Infrared Observations of Stellar Birth-places

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A few months ago, Drs. Nicolas Epchtein and Pierre Turon went to La Silla and mounted their specially-designed infrared photometer at the Cassegrain focus of the ESO 3.6 m telescope. Although the weather was unusually unpleasant, they succeeded in measuring a number of H II regions. In this article, they review observations of star birth-places in various spectral regions.

The earlier stages of star formation are still badly understood, theoretically as well as observationally, although a large amount of new relevant observations have been provided during the last decade thanks to the new spectral ranges opened to astronomical research: infrared and microwaves. Detection of optically invisible infrared point sources associated with compact H II regions or dense neutral clouds, discovery of large molecular clouds associated with cool dust and detection of OH and H_2O masers associated with infrared objects are the most conspicuous advances in the observational field. From these observations, astronomers have been able to set up a phenomenological picture of a typical star birth-place (fig. 1).

Observations of Stellar Birth-places in Different Spectral Regions

The only presently available technique to discover directly star-like objects in young complex regions is the near-infrared mapping and photometry with middle- and large-size ground-based telescopes. Far-infrared and millimetric observations are indeed of limited spatial resolution (~ 1 arcmin). As for H_2O masers mapped with aperture synthesis (radio) techniques, it is still unclear whether they are actual protostars or regions of peculiar physical conditions located at the edge of cocoons formed by newly-born, massive stars.

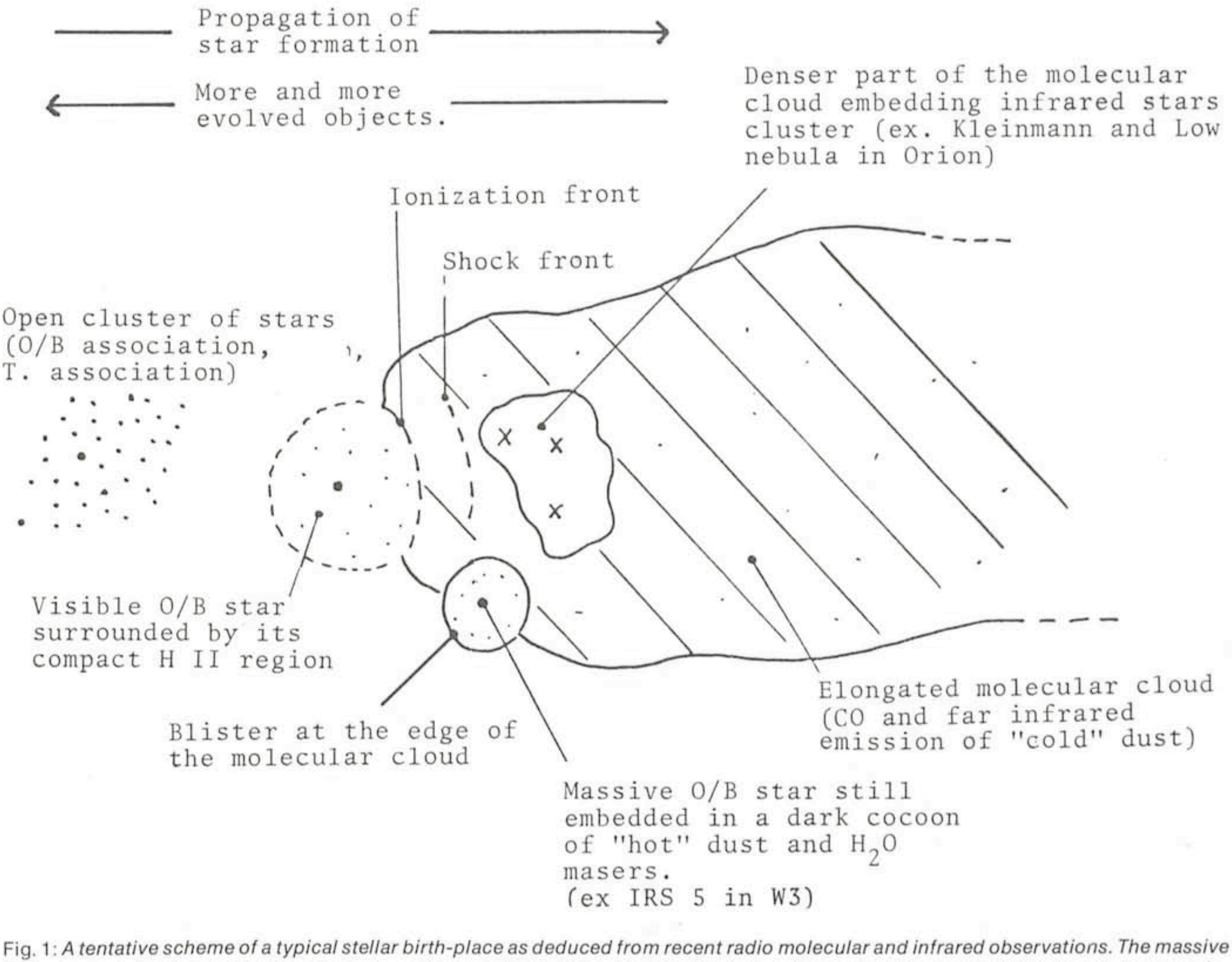

Fig. 1: *A tentative scheme of a typical stellar birth-place as deduced from recent radio molecular and infrared observations. The massive O/B stars are first formed at the edge of a molecular cloud. The ionization front goes forward inside the cloud leading to pressure instabilities (H_2 dissociation and temperature rise). The densest parts of the cloud are associated with infrared star clusters which are likely newly-born stars.*

Scanning of compact H II regions and of the densest parts of molecular clouds is an efficient way of detection of newborn stars. The study of the infrared colours can then provide a determination of the nature of the objects. Large colour indices mean a cool object or a highly-reddened star; in both cases an interesting object, related to the H II region or the molecular cloud: either a cool dust shell, a cocoon, surrounding a hot object still unable to ionize an H II region large enough to be detected in radio continuum, or an intrinsically cool object like a protostar in the free-fall phase or an early O-type star dimmed by several magnitudes in the visible and often associated with a very compact H II region.

Until now the criteria of determination are still unclear since the number of newly-discovered sources remains small except in a few well-studied regions like Orion or the molecular cloud ϱ Oph. If the object is assumed to be a reddened star, the infrared colours and a standard law of extinction can lead to a rough estimation of the spectral type and of the visual extinction. Moreover, if the distance is known, the absolute visual magnitude and hence the accurate spectral type may be derived. The evaluation of the integrated radio continuum emission over the whole H II region can confirm the presence of an optically unseen O-type star. Mapping at longer wavelengths (10 and 20 microns) is also of great value in order to detect colder objects or even more reddened stars and to determine total luminosities of H II regions, dust temperature and dust-to-gas densities ratios in the ionized medium.

In the southern sky, only a few objects have been mapped, either at 2 or 10 microns, and even fewer with high spatial resolution, obviously because of lack of large telescopes. This situation recently changed when three large optical telescopes became operational in the southern hemisphere. Resolutions of 1 or 2 arcsec at 10 microns can be obtained with telescopes of the 3.6 m class and without sophisticated techniques. The immediate result has been the discovery of complex structures in objects that looked simple at lower resolution.

Southern Compact H II Regions

A programme of mapping and photometry of the most compact southern H II regions was started in 1977 at the 1 m telescope with the standard ESO photometers. More recently, a home-made photometer was used at the 3.6 m telescope. This instrument, which was built at the Meudon Observatory, is fixed at the Cassegrain f/8 focus (fig. 2). It is made up of a liquid helium, liquid nitrogen jacketed dewar which holds a set of 8 cooled filters (in the range 8–30 microns), a 7 arcsec diaphragm and a Low germanium bolometer with a holding time of more than 30 hours. Since the ESO 3.6 m telescope is not yet equipped with a wobbling secondary mirror, an internal modulator is needed. Beam-switching is

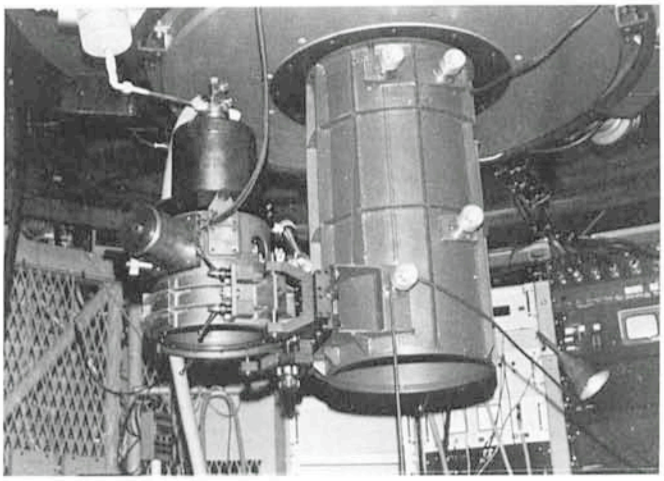

Fig. 2: *The infrared photometer fixed at the Cassegrain focus of the 3.6 m telescope. The dewar is seen on the left side of a tube which holds the "hot" optics and the modulator. The preamp. box and the filter driving handle can be seen on the left side of the dewar.*

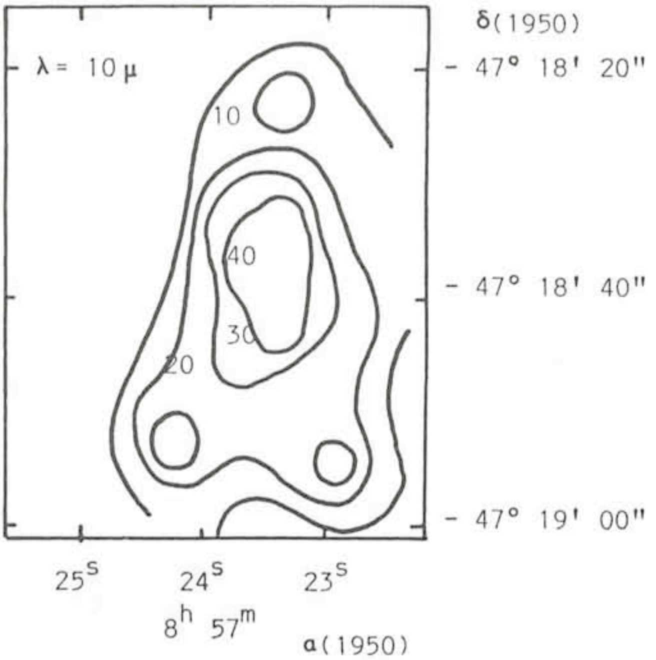

Fig. 3: *Ten-micron map of the compact H II region RCW38-IRS1, obtained with the ESO 3.6 m telescope. The resolution is 7 arcsec. The unit of intensity is 2.5 janskys (i.e. the contour labelled "40" corresponds to 100 janskys).*

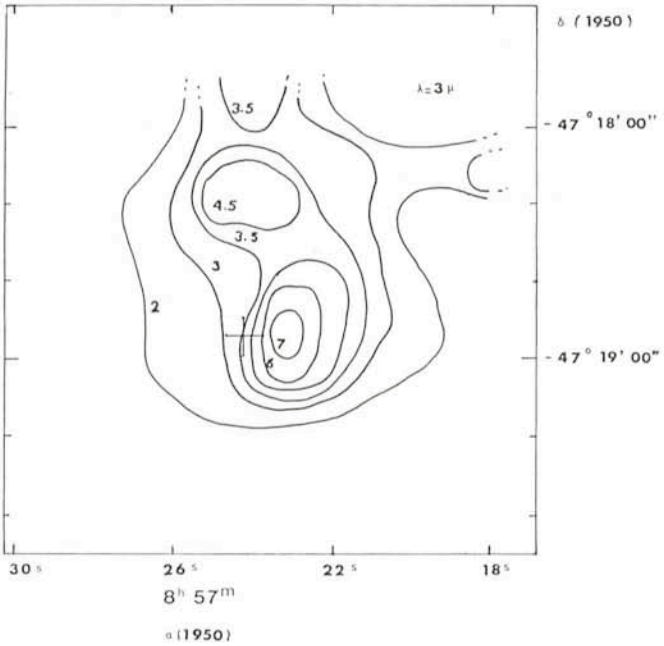

Fig. 4: *Three-micron map of RCW 38 obtained at the 1 m with the ESO InSb standard photometer. Resolution is 13 arcsec. Contour units are in .1 jansky in the diaphragm. The cross shows the location of IRS 2 which seems to be the exciting star of RCW 38.*

achieved by a spherical mirror mounted on the axis of a torque motor driven by a square wave generator and located at the image of the entrance pupil. This device is able to perform a square wave beam-switching of more than 30 arcsec at f = 30 Hz.

Despite rather bad weather conditions and although several points must be improved (baffling of the detector, data-acquisition system), our first run at the 3.6 m was very encouraging. We mapped several H II regions in our galaxy and the large LMC H II region, 30 Dor. The most significant result was obtained on the core of RCW 38 IRS1. We improved the resolution of the previous mapping by Frogel and Persson (1974) and discovered a complex structure of the source at 10 microns (fig. 3). The analysis is in progress to determine whether the structure is due to the presence of a cluster of sources or to a variation of dust opacity.

Maps of the same region were obtained at 2 and 3 microns at the 1 m telescope (fig. 4). At 3 microns the map is roughly similar to the map at 10 microns with the same resolution, a result which seems to indicate a smooth variation of dust temperature over the H II region and to support the idea that dust is more likely heated via Lyman α photons resonantly trapped inside the ionized medium than via Lyman continuum photons.

The mapping of 30 Dor was quite disappointing since we did not detect any source in a 40 x 40 arcsec area around the central exciting star R 136 at a level of 4 janskys at 10 microns in the 7 arcsec diaphragm. This result seems to be in agreement with the assumption that, in this region, the "hot" dust has been already blown away by stellar winds while "cold" dust is seen at 100 microns (Werner et al., 1978). We plan to reobserve this region at 20 microns under better weather conditions.

References

Frogel, J. A., Persson, S. E., 1974, *Astrophys. J.* **192**, 351.

Werner, M. W., Becklin, E. E., Gatley, I., Ellis, M. J., Hyland, A. R., Robinson, G., Thomas, J. A., 1978, *Mon. Not. R. Astron. Soc.* **184,** 365.

New Clock System for La Silla

One of the features of the La Silla observatory that impresses visitors most is the incredible number of clocks. Sure, nobody doubts that astronomers need accurate time—but why so many clocks?

The simple answer is that different times are used at an observatory for different purposes. We are all familiar with the *Local Time,* which on La Silla is the time used in Chile for civic purposes. In winter, it is 4 hours behind GMT (Greenwich Mean Time) and during the summer it is advanced by 1 hour. The time difference between Geneva and München in Europe and La Silla is therefore 5 hours from April to October and 4 hours during the rest of the year.

Astronomers often use the so-called *Universal Time* (UT) for their observations. Originally, UT was equal to GMT, but after introduction of a standard second that is based on the caesium atom (9 192 631 770 periods per second), a new system, the so-called *Universal Coordinated Time* (UTC), has come into use. This system is kept in step with the mean solar time, as defined by the motion of the Sun. Since the rotation of the Earth is slowing down, it is occasionally necessary to insert an extra second in the UTC.

Finally, the positions of celestial objects in the sky are given by the *Sidereal Time* (ST), which is determined by the stars.

On La Silla, Local Time, Universal Coordinated Time and Sidereal Time are shown. Until now, all clocks have been synchronized by a quartz clock, installed in the Schmidt building. However, this clock cannot be directly connected to the various telescope control systems. Furthermore, there is an increased need on La Silla for having a very high accuracy in time measurements, for instance when measuring ultra-rapid variations in quasars, etc.

It has therefore been decided to install a new clock system on La Silla, and a Caesium Beam Frequency Standard was ordered by Cermé in Paris, France. After a test period of six weeks in Geneva it will be shipped to La Silla. The accuracy should be sufficient for all purposes: for UTC it is better than 0.0001 sec/year and for ST it is better than 0.01 sec/year. In other words, we have to wait at least 10,000 years, before it is wrong by 1 second! Remains to be seen whether there will still be astronomers at La Silla by that time.

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The new atomic clock for ESO-La Silla. The various components are marked on the figure: (1) caesium frequency standard, (2) clock for time transport, (3) battery pack for time transport (10 hours), (4) frequency unit, (5) UTC time code generator, (6) ST time code generator, (7) spare time code generator, (8) line drive amplifiers, (9) battery pack for non-break power (4 hours).