*The **NOAO Data Lab***
Design, Capabilities and Community Development

Michael Fitzpatrick
for the Data Lab Team

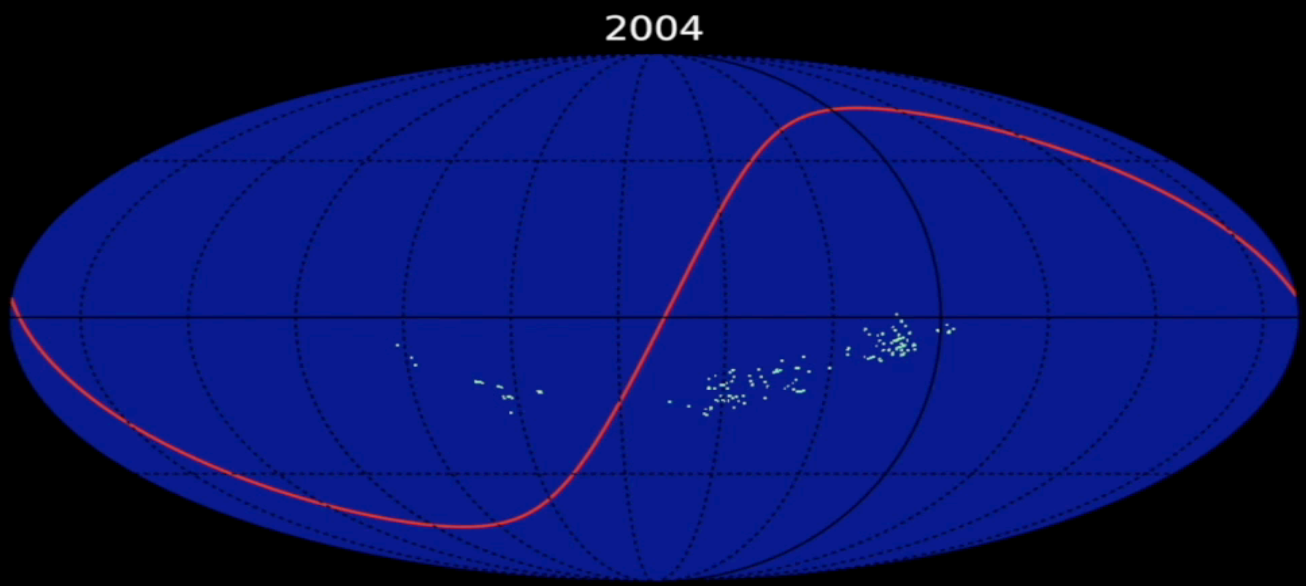
National Optical Astronomy Observatory
Cerro Tololo Inter-American Observatory
Kitt Peak National Observatory
Community Science and Data Center

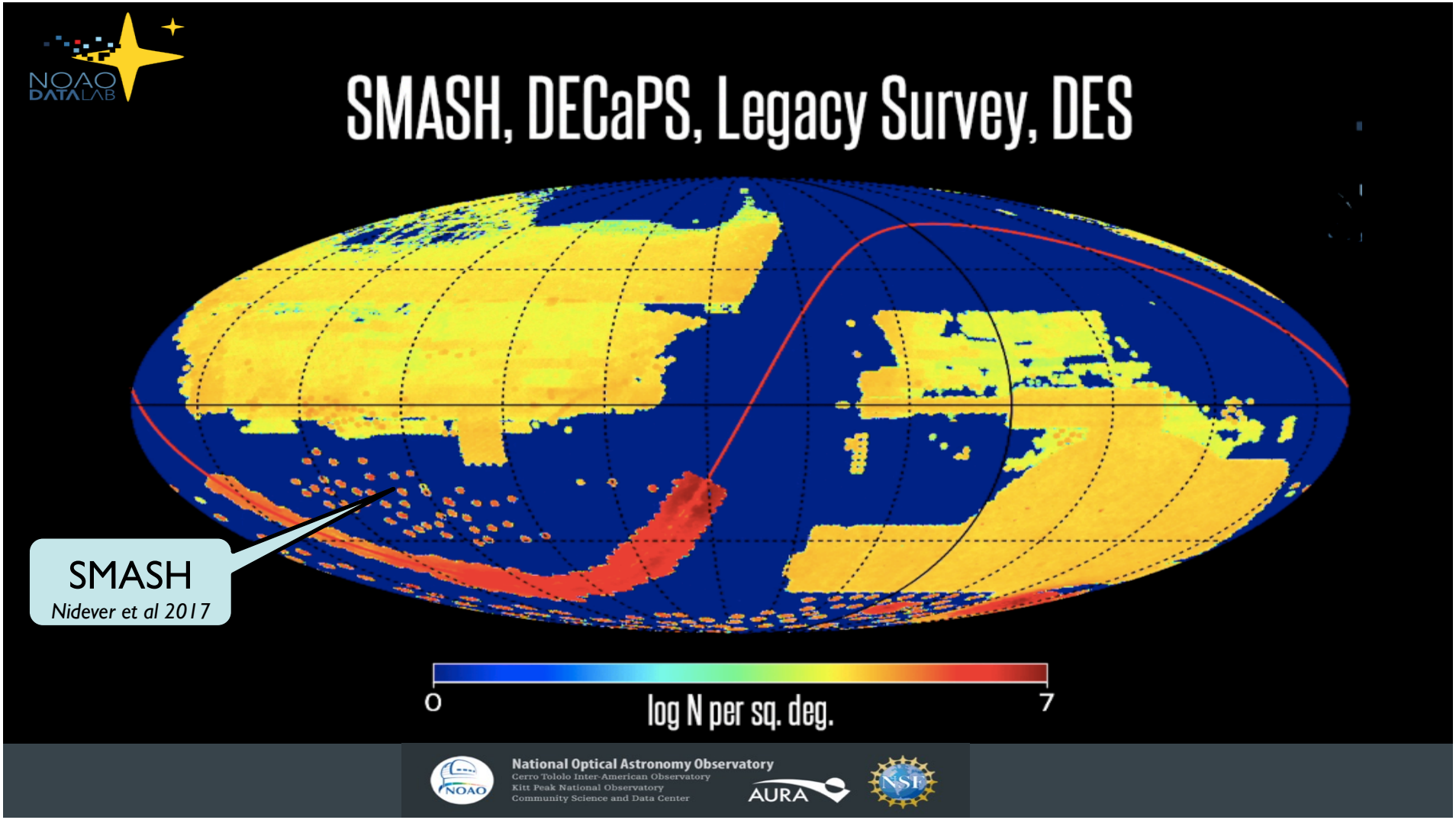
What is it?

Data Lab is Science Exploration Platform that provides:

- Repository for large datasets (*catalogs & their parent images*)
- Data access services (*VO, SQL/ADQL, TAP, SIA,…*)
- Virtual Storage (*VOSpace, MyDB, notebooks*)
- Gateway to remote data centers
- Data Sharing / Collaboration / Publication
- Website / authenticated portal / documentation
- Exploratory tools (survey coverage, catalogs overlays, …)
- Visualization tools (*all-sky browser, custom APIs*)
- Analysis facilities (*Jupyter, utility methods, Compute Service*)

Project Motivation




NOAO DATALAB
SMASH, DECaPS, Legacy Survey, DES
SMASH
Nidever et al 2017
0
log N per sq. deg.
7
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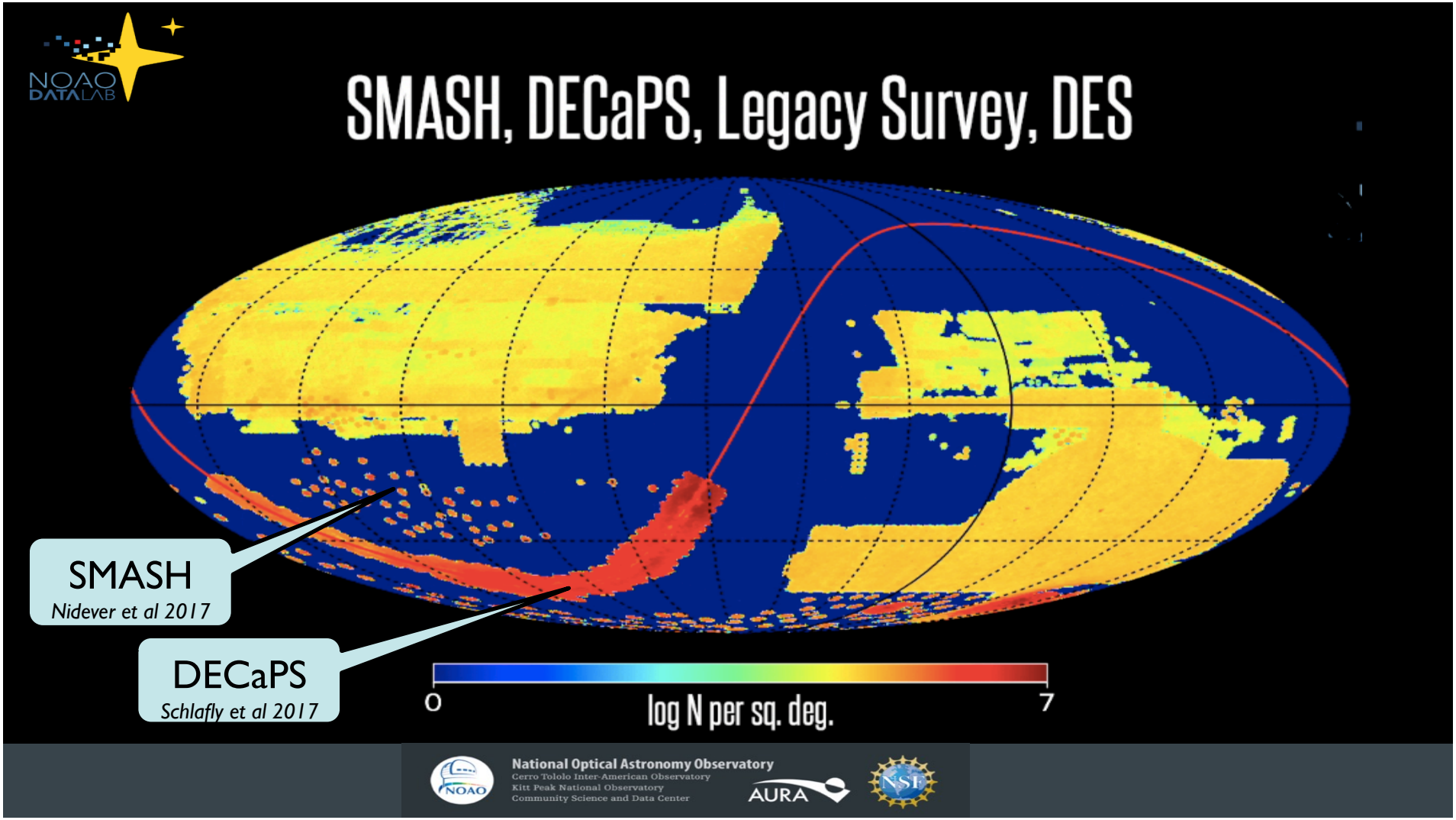
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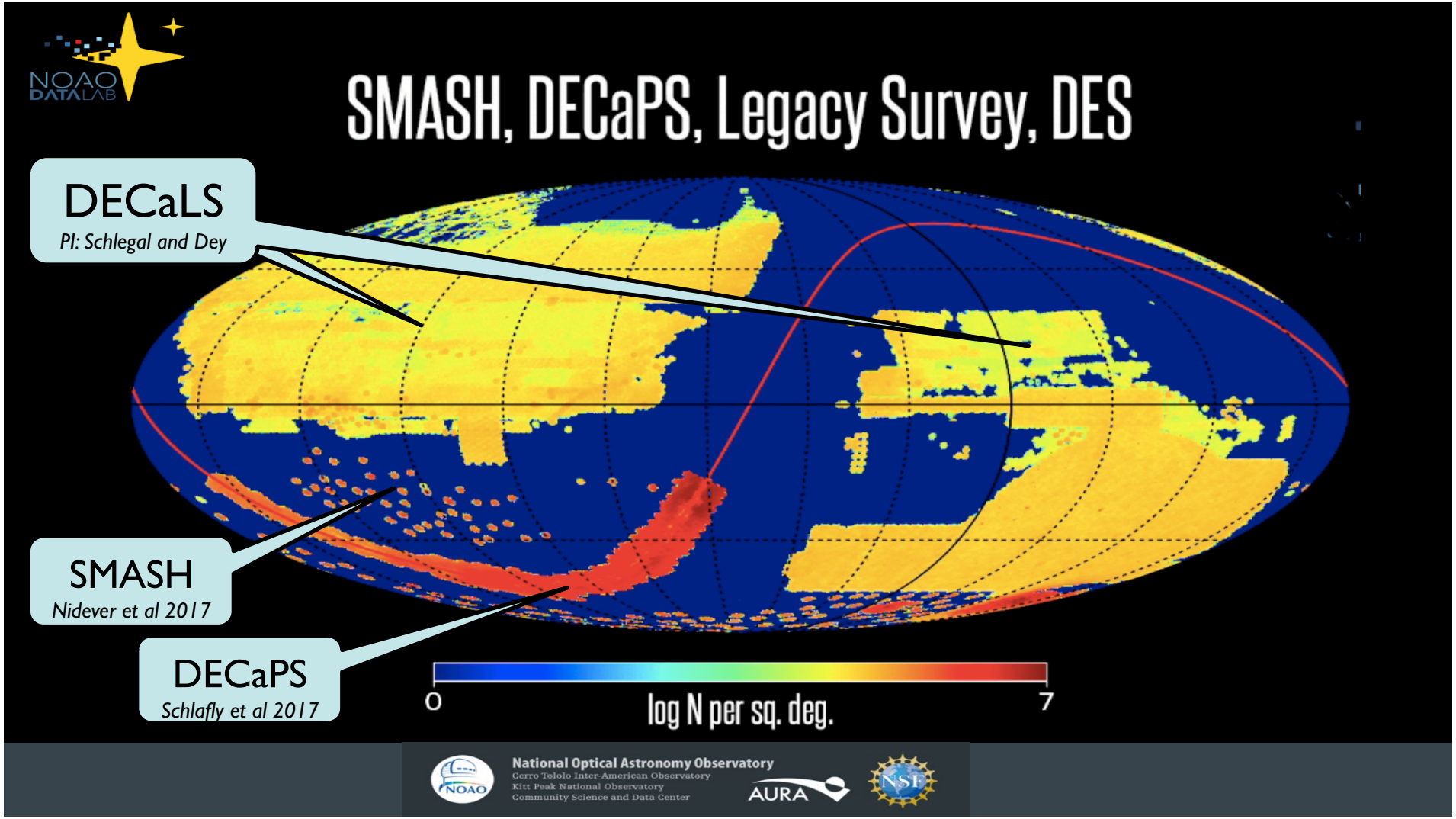
NOAO DATALAB
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PI: Schlegal and Dey
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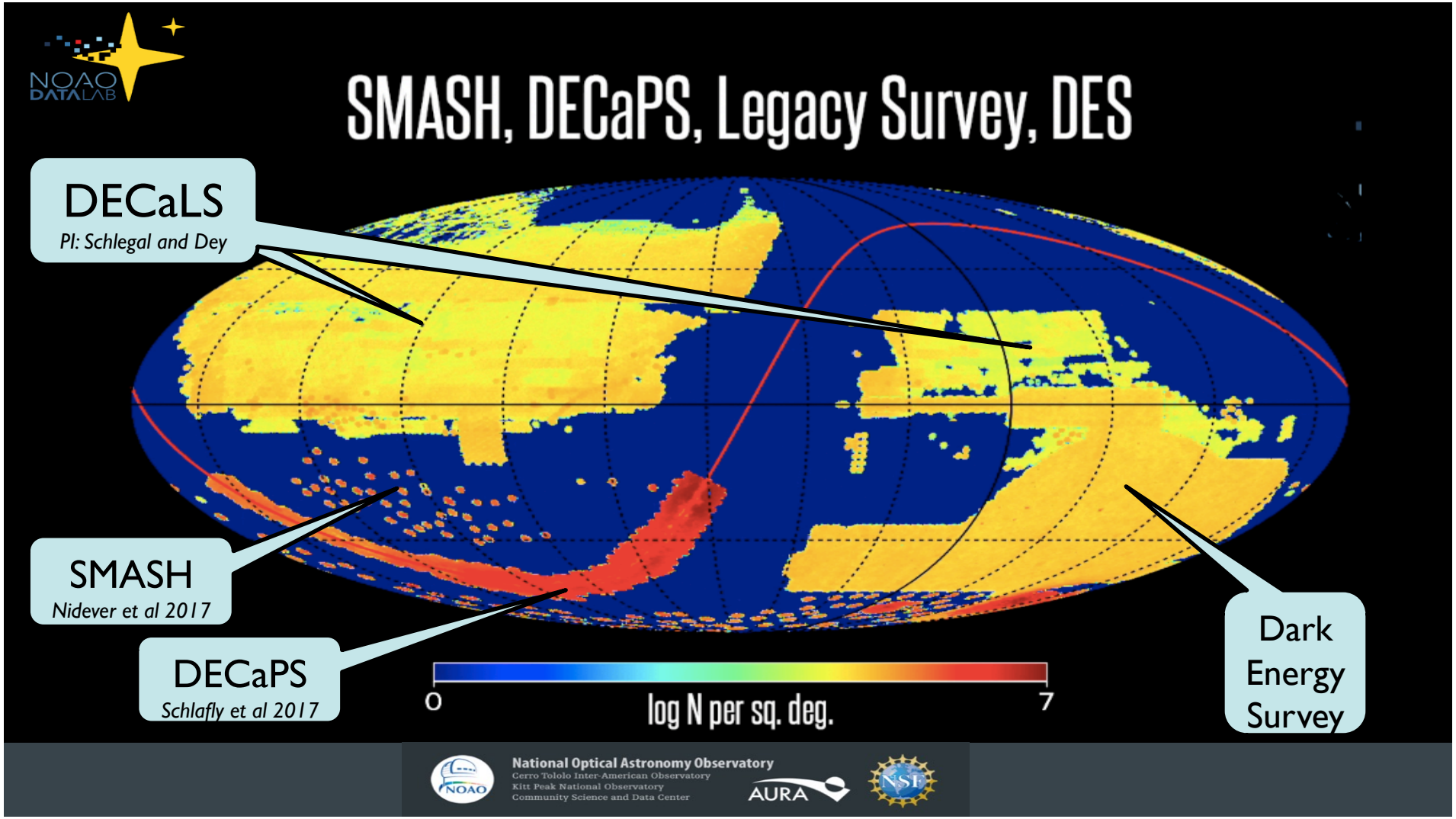
NOAO DATALAB
SMASH, DECaPS, Legacy Survey, DES
DECaLS
PI: Schlegal and Dey
SMASH
Nidever et al 2017
DECaPS
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Dark Energy Survey
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log N per sq. deg.
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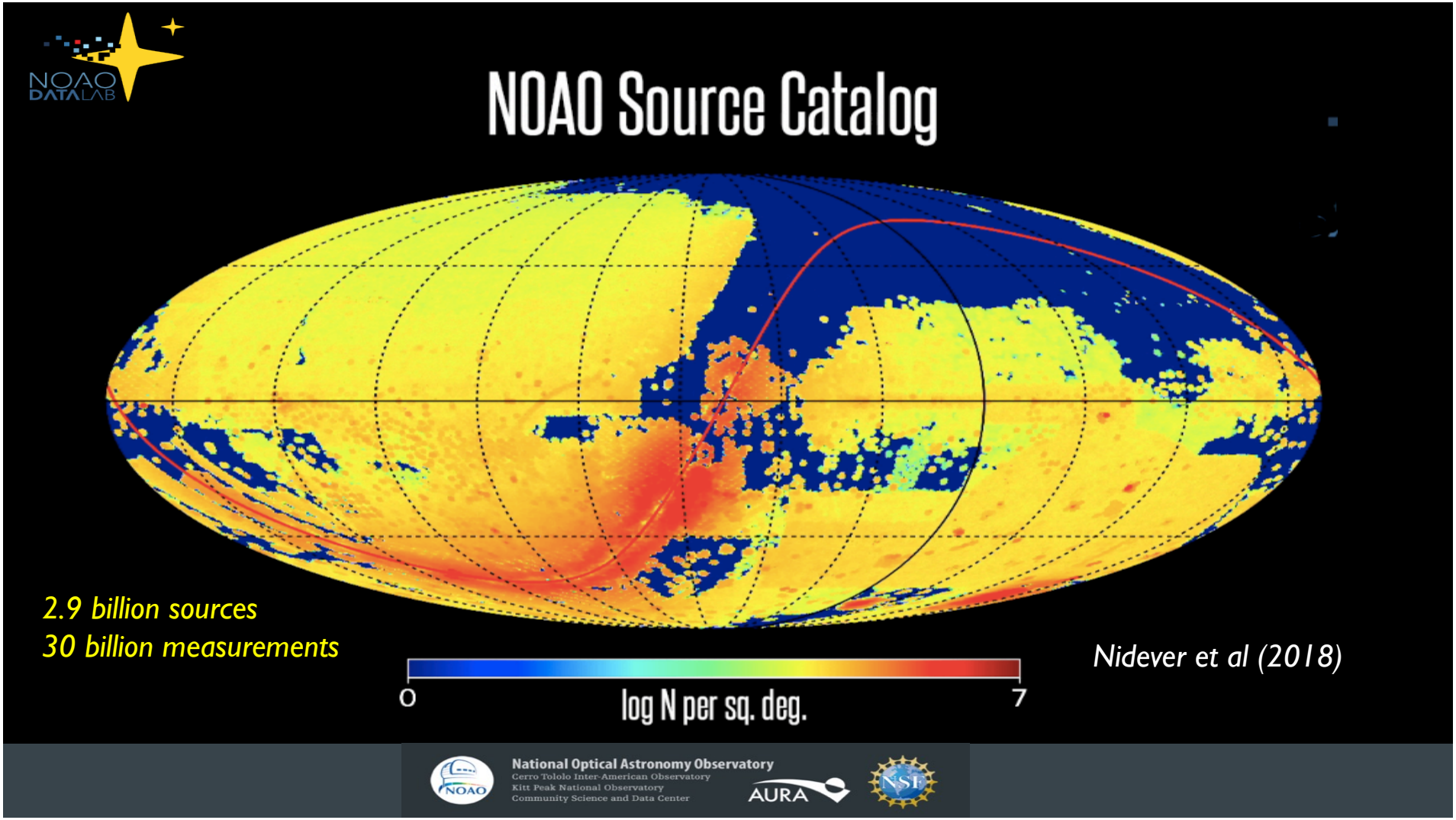

NOAO DATALAB
NOAO Source Catalog
2.9 billion sources
30 billion measurements
0
log N per sq. deg.
7
Nidever et al (2018)
National Optical Astronomy Observatory
Cerro Tololo Inter-American Observatory
Kitt Peak National Observatory
Community Science and Data Center
AURA
NSF

Data Holdings

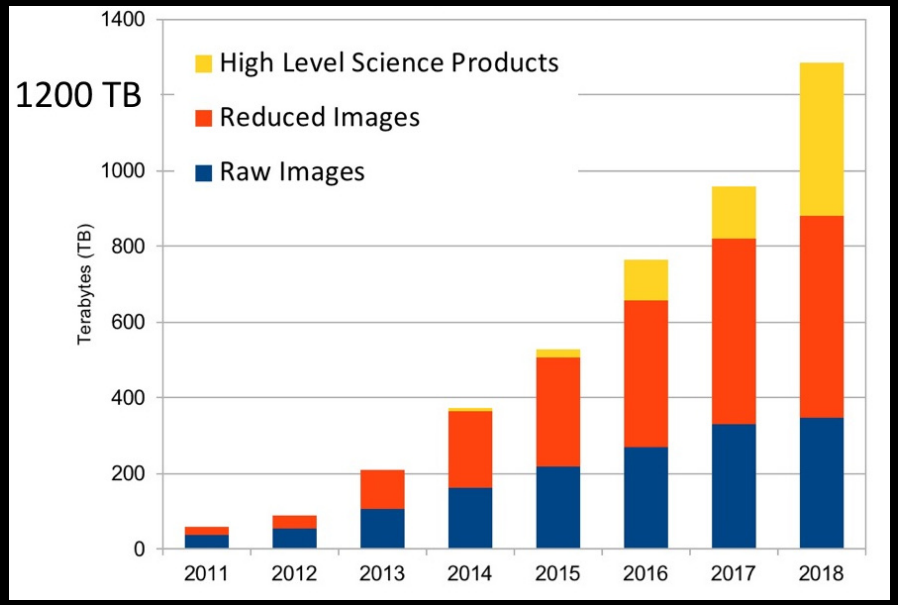
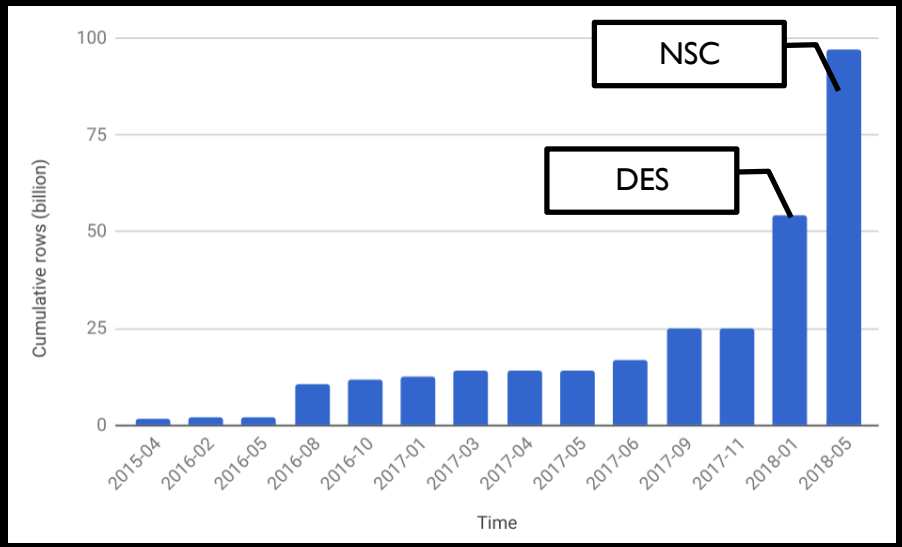


Image Archive Holdings (~1.2PB)

Catalog Database (100B rows, ~50TB)



Data Holdings

Catalog Data Holdings

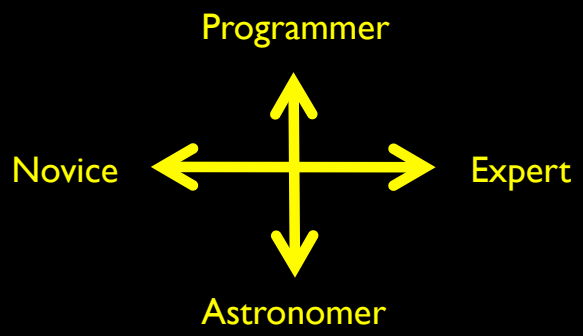
- 316 tables in 38 different schema
- 15 different image services (by survey, reduction type)
- Major Surveys: DES, DESI, DECaLS, DECaPS, PHAT, S-PLUS, NSC, ….
- Ref data: AllWISE, Gaia, USNO, 2MASS, SDSS, …..
- Planned(?) Datasets: CRTS, Vista HS, UKIDSS, Chandra/XMM XSC, ….

- *Q3C* spatial indexing + data clustering + type ordering for performance
- TAP access to all tables (including image metadata)
- Cone Search services for all tables w/ positional data
- Image cutout services (SIA)

Design Principles to Consider

Know your audience

- Astronomers and Programmers will approach your system in different ways
- They will have a range of experience and skills
- A good UI will be inclusive

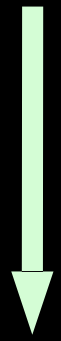


Design Principles to Consider

Allow multiple entry points into the system

- Web-based Portals
- Notebook Servers
- Command-line Tools
- Programmatic APIs

Novice User / Casual Browsing



Blackbelt User / Workflow Dev

Design Principles to Consider

Enable *user-developed* tools, don't just supply them

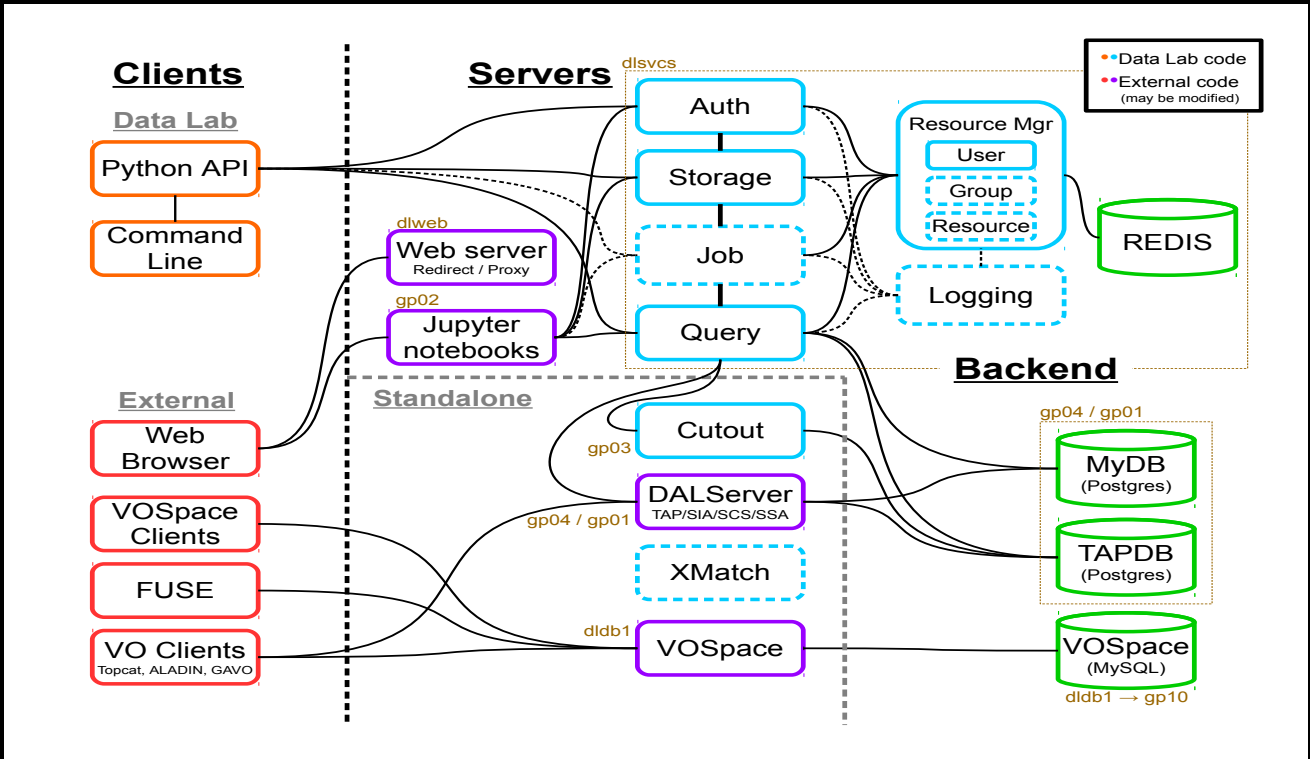
- Support legacy code where possible
- Publish/Share code and notebooks
- Host a repo to support user contributions
- Allow for user scripting and workflow development

Design Principles to Consider

Use established standards, but hide complexity

- Provide *Astronomer Friendly* interfaces
- Provide *Low-Level* interfaces
- Realize these are *separate* things (and that's okay) !
- Most of all: Enable Science!

Architecture/Service Overview



VO Inside

VO Protocols and Data Access

- **VOSpace** for Virtual Storage
- **TAP** for Catalog Access
  - **ADQL** query language (custom funcs in development)
- **SCS** for Catalog Access
- **SIA** for Image Access
  - SIA v1 in use, SIA v2 available
  - **ObsCore** data model for images
- **SSA** available for Spectral Access (not currently used)

- **VOTable** support in client interfaces
- **HiPS** for Discovery Tool base image layers (MOC use planned)
- **Universal Worker Service** (planned for Compute Service)
- **VOSI** for VOSpace/TAP/Manager services
- OAI **Publishing Registry** for services planned

Public Data Access

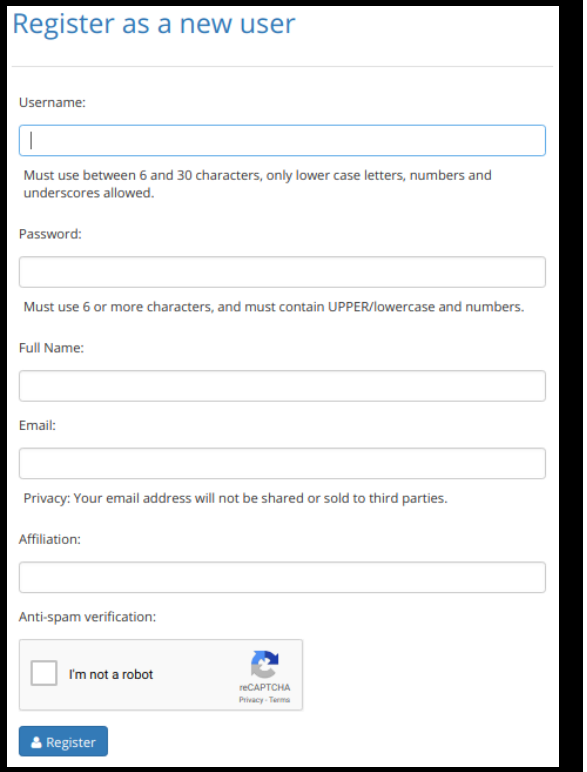
- Access to public image / catalog data does not require an account
- Anonymous Jupyter notebook server allows a '*Trial Run*' of Data Lab before creating an account
  - Scratch/demo notebooks, no persistence beyond session
  - Containerized environment initialized for each new user
- Downloadable *datalab* client and API allow anonymous desktop and programmatic access to Data Lab tools and services
- Web tools (*Data Discovery, Query Interface, etc*) can use anonymous access

User Accounts

User Account Creation

- Sign-up form for account request on web site
- New accounts require approval before resources are allocated
- Currently open to professional researchers only

- *Future plans for*
  - *EPO/student accounts (e.g. custom notebooks)*
  - *Group accounts*
  - *Limited public access using temporary storage/ compute services*



User Accounts

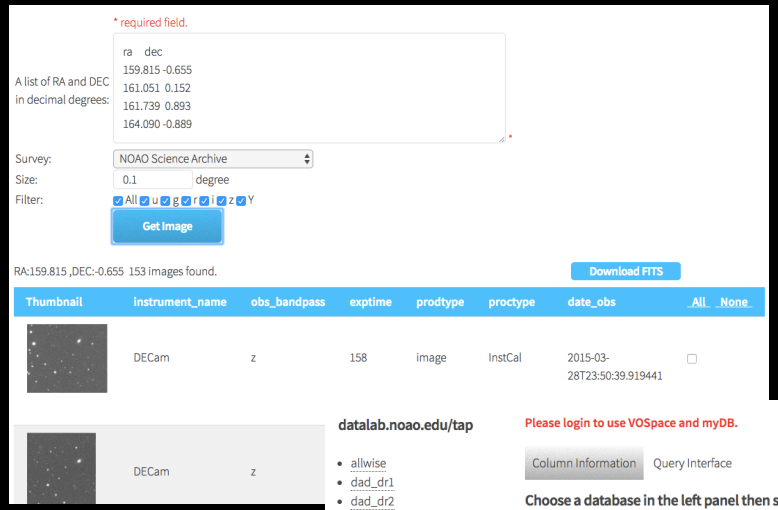
Resource Allocations

• Virtual disk storage:	1 TB
• MyDB database storage:	250 GB
• Jupyter notebook storage:	*no hard limit, but not unlimited*
• Sync query timeout:	120 sec (*max: 600 sec*)
• Async query timeout:	24-hrs (*max: unlimited*)

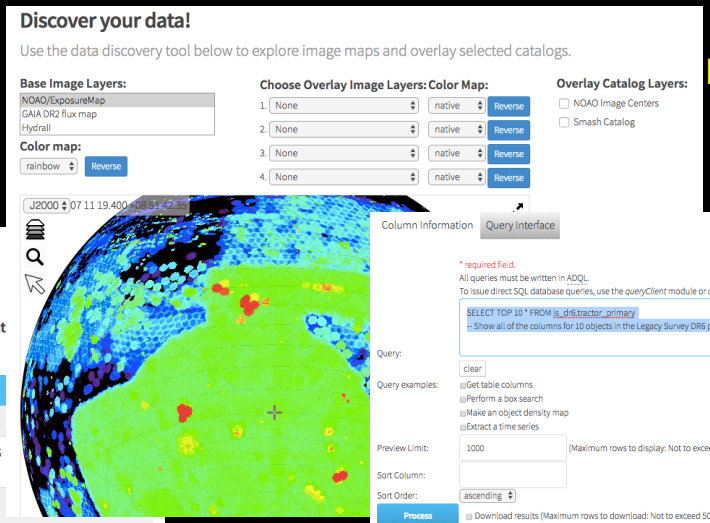
- Storage quotas are not (*presently*) strictly enforced
- Query timeouts can be extended using an API argument

Web Interfaces

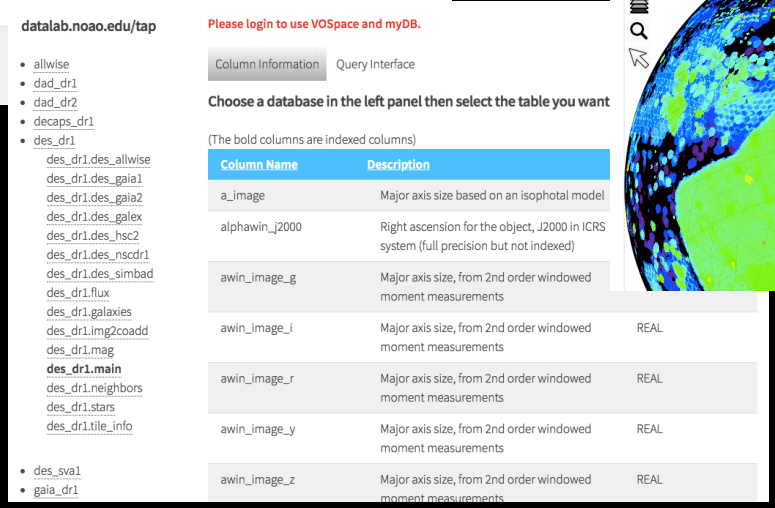
Image Cutouts



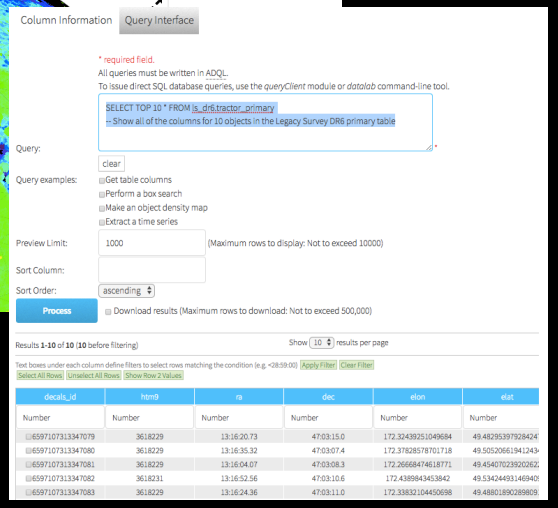
Data Discovery



Schema Browser



Query Interface



API and Command-line

Python API

```
from dl import storeClient as sc

sc.ls(format='long')
sc.ls('vos://sdss/spec')

data = sc.get ('mydata.csv')
stat = sc.put ('./mydata.csv', to='/sdss')

stat = sc.cp ('*.fits', '/raw')
```

datalab Command Client

```
% datalab ls –l
% datalab ls vos://sdss/spec

% datalab get 'vos://*.fits' out='./raw/'
% datalab put ./mydata.csv to='vos://sdss'

% datalab mkdir '/raw'
% datalab mv fr='*.fits' to='/raw'
```

API and Command-line

Python API

```
from dl import queryClient as qc

query = 'select * from usno.a2'
df = qc.query(query, fmt='pandas')


jobID = qc.query (adql=query)
while qc.status(jobID) != 'COMPLETED':
    time.sleep(1)
data = qc.results (jobID)
```

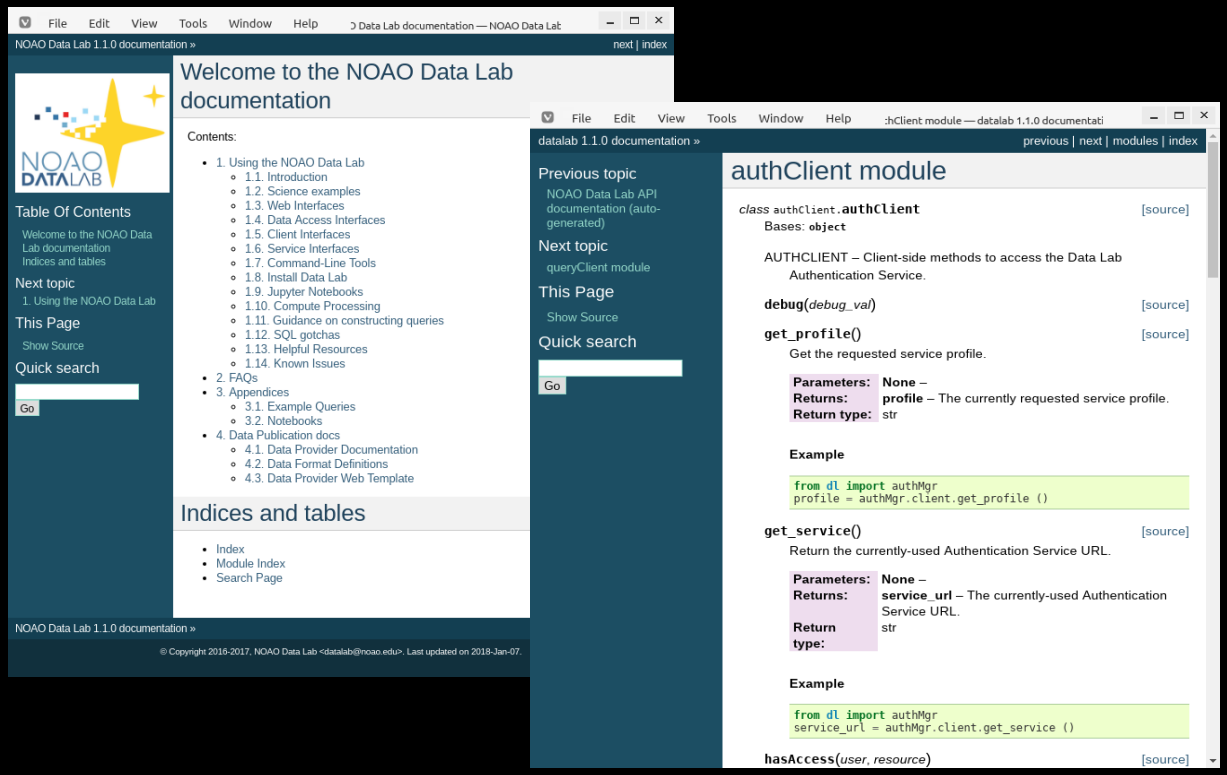
datalab Command Client

```
% sql = 'select * from usno.a2'
% datalab query $sql fmt=csv out=mydata.csv

% datalab query $sql async=true out='vos://mydata'

% datalab query $sql out='mydb://mydata'
% datalab import mydata.csv mydata
```

Online Documentation

User Manuals

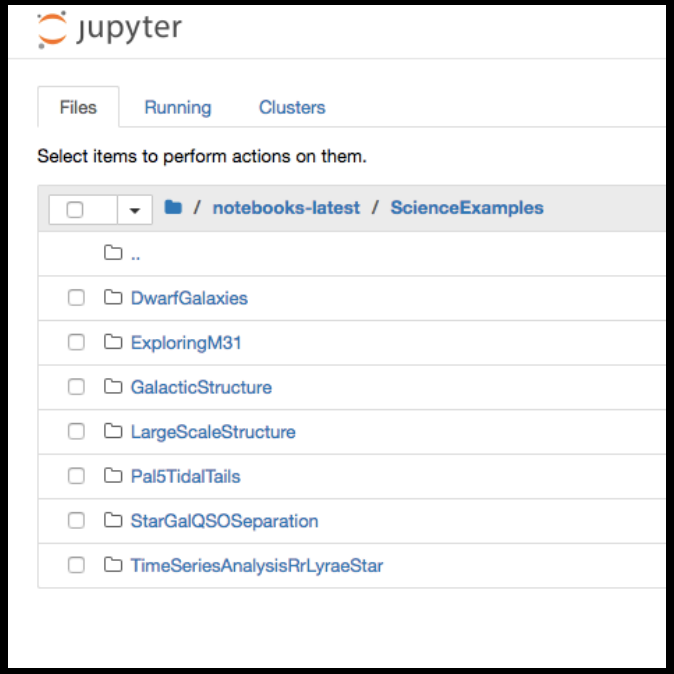
- Overviews
- *HowTo* guides
- API documentation
- Detailed science cases
- Glossary
- SQL examples
- Tips & tricks



Notebook Server

Default Notebooks

- *Getting Started* guides
- *HowTo* guides
- Data Access Overviews
- Science Examples



Notebook Server

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5.2 Construct and Submit a SQL Query

We apply a box search, selecting the RA and Dec limits that align with the region indicated above.

In [67]:
```
%%time

## Write SQL query statement as a string.
query2 = """
        SELECT obj_id, ra, dec, mean_mag_g_r, mean_mag_r_i,
        mean_mag_g, mean_mag_r, mean_mag_i, fracflux_g, fracflux_r, fracflux_i
        FROM decaps_dr1.object
        WHERE (ra>134.7 AND ra<135.7 AND dec<-43.7 AND dec>-44.9
        AND NOT mean_mag_g_r='Nan' AND NOT mean_mag_g_r='Infinity' AND NOT mean_mag_g_r='-Infinity'
        AND NOT mean_mag_r_i='Nan' AND NOT mean_mag_r_i='Infinity' AND NOT mean_mag_r_i='-Infinity')
        LIMIT 100000"""

# Sumbit the SQL query and return the output as a Pandas dataframe.
df2 = qc.query(sql=query2, fmt='pandas')
```

```
CPU times: user 58 ms, sys: 9 ms, total: 67 ms
Wall time: 12.4 s
```

Notebook Server

Default Notebooks

- *Getting Started* guides
- *HowTo* guides
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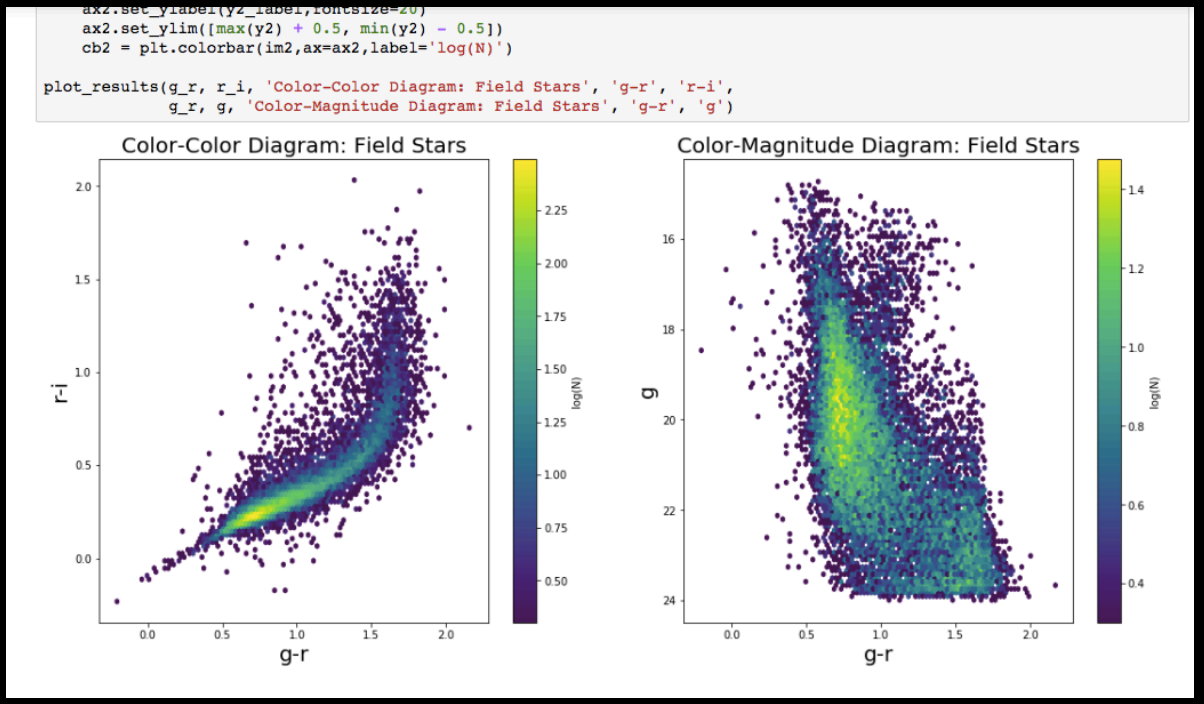
```
    ax2.set_ylabel(y2_label,fontsize=20)
    ax2.set_ylim([max(y2) + 0.5, min(y2) - 0.5])
    cb2 = plt.colorbar(im2,ax=ax2,label='log(N)')

plot_results(g_r, r_i, 'Color-Color Diagram: Field Stars', 'g-r', 'r-i',
             g_r, g, 'Color-Magnitude Diagram: Field Stars', 'g-r', 'g')
```



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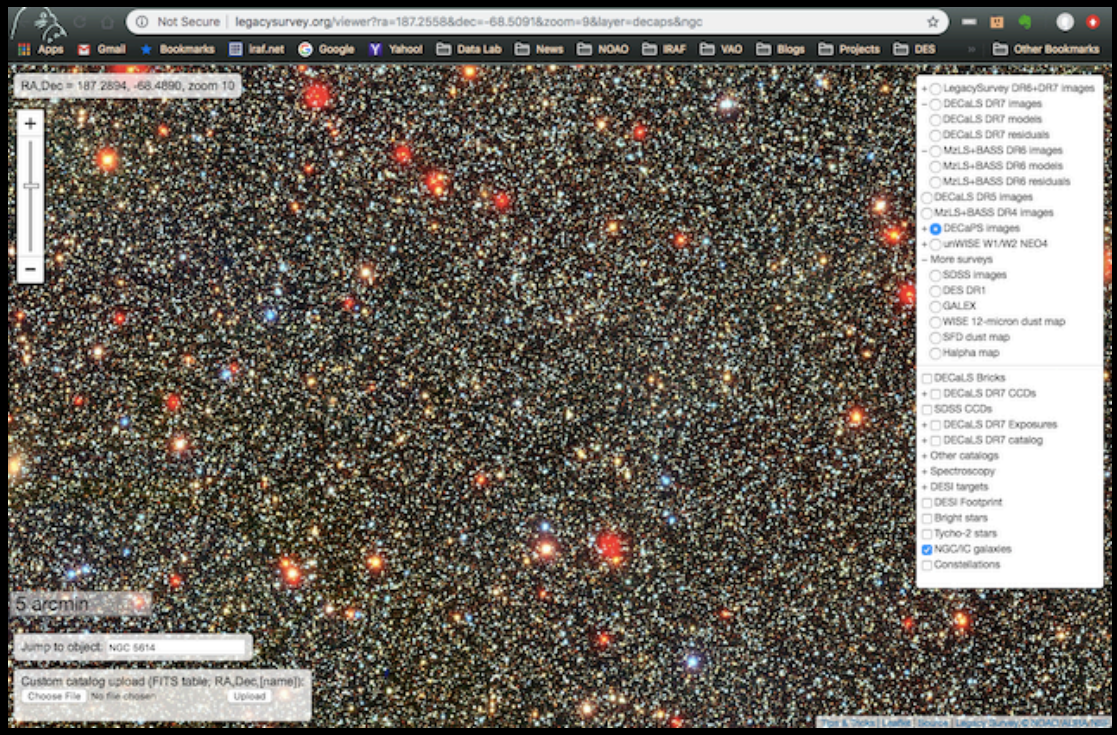


Community Development

Science/Example/Tutorial Notebooks:

- Presently a "*Contact Us*" model to contribute, would like to move to a "*Self Publish*" with a directory

Source Code:

- Repos to be made public once we complete packaging/docs and remove configuration details
- Client pull requests being accepted
- (Future) User-contributed compute containers (e.g. Docker hub)

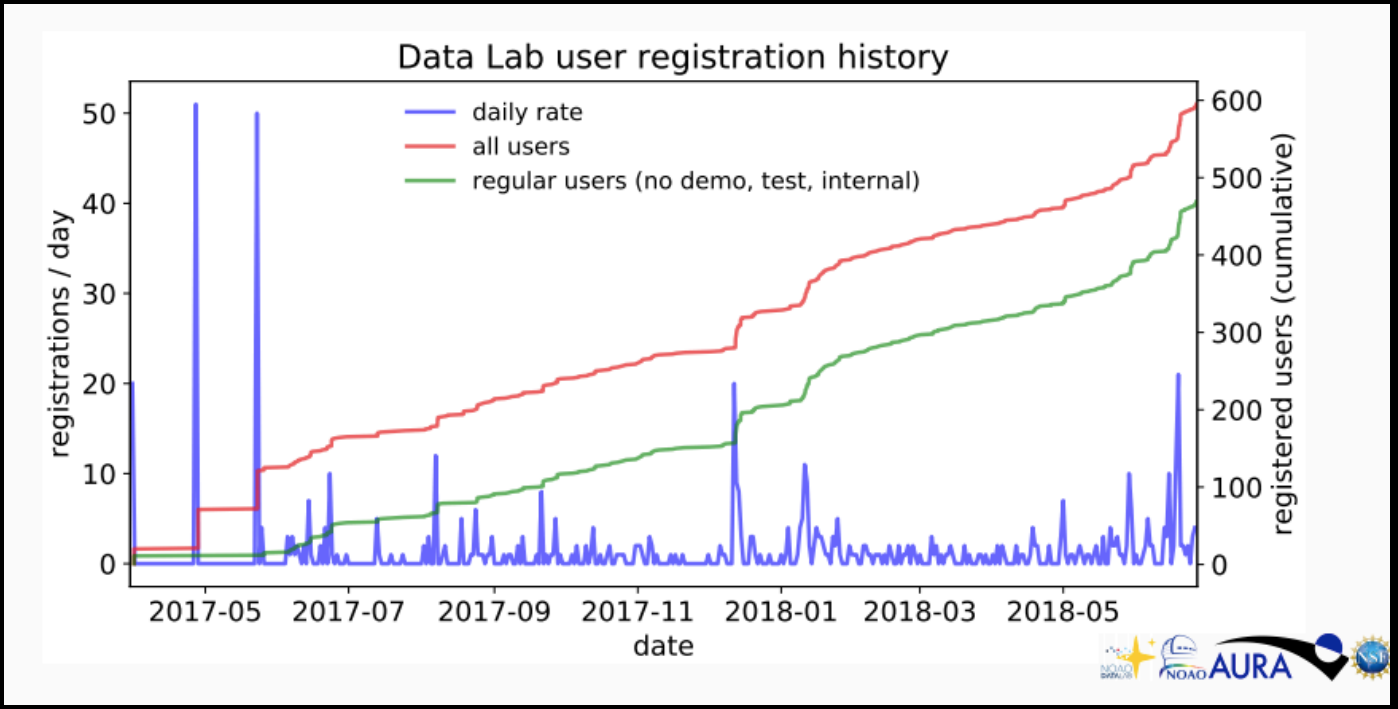
User Feedback!

Come see us at AAS 233 in Seattle

Lessons Learned

Lessons Learned

Lessons Learned



Thank You

Get your account:

http://datalab.noao.edu

Contact us:

datalab@noao.edu

@NOAODataLab