

Black Holes – You’ll never hear what sounds are inside.

One of my interests to attend the ASL-Workshop in Irbene was the availability of a radiotelescope that could be used for scientific work which meant that it could be used to gather data of diverse deep space phenomena. My general interest on black holes was motivated by a very personal research since 1998 on Black Holes On The Internet (BHOTI) which is still ongoing. By definition everything that enters a black hole can not escape, a circumstance that did catch my attention as someone who “practices art”. The following text will explain in short what a black hole is – there are many books¹ out there which are much more detailed – and how it can be detected.

How one might imagine a black hole

A Black Hole is a group of events, which You can escape not to far. That’s a very formal definition. Instead of saying that the black hole is a space or a object it is rather understood as a group of events which is maybe not so easy to read but a relative precise term. One can not escape far from this group of events? To understand this one should get a picture how a black hole comes into existence – according to theory. Still nobody has visited and experienced this phenomena. Scientists believe, they have found some events that could be black holes, but they are far out of reach of spaceshuttles.

First of all lets direct attention to the question what a *star* is. For instance our sun. It consists of different gases that are in an ongoing process of nuclear fusion, which produces light, heat and Helium. During that process the star is in a stable balance of the produced heat and the gravitational powers that forces into the star centers direction. After a while the Hydrogen and other atomar fuel is burned out. Our Sun still has 5 Million years of fuel, so don’t worry.

The star begins to cool down.

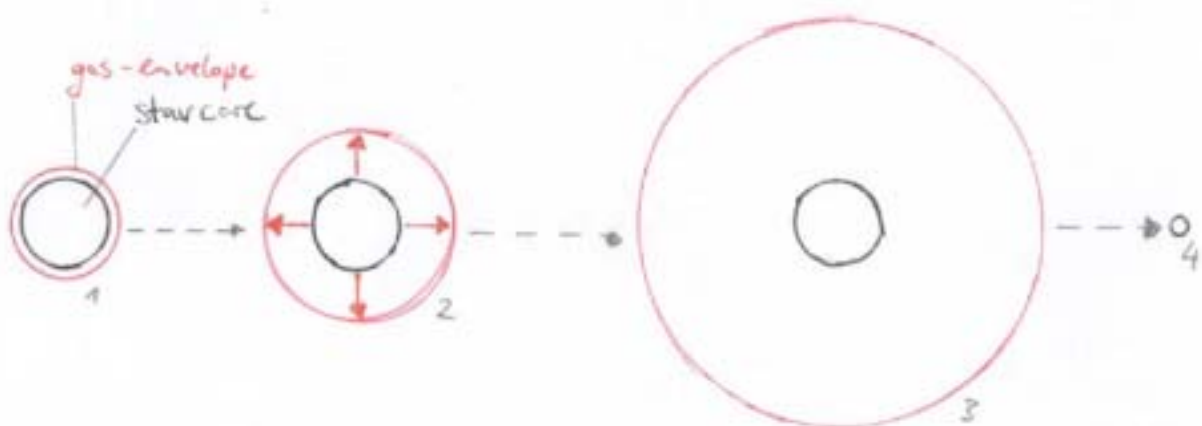


figure one: 1.) star with less than three sunmasses, 2.) Heliumcore with expanding gas-mantle, 3.) "Überriese", 4.) neutron star

¹ see "The Universe in a nutshell" by Stephen Hawking, or "The Elegant Universe" by Brian Greene

If the star has more than three sunmasses, the balance between the gravitational powers and the own materia can not be kept, which causes the star to collapse. That means that a region with a extremely density emerges. (Note: our sun has less than three sunmasses, so it will not become a black hole but a *white dwarf*)

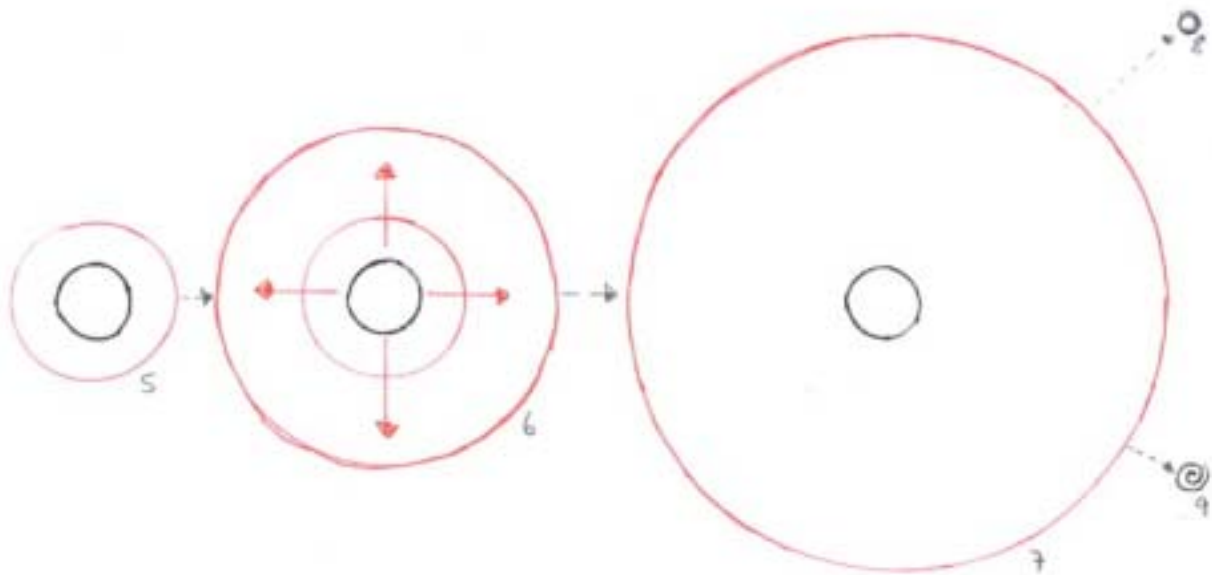


figure two: 5.) star with more than three sunmasses, 6.) Heliumcore with expanding gas-mantle, 7.) "Überriese" 8.) neutron star, 9.) black hole

The huge gravitational powers destroy all materia of the former star. These gravitational powers are so heavy, that even light can not escape. Nothing is faster than light (which spreads at ligh-tspeed), nothing can escape a black hole. The radius, where light-rays tries to but can't escape, is called event-horizon. That's why the black hole is black which means we cannot see into a black hole, and as well not hear the sounds that are inside (I imagine some constant low frequency rumble anyway).

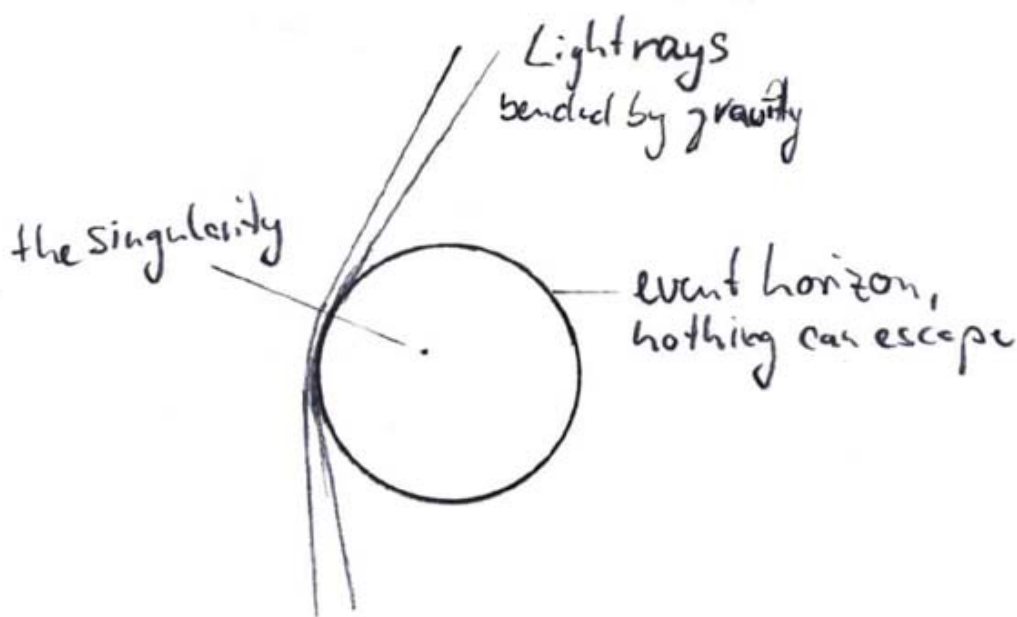


figure three: event-horizon, light-rays, singularity

If an Astronaut would fall into he couldn't communicate, because radio-waves are slower than lightwaves and thus cant escape. Besides that, the huge gravitational power just part the astronaut into atoms or whatever. The event-horizon functions as an membrane, things that fall into it, can not leave. Their mass is added to the black holes mass.

Is there something in this black hole? That's not resolved by now. One should keep on thinking of black holes as an mathematical an physical model. Anyway, there is something in the center of the black hole, that is called singularity. From the extreme gravitational pressure at the center follows that all mass is concentrated on a volume of zero. This affects the space-time to be bend into infinite. What's so fascinating about black holes is that they add up so much extreme phenomena, the singularity is one of them.

Beside the fact that it is not known, what' inside of them, it is possible to measure two qualities that is the black holes mass and direction of rotation – nothing else can be measured (from outside). When You see pictures of black holes, that show an accreditation-desk then these are caused by the massive gravitational powers that “suck” materia to the event horizon. Another ‘visible’ effect can be a jet, which is a stream of plasma that emerges from the event-horizon. It is in the discussion among scientist, how this effect comes into being in detail.

Maybe that's enough by now demonstrate why a Black Hole is called a group of events, which You can escape not to far.

How to detect Black Holes in astrophysics

When I entered Irbene-site and saw the telescope my heart jumped when realizing that it would be possible to access this extreme powerful tool. Of course this was a moment of great impression and great naivety. As I had to find out soon – and I should have known this before, because I had already read some literature – the Irbene Telescope was not able to provide me with data of a black hole that I could burn to CD-ROM and show around later among my friends. In general there are several ways to detect black holes, I'll list the most common of them here.

Lets remember a few facts. A black hole has a rate of rotation and a weight. That's the only qualities it has. The rotation and it's weight compressed on a small volume cause a very high gravitation that sucks materia beyond the event-horizon. It cannot be seen. It was never measured. A black hole itself remains invisible.

Instead one can obtain everything that is attracted by a black hole. Also background-radiation which in our perception seems to be bend can indicate a black hole that is in-between us and another source of radiation.

Lets dive into details.

a) gravitational radiation / interferometer

As described above black holes are regions with huge gravitational powers that bend time and space. When two black holes spiral together, which is called a binary system, the bigger will absorb the smaller one soon or later. The merging of both would cause a huge amount of called gravitational waves. A good way to imagine such a gravitational wave is to think of stone dropped into silent water and understand the ripples as waves in the space-time-continuum.



image: the 90 degree tunnels photographed from a airplane. source: http://www.geo600.uni-hannover.de/geo600/site/photos/Sep_97/Luftb3.gif

Five interferometers were built in Italy, USA and Japan since the 80s to detect these gravitational waves, one of them was finished in 2002 near Hannover in Germany. An interferometer consists of long evacuated pipes, 3 to 5 km long that are positioned 90 degree each to the other. Laser beams are directed through these vacuum-pipes, so if a gravitational wave would pass through it would change the amount of time the laser usually needs to travel through the relatively long pipe. If all five interferometers in the world perceive a change at the same time, this could indicate collisions of black holes or neutron star collisions.



image: evacuated pipe, source: http://www.geo600.uni-hannover.de/geo600/site/photos/Summer_97/tubeintrench.jpg

b) gravity lens / optical-telescope

Einstein's *General Theory of Relativity* says that gravity bends the space. Therefore, an object with a huge gravity (e.g., galaxy, black hole) between the Earth and a distant star system would bend the light that comes from the distant galaxy. A lens effect named MACHO-96-BLG5 was for instance observed with the Hubble telescope when watching the region. The object that might have caused this lens-effect was invisible so it's most likely that it was a black hole on its way passing through the objects in the background and our star-system.

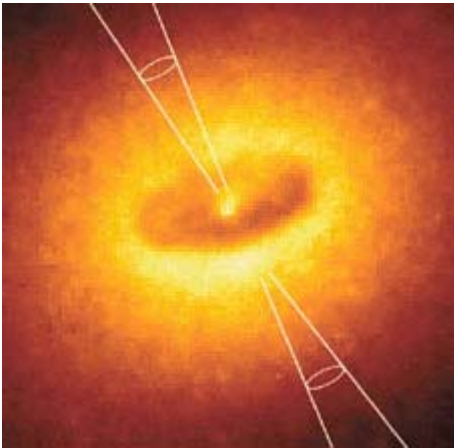


image source:<http://oposite.stsci.edu/pubinfo/pr/2000/03/>

c) supermassive black holes in the center of galaxy / radio-telescope

Most of the black holes are surrounded by materia that is other stars, planets and so on. So if one is looking for a black hole, it is necessary to look for materia that is spinning around a center and thus forms a disk, without that the center can be seen. When observing how these surrounding materia behaves and especially looking at the way it moves around of what is expected to be a black hole, it is possible to estimate the mass of what is in the center. If this mass is more then three times of the sun, than it's most likely a black hole.

One of the well known examples is to be found in the center of the galaxy NGC 4261. There is a region about the size of our solar system that is rotating and thus forms a spiral. The same time this region is super heavy – it has a weight of 1.2 billion times the sun. The only phenomenon that can cover this extreme quantities by now is a black hole.



NGC 4261 WFPC with illustration of jet. image source:
<http://oposite.stsci.edu/pubinfo/pr/1998/14/content/n4261lines.jpg>

Indication of a supermassive black hole that is situated within the center of the galaxy may be also given through a jet that is emitted. A jet is a compressed beam of plasma that emerges with a high speed from the event-horizon and is fed by the surrounding accretion disk. The jet can even reach outside of its own galaxy. Beside other forms of radiation that we can not perceive with radio-telescopes the jet also emits so called synchrotron radiation that is electrons moving near the speed of light and thus cause strong radiation receivable be terrestrial radio-telescopes.

One example for this variant is the core of the galaxy M-87. Although this region is just the size of our solar system its weight is 3 billion times the sun. On the image (which is composed by analyzing and computing the data of emitted radiation) one can see a jet starting at the small red point that emits synchrotron radiation an reaches about 6500 light years out of the region that is expected to be a black hole.

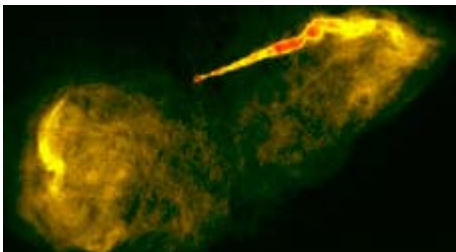


image source:<http://oposite.stsci.edu/pubinfo/pr/1999/43/>

What can radio-telescopes 'see'?

Well... radio-telescopes are blind. But they have a brilliant ear that can hear radio-waves the human ear would never perceive. While human listen radio waves in the range of 20 to 20.000 Hertz, a radio-telescope can receive a white range of frequencies from 1 to 40 Gigahertz. A change in the intensity of radio waves is marked by a change in the voltage at the output of the radio astronomy receiver.

This amount of voltage is combined with the time an the position to which the radio-telescope points to be saved in a data-file by a computer. One can produce nice schemes from that as this one:

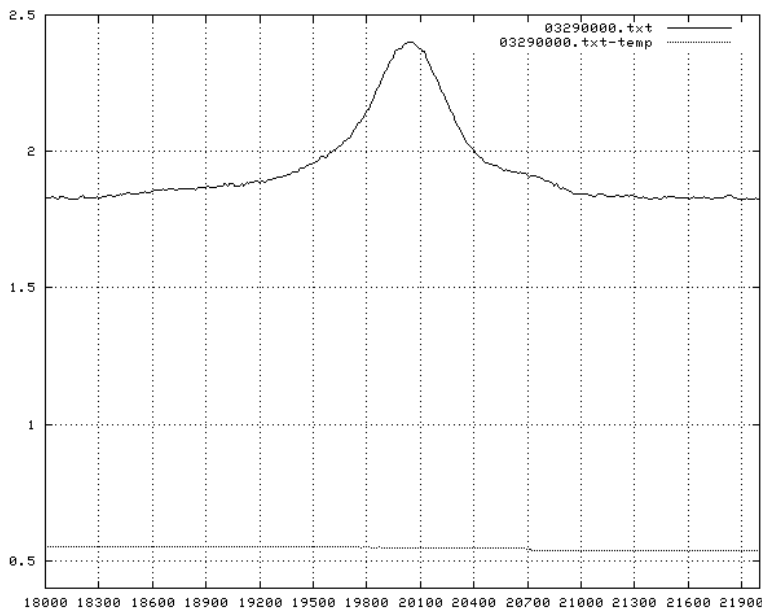


image: Scheme of an observation of Sagittarius A. The black hole at the center of our galaxy, source: <http://radio.uindy.edu/saga.gif>

On the bottom of this graph (x-coordinate) is printed the time in second. The example starts at 18000 seconds that is 5 hours after starting the observation. After 1900 seconds (ca 31 minutes) the voltage that can be read on the y-coordinate rises from 1.8 volts to 2.4. That raise is caused by the increase of radiation in a 35 GHz-wide spectrum (in the C-band) that the telescope had perceived. In the top right corner one finds the date of observation that is March 29th 2000. One source of information which radiation can be received from a certain position is the astronomical database of radio, x-ray and gamma ray sources called the Vizier-database². So the astronomers can compare what exactly was the source of radiation, which is in this example Sagittarius A which is taken from the 5-Meter Dish of the "Institute of Radio Astronomy at the University of Indianapolis"

Now one realizes that the colorful images are constructed on a computer by summarizing the single data as it is represented by the graph above. Often the data is gathered from several telescopes on earth, that coordinate their observations. So it becomes clear that I was really naïve when expecting I could get images of black holes from the VIRAC³ in Irbene. The Irbene-Telescope can easily gather data from sun or other planets of our galaxy, but to catch rich and comprehensive data from a black hole cooperation with other astronomers is necessary.

If I would have known that before, I'd never gone to Irbene. Oh, that's of course a lie. Then I never would have met all those people who came together that summer. And especially I would have never met Rasa, Raitis and Derek who organized this outstanding experience – Thank You! And if anyone has hints to Black Holes On The Internet, please let me know.

(francis hunger)

² <http://adc.gsfc.nasa.gov/vizier/>

³ <http://www.astr.lu.lv/VIRAC/virac.htm>