From moving groups to star formation in the Solar Neighborhood

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Introduction

- **A moving group is a group of stars in the vicinity of the Sun that move together.**

The main moving groups in the solar neighborhood include the Pleiades group (also known as the "Local Association"), the Hyades group, the Coma Berenices group, and the Sirius group (Ursa Major).

- **The traditional view is that these star clusters originated from disintegrating star clusters or massive star associations. Modern research suggests that these star clusters are actually dynamic structures spanning a wide age range, possibly shaped by the dynamics within the Milky Way disk (such as spiral arms, galactic bars and their resonances) and/or disturbances from external satellite galaxies.**

Numerous observational and numerical studies now suggest that classical moving groups are primarily kinematic structures spanning broad age ranges (several Gyr), likely shaped by internal disk dynamics—such as spiral arms, the Galactic bar, and their resonances (Quillen & Minchev 2005; Quillen et al. 2018; Barros et al. 2020)—and/or external perturbations from satellite galaxies (Minchev et al. 2010; Craig et al.2021)

- A central question concerning moving groups is how and why they include recently formed stars among their members.

- In this Letter, we leverage a sample of star clusters with precise 3D velocity measurements extending to distances of 1 kpc from the Sun.

Data

- **Gaia DR3 catalog with 7167 Galactic star clusters.**

They use the Gaia DR3-constructed catalog from Hunt & Reffert(2023), which uncovered 7167 Galactic star clusters.

- **Cross-matched with APOGEE-2 and GALAH DR3 for radial velocities.**

- **Data filtering**

Select high-quality samples within 1 kpc of the Sun, including 764 star clusters.
Retain 254 young star clusters (under 70 Myr in age) and add 27 Young Local Associations (YLAs).
The final analyzed sample contains 155 star clusters, which are divided into three families: Collinder 135 (39), Messier 6 (34), and Alpha Persei (82)

Two samples, young and old

To investigate whether the cluster families show co-movement with older clusters, we select an additional subset of clusters from the high quality sample of 764 clusters mentioned above, but with ages older than the cluster families (> 70 Myr). This subset contains 509 clusters, with a median age of 153 Myr.

Methods

- **Tools and Models :**

They using galpy and MWPotentient2014 models, including three components: disk, coresphere, and halo.
They adopt a circular velocity of 236 km s^−1, solar Galactocentric radius R⊙ = 8122, pc (Reid et al. 2019), and solar height z = 20.8, pc (Bennett &Bovy 2019). Using solar peculiar motion (U⊙, V⊙,W⊙) = (11.1, 12.24, 7.25), km, s^−1 (Schönrich et al. 2010).

- **Orbital Integral:**

Integrate the orbit of the star cluster backwards by 100 million years with a time step of 0.1 Myr.

Through this method, researchers are able to track the past positions and motion states of these star clusters.

Calculate the average orbital positions of three young star cluster families (Cr135, M6, and α Per).

young

Identifying cluster groups with HDBSCAN

Apply HDBSCAN clustering algorithm to the three-dimensional position of star clusters from 50 Myr ago (the time when the spatial population first appeared) to 100 Myr ago.

Set min_cluster size to 30 and cluster_delection_math to 'leaf' to identify three spatial populations.

At each time step, HDBSCAN assigns each star cluster to a recognized population or labels it as' noise ‘.

By calculating the most commonly assigned labels for each star cluster at all time steps, determine its final population affiliation.

This process is repeated 100 times, with random sampling from the uncertainty of the position and velocity of the star cluster each time to ensure the robustness of the results

old

Table 1. Moving group cluster statistics: column 2 shows the number of clusters, column 3 the total number of stars of the clusters, and column 4 the mean cluster age with 16th–84th percentile spread.

Name	N	N_{stars}	Age (Myr)
Pleiades	154	35935	184^{+72}_{-97}
Coma	100	18932	189^{+56}_{-85}
Sirius	44	8258	229^{+140}_{-108}
Not grouped	211	46076	313^{+223}_{-208}

Cluster orbits

- Figure 1 shows the positions of star clusters aged between 70-150 Myr on the XY plane of the Milky Way over the past 100 million years.

- Starting around 70 Myr ago, the star cluster separated into three distinct over dense regions, corresponding to the Hyacinth Cluster, the Corona Borennis Cluster, and the Sirius Cluster.

- The young star cluster families (such as α Per and M6) align with two of these over dense regions.The Cr135 family is aligned with another over dense area, but moves inward.

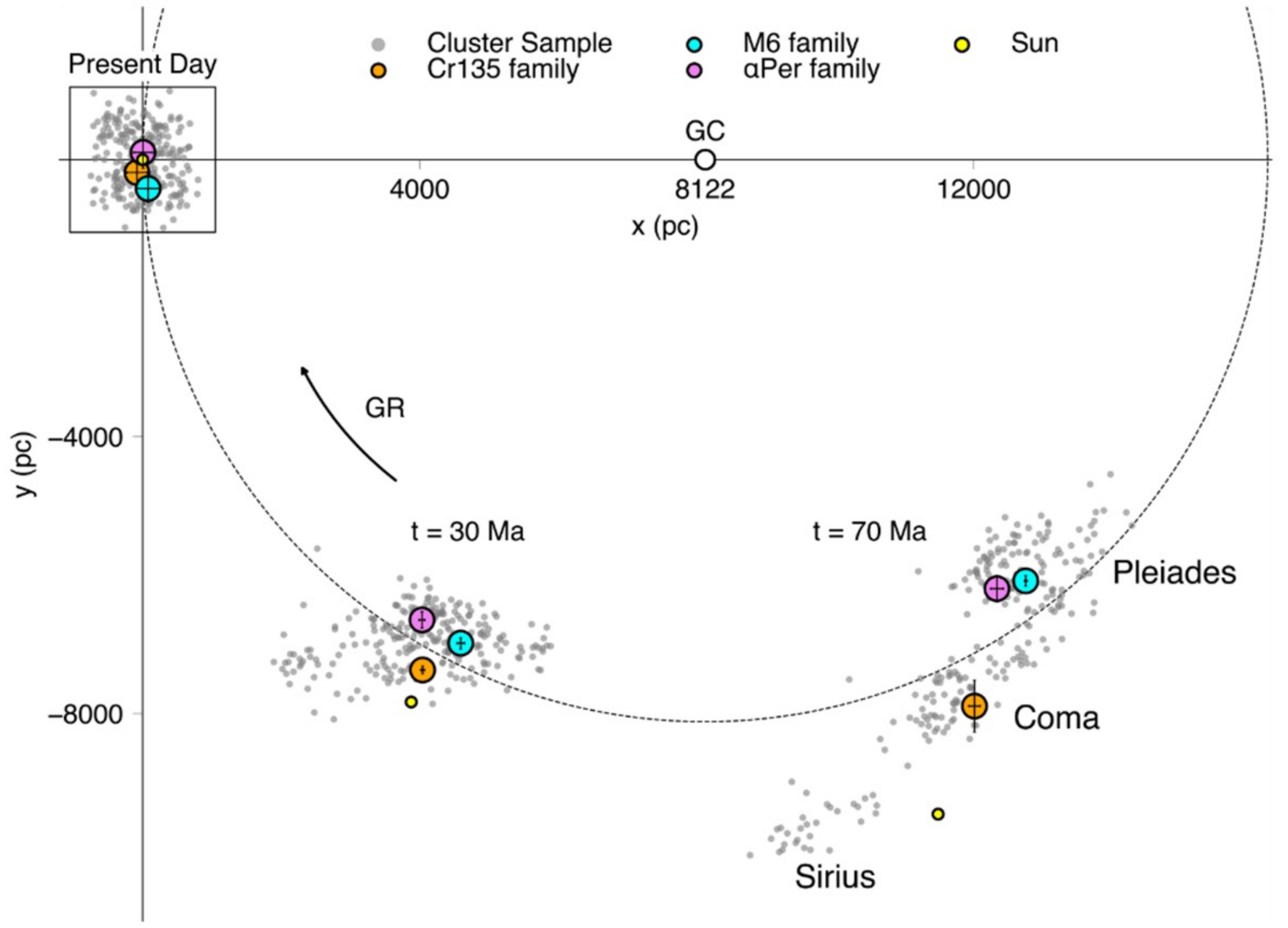

Fig. 1. A Galactic bird's-eye (XY) view of the clusters' orbits over time, showing over one half of of a circle (black, dashed line) of radius of $R_{\rm Sun}$ = 8122 pc extending from the Galactic Center to the Sun. The location of the Galactic Center and the direction of Galactic rotation are indicated. Individual clusters with ages between 70 and 150 Myr are represented as gray dots and are shown at three different times: the present (upper left), 30, and 70 million years ago (from left to right). The median location of each cluster family is displayed at the three time steps, with each family color-coded and labeled in the legend. The black bars for a given family indicate the standard deviation of its members' positions at each time step. Average positional uncertainties of the older clusters are too small to show, but at $t = -70$ Myr they reach 60 pc, slightly smaller than the grey point sizes. The three-dimensional interactive version of this figure has a time-slider showing the cluster positions at intermediate time steps with each frame centered on the location of the LSR: https://cswigg.github.io/cam_website/interactive_figures/swiggum+25_interactive_figure1.html.

Examining velocities and actions

Retrieve the radial velocity and high-quality parallax measurements of stars within 300 pc of the Sun from the Gaia database, and convert their ICRS coordinates to the Galactic Cylindrical Coordinate System.

Tangential velocity and radial velocity, as well as the distribution of tangential and radial inertia. Three arched over dense regions were revealed, corresponding to the Hyacinth Cluster, the Corona Borennis Cluster, and the Sirius Cluster. In the figure, it can be seen that the old star cluster is aligned with the moving group. The Cr135 family is associated with the Corona Borennis Cluster.

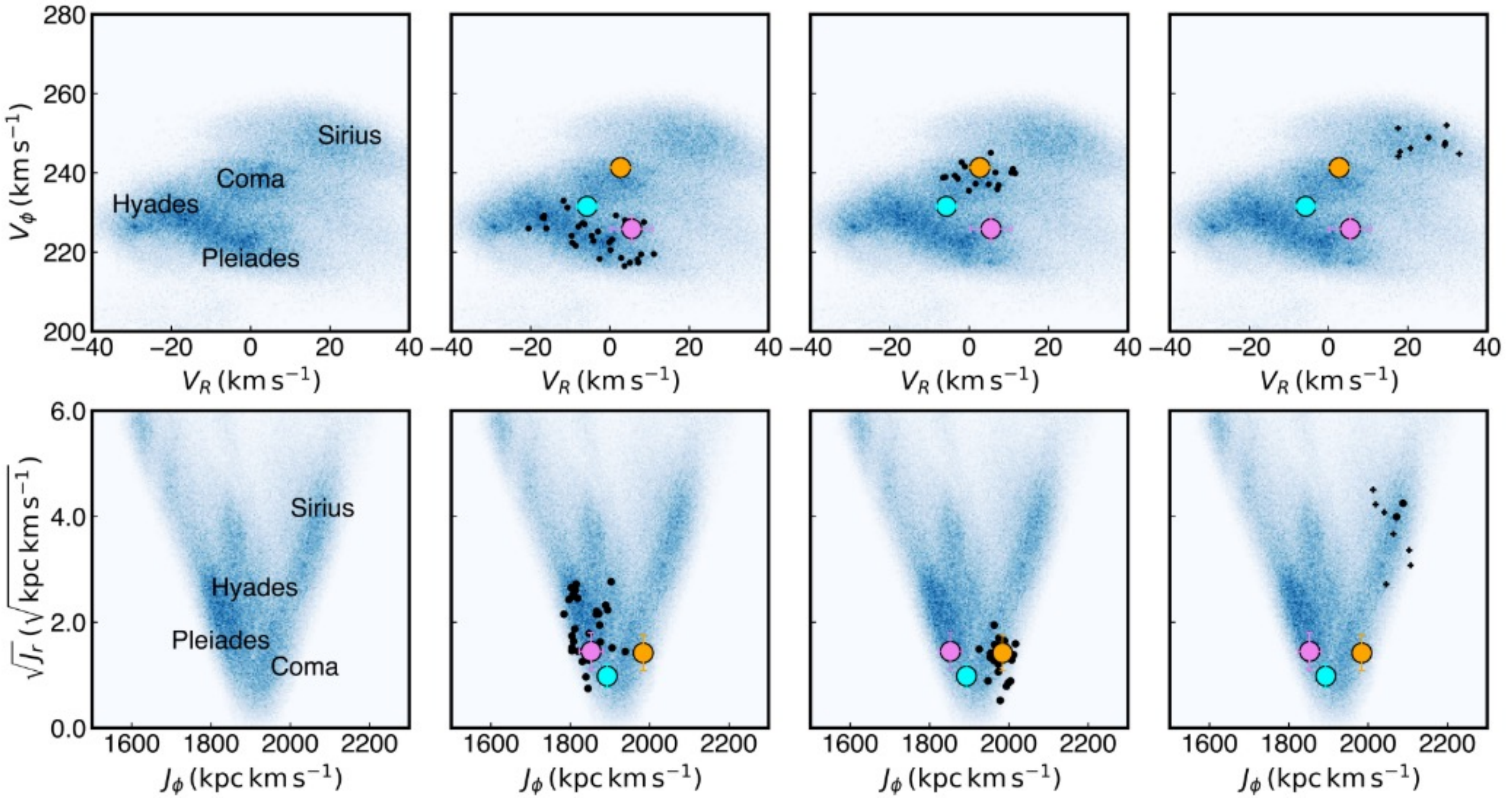

Fig. 2. Top row: A 2D histogram ($V_R - V_\phi$; white-to-blue colormap) shows the distribution of roughly 1.8 million stars within 300 pc, revealing arch-like overdensities corresponding to the Pleiades, Coma Berenices, and Sirius moving groups (labeled in the first panel). The second to fourth panels overlay black dots for clusters older than 70 Myr, each showing one HDBSCAN-identified group. Panels two and three include only clusters within 300 pc to match the stellar volume; panel four shows a group extending to 500 pc, with clusters beyond 300 pc marked as crosses. Each group aligns with a distinct moving group. Bulk velocities of the αPer (violet), M6 (cyan), and Cr135 (orange) families are shown with standard deviation error bars. **Bottom row**: Same as the top row, but showing $J_\phi - \sqrt{J_R}$ distributions instead.

Summary

- Moving groups in the solar neighborhood are linked to recent star formation.
- Three main groups identified: Pleiades, Coma Berenices, and Sirius.
- Galactic dynamics, particularly spiral arms, drive the formation and evolution of these groups.
- Future work will further explore the connection between star formation and Galactic structure.

Thank you for your attention!