

# Stellar Remnants: What They Are, Their Importance, and Recent Examples.

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# So, How Do We Know They Exist?...

- **Observations of Stellar Remnants**
  - Accretion of Matter: Extragalactic Jets from a Black Hole's Accretion Disk.
  - X-Ray Binaries: Star Systems (Binary) that are Luminous in the X-Ray Part of the Spectrum.
  - Quiescence and Advection-Dominated Accretion Flow: Faintness of the Accretion Disc; Almost All Energy Generated by Friction in the Disc is Swept Along with the Flow Instead of Radiated Away.
  - Quasi-Periodic Oscillations: X-Ray Emission from Accretion Disk Flickers at Certain Frequencies.
  - Galactic Nuclei: Galaxies with Unusual Characteristics, such as Unusual Spectral Line Emission and Very Strong Radio Emission.
  - Gravitational Lensing: Deformation of Space-Time Around a Massive Object Causing Light Rays to be Deflected Like Light Passing Through an Optic Lens.

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- **Black Holes - Timeline**
  - **1687**: Sir Isaac Newton – Gravity.
  - **1783**: John Michell – Escape Velocity Greater than Speed of Light.
  - **1796**: Simon Pierre LaPlace – Predicted Existence of Black Holes.
  - **1915**: Albert Einstein - Theory of General Relativity, Spacetime Curvature.
  - **1916**: Karl Schwarzschild - Used Einstein's Theory of General Relativity to Define a Black Hole.
  - **1926**: Sir Arthur Eddington & Einstein – Opposed Black Hole Theory.
  - **1935**: Subrahmanyan Chandrasekhar – White Dwarfs; Mass Limits.
  - **1964**: John Wheeler – Name “Black Hole”.
  - **1970**: Stephen Hawking – Modern Theory of Black Holes.
  - **1972**: Discovery of Cygnus X-1.
  - **1994**: Evidence of Supermassive Black Holes.

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- **Neutron Stars – Timeline**

- **1933:** Sir James Chadwick - Neutron.
- **1934:** Walter Baade & Fritz Zwicky - Existence of the Neutron Star.
- **1965:** Antony Hewish & Samuel Okoye - Crab Nebula Neutron Star.
- **1967:** Iosif Shklovsky - X-ray and Optical Observations of Scorpius X-1.
- **1967:** Jocelyn Bell & Antony Hewish - Regular Radio Pulses from CP 1919.
- **1971:** Riccardo Giacconi, Herbert Gursky, Ed Kellogg, R. Levinson, E. Schreier & H. Tananbaum - 4.8-Second Pulsations in an X-Ray Source in the Constellation Centaurus, Cen X-3.
- **1974:** Antony Hewish - Awarded the Nobel Prize in Physics "For His Decisive Role in the Discovery of Pulsars".
- **1974:** Joseph Taylor & Russell Hulse - First Binary Pulsar, PSR B1913+16.
- **2010:** Paul Demorest & Colleagues – Measured Mass of Millisecond Pulsar PSR J1614–2230 to be  $1.97 \pm 0.04$  Solar Masses (Shapiro Delay).

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- **White Dwarfs – Timeline**
  - **1783:** Friedrich Wilhelm Herschel – First White Dwarf Discovered in the Triple Star System of 40 Eridani.
  - **1910:** Henry Norris Russell, Edward Charles Pickering & Williamina Fleming - Discovered that 40 Eridani B was of Spectral Type A, or White.
  - **1914:** Walter Adams - Spectral Type of 40 Eridani B Officially Described.
  - **1917:** Adriaan Van Maanen - Discovered Van Maanen's Star, an Isolated White Dwarf.
  - **1922:** Willem Luyten - Name “White Dwarf”.
  - **1939:** 18 White Dwarfs Discovered by this Time. Luyten and Others Continued to Search for White Dwarfs in the 1940s.
  - **1950:** Over 100 White Dwarfs were Known.
  - **1999:** Over 2,000 White Dwarfs were Known.
  - **2011:** Sloan Digital Sky Survey has Found over 9,000 White Dwarfs, Mostly New.