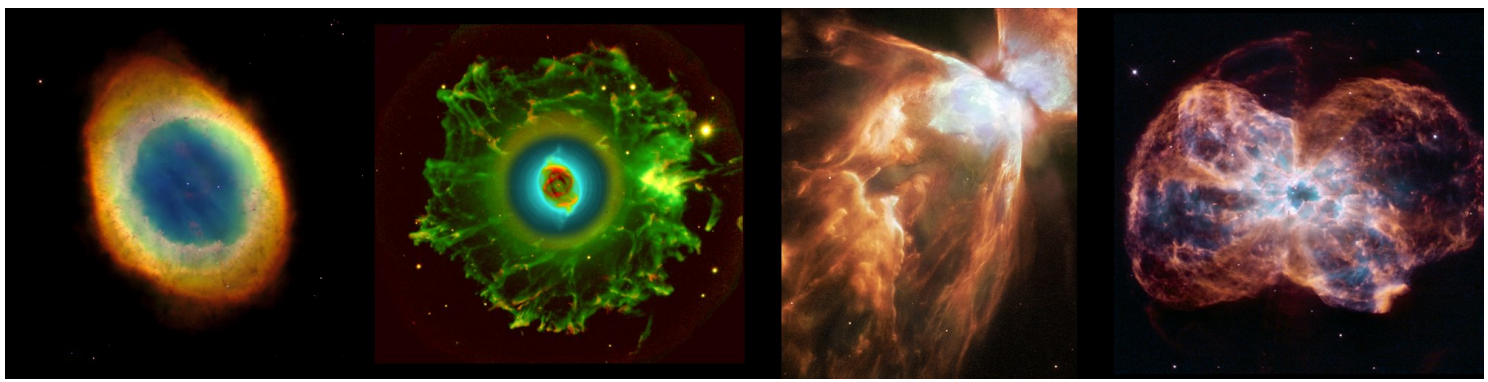
PHAS 1511: Foundations of Astronomy

Dr Roger Wesson

Research interests: deaths of stars. Planetary nebulae, novae and supernovae.



PHAS 1511: Foundations of Astronomy

- Course webpage:
- `http://www.tinyurl.com/PHAS1511`
- I will put each week's lecture notes on this page shortly after the lecture

PHAS 1511: Foundations of Astronomy

- Course text book: Universe (Freedman and Kaufmann), ninth edition
- Available from Waterstones – approx £46
- Also from Amazon – £46 new, possibly available cheaper second hand

Course overview

- We will learn about:
  - Basics of astronomy: time, coordinate systems, constellations
  - Electromagnetic radiation: how we find out about things at incomprehensible distances
  - Telescopes and detectors: From Galileo and Newton to Hubble and Herschel
  - Stars and galaxies: a brief overview
  - Into the dark: the strange topics at the forefront of modern astronomy

Useful resources

- My web page – lecture notes, problem sheets:
  `http://www.tinyurl.com/PHAS1511`
- The **Universe** web page has many useful things:
  `http://bcs.whfreeman.com/universe9e`
- Astronomy Picture of the Day is great:
  `http://zuserver2.star.ucl.ac.uk/~apod`

Ask questions!!

- Ask questions!!

Astronomy: basics

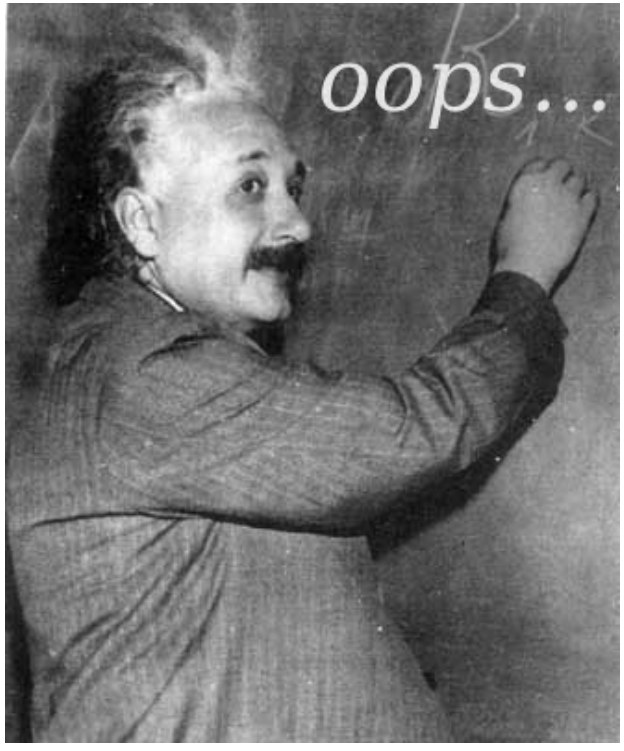
- Astronomy (Greek: **astron** + **nomos** = star law) is the oldest science. Ancient civilisations produced star charts and mapped the paths of the planets through the sky.

Astronomy: the scientific method

- Astronomy and astrology: an unfortunate similarity...
- Both spring from a desire to understand our place in the universe, but the distinguishing factor is the methods.
- Science proceeds by *testing hypotheses*: developing theories which make predictions. If the predictions are validated by observation, then the theory is OK... for now. If they are not, then it's back to the drawing board.
- Astrology makes no testable predictions... or if it does, it ignores the observations which disprove them!

Astronomy: the scientific method

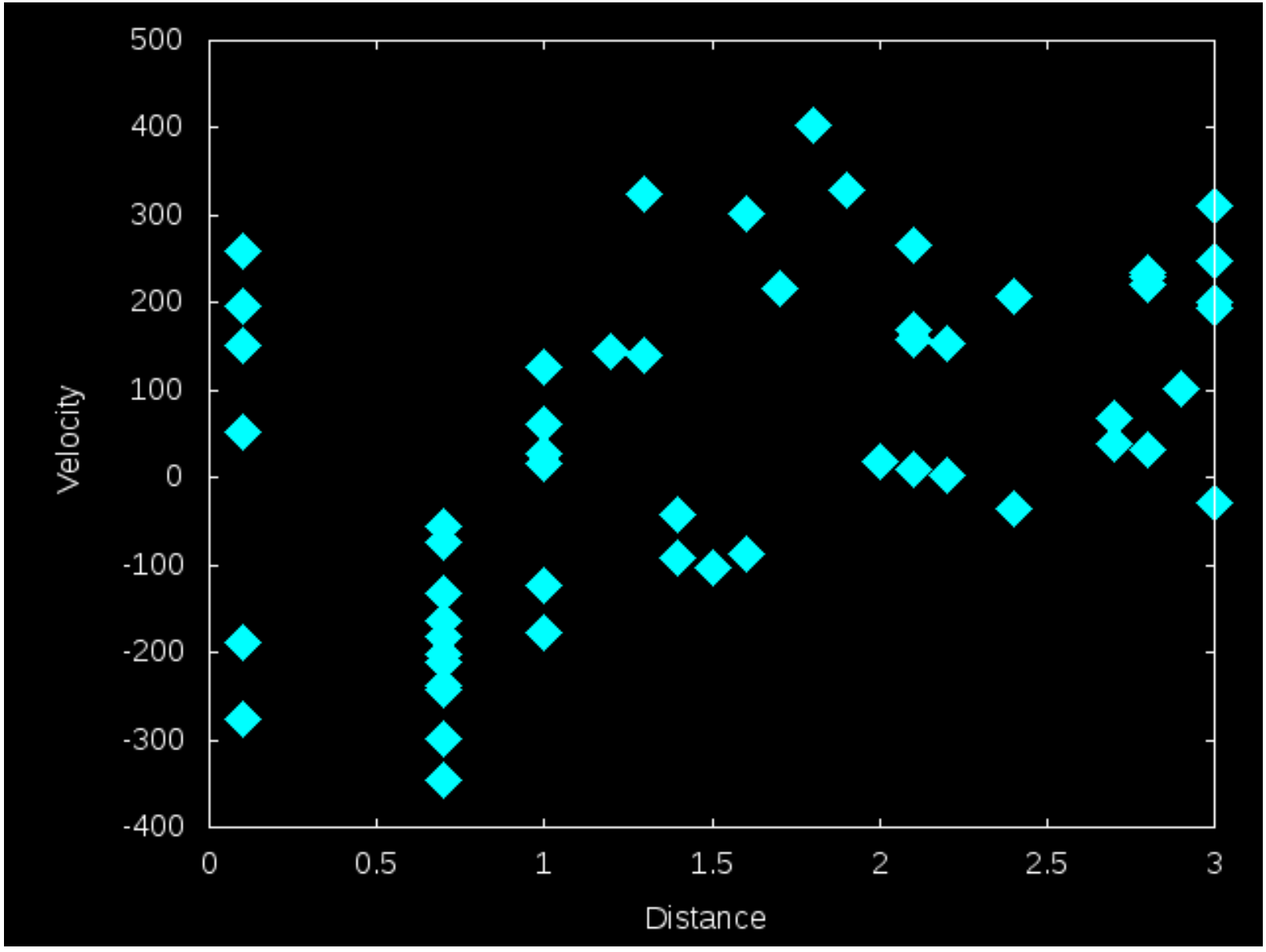
- Observations drive theory. Even the most elegant and wonderful theory can be disproved by one contradictory observation.
- Famous example: Einstein's 'greatest blunder'



Astronomy: the scientific method

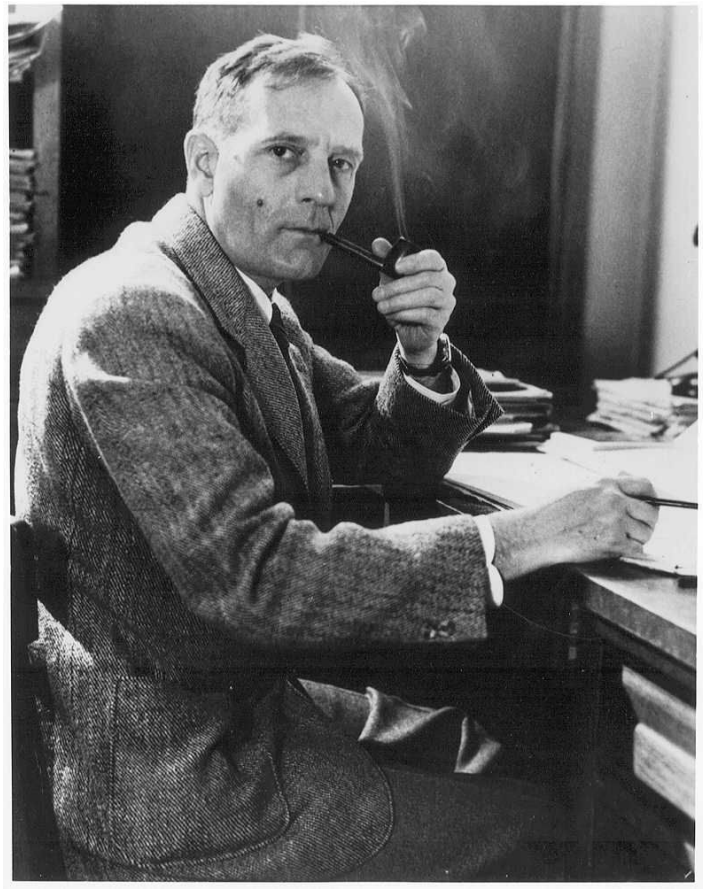
- In the early 20th century, it was only just becoming clear that the Solar System was in a galaxy, and that objects like the Andromeda Nebula were also galaxies

Astronomy: the scientific method

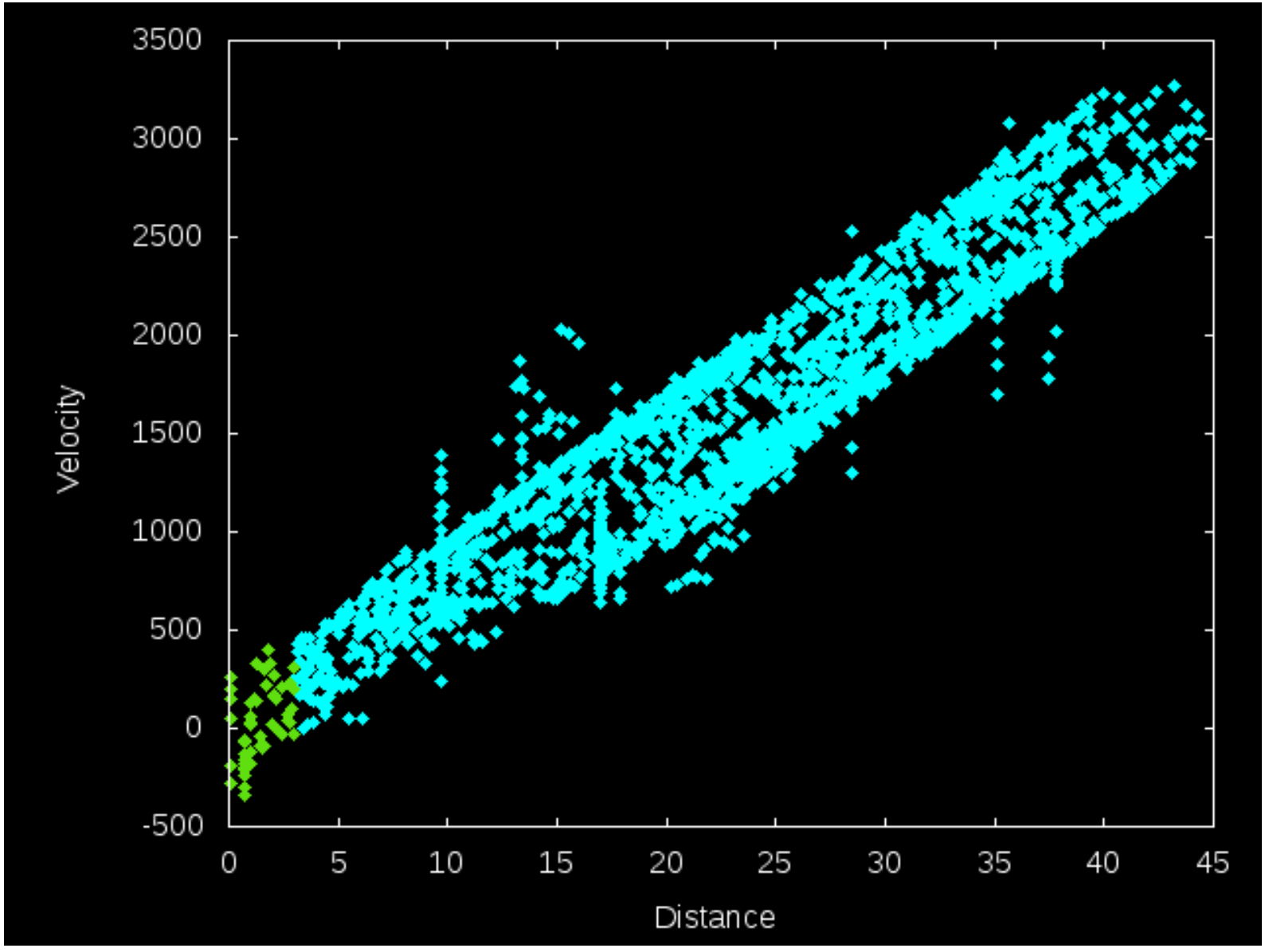


Astronomy: the scientific method

- Hubble looked further away and discovered the expansion of the universe.



Astronomy: the scientific method



Astronomy: the scientific method

- To make sense of the universe, we have to assume that it can be described by fundamental laws, and that these laws are the same everywhere and at all times.
- For example, the speed of light is 300,000 km/s, and we assume that this is a constant.

Astronomy: angles

- The sky appears to us like a sphere: everything is so far away that there is no perspective.
- So, positions in astronomy are measured with *angles*. A circle is divided into 360 degrees, so from the horizon to directly overhead (the *zenith*) is 90 degrees.
- The ‘pointers’ in the Plough are about 5 degrees apart

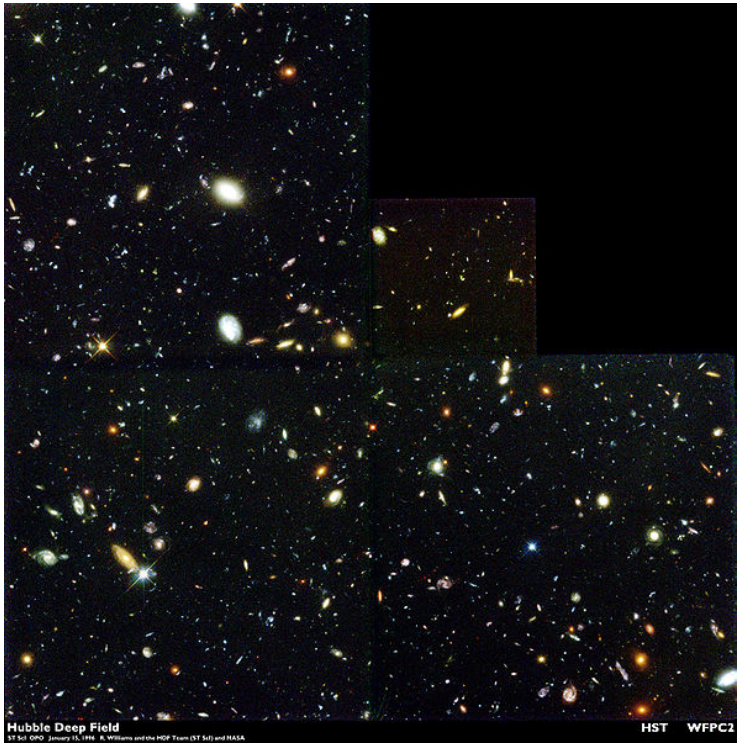
Astronomy: angles

Astronomy: angles

- Degrees are subdivided: 1/60 of a degree is an arcminute, and 1/60 of an arcminute is an arcsecond.
- A pound coin at a distance of three miles would have an angular diameter of one arcsecond.
- The Moon and the Sun are both about 30 arcminutes across.

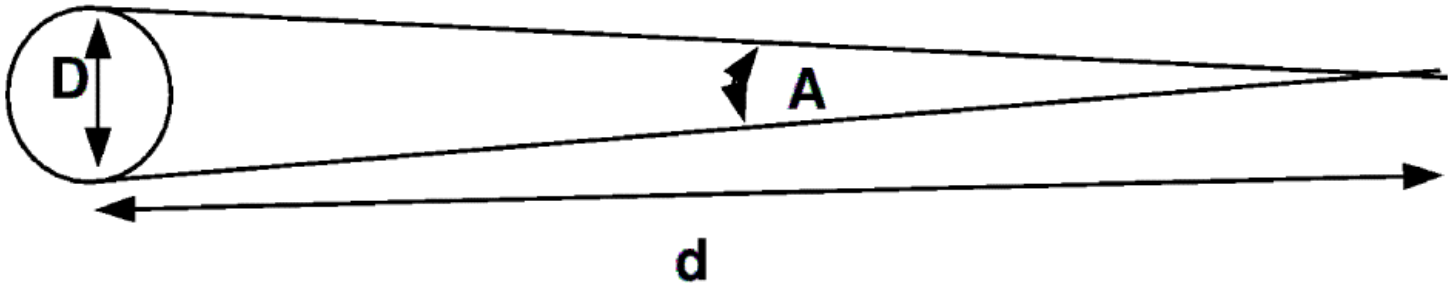
Astronomy: angles

- The human eye can resolve things as small as an arc-minute across.
- The Hubble Space Telescope can resolve things as small as 0.05 arcseconds across – much better! This image is 2.5 arcminutes across:



Astronomy: angles

- Relating angles and distances: if we know the actual size of an object, and its angular size, we can work out its distance.
- Or, if we know its distance, and its angular size, we can work out its actual size:



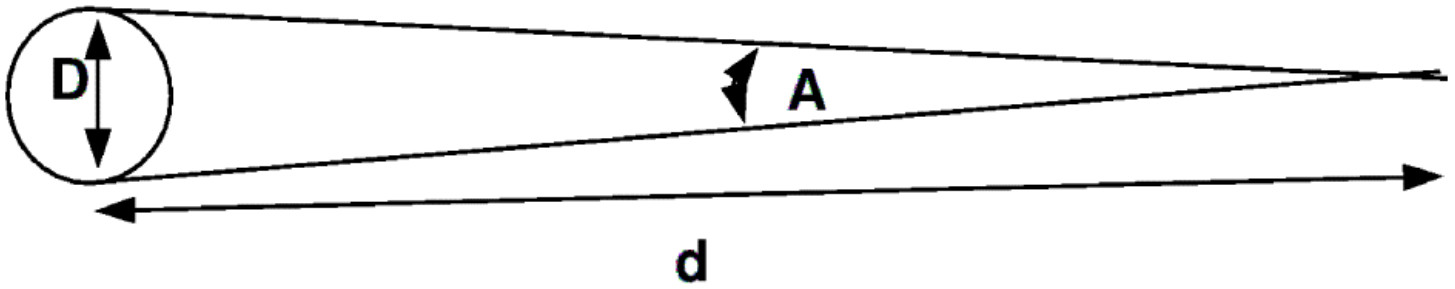
$$A = \frac{D}{d} \times 206265 \text{ arcseconds}$$

Astronomy: angles

- Example: the Sun is half a degree (=1800 arcseconds) across.
- Its distance is 150,000,000 km

$$
\begin{aligned}
A &= \frac{D}{d} \times 206265 \\
1800 &= \frac{D}{150,000,000km} \times 206265 \\
D &= \frac{1800 \times 150,000,000}{206265} \\
&= 1,300,000km
\end{aligned}
$$

- So, its diameter is 1,300,000 km

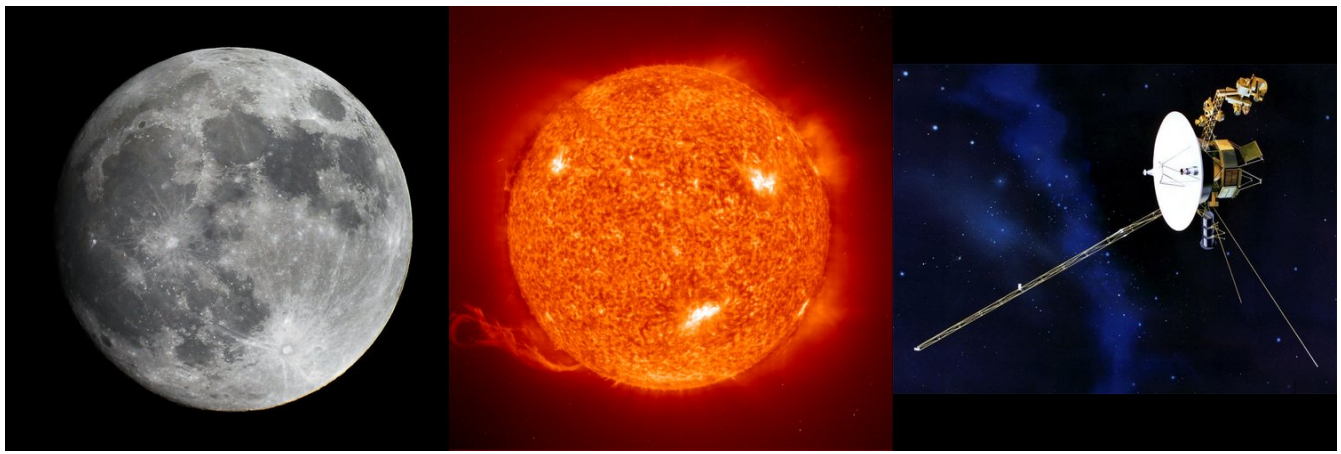


Astronomy: distances

- A warning: sensible scientists would use the SI (*Systeme Internationale*) system of units – metres, seconds, kilogrammes. Astronomers are not sensible scientists!
- There are many distance units in common use. Here are some:
- The average distance from the Earth to the Sun is called an *Astronomical Unit* or *AU.*
- There are about 150,000,000km in an AU
- The distance that light travels in a year is called a light year. There are 9,460,000,000,000 kilometres in a light year. The nearest star is almost four light years away.

Astronomy: distances

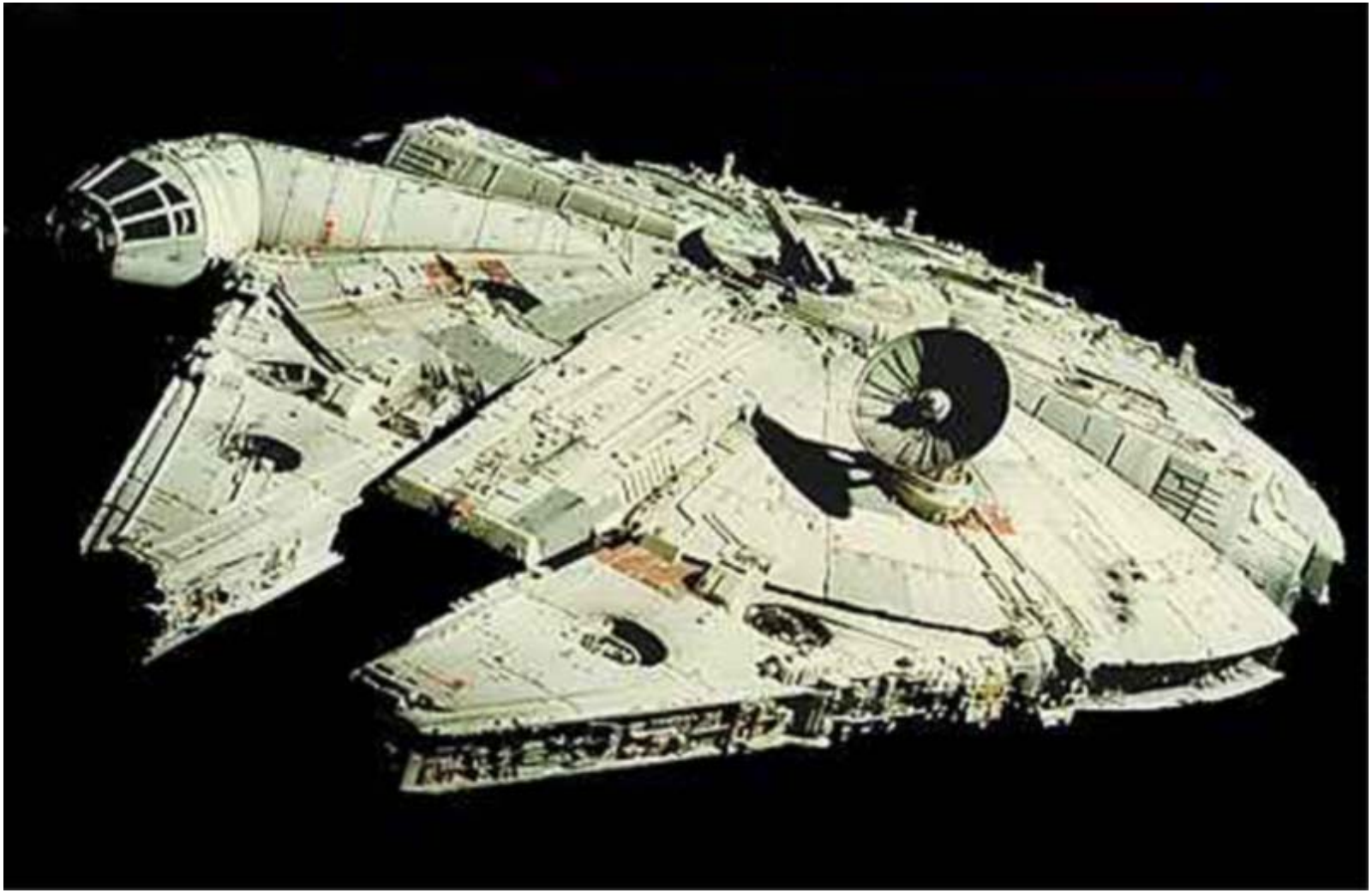
- Light-seconds, light-minutes, light-hours and other light-distances are also sometimes used:
- Moon : 1.25 light-seconds away from Earth (384,000 km)
- Sun : 8 light-minutes away (150 million km)
- *Voyager* probe : 16 light hours away (17 billion km)



Astronomy: distances

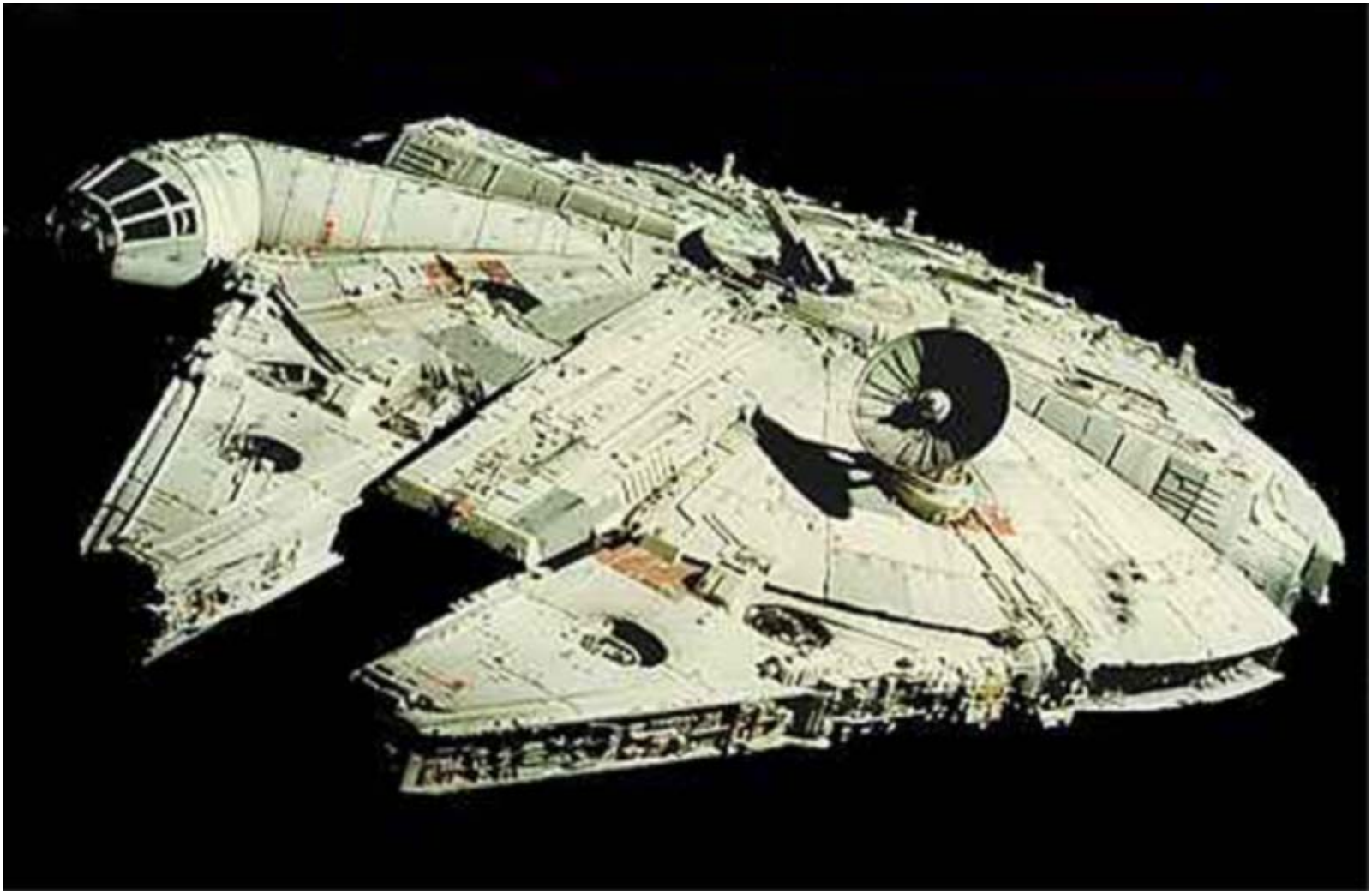
- Another very common unit is the *Parsec*. An object one *Astronomical Unit* across, at a distance of a parsec, would appear an arcsecond across.
- One parsec = 3.26 light years, or 206,264 astronomical units.
- Astronomical Units are very convenient in the Solar System. Light years and parsecs are convenient in the galaxy and beyond.

Astronomy: distances



“...this ship made the Kessel run in less than 12 parsecs...”

Astronomy: distances



Han Solo doesn’t know astronomical units...

Astronomy: distances

- Very large distances can be expressed with prefixes. You are probably familiar with some of these prefixes.

$$\begin{aligned} 1 \text{ kiloparsec} &= 1000 \text{ parsecs} \\ 1 \text{ megaparsec} &= 1,000,000 \text{ parsecs} \end{aligned}$$

Astronomy: mass and luminosity

- Masses in the solar system are often expressed in terms of the mass of the Earth, Jupiter or the Sun.
- Earth and the Sun have their own special symbol:

$$
\begin{array}{llll}
1M_{\oplus} & = 0.003M_J & = 0.000003M_{\odot} & = 5.97\times10^{24}\ \text{kg} \\
318M_{\oplus} & = 1M_J & = 9.5\times10^{-4}M_{\odot} & = 1.89\times10^{27}\ \text{kg} \\
333000M_{\oplus} & = 1060M_J & = 1M_{\odot} & = 1.99\times10^{30}\ \text{kg}
\end{array}
$$

Astronomy: mass and luminosity

- The luminosity of stars is often described in units of the Solar Luminosity: the amount of energy emitted by the Sun every second.

$$1 L_{\odot} = 3.84 \times 10^{26} W$$

- The size of stars is often described in units of the Solar Radius:

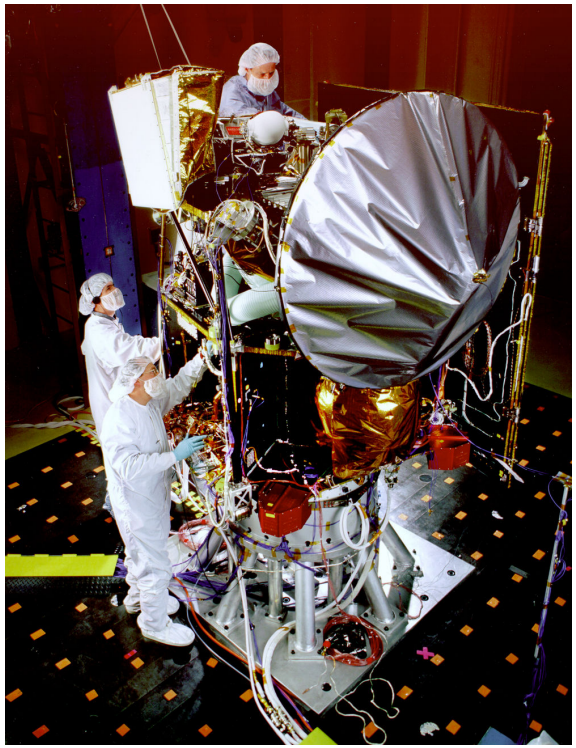
$$1 R_{\odot} = 696,000 km$$

Astronomy: unit conversion

- Converting between different units is a crucial skill in astronomy
- Google is very handy – type ‘one AU in furlongs’ and it will tell you

Astronomy: unit conversion – a cautionary tale

- Mars Climate Orbiter was launched in 1998. Due to a unit conversion error, the rockets which should have slowed it down on arrival at Mars did not fire with enough force, and it burned up in the Martian atmosphere



Astronomy: some maths

- You can see that distances in astronomy are huge. If we wanted to use centimetres to measure vast things, writing out so many zeroes would be inconvenient.
- So we use a shorthand notation.

1000	= 10 x 10 x 10	$= 10^3$
100,000	= 10 x 10 x 10 x 10 x 10	$= 10^5$
		$= 10^2 \times 10^3$
0.1	= 1/10	$= 10^{-1}$
0.001	= 1/(10 x 10 x 10)	$= 10^{-3}$
10^0	= 1	

Astronomy: some maths

- Large numbers are commonly written in the form

$$1.5 \times 10^8$$

- This is the number of kilometres in an Astronomical Unit. It could also be written 15×10^7 or 0.15×10^9. It is like describing 1000 as ten hundreds, or a hundred tens – it's the same number.

Astrometry

- Astronomy through the ages has largely been about measuring the positions of the stars – **astrometry**.
- Many ancient structures relate to the positions of the star. E.g. Stonehenge is arranged to indicate where the Sun will rise at particular times of year.

Constellations

- Some aspects of ancient astronomy have been handed down through the ages and are still in use today - eg **constellations**.
- The first map of the sky which divided it (arbitrarily) into sections called constellations was that of Ptolemy in the 2nd Century AD. Ptolemy's constellations are still in use today.

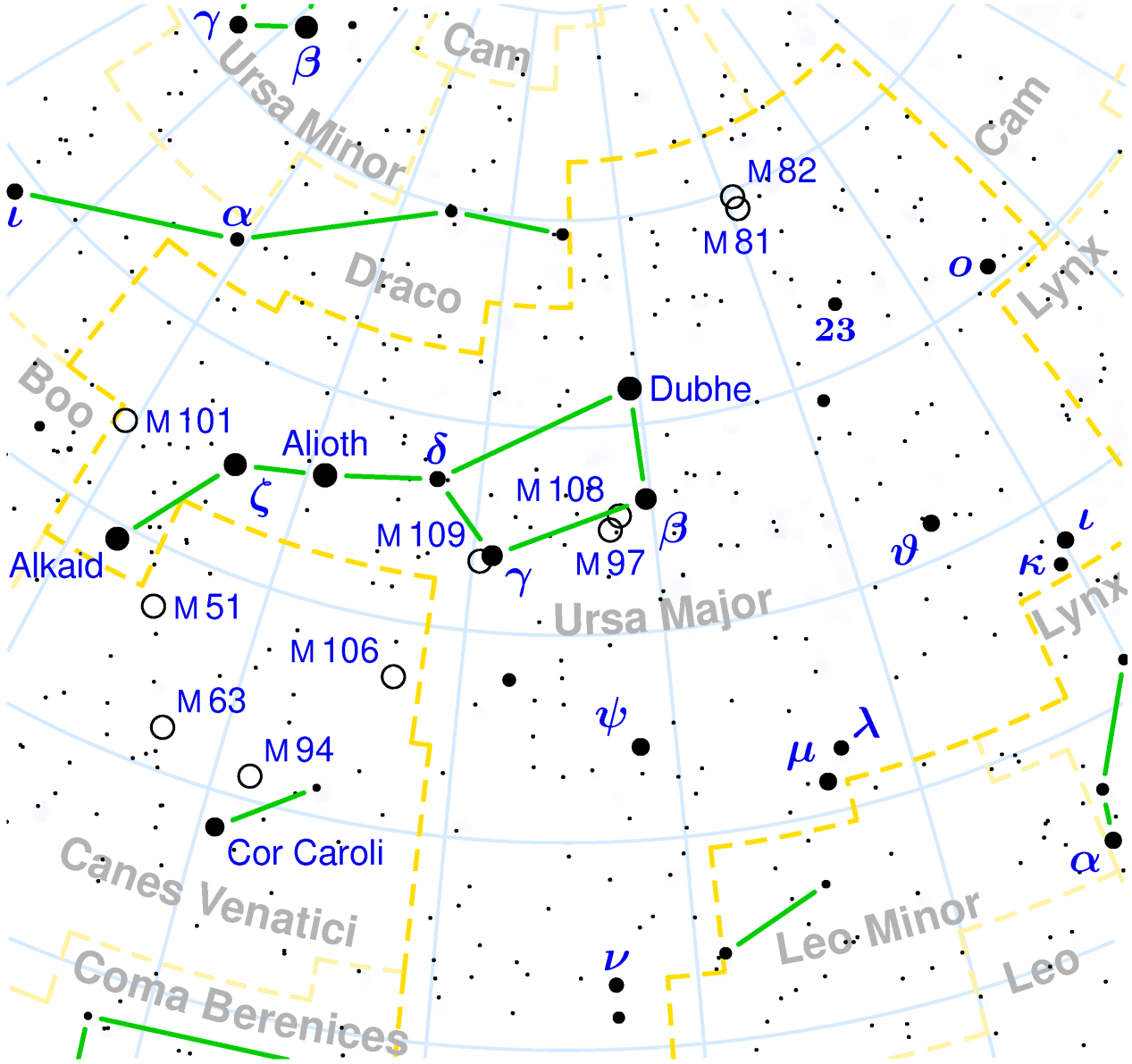
Constellations

- Other constellations are more recent inventions – particularly those in the southern hemisphere, which Ptolemy obviously never saw.
- In total, there are 88 constellations. 47 are from Ptolemy, 41 are modern inventions.

Constellations

- The constellations cover the whole of the sky. Some are large, some are small. Every part of the sky is in one constellation only.
- Some constellations contain recognisable patterns of stars, like the Plough and Orion. But every star (and every object of any kind) within the constellation's boundaries is part of the constellation, and not just the recognisable pattern.

Constellations



Star names

- Astronomical objects go by many names...

- The Pleiades

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- The Pleiades, Messier 45, Melotte 22, C 0344+239

Star names

- Bright stars have names used often since ancient times
- e.g. Sirius (from ancient Greek *Seirios* - “scorcher”)
- Deneb (from Arabic *dhaneb* - “tail”)
- Capella (from latin *capella* - “little goat”)

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- Appeared on a star chart produced by Niccolo Cacciatore...
- ...”Nicolaus Venator” in Latin!

Star names

- *Bayer letters*: given to stars by Johann Beyer in 1603
- eg α Orionis = Betelgeuse, β Orionis = Rigel
- Nominally ordered by brightness but often not - Rigel is brighter than Betelgeuse!

- *Flamsteed numbers*: assigned by John Flamsteed in 1725
- eg 51 Pegasi, the first sun-like star to have a planet discovered orbiting it
- “34 Tauri” turned out to be the planet Uranus!

- Other examples: Barnard’s Star, named after E.E. Barnard who discovered it

Other names

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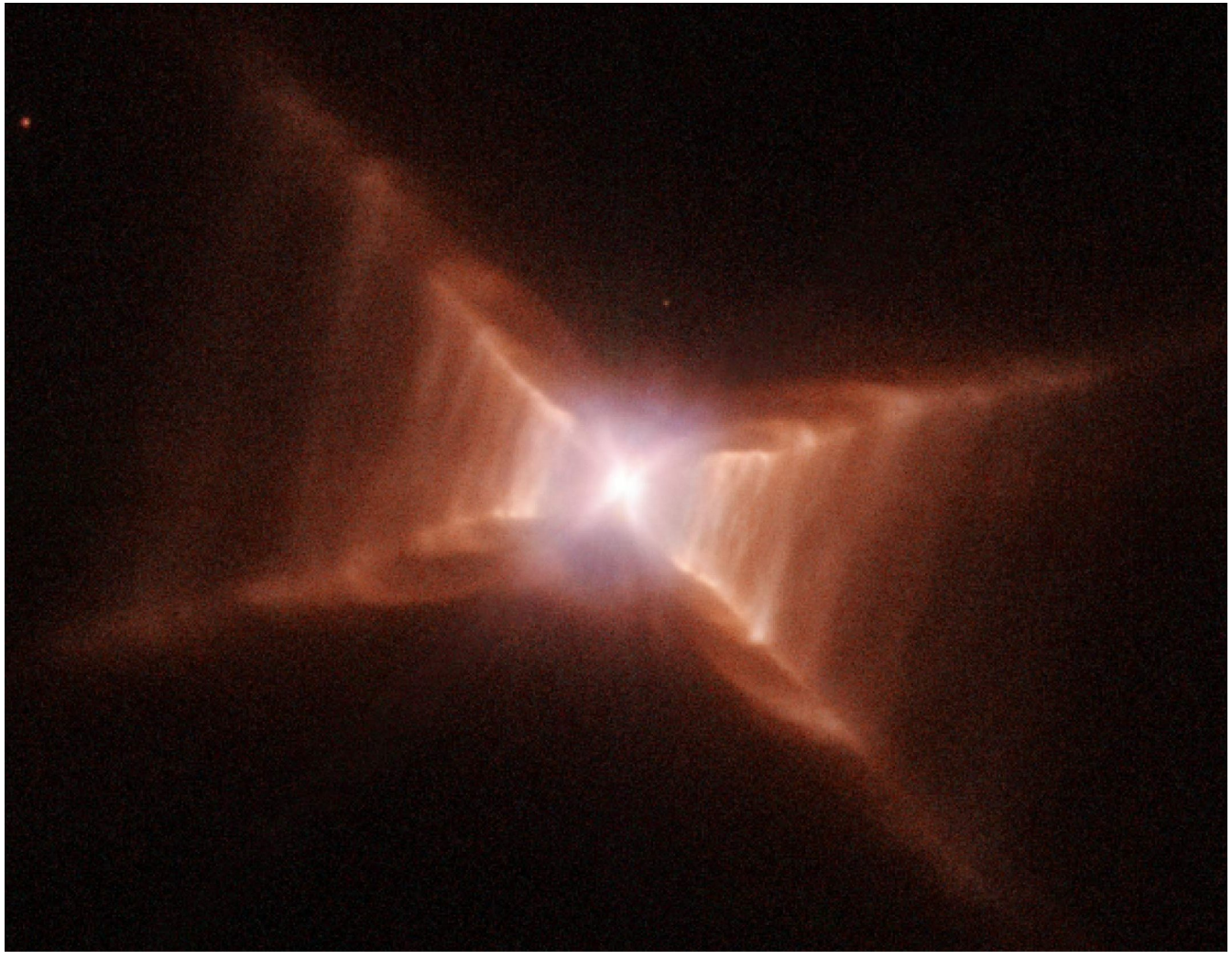

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