



# Discovering and Characterizing Near Earth Objects with Vera C. Rubin Observatory's *Legacy Survey of Space and Time (LSST)*

Lynne Jones, Siegfried Eggl,  
Mario Jurić , Željko Ivezić



# The Legacy Survey of Space and Time (LSST)

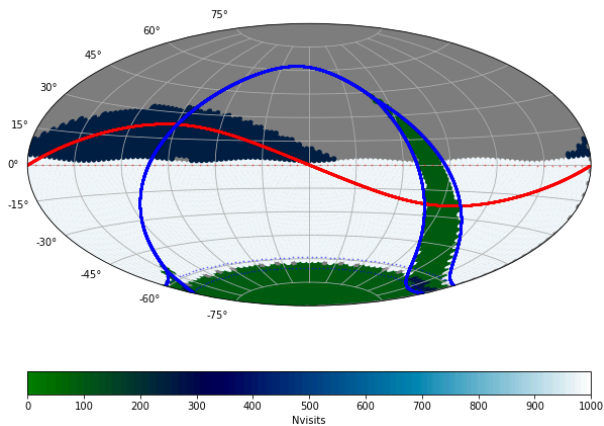
- Rubin Observatory
  - 8.4m (6.7m effective) telescope
  - 9.6 sq deg (3.2 Gpix) camera
  - Data processing pipelines to generate calibrated catalogs
- The LSST
  - 10 years of images in *ugrizy* filters
  - Primary science drivers
    - Dark energy / dark matter
    - Milky Way & Local Volume
    - Transient & Variable Universe
    - **Small bodies in the Solar System**



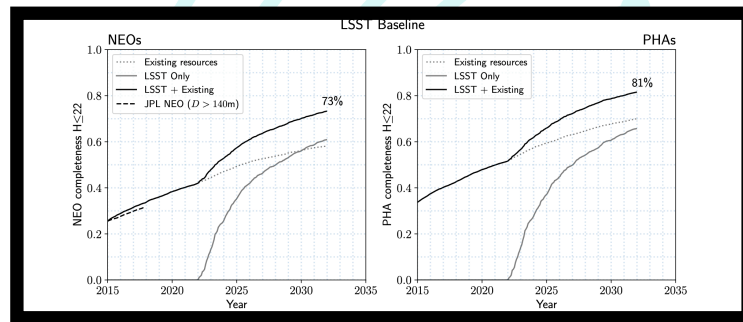
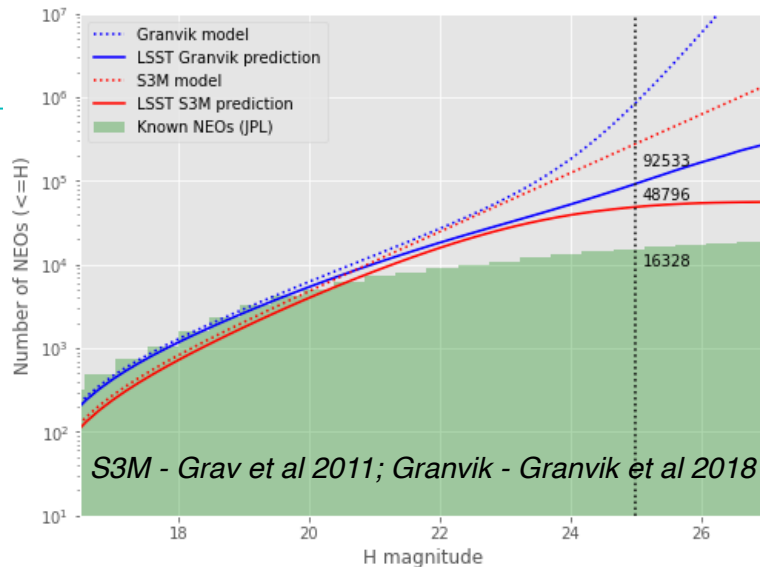
# NEO & PHA discovery

In current baseline strategy, after 10 years:

- 50-100K NEOs @  $H < 25$ 
  - Total? Large uncertainties.
- 62% - 67% NEO completeness @  $H < 22$

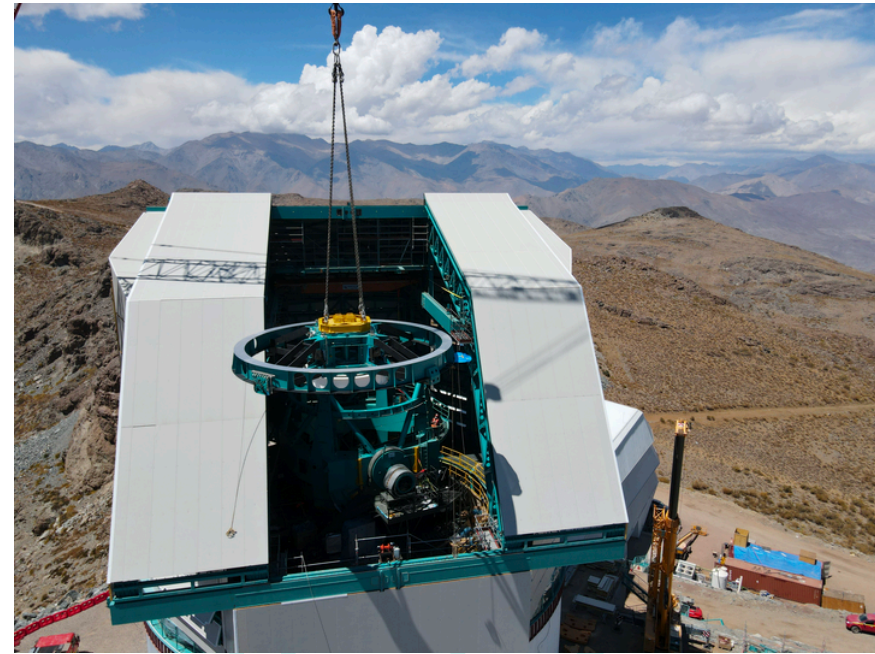
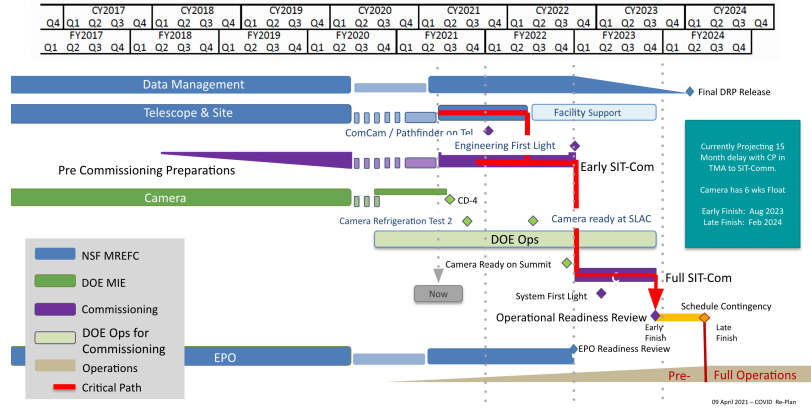


consistent with prior work:  
*Jones et al 2018,*  
*Veres & Chesley 2017*

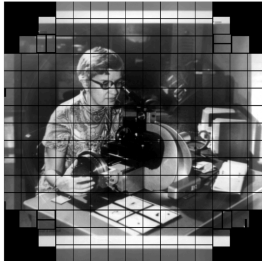


# Project Timeline

- Operations expected to start no sooner than Fall 2023 due to COVID delay



Amazing video of the TEA lift at <http://ow.ly/1mZV50DTgnX>





# Survey Strategy

- Basic strategy in place but options for “how to survey the sky” under consideration

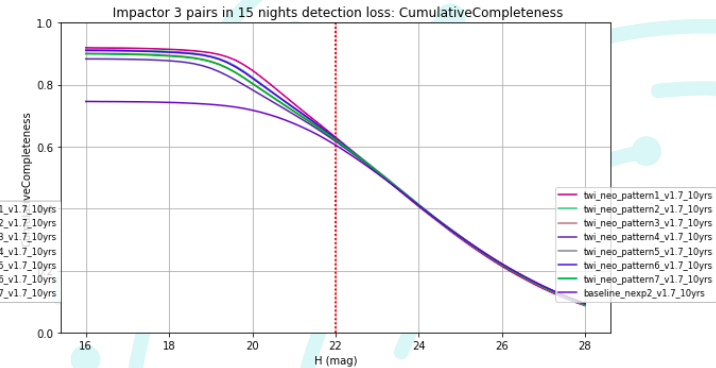
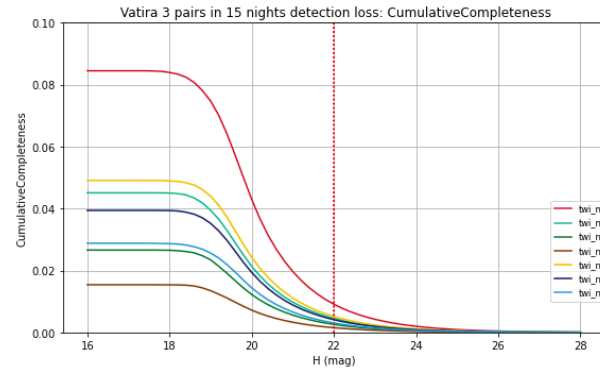
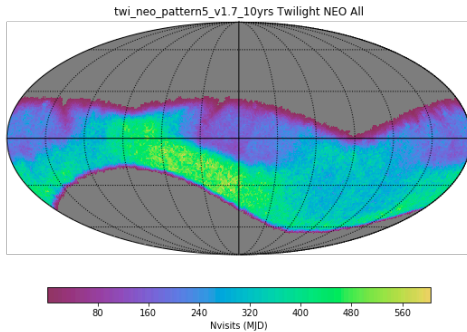
## Survey Strategy Timeline

- ◉ 2018 whitepapers on survey strategy, refining baseline
- ◉ 2019 LSST Science Advisory Council (SAC) recommendations for survey strategy simulations
- ◉ Aug 2020 LSST project delivers simulations & analysis to SAC and community
- ◉ Nov 2020 1st workshop
- ◉ April 2021 Cadence Notes due to Survey Cadence Optimization Committee (SCOC) - comments on early simulations
- ◉ Fall 2021 - SCOC recommendations for draft survey strategy simulations & 2nd workshop
- ◉ Dec 2021 - SCOC recommendations for initial survey strategy
- ◉ Early 2022 - project releases recommended survey strategy simulation
- ◉ Summer 2022 - fine-tuning and incorporation of early science goals, possible 3rd workshop
- ◉ Dec 2022 - SCOC and project deliver initial survey strategy plan & simulation
- ◉ Early 2023 - Scheduler in commissioning
- ◉ Fall 2023 - Survey operations begin



# Adding a short exposure twilight NEO-focused survey

- One survey option **may** be to spend some of the time between nautical and astronomical twilight for short (1s) visits at low solar elongation (<65 deg)
- Visits are in *riz* filters, triplets in each night the mini-survey is active
- Enables discovery of Vatiras, improves discovery of large impactors by ~20%

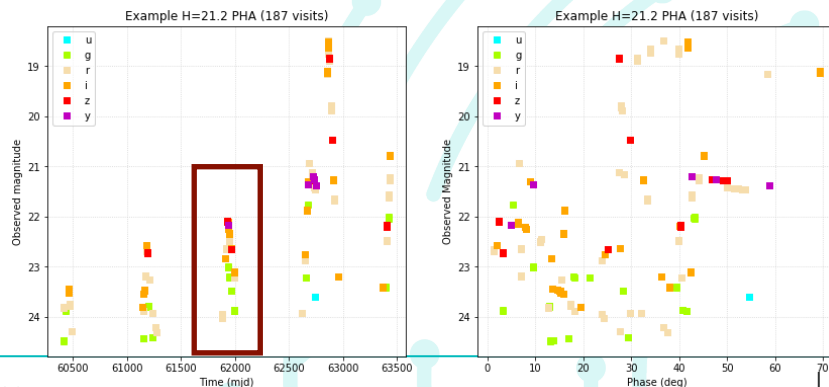
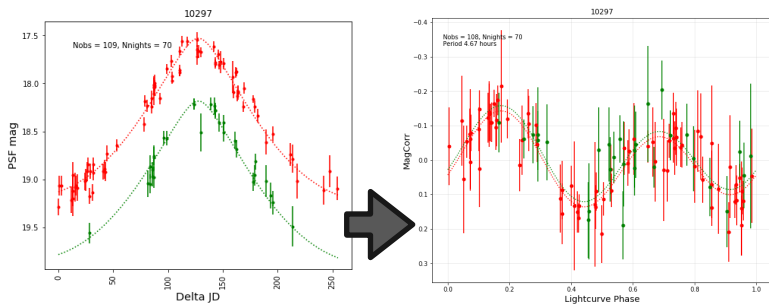
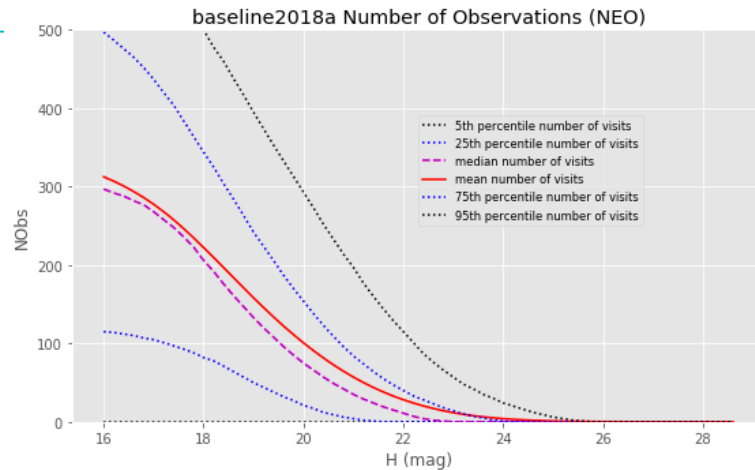


Distribution of twilight  
NEO visits over the sky

*Vatira population based on Granvik et al 2018, modified by Eggl.  
Impactor population prototype based on Chesley & Eggl, provided by Eggl.*

# NEO & PHA characterization

- Hundreds of observations in multiple filters
  - Colors
  - Rotation periods
  - Phase curves
  - Shapes
  - Detection of activity / volatiles / collisions



# Solar System Processing

- Data products include 60-second Alerts as well as Daily Catalogs
- Alerts include any observations of any known objects (tracks not needed)
- Trailed source fitting will allow quick identification of trailed sources in Alerts
- See <http://ls.st/Document-29545> for a summary of data products
- Development of pipelines ongoing
  - Integration test with MPC (see <https://dmtn-180.lsst.io/>)
  - New linking methods - HelioLinC3D

## A. Real-time Alerts ( $\geq 2M$ SSO observations/night)

Astrometry	$\pm 10$ mas (bright; $\pm 140$ faint)
PSF flux	$\pm 10$ mmag (bright end)
Aperture flux	$\pm 10$ mmag (bright end)
Trailed source fit	Flux and on-sky motion for fast-moving (trailed) objects
Appearance characterization	Moments and extendedness of the object's image
Spuriousness score	Probability that the detection is an artifact
Nearby static objects	Information on adjacent objects (up to three)
MPC designation	Given for known objects
Predicted position and magnitude	Given for known objects



# Rubin Observatory's LSST

---

- The LSST will be a significant resource for planetary defense, discovery and study of NEOs and PHAs
- Anticipate between 50-100k NEOs with  $H < 25$
- Construction of observatory and pipelines is ongoing
- Survey strategy being refined
- The LSST Solar System Science Collaboration - <http://lsst-sssc.github.io> - is a great resource to get started and build additional connections