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D10(BH) Weekly Discussion

Erin O'Connor

Mar 17 at 9:36am

3 37

Due this week

First, be sure to do the reading and watch the lectures:
Assigned reading and lectures

Then answer the following questions in this discussion forum (and yes, you may look to see what others write, but try to find what they might have missed and you should go back to the original reading and lectures to get answers for yourself). Then post your own question at the end, and then answer someone else's question. If no question is available, go ahead and check back later until the due date. If nothing comes available you can then pick any question you wish.

We hope to emulate a seminar classroom environment where students can share ideas. Always be respectful with all communications you have with your esteemed fellow colleagues (your fellow students) in this course.

- 1. DISCUSS in some detail something you found unusually interesting or intriguing in the reading or lecture material. Are there new insights that you have gained (something you had not thought of or considered before)? Focus on one of the concepts and explain as best you can in your own words. (4 pts)
- 2. Post a question that you have about something you read. Be sincere. What do you want to know? Write the word QUESTION all in caps, so that your fellow classmates know what your proposed question to the class is. (3 pts)
- 3. ANSWER the question of another student according to what we discussed in the lectures or what you read in the assigned readings (don't just make something up). Try to answer a question that no one else has responded to yet (but not a hard and fast rule). A good way to respond to another student's question would be to say something like, "Good question! The answer can be found on page..." and give the quote from the reading. You are free to reference other sources outside of class material, but always consider the credibility of the source, state what the source is, and give the link. (3 pts)

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Reply

Malachi Scott (https://canvas.sbcc.edu/courses/46681/users/409981)

Mar 22, 2022

For this discussion, I'd like to focus on Black holes and this weeks' assigned reading regarding them. The entirety of the reading was extremely interesting to me. Although, I'd like to begin with how well they simplified and gave comprehensible definition of what a black hole is. In John Mitchells paper he stated that "A star that was sufficiently massive and compact would have such a strong gravitational field that light could not escape: Any light emitted from the surface of the star would be dragged back by the star's gravitational attraction before It could get very far"... We now call these objects 'Black Holes'. An important note is with these said objects, we would not be able to see them as their light wouldn't reach us yet we would be able to still feel their gravitational attraction. This topic is extremely intriguing to me as I never realized black holes were formed by collapsing stars or that this was how they operated. In regards to my question, I was wondering if anyone could better explain everything being dragged back by the gravitational field; due to the fact that nothing can be faster than the speed of light and light is not escaping when we observe a black hole.

Reply

Sarah Savage (https://canvas.sbcc.edu/courses/46681/users/375381)

Apr 3, 2022

ANSWER:

Hi Malachi, my understanding about things being "dragged back by the gravitational field" is that it's similar to gravity here on Earth. Matter on Earth is stuck on Earth unless it can travel fast enough to escape Earth's gravity. A regular airplane can't fly fast enough to escape but a rocket can. That speed threshold is called Earth's escape velocity and every planet or star will have its own escape velocity depending upon its particular gravity. So when a star collapses into a black hole, it will have its own particular gravity based on its mass. Anything that gets close to the black hole will get "sucked" in unless it can go fast enough to escape the pull. It must go faster than the black hole's escape velocity. BUT once an object crosses the event horizon, it must move faster than the speed of light to escape. Since nothing can go faster than the speed of light, even light particles can't escape.

Reply

(http

Erin O'Connor (https://canvas.sbcc.edu/courses/46681/users/24247)

Apr 24, 2022

Regarding objects or stars being sucked into black holes, one has to be careful in not suggesting that black holes actually "suck" things in, but rather, black holes act just like a massive star in that objects can be trapped in orbit and if there's an accretion disk they can radiate energy which decays the orbit and they can subsequently spiral into the black hole. The reason this is an important distinction is that an object that wanders near a black hole will be pulled toward it and gain exactly the speed it needs to then escape. It's a conservation of energy type thing. Same thing happens with our solar system. Objects that come from outside of it rarely get trapped by the sun unless they give up energy somehow through an interaction, perhaps a partial collision or some type of gravitational deceleration.

Reply

(http

Erin O'Connor (https://canvas.sbcc.edu/courses/46681/users/24247)

Apr 24, 2022

About object being dragged into the black hole, or around the black hole, by the flowing of space-time, this concept is used to define a region of space around a black hole known as the ergosphere. I talk about that in my paper on black holes, although it's not discussed fully in the Hawking book. But if a black hole is spinning fast enough, there is a region of space around it where objects are dragged faster than the speed of light, even though they are not technically within the Event Horizon.

Reply

https:/

Lucca Gambone (https://canvas.sbcc.edu/courses/46681/users/405319)

Mar 31, 2022

Something I found interesting about the material for this week was the crash course video when it talked about planetary nebula, I think it is interesting how they can vary from star to star giving off very different looks. I also think it is cool that is expanding on the inside by ionized gas. I can't believe when a white dwarf blows off its outer layers to create such a beautiful look. something so chaotic creates something so pretty.

My question is how do nebula get formed in those weird and random shapes ?

Reply

(http

Abigail Jacobs (*She/Her*) (https://canvas.sbcc.edu/courses/46681/users/367167)

Apr 3, 2022

Hi Lucca!

I think your question is very interesting and with some reading, I found that nebulas get their shape from the speed of the wind as well as how quickly a red giant loses mass as it slowly dies.

Reply

(http

Franco Diaz Campo (https://canvas.sbcc.edu/courses/46681/users/403036)

Apr 5, 2022

Hi Lucca,

I think it isn't easy to know this question, you have to do excellent research to find the answer, but I think it is like that because of all the conditions the space has, the climate, the gravity, etc.

Reply

(http

Erin O'Connor (https://canvas.sbcc.edu/courses/46681/users/24247)

Apr 24, 2022

One of the main reasons why planetary nebulae can look so different has more to do with the direction with which you view them then whether they actually are looking different. Of course, both effects can cause a planetary nebula to look different. Some of them are spherically shaped and some of them are lobes extending perpendicular to the rotation of the progenitor star. But with the lobes, depending on if you look at it from the side, or from one end or the other, the planetary nebula can look very different. The colors have to do with the different types of gas and ionization states and depend on the different regions of temperature.

Reply

(http

Naomi Xu (https://canvas.sbcc.edu/courses/46681/users/27955)

Thursday

I kind of thought that too when I saw the eagle nebula, or the cat's paw, how is it that they're able to look so "accurate"? (unlike our constellations) but then I realized that that's just from our perspective/angle, if I were to rotate 90 degrees from it, it might just look like a blob.

Reply

Abigail Jacobs (*She/Her*) (https://canvas.sbcc.edu/courses/46681/users/367167)

Apr 3, 2022

Discussion:

I found the kilonova discovery video to be the most interesting, their projected explosion was crazy! The telescopes at the observatory have the most beautiful footage. I think it's also crazy that elements come from these explosions such as elements found in Jewelry. The fact that we have telescopes high tech enough to see explosions like this so far away and monumental is absolutely amazing and mind-blowing.

Question:

How close to earth would a kilonova creation have to be in order for us to see it and or feel the effects?

Reply

Luke Rutherford (https://canvas.sbcc.edu/courses/46681/users/373514)

Apr 3, 2022

Hi Abigail,

According to NASA, a supernova would have to be within 50-light years away for Earth to feel the effects. I couldn't find much on the kilonova but I imagine it is close to 50- light years.

Reply

Erin O'Connor (https://canvas.sbcc.edu/courses/46681/users/24247)

Apr 24, 2022

And it's exciting to think that the Las Cumbres Observatory, which has the global telescope network, is based right here in the Santa Barbara area. Kilonova are not as powerful as Supernova, but a supernova would wipe out all life on Earth if it were within several hundred light-years of us, so it is conceivable that a Kilonova that is too close to our solar system would also have devastating effects.

Reply

Sarah Savage (https://canvas.sbcc.edu/courses/46681/users/375381)

Apr 3, 2022

DISCUSS:

I'm feeling like I have a much better grasp on what a black hole really is. It's so complex and yet its structure and function is simple and straightforward. Putting together details from chapter 6, it has me thinking about the birth of our galaxy since we have a super massive black hole at our center. If it originated from a dying star, it seems like our galaxy could have been created by a central super massive star that blew off so much gas when it died that this gas created all the stars and planets we see today within our galaxy. The remaining material left behind was just a fraction of it, but is still 4.3 million solar masses and was large enough to hold the blown out gases together in orbit.

QUESTION:

Do you think this is possible? Or do you think Sagittarius A is the result of many mergers of smaller black holes into a super massive black hole? A combination?

Reply

Brian Wolden (https://canvas.sbcc.edu/courses/46681/users/274832)

Apr 3, 2022

Hi Sarah,

That's a really interesting idea! The amount of material involved in such a galactic formation is even more mind boggling than the numbers we deal with when already talking about supermassive black holes! I found some information about incredibly large stars (and then black holes) forming as "seed" black holes for the supermassive black holes in the center of galaxies. These black holes, having such a high mass to begin with, would then continue to consume huge amounts of additional material. Using computer simulations, they found that these black holes could reach 250,000 solar masses in just

200 million years! Related to this, I wonder if any galaxies have multiple supermassive black holes? I don't think I have ever heard of such a thing and, if they could exist, perhaps the would merge very rapidly due to their mutual attraction?

https://ec.europa.eu/research-and-innovation/en/horizon-magazine/how-did-supermassive-black-holes-grow-so-fast#:~:text=Black%20holes%20form%20after%20a,support%20its%20mass%20and%20collapses (https://ec.europa.eu/research-and-innovation/en/horizon-magazine/how-did-supermassive-black-holes-grow-so-fast#:~:text=Black%20holes%20form%20after%20a,support%20its%20mass%20and%20collapses) .

Reply

(http

Sarah Savage (https://canvas.sbcc.edu/courses/46681/users/375381)

Apr 6, 2022

Wow, great article and ideas. Thanks, Brian! “Seed black holes would need to draw in matter at a rate of at least 0.1 solar masses per year…” That is nuts!

Reply

(http

Erin O'Connor (https://canvas.sbcc.edu/courses/46681/users/24247)

Apr 24, 2022

You ask some very good questions. About the supermassive black holes at the center of galaxies, and how they originated, it has been determined that it they could not have formed from a single black hole that grew. The reason is that the rate of growth would have had to be so fast that its own light pressure would have pushed matter away and it would starved itself. So therefore, merging black holes or some other mechanism must be the cause. They could not have been formed from a single progenitor star either, because Stars seem to have a particular range of formation, and something that is 100 billion solar masses does not seem to be reasonable, or at least I have not heard of anyone suggesting this or doing research on such ideas.

Reply

(https:/

Malcolm Tircuit (https://canvas.sbcc.edu/courses/46681/users/427388)

Apr 3, 2022

DISCUSS:

I thought this chapter was one of the most interesting yet. The thought that a thing can be infinitely small and have infinite mass is incredible! Learning about what the event horizon is made me understand black holes and their properties way more. The diagrams in the lecture really helped me visualize why once something goes past the event horizon it cant come back out. It's also crazy that black holes were speculated to be a thing based on math before any real proof was presented.

QUESTION:

What would happen if a primordial black hole was on earth? Would it have a large or small impact?

Reply

(http

Alak Fryt (*He/Him*) (https://canvas.sbcc.edu/courses/46681/users/354278)

Apr 3, 2022

Hey Malcolm, so in short, I read that if a primordial black hole were to hit earth, it would be quite the catastrophe. A primordial black hole would cut through the earth's surface with ease but begin to slow down due to the gravitational interaction with the earth. Either the black hole would exit the other side of the earth leaving potential survivors or it could settle at the earth's core and eventually lead to the consumption of the earth as a whole.

Reply

(http

Sarah Savage (https://canvas.sbcc.edu/courses/46681/users/375381)

Apr 6, 2022

That is terrifying, Alak! Would we even know that this was happening?

Reply

(http

Erin O'Connor (https://canvas.sbcc.edu/courses/46681/users/24247)

Apr 24, 2022

What a great question, to ask about what an impact with a black hole might look like. It actually wouldn't look like an impact at all because the black hole would simply pass through the Earth as if it weren't there, creating a hole through the Earth, if we're talking about a small black hole. If it's a large black hole, the Earth will simply be swallowed into it and that will be that. This is only if we are talking a direct impact (which would be rare).

More commonly an object (like the Earth) would get close to a black hole and tidal forces would rip it to shreds first, then the accretion disc would swirl around the black hole.

Reply

Naomi Xu (https://canvas.sbcc.edu/courses/46681/users/27955)

Apr 3, 2022

I thought it was so interesting that you can't hide behind a black hole, which leads me to my question, how would we detect wormholes?

Reply

Brian Wolden (https://canvas.sbcc.edu/courses/46681/users/274832)

Apr 3, 2022

DISCUSSION

So much about the discussion of black holes, their formation, and the breakdown of our understanding of physics that happens within them is really fascinating and is one of the things that drew me to this class in the first place. These things are so much fun to try and wrap my head around. However, one of the things I found most enlightening about the material this week is the discussion of how LIGO detects gravitational waves. I had heard of LIGO before and the fact that gravitational waves warp the space around them seemed like a big hurdle to get over if one wants to actually detect them. The comparison of the perpendicular beams creating incredibly small differences leading to slightly less than perfect destructive interference makes a lot more sense. Thinking about how the gravitational waves are moving through LIGO, and therefore contracting some areas before others, was very helpful. As a side note, the level of sensitivity required for this to work, and the fact that we were able to achieve it, is simply amazing.

QUESTION

My first question is in regards to LIGO and our increasing sensitivity in detecting gravitational waves. What are the conceptual limits of this? Since the Earth interacting with the Sun emits gravitational waves, is it theoretically possible that we could use gravitational wave detection to map solar systems? I know the technology required is potentially impossible as well (or maybe the size of the arms would need to be as large as the galaxy or something like that) but

I am wondering if there is a fundamental quantum mechanical limit to how sensitive these devices can become.

My second question is a little weirder and may not make any sense. I was thinking about two black holes colliding with one another and I wondered if there was a point between those black holes, within the event horizon of both, where the gravitational pull of both "canceled" each other out, and allowed a perfectly positioned particle (or even photon) to pass through those event horizons and emerge outside of them, having been pulled equally in all directions. It seems like the gravitational pull from one black hole should be able to neutralize the pull from another. In relativistic terms, it would sort of ride a crest of destructive interference waves between the two black holes. Is this theoretically possible (even if practically impossible)? Does quantum mechanics play a role here and prevent the particle or photon from having a definite enough position? Or does this make no sense at all?

Reply

(http

Sarah Savage (https://canvas.sbcc.edu/courses/46681/users/375381)

Apr 7, 2022

ANSWER:
What a great question! You're definitely thinking outside the box. This seems possible to me. If one of the black holes were spinning, could this cause matter to be flung out and away from the merger? In which case, if timed perfectly, could a rocket enter the event horizon during the merger and be flung away to safety?

Reply

(http

Erin O'Connor (https://canvas.sbcc.edu/courses/46681/users/24247)

Apr 24, 2022

The sensitivity of LIGO is beyond comprehension. I was first told that its sensitivity was 1/5 of diameter of a proton, and perhaps that was its original design when first built, and that blew my mind. But then just chatting with Iair Arcavi before his Zoom talk, he told me that they had upgraded LIGO so that it has a sensitivity of one 100,000th of the diameter of a proton. I just can't even relate. So amazing.

Reply

(http

Erin O'Connor (https://canvas.sbcc.edu/courses/46681/users/24247)

Apr 24, 2022

Your question about conceptual limits to the sensitivity of LIGO, I think that's a bit complex. In addition to the sensitivity in measuring length, or length differences, one has to deal with noise. Noise can come from earthquakes, wind, any type of vibration produced by humans, but that is subtracted out and seems to be mitigated, but I think the type of noise is the limiting factor and causes some "blind" spots in LIGO's ability to find merging black holes.

The short answer is I don't really know what the physical (the physics) limitations might be, but they seem to have overcome so many of them already.

Reply

(http

Erin O'Connor (https://canvas.sbcc.edu/courses/46681/users/24247)

Apr 24, 2022

Great question about the balance point between two black holes. You're basically referring to LaGrange points. There are five LaGrange points around any two body problem, and we talk about them a bit in the intro to astronomy class because Trojan asteroids are 60 degrees in front of and behind Jupiter (or any planet) because these are two of the stable gravitational points, but there are also three other LaGrange points, one of them is where they have parked the James Webb Space Telescope, but another one is the one between the two bodies, but that's an unstable equilibrium point and any perturbation will cause the object to destabilize and fall toward one object or the other (toward one black hole or the other). This is what you're describing with the two black holes merging and finding that balance point in between, and it is hard to imagine that any object could remain in that point long enough to survive being swallowed up. The other tricky part is I don't see how the object would come back out of the black hole's Event Horizon once the two black holes merge, but you do pose some interesting theoretical questions that I think a grad student could explore more fully. Maybe someday that grad student will be you.

Reply

(https:/

Luke Rutherford (https://canvas.sbcc.edu/courses/46681/users/373514)

Apr 3, 2022

DISCUSS:

I find the cosmic censorship hypothesis interesting because it is hard to imagine singularities either ending time or the beginning of time. The massive amounts of gravity that make the

black hole also makes them that much more interesting. It is impossible to see past the event horizon unless you go there yourself.

QUESTION:

Are the only different types of black holes characterized by size and mass?

Reply

(http

Erin O'Connor (https://canvas.sbcc.edu/courses/46681/users/24247)

Apr 24, 2022

Yes, I think both the cosmic censorship hypothesis and the anthropic principle play a big role in what we perceive or do not perceive about the universe. These are insightful concepts that most people never think about. The only characteristics of a black hole that can be determined from outside of the black hole are mass, charge, and angular momentum. There is a recent article that I posted that shows that Wheeler's "no hair theorem does not strictly hold", so that there might be a possibility of "seeing" inside the black hole in that information is retained in the quantum mechanical description of the Event Horizon of a black hole.

Reply

(https:/

Alak Fryt (*He/Him*) (https://canvas.sbcc.edu/courses/46681/users/354278)

Apr 3, 2022

DISCUSSION:

I thought it was interesting thinking about blackholes that have a mass less than the Chandrasekhar limit. It was something I hadn't thought of before and thinking about John Wheeler's calculations of taking all the water from Earth's oceans and building a hydrogen bomb that could force the formation of a black hole is just crazy to me. And then the last bit at the end about black holes not actually being black was intriguing to me but in a way kind of made sense. Especially how larger black holes would be harder to find than smaller ones because of how much more compressed the area of "glow" would be compared to a much larger black hole.

QUESTION:

How accurate do you think the information from the movie "Interstellar" is about what it suggests about black holes? Obviously there is much of the movie that is purely sci-fi, but I feel like a lot of what the plot from "Interstellar" is based around is formed around what we know now about black holes and its manipulation of time and space.

Reply

(http

Erin O'Connor (https://canvas.sbcc.edu/courses/46681/users/24247)

Apr 24, 2022

Small miniature or primordial black holes or microscopic black holes are very intriguing indeed. I had never thought of that before either, and found it very interesting. As of yet, we have not found one so it is an area of great interest and it would be very exciting to confirm that these actually do exist. The movie Interstellar goes to great effort to depict the black hole as accurately as possible, having hired Kip Thorne a famous black hole researcher as a consultant. The visuals were generated with computers to accurately depict a real black hole, and the calculations regarding time dilation and other aspects of the black hole are accurate. There's a book that Kip Thorne wrote about the science behind the movie, and you can maybe find that online.

Reply

(https:/

Lexie Brent (https://canvas.sbcc.edu/courses/46681/users/122267)

Apr 3, 2022

I need to rewatch Interstellar now that I know about the (somewhat) accurate depiction of the black hole. That's so cool that the creative team thought it necessary to make the science fiction as scientific as possible. It's interesting to me that a supermassive black hole, which sounds much scarier than just a regular black hole, is actually "gentler" than a regular one in terms of getting close to the event horizon. I really liked the graphic where it was pointed out how the accretion disk is technically going behind the black hole but since it doesn't obscure anything from view we see the accretion disk as if it is going over the black hole. To visualize it in that way makes the black hole seem more mystical to me, almost as if it's not a physical thing that blocks light from behind it like other objects in space.

QUESTION: How long would it take for someone to be spaghettified? How much does that answer change depending on the size of the object being spaghettified?

Reply

(http

Sarah Savage (https://canvas.sbcc.edu/courses/46681/users/375381)

Apr 7, 2022

ANSWER:
I think the spaghettification process would also depend on the strength of the black hole's gravity, how fast it's sucking you in, and what the object is made of…it seems like it would be easier to pull apart two liquid atoms vs two solid atoms.

Reply

(http

Erin O'Connor (https://canvas.sbcc.edu/courses/46681/users/24247)

Apr 24, 2022

Yes, you will enjoy watching the movie Interstellar now that you know more about black holes. They do a lot of references to, and accurately calculate the effects of, a black hole. One example is the relativistic time-dilation on the planet. The "Tide" wave is also an example (different than a "tidal" wave). Another example is how our lead character does not get spaghettified when he approaches the Event Horizon, though what happens after entering the Event Horizon would be fabricated for the purposes of the movie. I'm not so sure you will end up in a library. Spoiler alert.

Reply

(http

Erin O'Connor (https://canvas.sbcc.edu/courses/46681/users/24247)

Apr 24, 2022

Falling into a black hole only takes a short time for the person falling in, perhaps just a matter of minutes, but as viewed by an outside observer, since time dilation gets stronger and stronger as you approach the Event Horizon, technically it will take infinite time for you to watch someone fall to the event horizon and you will never see them enter within it. For all practical purposes, though, you will have been spaghettified way before then, and when exactly depends on the mass of the black hole.

Reply

(https:/

Franco Diaz Campo (https://canvas.sbcc.edu/courses/46681/users/403036)

Apr 5, 2022

DISCUSSION

Hi everyone!

I found many exciting things we learned this week in this class! First of all, I want to emphasize the meeting with Dr. Iair Arcavi. It is one of the greatest we have ever had, and I liked its development. Another thing I wanted a lot was to watch all the videos related to Black Holes; it is one of the topics I like most to study since it is one of my passions. Lastly, I want to say that I enjoyed a lot watching all the videos of LIGO, I was interested in knowing a bit more about it, and with all the videos we watched, now I understand better all of it.

QUESTION

What is your favorite part of black holes?

Reply

(http

Erin O'Connor (https://canvas.sbcc.edu/courses/46681/users/24247)

Apr 24, 2022

I'm glad you enjoyed the meeting with Dr Iair Arcavi. Perhaps when he visits Santa Barbara again I will let the class know and we can meet him somewhere and chat about astronomy. About black holes, I find the time dilation effects the most interesting, and also how black holes interact with the laws of thermodynamics. Remember my research was in the thermodynamics of black hole heat engines, so I find this very interesting.

Reply

(http

Malcolm Tircuit (https://canvas.sbcc.edu/courses/46681/users/427388)

Thursday

Something I find incredibly interesting about black holes is the concept of a singularity. I still don't understand how something can have infinite mass and be infinitely small. That whole concept is crazy to me!

Reply