RNAAS RESEARCH NOTES OF THE AAS

AAS IOP

Impact of Rubin Observatory LSST Template Acquisition Strategies on Early Science from the Transients and Variable Stars Science Collaboration: Non-time-critical Science Cases

K. Hambleton[1], F. Bianco[2], G. Clementini[3], M. Dall'Ora[4], R. Egeland[5], N. Hernitschek[6,7], M. B. Lund[8], I. Musella[9], A. Prša[1], V. Ripepi[10], K. G. Stassun[6,7], R. A. Street[11], R. Szabó[12,13], and

On Behalf of the Rubin Observatory Transients and Variable Stars Science Collaboration

Published 2020 March 24 •

Research Notes of the AAS, Volume 4, Number 3

Article information

Export citation and abstract

BibTeX RIS

1. Introduction

Vera C. Rubin Observatory Legacy Survey of Space and Time, LSST, will revolutionize modern astronomy by producing an extremely deep (coadded depth ~27 mag) depth-limited survey of the entire southern sky (LSST Science Collaboration et al. 2009). The 8.4 m large-aperture, wide-field telescope, which is based in Cerro Pachón, will image the entire Southern sky every three nights in multiple bands (SDSS-*u*, *g*, *r*, *i*, *z*, *y*) and produce a fire-hose of data, 20 Tb each night, concluding in a 60 petabyte data set as the legacy of the 10 yr survey.

Extracting meaningful light curves from variable objects requires difference imaging to both identify variability and calibrate light curve data products. Templates, co-added groups of visits that act as an image of the "static" sky, are a key component of Difference Imaging Analysis (DIA) and as such are of paramount importance for all science that involves variable objects. As the "non-time-critical" science cases discussed here are mostly periodic, they generally do not depend upon the survey alert stream; however, templates are still crucial for performing science and calibrations during the first year. We provide recommendations for observing strategies for template acquisition starting from commissioning and through Year 1 of the survey.

1.1. Periodic Variables

The field of periodic variables is highly diverse and we therefore propose multiple sets of observations, all of which contribute to LSST's primary mission goals of "Understanding the Milky Way Structure and Formation" and "Observing the Transient and Variable Sky":

1. We advocate templates in at least two bands for the Galactic Bulge, the Magellanic Clouds, and the dwarf irregular NGC 6822. Two filters are required to identify RR Lyrae and Cepheid stars from color–color diagrams and further to disentangle the physical changes of effective temperature and mass-loss variations in luminous Blue variables. *i*- or *r*-filter images can provide deep templates in crowded regions and support cross-calibration while *y*- and *z*-band observations are preferred in more obscured areas.

2. The ultra faint dwarf galaxies Antlia 2 and Eri II would provide high science yield and the opportunity to validate the faint end of the survey's operations (Clementini et al. 2018). These two systems with a large number of RR Lyrae and large distance moduli provide a benchmark for the recovery of pulsating stars in low signal-to-noise ratio regimes. Two filters are required to determine the type of pulsator and distances through period–luminosity–color and period-

Wesenheit relations. We recommend obtaining templates for one or both of these diffuse galaxies in *g*- and *r*-band (or any two from *i*-, *r*- and *g*-bands.)

3. We additionally advocate for *r*-band templates for as wide an area as possible in the Galactic halo. This would provide nominal tests of the survey operations and pipelines and observations of periodic variables in the halo, which are important tracers of galaxy formation history and gravitational potential (e.g., Eyre & Binney 2009).

1.2. Eclipsing and Interacting Binary Stars

Eclipsing binary stars (EBs) span a wide range of orbital periods (<1 day to years). We advocate time-averaged templates constructed from images collected at variable temporal separation. Aliasing of variability periods in the collection of the template images could result in systematics propagating to the lightcurve obtained from DIA (for example, the Kepler mission accidentally used an EB with a period of ~1.69 days as a guide star, which resulted in a 1.69 day power excess in all Kepler light curves; Prša et al. 2011). An optimal strategy would collect images in a roughly logarithmic timescale with intervals from days to months.

Interacting binaries have higher densities in the galactic plane and are blue. We advocate templates in the Galactic Plane, with *g*- and *r*-bands to enable classification. To take into account the many variability timescales, the preferred strategy would collect images at different time intervals, as for eclipsing binaries.

1.3. Magnetically Active Stars

Observations of magnetically active stars have the potential to reveal rotational-scale (2–100 days) and decadal-scale variations analogous to the solar cycle. For most stars the fractional area covered by plage regions is larger than that of spots, with the result that the amplitude of the variations is larger at shorter wavelengths (Shapiro et al. 2016); thus we advocate *u*- and *g*-bands as they will provide the largest signal.

1.4. Transiting Planets and White Dwarfs

The unique subset of planets around white dwarfs will be potentially detectable with a single eclipse observation as planets are likely to be close in size to, or larger than, the host white dwarf (Agol 2011; Lund et al. 2018).

We advocate template images to be generated in the Galactic Plane, where most white dwarfs are located. Templates in *g*-, *r*- and *i*-bands would allow for unambiguous identification of white dwarf systems, and having templates and observations in *any* 2 of these bands would allow for very useful color information.

2. Recommendations

Synthesizing these science cases, we make the following recommendations:

1. Coverage of the Galactic Plane and selected nearby galaxies and regions, including crowded regions, is crucial to make strides in all Galactic variable science.

2. The large range of variability timescales requires that the templates be generated from images collected at a range of time separations. A roughly logarithmic scheme (from ~days to ~6 months) is recommended.

3. Templates in two colors benefit all science cases through the acquisition of colors that aids classification and extraction of physical parameters.

4. Template construction in *g*- and *r*- or *g*- and *i*-bands should be prioritized as they capture the requirements of most science cases.

In addition to being studied in alert-and-follow-up mode, several families of transients will be studies through statistical samples of "standalone" LSST data. Color samples will be necessary for these science cases to decontaminate samples or provide useful priors (see companion paper: Street et al. 2020).

References

- Agol E. 2011 *ApJL* **731** L31
  IOPscience ADS Google Scholar

- Clementini G., Musella I., Chieffi A. *et al* 2018 *The Gaia-LSST Synergy: Resolved Stellar Populations in Selected Local Group Stellar Systems* arXiv:1812.03298

ADS Preprint Google Scholar

Eyre A. and Binney J. 2009 *MNRAS* **400** 548
Crossref ADS Google Scholar

LSST Science Collaboration, Abell P. A., Allison J. *et al* 2009 *LSST Science Book* Version 2.0, arXiv:0912.0201
ADS Preprint Google Scholar

Lund M. B., Pepper J. A., Shporer A. and Stassun K. G. 2018 arXiv:1809.10900
ADS Preprint Google Scholar

Prša A., Batalha N., Slawson R. W. *et al* 2011 *AJ* **141** 83
IOPscience ADS Google Scholar

Shapiro A. I., Solanki S. K., Krivova N. A., Yeo K. L. and Schmutz W. K. 2016 *A&A* **589** A46
Crossref ADS Google Scholar

Street R., Bianco F. and Bonito R. 2020 *RNAAS* **4** 41
Google Scholar

Export references:

BibTeX RIS