The Extensive Substructure and Long Star-Forming Histories of Young Stellar Populations in the Solar Neighborhood

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Introduction

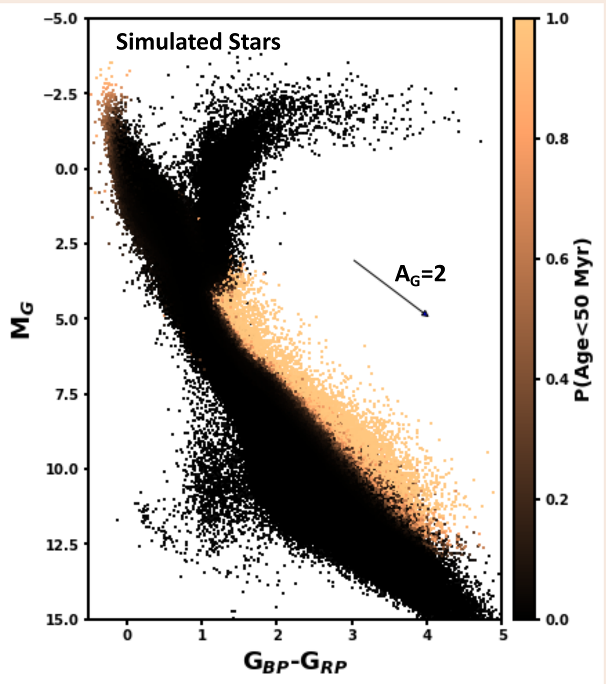
Through its exquisite photometry and astrometry of more than a billion stars in the Milky Way, the Gaia Data Release 2 [1] has allowed for unprecedented new investigations of nearby stellar populations. Research into young stars in particular can benefit greatly from this new data, as stars on the pre-main sequence often sit well above the main sequence in the HR diagram. This position in magnitude-space makes these stars distinguishable using photometric observations, especially for younger and less massive objects. Combining Gaia photometry and parallaxes, we are able to generate accurate Gaia absolute magnitude measurements for each of these stars, for which we can build a Bayesian approach to determine the probability that each star in a local Gaia sample (parallax>3) is young (Age<50 Myr). These new young populations will provide unprecedented insight into the young stellar populations in the solar neighborhood, while providing numerous new targets for studies on the early evolution of stellar and planetary systems.

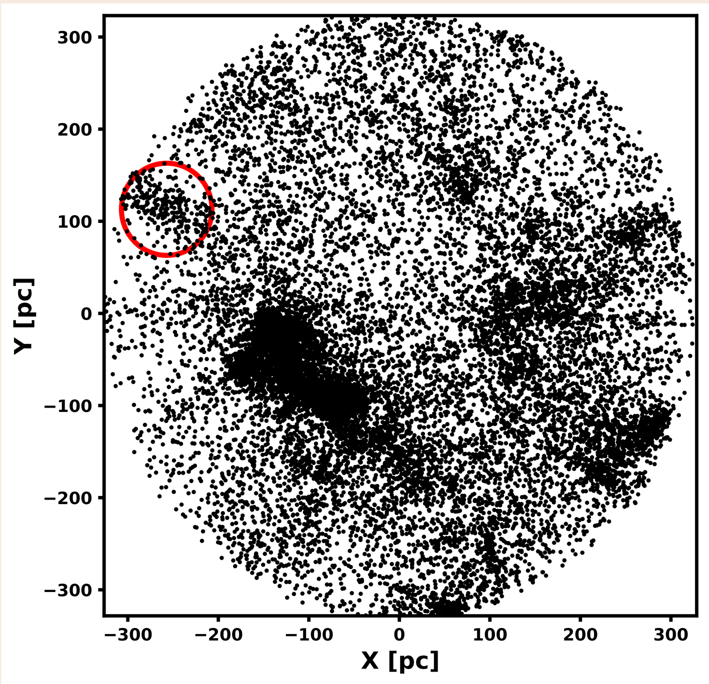
Star Identification

To create a Bayesian approximation for the probability of a star being young, P(Age<50 Myr) we:

1. Gather known probability distributions for the mass, age, metallicity, and multiplicity of field stars, creating a population of model stars reflective of those in the solar neighborhood
2. For each Gaia star, add reddening according to the reddening probability distribution from the Lallement et al. 2019 [2] maps
3. Generate age posterior distributions for each Gaia star according to the model stars that surround it in the HR diagram

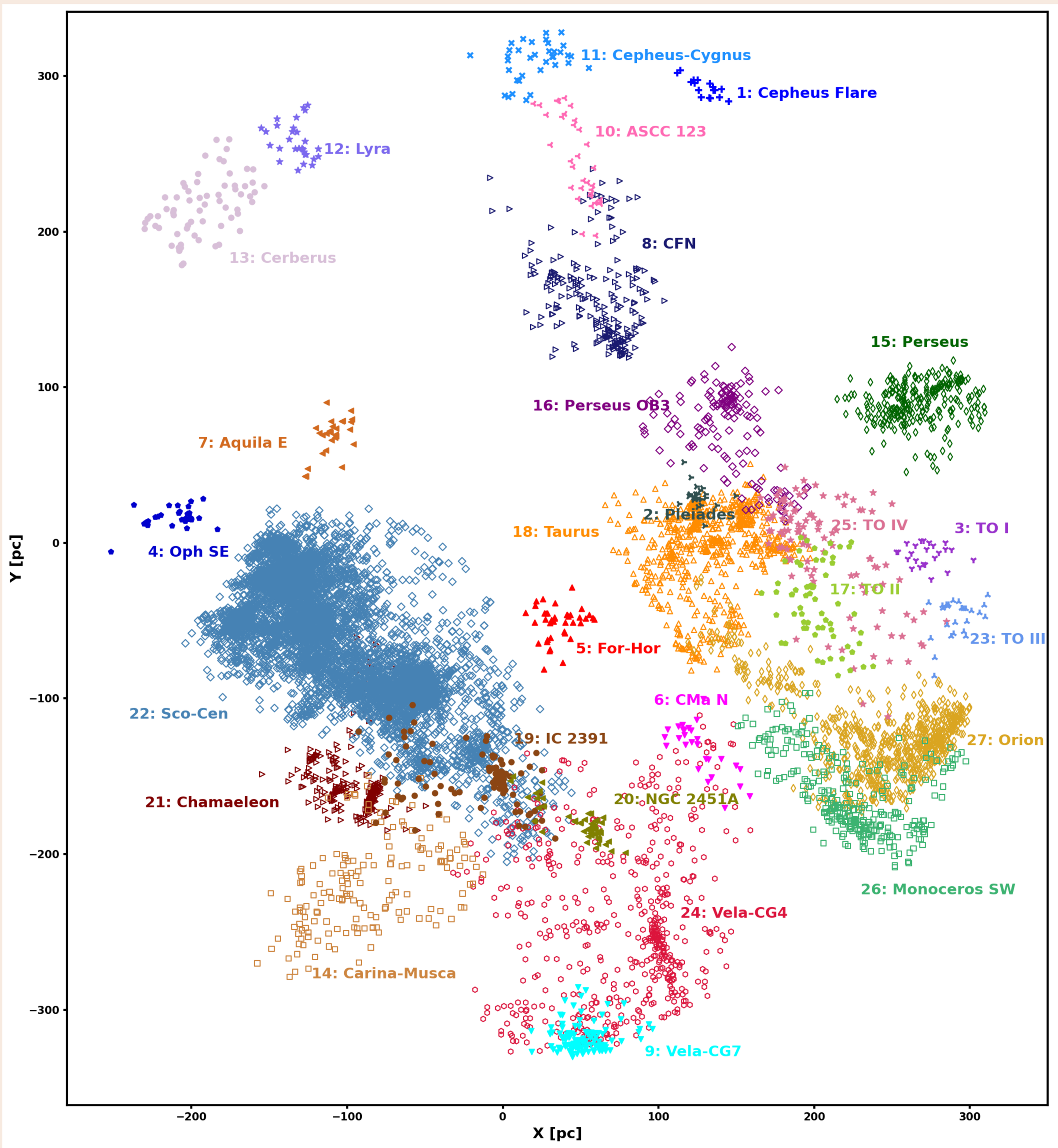
We identify 30518 candidate young stars in the solar neighborhood, mainly stars later than G8. Most clumps have common velocities, except for a few likely created by reddening anomalies (circled in the right panel). We also derive age estimates for each star from the age probability histograms, revealing apparent age trends.

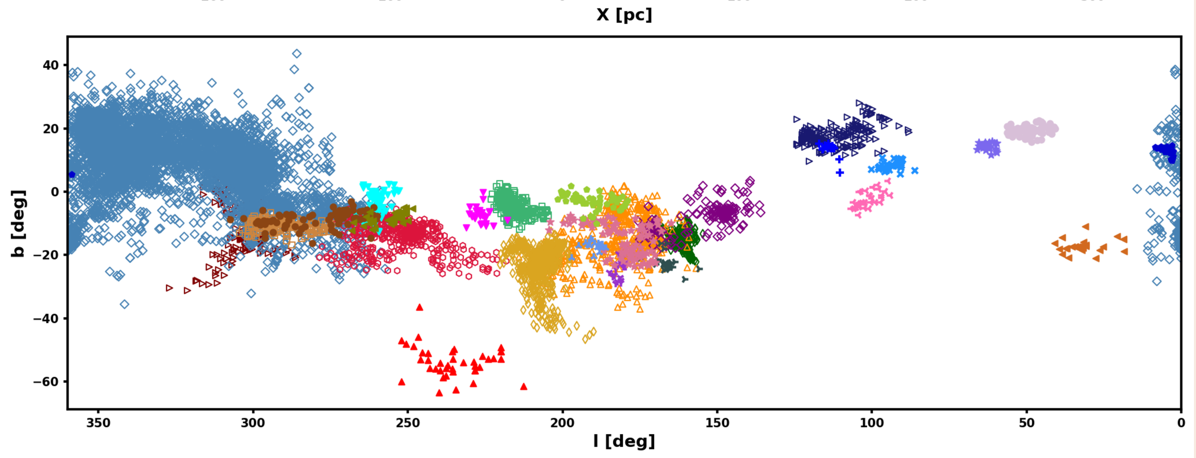




Clustering

Clustering in space-velocity coordinates identifies structures, and excludes most noise from reddening anomalies. We applied the HDBSCAN clustering algorithm [3] to our new population of candidate young stars, and the following figures show the top-level structures we identify.





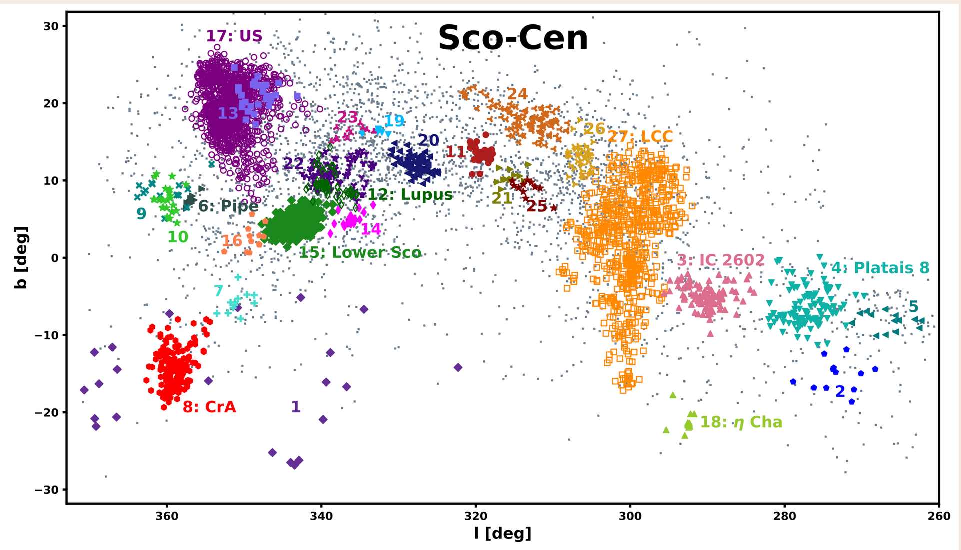
We identify 27 young stellar structures in the solar neighborhood, 12 of which have limited or no recognition in the literature. Nearly all of the remaining known structures show extents far beyond what was previously known.

We measure additional levels of subclustering for structures with visible substructure. These include:

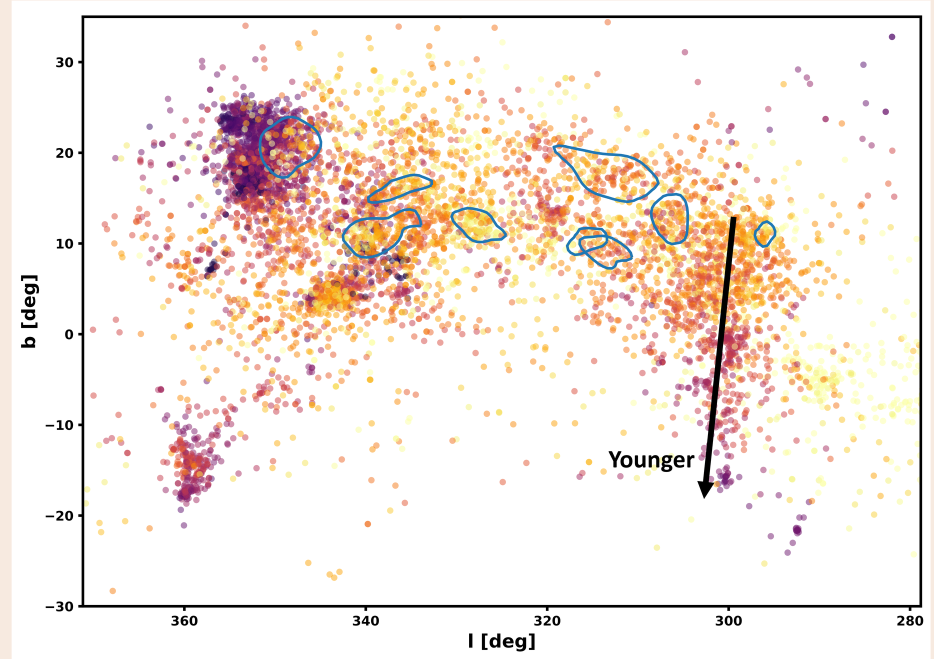
- Taurus: 11 constituent clusters, 4 of which divide into 2 subclusters each. Isochronal ages ~2-52 Myr
- Orion: 3 clusters, 1 divides into 3 subclusters, ages ~12-20 Myr
- Perseus: Two clusters, both of which have an old (~17 Myr) and an essentially newborn component
- Sco-Cen: 27 clusters, 16 subclusters, ages ~3-43 Myr

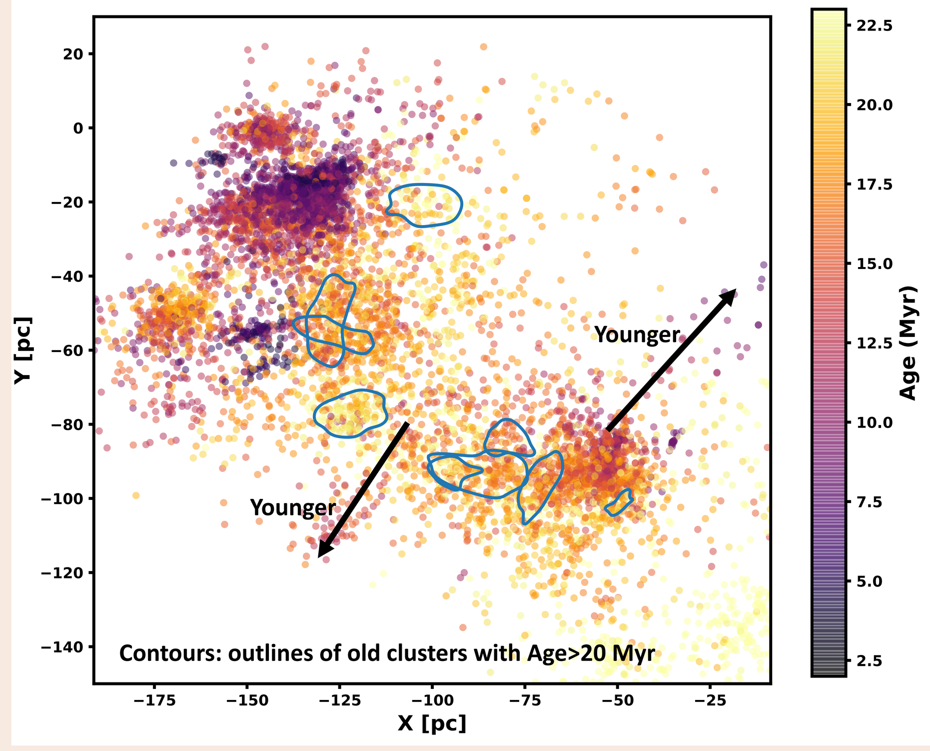
Sco-Cen

Sco-Cen is the largest association we identify with ~7400 members. Of its 27 constituent clusters, three (Upper Sco, Lower Centaurus-Crux, Lupus) subdivide further into smaller clusters.

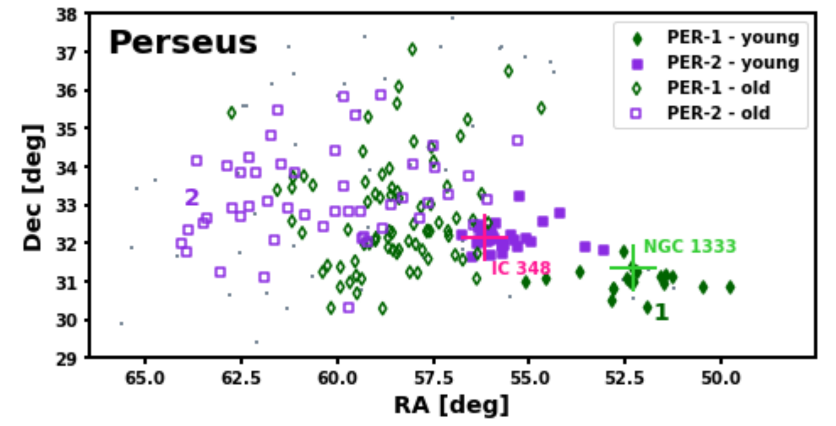


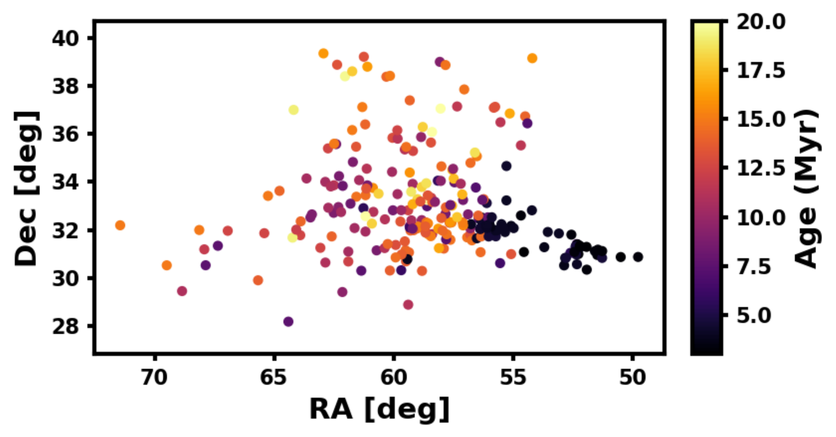
Aside from stars with >30 Myr isochronal ages near IC 2602, the oldest stars in Sco-Cen follow an arc across northern LCC and UCL with age ~20-23 Myr, which we call the Libra-Centaurus Arc. In most of Sco-Cen, groups farther from this arc are younger, with the clearest gradients being in LCC, towards TW Hydrae, and towards the subgroup SC-11 (all marked below). Most of Sco-Cen is therefore consistent with sequential star formation off of this arc of early star formation, with a propagation speed of 4 km/s.





Perseus and Other Groups





In Perseus, we find two subgroups, both of which contain younger regions associated with the Perseus Molecular Cloud clusters NGC 1333 and IC 348, as well as older regions to their east. The presence of distinct star formation bursts suggests that mechanisms for gas collection can continue after gas dispersal and spark a second star-forming event.

Eight other groups are given subclustering analyses in this work, including the near edge of Orion, where we identify significant extensions towards the sun, Taurus, where we uncover multiple populations older than 10 Myr, and the new Carina-Musca association, which may serve as a strong case study for turbulence-dominated star formation. Ask me about any group you're interested in!

Conclusion

We identify more than 30000 young stars in the solar neighborhood, found in a total of 27 top-level groups with numerous subclusters. In the known groups that we recover, the structures we reveal go far beyond the known populations, greatly expanding both the populations of stars available for surveys and the number of distinct structures that can be studied. We also derive isochronal ages for each group and subgroup, identifying new structures that provide insight into the progression of star formation in these nearby young stellar populations, such as the arc of old star formation in Sco-Cen and the newly-identified older populations in Perseus.

References

[1] Gaia Collaboration, Brown, A. G. A., Vallenari, A., et al.2018, A&A, 616, A1
[2] Lallement, R., Babusiaux, C., Vergely, J. L., et al. 2019,A&A, 625, A135
[3] McInnes, L., Healy, J., & Astels, S. 2017, The Journal of Open Source Software