Astronomy Bizarre
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Review for Test #3
SN 1987A, Neutron Stars and Black Holes

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 150,000 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 gamma rays from Nickle-56 and Cobalt-56 as they decay to form iron. Gamma rays, high-energy photons produced specifically by Colbalt-56, were also directly observed by satellite. SN 1987A ejected 0.07 $M_\odot$ of radioactive nickel.
- 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. The "breadstick" is nearly perpendicular to the rings and the "bagel" is expanding in the plane of the inner ring.

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 600 pulsars known, perhaps a billion neutron stars in the Galaxy.

Pressure support from quantum pressure of neutrons plus nuclear repulsion. Maximum mass of neutron star 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.

X-ray transients – 4 or 5 known in our Galaxy. Outburst every few years for a month. Probably a disk instability like a dwarf nova, but with the white dwarf replaced by a neutron star.

X-ray Bursters – about 30 known in our Galaxy. Burst every few hours for minutes. Probably the neutron star analog of a classical nova. Matter accretes on surface of neutron star. Hydrogen is supported by thermal pressure, burns to helium. Helium is supported by quantum pressure and is unregulated and explodes, producing the X-rays.

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

Soft gamm-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. Observerd 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.

Black Hole History – Mitchell, Laplace, escape velocity.

Conceptual problems with Newton’s Theory of Gravity

Einstein says there is no “force” of gravity. Matter curves space and curved space tells matter how to move.

Dimension – determined by the number of mutually perpendicular directions in a given space

Space versus Hyperspace

Parallel propagation – the process of constructing a straight line by extending a line segment parallel to itself.   Guaranteed to produce the shortest distance between starting, ending points. Works in curved as well as flat space.

Einstein says the space around a gravitating object (Earth, a star, a black hole) is curved in the same sense as a cone poked in a rubber sheet. The circumference of a circle drawn around such an object is less than 2π times the radius and “straight lines,” parallel propagated, the shortest distance between two points, curve around the object. One type of straight line in this kind of curved space follows the curved space and closes on itself. An orbit is interpreted as this kind of straight line.

Event Horizon —Since nothing with velocity less than or equal to the speed of light can pass backward through an event horizon, the information that an event occurred cannot pass through, so an event on the wrong side of an event horizon can never be known to an observer on the opposite side, hence the name.

Singularity—region in center of black hole where ordinary space and time cannot exist because of severe space time curvature and quantum uncertainty. The boundary of physics as we currently know it.

Tidal forces tend to draw any object into a “noodle” shape for two reasons: the force closer to the center is stronger and because two separated points the same distance from the hole tend to approach one another as they both try to fall directly toward the center.

Einstein says space around gravitating object “flows” inward, cause of free fall inward.

Einstein says that all objects accelerate at the same rate near a gravitating object because that object curves the space around it and small objects fall on the same “straight” lines, independent of their own nature.

Far away from a gravitating object, space is “flat” and there is no gravity. Black holes are “safe” from a distance.

Nature of Time in the vicinity of a black hole. Any observer always senses his or her own time as perfectly normal. But an observer at a large distance from the black hole where the force of gravity is small sees time passing more slowly for events occurring deep in the gravitational field of a black hole. Events right at the event horizon would show no passage of time to a distant observer. A distant observer watching another person falling toward the event horizon would perceive (other effects not interfering) that this second person gradually approached but never crossed the event horizon. An observer freely falling under the influence of no forces would plunge into the black hole after a finite (and normally short) passage of their own time.

Redshift—the redshift of the wavelength of photons received at a distance gets very large as the point of emission of the photon gets more deep in a gravitational field.

“Black Hole”—the large redshift of photons emitted near the event horizon coupled with the long passage of time between the arrival of these photons at a distant observer due to the apparent slowing of time means that events happening just outside the event horizon cannot, in practice, be “seen” by a distant observer—hence, “black hole” is a more accurate term than “frozen star” which does not connote the blackness.