

Interactive Computing and Running Jupyter Notebooks

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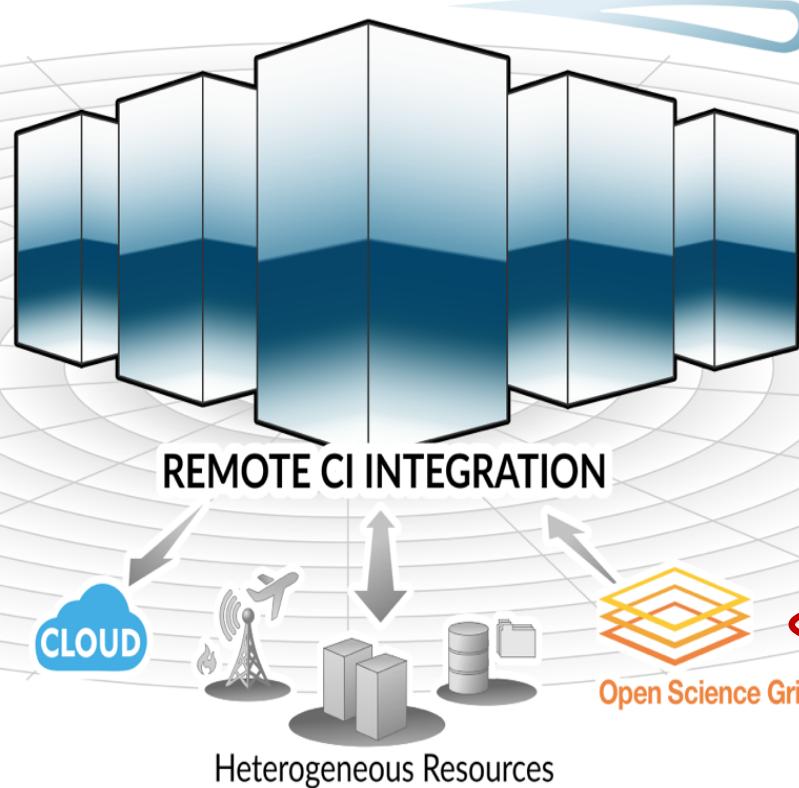
EXPANSE
COMPUTING WITHOUT BOUNDARIES

EXPANSE

COMPUTING WITHOUT BOUNDARIES
5 PETAFLOP/S HPC and DATA RESOURCE

HPC RESOURCE

13 Scalable Compute Units
728 Standard Compute Nodes
52 GPU Nodes: 208 GPUs
4 Large Memory Nodes



DATA CENTRIC ARCHITECTURE

12PB Perf. Storage: 140GB/s, 200k IOPS
Fast I/O Node-Local NVMe Storage
7PB Ceph Object Storage
High-Performance R&E Networking

LONG-TAIL SCIENCE

Multi-Messenger Astronomy
Genomics
Earth Science
Social Science

INNOVATIVE OPERATIONS

Composable Systems
High-Throughput Computing
Science Gateways
Interactive Computing
Containerized Computing
Cloud Bursting

For more details see the Expanse user guide @ https://www.sdsc.edu/support/user_guides/expanse.html

and the "Introduction to Expanse" webinar @ https://www.sdsc.edu/event_items/202006_Introduction_to_Expanse.html

Outline

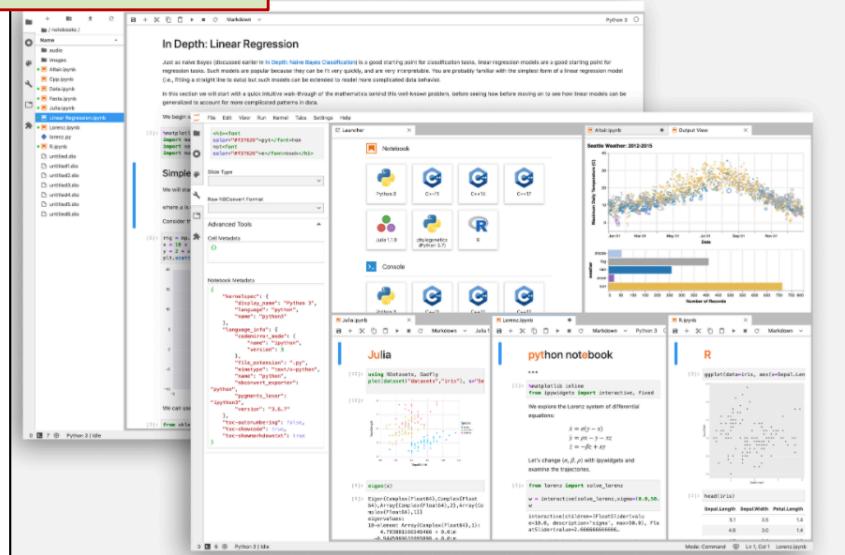
- What is Interactive High-Performance Computing?
- Types of Interactive Computing
- How to Access an Interactive Compute Node
- How to Run Applications
- How to Run Jupyter Notebooks

What is Interactive HPC-Computing

- In **computer science**, **interactive computing** refers to software which accepts input from the user as it runs.
 - **Interactive** software includes commonly used programs, such as word processors or spreadsheet applications.
- **Interactive HPC computing** involves *real-time* user inputs to perform tasks on a set of compute node(s) including:
 - Code development, real-time data exploration, and visualizations.
 - Used when applications have large data sets or are too large to download to local device, software is difficult install, etc.
 - User inputs come via command line interface or application GUI (Jupyter Notebooks, Matlab, R-studio).
 - Actions performed on remote compute nodes as a result of user input or program out.

Interactive HPC Scenarios

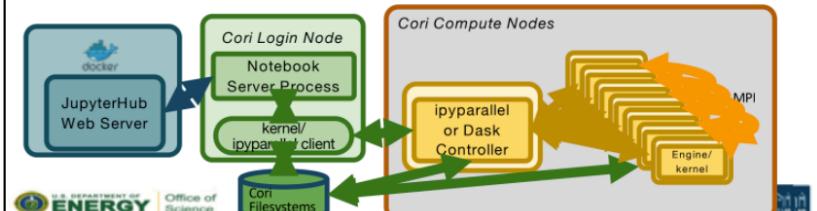
<https://jupyter.org/>



Interactive Distributed Computing with Jupyter (NERSC)

Jupyter architecture

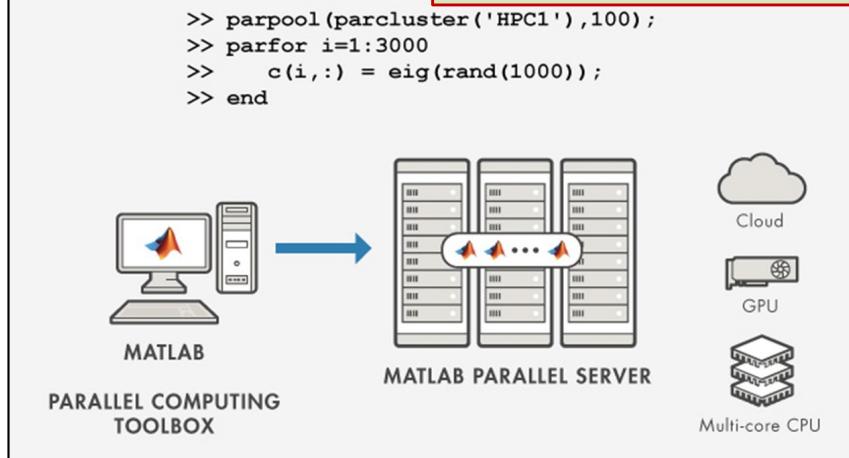
- Allocate nodes on Cori interactive queue and start ipyparallel or Dask cluster
 - Developed %ipcluster magic to setup within notebook
- Compute nodes traditionally do not have external address
 - Required network configuration / policy decisions
- Distributed training communication is via MPI Horovod or Cray ML Plugin



<https://drive.google.com/file/d/1-OFjrk1q3L1d3uakr2xkozrPn2c2VZpZ/view>

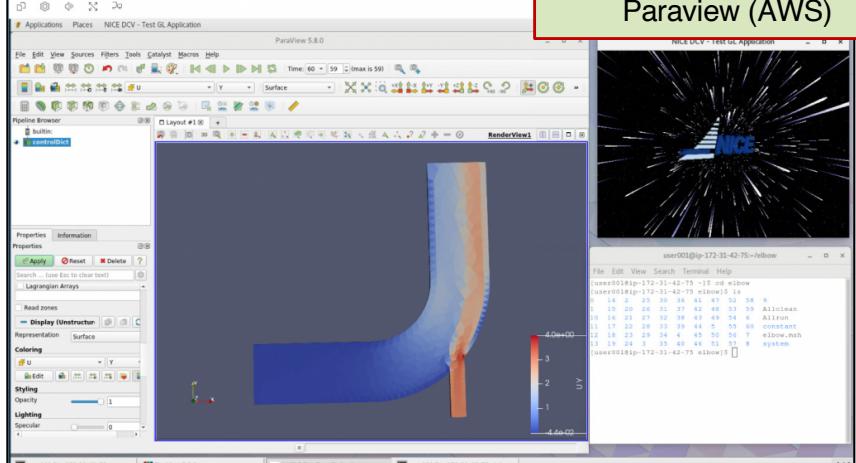
SDSC SAN DIEGO SUPERCOMPUTER CENTER

Parallel Matlab (AWS)



<https://azuremarketplace.microsoft.com/en-us/marketplace/apps/mathworks-inc.matlab-parallel-server-listing?tab=Overview>

Paraview (AWS)



<https://aws.amazon.com/blogs/compute/how-to-run-3d-interactive-applications-with-nice-dcv-in-aws-batch/>

UC San Diego

Accessing Interactive Compute Nodes on Expanse

- Use the *srun* command to obtain nodes for ‘live,’ command line interactive access:
- Notes:
 - account info is required
 - Start your testing using shared or debug partitions

CPU	<pre>srun --partition=shared --pty --nodes=1 --ntasks-per-node=16 --mem=248 -t 00:30:00 --wait=0 --export=ALL --account=abc123 /bin/bash</pre>
GPU	<pre>srun --partition=gpu-shared --pty -- nodes=1 --ntasks-per-node=16 -- mem=374 --gpus=1 -t 00:30:00 --wait=0 -- export=ALL --account=abc123 /bin/bash</pre>

Running Jupyter Services on HPC Systems at SDSC

- What is Jupyter?

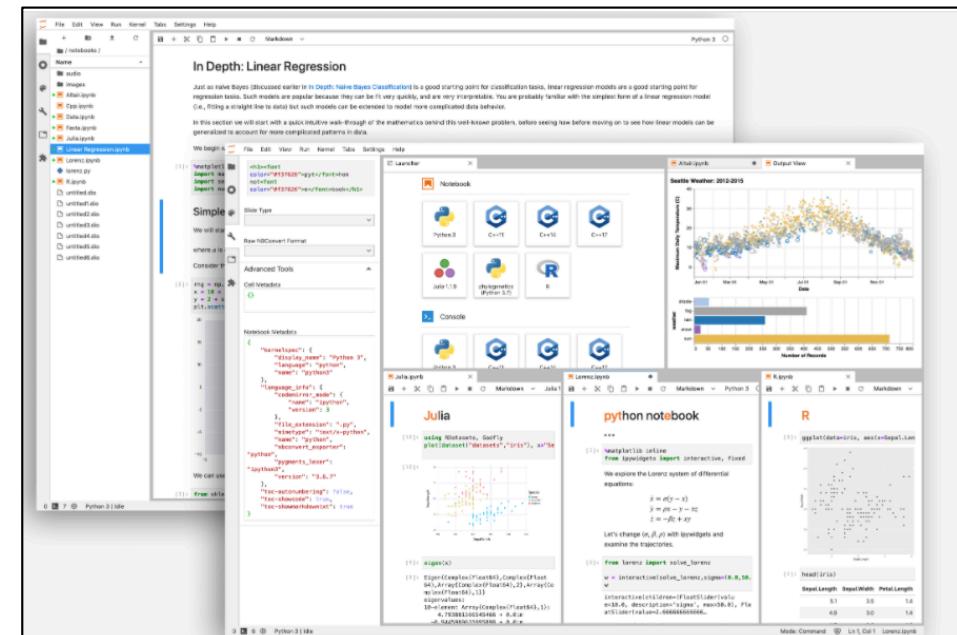
*Jupyter is a free, open-source, **interactive** web tool known as a computational notebook, which researchers can use to combine software code, computational output, explanatory text and multimedia resources in a single document. (J. Perkel, <https://www.nature.com/articles/d41586-018-07196-1>)*

- Common Jupyter Services:

- Jupyter Notebooks (single user)
- JupyterLab: advanced version of notebook
- JupyterHub: multiuser Jupyter service

- To run Jupyter services:

- Laptop/local host, use Anaconda:
 - <https://docs.anaconda.com/anaconda/install/>
- HPC systems: use miniconda:
 - <https://docs.conda.io/en/latest/miniconda.html>



Related Tutorial: <https://hpc-training.sdsc.edu/notebooks-101/notebook-101.html>

Using Anaconda on Local Host or Laptop

The screenshot shows the Anaconda Navigator interface. A red circle highlights the "CONDA NAVIGATOR" header. Another red circle highlights the "Launch" button for the JupyterLab application. A third red circle highlights the "Launch" button for the Notebook application.

localhost:8920/lab

MPT@SDSC

File Edit View Run Kernel Tabs Settings Help

Name

hello.java.nb.xkcd_plots.random-ans.ipynb test_bash.ipynb trapezoid.ipynb

rw-r--r--# 1 mthomas staff 6826 May 9 18:29 the-prisoner.jpeg
rw-r--r--# 1 mthomas staff 577704 Mar 23 17:55 titos-hand-cleanser-horiz.png
rw-r--r--# 1 mthomas staff 616544 Mar 23 17:21 titos-hand-cleanser.png
drwxr-xr-x 49 mthomas staff 1568 May 20 21:51 tools
rw-r--r--# 1 mthomas staff 760278 Apr 25 18:16 why-people-are-buying-so-much-toilet-paper-amid-corona.jpg
(base) quantum:~ mthomas\$ comet
Last login: Thu May 21 08:11:09 2020 from 76.176.117.51
Rocks 7.0 (Manzanita)
Profile built 12:32 03-Dec-2019
Kickstarted 13:47 03-Dec-2019

WELCOME TO CONDA NAVIGATOR

Applications on base (root) Channels

lab 1.0.2 JupyterLab An extensible environment for interactive and reproducible computing, based on the Jupyter Notebook and Architecture. Launch

jupyter 6.0.0 Notebook Web-based, interactive computing notebook environment. Edit and run human-readable docs while describing the data analysis. Launch

spyder 3.3.6 Scientific Python Development Environment. Powerful Python IDE with advanced editing, interactive testing, debugging and introspection features. Launch

glueviz 0.13.3 Glueviz Multidimensional data visualization across files. Explore relationships within and among related datasets. Install

orange3 3.19.0 Orange 3 Component based data mining framework. Data visualization and data analysis for novice and expert. Interactive workflows with a large toolbox. Install

rstudio 1.1.456 RStudio A set of integrated tools designed to help you be more productive with R. Includes R essentials and notebooks. Install

localhost:8807/tree/dev/sdsc....

T@SDSC

File Running IPython Clusters

Select items to perform actions on them.

Upload New

Name Last Modified File size

.. seconds ago

hello.ipynb 9 hours ago 731 B

hello_world.ipynb 9 hours ago 2 kB

hello.py 9 hours ago 168 B

hello.rb 9 hours ago 102 B

mthomas — jupyter_mac.command — python -bash — 82x43
! May 20 23:42:17 on ttys003
! jupyter_mac.command ; exit;
! mthomas@/anaconda3/bin/jupyter_mac.command ; exit;
! NotebookApp] The port 8888 is already in use, trying another port.
! NotebookApp] The port 8889 is already in use, trying another port.
! NotebookApp] The port 8890 is already in use, trying another port.
! NotebookApp] The port 8891 is already in use, trying another port.
! NotebookApp] The port 8892 is already in use, trying another port.
! NotebookApp] Loading IPython parallel extension
! NotebookApp] JupyterLab extension loaded from /anaconda3/lib/python2.7/jupyterlab
! NotebookApp] JupyterLab application directory is /anaconda3/share/jupyter
! NotebookApp] Serving notebooks from local directory: /Users/mthomas
! NotebookApp] The Jupyter Notebook is running at:
! NotebookApp] http://localhost:8798/?token=681f898da657418d5cce6909
! NotebookApp] or http://127.0.0.1:8798/?token=681f898da657418d5cce6909
! NotebookApp] Use Control-C to stop this server and shut down all kernels (press Enter to skip confirmation).
! NotebookApp]
! the notebook, open this file in a browser:
! /Users/mthomas/Library/Jupyter/runtime/nbserver-55091-open.html
! paste one of these URLs:
! localhost:8798/?token=681f898da657418d5cce6909&829b6064b3313c100fdc
! 127.0.0.1:8798/?token=681f898da657418d5cce6909&829b6064b3313c100fdc
! 69096829b6064b3313c100fdc
! [W 08:37:22.641 NotebookApp] 404 GET /static/components/react/react-dom.production.min.js (::1) 1.06ms referer=http://localhost:8798/tree?token=681f898da657418d5cce6909&829b6064b3313c100fdc

HPC Systems: Use Conda

- Conda: open-source package and environment management system:
 - Runs on Windows, macOS, and Linux.
 - Less overhead than Anaconda
- Created for Python programs:
 - Can package and distribute software for any language.
- Download: <https://docs.conda.io/projects/conda/en/latest/>
- To Install Conda on Expanse, see Notebooks tutorial:
 - <https://hpc-training.sdsc.edu/notebooks-101/notebook-101.html#software-prerequisites>
 - Note: do not put the conda activation code into the .bashrc or .bash_profile files
 - This ends up making the login process extremely long,
- When you are ready to use notebooks, run these commands

```
[user@login01 ~]. /home/user/miniconda3/etc/profile.d/conda.sh  
[user@login01 ~]conda activate  
(base) [user@login01 ~]
```
- Conda Cheat Sheet:
 - https://kapeli.com/cheat_sheets/Conda.docset/Contents/Resources/Documents/index

Conda Environments

(<https://docs.conda.io/projects/conda/en/latest/user-guide/concepts/environments.html>)

- You can load the conda environment in 2 ways: at login (from your .bash_profile) or via command line (when you are ready to use conda, run Jupyter)
 - On installation of miniconda, the code will install the activation commands in your .bashrc file automatically. This takes time which delays your login process.
 - SDSC recommends that you remove those lines and save in a text file.
- The example below shows how to do this:

```
Last login: Thu Mar  4 06:42:34 2021 from 76.176.117.51
[user@login01 ~]$ cat conda-activate.txt
### Commands to activate Conda environment
./home/user/miniconda3/etc/profile.d/conda.sh
conda activate
[user@login01 ~]$ ./home/user/miniconda3/etc/profile.d/conda.sh
[user@login01 ~]$ conda activate
(base) [user@login01 ~]$
```

- The **(base)** prefix to the command line prompt shows that we are running in the base conda environment. Note that (base) was not present until the conda activation commands were run.

Custom Conda Virtual Environments

- Use conda to create a virtual environment
 - \$ conda create --name example_env
- To see which virtual environments you've created:
`[user@login01 ~]conda env list`
- To use a particular virtual environment (e.g., one named 'example_env'), run:
`$ source activate example_env`
(Note: don't use 'conda activate')

Conda Enviromnet Example

```
(base) [user@login01 ~]$ conda list
# packages in environment at /home/user/miniconda3:
#
# Name           Version        Build  Channel
_libgcc_mutex    0.1            main
argon2-cffi      20.1.0       py38h7b6447c_1
[SNIP 20-30 lines]
zlib             1.2.11        h7b6447c_3
(base) [user@login01 ~]$ conda create --name demo_env
Collecting package metadata (current_repodata.json): done
Solving environment: done
## Package Plan ##
  environment location:
  /home/user/miniconda3/envs/demo_env
Proceed ([y]/n)? y
Preparing transaction: done
Verifying transaction: done
Executing transaction: done
#
# To activate this environment, use
#
# $ conda activate demo_env
#
# To deactivate an active environment, use
#
# $ conda deactivate
```

```
(base) [user@login01 ~]$ conda activate demo_env
(base) [user@login01 ~]$ conda list
# packages in environment at /home/ user
/miniconda3/envs/demo_env:
#
# Name           Version        Build  Channel
(demo_env) [user@login01 ~]$ conda install numpy
Collecting package metadata (current_repodata.json): done
Solving environment: done
[SNIP][several mins later]
(demo_env) [user @login01 ~]$ conda list
# packages in environment at /home/ user
/miniconda3/envs/demo_env:
#
# Name           Version        Build  Channel
_libgcc_mutex    0.1            main
blas             1.0            mkl
[SNIP]
xz               5.2.5          h7b6447c_0
 zlib            1.2.11         h7b6447c_3
(demo_env) [user @login01 ~]$
(demo_env) [user @login01 ~]$conda deactivate
(base) [user @login01 ~]$ conda deactivate
[user@login01 ~]$
```

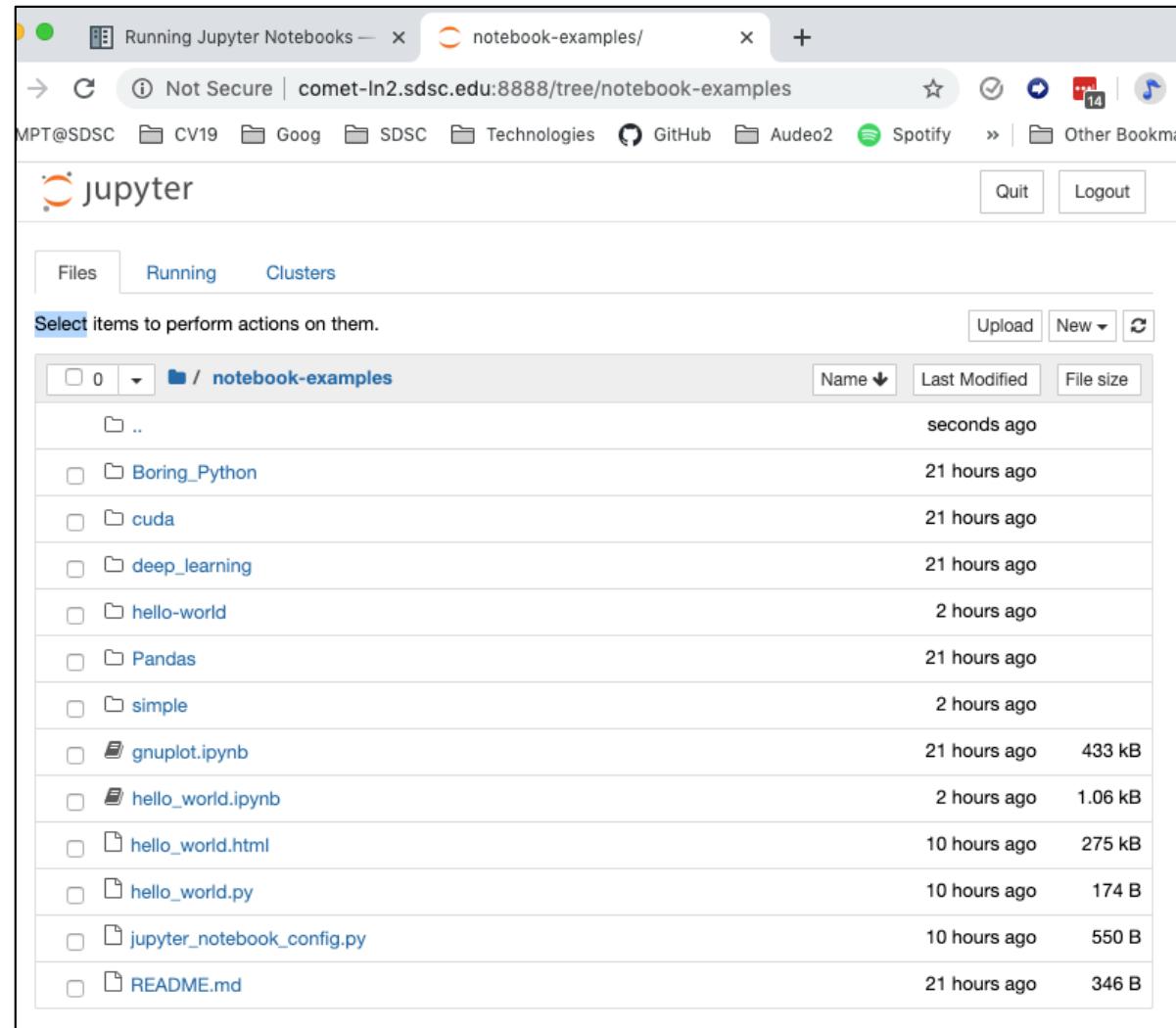
Installing Jupyter Servers

- To run Jupyter servers (notebooks, jupyterlab), you need to install them using *conda*.
- To Install Jupyter Notebooks, see:
 - <https://comet-notebooks-101.readthedocs.io/en/master/prerequisites.html#install-jupyter-notebook>
- To Install JupyterLab, see:
 - <https://comet-notebooks-101.readthedocs.io/en/master/prerequisites.html#install-jupyterlab>
- Note: installing conda, and Jupyter can take a very long time (5-10 minutes)

Jupyter Has a Key Vulnerability: Jupyter Servers Provide Access to HPC File Systems

SDSC Jupyter Services Policy:

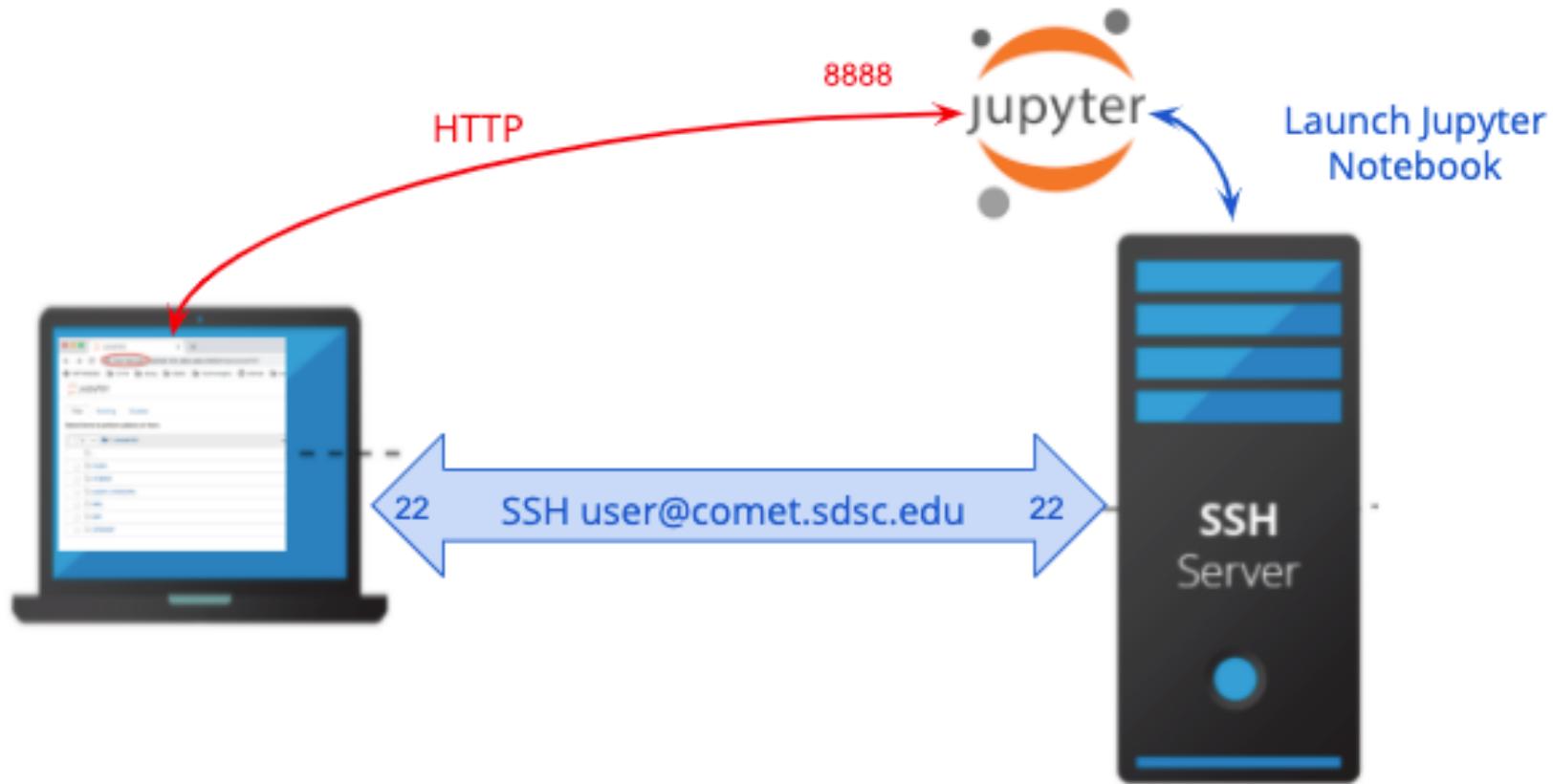
- Portals, JupyterHub, and other services cannot be mounted directly to disk (must be on VM or external)
 - Many use root in vulnerable ways
 - If a user launches Jupyter Lab or Notebooks, the jobs will be killed.
- No applications can run on login nodes
- **SDSC recommendation:**
 - use secure connections: when you choose unsecure connections your account is vulnerable to hacking



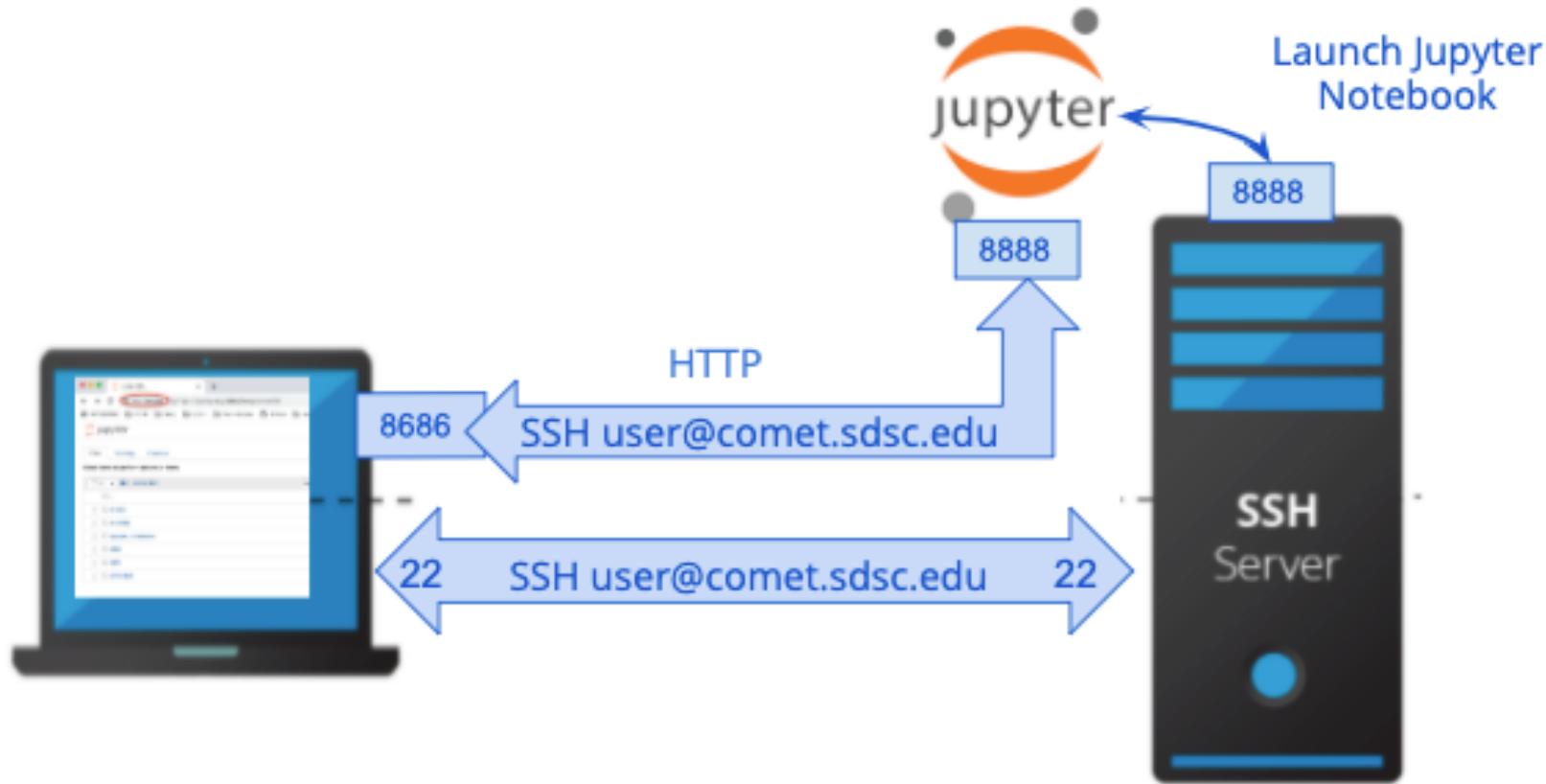
Methods for Running Notebooks on Comet/Expanse

- Connection scenarios:
 - Connection to Notebook over HTTP (insecure)
 - Connection to Notebook over SSH tunneling (secure, but inconvenient)
 - Connection to Notebook over HTTPS using the [Reverse Proxy Service](#) (very secure) [Beta testing]
 - Coming Soon: Galileo remote notebook launcher
- SDSC allows Jupyter Services to be run on the following nodes:
 - Interactive node
 - Compute node
 - GPU node

Connection over HTTP (unsecure)

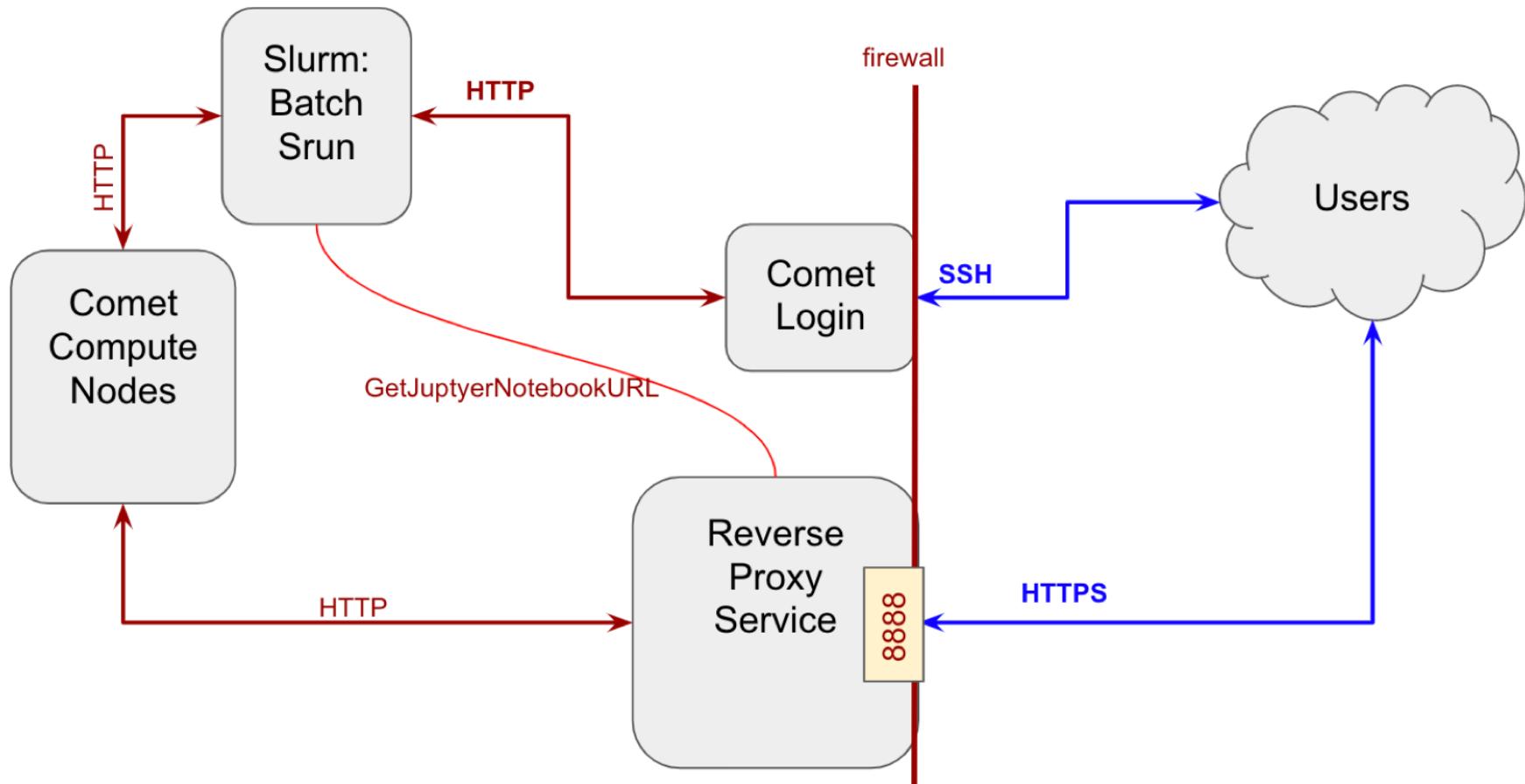


Secure Connection over SSH Tunneling (secure but inconvenient and unstable)



For instructions on how to set up SSH Tunneling, see:
<https://comet-notebooks-101.readthedocs.io/en/master/methods/tunneling.html>

SDSC Reverse Proxy Service (RPS) (secure, convenient and stable)



Documentation: <https://hpc-training.sdsc.edu/notebooks-101/>

GitHub Repo: <https://github.com/sdsc-hpc-training-org/reverse-proxy>

SDSC Reverse Proxy Service Usage

- Using RPS is very simple and requires no tunneling and is secure (produces HTTPS URLs).
- To use JRPS:
 - SSH to an Expanse login node: `login.expanse.sdsc.edu`
 - Clone the Repo:
`git clone https://github.com/sdsc-hpc-training-org/reverse-proxy.git`
 - Check your software environment on the login node: conda, Jupyter (notebooks, lab), and other Python packages needed for your application.
- See installation instructions:
 - <https://hpc-training.sdsc.edu/notebooks-101/notebook-101.html#software-prerequisites>
- Notebook Examples Repo:
 - <https://github.com/sdsc-hpc-training-org/notebook-examples>

Install Reverse Proxy Scripts

```
[user@login01 ~]$ git clone https://github.com/sdsc-hpc-training-org/reverse-proxy.git
Cloning into 'reverse-proxy'...
remote: Enumerating objects: 265, done.
remote: Counting objects: 63% (167/265)
remote: Counting objects: 100% (265/265), done.
remote: Compressing objects: 100% (167/167), done.
remote: Total 969 (delta 163), reused 192 (delta 97), pack-reused 704
Receiving objects: 100% (969/969), 7.60 MiB | 16.28 MiB/s, done.
Resolving deltas: 100% (553/553), done.
[user@login01 ~]$ Cloning into 'reverse-proxy'...
-bash: Cloning: command not found
[user@login01 ~]$
[user@login01 ~]$ cd reverse-proxy/
[user@login01 reverse-proxy]$ ls -al
total 118
drwxr-xr-x  9 user abc123   14 Mar  4 06:47 .
drwxr-x--- 28 user abc123   48 Mar  4 06:47 ..
drwxr-xr-x  2 user abc123    4 Mar  4 06:47 batch
-rw-r--r--  1 user abc123  588 Mar  4 06:47 .config
-rw-r--r--  1 user abc123 6148 Mar  4 06:47 .DS_Store
drwxr-xr-x  2 user abc123    5 Mar  4 06:47 .examples_images
drwxr-xr-x  8 user abc123   13 Mar  4 06:47 .git
-rw-r--r--  1 user abc123   12 Mar  4 06:47 .gitignore
drwxr-xr-x  2 user abc123    9 Mar  4 06:47 lib
-rw-r--r--  1 user abc123 5981 Mar  4 06:47 README.md
drwxr-xr-x  2 user abc123    5 Mar  4 06:47 slurm
drwxr-xr-x  2 user abc123    4 Mar  4 06:47 slurm_expanse
-rwxr-xr-x  1 user abc123 9555 Mar  4 06:47 start-jupyter
drwxr-xr-x  2 user abc123    4 Mar  4 06:47 torque
```

Usage

The `start-jupyter` script performs the following tasks:

- Sends request to the reverse proxy server (RPS) to get a one-time token and a port number
- Launches the `jupyter service` command using the token and port number.
- Prints a secure URL (https) containing the token to the terminal, so that the user can copy/paste the URL into a local browser.
- Coming soon: gpu notebooks; ML notebooks

```
./start-jupyter [-p <string>] [-d <string>] [-A <string>] [-b <string>] [-t time] [-i]
```

- -p: the partition to wait for (debug or compute). Default Partition is "compute"
- -d: the top-level directory of your Jupyter notebook. Default Dir is /home/\$USER
- -A: the project allocation to be used for this notebook. Default Allocation is your sbatch system default allocation (also called project or group)
- -b: the batch script you want to submit with your notebook. Only those in the `batch` folder are supported. Default batch script is ./batch/batch_notebook.sh
- -t: the time to run the notebook. Your account will be charged for the time you put here so be careful. Default time is 30 minutes.
- -i: Get extra information about the job you submitted using the script.

Using start-jupyter

base == active conda env

(1) Launch start-notebook process

(base) [user@comet-ln3 reverse-proxy]\$./start-jupyter -b slurm/jupyterlab.sh

Your notebook is here:

<https://headscarf-barber-unframed.comet-user-content.sdsc.edu?token=3b587a19a8c4ba79f3af754e9fa2a8f5>

Using default partition: compute

No time given. Default is 30 mins

```
(base) [user@comet-ln3 reverse-proxy]$ cat slurm/jupyterlab.sh
#!/bin/bash
##
## This is an example batch script which can be submitted as part of a
## reverse proxy jupyter notebook. This batch script creates the jupyter
## notebook on a compute node, while the start notebook script is used to
## submit this batch script. You should never submit this batch script on
## its own, e.g. `sbatch batch_notebook.sh`. Don't do that :). You can
## specify this particular batch script by using the -b flag, e.g.
## start_notebook.sh -b batch/batch_notebook.sh
##
## You can add your own slurm directives here, but they will override
## anything you gave to the start_notebook script like the time, partition, etc
## ATCH --nodes=1
## ATCH --ntasks-per-node=24
#####
## Define modules here. #####
#
```

(2) start-notebook builds batch script and submits job to Slurm queue; prints out the URL.

Comet Reverse Proxy Service

Phase 2 of 2: Mapped

Your job has started and checked in with the proxy. Please wait up to two minutes for the URL mapping to take effect.

Seconds to auto-reload: 4

Stop Reloading

(3) Grab URL, enter into browser. Monitor status window:
If the queue is busy this may take a long time

File Edit View Run Kernel Tabs Settings Help

hello_world.ipynb

remember to activate your Conda environment before running this notebook

```
(base) [mthomas@comet-12-66 reverse-proxy]$ ls
total 146
drwxr-xr-x 8 mthomas use300 18 Oct 29 13:17 .
drwxr-xr-x 3 mthomas use300 3 Oct 12 14:44 ..
drwxr-xr-x 2 mthomas use300 4 Oct 12 14:44 batch
-rw-r--r-- 1 mthomas use300 6148 Oct 12 14:44 .DS_Store
drwxr-xr-x 2 mthomas use300 5 Oct 12 14:44 .examples_images
drwxr-xr-x 8 mthomas use300 15 Oct 29 03:11 .git
-rw-r--r-- 1 mthomas use300 12 Oct 12 14:44 .gitignore
drwxr-xr-x 2 mthomas use300 6 Oct 12 14:44 lib
-rw-r--r-- 1 mthomas use300 5049 Oct 12 14:44 README.md
drwxr-xr-x 2 mthomas use300 4 Oct 12 14:44 slurm
... 1 mthomas use300 1309 Oct 12 15:15 slurm-36369149.out
use300 1855 Oct 29 03:59 slurm-36708798.out
use300 1820 Oct 29 04:06 slurm-36708915.out
use300 1424 Oct 29 2020 slurm-36718821.out
use300 7076 Oct 12 14:44 start-jupyter
use300 7585 Oct 12 14:44 start_notebook
use300 4 Oct 12 14:44 torque
use300 200 Oct 12 14:44 .torque_wml
--12-66 reverse-proxy]$ host
--12-66 reverse-proxy]$
```

(4) When notebook is ready on compute node, Jupyter service will appear in your browser

Security Note:

- The URL is like a password: DO NOT SHARE.
- The Jupyter service will run for as long as you requested. If you are done early, be sure to QUIT the notebook to save SU's

(5) When done, be sure to QUIT the Jupyter service – this will kill the job.

Using Reverse Proxy from Expanse Portal: Terminal Window

The screenshot shows the Comet Portal dashboard at portal.comet.sdsc.edu/pun/sys/dashboard/batch_connect/sessions. The top navigation bar includes links for Comet Portal, Files, Jobs, Clusters, Interactive Apps, and a search icon. The main content area shows "My Interactive Sessions" with sections for "Interactive Apps" (GUls, MATLAB, RSTUDIO) and a message stating "You have no active sessions." A yellow box labeled "(1) Log onto the Portal" highlights the browser window.

A terminal window titled "terminal" with the URL portal.comet.sdsc.edu/pun/sys/shell/ssh/comet.sdsc.edu. The session details show "Last login: Thu Oct 29 13:19:01 2020 from 76.176.117.51" and "Profile built 13:03 03-Dec-2019". The terminal displays a welcome banner and a notice about using Comet login nodes for processing tasks. A yellow box labeled "(2) Launch a terminal window" highlights the terminal window.

A browser window titled "jupyter" with the URL snowfall-blemish-puddling.comet-user-content.sdsc.edu/tree. The page shows a file tree with several directories like bigdatafiles, comet-dev-old, comet-examples, etc. A red circle highlights the "jupyter" link in the address bar. A yellow box labeled "(3) Copy the URL" highlights the browser window.

Name	Last Modified	File size
bigdatafiles	2 years ago	
comet-dev-old	9 months ago	
comet-examples	3 months ago	
comet-examples-OLD	6 months ago	
covabmc	2 months ago	
covABMClone	2 months ago	
cuda	a year ago	
dev	a month ago	
gnuplot	a month ago	
gpu-hackathon-notes	5 months ago	
hackathon	7 months ago	
hello-mpi	3 months ago	

A yellow box labeled "(5) Access your Jupyter Service" highlights the browser window.

A browser window titled "Comet Reverse Proxy Service" with the URL snowfall-blemish-puddling.comet-user-content.sdsc.edu/?token=ebc350e7f7.... The page displays "Phase 1 of 2: Pending" and "Waiting for your job to start on a compute node...". It shows "Seconds to auto-reload: 4" and a "Stop Reloading" button. A yellow box labeled "(4) Monitor status window: If the queue is busy this may take a long time" highlights the browser window.

Future Plans

- The Reverse Prosy Service runs on all SDSC HPC systems.
 - The RPS server is available for download if you want to test it. This is in “beta” development. See:
 - <https://github.com/sdsc-hpc-training-org/satellite-expanse>
- GPU Jupyter Services: in beta testing now; developing machine learning notebooks as well.
- Integrating into the Expanse user portal as an interactive service
- Global, system-wide installation: early testing & dev

Thank You

Resources

- Expanse User Guide
 - https://www.sdsc.edu/support/user_guides/expanse.html
- GitHub Repo for this workshop:
 - <https://github.com/sdsc-hpc-training-org/comet-to-expanse-transition/tree/main/2021-Comet-to-Expanse-Transition-Tutorial>
- GitHub Repo for Expanse Notebooks:
 - <https://hpc-training.sdsc.edu/notebooks-101/>
- SDSC Training Resources
 - https://www.sdsc.edu/education_and_training/training
 - <https://github.com/sdsc-hpc-training/webinars>
- XSEDE Training Resources
 - <https://www.xsede.org/for-users/training>
 - <https://cvw.cac.cornell.edu/expanse/>