# Study of Pre-Main Sequence Stars Born in LDN 1251

**M. Eredics**[1], **M. Kun**[2]

[1] Eötvös Loránd University
H-1518 Budapest, P.O.Box 32., Hungary
[2] Konkoly Observatory of the Hungarian Academy of Sciences
H-1525 Budapest, P.O.Box 67.
E-mail: eredicsm@astro.elte.hu, kun@konkoly.hu

**Abstract**

We observed the spectra of H$\alpha$ emission stars in the molecular cloud L1251 using the CAFOS spectrograph on the 2.2 m telescope of Calar Alto Observatory. We found 7 pre-main sequence stars born in the cloud and determined their spectral and luminosity classes. These spectroscopic data, supplemented with near-infrared (JHK) magnitudes allowed us to place these stars in the HR diagram. This paper discusses the evolutionary status of star formation in LDN 1251.

## 1. Introduction

Observational studies of dark clouds aimed at finding low mass star formation and the evolutionary status of young stellar objects have a long history. Observations of Lynds 1251, a part of the Cepheus Flare, located at 300±30 pc Kun (1998) from the Sun have shown this region to be forming low-mass stars at high efficiency. Several H$\alpha$ emission stars, probable pre-main sequence stars born in LDN 1251, have been found here (Grasdalen et al. 1973; Kun & Prusti 1993). In this paper, we present the spectral and luminosity classes for 8 pre-main sequence candidates. The placement of the stars on the Hertzsprung–Russell diagram allows a conservative estimate of the age of LDN 1251 as well.

## 2. Results

We studied the spectra of 8 H$\alpha$ emission star candidates in the molecular cloud LDN 1251 and determined their spectral types. Spectral types can be estimated using the strength of molecular bands and presence of atomic lines. The observed stars are late-K and M type objects, therefore we set them against G, K, M standards observed with the same resolution, and Pickles' (1998) spectral flux

library data. Spectral types were estimated using the depths of several molecular bands at $\lambda$7000–7200 Å (Kirkpatrick et al.1991) and the Na I at $\lambda$5890 Å and $\lambda$5896 Å.

H$\alpha$ emission and Li I absorption are the most important indicators of youth of solar type stars. We measured the equivalent width of H$\alpha$ and Li I $\lambda$6707 Å. We found that all but one our programme stars show H$\alpha$ and H$\beta$ emission, and the emission lines show inverse P Cygni profile except in H$\alpha$ 1. We found neither H$\alpha$ emission nor Li absorption in the spectrum of H$\alpha$ 41. This star is probably a foreground object not related to the cloud, therefore we omitted it from further studies. Li I absorption was neither detected in the spectrum of H$\alpha$ 2 due to the low S/N. We also identified the forbidden lines [OI] $\lambda\lambda$ 6300Å 6364Å in the spectra of H$\alpha$ 1, H$\alpha$ 44 and H$\alpha$ 45, and [SII] at $\lambda\lambda$ 6717Å 6731Å in H$\alpha$ 1. He I emission is also present in most spectra. Fig. 1 shows the observed spectra in the wavelength region 5800–7800 Å. The $J-H$ vs. $H-K$ two-colour diagram is presented in Fig. 2.

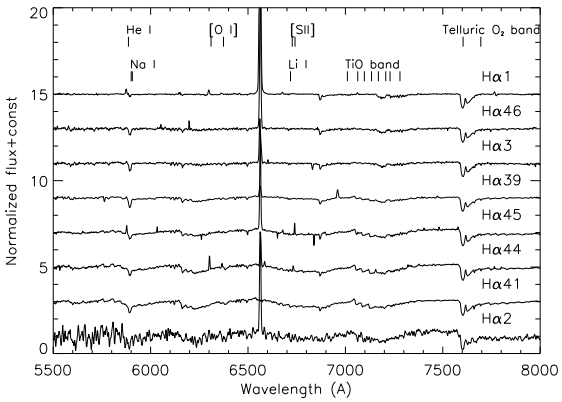


Figure 1: Spectra of the PMS stars in L 1251 in the wavelength region 5800–7800 Å.

In order to place the stars in the HRD we estimated their effective temperatures and bolometric luminosities. Effective temperatures can be obtained directly from the spectral types of the stars Hartigan et al. (1994). The J, H and K magnitudes of the stars were used to determine the bolometric luminosities with the assumption that the whole flux at 1.25$\mu$m ($J$ band) comes from the stellar photosphere. Then $J - M_{\rm J} = 5\log r - 5 + A_{\rm J}$ and $M_{\rm bol} = M_{\rm J} + BC_{\rm J}$ were used, where $r = 300 \pm 30$ pc is the distance of LDN 1251 Kun (1998), $A_{\rm J} = 2.635 E_{\rm J-H}$ is the interstellar absorption in the $J$ band Rieke & Lebofsky (1985), and $BC_{\rm J}$ is the bolometric correction (Hartigan et al. 1994). The results

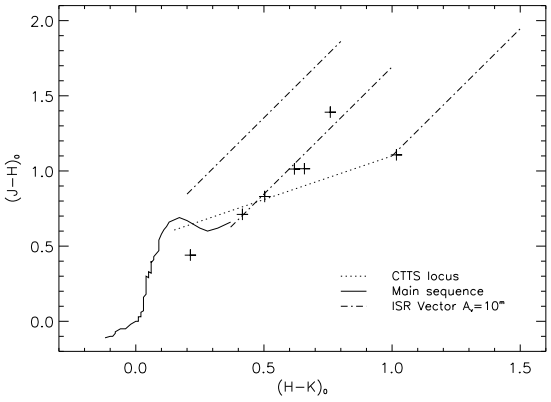


Figure 2: Positions of the T Tauri stars in L 1251 in the $J-H$ vs. $H-K$ diagram. Loci of zero-age main sequence and classical T Tauri stars, as well as the slope of interstellar reddening are indicated.

Table 1: Results of spectroscopy and photometry

| H$\alpha$ star | Sp $\pm$1 | EW[Å] [H$\alpha$] | [Li I] | J–H | H–K | $\log T_{eff}$ | $\log(L/L_\odot)$ | M $[M_\odot]$ | age [Myr] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | K5 | −96.07 | 0.24 | 1.391 | 0.759 | 3.643 | 0.668 | 0.6 | 0.2 |
| 2 | M2$\leq$ | −42.18 | – | 1.013 | 0.619 | $\leq$3.580 | $\leq -0.205$ | $\leq$0.4 | 0.7 |
| 39 | M0 | −5.90 | 0.35 | 1.015 | 0.658 | 3.580 | −0.325 | 0.4 | 1 |
| 3 | K7 | −24.35 | 0.41 | – | – | – | – | | |
| 41 | M2 | – | – | 0.440 | 0.213 | – | – | – | – |
| 44 | M1.5 | −12.12 | 0.30 | 0.711 | 0.416 | 3.553 | −0.687 | 0.4 | 2 |
| 45 | M1 | −37.22 | 0.26 | 0.830 | 0.503 | 3.562 | −0.445 | 0.4 | 1 |
| 46 | K5 | −60.22 | 0.35 | 1.107 | 1.017 | 3.643 | −0.077 | 0.8 | 2 |

of spectroscopy and photometry are shown in Table 1, and the positions of the programme stars in the HRD are displayed in Fig. 3.

## 3. Conclusions

We examined basic spectroscopic properties and near-infrared data of 8 pre-main sequence star candidates in the cloud LDN 1251. We confirmed the pre-main sequence nature of 7 of them. All the seven pre-main sequence stars are low mass (0.3-0.8 $M_\odot$) objects, and their spectra show classical T Tauri features. The Li absorption in the spectra and their positions in the HRD indicate that they are young objects, having ages of 1–2 million years. By the estimated age of H$\alpha$ 46 we think that the cloud is at least $2 \times 10^6$ yr old. The inverse P Cygni profile in the H$\alpha$ emission (except H$\alpha$ 1) suggests that gathering of mass from

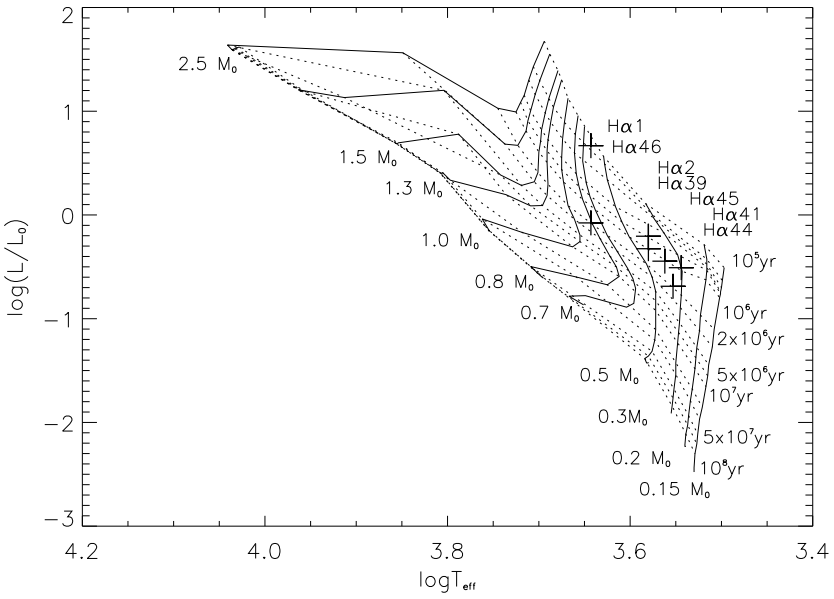


Figure 3: The T Tauri stars of L 1251 (crosses) in the HRD. Dotted lines indicate the isochrones and solid lines show the evolutionary tracks from D'Antona & Mazzitelli's (1994) model 1.

the accretion disks has not been finished in the H$\alpha$ stars yet.

## Acknowledgements

This research is based on spectroscopic observations obtained in the German-Spanish Astronomical Centre, Calar Alto, operated by the Max-Planck-Institute for Astronomy, Heidelberg, jointly with the Spanish National Commission for Astronomy, as well as on near-infrared observations taken at TIRGO (Gornergrat, Switzerland). TIRGO is operated by CAISMI-CNR Arcetri, Firenze, Italy. We acknowledge support by the OTKA grant T034584.

## References

D'Antona, F., Mazzitelli, I., 1994, ApJS 90, 467
Grasdalen, G.L., Kuhi, L.V., Harlan, E.A., 1973, PASP 85, 193
Hartigan, P., Strom, K.M., Strom, S.E., 1994, ApJ 427, 961
Kirkpatrick, J.D., Henry, T.J., McCarthy, Jr., D.W., 1991, ApJS 77, 417
Kun., M., 1998, ApJS 115, 59
Martín, E.L., Kun., M., 1996, A&AS 116, 467
Kun., M., Prusti, T., 1993, A&A 272, 235
Meyer, M.R., Calvet, N., 1997, AJ 114, 288
Pickles, A.J. 1998, PASP 110, 863
Rieke, G.H., Lebofsky, M.J., 1985, ApJ 288, 618