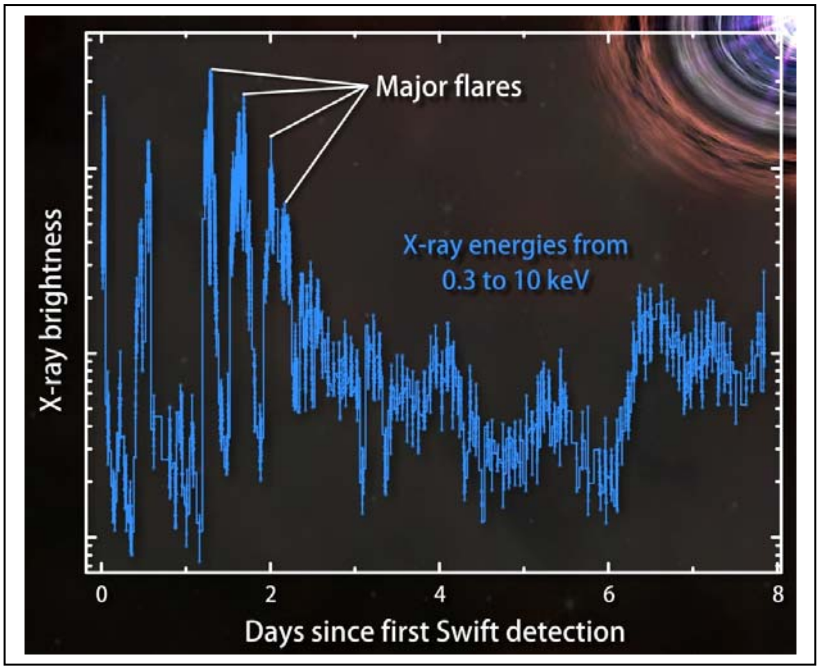

On March 28, 2011 Swift's Burst Alert Telescope discovered the source in the constellation Draco when it erupted with the first in a series of powerful X-ray blasts. The satellite determined a position for the explosion, now cataloged as gamma-ray burst (GRB) 110328A, and informed astronomers worldwide. As dozens of telescopes turned to study the spot, astronomers quickly noticed that a small, distant galaxy appeared very near the Swift position. A deep image taken by Hubble on April 4 pinpoints the source of the explosion at the center of this galaxy, which lies 3.8 billion light-years away.

That same day, astronomers used NASA's Chandra X-ray Observatory to make a four-hour-long exposure of the puzzling source. The image, which locates the object 10 times more precisely than Swift can, shows that it lies at the center of the galaxy Hubble imaged.

The duration of the x-ray bursts tells astronomers approximately how large the emitting region is, and since the source is a black hole, it gives the approximate diameter of the black hole. The radius of a black hole is related to its mass by the simple formula $R = 3\ M$,where M is the mass of the black hole in units of the sun's mass, and R is the radius of the Event Horizon in kilometers.

Problem 1 - What is the average duration of the three flare events seen in the X-ray plot above?

Problem 2 - Light travels at a speed of 300,000 km/s. How many kilometers across is the x-ray emitting region based on the average time of the three x-ray flares?

Problem 3 - The size of the x-ray emitting region from Problem 2 is a crude estimate for the diameter of the black hole. For reasons having to do with relativity, a better black hole size estimate will be 100 times smaller than your answer for Problem 2. From this better-estimate, about what is the mass of the black hole GRB110328A in solar masses?

Problem 1 - What is the average duration of the three flare events seen in the X-ray plot above?

Answer: There were about 3 flares in one day, so the average flare duration is about **8 hours**.

Problem 2 - Light travels at a speed of 300,000 km/s. How many kilometers across is the x-ray emitting region based on the average time of the three x-ray flares?

Answer: Distance = speed x time, so D = 300,000 km/s x 8 hours x (3600 sec/1 hour) = **8.6 billion kilometers.**

Problem 3 - The size of the x-ray emitting region from Problem 2 is a crude estimate for the diameter of the black hole. For reasons having to do with relativity, a better black hole size estimate will be 100 times smaller than your answer for Problem 2. From this better-estimate, about what is mass of the black hole in solar masses?

Answer: If 8.6 billion kilometers is the width of the emitting region, then the radius of the region is about 4.3 billion kilometers, and the estimated radius of the black hole is about 100 times smaller than this or 43 million kilometers. Since the radius of a black hole is R = 3 x M, the mass of the black hole is 43 million = 3 x M, or M = **14 million solar masses**.

Note: Astrophysicists have studied and modeled these kinds of events for decades, and it is generally agreed that gamma-ray bursts are probably caused by beams of particles and radiation leaving the vicinity of the black hole. Because of this, the estimated light-travel size of the emitting region from the changes in the gamma ray or x-ray brightness will greatly over-estimate the actual size of the emitting region. The 'factor of 100' is added to this calculation to account for this 'beaming' effect. Actual astrophysical models of these regions that take into account relativity physics are still in progress and will eventually lead to much better estimates for the black hole size and mass. Also, the relationship between black hole radius and mass that we used only works for black holes that do not rotate, called 'Schwarschild Black Holes'. In actuality, we expect most black holes to be rotation, at speeds that are perhaps even near the speed of light, and these will be significantly larger in size. These are called Kerr Black Holes.