Near Infrared Observations of Barnard's Merope Nebula (IC 349)

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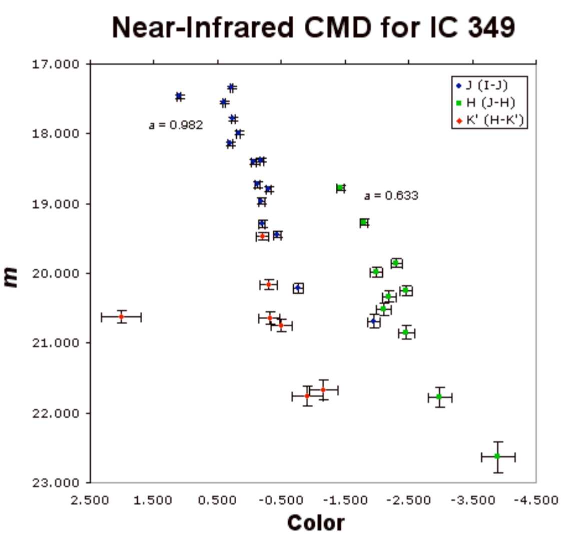
We report results of *JHK'* and narrowband near-infrared photometry of the reflection nebula IC 349 in the Pleiades. The data fail to show evidence for shock- or fluorescence-induced emission from the v=1-0 *S*(1) and v=2-1 *S*(1) transitions of H_2 and the 2-0 band head of ^{12}CO expected of species illuminated by soft-UV photons from the nearby star 23 Tauri. The lack of significant gas content supports the conclusion that there is no protostellar object within the nebula's dusty envelope; a new observational determination of the upper limit on the luminosity of a hypothetical protostar gives $-3.73 < \log [L/(L_{sun})] < -3.58$. Small-particle scattering in the nebular medium becomes negligible by K' (λ_o = 2.114 μm), suggesting that dust grain sizes are compatible with cold molecular cloud composition. Total mass estimates, based on both diffusion of assumed primordial gas in the nebula and integration of the observed dust column, range between $3\times10^{-7}\ M_{sun} < M < 8\times10^{-1}\ M_{sun}$. These results point toward an origin for IC 349 as a substellar-mass cloudlet escaped from a larger cloud complex, whose original gas content has been lost likely due to thermal diffusion.

Motivation

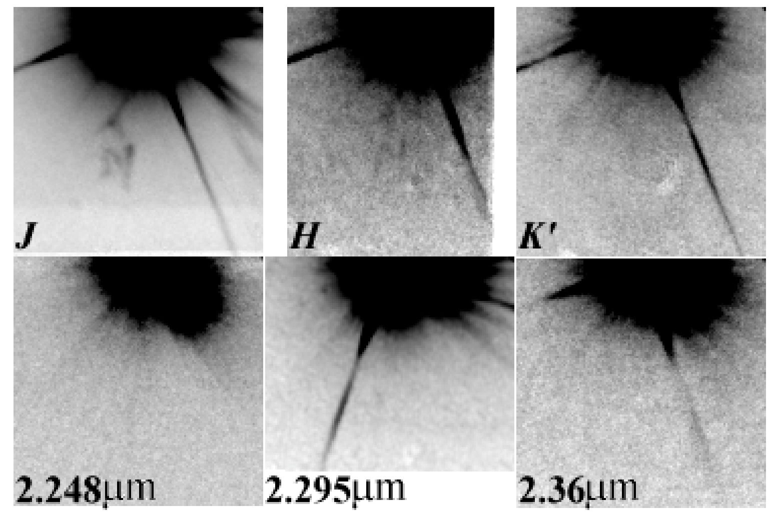
The bright reflection nebula IC 349 is an oddity within the Pleaides, morphologically unlike the filamentary nebulosity enveloping the cluster. Current models for this object propose an origin in a cold molecular cloud (Herbig & Simon 2001; hereafter H&S01). To test this suggestion, we searched for emission in typical CMC gas species H_2 and CO due to the interaction of the nebula with the radiative environment of 23 Tau; expected modes of excitement include shock (stellar wind) and/or fluorescence (illumination by stellar UV light). Additionally, determining the cutoff wavelength for small particle scattering constrains the upper limit of the distribution of dust grain sizes in the nebula. The Apache Point Observatory 3.5m telescope and GRism infrared IMager (GRIM) were used in January 2003 for both broadband and narrowband near-IR photometry of IC 349.



Observations and Results

Our narrowband images reveal no emission from H2 and CO above the level of sky noise, with a statistically insignificant enhancement of background in the CO 2-0 bandhead. Summed, sky-subtracted images (below right) show decreasing signal with increasing wavelength in the broadband filters, and virtually no signal at corresponding locations in the narrowband filters. The lack of gas emission corresponds with published, lower angular resolution submillimeter observations (Zuckerman & Becklin 1993; Herbig & Simon 2001). The plate scale in the images below is 0.473 arcsec/pixel.

Passband	Species	Total Integration (s)	Sky Level (mag sq-arcsec $^{-1}$)
J	N/A	587	12.436±0.003
H	N/A	473	12.332±0.004
K´	N/A	669	12.429±0.002
(2.122±0.02) μm	H_2 1-0 S(1)	4185	11.597±0.004
(2.22±0.09) μm	CO continuum	1245	11.269±0.006
(2.249±0.02) μm	H_2 2-1 S(1)	1245	11.494±0.001
(2.297±0.03) μm	CO 2-0 Bandhead	1777	11.510±0.001
(2.36±0.09) μm	CO Band	825	11.501±0.001



Photometry of regions selected to match Herbig and Simon's HST observations within 1 pixel (0.5") was performed and colors derived in near-IR passbands (left). When combined with the I_C magnitudes reported in H&S01, differential sorting of particles in the nebula is indicated in the color-magnitude diagram; indices are given for power-law fits to *J* (I_C-*J*) and *H* (*J-H*) data. These values indicate the efficiency with which particles of varying sizes are affected by the radiation environment of 23 Tau.

The *J* photometry was sufficiently robust to enable the calculation of limits on the luminosity of a hypothetical embedded protostellar object. A luminosity range of $-3.73 < \log [L/(L_{sun})] < -3.58$ was computed; this result is significantly less sky-limited than the value of $L/(L_{sun}) = 0.23 \pm 0.05$ we reported previously (Barentine & Esquerdo 1999). A protostar of this *L* on the D-burning line of low-mass PMS evolutionary tracks would radiate significantly ($T_{eff} \sim 2500$ K; Baraffe et al. 2002) in the wavelengths we imaged, yet no such point source is observed.

To compare this result with expected masses, we derived the mass of IC 349 in two ways: integrating the dust column densities reported by H&S01 and by thermal arguments taking into account the absence of gas emission reported here. We obtain a mass range of $3\times10^{-7}\ M_{sun} < M < 8\times10^{-1}\ M_{sun}$. While evolutionary tracks allow protostellar objects of this size, we find no corroborating observational evidence for one.

Conclusions

1. This work and other evidence strongly suggests that IC 349 is not the dust shroud of an embedded protostellar object.
2. Our near-IR narrowband imagery taken in conjunction with submilimeter data indicates a lack of significant molecular gas content in the nebula.
3. The observed extinction in IC 349 indicates the largest dust grains are comparable with expected values based on an origin scenario in a cold molecular cloud.

References

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Barentine, J. & Esquerdo, G., *AJ* **117**, 1402 (1999)
Herbig, G. & Simon, T., *AJ* **121**, 3138 (2001)
Zuckerman, B. & Becklin, E., *ApJ* **414,** 793 (1993)

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