OPEN DISCUSSION; SESSION III (Chairman: Per Olof Lindblad)

LINDBLAD: Thank you Dr Gallagher. You may remain up here, and as we will have the open discussion, may I ask the other speakers to come up to the stage. It's my impression listening to this that as far as galaxies are concerned we are lacking something like a grand unified theory here, so that we don't have to imply that we have different mechanisms for causing density waves in the Andromeda, in M51 or NGC 1365 and also not to imply different triggerings of star formations varying with the Hubble type of galaxies. May I ask for questions. Please?

MATHIS: We have not yet said much about the non-thermal radio emission. Can anyone tell me how much the non-thermal radio emission of galaxies is correlated with their present star formation rate and other properties?

GALLAGHER: I will answer the question, only because I was at Dr Wielebinski's talk yesterday. He showed from the work being done at Bonn with the 100 m telescope that there is an excellent correlation between the non-thermal radiation and the star formation rate measured by a variety of parameters. I have to admit I was very surprised, because the non-thermal radiation should depend upon both the injection of particles and the field geometry, whether the Galaxy is leaky or not, and yet it seems that galaxies are made from a common die.

BLACK: I want to make a couple of comments to amplify on points in the last lecture about molecules and molecular shielding. First of all, to put a number on the effects of molecular shielding, particularly in the case of CO, one could consider, for example, the inner 10 arcseconds or so of M82. From Brackett gamma line fluxes one could infer the density of ionizing photons, hence something like the local intensity of 1000 Å photons, which are effective in destroying H_2 and CO. In that radiation field the unshielded lifetime of CO molecules is approximately one year. In fact, with that in mind it becomes rather difficult to imagine, as some of the molecular line radio astronomers have claimed, that the molecular clouds in M82 are extremely small and extremely numerous and optically thin in CO lines. With such small column densities of CO in individual clouds they barely become self-shielding. The molecules survive such a short time that they will have to be formed on extremely rapid time scales. That brings me to another brief point about the hydrogen molecules. It was pointed out that a certain column density is required before the molecules become self-shielding and that that size also depends upon the ultraviolet intensity. There

J.-P. Swings (ed.), Highlights of Astronomy, 545–550.

are a couple of other effects, namely the formation rate that has to keep up with the destruction rate. This becomes quite interesting I think in the case of the metal-poor or dust-deficient systems in which there is probably also a much reduced grain surface area on which the molecules would form for the the formation rates considered here.

GALLAGHER: Hidden away on my slide was an R_G going down as the destruction rate went up. I agree with you completely.

STARK: In reference to the question about molecule destruction in M82: At IAU 115 in Tokyo two weeks ago, observers at Nobeyama Radio observatory reported 45 m telescope observations of M82 which were consistent with no molecules in the inner few parsecs. Also, the optically thin CO gas I found in the filaments in the halo of M82 is several kiloparsecs from the disruptive OB stars you mentioned.

LINDBLAD: Any comment on this? Any more questions?

SHAPIRO: This is a sort of ABC question. We have heard a lot about star bursts throughout this IAU General Assembly. I'm wondering naively, how do you define the star bursts; more specifically, is there some lower limits to the rates per unit time, per unit value, star formation, that would entitle it to be called a star burst?

LINDBLAD: Do you want to define it?

HUNTER: I at least think of a star burst as a global sort of phenomenon over the entire galaxy which glows until it bursts into flame. In terms of putting it quantitatively, I'm not sure but it is some sort of coherent increase in the star formation rate by many factors and that is then contrasted to the sort of statistical fluctuation in which just a given, a single star-forming region turns on and turns off in galaxies.

ROSA: I may add to this that there is quite the other view also that it depends entirely on the scale that you are looking at. In the case of these giant HII regions they are in the class of very large violent star-formation bursts of Terlevich and Melnick. These make up only the lower end of the luminosity function and what Terlevich and Melnick call bursts is a very localised (say on the scale of 20 parsecs) phenomenon that converts of the order of 10^5 $M_\odot$ or more mass into stars on a time scale of 1 million year or even less. So, the burst description in my view is very much dependent on which scales you are looking at.

ZINNECKER: I would like to comment on this definition of star burst because, as Michael Rosa said, the scale matters, so we want a scale independent definition. I think the definition from the observational point of view would just be in terms of surface brightness, so it would be the luminosity, the bolometric luminosity per unit area. Perhaps there is agreement or disagreement about that? Like for example 10^{10} $L_\odot$/kiloparsecs^2. That is the sort of thing one could have in mind, or 10^6 per (10 pc)^2.

https://doi.org/10.1017/S1539299600006900 Published online by Cambridge University Press

LINDBLAD: Please, diagree!

HUNTER: Well, again it depends on what you are measuring your surface brightness over. For example, in DDO 42, if you measure the surface brightness or if you look at the galaxy as a whole, it is not undergoing a burst of star formation. But if you look at that giant star-forming complex in there, that is an enormous event. Just because that galaxy is producing this giant star-forming region doesn't mean that the whole galaxy is undergoing a burst of star formation.

GALLAGHER: By those standards the M31 nucleus is bursting even though it is not forming stars. (Laughter)

GONDALEKHAR: It is a question for Dr Gallagher. Does he find any differences in dust content of galaxies with morphological type?

GALLAGHER: I don't think there is really enough information to tell. There are certainly dust differences in the optical. If you look in the IRAS system what you find is that as you go to the more gas-poor systems, the SA:s, the SO:s and the Ellipticals, certainly the amount or the optical depth of the dust in the interstellar medium goes down. Whether that is a physically very meaningful statement is hard to say, because the absolute amount of gas is also going down. The main difference that one sees now is that on average the Irregulars are more metal-poor and therefore the dust interacts less efficiently with the interstellar radiation field. I should also mention the work of Francois Viallefond who has argued the same point for the outer region of the M101 spiral galaxy, which is also metal-poor.

GONDALEKHAR: Can I make a quick comment on this? I have looked at three blue compact galaxies, observed by IRAS; Zwicky 18 is one of them with probable relevance to the point you made. The gas/dust ratio in this galaxy comes out to be greater than 10^5, so this galaxy should be transparent to ultraviolet radiation.

CAYREL: A question I address to Dr Rosa. You have shown a colour-luminosity diagram for the 30 Doradus complex. You have mentioned that the stars of lower mass were the apparently most evolved and the question is: would you exclude that these stars are pre-main-sequence stars?

ROSA: I think there is a misunderstanding. The lowest mass that we saw on the HR diagram is 40 $M_\odot$, and those are spectroscopically classified blue supergiants that are scattered about the area of the cluster. There is some information that the actual high-mass population that you saw near the main-sequence is more centered about the core of 30 Dor and that these blue supergiants, there are also from work of Hyland and McGregor red supergiants in the field, that they are the remnants of a more quiescent, in the terms of 30 Dor more quiescent, star formation event in the whole area of about 2 kiloparsecs. So they are certainly not pre-main-sequence stars.

https://doi.org/10.1017/S1539299600006900 Published online by Cambridge University Press

McCALL: I wish to draw your attention to recent work by Robin Arsenault and Jean-Réné Roy at L'Université Laval in Québec. They have just completed an extensive Fabry-Pérot survey of velocity dispersions in extragalactic HII regions. They find that the relation between diameter and velocity dispersion is that expected for a Kolmogorov turbulent cascade, and suggest that the velocity dispersion observed for a given HII region is set simply by the length scale of the interstellar medium sampled by the ionized gas.

LINDBLAD: You want to react?

ROSA: I agree that this is still another view on the topic and I'm certainly happy to find that this agrees perfectly with the view that this is coming from the energetic output of the OB association and not from gravitationally bound systems.

SHAPIRO: This is a question about star bursts and supernova bursts. I would like to ask any of the experts: is it certain, is it probable or is it merely possible that a region of stars bursts will also be a region of very frequent, almost explosively frequent supernova explosions?

LINDBLAD: Who wants to answer?

ROSA: I think that depends very much on the evolution in the upper mass range of the HR diagram and I would like to pass this question to André Maeder by asking him: what type of supernovae he expects for stars more massive than 40 $M_\odot$?

MAEDER: Above initial masses up to about 40, one expects the progenitor of supernovae to be blue stars and especially Wolf-Rayet stars. So this would give the kind of supernovae, like Cassiopeia A is supposed to be.

LINDBLAD: Do we have more questions?

CHATTERJEE: Do those elliptical galaxies which show gas and dust lanes show evidence of star formation? Has star formation in such galaxies been studied? Can anyone comment on this?

GALLAGHER: The best data are a study from the IRAS satellite observations that were done by Jura and these were for the fairly small or normal ellipticals, not like Centaurus A, where there is star formation in the dust lane. I think you see a range from fairly actively star-forming dust lanes all the way to systems where there is no evidence for ongoing star formation, which also by the way includes the center of M31. The IRAS observations seem to exclude much in the way of any embedded sources there, so it is a good example of an elliptical-like system.

LINDBLAD: May I ask Dr Hunter a question? It is claimed by Elmegreen that spiral arms do not trigger star formation. Star formation is just simply a function of the density of the material there. Is that something that you would agree to; do you find evidence that that would be the case, that star formation is just the first power of the density?

HUNTER: My understanding of what he says is that these spiral density waves cause the cloud formation. He is saying that they don't trigger directly the star formation but they do trigger the cloud formation and irregular galaxies seem to do it quite well without them; I wonder what the role is that these spiral density waves actually play, since irregular galaxies don't seem to need them.

WILLNER: I'm wondering if anyone has ever tried to get the initial mass function, or luminosity function or something for the molecular clouds themselves or for the giant HII regions. Suppose one defines the luminosity function of stars to be the number of stars in each luminosity, one could similarly define a luminosity function for HII regions to be the number of HII regions in any given luminosity, in other words, whether you have lots of big ones or lots of little ones or somewhat in between. The question is, has anyone done that and if so, does it differ in different types of galaxies?

ROSA: There are quite a number of what you would call luminosity functions for HII regions. Sydney van den Bergh as well as Hodge and Kennicutt and others study distributions in different galaxies and they always find power laws or exponential laws. I don't know how much that is related to the formation of star forming giant molecular clouds. There is also a luminosity function for molecular clouds in the sense that you have a large number of small, cool clouds and a lower number of giant, hot clouds.

STARK: Deidre Hunter has raised an interesting question: Why do stars form in spirals where there is a spiral density wave, whereas they form with apparently equal efficiency where there is none? A possible resolution of this apparent dilemma may be found in the formation of giant molecular clouds. The formation of giant molecular clouds is unstable. The giant molecular clouds will tend to grow until they have incorporated into themselves a large fraction of the interstellar medium. Once formed, they begin their own self-destruction by making stars, in an environment isolated from the rest of the galaxy. Giant molecular cloud formation will go to completion in most galaxies, whether they have density waves or not. If there are density waves, however, the instability will tend to go most readily there, and the giant molecular clouds and massive star formation will tend to be in the spiral arms.

HUNTER: So, you're saying that the spiral density waves just order the regions like in the Gerola and Seiden models, where it is just a means of putting it into this pattern.

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STARK: Right. You have to have a nucleation site where growth of those giant molecular clouds begin and then melt away and that is more likely to happen in a spiral density wave.

LINDBLAD: I think by this we conclude this session and we resume at four o'clock sharp.

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