AMMONIA OBSERVATIONS OF DARK CLOUDS CONTAINING HERBIG-HARO OBJECTS

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Abstract. A study in NH_3 was conducted towards H-H objects. Cloud fragmentation appears to have occurred in the regions mapped. Rotation is present with velocity gradients of 1-2 km s^{-1} pc^{-1}. We suggest that in the regions containing H-H objects, formation of stars of different spectral types may be taking place.

The Herbig-Haro (H-H) objects are semi-stellar knots or irregular patches of nebulosity whose optical spectra are characterized by emission lines of hydrogen, unusually strong lines of [SII] and [OI], and other lines associated with low excitation gas. Numerous models have been proposed to explain the nature of these objects, including *in situ* excitation from an embedded star, reflection nebulae illuminated by obscured but displaced young H-H stars, FU Orionis-type events, shock excitation of interstellar cloudlets and the stellar wind itself, as well as models of H-H objects as expired H_2O masers.

We present here a different approach to the problem of H-H objects, the study of their associated dark clouds. We observed the (J,K)=(1,1) line of NH_3 using the 36.6 m telescope of the Haystack Observatory. The purpose of this study is to confirm the association of H-H objects with high density material, set limits on local densities, search for dynamical interaction between H-H objects and ambient cloud matter, determine the spatial relationship between the optical H-H objects and the density distribution within the clouds, and to study the dynamics of associated dark clouds themselves. We surveyed 25 regions containing H-H objects, detecting NH_3 towards roughly half of them. We also mapped two of the strongest sources, the NGC1333 region and the Serpens object. The survey results combined with the mapping results indicate that although H-H objects are in general associated with dense neutral material with typical density $n(H_2) \gtrsim 5 \times 10^3$ cm^{-3}, some of these regions cannot be detected in NH_3 to very low limits. This is especially clear in the NGC1333 region, where some of the H-H objects are found in the lower-density periphery of the NH_3 cloud. Furthermore, regions containing H-H objects appear to be quiescent with line widths $\lesssim 0.6$ km s^{-1}, so that if

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dynamical interactions with dark cloud matter are present they must occur in the low density region where NH_3 cannot be detected. Although our data appear to argue against the *in situ* model, we note that the present study cannot detect very compact <0.02 pc condensations. The nondetection of compact HII regions and H_2O masers by Haschick et al. (1979) and Rodriguez et al. (1980) in the direction of H-H objects may be more relevant to the *in situ* question by eliminating the possibility of massive main sequence stars. Discrete and continuous outflow phenomena are also considered. We find that our present experiment cannot detect the very small ejected condensations proposed by Norman and Silk (1979) and Rodriguez et al. (1980), although observed hints of outflow from compact HII regions in the Serpens object may be consistent with a strong stellar wind. One major conclusion from our study is that there is poor spatial correlation between the detected dark cloud matter and other signposts of star formation such as the optical H-H objects, H_2O masers, compact HII regions, and IR sources, which themselves are not well correlated in position. Considering the various difficulties of all current models of the H-H phenomena, we suggest the possibility that the aforementioned signposts may not be directly related to each other. Instead, we may be observing the formation of a spectrum of stars with different masses and possibly in different stages of evolution. In this context, detected cloud fragments may be the sites of future star formation.

Mapping results of NGC1333 and Serpens reveal distinct density condensations with masses of 30-200 $M_\odot$. Rotation with a velocity gradient of the order of 1-2 km s^{-1} pc^{-1} is present, which accounts for the large scale velocity structures. Mutual rotation between fragments appears to be sufficient for stable orbits, although rotation by itself does not provide adequate support against the collapse of individual condensations. In particular there is in the NGC1333 region a massive fragment whose gravitational energy greatly exceeds the thermal energy; its apparent instability against collapse is confirmed by an observed region of enhanced line width spatially coincident with the densest position. Our results are also relevant to modeling of CO observations in the NGC1333 region. Snell and Loren (1977) proposed nonhomologous collapse to explain the CO line shapes observed towards NGC1333. We find however that the very narrow NH_3 lines observed in the high density core appear to be inconsistent with such a collapse law. More detailed modeling of the cloud structures in these regions appears to be necessary.

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