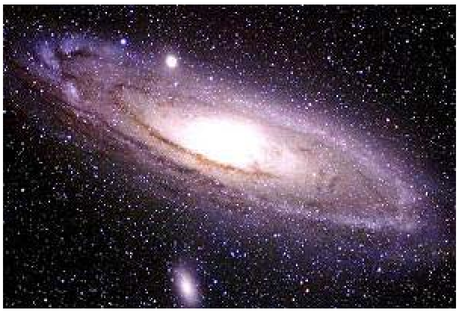
Black Hole Mystery at the Center of the Andromeda Galaxy



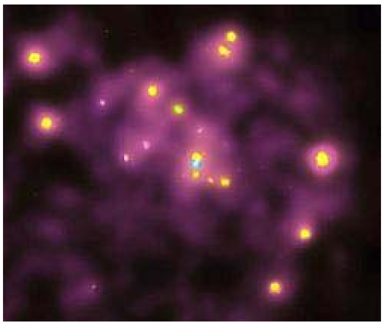
Two million light years away from our own Milky Way galaxy is the Andromeda galaxy photographed here. It is a spiral shape like the Milky Way galaxy and can be faintly seen with the naked eye in the northern sky. Photo courtesy NASA.

"Chandra's x-ray image of the cool temperatures in the black hole at the center of the Andromeda galaxy kind of flies in the face of what we think happens when matter falls into a black hole. It usually gets very hot.So, this is sort of a unique observation. I'm not aware of any other black hole systems where you see such cool x-ray radiation."

- Eliot Quataert, Ph.D., Astrophysicist -

January 28, 2000 Princeton, New Jersey - Observing x-ray and gamma ray emissions suggestive of a black hole at the center of many galaxies is old hat these days for astrophysicists. Our own Milky Way galaxy seems to have one and so does its nearby twin, the Andromeda galaxy. The suspected black hole at the center of the Milky Way is two and a half times more massive than our sun. But a black hole candidate at the center of Andromeda is 30 million times more massive than our sun.

One of the signatures of a black hole should be intense emissions of x-rays and gamma rays as matter and gases are drawn into the black hole, heating up to very high temperatures which can also be seen and measured. When NASA's Chandra X-ray Observatory took its first x-ray picture of Andromeda on October 13, 1999, there were more than 100 individual X-ray sources at the center. And one was located precisely at the galactic center where the black hole is thought to be.



This is a color coded Chandra X-ray picture of the Andromeda galaxy's central region. The yellow objects are stars, most likely binaries or double suns. The blue color at the center indicates temperatures cooler than the surrounding stars which surprised astrophysicists who expected to see very hot temperatures. Photo courtesy NASA.

The temperature data provided by Chandra's spectrometer showed the area where gasses and matter should be flowing into the black hole - the accretion disk - was only one million degrees. That's very cool compared to other black hole accretion disk temperatures. In fact, matter does not even register on an X-ray telescope until its temperature reaches about one million degrees. And the yellow suns in the Chandra X-ray image are ten million degrees. "The Chandra observation is telling us that an entirely different flow pattern could be operating around the Andromeda black hole. This could require a different class of models than we usually consider."

Interview:

Eliot Quataert, Ph.D., Astrophysicist, Institute for Advanced Study, Princeton, New Jersey: "How can black holes that suck in all matter and light around them co-exist with stars at the center of galaxies?

It's not really accurate to say that black holes suck in all matter and light around them. For example, when you're far away from a black hole, the gravitational force that the black hole pulls on something is pretty much the same as anything else that had the same mass as the black hole. So, it's only when you get real close to it where one starts to talk about how nothing can escape the black hole, even light can't get out. Where we are in the Milky Way on earth, there is no danger of our being sucked into the black hole at the center of our galaxy. That won't happen in the whole life time of the universe.

No chance that our sun and solar system couuld be sucked into that black hole?

Right.

What about the black hole in the constellation Cygnus near our solar system's position in the Milky Way Galaxy?

It's called Cygnus X-1 and it was, I think, the first x-ray source to be discussed as a probable black hole.

So that would be an example of a black hole out in the arms of a spiral galaxy and not in the center?

Right. This is also much smaller. This is a ten solar mass black hole, not millions. So, this is quite different and formed by stellar evolution. You have a really massive star that burns, goes through nuclear fusion, uses up all of the available nuclear fuel and runs out of any source of heat to support itself against gravity. Then at the end of its life if there is enough mass, the end state of the star is that it will collapse into a black hole.

The black hole in Andromeda is 30 million times more massive than our sun. What would be the minimum distance from that black hole from which matter and light would be pulled in?

There's kind of a characteristic distance that determines where the force of the black hole becomes more important than the force of the rest of the matter in the galaxy and that is roughly a light year for the Andromeda Galaxy.

Everything within one light year of that black hole at the center of the Andromeda Galaxy is being sucked into that black hole?

No, that's where the force of the black hole is more important. You can actually have a star that is perfectly happy even closer to the black hole than that on an orbit. It goes around and around the black hole.

You can have a star with planets orbiting around it within a light year of a black hole that is 30 times as massive as our sun and still orbit around without being sucked into it?

Yes. I don't know about the planet part, but in principle, yes.

Because masses can balance out each other?

Right. Just like the earth revolving around the sun is in a stable orbit where it's the force of gravity that causes the earth to go around the sun. If you put a star not to close to a black hole, you can get a similar orbit where the star is going happily around the black hole.

At about one light year. (5,878 trillion miles, the distance that light reaches traveling in a vacuum for a period of one year at 186,000 miles/second.)

Yes.

In between that star at one light year and the center of the black hole, what would be happening?

There probably would be a lot of gas swirling into the black hole, heating up as it goes in and emitting a lot of (X-ray and gamma) radiation. The surface of a black hole where matter and light begin to be drawn in is called the Event Horizon. And this is the radius where the force of gravity is stronger, so strong that everything that is at that radius gets pulled into the black hole. The event horizon at the Andromeda black hole is estimated to be comparable to the distance between the earth and the sun. Roughly an astronomical unit (A. U.). So, that's the distance at which the force of gravity is incredibly strong at the Andromeda black hole. But if you go much, much farther away from the black hole than that - for instance, a light year, then the force felt by an object is pretty much the same as if you replaced a black hole with anything else that had a comparable mass. So a black hole is not going to eventually suck everything up in the galaxy around it.

Which I think is a popular conception.

Yes, I think that is. I agree.

This explains how it is ossible for you and other astrophysicists to keep finding more and more black holes.

All over.

Black holes can live in harmony and balance with the rest of the matter universe.

Yes.

Which comes first, black holes or matter? There are white hole theories in which white hole matter comes from another universe or dimension through black holes and creates this universe and the initial big bang.

No, I don't think so. But this is very poorly understood how super massive black holes at the center of galaxies are formed. It's not well understood. It probably has something to do with how galaxies are formed in the early universe billions of years ago before you have much in the way of galaxies and stars. That's when it's believed that these massive black holes formed.

What is your personal opinion about whether the black holes come first and then quasars, or quasars come first?

Quasars are black holes, or are believed to be the accretion of matter into black holes. So, I guess my belief is that probably quasars and black holes formed about the time that galaxies formed.

You're saying that a quasar in your definition now is a primordial black hole in which there is a tremendous amount of matter swirling into it?

Yes.

The matter is swirling into the black hole causing these enormous radiations of energy observed in quasars?

Exactly. As it swirls in, it heats up. And as it heats up and things get hotter, they emit a lot of radiation.

If matter is going into the black hole, how could that contribute to the creation of a galaxy?

No, it doesn't contribute to the creation of a galaxy, but it probably happens at about the same time that the galaxy is forming. So, you probably have early in the universe several things happening. You start off with a big cloud of gas and some of that gas goes to the center of the cloud and gets really dense and forms a black hole. Some of it forms stars. So you have at the same time the formation of a black hole at the center and stars around it. But this is not well understood. These are topics on which observations are just becoming relevant, so it's very hard to say what is going on.

So you have the big bang and whatever is happening in that gigantic energy and light explosion, are black holes created first before galaxies?

No. You have the Big Bang and you wait a very long time before you have any structure of any kind. For a long time, you just have a smooth distribution of uniform gas. Then slowly at a later time - maybe a billion years later - you start to form stars, black holes. One of the outstanding questions is: were the first things that formed stars or black holes and that's not understood. My guess is stars because it's easier to form stars than black holes.

Why would there be a black hole after the formation of stars?

The general idea is that when you start to have lots of gas and stars at the center of the galaxy which is fairly natural in any way of forming a galaxy, then the density of the gas, how much gas there is, starts to get larger and larger at the center. Eventually, it leads to a runaway situation in which there is so much matter at the center of the galaxy that the force of gravity becomes more important than anything else. And that's when the gas and matter collapse to form a black hole.

Would that mean that every single galaxy in this universe has a black hole at the center?

I think that's a reasonable hypothesis - yes. From the observations of galaxies pretty close to us, it does seem that the majority have black holes.

What happens to all that matter at that accretion event horizon? Where does it all go?

(laughs) That's a good question. There isn't really a good answer to that in the physical theories such as General Relativity and its theory of gravity. It says that all the matter goes to a kind of point at the center, but that's not a very satisfactory answer. The problem is there isn't really a theory of physics that can describe what happens to the matter that gets to the center of the black hole. This is where General Relativity, which is the theory of gravity we have, starts to no longer be valid. And you need some new theory that combines quantum mechanics and gravity. And until that theory comes along, it's essentially impossible to say what happens. The leading hope right now is that String Theory can reconcile quantum mechanics and gravity which is what you need to do if you want to understand what's happening at the center of a black hole.

What is your own particular passion in all this?

I'm particularly interested in what happens to matter when it falls into a black hole. What can we tell from the radiation that we see from the vicinity of what we think is a black hole? What can we tell about what's going on?

What do you think is happening?

The general picture is that if you look at the center of a lot of galaxies, you see a lot of emission, high energy emissions, x-rays, gamma rays, and this is generally believed to be due to matter that is swirling into the black hole. It's heating up and when it gets hot, it emits a lot of radiation.

Even though it's emitting tremendous amounts of x-rays and gamma rays, it is not emitting light because the photons cannot escape the black hole.

This radiation we're talking about is not coming from the black hole itself which is a singularity in space/time. It's coming from the gas that falls into the black hole. The black hole itself essentially doesn't emit any radiation.

Why would the black hole at the center of Andromeda be cooler than the surrounding stars?

That's a very good question. Chandra's x-ray image of the cool temperatures in the black hole at the center of the Andromeda galaxy kind of flies in the face of what we think happens when matter falls into a black hole. It usually gets very hot. So, this is sort of a unique observation. I'm not aware of any other black hole systems where you see such cool x-ray radiation. Now we have to keep working on mathematical models for how the gas might be falling into the black hole and see if we can come up with one that matches the observed Chandra data.

Andromeda could be unique?

Yes, but it would be surprising if it were unique because there's not anything obviously special about it. There's nothing clearly different that would say that this black hole should look different than others.

Since Andromeda and Milky Way seem to resemble each other, assuming they are pretty much similar, does that mean the black hole at the center of the Milky Way Galaxy should also be cooler?

Chandra has also observed the black hole at the center of our galaxy and it does not appear to be this cool. There are other differences: the black hole at the center of our galaxy is about ten times less massive, about 2.5 solar masses, and has quite a bit less energy emission.

So basically there is an overall picture here that whether it is at the beginning of the universe or now that any matter that condenses on itself strongly enough is going to create a black hole?

Yes, if there are no other forces to support it. Exactly. So our sun doesn't because it has pressure from matter supported against gravity, so it doesn't collapse. Eventually our sun will probably become a white dwarf. If you take a star that's, say, ten times more massive than the sun or twenty times more massive than the sun, then you will probably end up with a neutron star. And if you take something that is 30 or 100 times more massive than the sun, then you'll probably end up with a black hole. That's the thinking.

The brown dwarf, how does that come about?

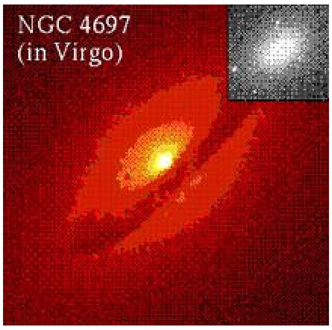
That's probably from the formation of stars. If you form something with not enough mass, less than a tenth of a solar mass, then you don't get hot enough to undergo nuclear fusion which is kind of the defining characteristic of a star.

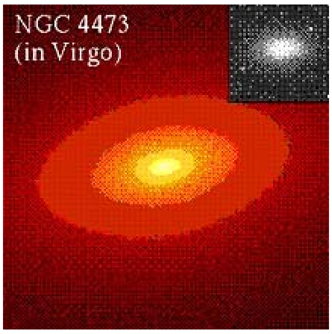
Brown dwarfs are suns that did not ignite, then?

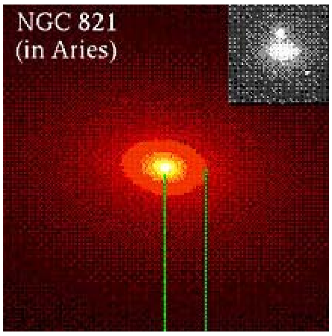
Yes. It's something that didn't become a star."

More Information:

At the recent American Astronomical Society meeting in Atlanta, Georgia, Dr. Douglas Richstone of the University of Michigan presented data about three apparent gigantic black holes in Earth's neighborhood. The "supermassive black holes" are in the constellations Virgo and Aries ranging from 50 million to 100 million light years from our planet.







Images from Hubble Space Telescope courtesy
astronomer Douglas Richstone, Ph.D., Univ. of Michigan, Ann Arbor,Michigan.

Each of the black holes is between 50 million and 100 million times the mass of our sun which puts them on a list of only twenty such massive black holes known to exist. Exactly why such massive black holes have been produced in suspected star and galaxy formations is still not known.

Stars that approach closely to the black hole without trespassing into the event horizon are sped up by its powerful gravitational pull. Measuring star speeds near strong x-ray and gamma ray emissions suspected to be the massive black holes helps scientists measure each black hole mass. In Aries NGC821, stars have been measured at 250 kilometers per second, or a half million miles per hour.

Websites:

http://www.astro.lsa.umich.edu

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