



Kepler meets Gaia: Binary Systems, Color-Magnitude Diagram, and Kinematic Analysis

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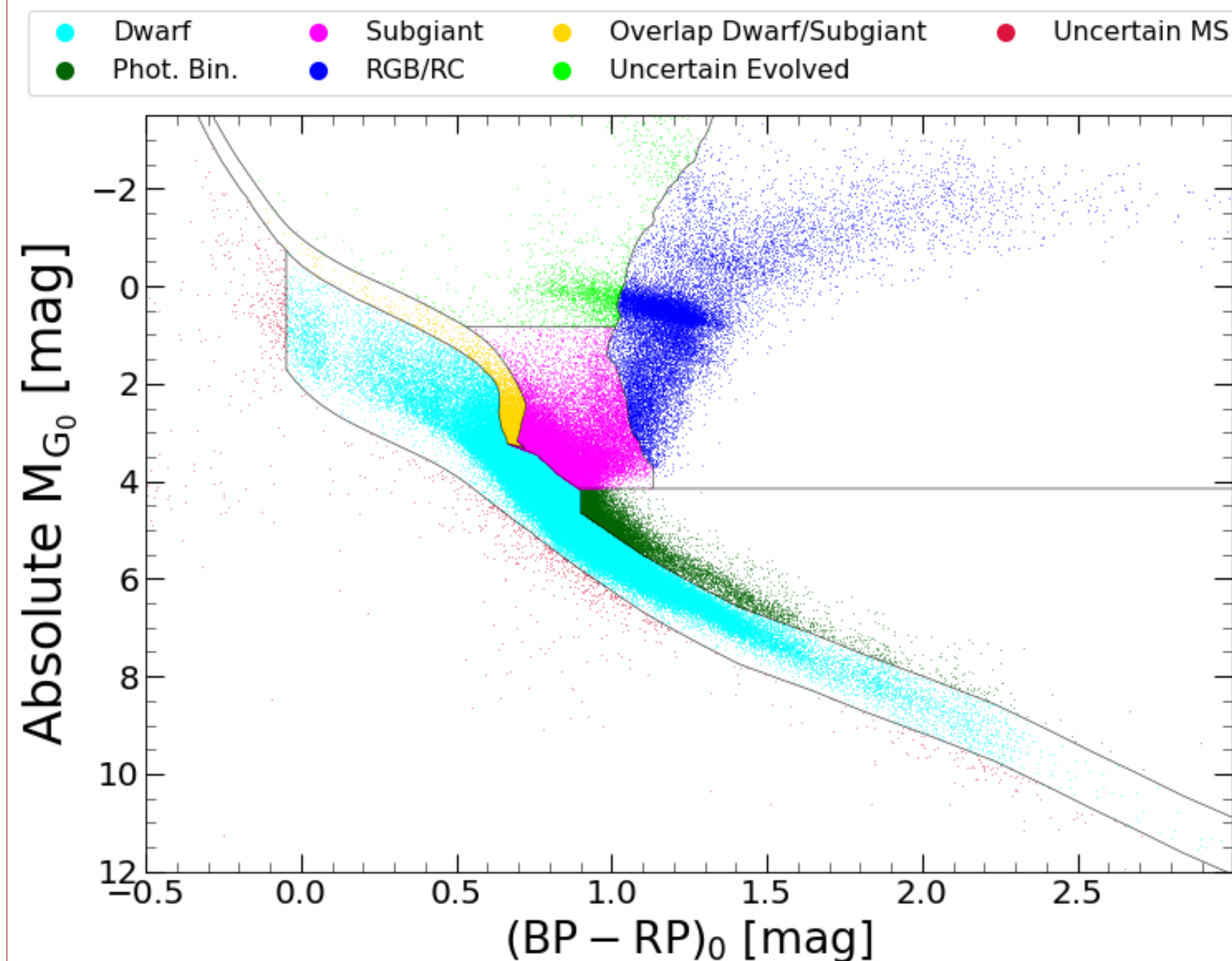


Fig. 1: *Gaia* color-magnitude diagram (CMD) for the *Kepler* targets. Each CMD category is shown in a different color, with their sizes listed in [Table 1](#).

Caveat: some odd features are present due to inaccuracies in the *gspphot* extinctions [8], i.e., red-giant-branch and red-clump stars with exceedingly blue $(BP - RP)_0$ colors. These artifacts are corrected when revised extinction maps are

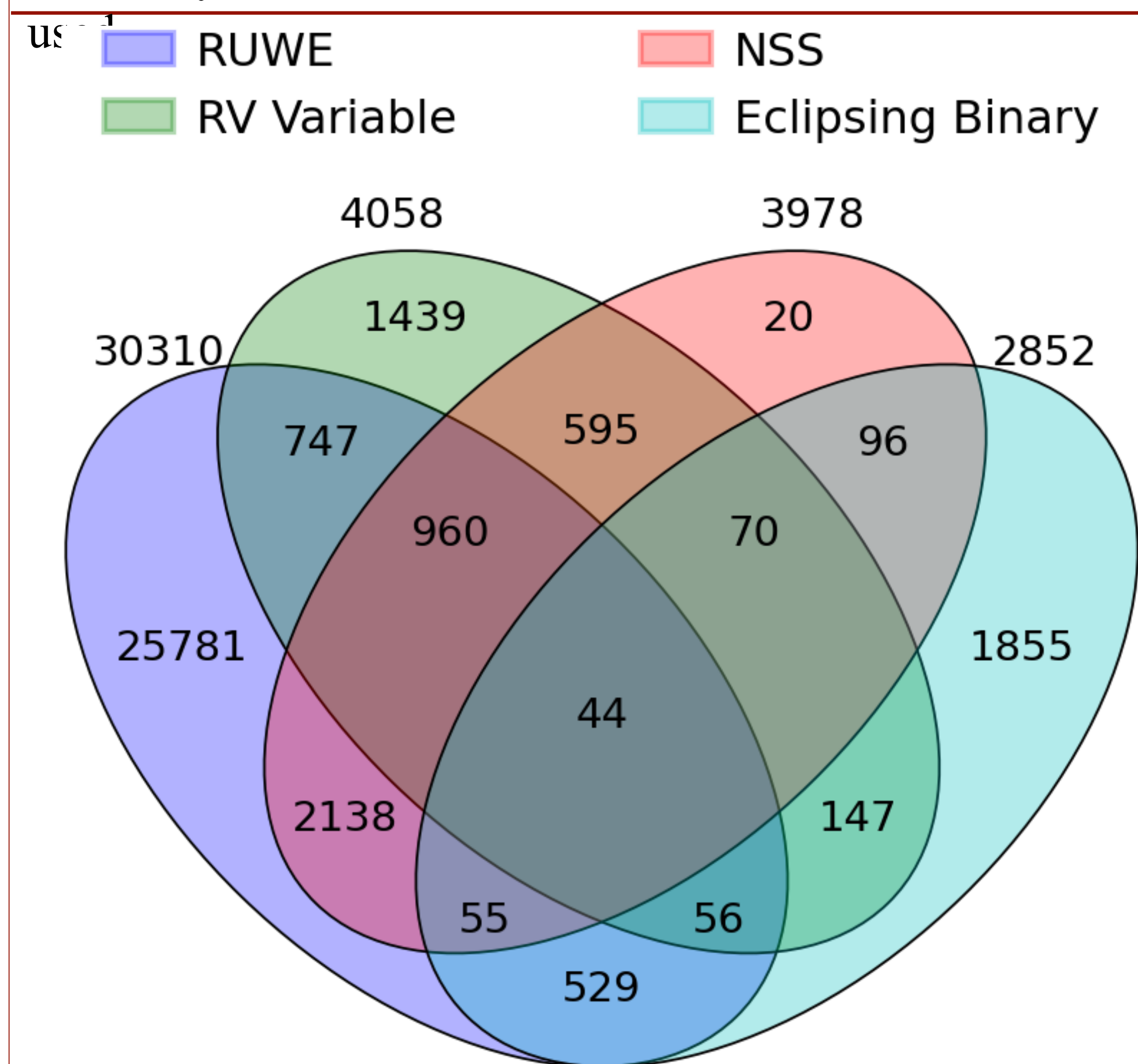


Fig. 2: Venn diagram of the 4 most numerous binary categories.

Category	N_{stars}	Percentage
Full <i>Kepler</i> Sample	197,096	100%
CMD Dwarf	117,629	59.7%
CMD Subgiant	29,401	14.9%
CMD RGB/RC	20,125	10.2%
CMD Photometric Binary	10,168	5.2%
CMD Overlap Dwarf/Subgiant	5,128	2.6%
CMD Uncertain Evolved	2,039	1.0%
CMD Uncertain MS	991	0.5%
CMD No Information	11,615	5.9%
Binary RUWE	30,310	15.4%
Binary RV Variable	4,058	2.1%
Binary NSS	3,978	2.0%
Binary Eclipsing	2,852	1.4%
Binary SB9	49	0.02%
Binary or Multiple NEA	73	0.04%
Binary Union	34,609	17.6%

Table 1: Summary of CMD and binary categories.

Context

- The *Kepler* observations [1] have provided unprecedented constraints for the fields of asteroseismology, stellar rotation and activity, exoplanets, and Galactic archaeology.
- Because of this, characterizations of the $\sim 200,000$ stars observed by *Kepler* remain of paramount importance.
- We present a state-of-the-art characterization of the *Kepler* targets based on *Gaia* data release 3 (DR3; [2,3,4,5]).

Color-Magnitude Diagram (CMD)

- Figure 1** shows the absolute and de-reddened CMD for the *Kepler* targets with *Gaia* DR3 counterparts.
- By combining the *Gaia* data with PARSEC models [6,7], we separate the sample into different CMD categories.
- Our CMD classification, and the coordinates of the CMD regions, can help to easily classify and separate different evolutionary stages from *Gaia* data alone.

Binary Systems

- We use the *Gaia* astrometry and radial velocity (RV) data to identify RUWE and RV-variable binary candidates [9].
- We flag binaries identified by the catalogs: *Gaia* Non-Single Stars (NSS), *Kepler* Eclipsing Binary, Spectroscopic Binaries (SB9), and NASA Exoplanet Archive (NEA).
- Figure 2** shows the degree of overlap between some of the binary categories.

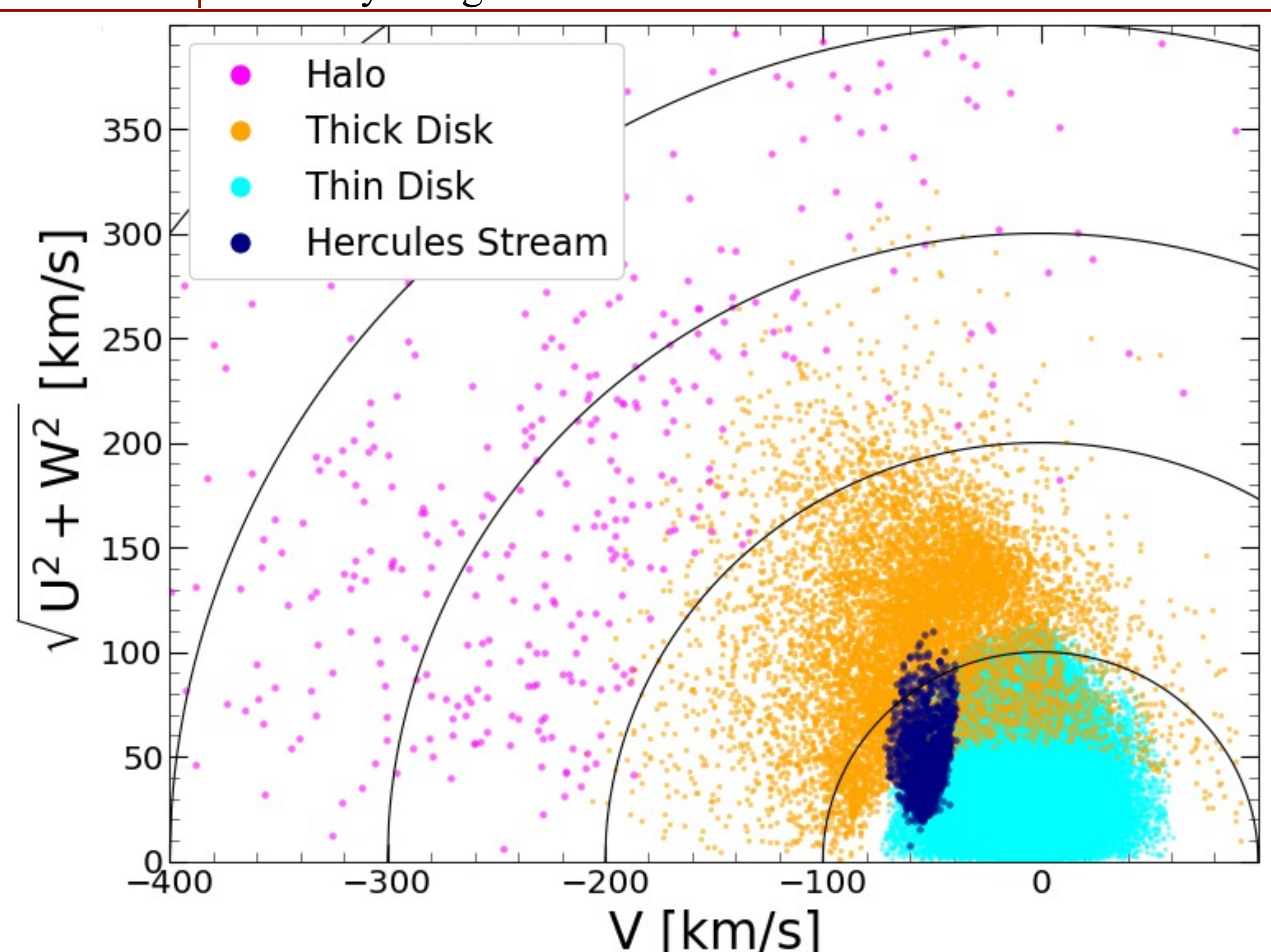


Fig. 3: Toomre diagram for the *Kepler* stars with *Gaia* astrometry and RVs.

Kinematic Analysis

- In **Figure 3**, we use the *Gaia* DR3 astrometry and RVs (available for $\sim 100,000$ stars) to perform a detailed kinematic analysis [10].
- The *Kepler* stars are classified among different Galactic components, namely Thin Disk, Thick Disk, and Halo, as well as the Hercules stream.
- We approximately triple the number of *Kepler*-field stars with kinematic classifications, in comparison with previous works [11].

References

For more details, please stay tuned for:

- Godoy-Rivera et al. (submitted)**
- Godoy-Rivera et al. (in prep)**

- [1] Borucki, W. J., Koch, D., Basri, G., et al. 2010, *Science*, 327, 977
- [2] Gaia Collaboration, Brown, A. G. A., Vallenari, A., et al. 2021, *A&A*, 649, A1
- [3] Gaia Collaboration, Arenou, F., Babusiaux, C., et al. 2023a, *A&A*, 674, A34
- [4] Bailer-Jones, C. A. L., Rybizki, J., Fournesneau, M., et al. 2021, *AJ*, 161, 147
- [5] *gaia-kepler.fun* by M. Bedell.
- [6] Bressan, A., Marigo, P., Girardi, L., et al. 2012, *MNRAS*, 427, 127
- [7] Chen, Y., Girardi, L., Bressan, A., et al. 2014, *MNRAS*, 444, 2525
- [8] Creevey, O. L., Sordo, R., Paillet, F., et al. 2023, *A&A*, 674, A26
- [9] Katz, D., Sartoretti, P., Guerrier, A., et al. 2023, *A&A*, 674, A5
- [10] Chen, D.-C., Xie, J.-W., Zhou, J.-L., et al. 2021a, *ApJ*, 909, 115
- [11] Chen, D.-C., Yang, J.-Y., Xie, J.-W., et al. 2021b, *AJ*, 162, 100