The NOAO Data Lab Project Introduction

Knut Olsen

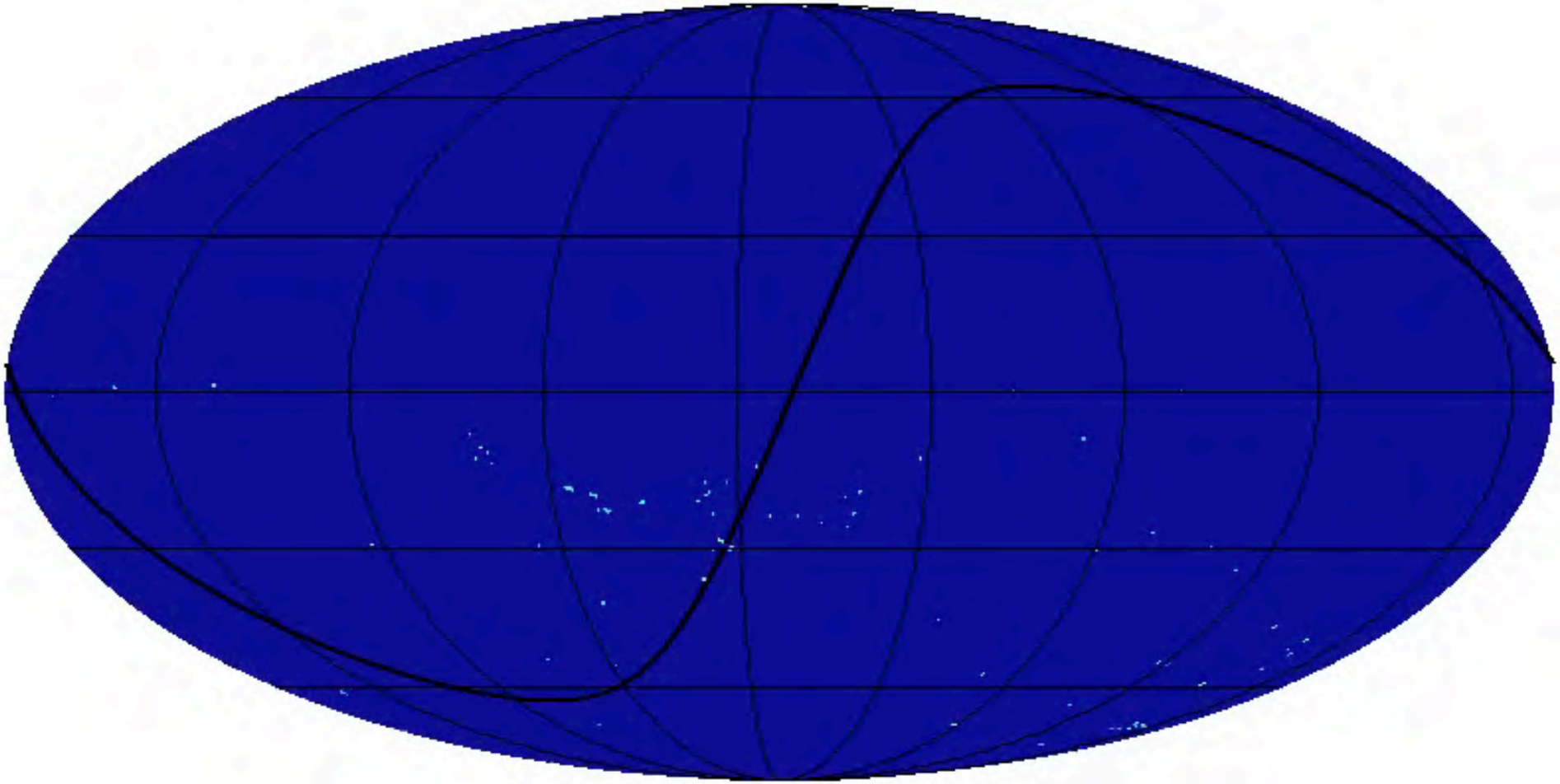
for the Data Lab team

Data Lab Team

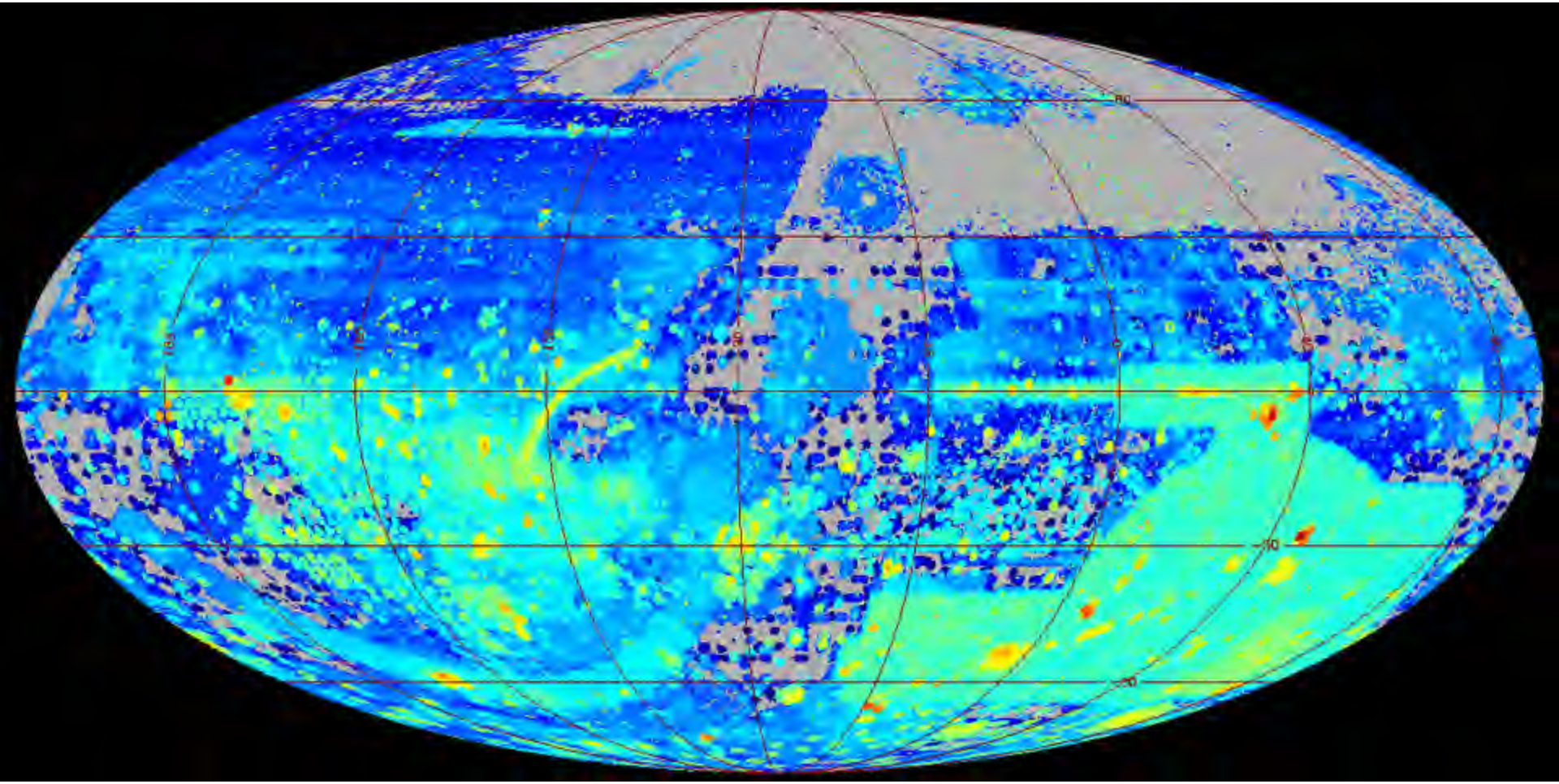
Current team:

- Mike Fitzpatrick, Lead Developer
- Matthew Graham, Scientist/Developer
- Wendy Huang, Software Engineer
- Stephanie Juneau, Data Scientist
- David Nidever, Data Scientist
- Robert Nikutta, Data Scientist
- Pat Norris, Test Engineer
- Knut Olsen, Project Scientist
- Steve Ridgway, Scientist
- Adam Scott, Database Architect
- Pete Wargo, System Administrator

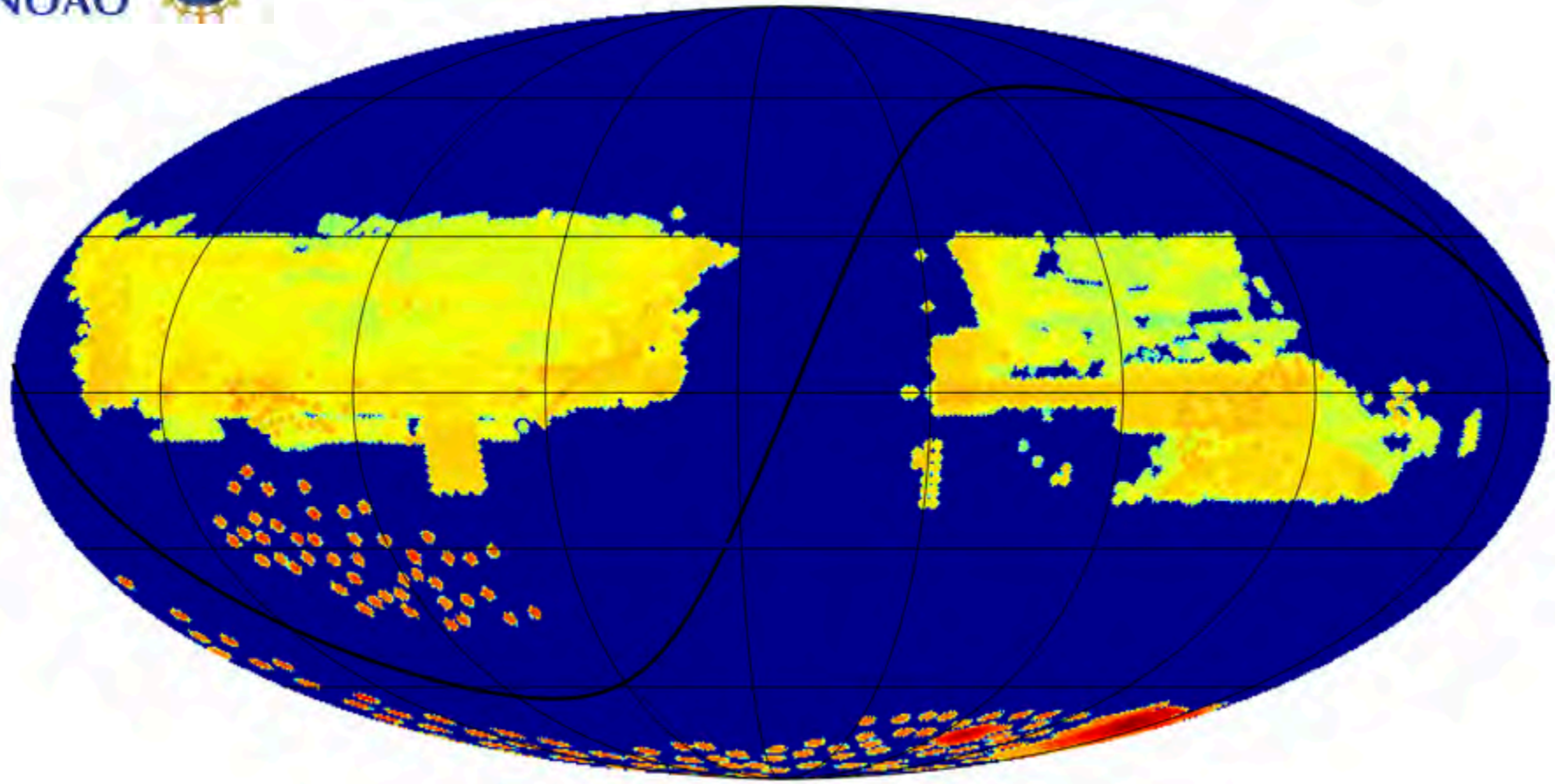
NOAO wide field imaging data over time



DECam and Mosaic data in February 2017

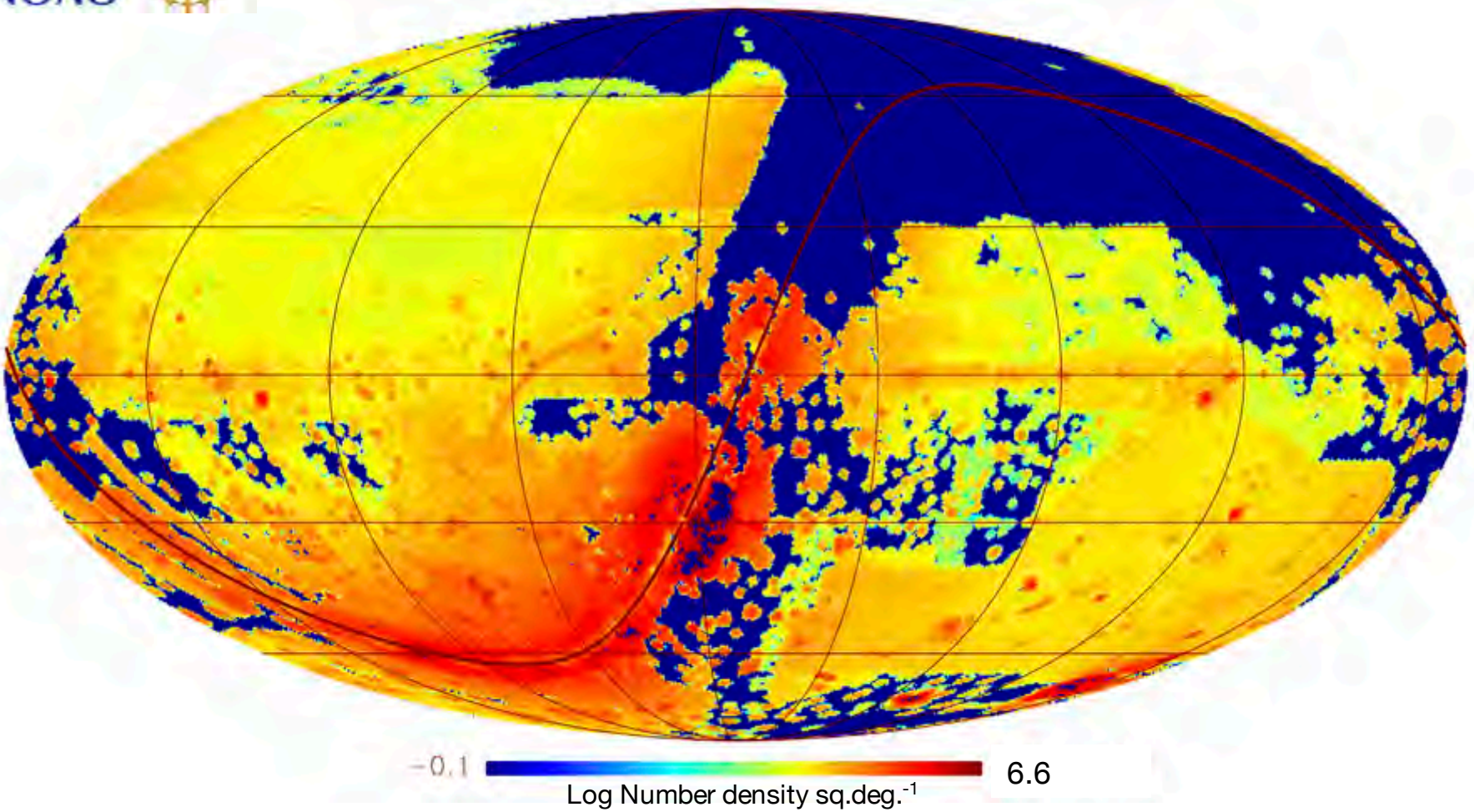


DECaLS DR3 and SMASH Catalogs



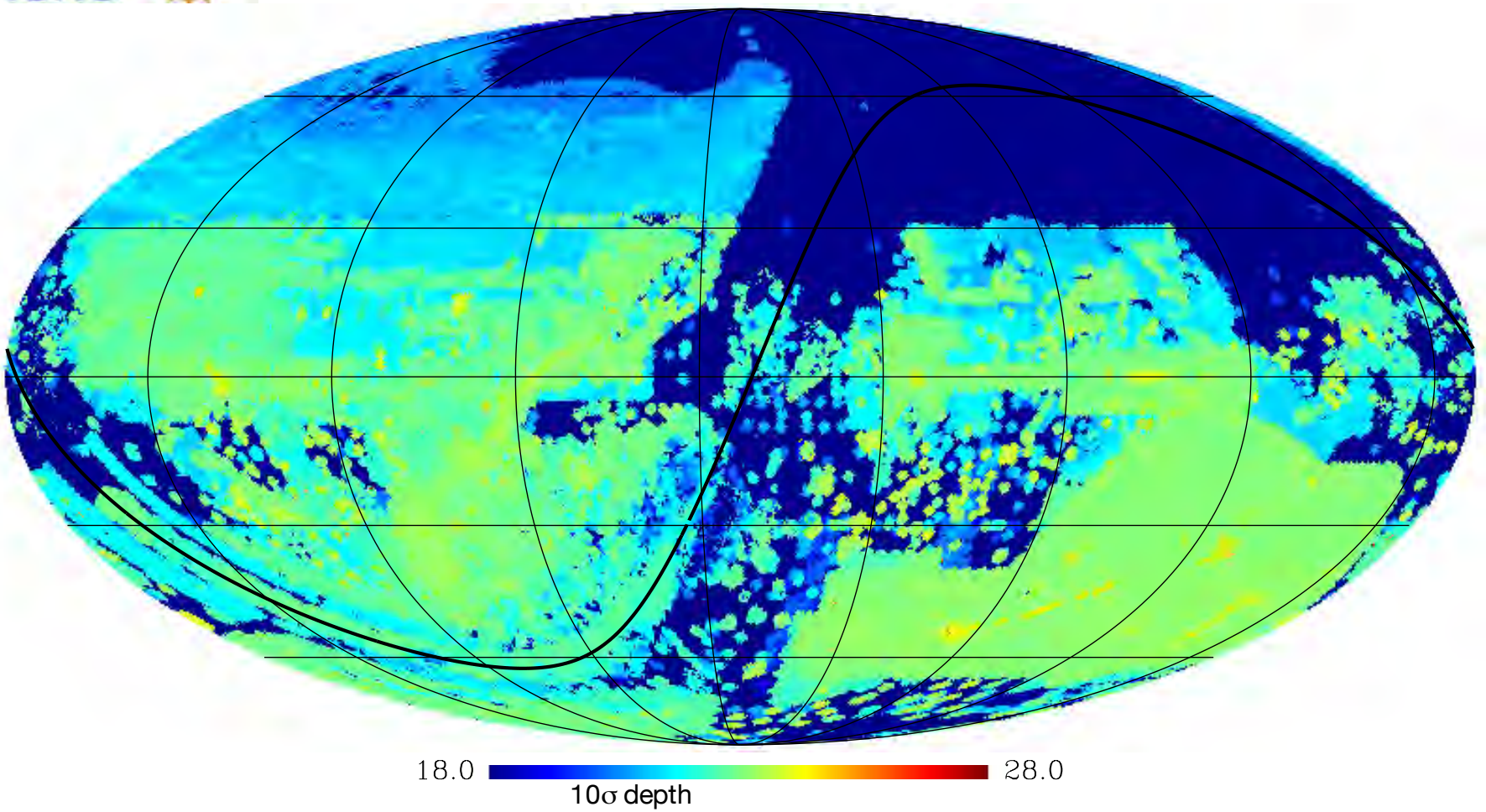
- 900 million objects available now through Data Lab database from these catalogs
- Also available: select tables from SDSS DR13, GAIA DR1, DES SVA1, the Allen NEO catalog, and USNO-A2/B

NOAO All Sky Catalog



- 2.5 billion objects, 20 billion measurements; aperture-based photometry
- Available soon

NOAO All Sky Catalog



- 2.5 billion objects, 20 billion measurements; aperture-based photometry
- Available soon

Data Volume and Complexity

~500 TB (February 2017) of on-target imaging data (t_{exp}>30s) currently from:

- Dark Energy Survey
- Legacy Surveys for DESI Targeting
- Community DECam and Mosaic programs and surveys

Hundreds of TB more coming

Total holdings at PB scale

Large catalogs coming:

- Dark Energy Survey – 45 TB
- Complete DESI Targeting Survey – ~5 TB
- Community programs and surveys – up to several TB each

NOAO Data Lab

- Goal:
- Efficient exploration and analysis of large datasets with an emphasis on NOAO wide-field 4-m telescopes
- Approach:
  - High-value catalogs from NOAO and external sources (e.g. SDSS, GAIA) and NOAO-based images linked to catalog objects
  - Data discovery
  - Developing intuition through interaction with selected catalog and image set of known objects
  - Automation of analysis to aid discovery of unknown objects

Data Lab in a Nutshell

Large Catalogs – Data Lab will serve TB-scale databases

Pixel Data – Data Lab will connect users to images and spectra in NOAO Science Archive

Virtual Storage – Minimizes data transfer

Visualization – Data Lab will enable data exploration

Compute Processing* – Data Lab will allow workflows to run close to the data

Additional features* – Access to published datasets and external data services, data publication, exportable workflows, distributable software

*Some limitations in first release

Summary of Current Functions

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

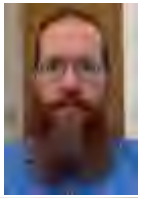
Major Milestones

- March 2015: Conceptual Design Review
  - Lisa Storrie-Lombardi (Chair), Severin Gaudet, Zeljko Ivezic, Connie Rockosi, Beth Willman reviewed Science Case & Requirements, System Architecture, Operations Concept & Requirements, and Schedule
- Fall 2015 hiring campaign
- June 2016 San Diego AAS Demo
- August 2016 Interim Review
  - Lisa Storrie-Lombardi (Chair), Severin Gaudet, Zeljko Ivezic, Ed Olszewski, Beth Willman, and Dennis Zaritsky reviewed progress and Year 2 plan
- January 2017 AAS SMASH DR1 and DECaLS DR3
- Summer 2017 first public release
- End 2017/Early 2018 NOAO All-Sky Catalog, Legacy Survey DR4/5, DES DR1

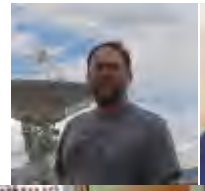
Outreach activities

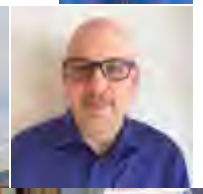
- San Diego AAS Demo (June 2016)
- Internal early adopter program (Sep 2016 – present)
- Big Data Academy Science Café sessions (February & April 2017)
- Demo and hacking at Detecting the Unexpected workshop (March 2017)
- LSST Data Science Fellowship program presentation and hack session (April 2017)
- Tucson local Tutorial (2 sessions, May 8 2017)
- Presentation and hacking at Time-domain Alert Science workshop (May 23 2017)
- Hack session at DESI Collaboration Meeting (June 2017)
- Detecting Dwarf Galaxies LSSTC Workshop (Fall 2017)

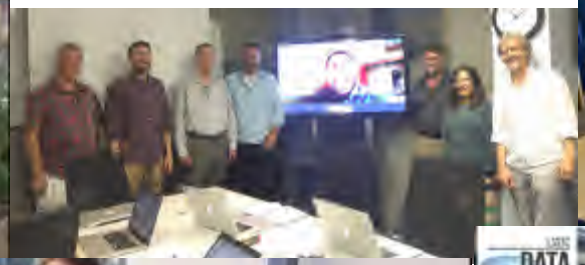
Public release 2017!

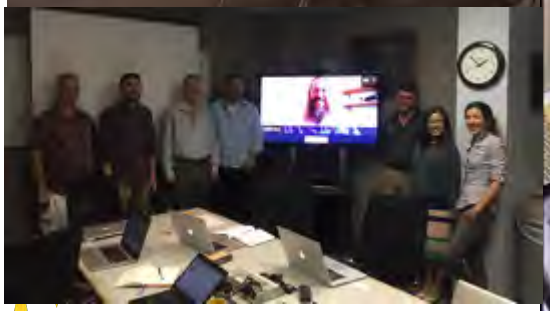


- Web: datalab.noao.edu
- Email: datalab@noao.edu
- GitHub: https://github.com/noao-datalab
- Twitter: @NOAODataLab









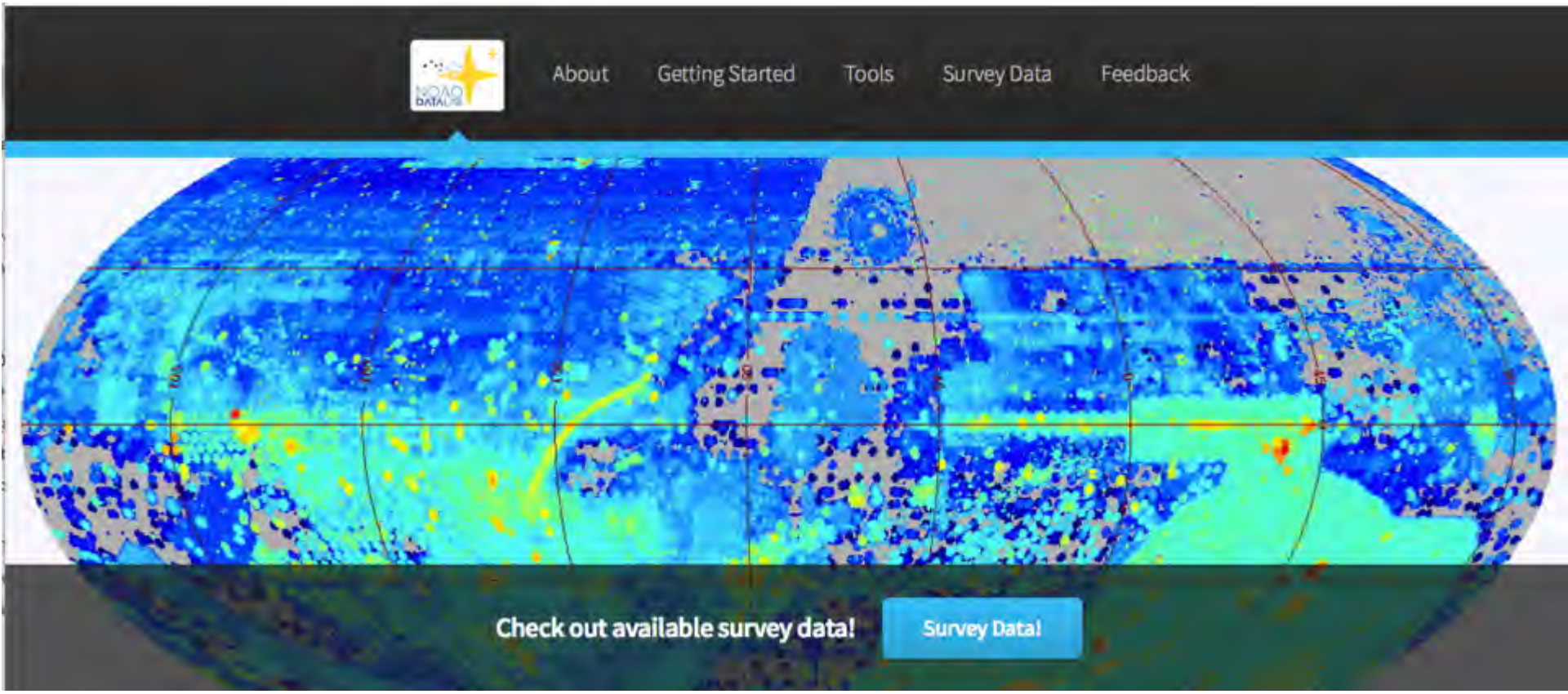
Science Examples

- Star/galaxy/QSO separation (Juneau)
- Hydra II and RR Lyrae star discovery (Nikutta)

Detailed slides

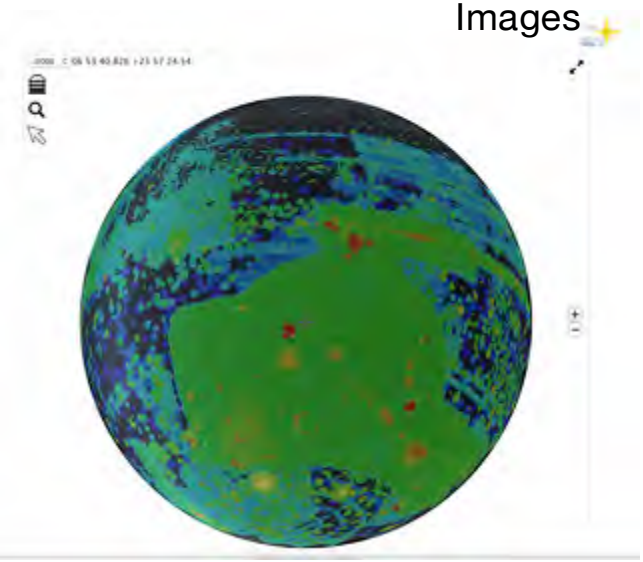
Getting started with the Data Lab

- datalab.noao.edu/tutdev

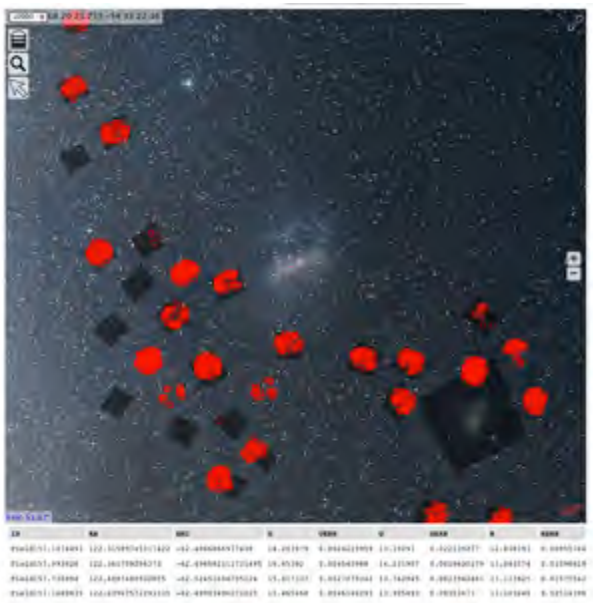


Exploring the sky

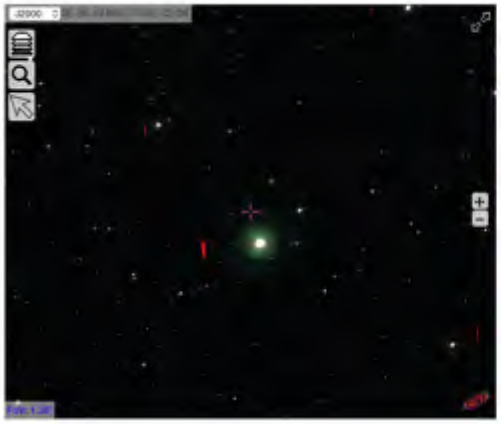
Images

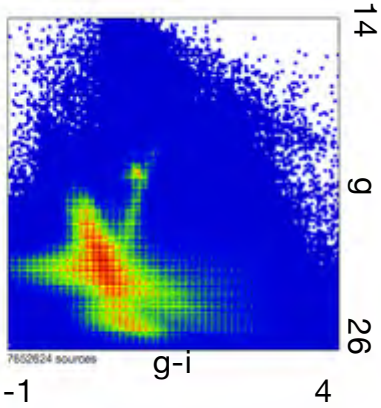


Catalogs



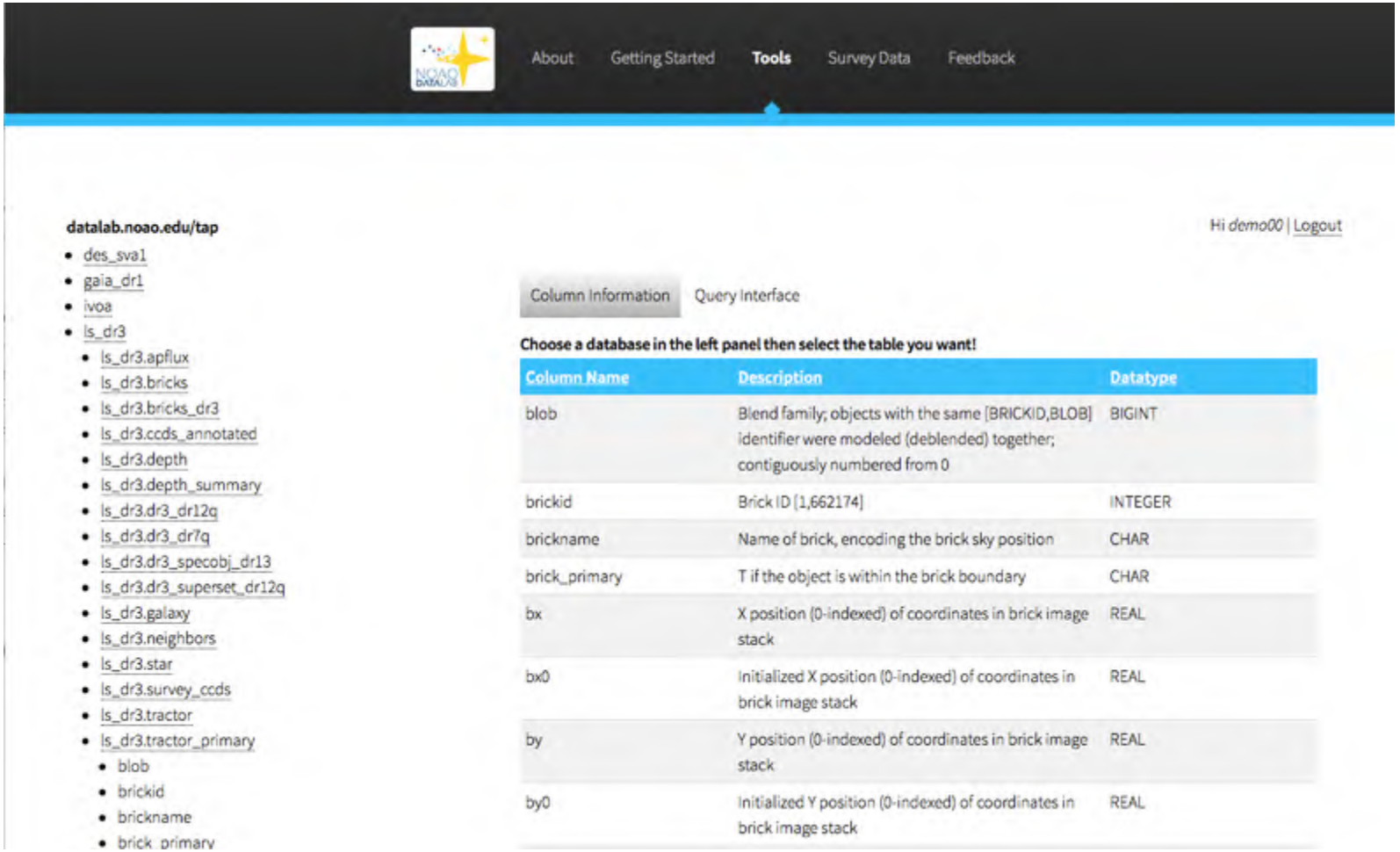
Catalog visualization (prototype)





Querying the catalogs

- Through the Data Lab website:



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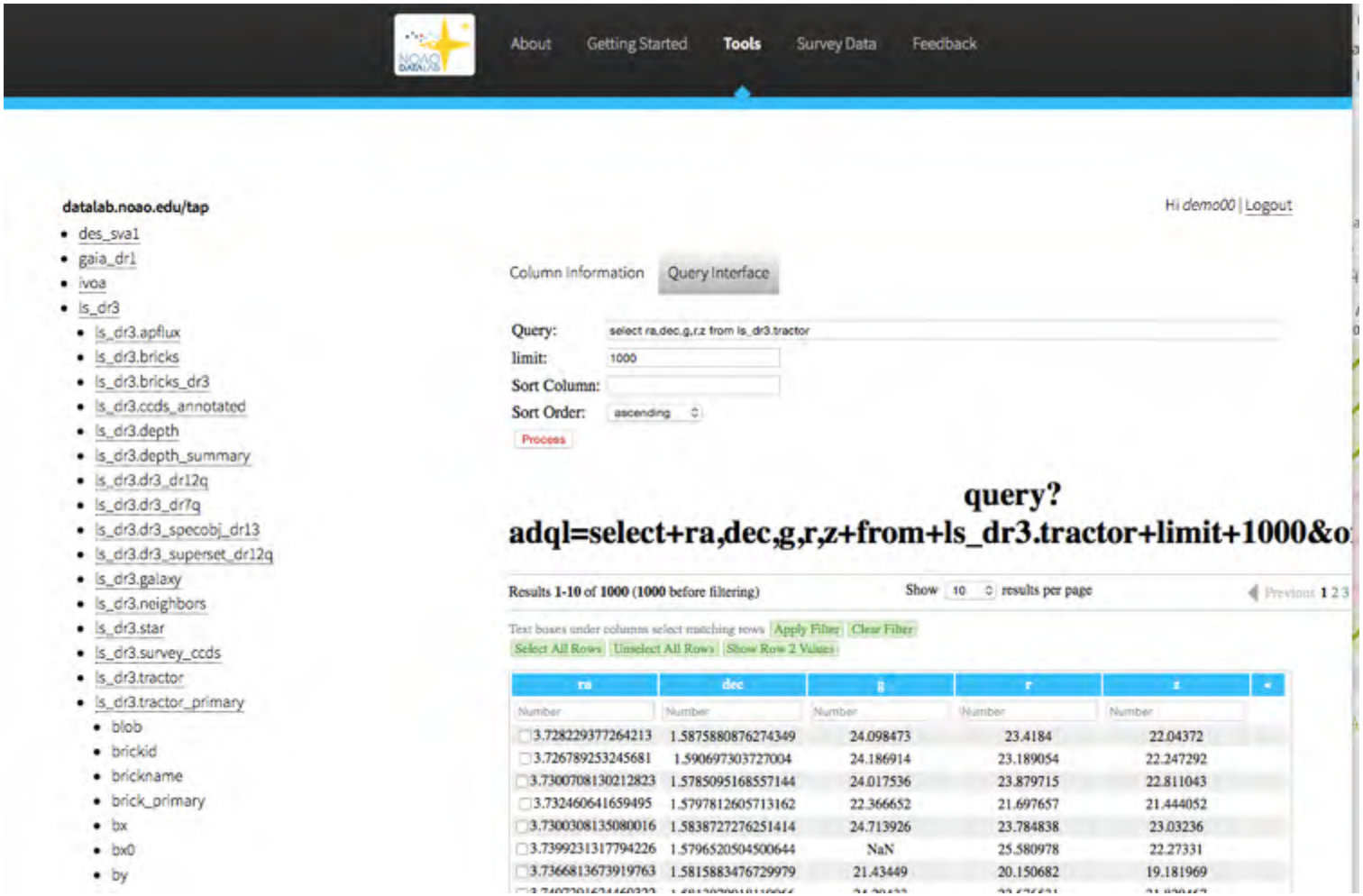


Querying the catalogs

- Through the datalab command:

```
[kolsen@gp02 ~]$ datalab login user=demo00 password=[redacted]
Welcome to the Data Lab, demo00
[kolsen@gp02 ~]$ datalab query sql="select * from usno.a2 limit 10"
id,raj2000_,dej2000_,actflag,mflag,bmag,rmag,epoch,raj2000,dej2000
0150-00069690,00:14:47.196,-68:49:48.92, , ,19.6,17.9,1981.81,3.696648,-68.830256
0150-00070481,00:14:54.972,-68:49:58.22, , ,19.8,18,1981.81,3.72905,-68.832839
0150-00069562,00:14:45.900,-68:49:37.66, , ,18,17.8,1981.81,3.69125,-68.827128
0150-00069750,00:14:47.844,-68:49:29.41, , ,19.4,18,1981.81,3.699348,-68.824837
0150-00070904,00:14:59.041,-68:49:25.26, , ,20.2,18,1981.81,3.746003,-68.823684
0150-00072260,00:15:12.458,-68:54:06.12, , ,18.9,17.1,1981.81,3.801909,-68.9017
0150-00072812,00:15:17.694,-68:54:09.03, , ,16.4,15.2,1981.81,3.823725,-68.902509
0150-00072863,00:15:18.280,-68:53:21.92, , ,17.7,16.5,1981.81,3.826164,-68.889423
0150-00073055,00:15:20.016,-68:53:23.36, , ,18.7,17.5,1981.81,3.8334,-68.889823
0150-00074055,00:15:29.570,-68:54:38.01, , ,19.3,18,1981.81,3.873206,-68.910559

[kolsen@gp02 ~]$ datalab query sql="select * from usno.a2 limit 10" out="mydb://usno_test2"
[kolsen@gp02 ~]$ datalab query sql="select * from usno.a2 limit 10" out="vos://foo2.csv"
[kolsen@gp02 ~]$
```

Querying the catalogs

- Through the Python queryClient module:

```
In [27]: from dl import authClient, queryClient

In [28]: token = authClient.login ('demo00','XXXXXXX')

In [29]: %%time
         query="SELECT id,ra,dec,gmag,rmag FROM smash_dr1.object WHERE fieldid=169 LIMIT 100"
         try:
           response = queryClient.query(token, sql = query, fmt = 'csv')
         except Exception as e:
           print e.message
           raise
         print response[:205]

         id,ra,dec,gmag,rmag
         169.458572,185.342365895208,-32.1201617232873,24.8856,24.6991
         169.460663,185.348188180985,-32.1200524648251,24.665,24.5361
         169.1065651,185.353177442806,-32.1208638198927,25.0639,24.6239
         CPU times: user 7.4 ms, sys: 956 µs, total: 8.36 ms
         Wall time: 53 ms
```

Querying the catalogs

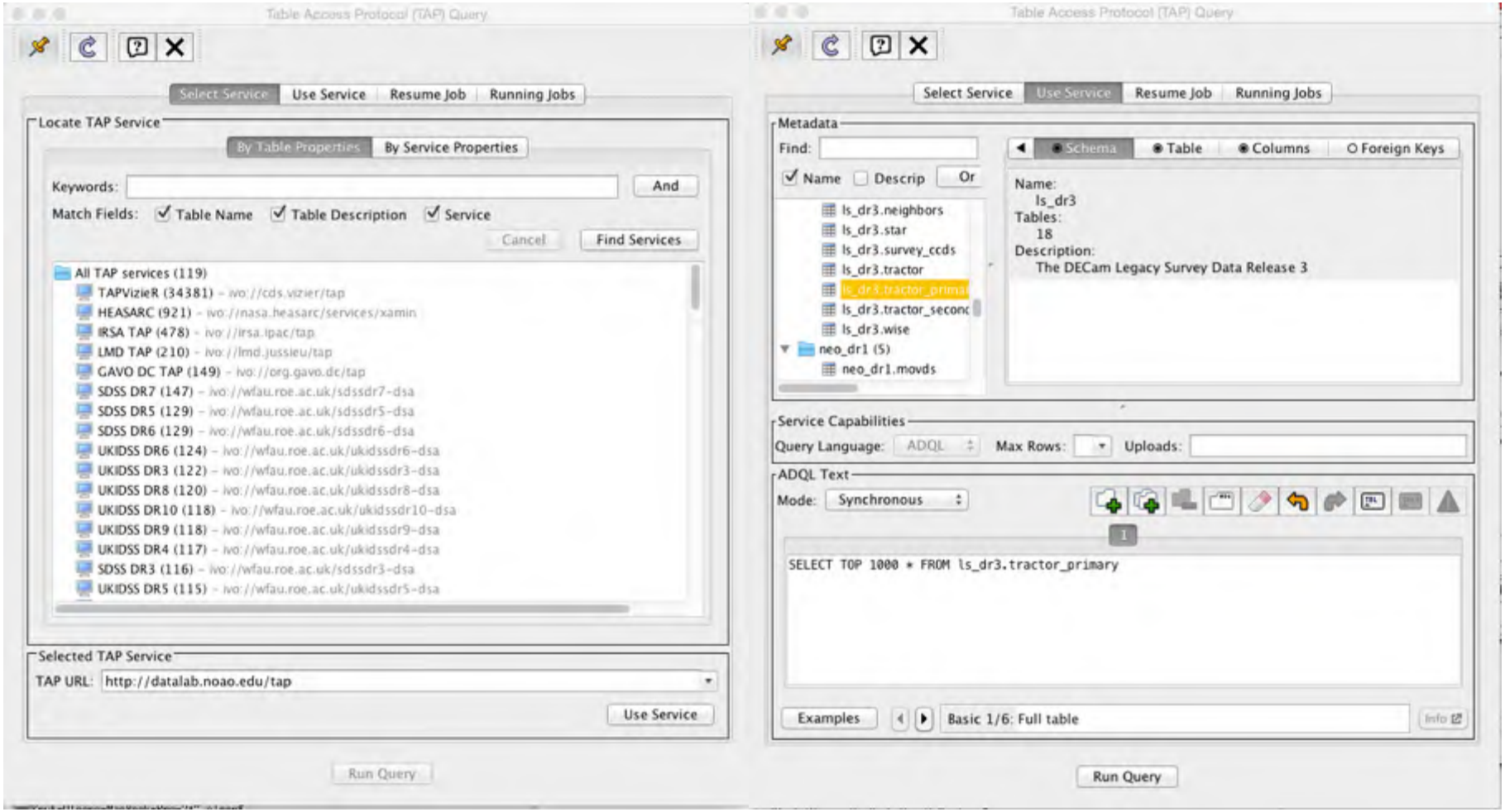
- Through the helpers.py module:

```
In [23]: %%time
         from dl import helpers
         Q = helpers.Querist('demo00',' [redacted] )
         tbl = Q(query,outfmt='table') # or:
         df = Q(query,outfmt='pandas')

         Returning Astropy Table
         Returning Pandas dataframe
         CPU times: user 18 ms, sys: 13.3 ms, total: 31.3 ms
         Wall time: 131 ms
```

Querying the catalogs

- Through TOPCAT:



Querying the images

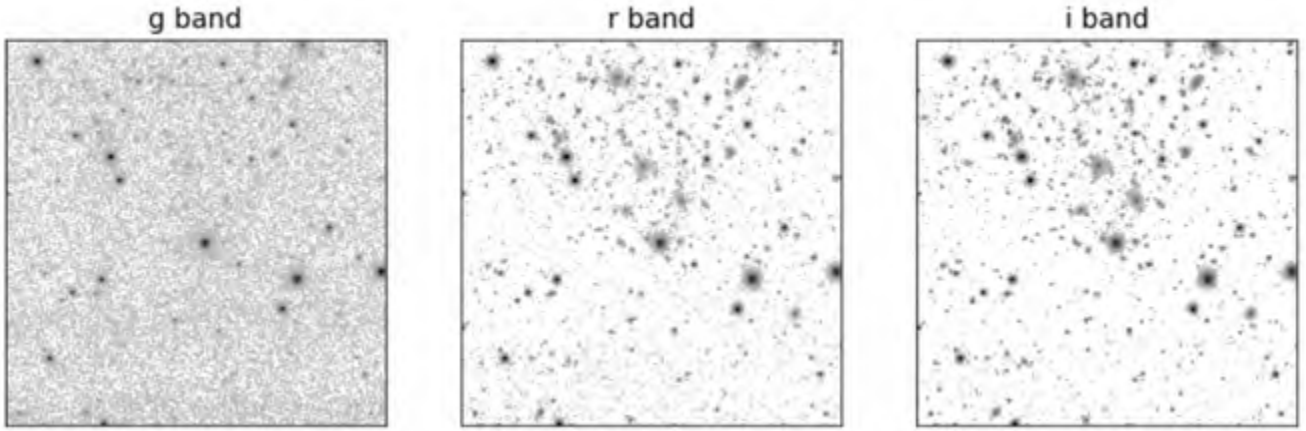
In [14]:

```
bands = list('gri')
images = download_deepest_images(tbl['ra'][1], tbl['dec'][1], fov=0.07, bands=bands) # FOV in de
```

```
The full image list contains 2514 entries
Band g: downloading deepest stacked image...
Band r: downloading deepest stacked image...
Band i: downloading deepest stacked image...
Downloaded 3 images.
```

In [15]:

```
plot_images(images,bands=bands)
```



Querying the images

```
# set up SIA
from pyvo.dal import sia
#DEF_ACCESS_URL = "http://datalab.noao.edu/sia/smash"
DEF_ACCESS_URL = "http://zeus1.sdm.noao.edu/siapv1"
svc = sia.SIAService(DEF_ACCESS_URL)

# a little func to download the deepest stacked images
def download_deepest_images(ra,dec,fov=0.1,bands=list('gri')):
    imgTable = svc.search((ra,dec), (fov/np.cos(dec*np.pi/180), fov), verbosity=2).votable.to_ta
    print "The full image list contains", len(imgTable), "entries"

    sel0 = (imgTable['proctype']=='Stacked') & (imgTable['prodtype']=='image') # basic selectio
    images = []
    for band in bands:
        print "Band %s:" % band,
        sel = sel0 & (imgTable['obs_bandpass']==band) # add 'band' to selection
        Table = imgTable[sel] # select
        row = Table[np.argmax(Table['exptime'].data.data.astype('float'))] # pick image with lo
        url = row['access_url'] # get the download URL
        print 'downloading deepest stacked image...'
        img = io.fits.getdata(utils.data.download_file(url,cache=True,show_progress=False,timeou
        images.append(img)

    print "Downloaded %d images." % len(images)
    return images

# multi panel image plotter
def plot_images(images,geo=None,panelsize=4,bands=list('gri'),cmap=matplotlib.cm.gray_r):
    n = len(images)
    if geo is None: geo = (n,1)

    fig = p.figure(figsize=(geo[0]*panelsize,geo[1]*panelsize))
    for j,img in enumerate(images):
        ax = fig.add_subplot(geo[1],geo[0],j+1)
        ax.imshow(img,origin='lower',interpolation='none',cmap=cmap,norm=matplotlib.colors.Powe
```

Saving the results

- myDB:

```
In [29]: query = "select * from usno.b1 limit 1000"
         try:
             response = queryClient.query (token, adql=query, fmt='csv',
                                           out='mydb://mags3')
             #queryClient.list (token, table='mydb://mags3')
         except Exception as e:
             # Handle any errors in the query.  By running this cell multiple times with the same
             # output file, or by using a bogus SQL statement, you can view various error messages.
             print (e.message)
         else:
             if response is not None:
                 print (response)            # print the response
             else:
                 print ("OK")

         http://dlsvcs.datalab.noao.edu/query/list?table=mydb://mags3
         OK
```

```
datalab query sql="select * from usno.a2 limit 10" out="mydb://usno_test2"
```

Saving the results

- Virtual storage:

```
try:
    response = queryClient.query (token, adql=query, fmt='csv',
                                  out='vos://mags.csv')
except Exception as e:
    # Handle any errors in the query.  By running this cell multiple times with the same
    # output file, or by using a bogus SQL statement, you can view various error messages.
    print (e.message)
else:
    if response is not None:
        print (response)            # print the response
    else:
        print ("OK")

# Remove the file we just created, but list it first to show it exists
storeClient.ls (token, name='vos://mags.csv')
storeClient.rm (token, name='vos://mags.csv')
```

```
datalab query sql="select * from usno.a2 limit 10" out="vos://foo2.csv"
```

Virtual storage

- File transfer:

```
[kolsen@gp02 ~]$ datalab put fr=/etc/hosts to=vos://
(1 / 1) /etc/hosts -> vos://hosts
[kolsen@gp02 ~]$ datalab get fr=vos://hosts to=/tmp/myhosts
(1/1) [====================] [   281B] hosts
```

Analysis

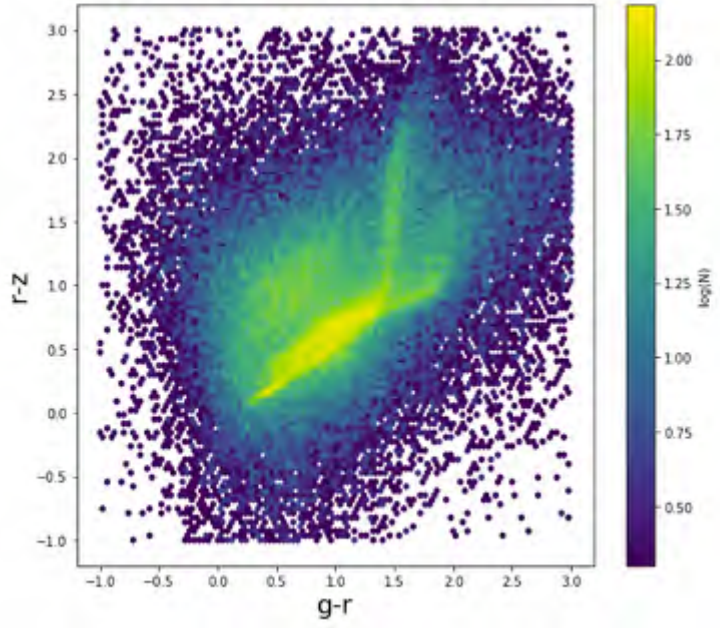
- Jupyter notebook server

Optical Color-Color Diagram

```
In [5]: col0 = trac['g_r']  #g-r color
        col1 = trac['r_z']  #r-z color

        # 2D-histogram of objects
        fig, ax1 = plt.subplots(1, 1, figsize=(9, 8))
        im1 = ax1.hexbin(col0, col1, bins='log', cmap=plt.cm.viridis,
                         mincnt=1, extent=(-1., 3, -1., 3))
        ax1.set_ylabel('r-z',fontsize=20)
        ax1.set_xlabel('g-r',fontsize=20)

        #color bar
        cb = plt.colorbar(im1,label='log(N)')
```



Pending: running custom code

- Containerization of tasks
- Job Manager to handle task running, interactions, and completion

Pending: data publication

- Document to provide guidance on schema, metadata for custom imaging, etc.
- Database ingest tools and metadata scraping
- Services to provide e.g. custom image and catalog HiPS generation for sky viewer
- Webpage template