DISCUSSION

MOUSCHOVIAS: I have a comment on the importance of magnetic fields in star formation. On the light side, theorists would rather like that the fields dissipated overnight. Unfortunately, it takes longer than the age of the universe to do so; the interstellar field will be with us for quite a while. Observers would rather not have to measure the field strength because it is very difficult to do so. Yet, the field strength *is* being measured (and it is in agreement with theoretical predictions). Seriously now, the most important role that the field plays in star formation is to resolve the most severe dynamical problem of star formation; namely, the angular momentum problem. Our calculations have shown that magnetic braking removes several orders of magnitude of angular momentum from a contracting blob of matter, thus allowing both binary stars (with orbital periods 10 hr - 100 yr) and single stars to form (see 1985, Astrophys. J. issue of Nov. 1 and references therein). This must and can happen at densities less than 10^6 cm^{-3} for the formation of binary stars, and at somewhat higher densities for single stars. Typical molecular cloud cores have already resolved their angular-momentum problem as far as binary-star formation is concerned.

The field, however, poses itself another severe problem, namely, the magnetic flux problem, which lies in the fact observed stellar fluxes are between 2 and 5 orders of magnitude smaller than they should be if the field were to remain frozen in the matter. Our calculations have shown that the field decouples dynamically from the matter at typical densities $\sim 10^6$ cm^{-3}, but the flux problem is resolved at higher densities $\leq 10^9$ cm^{-3} (see 1985, Astrophys. J. issue of April 15 and references therein).

Partly as a result of this meeting, I believe that the next IAU Symposium on Star Formation should have a review talk on the role of magnetic fields in that process.

RODRIGUEZ: I have a concern in what refers to the so-called optical "jets". If we look at the image of the elongated structure associated with HL and XZ Tau we see that it does not appear to be coming from any of the stars, but from a region in between. Actually, I believe that many of these structures are only projection effects. In the case of HL and XZ Tau we may have two interacting winds and what we are observing is the interface of these interacting winds.

WILSON: If you want to study the process of star formation, you must restrict yourself to nearby sources, where, with 1" - 10" angular resolutions, you can have equivalent linear sizes of 10^{15} - 10^{16} cm. In even the nearest galaxies, the narrowest beams average very inhomogeneous phenomena.

DICKEL: Comment on Nomenclature: The galactic and extragalactic investigators are using the same abbreviations for two different things: the standard SMC for Small Magellanic Cloud which is alright, and non standard, *to be avoided* SMC for small molecular cloud. We need a new abbreviation but I do *not* suggest LMC for Little Molecular Cloud nor TMC for Tiny Molecular Cloud.

GARCIA-BARRETO: I have two questions for Bruce Elmegreen: 1) do tight

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spiral arms seen in the nuclear part of barred galaxies come from density waves? 2) Do magnetic fields play any role in the formation of spiral arms or are they a by-product of the spiral arms?

ELMEGREEN: 1) Sanders and Tubbs (1980, Astrophys. J. 235, 803) proposed that the inner spirals in barred galaxies are shock fronts that trace out a gradual change in the orientation of elongated gaseous orbits. Elongated stellar orbits change their orientations by 90° at each of the orbit resonances, e.g. the inner Lindblad resonances and corotation. The gas cannot change its orbit as abruptly as the stars because the gas flow lines cannot cross. Thus the sudden change experienced by stellar orbits is replaced by a gradual change for gas that shocks. In any case, barred galaxies with inner spiral, probably have two inner Lindblad resonances. The spiral shock traces out the 90° shift between these two resonances. These inner spirals are primarily gaseous spirals, which may contain stars because of triggered star formation (this is an important exception to what appears to be a general lack of such triggering in normal spiral arms). The outer spiral arms in barred galaxies, and the spiral arms in non-barred galaxies, appear to be stellar spirals. They are both wave patterns. 2) Magnetic fields should influence the flow of gas in the inner spirals or barred galaxies and they should influence the flow of gas in the stellar spirals elsewhere. They cannot influence the stellar spirals directly.

SHU: I also have two questions for Bruce Elmegreen: 1) He raised, I believe, a very important possibility, namely that density waves may only bring the centers of stars closer together and not play a direct role in star formation. He also showed evidence for the star formation rate per molecular cloud being not enhanced in spiral arms. If this view is correct, doesn't it imply that there are *no* triggers of star formation *external* to molecular clouds? If star formation in one cloud could induce star formation in another cloud, should not there be more star formation in spiral arms where clouds are closer together? 2) The best evidence classically for density waves being involved, at least indirectly, in star formation comes from the relative positioning of dust lanes and giant H II regions. Elmegreen's interpretation of dust lanes was that they are shocks in a warm intercloud medium. But the observers tell me that dust lanes produce 1 mag or more of visual extinction. One mag of extinction in a face-on galaxy = 20 $M_{\odot}$ pc^{-2}. Does not this imply that dust lanes must comprise all phases of the ISM and not just a phase which has relatively a low mass fraction?

ELMEGREEN: 1) This view does not imply that there are no triggers. The triggering mechanism could be independent of the space density of clouds. Triggering may involve the motion of intercloud (H I) gas, which gets compressed by existing regions of star formation, and subsequently forms new molecular clouds to replace the old ones broken up by the star formation. Such gas motions could be independent of the cloud density. The mechanism for propagation is too poorly understood to predict its response to a density wave. 2) The shocked component that produces a dust lane might consist of both diffuse clouds and an intercloud medium, but not dense molecular

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clouds. The diffuse clouds have an internal pressure that is less than the shock pressure, whereas the dense molecular clouds often have a higher pressure because of self-gravity. The diffuse clouds are also more strongly coupled to the intercloud medium by magnetic fields than are the molecular clouds (i.e. molecular clouds are more ballistic than diffuse clouds). I believe that a composite fluid consisting of diffuse clouds and an intercloud medium could shock to produce the observed extinctions in dust lanes, and that many of the molecular clouds could flow right through.

KAHN: Star formation must take place in any galaxy that has spiral arms, spiral structure itself tends to randomize stellar velocities. When the stellar velocity distribution is too "hot" in a galaxy, then spiral arms no longer form there. Consequently, the continued existence of spiral structure depends on a continuing injection of newly formed stars with small random velocities.

HAYASHI C.: I would like to comment on item 9 in the table shown by Genzel, i.e. on the acceleration of bipolar flows where a considerable progress has been made by the work of Y. Uchida and K. Shibata, P. Pudritz and others. However, their models are not the same and it is not yet clear whether an accretion disk is differentially rotating or co-rotating. Five years ago, I studied magnetic properties of a preplanetary solar nebula by calculating the rates of amplification and decay of the magnetic field in various regions of the nebula where the degree of ionization of gases by cosmic rays is different. The magnitude of the magnetic viscosity determined by the above rates is very important in determining the rate of accretion flow and the degree of co-rotation. Now I think that it is better if the model of Uchida and Shibata based on their non-dimensional computation is modified in such a way that major accelerations occur in highly-ionized regions, at a distance of 10 - 50 solar radii from the stellar core for L1551. Then, the efficiency required for conversion of rotational energy into bipolar flow energy can be as low as 10^{-2} and the infall of an extremely large mass is not necessary.