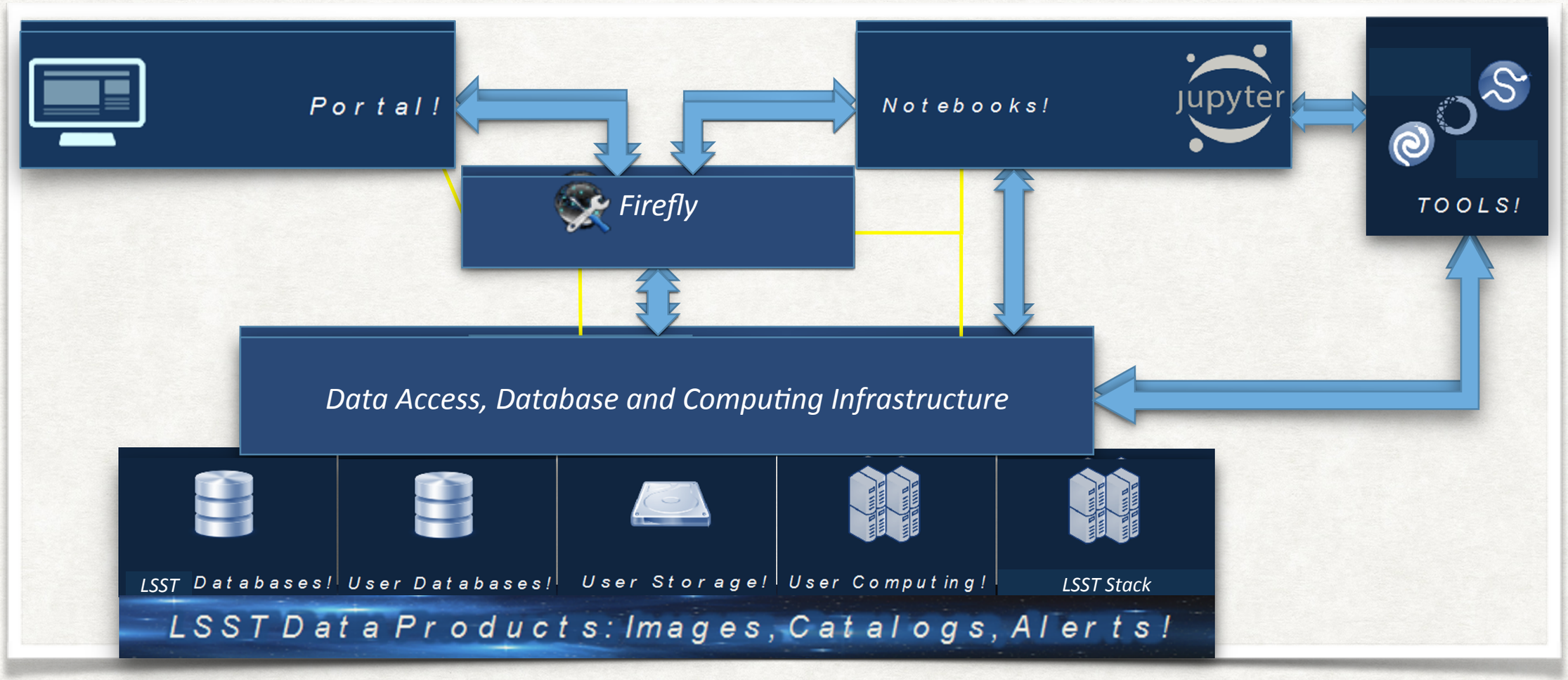
Python widgets for astronomy visualization

David Shupe (Caltech/IPAC)
Scientist, LSST and ZTF

on behalf of the LSST
Science User Interface & Tools team

Context: LSST Science Platform

Astronomy in 2020+



Too much data to download -> Remote workspaces

Python widgets for astronomy visualization

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- The Firefly visualization system

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- APIs to Firefly

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Firefly

Archive Access System

T. Roby et al. SPIE 2016

Firefly

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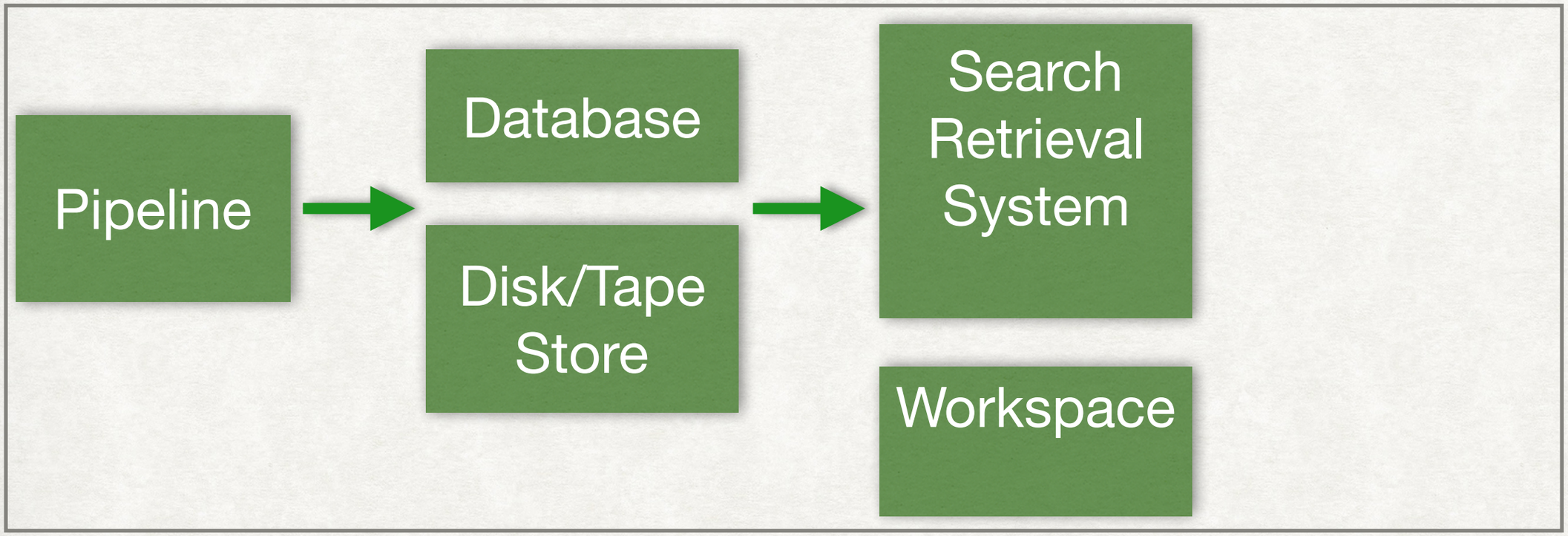

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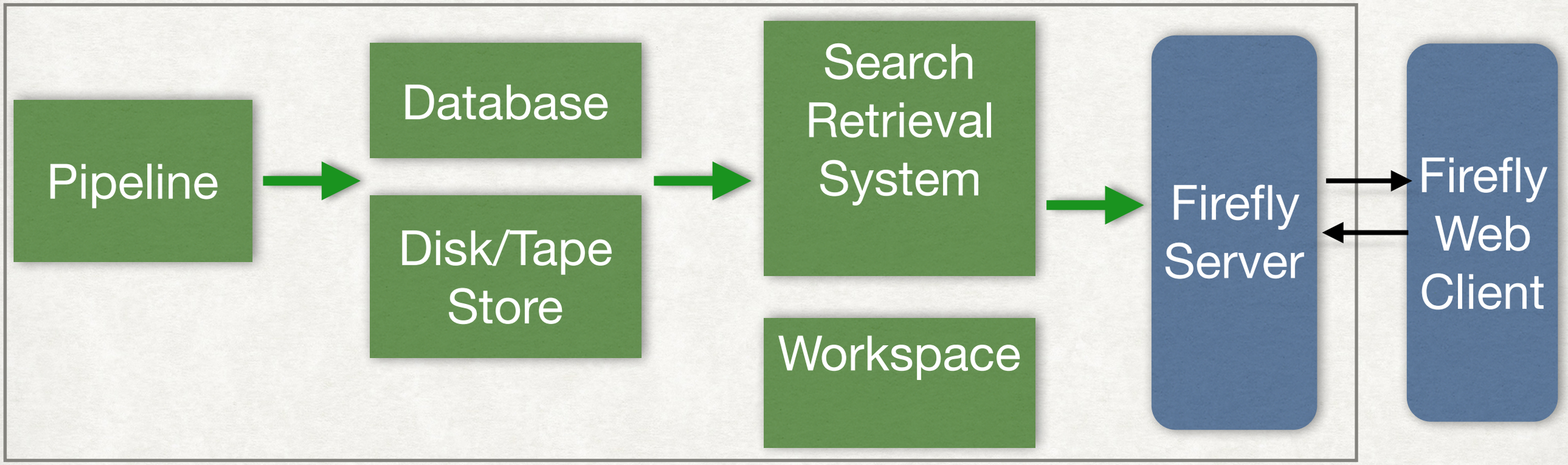
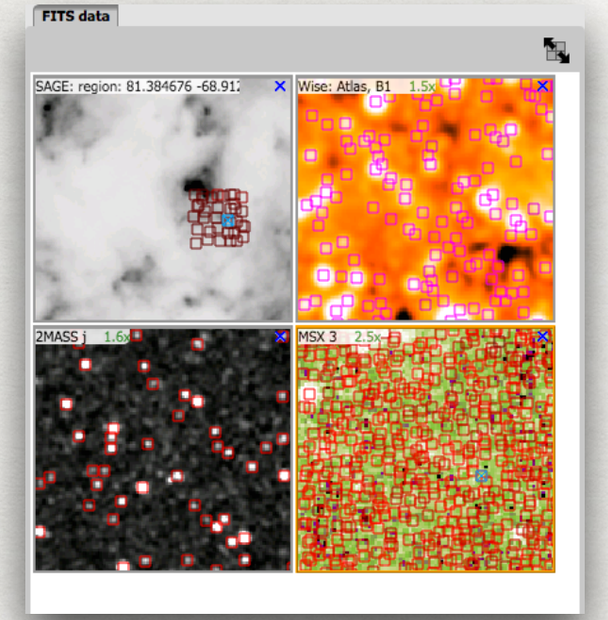


T. Roby et al. SPIE 2016

FITS Image Viewer

Table Display

XY Plot / Histogram



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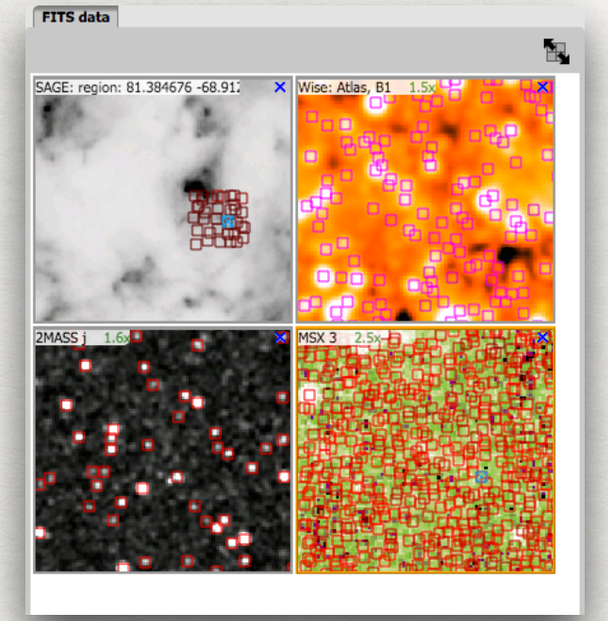

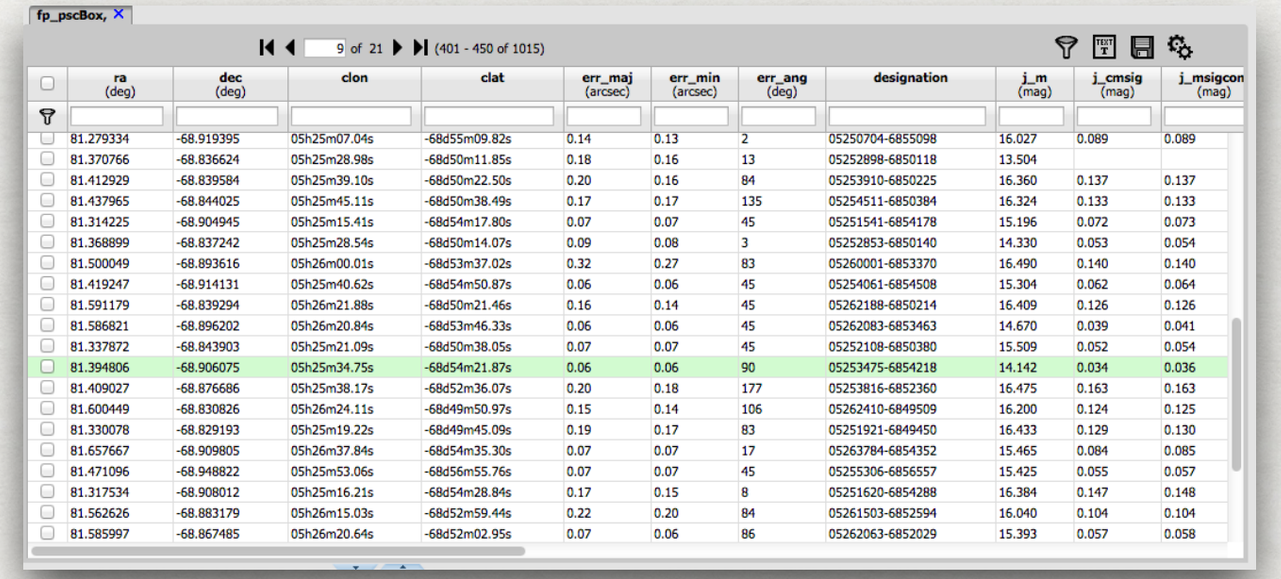

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81.370766	-68.836624	05h25m28.98s	-68d50m11.85s	0.18	0.16	13	05252898-6850118	13.504		
81.412929	-68.839584	05h25m39.10s	-68d50m22.50s	0.20	0.16	84	05253910-6850225	16.360	0.137	0.137
81.437965	-68.844025	05h25m45.11s	-68d50m38.49s	0.17	0.17	135	05254511-6850384	16.324	0.133	0.133
81.314225	-68.904945	05h25m15.41s	-68d54m17.80s	0.07	0.07	45	05251541-6854178	15.196	0.072	0.073
81.368899	-68.837242	05h25m28.54s	-68d50m14.07s	0.09	0.08	3	05252853-6850140	14.330	0.053	0.054
81.500049	-68.893616	05h26m00.01s	-68d53m37.02s	0.32	0.27	83	05260001-6853370	16.490	0.140	0.140
81.419247	-68.914131	05h25m40.62s	-68d54m50.87s	0.06	0.06	45	05254061-6854508	15.304	0.062	0.064
81.591179	-68.839294	05h26m21.88s	-68d50m21.46s	0.16	0.14	45	05262188-6850214	16.409	0.126	0.126
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81.337872	-68.843903	05h25m21.09s	-68d50m38.05s	0.07	0.07	45	05252108-6850380	15.509	0.052	0.054
81.394806	-68.906075	05h25m34.75s	-68d54m21.87s	0.06	0.06	90	05253475-6854218	14.142	0.034	0.036
81.409027	-68.876686	05h25m38.17s	-68d52m36.07s	0.20	0.18	177	05253816-6852360	16.475	0.163	0.163
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81.330078	-68.829193	05h25m19.22s	-68d49m45.09s	0.19	0.17	83	05251921-6849450	16.433	0.129	0.130
81.657667	-68.909805	05h26m37.84s	-68d54m35.30s	0.07	0.07	17	05263784-6854352	15.465	0.084	0.085
81.471096	-68.948822	05h25m53.06s	-68d56m55.76s	0.07	0.07	45	05255306-6856557	15.425	0.055	0.057
81.317534	-68.908012	05h25m16.21s	-68d54m28.84s	0.17	0.15	8	05251620-6854288	16.384	0.147	0.148
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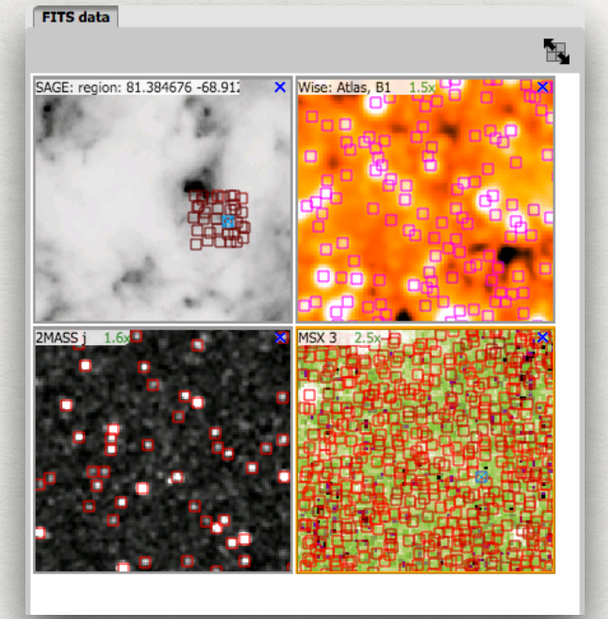

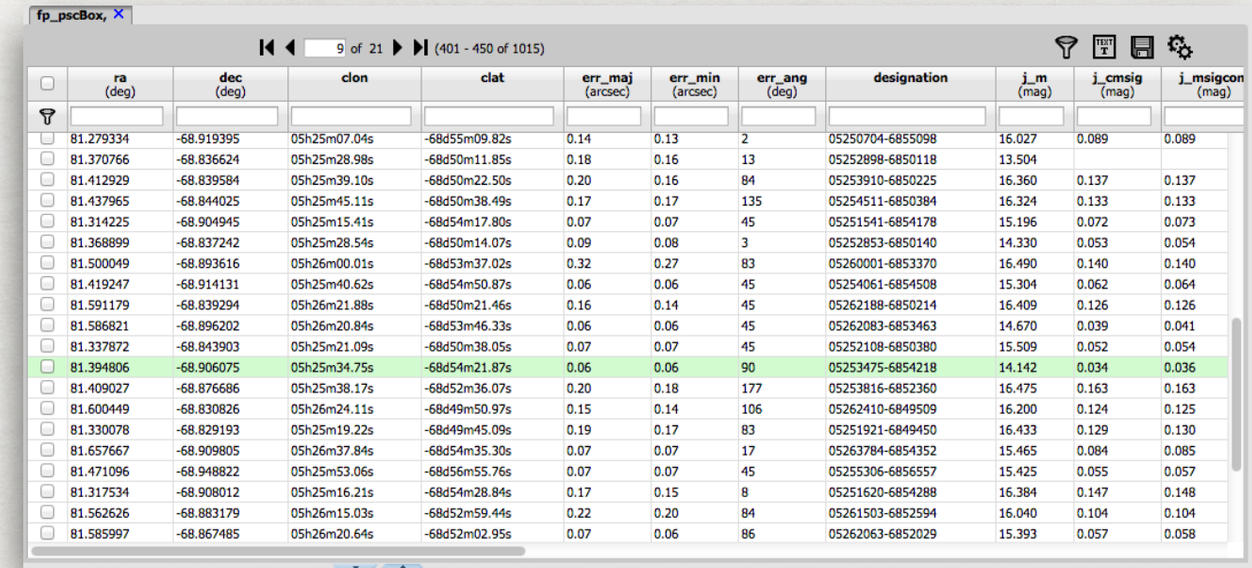

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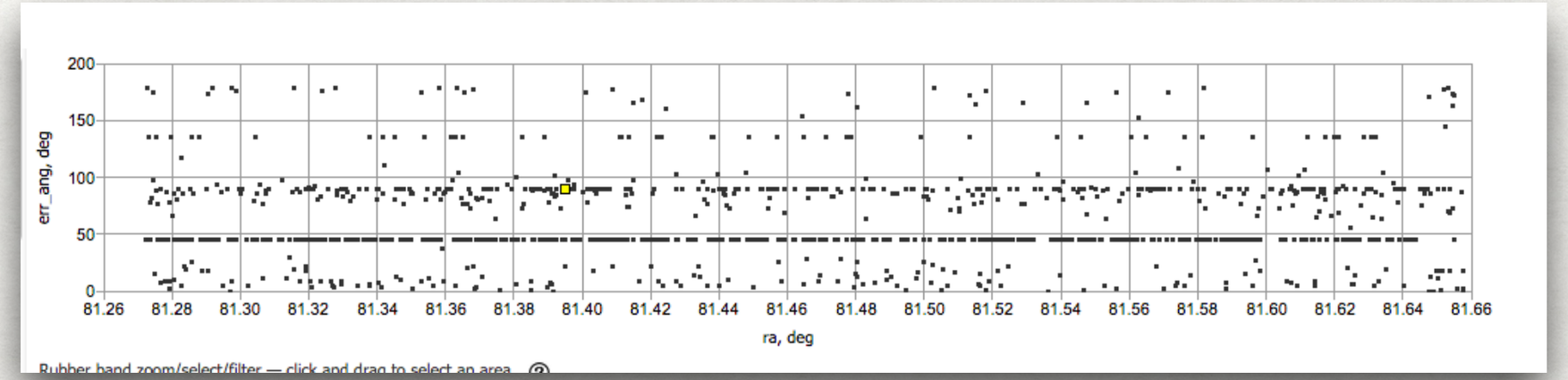

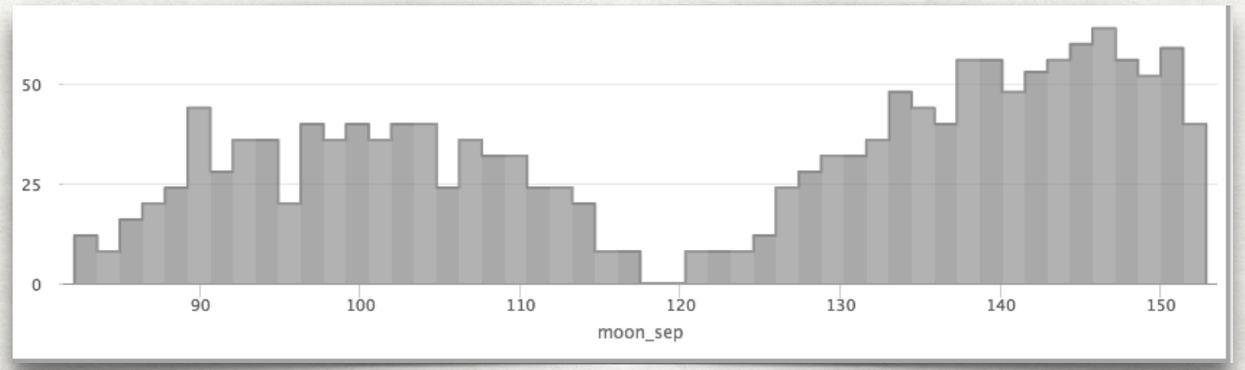

- Interactive
- Column math
- Zoom
- Filter

Many Faces of Firefly

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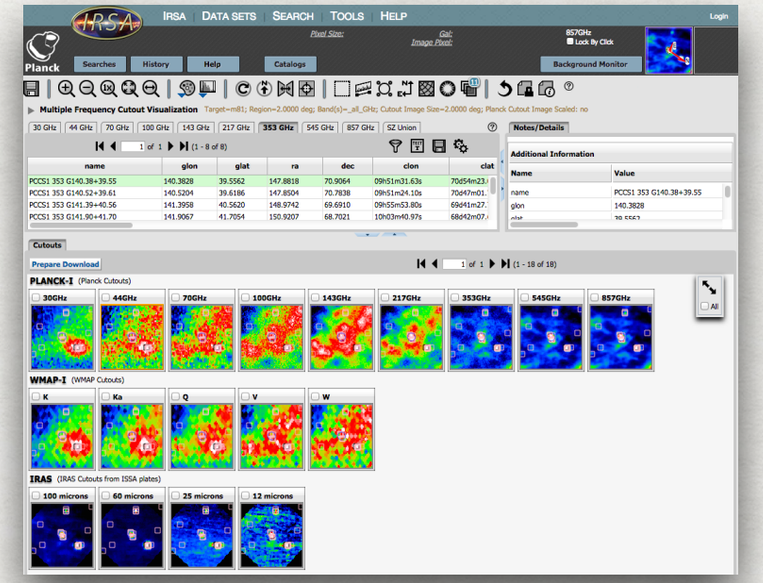

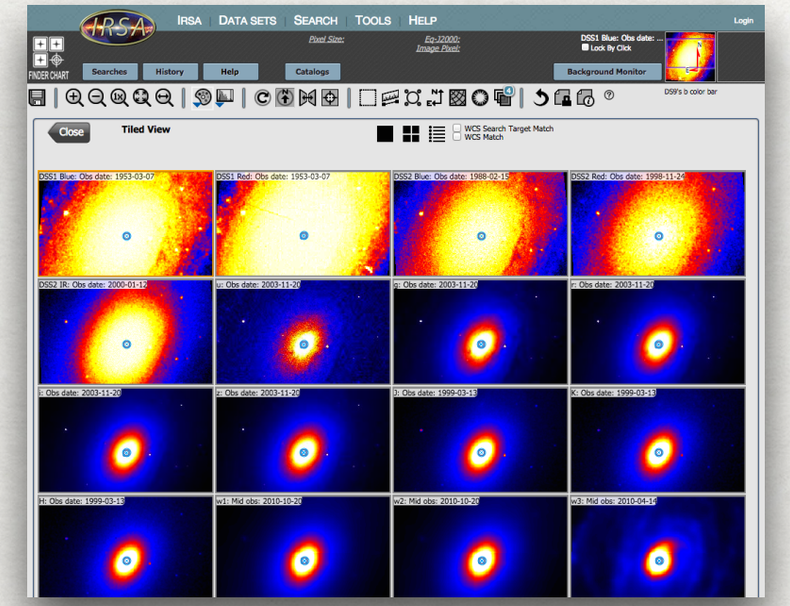

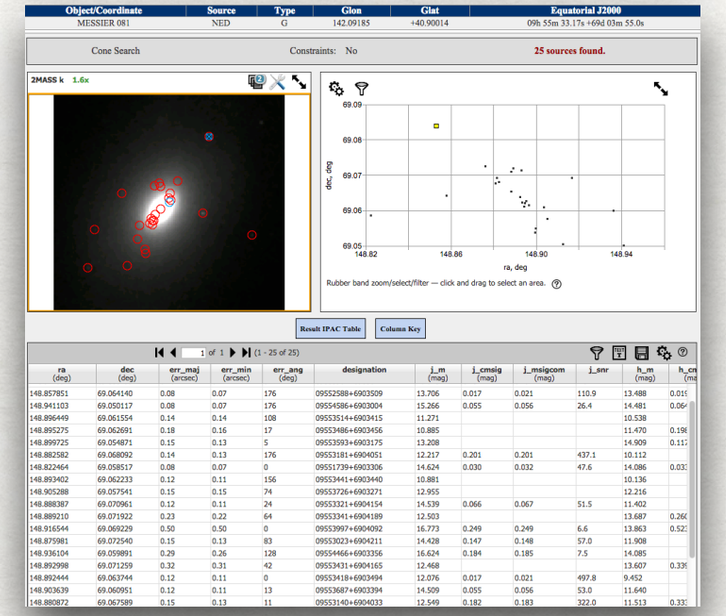

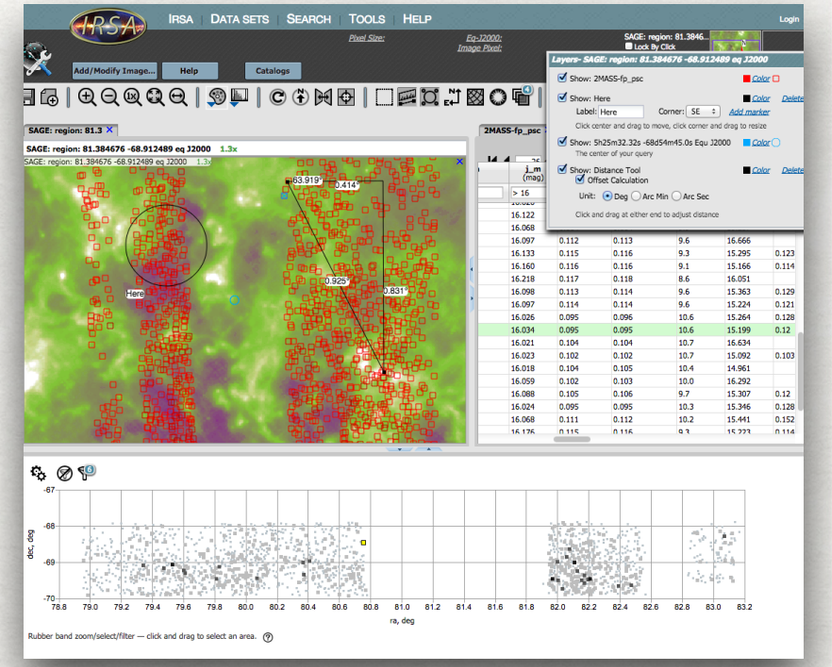

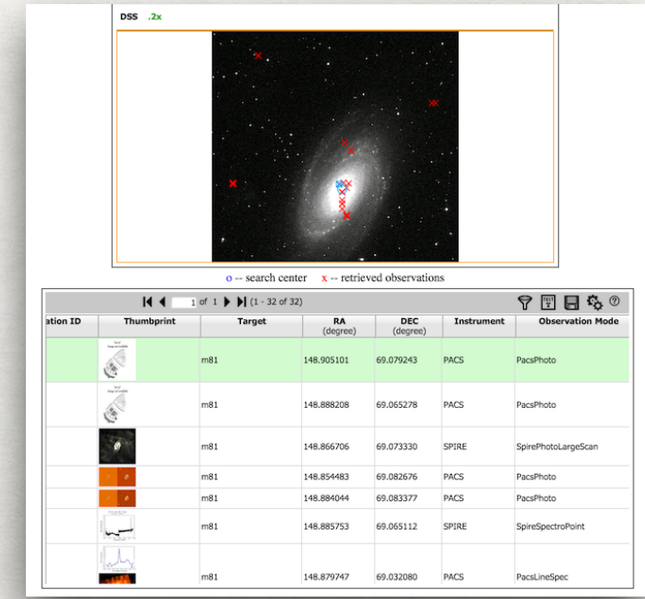

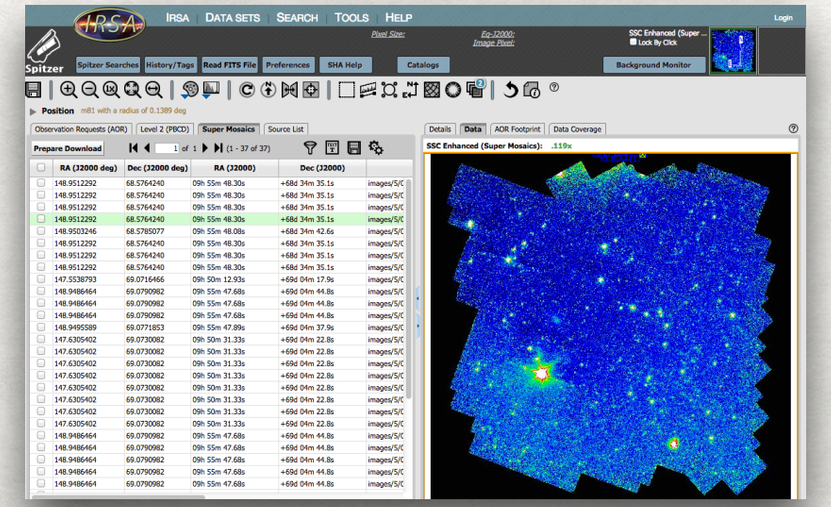

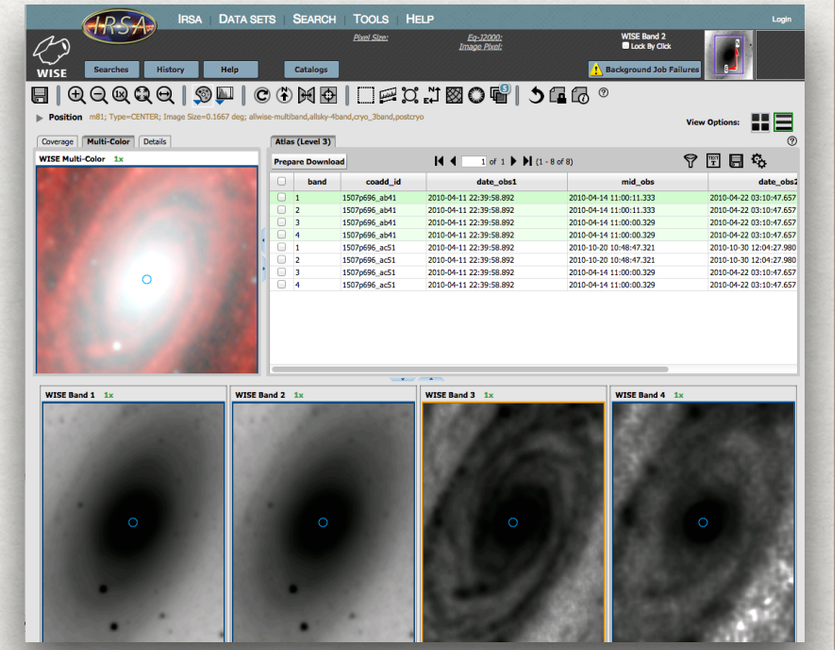

Using Firefly

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- Servers
  - Application at Infrared Science Archive
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    Download a single file, deploy using only Java 8

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- Programmatic
  - Javascript
  - Python with Firefly the single-page application
  - Widgets for Jupyter notebook / JupyterLab

Python widgets for astronomy visualization

- The Firefly visualization system
- APIs to Firefly
  - Javascript
  - Python: firefly_client
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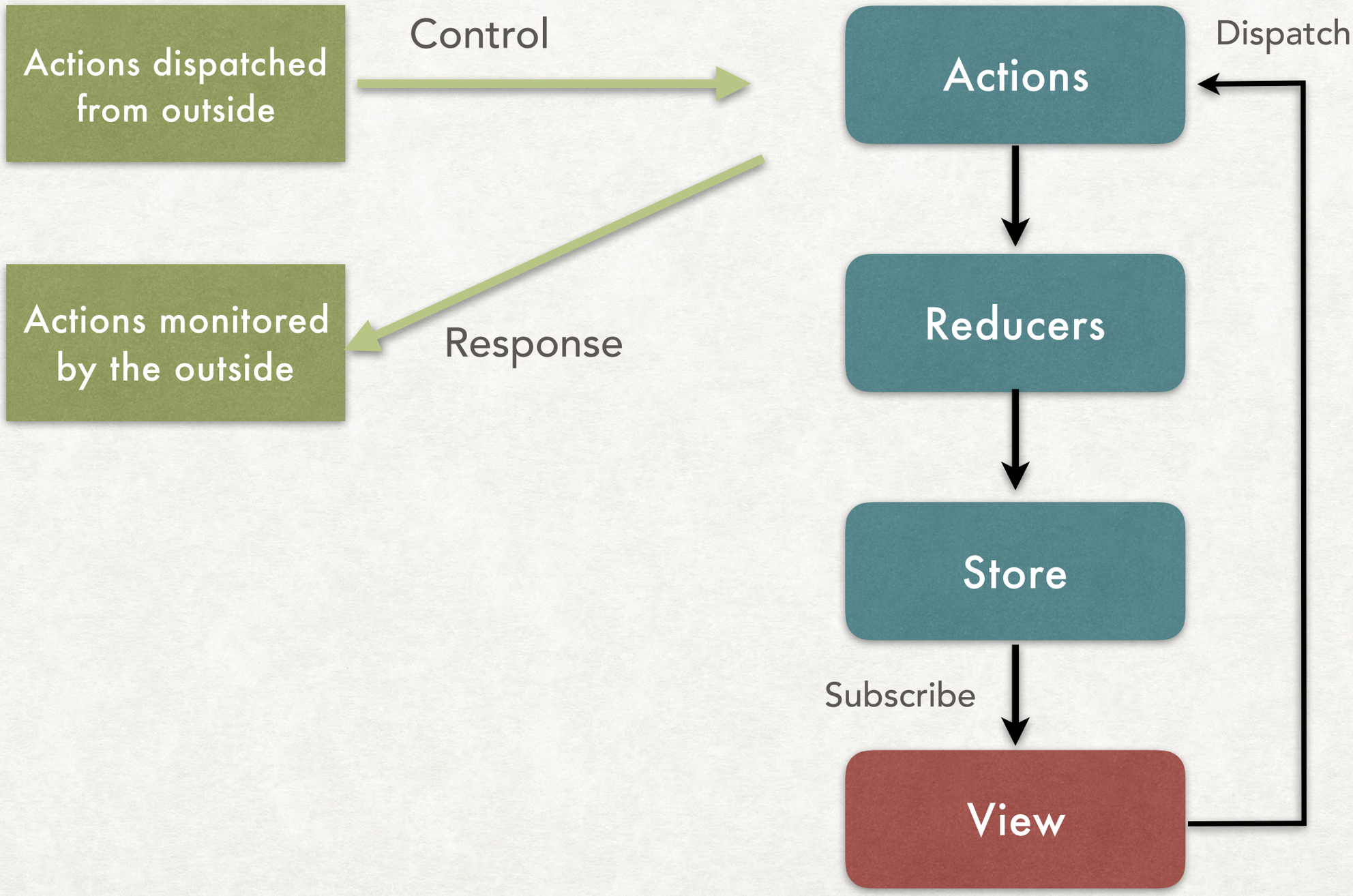
External and internal actions are enabled

Contemporary JavaScript framework



Javascript API falls out naturally

- Dispatch actions to make a change

```
var action= firefly.action;
```

- To change color:

```
action.dispatchColorChange({plotId:'myplot',
    cbarId:5});
```

- Zooming an image:

```
action.dispatchZoom({plotId:'myplot',
   userZoomType:'UP' });

action.dispatchZoom({plotId:'myplot',
   userZoomType:'LEVEL',level: zlevel,
   forceDelay: true });
```

Documentation for Javascript API

JavaScript Firefly Tools API

Firefly tools is an API that can be used from JavaScript. High-level API allows to render the main components of Firefly and make them share the same data model. Low-level API gives direct access to Firefly React componen and application state. Firefly tools API also allows to dispatch or add a listener to virtually any action, available Firefly internally. This makes it possible to extend Firefly by executing custom code on various UI events, like m move or region selection.

The main Firefly components are:

- FITS Visualizer
- Table
- Charts

These components can be setup to share the same data model. Therefore you can do the following combinatio

- Connect FITS viewer coverage image to a table
- Connect XY plot to a table. A Table with any data and a XY Plot showing plots from any two columns of th table.
- Tri-view: Table, FITS coverage, and XY Plot together showing the same data.

Lower level API is built around the following modules:

- `firefly.ui` - UI components
- `firefly.util` - utilities
- `firefly.action` - actions, changing application state

More information about lower level API can be found here:

- Rendering UI Components
- Dispatching and Watching Actions
- Other utilities
- Utility methods for FITS visualization
- Adding Context Extensions to FITS viewer
- Region Support

Starting Firefly Tools in JavaScript

firefly.lsst.io

Python API tracks Javascript closely

- **`firefly_client`** is a thin layer over Javascript API
- Pip-installable
- Dispatch actions, add listeners (callbacks)
- Image display for a local Firefly server:

```
import firefly_client

fc = firefly_client.FireflyClient('localhost:8080')

fval = fc.upload_file('myfile.fits')

fc.show_fits(fval)
```

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Forced photometry with LSST stack

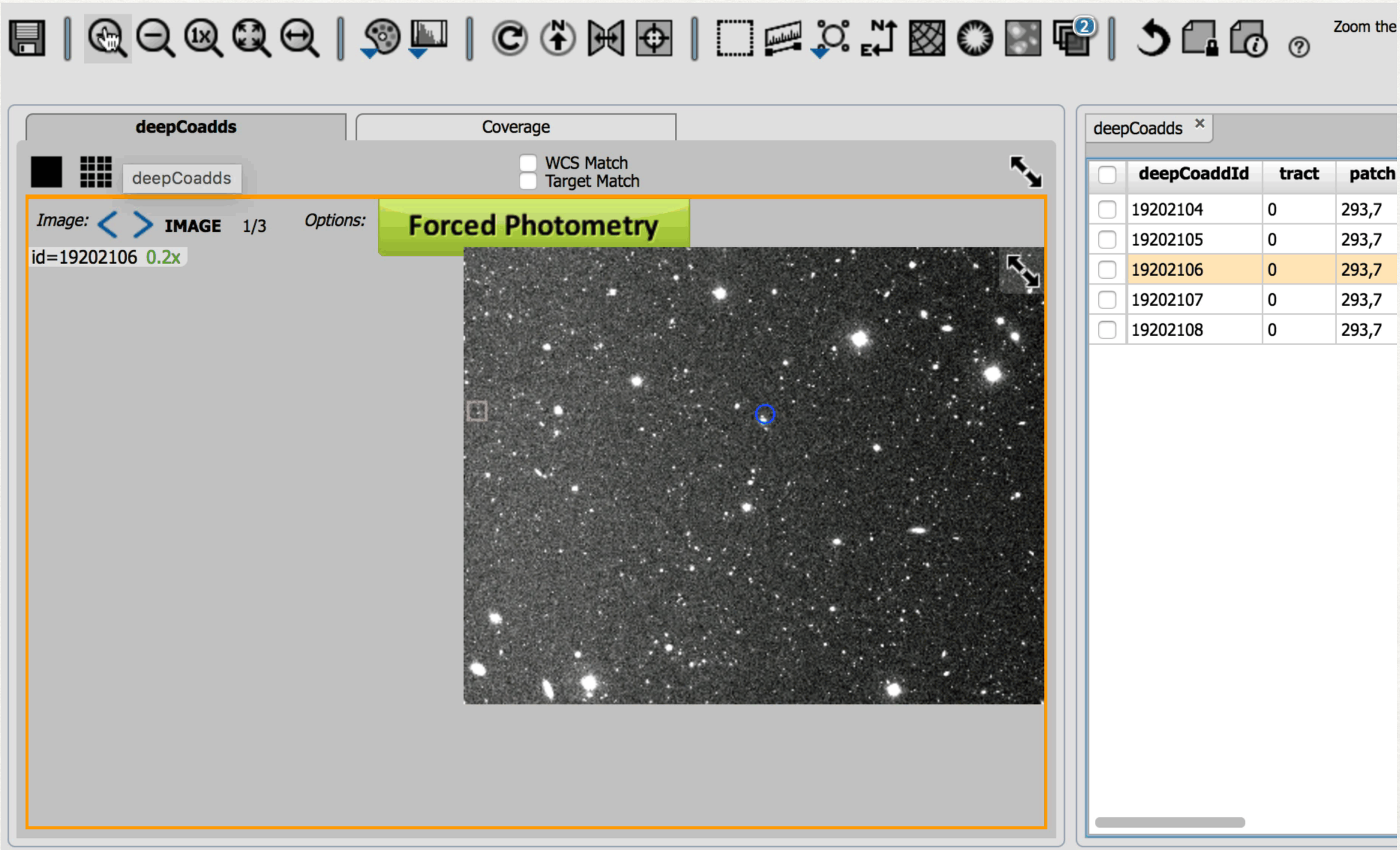
Setup with Jupyter notebook

- Define function for forced photometry for (ra, dec, filter)
- Callback listens for row selection and point events
- Extension added to Firefly to enable this button in point selection mode

The callback function applies `fetch_forcedphot` when activated in Firefly.

```
def callback_forcedphot(event, verbose=False):
    global src_cat
    selected_filter = None
    if verbose:
        for key in event:
            lsst.log.info(str(key) + " : " + str(event[key]))
        if 'data' in event:
            lsst.log.info('Dumping event data')
            for key in event['data']:
                lsst.log.info(str(key) + " : " + str(event['data'][key]))
    if 'table' in event['data']:
        if 'row' in event['data']['table']:
            if 'filterName' in event['data']['table']['row']:
                selected_filter = event['data']['table']['row']['filterName']
    if 'wpt' in event['data']:
        wpt = event['data']['wpt']
        wdata = wpt.split(';')
        ra = float(wdata[0])
        dec = float(wdata[1])
        if selected_filter is not None:
            outtab = fetch_forcedphot(ra, dec, selected_filter)
        else:
            outtab = fetch_forcedphot(ra, dec, myfilter)
        if outtab is None:
            lsst.log.error('No photometry returned')
            return
        outtab.write('fout.tbl', format='ipac')
        with open('fout.tbl', 'r') as original:
            data = original.read()
        with open('fout.tbl', 'w') as modified:
            modified.write(r"\datasource = img_url" + "\n" +
                           r"\ts_time = mjd" + "\n" +
                           r"\ts_value = base_PsfFlux_flux" + "\n" +
                           r"\positionCoordColumns = ra;dec;EQ_J2000" + "\n" +
                           data)
        tval = fc.upload_file('fout.tbl')
        fc.show_table(tval, tbl_id='Forced Phot')
        fc.show_xyplot(tbl_id='Forced Phot', xCol='mjd', yCol='base_PsfFlux_flux',
                       yError='base_PsfFlux_fluxSigma', yOptions='grid')
        if tv is not None:
            tv.url_or_path = tval
```

Add-on from Python: photometry on click



confluence.lsstcorp.org/display/DM/SUIT+demos

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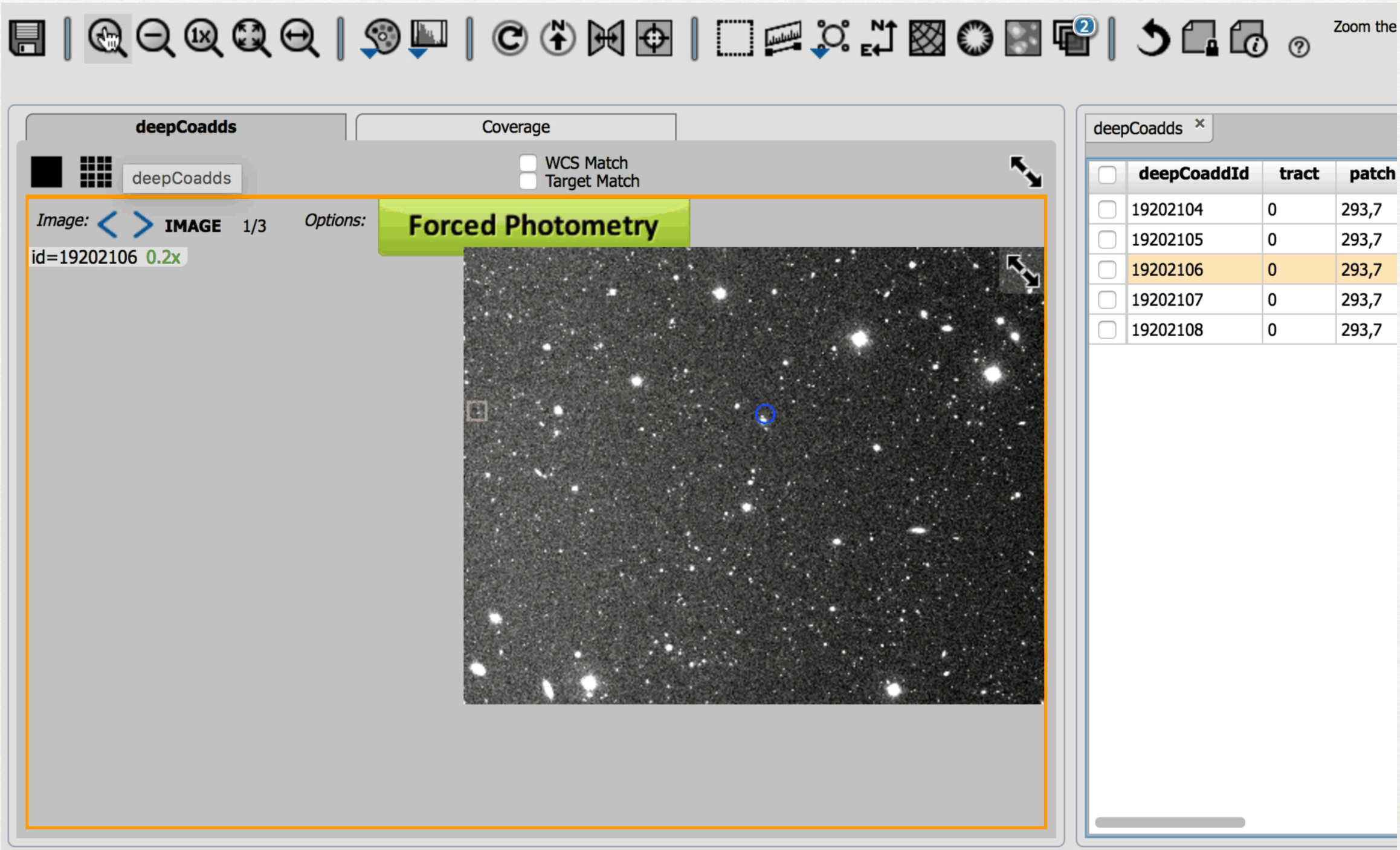

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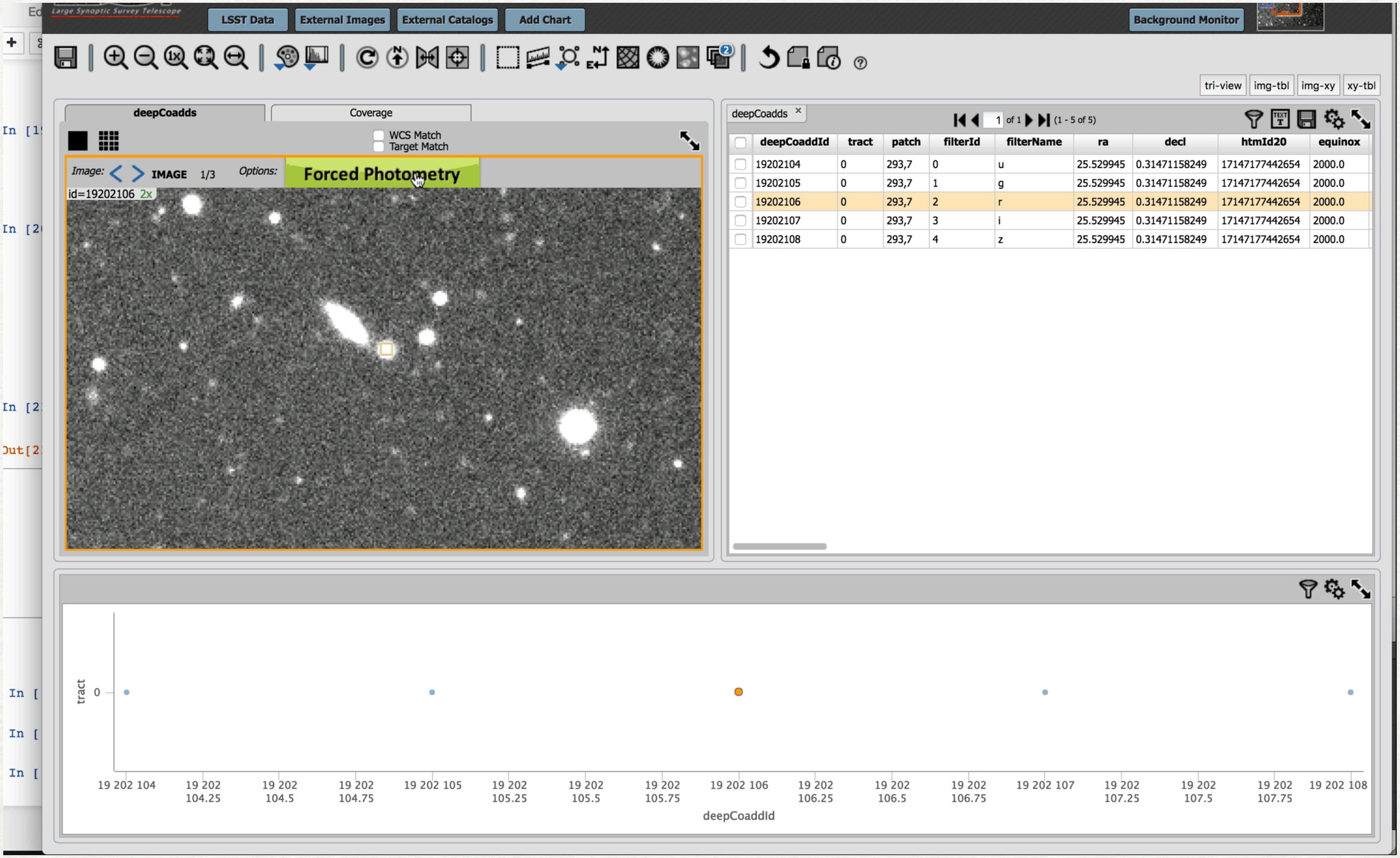
Table of results is returned to the browser



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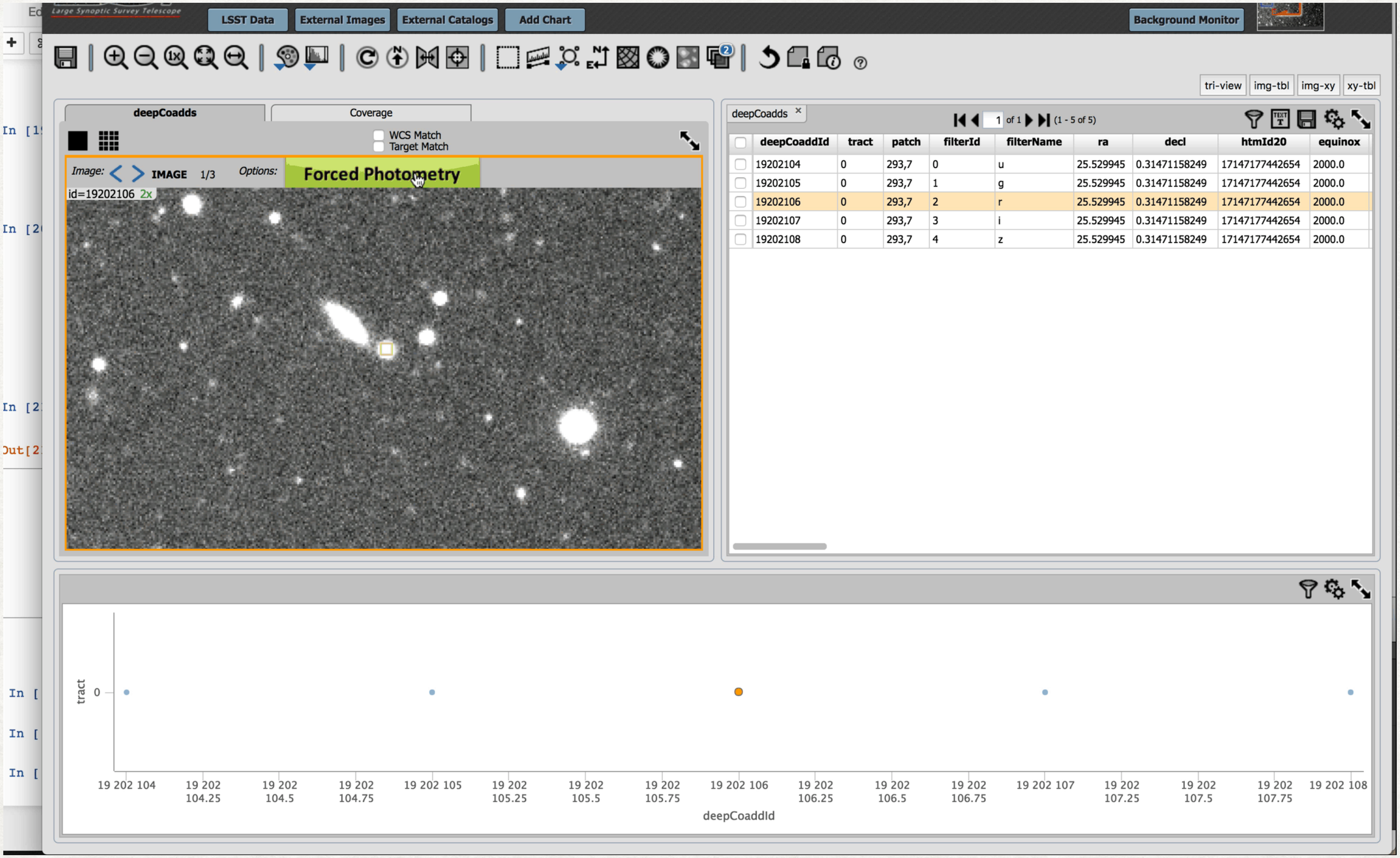

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Eventful Python objects that have a representation in the browser

ipywidgets.readthedocs.io

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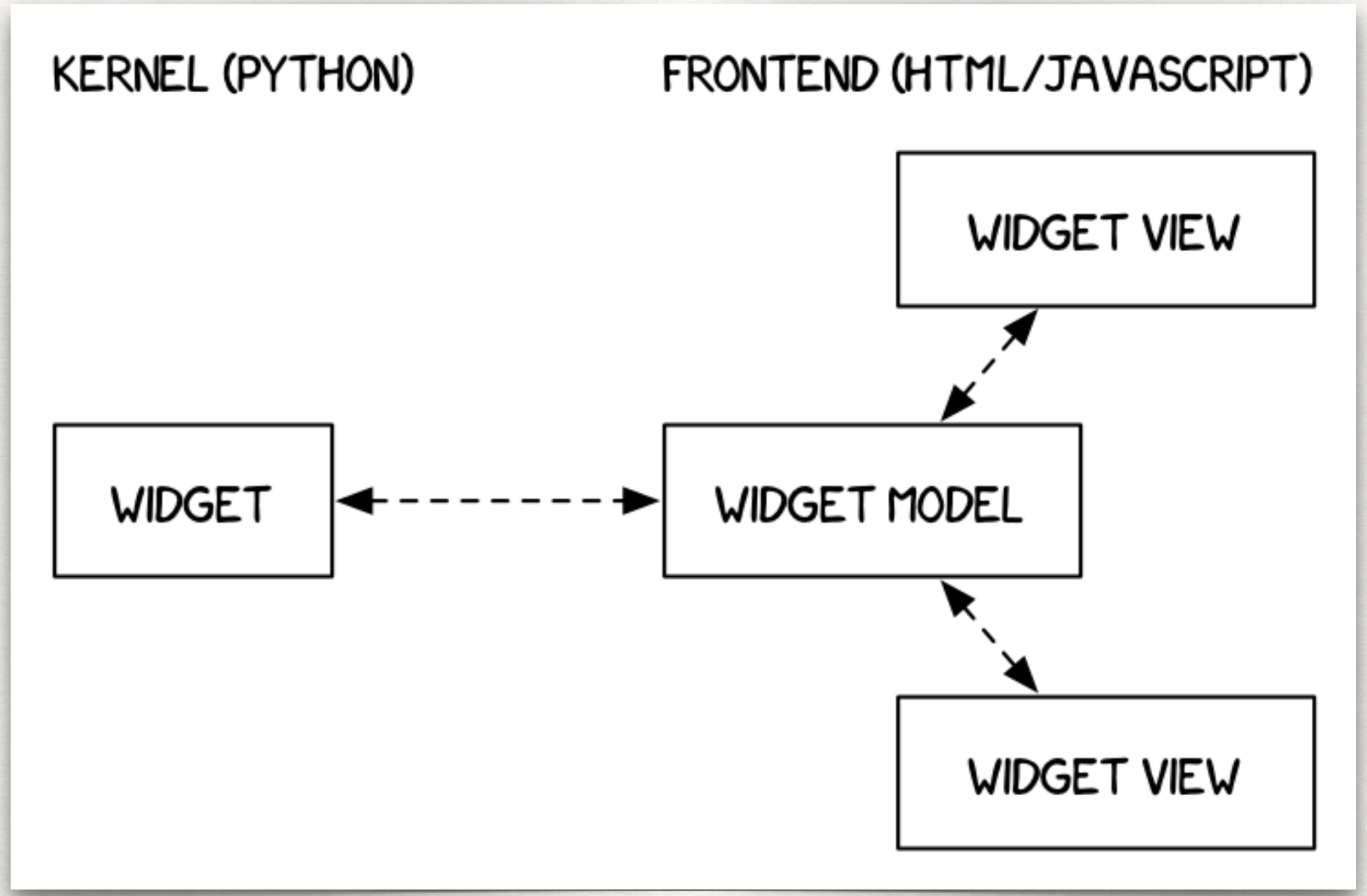

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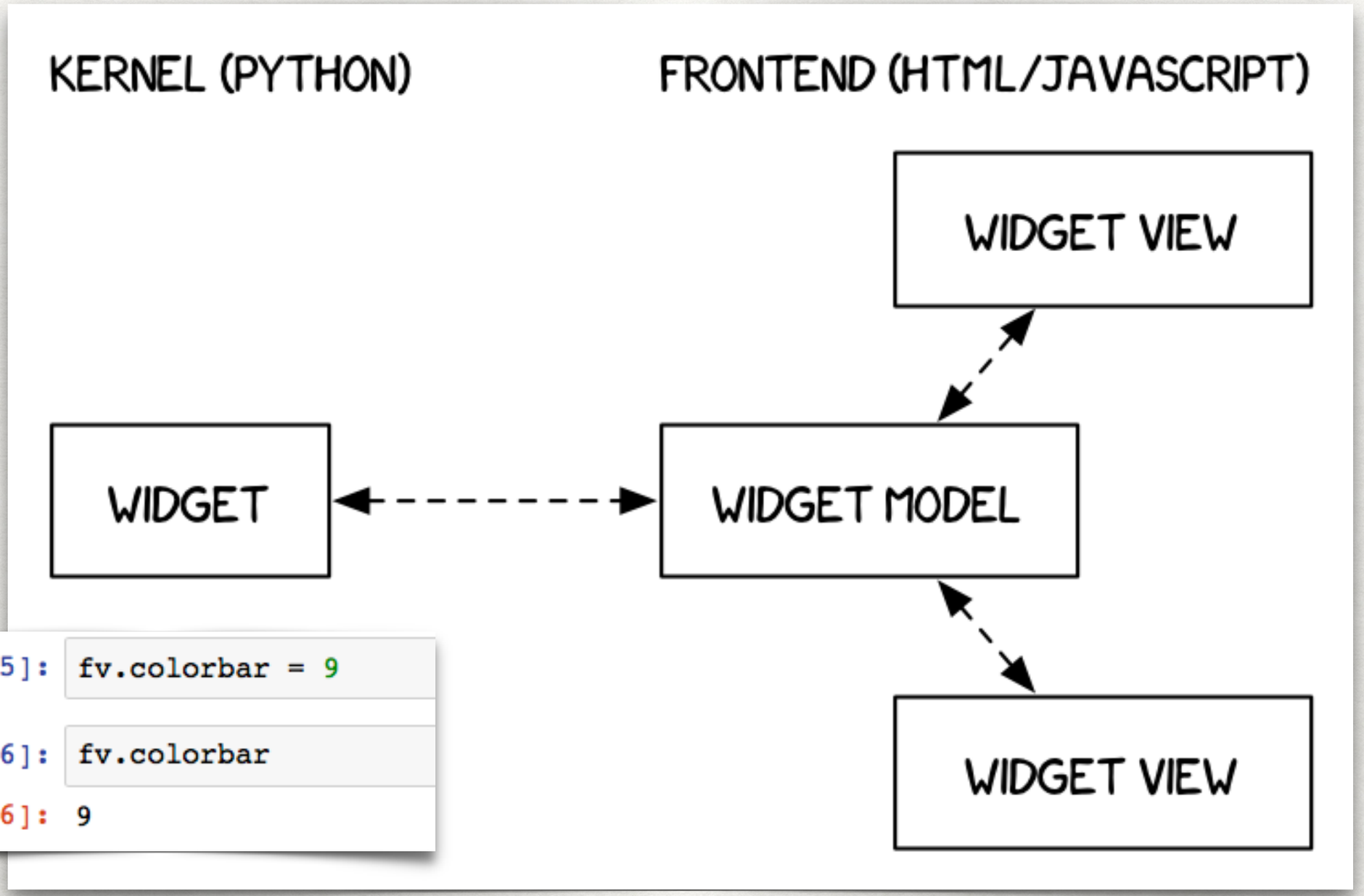
Eventful Python objects that have a representation in the browser




```
In [15]: fv.colorbar = 9

In [16]: fv.colorbar
Out[16]: 9
```

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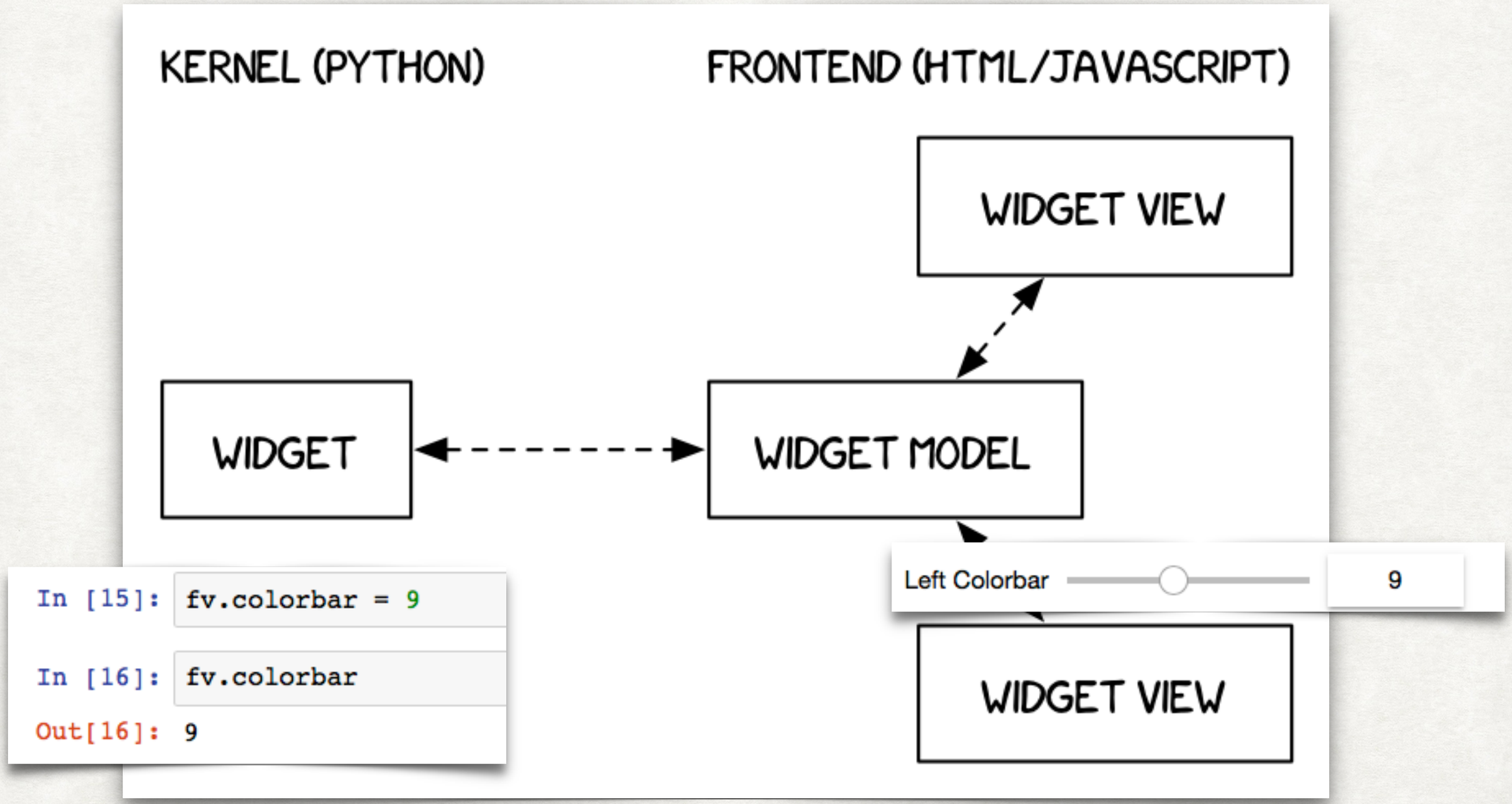

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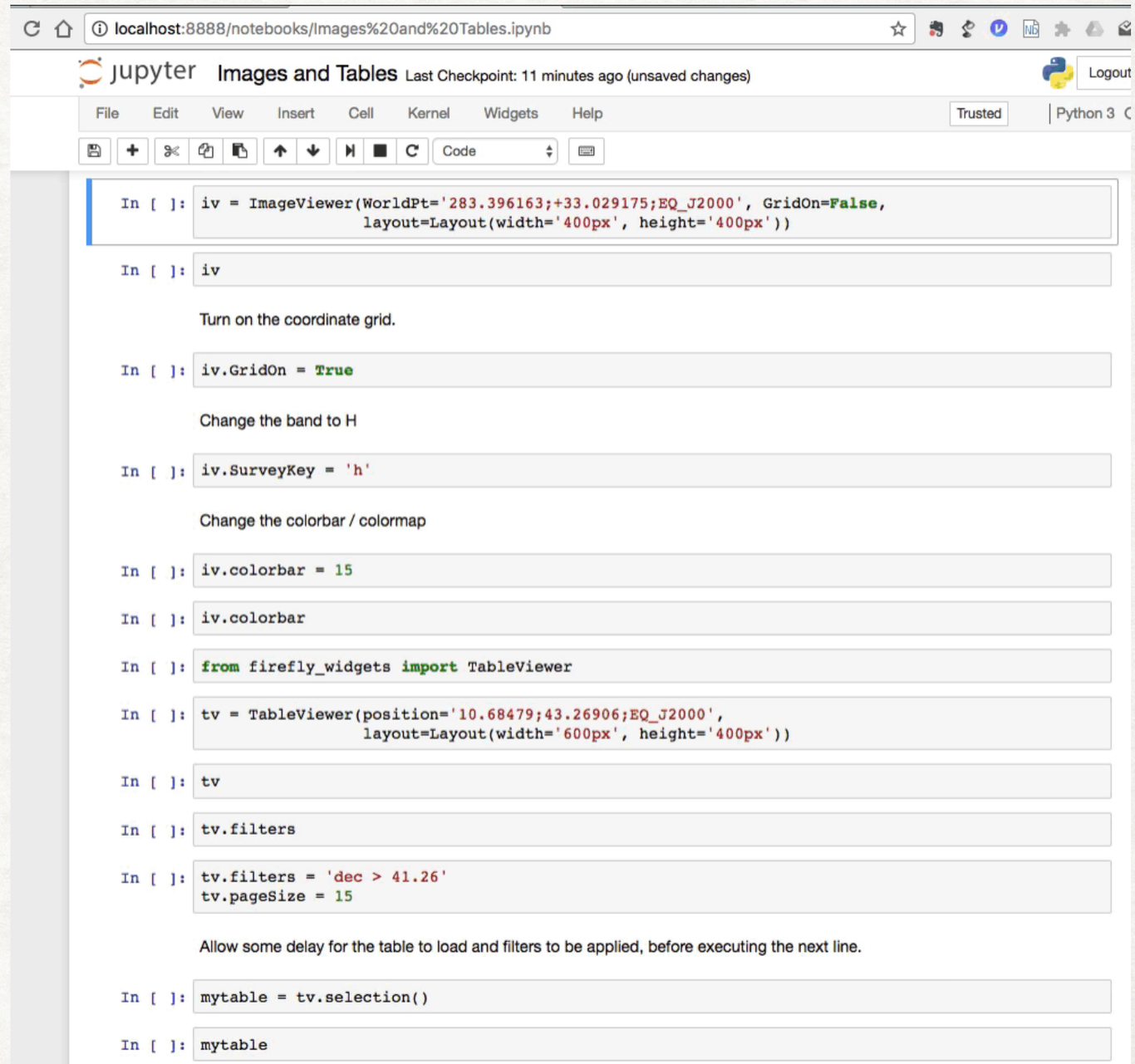
Firefly Widgets

- Available as **`firefly_widgets`**
- Interactive widgets for Images and Tables
- Widgets currently just past experimental state



github.com/Caltech-IPAC/firefly_widgets/examples

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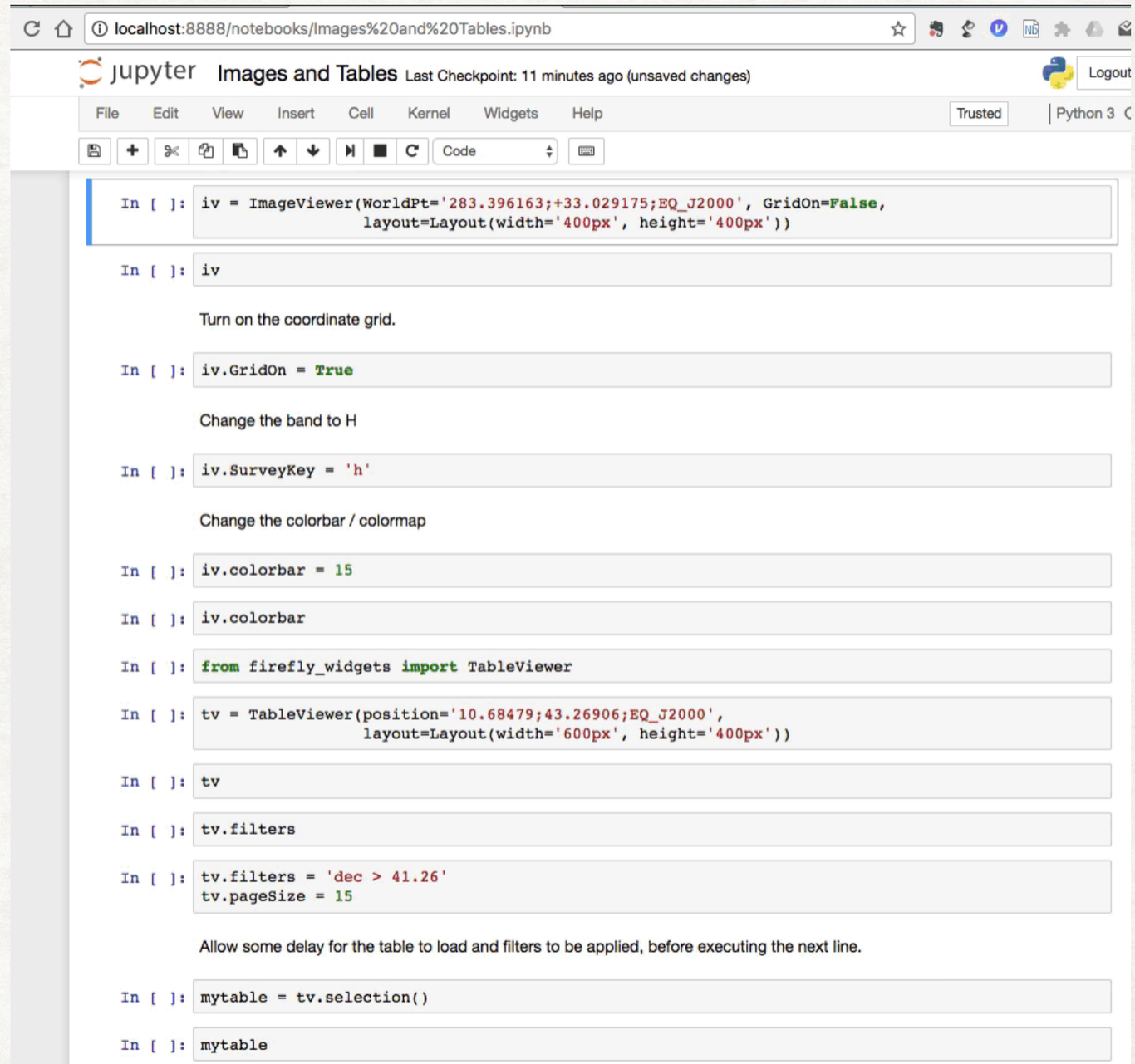

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Interactive Table Widget

localhost:8888/notebooks/Images%20and%20Tables.ipynb

jupyter Images and Tables Last Checkpoint: 21 minutes ago (autosaved)

File Edit View Insert Cell Kernel Widgets Help Trusted Python 3

```
In [ ]: from firefly_widgets import TableViewer

In [ ]: tv = TableViewer(position='10.68479;43.26906;EQ_J2000',
                         layout=Layout(width='600px', height='400px'))

In [ ]: tv

In [ ]: tv.filters

In [ ]: tv.filters = 'dec > 41.26'
        tv.pageSize = 15
```

Allow some delay for the table to load and filters to be applied, before executing the next line.

```
In [ ]: mytable = tv.selection()

In [ ]: mytable
```

If a path or URL is given to ImageViewer, it will read in the specified image instead of querying an archive.

```
In [ ]: mypath = ('http://web.ipac.caltech.edu/staff/roby/demo/wise-m51-band4.fits')
        fv = ImageViewer(url=mypath, GridOn=False,
                         layout=Layout(width='400px', height='400px'))

In [ ]: fv

In [ ]: fv.colorbar = 9

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Synchronize widget properties with other widgets

localhost:8888/notebooks/Image%20Colorbar%20Test.ipynb

jupyter Image Colorbar Test Last Checkpoint: a few seconds ago (unsaved changes)

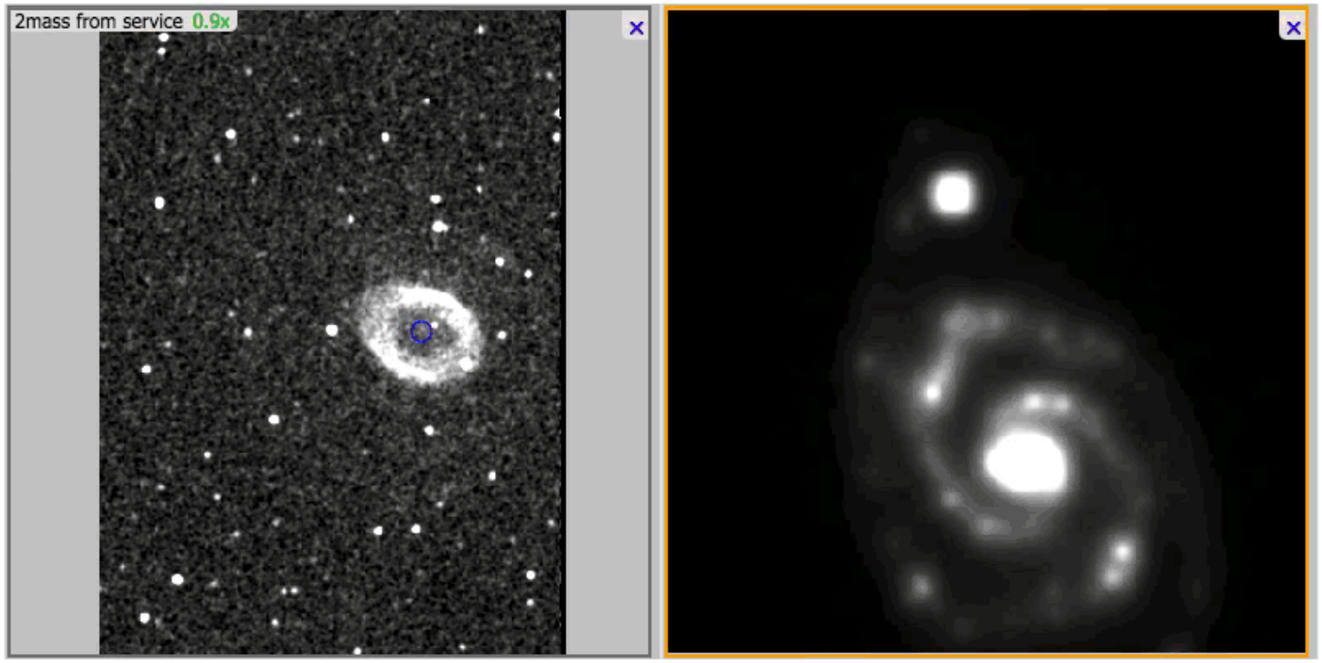
File Edit View Insert Cell Kernel Widgets Help Trusted Python 3

Markdown

In [9]:
```
left_link = jslink((iw1, 'value'), (iv, 'colorbar'))
right_link = jslink((iw2, 'value'), (fv, 'colorbar'))
both_link = jslink((iw1, 'value'), (iw2, 'value'))
```

In [10]:
```
HBox([VBox([iw1,iv]),VBox([iw2,fv])])
```

Left Colorbar 0 Right Colorbar 0



Unlink left column and right column

In [ ]:
```
both_link.unlink()
```

Re-link left column and right column

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Change the colorbar / colormap

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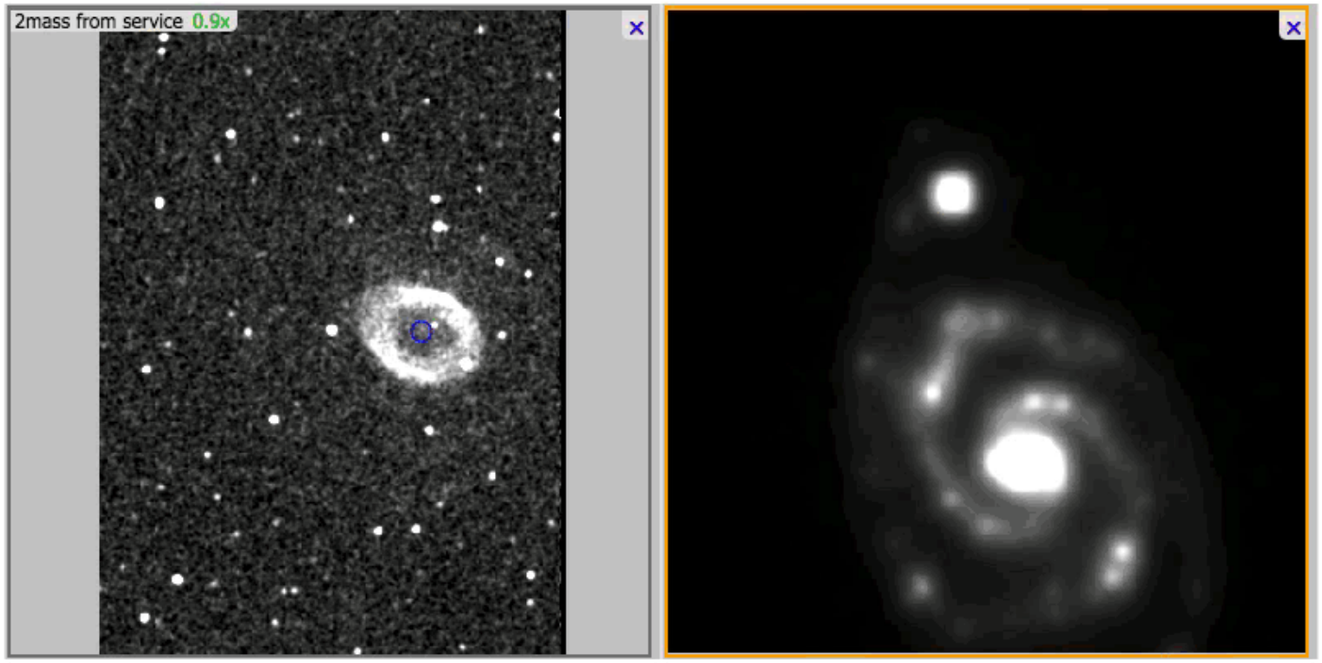

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- Use the cookiecutter template for Jupyter widgets
  - incorporates best practices for packaging
  - makes installation straightforward
- Development is light on Python side,
  heavy on Javascript
- Only some actions are good candidates for widget attributes
  - If action is done on the client — can change quickly
  - If action calls the server — can be slow

Python widgets for astronomy visualization

- The Firefly visualization system
- APIs to Firefly
- Example: Python interaction with the Firefly app
- Firefly widgets for Jupyter
- Resources

Resources for Firefly

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- See blog post at astropython.wordpress.com