

# Science-Driven Optimization of the LSST Observing Strategy







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- Highlights from the ongoing Observing Strategy study:
  - Humna Awan Large Scale Structure
  - Eric Bellm Transients
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  - Will Clarkson The Milky Way
  - Josh Meyers Weak Lensing
- Wrap-up

## The LSST Observing Strategy Community White Paper

Phil Marshall

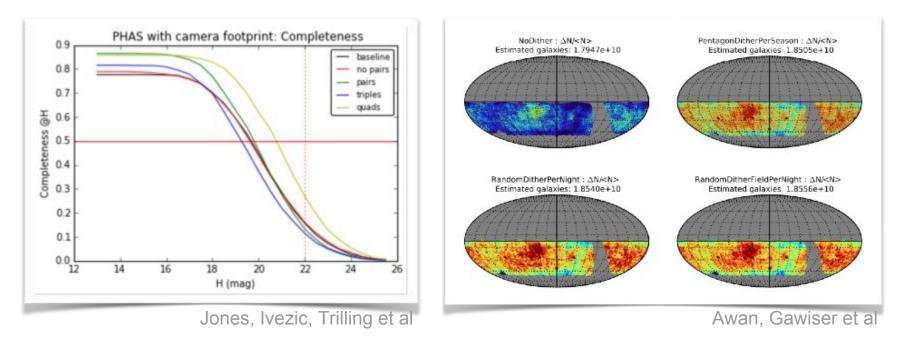
11:02am

LSST PCM, August 2016, Tucson



## LSST Science Depends on our Observing Strategy



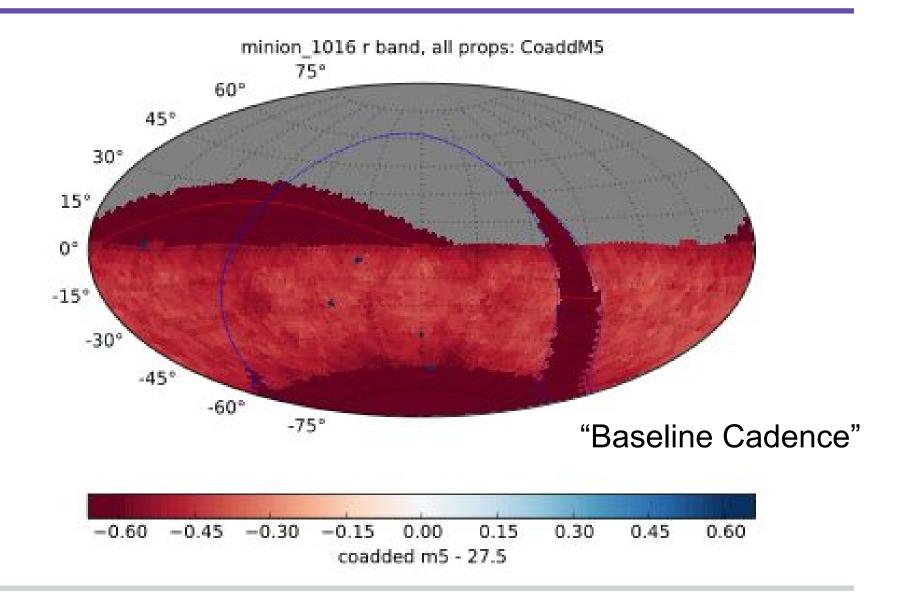


#### For example:

- Recovering the orbits of fast-moving asteroids needs multiple visits per night
- Cosmological galaxy clustering and weak lensing signals and systematics depend on catalog uniformity

### The LSST OpSim Sky







- The baseline observing strategy has been improving over time through a sequence of OpSim experiments
- Optimization of the LSST observing strategy must be science-driven
- To date, this has been achieved by reference to the science requirements captured in the SRD
- We can refine this optimization by actually testing the observing strategy against our science goals



- Science-based evaluation of a given OpSim realization of a particular observing strategy is enabled by the Project Sims team's "Metric Analysis Framework" (MAF)
- The success of any planned science project can be quantified by a **Figure of Merit** of the kind regularly used in the bottom line of observing proposals
- These Figures of Merit will likely depend on lower-level **diagnostics**, that summarize the OpSim output observing pattern ("cadence") in various useful ways
- Both Figures of Merit and diagnostics can be coded as MAF "Metrics"

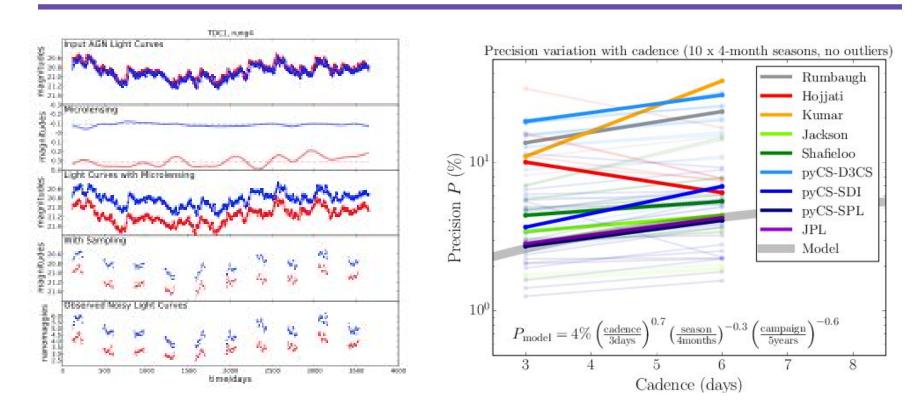


Science Case: collect hundreds of strongly lensed quasars, measure their time delays, and use each of them to probe cosmological distance with ~5% precision.

- A good **Figure of Merit** is the *precision in the final inferred Dark Energy parameters*
- A **proxy** for this FoM is the mean precision in the lens time delays measured from the light curves
- How well we can measure lensed quasar time delays from LSST light curves will depend on the *season length, mean inter-night gap, and campaign length* these summaries are **diagnostics**

### **Example: Strong Lenses**

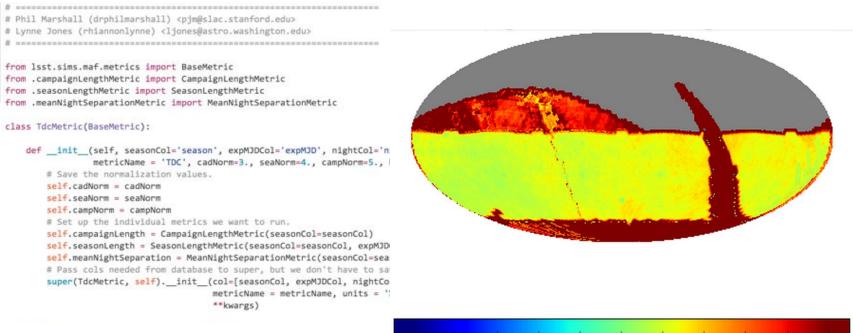




In the Time Delay Challenge project we simulated 1000s of mock light curves with model cadences defined in terms of the 3 diagnostic metrics, and derived a simple model for how the time delay precision we found depends on them.

### **Example: Strong Lenses**





#### MAF metric analysis:

0.500 1.000 1.500 2.000 2.500 3.000 3.500 4.000 4.500 5.000 TDC\_Precision (%)

- Simple precision model was coded as a "complex metric," dependent on the simpler diagnostic metrics
- MAF interacts with OpSim output database and enables standard visualizations and summaries



### **Better Together**

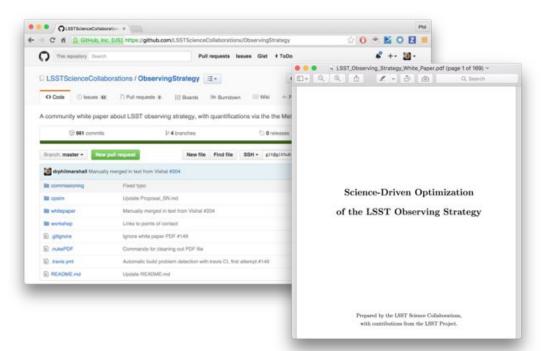
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O Code (1) Issues #	8 [] Put requests #     Bor	irds M Burndov	wn W	N 44			
Community white pap	er about LSST observing strateg	y, with quantifica	ations via th	ie the Met			
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III opsim	Update Proposal_SN.md				Science-Dr	iven Optin	nization
III whitepaper Manually merged in test from V		Vishal #204		of the LSST Observing Strategy			
workshop	Links to points of contact						
D gtignore	Ignore white paper PDF #148						
D marph	Commands for cleaning out Pl	of the					
E travis yml Automatic build problem detection with Inwis CI, first attempt #149							
	Update README.md						
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Doing our metric analyses as a community allows us benefit from sharing our MAF expertise, and to identify tensions and trade-offs early so we can work through them together ("cadence diplomacy") - and so provide good information to the Project and Science Advisory Committee

## **A Community White Paper**



Goal: a set of science cases, each quantified in terms of a Figure of Merit (or proxy) and a set of diagnostics, coded in the MAF, and leading to actionable conclusions.



All contributions welcome at

85 authors, 30+ science cases

https://github.com/
LSSTScienceCollaborations/ObservingStrategy



- The White Paper is designed to be a "living document," functioning as a work of reference for the Project, a common structure for a time-heterogeneous set of analyses, and a focus for its community
- Journal articles are being spun off from its sections and published by the science teams as we go
- "Version 1" of the White Paper is close to completion: we are aiming to post this to the arxiv (to advertize and accredit), following LSST Pub Board review
- We need important LSST science cases to be represented quantitatively and continuously as the observing strategy is discussed and evolved

## Update from the Sims Team

Zeljko Ivezic

11:15am

LSST PCM, August 2016, Tucson



### **Cadence-related Resources**



Last presentation to the SAC from April 2014: http://ls.st/q6r

#### **Outline:**

- 1) General cadence considerations
- introduction: flow-down of science goals
- cadence "conservation laws"
- 2) Baseline cadence
- basic characteristics
- possible modifications
- 3) Tools for further refinements
- OpSim and MAF
- 4) Mechanisms for changing the cadence- SAC, PST, Project Scientist
- 5) Getting community input
- cadence workshop series

All the talks from the August 2015 LSST Observing Strategy workshop in Bremerton are available from http://ls.st/kaq

Another potentially interesting related talk about "SRD constraints on LSST cadence parameters" from the last LSST Scheduler Workshop (Tucson, March 18-19, 2015): http://ls.st/u2u

OpSim entry point: http://ls.st/idp

MAF entry point: http://ls.st/ed6





The Project's "Operations Simulator," *OpSim*, attempts to emulate the survey scheduler and generate a database of *visit image metadata*: observation MJD, filter, observing conditions and so on.

OpSim follows a *greedy algorithm* to minimize a *cost function* that includes total overheads as well as deviation from a set of "proposals" that define the different components of the survey.

Each OpSim output database constitutes one realization of a particular observing strategy, or "cadence"





#### 1) New baseline cadence: minion\_1016

- Basic characteristics
- Known problems

#### 2) Preliminary cadence exploration

- Variations on the baseline cadence
- NEO optimization

#### 3) Update on OpSim/Scheduler development

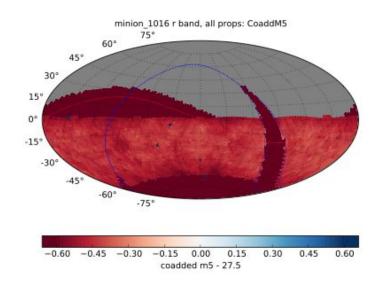


OpSim run **minion\_1016** (machineName\_runNumber) was proposed to the LSST Change Control Board to be adopted as the new baseline cadence.

It replaces the old baseline cadence, called **opsim3.61** 

Some old bugs (e.g. the "10-th year panic") are now fixed, but there are remaining known problems (e.g. the sky brightness model, the "western bias"). Baseline Cadence: minion 1016





#### Total number of visits: 2,447,931

85.1% DWF, 6.5% North Ecliptic, 1.7% Galactic Plane,2.2% South Celestial Cap, 4.5% DDF.

Mean number of filter changes per night: 4.3

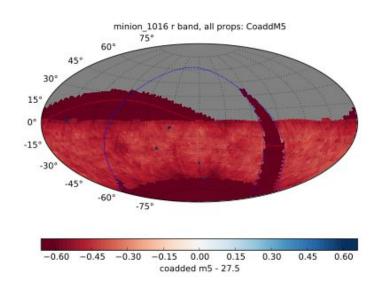
## Median visits per night: 816 303 observing nights/year.

18,000 sq.deg. received at least 888 visits per field, 8% higher than SRD

Mean slew time: 6.8 seconds. Survey efficiency: 73% (median total open shutter time per night divide by total observing time including readout and slew).

### Baseline Cadence WFD area: minion\_1016





#### 2,293 (overlapping) fields.

r band medians: IQ (FWHM): 0.78" airmass: 1.20, 5σ point source depth: 24.15

## Median no. of visits in *ugrizy*: (62, 88, 199, 201, 180, 180), ~10% higher than SRD.

Median trigonometric parallax and proper motion errors are 0.57 mas and 0.16 mas/yr, for bright sources and 5.5 mas and 1.6 mas/yr for point sources with r = 24

## Preliminary Cadence Exploration

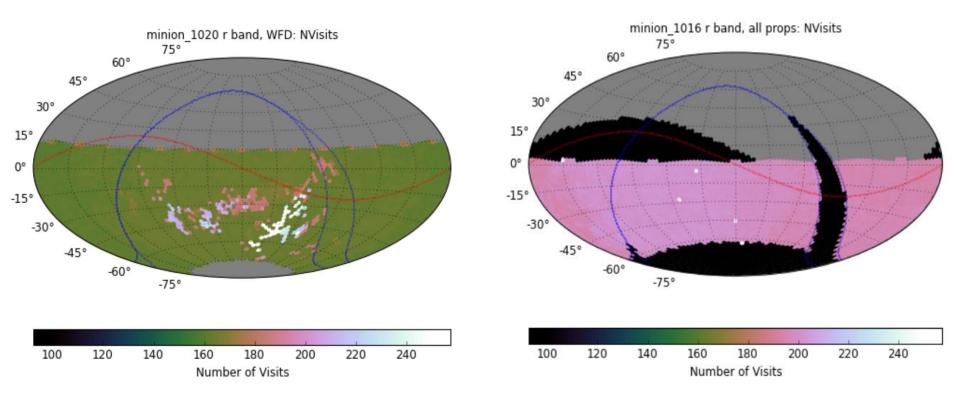


- Brief descriptions and MAF outputs at <a href="http://ls.st/x0q">http://ls.st/x0q</a>
- Detailed descriptions are in Chapter 2 of the Observing Strategy white paper:

minion_1016 — The New Baseline Cadence.
minion_1012 — Only Universal Cadence, with pairs of visits.
<pre>minion_1020 — A Pan-STARRS-like observing strategy.</pre>
minion_1013 — Only Universal Cadence, no visit pairs.
kraken_1043 — Baseline Cadence, but with no visit pairs.
enigma_1281 — NEO test: triplets of visits.
enigma_1282 — NEO test: quads of visits.
kraken_1052 — Baseline Cadence, but with 33% shorter exposure time.
kraken_1053 — Baseline Cadence, but 100% longer exposure time.
kraken_1045 — Baseline Cadence, but with doubled u-band exposure time.
kraken_1059 — Baseline Cadence, but with doubled u-band exp. time.
minion_1022 — Only Universal Cadence, with relaxed airmass limit.
minion_1017 — Only Universal Cadence, with stringent airmass limit.
astro_lsst_01_1004 — Extend Universal Cadence to the Galactic Plane.
ops2_1102 — "Swiss Cheese" rolling cadence, version 1.
enigma_1260 — "Swiss Cheese" rolling cadence, version 2.
enigma_1261 — "Swiss Cheese" rolling cadence, version 3.
ops2-1098 — "Control" simulation for comparison with the "Swiss Cheese" experiment
cadence simulations

## Preliminary Cadence Exploration

Do you prefer more area with fewer visits (left, the so-called Pan-STARRS cadence, green region), or the main survey in the baseline cadence (right, pink)?





#### **Proposed New OpSim Experiments**

Name	Proposer(s)	Issue Thread	Description	
No Extragalactic Visit Pairs	Marshall	#66	Dont observe in pairs of visits above the Galactic and Ecliptic planes	
Target of Opportunity Observations	Soares-Santos, Bellm	#75	simulate TOO Observations	
Coordination with WFIRST	Gawiser, Rhodes	#114	Add Special Survey to duplicate WFD observations of 2300 degrees during first 5 years	
NEO optimized runs	SS SC	#120	Find more and different NEOs	
Normal Plane	Strader (for SMWLV)	#162	Do Galactic Plane with normal WFD cadence	
Rolling Cadence Optimized for SN Cosmology	Jeonghee Rho [and SN Cosmology Team]	#159	Modified Rolling Cadence for densely populated SN light curves	

#### Available at: http://ls.st/yqq

### Update on OpSim/Scheduler development



Date	Opsim/Scheduler deliverables	Project Deliverables	Community deliverables	Opsim/ Scheduler work	
Jul – Dec 2015	Start Opsim refactoring	Prototype baseline cadence	Deliver initial metrics	Opsim/Scheduler Refactoring	
Aug – Dec 2015	Deliver ability to run Opsim	2015 Cadence workshop Evaluating survey geometry	Baseline		
June – Dec 2016	End Opsim Initial Refactoring V4 (1.0)	Ability to add proposals	cadence modification proposals		
Jan – June 2017	First report on initial metrics performance and proposed baseline cadences	Evaluation of baseline cadence	Cadence proposals in new scheduler	Scheduler Development	
June – Dec 2017		Delivery of look ahead			
Jan – June 2018	report on initial metrics performance and proposed baseline cadences	2018 Cadence workshop Delivery of iterated baseline cadence with	environment		
July – Dec 2018	Delivery of dithering Delivery of baseline scheduler				
Jan – June 2019	Publication of future targets Support weather forecasts				
July – Dec 2019	Delivery of full scheduler	Setup cadence committee	Committee Evaluation		
Jan — July 2020		Comcam operations	Community evaluation	Scheduler Community Optimization	

## Large Scale Structure

Humna Awan<sup>1</sup>, Eric Gawiser<sup>1</sup>, Peter Kurczynski<sup>1</sup>, Lynne Jones<sup>2</sup>, et al.

11:32am <sup>1</sup>Rutgers University, <sup>2</sup>University of Washington

LSST PCM, August 2016, Tucson



#### Outline



Investigate the impacts of Observing Strategy (OS) that affect LSS studies

- Coadded depth (*r*-band)
- Artificial galaxy clustering

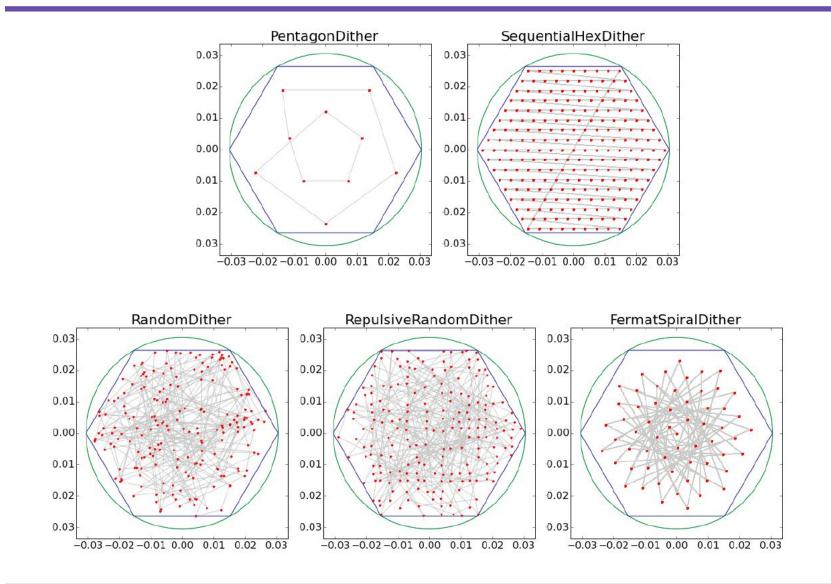
Awan et al. 2016 (arXiv:1605.00555)

Analysis Tools:

- OpSim output minion\_1016 + *i*-band mock catalogs
- Hierarchical Equal Area isoLatitude Pixelzation (HEALPix) package
  - Tile the sky with equal area pixels
  - Resolution:  $N_{side}$  = 256  $\Leftrightarrow$  190 HEALpixels per FOV



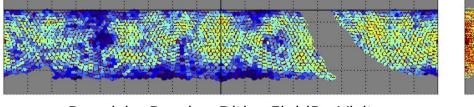
#### **Dither Geometries**



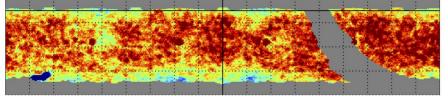
#### **OS: Impacts on Coadded Depth**



NoDither

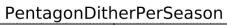


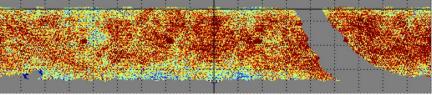
RepulsiveRandomDitherFieldPerVisit



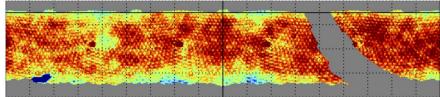
SequentialHexDitherFieldPerVisit

27.04 27.08 27.13 27.17 27.21 *r*-band Coadded Depth

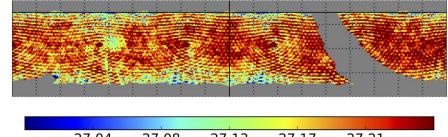




FermatSpiralDitherFieldPerVisit



SequentialHexDitherFieldPerNight



27.04 27.08 27.13 27.17 27.21 *r*-band Coadded Depth

(Good) dithering strategies do not lead to the honeycomb pattern seen in the NoDither run

#### **Artificial Structure & LSS Systematics**

- Calibration errors, dust extinction, poisson noise: dust dominates.
- Calculate N<sub>qal</sub> using mock LSST light cone catalogs (Padilla et al.)
- Find fluctuations in the galaxy counts. Implement magnitude cuts.

#### LSS Systematics

- Measured power spectrum:  $C_{\ell,measured} = \sum_{\ell'} |W_{\ell-\ell'}|^2 \langle C_{\ell'} \rangle + \delta C_{\ell}$   $\circ \langle C_{\ell} \rangle = C_{\ell,LSS} + \frac{1}{\bar{\eta}}$  : expected power spectrum on the full sky

  - $\delta C_{\ell}$  is an error whose variance is  $(\Delta C_{\ell})^2 = \frac{2}{f_{sky}(2\ell+1)} \langle C_{\ell} \rangle^2$
- OS introduces power, measureable even with no LSS and negligible shot noise.
- <u>Limiting factor</u>: uncertainty in the OS-induced bias:  $(\sigma_{C_{\ell,measured}})^2 = (\Delta C_{\ell})^2 + (\sigma_{C_{\ell,OS}})^2$

**OSBias Metric** 

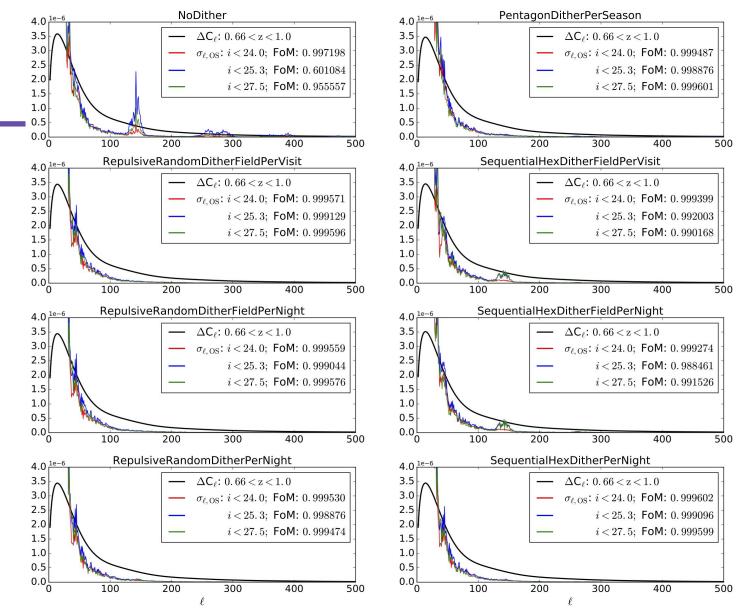
$$FoM \equiv \frac{Variance due to statistical floor}{Total variance (due to statistical floor + OS bias)} = \frac{\sum_{\ell} (2\ell + 1)\Delta C_{\ell}^2}{\sqrt{\left(\sum_{\ell} (2\ell + 1)\sigma_{\ell,OS}^2\right)^2 + \left(\sum_{\ell} (2\ell + 1)\Delta C_{\ell}^2\right)^2}}$$

Consider 100<\ell<300. Optimum: FoM=1



ExGal/Coadd Metric GalaxyCounts Metric ΔN/N Metric

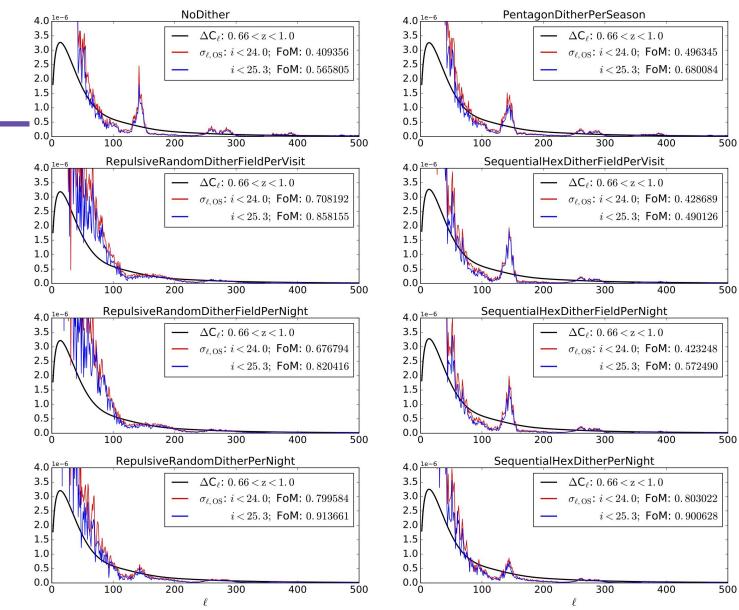
## 10-year Survey



Most dither strategies are effective (even per season!)

• Exceptions: SequentialHex on some timescales

#### 1-year Survey



Best dither strategies bring the OS-induced uncertainties \*close\* to the statistical floor. Some are as bad as NoDither.



- Dithering reduces OS-induced artifacts; effective over full survey period.
  - NoDither severely harms 10-year analysis; systematics correction methods will be necessary for Gold Sample.
  - Investigate the effectiveness of systematics reduction methods, e.g. mode projection: especially important for after one year of survey.
- More careful analysis of the OS impacts on LSS systematics still needed:
  - Interaction with other probes, e.g. WL
  - Rotational dithers
- Galaxy sample emulator: number of LSST galaxies for a sample with specified cuts in redshift and magnitude.

## **Transients**

#### Eric Bellm, on behalf of the LSST TVS working group\*

11:40am \*Especially Fed Bianco, Stefano Valenti

LSST PCM, August 2016, Tucson



## Transient Science Productivity is Tightly Coupled to Cadence



- Have to identify rare events in the alert stream in real time in order to rapidly trigger scarce & valuable follow-up resources.
- Information content of LSST data is vital to identify rare events with reasonable purity
  - Cadence of observations
  - Color information

For example: a new transient is discovered at 23rd mag on the outskirts of a local galaxy.

Is it a young SN, or a background SN Ia near peak? Do you trigger 30m spectroscopy?

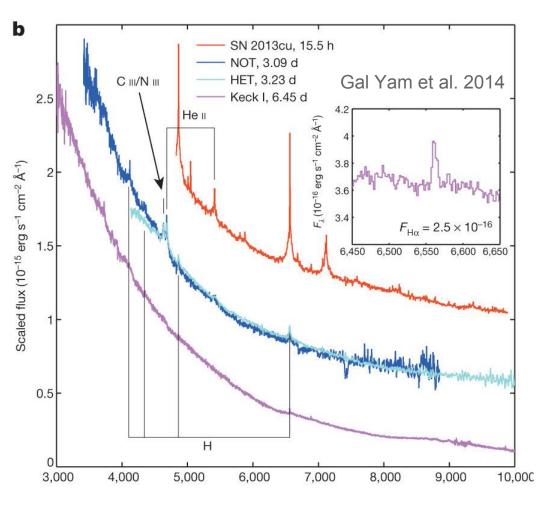
## Young Transients are Extremely Valuable



- Supernovae:
  - Flash spectroscopy
  - Radius/binarity constraints; measure explosion time
  - Shock interaction signatures
- Gamma-ray bursts
  - Orphan afterglows (jet structure)
  - Dirty fireballs
  - High-z GRBs from first stars
- Exotic transients

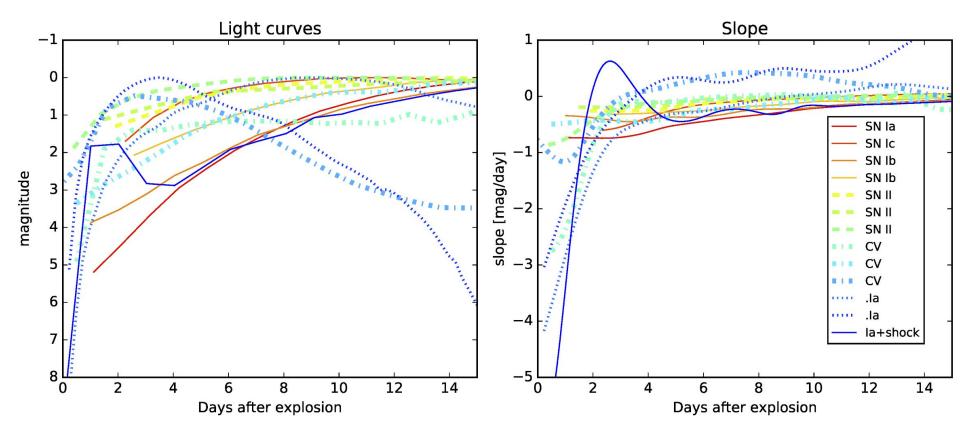
Science FOM:

 Enable follow-up & characterization



Number of events *discovered* < 1 day after explosion





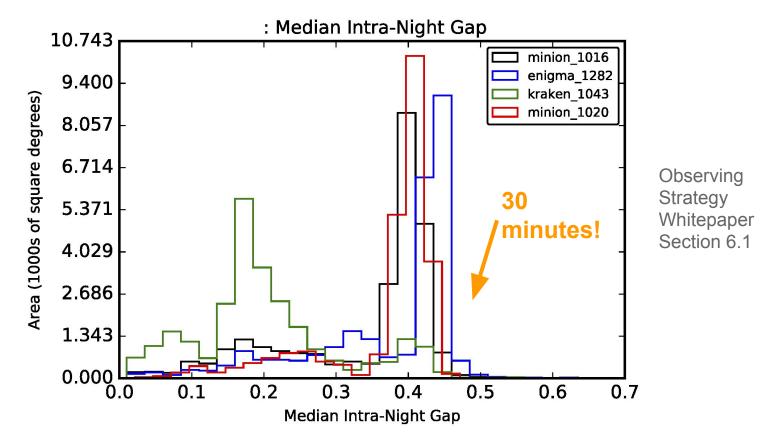
They also typically have bluer colors

Valenti & Bianco Observing Strategy Whitepaper Section 6.2

### LSST's Baseline Cadence offers Little Discriminating Power.



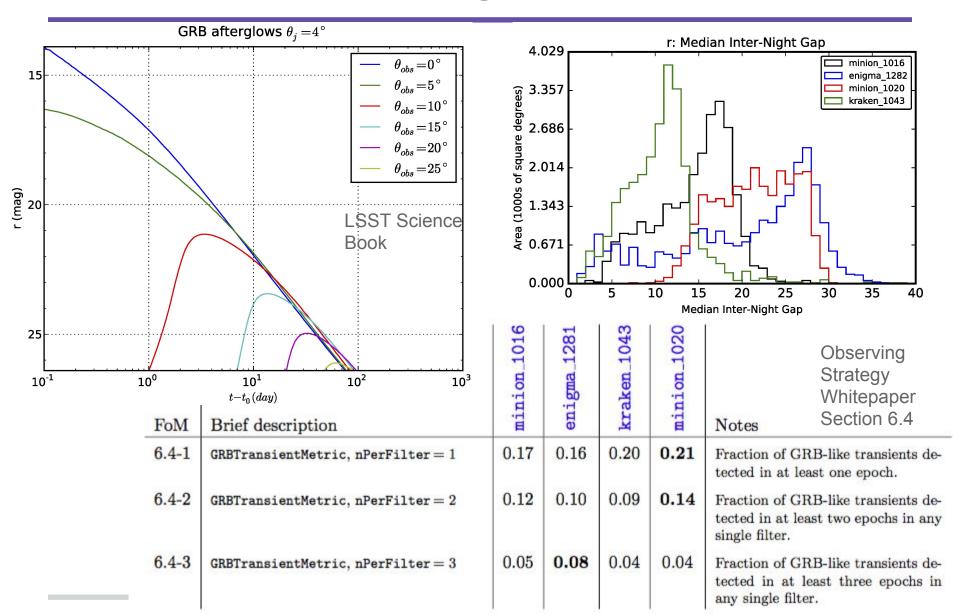
**Use** IntraNightGapMetric **as a diagnostic for sampling**:



30 minute gap is *too short* to distinguish young, rising lightcurves from slowly evolving old events!

#### **Current LSST Cadences are also Poor for Detecting GRBs**





### Improved Nightly Sampling will Sharply Increase Discoveries



Improving cadences for young transient discovery, by priority:

- 1. Rolling cadence to provide previous-night upper limit
- 2. 3-4 nightly visits > 2 hours after the first, same filter
- Initial visit pair in two different filters? (For color constraint)

We are working on MAF metrics to get true detection rates for young transients: we need to Monte Carlo populations.

Join us at the hack session!

# **Stellar Variability**

Mike Lund

11:48am

LSST PCM, August 2016, Tucson



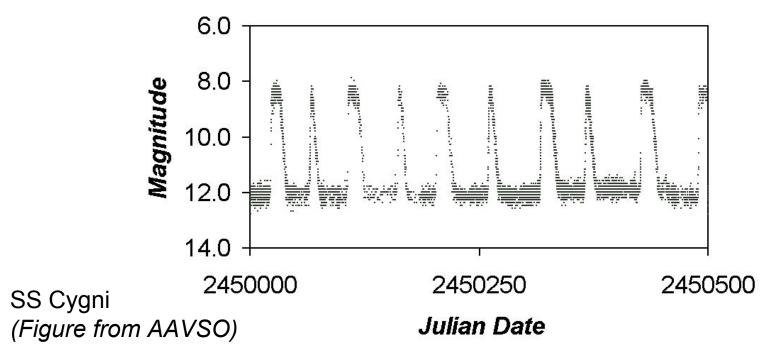


- Two broad categories of variability:
- Intrinsic variability
  - Flare stars
  - Novae
  - RR Lyrae, Cepheids
- Extrinsic variability
  - Eclipsing binaries
  - Planets
  - Circumstellar disks
- Includes both periodic and non-perodic variability



Metric: 'Triplets' diagnostic metric

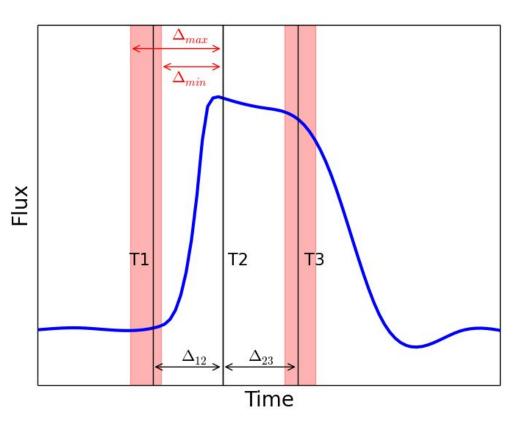
Goal: Determine how common sets of observations will be that allow for detection and basic characterization of Dwarf Nova behavior.





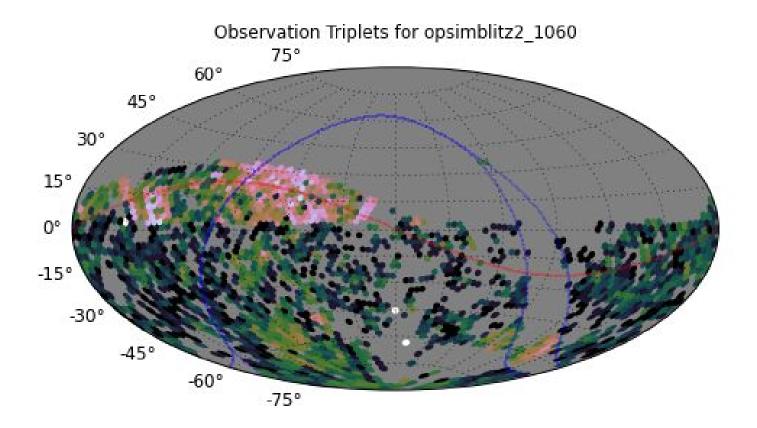
The "Triplets" metric is a generic diagnostic metric for many variability signals that share similar properties

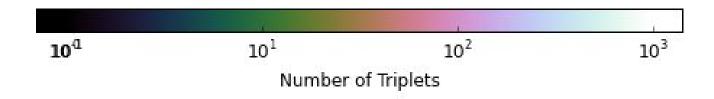
- Three observations:
  - Two observations during the event to confirm
  - One observation prior, to constrain start time
- Doesn't directly use light curve in the metric



#### **Metric Results**









Triplets metric for dwarf novae: Required space between successive observations to be between 9 and 11 days

Quick results: Deep drilling fields score well; Northern Ecliptic spur seems more useful than the main WFD area

Metric can be applied to other sources of stellar variability by adjusting the parameters

Also see Lund et al. 2016 for more metrics

# Solar System

**David Trilling** 

11:56am

LSST PCM, August 2016, Tucson



Case Study: Near Earth Objects

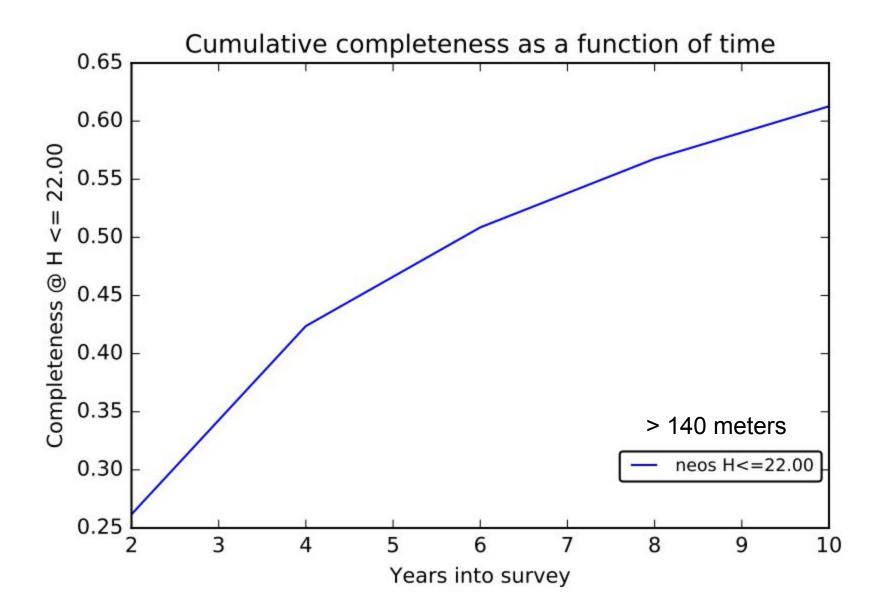


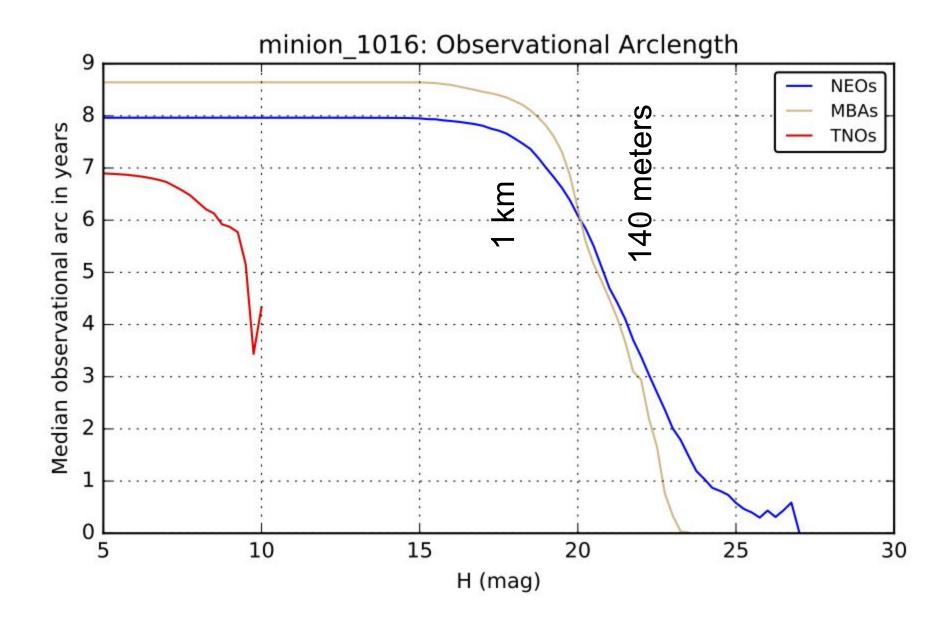
- Near Earth Objects also known as NEOs
- Science:

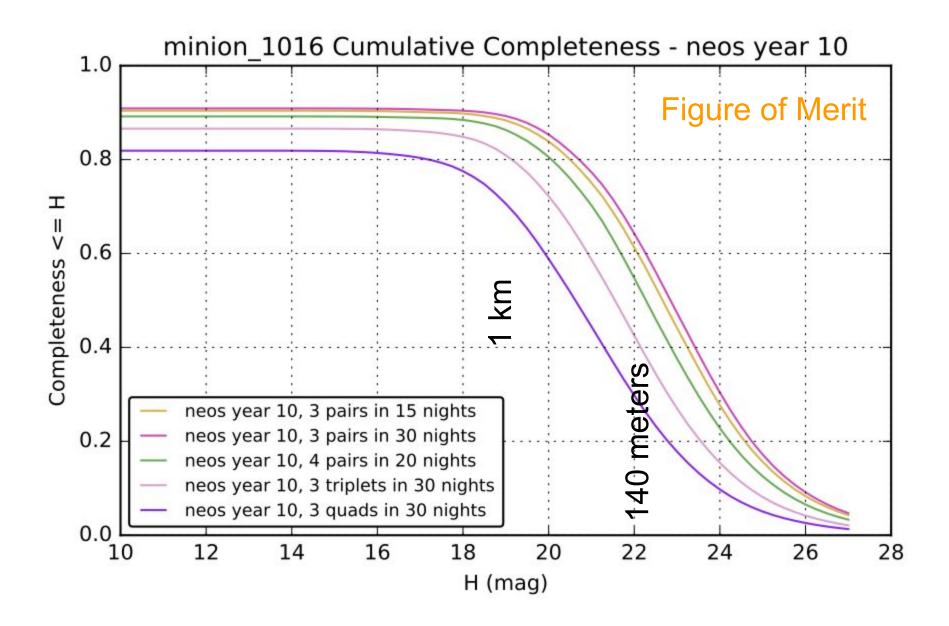
1) Composition of bodies in near Earth space

2) Orbits / impact threat

- Things we want to know (for a given cadence):
  - How many NEOs would be discovered?
  - Completeness as a function of size?
  - How well do we know the orbit?









Lots of parallel examples for main belt asteroids, trans-Neptunian objects, comets, etc. etc.





Conclusions:

- 1) Tools exist to measure success rates
- 2) Different requirements give varying success rates
- Some aspects are less straightforward to calculate -more modeling (or thought) needed

# Cosmological Supernovae

**Rahul Biswas** 

12:04pm

LSST PCM, August 2016, Tucson



#### **SN Science Use Cases** In White Paper and For Later



#### Constraining Dark Energy: SN at range of z

- Needs large numbers of well characterized light curves in each redshift bin
- For lower redshifts, this requires a *large sky area* (i.e. WFD)

## Across the sky: Only possible because of WFD

- Use SNIa as tracers of LSS with a radial distance measure
- Use SNIa to study the isotropy of the universe at low redshift
- Use SNIa as a tracer for dim, dwarf galaxies to be followed up with other instruments

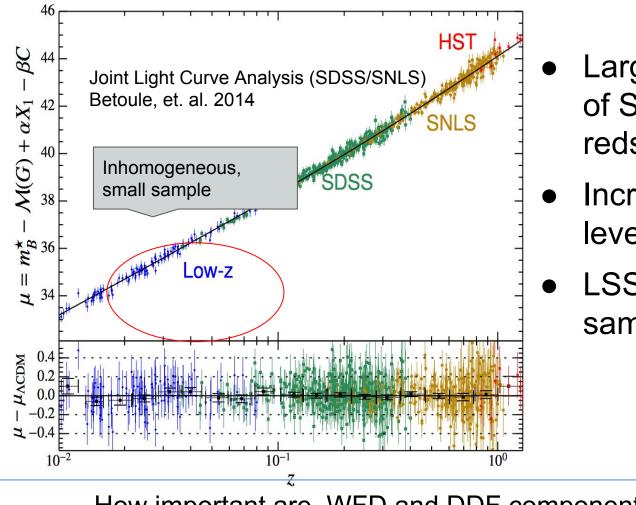




#### What kind of sky coverage is important for SN Cosmology ? Where should we evaluate metrics ?

# Improvements with LSST to the current State of Art



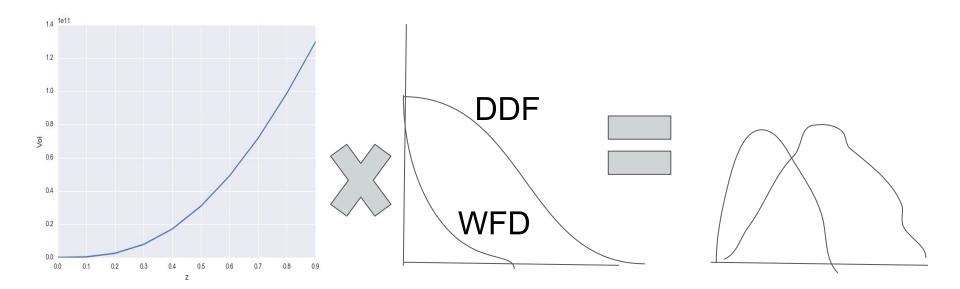


- Larger numbers of SNe in each redshift bin
- Increase the lever arm size
- LSST Low-z sample

How important are WFD and DDF components to SN

#### **SN Cosmology in LSST: Yield Schematics**





- Higher redshift SN from DDF : cadence + detection
- Low redshift SNe will come from the WFD: cadence

FoM should be evaluated over all sky, but at each redshift slice different components are important



Detection
 Classification
 Characterization
 Training Sets + Characterization
 (templates)
 (light curves fits)

Composite FoM : *Coherent product* of FoMs of above steps (not just a simple product of metrics)

Bad			Good		
Detection	classification	character	Detection	classification	character
•	R	æ	•	•	•
	6	8			
8	8	8		R	

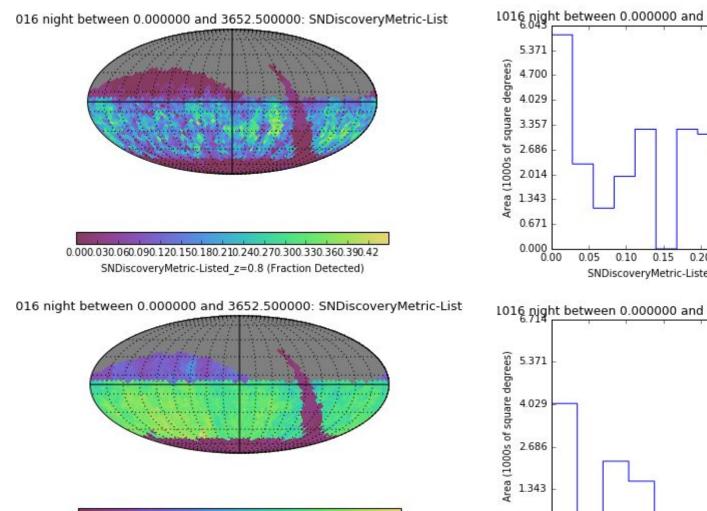


Attempted using single repeating light curve at a particular redshift bin

- Detection FoM : Include only those SNe which will be triggered by LSST processing ie. SN must have at least one 5 sigma observation (but more information in images)
- Classification : No metric yet. Using small numbers of light curves does not allow one to answer questions about ensembles
- Characterization : fit to current light curve model, and obtain uncertainty on approximate distance modulus. The FoM is the sum of inverse variances on distance modulus and can be thought of as an effective number of SN.

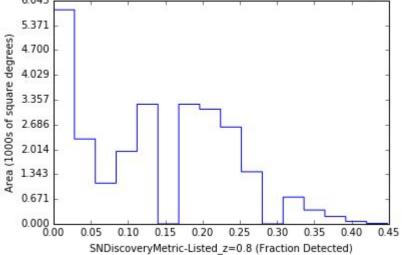
#### **Evaluating Detection at** different redshifts



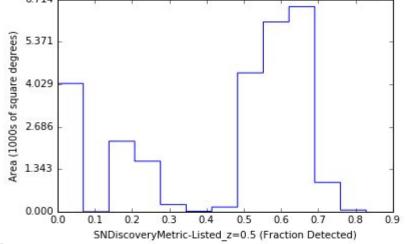


0.000.060.120.180.240.300.360.420.480.540.600.660.720.78 SNDiscoveryMetric-Listed z=0.5 (Fraction Detected)



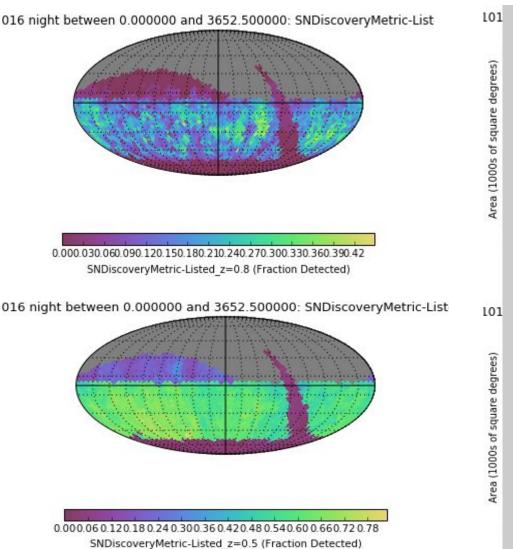


1016 night between 0.000000 and 3652.500000: SNDiscoveryMetric-Lis



# Metric is important at different redshift slices





- Detection of SN at z=0.5 is reasonably good, but not very good at z=0.8. This is OK for WFD, because the light curves will probably not be useful
- For DDF we need to do a more careful study because DDF provides decent light curves at these redshifts.

-Lis





- Simplistic simulation-based metrics sometimes possible, but not always
- Rolling Cadence: SN light curves need (~4/5 day cadence in band) for 3 bands, do not favor increasing area for worse cadence, but really need an OpSim run to tests on
- Deep Drilling Fields will provide good light curves but simulations are not 'optimal for SNe':
  - 1. SNe have no flux in rest frame UV, so blue bands at high redshift are sub-optimal.
  - 2. Spreading observations over time is better (but depends on processing methods). So Observing Strategy should be thought of in conjunction with processing methods.

# The Milky Way

Chapter editors: Will Clarkson, Kathy Vivas

12:12pm

LSST PCM, August 2016, Tucson



# The Milky Way: a <u>sample</u> of science cases



1. Cases led by stellar density or focusing on the inner Milky Way:

The next Galactic SN

Detecting quiescent black hole X-ray binaries

Radial migration in the Milky Way disk 2. Latitude-agnostic cases (mostly in the main survey areas)

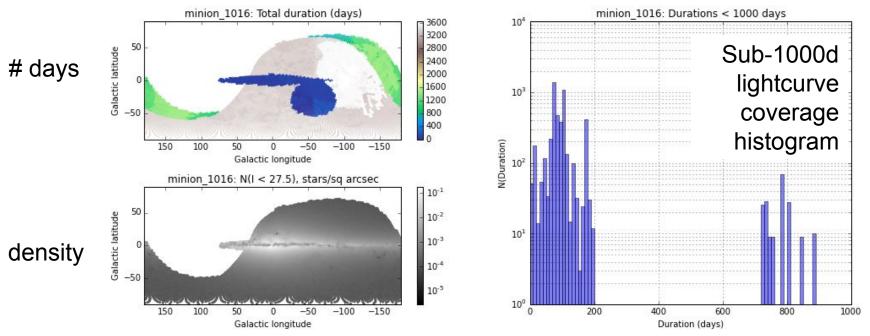
Brown dwarf mass function in the Solar neighborhood

Proper motion-discovered halo tidal streams

*Outer distance limit to halo structure from RR Lyraes* 

### 1. Density-led or inner-Milky Way cases – I. Dominant effects





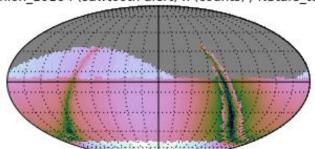
Most OpSim runs tend to finish inner-MW observations within the first year. Parameter-range *given* adequate inner-plane coverage is still largely unexplored. Exceptions: **PanSTARRS-like** and **astro\_lsst\_01\_1004**.

Opportunity: what OpSim runs do we need to propose?

Precursor outburst for the next Galactic Supernova

#### Baseline (minion\_1016, pre-Aug 2016): **FoM = 0.13**

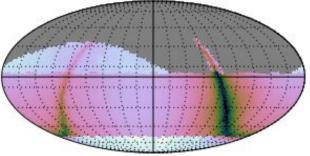
minion\_1016 : (sawtooth alert) x (counts) / NStars\_total

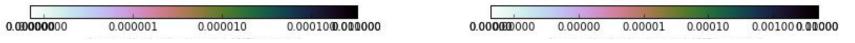


$$FoM_{preSN} \equiv \frac{\sum_{i}^{sightlines} f_{var,i} N_{*,i}}{\sum_{i}^{sightlines} N_{*,i}}$$

#### Extending Wide-Fast-Deep to the inner MW: **FoM = 0.73**

astro\_lsst\_01\_1004 : (sawtooth alert) x (counts) / NStars\_total





As we might expect, this FoM suggests this science case is disadvantaged by the current baseline strategy.

## 1. Density-led or inner-Milky Way cases – II. Example FoM:



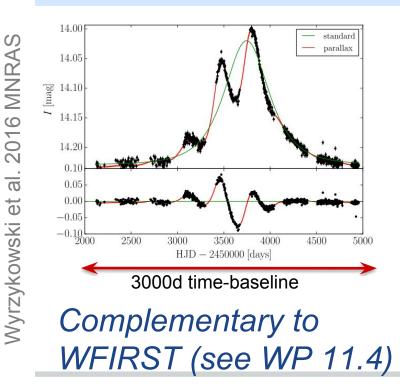
## 1. Density-led or inner-Milky Way cases – III. "New" ground:

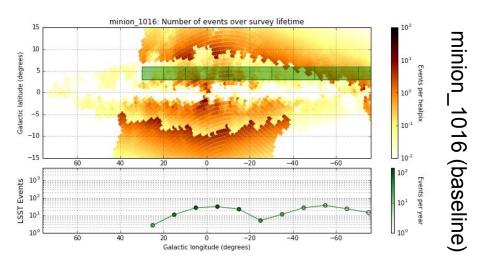


Opportunity: FoMs for cases currently incompletely developed. E.g. stellar microlensing:

Slow microlens  $\rightarrow$  compact object mass function

## Proxy: microlens event yield (> 8 days) scaled from OGLE





Up to ~20 µlens events detected in each of the green areas. "Unconference" Thurs 6:30pm Murphey

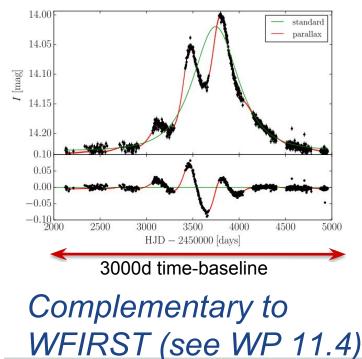
## 1. Density-led or inner-Milky Way cases – III. "New" ground:

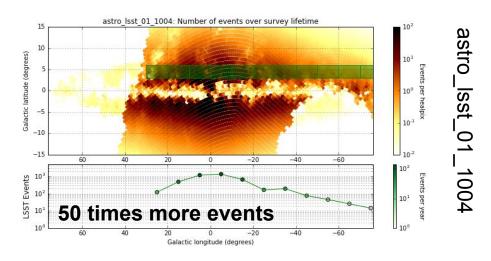


Opportunity: FoMs for cases currently incompletely developed. E.g. stellar microlensing:

Slow microlens  $\rightarrow$  compact object mass function

## Proxy: microlens event yield (> 8 days) scaled from OGLE





Up to ~1000 µlens events detected in each of the green areas. "Unconference" Thurs 6:30pm Murphey

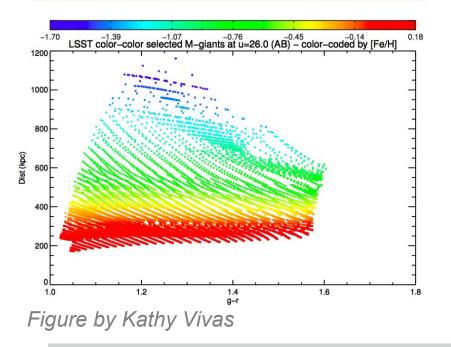
### 2. Latitude-agnostic cases: FoMs needed from Metrics



Opportunity: specify a FoM for your science case from already-existing metrics.

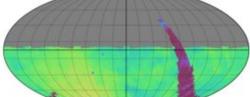


Distance at which RR Lyrae could be detected at u=26 (color-code Fe/H)

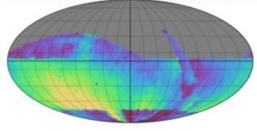


10-year parallax coverage for y-band only (top) and {g or r or i or z} (bottom)





minion\_1016 ( g or r or i or z) and night < 10000: ParallaxCoverageMetric



0.3236 0.40 0.44 0.48 0.52 0.56 0.60 0.64 0.68 0.72 0.76 0.80 ParallaxCoverageMetric (ratio) y-only after 10 years Range 0-1

g | r | i | z after 10 years Range 0-1

- The Milky Way: Status and Needed Input
- Example FoMs run on a few OpSim runs.
- Others in development (best-effort):
  - E.g. star/galaxy separation, recovery of qLMXB population;

#### Now needed:

- What OpSim runs needed for inner MW? Short exposures (e.g. {2s, 13s})? Inclusion of twilight survey? (Stubbs, WP10.3);
- 2. Inclusion of **astro\_lsst\_01\_1004** in FoM assessment for <u>all</u> the science cases;
- 3. Implementation of FoMs already specified;
- 4. New FoMs. e.g: Stellar microlensing; Solar Neighborhood; Galactic structure







# Weak Lensing

Josh Meyers

12:20pm

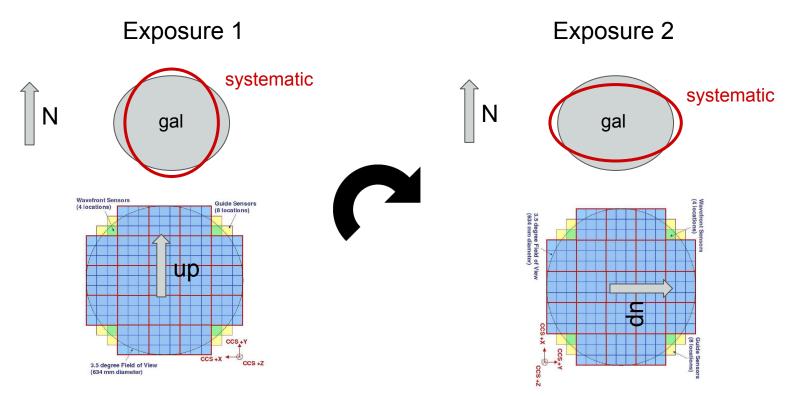
LSST PCM, August 2016, Tucson



### **Rotational Dithering**



• Rotational dithering can mitigate shape measurement systematics locked to the focal plane, such as the residual brighter-fatter effect.

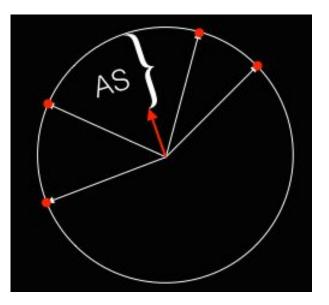


• 90 degree difference in position angle => systematics roughly cancel.

## **AngularSpread metric**



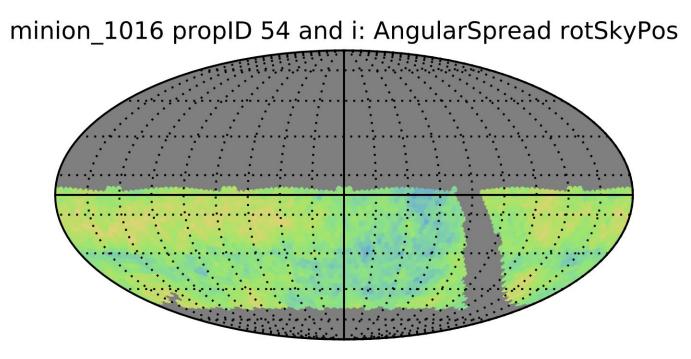
- Need to characterize the distribution of rotSkyPos the angle between North and camera "up".
- Need to acknowledge that 0 degrees = 360 degrees.
- AngularSpread metric:
  - Map angles onto 2D unit circle
  - Compute 2D mean vector
  - Measure distance from the unit circle.

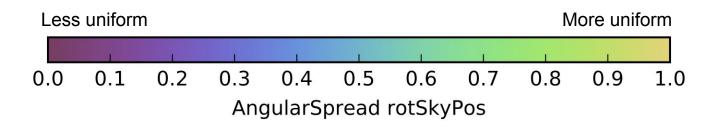


• Additional WL caveat: period is 180 degrees, not 360 degrees

#### **Rotational Uniformity** Natural rotation only



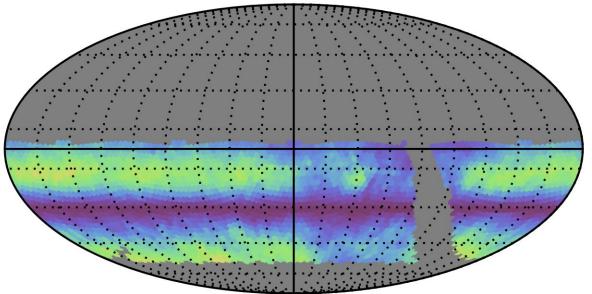


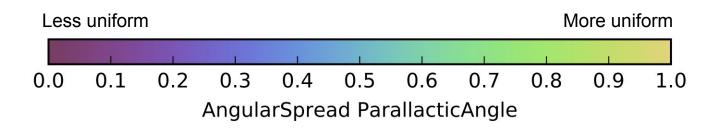


#### **Rotational Uniformity** Natural rotation only



minion\_1016 propID 54 and i: AngularSpread ParallacticAngle



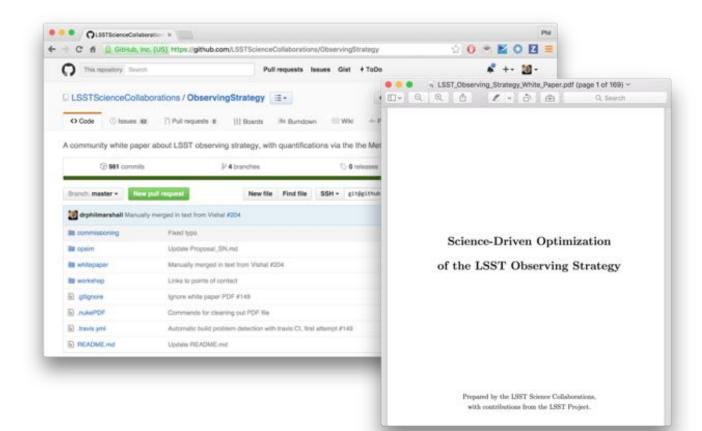




- (1 AngularSpread of rotSkyPos) is a potential FoM proxy we expect this metric to be proportional to residual shear correlation function, but we need to quantify this.
- Look at metrics for year 1 weak lensing science, best seeing.
- Investigate strategies to increase rotational uniformity
  - Random rotational dither once a night?
  - Random rotational dither every filter change?
  - Targeted rotational dither?

#### Thanks!





#### https://github.com/ LSSTScienceCollaborations/ObservingStrategy

## **Extra Slides**

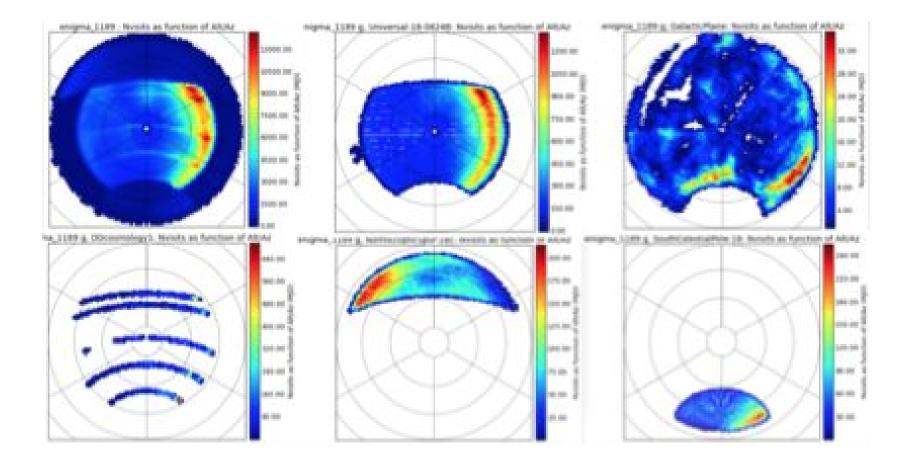


## **Baseline Cadence**



#### **Western bias**

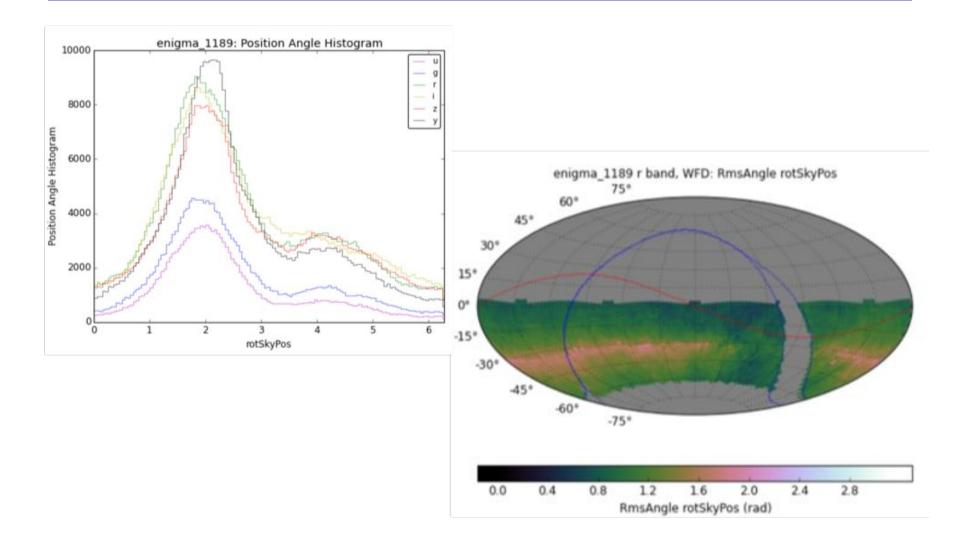




In the baseline cadence, a disproportionate amount of time is spent looking west.

#### **Rotation angle distribution**







### **Median Inter-night Gap**

