tinction values without heavy reliance on recombination line model calculations. It is our intention in this context to investigate in proposed follow-up observations of galactic H II regions whether this observing technique gives consistent results when compared with data derived from the Balmer line decrement method.

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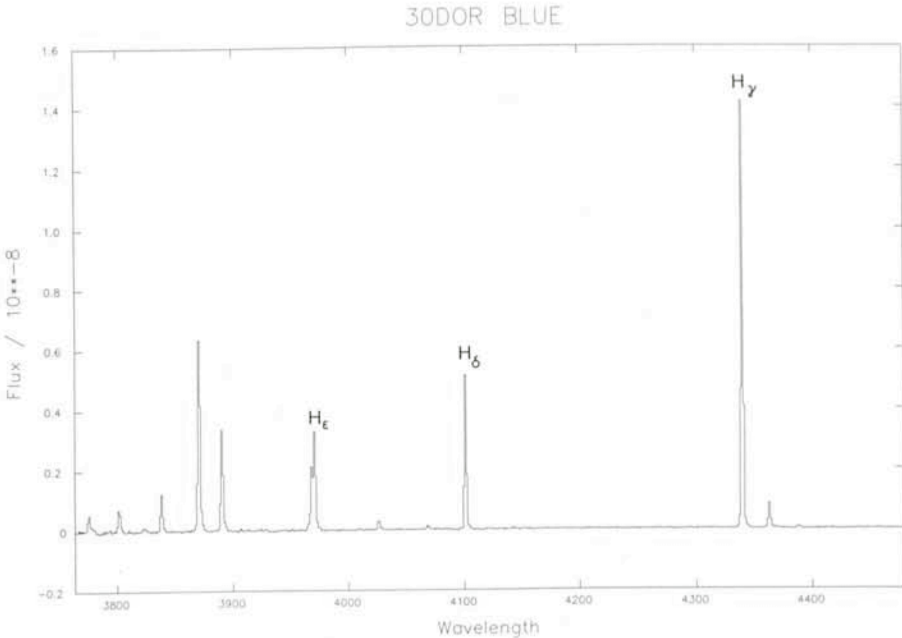

Figure 2: *30 Doradus, blue wavelength region, sky-corrected and flux calibrated. The Hε line is blended with the [Ne III] 3967 Å line.*

Star Formation in Dwarf Irregular Galaxies

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1. Introduction

Contrary to the more spectacular and appealing Spiral and Elliptical Galaxies, for a long time Irregular Galaxies have not been considered to deserve detailed studies. Only in the last decade, the difficulty found in the interpretation of the major evolutionary processes taking place in bigger, more complicated galaxies, has led to new interest in Irregulars, which should be easier to understand, for a number of circumstances. The structures of Irregular Galaxies appear, in fact, to be simple, with no combination of halo and disk phases and no special evidence of dynamical phenomena playing an important role. They contain a large amount of gas, easily detected by radio telescopes, which means that they are in a relatively early stage of the evolution. Besides this, their visible stellar content is young enough to indicate that Star Formation is active in these galaxies, several H II regions are present and allow the derivation of the metallicity, even at large distances. For all these reasons, Irregular Galaxies seem to offer a suitable ground for studying the basic phenomena controlling the evolution of galaxies.

Extensive studies by several authors have confirmed the above general features (see Viallefond, 1988, for a recent review), suggesting that Irregular Galaxies are presently the best candidates for the identification of the properties of primordial galaxies, which makes them particularly interesting from the cosmological point of view. On the other hand, the detailed study of the stellar content of Irregulars has opened some important questions on how the Star Formation processes have been operating in these systems. The Initial Mass Function (IMF) has been suggested to be considerably flatter than in our own Galaxy (Terlevich and Melnick 1983), but Matteucci and Tosi (1985) argued that a normal Salpeter function is more appropriate. As for the Star Formation Rate (SFR), according to Gallagher, Hunter and Tutukov (1984), Dwarf Irregulars are likely to have undergone a continuous, maybe even constant Star Formation, as seems the case for giant Irregulars and late type Spirals, while Matteucci and Chiosi (1983), on theoretical grounds, have rather suggested a bursting Star Formation Rate.

To try to answer these questions and to better understand the evolution of these galaxies, we have undertaken a project of CCD photometry of some Dwarf Irregulars in the Local Group. Our aim is to derive as deep as possible Colour-Magnitude (CM) diagrams to be compared with theoretical simulations performed with different prescriptions for the SFR and the IMF. In this respect, it is worth noting that the stellar content in these galaxies is not so crowded as to prevent a good resolution with optical telescopes, when adequate techniques for the data reduction are used. The relatively small distances ($m - M \lesssim 26$ mag) of Dwarf Irregulars in the Local Group allow to resolve their stellar content down to $M_v \simeq -1$ to 0, which corresponds to Main-Sequence stars of approximately 2 $M_\odot$. We will then be able to derive information on the SF which occurred over the last ~1 Gyr.

2. Data Acquisition and Reduction

Besides DDO 221 (WLM), for which results have already been published (Ferraro et al., 1989), the programme galaxies are DDO 70 (Sextans B), DDO 209 (NGC 6822), DDO 210 and DDO 236

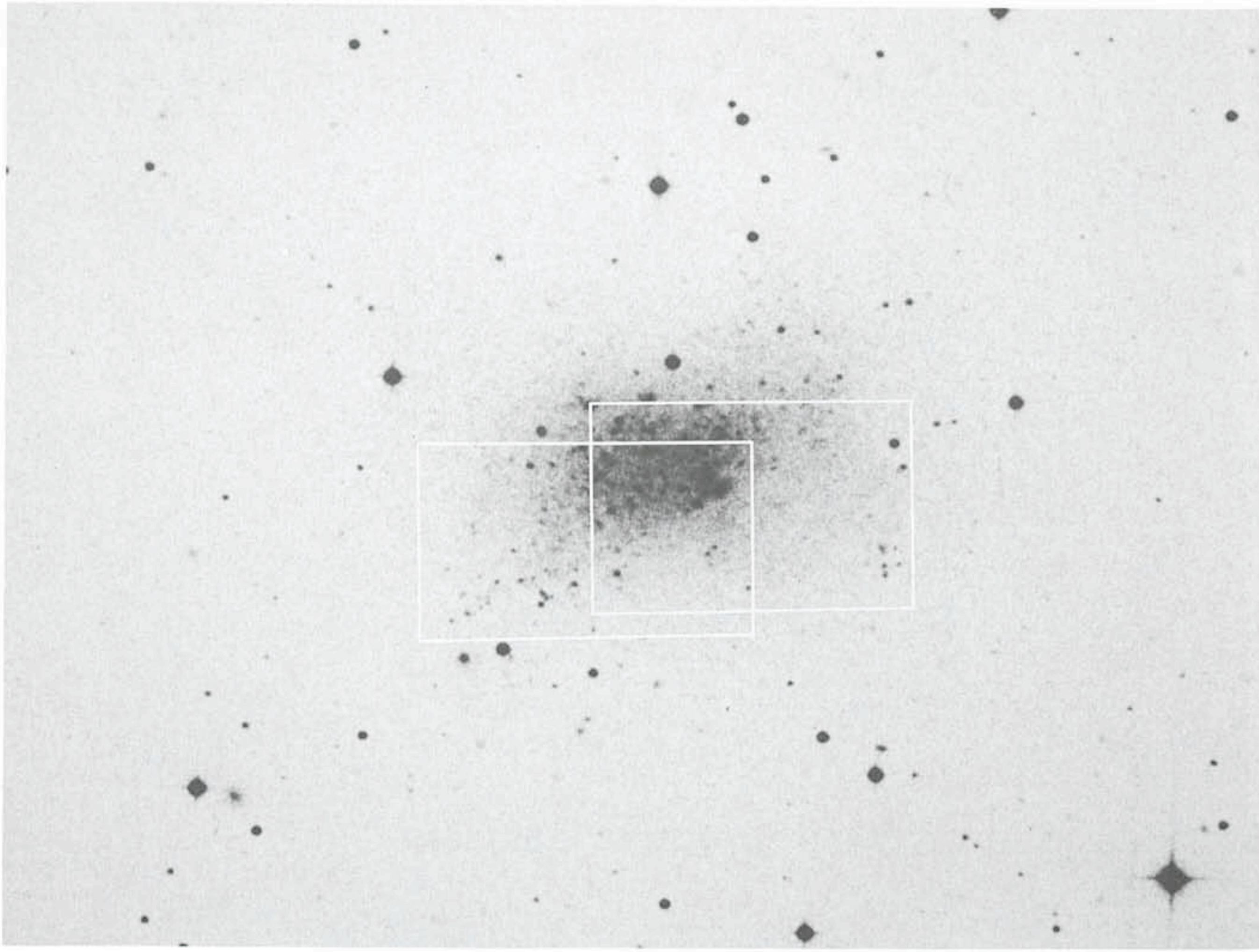

Figure 1: *Optical photograph of Sextans B from a 2-hr IIIa-J ESO Schmidt plate with our observed CCD fields superimposed.*

(NGC 3109). For each galaxy, at least one external and two internal fields are being studied, to analyse the possible differences among various regions and to properly treat background and foreground contamination. All the observing runs have been allocated at the ESO-MPI 2.2-m telescope in Chile. Sextans B has been observed in Johnson B, V and R filters and in the Gunn I filter in March 1988 and 1989. DDO 209 and DDO 210 are being observed at the end of July 1989 and DDO 236 in February 1990. Therefore, here we will only present some results relative to Sextans B (Fig. 1).

Preliminary data reduction has been performed using DAOPHOT (Stetson 1987) and, as a further check of the accuracy of our results, we are re-reducing them with ROMAFOT (Buonanno 1989). These packages are the most suitable for the data analysis in crowded fields, and from the results obtained so far, it seems that they give similar magnitudes and photometric errors in each filter down to V ~ 25. The different approach in the stellar detection and fitting, though, seem to imply a larger completeness factor in the samples reduced with ROMAFOT.

In order to derive an accurate CM Diagram, out of all the detected stars we retain only those with photometric error smaller than 0.1 mag. A further selection has been done on the basis of the location of the stars in the two-colour, (B–V) vs (V–R), diagram (see Fig. 2 for Region 2 of Sextans B). The resulting CM diagrams are shown in Figure 3 for the two observed regions, and, due to the applied selection criteria, they should be accurate enough to allow a meaningful comparison with theoretical predictions.

3. Interpretation of the Data

For a better understanding of the CM diagrams in terms of a combination of the various effects due to stellar evolution, Star Formation and IMF, we have developed a numerical code which generates synthetic, theoretical HR diagrams, by Monte Carlo simulations. The computations are based on a homogeneous set of stellar evolutionary tracks, assume different IMFs and SFRs, and take into account the observational photometric errors and completeness factor at each magnitude level. Different choices for the tracks in the data base are possible, with or without overshooting from convective cores, and the conversion from the theoretical

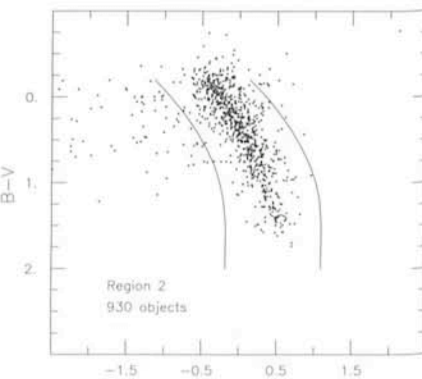

Figure 2: *Two-colour diagram for Region 2 of Sextans B. Only stars with photometric errors smaller than 0.1 mag are shown. The curves are located at 2σ from the mode of the stellar distribution and the objects outside this region are rejected.*

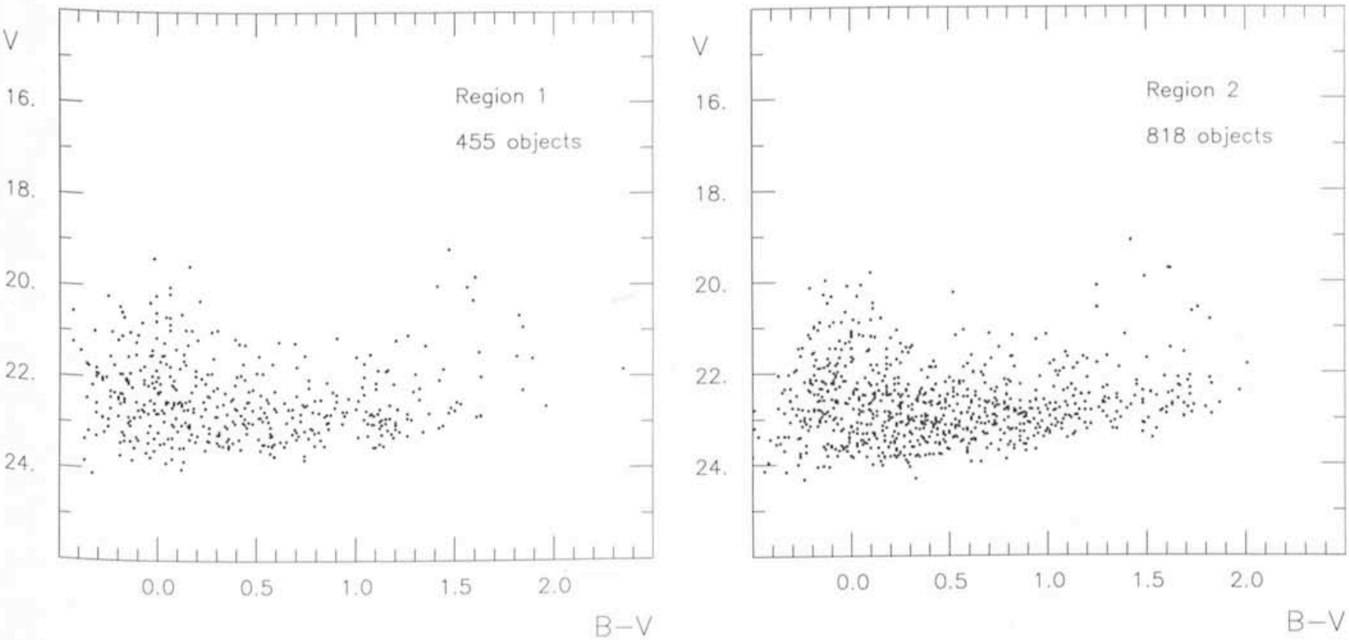

Figure 3: *CM diagrams of the stars selected from the observations of Regions 1 and 2 of Sextans B.*

Log L vs Log T_e plane to the observational M_v vs (B−V) plane are performed by means of linear interpolation in tables kindly provided by C. Chiosi (private comm.). The comparison between the theoretical HR diagrams derived with different prescriptions and the observed CM diagrams is performed in terms of the object distribution in different cells on the M_v vs (B−V) plane, and allows to choose the combination of SFR and IMF which is most consistent with the data. Notice that this procedure represents a significative improvement with respect to the classical Isochrone fitting method, as it is able to account for the stochastic nature of the Star Formation process, the effect of small number statistics, and the spread introduced by the photometric errors.

Figure 4 shows one of the simulated diagrams which is in better agreement with the observational data for Region 2 of Sextans B. The adopted distance modulus is m − M = 26.1 mag, as derived from Sandage and Carlson's (1985) Cepheids, using, however, the revised period-luminosity-colour relation by Feast and Walker (1987). Evolutionary sequences with Z = 0.001 and convective overshooting (Bertelli et al., 1986) have been used to produce this diagram. Standard tracks do not seem to populate consistently the blue supergiant region, due to the short extension of the loops during the core Helium burning stage. In this respect we notice, however, that the very occurrence and extension of the loops in the HR diagram is fairly sensitive to details in the input physics used in computing the stellar models (cf. Renzini, 1984). The B−V distribution of the red supergiant stars, instead, turns out to be too extended, with respect to the simulations, regardless of the underlying evolutionary scenario. This cannot be easily attributed to observational errors, since special care has been taken in the data handling, as described above. We rather suggest that the adopted conversions from the theoretical Log L vs Log T_e to the observational M_v vs (B−V) plane are inadequate to describe the extremely low gravities and temperatures of the red supergiants. The conclusions that we are going to derive for the history of Star Formation will not, however, be sensitive to this uncertainty.

The diagram in Figure 4 displays the results for a SFR which has been constant over the last billion years, but has ceased to act 2.5×10^7 yr ago: had it

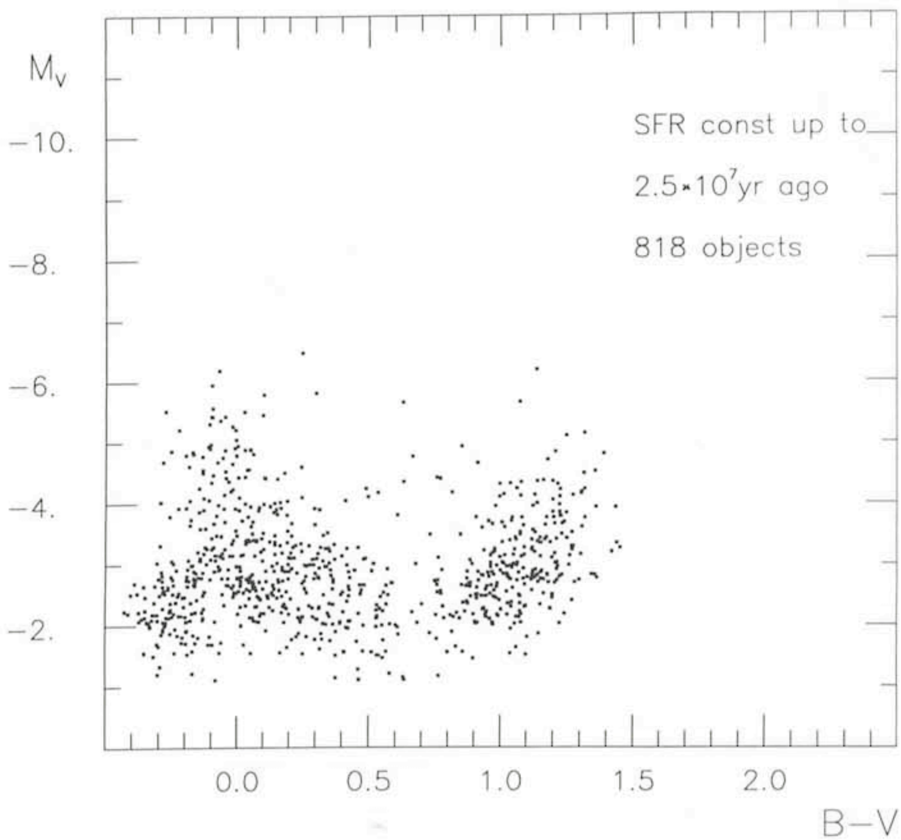

Figure 4: *Simulated CM diagram for Region 2 of Sextans B for an adopted distance modulus of m-M = 26.1 mag and a constant star formation which stopped 2.5×10^7 yr ago.*

continued up to now, a blue plume corresponding to massive Main Sequence stars would be present in the CM diagram, contrary to the observational evidence. Similar results can be obtained with two long and distinct episodes of Star Formation, but short and separated bursts do not give a satisfactory agreement with the data, since the distribution of objects happens to be too clumpy around the corresponding isochrones.

Three types of IMF have been tested: the relatively steep IMF by Tinsley (1980), which is in good agreement with the solar neighbourhood data; the IMF suggested by Melnick (1987), which is very flat for the low metallicity appropriate for Sextans B; and Salpeter's IMF, which is intermediate between the other two. This latter, which turned out to be the only IMF consistent with the data on WLM (Ferraro et al. 1989), leads to a satisfactory agreement also in the case of Sextans B, although a further check has to be done, comparing the theoretically predicted with the observed luminosity function.

From Figure 3 it can be noticed that the two examined regions of Sextans B, and therefore all the galaxy, have undergone a similar history of Star Formation, as the distribution of stars in the CM diagram is virtually the same. This is not a trivial consequence of the small size (R $\lesssim$ 2 Kpc) of this galaxy, though. Indeed WLM has a similar size, but one region shows the effect of a recent burst of star formation, unlike the rest of the galaxy. In both galaxies, however, an underlying population of stars up to 1 Gyr old is present in every examined region, and the differences appear to concern only the very recent SF activity. From the data relative to these two galaxies, it seems therefore that Star Formation in Dwarf Irregulars is generally a rather continuous process, a result which will be checked against the observations of the other galaxies in our sample. If this conclusion will be confirmed, we anticipate an impact on the current theoretical interpretation of the chemical evolution of Dwarf Irregular galaxies. A continuous SF, in fact, provides a large heavy element production, which would be incompatible with the observed low metallicities typical of these systems.

As a possible solution, strong galactic winds triggered by Supernovae explosion (Matteucci and Chiosi 1983) can be invoked to remove most of the enriched gas. Yet, from the results of model computations, a bursting mode of SF is preferable, even when the action of galactic winds is taken into account (cf. Matteucci and Tosi 1985).

4. Conclusions

The history of Star Formation in Dwarf Irregular galaxies can be studied in a very efficient way through the analysis of their Colour-Magnitude diagrams, yielding significant results for the general understanding of the evolution of galaxies, when data are collected for a number of cases. Unfortunately, the number of Dwarf Irregulars which can be studied in detail with ground-based telescopes is relatively small. We believe, however, that our sample of about ten regions in five galaxies will be significant enough to draw some general conclusion and will provide a useful base for further studies with the Hubble Space Telescope.

Acknowledgements

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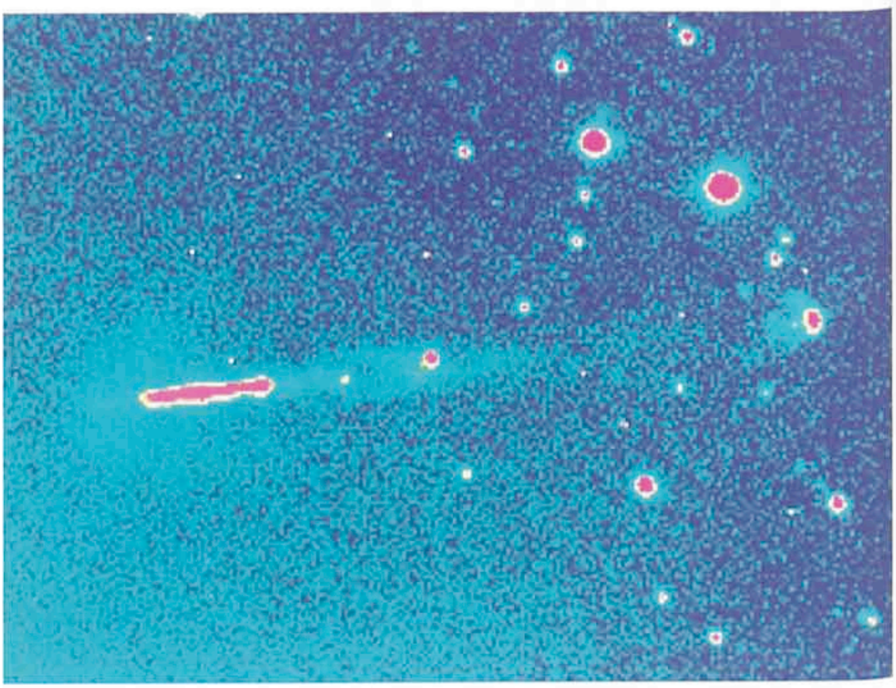

The Large Jet in the HH-111 Complex

This false-colour picture shows a newly discovered large jet in the HH-111 complex, just north of the celestial equator in Orion.

The straight jet emerges from the surrounding interstellar cloud in the left part of the picture. The outline of the cloud is vaguely visible by the brighter background near the lower edge of the picture. Also seen is a diffuse reflection nebula where the jet emerges. This nebula is illuminated by the light from a newborn star, hidden deep within the cloud. Because of the heavy obscuration, the star itself is not visible on this photo. The jet produces a "bow-shock" nebula; this is the bright, mushroom-shaped nebula in the right part of the picture. The round points are background stars in the Milky Way.

The picture was produced as a composite of four 1-hour CCD exposures, obtained with the Danish 1.5-m telescope at La Silla through a narrow optical filter. The light seen here from the jet is emitted by singly ionized sulphur atoms.

This new object was discussed in detail at the recent ESO Workshop on "Low mass star formation and pre-main sequence objects".