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Astrometry and Spectroscopy as Tools Toward Visual–Binary Masses

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Following the diversified topic of this conference, let me present a variety of comments — not all new, but resulting from a long string of stars drifting across the desk. The chase after visual orbital elements is not exactly a self–purpose but is aiming at further data, in particular, at good masses. The last published lists of high–quality mass determination represent the status of 20 years ago; but a compilation at this time would probably not last long as the progress promises to quicken.

We have 1000 positional (visual/photographic/speckle) orbits, among them about 700 acceptable in the range from fair to definitive. Yet less than 10% of them give good component masses. Most of them are outside the range of parallax measures with the requisite, high precision (that unfortunatly holds for the Hyades); some frustrate the parallax measurer by displaying wedge– and peanut–shaped images, and the more exciting cases of abnormal, non-main–sequence components often cannot get good mass ratios owing to large distances or long periods.

The next substitute to look for are radial velocities. These have played a rather modest role in this context owing to three limitations, all of which are in the process of changing: the shorter and more intermittent spectroscopic coverage, the restriction to brighter magnitudes (thus biased against low–luminosity visual pairs), and the problem to unscramble blended lines. Yet positional observation also has a specific, intrinsic advantage, i.e. the powerful tool of the position angle. It is a monotonous (not periodic) function; thus it provides a superior time resolution by recurrence, and also the areal constant which in most cases is a well–determined constraint in the parameter space of the elements. From a fair number of combined visual–spectroscopic orbits, the experience is not surprising that the radial–velocity input has a comparatively low weight in the elements themselves (except sometimes in spectroscopically well–covered periastron passages at high eccentricities), but the K_1 amplitude often gives a smaller error bar for the masses than the directly measured parallax does. Sometimes the visual elements put as constants into the spectroscopic solution are totally erroneous (Kpr 114 and β LMi). In general, the relative insensitivity of radial velocities to elements at small amplitudes and at long periods is also seen from the fact that, of some forty combined orbits, less than half are listed in the spectroscopic catalog with elements that are also positionally acceptable.

Some 30 visual pairs have spectroscopic subsystems (again counting only the objects which figure in both orbit files), for instance, 80 Tauri which is one of the few surviving A type Hyades, and a single–lined triple. High–resolution spectrometers are progressing with the task to decide, which of numerous suspected sub-systems are real and which are not.

The application of astrometry to spectroscopic pairs has been quite limited;

the two preferentially studied objects (nearby *versus* bright stars) have little overlap. The apparently low number of stars that vary orbitally, revealed by the high-precision spectrometers, diminishes the chances of having such objects within range of easy astrometric verification. γ Cep has a substantial parallax, a deceleration of proper motion which suggests a very long period, and also a distinct RV change which, however, appears to belong to a much shorter period, and also a distinct RV change which, however, appears to belong to a much shorter period; thus some more unscrambling is to be done.

To turn now to the application of classical astrometry to visual binaries (our main target over the last decade) — I find a somewhat unexpectedly high number of evolved pairs: Where orbits and parallaxes do not yield a mass/luminosity placement on the main sequence, the stars must be mild subgiants (despite the spectral class V). Abnormal mass ratios are not rare: The mass of the faint companion in 85 Peg (subgiant) easily suffices for a double red dwarf. More complex is ADS 13125, a 7th-mag single-lined G9; the visual orbit is safe, the single-lined spectrum belonging to the primary shows a short period (R. Griffin), and now — after a recent visual periastron passage — a mass excess in the secondary is confirmed. Thus even if the Griffin component is featherweight, a massive white dwarf as a fourth body may be needed to make the system match the observations. Some more formerly suspected doubles (some with published orbits) have been disproven. At the refractor, the confidence line for long-term effects is about at 20 mas. Semiamplitudes above are reasonably safe while those below 15 mas have a high mortality rate.

LPM 837 is a speckle binary whose orbit showed up in our 50-yr astrometric series, but with a slightly longer period (2.27 yr) than is published. BD +50 1725 is a much-observed candidate for a very small RV variation; our coverage shows nothing at a noise level of 10 mas, which at a parallax of $0\overset{''}{.}21$ places a sharp upper limit on spectroscop[ic periods. VV Lyn is a long-period astrometric binary and was suspected of a large RV variation. A much smaller change found isntead at CORAVEL (I owe this information to A. Duquennoy) is still too high for the astrometric orbit. Hence the possibility exists that the star has two substellar companions.

A list of stars within 6 parsec counts 94 objects in 67 systems: seven (including the sun) of solar type and brighter, six degenerates, and 81 from the lower main sequence (mostly dM, up to a few G5 – K0). Only five of the stars or systems are fainter than 13 mag, and three of these are recent additions. they also are the only ones with a hemispheric asymmetry: Stars $m<13$ are evenly split North/South = 1:1, but the five faint stars are northern. Concerning other incompleteness, the conclusions are somewhat conflicting: the apparent star density decreases if the surveyed volume is extended to 7 or 8 pc, so there should be some deficit at the faint end already within 6 pc. On the other hand, it can be estimated how many of the very faint stars should show large proper motions. Luyten's NLTT is presumably nearly complete to at least $m = 17$, and does not show that many candidates. Overall, the luminosity function and hence for red dwarfs the mass-frequency function, does not appear to stay level even below 0.15 or 0.12 $\mathcal{M}_\odot$; it drops off.

As for the binaries among these nearest stars: The limited sample down to middle-K types should have some (but not much) incompleteness and is within explicable range of the statistically predicted 80% to 85% membership rate which sounded so incredible when published in the 1960's. The rate drops for late-K to M stars, and notably under-represented are the short periods. This cannot be due solely to lack of RV coverage. If existing, some of these cases would have been spotted by the long-term astrometric series.

Much printed output centers on the very low (sub-nuclear) masses. The use of a specific term "substellar" or "brown" dwarf has been criticized in view of structural similarity with nuclear (red-dwarf) star models. I thnk that the distinction is justified. It is deeply ingrained what was learned in the Astro-1 class, that stars have a mass-luminosity relation; hence the warning sign that some objects don't is feasible. The newsmedia mess *deja vu* twenty years ago around the magic word "planet" has now spread in that lots of "brown dwarfs are discovered" merely on the basis of alleged low luminosities. This is about as logical as to first identify cancer as a non-infectuous disease, and then try to diagnose it with a fever thermometer. The way to identify substellar objects is only via the mass. In fact, the existence of a critical nuclear mass means that the faint end of the main sequence drops to virtually infinite magnitudes at a finite mass, and objects with an undeclared source of income — be it transient shell burning of unstable isotopes, or shrinkage — are likely above the red-dwarf mass-luminosity line. Another opinion voiced is that no "brown dwarfs" have been found at all.

Since I last discussed the lower main-sequence graph (at the Flagstaff 1981 conference) it has been considerably "cleaned". Data points have been added, others moved (primarily toward higher masses, owing to revised, smaller parallaxes), and the concentration toward a line M(bol) = 6 – 6.5 log(mass) is better defined. And this makes a few "illegal aliens" stand out more with their abnormal luminosities: Wolf 424, Hei 299 (over-luminous but of uncertain mass); and among the unresolved companions (for which the luminosities are unknown) DT Vir, possibly now VV Lyn, and the fifth body in the σ CrB system.

There seems to be currently a dispute over the lifetime of substellar dwarfs. I would say, it is at least 20 years — because that long we have known about some of them.