

# Cool Star Beginnings: YSOs in the Perseus Molecular Cloud

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**Abstract.** Nearby molecular clouds, where there is considerable evidence of ongoing star formation, provide the best opportunity to observe stars in the earliest stages of their formation. The Perseus molecular cloud contains two young clusters, IC 348 and NGC 1333, and several small dense cores of the type that produce only a few stars. Perseus is often cited as an intermediate case between quiescent low-mass and turbulent high-mass clouds, making it perhaps an ideal environment for studying “typical” low-mass star formation.

We present an infrared study of the Perseus molecular cloud with data from the *Spitzer Space Telescope* as part of the “From Molecular Cores to Planet Forming Disks” (c2d) Legacy project (Evans et al. 2003). By comparing *Spitzers* near- and mid-infrared maps, we identify and classify the young stellar objects (YSOs) in the cloud using updated extinction corrected photometry. Virtually all of the YSOs in Perseus are forming in the clusters and other smaller associations at the east and west ends of the cloud with very little evidence of star formation in the midsection even in areas of high extinction.

## 1. YSO Identification

The Perseus molecular cloud was mapped with two of the *Spitzer Space Telescope’s* instruments, IRAC and MIPS. Figure .1 is a three-color composite map of Perseus from the IRAC 4.5 and 8  $\mu\text{m}$  and MIPS 24  $\mu\text{m}$  data.

For all *Spitzer* data, young stellar objects (YSOs) must be distinguished from reddened background galaxies. We follow the method of YSO selection developed by the c2d team in which YSOs are distinguished from reddened background galaxies using color-color and color-magnitude diagrams in the 2MASS (H and K), IRAC (4.5 and 8  $\mu\text{m}$ ), and MIPS (24  $\mu\text{m}$ ) bands. A detailed description can be found in the c2d data delivery document (Evans

et al. 2007) and by Harvey et al. (2007). In Figure .2, cyan circles are YSOs, red crosses are extragalactic sources. 369 YSOs were identified in Perseus.

## 2. YSO Classification

All of the YSOs were placed in one of four classes according to their spectral index,  $\alpha$ : Class I, Flat (i.e., flat-spectrum), Class II, and Class III following the class definitions of Green et al. (1994). The spectral index is defined by a least squares fit to the photometry of the source between 2 and 24  $\mu\text{m}$ . The near-infrared flux data is from 2MASS. We have updated the *Spitzer* fluxes with new extinction corrections, adopting the sum of the absorption and scattering cross sections in order to correct for the total line-of-sight extinction. We find 70 Class I, 32 Flat, 231 Class II, and 36 Class III sources in Perseus. Perseus has a particularly large fraction of Class I sources compared to other star forming clouds (Evans et al. 2009).

## 3. YSO Distribution

The majority, 67%, of the YSOs in Perseus are associated with the young clusters NGC 1333 and IC 348i. Most of the rest of the star formation activity in Perseus occurs in the regions around the clusters, to the eastern and western ends of the cloud complex. The middle of the cloud is nearly empty of YSOs despite containing regions of high visual extinction (contours on Figure .3). NGC 1333 and the western half of Perseus contain three-quarters of the total number of embedded YSOs (Class I and Flat sources). Class II and III greatly outnumber Class I objects in eastern Perseus and IC 348. These results are consistent with previous age estimates for the clusters,  $< 1$  Myr for NGC 1333 (Wilking et al. 2004) and 2 Myr for IC 348 (Lada et al. 2006). Across the cloud, 63% of YSOs and all of the Class I and Flat sources are in areas where  $A_v \geq 5$ , indicating a possible extinction threshold for the early stages of star formation.

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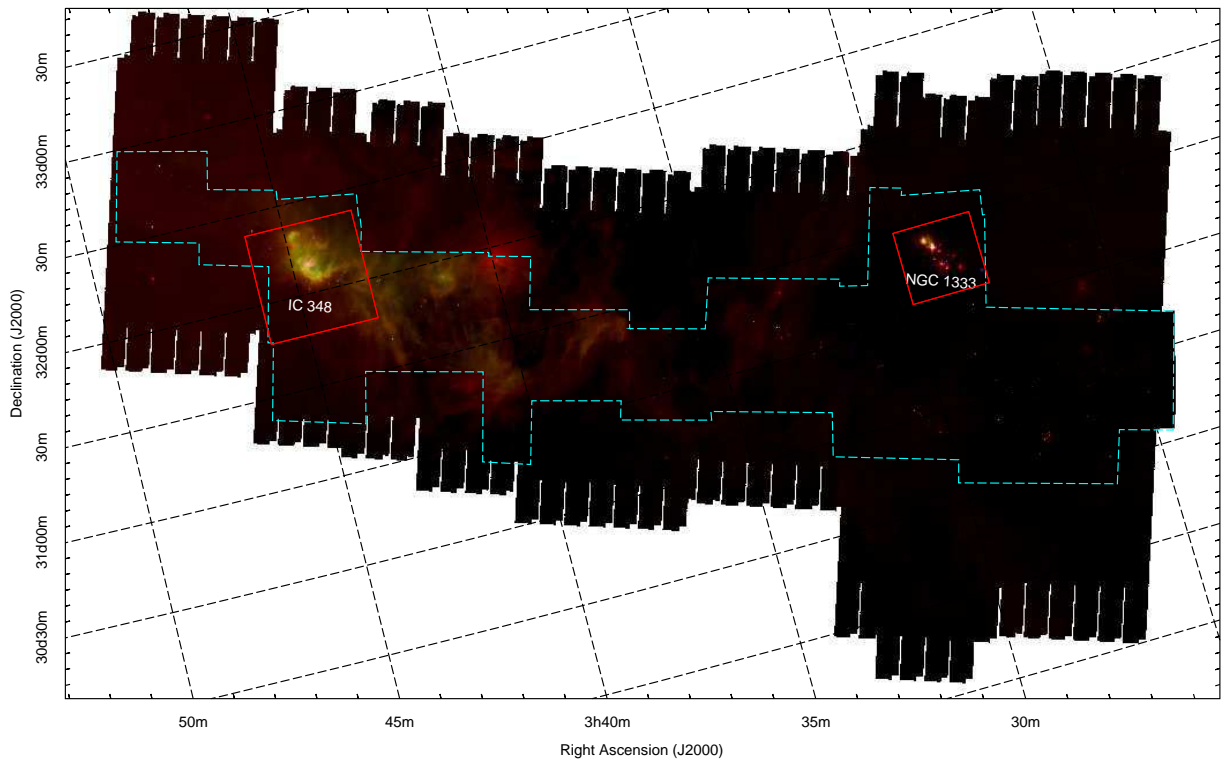


Figure .1: Three-color (4.5, 8, and 24  $\mu\text{m}$ ) mosaic of Perseus. Edges of the image are the MIPS scan region. The IRAC observation area is given by the dashed line. The red boxes indicate the IC 348 and NGC 1333 cluster regions.

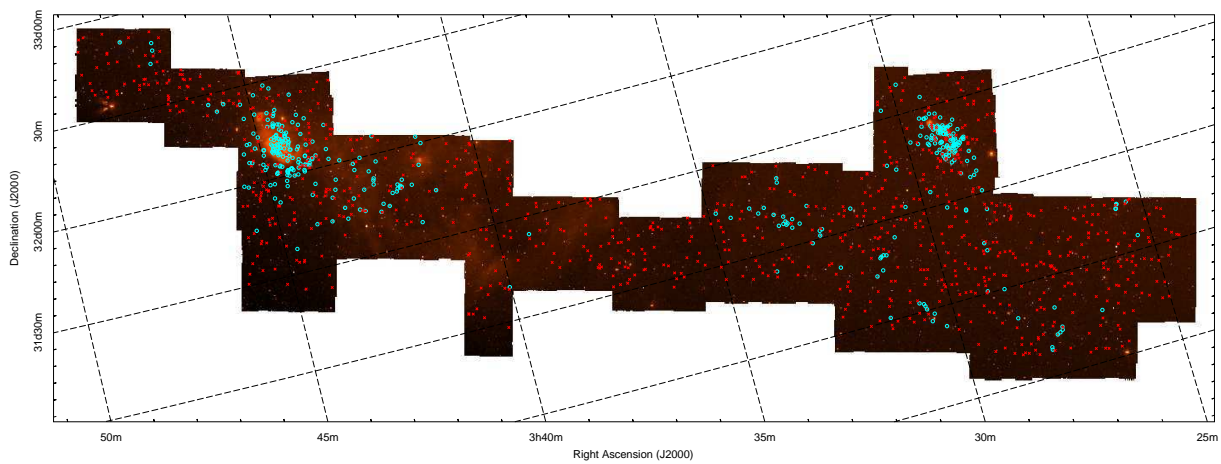


Figure .2: Distribution of YSOs (cyan circles) and extragalactic sources (red X's) on the IRAC 4.5  $\mu\text{m}$  map of Perseus.

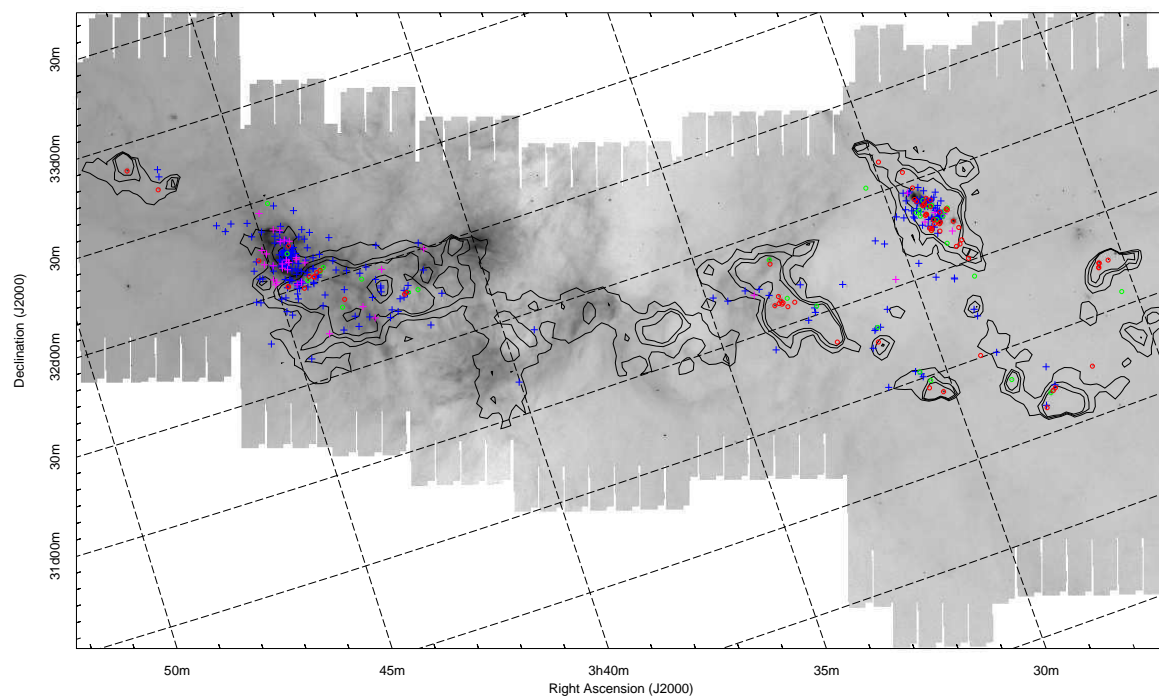


Figure .3:  $24 \mu\text{m}$  map of Perseus overlaid with  $A_v = 4, 6,$  and  $8$  contours. The circles give the positions of the YSOs. Symbols indicate class: Class I = red circle, Flat = green circle, Class II = blue cross, Class III = magenta cross.