DISTRIBUTED STAR FORMATION IN THE M17 GIANT MOLECULAR CLOUD

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ABSTRACT

We have found 159 candidate young stellar objects (YSOs) within a 0.5-deg (14 pc at 1.6 kpc) radius of the M17 H II region by fitting model spectral energy distributions (SEDs) to point-source fluxes from the GLIMPSE Archive, combined with MIPSGAL 24 and 70 μm photometry and WISE point-source fluxes where available. Bright diffuse and HI foreground emission dramatically reduces the IRAC point-source sensitivity in the M17 H II region, so all but a few of the YSOs detected outside the H II region. YSOs in the earliest stages of formation are distributed throughout the extended OFF region of M17 giant molecular cloud. YSOs appear to be located beyond the previously measured extent of the molecular gas. Our YSO sample has a possible blue IMF that is completely above –3.6. Extrapolating the IMF to the hydrogen-burning limit of ~0.1 M☉, we estimate that 4000–5000 stars are currently in the process of forming in this molecular cloud. High resolution Chandra imaging of M17 in X-rays (Brown et al. 2007) has uncovered a population of 8,000–10,000 young stars within ~37 NGC 6818, the central ionizing cluster; our sample represents a complementary population. The M17 giant molecular cloud continues to form stars at a rate comparable to that which produced the NGC 6818 cluster.

OVERVIEW — M17 is a well-studied nearby (1.4–1.9 kpc; Povich et al. 2007) massive star-forming region featuring a “bouquet” H II region enshrouded by a side of a giant molecular cloud. Positions of YSO candidates are marked by colored circles on a GLIMPSE false-color image of M17. A distance of a 1-degree field centered on the M17 H II region. Active star formation is apparent out to the edge of our YSO search radius. The distributions of YSOs and diffuse 8 μm (H2) emission tracing dust and molecular gas exposed to UV radiation. Povich et al. (2007) indicate that the molecular cloud extends 15.5° (7.1 pc) beyond the boundary of its dense core (CO contours from Scoville et al. 1987). The cloud may be forming numerous small clusters of 1 M⊙ YSOs. A few YSOs are evident, many of them associated with IR dark clouds silhouetted against the 8 μm background emission.

THREE REGIONS OF INTEREST — Enlargements of the three boxed areas in Figure 1 are shown in combined GLIMPSE/MIPSGAL true-color images (F438W, F812W, F217NH, F255W) of M17. Scattered set 3 arcmin (0.9 pc). Plots show SEDs fit with a broad phase of selected individual YSO candidates. The colored curves show the models in different epochs, and the dashed curves are the stellar photometry in the absence of circumstellar dust. The upper limits are higher than the model fitting. The upper limits are plotted as triangles.

(1) This prominent, star-forming IR dark cloud appears to be connected to M17 by an arc of diffuse 8 μm emission. The set of well-fit models to the example Stage III YSO (top) presents luminosity ranges of ~2 M⊙, ~15–100 L☉. The Stage II YSO is marginally fit at 24 μm, model ~6–10 M⊙, 200–1500 L☉, the value for luminosity including a contribution from accretion. This source exhibits excess emission at 4.5 μm, a sign of ongoing protostellar activity.

(2) A cluster of YSOs produce a point-spread IR diffuse emission structure. The bottom half of the core is well-fit by SEDs of ~6–8 M⊙, 100–500 L☉, if the fit is in the bands most strongly contaminated by X-ray emission as usual in upper limits only.

(3) Two candidate YSOs appear to lie on a dense filament seen in emission. The brighter Stage II YSO (3–10 M⊙, 100–1000 L☉, below the filament) seems to be unresolved. It has been previously cataloged as an IRAS point source.

INITIAL MASS FUNCTION (IMF) — Using the Robitaille et al. (2006) models to constrain the masses of our 350 YSO candidate, we construct an IMF of the star-forming region of the M17 molecular cloud. This IMF turns over below a stellar mass ~3 M⊙, our completeness limit. Using the Orion IMF (Momose et al. 2003) to the bottom of our IMF where we are complete, we place the total population of the M17 molecular cloud region at ~1500–600 YSOs.

REFERENCES


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YSO Evolutionary Stages

Following the criteria of Robitaille et al. (2006), we use the envelope accretion rate and the circumstellar disk mass, normalized by the mass of the central star, to separate the models fit to our detected YSOs into evolutionary stages:

Stage 0/1: dM/dt/MD > 10^-6 yr^-1
Stage II: dM/dt/MD > 10^-6 yr^-1
Stage III: dM/dt/MD > 10^-6 yr^-1

The color-coding of the circles on the images corresponds to the most probable stage of the source. The Stage taxonomy parallels the YSO classification scheme of Lada et al. (2006), heavily emphasizes an indistinguishable, debris envelope (25% of our sample), Hα optically thick circumstellar disk (44%) and Hβ optically thin disk (54%). The SEDs of Stage III YSOs are the most difficult to separate from stellar photometry because their IR excesses are small. Because stars is a conservative sample, with a goal of reliability over completeness, we probably underestimate Stage III YSOs.

RESULTS

The M17 giant molecular cloud harbors a distributed YSO population that roughly half the size of the concentrated H I region, population. Brown et al. (2007) take a population of 8000–10,000 young stars and YSOs for the M17 region by scaling the X-ray luminosity function of their sources in that of Orion. This corresponds to a total mass in stars of 6300–8000 M☉. Because NGC 6818 is younger than 1 Myr, and star formation is ongoing in the H II region (Liang et al. 2002), we assume an average age of 5–10 Myr for the stellar population, yielding a star formation rate of 0.013±0.006 M☉ yr^-1. The IR-detected YSOs are more prevalent and more numerous than the stars in the NGC 6618 cluster, and therefore younger than the average age of the X-ray-detected stars and YSOs in the H II region. Based upon these evolutionary stages and clustering properties, we estimate an average age of ~5–10 Myr for the YSOs in the molecular cloud.

SPECIAL THANKS to Tom Robitaille, Brian Harley, Marilyn Meade, and Reny Indebetouw.

GLIMPSE and MIPSGAL are Spitzer Legacy Science Programs. GLIMPSE has surveyed the entire 180 square degrees of the Galactic Plane with the IRAC instrument on board the Spitzer Space Telescope. MIPSGAL has surveyed the same area with the MIPS instrument.

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