How Stars are Born

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There is a vivid interest among astronomers in the early phases of star formation. In the last issue of the Messenger *(No. 11, p. 14) a catalogue of stellar birth places was introduced. The present article discusses radio, infrared and optical observations of a particularly interesting object. The authors are Drs. Anthony C. Danks (ESO-Chile) and Peter A. Shaver (Kapteyn Astronomical Institute, University of Groningen, the Netherlands).*

In recent years both radio and infrared astronomy have revealed details of the dusty environment of star formation. These regions are characterized by the presence of "Compact H II regions" (compact, bright radio continuum sources — Mezger *et al.*, 1967), which are often associated with H_2O and type I OH masers (showing 1665 and 1667 MHz emission — Habing *et al.*, 1972). Infrared sources (1 to 30 μm) are often seen in or nearby the compact H II regions and sometimes combinations of these sources can be found close to visible H II regions.

The "Cocoon" Model

These regions can best be explained quantitatively by the recent models of Kahn (1974) and Cochran and Ostriker (1977), who propose the following scenario: A protostar ($M \approx 40\ M_\odot$) forms by accretion in a dusty interstellar cloud. As the star's luminosity increases with time, the accretion is halted by radiation pressure. A dusty "cocoon" remains, within which is a smaller ionized zone surrounding the star. In this phase the dust and gas are competing for stellar photons and a situation can arise where the dust is heated to a higher temperature than the surrounding gas and can give rise to the necessary infrared radiation capable of pumping the H_2O and OH masers. As the star evolves the cocoon fragments and the compact H II region become visible. At a later stage, as the star settles into the Main Sequence and the dust shell dissipates further, a conventional Strömgren sphere (H II region) may become visible. This later stage may be exemplified by regions such as S88B (Pipher *et al.*, 1977) or Sharpless 2–106 (Sibille *et al.*, 1975) where visible Hα emission is seen. Here the infrared source may be interpreted as an O star with high visual extinction due to dust.

Observations at Westerbork and La Silla

To investigate the various phases and accompanying physics of these regions, the authors have instigated a programme to study regions of star formation using the ESO infrared equipment at the 1 m ESO telescope at La Silla.

First results of this programme are shown in Figures 1 and 2. In Figure 1 the radio brightness contours are shown for the source G12.2–0.1. These observations were made with the Westerbork Synthesis Radio Telescope at a wavelength of 6 cm; the beam size was 6x31 arcseconds. The compact H II region is indicated by A and two other radio bright regions are indicated by B and C. Although the Westerbork beam is elongated at this low declination, the radio contours can still be seen to trace out a shell-like structure. We have marked also the positions of the OH source (Evans, private communication) and H_2O sources (Genzel and Downes, 1978).

Subsequent mapping of the region at 2.2 μ at La Silla using a 10 arcsec diaphragm and 37 arcsec chop on the sky revealed 3 infrared sources. Two are shown in Figure 1, indicated as IRS 1 and 2; the third was detected in the reference beam and is just outside Figure 1. Of these sources, IRS 1 is the most interesting, coinciding with the compact H II region. Recent position measurements of the H_2O source by Jack Welch and Mel Wright using the Hat Creek Interferometer put component A, IRS 1, and the H_2O source within 2 arcsec or 0.03 pc — an unusually close association (the source distance of 3.7 kpc was estimated from the H110α, H_2CO, OH, and H_2O radial velocities).

We have measured the spectrum of IRS 1 from 1 to 5μ and this is shown in Figure 2. The upper line in Figure 2 repre-

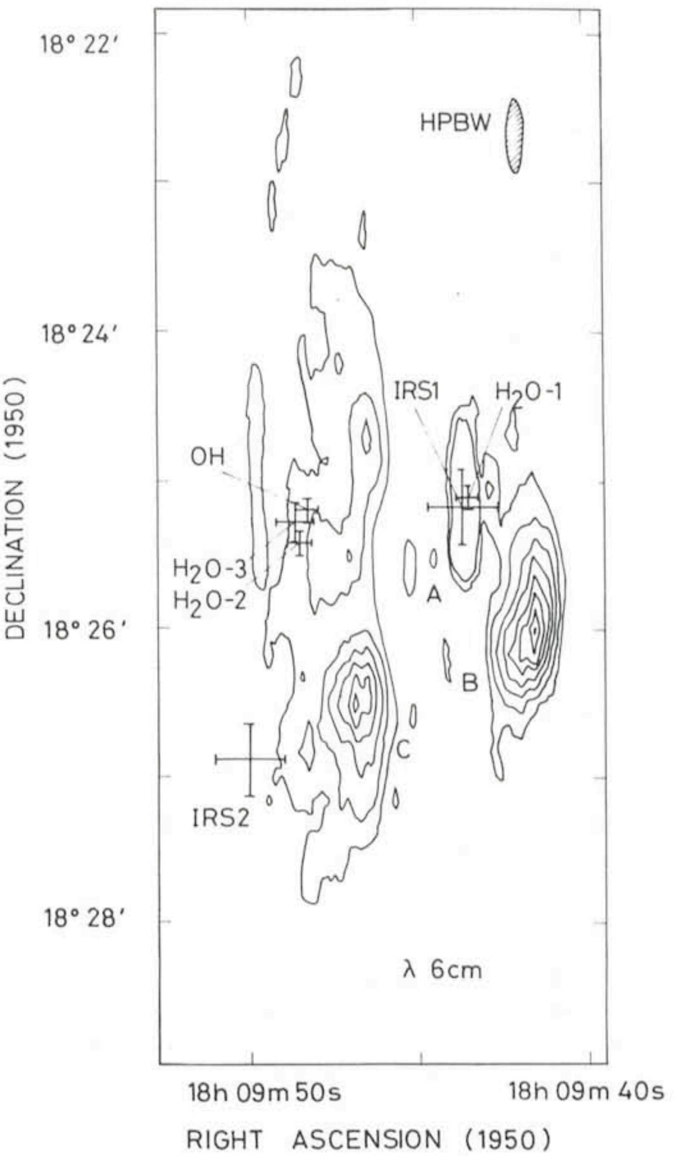

Fig. 1. — *6 cm map of G12.2–0.1. The hatched ellipse shows the half-power beamwidth. Three continuum sources are indicated as A, B and C. The positions of the OH, H_2O and infrared sources are shown as crosses.*

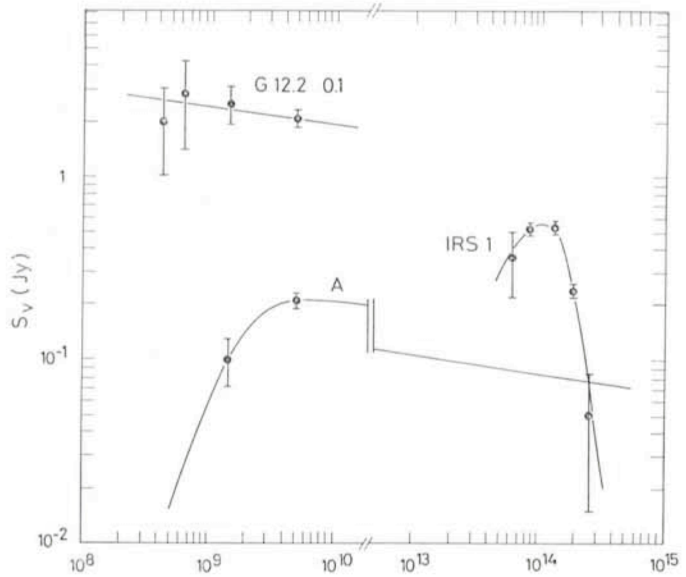

Fig. 2. — *Continuum spectrum of the entire G12.2–0.1 complex (top) and for component A and IRS 1 (bottom).*

sents the total integrated radio flux densities for the entire region. The infrared spectrum of IRS 1 appears to be stellar, an O3–O5 type star with $A_V \approx 23$ mag. However such an early O star would be capable of ionizing an H II region with 100 times the flux of the observed radio source G12.2–0.1. If the star were of spectral type O5 or later then most of the near-infrared emission could arise from a hot circumstellar cocoon (> 1000 K), and even an O7 star would still be capable of powering the radio source. The close H_2O maser association further strengthens our belief that IRS 1 is a cocoon star. Further, longer wavelength infrared observations are planned in the coming season in order to determine the spectral type of IRS 1.

Sources of this nature are often associated with large molecular complexes, and ^{13}CO observations have recently been carried out by Michael Scholtes at McDonald. ^{13}CO emission has been detected, and ^{12}CO observations will be made in the near future.

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A Magic Eye for Astronomical Spectrophotometry

The ability of a telescope to detect faint celestial objects not only depends on the linear size of the telescope, but also upon the efficiency of the light detectors that are used to register the light. For many years, most astronomical spectra were obtained on photographic plates. However, even the best of these rarely achieve detective quantum efficiencies above a few per cent, i. e. they only "catch" two or three out of every one hundred photons hitting the emulsion. During the past decade much effort has therefore been concentrated in astronomy on how to improve the detector efficiency in order to make small telescopes "larger" and large telescopes "very large". For instance, a telescope with a mirror diameter of one metre and a detector efficiency of 50 per cent is (for many astronomical applications) equivalent to a 5 metre telescope with a 2 per cent detector.

In this article, ESO engineer Rudi Zurbuchen from the Geneva group discusses one of the new detectors, the RETICON array.

New Detectors in Astronomy

Times when astronomers forgot their numb fingers, whilst gazing through the eyepiece of a telescope and admiring celestial objects are definitely over. Today's astronomy and the use of its large optical telescopes require less subjective and much more powerful eyes. In many astronomical applications electronic detectors are more and more taking over from the photographic plate. One of them, planned to be used with the instruments of the ESO 3.6 metre telescope, is described here. The actual hardware and software system is presently being developed by a team of ESO's Instrument Development Group and will be the subject of a subsequent article.

A large amount of significant astronomical information such as physical state, material composition and radial velocity of a stellar object is retrieved from the precise measurement of the object's spectrum. The light levels associated with spectrophotometric measurements on a good observing site can be very low and the requirements imposed upon efficient light detectors used in this field are accordingly high.

The widely-used singel-channel scanning mode of conventional spectrometers suffers badly from a poor detection efficiency which is partly due to the high light loss inherent to the sampling principle but also to the modest quantum efficiency of even modern photon multiplier tubes. An additional disadvantage of the single-channel scanner is its sensitivity to atmospheric variations.

The RETICON Diode Array

Among the flood of newly-developed electronic photodetectors there is one which is particularly attractive for spectrophotometric applications. It is a self-scanned linear photodiode array manufactured by the RETICON Corporation, Sunnyvale, California. Several other array devices are potentially good competitors but the RETICON seems, at least for the time being, to be the only one which provides as well a diode sufficiently large to cover a typical astronomical spectrum image over its total height, as an adequate linear field and thereby spectral range.

Reticon linear arrays are available with up to 1872 individual photodiodes with centre-to-centre spacings as small as 15 μm. The first RETICON which will be used for the 3.6 m telescope instrumentation programme is a dual 1024-element array with a 25 μm centre-to-centre spacing and an active aperture width of 430 μm. The dual configuration allows simultaneous integration of object and background signals and will be used as a near infrared detector for the low-dispersion spectrograph of the 3.6 m telescope Cassegrain focus. Another similar array is planned to be operated on the coudé échelle high-dispersion spectrometer (see article by D. Enard in *Messenger* No. 11, December 1977).

The RETICON is a monolithic integrated circuit and as such exhibits excellent geometric accuracy and stability. Besides the photodiodes, the circuit has integrated into the same silicon chip the analog switching circuitry needed for reading out the diode