15. Frontiers of Black Hole Research

Black hole astrophysics

Questions:

What is the population of "inactive" stellar mass black holes?

Which stars make black holes, and how?

What "seeds" the growth of supermassive black holes?

How do supermassive black holes regulate their host galaxies and vice versa?

What is the physics of accretion flows and jets?

Could primordial black holes be dark matter?

Are there unexpected sources of gravitational waves?

Methods:

X-ray, optical, and radio surveys, including time variability and gravitational microlensing.

X-ray spectroscopy of accreting black holes.

Event horizon telescope.

Gravitational waves (LIGO and its kin, pulsar timing, eventually LISA).

Theoretical models, especially computer simulations of accretion flows.

Black hole fundamentals

Questions:

Do black holes and gravitational waves have the properties predicted by General Relativity?

Is GR the correct "classical" theory of gravity?

What happens inside the black hole event horizon?

How do we unify General Relativity and quantum mechanics into a theory of quantum gravity, allowing for discreteness and uncertainty in spacetime itself?

What happens to the information "lost" when a black hole evaporates?

Does quantum gravity only matter near the black hole singularity, or does it affect black hole structure out to and at the event horizon?

(For more, see the "Fuzzballs" video linked near the bottom of the course web page.)

Methods:

Gravitational waves, with LISA especially promising because of its high-precision measurements.

Event horizon telescope.

Cosmological surveys that measure the influence of gravity on cosmic scales.

Theory, including string theory and its variants.

Black hole speculations

Questions:

Could wormholes exist in nature? Could they be usable?

Is something like "warp drive" physically possible?

Is time travel physically possible?