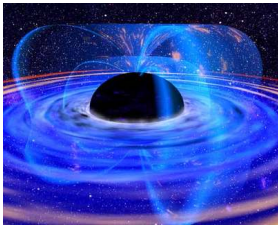


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Black holes



The stars evolve. They are born, they live, they age, they die. The stars come in different sizes and with different masses. They are burning their nuclear fuel, which are the atomic cores – from hydrogen to iron, stepwise. The reactions involved in burning the fuel release energy, which then creates radiation pressure. The star lives by balancing radiation pressure from within outwards and the gravitational pull inwards toward the center of the star. When the fuel is depleted, the production of the radiation pressure goes drastically down, so that we more or less only have the gravitational pull left. The result of this is the implosion of the star. When this happens, some of the star's material is blown or thrown away, while the star remnant can have a rather “tragic” ending of its life.

If the mass of the remnant object is significant (above 3 solar masses), the implosion of the star continues – the gravity is too strong for anything to counter it. The result is a creation of a *black hole*

– a singularity, an object of viciously strong gravity and extremely small size that neither objects with mass or any light can escape its gravitational pull. Hence the name

black –

no light is emitted from the object, so

o it is hidden from our sight.

We can study two types of black holes - *supermassive black holes* and *galactic black holes*. The first ones are found in the centers of the galaxies and weight between 1 million and 1 billion solar masses. Galactic black holes, on the other hand, are far from that heavy, and are often found in binary systems in our own galaxy, making them interesting and tempting to study.

We can “see” black holes!

But how do we know about their existence besides the proof of their existence from the theoretical calculations, if we can not observe them directly?

We can neither directly see the wind in the air. But we are more than certain that the wind is there, as we can feel it or observe its influence on its surroundings. We can feel the wind on our skin when walking on a sunny, but windy day. We can see the trees swinging back and forward when the wind is present, or the newspaper flying and “jumping” up and down on a street.

The same is for the black holes. Its presence can be discovered by looking at its surroundings – how they are effected by it.

There is one major effect a black hole (specifically *galactic* ones) can have on its surroundings: creation of an *accretion disk* around itself made out of the material from an orbiting star in its vicinity.

A deadly dance



the energy spectrum, the iron line feature is a prominent feature in the energy spectrum of the black hole.

α line). The line which is then created is mainly due to the iron material in the accretion disk. The vicinity of the black hole gives rise to relativistic effects which then distort the look of the iron line feature in the energy spectra. The line slightly moves from its place it would usually have if the black hole was not present and it also gets broadened. Effects involved are

Doppler boosting

and shift

and

gravitational redshifting

. They depend highly on the mass of the black hole, its spin and on the geometrical shape of the accretion disk. So, the broadening contains information about the parameters of the accretion disk and the properties of the black hole itself. For example, the iron line is broader if the black hole is rotating, since the closest orbit around the black hole is closer to the rotating black holes than to non-rotating ones – so the velocities are higher, the gravitational redshifting higher, etc.

There is a lot of room for the interpretation of the iron line emission feature in the energy spectrum. It is strongly dependent on the structure and the shape, shortly - the *geometry* of the accretion disk and the accretion flow. We ask questions such as

where do the highest energetic X-rays

come from (the hot plasma in vicinity of the disk or a radio jet),

what is the geometry of the disk

(thin or thick structure) and

what is the ionization structure of the disk

.

Interpretation is mainly done by analyzing the data: comparing theoretical models with the data acquired from the Earth-orbiting X-ray observatories - XMM-Newton, Chandra and Suzaku. The analysis provides us with the parameters describing both the black hole and the accretion disk (i.e. spin, geometry, inclination, energy of the line, etc.). Extending the theoretical models to different accretion geometries will provide even more accurate parameter values, and give us

better understanding of the reality of these interesting objects.

[illegible]

X-ray observatories: XMM-Newton and Chandra.

1: $1\text{eV} = 1.602\text{E-}19 \text{ Joules}$