Friday, April 14, 2017

Exam 4, Skywatch 4, Friday, April 21.

Reading for Exam 4:

Chapter 8 Neutron Stars - Sections 8.1, 8.2, 8.5, 8.6, 8.10;
Chapter 9 Theory of Black Holes: 9.1 to 9.5, 9.8

Astronomy in the news?

Goal:

To understand the conflict between Einstein's theory of gravity and the Quantum theory.

Goal:

To understand how Stephen Hawking added some quantum theory to Einstein’s theory and revolutionized our understanding of black holes.

Black Hole Evaporation
Hawking Radiation - Chapter 9 § 6

Nature of vacuum in Quantum Theory - cannot specify the energy of anything precisely, even "zero" in a vacuum:

Vacuum "boils" with creation/annihilation of particles/anti-particles. Easiest to make photon = anti-photon (no mass) but also $e^- e^+$, $p^+ p^-$, neutron anti-neutron, neutrino anti-neutrino

=> affects behavior of electrons in atoms - *measured to high accuracy*

Quantum Fuzzy Event Horizon - at the event horizon, the position of the event horizon and of particles is *quantum uncertain*

One particle in a pair can be swallowed, the other escapes - carries off mass, energy - pure quantum effect.

Black holes are not just one-way affairs, with quantum effects they will lose mass and energy - Stephen Hawking's dramatic discovery.

Hawking Radiation

Loss of energy is not arbitrary, it may come out in a very precise form…

According to Hawking, Black Holes radiate *Hawking radiation* as if they had a precise temperature that depends (inversely) on the mass.

Black holes are not totally black

Given enough time, black holes will evaporate!

Hawking Radiation

If the black hole has the mass of a star, the time to evaporate will be ***much*** longer than the age of the Universe, so unimportant in practical terms.

If the black hole has the mass of a mountain or asteroid, it can evaporate in the age of the Universe (13.8 billion years).

As mass $\downarrow$ T $\uparrow$

With energy loss, less mass, hotter, more radiation. Runaway process.

Small mass black holes can disappear within the age of the Universe, ending in a final explosion of gamma-ray radiation.

Theories that mini-black holes might be created in the Big Bang (but no hint in any observation).

§ 9.7 Fundamental Properties of Black Holes

According to Einstein, the fundamental properties of black holes are electrical charge (usually taken to be zero), mass, and spin (angular momentum).

All other properties, radius of event horizon, Hawking temperature, come from that.

They have no other properties like mountains, structure, chemical composition, DNA,

Not even the number of protons, electrons and neutrons that fell in
=> *profound information loss*.

Thought experiment: one neutron star, one anti-neutron star.

Neutron star + Anti-neutron star => gigantic explosion!

Black Hole + Black Hole => One large Black Hole

Black holes transcend ordinary physics of matter/anti-matter

Information Loss??

Black holes have only three fundamental properties: mass, spin, and electrical charge (= 0 in practice)

Deep issue.

What happens to the ***information*** about all the stuff that fell into the black hole?

Quantum theory insists there must be no loss of information.

Maybe the information is in the Hawking radiation or maybe it is still somehow in the singularity.

Does the singularity evaporate and disappear? Don’t know in absence of a theory of ***Quantum Gravity.***

The problems get ever deeper.

With *quantum entanglement*, you can’t cleanly differentiate the observer who watches the volunteer turn black at the event horizon and the volunteer who rapidly plunges in and dies. With Hawking radiation, the volunteer may hit a blazing “firewall” and die that way.

Hawking recently suggested that maybe event horizons are not permanent.

Total confusion in physics as to the correct way to think about all this.

Thinking about black holes remains on the intellectual frontiers.

A proper theory of quantum gravity may reconcile these issues.

Book by Leonard Susskind - Black Hole Wars: My Battle with Stephen Hawking to Make the World Safe for Quantum Mechanics, will discuss later. You may be a hologram…

Goal:

To understand how we search for real black holes and why binary systems with mass transfer and accretion disks are so important.

Chapter 10 - Finding Black Holes for Real

Reading: Chapter 10, Sections 10.1-10.4, 10.9

We know that massive stars evolve to form iron cores that absorb energy and collapse. A compact object must be left behind.

Some explode and leave rotating, magnetic pulsars

Some explode and leave highly magnetic magnetars

Some explode but leave black holes or completely collapse to leave black holes

We don't know which massive stars do which! Tendency to think that more massive stars are more prone to making black holes, but the rotation of the star, the presence of a binary companion, and other factors may influence the outcome.

We do know that black holes exist, so some stars make them.

Black holes are so weird and so important that the standards of evidence have to be high!

Most current evidence is still primarily circumstantial, but very strong:

Stellar mass black holes (several to ~ 10 solar masses), in binary systems in our Galaxy or nearby galaxies

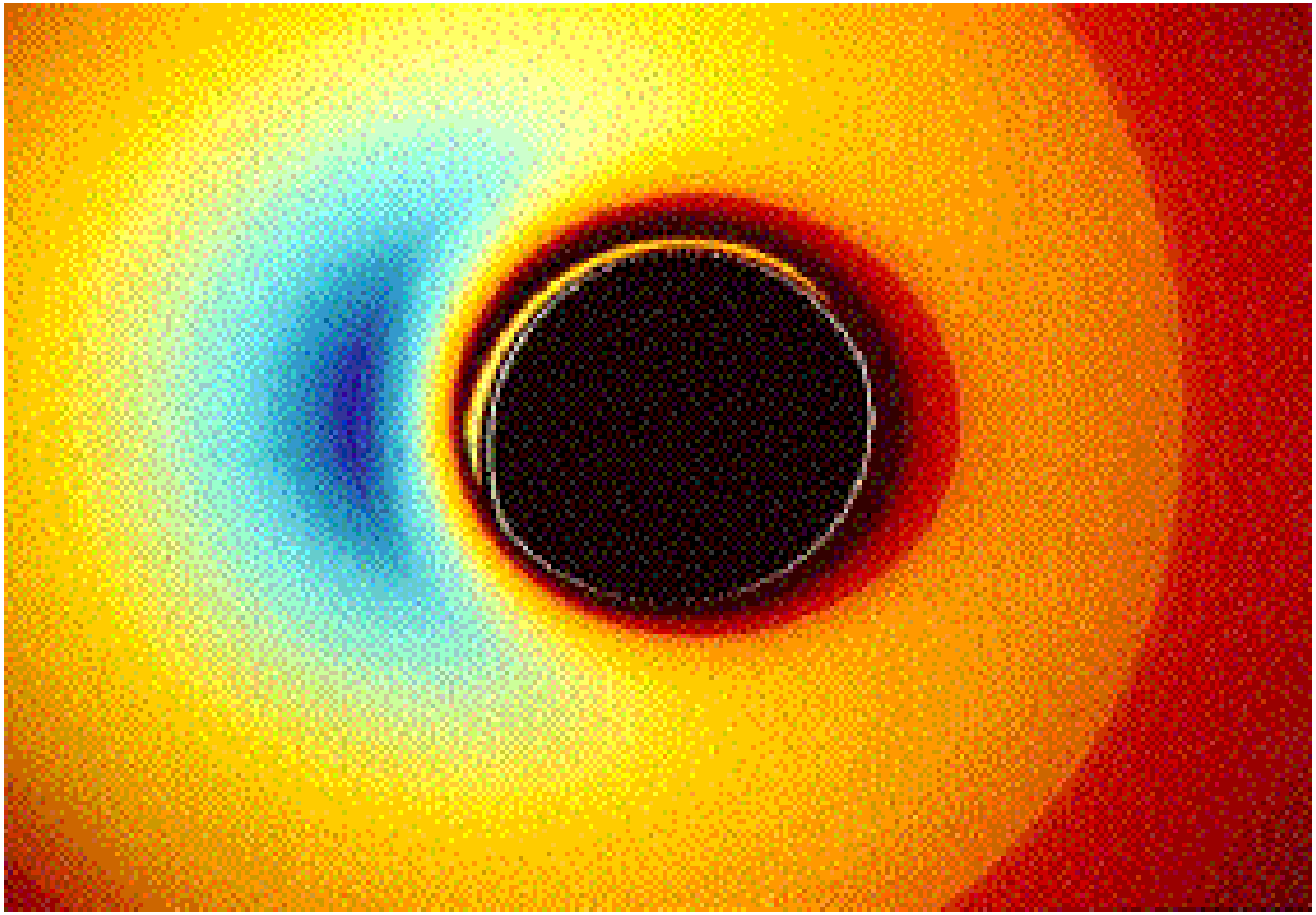
Intermediate mass black holes (~ 1000 - 10,000 solar masses)??, in binary systems or stellar clusters in our Galaxy or nearby galaxies

Supermassive black holes (million to a billion solar masses) in the middle of our Galaxy and in the middle of many, many others.

Recent evidence from gravitational radiation is ***proof***.

Goal is to get close-up study of strongly warped space:

Event Horizon Telescope, array of radio telescopes plans to examine the massive black hole in the center of the Milky Way



Perez and Wagoner, Stanford: computer simulation of radiation from inner black hole accretion disk

Black Holes for Real

There may be 1 - 100 million black holes in the Galaxy made by collapsing stars over the history of the Galaxy.

That means that the nearest black hole may be only a few tens of light years away. How do we find them?

Black holes made from stars are really black! (Negligible Hawking radiation).

Those alone in space are not impossible to find, but very tough.

Event horizon of 10 solar mass black hole has a radius of 30 km ~ 20 miles, somewhat bigger than size of Austin, easily fit between Georgetown and San Marcos

Very black

None yet identified.

Black Holes for Real

Look for binary systems, where mass accretion occurs.

Will not see the black hole, do not yet have the technology to “see” a black spot from a stellar mass black hole.

Can detect the ***halo of X-rays*** from orbiting matter, the accretion disk, near the event horizon that will reveal the presence and nature of the black hole.

Look in accreting binary systems!