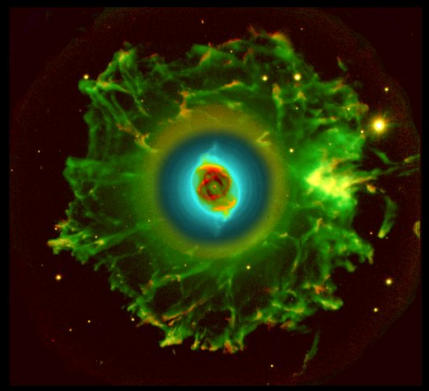
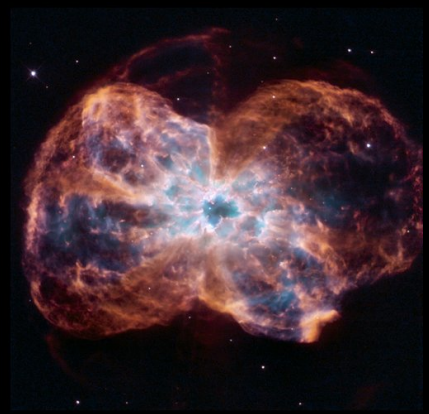
PHAS 1511: Foundations of Astronomy

Dr Roger Wesson

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



PHAS 1511: Foundations of Astronomy

- Course webpge:
- `http://zuserver2.star.ucl.ac.uk/~rwesson/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), eighth edition
- Available from Waterstones – approx £38
- Also from Amazon – £38 new or about £20 second hand

Course overview

- We will learn about:
- Basics of astronomy: time, coordinate systems, constellations
- The contents of the universe: stars, galaxies and clusters
- How we study the universe: particles, radiation, telescopes and detectors

Useful resources

- My web page – lecture notes, problem sheets:
- `http://zuserver2.star.ucl.ac.uk/~rwesson/PHAS1511`
- The **Universe** web page has many useful things:
- `bcs.whfreeman.com/universe8e`
- Astronomy Picture of the Day is great:
- `www.star.ucl.ac.uk/~apod`

Ask questions!!

- Ask questions!!

This lecture

- We will cover:
  - How astronomy works – the scientific method.
  - Angles and measurements used in astronomy
  - A convenient way to write large numbers
- Then a broad overview of:
  - The Galaxy
  - Extragalactic astronomy
  - Cosmology

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.
- Early astronomy was all about measuring positions – astrometry. *astron + metria* = measuring the stars.
- Astrometry is crucial – before we can study the stars, we need to be able to find them.

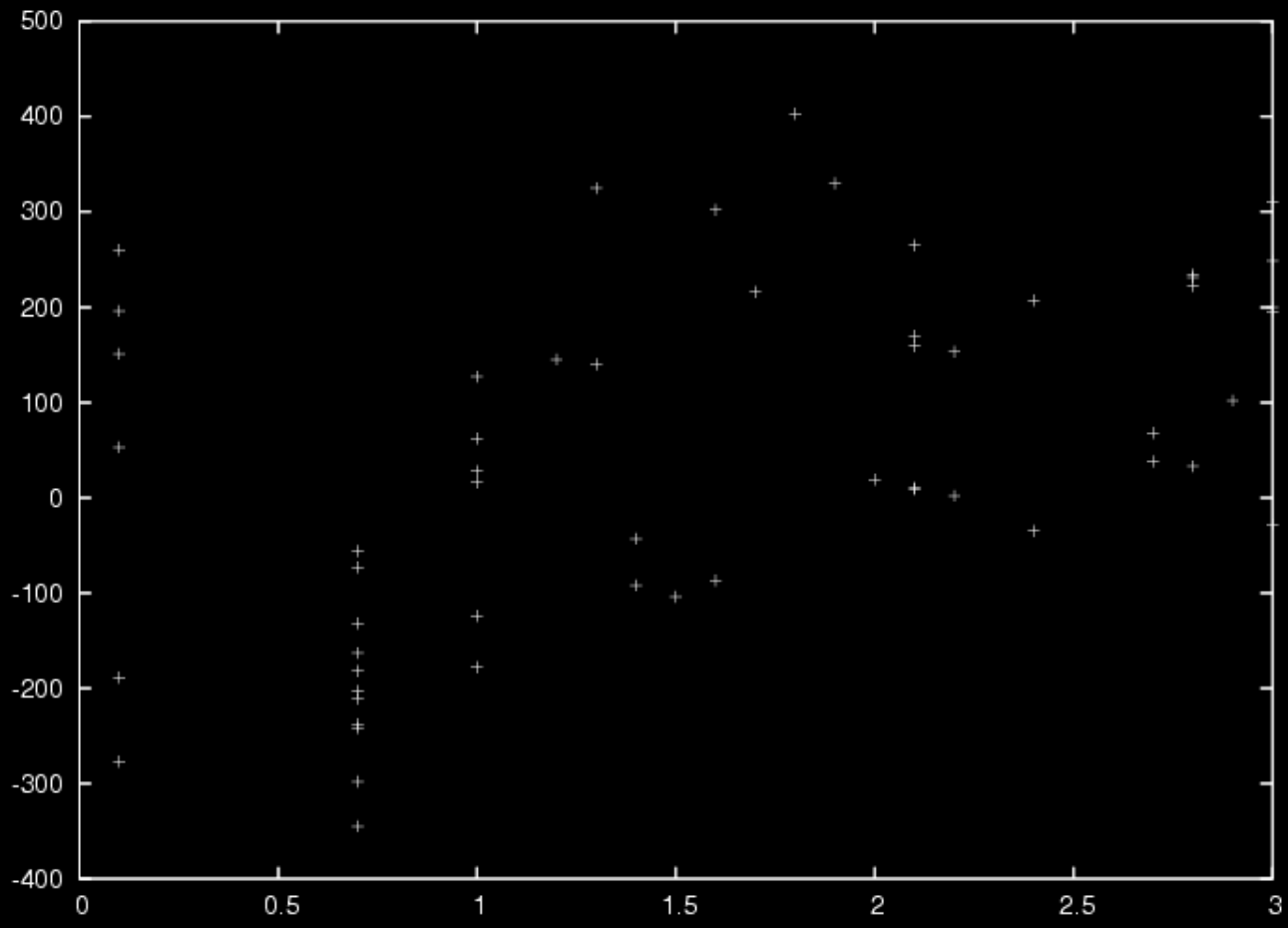
Astronomy: the scientific method

- 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

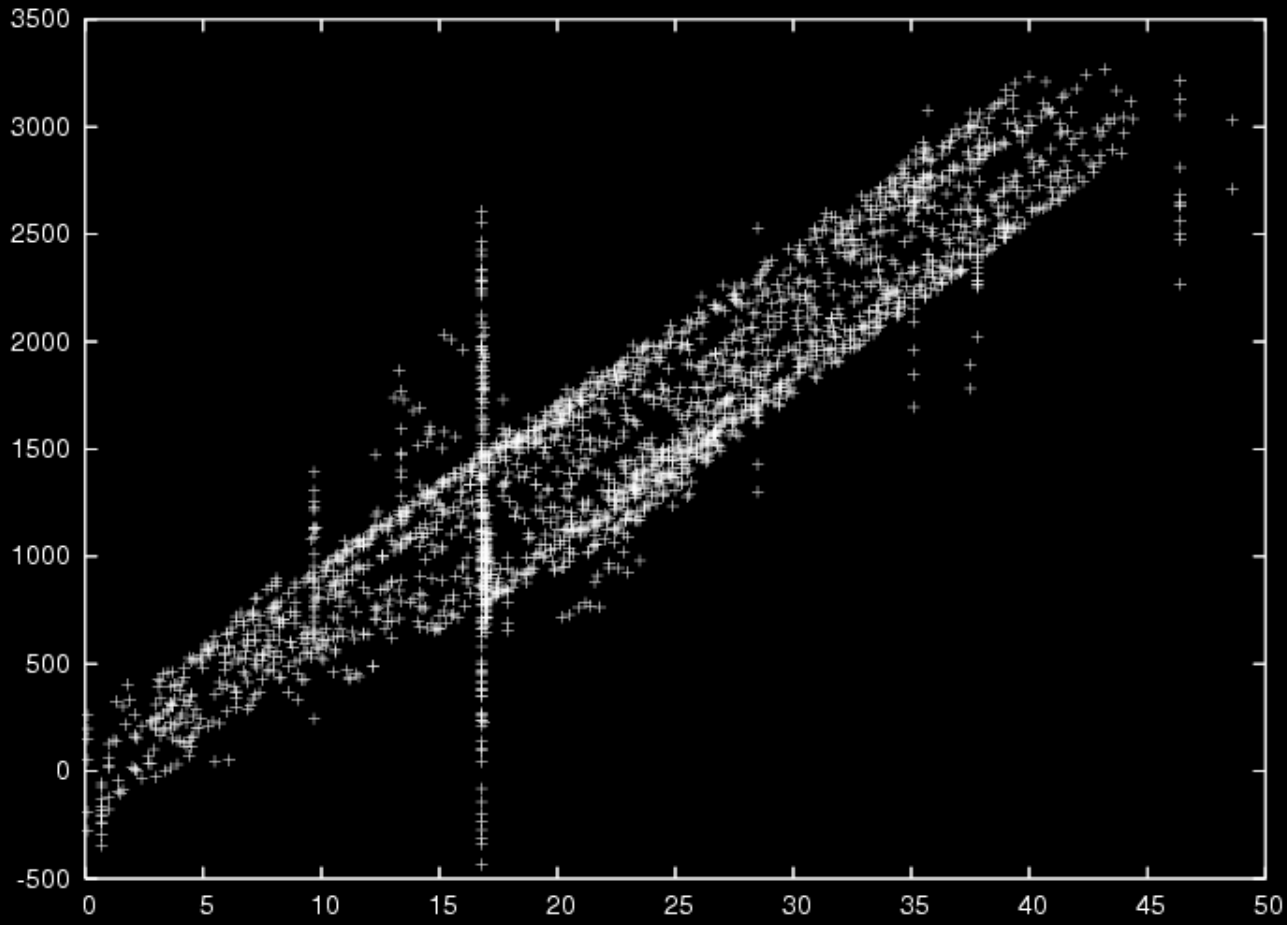
- Observations drive theory. Even the most elegant and wonderful theory can be disproved by one contradictory observation.
- Famous example: Einstein's 'greatest blunder'

Astronomy: the scientific method



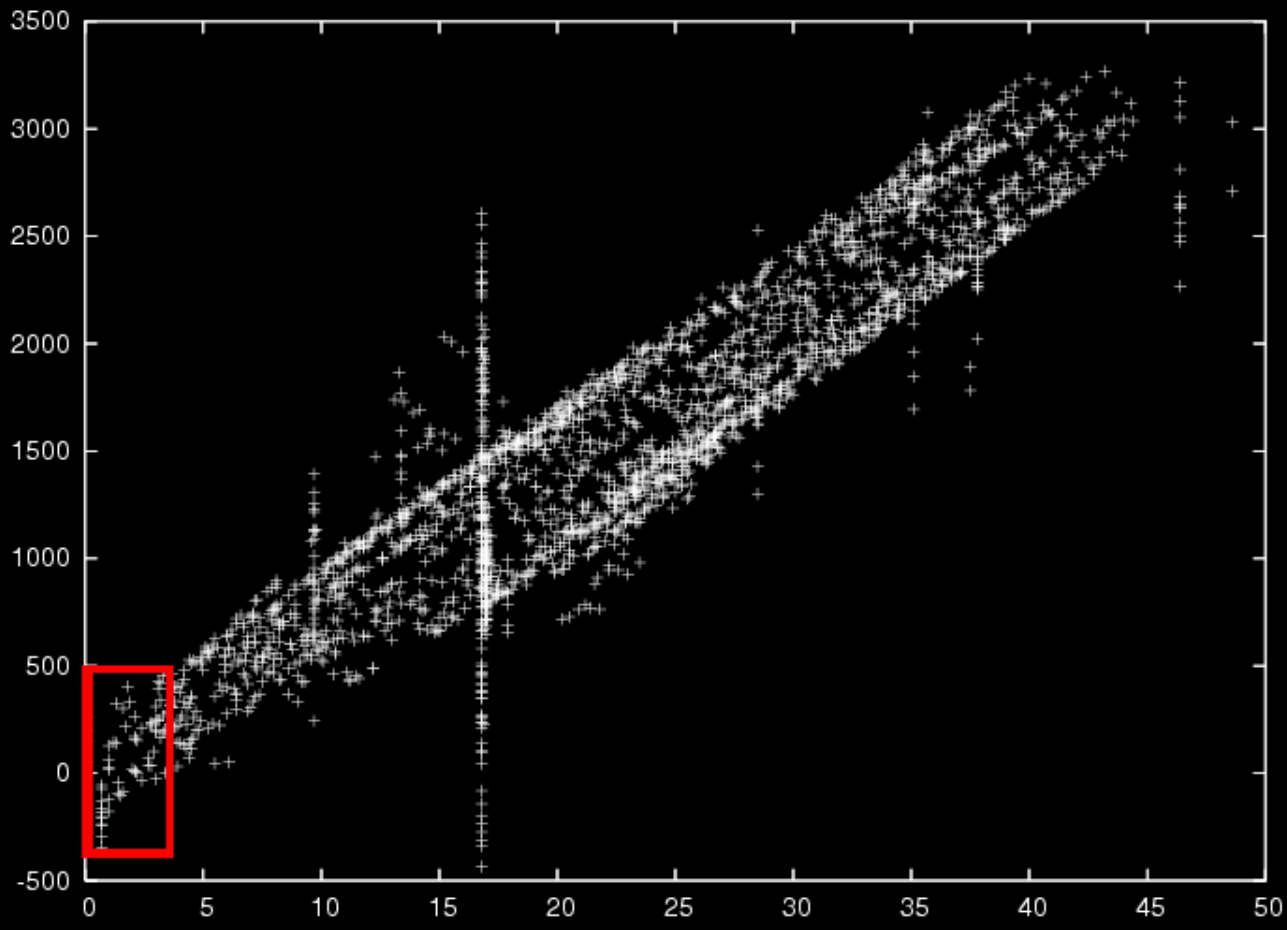
As far as Einstein knew, the universe was neither contracting nor expanding.

Astronomy: the scientific method



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

Astronomy: the scientific method



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

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

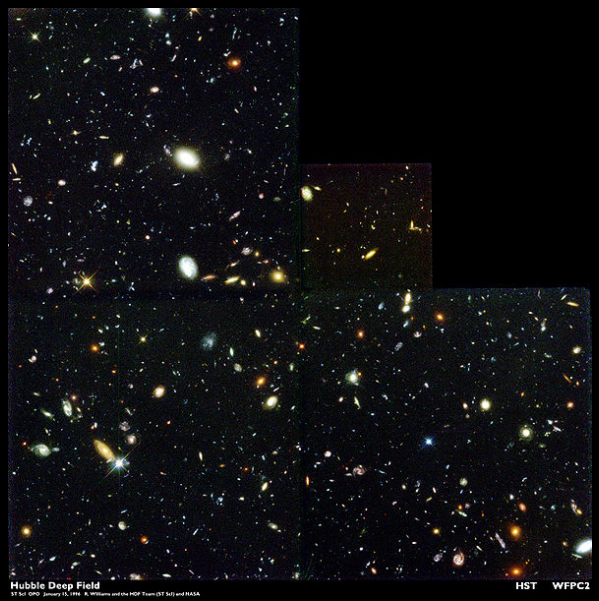
Astronomy: angles

Astronomy: angles

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

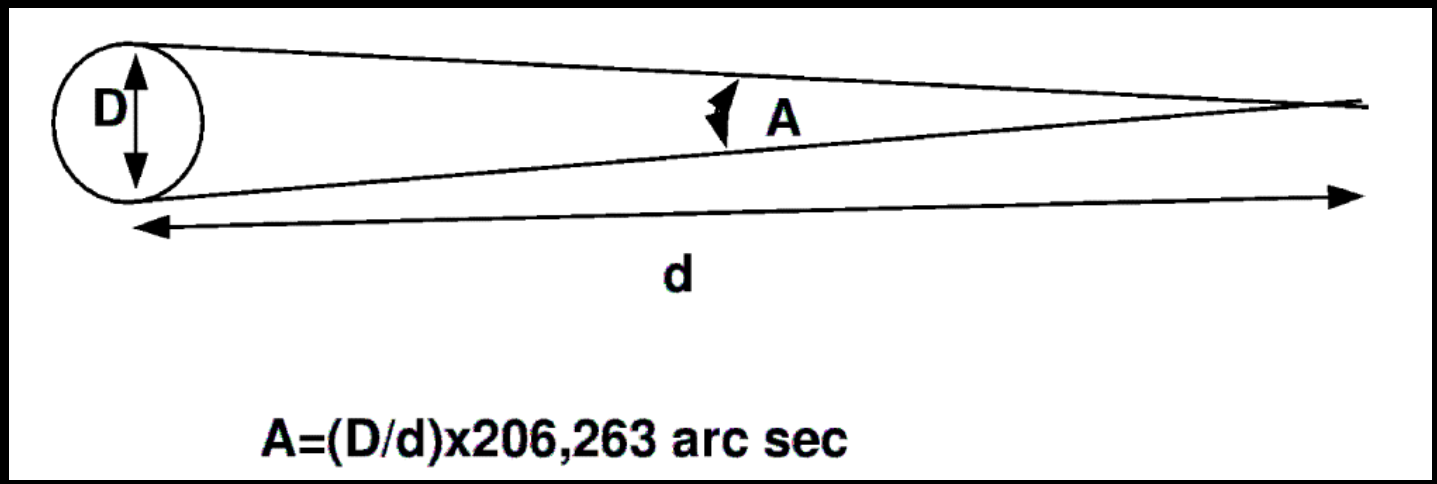
Astronomy: angles

- 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!



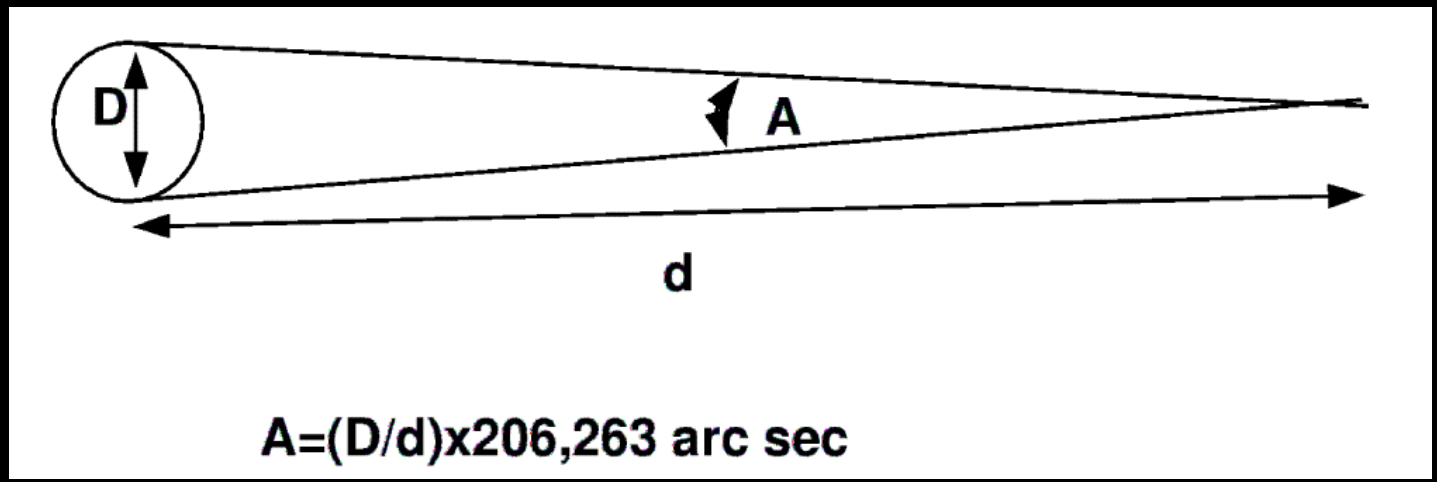
Astronomy: angles

- 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:



Astronomy: angles

- Example: the Sun is half a degree (=1800 arcseconds) across.
- Its distance is 150,000,000 km
- So, its diameter is 1,300,000 km

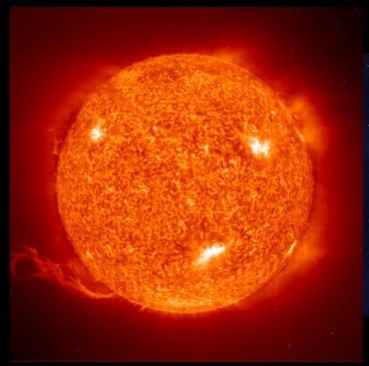


Astronomy: distances

- 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:
- The Moon is 1.25 light-seconds away from Earth
- The Sun is 8 light-minutes away
- The *Voyager* probe, launched in 1977, is 15.3 light hours away (half a light hour further than this time last year)


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

- Very large distances can be expressed with prefixes. You are probably familiar with these:
- 1 kiloparsec = 1000 parsecs
- 1 megaparsec = 1,000,000 parsecs

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:
- $1M_{\oplus} = 0.003M_J = 0.000003M_{\odot} = 5.97\times10^{24}$ kg
- $318M_{\oplus} = 1M_J = 9.5\times10^{-4}M_{\odot} = 1.89\times10^{27}$ kg
- $333000M_{\oplus} = 1060M_J = 1M_{\odot} = 1.99\times10^{30}$ kg

Astronomy: mass and luminosity

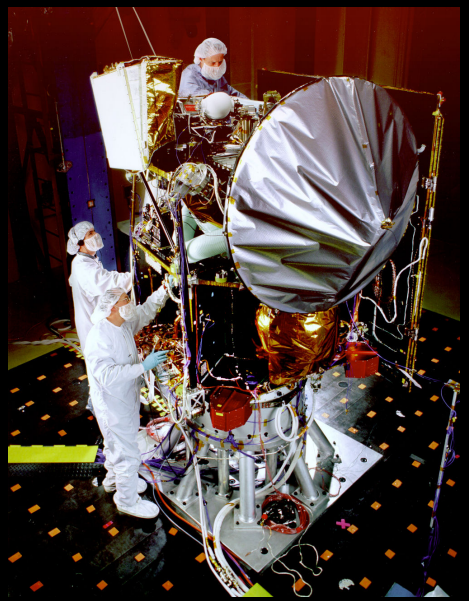
- The luminosity of stars is often described in units of the Solar Luminosity: the amount of energy emitted by the Sun every second.
- $1\ L_\odot = 3.84 \times 10^{26}$ W
- The size of stars is often described in units of the Solar Radius:
- $1\ R_\odot = 696{,}000$ km

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
- (astronomers use many strange units, but luckily the furlong is not actually one of them)

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

Astronomy: some maths

- Generally:
- $10^{x+y} = 10^x \times 10^y$
- $10^{x-y} = 10^x / 10^y$
- Large numbers are commonly written in the form
- 1.5×10^8
- This is the number of kilometres in an Astronomical Unit. It could also be written 15×10^7 or 0.15×10^8. It is like describing 1000 as ten hundreds, or a hundred tens – it's the same number.