The Interstellar Medium

HI and HII Regions

HI is neutral hydrogen; HII is ionized hydrogen (what we chemists call H+).

The red color comes from hydrogen electrons which have been excited (promoted to higher energy levels) and then relax, giving off that energy in the form of visible light. The strongest emission wavelength for H is at 656.6 nm, which is called H-α (hydrogen-alpha). The blue in this image is H-β and the green Oxygen-III.

The excitation energy for this object is the bright yellow region off-center. Wind from the young, hot stars in this image blow the gas into the wispy filaments you see.

A true-color image of the LMC HII region N159 taken with HST.

Dust (what about HI?)

- The dark objects in the image at left are globules, or extremely dense dust clouds. They absorb visible light.
- Many times dust clouds surround molecular clouds (especially HII regions) where star formation is occurring, making it difficult to image young stars in visible light.
- In this image, the dust clouds are surrounded by a number of O stars. The O stars put out intense UV radiation which is destroying the globules slowly. Radio imagery shows the dust particles moving around in the globules. These globules possibly would have become stars if not for the activity of the O stars.
- Each cloud is about 1.4 ly wide and together they contain about 15 Ms.

More Dust

Dust has two major effects:

1. Extinction – prevents transmission of visible light by absorbing it.

Composition of interstellar dust grains (Leiden Observatory)

Radio observing

1. Synchrotron radiation – very directional, polarized. Caused by electrons moving in a magnetic field. This differs from other types of radiation in that it is isotropic (directional). Thus, we can learn more from this type of radiation.

The Egg Nebula, at right, shown in polarized visible light. The polarization shows the direction the light is affected by dust. This is analogous to what hapens with radio waves.

Optical(1) and X-ray(2) images of a jet in M87 from a black hole at its center.

21-cm Radiation

1. Hydrogen atoms contain one electron. All electrons have a property called “spin” which is analogous to the same quality in a top: tops can spin in either direction, but when electrons change spin directions, we say their tops point down (spin “up” or “down”). This is similar to the right-hand rule for angular momentum.

2. The spin direction in an H atom is random, and occasionally it flips. When it does so, 21-cm radiation is released. A wavelength of 21 cm is very low energy. In the radio part of the spectrum.

Image courtesy of Nick Strobel’s Astronomy Notes.

Centaurus A, an active galaxy. Blue = X-ray; the green is 21-cm radiation showing atomic H.
21 cm Radiation: (uhn) What is it good for?

1. 21-cm radiation is unique to H – no misinterpreting.
2. It is not impeded by dust.
3. Doppler shift is easy to observe, so we can tell the velocity of any H cloud we look at.

Watch the pretty cloud at the right.
- Using Kepler’s laws, we can predict how fast an object should be revolving around the galactic center at a given distance (remember this is independent of mass).
- The fact that things farther out should complete less of a rotation in the time a closer thing would is called differential rotation.
- We can measure differential rotation from the Doppler shift of 21-cm radiation! Thus, we can map out the positions of H clouds in the galaxy and see structure without having to take a picture from outside.

Molecules in Spaaaaace

At left we see clouds of $^{13}$CO in Orion. The different colors represent gas at different velocity intervals: the red colored gas is the most blueshifted, and the green colored gas is at rest. The lower triangular shaped cloud is Orion A, while the mass of ionized gas to the upper left is Orion B. The Orion Nebula, the current densest concentration of new stars in this region is within the bright yellow spot in Orion A, just below the red-colored gas at the top of the cloud.

Molecules are often formed in dust grains, which stabilize the atoms being close together. They are easily destroyed by the intense radiation in space, but we see a number of different types of molecules, many of which can exist in the dense atmosphere on earth.

Other molecules seen in space include amino acids, benzene, acetylene, acetaldehyde, and lots of other simple, stable molecules which could indicate how simple chemical compounds, and even the first molecules supporting life, were on the earth (comets bearing life…?)