Lecture 1: Introduction to Spark and HPC

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COM6012: Scalable ML

https://images.techhive.com/images/article/2016/08/thinkstockphotos-462205183-100677682-large.jpg

Week 1 Contents / Objectives

- The Big Data Problem: Why Spark?

- What is Spark?: The Essentials

- An Example of Spark: Log Mining

- How to Use Spark: PySpark, HPC, Resources

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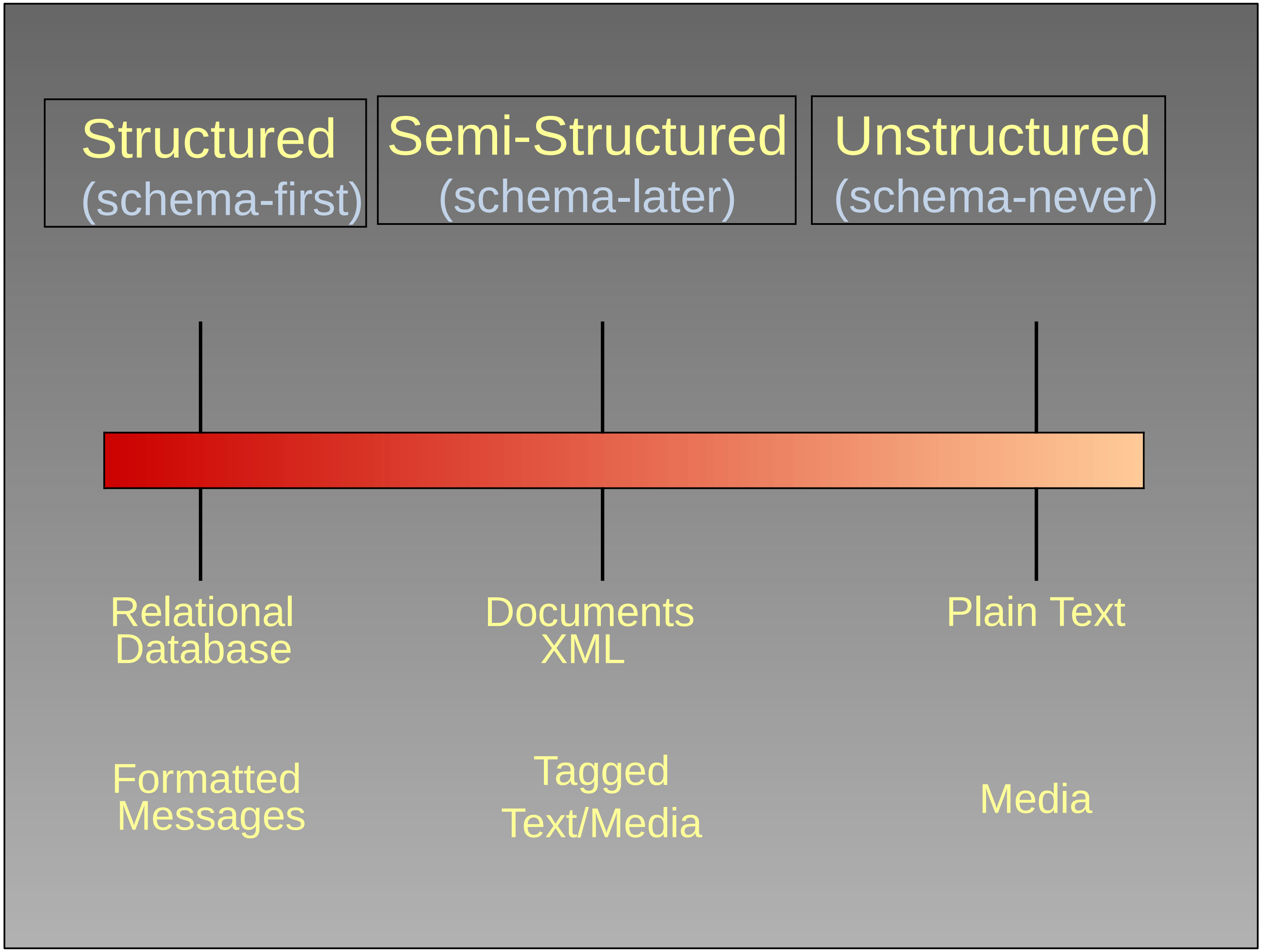
Where Does Big Data Come From?

- All happening online, e.g. tracking of:
  - Clicks
  - Billing events
  - Server requests
  - Transactions
  - Network messages
  - Faults
  - …

Where Does Big Data Come From?

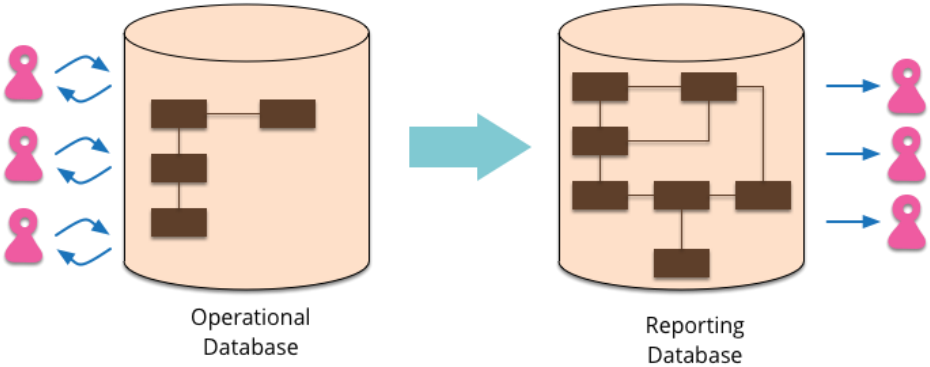
- User generated content: web + mobile

Data Structure Spectrum



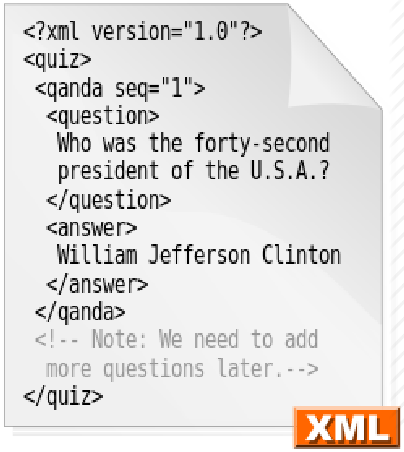
Structured Data

- Database: relational data model → how a database is structured and used
- Schema: the organisation of data as a blueprint of how the database is constructed
  - The programmer must statically specify the schema
  - Decreasing ← consumer/media app, enterprise search
- SQL: Structured Query Language

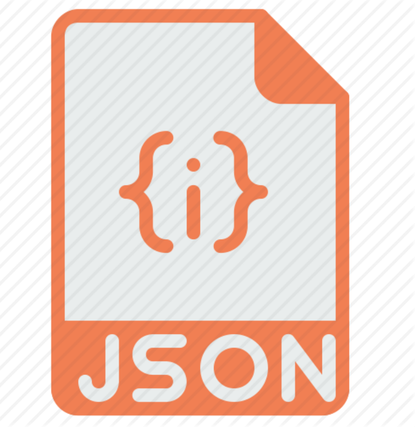


Semi-Structured Data

- Self-describing rather than formal structures, tags/markers to separate semantic elements
- The column types → the schema for the data
  - Spark dynamically infers the schema while reading each row
  - Programmer statically specifies the schema
- Examples:

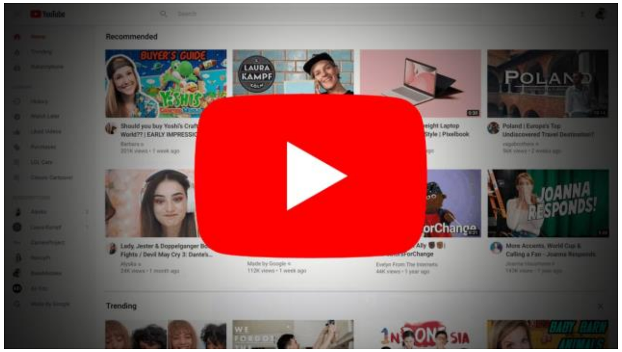


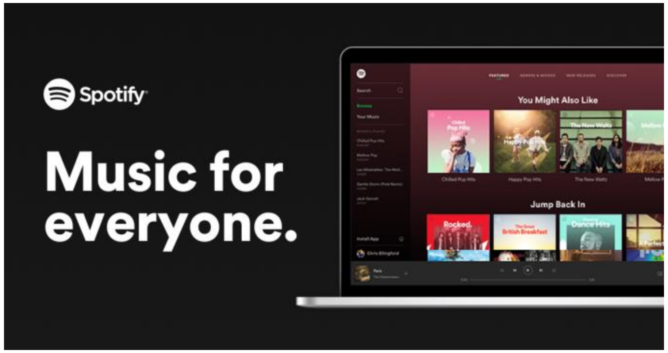
```
<?xml version="1.0"?>
<quiz>
 <qanda seq="1">
  <question>
   Who was the forty-second
   president of the U.S.A.?
  </question>
  <answer>
   William Jefferson Clinton
  </answer>
 </qanda>
 <!-- Note: We need to add
  more questions later.-->
</quiz>
```



Unstructured Data

- Only one column with string or binary type
- Examples

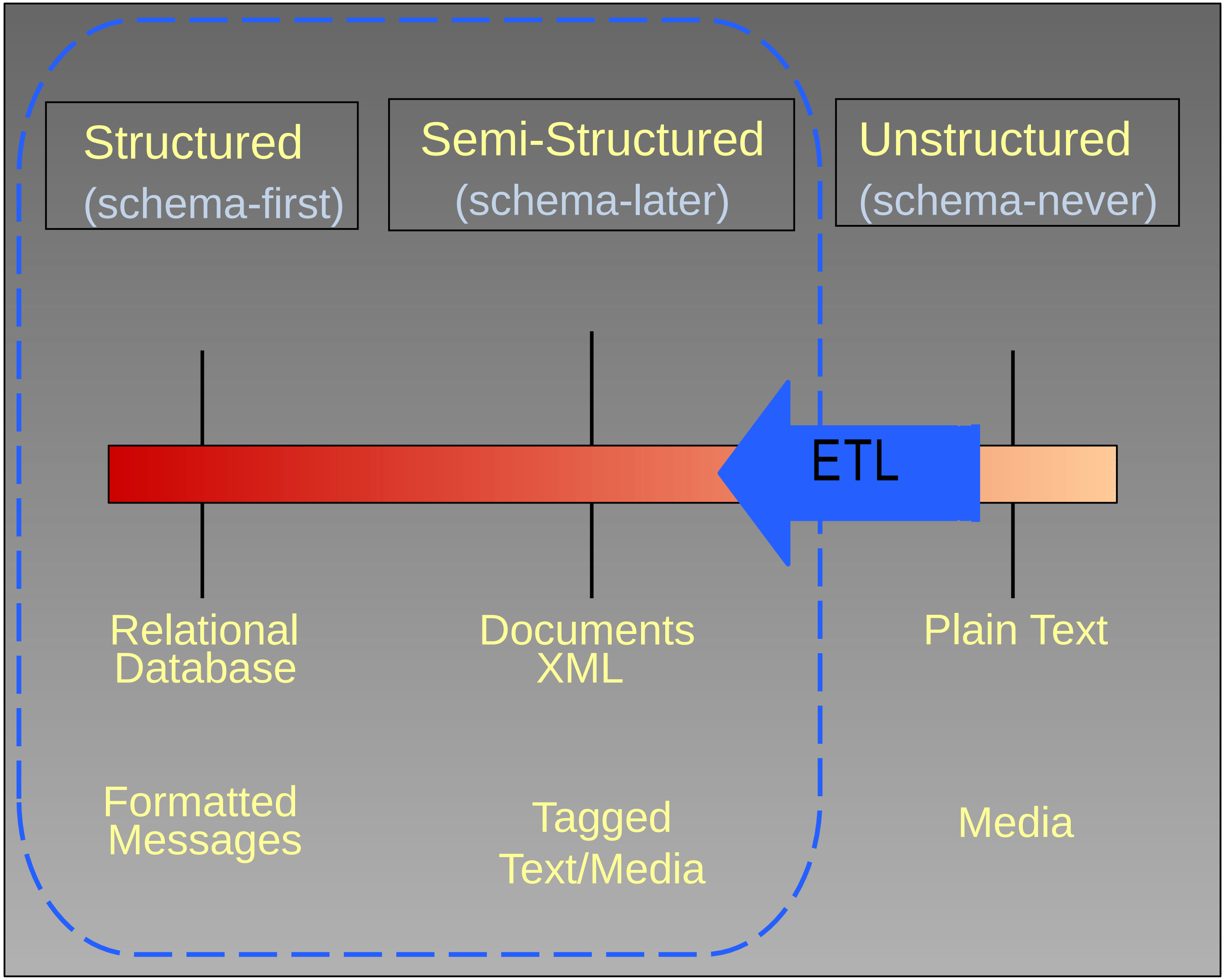




Search
My user name
Lorem ipsum dolor sit amet, consectetuer adipiscing elit.
Lorem ipsum and 291 others
55 comments
Like
Comment
Share

- Note: File formats ≠ data structure

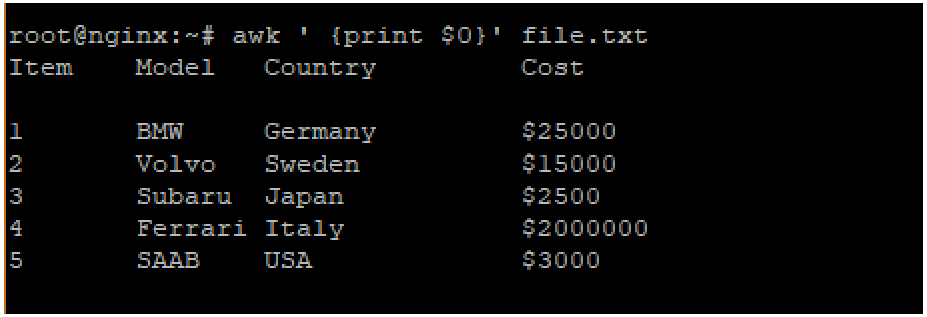
Traverse the Data Structure Spectrum



- Impose structure on unstructured data
  - Extract
  - Transform
  - Load

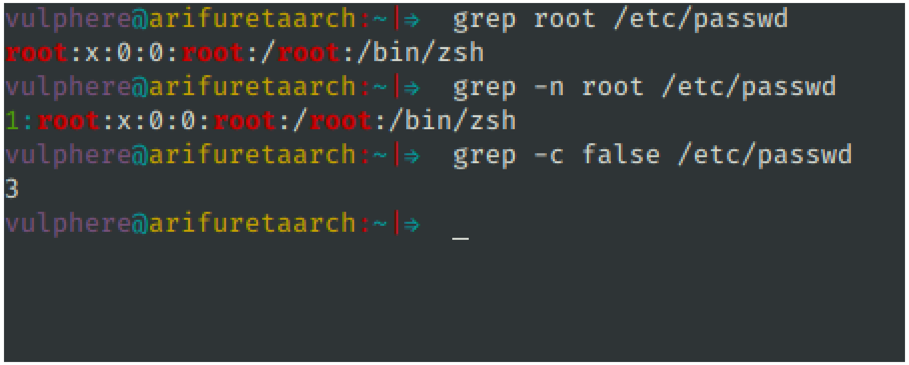
Traditional Analysis Tools

- Unix shell commands (awk, grep, ...)



```
root@nginx:~# awk ' {print $0}' file.txt
Item    Model   Country         Cost

1       BMW     Germany         $25000
2       Volvo   Sweden          $15000
3       Subaru  Japan           $2500
4       Ferrari Italy           $2000000
5       SAAB    USA             $3000
```

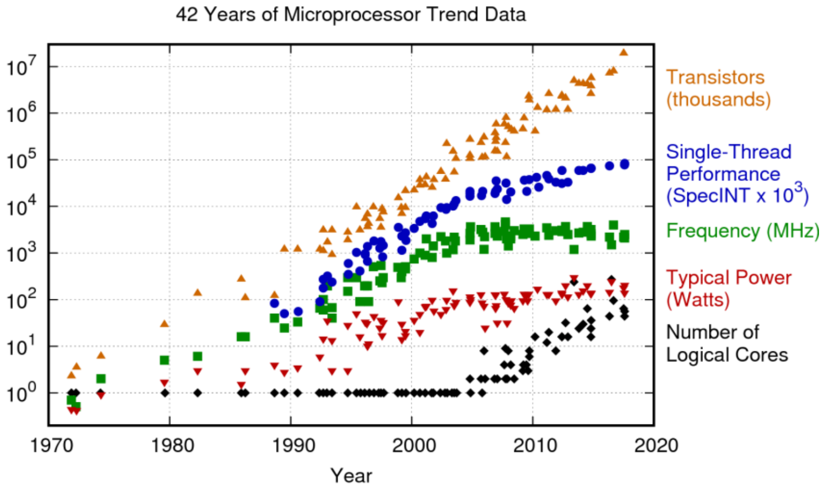


```
vulphere@arifuretaarch:~|⇒  grep root /etc/passwd
root:x:0:0:root:/root:/bin/zsh
vulphere@arifuretaarch:~|⇒  grep -n root /etc/passwd
1:root:x:0:0:root:/root:/bin/zsh
vulphere@arifuretaarch:~|⇒  grep -c false /etc/passwd
3
vulphere@arifuretaarch:~|⇒  _
```

All run on a single machine!

The Big Data Problem

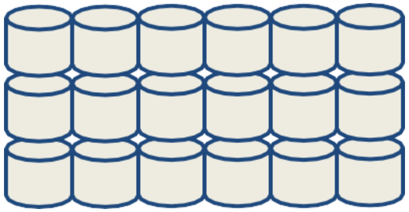
- Data growing faster than computation speeds
- Growing data sources
  - Web, mobile, scientific, …
- Storage getting cheaper
- But, stalling CPU speeds and storage bottlenecks



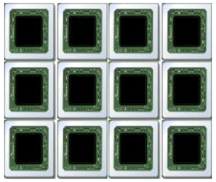
Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten
New plot and data collected for 2010-2017 by K. Rupp

Solution for the Big Data Problem

- One machine cannot process or *even store* all the data!
- Solution: distribute data over a cluster of machines



Lots of hard drives



… and CPUs

… and memory!

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Apache Spark

- Fast and general cluster computing system
- Interoperable with hadoop Map Reduce
- Improves efficiency through:
  - In-memory computing primitives
  - General computation graphs

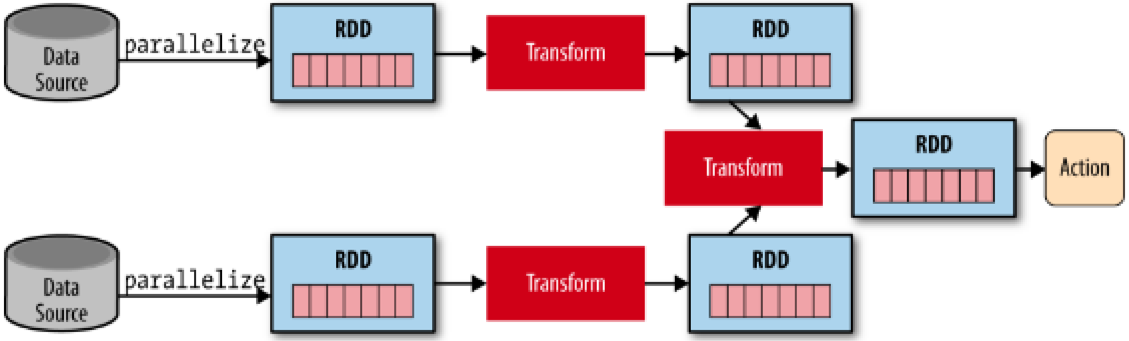
→ Up to 100× faster (2-10× on disk)

- Improves usability through:
  - Rich APIs in Scala, Java, Python
  - Interactive shell

→ 2-5× less code

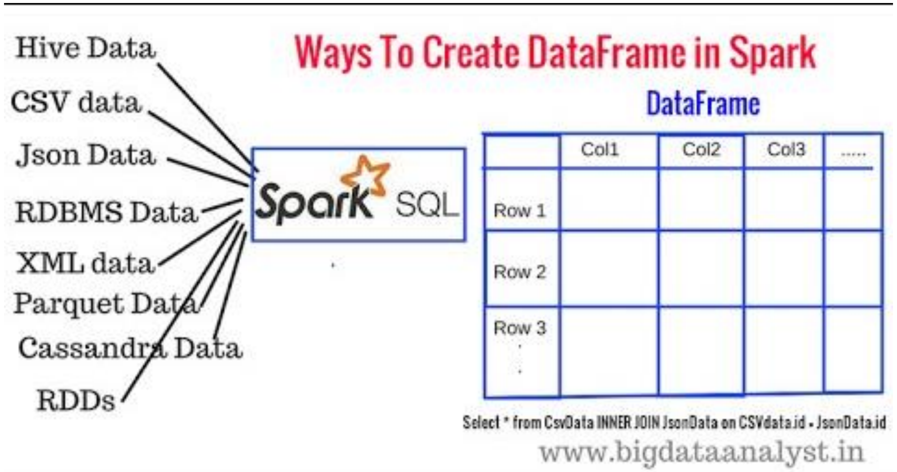
Spark Model

- Write programs in terms of transformations on distributed datasets
- Resilient Distributed Datasets (RDDs)
  - Collections of objects that can be stored in memory or disk across a cluster
  - Parallel functional transformations (map, filter, ...)
  - Automatically rebuilt on failure



Spark for Data Science

- DataFrames
  - Structured data (SQL)
  - Familiar API based on R/Python Pandas
  - Distributed, optimised implementation
- Machine learning pipelines
  - Simple construction and tuning of ML workflows



Ways To Create DataFrame in Spark

DataFrame

	Col1	Col2	Col3	.....
Row 1				
Row 2				
Row 3 . .				

```
Select * from CsvData INNER JOIN JsonData on CSVdata.id = JsonData.id
```

www.bigdataanalyst.in

Spark Computing Framework

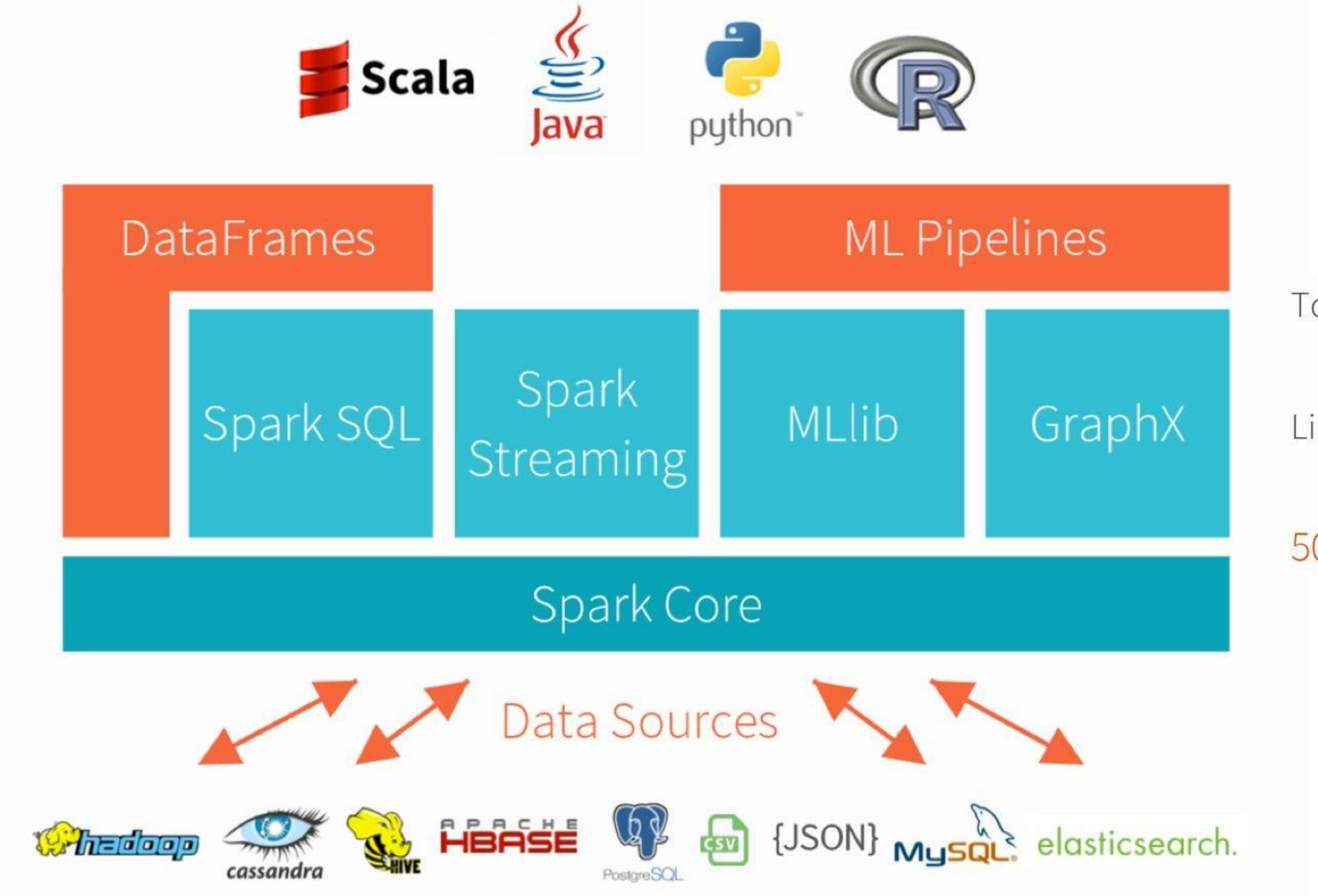
- Programming abstraction and parallel runtime to hide complexities of fault-tolerance and slow machines

"Here's an operation, run it on all of the data"

JUST DO IT.

- I don't care where it runs (you schedule that)
- In fact, feel free to run it twice on different nodes (e.g. when it fails)

Apache Spark Ecosystem



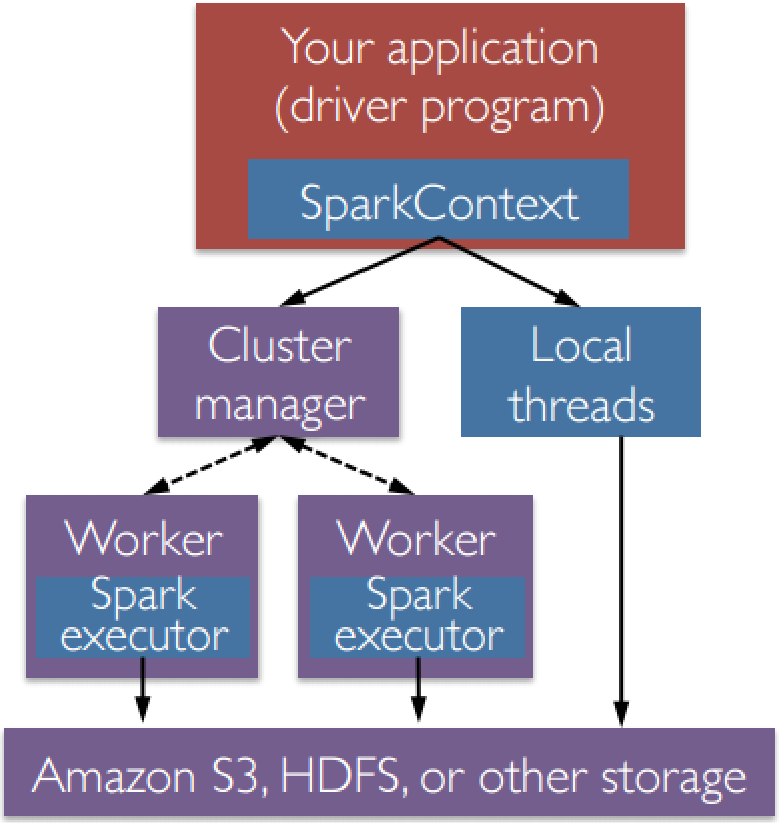
Total contributors: 150 → 500

Lines of code: 190K → 370K

500+ active production deployments

https://i.pinimg.com/originals/e7/f3/2d/e7f32d041846a5938a09e192bdf3885d.jpg

Spark Components



- A Spark program first creates a SparkSession object as the driver (including SparkContext)
  - Tells Spark how/where to access a cluster
  - Connect to cluster managers
- Cluster managers
  - Allocate resources across applications
- Spark executor (worker):
  - Run computations
  - Access data storage

SparkSession and SparkContext

- SparkSession
    - Entry point for DataFrame API, create DataFrames
    - PySpark shell automatically create SparkSession as spark
    - Programs: must create a new SparkSession first (see lab)
- SparkContext
    - Entry point for Spark functionality, create RDDs
    - Connect to a Spark cluster
    - Associated with a SparkSession
    - PySpark shell automatically create SparkContext as sc
    - Programs: sc = spark.sparkContext

The *'Master'* Parameter for a SparkSession

- Determines cluster type and size

Master Parameter	Description
`local`	run Spark locally with one worker thread (no parallelism)
`local[K]`	run Spark locally with K worker threads (ideally set to number of cores)
`spark://HOST:PORT`	connect to a Spark standalone cluster; PORT depends on config (7077 by default)
`mesos://HOST:PORT`	connect to a Mesos cluster; PORT depends on config (5050 by default)

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Spark Example: Log Mining (w/t RDD)

Load error messages from a log into memory, then interactively search for various patterns

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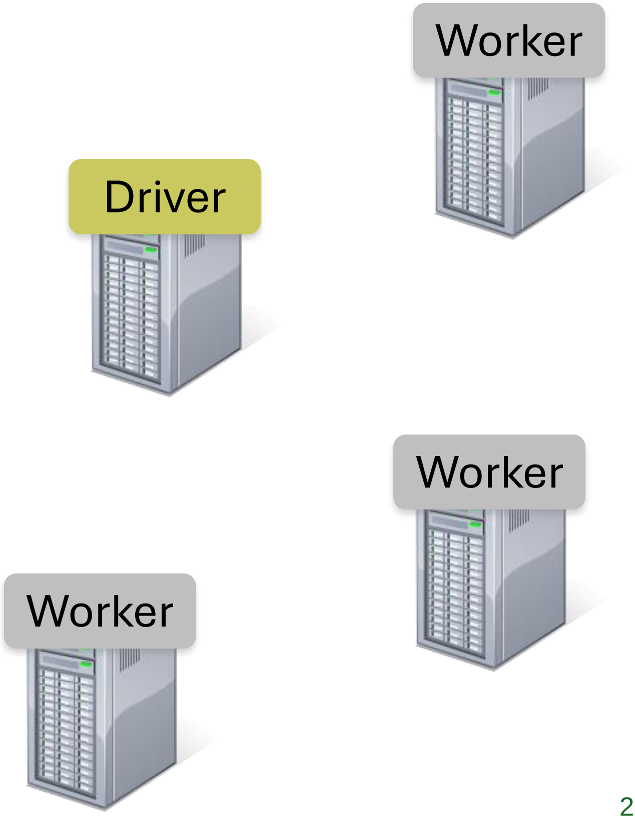
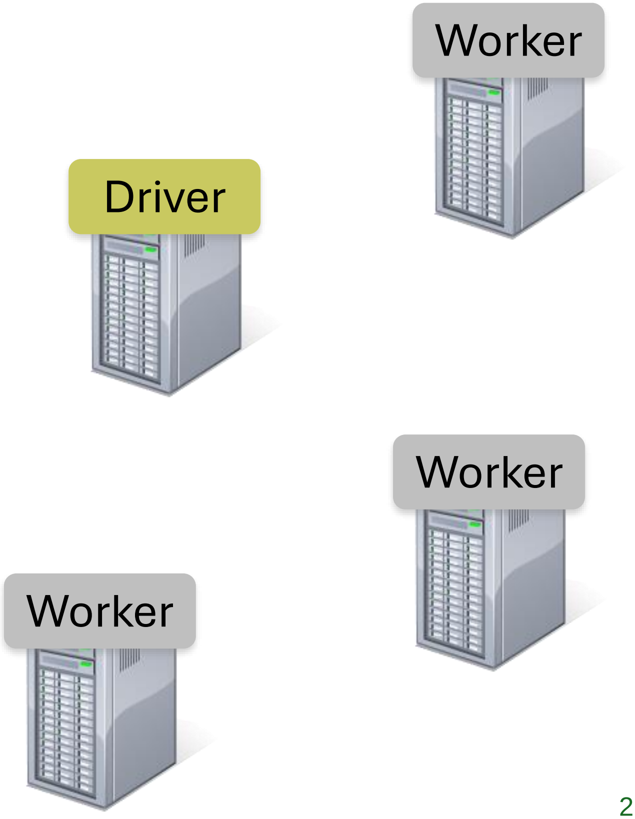


Spark Example: Log Mining

Load error messages from a log into memory, then interactively search for various patterns

```
lines = spark.textFile(“hdfs://...”)
```



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Base RDD

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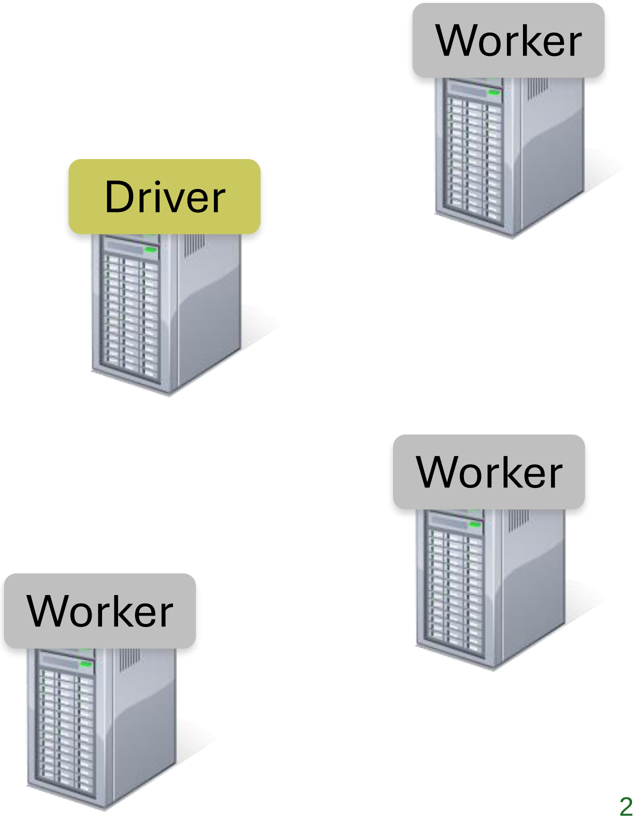

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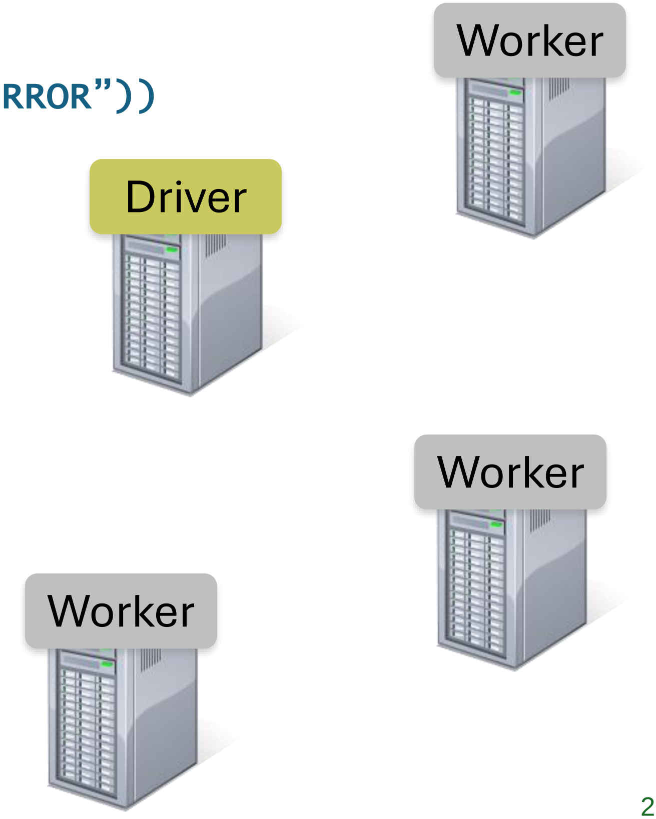

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Transformed RDD

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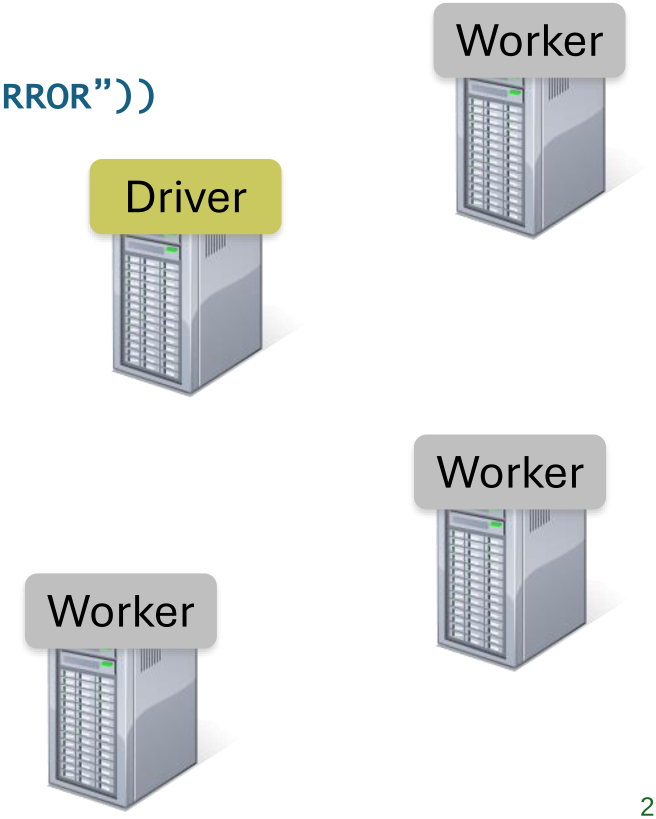

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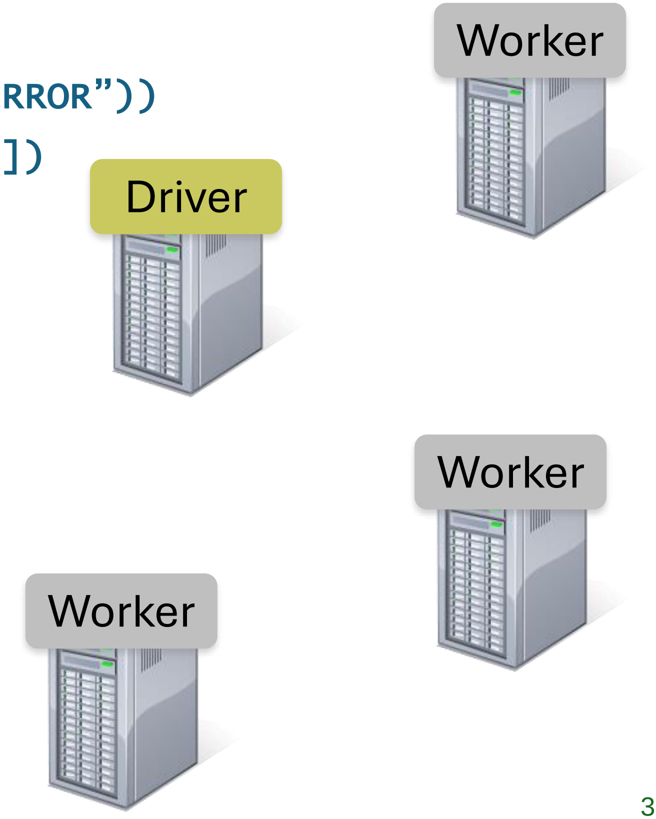
messages.cache()


messages.filter(lambda s: "mysql" in s).count()
```



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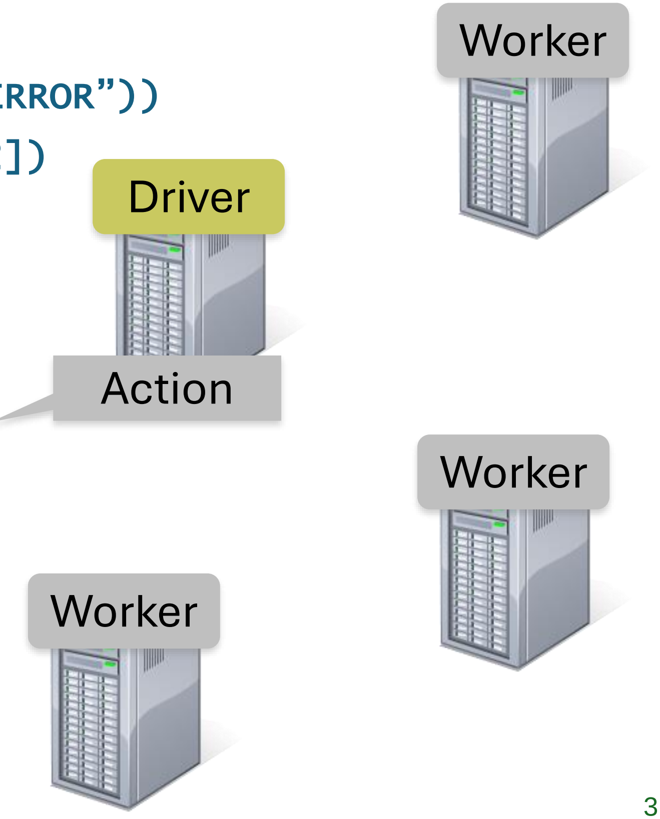

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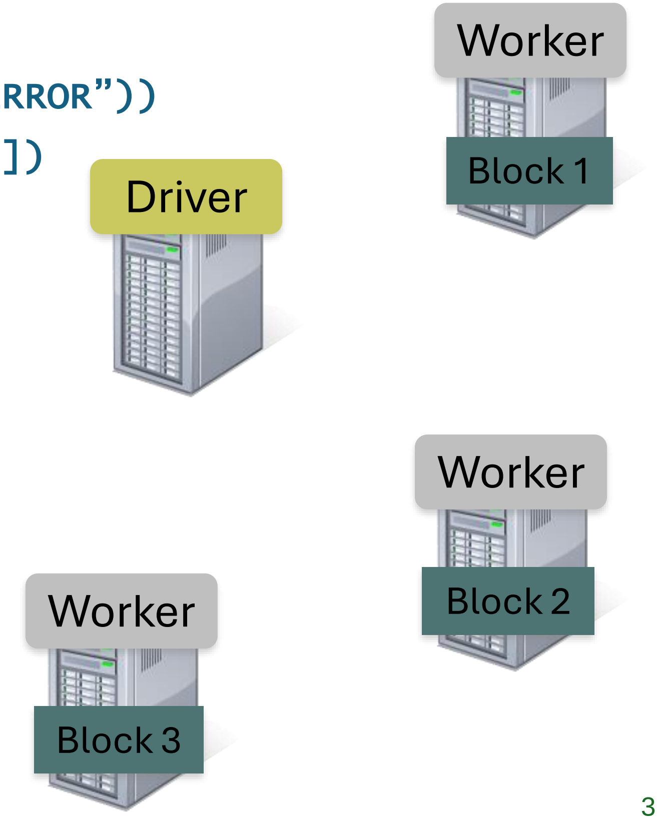

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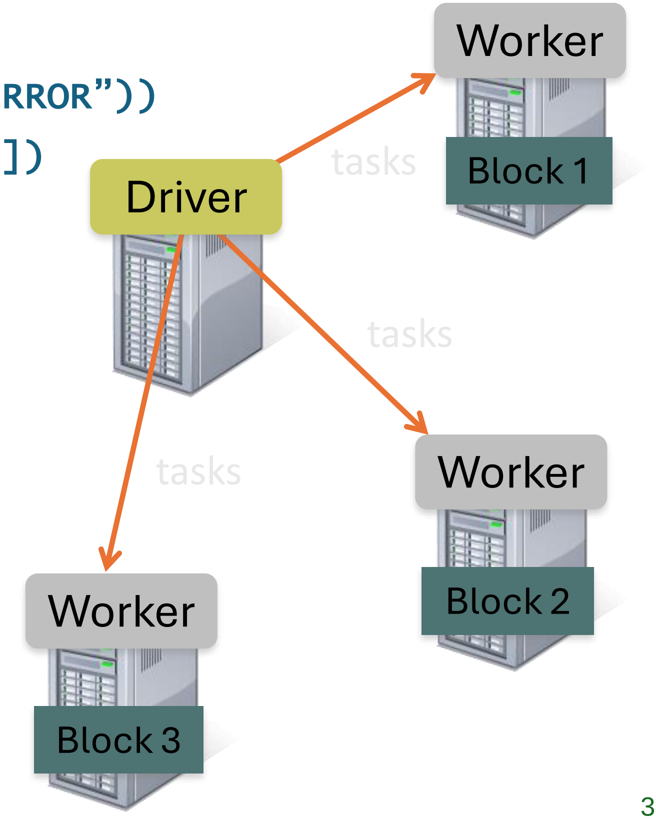

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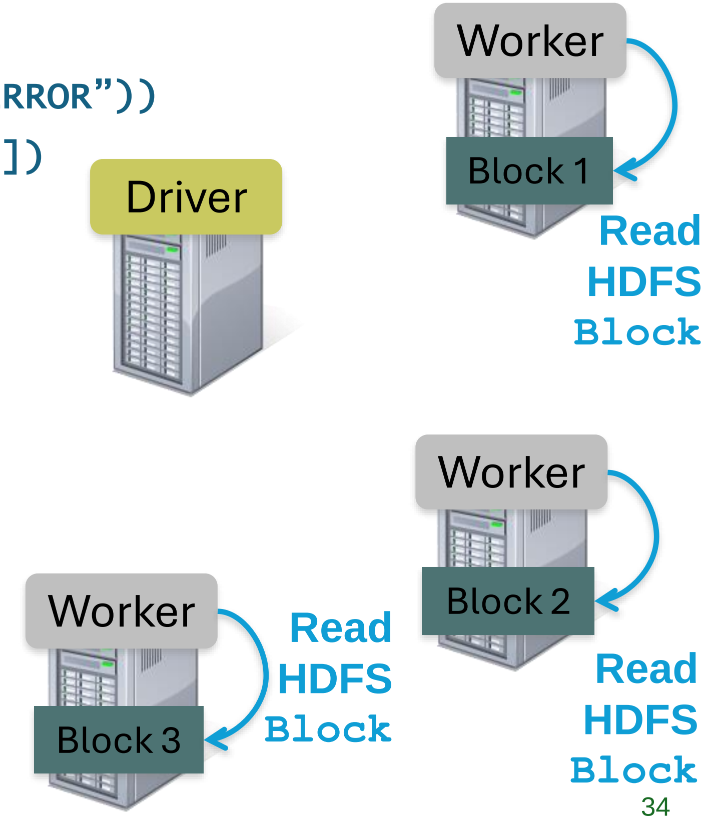

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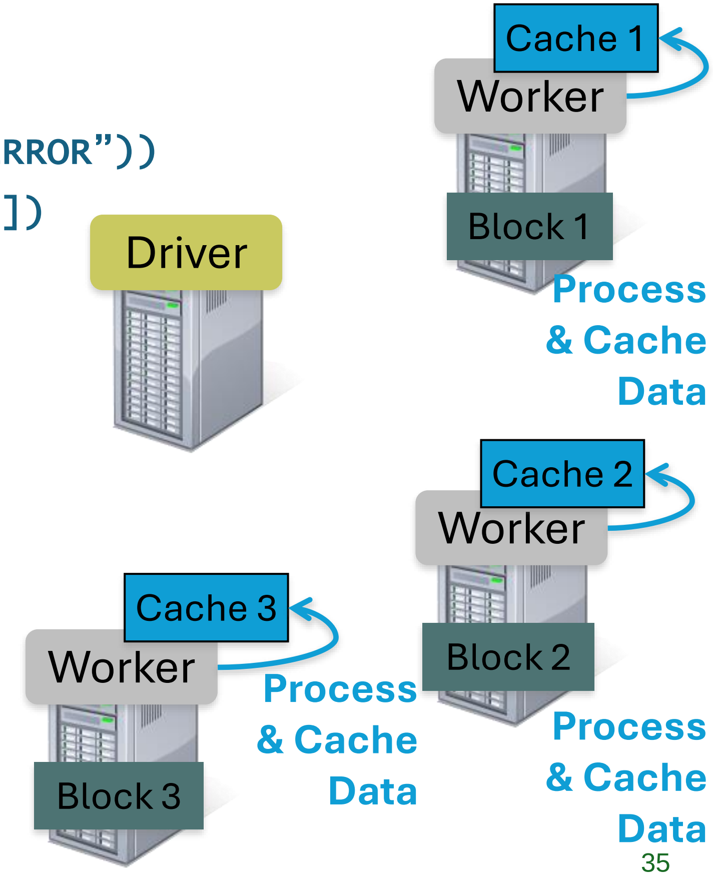

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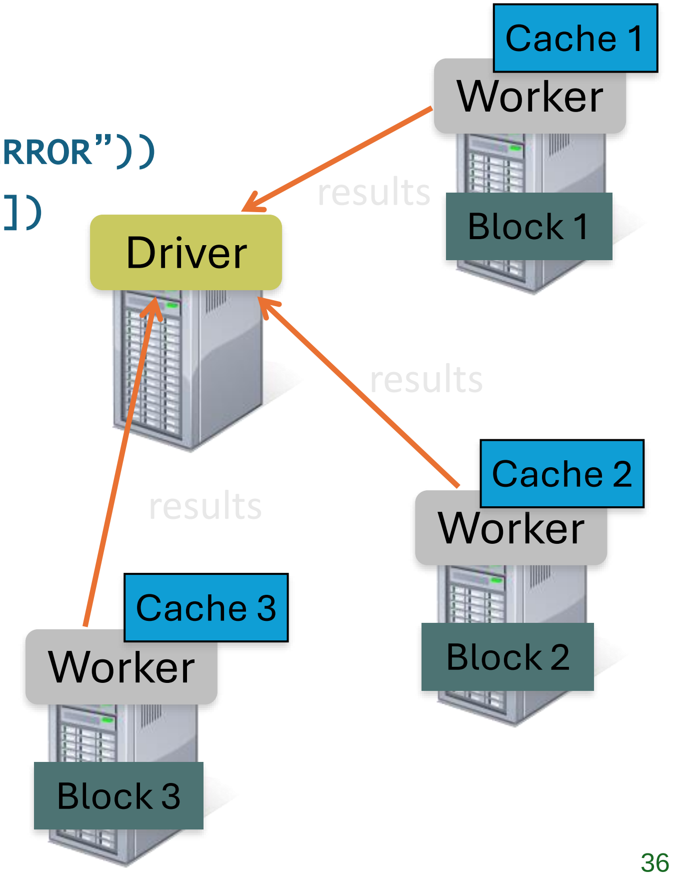

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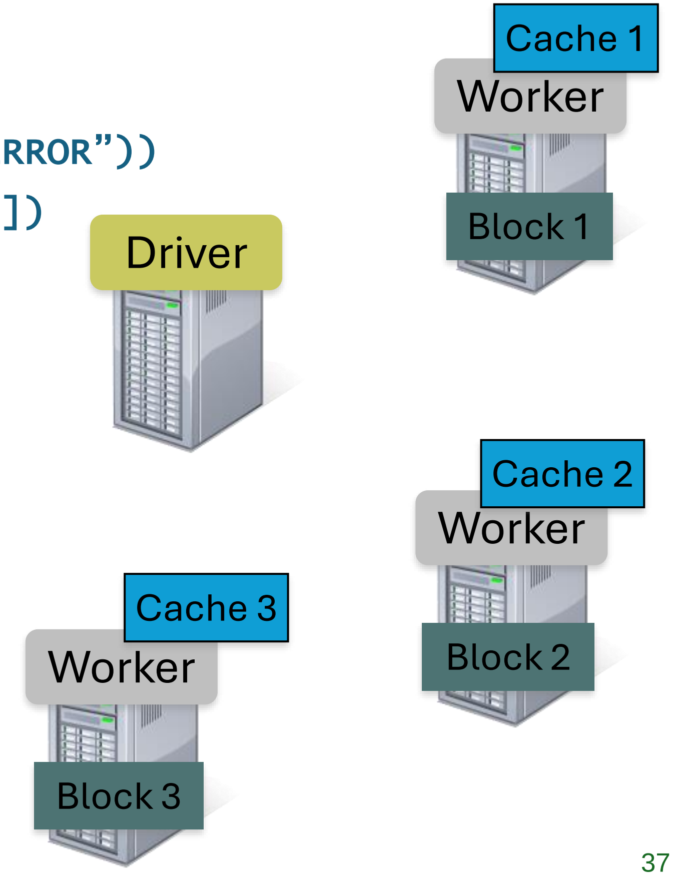

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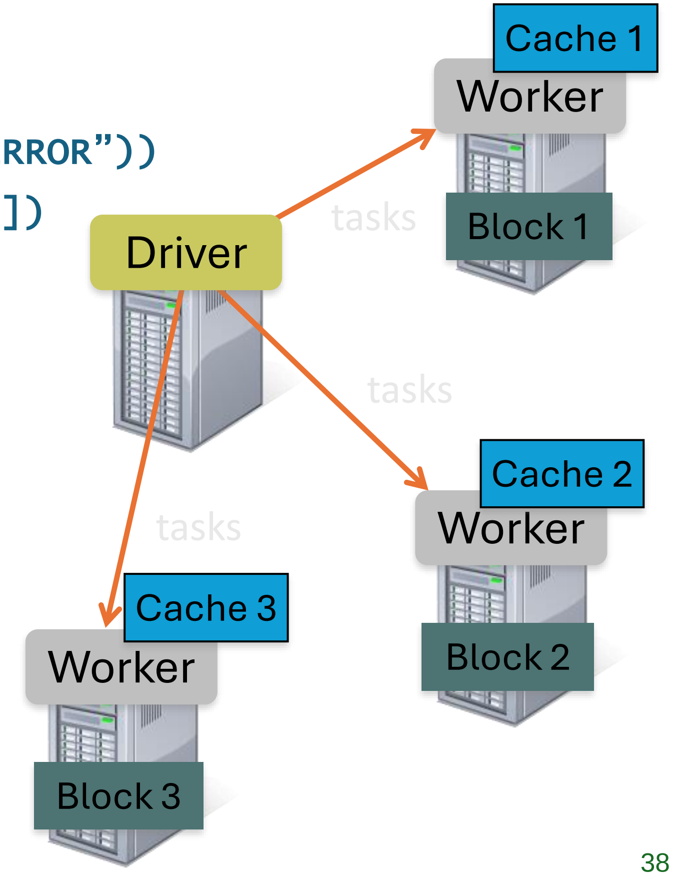

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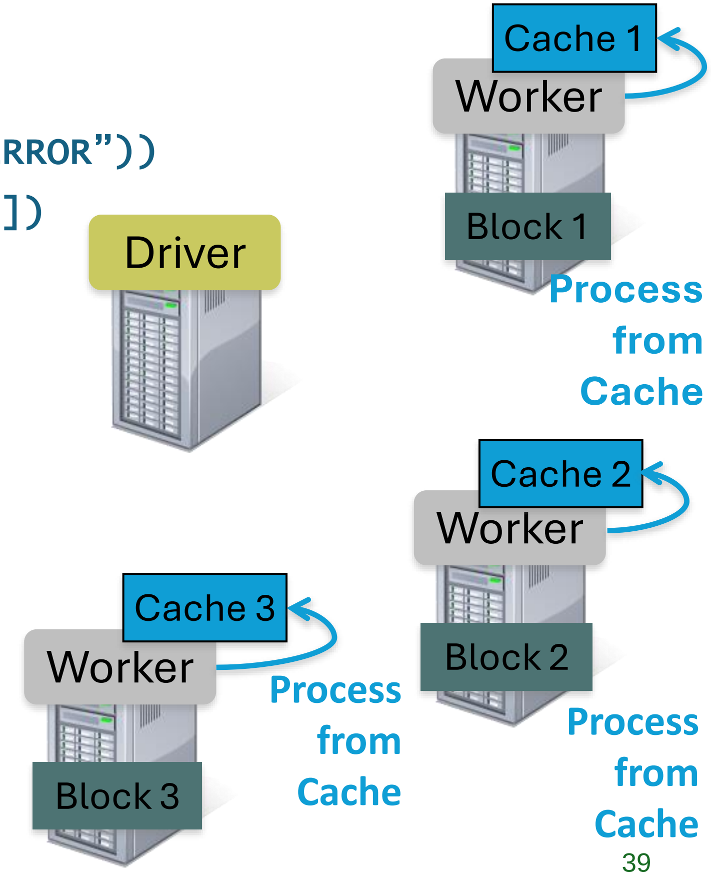

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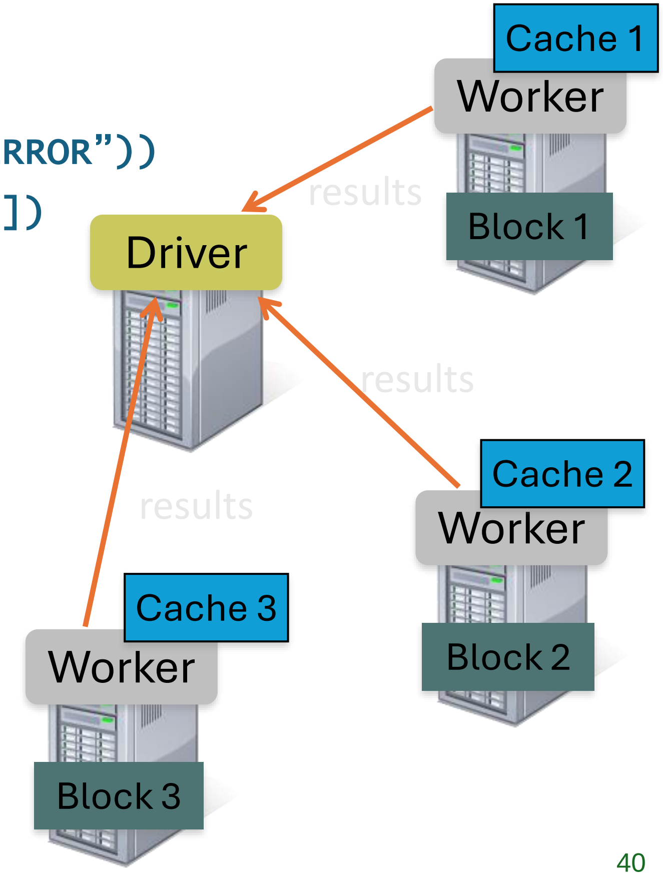

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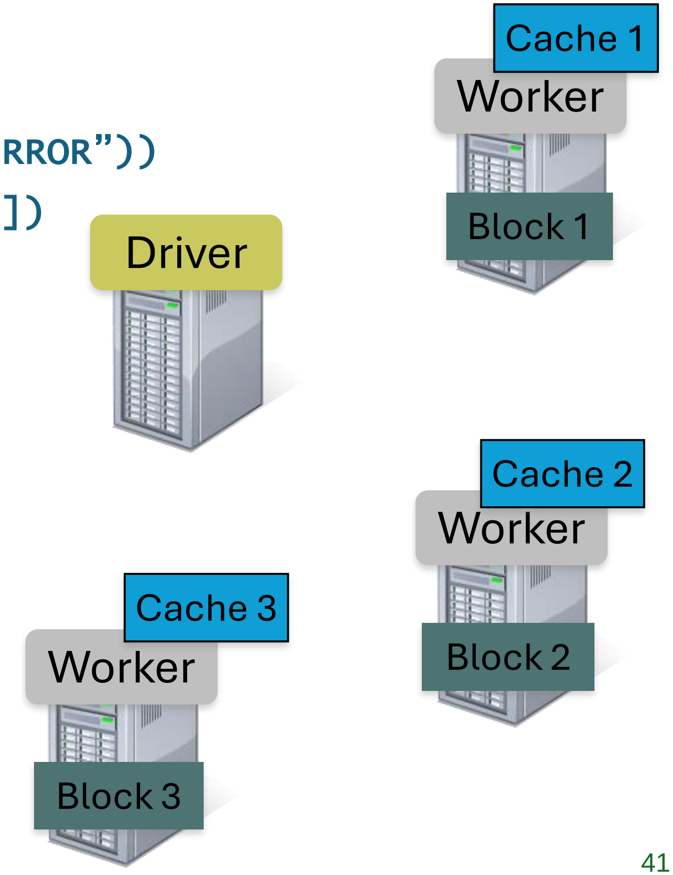

Cache your data ➔ Faster results

Full-text search of Wikipedia

- 60GB on 20 EC2 machines
- 0.5 sec from mem vs. 20s for on-disk

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Spark Program Lifecycle

- Create DataFrames from external data or createDataFrame from a collection in a driver program
- Lazily transform them into new DataFrames
- cache( ) some DataFrames for reuse
- Perform actions to execute parallel computation and produce results

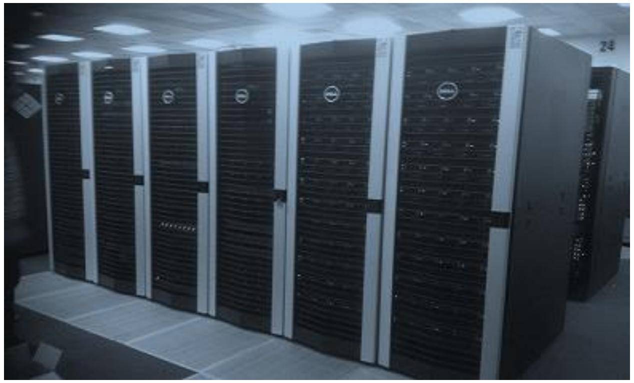
Use Spark Transformations and Actions wherever possible: Search DataFrame reference API

PySpark 3.5.0

- Need: Java, Python, Spark
- See lab 1 on how to install on HPC
- To install on Windows (optional)
  - Lab 1 instructions: Install Java JRE, Python, Spark
  - Or pip install pyspark==3.5.0
- To install on Linux/Mac (optional): see lab references

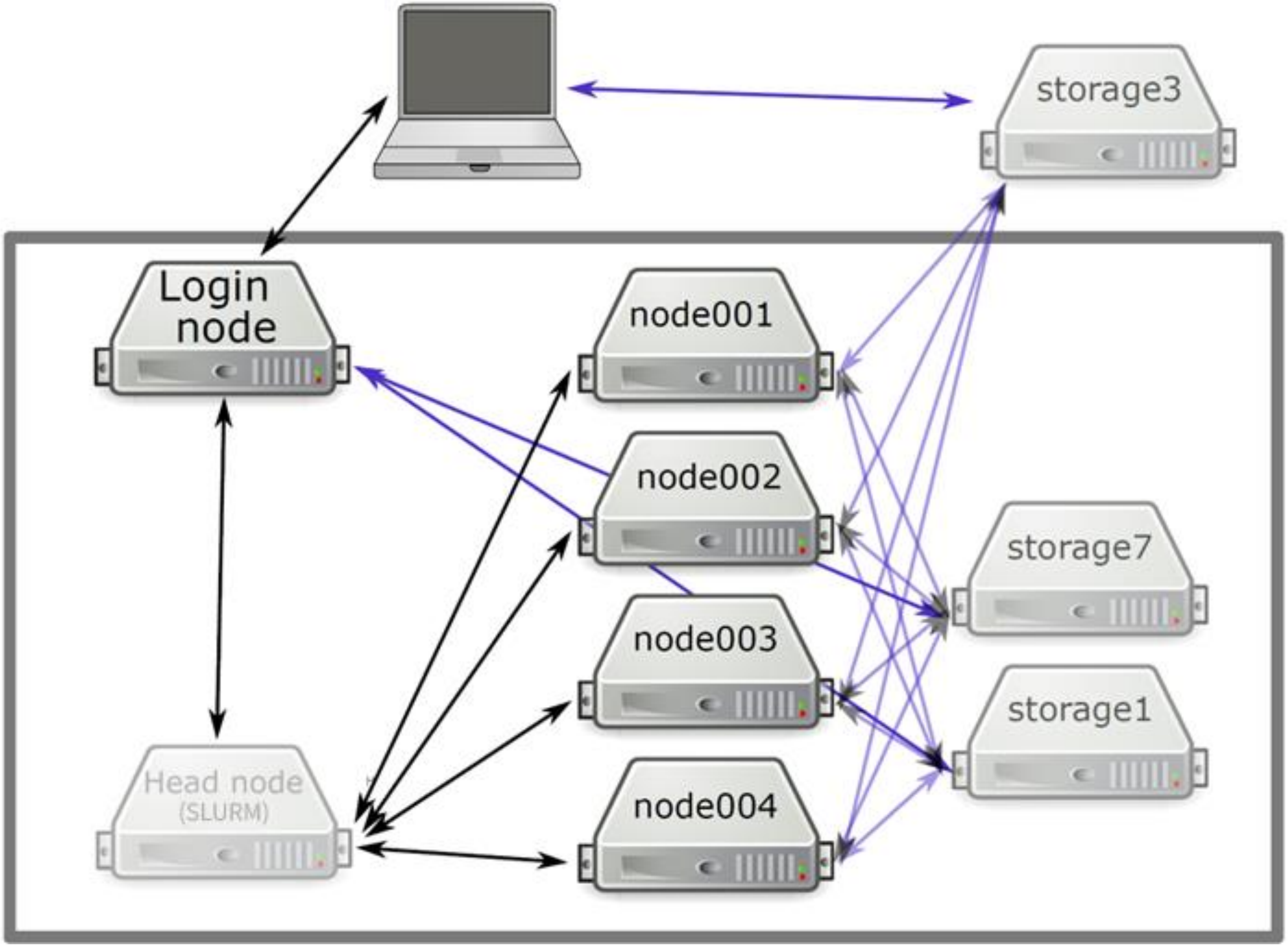
University of Sheffield’s HPC

STANAGE



- VPN: a **MUST** for the first time
- Account created for you already!
- Training (due 9th Feb Friday-AS0): HPC Driving License test
- SSH access via stanage.sheffield.ac.uk
  - Windows: MobaXTerm
  - Linux/MAC OS: terminal (command line)

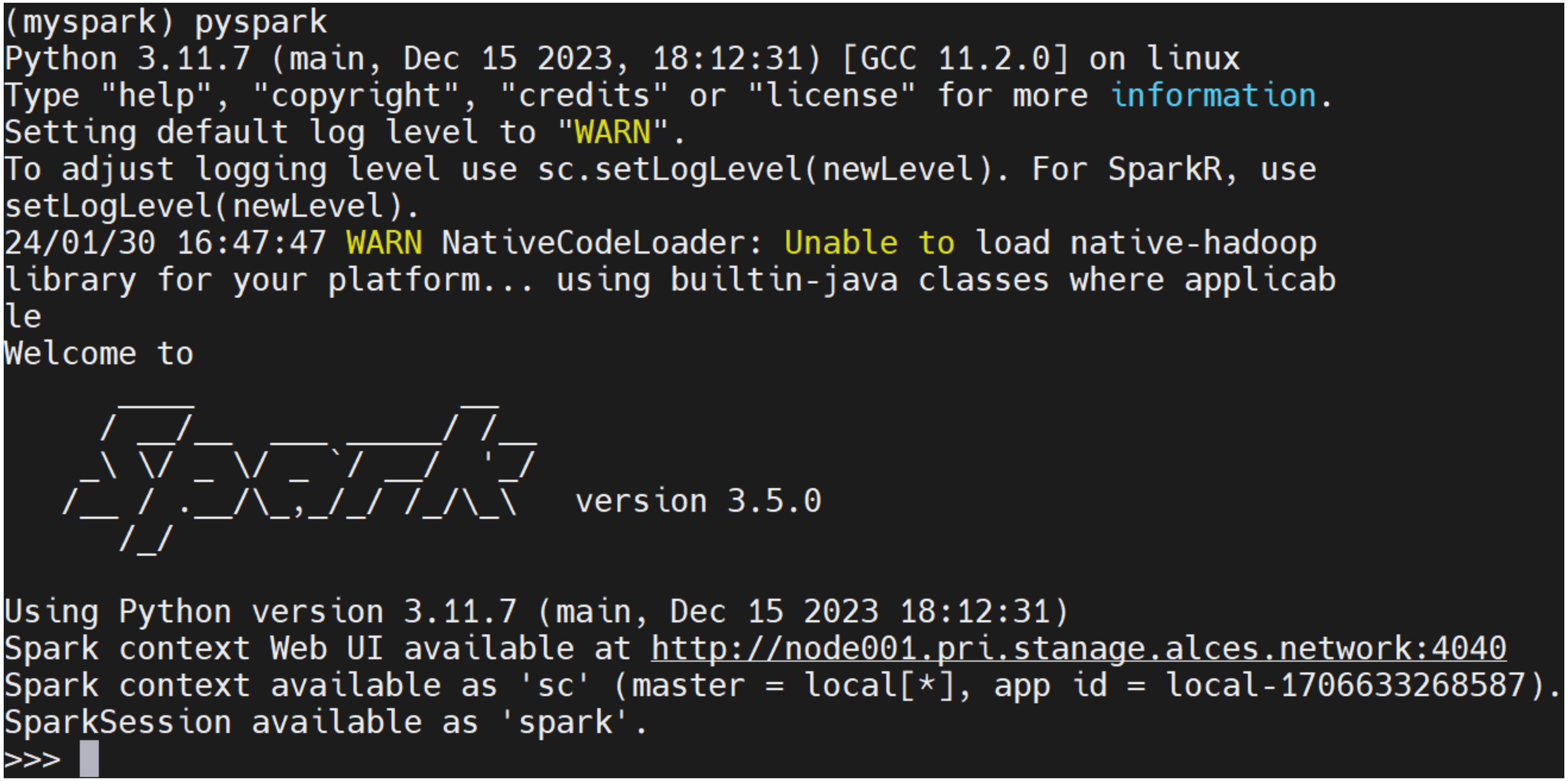
HPC Cluster Structure



Storage

Location	Quota	Speed	Suitable for?
/users/$USER	50GB	>	Personal data
/mnt/parscratch/	-	>>>	Temporary large files
/tmp	-	>>>	Temporary lots of small files

Interactive Session

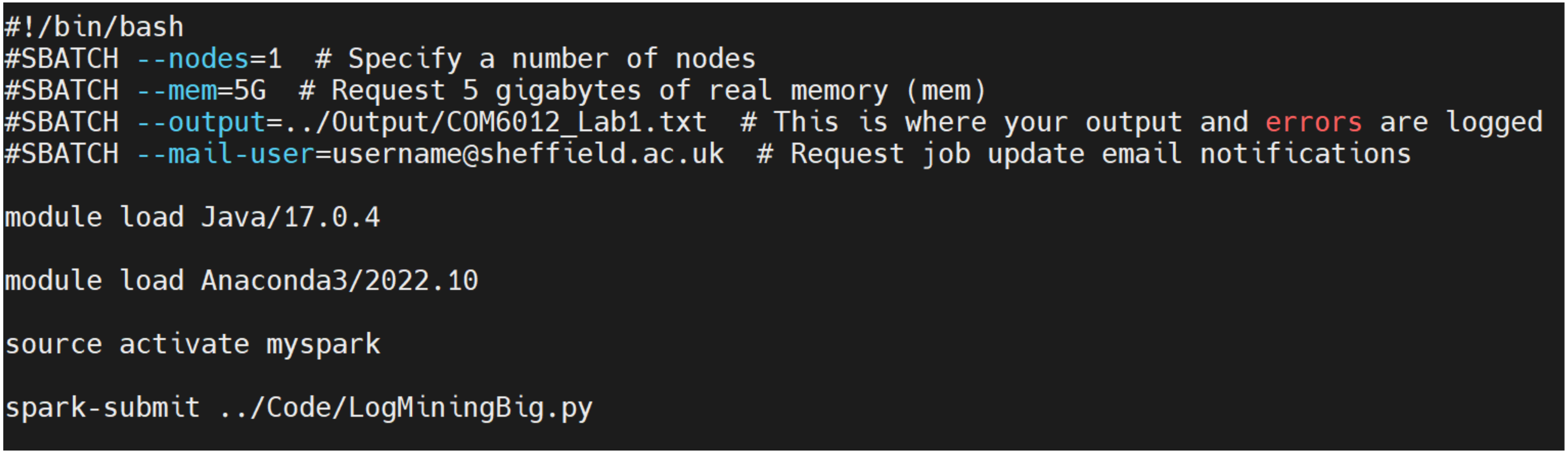


```
(myspark) pyspark
Python 3.11.7 (main, Dec 15 2023, 18:12:31) [GCC 11.2.0] on linux
Type "help", "copyright", "credits" or "license" for more information.
Setting default log level to "WARN".
To adjust logging level use sc.setLogLevel(newLevel). For SparkR, use
setLogLevel(newLevel).
24/01/30 16:47:47 WARN NativeCodeLoader: Unable to load native-hadoop
library for your platform... using builtin-java classes where applicab
le
Welcome to
      ____              __
     / __/__  ___ _____/ /__
    _\ \/ _ \/ _ `/ __/  '_/
   /__ / .__/\_,_/_/ /_/\_\   version 3.5.0
      /_/

Using Python version 3.11.7 (main, Dec 15 2023 18:12:31)
Spark context Web UI available at http://node001.pri.stanage.alces.network:4040
Spark context available as 'sc' (master = local[*], app id = local-1706633268587).
SparkSession available as 'spark'.
>>>
```

Batch Session – Shell Script xx.sh

Create a file `Lab1_SubmitBatch.sh`



```
#!/bin/bash
#SBATCH --nodes=1  # Specify a number of nodes
#SBATCH --mem=5G  # Request 5 gigabytes of real memory (mem)
#SBATCH --output=../Output/COM6012_Lab1.txt  # This is where your output and errors are logged
#SBATCH --mail-user=username@sheffield.ac.uk  # Request job update email notifications

module load Java/17.0.4

module load Anaconda3/2022.10

source activate myspark

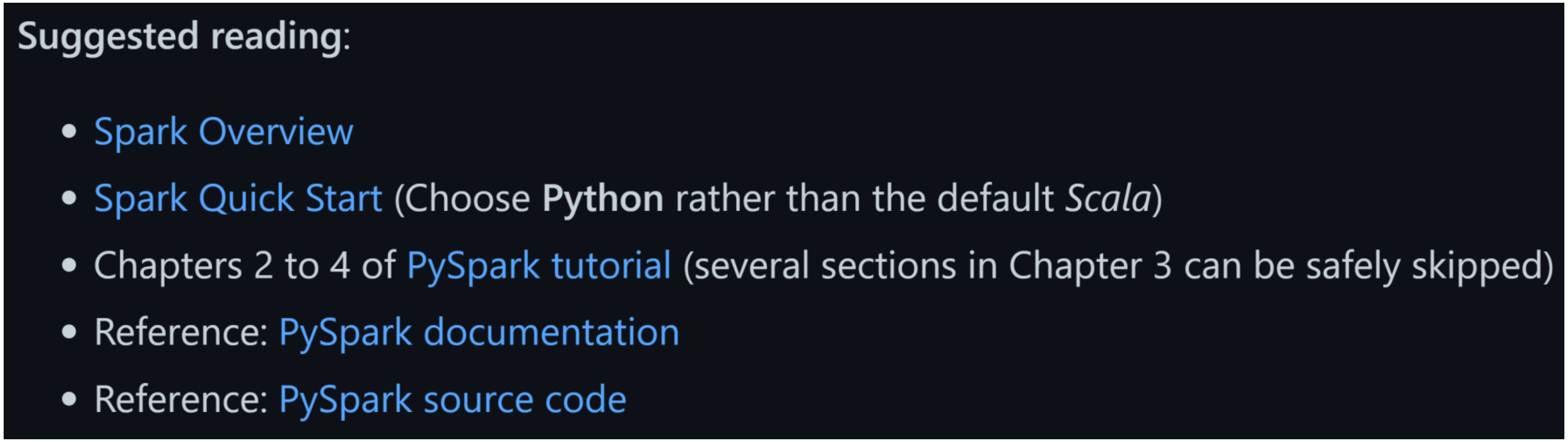
spark-submit ../Code/LogMiningBig.py
```

Batch Session: Submit & Relax

- sbatch your job (can run at the login node): see Lab 1
- Then?
  - Close the terminal and leave
  - Wait for pre-set email notification
  - Check status: squeue
  - Cancel job: scancel
- How much resources to request
  1. Run short test jobs
  2. View resource utilisation
  3. Extrapolate
  4. Submit larger jobs

Spark Resources

- Apache Spark Documentation
- PySpark tutorial
- Spark videos on YouTube
- Open source code
- Suggested reading in labs



Suggested reading:

- Spark Overview
- Spark Quick Start (Choose **Python** rather than the default *Scala*)
- Chapters 2 to 4 of PySpark tutorial (several sections in Chapter 3 can be safely skipped)
- Reference: PySpark documentation
- Reference: PySpark source code

Acknowledgements

- Some slides (sec. 1) are modified from the "Introduction to Apache Spark" course by Prof. A. D. Joseph, University of California, Berkeley.
- This module benefits from many open resources. See the acknowledgement on our GitHub page.
- There are many other resources that I have consulted but may somehow lost track of the origins.

Thank-you-word-cloud.jpg (967×522) (wikimedia.org)