

Review for Test #3
Super-luminous Supernovae, Supernova 1987A, Neutron Stars, Einstein's Gravity

ROTSE – a set of four small robotic telescopes, one at McDonald Observatory, capable of rapid response and searching large volumes of space for supernovae.

Texas Supernova Search – a program to search for new supernovae using the ROTSE telescope at McDonald Observatory in the Davis Mountains of West Texas.

Super-luminous supernovae – a new class of supernovae that are 10 to 100 times brighter than normal supernovae discovered by the Texas Supernova Search. Some require very large masses, about 100 times the mass of the Sun.

Shell-shock model – this model proposes that the progenitor star expelled a dense shell of material to a distance of about 100x the radius of the Earth's orbit before the explosion. The material exploded in the supernova then collides with that shell that radiates the heat of collision very effectively.

Pair-formation supernovae – very massive stars, 100 to 200 times the mass of the Sun, are predicted to form matter and anti-matter, electron-positron pairs when they develop hot cores of oxygen. Converting heat energy to mass reduces pressure and causes the oxygen core to contract, heat, and explode, leaving nothing behind. These explosions are predicted to produce a great deal of nickel-56 (10's of solar masses) and hence to be bright. Pair-formation supernovae have been proposed to explain some super-luminous supernovae.

Some super-luminous supernovae would require more mass of nickel-56 than the total mass ejected as determined by the time of rise and fall of the light curve. This is a physical impossibility, so these super-luminous supernovae cannot be pair formation supernovae, and are probably shell-shocks. Others are compatible with the pair formation model.

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.

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.

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.

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