Raspberry Pi for HPC & Education

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To cover

- Why/What?
- Hardware overview
- Install Base OS
- Install packages
- Some things you can do
- Multinode setup (maybe not the best way)

What / Why?

- Raspberry Pi
  - A low cost single board computer
  - Actually very capable
  - Can install most HPC software
  - Can be used to teach HPC concepts
    - User level
    - Sys admin level

Raspberry Pi Foundation
https://www.raspberrypi.org/about/

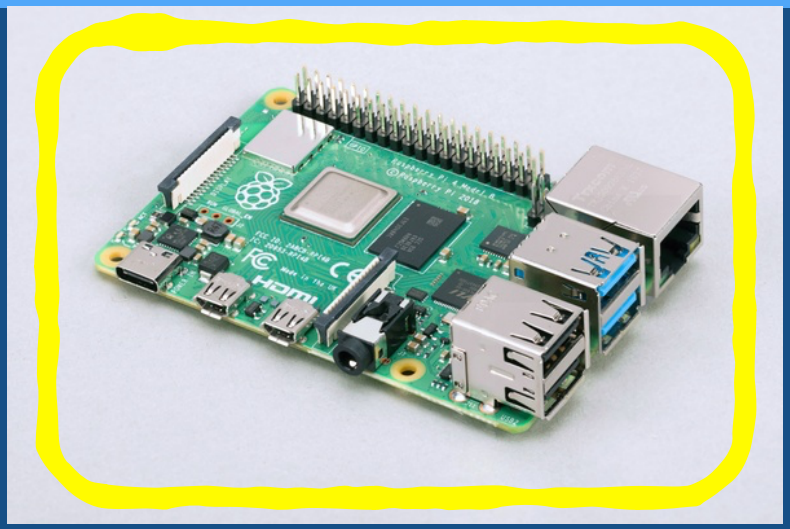
The Raspberry Pi Foundation is a UK-based charity that works to put the power of computing and digital making into the hands of people all over the world. We do this so that more people are able to harness the power of computing and digital technologies for work, to solve problems that matter to them, and to express themselves creatively.

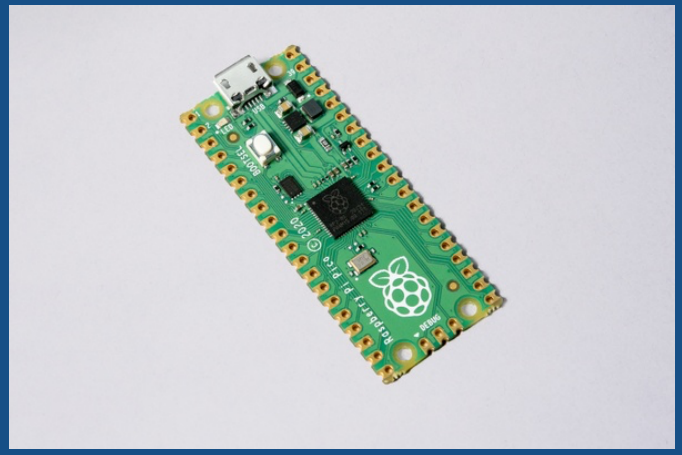
What / Why?

- Things to be taught
  - Programming - Fortran, C, Python, R, Mathematica, Julia, Jupyter, Matlab (octave)
  - Parallel Computing (MPI, OpenMP...)
  - Sys admin (Installing software, configuring)
    - Each person can be given their own disk for $22
    - If trashed - erase and reinstall base OS
- **I learned many things applicable to my day job**

Hardware

- Pis come in three varieties
  - Single board computer
  - Computer in a keyboard
  - Pico

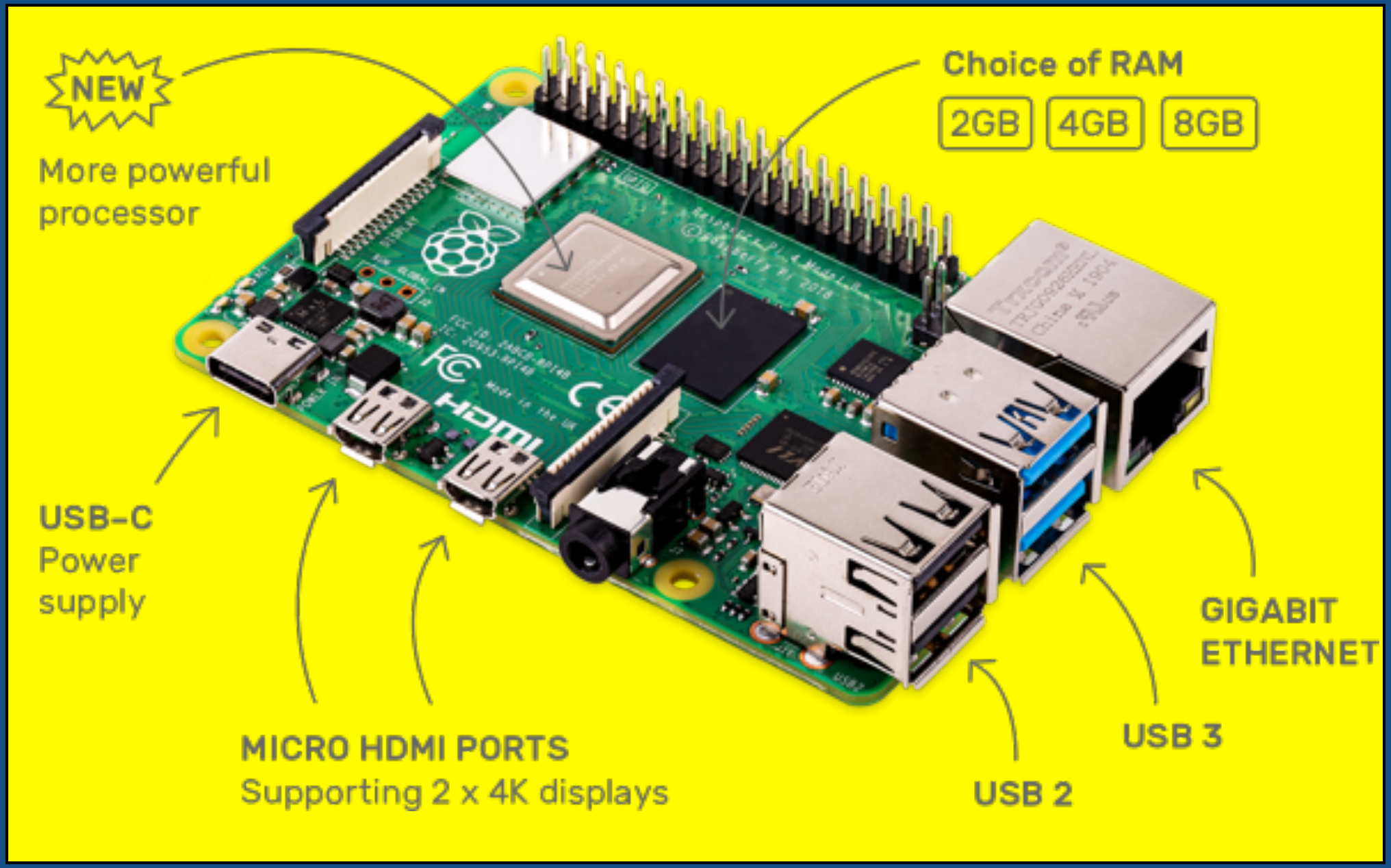




Single board Computer Specs

- 2-8 GB, $35-$75
- 4 core 64 bit@1.5GHz
- Wireless and Wired
- 2 monitors
- Micro-SD card slot (for "disk")
- 40 pin GPIO
- 2 1/4" X 3 1/2"

Single board Computer Specs



Also needed

- A working machine to use to load software
- SD card (1 per node) $22.50 for 128BG
- Keyboard / mouse (Only need 1)
- Monitor / Cable (Only need 1)
- MicroSD usb reader
- Network (wired is better)
- Power supply $8
- Case (optional) $10
- Imaging Software (Free)
  - balenaEtcher or Raspberry Pi Imager

11x15 mm

Node Cost

Component	Cost
Pi (4 GB)	$55
SD Card (128 GB)	$23
Power supply	$8
Case	$10
Total	$96

± $20 for 2 or 8 GB

My three compute node cluster

My Pi cluster

- Head node/file server (pie)
- Three Compute nodes
  - pi00, pi01,pi02
  - 4 core, 4GB nodes
- Web server (not shown)
- Ethernet interconnect
- lmod
- gcc 10.x
- OpenMPI & MPICH
- R 4.x.x
- Python 3.9.x
- Jupyter
- Julia
- spack
- slurm

Install Base OS

- The official installer - Raspberry Pi Imager
  - 45 Second video
  - https://youtu.be/ntaXWS8Lk34
  - Will download OS on the Fly
- I used balenaEtcher (Maybe not in the future)
  - Download "Raspberry Pi OS with desktop and recommended software"
  - Mount SD card on your laptop
  - Start balenaEtcher
  - Point to the download file and your mounted disk
  - Hit go

Side note: There are as many youtube videos on doing things on Raspberry Pis than there are for making bread!

https://www.raspberrypi.org/software/operating-systems

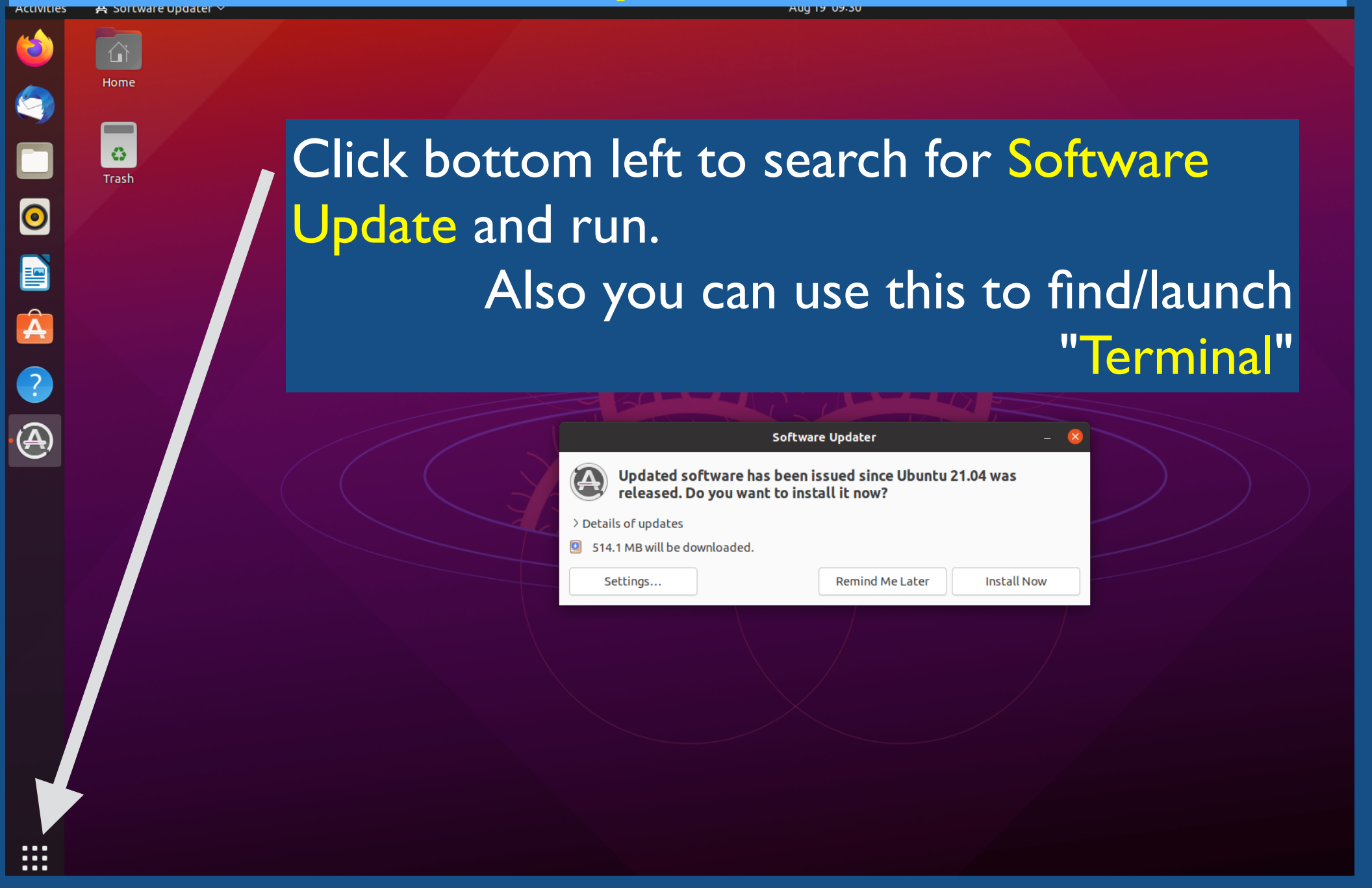
Other OS versions

- I highly recommend using a 64 bit Ubuntu system over "official" 32 bit system
- Ubuntu
- https://ubuntu.com/download/raspberry-pi
  - ubuntu-21.04-preinstalled-desktop-arm64+raspi.img.xz
- Install with balenaEtcher or Raspberry Pi Imager
- Advantages:
  - Newer versions of software (Compilers, Julia, R…)
  - 64 bit - makes some install easier or possible
  - spack works better
- Don't get Mathematica or VNC Viewer by default

After OS is installed on card

- Connect monitor / keyboard / mouse
- Put card in PI and boot
- You'll need to answer some questions
- Will want to update and reboot
- You're off and running...
  - No C, Fortran, Julia, R or current python
  - Time to install "stuff"

Update


Activities
Software Updater
Aug 19 09:30
Home
Trash
Click bottom left to search for Software Update and run.
Also you can use this to find/launch "Terminal"
Software Updater
Updated software has been issued since Ubuntu 21.04 was released. Do you want to install it now?
Details of updates
514.1 MB will be downloaded.
Settings...
Remind Me Later
Install Now

Installing stuff

- The main command for installing software is:
  - sudo apt install -y application
    - sudo = run at root
    - -y don't ask for confirmation
    - Application = what to install

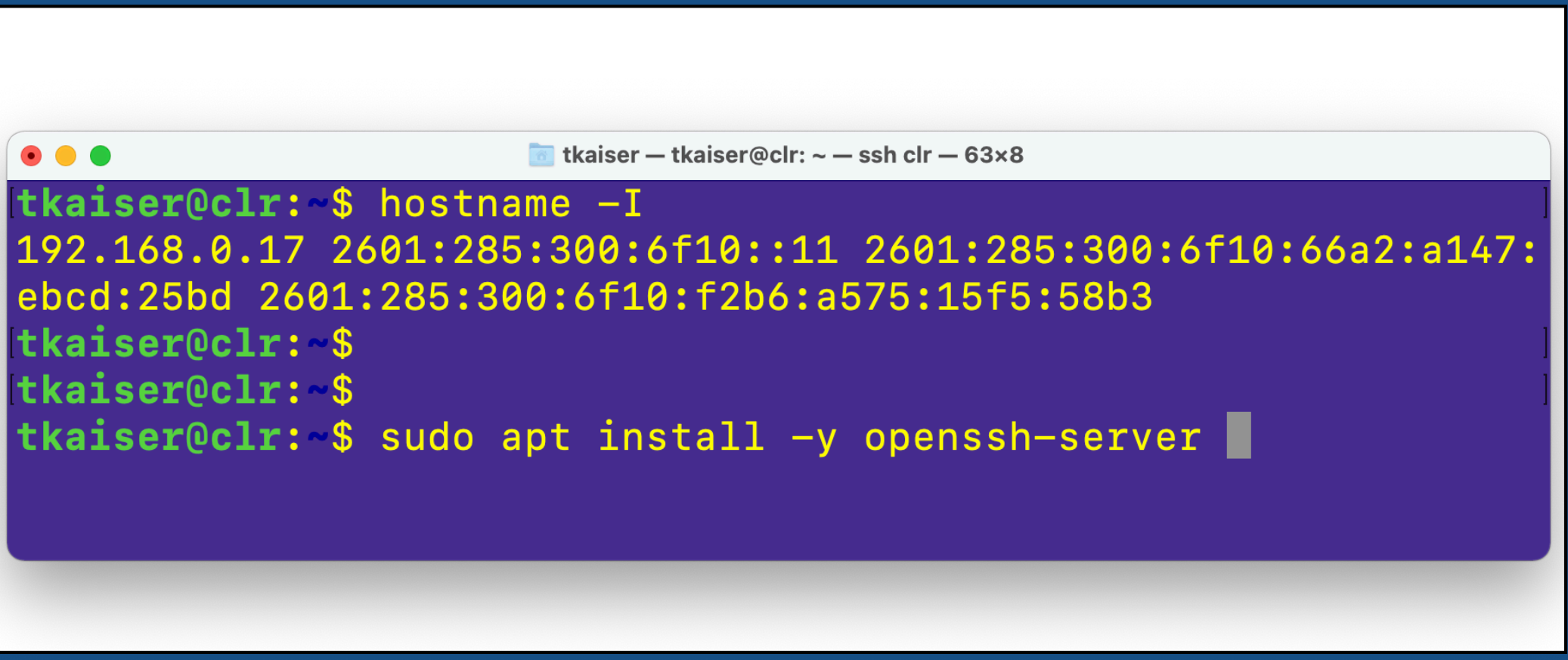
First thing to install is git

- sudo apt update
- sudo apt install -y git
- Git is a version control system
- It can download "stuff"
- We'll use it to download my install scripts

Optional

- If you want to run the rest of the install from remote machine you will need to:
  - sudo apt install -y openssh-server
    - Enables remote login via ssh
  - hostname -I (That's an uppercase i)
    - Gets the IP address of the machine
- Then you can ssh to the node

IP address and ssh server



Other ways to install

- #2 Install from source
- #3 Use spack
  - A package management system
  - Designed for HPC machines
  - https://spack.io
  - https://spack.readthedocs.io
  - Default installs can reinvent the wheel

We'll do all three!

What/How to Install

- I have a script that will install a good set of HPC software…
  - `cd ~`
  - `git clone https://github.com/timkphd/examples.git`
  - `cp -r tims-tools/piubuntu ~`
  - `cd ~/piubuntu`
  - `sudo visudo`
    - `Add the line "your username" ALL=(ALL) NOPASSWD:ALL`
  - `source runall`

The examples directory contains may HPC related files

What is does

- Creates base system with sudo apt install -y application
- Installs OpenMPI and MPICH from source
- Uses spack to install lmod
- Uses spack to install python 3 times (Why?)
- Installs pip using each version of python
- Installs MPI4PY for 2 versions of MPI and python
- Installs R from source
- Installs several R packages including Rmpi
- Sets up environment files

Install Scripts

Script	Function	Method	Seconds
runall	**Runs all of the scripts below**	**bash**	**19,402**
aptinstalls	gnu compilers, utilities, base libs, **slurm**	apt install	911
mpiinstalls	MPICH and OpenMPI	source	3,929
spack00	Lmod and python 3.8.0	spack	4,424
spack01	python 3.9.6	spack	545
spack02	python 3.9.6	spack	545
pipit	pip and "standard packages"	python and pip	712
dompi4py	MPI4py for our two new pythons	pip	638
dor	(R 4.1.0 and basic libs) X 2	source / R	2,473
rmods	Creates modules for R	bash	0
dormpi	(MPI and Data Science for R) X 2	R script	5,217
dostackmo	Creates "combo" modules for python/R/MPI	bash	0
srun_node	Adds "srun" alias for mpiexec & creates hostlist	bash	5
dokeys	Creates ssh keys	bash	3

To Show user level software:
source ~/myenv module avail

```
/nopt/mods/r
  r/4.1.0_01    r/4.1.0_02 (D)

/nopt/mods/mpi
  mpich/3.4.1_stack    mpich/3.4.1 (D)    openmpi/4.1.0_stack    openmpi/4.1.0 (D)

/nopt/spk/level02/modules/lmod/linux-ubuntu21.04-aarch64/gcc/10.3.0
  python/3.9.6_02 (D)

/nopt/spk/level01/modules/lmod/linux-ubuntu21.04-aarch64/gcc/10.3.0
  python/3.9.6_01

/nopt/spk/level00/modules/lmod/linux-ubuntu21.04-aarch64/gcc/10.3.0
   berkeley-db/18.1.40-nj7gypi    lmod/8.5.6-4amtbkt                  python/3.8.0-dwf4ghr
   bzip2/1.0.8-glrfxb2            lua-luafilesystem/1_7_0_2-k7obtoe   readline/8.1-3qxwski
   diffutils/3.7-5oaepdl          lua-luaposix/35.0-yku6wej           sqlite/3.35.5-iv3rnvb
   expat/2.4.1-nlolzhu            lua/5.3.5-ji4jauz                   tcl/8.6.11-74zy2v3
   gdbm/1.19-pl57ita              ncurses/6.2-5ffj5hu                 unzip/6.0-usw6jzm
   libbsd/0.11.3-tmgxbvf          openssl/1.1.1k-ez6bhqv              util-linux-uuid/2.36-wo2xhfw
   libiconv/1.16-57okyhj          perl/5.34.0-thetnao                 xz/5.2.5-jueborm
   libmd/1.0.3-oi4im6e            pkgconf/1.7.4-eahzaay               zlib/1.2.11-xveafvj
```

Multinode with connected monitor

- Clone the disk
- Boot on new node
- run `hostname -I` to get the IP address
- Rename it

```
sudo nano /etc/hostname
sudo nano /etc/hosts
sudo reboot now
```

- Add the address to the file ~/bin/nodelist 4 times on all nodes
- Create a file .ssh/config and add lines of the form for each node:

- chmod 600 .ssh/config
- ssh from each node to the other

```
Host pi01
Hostname 192.168.0.40
```

Multinode without connecting a monitor

- Clone the disk
- Run sudo nmap -sn 192.168.0.0/24 | grep 192
- Start
- Run sudo nmap -sn 192.168.0.0/24 | grep 192 and compare
- Ssh to the new node
- Rename it

```
sudo nano /etc/hostname
sudo nano /etc/hosts
sudo reboot now
```

- Add the address to the file ~/bin/nodelist 4 times on all nodes
- Create a file .ssh/config and add lines of the form for each node:

```
Host pi01
Hostname 192.168.0.40
```

- chmod 600 .ssh/config
- ssh from each node to the other

One way to clone a drive

- Use Apple Disk Utility and balenaEtcher
- Need to set Security to allow Apple Disk Utility to make copy
  - https://discussions.apple.com/thread/250912433
- Instructions for using Apple Disk Utility: See Step 2 of:
  - https://gallaugher.com/make-a-copy-of-a-raspberry-pi-sd-card-mac/
- Rename Image *.iso
- balenaEtcher to copy from *iso to new card

Recent Updates

- Installed Head node
  - External drive
  - NFS
- Thanks to Tom MacKell
  - Slurm (actually now part of the base install)
  - Installed XFCE desktop environment

Demo:

- MPI hello world
- Hybrid MPI/OpenMP program
- Mpi4py
- Jupyter Notebook
  - Python
  - Julia
  - R

Setup XFCE

Thomas MacKell Jr.

Full notes are in Install_notes

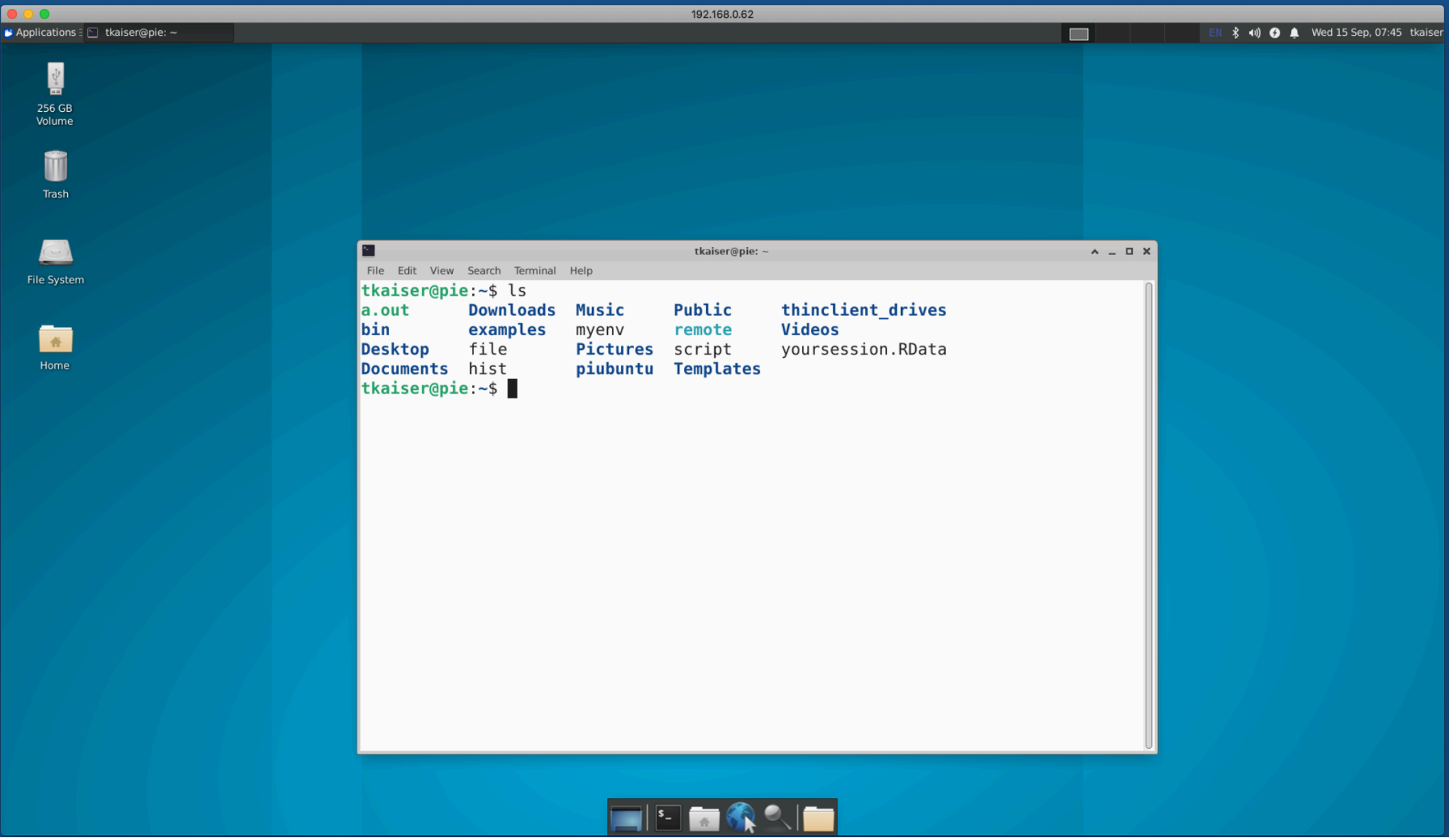
Setup XFCE

- The default desktop has "issues" when connecting remotely
- Xfce is a lightweight desktop environment
- Works well connecting with Microsoft Remote Desktop

Setup XFCE

```
sudo apt install xubuntu-desktop ## Select gdm3

sudo apt install xrdp

sudo adduser xrdp ssl-cert

sudo systemctl restart xrdp

sudo ufw allow 3389

echo "xfce4-session" > ~/.xsession
```

New Desktop


192.168.0.62
Applications
tkaiser@pie: ~
EN
Wed 15 Sep, 07:45
tkaiser
256 GB Volume
Trash
File System
Home
tkaiser@pie: ~
File Edit View Search Terminal Help
tkaiser@pie:~$ ls
a.out Downloads Music Public thinclient_drives
bin examples myenv remote Videos
Desktop file Pictures script yoursession.RData
Documents hist piubuntu Templates
tkaiser@pie:~$

Installing Slurm Notes

Thomas MacKell Jr.

Full notes are in Install_notes

Configuring Slurm

- Slurm is now installed with the script but it needs to be configured
- cd /usr/share/doc/slurmctld/slurm-wlm
- python3 -m http.server
  - This starts a web severer
- On your desktop machine go to 192.168.x.x:8000
- Fill out the form at slurm-wlm-configurator.html

Configuring Slurm

- Save the file and copy to your head node
- Or use the example in the scripts folder and edit as needed
- sudo cp the file to /etc/slurm/slurm.conf

Enable munge

- Does authentication for slurm

create new munge key #if need
sudo dd if=/dev/urandom bs=1 count=1024 > /etc/munge/munge.key

sudo copy over /etc/munge/munge.key from master to all nodes

sudo chown munge: /etc/munge/munge.key
sudo chmod 400 /etc/munge/munge.key

sudo systemctl enable munge
sudo systemctl start munge

Start Slurm

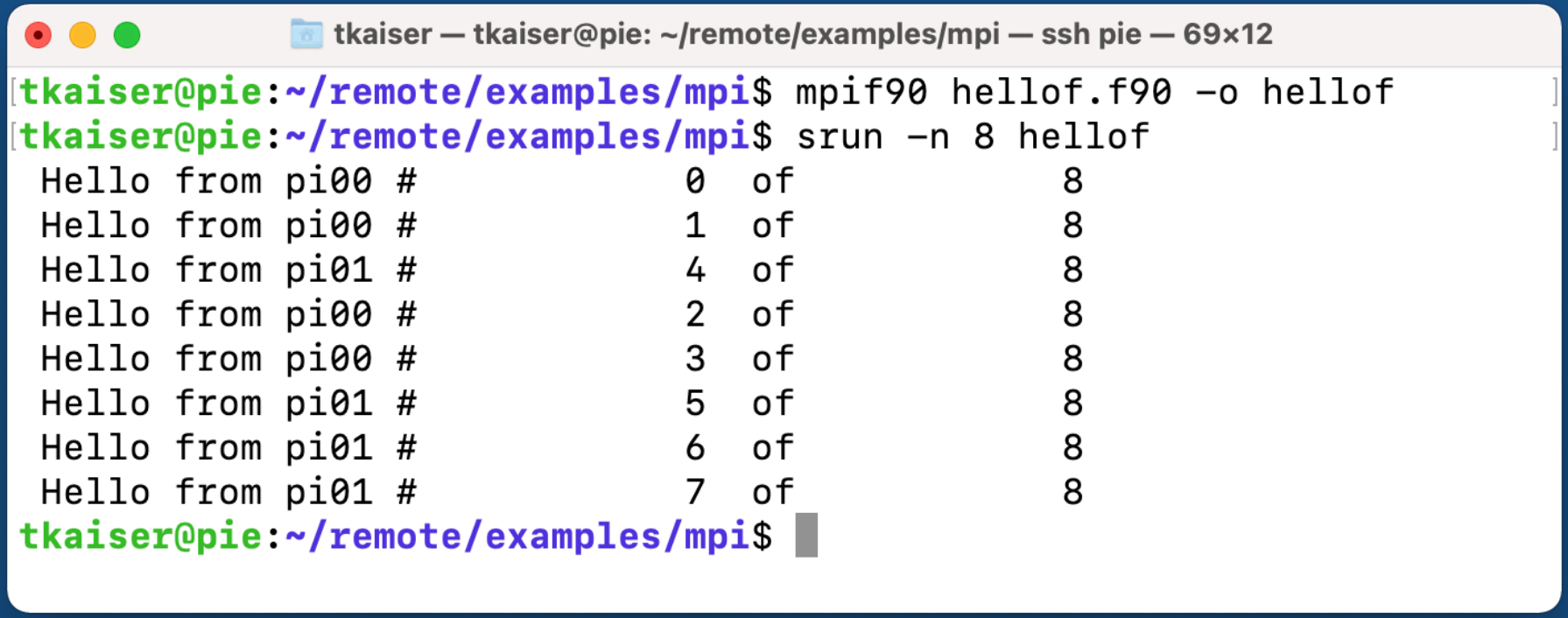
Start slurm For pi-master node

sudo systemctl enable slurmctld
sudo systemctl start slurmctld

start Slurm For compute nodes

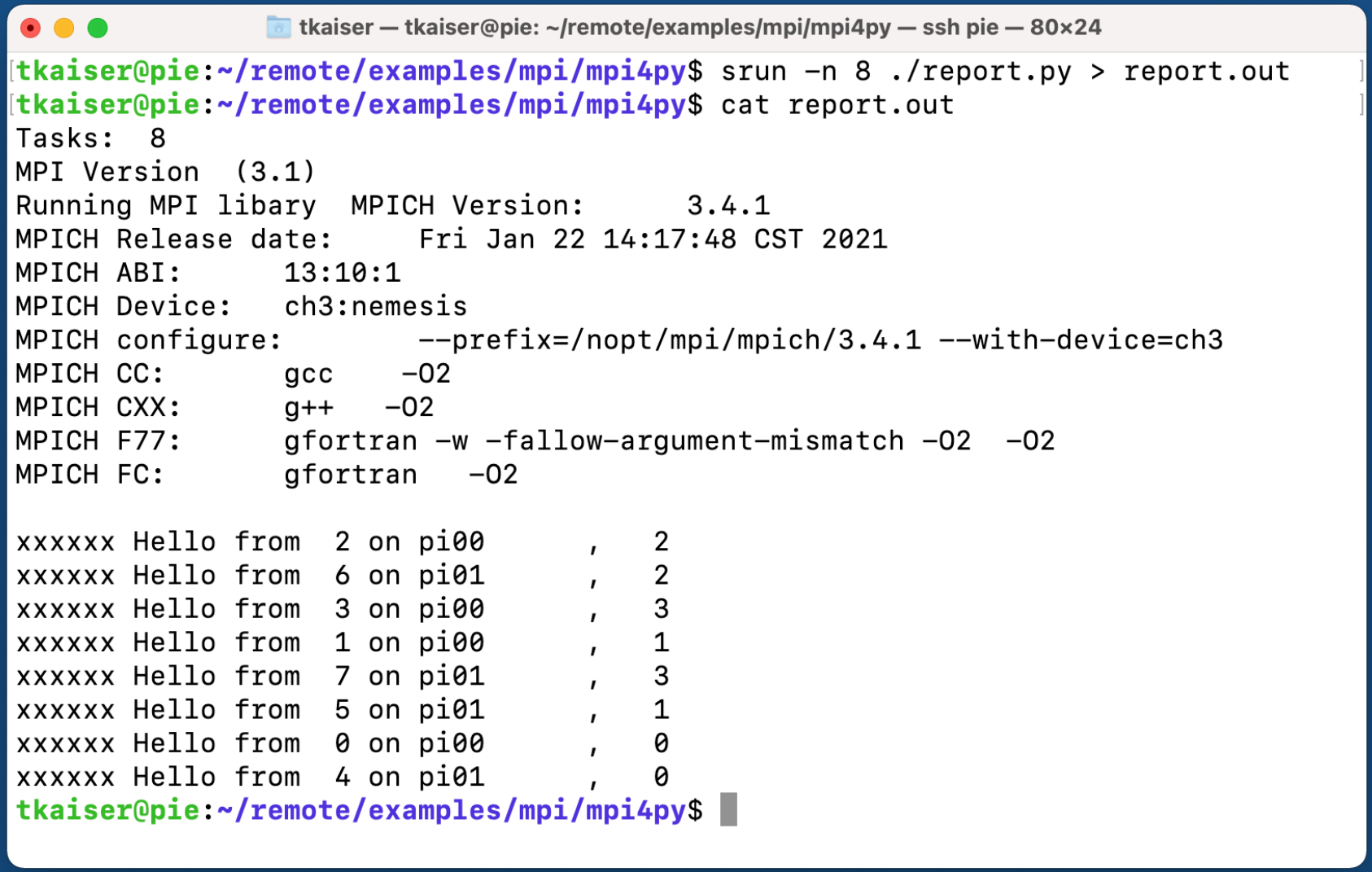
copy over /etc/slurm/slurm.conf to all nodes
sudo systemctl enable slurmd
sudo systemctl start slurmd

MPI Program



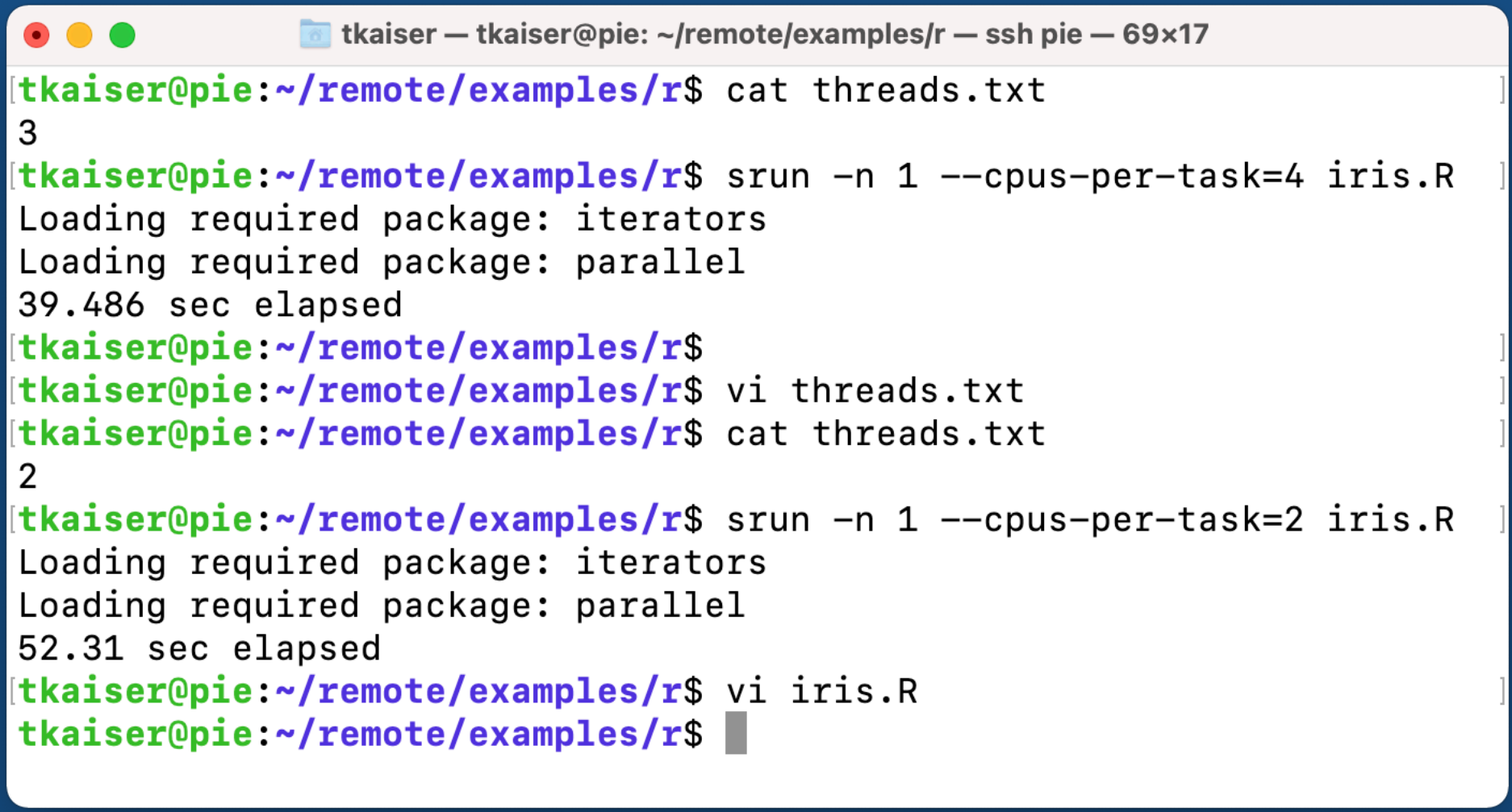
Hello world in MPI. Prints Hello, name of the node task # and number of tasks.

MPI in Python



Hello world in python MPI. Also prints MPI compiler information and core on which task is running.

R using foreach/doParallel libraries



Running test on Iris data set with 2 or 3 spawned tasks

Hybrid MPI/OpenMP

tkaiser — tkaiser@pie: ~/remote/examples/hybrid — ssh pie — 67×23

```
tkaiser@pie:~/remote/examples/hybrid$ export OMP_NUM_THREADS=1
tkaiser@pie:~/remote/examples/hybrid$ srun -n 4 --tasks-per-node=2
./a.out
             0
task    thread             node name    color  newid  core_id
0001    00                      pi00     0000   0001        01
0000    00                      pi00     0000   0000        00
0002    00                      pi01     0002   0000        00
0003    00                      pi01     0002   0001        01
tkaiser@pie:~/remote/examples/hybrid$ export OMP_NUM_THREADS=2
tkaiser@pie:~/remote/examples/hybrid$ srun -n 4 --tasks-per-node=2
--cpus-per-task=2 ./a.out
             0
0002    00                      pi01     0002   0000        01
0003    00                      pi01     0002   0001        02
0003    01                      pi01     0002   0001        03
0002    01                      pi01     0002   0000        00
task    thread             node name    color  newid  core_id
0001    00                      pi00     0000   0001        02
0000    00                      pi00     0000   0000        00
0000    01                      pi00     0000   0000        01
0001    01                      pi00     0000   0001        03
tkaiser@pie:~/remote/examples/hybrid$
```

Hybrid MPI/OpenMP showing distribution including core