Report from the 2nd Solar System Readiness Sprint

Summary by SSSC co-chair Meg Schwamb (Gemini Observatory)

Sprint Purpose

Over its 10 year lifespan, the Large Synoptic Survey Telescope (LSST) could catalog over 5 million Main Belt asteroids, almost 300,000 Jupiter Trojans, over 100,000 NEOs, over 40,000 KBOs, and over 10,000 comets. Many of these objects will receive hundreds of observations in multiple bandpasses. The LSST Solar System Science Collaboration (SSSC) is preparing methods and tools to analyze this data, as well as understand optimum survey strategies for discovering moving objects throughout the Solar System.

The SSSC hosted a sprint June 4--6, 2019 in Chicago, IL. The goal is to continue the preparatory work needed to provide input into LSST cadence decisions and be ready to analyze and interpret LSST science data. This includes laying the infrastructure ad groundwork for joint computational tools, drafting user-contributed data products, developing MAF (Metrics Analysis Framework) metrics, discussing funding proposals and new collaborations, brainstorming possible citizen science and machine learning applications to LSST Solar System data. The next several years before LSST science operations commence at the end of 2022 are crucial for building this foundation in order to maximize LSST Solar System science. To further these goals, the three-day LSST Solar System Collaboration Readiness Sprint (workshop) at Adler Planetarium was convened to bring planetary researchers together to collaborate and work together on LSST related projects.

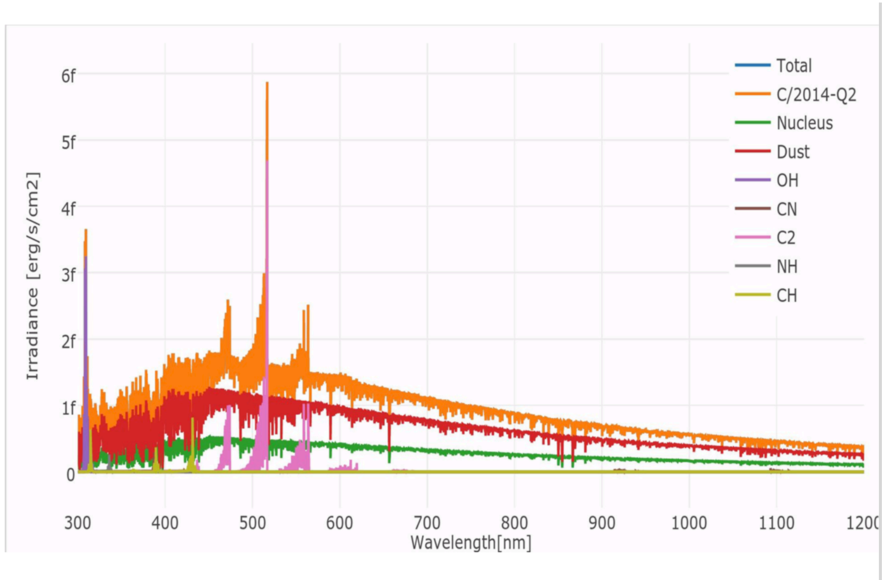
Sprint Logistics

The Sprint took place from June 4-6, 2019 at the Adler Planetarium with 15 scientists in attendance. There were a series of invited talks to provide important background and overview information about LSST, LSST construction and commissioning timelines, the Zoonvierse project builder platform (the LSST citizen science partner), and LSST project generated Solar System data products. Participants pitched projects and divided into dedicated project groups with topical discussion sessions planned for each day. After 3 days of learning and sprinting, here are some of the key results from the meeting.

Sprint Results

Creating Better Representations of Low Albedo/Dark Objects

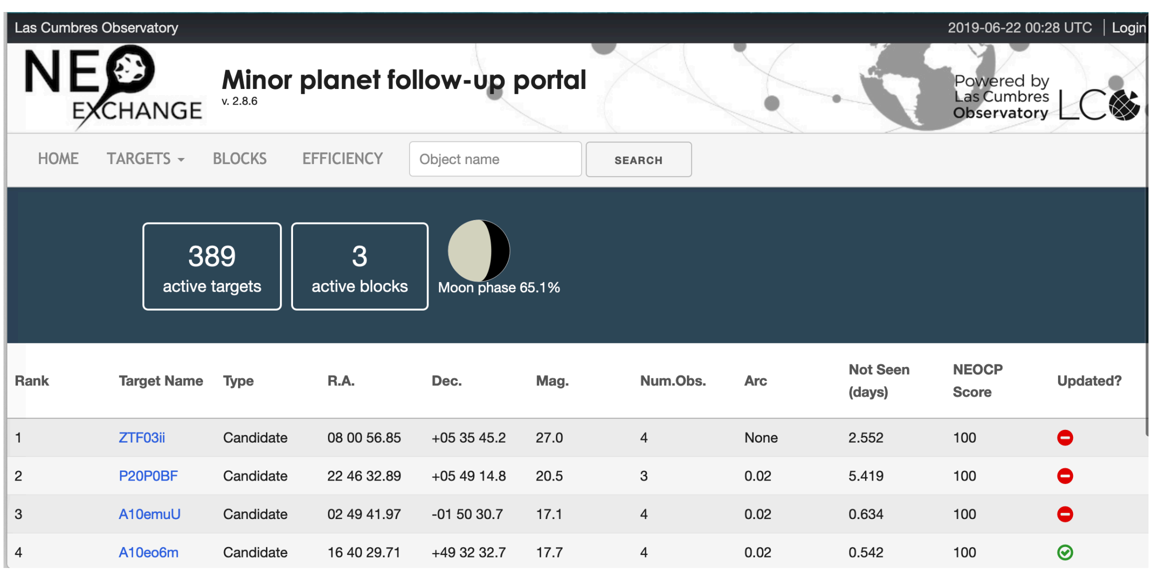
Tim Lister and Lynne Jones created synthetic optical spectra of darker asteroid taxonomic classes not well represented in the LSST simulator’s Solar System surface library in order to better test what their detection frequency will be in the various versions of the proposed LSST observing cadence and improve the accuracy of LSST moving object simulator’s population estimates.



Using throughputs (atmosphere, mirrors, lens, detector, filters) in SYNPHOT, Tim made synthetic spectra for D-type asteroids (see above). D-type asteroid spectra also serve as a suitable surface proxy non-active comet comet nuclei. These spectral energy distributions will be incorporated into the LSST moving object simulator.

Target and Observation Manager (TOM) Systems

Tim Lister presented the Las Cumbres Observatory Target and Observation Manager (TOM) systems and gave a demonstration of the NEO exchange (https://lco.global/neoexchange/). Mario Jurić, Wes Fraser, Tim Lister, Mike Kelley, Henry Hsieh, and Meg Schwamb discussed how these tools could be expanded and applied to future LSST Solar System observing follow-up.



Developing Active Object Metrics for LSST Cadence Input and Discovery Population Estimates

Mike Kelley, Tim Lister, Geza Gyuk, Darin Ragozzine, and Siegfried Eggl worked towards developing metrics that can be used to rank the various LSST operations survey cadence simulations with respect to achieving Solar System active object science goals and identified target comet populations to test. Over the three days they:

- Interrogated all Active Objects Science Priorities in the Solar System Science Roadmap.
- Identified several useful quantities to calculate.
- Identified the need for a semi-realistic template comet (photometric) model.
- Identified orbital populations to test.

They also identified a list of metrics to evaluate how well comet/active objects science goals can be evaluated for LSST operations simulations of varying proposed cadences including:

- Discovery Test - Can the object be discovered?
- Active Object / Extendedness Test - Is activity assessment possible?
- Outburst Discovery Test - Can a cometary outburst be discovered?
- Light curve Analysis Test - Is light curve coverage good enough to define long-term activity trend?
- Astrometry Test- Is astrometry useful?

Educational Material for Researchers New to the LSST Solar System Science Collaboration

Matt Wiesner, Darin Ragozzine, and Meg Schwamb developed on-boarding content for new SSSC members.

Introduction to the LSST Solar System Science Collaboration

What is the LSST SSSC

The SSSC exists to both support scientists in preparing for and using the revoluationary LSST data and to provide recommendations to the LSST project that support solar system science. The SSSC is actively searching for new members whatever your current role in LSST or the planetary science community.

Aim of the SSSC

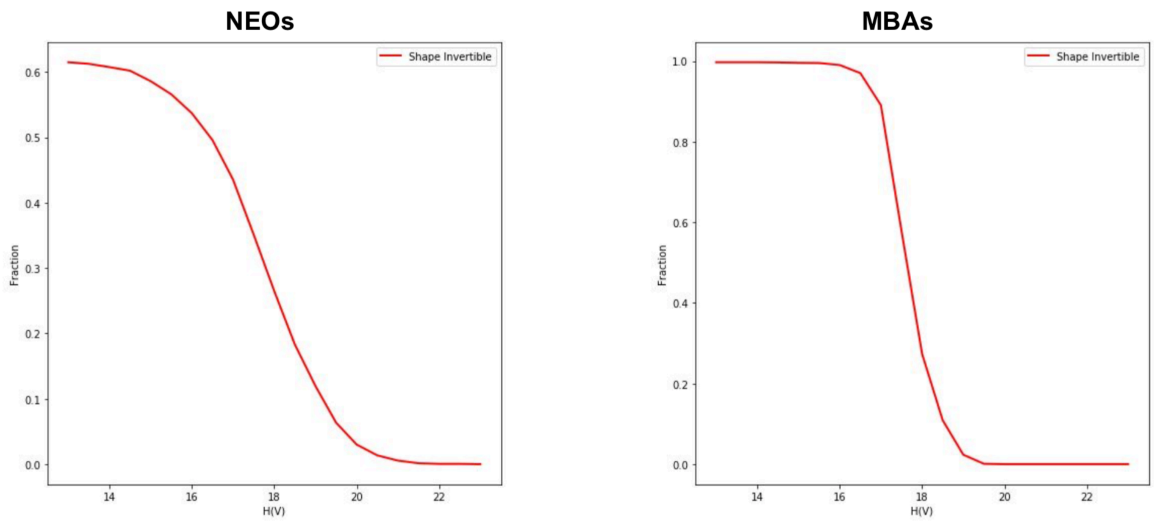
The current aims of the SSSC are focusing on being prepared to do powerful science before the full survey starts in late 2022. This preparation includes developing software tools, seeking funding, and forming efficient collaborations. We are also actively participating in shaping decisions by LSST that affect our science (such as cadence optimization). As we get closer to the survey, these activities will continue to ramp up and will transition into working on LSST first science papers. The SSSC currently communicates through email lists, slack, telecons, and annual meetings.

SSSC organization

The SSSC is led by two co-chairs and is organized into five Working Groups that serve as avenues for communication and collaboration: Near-Earth and Interstellar Objects, Inner Solar System, Outer Solar System, Active Objects, and Software/Infrastructure. There is an enormous amount of work to do… if you are

Near Earth Asteroid (NEO) and Main Belt Asteroid (MBA) Light curve Metrics

Wes Fraser and Steve Chesley developed metrics and python software to examine how many NEOs and MBAs in each proposed LSST cadence scenario will have sufficient observations for light curve shape inversion modeling. This will be used to evaluate the various proposed LSST observing cadences.



Fraction of LSST detections NEOs and MBAs in the current LSST baseline cadence as a function of absolute magnitude with sufficient numbers of observations to apply light curve inversion techniques to estimate the sizes and shapes of these bodies.

Develop Python wrapper to JPL orbit and uncertainty propagation libraries for implementation into LSST Moving Object Processing System (MOPS)

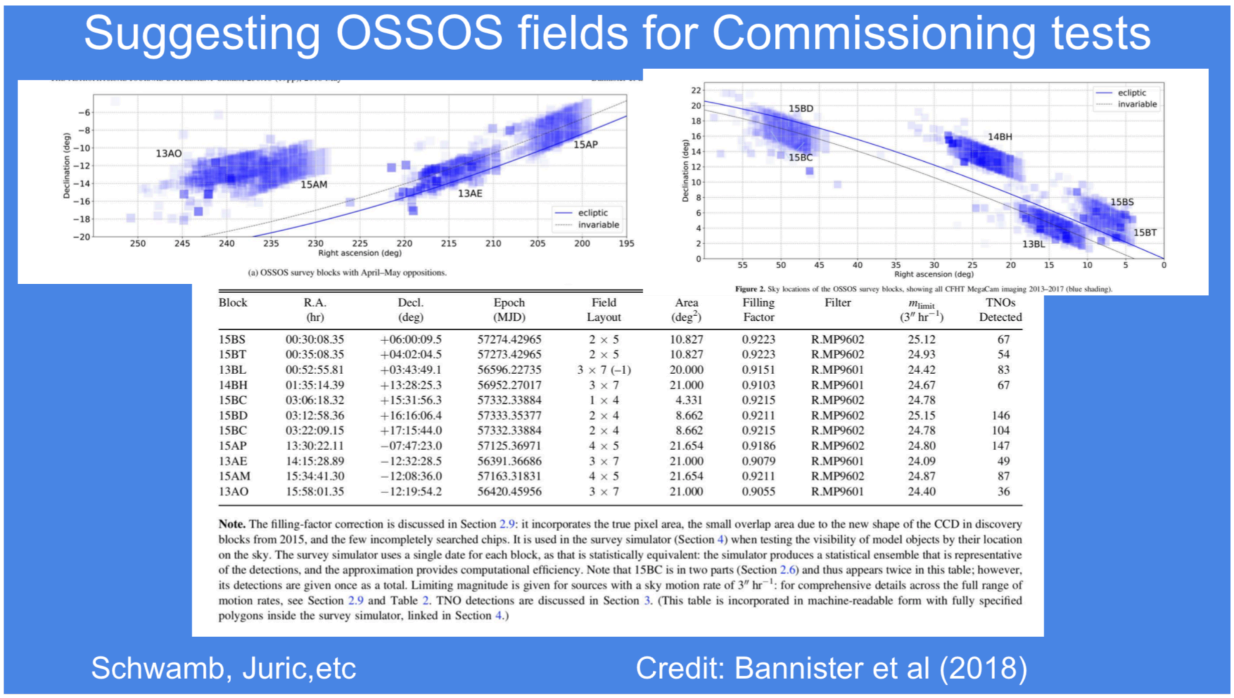
Steve Chesley, Siegfried Eggl, and Mairo Jurić focused on integrating the JPL orbit and uncertainty propagation routines into the LSST MOPS framework. The JPL routines are written in Fortran and the key step was to develop python interfaces to the JPL code. They started development MOPS Solar System dynamics python module for initialization and ephemeris computation. This module was able to be compiled and will be tested during the next several months.

Exploring Potential Citizen Science to LSST Solar System Science Cases

Mairo Jurić, Meg Schwamb, Cliff Johnson, Tim Lister, and Laura Trouille brainstormed science cases for Zooniverse online citizen science projects utilizing LSST alert stream data products and commissioning data.

Brainstorming Methods for Testing/Commissioning the LSST Moving Object Processing System (MOPS)

Mairo Jurić, Meg Schwamb, Wes Fraser, Henry Hsieh, and Mike Kelley discussed possible observations during commissioning that could test and validate the LSST MOPS pipeline. Suggestions included observing a bright comet to evaluate how far from the coma and tail do the LSST image subtracting pipelines work successful and observing a field previously surveyed by the Outer Solar System Origins Survey (OSSOS). OSSOS searched for distant Solar System objects fainter than the LSST's brightness limit but over a very small region of sky. This provides a sample of distant Solar System objects with well characterized orbits that can be used to empirically measure the LSST MOPS detection efficiency as a function of magnitude.



Block	R.A. (hr)	Decl. (deg)	Epoch (MJD)	Field Layout	Area (deg^2)	Filling Factor	Filter	m_{limit} ($3'' hr^{-1}$)	TNOs Detected
15BS	00:30:08.35	+06:00:09.5	57274.42965	2 × 5	10.827	0.9223	R.MP9602	25.12	67
15BT	00:35:08.35	+04:02:04.5	57273.42965	2 × 5	10.827	0.9223	R.MP9602	24.93	54
13BL	00:52:55.81	+03:43:49.1	56596.22735	3 × 7 (–1)	20.000	0.9151	R.MP9601	24.42	83
14BH	01:35:14.39	+13:28:25.3	56952.27017	3 × 7	21.000	0.9103	R.MP9601	24.67	67
15BC	03:06:18.32	+15:31:56.3	57332.33884	1 × 4	4.331	0.9215	R.MP9602	24.78	
15BD	03:12:58.36	+16:16:06.4	57333.35377	2 × 4	8.662	0.9211	R.MP9602	25.15	146
15BC	03:22:09.15	+17:15:44.0	57332.33884	2 × 4	8.662	0.9215	R.MP9602	24.78	104
15AP	13:30:22.11	−07:47:23.0	57125.36971	4 × 5	21.654	0.9186	R.MP9602	24.80	147
13AE	14:15:28.89	−12:32:28.5	56391.36686	3 × 7	21.000	0.9079	R.MP9601	24.09	49
15AM	15:34:41.30	−12:08:36.0	57163.31831	4 × 5	21.654	0.9211	R.MP9602	24.87	87
13AO	15:58:01.35	−12:19:54.2	56420.45956	3 × 7	21.000	0.9055	R.MP9601	24.40	36

Note. The filling-factor correction is discussed in Section 2.9: it incorporates the true pixel area, the small overlap area due to the new shape of the CCD in discovery blocks from 2015, and the few incompletely searched chips. It is used in the survey simulator (Section 4) when testing the visibility of model objects by their location on the sky. The survey simulator uses a single date for each block, as that is statistically equivalent: the simulator produces a statistical ensemble that is representative of the detections, and the approximation provides computational efficiency. Note that 15BC is in two parts (Section 2.6) and thus appears twice in this table; however, its detections are given once as a total. Limiting magnitude is given for sources with a sky motion rate of $3'' hr^{-1}$: for comprehensive details across the full range of motion rates, see Section 2.9 and Table 2. TNO detections are discussed in Section 3. (This table is incorporated in machine-readable form with fully specified polygons inside the survey simulator, linked in Section 4.)

Acknowledgements

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