Astronomy's mystery molecule

An unknown molecule called "X-ogen" is present in at least eight celestial radio sources

by Dietrick E. Thomsen

Molecular astronomers observe lines in the radio spectra of the interstellar clouds. These lines correspond to the resonant frequencies of molecules. To identify the molecules present, scientists match the lines from the clouds with lines from known molecules measured in the laboratory. Sooner or later the lines discovered by radio astronomers have been identified, except for one conspicuous holdout. This is a line at about 89,189 megahertz (3.4 millimeters wavelength) which for want of a more substantive identification has been temporarily designated "X-ogen."

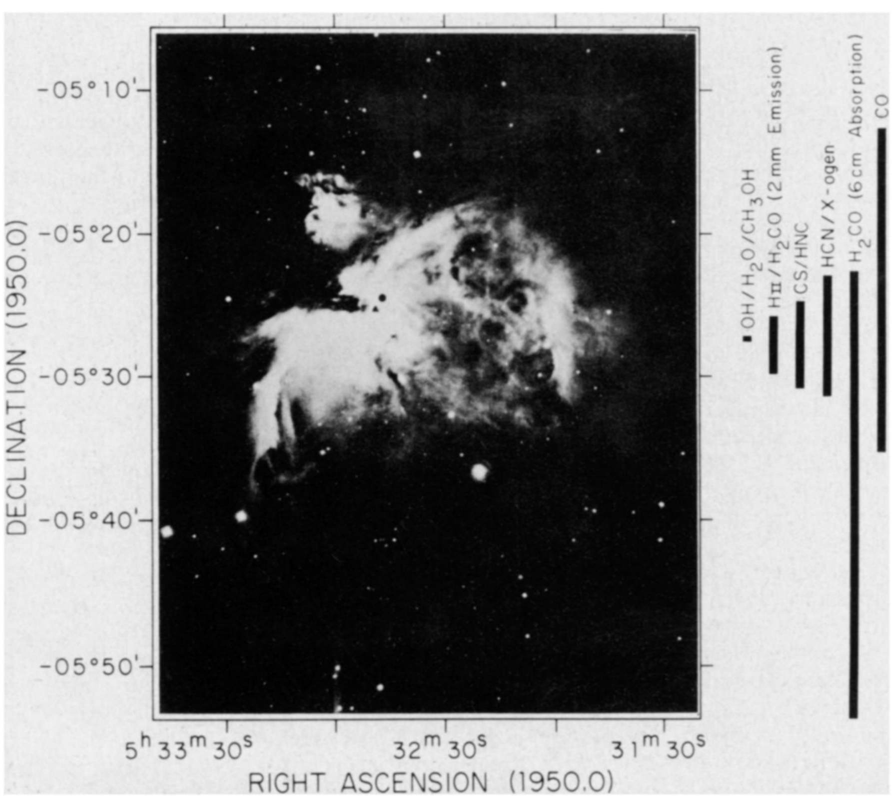
X-ogen was first noticed about three years ago. The latest report on the subject, by David Buhl of the National Radio Astronomy Observatory and Lewis E. Snyder of the University of Virginia (in the March 15 ASTROPHYSICAL JOURNAL), shows that it is found in at least eight locations in the sky: W3(OH), Orion, Sagittarius A, W51, W3(companion), NGC 2024, NGC 6334N and K3-50.

Its appearance in so many places puts a first constraint on what X-ogen may be. Buhl says it ought to be a molecule with no more than two atoms from the group of heavy atoms that are plentiful in interstellar clouds: carbon, nitrogen, oxygen and perhaps sulfur. Molecules with more than two heavy atoms have so far been seen only in the galactic center. Elsewhere their emissions (if they exist) are too faint to be seen with present receivers. Buhl expects that this situation will change as more sensitive receivers are employed, but for the moment it provides a rule of thumb that says X-ogen has no more than two heavy atoms.

Other evidence can be gathered by studying the places where X-ogen appears in company with other molecules. One very good place is the Orion nebula, where a number of different molecules have been found.

The emissions of the different molecules in the Orion nebula cover different extents of sky. The most extended is carbon monoxide (CO). The least—except for hydroxyl (OH) and water masers in the very center of the cloud—is formaldehyde (H_2CO). X-ogen appears closely associated with hydrogen cyanide (HCN) in a somewhat middle range: extending for about eight minutes of arc in the north-south direction.

Buhl and Snyder conclude that the differences in extent arise from the way in which the molecules gain the energy that they radiate to indicate their presence. The mechanism is most probably collisions with hydrogen molecules, which ought to be much more abundant than the other molecules in the cloud. Whether there will be enough collisions to give rise to recordable radio emission depends on the density of the hydrogen and the structure of the other molecule. Some molecules need denser hydrogen than others to be excited enough to



Buhl and Snyder/Astrophys. J.

Orion nebula: Bars indicate the north-south extent of various molecules.

reach the threshold of observability. The hydrogen is densest at the center of the cloud and grows gradually less dense as one proceeds outward.

Carbon monoxide can be sufficiently excited in areas where there are fewer than 10,000 molecules of hydrogen per cubic centimeter. Formaldehyde, hydrogen cyanide and X-ogen require more than a million hydrogen molecules per cubic centimeter. X-ogen's close correspondence with hydrogen cyanide leads to the conclusion that its structure has similarities with that of hydrogen cyanide.

There is another constraint. Compounds of nitrogen and oxygen that do not contain carbon are unstable. As Buhl puts it, "They don't hold up very well." It has something to do with the bonding of carbon, he says. This restricts the question to molecules with CN, CO or CC as bases.

With these conditions a number of suggestions have been made: hydrogen isocyanide (HNC), or the radicals HCO^+ or CCH. "In a sense the problem is narrowed down," says Buhl, "but it takes a little arm waving to do it."

At this point calculation can be an aid. From knowledge of the structure of similar molecules, the weights and the spacing of atoms in HNC, HCO^+ or CCH can be estimated. From this information Snyder has been able to calculate the energy levels of these molecules, and he has found that all of them have fundamental resonance frequencies at about 90,000 megahertz. But the accuracy of such calculations is not very great, and positive identifications cannot be made from them.

In most of molecular astronomy, laboratory work has been a great aid. If laboratory experiments can determine the resonance spectrum of a suspected substance, then observers can tell whether the lines match observation and thus identify the celestial species. But no laboratory study has turned up a candidate for the X-ogen line. This may be because the substance either does not exist under terrestrial conditions or has too short a lifetime to be detected. In the laboratory, for example, CCH would quickly grab another hydrogen and become acetylene. Buhl believes that future progress toward an identification is more likely to come from searching for another line of the X-ogen spectrum; the relationship between two lines would maybe narrow things down far enough for a determination.

For the moment X-ogen remains an enigma. Whether or not it is eventually identified, the future is likely to see other mysteries. Molecular astronomers are in fact lucky to have only one such problem, and Buhl doesn't expect the luck to last. In the future he expects that "the situation will get more cluttered with unidentified lines." □

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—*The Editor*