# BigData Analytics with Spark and Hadoop at OSC

10/11/2018
OSC workshop

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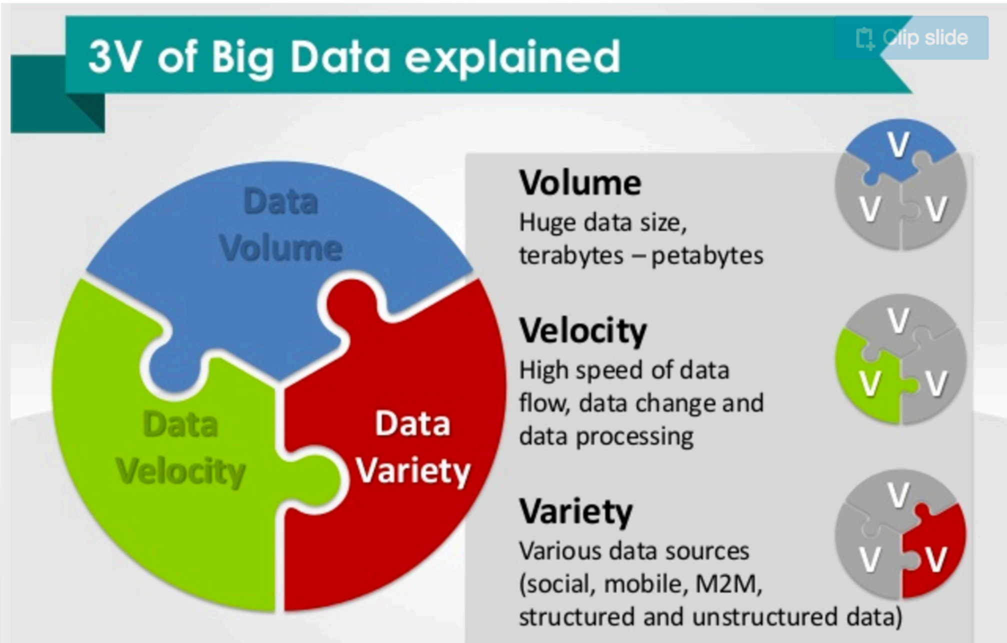
# What is BigData

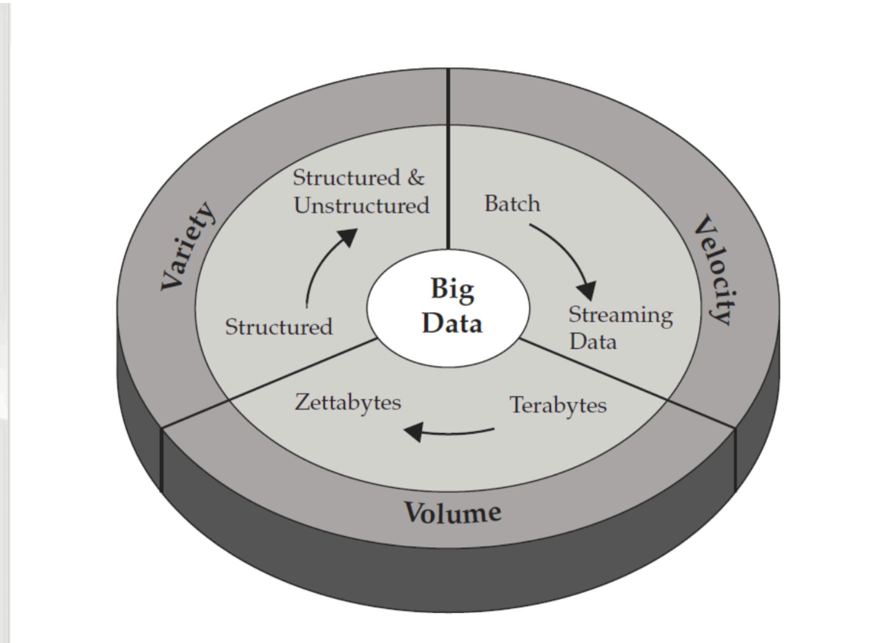
Bigdata is an evolving term that describes any voluminous amount of structured and unstructured data that has the potential to be mined for information.

Bigdata generates value from the storage and processing of very large quantities of digital information that cannot be analyzed with traditional computing techniques

Helps to solve new problem or old problem in a better way

# The 3V of Big Data



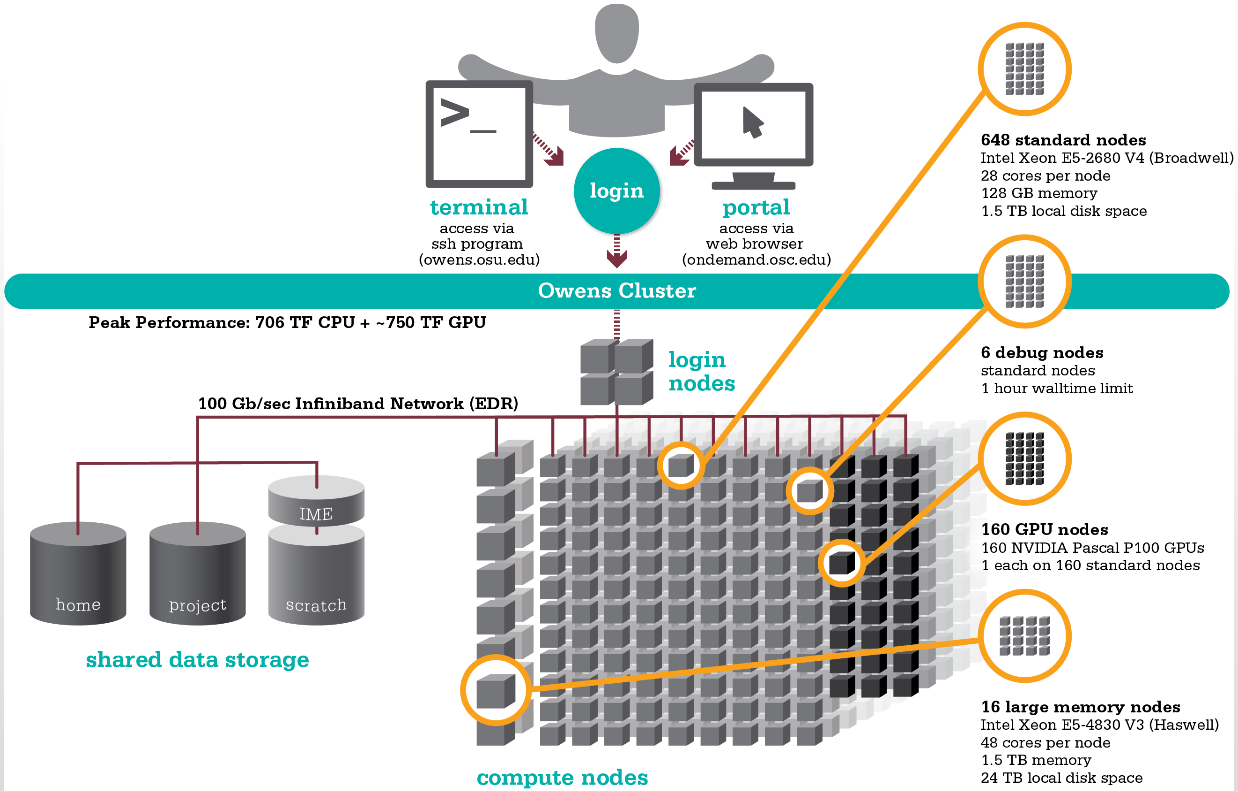

- Key enablers for the growth of “Big Data” are:
  - Increase of storage capacities
  - Increase of processing power
  - Availability of data

# Data Analytical Tools

| | Examples | Characteristics | Typical tools | Analytical methods |
|---|---|---|---|---|
| Small Data (megabytes) | Sales records, Customers database (small and medium companies) | Hundreds – thousands of records | Personal computer, Excel, R, other basic statistics software | Simple statistics |
| Large Data (gigabytes-terabytes) | Customer databases (big companies) | Millions of records, mostly structured data | Server workstation computer, Relational database systems, data warehouses | Advanced statistics, business intelligence, data mining, |
| Big Data (terabytes – petabytes) | Customer interactions (social media, mobile), multimedia (video, images, free text), location-based data, RFIM | Over millions of records, distributed, unstructured | Cloud, data centers, Distributed databases, NoSQL, Hadoop | MapReduce, Distributed File Systems |

# Data Analytical nodes@OSC

Owens' data analytics environment is comprised of 16 nodes, each with 48 CPU cores, 1.5TB of RAM and 24TB of local disk.




**$HOME:**
500GB/per user
Backed up daily
Permanent storage

**Local disk:$TMPDIR**
1.5TB or 24TB
Not backed up
Temporary storage

**/fs/scratch:**
1200TB
Not backed up
Temporary storage

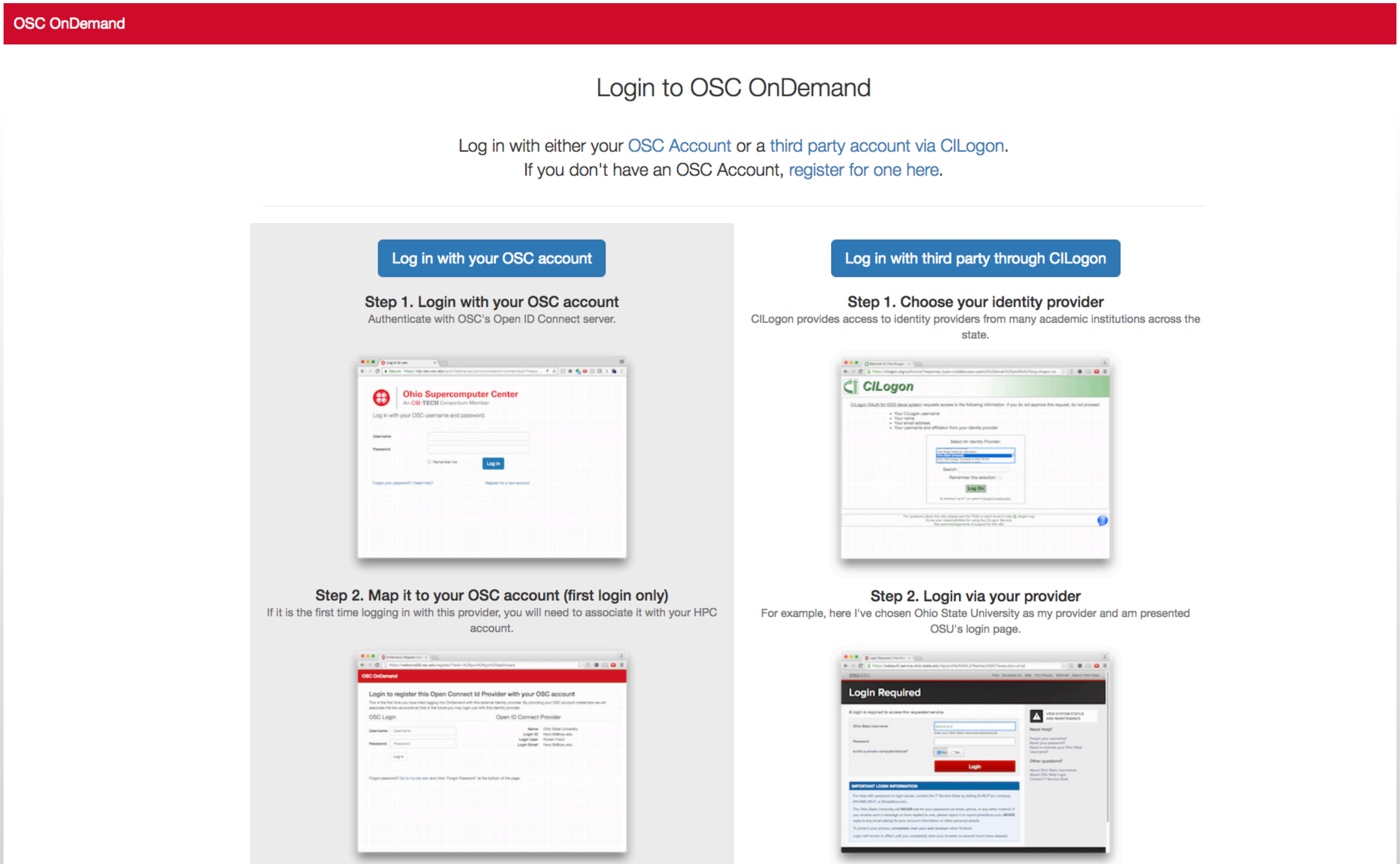
**/fs/project:**
Upon request
1-5TB
Backed up daily
1-3 years

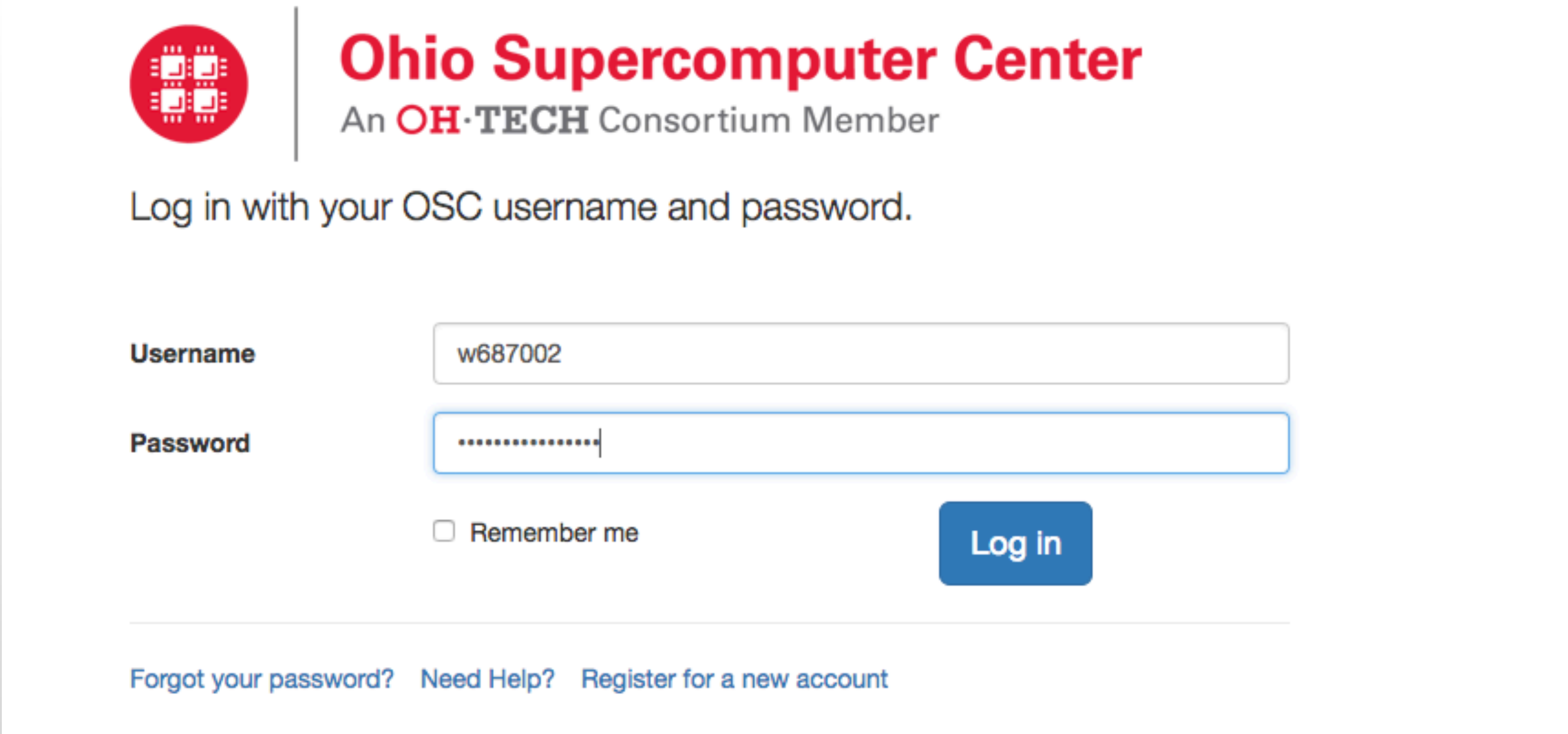
# OSC OnDemand  ondemand.osc.edu

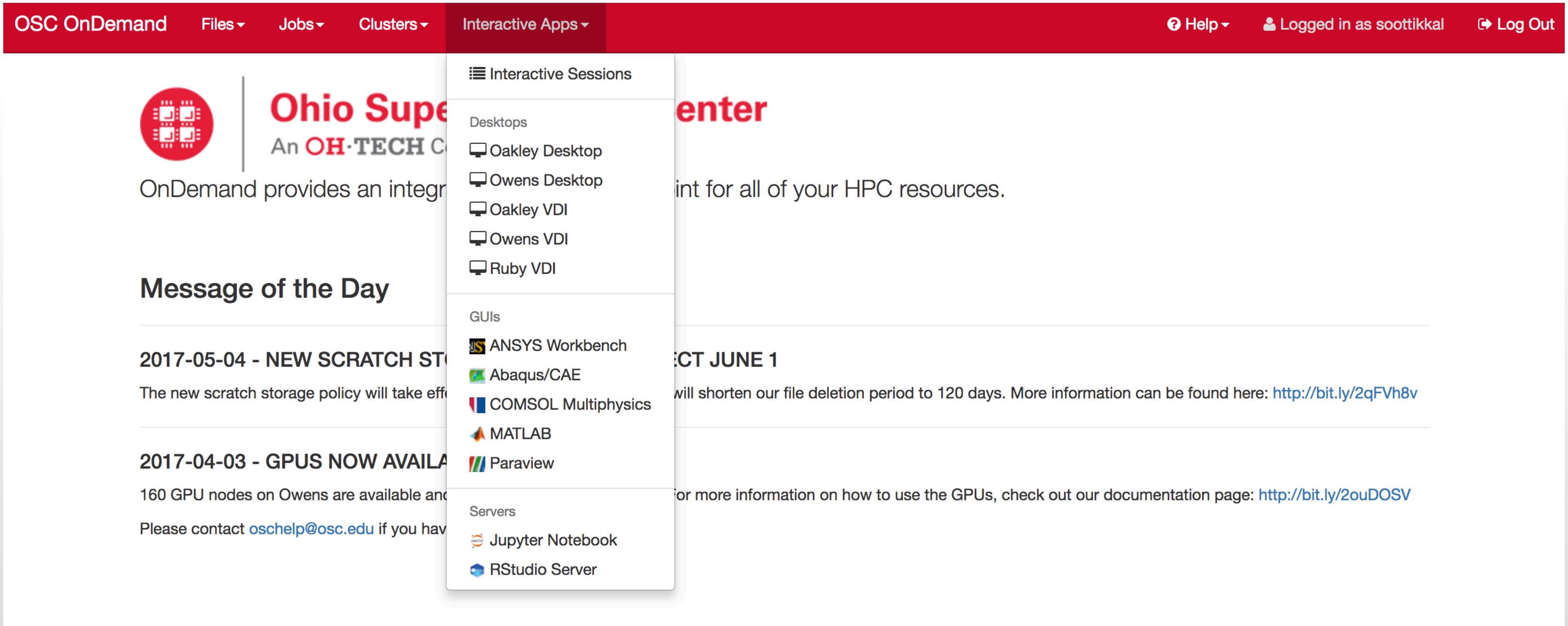
- 1: User Interface
  - Web based
    - Usable from computers, tablets, smartphones
    - Zero installation
  - Single point of entry
    - User needs three things
      - ondemand.osc.edu
      - OSC Username
      - OSC Password
    - Connected to all resources at OSC
- 2: Interactive Services
  - File Access
  - Job Management
  - Visualization Apps
    - Desktop access
    - Single-click apps (Abaqus, Ansys, Comsol, Paraview)
  - Terminal Access

**Tutorial available at osc.edu/ondemand**

# Go to https://ondemand.osc.edu/




Ohio Supercomputer Center
An OH·TECH Consortium Member
Log in with your OSC username and password.
Username
w687002
Password
Remember me
Log in
Forgot your password?
Need Help?
Register for a new account


OSC OnDemand
Files
Jobs
Clusters
Interactive Apps
Help
Logged in as soottikkal
Log Out
Interactive Sessions
Desktops
Oakley Desktop
Owens Desktop
Oakley VDI
Owens VDI
Ruby VDI
GUIs
ANSYS Workbench
Abaqus/CAE
COMSOL Multiphysics
MATLAB
Paraview
Servers
Jupyter Notebook
RStudio Server
Ohio Supe
enter
An OH·TECH C
OnDemand provides an integr
int for all of your HPC resources.
Message of the Day
2017-05-04 - NEW SCRATCH ST
CT JUNE 1
The new scratch storage policy will take eff
will shorten our file deletion period to 120 days. More information can be found here: http://bit.ly/2qFVh8v
2017-04-03 - GPUS NOW AVAILA
160 GPU nodes on Owens are available anc
For more information on how to use the GPUs, check out our documentation page: http://bit.ly/2ouDOSV
Please contact oschelp@osc.edu if you hav

Exercise-1

Login to OSC OnDemand

# Data Analytics@OSC

Python: A popular general-purpose, high-level programming language with numerous mathematical and scientific packages available for data analytics.

R: A programming language for statistical and machine learning applications with very strong graphical capabilities.

MATLAB:A full featured data analysis toolkit with many advanced algorithms readily available.

Spark and Hadoop: Frameworks for running map reduce algorithms

Intel Compilers: Compilers for generating optimized code for Intel CPUs.

Intel MKL: The Math Kernel Library provides optimized subroutines for common computation tasks such as matrix-matrix calculations.

Statistical software: Octave, Stata, FFTW, ScaLAPACK, MINPACK, sprng2

# R and Rstudio

R is a language and environment for statistical computing and graphics. R provides a wide variety of statistical and graphical techniques and is highly extensible.

## Availability:

The following versions of R are available on OSC systems:

| VERSION | OAKLEY | OWENS |
|---|---|---|
| 3.0.1 | X | |
| 3.1.3 | X | |
| 3.2.0 | X | |
| 3.3.1 | X* | X |
| 3.3.2 | | X* |
| 3.4.0 | | X |
| 3.4.2 | | X |
| 3.5.0 | | X |

# Running R interactively

### Set-up

In order to configure your environment for the usage of R, run the following command:

```
module load R
```

### Using R

Once your environment is configured, R can be started simply by entering the following command:

```
R
```

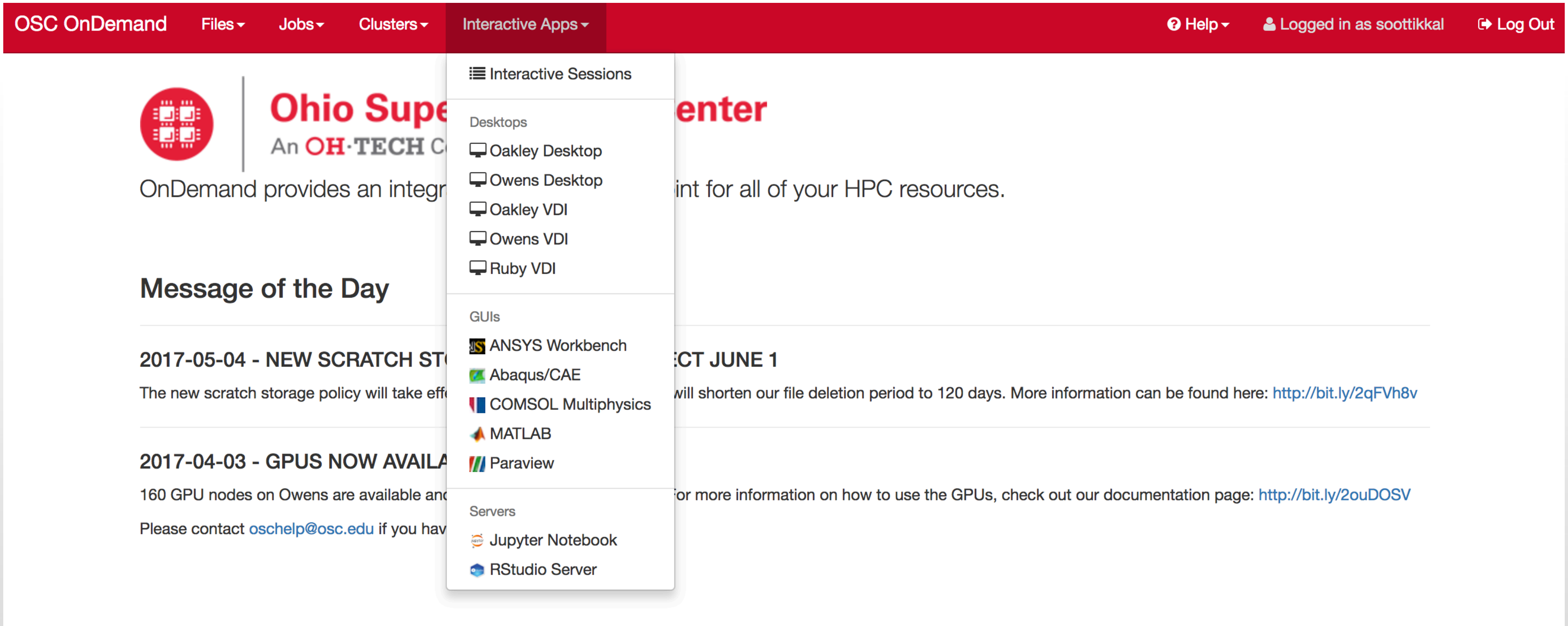
For a listing of command line options, run:

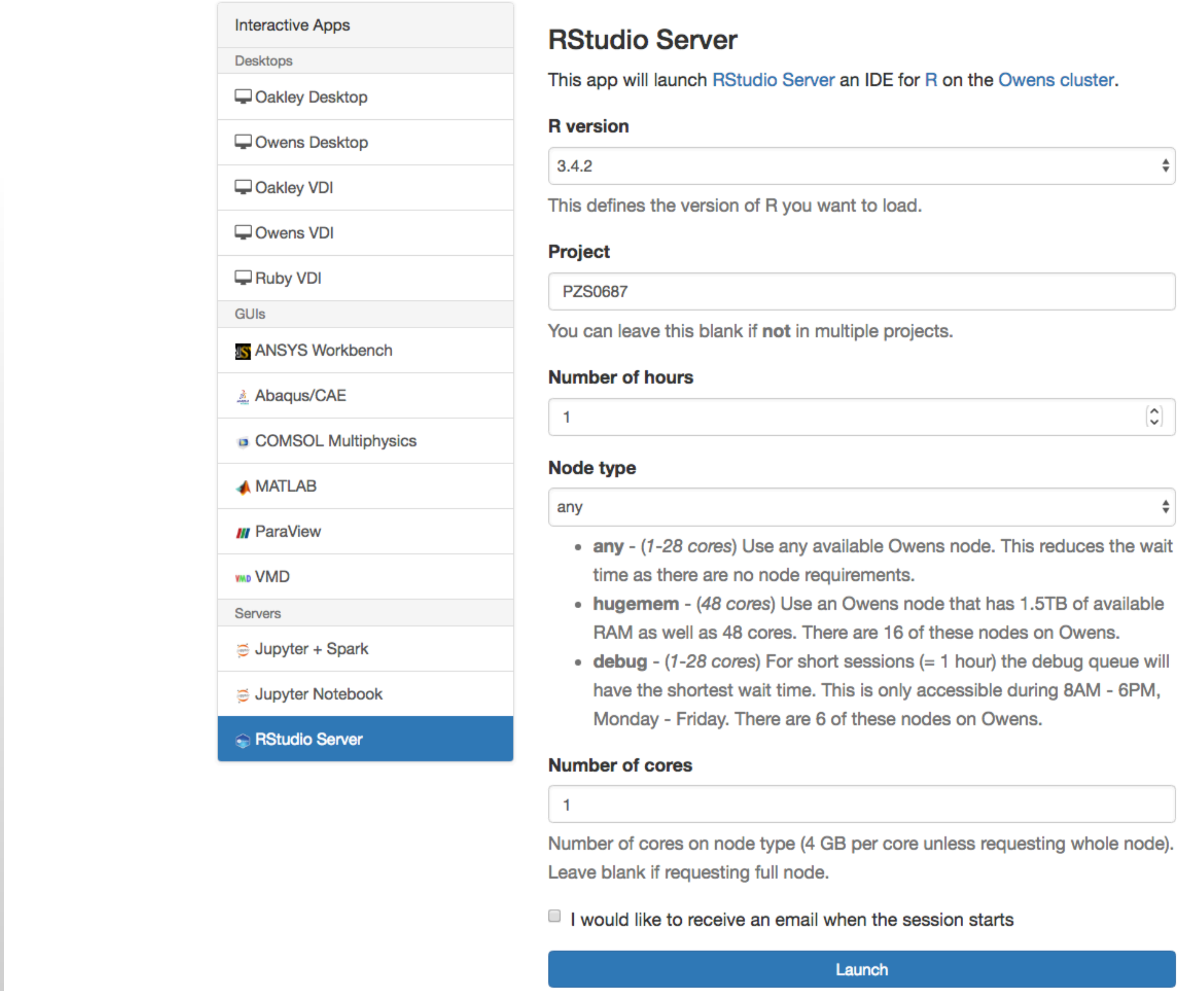
```
R --help
```

# Batch Usage

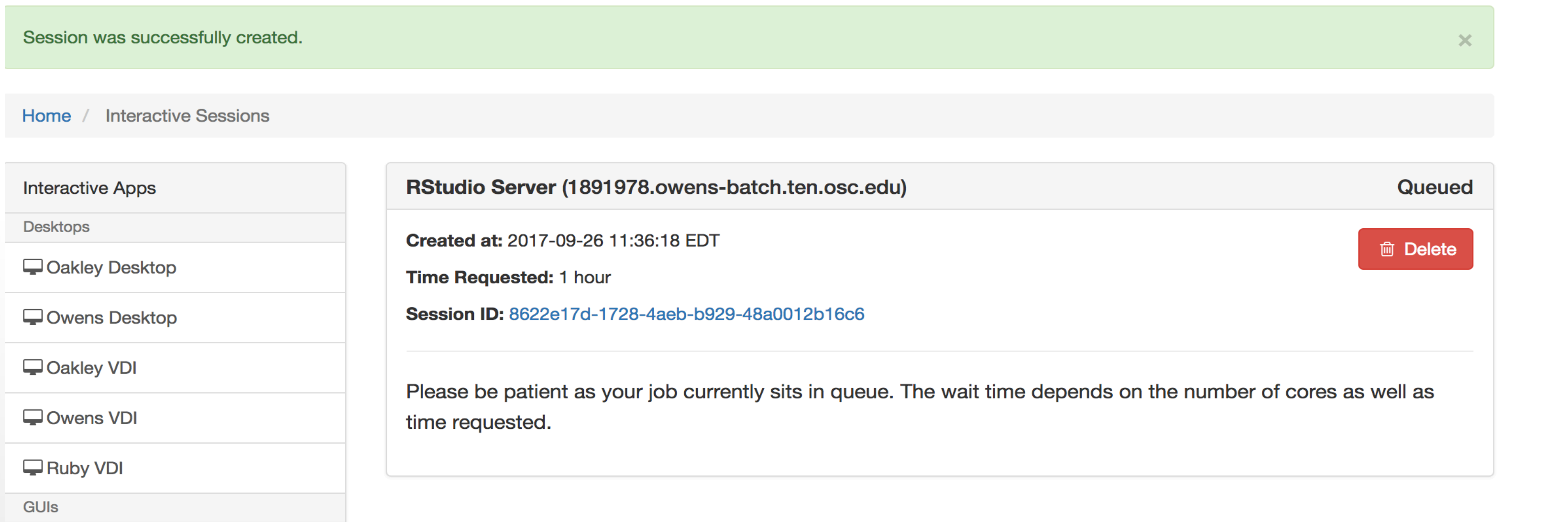
```
#PBS -N R_ExampleJob
#PBS -l nodes=1:ppn=12

module load R
cd $PBS_O_WORKDIR
cp in.dat test.R $TMPDIR
cd $TMPDIR

R CMD BATCH test.R test.Rout

cp test.Rout $PBS_O_WORKDIR
```

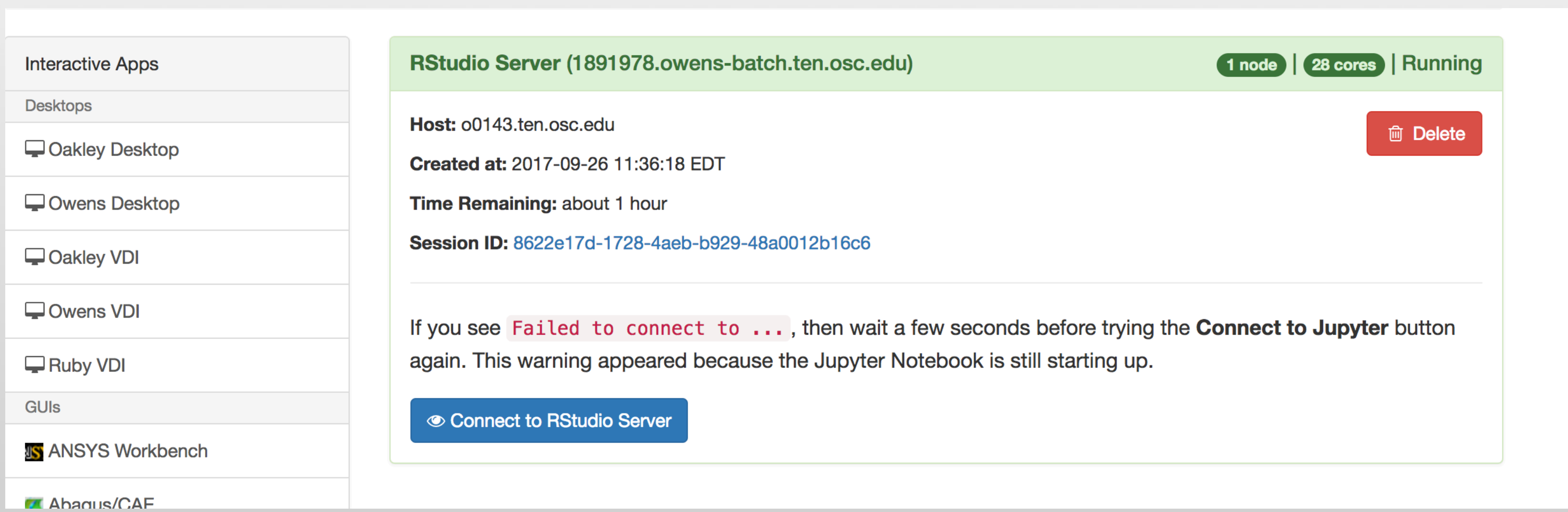
# Rstudio on Ondemand

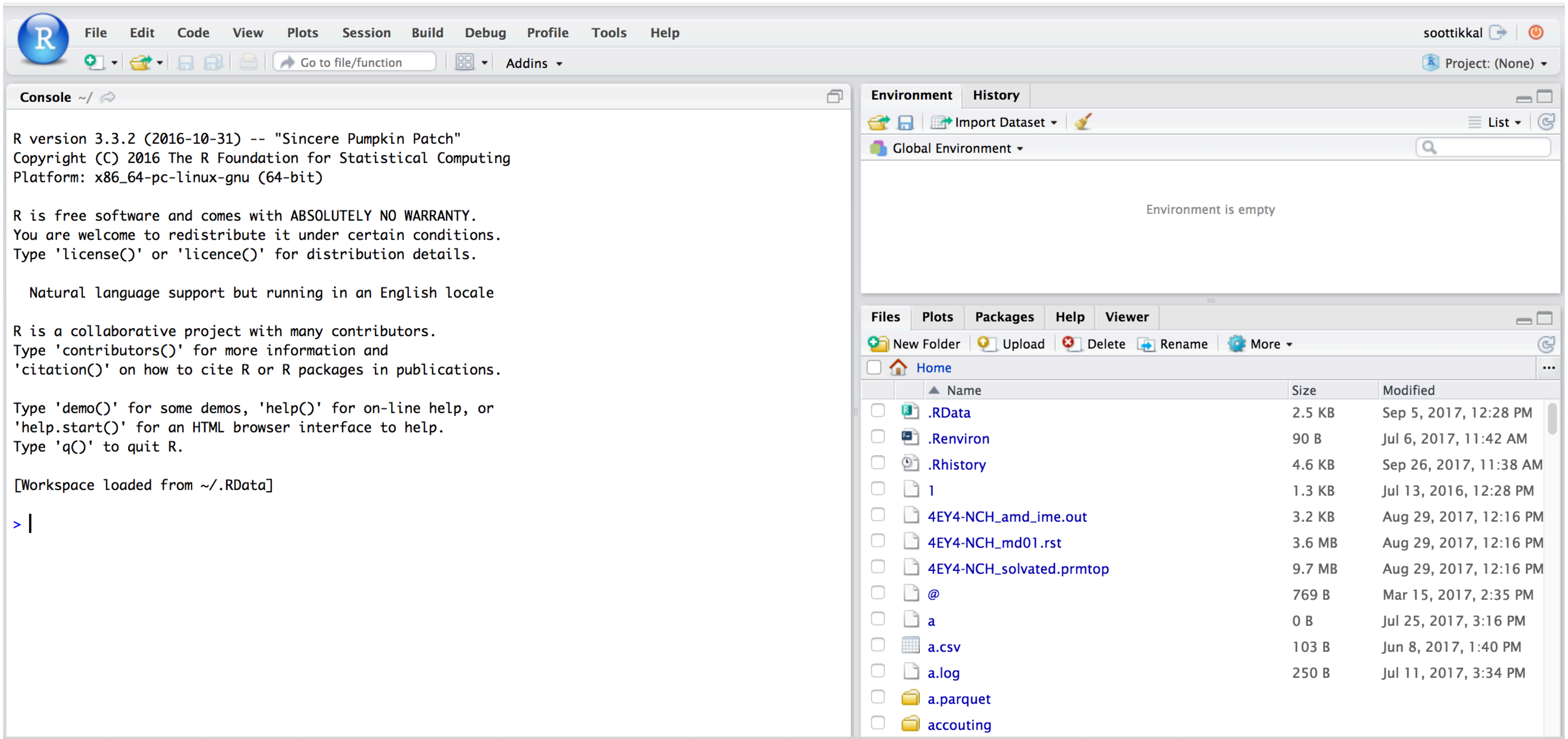


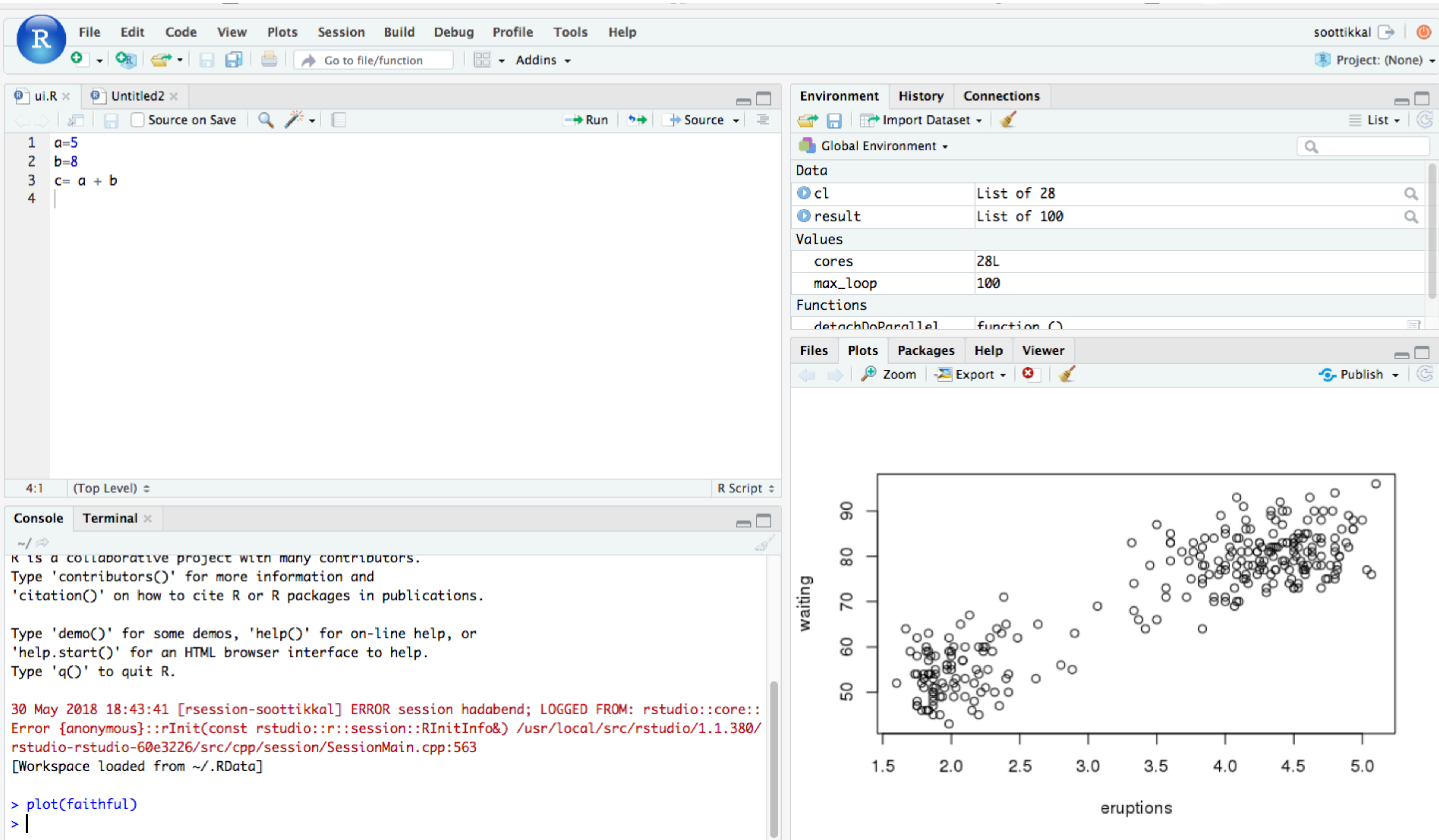


Interactive Apps
Desktops
Oakley Desktop
Owens Desktop
Oakley VDI
Owens VDI
Ruby VDI
GUIs
ANSYS Workbench
Abaqus/CAE
COMSOL Multiphysics
MATLAB
ParaView
VMD
Servers
Jupyter + Spark
Jupyter Notebook
RStudio Server
RStudio Server
This app will launch RStudio Server an IDE for R on the Owens cluster.
R version
3.4.2
This defines the version of R you want to load.
Project
PZS0687
You can leave this blank if not in multiple projects.
Number of hours
1
Node type
any
any - (1-28 cores) Use any available Owens node. This reduces the wait time as there are no node requirements.
hugemem - (48 cores) Use an Owens node that has 1.5TB of available RAM as well as 48 cores. There are 16 of these nodes on Owens.
debug - (1-28 cores) For short sessions (= 1 hour) the debug queue will have the shortest wait time. This is only accessible during 8AM - 6PM, Monday - Friday. There are 6 of these nodes on Owens.
Number of cores
1
Number of cores on node type (4 GB per core unless requesting whole node). Leave blank if requesting full node.
I would like to receive an email when the session starts
Launch


Session was successfully created.
Home / Interactive Sessions
Interactive Apps
Desktops
Oakley Desktop
Owens Desktop
Oakley VDI
Owens VDI
Ruby VDI
GUIs
RStudio Server (1891978.owens-batch.ten.osc.edu)
Queued
Created at: 2017-09-26 11:36:18 EDT
Time Requested: 1 hour
Session ID: 8622e17d-1728-4aeb-b929-48a0012b16c6
Delete
Please be patient as your job currently sits in queue. The wait time depends on the number of cores as well as time requested.


Interactive Apps
Desktops
Oakley Desktop
Owens Desktop
Oakley VDI
Owens VDI
Ruby VDI
GUIs
ANSYS Workbench
Abaqus/CAE
RStudio Server (1891978.owens-batch.ten.osc.edu)
1 node | 28 cores | Running
Host: o0143.ten.osc.edu
Created at: 2017-09-26 11:36:18 EDT
Time Remaining: about 1 hour
Session ID: 8622e17d-1728-4aeb-b929-48a0012b16c6
Delete
If you see Failed to connect to ..., then wait a few seconds before trying the Connect to Jupyter button again. This warning appeared because the Jupyter Notebook is still starting up.
Connect to RStudio Server


File
Edit
Code
View
Plots
Session
Build
Debug
Profile
Tools
Help
soottikkal
Go to file/function
Addins
Project: (None)
Console ~/
R version 3.3.2 (2016-10-31) -- "Sincere Pumpkin Patch"
Copyright (C) 2016 The R Foundation for Statistical Computing
Platform: x86_64-pc-linux-gnu (64-bit)
R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.
Natural language support but running in an English locale
R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.
Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.
[Workspace loaded from ~/.RData]
>
Environment
History
Import Dataset
List
Global Environment
Environment is empty
Files
Plots
Packages
Help
Viewer
New Folder
Upload
Delete
Rename
More
Home
Name
Size
Modified
.RData 2.5 KB Sep 5, 2017, 12:28 PM
.Renviron 90 B Jul 6, 2017, 11:42 AM
.Rhistory 4.6 KB Sep 26, 2017, 11:38 AM
1 1.3 KB Jul 13, 2016, 12:28 PM
4EY4-NCH_amd_ime.out 3.2 KB Aug 29, 2017, 12:16 PM
4EY4-NCH_md01.rst 3.6 MB Aug 29, 2017, 12:16 PM
4EY4-NCH_solvated.prmtop 9.7 MB Aug 29, 2017, 12:16 PM
@ 769 B Mar 15, 2017, 2:35 PM
a 0 B Jul 25, 2017, 3:16 PM
a.csv 103 B Jun 8, 2017, 1:40 PM
a.log 250 B Jul 11, 2017, 3:34 PM
a.parquet
accouting


File Edit Code View Plots Session Build Debug Profile Tools Help
soottikkal
Go to file/function
Addins
Project: (None)
ui.R
Untitled2
Source on Save
Run
Source
a=5
b=8
c= a + b
4:1
(Top Level)
R Script
Console
Terminal
R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.
Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.
30 May 2018 18:43:41 [rsession-soottikkal] ERROR session hadabend; LOGGED FROM: rstudio::core::Error {anonymous}::rInit(const rstudio::r::session::RInitInfo&) /usr/local/src/rstudio/1.1.380/rstudio-rstudio-60e3226/src/cpp/session/SessionMain.cpp:563
[Workspace loaded from ~/.RData]
> plot(faithful)
Environment
History
Connections
Import Dataset
List
Global Environment
Data
cl
List of 28
result
List of 100
Values
cores
28L
max_loop
100
Functions
Files
Plots
Packages
Help
Viewer
Zoom
Export
Publish
waiting
eruptions
50
60
70
80
90
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0

# Exercise-2

# Launching Rstudio App

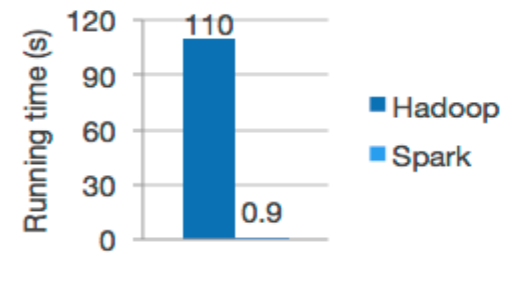
# Apache Spark

Apache Spark is an open source cluster computing framework originally developed in the AMPLab at University of California, Berkeley but was later donated to the Apache Software Foundation where it remains today. In contrast to Hadoop's disk-based analytics paradigm, Spark has multi-stage in-memory analytics.

## Speed

Run programs up to 100x faster than Hadoop MapReduce in memory, or 10x faster on disk.

Spark has an advanced DAG execution engine that supports cyclic data flow and in-memory computing.



Logistic regression in Hadoop and Spark

## Ease of Use

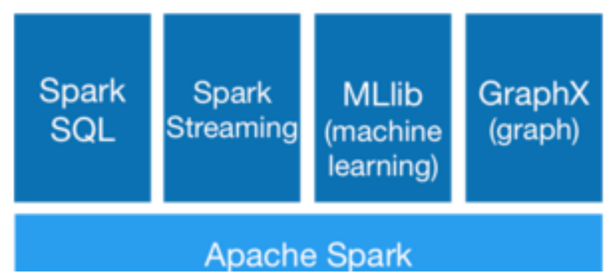
Write applications quickly in Java, Scala, Python, R.

Spark offers over 80 high-level operators that make it easy to build parallel apps. And you can use it *interactively* from the Scala, Python and R shells.

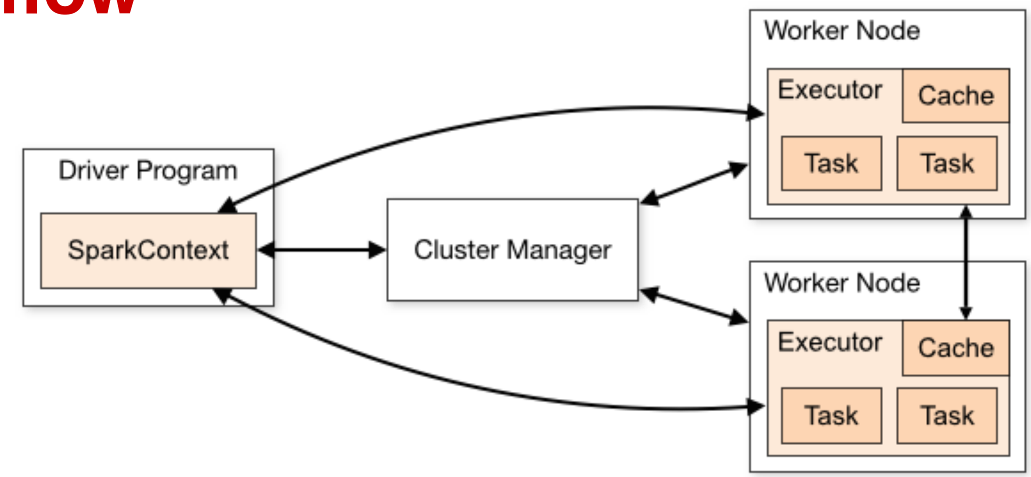
## Generality

Combine SQL, streaming, and complex analytics.

Spark powers a stack of libraries including SQL and DataFrames, MLlib for machine learning, GraphX, and Spark Streaming. You can combine these libraries seamlessly in the same application.



# Spark workflow




Spark applications run as independent sets of processes on a cluster, coordinated by the SparkContext object in your main program (called the driver program).

Requires cluster managers which allocate resources across applications.

Once connected, Spark acquires executors on nodes in the cluster, which are processes that run computations and store data for your application.

Next, it sends your application code (defined by JAR or Python files passed to SparkContext) to the executors. Finally, SparkContext sends tasks to the executors to run.

# RDD- Resilient Distributed Datasets

RDD (Resilient Distributed Dataset) is the main logical data unit in Spark. They are

- Distributed and partitioned
- Stored in memory
- Immutable
- Partitions recomputed on failure

# RDD- Transformations and Actions

Transformations are executed on demand. That means they are computed lazily. Eg: filter, join, sort

Actions return final results of RDD computations. Actions triggers execution using lineage graph to load the data into original RDD, carry out all intermediate transformations and return final results to Driver program or write it out to file system. Eg: collect(), count(), take()

# RDD Operations

| Transformations | Actions |
|---|---|
| map(func) | take(N) |
| flatMap(func) | count() |
| filter(func) | collect() |
| groupByKey() | reduce(func) |
| reduceByKey(func) | takeOrdered(N) |
| mapValues(func) | top(N) |
| … | … |

# Interactive Analysis with the Spark Shell

$SPARK_HOME/bin/pyspark  # Opens SparkContext

```
Python 2.7.5 (default, Oct 11 2015, 17:47:16)
[GCC 4.8.3 20140911 (Red Hat 4.8.3-9)] on linux2
Type "help", "copyright", "credits" or "license" for more information.
Using Spark's default log4j profile: org/apache/spark/log4j-defaults.properties
Setting default log level to "WARN".
To adjust logging level use sc.setLogLevel(newLevel).
17/02/23 10:16:30 WARN NativeCodeLoader: Unable to load native-hadoop library for your platform... using builtin-java classes where applicable
Welcome to
      ____              __
     / __/__  ___ _____/ /__
    _\ \/ _ \/ _ `/ __/  '_/
   /__ / .__/\_,_/_/ /_/\_\   version 2.0.0
      /_/

Using Python version 2.7.5 (default, Oct 11 2015 17:47:16)
SparkSession available as 'spark'.
>>>
```

1. **Create a RDD**

```
>>> data = sc.textFile("README.md")
```

2. **Transformation of RDD**

```
>>>linesWithSpark = data.filter(lambda line: "Spark" in line)
```

3. **Action on RDD**

```
>>> linesWithSpark.count()   # Number of items in this RDD
12
```

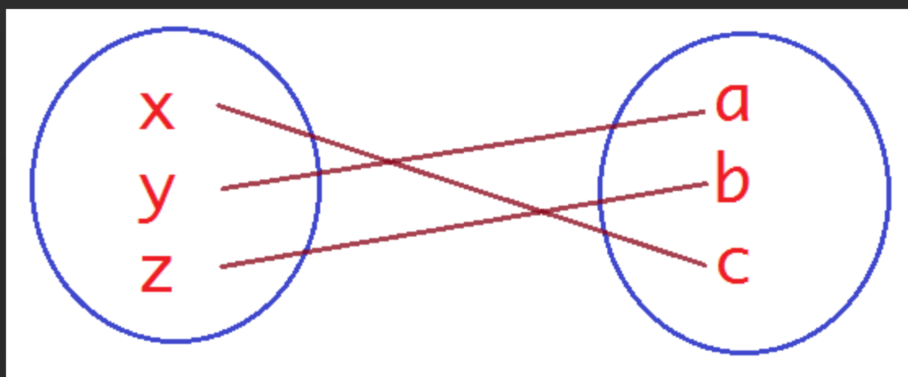
4. **Combining Transformation and Actions**

```
>>> data.filter(lambda line: "Spark" in line).count() # How many lines contain "Spark"?
12
```

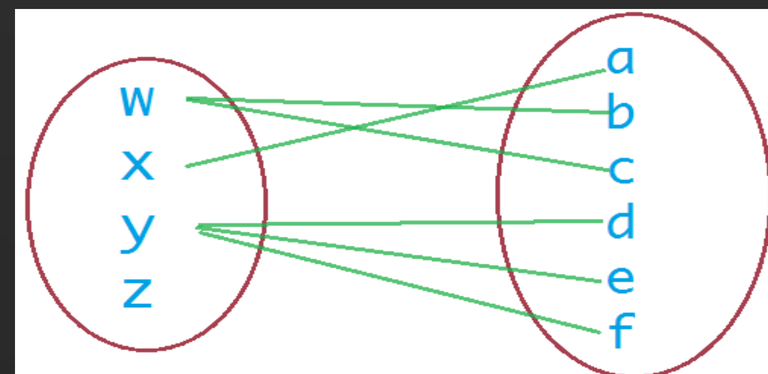
# Word count Example

Map: One element in input gets mapped to only one element in output.
Flatmap: One element in input maps to zero or more elements in the output.

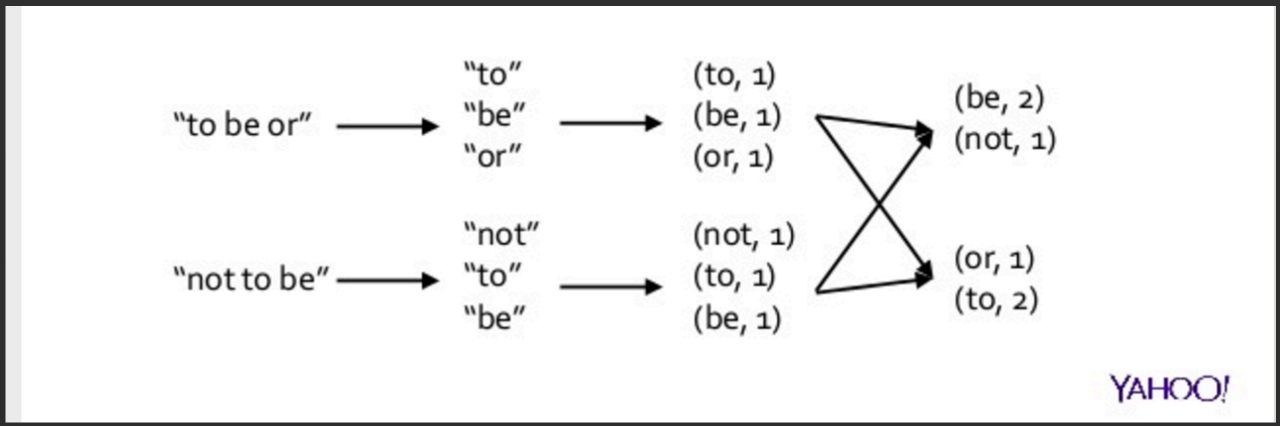
Map




Flatmap



# Word count Example




```
>>>wordCounts = data.flatMap(lambda line: line.split()).map(lambda word: (word,1)).reduceByKey(lambda a, b: a+b)

>>> wordCounts.collect()
```

# Spark documentation at OSC

https://www.osc.edu/resources/available_software/software_list/spark

## versions

The following versions of Spark are available on OSC systems:

| VERSION | OAKLEY | OWENS |
|---|---|---|
| 1.5.2 | X | |
| 1.6.1 | X | |
| 2.0.0 | X* | X* |
| 2.1.0 | | X |

## Set-up

In order to configure your environment for the usage of Spark, run the following command:

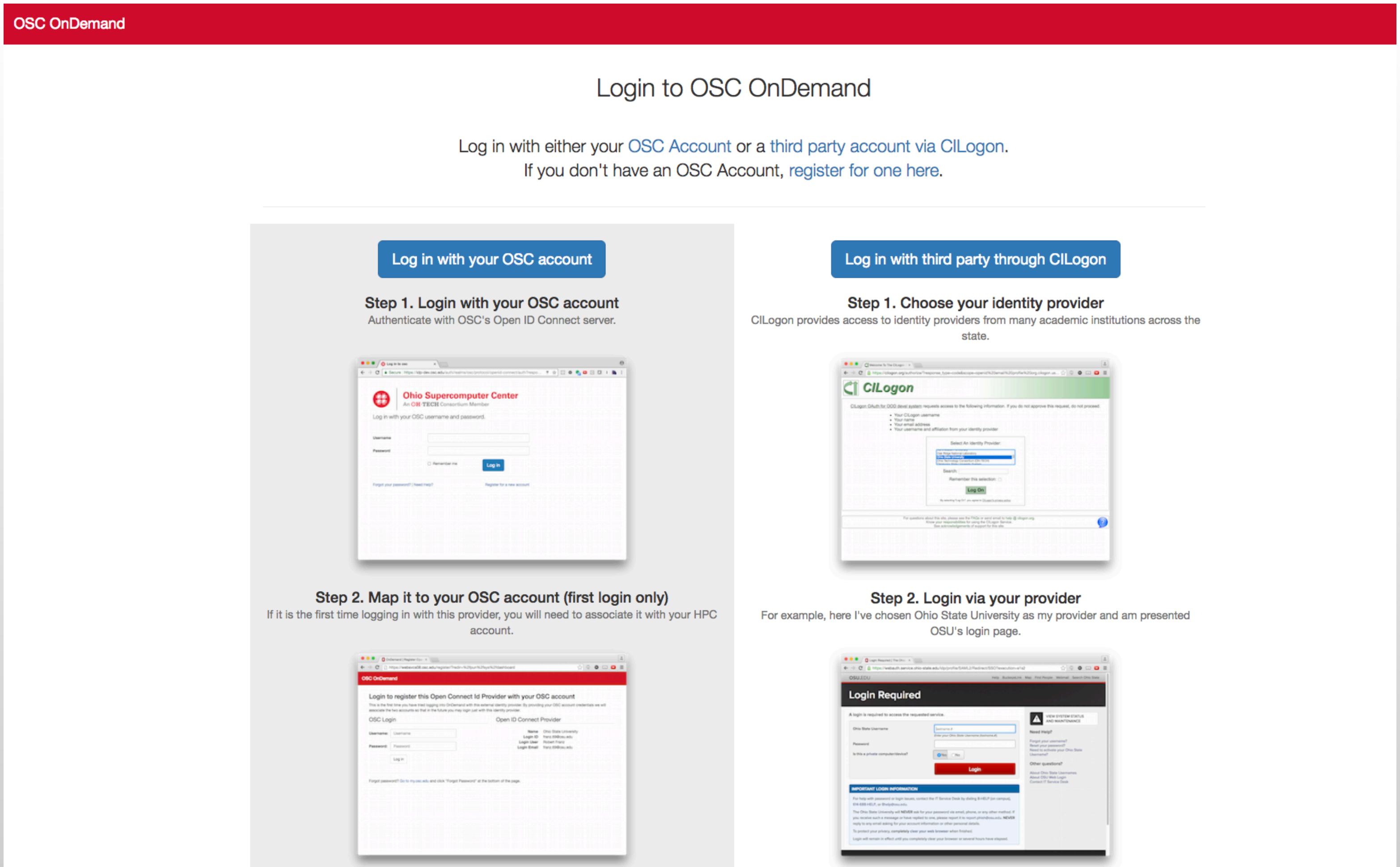
```
module load spark
```

In order to access a particular version of Spark, run the following command

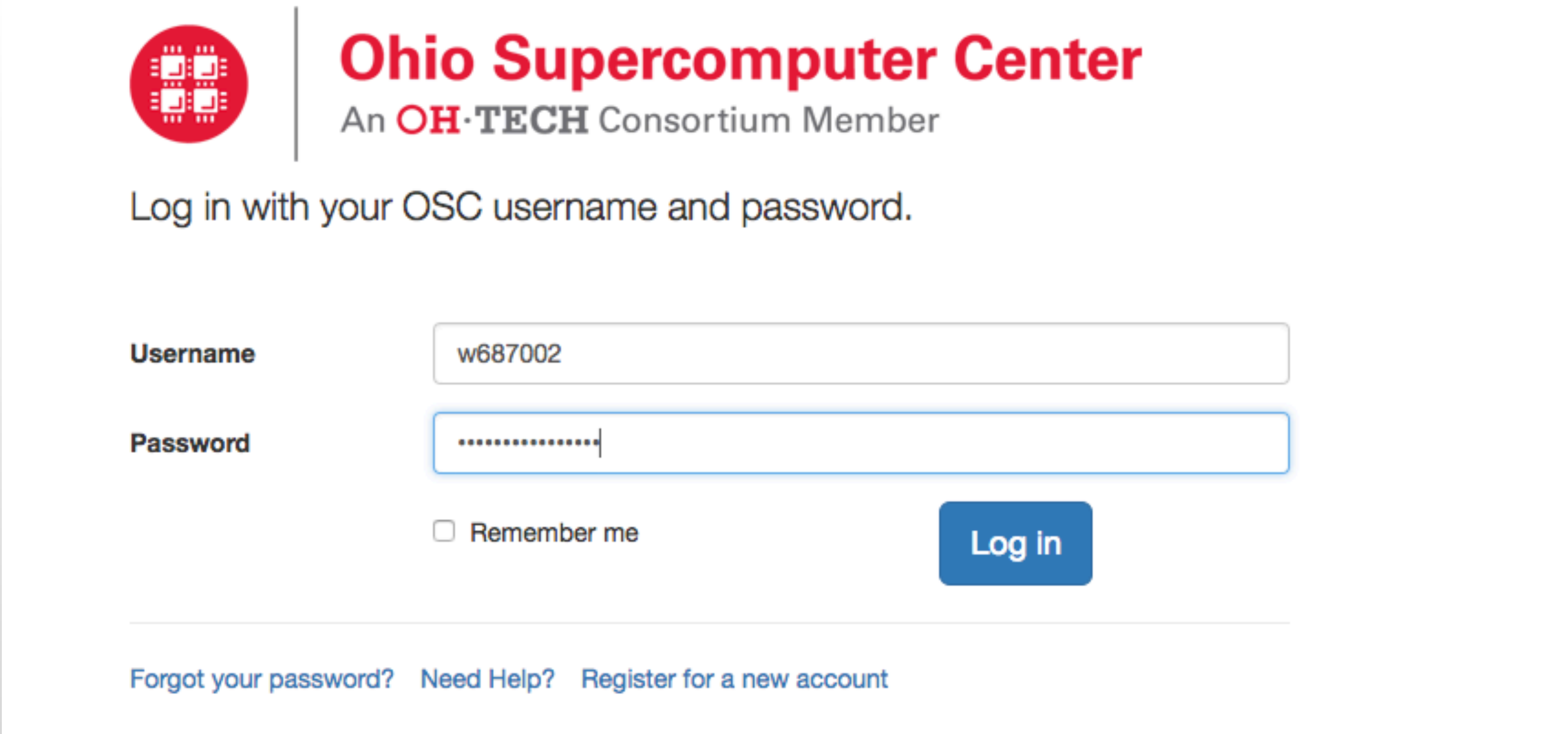
```
module load spark/2.0.0
```

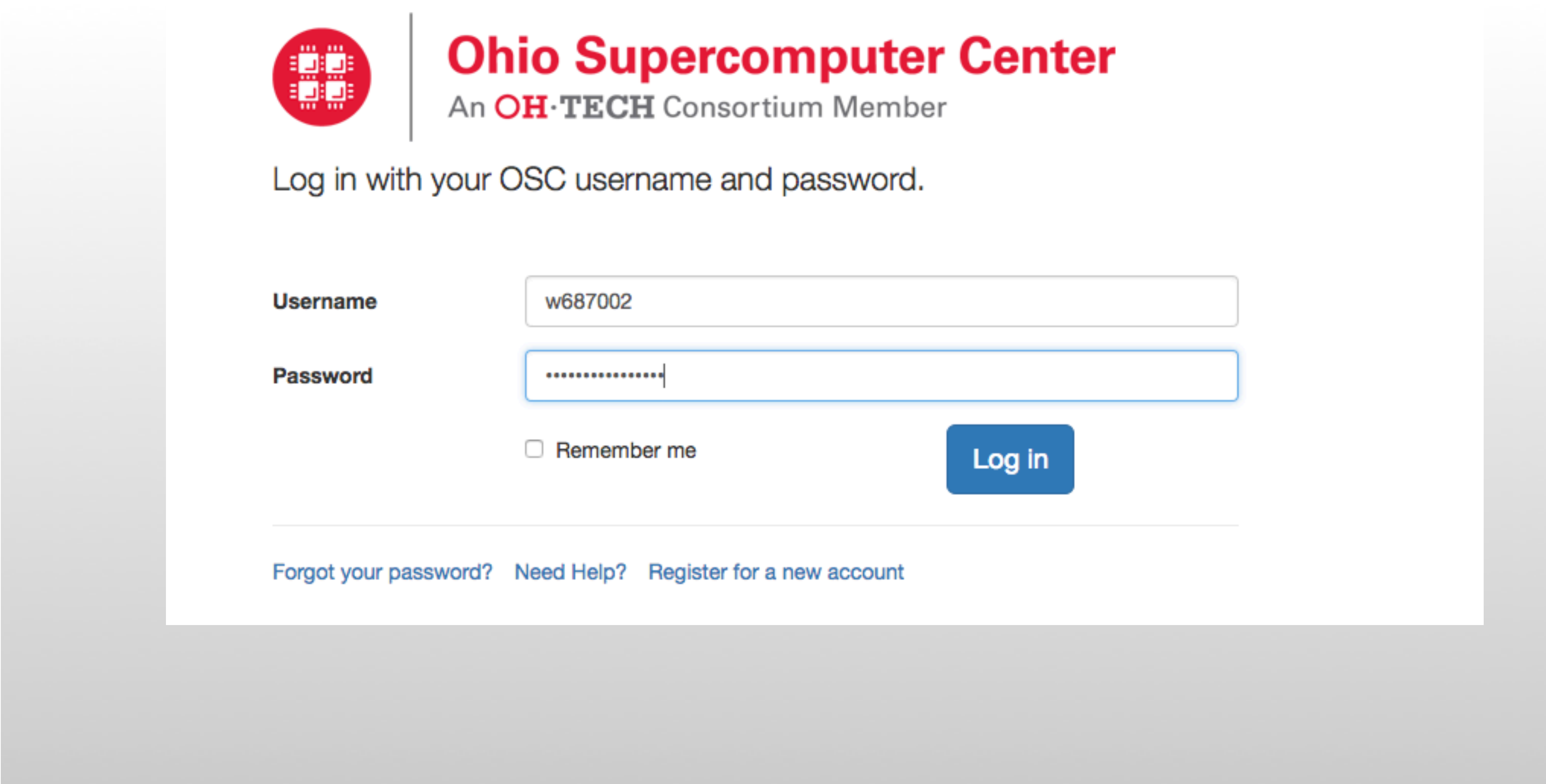
# Running Spark interactively: Jupyter+Spark App

Go to https://ondemand.osc.edu/

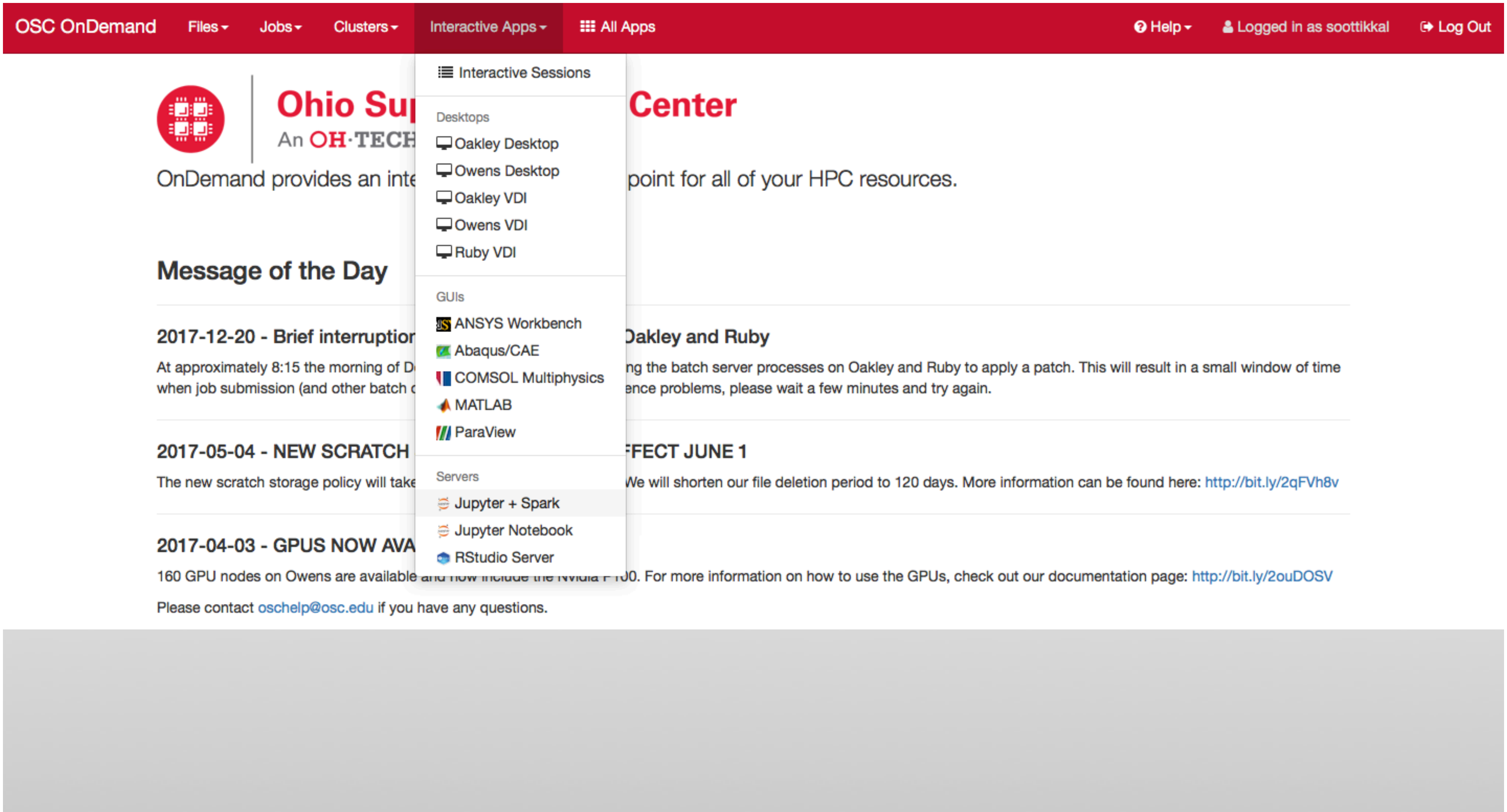


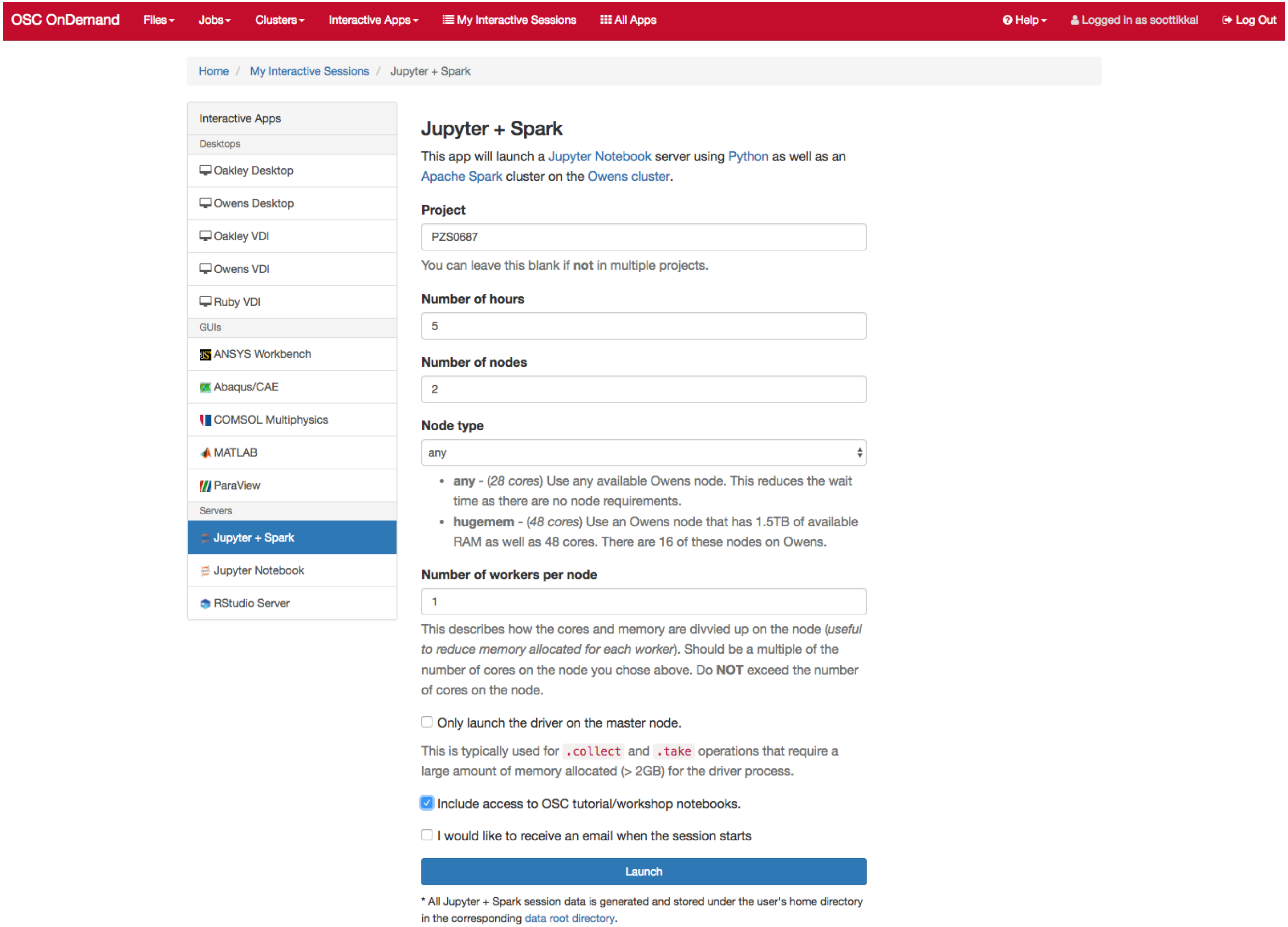
Log on with your OSC credentials.

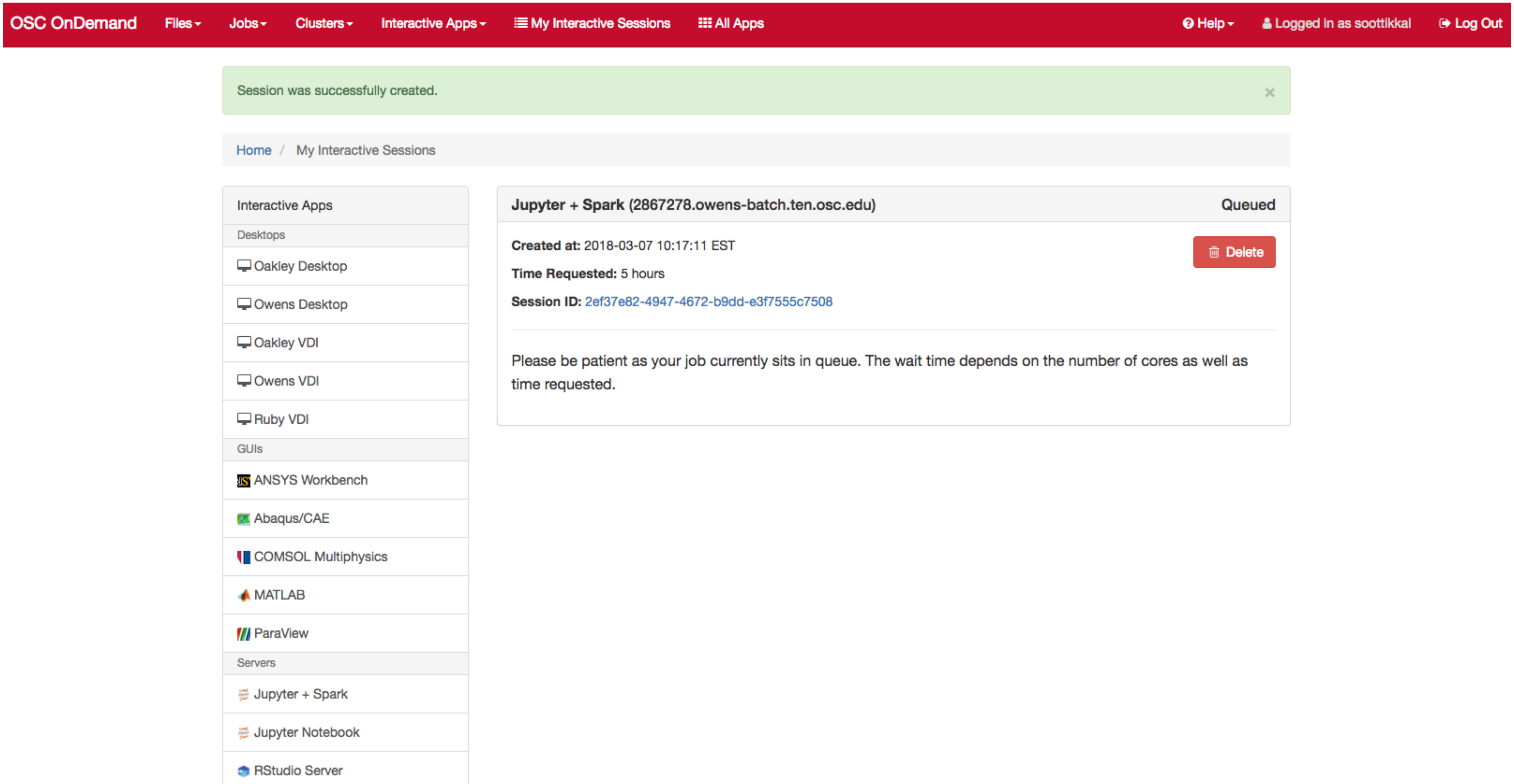


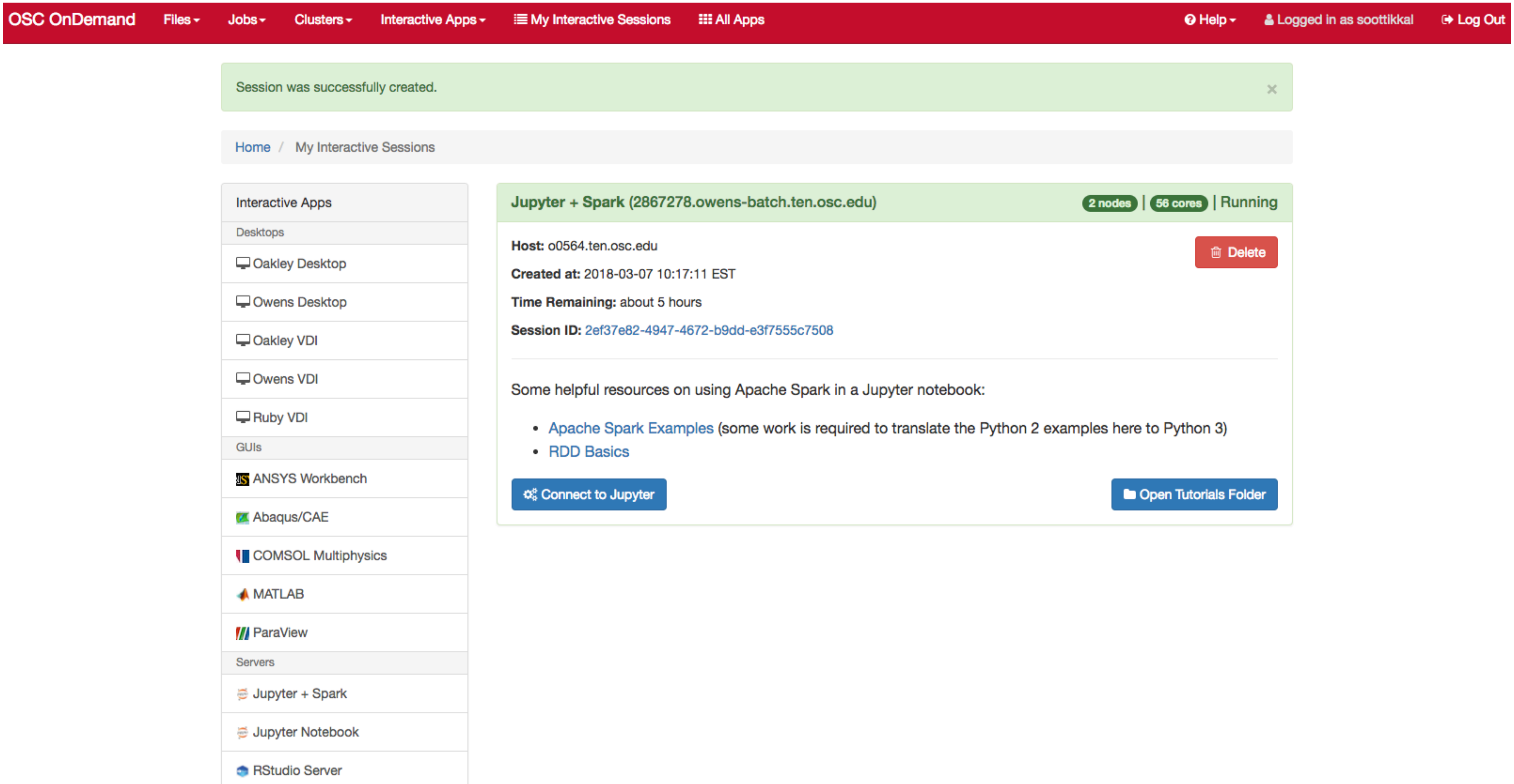

Ohio Supercomputer Center
An OH·TECH Consortium Member
Log in with your OSC username and password.
Username
w687002
Password
Remember me
Log in
Forgot your password?
Need Help?
Register for a new account

Choose Jupyter+Spark app from the Interactive Apps option.



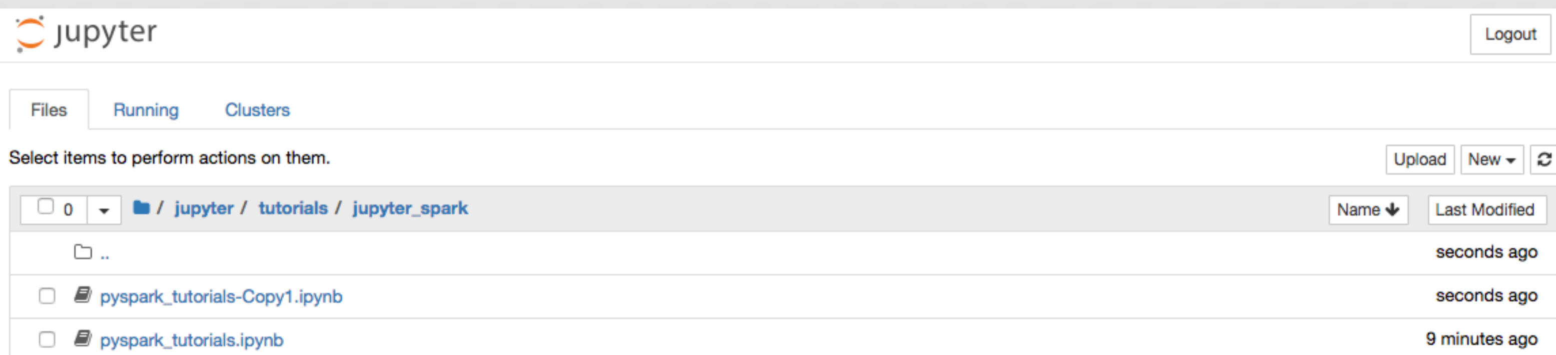

OSC OnDemand
Files
Jobs
Clusters
Interactive Apps
My Interactive Sessions
All Apps
Help
Logged in as soottikkal
Log Out
Home / My Interactive Sessions / Jupyter + Spark
Interactive Apps
Desktops
Oakley Desktop
Owens Desktop
Oakley VDI
Owens VDI
Ruby VDI
GUIs
ANSYS Workbench
Abaqus/CAE
COMSOL Multiphysics
MATLAB
ParaView
Servers
Jupyter + Spark
Jupyter Notebook
RStudio Server
Jupyter + Spark
This app will launch a Jupyter Notebook server using Python as well as an Apache Spark cluster on the Owens cluster.
Project
PZS0687
You can leave this blank if not in multiple projects.
Number of hours
5
Number of nodes
2
Node type
any
any - (28 cores) Use any available Owens node. This reduces the wait time as there are no node requirements.
hugemem - (48 cores) Use an Owens node that has 1.5TB of available RAM as well as 48 cores. There are 16 of these nodes on Owens.
Number of workers per node
1
This describes how the cores and memory are divvied up on the node (useful to reduce memory allocated for each worker). Should be a multiple of the number of cores on the node you chose above. Do NOT exceed the number of cores on the node.
Only launch the driver on the master node.
This is typically used for .collect and .take operations that require a large amount of memory allocated (> 2GB) for the driver process.
Include access to OSC tutorial/workshop notebooks.
I would like to receive an email when the session starts
Launch
* All Jupyter + Spark session data is generated and stored under the user's home directory in the corresponding data root directory.


OSC OnDemand
Files
Jobs
Clusters
Interactive Apps
My Interactive Sessions
All Apps
Help
Logged in as soottikkal
Log Out
Session was successfully created.
Home / My Interactive Sessions
Interactive Apps
Desktops
Oakley Desktop
Owens Desktop
Oakley VDI
Owens VDI
Ruby VDI
GUIs
ANSYS Workbench
Abaqus/CAE
COMSOL Multiphysics
MATLAB
ParaView
Servers
Jupyter + Spark
Jupyter Notebook
RStudio Server
Jupyter + Spark (2867278.owens-batch.ten.osc.edu)
Queued
Created at: 2018-03-07 10:17:11 EST
Delete
Time Requested: 5 hours
Session ID: 2ef37e82-4947-4672-b9dd-e3f7555c7508
Please be patient as your job currently sits in queue. The wait time depends on the number of cores as well as time requested.


OSC OnDemand
Files
Jobs
Clusters
Interactive Apps
My Interactive Sessions
All Apps
Help
Logged in as soottikkal
Log Out
Session was successfully created.
Home / My Interactive Sessions
Interactive Apps
Desktops
Oakley Desktop
Owens Desktop
Oakley VDI
Owens VDI
Ruby VDI
GUIs
ANSYS Workbench
Abaqus/CAE
COMSOL Multiphysics
MATLAB
ParaView
Servers
Jupyter + Spark
Jupyter Notebook
RStudio Server
Jupyter + Spark (2867278.owens-batch.ten.osc.edu)
2 nodes | 56 cores | Running
Host: o0564.ten.osc.edu
Created at: 2018-03-07 10:17:11 EST
Time Remaining: about 5 hours
Session ID: 2ef37e82-4947-4672-b9dd-e3f7555c7508
Delete
Some helpful resources on using Apache Spark in a Jupyter notebook:
Apache Spark Examples (some work is required to translate the Python 2 examples here to Python 3)
RDD Basics
Connect to Jupyter
Open Tutorials Folder

You will see a file called pyspark_tutorials.ipynb. Please check on the file and click on duplicate to make a copy of the file.


You will see a new file pyspark_tutorials-Copy1.ipynb is created. Double-click on the pyspark_tutorials-Copy1.ipynb file will launch Jupyter interface for Spark to proceed with the tutorials.



jupyter pyspark_tutorials-Copy1 Last Checkpoint: 3 minutes ago (autosaved)

This tutorial demonstrates how to analyse both structured and unstructured data using pyspark.

## Unstructured data

The fisrt step is to create a RDD for the data file called README.md.

```
In [ ]: data = sc.textFile("/users/PZS0680/soottikkal/workshop/Bigdata/guide/README.md")
```

Once a RDD is created, we can do operations on the RDD. For example, count the number of lines of RDD

```
In [ ]: data.count()
```

See what's in the RDD

```
In [ ]: data.take(3)
```

```
In [ ]: data.collect()
```

The first command shows the first three lines (each line is preceded by the letter u)of RDD while the second shows the entire file. We should be cautious with collect() function when data size is large as it requires a large amount of memory allocated for the driver node.

# Exercise-3
# Launching Jupyter + Spark App

https://www.osc.edu/content/launching_jupyter_spark_app

# Spark RDD

In this example, we are couting how many times each word appears in a file called README.md. The fisrt step is to create a RDD from the data file called README.md. We will do some simple operations like count, take, collect on the RDD. Then we will use transfomations like filter, flatmap and map to get the wordcount.

In [ ]:
```
data = sc.textFile("/users/PZS0645/support/workshop/Bigdata/README.md")
```

Once a RDD is created, we can do operations on the RDD. For example, count the number of lines of RDD

In [ ]:
```
data.count()
```

In [ ]:
```
#See what's in the RDD
data.take(3)
```

In [ ]:
```
data.collect()
```

The first command shows the first three lines (each line is preceded by the letter u)of RDD while the second shows the entire file. We should be cautious with collect() function when data size is large as it requires a large amount of memory allocated for the driver node to collect entire data

In [ ]:
```
#Check the data type
type(data)
```

Next we'll do a simple transformation: filter all the lines with "Spark" in them and count such lines.

In [ ]:
```
linesWithSpark = data.filter(lambda line: "Spark" in line)
```

In [ ]:
```
linesWithSpark.count()
```

# Spark DataFrame

Making a Simple DataFrame from a Tuple List.

In [34]:
```
# Make a tuple list
a_list = [('a', 1), ('b', 2), ('c', 3)]
```

In [35]:
```
# Create a Spark DataFrame, without supplying a schema value
df_from_list_no_schema = \
sqlContext.createDataFrame(a_list)
```

In [36]:
```
# Print the DF object
print (df_from_list_no_schema)
```

```
DataFrame[_1: string, _2: bigint]
```

In [37]:
```
# Print a collected list of Row objects
print (df_from_list_no_schema.collect())
```

```
[Row(_1='a', _2=1), Row(_1='b', _2=2), Row(_1='c', _2=3)]
```

In [38]:
```
# Show the DataFrame
df_from_list_no_schema.show()
```

```
+---+---+
| _1| _2|
+---+---+
|  a|  1|
|  b|  2|
|  c|  3|
+---+---+
```

# Spark SQL

Inorder to run SparkSQL querries, we have to register the dataframe as table.

```
In [ ]: data.registerTempTable("interactions")
```

Now we can querry on the table called *interactions* based on conditions. For example, select tcp network interactions with more than 1 second duration and no transfer from destination

```
In [ ]: tcp = sqlContext.sql(" SELECT duration, dst_bytes FROM interactions WHERE protocal_type ='tcp' AND duration>1000 AND ds
```

```
In [ ]: tcp.show(5)
```

# Spark Mllib

1. Logistic regression: to predict a binary response
2. Kmeans clustering: to clusters the data points into a predefined number of clusters

# Exercise-4

# Spark Interactive Analytics

# Running Spark interactively in batch

To run Spark interactively, but in batch on Owens please run the following command,

```
qsub -I -l nodes=4:ppn=28 -l walltime=01:00:00
```

When your interactive shell is ready, please launch spark cluster using the pbs-spark-submit script

```
pbs-spark-submit
```

You can then launch the interface for pyspark  as follows,

```
pyspark --master spark://nodename.ten.osc.edu:7070
```

```
Python 2.7.5 (default, Oct 11 2015, 17:47:16)
[GCC 4.8.3 20140911 (Red Hat 4.8.3-9)] on linux2
Type "help", "copyright", "credits" or "license" for more information.
Using Spark's default log4j profile: org/apache/spark/log4j-defaults.properties
Setting default log level to "WARN".
To adjust logging level use sc.setLogLevel(newLevel).
17/02/23 10:16:30 WARN NativeCodeLoader: Unable to load native-hadoop library for your platform... using builtin-java classes where applicable
Welcome to
      ____              __
     / __/__  ___ _____/ /__
    _\ \/ _ \/ _ `/ __/  '_/
   /__ / .__/\_,_/_/ /_/\_\   version 2.0.0
      /_/

Using Python version 2.7.5 (default, Oct 11 2015 17:47:16)
SparkSession available as 'spark'.
>>>
```

# Running Spark non-interactively

## Using Spark

In order to run Spark in batch, reference the example batch script below. This script requests 6 node on the Oakley cluster for 1 hour of walltime. The script will submit the pyspark script called test.py using pbs-spark-submit command into the PBS queue.

```
#PBS -N Spark-example

#PBS -l nodes=6:ppn=12

#PBS -l walltime=01:00:00

module load spark

cd $PBS_O_WORKDIR

cp test.py $TMPDIR

cd $TMPDIR

pbs-spark-submit test.py  > test.log

cp * $PBS_O_WORKDIR
```

# Running Spark using PBS script

## 1. Create an App in python: stati.py

```
from pyspark import SparkContext
import urllib
f = urllib.urlretrieve ("http://kdd.ics.uci.edu/databases/kddcup99/kddcup.data.gz","kddcup.data.gz")

data_file = "./kddcup.data.gz"
sc = SparkContext(appName="Stati")
raw_data = sc.textFile(data_file)

import numpy as np

def parse_interaction(line):
    line_split = line.split(",")
    symbolic_indexes = [1,2,3,41]
    clean_line_split=[item for i, item in enumerate(line_split) if i not in symbolic_indexes]
    return np.array([float(x) for x in clean_line_split])

vector_data=raw_data.map(parse_interaction)


from pyspark.mllib.stat import Statistics
from math import sqrt

summary = Statistics.colStats(vector_data)


print ("Duration Statistics:")
print (" Mean %f" % (round(summary.mean()[0],3)))
print ("St. deviation : %f"%(round(sqrt(summary.variance()[0]),3)))
print (" Max value: %f"%(round(summary.max()[0],3)))
print (" Min value: %f"%(round(summary.min()[0],3)))
```

## 2. Create a PBS script: stati.pbs

```
#PBS -N spark-statistics
#PBS -l nodes=18:ppn=28
#PBS -l walltime=00:10:00
module load spark/2.0.0
cp stati.py $TMPDIR
cd $TMPDIR
pbs-spark-submit stati.py > stati.log
cp *  $PBS_O_WORKDIR
```

## 3. Run Spark job

```
qsub stati.pbs
```

## 4. Output: stati.log

```
sync from spark://n0381.ten.osc.edu:7077
starting org.apache.spark.deploy.master.Master,  logging to
/nfs/15/soottikkal/spark/kdd/spark-soottikkal-org.apache.spark.deploy.master.Master-1-
n0381.ten.osc.edu.out
failed to launch org.apache.spark.deploy.master.Master:
full log in /nfs/15/soottikkal/spark/kdd/spark-soottikkal-
org.apache.spark.deploy.master.Master-1-n0381.ten.osc.edu.out

Duration Statistics:
Mean 48.342000
St. deviation : 723.330000
Max value: 58329.000000
Min value: 0.000000
Total value count: 4898431.000000
Number of non-zero values: 118939.000000


SPARK_MASTER=spark://n0381.ten.osc.edu:7077
```

# Exercise-5
# Spark non-interactive jobs

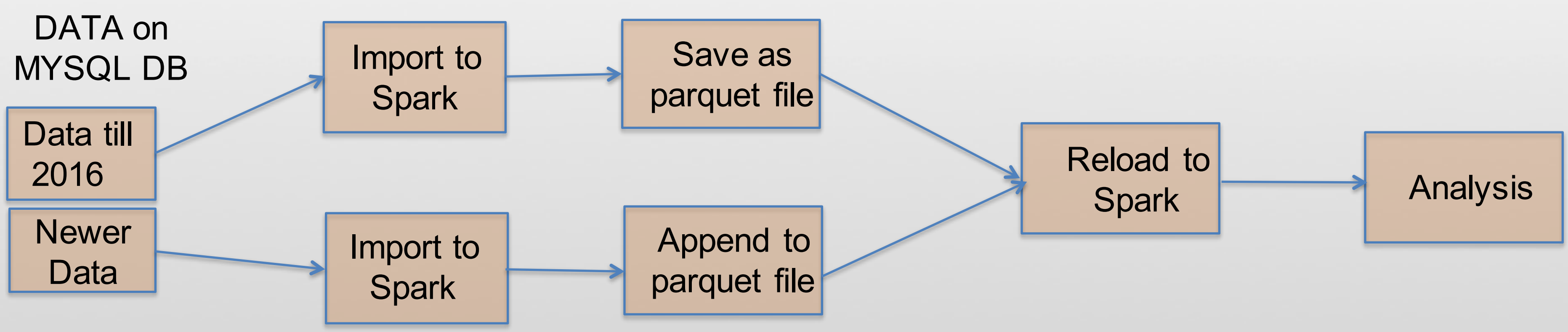
https://www.osc.edu/content/submitting_non_interactive_jobs

CASE STUDY

## Data mining of historical jobs records of OSC's clusters

Aim: To understand client utilizations of OSC recourses.

Data: Historical records of every Job that ran on any OSC clusters that includes information's such as number of nodes, software, CPU time and timestamp.



# Pyspark code for data analysis

#importing data

```
df=sqlContext.read.parquet("/fs/scratch/pbsacct/Jobs.parquet")
df.show(5)
```

| jobid | username | system | nproc | submit_date | end_date | jobname | sw_app | queue |
|---|---|---|---|---|---|---|---|---|
| 13780.owens-batch... | [illegible]3 | owens | 280 | 2016-09-28 | 2016-10-08 | MMPCDH24EC1-3-2eq... | namd | parallel |
| 13786.owens-batch... | [illegible]4 | owens | 96 | 2016-09-28 | 2016-10-05 | FR181-011DS | foam | parallel |
| 13798.owens-batch... | [illegible]0 | owens | 252 | 2016-09-28 | 2016-10-03 | TSRD-5-3-012DS | foam | parallel |
| 13800.owens-batch... | [illegible]0 | owens | 252 | 2016-09-28 | 2016-10-02 | TSRD-5-3-013MSE | foam | parallel |
| 13804.owens-batch... | [illegible]0 | owens | 252 | 2016-09-28 | 2016-10-02 | TSRD-5-3-014MSE | foam | parallel |

#Which types of queue is mostly used

```
df.select("jobid","queue").groupBy("queue").count().show()
```

| queue | count |
|---|---|
| debug | 157 |
| serial | 288174 |
| montecarlo | 12 |
| parallel | 41214 |
| hugemem | 102 |
| largeparallel | 60 |
| longserial | 66 |
| dedicated | 8 |

#Which software is used most?

```
df.select("jobid","sw_app").groupBy
("sw_app").count().sort(col("count").desc()) .show()
```

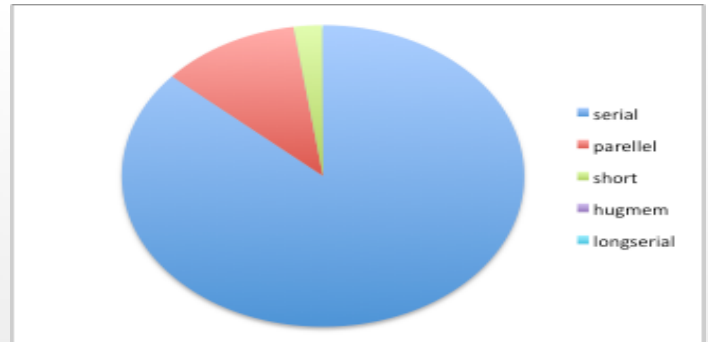
| sw_app | count |
|---|---|
| condor | 40199 |
| fastsimcoal | 39535 |
| null | 36914 |
| amber | 35304 |
| real_exe | 31076 |
| molcas | 23695 |
| vasp | 18164 |
| gadget | 13880 |
| bam | 13189 |
| hpl | 9820 |

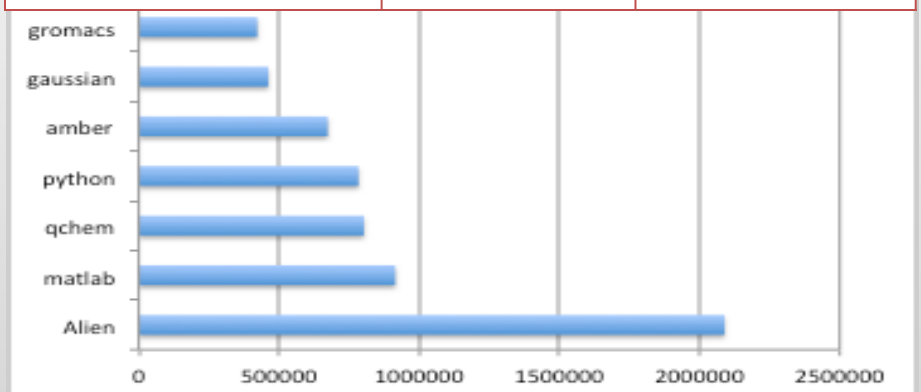
#who uses gaussian software most?

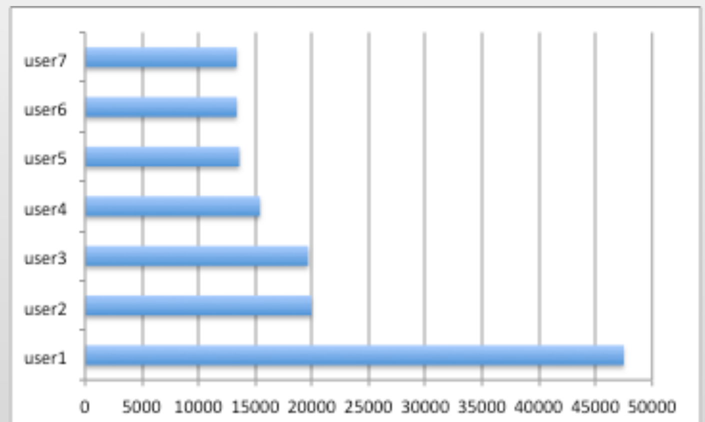
```
df.registerTempTable("Jobs")
sqlContext.sql(" SELECT username FROM
Jobs WHERE sw_app='gaussian' " ).show()
```

# Results

| Statistics | MYSQL | SPARK |
|---|---|---|
| Job vs CPU | 1 hour | 5 sec |
| CPU vs Account | 1.25 hour | 5 sec |
| Walltime vs user | 1.40 hour | 5 sec |



# Running Hadoop at OSC

A Hadoop cluster can be launched within the HPC environment, but managed by the PBS job scheduler using Myhadoop framework developed by San Diego Supercomputer Center. (Please see http://www.sdsc.edu/~allans/MyHadoop.pdf)

## Availability & Restrictions

Hadoop is available to all OSC users without restriction.

The following versions of Hadoop are available on OSC systems:

| VERSION | OAKLEY | OWENS |
|---|---|---|
| 3.0.0* | | X |

NOTE: * means it is the default version.

## Set-up

In order to configure your environment for the usage of Hadoop, run the following command:

```
module load hadoop
```

In order to access a particular version of Hadoop, run the following command

```
module load hadoop/3.0.0-alpha1
```

# Using Hadoop: Sample PBS Script

```
#PBS -N hadoop-example

#PBS -l nodes=6:ppn=12

#PBS -l walltime=01:00:00

setenv WORK $PBS_O_WORKDIR

module load hadoop/3.0.0-alpha1

module load myhadoop/v0.40

setenv HADOOP_CONF_DIR $TMPDIR/mycluster-conf-$PBS_JOBID

cd $TMPDIR

myhadoop-configure.sh -c $HADOOP_CONF_DIR -s $TMPDIR

$HADOOP_HOME/sbin/start-dfs.sh

hadoop dfsadmin -report

hadoop  dfs -mkdir data

hadoop  dfs -put $HADOOP_HOME/README.txt  data/

hadoop  dfs -ls data

hadoop jar $HADOOP_HOME/share/hadoop/mapreduce/hadoop-mapreduce-examples-3.0.0-alpha1.jar
wordcount data/README.txt wordcount-out

hadoop  dfs -ls wordcount-out

hadoop  dfs  -copyToLocal -f  wordcount-out  $WORK

$HADOOP_HOME/sbin/stop-dfs.sh

myhadoop-cleanup.sh
```

# Using Hadoop: Sample PBS Script

```
#PBS -N hadoop-example

#PBS -l nodes=6:ppn=12

#PBS -l walltime=01:00:00

setenv WORK $PBS_O_WORKDIR

module load hadoop/3.0.0-alpha1

module load myhadoop/v0.40

setenv HADOOP_CONF_DIR $TMPDIR/mycluster-conf-$PBS_JOBID

cd $TMPDIR

myhadoop-configure.sh -c $HADOOP_CONF_DIR -s $TMPDIR

$HADOOP_HOME/sbin/start-dfs.sh

hadoop dfsadmin -report

hadoop  dfs -mkdir data

hadoop  dfs -put $HADOOP_HOME/README.txt  data/

hadoop  dfs -ls data

hadoop jar $HADOOP_HOME/share/hadoop/mapreduce/hadoop-mapreduce-examples-3.0.0-alpha1.jar
wordcount data/README.txt wordcount-out

hadoop  dfs -ls wordcount-out

hadoop  dfs  -copyToLocal -f  wordcount-out  $WORK

$HADOOP_HOME/sbin/stop-dfs.sh

myhadoop-cleanup.sh
```

# Exercise-6
# Hadoop jobs

https://www.osc.edu/content/submitting_non_interactive_jobs

# References

## 1. Spark Programming Guide

https://spark.apache.org/docs/2.0.0/programming-guide.html

-Programming with Scala, Java and Python

## 2. Data Exploration with Spark

http://www.cs.berkeley.edu/~rxin/ampcamp-ecnu/data-exploration-using-spark.html

## 3. Hadoop

http://hadoop.apache.org/

## 4. OSC Documentation

https://www.osc.edu/documentation/software_list/spark_documentation
https://www.osc.edu/resources/available_software/software_list/hadoop

# Thank you!

- Questions or comments: soottikkal@osc.edu
- General questions about OSC service: oschelp@osc.edu