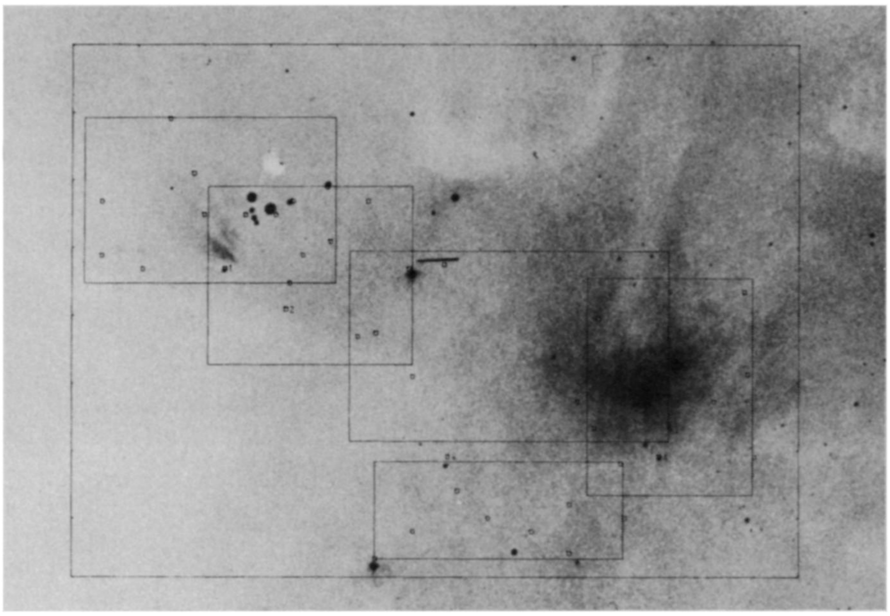

S. E. and K. M. Strom

The Ophiuchus dark cloud observed by the Stroms. Stars show as dark dots.

Where stars are born

Infrared probes the dark places of stellar beginnings

by Dietrick E. Thomsen

Stars are born. They grow old. And they die, ending up ultimately as white dwarfs, neutron stars or black holes. Much is known about the middle age of stars, but until recently their birth was largely veiled. Stars are born in the interstellar clouds. The dust obscures the view for optical astronomy so it has only been since the advent of infrared and radio astronomy, to which the clouds are more transparent than to visible light, that the early stages of stellar history could be studied.

Among the astronomers now interested in the early stages of stellar life are a husband and wife team, S. E. Strom and K. M. Strom of Kitt Peak National Observatory. The question their current work seeks to answer is, as S. E. Strom puts it: "Are there any states of evolution which we might uncover from infrared or radio that are not as yet predicted?" They use recent theoretical constructs on collapse of stars as a guideline for what one might look for. "You might come in for a lot of surprises."

Some surprises have been found and there are points where the theory needs adjusting. This was more or less expected since the theory is very idealized. The usual picture considers only the collapse of gaseous matter into a protostar under the influence of gravity. Neither rotation nor magnetic fields are considered.

The picture that the Stroms present has instead of a slow homologous collapse a rapid buildup of density concentrations. In this view, once an inhomogeneously dense region appears it will get richer quickly until a dense object of nearly stellar mass surrounded by a low-density envelope of matter still condensing onto the protostar is formed. This envelope should be observable in the infrared part of the spectrum.

Most previous searches for protostars have been done in ionized hydrogen clouds. Very little attention has been paid to dust clouds, and the Stroms wanted to see if star formation in dust clouds went on at the same rate as in ionized hydrogen areas. They believed the detection of young stars would be possible since by their figures the dust, which would cut visible light by a factor of a hundred billion billion, would cut infrared by only a hundred or a thousand. The particular dark cloud chosen is in the constellation Ophiuchus.

The first conclusion from the observations is that the number of stars embedded in the cloud is much larger than anyone would have expected. The density of stars brighter than second magnitude is greater than in any other known cluster, says S. E. Strom. In numbers the star density in the Ophiuchus cloud is about 20 per cubic parsec; in comparison the Pleiades, a well-known cluster, has a density of only 6 stars per cubic parsec.

The next question is: Are they pre-main sequence? Main sequence stars are those that have reached a stable size and have commenced hydrogen burning in their cores. (The term comes from the Hertzsprung-Russell diagram, a graph that plots stars' luminosity against their spectral class. The main sequence contains most of the stars plotted and extends in a flat S-curve across the diagram from fairly bright white stars to duller red ones.) If the stars observed in the Ophiuchus cloud are newborn or fairly young they should not yet have reached the main sequence, but should be evolving toward it.

Some of the stars seen in the cloud look like blackbodies, but many have the strong infrared radiation characteristic of young stars and are probably pre-main sequence.

". . . We are observing an extraordinary cluster of newly born stars," conclude the Stroms in a paper written with G. L. Grasdalen. This means, as S. E. Strom says, that star formation takes place more extensively than anyone would have suspected.

Another difference from expectation is that the young stars are not approaching the main sequence as rapidly as theory would have them do. "Many we thought were on the way to the main sequence are still in dynamic evolution [collapse]" says S. E. Strom. "Many look normal but are not approaching the main sequence." This is theoretically unexpected. Theory would have had the stars approach main sequence early in their lives.

What happens to the circumstellar envelopes? Apparently in some cases at least they become disks. Evidence for disks shows up in 20 cases in a sample of 100. This again differs from previous models which do not take rotation into account. There appear to be some large rotational velocities present. Ultimately the disks may either dissipate or become planetary systems.

Finally, there is the effect of the presence of so many stars on the clouds in which they are found. Many molecular astronomers had hoped that they might find some really complicated chemical species in the dust clouds, assuming that the dust would shelter chemical activity from light that would dissociate the molecules. Now it appears that the clouds have within themselves an unexpected number of light sources, and the chemistry may not be able to proceed as readily as molecular astronomers would like. □