Spatial Distribution of Stars in the Monoceros R2 Region Using Gaia Data Release 3

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Introduction

Monoceros R2 (Mon R2) is a star-forming region located at a distance of 830 parsecs (pc). Mon R2 harbors a hub-filament system (HFS), which is a transition stage connecting parsec-scale filaments and protoclusters. Treviño-Morales et al. (2019) studied the morphology and dynamical properties of this HFS by using the gas emission lines and column density data. However, such gas observations provide only projected information on the plane of sky. To gain a deeper understanding of the relationship between the stars and their forming region, we use the *Gaia* data. *Gaia* is a sky survey mission of the European Space Agency. *Gaia* Data Release 3 (GDR3) was published in 2023. It provides stellar physical properties, including 3-dimensional spatial and velocity distribution.

Data

1. GDR3 extraction query:
   RA: 91.94825°
   Dec: -6.3785°
   Radius: 20 arcmin
2. Selection on proper motion (PM):
   PM RA (mas · yr^{-1}): -7 ~ 7
   PM Dec (mas · yr^{-1}): -7 ~ 7

Method

1. Apply statistical subtraction to remove the proper motion background, since stars belonging to the same system share similar velocities that differ from those of the foreground and background stars.
2. Select stars within the Mon R2 range by plotting a parallax histogram and identifying the dominant peak, which was assumed to correspond to the distance of Mon R2. Stellar distances were then estimated using a Bayesian approach.
3. Analyze the spatial distribution of the selected stars using principal component analysis (PCA), and compare the results with those obtained from random samples.

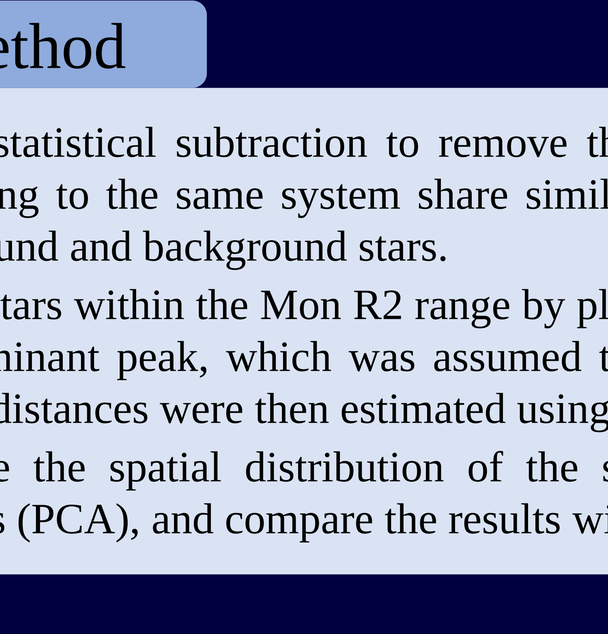
Results

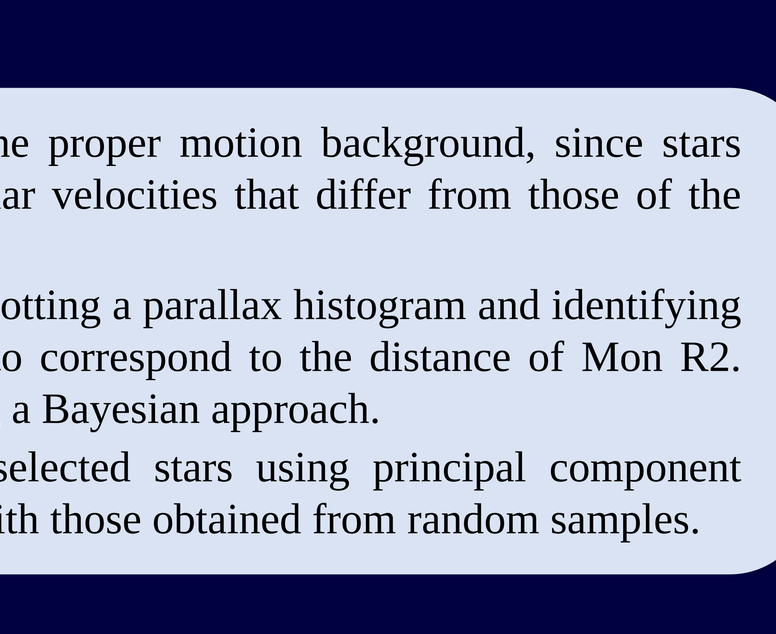
In the first step, we compared the target field with ten background datasets and identified a cluster in the proper motion data. In the upper-left figure, the black points represent the background, while the blue points represent the stars identified as cluster members. We selected the stars marked in blue as candidate members of Mon R2, yielding 376 stars.

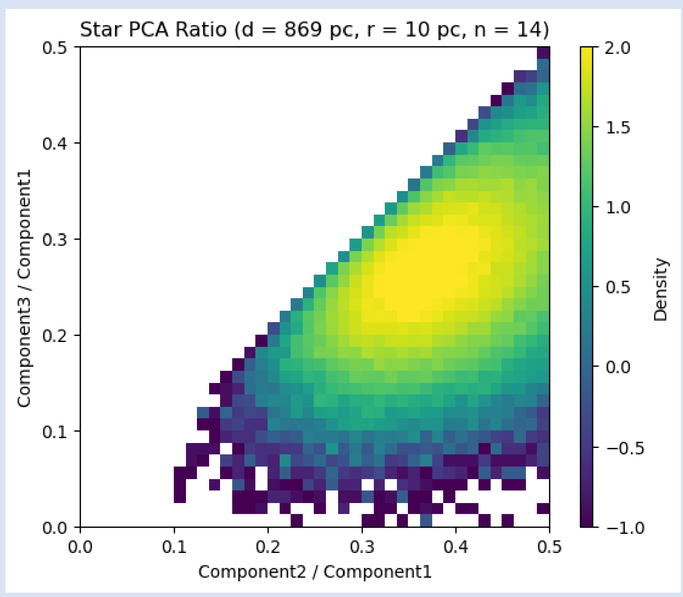
In the second step, we identified a dominant peak at 1.05~1.25 milliarcseconds (mas), as shown in the upper-right figure. We assumed the center of Mon R2 to be located at 1.15 mas (869 pc) and selected stars within this range, leaving 115 stars. Before proceeding, we estimated stellar distances using a Bayesian approach, since relying solely on the inverse of parallax would produce an elongated spatial distribution.

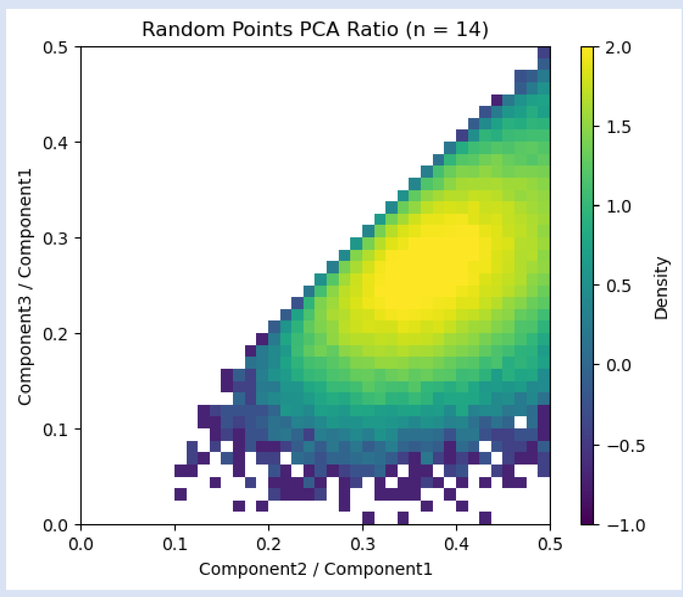
In the final step, we applied principal component analysis (PCA) to examine whether the stellar distribution in Mon R2 differs from a random distribution. The stellar positions were determined by considering the dispersion in RA and Dec together with the probability distribution of distances, and then transformed into a Cartesian coordinate system. PCA was performed on stars located within a 10-parsec-radius sphere centered on Mon R2, and the analysis was repeated until the results converged. On average, 14 stars remained in this selection.

The lower-left figure shows the ratio analysis results for 14 stars in the Mon R2 region, while the lower-right figure shows the results for randomly generated samples. We found no significant difference between the two results, suggesting that the stellar distribution is consistent with a random distribution. The results is different from our hypothesis, and we attribute this outcome to the small number of stars in the sample.









Conclusions

1. We reduce the background sources with the statistical subtraction. The spatial distribution shows no significant difference between random distribution.
2. In future works, more selection conditions, such as the HR diagram and the radius of Mon R2 region, will be considered for a better selection to Mon R2 stars.

Reference

Carrera, R., Pasquato, M., Vallenari, A., et al. 2019, A&A, 627, A119.

Treviño-Morales, S. P., Fuente, A., Sánchez-Monge, Á., et al. 2019, A&A, 629, A81.

Vallenari, A., Brown, A. G., Prusti, T., et al. 2023, A&A, 674, A1.

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