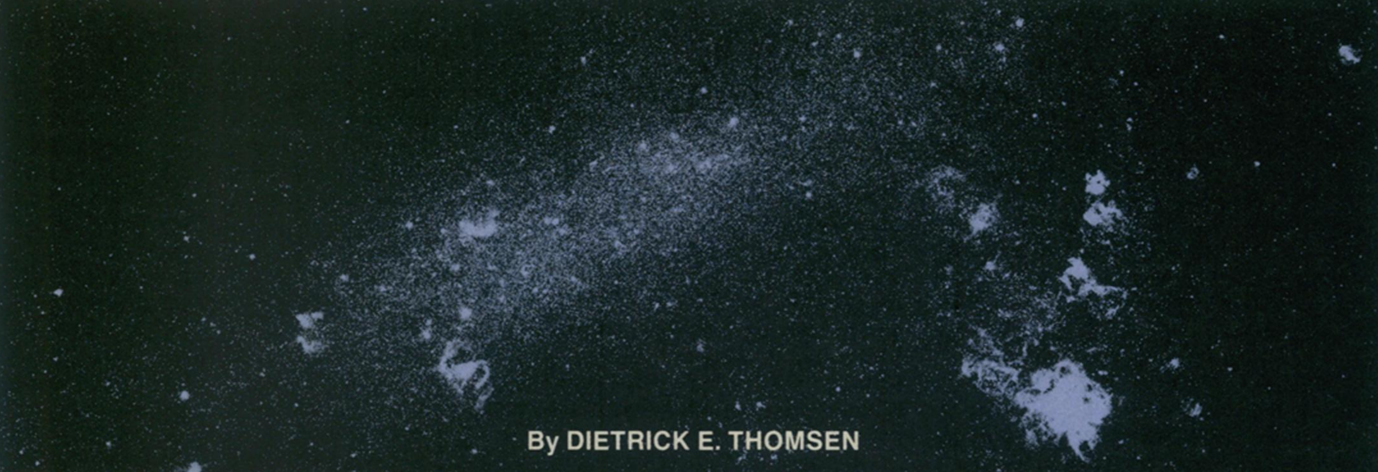
IRREGULAR WAYS OF MAKING STARS



By DIETRICK E. THOMSEN

One of the very basic questions of astrophysics is how stars form. Obviously they form out of the gaseous and dusty matter—the interstellar matter—of the galaxies they inhabit. Gravity must play a role. Something triggers a concentration of this matter, which then draws more and more to itself until a star is born. But what factors and conditions are universally necessary for efficient star formation?

Much of what astronomers know or think they know about star formation comes from studies of regions where it is prominent in regularly shaped galaxies, particularly spirals like our own Milky Way. However, stars are also formed quite efficiently in galaxies of quite different forms, the so-called giant irregulars. For her doctoral dissertation, which won this year's Trumpler Award of the Astronomical Society of the Pacific (ASP), Deirdre Hunter of Kitt Peak National Observatory in Tucson, Ariz., studied star formation in irregularly shaped galaxies. Her conclusions, based on what she and others have done in this field, lead one to wonder what the universal factors necessary for star formation are. Her work seems to raise more questions than it answers, and in her description of it at the recent ASP meeting in Santa Cruz, Calif., she repeatedly said, "We don't know; we don't have a theory for this."

One of the features of spiral galaxies that astrophysicists generally suppose has a good deal to do with star formation is the density waves also known as spiral arms. The interstellar matter tends to lie a good deal thicker in the spiral arms, and it is thought that this kind of compression helps trigger the formation of individual clumps that develop into stars. Spiral arms are conspicuously lacking in the irregular galaxies — the Magellanic Clouds are easily visible examples of the sort Hunter studied — and she points out: "These galaxies are very successful at forming stars without benefit of spiral density waves." And so it appears that "spiral density waves are not necessary to vigorous production of stars."

She looked for other global structural or compositional factors that might affect the star formation rates of the irregular galaxies (which can vary over a factor of 100), but none of these —the mass of the galaxy, the fraction of that mass that is interstellar gas, the gas to luminosity ratio — seems to affect the star formation rates of the galaxies.

This suggests that local factors are more important than characteristics of the whole galaxy. The distribution of stars and star-forming regions in these galaxies is "chaotic but not random," she says. They tend to follow chains and arcs of regions of ionized hydrogen. They are organized on the local scale and clumped on the global scale "for reasons we don't understand," Hunter says. Star-forming activity also seems to move around the galaxy over time.

From dynamical studies of the areas of star formation it seems that once a cloud starts to collapse into stars, "it forgets what kind of galaxy it's in," Hunter says. Astronomers believe that in spirals, density waves trigger the collapse. "In irregulars we don't know what triggers it," she says. However, it gets triggered, and that implies that further progress is determined by local conditions in the collapsing cloud. That leads to another quandary, she says. If star formation happens in both types of galaxy and it is dominated by local conditions in the collapsing clouds, those conditions, particularly the composition of the interstellar matter, ought to be similar. They aren't.

From studies of spirals it appears that star formation needs a lot of hydrogen gas. Irregulars do have plenty of this, but it extends far into space beyond the visible extent of the galaxy. In view of this extended gas, Hunter asks why star formation doesn't extend to larger radii — why does the gas in the outer region not participate? Maybe it is falling into the centers to fuel star formation there, but no dynamical evidence for such infall has been found.

In other respects the interstellar matter of the irregulars differs seriously from the spirals. The irregulars don't have much dust. They don't have much in the way of molecular clouds, and their metal content is several times less than that of spirals. All these are factors supposed to affect star formation in spirals. "We don't understand what this means," Hunter says. "It raises the question, what is the role of dust and molecular clouds in star formation in irregular galaxies?"

And finally, the only model that has been put forth for how star formation occurs in these galaxies, which involves energy present in the ionized hydrogen regions, lacks observational support. Hunter concludes: "We have no model for how star formation happens in these galaxies."

Another mystery is the history of star formation in irregular galaxies. Most of them show evidence for a fairly steady rate of star formation over the estimated history of the universe, but a few — NGC 1569 is an example — show rates so high they could not possibly be maintained for so long. They must be undergoing global bursts of star formation. "Why would a galaxy suddenly burst into flame?" Hunter asks. "We don't know."

Yet another mystery: It is giant irregular galaxies that are successful in forming stars. Dwarf irregulars pose the opposite problem. Hunter asks: "Why are they not successful in forming stars?" These unsuccessful dwarfs have the same global properties as the successful giants. "A clear understanding of these two groups of irregular galaxies," she says, "is important to the understanding of star formation processes in general." □