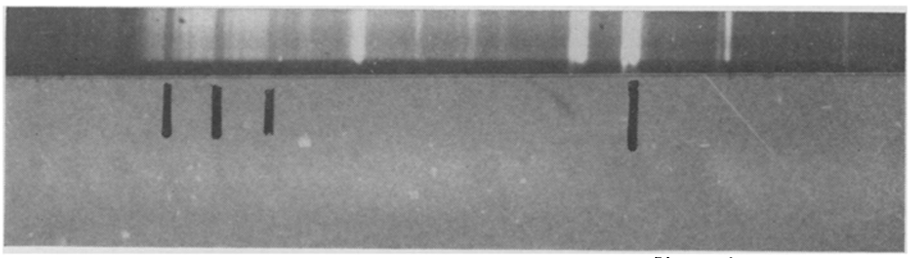
Material to make stars

Discovery of molecular hydrogen in space supports theories of stellar formation



Photos: Naval Research Lab

Three lines show match of starlight's H_2 lines to standard spectrum above.

Hydrogen is the most abundant chemical element in the universe. It constitutes 85 percent of the total mass of the sun, stars and bright nebulosities.

Hydrogen comes in two chemical varieties: atomic hydrogen, in which individual hydrogen atoms stand alone, and molecular hydrogen, in which two atoms are bound into a molecule.

Current theories of stellar formation postulate that stars condense out of clouds of molecular hydrogen.

A hydrogen molecule is shaped like a dumbbell and is capable of rotating end-over-end. These rotations would be excited by the heating that accompanies stellar formation, and the molecules would then radiate the energy they have gained as infrared light. This efficient dissipation of heat by the hydrogen molecules allows the contraction of the gas cloud into a star to proceed more rapidly than would otherwise be possible.

Although astronomers have observed objects radiating infrared light that they take to be young stars or stars in the process of condensation, until now they have not had direct evidence of the existence of the molecular hydrogen from which the stars were supposed to be condensing. The first direct evidence is provided by an experiment by Dr. George C. Carruthers of the Naval Research Laboratory, flown on an Aerobee rocket on March 13. The observation supplies a missing link in the chain of stellar evolution and, by showing that the raw material exists, gives evidence to support the supposition that new stars can and do form in the Milky Way galaxy at the present time.

Carruthers: Raw material for stars.

Atomic hydrogen betrays its presence by emitting or absorbing a characteristic radio signal of 21 centimeters wave length; astronomers have gathered abundant evidence of the presence and even the predominance of atomic hydrogen in interstellar space. In cold clouds the molecular variety can be seen only by finding its characteristic pattern of absorption in the ultraviolet.

To make the observation of molecular hydrogen three criteria must be satisfied: There must be a star shining through a suspected cloud of molecular hydrogen; the observing equipment must be lifted above the earth's atmosphere, which absorbs the ultraviolet, and the equipment must be sensitive enough to record the faint absorptions of the hydrogen.

Dr. Carruthers developed special equipment and looked at light from the star Xi Persei. The light of that star is partially obscured by a dust cloud between it and the earth, and it is in such clouds that astronomers suspected molecular hydrogen would be.

Dr. Carruthers reports that he found the characteristic molecular-hydrogen absorption pattern called the Lyman band series in the spectrum of Xi Persei. From the strength of the absorption he calculates that the amount of molecular hydrogen in the line of sight to Xi Persei is more than 10 percent of the amount of atomic hydrogen in that line of sight. He suggests that in dust clouds much denser than the one in the line of sight to Xi Persei the hydrogen present may be almost entirely molecular.

The thicker dust clouds are hard to observe in this way because they completely obscure stars. Radio observation has shown them deficient in atomic hydrogen, and this information supports the idea that any hydrogen they have must be molecular.

The reason for looking for molecular hydrogen in dust clouds and for connecting its abundance to the density of the dust is that the dust is supposed to act as a catalyst in the formation of the molecules. In regions of space free of dust atomic hydrogen predominates, because the same ultraviolet light with which one hopes to observe molecular hydrogen tends to break up the molecules. Once the atoms are separated, two of them cannot form a new molecule simply by coming together. There has to be a third body in the collision to take away the excess momentum and allow the two atoms to settle down together and form a molecule.

"They just bounce apart without something to take up the excess momentum," says Dr. Carruthers.

The dust grains can be such a catalyst, and the evidence now seems to show that they are. The denser the dust clouds, the higher is the probable rate of three-body collisions among hydrogen atoms and dust grains. Thus in the clouds it is possible for hydrogen molecules to form at a faster rate than ultraviolet light can dissociate them, so there will always be a certain amount of molecular hydrogen present.

Molecular hydrogen is the dominant form in the earth's atmosphere since there is little ultraviolet to dissociate it and many opportunities for three- or many-body collisions to recombine it.

The interstellar dust seems to perform a catalytic function for other molecules; it is in the dust clouds that such substances as water and formaldehyde (SN: 4/12/69, p. 351) have been found.

The young stars that are supposed to form out of the molecular hydrogen are also found in the dust clouds, so the whole picture fits neatly together. □