Astronomy 150:
Killer Skies

This Class (Lecture 26):
Compact Objects in the Solar System

Next Class:
The Milky Way

HW 9 due on Sunday

Music: ***Rocket Man– Elton John***

Outline

- Maybe black holes aren't black
  - Hawking radiation
- We have strong evidence of black holes
- If a compact object enters the Solar System?
  - Bad time, but very, very, very unlikely over the age of the Universe.

Spaghettification

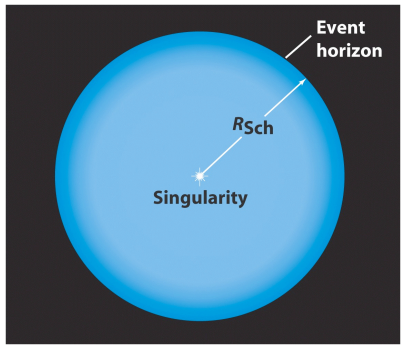
- If someone falls into a black hole, they will get pulled apart.
- They turn into a stream of sub-atomic particles.
- Human into spaghetti.

- And all of this is still outside the event horizon!

http://www.youtube.com/watch?v=h1iJXOUMJpg

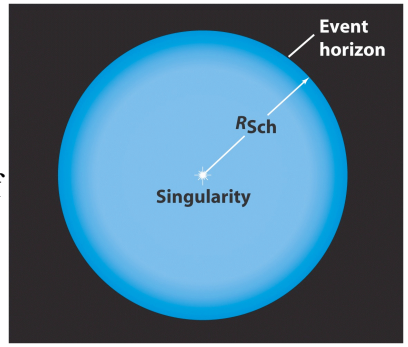
Life inside a Black Hole?

- From someone far away, material seems to take infinite time to fall in, clocks stop near the horizon.
- Once inside event horizon (R_{Sch}), no getting out
- All matter ⇒ center ⇒ point (?) "singularity"
- Known laws of physics break down



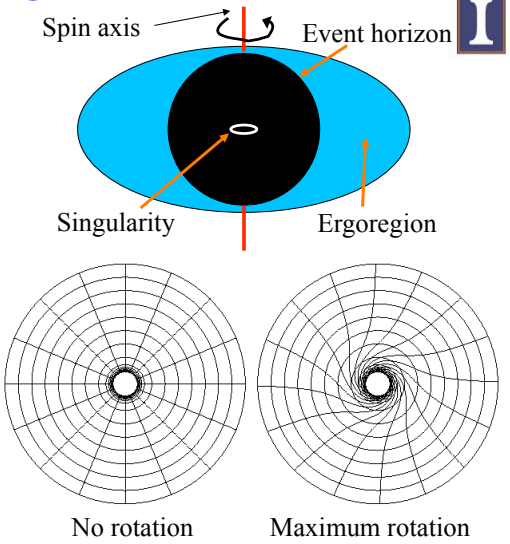
Life inside a Black Hole?

- A few points to make:
  - We know that all observers travel to center
  - Don't know what happens there
  - Regardless, certain that you die if you go in
  - In a way, it's not a relevant question, since can't get info out even if went in
  - Active subject of research!



Rotating Black Holes

- First studied by Roy Kerr in the early 1960s
- Region just outside horizon where you are dragged along by spacetime
- Can't stand still in ergoregion without falling in
- Singularity is a torus



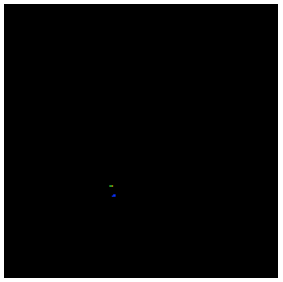
Question

The Schwarzschild radius of a black hole is the distance at which

a) the mass of the black hole is distributed; the outer rim of the back hole.
b) the speed of light is zero.
c) nothing can escape as the escape speed is greater than, or equal to, the speed of light.
d) pictures of penguins painting pandas become only red.
e) the laws of physics break down.

Approaching a Black Hole

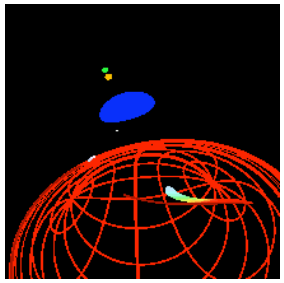
- A quad system with a black hole (30 $M_\odot$), a blue star (60 $M_\odot$), a yellow star, and a green star.
- Schwarzschild radius is marked in red.
- Up to last stable orbit $3R_{Sch}$



http://casa.colorado.edu/~ajsh/schw.shtml

Orbiting the Black Hole: Our POV

- Orbiting (unstable) at 2 R_{Sch}, we fire a white probe.
- The probe appears to freeze at the horizon of the black hole, joining the frozen images of probes fired on previous orbits. If we could see a probe clock, it would appear to halt.
- The changing colors of the probe show how it becomes more and more redshifted, from our point of view.
- From the probe point of view, it neither freezes nor redshifts, but careers on through the horizon toward the singularity of the black hole.



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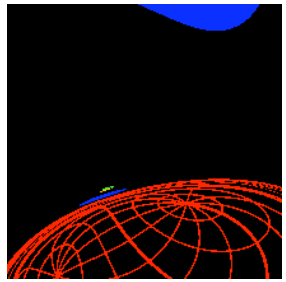
Going In

- Start out at 1.5 R_{Sch}, the last orbital position, requiring light speed.
- Inside of that, orbits go inside R_{Sch}
- Tidal forces at R_{Sch} for this object is about 1 million g's along a human.
- As we fall in, we free-fall quickly to the singularity
- The blue-shifted Universe is mostly x and γ-rays.
- The tidal force has become so strong that all images are concentrated into a thin line about (what is left of) our waist.



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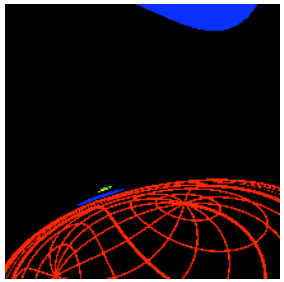
Going In

http://www.youtube.com/watch?v=GYKyt3C0oT4&NR=1



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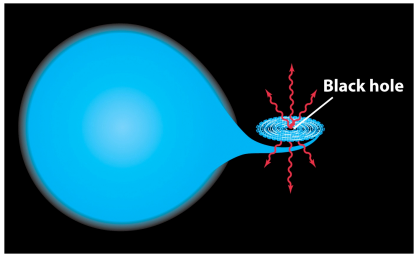
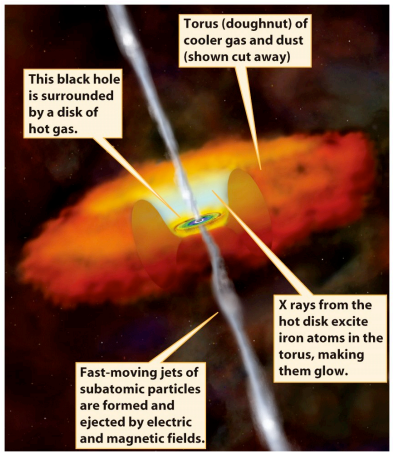
How To See A Black Hole

- If a black hole emits no light, how do we see it?
  - Have to look for ones with accretion disks!
- We look for interactions between the black hole and a companion
  - Black hole pulls mass from the companion which forms a disk
  - The gas in the disk is compressed and heated so that it gives off X-rays



Black Holes

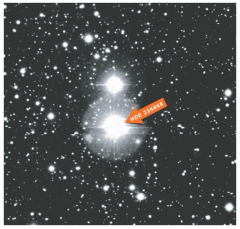


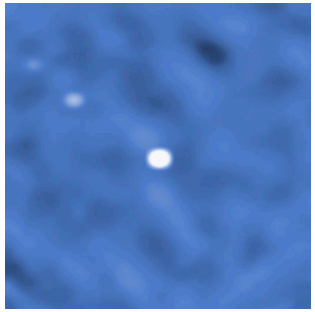

An artist's impression of Cygnus X-1

http://www.youtube.com/watch?v=MD5lOpxDEII
1:35-2:20

Cygnus X-1

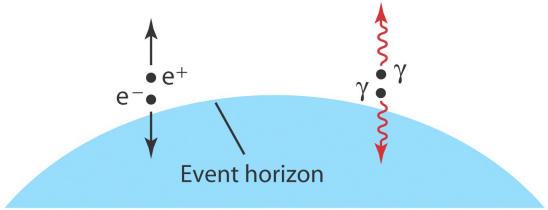
- Binary system with unseen 7 solar mass companion
- Spectrum of X-ray emission consistent with that expected for a black hole
- Rapid fluctuations consistent with object a few km in diameter

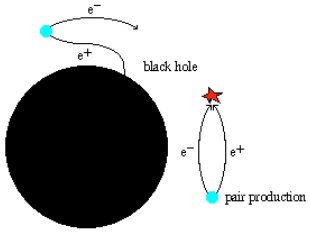


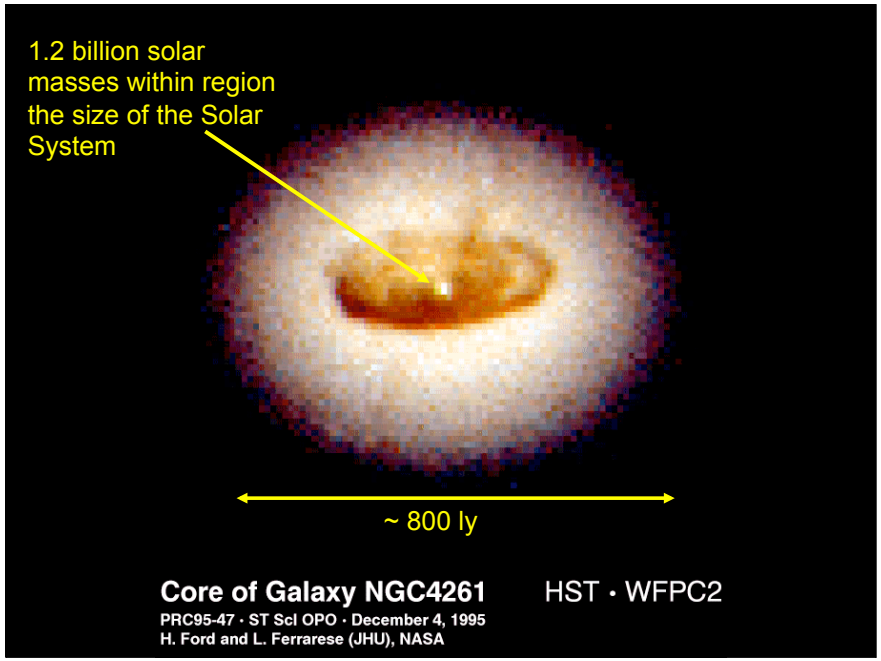


Hawking Radiation

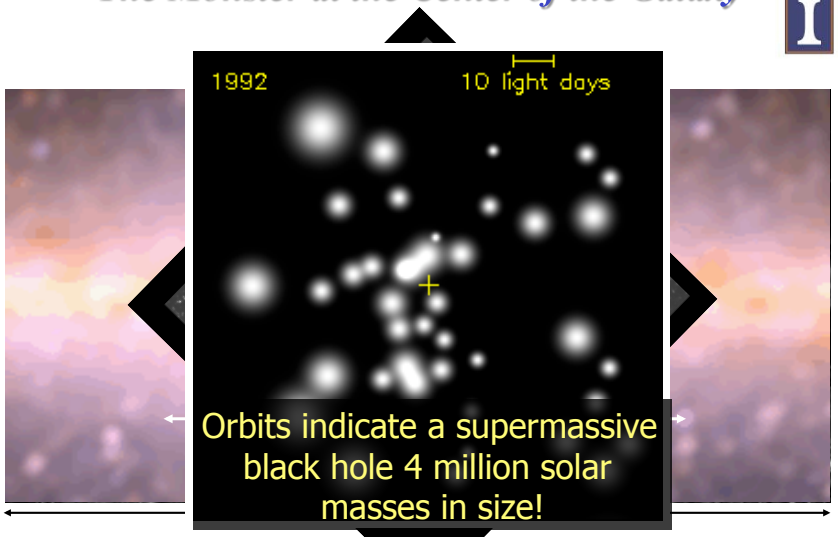
- Black holes are not truly black!
- Quantum mechanical effects near event horizon cause them to produce blackbody-like radiation
- Temperature **increases** as mass **decreases**
- Too dim/cool to see for stellar-mass black holes







The Monster at the Center of the Galaxy

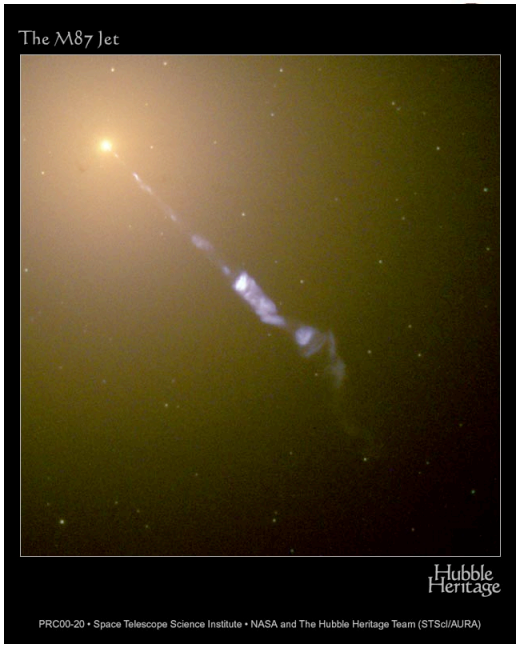


~ 100 pc [illegible] nfrared)

http://www.youtube.com/watch?v=[illegible]nv-6qLM8Y 0:48

The Jet of M87

- Huge jet from the center of this galaxy (50 Mlyrs away).
- 5000 light years in length!
- The jet is probably created by energetic gas swirling around a massive black hole at the galaxy's center
- We'll come back to this



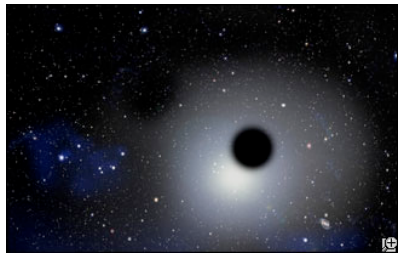
Question

Black holes are

a) Impossible to detect
b) Have hair
c) Not seen directly, but there is strong evidence of their existence
d) Bright emitters of Hawking radiation
e) Going through our hands by the millions

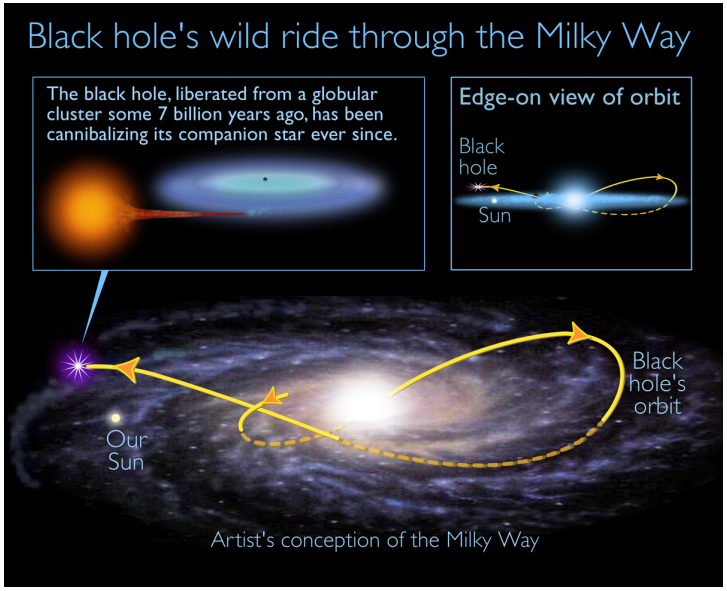
Rogue Black Holes?

- The Galaxy has been accruing black holes for billions of years.
  - Stellar corpses
  - Primordial?
  - Globular cluster kick them out
  - Cores of consumed galaxies



- Might we expect a black hole to enter our Solar System?
- If so what might happen?

Rogue Black Holes: Example



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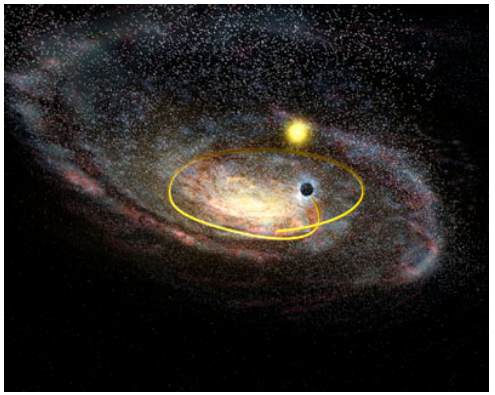
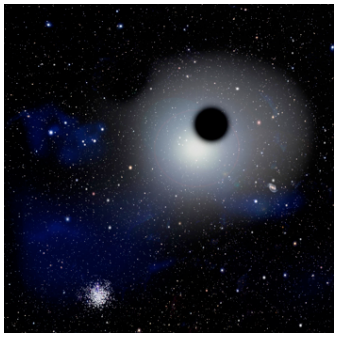


GRO J1655-40, about 7 solar masses, has a stellar companion. System moving at 110 km/s! Supernova can create high speed corpses.

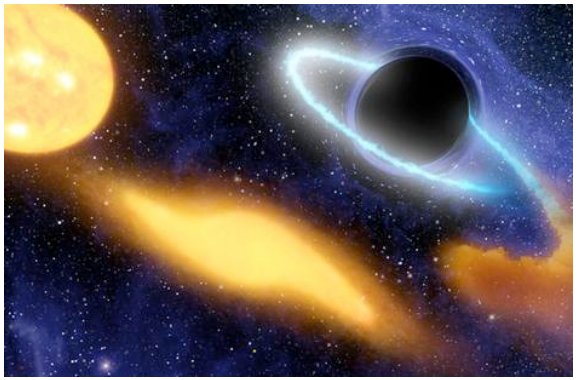
Rogue Black Holes: Example



The Milky Way has collided with many smaller galaxies. When this happens the smaller galaxy's massive center black hole. Hundreds of these could be rogue in the Milky Way– 1000's to 100,000's of solar masses!

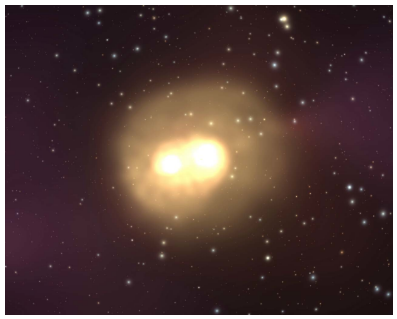
Stars Collide?

- The Galaxy may have a lot of black holes.
- But, Space is Freaky Big!
- Stars still are much, much, much more common than black holes.
- Closest known black hole is Cygnus X-1, which is 6500 lyrs away.



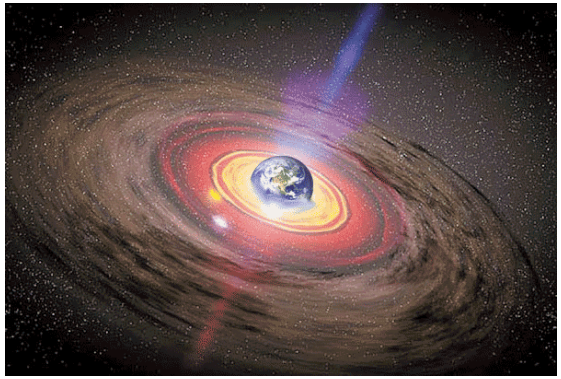
Stars Collide?

- Chance of interacting with another star is very, very unlikely.
- Star comes within 3.26 light years every 100,000 years.
- Chances for a star to influence Solar System, you would have to wait more than the age of the Universe!



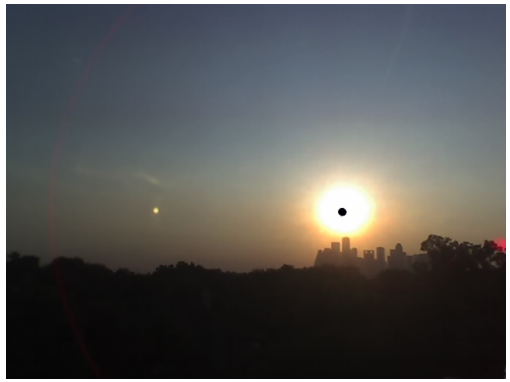
But What If?

- Remember unless it is feeding, it will be hard to detect a nearby black hole.
- What if a run away stellar black hole (~10 solar mass) was heading right for the Earth?
- What would be the effects?



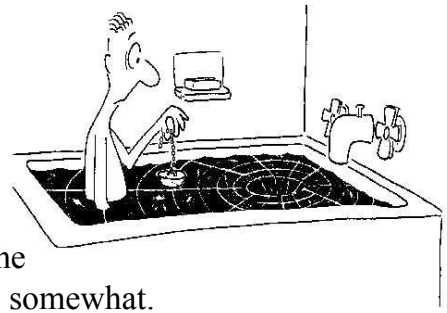
But What If?

- Many of the early effects of a nearby blackhole would be the same as a nearby star.
- We could go from a single star system to a binary system.
- Planets would be pulled two ways, orbits will change.
- At some point the farther out planets will be pulled harder by the new object.



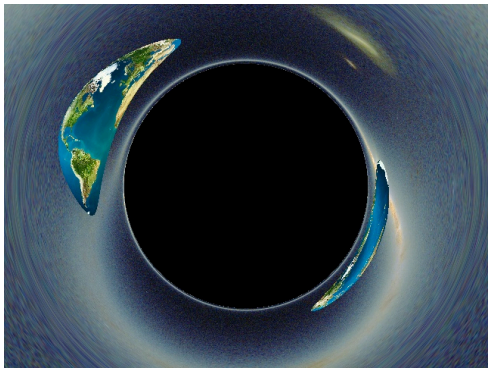
But What If?

- Planets may orbit the black hole or be flung from the Solar System.
- For two massive object interaction, lower mass objects will often be ejected.
- At first, people won't notice too much, even though the orbit starts to change somewhat.



But What If?

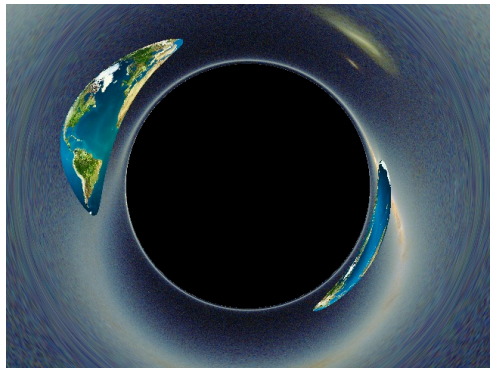
- When a 10 solar mass black hole gets about 3 AU away, it will have more pull than the Sun.
- The Earth will then no longer be bound to the Sun.
- It will either be ejected out of the Solar System, fall into the Sun, or fall into the black hole.
- No matter which, all options are bad for us.



http://www.naturalbuy.com/wp-content/uploads/2009/10/earth-orbiting-black-hole.jpg

But What If?

- Spaghettification will take affect on the Earth as it did our helpless astronaut earlier.
- Black hole's tidal forces begin to dominate
- Tides get huge!
- Floods. Tidal waves Millions dead!



http://www.naturalbuy.com/wp-content/uploads/2009/10/earth-orbiting-black-hole.jpg

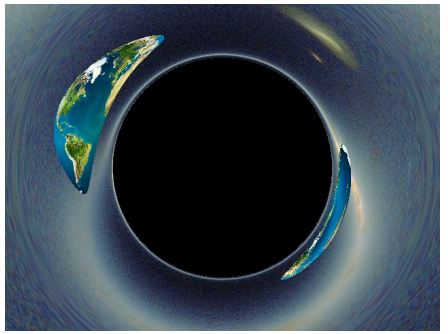
But What If?

- When the black hole is 7 million miles away, it's force on you is greater than the Earth's.
- Moon already ejected from system.
- Tides are 20,000 times worse.
- You are weightless.
- With a small kick you can fly upward.
- Earthquakes, continents torn apart.

http://home.vicnet.net.au/~hmwkhelp/images/tidal.wave1.jpg

But What If?

- Final tides are too much for Earth to handle.
- Earth is torn apart like astronaut from before.
- You are killed from either suffocating or if you grabbed a spacesuit spaghettification or from the accretion disk radiation.
- Adding the Earth doesn't really make it any bigger, still about 40 miles across.



http://lh3.ggpht.com/_4ruQ7t4zrFA/SdG3vEI963I/AAAAAAAAB70/Yb5XCaaVITQ/earth-orbiting-black-hole.jpg

But What If?

- For the rest of the Solar System, it will depend on the orbits.
- If the black hole doesn't get close to the Sun, it will be fine, otherwise, it may get torn apart too.
- Then, the black hole likely moves on.

http://www.intute.ac.uk/hottopics/spotlight/images/SPT59-smallest-black-hole-birds-eye-view.jpg

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