SSSC Commissioning Notes

In this document, the Vera C. Rubin Observatory Legacy Survey of Space and Time (LSST) Solar System Science Collaboration (SSSC) has compiled a series of commissioning notes, proposing on-sky observing strategies during commissioning that would enhance opportunities for science validation and testing of the Rubin Observatory's data management pipelines. The SSSC has ranked the commissioning notes below into priorities (high, medium, and low) based on the expected contribution to verifying the scientific capability of Rubin Observatory and informing Year 1 LSST operations.

PROPOSED HIGH PRIORITY WIDE-FAST-DEEP OBSERVING COMMISSIONING TASKS

Validation of Incremental Template Generation

Proposed by: Meg Schwamb & Mario Jurić

Email Contact for Further Information: mschwamb.astro@gmail.com, mjuric@astro.washington.edu

RA(s)/Decs(s): Agnostic to the specific pointing and cadence of observations

Filter(s) Required: grizy

Brief Description of Observing strategy:

Wide-Fast-Deep (WFD) cadence might be preferable to fully characterize the incremental template generation pipelines, but observing strategy is flexible. The main constraint is obtaining the appropriate number of images per filter that meet the criteria for template generation.

Rationale:

These proposed observations will test and validate the incremental template generation capability of the data management pipelines and confirm incremental templates can be successfully generated at the start of operations for Solar System objects to be detected in nightly Rubin Observatory observations if incremental template generation is active in LSST Year 1.

Which Solar System population(s) science validation does this benefit?:

All Solar System science

Characterizing Moving Object Linkages in Different Color Nightly Pairs

Proposed by: Eric Christensen & Tim Lister

Email Contact for Further Information: tlister@lco.global, eric@lpl.arizona.edu

RA(s)/Decs(s): Opposition region

Filter(s) Required: g, r, i

Brief Description of Observing strategy:

Pairs of images on 10-20 contiguous fields, revisited every 3-10 days.

Cadence should approximately be the Wide-Fast-Deep (WFD) survey, so nightly pairs should be separated by ~30 minutes and could be taken in the same or different filters. The goal would be to have 5-10 revisits of these fields over the course of the 2-month commissioning period. Linking can be validated against known objects in the field; there will be thousands down to V~24. This also provides an early opportunity for blind detection of new MBAs (Main Belt Asteroids), comets, TNOs (Trans-Neptunian Objects), and more distant NEOs (Near Earth Objects), possibly including Potentially Hazardous Asteroids (H<=22; Earth MOID [Minimum Orbit Intersection Distance] <0.05 au).

Cost for pairs of images on 20 contiguous fields would be on order ~30 minutes per visit, repeated 5-10 times during commissioning = 2.5 - 5 hours. Templates are required, but visiting the same or slightly dithered field centers may enable template generation.

Note that the choice of the opposition region maximizes the number of detectable objects, but other low-ecliptic latitude regions may be acceptable. This commissioning test may be able to be combined with other tests interested in detection (e.g. outer solar system, comets) that have stronger constraints on field centers.

Rationale:

Linking with pairs of images per night and in different filters has not been demonstrated in other surveys and will be critically important for operation of the main survey. Most solar system science enabled by LSST rests on a foundation of robust moving object detection and linking/attribution.

Which Solar System population(s) science validation does this benefit?:

All but particularly slow moving TNOs and fast moving NEOs. Unlikely to sample more exotic populations such as minimoons or interstellar objects.

Bright Comet Stress Test

Proposed by: Mike Kelley & Matthew Knight

Email Contact for Further Information: msk@astro.umd.edu, astromatthew@gmail.com

RA(s)/Decs(s):

Targets unknown until commissioning period is determined.

Candidate Comet Target Possibilities for 2021-2023: 67P/Churyumov-Gerasimenko (V_{total}~8 mag), 19P/Borrelly (V_{total}~9 mag), 103P/Hartley 2 (V_{total}~7 mag), 62P/Tsuchinshan 1 (V_{total}~7 mag), C/2017 K2 (PanSTARRS) (V_{total}~6 mag). Additional, as yet undiscovered, long period comets may also be viable.

Note that V_{total} is integrated over a large field of view. Comet proper motion and brightness in small apertures may prevent saturation, even for very bright objects.

Filter(s) Required:

Minimum u, g, r. Comets tend to be brightest at g and r. Both bands may have an ion tail. u contains a prominent CN gas emission band.

Brief Description of Observing strategy:

Single exposure in a night, a few nights of images (not necessarily consecutive). Enough for comet motion to avoid chip gaps and move to other rafts on the camera. Approximately 9 exposures per comet (3 filters, 3 epochs), and we recommend the brightest 3 comets in the sky for a total of 27 exposures. In order to test difference imaging and alert generation, templates for the fields without the comets must be available.

Rationale:

To test the camera's science capabilities and exercise the calibration pipeline in the presence of a bright moving object, including: (1) astrometric calibration; (2) photometric calibration; (3) reference image subtraction; (4) alert generation of the comet itself (e.g., cutout size, photometric metadata); (5) alert generation of the field (including artifact mitigation); (6) data retrieval from image cutout services; (7) ability to reconstruct a comet's surface brightness across chip boundaries; (8) science analysis techniques on large cometary objects.

Which Solar System population(s) science validation does this benefit?:

Primarily comets, but potentially any active object.

Validating Solar System Processing Performance with Outer Solar System Objects in Wide-Fast-Deep conditions

Proposed by: Meg Schwamb, Michele Bannister, Hsing-Wen (Ed) Lin, Mario Jurić, & Rosemary Dorsey

Email Contact for Further Information: michele.bannister@canterbury.ac.nz, mschwamb.astro@gmail.com, hsingwel@umich.edu, mjuric@astro.washington.edu

RA(s)/Decs(s):

A range of pointings are available, observable across a wide range of the year from two surveys (OSSOS [Outer Solar System Origins Survey; Bannister et al. 2018] and DEEP [Deep Ecliptic Exploration Project; Trilling et al. 2019]) that have high detection efficiency and limiting magnitudes at or deeper than the main LSST Wide-Fast-Deep (WFD) Survey. Note that these are moving-object surveys: exact RA/Dec pointings to give ideal clusters of TNOs (Trans-Neptunian Objects) would be updated close to the time of observation.

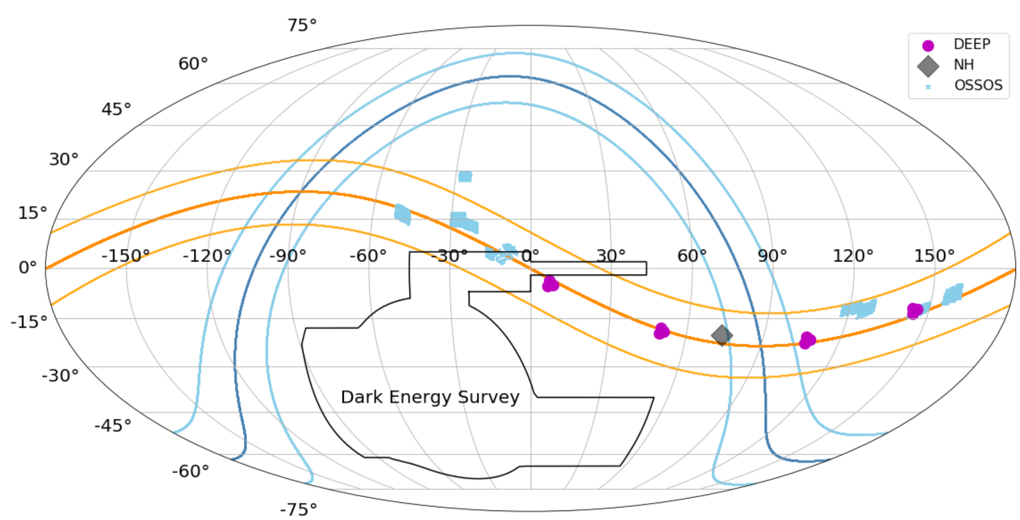
- OSSOS Blocks - near ecliptic, characterized TNO detection efficiency (“depth”) to ~r = 25.2
- DEEP survey fields - Near ecliptic, depth r ~ 26.5
- OSSOS fields: Table 1 of Bannister et al. 2018.

Table 1
Areas of the Sky Observed for Discovery by OSSOS

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

Table Credit: [Bannister et al. 2018]

DEEP fields: A0: (216, -12.5), overlap with OSSOS AE, one month arc
A1: (253, -21.5), one month arc
B0: (310, -19), one night arc
B1: (353, -5), one year arc



OSSOS and DEEP sky coverage. Image Credit: Ed Lin

Filter(s) Required: r priority, ugriz if possible

Brief Description of Observing strategy: Standard LSST observing strategy for these locations.

Rationale:

These fields provide an opportunity to detect low signal to noise detections from the image differencing system, test stack-and-shift software, and the Rubin SSP (Solar System Processing) pipelines. OSSOS (Outer Solar System Origins Survey; Bannister et al. 2018) and DEEP (Deep Ecliptic Exploration Project; Trilling et al. 2019) surveys have a few regions on the sky where the KBO population is mapped to a depth compatible with the LSST or deeper.

Which Solar System population(s) science validation does this benefit?:

Outer Solar System objects. Complementary with all other image deep stacking cases from other science collaborations.

Comet Mix

Proposed by: Henry Hsieh & Matthew Knight

Email Contact for Further Information: hhsieh@psi.edu, astromatthew@gmail.com

RA(s)/Decs(s): Targets unknown until commissioning period is determined.

Filter(s) Required: g or r

Brief Description of Observing strategy:

Observations of a mix of comets of different brightnesses and morphologies with typical LSST exposure times and cadences (should be appropriate for testing the LSST Solar System Processing (SSP) pipeline's default linking algorithms; estimated ~6-10 pointings per object over multiple days); examples of "comet parameter space" to cover include

- bright, highly active comets (i.e., bright nucleus + strong coma)
- weakly active comets (i.e., bright nucleus + weak coma; e.g., 133P, 162P)
- diffuse comets (i.e., faint/undetectable nucleus + strong coma; e.g., P/2010 A2)
- faint comets (i.e., faint nucleus + faint coma)

- high-airmass comet observations
- comets with large non-sidereal sky-plane velocities (i.e., with significant trailing during a single LSST exposure)
- comets in dense star fields

Observing time estimate: preferred - three comets per category above (so 3x7=21 total; 6-10 pointings per object ==> ~200 pointings); minimum - one comet per category above (so 7 total; 6-10 pointings per object ==> ~70 pointings). The sample size is flexible; some of the goals may also be achievable as part of other proposed commissioning programs

Rationale:

Aim is to test activity detection algorithms (both the baseline LSST algorithm and community-developed algorithms) as well as test the ability of the LSST pipeline to perform moving object functions (e.g., detection, centroiding, linking, photometry) on extended objects with different brightnesses and morphologies.

Which Solar System population(s) science validation does this benefit?:

Active objects and all other populations (NEOs [Near Earth Objects], inner solar system, outer solar system) that may potentially contain active objects.

MEDIUM PRIORITY WIDE-FAST-DEEP OBSERVING COMMISSIONING TASKS

Using Giant Planet Systems to Test Detection of Faint Sources Immediately Adjacent to Saturating Sources

Proposed by: Matthew Tiscareno & Mark Showalter

Email Contact for Further Information: matt@seti.org

RA(s)/Decs(s): Target between one and four of the giant planets, which are moving targets.

Filter(s) Required: ugrizy

Brief Description of Observing strategy:

When Rubin Commissioning requires observing a bright source to the point of saturation, use the giant planets as the bright source. First priority: Uranus or Neptune. Second priority: Jupiter or Saturn.

Rationale:

Images can have high science value even when dominated by bright glare. Pixels that are truly saturated are useless, but those are usually few. Any unsaturated glare can be subtracted away using various established methods (e.g., Showalter et al. 2019, Nature). The science quality of the images is governed by the instrument's detailed Extended Point-Spread Function (EPSF) and saturation patterns, which are currently unknown for Rubin.

The technical challenge is to detect a faint target that is immediately adjacent to a bright source. As a general paradigm, the applications to astrophysical as well as planetary observations may be numerous. Such observations should be possible, but there are important questions. How far does the saturation extend? How much of the image is subtractable unsaturated glare? How much structure does the glare have, and does that (rather than bare sensitivity) determine the faintest detectable object? We won't know the answers to these questions until we take observations, and commissioning is the first opportunity to do so.

For the giant planet systems, our estimates indicate that the most scientifically interesting moons should be visible. Thus they provide an array of brightness levels for testing detectability of faint objects adjacent to their planets. Wide-Fast-Deep (WFD) survey science for the giant planet systems, which would be enabled by this action, is considerable. The strongest case is for Uranus, whose inner moons show strong signs of orbital chaos that is poorly understood (Showalter and Lissauer 2007, Science).

Which planet to use?
Note the apparent magnitudes: Jupiter (–2), Saturn (0), Uranus (6), Neptune (8).
Uranus is the single best choice, because it has less saturation and complication than Jupiter or Saturn, but it is brighter than Neptune (the latter is a mild preference).
If we can have only one and Uranus is not available, then Neptune is a second choice.
If we do have Uranus or Neptune and can have only one nother, then Jupiter or Saturn.
If we can have all four, that would be best.

Which Solar System population(s) science validation does this benefit?:

Outer Solar System in particular, but should benefit all populations.

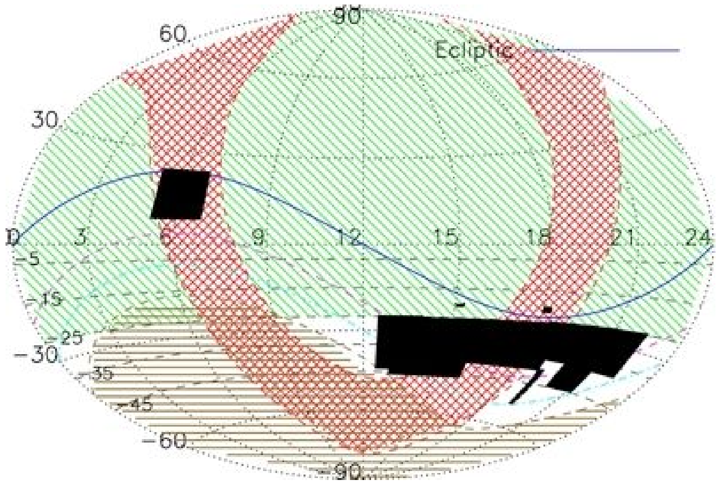
Testing SSP Linking Performance and False Positive Rate in the Galactic Plane/at Ultra High Background Star Densities

Proposed by: Mario Jurić, Meg Schwamb, Hsing-Wen (Ed) Lin, Michele Bannister, & Rosemary Dorsey

Email Contact for Further Information: mjuric@astro.washington.edu, mschwamb.astro@gmail.com, michele.bannister@canterbury.ac.nz, hsingwel@umich.edu

RA(s)/Decs(s):

Target a field on/near the ecliptic that includes known detections in low galactic latitudes/in the galactic plane**. Options include the** New Horizon Search Fields (e.g. Arrokoth detection V~27 mag) around (RA (deg) 286.25, Dec:-20.165) searched via Suprime-Cam or HSC (Hyper Surpime-Cam) or Sheppard et al. 2011 survey searched down to apparent R mag~21.6 or target on the Neptune Trojan 2011 HM102 (V=22.75 mag) found in the New Horizons Suprime-Cam Search (see Parker et al. 2013).



Sheppard et al. (2011) shallow galactic plane survey search region (in black). Image credit: [Sheppard et al. 2011](#)

Filter(s) Required: r (gri would be okay as well)

Brief Description of Observing strategy:

Wide-Fast-Deep-type cadence. There many be a need for additional exposures if the field is chosen with a known moving target fainter than ~22 R mag, if no suitably bright enough KBOs are visible in a single LSSTcam exposure

Rationale:

The false positive rate for Solar System Processing (SSP) linking and detections in high stellar density sky regions (at low galactic latitude) will be compared to the performance at non-crowded fields. The stellar crowding may prove significantly more challenging for the moving object pipeline and the data management image subtraction pipeline. These commissioning observations would be the only opportunity before the start of the LSST survey to work on improving the SSP pipeline if adjustments are needed to reach design requirements in high star density fields.

Which Solar System population(s) science validation does this benefit?:

Outer Solar System in particular, but should benefit all populations.

Characterizing Activity/Moving Object Detection Across the FoV Test

Proposed by: Cyrielle Opitom, Matthew Knight

Email Contact for Further Information: copi@roe.ac.uk, astromatthew@gmail.com

RA(s)/Decs(s):

A low ecliptic field including at least a faintly active comet. Fields will be provided when the exact commissioning period is known.

Filter(s) Required: g or r

Brief Description of Observing strategy:

Point to a low ecliptic field and take several exposures with normal LSST exposure time with a 20-points (the exact number of dithering positions can be adjusted) dithering pattern to place the comet in various parts of the field of view, in particular the edges. Repeat the observation on a second night. This test could potentially be merged with another test targeting a low ecliptic field. Low ecliptic fields will have many asteroids to study, in addition to the target comet.

Rationale:

Test the detection and alert generation for moving targets and extended object characterization across the FoV (Field-of-View). This test will allow us to assess how potential PSF (Point Spread Function) variation or illumination differences across the FoV might affect the detection of faint moving objects or faint activity levels by the data management pipeline.

Which Solar System population(s) science validation does this benefit?:

This benefits the science of detecting faint activity levels around comets/or main belt comets

PROPOSED HIGH PRIORITY COMMISSIONING TASKS NOT RELATED TO THE WIDE-FAST-DEEP SURVEY

Low Elongation Stress Test : Twilight Observations and Near-Sun Comets

Proposed by: Quanzhi Ye & Matthew Knight

Email Contact for Further Information: qye@umd.edu, astromatthew@gmail.com

RA(s)/Decs(s): Track of the Kreutz group (orbit sample available in SSSC LSST Cadence Optimization Orbit Test Populations)

Filter(s) Required: r at minimum; ugriz if possible.

Brief Description of Observing strategy:

We propose to observe a few fields (numbers negotiable) of varying solar elongation in twilight (the smaller, the better; thinking of 35-55 deg) along the pre-perihelion Kreutz track. We request a total of 4-6 pointings per field over a few days in order to facilitate object detection/linkage (i.e. similar to typical Wide-Fast-Deep LSST cadence). We prefer to test different filters (u through z) and exposure times (tentatively 1, 5, 30 seconds, but specific times are negotiable) to better characterize the performance of the camera and the LSST pipeline to detect faint, extended objects in high and variable sky background, though a limited test with r-filter only will still be useful. We note that Kreutz track is best visible in Chilean summer months (September to March), but observations during winter months can be accommodated.

Rationale:

The goal is to test the hardware limit and the data processing pipeline in twilight condition (low solar elongation/high airmass). We will measure the variation of image quality and sky brightness as a function of solar elongation, airmass, exposure times, and possibly filter, to establish the limits of hardware/software and explore the best strategy (in terms of minimum optimal solar elongation/airmass, exposure times, cadence, and filter) to conduct this kind of observations. We will also constrain the ability to detect faint, extended objects under varying conditions. The program can be executed with a single r filter at the minimum; a full test with other filters (u through z) will help identify the best filter to be used for comet detections in twilight. The program size negotiable

Which Solar System population(s) science validation does this benefit?:

Near-Sun comets, interior-Earth NEOs (Near Earth Objects), active object detection, measurement of the impact of mega-constellations (e.g. Starlink) to twilight, low-elongation observations.

Testing of Camera and Telescope Performance During Twilight and Validation of Asteroid Detection with a Varying Sky Background

Proposed by: Bryce Bolin
Email Contact for Further Information: bbolin@caltech.edu

RA(s)/Decs(s):

Evening and morning sky during 12-18 degrees twilight within 30-60 degrees of the Sun pointing the telescope as low as 15-20 degrees within the mechanical and tracking limits allowed by the telescope.

Filter(s) Required: primarily r-band, can be expanded to include other filters

Brief Description of Observing strategy:

If flexibility during commissioning allows, we will follow the twilight observation recommendations of Marshall et al 2017 and Seaman et al. 2017 by observing the portion of the sky within ~30-60 degrees of the Sun during the 20-30 minute duration of 12-18 degrees twilight. This will require us to point the telescope as low as ~20 degrees elevation (or even lower if possible allowing for closer Solar elongation pointing distances) towards the Solar direction which is much lower than the typical airmass < 1.5 of the WFD (Wide-Fast-Deep) survey.

If commissioning flexibility allows shorter exposures than the standard 30 s exposure, we will test exposure times in r filter between 0.1, 1, 5 s and 15 s in duration enabling a limiting magnitude in twilight sky of between r ~18 and 24 as seen in Fig. 1 below adapted from Marshall et al 2017.

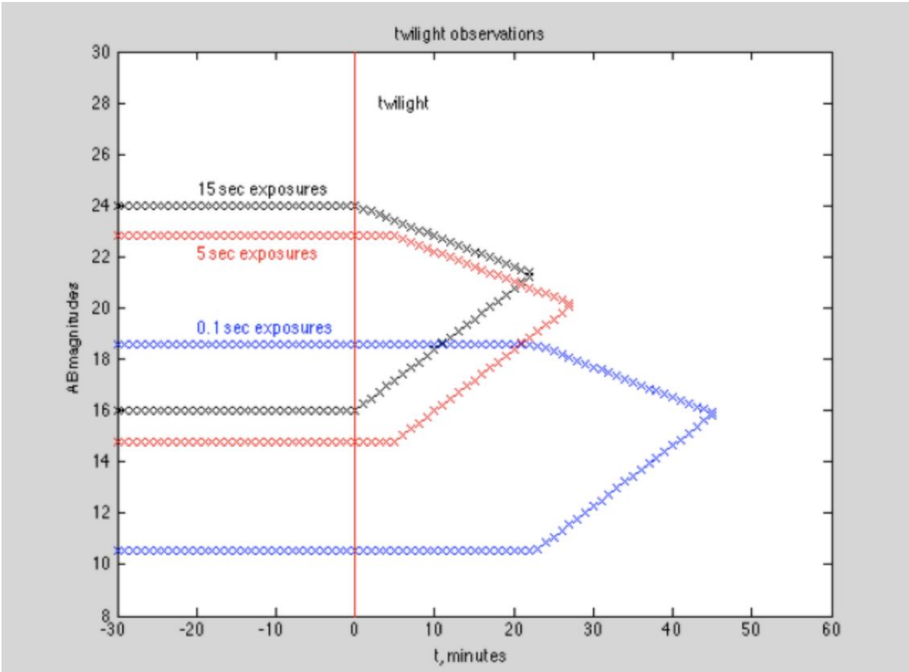


Figure 1: adapted from [Marshall et al 2017](#) showing the estimated dynamic range of twilight observations for 15 s, 5 s and 0.1 s exposures in r band assuming 5 sigma detections as a function of time with respect to the start of twilight. Shorter exposures allow for observations longer into twilight at a cost of brighter limiting magnitude. In addition, for a fixed exposure time, the limiting magnitude decreases with time into twilight due to increasing sky brightness.

We will aim to observe within ~30-60 degrees of the Sun as close to the ecliptic as possible. Due to the 30 degrees south latitude of the Rubin Observatory site, observing near the ecliptic during morning twilight is more feasible during the late Winter months and observing near the ecliptic during evening Twilight is more feasible during the late Summer months. The evening or morning twilight sessions can occur on each night or every other night during evening or morning twilight providing a 1-2 night separation between trackelts of detected moving objects between each evening/morning twilight survey session.

Each twilight session will ideally use fields that are within the 30-60 degrees of the Sun, but larger elongations can still be useful to test the performance of the camera and telescope and camera if pointing to such low elevations is not feasible. Each field will consist of a pair of r band exposures using the 0.1 s, 1 s, 5 s, 15 s exposures described above. The number of fields observed will be at the discretion of the survey planning effort, but it would be useful to obtain at least 5-10 fields covering a variety of Solar elongations during different times with respect to twilight for the purpose of assessing the camera's performance during the evolving sky brightness and pointing conditions of twilight observations. It will also be useful to test the camera performance using different exposure times pointed towards zenith during twilight.

If flexibility allows, we may also request that specific fields containing known objects at small Solar elongations such as known inner-Earth/inner-Venus asteroids are targeted. Similarly, serendipitous observation of known Main Belt objects will also be used in the low Solar elongation fields.

Rationale:

The camera's performance during twilight has been estimated by [Marshall et al 2017] however the camera's true performance during twilight is unknown. We will test the camera performance of the camera during 12-18 degrees evening and morning twilight conditions when the telescope is pointed at low elevations of ~20 degrees towards low Solar elongations between ~30-60 degrees and at directions pointed further from the Solar direction such as at zenith. We will determine the camera's limiting magnitude and saturation magnitude as a function of time relative to the start of twilight for different exposure times from 0.1 to 15 s in r band. Assessing the camera's performance during twilight will help determine the ideal exposure time for twilight observations at different Solar elongation distances. This will directly contribute to survey planning and usage of Twilight time for both Solar System and non-Solar System Science.

In addition to assessing the camera's performance in twilight, small Solar elongation conditions, we will also test the telescope's capability at pointing in a low elevation conditions. Using the fact that the telescope's field of view is 3.5 degrees across, pointing the telescope towards the Solar direction during 18 degrees twilight as low as ~20 degrees elevation would roughly translate to observing within ~30 degrees of the Sun. However, pointing the telescope as low as ~20 degrees can result in different mechanical stresses and a change in hardware performance such as telescope tracking. Therefore, our low solar elongation, low elevation observation tests will be useful for assessing the performance of the telescope at low solar elongations.

In addition to testing the camera and telescope performance during low elevation twilight observations, the twilight observations will serve as a dataset to test the extraction of moving objects such as inner-Earth asteroids. Observations during twilight may result in variable sky brightness in the images such that the extraction performance of the moving object detection pipelines may not be able to use both images taken in a single twilight survey observation. Therefore, internight linking of asteroids observed during the twilight sessions may have to use single detections from a single night as opposed to pairs separated by the time interval between twilight observing sessions.

As described above, we will also target fields containing known low-Solar elongation asteroids if commissioning flexibility allows. Targeting fields containing known objects will test the extraction and moving object identification pipelines and recognition of known objects in observations taken during twilight observing conditions.

Which Solar System population(s) science validation does this benefit?:

Testing the camera and telescope performance during twilight benefits Solar System science cases using twilight, near-sun observations such as the search for inner-Venus/inner-Earth/Earth Trojan objects at ~300 degrees to ~60 degrees Solar elongation as well as Sun-grazing comets. On a side note, this test will also benefit other non-Solar System related science that uses observations during twilight.

LOW PRIORITY COMMISSIONING OBSERVING PROPOSALS

Search for Additional Lucy Targets

Proposed by: Hal Levison & Cathy Olkin

Email Contact for Further Information: hal@boulder.swri.edu, olkin@boulder.swri.edu

RA(s)/Decs(s):

TBD. Trojans that come close to the Lucy spacecraft periodically form tight concentrations in the sky. The location of the knots changes with observing epoch. See (Schwamb et al, 2018)

Filter(s) Required: Any combination of g,r,i, or z

Brief Description of Observing strategy:

Any commissioning observing sequence designed for testing the Solar System processing pipelines would suffice. The number of fields and observing cadence is flexible.

Rationale:

Lucy is an upcoming NASA Discovery mission to explore the Jupiter Trojans. The primary goal of Lucy is to study a wide variety of these objects in order to detangle the formation and evolution of the outer Solar System. Finding more targets for Lucy will increase its scientific impact. Given that many tests of the moving object pipeline are agnostic to the location of the field, picking fields that might have Lucy targets could have significant scientific benefits with no impact on commissioning. Measurements that are obtained during the entire commissioning period would be important for mission planning because the candidate fly-by targets discovered during Rubin commissioning will have a 1 year arc measured during Year 1 Operations, sufficient for initial orbital characterization.

Which Solar System population(s) science validation does this benefit?: Jupiter Trojans

Testing Template Generation, Astrometry and Linking with DART mission target Didymos

Proposed by: Siegfried Eggl

Email Contact for Further Information: eggl@uw.edu

RA(s)/Decs(s): Derived from the orbit of 65803 Didymos

Filter(s) Required: g, (r)

Brief Description of Observing strategy:

Generate templates at the anticipated observation positions of Didymos. Observe Didymos with WFD (Wide-Fast-Deep) like cadence (2 observations per night over 3 nights) in two filters if possible, before the Double Asteroid Redirection Test (DART) impact (Fall 2022).

Cost for pairs of images during commissioning would be 6 x 30s, if one filter is available. Twice that if the observations can be performed in both filters.

Rationale:

The near-Earth asteroid system 65803 Didymos is the target of NASA's Double Asteroid Redirection Test (DART). High quality astrometric observations of the Didymos system before the arrival of DART would significantly enhance the chances of detecting the shift in the heliocentric trajectory of Didymos caused by the DART impact. The proposed generation of templates for the predicted observation positions and the acquisition of astrometric observations of a known near-Earth object with a WFD like cadence would allow for an end-to-end test of LSST Solar System Processing.

Which Solar System population(s) science validation does this benefit?:

NEOs (Near Earth Objects) as well as Main Belt asteroids that may be observed in the acquired images.

Multi-bandpass H,G Measurements of Main Belt and Trojan Asteroids from Sparse Phase Curve Photometry

Proposed by: Bryce Bolin

Email Contact for Further Information: bbolin@caltech.edu

RA(s)/Decs(s): +/- 20 degrees of opposition region.

Filter(s) Required: g,r,i,z

Brief Description of Observing strategy:

We will use nightly image pairs taken per g, r, i and z filter approximating the WFD (Wide-Fast-Deep) survey over the two month commissioning survey to obtain pairs of detections of Main Belt asteroids in g, r, i or z filters. The pair of observations per night should be in different filters for more filter coverage, but can be in the same filter.

The goal would be to obtain ~15-20 observations of each Main Belt asteroid in each g, r, i and z filter during the commissioning period covering phase angles between 0-20 degrees. Our observations would also include Trojan asteroids if the commissioning months occur when opposition is passing through the Trojan cloud.

Rationale:

We will test the Rubin Observatory data pipeline to extract and link detections of asteroids in the Main Belt over a 2 month period. The outcome of the test will also be to use the output of the pipeline to make photometric measurements of the asteroid detections.

We will obtain ~20 photometric data points of asteroids spread over phase angles 0-20 degrees and use these data points to calculate their absolute magnitude, H, and phase slope, G, including the opposition effect on data points taken within 5 degrees of opposition. We will also apply the three parameters, H, G1 and G2, phase function of Muinonen et al. (2010) to these data.

Which Solar System population(s) science validation does this benefit?:

Complimentary to testing moving object linkages. Identifying the linked objects from from the WFD cadence will enable photometric measurements of the detected objects to be made and used in the phase curve calculations

Sparse Rotation periods/Constraints on low-level activity of km-scale Main Belt Asteroids and Jupiter Trojans with sparse lightcurve photometry

Proposed by: Bryce Bolin

Email Contact for Further Information: bbolin@caltech.edu

RA(s)/Decs(s): Overlap of Trojan clouds with opposition region

Filter(s) Required: r

Brief Description of Observing strategy:

We will observe a tessellated 3x3 field centered on opposition during the passage of the Trojan clouds through opposition giving a coverage of ~100 sq. deg. of sky. Each field will be imaged with 30 s exposure times in r band providing a SNR (Signal-to-Noise ratio) of ~15 for r~23.8 mag detections providing a photometric uncertainty of ~0.07 mag per detection.

Each field will be imaged 15-20 times per night when the fields have airmass > 2 each night over 3 consecutive nights providing ~40-60 photometric data points per object the fields over a ~70 h baseline. The fields will be shifted on each night roughly with the mean drift rate and direction of Main Belt/Trojan objects along the ecliptic. Our 3x3 tessellated Rubin Observatory fields will provide directions of ~30,000 Main Belt objects and ~1,000 Trojan objects down to a km scale.

The time interval between detections will be ~15-20 minutes, though we will adjust our survey cadence to image the center two fields closest to opposition at a higher cadence to make our observations sensitive to rapid rotators.

Rationale:

We will determine the rotation period distribution of Main Belt asteroids and Trojans for objects down to a km-scale. We expect that smaller Main Belt and Trojan objects should have a shorter rotation period distribution compared to larger objects. Our observations will also be sensitive to detecting fast-rotating objects which will provide constraints on the structural integrity of km-scale Main Belt asteroids and Trojans if fast-rotators are detected. In addition, our data set will provide extremely deep detections of Main Belt and Trojan down to a sub-km scale providing limits on the occurrence of low level activity of objects down to this scale testing the predictions of Sonnett et al. 2011 based on observations of km-scale Main Belt asteroids with r~23 mag data.

Which Solar System population(s) science validation does this benefit?:
complimentary with active objects working group for testing extendedness of detections related to moving objects