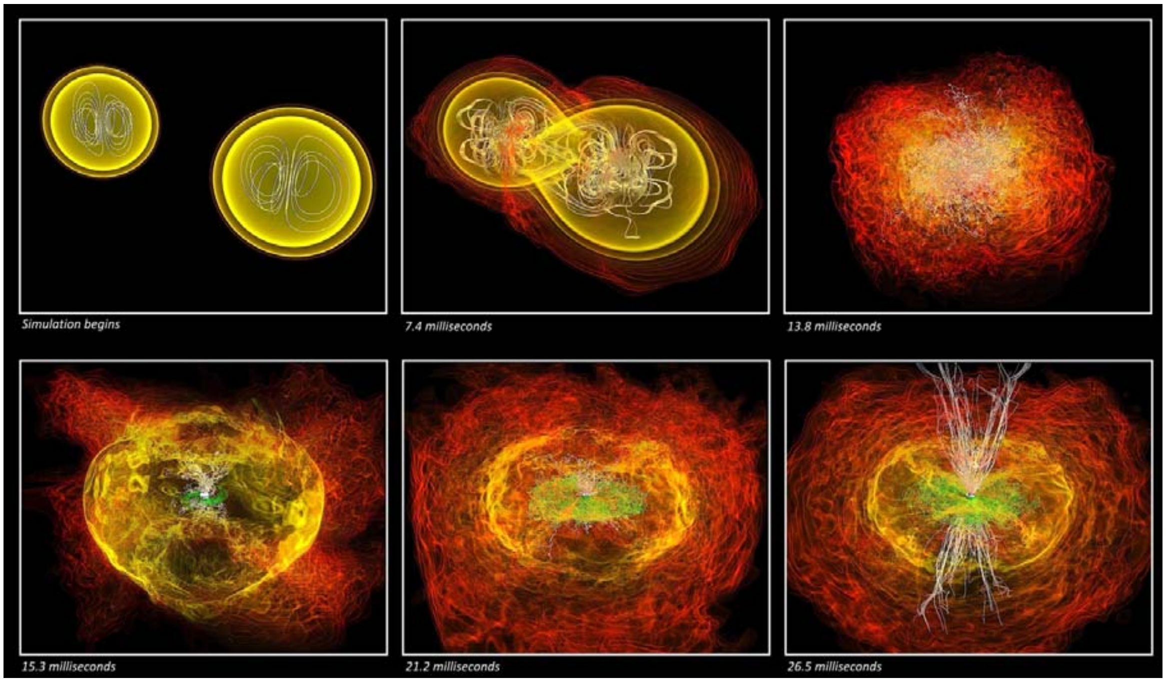

Once astrophysicists understand the physics involved, they can use supercomputers to model events that can never be observed first-hand. The panel of images above was created by Dr's Koppits and Rezolla, and shows what happens to two neutron stars when they collide and merge. They wanted to find out whether the magnetic fields re-arrange themselves to allow jets of matter to be 'beamed out' of the collision area. Each image, from the upper left to the lower right, represents snapshots of the event calculated by the supercomputer at 0.0, 0.007, 0.014, 0.015, 0.021 and 0.026 seconds. The width of each image is about 48 kilometers. Each neutron star, the dense core of a star after a supernova, has a mass of about 1.5 times our own sun.

Problem 1 - How fast were the two neutron stars approaching each other between 0.007 and 0.014 seconds after the star of the calculation?

Problem 2 - The radius of a black hole with a mass of M solar masses is given by the formula R = 3.0 M, where R is the radius of the event horizon in kilometers. If the last calculated image at 0.026 seconds represents the final size of the neutron star merger, will it become a black hole?

Problem 3 - The double cone formed by the neutron star's magnetic field is shown in the last computed image at 0.026 seconds after the start of the collision. Astrophysicists predict that high-speed particles and radiation will flow out of the neutron stars within this 'beaming channel' formed by these concentrated magnetic fields. From the measured angle, and by using any method, what will be the width of this beam by the time it leaves its galaxy and reaches our Milky Way located 5 billion light years away in A) light years? B) Milky Way diameters if 1 MW = 100,000 light years?

Problem 1 - How fast were the two neutron stars approaching each other between 0.007 and 0.014 seconds after the star of the calculation?

Answer: The width of each image is 48 kilometers, and using a millimeter ruler, the width is about 48 millimeters, so the scale is 1 kilometer/mm. The center to center separation between the neutron stars was 18 millimeters or 18 kilometers at 0.007 seconds, and 0 millimeters at 0.014 seconds, so the distance traveled was 18 kilometers in (0.014 – 0.007) = 0.007 seconds. The speed is then S = 18 km/0.007 sec or **2600 kilometers/sec**.

Problem 2 - The radius of a black hole with a mass of M solar masses is given by the formula R = 3.0 M, where R is the radius of the event horizon in kilometers. If the last calculated image at 0.026 seconds represents the final size of the neutron star merger, will it become a black hole?

Answer; If no mass is lost, the final mass is 3.0 solar masses, so the radius of the black hole will be R = 9 kilometers. For a black hole to form, the mass must be located inside this radius. The last image shows that the matter in the collision has an extent of about 20 km, so a black home will **probably not form**.

Problem 3 - The double cone formed by the neutron star's magnetic field is shown in the last computed image at 0.026 seconds. Astrophysicists predict that high-speed particles and radiation will flow out of the neutron stars within this 'beaming channel' formed by these concentrated magnetic fields. From the measured angle, and by using any method, what will be the width of this beam by the time it leaves its galaxy and reaches our Milky Way located 5 billion light years away in: A) light years? B) Milky Way diameters if 1 MW = 100,000 light years?

Answer: Students may use a protractor to measure this angle. Answers near 30 degrees are acceptable.

A) Method 1: Students may draw a scaled drawing of this event.

Method 2 : The full circumference of the circle is 360 degrees, so a 30-degree segment represents about (30/360) = 1/12 of the full circumference. The circumference is 2 p d = 6.24 x 5 billion = 31 billion light years, so 1/12 of this is **about 2.6 billion light years**.

Method 3: The tangent of one-half the angle is equal to the ½ of the width of the beam divided by the distance to the Milky Way, so w = 2 d x Tan(θ/2). For θ = 30 and d = 5 billion light years, w = **2.7 billion light years**.

B) Width = 2.7 billion x (1 MW/100,000 ly) = **27,000 Milky Way diameters!**

Note: The outflowing energy tends to be even more tightly beamed than this rather large angle. Estimates of about 0.6 degrees are not uncommon when actual beaming events are observed and analyzed. The width of this beam at a distance of 5 billion light years is more like (0.6/30)x2.7 billion light years or about 50 million light years. This is about 500 times the width of the Milky Way!