Pulsars, Neutron Stars and Black Holes

**Model of a Neutron Star**

- **Neutron star**
  - Mass: ~1.5 times the Sun
  - **Solid crust**: ~1 mile thick
  - **Diameter**: ~12 miles
  - **Heavy liquid interior**: Mostly neutrons, with other particles
The Crab Nebula and the pulsar
Lighthouse Model

Pulsar = Rotating Neutron Star

Crab nebula in X-rays
Observational Evidence – X-ray Binaries

- Jet
- Accretion disc
- Disc wind
- X-ray heating
- Hot spot
- Accretion stream
- Companion star
Black Holes -- depends on mass of collapsed core
A Little Bit of Relativity

**Special Relativity --- basic concepts**

Your physical reality is independent of how fast you are moving.
The speed of light is a constant independent of your velocity
The equivalence of matter and energy \( E= mc^2 \)

**Consequences --- length contraction**

- time dilation
- mass increases (faster than light space ships?)
General Relativity -- with gravitation and acceleration

How space (its shape) and time change in the presence of mass

The shape of space is distorted – space curvature -- and time slows down

Curvature or warping of space due to gravity
The 3 famous astronomical tests of general relativity the curvature of space time alters the path and wavelength of light.

1. Deflection of light by Sun -- eclipses
2. the advancement of the perihelion of Mercury
3. Gravitational redshift measured in spectra of stars
A GRAVITATIONAL SINGULARITY
-- A.K.A. “BLACK HOLE”
Schwarzschild radius or event horizon

\[ R_s = \frac{2MG}{c^2} \]

\[ R_s = 3 \frac{M_{BH}}{M_{sun}} \]

Diagram of a black hole warping spacetime, from a T-shirt. The radius of the black hole, \( R_s \), is \( R_s = \frac{2MG}{c^2} \), where \( G \) is Newton’s constant, \( M \) is the mass of the black hole, and \( c \) is the speed of light.
Observational Evidence – affect on the environment
Journey into a Black Hole -- what do you and the intrepid astronaut observe, experience?
On the fringes ---

white holes and wormholes, interstellar travel and you