ZTF Surveys & Performance

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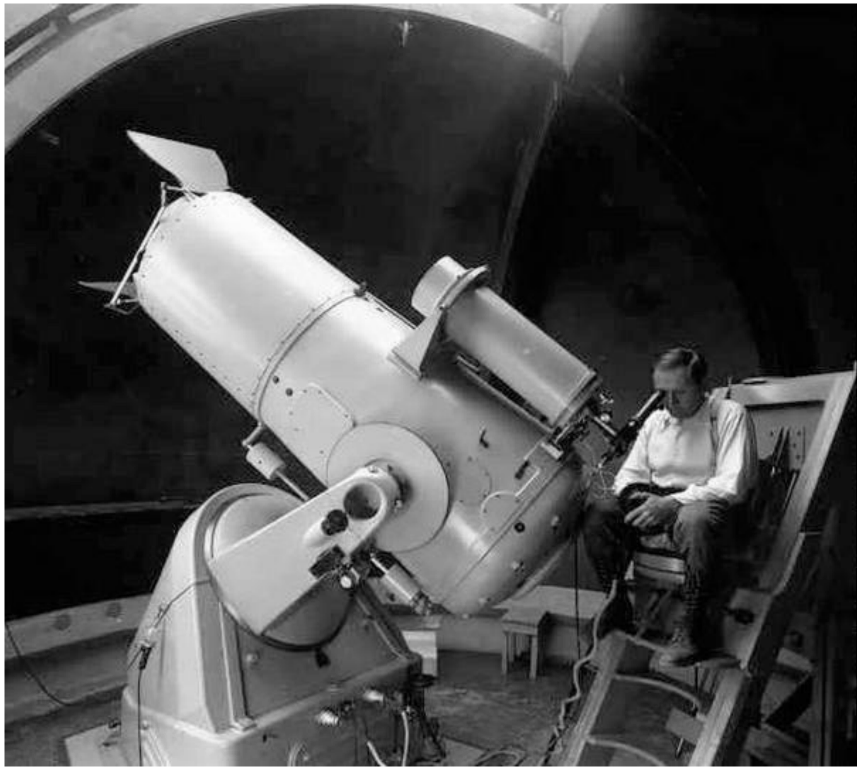
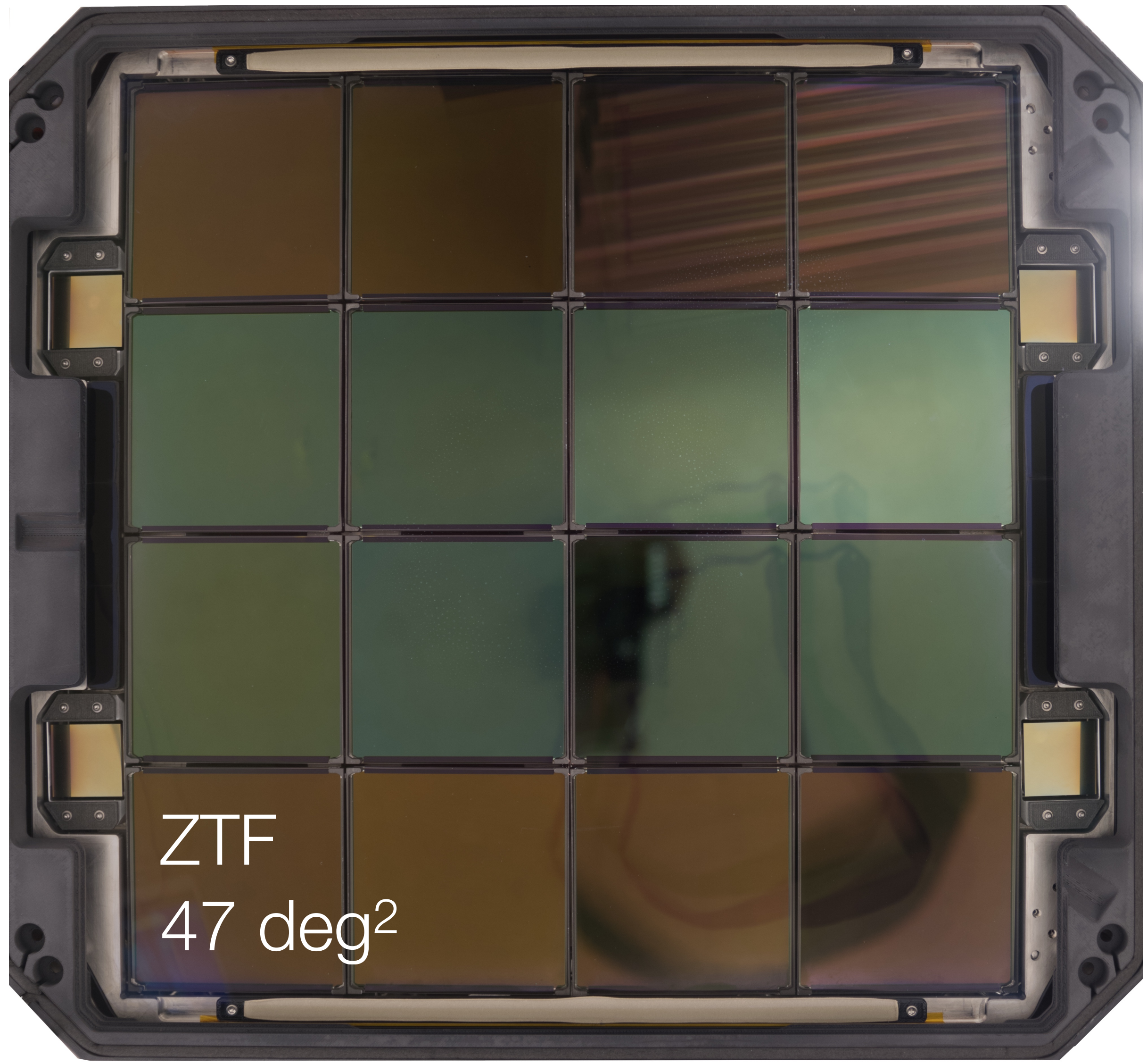


ZTF surveys with a powerful new wide-field camera.

	ZTF
Active Area	47.7 deg^2
Exposure Time	30 sec
Readout time	8.2 sec
Filters	g / r / i
Image Quality (FWHM)	2.1" / 2.0" / 2.1"
Limiting magnitude	20.8 / 20.6 / 19.9
CCDs	16x 6k x 6k 1.0"/pixel
Filter change time	~ 110 sec with slew to slow
Areal survey rate	4300 deg^2/hr



Bellm+ 2019a

A PASP Focus Issue provides key references for ZTF.

Publications of the Astronomical Society of the Pacific

https://zwicky.tf/3w9

The Zwicky Transient Facility

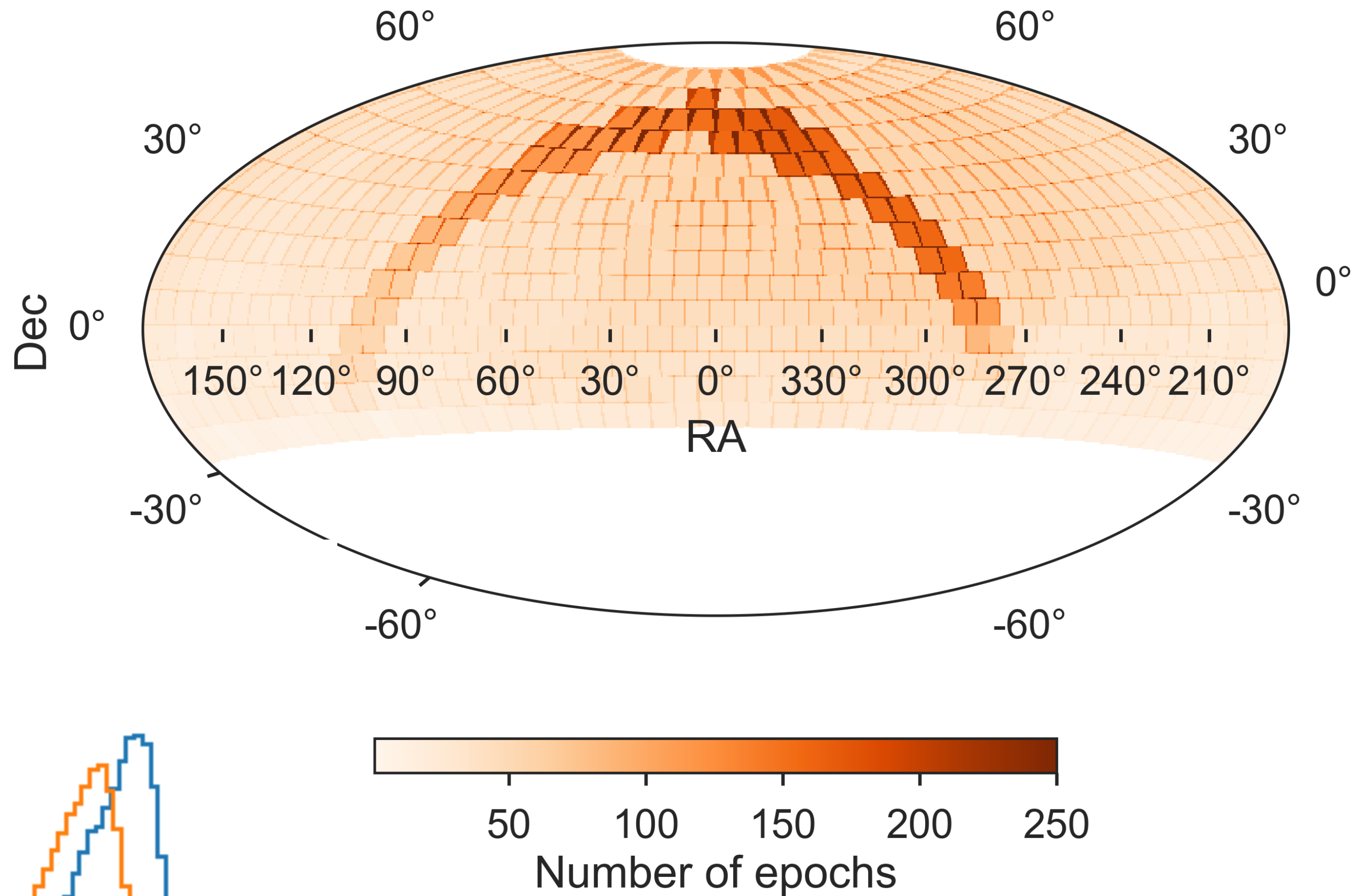
Eric C. Bellm, *University of Washington, USA*

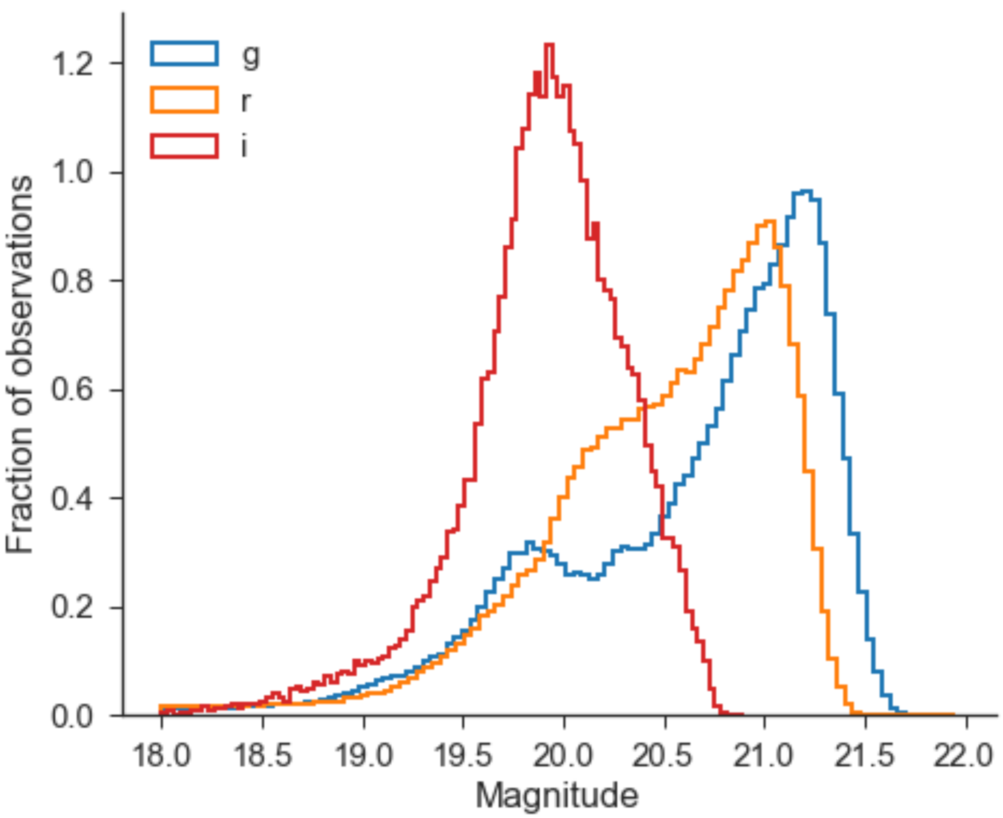
The Zwicky Transient Facility (ZTF) is a new optical time-domain survey using the 48 inch Schmidt Telescope at Palomar Observatory. An innovative new wide-field CCD mosaic camera provides a 47 square degree instantaneous field of view and fast readout time. This capability enables ZTF to conduct wide-area, high-cadence surveys designed to discover rare astrophysical transients, variables, and moving objects. A dedicated data system provides rapid reduction and near-real-time dissemination of public alerts that anticipate those of the Large Synoptic Survey Telescope. Articles in this focus issue present a broad overview of the ZTF project, including:

Credit: Caltech Optical Observatories

- Origins of and scientific motivations for the ZTF project
- Detailed system specifications
- Design of the camera and observing system
- Implementation of the data reduction pipelines and data archive
- Software tools developed to enable ZTF science, including the alert distribution system, machine learning classifiers, and web portals
- An overview of the planned ZTF surveys
- On-sky performance
- Expected scientific returns
- First scientific results

ZTF sources are well-matched for SDSS followup.





ZTF is conducting an unusually large number of surveys simultaneously.

Program	Survey	Total Area	Cadence
Public Surveys (MSIP; 40%)	Northern Sky Survey	23,675 deg^2	3 day cadence 1 g, 1 r
	Galactic Plane Survey	2800 deg^2	1 day cadence 1 g, 1 r
ZTF Collaboration Surveys (40%)	Extragalactic High Cadence Survey	3000 deg^2	4 day cadence 1 i
	i-band Survey	10,725 deg^2	1 day cadence 3 g, 3 r
	Target of Opportunity	Varies	Varies
	High-Cadence Plane Survey	~2100 deg^2	> 2.5 hours continuous, r
	Twilight Survey	N/A	4 r
	Asteroid Rotation Survey	N/A	> 25 r
Caltech TAC Surveys (20%)	Varies	Varies	Varies

We optimize ZTF for discovery.

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

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

Bellm 2016, Bellm+ 2019b

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optimization algorithm

objective function

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

observing strategy

Bellm 2016, Bellm+ 2019b

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)									

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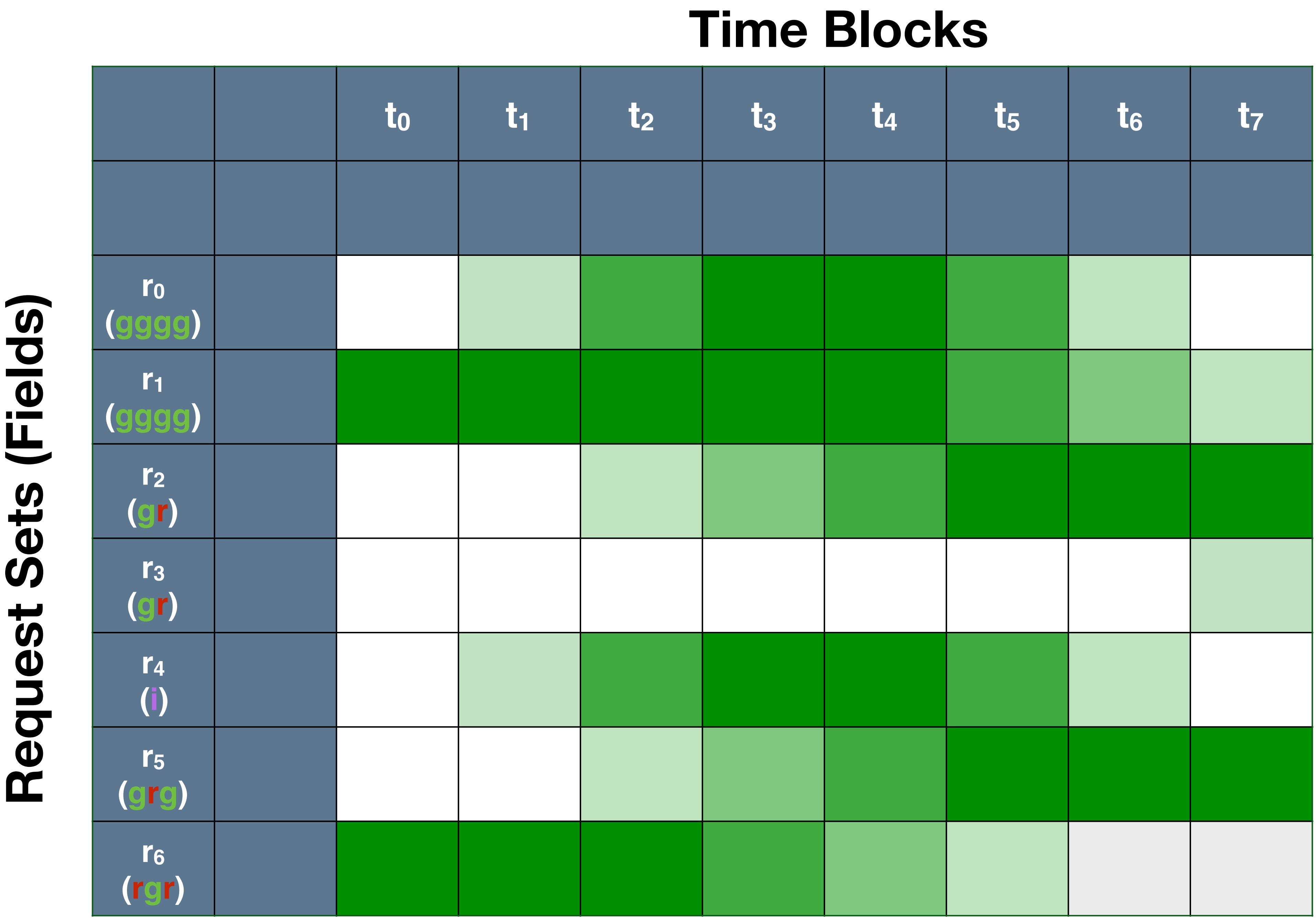


We use Integer Programming techniques to perform nightly optimization.

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

Bellm+ 2019b

And enforce one filter per slot + program balance

A grid approach enables a nightly solution.

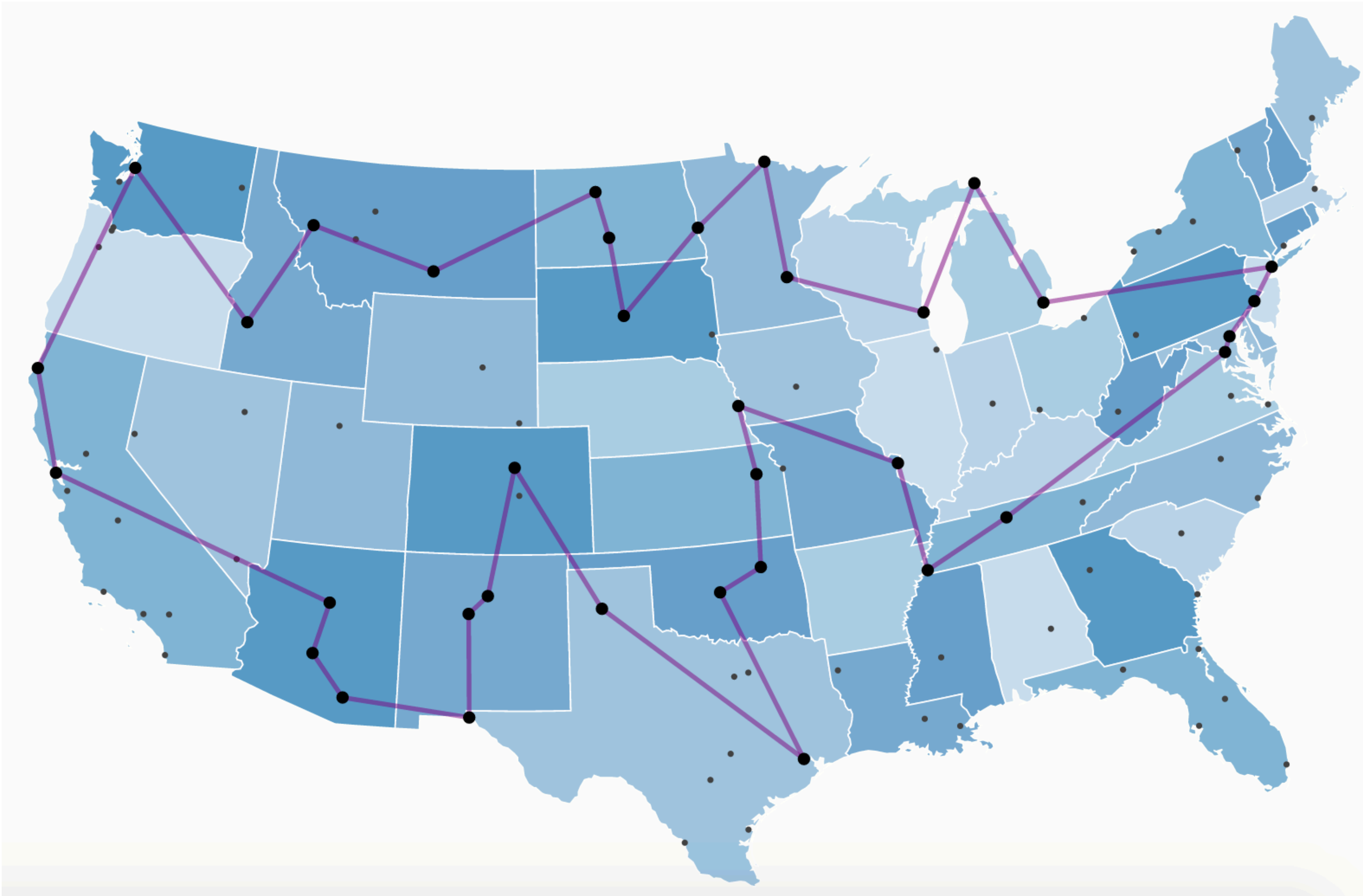
Time Blocks

Request Sets (Fields)

		t_0	t_1	t_2	t_3	t_4	t_5	t_6	t_7
		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)	$Y_6=0$								

Then we sequence each block by solving the TSP.

Distances defined by slew time between requests in this block.



HA and Declination slews don't change with slot, but dome slews do.

Optimization requires tradeoffs!

Strengths:

obtains requested observations exactly

maintains cadences

uses lookahead to schedule observations for best conditions

treats surveys uniformly

maintains balance between programs

minimizes slew time*

Weaknesses

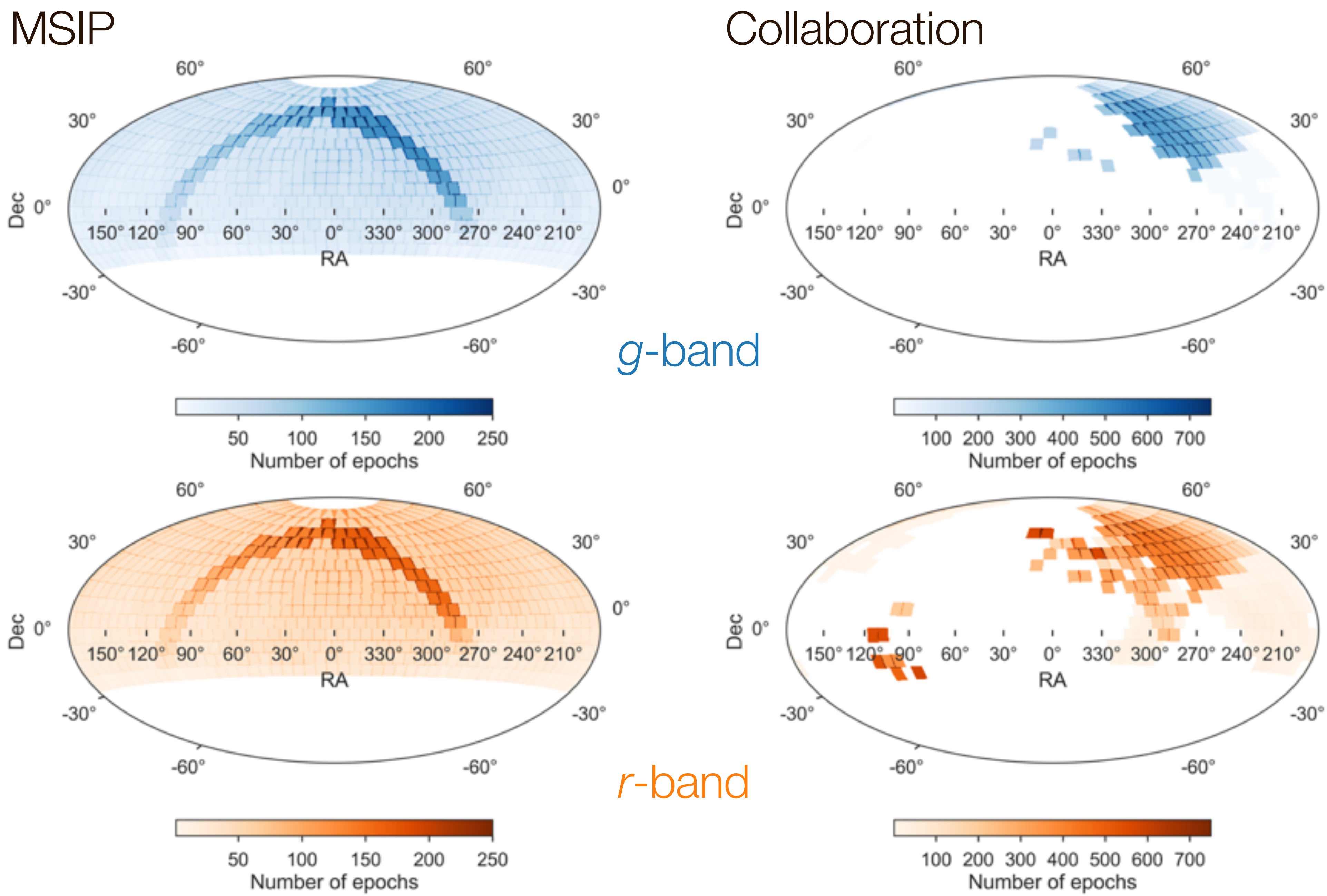
cannot guarantee filter order within the night

cannot enable specifying exact times between observations*

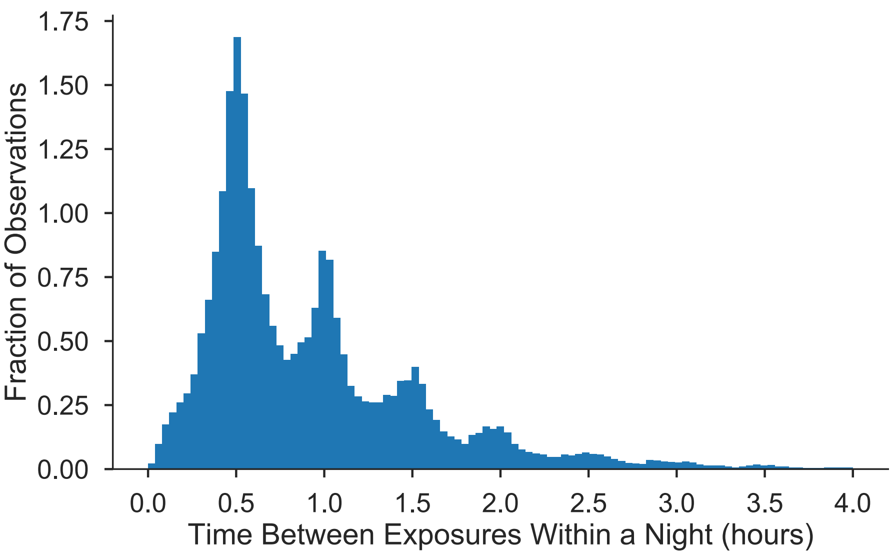
does not always fill all observing time

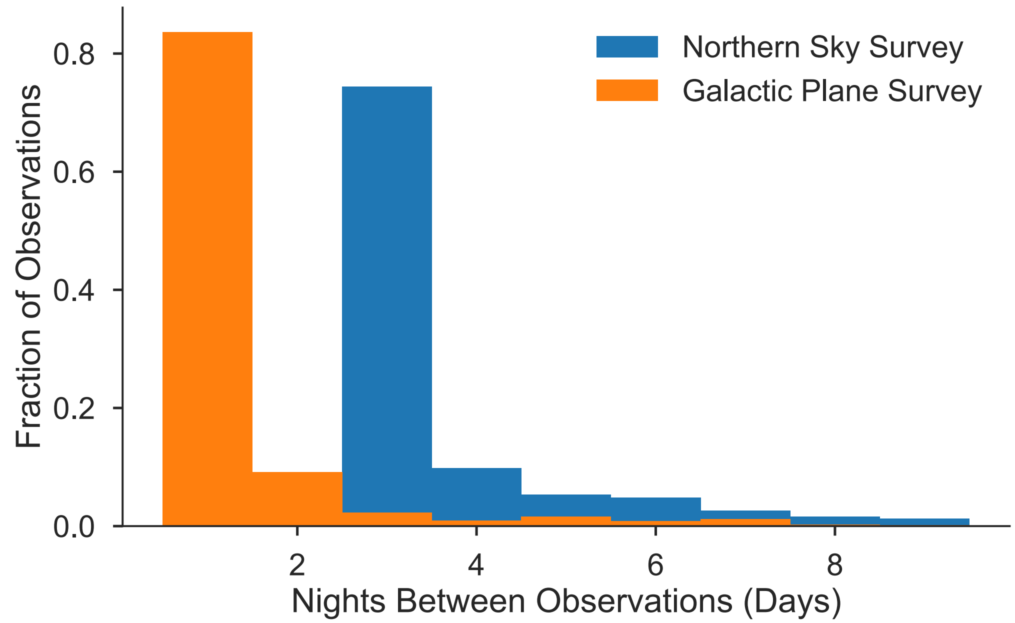
does not (yet) dynamically adapt to clouds, seeing, etc.

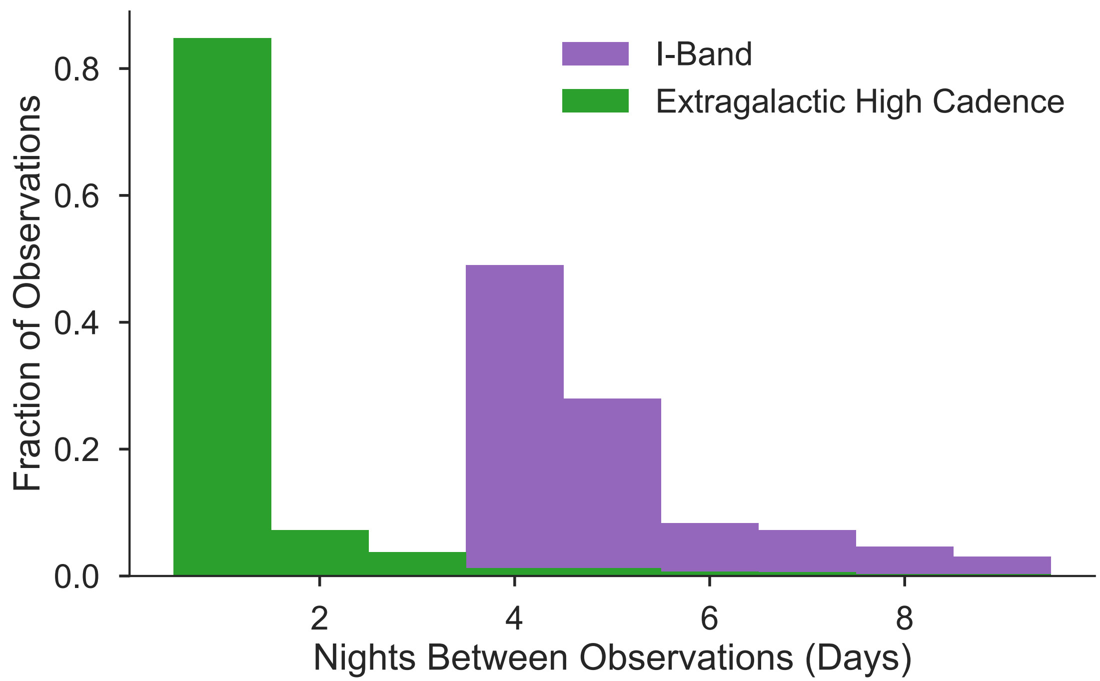
ZTF provides extensive coverage of the Northern sky.



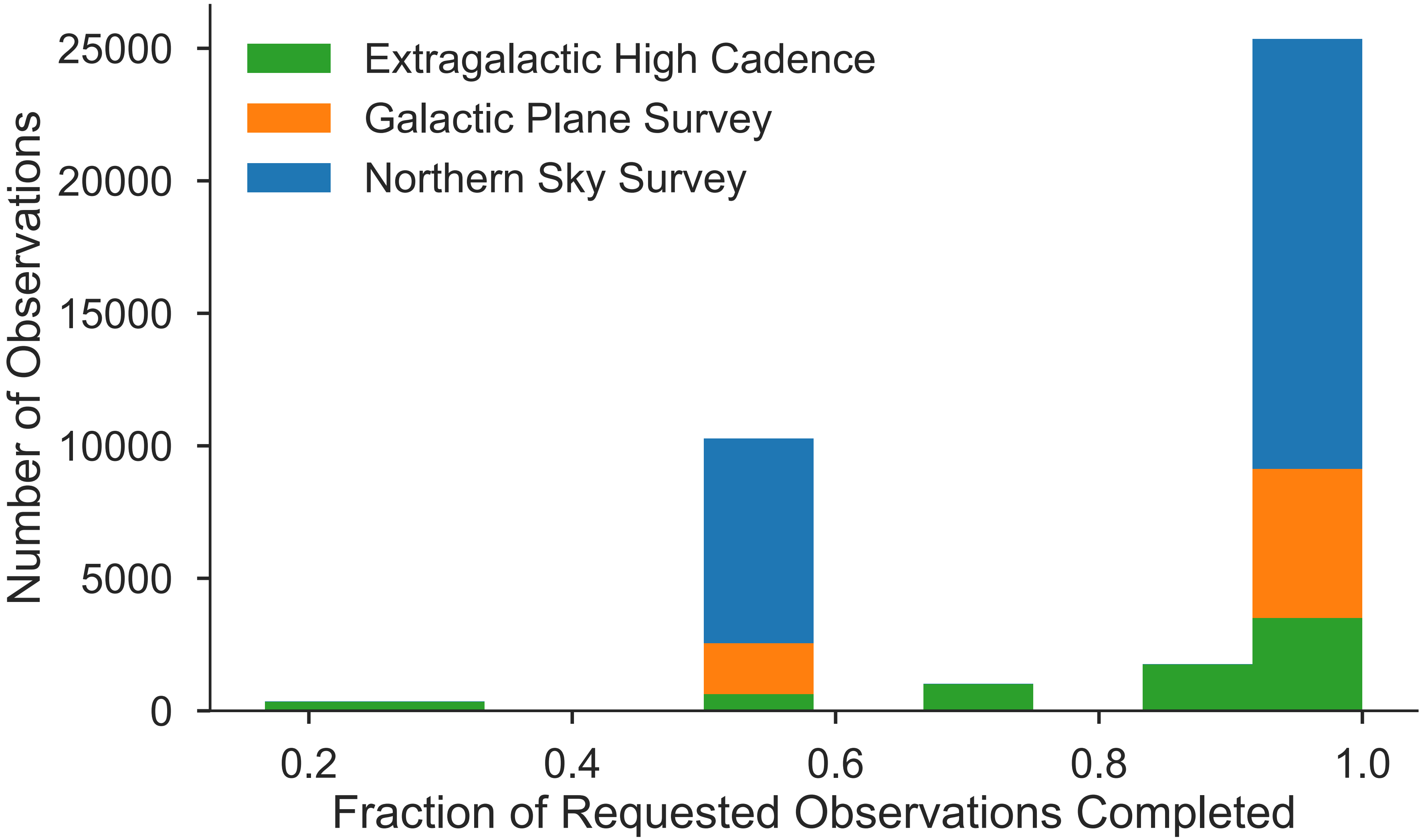
A variety of simultaneous observing programs can be conducted.







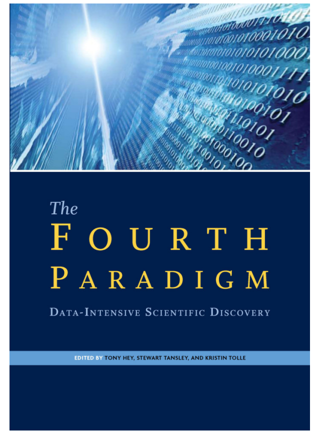
Sequence completion is very high.



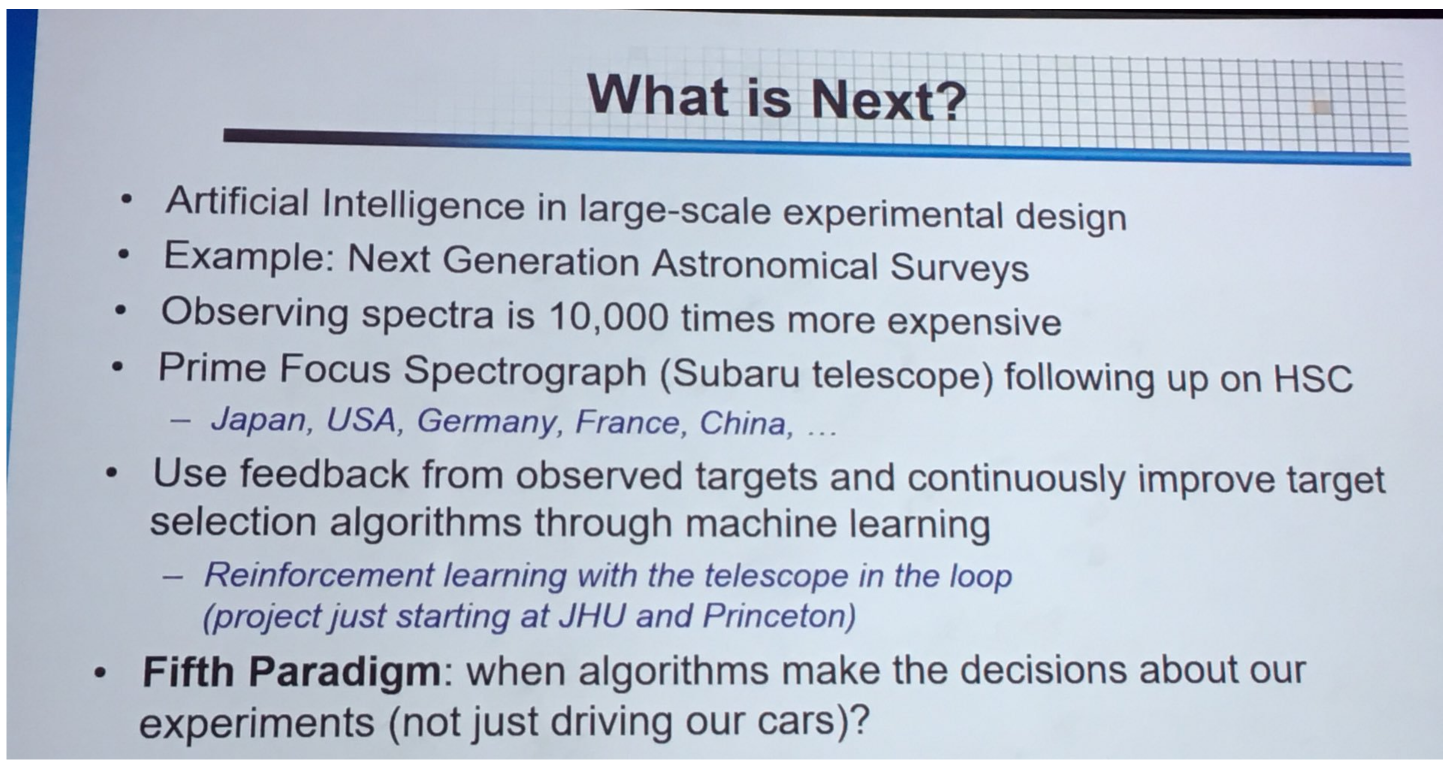
ZTF II x SDSS V: The Fifth Paradigm?

Scientific Paradigms:

1. Observation
2. Analytic Theory
3. Computational Science
4. Data-Intensive Science
5. **Algorithmically-Driven Science ("Self driving surveys")**



Alex Szalay



Conclusions

ZTF is conducting a powerful time-domain survey across the Northern Hemisphere Sky, with hundreds of epochs yearly in three bands

Image depths make ZTF sources well-matched to SDSS-V followup

The ZTF scheduler can deliver multiple simultaneous time-domain surveys simultaneously

The future of surveys is algorithmic!
Could ZTF-II and SDSS-V scheduling be coupled?