Astronomy Bizarre
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Review for Test #3
Supernovae (cont.), Supernova 1987A, Neutron Stars

Gravitational Radiation — A systematic "wiggling" of the curvature of space sends out gravitational waves of space curvature. Carry energy, angular momentum from a binary star system.

Double white dwarfs — If the first white dwarf does not grow and explode, the second star can evolve to produce a white dwarf, resulting in two orbiting white dwarfs. These will spiral together by gravitational radiation, until smaller mass, larger radius white dwarf fills its Roche lobe. Mass transfer causes small white dwarf to be transferred essentially entirely to the larger one. May get larger white dwarf or, thermonuclear explosion.

Light curves – brightness versus time of supernova. Type Ia brightest, Type Ib, Type Ic, Type II dimmer.

Light curve mechanisms – shock energy plus radioactive decay. Ejecta must be large in radius, about 100 times the size of the Earth's orbit, before the matter is transparent enough for light to leak out. If the star is too small originally (Ia, Ib, Ic) all shock energy goes into energy of motion; light curve must be from radioactive decay.

Explosion of carbon and oxygen or silicon – equal numbers of protons and neutrons, so first make nickel-56. Weak force causes radioactive decay in 6 days (half-life) to cobalt-56 and then in 77 days (half-life) to iron-56. Heat from decay provides delayed source of light.

Type Ia brighter, need more nickel than Ib, Ic, hence different mechanism. A thermonuclear explosion of carbon/oxygen, not core collapse, produces ~1/2 $M_\odot$ of nickel.

Type II arise in red giants that are already large prior to explosion so they do not lose much heat to expansion and cooling. They thus radiate energy from the original explosion in the “plateau” phase, with evidence for radioactive decay at a later time.

In core collapse supernovae, Type Ib, Ic, Type II, radioactive nickel is produced by shock wave that induces rapid burning of silicon layer surrounding iron core. This produces ~ 0.1 $M_\odot$ of nickel

Supernova 1987A

- The first supernova observable by the naked eye in about 400 years. It is directly observable only in the southern hemisphere.
- Large Magellanic Cloud – small irregular satellite galaxy about 170,000 light years from the Milky Way, the site of the explosion of Supernova 1987A.
- 30 Doradus or the Tarantula Nebula – the glowing region of new star formation near the site of the explosion of SN 1987A.
- SN 1987A was detected in radio, infrared, optical, ultraviolet, X-ray, and gamma ray bands of the electromagnetic spectrum.
- The star that exploded was a blue super giant. There was initial confusion over the identity of the star that exploded. Two stars are visible in photographs taken before the supernova, and two stars were still detected by satellite in the ultraviolet after the explosion. There originally were three stars in the same vicinity.
- Neutrinos were detected, proving that SN 1987A underwent iron core collapse to form a neutron star. No neutron star has been detected. Dim compact object in Cas A might be related. A black hole is still a possibility.
- Light Curve of SN 1987A – Shock breakout in first day. Subsequent peak and tail of the curve are explained by energy of radioactive decay.

- Rings – The rings around SN 1987A were created by the star before it exploded, perhaps when it consumed a companion star. The ejecta of the supernova have begun to collide with the ring.
- Jets – The shape and motion of the matter ejected by SN1987A are roughly consistent with the expanding "breadstick and bagel" configuration expected from the model of jet-induced supernovae.

Superluminous supernovae – 10 to 100 times brighter than "normal" supernovae. Long time to rise to maximum implies large mass, many 10s of solar masses.

Shell-shock model – massive star may eject shell of matter. If the shell is already sitting at a distance of 100 times the size of the Earth's orbit, then when the supernovae explodes and collides with the shell there is very little expansion and cooling so energy of motion is efficiently turned into radiation to give very bright light output.

Pair-formation supernova – very massive stars, more than 100 solar masses, are so hot inside after they form oxygen cores they can turn photons into matter and anti-matter, electrons and positrons. This lowers the pressure and destabilizes the star. The star contracts, burns oxygen, and totally explodes. This mechanism makes 10s of solar masses of nickel-56, and so might make a very bright explosion.

Neutron stars – mass of sun, radius ~ 10km, density like atomic nucleus, huge gravity at surface

Discovery of pulsars – pulsating radio sources

Interpretation of pulsars as rotating magnetized neutron stars.

Role of magnetic field to cause radiation, misalignment of rotation axis, magnetic axis

Production of pulses – probably related to strong electric, magnetic fields at magnetic poles.

About 2000 pulsars known (600 in book is outdated), perhaps a billion neutron stars in the Galaxy

Pressure support from quantum pressure, of neutrons, plus nuclear repulsion. Maximum mass of neutron star is about 2 solar masses.

Neutron stars as binary X-rays sources.

X-ray pulsars – accreted gas channeled to magnetic poles, "pulsar" by lighthouse effect if magnetic axis is tilted with respect to the spin axis

Magnetars – neutron stars with magnetic fields 100 to 1000 times stronger than the Crab nebula pulsar.

Soft gamma-ray repeaters – objects that emit intense bursts of low energy gamma rays and X-rays for a few minutes every few years. Periodic "pulses" after the initial flash. Observed spin-down rates imply they are magnetars. One soft gamma-ray repeater actually caused aurorae and interfered with terrestrial radio communications August 1998, another flared on the far side of our Galaxy, and was detected on December 27, 2004.