Gravitational The cosmic **Special** lensing Future? calendar Age of the Earth Relativity Precession of **Red shift** Age of the Ideas of Mercury Structure and Universe General evolution of Relativity Luminosity Parallax stars Relativity Measurement Neutron stars Cosmology Size of the **Exotic case** Earth Universe studies Solar System Black holes, quasars Galaxy ... A human history Detecting of cosmology Gravity Newton/Kepler planets orbiting **Planets &** Einstein other stars moons Computer Simulation The Solar (+) System The Earth

The Cosmos is all that is or ever was or ever will be.

In the last few millennia we have made the most astonishing and unexpected discoveries about the Cosmos and our place within it, explorations that are exhilarating to consider. They remind us that humans have evolved to wonder, that understanding is a joy, that knowledge is prerequisite to survival.

I believe our future depends on how well we know this Cosmos in which we float like a mote of dust in the morning sky.



Carl Sagan (1934-1996) Cosmos pp20

Stars & Galaxies

A star is a luminous sphere of plasma held together by its own gravity.

The nearest star to Earth is the Sun.

For at least a portion of its life, a star shines due to **thermonuclear fusion** of hydrogen into helium in its core, releasing energy that traverses the star's interior and then radiates into outer space.





Stage 3 The process is completed when two Helium-3 nuclei fuse to make Helium-4



Low-mass stars

High-mass stars

Mid-sized star The Sun

Red giant Arcturus

Red dwarf Proxima Centauri

Black

dwarf

Blue dwarf

White

dwarf

Sirius B

Protostar /1647 Orionis

> Star-forming nebula Eagle Nebula

Massive star Spica Rec

Red supergiant Betelgeuse

Planetary nebula *Dumbbell Nebula*

Neutron star LGM-1 pulsar

Supernova Kepler's Star (remnant: Crab Nebula)

Black hole Cygnus X-1

The lifecycle of a star – much of what happens depends upon its mass



The Crab Nebula, remnants of a supernova that was first observed around 1050 AD



Mass-radius diagram for objects of planetary and stellar mass.





Hertzsprung-Russell diagram

1910 by Ejnar Hertzsprung and Henry Norris Russell



Colliding spiral galaxies



NGC 4414, a typical spiral galaxy in the constellation Coma Berenices, is about 55,000 light-years in diameter and approximately 60 million light-years away from Earth.

Galaxies are gravitationally bound systems of stars, gas, dust, planets and dark matter

Galaxies range from a few thousand stars to over 10¹⁴ stars

There are approximately 170 billion galaxies in the observable universe!



Centre is a bright radio source (Sagittarius A*, _____ which is likely to be a supermassive black hole)



The Milky Way

200-400 billion stars. Its mass is between 0.8 and 1.5 x 10¹² solar masses. 100,000-120,000 light years diameter Rotation period about 300 million light years



Gemini Ursa Major Pegasus 2 Corona Coma Borealis Perseus Berenices local group 9 Hercules Virgo • Leo 300 million light years 1239 600 million light years





Andromeda Galaxy — NASA, Hubble Telescope



The Spitzer Infrared Nearby Galaxies Survey (SINGS) Hubble Tuning-Fork

