

# Cadence Studies with

ztf\_sim

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# ztf\_sim development is underway.

[https://github.com/ZwickyTransientFacility/ztf\\_sim](https://github.com/ZwickyTransientFacility/ztf_sim)

Already has:

- telescope state machine

- realistic field grids (from Eran)

- weather losses (from PTF & iPTF)

- exports pointing history to LSST MAF

- flexible cadence specification with access to pointing history

- simple greedy scheduler

Immediate priorities:

- sky brightness calculations

- airmass contribution to SNR

# It helps to break down the problem.

<b>Constraints</b>	site, telescope, & camera properties 40/40/20 observing time split
<b>High-level Goals</b>	e.g., roughly equalize # of epochs in g & r split time between two pointing grids
<b>Observing Programs</b>	“TILU”, “Wide Load”, MSIP NSS & GPS,...
<b>Nightly Field Selection</b>	(Tom Barlow)
<b>Sequencing</b>	objective function + algorithm
<b>Observation</b>	
<b>(Recomputes)</b>	
<b>Cadence Analysis</b>	open shutter time, slew distance, airmass distribution, cadence histograms...

# It helps to break down the problem.

<b>Constraints</b>	<b>site properties</b>
<b>High-level Goals</b>	Dec range weather seeing
<b>Observing Programs</b>	
<b>Nightly Field Selection</b>	<b>telescope properties</b> slew rates
<b>Sequencing</b>	<b>camera properties</b> readout time
<b>Observation</b>	filter selection filter exchange overhead
<b>(Recomputes)</b>	<b>40/40/20 observing time split</b>
<b>Cadence Analysis</b>	

# It helps to break down the problem.

Constraints	<p><b>some <i>ideas</i></b></p> <p>build reference images all-sky at the start of the survey</p> <p>equalize # of observations in g &amp; r</p> <p>get near-simultaneous colors—or not</p> <p>split time between two pointing grids</p> <p>cover the whole sky every few days</p> <p>obtain roughly equal exposures per field yearly</p> <p><b><i>your ideas</i></b></p>
<b>High-level Goals</b>	
Observing Programs	
Nightly Field Selection	
Sequencing	
Observation	
(Recomputes)	
Cadence Analysis	

# It helps to break down the problem.

Constraints	<b>specifies set of fields, cadence</b> (including plan for missed visits!)
High-level Goals	
<b>Observing Programs</b>	“observe the sky above $X > 2$ in two epochs/night separated by 1 hour”
Nightly Field Selection	iPTF examples: TILU, Wide Load
Sequencing	Collaboration, MSIP, and Caltech TAC will have (at least) one program each
Observation	MSIP Northern Sky Survey, Galactic Plane Survey
(Recomputes)	
Cadence Analysis	<i>need a few different ideas to simulate</i>

# What are the relevant limits?

## **Sky area:**

Dec > -30: 3pi survey (30,835 deg<sup>2</sup>)

## **Observing time** (12 degree twilight and darker):

12.2 hours (winter solstice) - 7.6 hours (summer solstice)  
(40% time for MSIP: 4.9-3.0 hours)

## **Total nightly sky** ( $X > 2.2$ ):

27k deg<sup>2</sup> (winter) - 21k deg<sup>2</sup> (summer)

## **Time to survey visible sky:** (45 sec/exposure)

7.2 hours (winter) - 5.6 hours (summer)

## **=> Cadence for an “all sky” MSIP survey with 2 exp/night:**

3 days (winter) - 4 days (summer)

# It helps to break down the problem.

Constraints	“spherical cow” schedule to simulate?
High-level Goals	<b>MSIP</b> : 2x/night, 3-4 day cadence
<b>Observing Programs</b>	<b>Collaboration</b> : hourly cadence? (3x-5x/night)
Nightly Field Selection	rotate each night—5-7 night revisits
Sequencing	<b>Caltech</b> : random field selection? TOOAs?
Observation	<i>filter distribution? perturbations?</i>
(Recomputes)	
Cadence Analysis	



# It helps to break down the problem.

Constraints

High-level Goals

Observing Programs

**Nightly Field Selection**

Sequencing

Observation

(Recomputes)

Cadence Analysis

**Tom Barlow**

which fields in the observing programs get assigned to a night?

Tries to interleave programs for efficiency, account for weather forecast

for ztf\_sim, have to simulate this function: *ideas welcome*

For actual ZTF survey, can still use human

# It helps to break down the problem.

**Constraints**

**spherical cow simulation:**

**High-level Goals**

**MSIP:** prioritize oldest fields

**Observing Programs**

**Collaboration:** maintain strict rotation

**Nightly Field Selection**

**Caltech:** (random)

**Sequencing**

**Observation**

**(Recomputes)**

**Cadence Analysis**

# It helps to break down the problem.

Constraints

High-level Goals

Observing Programs

Nightly Field Selection

**Sequencing**

Observation

(Recomputes)

Cadence Analysis

in what order are nightly fields observed?

PTF: Eran's greedy algorithm

iPTF: Tom Barlow

NP-hard optimization problem!

*worse than Traveling Salesman*

time-varying costs & values;

time windows; scheduling-time

dependencies; multiple programs

need:

(scalar) objective function

optimization algorithm

# It helps to break down the problem.

Constraints

High-level Goals

Observing Programs

Nightly Field Selection

Sequencing

Observation

(Recomputes)

Cadence Analysis

## Objective function

Maximize volume (/SNR)-weighted number of fields observed in specified cadence windows

$$V \propto D^3 \\ \propto 10^{0.6m_{\text{lim}}}$$

## Self-consistently includes:

airmass

moon brightness & distance, filter

twilight

slew times

(seeing)

# It helps to break down the problem.

**Constraints**

**High-level Goals**

**Observing Programs**

**Nightly Field Selection**

**Sequencing**

**Observation**

**(Recomputes)**

**Cadence Analysis**

**optimization algorithm**

simple greedy algorithm, for now

will explore more advanced approaches later

slot-based lookahead

literature approaches include  
tabu search, ant colony optimization,  
simulated annealing, genetic  
algorithms...

# It helps to break down the problem.

<b>Constraints</b>	<b>simulated observations</b> PTF/iPTF weather losses realistic telescope dynamics (eventually: TOO interrupts)  Goal: interface with real observing system
<b>High-level Goals</b>	
<b>Observing Programs</b>	
<b>Nightly Field Selection</b>	
<b>Sequencing</b>	
<b>Observation</b>	
<b>(Recomputes)</b>	
<b>Cadence Analysis</b>	

# It helps to break down the problem.

<b>Constraints</b>	Greedy algorithms recompute continuously
<b>High-level Goals</b>	
<b>Observing Programs</b>	Others require consideration of recompute intervals:
<b>Nightly Field Selection</b>	iPTF: nightly “recomputes” (Tom Barlow)
<b>Sequencing</b>	recompute at block intervals (20 minutes?)
<b>Observation</b>	respond to TOO, weather losses, actual sequence of observations
<b>(Recomputes)</b>	
<b>Cadence Analysis</b>	

# It helps to break down the problem.

<b>Constraints</b>	<b>technical metrics</b>
<b>High-level Goals</b>	objective function
<b>Observing Programs</b>	open shutter time
	slew distance histogram
	observing sequence completion
<b>Nightly Field Selection</b>	<b>science metrics</b>
	transient discovery
	lightcurve sampling
<b>Sequencing</b>	period recovery
<b>Observation</b>	<i>your ideas needed here!</i>
<b>(Recomputes)</b>	<b>LSST MAF; astrobject</b>
<b>Cadence Analysis</b>	<i>can't optimize everything! use metrics to understand tradeoffs.</i>



# Your ideas will guide development.

High-level goals

Observing Programs

Cadence Analysis