P1724 AND RXJ0511.2+1031 – RUN-AWAY T TAURI STARS ?

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ABSTRACT.
The weak-line T Tauri star P1724 (HBC 452) is located only 15′ north of the Trapezium cluster in Orion. With our high-resolution spectra, we measure its radial velocity to be +23 $km\ s^{-1}$, i.e. consistent with Orion membership. Previous proper motion studies of T Tauri stars in the general direction of Orion have concluded that the probability of membership of P1724 to Orion lies between 0 % and 97 %. In fact, the proper motion of P1724 points away from the Trapezium, as also confirmed by our new proper motion data with ∼ 100 yrs epoch difference (STARNET = GSC1.2 + AC). Hence, P1724 may have been ejected (in a three-body encounter) out of the Trapezium as a run-away T Tauri star. Its spectral energy distribution identifies P1724 as a naked T Tauri star, which may have lost its disk during the encounter. Its HR diagram age is consistent with its 3D velocity (∼ 10 $km\ s^{-1}$ relative to the Trapezium) and its current distance from the Trapezium.

The ROSAT X-ray source RXJ0511.2+1031 has been identified as a weak-line T Tauri star with spectral type K7 and strong lithium absorption, W_λ(Li)= 0.65Å. It is located in the λ Ori region and its radial velocity indicates that it moves towards us at ∼ 10 $km\ s^{-1}$ relative to Orion. RXJ0511.2+1031 appears to be a single T Tauri star with small rotational velocity, just as would be expected for a recently ejected run-away T Tauri star.

1. Introduction

The ROSAT All-Sky Survey (RASS) has covered the entire sky in X-rays to a certain flux limit, enabling searches for T Tauri stars (TTS), i.e. low-mass pre-main sequence (PMS) stars, just about anywhere. In particular, the weak-line TTS (wTTS) are known to be strong X-ray emitters from the work with the *Einstein Observatory.* Classical TTS (cTTS), which show strong emission lines and strong infrared (IR) excess indicative of circumstellar disks, display weaker X-ray emission than wTTS (e.g. Neuhäuser et al. 1995a). For a summary of the ROSAT follow-up studies, see Neuhäuser (1997).

Surprisingly, new TTS have not only been found among ROSAT sources in star forming regions, but also several degrees away from the clouds, i.e. outside the active star forming sites. Discoveries have been reported, e.g. by Neuhäuser et al. (1995b, 1997a) and Magazzù et al. (1997) south of the Taurus clouds, as well as by Alcalá et al. (1995, 1996, 1997) and Covino et al. (1997) near the Chamaeleon and Orion clouds.

Many TTS found up to several degrees away from any nearby molecular cloud seem too young to have dispersed out of the Taurus clouds with velocities similar to the small velocity dispersions observed among TTS and clouds in central Taurus (2 to 3 $km\ s^{-1}$, Herbig et al. 1977, Jones & Herbig 1979, Hartmann et al. 1986). The question then arises as to how and where these young PMS stars formed. They may have formed locally (as suggested by Feigelson 1996), but we see no residual gas left behind. Alternatively, they may have formed in the central cloud cores and were subsequently ejected with velocities larger than the typical dispersions in the radial velocities and proper motions (as suggested by Sterzik & Durisen 1995), becoming what have been referred to as run-away TTS (raTTS).

For a more thourough discussion of the ROSAT observations, optical follow-up studies, and the concept of run-away T Tauri stars, see the article by Neuhäuser in this proceedings.

2. P1724: A run-away TTS ejected from the Trapezium ?

Parenago (1954) presented a list of Orion nebula stars which included star number 1724, now called P1724, that has subsequently been shown to be one of the most active TTS known, as evidenced by the detection of a very powerful X-ray flare (Gagné et al. 1995; Preibisch et al. 1995). P1724 is a relatively bright ($V \simeq 10.6$ mag) star located only $15'$ north of the Trapezium cluster in Orion. There have been a number studies of the proper motion of P1724, and the probability of membership to the Orion association according to different authors has ranged from 0% and 97%. Preibisch et al. (1995) presented a low-resolution spectrum showing $W_\lambda(H\alpha) = 4$Å and W_λ(Li)= 0.47Å. P1724 does not show excess infrared emission, and there is no IRAS source in the vecinity (Weaver & Jones 1992). Hence, one can classify this star as wTTS.

Recently, Neuhäuser et al. (1997) have studied this star in great detail, with the following results:

Based on deep R band imaging, no companion is found down to a separation of $\sim 1''$ and a magnitude difference of $\Delta R = 7$ mag. With hundreds of V, R, and I measurements obtained within twelve weeks, its rotation period is confirmed to be about 5.68 days. Repeated high-resolution spectra show very low amplitude radial velocity variability. Although this could conceivably be caused by a spectroscopic binary companion with a minimum mass of $\sim 40\ M_{jup}$, this interpretation is disregarded for two reasons: Firstly, the radial velocity variation shows the same period as the photometric variability, which is very unlikely to happen by chance if the phenomena are unrelated. Secondly, a series of high-resolution, high S/N spectra exhibit variations in the line profiles that are common in spotted stars. Data reduction by Doppler-imaging techniques yields an image showing a pronounced dark feature at relatively low latitude. Its derived size and temperature indicate that it can easily produce the observed photometric and spectroscopic variability.

Multiple high-resolution spectra yield a rotational velocity $v \cdot \sin i = 71\ km\ s^{-1}$, and a mean radial velocity of $+23\ km\ s^{-1}$ that is consistent with kinematic membership to the Orion star forming region. Therefore, the distance to P1724 is most likely also $\sim 460\ pc$. Based on the proper motion of P1724 as listed in the STARNET catalog, the derived 3D space velocity shows that P1724 moves north relative to the Trapezium; in other words, its proper motion differs from most Trapezium stars, which is the reason why some earlier proper motion studies concluded that P1724 may not belong to the Orion star forming region.

Optical (UBVRI) and infrared (JHK) photometry of P1724 as well as the spectral energy distribution are presented, showing that P1724 is a naked (weak-line) T Tauri star. The bolometric luminosity is estimated to be 51 $L_\odot$, the spectral type to be K0, and the radius to be 9.0 $R_\odot$ (from both the Stefan-Boltzmann law based on the luminosity and temperature, and from the Barnes-Evans relation, which is consistent with a nominal distance to P1724 of ~ 460 pc).

Although P1724 has lost all its circumstellar material, its bolometric luminosity places it very close to the birth line at an age of only $\approx 2 \cdot 10^5$ years, with a mass of ≈ 3 $M_\odot$ (consistently found from four different sets of pre-main sequence tracks and isochrones). This age is consistent with its present location and 3D space motion (~ 10 km s^{-1} relative to the Trapezium) under the assumption that it was ejected from the Trapezium $\approx 2 \cdot 10^5$ yrs ago.

P1724 thus appears to be a single, very young, naked, weak-line TTS moving north relative to the Trapezium, but sharing the Orion radial velocity. All the observations are consistent with P1724 being a run-away TTS, ejected from its birth place, the Trapezium cluster, only $\sim 2 \cdot 10^5$ years ago (Neuhäuser et al. 1997b).

Although the relatively large mass of this star, neither the Sterzik & Durisen (1995) nor the Kroupa (1995) scenario rule out the ejection of such massive stars, they are just a priori less likely. However, due to observational biases, it may even be more likely to find such a massive (and, hence, luminous) raTTS.

3. RXJ0511.2+1031: A raTTS candidate near λ Orionis

One of the newly-discovered PMS stars south of Taurus, RXJ0511.2+1031, has been identified as a very promising raTTS candidate. It was identified as a TTS with follow-up observations of ROSAT sources south of the Taurus clouds (Magazzù et al. 1997, Neuhäuser et al. 1997a). This star has a spectral type K7 with $H\alpha$ emission (Magazzù et al. 1997) and $W_\lambda(\mathrm{Li}) = 0.65$Å (which is the largest in the Magazzù sample). It is located on the λ Ori cloud. If it originated in Orion, it is now moving towards us with a radial velocity of ~ 10 km s^{-1} relative to the Orion clouds. This velocity translates into ~ 10 pc per million yrs, so that one would still expect the star to be more distant than ~ 400 pc if it originated in λ Ori, at ~ 460 pc. Unfortunately, its proper motion has not yet been measured. Repeated high-resolution spectra show no indications of binarity (Neuhäuser et al. 1997a), and Sterzik et al. (1997) found no visual companions down to $0.6''$ separation and ΔR up to 7 mag. The small observed rotational velocity of only ~ 5 km s^{-1} for this star (N97) is consistent with the predictions for recently ejected raTTS (Armitage & Clarke 1997). This star has $V \simeq 14$ mag (from the GSC), while many other stars in the sample south of Taurus have $V \simeq 11$ to 12 mag (Magazzù et al. 1997). Such a difference in brightness is consistent with the difference in distance between Taurus and Orion.

References

Alcalá J.M., Krautter J., Schmitt J.H.M.M., Covino E., Wichmann R., Mundt R., 1995, A&A Suppl. 114, 109

Alcalá J.M., Terranegra L., Wichmann R., Chavarria C., Krautter J., Schmitt J.H.M.M., Moreno-Corral M.A., de Lara E., Wagner R.M., 1996, A&AS 119, 7

Alcalá J.M., Krautter J., Covino E., Neuhäuser R., Schmitt J.H.M.M., Wichmann R., 1997, A&A 319, 184

Armitage P.J. & Clarke C.J., 1997, MNRAS 285, 540

Covino E., Alcalá J.M., Allain S., Bouvier J., Terranegra L., Krautter J., 1997, A&A, in press

Feigelson E.D., 1996, ApJ 468, 306

Gagné M., Caillault J.-P., Stauffer J.R., 1995, ApJ 445, 280

Hartmann L.W., Hewett R., Stahler S., Mathieu R.D., 1986, ApJ 309, 275

Herbig G.H., 1977, ApJ 214, 747

Jones B.F. & Herbig G.H., 1979, AJ 84, 1872

Kroupa P., 1995, MNRAS 277, 1522

Magazzù A., Martín E.L., Sterzik M.F., Neuhäuser R., Covino E., Alcalá J.M., 1997, A&A Suppl. 124, 449

Neuhäuser R., 1997, Science 276, 1363

Neuhäuser R., Sterzik M.F., Schmitt J.H.M.M., Wichmann R., Krautter J., 1995a, A&A, 297, 391

Neuhäuser R., Sterzik M.F., Torres G., Martín E.L., 1995b, A&A 299, L5

Neuhäuser R., Torres G., Sterzik M.F., Randich S., 1997a, A&A 325, 647

Neuhäuser R., Wolk S., Torres G., et al., 1997b, A&A, to be submitted

Parenago P.P., 1954, Trudy Gosud. Astron. Sternberga 25, 1

Preibisch Th., Neuhäuser R., Alcalá J.M., 1995, A&A 304, L13

Sterzik M.F. & Durisen R., 1995, A&A 304, L9

Sterzik M.F., Durisen R.H., Brandner W., Jurcevic J., Honeycutt R.K., 1997, AJ, in press

Weaver M.B. & Jones G., 1992, ApJS 78, 239

Wichmann R., Bastian U., Krautter J., Jankovics I., Rucinski S.M., 1997, MNRAS, submitted