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ThaiPASS 2018
Why we use Python

Lawrence Bilton, James Keegans, Thomas Lawson

8/10/2018

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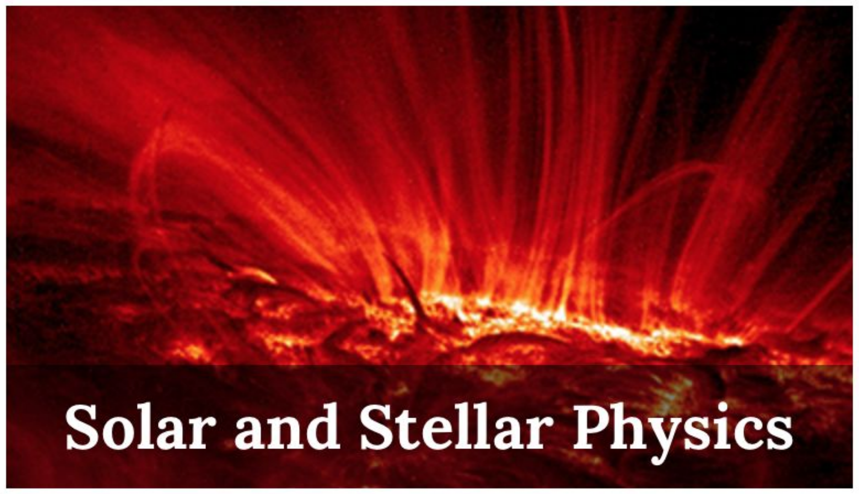
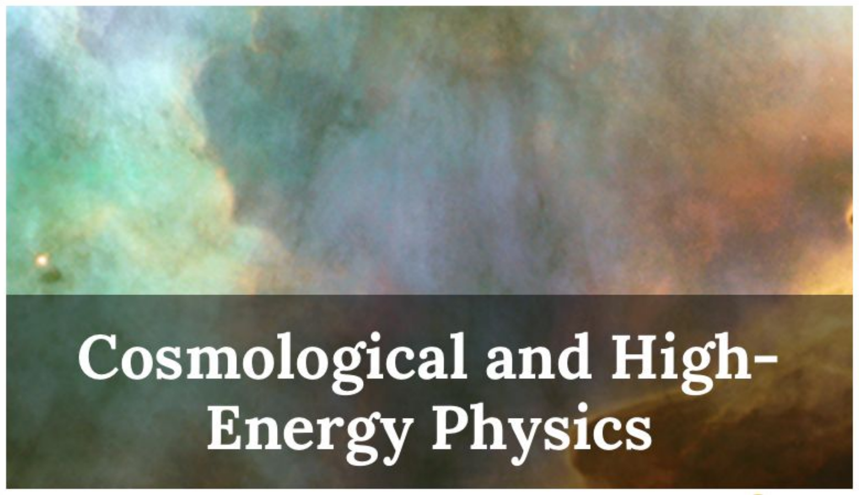
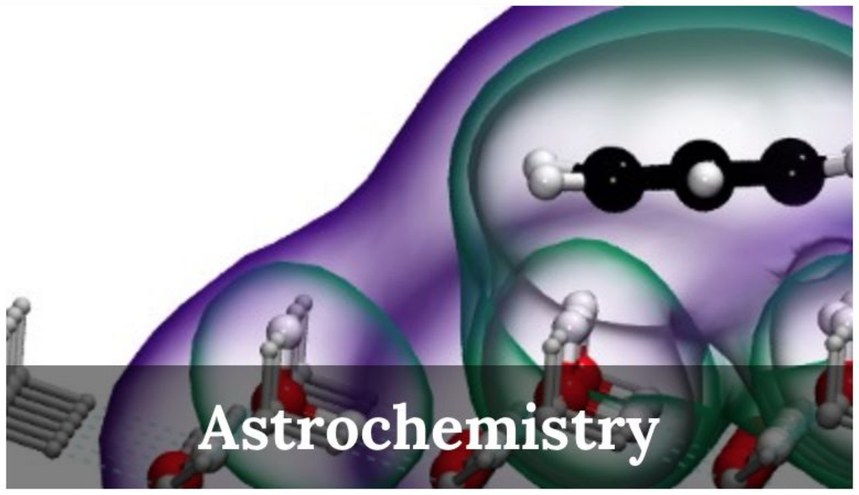
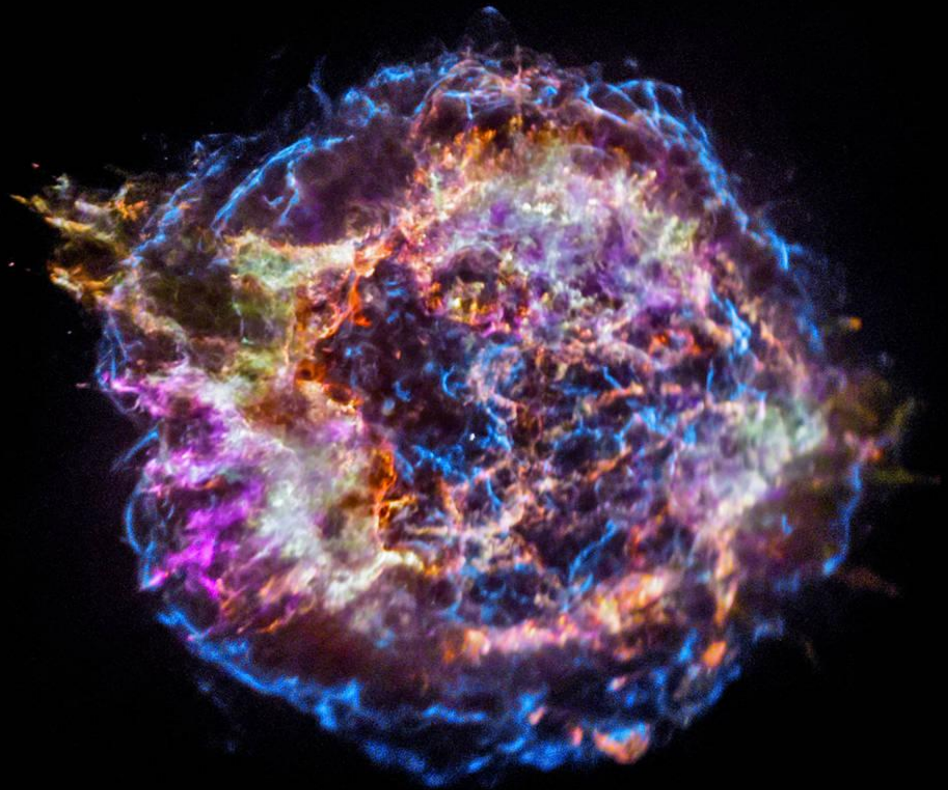
Introduction: who are we and what do we do?


Solar and Stellar Physics


Galaxy and Galaxy-Cluster Physics


Cosmological and High-Energy Physics


Astrochemistry



Cassiopeia A - A dying star throwing its material into the wider universe.

Image credit: NASA/CXC/SAO

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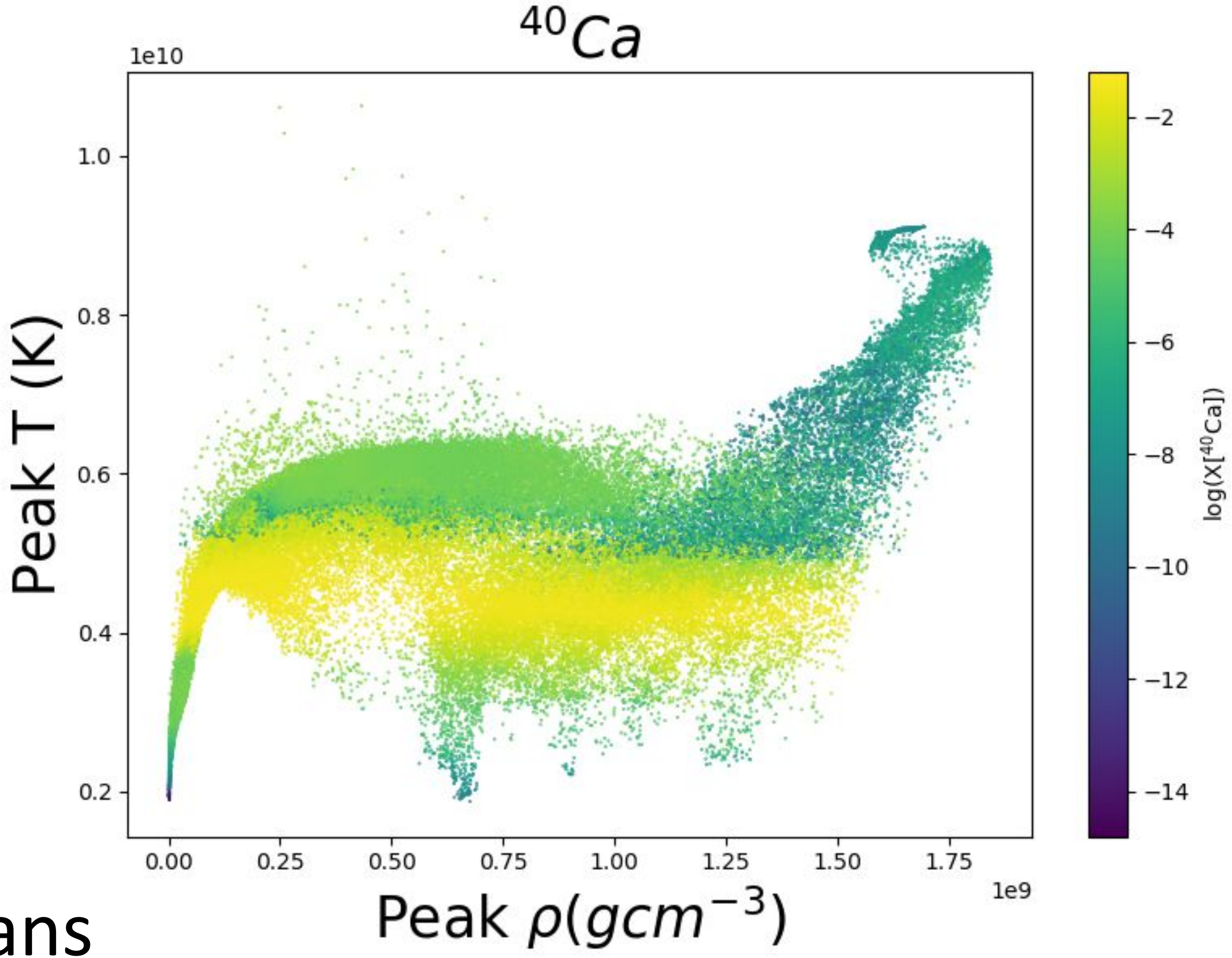
This plot shows the distribution of ^{40}Ca in a model of a type Ia supernova.

The most abundant isotope of calcium.

This shows where in the star ^{40}Ca is produced by Temperature and Density



Mr James Keegans

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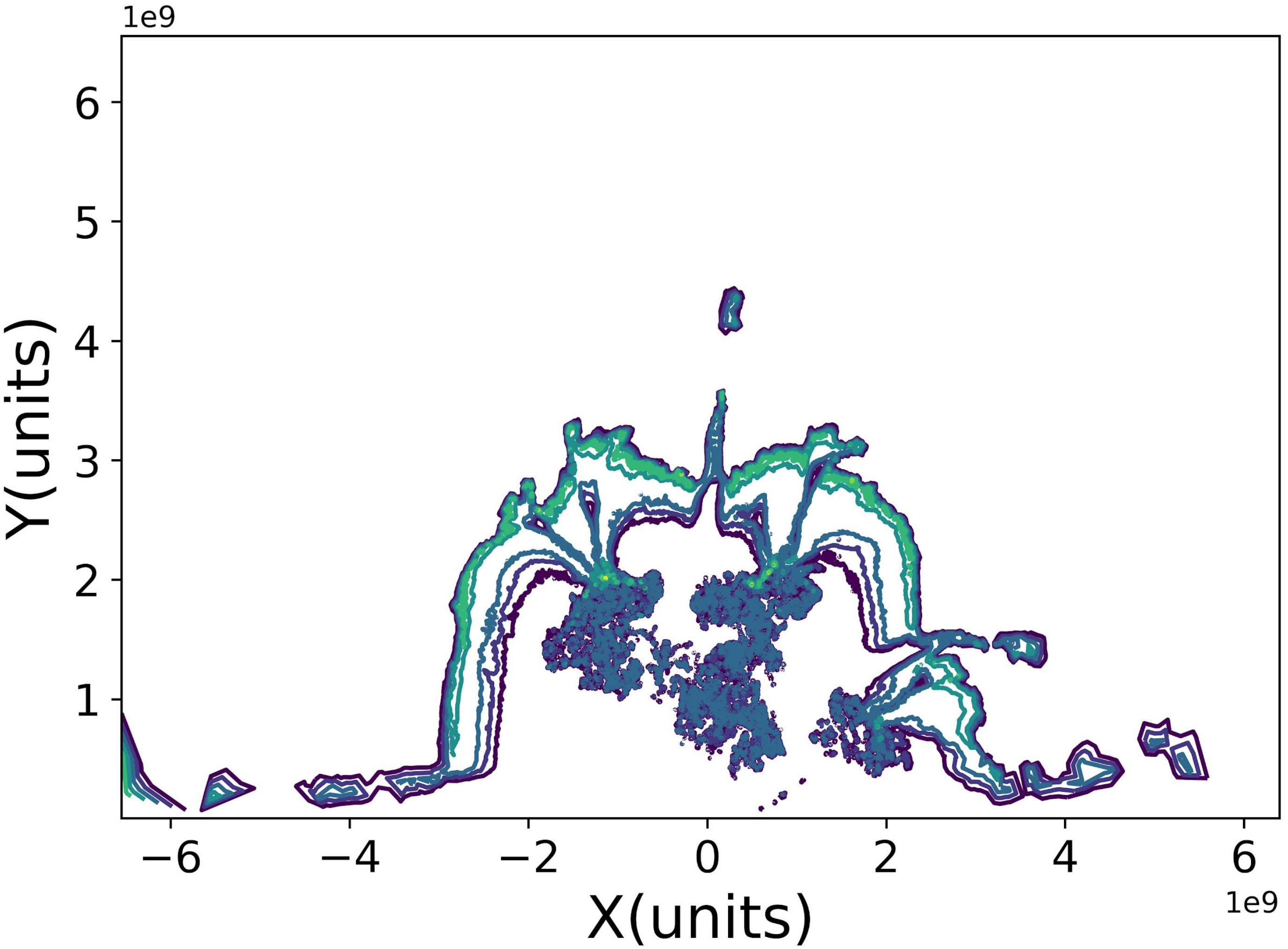
Here you can see where it is produced in X/Y coordinates

It's not symmetric - just like the real SN explosion!

(but there are differences…)



Mr Lawrence Bilton

Observational Astronomer -Handles real data from telescopes

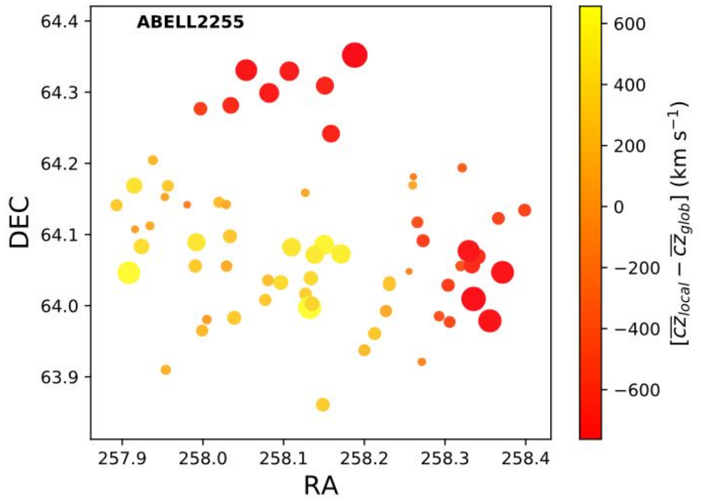
Data Handling

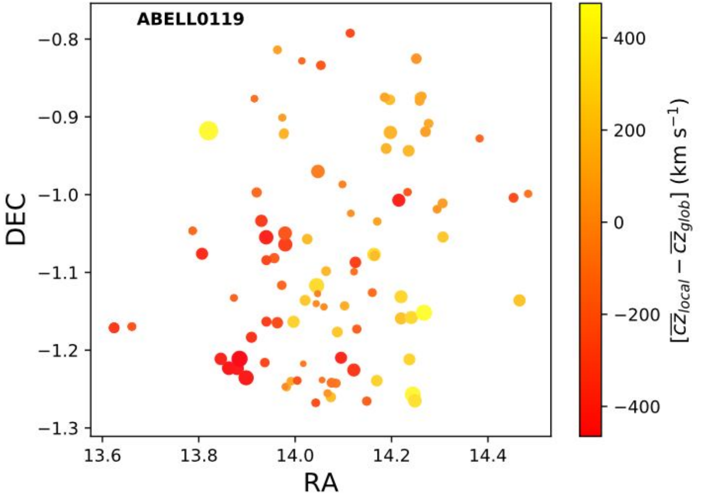
For example:

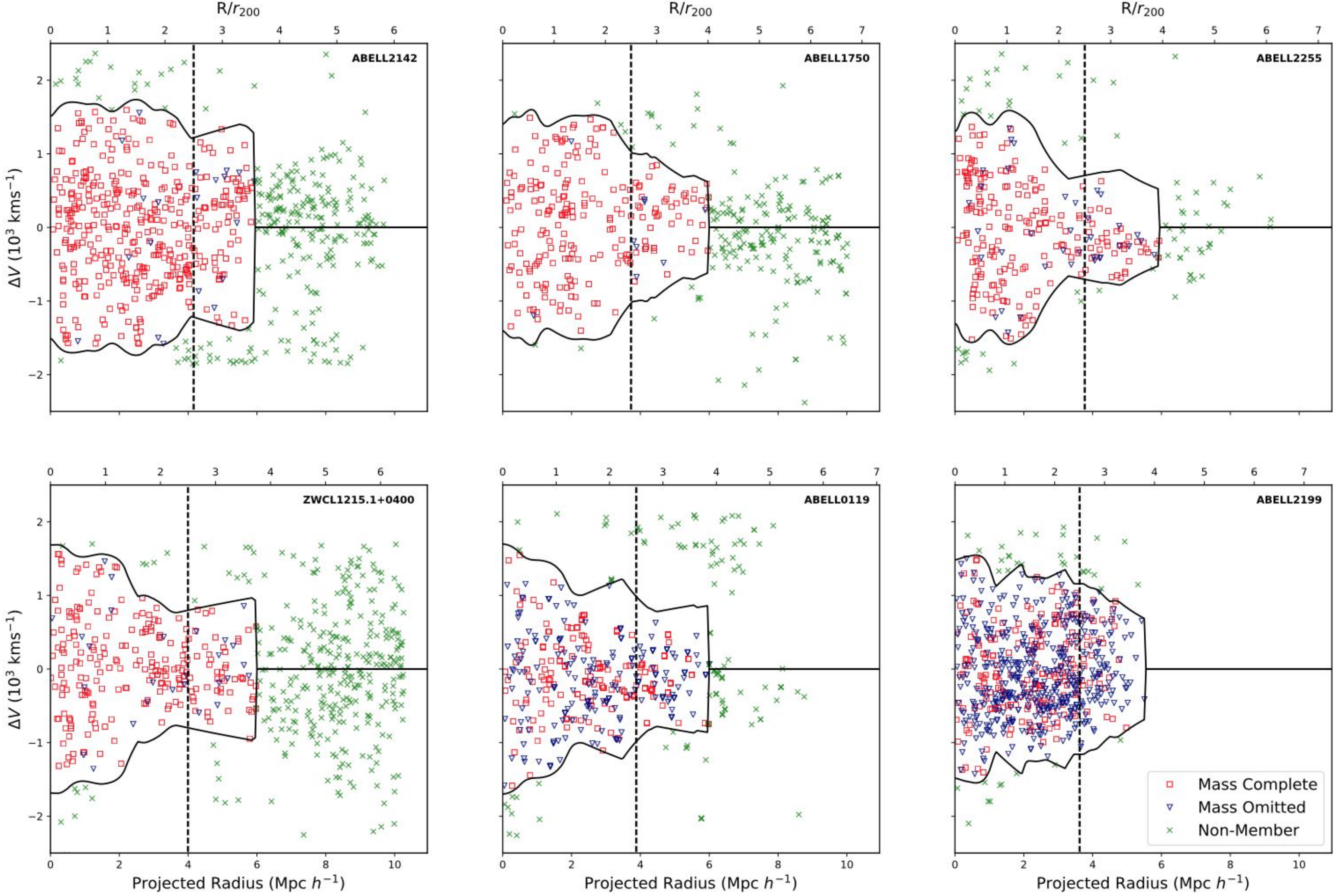
- Cross-Matching -Bringing data together
- Numerical Analysis

Data Visualisation

Allows to present the results of the data handling above (basically, make pretty looking plots/diagrams).






ABELL2142
ABELL1750
ABELL2255
ZWCL1215.1+0400
ABELL0119
ABELL2199
R/r_{200}
ΔV (10^3 kms^{-1})
Projected Radius (Mpc h^{-1})
Mass Complete
Mass Omitted
Non-Member

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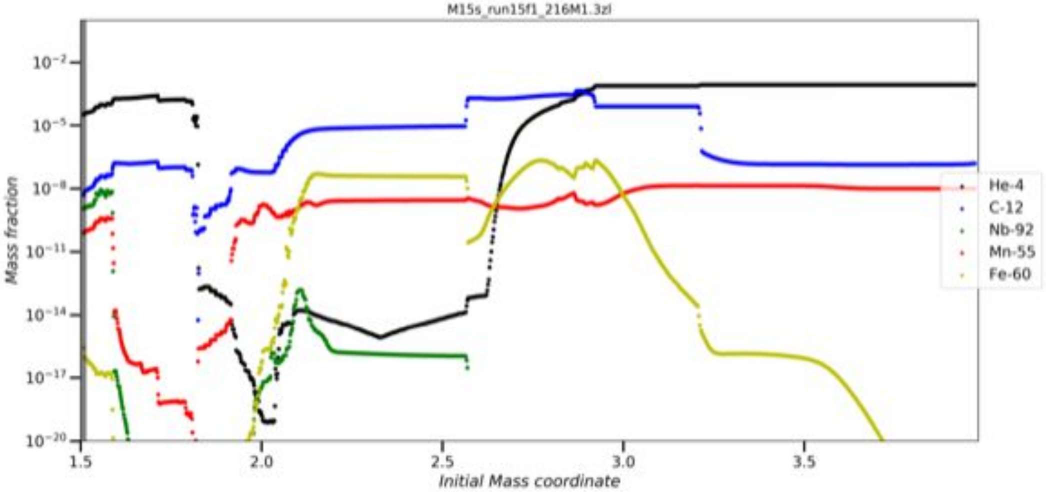
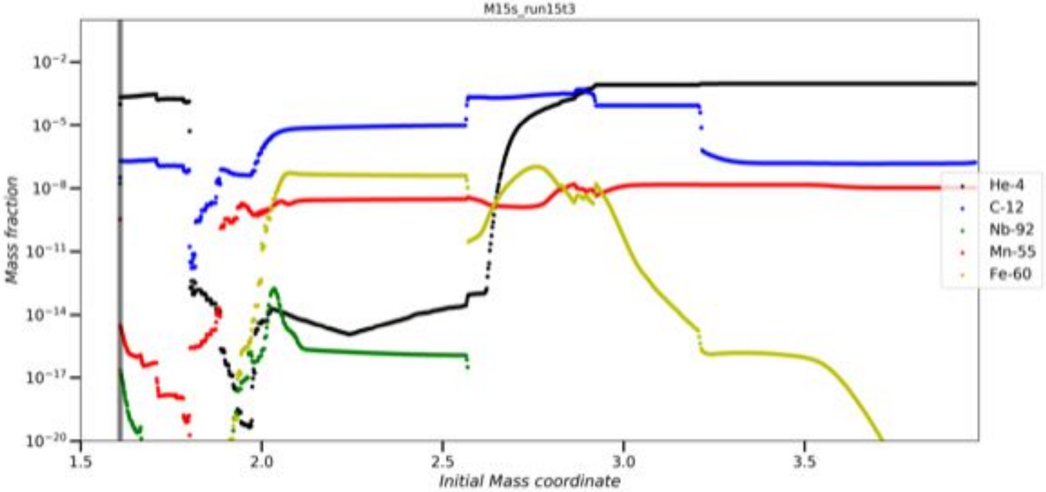
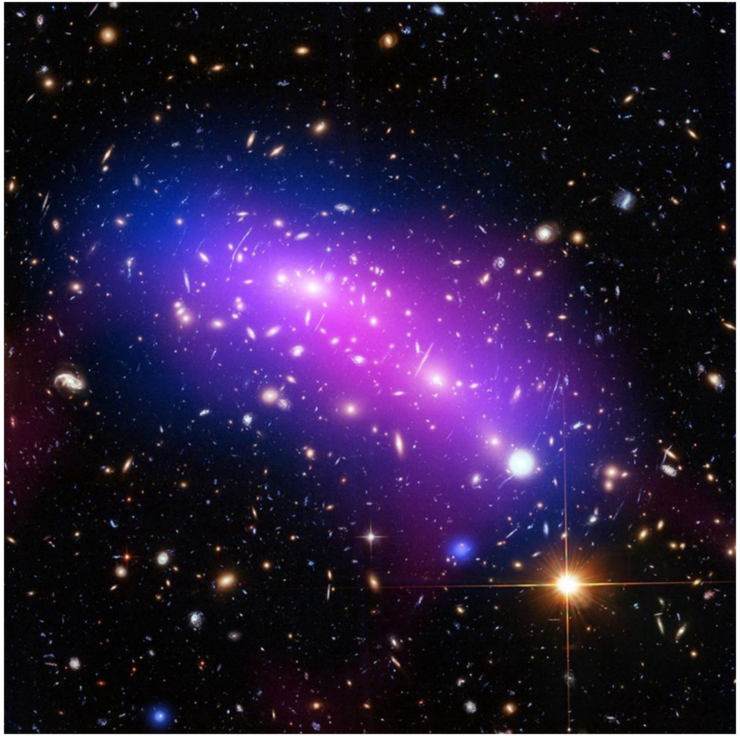
Mr Thomas Lawson





Mr Matthew Hunt (UoH)



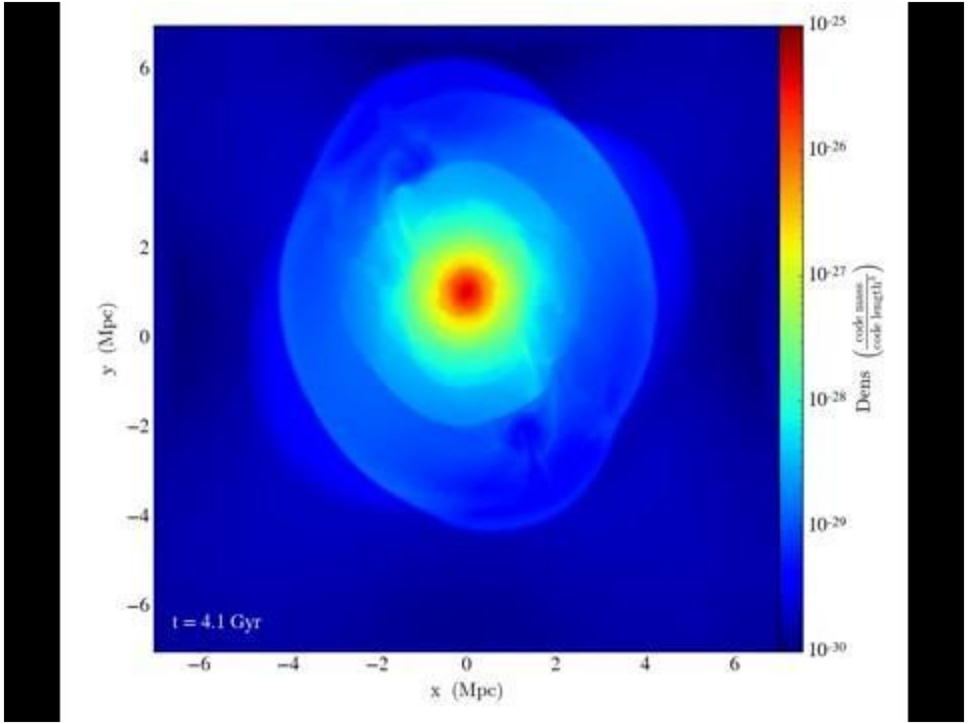


Image credit: X-ray: NASA/CXC/CfA/M.Markevitch et al.; Lensing Map: NASA/STScI; ESO WFI; Magellan/U.Arizona/D.Clowe et al.; Optical: NASA/STScI; Magellan/U.Arizona/D.Clowe et al.Composite from Ethan Siegel Medium.com

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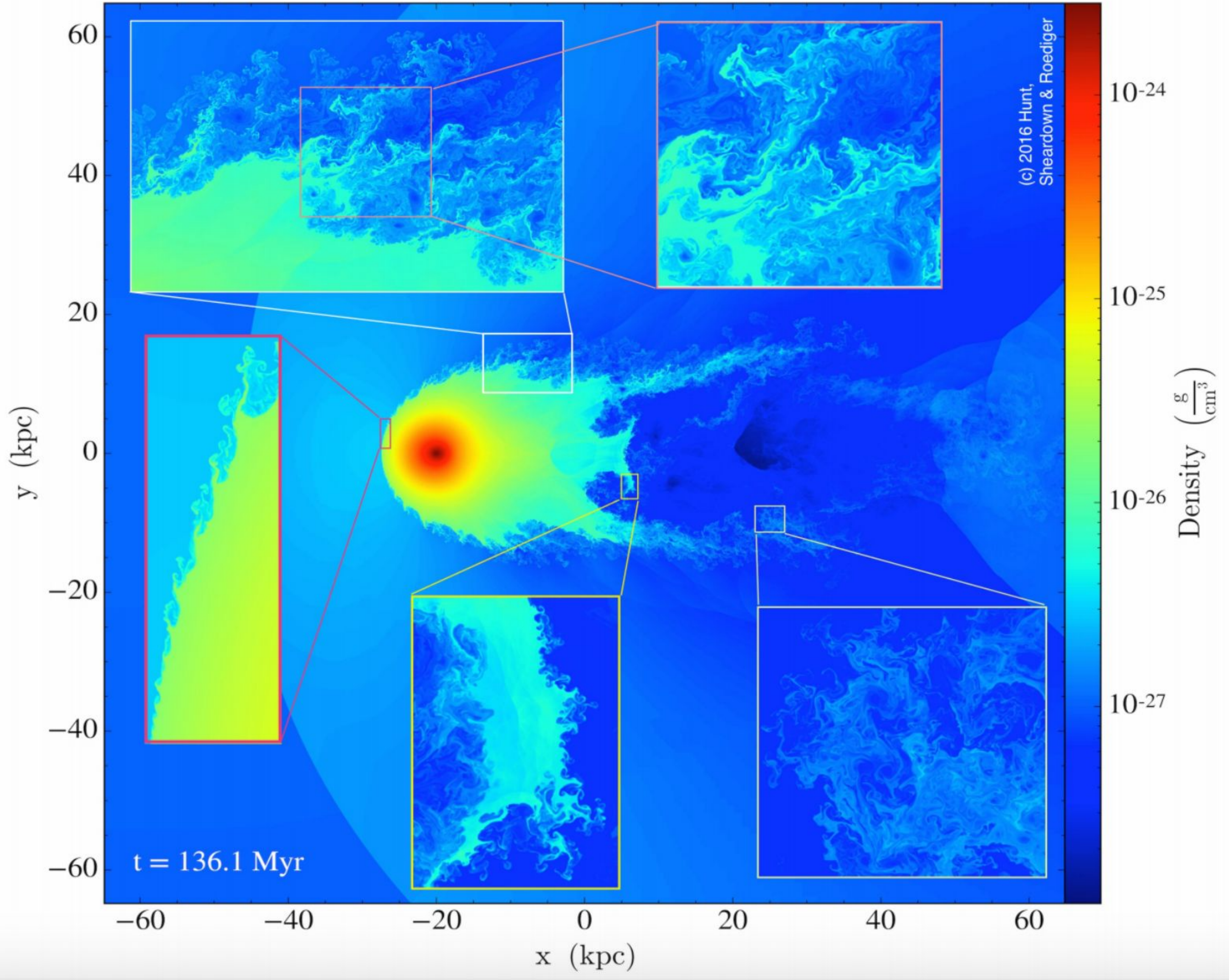
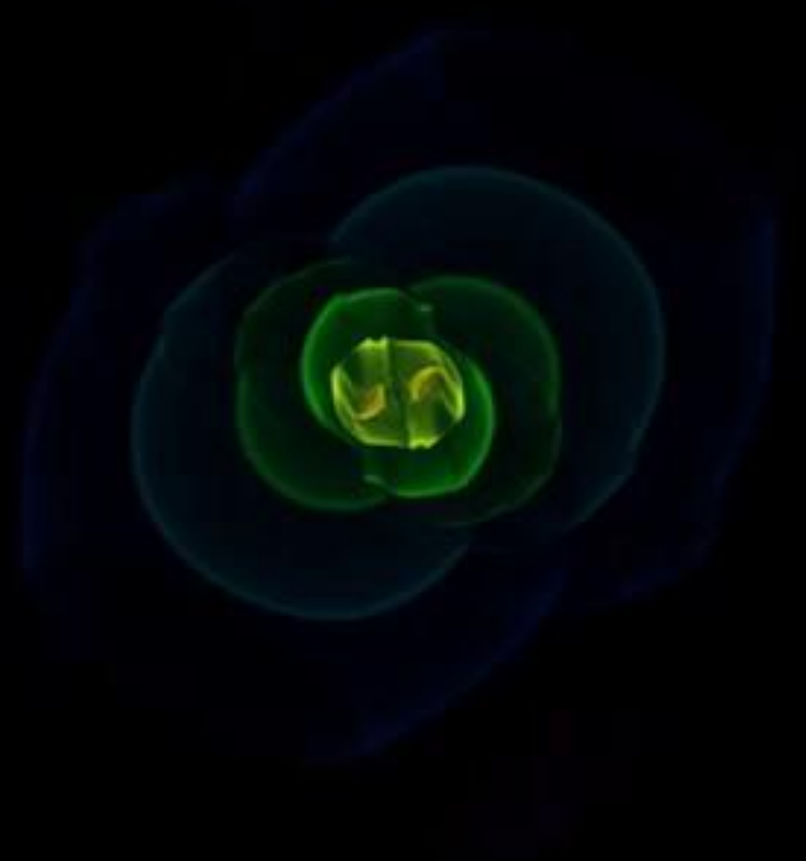
Mr Matthew Hunt (UoH)





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Introductory Notebooks - Progress and Questions

You should, after working through these, be able to use

1. Lists and arrays
2. Loops
3. Mathematical operations
4. Read and write to files
5. Plot graphs
6. Define functions…

Many useful tools - and the start of learning python!

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What we're going to do:

9:00 - 9:20 - Introduction to Python

9:20 - 10:00 - Problem solving - introductory and advanced notebooks

Break

10:30 - 12:00 - Kepler's Laws of Planetary Motion

Lunch

13:30 - 15:00 - HR Diagrams and Stellar Evolution

Break

15:30 - 17:00 - Kepler's Laws and Numerical Derivatives

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Any Questions?

Please raise your hand

OR

Add your question to this list - and we can cover this with everyone:

https://docs.google.com/document/d/1w06yUGz8Em_XtoV2YKJTZvTa42JoMHc7GNtKkrXvE2I/edit?usp=sharing

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Notebooks and Mini Tasks

The UK team will come round and help you with any problems you had with the starter pack.

We will also help you with the work you've started on the mini tasks.

When you're happy with these, we'll be ready to move on to the next step.

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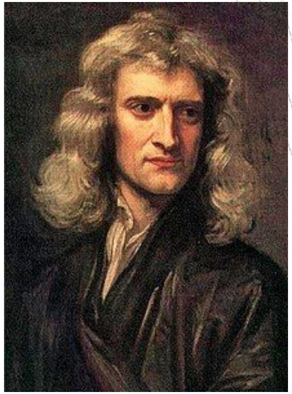
History

- Between 1609 and 1619 Johannes Kelper outlined his famous 3 laws of planetary motion, based on observations made by Tycho Brahe.
- In 1687 Sir Isaac Newton produced a theoretical explanation for why the orbits are their shape and allowed for the calculation of velocities that a satellite would need to reach orbit.



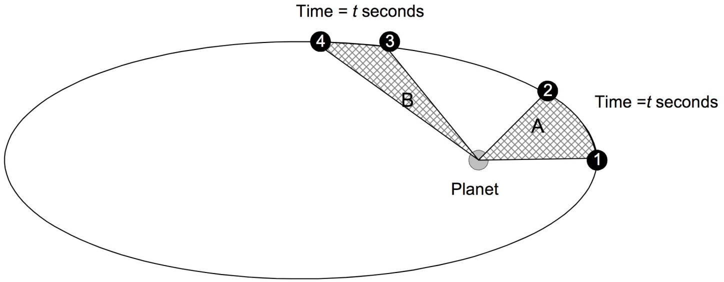
Kepler's first law

- The first law states that a body orbiting around a larger body will describe an orbit that is an ellipse, with the planet at its foci.
- An ellipse is a circle with a degree of eccentricity, this is denoted by e.

This eccentricity is defined by the fraction of the ellipse which separates the focus from the center

Kepler’s second Law

- If we draw a line from the orbiting object to the planetary loci, the line will sweep out the same area in equal intervals of time.
- In the image to the right we have two arcs of orbit. The time these arcs take to pass through is the same, as is the area of A and B.



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Kepler’s third law

$$T^2 = \frac{4\pi^2 a^3}{GM}$$

The third law states that the square of the orbital period is proportional to the cube of the major axis of orbit, and the mass of the object that is being orbited.

This means that as the orbit gets bigger, the orbiting object will take longer to complete a single orbit.

All other symbols in equation to the left are constants.

G is the universal gravitational constant

Why are they useful

Simple laws, but can be used with newton’s gravitational laws to describe the orbits of bodys.

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Newtonian Gravity

$$F = \frac{GM_1M_2}{r^2}$$

- In Newtonian mechanics any two objects with mass attract each other, over a distance.
- Imagine two masses, m1 and m2, separated by a distance r.
- The attractive force between them follows a r-squared law.

Deriving orbital velocity

$$F = \frac{GM_1M_2}{r^2}$$

$$F = \frac{mv^2}{r}$$

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Session 1: Kepler's Laws

Defining functions

Plotting

Arrays and loops

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Session 2: The Hertzsprung-Russell Diagram: Brief Introduction

We will cover:

- Brief history of the concept.
- Colour-Magnitude Diagrams (CMD).
- The Hertzsprung-Russell Diagram.

The Hertzsprung-Russell Diagram: Brief Introduction

History

- In the late 1800s and early 1900s large-scale spectroscopic survey observations on stars were made.
- Led to the spectral classification of stars.
- Found that the strength of certain spectral features (e.g.. hydrogen lines) can indicate a star’s temperature.
- Knowing the **apparent magnitude** of stars within the same cluster/group of stars means we can convert to **absolute magnitude**, indicating how luminous the star is.


Henry Russell


Ejnar Hertzsprung

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Wait!...What is a magnitude?

It is how astronomers measure the brightness of an object in the night sky.

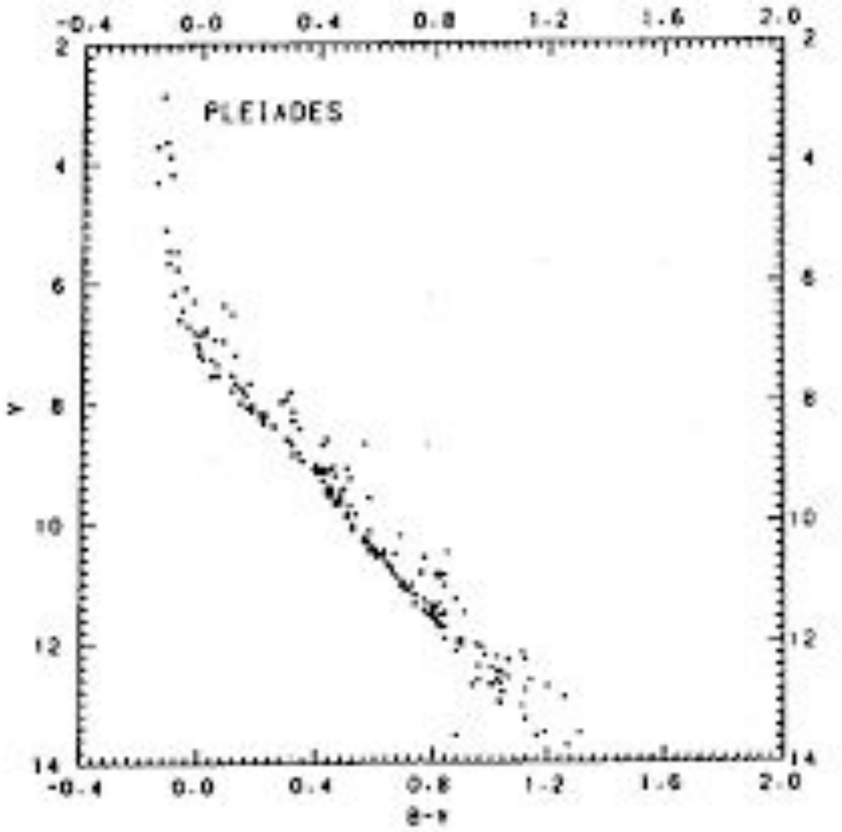
The confusing part?... the more negative the magnitude is, the brighter the object (For example: StarOne = -5 is brighter than StarTwo = 3.

Apparent Magnitude - The brightness of an object as seen from the Earth.

Absolute Magnitude - The calculated brightness of an object as seen from the object. (i.e. if you stood next to the object)

The Hertzsprung-Russell Diagram: Brief Introduction

- The magnitudes of stars can be recorded through different “Filters” (at specific wavelengths of visible light).
- If we find the difference in magnitude between two filters, this provides us with the colour of a star (for example: g-r in mini project one).
- The Pleiades is an **Open Cluster** of stars (see right), with V filter vs. the B-V colour.
- The Pleiades contains a “bluer”, “hotter” and “younger” population of stars.



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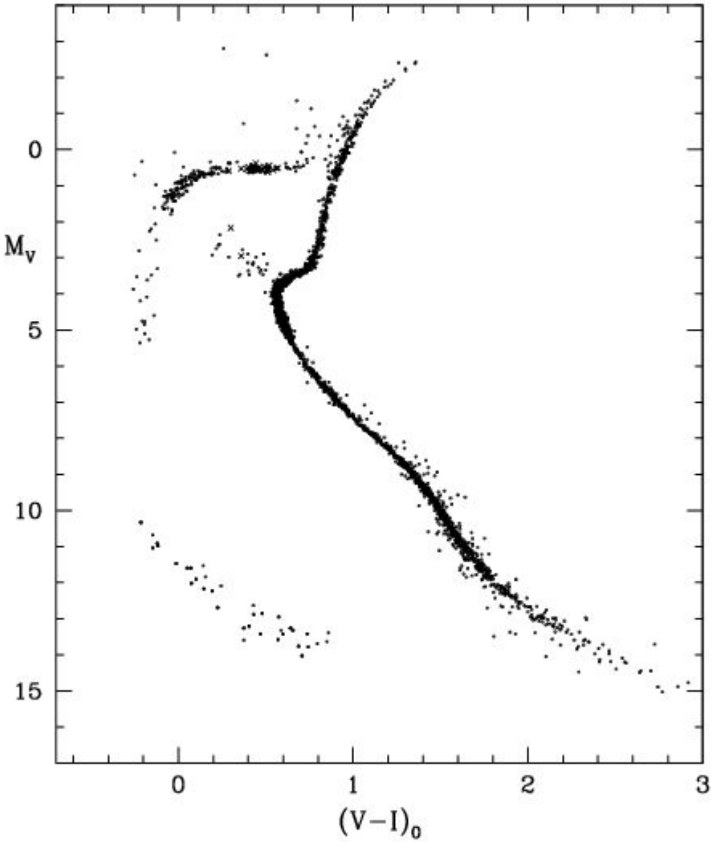
The Hertzsprung-Russell Diagram: Brief Introduction



- To the right is the **Globular Cluster** NGC5128 with the absolute magnitude in V filter vs. the V-I colour.
- Globular clusters contain on average “redder”, “cooler”, and “older” populations of stars.
- Notice something different about this CMD compared to the Pleiades?...

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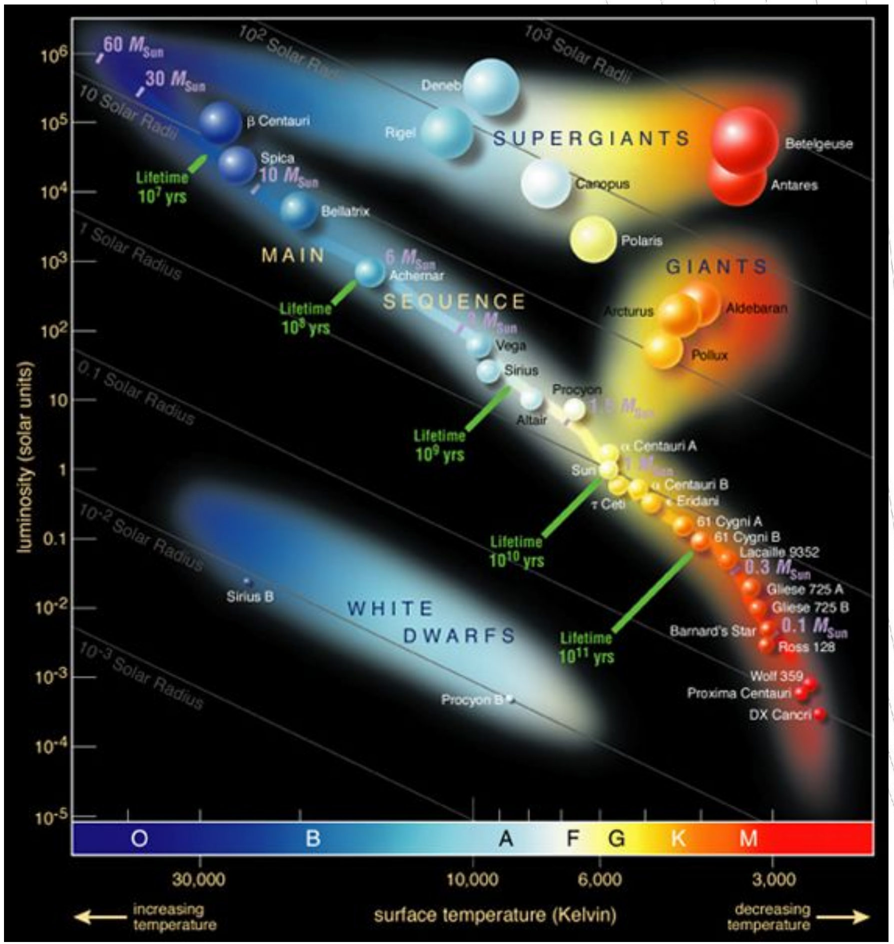
The Hertzsprung-Russell Diagram: Brief Introduction

- CMDs lead to the Hertzsprung-Russell diagram (see right).
- Allows us to see determine and understand the evolution of a star from its birth to death.



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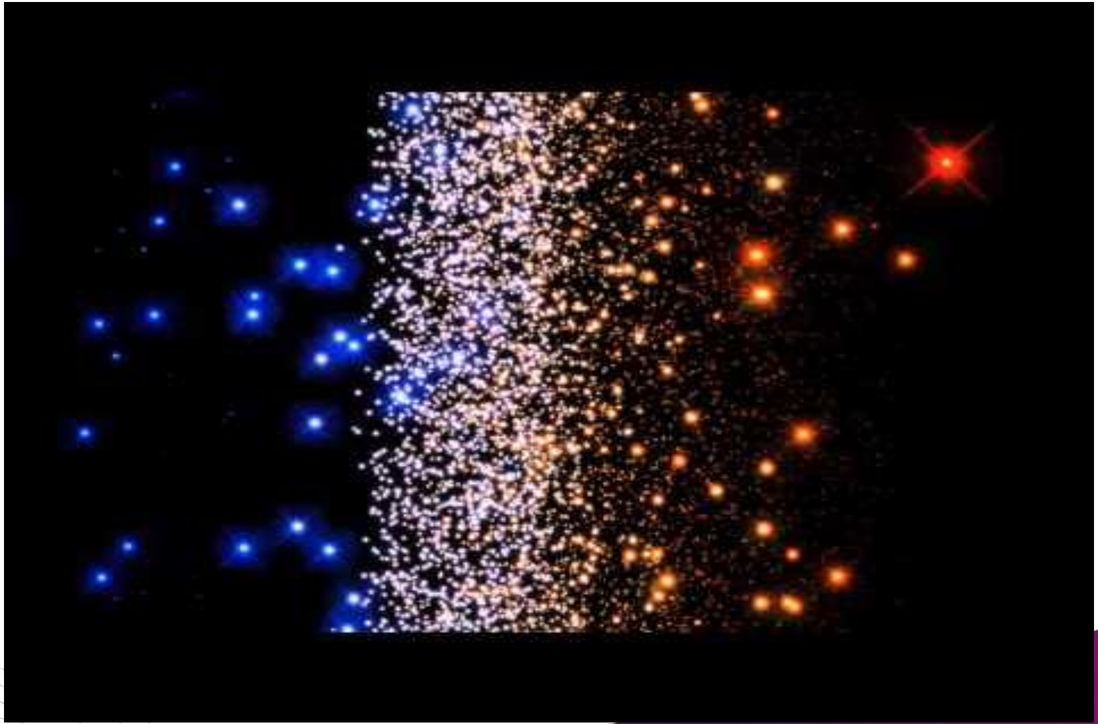
The Hertzsprung-Russell Diagram: Brief Introduction



Session 3: Linear solver - Forward Euler

- Leonhard Euler was a prolific mathematician of his time, at his peak, producing one mathematical paper per week.
- This led to the development of the **Forward Euler Method** in his book Institutionum calculi integralis.
- This method is simple, but powerful. During this morning you will find out how to implement this method to solve solutions for keplerian orbits.

What is the Euler method?

- The Euler method is a numerical first order, ordinary differential equation solver.

- This means that it is a method of numerically integrating an equation.

- The Forward Euler can be defined as:

$$y_{n+1} = y_n + hf(t_n, y_n).$$

Deriving the Euler method with Taylor Series

- We can derive the Euler method with the Taylor Expansion:

$$f(a)+\frac{f'(a)}{1!}(x-a)+\frac{f''(a)}{2!}(x-a)^2+\frac{f'''(a)}{3!}(x-a)^3+\cdots,$$

Or.. $$\sum_{n=0}^{\infty}\frac{f^{(n)}(a)}{n!}(x-a)^n,$$

- This eventually gives:

$$y(t_0+h)=y(t_0)+hy'(t_0)$$

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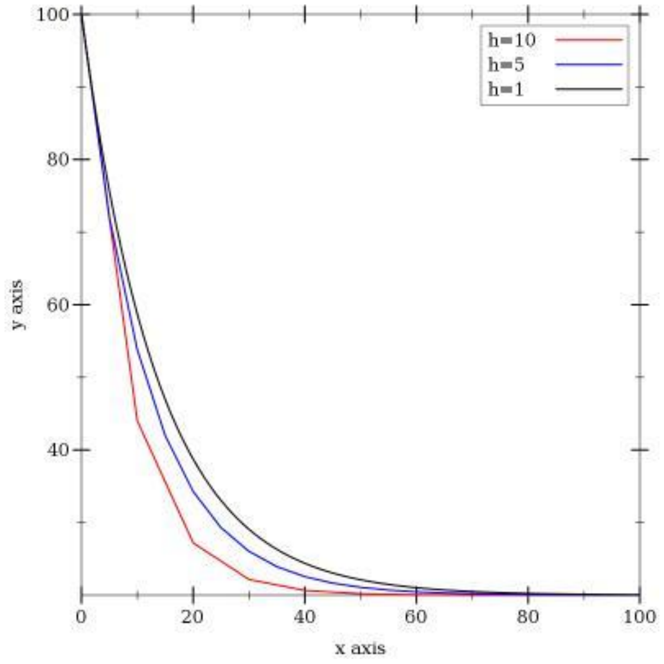
How does it work?

- It achieves this by taking a known differential equation, and treating each point as the slope of a tangent line to the curve.
- By taking small steps along the curve and solving the next step we can compute an approximation to the curve.
- The size of the step impacts the accuracy of the approximated curve



Numerical derivative

$$f'(x) = \frac{f(x+\delta) - f(x)}{\delta}$$

derivative

A key part of the equation for the Euler method is calculating the derivative

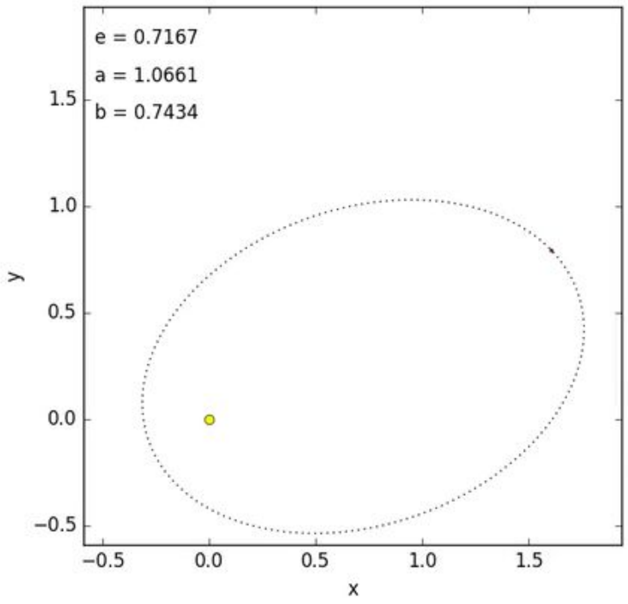
Calculating the derivative computationally can be estimated using the following simple equation:

This works by calculating the difference between your function at the value you input, and at a step forward, delta.

This method of estimating the derivative is only true if the delta value is small enough.

Where would we use this method?

- The primary reason an astronomer codes is to perform numerical calculations.
- Think back to the Kepler mini project…
- We can continue to expand on this mini project by implementing the Euler method to model the orbits themselves.



Creating a solver

You will be using the Euler method to calculate the orbital path of an object.

This will require four key parameters: x position, y position, x velocity contribution, y velocity contribution.

We can calculate the next step in the orbit using the derived velocity and acceleration, and putting them into the Euler equation.

$$x(t_0 + h) = x(t_0) + hx'(t_0)$$

$$y(t_0 + h) = y(t_0) + hy'(t_0)$$

$$\mathbf{v}_x(t_0 + h) = \mathbf{v}_x(t_0) + h\mathbf{v}'_x(t_0)$$

$$\mathbf{v}_y(t_0 + h) = \mathbf{v}_y(t_0) + h\mathbf{v}'_y(t_0)$$

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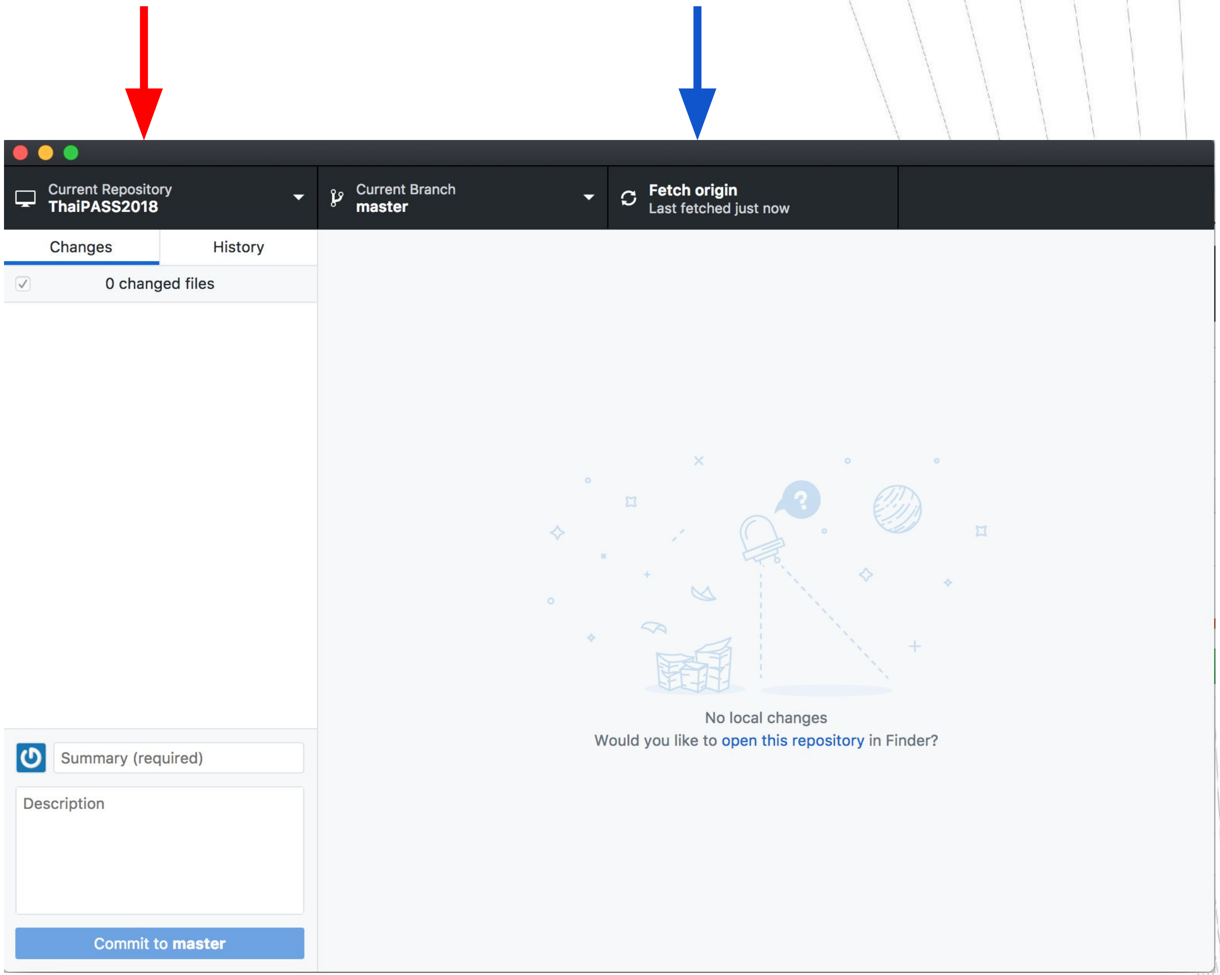
Let's update your ThaiPASS GitHub Directory.



- Go to GitHub Desktop, the programme used to download the 'StarterPack' files.
- Make sure you have the "ThaiPASS2018" repository selected (red arrow).
- Then, click on the "Fetch origin" button (blue arrow).
- This will now update and download new tasks! :-)