New Tricks with the Joker: Using the Infrared to Reveal Hidden Binary Star Systems

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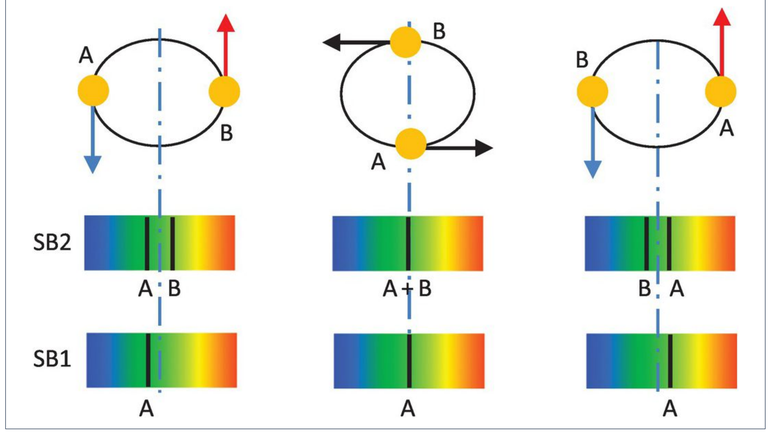
ABSTRACT: Fifty percent of stars in the night sky are actually binary star systems, but finding and characterizing them requires significant data, time, and analysis. Studying the brighter star of the pair is fairly straightforward, but the secondary is commonly hidden. Using the infrared spectroscopy data from the Sloan Digital Sky Survey combined with the WIYN Open Cluster Survey, we create a longer baseline with which we can better characterize these stars. The Joker, a new Monte Carlo analysis technique, will help us reveal the hidden binary stars by producing solutions for the orbits of the systems. Finding new binary stars can help us better understand the demographics and composition of our chosen star cluster, NGC 6819, and also allow us to learn more about each individual companion of the systems.

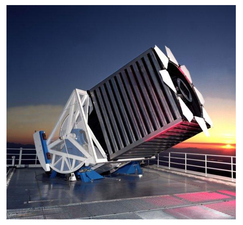
SPECTROSCOPIC BINARY SYSTEMS

When binary star systems are classified by the doppler shifts on their emitted light, they're called spectroscopic binaries. We can see the spectra blueshift and redshift, and periodicity in the radial velocity (RV) measurements. However, we don't always get the same amount of information from this analysis, which leads to two subcategories of spectroscopic binaries: single-line spectroscopic binaries (SB1) and double-line spectroscopic binaries (SB2). In the spectra of an SB1 system, you can only see the emission from one star that essentially overpowers its companion. In the spectra of SB2 stars, you are able to distinguish the individual spectra from each other.



WOCS AND APOGEE

Our data comes from the WIYN Open Cluster Survey (WOCS) and the Apache Point Observatory Galactic Evolution Experiment (APOGEE). Both have radial velocity data of comparable quality and cover our chosen open cluster, NGC 6819. WOCS, the older of the two surveys, was conducted in the visible spectrum, limiting the ability to detect lines from the fainter companion star. Combined with APOGEE, taken in the infrared spectrum, we'll have a longer baseline for our data, making it easier to distinguish the individual spectra and RVs of each of the stars.



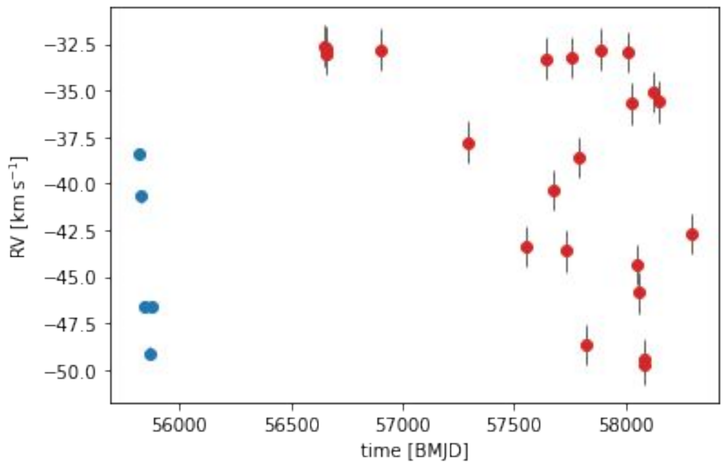
This could potentially allow us to reclassify systems from SB1s to SB2s, allowing for a better characterization of the binary populations in NGC 6819, and of the cluster as a whole.

THE JOKER

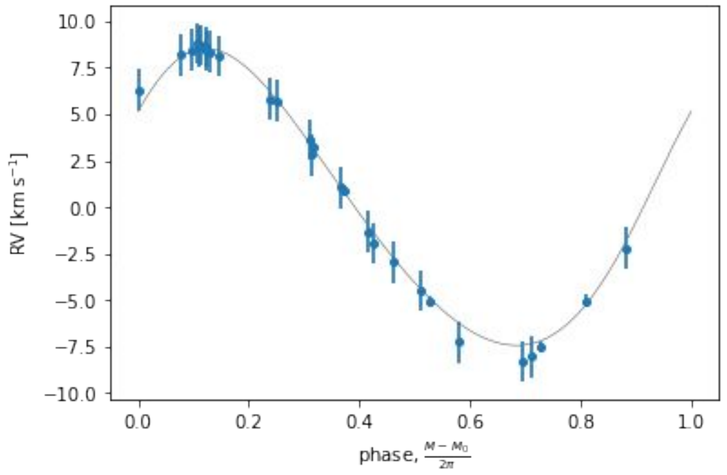
The Joker is a Monte Carlo sampler that uses radial velocity measurements to produce potential orbital solutions for binary systems (Price-Whelan, A. M., et al. 2017). It is able to take in sparse, or low-quality data, and produce reasonable fits. The Joker has been used to analyze APOGEE data previously, but our combination of APOGEE and WOCS data will constrain the possible solutions the Joker can provide. This is because we'll provide it with more data points *and* a longer baseline.

PRELIMINARY RESULTS

The following is an example of a test on the binary system 2M00344509+8512058. This star had 28 visits from APOGEE (red) and WOCS (blue) combined.



The Joker finds a solution to the data and then phase folds it to provide us with the orbital solution.



FUTURE WORK

Our test cases assure us that the Joker is able to take in our combined WOCS and APOGEE data, giving us the confidence to move on to analyzing all the matched stars in NGC 6819. This analysis could be extended to include other open clusters that have WOCS and APOGEE data like NGC 7789, NGC 188, and M67.

Not only will we understand the individual stars better, but we can also learn more about the chemical composition of the cluster as a whole. Since the chemistry of a star is determined by its spectra, as we attempt to reclassify, we're also redetermining the stellar spectra. This means the updated data could reveal that the cluster is made up of different elements than previously determined.

REFERENCES

- Price-Whelan, A. M, Hogg, D. W., Foreman-Mackey, D., Rix, H. 2017, ApJ
- Terrien, Ryan C., et al. 2014, ApJ

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Fifty percent of stars in the night sky are actually binary star systems, but finding and characterizing them require significant data, time, and analysis. Studying the brighter star of the pair is fairly straightforward, but the secondary is commonly hidden. Using data from multiple Sky Surveys and a software called the Joker we will work to reveal and characterize these hidden binary stars.