

11/16/07

Informal discussion, Wednesday, November 21

Astronomy in the News -

Pic of the day - Orion with trail of
fuel dump from booster rocket



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Supermassive Black Holes

Long suspected in quasars, active galactic nuclei: huge power from small volume, billion solar mass black hole could do it.

More recently, proof that many (even most!) ordinary galaxies also have a supermassive black hole in their centers (dead quasar).

Again, do not yet see a “dark spot” but use Kepler’s Laws, motion of many stars, gas \Rightarrow orbital period, separation

3.7 million M_{\odot} black hole in our Galaxy UCLA [link - movie]

Up to billion M_{\odot} black holes in quasars.

Jet from billion M_{\odot} black hole in center of M87, large elliptical galaxy in the Virgo cluster (find Virgo!)



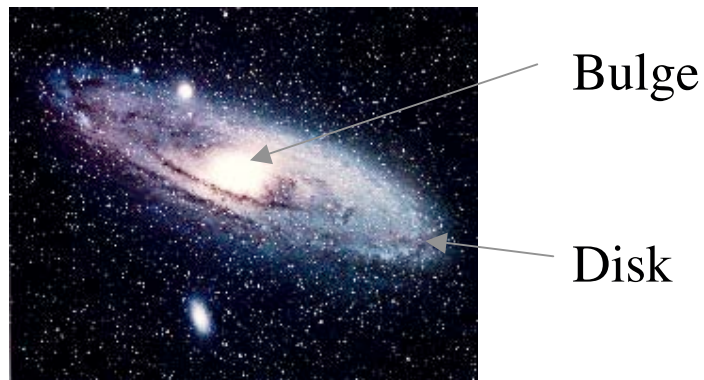
Surprising discovery:

It was long thought that supermassive black holes were somewhat incidental to galaxies,

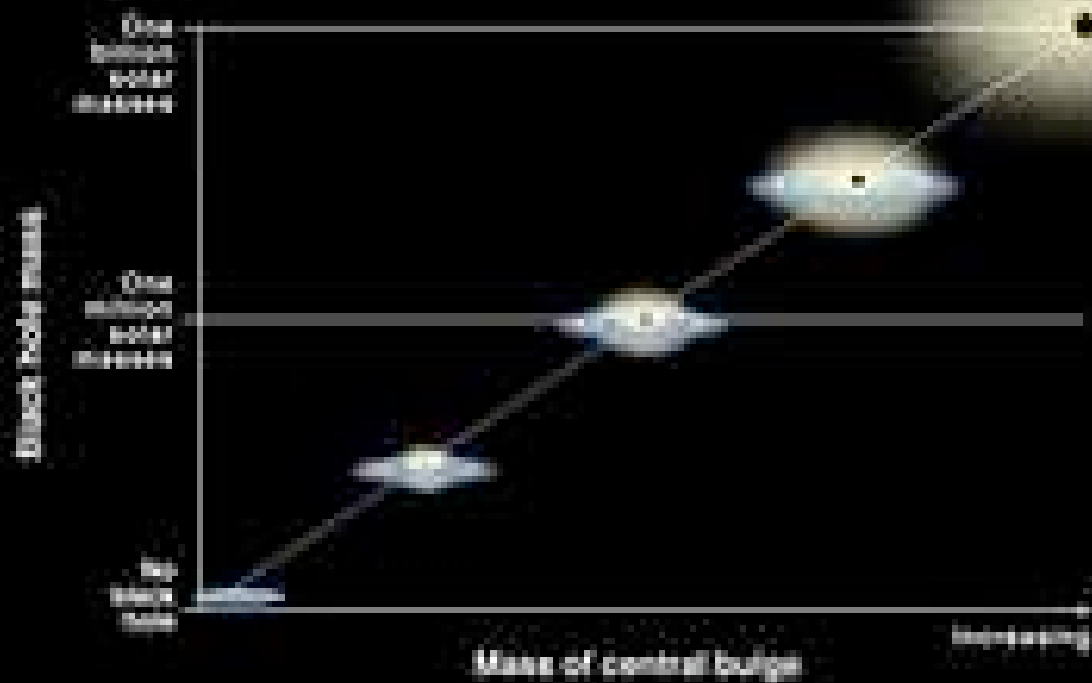
Formed of matter that somehow drained into the center of the galaxy, so galaxy could have large mass or small mass black hole depending on circumstances.

Recent work by Karl Gebhardt (UT) has shown that even stars so far from the center that they cannot possibly feel the gravity of the black hole *now* are moving in such a way that ***the larger the mass black hole, the higher the speed of the stars!***

Andromeda
M31



Correlation Between Black Hole Mass and Bulge Mass



The implication is that the mass of the galaxy (at least the inner portions, the Bulge) is always close to 800 times the mass of the black hole.

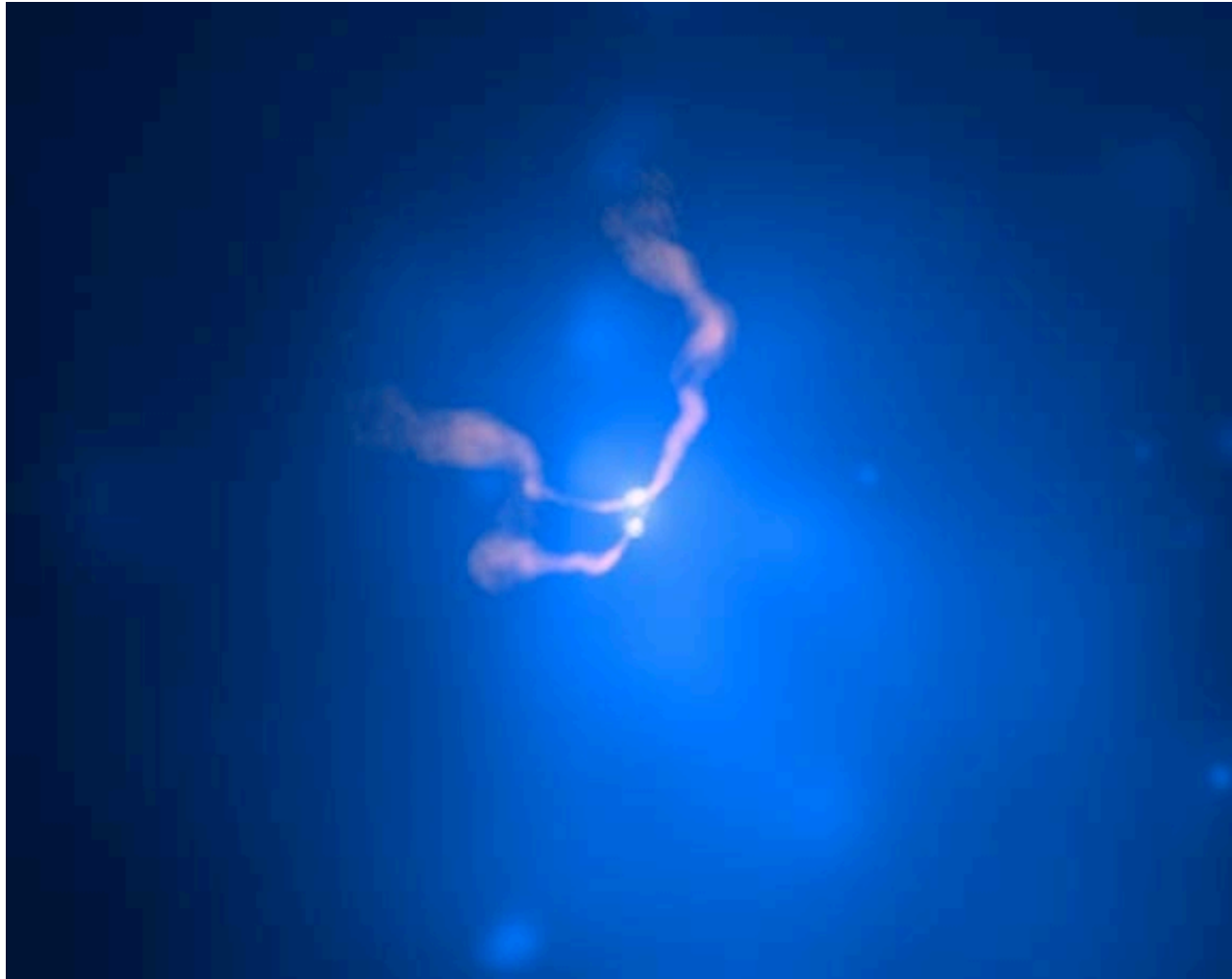
This means that *the formation of the black hole is somehow intimately connected with the formation and structure of the whole galaxy.*

Galaxies “know” how big a black hole to make.

Mechanism uncertain: Does the galaxy control the black hole or the black hole somehow control the galaxy?

Most popular current idea: energy from accretion of matter into disk around black hole feeds back to the surrounding galaxy, blowing excess galaxy gas away when galaxies are young and growing.

Colliding black holes in 3C75, feed energy back into the stars and gas of the colliding galaxies.



The latest chapter in the story:

Intermediate mass black holes, of order 1000 - 10,000 M_{\odot}

First suspected from very bright X-ray sources,

Even the gravity of a neutron star would not be enough to bind the mass (see Eddington limit luminosity, Chapter 2, Section 2).

This remains controversial.

Gebhardt and co-workers have apparently found intermediate mass black holes in *globular clusters* using stellar velocities.

Globular clusters are old, nearly spherical clusters containing about 100,000 stars.

Remarkably, these black holes may follow exactly the same bulge mass, black hole mass relation as galaxies, the black hole is about one thousandth of the mass of the globular cluster!

These star clusters also “know” how big a black hole to form!

Maybe a clue to how the process works in whole galaxies.

M 15 in our Galaxy, 4000 M_{\odot} black hole



G1 in Andromeda galaxy, 20,000 M_{\odot} black hole

One Minute Exam

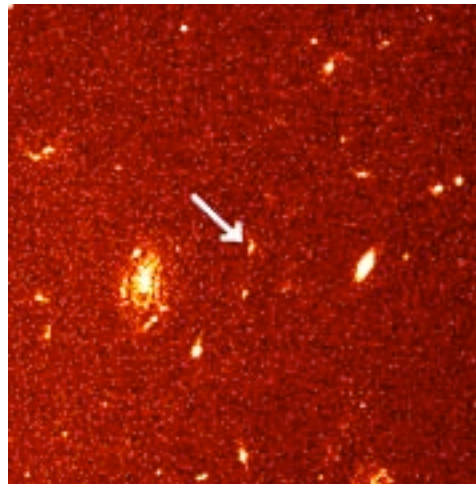
What is the relation between the mass of a supermassive black hole and the galaxy in which it resides?

- A) There is none, the black hole can be big or small, depending on how it grew and for how long
- B) The larger the mass of the galaxy, the smaller the mass of the black hole
- C) The larger the mass of the galaxy, the larger the mass of the black hole
- D) The larger the radius of the galaxy, the larger the mass of the black hole

Gamma-Ray Bursts (Chapter 11)

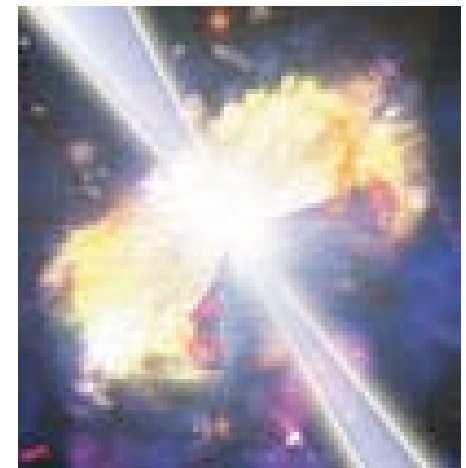
Cosmic explosions, flashes of gamma-rays lasting about 30 seconds, detected by satellites.

Seen across the Universe.



High Energy Transient Explorer

Energy is expelled in narrow jets.
Energy comparable to that of supernovae,
but all in gamma-rays, with later *afterglow*
in X-ray, radio and optical radiation.
Birth of a black hole?

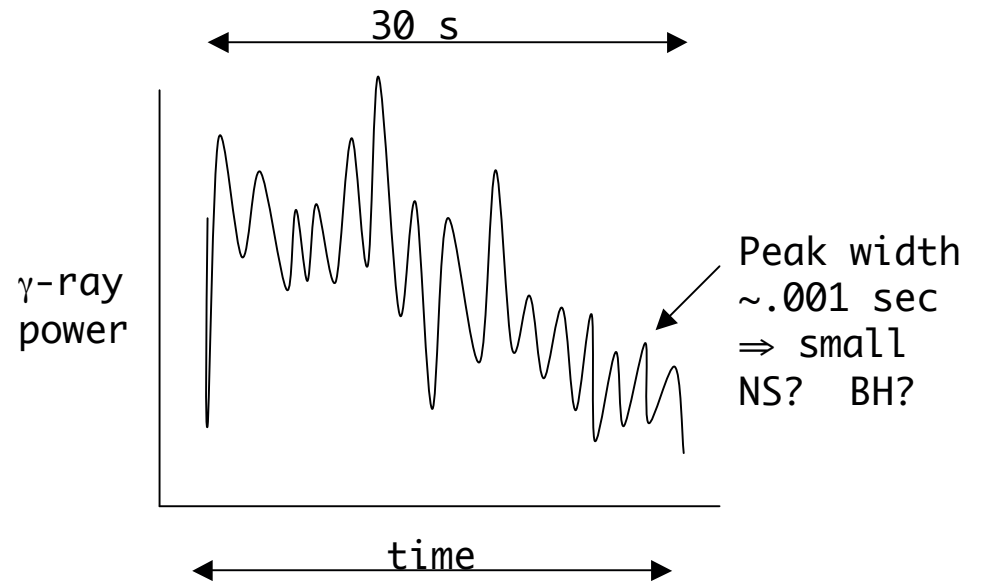


Gamma-Ray Bursts unite *stars* and *cosmology*

Mystery since late 60's - satellites to monitor space nuclear test ban treaty, avoid confusion between astronomical effects, and bombs

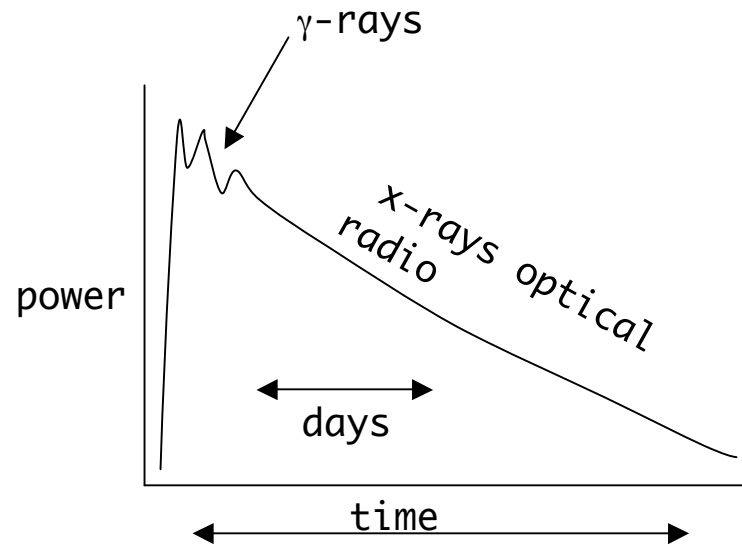
Flare of γ -rays lasts ~ 30 sec

Never Repeat - for 30 years, no optical counterpart,
Can't focus gamma-rays.
Did not know which of millions of stars to look at.



Did not know the distance: guesses ranged from within the Solar system to cosmologically distant

Revolution in 1997: 1st detection of “after glow” - optical, radio, X-ray, fading light



Position localized - could bring full armament of modern astronomy to bear on the fading radiation.

⇒ Found bursts were in distant galaxies - all at huge, cosmological distances, billions of light years away.

⇒ Very bright to shine that far

January 23, 1999 optical flash associated with the gamma-ray burst itself (need to discover, swivel telescope, look in 30 seconds!)

9th magnitude - human limit 6th magnitude, could almost see with naked eye, could have seen with good binoculars, but half way across the Universe! ***Brightest optical event ever recorded.***

If gamma-ray bursts shine equally in all directions, the energy released in gamma rays would be $3000 \times \text{SN}$ or $30 \times$ core collapse neutrinos.

Comparable to total annihilation into pure energy of entire star!