

Introduction to Interactive HPC

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What is Interactive Computing?

Interactive Computing is about immediacy. When the human requests an action, the computer immediately responds. When the computer finishes a task, the human immediately perceives the result.

- Software GUIs
- Prototyping workflows
 - Design your workflow for a single node (multi-core) or small set of nodes
 - Discover and test new tools/concepts
 - Profile, optimize and debug
- Data Visualization

Why Interactive HPC?

HPC is part of a larger research workflow

Dr. so-and-so needs to explore a huge dataset

Needs: interactivity, analytics tools, large memory/storage

Dr. such-and-such is preparing to create a cutting-edge simulation visualization

Needs: interactivity, remote visualization, compute, bandwidth

A grad student is prototyping a new algorithm

Needs: interactivity, dev and debug tools, time to iterate

Tutorial Outline

- Batch vs. Interactive Computing @ MSI
- Getting Started with Interactive Resources
 - Connecting to MSI
 - Conscientious Computing
 - Prototyping Workflows
- Hands-on
 - Remote desktops
 - Jupyter Notebooks



Researcher

Needs compute resources

Secure Network

On-campus eduroam or ethernet
Off-campus via UMN VPN

MSI Access Gateway

OnDemand Portal
SSH Command Line
Other Web Portals

HPC Compute

Computation on MSI clusters
Agate, Mangi, Mesabi

Data Storage

Primary - Home+Project Dirs
2nd Tier - object storage
Scratch storage areas

MSI Access Overview

Resource Allocations

ALL groups will have access to these basic resources:

- High Performance Computing cluster access
- High Performance Storage
 - 150 GB home directory quota or more if requested
 - Home and project storage accessible from most MSI systems
- Access to interactive gateways
- Access to MSI labs
 - contact us to activate your Ucard for physical access

Survey of Options

...



Batch Jobs

- When should you use Batch Jobs?
 - *Whenever possible!* This is the traditional way to work in HPC
 - Share resources and be considerate of other researchers
- What are the benefits of Batch Jobs?
 - Headless execution of automated processes
 - Long runtimes
 - Large core counts
 - A scheduler packs jobs in hardware to maximize utilization, reduce latency, etc.

Interactive Options

- **OnDemand Portal**
- **Interactive batch** (srun via the command line)
- **Jupyter portal** (sharable reproducible computing)
- **Galaxy portal** (graphically compose workflows)
- **Specialized solutions**
 - ◆ CITRIX for Windows apps
 - ◆ Stratus “private cloud” instances

OnDemand Portal

<https://ondemand.msi.umn.edu>

- ❖ **OnDemand Web Portal is a new offering in 2022**
- ❖ One-stop access portal for interactive HPC services
 - Remote desktop access
 - Command line terminal
 - File browser
 - Launchers for common GUI scientific applications
 - JupyterLab server access
 - RStudio server access

OPEN

 **nDemand**

Interactive Command Line

ssh <username>@<resource>.msi.umn.edu

See: <https://www.msi.umn.edu/content/connecting-hpc-resources>

- SSH is the traditional first point of access to MSI resources
- Access **agate mesabi** or **mangi**
- Uses ssh program available on most personal computers

These “login nodes” are shared by many MSI users. They are NOT for heavy computational tasks. Appropriate uses include:

- ✓ Browsing and editing files
- ✓ Submitting jobs
- ✓ Querying job status and other informational commands
- ✓ Browsing software modules
- ✓ *Light* testing or software compilation

```
Microsoft Windows [Version 10.0.19041.746]
(c) 2020 Microsoft Corporation. All rights reserved.

C:\Users\          ssh landw020@mangi.msi.umn.edu
Password:
Last login: Wed Feb 10 15:06:20 2021 from x-10-21-31-220.vpn.umn.edu
-----
University of Minnesota Supercomputing Institute-----
-----
University of Minnesota Supercomputing Institute
Mangi
AMD EPYC Linux Cluster
-----
For assistance please contact us at https://www.msi.umn.edu/support/help.html
help@msi.umn.edu, or (612)626-0802.
-----
Home directories are snapshot protected. If you accidentally delete a file in
your home directory, type "cd .snapshot" then "ls -lt" to list the snapshots
available in order from most recent to oldest.

January 6, 2021: Slurm is now the scheduler for all nodes.
-----
landw020@ln1002 [~] %
```

Interactive Batch with ‘srun’

```
srun <resource requests> --pty bash
```

See: <https://www.msi.umn.edu/content/interactive-queue-use-srun>

- Dedicated compute resources via the scheduler
- Command line terminal running on the cluster
 - ◆ similar to a SSH session
- Supports all usual Slurm options and commands
- Best used with interactive [partitions](#)
 - ◆ have priority access for small interactive job requests
- Job terminates when shell exits or connection broken

Example:

```
srun -N 1 --ntasks-per-node=4 --mem-per-cpu=1gb -t 1:00:00 -p interactive --pty bash
```

Jupyter Notebooks Portal

<https://notebooks.msi.umn.edu>

See:

<https://www.msi.umn.edu/support/faq/how-do-i-get-started-jupyter-notebooks>

- JupyterLab web-based computational workspace
- Jupyter Notebook document-oriented computing
- Python and R support provided, users can install additional languages/environments
- Integrated terminal, file editing and browsing
- Runs via scheduler, multiple resource options available
- Session persists until time expires or manually shut down

Web Portals: Galaxy

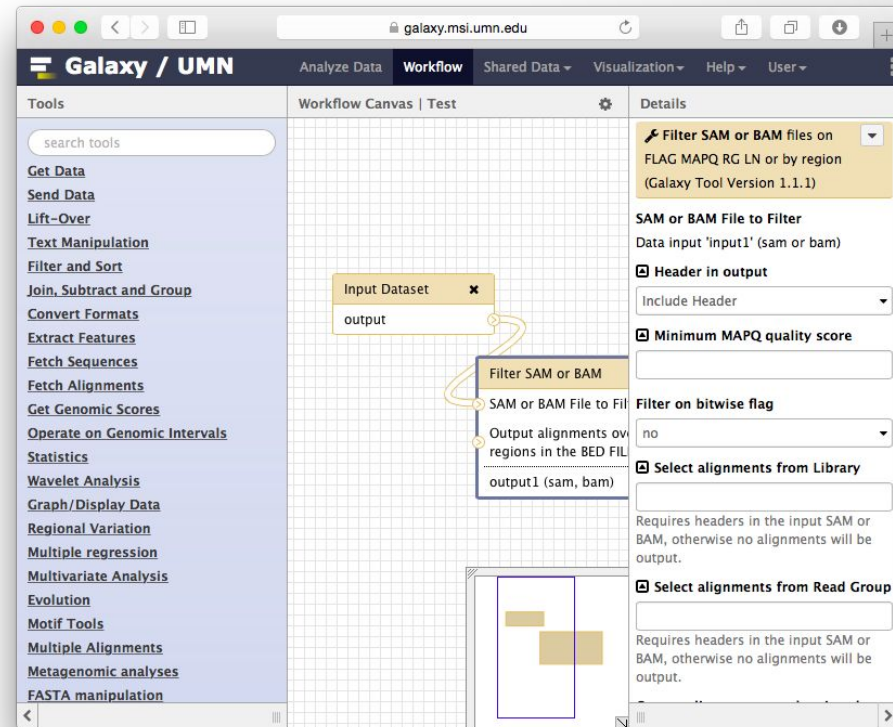
<http://galaxy.msi.umn.edu>

Galaxy is a web-based workflow manager, principally for bioinformatics/'omics research

- Compose data analysis workflows in a unified data flow view
- Workflows execute when requested on MSI compute clusters
- Wide variety of bioinformatics and 'omics applications available as tools

See

<https://www.msi.umn.edu/content/galaxy> for additional details, especially regarding linking data into Galaxy



The screenshot displays the Galaxy web interface at galaxy.msi.umn.edu. The main area is the 'Workflow Canvas | Test' view, showing a workflow with two tools: 'Input Dataset' and 'Filter SAM or BAM'. The 'Filter SAM or BAM' tool is selected, and its configuration panel is visible on the right. The configuration includes a dropdown menu for 'Filter SAM or BAM files on' set to 'FLAG MAPQ RG LN or by region (Galaxy Tool Version 1.1.1)'. Below this, there are checkboxes for 'Header in output', 'Minimum MAPQ quality score', 'Filter on bitwise flag' (set to 'no'), and 'Select alignments from Library'. The 'Workflow Canvas' shows the 'Input Dataset' tool connected to the 'Filter SAM or BAM' tool, with the output of the first tool being the input of the second.

Need Windows?

MSI no longer provides Windows application servers.

Select HPC applications that require Windows are available through partnership with OIT via CITRIX

See:

www.msi.umn.edu/support/faq/how-do-i-connect-citrix-windows-virtual-machine for access to Apps.umn.edu



Researcher

Needs compute resources

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On-campus eduroam or ethernet
Off-campus via UMN VPN

MSI Access Gateway

OnDemand Portal
SSH Command Line
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Hands-On: Getting Connected

Pre-requisites to connect

Campus VPN

<https://it.umn.edu/services-technologies/virtual-private-network-vpn>

- MSI services are only available to on-campus network addresses
- Especially during the pandemic, many users are working off-campus
- VPN clients and instructions are available from OIT for most operating systems and mobile devices

DUO Authentication

<https://it.umn.edu/services-technologies/self-help-guides/duo-set-use-duo-security>

- DUO 2-factor authentication is required for most MSI services
- DUO is also required to connect to the campus VPN

Sidebar: Windows SSH and File Transfer

Current Windows 10+ computers will have ssh/scp available from the Windows terminal.

For users who desire a graphical ssh or file transfer client:
<https://winscp.net/eng/downloads.php>

Download and install both WinSCP and PuTTY*

*MSI recommends WinSCP and PuTTY for Windows users, but does not offer support for these programs. Contact your local IT department for assistance.

Choosing a Cluster/Partition

See: <https://www.msi.umn.edu/content/choosing-job-partition>

- ❖ Long running jobs and batch jobs run on Agate/Mesabi/Mangi
- ❖ MSI compute clusters are heterogeneous (e.g., up to 1TB Memory, GPUs, SSDs, etc.)
 - **Think:** match your needs to available configurations
 - **Do:** reserve the (CPU/RAM/GPUs/etc) that you need
 - **Avoid:** reserving much more (waste, long queue times) **or** less than required (job doesn't finish before walltime expires)

For interactive use, begin with the **interactive** partition and experiment from there.

Interactive Services OnDemand

...



OnDemand Walkthrough

https://www.msi.umn.edu/content/using-openondemand' and 'For assistance please contact us at <https://www.msi.umn.edu/content/helpdesk>, help@msi.umn.edu, or (612)626-0802.'"/>

<https://ondemand.msi.umn.edu/>

OnDemand Walkthrough



Services accessed through menu bar



Minnesota
Supercomputing Institute

UNIVERSITY OF MINNESOTA
Driven to Discover[®]

OnDemand provides an integrated, single access point for all of your HPC resources.

Message of the Day

Open OnDemand is a web-based portal for interactive access to MSI's compute clusters. You can access your MSI files, view your current jobs on the MSI clusters, and access a command line or interactive desktop on a cluster compute node, with configurable memory and compute resources. You also have access to a set of familiar servers, interactive development environments, and graphical user interfaces that have been adapted to use the Open OnDemand platform.

For more information about Open OnDemand at MSI, please visit <https://www.msi.umn.edu/content/using-openondemand>

For assistance please contact us at <https://www.msi.umn.edu/content/helpdesk>, help@msi.umn.edu, or (612)626-0802.



OnDemand Walkthrough

Open OnDemand Files ▾ Jobs ▾ Clusters ▾ Interactive Apps ▾ 

 ▾  ▾  

Return to
landing page

Dashboard of
running and
completed
interactive activities

Job list and composer app
(web interface panels to
queue and **sbatch**)

OnDemand Walkthrough

Open OnDemand **Files** Jobs Clusters Interactive Apps My Interactive Sessions

Home Directory
/home/support

File browser access

File browser:

- browse/navigate/manage files
- upload/download files up to few GB size
- access different starting dirs if you have multiple groups/projects

Open in Terminal New File New Directory Upload Download Copy/Move Delete

/ home / support / milligan / Change directory Copy path

Show Owner/Mode Show Dotfiles Filter:

Showing 92 of 236 rows - 0 rows selected

Type	Name	Size	Modified at
Folder	a_jupyter_demo	-	11/1/2022 9:05:20 PM

OnDemand Walkthrough

The screenshot shows the OnDemand web interface. At the top, there is a navigation bar with the following items: "Open OnDemand", "Files", "Jobs", "Clusters" (highlighted in yellow), "Interactive Apps", and "My Interactive Sessions". A dropdown menu is open under "Clusters", showing two options: ">_Agate Shell Access" and ">_Mesabi Shell Access". Below this menu, a blue box labeled "Command line terminal access" has an arrow pointing up towards the dropdown. To the right, a light blue box titled "Command line terminal:" contains a list of instructions: "SSH" in a web browser (almost), Launch terminal on cluster headnode, Roughly equivalent to e.g. `ssh <username>@agate.msi.umn.edu`, and Also launch in specific directory via file browser pane. A blue arrow points from this box to the "Open in Terminal" button in the file browser pane. The file browser pane shows a path: `/ home / support / milligan /`. Below the path are several buttons: "Open in Terminal" (circled in red), "New File", "New Directory", "Upload", "Download", "Copy/Move", and "Delete". At the bottom of the pane, there is a "Change directory" button and a "Copy path" button.

Open OnDemand Files Jobs Clusters Interactive Apps My Interactive Sessions

>_Agate Shell Access
>_Mesabi Shell Access

Command line terminal access

Command line terminal:

- "SSH" in a web browser (almost)
- Launch terminal on cluster headnode
- Roughly equivalent to e.g.
`ssh <username>@agate.msi.umn.edu`
- Also launch in specific directory via file browser pane

>_ Open in Terminal + New File New Directory Upload Download Copy/Move Delete

/ home / support / milligan / Change directory Copy path

OnDemand Walkthrough

The screenshot shows the OnDemand web interface. At the top, there is a dark red navigation bar with the following items: 'Open OnDemand', 'Files', 'Jobs', 'Clusters', 'Interactive Apps' (highlighted in yellow), and 'My Interactive Sessions'. The 'Interactive Apps' dropdown menu is open, showing the following categories and items:

- Desktops
 - Desktop
 - Persistent Desktop
- GUIs
 - ANSYS Workbench
 - IGV
 - MATLAB
- IDEs
 - Abaqus
 - COMSOL Multiphysics
 - IDL
 - Mathematica
- Servers
 - Jupyter
 - RStudio Server

A light blue text box on the left contains the following text:

- Interactive Apps menu lists available application launchers
- Each launcher leads to a session options page
- Each session runs as an interactive job on a cluster resource
- Launchers also available via the Interactive Sessions dashboard

Red arrows point from the text box to the 'Desktops', 'GUIs', and 'Servers' sections of the dropdown menu. A long red arrow points from the bottom of the text box to the 'My Interactive Sessions' button in the navigation bar.

OnDemand Walkthrough

Session was successfully created. ✕

Home / My Interactive Sessions

Interactive Apps

- Desktops
 - Desktop
 - Persistent Desktop
- GUIs
 - ANSYS Workbench
 - IGV
 - MATLAB
- IDEs
 - Abaqus
 - COMSOL Multiphysics
 - IDL
 - Mathematica
- Servers
 - Jupyter
 - RStudio Server

Desktop (71087165)

1 node | 2 cores | Running

Host: acn23.agate.msi.umn.edu Delete

Created at: 2023-02-16 12:31:57 CST

Time Remaining: 3 hours and 58 minutes

Session ID: a2a0db19-7a3a-45a0-9e90-eddca9bfd03b

Compression: 0 (low) to 9 (high) | Image Quality: 0 (low) to 9 (high)

Launch Desktop View Only (Share-able Link)

RStudio Server (71064307)

Completed

Created at: 2023-02-13 23:32:26 CST Delete

Session ID: 713d240a-60e3-488d-a2a4-3d5d80dcfd9a

For debugging purposes, this card will be retained for 5 more days

RStudio Server (71061783)

Completed

My Interactive Sessions

List job status for interactive sessions: queued, running, finished

Launch into a running session (usually opens new browser tab)

Access full menu of interactive launchers

OnDemand Walkthrough

Session was successfully created. ✕

Home / My Interactive Sessions

Interactive Apps

- Desktops
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For debugging purposes, this card will be retained for 5 more days

Delete

RStudio Server (71061783)

Completed

My Interactive Sessions

Delete a running or queued session to cancel the job and release compute resources early

Deleting a completed job removes it from this dashboard; no other effect

OnDemand Walkthrough

Interactive Apps
Desktops
Desktop
Persistent Desktop
GUIs
ANSYS Workbench
IGV
MATLAB
IDEs
Abaqus
COMSOL Multiphysics
IDL
Mathematica
Servers
Jupyter
RStudio Server

Remote desktop sessions
VNC embedded in a web browser

Runs on compute node in
selected cluster resource

These launchers start a
remote desktop session
and launch corresponding
application

Jupyter and RStudio servers run on compute node

Web interface proxied through OnDemand

OnDemand Walkthrough

Home / My Interactive Sessions / Jupyter

Interactive Apps

Desktops

- Desktop
- Persistent Desktop

GUIs

- ANSYS Workbench
- IGV
- MATLAB

IDEs

- Abaqus
- COMSOL Multiphysics
- IDL
- Mathematica

Servers

- Jupyter**
- RStudio Server

Jupyter

This app will launch a Jupyter server using Python.

Cluster:

Jupyter interface:

This defines the interface of Jupyter you want to start (Notebook or Lab).

Jupyter Python:

This defines the Python distribution of Jupyter you want to start.

Account:

Resources:

Time Limit:

Shorter times will probably start faster

I would like to receive an email when the session starts

Example launcher: Jupyter server

Options to customize most aspects of the interactive job

- cluster / partition
- group (if multiple available)
- resource requests
- launcher-specific parameters (e.g. Python environment for Jupyter servers)

OnDemand Walkthrough

Open OnDemand Files ▾ Jobs ▾ Clusters ▾ Interactive Apps ▾ 

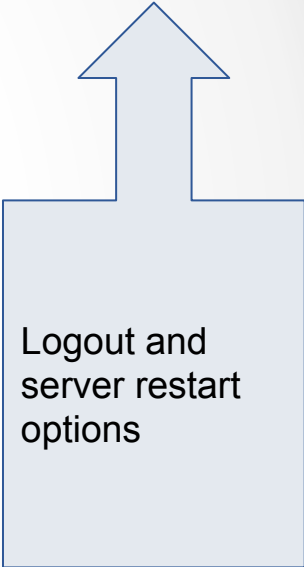
 ▾  ▾  

Session cleanup

OnDemand sessions run as scheduled jobs: cancel jobs or use desktop “logout” to end jobs and release resources early, or allow them to close automatically when walltime expires

Logging out from this page clears browser login but otherwise has no effect on active OnDemand sessions

Rarely may need to use “restart server” option to recover from failures



Logout and
server restart
options

Interactive Jobs with **srun**

...



Selecting Resources

- SSH to any cluster headnode:
 - `ssh <username>@agate.msi.umn.edu` or
 - `ssh <username>@mesabi.msi.umn.edu` or
 - Launch interactive terminal in OnDemand
- Queue an Interactive job on the cluster:
 - `srun <job options> --pty bash`

Selecting Resources

Options to `srun` specify job requirements:

- `srun` [options]
 - `--time=8:00:00` job can run for up to 8 hours
 - `-N 1 --cpus-per-task=4` job requests 4 CPUs on one node
 - `--mem=2500m` job requests 2500 MB (2.5GB) of RAM
 - `-p interactive`
 - `--pty bash` job must specify shell program to run
- Enable graphics via X-tunneling (`--x11`)
 - not available in web terminals (OnDemand, Jupyter, etc)

Selecting Resources

Example - basic interactive session with 4 CPU cores,
8 GB RAM, 4 hours runtime:

```
srun -N 1 --ntasks-per-node=4 --mem-per-cpu=1gb -t 1:00:00 -p interactive --pty bash
```

Example - interactive session for machine learning with 1 A40 GPU,
12 CPU cores, 1 hour runtime:

```
srun -n 12 -t 1:00:00 -p interactive-gpu --gres=gpu:a40:1 --pty bash
```

Software Modules

See: <https://www.msi.umn.edu/content/accessing-software-resources>

- See all modules available
 - `module avail`
- Load a module (adds commands to your shell)
 - `module load python3`
- Run the software from the module
 - `ipython`

```
Terminal 1
milligan@cn0060 [~] % module avail python
----- /panfs/roc/soft/modulefiles.hpc -----
python/3.7.1_anaconda      python3/3.7.1_anaconda
python2/2.7.15_anaconda

----- /panfs/roc/soft/modulefiles.common -----
python/3.2.3
python/3.4
python/3.6.3(default)
python2/2.7.12_anaconda4.1.1
python2/2.7.12_anaconda4.2(default)
python2/2.7.16_anaconda2019.10
python3/3.4
python3/3.5.2_anaconda4.1.1
python3/3.6.3_anaconda5.0.1(default)
python3/3.7.4_anaconda2019.10
python3/3.8.3_anaconda2020.07_mamba
```

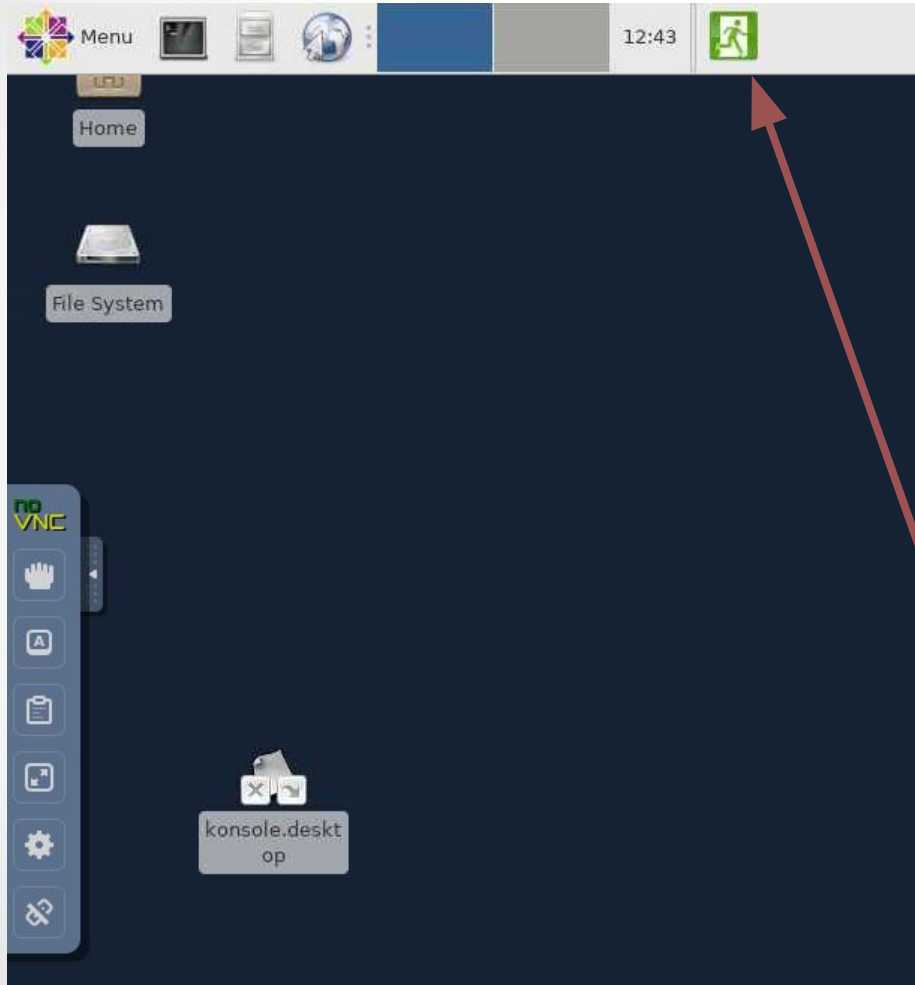
Optional: SSH Keys

- SSH keys allow terminal logins without typing a password repeatedly
- Some applications may automatically make SSH connections and may require SSH keys
- See: www.msi.umn.edu/support/faq/how-do-i-setup-ssh-keys

Clean up your session

- Delete the session (choose one)
 - Exit out of all connections
 - scancel <job ID>
- What happens on disconnect/delete?
 - All computation stops
- How to resume?
 - Start from zero; or load intermediate files (if you created them)

Interactive Linux Desktops



Interactive desktop: noVNC session proxied through OnDemand server

Graphical fidelity will suffer on low-bandwidth connections but quality can be adjusted to maintain usability

Good connections allow graphically intensive apps, GPU accelerated graphics available on GPU nodes

Session persists until logged out on desktop - don't forget to log out to release resources when done!

Session Clean-up and Resume

- What is lost when the connection drops?
 - Instance: if not expired, reconnect to the same Instance
 - Data: no loss
- What if you Logout?
 - Instance: Terminated; Reconnect and start fresh
 - Data: Scratch data is deleted periodically* (clean up after yourself to be sure); No loss for data in group home
- How do you reconnect?
 - Login again through OnDemand Interactive Sessions dashboard

Hands-On: Interactive Development and Data Interrogation with Jupyter

...



Start your Jupyter Session

Server Options

Select a job profile:

Mesabi Interactive - 3 cores, 8 GB, 12 hours, 48 GB local scratch

Start



Server Options

Select a job profile:

Mesabi Interactive - 3 cores, 8 GB, 12 hours, 48 GB local scratch

Mesabi Interactive - 3 cores, 8 GB, 12 hours, 48 GB local scratch

Mangi AMD Medium - 2 cores, 32 GB, 4 hours, 64 GB local scratch

Mesabi High-mem - 12 cores, 128 GB, 4 hours, 180 GB local scratch

Mangi AMD wide - 24 cores, 45 GB, 4 hours, 75 GB local scratch

K40 GPU session - 12 cores, 60 GB, 4 hour, 100 GB local scratch, 1 K40 GPU

- Visit notebooks.msi.umn.edu
- Select the default interactive job
- There will be a short wait while the background job starts running
- When ready, the JupyterLab workspace will load in your web browser window

JupyterLab Workspace

See: <https://jupyterlab.readthedocs.io/en/stable/user/interface.html>

- Rich tabbed multi-document workspace
- File navigation able to access home and group directories
- Reproducible, sharable computational stories in Jupyter Notebooks
- View and edit text and other files directly in JupyterLab
- Command line terminal available

File Edit View Run Kernel Tabs Settings Help

Files

Running

Commands

Cell Tools

1024px-Hubble_Intera... 5 months ago

bar.vl.json 9 minutes ago

Dockerfile 5 months ago

iris.csv 6 months ago

japan_meteorological_a... 5 months ago

Museums_in_DC.geoj... 6 months ago

README.md 5 months ago

zika_assembled_gen... 5 months ago

Data.ipynb Python 3

Open a CSV file using Pandas

```
In [5]: 1 import pandas
2 df = pandas.read_csv('../data/iris.csv')
3 df.head(20)
```

```
Out[5]:  sepal_length  sepal_width  petal_length  petal_width  species
0         5.1         3.5         1.4         0.2     se
1         4.9         3.0         1.4         0.2    setosa
2         4.7         3.2         1.3         0.2    setosa
3         4.6         3.1         1.5         0.2    setosa
4         5.0         3.6         1.4         0.2    setosa
5         5.4         3.9         1.7         0.4    setosa
6         4.6         3.4         1.4         0.3    setosa
7         5.0         3.4         1.5         0.2    setosa
8         4.4         2.9         1.4         0.2    setosa
9         4.9         3.1         1.5         0.1    setosa
10        5.4         3.7         1.5         0.2    setosa
11        4.8         3.4         1.6         0.2    setosa
12        4.8         3.0         1.4         0.1    setosa
13        4.3         3.0         1.1         0.1    setosa
14        5.8         4.0         1.2         0.2    setosa
```

JupyterLab Demo

JupyterLab: The next generation user interface for Project Jupyter

<https://github.com/jupyter/jupyterlab>

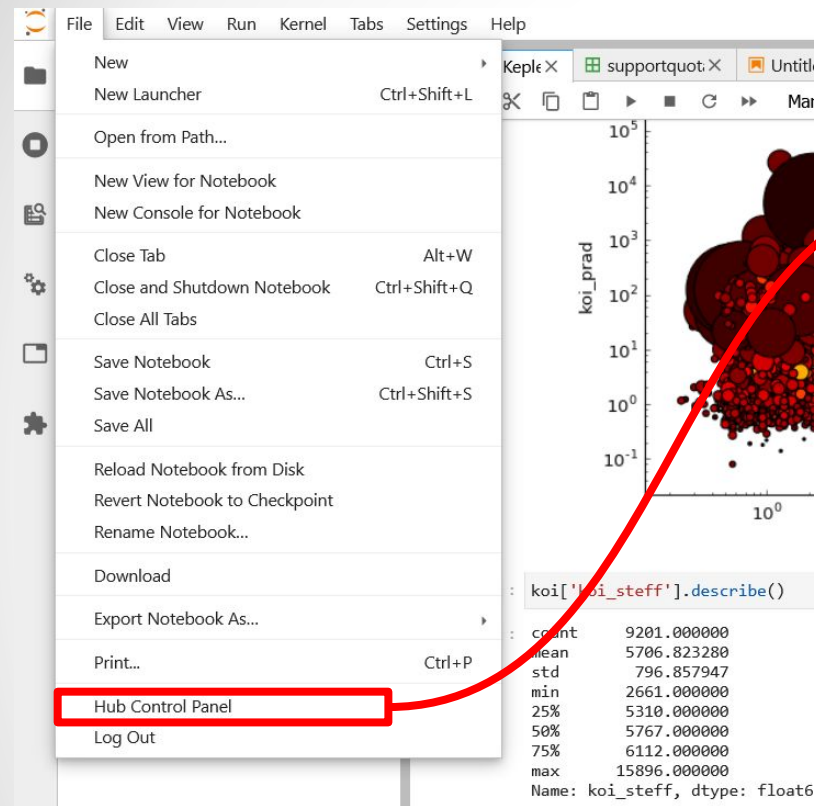
It has been a collaboration between:

- Project Jupyter
- Bloomberg
- Anaconda

1) Building blocks of interactive computing

bar.vl.json 1024px-Hubble

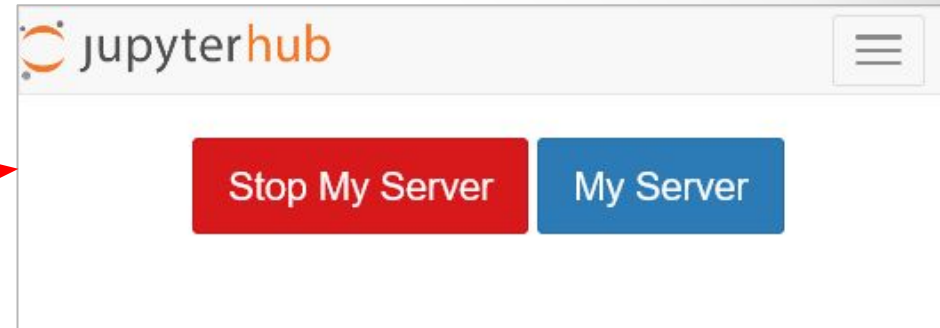
Jupyter Cleanup



The image shows the Jupyter Notebook interface with the 'File' menu open. The 'Hub Control Panel' option is highlighted with a red box. A red arrow points from this box to the Hub Control Panel in the adjacent screenshot.

```
File Edit View Run Kernel Tabs Settings Help
New
New Launcher Ctrl+Shift+L
Open from Path...
New View for Notebook
New Console for Notebook
Close Tab Alt+W
Close and Shutdown Notebook Ctrl+Shift+Q
Close All Tabs
Save Notebook Ctrl+S
Save Notebook As... Ctrl+Shift+S
Save All
Reload Notebook from Disk
Revert Notebook to Checkpoint
Rename Notebook...
Download
Export Notebook As...
Print... Ctrl+P
Hub Control Panel
Log Out
```

Keple X supportquot: X Untitl
10⁵
10⁴
10³
10²
10¹
10⁰
10⁻¹
koi_prad
10⁰
: koi['koi_steff'].describe()
: count 9201.000000
mean 5706.823280
std 796.857947
min 2661.000000
25% 5310.000000
50% 5767.000000
75% 6112.000000
max 15896.000000
Name: koi_steff, dtype: float64



The image shows the Jupyter Hub Control Panel. It features the 'jupyterhub' logo and a hamburger menu icon. Two buttons are visible: a red 'Stop My Server' button and a blue 'My Server' button.

- Jupyter sessions persist (for 4 or 12 hours) even if you disconnect or log out
- You can disconnect and reconnect as many times as you want or from different locations
- To terminate a session and stop using resources, access the Hub Control Panel and select Stop My Server

Additional Documentation

- [Overview of IPython's architecture for parallel and distributed computing.](#)
- [Detailed discussion of IPython cluster controller and engines.](#)
- [Discussion of IPython magic commands](#)
- [Official IPython documentation](#)

Questions?



These slides and the hands-on guide will be posted to <http://msi.umn.edu> (see the “MSI Tutorials” section)

