4. STAR FORMATION AND CLUSTERING

STAR FORMATION IN THE MAGELLANIC CLOUDS

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ABSTRACT. An overview of the understanding of processes of star formation in the Magellanic Clouds, including a historical perspective, is given. The current status is reviewed with emphasis on evidence for sequential star formation in large associations, on optical and infrared discoveries of possible pre-main sequence objects in luminous young clusters and 30 Doradus. The history of star formation in both Clouds, and evidence for differences between the processes of star formation in the Clouds and the Milky Way are discussed.

1. Introduction

The aim of this review is to give an overview of ideas and thoughts on star formation in the Magellanic Clouds, as they have developed over the past few years. Three main areas of investigation will be covered in broad-brush fashion: the past history of star formation in the Clouds; recent star formation including the distribution of regions and self-propagating and sequential star formation as manifested particularly in the LMC, and finally, a discussion of current star forming activity and some candidate protostars. Following speakers will expand on these topics in greater detail.

It is my intention to highlight those areas in this general field where obvious problems or ambiguities exist. Hopefully, many of these will be well and truly resolved during the course of this symposium, and for those areas which remain controversial, following contributions will provide a clear path for further advances.

Currently the star formation rate is significantly different in the two Clouds, with the ratio of the mass loss rate per year to the mass of HI, $M*/M_{HI}$, lying in the range 1.6 - 0.7 (Gyr^{-1}) for the LMC, and 0.6 - 0.2 for the SMC. Unexpectedly, perhaps, the rate seems to be totally uncorrelated with the gas fraction in the galaxies (see reviews by Lequeux 1984, Westerlund 1985, and Dopita 1985, 1987). In this paper those similarities and/or differences which exist between the two Clouds will be indicated, in the hope that further light might be shed on some of the reasons for the major problems which still confront us.

2. Past History of Star Formation in the Clouds

It is not possible to divorce star formation within the Magellanic Clouds from a

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consideration of interactions between the Clouds themselves, and dynamical encounters with the Galaxy. It is important to keep sight of these in any interpretations we make regarding the past history of star formation in the Clouds. Whether one accepts the model of Fujimoto and Murai (1984), which suggests that close encounters of the LMC and SMC may have occurred a number of times since the formation of the galaxies, most would accept that a close encounter is likely to have occurred ~ 8 x 10^8 years ago. This encounter may have been responsible for the disruption of the SMC, and formation of the Magellanic Stream (Mathewson and Ford 1984). If so, one might expect to see the results of such an encounter in the record of past star formation rates.

The methods by which the past star formation history of the Clouds may be inferred depend in principle on theories of stellar evolution and population synthesis, and the theory of chemical enrichment of the interstellar medium (ISM) during evolution. They are parameterised by an initial mass function (IMF), and the mass fraction which resides in the ISM. With these in place it is possible to determine the history of star formation for a galaxy from the comparison of observed luminosity functions, chemical composition, and H-R diagrams with predicted age/metallicity/colour relations.

Galactic colours can be used with careful modelling to determine information on the past history of star formation. In particular, Larson and Tinsley (1978) among others, showed that a galaxy's position in the UBV diagram is determined primarily by its average past star formation rate. *Recent* star formation makes the biggest impact on the far UV fluxes, and a combination of colours allows the determination of the ratio of current star formation rate to the average past rate, on the assumption of an IMF and age (Rocca-Volmerange *et al.* 1981). The Clouds are a special case of this kind of application, and typically reveal that their star formation rates have been relatively constant, a drastically different result from that of the Galaxy.

Field studies have contributed significantly to our understanding of the past history of star formation in the Clouds. From colour magnitude diagrams, (Hardy *et al.* 1984, Frogel and Blanco 1983, Stryker and Butcher 1981, and Butcher 1977) the following picture of star formation has been drawn. In the Bar region of the LMC, star formation occurred in the form of a major burst some 3 x 10^9 years ago, and,with quiescent periods of low star formation in between, continued at a lower rate till about 10^8 years ago. On the basis of these studies, and a number of other field studies (Stryker 1984 and references therein)it is possible to show the presence of a radial drop off in the age of the youngest stars moving outwards from the Bar (Stryker's Figure 1); at the same time, the ratio of red to blue stars appears to remain constant for about 4° before dropping off. Is this consistent with the recent colour results of Bothun and Thompson (1988)? Their wide field data (Figure 1) show the mean colour of the stellar population becoming redder as one goes from north to south across the Bar, and they suggest that this indicates the younger population is to the north. Similar deep field studies by Brück and his collaborators (Brück 1978, 1980, Brück and Marsoglu 1978, Hawkins and Brück 1982, 1984), and several other researchers (Hardy and Durand 1984, Mould *et al.* 1984) reveal an interesting history in the SMC. There too is evidence for a large population of stars with ages ~3 x 10^9 years old. The median age of star formation appears to be older than that in the LMC although there is still considerable recent star formation.

Another piece of evidence on the star formation history of both Clouds is that there exist some very old stars, and some very old clusters (NGC 121 and Lindsay 1 in the SMC, and several in the LMC) with some similarities to the globular clusters in the Galaxy. However, the numbers are very small, the LMC does not have a significant halo population, and it is apparent that star formation was not very active 10^{10} years ago.

A useful way of investigating the overall history of star formation in the Clouds is

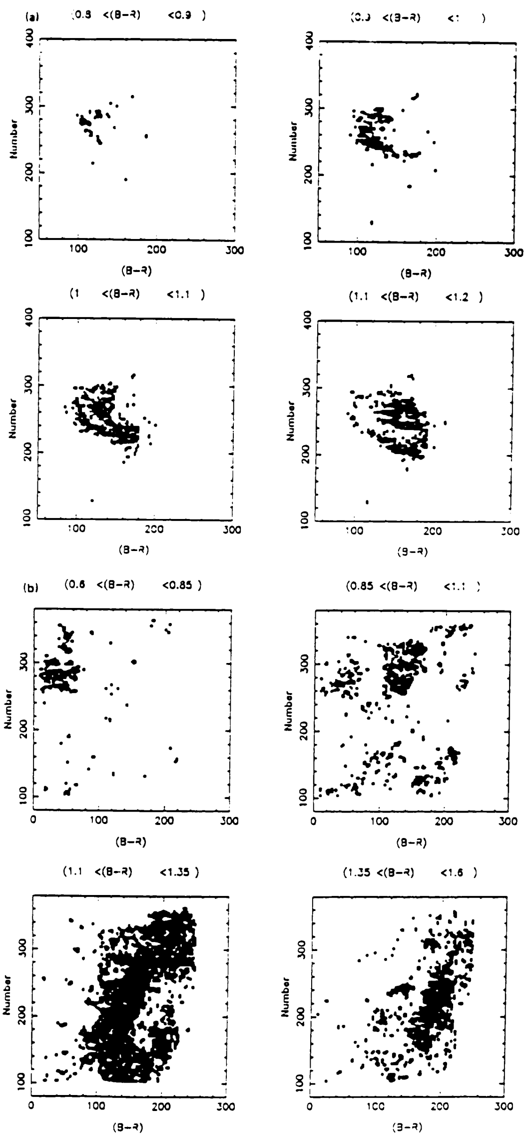


Fig. 1 (a,b) B - R colour distributions for the SMC and LMC from Bothun and Thompson 1988. East is up and North to the left.

through abundance-age relations for clusters using their integrated colours, first put into true perspective by Searle *et al.* (1980). Further work on clusters (Cowley and Hartwick 1982, Searle 1984) suggests that while there is a clear correlation between age and metallicity for the cluster population, the Clouds differ significantly from the Galaxy, in that metal enrichment has been very slow but steady. In modelling of the Hydrogen

Metals Diagnostic (HMD) diagram, Searle (his Figure 4) showed that the observational points lie between a model based on a uniform rate of star formation and one comprising a major (Gaussian) burst of star formation peaking ~3 Gyrs ago plus a low uniform background rate of star formation. Both Mateo (1988) and Smith *et al.* (1988) in recent analyses derive an age-metallicity relation for Cloud clusters, illustrating dramatically the steady chemical enrichment of the galaxies.

The age distribution and history of formation of LMC clusters has also recently been discussed by Hodge (1988) who presents evidence for highly non-uniform cluster formation rates, differing widely in different fields (Figure 2), but his global results do not show clearly the apparent lack of clusters with ages between 4 and 10 Gyrs as suggested by Jensen *et al.* (1988).

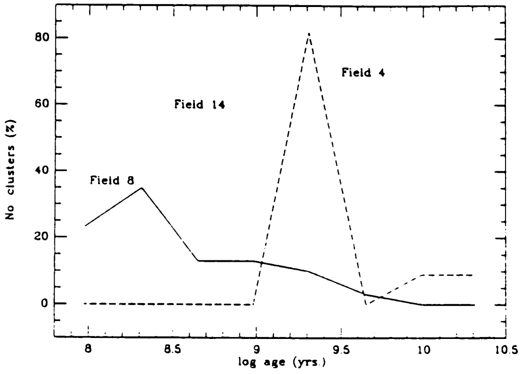


Fig. 2 The distribution of clusters as a function of age for fields for which it is very non uniform. The plots are for the percentage of each sample within equal intervals in log (age). From Hodge (1988). Results for Field 14 did not show up on the original.

The present metallicity characteristics of stars and the ISM in the Clouds reveal information about several important abundance ratios which shed light on the past history of star formation. The C/O ratio is low as determined from HII regions and the ISM. This is clearly consistent with a hypothesis for the relative youth of the stellar population in the Clouds. The stars thought to be responsible for CN enrichment of the ISM via mass loss and planetary nebulae ejection (Kaler, 1974 Peimbert and Torres-Peimbert 1971) are carbon stars with masses $< 3\ M_\odot$. While presently there are large numbers of carbon stars in both Clouds, the proposed youth of the population suggests that the contribution of evolved carbon stars is too small to alter the C/O ratio.

The O/Fe ratio has proved to be more of a headache to understand (Lequeux 1984). It has been found in both Clouds that oxygen is more deficient than the iron peak elements (Foy 1983, Dopita 1987). Dopita explains this apparent anomaly (opposite to the effect found in metal poor stars in the solar neighbourhood), in terms of the nucleosynthesis processes of stars of different mass. The effect can be achieved by hypothesising that the early burst of star formation in the Galaxy was violent, and possessed a greater proportion of high mass stars than current star forming events, i.e. the IMF of this burst was flatter that the current IMF. It is worth considering a search for further evidence of this different IMF, since there is little evidence for significantly different IMFs from that of Salpeter.

The picture which has emerged for the history of the Clouds is one of a continuous slow rate of star formation with the likelihood of a marked increase in star formation peaking some 3 Gyrs ago, and with a dispersion of about two Gyrs. Dopita (1987) identifies this late peaking of star formation with the formation of the disks of the galaxies. It has been suggested that there is no evidence in the time sequences of star formation, for star formation induced by dynamical interactions of the Clouds. The evidence, if it is there, thus has to be looked for more carefully, and may not be discernible in the global properties of the galaxies.

3. Recent Star Formation

3.1 DISTRIBUTION OF RECENT STAR FORMATION REGIONS

The distribution of recent star formation regions in the Clouds is easy to determine, in a host of different ways. The deep Hα survey of Davies *et al.*(1976) gives probably the best initial determination of recent star formation. When one adds to this the global colour morphology (Bothun and Thompson 1988), IRAS data, radio continuum data, the distribution of blue stars, in particular OB and WR stars, far UV data, red and blue supergiants and cepheids, molecular data (such as CO), and even HI (although in some senses there is an anticorrelation of HI and young stars) one can see that there is no shortage of tracers of recent star formation. What do these tracers reveal, not only about the distribution itself, but also about the underlying cause for such a distribution? How do the two Clouds compare?

Globally, one may compare the two galaxies using the recent Bothun and Thompson data as an illustration (Fig. 1). In the LMC the distribution of the blue population is basically irregularly dotted in clumpy fashion over the face of the whole galaxy, but generally avoiding the Bar. Several large regions can be identified, including the Constellation III region and 30 Doradus, with the spatial scales ranging from a few hundred parsecs up to ~2kpc. While the distribution is generally random, there is a clear concentration of the largest areas along the eastern edge of the LMC. Indeed, if the LMC is considered as an edge-on disk ploughing its way into the hot halo of the Galaxy, the eastern side is where the ram pressure will be felt most, compressing the HI density contours as observed (Mathewson and Ford 1984). This interaction and the resulting turbulence generated in the HI could well be responsible for the concentration of recent star formation regions along the eastern edge (Dopita 1987).

Feitzinger (1984, 1987), Feitzinger and Braunsfurth (1984) and Spicker and Feitzinger (1988), have investigated the spatial distribution, dimensions and spatial scales of a variety of tracers of star formation, including 21cm, radio continuum and IRAS surveys. The structures reveal similar morphology to optically identified star forming regions, and their work suggests that in the LMC stochastic self-propagating processes are not only responsible for the observed distribution, but could form spiral arm filaments.

The distribution of recent star forming regions in the SMC reveals a quite different pattern from that in the LMC. There are two major concentrations of young stars. One is concentrated to the north east of the central bar population, and the other to the east and south east (the Inner Wing region). Further to the east, towards the LMC is a third concentration of young blue stars associated with a supergiant HII shell. The major feature can be seen in Bothun and Thompson's (1988) images, which agrees well with de Vaucouleurs (1955) work. There is a well connected structure in the colour range $0.9 < (B - R) < 1.0$, presumably reflecting recent star formation, which differs markedly from the random appearance of the LMC distribution. Although one is tempted to identify the proposed recent disruptive encounter between the two Clouds (Mathewson and Ford 1984, Fujimoto and Murai 1984) as a crucial element in their star formation histories, (Dopita 1987), one wonders what caused the remarkable differences between the two Clouds.

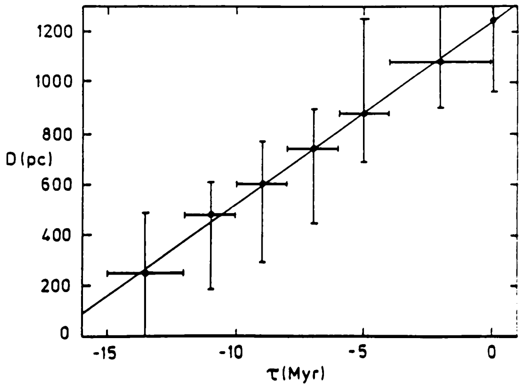
3.2 SELF-PROPAGATING AND SEQUENTIAL STAR FORMATION

Ideas on the localization of star formation in the LMC to a number of large constellations (1 - 2 kpc) have been around for almost forty years (Nail and Shapley 1953), and we are still coming to grips with the details. From the overall distribution of recent star forming regions as discussed in the previous section, it is fairly obvious that most active regions of star formation appear to be confined to the edges of the supergiant shells and loops of ionized material identified from deep Hα plates (Goudis and Meaburn 1978). It is also evident from the stellar populations that in the recent past (up to 5 x 10^7 years ago), star formation was occuring within the central regions of these shells. It has been suggested by numerous authors that these observations demonstrate the outward propagation of star formation. Indeed, since the early 1980s, the idea of stochastic, self-propagating star formation in the LMC has become exceedingly popular, and has been developed by many authors, e.g. Feitzinger *et al.* 1981, Braunsfurth and Feitzinger 1983, Dopita *et al.* 1985, Lortet and Testor 1988. The fundamental idea is that the supergiant "gas structures then are not caused by one star generation, but by a quick succession of stellar generations, spreading out from one ignition region" (Feitzinger, 1984). The sizes are to a large extent a reflection of the time since the initiating star formation event, and the velocity with which gas is expelled from the central region into the surrounding ISM.

This is an extremely pretty picture, but many questions remain. For example, is the process really contagious, propagating from one region to another? If so, did the same kind of process operate in the time of peak star formation some 3 - 5 Gyrs ago, or did that major burst of star formation occur differently? Would the random looking processes we currently see smooth out sufficiently over the required timescale to produce the bar like structure?

3.2.1. *Shapley Constellation III.* The best example of stochastic self-propagating star formation is Shapley Constellation III (Westerlund and Mathewson 1966). In a benchmark study of this region (also called LMC 4) Dopita *et al.* (1985)[DMF] used Isserstedt's (1984) stellar ages to argue convincingly that star formation has been propagating steadily outwards for the past 15 Myr (Figure 3). They also show that their model is dynamically consistent with the observations and provides sufficient energy via stellar winds. Star formation itself is believed to be initiated by compression of the HI gas by mass loss winds from the previous generation of hot stars. One possible mechanism for this to take place at the edge of mass loss bubbles has been given by Dopita (1981). The inner part of the LMC 4 region is devoid of neutral hydrogen, much of which is believed to have been swept up in the shell, and active star formation is occurring on the periphery, as shown by the presence of bright HII regions and the Lucke and Hodge (1970) young clusters. In the picture developed by DMF, star formation is arrested by the depletion of HI, as a significant fraction is ejected upwards out of the plane of the disk.

The simple picture outlined by DMF is disputed by both Westerlund (1985) and Reid *et al.* (1987). While both acknowledge the evidence of recent star forming activity being concentrated around the periphery of LMC 4, they claim that the distribution of stellar populations of different age, in particular the M supergiants, does not support the elegant simple picture. Westerlund suggests that an age spread of 5 x 10^6 years within a generation might reconcile these problems. Reid *et al.* also claim that the ages and spatial distribution of the Lucke and Hodge clusters present a more complicated picture. As seen in Figure 4, there is no simple age progression outwards for these clusters. A more appropriate suggestion might be that a burst of star formation some 10^7 years ago occurred over a larger region, and that the remaining clusters have been formed on average towards the outer edge of the ring, in a subsequent burst. The timescales appropriate here are reminiscent of those apparent for the two stellar populations in 30 Doradus (Hyland *et al.* 1978, McGregor and Hyland 1981).



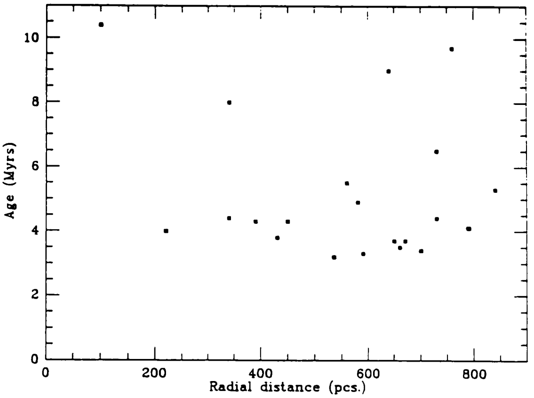


Fig. 3 (Top) The progression of the mean projected diameter of the star forming region with time in Constellation III as derived by Dopita *et al.* (1985) from the results of Isserstedt (1984).

Fig. 4 (Bottom) Radial distance from the centre of Shapley III plotted against age for the Lucke and Hodge associations. From Reid *et al.* (1987).

3.2.2. *Other Regions.* Testor and Lortet (1987) and Lortet and Testor (1988) have investigated several regions in the LMC and also the N83-84-85 regions in the SMC in terms of their recent star formation history and Heydari-Malayeri and Testor (1983) have investigated N11. Using the ages of WR stars of different sub-types together with ages derived from the spectral types of the OB stars and M supergiants, Lortet and Testor determined that in the regions they studied, there were age spreads of 4 - 10 Myr ranged over spatial scales of ~ 100pc. They could identify clear trends in age, as the apparent region of star formation propagated over a region, and suggested that this technique, and the use of the morphology, excitation and brightness of associated nebulae is a superior method for determining the detailed variation in age over star forming regions.

In an interesting side remark, they comment that it is the non-spherical distribution of the neutral gas which makes the investigation and interpretation of the propagation of star formation possible at all. Expanding on this idea, perhaps the reason that there has been so little evidence for similar self-propagating processes in the SMC reflects the more 3-dimensional nature of the neutral gas distribution there, with the significant 'depth' of the cloud, in comparison to the true disk-like nature of the LMC.

It is interesting to note that all the regions of recent star formation activity studied, show evidence for the presence of multiple generations of stars, with an almost common time for the initial commencement of star formation. One may speculate on the cause for an almost global burst of star formation commencing 2 - 5 x 10^7 years ago. The timescale does not appear to be correct for this event to be causally linked with the previously mentioned tidal encounter.

4. Current Star Forming Activity

In previous discussions of star formation in the Clouds, scant attention has been paid to the evidence and observation of *current* star formation. Perhaps this is due to the fact that such studies cannot reveal much about the past history and overall evolution of the Clouds, but only provide information about current physical processes. Nevertheless, such information may be particularly valuable in delineating the details of the star formation process, which possibly differ significantly from such processes in the Galaxy.

The first far-infrared observations of LMC HII regions (Werner *et al.* 1978) immediately revealed unexpected differences between those and galactic HII regions (later confirmed by IRAS). In particular, the Cloud regions do not possess high surface brightness cores such as are common in the Galaxy. Gatley *et al.* (1981, 1982) realised that candidate high mass protostars should be measurable in the near infrared with available instrumentation and telescopes, if star formation is continuing in the Clouds. Using near infrared techniques, and with a judicious choice of regions, they discovered the first protostars in both the LMC (in N159) and SMC (in N76B). Not surprisingly, given the indicators used for the choice of regions, (the presence of nearby OH, H_2O masers [Caswell and Haynes 1981, Scalise and Braz 1981], CO emission [Huggins *et al.* 1975], dust) these were similar in many respects to Galactic protostars. Epchtein *et al.* (1984) found new infrared sources in ionised regions associated with the bright HII regions N105 and N160A, which, although quite different from the previous sources are also likely to be pre-main sequence objects. Detailed follow up studies (see e.g. Figure 5) by Jones *et al* (1986) in both the far and near infrared define the overall properties of these star forming regions.

More recently, Hyland *et al.* (1990), and Hyland and Jones (this conference) have reported an investigation of the 30 Doradus region in the near infrared. They have identified four new candidate protostars in a region which differs markedly from the others previously studied. Two of these lie close to (but not coincident with) the far-infrared brightness peaks (Werner *et al.* 1978), but data with higher spatial resolution is required to determine whether there is a causal relationship in this alignment. More importantly, each source is aligned with a knot of optical [OIII] nebular emission, which suggests a close

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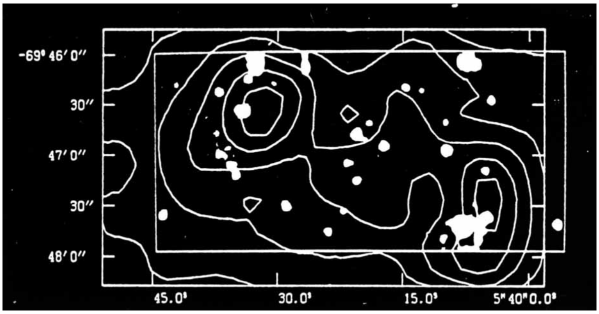

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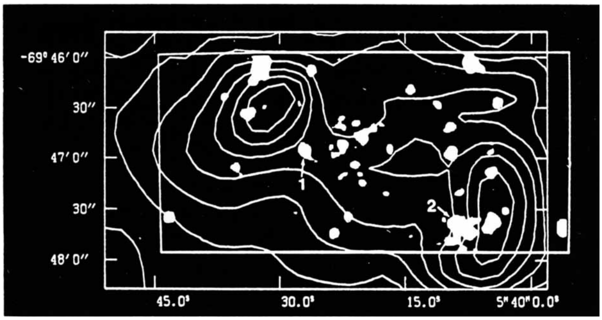

Fig. 5 The distributions of FIR flux in relation to the near IR images of N159. Protostar candidates 1 and 2 are indicated in the K image. From Jones *et al.* (1986).

relationship between these sources and the high excitation ionised blobs which have been identified in other Cloud regions (see below), and also suggests an interpretation of the star forming process for these stars. The mechanism proposed is that of the compression of gas by intersecting arcs of ionised material, ejected as mass loss winds from very young massive stars, in a manner suggested in the discussion of sequential, self-propagating star formation (Section 3). It would appear that this process, which differs from that of classical star formation in molecular clouds, can by-pass the cold molecular phase, and apparently lead to a very efficient process of star formation, if the dimensions and densities of the nebular knots in 30 Doradus are typical.

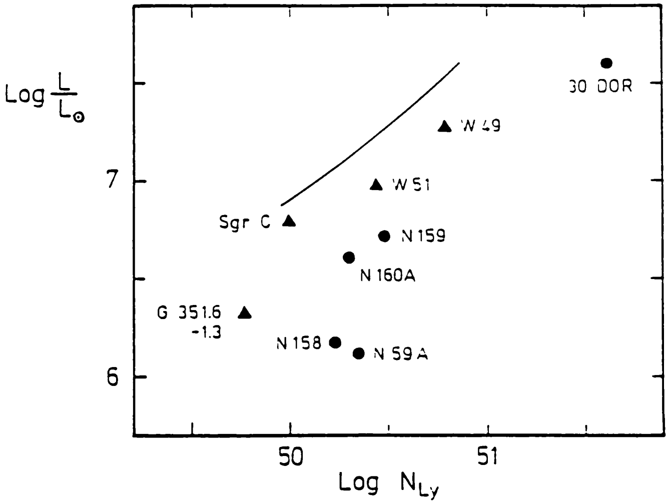

Fig. 6 A plot of the FIR luminosity versus the number of ionising photons. The line represents the expected relationship for a normal IMF cluster. The points plotted represent HII regions in the LMC and the Galaxy, showing the relative deficiency in luminosity for the Cloud regions. Adapted from Jones *et al.* (1986).

The two most striking properties of the infrared-identified protostar candidates and their associated HII regions are as follows:

- All four of the LMC HII regions studied by Jones *et al.* are underluminous for the number of ionising photons they produce (Figure 6), which may either be an indication of a truncation of the IMF, leading to a deficiency of intermediate mass stars relative to high mass stars, or due to geometrical effects (including a low dust component) which allow leakage of luminosity from the regions.

- There is an apparent absence of candidate protostars fainter than K~12, which is well above the limit of the surveys. This may also imply a truncation of the IMF, at least for the present phase of star formation, although for clusters covering a wide age range, there is no evidence for such a change (Mateo 1988b).

One of the most exciting advances in recent years in the identification of current star formation in the Magellanic Clouds, has been the visual identification of an increasing number of possible pre-main sequence objects. These are the excited ionised blobs in LMC HII regions which have been studied in depth by Heydari-Malayeri and Testor (1983, 1986) and one in N81 in the SMC (Heydari-Malayeri *et al.* 1988).

These appear to be an important new constituent of star forming regions of the Clouds. Their association with infrared sources in some regions is clearly established, but their relationship to the high-density knots in 30 Doradus has yet to be clarified. Nevertheless, they appear to be extremely young luminous stars, either just on the main sequence, or immediately prior to arriving on the main sequence. Walborn and Blades (1987) have also identified two early O stars embedded in [OIII] density enhancements in the 30 Doradus region, which they suggest are signs of continuing star formation. The idea that these are manifestations of the suggested star formation scenario in hot dense gas mentioned above, warrants intensive investigation.

5. Summary

Despite the great advances in studies of star formation in the Magellanic Clouds over the past decade, some of the most fundamental questions remain to be answered. These include:

Why has star formation taken place at a relatively constant rate in the Clouds, and not followed the prompt disk formation and associated star formation process undergone by the Galaxy?

Why does the rate of star formation in the Clouds appear not to depend on the gas content of the galaxies?

Have the Clouds been affected in their star formation processes by interaction between themselves? In particular, if there is no evidence for concurrent bursts of star formation within the Clouds which can be ascribed to such interactions, is it possible that their binary nature may actually inhibit star formation, and hence also have been the major influence in preventing a Milky Way-like history?

Is the IMF constant with time, and are there theoretical reasons for favouring high mass stars in the hot type of star formation process which seems to be common in the LMC?

When these questions are answered, we will be well on the way to a true understanding of our companion galaxies.

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References

Bothun, G.D., Thompson, I.B. (1988), *Astron. J.* **96**, 877.

Braunsfurth, E., Feitzinger, J.V. (1983), *Astron. Astrophys.* **127**, 113.

Brück, M.T. (1978), *Astron. Astrophys.* **68**, 181.

Brück, M.T. (1980), *Astron. Astrophys.* **87**, 92.

Brück, M.T., Marsoglu, A. (1978), *Astron. Astrophys*, **68**, 193.

Butcher, H.R. (1977), *Astrophys. J.* **216**, 372.

Caswell, J.L., Haynes, R.F. (1981), *M.N.R.A.S.* **194**, 33P.

Cowley, A.P., Hartwick, F.D.A. (1982), *Astrophys. J.* **259**, 89.

Davies, R.D., Eliott, K.H., Meaburn, J. (1976), *Mem. R. astr. Soc.* **81**, 89.

de Vaucouleurs, G. (1955), *Astron. J.* **60**, 219.

Dopita, M.A. (1981), *Astrophys. J.* **246**, 65.

Dopita, M.A. (1985), *Birth and Evolution of Massive Stars and Stellar Groups*, W. Boland, H. van Woerden (eds.) (Reidel: Dordrecht) p.269.

Dopita, M.A. (1987), *IAU Symp 115 Star Forming Regions*, M. Peimbert, J. Jugaku (eds.) (Reidel: Dordrecht) p.501.

Dopita, M.A., Mathewson, D.S., Ford, V.L. (1985), *Astrophys. J.* **297**, 599.

Epchtein, N., Braz, M.A., Sevre, F. (1984), *Astron. Astrophys.* **140**, 67.
Feitzinger, J.V. (1984), IAU Symp 108 *Structure and Evolution of the Magellanic Clouds*, S. van den Bergh, K.S. de Boer (eds.) (Reidel: Dordrecht) p.89.
Feitzinger, J.V. (1987), *IAU Symp 115 Star Forming Regions*, M. Peimbert, J. Jugaku (eds.) (Reidel: Dordrecht) p.521.
Feitzinger, J.V., Braunsfurth, E. (1984), *Astron. Astrophys.* **139**, 104.
Feitzinger, J.V., Glassgold, A.E., Gerola, H., Seiden, P.E. (1981), *Astron. Astrophys.* **98**, 371.
Foy, R. (1983), *Messenger*, no. **31**, 24.
Frogel, J.A., Blanco, V.C. (1983), *Astrophys. J.* **274**, L57.
Fujimoto, M., Murai, T. (1984), *IAU Symp 108 Structure and Evolution of the Magellanic Clouds*, S. van den Bergh, K.S. de Boer (eds.) (Reidel: Dordrecht) p.115.
Gatley, I., Becklin, E.E., Hyland, A.R., Jones, T.J. (1981), *M.N.R.A.S.* **197**, 17P.
Gatley, I., Hyland, A.R., Jones, T.J. (1982), *M.N.R.A.S.* **200**, 521.
Goudis, C., Meaburn, J. (1978), *Astron. Astrophys.* **68**, 189.
Hardy, E., Durand, D. (1984), *Astrophys. J.* **279**, 567.
Hardy, E., Buonanno, R., Corsi, C., Janes, K., Schommer, R. (1984), *Astrophys. J.* **278**, 592.
Hawkins, M.R.S., Brück, M.T. (1982), *M.N.R.A.S.* **198**, 935.
Hawkins, M.R.S., Brück, M.T. (1984), *IAU Symp 108 Structure and Evolution of the Magellanic Clouds*, S. van den Bergh, K.S. de Boer (eds.) (Reidel: Dordrecht) p.101.
Heydari-Malayeri, M., Testor, G. (1983), *Astron. Astrophys.* **118**, 116.
Heydari-Malayeri, M., Testor, G. (1986), *Astron. Astrophys.* **162**, 180.
Heydari-Malayeri, M., Le Bertre, T., Magain, P. (1988), *Astron. Astrophys.* **195,** 230.
Hodge, P.W. (1988), *Publ. Astr. Soc. Pacific* **100**, 576.
Huggins, P.J., Gillespie, A.R., Phillips, T.G., Gardner, F., Knowles, S. (1975), *M.N.R.A.S.* **173**, 69P.
Hyland, A.R., Jones, T.J. (1990), these proceedings.
Hyland, A.R., Straw, S., Jones, T.J., Gatley, I. (1990), in preparation.
Hyland, A.R., Thomas, J.T., Robinson, G. (1978), *Astron. J.* **83**, 20.
Isserstedt, J. (1984), *Astron. Astrophys.* **115**, 97.
Jensen, J., Mould, J., Reid, N. (1988), *Astrophys. J. Suppl. Ser.* **67**, 77.
Jones, T.J., Hyland, A.R., *et al.* (1986), *M.N.R.A.S.* **219**, 603.
Kaler, J.B. (1974), *Astrophys. J.* **188**, L15.
Larson, R.B., Tinsley, B.M. (1978), *Astrophys. J.* **219**, 46.
Lequeux, J. (1984), *IAU Symp 108 Structure and Evolution of the Magellanic Clouds*, S. van den Bergh, K.S. de Boer (eds.) (Reidel: Dordrecht) p.67.
Lucke, P.B., Hodge, P.W. (1970), *Astron. J.* **75**, 171.
Lortet, M.-C., Testor, G. (1988), *Astron. Astrophys.* **194**, 11.
Mateo, M. (1988), *IAU Symp 126 The Harlow-Shapley Symposium on Globular Cluster Systems in Galaxies*, J.E. Grindlay, A.G. Davis Philip (eds.) (Kluwer: Dordrecht) p.557.
Mateo, M. (1988b), *Astrophys. J.* **331**, 261.
Mathewson, D.S., Ford, V.L. (1984), *IAU Symp 108 Structure and Evolution of the Magellanic Clouds*, S. van den Bergh, K.S. de Boer (eds.) (Reidel: Dordrecht) p.125.
McGregor, P.J., Hyland, A.R. (1981), *Astrophys. J.* **250**, 116.

Mould, J.R., Da Costa, G.S., Crawford, M.D. (1984), *Astrophys. J.* **280**, 595.

Nail, V. McK., Shapley, H. (1953), *Proc. Nat. Acad. Sci.* **39**, 358.

Peimbert, M., Torres-Peimbert, S. (1971), *Astrophys. J.* **168**, 413.

Reid, N., Mould, J., Thompson, I. (1987), *Astrophys. J.* **323**, 433.

Rocca-Volmerange, B., Lequeux, J., Maucherat-Joubert, M. (1981), *Astron. Astrophys.* **104**, 177.

Scalise, E., Braz, M.A. (1981), *Nature*, **290**, 36.

Searle, L. (1984), *IAU Symp 108 Structure and Evolution of the Magellanic Clouds,* S. van den Bergh, K.S. de Boer (eds.) (Reidel: Dordrecht) p.13.

Searle, L., Wilkinson, A., Bagnuolo, W.G. (1980), *Astrophys. J.* **239**, 803.

Smith, H.A., Searle, L., Manduca, M. (1988), *IAU Symp 126 The Harlow-Shapley Symposium on Globular Cluster Systems in Galaxies*, J.E. Grindlay, A.G. Davis Philip (eds.) (Kluwer: Dordrecht) p.563.

Spicker, J., Feitzinger, J.V. (1988), *Astron. Astrophys.* **191**, 10.

Stryker, L.L. (1984), *IAU Symp 108 Structure and Evolution of the Magellanic Clouds*, S. van den Bergh, K.S. de Boer (eds.) (Reidel: Dordrecht) p.79.

Stryker, L.L., Butcher, H.R. (1981), *IAU Colloqium 68*, A.G. Davis Philip, D.S. Hayes (eds.) (L. Davis Press: Schenectady) p.255.

Testor, G., Lortet, M.-C. (1987), *Astron. Astrophys.* **178**, 25.

Walborn, N.R., Blades, J.C. (1987), *Astrophys. J.* **323**, L65.

Werner, M.W., Becklin, E.E., *et al.* (1978), *M.N.R.A.S.* **184**, 365.

Westerlund, B.E. (1985), *Birth and Evolution of Massive Stars and Stellar Groups*, W. Boland, H. van Woerden (eds.) (Reidel: Dordrecht) p.259.

Westerlund, B., Mathewson, D.S.(1966), *M.N.R.A.S.* **131**, 371.