Science AMA Series: I'm Michael Tremmel, an astrophysicist studying supermassive black holes and galaxies using computer simulations. I'll be talking about supermassive black holes, their galaxies, and why some may be "wandering" around. AMA!

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April 17, 2023

Abstract

Edit: Thanks everyone for the questions so far! I'll be taking a break, but I will periodically check back throughout the rest of the day and tomorrow as well if there are any more questions! This was fun, thank you! I am a postdoctoral fellow at the Yale Center for Astronomy and Astrophysics. My research involves using large computer simulations to model the growth and evolution of galaxies and their supermassive black holes. My recent work, where we predict that massive galaxies like our own should host several "wandering" supermassive black holes, has recently been the subject of a press release. Given that this work has generated some interest on reddit, I thought this would be a great opportunity to answer questions about this paper, as well as supermassive black holes in general. Why do we care about supermassive black holes and how does this study help change how we understand them? I'll be back at 1 pm ET to answer your questions, AMA!

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MICHAEL_TREMMEL R/SCIENCE

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CORRESPONDENCE:

DATE RECEIVED:
May 08, 2018

DOI:
10.15200/winn.152570.01050

ARCHIVED:
May 07, 2018

CITATION:
Michael_Tremmel , r/Science , Science AMA Series: I'm Michael Tremmel, an astrophysicist studying supermassive black holes and galaxies using computer simulations. I'll be talking about supermassive black holes, their galaxies, and why some may be “wandering” around. AMA!, *The Winnower* 5:e152570.01050 , 2018 , DOI: 10.15200/winn.152570.01050

Is it possible that when these types of black holes “wander” can they possibly carry celestial bodies with them or do they travel alone?

Demie3DS

Good question! This is definitely possible. If these supermassive black holes were once in the centers of their own galaxy, they could have a whole cluster of stars around them. It is very possible that such a structure would survive the galaxy merger, so these "wanderers" could have some stars orbiting around them. The hard part is to actually see it!

Are black holes *black*?

The_impericalist

Yes, in the sense that by their very nature they do not reflect nor give off any light. That is because any light emitted within the event horizon will be sucked back in! In other words, the escape velocity, the speed that must be attained in order to escape the gravitational field, is greater than the speed of light inside the event horizon.

Now, taking your question a bit further... when black holes suck stuff up (gas and sometimes even

nearby stars), the stuff it "eats" gets very hot as it gets sucked down into the black hole's gravitational well. As that happens, this very hot material emits a lot of light. This is how we can "see" black holes from far away!

There is also the concept of Hawking radiation, where there is actually light coming from the event horizon of the black hole due to quantum mechanical processes (this has to do with virtual particles and things like that...)

Still, all of this "light" is indirect. It isn't the black hole doing the emitting (or reflecting), but rather other things emitting light after experiencing the gravity of the black hole.

Hello. I really appreciate the research and time you guys put into studying space. I've always been fascinated by space and hope to travel in space and discover even more phenomenons. But I've always been curious, what is the objective of studying celestial bodies in space and what do you hope to achieve in the end?

sisterfister27

Hmmm this is a very philosophical question... One of the reasons I love astrophysics is that it is one of the sciences that is still (mostly) about science for its own sake. Knowledge for the sake of knowledge. I wouldn't say there is any bigger picture achievement other than simply knowing more about our Universe and the structures within it (including our own galaxy and planet!).

Is a black hole permanent? Is there any way to reverse one?

I usually see black holes depicted in movies as spinning. Do they actually spin or just suck from all directions kind of like a quicksand hole would look like?

If they do spin, is it always in one direction? What determines this?

dannydsan

Actually no, they aren't permanent!... well, at least not technically. All black holes actually emit something called Hawking radiation (yes, THAT Hawking) and this process causes them to "evaporate", or lose mass over time. However, how long this takes is proportional to the black hole's mass. Any black hole we care about from the standpoint of astronomy or astrophysics will take trillions of years to have their mass decrease by any appreciable amount. However, this is why we aren't concerned about things like particle accelerators creating singularities by accident. Back when CERN was just getting started, people were getting scared at the prospect of them creating a microscopic black hole that would grow and consume all of the planet. This fear is unfounded because such a tiny black hole (and we are talking veeeeery tiny, with sub-atomic masses) would evaporate entirely due to Hawking radiation in a tiny fraction of a second.

Would it be possible in our lifetime to send some kind of tech through a blackhole for science?

fabes_

Unfortunately not in our lifetime I don't think... for a couple of reasons. The most basic limitation is that we don't have any means of fast interstellar travel. As things stand, it would take much more than a lifetime (more like thousands actually) to reach even the closest star to our own, let alone a black hole, the closest of which is 1000 times that distance!

The other limitation is technology. Once something goes through a black hole, as far as we know, the information is lost to us. It can no longer communicate with the outside. Strangely enough were we to look continuously at an object falling onto a black hole, an outside observer would never actually see it fall in! All we would see is it get close and closer to the event horizon. This is due to time dilation as gravity becomes more extreme. Oh, and any form of light communication would have its wavelength increase larger and larger as it got closer and closer. So, eventually it would go out of any communication channel's wavelength range.

How do you work out the age of a black hole?

elpigeo

We really can't with supermassive black holes... All we can do is look for black holes at different times in the Universe's history (i.e. by looking for black holes very far away from us). By getting a handle on how the population of supermassive black holes changes over time we can figure out how they evolve in mass, when they grow the most, etc.

Now, for "normal" or "stellar mass" black holes, those that come from massive stars and are much smaller than supermassive black holes, we can generally work out their age using what we know about how stars form and evolve. Stellar mass black holes that we can actually detect are often eating gas off of a companion star and we can determine some constraints on the black hole's age based on observing the companion star.

So, from my very limited knowledge on the subject, black holes originate from collapsed stars. So if that is a true statement, how do "wandering" come into existence? Were they at one point wandering stars or was there some other factors that create them?

deltafrce

Ah ok so this is a very important distinction to make. There are many "stellar mass" black holes (generally 1 - 10 and maybe up to 100 times the mass of our sun) within the galaxy. These are the natural result of stellar evolution. A star "dies" and ceases to produce the fusion in its core necessary to hold it up against gravity and the core collapses. If the star is massive enough, the core collapses all the way into a singularity (a black hole).

The black holes I study, and the ones I discussed in my work on "wandering" black holes, are supermassive black holes. These are 100,000 to 1 billion times the mass of our sun and are thought to exist primarily at the centers of galaxies. How they came to exist is still an active area of research. The main challenge is that if we assume these black holes started off small (1 or 10 times the mass of our sun) it is *really* hard to figure out a way for them to grow to billions of times the mass of our sun. To complicate it further, astronomers have observed a supermassive black hole of more than a billion solar masses that existed when the Universe was not even 1 billion years old. That is not a very long time to grow that much... Likely these black holes were formed by a very different process compared with stellar mass black holes... but the jury is still out on this! In fact, if we are ever able to observe "wandering" black holes, it may place a really interesting constraint on how they form. More likely is that observing gravitational waves with the LISA observatory (planned to launch in ~20 years) will give us the best constraints on this matter... though how much of a constraint it will provide is also uncertain!

Are there any signs of celestial bodies or black holes that have been identified outside the generally accepted bounds of a galaxy?

deltafrce

First, there are no hard "bounds" to a galaxy. Even in the Milky Way, there is the Galactic Disk with its nice spiral arms, but there is also an extended "halo" of stars that extends far beyond the disk. These stars also exist around other galaxies and are actually quite interesting! Once can see structures in these stars that come from previous galaxy mergers. Maybe one day we will even detect a wandering supermassive black hole! However, these stars are hard to see in other galaxies because the stellar halos have a very low density (i.e. they do not emit a lot of light per unit area on the sky). However, as we develop better tools to look at this diffuse emission, we are seeing more and more that there is a lot going on in the outskirts of galaxies.

I'm late to the party but thank you for doing this AMA! If you happen to see this and have a moment, what are the most realistic methods for "detecting" these black holes? Would we basically need to find stars with crazy orbits like we find around Sag A*? If so, are there any promising candidate stars that could be being influenced by wandering black holes?

Thanks again for taking time to do this!

clayt6

Hello again! I really appreciate all the interest in the article generated by your post the previous week. I'm glad it led me to doing this AMA!

I think there are a few good avenues to study in terms of finding "wandering" supermassive black holes.

The first is to look for stellar orbits feeling the gravity of the black hole. These don't necessarily have to be crazy orbits. The centers of galaxies often have nuclear star clusters of order the same mass as the black hole at their centers (I will say that this is still an active area of research in the community). Even if a galaxy is disrupted, such dense clusters of stars surrounding a supermassive black hole could survive. While we don't resolve such detailed structures in our simulations, in theory we could look for them and calculate the ratio of total mass to luminous mass (i.e. stars) based on stellar orbits, unveiling the "hidden" mass of a black hole. Again, these are not necessarily crazy orbits but still orbits that are affected by the gravity of an unseen massive object. Likely such a method would be confined to our own galaxy or very nearby galaxies like Andromeda and even then it would be like finding a needle in a haystack I think.

The second method is through gravitational lensing. As a massive body passes in front of things relative to us it will distort the light before it reaches Earth. If we were to detect such distortions we could infer the existence of a massive body that is quite small (i.e. a black hole of a million or more solar masses). However, this is incredibly difficult as even for such a massive object the effect can be small (for reference lensing is often detected from galaxy clusters, the most massive and largest objects in the Universe). One interesting way is to look for distortions in light already lensed by another object. Sometimes a massive lens will crease a very thin image of the background object, such that small perturbations from other massive bodies (secondary lenses) become evident. There are some people at Yale working on this, but so far there are just not many examples of such perfect, thin lenses to make it likely we see anything. Still, as our abilities get better maybe this will become a viable method.

Finally, It may be possible to detect the wanderers in a slightly more direct way. Some may still periodically feed on nearby gas and become luminous. These may contribute to at least a portion of the population of "ultra luminous" X-ray sources, point sources with luminosities that seem too high to be caused by a normal stellar mass black hole, but are not in the galactic center and much less luminous than a typical active galactic nuclei. In addition to gas, black holes can also feed on stars if

they happen to come too close. The stars become tidally disrupted due to the strong *differential* force of gravity nearby the black hole (the same reason why Neil deGrasse Tyson talks about "spaghettification"). When this happens, the star/stripped material let out a lot of light for a short time. In theory this should occur for both central and wandering supermassive black holes. The problem is that we would only ever detect a subset of the black holes that happen to be luminous for some reason. Still, it could give an idea that they exist and help us understand their population. The question is just how common or rare is it for them to be luminous?

is light being pullet by the black hole?

alexander5261

Yes! Light is affected by gravity just like we are used to thinking of massive objects being affected by gravity. Light is bent and its wavelength/frequency shifted as it goes through gravitational fields. That very cool image shown in the movie interstellar was made simulating the paths light takes around a black hole. The light that comes to you, the observer, often has passed several times around the object before reaching your eyes! In other words, light doesn't travel in a straight line... it travels around something called a geodesic in general relativity. Such a path is affected by the warping of space-time caused by a massive body.