Pulsar Glitches

For Prelims: Pulsar Glitches, PSR B1919+21, **Neutron Stars**, Properties of Superfluids.

For Mains: Pulsar Glitches, Achievements of Indians in science & technology.

Source: TH

Why in News?

In 1967, two astronomers at the University of Cambridge discovered the First Pulsar, later named **PSR B1919+21**, setting the **stage for a journey into the depths of neutron stars and their enigmatic pulsar counterparts.**

What are Pulsars?

- **About:**
  - Pulsars are **rapidly rotating** Neutron Stars that blast out pulses of radiation at **regular intervals** ranging from seconds to milliseconds.
  - Pulsars have **strong magnetic fields** that funnel particles along their magnetic poles accelerating them to relativistic speeds, which produces two powerful beams of light, one from each pole.
  - The periodicity of pulsars is caused by these beams of light crossing the line of sight on Earth, with the pulsar appearing to 'switch off' at points when the light is facing away from Earth.
    - The time between these pulses is the **'period' of the pulsar.**

What are the Theories Related to the Discovery of the Pulsars and their Behaviour?

- **Link with the Discovery of Neutrons:**
  - The discovery of pulsars is **closely linked to James Chadwick's 1932 discovery of neutrons.**
    - Neutrons in a group resist having the same energy, **seeking the lowest available energy level.** When heavy stars die, their cores implode. If they aren't heavy enough to become black holes, **they collapse into a ball of neutrons, creating a neutron star.**
- **Pulsars as Rotating Neutron Stars:**
  - The signals, coming from a very small patch of the sky and that they repeated frequently, led **scientists to identify Pulsars as Rotating Neutron Stars.**
    - Radio signals emitted from near the poles of such a star would form a narrow cone that sweeps past the earth with every rotation – like the light from a **lighthouse shining over a ship on the sea.**

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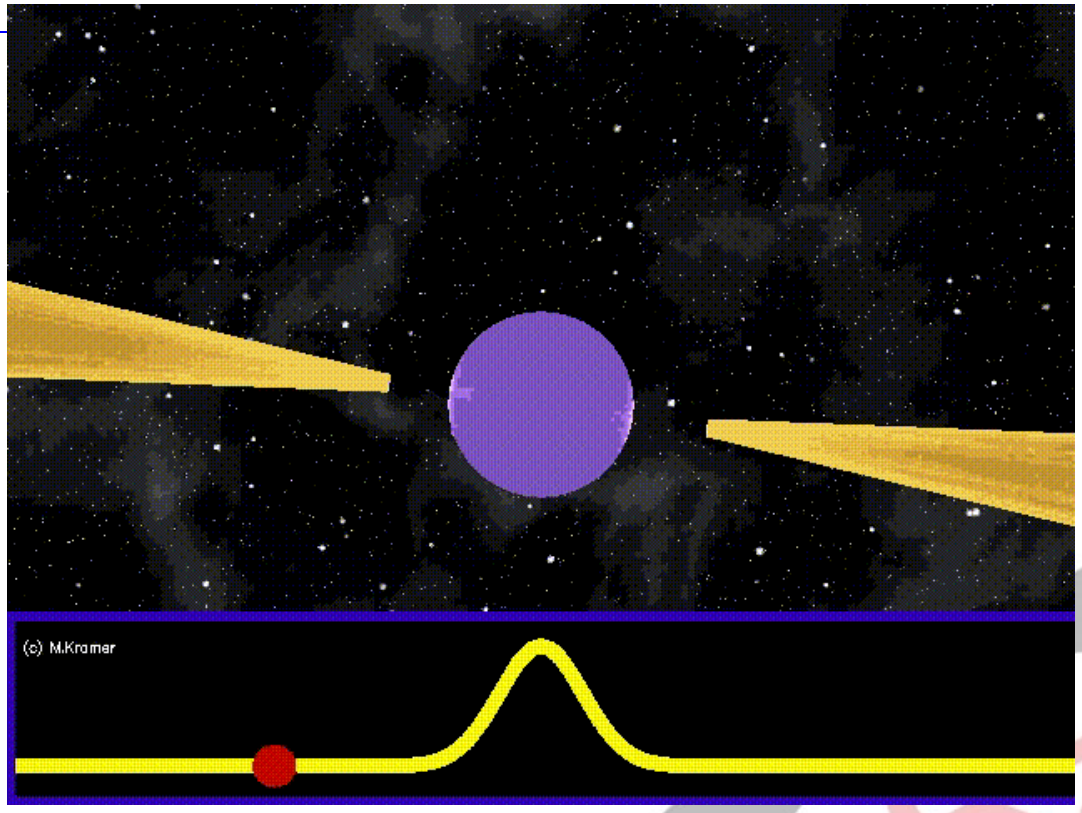

- **Unexpected Glitches:**
  - **Over time, the neutron stars experienced a slowing of their rotation.** The energy preserved through this reduction in rotation rate was **utilised to propel electric charges outside the star,** resulting in the generation of radio signals.
  - In 1969 when researchers observed **a glitch in the pulsar PSR 0833-45.**
    - Glitches, characterised by abrupt **changes in rotation rate of pulsar followed by gradual relaxation**, introduced a new layer of complexity to pulsar dynamics.
  - The subsequent decades witnessed the observation of over 3,000 pulsars, with around 700 glitches recorded.
    - These glitches became intriguing phenomena, prompting scientists to delve deeper into the underlying mechanisms governing these celestial events.

How are the Pulsars Formed?

- **Supernova Explosion:**
  - Pulsars are formed from the **remnants of massive stars with masses between 1.4 and 3.2 times** that of our Sun. When such a star exhausts its nuclear fuel, it undergoes a supernova explosion.
- **Formation of Neutron Star:**
  - The outer layers of the **star are blasted off into space** during the supernova, and the inner core contracts due to gravity. The gravitational pressure becomes so intense that **it overcomes the electron degeneracy pressure,** causing electrons and protons to be crushed together to form neutrons.
- **Neutron Star Characteristics:**
  - The resulting object is a neutron star, which is extremely dense and **has a strong gravitational field (about 2 x 10^11 times that of Earth's gravity).**
- **Angular Momentum Conservation:**
  - As the star collapses, it **conserves its angular momentum**. The collapse leads to a much smaller size, **causing a dramatic increase in rotational speed.**
- **Pulsar Emission:**
  - The rapidly rotating **neutron star emits beams of electromagnetic radiation along its magnetic field lines.** If Earth intersects these beams as the neutron star rotates, astronomers **observe periodic pulses of radiation,** and the object is identified as a

pulsar.

How are Pulsars Linked with the Chandrasekhar Limit?

- The Chandrasekhar limit is the **maximum mass a stable white dwarf star can have**. It's about **1.4 times the mass of the sun.**
    - The **limit was named after Subrahmanyan Chandrasekhar,** an Indian-born astrophysicist who calculated it in 1930.
- If a star is more massive than the Chandrasekhar limit, it will continue to **collapse and become a neutron star**. This collapse is caused by the force of gravity.
- The pulses from a pulsar appear periodic because they come at the same rate as the rotation of the neutron star. From a distance, the **pulses look similar to a lighthouse beam rotating.**

What led to the Occurrence of Glitches in Pulsars?

- **Neutron Star Structure:**
    - A neutron star, **characterised by a solid crust and a superfluid core,** provides a unique backdrop for the interplay of forces governing celestial dynamics.
    - The contrast between the crust's deceleration and the sustained vortex speed within the superfluid core becomes pivotal in comprehending the origins of glitches.
- **Superfluid State Inside Neutron Stars:**
    - Post-glitch behaviour strongly suggests the **presence of a superfluid state inside these cosmic entities.**
        - The neutron star is a 20-km-wide sphere with a solid crust and a core. The **core predominantly contains the superfluid, and no solid parts.**
- **Peculiar Properties of Superfluids:**
    - Superfluids, when set in motion inside a container, exhibit an extraordinary characteristic — they continue moving indefinitely. This property of perpetual motion without friction becomes crucial in understanding the behavior of the superfluid core within neutron stars.

Note

Despite advancements, the **glitch mechanism remains a subject of ongoing scientific inquiry.** Contested details, triggers in space, and the evolution of glitches over time provide fertile ground for further exploration.

UPSC Civil Services Examination, Previous Year Questions (PYQs)

Q. Recently, scientists observed the merger of giant ‘blackholes’ billions of light-years away from the Earth. What is the significance of this observation? (2019)

(a) ‘Higgs boson particles’ were detected.

(b) ‘Gravitational waves’ were detected.

(c) Possibility of intergalactic space travel through ‘wormhole’ was confirmed.

(d) It enabled the scientists to understand ‘singularity’

Ans: (b)

Q. Consider the following (2008):

Assertion (A): Radio waves bend in a magnetic field.

Reason (R): Radio waves are electromagnetic in nature.

Which of the following is correct?

(a) Both A and R are individually true, and R is the correct explanation of A

(b) Both A and R are individually true, but R is not the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

Ans: (a)