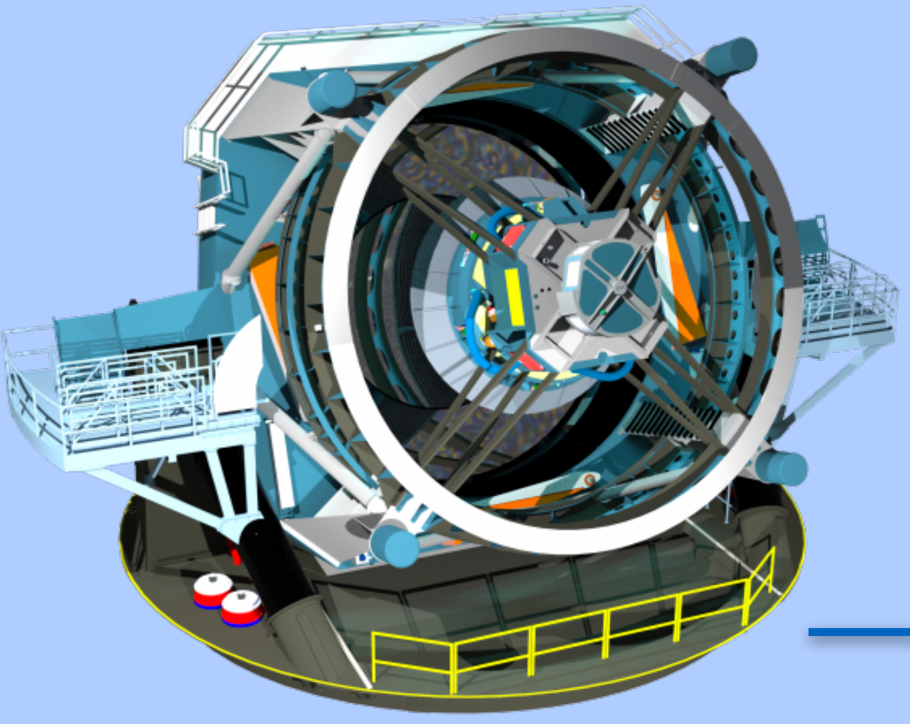
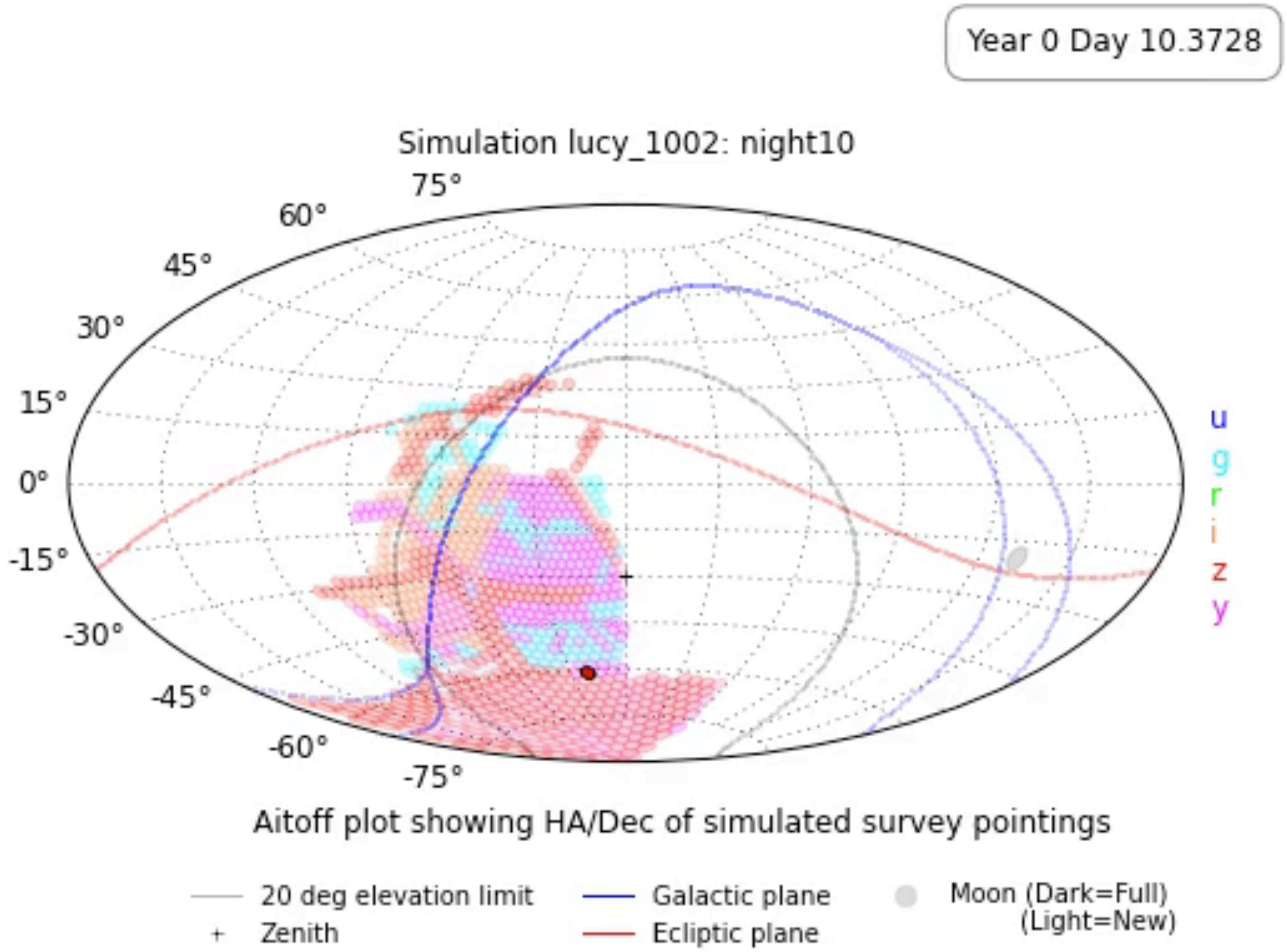
An Overview of Scheduler Metrics

Lynne Jones

March 2015 Scheduler Workshop



- The scheduler generates a simulated pointing history for LSST



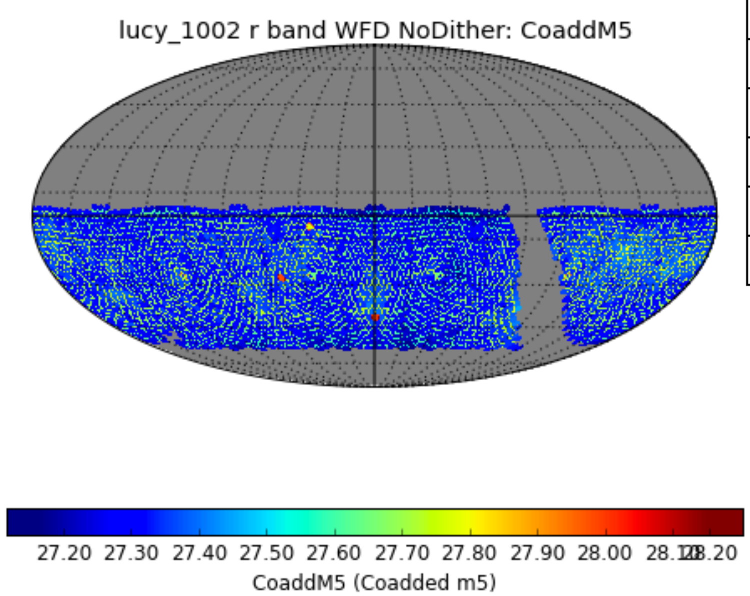
- *How do we know if the observing strategies and scheduling choices that generated that pointing history were optimal (or even 'good enough')?*

Evaluating the scheduler: Metrics

- **Science metrics**
  - Evaluate scientific performance of scheduler
  - Does survey meet minimum/design/stretch science requirements laid out in Science Requirements Document (SRD)?
  - How well does survey perform in a wide variety of other science goals?
- **Technical metrics**
  - Evaluate technical performance of scheduler
  - Were requested visits obtained? In desired conditions? How efficiently did scheduler obtain visits?

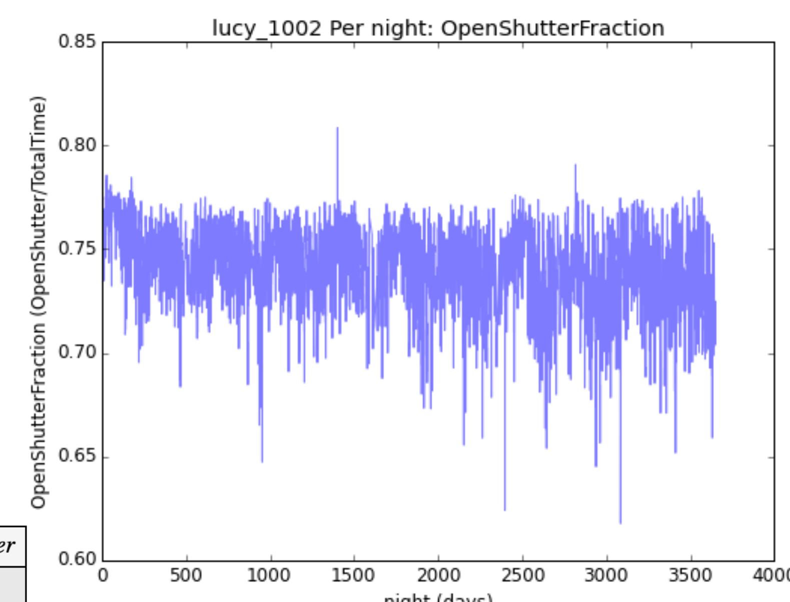
Metrics analysis framework (**MAF**)

- MAF is an open-source python framework designed to evaluate simulated surveys (scheduler outputs)
  - Flexible - apply customizable set of metrics
  - Extensible - easily generate new metrics
  - Evaluate metrics across the sky on a variety of spatial scales (e.g. healpixel grids) or on other subdivisions of pointing history (e.g. airmass or seeing grid) and generate visualizations + summary statistics



Group: *E: Coadded depth*; Subgroup: *All Props*; Slicer: *Op*

MetricName	Metadata	Median	Mean	Rms
CoaddM5	u band, all props	26.05	25.93	0.37
CoaddM5	g band, all props	27.13	26.98	0.34
CoaddM5	r band, all props	27.29	27.03	0.54
CoaddM5	i band, all props	26.54	26.35	0.48
CoaddM5	z band, all props	25.25	25.17	0.28
CoaddM5	y band, all props	24.30	24.08	0.49



Group: *A: Summary*; Subgroup: *3: Obs Per Night*; Slicer: *OneDSlicer*

	Filter Changes	NVisits	OpenShutterFraction
	Per night	Per night	Per night
Median	2.00	824.50	0.74
Mean	3.92	814.63	0.74
Rms	3.92	185.28	0.0205

Evaluating the scheduler: Metrics

- **Science metrics**
  - Evaluate scientific performance of scheduler
  - Does survey meet minimum/design/stretch science requirements laid out in Science Requirements Document (SRD)?
  - How well does survey perform in a wide variety of other science goals?
- **Technical metrics**
  - Evaluate technical performance of scheduler
  - Were requested visits obtained? In desired conditions? How efficiently did scheduler obtain visits?

Science metrics: SRD

- Science Requirements Document (SRD) - LPM-17
- Intentionally provides limited constraints on cadence
- Specifications flow from four primary science drivers for LSST and provide minimum/design/stretch goals
  - Failing minimum requirements implies significant problems addressing main science drivers (as well as other science)

Science metrics: SRD

- Sky area uniformly covered by the main (WFD) survey
- Median number of visits in all bands across this sky area
- Sky area with nearly uniform sampling on short timescales, 40 s - 30 min
- Median trigonometric parallax and proper motion accuracy for r=24 unresolved sources

Specification: The sky area uniformly covered by the main survey will include Asky square degrees (Table 22).

Quantity	Design Spec	Minimum Spec	Stretch Goal
Asky (deg^2)	18,000	15,000	20,000

Table 22: The sky area uniformly covered by the main survey.

Specification: The sum of the median number of visits in each band, Nv1, across the sky area specified in Table 22, will not be smaller than Nv1 (Table 23).

Quantity	Design Spec	Minimum Spec	Stretch Goal
Nv1	825	750	1000

Table 23: The sum of the median number of visits in each band across the sky area specified in Table 22.

Specification: At least RVA1 square degrees will have multiple observations separated by nearly uniformly sampled time scales ranging from 40 sec to 30 min (Table 25).

Quantity	Design Spec	Minimum Spec	Stretch Goal
RVA1 (deg^2)	2,000	1,000	3,000

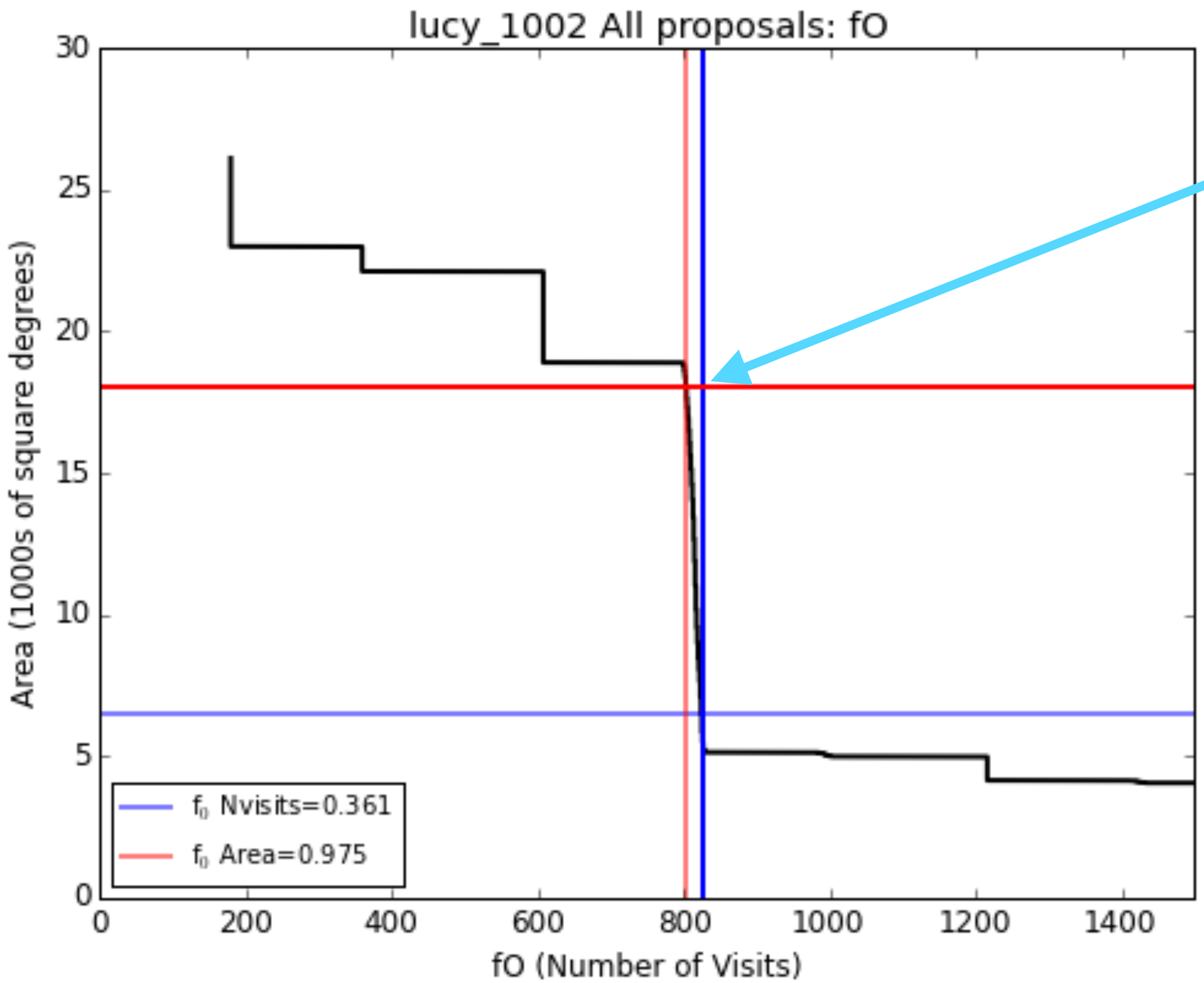
Table 25: The minimum area with fast (40 sec – 30 min) revisits.

Specification: The median trigonometric parallax accuracy across the main survey area for unresolved sources with $r = 24$ must be at least SIGpara mas. The median proper motion accuracy per coordinate across the main survey area for such sources must be at least SIGpm The median trigonometric parallax accuracy across the main survey area for unresolved sources detected only in the y band (at 10σ) must be at least SIGparaRed mas. (Table 26).

Quantity	Design Spec	Minimum Spec	Stretch Goal
SIGpara (mas)	3.0	6.0	1.5
SIGpm (mas/yr)	1.0	2.0	0.5
SIGparaRed (mas)	6.0	10.0	3.0

Table 26: The required trigonometric parallax and proper motion accuracy.

SRD metrics: Area and Nvisits

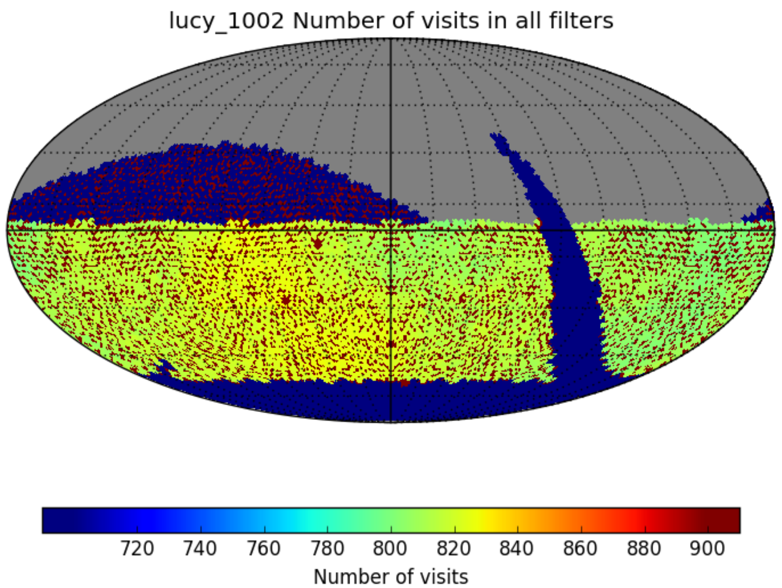


Area/Nvisits design goal:
18000 sq deg with
at least 825 visits

In this simulated survey:

An area of 6498 sq deg
(fO Nvisits: 0.361*18000)
received at least 825 visits

18000 sq deg received at least 801 visits
(fO Area: 0.975*825)



Science metrics: SRD

- Sky area uniformly covered by the main (WFD) survey
- Median number of visits in all bands across this sky area
- Sky area with nearly uniform sampling on short timescales, 40 s - 30 min
- Median trigonometric parallax and proper motion accuracy for r=24 unresolved sources

Specification: The sky area uniformly covered by the main survey will include Asky square degrees (Table 22).

Quantity	Design Spec	Minimum Spec	Stretch Goal
Asky (deg^2)	18,000	15,000	20,000

Table 22: The sky area uniformly covered by the main survey.

Specification: The sum of the median number of visits in each band, Nv1, across the sky area specified in Table 22, will not be smaller than Nv1 (Table 23).

Quantity	Design Spec	Minimum Spec	Stretch Goal
Nv1	825	750	1000

Table 23: The sum of the median number of visits in each band across the sky area specified in Table 22.

Specification: At least RVA1 square degrees will have multiple observations separated by nearly uniformly sampled time scales ranging from 40 sec to 30 min (Table 25).

Quantity	Design Spec	Minimum Spec	Stretch Goal
RVA1 (deg^2)	2,000	1,000	3,000

Table 25: The minimum area with fast (40 sec – 30 min) revisits.

Specification: The median trigonometric parallax accuracy across the main survey area for unresolved sources with $r = 24$ must be at least SIGpara mas. The median proper motion accuracy per coordinate across the main survey area for such sources must be at least SIGpm The median trigonometric parallax accuracy across the main survey area for unresolved sources detected only in the y band (at 10σ) must be at least SIGparaRed mas. (Table 26).

Quantity	Design Spec	Minimum Spec	Stretch Goal
SIGpara (mas)	3.0	6.0	1.5
SIGpm (mas/yr)	1.0	2.0	0.5
SIGparaRed (mas)	6.0	10.0	3.0

Table 26: The required trigonometric parallax and proper motion accuracy.

Science metrics: SRD

- Sky area uniformly covered by the main (WFD) survey
- Median number of visits in all bands across this sky area
- Sky area with nearly uniform sampling on short timescales, 40 s - 30 min
- Median trigonometric parallax and proper motion accuracy for r=24 unresolved sources

Specification: The sky area uniformly covered by the main survey will include Asky square degrees (Table 22).

Quantity	Design Spec	Minimum Spec	Stretch Goal
Asky (deg^2)	18,000	15,000	20,000

Table 22: The sky area uniformly covered by the main survey.

Specification: The sum of the median number of visits in each band, Nv1, across the sky area specified in Table 22, will not be smaller than Nv1 (Table 23).

Quantity	Design Spec	Minimum Spec	Stretch Goal
Nv1	825	750	1000

Table 23: The sum of the median number of visits in each band across the sky area specified in Table 22.

Specification: At least RVA1 square degrees will have multiple observations separated by nearly uniformly sampled time scales ranging from 40 sec to 30 min (Table 25).

Quantity	Design Spec	Minimum Spec	Stretch Goal
RVA1 (deg^2)	2,000	1,000	3,000

Table 25: The minimum area with fast (40 sec – 30 min) revisits.

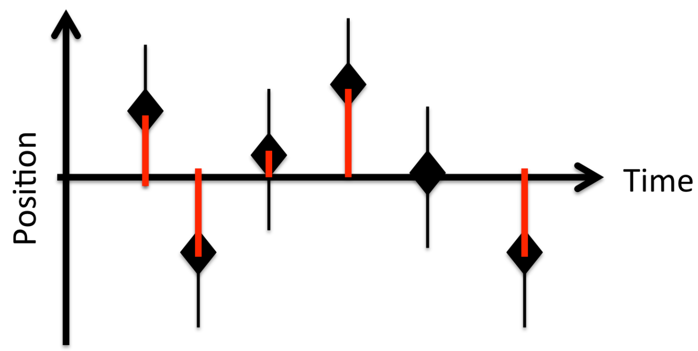
Specification: The median trigonometric parallax accuracy across the main survey area for unresolved sources with $r = 24$ must be at least SIGpara mas. The median proper motion accuracy per coordinate across the main survey area for such sources must be at least SIGpm The median trigonometric parallax accuracy across the main survey area for unresolved sources detected only in the y band (at 10σ) must be at least SIGparaRed mas. (Table 26).

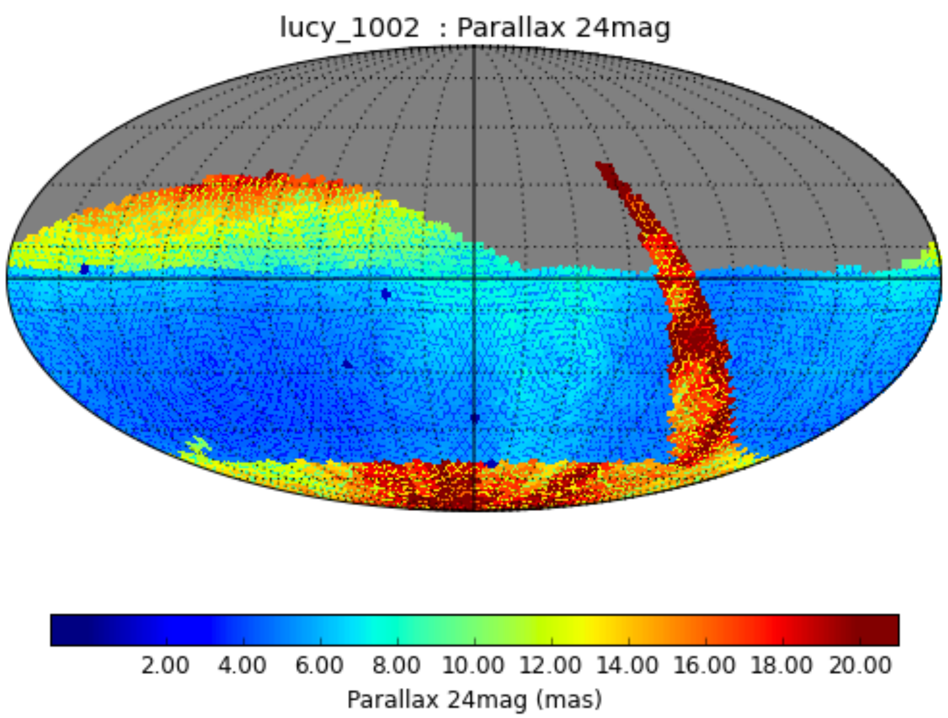
Quantity	Design Spec	Minimum Spec	Stretch Goal
SIGpara (mas)	3.0	6.0	1.5
SIGpm (mas/yr)	1.0	2.0	0.5
SIGparaRed (mas)	6.0	10.0	3.0

Table 26: The required trigonometric parallax and proper motion accuracy.

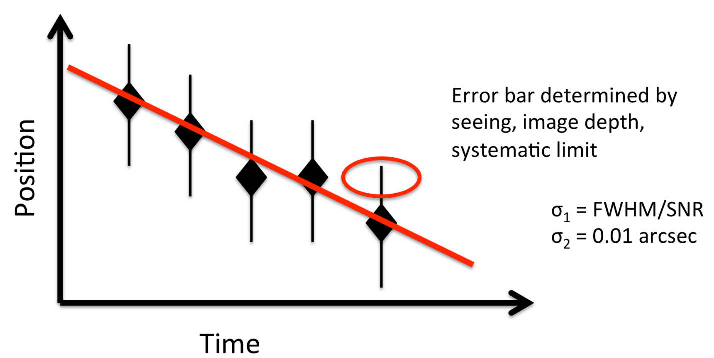
SRD metrics: parallax and proper motion

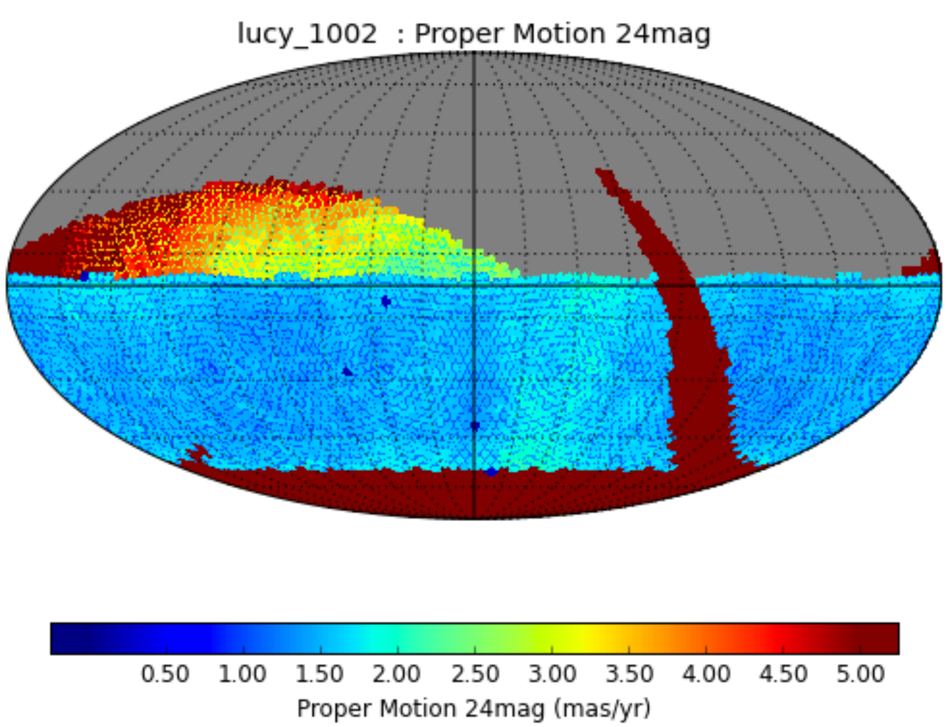
Parallax precision estimated from parallax factor (time of observation), astrometric error (SNR) per visit, and errors in resulting fit for parallax (separate RA/Dec fits)





Proper motion precision estimated from time of visits, astrometric error (SNR) of visit, and errors in resulting fit to a straight line.



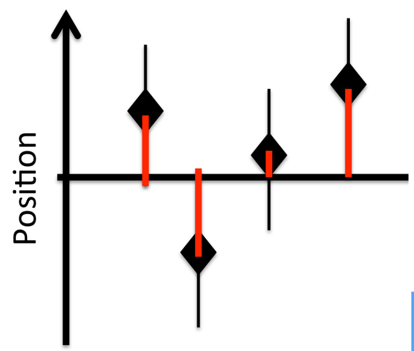


(Does not yet account for refraction-induced errors and assumes parallax/pm decoupled)

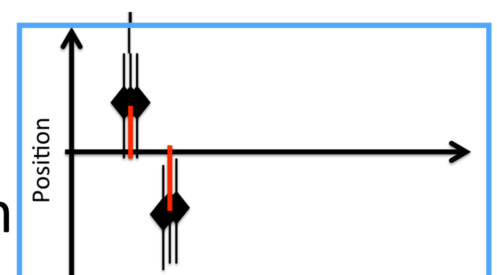
Design goal: 3 mas parallax / 1 mas/yr pm

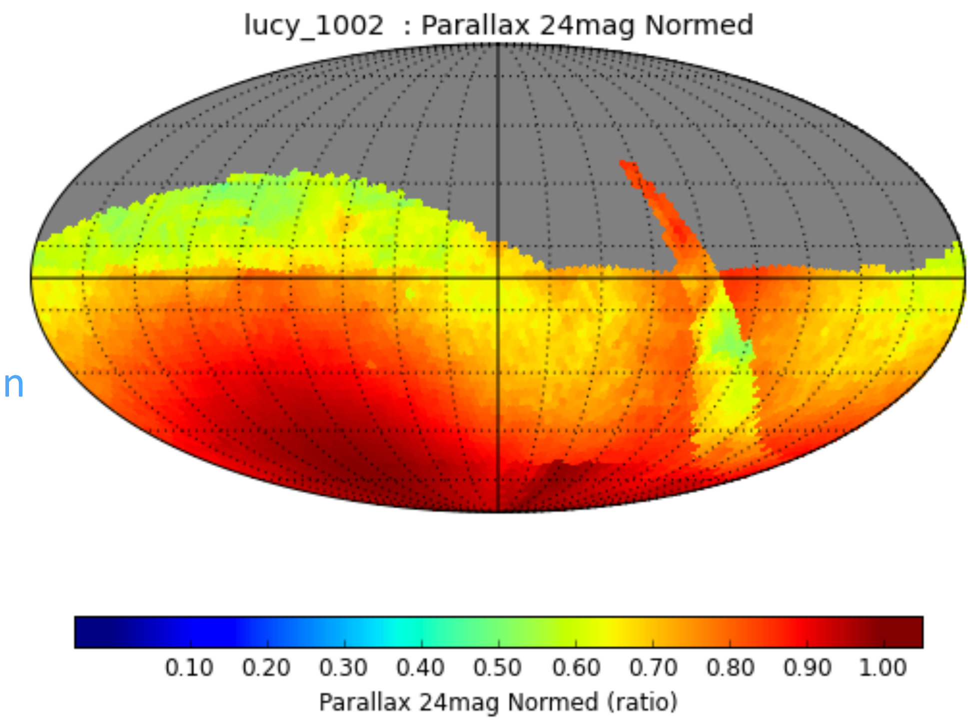
SRD metrics: parallax and proper motion

Parallax precision estimated from parallax factor (time of observation), astrometric error (SNR) per visit, and errors in resulting fit for parallax (separate RA/Dec fits)

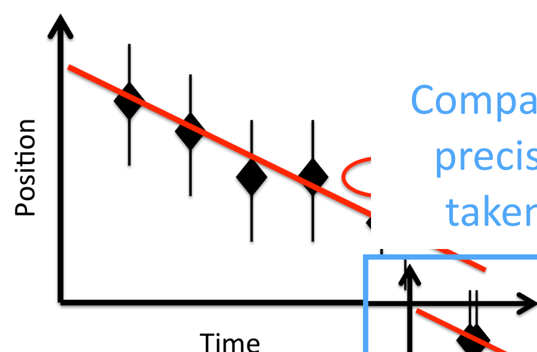


Compare to parallax precision if observations taken with max parallax factor

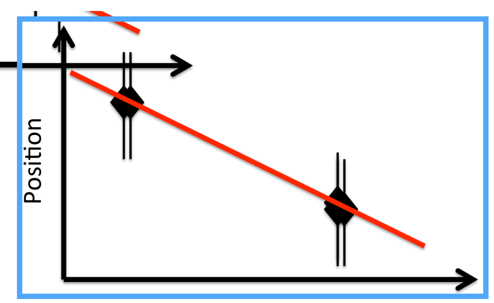


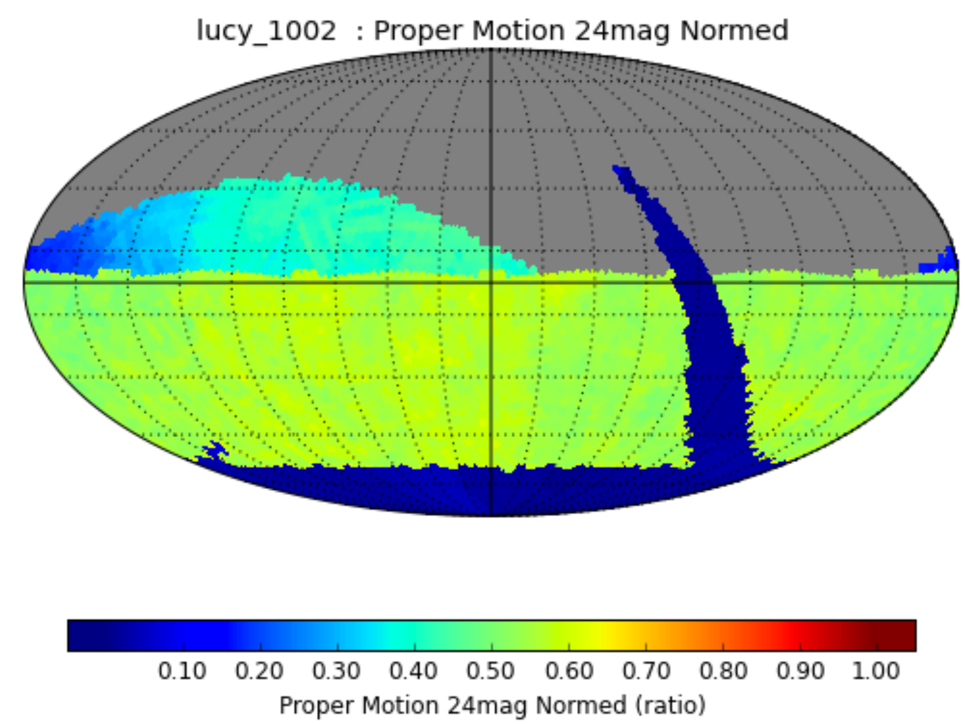


Proper motion precision estimated from visits, astrometric error (SNR) of visit, and errors in resulting fit to a straight line.



Compare to proper motion precision if observations taken on first + last day





(Does not yet account for refraction-induced errors and assumes parallax/pm decoupled)

'Normed' plots : 1 = 'optimal' scheduling

Science metrics: wider goals

- Beyond these few SRD minimum/design/stretch specifications, additional metrics are desirable to evaluate performance for a wide variety of science goals.
- Without quantitative thresholds, these metrics can be used to rank simulations against each other. Eventually, thresholds could evolve (depending on requirements to enable various science cases).
- There are infinite possibilities. We can run metrics and use them to investigate and rank simulated surveys, but we will require scientific input to winnow metrics and determine relative weights before operations.

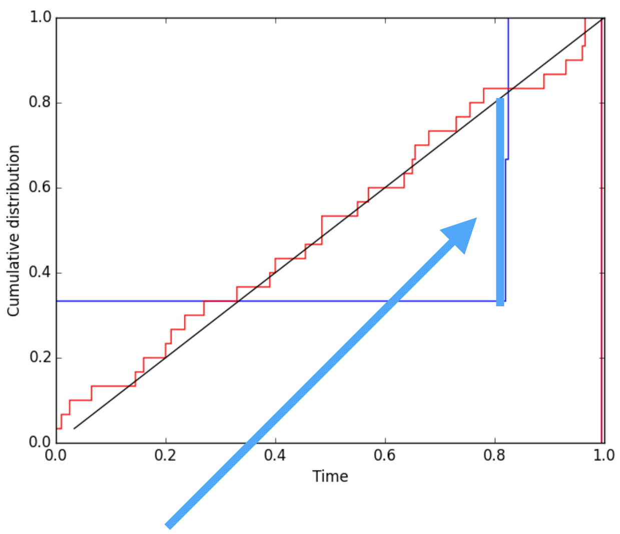
Science metrics: wider goals described in the SRD

- Uniformity in time and spatial coverage
- Coadded depth in each filter
- Good seeing and low airmass for *r* and *i* visits
- Number of visits with seeing better than X
- Uniformity and wide range of rotation angles between telescope, camera and sky
- Moving object detection and characterization (visit timing, modified by Solar System Object motion)
- Transient detection and identification (visit timing, coupled with range of filters in those visits)
- Timescales available for color measurements

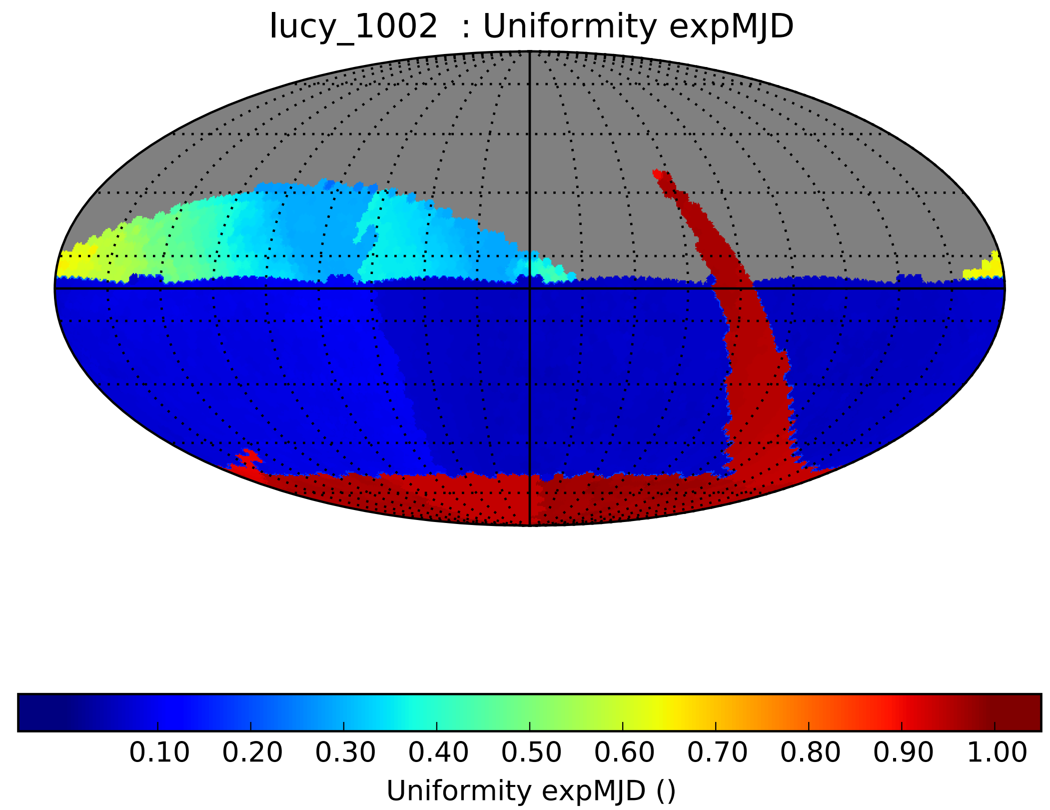
Science metrics: wider goals described in the SRD

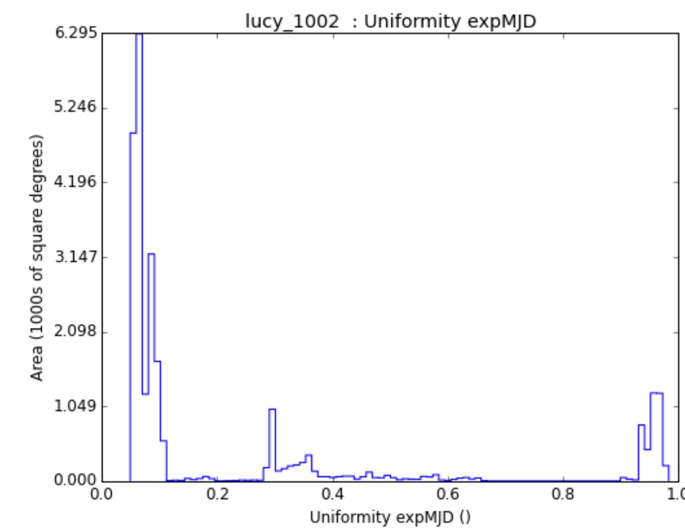
Large Synoptic Survey Telescope

Temporal uniformity of visits



‘Dmax’ = max difference between cumulative sum of visit times vs. straight line
0 = perfectly uniform
1 = perfectly nonuniform





Science metrics: wider goals from the Community

- Variable star period recovery
- Phase coverage for variables
- Detection of planetary transits
- Transient detection
- Identification and characterization of time delays in lensed quasars
- Uniformity in Large Scale Structure measurements
- ……
    - These can also be quite time consuming and may require simplification into more heuristic metrics

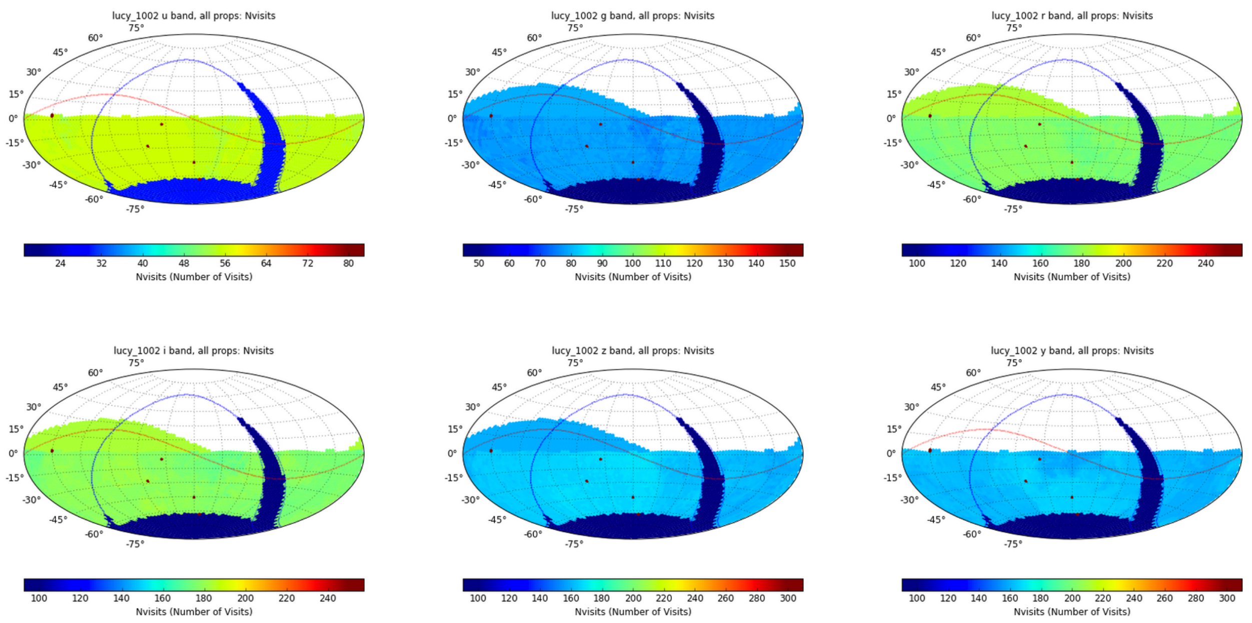
Evaluating the scheduler: Metrics

- **Science metrics**
  - Evaluate scientific performance of scheduler
  - Does survey meet minimum/design/stretch science requirements laid out in Science Requirements Document (SRD)?
  - How well does survey perform in a wide variety of other science goals?
- **Technical metrics**
  - Evaluate technical performance of scheduler
  - Were requested visits obtained? In desired conditions? How efficiently did scheduler obtain visits?

Technical metrics

- Did the scheduler achieve what it was asked to do? How efficient was the performance of the survey strategy?
  - Number of visits per filter per field and 'completeness'
  - Seeing, airmass, sky brightness distributions
  - Hour angle, normalized airmass distributions
  - Slew time distributions
  - Open shutter fraction, number of filter changes
  - Many more possibilities

Technical metrics: Nvisits + completeness



Number of visits per field, per filter

Group: *C: NVisits*; Subgroup: *All Props*; Slicer: *OpsimFieldSlicer*											
MetricName	**Metadata**	**Median**	**Mean**	**Rms**	**m3Sigma**	**p3Sigma**	**Count**	**25th%ile**	**75th%ile**	**Min**	**Max**
Nvisits	**u band, all props**	55.00	67.26	393.57	0	5	2817	55.00	56.00	30.00	10031.00
Nvisits	**g band, all props**	78.00	76.16	141.86	0	5	3338	77.00	79.00	30.00	4146.00
Nvisits	**r band, all props**	176.00	165.32	285.57	0	5	3339	174.00	178.00	30.00	8247.00
Nvisits	**i band, all props**	178.00	166.12	277.68	0	5	3339	175.00	180.00	30.00	7940.00
Nvisits	**z band, all props**	164.00	156.47	347.63	0	5	3339	160.00	167.00	30.00	9835.00
Nvisits	**y band, all props**	162.00	149.65	281.03	0	5	2817	160.00	164.00	30.00	7199.00

Completeness

Group: *F: Completeness*; Subgroup: *WFD*; Slicer: *OpsimFieldSlicer*							
	Completeness_u	**Completeness_g**	**Completeness_r**	**Completeness_i**	**Completeness_z**	**Completeness_y**	**Completeness_Joint**
	WFD only	**WFD only**	**WFD only**	**WFD only**	**WFD only**	**WFD only**	**WFD only**
TableFraction 0 == P	0	0	0	0	0	0	0
TableFraction 0 < P < 0.1	0	0	0	0	0	0	0
TableFraction 0.1 <= P < 0.2	0	0	0	0	0	0	0
TableFraction 0.2 <= P < 0.3	0	0	0	0	0	0	0
TableFraction 0.3 <= P < 0.4	0	0	0	0	0	0	0
TableFraction 0.4 <= P < 0.5	0	0	0	0	0	0	0
TableFraction 0.5 <= P < 0.6	0	0	0	0	0	0	0
TableFraction 0.6 <= P < 0.7	0	0	0	0	0	0	0
TableFraction 0.7 <= P < 0.8	0	0	0	0	0	0	0
TableFraction 0.8 <= P < 0.9	0	0	0	0	0	0	0
TableFraction 0.9 <= P < 1	1173	2283	2290	2287	53	159	2290
TableFraction 1 == P	1117	7	0	3	91	319	0
TableFraction 1 < P	3	3	3	3	2149	1815	3

Summary

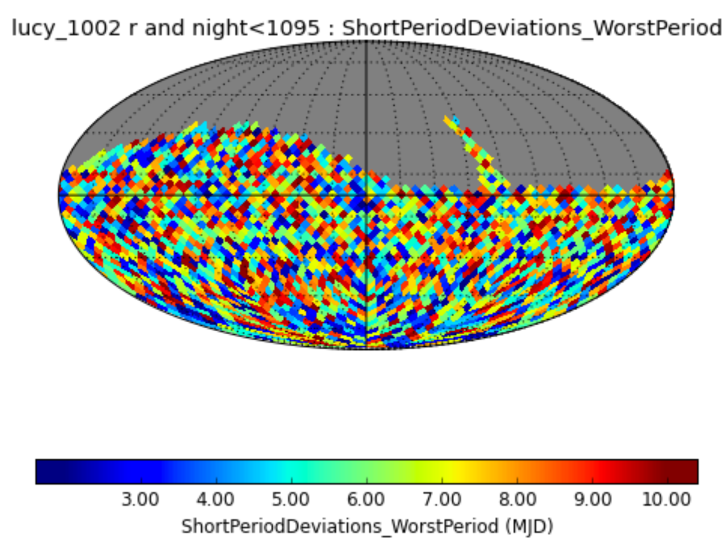
- Science and technical metrics
  - Science metrics include specifications from SRD, metrics describing science-related goals from SRD and metrics addressing science cases contributed from the community
  - Technical metrics include evaluation of scheduler programmed goal achievement and efficiency of scheduling strategy
- Are we thinking of the right things for metrics? Are our metrics useful? Are we missing metrics?
- Currently we're evaluating metrics at the end of the simulated survey to compare/rank/update observing strategy for the next simulation. How do we (should we) move toward folding metrics into scheduler as a feedback mechanism? (More discussion on this topic during second day of workshop).

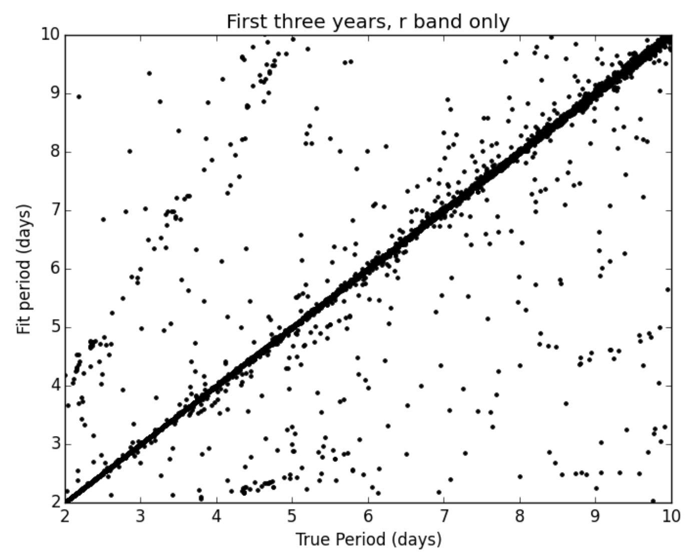
Additional metric examples

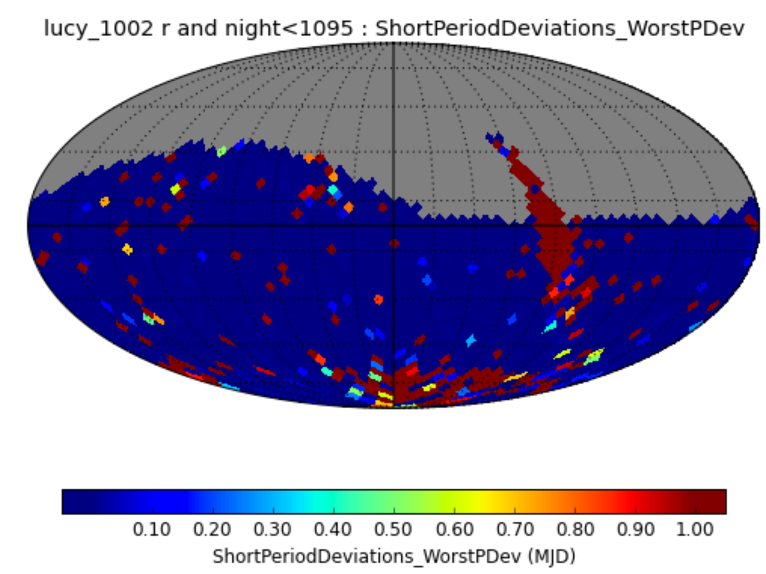
Period recovery for variables

Generate simple light curve based on a sinusoid (using a range of periods).
Fit period based on observations (with SciPy LS method).
Report PeriodDeviation [(fit-true)/true period].

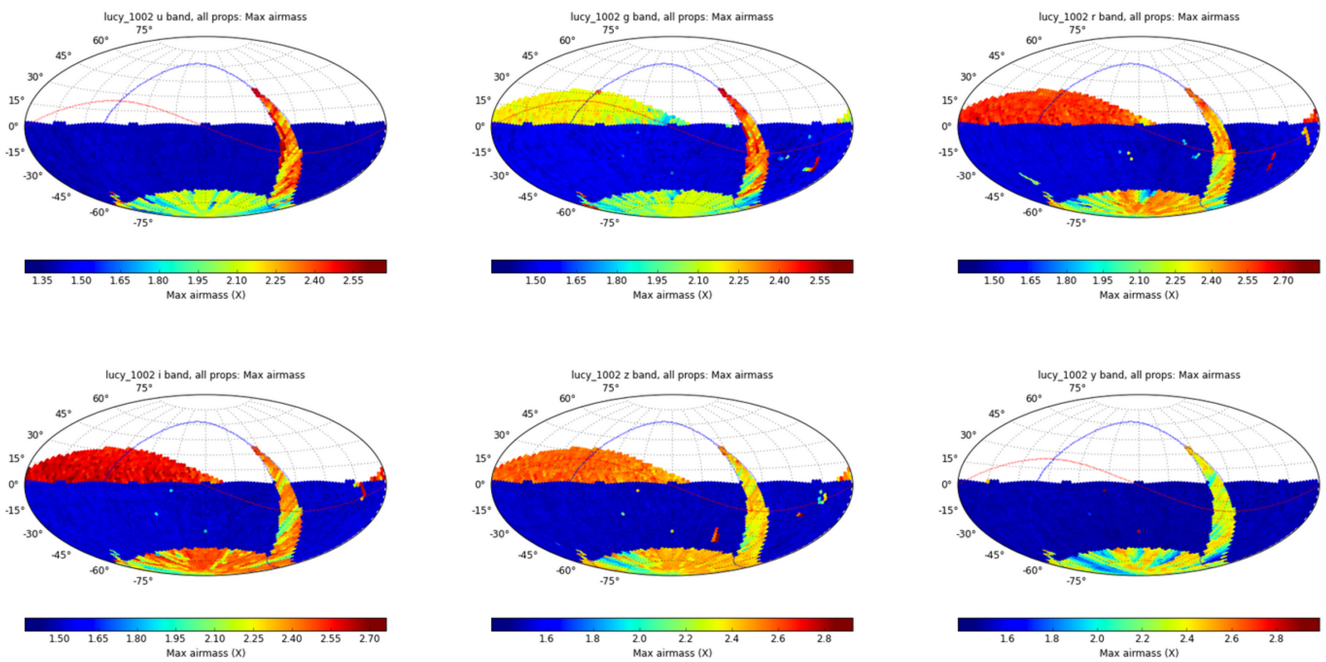
Example with periods ranging from 2-10 days, using 3 years of *r* band observations.



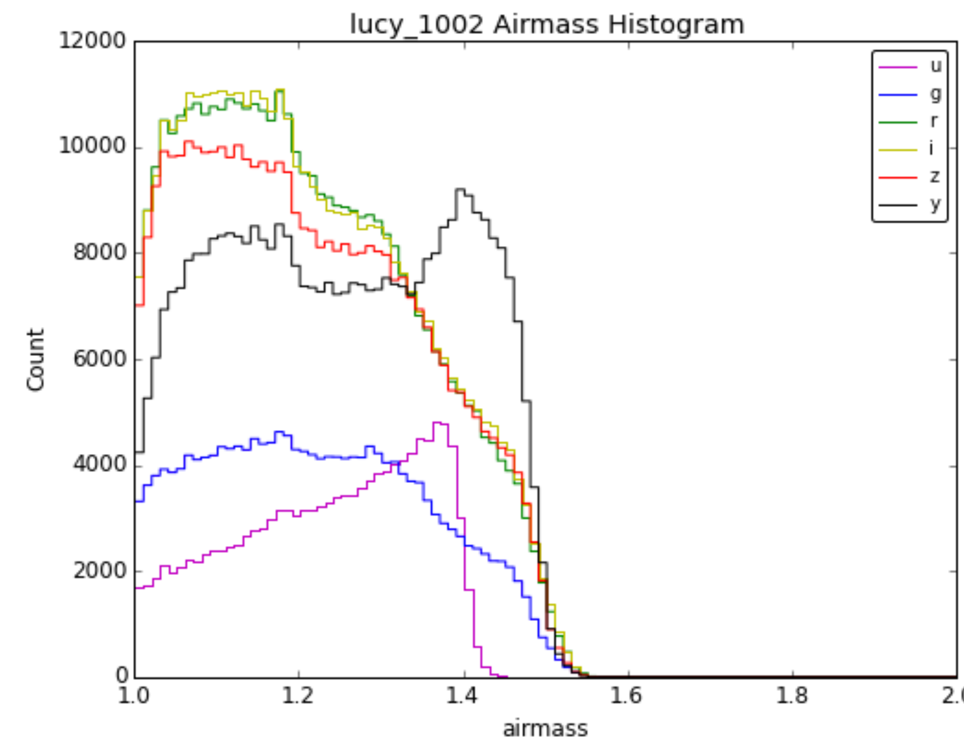




Technical metrics

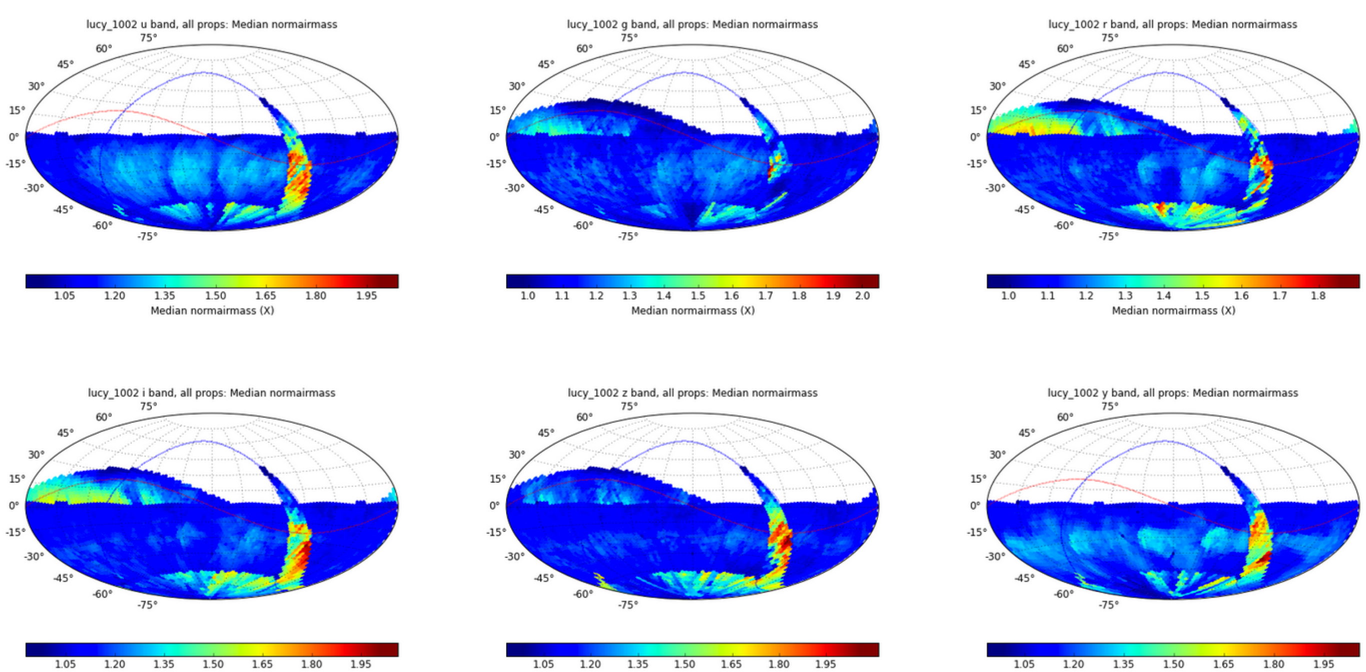


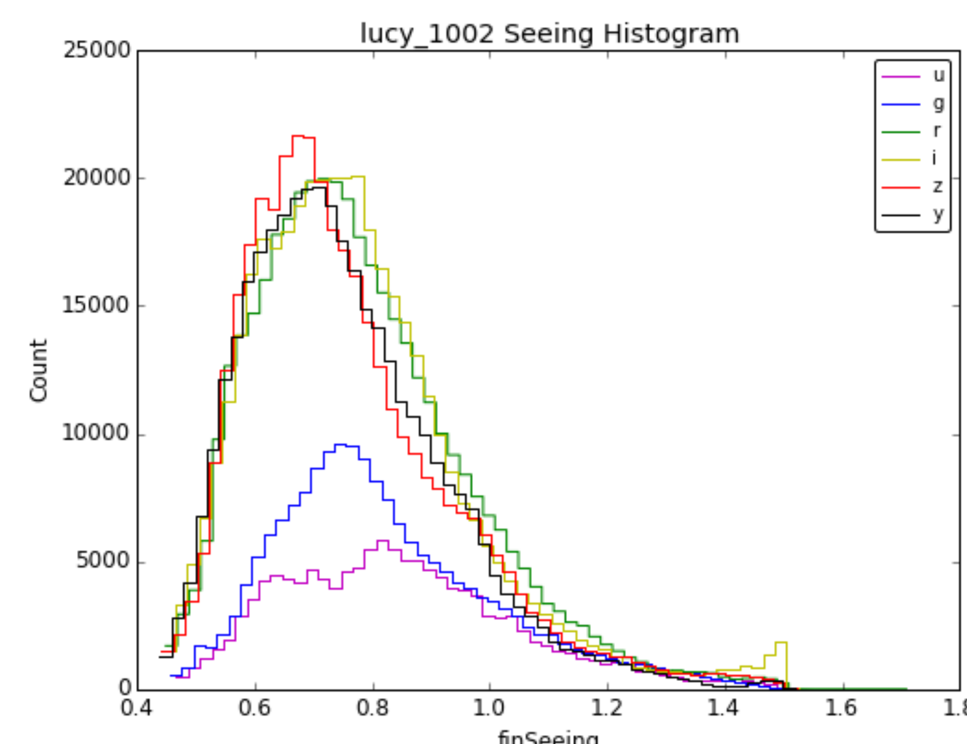
Max airmass per field (and mean, min..).



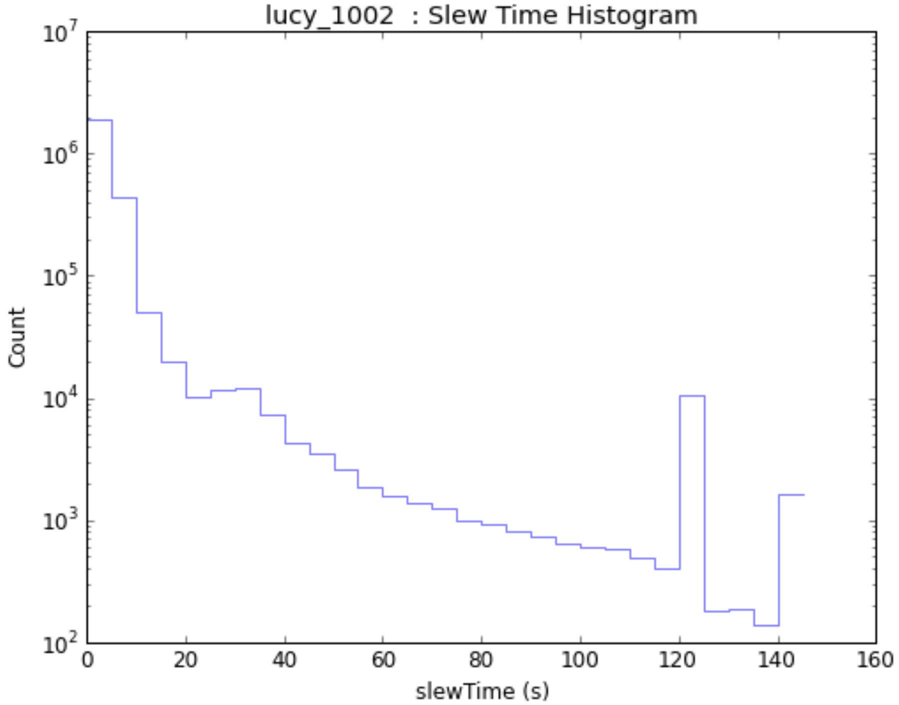
Airmass (above) and seeing (below) distributions for all visits

Median normalized airmass (airmass/minimum airmass possible for each field).





Technical metrics



Group: *L: Slew*; Subgroup: *Slew Activity*; Slicer: *UniSlicer*							
	ActivePerc	**ActiveAve**	**Max**	**ActivePerc in crit**	**ActiveAve in crit**	**Total Ave**	**Contribution**
DomAlt	91.14	3.41	60.24	2.19	7.89	3.11	0.21
DomAz	91.37	5.36	121.96	30.08	8.46	4.90	3.30
TelAlt	91.14	1.71	30.12	49.95	1.78	1.55	0.24
TelAz	91.14	1.63	52.32	8.59	1.60	1.48	0.03
Rotator	0.50	11.54	29.21	0.02618	0.02618	0.06	0.0000
Filter	0.48	120.00	120.00	0.48	120.00	0.58	10.59
TelOpticsOL	91.14	0.80	29.12	0.0065	5.99	0.73	0.0004
Readout	100.00	2.00	2.00	6.97	2.00	2.00	0.04
Settle	92.90	3.00	3.00	60.27	3.00	2.79	0.83
TelOpticsCL	1.24	20.00	20.00	1.24	20.00	0.25	0.76

Slew time histogram (note big bump for filter changes) and statistics.

Number of filter changes per night. Open shutter fraction per night.