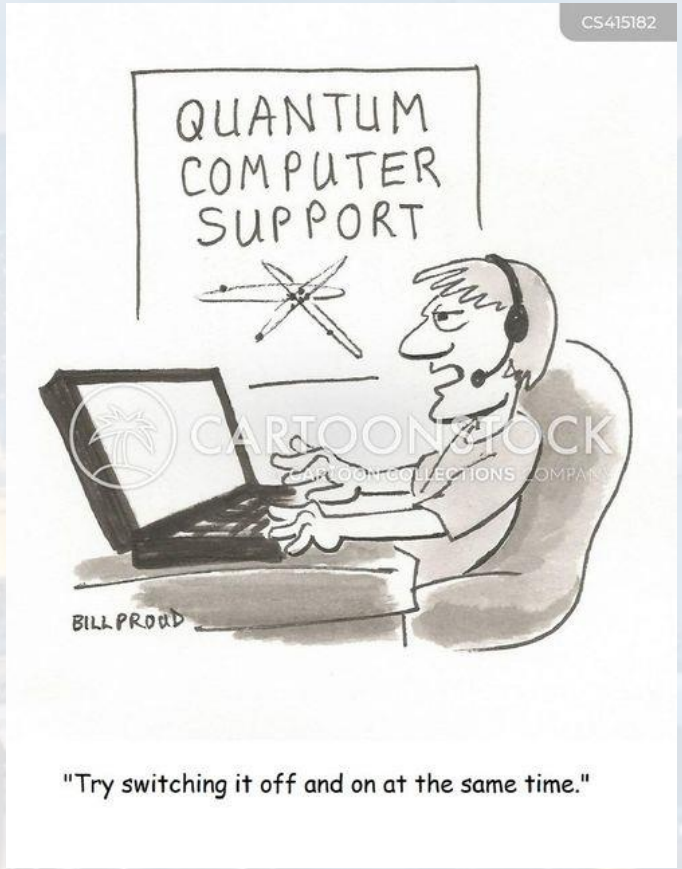
Berkeley
UNIVERSITY OF CALIFORNIA

M. Hohle:

Physics 77: Introduction to Computational Techniques in Physics



Introduction to Computational Techniques in Physics: syllabus

syllabus:

- Introduction to Unix & Python	(week 1 - 2)
- Functions, Loops, Lists and Arrays	(week 3 - 4)
- Visualization	(week 5)
- Parsing, Data Processing and File I/O	(week 6)
- Statistics and Probability, Interpreting Measurements	(week 7 - 8)
- Random Numbers, Simulation	(week 9)
- Numerical Integration and Differentiation	(week 10)
- Root Finding, Interpolation	(week 11)
- Systems of Linear Equations	(week 12)
- Ordinary Differential Equations	(week 13)
- Fourier Transformation and Signal Processing	(week 14)
- Capstone Project Presentations	(week 15)

Introduction to Computational Techniques in Physics: syllabus

Week	Dates	Topics	Reading	Lecture Slides	Workshop	Homework
1 - 2	Aug 28th / Sep 4th	Introduction to Unix and Python	K&N Ch. 1			
3 - 4	Sep 11th / Sep 18th	Functions, Loops, Lists, Arrays	K&N Ch.2-3			
5	Sep 25th	Visualization	K&N Ch. 4, K&N Ch. 6.3-6.4			
6	Oct 2nd	Parsing, Data Processing, and File I/O	K&N Ch. 4			
7 - 8	Oct 9th / Oct 16th	Statistics and Probability, Interpreting Measurements	Hughes			

Introduction to Computational Techniques in Physics: syllabus

Week	Dates	Topics	Reading	Lecture Slides	Workshop	Homework
9 - 10	Oct 23rd / Oct 30th	Random Numbers, Simulation	K&N Ch. 6, Newman Ch. 10			
11 - 12	Nov 6th / Nov 13th	Numerical Integration and Differentiation	K&N Ch. 6 Newman Ch. 5			
13	Nov 20th	Root finding, Interpolation	K&N Ch. 6.5 Newman Ch. 6			
14	Nov 27th	Systems of Linear Equations	Newman Ch. 6 K&N Ch. 6.6			
15	Dec 4th	Ordinary Differential Equations	K&N Ch. 6.8-6.9 Newman Ch. 8			
16	Dec 11th	Fourier Transforms, Signal Processing	Newman Ch. 7			
17	Dec 18th	Capstone Project Presentations				

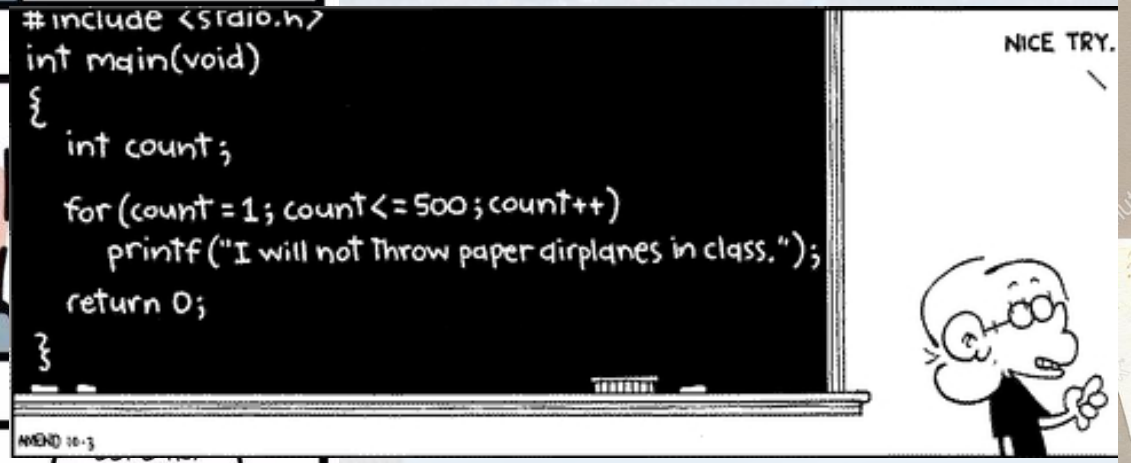
Introduction to Computational Techniques in Physics: syllabus

Lecture:	Wednesdays, 2 - 4pm, Physics Building 251
Workshops:	Fridays, 2 - 4pm (section 1) Social Science, 170 and
	Fridays, 4 - 6pm (section 2) Social Science, 140
Office Hours:	Wednesdays, 4 – 6pm, 397 Physics North (17)
Instruction begins:	August 28, 2024
Instruction ends:	Friday, December 13, 2024
my contact:	markus.hohle@berkeley.edu
TA:	Krish Desai krish.desai@berkeley.edu
check out:	Google Colab
	bcourse
	datahub.berkeley

Introduction to Computational Techniques in Physics: syllabus

Mixed Audience

beginner ★ **medium** ★ **advanced** ★

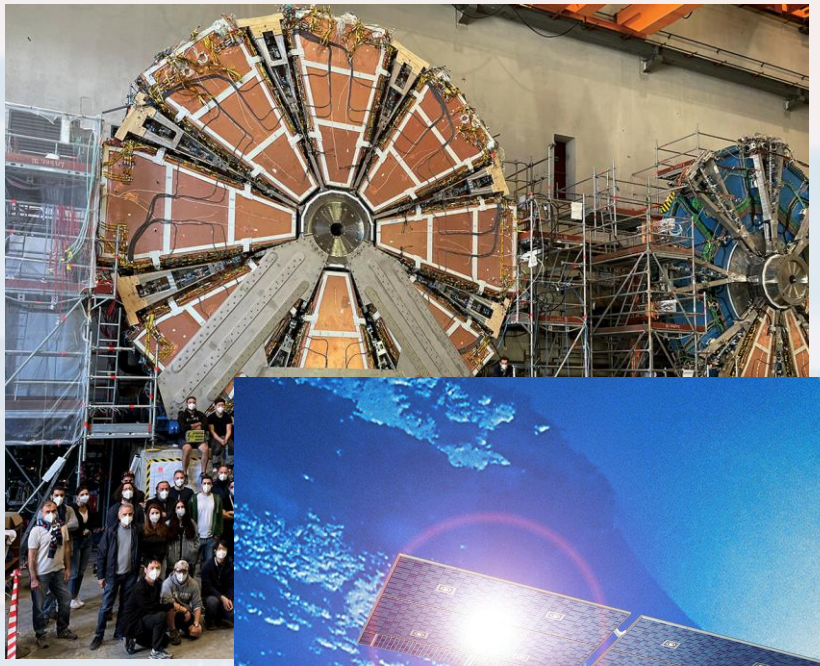


motivation: The good old days:

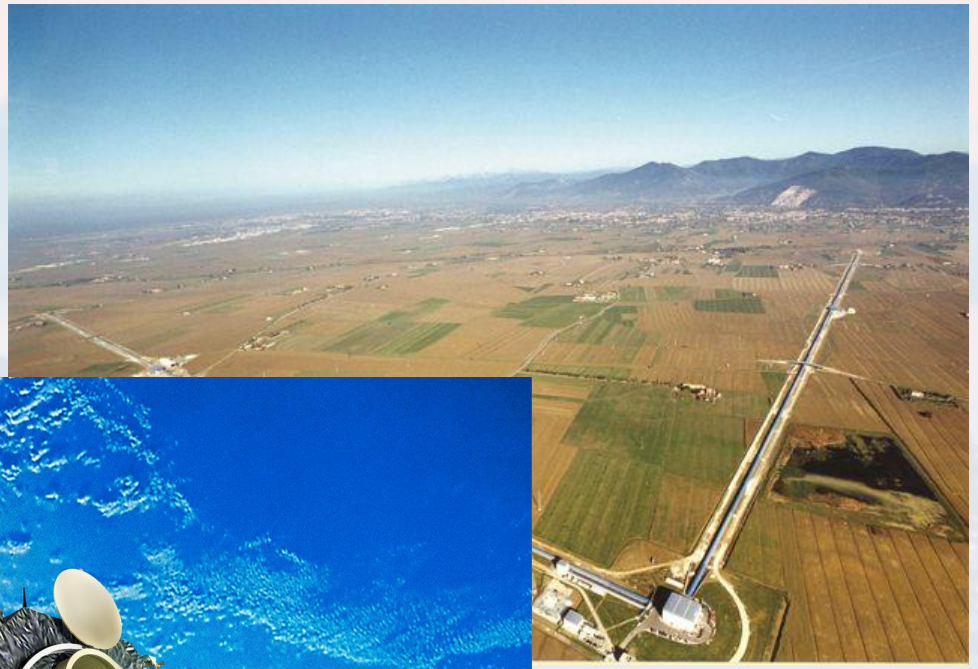
Salar de Uyuni, Bolivia, Mar 2003

Introduction to Computational Techniques in Physics: syllabus

motivation:



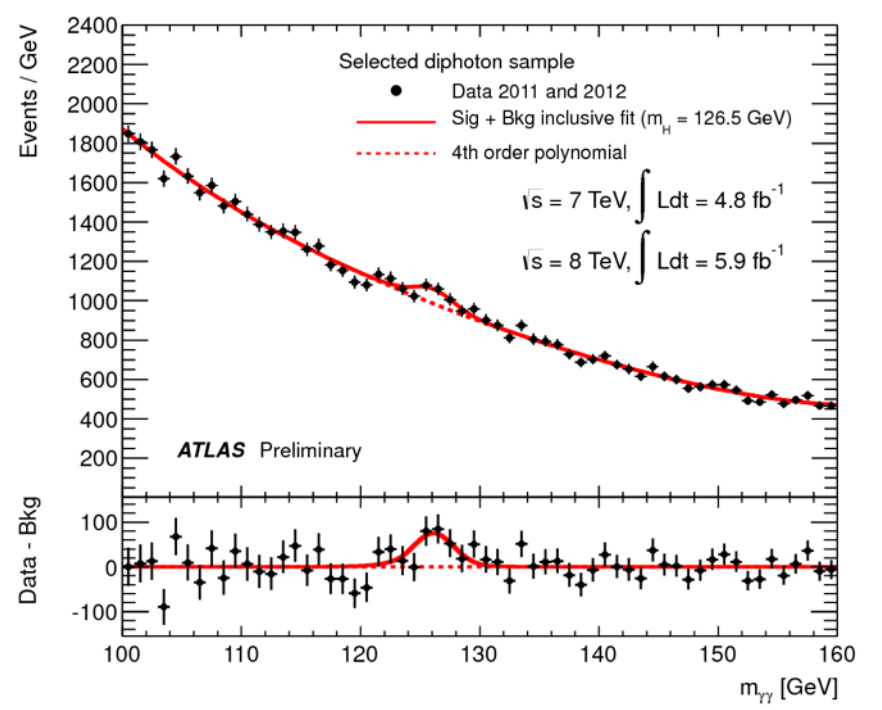
source: CERN



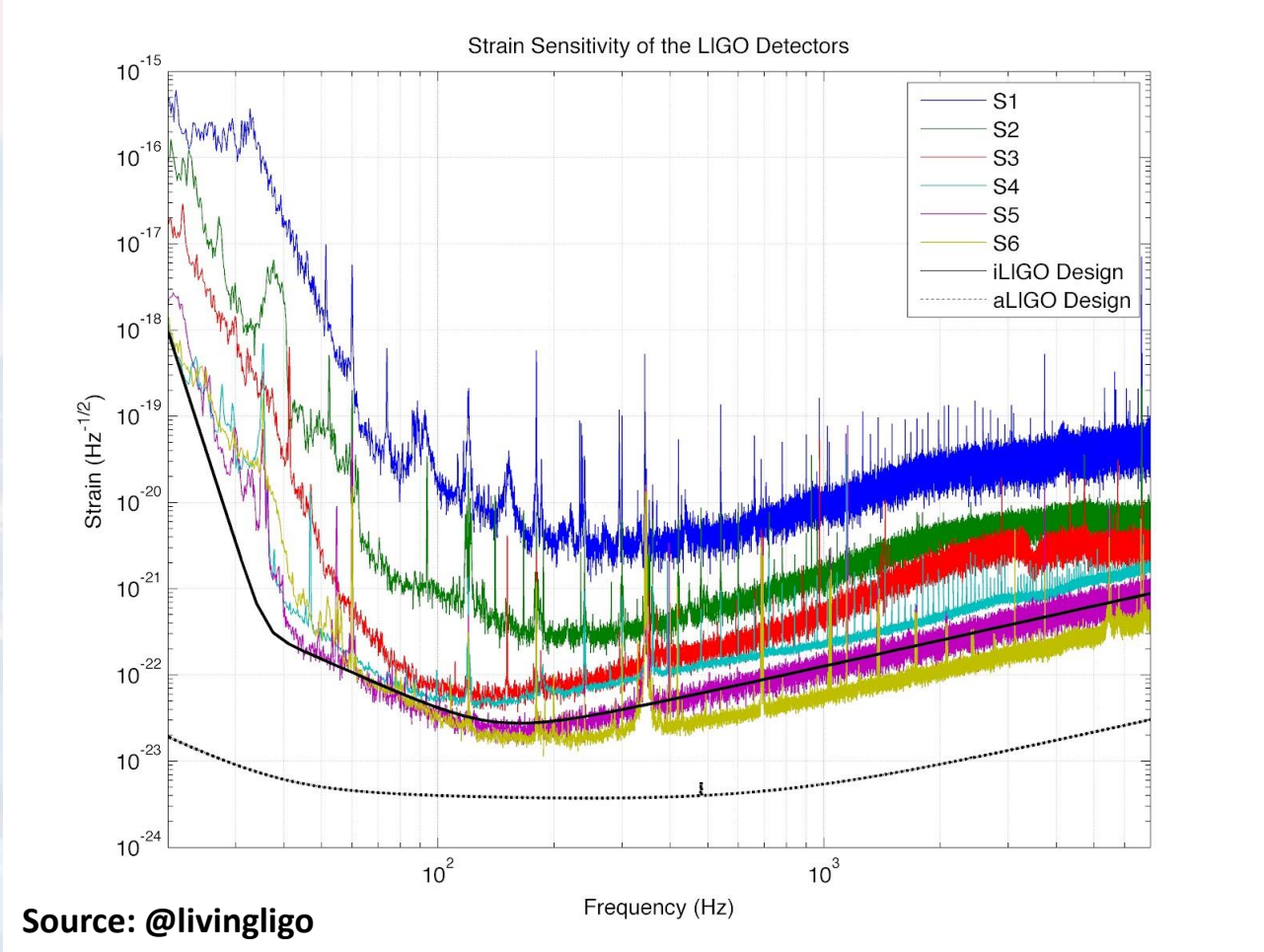
source: LIGO collaboration

source: ESA

motivation:

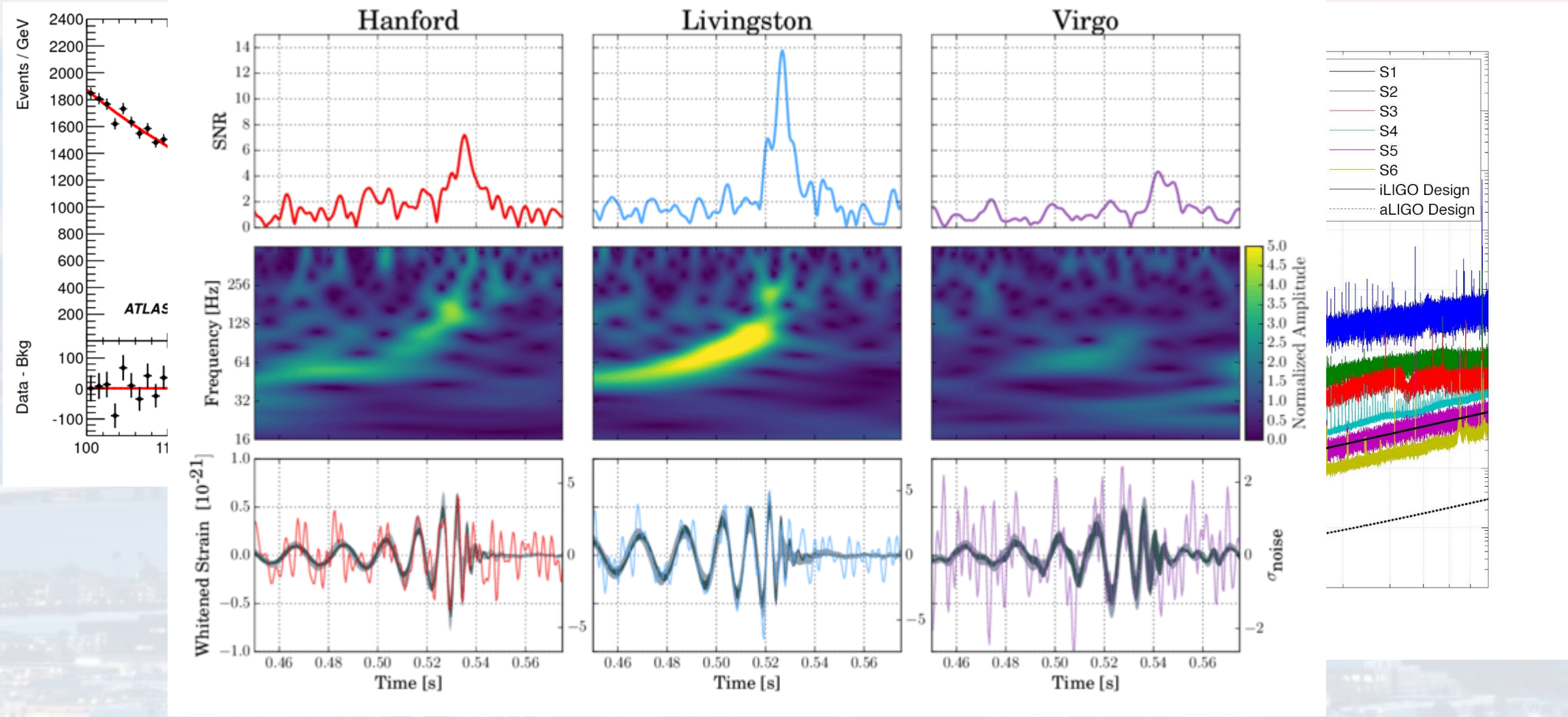


Source: CERN/ATLAS



Source: @livingligo

motivation:



Source: Sergio Gaudio Embry-Riddle Aeronautical University, Prescott, United States · Physics

goal: being able to write code like this…

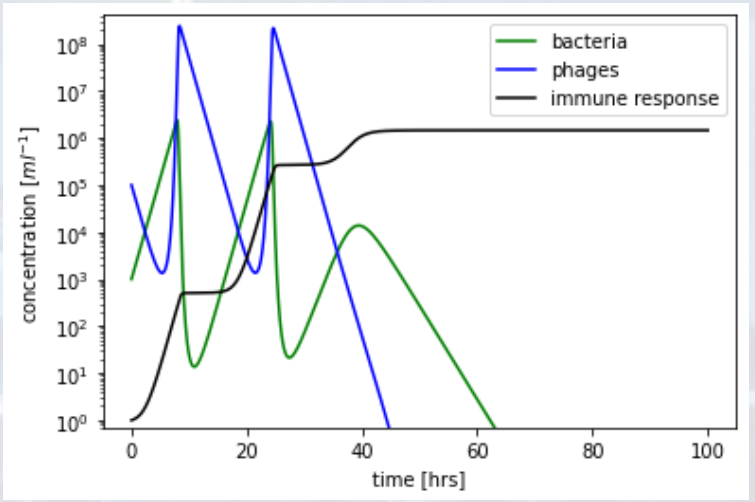
```
@my_timer
class SignalDetect():

    def __init__(self, T, Range_phi = [0, 2*np.pi], dphi = 0.01,\
                                        MaxM = 20, **Opts):

    L = listdir(getcwd())
    [remove(i) for i in L if '.npy' in i]

        ...
```

…and simulating systems like that



Leung & Weitz 2016

Introduction to Computational Techniques in Physics: syllabus

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syllabus:	**- Introduction to Unix & Python**	**(week 1 - 2)**
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Operating **S**ystem: interface between human and computer

→ **G**raphical **U**ser **I**nterface: Windows, OS X, iOS, Android

→ text based: MS-DOS

→ mixed: Unix

Unix:
- Bell Labs, early 70s
- Written in C and Assembly

Linux:
- as a an alternative to Unix
- Linus Torvalds (1991)
- Ubuntu, SUSE, … **Scientific Linux**

efficient, fast, robust optimized, but…

… not suitable for the *standard* user

Programming Languages: → translate human instructions to a form understandable by a computer

the *"style"* of programming

procedural: functions/ routines that call each other
(Fortran, ALGOL, COBOL, BASIC, Pascal, C)

object oriented (OOP): creating objects/types of different properties (see later)
C++, Fortran 2003, Java, MATLAB, **Python**, Ruby, …

how a programming language *"talks"* to your CPU or GPU

compiled language: close to the resulting machine code, **fast**
Fortran, C, C++, Java, Cobol, Pascal

source: wikipedia

interpreted language: an interpreter translates between source code and machine code. **Slower, but simpler syntax**
Perl, Raku, **Python**, MATLAB

Bits & Bytes: We need only **two** states: **on** and **off**

How many different states can I create with 8 switches?

$n = 8$

$2 \times 2 \times 2 \ldots = 2^n$

smallest memory cell: 8bits = 1byte
bit stands for **binary digit**

For some reason humans use **ten** states a = {0, 1, 2, 3, 4, 5, 6, 7, 8, 9}

$$N_{dec} = \sum_{i=0} a_{ji}\, 10^i$$

0	00000000
1	00000001
2	00000010
3	00000011
4	00000100
5	00000101
6	00000110
7	00000111
8	00001000
9	00001001
10	00001010
11	00001011
12	00001100
13	00001101
14	00001110
15	00001111
16	00010000
…	

Bits & Bytes: We need only **two** states: **on** and **off**

For some reason humans use **ten** states a = {0, 1, 2, 3, 4, 5, 6, 7, 8, 9}

$$N_{dec} = \sum_{i=0} a_{ji}\, 10^i$$

vs **two** states a = {0, 1}

$$N_{bin} = \sum_{i=0} a_{ji}\, 2^i$$

Let's write the number 15 in: *decimal, binary* and to base *three:*

0	00000000
1	00000001
2	00000010
3	00000011
4	00000100
5	00000101
6	00000110
7	00000111
8	00001000
9	00001001
10	00001010
11	00001011
12	00001100
13	00001101
14	00001110
15	00001111
16	00010000
…	

Bits & Bytes: We need only **two** states: **on** and **off**

8 bits	= 1 byte (B)
1 kB	= 1024 B
1 MB	= 1024 kB etc

So, we are fine with natural numbers…

… what is with negative numbers…

…or fractions…

…or π and e

→ float and double numbers need three *fields*:

- sign
- exponent
- fraction

more here

0	00000000
1	00000001
2	00000010
3	00000011
4	00000100
5	00000101
6	00000110
7	00000111
8	00001000
9	00001001
10	00001010
11	00001011
12	00001100
13	00001101
14	00001110
15	00001111
16	00010000
…	

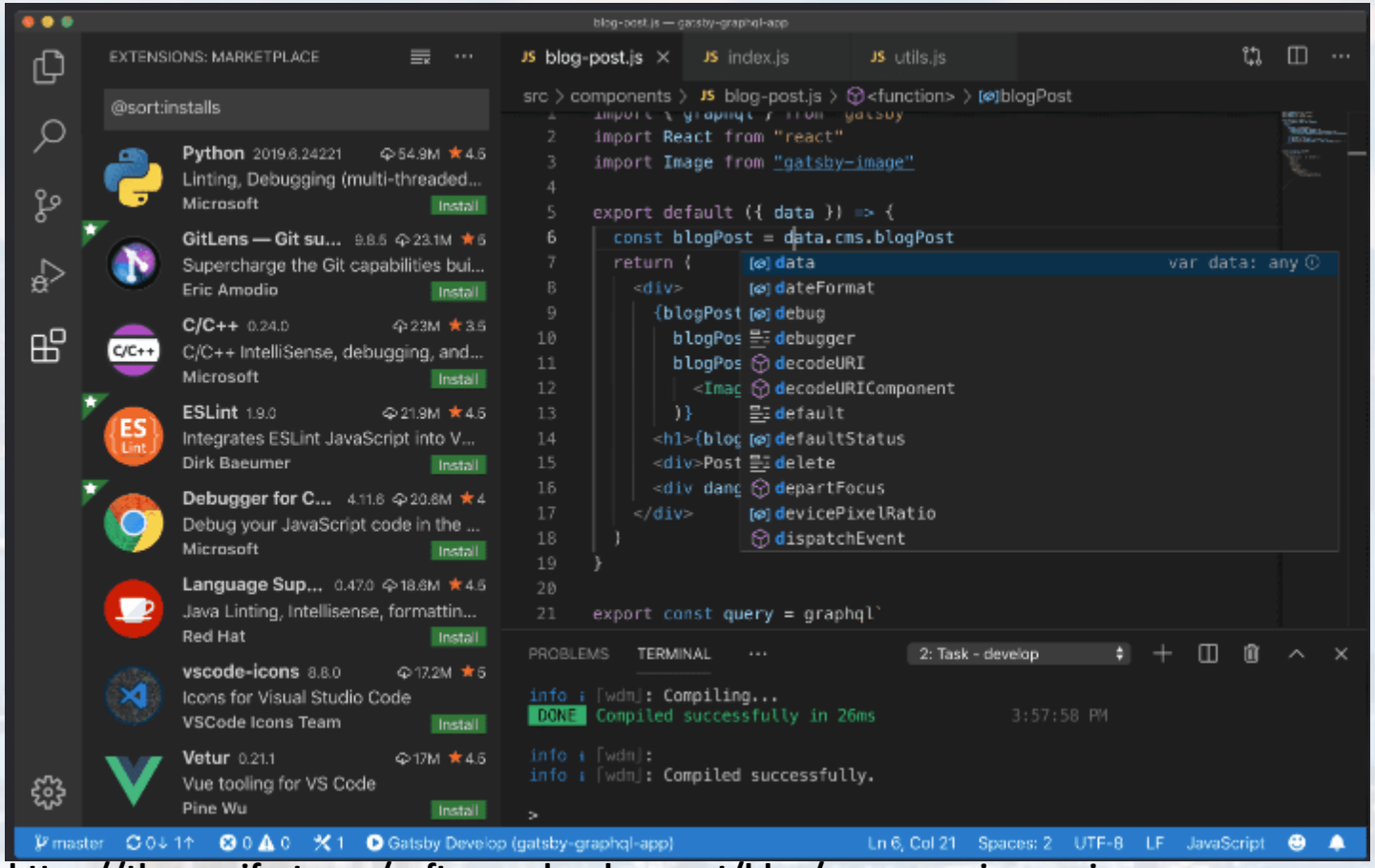
Bits & Bytes:

	rel. approx. error (ϵ)	range
16 bit int		-32768 … 32767
32 bit int		$\approx -10^9 \ldots 10^9$
32 bit float	$\approx 10^{-8}$	$\approx 10^{-38} \ldots 10^{38}$
64 bit double	$\approx 10^{-16}$	$\approx 10^{-308} \ldots 10^{308}$

0	00000000
1	00000001
2	00000010
3	00000011
4	00000100
5	00000101
6	00000110
7	00000111
8	00001000
9	00001001
10	00001010
11	00001011
12	00001100
13	00001101
14	00001110
15	00001111
16	00010000
…	

Luckily, Python will tell us when an operation doesn't makes sense based on precision, but still: **be cautious!**

build your environment



https://themanifest.com/software-development/blog/programming-engineer

1) if your OS is Windows

→ install Windows Subsystem for Linux (WSL)

→ follow the instructions here

2) if your OS is Unix/Linux

→ we can start right away!

3) optional

→ once you have Linux, there are lot's of useful tools you can install and link together

- Google Chrome
- Visual Studio Code (aka VS Code)
- NodeJS
- Docker

1) useful commands in Linux
2) installing ANACONDA
3) setting up your environment

list your files and folders

`ls`


```
(base) mmh_user@DESKTOP-PPSA666:~$ ls
Anaconda3-2023.09-0-Linux-x86_64.sh  AppAcademy  Untitled.ipynb  snap
Anaconda3-2024.06-1-Linux-x86_64.sh  Downloads    anaconda3
```

files

folder

shell scripts
→like executables

list your files and folders

`ls` `-lrt` called *flags*

- **`l`** stands for *long*: shows a file with all permissions and properties, each per line
- **`r`** stands for *reverse* (oldest first)
- **`t`** stands for the *time* flag (as criterium for r)

```
(base) mmh_user@DESKTOP-PPSA666:~$ ls -lrt
total 2158464
drwx------  2 mmh_user mmh_user       4096 Apr  8 20:03 Downloads
drwx------  3 mmh_user mmh_user       4096 Apr 10 19:16 snap
drwxr-xr-x  5 mmh_user mmh_user       4096 Apr 24 18:29 AppAcademy
-rwxr-xr-x  1 mmh_user mmh_user 1153404010 Jul 24 12:36 Anaconda3-2023.09-0-Linux-x86_64.sh
-rwxr-xr-x  1 mmh_user mmh_user 1056829859 Aug  5 18:53 Anaconda3-2024.06-1-Linux-x86_64.sh
drwxr-xr-x 31 mmh_user mmh_user       4096 Aug  5 19:22 anaconda3
-rw-r--r--  1 mmh_user mmh_user        616 Aug  5 19:30 Untitled.ipynb
```

1) **useful commands in Linux**
2) installing ANACONDA
3) setting up your environment

list your files and folders

```
ls      -lrt
```

but these are only those files you *see*.
try:

```
ls      -la
```

will be important (see later)

pointer/ links/aliases

```
(base) mmh_user@DESKTOP-PPSA666:~$ ls -la
total 2158640
drwxr-x--- 23 mmh_user mmh_user       4096 Aug  5 19:41 .
drwxr-xr-x  3 root     root           4096 Apr  2 21:35 ..
drwxr-xr-x  4 mmh_user mmh_user       4096 Apr  3 04:49 .aa-setup-checker
drwxr-xr-x  3 mmh_user mmh_user       4096 Aug  4 13:14 .anaconda
lrwxrwxrwx  1 mmh_user mmh_user         21 Apr  3 04:31 .aws -> /mnt/c/Users/MMH/.aws
lrwxrwxrwx  1 mmh_user mmh_user         23 Apr  3 04:31 .azure -> /mnt/c/Users/MMH/.azure
-rw-------  1 mmh_user mmh_user      26898 Aug  5 23:07 .bash_history
-rw-r--r--  1 mmh_user mmh_user        220 Apr  2 21:35 .bash_logout
-rw-r--r--  1 mmh_user mmh_user       4582 Jul 24 12:40 .bashrc
drwx------ 11 mmh_user mmh_user       4096 Aug  5 19:42 .cache
drwxr-xr-x  2 mmh_user mmh_user       4096 Jul 24 12:42 .conda
-rw-r--r--  1 mmh_user mmh_user         25 Aug  5 19:03 .condarc
drwx------  6 mmh_user mmh_user       4096 Aug  5 19:45 .config
drwxr-xr-x  5 mmh_user mmh_user       4096 Apr  3 04:31 .docker
```

list your files and folders

```
ls      -lrt
```

```
ls      -la
```

You can search for files/folders with particular substrings using a “wildcard”

```
ls      *.py
ls      *py*
```

```
(base) mmh_user@DESKTOP-PPSA666:~$ ls -lrt *A*
-rwxr-xr-x 1 mmh_user mmh_user 1153404010 Jul 24 12:36 Anaconda3-2023.09-0-Linux-x86_64.sh
-rwxr-xr-x 1 mmh_user mmh_user 1056829859 Aug  5 18:53 Anaconda3-2024.06-1-Linux-x86_64.sh

AppAcademy:
total 12
drwxr-xr-x 13 mmh_user mmh_user 4096 Apr 17 18:34 HTMLExercises
drwxr-xr-x  4 mmh_user mmh_user 4096 Apr 23 21:13 GitExercises
drwxr-xr-x  7 mmh_user mmh_user 4096 May  3 23:36 JavaExercises
```

changing your directory

`cd`	always leads back to the home directory
`cd ../`	one level up
`cd ../my_dir`	one level up, down to my_dir
`cd another/dir`	one level down to dir
`mkdir test`	creating the new directory *test*
`rm –r test`	removing the directory using the flag *r* (here: recursively)
`rm any_file`	when removing a file, no flag is needed

Danger: Be careful with rm! There is no undelete command in Unix!

copying files and folders

```
cp my_file ../somewhere/else

cp my_file_original my_file_copy

cp my_file ../somewhere/else/my_file_copy

cp -r /entireDirectory somewhere/else/to/new_destination
```

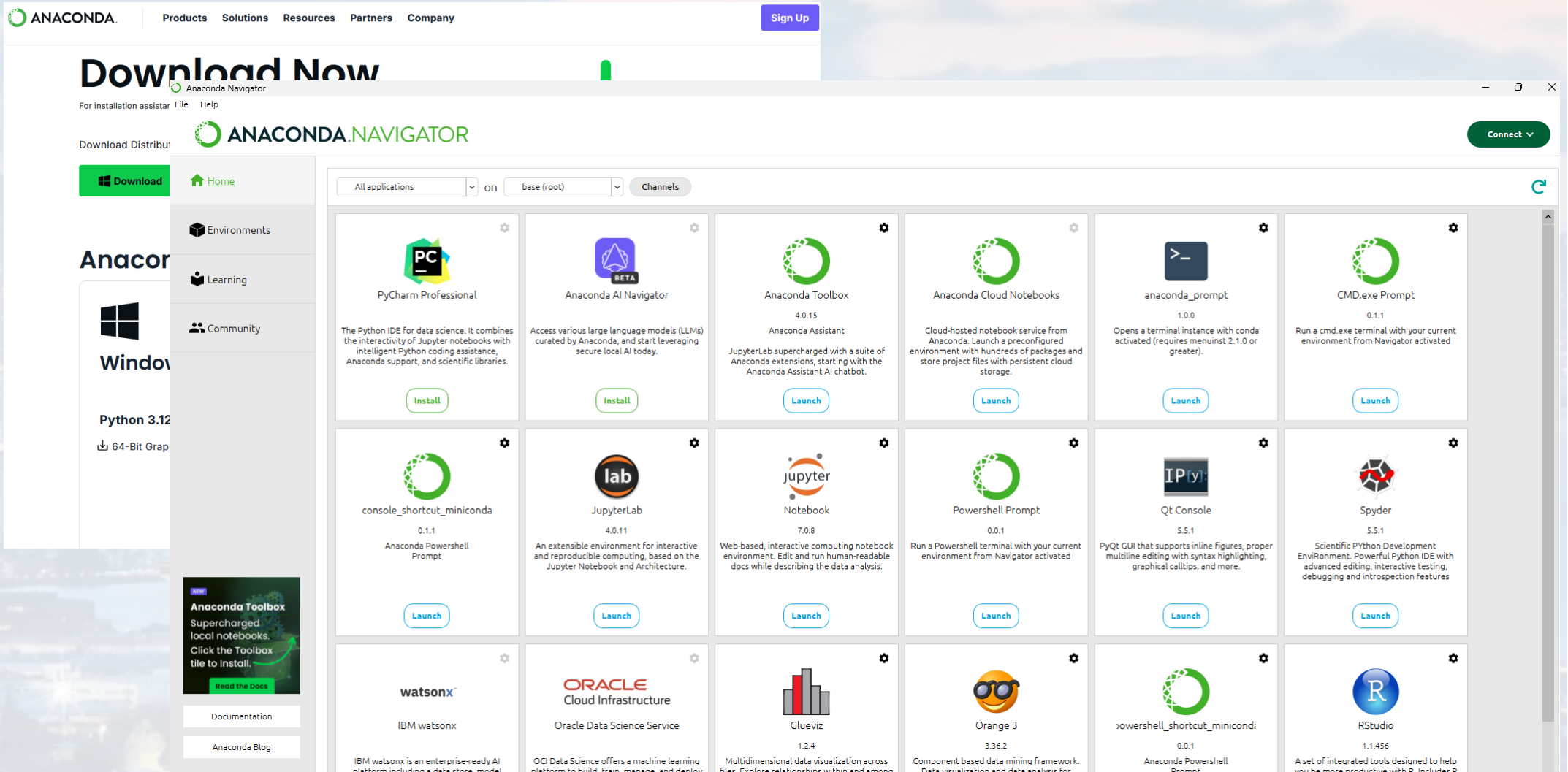
note: the flag *r* is needed to copy the directory with all the sub directories

note: there are way more commands and flags we will be learning soon :)

You can install ANACONDA Navigator **for Windows**

here

1) useful commands in Linux
2) **installing ANACONDA**
3) setting up your environment



You can install ANACONDA Navigator **for Linux**

1) we move into the home directory (cd) and run the curl (Client URL) command in order to download the ANACONDA installer from here

```
curl -O https://repo.anaconda.com/archive/Anaconda3-2024.06-1-Linux-x86_64.sh
```

2) running the installer

```
bash ~/Downloads/Anaconda3-2024.06-1-Linux-x86_64.sh
```

3) it might give us an error message “permission denied”

→ turning the installer shell script into an “executable” using chmod

```
chmod +x Anaconda3-2024.06-1-Linux-x86_64.sh
```

4) run the installer manually

```
./Anaconda3-2024.06-1-Linux-x86_64.sh
```

3) it might give us an error message “permission denied”

```
chmod +x Anaconda3-2024.06-1-Linux-x86_64.sh
```

4) run the installer manually

```
./Anaconda3-2024.06-1-Linux-x86_64.sh
```

5) confirm license terms by typing *yes* and press *enter*

6) you might need to refresh your terminal by running

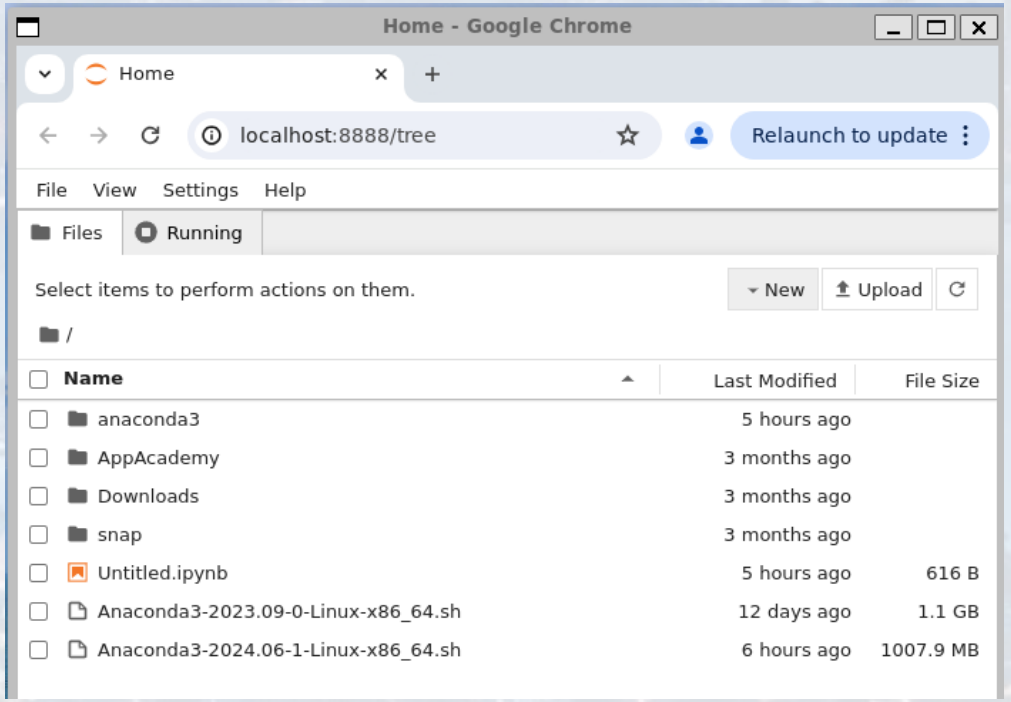
```
source ~/.bashrc
```

Now Anaconda should be working. Type

```
conda install python
```

finally, run

```
jupyter-notebook &
```



Note: conda on unix doesn't work well with Spyder


```
(base) mmh_user@DESKTOP-PPSA666:~$ spyder &
[1] 52032
(base) mmh_user@DESKTOP-PPSA666:~$ Could not load the Qt platform plugin "xcb" in "" even though it was found.
This application failed to start because no Qt platform plugin could be initialized. Reinstalling the application may fi
x this problem.

Available platform plugins are: eglfs, minimal, minimalegl, offscreen, vnc, webgl, xcb.


[1]+  Aborted                 spyder
(base) mmh_user@DESKTOP-PPSA666:~$
```

creating a conda environment for the Spyder IDE:

```
conda create -n spyder-env -c conda-forge python=3.11 spyder
```

activating the environment:

```
conda activate spyder-env
```

Note: conda on unix doesn't work well with Spyder

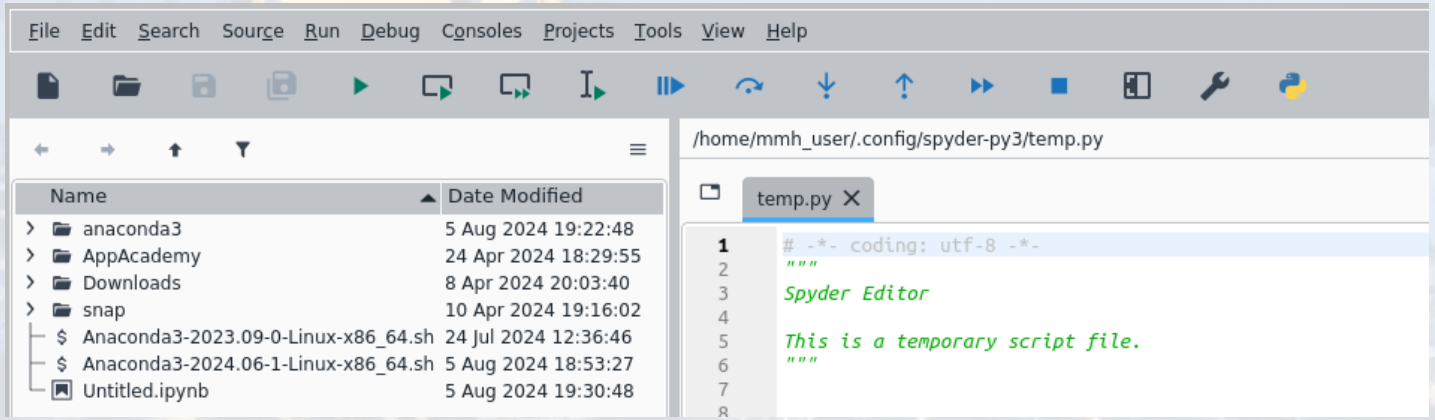
creating a conda environment for the Spyder IDE:

```
conda create -n spyder-env -c conda-forge python=3.11 spyder
```

activating the environment:

```
conda activate spyder-env
```

```
(base) mmh_user@DESKTOP-PPSA666:~$ conda activate spyder-env
(spyder-env) mmh_user@DESKTOP-PPSA666:~$ spyder &
[1] 53245
(spyder-env) mmh_user@DESKTOP-PPSA666:~$ fromIccProfile: failed minimal tag size sanity
```



depending on your project, you can create many different conda environments

```
conda create -n <MyEnv> python=3.10  scipy=0.17.3
```

showing all libraries:

```
conda list
```

showing all environments

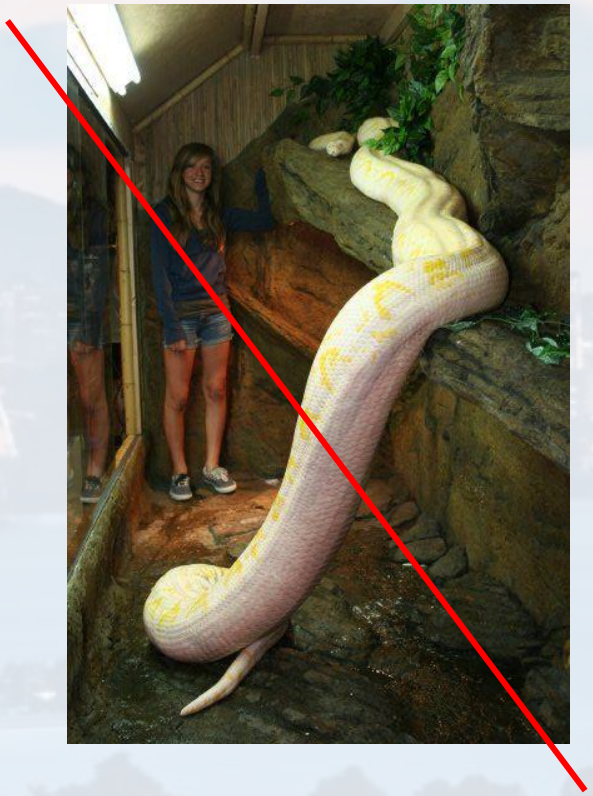
```
conda info --envs
```

```
(base) mmh_user@DESKTOP-PPSA666:~$ conda info --envs
# conda environments:
#
base                  *  /home/mmh_user/anaconda3
spyder-env               /home/mmh_user/anaconda3/envs/spyder-env
```

Now it is time for python!

- 1990, von Guido van Rossum

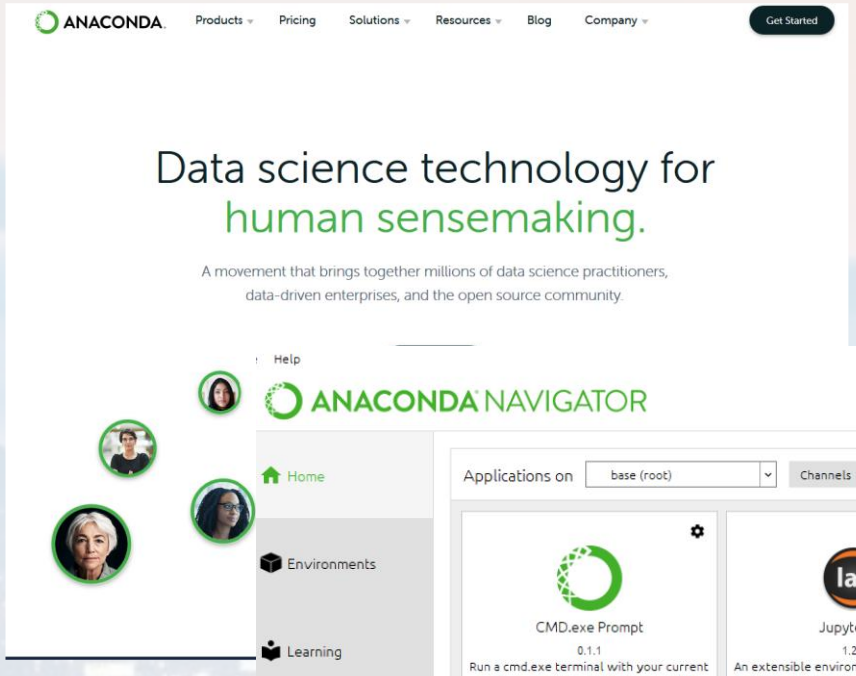
- named after **“Monty Python”**, not the serpent



- idea: flexible, simple and compact syntax, extendable

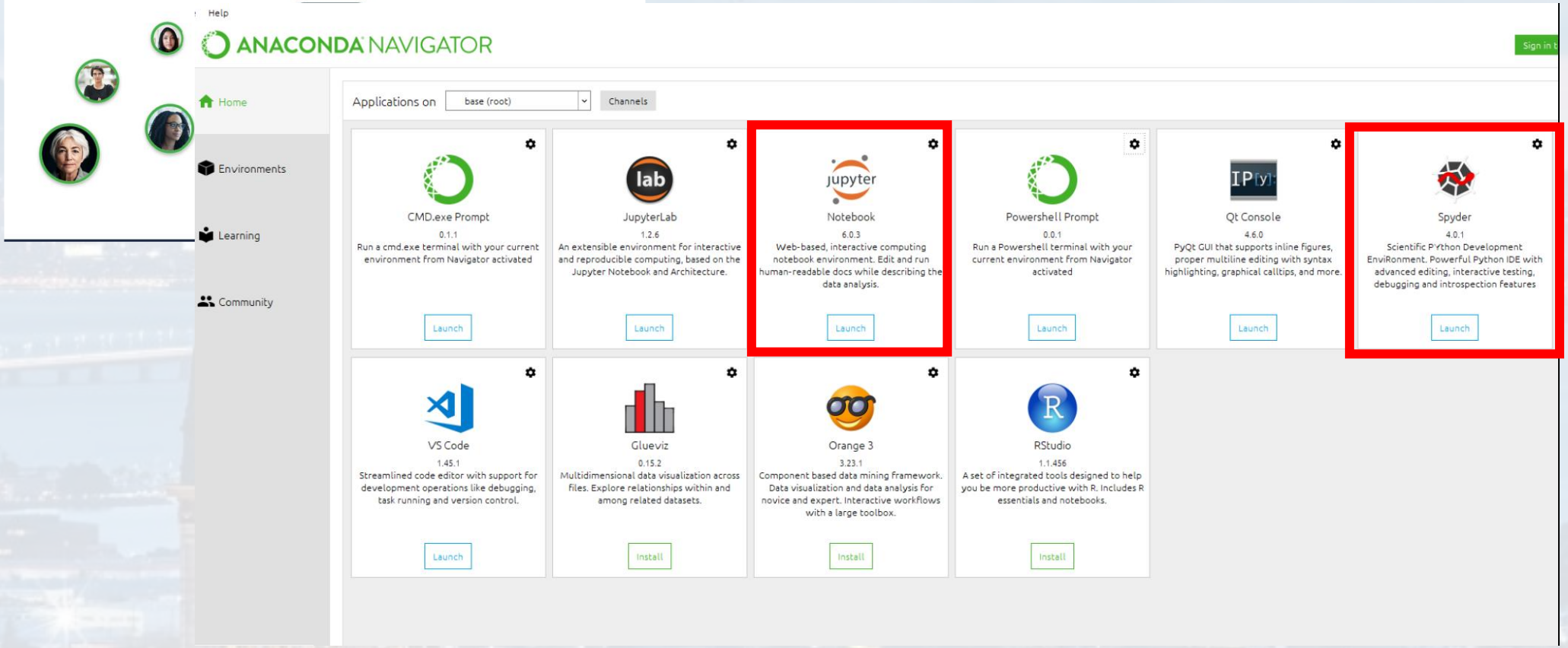
TIOBE index July 2024

Jul 2024	Jul 2023	Change	Programming Language	Ratings	Change
1	1		Python	16.12%	+2.70%
2	3	↑	C++	10.34%	-0.46%
3	2	↓	C	9.48%	-2.08%
4	4		Java	8.59%	-1.91%
5	5		C#	6.72%	-0.15%
6	6		JavaScript	3.79%	+0.68%
7	13	⇈	Go	2.19%	+1.12%
8	7	↓	Visual Basic	2.08%	-0.82%
9	11	↑	Fortran	2.05%	+0.80%
10	8	↓	SQL	2.04%	+0.57%
11	15	⇈	Delphi/Object Pascal	1.89%	+0.91%
12	10	↓	MATLAB	1.34%	+0.08%
13	17	⇈	Rust	1.18%	+0.29%
14	16	↑	Ruby	1.16%	+0.25%
15	12	↓	Scratch	1.15%	+0.08%
16	9	⇊	PHP	1.15%	-0.27%

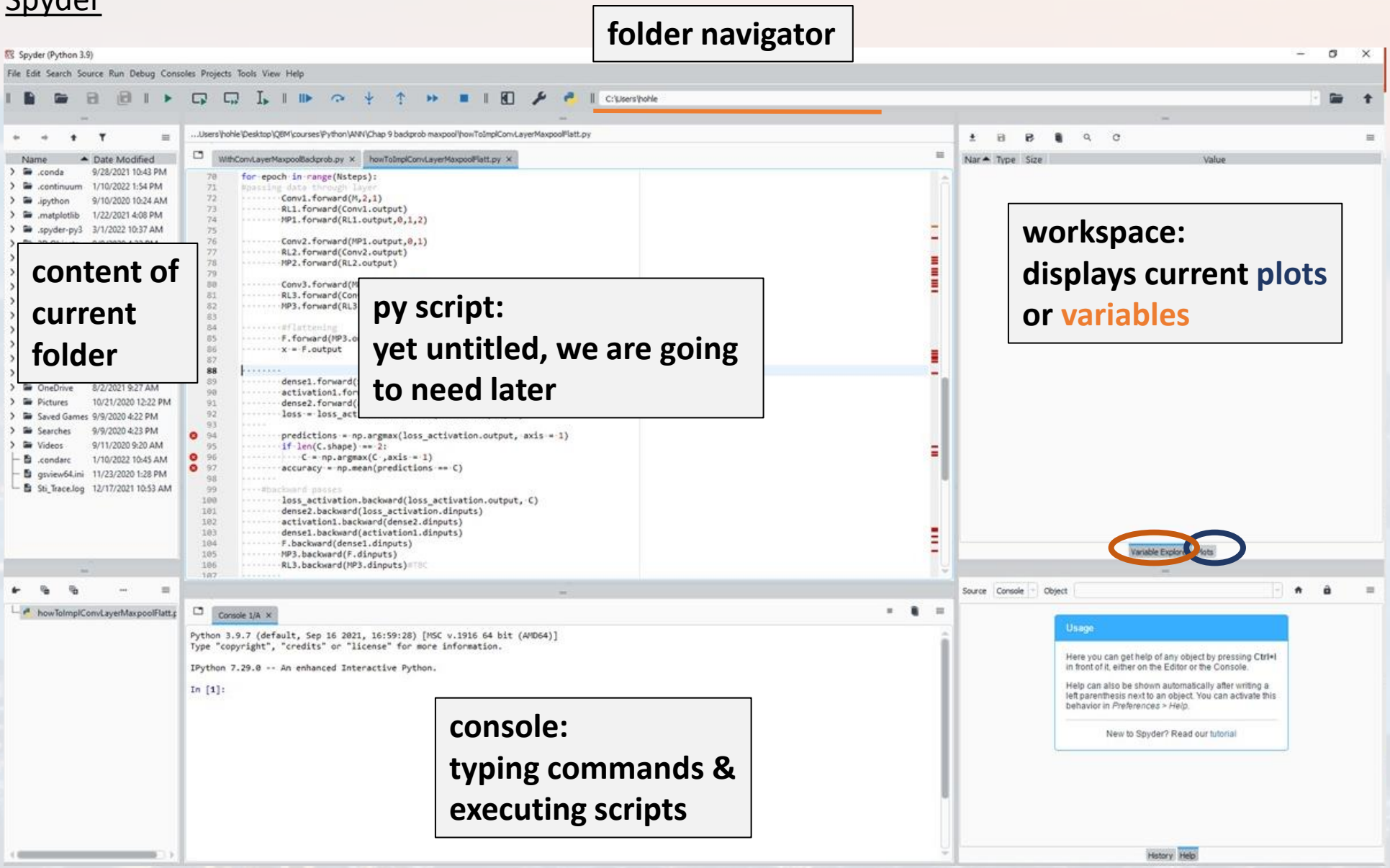


https://www.anaconda.com/

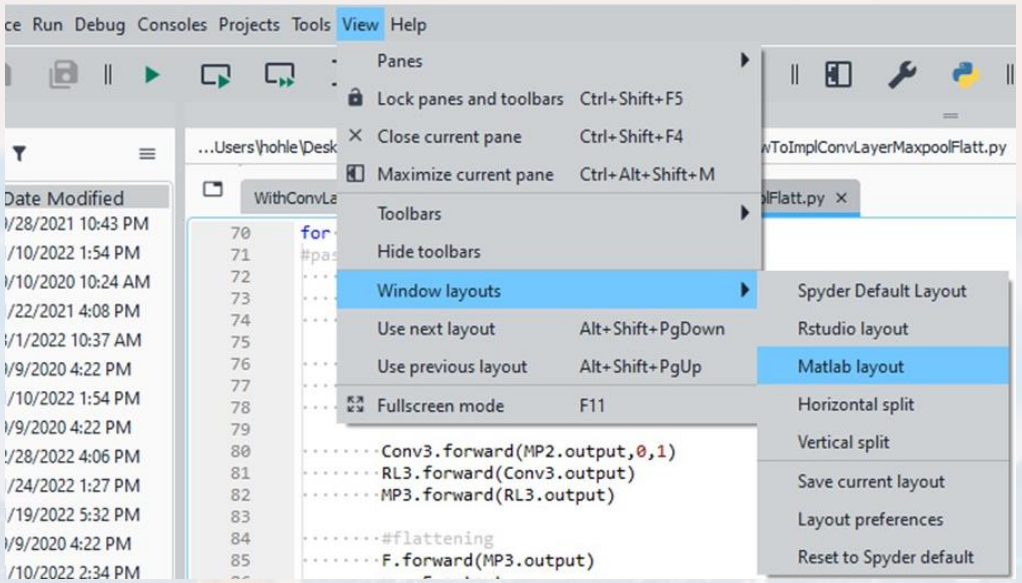
ANACONDA.



Spyder

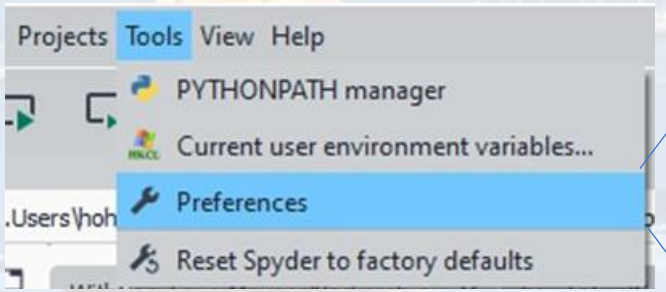

folder navigator
content of current folder
py script:
yet untitled, we are going to need later
workspace:
displays current plots or variables
console:
typing commands & executing scripts

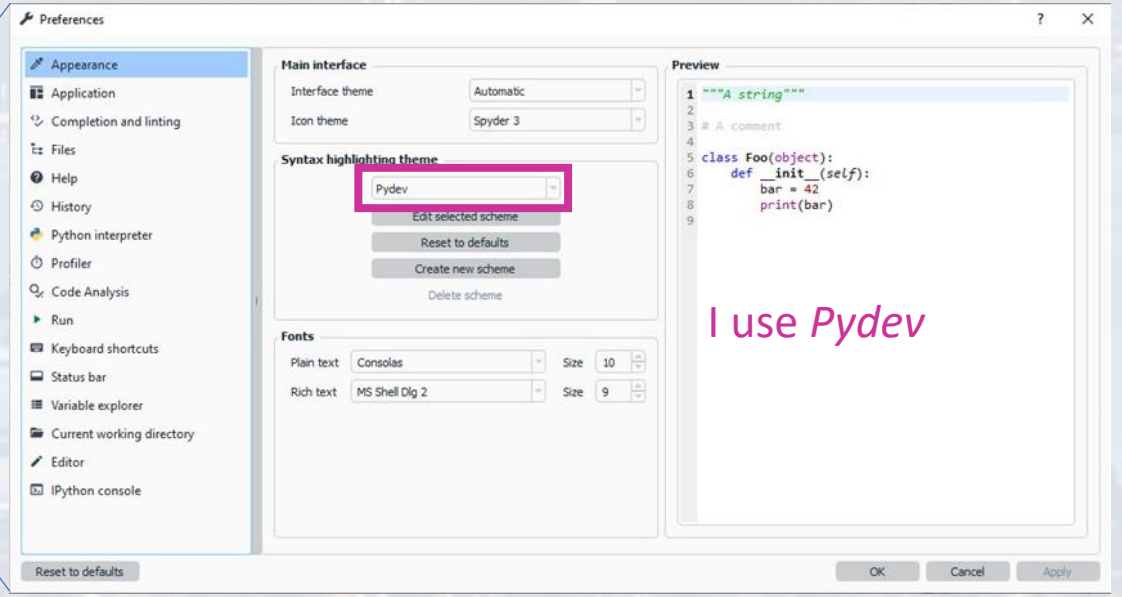
Spyder



settings:
toolbar: *View* → *Window layouts*

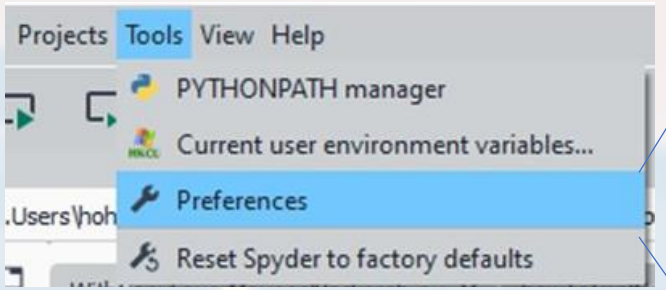
e. g. Matlab

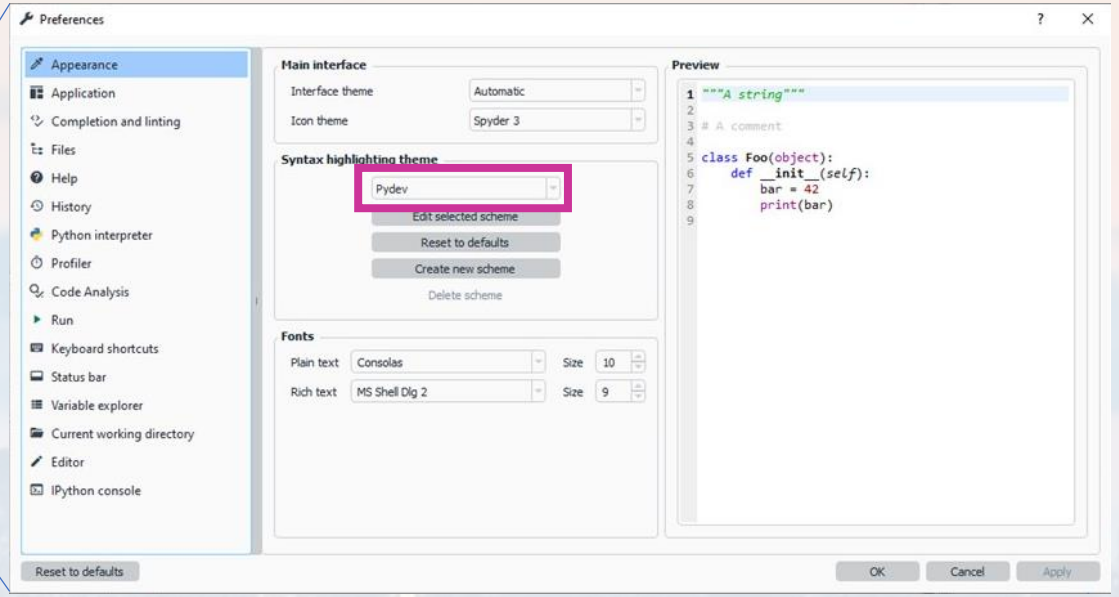


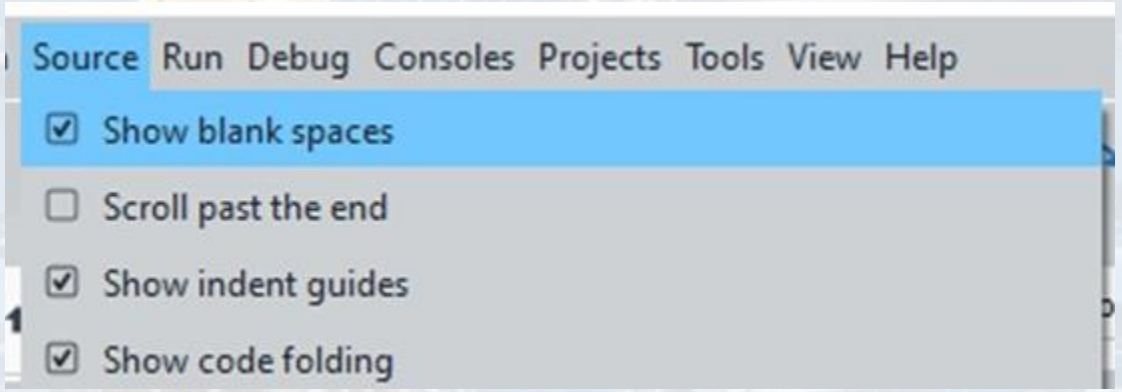


I use *Pydev*

Spyder

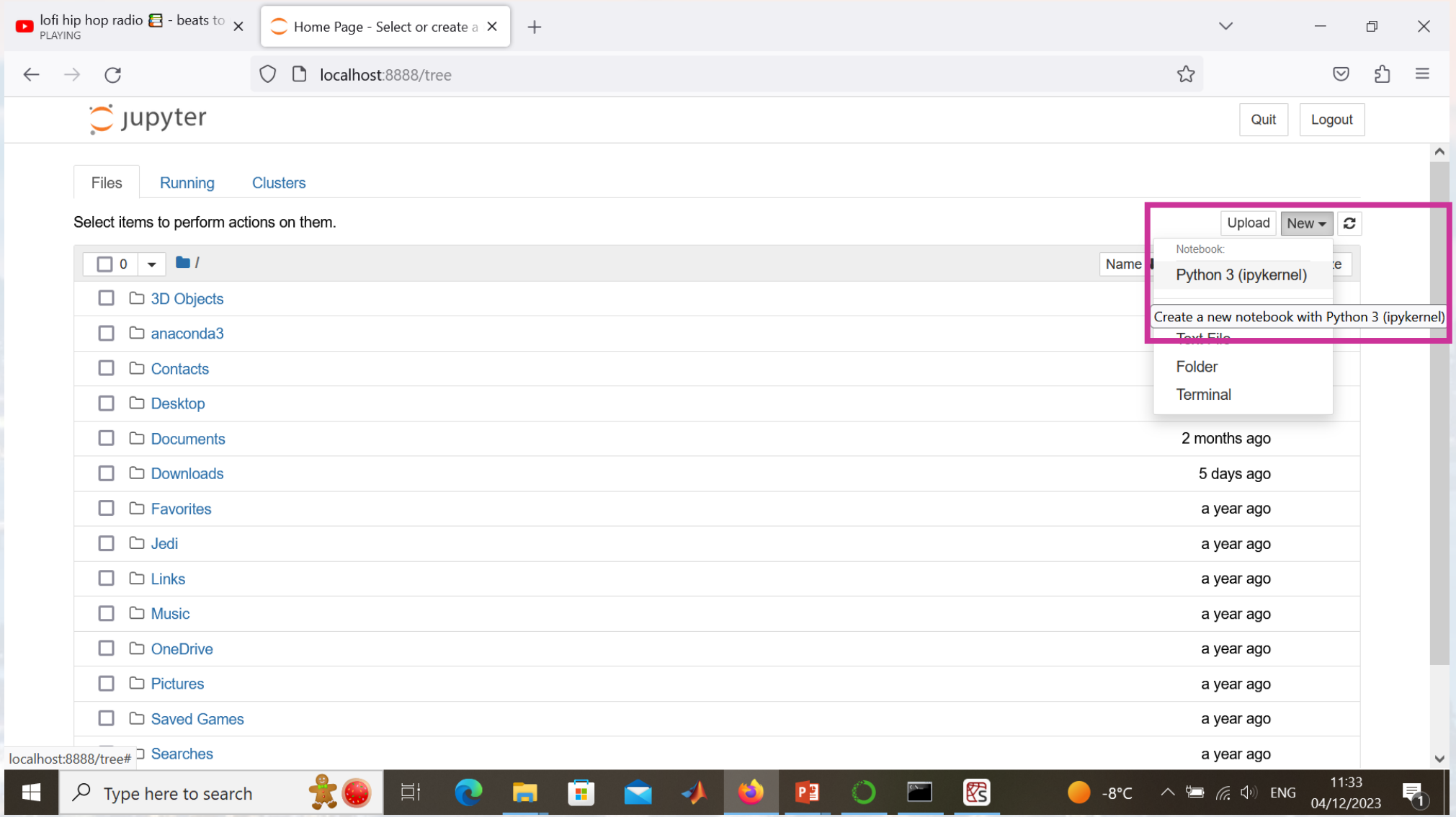




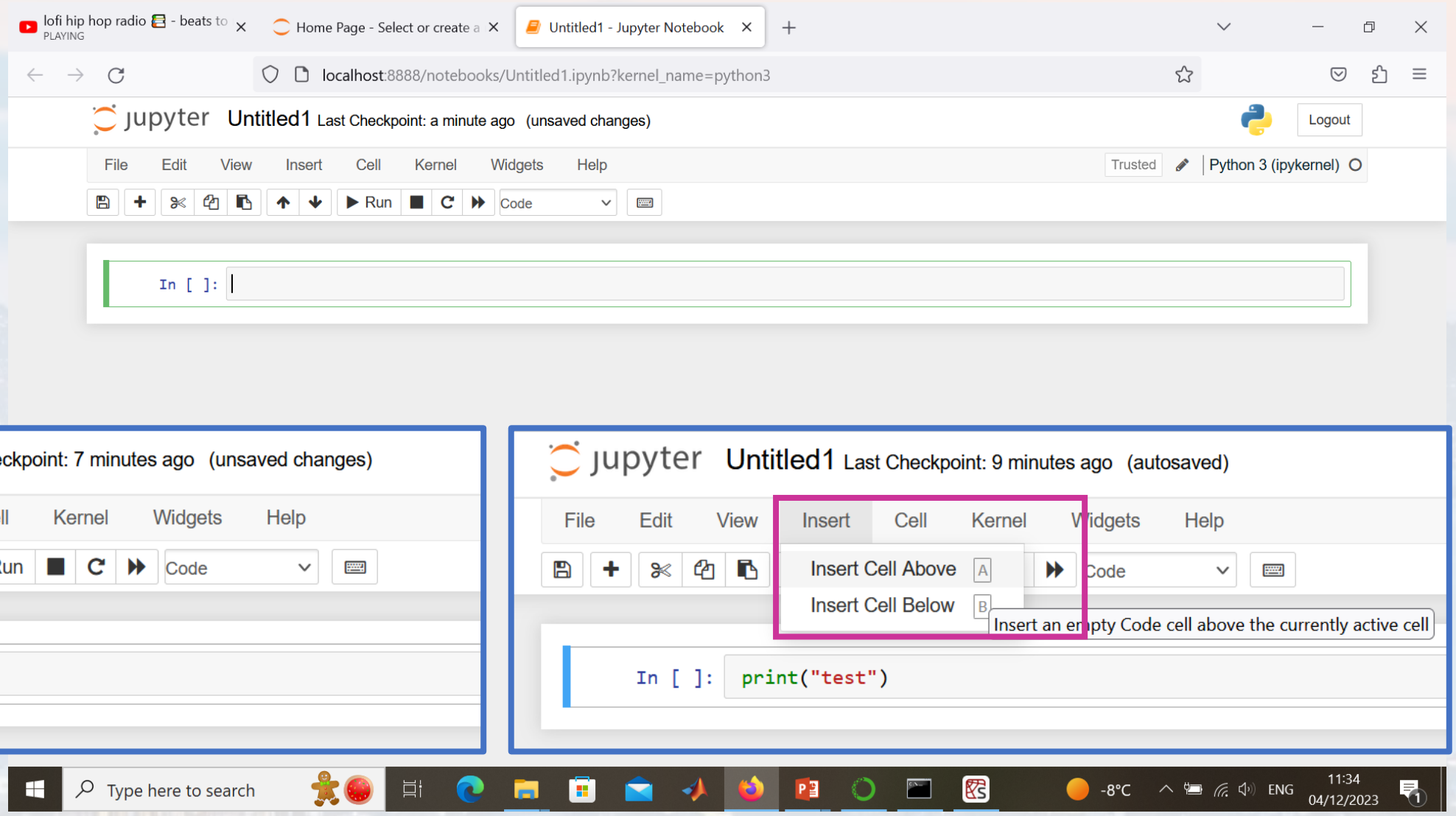


blanks are relevant for synthax!

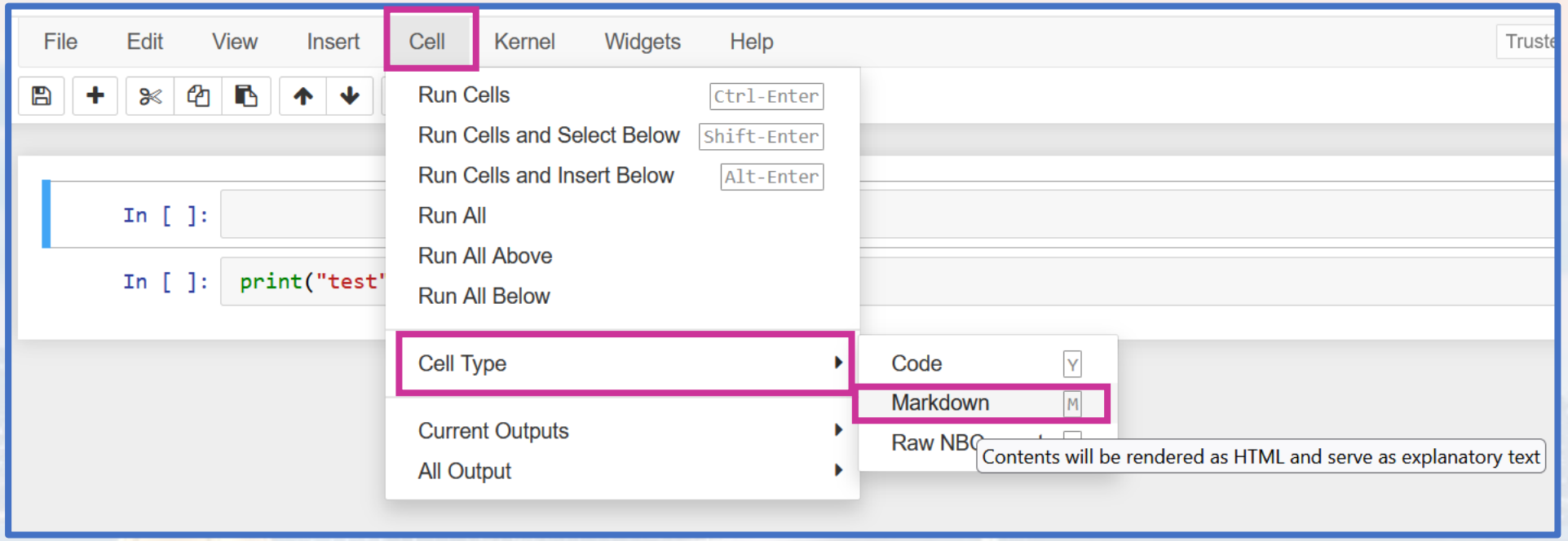
Jupyter


lofi hip hop radio - beats to
PLAYING
Home Page - Select or create a
localhost:8888/tree
jupyter
Quit
Logout
Files
Running
Clusters
Select items to perform actions on them.
Upload
New
Notebook:
Python 3 (ipykernel)
Create a new notebook with Python 3 (ipykernel)
Folder
Terminal
0
/
Name
3D Objects
anaconda3
Contacts
Desktop
Documents
2 months ago
Downloads
5 days ago
Favorites
a year ago
Jedi
a year ago
Links
a year ago
Music
a year ago
OneDrive
a year ago
Pictures
a year ago
Saved Games
a year ago
Searches
a year ago
localhost:8888/tree#
Type here to search
-8°C
ENG
11:33
04/12/2023

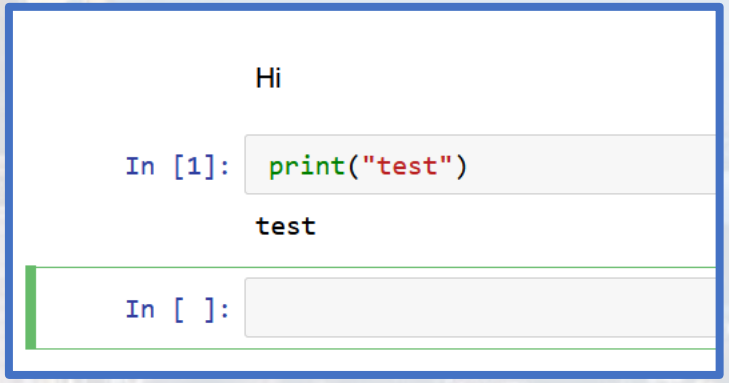
Jupyter


lofi hip hop radio - beats to
PLAYING
Home Page - Select or create a
Untitled1 - Jupyter Notebook
localhost:8888/notebooks/Untitled1.ipynb?kernel_name=python3
jupyter Untitled1 Last Checkpoint: a minute ago (unsaved changes)
Logout
File Edit View Insert Cell Kernel Widgets Help
Trusted
Python 3 (ipykernel)
Run
Code
In [ ]:
jupyter Untitled1 Last Checkpoint: 7 minutes ago (unsaved changes)
File Edit View Insert Cell Kernel Widgets Help
Run
Code
In [ ]: print("test")
jupyter Untitled1 Last Checkpoint: 9 minutes ago (autosaved)
File Edit View Insert Cell Kernel Widgets Help
Insert Cell Above A
Insert Cell Below B
Insert an empty Code cell above the currently active cell
Code
In [ ]: print("test")
Type here to search
-8°C
ENG
11:34
04/12/2023

Jupyter

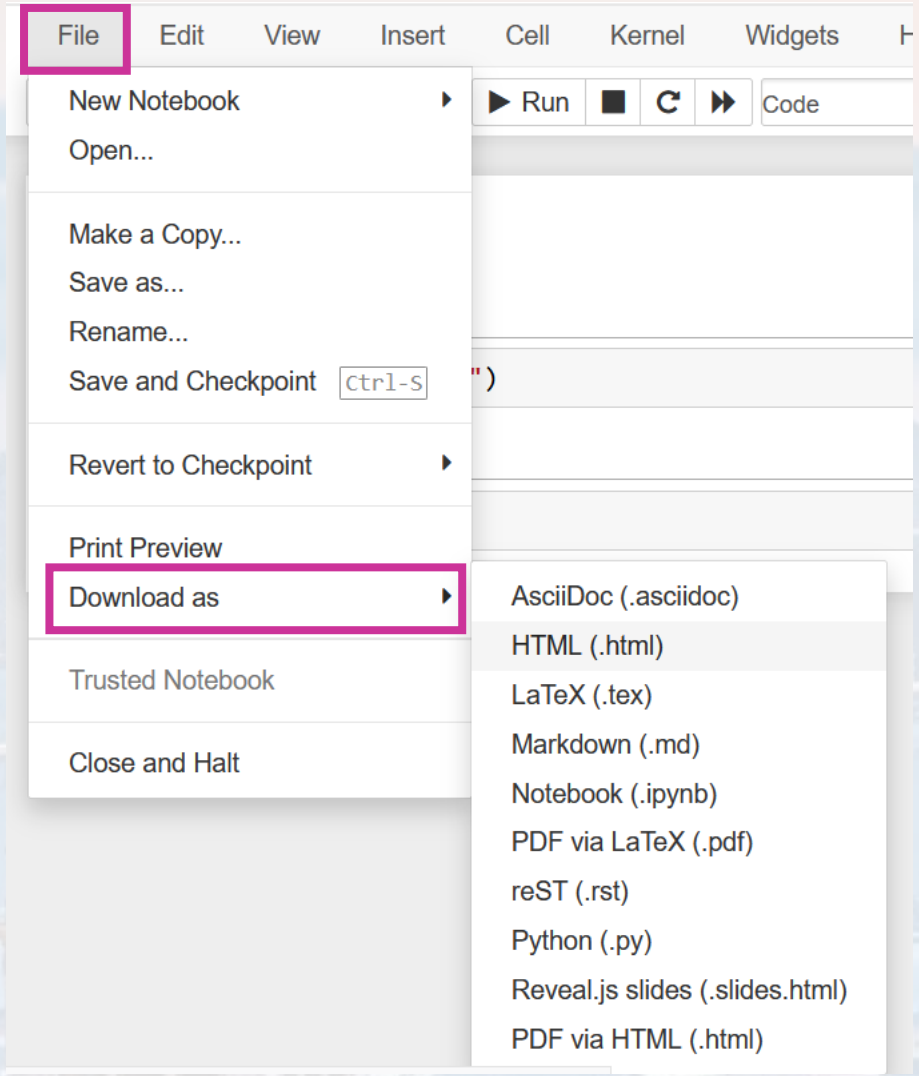


type something → click ***run***



web: Jupyter → markdown styles (including LaTeX)

Jupyter


File
Edit
View
Insert
Cell
Kernel
Widgets
New Notebook
Open...
Make a Copy...
Save as...
Rename...
Save and Checkpoint Ctrl-S
Revert to Checkpoint
Print Preview
Download as
Trusted Notebook
Close and Halt
Run
Code
AsciiDoc (.asciidoc)
HTML (.html)
LaTeX (.tex)
Markdown (.md)
Notebook (.ipynb)
PDF via LaTeX (.pdf)
reST (.rst)
Python (.py)
Reveal.js slides (.slides.html)
PDF via HTML (.html)

basic types:

```
String = 'Hello ' + ''World''

List   = [1, 2, 3, 5, ''World'' ]      #default

Tuple  = (1, 2)

Dict   = {'A': 1, 'B': 2}

Array  = np.array([1, 2, 3, 5])

pd.DataFrame
```

other objects:

```
class

def      #function/method
```

- labels and titles of plots
- paths and file names
- error messages

```
String    = 'Hello ' + ''World''
List      = [1, 2, 3, 5, ''World'' ]
Tuple     = (1, 2)
Dict      = {'A': 1, 'B': 2}
Array     = np.array([1, 2, 3, 5])
pd.DataFrame
```

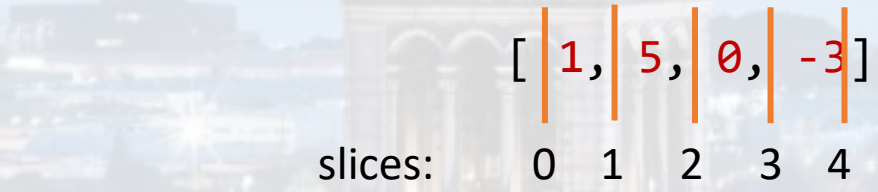
```
string1 = 'Hello Students'

string2 = ', how are you'

string12 = string1 + string2
Out[1]: 'Hello Students, how are you'
```

concatenating is incredibly easy!

```
S = 'abc'
3*S
Out[2]: 'abcabcabc'
```

```
string12[2:6]
```

slicing



- labels and titles of plots
- paths and file names
- error messages

```
String    = 'Hello ' + ''World''
List      = [1, 2, 3, 5, ''World'' ]
Tuple     = (1, 2)
Dict      = {'A': 1, 'B': 2}
Array     = np.array([1, 2, 3, 5])
pd.DataFrame
```

slicing

```
string12[2:6]
```

```
[ 1, 5, 0, -3]
slices:  0  1  2  3  4
```

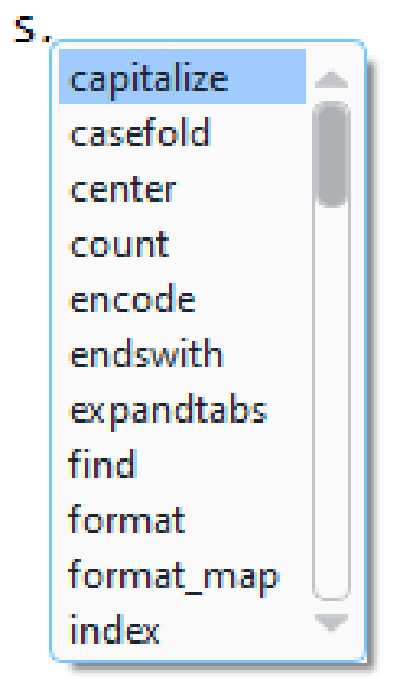
```
[1, 5, 0, -3]
index:   0  1  2   3

index:  -4 -3 -2  -1
```

indexing

```
string12[-1]

string12[1:]

string12[:-1]
```

- labels and titles of plots
- paths and file names
- error messages

```
String    = 'Hello ' + ''World''
List      = [1, 2, 3, 5, ''World'' ]
Tuple     = (1, 2)
Dict      = {'A': 1, 'B': 2}
Array     = np.array([1, 2, 3, 5])
pd.DataFrame
```



try some of the functions like

```
S.count()
S.find()
```

default type in python

```
L = [1, 2, 3, -2]

2*L

Out[3]: [1, 2, 3, -2, 1, 2, 3, -2]


type(L)

Out[4]: list
```

```
String    = 'Hello ' + ''World''
List      = [1, 2, 3, 5, ''World'' ]
Tuple     = (1, 2)
Dict      = {'A': 1, 'B': 2}
Array     = np.array([1, 2, 3, 5])
pd.DataFrame
```

default type in python

```
String    = 'Hello ' + ''World''
List      = [1, 2, 3, 5, ''World'' ]
Tuple     = (1, 2)
Dict      = {'A': 1, 'B': 2}
Array     = np.array([1, 2, 3, 5])
pd.DataFrame
```

be careful:

```
L1 = [1, 2]
L2 = L1

L1[0] = 5
print(L2[0])
```

What is the result? What happens if you do the same with an `int`?

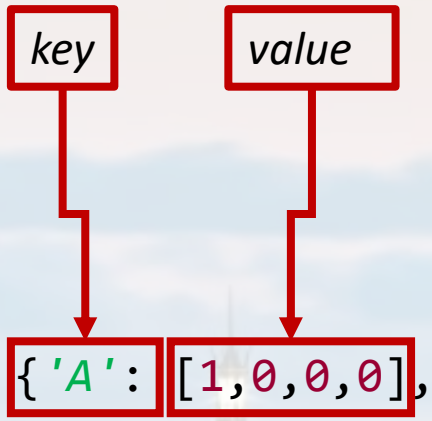
```
L1 = [1, 2]
L2 = L1.copy()

L1[0] = 5
print(L2[0])
```

`lists, dictionaries, sets` and `bytearrays` are **mutable.**

```
String    = 'Hello ' + ''World''
List      = [1, 2, 3, 5, ''World'' ]
Tuple     = (1, 2)
Dict      = {'A': 1, 'B': 2}
Array     = np.array([1, 2, 3, 5])
pd.DataFrame
```

```
L1 = [1,2,4]

L2 = ['a', 'b', 'c']

T = (L1, L2)

len(T)
Out[5]: 2


T[1]
Out[6]: ['a', 'b', 'c']

type(T)
Out[7]: tuple


(out1, out2) = T
out1
Out[8]: [1, 2, 4]
```

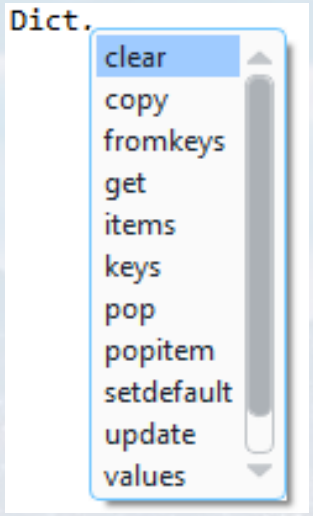
```
String    = 'Hello ' + ''World''
List      = [1, 2, 3, 5, ''World'' ]
Tuple     = (1, 2)
Dict      = {'A': 1, 'B': 2}
Array     = np.array([1, 2, 3, 5])
pd.DataFrame
```




```
Dict = {'A': [1,0,0,0], 'C': [0,1,0,0], 'G': [0,0,1,0], 'T': [0,0,0,1]}

Dict['A']
Out[9]: [1, 0, 0, 0]


type(Dict)
Out[21]: dict
```

check out

```
String    = 'Hello ' + ''World''
List      = [1, 2, 3, 5, ''World'' ]
Tuple     = (1, 2)
Dict      = {'A': 1, 'B': 2}
Array     = np.array([1, 2, 3, 5])
pd.DataFrame
```



try some of the functions like

```
Dict.values()
Dict.pop('A')
Dict.update({'U': [2, 0, 0, 0]})
```

```
String    = 'Hello ' + ''World''
List      = [1, 2, 3, 5, ''World'' ]
Tuble     = (1, 2)
Dict      = {'A': 1, 'B': 2}
Array     = np.array([1, 2, 3, 5])
pd.DataFrame
```

syntax:

[ ] → **arrays** (lists, np.array, data frames → see next week)

( ) → functions or **tuple**

```
T = (a, v)

(a_new, v_new) = T
```

{} → **Dictionaries**

```
Dict = {'A': [1,0,0,0], 'C': [0,1,0,0], 'G': [0,0,1,0], 'T': [0,0,0,1]}

Dict['A']
Out[8]: [1, 0, 0, 0]
```

syntax:

```
Dict.
```

clear
copy
fromkeys
get
items
keys
pop
popitem
setdefault
update
values

type:

```
dir(dict)
```

```
'__class_getitem__',
'__contains__',
'__delattr__',
'__delitem__',
'__dir__',
'__doc__',
'__eq__',
'__format__',
'__ge__',
'__getattribute__',
'__getitem__',
'__getstate__',
'__gt__',
'__hash__',
'__init__',
'__init_subclass__',
'__ior__',
'__iter__',
'__le__',
'__len__',
'__lt__',
'__ne__',
'__new__',
'__or__',
'__reduce__',
'__reduce_ex__',
'__repr__',
'__reversed__',
'__ror__',
'__setattr__',
'__setitem__',
'__sizeof__',
'__str__',
'__subclasshook__',
'clear',
'copy',
'fromkeys',
'get',
'items',
'keys',
'pop',
'popitem',
'setdefault',
'update',
'values']
```

attributes

functions aka methods

```
String    = 'Hello ' + ''World''
List      = [1, 2, 3, 5, ''World'' ]
Tuble     = (1, 2)
Dict      = {'A': 1, 'B': 2}
Array     = np.array([1, 2, 3, 5])
pd.DataFrame
```

Introduction to Unix & Python

Thank you for your attention!