Temporal-spatial distribution of YSOs nearby Taurus region

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outline

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Introduction

Taurus

- As part of the Local Bubble(LB), centered at the Sun with a radius of roughly 300 pc, the Taurus star-forming region (SFR) is located approximately 145 pc to the west of the Sun, and covers an extension of more than 100 deg2 on the sky. Its proximity to the Sun favors observations and makes Taurus one of the most studied nearby SFRs.

GYSOs & DYSOs

- Esplin & Luhman (2019) studied the clustering properties of the identified YSOs in Taurus. They found that the YSOs in Taurus are kinematically correlated and that most of them concentrate in several dense sites within the Taurus molecular cloud. Based on this finding, they confirmed 532 new YSOs (hereafter referred as the GYSOs).
- Surveys of the Taurus region have also found that there are a certain number of YSOs that display clear evidence of youth but are sparsely distributed in the region (hereafter, DYSOs). Kraus et al. (2017) studied these stars and found that they are relatively old (10-20 Myr) and diskfree. The proper motions of DYSOs are broadly co-moving with the GYSOs, suggesting that these stars might be the formerly formed populations of Taurus.
- The age gap between the DYSOs and the GYSOs (≤5 Myr) drives to postulate that there may be some young stars of 5-10 Myr that have not been discovered yet. These stars may offer the opportunity to study the relationship between the GYSOs and the DYSOs, and to understand the star formation processes in the Taurus region.

Data selection and analysis

- The primary data for this work were taken from Gaia DR3.
- To cover the entire Taurus region and ensure stars are associated with it, Set the search area to $55° \le RA \le 90°$, $10° \le DEC \le 35°$ and within 100 to 300 pc from the Sun.
- Excluded stars in the region $55° \le RA \le 70°$ and $30° \le DEC \le 35°$ to remove stars from the Perseus region.
- Signal-to-noise ratios in parallax greater than 5; Photometric errors in G_{BP} and G_{RP} bands less than 5%.

- An age cut of 20 Myr was applied in the CMD to eliminate field stars. Selected stars that are below the black solid line to exclude evolved stars.
- The extinctions of stars were corrected based on the 3D extinction map of Green et al. (2019) and the extinction law of Wang & Chen (2019).
- Based on these criteria, 7046 stars were selected. 388 stars have previously been identified. The identities of the remaining 6658 stars will be further evaluated.

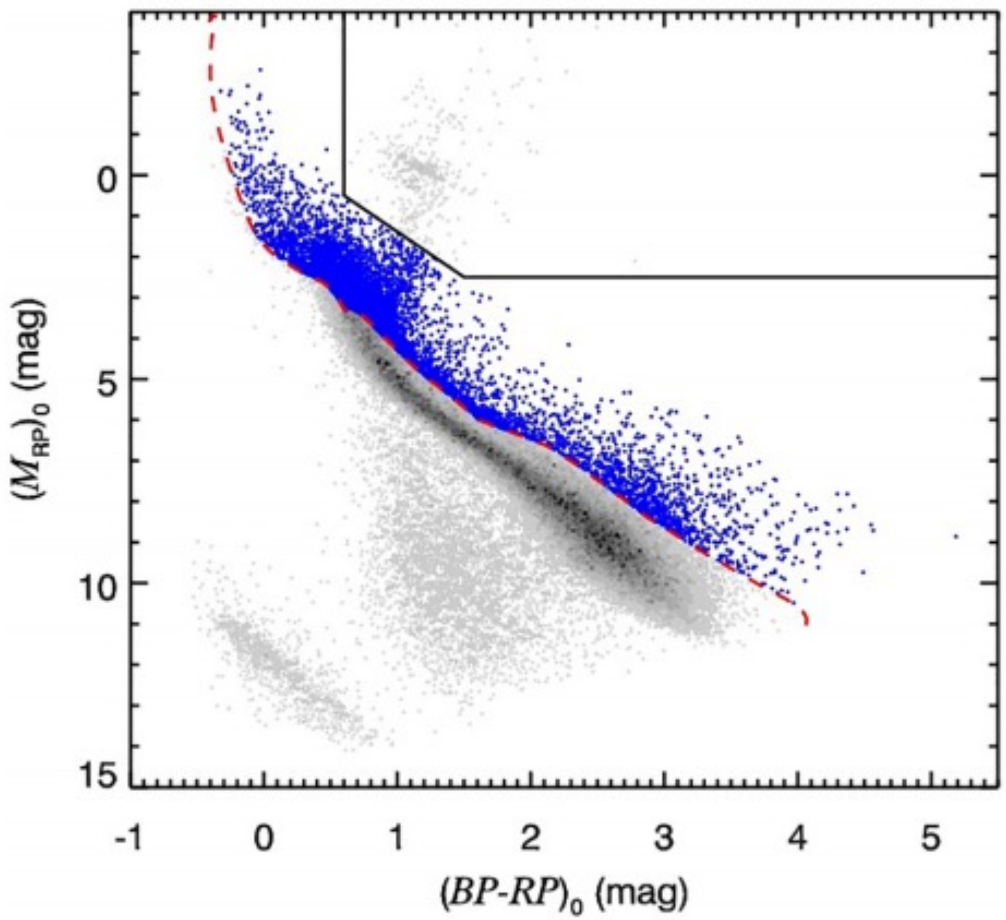

Figure 1 (Color online) The G_{BP}-G_{RP} vs. $M_{G_{RP}}$ color-magnitude diagram shows the stars (gray dots) and includes the 20 Myr isochrone to eliminate field stars. The red dashed line denotes the 20 Myr isochrone of the PARSEC model [23] with solar metallicity [24]. The black solid line is defined by the points (0.6, −5.0), (0.6, 0.5), (1.5, 2.5), (5.6, 2.5), and (5.6, −5.0) to remove evolved stars. The selected candidates are shown as blue solid dots.

Identification of new YSOs

- As protostars continue to contract, accretion disks form around them due to the conservation of angular momentum. Because of the emission from the disk, YSOs typically exhibit excess emission in the near- and mid-infrared bands.
- In this work, they utilized the photometric data from the near- and mid-infrared bands of the 2MASS and ALLWISE Source Catalogues to search for disk-bearing stars. Through color analysis, four new YSOs were identified.
- The Li I absorption line at 6708 Å is also a strong indicator of youth for late K- and M type stars, particularly for those with spectral types later than K7. Among the 6658 YSO candidates, 5201 stars have been released with low-resolution spectra in LAMOST DR7. Examined the spectra of candidates with spectral types later than K7 and found that 141 of them exhibit a clear Li I absorption line (with equivalent widths greater than 50 mÅ).
- At last, they have identified 145 new YSOs (hereafter referred to as NYSOs).

Color magnitude diagram of the YSOs in Taurus

- Figure 4 present the dereddened CMD of these NYSOs as cyan five-pointed stars. To enhance the extinction estimation for them, they compiled and cross-matched archival data from Pan-STARRS, SDSS, APASS9, Tycho-2, and 2MASS. The extinction values for each star were then determined by minimizing the χ^2 difference between the observed SED and model SEDs. GYSOs and DYSOs marked as blue solid dots and red asterisks, respectively. The figure shows that the NYSOs are mostly late-type stars (K- and M-type) and comparatively old, which is as expected.

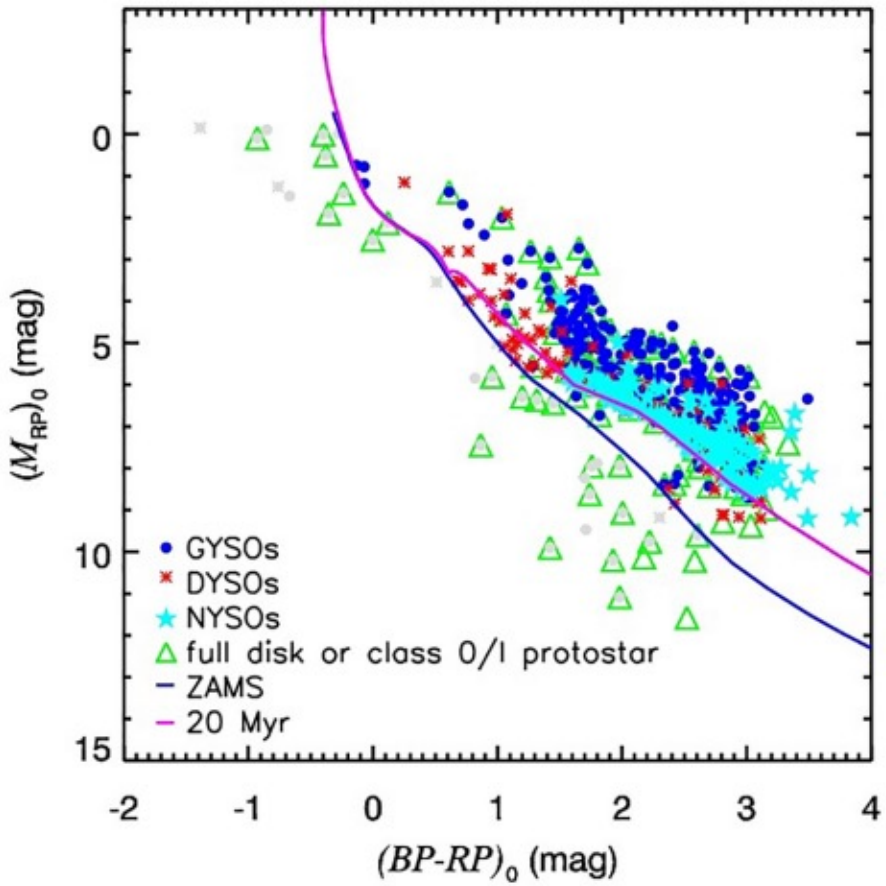

Figure 4 (Color online) The dereddened color-magnitude diagram for the NYSOs in this work is shown as cyan five-pointed stars. Also plotted are the DYSOs (red asterisks) and GYSOs (blue solid dots) with high photometric quality (i.e., stars with $e\_F_{BP}/F_{BP} \leqslant 0.1$ and $e\_F_{RP}/F_{RP} \leqslant 0.1$) from the literature. The class 0/I or full-disk YSOs classified by Esplin et al. [11] are marked as green triangles. The blue solid line and purple solid line represent the zero age main sequence (ZAMS) of solar metallicity [37] and the 20 Myr isochrone from the PARSEC model [23], respectively.

Relationship between NYSOs, GYSOs and DYSOs

- Figure 5 show the spatial distribution of the NYSOs. The figure reveals that the majority of YSOs are clustered in several regions of dense interstellar medium. These stars are predominantly GYSOs (blue solid dots), which are younger and share a common motion. In contrast, the NYSOs (cyan solid five-pointed stars) and DYSOs (red asterisks) are sparsely distributed in areas of low extinction.

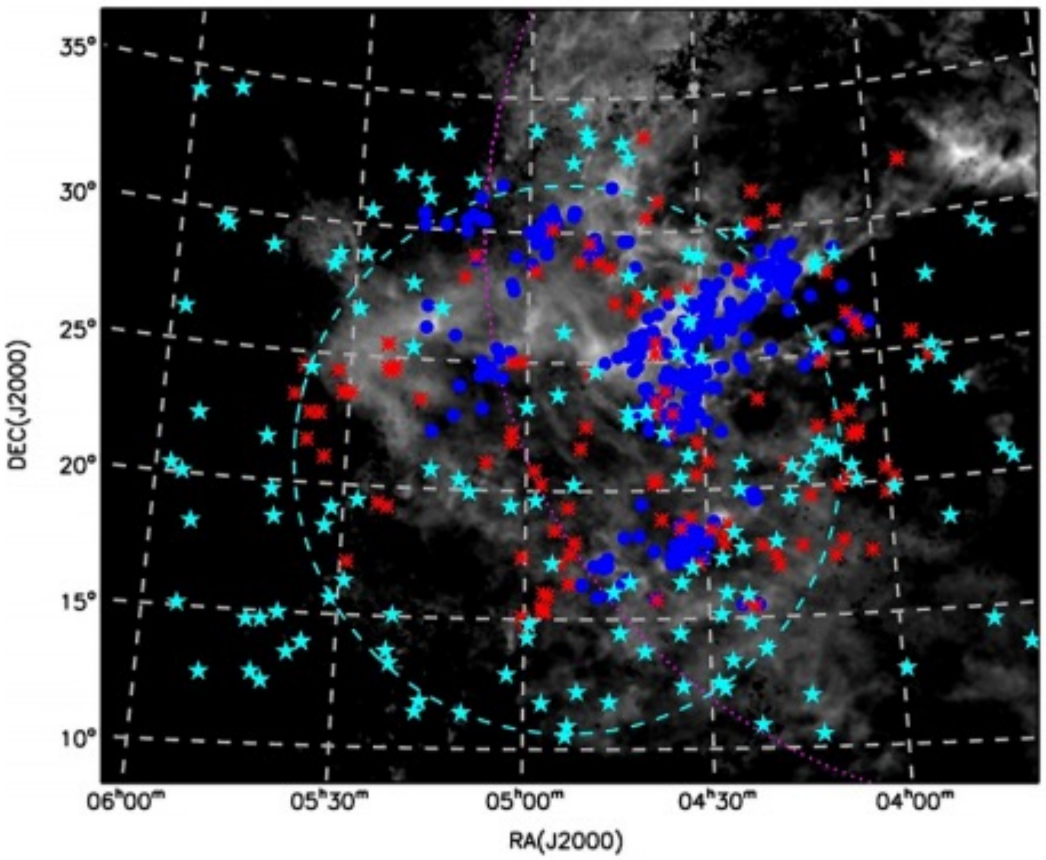

Figure 5 (Color online) The locations of the YSOs identified in this work are shown as cyan five-pointed stars. Also plotted are the identified GYSOs [17] (blue solid dots) and DYSOs (red asterisks). The peripheries of the Per Tau shell and Tau ring are marked with a purple dotted line and a cyan dashed line, respectively. The background contour represents the 0-300 pc cumulative extinction from Green et al. [25].

Relationship between NYSOs, GYSOs and DYSOs

- Figure 6 shows the distribution of the tangential velocities of YSOs. The GYSOs are clustered around (1.5, –2) km s−1, while DYSOs are diffusely distributed. The NYSOs are far from those of the GYSOs and are sparsely distributed. Additionally, they discovered that almost none of the NYSOs are positioned within 3 pc of the cluster members, suggesting that the NYSOs may not be associated with the kinematic clusters of Luhman. In contrast, the NYSOs overlap spatially with the DYSOs and exhibit similar kinematics, indicating that they are more likely to be kinematically associated with the DYSOs of Taurus.

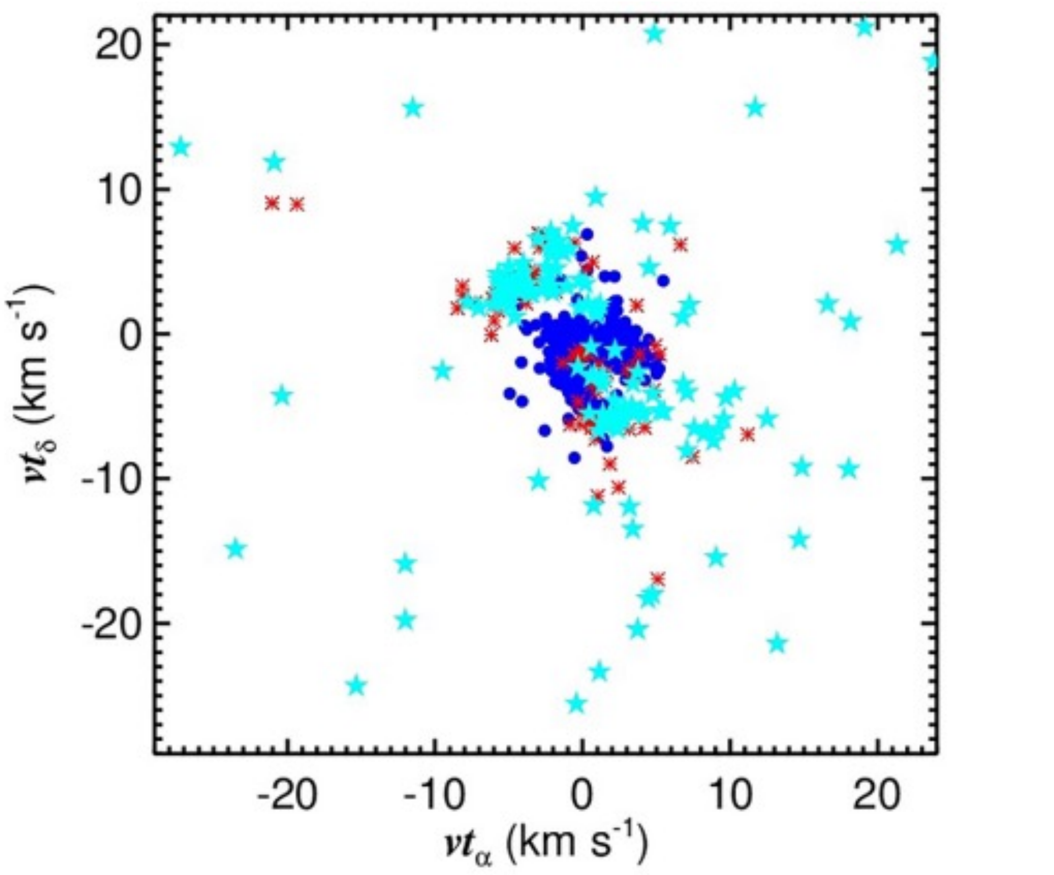

Figure 6 (Color online) The tangential velocities of the YSOs identified in this work are shown as cyan solid five-pointed stars. Also plotted are the identified GYSOs in Taurus (blue solid dots) and the DYSOs (red asterisks).

Temporal-spatial distribution of the YSOs

Relationship between the LB and the YSOs

- The Local Bubble (LB) is a structure centered on the Sun with a radius of ~300 pc, filled with hot (~10^6 K) and low-density interstellar medium. The Taurus region is also part of the LB.
- They excluded samples with spectral types later than M6 to eliminate brown dwarfs, and removed stars below the ZAMS of solar metallicity to eliminate stars whose in an abnormal location on the CMD due to edge-on disk or variability. Finally, constructed a sample of 519 YSOs.

Relationship between the LB and the YSOs

- The GYSOs and DYSOs are respectively divided into four and eight bins according to their distances from the LB. The ages for each bin are derived by minimizing χ^2 to the isochrones of PARSEC. The error bars indicating the 1-sigma dispersion.
- They set the window size and treated all DYSOs within the window as a single group and estimated their ages. By sliding the window, they obtained the ages of DYSOs relative to their proximity to the LB and present it with a red solid line, shaded area indicates the 1-sigma dispersion of the ages.
- On the right side of Figure 7 is the case of constructing the sample using 20 Myr isochrones instead of the ZAMS, and the results are essentially consistent.

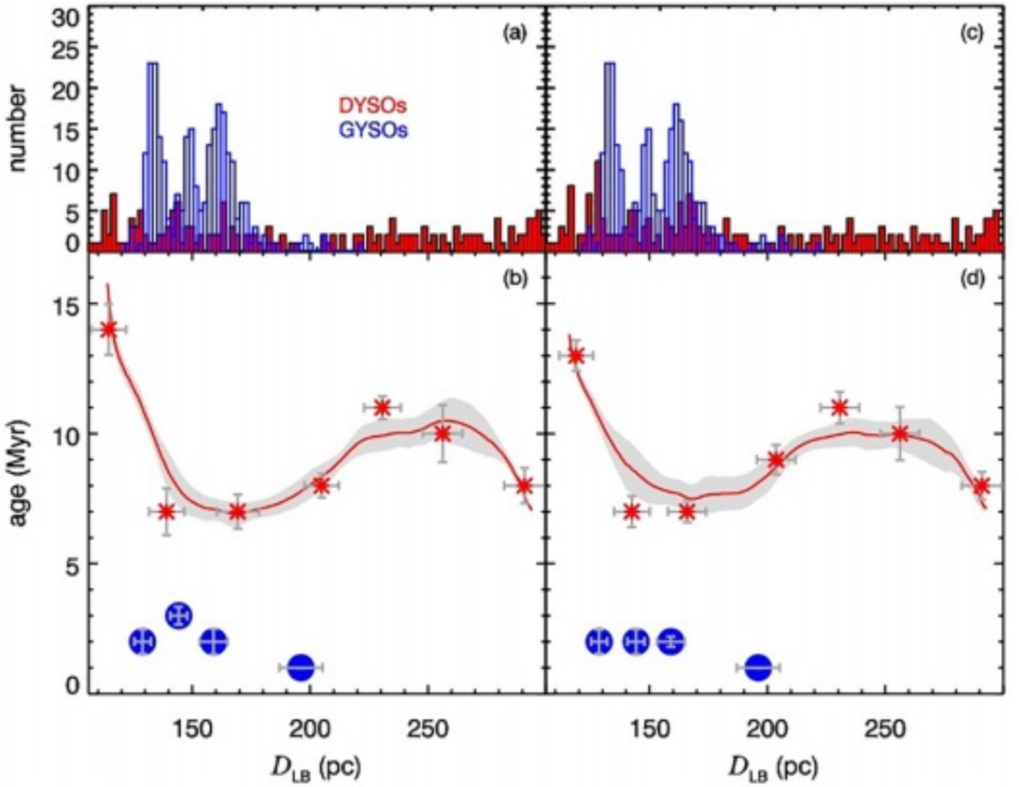

Figure 7 (Color online) (a) The red histogram shows the distance distribution of DYSOs, while the blue histogram indicates the distribution of GYSOs. (b) The red solid line denotes the average age of the DYSOs measured using different sliding window sizes, while the shaded region represents the 1-sigma dispersion. The blue solid dots, along with the error bars, indicate the ages of the GYSOs in the four distance bins and their 1-sigma dispersion from the Monte Carlo simulations, respectively. Panel (c) is the same as panel (a), and panel (d) is the same as Panel (b), but for the sample selected using the 20 Myr isochrone (see the purple solid line in Figure 4) instead of the ZAMS curve.

Relationship between the LB and the YSOs

- The DYSOs generally show a tendency that the farther they are from the LB, the younger they are, which is consistent with the supernovae-driven formation scenario of the LB. It is proposed that the DYSOs might be contemporary products of the LB. In contrast, GYSOs represent a much younger population, with ages ranging from approximately 1 to 2 Myr, and distances between 120 and 220 pc from the LB. Therefore, while they may also be associated with the LB, their formation would appear to be more recent and possibly more localized.
- The results also reveal a distinct decrease in the ages of DYSOs between 120 and 220 pc from the LB. Interestingly, this is precisely where the young GYSOs are located. An intuitive explanation is that there is a portion of younger YSOs that coevally formed with the GYSOs, but due to kinematic reasons, they were not recognized and were instead classified as DYSOs.

Relationship between the LB and the YSOs

- Figure 10 analyzes the kinematics of stars located above the 5 Myr isochrone on the CMD. The "CMD-younger" DYSOs are denoted by black asterisks. The tangential velocities of GYSOs show a clear clustering trend. In contrast, the younger subset of DYSOs, although somewhat closer to the GYSOs, does not exhibit a distinct distribution from the majority of DYSOs.

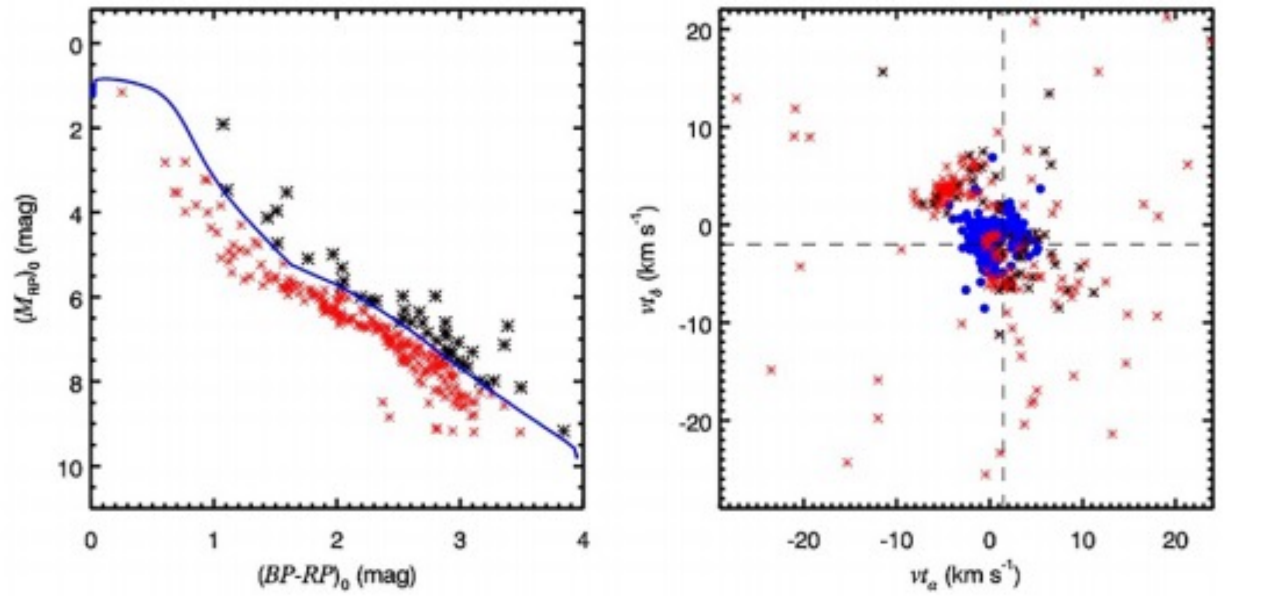

Figure 10 (Color online) The color-magnitude diagram of the DYSOs (red asterisks) is shown in the left panel. The "CMD-younger" DYSOs, selected with the 5 Myr isochrone from PARSEC (blue solid line), are denoted by black asterisks. The right panel depicts the tangential velocities of the YSOs in the Taurus direction. The GYSOs and DYSOs are marked by blue dots and red asterisks, respectively, while the "CMD-younger" DYSOs are denoted by black asterisks.

The Per-Tau shell and the Tau ring

- Recently, Bialy et al. (2021) studied the dust density within the extensive Perseus-Taurus region and identified two distinct structures: the “Per-Tau shell” and the “Tau ring”.

- Figure 8 present a comparison of the spatial locations of YSOs, the Per-Tau shell, and the Tau ring in Cartesian coordinates. The findings suggest that most YSOs are located either inside or outside the Tau ring. Some YSOs seem to follow the periphery of the Per-Tau shell, but there is no strong correlation between their ages and distances to the Per Tau shell. This suggests that these two structures are not decisive factors in the star-forming process in the Taurus region.

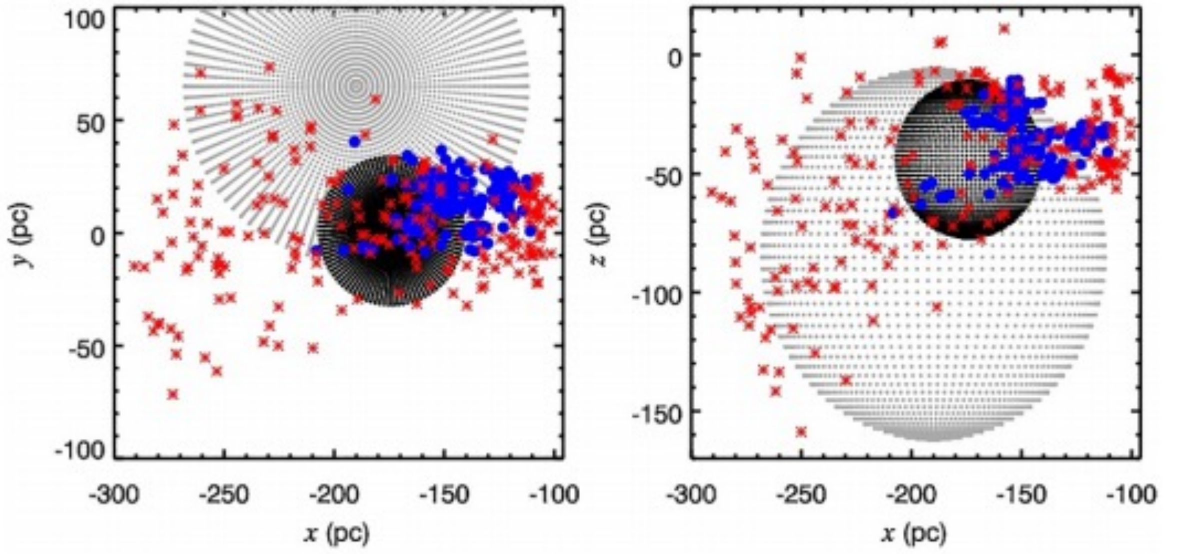

Figure 8 (Color online) The distribution of GYSOs (blue solid dots) and DYSOs (red asterisks) is shown in the *xy* and *xz* planes. Also presented are the general shapes of the Taurus ring and the Perseus-Taurus shell, which are denoted by black and gray spheres, respectively.

Summary

- They targeted stars in the Taurus region that are located at distances between 100 and 300 pc from the Sun. Selected stars that lie above the 20 Myr isochrone on the CMD as candidate objects. Analyzed the spectra of the candidates with spectral types later than K7 and identified 141 new YSOs exhibiting distinct Li I absorption lines.
- Examined the spatial distribution and kinematics of the new YSOs in relation to previously identified objects. The findings suggest that the new YSOs are more likely to be diskless DYSOs rather than protostellar GYSOs.
- Analyzing YSOs’ ages in relation to their proximity to the LB, they discovered a strong correlation between the age of the YSOs and their distance from the LB. This correlation strongly supports the supernovadriven formation scenario of the LB.
- Using the same method, we discussed the relationship between the YSOs and the Per Tau shell as well as the Tau ring. The results suggest that the formation of the YSOs may not be correlated with these two structures.

Thanks