The most distant galaxy cluster yet has been discovered by combining data from NASA's Chandra X-ray Observatory and optical and infrared telescopes. The cluster is located about 10.2 billion light years away, and is observed as it was when the Universe was only about a quarter of its present age. The galaxy cluster, known as JKCS041, beats the previous record holder by about a billion light years. Galaxy clusters are the largest gravitationally bound objects in the Universe.

JKCS041 was originally detected in 2006 in a survey from the United Kingdom Infrared Telescope (UKIRT). The Chandra data were the final - but crucial - piece of evidence that showed JKCS041 was, indeed, a genuine galaxy cluster. Clusters of galaxies have such strong gravitational fields that they can serve as a bottle for very high temperature gas. These gases often emit x-ray light that can be detected by observatories such as Chandra. The discovery of such a high-temperature gas between the galaxies in JKCS041 supports the original idea that the galaxies seen in that direction are, in fact, members of a cluster. From the X-ray information, astronomers can also measure the total mass of the entire cluster that is responsible for creating the gravitational field holding the gas in place.

Problem 1 - The Chandra satellite detected x-rays coming from the region of the sky containing the galaxy cluster JKS041. The electrons in the gas are emitting the X-rays, and colliding at high speed with the protons in the gas. The energy of the x-rays at the time they were emitted by the hot gas was 21,400 electron Volts (eV). This energy is shared equally between the electrons and protons. The speed of a proton is related to its kinetic energy by $E = 1/2mV^{2}$ where E is the energy in Joules, V is the proton speed in meters/sec, and m is the mass of a proton ($m = 1.7 \times 10^{-27}$ kg). About how fast are the protons moving? (Note: 1 eV = 1.6×10^{-19} Joules)

Problem 2 -The escape velocity (in km/s) from a body is given by $V = 0.17 (M/R)^{1/2}$ where M is the mass in multiples of the mass of our sun, and R is the average distance, in light years, between the body and the gas particle. Example, for the Milky Way, R = 50,000 light years and M = 300 billion so V = 420 km/sec. Compared to the sun, about how much mass do you need to confine the gas cloud observed by Chandra, if the cluster of galaxies has a radius of about 1 million light years A) in units of the sun's mass? B) In terms of the number of Milky Way galaxies where 1 Milky Way is about 2×10^{12} solar masses?