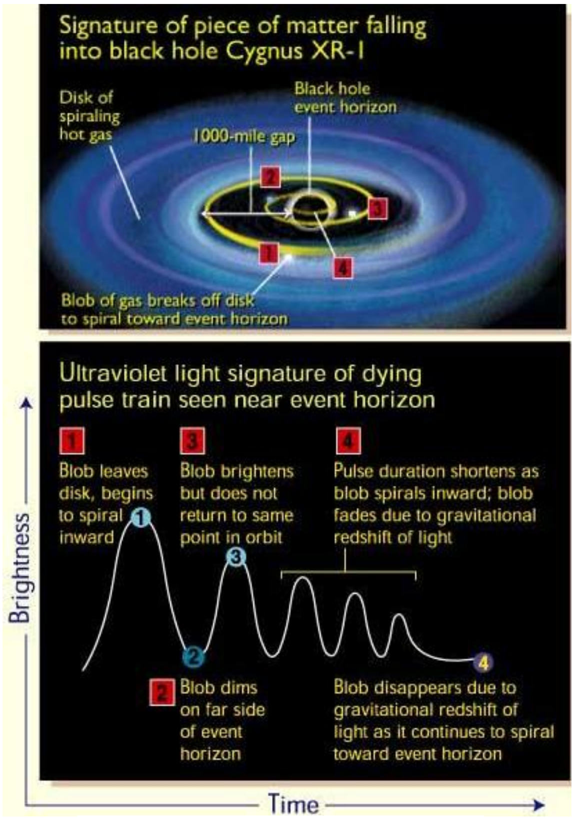
Black Hole...Fade-out!



$$L = L_0 e^{\frac{-2T}{3\sqrt{3}\ 2M}}$$

As seen from a distance, not only does the passage of time slow down for someone falling into a black hole, but the image fades to black!

This happens because, during the time that the object reaches the event horizon and passes beyond, a finite number of light particles (photons) will be emitted. Once these have been detected to make an image, there are no more left because the object is on the other side of the event horizon and the photons cannot escape. A star, collapsing to a black hole, will be going very fast as it collapses, then appear to slow down as time 'dilates'. Meanwhile, the image will become redder and redder, until it literally fades to black!

Photographs taken by the Hubble Space Telescope of the black-hole candidate called Cygnus XR-1 detected two instances where a hot gas blob appeared to be slipping past the event horizon for the black hole. Because of the gravitational stretching of light, the fragment disappeared from Hubble's view before it ever actually reached the event horizon. The pulsation of the blob, an effect caused by the black hole's intense gravity, also shortened as it fell closer to the event horizon. Without an event horizon, the blob of gas would have brightened as it crashed onto the surface of the accreting body. See The Astrophysical Journal, 502:L149–L152, 1998 August 1

Diagram courtesy Ann Field (STScI)

Problem 1 - The simple formula predicts the exponential decay of the light from matter falling in to a black hole. T is the time in seconds measured by distant observer, and M is the mass of the black hole in units of solar masses. How long does it take for the light to fall to half its initial luminosity (i.e. power in units of watts) given by L_0 for a M =1.0 solar mass, stellar black hole?

Problem 2 - How long will your answer be, in years, for a supermassive black hole with M = 100 million times the mass of the sun?

Problem 3 - A supermassive black hole 'swallows' a star. If the initial luminosity, L_0, of the star is 2.5 times the sun's, how long will it take before the brightness of the star fades to 0.0025 Suns, and can no longer be detected from Earth?

Answer Key:

Problem 1 - The simple formula predicts the exponential decay of the light from matter falling in to a black hole. T is the time in seconds measured by distant observer, and M is the mass of the black hole in units of solar masses. How long does it take for the light to fall to half its initial luminosity (i.e. power in units of watts) given by L_0 for a M =1.0 solar mass, stellar black hole??

Answer - Set L = 1/2 L_0, and M = 1.0, then solve for T. The formula is 0.5 = e (-0.19 T) Tale the natural logarithm of both sides to get -0.69 = -0.19 T so T = 3.6 seconds.

Problem 2 - How long will your answer be, in years, for a supermassive black hole with M = 100 million times the mass of the sun?

Answer, The formula will be 0.5 = e (- 1.9 x 10^{-9} T) so -0.69 = -1.9 x 10^{-9} T, and T = 3.6 x 10^{8} seconds. If there are 3.1 x 10^{7} seconds in 1 year, T = 11.5 years.

Problem 3 - A supermassive black hole 'swallows' a star. If the initial luminosity, L_0, of the star is 2.5 times the sun's, how many years will it take before the brightness of the star fades to 0.0025 Suns, and can no longer be detected from Earth?

Answer:

0.0025 L_{sun} = 1.0 L_{sun} e (-1.9x10-9 T)
Ln(0.0025) = -1.9x10^{-9} T
-6.0 = -1.9x10^{-9} T
T = 6.0/1.9x10^{-9}
T = 3.2 x 10^{9} seconds
T = 3.2 x 10^{9} seconds x (1.0 year /3.1 x 10^{7} seconds)
T = 103 years.