



Astronomy and Python

Using coding activities to teach astronomy

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<https://forms.gle/C1hXshdmpwuZkMQB9>



Dimitrios

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- General Science (Physics Specialism)
- Astronomy Module for BTEC Applied Science

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<https://www.youtube.com/channel/UCf8Sg-cgLNubyCM5Em8eDZg/>

<https://github.com/astroDimitrios/Astronomy>

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Teaching with Notebooks

Online – suitable for virtual learning

Free – open source software and activities

Integrates a **new skill** into students learning

Provides **interactivity** where no standard physical activity exists

Brings **astronomical data** into the classroom

The screenshot displays a Jupyter Notebook titled "solarImagesTeacher" with a menu bar (File, Edit, View, Insert, Cell, Kernel, Widgets, Help) and a toolbar. The notebook content includes a title "Introduction to the Sun", a copyright notice for Dimitrios Theodorakis, and a Python code cell (In [14]:) that imports various libraries like numpy, matplotlib, and astropy. Below the code, there is a section titled "AIM - To access image data on the sun and visualise it in different wavelengths" followed by a "Predict" section with three questions. Another section titled "Let's go: Today's Sun" introduces the SunPy package. A second Python code cell (In [3]:) shows imports for SunPy modules. The interface also shows a "Memory: 188 / 8192 MB" status at the bottom right.

```
In [14]: import numpy as np
import matplotlib.pyplot as plt
from matplotlib import rc
import matplotlib.gridspec as gridspec
import matplotlib.colors as colors
import astropy.units as u
from astropy.utils.exceptions import AstropyWarning
import warnings
import glymur
from IPython.display import Image
%matplotlib inline
warnings.simplefilter('ignore', category=AstropyWarning)
```

AIM - To access image data on the sun and visualise it in different wavelengths

Predict

Have a think about these questions and make some predictions! Be sure to tell someone else what you predict.

- 1) Do you think the sun looks the same in all wavelengths?
- 2) Are there parts of the sun we can only see in certain wavelengths?
- 3) How do astronomers deal with such a large amount of data?

Let's go: Today's Sun

We are going to use a python package called [SunPy](#) to look at images of the sun from SDO and other telescopes. Let's load SunPy now:

```
In [3]: import sunpy.map
from sunpy.database.tables import display_entries
from sunpy.net import Fido, attrs as a
from sunpy.database import Database
from sunpy.io.file_tools import read_file
from sunpy.timeseries import TimeSeries
from sunpy.data.sample import NOAAINDICES_TIMESERIES as noaa_ind
import sunpy.data.sample as sample_data
```

We can use the Heliviewer to get a Jpeg of the Sun from today:



The Jupyter Notebook

Jupyter – Interactive data science online and in many languages

My notebooks are in **Python 3** – widely used by astronomers

Support for the **Markdown** markup language, **LaTeX**, and **Html**.

Can be run **free online**: <https://jupyter.org/try>

Or through Google with Colab or Microsoft with Codespaces

Docs:

<https://jupyter-notebook.readthedocs.io/en/stable/notebook.html>

The screenshot shows a Jupyter Notebook interface. At the top, there's a header with the Jupyter logo, the notebook name 'solarImagesTeacher', and a status '(unsaved changes)'. Below this is a menu bar with options: File, Edit, View, Insert, Cell, Kernel, Widgets, Help. A toolbar with icons for file operations and execution is also visible. The main content area has a title 'Introduction to the Sun' and a subtitle '© Dimitrios Theodorakis GNU General Public License v3.0'. The first code cell, labeled 'In [14]:', contains Python code for importing libraries like numpy, matplotlib, and astropy. Below the code cell, there's a section titled 'AIM - To access image data on the sun and visualise it in different wavelengths' followed by a 'Predict' section with a paragraph and three numbered questions. The second code cell, labeled 'In [3]:', contains code for importing sunpy and related modules. Below this code cell, there's a paragraph about using the Heliviewer to get a Jpeg of the Sun from today.



My Notebooks

2 intro activities (1&2)

12 main activities

Some focus solely on visualisation and others just maths – most are a mix. Teacher version includes answers.

1.5 – 2 hours each

(+2 coding challenges)

Can all be seen in **Binder**:

<https://mybinder.org/v2/gh/DimitriosAstro/Astronomy/master?filepath=Code>

AstPy Number	Description	Data Files	Comments
1	Intro to Python and Numpy		
2	Challenge: Bouncing Balls		Bit harder than intro - adds plotting + animation.
3	Stellar Fusion	Nuclear masses and binding energies (csv)	Binding energy anim and calcs including coulomb potential well.
4	Solar Images	Various SDO HMI and AIA FITS	Getting and potting SDO/SOHO Images.
5	Solar Radiation		Blackbody rad, Wien's law etc. Effective temperature of planets.
6	Sunspots	SDO HMI Fits	Calculation of solar rotation period (interactive and automatic). Sunspot identification and sunspot tracking (automatic).
7	Lunar Surface	LOLA DEM, LOLA Raw Topographic Data for Catalan Crater	Annotating your image of the moon from a telescope. Calculating resolution, crater heights and diameters. Comparing to Lunar Reconnaissance Orbiter (LRO) and Lunar Orbiter Laser Altimeter (LOLA) data.
8	Planets	Orbital data, density, radius, mass etc.	Comparing planets by looking at data from the NASA Planetary Factsheet such as mass and radius etc. Looking briefly at exoplanet detection and observational bias.
9	Planetary Interiors	Structure of the planets csv and chemical composition of the Earth csvs.	Visualising the interiors of planets, visualise the chemical composition of the Earth's interior.
10	Planetary Atmospheres	Chemical composition of planetary atmospheres. Exobase altitudes and temperatures (with escape velocities).	Visualising and comparing the chemical composition of planetary atmospheres. Calculating whether a planet can hold onto a gas using escape velocities and kinetic theory.
11	Earth's Heat	Geothermal gradient data and pressure data.	Visualise the thermal gradient of the Earth. Model the geotherm of the lithosphere. Calculate energy transfer via conduction and latent heat.
12	Earth's Atmosphere	Data to construct the international standard atmosphere (ISA) model.	Visualising the temperature, pressure, density, and speed of sound variation with altitude using the ISA model.
13	Martian Surface		COMING SOON!
14	Planetary Rings	Data on the ring structure for all gas giants and data on their moons.	Visualising the ring structure of Saturn and the other gas giants. Calculating roche limits for some moons.
15	Ring Dynamics	Data on Saturns moons.	Visualising the Roche limit with an N-body simulation. Calculating the locations of mean-motion resonances. Looking at bending and density waves, and the effects of shepherd moons.



Example Notebook

Jupyter solarImagesTeacher (unsaved changes)

Join this repo's Video Chat Visit repo Copy Binder link

File Edit View Insert Cell Kernel Widgets Help Not Trusted Python 3

Run Download GitHub Binder Memory: 188 / 8192 MB

Introduction to the Sun

© Dimitrios Theodorakis GNU General Public License v3.0 <https://github.com/DimitriosAstro/Astronomy>

```
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AIM - To access image data on the sun and visualise it in different wavelengths

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import sunpy.data.sample as sample_data
```

We can use the Helioviewer to get a Jpeg of the Sun from today:

All activities start with the **AIM** and some **Predictions**

Most activities have some requirements to import first

Activity starts at **Let's go:**



Example Notebook

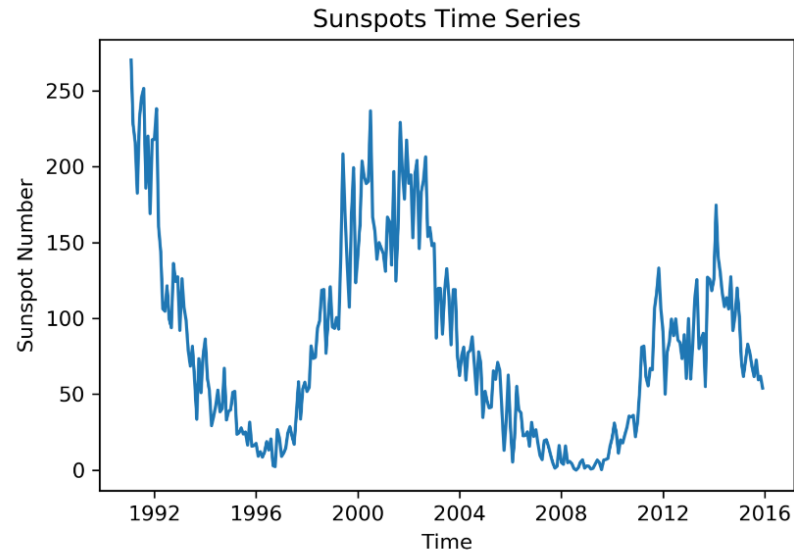
Final Comments
often with
suggestions on
where to go next
for more info

Challenge activity
suggestions

Could be used as
an assessment

Easy to hard

References and
Resources



The sun has a 11 year cycle which you can see from the graph. You can also see that sunspot activity at the peak of the cycle has been decreasing over the last two decades. Visit the docs here to see this code snippet and the smoothed (time averaged) version of this series.

Challenge

- 1) Make LASCO plots for the other detectors
- 2) Make an animation of the flare shown above using the code in the SunPy docs
- 3) Make a graph of sunspot number vs time from the 19th century to today using: <http://www.sidc.be/silso/datafiles>

References and Resources

SunPy - <https://sunpy.org/>
Pereria, T. M. D., https://folk.uio.no/liago/teaching/ast2210/sunpy_aia/ - Sunspot animations
Sunspot Number Data - SILSO, Royal Observatory of Belgium, <http://www.sidc.be/silso/datafiles>
Source keywords for searches - https://sdac.virtualsolar.org/cgi/show_details?keyword=SOURCE
Instrument keywords for searches - https://sdac.virtualsolar.org/cgi/show_details?instrument=HMI
SDO Images from today - <https://sdo.gsfc.nasa.gov/data/>
HMI Instrument page - <http://hmi.stanford.edu/>

In []:



Improvements

- Add space for students to write answers (make sure Q's have numbers)
- Place for student name and class
- Add contents at the top to make navigation easier
- Add inline images using HTML where possible
- Difficulty rating for activities?

PLAN:

- Example live notebook
- How to upload the files I sent to jupyter.org/try
- Breakout rooms so you can try one of the activities I sent via email
- Final 5-10 mins back to round up and ask questions

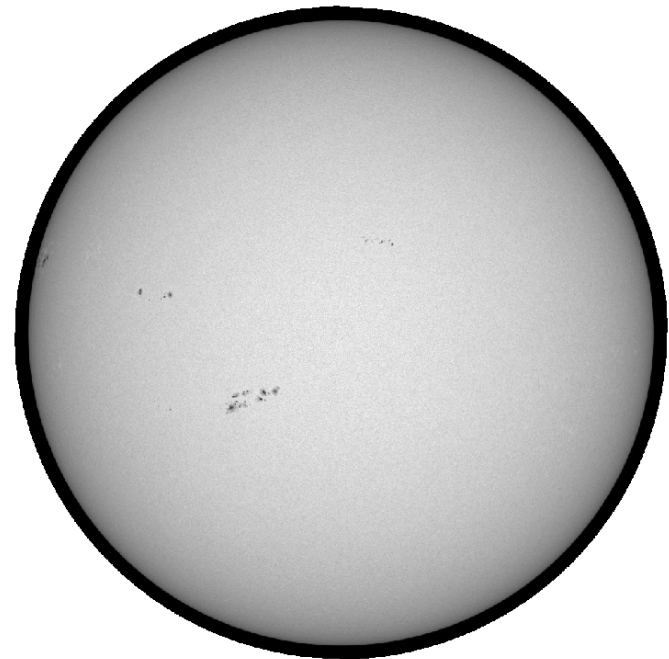


Example LIVE Notebook

<https://github.com/astroDimitrios/Astronomy/tree/master/Code/AstPy-6%20Sunspots>

AstPy-6 Sunspots

- Identification of sunspots in SDO HMI continuum images
- Calculation of the sidereal and synodic rotation periods of the sun
- Automatic identification and tracking of sunspots using SunPy (challenge)





Where next?

I will continue to make more notebooks!

It would be great if this became a community project!

Be sure to email me if you're interested in:

- Making notebooks
- Using/testing notebooks in your classroom
- Translating notebooks
- Want to chat about astronomy and python!



Any Questions?

Thanks! Don't forget to star my GitHub repo
and follow me on Twitter and YouTube.



<https://forms.gle/hN3429sc4hjvt5iL6>