Cosmic Catastrophes | Wheeler
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Review for Test #4
Gamma-Ray Bursts, and Cosmology

Clues for black holes – look for binary system where X-rays are produced in accretion disk before matter disappears down the black hole and Kepler's law helps to determine mass greater than maximum mass of neutron star.

Cygnus X-1—First candidate black hole in a binary star system. Object of 10 $M_\odot$ emits X-rays and orbits unevolved star of 30 $M_\odot$. Small probability that 10 $M_\odot$ object is itself a 9 $M_\odot$ star transferring mass to a 1 $M_\odot$ neutron star. The 9 $M_\odot$ star could be lost in glare of 30 $M_\odot$ star.

Black holes candidates with low mass companion stars—for these systems the "unseen" X-ray emitting star is more massive than the unevolved companion. No third ordinary star could remain unseen.

Black hole X-ray novae—all recently discovered black hole candidates sit undiscovered for decades then flare for a few months. Thought to be flushing instability in accretion disk, occurs in systems with low mass unevolved companions.

Milky Way Galaxy – contains a 4 million solar mass black hole as determined by orbits of stars near the center.

Galaxy/Black Hole connection – The velocity of stars that respond to the bulge mass of a galaxy are correlated with the mass of the central supermassive black hole despite the fact that they are presently much too far from the black hole to sense its gravity. The bulge mass is always about 80 times the black hole mass. This suggests that the processes that cause the development of whole galaxies are nevertheless closely linked to the growth of the black hole when both first formed.

Gamma-ray bursts – flashes of gamma-ray energy detected by satellites about once per day lasting about 10 to 30 seconds.

Distribution in space – the gamma-ray bursts occur randomly all over the sky, so they are not associated with our Galaxy.

Optical Counterparts – discovered only in 1997, these allow gamma-ray bursts to be associated with other phenomena. They are in galaxies at cosmological distances.

After-glow – fading radiation in radio, optical, and x-ray lasting for weeks or months after main burst, collision of ejected material with matter surrounding the star.

Gamma-ray bursts occur in star-forming regions in spiral galaxies, so associated with massive, short-lived stars and hence core collapse.

The energy of a gamma-ray burst is focused in a jet moving at near the speed of light, with an energy comparable to a supernova.

GRB030329 – Gamma-ray burst in March of 2003 proved that at least this burst was associated with a Type Ic supernovae. Several others have been associated with Type Ic since then.

The most popular idea is that gamma-ray bursts represent the birth of black holes, but the birth of magnetars is also considered.

Gamma-ray bursts and cosmology - gamma-ray bursts are so bright they might be the first objects observable as stars first began to form and die at the end of the "Dark Ages" after the Big Bang cooled off.

Big Bang – the initial expansion of the Universe from a condition of very high density and temperature ("singularity").

Expansion of the Universe – space expands and pulls all distant galaxies apart with a speed that increases with distance. There need not be a 3-D center, a 3-D edge nor a 3-D outside to our 3-D Universe.

Age of the Universe is about 13.7 billion years, determined from the distance to supernovae (and other things) and the velocity of recession as measured by the Doppler shift.

Traditional Types of Universes – "flat" infinite in extent, will expand forever approaching zero velocity; "open" infinite in extent, will expand forever at a finite velocity; "closed" finite in extent and volume, will recollapse (neglecting Dark Energy).

Dark Matter – the vast majority of the gravitating material in the Universe emits no detectable radiation and is not, nor has ever been, composed of "ordinary" gravitating matter as we know it composed of protons, neutrons and electrons.

Clumping of Dark Matter was critical to convert smoothly spread matter into clumps and hence the galaxies and stars we see today.

Supernovae as sign posts – comparing the apparent brightness to the known intrinsic brightness allows a measure of distances.

Type Ia supernovae – brightest, best current tool for measuring distances. Exploding white dwarf in a binary system.

Accelerating Universe – measurement of supernovae has suggested that the expansion of the Universe is not decelerating at all at the current time, but accelerating.

Dark Energy– if the Universe is accelerating, there seems to be an extra force associated with empty space. In the context of Einstein's theory of gravity, this force could be provided by the cosmological constant. Physically, this quantity is associated with an energy of the vacuum of space, a Dark Energy that anti-gravitates.

Composition of the Universe – about 2/3 Dark Energy, about 1/3 Dark Matter, only a few percent "ordinary" matter.

Shape of the Universe – flat in three dimensions. The sum of the Dark Energy, Dark Matter and "ordinary" matter is exactly right, within observational uncertainty, to render the Universe flat. Theory suggests it is essentially exactly flat.

With the Dark Energy, the Universe could expand to become a dark void, everything could be pulled apart in a Big Rip, or the Universe could recollapse to a singularity.

Conflict between Gravity and Quantum Theory – Need quantum gravity to understand the singularity at the birth of Big Bang and in black holes, and quantum foam.

String theory is the best current candidate for a theory of quantum gravity. It requires 10 spatial dimensions (7-dimensional hyperspace) plus time.