



VLAAMS
SUPERCOMPUTER
CENTRUM



Vlaanderen
is supercomputing

KATHOLIEKE UNIVERSITEIT
LEUVEN

universiteit
hasselt
KNOWLEDGE IN ACTION



HPC - introduction

Mag Selwa & Ehsan Moravveji

ICTS, Leuven

<https://github.com/hpcleuven/HPC-intro>

8 October 2019



What is HPC

High-performance computing (HPC) uses supercomputers and computer clusters to solve advanced computation problems.



What a supercomputer is **NOT**



Actually, it is more like




The concept is simple: **Parallelism** = applying multiple processors to a single problem

Why supercomputer?


- Consider your favorite computational application
 - One processor can give results in N hours
 - Why not use N processors
 - and get the results in just one hour?
- The concept is simple: **Parallelism** = applying multiple processors to a single problem

Parallel Computing

- Serial:
 - one program, on one core
- 'Embarrassingly parallel' problems:
 - lots of runs of one program, with different parameters
- Problems that require 'real' parallel algorithms
 - OpenMP
 - MPI : Message Passing Interface



Talk to us about
worker framework



Lucky
you!

Overview

- What is the VSC?
- What is a cluster?
- Infrastructure
- Software environment
- How to get started
- How to submit jobs
- Hands-on

VSC & compute clusters



Vlaams Supercomputer Centrum (VSC)

- VSC is a virtual organization, founded in 2007
 - Goals
 - Provide infrastructure for high performance computing
 - Provide support for high performance computing
 - Participants: Flemish universities & associations
 - Funding
 - FWO/Hercules Foundation
 - Flemish government (EWI)
 - Virtual
 - But with real hardware
 - 1 user database
 - Uniform user experience



HPC services

Basic support

- Monitoring and reporting
- Helpdesk (hpcinfo@kuleuven.be)

Application support

- Installation and porting
- Optimisation and debugging
- Benchmarking
- Workflows and best practices

Training

- Documentation and tutorials
- Scheduled trainings / workshops
- On request workshops
- One-to-one sessions

Bird's eye view on a cluster

Many independent computers, each with its own operating system, memory, hard disk,...

Accessed via **login nodes**

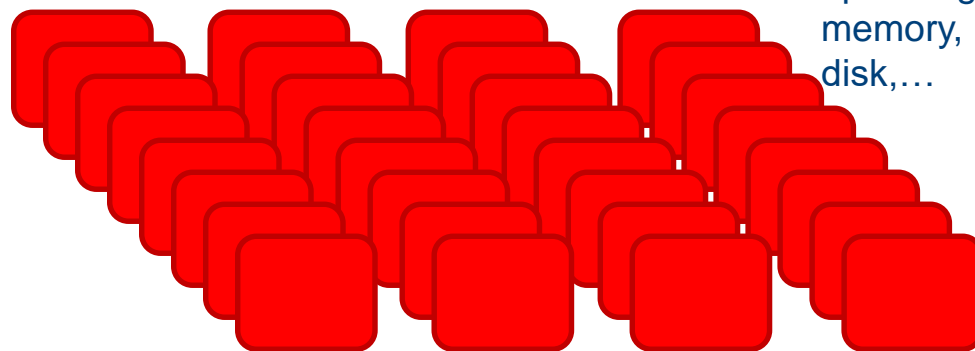
- For job submission, debugging, pre/post processing
- *Shared resources*: everyone works on the same (set of) login nodes

Researchers

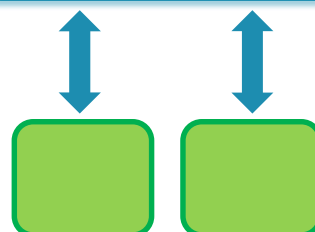


Cluster

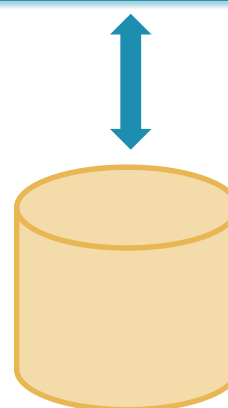
Compute nodes



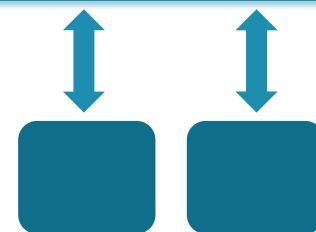
Infiniband interconnect



Login nodes

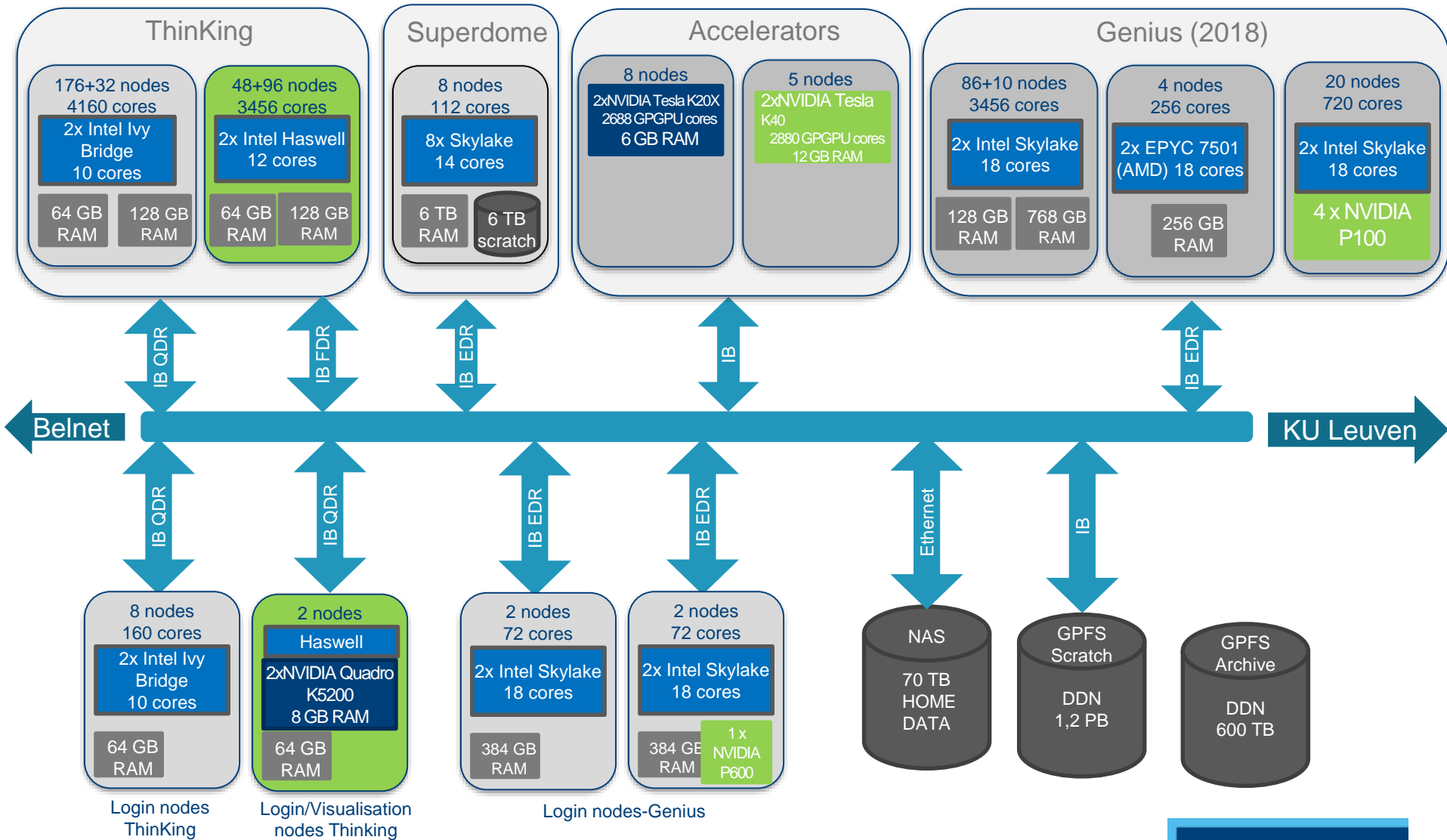


Storage



Service nodes

Administration - queue system, job scheduler, user management,...



Genius

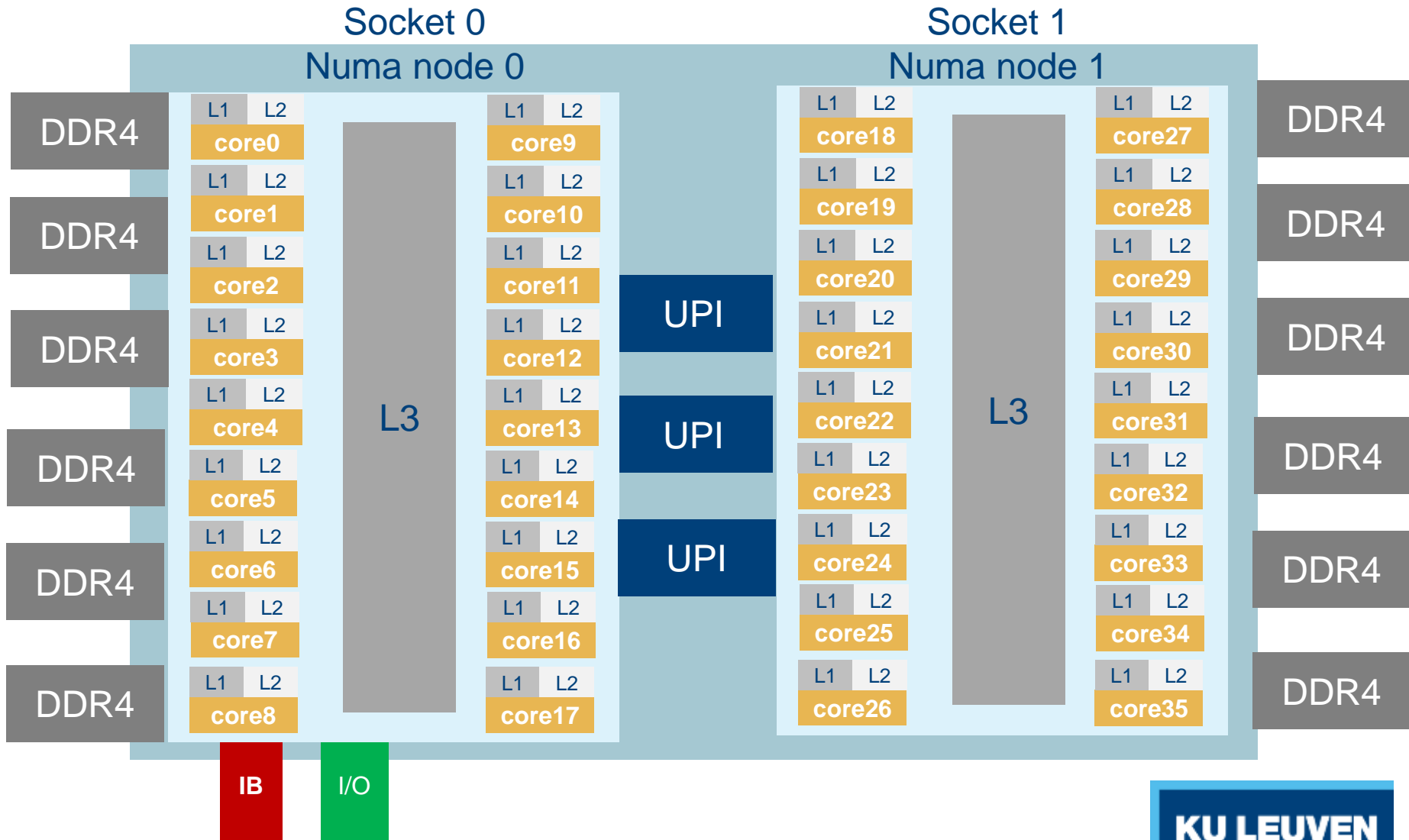
New cluster



Genius (2018)

Type of node	CPU type	Inter-connect	# cores	installed mem	local discs	# nodes
SkyLake	Xeon 6140	IB-EDR	36	192 GB	800 GB	86
SkyLake large mem	Xeon 6140	IB-EDR	36	768 GB	800 GB	10
SkyLake GPU	Xeon 6140 4xP100 SXM2	IB-EDR	36	192 GB	800 GB	20
SkyLake Superdome	Gold 6132	Flex Grid	14	6 TB	6 TB	8
AMD	EPYC 7501	IB-EDR	64	256 GB	800GB	4

Skylake compute node



System comparison

	Tier 2			
	ThinKing Cluster		Genius (2018)	
Total nodes	176 / 32	48 / 96	86 / 10	4
Processor type	Ivybridge	Haswell	Sky Lake	AMD
Base Clock Speed	2.8 GHz	2.5 GHz	2.3 GHz	2.0 GHz
Cores per node	20	24	36	64
Total cores	4,160	3,456	3,456	256
Memory per node (GB)	64 / 128	64 / 128	192 / 768	256
Memory per core (GB)	3.2 / 6.4	2.7 / 5.3	5.3 / 21.3	1
Memory bandwidth/socket	60 GB/s	68 GB/s	128GB/s	318GB/s
Peak performance (Flops/cycle)	4 DP FLOPs/cycle: 4-wide AVX addition OR multiplication	8 DP FLOPs/cycle: 4-wide FMA (fused multiply-add) instructions AVX2	16 DP FLOPs/cycle: 8-wide FMA (fused multiply-add) instructions AVX-512	instructions AVX-512
Network	Infiniband QDR 2:1	Infiniband FDR	Infiniband EDR	Infiniband EDR
Cache (L1 KB/L2 KB/L3 MB)	10x(32i+32d) / 10x256 / 25 MB	12x(32i+32d) / 12x256 / 30MB	18x(32i+32d) / 18x1024 / 25 MB	32x(64i+32d) / 32x512 / 64 MB

Storage

NetApp, DataDirect (DDN)

Overview of the storage infrastructure

HPC cluster storage at KU Leuven consists of 3 different storage types, optimized for different usage, with different characteristics

- **NAS storage**, fully back-up with snapshots for `home` and `data`
- **Scratch storage**, fast parallel filesystem
- **Archive storage**, to store large amounts of data for long time

Overview of the storage infrastructure

- Home directory (3GB)
 - Location available as `$VSC_HOME`
 - The data stored here should be relatively small (e.g., no files or directories larger than a gigabyte, although this is allowed), and not generating very intense I/O during jobs.
 - Typically all kinds of configuration files are stored here, e.g., ssh-keys, .bashrc, or Matlab, and Eclipse configuration, ...

Overview of the storage infrastructure

- Data directory (75 GB)
 - Location available as `$VSC_DATA`
 - A bigger 'workspace', for software, datasets, results, logfiles,
 - This filesystem can be used for higher I/O loads, but for I/O bound jobs, you might be better off using one of the 'scratch' filesystems.

Overview of the storage infrastructure

- Scratch directories (default: 100GB)
 - Free temporary upgrade of quota
 - For temporary or transient data; there is typically no backup for these filesystems, and 'old' data is removed automatically after 28 days (21 days is the duration of longest job allowed on the cluster)
 - Currently `$VSC_SCRATCH` (`$VSC_SCRATCH_SITE`) are defined, for space that is available per user per site

Overview of the storage infrastructure

- Scratch directories (200GB)
 - `$VSC_SCRATCH_NODE` defined for space that is available per node (to be used only during the job execution, need to copy the data as everything will be erased after the job ends).

Tip:

- Do not use `/tmp` directory on compute node (very limited space ~10GB, once exceeded the system and your job will crash).
- Use `$VSC_SCRATCH_NODE (/local_scratch)` instead (~200GB)

Storage areas

Name	Variable	Type	Access	Backup	Quota
/user/leuven/30X/vsc30XXX	\$VSC_HOME	NFS	Global	YES	3 GB
/data/leuven/30X/vsc30XXX	\$VSC_DATA	NFS	Global	YES	75 GB
/scratch/leuven/30X/vsc30XXX	\$VSC_SCRATCH \$VSC_SCRATCH_SITE	GPFS	Global	NO	100 GB
/node_scratch (Genius)	\$VSC_SCRATCH_NODE	ext4	Local	NO	200GB

Do not use /vsc-hard-mounts/leuven-data/... path instead
(mount point can be changed)

Use /user/leuven/304/vsc30468 for \$VSC_HOME
/data/leuven/304/vsc30468 for \$VSC_DATA
/scratch/leuven/304/vsc30468 for \$VSC_SCRATCH

To check available space:

- `$ myquota`
- `$ quota -s ($VSC_HOME and $VSC_DATA)`
- `$ mmlsquota --block-size auto vol_ddn2:leuven_scratch ($VSC_SCRATCH)`

Storage

- **Where to request:**
<https://admin.kuleuven.be/icts/onderzoek/hpc/hpc-storage>.
- **More info:**
<https://icts.kuleuven.be/sc/english/research/HPC>.



Login nodes

Access & data transfer, NX

Login Hosts on Different Machines/partitions

To login (with PuTTY or SSH client), you need VSC number and a hostname

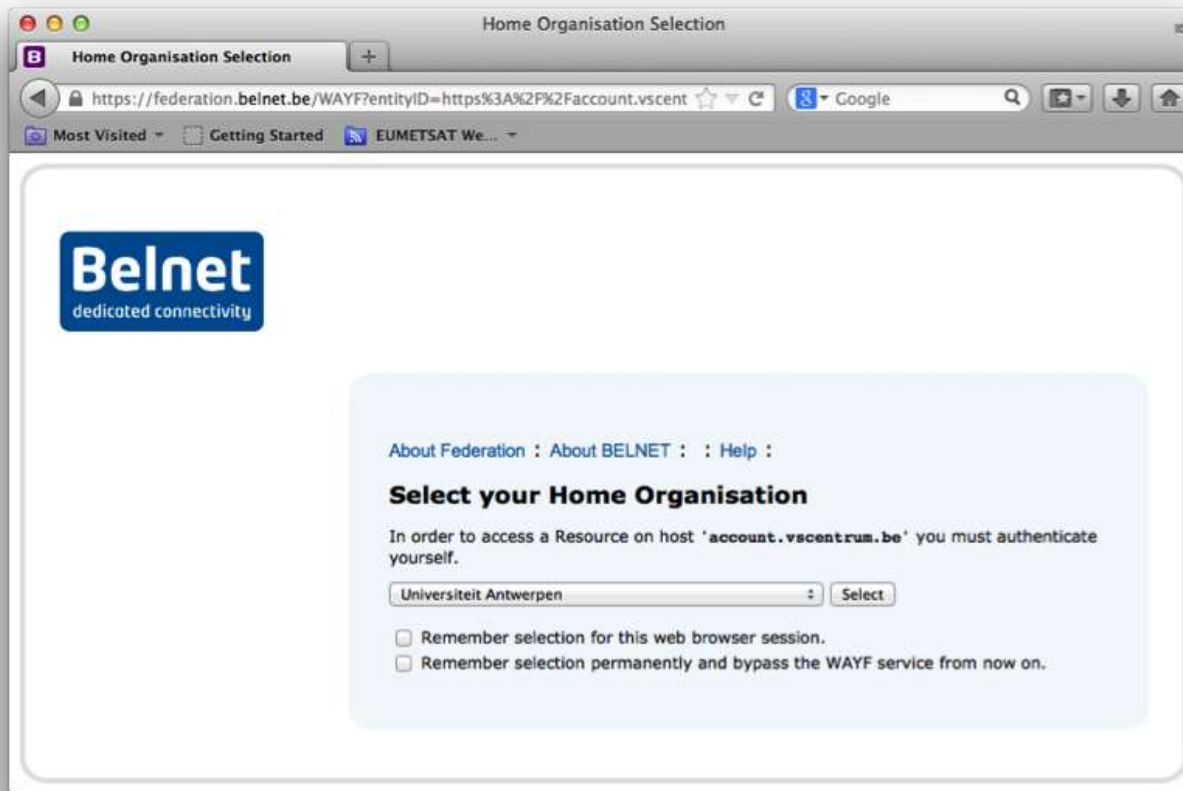
```
$ ssh -X vscXXXXXX@<hostname>
```

Cluster / Partition	<hostname>	Remark(s)
ThinKing: IvyBridge	login5-tier2.hpc.kuleuven.be login6-tier2.hpc.kuleuven.be	
ThinKing: Haswell	login7-tier2.hpc.kuleuven.be login8-tier2.hpc.kuleuven.be	Visualization - TurboVNC
Genius	login1-tier2.hpc.kuleuven.be login2-tier2.hpc.kuleuven.be	
	login3-tier2.hpc.kuleuven.be login4-tier2.hpc.kuleuven.be	Visualization - NX
Genius: Superdome	Any Genius login node	module load superdome

- General login name:
- login.hpc.kuleuven.be → Genius
- login-genius.hpc.kuleuven.be
- login-thinking.hpc.kuleuven.be

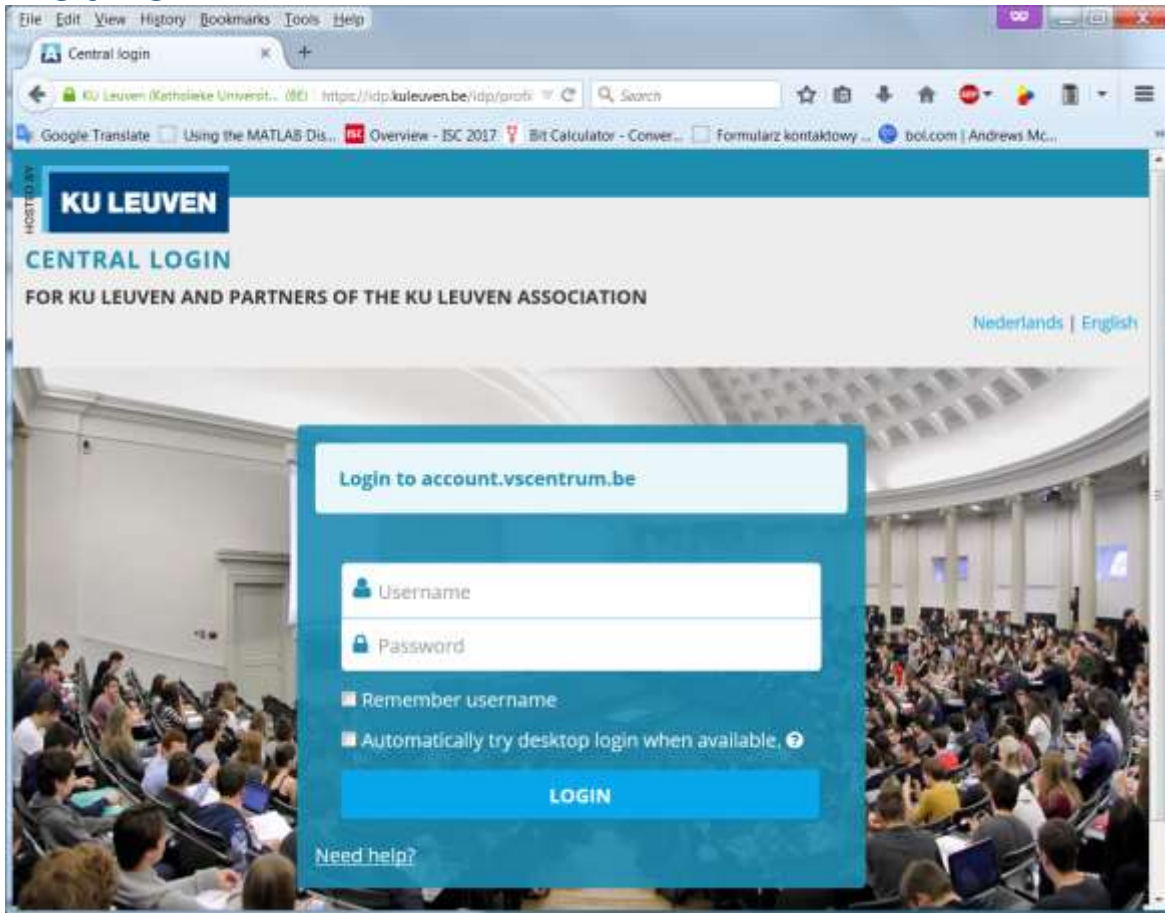
Account request

- <https://account.vscentrum.be/>



Account request

- <https://account.vscentrum.be/>
- KU Leuven



The screenshot shows a web browser window displaying the 'Central login' page for KU Leuven. The page header includes the KU Leuven logo and the text 'CENTRAL LOGIN FOR KU LEUVEN AND PARTNERS OF THE KU LEUVEN ASSOCIATION'. A language selector shows 'Nederlands' and 'English'. A large, semi-transparent login overlay is centered on the page. The overlay has a title 'Login to account.vscentrum.be' and contains fields for 'Username' and 'Password'. Below these fields are two checkboxes: 'Remember username' and 'Automatically try desktop login when available, ⓘ'. A blue 'LOGIN' button is at the bottom of the overlay. A link for 'Need help?' is located at the bottom left of the overlay. The background of the page shows a large lecture hall filled with students.

File Edit View History Bookmarks Tools Help

Central login

KU Leuven (Katholieke Universiteit Leuven) <https://idp.kuleuven.be/idp/profile> Search

Google Translate Using the MATLAB Dis... Overview - ISC 2017 Bit Calculator - Conver... Formularz kontaktowy ... bol.com | Andrews Mc...

KU LEUVEN

CENTRAL LOGIN

FOR KU LEUVEN AND PARTNERS OF THE KU LEUVEN ASSOCIATION

Nederlands | English

Login to account.vscentrum.be

Username

Password

☐ Remember username

☐ Automatically try desktop login when available, ⓘ

LOGIN

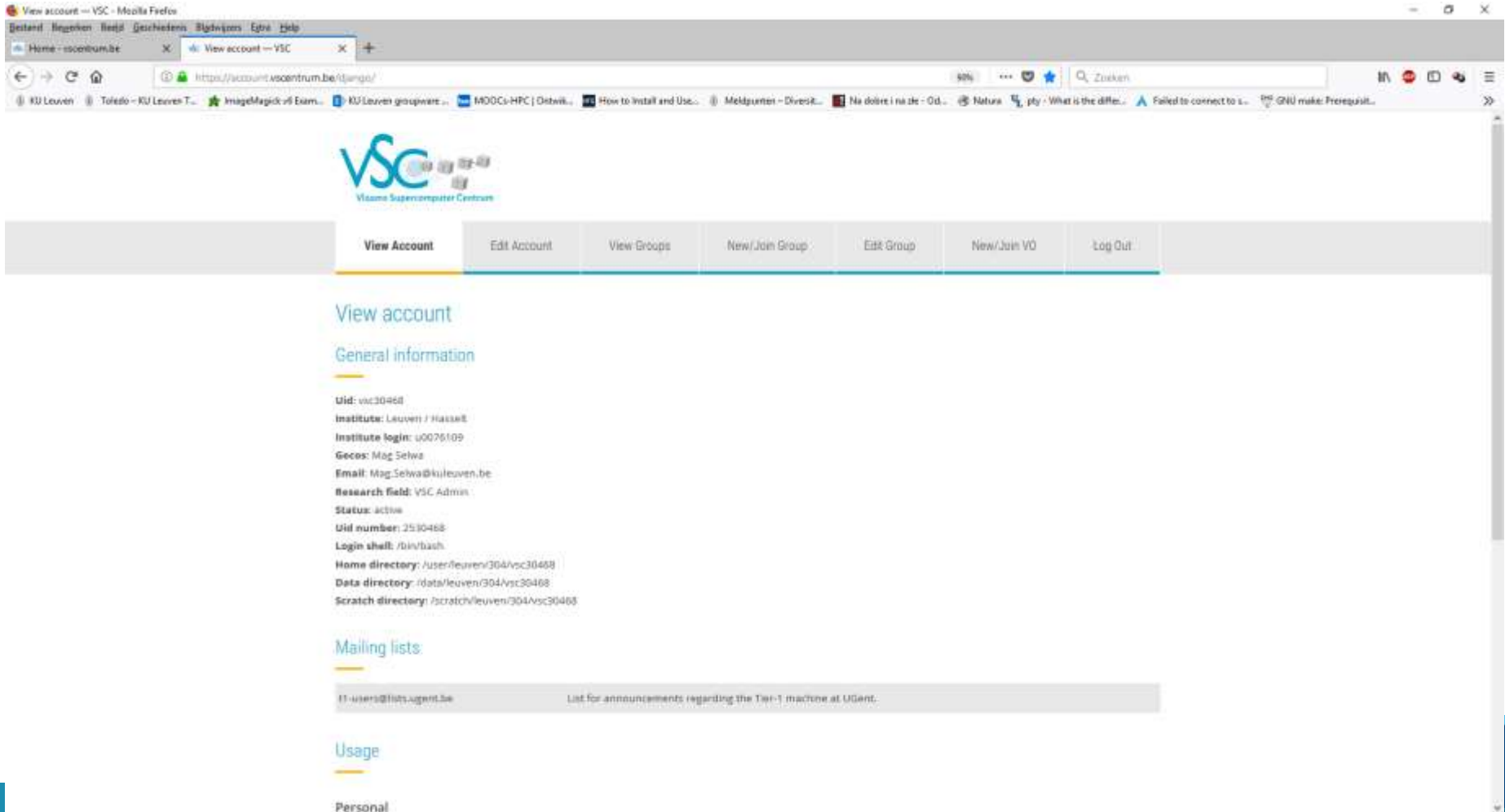
[Need help?](#)

Account request

- <https://account.vscentrum.be/>
- Authentication: Staff/student-id, e-mail
- In case of change – please inform us (access to the webpage may not be possible, SSH to the cluster not affected by that)

Account vs. VSC website

- <https://account.vscentrum.be/>



The screenshot shows a web browser window with the title "View account - VSC - Mozilla Firefox". The address bar displays the URL "https://account.vscentrum.be/tango/". The page features the VSC logo (Vlaams Supercomputer Centrum) and a navigation bar with links: "View Account", "Edit Account", "View Groups", "New/Join Group", "Edit Group", "New/Join VO", and "Log Out". The "View Account" link is highlighted.

The main content area is titled "View account" and "General information". It displays the following details:

- Uid: vac30468
- Institute: Leuven / Hasselt
- Institute login: u0076109
- Gecos: Mag Selwa
- Email: Mag.Selwa@kuleuven.be
- Research field: VSC Admin
- Status: active
- Uid number: 2530468
- Login shell: /bin/bash
- Home directory: /user/leuven/304/Vsc30468
- Data directory: /data/leuven/304/Vsc30468
- Scratch directory: /scratch/leuven/304/Vsc30468

Below the general information, there is a section for "Mailing lists" with a table:

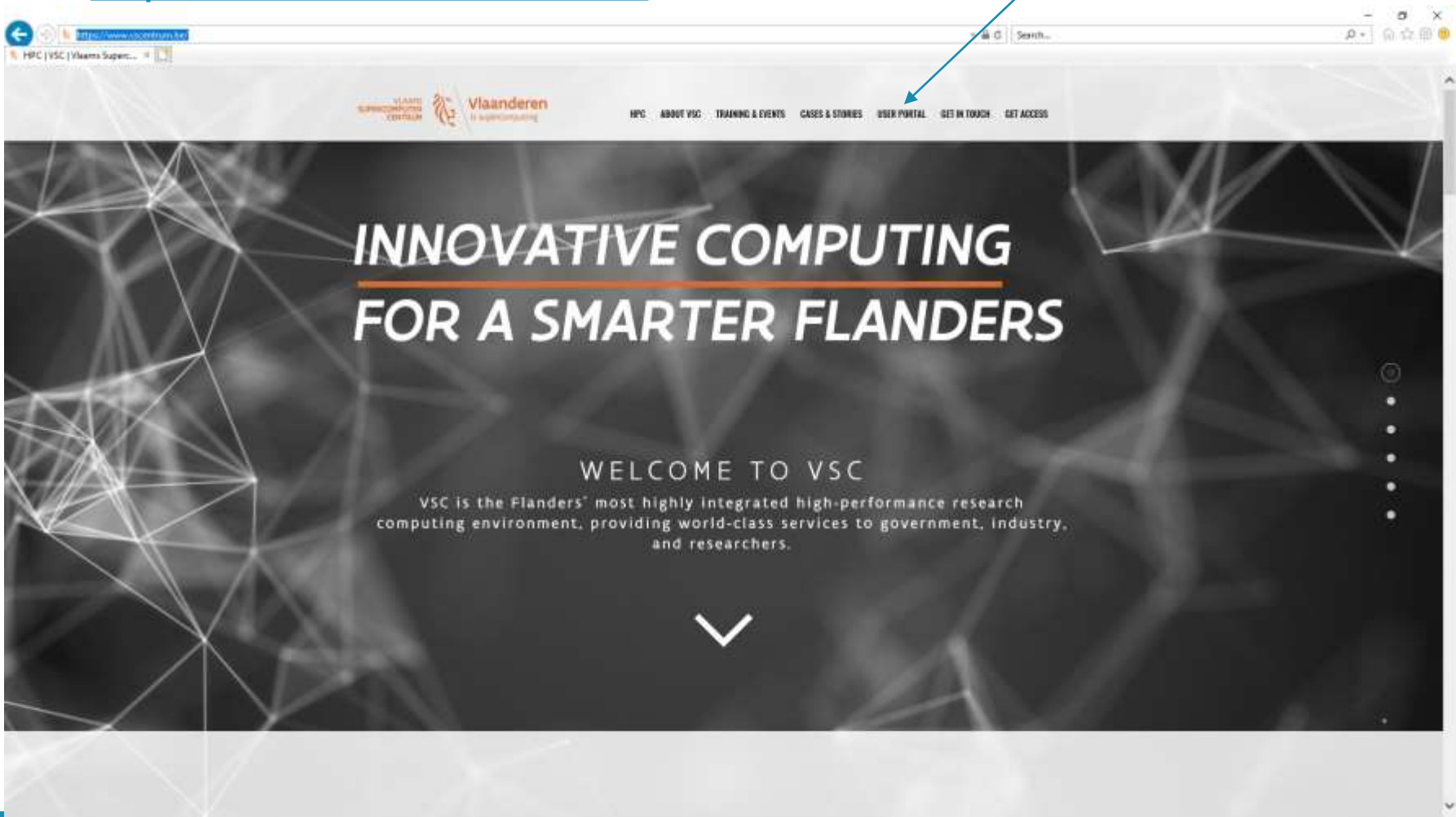
Mail list	Description
IT-users@lists.ugent.be	List for announcements regarding the Tier-1 machine at UGent.

The page also includes sections for "Usage" and "Personal" information, which are partially visible at the bottom.

Account vs. VSC website

- <https://www.vscentrum.be/>

Help and info



I deleted my key...

- If the **private key** is deleted from your computer – you need to generate another pair and upload the public key through the account page
- If the **public key** is deleted from the cluster
 - go to the account webpage (<https://account.vscentrum.be>) and under "Edit Account" reset SSH permissions
 - or upload it again through the account page
 - or contact us how to get the deleted files back to your directory
- I **forgot the passphrase** = I do not have a useful key pair = you need to generate another pair and upload the public key through the account page

I change the operating system...

- Update the system – nothing needs to be done
- Switch between Windows and Linux/Mac OS:
 - You may **generate another key-pair** and upload the public key through the account page
 - You can **convert the existing private key** so that your public key does not have to be replaced:
https://vlaams-supercomputing-centrum-vscdocumentation.readthedocs-hosted.com/en/latest/_downloads/e7a2b5135d512681fdee66773cd88177/nx_config_guide.pdf

SSH overview

Private keys are always secret

- Anyone who can access your private key can log in as you!
- Set a passphrase on your private key
- Private key is encrypted with this passphrase
- Always a pair of keys is needed
- Both keys need to be generated together

Generate the key

Linux/Mac OS users:

- Use “*ssh-keygen* ” *command to generate key pair*
- **Be sure to give your key a passphrase!**
- Default ssh key format: RSA 4096 bit

```
user@desktop:~> ssh-keygen -t rsa
Generating public/private rsa key pair.
Enter file in which to save the key (/home/user/.ssh/id_rsa):
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /home/user/.ssh/id_rsa.
Your public key has been saved in /home/user/.ssh/id_rsa.pub.
The key fingerprint is:
f6:61:a8:27:35:cf:4c:6d:13:22:70:cf:4c:c8:a0:23
```

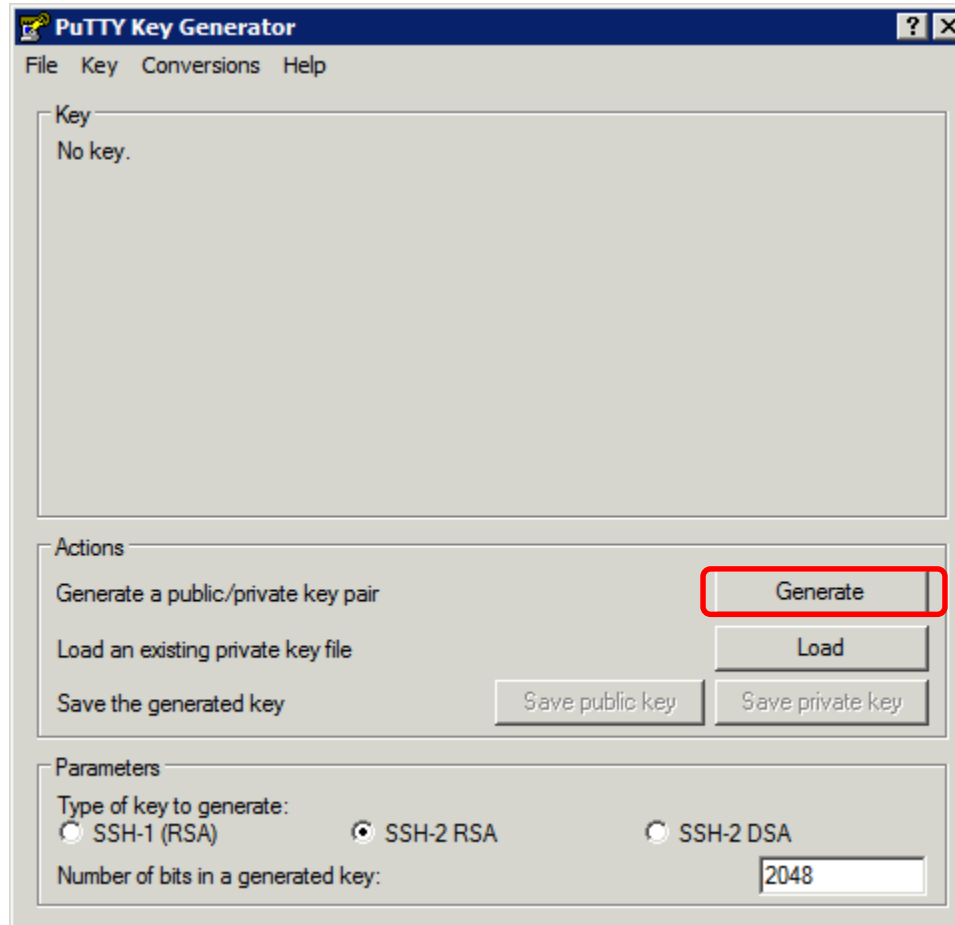
Generate the key

Linux/Mac OS users:

- Use “*ssh-keygen*” command to generate key pair
- **Be sure to give your key a passphrase!**
- Default location: `~/.ssh/id_rsa` (`~/.ssh/id_rsa.pub`)
- If other location: `ssh -i location-of-the-file`
- **keychain**: ssh agent to load the key with passphrase for current linux session

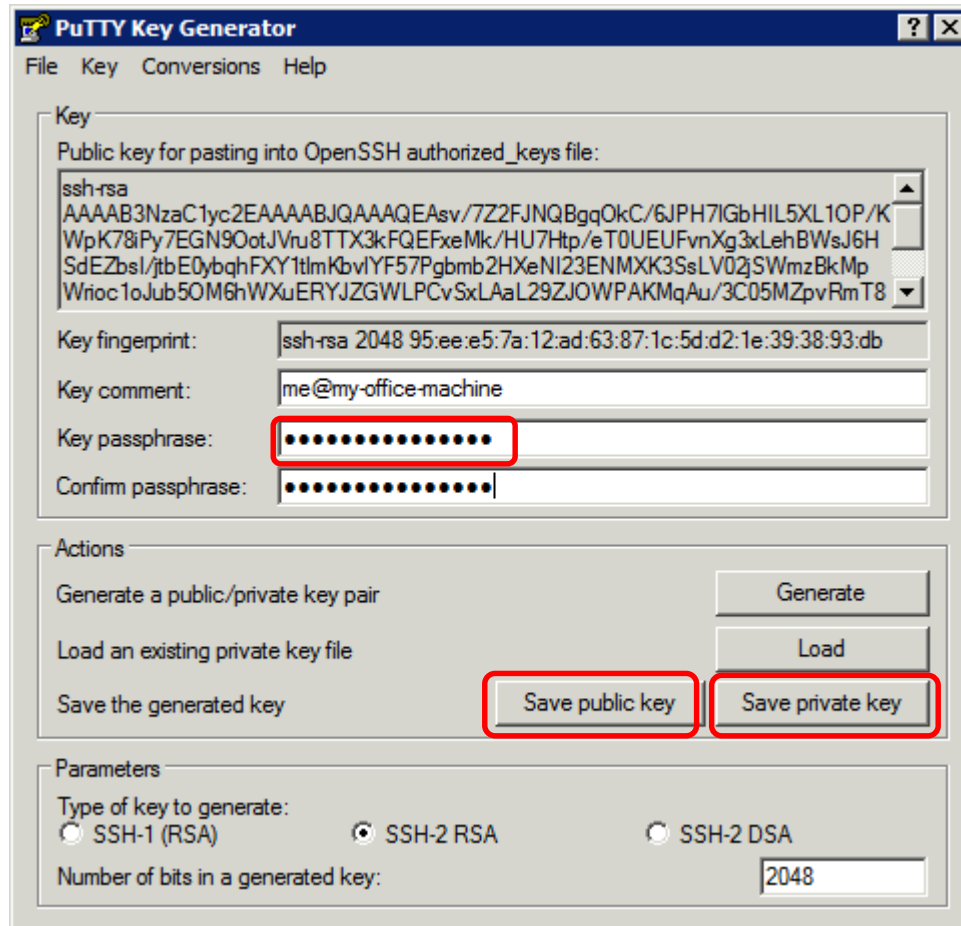
Generate the key

Windows users: use the PuTTYgen key generator.



Generate the key

Be sure to give your key a passphrase!



The screenshot shows the PuTTY Key Generator window. The 'Key' section displays the public key for pasting into the OpenSSH authorized_keys file. The 'Key fingerprint' is shown as 'ssh-rsa 2048 95:ee:e5:7a:12:ad:63:87:1c:5d:d2:1e:39:38:93:db'. The 'Key comment' is 'me@my-office-machine'. The 'Key passphrase' and 'Confirm passphrase' fields are both filled with dots and are highlighted with red rectangles. The 'Actions' section has three buttons: 'Generate', 'Load', and 'Save the generated key'. The 'Save the generated key' button is highlighted with a red rectangle, and it has two sub-buttons: 'Save public key' and 'Save private key', both of which are also highlighted with red rectangles. The 'Parameters' section shows 'Type of key to generate' with 'SSH-2 RSA' selected, and 'Number of bits in a generated key' set to '2048'.

PuTTY Key Generator

File Key Conversions Help

Key

Public key for pasting into OpenSSH authorized_keys file:

```
ssh-rsa
AAAAB3NzaC1yc2EAAAABJQAAQEAfv/7Z2FJNQBgqOkC/6JPH7IGbHIL5XL1OP/K
WpK78iPy7EGN9OotJVru8TTX3kFQEFxeMk/HU7Htp/eT0UEUFvnXg3xLehBWsj6H
SdEZbsl/jtbE0ybqhFXy1tlmKbviYF57Pgbmb2HXeNI23ENMXK3SsLV02jSWmzBkMp
Wrioc1oJub5OM6hWXuERYJZGWLPCvSxLAaL29ZJOWPAKMqAu/3C05MZpvRmT8
```

Key fingerprint: ssh-rsa 2048 95:ee:e5:7a:12:ad:63:87:1c:5d:d2:1e:39:38:93:db

Key comment: me@my-office-machine

Key passphrase:

Confirm passphrase:

Actions

Generate a public/private key pair Generate

Load an existing private key file Load

Save the generated key Save public key Save private key

Parameters

Type of key to generate:

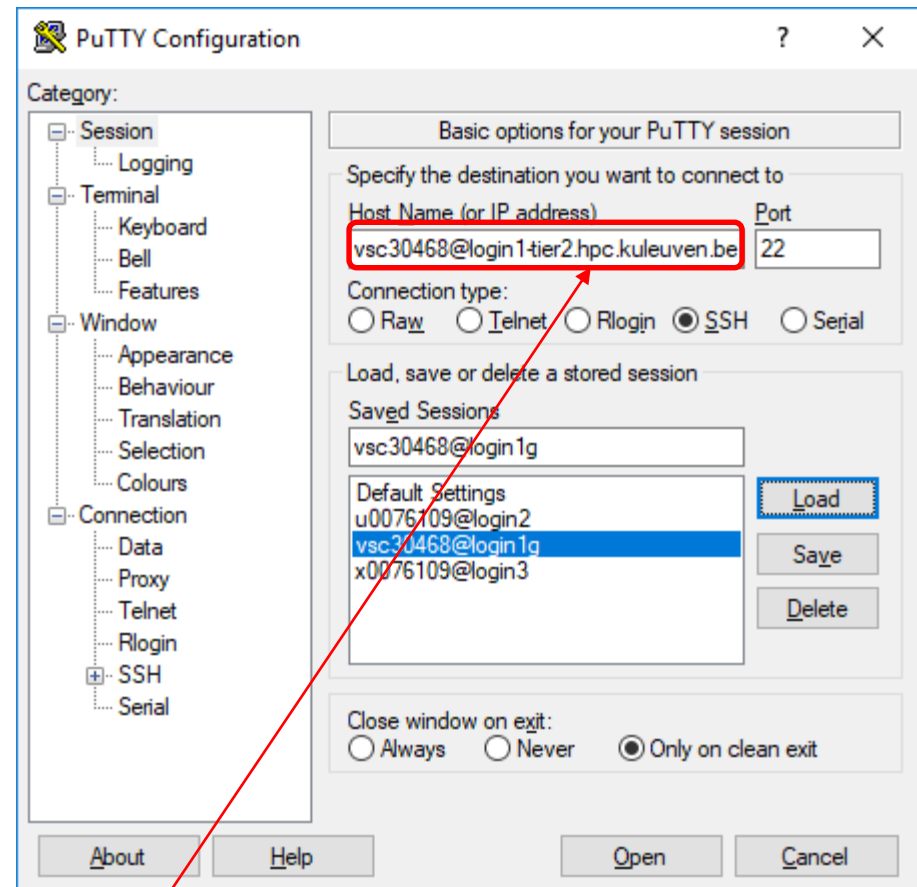
☐ SSH-1 (RSA) ☒ SSH-2 RSA ☐ SSH-2 DSA

Number of bits in a generated key: 2048

Connecting to the cluster: text mode

Windows users:

- PuTTY is a simple-to-use and freely available GUI SSH client for Windows.
- Pageant can be used to manage active keys for PuTTY, WinSCP and FileZilla so that you don't need to enter the passphrase all the time.

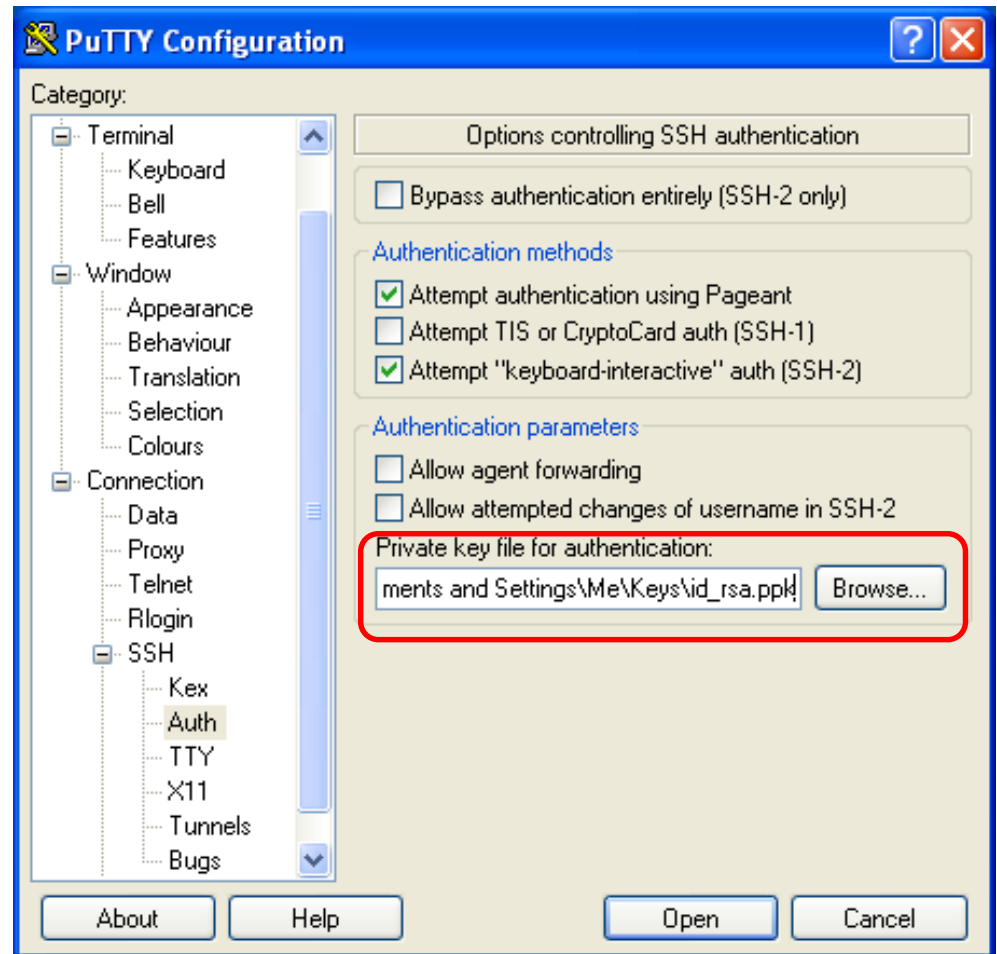


`vsc3XXXX@login1-tier2.hpc.kuleuven.be`

Connecting to the cluster: text mode

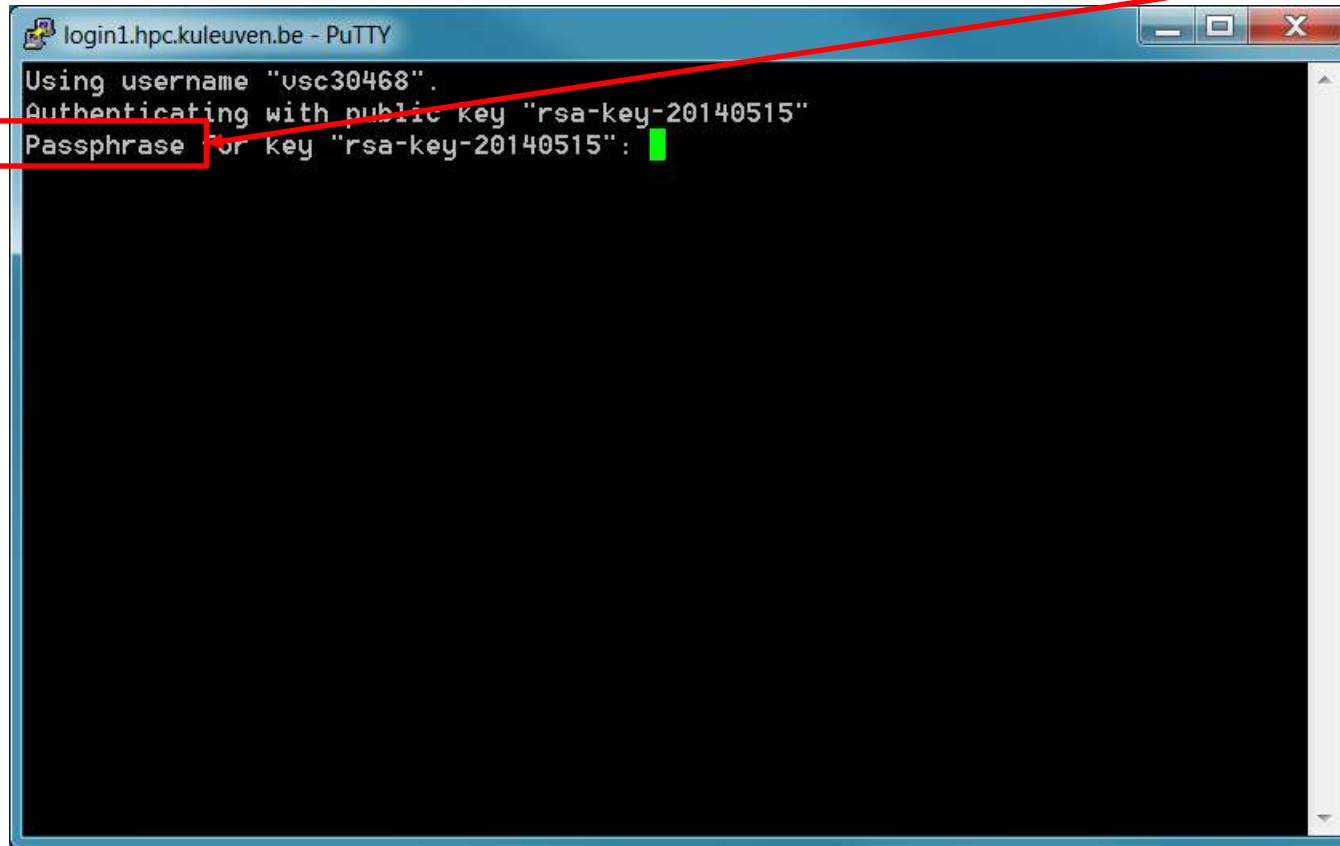
Windows users:

- PuTTY is a simple-to-use and freely available GUI SSH client for Windows.



Connecting to the cluster: text mode

Windows users:



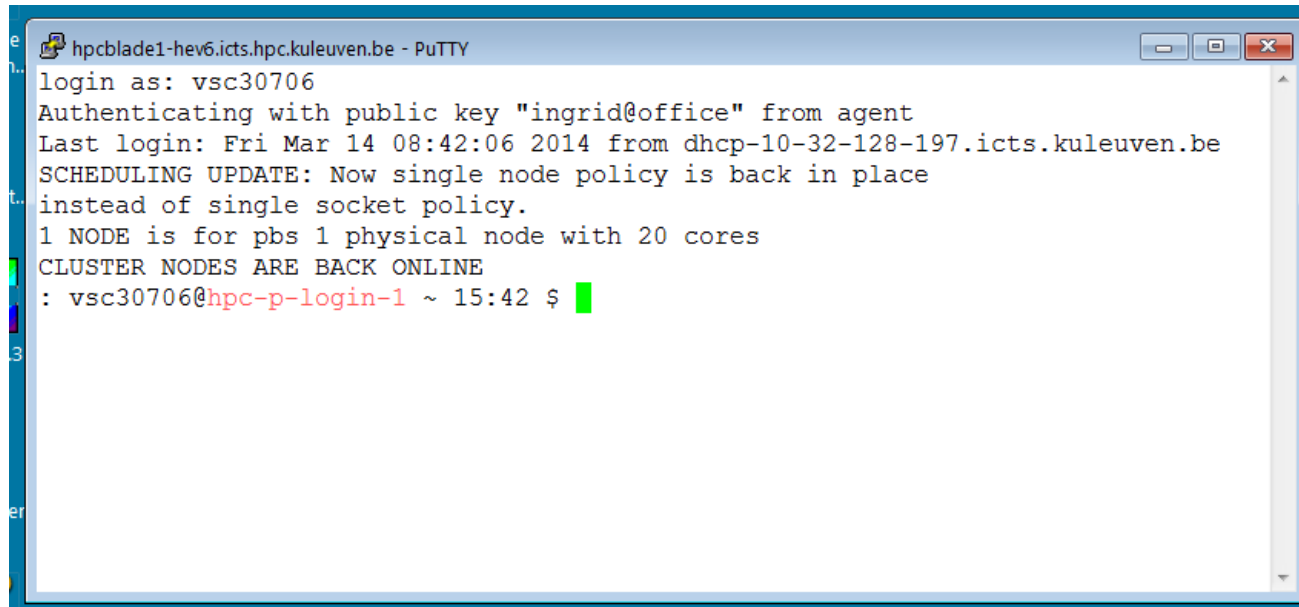
```
login1.hpc.kuleuven.be - PuTTY
Using username "usc30468".
Authenticating with public key "rsa-key-20140515"
Passphrase for key "rsa-key-20140515": █
```

If asked for **password** no for passphrase – please stop connecting and contact suport, otherwise after a few attempts you will be blocked for 24hrs

How to get started?

- Linux users:

`ssh vsc3XXXX@login1-tier2.hpc.kuleuven.be`



```
hpcblade1-hev6.icts.hpc.kuleuven.be - PuTTY
login as: vsc30706
Authenticating with public key "ingrid@office" from agent
Last login: Fri Mar 14 08:42:06 2014 from dhcp-10-32-128-197.icts.kuleuven.be
SCHEDULING UPDATE: Now single node policy is back in place
instead of single socket policy.
1 NODE is for pbs 1 physical node with 20 cores
CLUSTER NODES ARE BACK ONLINE
: vsc30706@hpc-p-login-1 ~ 15:42 $
```

If asked for **password** no for passphrase – please stop connecting and contact support, otherwise after a few attempts you will be blocked for 24hrs

... and you are in!

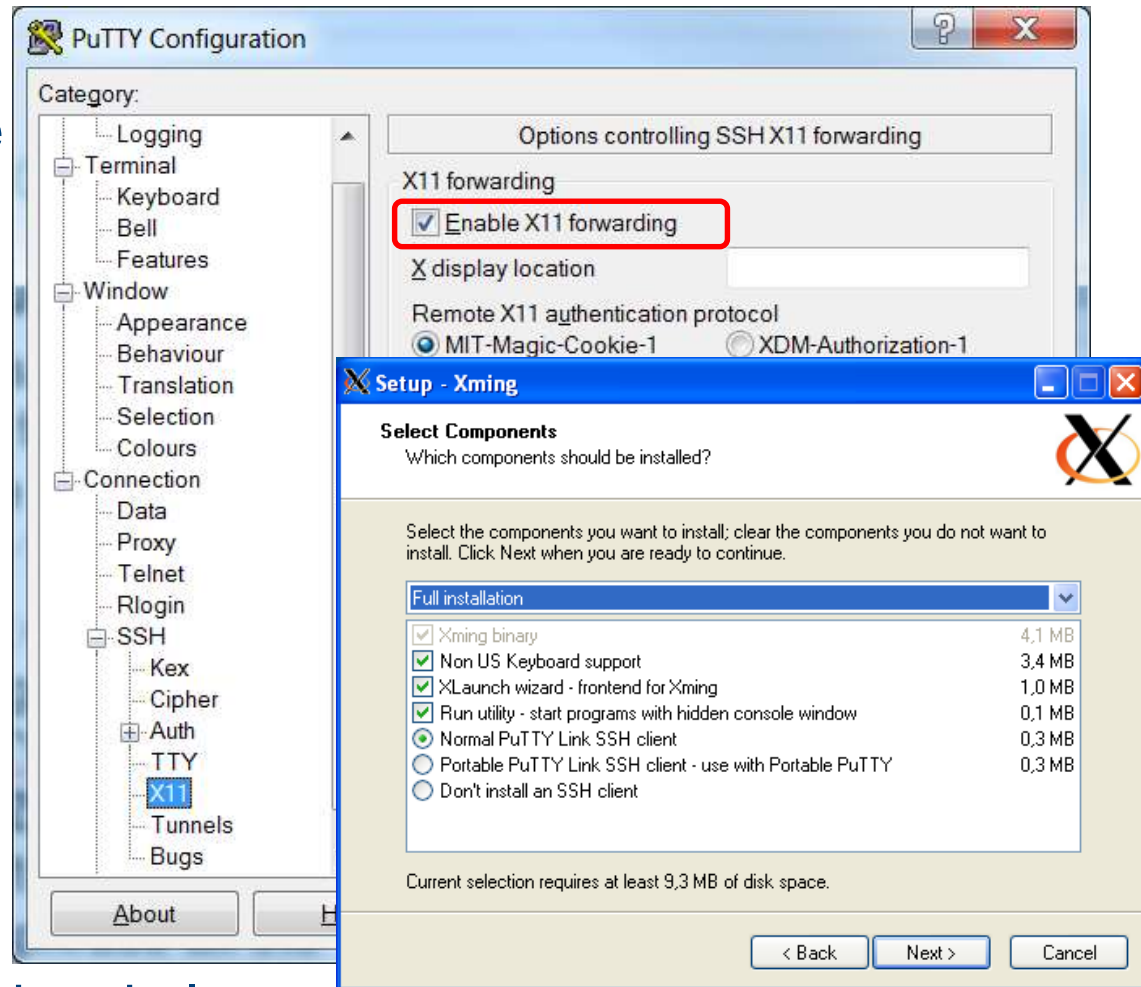
Connecting to the cluster: display graphics

Windows users:

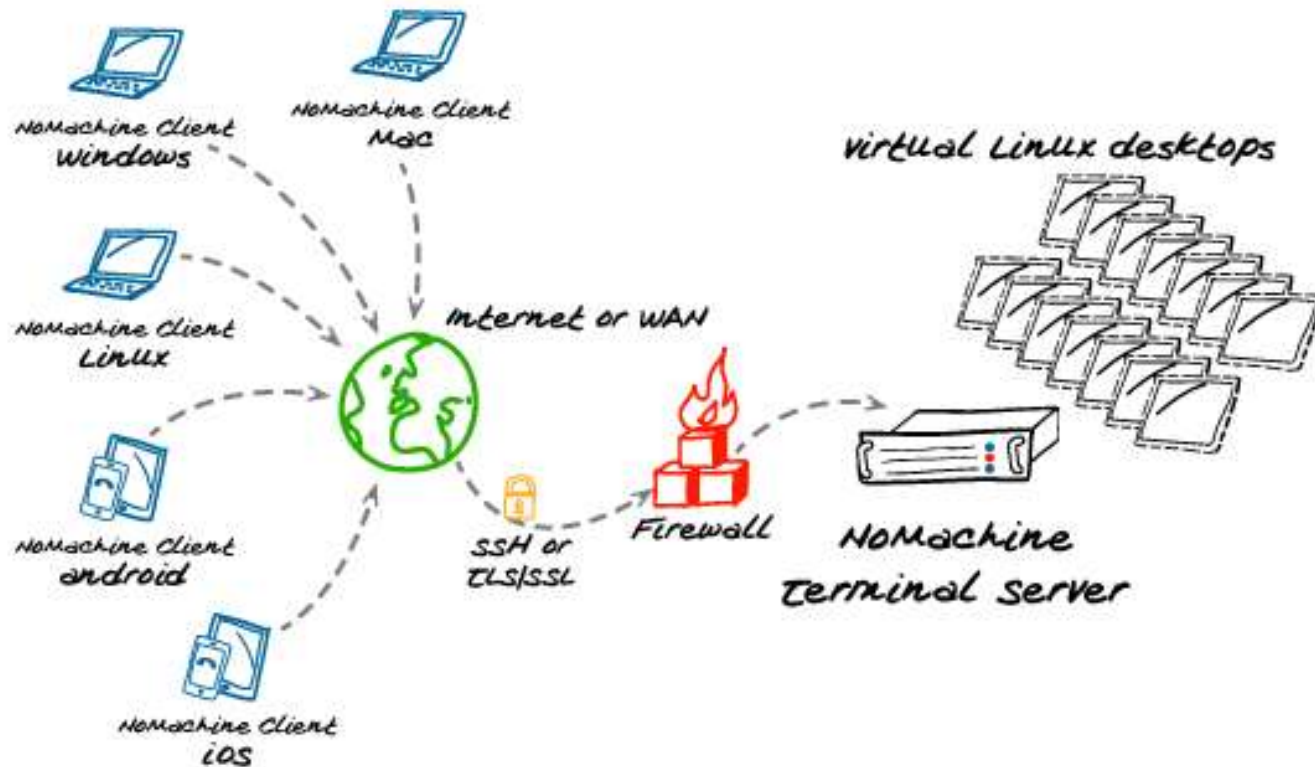
- PuTTY is a simple-to-use and freely available GUI SSH client for Windows.
- Pageant can be used to manage active keys for PuTTY
- **Xming**: using X-windows to display graphical programs

Linux users:

- `ssh -X vsc3XXXX@login.hpc.kuleuven.be`



What is NX?

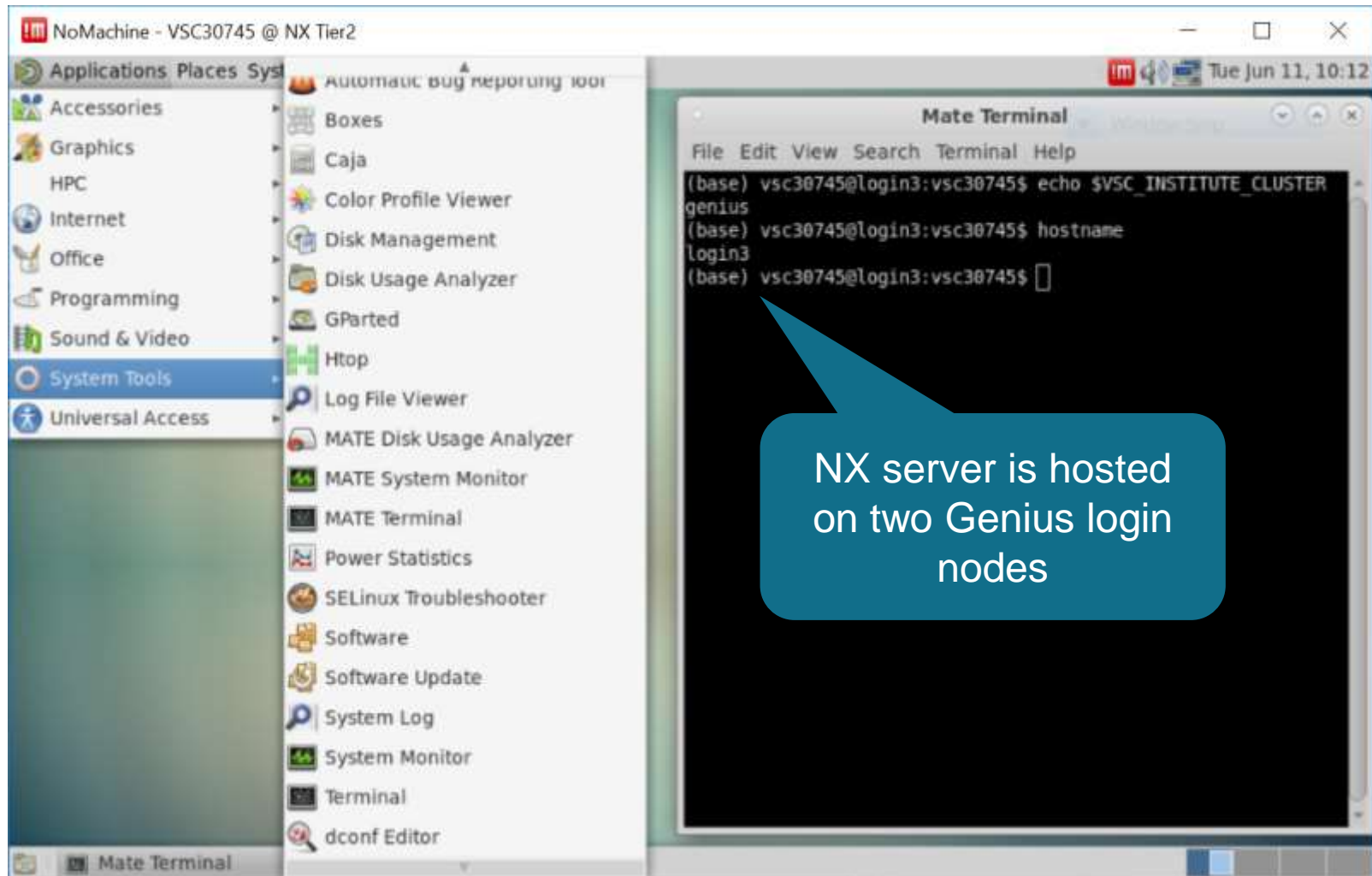


NX works by creating an nx-user on the server machine whose shell is executed any time a remote NX user connects to SSH using NX Client.

Main advantages of NX

- NX also allows to suspend and resume sessions and keeps session open (disconnected up to 30 days),
- During suspension, the processes invoked inside the session continue to run,
- Alternative for people using screen,
- More interactive jobs,
- Easy in use for editing, file management, developing software,
- Different limits of CPU (regular login node 36 min, NX node extended to 2 hrs).

NX virtual desktop



NX: available software

- **Accessories:** Gedit, Vi IMproved, Emacs (dummy version), Calculator,
- **Graphics:** gThumb (picture viewer), Xpdf Viewer,
- **Internet:** Firefox,
- **HPC: Computation:** Matlab (2018a), RStudio, SAS;
Visualisation: Paraview, VisIt, VMD
- **Programming:** Meld Diff Viewer (visual diff and merge tool),
- **System tools:** File Browser, Terminal,
- **Additionally:** Gnuplot (graphing utility), Filezilla (file transfer tool), Evince (PDF, PostScript, TIFF, XPS, DVI Viewer),
- Software launched through modules from Terminal.

NX: How to get started

- https://vlaams-supercomputing-centrum-vscdocumentation.readthedocs-hosted.com/en/latest/access/nx_start_guide.html?highlight=nx
- **Configuration guide:** https://vlaams-supercomputing-centrum-vscdocumentation.readthedocs-hosted.com/en/latest/access/nx_start_guide.html?highlight=nx#nomachine-nx-client-configuration-guide

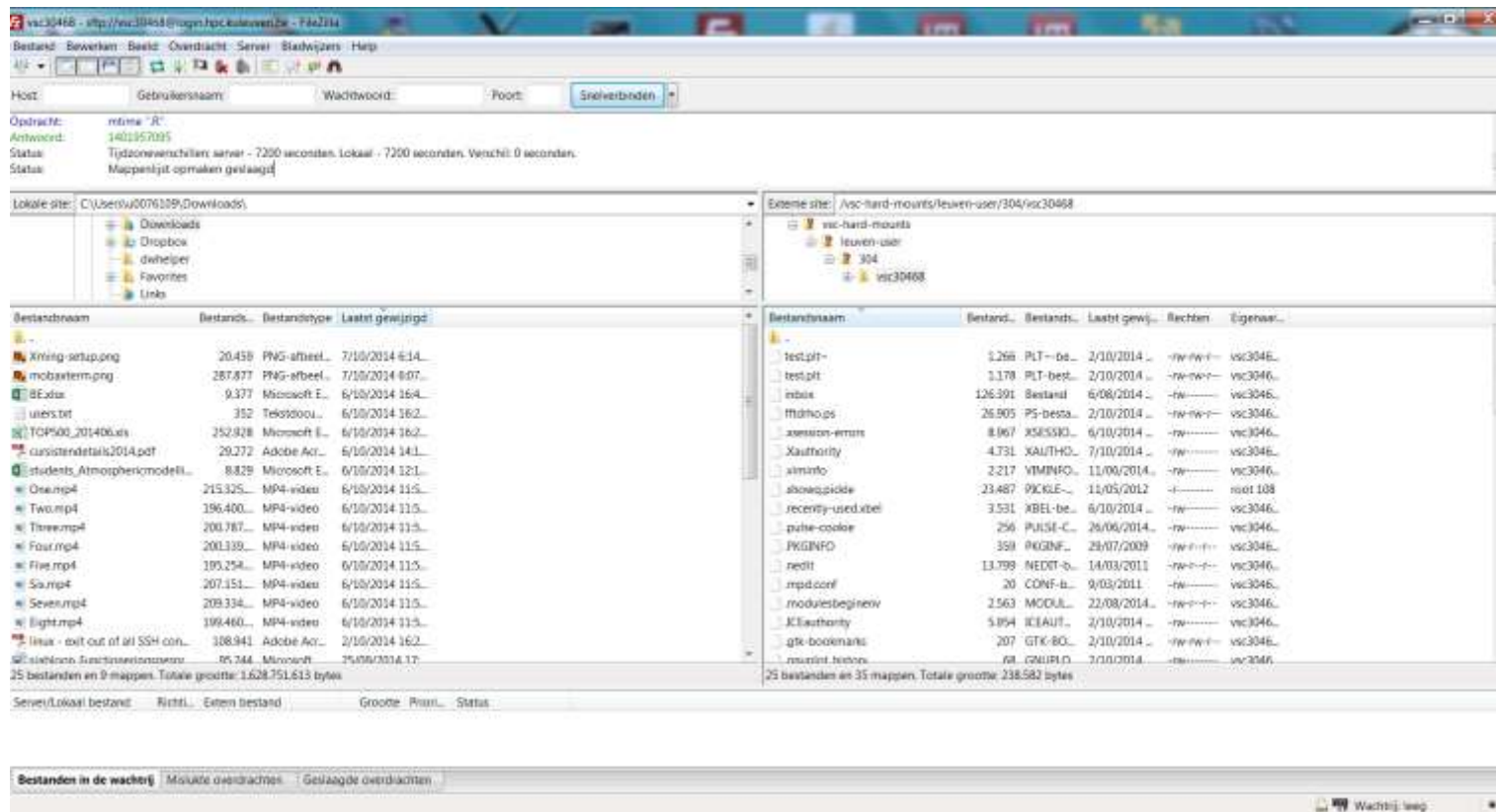
**NX node is a login node (shared between other all the users).
Do not run your jobs there!**

- **needs conversion of key for windows systems or pageant**

Connecting to the cluster: file transfer

Windows users:

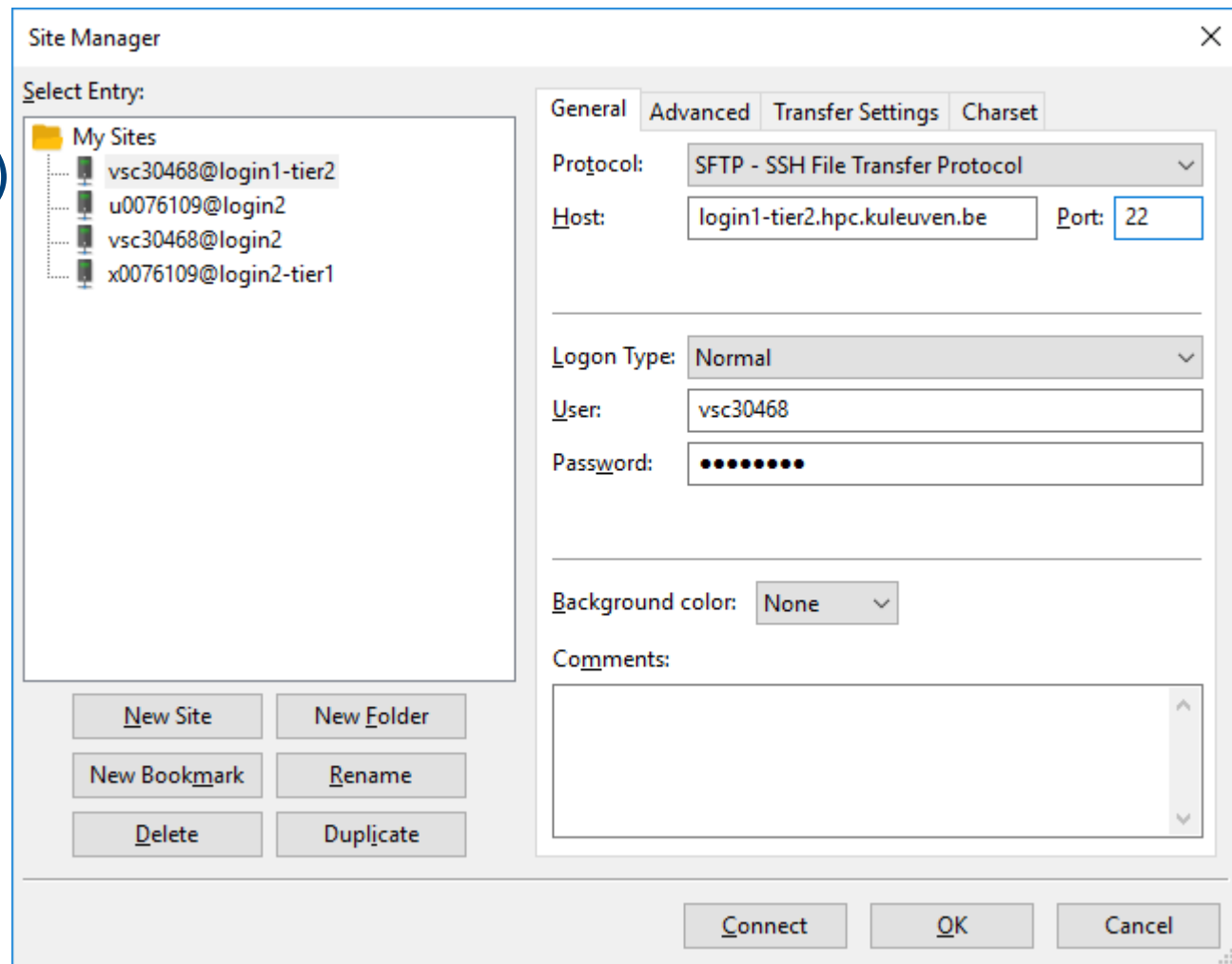
- Filezilla (SFTP)
- WinSCP



Connecting to the cluster: file transfer

Windows users:

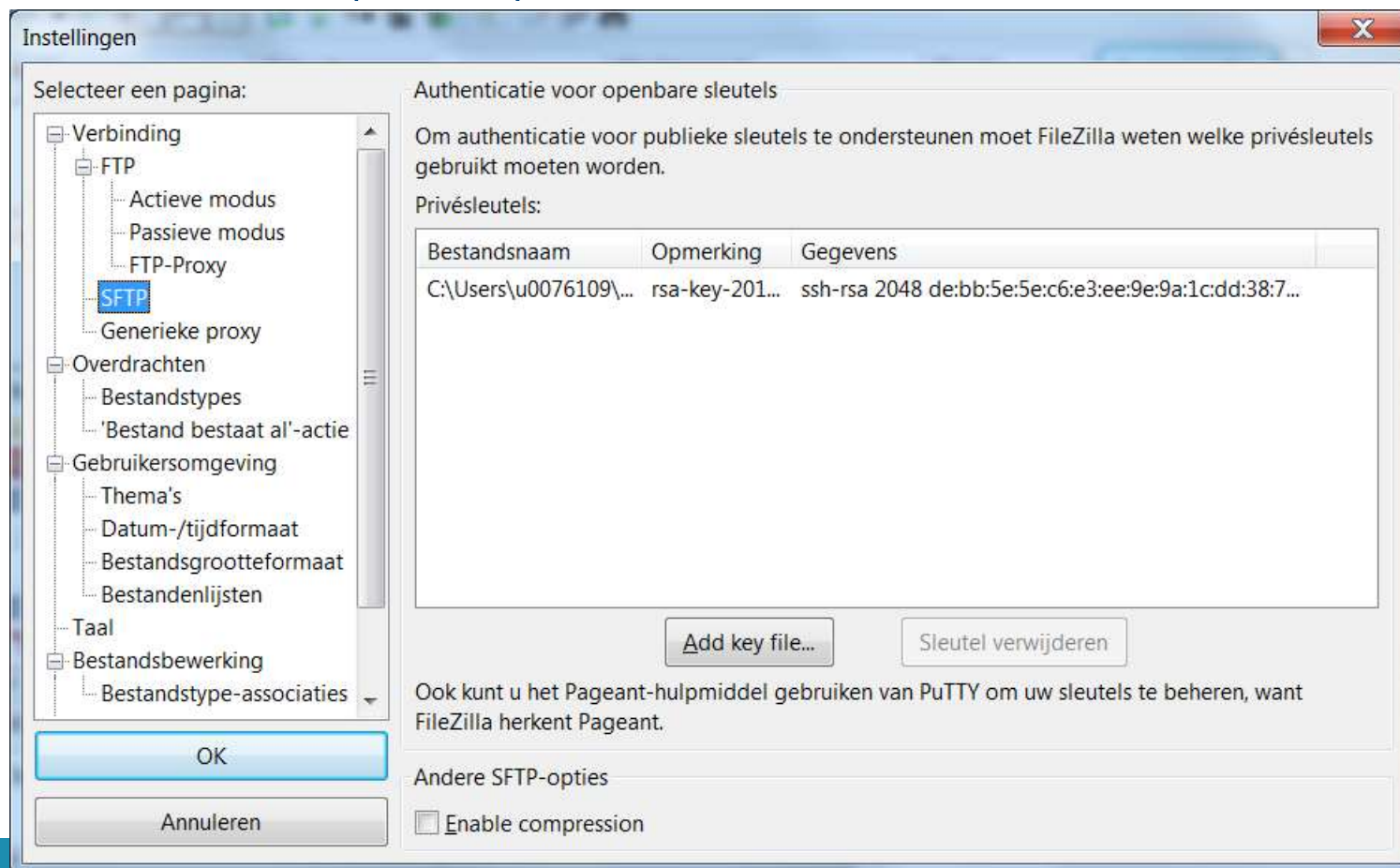
- Filezilla (SFTP)



Connecting to the cluster: file transfer

Windows users:

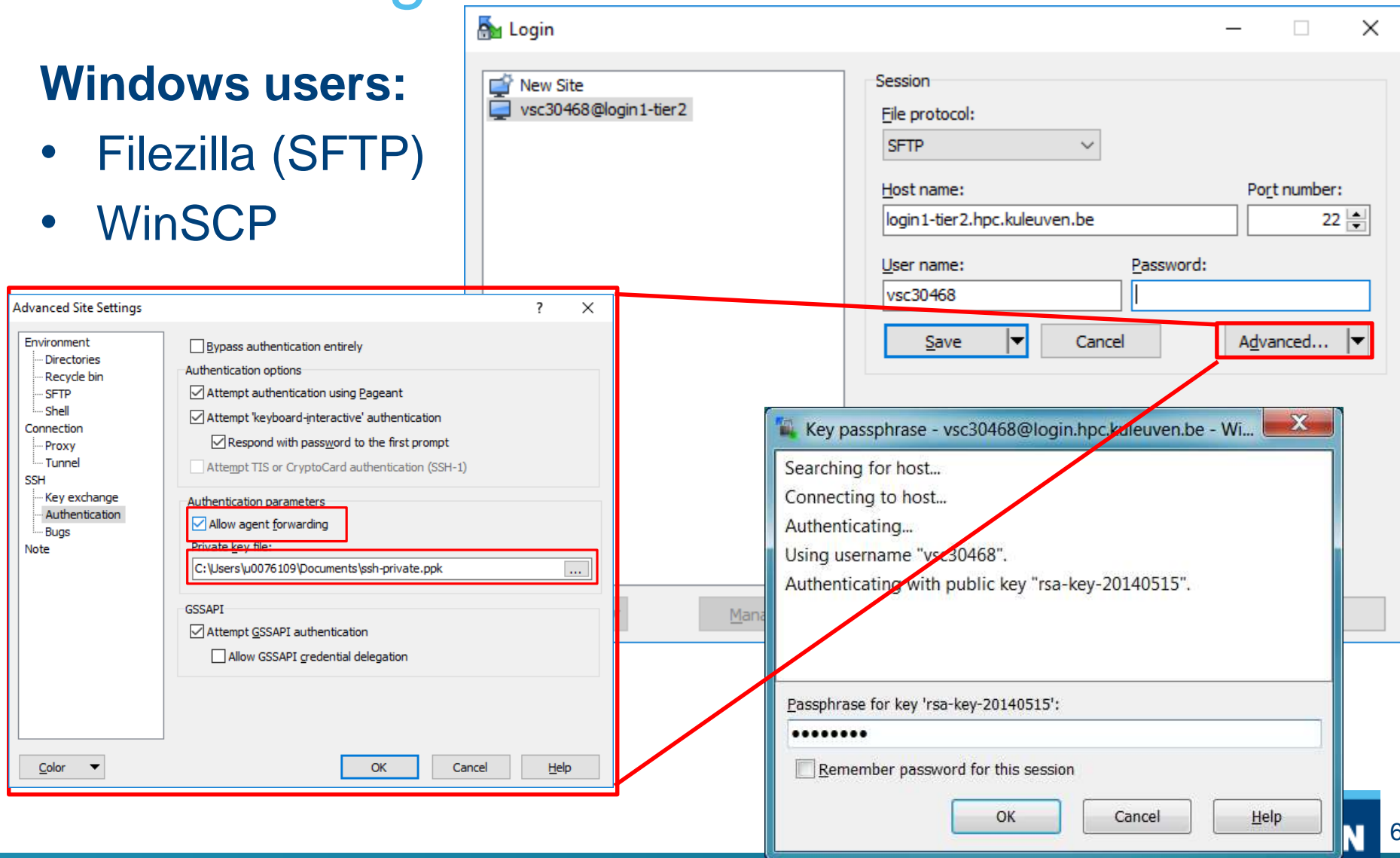
- Filezilla (SFTP)



Connecting to the cluster: file transfer

Windows users:

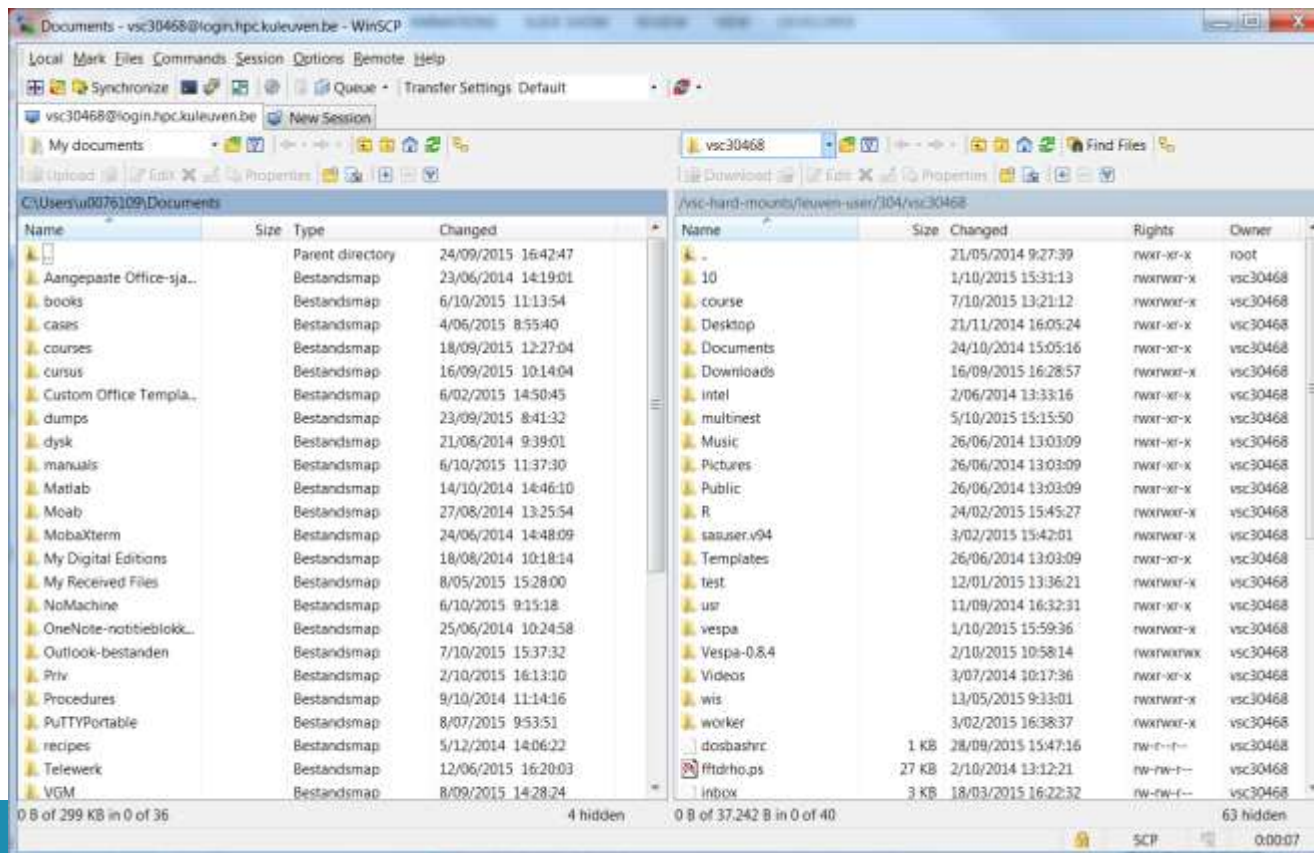
- Filezilla (SFTP)
- WinSCP



Connecting to the cluster: file transfer

Windows users:

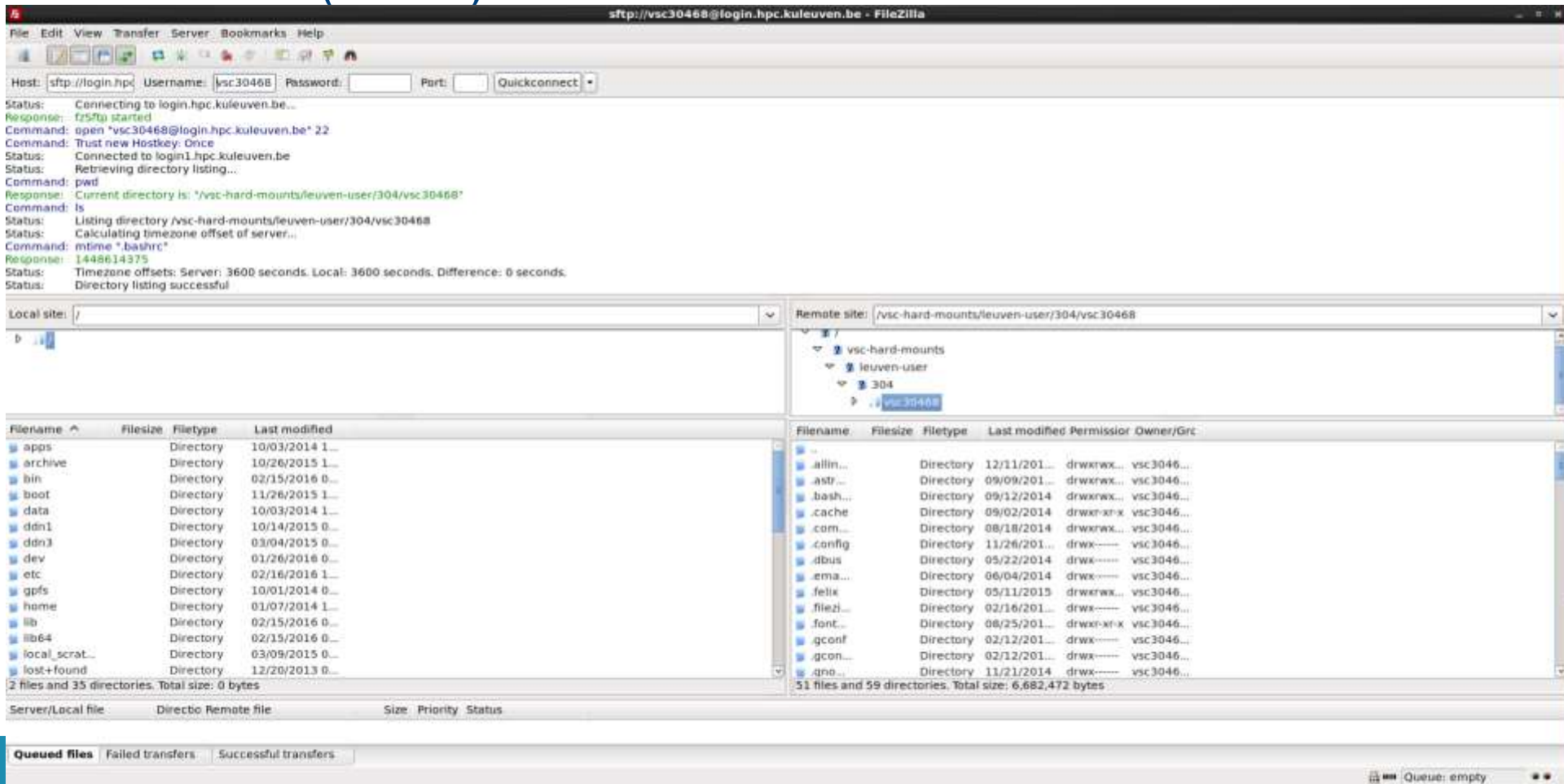
- Filezilla (SFTP)
- WinSCP



Connecting to the cluster: file transfer

Linux/Mac users:

- Filezilla (SFTP)

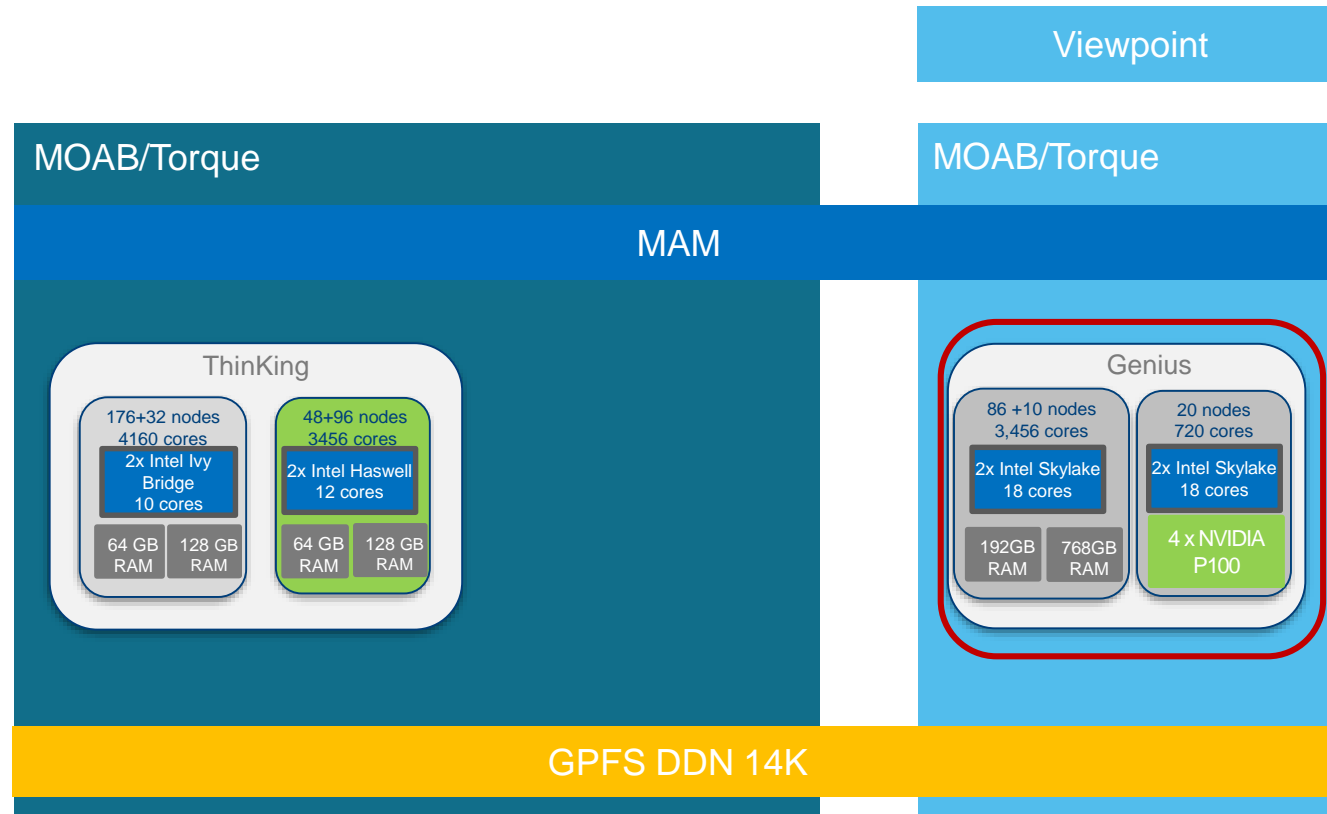


Hands-on 1



- Login on the account webpage <https://account.vscentrum.be/> and join the `lp_hpcinfo_training` group
- Login to the cluster
- Check your available space in `$VSC_HOME`, `VSC_DATA` and `$VSC_SCRATCH` directory

Production phase



Jobs need to be submitted separately to Thinking or Genius from login nodes

Torque/Moab - Genius

- **Jobs have to be submitted from new (Genius) login nodes**
- Some commands:
 - `$ qsub ...` : Submit a job, returns a job ID

```
$ qsub test.sh  
50001435.tier2-p-moab-2.icts.hpc.kuleuven.be
```
 - `$ qdel <job-id>` : Delete a queued or running job

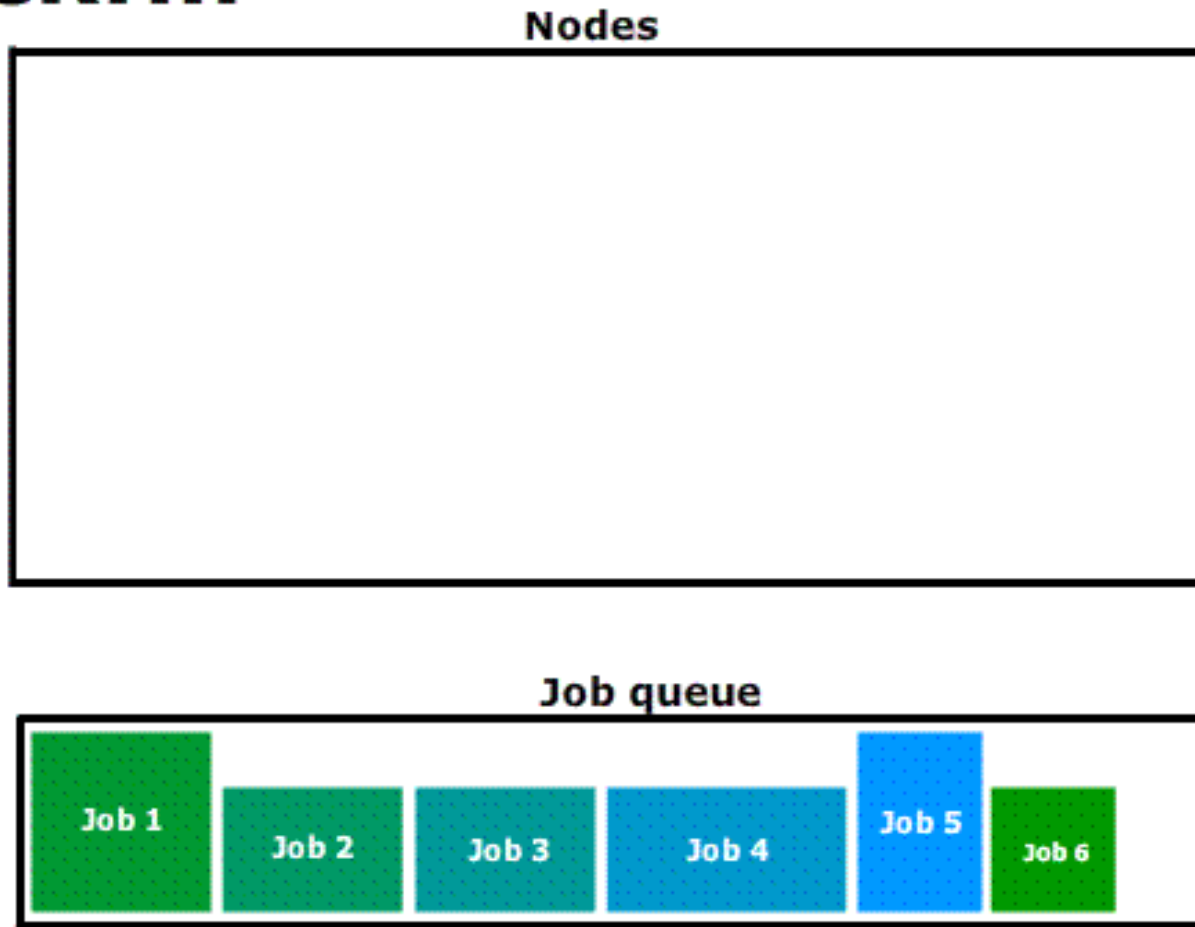
```
$ qdel 50001435
```
 - `$ qstat` : Get the status of your jobs on the system
- **CPU nodes: SINGLE** user policy (only **1 user** per node), Single core jobs can end up on the same node, but are accounted on a job basis.

Job Scheduler: Moab

- The job scheduler decides when and where to run jobs using a priority queue
 - Queries resource manager for runnable jobs
 - Priority is determined by:
 - static properties: credentials, QoS, job resources
 - dynamic properties: fair share, queue time,
 - Tries to optimize resource usage and
 - favors **parallel jobs**,
 - **fair use** of resources for all users (taking into account computation during past 7 days),
 - ensures liveness, regardless of starting priority, job will eventually have highest priority
 - Small jobs - **backfill**
 - Orders resource manager to start (or stop ...) jobs
 - Max queueable jobs per user (100 small, 25/10 big)

Job Scheduler: Moab

Backfill



Job Scheduler: Moab

- Some Moab commands:
 - `$ checkjob <job-id>` : shows job information
 - `$ showstart <job-id>` : shows the ***earliest*** time job *can, not will* start (at the time of the query)

Understanding Showstart

```
$ showstart 50036840
```

INFO: cannot determine start time for job 50036840

```
$ showstart 50036840
```

job 50036840 requires 360 procs for 00:15:00

Estimated Rsv based start in	00:01:00 on Fri Nov 16 12:27:32
Estimated Rsv based completion in	00:16:00 on Fri Nov 16 12:42:32

Best Partition: pbs

Understanding checkjob

- `$ checkjob <job-id>` : shows job information

job 50029503

AName: my-test
State: BatchHold
Creds: default_project class:q72h qos:normal
WallTime: 00:00:00 of 3:00:00:00
BecameEligible: Mon Oct 29 19:11:13
SubmitTime: Mon Oct 29 16:56:04
(Time Queued Total: 22:10:10 Eligible: 19:56:00)

Job Templates: 72hour
TemplateSets: DEFAULT,72hour.set
NodeMatchPolicy: EXACTNODE
Total Requested Tasks: 36

Req[0] TaskCount: 36 Partition: pbs
Memory >= 5120M Disk >= 0 Swap >= 0
Dedicated Resources Per Task: PROCS: 1 MEM:
5120M
NodeSet=ONEOF:FEATURE:[NONE]

Allocated Nodes:
[r22i13n10:36]
Applied Nodeset: r22i13

SystemID: Moab
SystemJID: 50031650
Notification Events: JobFail

IWD:
/ddn1/vol1/site_scratch/leuven/304/vsc30468/TEST
Partition List: pbs
Flags: RESTARTABLE,FSVIOLATION
Attr: FSVIOLATION,checkpoint,72hour.set
StartPriority: -3294
IterationJobRank: 0

Holds: Batch:CannotDebitAccount
NOTE: job cannot run (job has hold in place)

Problem with the project = no
(not enough) credits available

Understanding Checkjob

\$ checkjob 50036840

Req[0] TaskCount: 1 Partition: thinking

Memory >= 2400M Disk >= 0 Swap >= 0

Dedicated Resources Per Task: PROCS: 1 MEM: 4096M

NodeSet=ONEOF:FEATURE:[NONE]

SystemID: Moab

SystemJID: 20280125

Notification Events: JobFail

Just a notification,
nothing to be
worried about

Partition List: thinking

Flags: RESTARTABLE

Attr: checkpoint

StartPriority: 1977

Holds: System:CannotDebitAccount

Problem with the project
= no (not enough) credits
available

NOTE: job cannot run (job has hold in place)

Understanding Checkjob

```
$ checkjob 50036840
```

```
Req[0] TaskCount: 20 Partition: thinking
```

```
Memory >= 2400M Disk >= 0 Swap >= 0
```

```
Opsys: --- Arch: --- Features: haswell
```

```
Dedicated Resources Per Task: PROCS: 1 MEM: 2400M
```

```
NodeSet=ONEOF:FEATURE:[NONE]
```

```
Allocated Nodes:
```

```
[r4i2n6:20]
```

```
SystemID: Moab
```

```
SystemJID: 20292673
```

Notification is personalized

```
#PBS -m abe
```

```
#PBS -M mag.selwa@kuleuven.be
```

```
Notification Events: JobFail Notification Address: mag.selwa@kuleuven.be
```

```
StartCount: 1
```

```
Partition List: thinking
```

```
Flags: RESTARTABLE
```


Moab Allocation Manager

$$\#credits = (0.000278 \cdot walltime \cdot \#nodes) \cdot f_{type}$$

Project credits valid for all Tier-2 clusters:

- ThinKing,
- GPU,
- Genius,
- Superdome

$$f_{type} = \begin{cases} 4.76 & \text{ThinKing IvyBridge} \\ 6.68 & \text{ThinKing Haswell} \\ 2.86 & \text{ThinKing GPU} \\ 0 & \text{Superdome} \\ 10 & \text{Genius Thin node} \\ 12 & \text{Genius large memory} \\ 20 & \text{Genius GPU (full node 4xP100)} \\ 5 & \text{Genius GPU 1/4 (1xP100)} \end{cases}$$

Example: `-l walltime=1:00:00 -l nodes=1:ppn=1`

$$\#credits = (0.000278 \cdot 3600 \cdot 1) \cdot 10 = 10.01$$

`-l walltime=1:00:00 -l nodes=1:ppn=36`

$$\#credits = (0.000278 \cdot 3600 \cdot 1) \cdot 10 = 10.01$$

Single user per node policy

Credits

Credits card concept:

- **Preauthorization**: holding the balance as unavailable until the merchant clears the transaction
- Balance to be held as unavailable: based on requested resourced (walltime, nodes)
- **Actual charge** based on what was really used: used walltime (you pay only what you use, e.g. when job crashes)
- See output file

How to check available credits?

```
$ mam-balance
```

How to check the cost of job?

```
$ module load accounting  
$ gquote ...
```

Types of queues and default values and limits

- To obtain more detailed information on the queues

\$ qstat -f -Q <queuenam>

- `qstat -f -Q q1h`

Queue: q1h

queue_type = Execution

max_user_queuable = 200

total_jobs = 37

state_count = Transit:0 Queued:21 Held:0 Waiting:0 Running:0 Exiting:0 Complete:16

resources_max.walltime = 01:00:00

resources_min.walltime = 00:00:01

resources_default.nodes = 1:ppn=36

resources_default.partition = pbs

resources_default.pmem = 5gb

resources_default.walltime = 01:00:00

mtime = 1540971884

resources_assigned.nodect = 0

resources_assigned.mem = 0b

enabled = True

started = True

Software

modules



Software: Genius

- Operating system
 - CentOS 7.4.1708, 64 bit
 - Kernel 3.10.0-693.17.1.el7.x86_64
- Applications
- For development
 - Compilers & basic libraries \equiv tool chains
 - Libraries
 - Tools: debuggers, profilers

Different on each cluster!

Use modules

If no module is loaded:
You can use only software
available on the basic CentOS
Linux: older versions of
software, without extensions

Available tool chains

	intel tool chain	foss tool chain
Name	intel	foss
version	2018a	2018a
Compilers	Intel compilers (v 2018.1.163) icc, icpc, ifort	GNU compilers (v 6.4.0-2.28) gcc, g++, gfortran
MPI Library	Intel MPI	OpenMPI
Math libraries	Intel MKL	OpenBLAS, LAPACK FFTW ScaLAPACK

Tool chain: set of programming tools to build an application

Never mix different toolchains!

Modules

Set the environment to use software package:

- `$ module available` or `module available Py`
 - Lists all installed software packages
- `$ module av |& grep -i python`
 - To show only the modules that have the string 'python' in their name, regardless of the case
- `$ module load Python/2.7.14-foss-2018a`
 - Adds the 'matlab' command in your PATH
- `$ module load GCC`
 - 'Load' the (default) GCC version – not recommended, not reproducible
- `$ module list`
 - Lists all 'loaded' modules in current session
- `$ module unload Python/2.7.14-foss-2018a`
 - Removes all only the selected module, other loaded modules – dependencies are still loaded
- `$ module purge`
 - Removes all loaded modules from your environment

Modules

- `$ module swap foss intel`
 - **= module unload foss; module load intel**
- `$ module try-load packageXYZ`
 - **try to load a module with no error message if it does not exist**
- `$ module keyword word1 word2 ...`
 - **Keyword searching tool, searches any help message or whatis description for the word(s) given on the command line**
- `$ module help foss`
 - **Prints help message from modulefile**
- `$ module spider foss`
 - **Describes the module**

Modules: Genius

- **ml** – convenient tool
- `$ ml`
 - = module list
- `$ ml foss`
 - =module load foss
- `$ ml -foss`
 - =module unload foss (not purge!)
- `$ ml show foss`
 - Info about the module

More info: http://lmod.readthedocs.io/en/latest/010_user.html

Get started



Prices

Introduction credits

- Maximum 2000
- Valid up to 6 months



Project credits

- Commercial partner **0.06 €**
- Internal funding, IWT, FWO, European funding **0.0035 €**
- Minimum purchase 5000 credits

Storage

- /scratch, temporary quota upgrade
- /data 25 GB , 14.63 €/year
- HPC archive 1 TB, 70 €/year
- /staging 1 TB, 130 €/year



Application support

- Software Installation
- Debugging & profiling up to 5 days
- Parallelization & optimization up to 5 days



Training

- Scheduled courses
- Infosessions
- Thematic workshops



Prices and information: <https://icts.kuleuven.be/sc/english/HPC>

Extra services

- Request introduction credits
<https://admin.kuleuven.be/icts/onderzoek/hpc/request-introduction-credits>
- Request project credits
<https://admin.kuleuven.be/icts/onderzoek/hpc/request-project-credits>
https://icts.kuleuven.be/sc/forms/Aanvraagformulier_HPC_Credits
- Extra project credits (to add to existing project)
<https://admin.kuleuven.be/icts/onderzoek/hpc/extra-project-credits>
- Request extra storage
<https://admin.kuleuven.be/icts/onderzoek/hpc/hpc-storage>

Job types

- 1) **Batch jobs** are by far the most common, and allow for the most efficient use of the infrastructure. Essentially, a batch job is a bash shell script that is executed on a compute node, and that can spawn a parallel computation on many nodes. These jobs are placed in the queue, and the user can forget about it until it is finished.
- 2) **Interactive jobs** are intended to work on one or more compute nodes interactively. This can be useful in the context of software development for debugging and profiling applications, or for interactive calculations or visualizations. Basically, one gets a shell on one of the compute nodes.
- 3) To get GPU(s), you can use **JupyterHub** with your internet browser

Glossary

- **Walltime:** the actual time an application runs (as in clock on the wall), or is expected to run. When submitting a job, the walltime refers to the maximum amount of time the application can run. For accounting purposes, the walltime is the amount of time the application actually ran, typically less than the requested walltime.
- **Memory requirement:** the amount of RAM needed to successfully run an application. It can be specified per process for a distributed application, expressed in GB.
- **Storage requirement:** the amount of disk space needed to store the input and output of an application, expressed in GB or TB.

Interactive jobs

- `$ qsub -I`
 - opens shell on a compute node for 1h
- `$ qsub -I -X`
 - opens shell, with X-forwarding
- `$ qsub -I -l nodes=2:ppn=36,walltime=8:00:00`
 - open shell for 8h, with access to 2 nodes, 36 cores each

ppn: number of
cores



Time of the job execution of the
cluster

Simple batch job

- Contents of file `myjob.pbs` (a PBS job script, actually bash):

```
#!/bin/bash -l  
echo Hello World
```


- To run job, enter


```
$ qsub myjob.pbs -A lp_hpcinfo_training  
50009076. tier2-p-moab-2.tier2.hpc.kuleuven.be
```

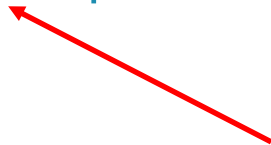
Result

```
$ ls  
myjob.pbs  
myjob.pbs.e520009076  
myjob.pbs.o520009076
```


Error and output files

- Error file `myjob.pbs.e50009076`
 - Contains any errors that occurred during execution
 - Useful to determine why your job failed
 - Always created, if no problems – file is empty
- `forrtl: error (78): process killed (SIGTERM)`
`Stack trace terminated abnormally.`

Programming problem
- `=>> PBS: job killed: walltime 432031 exceeded limit 432000`

Too short walltime
- `IOError: [Errno 122] Disk quota exceeded`

Not enough disk space

Error and output files

- Output file `myjob.pbs.o50009076`
 - Contains output to standard output
 - Info about requested resources and used resources

time: 900

nodes: 1

procs: 1

account string:

lp_hpcinfo_training

queue: q1h

Error and output files

- **Output file** `myjob.pbs.o50132389`

Allocated nodes:

r05i01n16

Job ID: 50132389. tier2-p-moab-2.tier2.hpc.kuleuven.be

User ID: vsc30468

Group ID: vsc30468

Job Name: cmeAMRnew.sh

Session ID: 52711

Resource List: neednodes=1:ppn=1,nodes=1:ppn=1,pmem=1gb,walltime=00:15:00

Resources Used: cput=00:00:36,mem=937748kb,vmem=1472672kb,walltime=00:00:37

Queue Name: q1h

Account String: lp_hpcinfo_training

time: 37

nodes: 1

procs: 1

account: lp_sys

Batch job with resource specifications

- From command line

```
$ qsub -l walltime=10:00:00 myjob.pbs
```

If not specified:
walltime=01:00:00

- In a PBS job script

```
#!/bin/bash -l
#PBS -l walltime=10:00:00
#PBS -l nodes=2:ppn=36
#PBS -l pmem=5200mb
#PBS -N myjob2
#PBS -A default_project
#PBS -o $PBS_JOBID.stdout
#PBS -e $PBS_JOBID.stderr
#PBS -m ae
#PBS -M my.name@kuleuven.be
```

If not specified:
nodes=1:ppn=1

If not specified:
pmem=5gb

If not specified: job will not start

- default_project = intro credits
- lp_my_project_ = project credits
- **lp_hpcinfo_training** = project credits for the course exercises

Capture standard
output and error
during at runtime

My first pbs script

```
#!/bin/bash -l
#PBS -l walltime=00:30:00
#PBS -l nodes=1:ppn=36
#PBS -N testjob
#PBS -A lp_hpcinfo_training
#PBS -m abe
#PBS -M my-name@kuleuven.be
```

```
module purge
module load matlab/R2018a
```

```
cd $VSC_SCRATCH
cd $PBS_O_WORKDIR
```

```
matlab -nojvm -nodisplay -r mat
exit 0
```

Clean the modules loaded by default in .bashrc
Load all the necessary modules (new shell is started for each job)

Go to the directory where your code and input files are located
\$PBS_O_WORKDIR= location from which the job was submitted

Execute the code

Do not add unnecessary statements – in case of problem real exit code is overwritten, finding source of problem may be impossible

Using GPU(s)

- On Genius, you can request a fraction of a node with 1, 2, 3 or 4 GPUs.
- Then, you will be granted a fraction of cores and memory, too.
- E.g.

```
$> qsub -l partition=gpu,nodes=1:ppn=9:gpus=1
```

1 GPU

```
$> qsub -l partition=gpu,nodes=1:ppn=18:gpus=2
```

2 GPUs

```
$> qsub -l partition=gpu,nodes=1:ppn=27:gpus=3
```

3 GPUs

```
$> qsub -l partition=gpu,nodes=1:ppn=36:gpus=4
```

Full Node

Remarks

- Different users may use the same node
- Note: `pmem=5gb` is still OK
- You will be debited for credits the same fraction of node costs as you use

```
#!/bin/bash -l
```

PBS Script

```
#PBS -l walltime=00:30:00
```

```
#PBS -l partition=gpu
```

```
#PBS -l nodes=1:ppn=18:gpus=2
```

```
#PBS -N testjob
```

```
#PBS -A lp_hpcinfo_training
```

```
#PBS -m abe
```

```
#PBS -M my-name@student.kuleuven.be
```

Large-Memory Jobs

You have two options:

1) Use (10) dedicated large-memory machines on Genius

```
$> qsub -l partition=bigmem,nodes=2:ppn=36,mem=760gb
```

2) Or use the Superdome machine

```
$> module load superdome
```

```
$> qsub -l partition=superdome \  
-q nodef -l pmem=50gb \  
-L tasks=1:lprocs=28:place=numanode
```

PBS Script

Remarks

- pmem is memory per process, i.e.
$$\text{pmem} = \text{mem} / \text{ppn}$$
- Set either mem OR pmem
- Always set 4 – 8 GB memory for the operating system

```
#!/bin/bash -l  
#PBS -l walltime=00:30:00  
#PBS -l partition=bigmem  
#PBS -l nodes=2:ppn=36  
#PBS -l mem=760gb  
#PBS -A lp_hpcinfo_training  
#PBS -m abe  
#PBS -M my-name@student.kuleuven.be
```

Debugging / Testing Jobs

- Sometimes, you need to test/debug your (parallel) application quickly
- ThinKing and Genius have each **2** dedicated nodes for debugging purposes
- Such jobs do **not** go to the normal queue, so they start faster
- Max. walltime is **30 minutes**
- You must specify Quality of Service (qos)

Request Debugging Nodes

```
$> qsub -l nodes=2:ppn=10 -l partition=gpu -l qos=debugging -l  
walltime=30:00 -A lp_hpcinfo_training
```


Managing & Monitoring Jobs

Command	Purpose
<code>\$> qsub ...</code>	Submit a job (batch/interactive)
<code>\$> qdel <JobID></code>	Delete a specific job
<code>\$> checkjob -v -v -v <JobID></code>	Very detailed job info (very useful to diagnose issues)
<code>\$> qstat -n</code>	Status of all recent jobs
<code>\$> qstat -Q -f</code>	Info about available queues
<code>\$> showstart <JobID></code>	Give a <i>rough</i> estimate of start time
<code>\$> showq</code> <code>\$> showq -p gpu</code>	Show minimal info about a queue or partition (<code>-p</code>)
<code>\$> pbsstop</code>	Overview of the cluster
<code>\$> mam-balance</code>	Overview of different credit projects that you can use (<code>qsub -A <Project></code>)
<code>\$> mam-list-allocations</code>	Detailed overview of your credit projects

How do I acknowledge the VSC in publications?

- Acknowledging the VSC in all relevant publications helps the VSC secure funding, and hence you will benefit from it in the long run as well. It is also a contractual obligation for the VSC.
- If you are in the KU Leuven association, you are also requested to add the relevant papers to the virtual collection "High Performance Computing" in Lirias – it helps to generate the publication lists with relevant publications.
- Please use the following phrase to do so in **Dutch** “*De rekeninfrastructuur en dienstverlening gebruikt in dit werk, werd voorzien door het VSC (Vlaams Supercomputer Centrum), gefinancierd door het FWO en de Vlaamse regering – departement EWI*”,
- or in **English**: “*The computational resources and services used in this work were provided by the VSC (Flemish Supercomputer Center), funded by the Research Foundation - Flanders (FWO) and the Flemish Government – department EWI*”.

Hands-on 2



- Copy /apps/leuven/training/HPC_intro to your \$VSC_DATA directory and go to this directory

```
cp -r /apps/leuven/training/HPC_intro $VSC_DATA;  
cd $VSC_DATA/HPC_intro
```
- Submit jobscript cpujob.pbs to the cluster

```
qsub cpujob.pbs
```
- Check the status of your job(s) (`qstat`)
- Analyze outputs (i.e. display the output file – commands `cat filename` or `more filename` or `less filename`)
- If you compute other types of jobs – try sas/matlab/mpi job

Questions

- Now
- Helpdesk:
hpcinfo@kuleuven.be or
https://admin.kuleuven.be/icts/HPInfo_form/HPC-info-formulier
- VSC web site:
<http://www.vscentrum.be/>
 - VSC documentation: <https://vlaams-supercomputing-centrum-vscdocumentation.readthedocs-hosted.com/en/latest/>
VSC agenda: training sessions, events
- Systems status page:
<http://status.kuleuven.be/hpc>

While we don't have...



Talk to us!!!

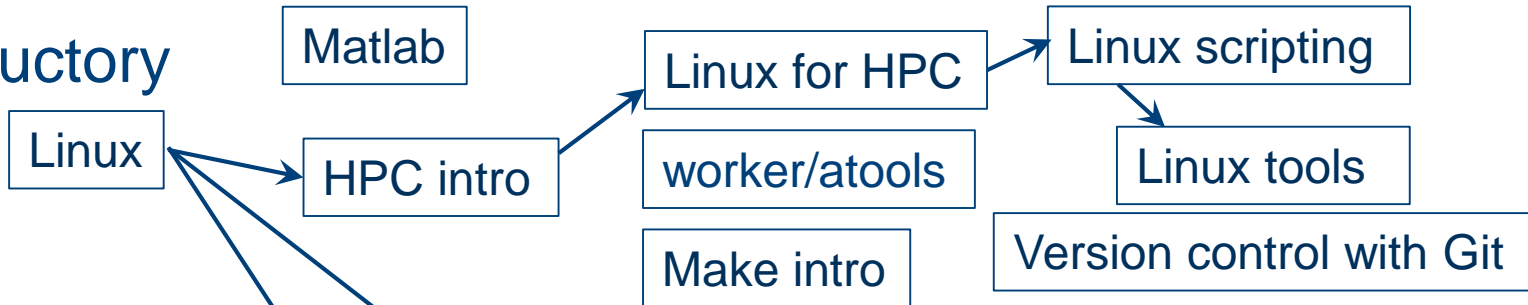
Do not send screenshots – we need to retype all the paths/commands

Please send the copied output and all the info:

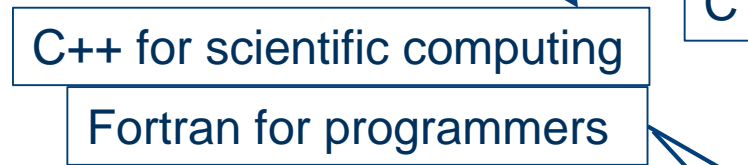
- vsc id
- job id
- submitted script
- error/output file of the job

VSC training 2019/2020

- Introductory

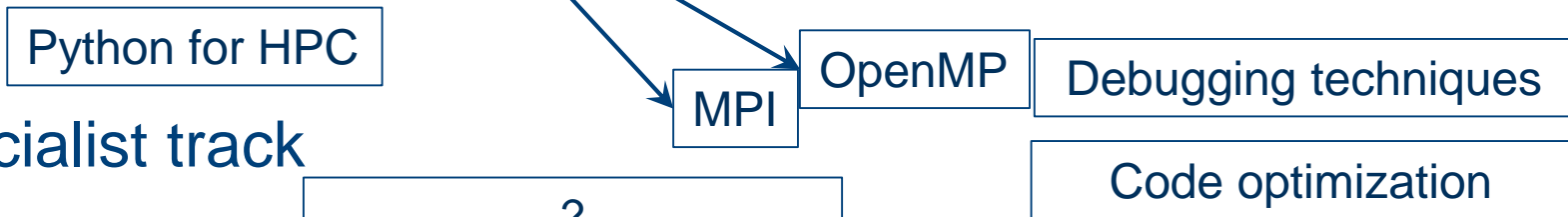


- Intermediate



- Python as a second language
- Python: System programming
- Scientific Python
- Software engineering
- Python for data science

- Advanced



- Specialist track



Info sessions:

- Containers
- Notebooks

Stay up-to-date <https://www.vscentrum.be/training>