# Hinode Studies Loopy Sunspots!

The solar surface is not only a hot, convecting ocean of gas, but is laced with magnetism. The sun's magnetic field can be concentrated into sunspots, and when solar gases interact with these magnetic fields, their light lets scientists study the complex 'loopy' patterns that the magnetic fields make as they expand into space. The above image was taken by NASA's TRACE satellite and shows one of these magnetic loops rising above the surface near two sunspots. The horseshoe shape of the magnetic field is anchored at its two 'feet' in the dark sunspot regions. The heated gases become trapped by the magnetic forces in sunspot loops, which act like magnetic bottles. The gases are free to flow along the lines of magnetic force, but not across them. The above image only tells scientists where the gases are, and the shape of the magnetic field, which isn't enough information for scientists to fully understand the physical conditions within these magnetic loops. Satellites such as Hinode carry instruments like the EUV Imaging Spectrometer, which lets scientists measure the temperatures of the gases and their densities as well.

Problem 1: The Hinode satellite studied a coronal loop on January 20, 2007 associated with Active Region AR 10938, which was shaped like a semi-circle with a radius of 20,000 kilometers, forming a cylindrical tube with a base radius of 1000 kilometers. What was the total volume of this magnetic loop in cubic centimeters assuming that it is shaped like a cylinder?

Problem 2: The Hinode EUV Imaging Spectrometer was able to determine that the density of the gas within this magnetic loop was about 2 billion hydrogen atoms per cubic centimeter. If a hydrogen atom has a mass of $1.6 \times 10^{-24}$ grams, what was the total mass of the gas trapped within this cylindrical loop in metric tons?

## Answer Key:

**Problem 1:** The Hinode satellite studied a coronal loop on January 20, 2007 associated with Active Region AR 10938, which was shaped like a semi-circle with a radius of 20,000 kilometers, forming a cylindrical tube with a base radius of 1000 kilometers. What was the total volume of this magnetic loop in cubic centimeters assuming that it is shaped like a cylinder?

Answer: The length (h) of the cylinder is 1/2 the circumference of the circle with a radius of 20,000 km or $h = 1/2 (2\pi R) = 3.14 \times 20{,}000$ km = 62,800 km

The volume of a cylinder is $V = \pi R^2 h$ so that the volume of the loop is

$V = \pi (1000 \text{ km})^2 \times 62{,}800$ km

$= 2.0 \times 10^{11}$ cubic kilometers.

1 cubic kilometer = $10^{15}$ cubic centimeters so

= **$2.0 \times 10^{26}$ cubic centimeters**

**Problem 2:** The Hinode EUV Imaging Spectrometer was able to determine that the density of the gas within this magnetic loop was about 2 billion hydrogen atoms per cubic centimeter. If a hydrogen atom has a mass of $1.6 \times 10^{-24}$ grams, what was the total mass of the gas trapped within this cylindrical loop in metric tons?

Answer: The total mass is the product of the density times the volume, so

Density = $2 \times 10^{9}$ particles/cc x ($1.6 \times 10^{-24}$ grams/particle) = $3.2 \times 10^{-15}$ grams/cm$^3$

The approximate volume of the magnetic loop in cubic centimeters is

$V = (2.0 \times 10^{11} \text{ km}^3) \times (1.0 \times 10^{15} \text{ cm}^3/\text{km}^3)$

$= 2.0 \times 10^{26} \text{ cm}^3$

Mass = Density x Volume = $(3.2 \times 10^{-15} \text{ grams/cm}^3) \times (2.0 \times 10^{26} \text{ cm}^3) = 6.4 \times 10^{26-15}$ = $6.4 \times 10^{11}$ grams or $6.4 \times 10^{8}$ kilograms or **640,000 metric tons.**