stellar extinction that preclude such studies at visual wavelengths. The colours and luminosity of these stars resemble those of previously known OH/IR stars, which, in addition to being bright in the infrared, emit intense radiofrequency radiation in the spectral lines of the OH radical. Ground-based observations (J. Frogel, Kitt Peak; M. Feast, South African Observatory) confirm that many IRAS stars found in the bulge are late-type M giant stars, with luminosities as large as 10^3 to 10^4 $L_{\odot}$, that are losing mass at a rate of 10^{-6} to 10^{-4} solar masses per year. The age of these stars and the mass of their main sequence progenitors are quite uncertain, but an intriguing possibility is that they were originally one-solar-mass stars and are no more than a few billion years old, far less than the age of the Galaxy. In that case, there may have been a burst of star formation in the bulge of the Galaxy that resembled bursts seen towards other infrared-bright galaxies detected by IRAS.

B. Zuckerman (University of California, Los Angeles) gave two reasons why an understanding of the mass loss in these late-type stars is important. First, as we observe many white dwarf stars and relatively few supernovae in the Galaxy, mass loss must provide the mechanism whereby stars more massive than 1.4 solar masses lose enough material to avoid a catastrophic demise when their nuclear fuel has been consumed. Second, it is through mass loss that the carbon, nitrogen and oxygen produced by nuclear burning are injected into the interstellar medium for subsequent processing into new stars, planets and, eventually, astronomers. By using a combination of IRAS measurements and millimetre-wavelength observations of gas outflows for a large sample of IRAS stars, it will be possible to learn much about the dynamics and chemistry of the mass-loss process and its relation to later stages of stellar evolution.

P. Bedijn (Heidelberg) explained the cause of mass loss in terms of a positive feedback mechanism coupled to global pulsations of the star. His theory derived support from the fact that more than half of the IRAS sources varied in brightness by as much as a factor of three over the course of the IRAS mission.

After the mass-loss phase ends, it is thought that late-type giants become planetary nebulae which consist of a 50,000 K star surrounded by a thin shell of ionized gas. A. Leene and S. Pottasch (Leiden) used 8 to 22-micron spectra obtained with the Low Resolution Spectrometer to show that for some of the more than 700 planetaries detected by IRAS, the radiation does not come from hot dust, but rather from spectral lines from ionized gas. Emission from spectral lines of S IV (triply ionized sulphur), Ne II, O IV and S III account for all of the radiation detected by IRAS in the 12- and 25-micron bands of the survey. Leene and Pottasch predicted that lines of N II and O III could account for some or all of the 60- and 100-micron radiation detected in the survey for these objects. IRAS maps of planetary nebulae can be used to examine the temperature, abundance, density and excitation of these ionized species.

IRAS is also well suited to studying the other extreme of the life history of stars — their birth out of the interstellar medium. The physics of star formation represents a fundamental problem in modern astronomy which is relevant both to the structure of our own Galaxy as well as to the energy production mechanisms for the most luminous starburst galaxies detected by IRAS. As B. Elmegreen (IBM, T.J. Watson Center) pointed out, IRAS data at the highest sensitivity and spatial resolution can be used to study the detailed physics of star formation, and IRAS images can be used to study large-scale processes in the interstellar medium that produce stars.

One mechanism for the formation of stars that has been discussed for many years is that H II regions around newly formed massive O and B stars trigger the fragmentation and subsequent collapse into new stars of adjacent material in a giant molecular cloud. By examining the 60- and 100-micron images produced by IRAS, P. Schwartz (US Naval Research Laboratory) found circumstantial evidence for loops and rings of star formation surrounding earlier sites of star formation. One such loop is 250 pc in diameter and contains many H II regions and embedded young stars. If further examination of the IRAS images shows that star formation is often associated with structures of this type, then the case for triggered or sequential star formation will be greatly bolstered. As Schwartz emphasized, large-scale morphological studies of this kind are possible only with the advent of the IRAS images that present to the eye in a single picture both the distribution of the interstellar matter and the presence of embedded young stars.

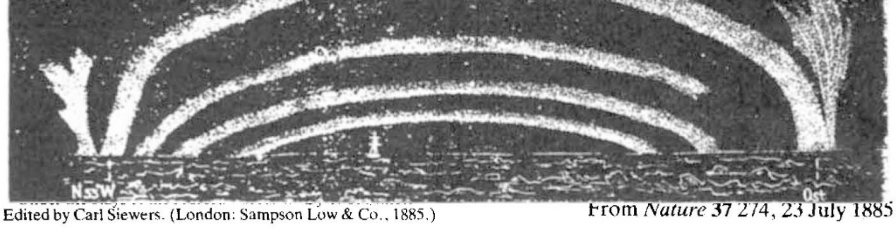
A second way by which star formation may proceed is to compress small globules of intersellar material enough to overcome the supporting motions within the cloud and so initiate a gravitational implosion that leads to the formation of one or more stars. It is possible that many solar-type stars form in this manner, rather than in the triggered fashion of the more massive stars. The existence of this more sedate and spontaneous type of star formation has been demonstrated by P. Myers (Center for Astrophysics), C. Beichman (California Institute of Technology), S. Harris and J. Emerson (Queen Mary College, London) and R. Jennings (University College, London) who examined more than 100 small clumps of interstellar gas in the Taurus and Ophiuchus molecular clouds, some 150 pc away. These clumps contain between 5 and 50 solar masses of material and represent the simplest possible sites for star formation. The IRAS survey shows that about half of these clouds are associated with infrared point sources. Although a few objects can be identified with visible pre-main sequence stars (T Tauri stars), the remainder have no visual counterparts. The invisible sources have very low colour temperatures, about 100 K, and luminosities of 0.5–10 $L_{\odot}$. Although it is not possible to determine the masses of such objects accurately, it is likely that stars of about 0.5–1 solar mass are being formed in these clumps.

The most important, but as yet unanswered, question about these embedded infrared sources concerns their evolutionary status. Some of the invisible infrared objects are probably T Tauri-like stars, no older than 10^5 years, that obtain their energy from the slow contraction of a stellar core in quasi-static equilibrium, but which are still obscured from view by placental gas and dust. On statistical

100 years ago

THE AURORA

MR TROMHOLT has rendered a great service to science by the travels and observations recorded in these volumes[1]; indeed, it would not perhaps be going too far to say that we have here, brought before us in the most interesting manner, one of the best organised attempts to study the aurora that has been made for many years, the credit for which must be given to the organisers of the International Polar Research Expedition of 1882-83. The results, however, recorded in these volumes are by no means limited to the height of the aurora. The constant study afforded to Mr. Tromholt of one of the most awe-inspiring phenomena which it is given to man to witness have permitted generalisations to be reached and hypotheses to be broached of the greatest scientific interst. Mr Tromholt holds that *the auroral zone moves northwards and southwards daily, yearly, and eleven yearly.* To speak in vacuum-tube language, instead of one rigid stria, we may have many striæ, and these moving towards or away from the auroral pole as ordinary striæ move towards or away from the negative pole.



1. Edited by Carl Siewers. (London: Sampson Low & Co., 1885.)

From *Nature* 37 274, 23 July 1885.