Source : www.thehindu.com Date : 2019-05-03

YOUR QUESTIONS ON BLACK HOLES ANSWERED

Relevant for: Geography | Topic: The Earth and the Solar System

The image of the black hole released by the Event Horizon Telescope team. | Photo Credit: REUTERS

Following the release of the first image of a black hole by the Event Horizon Telescope and collaborators, we had a podcast in which radioastronomer Niruj Mohan Ramanujam chatted with The Hindu's science correspondent Shubashree Desikan about various things related to a black hole.

While they were able to address some of the questions posed by Twitter people on this occasion, there were many more interesting questions that they did not have the time to answer. We got the help of Bengaluru-based astrophysicist Prajval Shastri to answer these questions. She has gone into detail in her replies and we thank her and Niruj for participating in this interactive programme.

Here are the questions followed by Dr. Shastri's answers:

Sreeram @ASreeram1998:

Prajval Shastri: The existence of this black hole was first guessed at because the Messier87 galaxy when imaged at radio frequencies shows the signature twin-jets of plasma that are squirted out at near-relativistic speeds to reach well beyond the galaxy into intergalactic space. Furthermore, studying the movement of gas clouds in the central region shows gas moving at enormous speeds both towards and away from us, and these speeds are consistent with the hypothesis that the gravitational force of a central billion-solar mass black hole drives this gas. Matter in the close vicinity of a black hole shines because it gets extremely hot, and light from "behind" the black hole also reaches us because the gravitational field of the black hole bends this light towards us. The black hole can thus be seen in silhouette against the shining surrounding matter, if one has telescopes with sharp enough vision, which the Event Horizon Telescope had.

nihal naidu @nihalnaidu123:

Prajval Shastri: The gravitational field at a point is dominated by that due to the masses that are closest and heaviest. Near a black hole the gravitational field is very intense because a black hole contains a huge amount of mass within a relatively small volume. Matter going into it increases the mass of the black hole.

Sruthi Radhakrishnan @sruthirk:

Prajval Shastri: If you mean how accurate the depiction was, in the movie the depiction was very close to our current understanding of the physics of black holes and what happens to the material that reaches its vicinity, but not exactly. The depiction does not show the consequences of the Doppler effect on the light from the material that is swirling into Gargantua. Known physics predicts that the part of the matter that is moving towards us will be Doppler-shifted to higher frequencies and so appear slightly bluer and brighter, and similarly the part of the matter that is moving away from us will be Doppler-shifted to lower frequencies and so appear slightly redder and dimmer. This more precise depiction appears in the paper that the Double Negative team published, but not in the movie.

Adarsh @Adarsh53058127:

Prajval Shastri: By yellow portion if you are referring to the yellow blobs in the shining “doughnut” seen in the EHT image, then those portions are shown as yellow because are slightly brighter than the rest of the doughnut. Note that the image is rendered in false colour, which means that each colour is used to represent how bright the source is at that position - those are not the real colours of the source. So in this case yellow was used to represent the brighter parts and red to represent the slightly fainter parts. The source was imaged at millimetre frequencies which humans cannot see, and therefore do not have a “colour” in the everyday sense of the word. The whole doughnut is hot gaseous matter. We cannot infer the composition of this matter yet because no atomic spectral lines have been seen from it yet. Even if they were seen, however, they would not tell us about the composition of what is inside the black hole, because they would not be coming from within the black hole. We do not get any light or other signals from within the black hole, and current physics says that we cannot.

Wridh Paul @PaulWridh:

Prajval Shastri: Sorry I cannot answer questions about what theories are applicable within the event horizon of the black hole. It would be nice if a general relativist addresses them. Andrew Hamilton of JILA, Colorado has interesting material on speculations as to what happens within the event horizon of a black hole.

Jitendra Kundu @jkundu675:

Prajval Shastri: Black holes have an intense gravitational field near them because of the large amount of mass they have which is concentrated in a very small volume. If one defines the density of a black hole as the ratio of its mass to its volume, then the density decreases as the size of the black hole increases. So the “density” would depend on the size of the black hole. The “density” of black holes left behind by stellar death is much, much higher than that of the earth, whereas the “density” of the central giant black hole in M87 whose silhouette the EHT discovered, is very roughly similar to that of the air around us.

Swadhinta @swadhinta77:

Prajval Shastri: The answer to the first question depends on the context - e.g., Help us physicists? Broad answer: the discovery has opened the door to several new lines of scientific investigation, enabling quantitative estimates of black hole related parameters. It has provided another laboratory to test the predictions of the general theory of relativity. It has made clear that by deploying millimetre telescopes in space we will be able to enlarge our inventory of black hole silhouettes in the universe.

Help us astronomical instrumentationalists and engineers? Answer: the sharpest image of the sky so far has been obtained, and the techniques used have wide applicability beyond just the study of black holes to a whole range of objects in the cosmos that emit at millimetre frequencies.

Help us the general public? Broad answer: As with all landmark astrophysics discoveries, this finding is not only another demonstration of the wonder of nature that we love, but also a demonstration that the physical laws that humans have arrived at by intellectually driven activity on earth seem to hold over mind-bogglingly vast distances into the far reaches of the universe. While profound in itself, these ideas also have implications for how humans think about their

own place in the vast context of the universe.

Ankush Sharma @aviro17:

Prajval Shastri: Perhaps. Black holes have been predicted to lose energy via Hawking radiation. This phenomenon has not been observed, but the bigger the black hole, the longer it would take to evaporate away.

Adarsh @Adarsh53058127:

Prajval Shastri: The interior of black holes has not been studied since we cannot hope to see light or other information from inside a black hole coming out.

Ankaj kumar @saikapian6835:

Prajval Shastri: We cannot exactly predict the changes, but the black hole would have grown in mass for one thing. Perhaps the matter swirling around it would have squirted out more plasma in the form of “twin jets”.

Vaibhav Bhatnagar @Vaibhav40162166:

Prajval Shastri: The Event Horizon Telescope project itself was launched about 10 years ago but it builds on a vast amount of scientific and technological research that preceded it over many decades.

Anjali @_Anjali_96:

Prajval Shastri: It is the hot gaseous material that is swirling into the black hole that is being consumed by the black hole, and the light is coming from this swirling material.

Ripu_Mardanan @lsk2007:

Prajval Shastri: Light bends around any massive object, whether you or me or the earth or the Sun or a black hole. The bending around smaller objects is way too small to be noticed. The bending of light around the Sun has been measured (the famous 1919 experiment during a total Solar Eclipse, which was consistent with the prediction of Einstein’s theory). The bending of light around a black hole is very significant because of its extremely large mass. Because of this bending, we see light from material that is behind the black hole, which we would not see if light were traveling in straight lines.

Rahul Balakrishnandas @rahul_2803:

Prajval Shastri: What happens when one enters a black hole or what wormholes do are currently a matter of speculation.

Himali @Himali_Tripathi:

Prajval Shastri: The image is consistent with the prediction of Einstein’s general theory of relativity and is an independent substantiation of the theory. The discovery has opened the door to a whole new line of investigation that could bring new results.

sai sowmya @sowmyasd:

Prajval Shastri: If you mean the recent black hole study by the Event Horizon Telescope, it is useful to physicists because it is a realisation of the closest we can get to obtaining ‘direct’ evidence for the existence of a black hole. What is observed is consistent with what is predicted by theory. LIGO discovered the biggest ‘stellar’ black hole we know, ie the black hole that was left behind by stellar death. However LIGO will not be able to detect the gravitational waves produced by the merging of giant black holes of the kind that was seen by the Event Horizon Telescope. An instrument such as LISA is necessary for that.

Abhijit Singh @Abhijit75001643:

Prajval Shastri: To see what might happen inside a black hole, do see Andrew Hamilton’s website in JILA Colorado, USA.

Manendu Dutta @manendu_dutta:

Prajval Shastri: The giant black hole in SagA* is roughly a 1000 times smaller than the one discovered in Messier87. Both black holes are growing because of nearby matter plunging into them but the one in Messier87 is growing faster.

Nikhil @jeansjacket:

Prajval Shastri: India does not have a telescope like the Event Horizon Telescope which can image the silhouette of a black hole. The sharpness of vision required for this experiment required a telescope operating at millimetre frequencies which India does not have. However, black holes can be studied by a variety of methods other than looking for the black hole silhouette, and India does have several telescopes that can study black holes in these ways, as well as dark matter. Such investigations are ongoing and many findings have been published.

Rohit Jaiswal @ron_hunk:

Prajval Shastri: Rephrasing the 2nd question: Why can’t the dark circle seen in the centre of the doughnut-like image that the Event Horizon Telescope found be simply empty space that is not emitting light? It can be, but there is all the prior knowledge we have about the Messier87 galaxy, its central region, the twin jets of plasma that emerge from its central parts out into intergalactic space and the estimate of its central black hole mass, and all of these facts taken together with the latest EHT image are consistent with the idea that there is a billion solar mass black hole in the centre of the Messier87 galaxy.

Ashish Dhandale @ADhandale:

Prajval Shastri: This exploration is an independent way of investigating black holes compared to what has gone on over the last several decades and is thus an independent substantiation of our understanding of the physics of black holes. it is useful to physicists because it is a real demonstration of the closest we can get to obtaining ‘direct’ evidence for the existence of a black hole. What is observed is consistent with what is predicted by theory. This result in particular and the study of the universe in general is a very natural path for the curious human mind to pursue, because we are all lovers of nature and seek to understand it. Our understanding also reveals to us our place in the universe.

Abhishek Tiwari @Abhishekpopo:

Prajval Shastri: If you really want/need to teach about black holes to a 6yr old: One way might be to demonstrate how if you throw a ball up it falls back on earth, and how you would have to

throw it with really high speed for it to escape the earth. Then try to talk about light from a torch and what it would take to not allow that light to escape.

Ayush Sharma @AyushSh09232475:

Prajval Shastri: If you mean how intense is the gravitational force due to the central giant black hole in Messier87, it depends on how far you are from it. The standard formula for gravitational force can be used.

Safiullah @Safiull80253628:

Prajval Shastri: Depends on where the planets are. If they are in the vicinity of their stars, the star could expand during some phase of its life to consume these planets, similar to what would happen in any other region with stars and planets, in any galaxy. So those planets would have a shorter life than the central black hole. If the planets are around stars that are very close to the black hole they could all get attracted towards the black hole and get consumed by the black hole. On the other hand there could be free-floating planets around in the galaxy which are far enough away not to be influenced by the central black hole and could survive for a long time.

Nipoon @NipoonJ:

Prajval Shastri: E=mc2 applies to black holes just as it applies to any other phenomenon - i.e., whenever matter gets converted to energy or vice versa. For example when the first coalescence of two black holes was discovered by LIGO in 2015, the mass of the coalesced black hole was less than the sum of the masses of the original coalescing black holes by about three solar masses which was converted into energy.

Sampa C Lahiri @SampaLahiri:

Prajval Shastri: There are some theories that predict that CERN might detect “quantum black holes” but there is no evidence for such black holes so far. If at all, such black holes might be produced as a result of particle collisions. However, particle collisions happen in nature quite commonly, and no ill-effects have been so far seen or predicted.

Chowkidar Rahul Pradhan @RahulPr37178707:

Prajval Shastri: Astrophysicists use a variety of methods to determine distances to objects in the universe, depending on how far they are - from laser-ranging for the nearest planets to using the expansion of the universe. For very distant objects in the cosmos, the expansion of the universe implies that more distant objects have higher cosmological redshifts. In this context M87 is considered relatively “nearby” because the stars in the galaxy can be classified and studied in quite detail - from which the distance of the galaxy can be derived because the power that some particular kinds of stars emit is known, and the distance can be calculated from how bright they appear.

Chowkidar Akshay @avi1812:

Prajval Shastri: Rendering has to happen for a variety of reasons. For e.g. false colours have been used to visualise how bright each pixel is because the actual measurements are taken at millimetre frequencies which the eye cannot see.

Rahul Balakrishnandas @rahul_2803:

Prajval Shastri: If you have a black hole which has the same mass as a star, then the gravitational force due to each at the same respective distance will be the same. When a black hole forms as a result of stellar death, however, the star would have lost some mass in the final explosion so the mass of the black hole left behind would be less than the mass of the original star, and so the gravitational force at a given distance from it would be less after the star has exploded. On the other hand, when a star becomes a black hole, it becomes much much smaller in size, and so one can get very close to it (one could not have gotten so close to the star without penetrating the surface of the star) and at that nearby point of course the gravitational force will be large.

Tarun Kadian @Tarunkadian007:

Prajval Shastri: In our current understanding, no.

Vishakh Govindan @VishGovindan:

Prajval Shastri: In principle they could and maybe some supermassive black holes may have formed this way. But we see billion-solar mass black holes very, very far away, which means very early in the life of the universe, and there is not enough time from when the universe began to build the black holes just by coalescence of stars. So perhaps the supermassive black holes form from the direct collapse of matter into rather large black hole “seeds”.

Lakshmi Menon @menon_laksh:

Prajval Shastri: We do not receive any light or signals from within a black hole so we cannot investigate the interior of a black hole. To see what might happen inside a black hole, do see Andrew Hamilton’s website in JILA Colorado, USA.

DC612 @bhoovi:

Prajval Shastri: The EHT image was taken at millimetre frequencies which the human eye cannot see. So the image is rendered in ‘false colours’. The actual colours are the choice of the renderer. In this case the yellower colour represents a higher brightness. They could well have used a different set of colours, e.g.. blue and white, or green and purple.

vishwas @naam_he_vishwas:

Prajval Shastri: Some black holes are formed as a result of stellar death and are left behind after the star’s final explosion. Supermassive black holes may be formed by coalescing of smaller black holes, which in turn formed by the direct collapse of large clouds of gas early in the universe. There are a lot of details about the newly discovered silhouette of the central giant black hole recently discovered in M87, all of which may be difficult to cover here. The essence of the discovery is that the red and yellow “doughnut” shows light coming from hot matter that is swirling into the giant black hole in the very centre of M87 and the inner dark circular region represents the silhouette of this black hole.

Karunaimaran @Karunaimara:

Prajval Shastri: Not sure.

Shubashree: This is an interesting question which I discussed with Atish Dabholkar who is head if International Centre for Theoretical Physics in Trieste, Italy, when I interviewed him. This is what he said: Ramanujan was interested in the well known counting problem of partitions – for

example, if you take the number 3, it can be written as 1+1+1 or 1+2 or 2+1 or just 3. Each of these is a partition of number 3. As you go to larger and larger numbers it becomes difficult to count the number of partitions you can do. Ramanujan and GH Hardy developed a method to count the partitions of large number. This is directly used in estimating a black hole's entropy. Later on he talked about more exotic things called Mock Modular Formss, which have been used by Atish Dabholkar and collaborators in studying multi-centred black holes.

prajjawaltyagi @prajjawaltyagi6:

Prajval Shastri: Several people thought of the idea of an object so heavy that its escape velocity was the speed of light as early as in the 18th c (e.g. John Mitchell). Once Einstein put forward his General Theory of relativity (1915), Karl Schwarschild found (1916) that one solution to Einstein's equations described a black hole.

Nipoon @NipoonJ:

Prajval Shastri: The nearest known black hole to us is called V616 Mon and is about 3000 light years away. As of now we do not know of technology that harness black holes as an energy source.

Nipoon @NipoonJ:

Prajval Shastri: The Event Horizon Telescope imaged the environment of the black hole at millimetre frequencies sharply enough that it was able to see the silhouette of the (dark) black hole against the millimetre light from the matter swirling into the black hole.

Mahesh Gajera @MaheshGajera95:

Prajval Shastri: To see what might happen inside a black hole, do see Andrew Hamilton's website in JILA Colorado, USA. Black holes are not known to or predicted to explode. They are predicted to evaporate by emitting Hawking radiation but this phenomenon has not been observed so far.

NIKUL PARMAR @NIKULPA37650361:

Prajval Shastri: The size of the black hole depends on its mass and increases with mass.

Ashutosh Pandey @asprinceashu:

Prajval Shastri: Not that we know of. Theoretically black holes could evaporate away by emitting Hawking radiation which is a quantum physics effect but this phenomenon has not been observed, and in any case, would be an extremely slow process for the large black holes that we know of in the cosmos.

Vaibhav patil @Vaibhav49727131:

Prajval Shastri: The environments of black holes are extremely interesting physics laboratories - that is why physicists search for them. To see what might happen inside a black hole, do see Andrew Hamilton's website in JILA Colorado, USA.

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