HIGH ENERGY EMISSION FROM COMPACT OBJECTS

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INTRODUCTION:

It is the study of the astronomical phenomena involving highly energetic electromagnetic radiations. Emergent from early findings on cosmic rays- energetic particles and radiation of great penetrating power that enter our atmosphere from space. Major research areas include studies on Black Holes, Neutron Stars, White Dwarfs, Active Galaxies, Supernovae and so on.

The two most important properties governing ordinary stars:

- Ordinary stars are self gravitating, and therefore have to be hot inside to sustain the thermal pressure that resists the inward pull of gravity.
- Space outside is dark and cold. Thus heat flows continuously from star to the universe.

As long as the star behaves as a classical gas, there is no true thermodynamic equilibrium possible under the above circumstances...the star continues to lose heat until all of its fuel is burnt out. There are four possible ends to the star:

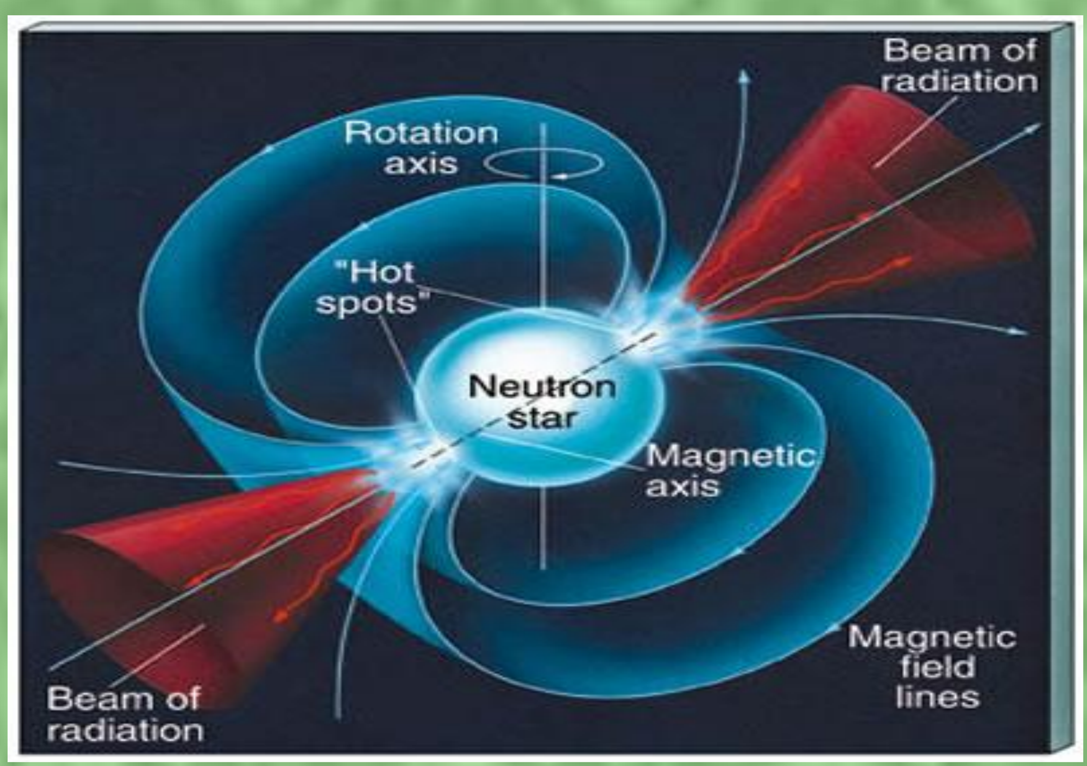
- Nothing may be left
- White Dwarf
- Neutron Star
- Black Hole

In the galaxy, most stars appear in pairs or multiples which have profound effects on each other's life history. Observational classifications of binary systems are:

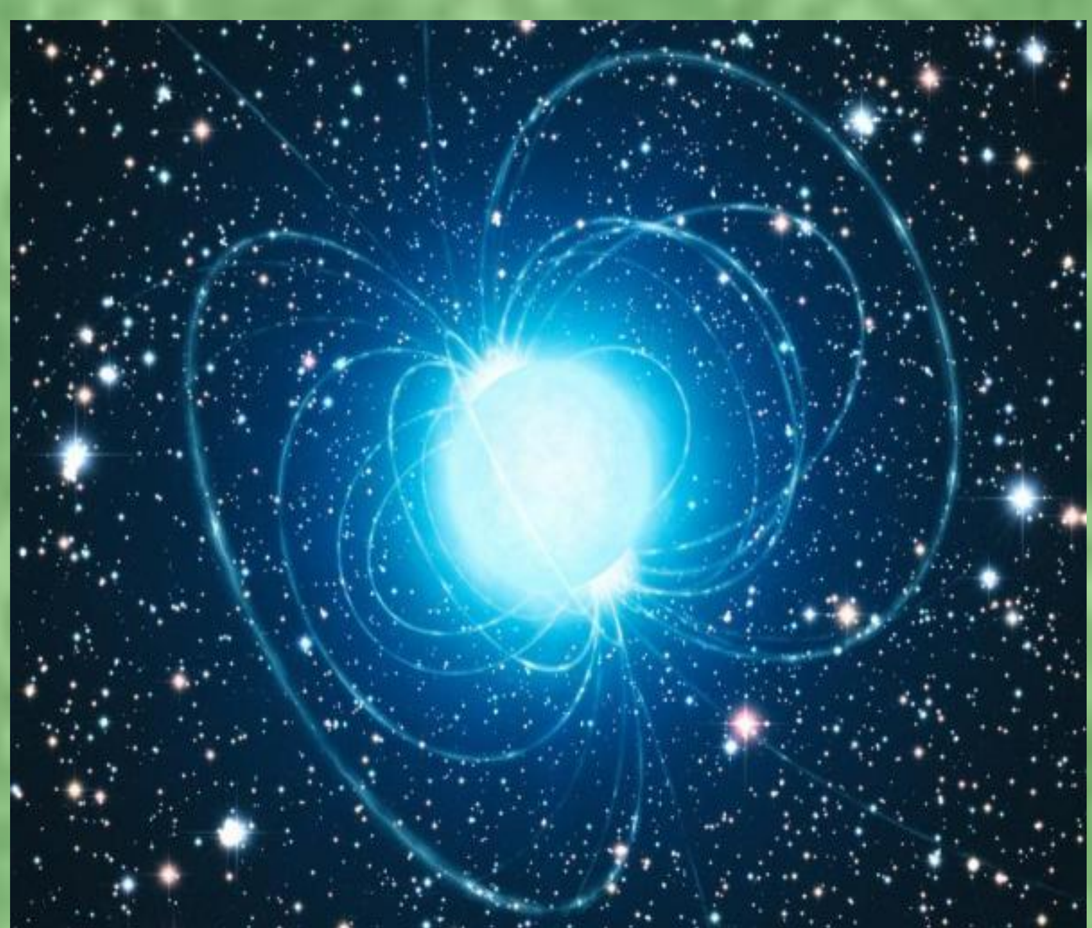
- Astrometric binary
- Visual binary
- Spectroscopic binary
- Eclipsing binary

In general the more massive star evolves faster and reaches the white dwarf or neutron star or black hole stage. Since these objects have a high gravitational field, mass from the second star starts falling into the first star. Due to conservation of angular momentum, gas falling into the gravitational well created by a massive object will typically form a disc-like structure around the object. Friction within the disc causes angular momentum to be transported outward, allowing matter to fall further inward, releasing potential energy and increasing the temperature of the gas resulting in a X-ray binary.

Neutron Star



- If the core had a mass larger than *Chandrashekhar's limit*, it will collapse to neutron star. At such high compression, all the free electrons are forced to combine with the protons in the nuclei of atoms to form a mass of neutrons.
- Pulsars are magnetized spinning neutron stars and are regularly pulsing radio sources. Such rotating stars can apparently produce rotating beam of radiation, which leads to series of spaced pulses and it is seen by all who came in the path of sweeping beam.
- **Characteristics:**
  - Pulsars have periods in the range 1.6ms to 4.3sec.
  - Pulsar periods increase very slowly and never decrease(except for occasional glitches). Glitches are sudden spin ups in rotation period, relaxing back in days to years with no significant change in pulsed electromagnetic radiation.
  - They are remarkably good clocks measured up to 13 significant digits.
- **Observed Properties:**
  - All exhibit radio emission in the form of period pulse.
  - In addition to large period jumps or "micro glitches" observed for few pulsars, irregular fluctuations have also been detected in period of numerous pulsars. This jitter in pulsar clock is known as "timing noise".
- The rotation of neutron star possessing a magnetic field generates powerful electric pulses in space surrounding the stars. Because of electric fields, the surrounding region can't be empty but must contain plasma.
- Binary X-ray sources displaying periodic variation are called binary X-ray pulsars.
- The radiation must be emitted in a relatively narrow beam, fixed in orientation with respect to neutron stars. It produce rather broadband radiation at both radio and optical frequency.



Black Hole

- A black hole can not be seen because strong gravity pulls all of the light into the middle of the black hole. But scientists can see how the strong gravity affects the stars and gas around the black hole. Scientists can study stars to find out if they are flying around, or orbiting, a black hole.
- The theory of general relativity predicts that a sufficiently compact mass will deform space time to form a black hole.
- It is called "black" because it absorbs all the light that hits the horizon, reflecting nothing, just like a perfect black body in thermodynamics.
- Black holes of stellar mass are expected to form when a star of more than 5 solar masses runs out of energy fuel.
- After a black hole has formed it can continue to grow by absorbing mass from its surroundings. By absorbing other stars and merging with other black holes, supermassive black holes of millions of solar masses may form.
- the presence of a black hole can be inferred through its interaction with other matter and with light and other electromagnetic radiation.
- The simplest black holes have mass but neither electric charge nor angular momentum.
- **Event horizon:** of a black hole in space where the escape velocity is higher than the speed of light. This region is typically considered the "black hole". Nothing can escape it, both photons and matter are pulled into it.
- **Schwarzschild radius:** It is the radius 'R' an object of mass 'M' has to have for the escape speed from its surface to equal the speed of light.

$$R=2GM/c^2$$

- Apart from quantum mechanical effects, any object whose radius 'R' becomes smaller than its Schwarzschild radius is doomed to collapse to a single point.
- No known force in nature can resist this collapse to singularity with an infinite density.

Active Galactic Nuclei

Small percentage of observed galaxies show violent activity well beyond the normal characteristics of stars:

- **Non-thermal emission:** Typical black body emission is not observed, instead the intensity versus wavelength curve resembles the power law. The efficiency calculations show that the source is not thermonuclear reaction.
- **Jets from the galaxy:** Jets of relativistic or high energy particles are observed that span over enormous region and cause intense radio emission from the inter galactic medium.
- **High luminosity and variability:** These objects are highly luminous, outshining the entire galaxy. Also the luminosity output varies drastically within very short intervals, as small as hours, indicating that the source has small dimension.
- **Large redshifts:** The redshifts that are observed are high. None have been found with a blue shift. This suggests a violent explosion that has drifted them apart and has resulted in these high energy sources racing away from us.
- **Broad spectral lines:** Some have broad spectral lines which can only be explained by gravitational redshifts- the object must thus be very compact to undergo such effects.
- They are generally *strong X-ray sources*, a phenomena attributed to stellar mass colliding into the accretion disk of the compact object due to its high gravitational field.

These objects have been broadly categorized into two classes:

- Seyfert Galaxies
- Quasars

The most promising theoretical explanation of the AGN is that of a super massive black hole sitting at the center of the galaxy, having a mass ~10^9 M_{sun} and accreting surrounding material at the rate of 1-10M_{sun} per year. The resultant luminosity is ~10^{47} erg/sec, a rate greater than ten trillion times that of sun!