Rubin Observatory

Proposed Metrics

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Thank you to all contributors!

LSST CORPORATION LSST: Science Collaborations TVSSC

GW-follow up ToO Metrics

Author: Raffaella Margutti <rafmargutti@gmail.com>

$$S_{\mathrm{NS-NS}} = \frac{(1 + 2f_{\mathrm{early}})N_{\mathrm{det}}}{3N_{\mathrm{NS-NS}}}$$

Heuristic quantifier of the success of the GW-follow up program (here applied to NS mergers)

where N_{NS-NS} is the number of NS-NS mergers detected by GW interferometers that satisfy the ToO activation criteria, N_{det} is the number of associated kilonova detections in LSST ToOs, and f_{early} is the fraction of these detections that lead to an identification within 1 day.

Implementation status: NA

Threshold conditions:

- PRIMARY: Implementation of ToO capabilities as part of normal survey operation
- Minimal strategy: 1% of LSST time in ToOs, multiple filters

Documentation status:

- Metric concept and motivation fully described in White Paper: https://arxiv.org/pdf/1812.04051.pdf

Note from D. Scolnic - seee similar metric from DESC at end of slides

CadenceOverVisibilityWindowMetric

Author: Rachel Street <rstreet@lco.global>

Compares lightcurve cadence achieved by LSST with give desired cadence for a given sky pointing and observing window

Threshold conditions:

- Desired cadence: 1 day (stellar lenses), 7 days (compact object lenses)
- Observing window: 10yr baseline for WFD or duration of DDF

Implementation status:
Code written, integrated with sim_maf_contrib

Documentation status:

- Doc strings throughout code, outline in White Paper
- Full documentation TBD

StarCountsMetric

Author: Mike Lund <mike.lund@gmail.com>

Calculates the numbers of stars within a given pointing between distances from the observer D1 -> D2

Threshold conditions:

- D1 = zero, D2 = 12pc to encompass entire survey

Implementation status:
Code written, integrated with sim_maf_contrib

Documentation status:

- Outline in White Paper
- Full documentation TBD

UniformityMetric

Author: Peter Yoachim/Lynne Jones

Calculates how uniformly observations of a given pointing are spaced in time

Threshold conditions:

- surveyLength (defaults to 10yrs)

Implementation status:
Fully integrated with sims_maf

Documentation status:

- Unknown

CampaignLengthMetric

Author: Phil Marshall

Calculates the length of time for which a given pointing is observed in total

Threshold conditions:

- None

Implementation status:
Code written, integrated with sim_maf_contrib

Documentation status:

- Unknown

NumObsInSurveyTimeMetric

Author: Somayeh Khakpash

Calculates the number of observations obtained of a given pointing by LSST within the survey window of another ongoing survey

Threshold conditions:
Dates of the simultaneous survey windows, configured for RGES:
('2026-01-01', '2026-03-13'), ('2026-07-01', '2026-09-10'), ('2027-01-01', '2027-03-13']),
('2029-07-01', '2029-09-10'), (2030-01-01', '2030-03-13'), ('2030-07-01', '2030-09-10')

Implementation status:
Code written, integrated with sim_maf_contrib

Documentation status:

- Outline in White Paper
- Full documentation TBD

IntervalBetweenObsMetric

Author: Somayeh Khakpash

Calculates mean, median or standard deviation of intervals between observations during simultaneous windows/Inter-seasonal gap of another survey

Threshold conditions:
Dates of the simultaneous survey windows, configured for RGES:
('2026-01-01', '2026-03-13'), ('2026-07-01', '2026-09-10'), ('2027-01-01', '2027-03-13']),
('2029-07-01', '2029-09-10'), (2030-01-01', '2030-03-13'), ('2030-07-01', '2030-09-10')

Implementation status:
Code written, integrated with sim_maf_contrib

Documentation status:

- Outline in White Paper
- Code commented
- Full documentation TBD

NRevisitsMetric

Author: Lynne Jones

Calculates the number of consecutive visits to a given pointing with time differences less than dt

Threshold conditions:

- dt= 1 day (stellar lenses), 7 days (compact object lenses)

Implementation status:
Fully integrated with sims_maf

Documentation status:

- Unknown

EventTriggerMetric

Author: Mike Lund <mike.lund@gmail.com>

Compares the minimum time between observations with the maximum spacing where alerting of the desired event is still possible while the event is in progress

Threshold conditions:

For Wide-Fast-Deep:
Delmax (viable time to detect event): 30d (stellar lenses), 150d (compact object lenses)
Delmin (minimum time between observations): ~1 day (stellar lenses), ~7 days (compact objects)

For DDF in Bulge:
Planetary anomalies: DelMax = 4hrs DelMin = 15min
Stellar lenses: DelMax = 5 days DelMin = 1 day
Stellar remnant lenses: DelMax = 30days DelMin = 2 days

EventTriggerMetric (continued)

Implementation status:
Code written but not integrated

Documentation status:

- Outline in White Paper
- Paper in prep?

LowSurfaceBrightnessMetric

Author: Seppo Laine <seppo@ipac.caltech.edu>

Requirements for low surface brightness science from the WFD survey (pipeline should not mask/subtract such emission)

Implementation status: Main requirement is availability of individual images, not stacked (for elimination of scattered light in the images).

We prefer longer exposure times. 2 x 15 sec is acceptable per visit but can trade visits/exposure time

Threshold conditions:

- More than 10 visits (expect 825) with 2x15 sec exposures in each visit (equivalent total time)
- Require at least two - three bands of such deep images outside |b| > 20 deg
- Prefer uniform coverage and need a large background area for background subtraction

Documentation status:

- Requirements described in the white paper at https://docushare.lsstcorp.org/docushare/dsweb/Get/Document-30590/laine_lsb_streams_wfd.pdf

BulgeStatic Metric

Author: Will Clarkson <wiclarks@umich.edu>

Implementation of the Gonzalez et al. (2018) Cadence Whitepaper metric, summed over all fields into the proposed Figure of Merit for static-bulge science. (Involves comparison with external bulge MSTO map.)

Implementation status: Implemented in python but possibly not very efficiently (the standard crowding_to_precision metric is evaluated for each filter separately as is the proper motion metric in one filter, saved to .npz files, then re-loaded for combination into the Figure of Merit).

Threshold conditions / continuing work:

- Magnitude limit for “good” fields in the presence of crowding should reach the bulge MSTO
- Needed: proper motion metric at spatially-variable apparent magnitude;
- In progress: calibration of the relationship between the crowding_to_precision metric and the depth actually achieved in archival observations; refinement of target depth based on experience

Documentation status:

- Gonzalez et al. (2018 arXiv:1812.08670): The Definitive Map of the Galactic Bulge

LikelihoodScore Metric

Author: Fabio Ragosta <fabio.ragosta@inaf.it>

The metric estimates the intersection for each healpixel between the likelihood score distribution for the proper motion of objects from an atypical and typical velocity distribution function

Implementation status: Code written.

The metric takes the signal to noise ratio as one of the input.

Threshold conditions:

- At least two detections of the object during the surveyDuration

NOTE: the metric works together with the TransientPM Metric and the Confusion Metric to analyse the ability of an Opsim to detect unexpected anomalies.

Confusion Metric

Author: Fabio Ragosta <fabio.ragosta@inaf.it>

The metric estimates the Confusion Index (the number of objects detected in the error area of a detection) in the reduced proper motion diagram from a known dataset.

Implementation status: Code written.

The metric takes the signal to noise ratio as one of the input.

NOTE: the metric works together with the LikelihoodScore Metric and theTransientPM Metric to analyse the ability of an Opsim to detect unexpected anomalies.

TransientPM Metric

Author: Fabio Ragosta <fabio.ragosta@inaf.it>

The metric estimates the number of transient for which we can measure the proper motion for each healpixel.

Implementation status: Code written.

The metric takes the signal to noise ratio as one of the input.

Threshold conditions:

- At least two detections of the object during the surveyDuration

NOTE: the metric works together with the LikelihoodScore Metric and the Confusion Metric to analyse the ability of an Opsim to detect unexpected anomalies.

filterPairTGapsMetric

Author: Xiaolong Li <lixl@udel.edu>

The metric counts the number of time gaps between two filters for each field.

Implementation status: code written

Threshold conditions:

- The metric takes observation time, and filter as inputs

Documentation status:

- Not documented

DCR Metric

Author: Gordon Richards <gtr@physics.drexel.edu>, Bee Martin, Weixiang Yu, Christina Peters

Gives some sense of how much information will be provided by DCR, assuming that LSST reports DCR properties in the same way that SDSS did. Right now, we are mainly looking to see if the natural cadence produces so many observations that nothing special is needed to take advantage of DCR.

Implementation status: Some code (not yet in MAF framework) at https://github.com/RichardsGroup/LSSTprep/blob/master/DCR/DCR_AGN_metric_analysis.ipynb

Threshold conditions:
N/A

Documentation status:
Barely documented at all. Described in DCR whitepaper:
https://docushare.lsstcorp.org/docushare/dsweb/Get/Document-30573/richard_dcr_wfd.pdf

AGN Structure Function Metric

Author: Gordon Richards <gtr@physics.drexel.edu>, Weixiang Yu

Looks at distribution of pairs of observations with the goal of gauging how accurately we can compute AGN “structure functions”. We now need to turn that information into an actual metric.

Implementation status: Started some code at

https://github.com/RichardsGroup/LSST_OpSim/blob/master/contrib/04_Log_Delta_T_MetricWFDvsDDF.ipynb

Threshold conditions:
N/A

Documentation status:
Not at all documented, but the problem is described by the following whitepaper:
https://docushare.lsstcorp.org/docushare/dsweb/Get/Document-30572/richards_agn_rolling_wfd.pdf

DDF Footprint Metric

Author: William Brandt <wnbrandt@gmail.com>

We require that the LSST DDFs cover the prime multiwavelength data available in each of the four fields, as illustrated in Figures 1-5. In choosing the field central positions provided in Section 3.2, we have prioritized ensuring overlap with the sky regions covered by the SERVS, XMM-SERVS, VIDEO, and Spitzer DEEPDRILL programs; the SERVS, XMM-SERVS, and VIDEO coverage is closely overlapping. Deep Herschel coverage is also deemed essential, since it is needed for measurements of star formation in AGN hosts and will be irreplaceable in the near future. A relevant existing metric is "NightPointingMetric".

Implementation status: No code yet - described in the white paper arXiv:1811.06542

Threshold conditions:

- Footprint must cover the prime multiwavelength data

Documentation status:

- Concept and motivation are in the white paper arXiv:1811.06542

DDF Cadence Metric

Author: William Brandt <wnbrandt@gmail.com>

We require the DDFs to be observed at least every two nights in grizy in as regular a manner as possible. Many additional relevant details, including u-band requirements, are provided in Section 3.4. Multiple-band coverage is especially required for photometric RM of AGN accretion disks, general AGN variability characterization, and SMBH transient characterization (see Section 2). Longer sampling timescales would have a substantial negative effect upon this program. Even a minor increase in the sampling timescale (e.g., from two nights to three-or-four nights) would damage the rapid time-domain science including continuum RM studies of accretion disks, general/exceptional AGN variability studies, and exploration of transient SMBH phenomena. A larger increase in the sampling timescale would damage the program even more broadly; e.g., harming photometric support of multi-object spectroscopic RM campaigns.

Implementation status: No code yet - described in the white paper arXiv:1811.06542

Threshold conditions:

- DDFs to be observed at least every two nights in grizy in as regular a manner as possible.

Documentation status:

- Concept and motivation are in the white paper arXiv:1811.06542

DDF Uniform Depth Metric

Author: William Brandt <wnbrandt@gmail.com>

To optimize photometric-redshift derivation and source characterization for AGNs and galaxies in the DDFs, we would like to achieve a relatively uniform depth across the LSST filters. This is economically possible for ugri but less so for z and y. We thus request, every two nights, 1 visit in g, 1 visit in r, 3 visits in i, 5 visits in z, and 4 visits in y. Here each visit is the standard 30 s. The 3 visits in i can be back-to-back for sake of efficiency, as can the 5 visits in z and 4 visits in y. The u-band is addressed in Section 3.4. This pattern of visits across the LSST bands has been developed with some coordination with the requirements of the DESC, and it will satisfy our desires for total ugrizy depths described in Section 1.

Implementation status: No code yet - described in the white paper arXiv:1811.06542

Threshold conditions:

- DDFs need to achieve uniform depth, to the extent possible, across filters.

Documentation status:

- Concept and motivation are in the white paper arXiv:1811.06542

DDF Long Seasons Metric

Author: William Brandt <wnbrandt@gmail.com>

We require the longest observing seasons possible. For example, this increases the chances of robust RM lag detection, allows access to longer RM lags corresponding to higher SMBH masses, minimizes missed RM lags due to non-overlapping data in cross-correlation analyses, and aids searches for SMBH binaries. The current planning for SDSS-V calls for its RM fields to be observed spectroscopically for 6-7 months each year, and we expect similar windows for 4MOST RM. We request that the LSST observations span, at least, this same time window plus 1-1.5 month precursor observations every season before the spectroscopic observations begin. The precursor observations will allow the "driving" AGN continuum to be sampled earlier than the "responding" BLR emission. We can tolerate airmass values up to ~ 2.0 in order to achieve these long (7-8.5 month) LSST observing seasons.

Implementation status: No code yet - described in the white paper arXiv:1811.06542

Threshold conditions:

- DDFs need to achieve the longest observing seasons possible - 7-8.5 months.

Documentation status:

- Concept and motivation are in the white paper arXiv:1811.06542

DDF Image Quality Metric

Author: William Brandt <wnbrandt@gmail.com>

We request that the delivered r-band image quality be better than 1.2", with other filters to be scaled accordingly.

Implementation status: No code yet - described in the white paper arXiv:1811.06542

Threshold conditions:

- DDFs need to achieve an r-band image quality of 1.2” or better, with other filters to be scaled accordingly.

Documentation status:

- Concept and motivation are in the white paper arXiv:1811.06542

Young Stars and their Variability

Author: Rosaria (Sara) Bonito <rosaria.bonito@inaf.it>

Investigation of stellar variability due to accretion process, also in eruptive bursts (EXors); rotation; stellaractivity; etc.., young stellar clusters

Implementation status: authors: selected field observed once every 30 minutes in g, r,and i bands. Figure of Merit: 140 points in each filter in 1 week. Wide Fast Deep:: 80, 180, and 180 visits in g, r, and i filters respectively in ten years, i.e.: 0.15, 0.35, and 0.35 observations per week in g, r, and i filter respectively instead (ratio = 0.15/140 or 0.35/140, i.e. 0.00107143, 0.00250000). Number of visits on the Galactic Plane, in 10 years (p.55 SB, sect.3.1) are lower: <30 in all filters (<1 every four months).

Threshold conditions:

- 1 week every year (rolling cadence)
- Centered on Eta Carinae (RA, Dec= 10 45 03.5362075818-59 41 04.053436648)

Documentation status:

- Metric concept and motivation described in the White Paper: Bonito & Hartigan et al. 2018 9https://docushare.lsstcorp.org/docushare/dsweb/Get/Document-30505/bonito_carina_dd.pdf0

A Photo-z Metric?

Author: Melissa Graham & Alex Malz (& Francois Lanusse?)

A metric that evaluates the quality of photo-z based on the coadd depth in *ugrizy* for a given OpSim.

Implementation status: Conceptual. Goal is to merge at least three components: (1) Humna Awan's MAF which returns the coadd depth in *ugrizy* in extragalactic fields; (2) MLG's CMNN Photo-z Estimator which intakes coadd depths, simulates photo-z for a mock galaxy catalog, and returns a variety of photo-z quality statistics; (3) estimation of the information content in the space of redshift based on the information content in the space of photometry. But how to do this, and how to distill the pz quality statistics, is what we're working on.

Threshold conditions:

- ???

Documentation status:

- CMNN Photo-z Estimator was used for the DESC WFD white paper (not embedded in a MAF tho).
- CMNN Photo-z Estimator GitHub; Graham+2018; Graham+2020.

U-band of High-Cadence Fields

Author: Benne Holwerda <benne.holwerda@gmail.com>

U-band observations to the same cumulative depth as the high-cadence fields.

Implementation status: No specific code but an analysis how u-band information supplements SWIFT and GALEX deep observations.

Does the metric require a minimum exposure time and/or take signal-to-noise into account? Yes. The requirement does not specify a cadence making this a few night commitment when the u-band filter is installed.

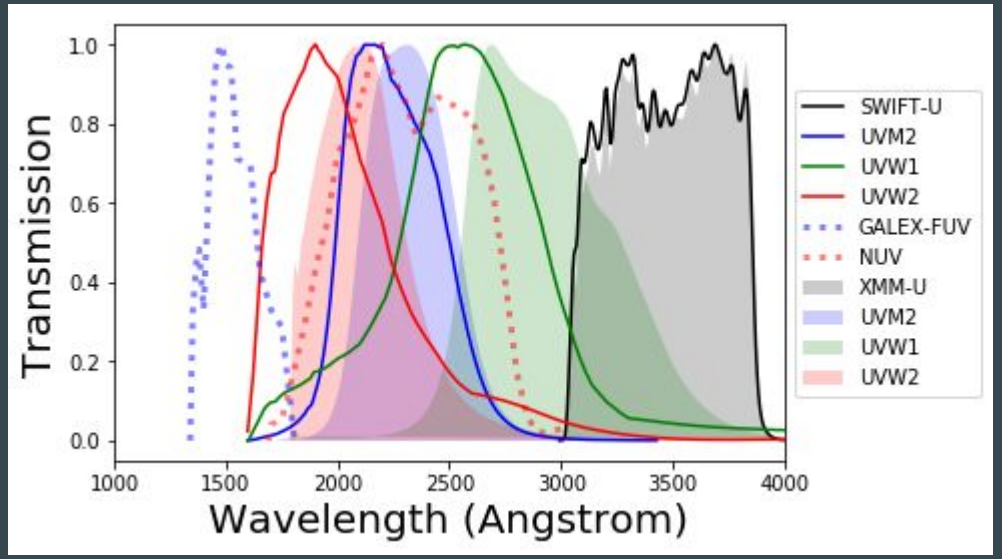
- Exposure time of several tens of hours on 4 fields, no constraints on timing

Documentation status:

- Does the code have complete doc strings throughout? - no
- Was the metric concept and motivation described in a White Paper? - somewhat?
- Is there full documentation? Has it been described in a publication? - proposals only.

U-band of High-Cadence Fields

SDSS-u band is between the high-cadence gri filters and the ultraviolet information from GALEX and SWIFT (or XMM-OM)

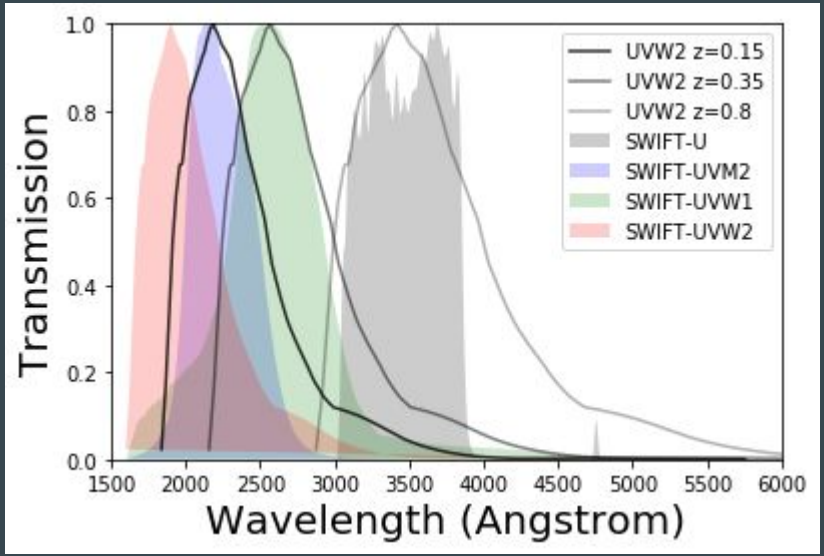


U-band of High-Cadence Fields

This means that it spans near-ultraviolet for objects that are at z~0.8.

With deep GALEX (and SWIFT) observations of the LSST deep drilling fields, u-band provides:

a) NUV information on higher redshift objects.
b) A bridge in the SED between UV and optical.



TDEsPopMetric

Authors: Xiaolong Li, Katja Bricman, Sjoert van Velzen, Peter Yoachim, Lynne Jones <katja.bricman@ung.si>

The metric estimates the fraction of TDEs detected given multiple detection criteria.

Implementation status: code written, integrated with sim_maf_contrib

Mainly depends on the multi-band coverage in ~1 month around peak of the event.

Documentation status:

- The metric concept was partially outline in two White Papers: https://arxiv.org/abs/1812.07036 and https://arxiv.org/abs/1812.06054.
- Comparison of 1.4, 1.5 and 1.6 runs: https://github.com/rhiannonlynne/notebooks/blob/master/TDE%20comparison.ipynb
- No other documentation.

Static Probes Figure of Merit

Author: Husni Almoubayyed <halmouba@andrew.cmu.edu>

Emulator for the 3x2pt Dark Energy Task Force figure of merit. Currently purely statistical (no systematics).

Implementation status: Fully implemented in MAF
https://github.com/lsst/sims_maf/blob/master/python/lsst/sims/maf/metrics/summaryMetrics.py

- Mainly depends on the area and median i-band co-added depth (after cuts in depth, extinction, WFD only, requires 6 band coverage).

Documentation status:

- Code is documented
- Metric described in https://arxiv.org/abs/1812.00515v2

Weak Lensing Systematics Metric (WeakLensingNVisits)

Author: Husni Almoubayyed <halmouba@andrew.cmu.edu>

Uses the average number of i-band visits as a proxy for performance of WL systematics (higher number → better). This is achieved after making several cuts (extinction, WFD only, requires 6 band coverage, depth cut.)

Implementation status: Fully implemented in MAF https://github.com/hsnee/sims_maf/blob/master/python/lsst/sims/maf/metrics/weakLensingSystematicsMetric.py

- Depends on e.g. area, co-added depth, duration of exposures, footprint, etc.

Documentation status:

- Code is documented
- Metric is described in https://arxiv.org/abs/2006.12538

Extragalactic Footprint Metric

Author: Humna Awan <awan@physics.rutgers.edu>

Calculates the survey footprint useful for most extragalactic science: E(B-V) limited, i-band depth limited, requires coverage in all 6 bands.

Implementation status: In mafContrib by the author here; faster version by the MAF team here.

Threshold conditions:

- E(B-V)
- i-band dust-extinguished, co-added depth
- 6-filter coverage

Documentation status:

- Does the code have complete doc strings throughout? Yes.
- Was the metric concept and motivation described in a White Paper? Yes; Lochner+2018.
- Is there full documentation? Has it been described in a publication? Not yet; Lochner+, in prep.

Ngal (Number of Galaxies) Metric

Author: Humna Awan <awan@physics.rutgers.edu>

Calculates the number of galaxies that reach S/N for “gold sample” of galaxies by survey year-10.

Implementation status: In mafContrib by the author here; updated version by the MAF team (in review).

Threshold conditions:

- Same as for the extragalactic footprint metric
- Additional limiting mag for extended source i-band coadded depth.

Documentation status:

- Does the code have complete doc strings throughout? Yes.
- Was the metric concept and motivation described in a White Paper? Yes; Lochner+2018.
- Is there full documentation? Has it been described in a publication? Not yet; Lochner+, in prep.

Number of Supernova Transient Metrics

Author: Philippe Girs <philippe.gris@clermont.in2p3.fr>

Calculates number of SNe expected from LSST, both WFD and DDF. Calculates max redshift. Calculates cadence gaps.

Implementation status: In mafContrib by the author here; updated version by the MAF team (in review).

Documentation status:

- Does the code have complete doc strings throughout? Yes.
- Was the metric concept and motivation described in a White Paper? Yes; Lochner+2018.
- Is there full documentation? Has it been described in a publication? Not yet; Lochner+, in prep.

Number of Strong Lensing Metrics

Author: Sherry Suyu <suyu@mpa-garching.mpg.de>, Simon Birrer

Calculates number of SL SNe expected from LSST for WFD.

Implementation status: In mafContrib by the author here; updated version by the MAF team (in review).

Documentation status:

- Does the code have complete doc strings throughout? Yes.
- Was the metric concept and motivation described in a White Paper? Yes; Lochner+2018.
- Is there full documentation? Has it been described in a publication? Not yet; Lochner+, in prep.

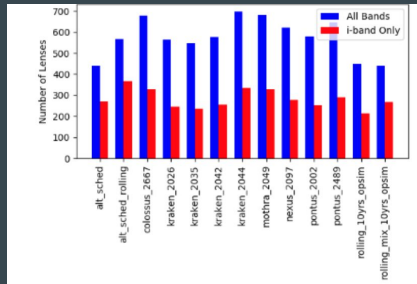


Figure 17. Number of "golden lenses" in sky areas with accuracies <0.2%

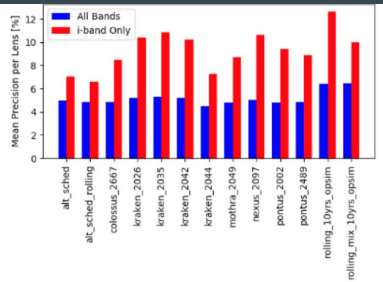


Figure 18. Mean precision per lens (percent) in sky areas with accuracies <0.2%

Number of Kilonovae detected

Author: Christian Setzer <christian.setzer@fysik.su.se>

Calculates number of KNe discovered from LSST for WFD.

Implementation status: In mafContrib by the author here; updated version by the MAF team (in review).

Documentation status:

- Does the code have complete doc strings throughout? Yes.
- Was the metric concept and motivation described in a White Paper? Yes; Lochner+2018.
- Is there full documentation? Has it been described in a publication? Not yet; Lochner+, in prep.

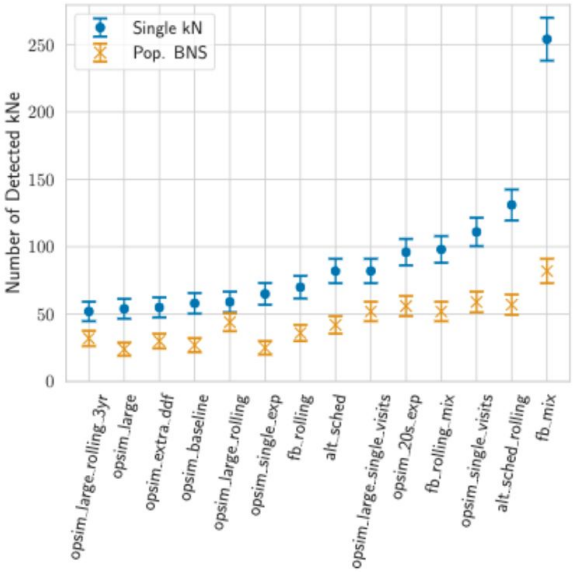


Figure 20. Total number of detected kNe over the 10-year survey duration, for two kN models and the multiple survey strategies considered in this work. The model based on GW170817, i.e., the Single kN model, predicts a higher number of detections than the model, Pop. BNS, based on a population of kNe. However, the general trend of detections between models is very similar.

Northern Ecliptic Spur Metrics

Author: Meg Schwamb (mschwamb.astro@gmail.com)

Calculates number of detections for different orbital populations

Implementation status: The MAF moving objects simulator tools are already implemented by the MAF team. Some of the moving object populations are already represented in the current cadence simulation analysis from Rubin Observatory. A few of the other populations have not yet been included (Neptune Trojans and some of the resonant island populations).

Documentation status: NA

Twilight NEO Search

Author: Rob Seaman, Meg Schwamb (mschwamb.astro@gmail.com)

Calculates number of detections of Near Earth Asteroids observed in twilight when the WFD and other mini-surveys and deep drilling field observations are not occuring.

Implementation status: The MAF moving objects simulator tools are already implemented by the MAF team. Has been included in the current suite of simulations by the MAF team. (Thanks MAF Team)

Documentation status: Documented in the report to the SCOC

Breakout sessions

Remember: Switch to Yotribe

Suggested breakouts:

- Time sampling metrics [ALMA]
- Footprint metrics [Paranal]
- Depth metrics [La Silla]

Extra slides

Template Metric Slide

Author: Firstname Lastname <email@email.com>

What does it do

Implementation status: Has code been written? By authors or by MAF team? Is it integrated with the MAF?

Does the metric require a minimum exposure time and/or take signal-to-noise into account?

Threshold conditions:

- Duration
- Do these conditions depend on any parameter, e.g. footprint?

Documentation status:

- Does the code have complete doc strings throughout?
- Was the metric concept and motivation described in a White Paper?
- Is there full documentation? Has it been described in a publication?