

## The Dark Spell of a Blackhole

A blackhole is by far the most fascinating object for most. Let see what a blackhole is.

If you wish to put something in an orbit around Earth, you need to push it away (launch) with a certain velocity. This velocity, escape velocity, is 7 miles/sec. It is determined by the mass of the Earth and its radius. If you compress the mass in a small radius, or increase the mass, the escape velocity will be higher. The escape velocity from Jupiter is ~37 miles/sec. From the sun its higher still. If you were to compress the sun's mass in a really really tiny sphere (for its mass), the escape velocity will exceed the velocity of light. What that means is that not even light could escape it. And since the velocity of light (186000 miles/sec) is the highest there can be, nothing can escape such a body. We have made a blackhole!



Artist's conception of a stellar blackhole stripping gas from a neighboring star and in the process resulting in observable X-rays from the heated gas.

<http://www.msnbc.msn.com/id/21546006/>

Can we really compress the sun to such a small sphere? We almost can. Let us first see why the sun shines and why it stays the size it is. It shines because the Hydrogen inside it is being converted to Helium (and the Helium to higher elements). These fusion processes are what produce the heat and light. This radiation being generated in the innards of the sun also has pressure. This pressure keeps the outer layers of the sun from falling towards the center. Think of the sun's material as being made of layers like that of an onion. The outermost layer feels the gravitational pull of all the inner layers. But for the outward radiation pressure, it would collapse inside. But once the fuel burns out and the fusion processes cannot be supported by existing conditions (density, temperature etc.) the radiation pressure vanishes, and the outer layers do fall inside. A star the mass of sun becomes a white dwarf and compresses to the size of Earth. Why does it not compress further? Another outward pressure takes over. This pressure is called the degeneracy pressure. The electrons in the atoms are Fermions. What that means is that two electrons cannot occupy the same energy level. If you try to squeeze them, they resist and this builds up pressure. But if the mass of the star is over ~1.4 solar masses (i.e. 1.4 times the mass of the sun), this squeeze from outside overwhelms the electrons until they cannot resist anymore. They give in and combine with protons to form neutrons and we get a big hulk of neutrons. The sun would be a ball of only 6 km diameter if it were to become a neutron star, and the entire process would take just about an hour. But why does it stop there? Because, like electrons, neutrons are Fermions too, and the same rules apply, except that neutrons are more vehement about pushing back and can hold out against a bit more mass (gravitational force). But only so much. If the collapsing star (technically called a progenitor) is over 4 solar masses THEN we get a complete collapse and the star becomes a blackhole, vanishing into oblivion (for all visible purposes). This is how stellar sized blackholes are made. These can then feed on surrounding matter getting more massive and more influential. The radius around the center from which nothing escapes is called the Swarzschild radius.

Are these the only kinds of blackholes? By no means. We know two other types. At the centers of globular clusters (clusters of several 100000 stars within larger galaxies like the Milky Way galaxy) lurk blackholes with thousands to tens of thousands of solar masses. At the centers of big galaxies are even more massive blackholes, measuring hundreds of thousands to billions of solar masses. It is these that are often in the news generally due to the large masses and energetic jets that are involved.

Theoretically it is possible for much smaller blackholes to exist too. Though nothing escapes blackholes, they do emit a radiation, called Hawking radiation. This output is inversely proportional to the mass of the blackhole. For large blackholes, this energy output is much smaller than what they get from the surrounding medium (which is very cold, but not even the intergalactic space is at absolute zero. You can hear this "temperature" in the form of noise when you tune your radio or television between two stations. This is a relic left behind by the big bang). So larger blackholes suck energy, matter from outside and get more massive. Smaller blackholes (and we are talking about a fraction of a mm here) will, on the other hand, radiate more energy, thereby lose mass, radiate even more energy, and very quickly vanish in a puff of intense radiation.

New research continues to happen and at this frontier for some of the details there exist many competing alternatives and often more questions than answers. Do blackholes have observationally measurable properties? Most such bodies start life as certain equations. It is solutions to these equations that suggest what type of observation properties one is likely to encounter. The widely accepted theories suggest that there are three such properties: mass, charge and angular momentum. What happens, for instance, to the information that went into a blackhole? Barring the three properties above, we seem to lose track of what it is that went inside. There are fundamental laws that state that the format of information can change, but it cannot be destroyed. This issue will also be resolved one day. What we know for sure, if only from indirect observations, is that blackholes do exist and they do affect their surroundings.

What are these observations? Though the gravitational force of a blackhole inside the Swarzschild radius is total, outside it is not different from the gravitational pull of another body of an equivalent mass. But when a massive blackhole is what we have at hand, this force is tremendous, pulling surrounding material with a great speed. The friction and collisions during this accretion process leads to the emission of x-rays (and other radiation) which can be seen from far off. That is how we know of the existence of blackholes.

Blackholes will continue to fascinate people in different ways. Larry Niven even wrote sci-fi titled "How to commit murder using a mini-black hole". Who says science is not useful?

Accretion on to a galaxy blackhole leads to an X-ray jet. Shown here is a Chandra image of the system called 3C321. Here a jet from a galaxy is seen to zap another galaxy.  
[http://www.nasa.gov/mission\\_pages/chandra/news/07-139.html](http://www.nasa.gov/mission_pages/chandra/news/07-139.html)



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