Near-Infrared Colors of Young Stellar Objects

Lee, Hsu-Tai[1] and Chen, W. P.[1,2] ; [1]Graduate Institute of Astronomy, National Central University , Chung-Li, Taiwan, [2]Department of Physics, National Central University, Chung-Li, Taiwan
Email (HL): eridan@astro.ncu.edu.tw

Abstract

We present our analysis of the near-infrared colors of the Two-Micron All-Sky Survey (2MASS) Second Incremental Release Point Source Catalog. Known Herbig Ae/Be stars and classical and weak-lined T Tauri stars, are found to occupy distinctly separated regions on the $J-H$ vs. $H-Ks$ color-color diagram, thereby providing a useful tool to identify young stellar candidates, especially in star forming regions, out to a distance of about 2 kpc. We present how the 2MASS database has been successfully applied to the Orion B molecular cloud (L1630) to select candidates for subsequent optical spectroscopic observations that have led to efficient identification of a bona fide young stellar population in the region.

1 Young Stars and JHK Colors

Pre-main sequence (PMS) stars are known to have IR excess emission originating from heated dust in the circumstellar material. As young stars evolve and clear the surrounding materials, they show different amounts of IR excesses, hence their near-infrared colors (Lada & Adams 1992). Hillenbrand et al. (1992) already knew that HAEBE stars generally have more near-infrared excesses than T Tauri stars.

The Two-Micron All-Sky Survey (2MASS) provides J (1.25 μm), H (1.65 μm) and Ks (2.17 μm) band detections to 15.8 mag., 15.1 mag., and 14.3 mag., respectively, with S/N greater than 10. The comprehensive database offers a good opportunity to identify young star candidates associated with or even embedded in molecular clouds. Figure 1 plots the 2MASS (Second Incremental Release Point Source Catalog) (J-H) vs (H-Ks) color-color diagram, in which known young stellar populations, such as classical T Tauri stars (CTTS, Herbig & Bell 1988), weak-lined T Tauri stars (WTTS, Alcala et al. 1996), and Herbig Ae/Be stars (HAEBE, Thé et al. 1994) can be seen to be reasonably well separated.

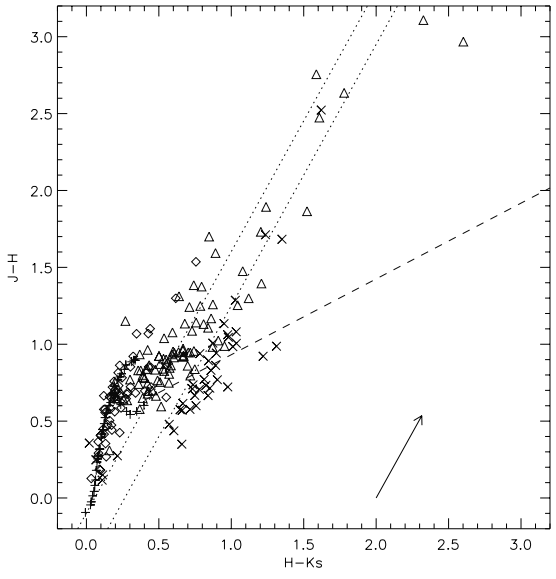

Figure 1: The 2MASS color-color diagram, in which known stellar populations are segregated. Open triangles are classical T Tauri stars; diamonds are main-sequence stars, giants, and weak-lined T Tauri stars; crosses are Herbig Ae/Be stars. The arrow marks the extinction vector for $A_V = 5$ mag.

Also shown in Figure 1 are the loci for main sequence and for giant stars, where the WTTS also distribute. The CTTS are found to lie approximately between the two parallel lines, defined by $(J-H) = 1.7(H-Ks) - 0.0976$ and $(J-H) = 1.7(H-Ks) - 0.45$, with the slope determined by the near-infrared reddening. The HAEBE are located to the right of these two parallel lines. The dashed line in Figure 1 represents the dereddened CTTS locus (Meyer, Calvet, & Hillenbrand 1997) modified with the 2MASS photometry (Carpenter 2001), with $(J-H) = 0.723(H-Ks) + 0.560$. The fact that different kinds of PMS stars occupy separated regions on the (J-H) vs (H-Ks) color-color diagram enables us to identify candidate young stars, especially in star-forming regions where background contamination is relatively low. The 2MASS database is particularly useful in terms of color information, because the data usually were taken nearly simultaneously. This is important because a majority of PMS are variables. We have successfully applied the 2MASS color criteria to select young stars in the open cluster NGC 6823 (Hojaev et al. 2002). Here we report the results for the well known Orion B molecular cloud.

2 Young Star Candidates in Orion B

We applied the above 2MASS color criteria to bright sources with J<15 mag in the Orion B star-forming region (RA=5h28m to 5h52m, DEC=-4d to 0d12m) to look for CTTS and HAEBE candidates. At a distance of about 480 pc (Genzel et al. 1981), the Orion B molecular cloud is one of the nearest active star-forming regions, with a wealth of high-mass OB stars, intermediate-mass HAEBEs and low-mass TTSs.

Sources with a neighboring star < 5" have not been included because of possible photometric confusion. As a result, a total of 14 HAEBE and 85 CTTS candidates have been selected.

Medium-resolution spectra have been obtained for 23 PMS candidates in the Orion B molecular cloud in February 2002 with the Beijing Astronomical Observatory 2 m telescope. Three HAEBE have been found, with strong H α emission. In addition, 14 stars are identified as CTTS that show prominent H_α emission and the presence of the λ6707 Li absorption line. Typical spectra of a Herbig Ae/Be and of a T Tauri star, respectively, are shown as Figure 2. Table 1 lists these newly found TTS and HAEBE, with their coordinates, 2MASS fluxes, and optical identifications, if any.

3 Conclusion

We have successfully applied the separation of near-infrared colors to select young stars from the 2MASS database. The 2MASS database proves to be a very useful tool to select PMS candidates in star-forming region because of the comprehensiveness and the uniformity of the survey, and the nearly simultaneous photometric measurements. Based on the 2MASS colors, we selected YSO candidates in the Orion B star formation region. Of the 17 sources bright enough to warrant spectral observations, all turned out to be bona fide YSOs, with 14 CTTS and 3 HAEBE, demonstrating the effectiveness of our method. Young star candidates, especially for those associated with molecular clouds, could be thus identified out to a distance of about 2 kpc.

We thank the staff at the Beijing Astronomical Observatory for their assistance during our observing run.

References

Alcalá, J. M., et al. 1996, A&AS, 119, 7
Carpenter, J. M. 2001, AJ, 121, 2851
Genzel, R., Reid, M. J., Moran, J. M., & Downes, D. 1981, ApJ, 224, 884
Hojaev, A. S., Chen, W. P., Lee, H. T., & Yeh, W. H. 2002, these Proceedings
Herbig, G. H. & Bell, K. R. 1988, Lick Observatory Bull. No. 1111
Hillenbrand, L., et al. 1992, ApJ, 397, 613
Lada, C. J. & Adams, F. C. 1992, ApJ, 393, 278,
Meyer, M. R., Calvet, N., & Hillenbrand, L. A. 1997, AJ, 114, 288
Rho, J. et al. 2001, ApJ, 562, 446
Thé, P. S.; de Winter, D., & Perez, M. R. 1994, A&AS, 104, 315

2MASS Objects	J	H	Ks	Type	Counterpart
J0529233-012515	12.04	11.25	10.70	CTTS	Kiso A-0903 176
J0530187-020158	9.69	9.40	8.94	HAEBE	HD 290543
J0531206-004920	12.13	11.21	10.55	CTTS	Kiso A-0904 1
J0533187-003614	10.36	9.31	8.63	CTTS	IRAS 05307-0038
J0533433-010835	10.81	10.06	9.50	CTTS	HBC 105
J0537189-002042	11.60	10.85	10.35	CTTS	Kiso A-0904 58
J0537590-010553	10.82	9.96	9.35	CTTS	
J0538053-011522	8.89	8.21	7.41	HAEBE	IRAS 05355-0117; HD 290764; V1247 Ori
J0538273-024510	11.95	10.78	9.92	CTTS	2RXP J053827.3-024508; Kiso A-0976 328
J0540224-021540	12.37	11.42	10.80	CTTS	
J0541414-014353	10.41	9.11	8.22	CTTS	1RXH J054141.1-014348
J0541471-021638	9.04	8.14	7.54	CTTS	1RXH J054147.1-021636
J0543082+000021	11.06	9.98	9.22	CTTS	Kiso A-0904 148
J0544036-021637	12.39	11.51	10.88	CTTS	Kiso A-0904 153
J0544188+000841	8.01	7.55	6.90	HAEBE	IRAS 05417+0007; HD 38238; V351 Ori
J0544292-012217	11.36	10.42	9.76	CTTS	
J0545251-003723	10.86	10.04	9.45	CTTS	IRASF05428-0038; Kiso A-0904 167; 1RXS J054525.0-003715

Table 1: Hα emission-line stars in NGC 6823

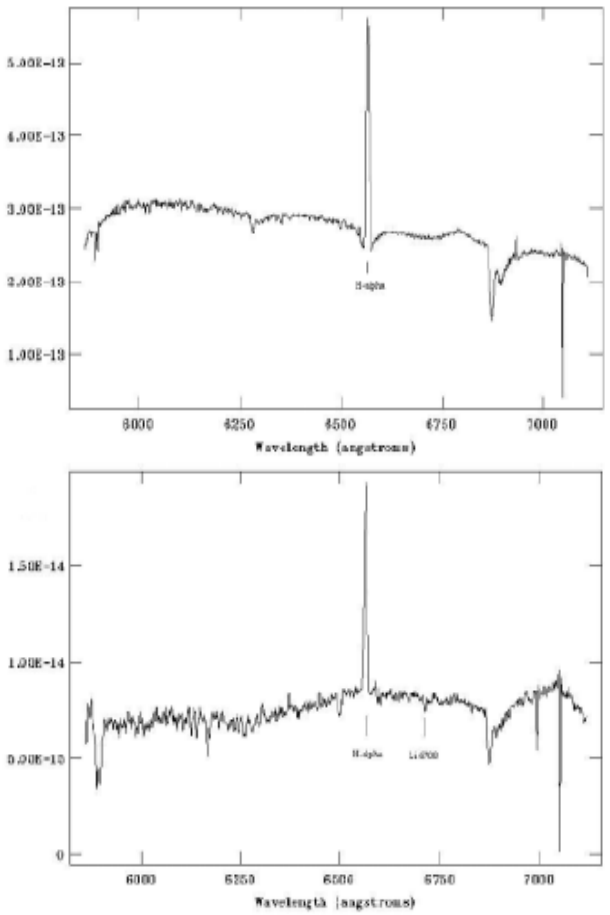

Figure 2: Sample spectra taken at Beijing Observatory (top) of a Herbig Ae/Be star 2MASS0538053−011522, showing a prominent H_α emission line, and (bottom) of a T Tauri star 2MASS0533433−010834 showing, in addition to a prominent H_α emission line, the λ6707 lithium absorption line.