

Astronomical Data Access in the Era of Scientific Cloud Computing

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LIneA Webinar
July 5th, 2018

Outline



- What does Data Access mean?
- Scientific Platforms and Gateways
- The Notebook revolution
- Scientific Cloud computing
- Containerization
- Kubernetes
- Applications

What is a Data Release?

Data Products

Interfaces

Documentation

Support

What is a Data Release?

Data Products

Preparation
Vetting
Checks
Consistency
Integrity
Redundancy
Data Model
Storage
Backups
Recovery
Hardware

Interfaces

Development
Version control
Licenses
Data Access
Languages
Sustainability
Guidelines
Scalability
Deployment
Hardware
Maintenance

Documentation

Papers
Web
Code
Data Model
Data Access
Data Format
Guidelines
Accessible
Maintenance
Contributions

Support

Short Term
Long Term
Forum
Help
Understanding
Deployment
Privacy
Maintenance
Focused
Distributed

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What is Data Access?

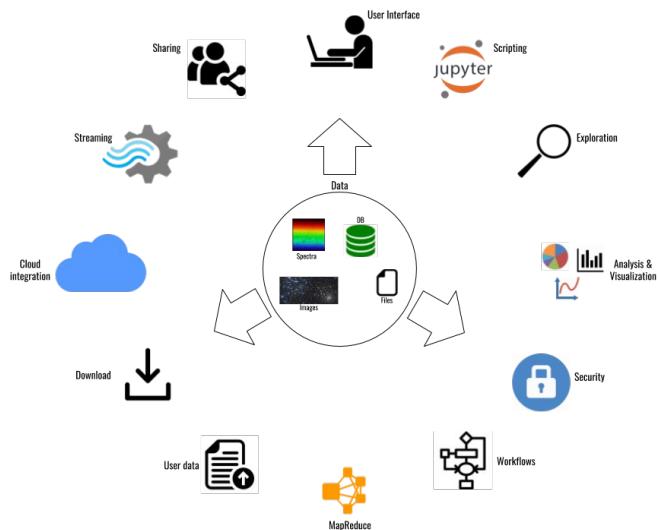


Several meanings around a central data repository with common components

- Storage
- Security
- Retrieving
- Interacting
- Modifying
- Understanding

Scientific Platforms and Gateways

... and many of these concepts are also associated with Scientific Platforms and Gateways (and Science portals, Science servers, etc.)



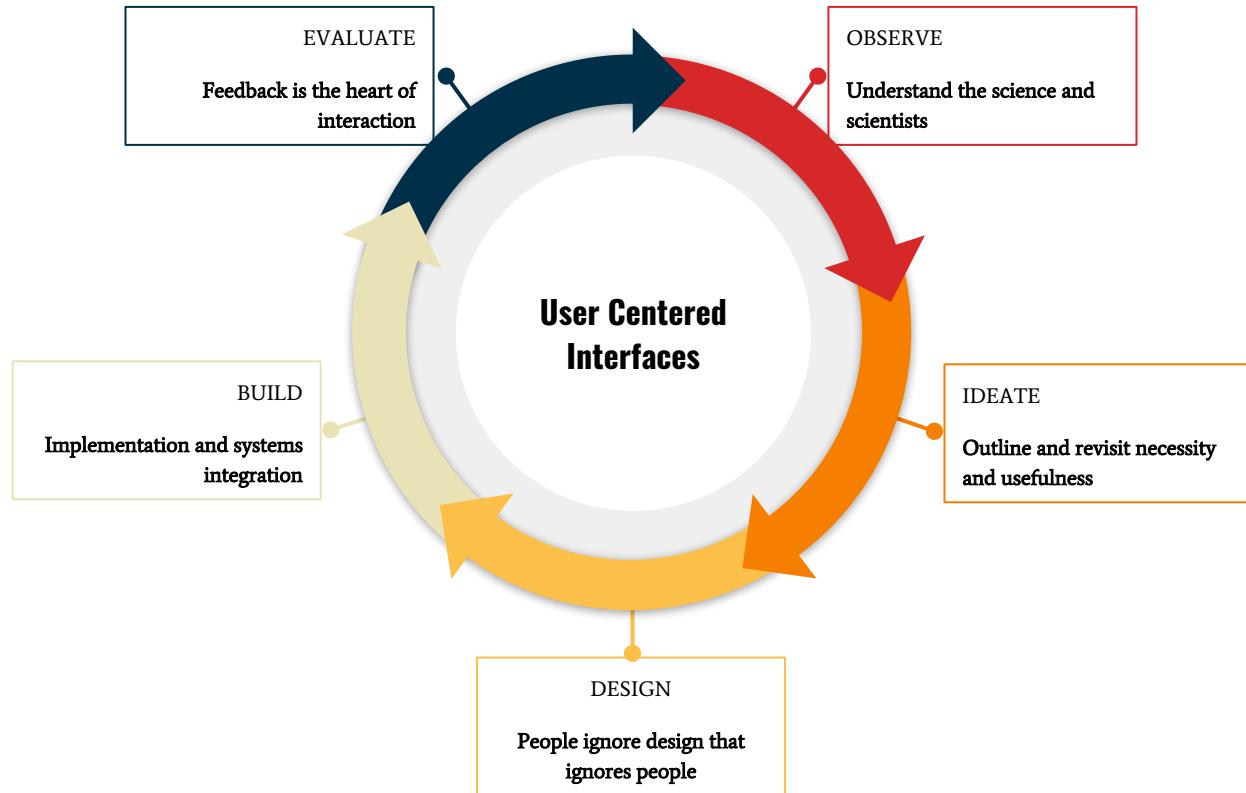
“Science gateways allow science & engineering communities to access shared data, software, computing services, instruments, educational materials, and other resources specific to their disciplines.”
(Science Gateways Institute)

“Science gateways is a place to do collaborative scientific related activities” (Me)

User (Scientist) Centered Design

Data Access would not exists without a user interface, but will only succeed if it is user driven.

“... In an ideal world, a user would remember every function after only a single use, but we do not live in idealism. The reality is that familiarity and intuition must be consciously designed into the interface”

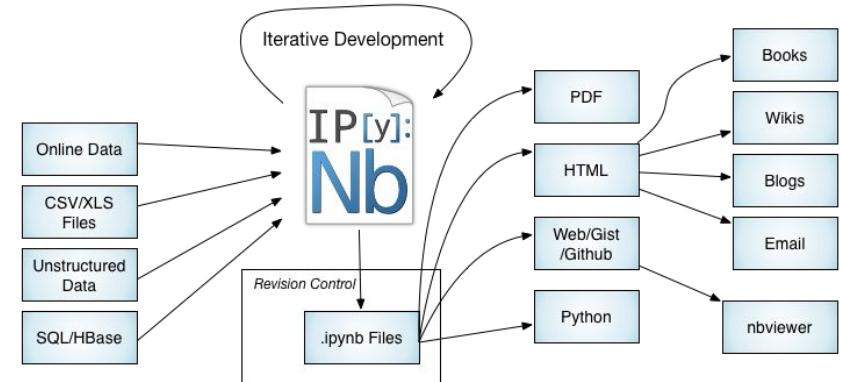
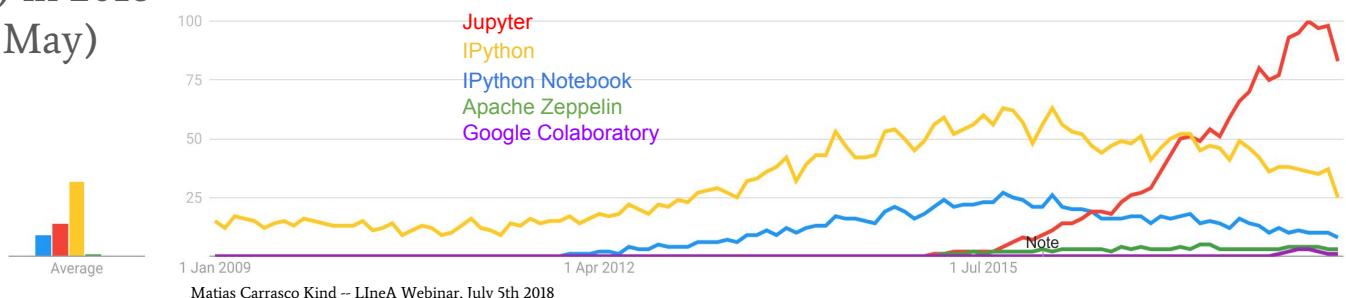


The Notebook Revolution



The Notebook Development

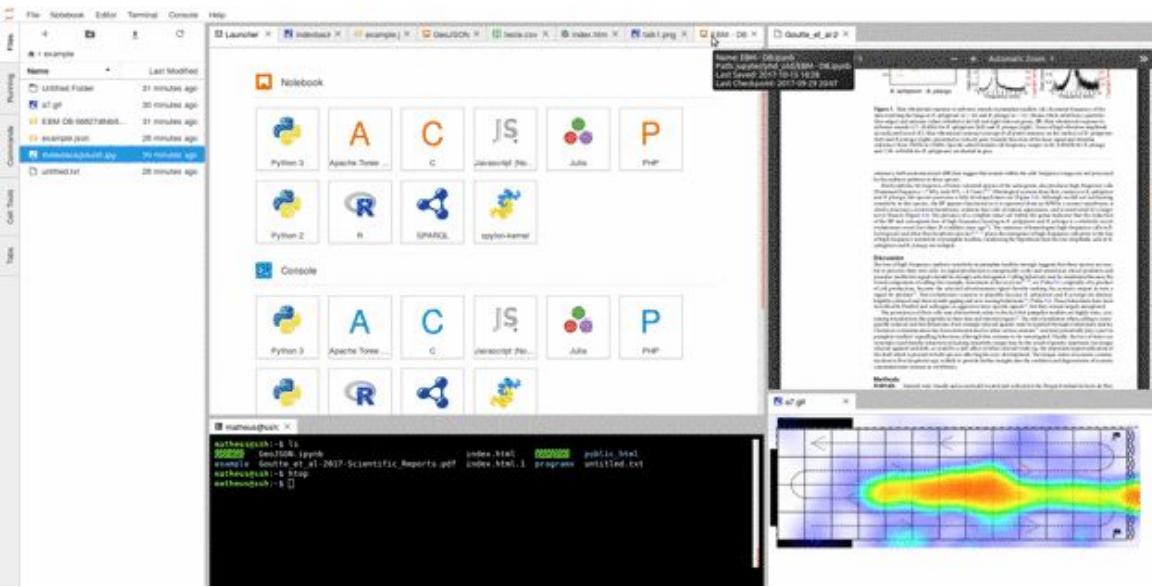
- Started from ideas like Matlab, Maple or Mathematica ~1988
- IPython has been around since 2001
- Sage Notebook released in 2005 (uses IPython)
- IPython Notebook was released in 2011
- IPython Notebook moved to Jupyter in 2014
- Apache Zeppelin created in 2015 (JVM and integrated with Apache Products)
- Beaker Notebook 2015 (moved to BeakerX)
- Google Colaboratory released in Oct 2017 (from ideas back in 2014)
- Cocalc (by SageMath) in 2018
- Jupyter Lab Beta 2.0 (May)



The Jupyter Notebook



- Computational narrative
- Scripting interface
- Scientific oriented interface
- Customizable
- Collaborative
- Adopted by many projects, DES, LSST
- Widgets
- Big Data Integration (Spark)
- Interactive plots
- Multiple Kernels (Python, R, Julia, Scala, etc.)

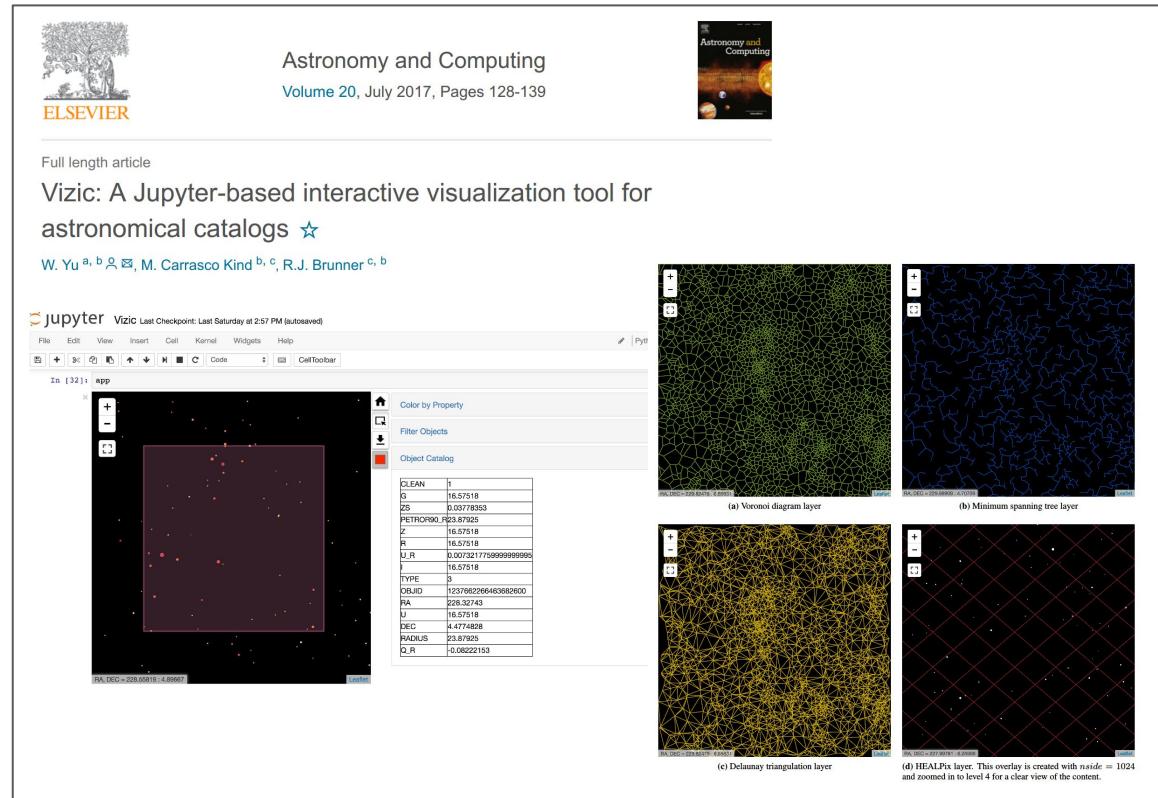


Jupyter in Astronomy

- Becoming standard practice to publish notebooks along with papers, including LIGO results (and many others)
- One of the most common tools used by Astronomers to do analysis
- ... and education
- Multi user interface adopted by many projects (DES, LSST, NASA, STScI, NOAO, etc)
- Tools and extensions developed by/for astronomers

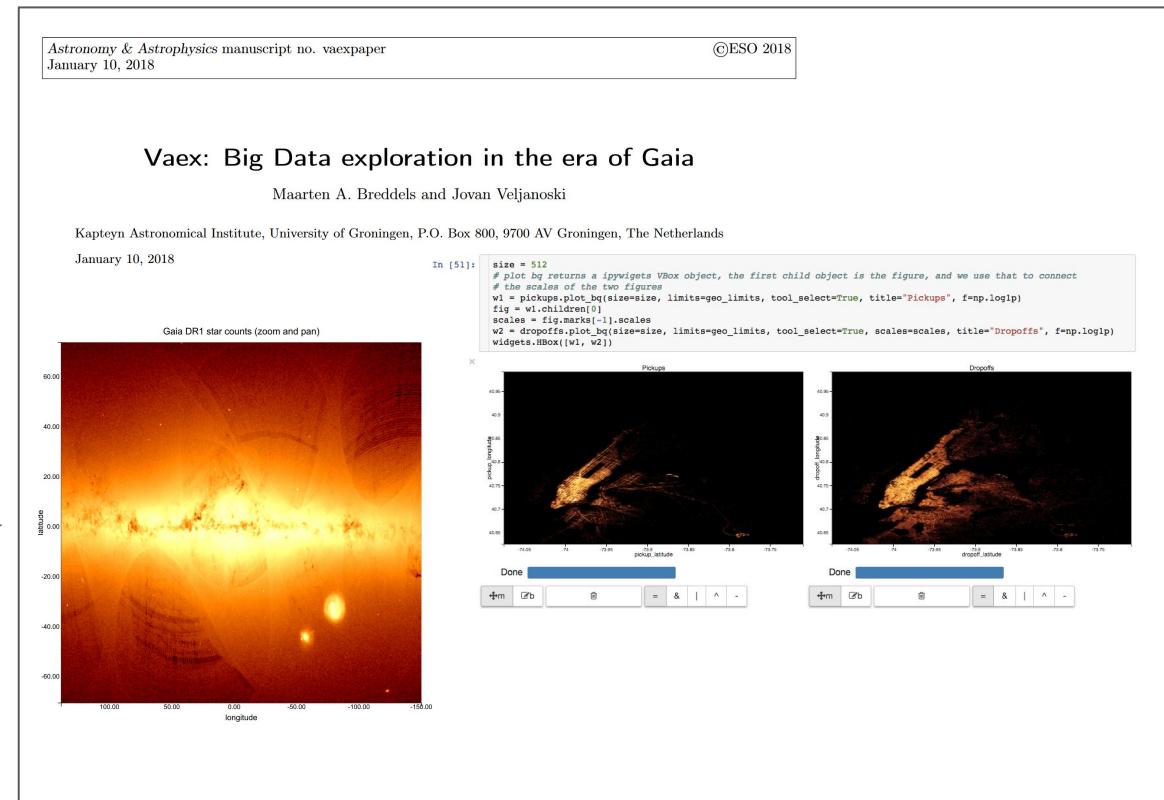
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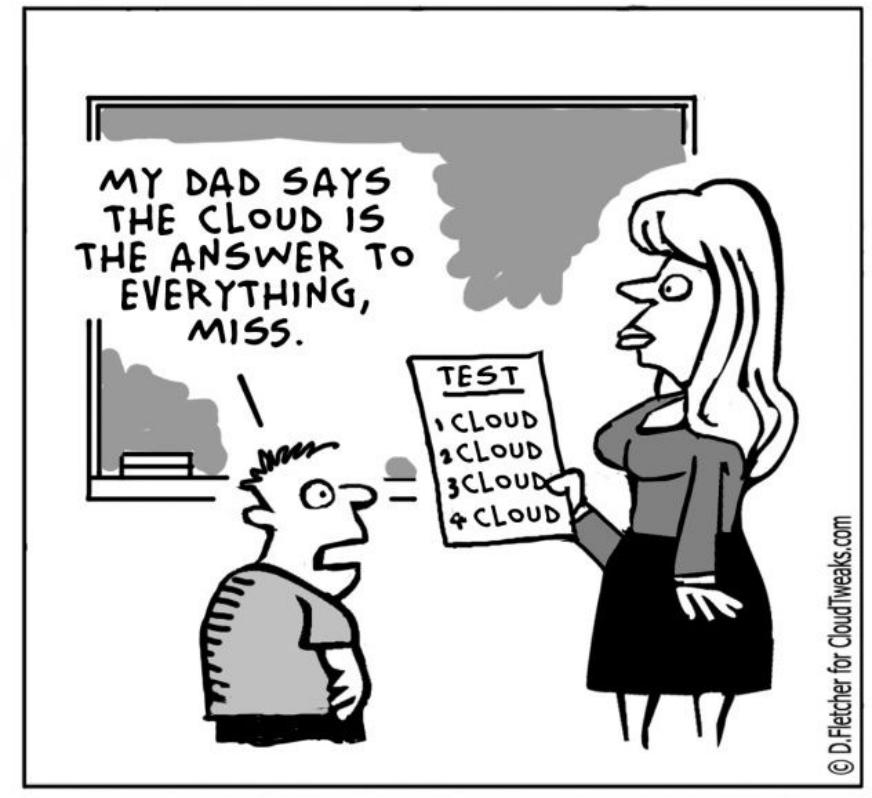
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Scientific Cloud Computing

Cloud is about how you do computing, not where you do computing.



Why we should be doing science on the cloud

- Remote and dynamic data (!= Big data)
- Big data ⇒ Data Gravity
- Remote software/server
- Easy to deploy*
- Asynchronous
- Web applications / Shareable
- Serverless applications
- Tablets/ChromeOS
- more...

Will we get to have Science
as a Service (SClaaS?)

Programming tools: Scala, IPython, Azure ML, ...

Frameworks: Spark, Hadoop, Yarn, HDInsight, Reef, Twister, Brisk

Software Defined Storage

Cloud OS

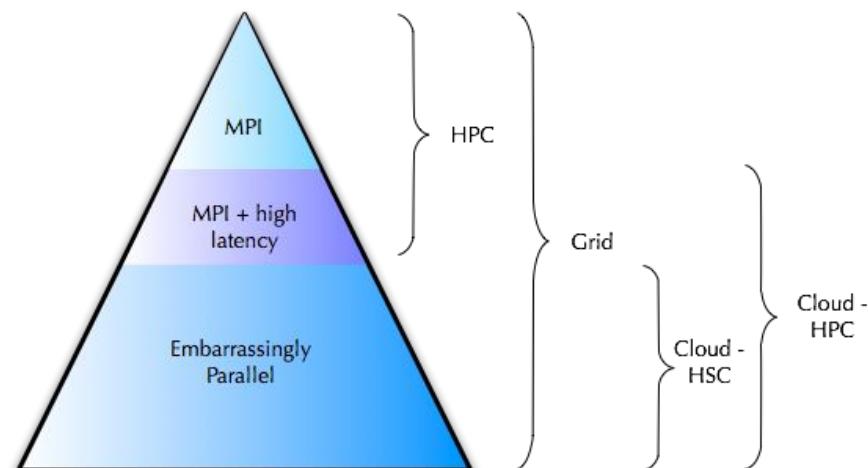
Software Defined Networks

Hardware Abstraction/Virtualization

*arguable

Why we shouldn't be doing science on the cloud

- Because there is no a real reason for it
- HPC is not there yet, large latencies and bad bisection bandwidth
... but HPC is adopting cloud technologies
- Full control on data and application
- Security concerns
- Faster development*
- Billing (if a commercial provider)
- more ...

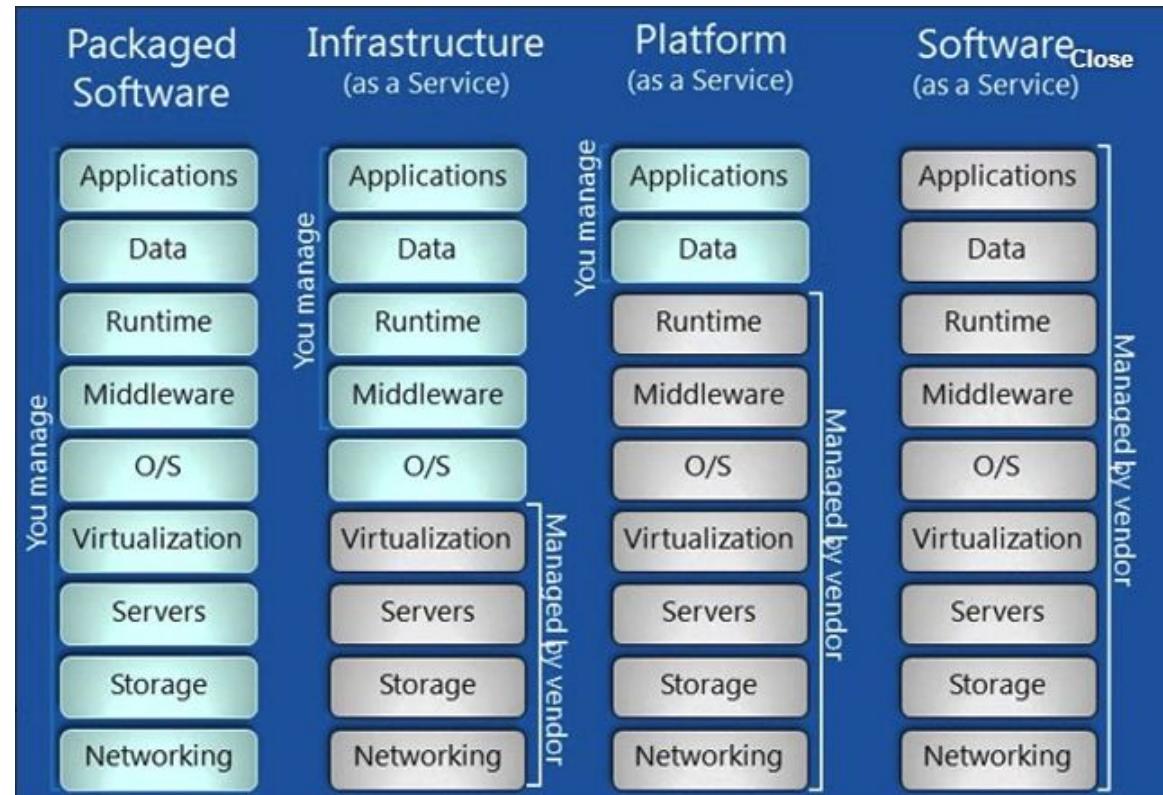


*arguable (CI, CD)

What kind of science?

- HTC vs HPC
- Interactive
- Small projects
- Visualizations
- Short term projects*

*arguable



Which Clouds?

Amazon Web Services (AWS) – 40%

Microsoft Azure – about 50% of AWS

Google Cloud – 3rd place

IBM Bluemix – growing fast

Salesforce, DigitalOcean, Rackspace,

1&1, UpCloud, CityCloud, CloudSigma,

CloudWatt, Aruba, CloudFerro, Orange,

OVH, T-Systems

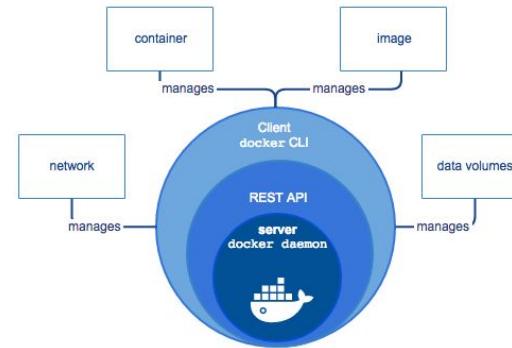


Cloud for Research: Aristotle,
Bionimbus, Jetstream, Chameleon, RedCloud



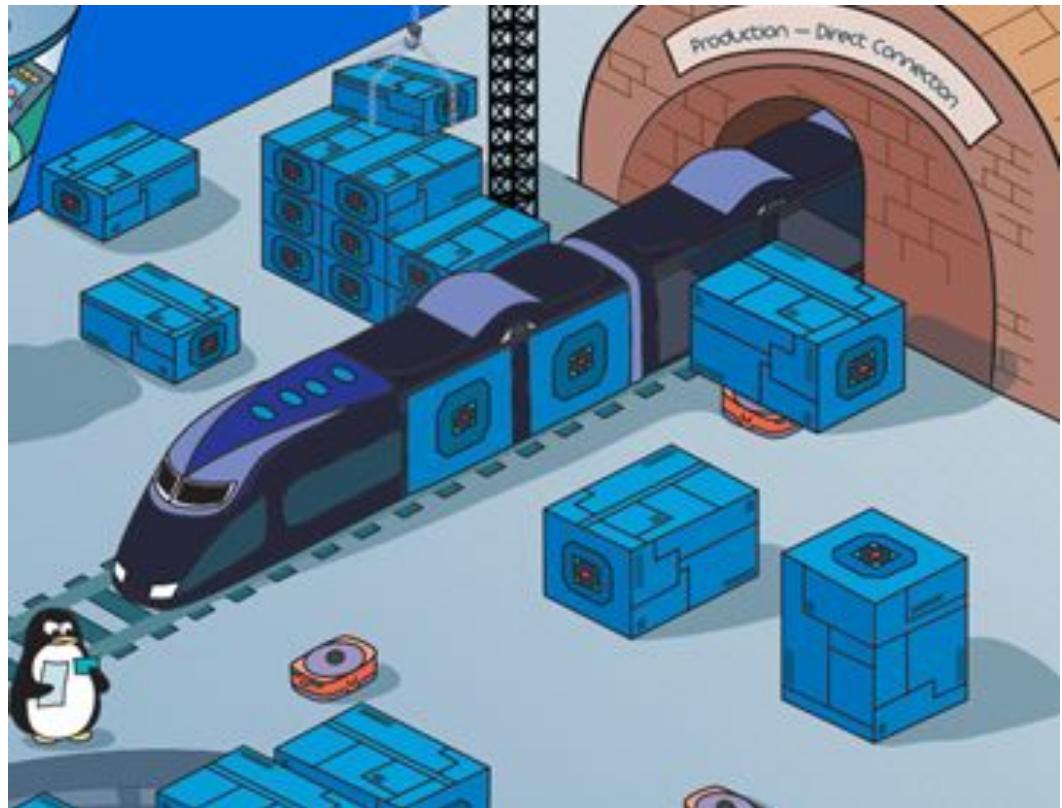
Containerization to the rescue

- It's been around for over 10 years, but popular since 2014 thanks to Docker
- Many other alternatives (rkt, kata, shifter, singularity, etc...)
- Lightweight, stand-alone, executable package of a piece of software that includes everything to run it
- Not just applications
- Software designed storage
- Software designed network



Container organization and orchestration

- We can create a container with an application inside, now what?
- Need to consider:
 - Resource needs
 - Fault tolerant
 - Load balancing
 - Storage management
 - Lifecycle
 - Service Discovery
 - Scalability



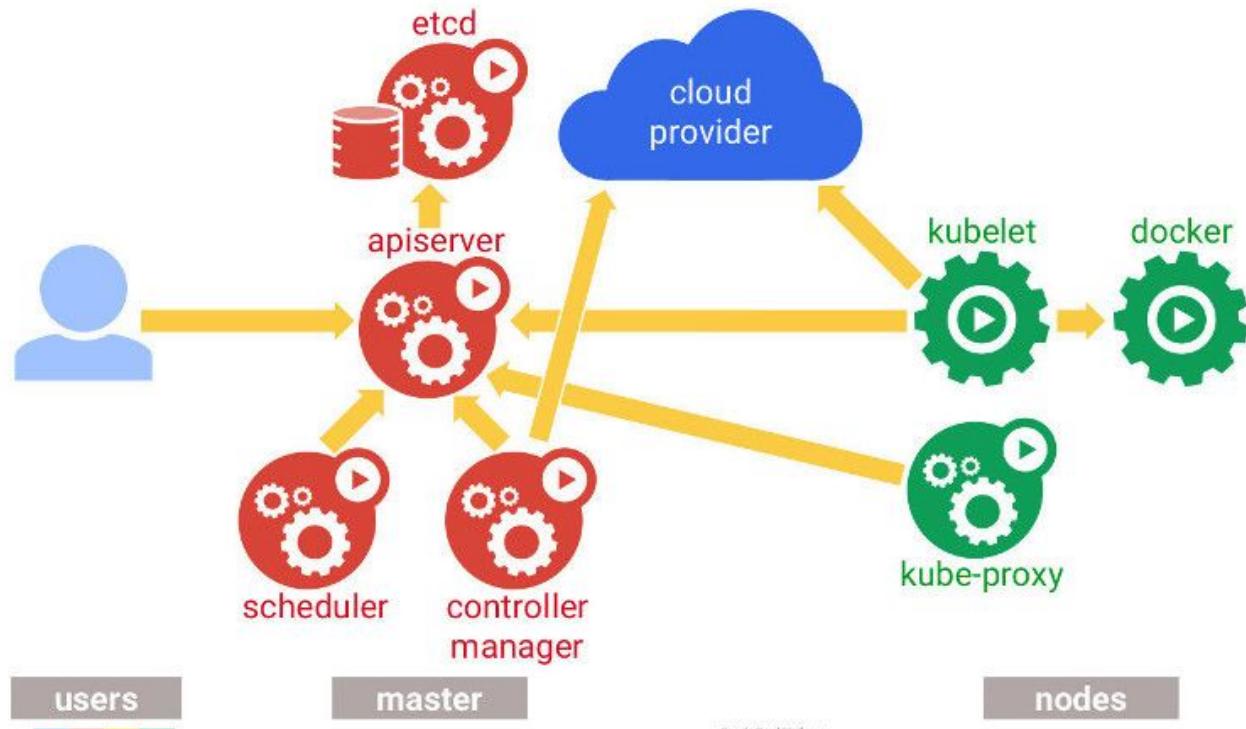
The Kubernetes Factor

- It solves all previous issues and more (not the only one but most popular)
- Open source container management and orchestration platform
- Developed by Google, made open sourced
- One of top 5 most commented open source repositories and #2 in number of pull request
- Standard within all cloud platforms
- Flexible and extensible, customize schedulers
- Is changing the cloud computing paradigm



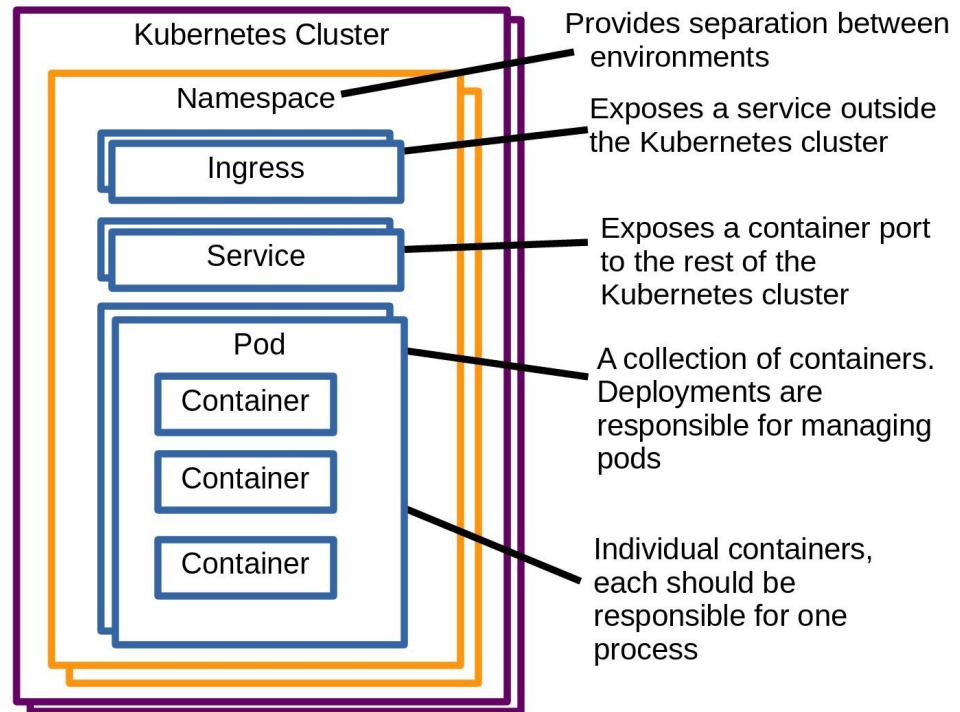
Kubernetes Overview

- Cloud democratization
- Easy deployment
- Controls most of the aspects
- Adopted at NCSA, CERN, LSST, NASA
- Edge Computing
- Scalability
- Federation
- Resource Manager

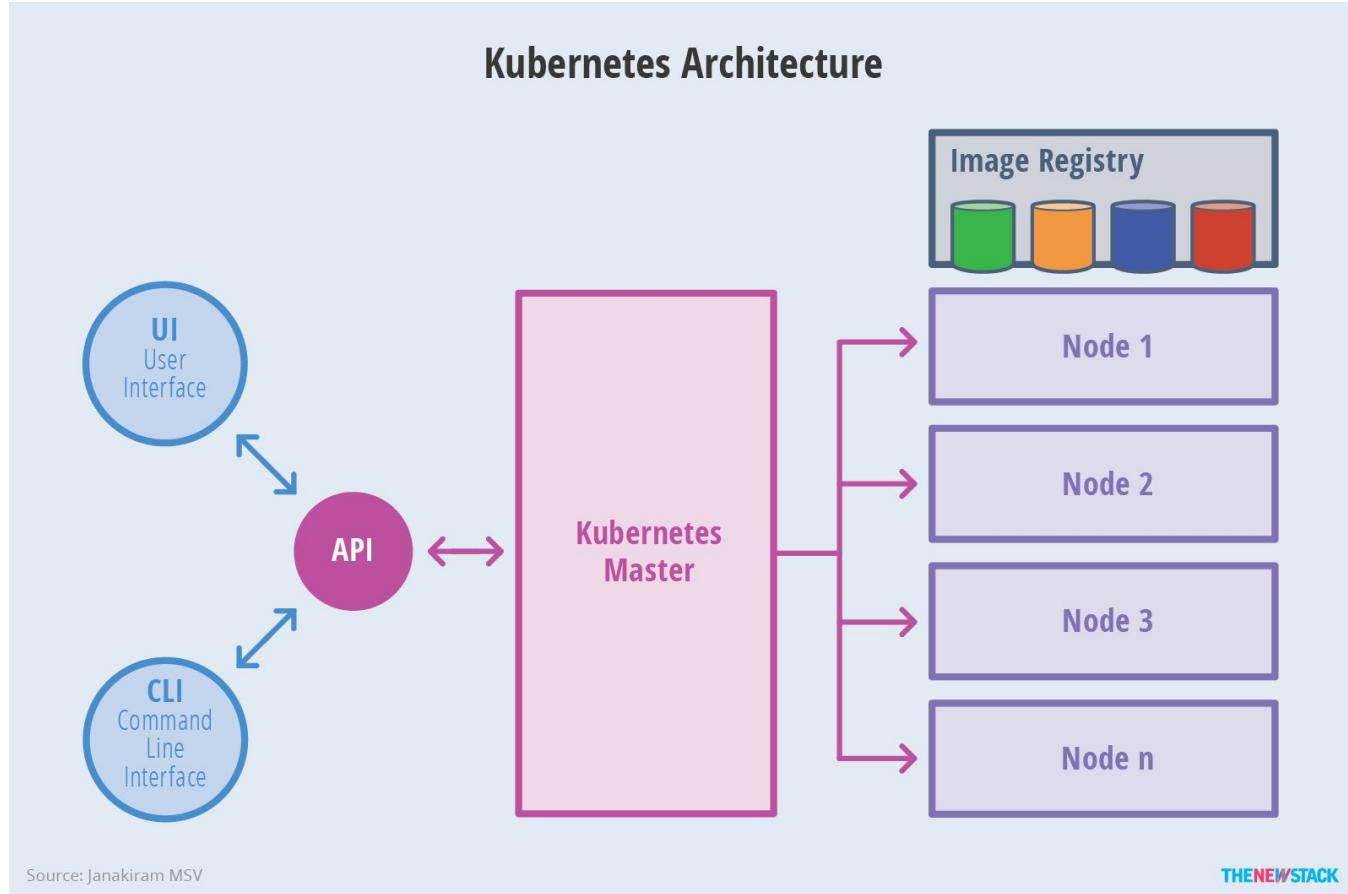


Kubernetes Key Concepts

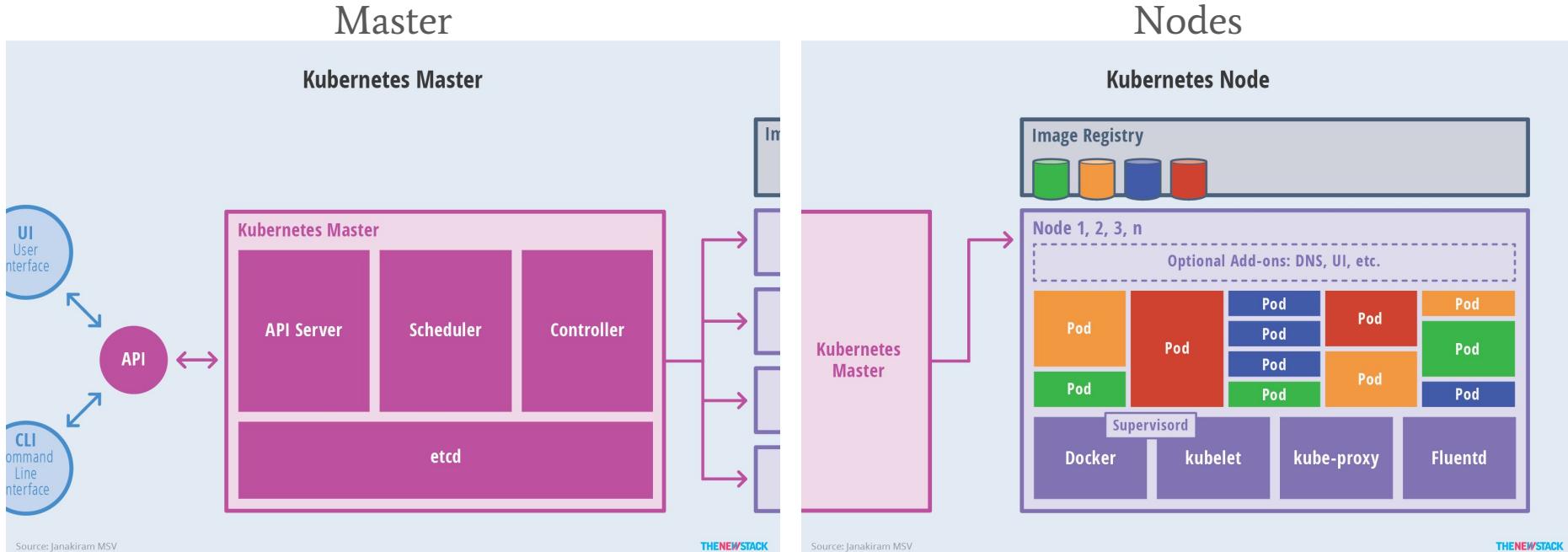
- **Pod** - A group of Containers
- **Labels** - Labels for identifying pods
- **Kubelet** - Container Agent
- **Proxy** - A load balancer for Pods
- **etcd** - A metadata service
- **cAdvisor** - Container Advisor provides resource usage/performance statistics
- **Replication Controller** - Manages replication of pods
- **Scheduler** - Schedules pods in worker nodes
- **API Server** - Kubernetes API server



The Kubernetes Architecture



The Kubernetes Architecture



Applications



- DES Infrastructure
- LSST Science Platform (next week's talk)
- Anomaly detection service

The Dark Energy Survey



- 4 meters telescope, 520 Mpx camera
- 5 year survey, $\frac{1}{8}$ of the sky, Telescope in Chile, data @ NCSA, about to start 6th season
- Main Goal: To constrain the models of the Universe regarding Dark Energy and Dark Matter.
- Many other Science Cases! (New dwarf planet, New galaxy satellites, Supernovae, etc)
- 1 - 3 TB of data per night, 1 PB of data
- Processing done at FermiGrid, Campus Cluster and Blue Waters
- Thousands of images and billions of rows, ~500 millions objects
- 1st Public Data Release in January 2018
- NCSA provide means to access and interact with data → Containers

The DES Data Access

Challenges:

- Data access wasn't very clear in original proposal
- People
- Time
- Collaborations Needs
- All the rest of technical challenges



- DES Survey: Gold (Data) Mine
- DESDM: Excellent job at mining the data
- Consumers outside the mine
- Need to bring/expose gold (data) outside
- Tools and interfaces
- DES DR1 is out!

easyaccess: DES command line tool

```
matias@XPS:~$ e
```

- DES DB in Oracle
- Specifically designed for DES (internal and public)
- Enhanced SQL command line interpreter in Python
- Astronomer friendly
- Python API, web interface
- There are many other CLI and GUI clients.
- Needed a simple tool, easy to use and install
- Autocompletion
- Load/Save to hdf5, fits, csv

DES Labs: Collection of containerized tools for DES



DES Labs

- March 2015
- Used by the Collaboration
- Running using Kubernetes at NCSA cloud
- Currently being migrated to match DR1 Infrastructure

Easyaccess web



Jupyterhub + easyacces



DES cutouts



Footprint



Easyaccess online



DESDM Services status



External Links

Science Server



NOAO Data Lab



CosmoHub



NCSA DESaccess: DR1 Infrastructure



DARK ENERGY SURVEY desaccess

mck
mcarras2@illinois.edu[Home](#)[DB access](#)[DR1 Table Schema](#)[Example Queries](#)[Cutout Service](#)[DR1 Footprint](#)[My Jobs](#)[DES JupyterLab](#)[Help](#)

Welcome Ma!

[DB ACCESS](#)

Oracle SQL web-client

[More...](#)[DR1 TABLE SCHEMA](#)

Browse all tables

[More...](#)

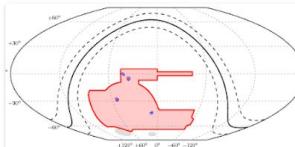
```
SELECT dr1.RA,dr1.DEC,dr1.COADD_OBJECT_ID
FROM dr1_main sample(0.01) dr1
WHERE
dr1.MAG_AUTO_G < 18 and
dr1.WAVG_SPREAD_MODEL_I + 3.0*dr1.WAVG_SPREADERR_M
dr1.WAVG_SPREAD_MODEL_I + 1.0*dr1.WAVG_SPREADERR_M
dr1.WAVG_SPREAD_MODEL_I - 1.0*dr1.WAVG_SPREADERR_M
dr1.WAVG_SPREAD_MODEL_I > -1 and
dr1.IMAFLAGS_ISO_G = 0 and
dr1.IMAFLAGS_ISO_R = 0 and
dr1.IMAFLAGS_ISO_I = 0 and
```

[EXAMPLE QUERIES](#)

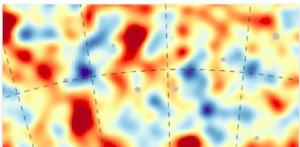
See some example queries as a start

[More...](#)[CUTOUT SERVICE](#)

Retrieve cutouts from specific area

[More...](#)[DR1 FOOTPRINT](#)

Interactive globe

[More...](#)[MY JOBS](#)

List of submitted jobs

[More...](#)[DES JupyterLabs](#)

(Beta) Jupyter Labs

[More...](#)[HELP](#)

Help form

[More...](#)

des.ncsa.illinois.edu/easyweb

NCSA DESaccess: DB access



DARK ENERGY SURVEY desaccess



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Home

DB access

DR1 Table Schema

Example Queries

Cutout Service

DR1 Footprint

My Jobs

DES JupyterLab

Help

Query box

Insert your query in the box below. Data results for "Quick" Jobs (30 sec.) will be displayed at the bottom.

```

1 --
2 -- Example Query --
3 -- This query selects stars around the center of globular cluster M2
4 SELECT
5 COADD_OBJECT_ID,RA,DEC,
6 MAG_AUTO_G,G,
7 MAG_AUTO_R,R,
8 WAVG_MAG_PSF_G,G_PSF,
9 WAVG_MAG_PSF_R,R_PSF
10 FROM DR1_MAIN
11 WHERE
12 RA between 323.36-0.12 and 323.36+0.12 and
13 DEC between -0.82-0.12 and -0.82+0.12 and
14 WAVG_SPREAD_MODEL_I + 3.0*WAVG_SPREADERR_MODEL_I < 0.005 and
15 WAVG_SPREAD_MODEL_I > -1 and
16 IMAFLAGS_ISO_G = 0 and
17 IMAFLAGS_ISO_R = 0 and
18 FLAGS_G < 4 and
19 FLAGS_R < 4
20

```

Submit Job

Clear

Check

Quick

See Examples

Output file (.csv, .fits or .h5). Enable in order to submit.

Output file



Options:

Compressed files (csv and h5 files). Slightly longer jobs but smaller files

Job Name (optional)

Send email after completion

Email

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NCSA DESaccess: Cutouts Service

DARK ENERGY SURVEY desaccess

Coadds Images Cutout Form

Upload the file with the positions or enter the positions by hand and run the desthumb generator

Upload File (csv, with RA,DEC as uncommented header)

Enter Values

Xsize (in arcminutes): 1.0

Ysize (in arcminutes): 1.0

Job Name

Send email on completion

Return just list of files (do not produce and display pngs, i.e. faster)

Submit Job

Clear Form

mck
mcarras2@illinois.edu

?

Home

DB access

DR1 Table Schema

Example Queries

Cutout Service

DR1 Footprint

My Jobs

DES JupyterLab

Help

des.ncsa.illinois.edu/easyweb

NCSA DESaccess: Asynchronous Jobs



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Home

DB access

DR1 Table Schema

Example Queries

Cutout Service

DR1 Footprint

My Jobs

DES JupyterLab

Help

My Jobs

#	Status	Job Name	Job type	Execution time (s)	Cancel Job	Queries	Results	Files
0	Green	Name: Job id: 6b4ca2cb-b544-4441-9bfb-58cd4968a338 6 days and 0 hours ago (Expired)	query	0	X	Query	Cutouts	Files
1	Green	Name: Job id: daf5ee3c-461e-42ed-8efb-5fcfbf684047 6 days and 0 hours ago (Expired)	cutout	1	X	Query	Cutouts	Files
2	Green	Name: testapi Job id: 0d6c5a58-b00a-4798-834f-9816c6fa98e5 7 days and 4 hours ago (Expired)	cutout	3	X	Query	Cutouts	Files
3	Green	Name: testapi Job id: 12861656-8075-4629-8e4f-fd4378013634 7 days and 4 hours ago (Expired)	cutout	3	X	Query	Cutouts	Files
4	Green	Name: testapi Job id: d9a37fe9-209b-4296-b87d-c6567cde0649 7 days and 4 hours ago (Expired)	cutout	1	X	Query	Cutouts	Files
5	Green	Name: Job id: 6d10cf32-3cd6-4050-bb90-344268dd615f 7 days and 5 hours ago (Expired)	cutout	1	X	Query	Cutouts	Files
6	Red	Name: testapi Job id: b85e747-5201-4e49-a0eb-2fb6b7f266de 7 days and 5 hours ago (Expired)	cutout	-1	X	Query	Cutouts	Files
7	Green	Name: Job id: f8be56a-4685-49ff-b7be-603310ccdeb 8 days and 16 hours ago (Expired)	query	577	X	Query	Cutouts	Files
8	Green	Name: Job id: df8a57c4-b1d5-4332-80d5-a08a27b537d9 8 days and 16 hours ago (Expired)	query	1042	X	Query	Cutouts	Files
9	Red	Name: Job id: 7ffab550-4d38-441f-a037-ed659b3b79c9 8 days and 16 hours ago (Expired)	query	-1	X	Query	Cutouts	Files
10	Green	Name: Job id: fcacaaec-9d63-45a4-92f2-4f847b9b415c 8 days and 16 hours ago (Expired)	query	9	X	Query	Cutouts	Files
11	Green	Name: Job id: a88b79cc-fd71-4e20-a33d-92b5be98106f 8 days and 17 hours ago (Expired)	query	9	X	Query	Cutouts	Files
		Name: demo1						

REFRESH

DELETE

des.ncsa.illinois.edu/easyweb

NCSA DESaccess: Footprint and Jupyter Labs

DARK ENERGY SURVEY desaccess

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mcarras2@illinois.edu

DES DR1 Footprint

Use the footprint tool to search a tile by position or name.
Double click to select a tile.

Position (ra,dec) Tilename

Coordinates DR1 TILES HPIX nside=32

Tile properties

Name :
Tile Center :
No Objects :
RA Corners :
DEC Corners :

Get Tile Files

Click [here](#) to get access to all the tiles

Home
DB access
DR1 Table Schema
Example Queries
Cutout Service
DR1 Footprint
My Jobs
DES JupyterLab
Help

DARK ENERGY SURVEY desaccess

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DES Jupyter Labs (Beta)

This feature is experimental only. Please use with caution.
You can launch, access and delete your Jupyter Notebook. This Notebook will run with 1 CPU and 2GB of RAM.

Deploy Lab Delete Lab

Status

● Ready
Status: Running
 Go To Lab

REFRESH

Home
DB access
DR1 Table Schema
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des.ncsa.illinois.edu/easyweb

NCSA DESaccess: Labs with access to Jobs and easyaccess

File Edit View Run Kernel Tabs Settings Help

Running

Commands

Cell Tools

Files

+

basics_plotting x

Markdown v

Python 3

Name Last Modified

- 0d6c5a58-b00a-4798... 7 days ago
- 0fa487cd-75a5-4015... 7 days ago
- 12861656-8075-4629... 7 days ago
- 1aae7465-aef6-44fc... 7 days ago
- 507683dc-53d6-4033... 7 days ago
- 6b4cac2b-b544-44e1... 6 days ago
- 6d10cf32-3cd6-4090... 7 days ago
- 7ffd5b50-4d38-441f-a... 10 hours ago
- 810a2aee-a8d7-4356... 16 days ago
- 8b7290af-8a2e-4ace-... 7 days ago
- b8fea56a-4685-49f9-... 10 hours ago
- b88b79cc-fd71-4ed0-... 10 hours ago
- b85ea747-5201-4e49... 7 days ago
- d3822272c23d4a3b6c... 7 days ago
- d9a37fe9-209b-4296-... 7 days ago
- dafee3c-461e-42ed-... 6 days ago
- df8a57c4-b1d5-4332-... 10 hours ago
- fcaacdec-96d3-45a4-... 10 hours ago
- 0d6c5a58-b00a-4798... 7 days ago
- 0d6c5a58-b00a-4798... 7 days ago
- 12861656-8075-4629... 7 days ago
- 12861656-8075-4629... 7 days ago
- 6b4cac2b-b544-44e1... 6 days ago
- 6d10cf32-3cd6-4090... 7 days ago
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- b85ea747-5201-4e49... 7 days ago
- d9a37fe9-209b-4296-... 7 days ago
- d9a37fe9-209b-4296-... 7 days ago
- dafee3c-461e-42ed-... 6 days ago
- dafee3c-461e-42ed-... 6 days ago
- quickResults.csv 6 days ago

<Figure size 720x720 with 0 Axes>

MAG AUTO I

MAG_AUTO_R

Some interactive plots using Bokeh and Holoviews

In [9]: `import holoviews as hv
hv.extension('bokeh')`

In [10]: `hextiles = hv.HexTiles(df, [('MAG_AUTO_R', 'R'), ('MAG_AUTO_I', 'I')], [], extents=(20,26,20,28))`

In [11]: `hextiles.options(width=500, height=500, min_count=0, tools=['hover'], colorbar=True) * hv.`

Out[11]:

Terminal 4 x

DARK ENERGY SURVEY DATA MANAGEMENT

easyaccess 1.4.4. The DESDM Database shell.
Connected as nck to desdr.
** Type 'help' or '?' to list commands. **

General Commands (type help <command>):

```
clear edit help history prefetch version
config exit help_function import shell
```

DB Commands (type help <command>):

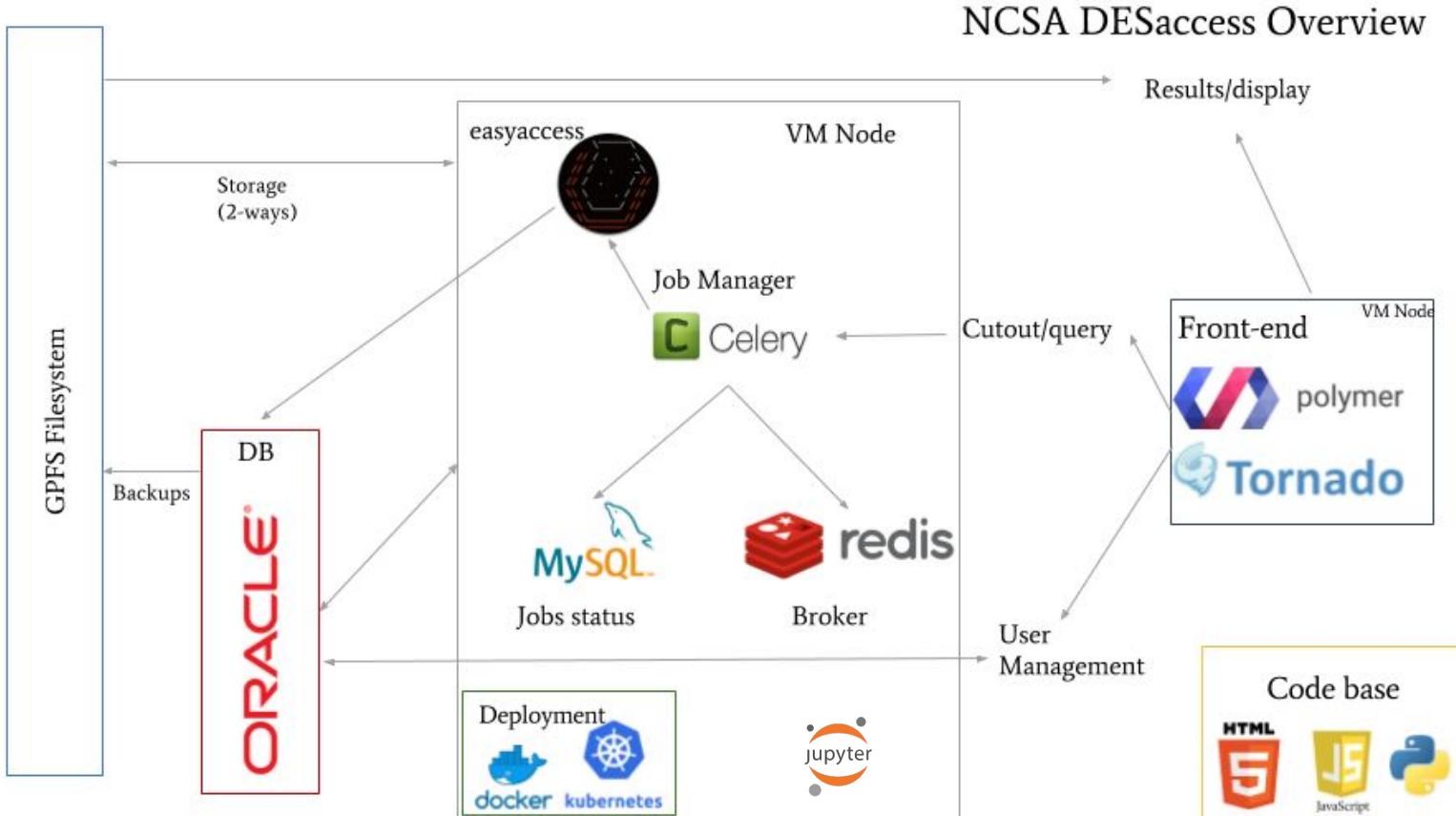
```
describe_table loadsql refresh_metadata_cache show_db
find_tables show_index
find_tables_with_column set_password whoami
```

Default Input

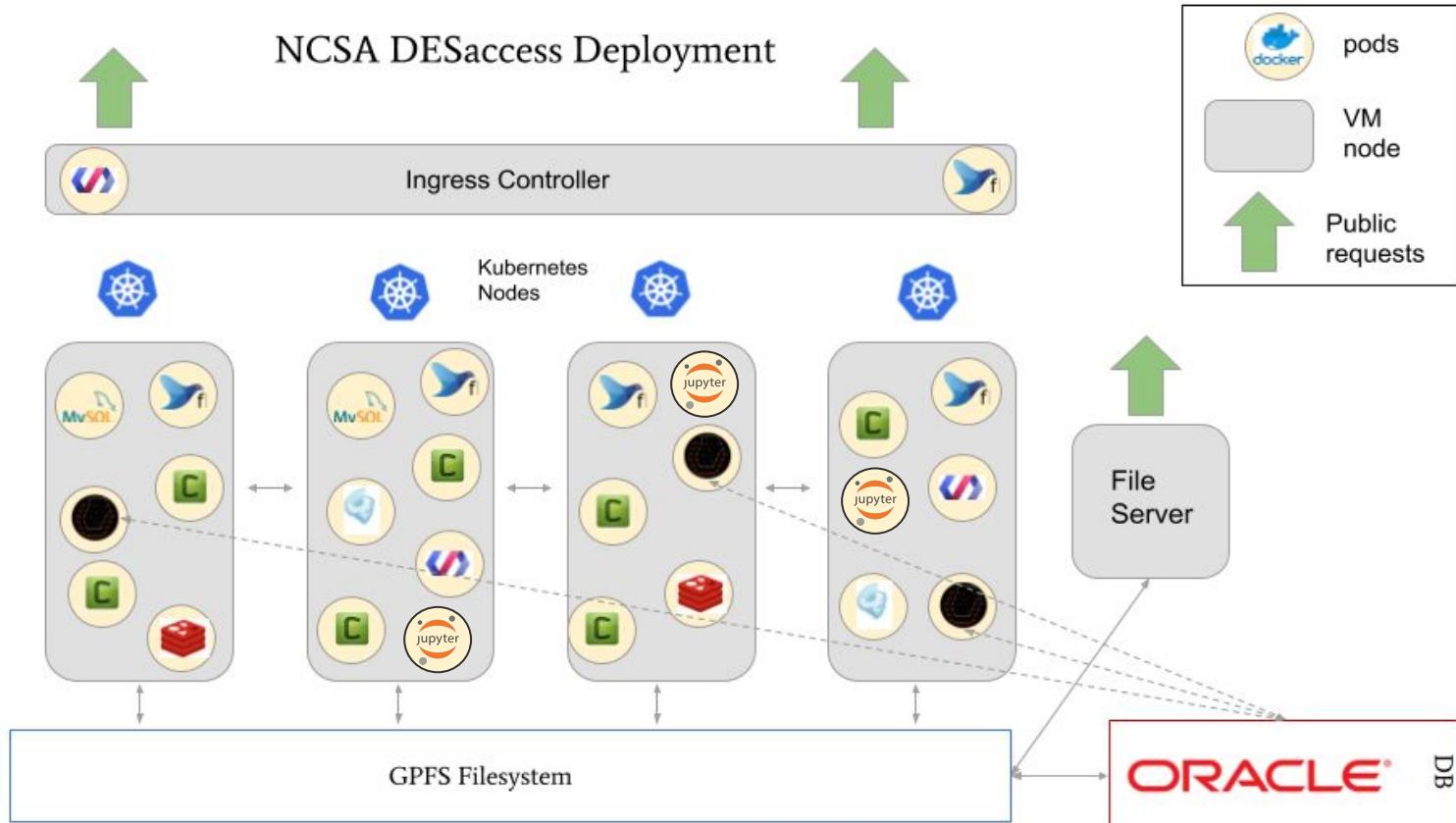
```
* To run SQL queries just add ; at the end of query
* To write to a file : select ... from ... where ... ; > filename
* Supported file formats .csv, .tab., .fits, .h5)
* To check SQL syntax: select ... from ... where ... ; < check
* To see the Oracle execution plan : select ... from ... where ... ; < explain
* To access an online tutorial type: online_tutorial
```

DESDB -> []

NCSA DESaccess: Technology Overview



NCSA DESacces: Deployment



LSST Science Platform

Stay tuned for next week webinar



LSST Users

Internet

LSST Science Platform



Portal



JupyterLab



Web APIs



Data Releases



Alert Streams



User Databases



User Files



User Computing



Software Tools

SCIaaS Example: Anomaly detection service

Goal: Build a resilient scalable anomaly detection service.

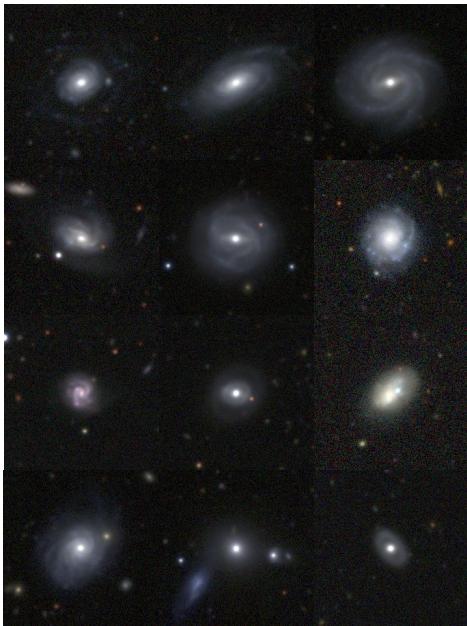
Motivation: Astronomical data (both literal and figurative)

Algorithm: Extended Isolation Forest

Infrastructure: Kubernetes cluster

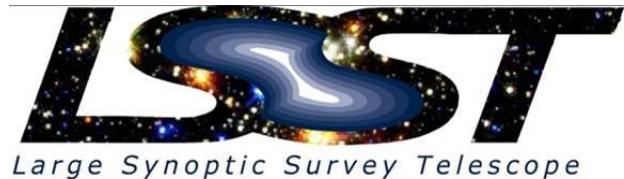
MapReduce package: Spark

Part of the Motivation



Astronomy is just one example where data exploration needs to be automated.

Large catalogs, Large number of images, many unexpected objects/problems → Anomaly detection



- In operations 2020
- Every night for 10 years
- 18 billions objects (first year), ~40 billions by the end of survey
- ~1500 images per night
- Stream and static data
- Target to capture new physics (moving and variable objects)

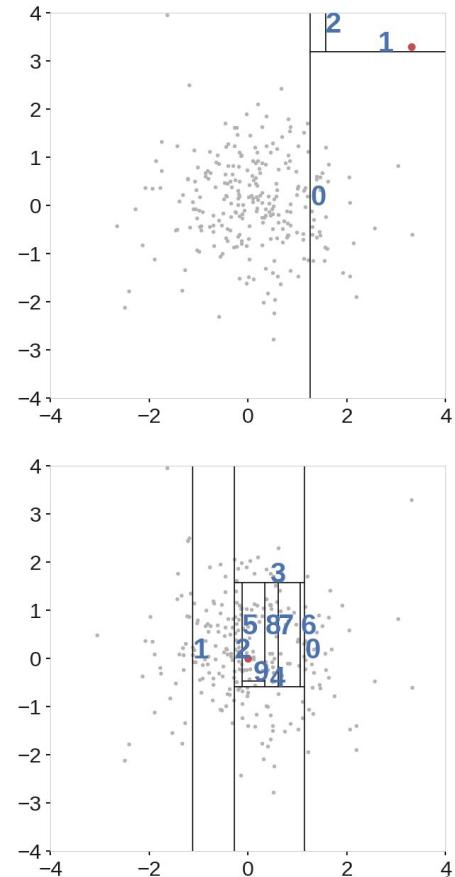


- More than 500 nights of observation over 5 years
- 500 millions cataloged galaxies and 100 millions stars
- Many open problems: Systematics, new objects, new physics, etc.
- Almost completed

Anomaly Detection with Isolation Forest

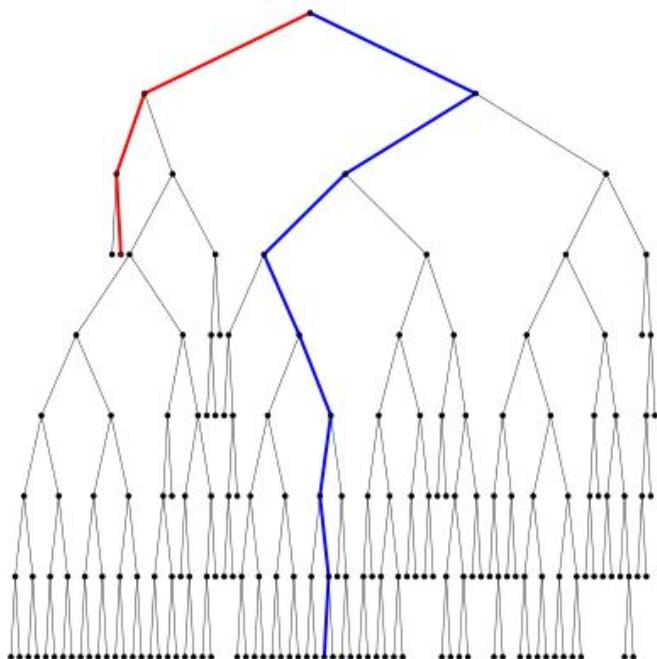
- Few and different to be isolated quicker
- For each tree:
 - Get a sample of the data
 - Randomly select a dimension
 - Randomly pick a value in that dimension
 - Draw a straight line through the data at that value and split data
 - Repeat until tree is complete
- Generate multiple trees → forest
- Anomalies will be isolated in only a few steps
- Nominal points in more
- To score points:
 - Run point down tree, record path
 - Repeat for each tree, aggregate scores
 - Score distribution

$$s(x, n) = 2^{-\frac{E(h(x))}{c(n)}}$$

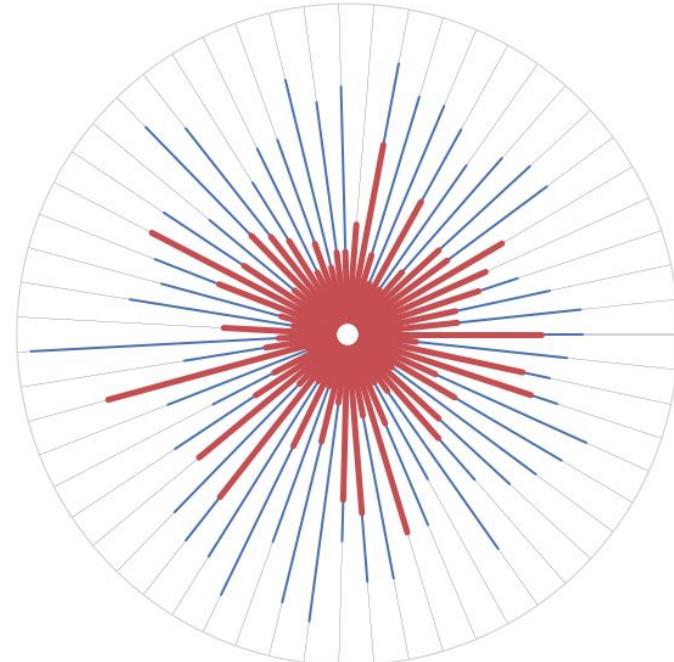


Anomaly Detection with Isolation Forest

Single Tree scores for
anomaly and **nominal** points



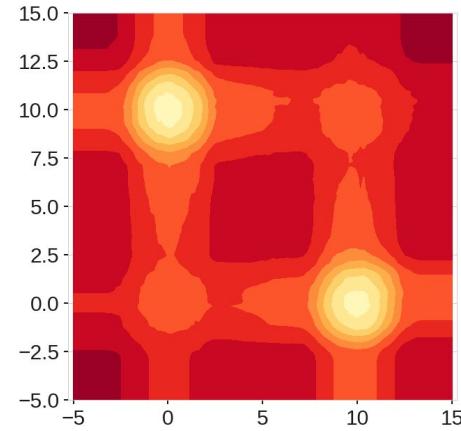
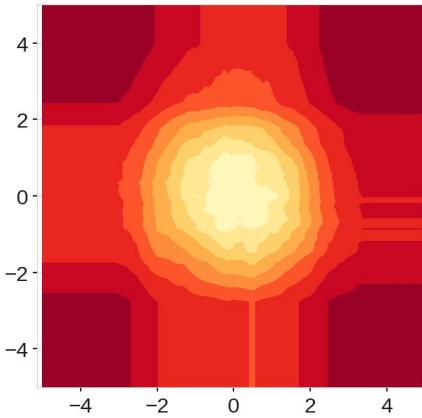
Forest plotted radially.
Scores for **anomaly** and
nominal shown as lines



Anomaly Detection with Extended Isolation Forest

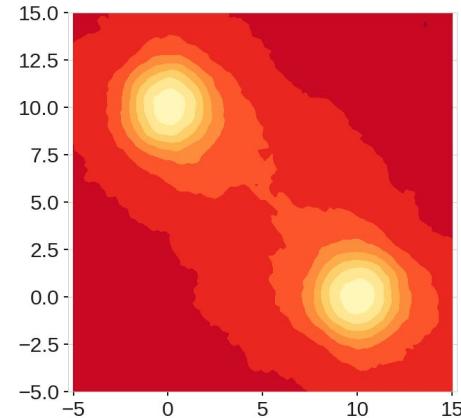
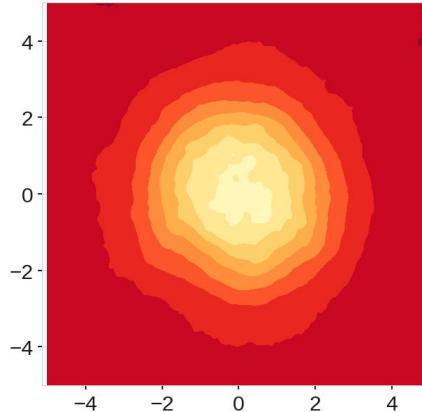
Isolation Forest:

- ✓ Model free
- ✓ Computationally efficient
- ✓ Readily applicable to parallelization
- ✓ Readily application to high dimensional data
- ✗ Inconsistent scoring seen in score maps



Extended Isolation Forest:

- ✓ Model free
- ✓ Computationally efficient
- ✓ Readily applicable to parallelization
- ✓ Readily application to high dimensional data
- ✓ Consistent scoring



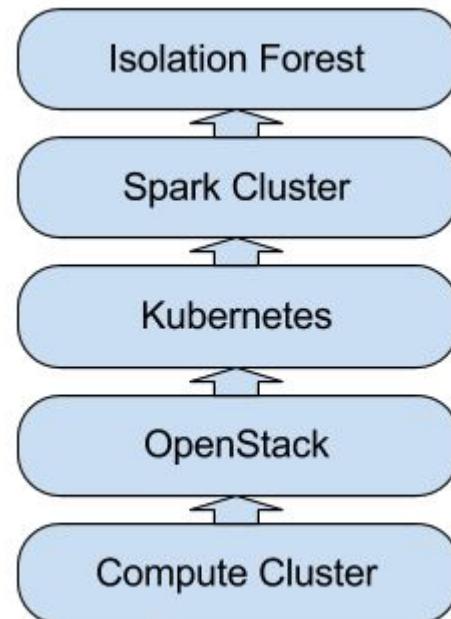
Technology Stack For Anomaly Service

Batch and online anomaly detection for scientific applications in
a Kubernetes environment

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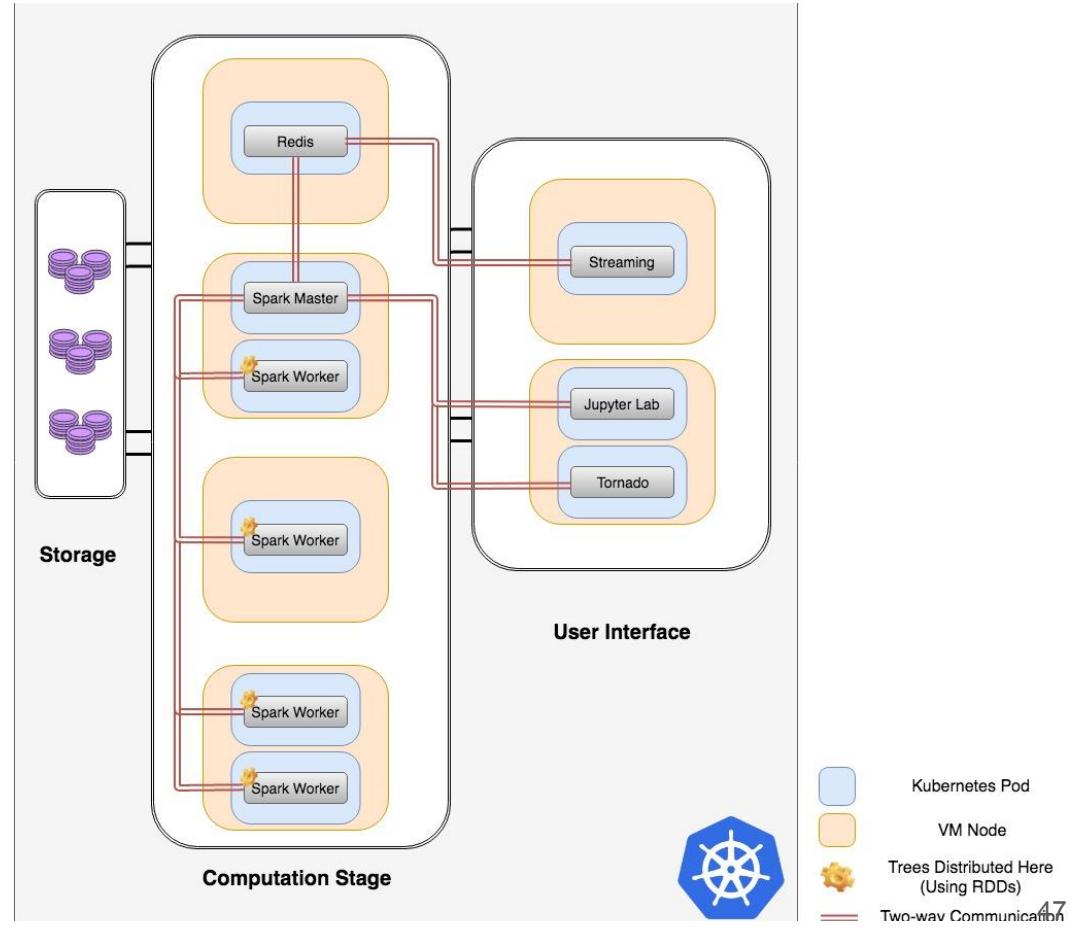
- Use Extended Isolation Forest as core algorithm
- Use Spark to parallelize trees and scoring
- Use Redis as a broker communicator
- To easily deploy in any environment, use Docker
- For orchestration of Docker containers, use Kubernetes
- Kubernetes cluster built on top of OpenStack, but it can be deployed also in AWS, GKE, etc.



Framework Architecture

There are three main components:

1. Storage
2. Computation Stage
3. User Interface / Streaming



Framework Architecture

Storage:

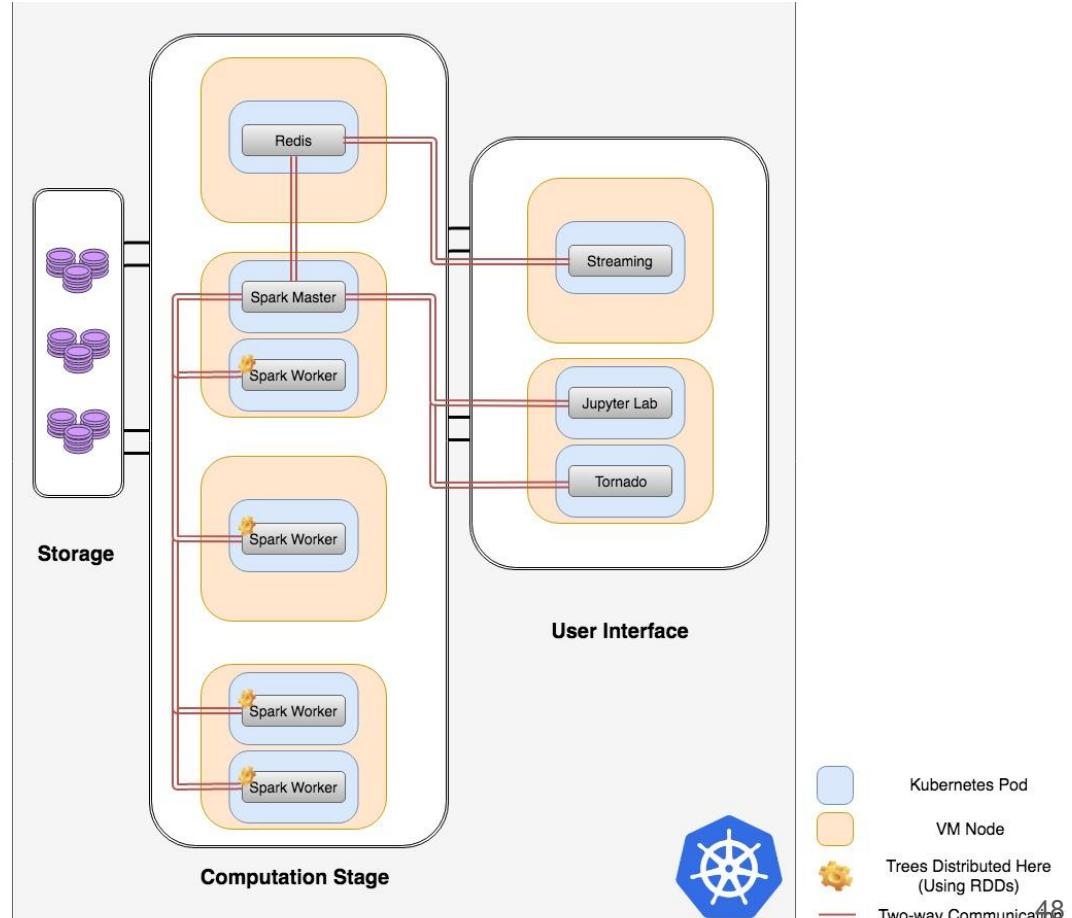
- NFS (Kubernetes PV/PVC)
- Redis
- RDD for Trees and Spark

User Interface:

- Jupyter notebooks
- Interactive web app for submitting jobs
- Streaming service

Computation Stage:

- Spark Master and Workers
- Communicator with Spark Master
- Subscription



Deployment

- Kubernetes allows very easy deployment, orchestration, scalability, resilience, replication, workloads and more
- Federation of services and Jobs
- From 0 to anomaly service → in minutes and config files
- Scale up/down (spark cluster and front-end) → Auto-scaling as an option
- Prototype support multiple users/projects, batch and streaming process
- Fault tolerant, disaster recovery



Example: Jupyter Notebooks

jupyter IFParallelExample Last Checkpoint: 4 minutes ago (autosaved)

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Create Spark Context

```
In [123]: from pyspark import SparkContext, SparkConf
In [124]: conf = SparkConf().setAppName("JupyterExamples").setMaster("spark://spark-master:7077")
conf.set("spark.cores.max", 4)
Out[124]: <spark.conf.SparkConf at 0x7f7419428470>
In [134]: if sc:
    sc.stop()
sc = SparkContext(conf=conf)
```

Imports

```
In [135]: import matplotlib.pyplot as plt
import numpy as np
from scipy.stats import multivariate_normal
import random as rn
import iso.forest as iso
import seaborn as sb
import time
sb.set_style(style="whitegrid")
sb.set_color_codes()
```

Helper Functions

```
In [136]: def getBlobData(N=2000):
    mean = [10, 1]
    cov1 = [[10, 0], [0, 1]] # diagonal covariance
    Nobj = 4000
    x, y = np.random.multivariate_normal(mean, cov, Nobj).T
    #Add manual outlier
    x[0]=3.3
    y[0]=3.3
    X=np.array([x,y]).T
    plt.figure(figsize=(7,7))
    plt.scatter(x,y,s=45,c=[0.5,0.5,0.5],alpha=0.3)
    plt.show()

    return (x,y,X)

In [137]: def getMultiblobData(N=2000):
    mean1 = [10, 0]
    cov1 = [[1, 0], [0, 1]] # diagonal covariance
    mean2 = [0, 10]
    cov2 = [[1, 0], [0, 1]] # diagonal covariance
```

jupyter IFParallelExample Last Checkpoint: 5 minutes ago (autosaved)

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```
plt.plot(X[:,0],X[:,1],'o', markersize=10, color=[0.5,0.5,0.5],alpha=0.3)
plt.axis('equal')
plt.show()
return (x,y,X)

In [138]: def getSinusoidData(N=4000):
    x = np.random.rand(N)*8*np.pi
    y = np.sin(x) + np.random.randn(N)/4.

    #Add manual outlier
    x[0]=3.3
    y[0]=3.3
    X=np.array([x,y]).T

    fig=plt.figure(figsize=(7,7))
    fig.add_subplot(111)
    plt.plot(X[:,0],X[:,1],'o', markersize=10, color=[0.5,0.5,0.5], alpha=0.3)

    plt.show()
    return (x,y,X)

In [139]: def partition(l,n):
    return l[i:i+n] for i in range(0,len(l),n)

In [140]: def runIF(X):
    data = sc.parallelize(partition(X,int(len(X)/8)))
    forest = data.map(lambda x: iso.IForest(x,ntrees=100, sample_size=256))
    S_t = forest.map(lambda F: F.compute_paths(X))
    S = S_t.reduce(lambda a,b: a+b)
    return S

In [141]: def plotResults(x,y,scores):
    plt.rcParams['figure.figsize'] = (15, 5)
    plt.figure()
    plt.subplot(1,2,1)
    plt.densityplot(score, kde=True, color=[0.5,0.5,0.5])
    plt.xlabel('Anomaly Score', fontsize=20)
    plt.subplot(1,2,2)
    sns.prcplot(score)
    plt.scatter(x,y,s=45,c=[0.5,0.5,0.5],alpha=0.3)
    plt.scatter(x[ss[-10:]],y[ss[-10:]],s=55,c='r')
    plt.scatter(x[ss[:10]],y[ss[:10]],s=55,c='g')
    plt.show()
```

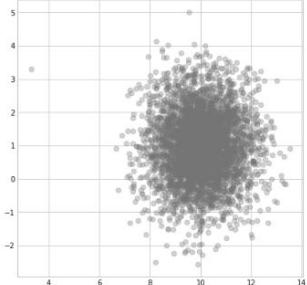
Examples

Example: Jupyter Notebooks

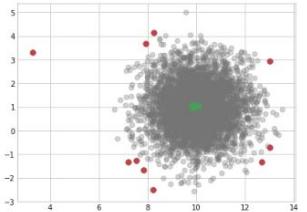


Blob

```
In [148]: x,y,X = getBlobData()
```

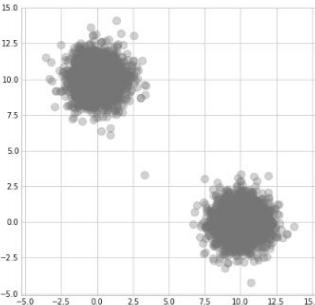


```
In [149]: S = runIF(X)  
plotresults(x,y,S)
```

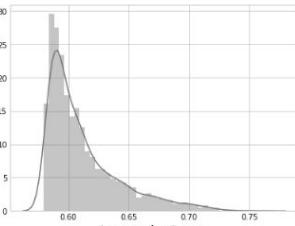
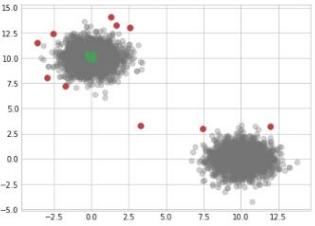


MultiBlob

```
In [150]: x,y,X = getMultiBlobData()
```



```
In [151]: S = runIF(X)  
plotresults(x,y,S)
```



Final Remarks

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- It's all about the user
- Jupyter as Scientific tool
- Science on the cloud is happening in many scientific fields including Astronomy
- Containerized solutions to ease management of the applications
- HPC is adopting cloud technologies to leverage the benefits of both worlds
- Kubernetes provide means to have 'the cloud' outside the commercial world
- Production services for large datasets

... this is changing the way we do astronomy

Thank you!

Questions?

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Extra Slides
