The Vera C. Rubin Observatory and “small” telescopes

Will Clarkson (University of Michigan-Dearborn)
Rubin Science Collaborations Coordinator

Saturday June 3, 2023

Small Ground and Space Telescopes in the New Era of Big Telescope Surveys
AAS 242 / AAVSO

Image:https://www.lsst.org/news/see-whats-happening-cerro-pachon

Prediction: the Rubin Observatory's LSST will ***increase*** the scientific need for "small"-aperture observations and the AAVSO.

LSST will identify clean samples of highly interesting targets, across all areas of astronomy, many of which will require the kind of investigations that can only be conducted with small-aperture observatories and/or with the kind of coverage that only collectives like the AAVSO can provide.

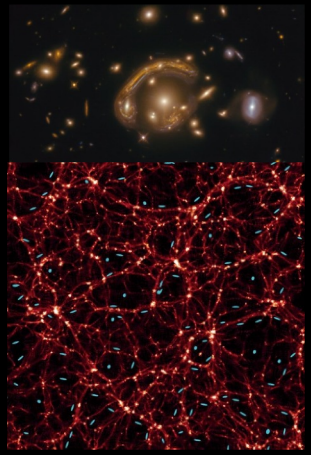
- Rubin provides the data products, the community does the science.
- To contribute scientifically, consider joining one of the Rubin Science Collaborations (coordinator: Will Clarkson, wiclarks@umich.edu).
- Engaging astronomers at small and under-resourced institutions in preparing for LSST science, is a priority for the Science Collaborations and for Rubin via its Community Science Team (CST, lead: Melissa Graham, mlg3k@uw.edu).
- There is a path for amateur astronomers to request data rights for proprietary data and services (may require justification of why already-planned public data will not be sufficient).

Rubin science pillars

Slide credit: Melissa Graham

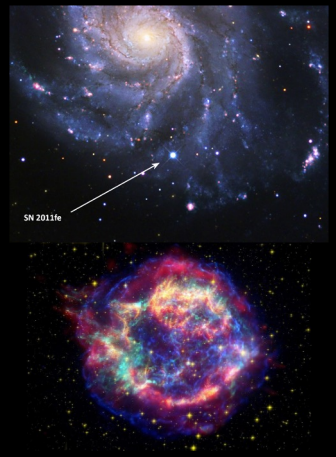
Cosmology

Understand dark energy and dark matter, and the origin and fate of the universe, by studying gravitational lensing and large-scale structures across cosmic time.



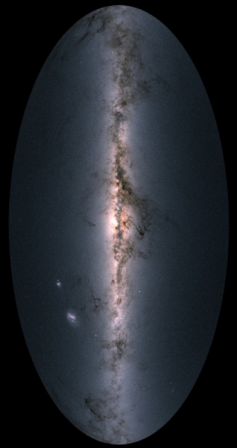
Transient Phenomena

Understand evolutionary processes by studying how stars and compact objects (e.g., black holes) change brightness, interact, merge, and explode.



The Milky Way

Understand the structure and evolution of our Galaxy's bulge, disk, and halo – and its satellites and tidal streams – by mapping the stars of the Milky Way.

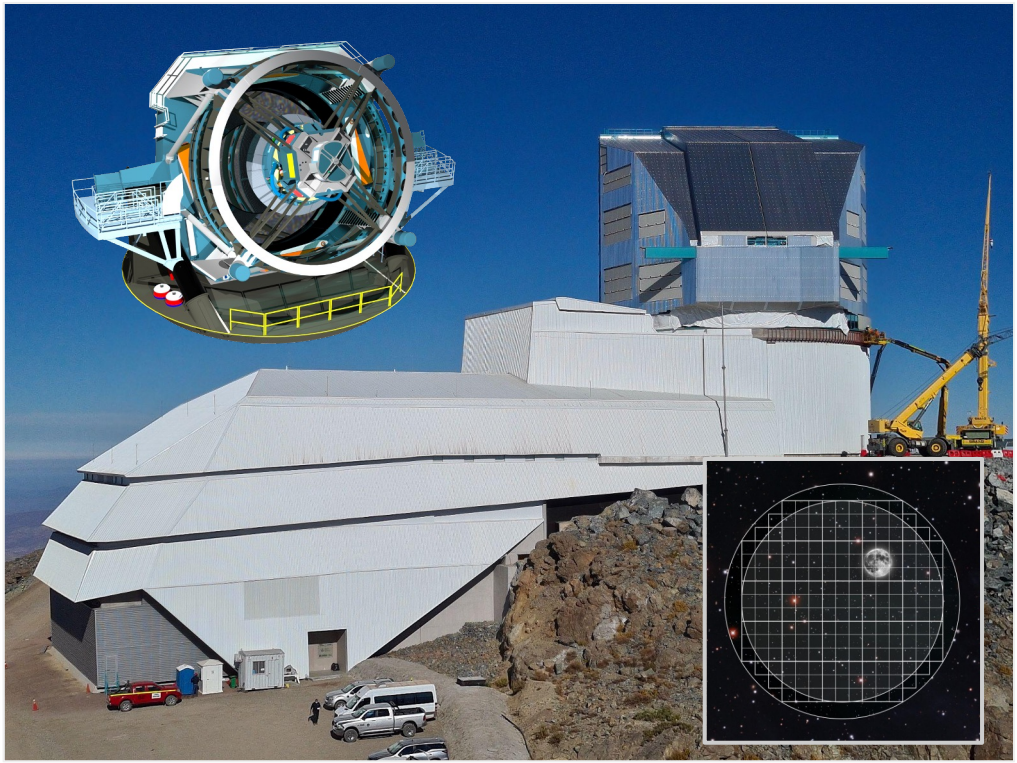


The Solar System

Understand the formation and evolution of our Solar System, and the risk of potentially hazardous asteroids, by making a full inventory of objects down to ~100 m scales.

The Vera C. Rubin Observatory

Slide credit: Melissa Graham



The Vera C. Rubin Observatory is located on Cerro Pachón in Chile. The Simonyi Survey Telescope's primary mirror has an 6.7 meter *effective* diameter and its camera an 9.6 deg^2 field-of-view and six optical-NIR filters: *ugrizy* (320-1050 nm).

Once construction and commissioning are complete, Rubin Observatory will execute the 10-year **L**egacy **S**urvey of **S**pace and **T**ime (**LSST**: early 2025-2035):

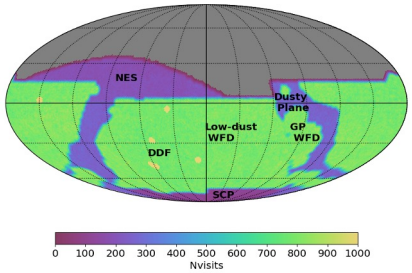
- single-image depths (point source; AB)
  - *ugrizy* = 23.9, 25.0, 24.7, 24.0, 23.3, 22.1 mag
- 10-year LSST depths (point source; AB)
  - *ugrizy* = 26.1, 27.4, 27.5, 26.8, 26.1, 24.9 mag

See Ivezić et al. (2019) for details about the design and the science goals. Also: https://www.lsst.org/scientists/keynumbers

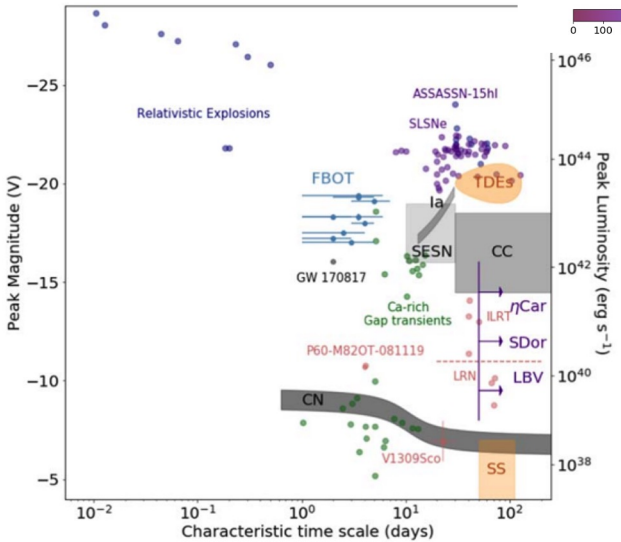
The Legacy Survey of Space & Time (LSST)

Large, complex datasets (key numbers):

- 20TB (~1 SDSS) per night for 10y
  - Catalog ~ 15 PB, total holdings ~300 PB
- ~17 billion stars, 20 billion galaxies, >800 visits each, r <~ 24.7 (per visit), 27. 5 (10y)
  - ugrizy (320-1050 nm)
  - e.g. ~300 million MS stars with photometric [Fe/H] out to ~100 kpc
- Orbits of ~6 million Solar System objects
- Variability measurements
  - ~10 million alerts ***per night*** within 60 seconds of shutter open
  - Sensitivity to variability on timescales ~30 minutes - 10 years (~Jan 2025 - 2035)



Above: candidate survey footprint in Equatorial coordinates

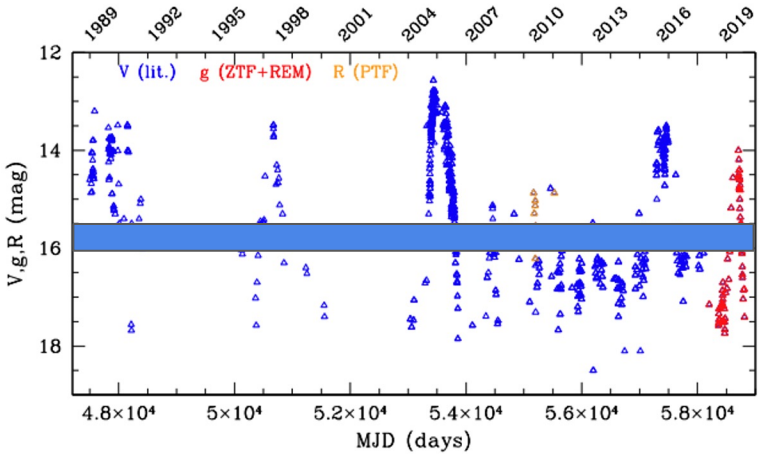


Luminosity-timescale coverage of transients to which LSST should be sensitive. From Li et al. 2022, as modified with permission from Ivezic et al. 2019.

For more on Rubin data products, see this Zenodo document (Graham et al. 2023)

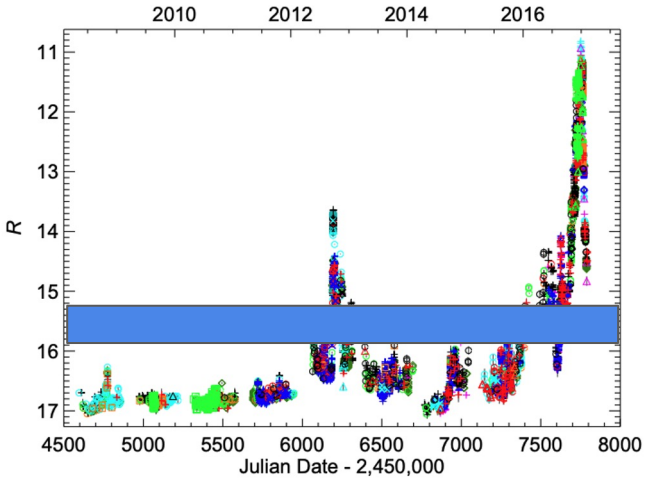
“If Rubin will do all this, what’s left for the rest of us?”

Tens of billions of objects (in *ugrizy)*, ~800 visits for most objects over 10 years, billions [sic] of transients, unprecedented size and precision of photometric catalogs… → ***“small” telescope investigations will be needed more than ever.*** Just two examples:



ExOr variable V1118 Ori
(i.e. young eruptive protostar)

Blue bars:
rough LSST
saturation limit
in r-band



Blazar CT 102
(i.e. radio-loud active galactic nucleus)

Figures from the Transients & Variable Stars (TVS) Science Collaboration Roadmap: Hambleton et al. (2022)

“How can I help with LSST science?”

Rubin Observatory produces data products (images and catalogs) and tools and services for data analysis (the Rubin Science Platform), but it does not do follow-up (of optical transients and variables) and it does not do science.

Everyone is welcome to do *any kind of science that interests them*; no science is ‘reserved’.

All are encouraged to make an account at Community.lsst.org to stay informed and ask questions.

“How can I contribute to LSST science if I don’t have time to start my own project?”

“What should I do with my small observatory to complement LSST science?”

If these questions resonate with you, the **best way to contribute to LSST science is to join a Rubin Science Collaboration (SC)**. Ways to contribute might include:

- Create plans and shared software for follow-up observations of interesting targets
  - The Transients & Variable Stars (TVS) and Active Galactic Nuclei (AGN) SCs probably most relevant
    Join topical working groups and contribute your expertise
- Join (or initiate!) large scale science projects planned within the SC

The Rubin Science Collaborations

Solar System Science Collaboration (Meg Schwamb, Colin Orion Chandler)

Dark Energy Science Collaboration (Katrin Heitmann, Renee Hlozek)

Informatics & Statistics Science Collaboration (Francois Lanusse, Ashley Villar)

Transients & Variable Stars (Igor Andreoni, Sara Bonito)

Galaxies Science Collaboration (Sugata Kaviraj, Simona Mei)

Stars, Milky Way & Local Volume (Peregrine McGehee, Will Clarkson)

Strong Lensing Science Collaboration (Timo Anguita, Graham Smith)

Active Galactic Nuclei (Niel Brandt, Gordon Richards)

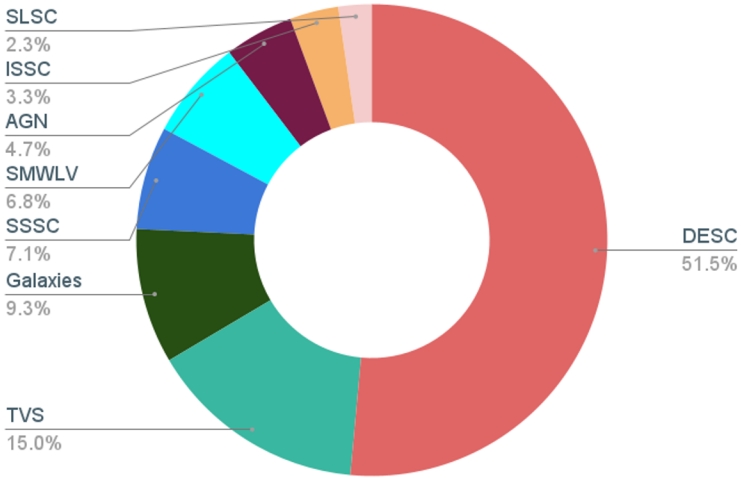
SC Coordinator: Will Clarkson (wiclarks@umich.edu)

Find out how to join at *https://www.lsstcorporation.org/science-collaborations*

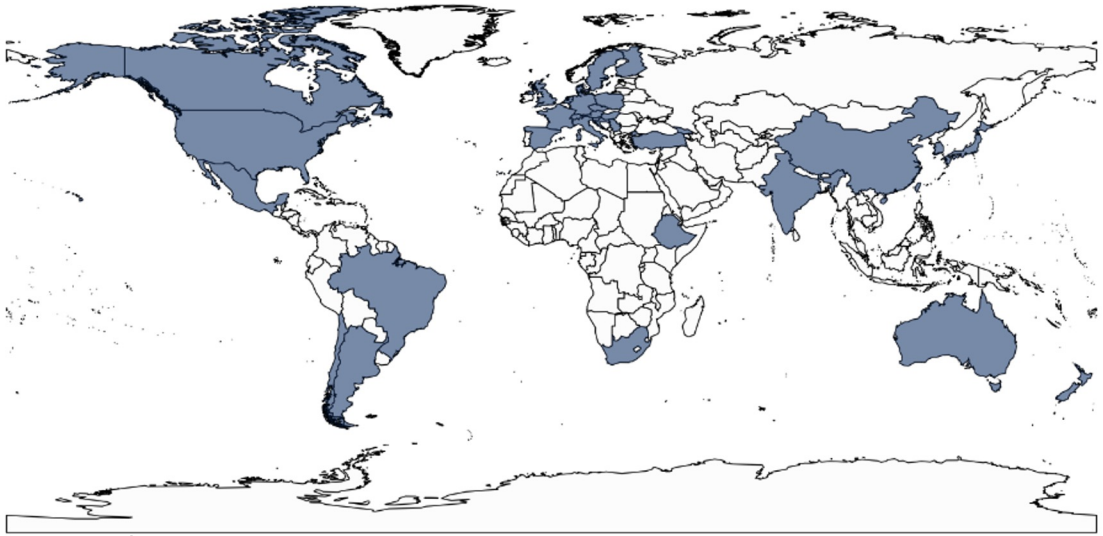
The Rubin Science Collaborations

SCs Federation Charter

8 Science Collaborations as autonomous, self-managed teams



>2000 people, 2500 affiliations, 6 continents, 33 countries



SC Coordinator: Will Clarkson (wiclarks@umich.edu)

Find out how to join at *https://www.lsstcorporation.org/science-collaborations*

Small research institutions & teaching colleges

The Rubin Science Collaborations are also working to widen participation in LSST science.

Example: the 1-year program **preparing for Astrophysics with LSST** (PI Rachel Street) funded by the Heising-Simons Foundation (https://lsst-sci-prep.github.io/)

Widening participation in Rubin science

- 35 “Kickstarter” projects at the ~€10k-20k level
  - International collaborations (members in Argentina, Australia, Brazil, Chile, Croatia, Denmark, France, Italy, New Zealand, Serbia, Spain, UK and the USA)
  - Emphasis on meaningful partnerships with newcomers
- 12 ApJS manuscripts funded so far

Access to professional training in software development & requirements engineering

- Professional training provided by Software Sustainability Institute and the Software Carpentries
- Paid for IEEE Course in software requirements engineering

Small research institutions & teaching colleges

The Rubin Observatory Community Science team (CST) is working to engage astronomers at small and underserved institutes* in preparing for LSST science.

*e.g., non-R1/R2; minority-serving; primarily-undergraduate.

In 2022-23, the CST talked to representatives of 15 small institutes to identify barriers to science, answer questions, and help create custom plans for LSST preparations with Data Preview 0 (DP0).

The CST is currently working on identified action items to support astronomers at small institutes, and will continue these one-on-one conversations.

If you would be interested to talk, email Melissa Graham (mlg3k@uw.edu).

Data Preview 0: a simulated set of LSST-like images and catalogs in the same format, and accessible via the same tools and services (Rubin Science Platform), as will be used with future real data.

To start your learning journey with DP0, visit dp0-2.lsst.io and follow the ‘getting started checklist’.

Amateur astronomers

The alert stream is public, and the independent alert brokers already offer public access services.

Rubin EPO* portal will also provide public access to a limited amount of LSST data (TBD).

*EPO = Education and Public Outreach (rubinobs.org)

Rubin data rights are required to access and analyse the *proprietary* data products and services, such as images, annual data releases, and the Rubin Science Platform.

To clarify this, I need to say a few words about how LSST data access will work:

Rubin Data Policy

Rubin Data Policy: ls.st/rdo-013
List of international data rights holders: lsst.org/scientists/international-drh-list

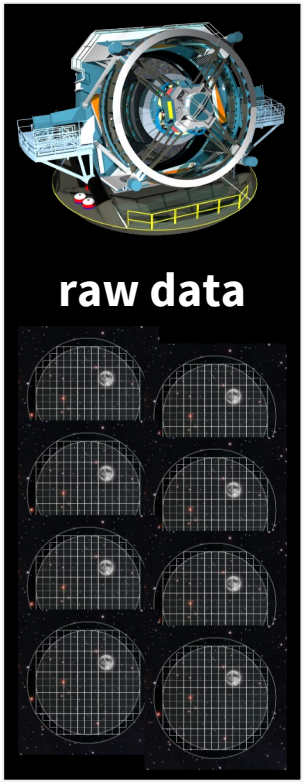
Data rights holders: scientists (and students) working (or enrolled) at US or Chilean institutes, and named members of the international in-kind contribution teams.

Proprietary: Annual data release data products, images and catalogs, and the prompt-processed images (for 2 years). Access to the Rubin Science Platform.

Public: alert packets and prompt catalogs, all other data after 2 years, and all documentation and support resources such as the Community Forum (Community.lsst.org).

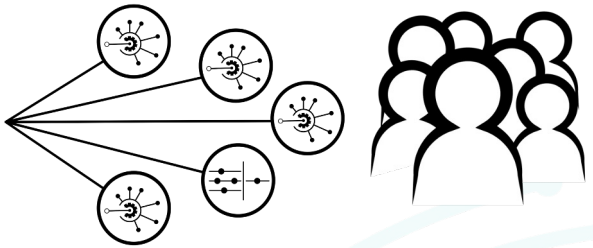
Data Products

world public



Difference Image Analysis (DIA)

In 60s, raw images are processed, a template is subtracted, and difference-image sources are detected, associated, characterized, and…



…distributed as alerts to brokers, where they can be rapidly analyzed by users.

PPDB contents are public

all images are proprietary

In 24h, the Prompt Products Database (PPDB) is updated with the DIA data products.

Yearly data releases include DIA, coadded images, and catalogs for all data to date.

The Prompt (24h) and Data Release (annual) data products will be available for users to analyze via the Rubin Science Platform.

proprietary to data rights holders

How can those without data rights participate?

- Do time-domain science with alerts and brokers
- These LSST Science Collaborations do not require data rights to join*
  Active Galactic Nuclei
  Informatics & Statistics
  Transients & Variable Stars
  Stars, Milky Way & Local Volume

(Note: LSST Science Collaborations cannot confer data rights)

- Collaborate with Rubin data rights holders (RDRH)
  - RDRH can share derived data products (i.e., that "cannot be used to recreate proprietary LSST data")
  - RDRH can share <1000 objects for follow-up with external facilities (number is not final)
  - non-RDRH can co-author papers based on proprietary LSST data
- Use the public EPO data products in their classrooms (rubinobs.org)
- Access post-proprietary data served via in-kind contributors
  - E.g., the Canadian Astronomical Data Center expects to be able to provide public access to the LSST
    - The exact scope (static sky vs. the full synoptic survey) is still being defined.
    - E.g. static-source {ugrizy} magnitudes expected early 2027 (first 6mo), early 2029 (full survey area), then annual data releases

CADC/CCDA
Canadian Astronomy Data Centre

Amateur astronomers

The alert stream is public, and the independent alert brokers already offer public access services. Rubin EPO* portal will also provide public access to a limited amount of LSST data (TBD).

*EPO = Education and Public Outreach (rubinobs.org)

Rubin data rights are required to access and analyse the *proprietary* data products and services, such as images, annual data releases, and the Rubin Science Platform.

There is a path to data rights for amateur astronomers in the Rubin Data Policy (ls.st/rdo-013):

- "*Amateur astronomers who wish to do non-profit scientific research may also submit requests for verification of eligibility [for Rubin data rights] … which may require a justification of why the EPO-provided resources are insufficient*" (DPOL-401; page 12)

If you think you might need to request a verification of eligibility to do LSST-related science as an amateur astronomer, reach out to Melissa Graham (mlg3k@uw.edu).

Amateur astronomers and SatHub

~Half a million LEO satellites* expected during the LSST interval (~2024-2034) → characterization of satellite brightness in-orbit will be crucial. This provides a path for observers with “small” telescopes to contribute directly to the success of the Rubin Observatory’s LSST (and, indeed, all present and future optical/IR surveys)..

*Source: Jonathan McDowell, https://planet4589.org

Consider signing up to the IAU’s SatHub initiative: https://cps.iau.org/sathub/

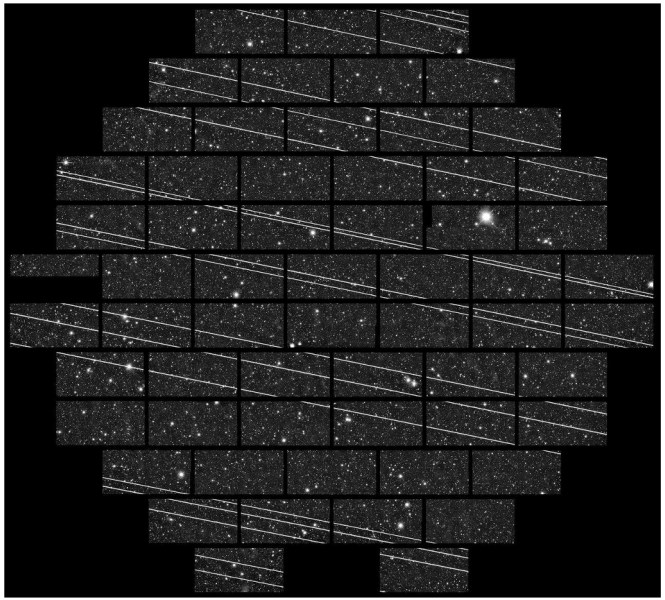


Image credit: CTIO/NOIRLab/NSF/AURA/DECam DELVE Survey

Prediction: the Rubin Observatory's LSST will ***increase*** the scientific need for "small"-aperture observations and the AAVSO.

LSST will identify clean samples of highly interesting targets, across all areas of astronomy, many of which will require the kind of investigations that can only be conducted with small-aperture observatories and/or with the kind of coverage that only collectives like the AAVSO can provide.

- Rubin provides the data products, the community does the science.
- To contribute scientifically, consider joining one of the Rubin Science Collaborations (coordinator: Will Clarkson, wiclarks@umich.edu).
- Engaging astronomers at small and under-resourced institutions in preparing for LSST science, is a priority for the Science Collaborations and for Rubin via its Community Science Team (CST, lead: Melissa Graham, mlg3k@uw.edu).
- There is a path for amateur astronomers to request data rights for proprietary data and services (may require justification of why already-planned public data will not be sufficient).

SPARE SLIDES

For more information:

- Rubin Key Numbers
- Project status (updated ~monthly)
- Science drivers, system characteristics: Ivezic et al. 2019
- Current LSST survey strategy recommendation (via SCOC)
    - The Deep Drilling fields
- Rubin Data Rights policy
- Data products that Rubin will and will not provide: Melissa Graham et al. 2022 (Zenodo).

- Community.lsst.org
- The Rubin Science Collaborations (coordinator: Will Clarkson: wiclarks@umich.edu)
- The Rubin Observatory Community Science Team (head: Melissa Graham)

Project timescales

For monthly updates: https://www.lsst.org/about/project-status

Some schedule milestones (current expectations, not including 6 week schedule contingency):

System first light: **2024 August**
System validation surveys complete: **2024 December**
Main survey start: **2024 December - 2025 March**
Main survey end: **10 years after survey start (~2035 Jan)**

Data Preview 2 (commissioning): **public Q1 2027**
Data Release 1 (first 6 months survey): **public Q4 2027**

Image credit: Jacqueline Ramseyer Orrell/SLAC National Accelerator Laboratory, 22 October 2022