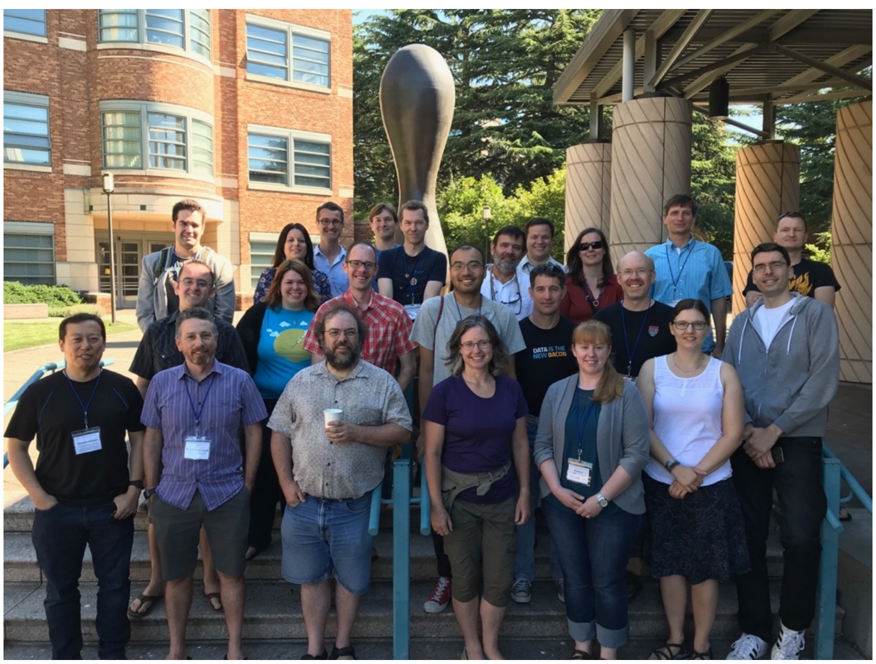
Report from the 2018 Solar System Readiness Sprint

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



Attendees of the 2018 LSST SSSC Readiness Sprint

Sprint Purpose

Development on LSST's Moving Object Processing Pipeline has restarted and calls for cadence white papers (deep drilling fields and mini-surveys) are expected in the next year. Thus 2018 is a crucial year to build the foundation of software tools to support these efforts and start the process of building added-value products. The three-day Solar System Science Collaboration Readiness Sprint (workshop) at the University of Washington was convened to kick-start these efforts.

Sprint Logistics

The Sprint took place from July 10-12, 2018 at the University of Washington, with nearly two dozen scientists in attendance. There were a series of invited talks to provide important background and overview information about LSST and project generated Solar System data products. A Jupyter Hub Workspace was set up which included all the LSST simulation and software tools installed so attendees (most of whom had never used these tools before), could get to work without spending time installing software packages. 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

Asteroid Filters

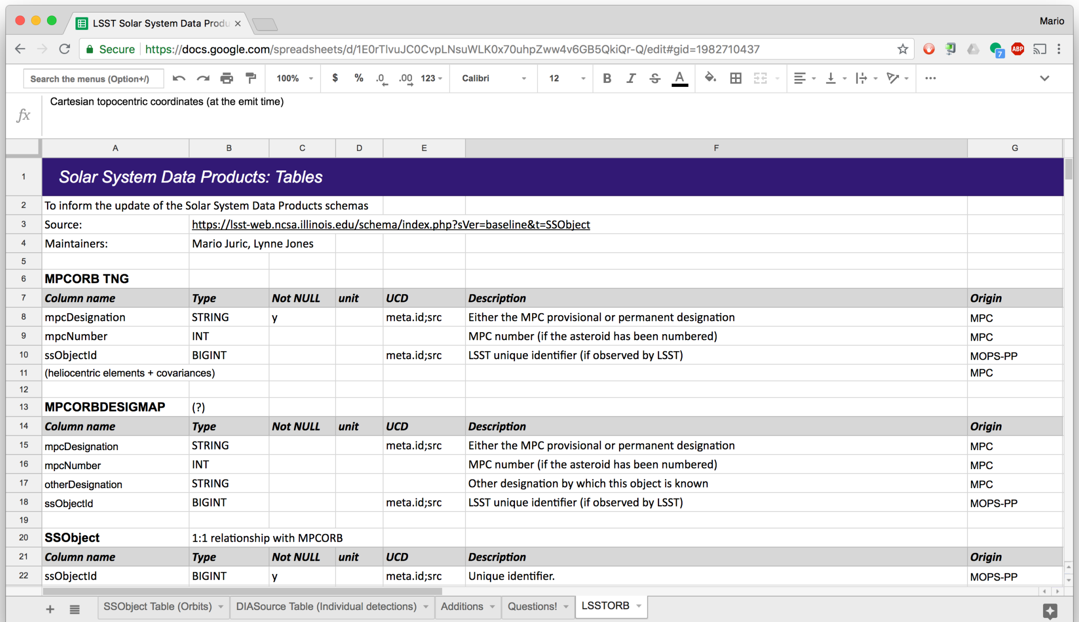
Andy Rivkin (shown here explaining orbits for the "Astronomy on Tap" public outreach session of the Sprint) explored filters for LSST asteroid taxonomy. If one only has 3 out of 4 filters, then gri is pretty good if precision is high; grz is okay on average (nb. Sloan filters are not the same as LSST filters).

Near-Earth Object Characterization

Josef Durech experimented with code to get shapes, spin poles, and colors for NEOs. He based the study on three years of ATLAS data (http://atlas.fallingstar.com/home.php). He found that with only 50 points (SNR>30) in 2 colors covering a range of phase angles, he could recover and NEO's correct period, color, shape, and spin pole.

Solar System Data Products

Mario Juric presented the previous Solar System data products schema (i.e., data format and values to be calculated and reported by the LSST Solar System and prompt data products pipelines). **Matt Holman, Matt Payne Steve Chesley, Meg Schwamb, Lynne Jones, Siegfried Eggl, and Mario Juric** developed an updated data products schema (see screengrab) including assessing past survey results from the Solar System Science Collaboration. Mario will start putting this new schema through the LSST Data Management control process.


Cartesian topocentric coordinates (at the emit time)

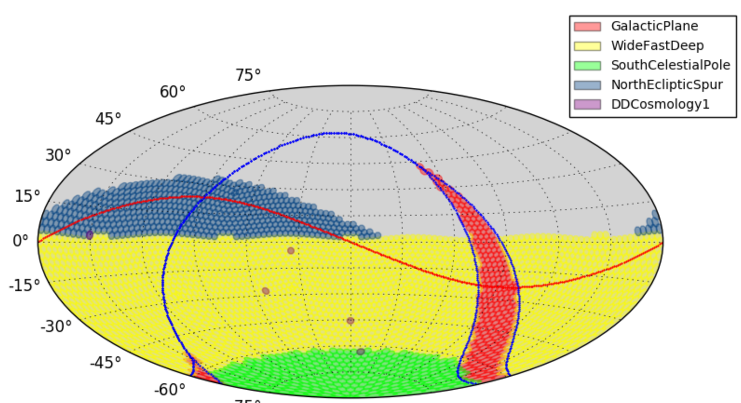
Solar System Data Products: Tables

To inform the update of the Solar System Data Products schemas						
Source:	https://lsst-web.ncsa.illinois.edu/schema/index.php?sVer=baseline&t=SSObject					
Maintainers:	Mario Juric, Lynne Jones					
MPCORB TNG						
Column name	***Type***	***Not NULL***	***unit***	***UCD***	***Description***	***Origin***
mpcDesignation	STRING	y		meta.id;src	Either the MPC provisional or permanent designation	MPC
mpcNumber	INT				MPC number (if the asteroid has been numbered)	MPC
ssObjectId	BIGINT			meta.id;src	LSST unique identifier (if observed by LSST)	MOPS-PP
(heliocentric elements + covariances)						MPC
MPCORBDESIGMAP	(?)					
Column name	***Type***	***Not NULL***	***unit***	***UCD***	***Description***	***Origin***
mpcDesignation	STRING			meta.id;src	Either the MPC provisional or permanent designation	MPC
mpcNumber	INT				MPC number (if the asteroid has been numbered)	MPC
otherDesignation	STRING				Other designation by which this object is known	MPC
ssObjectId	BIGINT			meta.id;src	LSST unique identifier (if observed by LSST)	MOPS-PP
SSObject	1:1 relationship with MPCORB					
Column name	***Type***	***Not NULL***	***unit***	***UCD***	***Description***	***Origin***
ssObjectId	BIGINT	y		meta.id;src	Unique identifier.	MOPS-PP

SSObject Table (Orbits) | DIASource Table (Individual detections) | Additions | Questions! | LSSTORB

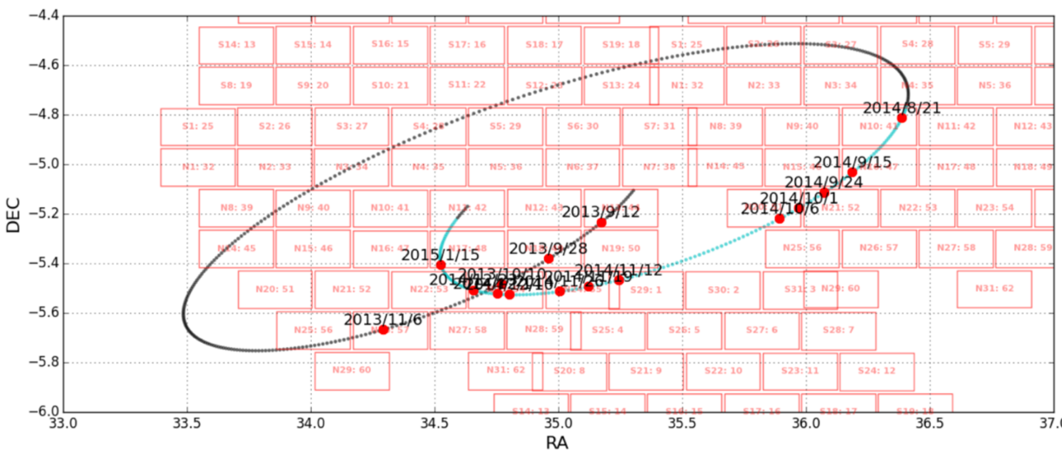
Resonant TNO populations and the North Ecliptic Spur

Kat Volk and Meg Schwamb explored a toy model of resonant TNO populations and how the North Ecliptic Spur (NES; see blue region in figure) will work for detection. For 2:1 resonances, leading and trailing islands form. In baseline simulations, 300-500 TNOs can be detected. Without the NES, one would lose much more in the leading island than in the trailing island; e.g., detections would be down to 420 and 120. This is roughly the best case resonance; i.e., other resonances will be even more strongly unbalanced.



Lessons from the DECam Solar System Survey

David Gerdes mined the DECam Solar System Survey for ideas for LSST surveys. As an example of capabilities, the image below shows the plutino named 2013 RD98 (red dots) moving through DECam supernova field of view in two distinct seasons (2013 and 2014); each red rectangle is one DECam CCD. Gerdes focused on science, but examined the LSST testbed too. One suggestion is a deep TNO survey (can reach to magnitude 26, and maybe 26.5 with shift-and-stack), with a focus on Neptune Trojans. Other options include 300 colors / light curves for Main Belt Asteroids with a focus on the small end size distribution. For LSST, this helps think about the need for a mini deep-drilling survey, potentially including light curves. Next step: gather collaborators.



Metrics for KBO colors and light curves

Wes Fraser, **Audrey Thirouin**, and **Darin Ragozzine** collaborated to define KBO color and light curves metrics. The hardest part is to determine the correct rotation period: one needs to use the LSST cadence from OpSim and power spectrum to make sure that there is a significant peak that matches the period. If there are 30 or more points in a given apparition, then the period can usually be recovered. To get resolved light-curve colors, it is necessary to acquire 30 colors in 2 filters. The number of KBOs that will have well-resolved light curves and colors is about 90% on the bright end (H=4) but effectively 0% at H=8.

Outer Solar System Deep Fields

Chad Trujillo explored outer solar system deep fields with areas ranging over 10, 100, or 1000 square degrees. One can reach limiting magnitudes of 26.7 using 2 x 600s images. This will result in a factor increase of t^(q-1)/4 = ~100 in number of Trans-Neptunian Objects (TNOs). He will post his results online so others can help. A Super-deep survey of the North Ecliptic Spur that could potentially discover ~100 times as many Kuiper belt objects (KBOS)!

LSST Solar System Software Roadmap

Henry Hsieh worked on a white paper that organizes all the possibilities for developing capabilities and products wanted by the Solar System community that will not be provided directly by LSST project. It should lay the groundwork for future proposals by identifying software needs and priorities in detail.

Cometary Metrics

Mike Kelley described a Jupyter notebook with cometary magnitudes and some simulated LSST observations. He described one path forward: looking for “blind spots” and “sweet spots” in orbital element space. The goal is to establish LSST completeness limits for various cometary populations, and write this up in a paper. He is also assessing whether the North Ecliptic Spur is important for main belt comets, or for asteroids in cometary orbits.

Porting LSST Orbit Integrator to Conda

Michael Aye discussed plans on creating a conda package for OpenOrb. OpenOrb is the orbit integrator used by the LSST simulations package to enable development of a model set of objects with specific orbits and H mags, and permit assessment of what LSST would detect of that given orbital population. Conda is a python coding environment, which is now the accepted default for astronomy (e.g., Gemini and STScI have now switched to it for their data reduction packages). **Michael Mommert** (shown at the Astronomy on Tap outreach event) provided further discussion of python OpenOrb capabilities, specifically to get more information for metrics (e.g., heliocentric longitude, latitude, true anomaly, etc.)

Potentially Hazardous Asteroids

Bryce Bolin, working with **Lynne Jones** and **Ed Lu**, is simulating detections of impacting asteroids with LSST. **Josef Durech** is adding authentic asteroid shape information to generate more realistic lightcurves.

Cadence Optimization White Papers

David Trilling and Meg Schwamb led discussions and initial brainstorming for mini-survey and deep drilling fields in response to the [LSST cadence optimization call for white papers](). The white papers are the community's only chance before the start of LSST operations to give our feedback on what LSST does with the time outside of the main Wide-Fast-Deep Survey (which goes nominally from 0 dec and southward). Discussions focused on possibilities for extending to the Northern Ecliptic and a Deep drilling field (a series of telescope pointings with many repeat exposures)

Acknowledgements

Thank you to the LSST Corporation and B612 Foundation for supporting and making the first LSST Solar System Readiness Sprint possible.

Future LSST Solar System Science Collaboration Activities

LSST 2018 Project and Community Workshop, August 13-17, 2018

There will be three solar-system-themed sessions at LSST2018:

1) Pipeline Development and Cadence Optimization for Solar System Science 1;

2) Preparing to Do Solar System Science with LSST; and

3) Blending Challenges in Solar System Science.

Activities at the 2018 AAS Division for Planetary Sciences Meeting

There will be two LSST events sessions at the 2018 DS meeting:

1) LSST and the Solar System Workshop; and

2) LSST Solar System Hackathon.

Appendix: Resources and Information

LSST Solar System Science Collaboration website

http://www.lsstsssc.org

LSST Solar System Roadmap

https://arxiv.org/abs/1802.01783

The Large Synoptic Survey Telescope (LSST) is uniquely equipped to search for Solar System bodies due to its unprecedented combination of depth and wide field coverage. Over a ten-year period starting in 2022, LSST will generate the largest catalog of Solar System objects to date. The main goal of the LSST Solar System Science Collaboration (SSSC) is to facilitate the efforts of the planetary community to study the planets and small body populations residing within our Solar System using LSST data. To prepare for future survey cadence decisions and ensure that interesting and novel Solar System science is achievable with LSST, the SSSC has identified and prioritized key Solar System research areas for investigation with LSST in this roadmap. The ranked science priorities highlighted in this living document will inform LSST survey cadence decisions and aid in identifying software tools and pipelines needed to be developed by the planetary community as added value products and resources before the planned start of LSST science operations.

LSST Solar System Science Collaboration Working Groups

Active objects (Lead: Mike Kelley) - all categories of activity in the minor planet populations: short period comets, long period comets, main belt comets, impact- or rotationally-generated active asteroids,etc

Community software/infrastructure development (Lead: Henry Hsieh**)** - people interested in helping build databases, software packages, etc to be used by the Solar System community on LSST data

Inner Solar System (Lead: Cristina Thomas**)** - main belt asteroids, Jupiter Trojans, and Jupiter irregular satellites

NEOs (Near-Earth Objects) and Interstellar Objects (Lead: Steve Chesley**)** - objects on orbits inward of or diffusing inward from the asteroid main belt and objects on unbound orbits passing through the Solar System

Outer Solar System (Leads: Darin Ragozzine and Matt Holman**)** - KBOS, Centaurs, Oort cloud, Saturn/Neptune/Uranus Trojans, and Saturn/Neptune/Uranus irregular satellites