NOAO Data Lab Capabilities in Support of (LSST) Solar System Science

Francisco Valdes (NOAO)

NOAO Data Lab Team

- Here to learn more about needs and LSST than to present actual capabilities

- Don't want to oversell

- Data Lab is about enabling user code on big data rather than providing canned applications
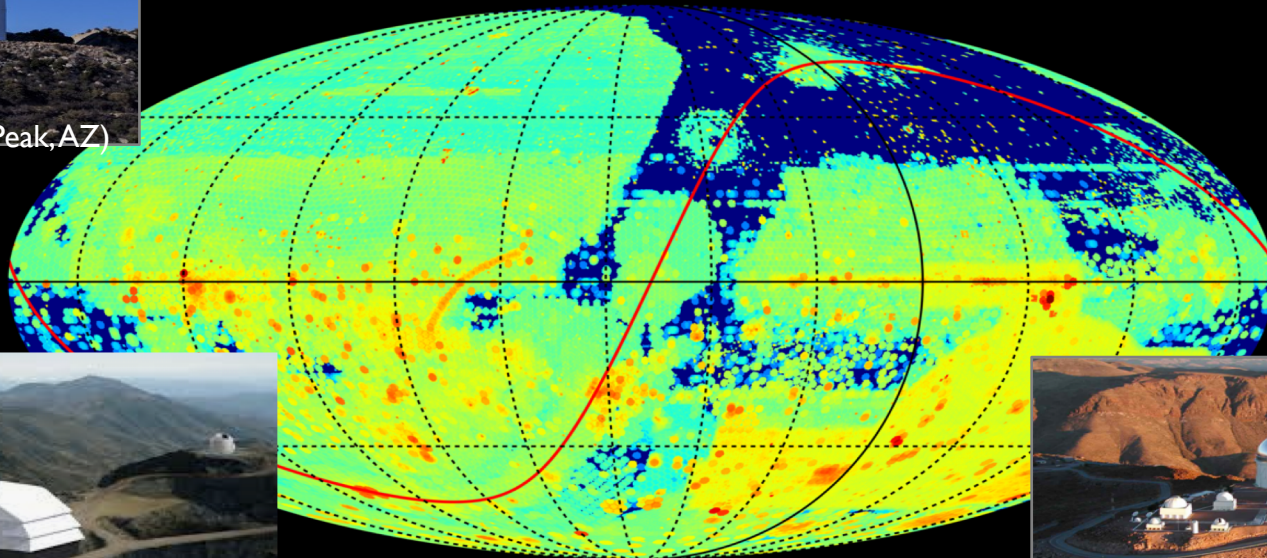
NOAO Data Lab
datalab.noao.edu

Mayall 4m (Kitt Peak, AZ)

LSST (Cerro Pachon)

Blanco 4m (Cerro Tololo, Chile)

Goal

Efficient exploration and analysis of large astronomy datasets with an emphasis on NCOA facilities

National Optical Astronomy Observatory
Cerro Tololo Inter-American Observatory
Kitt Peak National Observatory
Community Science and Data Center

AURA   NSF

Data Lab in a Nutshell

- **Large Catalogs** – TB-scale databases

- **Pixel Data** – images & spectra in NOAO Science Archive

- **Virtual Storage** – 1 TB per user to minimize data transfer

- **Visualization** – data exploration & interpretation

- **Compute Processing** – workflows run close to the data

- **++** Access to published datasets, data publication, exportable workflows, distributable software

Data Lab 1.0 released in June 2017

Data Lab 2.0 released in June 2018

Summary of Current Data Lab Functions

Function	Method
Sky exploration	Image discovery tool Catalog overlay tool
Authentication	Web interface datalab command Python authClient, DL interface
Catalog query	Web interface datalab command line (CLI) Python queryClient, DL interface TOPCAT
Image query	Simple Image Access (SIA) service
Query result storage	myDB Virtual storage space
File transfer	datalab command and Virtual storage space
Analysis	Jupyter notebook server

Datasets at the NOAO Data Lab

Facilities Featured Surveys:

DESI imaging Legacy Survey (LS): ~860 million objects in DR4+5

SMASH: ~100 million objects in DR1

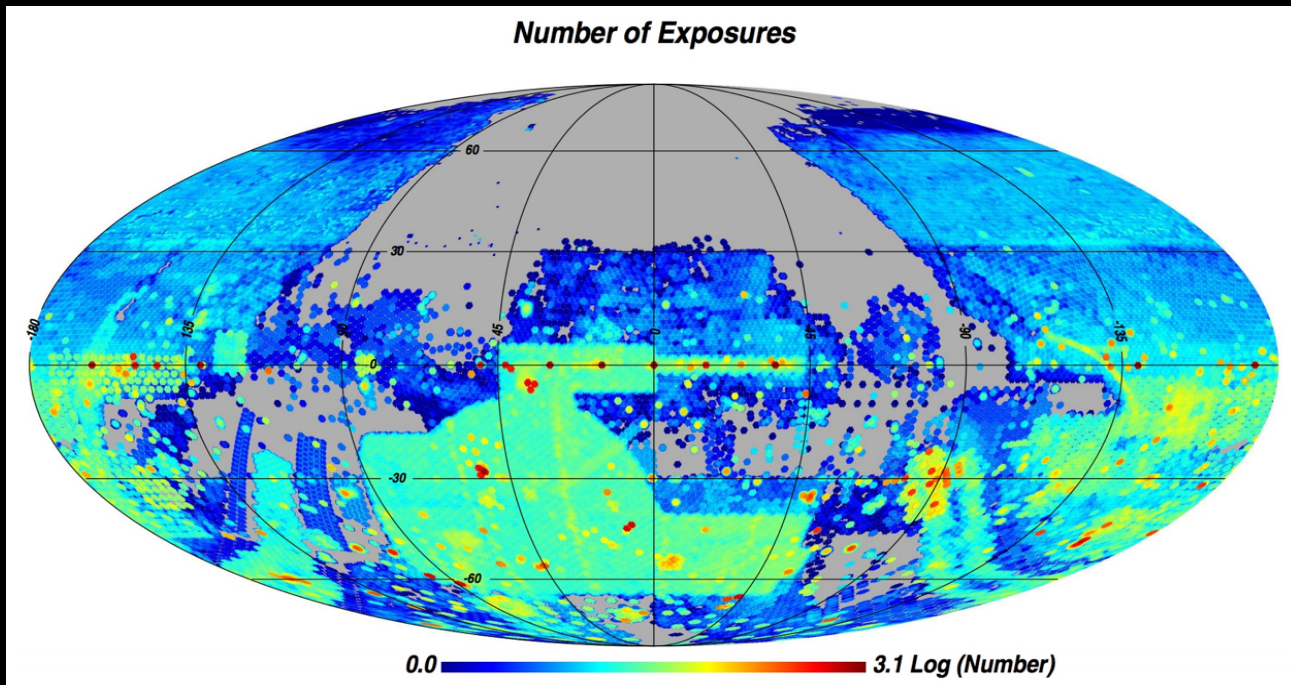DES: ~400 million objects in DR1

DECaPS: ~2 billion objects

NOAO All-Sky Source Catalog (NSC): ~2.9 billion objects

+ NSC & DECaPS "single-epoch": ~50 billion measurements

Additional Surveys:

select tables from SDSS/BOSS DR13 & DR14, GAIA DR1 & DR2, DES SVA1, the DECam Asteroid Database (DAD), and USNO-A2/B, *skinny* Pan-STARRS DR1, etc.

NOAO DATALAB

National Optical Astronomy Observatory
Cerro Tololo Inter-American Observatory
Kitt Peak National Observatory
Community Science and Data Center

AURA   NSF

NOAO Source Catalog (Nidever+2018)

Number of Exposures

0.0 ▬▬▬▬▬▬▬▬ 3.1 Log (Number)

- DDR1 available: ~2.9 billion objects, 30+ billion measurements; basic aperture photometry
- Discussion about new PSF-based photometry extraction for DR2

Get in touch!

Web: datalab.noao.edu

Email: datalab@noao.edu

GitHub: https://github.com/noao-datalab

Twitter: @NOAODataLab

Identifying Primary Capabilities in Solar System Astronomy

The capabilities required in the **Data Lab (DL)** for solar system astronomy (excluding solar astronomy and surface mapping) can be summarized into seven basic areas:

1. Check if an observation (a 3D coordinate*) is of a known planet/dwarf planet/minor planet/comet.

   * A time and two sky coordinates. A required capability is conversion between UTC+equitorial and other solar system coordinates (e.g. ecliptic, heliocentric, TAI, etc.)

2. Extract (LSST) alerts about things classified as moving objects, or whatever broker criteria is requested, with 3D coordinates.

3. Get orbital parameters for known objects or estimate them from observations.

4. Compute emphemera forward and backwards in time given orbital parameters.

5. Discover images with specified 3D coordinates and get cutouts (with montage/blinks/movie visualization) if desired.

6. Measure (flux, 3D coordinate) for asteroids/comets from imaging material taking into account non-PSF shapes in one or both dimensions

7. Search large source catalogs for moving objects.

All this should be inferred to work on large sets of candidates and catalogs.

Data Lab Status and Plans

1. Host a regularly updated copy of the MPC database. **YES**

2. Host a database of LSST alerts and broker helpers to select objects based on some user criteria including moving object. **TBD**

3. Discovery tool for images (LSST & NSA) with a 3D coordinate. **YES**

4. Cutout tool for extraction of sources based on discovery. **YES**

5. Montage and movie/blink tool for cutout sets. **YES (in user code)**

6. Measure an asteroid observation (flux, position) which may have a PSF in one dimension and extension in the other dimension or non-PSF in both dimensions. **LIMITED**

   – *One or two standard tools are available (e.g. SExtractor). More sophisticated modeling done by user code.*

Data Lab Status and Plans

7. Compute an ephemeris given orbital parameters. **TBD**

   – *Importing orbit code in DL is TBD. Queries to outside websites (e.g. MPC) is possible but problematic for large sets.*

8. Estimate orbital parameters from a set of 3D coordinates. **TBD**

9. Digest2 **Maybe DL helper or in user code**

10. Coordinate conversion tool for solar system coordinates. **Probably in user code with readily available libraries like Astropy**

11. Make light curves, color plots, etc. from measurements. **YES**

12. General large catalog search on source catalogs with multiple epochs / bands where a only single detections were found at a position. **YES**

Science Cases

LSST/SSSC

–   Near Earth Objects (NEOs)

–   Interstellar Objects

–   Detecting or Testing the Hypothesis of a Planet-sized Body Orbiting Beyond Neptune

–   Active Asteroids

Others:

–   Identify asteroid families

–   Identify new candidates for space missions (ala MANOS)

–   Measure distribution of binary or bound asteroid systems

–   Survey for objects missed by LSST and other public surveys -- particularly TNOs not visible to LSST (e.g. northern hemisphere or fainter) or pre-LSST in DES/NSC/LS or other available catalogs.

–   Expand cataloged SS object colors by bringing in other bands (WISE, etc)

- Are important Use Cases missing?

- LSST Alerts:
  - Known objects will be identified? With their orbital parameters?
  - Single epoch transients will be identified?
  - Transients that link as asteroids (over a month) will be identied? With MOPS orbital parameters?

- LSST Images:
  - What cutouts will be available for alerts?
  - Will cutouts from legacy images be available for precovery?