This young star cluster, barely 1 million years old, is still surrounded by the clouds of interstellar gas and dust from which it formed. The nebula, located 20,000 light-years away in the constellation Carina, contains a central cluster of 50, huge, hot stars.

The image to the left was taken by the Hubble Space Telescope, and is 20 light years across.

The massive, hot stars in this cluster emit nearly 1/3 of their light at ultraviolet wavelengths and shorter. A single ultraviolet photon, when it encounters a hydrogen atom, can fully ionize the atom so that the lone electron is stripped away from the hydrogen's proton nucleus. These stars produce so many ultraviolet photons that they can ionize the entire gas cloud that surrounds them to a distance of many light years.

Problem 1 - A star with a temperature of 40,000 K emits about $6x10^{49}$ ultraviolet photons each second. The density of the hydrogen gas surrounding the star is about 100 atoms/cm^3. How many hydrogen atoms exist in a volume of space with a radius of 3 light years? (1 ly = 9.5×10^{17} centimeters.)

Problem 2 - The size of an ionized region is determined by the balance between the rate at which ultraviolet photons are ionizing the hydrogen atoms, and the rate at which the electrons 'recombine' with the protons to re-form the hydrogen atom. A formula that determines the radius of an ionization region is given by

$$R^3 = 2.6x10^{11}\frac{P}{n^2}$$

If P = $6.0x10^{49}$ photons/sec and n = 100 atoms/cm^3, what is the radius of this nebula in light years?

Image credit: NASA, ESA, R. O'Connell (University of Virginia), F. Paresce (National Institute for Astrophysics, Bologna, Italy), E. Young (Universities Space Research Association/Ames Research Center), the WFC3 Science Oversight Committee, and the Hubble Heritage Team (STScI/AURA)

Problem 1 - A star with a temperature of 40,000 K emits 6.0×10^{49} ultraviolet photons each second. The density of the hydrogen gas surrounding the star is about 100 atoms/cm^3. How many hydrogen atoms exist in a volume of space with a radius of 12 light years? (1 ly = 9.5×10^{17} centimeters.)

Answer: R = $12 \times 9.5 \times 10^{17}$ cm = 1.1×10^{19} centimeters. V = 4/3 π R^3, so V = 1.66(3.14) $(1.1 \times 10^{19})^3$ = 5.6×10^{57} cm^3. The number of hydrogen atoms is just N = 100 atoms/cc x 5.6×10^{57} cm^3 = **5.6×10^{59} atoms**.

Problem 2 - The size of an ionized region is determined by the balance between the rate at which ultraviolet photons are ionizing the hydrogen atoms, and the rate at which the electrons 'recombine' with the protons to re-form the hydrogen atom. A formula that determines the radius of an ionization region is given by

$$R^3 = 2.6x10^{11} \frac{P}{n^2}$$

If P = 6.0×10^{49} photons/sec and n = 100 atoms/cm^3, what is the radius of this nebula in light years?

Answer: $$R^3 = 2.6x10^{11} \frac{(6.0x10^{49})}{100^2}$$ so

$R^3 = 1.6 \times 10^{57}$

R = 1.1×10^{19} cm.

Then R = 1.1×10^{19} cm x (1 ly/9.5×10^{17} cm) = **12 light years**.

Note: NGC-3603 contains 50 of these stars. At the above gas density, this cluster can form a nebula with a radius of at least 12 light years x $50^{1/3}$ = 44 light years, which is quite a bit larger than the scale of the Hubble image.