*Computational Star Formation*
*Proceedings IAU Symposium No. xxx, 2010*
*A.C. Editor, B.D. Editor & C.E. Editor, eds.*

DOI: 00.0000/X000000000000000X



# Low-mass Star Formation: Observations

**Neal J. Evans II**[1]

[1]Department of Astronomy, The University of Texas at Austin, 1 University Station, C1400
Austin, TX 78712-0259, USA
email: nje@astro.as.utexas.edu

**Abstract.** I briefly review recent observations of regions forming low mass stars. The discussion is cast in the form of seven questions that have been partially answered, or at least illuminated, by new data. These are the following: where do stars form in molecular clouds; what determines the IMF; how long do the steps of the process take; how efficient is star formation; do any theories explain the data; how are the star and disk built over time; and what chemical changes accompany star and planet formation. I close with a summary and list of open questions.

**Keywords.** stars: formation, infrared: ISM, submillimeter

## 1. Introduction

Recent large-scale surveys of nearby molecular clouds have provided a solid statistical basis for addressing some long-standing questions about the formation of low-mass stars. Ideally, one would like unbiassed surveys at wavelengths ranging from radio to X-ray of all molecular clouds within some radius of the Sun. Radio and X-ray surveys probe non-thermal and transient events; millimeter continuum surveys probe the mass and structure of the dust, thereby tracing the gas, the far-infrared contains the luminosity information for embedded stages, the mid-infrared probes the disk, the near-infrared probes the inner disk and star, and the visible and ultraviolet probe the star and ongoing accretion. Together, these define the most basic properties of the molecular cloud material and the forming star. While we will concentrate on the continuum in this review, spectroscopic information provides vital complementary information (e.g., see §8). Again, a wide wavelength range for spectroscopy is ideal.

The most significant recent additions to our arsenal include large scale surveys of the nearby clouds in the Gould Belt in the mid-infrared with Spitzer (Evans et al. 2003, Evans et al. 2009, Allen et al. 2010 and references therein) and in the millimeter continuum (Enoch et al. 2006, Young et al. 2006, Enoch et al. 2007, Enoch et al. 2008, Enoch et al. 2009). The Spitzer-based surveys will soon by joined by a complete survey with Herschel spanning the wavelengths between mid-infrared and millimeter (André et al. 2010 and André in this volume). Sometime later, the same clouds will be surveyed completely in millimeter continuum with SCUBA-2 on the JCMT (Ward-Thompson et al. 2007).

## 2. Where do Stars Form in Molecular Clouds?

Spitzer surveys of 20 clouds in the Gould Belt, now including nearly all clouds within 500 pc, have provided a much more complete data base of Young Stellar Objects (YSOs) (Evans et al. 2009, Güdel et al. 2007, Rebull et al. 2010, Allen et al. 2010). These surveys have clearly established that star formation is not evenly distributed over molecular clouds. Instead, star formation proceeds in a clustered manner, concentrated in regions of high extinction (Jørgensen et al. 2008, Evans et al. 2009). Using the criterion of Lada & Lada (2003) of 1 $M_\odot$ $pc^{-3}$, 91% of the stars in the c2d survey (Evans et al.

2009) and 75% of those in a larger sample, including Taurus and all Gould Belt clouds, but excluding Orion, form in a clustered environment (Bressert et al. 2010). Clustering is a matter of degree, with a broad range of surface densities and no clear sign of separate "clustered" and "distributed" modes. Furthermore, the degree of clustering is stronger in younger SED classes, such as Class I and pre-stellar cores, suggesting that the Class II sources have dispersed slightly since their formation.

Using only the Class I and Flat SED classes to avoid any dispersal issues, Heiderman et al. (2010) have found evidence for a threshold gas surface density above which star formation is much faster. This threshold lies roughly at $A_V = 8$ mag, or 120 $M_\odot$ pc$^{-2}$. A very similar threshold was identified by Lada (2010) from an independent analysis. Since most of the mass of molecular clouds lies below this threshold, at least in local clouds, a threshold may yield insight into why star formation efficiencies are so low in molecular clouds (see §5).

## 3. What Determines the IMF?

This age-old question has been revivified by catalogs of prestellar cores that show a mass function somewhat similar to that of stars but shifted to higher masses (e.g., Motte et al. 1998, Johnstone et al. 2000, Enoch et al. 2008, Sadavoy et al. 2010). Similar distributions were found for starless, but unbound and hence not prestellar (see di Francesco et al. 2007 for definitions) cores in the Pipe Nebula (Lada et al. 2008). These results are consistent with a picture in which the IMF is set by the process of core formation and favor a picture in which about 1/3 of the core mass is incorporated into the star. However, arguments have been advanced that some cores will evolve faster [either the less massive (Clark et al. 2007) or the more massive (Hatchell & Fuller 2008)], and hence the current core mass function is not consistent with a one-one mapping onto the IMF. Swift & Williams (2008) have explored other issues, and Reid et al. (2010) have argued that existing measurements of the clump mass spectrum are highly compromised by limitations of the observational techniques, such as sensitivity, spatial resolution, and spatial filtering of large scale emission. While these theoretical issues will be hard to resolve, the statistics should at least improve as the Herschel Gould Belt surveys become available (for a preview, see article by André in this volume).

## 4. How Long Do the Stages of the Process Take?

The major evolutionary organizing principle for star formation has been the Class system, first introduced by Lada (1987) and extended by Greene et al. (1994) and André et al. (1993), using the shape of the SED, measured in various ways to establish a putative evolutionary scheme from prestellar cores to Class 0 to Class I to Flat SED to Class II to Class III. Recently, Robitaille et al. (2006) has usefully distinguished the SED Class from the physical Stages, which proceed from Prestellar to Stage 0 (most of mass still in envelope) to Stage I (most of mass in central star and disk but still substantial envelope) to Stage II (envelope gone, but substantial disk) to Stage III (disk mostly gone, mass in star). The history of this system has been reviewed by Evans et al. (2009). The connection of Class to Stage is generally accepted, but orientation effects can easily confuse a neat identification of Class with Stage: for example, a face-on Stage 0 source may be classified as a Class I source, while an edge-on Stage I source could have a Class 0 SED.

The method of assigning durations to these Classes is to count the numbers in each Class, relating the numbers to the durations by pinning all durations to one that is assumed to be known. One has to further assume that star formation has been continuous over a time longer than the duration of the class used to calibrate ages and that other variables, such as mass, are not important. With these caveats in mind, the results of the c2d studies of nearby clouds with Spitzer led to longer durations for Class I and Class 0 than had previously been derived. The durations are all pinned to a timescale of 2 Myr for the Class II phase, based on studies of infrared excess frequency in clusters of known ages. That age is uncertain by $\pm1$ Myr and should be thought of as half-life, rather than a fixed duration for each individual star. Using the latest, but still preliminary, statistics from the combined c2d plus Gould Belt projects (3124 YSOs in 20 clouds), the Class I duration would be $0.55 \pm 0.28$ Myr and the Flat SED lasts $0.36 \pm 0.18$ Myr, where the uncertainties are due to the uncertainty in the Class II duration. In this calculation, Class 0 is included with Class I. If they are separated using the $T_{bol}$ criterion, the Class 0 phase lasts 0.16 Myr (Enoch et al. 2009, Evans et al. 2009), substantially longer than earlier estimates. Using the millimeter surveys together with the infrared to separate out the prestellar cores, Enoch et al. (2008) found a duration of 0.43 Myr for prestellar cores once the mean density of the core exceeded the detection threshold of about $n = 2 \times 10^4$ cm$^{-3}$. Most cores had higher mean densities, and more careful comparison suggested a duration roughly 3 times the free-fall time (Enoch et al. 2008). This is another area that should be revolutionized by Herschel observations of the Gould Belt clouds.

## 5. How Efficient is Star Formation?

The c2d and Gould Belt surveys provide a uniform analysis of a much more complete sample of YSOs. Eventually the Taurus cloud and some other clouds should be brought into this analysis. Currently, we use the same 3124 YSOs ($N_{YSOs}$) in 20 clouds discussed in §4. These surveys are about 90% complete to about 0.05 $L_\odot$. The total mass of YSOs is calculated from $M_* = N_{YSOs} \times 0.5$ $M_\odot$, where 0.5 $M_\odot$ is the mean stellar mass. The star formation rate is then $SFR = M_*/t_{II}$ $M_\odot$ Myr$^{-1}$, where $t_{II}$ is the duration of the Class II phase in Myr. The YSO counts are incomplete for Class III objects, so we are effectively computing a star formation rate averaged over the last 2 Myr. For efficiencies, we compare the mass in stars to the mass in the molecular cloud, measured from extinction mapping over the same region in which YSOs are counted (generally $A_V \geqslant$ 2 mag). For clouds with millimeter continuum maps, the mass in dense gas can be computed from the sum over masses of all the dense cores.

Based on the sum of all stellar and cloud masses for all 20 c2d and Gould Belt clouds, about 3% of the mass is in YSOs younger than 2 Myr and the mass in dense cores ranges from 2% to 5% for the three clouds with complete maps. In contrast, the total mass in YSOs is very similar to that in dense cores, suggesting that star formation is rapid and efficient once the dense cores have formed. Clearly, star formation is not very efficient for the clouds as a whole, but the efficiency of star formation is quite high once dense cores have formed.

While not efficient in an absolute sense, star formation in the local clouds is much more efficient than would be predicted from the Kennicutt-Schmidt relations used in extragalactic studies. The relations predict the star formation rate surface density from the gas surface density (e.g., Kennicutt 1998). While a few of the least active clouds in the Gould Belt sample lie on the extragalactic relation, almost all lie well above, most by an order of magnitude (Evans et al. 2009). This discrepancy has been explored in detail by Heiderman et al. (2010), who find evidence for a threshold surface density, as discussed above. They suspect that the measures of gas surface density in other galaxies, based almost entirely on CO emission, include large amounts of gas below the threshold (§2).

## 6. Do Any Theories Explain the Data?

The existing data provide some reality checks for star formation theories. For example, the most commonly used picture of low-mass star formation is inside-out collapse (Shu 1977). In this picture, collapse begins at the center of a singular isothermal sphere, and a wave of infall propagates outward at the sound speed ($c_s$). The end of infall is less defined in this model, but it is usually assumed that, when the infall wave reaches the outer boundary of the core, the remainder of the core falls in. The time for this is equal to the time taken for the infall wave to reach the outer boundary. (For a more correct treatment of the evolution of a core with a distinct boundary, see Vorobyov & Basu 2005a). For a kinetic temperature, $T_K = 10$ K, $c_s = 0.19$ km s$^{-1}$. If we associate the time indicated above for the Class I phase of 0.55 Myr with the final infall of the last bit of envelope, the wave of infall would have reached the outer boundary in 0.55/2 Myr. The corresponding radius would be $r_{out} = c_s t_I/2 = 0.055$ pc, roughly consistent with many of the core size distributions (e.g., Enoch et al. 2008) and the mean separation of YSOs in clusters of $0.072 \pm 0.006$ pc (Gutermuth et. al 2009).

The density distribution of the initial state is set by the temperature in the simplest version of this model. Thus, the mass available in the mean duration of a Class I source is also set. If a fraction $f$ ends up in the star, the resulting stellar mass is $M_\star = 0.86f$ M$_\odot$. If $f = 0.3$, as suggested above, the resulting mass is 0.26 M$_\odot$, near the mode of the IMF. Thus a simple picture of cores undergoing inside-out collapse meets some general consistency checks.

However, serious problems appear when we compare the luminosity function of the YSOs in the c2d sample to predictions for the Shu model. The Shu model predicts a mass infall rate of $\dot{M}_{inf} = 1.6 \times 10^{-6}$ M$_\odot$ yr$^{-1}$. The radiation released by this infall onto an object of 0.08 M$_\odot$, at the boundary between brown dwarfs and stars, and radius of 3 R$_\odot$ produces a luminosity $L_{acc} = 1.6$ L$_\odot$. Most (59%) of the YSOs in the c2d clouds lie below this luminosity (Dunham et al. 2010). More generally, the distribution of sources in the $T_{bol}$-$L_{bol}$ plane (Evans et al. 2009 is very poorly represented by tracks that follow the Shu solution and use radiative transfer to calculate the SED as a function of time (Young & Evans 2005).

These issues are not peculiar to the Shu model. In fact, almost all other models feature faster infall and will produce a still larger discrepancy with the data. One is faced with the problem of decreasing the typical (observed) accretion rate onto the star, while still removing the envelope in about 0.5 Myr and building the star.

## 7. How Are the Star and Disk Built over Time?

The problem of low luminosities and a very large spread (at least three orders of magnitude) in luminosity must be telling us about the process of growth of the disk and star. Because the vast majority of the gravitational energy is released when matter accretes onto the star, rather than onto the disk, storing matter in the disk is an obvious option. Since there is no reason that the accretion rate from disk to star should be synchronized with the infall rate onto the disk, it is very plausible that material accumulates in the disk until an instability causes a fast matter transfer to the star, followed by a slower rebuilding of the disk from the envelope. This picture of episodic accretion explains the high incidence of low luminosity values (little or no accretion onto the star) and the large spread in luminosity (small numbers of sources caught in a high-accretion state).

Indeed, Kenyon et al. (1990) suggested this solution to the problem of low luminosity, which was apparent even with IRAS data. The Spitzer data has only exacerbated the problem, and the episodic accretion solution is even more attractive. Furthermore, simulations of the flow from envelope to disk to star show instabilities and rapid variations in accretion onto the star (Vorobyov & Basu 2005b, Vorobyov & Basu 2006). Observationally, there is direct evidence in the form of FU Orionis events (Hartmann & Kenyon 1996), outflow morphologies showing multiple ejection events (e.g., Lee et al. 2007), and studies of low luminosity sources with extended outflows. These last studies show that minimum mean luminosities needed to drive the observed outflows exceed the current luminosity of the YSO (Dunham et al. 2006, Dunham et al. 2010a).

To put these ideas on firmer footing, Dunham et al. 2010b explored a simple model of episodic accretion, including full 2D radiative transfer with outflows removing matter from a Terebey et al. (1984) rotating collapse model. He could reproduce reasonably well the observed luminosity distribution and the distribution in the $T_{bol}$-$L_{bol}$ plane.

If accretion onto the star is episodic, there are substantial consequences. First, the connection between Stages and Classes becomes even more tenuous, as the luminosity flares can move an object in one Stage back and forth across Class boundaries. Second, the luminosity is not an indicator of stellar mass until nuclear burning dominates accretion luminosity. Third, there may be long-term consequences for the star, causing incorrect estimates of stellar ages (Baraffe et al. 2009) and possibly the low lithium abundances in young stars (Baraffe et al. 2010). Finally, the initial conditions for planet formation may be determined by the timing of the last accretion event: if it happens just before the last of the envelope falls onto the disk, the star will start with a low-mass disk; conversely, if the disk was close to its maximum stable mass when the last of the envelope accretes, the star would have a massive disk.

## 8. What Chemical Changes Accompany Star and Disk Formation?

While we have focused on the macroscopic changes as material flows from envelope to disk to star, microscopic changes to the chemical state occur during the process. Infrared spectroscopy from the ground and from Spitzer have revealed a rich spectrum of ices on dust grains before (Knez et al. 2005) and during (Boogert et al. 2008, Pontoppidan et al. 2008, Öberg et al. 2008, Bottinelli et al. 2010) the infall phase. The size distribution of dust grains shifts to larger grains in molecular clouds, as compared to the diffuse interstellar medium (Flaherty et al. 2007, Chapman et al. 2009). A new model of dust opacities in dense cores that incorporates these aspects, especially the ice features, is needed to fit SED data that include mid-infrared spectroscopy (e.g., Kim et al. 2010).

The flip side of the formation of ices is severe depletion of the gas phase species via freeze-out onto grains (for reviews, see Ceccarelli et al. 2007, van Dishoeck 2009). This can reach extreme levels in prestellar cores. As a forming star increases in luminosity, central heating can evaporate some ices, producing a complex pattern of abundance (Jørgensen et al. 2004). To interpret molecular line observations correctly, one should ideally use fully self-consistent chemo-dynamical models (Lee et al. 2004, Evans et al. 2005, Chen et al. 2009) that track the chemistry during collapse. Episodic accretion models further complicate the picture, as the changes in luminosity can subject the grains to the equivalent of freeze-thaw cycles that may drive greater differentiation and complexity. For a concrete example, CO frozen on grains may be converted to $CO_2$ (Pontoppidan et al. 2008, which does not evaporate as easily as the CO; repeated cycles can systematically deplete the CO in the envelope (Kim et al. 2010).

When the envelope material falls onto the disk, some ices may evaporate (Watson et al. 2007) and outflows will drive further thermal and chemical changes along the outflow walls, which are nicely traced by very high-J CO lines observable with Herschel PACS spectroscopic observations (van Kempen st al. 2010a, van Kempen st al. 2010b).

## 9. Summary and Open Questions

The main points are summarized here.

(*a*) Stars form mostly in clustered environments, but the degree of clustering varies smoothly over a wide range.

(*b*) The core mass function is similar to the initial mass function of stars, but shifted to higher masses. If the core mass function maps to the IMF, the shift suggest an efficiency of about 1/3. However, there are many caveats in this discussion.

(*c*) The timescales for the Class 0 and Class I SED classes are longer than previously thought. Based on number counts, they are roughly 0.16 Myr for Class 0 and 0.55 Myr for Class I.

(*d*) Efficiencies for star formation over the last 2 Myr are low ($\sim 3\%$) in nearby clouds, but quite high ($> 25\%$) in dense cores.

(*e*) Star formation rate surface densities are much higher for a given gas surface density that would be predicted by Kennicutt-Schmidt relations.

(*f*) Both the discrepancy with the Kennicutt-Schmidt relations and the low absolute efficiency are likely related to a surface density threshold for efficient star formation that is not met by the great majority of the cloud mass in nearby clouds, nor in normal galaxies.

(*g*) A simple inside-out collapse picture for a core is consistent with much of the data on sizes and masses, but no model with uniform accretion reproduces the distribution of YSOs in the $T_{bol}$-$L_{bol}$ plane. Episodic accretion is strongly indicated.

(*h*) Complex chemical changes accompany the large-scale flows of matter, as material moves from gas to ice and back. Simple models of abundances that are constant, either in time or space, can be misleading.

The most significant open questions are summarized here.

- What sets the mass of stars? Is it the core mass function, or is it feedback?
- How do brown dwarfs form? A core forming a brown dwarf would have to be very small and very dense to be bound.
- What controls the threshold for star formation? While a surface density threshold is indicated by the data, this may be a secondary indicator for a more complex set of variables, including volume density, turbulent velocity, magnetic field, ionization, etc.
- And finally a question that has been with us since the early days of molecular clouds: why is star formation so inefficient?

I would like to acknowledge the collaboration of A. Heiderman, M. Dunham, L. Allen, D. Padgett, and E. Bressert in preparing this review. Support for this work, part of the *Spitzer* Legacy Science Program, was provided by NASA through contracts 1224608 and 1288664 issued by the Jet Propulsion Laboratory, California Institute of Technology, under NASA contract 1407. Support was also provided by NASA Origins grant NNX07AJ72G and NSF grant AST-0607793 to the University of Texas at Austin.

## References

Allen, L., Koenig, X., Gutermuth, R., & Megeath, T. 2010, Bulletin of the American Astronomical Society, 41, 559

André, P., Ward-Thompson, D., & Barsony, M. 1993, Astrophys. J., 406, 122

André, P., et al. 2010, Astr. Ap., 518, L102

Baraffe, I., Chabrier, G., & Gallardo, J. 2009, Astrophys. J. (Letters), 702, L27
Baraffe, I., & Chabrier, G. 2010, Astr. Ap., in press
Boogert, A. C. A., et al. 2008, Astrophys. J., 678, 985
Bottinelli, S., et al. 2010, arXiv:1005.2225
Bressert, E., et al. 2010, submitted to MNRAS.
Ceccarelli, C., Caselli, P., Herbst, E., Tielens, A. G. G. M., & Caux, E. 2007, Protostars and Planets V, 47
Chapman, N. L., Mundy, L. G., Lai, S.-P., & Evans, N. J. 2009, Astrophys. J., 690, 496
Chen, J.-H., Evans, N. J., Lee, J.-E., & Bourke, T. L. 2009, Astrophys. J., 705, 1160
Clark, P. C., Klessen, R. S., & Bonnell, I. A. 2007, Mon. Not. Roy. Astr. Soc., 379, 57
di Francesco, J., Evans, N. J., II, Caselli, P., Myers, P. C., Shirley, Y., Aikawa, Y., & Tafalla, M. 2007, in Protostars and Planets V, ed. B. Reipurth, D. Jewitt, & K. Keil (Tucson: Univ. Arizona Press), 17
Dunham, M. M., et al. 2006, Astrophys. J., 651, 945
Dunham, M. M., Evans, N. J., Terebey, S., Dullemond, C. P., & Young, C. H. 2010b, Astrophys. J., 710, 470
Dunham, M. M., Evans, N. J., II, Bourke, T. L., Myers, P. C., Huard, T. L., & Stutz, A. M. 2010a, submitted to Astrophys. J.
Enoch, M. L., Evans, N. J., Sargent, A. I., & Glenn, J. 2009, Astrophys. J., 692, 973
Enoch, M. L., Evans, N. J., II, Sargent, A. I., Glenn, J., Rosolowsky, E., & Myers, P. 2008, Astrophys. J., 684, 1240
Enoch, M. L., Glenn, J., Evans, N. J., II, Sargent, A. I., Young, K. E., & Huard, T. L. 2007, Astrophys. J., 666, 982
Enoch, M. L., et al. 2006, Astrophys. J., 638, 293
Evans, N. J., II, et al. 2003, Pub. Astr. Soc. Pacific, 115, 965
Evans, N. J., et al. 2009, Astrophys. J., 181, 321
Evans, N. J., II, Lee, J.-E., Rawlings, J. M. C., & Choi, M. 2005, Astrophys. J., 626, 919
Flaherty, K. M., Pipher, J. L., Megeath, S. T., Winston, E. M., Gutermuth, R. A., Muzerolle, J., Allen, L. E., & Fazio, G. G. 2007, Astrophys. J., 663, 1069
Greene, T. P., Wilking, B. A., André, P., Young, E. T., & Lada, C. J. 1994, Astrophys. J., 434, 614
Güdel, M., Padgett, D. L., & Dougados, C. 2007, Protostars and Planets V, 329
Gutermuth, R. A., Megeath, S. T., Myers, P. C., Allen, L. E., Pipher, J. L., & Fazio, G. G. 2009, Astrophys. J. Suppl., 184, 18
Hartmann, L., & Kenyon, S. J. 1996, Ann. Rev. Astr. Astroph., 34, 207
Hatchell, J., & Fuller, G. A. 2008, Astr. Ap., 482, 855
Heiderman, A., Evans, N. J., II, Allen, L. E., Huard, T., & Heyer, M. 2010, submitted to Astrophys. J.
Johnstone, D., Wilson, C. D., Moriarty-Schieven, G., Joncas, G., Smith, G., Gregersen, E., & Fich, M. 2000, Astrophys. J., 545, 327
Jørgensen, J. K., Johnstone, D., Kirk, H., Myers, P. C., Allen, L. E., & Shirley, Y. L. 2008, Astrophys. J., 683, 822
Jørgensen, J. K., Schöier, F. L., & van Dishoeck, E. F. 2004, Astr. Ap., 416, 603
Kennicutt, R. C., Jr. 1998, Astrophys. J., 498, 541
Kim, H. J., Evans, N. J., II, Dunham, M. M., Chen, J.-h., Lee, J.-E., Bourke, T. L., Huard, T. L., Shirley, Y. L., & De Vries, C. 2010, submitted to Astrophys. J..
Knez, C., et al. 2005, Astrophys. J. (Letters), 635, L145
Lee, J.-E., Bergin, E. A., & Evans, N. J., II 2004, Astrophys. J., 617, 360
Lee, C.-F., Ho, P. T. P., Hirano, N., Beuther, H., Bourke, T. L., Shang, H., & Zhang, Q. 2007, Astrophys. J., 659, 499
Kenyon, S. J., Hartmann, L. W., Strom, K. M., & Strom, S. E. 1990, Astron. J., 99, 869
Motte, F., Andre, P., & Neri, R. 1998, Astr. Ap., 336, 150
Lada, C. J. 1987, IAU Symp. 115: Star Forming Regions, 115, 1
Lada, C. J., & Lada, E. A. 2003, Ann. Rev. Astr. Astroph., 41, 57
Lada, C. J., Lombardi, M., & Alves, J. F. 2010, submitted.

Lada, C. J., Muench, A. A., Rathborne, J., Alves, J. F., & Lombardi, M. 2008, Astrophys. J., 672, 410

Öberg, K. I., Boogert, A. C. A., Pontoppidan, K. M., Blake, G. A., Evans, N. J., Lahuis, F., & van Dishoeck, E. F. 2008, Astrophys. J., 678, 1032

Pontoppidan, K. M., et al. 2008, Astrophys. J., 678, 1005

Rebull, L. M., et al. 2010, Astrophys. J. Suppl., 186, 259

Reid, M. A., Wadsley, J., Petitclerc, N., & Sills, A. 2010, arXiv:1006.4320

Robitaille, T. P., Whitney, B. A., Indebetouw, R., Wood, K., & Denzmore, P. 2006, Astrophys. J. Suppl., 167, 256

Sadavoy, S. I., et al. 2010, Astrophys. J., 710, 1247

Shu, F. H. 1977, Astrophys. J., 214, 488

Swift, J. J. & Williams, J. P. 2008, Astrophys. J., 679, 552

Terebey, S., Shu, F. H., & Cassen, P. 1984, Astrophys. J., 286, 529

van Dishoeck, E. F. 2009, Astrophysics in the Next Decade, 187

van Kempen, T. A., et al. 2010a, Astr. Ap., 518, L128

van Kempen, T. A., et al. 2010b, Astr. Ap., 518, L121

Vorobyov, E. I., & Basu, S. 2005a, Mon. Not. Roy. Astr. Soc., 360, 675

Vorobyov, E. I., & Basu, S. 2005b, Astrophys. J. (Letters), 633, L137

Vorobyov, E. I., & Basu, S. 2006, Astrophys. J., 650, 956

Ward-Thompson, D., et al. 2007, Pub. Astr. Soc. Pacific, 119, 855

Watson, D. M., et al. 2007, Nature, 448, 1026

Young, C. H., & Evans, N. J. 2005, Astrophys. J., 627, 293

Young, K. E., et al. 2006, Astrophys. J., 644, 326