Black Holes

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Newtons law of gravitation

Remember Newtons formula of gravitation:

$$F_G = G \cdot \frac{m_1 \cdot m_2}{r^2}$$

Now, let's calculate how much energy you need, to exit the gravitation:

$$E = \int F_G \, ds = \int G \cdot \frac{m_1 \cdot m_2}{r^2} dr = -G \cdot \frac{m_1 \cdot m_2}{r}$$

The Event Horizon

$$E = m \cdot c^2$$

The most famous formula of Einsteins theory of relativity means, that every energy has got a mass.

If you need more energy, to exit the gravitation, than you got through the equation on top, you can not.

When does this case become true?

$$m_2 \cdot c^2 = G \cdot \frac{m_1 \cdot m_2}{r} \quad \Leftrightarrow \quad c^2 = G \cdot \frac{m_1}{r} \quad \Leftrightarrow \quad r = m_1 \cdot \frac{G}{c^2}$$

The radian r is called **event horizon** and propotional to the mass of the object in it.
If the objects are smaller than the event horizon we call it **black hole**.

The Event Horizon

$G = 6.674\ 28(67) \cdot 10^{-11}\ m^3 / (kg\ s^2)$ (CODATA)
$G / c^2 = 7{,}42613(74) \cdot 10^{-28}\ m / kg$

Typical radians of event horizons:

object	**mass**	**event horizon**	**radian**
Proton	$1{,}672 \cdot 10^{-27}$ kg	$1{,}242 \cdot 10^{-54}$ m	$1{,}4 \cdot 10^{-15}$ m
Atom (U)	$3{,}953 \cdot 10^{-25}$ kg	$2{,}936 \cdot 10^{-52}$ m	10^{-10} m
Human	80 kg	$5{,}941 \cdot 10^{-26}$ m	2 m
Moon	$7{,}348 \cdot 10^{22}$ kg	$5{,}483 \cdot 10^{-5}$ m	$1{,}737 \cdot 10^{6}$ m
Earth	$5{,}974 \cdot 10^{24}$ kg	$4{,}436 \cdot 10^{-3}$ m	$6{,}371 \cdot 10^{6}$ m
Sun	$1{,}989 \cdot 10^{30}$ kg	1477 m	$6{,}955 \cdot 10^{8}$ m

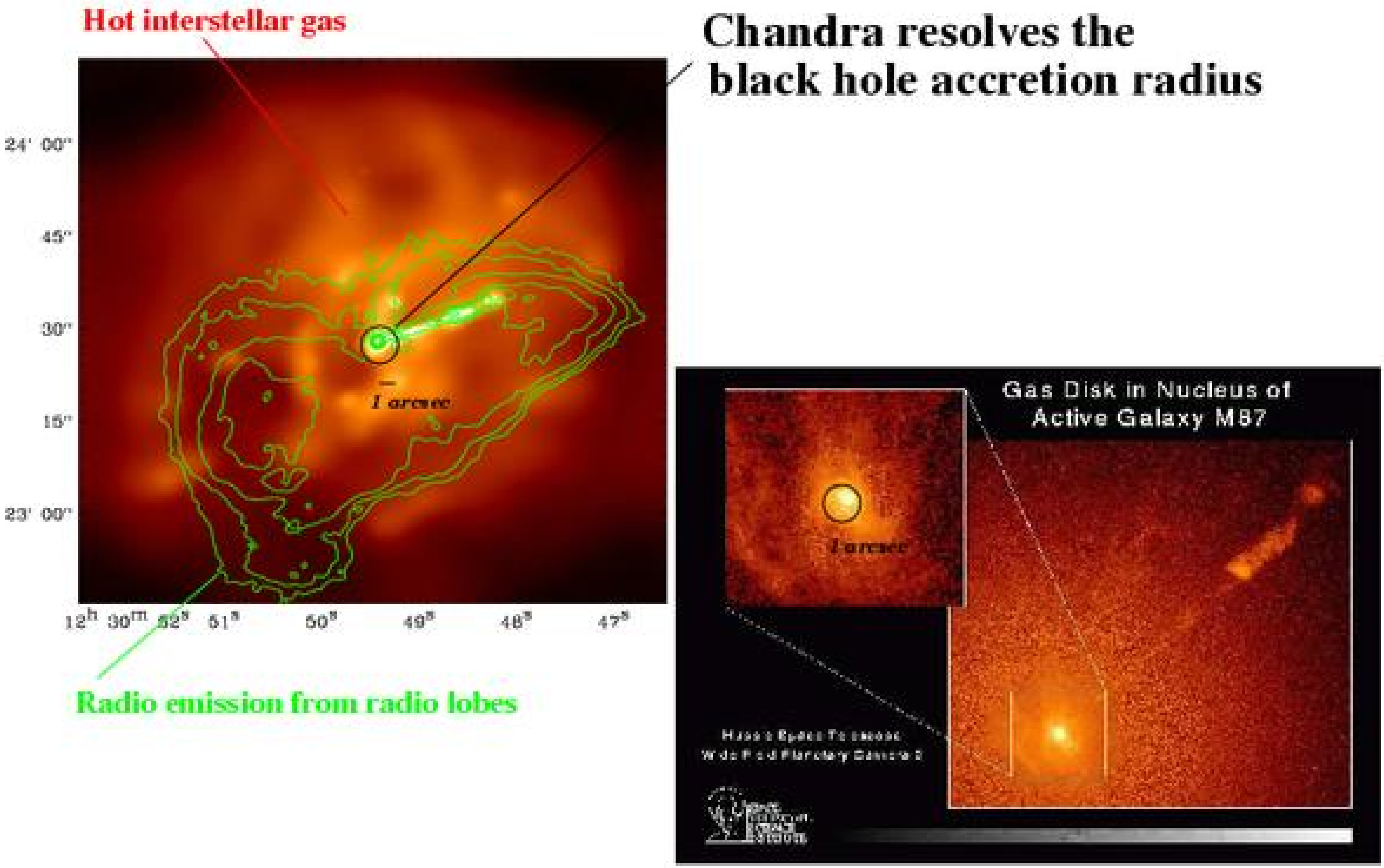
Accretion disks

If something falls into a black hole (the favorite food of black holes are stars, but they will eat everything), the kinetic friction will warm it. So we can see this. We call this scream of death, because it seems sure, it falls into the black hole and never will come back. There're many pictures in false colors of this event.

I got someone for you:

You will also see jets. Cause of the magnetic field, some materia is ripped of the accretition disk and accelerated nearly to light speed.

Accretion disks



Time dilation

One consequence of Einsteins relativity is the time dilation in a gravitational field for example the one of a black hole. This means an observer outside of the gravitational field sees all action in it in slow motion.

You get closer to the event horizon => The time passes slower

You are at the event horizon => The time halts

What can we do with this?

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Today: Seq 1 - How to travel i…

What we need:

- A black hole (at clo… quaters)
- A spaceship (fu…

…k hole
…e (in the …ional field)
…areful not to slip into the black hole
4. Get out
5. Watch the future

WARNING !!!

The time traveling is only one way and you will never come back. So be sure, if you really want this !!!

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Today: Seq 2 - How to find a black hole?

The problem:

- We can't see black holes, because the universe is black, too.
- How can we find them?

The solution:

- ➔ Buy a spyglass (a sattelite gamma-detector will work better, but it's very expensive).
- ➔ Watch out for accretition disks. They emit bright gamma radiation.
- ➔ Watch out for jets

Problem:

- ➔ Other objects can look like this, too.

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Today: Seq 2 - How to find a black hole?

The problem:

- We can't see black holes, because the universe is black, too.
- How can we find them?

The ultimative solution:

- ➔ Take serveral pictures
- ➔ Watch out for gravitation lensing

Hawking Radiation

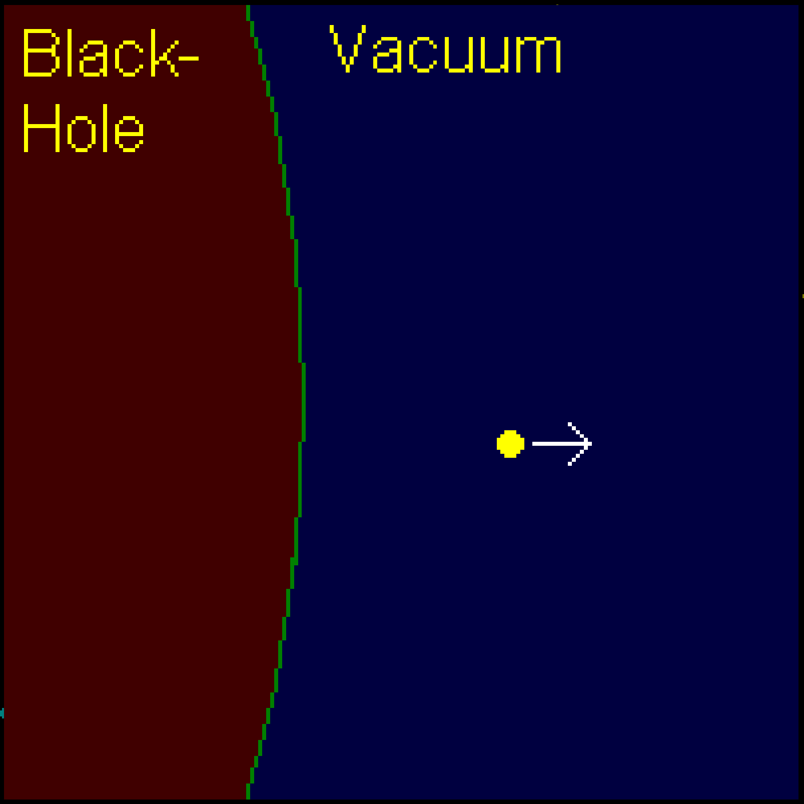
Steven Hawkings was the first one, who forecasted black holes radiating.

Imagine the following:

A new pair of particle and antiparticle is created from vacuum near the event horizon. This can happen for a short time.

One particle falls into the black hole, the other flys away.

Usually the two particles would delete themselve, but now the remainig particle has no partner to delete and can fly away.



Hawking Radiation

As we have radiation, thermodynamics allows us to assign a temperature to the black hole. It is only dependend on the mass of the black hole:

$$T = \frac{\hbar c^3}{8\pi k G} \cdot \frac{1}{M} = \frac{1{,}227 \cdot 10^{23}\, K\, kg}{M}$$

You see: The smaller the black hole, the higher the temperature and the more radiation.
Maybe you think, if it radiates, it must loose energy and get smaller because of energy conservation and $E=mc^2$.
You are right. Some people calculated when a black hole lost all energy and dissappears:

$$t = c_{onst} \cdot M^3, \quad c_{onst} = 8{,}4 \cdot 10^{23} \frac{s}{kg^3}$$

Hawking Radiation

Let's have a look on our black-hole-objects. What is their temperature and life time?

object	mass	temperature	life time
Proton	$1,672 \cdot 10^{-27}$ kg	$7,339 \cdot 10^{49}$ K	$3,927 \cdot 10^{-57}$ s
Atom (U)	$3,953 \cdot 10^{-25}$ kg	$3,104 \cdot 10^{47}$ K	$5,189 \cdot 10^{-50}$ s
Human	80 kg	$1,534 \cdot 10^{21}$ K	$1,363 \cdot 10^{22}$ Y
Moon	$7,348 \cdot 10^{22}$ kg	1,67 K	$1,056 \cdot 10^{85}$ Y
Earth	$5,974 \cdot 10^{24}$ kg	0,020545 K	$5,599 \cdot 10^{90}$ Y
Sun	$1,989 \cdot 10^{30}$ kg	$6,169 \cdot 10^{-8}$ K	$2,095 \cdot 10^{107}$ Y

Some people think, a black hole with a size of a proton can eat up the whole earth. But if you have a look at the life time, there's no danger.

Entropy

Entropy the the gauge of untidieness and the opposite of information.

John Wheeler, an american theoretical physicist, said: „Black holes have no hair." What does this mean?

A black hole has no information of either mass, electric charge or angular momentum.

A black hole has **<u>no</u>** information of either mass, electric charge or angular momentum.

This means, you can't look inside a black hole, because there's nothing to see. Every structured materia will loose its structue if it falls in one.

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Today: Seq 3 - How to erase hard disks?

The problem:

- A friend calls us the police, FBI, CIA, mafia or George W. Bush in person will arrive in 5 minutes and want's to have the data on our hard disk.

The solution:

Erase all data with a file-shredder program like „Eraser“ or „Tune up shredder“.

Good idea if you do it before, but 5 minutes is not enough.

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The better solution:

Burn up the hard disk, shredder it with an axe or electromagnet.

Very good idea, it should help in most practical cases, but what if you want to erase it theoretically.
So that no one will ever be able to get the data?

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The ultimative solution:

Start your spaceship full of fuel for timetraveling and put the hard disk into a black hole. All structure and all data is lost forever.

If it's Gorge W. Bush you can alternate start internet tv an say, that this is no computer - he will belive it.

Data Sources

Constants: CODATA 2006
Uranmass:
http://www.dsemmler.de/Schule/Hausaufgabenforum/Data/CH_11_Periodensystem.pdf
Moondata: http://en.wikipedia.org/wiki/Moon
Earthdata: http://en.wikipedia.org/wiki/Earth
Sundata: http://en.wikipedia.org/wiki/Sun
Gravitation time dilation formula:
http://www.quantenwiki.de/Gravitationspotenzial_der_Sonne#gravitative_Zeitdilatation
Temperature and life time formula and constants:
http://de.wikipedia.org/wiki/Schwarze_L%C3%B6cher#Entropie_und_Temperatur
http://en.wikipedia.org/wiki/Black_Holes
http://de.wikipedia.org/wiki/Zeitdilatation#Zeitdilatation_durch_Gravitation
Prof. Metags Exphy-Script

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