Killer Skies

- **Homework 8** due tonight
- Asteroid Lab and Night Obs due Friday
- Solar Observing this week
- Last time: Spaghettification
- Today: Earth v. Black Hole

"It's black, and it looks like a hole. I'd say it's a black hole."

Music: *Spaceboy*– Smashing Pumpkins

Solar Observing This Week

Still Happening:

M-Tu, 10:30am-1:30pm, weather permitting (extending)

At Campus Observatory

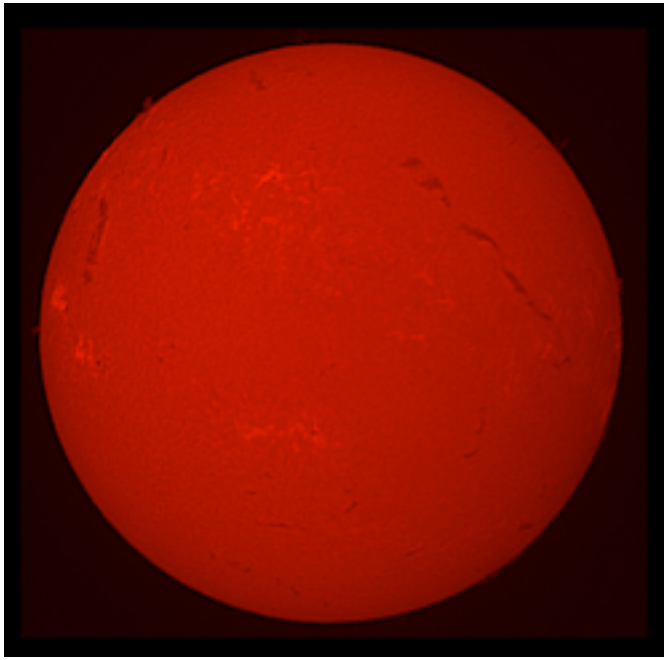
(behind building)

Assignment details and report form on class website

Report due Nov 22nd

Subscribe to Solar Observing Status Blog for weather-related notices

http://illinois.edu/blog/view/414

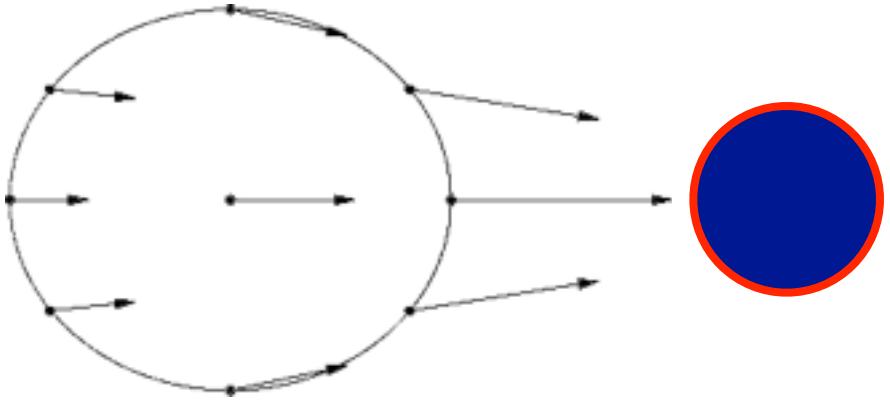


Recap: Living with Black Holes

Black Hole Threat

when far away:

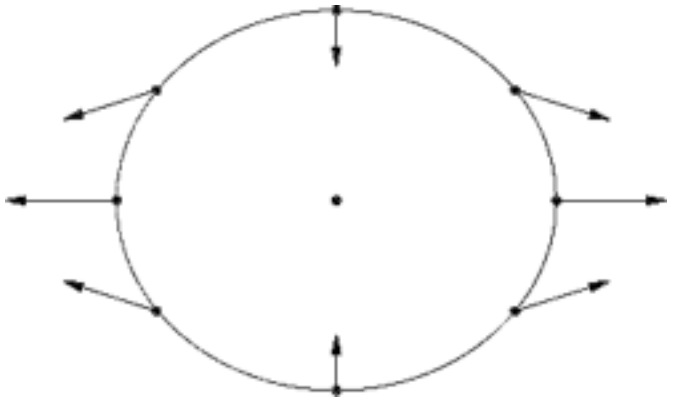
- gravity no stronger than star of same mass
- not particularly dangerous



pattern of gravity forces

when near horizon:

- gravity very strong
- tidal forces huge:
  - stretching along direction towards BH
  - squeezing perpendicular



force differences from average

Black Hole Singularity: The Frontier

Black hole singularity is subject of intense research

- there is much we don't know

A few remarks:

- we do know that all infalling stuff travels to center
- don't know what happens once there
- regardless, certain that you die if you go in
- in a way, it's not a relevant question

  can't get info out even if went in (no Nobel Prize!)
- once crushed to < 10^{-33} cm, quantum mechanics important

  i.e., to understand, need quantum theory of relativistic gravity!

  a theory of gravity that includes both relativity and quantum mechanics

  ... but there isn't one...yet
- if you have quantum gravity theory, please tell instructor

  and we'll publish it (you don't mind if my name goes first do you?)

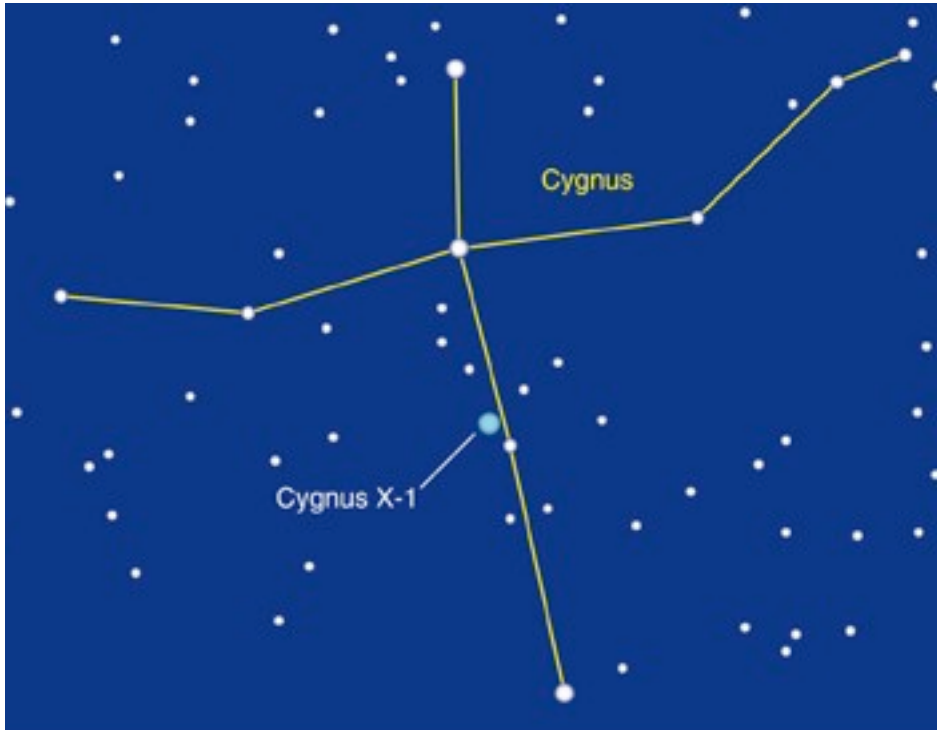
Stars Collide?

The Galaxy may have a lot of black holes.

But, Space is Freaky Big!

Closest known black hole is Cygnus X-1, 6500 lyrs away

Stars still are much, much, much more common than black holes.



How likely is a star colliding with our Sun?

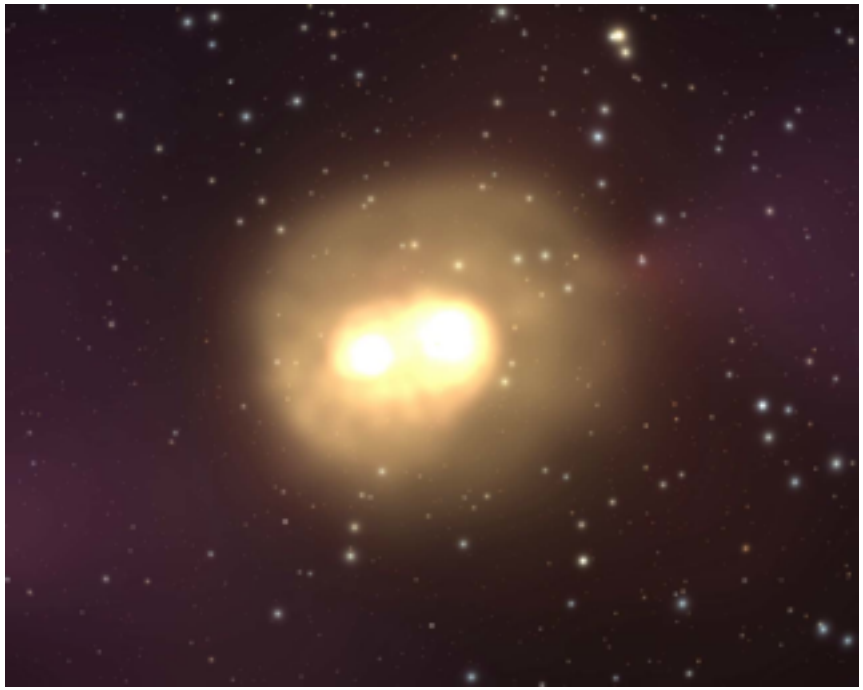
And Star Collision Unlikely

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 planets in Solar System?

You would have to wait more than the age of the Universe!



Rogue Black Holes?

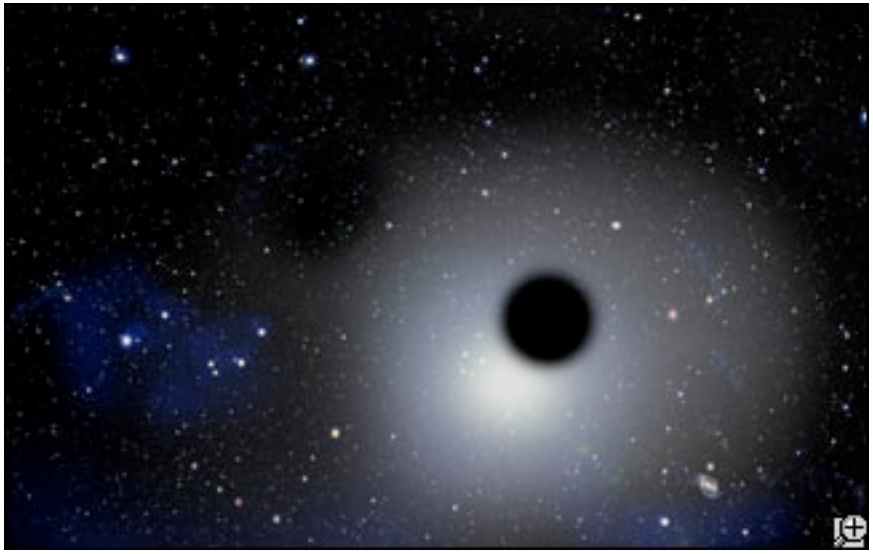
Average distance to a black hole should be ~100 light years!

That's less common than stars, but sounds close!

So, very, very, very unlikely for a black hole to enter our Solar System

But what if. What might happen?

We are talking something that is more massive than Sun, but compact!



But What If?

Black hole colliding with the Earth would of course be a disaster.

At the end, Earth is destroyed by tidal forces, ripped apart.

Or even if black hole misses, it could throw Earth out of our nice orbit, which is still bad.

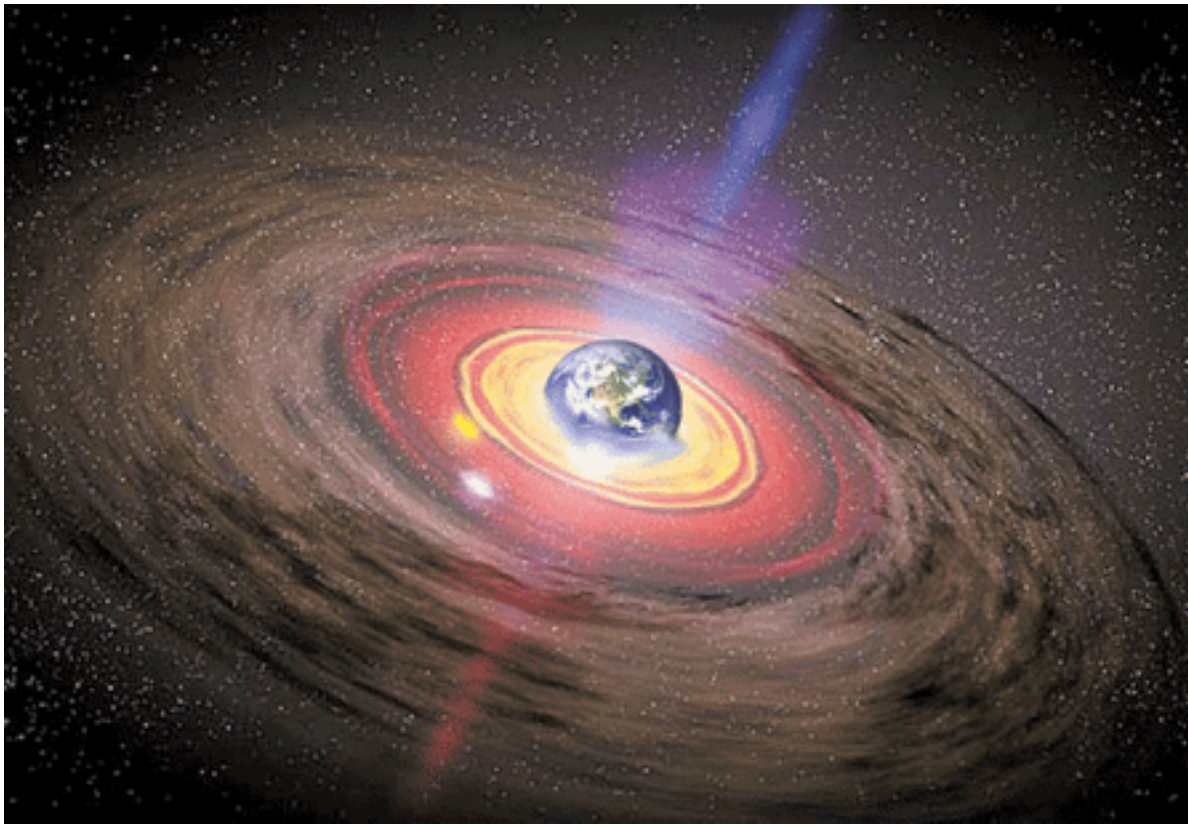
http://www.intute.ac.uk/hottopics/spotlight/images/SPT59-smallest-black-hole-birds-eye-view.jpg

Quiet Killer

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?

Would be hard to see until something else happened



IClicker Question

If a black hole ten times more massive than our Sun were lurking just beyond Pluto's orbit, we'd have no way of knowing it was there.

A. Correct. Black holes do not emit light so they cannot be detected.

B. Correct. Such a low mass black hole would have no influence on the solar system unless it impacted a planet.

C. Incorrect. Such a black hole would measurably affect the orbits of the planets.

D. Incorrect. X-ray observations would reveal its presence as it sucked in material around it.

E. Incorrect. It would be readily apparent as a pulsating radio source in the outer solar system.

Answer C

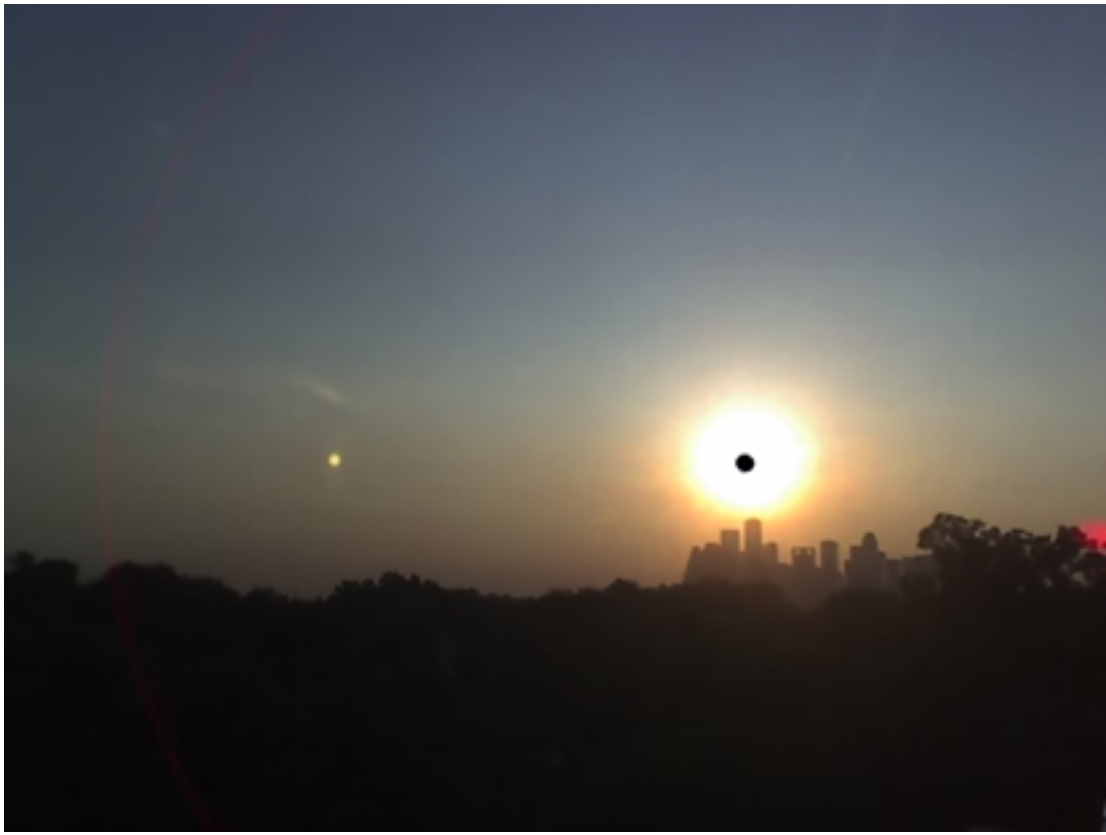
Orbital Effects

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.

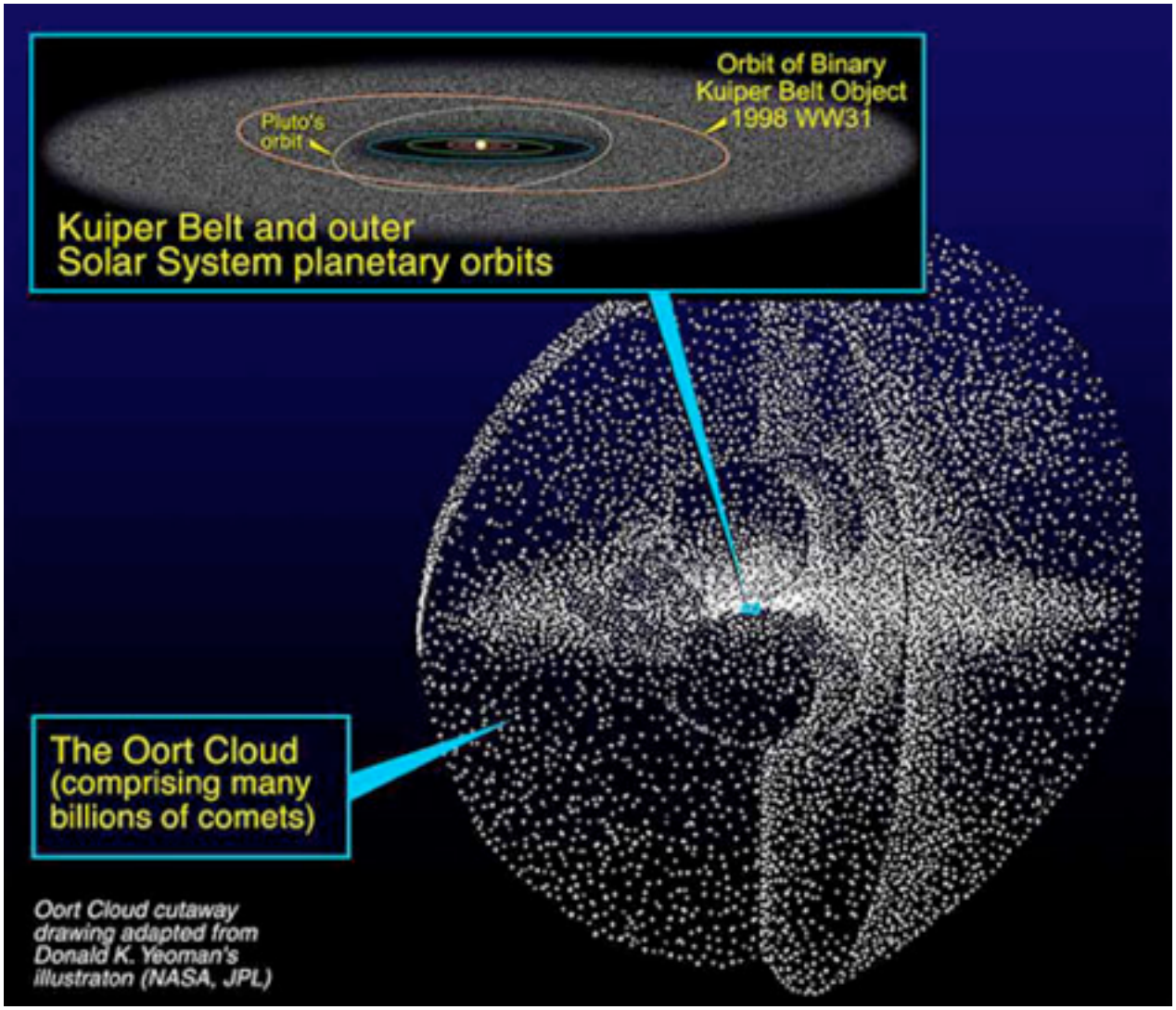
Planets would be pulled two ways, orbits will change.

At some point the farther out planets will be pulled harder by the new object.



First encounter: Oort Cloud

The black hole's gravity will first affect the Oort Cloud



Oort Cloud comets are scattered into the inner solar system, creating an impact threat

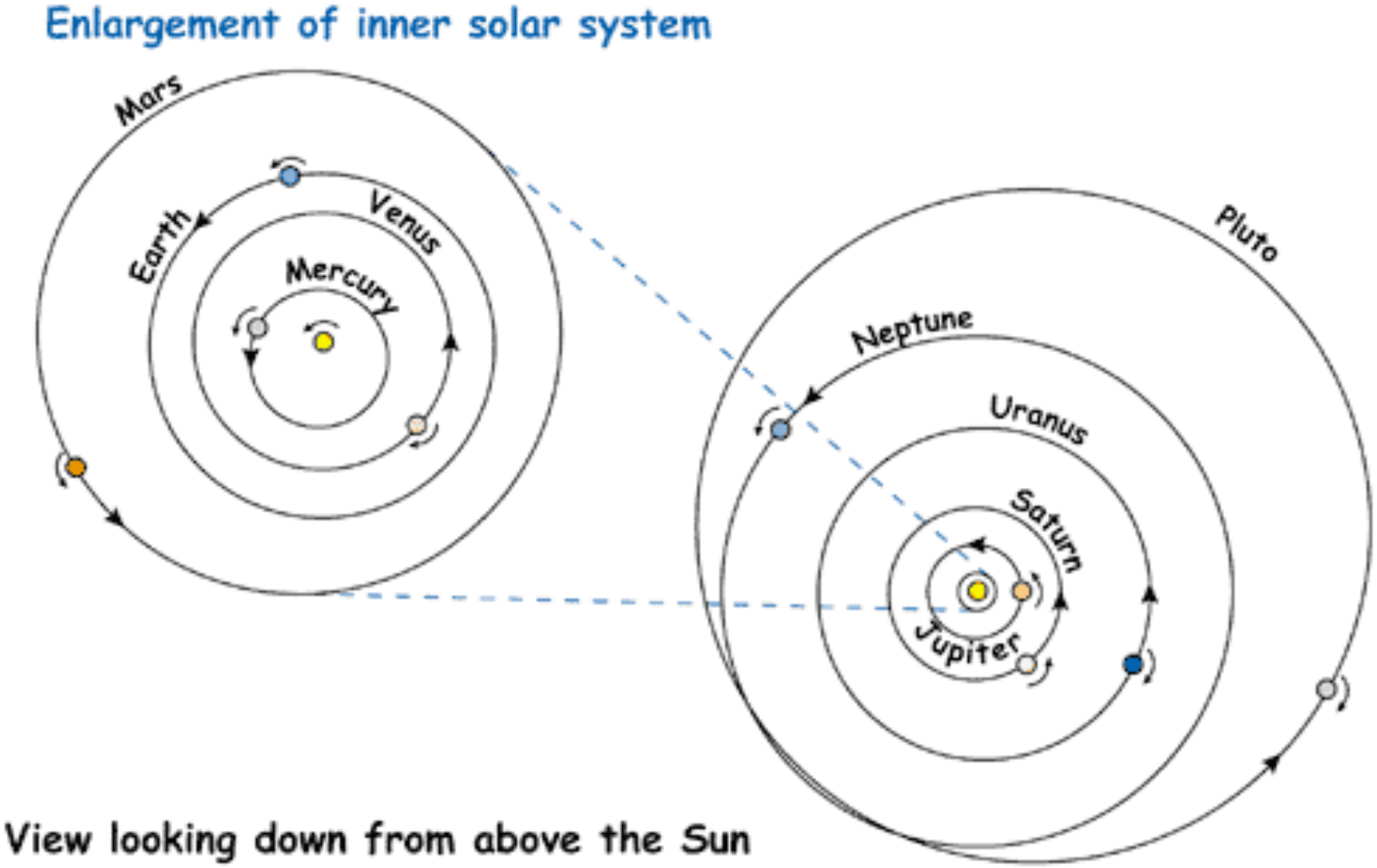
Fring Fling

Planets may orbit the black hole or be flung from the Solar System.

For two massive object interaction, lower mass object will often be ejected-- that's the Sun here.

At first, people won't notice too much, even though the orbit starts to change somewhat.

But imagine the worst case scenario: the black hole is headed straight for the Earth and the Sun



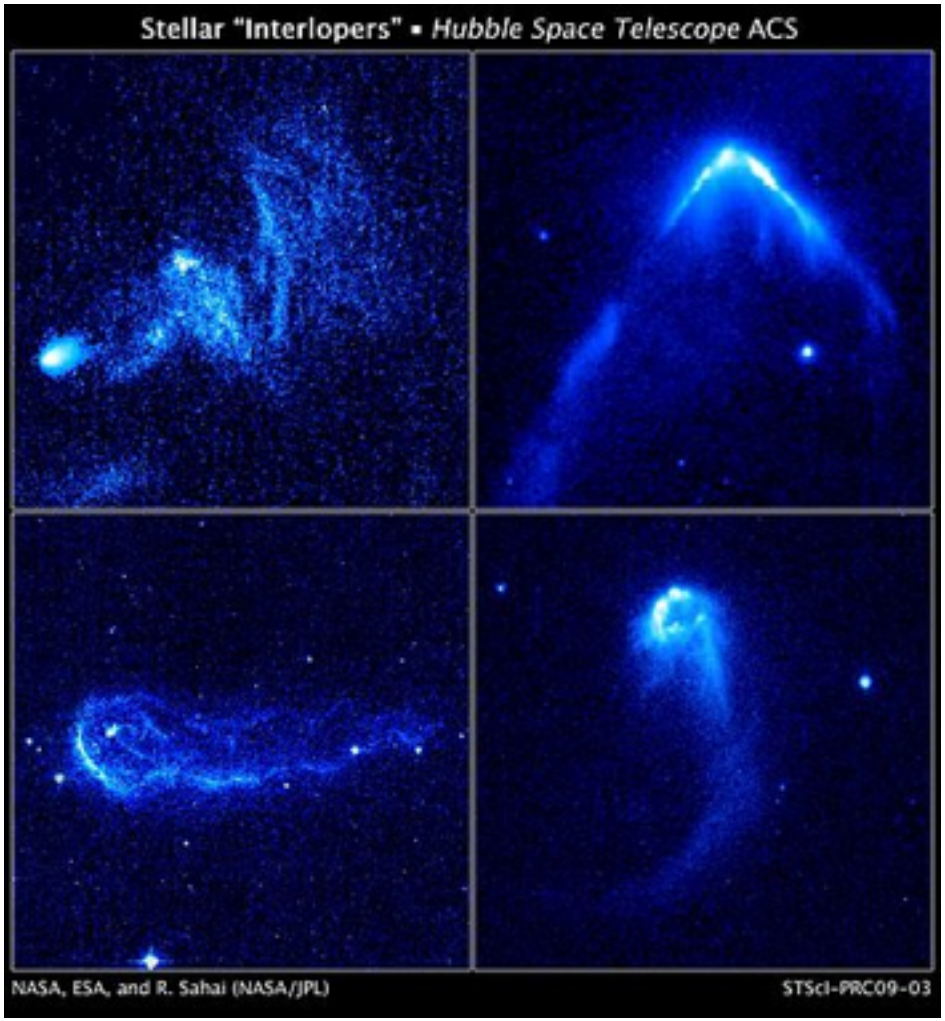
Planets' orbits will be altered by the black hole's gravity

Planets would be pulled two ways, orbits will change.
At some point the farther out planets will be pulled harder by the black hole.
At first, people won't notice too much, even though the orbit starts to change somewhat.

Ejected Planets?

Planets may orbit the black hole or be flung from the Solar System

In a two massive object interaction (Sun & black hole), lower mass objects (planets) will often be ejected



Run away stars

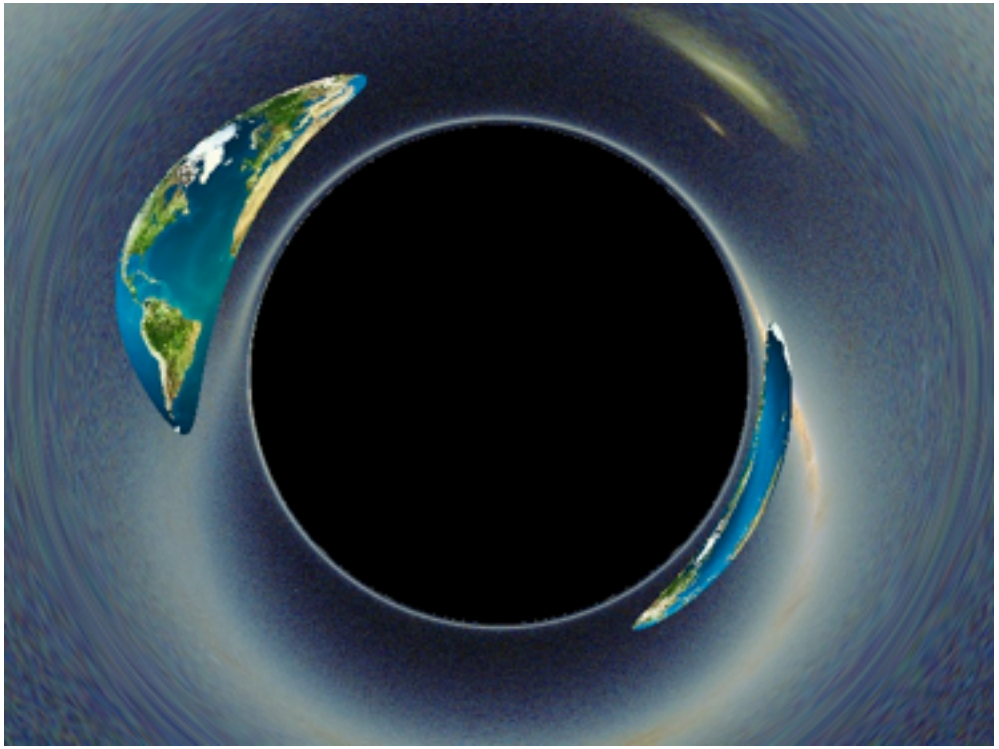
Hubble Space Telescope image of a possible ejected planet from a star's planetary system

Too Close for Comfort

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

Tidal Tsunamis

The black hole's gravity will create enormous tides on Earth, flooding all but the highest areas

When a 10 solar mass black hole gets about 3 AU away, it will have more pull than the Sun.
Black hole's tidal forces begin to dominate
Tides get huge! Floods. Tidal waves
Millions dead!

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

Last moments of the Earth

Tidal forces from the black hole become enormous

- Massive earthquakes
- Atmosphere, oceans pulled off Earth

Earth is literally torn apart by black hole's gravity

Earth is devoured by the black hole

Spaghettification will take affect on the Earth as it did our helpless astronaut earlier.
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.

Earth Spaghettification

Finally tides are too much for Earth to handle.

Earth is torn apart like astronaut from before-- Earth spaghettification.

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 black hole any bigger, still about 40 miles across.

Thank you Ma'am

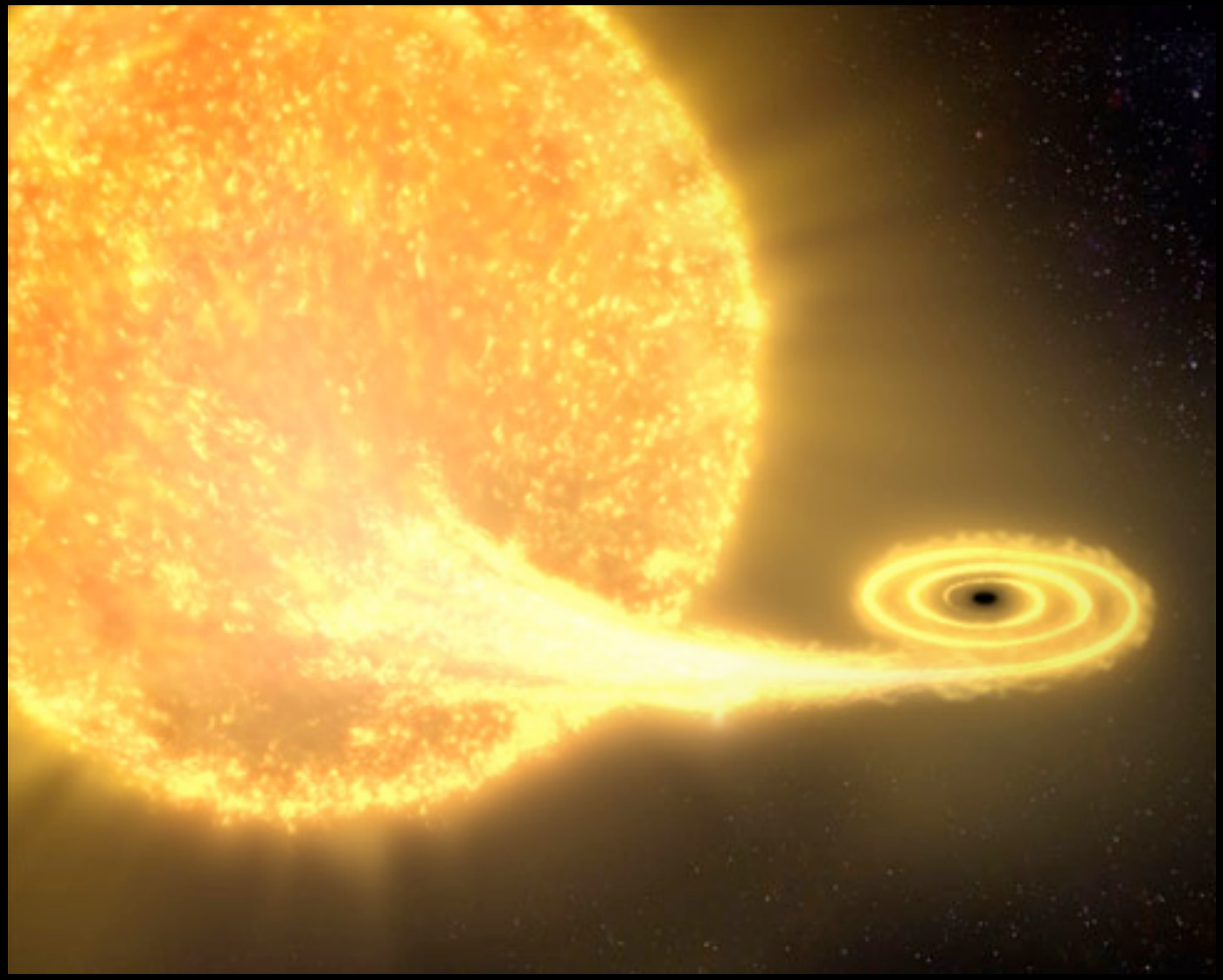
For the rest of the Solar System, it will depend on the orbits.

If the black hole doesn't get close to the Sun, the Sun 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

The Sun could also be consumed by the black hole



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.

Earth V. Black Hole

http://www.youtube.com/watch?v=asHpCetT-3A

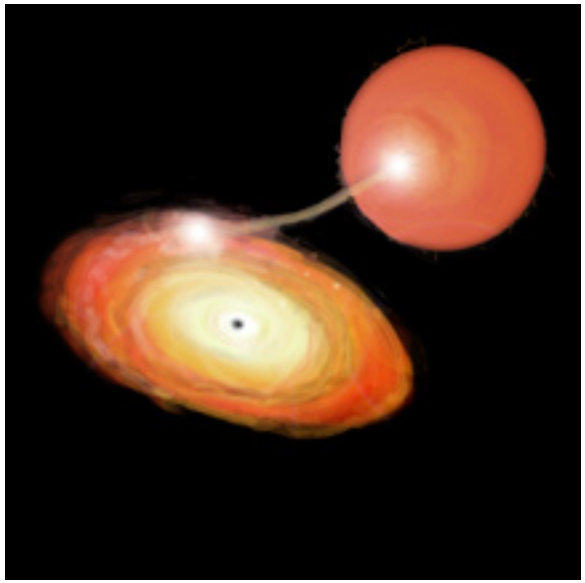
Other Compact Objects?

There are a lot of white dwarfs or other non-black hole compact objects in the Galaxy.

Still not very likely to interact with one.

Collision is very unlikely, but could eject us or destroy the Sun.

Very, Very unlikely, but probably more likely than a black hole.



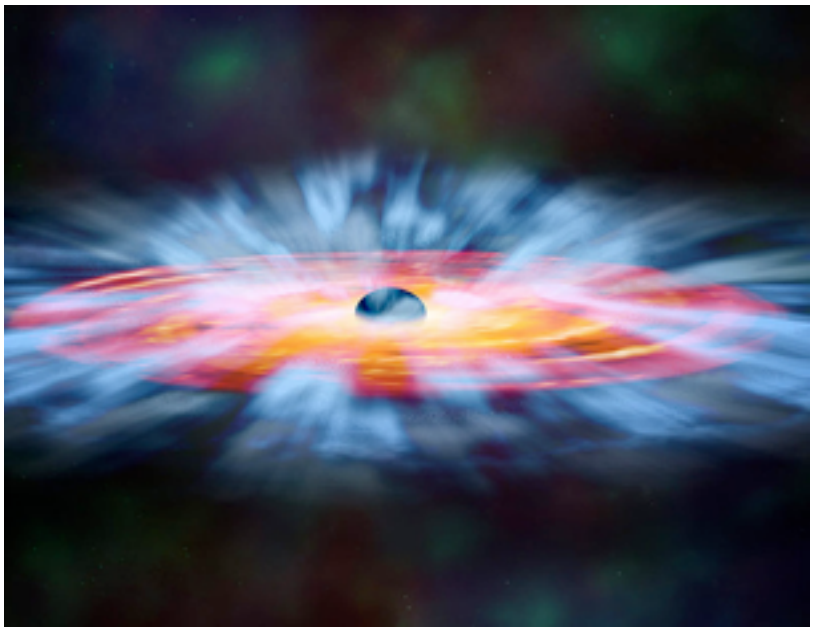
Micro-Black Holes?

You don't need a lot of mass to make a black hole, just high density.

What about very low mass black holes?

Primordial black holes have never been seen, but if a few ton black hole hits the Earth, it is about as bad as a 10 solar mass back hole.

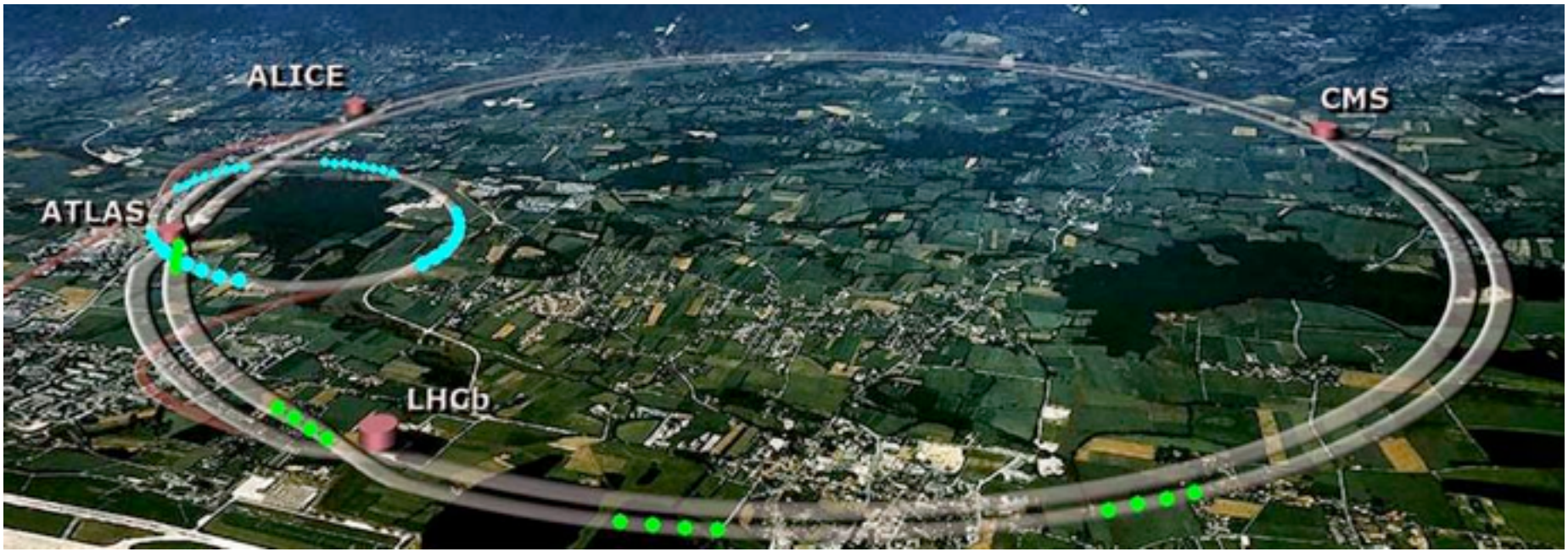
Smash together nuclear particles at high speed and you perhaps can get high enough densities.



Won't mess with orbits as much

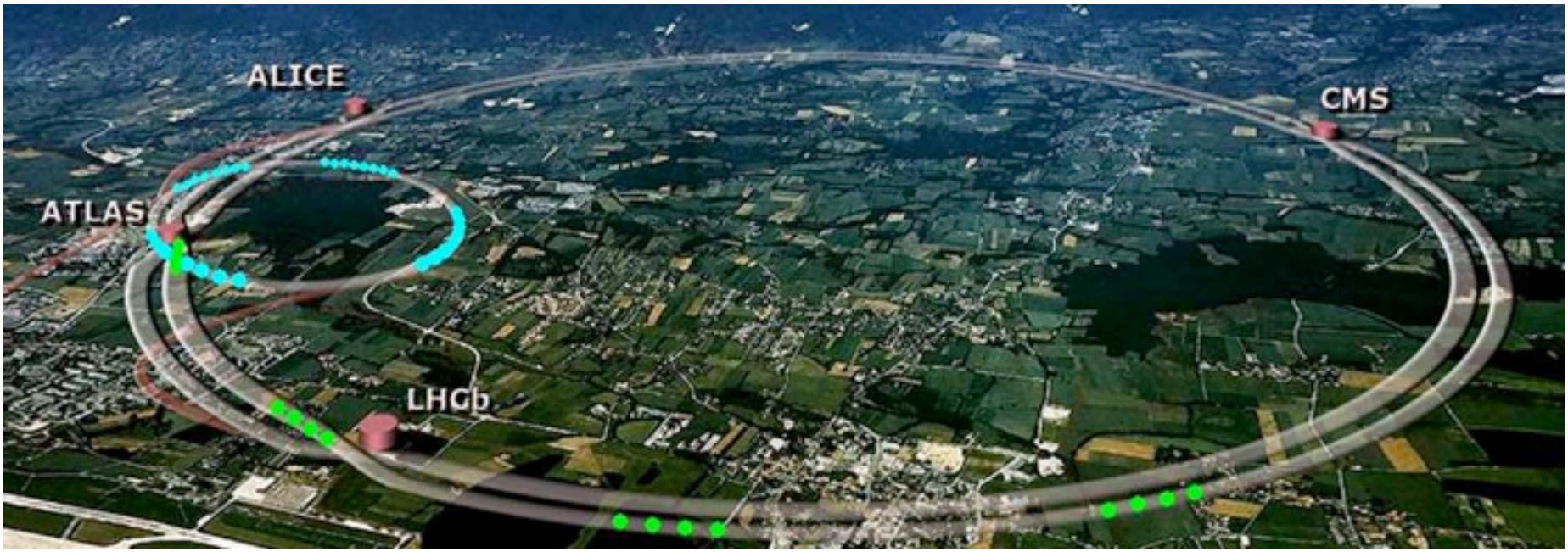
Man-Made Micro-Black Holes?

- What if we make our own?
- The Large Hadron Collider (LHC) near Geneva might be able to make them.
- Takes protons and accelerate them to 99.99% the speed of light, then crash the protons together.



Man-Made Micro-Black Holes?

- When the particles smash together new particles are created sometimes, which quickly decay
- Main point of the LHC is to look for the Higgs Boson, which is theoretically expected to be responsible for mass.



But maybe can smash with high density and make micro black holes

In 2009, it was claimed that particle physics experiments at the Large Hadron Collider could create *micro black holes*
Could these swallow the Earth?

http://www.youtube.com/watch?v=BXzugu39pKM

i>clicker poll

Are you worried about micro black holes produced by the Large Hadron Collider?

A. Yes - I'm flying to Switzerland tonight to stop those mad scientists!
B. No - I'm sure scientists have evaluated the risks and concluded there's no danger
C. Unsure - I'm going to Google this right after class and see what the internets have to say
D. As long as it happens after Thanksgiving Break, don't care, just get me outta here!

Answer: B -- it has been thought about and the fact of cosmic rays is important.

The LHC

http://www.thedailyshow.com/watch/thu-april-30-2009/large-hadron-collider

Could the LHC produce a micro black hole?

Probably not

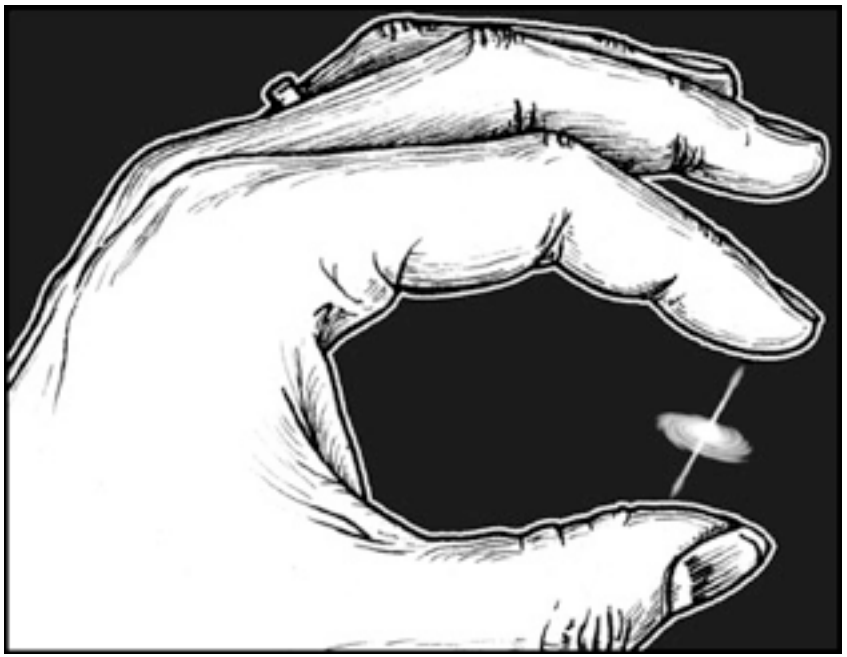
Expected energy needed for micro black hole ~10^{19} GeV (10^{9} J)

Far beyond the limits of current technology

- **LHC would need to be 1000 light years across to produce that much energy**

…but these reassurances are based on known particle theory

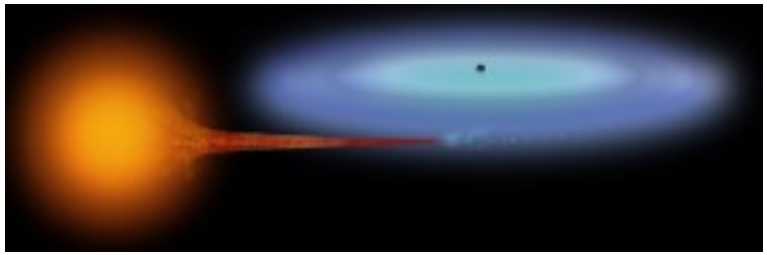
- **what if this is a big nasty surprise waiting?**



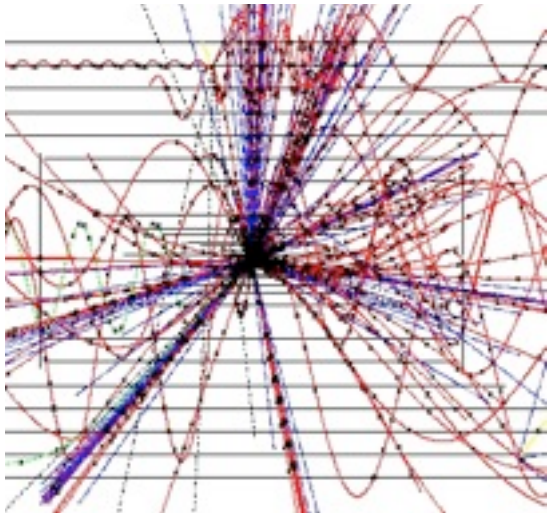
A paper by Choptuik and Pretorius, published on March 17, 2010 in Physical Review Letters, presented a computer-generated proof that micro black holes must form from two colliding particles with sufficient energy, which might be allowable at the energies of the LHC if additional dimensions are present other than the customary four (three space, one time).
So, it is possible, if spacetime has more dimensions that four!

Black Hole Evaporation

- "Normal" black holes:
  - Mass: $M_{BH} \sim M_{sun}$
  - Size: kilometer
  - Temperature: 0.01 K
  - Lifetime: ~ nearly forever



- Micro black holes:
  - Mass: $M_{BH} \sim 1000\ M_{proton}$
  - Size: 10^{-18} m
  - Temperature: 10^{16} K
  - ***Lifetime: 10^{-27} s***



They explode!

Hawking Radiation

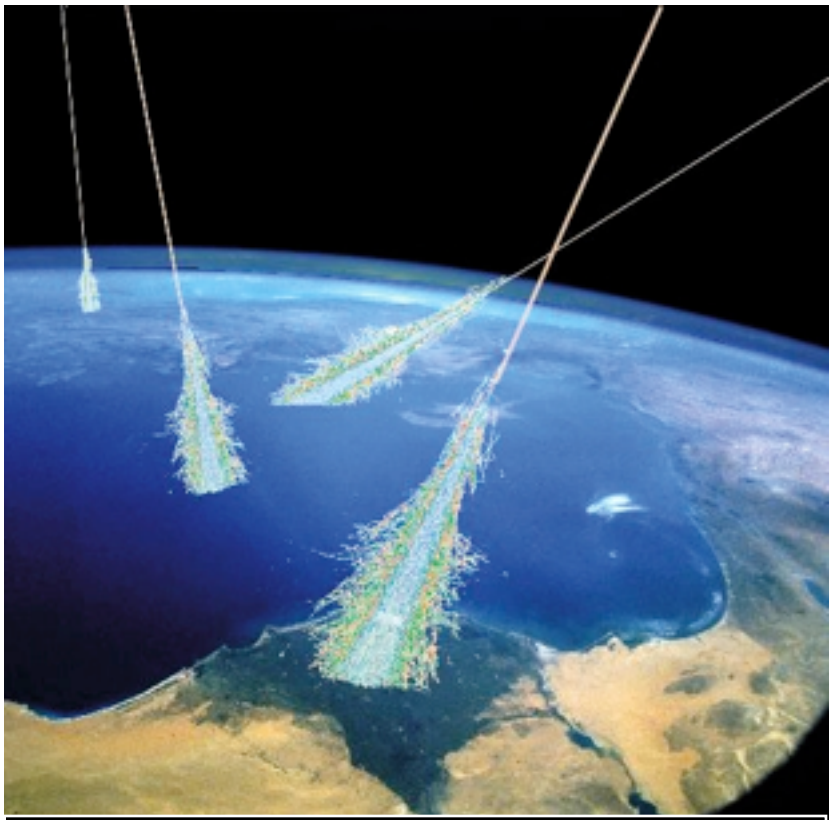
Cosmic rays produce more energetic collisions than the LHC

Cosmic ray collisions have more energy than the LHC and happen every day!

If LHC can produce black holes, so can cosmic rays!

- **Over the lifetime of the Earth, cosmic-ray bombardment amounts to huge number of LCH experiments**
- **But Earth is still here!**

Thus, even if stable micro black holes exist, not dangerous



Cosmic rays hitting Earth's atmosphere

in hypothetical scenarios with stable black holes that could damage Earth, such black holes would have been produced by cosmic rays and would have already destroyed known astronomical objects such as the Earth, Sun, neutron stars, or white dwarfs. Further, microscopic black holes generated from a particle accelerator are very small in size and are expected to have a high velocity, making it impossible for them to accrete a dangerously large amount of mass before leaving the earth for good.

Question

If micro-black holes can be created by CERN, and **if** they do not vaporize instantaneously, why are we still not concerned about them?

a) The chances are just too low.
b) Cosmic rays would also make them, and we are still here.
c) There is only a 50/50 chance.
d) It's in Switzerland, so there isn't much to lose.
e) Even if all true, black holes can only be made in supernovae. And I don't see any massive stars here.

Answer: B.

Answer A is not a bad choice, but what chances is not clear, so B is a better choice.

Mitigation

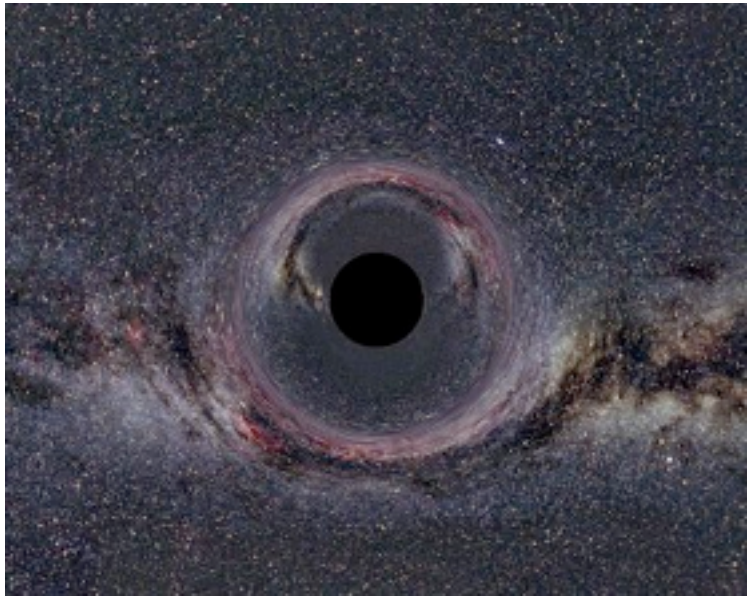
None or very little warning for some objects.

For some objects much more warning.

Try to play general relativity engineer?

Can we predict accurately enough the orbits?

Leave the Solar System.



Imagine

An amateur astronomer trying to see Uranus is the first to notice. It's in the wrong place!

Later, Jupiter is in the wrong place, then Mars!

Even the Sun has moved!

What is happening?! Oh, the Earth has moved.

Panic spreads as scientist realize that a compact object has entered the Solar System and its mass is throwing off the orbits!

Once the orbit was fixed for the object, telescopes looked for the object, but nothing– a black hole!

Imagine

A black hole coming right at us at 500 miles/sec.

As it gets closer tidal effects– floods, earthquakes, and tsunamis.

As the 10 solar mass black hole reaches 7 million miles away, its gravitational pull equals that of Earth, everything on Earth is weightless.

Then, the pull of the black hole is more than Earth.

As the Earth gets shredded, you try to remember what Leslie said about black holes!