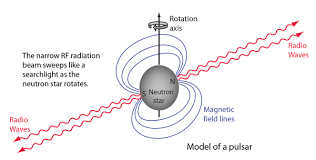
**Cosmology/Astrophysics**

Session 3: **Modern Cosmology**

**Modern ideas about the universe are based on observations:**

* Microwave Background Radiation: this is radiation in the microwave region of the electromagnetic spectrum which is seen wherever you look (into space) but is not obviously coming from any particular direction.It is thought to be the “afterglow” of the Big bang.
* Until 1609 all observations were made with the naked eye (before the invention of telescopes).
* 1932: the first radio signals were detected, which was a surprise at the time. It was realised that space is full of radio waves, produced by stars, blackholes...
* 1949: the first radio waves from outside the Milky Way were observed... coming from the Crab nebula.
* 1968: Jocelyn Bell Burnell discovered the first known pusar. Pulsars radiate two steady, narrow beams of light in opposite directions. Although the light from the beam is steady, pulsars appear to us to flicker, or pulse, because they also spin.



Pulsars belong to a family of objects called [neutron stars](https://www.space.com/22180-neutron-stars.html) that form when a star more massive than the sun runs out of fuel in its core and collapses in on itself. This typically creates a massive explosion called a [supernova](https://www.space.com/6638-supernova.html). The neutron star is the dense remnant. Neutron stars are typically about 12.4 to 14.9 miles in diameter, but they can contain up to twice the mass of the sun, so they are very dense indeed.

* 1974: Penrose and Hawkins predicted the existence of black holes.
* 1990: the Hubble telescope was launched into orbit.. This was the first telescope to be placed outside the Earth’s atmosphere, so giving a clearer picture of the cosmos.
* 2012: The first visual observations were made of a black hole. We have no idea what happens inside a black hole and can only observe the halo of matter around it.
* 2016 LIGO (Laser Interferometer Gravitational-wave Observatory) first detected gravitational waves.

**Current beliefs about the beginning of the universe**

* Big Bang: the start of everything! Nothing existed before the Big Bang: not space or time. An infinitessimally small universe sprang into existence (and time began). Dilemma: how did this happen?
* Inflationary Epoch from **time 0 to 10 -32 s**. At this point the universe was opaque.
* Recombination Era **10 -32 s to 10 -6 s**. Cosmic Neutrino Background was formed. A neutrinos is a subatomic particle with mass close to zero and no electrical charge. They interact very weakly with matter and, so, are very hard to detect. There was a massive burst of them at the beginning of the universe.
* **Up to 1 minute**: elementary particles combined
* **2 – 20 minutes**:nuclear fusion formed heavier nuclei from hydrogen nuclei.
* **18,000 years**: hydrogen nuclei join up with electrons to form hydrogen atoms...

**Beliefs about the current state of the universe**

It consists of strands of galactic matter mixed with dark matter. No-one knows what dark matter is. It can’t be directly observed but its presence can be inferred because it has gravitational influence.

Only 6% of the matter in the universe is visible. The rest is dark matter and dark energy. The dark energy is driving the expansion of the universe.

Hubble discovered that at the edge of the observable universe, objects are moving away from us at very high speeds. In other words, the universe is expanding, creating more space-time as it expands. *The universe does not expand "into" anything and does not require space to exist "outside" it*. (Wikipedia), The further from us, the faster the objects are moving.

NB: Einstein initially believed that the universe was static, even though his General Theory of Relativity predicted that it must be expanding. He later changed his mind.

**Current beliefs about the fate of the universe**

The fate of the universe is the subject of surrent research and debate. There are several competing theories:

* **Big Rip**: the expansion continues for ever. This would result in the tearing apart of galaxies, black holes, stars and even our own planet.
* **Big Crunch**: the gravitational effects of the matter in the universe would gradually start to overcome the expansion, so that it would eventually start to contract, eventually going back to the state it was in at the start (Big bang in reverse,
* **Big Bounce**: Having contracted back down to an infinitessimally small universe, the process of expansion would start all over again. (to be repeated over and over in approx 3 billion-year cycles)