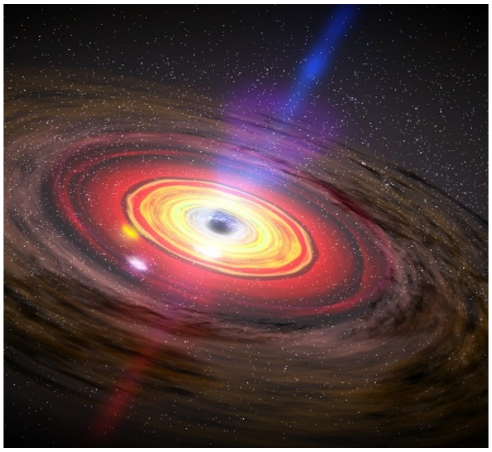

The centers of most galaxies contain massive black holes that are often consuming nearby gas and stars. As they do this, they grow in mass, and the heated gases emit huge amounts of energy.

Today we know of many nearby 'supermassive' black holes that contain billions of times the mass of our sun. Astronomers think that they grew so large by steadily consuming matter over nearly the entire age of our universe, which is about 13.7 billion years. What we don't know is how quickly they consumed the stars and matter around them to get as big as they are today.

The most massive black hole known was discovered in 2012, and is located in the core of the nearby galaxy NGC-1277. It has a mass equal to 17 billion times the mass of our sun (17 billion solar masses). The most distant supermassive black hole was discovered in 2009 and contains about 1 billion times the mass of our sun. This galaxy, called CFHQSJ2329-0301, is so far away its light took 12.8 billion years to reach Earth. The galaxy, at the time we are now seeing, it is only about 600 million years old.

An astronomer wants to create a simple model of how the NGC-1277 black hole has grown over time. Galaxies in our universe went through a very rapid star forming phase that ended about 8 billion years ago, and are now producing stars at a more sluggish rate since then. The astronomer imagines that the NGC-1277 supermassive black hole changed in a similar way with a rapid phase of growth followed by a slower phase of growth to the present time. For the rapid phase of growth, he uses the CFHQSJ2329-0301 black hole as a model. For the slow growth phase, he uses the Milky Way black hole as a model.

Problem 1 – What was the average rate at which the CFHQSJ2329-0301 black hole gained mass? Give your answer in solar masses per year.

Problem 2 – Write an equation that gives the mass of the NGC-1277 black hole using the CFHQSJ2329-0301 black hole as a guide, and starts with a black hole 'seed' mass of 1,000 solar masses. If the NGC-1277 black hole kept growing at the same rate, how massive would it be now (12.8 billion years after most galaxies in our universe formed)?

Problem 3 – Write a second linear equation that assumes a mass growth rate that is 1/10 of the initial rapid phase. When does this new, slower, growth phase have to start so that the current mass of the black hole is exactly 17 billion solar masses?

Answer Key

Problem 1 – What was the average rate at which the CFHQSJ2329-0301 black hole gained mass.

Answer: rate = 1 billion suns/600 million years = 1.7 solar masses/year.

Problem 2 – Write an equation that gives the mass of the NGC-1277 black hole using the CFHQSJ2329-0301 black hole as a guide, and starts with a black hole 'seed' mass of 1,000 solar masses. If the NGC-1277 black hole kept growing at the same rate, how massive would it be at the present time, which is 12.8 billion years later?

Answer: Mass = 1000 + 1.7T.
For T = 12.8 billion years,
mass = 1000 + 1.7(12.8 billion) = 21.7 billion suns.

Problem 3 - Write a second linear equation that assumes a mass growth rate that is 1/10 of the initial rapid phase. When does this new, slower, growth phase have to start so that the current mass of the black hole is exactly 17 billion solar masses?

Answer: There are two time periods T1 is the rapid phase and T2 is the slow phase,
but T2 = 12.8billion years – T1
so
m = m1 + 0.17T2
and so:
17 billion = m1 + 0.17(12.8 billion – T1)
17 billion = m1 + 2.2 billion – 0.17T1
14.8 billion = m1 – 0.17T1

M1 is provided by the first growth rate given by m1 = 1000 + 1.7T1
So:

14.8 billion = (1000 + 1.7T1) – 0.17T1
14.8 billion = 1.53T1
So T1 = 9.7 billion years.

So, NGC-1277 grows at a rate of 1.7 solar masses/year for the first 9.7 billion years and grows to a total mass of 16.5 billion solar masses, then it grows at a rate of 0.17 solar masses/year for the next 12.8-9.7 = 3.1 billion years by adding an additional 0.5 billion solar masses, to reach a final mass of 16.5 + 0.5 = 17 billion solar masses.

Note: our Milky Way's black hole has a masses of 4 million solar masses, and may be about 12 billion years old, for an average growth rate of 0.0003 solar masses/year, but other more massive galaxies have denser core regions and average rates between 0.1 and 1.0 are not that unusual. The most luminous galaxies, called quasars, have mass growth rates of 5 to 10 solar masses/year or more for short periods of time (a few 100 million years).