IC-443 supernova remnant located 5,000 light years from Earth. The purple color shows the location of the gamma rays seen by Fermi. The supernova remnant has many filaments of gas in which the cosmic rays are boosted in speed.

Cosmic rays are fast-moving particles that travel through space at nearly the speed of light, though they are not electromagnetic radiation at ll. Instead, they are typically electrons and the nuclei of atoms such as hydrogen and helium. Since their discovery in the 1940s, astronomers have speculated that they are created when stars explode as supernovae. The tremendous energy of the explosion ejects matter from the outer layers of the star into space. As this matter spreads out into individual atoms and nuclei, they become the particles we see in cosmic rays.

NASA's Fermi Gamma Ray Observatory has studied the gamma rays that comes from the remains of two nearby supernovae called IC-443 and W44, and has confirmed that the expanding matter does produce cosmic rays.

In space, the average density of cosmic rays is about 0.005 cosmic rays/meter^{3}.

Problem 1 – The Milky Way is a disk shaped system of stars with a radius of 50,000 light years and a thickness of about 3,000 light years. One light year is equal to 9.5×10^{15} meters. What is the volume of the Milky Way galaxy in cubic meters?

Problem 2 - About what is the total number of cosmic rays in the Milky Way galaxy?

Problem 3 – Suppose a single supernova can eject 2.0×10^{30} kilograms of matter into space. If the mass of a single proton is 1.6×10^{-27} kg, how many hydrogen nuclei does this represent?

Problem 4 – About how many supernova would be required to 'fill up' the Milky Way with cosmic rays if all of the ejected mass in hydrogen atoms were converted into cosmic rays?

Problem 1 - The Milky Way is a disk shaped system of stars with a radius of 50,000 light years and a thickness of about 3,000 light years. One light years is equal to 9.5x1015 meters. About what is the volume of the Milky Way in cubic meters?

Answer: The volume of the galaxy is $V = \pi R^2 H = 3.141 \times (50000 \times 9.5 \times 10^{15})^2 (3000 \times 9.5 \times 10^{15}) =$ **2.0×10^{61} meters^3**.

Problem 2 - About what is the total number of cosmic rays in the Milky Way galaxy?

Answer: $N = 0.005 \times 2.0 \times 10^{61} = 1.0 \times 10^{59}$ cosmic rays.

Problem 3 – A single supernova can eject 2.0×10^{30} kilograms of matter into space. If the mass of a single proton is 1.6×10^{-27} kg, how many hydrogen nuclei does this represent?

Answer: 2.0×10^{30} kg x (1 hydrogen atom/1.6×10^{-27} kg) = **1.3×10^{57} hydrogen atoms**.

Problem 4 – About how many supernova would be required to 'fill up' the Milky Way with cosmic rays if all of the ejected mass in hydrogen atoms were converted into cosmic rays?

Answer: 1.0×10^{59} cosmic rays x (1 Supernova/1.3×10^{57} hydrogen atoms) = **77 supernova**.

Note: These are only estimates that fit the simple origins model we used. In fact, the actual amount of matter converted into cosmic rays per supernova explosion is far less than what was used in Problem 3. The present population of cosmic rays has been built up over billions of years as millions of stars have become supernova. Each supernova adds its share to the Milky Way's cosmic ray 'atmosphere'. Over time, many of these cosmic rays actually leave the Milky Way galaxy entirely. The Milky Way is not a closed vessel that accumulates cosmic rays but a leaky bag.