LSST Solar System Science (excluding NEOs)

Meg Schwamb
(Gemini Observatory)
@megschwamb

@lsstsssc

Cred

Large Synoptic Survey Telescope
Solar System Science Collaboration

LSST Solar System Science Collaboration (SSSC)

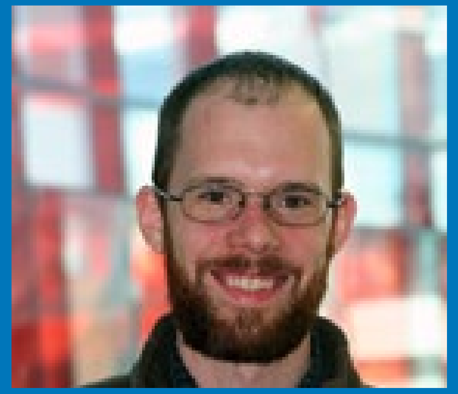
 

David Trilling & Meg Schwamb
SSSC Co-Chairs

LSST
Large Synoptic Survey Telescope
Solar System Science Collaboration

www.lsstsssc.org

Wes Fraser
LSST: UK Solar System POC



Active objects Working Group (Lead: Mike Kelley): broadly consisting of 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 Working Group (Lead: Henry Hsieh): broadly consisting of people interested in helping build databases, software packages, etc to be used by the Solar System community on LSST data

Inner Solar System Working Group (Lead: Cristina Thomas): broadly consisting of the main belt, Mars/Jupiter Trojans, and Jupiter irregular satellites

NEOs (Near Earth Objects) and Interstellar Objects Working Group (Lead: Steve Chesley): broadly consisting of objects on orbits inward of or diffusing inward from the main belt as well as interstellar objects temporarily residing in the Solar System

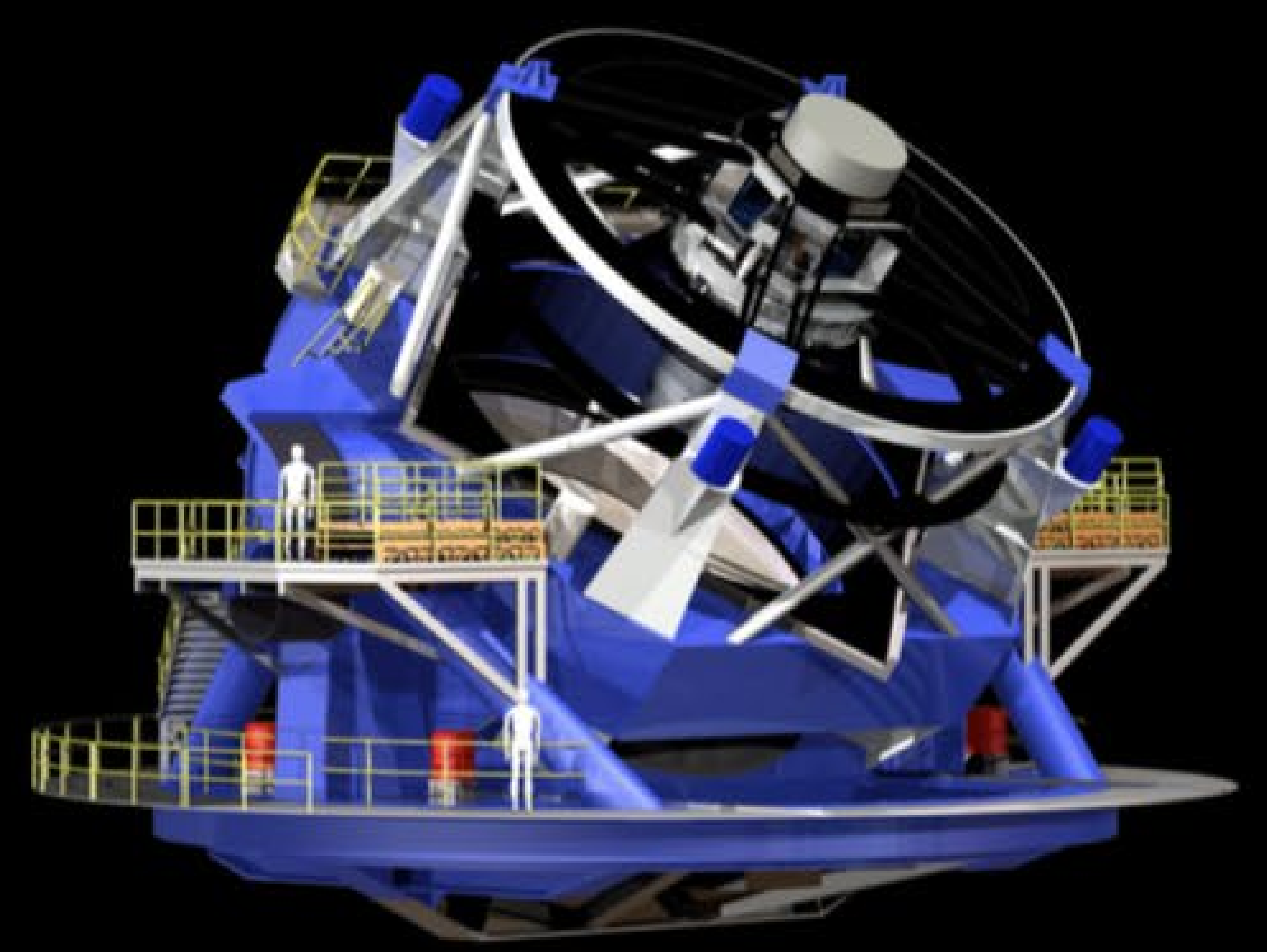
 

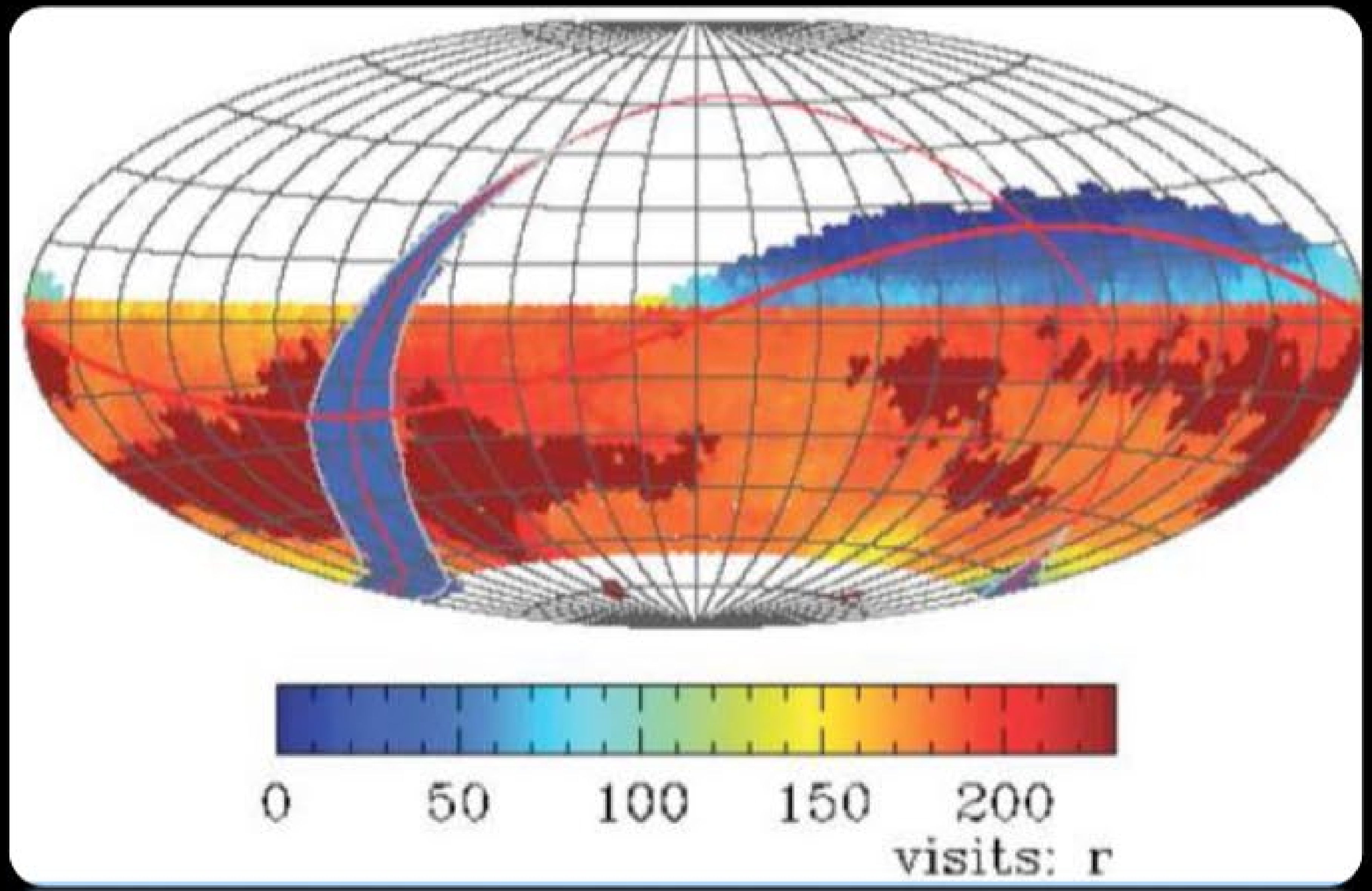
Outer Solar System Working Group (Lead: Darin Ragozzine and Matt Holman): broadly consisting of KBOs, Centaurs, Oort cloud, Saturn/Neptune/Uranus Trojans, and Saturn/Neptune/Uranus irregular satellites

LSST: A Deep, Wide, Fast, Optical Sky Survey

8.4m telescope | 18000+ deg^2 | 10mas astrom. | r<24.5 (<27.5@10yr)

ugrizy | 0.5-1% photometry





3.2Gpix camera | 30sec exp/4sec rd | 15TB/night | 37 B objects

Imaging the visible sky, once every 3 days, for 10 years (825 revisits)

Slide Credit: Mario Jurić

It’s Really Coming! Science Operations Start in 2022
Next 3 years is the time to prepare!

Slide Credit: LSST/AURA/LSSTC

Coating Chamber has arrived on site

Optical Coating Chamber in transit to the summit – Puclaro Tunnel

Optical Coating Chamber entering the summit facility

Slide Credit: Victor Krabbendam

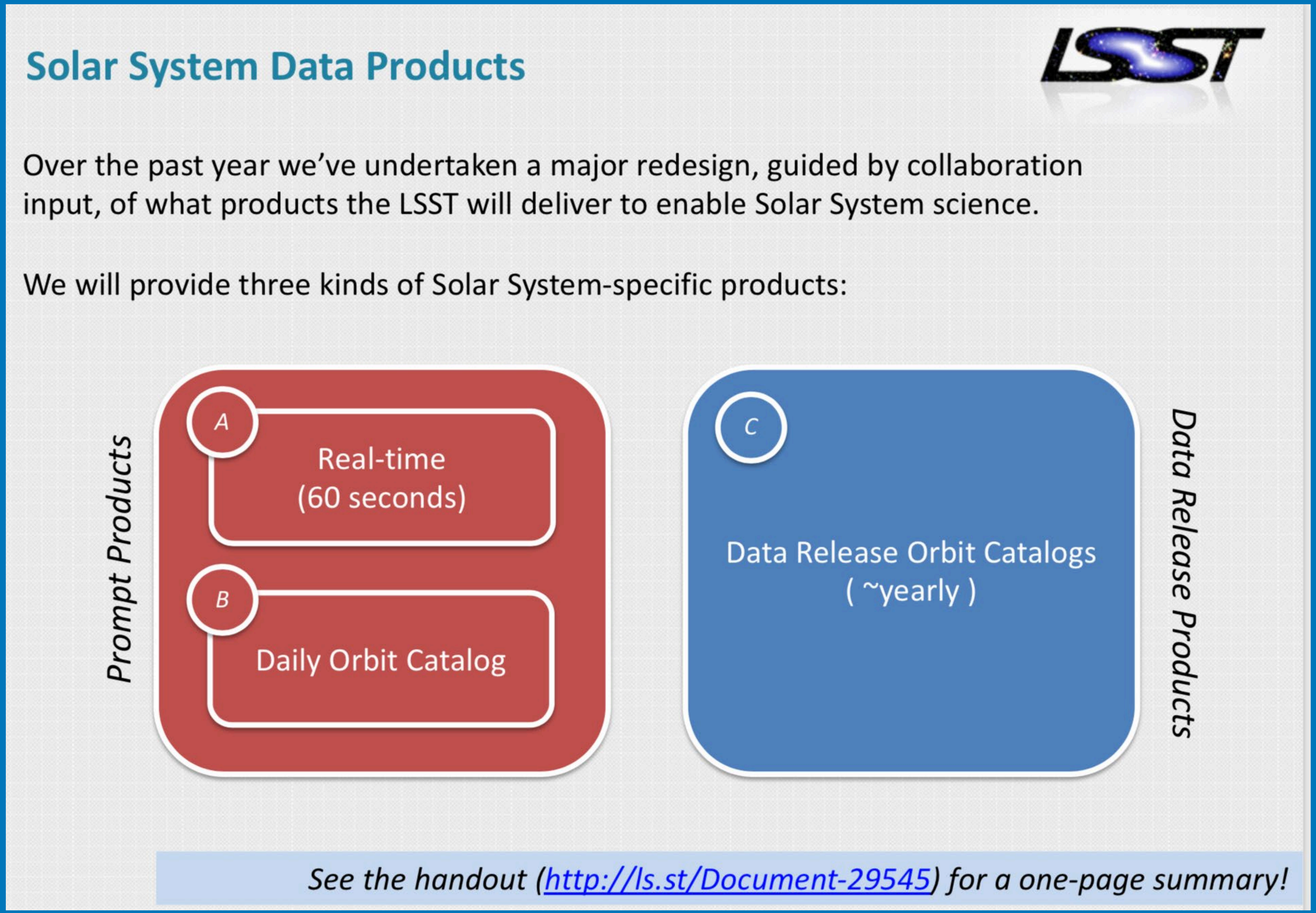
Expected LSST Yield

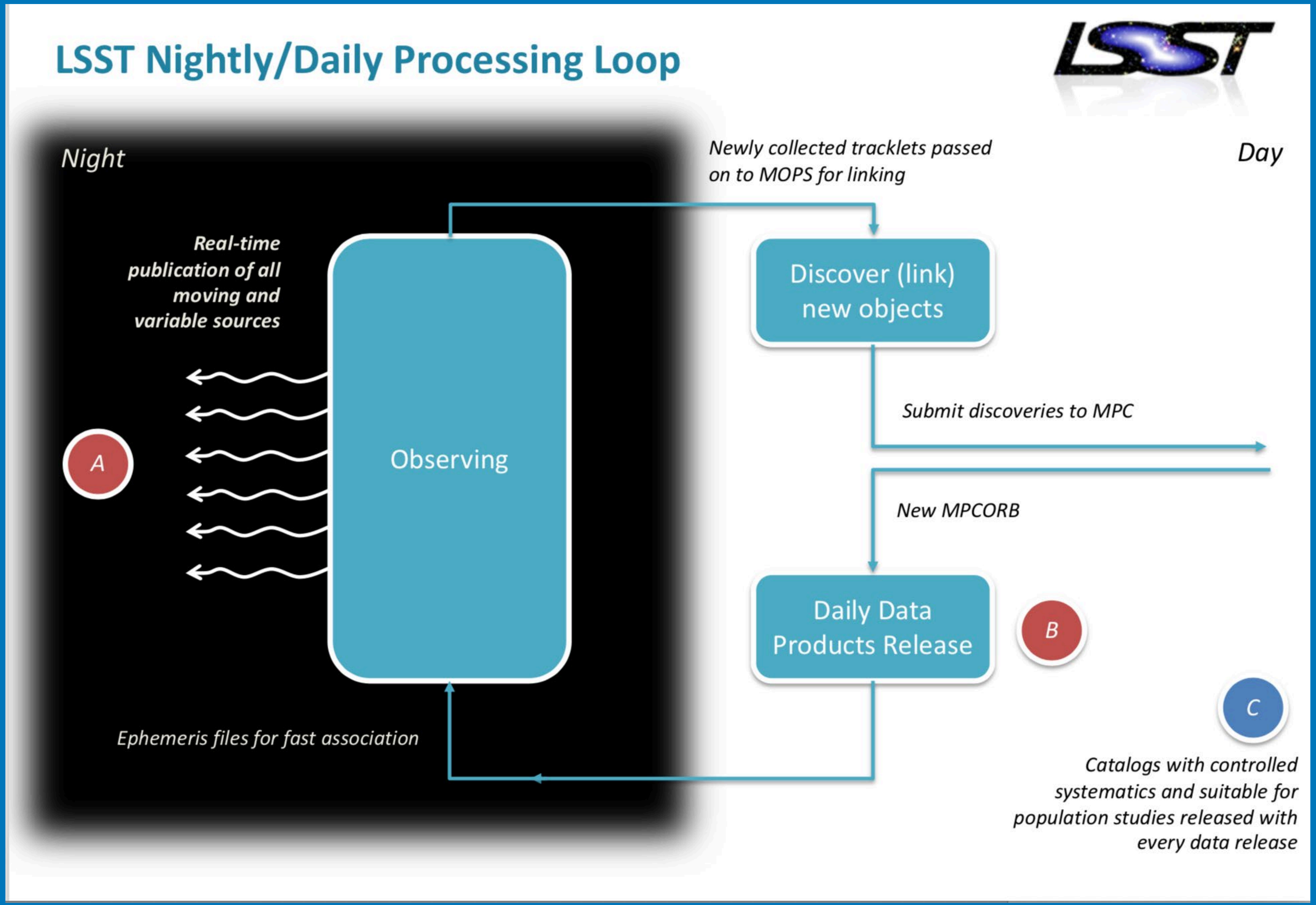
	Currently Known	LSST Discoveries	Median number of observations	Observational arc length
Near Earth Objects (NEOs)	~14,500	100,000	(D>250m) 60	6.0 years
Main Belt Asteroids (MBAs)	~650,000	5,500,000	(D>500m) 200	8.5 years
Jupiter Trojans	~6,000	280,000	(D>2km) 300	8.7 years
TransNeptunian + Scattered Disk Objects (TNOs + SDOS)	~2,000	40,000	(D>200km) 450	8.5 years
Interstellar Objects (ISOs)	1	10	?	?

ugrizy photometry

Slide Credit: LSST Science book/Lynne Jones

What is LSST project Providing



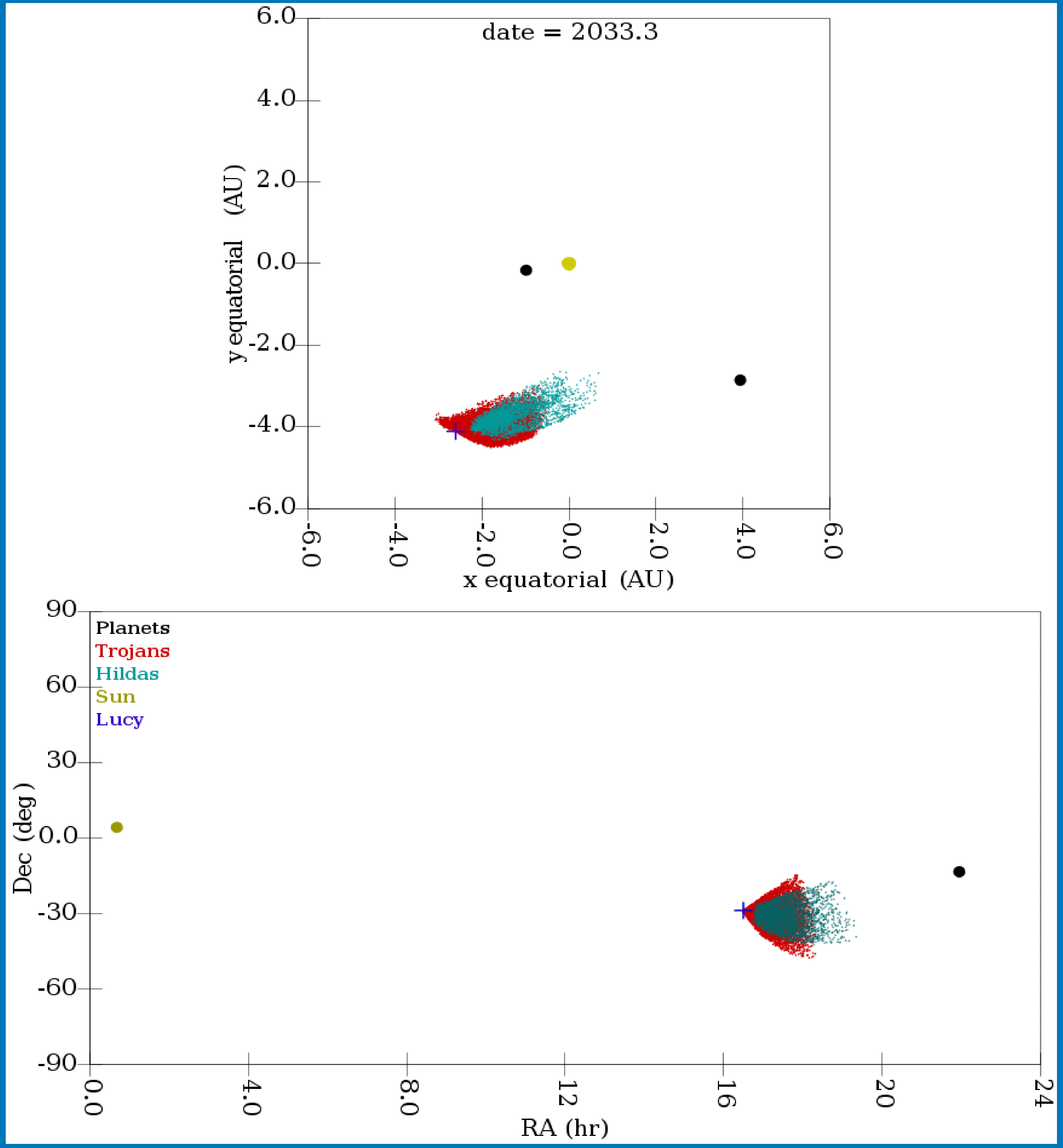


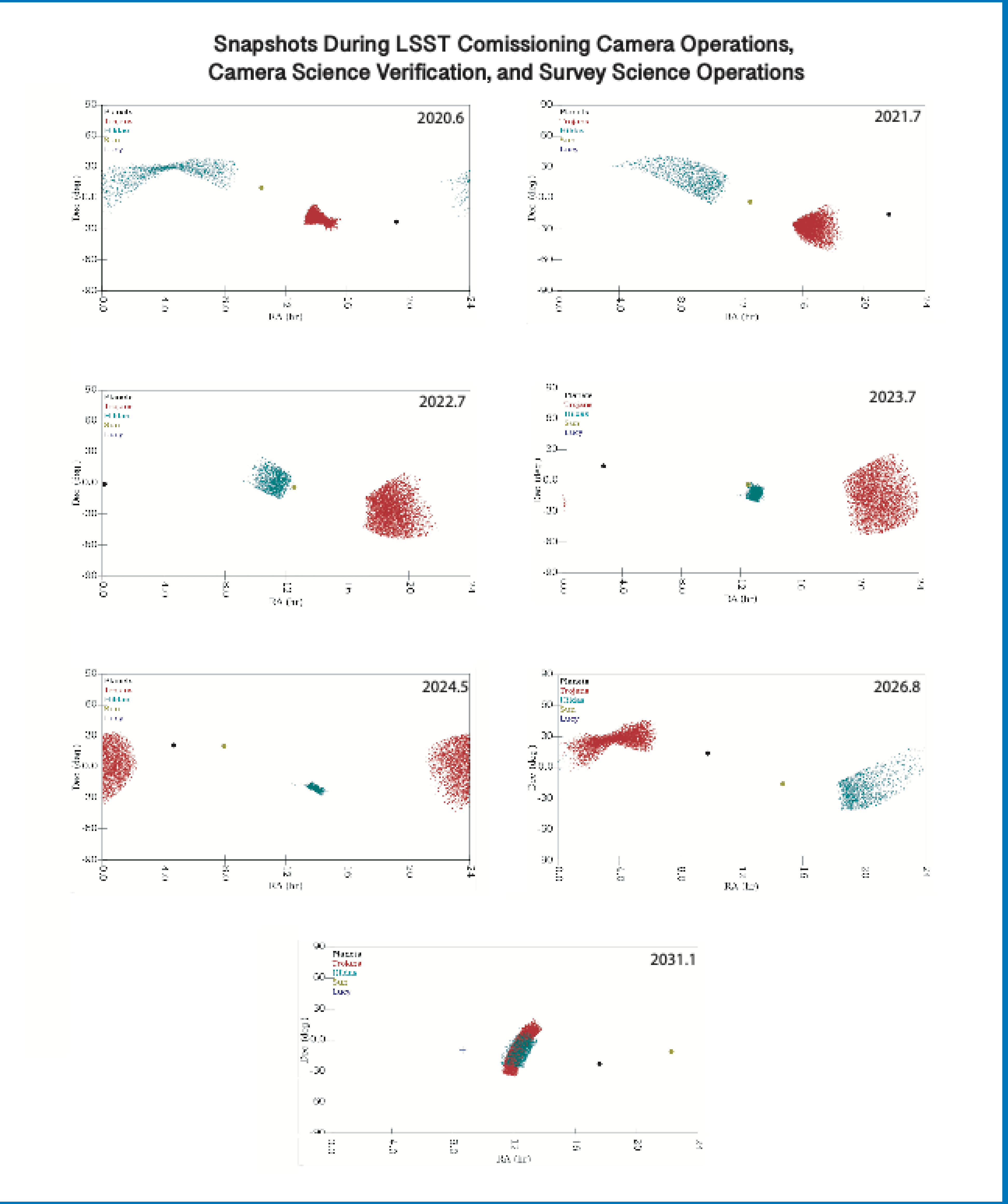
See http://ls.st/Document-29545

Slide Credit: Mario Jurić

What LSST Can Do

finding new small body targets for future NASA mission (e.g. Lucy)

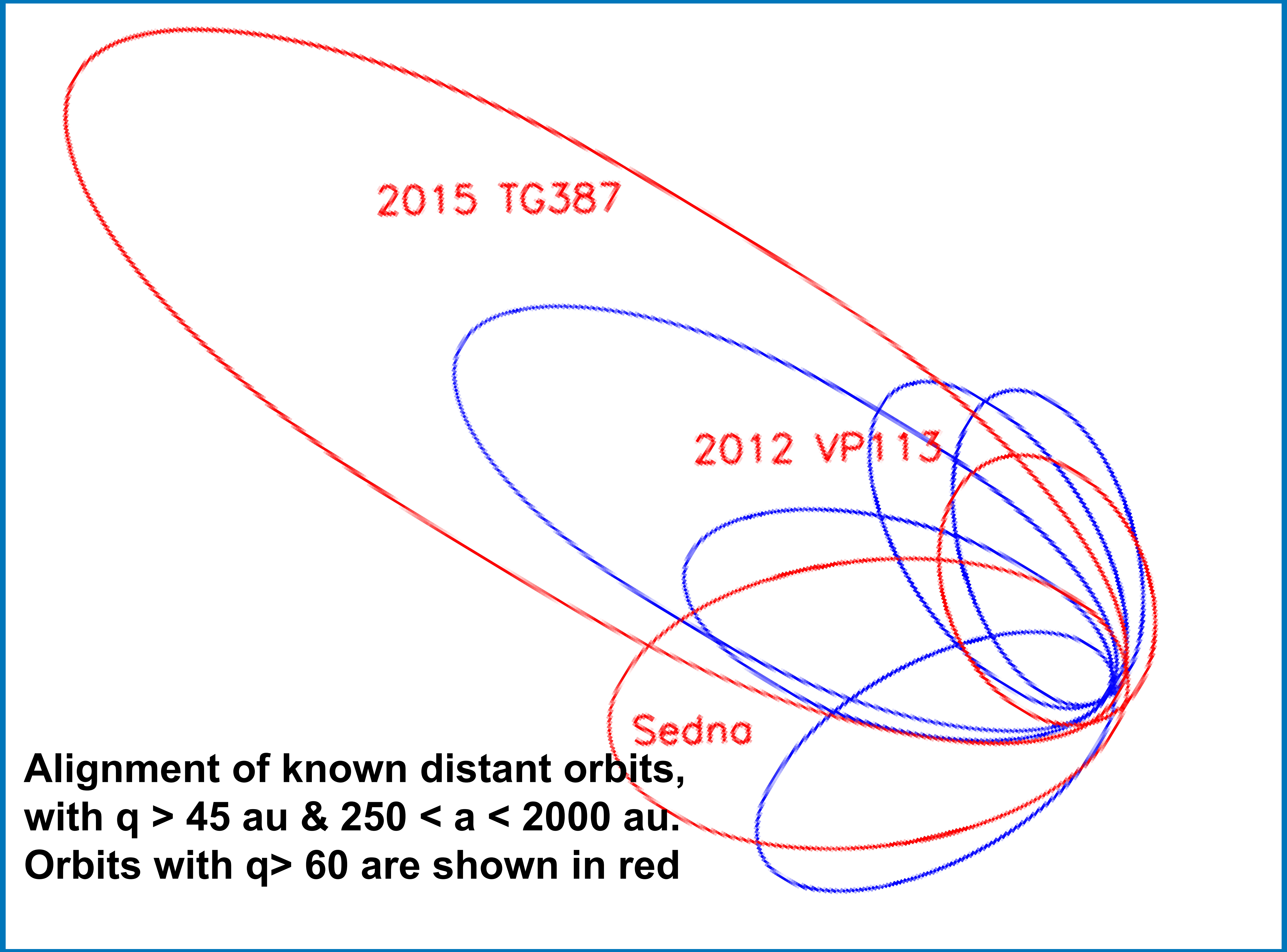




Schwamb et al. (2018 - RNAAS) https://doi.org/10.3847/2515-5172/aade00

What LSST Can Do

Explore the Origin of Sedna’s Strange Orbit and Test the Existence of Planet 9



Alignment of known distant orbits, with q > 45 au & 250 < a < 2000 au. Orbits with q> 60 are shown in red

Image Credit: S. Sheppard

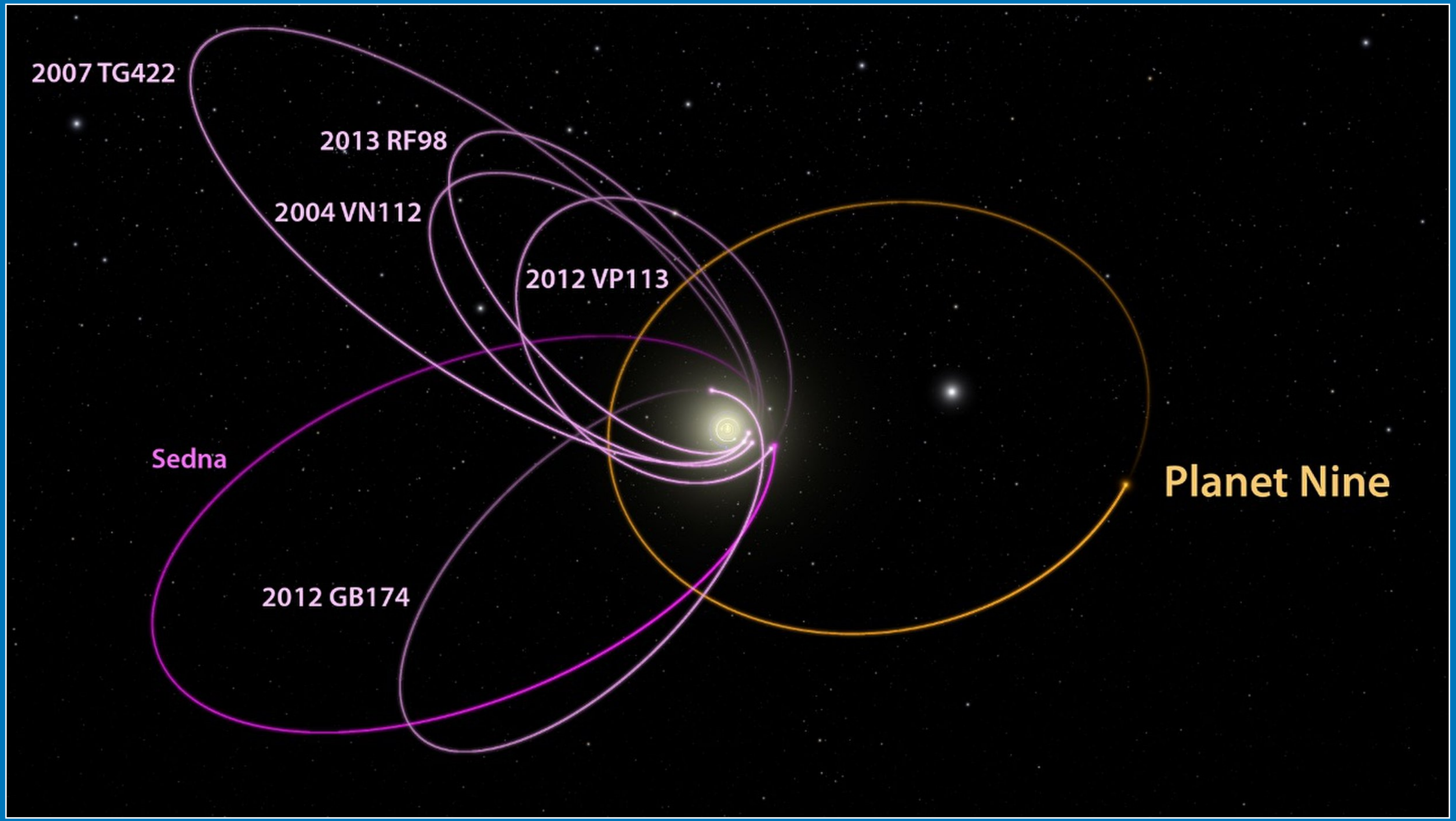
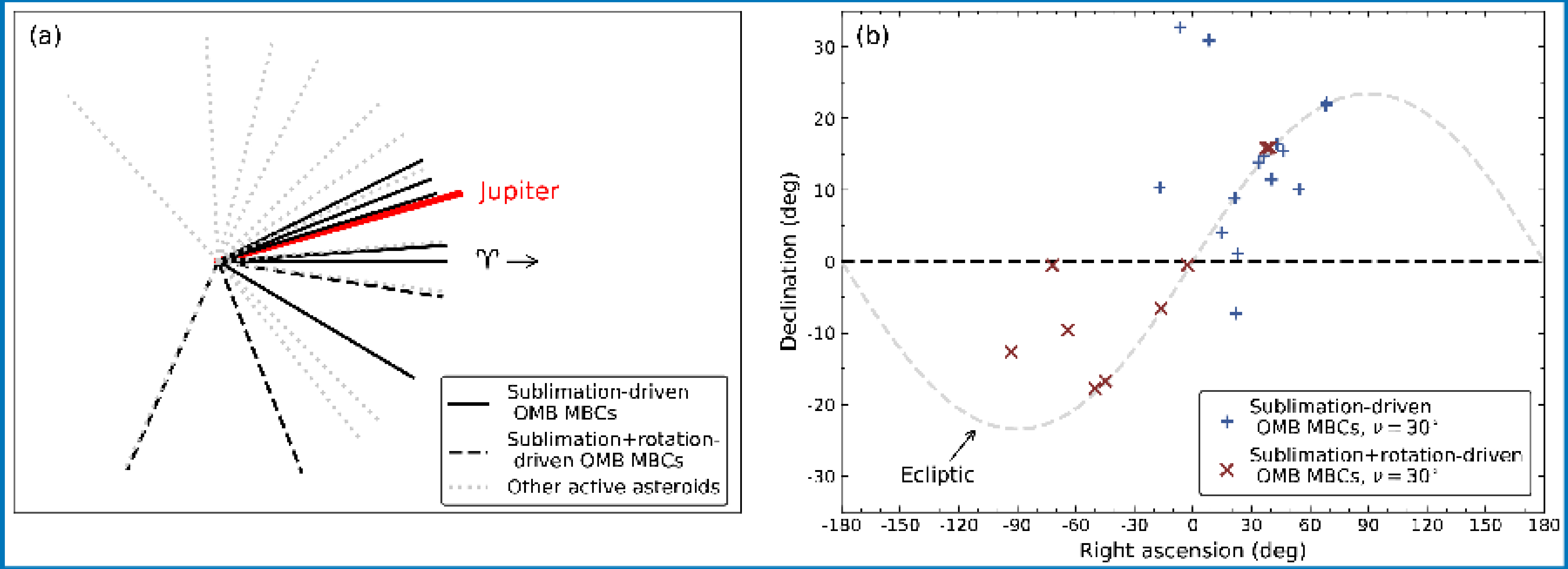


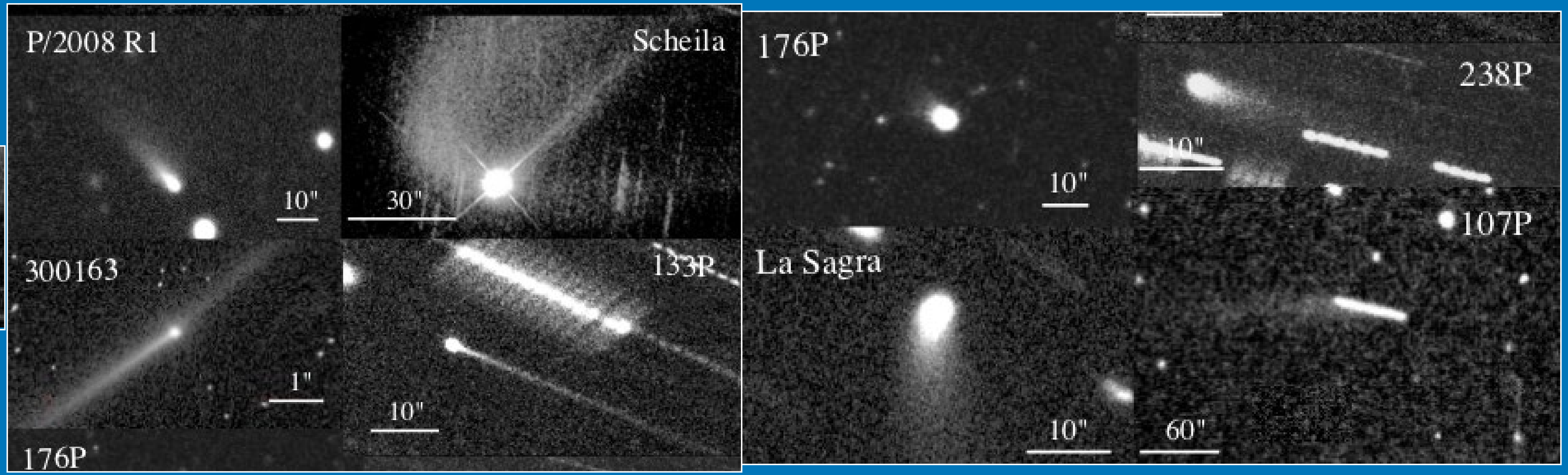
Image Credit: R. Hurt/JPL-Caltech

What LSST Can Do

Explore the Origin of Main Belt Comets and Active Asteroids



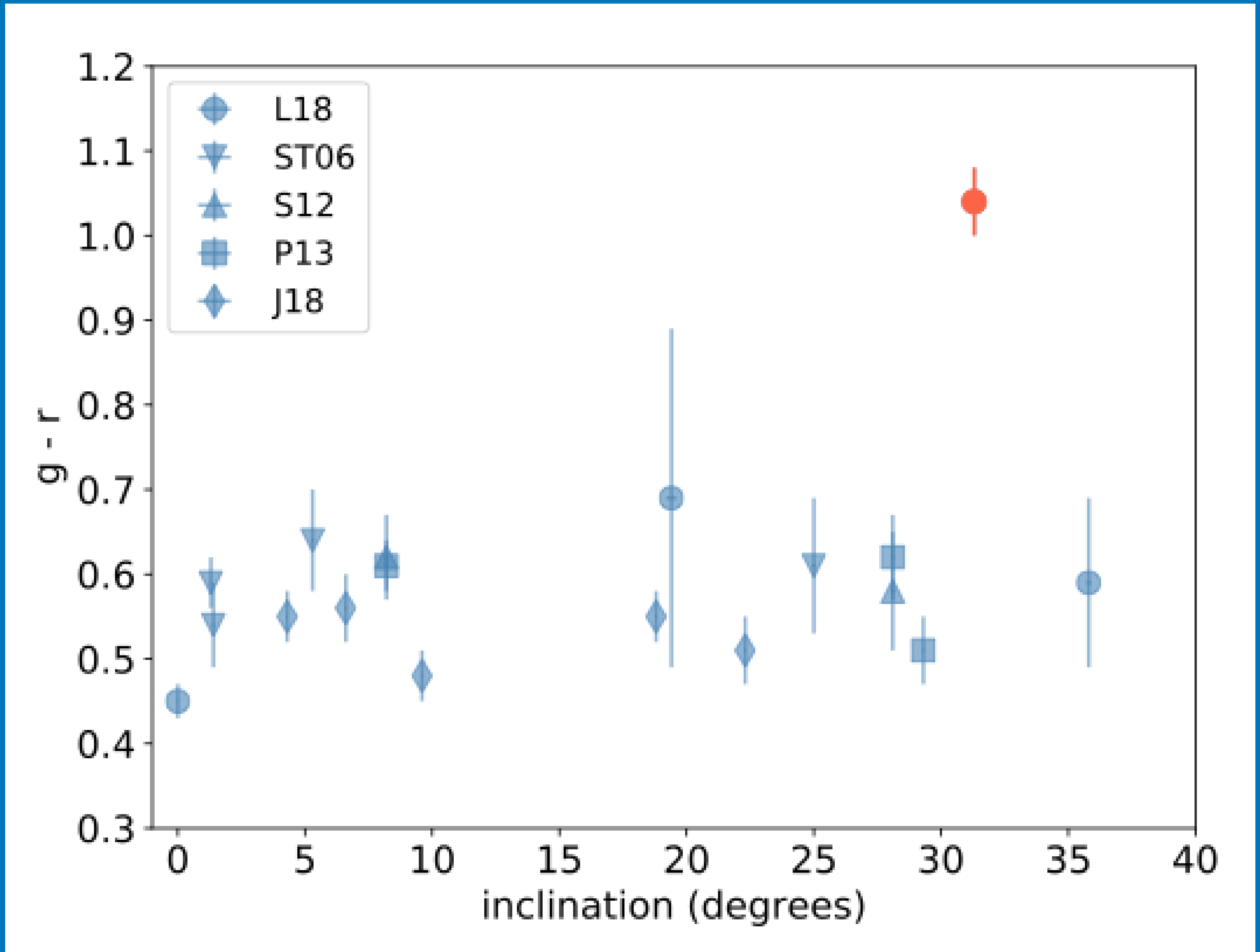
Ki et al (2018).Adapted by Henry Hsieh



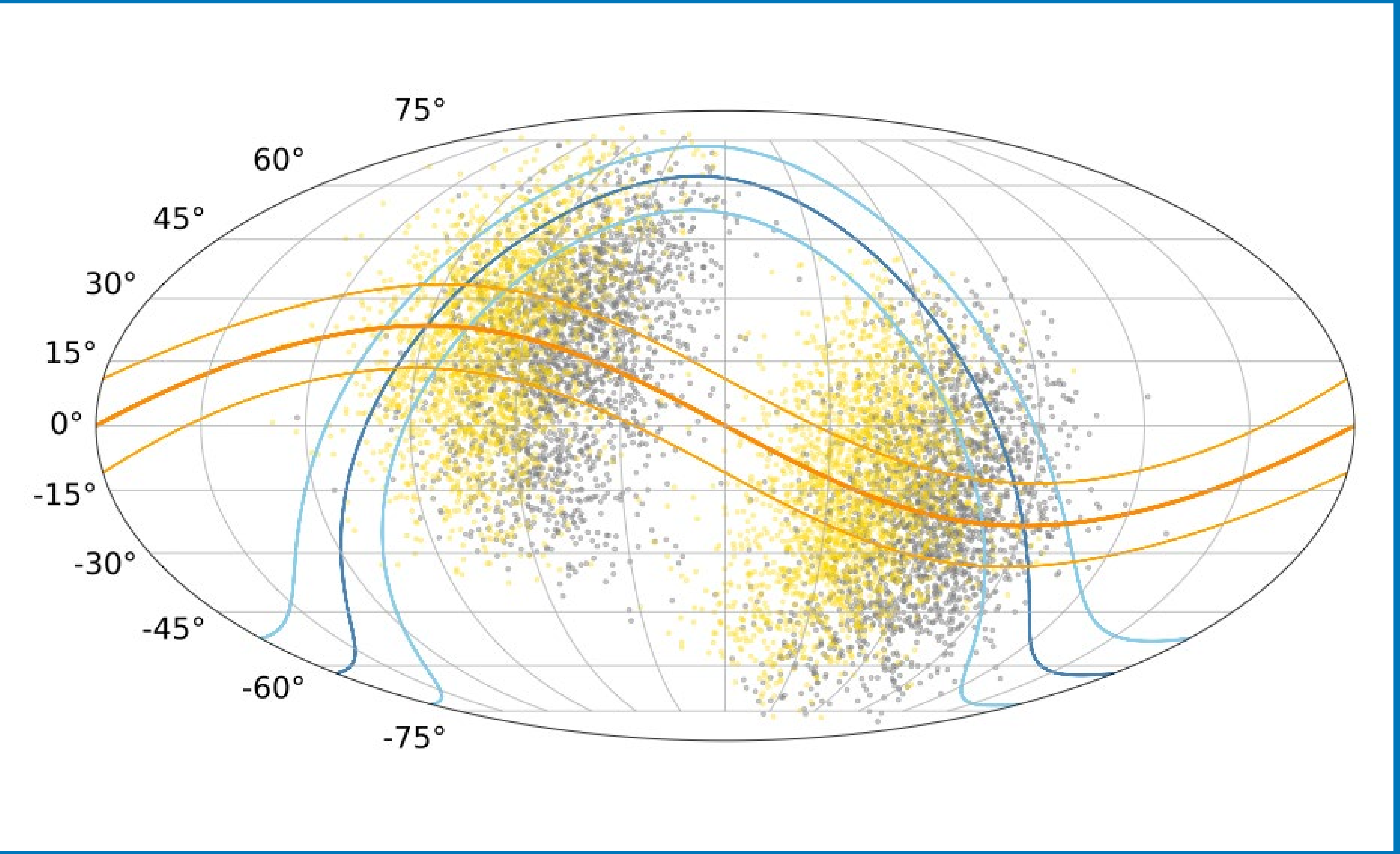
Jewitt (2012)

What LSST Can Do

Probe the Neptune Trojans Color-Inclination & Explore the Implications for Origin/Neptune Migration



Lin et al. (2018)



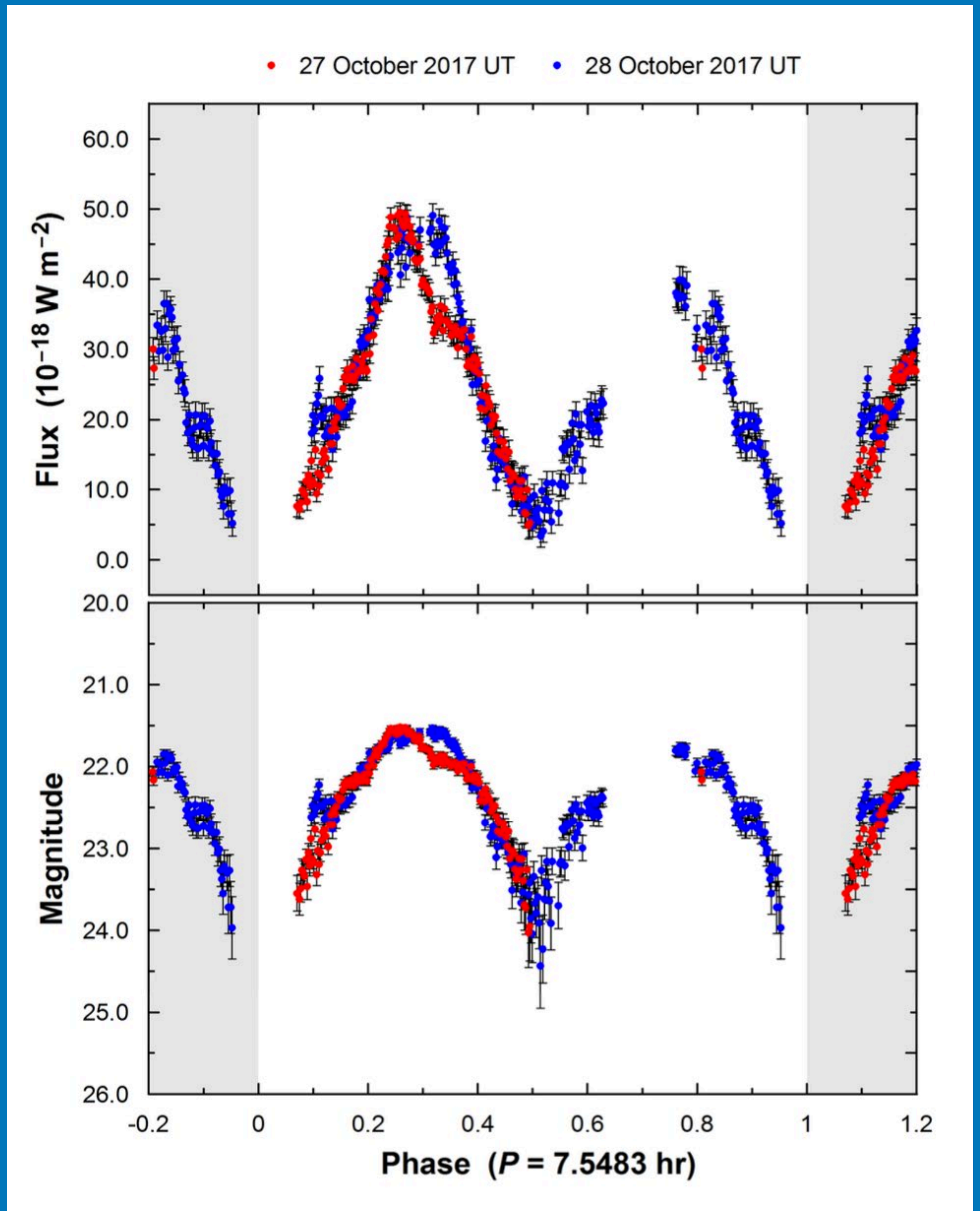
On-sky positions of Neptune Trojans in 2022 (grey) & 2032 (yellow)

Credit: Edward Lin

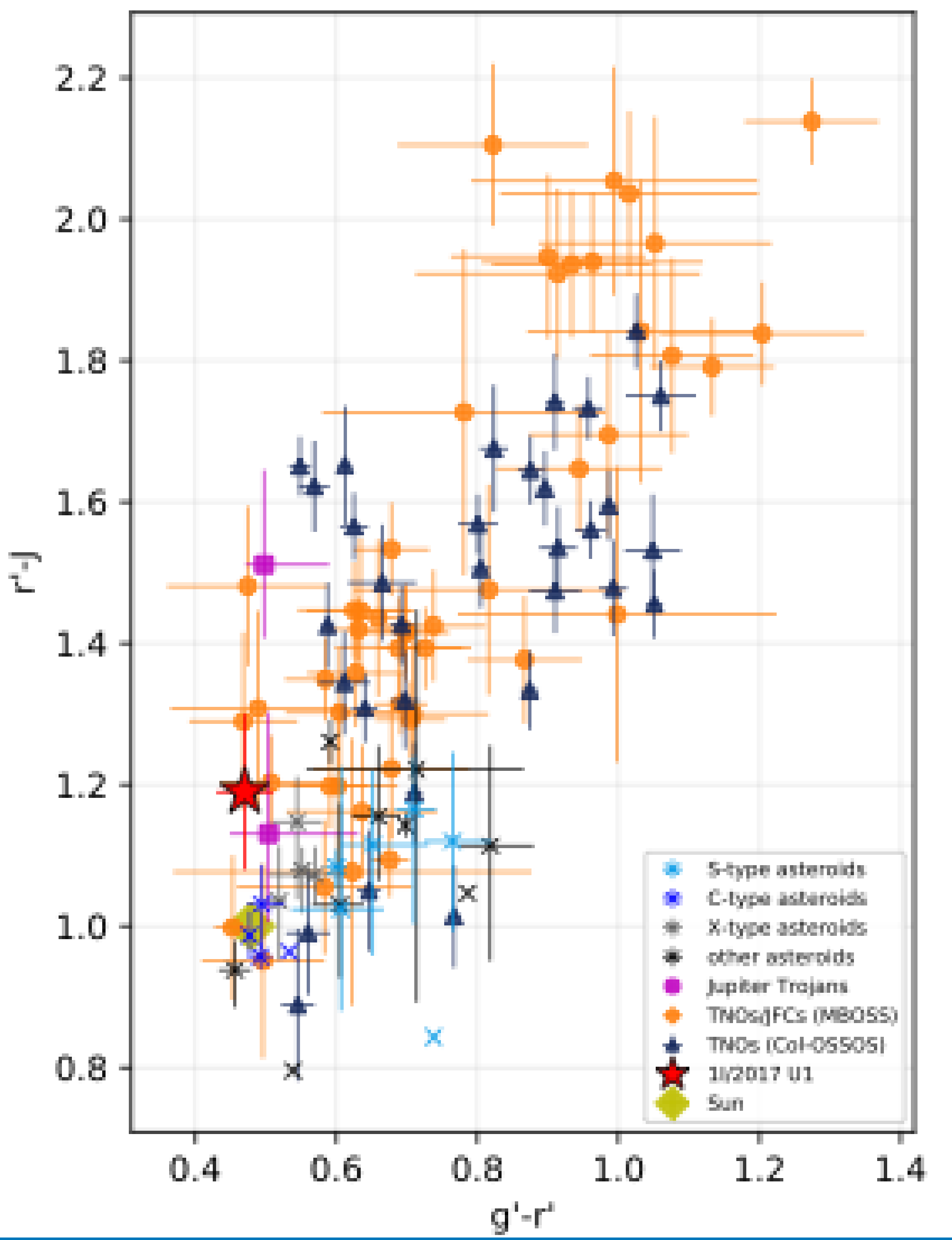
What LSST Can Do

Interstellar Object Discoveries

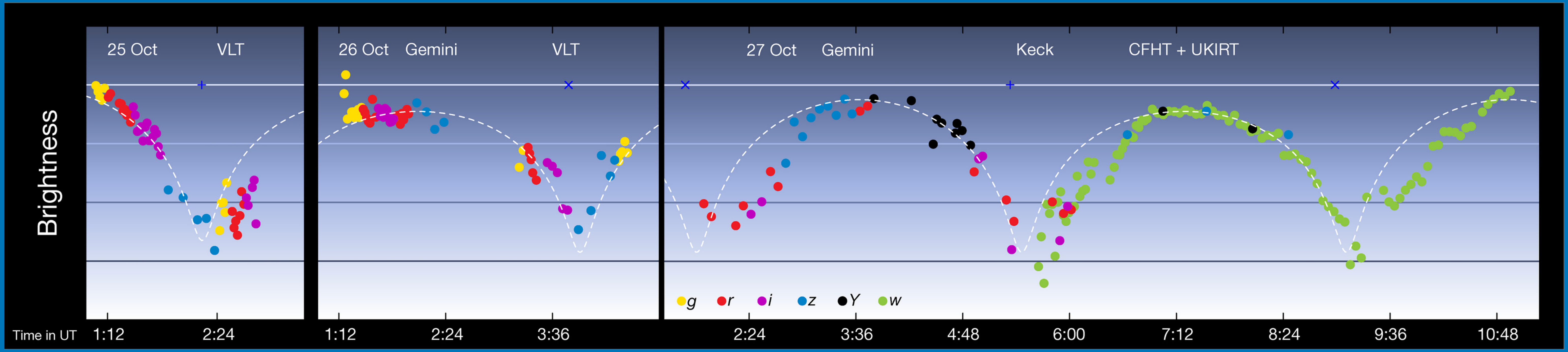
Credit: NASA/JPL-Caltech



Credit:Drahus et al. (2018)



Credit: Bannister, et al. (2017)



Meech et al (2018)

LARGE SYNOPTIC SURVEY TELESCOPE SOLAR SYSTEM SCIENCE ROADMAP

Megan E. Schwamb,[1] R. Lynne Jones,[2] Steven R. Chesley,[3] Alan Fitzsimmons,[4] Wesley C. Fraser,[4] Matthew J. Holman,[5] Henry Hsieh,[6] Darin Ragozzine,[7] Cristina A. Thomas,[6,8] David E. Trilling,[8] and Michael E. Brown[9]

on behalf of the LSST Solar System Science Collaboration

https://arxiv.org/abs/1802.01783

[1] *Gemini Observatory, Northern Operations Center, 670 North A'ohoku Place, Hilo, HI 96720, USA*

[2] *Department of Astronomy, University of Washington, 3910 15th Ave NE, Seattle, WA 98195, USA*

[3] *Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA, 91109, USA*

[4] *Astrophysics Research Centre, Queen's University Belfast, Belfast BT7 1NN, UK*

[5] *Harvard-Smithsonian Center for Astrophysics, 60 Garden St., MS 51, Cambridge, MA 02138, USA*

[6] *Planetary Science Institute, 1700 East Fort Lowell Road, Suite 106, Tucson, AZ 85719, USA*

[7] *Brigham Young University, Department of Physics and Astronomy, N283 ESC, Provo, UT 84602, USA*

[8] *Department of Physics and Astronomy, Northern Arizona University, P.O. Box 6010, Flagstaff, AZ 86011, USA*

[9] *Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125, USA*

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ABSTRACT

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.

Identifying Software Development That Community Will Have To Do

A SOFTWARE ROADMAP FOR SOLAR SYSTEM SCIENCE WITH THE LARGE SYNOPTIC SURVEY TELESCOPE

Megan E. Schwamb,[1] Henry Hsieh,[2] Michele T. Bannister,[3] Steven R. Chesley,[4] Wesley C. Fraser,[3] R. Lynne Jones,[5] Mario Jurić,[5] Michael S. P. Kelley,[6] Darin Ragozzine,[7] David E. Trilling,[8] and Kathryn Volk[9]
on behalf of the LSST Solar System Science Collaboration

[1] *Gemini Observatory, Northern Operations Center, 670 North A'ohoku Place, Hilo, HI 96720, USA*
[2] *Planetary Science Institute, 1700 East Fort Lowell Road, Suite 106, Tucson, AZ 85719, USA*
[3] *Astrophysics Research Centre, School of Mathematics and Physics, Queen's University Belfast, Belfast BT7 1NN, UK*
[4] *Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA, 91109, USA*
[5] *Department of Astronomy, University of Washington, 3910 15th Ave NE, Seattle, WA 98195, USA*
[6] *Department of Astronomy, University of Maryland, College Park, MD 20742-2421, USA*
[7] *Brigham Young University, Department of Physics and Astronomy, N283 ESC, Provo, UT 84602, USA*
[8] *Department of Physics and Astronomy, Northern Arizona University, P.O. Box 6010, Flagstaff, AZ 86011, USA*
[9] *Lunar and Planetary Laboratory, University of Arizona, 1629 E. University Blvd., Tucson, AZ 85721, USA*

The Large Synoptic Survey Telescope (LSST) will provide an unprecedented view of the Solar System. The 8.4-m telescope, currently under construction in Cerro Pachón, will host a 9.6 deg^2 field-of-view camera (Ivezić et al. 2008; LSST Science Collaboration et al. 2009). LSST will detect millions of asteroids and tens of thousands of distant Solar System bodies, within approximately 16 and 24.5 magnitudes (in r-band). Over a ten year period, most of these minor planets will receive hundreds of observations divided between 6 filters (ugrizy).

The data products that the LSST project will deliver for Solar System detections is described in the recently updated LSST Data Products Definition Document (DPDD; Jurić et al. 2013). The LSST Solar System Science Collaboration (SSSC)[1] developed a science roadmap (Schwamb et al. 2018) which outlines the collaboration's highest ranked research priorities utilizing LSST. To achieve these goals, the SSSC has identified crucial community software products/tools that will be required but not provided by the LSST project. These will have to be developed by the SSSC and the broader planetary community. To spur this effort, we present below the SSSC?s top priority software development tasks required to maximize LSST Solar System science.

COMMUNITY SOFTWARE UTILITIES NEEDED DURING YEAR 1 OF LSST OPERATIONS

- Tools to extract cutouts from raw, reduced, and deep-stacked LSST images at locations where a specified orbit is predicted to appear, accounting for the uncertainty in the orbital parameters.
- A utility to convert LSST heliocentric orbital element catalogs to barycentric.
- A shift-and-Stack moving object pipeline to search for moving sources below the detection limit of any individual image, adopting a suite of orbits and aligning and coadding a collection of exposures along those trajectories in order to look for evidence for a source.

Schwamb et al. RNAASin prep

More details can be found on the SSSC’s webpage

www.lsstsssc.org

LSST is providing the moving object detections (for $\lesssim$ 200 au) but…

To maximize small body science, the planetary community needs much more

1) Create a slow moving detection pipeline to find objects beyond 200 au,creating algorithms to identify cometary activity observed in LSST detections
2) Characterize LSST interstellar object discoveries
3) Develop a survey simulator to compare orbital populations to LSST detections (probe giant planet migration,Planet 9 models, etc)
4) Analyze the orbital distribution of main belt comets and explore link to water on Earth
5) Advanced deep detection algorithms for moving objects

etc…

The next 3 years are crucial in planning and preparation for LSST small body observations throughout the Solar System, and the science yield can be maximized with modest effort to develop predictive and analysis tools.

We suggest NASA host a series of small body workshops focused on discussions about ground-based follow up of LSST discoveries and other related preparatory work

First LSST Solar System Readiness Sprint Outcomes

July 10-12, 2018 @ Seattle WA

- 8 LSST Cadence Optimization White Papers
- Complete proposal for changes to the LSST Solar System database schema
- SSSC Software Roadmap
- 20 researchers familiar with the LSST metric analysis framework and simulation tools

Possible Recommendation for SBAG consideration

Given the imminent potential for small body science with LSST, we recommend SBAG advocate that the Planetary Science Division should add language in the 2020 and 2021 ROSES calls for PDART, Solar System Observations, and other related funding opportunities to **particularly encourage LSST preparatory work**

Representative examples of preparatory work might include: development of a survey simulator to compare orbital populations to LSST detections; and/or development analysis tools to characterize expected detections; and/or hosting workshops to enable the small-body community to be best prepared to take advantage of LSST’s expected bonanza.

Backup slides

In 2006, at the specific encouragement of OPAG, the formal 2006 NASA ROSES call included this language of encouragement for Uranus equinox observations:

"In 2007, Uranus will reach equinox, providing an opportunity to gather new observations using astronomical tools not available during the previous equinox in 1965. Along with the Planetary Atmospheres and Outer Planets Research programs, Planetary Astronomy encourages proposals that take advantage of this rare opportunity to investigate equinoctial phenomena such as ring plane crossings, mutual uranian satellite occultations, diurnally-driven auroral activity, and atmospheric radiative balance changes driven by rapidly varying insolation."

Total modification to ROSES was the above text, and no funding was added. This two-sentence addition to ROSES was tremendously helpful to the science yield for Uranus equinox.