# CONCLUDING REMARKS

RICHARD B. LARSON
*Yale Astronomy Department*
*Box 6666*
*New Haven, CT 06511, USA*

At this meeting, we have heard about many interesting new developments in the study of fragmentation and star formation; yet it must be admitted that most of the processes involved are still poorly understood, and a fully quantitative understanding of star formation remains a distant goal. Perhaps, however, we can at least begin to formulate more clearly some of the questions that need to be addressed. Also, we have seen that new techniques, particularly in the observational study of regions of star formation, promise to yield rapid progress in answering certain of these questions. Therefore, rather than attempting to summarize what has been learned, I have chosen to conclude with a list of some of the outstanding questions which seem to me to be raised but not yet answered by the work that has been presented; I hope that these issues will be the subject of much continuing research.

*The Initial Mass Function.* A major motivation for observational studies of the IMF has always been to advance our understanding of star formation, but what constraints, exactly, does the observed IMF place on a theoretical understanding of star formation? A fundamental question is whether star formation tends to make stars with a characteristic mass; if so, this mass is a basic quantity that theory should attempt to explain. My impression is that one solar mass is indeed a characteristic stellar mass, but this question will not be completely settled until the IMF for very low-mass stars is reliably determined. A well-defined and universal slope for the upper IMF would be another parameter that theory should attempt to explain. At present, observations do not closely constrain the slope of the upper IMF, and the question of its possible variability remains open; however, observations are gradually placing better constraints on such variability.

*Cloud Structure.* Several contributions to this meeting addressed the structure of star forming clouds, but left unanswered the question of what structural studies can teach us about the physics of these clouds. Do filamentary shapes, fractal geometries, etc., contain important clues to the origin and evolution of interstellar clouds? As with terrestrial clouds, one might expect to see structural evidence for hierarchical processes such as turbulence, but whether this is true in interstellar clouds remains unclear. By contrast, the cometary shapes of some star forming clouds seem to me to provide fairly compelling evidence for hydrodynamic interaction with a surrounding medium, a phenomenon that has so far received relatively little theoretical attention.



*R. Capuzzo-Dolcetta et al. (eds.), Physical Processes in Fragmentation and Star Formation,* 461–463.

*Cloud Dynamics.* A major theme of this meeting has been the internal dynamics of star forming clouds; some new approaches to this subject were suggested here, but this remains perhaps the most poorly understood aspect of star formation, owing to its obvious complexity. It has been clear for many years that large molecular clouds possess supersonic internal motions which have been loosely described as "turbulence", but their nature and origin have remained quite unclear – are they best described in terms of eddies, clump motions, stochastic shock waves, magnetohydrodynamic waves, or some combination of all of these? Almost certainly, a description involving only classical eddy turbulence is not adequate, and magnetohydrodynamic waves have recently become more popular. Several formalisms for describing chaotic motions in molecular clouds have been proposed here, based on some of the above ideas, but they do not yet appear to have much predictive power or to make much contact with observations. I believe that efforts in this direction will be most fruitful if they focus on producing observationally testable predictions, and if theoretical work maintains close contact with observations.

*Fragmentation.* Molecular clouds are observed to be very clumpy, which is not surprising given that they contain many Jeans masses, but what processes or forces actually generate the clumps? It is worth noting that, while gravity and magnetic fields may be the dominant forces in molecular clouds, gravity can only amplify existing density enhancements and magnetic fields can only resist this tendency; but neither gravity nor magnetic fields can create density enhancements *ab initio*. However, purely hydrodynamic phenomena such as turbulence or shocks can create density fluctuations which can then be amplified by gravity. Thus, understanding the internal dynamics of star forming clouds is probably an essential aspect of understanding fragmentation.

*Protostellar Collapse.* For the formation of low-mass stars, a generally accepted picture seems to be emerging that involves the initial slow development of cloud cores via ambipolar diffusion, followed by a dynamical collapse that forms a small stellar core which then continues to gain mass by accretion. The predicted final properties of the stellar core are in good agreement with the observed properties of T Tauri stars, and circumstellar disks are also predicted when rotation is included. We have heard, however, that the core can show surprisingly complex behavior characterized by very large-amplitude oscillations before settling into hydrostatic equilibrium. Only a few percent of the total mass is involved in these oscillations, so it is not clear whether the final properties of the stellar core at the end of the accretion phase are much altered; it will be interesting to pursue the calculations further to answer this question.

*Binary Formation.* The formation of binary stars is not yet well understood, but two possible mechanisms for making binaries were discussed at this meeting, namely formation by fragmentation and formation by capture due to gravitational drag with disks. It may well be that binaries form in both ways, or even that fragmentation and gravitational drag work together in many cases. It may also be that the final result is not very directly related to the initial conditions, and that quasi-chaotic effects are important. Again, it will be important to try to produce testable predictions that can be compared with the available data on binary stars.

*Cluster Formation.* It seems clear that many very complex processes are involved in the formation of star clusters; indeed, the formation of a cluster of stars may be the culminating event in the history of a star forming cloud, involving all of the effects that have been discussed. Rather than attempting to develop models for such a complex sequence of events, the best hope for understanding cluster formation is probably to rely strongly on