OPEN DISCUSSION; SESSION I (Chairman: Ken Janes)

JANES: Let us begin the discussion phase of this session. To start with, Tom Ray would like to give a brief presentation.

RAY: It has been known for some time that energetic mass loss occurs in the early stages of star formation. This is illustrated not only by large scale bipolar outflows but by smaller scale supersonic jets. These jets have spectra similar to those of Herbig-Haro (HH) objects, i.e. characterized by low excitation emission lines. They will therefore appear bright in the R band (or through a suitable emission

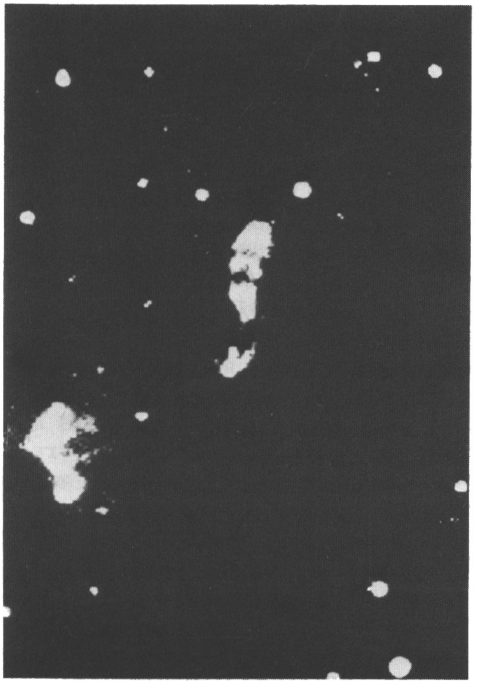

Figure 1: GGD 34 (centre) and HH 105 (lower left). North is to the right. This is a 15 min. exposure in SII (6730 Å, 50 Å wide). GGD 34 is seen to consist of a quasi continuous stream of HH objects associated with a conical reflection nebula. The latter is clearly evident in a V band shot whereas, in the same shot, the HH objects are invisible.

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line filter e.g. Hα or SII (6730 Å)), but very faint in the V or I bands. By comparison, a reflection nebulosity will appear bright in all three bands but faint in Hα.

In September 1985, we began a search for jets from young stars using the 100" Isaac Newton Telescope on La Palma. All our observations were done using a thin RCA CCD at the prime focus of the INT (CCD field of approximately 7'x3'). Seeing was about 1" or better. Our findings will be published elsewhere, so we wish only to make a preliminary report of our observations here. In total we found five new jets associated with HH 3, HH 24, HH 105, GGD 34 and RNO 43. Fig. 1 shows two examples: GGD 34 and HH 105. We have also found two new HH objects in the Cepheus A cloud. The HH objects lie close to the axis of the known CO bipolar outflow, on the blue shifted side. This is to be expected, since the blue shifted side has a lower extinction.

JANES: Perhaps we should move on to have some more discussion. You can either make general comments or address your questions to one of the speakers. Do you have any questions to start with?

McKEITH: I work with Philip Dufton and F.P. Keenan on CNO abundances in loose associations and clusters. Well, we did look at the OB cluster in Orion and also the Pleiades cluster. It would seem to me that the Pleiades cluster, being a very young cluster, would be a good candidate for the kinematics as discussed in the second paper. Therefore I would like to ask: Is it a good candidate and why hasn't it been looked at in this context? Secondly: what effect would the rotational energy, because some of these stars have very high v*sin i, have on the dissolution of the cluster? Thirdly, because it is a possibility, what about binaries and multiples; in other words, the total energy is the spatial energy, rotational energy and orbital energy and this then being a very young unevolved cluster, would this not be an obvious first choice?

MATHIEU: Well, in fact it is an obvious choice and it has been done. An excellent proper-motion study of the Pleiades has recently been completed by Floor van Leeuwen. He measures internal motions on the order of 0.6 km/sec. This, in conjunction with his structural analysis of the cluster, is consistent with the cluster having relaxed to an equilibrium configuration. He found a total mass, the virial mass on the order of 1000-2000 $M_\odot$. I did not quite understand your point about the v*sin i of the stars with relevance to dynamics.

McKEITH: Well, if you consider the total energy of the initial molecular cloud, before star formation, perhaps it is simplistic to assume that part of that energy goes into the rotational energy of the stars, as well as the spatial energy. If there were multiple stars formed the total energy in the cloud would in other words be distributed between the spatial energy, kinetic energy of the stars, the orbital energy and the rotational energy.

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I'm questioning whether the rotational velocity of the stars and the multiple binary energy was taken into consideration?

MATHIEU: Certainly the rotational energy of a star-forming cloud is an important contributor to the support of the cloud and similarly to the support of the stellar system which forms out of the cloud. Note again, for example, the rotation of the cloud surrounding K3-50. The energy in multiple star systems is less relevant to the global dynamics unless that energy is tapped via close encounters. Except in the smallest systems I would expect the rate of that energy input to be small enough to be negligible on time-scales of a few million years.

JANES: Maybe we can continue with some other point.

LYNGÅ: I believe you when you say that the formation of a bound cluster is an unusual thing. Would you then not expect the initial mass function for clusters to be different from that of the field?

MATHIEU: I think one must be conscious of this point. I would simply say that I'm not sure that we expect it, one might just not be surprised.

ZINNECKER: Perhaps the cluster initial mass function is the same as the field star initial mass function, but perhaps it is not. This is unclear at present. As I said, there may be this turn-over at the lower mass end. Many clusters seem to show this feature, though we cannot be sure because of incompleteness and because of the core-halo structure. It could be that for the clusters the gas is around for a longer time and so the accretion can proceed for a longer time and the lower masses are just not there because of this. The other thing to keep in mind is that most stars should be forming in the giant molecular clouds, in the 10^5 M_o giant molecular cloud, because that is where most of the mass of the interstellar matter is. So what we really have to ask is whether the initial mass function averaged over a giant molecular cloud is somewhat like the field star initial mass function.

JANES: Thank you. Do we have some further discussion?

SAGAR: A question to Hans Zinnecker. In your talk you mentioned that Cohen and Kuhi avoided the use of bolometric correction, reddening etc. However, this is not the case. Of course, they have estimated in a better way using IR observations. In order to compare the theory with observations either one has to convert observed colour-magnitude diagram into $\log(L/L_\odot)$ - $\log T_{eff}$ plane or vice versa. Cohen and Kuhi have converted Iben tracks from $\log(L/L_\odot)$ - $\log T_{eff}$ plane into the observed colour-magnitude diagram.

ZINNECKER: I'm not sure whether I agree. It seems to me that Cohen and Kuhi have made a step in the right direction. By measuring the flux in different bands including the infrared they can integrate the energy distribution to get the bolometric luminosity directly, while a measure of the effective temperature is obtained from this optical spectroscopy. Therefore they get the HR diagram directly. Now, I think, if you go from the colour-magnitude diagram to an HR diagram, this is more indirect and subject to more uncertainties, especially for pre-main-sequence stars for which the normal calibrations and bolometric corrections may not apply.

DAS GUPTA: These stars have velocities of the order of 1 km/s. Would you expect them to rise above the disk of the galaxy?

MATHIEU: No. The velocity dispersions of even the material most confined to the disk (e.g., giant molecular clouds) are of order 5-10 km/sec, so the internal motions of stars in young clouds would not significantly affect their galactic distribution.

TARAFDAR: This is a question for the third speaker. I am S.P. Tarafdar from India. Is there any difference in star formation efficiency in associations or in clusters or in field stars? Why I am asking is because clusters seem to be bound. Maybe that before dispersion takes place, more matter will go to the star, rather than association, probably efficiency will be low, because it will break up.

MATHIEU: Suspected differences in cluster and field mass functions have been a question of interest since the early work of van den Bergh and Sher. While the evidence mounts that differences do exist, generally in the sense of a paucity of low mass stars in clusters (see recent review by Scalo), the quality of the observational data is still such that it remains difficult to look for any general trends among the clusters. The initial mass function of associations is I think one of the more fundamental unknowns. The determination of the IMF in associations is difficult due to extensive field contamination, but the group at Leiden is beginning to make important progress on this problem with photometry and ultimately HIPPARCOS.

Another aspect of this problem is just now coming to light, in particular the question of whether stars of all mass form cospatially. I will show again the figure of the λ Orionis region. Notice that in the vicinity of the OB association there is actually a paucity of Hα stars; nor is there any evidence of a concentration of fainter stars in the region on the POSS as might be expected if one predicted the total number of stars by fitting the Miller and Scalo initial mass function to the observed high-mass stars. It would seem then that, at least in this region, the most massive stars and the low-mass stars have not formed in the same locations. In other words, the initial mass function may very well not be "universal" on the scale of star-forming regions (although it may very well be more universal on the scale of entire giant molecular clouds). In a similar vein, the young cluster NGC 6530 (private communication, McNamara) appears to already be mass segregated and R. Sagar tells me that he sees a similar effect in other young clusters. Whether this is the result of formation or dynamics I think remains unclear, but if the latter can be ruled out then again we may have evidence for high and low mass stars not forming in identical volumes of a star-forming region.

ZINNECKER: I agree entirely with that. I'd just like to add the case of NGC 2264, where Adams, Strom and Strom have found these halo low-mass stars. Previously the initial mass function of NGC 2264 seemed to turn over, but now if you include the core-halo structure, the halo of low-mass stars, then it is a Salpeter function down to 0.3 solar masses. So I think it is very important to keep in mind over what scales we average the initial mass function before we speak of a sort of universal initial mass function. It is just a statistical effect that it looks universal. I think there are so many processes that contribute and after sufficient averaging it looks similar everywhere.

JANES: We have time for one or two more questions. Do we have any more?

FREEMAN: Presumably, the efficiency of star formation in the sense that Bob Mathieu was talking about, does depend rather much on the details of the very top end of the mass function. Can anyone tell me how many stars, say about 20 $M_\odot$, you would actually need to clean out a proto-cluster, so that the thing would no longer be bound?

JANES: Does anyone want to answer that question?

MATHIEU: Over the scale of a few parsecs, in which for example a cluster might form, only one massive star is needed and indeed it may be possible that outflows from low-mass stars will suffice. To disrupt an entire molecular cloud requires more energy of course and thus probably more massive stars, although λ Orionis seems to have been quite successful without additional O-type stars.

JANES: Any further questions?

ZINNECKER: I'd like to make a comment to two. It seems important to me what the structure, what the clumpy structure of the molecular cloud is. If there is high clumpiness, then this one O star that sends its radiation into the cloud may, in fact, do one of two things: either it will quench all the star formation or it will implode a few fragments. Whether it can implode low-mass fragments and that way cause a last burst of low-mass star formation in that cluster, I don't know, but it seems more likely that it can only implode other high-mass fragments.

JANES: I might address a question to André Maeder on something slightly related. Does the time scale of the mass loss that you are talking about have any relevance to the blowing away of gas in the clusters, or is that too long a time scale to be important for dispersing the gas around these clusters that we have been hearing?

MAEDER: What do you exactly mean by the time scale of the mass loss? In terms of internal structure one speaks of the time necessary for losing half of the stellar mass, but that depends on the velocity and on the

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efficiency. Now, what can be said is that it is clear that the wind dominates the energetics around OB associations. That is very clear, but the time will depend on the velocity and on the size of the association.

JANES: And your model does not include this?

MAEDER: No, the model concerns the internal structure and not the structure of the overall association.

JANES: If there are no more questions I thank you all and the speakers.