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Molecolar hydrogen knots in Chamaeleon I dark cloud

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Abstract. We have searched for shock-excited molecular hydrogen knots in five selected areas of the Chamaeleon I dark cloud using narrow-band images centered on the H_2 line and neighboring continuum. In the northern part of the cloud (Cha IN), we found seven new H_2 knots, five of which are aligned in the direction of a previously known CO molecular bipolar outflow. The class I low mass stellar object ISO-ChaI 192 that shows the characteristics of an FU Orionis-type star, is the driving source of the molecular flow and is the exciting star of five knots. In the other three searched areas including very low mass young objects, candidate and bona-fide young brown dwarfs, we fail to detect any H_2 emission at our sensitivity limit of $\sim 10^{-17}$ W/m^2.

Key words. dark clouds – very low mass YSOs – young brown dwarfs

1. Introduction

In the recent years a number of young low mass stars and sub-stellar objects have been found in several nearby clouds. In particular an extensive search for young brown dwarfs was undertaken in the Chamaeleon I dark cloud using deep $H\alpha$ surveys, (Neuhäuser & Comerón 1999, Comerón et al. 2000) and mid-IR observations with ISOCAM (Persi et al 2000). A complete census of the very low mass stars and young brown dwarfs in this dark cloud is reported by López Marti et al.(2004), and Luhman (2004). One of the controversial point is connected with the formation of these sub-stellar systems. Recent observations suggest that young brown dwarfs and transition objects undergo a T Tauri-like accretion phase. In fact mid-IR observations have shown the presence of circumstellar disks around these objects (Natta & Testi 2001, Apai et al. 2002, Mohantly et al. 2004), and signs of accretion-related activity have been found (see i.e. Muzerolle et al. 2003, Natta et al. 2004). In addition Fernández & Comerón (2001) and Barrado y Navascués et al. (2004) strongly suggest that young brown

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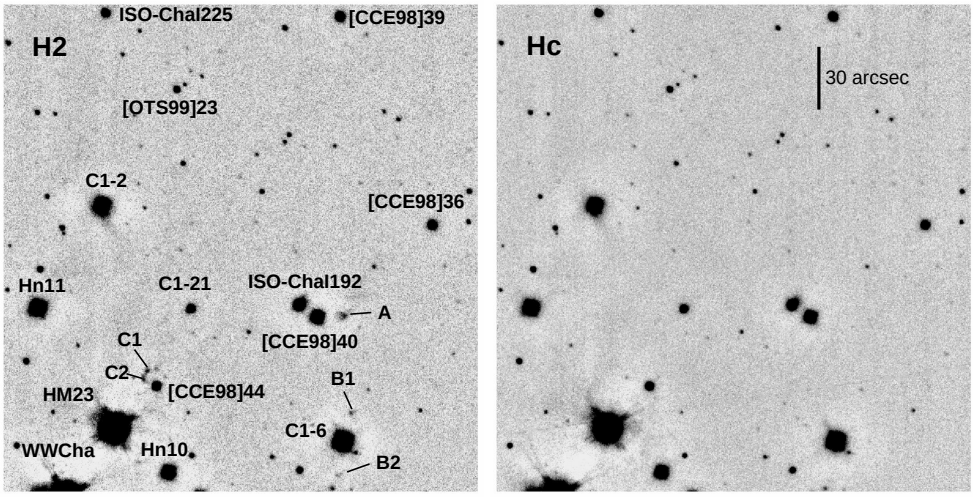

Fig. 1. NTT H_2 and 2.09 μm continuum images of in Cha IN, showing a field of 231×231 square arcsec. N is up and E to the left. Previously known infrared sources and young stellar objects in the region are reported on the H_2 image.

dwarfs may also generate jets/outflows analogous to those observed in classical T Tauri stars (Bontemps et al. 1996). For this reason, we have searched for H_2 outflows in five regions of the Chamaeleon I dark cloud, characterized by the presence of young brown dwarfs and young objects with masses close to the H-burning limit. Most of the results here discussed are reported in a recent paper by Gómez et al.(2004).

2. Observations

Five regions of the Chamaeleon I dark cloud listed in Table 1 were observed with the ESO NTT near-infrared spectrograph/imaging camera SOFI . The images were taken with a plate scale of 0.29"/pix using the H_2 (2.12 μm) and the adjacent continuum (H_{cont}) at 2.09 μm filters. Additional images were obtained in H_2, Br_γ and Ks filters with the near-IR camera PANIC (Perssons Auxiliary Nasmyth Infrared Camera) on the Magellan Clay 6.5 m telescope at Las Campanas (Chile). All the images were calibrated using infrared standard stars. The details of the observations are given by Gómez et al.(2004).

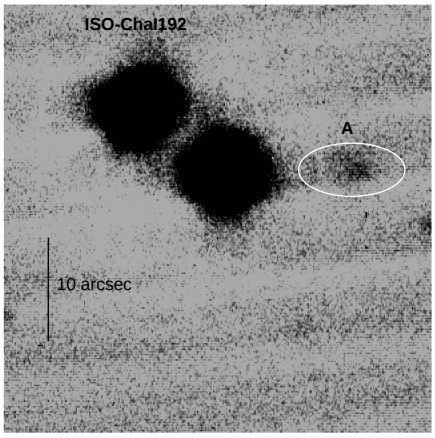

Fig. 2. Magellan (Clay) H_2 image of the knot A

3. Results

We identified four shocked regions (A, B, C, and D) in the northern part of the cloud (Cha IN), by comparing the 2.12 μm with the continuum frame. Figure 1 shows the SOFI images of this region characterized by the presence of a CO bipolar outflow discovered by

Table 1. List of the observed regions in ChaI

Region	α(J2000.)	δ(J2000.)	IR Sources
Cha IN	11:09:29.4	-76:33:28	ISO-ChaI 192, Hn 11, HM 23, WWCha
			Hn 10, ISO-ChaI 225, C1-6, C1-2
CED 110	11:07:16.5	-77:22:40	Ced 110-IRS4, Ced 110-IRS6
			ISO-ChaI 97,B35, ISO-ChaI 86
ChaI138/143	11:08:21.1	-77:30:34	ISO-ChaI 138, ISO-ChaI 143
Cha Hα	11:08:25.0	-77:39:30	Cha Hα 4,5,10,11
(KG2001)102	11:09:49.0	-77:31:20	[KG2001]102 A,B,C

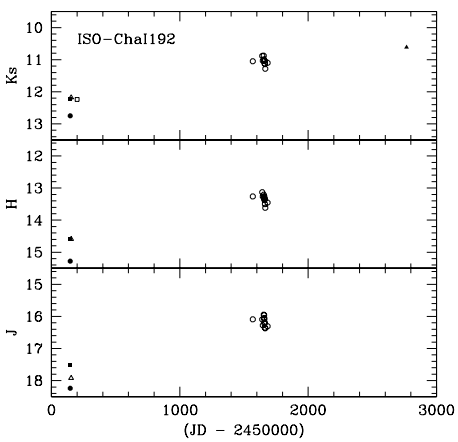

Fig. 3. $JHKs$ variability of ISO-ChaI192

Mattila et al.(1989), and several low mass young stars and IR sources reported in the last column of Table 1. The H_2 knot A shows an extended morphology as seen in the Clay image of Figure 2, and is very close to the low mass Class I source ChaI-192 known also as Cha INa2, discovered by Persi et al.(1999). From an analysis of the near-IR photometry collected at different epochs, results that this source is highly variable (Figure 3). The observed near-IR nebulosity in ISO-ChaI192, its $JHKs$ variability, and the presence of vibrationally excited H_2 emission, identifies this source as a young low mass FU Orionis-type pre-main sequence star (Persi et al. in preparation) similar to the source PP 13S observed in the dark cloud L1473 (Aspin & Sandell 2001). Therefore,ISO-ChaI192 located nearly at the center of the molecular bipolar outflow, is the exciting star of the observed H_2 knots A,C1,C2,C3, and D that are aligned along the direction of the bipolar outflow. The others two knots B1 and B2 in Fig.1 are probably associated with the class II T-Tauri star C1-6.

In the others four regions, including very low mass Class I and Class II young stars, confirmed young brown dwarfs (ChaHα10 and ChaHα11, López Marti et al. 2004; [KG2001]102A, Persi et al.2004), and objects just above the H-burning limit ISO-ChaI138 and ISO-ChaI143; Gómez & Persi 2002) no H_2 knots were found at our sensitivity limit in line flux of $\sim 10^{-17} W/m^2$. This result is consistent with the very low accretion rate of 10^{-10}-10^{-12} M$\odot$/y estimated by Natta et al.(2004) for transition objects and young brown dwarfs. Following the prediction by Wolk & Back (1990), sub-stellar objects at the distance of Cha I (d=160 pc), outflow luminosities would give fluxes in the range $\sim 10^{-17}$- $10^{-19} W/m^2$.

The H_2 and $Hcont$ images of the region containing the bona-fide young brown dwarf ChaHα 10 and 11 reported in Figure 4 show very faint companion candidates specially around the YBD ChaHα 10 and ChaHα 4 in agreement with the HST observations of Neuhäuser et al. (2002). A possible multiple system around the YBD [KG2001]102 has been also reported by Tapia et al. (this conference).

Combined near-IR and ISOCAM observations of the central region of Cha I (CED 110) have identified two Class I very low mass young stars (ISO-ChaI86, and ISO-ChaI92) and an object associated with an infrared nebula (ISO-ChaI84(IRS4)) (Persi et al.2001). In this region no H_2 emission has been detected. In particular our images in the narrow-band filters H_2 and Brγ of the nebulous object (Figure

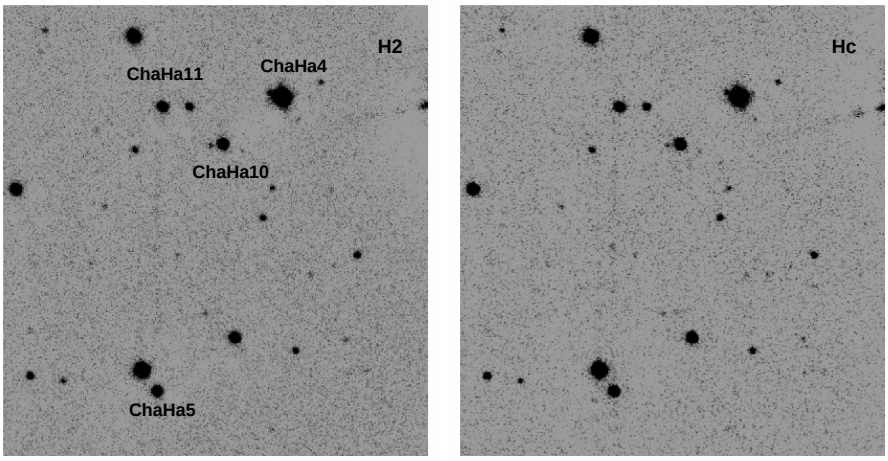

Fig. 4. NTT H_2 and 2.09 μm continuum images of the region containing the young brawn dwarfs ChaHα 10 and 11. N is up and E to the left.

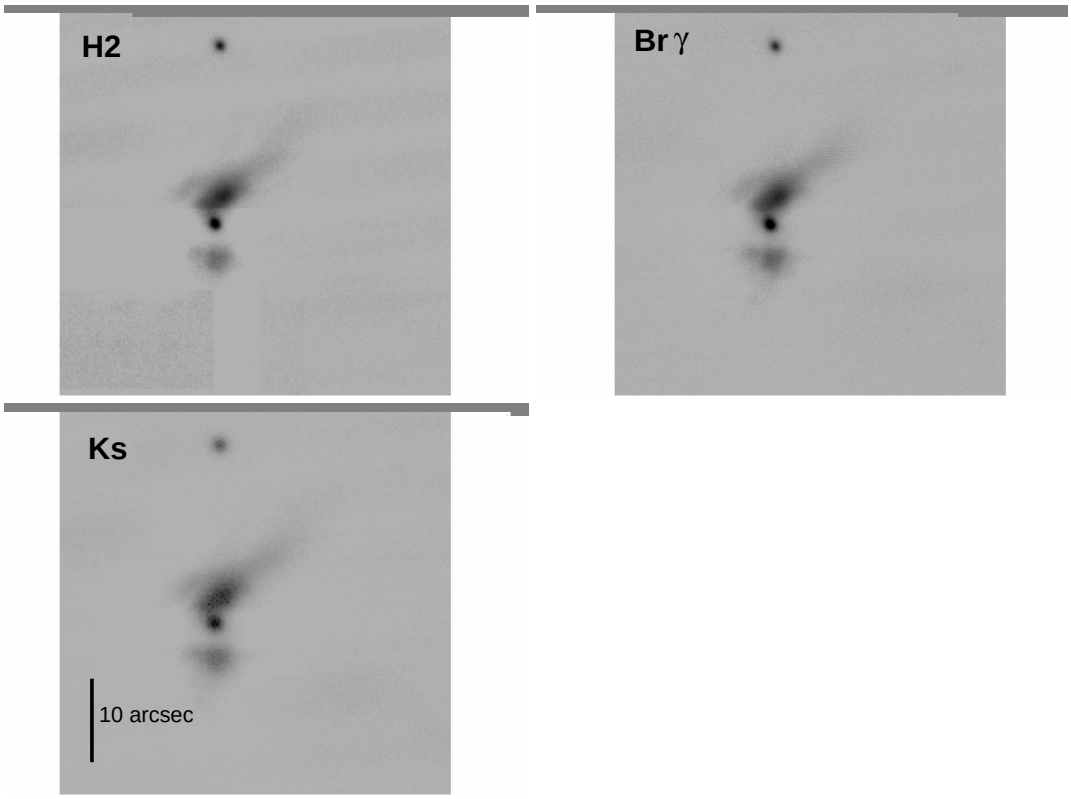

Fig. 5. Magellan (Clay) H_2, Ks and $Br\gamma$ images of ISO-ChaI 84. The field of view is 49×49 square arcsec. N is up and E to the left.

5), indicate that the bipolar infrared nebula observed in ISO-ChaI84(IRS4) extending north-south, is due to the scattered light from a dust disk surrounding the central young low-mass star.

4. Conclusions

From our search for shock-excited molecular hydrogen knots in five region of the Chamaeleon I dark cloud, we found seven H2 knots in the northernmost area (Cha IN). Five of these knots are roughly aligned in the direction of the ^{12}CO(1-0) outflow previously detected by Mattila et al. (1989). The other two knots also lie relatively nearby although not in the direction of the CO outflow. We identify the Class I source ISO-ChaI192, probably a very young FU-Orionis type star as the exciting source of knots A, C1, C2, C3 and D. This object has been previously associated to the ^{12}CO(1-0) outflow by Persi et al. (1999).

We propose C1-6, a ~ 0.2 M$\odot$ star in the region, as the exciting source of knots B1 and B2 mainly based on morphological or geometrical arguments. These knots seem to emanate from opposite sides of the pre-main sequence star C1-6.

We failed to detect H_2 knots associated with several young very low mass stars lying in the others areas of the cloud that were observed. These regions harbor transition stellar/sub-stellar objects, bona-fide young brown dwarfs and Class I-II low mass stars. This negative result may be due to our sensitivity limit of about $\sim 10^{-17}$ W/m^2, in view of the extremely low mass accretion rates derived for brown dwarfs . Deeper 2.12 μm images of these objects may detect fainter emissions and provide new insight into the outflow events in very low mass and sub-stellar objects.

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