

# **The Universe on the Grandest Scales**

Jim Barrett  
(with inspiration from Sean Elvidge)

# Me!



- PhD Student at University of Birmingham
- Gravitational Waves and Binary Evolution
- More on this later in the week

# Me!

Born 1991  
Lowestoft, Suffolk

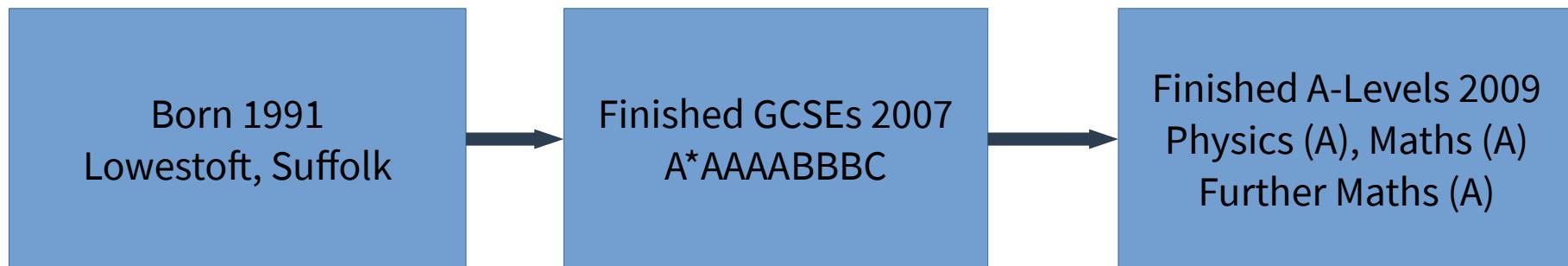
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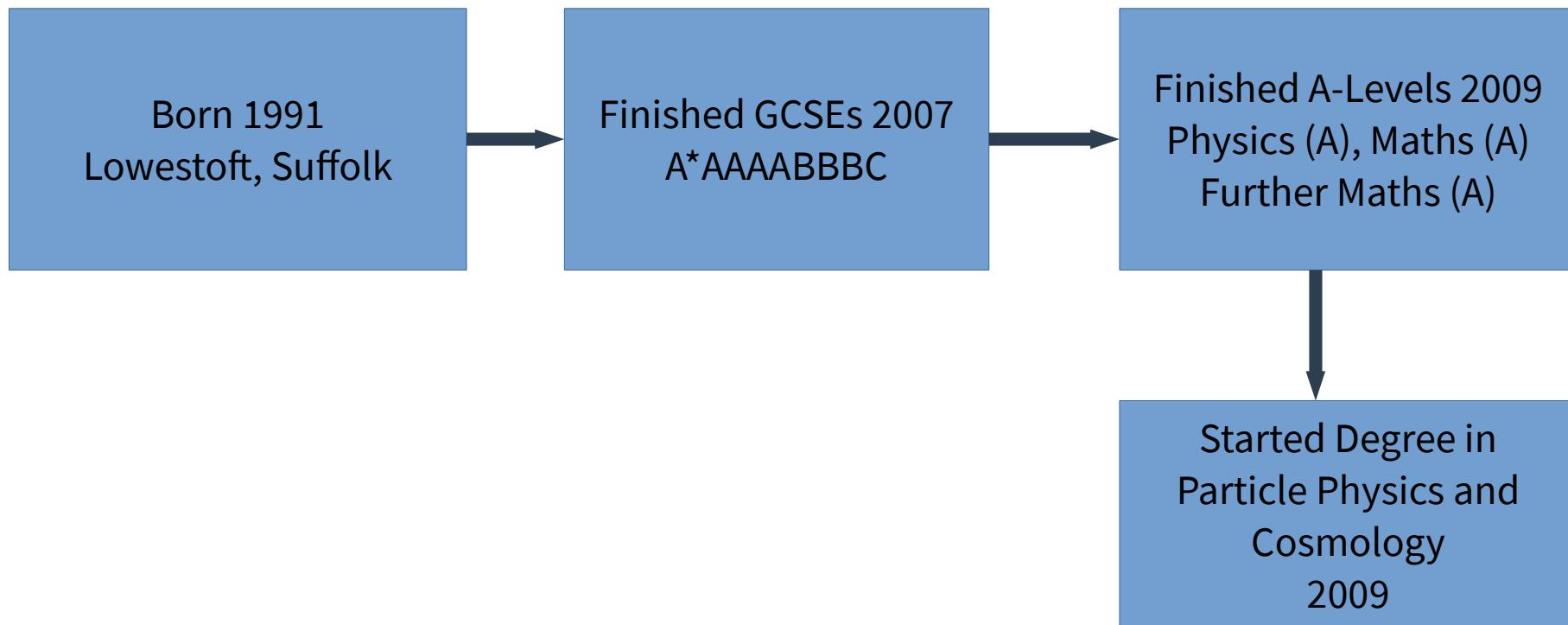


Finished GCSEs 2007  
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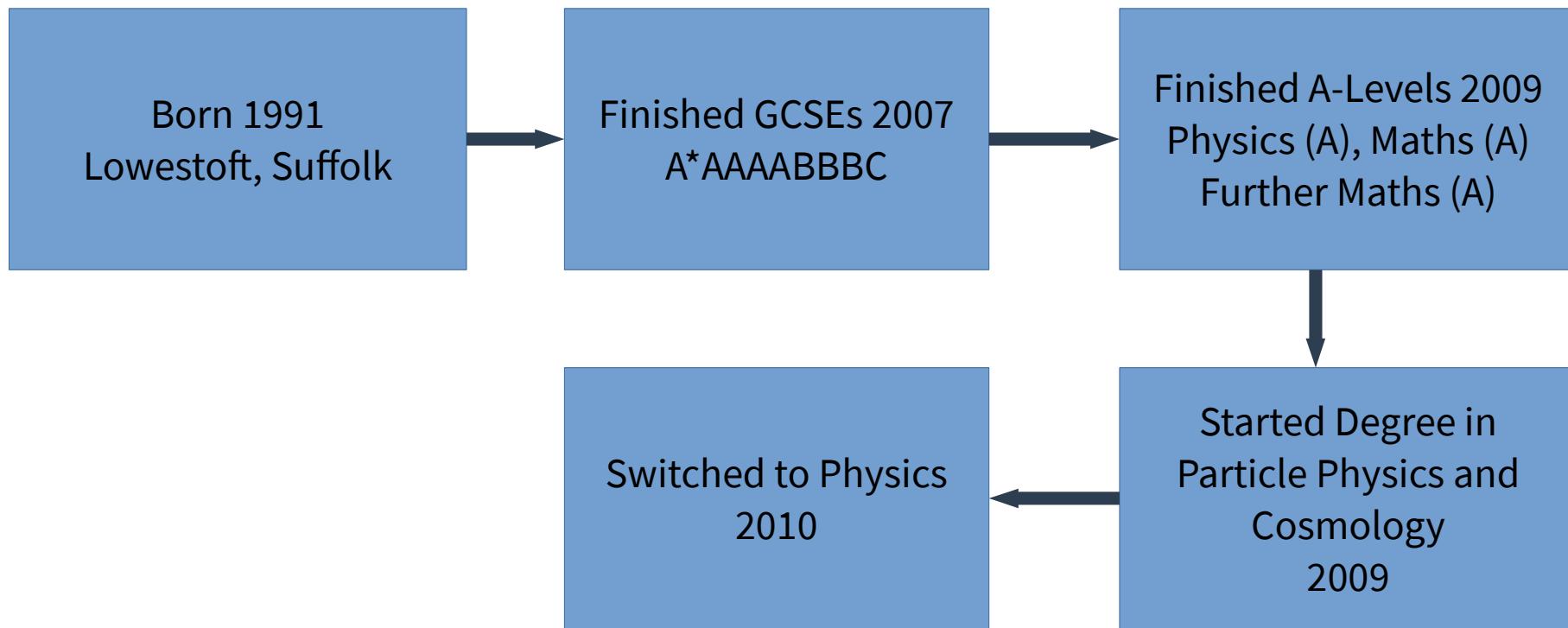
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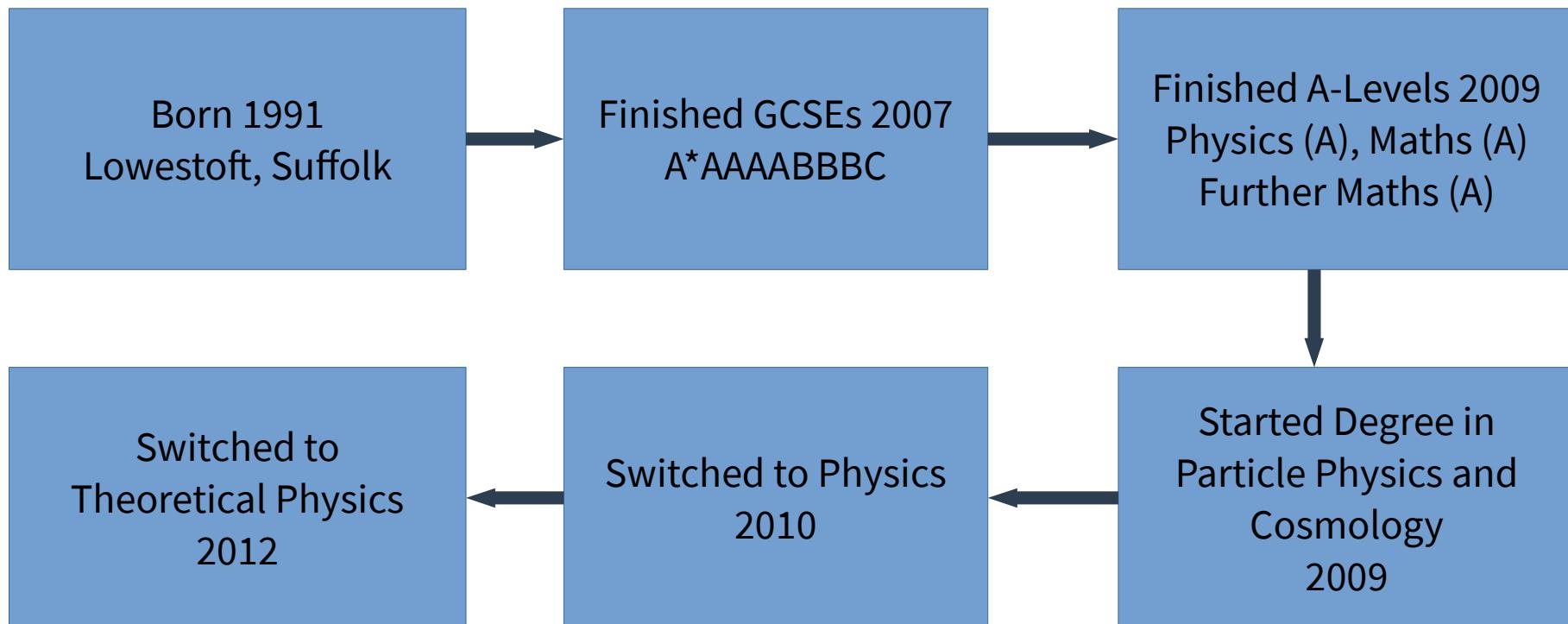
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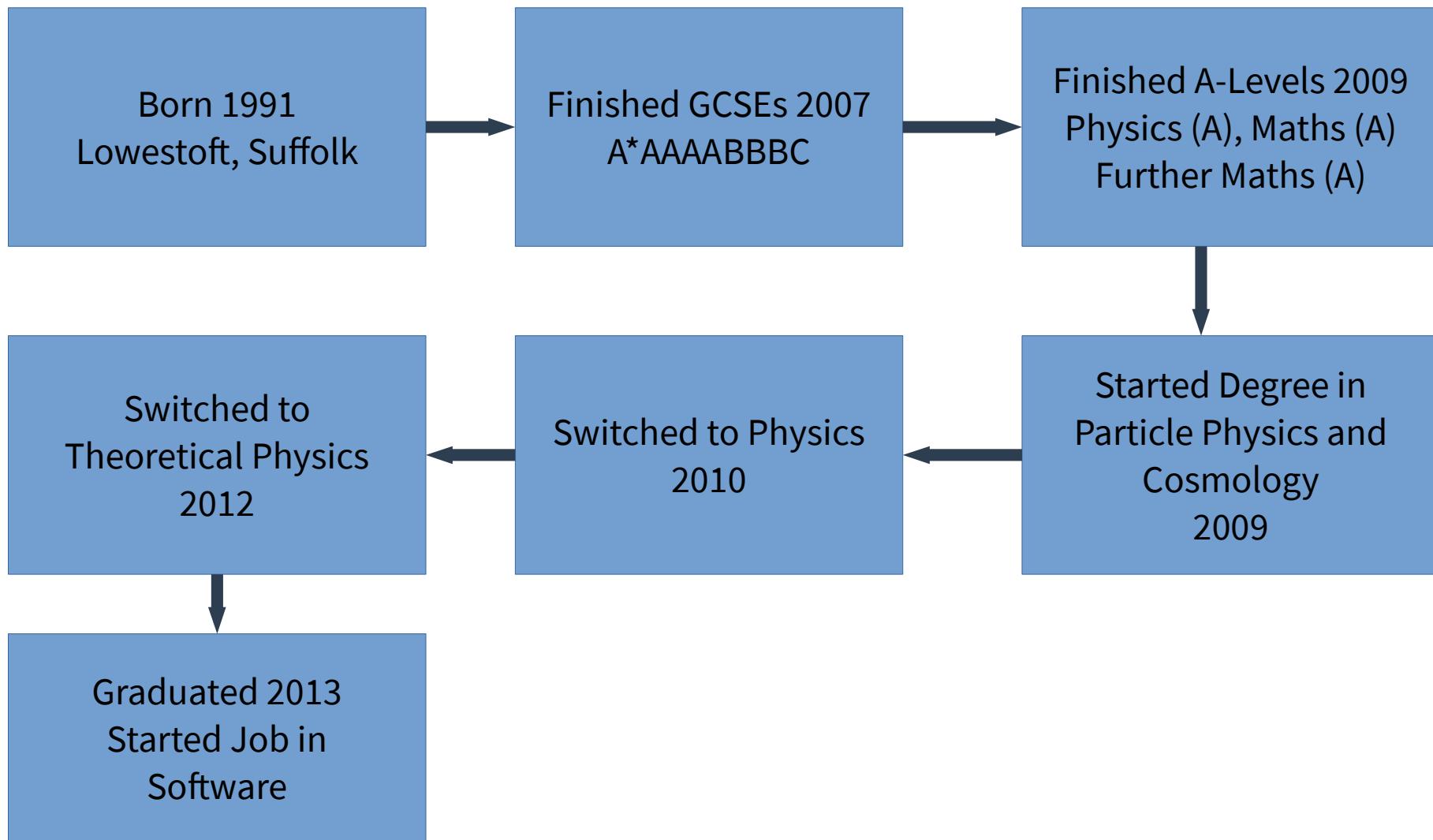
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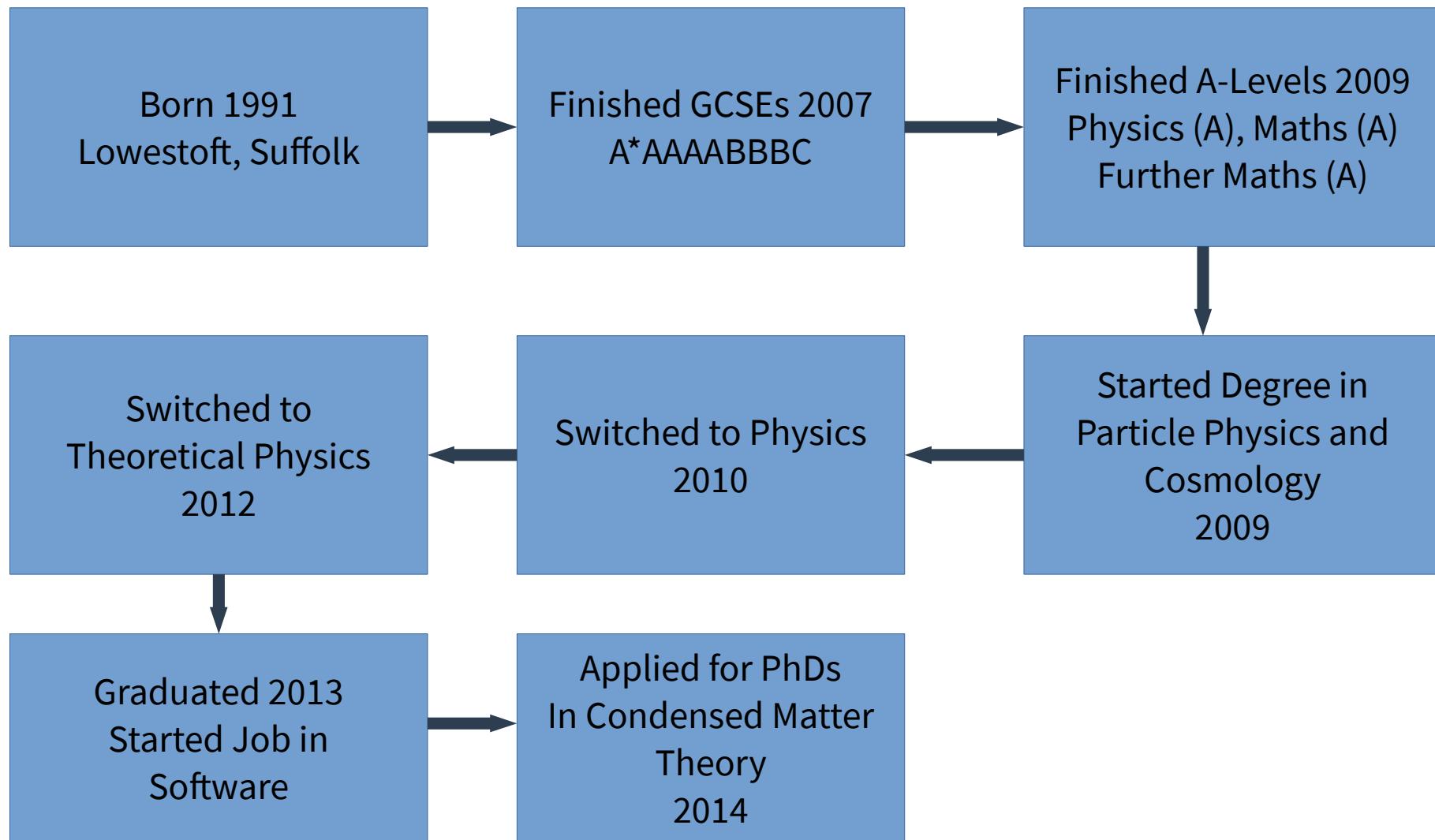
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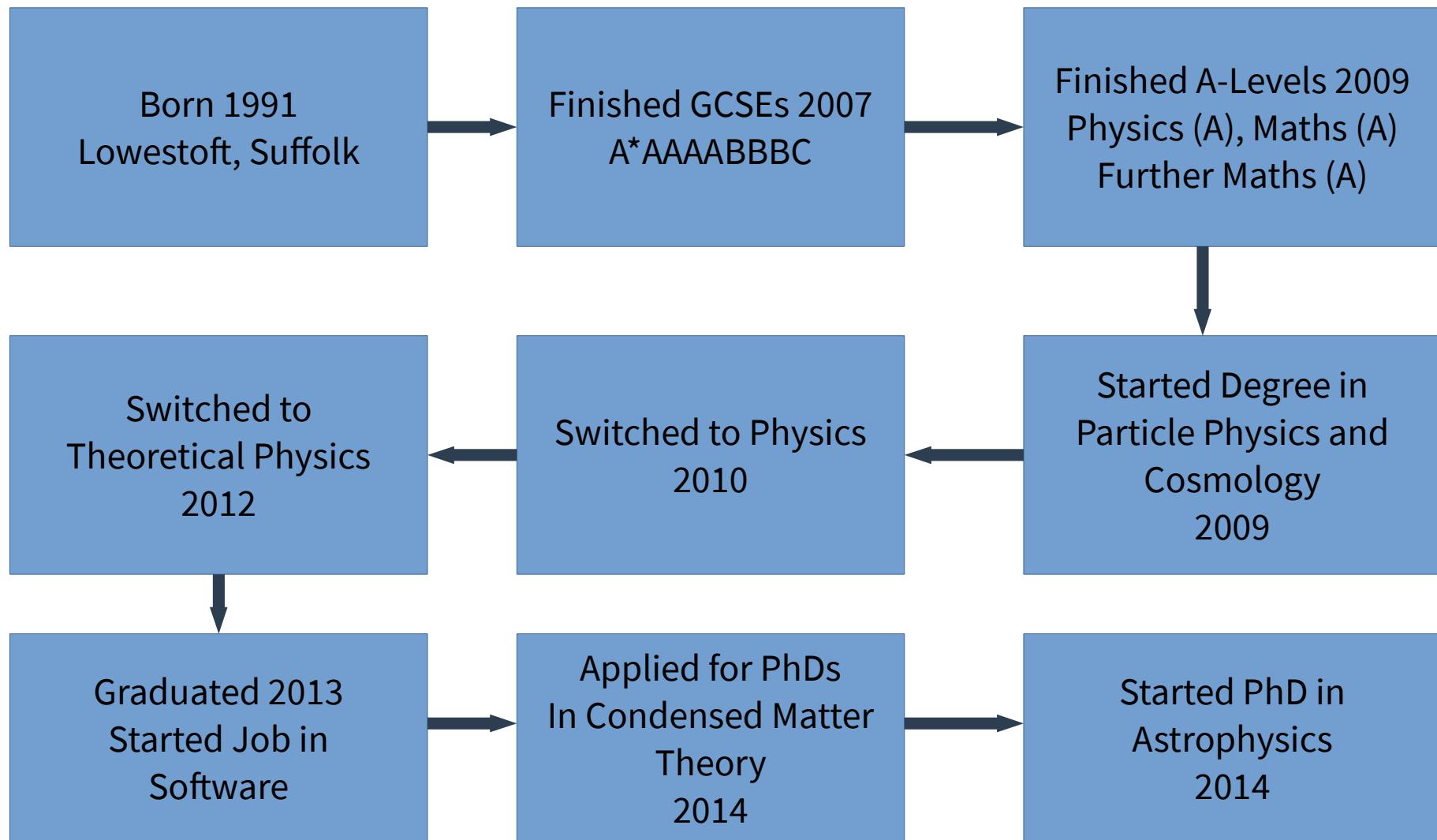
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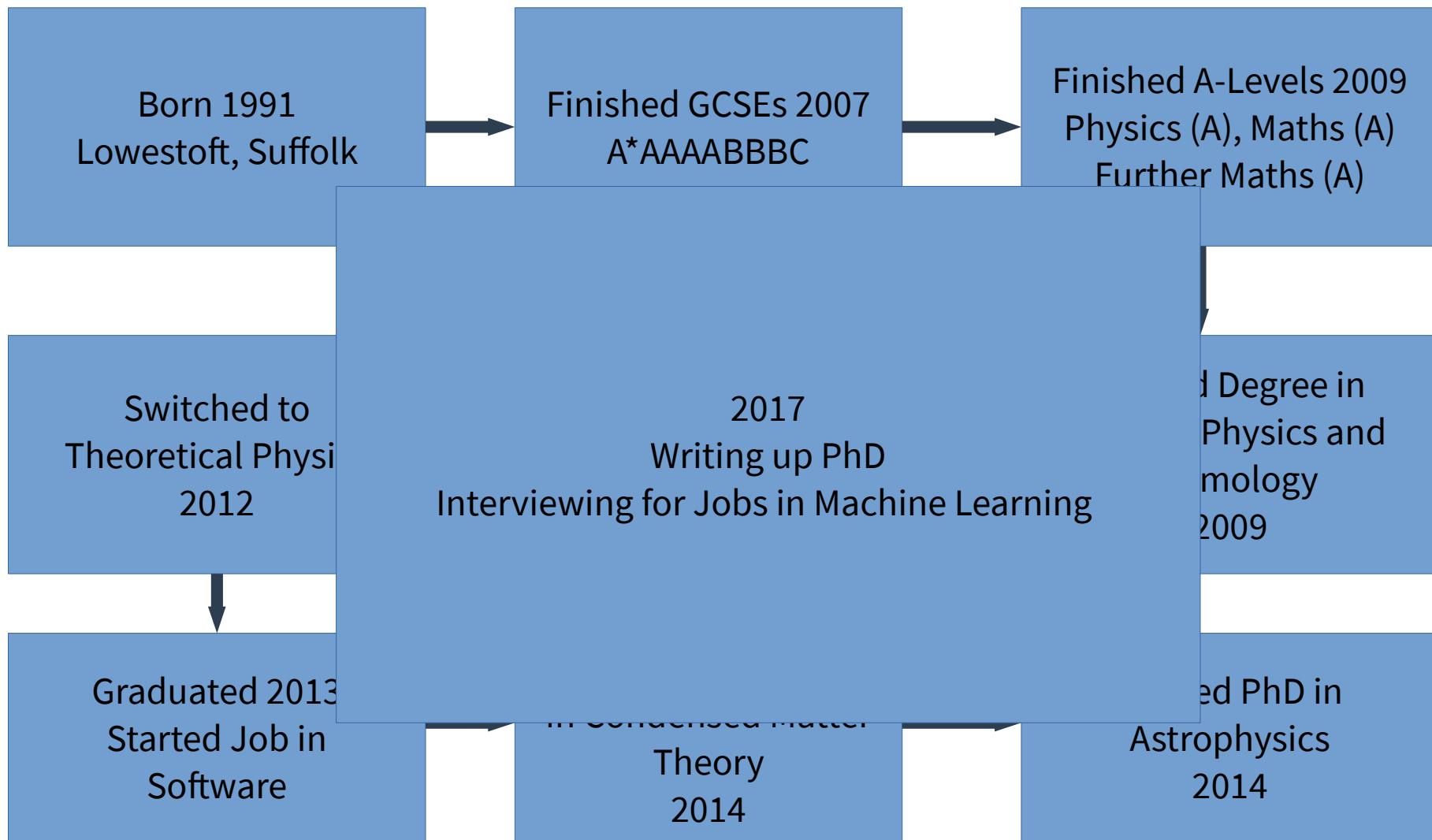
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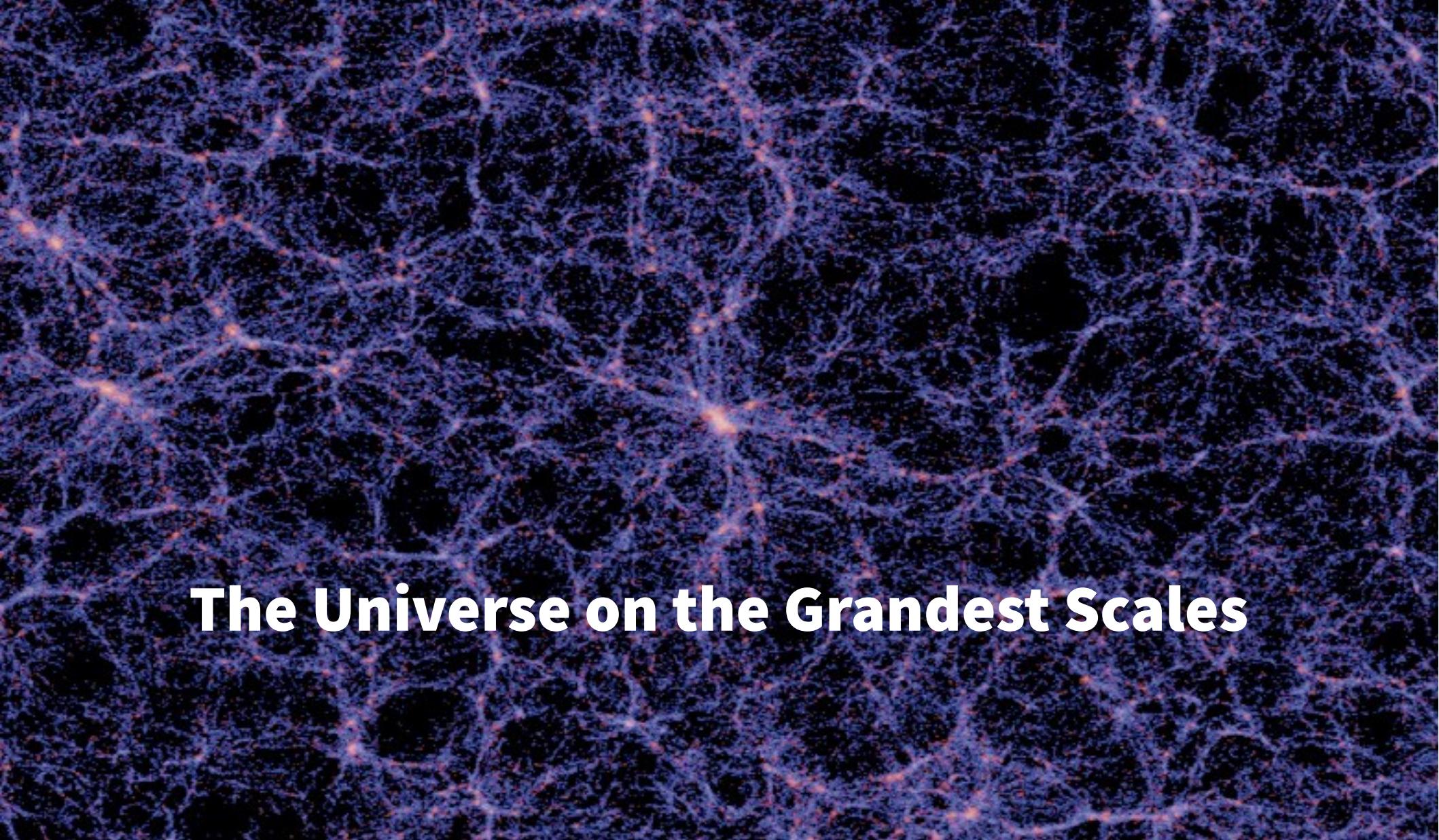


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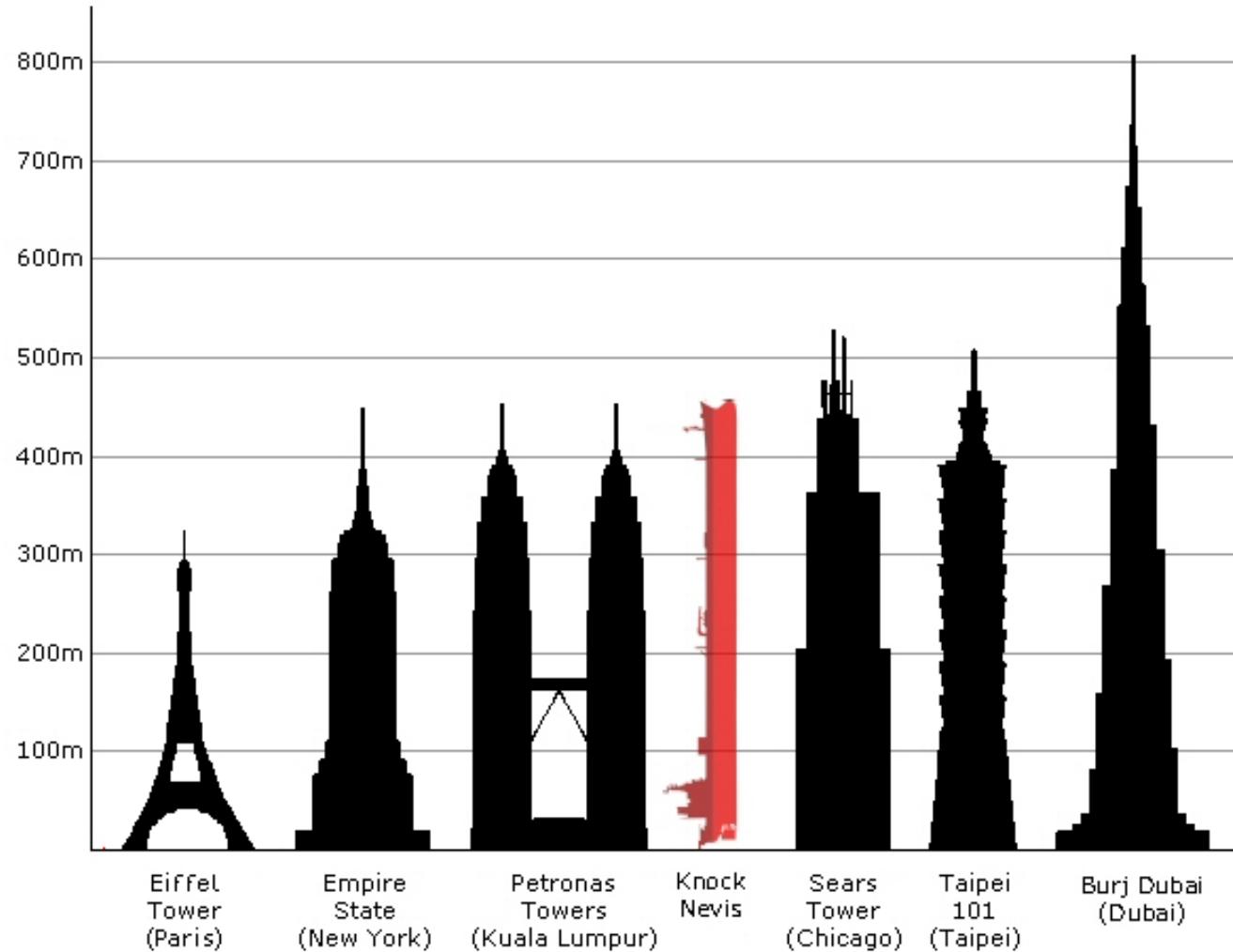


# **The Universe on the Grandest Scales**

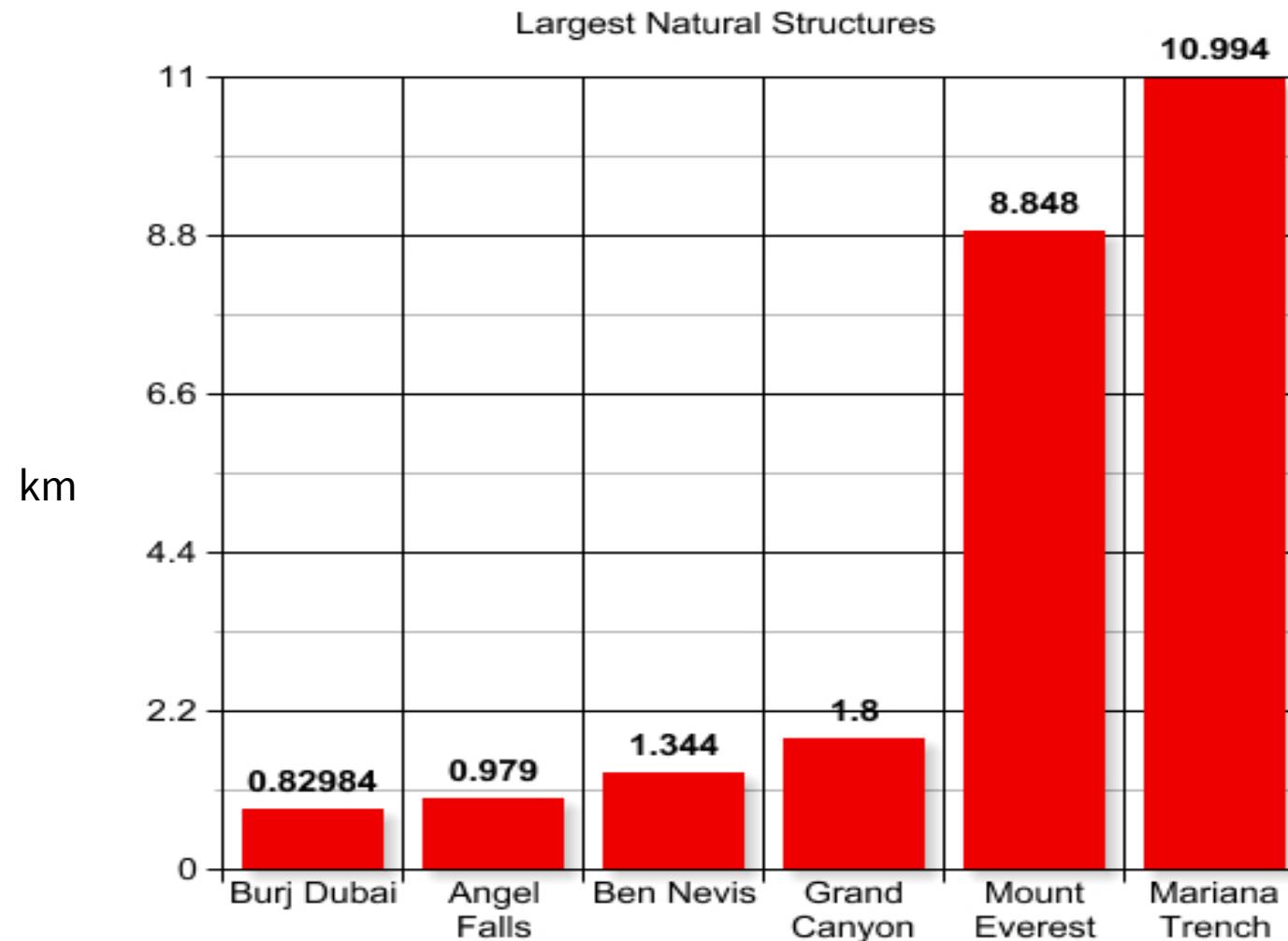
# Contents

- Big Stuff
- Parallax and Parsecs
- Cosmology

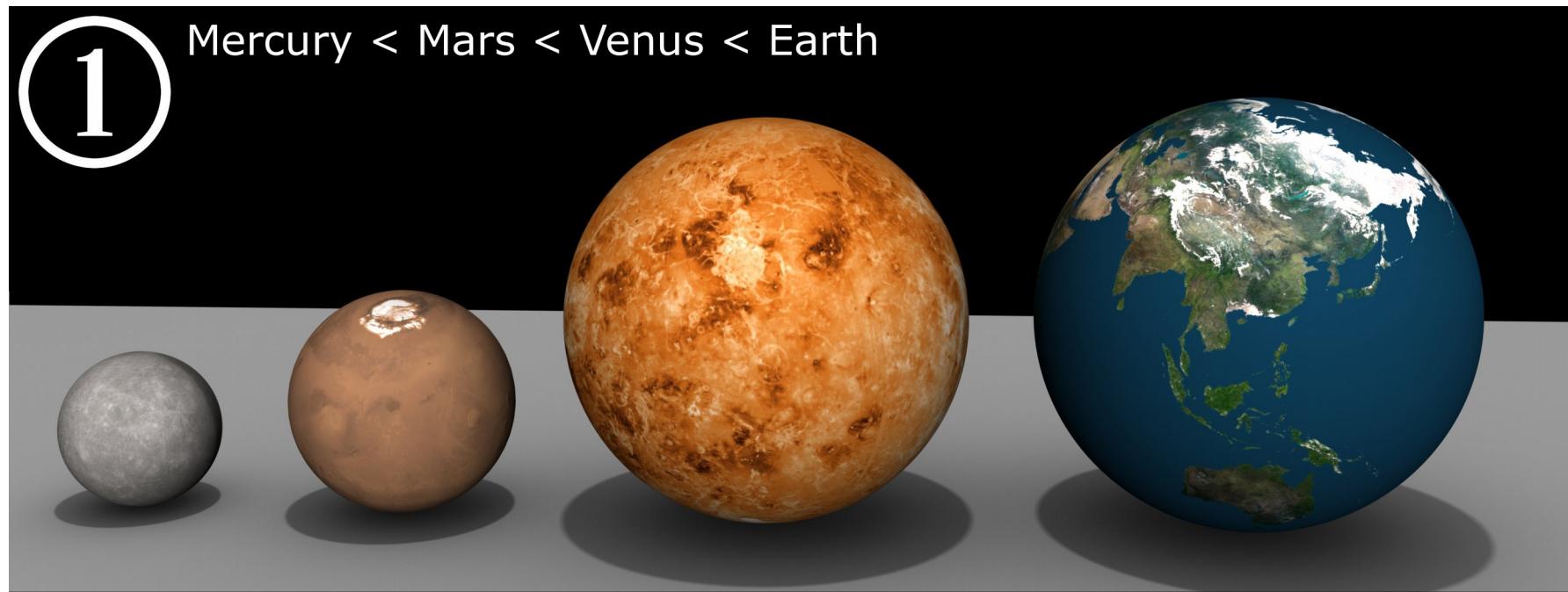
# Big Stuff on Earth



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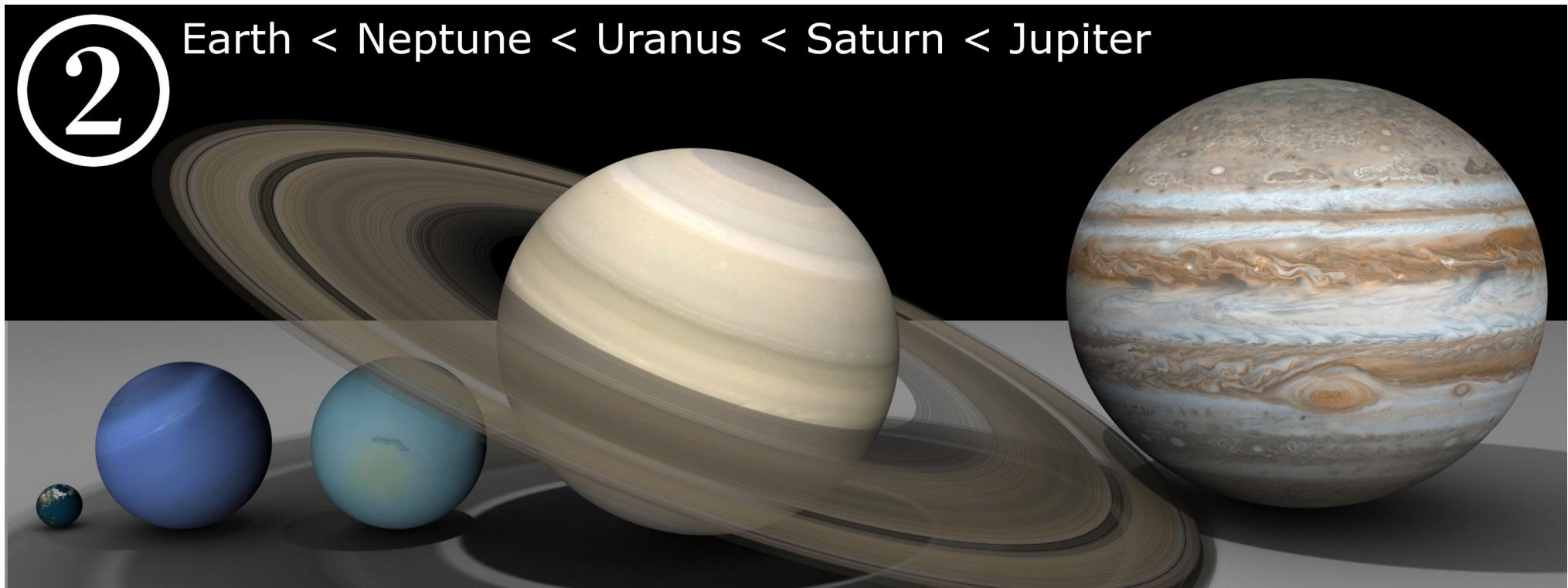
# Planets



# Planets

②

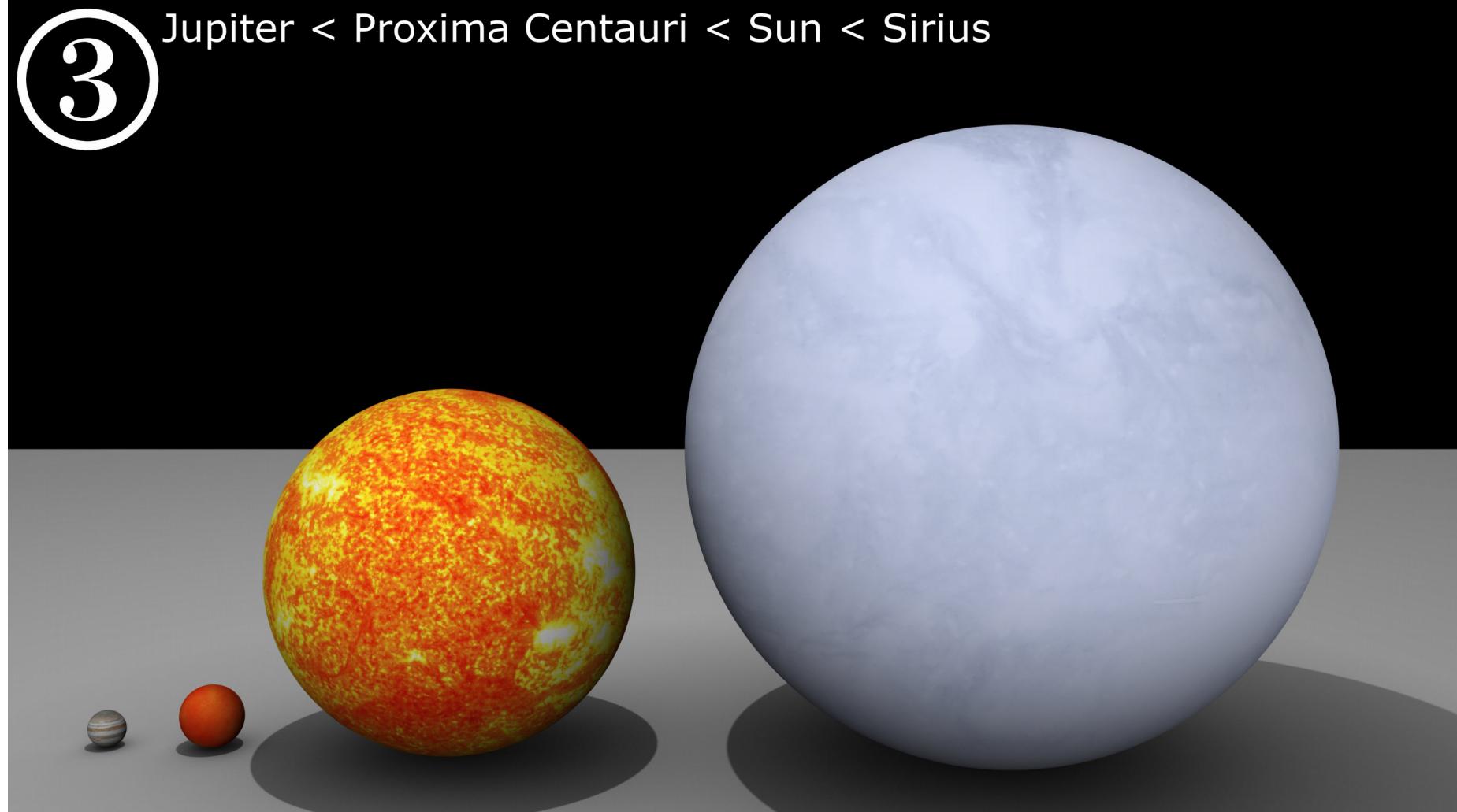
Earth < Neptune < Uranus < Saturn < Jupiter



# Exercise

- How far is the moon from the Earth?
- How big is the Sun?
- How far away is the Sun?

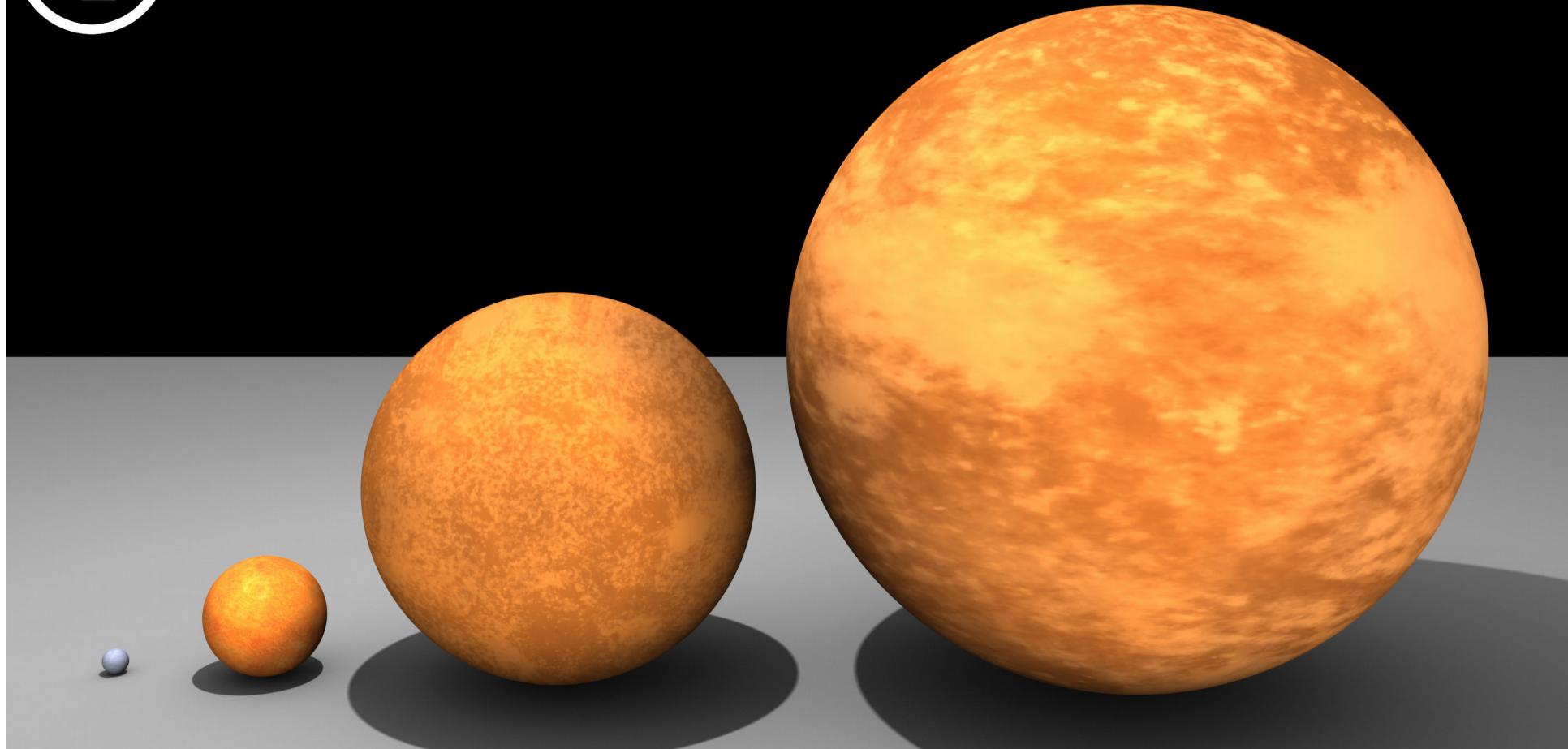
# Scaling it up - Stars



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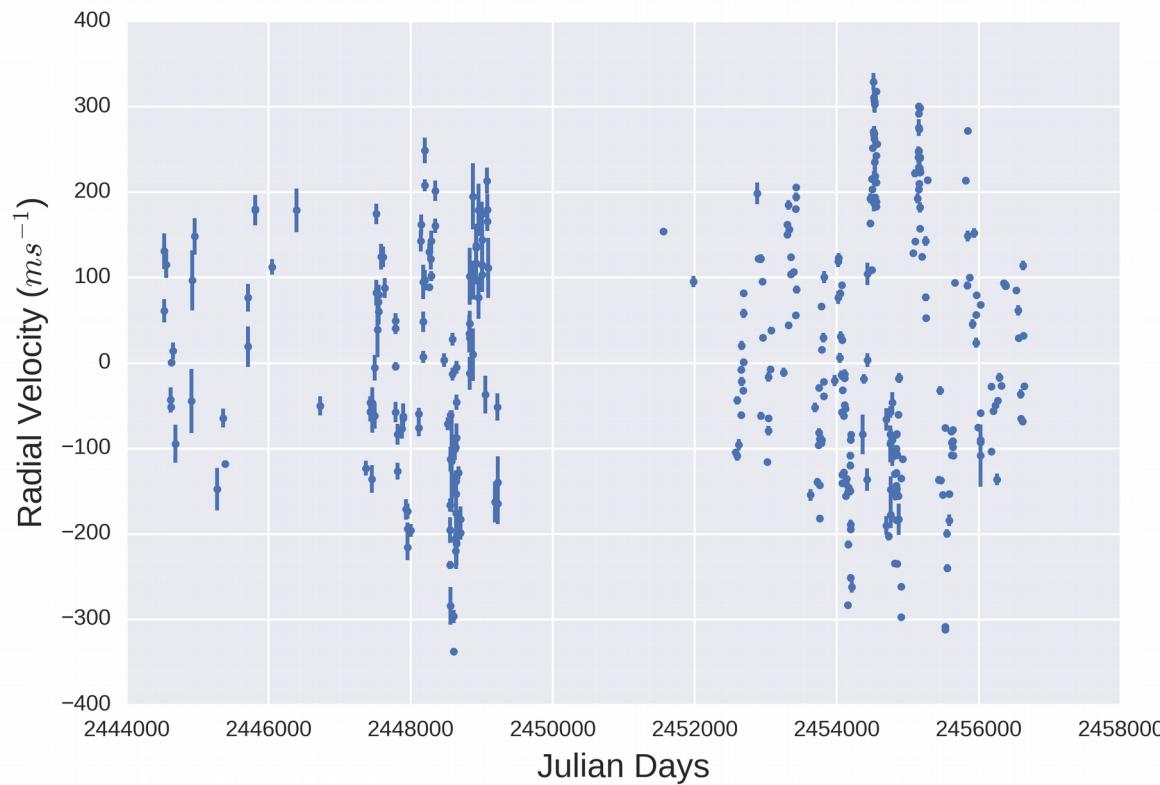
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Sirius < Pollux < Arcturus < Aldebaran

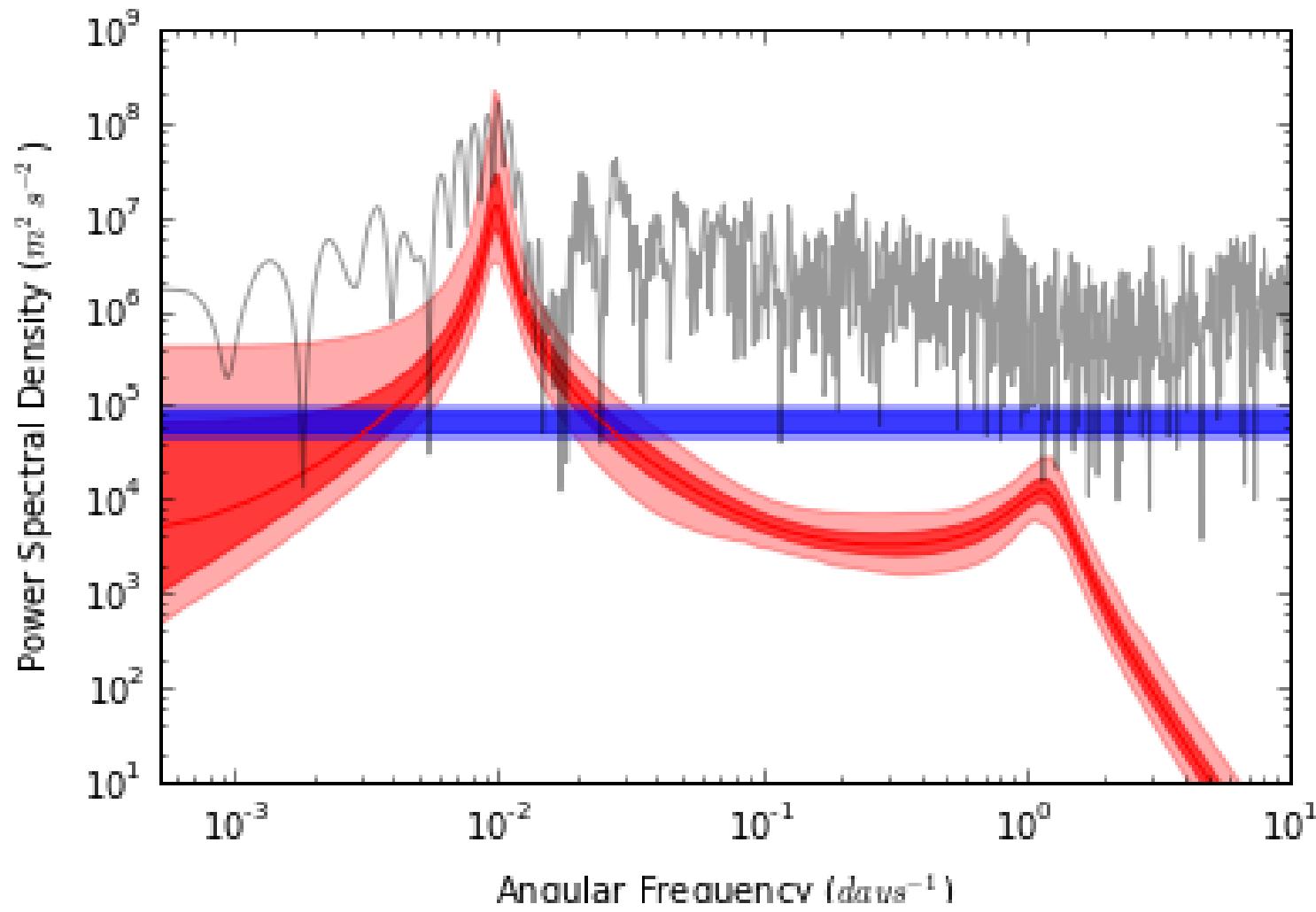


# Brief Aside - Aldebaran

- My first research project
- Looking for periodicity in bad data



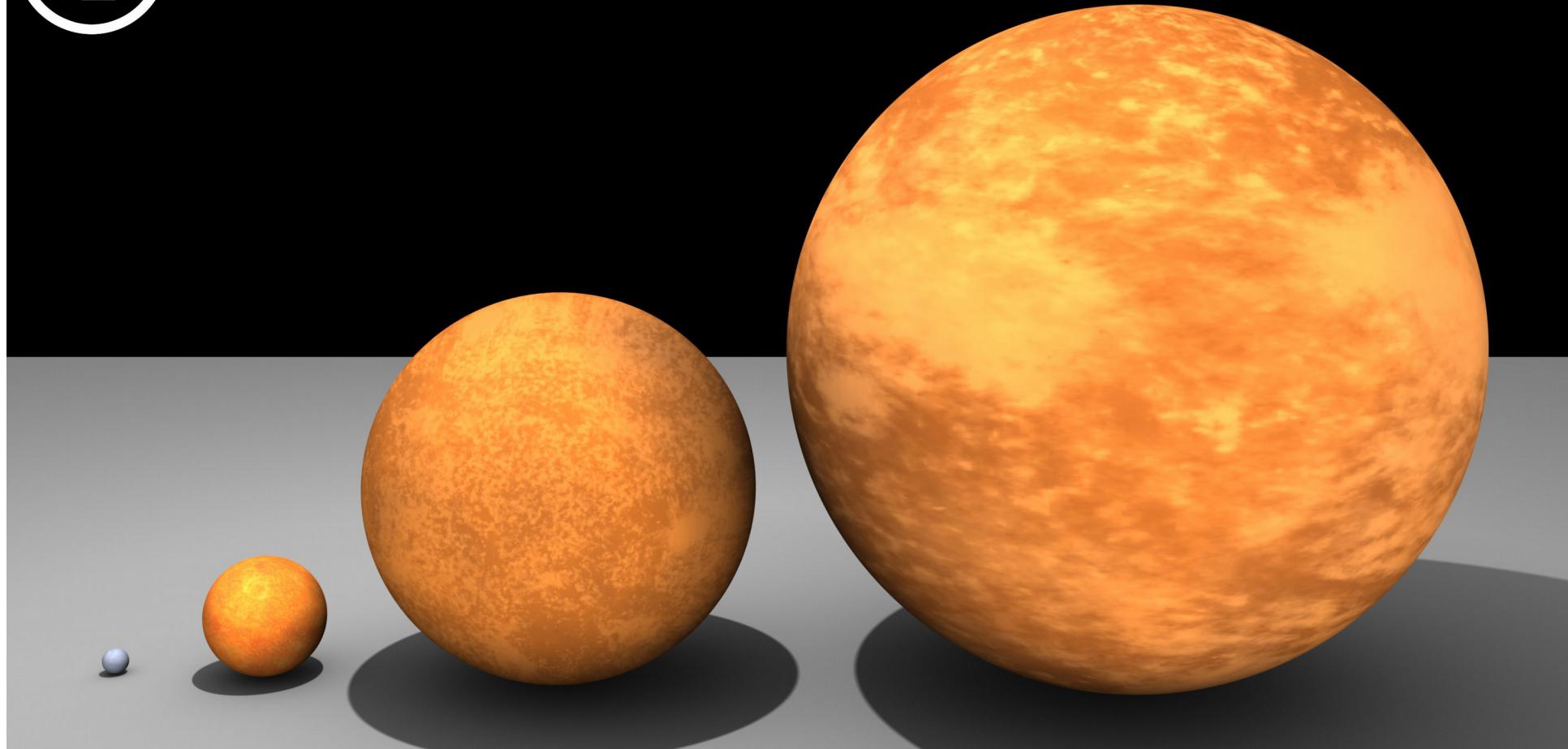
# Brief Aside - Aldebaran



# Scaling it up - Stars

4

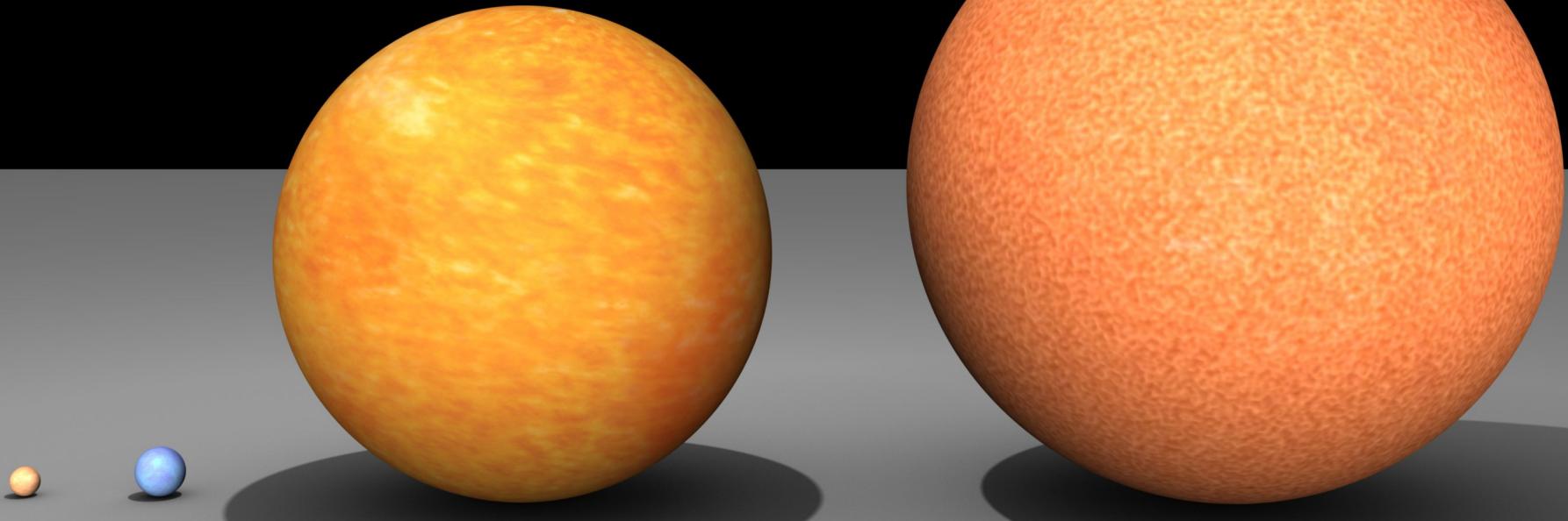
Sirius < Pollux < Arcturus < Aldebaran



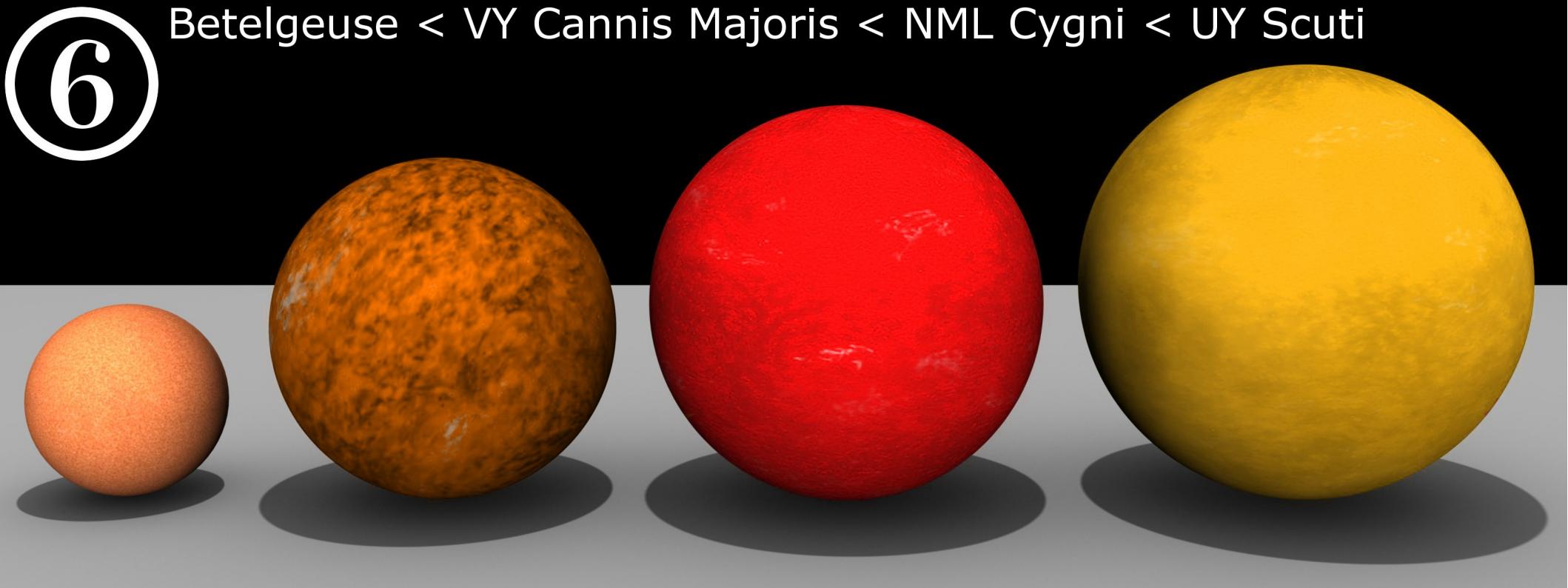
# Scaling it up - Stars

5

Aldebaran < Rigel < Antares < Betelgeuse



# Scaling it up - Stars



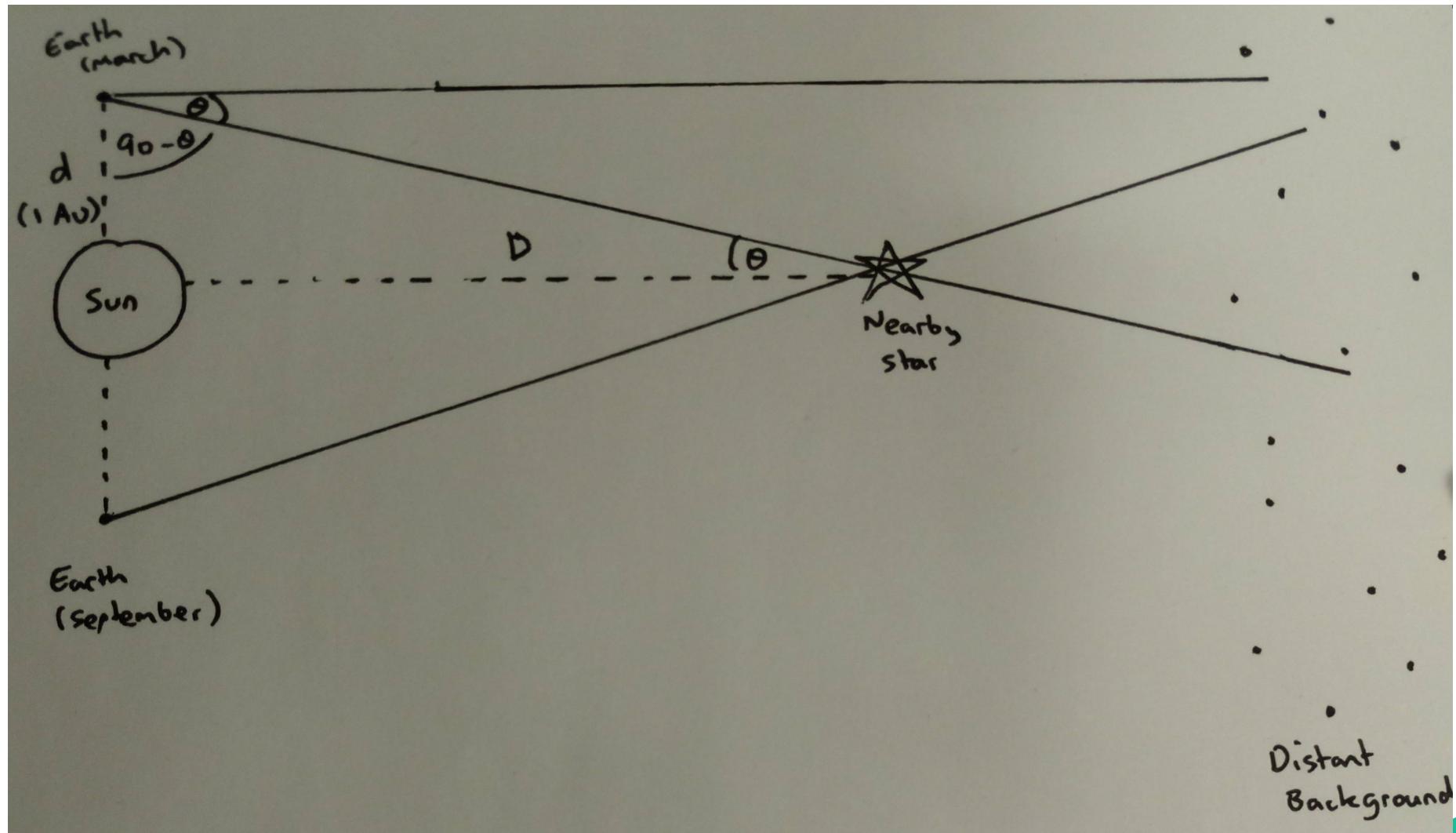
Radius of Earth ~ 6300km

Radius of UY Scuti ~  $1.1 \times 10^9$  km

# Distances to Stars

- All of the sizes so far pale in comparison to the distance between stars.
- The *closest* star to us, α-Centauri, is ~4.37 lightyears away
- ~ 20000 UY Scuti
- How can we measure these distances?

# Parallax



# Tiny Angles

Unit	Number of Degrees
Degree ( ° )	1
Arcminute ( am )	1/60
Arcsecond ( as )	1/3600
Milliarcsecond ( mas )	1/3600000
Microarcsecond ( μas )	1/3600000000

# Worksheet

# Biggest Scales - Galaxies

- Milky Way
- 100 Billion Stars
- ~150000 lightyears in diameter

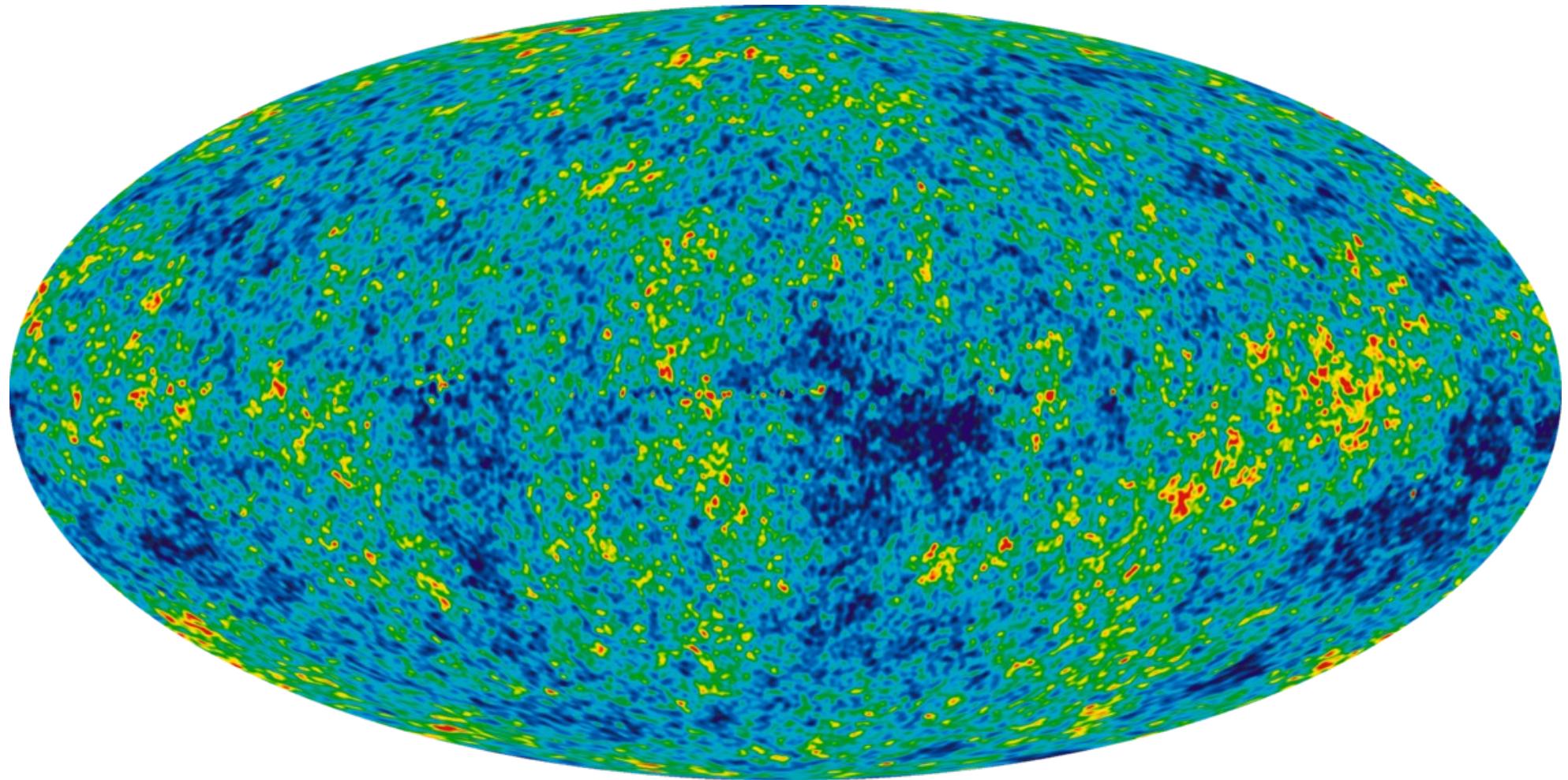


# Biggest Scales – Galaxy Clusters

- 100s to 1000s of Galaxies
- Up to  $10^{15}$  suns worth of mass



# Biggest Scales – Observable Universe

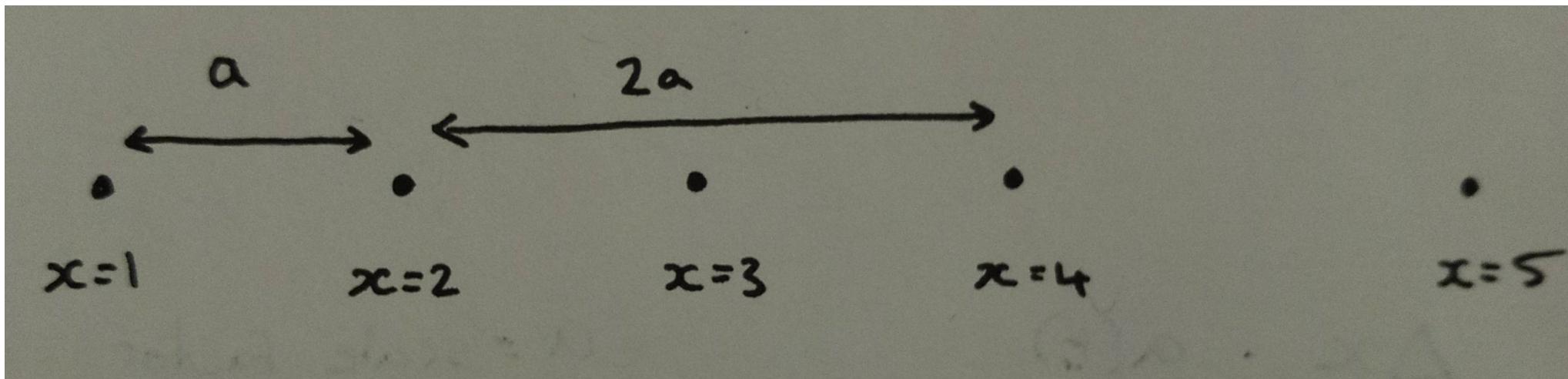


# Cosmology

- Study of the universe as a whole
- “Standard Model” of Cosmology brings us from the Big Bang to the present day expanding universe
- We will derive one key result;
- Hubble’s law

# Cosmology in 1D

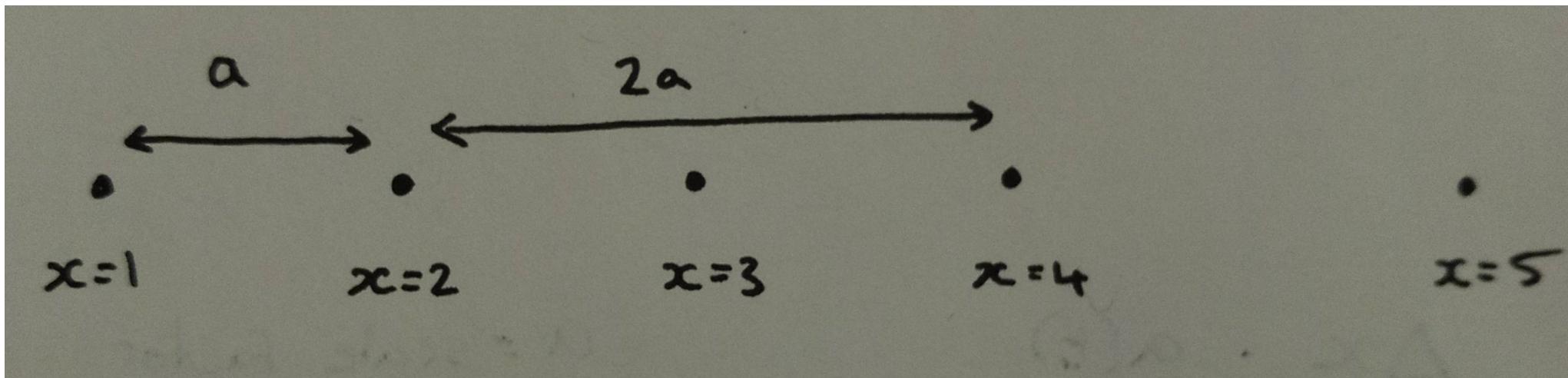
- Leonard Susskind lectures on Youtube
- Evenly spaced Galaxies in a line, each one is a distance “ $a$ ” from its nearest neighbours
- We label the galaxies as  $x=1, x=2$  etc



# Cosmology in 1D

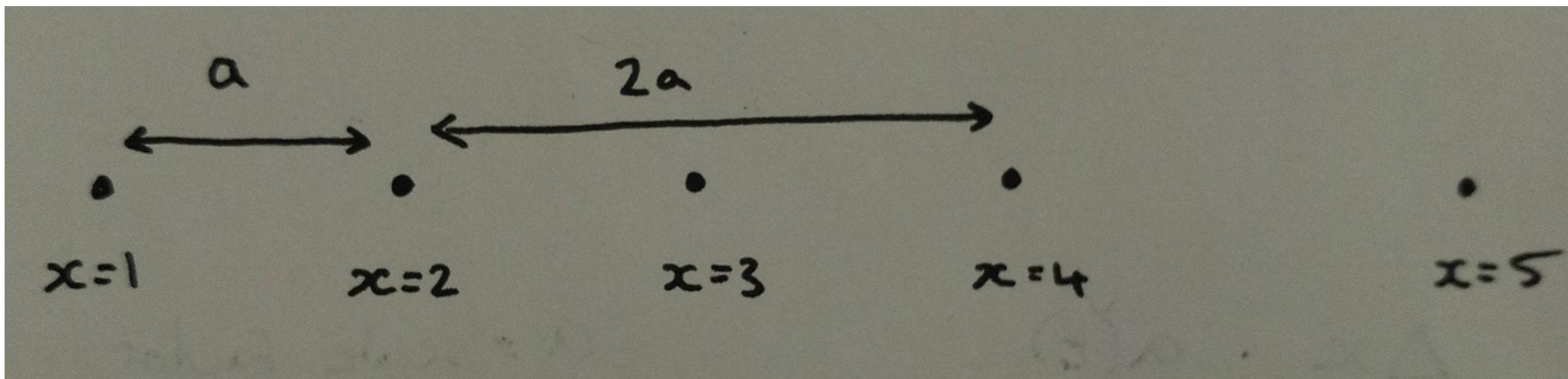
- The distance between two galaxies is;

$$D = a\Delta x$$



# Cosmology in 1D

- Imagine the galaxies are on a piece of elastic, and two giants stand at either end pulling it apart.
- Our galaxy labels don't change, and they're still evenly spaced. But now  $a$  changes with time



# Cosmology in 1D

- The distance between two galaxies is;

$$D = a\Delta x$$

$$V = \frac{d}{dt} a\Delta x = \dot{a}\Delta x$$

# Cosmology in 1D

- Sneaky trick time

$$D = a\Delta x$$

$$V = \dot{a}\Delta x = -\frac{\dot{a}}{a} a\Delta x$$

# Cosmology in 1D

- $\dot{a}/a$  over  $a$  has another name, the Hubble constant

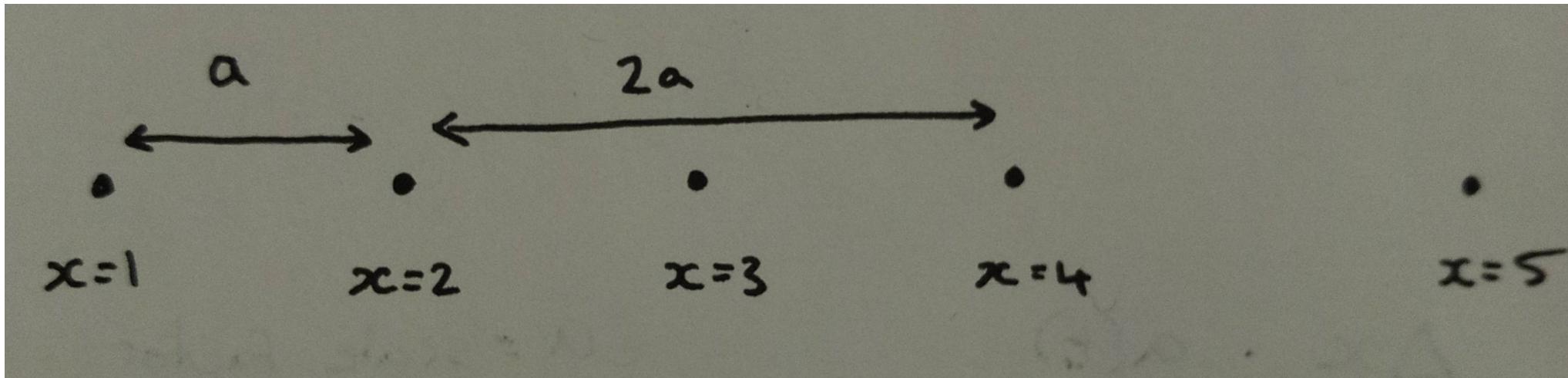
$$V = -\frac{\dot{a}}{a} D$$

$$V = H_0 D$$

# Cosmology in 1D

- The bigger the distance, the bigger the velocity

$$V = H_0 D$$



# Questions?