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Opportunities for High Impact Solar System Science During Year 1 of the Legacy Survey of Space and Time (LSST)

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INTRODUCTION

Beginning in late 2022, the Vera C. Rubin Observatory will carry out the widest and deepest optical survey to date, the Legacy Survey of Space and Time (LSST; Ivezić et al. 2019). LSST will capture the entire available sky every few nights in 6 broad-band filters (*ugrizy*), providing an unprecedented dataset to explore the Solar System's inventory (LSST Science Collaboration et al. 2009). The LSST's Solar System Processing (SSP) will run daily and detect moving Solar System bodies out to ∼200 au. SSP requires the input of sources detected in LSST's difference images. The LSST image subtraction pipeline uses a master template representing the static sky, periodically (re)built during Data Release (DR) production. The first set of high fidelity templates (and the start of moving object/transient science) is therefore expected post-DR1, a year after observing starts. The Rubin Observatory is evaluating options for accelerated incremental template generation (e.g. on a monthly or weekly basis) in LSST Year 1 Operations (LOY1; Graham et al. 2019). Based on the LSST Solar System Science Collaboration's (SSSC) science roadmap (Schwamb et al. 2018), we highlight some high impact Solar System science opportunities that this change would enable. For these science cases, template generation options that maximize the sky coverage in LOY1 where SSP can run daily are strongly preferred, even if the incremental templates result in noisier image subtraction compared to DR1.

OPPORTUNITIES FOR SOLAR SYSTEM SCIENCE DURING LSST YEAR 1

Interstellar Objects

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LSST will usher in a new era for interstellar objects, rogue planetesimals passing through our Solar System. These bodies sample planet formation around other stars within the Milky Way, providing rare opportunities to apply the same observational techniques that we use on planetesimals within our Solar System. LSST is expected to detect several interstellar objects on hyperbolic orbits per year (e.g. Rice & Laughlin 2019). As with 1I/'Oumuamua, there may only be a few weeks of time to observe these rare objects ('Oumuamua ISSI Team et al. 2019); immediate follow-up after discovery is crucial. Without daily SSP detections in LOY1, interstellar discoveries will likely be too faint to observe with our largest ground-based and space-based telescopes by the time they are found at LSST DR processing.

Potential Earth Impactors

Potential non-life-threatening Earth impactors discovered by LSST will need rapid follow-up to determine their impact probabilities. Daily LSST Solar System detections would enable prompt action by the community. This would provide some warning to the predicted impact zone as well as enable pre-impact studies of the object and increase the likelihood of recovering meteorite fragments such as was done for 2008 TC3, 2014 AA, and 2018 LA. All three impactors were discovered less than 1 day before impact (Farnocchia et al. 2016, 2017; de la Fuente Marcos & de la Fuente Marcos 2018).

Disruption/Fragmentation Events and Cometary Outbursts

In LOY1, LSST will observe disruption/fragmentation events and cometary outbursts within the asteroid, comet, and Centaur populations. The timescales for needed follow-up observations are short (hours to days), and the data cannot be obtained if these events are not discovered until later. The few asteroid disruptions and comet fragmentation events observed to date have been extremely diverse (e.g. Ishiguro et al. 2016; Hainaut et al. 2019). LSST could have significant impact, with real time Solar System alerts enabling prompt community follow-up to probe the nature of these processes.

Stellar Occultations

Combining daily SSP astrometry of known minor planets, discovered in previous surveys, with *Gaia* data will enable highly accurate stellar occultation predictions in LOY1 (Camargo et al. 2018). These events, where a Solar System planetesimal passes in front of a background star, can be followed up with ground campaigns to measure sizes/shapes to extreme precision (with a few km accuracy) and also identify rings, extended dust structures, or atmospheres around these bodies (e.g. Braga-Ribas et al. 2014; Buie et al. 2020).

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REFERENCES

Braga-Ribas, F., Sicardy, B., Ortiz, J. L., et al. 2014, Nature, 508, 72, doi: 10.1038/nature13155

Buie, M. W., Porter, S. B., Tamblyn, P., et al. 2020, arXiv e-prints, arXiv:2001.00125. https://arxiv.org/abs/2001.00125

Camargo, J. I. B., Desmars, J., Braga-Ribas, F., et al. 2018, Planet. Space Sci., 154, 59, doi: 10.1016/j.pss.2018.02.014

de la Fuente Marcos, C., & de la Fuente Marcos, R. 2018, Research Notes of the American Astronomical Society, 2, 131, doi: 10.3847/2515-5172/aad551

Farnocchia, D., Chesley, S. R., Brown, P. G., & Chodas, P. W. 2016, Icarus, 274, 327, doi: 10.1016/j.icarus.2016.02.056

Farnocchia, D., Jenniskens, P., Robertson, D. K., et al. 2017, Icarus, 294, 218, doi: 10.1016/j.icarus.2017.03.007

Graham, M. L., Bellm, E. C., Slater, C. T., Guy, L. P., & the DM System Science Team. 2019, DMTN-107;Options for Alert Production in LSST Operations Year 1, Tech. rep. https://dmtn-107.lsst.io/

Hainaut, O. R., Kleyna, J. T., Meech, K. J., et al. 2019, A&A, 628, A48, doi: 10.1051/0004-6361/201935868

Ishiguro, M., Kuroda, D., Hanayama, H., et al. 2016, AJ, 152, 169, doi: 10.3847/0004-6256/152/6/169

Ivezić, Ž., Kahn, S. M., Tyson, J. A., et al. 2019, ApJ, 873, 111, doi: 10.3847/1538-4357/ab042c

LSST Science Collaboration, Abell, P. A., Allison, J., et al. 2009, arXiv e-prints, arXiv:0912.0201. https://arxiv.org/abs/0912.0201

'Oumuamua ISSI Team, Bannister, M. T., Bhandare, A., et al. 2019, Nature Astronomy, 3, 594, doi: 10.1038/s41550-019-0816-x

Rice, M., & Laughlin, G. 2019, ApJL, 884, L22, doi: 10.3847/2041-8213/ab4422

Schwamb, M. E., Jones, R. L., Chesley, S. R., et al. 2018, arXiv e-prints, arXiv:1802.01783. https://arxiv.org/abs/1802.01783