

Where Time Stands Still

Understanding black holes in the cosmos

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Indian mythology has this story about king Kukudmi who had a beautiful daughter Revati with many eligible suitors. In a dilemma over how to choose the right husband for her, Kukudmi took her to see no less a person than the creator Brahma himself. Brahma was involved in some work at the time and told Kukudmi to 'wait a second' till he could attend to him. Kukudmi waited and when Brahma made himself available, presented his problem to him. Brahma laughed. "Your brief wait here has meant that several aeons have elapsed on the Earth. So all those prospective husbands for Revati are no more". He advised Kukudmi to get back to Earth and marry his daughter to Balarama, the brother of Krishna.

This story finds strange echoes in the remarkable phenomena that astronomers are familiar with, namely black holes, for time plays strange tricks as one approaches a black hole. Before coming to this phenomenon, let us take a brief look at what a black hole is supposed to be and how it could form.

A black hole is briefly described as an object which is so compact that its strong gravity prevents even light from leaving its surface. The strength of gravity on a heavenly body is measured by how difficult it is to leave its surface. Let us compare a black hole with the Earth. If a footballer kicks a ball up in the air it drops back, being attracted by the gravity of the Earth. If he kicks it harder, it would rise higher, but will eventually drop down. Is there a limiting speed beyond which a ball leaving the Earth would just keep going farther and never come back?

Twelfth standard mathematics will be enough to calculate the answer. The limiting speed is a little more than 11 kilometres per second, far above the kicking ability of a Pele

or a Beckham. But modern space technology has that capability. Spaceships which are launched towards the outer planets, exceed that speed limit. The speed limit is, not surprisingly, called the escape speed and it is an indicator of how powerful the gravitational pull of the body is. The escape speed for the Sun is more than that for the Earth, being above 42 kilometres per second. The escape speed for a black hole, by contrast, is the speed of light, that is, three lakh kilometres per second.

If the Earth were compressed to a quarter of its size, its escape speed would double. The weights of us earth dwellers would magnify sixteenfold, thus indicating how powerful the

within it to counter its own contracting force of gravity. Such an object would keep on shrinking and shrinking till it became compact enough to be called a black hole. We need such a shrinking object to connect up with the experience of king Kukudmi.

Imagine two observers A and B who are in constant communication through light signals. A is a distant observer while B sits on the surface of the shrinking object. Both enter into an agreement whereby they send signals to each other once every minute. This agreement works in an uneventful way to start with. But as time proceeds, A will discover that B's signals do not reach him every minute. In fact,

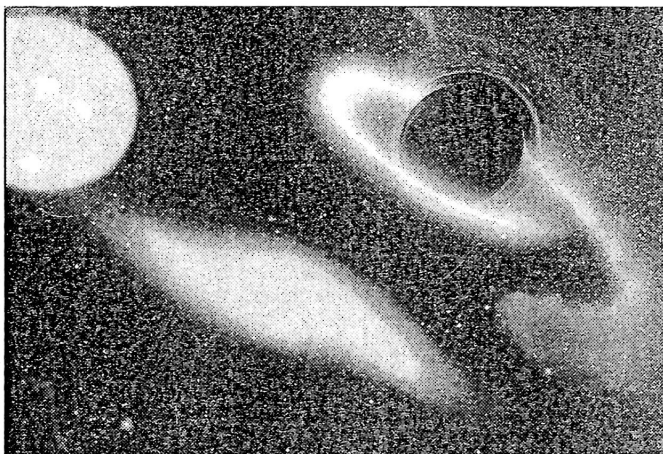
the interval between the signals grows progressively, to an hour, a day, even a month. And there would come a time when A's wait is so prolonged that he would be left wondering when B's next signal would come, indeed if it would come at all.

The mystery behind why this happens is resolved if we take note of Einstein's general theory of relativity. The theory of relativity tells us that whenever the force of gravity in a region grows in strength, time there flows more slowly. As the object shrinks, the force of gravity on it grows and the watch of observer B runs more and more slowly than the watch of the faraway observer A. So, although

B diligently sends his signals every minute, as measured by his watch, to A the interval between signals is longer than a minute. This effect is known as time-dilatation. And at the stage of becoming a black hole, time dilatation reaches infinity and B's time almost stands still as noted by A's watch. So one can say that Brahma's den was close to becoming a black hole and Kukudmi was experiencing no more than time dilatation!

Black holes, for many of us, are a here-and-now phenomenon. Doesn't time stand still in a government office?

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Earth's gravity has become. If the Earth were compressed further, it would finally become a black hole when its diameter shrank to around 18 millimetres. For the Sun to become a black hole, its diameter would have to become as small as six kilometres, much smaller than its present diameter of 14 lakh kilometres. But we can rest assured that neither the Sun, nor the Earth have a contracting tendency strong enough to become black holes. The internal pressures in these bodies are capable of preventing this outcome.

While looking for a candidate to become a black hole, astronomers look for an object so massive, that there is no known physical agency