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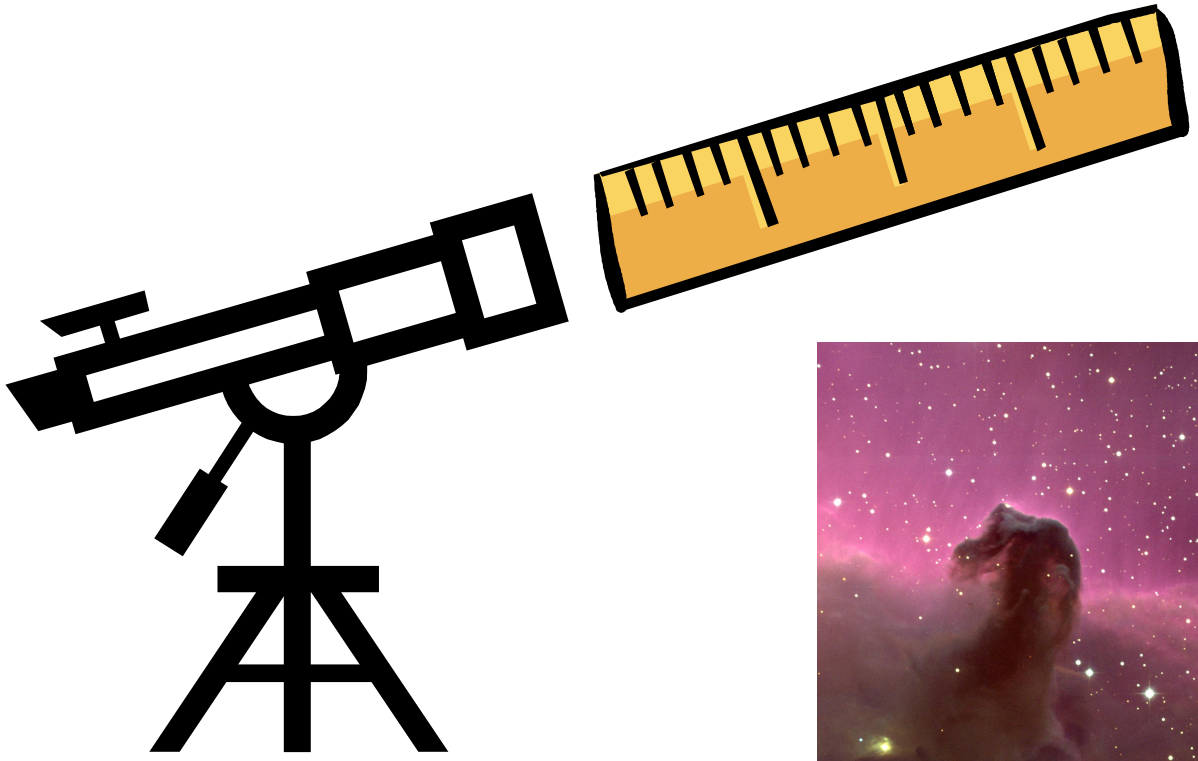
ARC CENTRE OF EXCELLENCE
FOR ALL-SKY ASTROPHYSICS

How Big is the Universe?

James Allison
University of Sydney



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The Big Questions

- How far away are objects in the sky?
- How big is the Universe?
- How fast is the Universe expanding?

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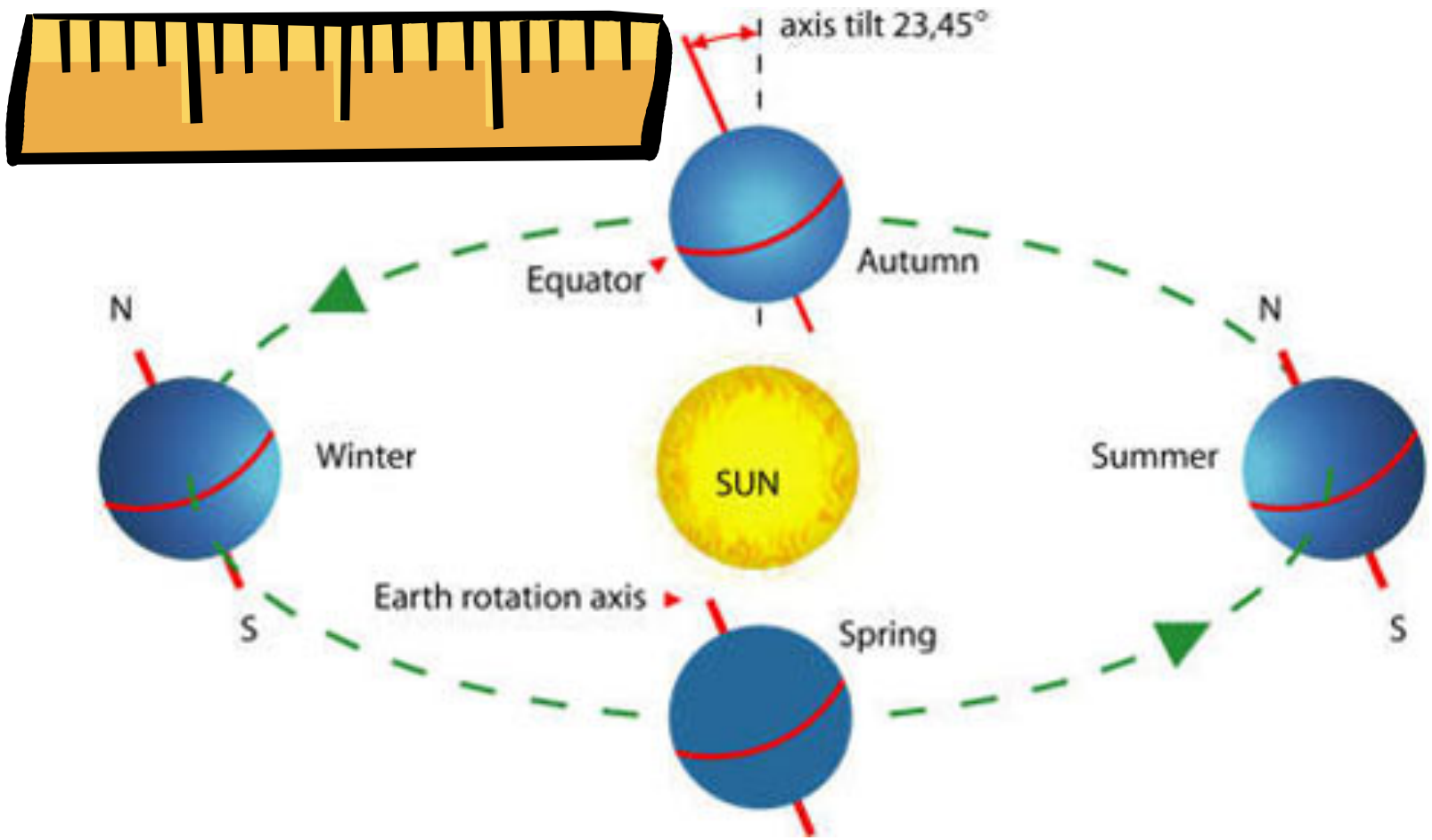
How Big is Big?

- Most scientists use metres, but for astronomers this is just too many zeros to write down!

- The nearest **star** is **40,000,000,000,000,000** metres
- The nearest **galaxy** of stars is **25,000,000,000,000,000,000,000** metres

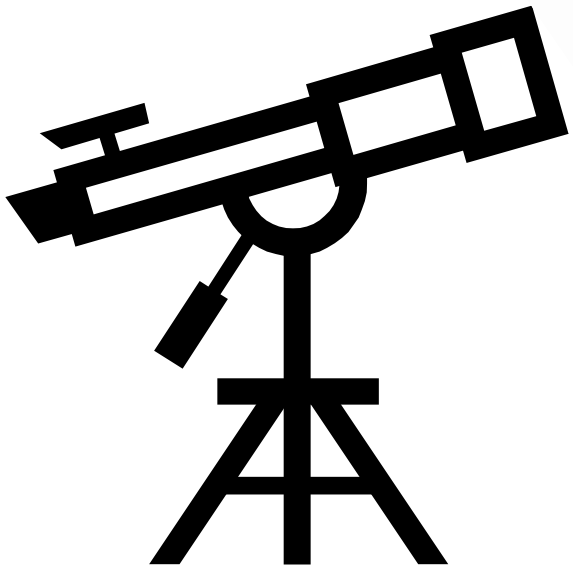
The Astronomical Unit

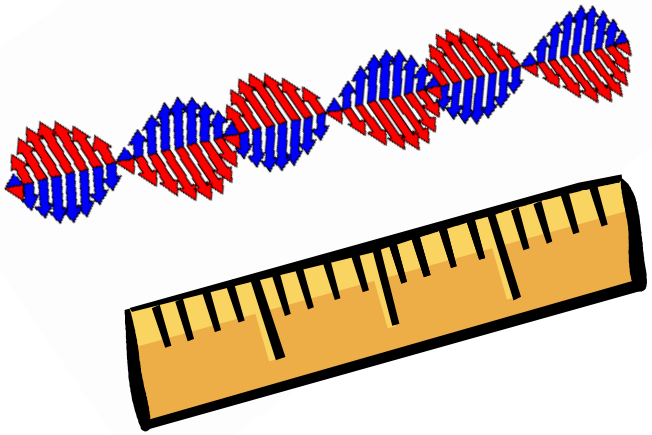
› **The Astronomical Unit** = Between the Earth and the Sun or **149,597,870,700 metres**



The Light-year

› **The Light-year** = The distance travelled by light in one year or **9,460,730,472,580,800 metres**





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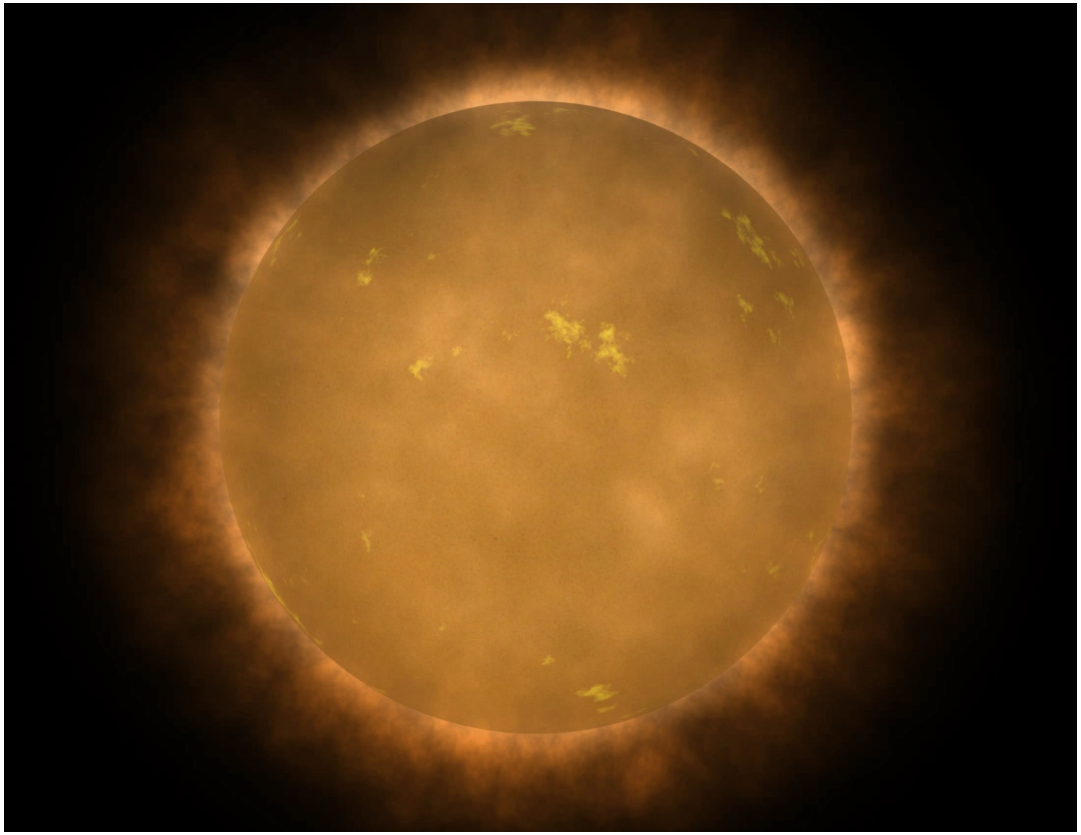
The nearest star

- **So we would normally say …**
- The nearest **star** is **4.2 Lyrs** away

Proxima Centauri



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The nearest galaxy

- **So we would normally say …**
- The nearest **galaxy** of stars is **2.6 million Lyrs** away

The Andromeda Galaxy

Measuring distance

How do we measure 1AU?

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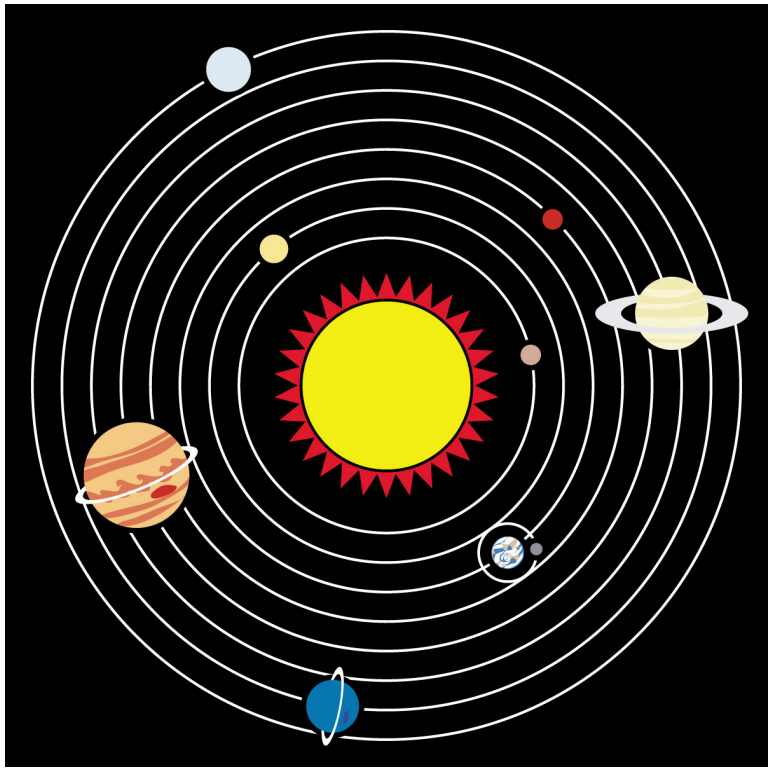
Distance to the Sun

- The distance to the Sun can be measured using the transit of Venus

- A transit is where the planet moves across the Sun

- We can measure this at different places on Earth

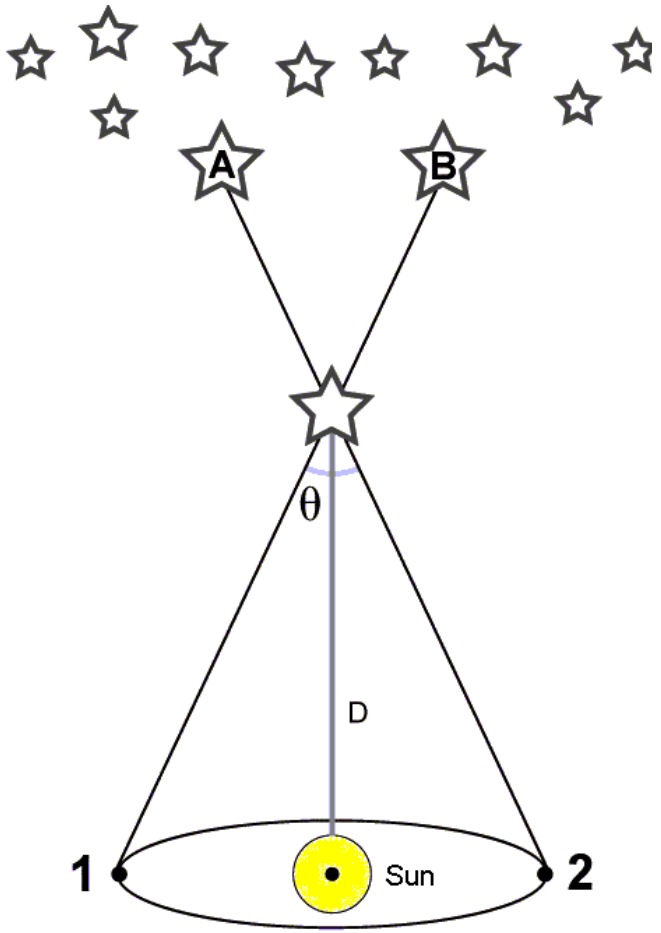


Measuring distance

How far away are the nearest stars?

Distance to the stars

- Some **stars** are closer than others
- As we orbit the Sun the nearest stars appear to **move around** in front of the others
- How much they move depends on their **distance**



Parallax

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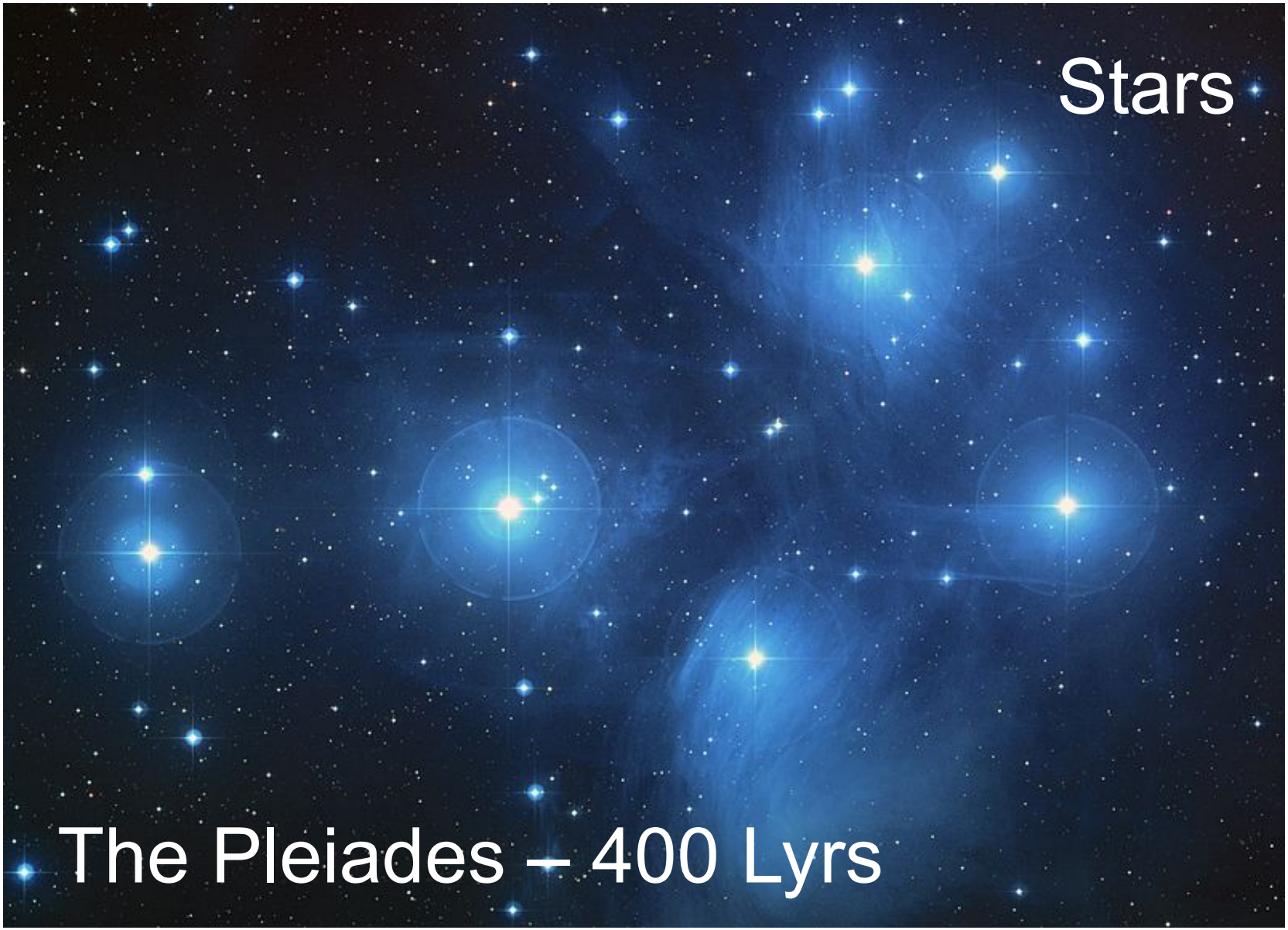
What sort of objects are here?



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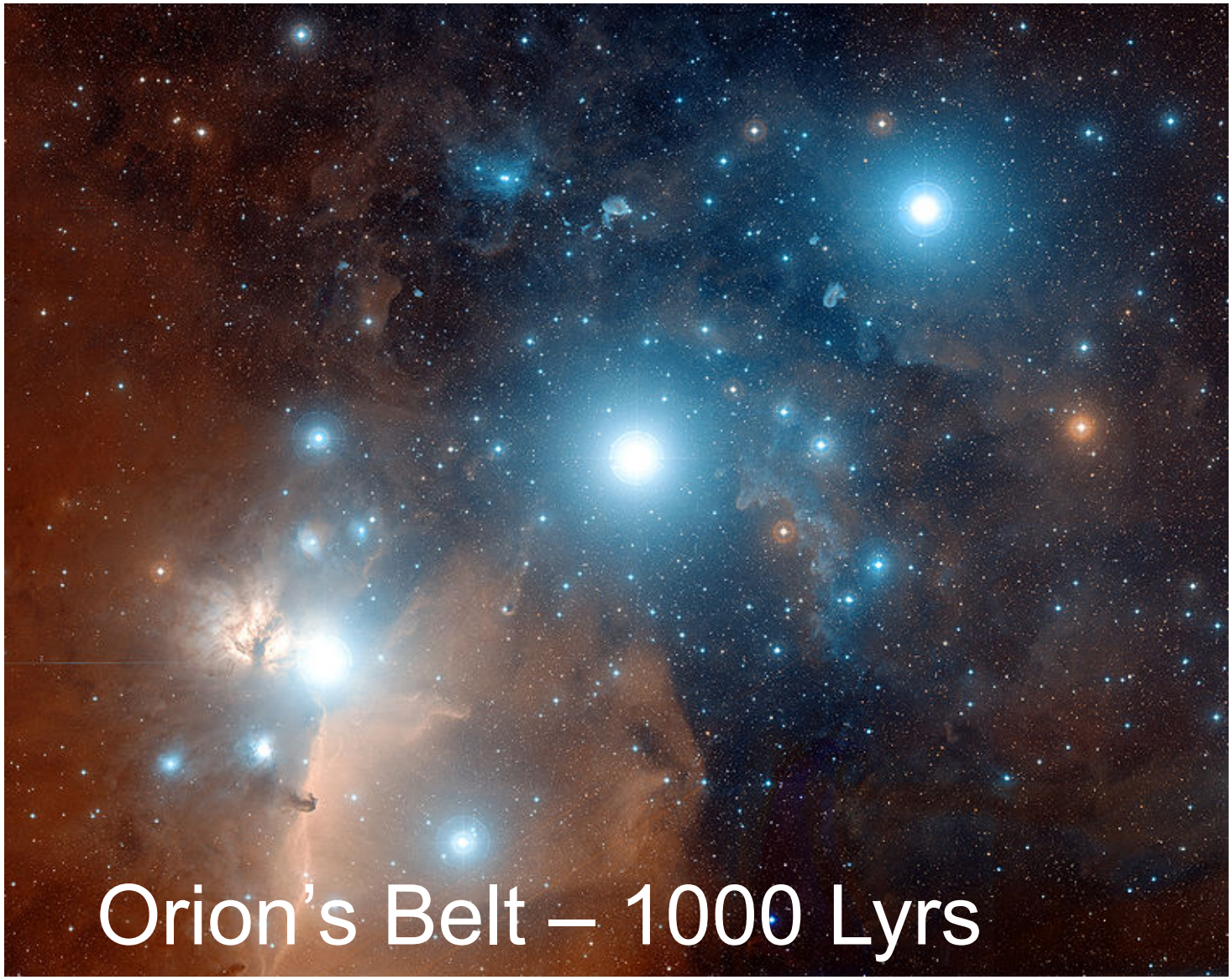
What sort of objects are here?



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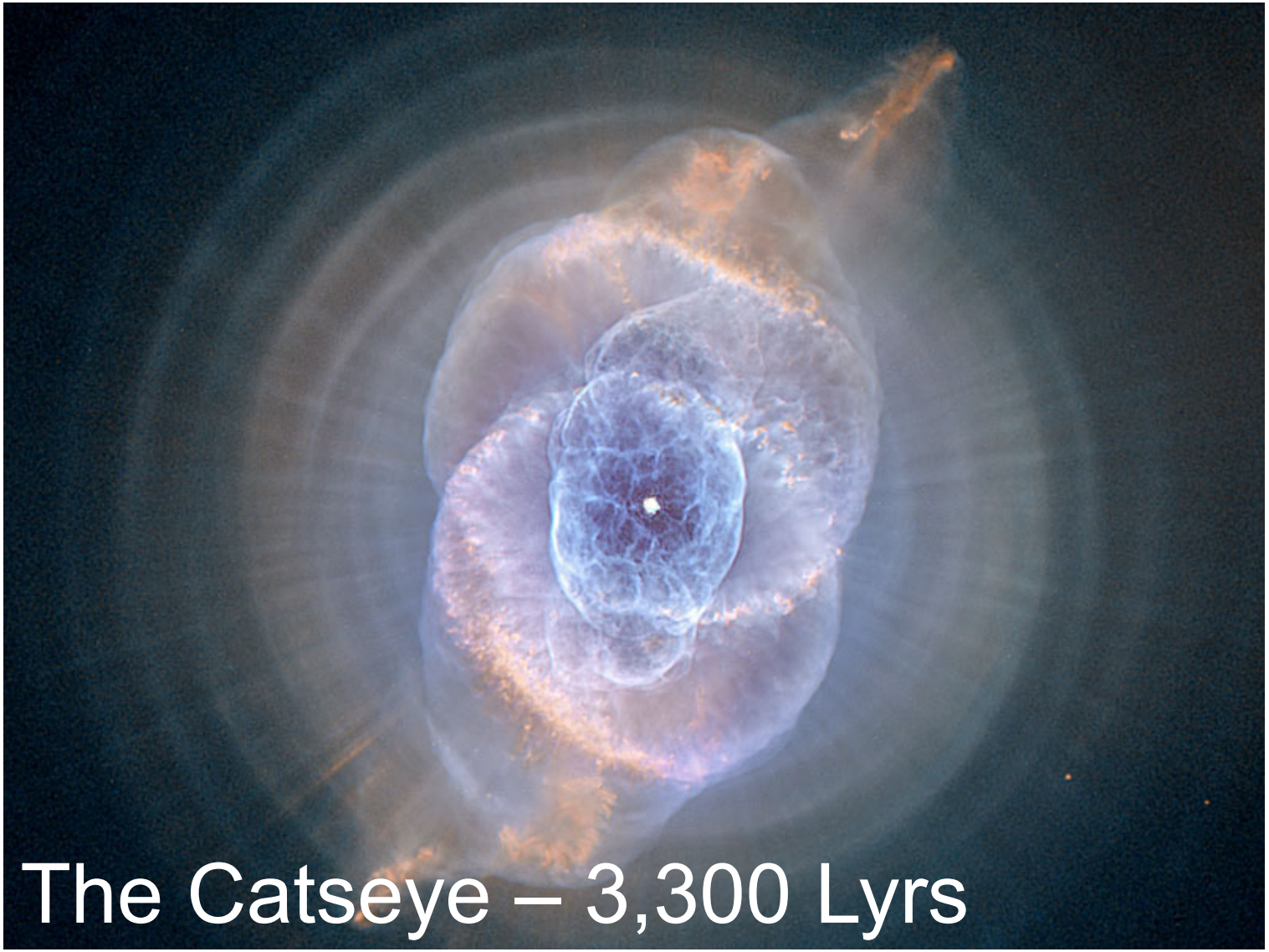


Distance to the galaxies

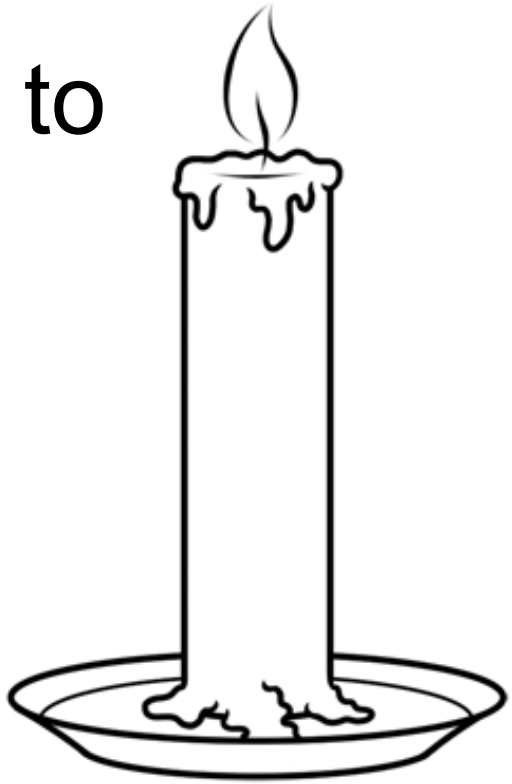
What about further stars, and even other galaxies?

Brightness and distance

- The brightness of an object depends on how far away it is

- So we can use their brightness to measure their distance

Standard Candles



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Standard Candles

› Supernovae are Standard Candles

Standard Candles

- The amount of light produced depends on the duration of the explosion
- So we measure the duration to estimate the amount of light produced
- We then measure the brightness to estimate the distance

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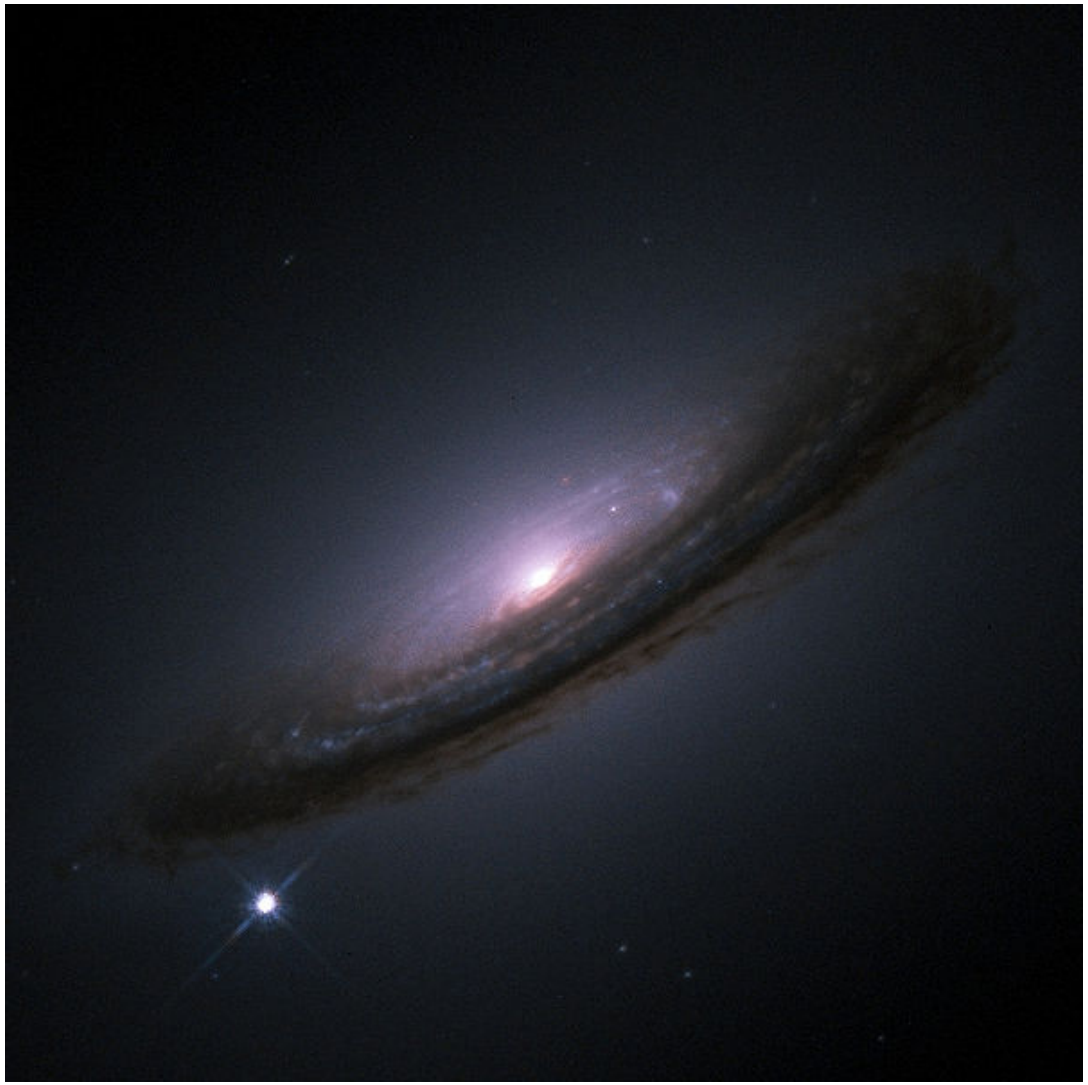
Supernovae

- Supernovae are seen in our galaxy and in other galaxies that are millions of light years away



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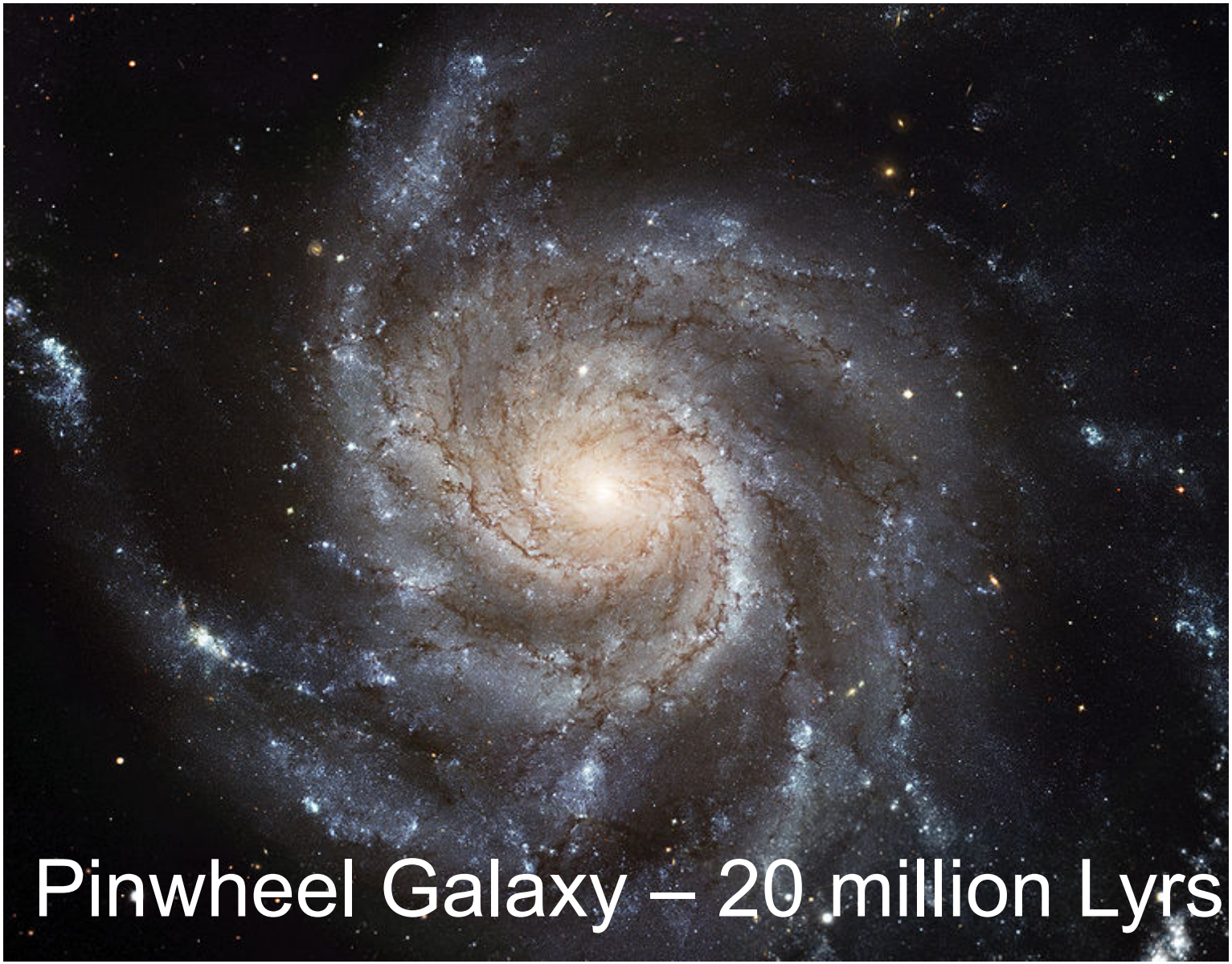

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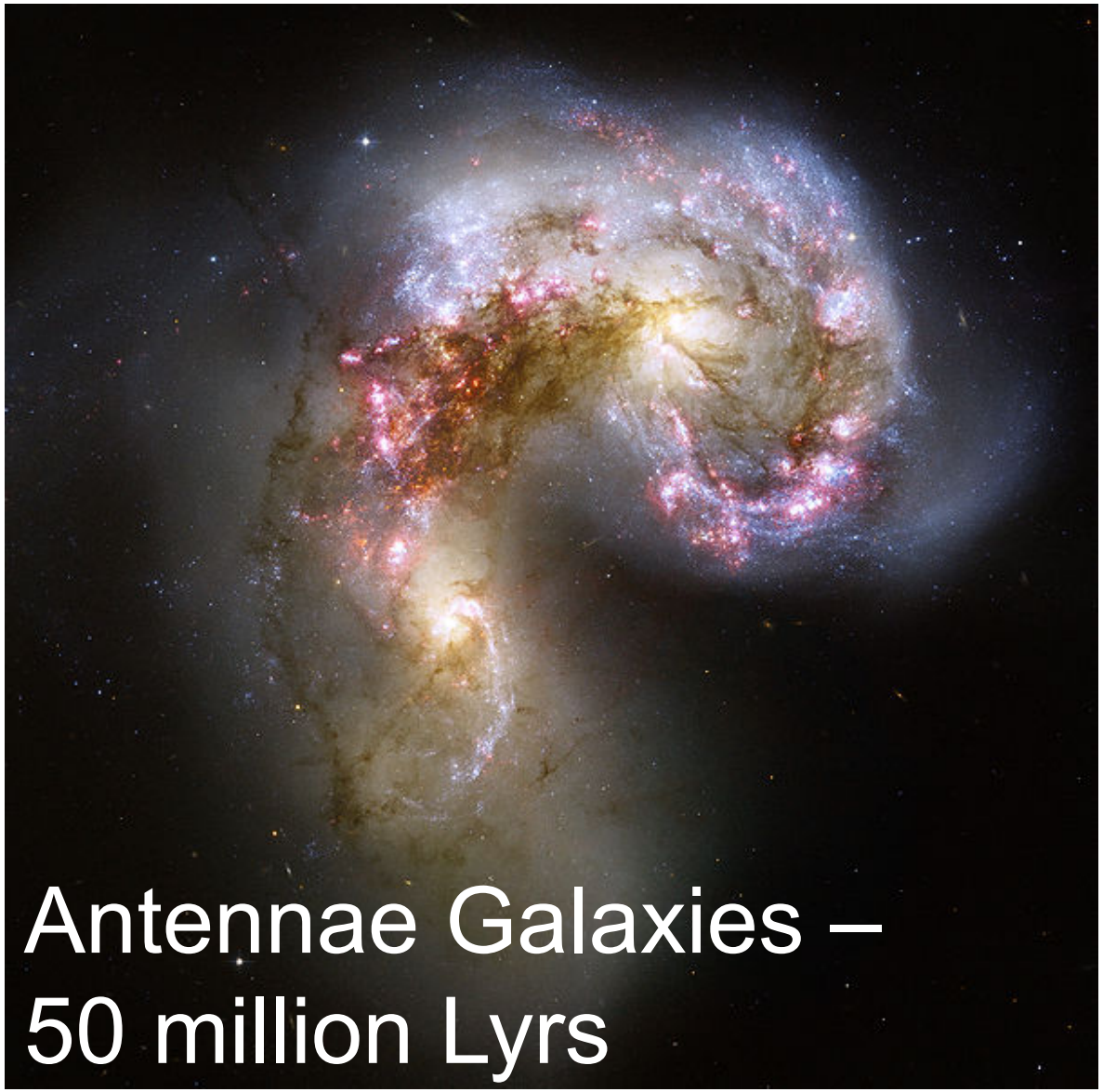

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The Cosmic Ladder

- Each method of measuring distance builds on the last one
- The Earth-Sun distance is used for Parallax
- Parallax is used for the Supernovae

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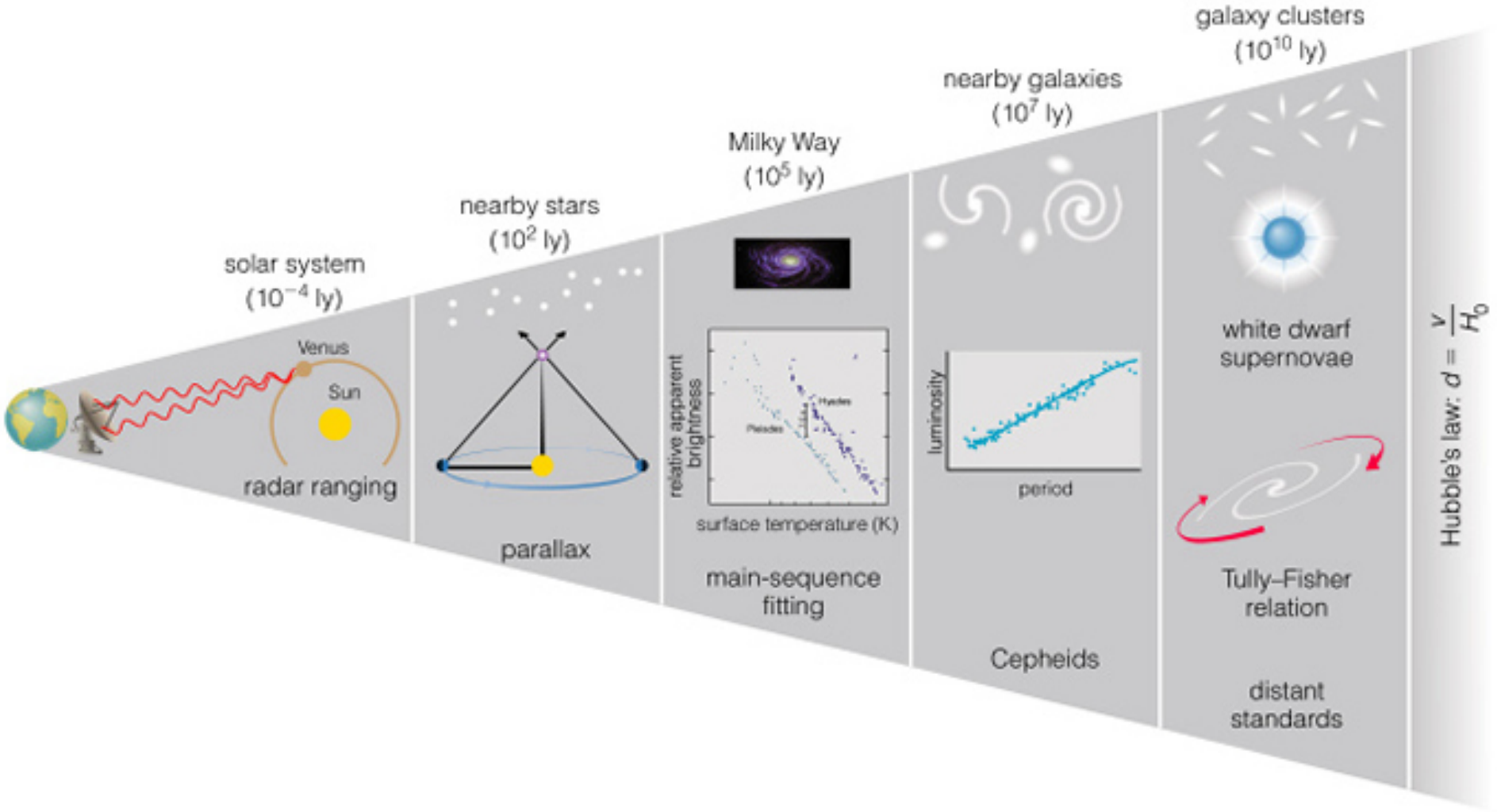
The Cosmic Ladder



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The largest objects

- As we look further away we see larger objects
- First stars, then other galaxies, and finally giant groups of galaxies
- If we look far enough away see start to see the largest structures in the Universe

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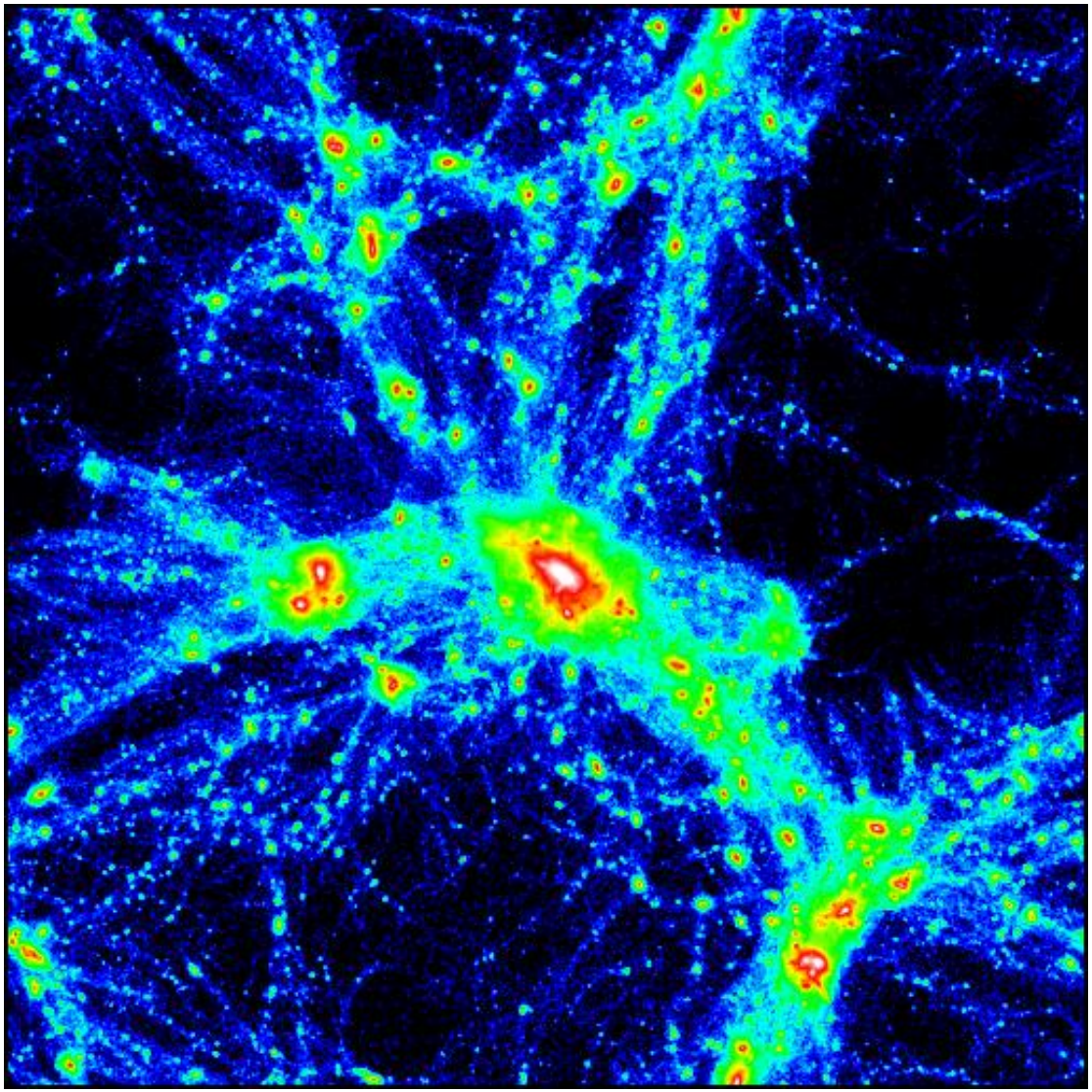
The largest objects



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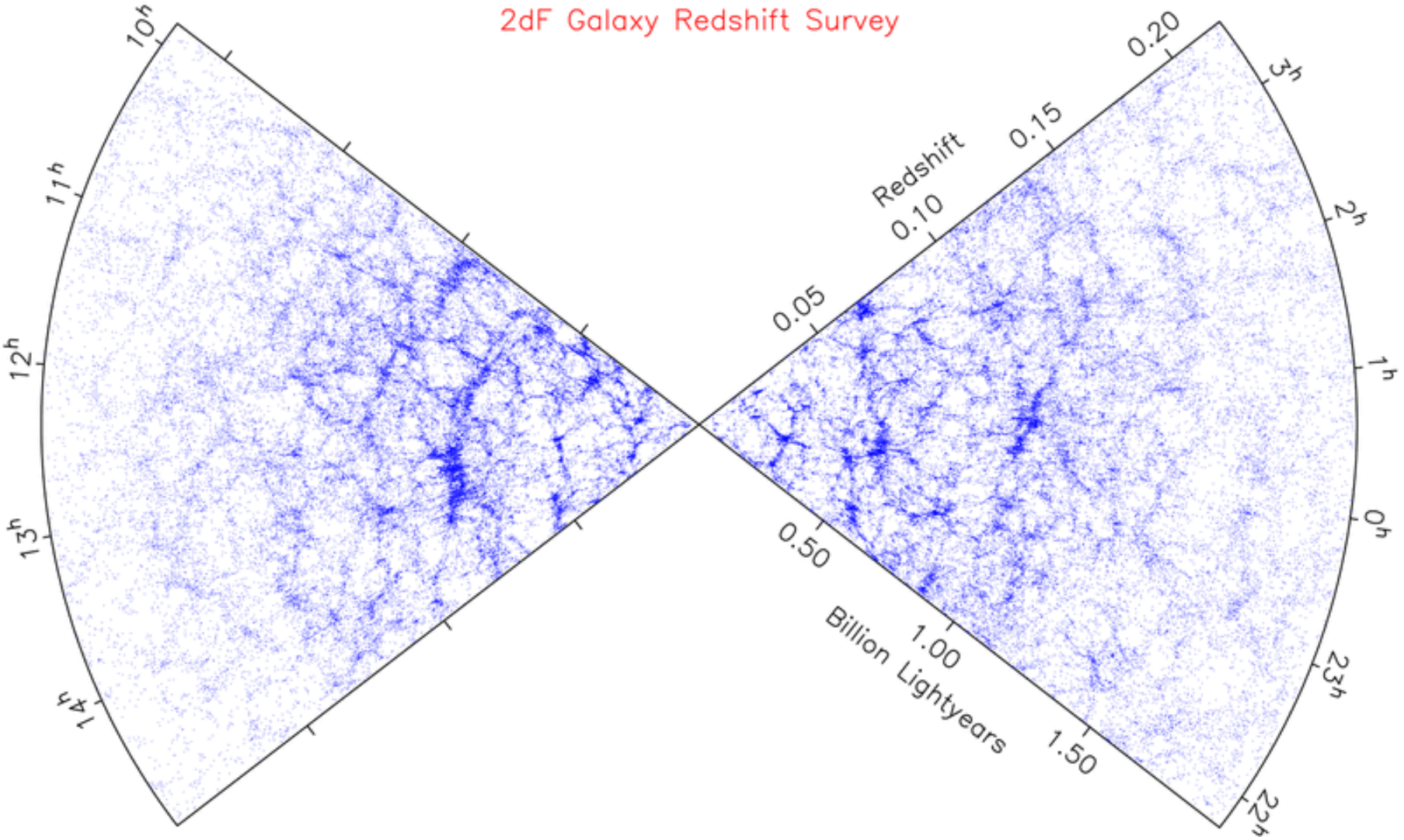
The largest objects



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Time and distance

- It takes time for the light to reach us
- So everything we see in the Universe is really a picture from some time ago
- The greater the distance, the longer ago we are seeing the object

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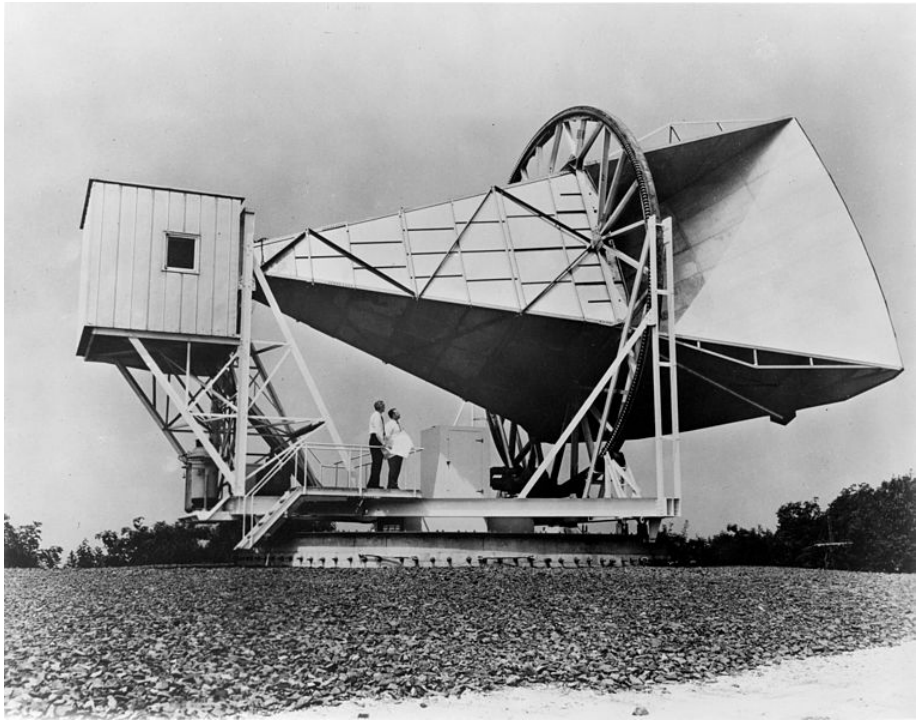
Time and distance

- We see the **Moon** from **1.282 seconds** ago
- We see the **Sun** from **8 minutes** ago
- We see the centre of **our Galaxy** from **27,200 years** ago

How far back?

- How far back can we go?

- In the 1960s Cosmic Microwave radiation was discovered



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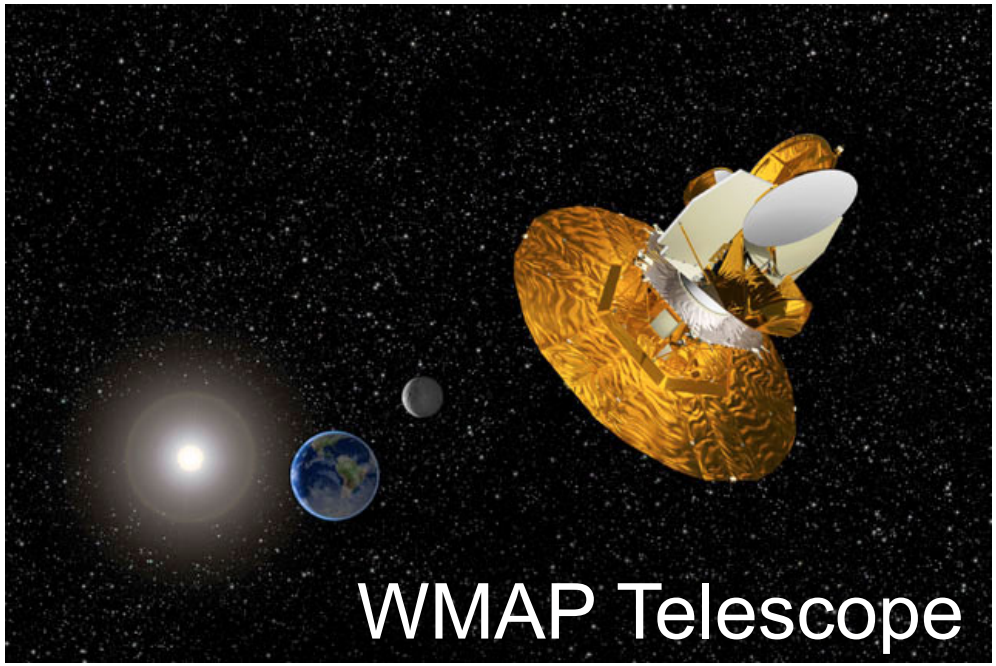
Cosmic Microwaves

- This radiation is seen in all directions
- There is some even in your TV set!



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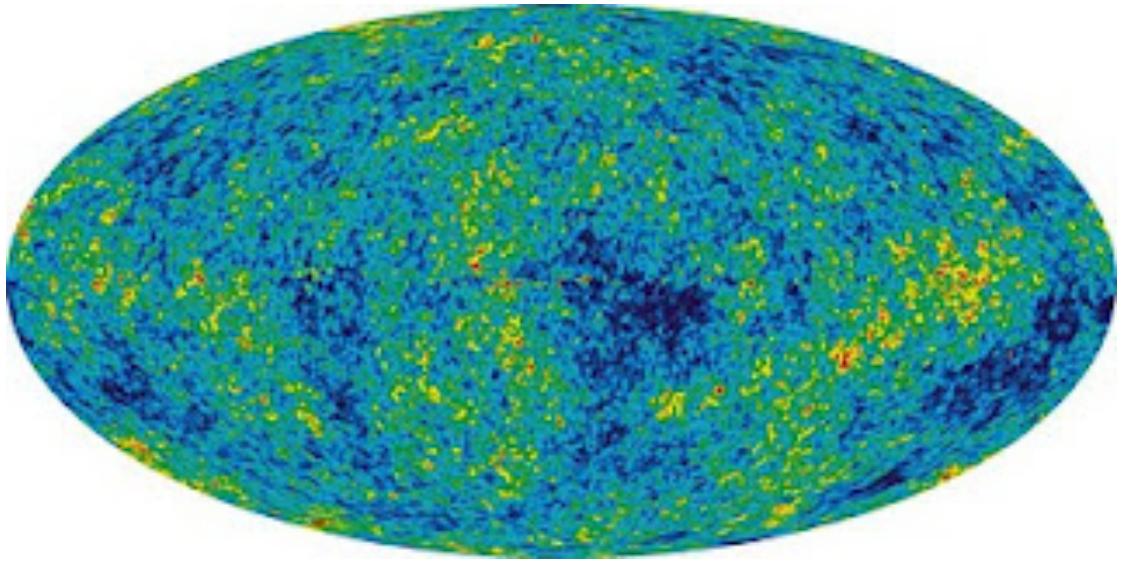
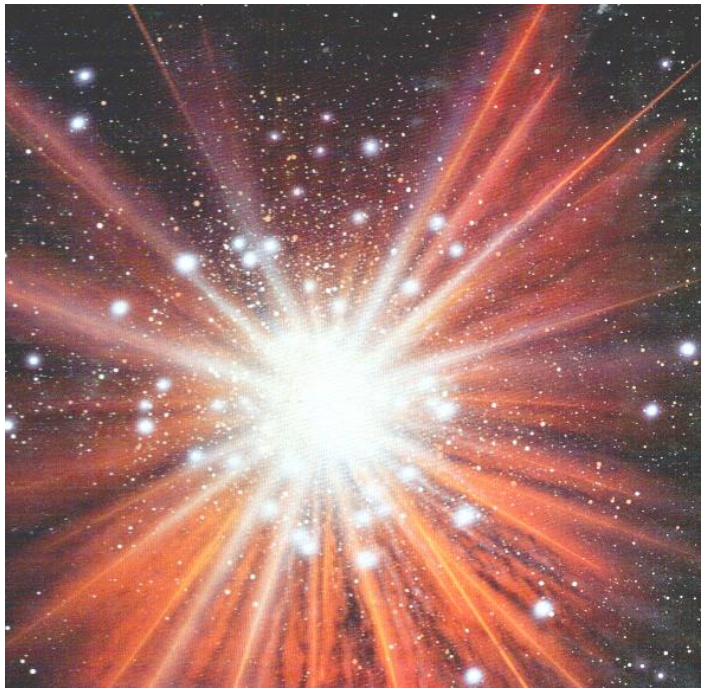
The oldest light

- We are actually seeing the oldest light in the Universe
- This was created in the Big Bang
- A picture of the beginning





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How Big is the Universe?

- This radiation tells Cosmologists how old, and so how big the Universe is

- The observed **Universe** is **13 billion years old**, so its size is 10s of billions of light-years

- Compare with the Sun and Earth, which are 4.5 billion years old

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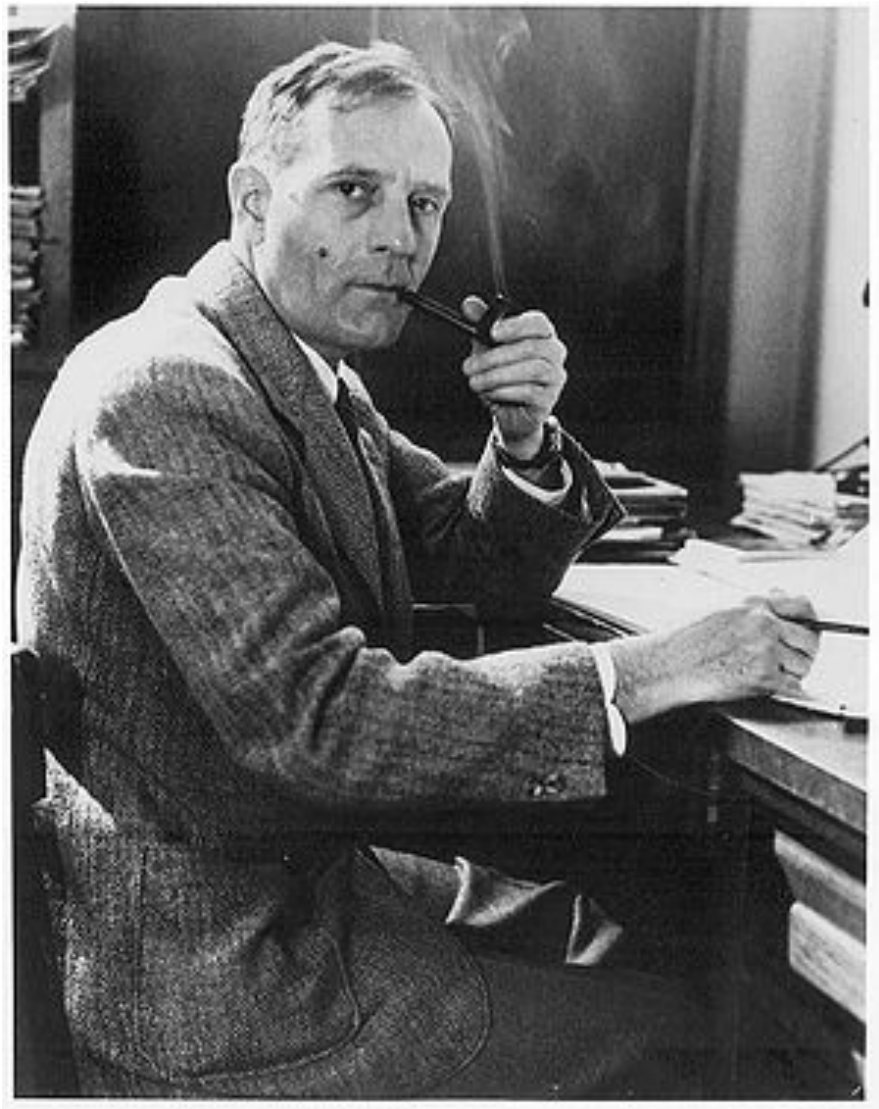
The Universe is expanding

- Hubble's observations of "island universes" in the 1930s



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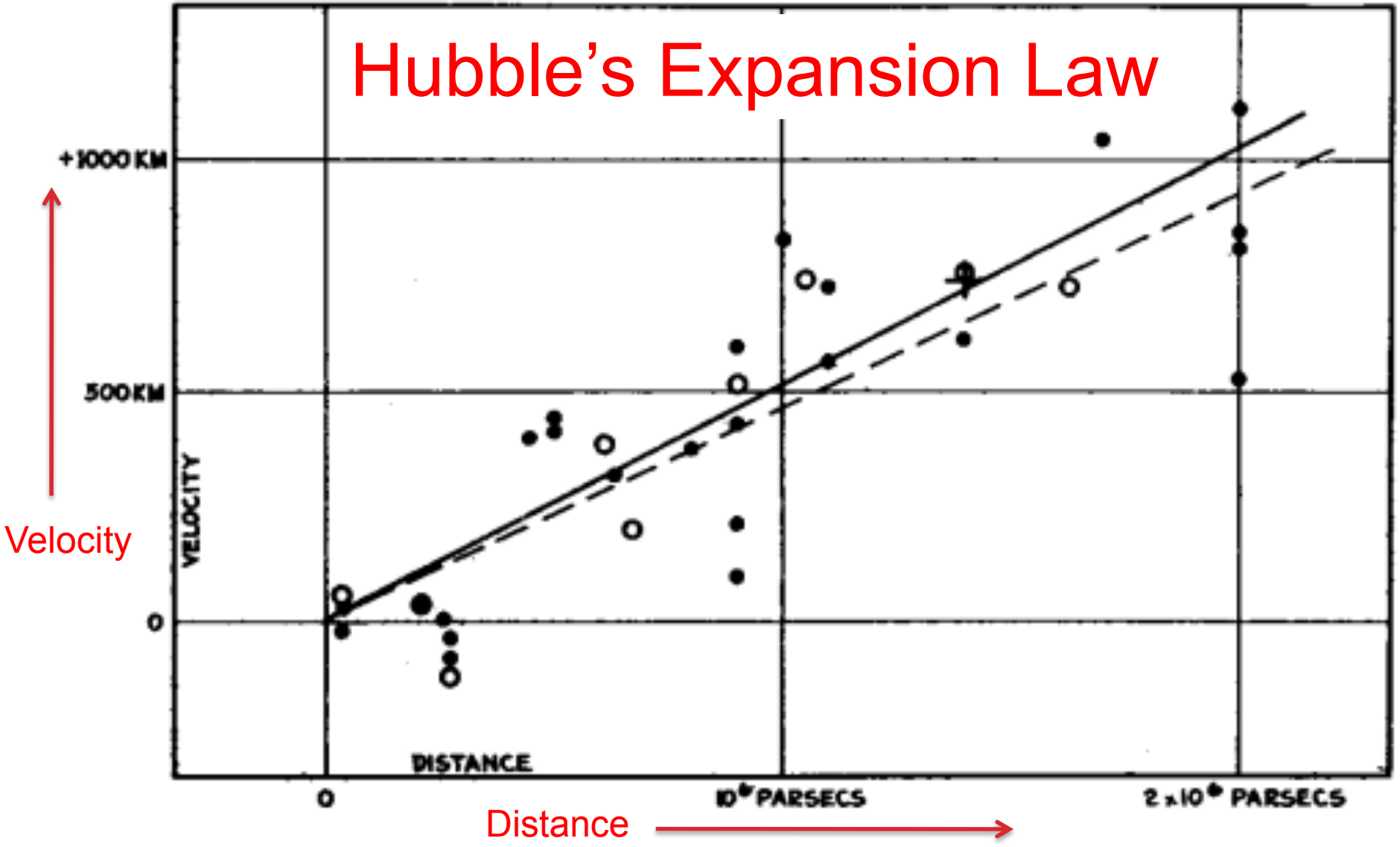
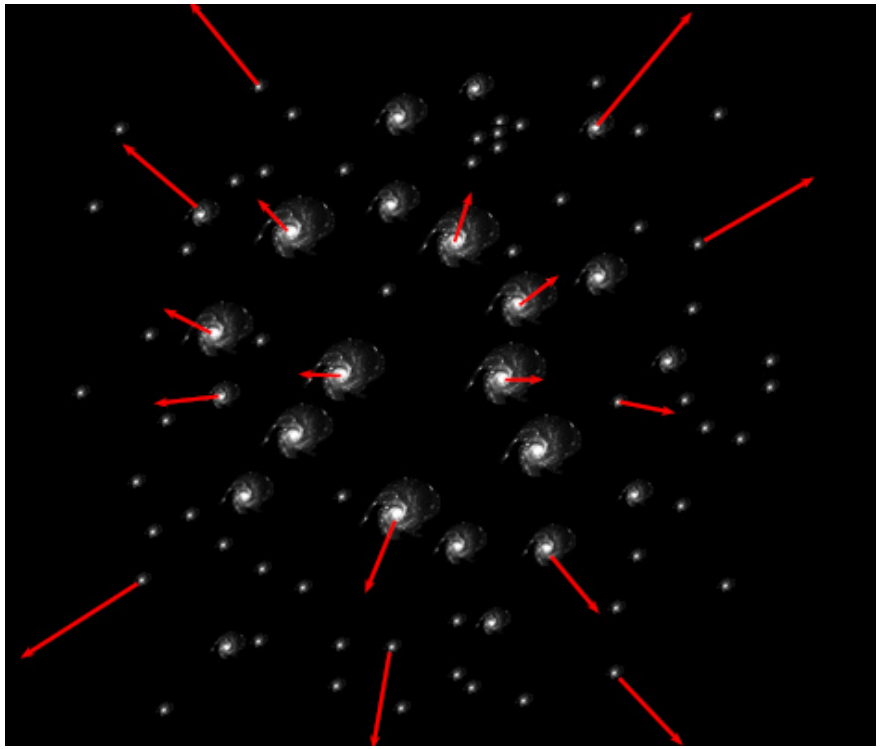
The Universe is expanding



The Universe is expanding

- The Universe is expanding
- Galaxies are moving away from us and each other
- The further away they are the faster they are moving



The expansion is increasing

- We use the “standard candle” supernovae to look further away
- We find that the universal expansion is accelerating
- This discovery won the 2011 Nobel Prize in Physics

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Dark Energy

- Force is proportional to acceleration
- Gravity is an attractive force, pulling things together
- Why do we see the mass in the Universe accelerating away?

A question for future scientists

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The Big Picture