Spitzer Explores a Dusty Young Star

This is an image taken by the Spitzer Space telescope in the infrared part of the electromagnetic spectrum. Instead of seeing the light from stars, it sees mainly the light from heated dust grains in space, glowing with temperatures between 100 to 200 K degrees.

These bright young stars are found in a rosebud-shaped (and rose-colored) nebulosity known as NGC 7129. The star cluster and its associated nebula are located at a distance of 3300 light-years in the constellation Cepheus. A recent census of the cluster reveals the presence of 130 young stars. The stars formed from a massive cloud of gas and dust. Most stars in our Milky Way galaxy, including our own sun, are thought to form in such clusters.

Most of the infrared light comes from a deeply embedded proto-star called FIR-2, which produces 430 times the total power of the sun, with a temperature of about 35 K. We can use this information to estimate the mass of this nebula!

Problem 1 - A single dust grain is about 0.2 microns in diameter, and has a density of about 2 grams/cm^3. What is the total mass, in grams, of this dust grain if it has a spherical shape?

Problem 2 - What is the total power produced by this infrared source if the power from the sun is 3.8 x 10^{33} ergs/sec?

Problem 3 - A single dust grain, 0.2 microns in diameter, at a temperature of 35 K, emits about 7.0 x 10^{-13} ergs/sec of power. How many dust grains are needed to produce the infrared power observed from FIR-2?

Problem 4 - From your answer to Problem 1 and 3, what is the total mass of dust grains involved in producing the infrared light from FIR-2; A) in grams? B) In units of the sun's mass which is 1.9 x 10^{33} grams?

Problem 5 - By mass, the interstellar medium consist of 99% gas and 1% dust grains. If the gas within FIR-2 has the same composition, what is the total mass of the interstellar medium within FIR-2 in Solar Masses?

Answer Key:

Problem 1 - A single dust grain is about 0.2 microns in diameter, and has a density of about 2 grams/cm^{3}. What is the total mass, in grams, of this dust grain if it has a spherical shape?

Answer: Radius = 1.0 microns,
Mass = Volume x Density
= 4/3 π R^{3} x Density
= 4/3 x 3.14 x (0.1 x 10^{-4})^{3} x 2.0
= 8.4 x 10^{-15} grams

Problem 2 - What is the total power produced by this infrared source if the power from the sun is 3.8 x 10^{33} ergs/sec?

Answer: Power = 430 x 3.8 x 10^{33} ergs/sec **= 1.6 x 10^{36} ergs/sec**

Problem 3 - A single dust grain, 0.2 microns in diameter, at a temperature of 35 K, emits about 7.0 x 10^{-13} ergs/sec of power. How many dust grains are needed to produce the infrared power observed from FIR-2?

Answer: Number = 1.6 x 10^{36} ergs/sec / 7.0 x 10^{-13} ergs/sec/dust grain
= 2.3 x 10^{48} dust grains

Problem 4 - From your answer to Problem 1 and 3, what is the total mass of dust grains involved in producing the infrared light from FIR-2; A) in grams? B) in units of the sun's mass which is 1.9 x 10^{33} grams?

Answer: A) 8.3 x 10^{-15} grams / dust grain x 2.3 x 10^{48} dust grains **= 1.9 x 10^{34} grams**
B) 1.9 x 10^{34} grams / 1.9 x 10^{33} grams = **10.0 Solar Masses.**

Problem 5 - By mass, the interstellar medium consist of 99% gas and 1% dust grains. If the gas within FIR-2 has the same composition, what is the total mass of the interstellar medium within FIR-2 in solar Masses?

Answer - 100 x 10.0 = **1000 Solar Masses**.

The actual dust mass has been estimated as about 6 solar masses by C. Eiroa (AA 1998, v. 335, p. 243. and Muzerolle, et al, 2004, ApJ Suppl. V. 154, p.379.) The largest uncertainty in the problem is the size of the dust grain and the infrared radiation power emitted by the dust grain. This problem assumed that the dust grain size is typical of what is found for interstellar dust grains. But in the environment of the protostar, dust grain sizes are expected to vary due to grain growth. Also, the reflectivity (albedo) of the dust grain depends on its composition and size in a complex way.