Astronomy Bizarre Wheeler
309N, Spring 2004 April 20, 2004
(45005)

Review for Test #4

BLACK HOLES, GAMMA-RAY BURSTS AND COSMOLOGY

Origin of Stellar Mass Black Holes – 5-10 solar mass black holes probably arise as the heavy-element cores of stars that were three to four times more massive on the main sequence. Extra mass is lost in a "wind" or to a binary companion.

Other ways to discriminate black holes from neutron stars – neutron stars have hard surfaces that will emit different X-ray radiation than an accretion disk alone. Strong gravity effects might be detectable in future X-ray or gravity-wave experiments, for instance direct evidence for a Kerr geometry.

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.

Black holes may also be surrounded by a very hot, electron-positron pair-forming region that can produce high-energy X-rays or gamma-rays. This behavior is not associated with neutron stars.

SS433 – probable black hole binary system sends out twin jets at 80% the speed of light.

Superluminal sources – radio sources that appear to expand at greater than the speed of light. An optical illusion where a jet moving at 99% the speed of light, so that it chases its own light, is aimed at the Earth.

Some quasars, active galactic nuclei thought to contain supermassive black holes, display "superluminal" motion.

Some stellar mass binary black holes called micro-quasars or mini-quasars display "superluminal" radio jets; more circumstantial evidence for black holes since neutron stars are not observed to do this.

Quasars – sources as bright as 100 to 100,000 ordinary galaxies in the center of some distant galaxies. From the rapid variation of the light (hours to days) can be no larger than a solar system; suspected supermassive black hole.

Eddington Limit – critical luminosity proportional to the mass of a gravitating object such that if the object is brighter than this the gas surrounding the object will be blown away.

Mass limit – an accreting object must have a mass large enough that its Eddington Limit luminosity is greater than the observed luminosity. The large luminosity of quasars demands that the source of gravity be 100 million to 1 billion solar masses; probably a supermassive black hole.

Event horizon of a supermassive black hole would be about the size of the Earth's orbit; consistent with size limit from variation in luminosity of quasars.

Normal galaxies – orbits of stars near the center indicate most have supermassive black holes. These black holes must not be accreting matter at a high rate or they would be very bright. They may have been quasars in the past.

Milky Way Galaxy – contains a 3 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 total 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 black hole mass is always about 1/2% of the total galaxy 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.

Intermediate mass black holes – 100 to 1000 solar mass black holes. First suspected from very bright X-ray sources in other galaxies requiring large masses so the Eddington limit would not be violated. More recent evidence is based on the motion of stars near the center of old globular star clusters. The mass of the black hole is deduced to be about 1/2% of the cluster mass, suggesting that globular clusters and their black holes formed by the same combined mechanism as whole galaxies and their supermassive black holes.

Betelgeuse – evolved, red giant star of 15 solar masses; it will collapse to make a neutron star (or maybe black hole) and a supernova explosion.

Cosmic gamma-ray bursts – 30-second bursts of gamma-rays. "Afterglow" lasting days to months discovered in 1997 opened the way to proof they are in very distant galaxies. Energy is tightly collimated in "jets" with an energy compatible to the kinetic energy of a supernova, but in gamma-rays. Definite connection between a "normal" gamma-ray burst and a supernova explosion in event of March 29, 2003. Gamma-ray bursts are probably associated with the birth of black holes in the collapse of a massive star.

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.

Types of Universes – "flat" infinite in extent, will expand forever approaching zero velocity; "open" finite in extent, will expand forever at a finite velocity; "closed" finite in extent, will recollapse (neglecting cosmological constant).

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.

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.

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

Cosmological Constant – 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 about a few percent "ordinary" matter.

Shape of the Universe – flat. 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.

Most recent result from supernovae – the accelerating phase took over from the earlier decelerating phase about five billion years ago.

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.