Identification and Radial Velocity Extraction for 100+ Double-Lined Spectroscopic Binaries

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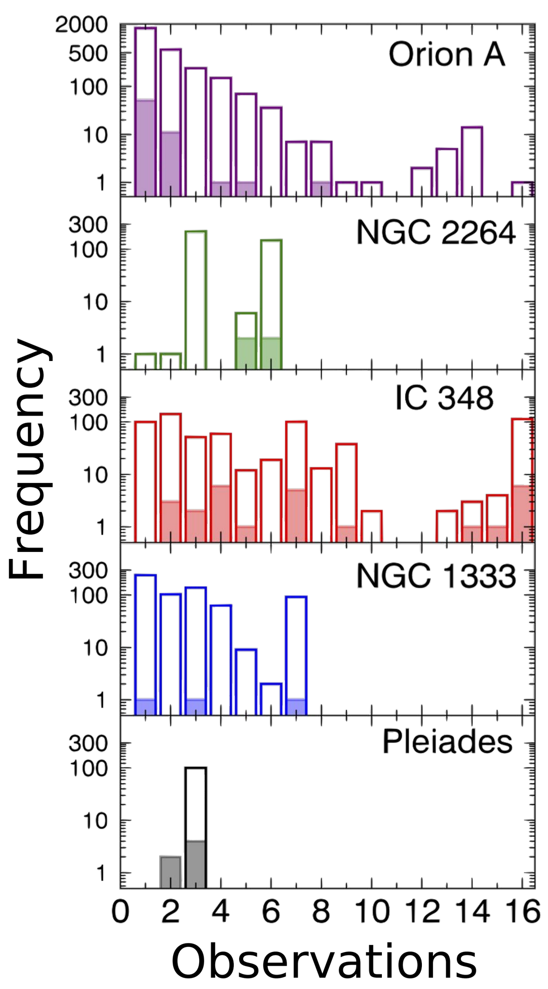
1 Introduction

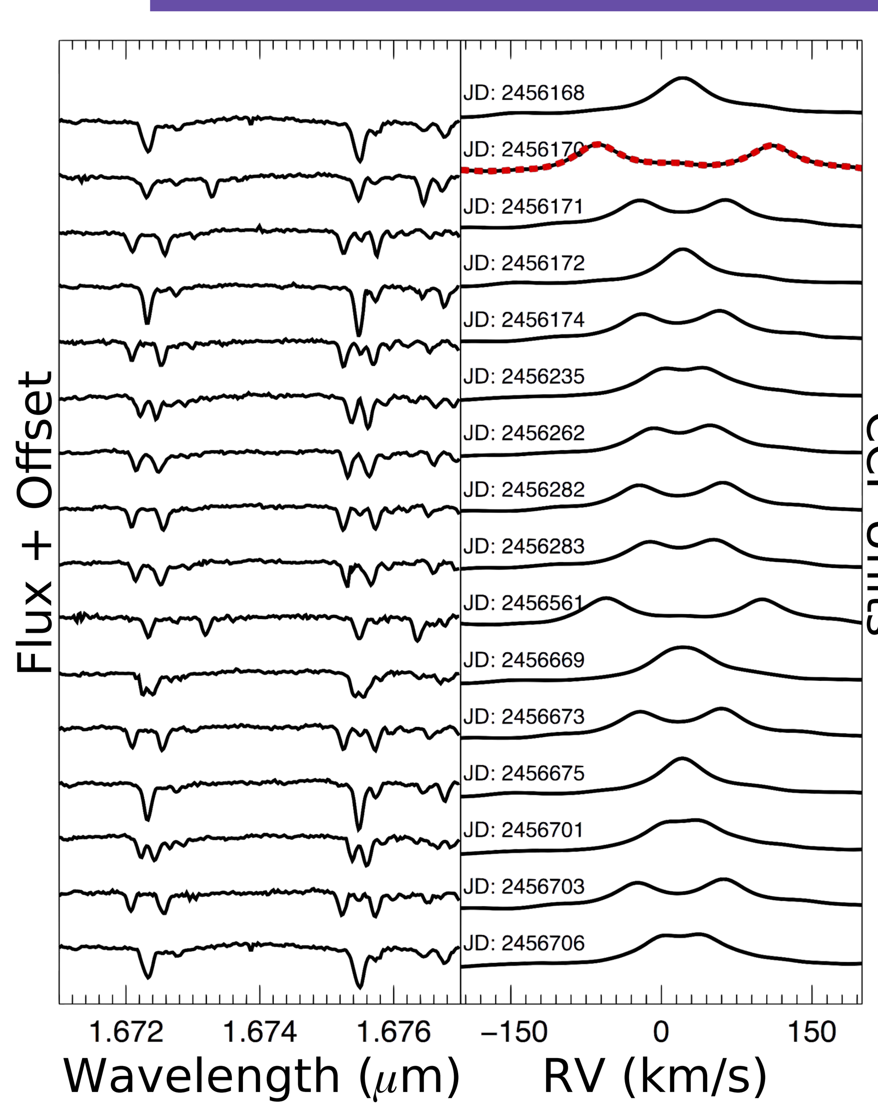


Binary stars enable direct measurements of stellar parameters, and binary frequency & configurations are direct tests for stellar formation models. Double-lined spectroscopic binaries (SB2s) are pairs of stars that cannot be visually separated. We use cross-correlation functions (CCFs) to find these SB2s. Our results include:

- SB2s in five fields encompassing the young (< 200 million years) clusters IC 348, NGC 1333, Orion A, NGC 2264, and Pleiades.
- 104 SB2s identified and radial velocities (RVs) extracted from APOGEE near-infrared spectra.
- Binary orbital parameters and cluster membership estimates for all SB2s with multiple spectra.

Fig. 1: Total number of sources in each cluster field (empty bars), compared with the number we identified as SB2s (filled bars), separated by the number of observations available. IC 348 and NGC 1333 are both in the Perseus Molecular Cloud.

2 Cross-Correlation Functions



- CCFs are produced by comparing observed spectra to rest-frame synthetic spectra.
- Synthetic spectra are shifted with respect to the observed spectra.
- For each shift the product of the two spectra is summed.
- When the spectra agree, the sum is large, and the CCF has a peak.
- If the spectra agree at two shifts, the CCF will have two peaks, one for each star.

Fig. 2: The observed spectra (left) and corresponding CCFs (right) for a system in our sample. This is an especially clear example, with single- and double-peaks visible in the spectra and CCFs.

3 Radial Velocities

- In CCFs with two peaks, the separation of the peaks is determined by the star's Doppler shifts.
- RVs are determined for each SB2 component by fitting a dual Lorentzian profile to the CCF.
- The height of each CCF peak is used to associate RV measurements with individual stellar components.
- Equal mass binaries produce CCF peaks of equivalent height; assignment of RVs is ambiguous in these cases.

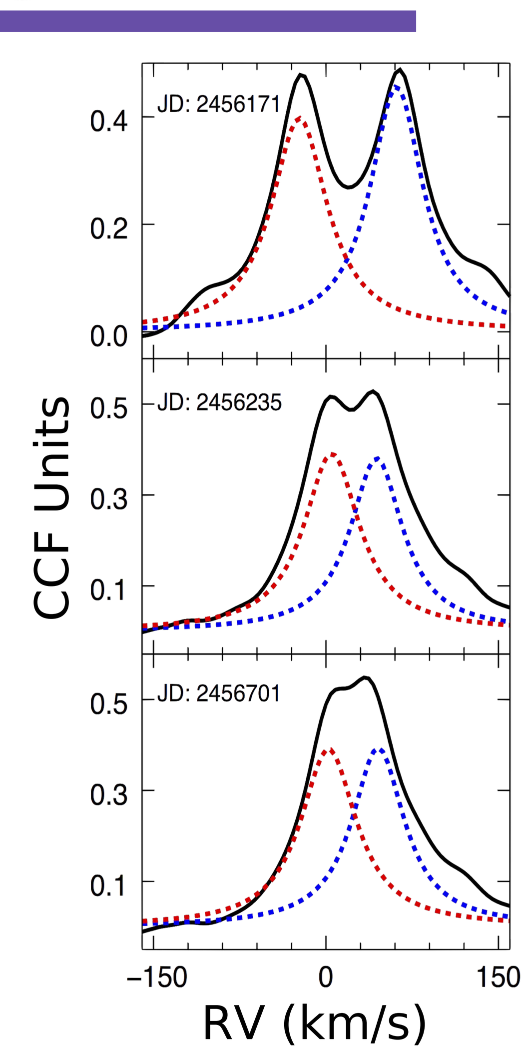
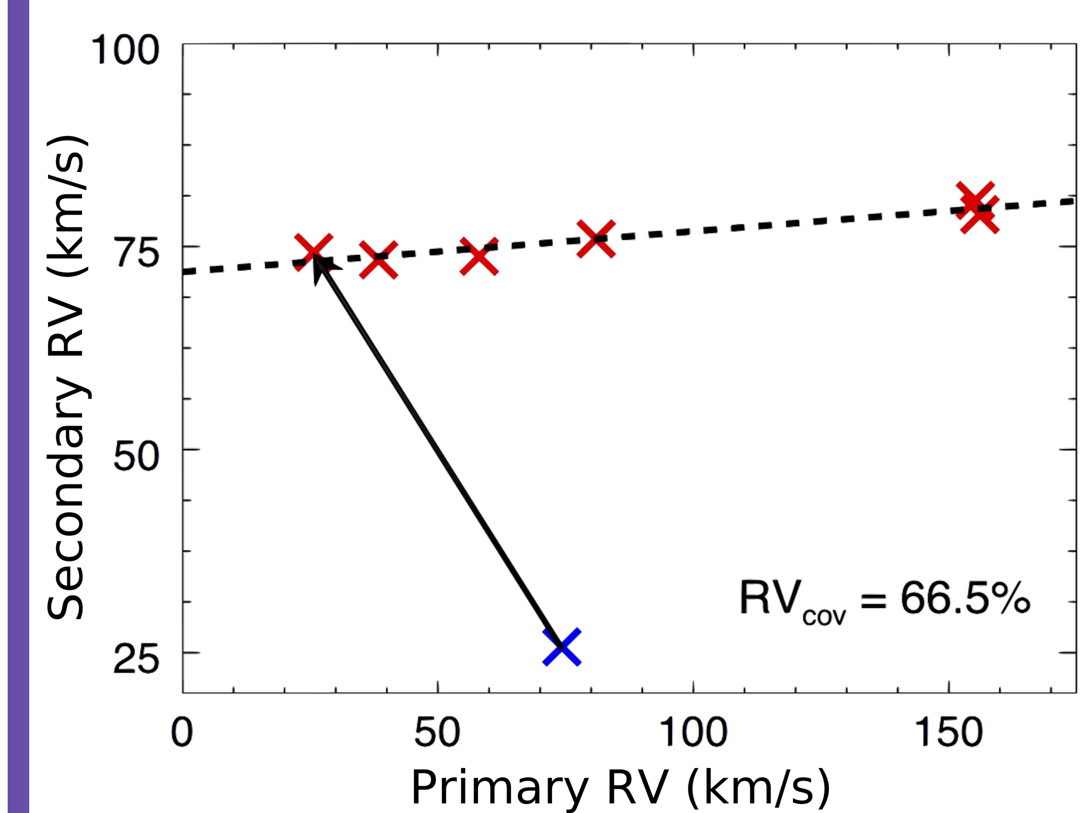


Fig. 3: Three CCFs from Fig. 2, with Lorentzians overlaid. The CCF peaks shift in time, indicating variability in the RV of each component. Identifying SB2s is easiest when the CCF peaks are fully separated (top panel) and more difficult when the peaks are merged (bottom panel).

4 Mass Ratios & Systemic Velocities



- For systems with multiple observations, we estimate the mass ratio and systemic velocity.
- Mass ratios are the inverse of the component RV ratio, or the slope of the Wilson plot best fit line.
- The systemic velocity is the system's center-of-mass RV.
- Systemic velocity can be estimated when the primary and secondary RVs are equal.
- This is when the stars radial motion is due to the systemic velocity and when the stars are moving perpendicular to our line of sight.

Fig. 4: Example Wilson plot (Primary RV versus Secondary RV). One of the RVs was misassigned (blue), so its assignment was flipped to match the rest of the visit RVs. The RV coverage measure is important in choosing which SB2s will return robust fit orbits.

5 Cluster Membership

- To test cluster membership, we compare each SB2's systemic velocity to its cluster's mean RV.
- Though each source is in one of the five cluster fields, not all of them are actually gravitationally bound to that cluster.
- We set a conservative 10 km/s cutoff for cluster membership.
- Systems that are consistent with cluster membership are generally younger, while the non-members are more evolved.

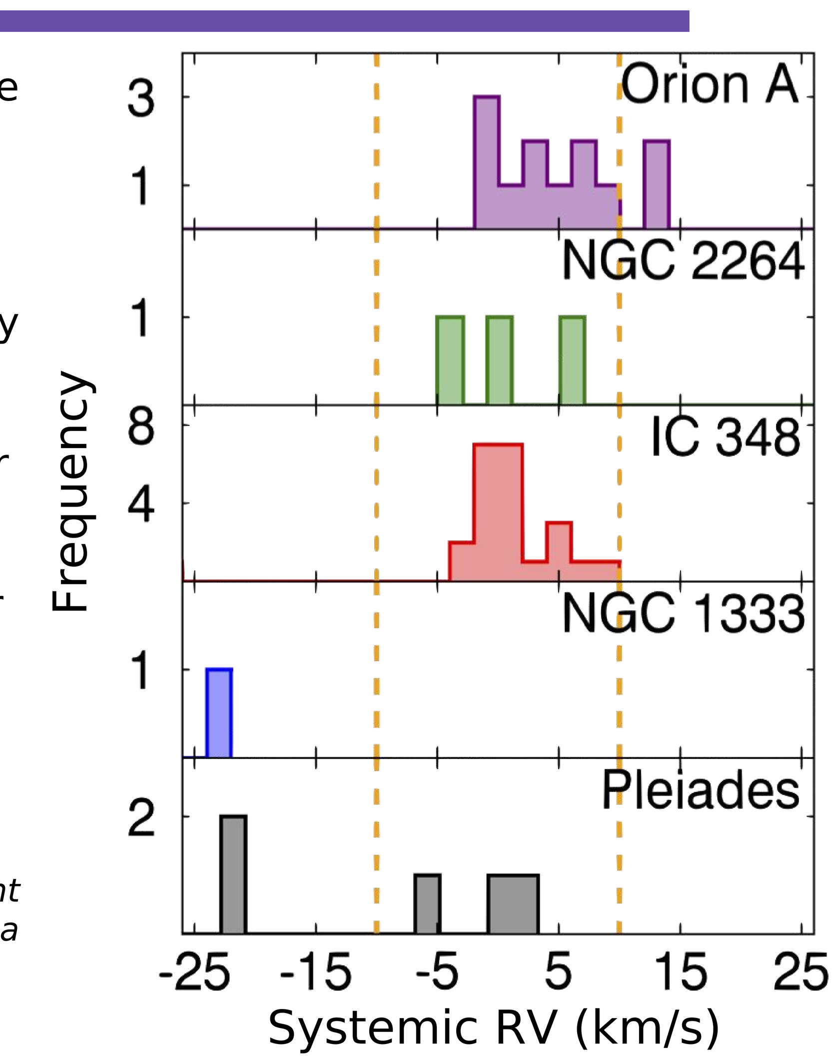
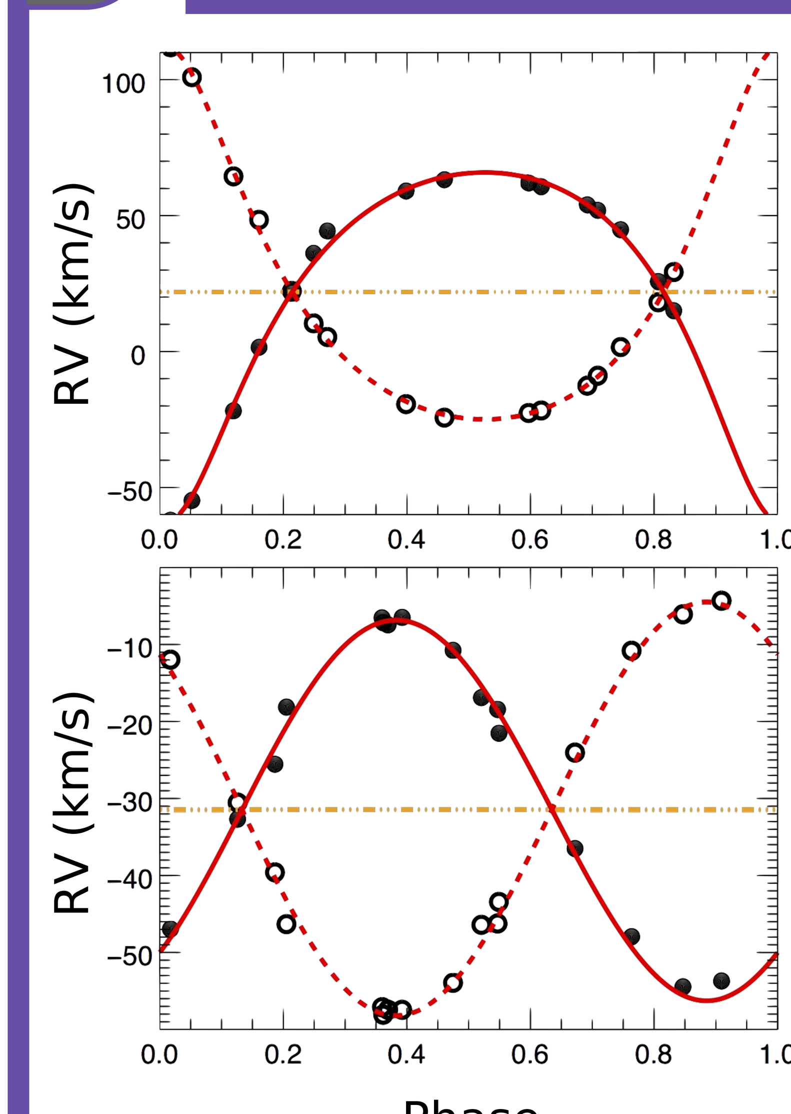


Fig. 5: Each SB2's systemic velocity, with the relevant cluster's mean RV subtracted. Dashed lines indicate a 10 km/s cutoff, which is our criteria for membership. Cluster RVs are taken from the literature.

6 Orbital Fits



- For two systems, orbital parameters are fit using a random walk method.
- The fitting method requires 8+ observations and good RV coverage.
- We additionally require a 98% significant period, as calculated from a Lomb-Scargle periodogram.
- The orbital parameters fit include period, eccentricity, systemic velocity, and the primary and secondary RV amplitudes.
- The systemic velocities calculated here agree well with our earlier estimation.

Fig. 6: Phased orbits for two 16 visit SB2s with RVs overlaid. Both systems are in the IC 348 field, but both are unlikely to be members. The solid and dashed lines are the primary and secondary components, respectively. The orange dot-dashed line is the systemic velocity.