ZTF Scheduling: Phase II

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ZTF Phase I was—I think—the most complex time-domain survey ever scheduled.

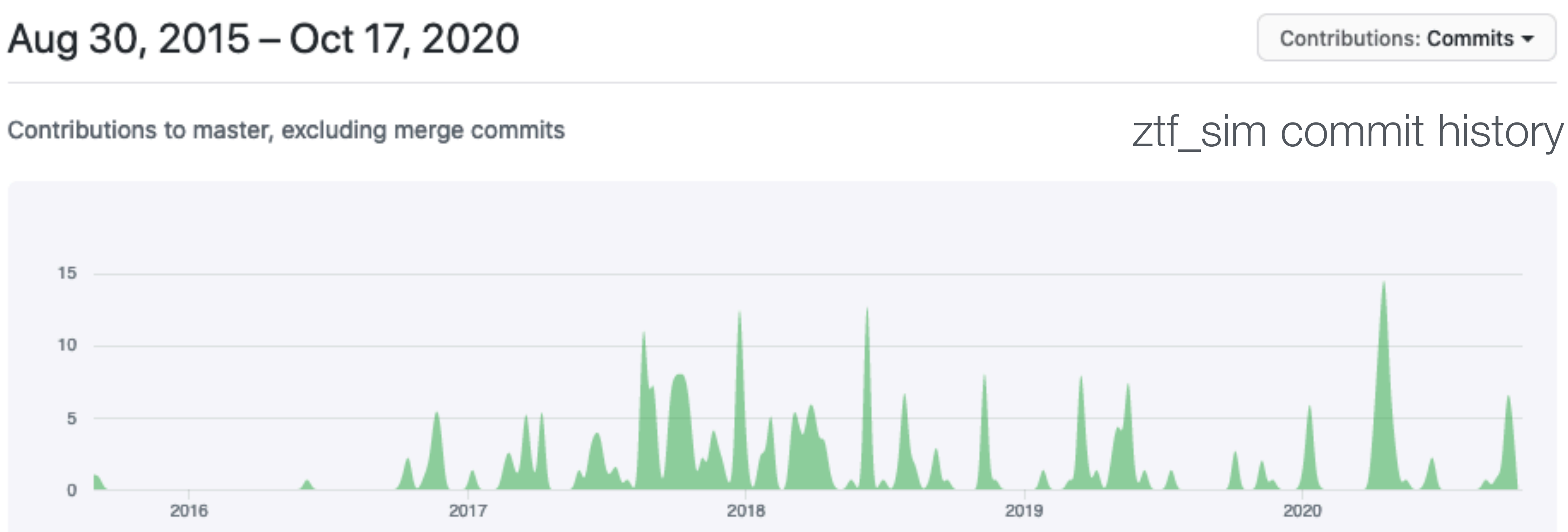
~475k exposures

cadenced surveys, time-constrained, deep drilling, TOOs…

Multiple surveys for each of MSIP, partnership, & Caltech, each with a minority share of the total survey

individual surveys changed frequently

88+ survey configurations over 2.5 years: >3 changes/month



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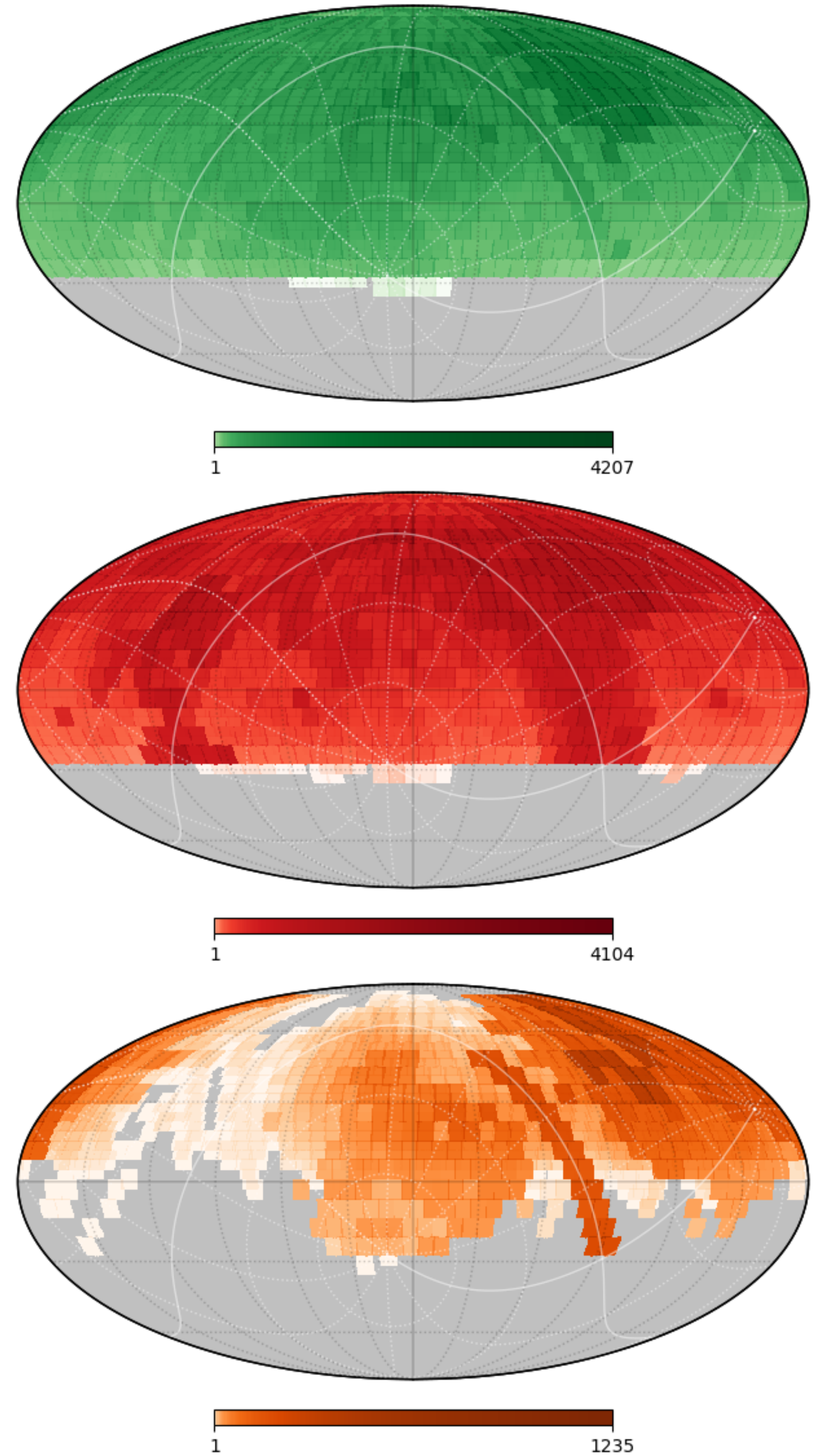
propID	subprogram	percent
1	all_sky	24.8%
	TESS	4.9%
	fallback	4.1%
	nightly_plane	3.5%
	SRG	1.1%
2	high_cadence	12.1%
	Partnership_Plane	9.5%
	ZUDS	6.7%
	fallback	5.4%
	Partnership_Twilight	2.8%
	i_band	2.5%
	ToO	1.8%
	Asteroid_Lightcurve	1.4%
	M31	0.0%
3	1DC	9.8%
	Caltech_Plane	4.5%
	fallback	2.5%
	TESS	1.0%
	Caltech_RRLyr	0.7%
	Blank	0.5%



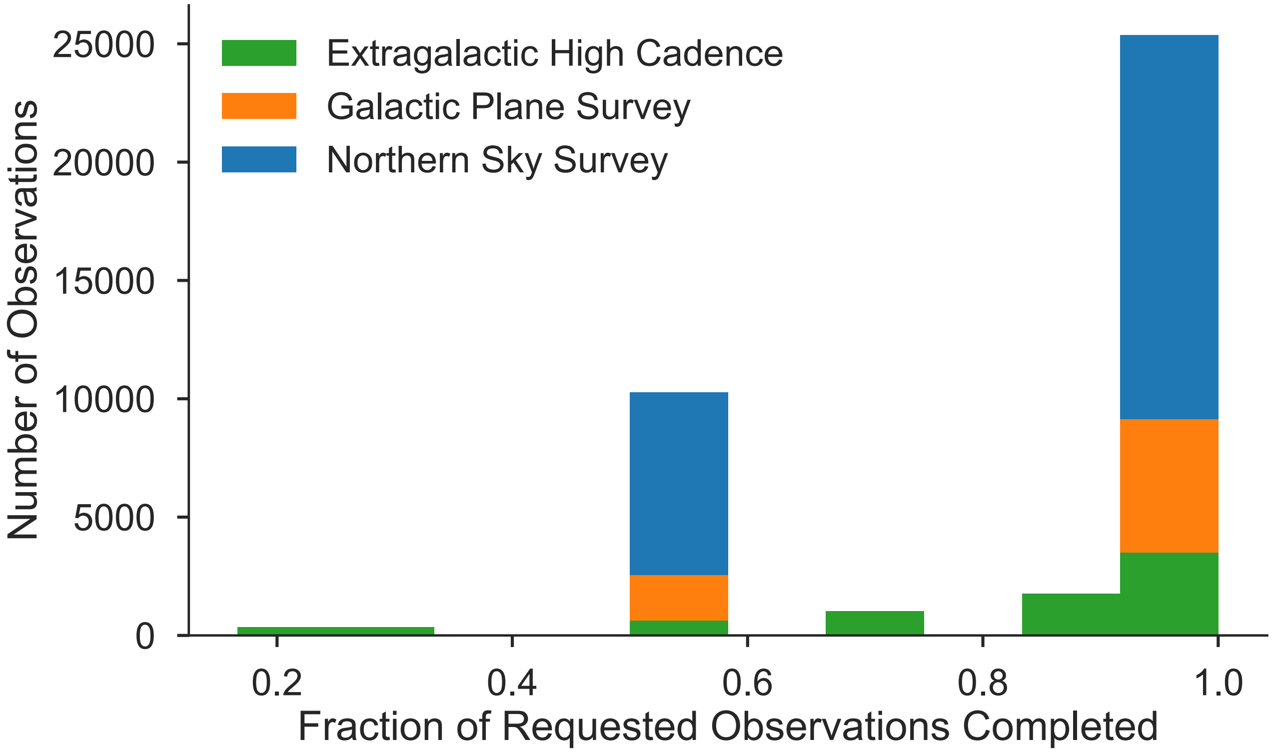
Many aspects of the scheduling were successful.

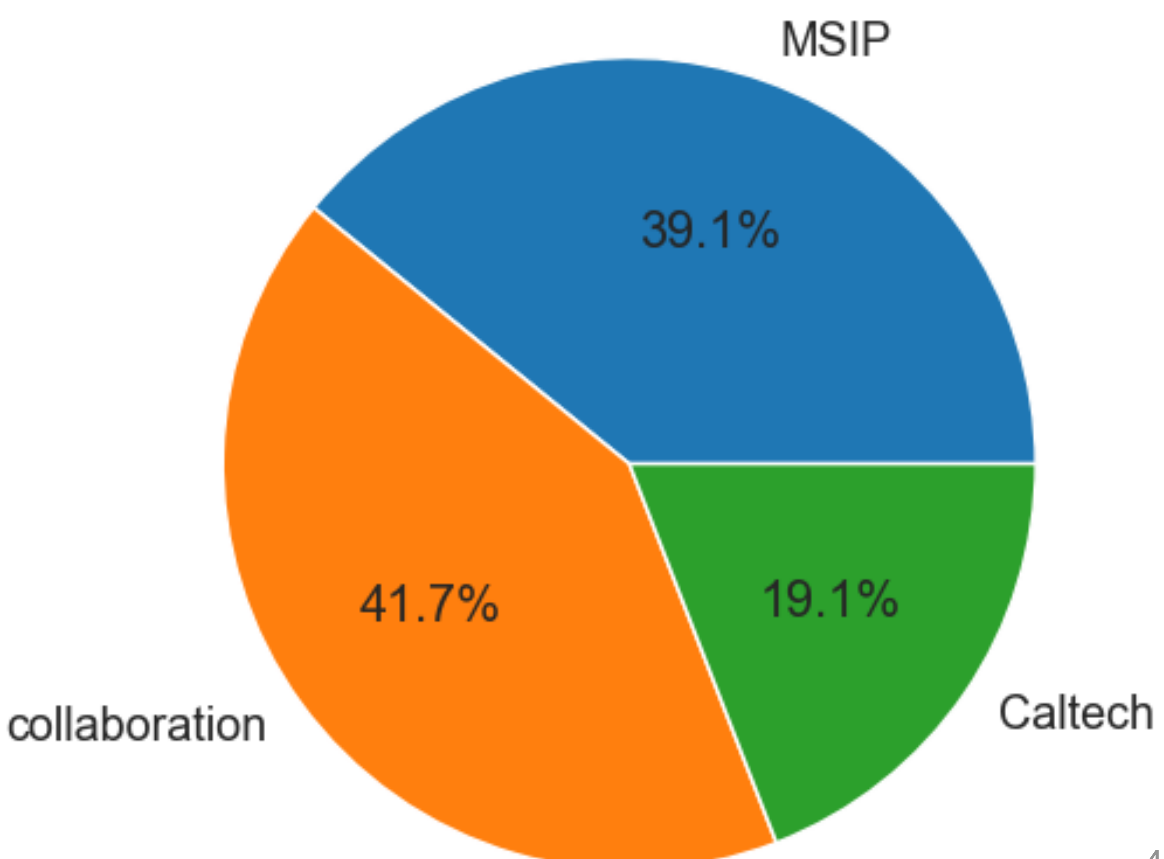
Programs were executed as designed.

Slew & filter-change overheads were minimized.

Self-serve TOOs mostly ran well.

Overall program balance was adequate.





Some things could have been better.

Optimization setup was not well-suited to high-cadence survey or low-declination fields

both now improved!

Lack of good visualization tools to identify program conflicts ahead of time

constant program churn ⇒ lots of labor-intensive work for me

manual & error-prone ⇒ some missed observing time,

overall less effort for other scheduler improvements

The survey complexity created some issues.

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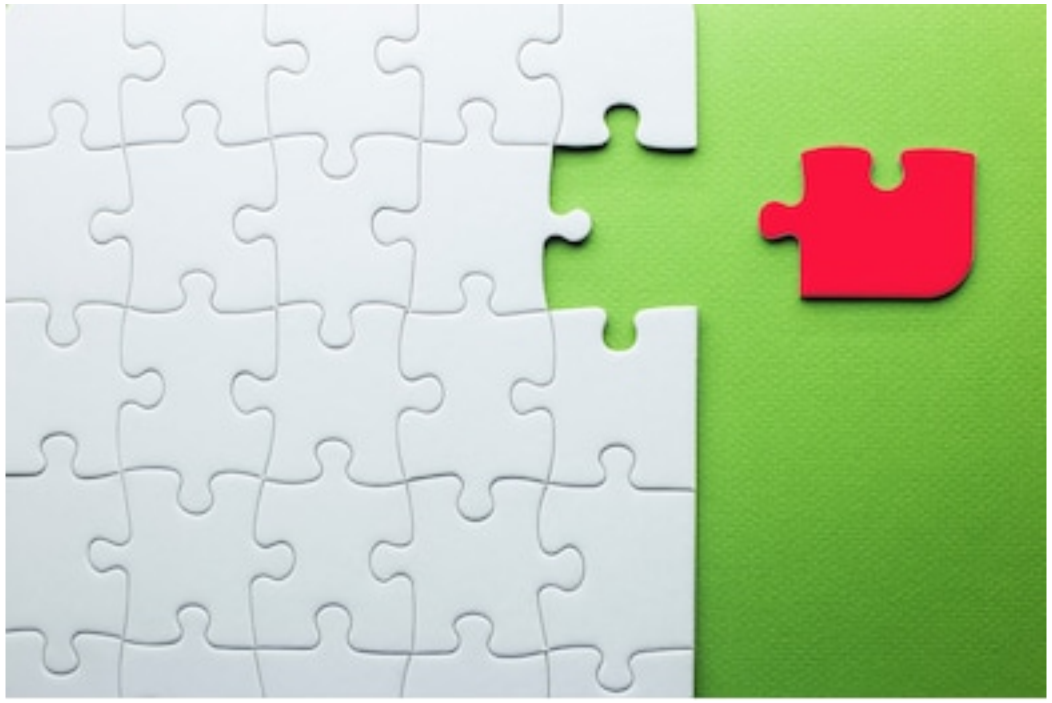
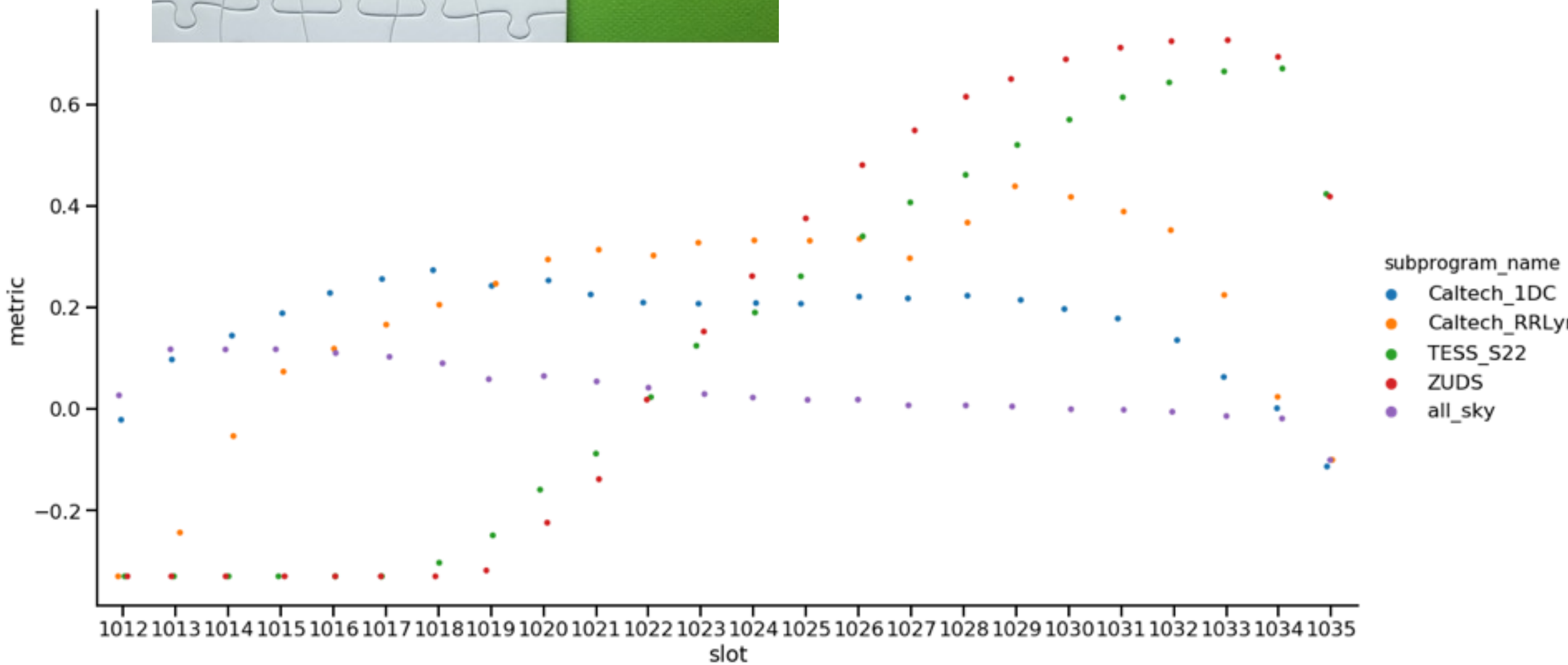
where possible, fallback time was used for reference building and grid-2 observations.

Independently-designed surveys don’t necessarily fit together….





What's new in Phase II? Survey changes…

MSIP → 50% of telescope time
single survey: 2-day cadence g+r
greater focus on completeness at low declination (LSST… 👀)

Partnership → 30% of telescope time
small set of surveys, to run for long periods

Caltech, 20% of telescope time
TBD

… scheduler improvements…

- ✅ within-night spacing of high-cadence observations
- ✅ improved treatment of low dec fields
- ✅ solver gives MSIP its exact allocation
- ✅ new capabilities for managing nightly survey footprints

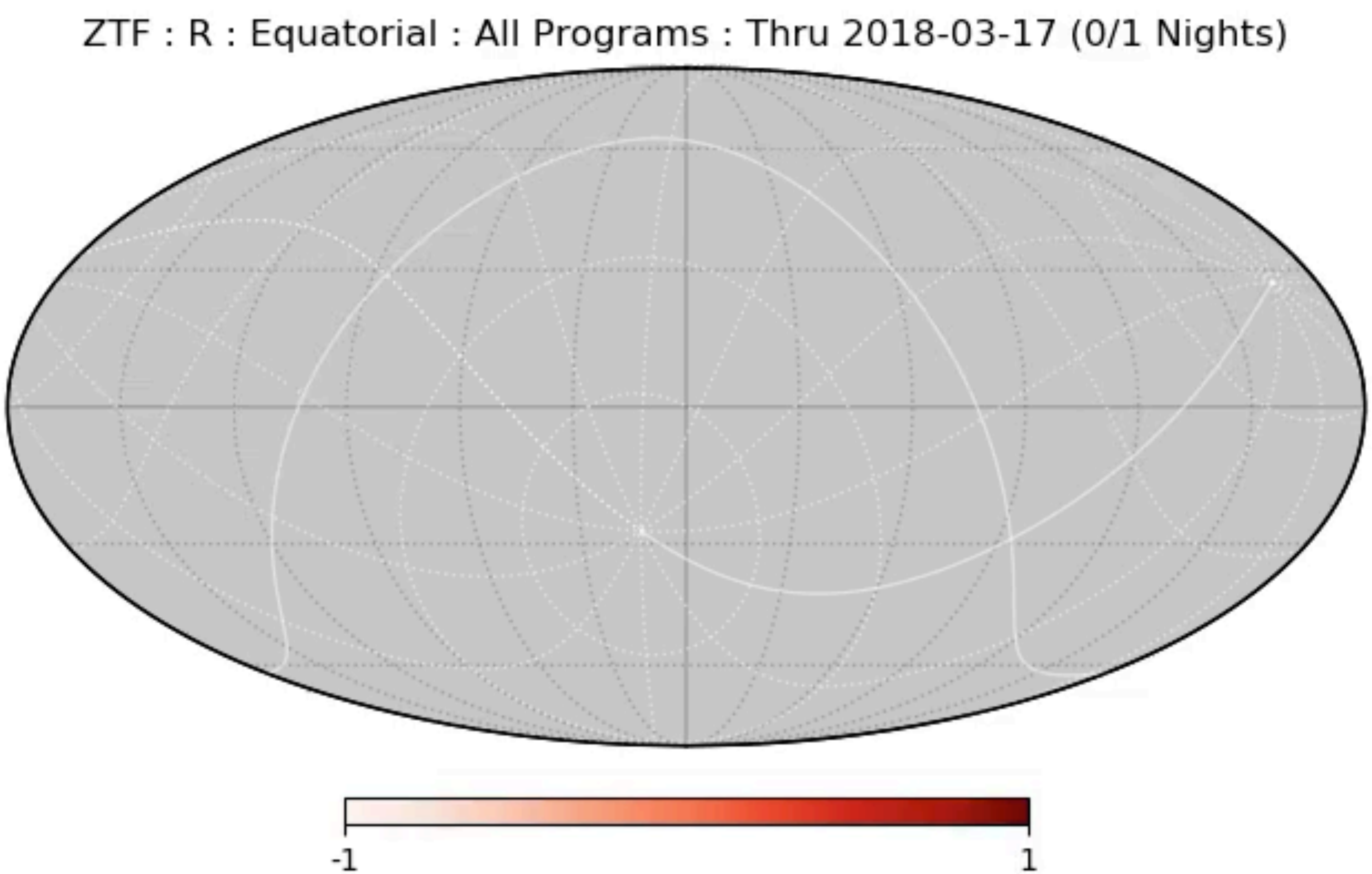
🛬 rescheduling missed observations

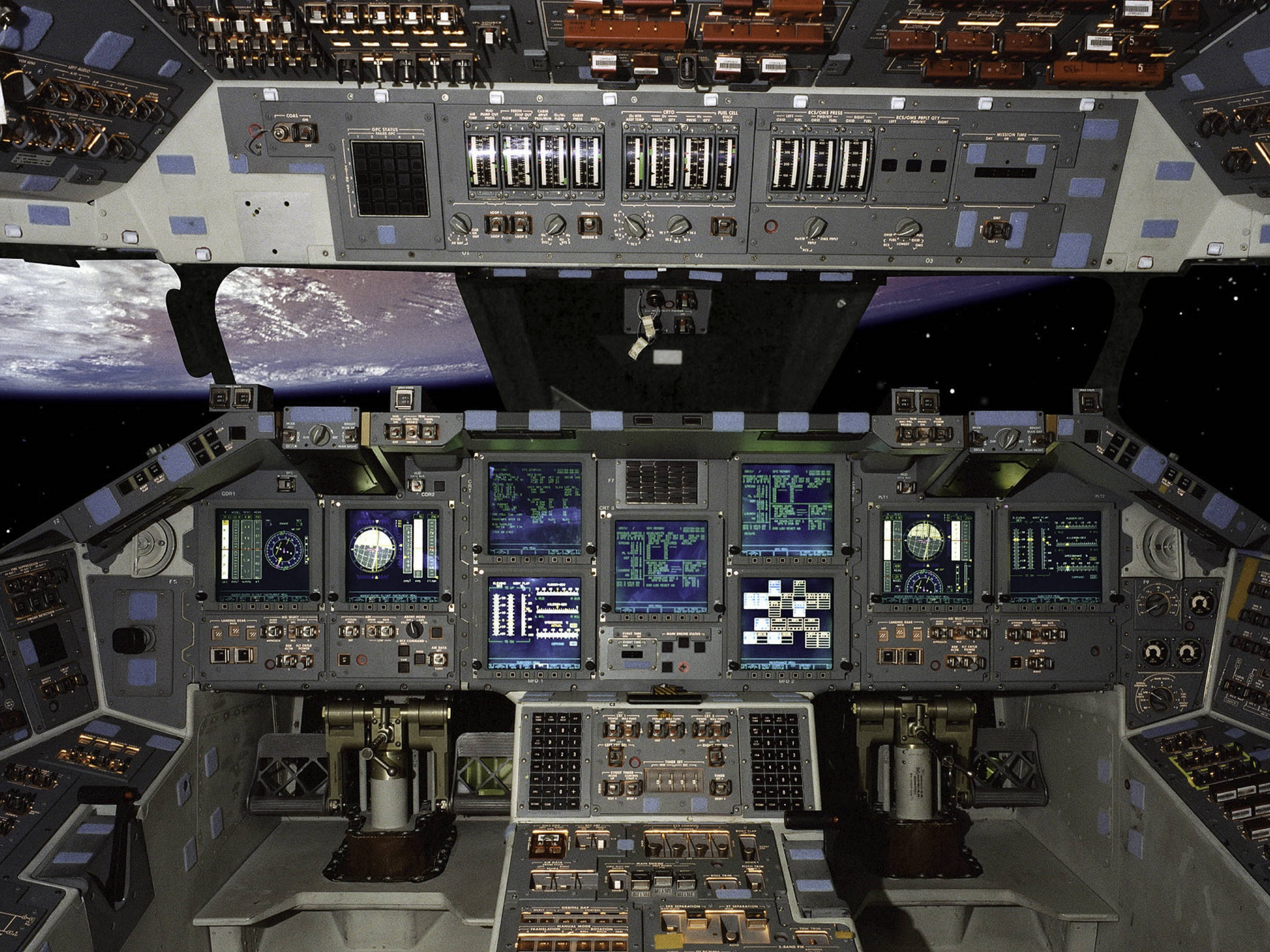
🚧 reporting public survey plans in advance
   - ➡️ inter-program scheduling now possible & allowed

💡 … your ideas?

… even better performance & more discoveries?

Simpler, longer-lived surveys
+ more automated schedule handling
+ better visualization and monitoring
+ more eyes on the survey?






Here’s to three years more surveying the sky together!

ZTF scheduling maximizes the volume surveyed:

Maximize volume surveyed per image:

$$V = \frac{4\pi}{3} d^3$$

$$\propto 10^{0.6 m_{\rm lim}}$$

(to maximize SNR, use $10^{0.8 m_{\rm lim}}$)

Limiting magnitude depends on:

filter, sky brightness, airmass, seeing

optimization algorithm

objective function

So: maximize the ***volume-weighted*** number of images observed in acceptable cadence windows.

constraints

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In Phase II: normalize the metric by its value when that field transits the meridian.

A grid approach enables a nightly solution.

Time Blocks

Request Sets (Fields)

		t_0	t_1	t_2	t_3	t_4	t_5	t_6	t_7
r_0 (gggg)									
r_1 (gggg)									
r_2 (gr)									
r_3 (gr)									
r_4 (i)									
r_5 (grg)									
r_6 (rgr)									

We use Integer Programming techniques to perform nightly optimization.

Bellm+ 2019b

V_{rtf} Volume factor for request field r at time t in filter f

Y_{rtf} ("yes") =1 if we observe r at t in f, 0 otherwise

maximize $$\sum_{r\in R}\sum_{t\in T}\sum_{f\in F} V_{rtf} Y_{rtf}$$

GUROBI OPTIMIZATION

subject to

$$\sum_{t\in T} Y_{rtf} \leq n_{rf} \;\forall\; r \in R, f \in F$$

number of requests in this set

$$\sum_{r\in R} Y_{rtf} \leq n_{\max} \;\forall\; t \in T$$

number of observations in this slot

And enforce one filter per slot + program balance

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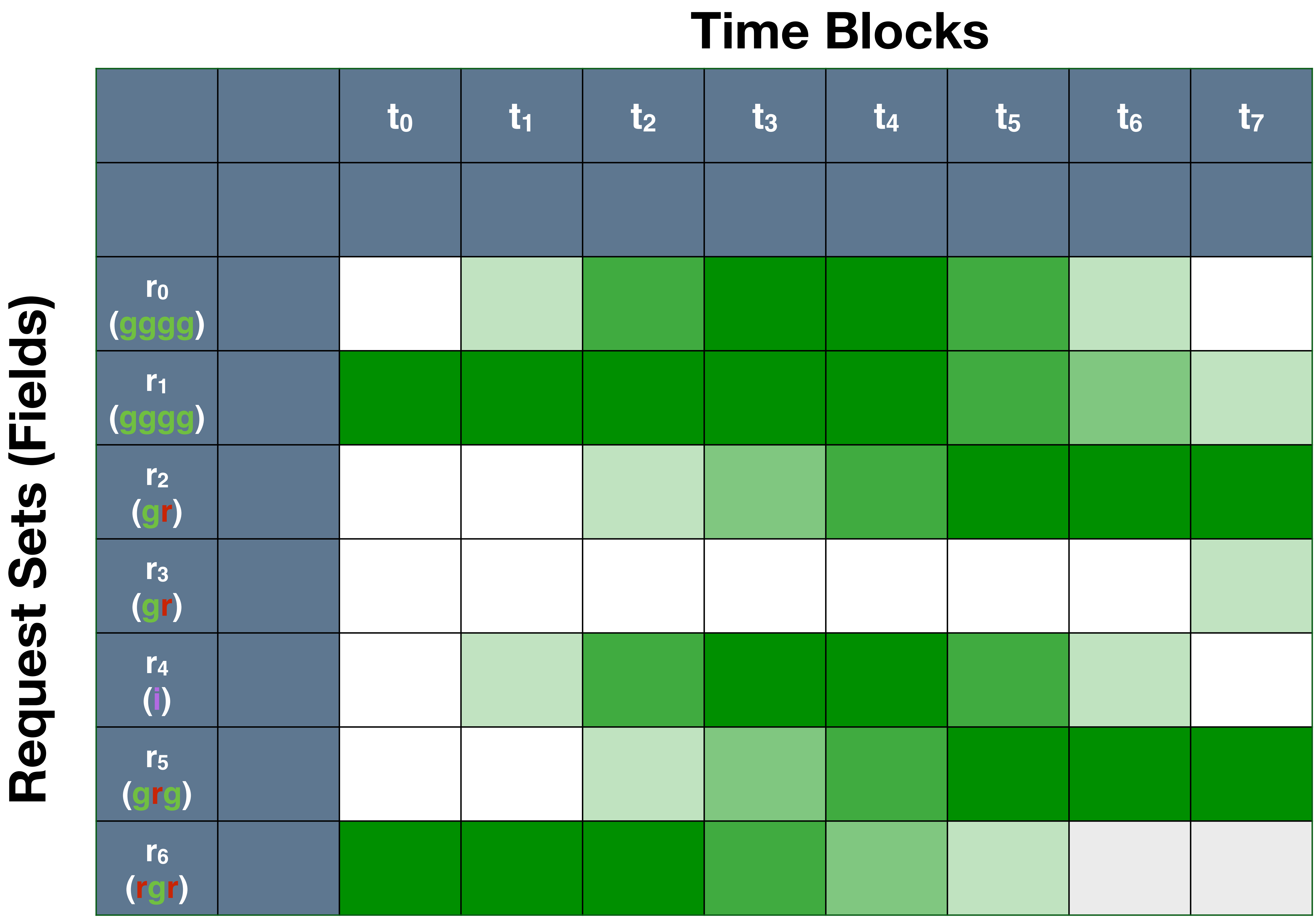

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Request Sets (Fields)

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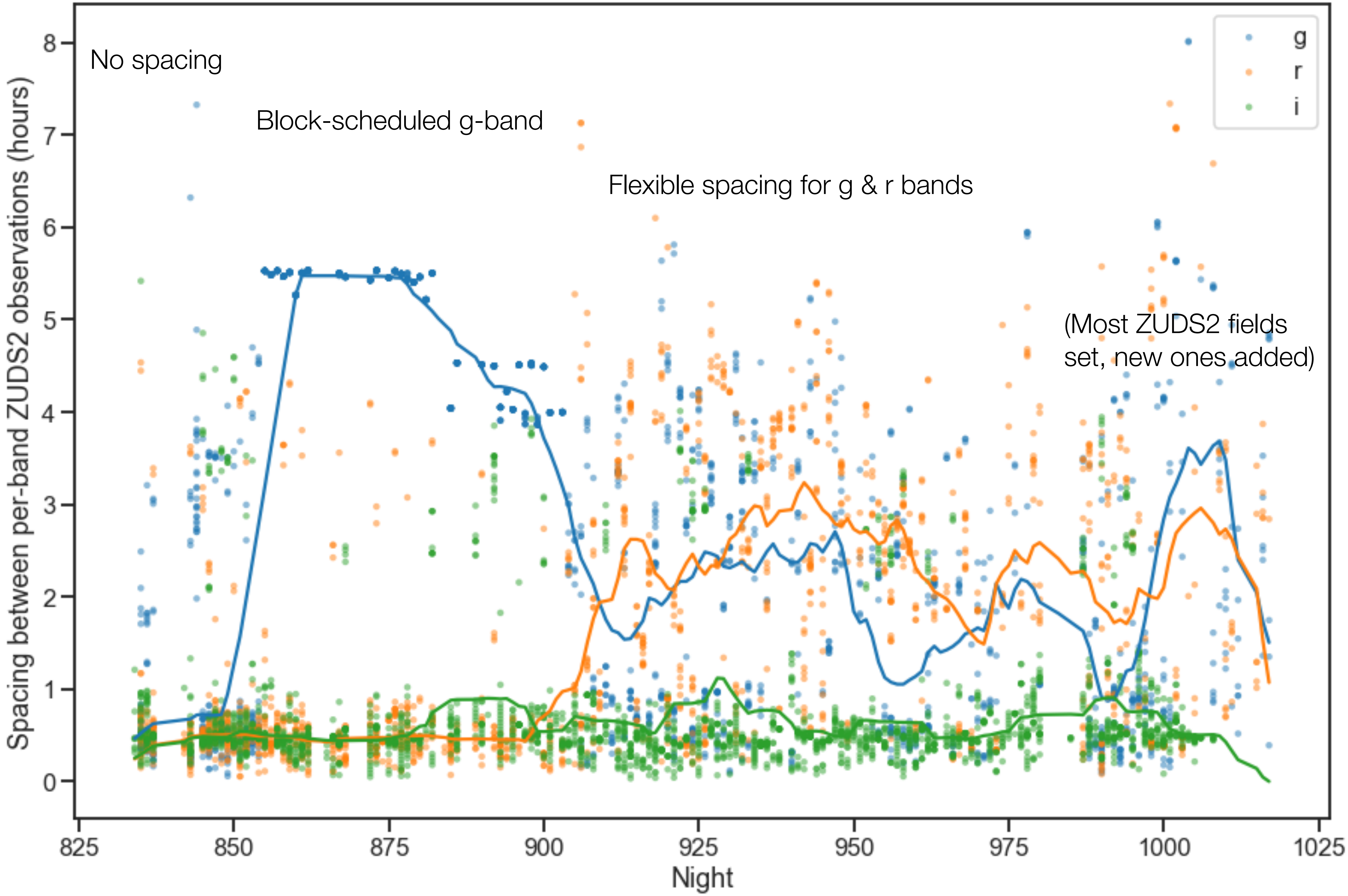
		g	r	g	g	i	g	g	r
r_0 (gggg)	Y_0=1			X	X		X	X	
r_1 (gggg)	Y_1=1	X		X	X		X		
r_2 (gr)	Y_2=1							X	
r_3 (gr)	Y_3=0								
r_4 (i)	Y_4=1					X			
r_5 (grg)	Y_5=1						X	X	X
r_6 (rgr)	Y_6=0								

Flexible intranight spacing of ZUDS2 worked effectively in practice.

points are pairwise per-band separations of one field;
lines are 12-day boxcar-smoothed medians



MSIP is now regularly observing at -31 deg declination.