Magnetic Fields and Massive Star Formation

Qizhou Zhang (Harvard-Smithsonian CfA)

Stars are assembled in molecular clouds when matters condense and collapse under the gravitational pull. Massive stars (M > 8 Msun) are found mostly in clusters together with lower mass stellar objects (Lada & Lada 2003). How parsec-scale, massive molecular clumps collapse and fragment to give rise to a cluster of stars has been one of the central questions in star formation in the past decade. Jeans mass, the characteristic mass of fragments, is $\sim$ 1Msun for typical physical conditions in (pre)cluster forming clumps (Zhang et al. 2009, 2015). This mass, after taking account the star formation efficiency, is close to the stellar mass at the peak of the Initial Mass Function (IMF), thus may explain the formation of most stars in a cluster (Larson 2005). Massive stars, on the other hand, contain masses at least one order of magnitude greater than the average Jeans mass in a (pre)cluster forming clump. Therefore, their formation poses a direct challenge to the current understanding of cloud fragmentation.

Magnetic fields can suppress fragmentation and increase the equivalent Jeans mass in clouds to facilitate massive star formation. Simulations show that a rotating core with some angular momentum can fragment into multiple objects (e. g., Boss & Bodenheimer 1979; Bate & Burkert 1997). The presence of strong magnetic fields suppresses fragmentation via so-called 'magnetic braking' (e.g. Hosking & Whitworth 2004; Mellon & Li 2008), which is very effective in removing a significant part of the initial angular momentum through torsional Alfven waves. Similarly, magneto-hydrodynamic simulations of turbulent massive dense cores show a low fragmentation level in strongly magnetized cores (e. g., Vazquez-Semadeni et al. 2005; Hennebelle et al. 2011; Commercon et al. 2011; Myers et al. 2013), suggesting again the potential relevance of the magnetic field in regulating the fragmentation process of a massive dense core.

Despite the general agreement in theoretical studies and numerical simulations that magnetic fields directly affect cloud fragmentation, the actual role of magnetic fields in star formation remains controversial larger due to a lack of direct observations. The recently improvement in sensitivity of millimeter and sub-millimeter interferometers enables observations of large sample of star forming regions, and promises to provide statistically meaningful constraints on the role of magnetic fields in stellar mass assembly. We recently completed a legacy project using the Submillimeter Array (SMA) to survey dust polarization of an unprecedentedly large sample of massive molecular clumps to study the role of magnetic fields during the collapse of molecular clumps and the formation of dense cores (Zhang et al. 2014). To better constrain the dynamics, we obtained spectral line data in NH_3 with the Jansky Very Large Array (VLA) for the entire sample. In addition, we were granted observing time with high priority to follow-up the most intriguing targets in the sample using the Atacama Large Millimeter/Submillimeter Array (ALMA).

The research project described above consists of two components: (1) analysis of new observations of dust polarization from ALMA, and spectral lines data from the VLA and SMA; (2) using magneto hydrodynamic simulations and radiative transfer tool to produce synthetic data to help interpreting the observations. Depending on the time commitment, students will have opportunities to lead either a short term project that fits the time scale of a Research Exam as required by the Department, and/or a multi-year research program as a PhD dissertation.

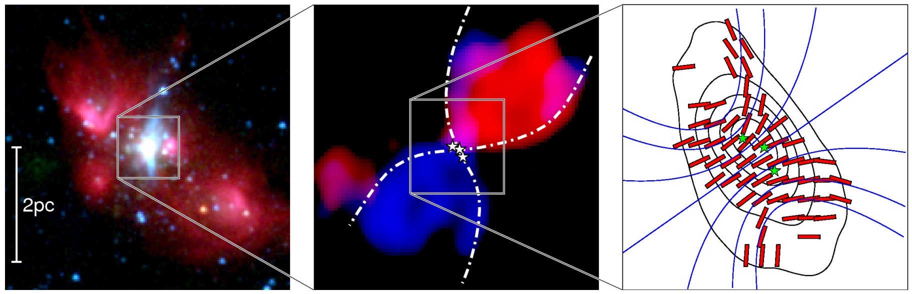

Figure 1: Left: Three color composite image of massive star forming region G240.31+0.07. Data from the Spitzer IRAC bands in 3.6, 4.5, and 8.0 μm are coded in blue, green, and red, respectively. Middle: Color image of the blue- and red-shifted bipolar outflow observed in CO. Right: Red line segments indicate the orientation of the magnetic field overlaid on the contour map of the 0.88 mm dust emission. Blue lines show the parabolic shape of magnetic fields from the best-fit model (Qiu et al. 2014; Zhang et al. 2014).

References:

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