Confirming the "Lobster" Diagram: Unresolved Companions in K+K Wide Binaries with TESS and Kepler

Zachary Hartman[1,2], Sébastien Lépine[1], Gerard van Belle[2]

1. Georgia State University, 2. Lowell Observatory

Contact Email:
hartman@astro.gsu.edu

We present an analysis of TESS and Kepler light curves for 4,947 K+K wide binaries from the SUPERWIDE Catalog. We use these systems to examine the usefulness of the "Lobster" diagram, a plot which allows for the identification of over-luminous components in wide binaries using Gaia data alone. These over-luminous components are believed to be unresolved binaries, making the wide binaries a triple (or even quadruple) system. To confirm this, we search through the high cadence light curves from TESS, Kepler and K2 and the data products produced from the MIT Quick Lookup Pipeline for signals from eclipses and from rotational modulation in spotted fast-rotating stars. We identify 64 eclipsing systems and 115 systems showing signs of fast rotation. We highlight the systems containing eclipsing systems, fast rotators (P<5 days) and rotators (P>5 days) on the "Lobster" diagram. Eclipsing binaries are overwhelmingly found to be in areas that show a component is over-luminous. Fast rotators are also more likely to be found in these areas while stars showing rotation with periods > 5 days are more likely to be found where true wide binaries are believed to be located.

K+K Wide Binaries and the "Lobster" Diagram

- We select 4,947 K+K wide binaries from (Hartman & Lépine 2020) that satisfy two criteria:
  - Gaia B_P-R_P color between 1.01 and 1.81
  - Probability of being a wide binary > 95%
- Primary star is the component with the bluer color
- To examine over-luminosity, we define an over-luminosity factor:
  - Component M_G - dividing line M_G at the component's color
  - Negative means the component is over-luminous relative to the dividing line
- Plotting the factors for the primary and secondary components against each other gives Figure 2, also known as the "Lobster" diagram.
- As the metallicities between the components are roughly the same, if both stars are "single", the over-luminosities should be correlated and follow a 1-1 line.

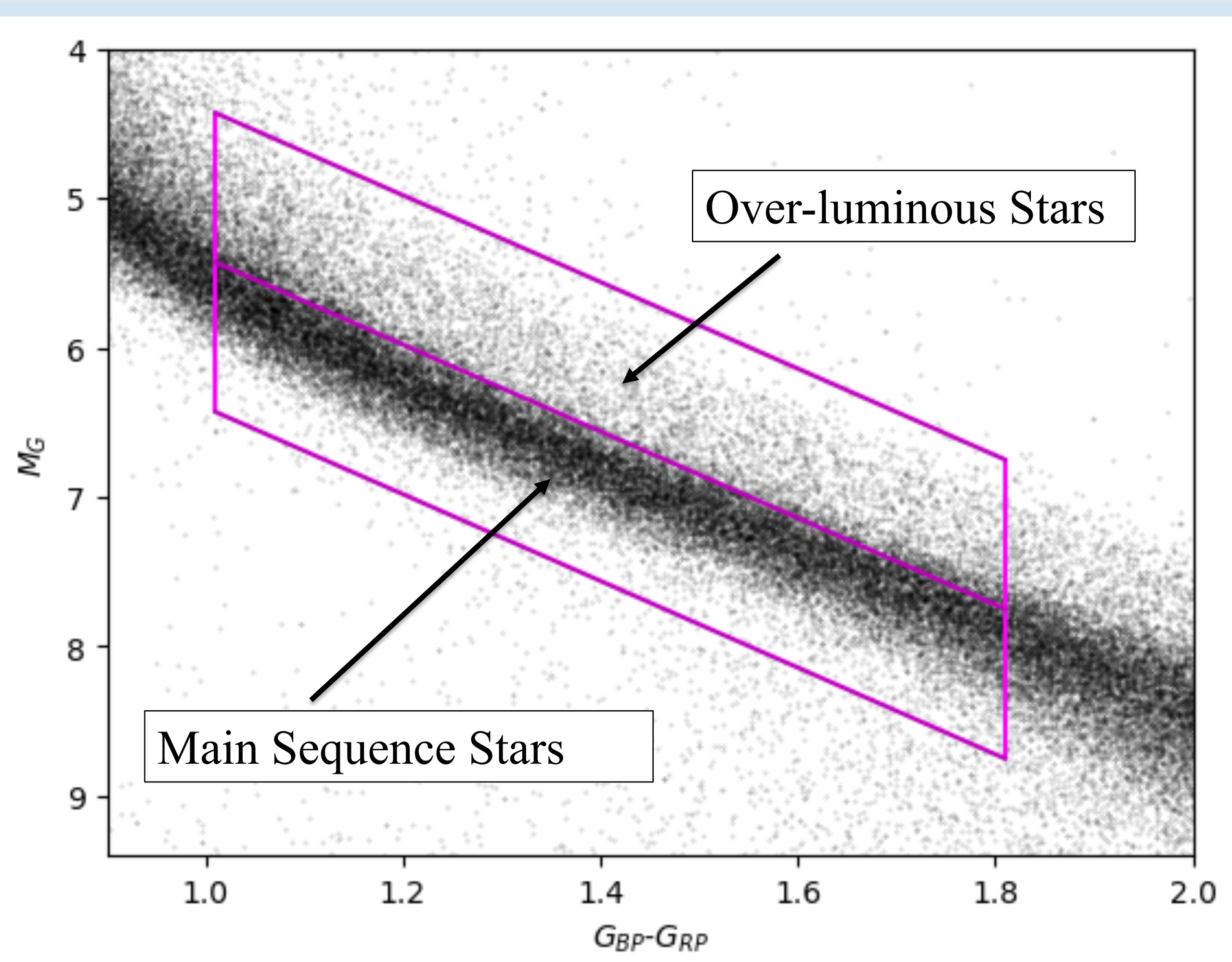

Figure 1: Color-magnitude distribution for the SUPERWIDE catalog in the area of the K dwarfs. Both primary and secondary components are plotted. The magenta box shows the area of interest for this analysis, spanning from Gaia B_P-R_P of 1.01 to 1.81 and +/- 1 magnitude from the middle magenta line that represents the dividing line used for the calculation of the overluminosity factor.

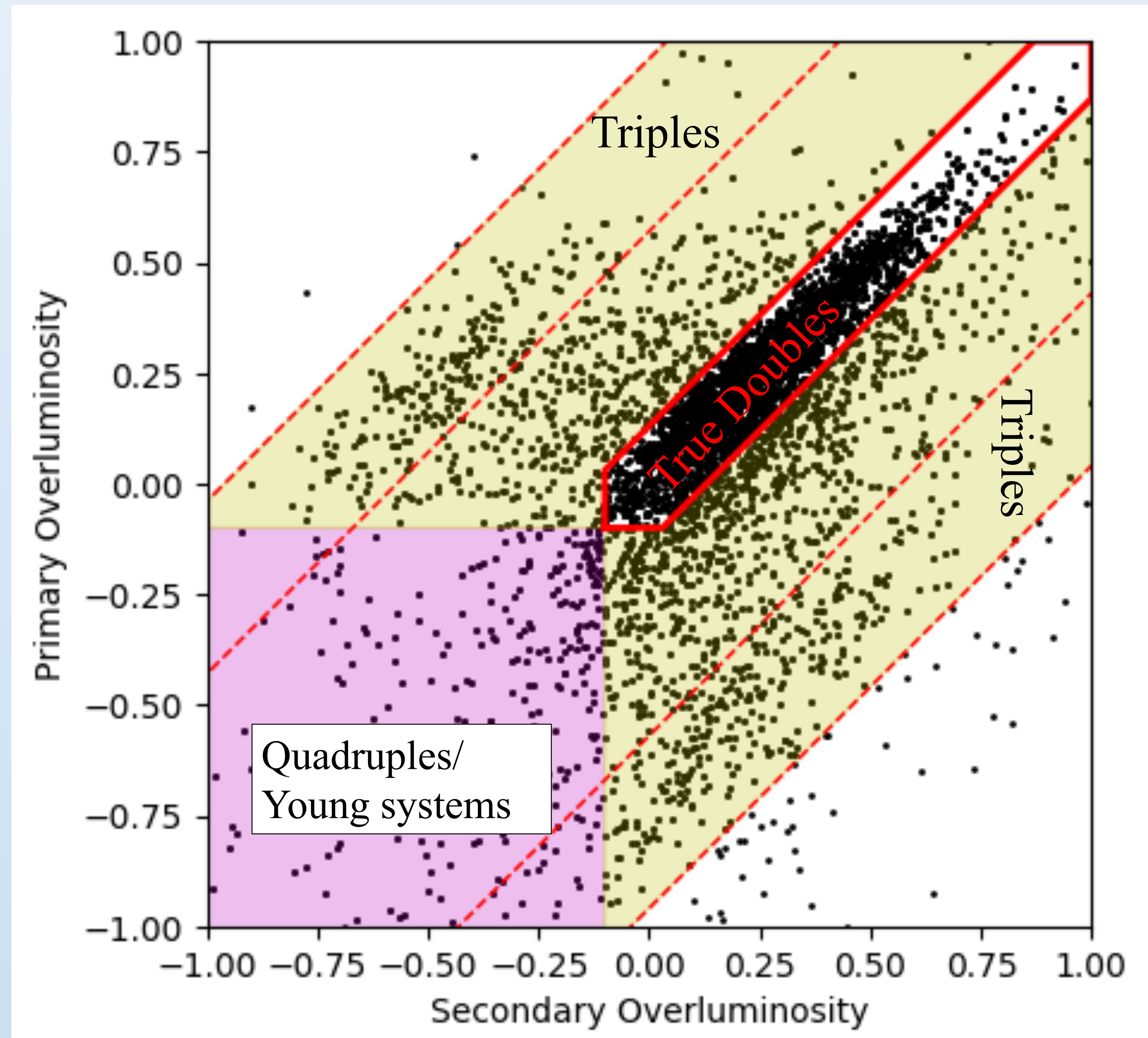

Figure 2: The "Lobster" diagram comparing the over-luminosity factors of the primary and secondary components of the selected K+K wide binaries. There are four regions of interest. The true double star sequence shows where true wide binaries are found. The yellow shaded regions show where unresolved triples are located and can be to either side of the true double "body" depending on which component is over-luminous. The regions bordered by the dashed red lines show where unresolved equal mass binaries should be located. Finally, the magenta shaded region shows where potential quadruple and wide binaries consisting of young systems should appear.

Close Companions From TESS and Kepler

To determine if the over-luminous components we find from the "Lobster" diagram consist of unresolved binaries, we conduct a search of the available TESS and Kepler light curves through MAST. Using the LightKurve package in Python (Lightkurve Collaboration 2018) and querying the MIT Quick Look-up Pipeline (QLP, Huang et al. 2020a), we search through the available high cadence light curves from TESS and Kepler and available light curves from the QLP. Gathering the light curve, we examine them for either transiting signals or signs of rotation. In the end, we find 64 eclipsing systems and 115 systems showing rotation. In Figures 3, 4 and 5, we plot where the systems that host these signals lie in the "Lobster" diagram in three groups, eclipsing systems, fast rotators with periods < 5 days and rotators with periods > 5 days. We find that the vast majority (76%) of wide binaries where one component is an eclipsing system lie outside of the true double sequence. We find this trend continues for fast rotators (71%) while it disappears for rotators with periods > 5 days (40%). This provides additional evidence that fast rotators consist of non-eclipsing binary stars as pointed out in Simonian et al (2019).

Conclusions and References

- Eclipsing systems are overwhelmingly found outside of the single star sequence of the "Lobster" diagram
- Fast rotators with P<5 days are also more likely to be found outside of the true double sequence
- Rotators with P>5 days do not show this trend, pointing towards fast rotators being spun up by a binary companion
- We conclude that the "Lobster" diagram can be used to identify which components of wide binaries consist of short period unresolved binaries.

Hartman, Z. & Lépine S., 2020, ApJS, 247, 66.
Huang C. X., Vanderburg A., Pál, A., et al. 2020, RNAAS, 2, 204
Lightkurve Collaboration, 2018,ASCL, 1812.013
Simonian, G. V. A., Pinsonneault M. H., Terndrup D. M., 2019, ApJ, 871, 174

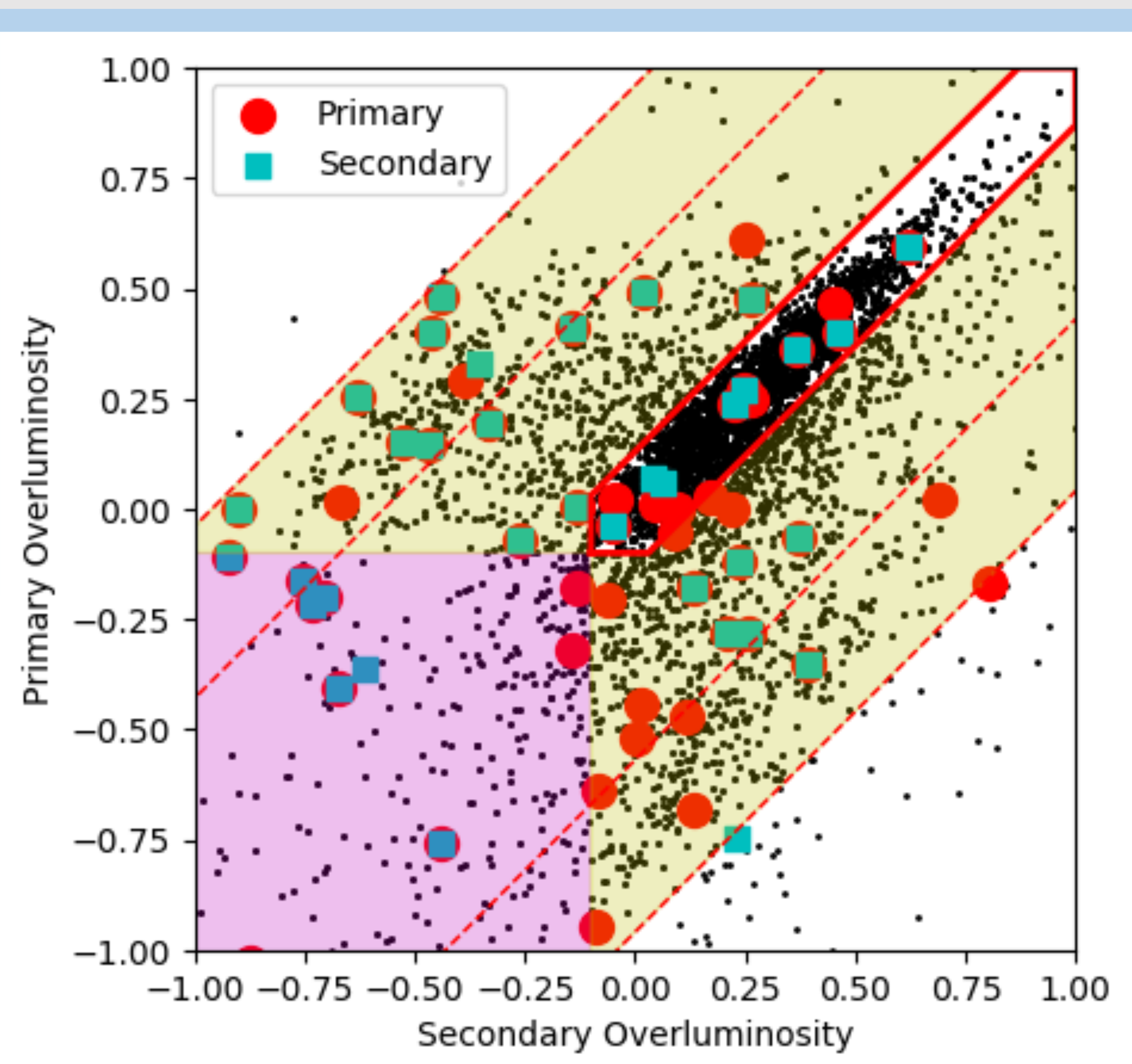

Figure 3: Lobster diagram with the location of systems consisting of eclipsing systems highlighted. Red circles represent binaries where the primary has a light curve while the teal circles show the same for the secondary component.

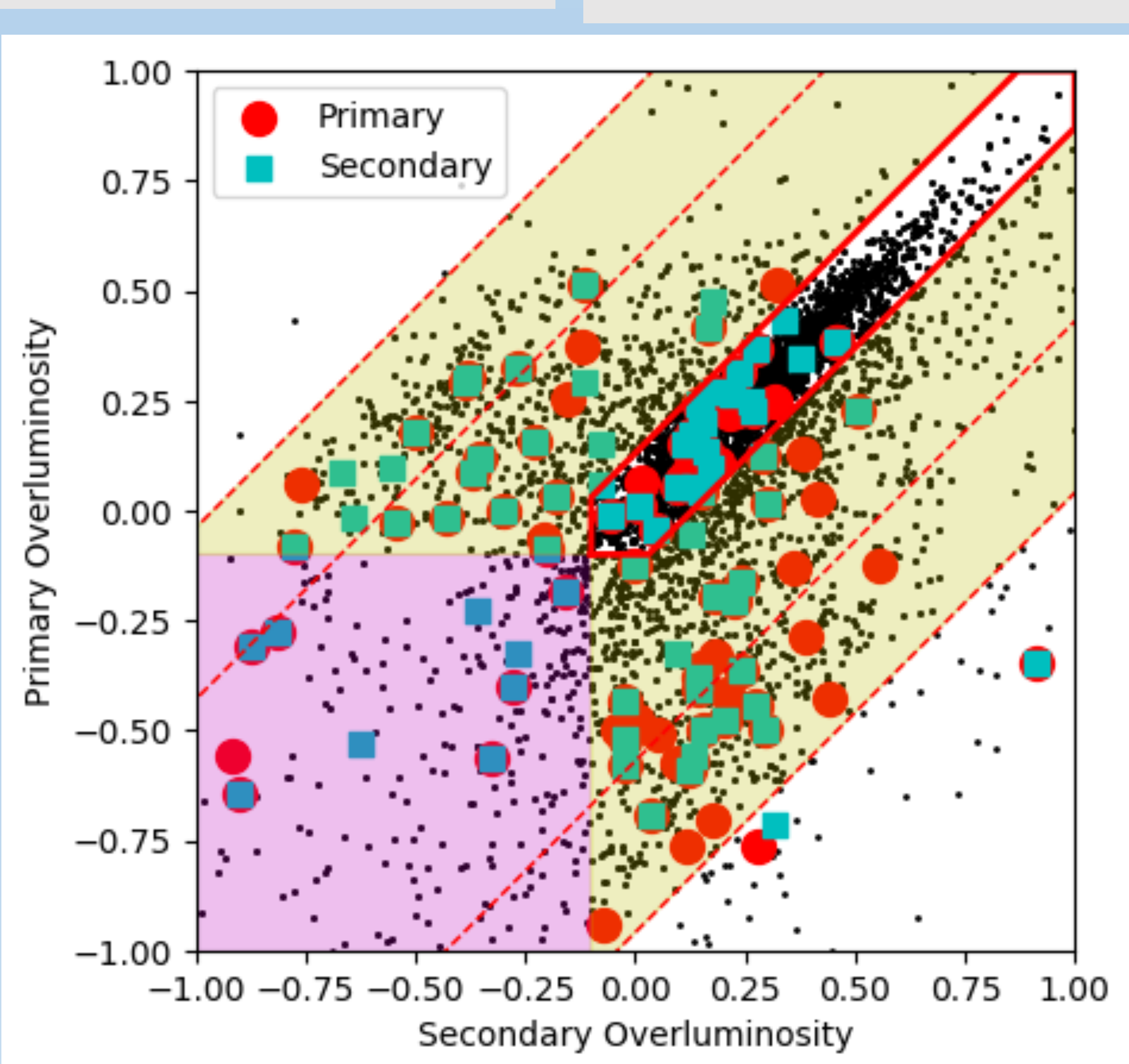

Figure 4: Lobster diagram with the location of systems consisting of fast rotators (P<5 days) highlighted. Red circles represent binaries where the primary has a light curve while the teal circles show the same for the secondary component.

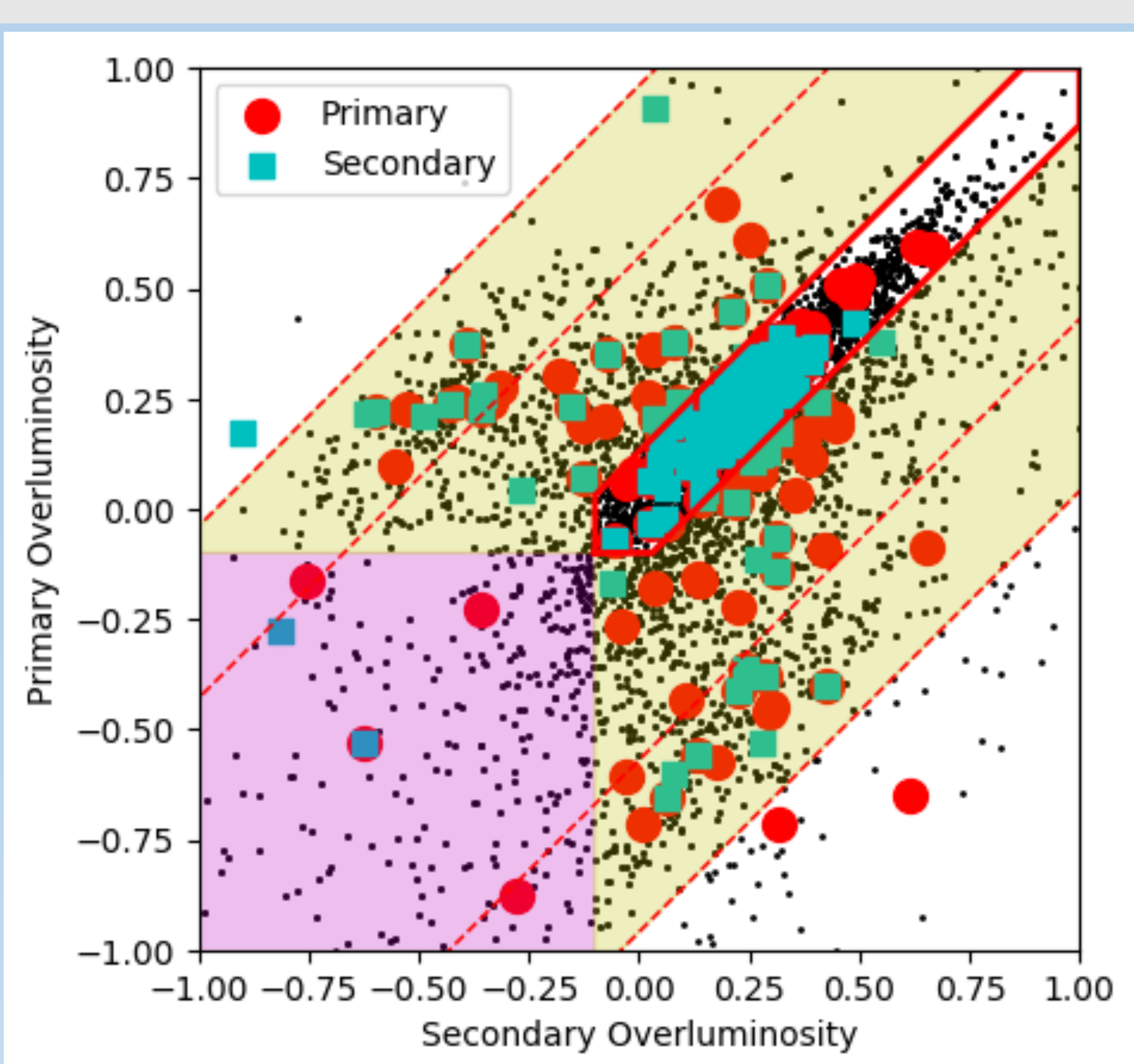

Figure 5: Lobster diagram with the location of systems consisting of slow rotators (P>5 days) highlighted. Red circles represent binaries where the primary has a light curve while the teal circles show the same for the secondary component.