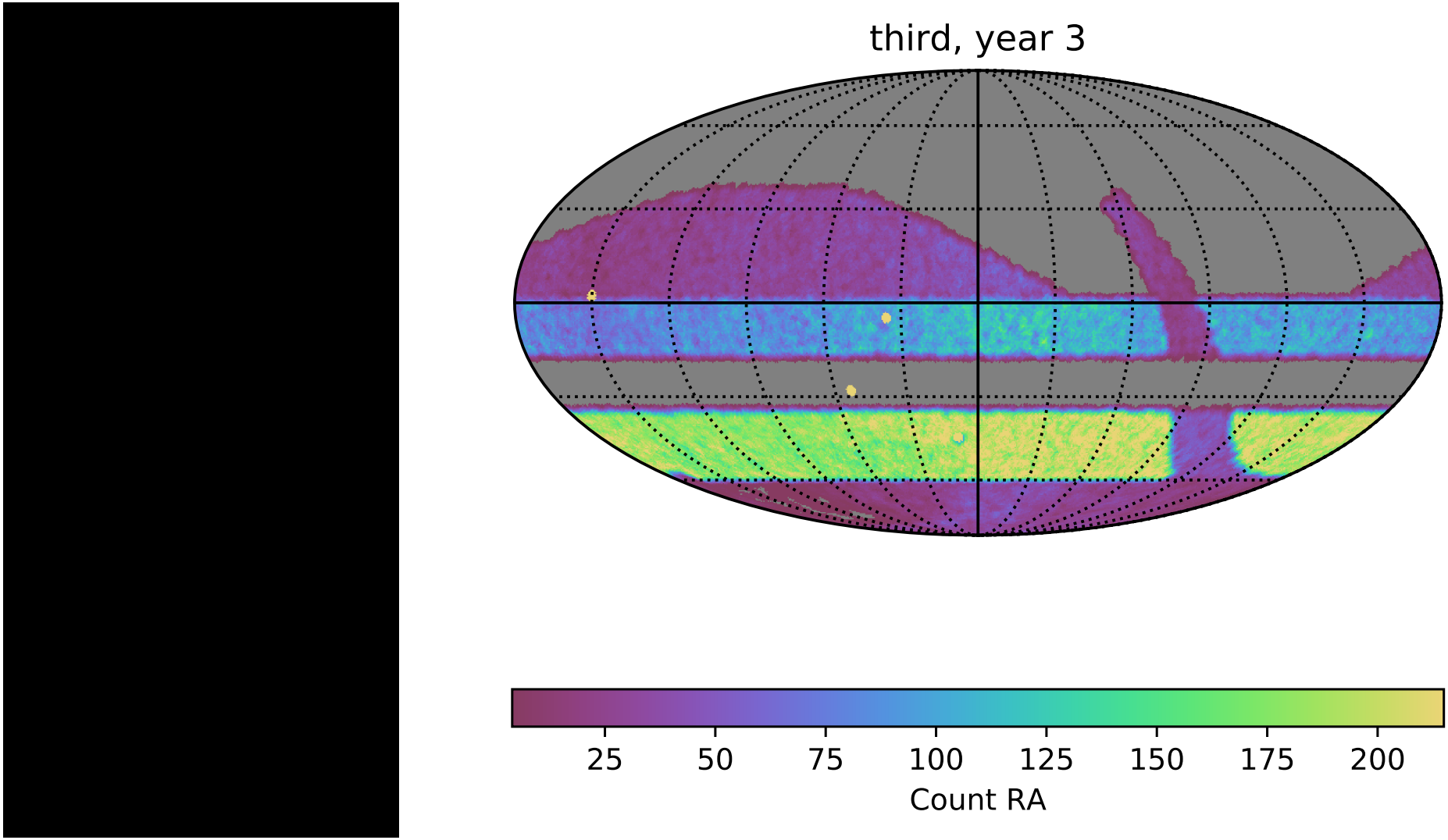
Rolling Cadence: Mask 1/3 of WFD region each year.

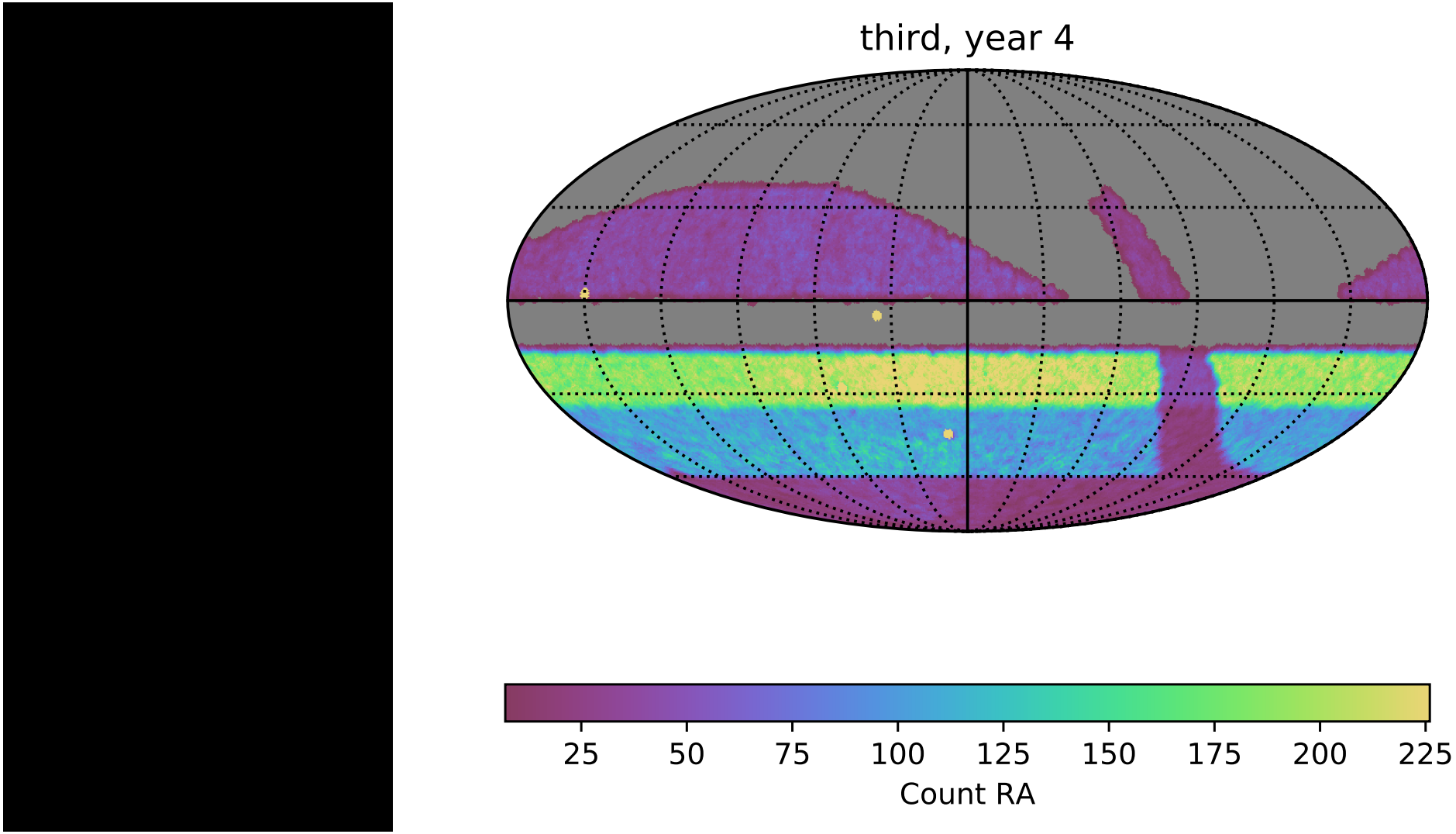
Now 120-130 observations/yr





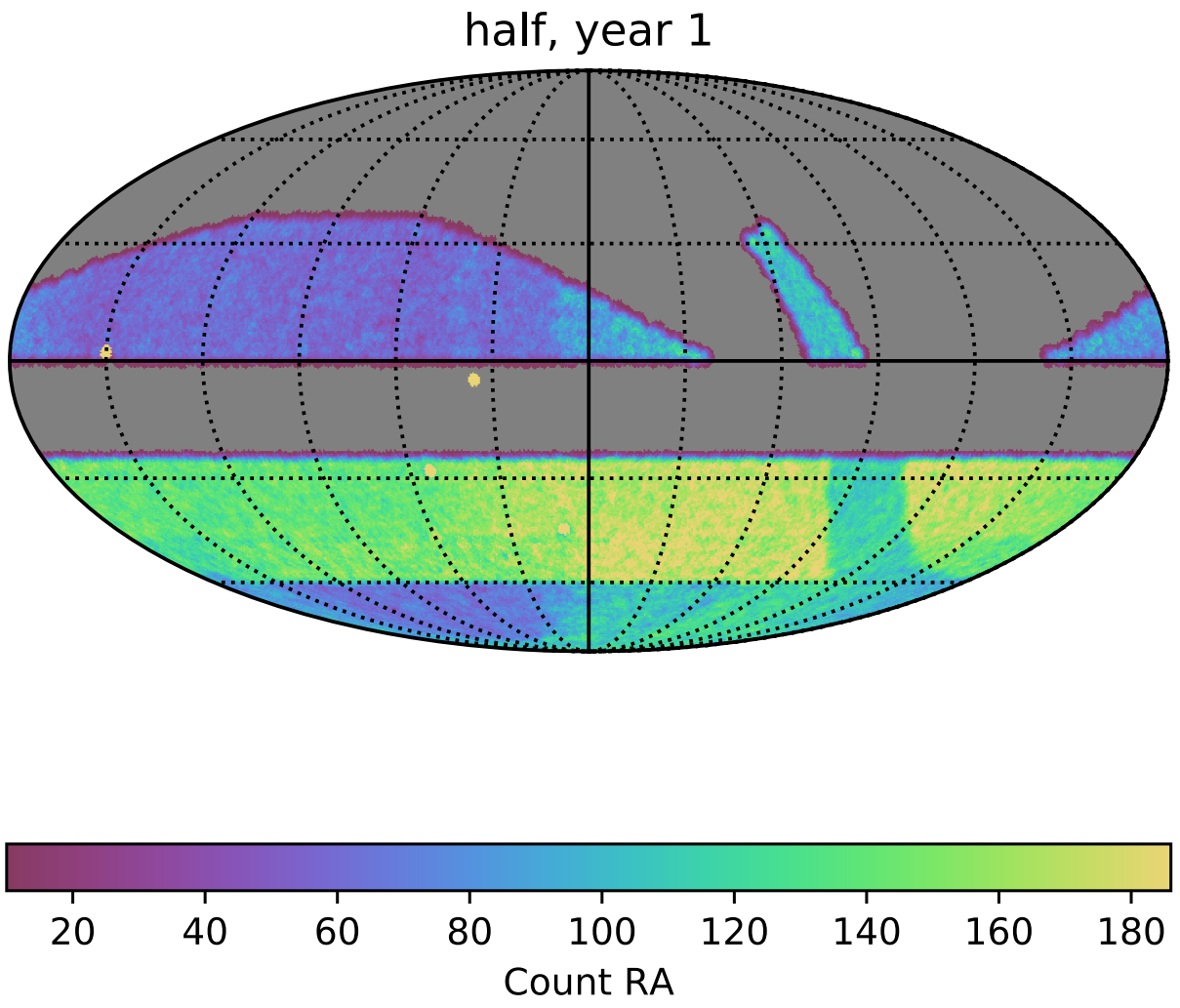

third, year 2
25
50
75
100
125
150
175
200
225
250
Count RA

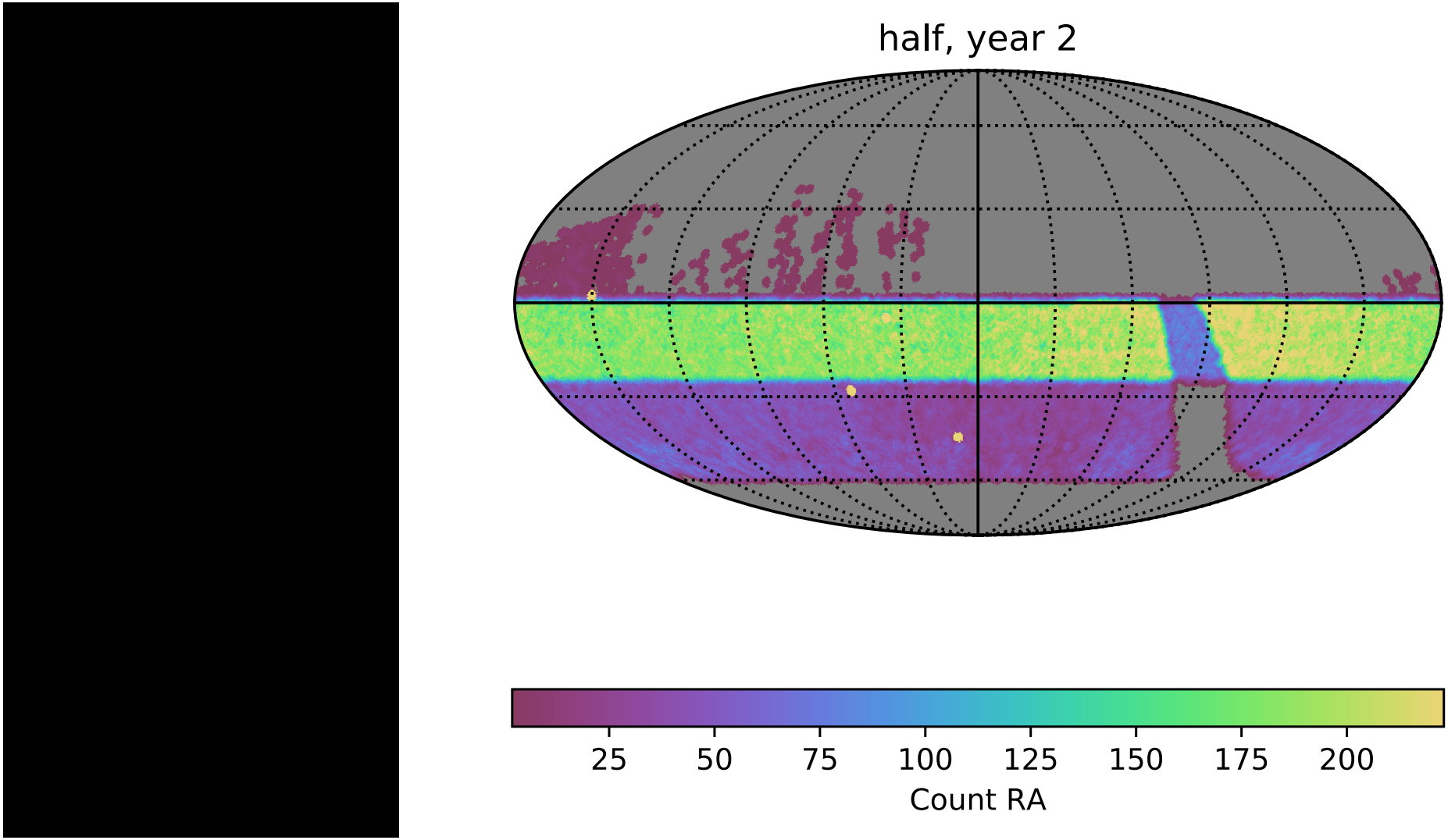

third, year 3
25
50
75
100
125
150
175
200
Count RA

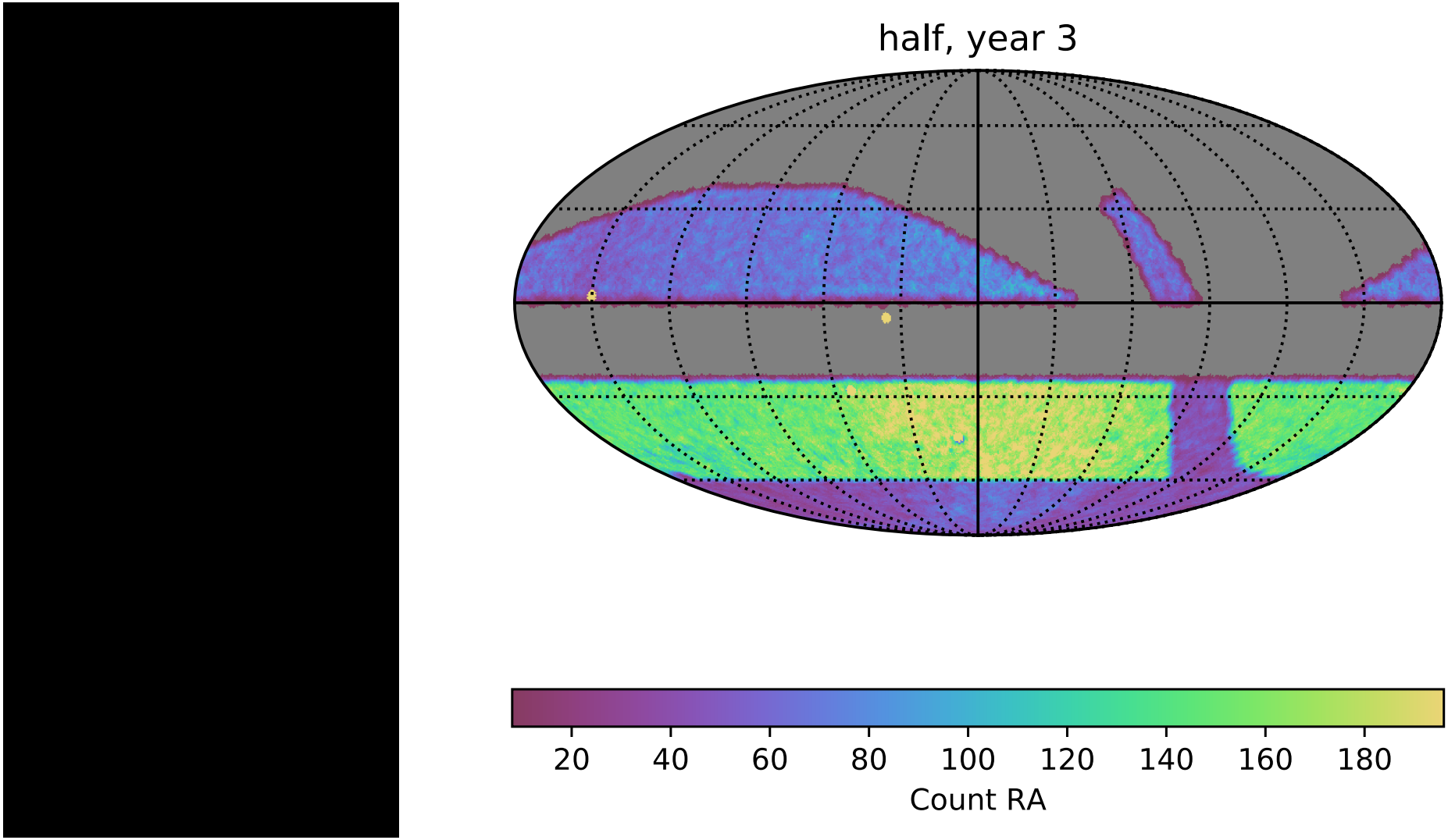

third, year 4
25
50
75
100
125
150
175
200
225
Count RA

Now Mask half the WFD region. Then unmask next year

140-160 obs/yr

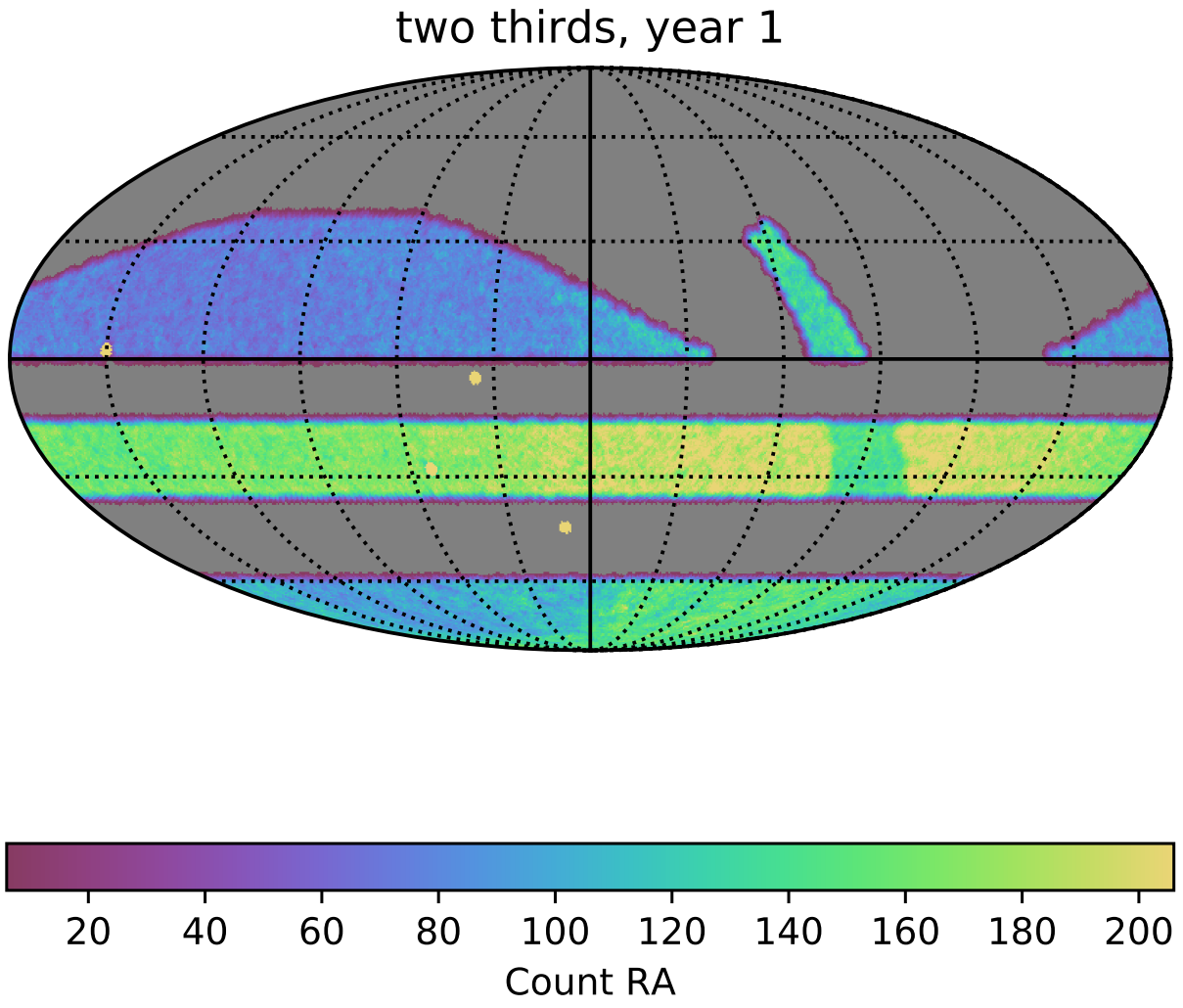


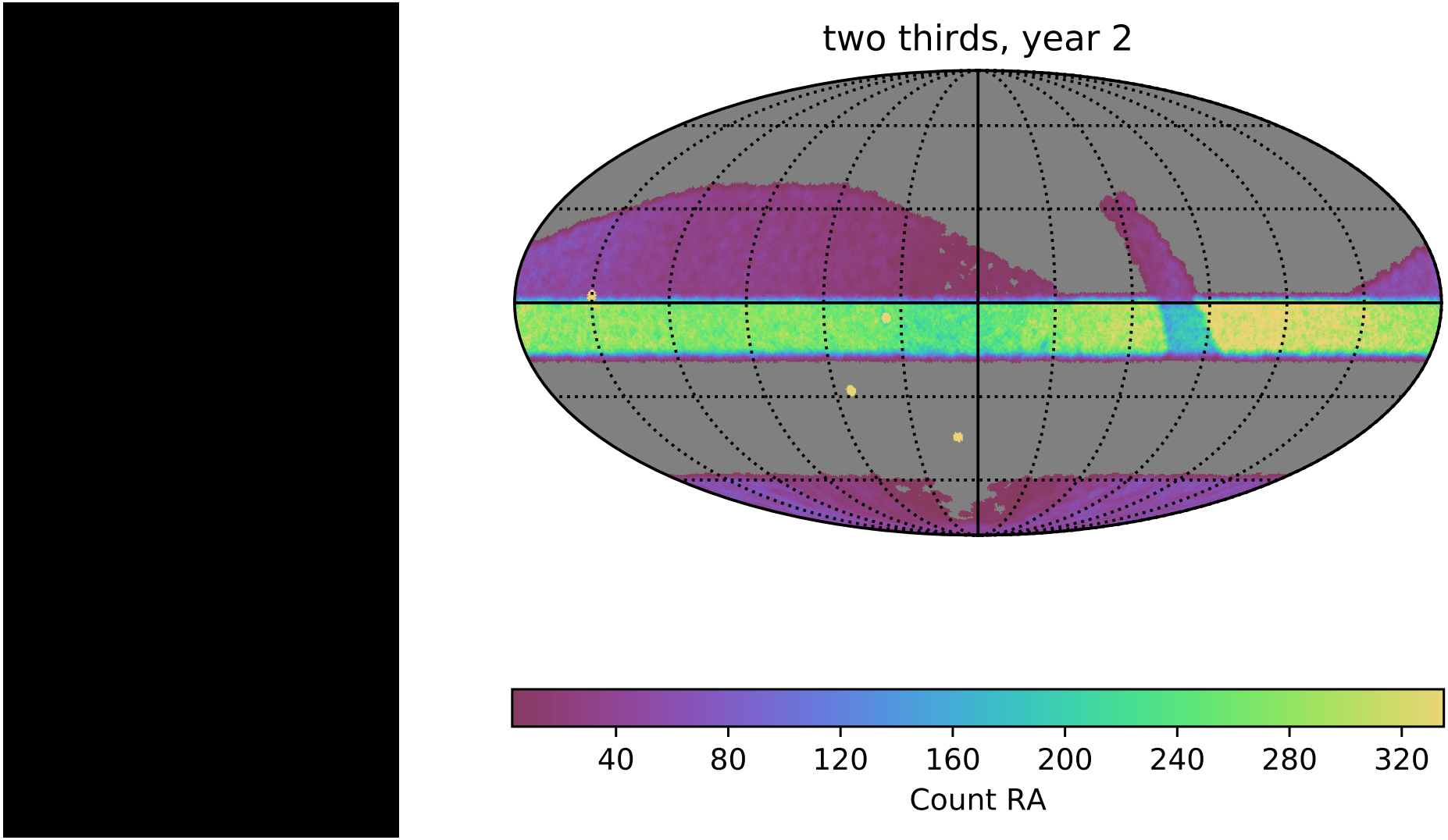

half, year 2
25
50
75
100
125
150
175
200
Count RA


half, year 3
20
40
60
80
100
120
140
160
180
Count RA

Mask 2/3 of WFD

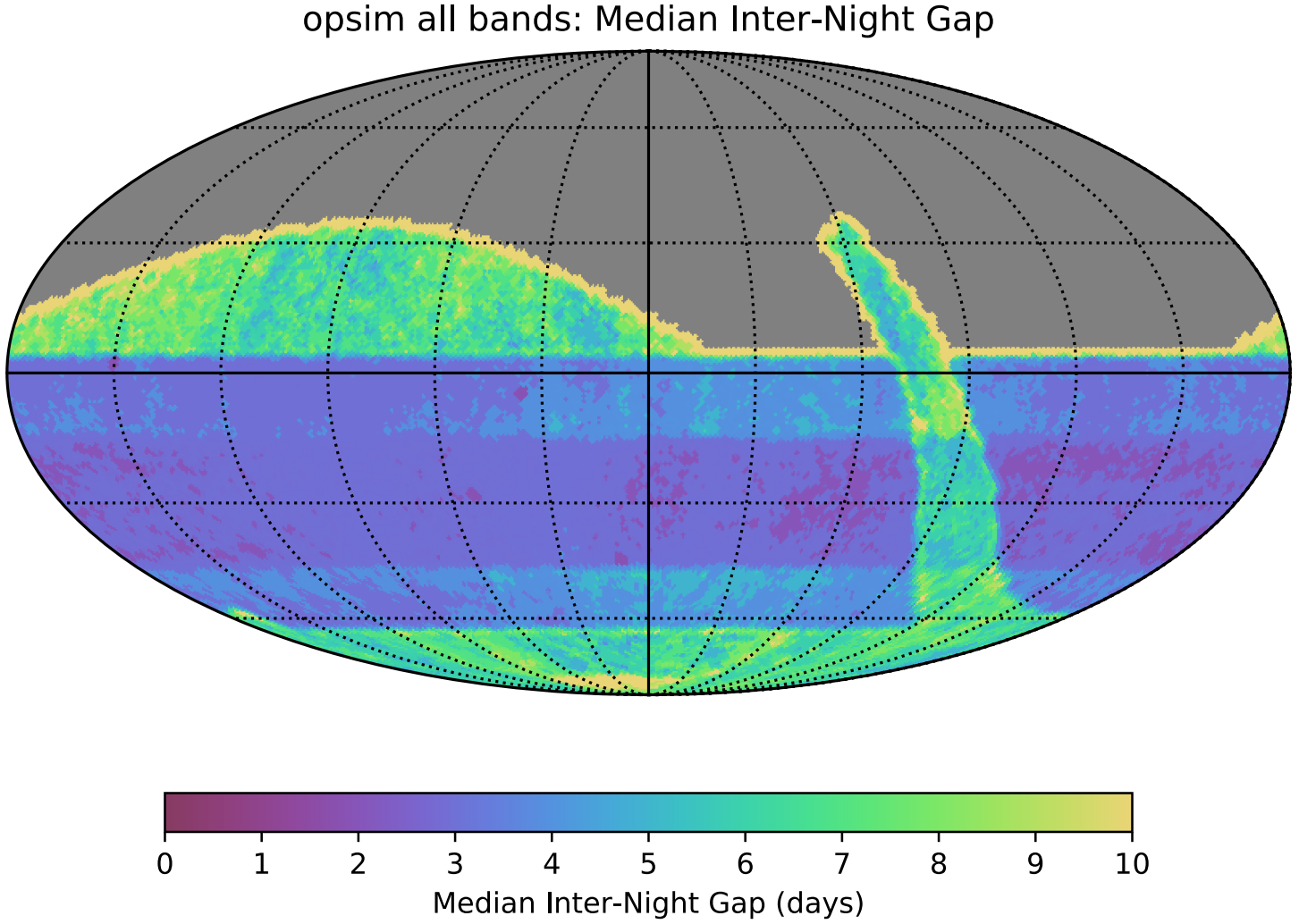
160-180/yr



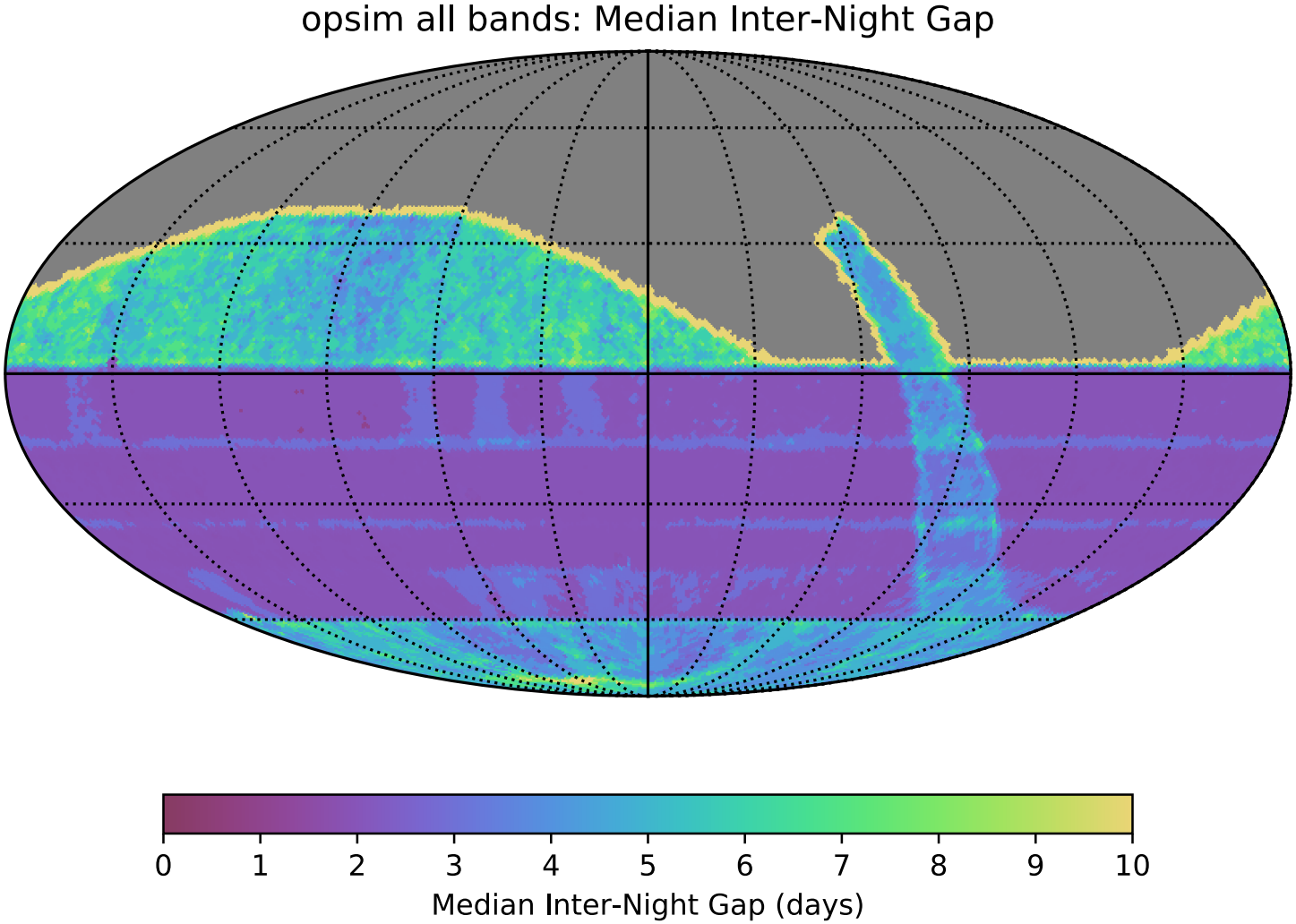

two thirds, year 2
40
80
120
160
200
240
280
320
Count RA

Baseline:

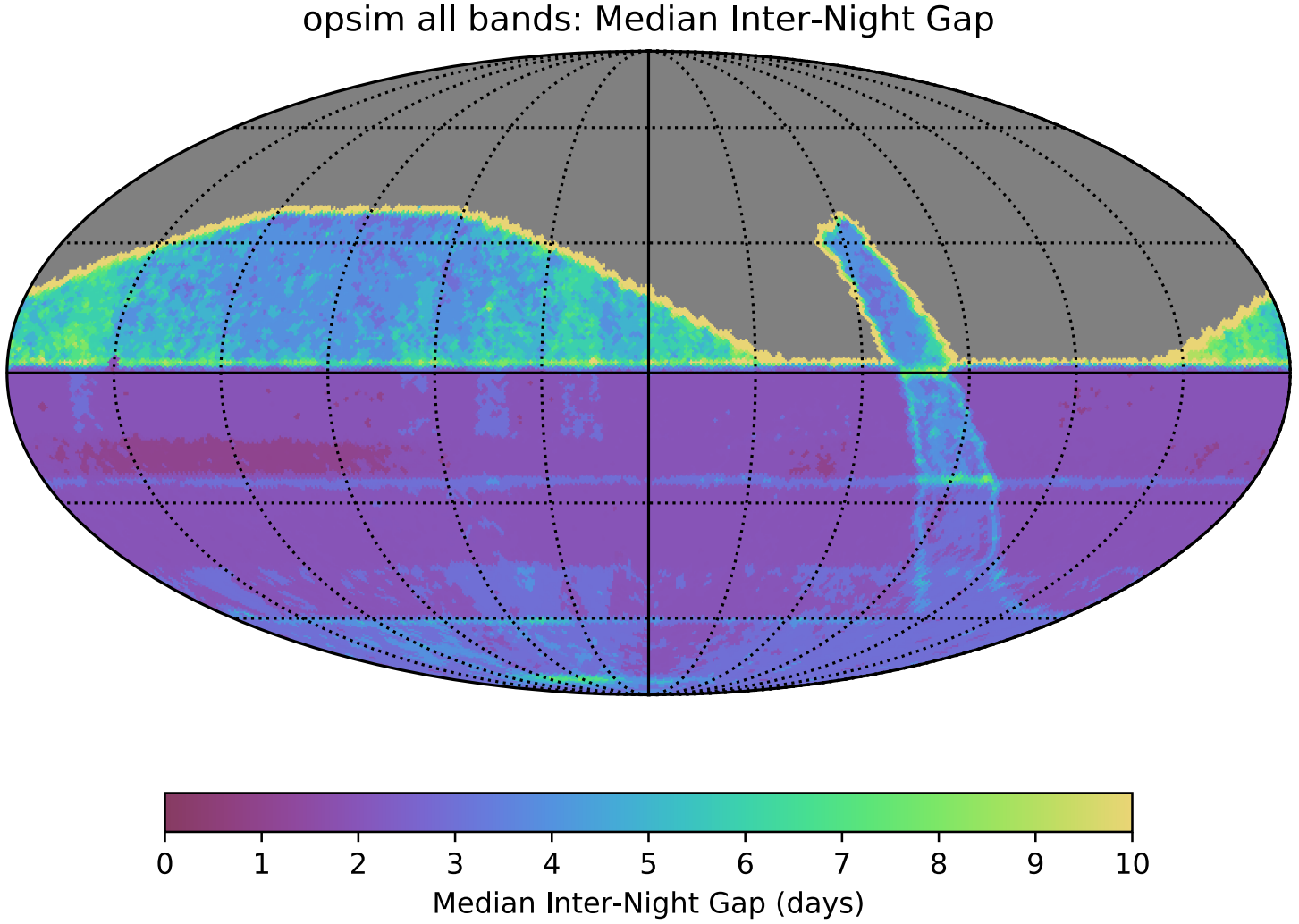
Median inter-night gap of 3.95 days



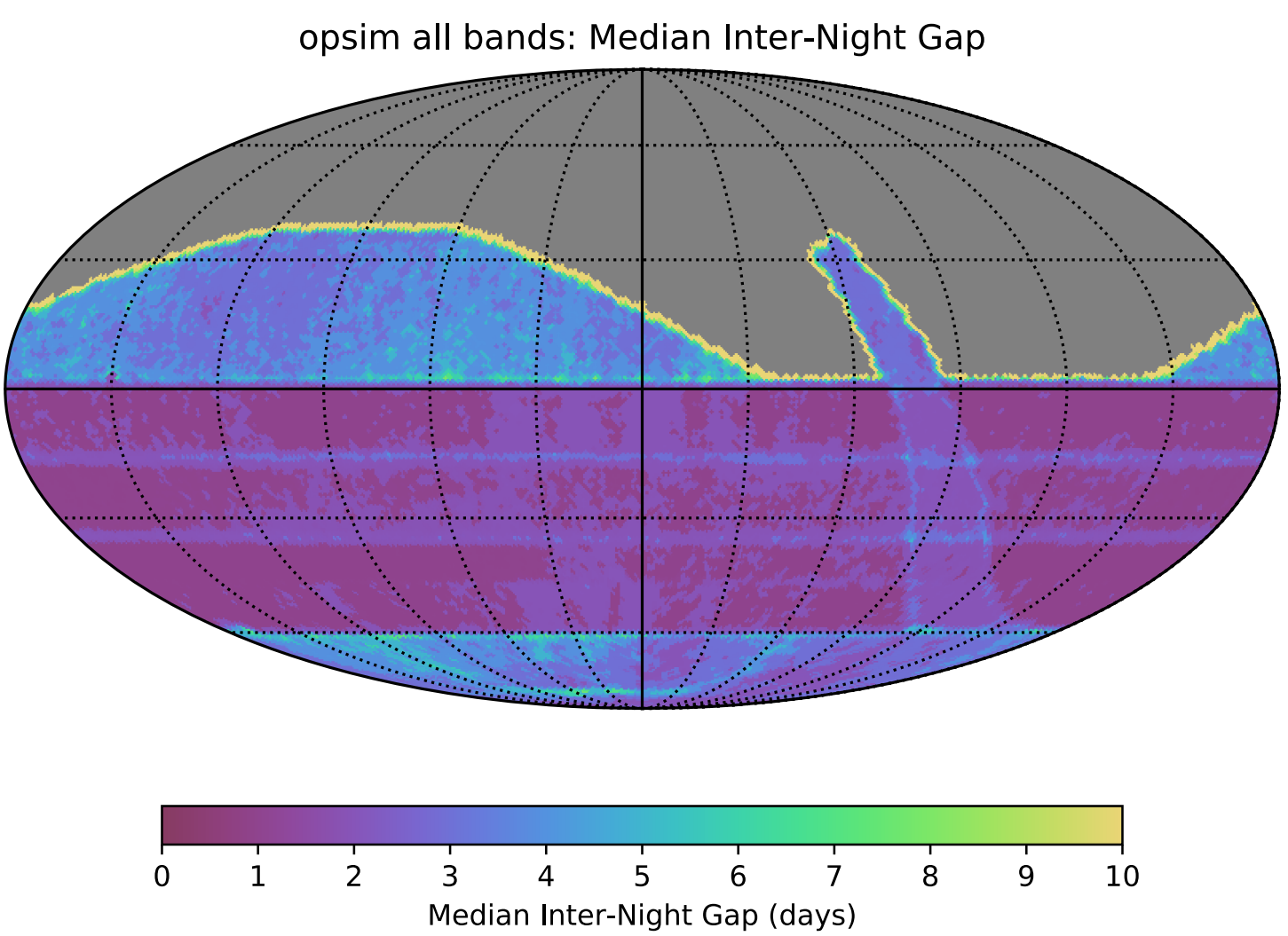
1/3 rolling cadence Median gap of 2.06 days



Half-sky rolling cadence: Median gap 2.01 days

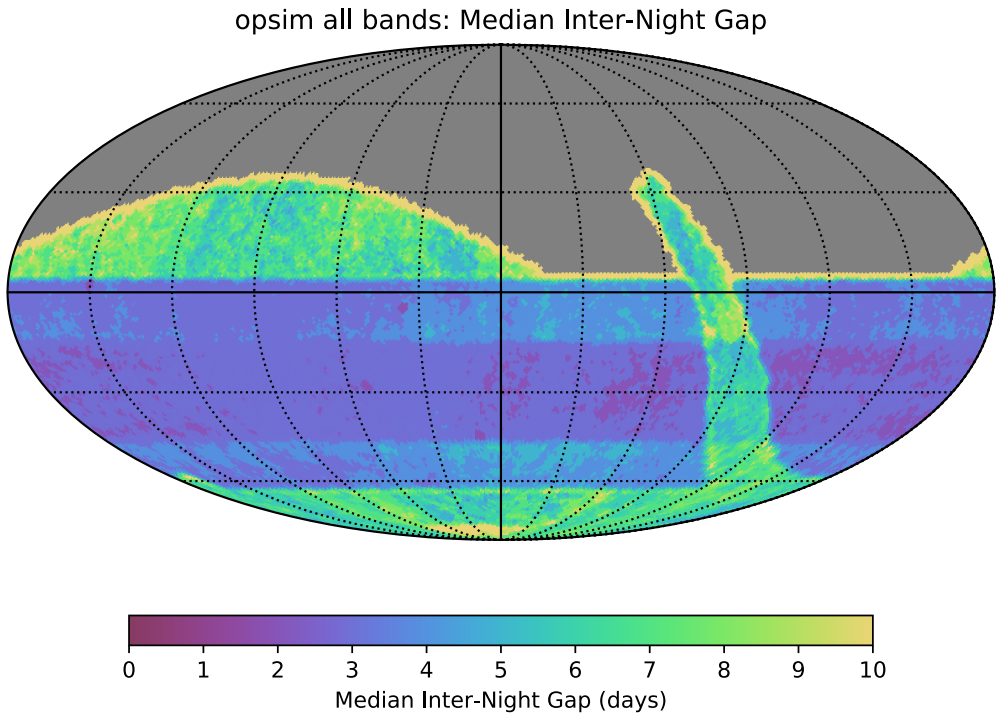


2/3 rolling cadence: Median gap 1.97 days

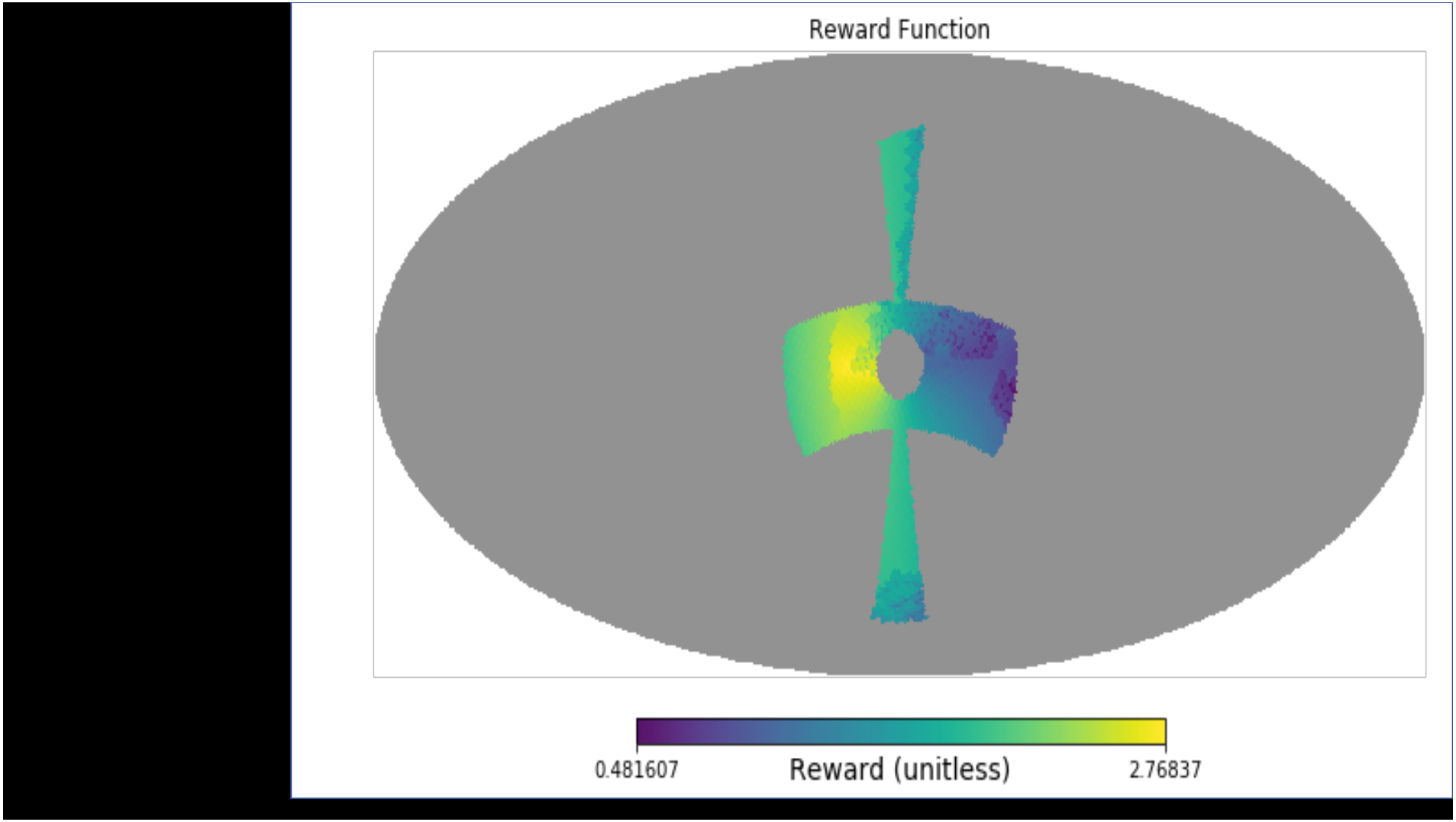


Rolling cadence takeaway:

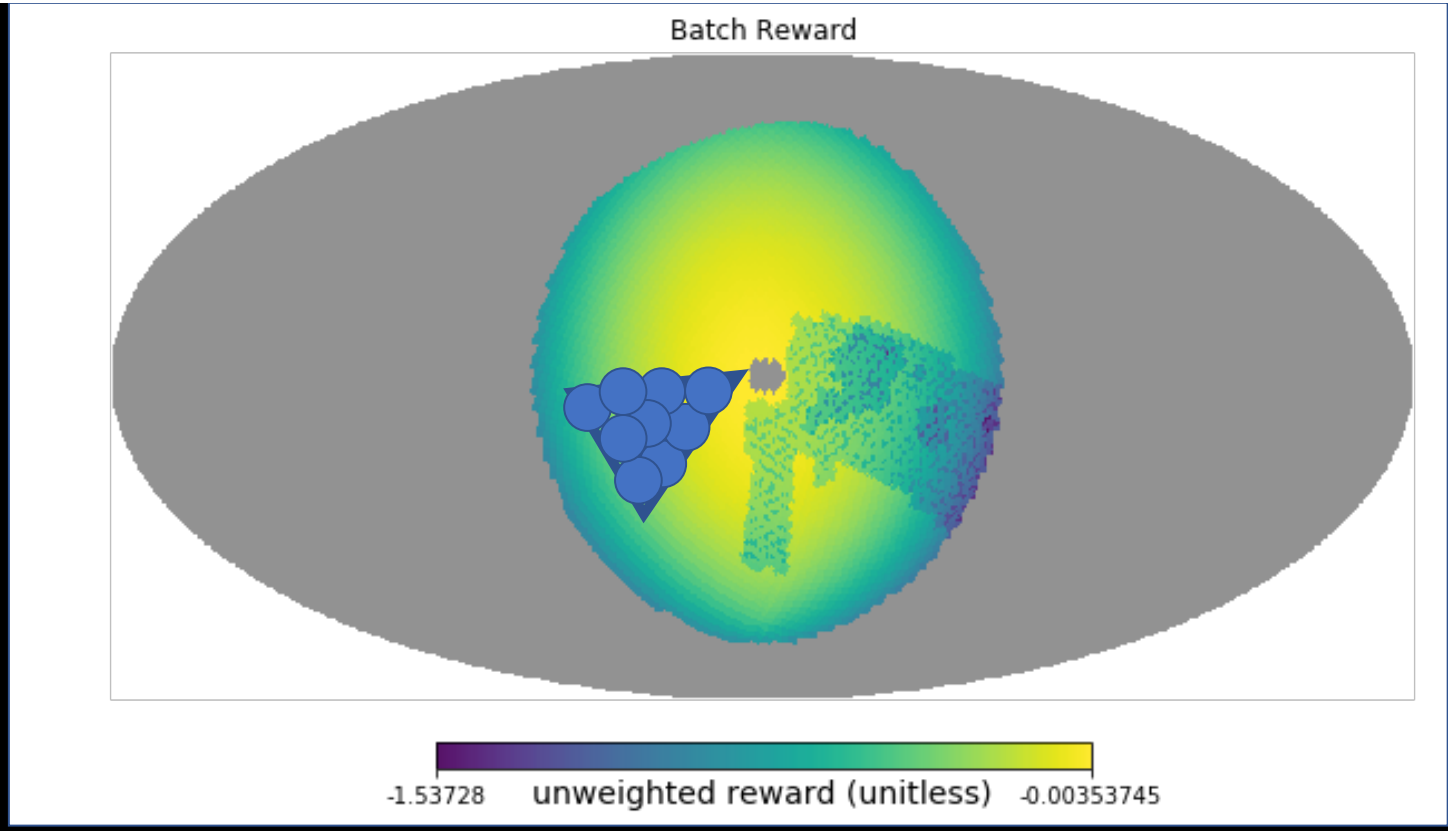
- The baseline tends to have 4-day gaps (in all filters)
- Overly aggressive rolling cadence can cut that down to 2
- I often head 3 is the magic number for SNe, so we should be able to get close



We need to do the slightly more sophisticated experiment where we increase cadence but still observe the full sky each year (rather than masking the target map, just set it to a lower value)

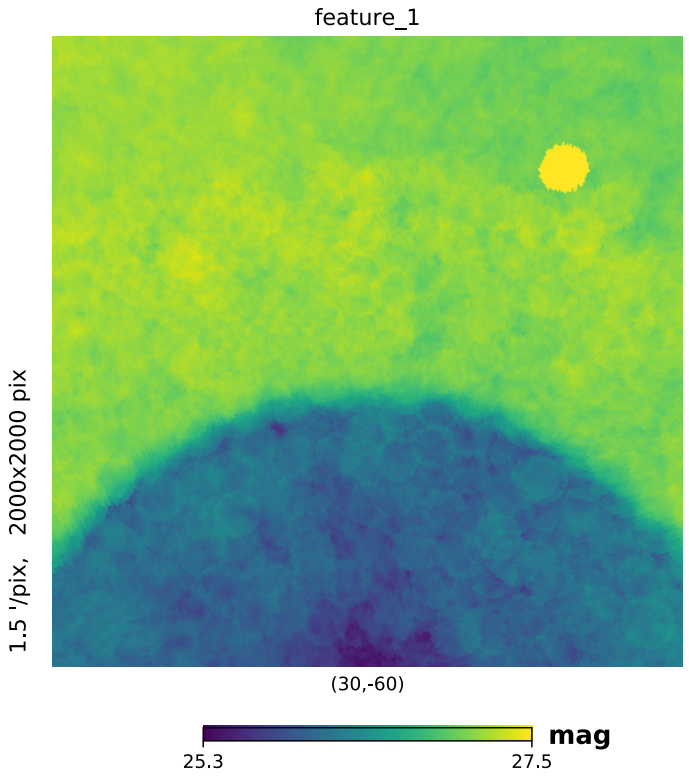

Reward Function
0.481607
Reward (unitless)
2.76837

Rather than have a greedy algorithm pick single observations, have a greedy algorithm select a large chunk of sky. Then solve the traveling salesperson to keep slewtime down. Go through the block twice to get pairs.

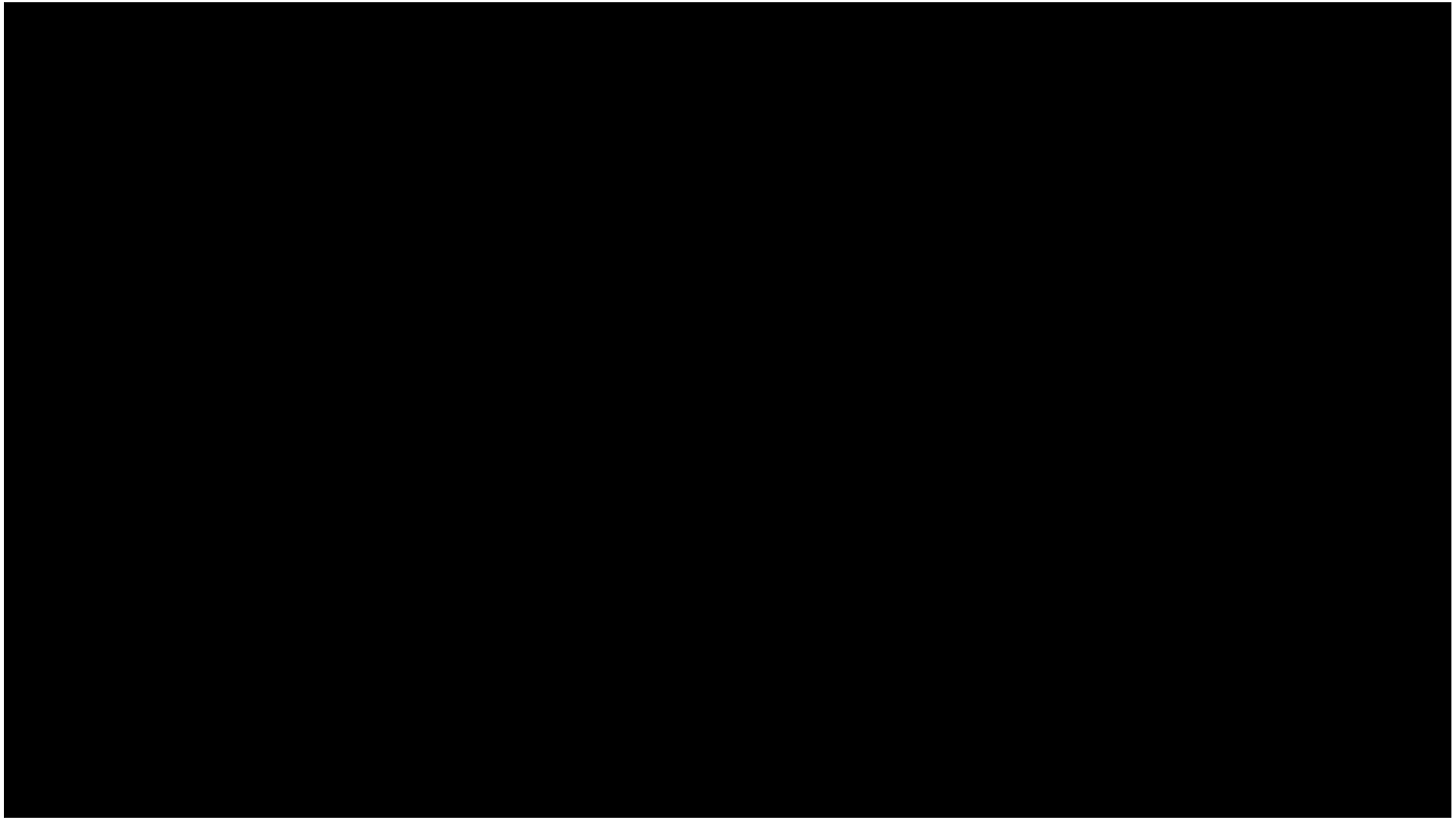


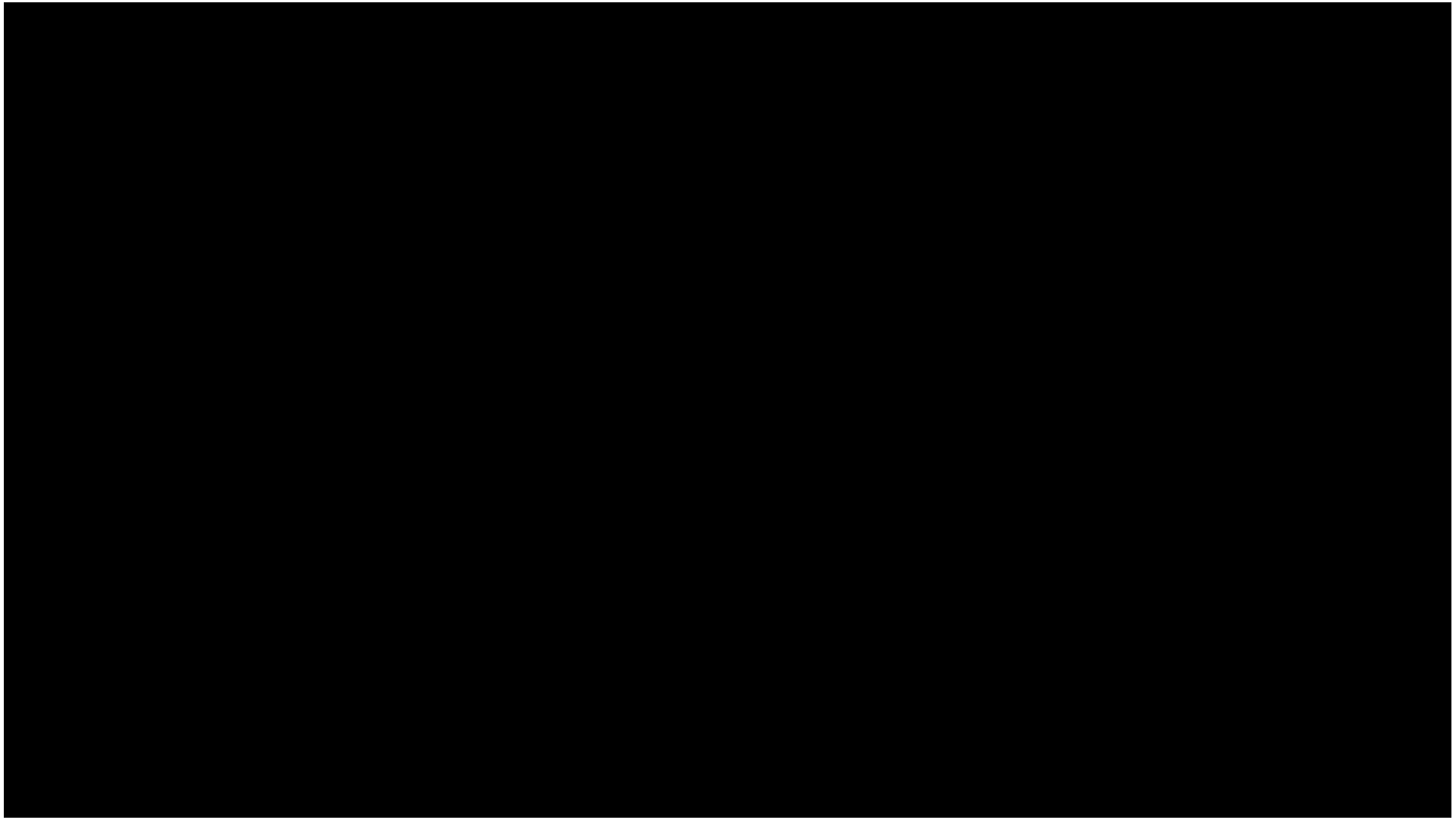
Future Plans:

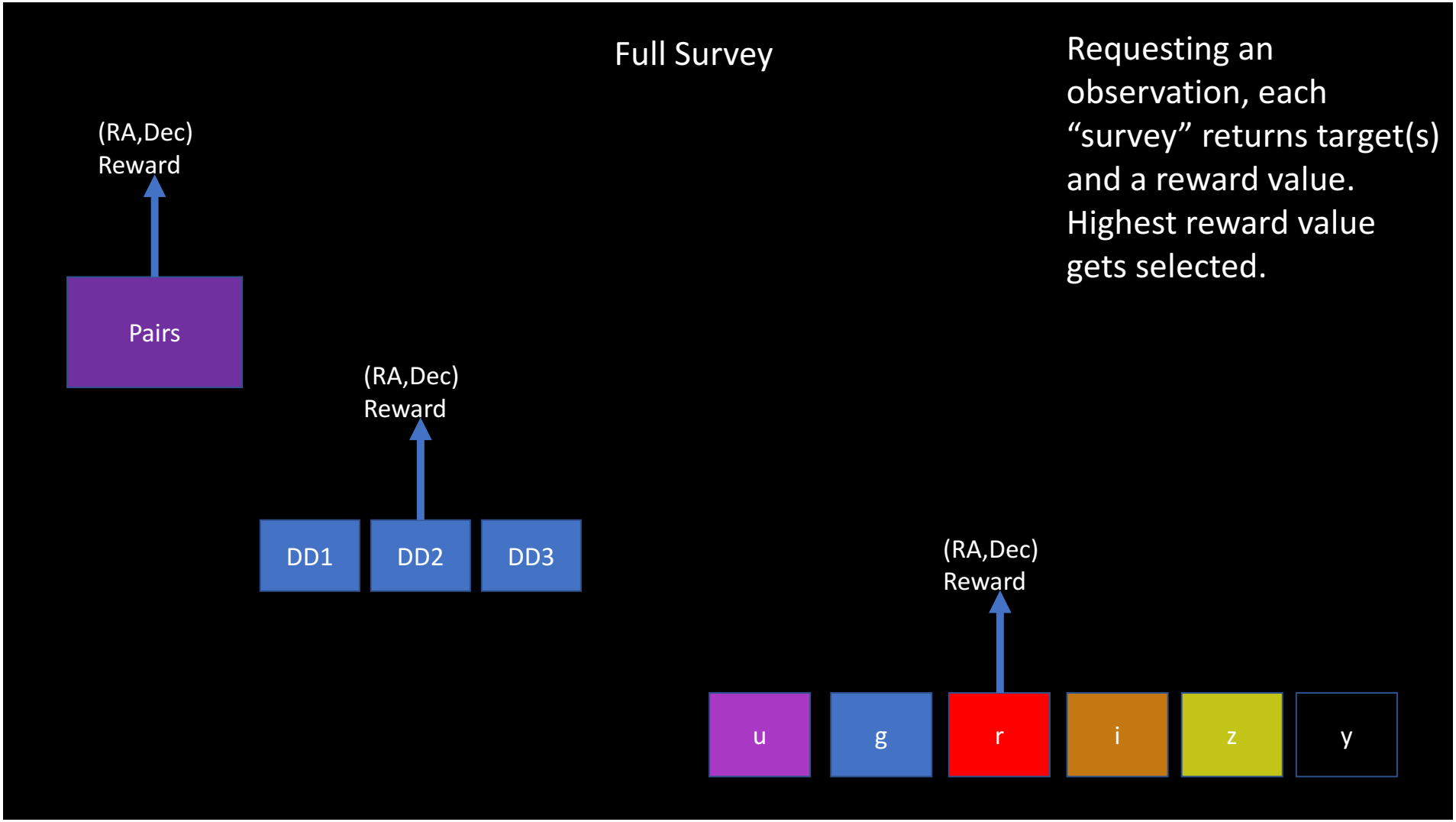
- Double check that all-sky re-tessellation is good for ubercal (it should be great)
- Schedule large areas rather than single visits
- More sophisticated DD cadence
- We (still) need a dither strategy for the DD fields
- We (still) need a strategy for dithering in camera rotator angle
- More sophisticated rolling cadence
- Adjust WFD area for summer/winter
- Galactic plane as part of WFD
- Try to enforce particular WFD cadence with a new basis function?
- Depth uniformity basis function?
- Special 1st year strategy to get templates
- I'd like to try new sky tessellations

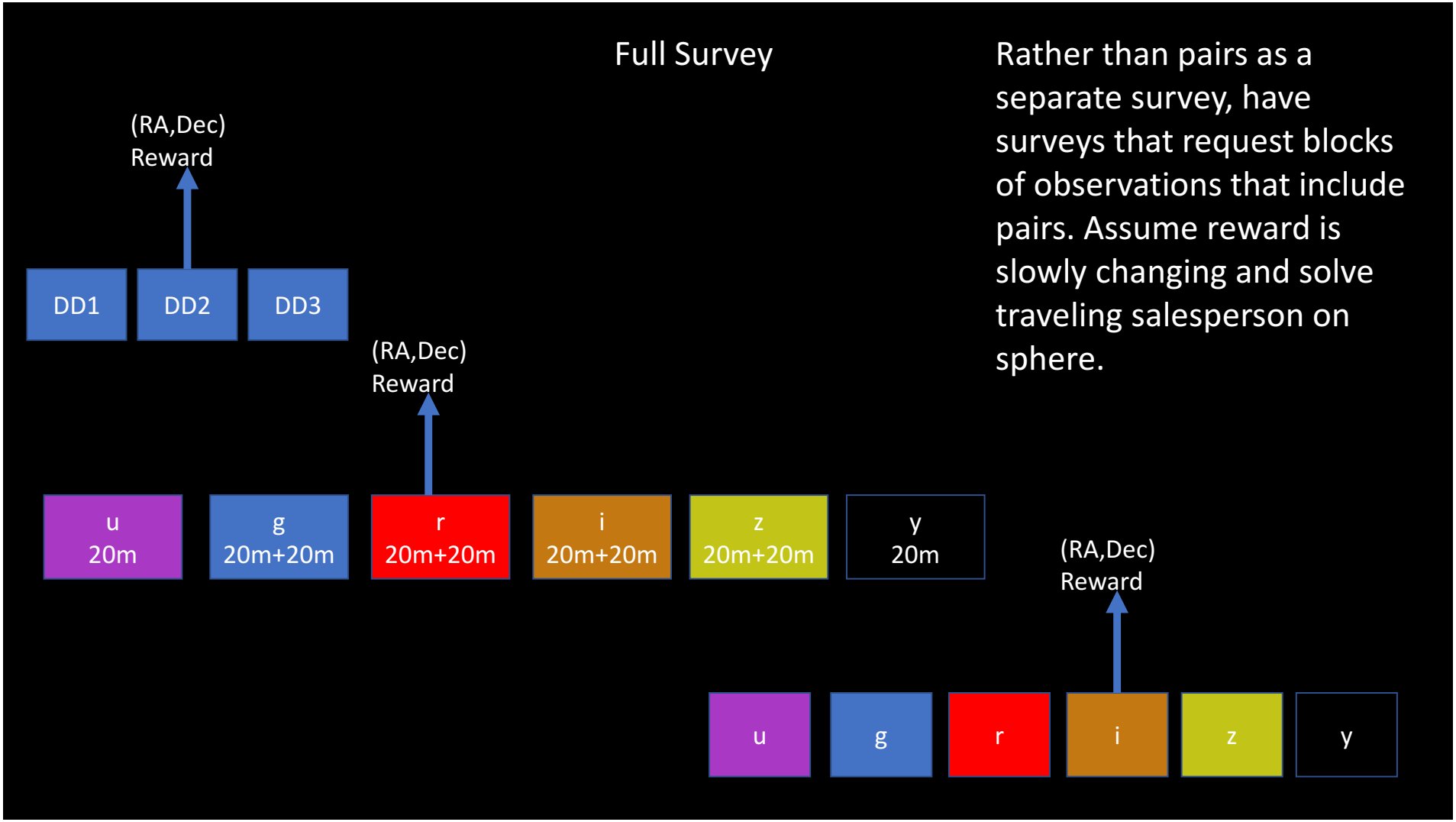


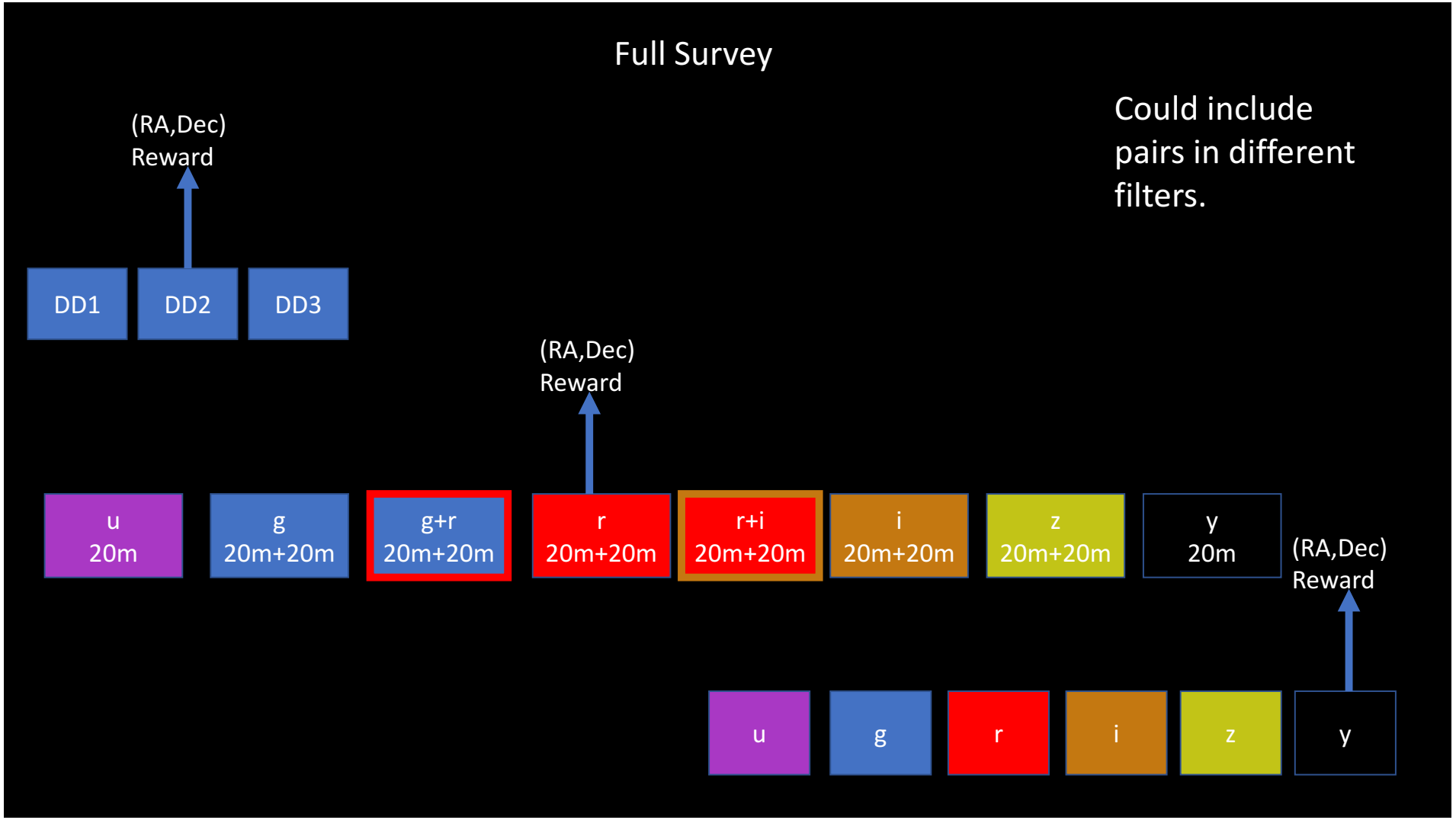
Red = I think DESC could help a lot with that






Full Survey
Requesting an observation, each "survey" returns target(s) and a reward value. Highest reward value gets selected.
(RA,Dec)
Reward
Pairs
(RA,Dec)
Reward
DD1
DD2
DD3
(RA,Dec)
Reward
u
g
r
i
z
y


Full Survey
Rather than pairs as a separate survey, have surveys that request blocks of observations that include pairs. Assume reward is slowly changing and solve traveling salesperson on sphere.
(RA,Dec)
Reward
DD1
DD2
DD3
(RA,Dec)
Reward
u
20m
g
20m+20m
r
20m+20m
i
20m+20m
z
20m+20m
y
20m
(RA,Dec)
Reward
u
g
r
i
z
y


Full Survey
(RA,Dec)
Reward
Could include pairs in different filters.
DD1
DD2
DD3
(RA,Dec)
Reward
u
20m
g
20m+20m
g+r
20m+20m
r
20m+20m
r+i
20m+20m
i
20m+20m
z
20m+20m
y
20m
(RA,Dec)
Reward
u
g
r
i
z
y