

HOMEWORK ASSIGNMENT # 3

Due: Monday, 3 May

Read the article “It’s a dusty Universe: surface science in space” and answer the following questions:

1) How do we know that there are dust particles in space? Could the observations mean that there is just lots of dense gas?

ANS: Dust particles are detected and analyzed by a variety of methods, which leave no doubt that the particles exist. First, there is the shape of the so-called extinction curve. As starlight passes through the interstellar medium, it is reduced in intensity with a characteristic dependence on wavelength caused by small particles rather than gas-phase species. This dependence is known as the extinction law. Secondly, dust particles scatter and polarize starlight. Third, broad absorption and emission features in the infrared cannot be due to molecules, which possess narrow features, but are ascribed to vibrational transitions of molecular species on grain mantles and within grain cores. Fourth, absorbed starlight is reradiated as a thermal black body continuum, typically peaking in the infrared. For gas to have this effect would require huge densities such as in stars. Fifth, in regions with dust particles, the abundances of heavy elements are reduced in the gas from what they are in stars, where the temperatures are too high for dust particles to exist. Finally, we can collect interplanetary dust particles, some of which are probably interstellar in origin.

2) What is your favorite candidate for the material that makes up the cores of dust particles? Why?

ANS: The strongest spectroscopic evidence suggests two carriers for dust particle cores: silicates, detected via vibrational transitions in the infrared against continuum sources (see Figure 2) and some type of carbonaceous material, detected via a bump in the extinction curve in the far UV and via vibrational emission spectra from regions near sources of UV radiation (see Figure 3). Collection of local material suggest glassy particles with both carbon and mineral silicates.

3) How can we tell that dust particles in dense interstellar clouds have mantles?

ANS: The basic evidence is infrared spectroscopy. The spectrum in figure 2 shows peaks for vibrational transitions of the following ices: water, carbon monoxide, carbon dioxide, methanol, methane, and possibly some other species. These peaks are only detected in absorption in dense cold portions of interstellar clouds.

4) Write down the rate law for formation of molecular hydrogen on the surfaces of dust particles. (See Section 5 of the article.)

ANS:
$$\frac{dN_{H_2}}{dt} = K_{H-H} N_H N_H; \quad K_{H-H} = [v_H \exp(-E_H / kT)] / N_{tot}$$

where N_i is the number of atoms/molecules per grain of species i , v_H is the frequency of the H atom on the surface, E_H is the barrier against diffusion of H atoms from one potential well to its nearest neighbor, and N_{tot} is the total number of sites on the grain.