Exploring the Large-Scale Structure of an Intermediate-Mass Star Forming Cloud: Results from HARP

J. O'Linger (SSC), G. Moriarty-Schieven (JAC), and G. Wolf-Chase (Adler Planetarium & U. Chicago)

Abstract

We present early results from an October 2007 HARP observing run at the JCMT. The primary goal of our project was to map an isolated intermediate-mass star forming region known as L1340 in order to investigate the possible effects produced by these late B spectral types on further star formation in their natal environment. The ^{12}CO J=3-2 data reveal intriguing structures in the cloud, including shells and arcs associated with the intermediate-mass stars. A number of our (as yet unpublished) 850 micron SCUBA sources appear to be coincident with the southern-most edge of the largest shell, which encompasses a trio of B stars. We discuss our HARP results in the light of our previously acquired data (near-infrared, submillimeter, and multi-J CO data) and archival data from the literature. JO acknowledges financial support by NASA Grants to the Spitzer Science Center, California Institute of Technology.

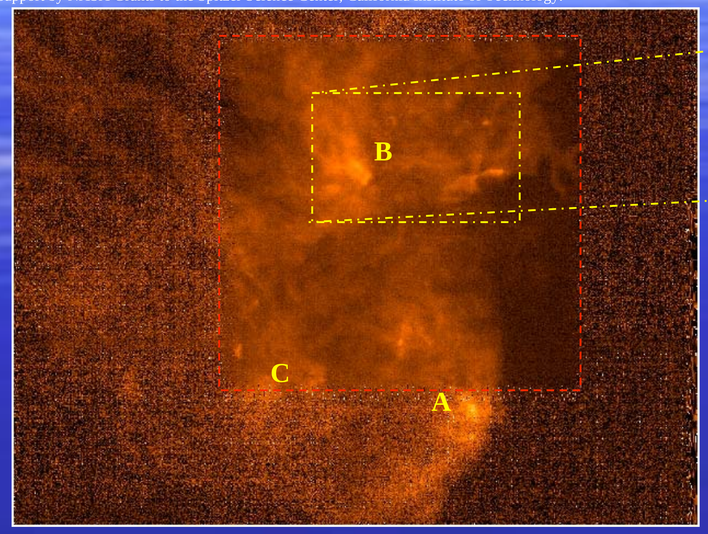

Figure 1: L1340 as seen by HARP in ^{12}CO J=3-2 (integrated data from -17.4 to -12.3 km/s). L1340 is located in Cassiopeia at a distance of 600 pc. The cloud consists of three separate "clumps" as distinguished by C^{18}O observations, labeled A, B, and C. [1] The red dashed box delineates the "deeper" map, mentioned in the Observations section. The yellow box shows the extent of the SCUBA maps (Figure 2).

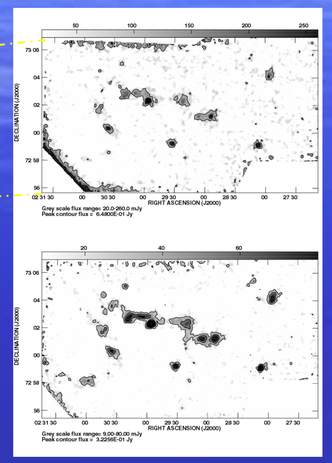

Figure 2: SCUBA maps of L1340B at 450 microns (panel a), and 850 microns (panel b). Many of these dust cores show evidence of outflows, in CO and in H_2, indicative of an embedded protostellar population.

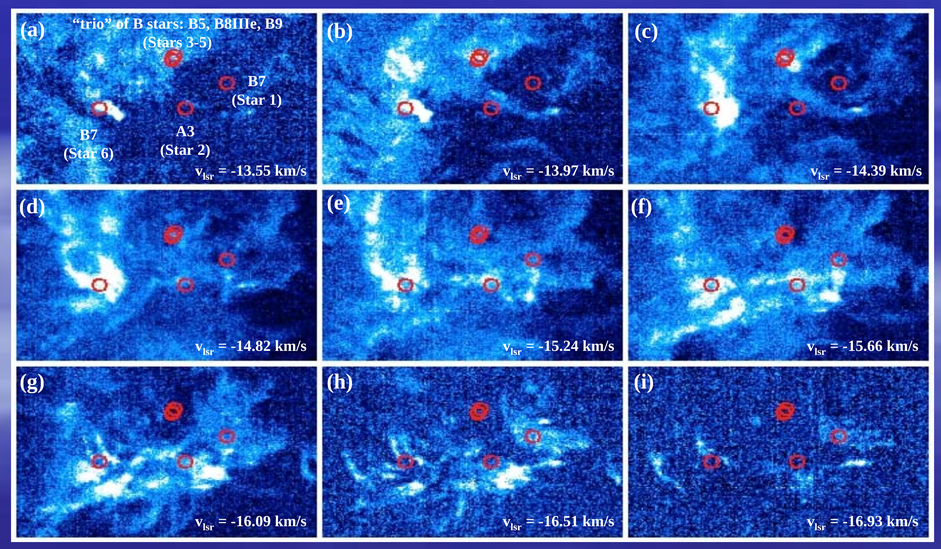

Figure 3: ^{12}CO J=3-2 channel maps of a 16'x26' area centered on L1340B. This portion of the cloud contains six intermediate-mass stars, indicated in each panel by red circles. Panel (a) displays the spectral types and "nicknames" of each star as well. From west to east the six stars are: 2MASSJ02281033+7302197 (B7), 2MASSJ02290319+7259366 (A3), 2MASSJ02291684+7305197 (B5), 2MASSJ02292062+7304514 (B8IIIe) + 2MASSJ02292000+7304545 (B9) (binary system), 2MASSJ02305253+7259353 (B7) [2]. These shall be referred to (for purposes of this poster) as Stars 1-6, respectively. Stars 3-5 make up the "trio of B stars" in the northern part of L1340B, previously mentioned in the abstract. As may be seen in panels (a), (b) and (c), Star 1, a B7 spectral type, lies near the center of a bubble-like void in the CO at those velocities. The "trio" of B stars seems to have had an impact on the cloud structure as well; from the CO data displayed in panels (d) – (h), the winds from these late-B stars have sculpted a large cavity in the northern part of the cloud core. These results agree with the findings of Churchill et. al, 2006 [3], who discovered that 75% of "bubbles" discovered in the GLIMPSE survey (Spitzer Legacy Project) were associated with stars of spectral types B5 – B9.

HARP Observations

We have mapped the entire (~one square degree) L1340 molecular cloud in ^{12}CO J=3-2 using HARP at the JCMT in ~ four hours, achieving an RMS ranging from 1.08 – 0.74K per 0.423 km/s channel (Figure 1). In addition we obtained a second map (total time = 15 hours, RMS ~0.33K per 0.423 km/s channel) of a smaller area (30'x30'), focusing mainly on the L1340B cloud core, for which we have significant ancillary data, including SCUBA maps at 450 and 850 microns (Figures 2a and 2b).

Bubbles or shells associated with B stars in HARP data

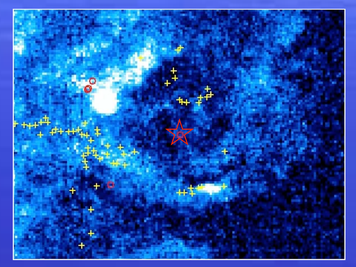

Figure 4: HARP channel map at v_{lsr} = -14.39 km/s (see Figure 3c). Close-up on western bubble feature associated with Star 1 (indicated by red star). Other intermediate-mass stars are shown by red circles; SCUBA core positions are marked with yellow crosses. A number of the SCUBA cores appear to lie near or on the periphery of the bubble.

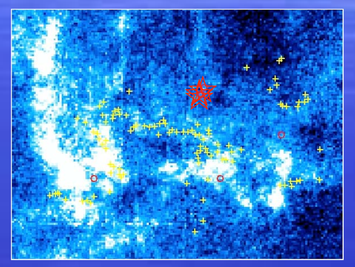

Figure 5: HARP channel map at vlsr = -15.24 km/s (see Figure 3e). Close-up on northern bubble feature associated with the "trio" of B stars (Stars 3-5, indicated by red stars). Other intermediate-mass stars are shown by red circles, SCUBA core positions are marked with yellow crosses. Note the remarkable correspondence of the SCUBA dust ridge with the southern edge of the CO bubble.

Bubbles or shells seen in other L1340 data sets

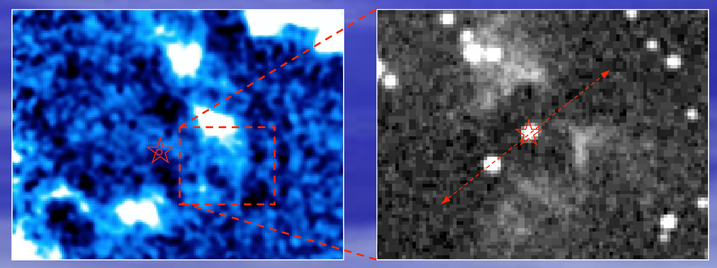

Figure 6: SCUBA 850 micron data are shown in panel (a); DSS archival data (optical) in panel (b). Panel (a) shows SCUBA cores arranged in an arc framing a B7 star (Star 6). The position of the B7 star (indicated with a red star) with respect to the dust cores is rather reminiscent of scenarios from the literature describing a massive star moving through ambient interstellar material and pushing it like a snowplow. [4,5] NOTE: we have not yet ascertained whether the star in question is actually moving. The red dashed box marks the area of the DSS image in panel (b). The DSS image on the right shows a very young stellar object (Class I), known to be driving an outflow, the position angle of which is indicated by the double-pointed red arrow. This Class I object appears to be blowing a small bubble of its own on the edge of the larger SCUBA arc, seen in the reflection nebulosity surrounding the star.

Results

We have mapped the L1340 cloud in ^{12}CO J=3-2 using HARP at the JCMT, and have found intriguing bubbles and shell structures associated with some of the intermediate-mass stars which lie within the cloud boundaries. In addition, a number of dust cores mapped earlier by SCUBA appear to coincide spatially with the edges of these bubbles. We know from our ancillary CO and H_2 data that many of these cores harbor embedded protostellar objects driving outflows. Our SCUBA data also reveal a spectacular arc of dust cores around a B-star on the eastern edge of the cloud. This arc contains a protostellar object driving a CO outflow which appears (in optical data) to be forming its own bubble-like structure. Due to the spatial coincidence of younger objects along the edges of bubbles and shells formed by main-sequence intermediate-mass stars, it appears that L1340B may contain several examples of triggered star formation.

References

1) Kun, M., et al., 1994, A&A, 292, 249
2) Kun, M. 2007, private communication
3) Churchill, E., et al., 2006, ApJ, 649, 759
4) Weaver, R., et al., 1997, ApJ, 218, 377
5) Tan, J. 2004, ApJL, 607, 47