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Nomenclature for Multiple Systems Containing Close Binaries

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Abstract.
I would like to discuss the difficulty of developing and maintaining a hierarchical designation scheme for components of multiple systems, when components are found by more than one method. Such a sequence of discoveries can easily lead to conflict between the initial nomenclature, which gets established in the literature, and that based on a scheme that is in broader use, or is more physically representative, or both. I will describe as an example a hypothetical complex system whose hierarchical description depends on the sequence in which discoveries are made, and whose designation in discovery order is ambiguous. In the end I urge flexibility in designations.

1. The designation problem

I am concerned about the difficulties inherent in applying either a hierarchical scheme, or one based upon order of discovery, when inner systems are discovered independently of, and perhaps before, the outer ones. Such complex multiples exist among purely spectroscopic, spectroscopic-photometric, spectroscopic-visual, and purely visual multiple systems. If we alter designations as new components are discovered, this will lead to confusion in the literature, but it seems necessary if we are to maintain a hierarchical designation scheme. I shall illustrate the problem with real systems and a hypothetical one. Really complex systems can even call into question what we mean by order of discovery, as I shall attempt to show. And although the concepts of 'Primary' and 'Secondary' are vital to hierarchical schemes, observers using different techniques define those concepts differently, which can lead to ambiguity.

I have in fact been concerned with this matter for some time, and spoke about some facets of it at the Multi-Commission Meeting convened at the Manchester General Assembly three years ago. At the time I was speaking from a perspective very familiar to me, that of a spectroscopist. This time I shall try to represent a broader spectrum of interests, encompassing the activities of all of Commission 42. This is not an easy task, although I can claim some acquaintance with photoelectric photometry and light curves.

Three years ago I expressed general support for the hierarchical scheme proposed for the Washington Multiplicity Catalog, perhaps underestimating the difficulty of assigning hierarchical levels in visual systems where little relative motion is seen for long periods. This perhaps explains the persistence of labels C, D, etc. for components of wide multiples. I pointed out then the difference that might have occurred in labeling the components of Castor, had the bright pair

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been closer together and hence detected spectroscopically first. I also expressed concern about the assignment of 'primary' and 'secondary' labels, noting that visual observers generally do this by ranking in order of brightness, presumably in the optical range or part of it. Photometrists, however, can easily tell which star is hotter, but must solve the light curve to decide which is larger, and deduce from both pieces of information which is more luminous. By contrast, spectroscopists ideally attach the label 'primary' to the more massive star. This would not always be the brighter, even in relatively simple cases. In a poster I recently presented at Colloquium 191, jointly with Roger and Elizabeth Griffin, we described a system where there is a difference close to three magnitudes in the stars' visible light, yet they are almost equal in mass, one being a giant and the other a subgiant, which will soon commence to traverse the steep giant branch of its evolutionary track. This is the ideal situation; spectroscopists in the real world often simply label the star whose spectrum is easier to measure as the primary. Witness the case of Capella, whose components are nearly equal in both mass and luminosity, but vastly different in the ease with which radial velocities may be measured, owing to the different rotational broadening of their spectra.

2. An example

As an illustration of the difficulties one might encounter with a really complicated system, let me turn to the fortunately fictitious 'strawman' multiple system promulgated by Helene Dickel four years ago to stimulate interest in the nomenclature problem. She assigned what I regarded as an implausible discovery sequence to it. After some thought I responded with another one, much more plausible in my view, but which led to much uncertainty with regard to the proper labeling of the components. let me now review that skeptical response, slightly revised in the most recent developments from its original form. The system described is ultimately found to have nine components, including two planets in orbits around the brightest star. The latter has a nearby visual companion and a distant common-proper-motion companion, both of which are triple stellar systems in their own right.

I retained the original notation, and kept the identifications of components 1 through 9. Objects 1 and 2 are planets around bright star 3, while 4, 5 and 6 are components of its visual companion and 7, 8 and 9 those of the common-proper-motion companion. I retained the assumption that components 4 and 5 were quite close together, compared with the separation of 6 from their center of gravity, and likewise that 7 and 8 were closer to each other than they were to 9. I also assumed that the orbital period of planet 1 was much longer than that of planet 2, so as to make plausible a smaller amplitude of the radial-velocity variation of star 3 due to the presence of 1 than that due to 2, and thus to retain the original order of the planets' discoveries. The discovery sequence I proposed was as follows, and the apparent structure of the system at each stage is illustrated in Figure 1, where the discoveries described below are identified by their dates.

1. A wide pair of stars is found to have common proper motion in 1850.

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Discovery Sequence

Detected directly: ⊙
Presence inferred: ○

	AB	C
1850 - C.p.m. pair	⊙	⊙
1900 - Visual pair	⊙ ⊙	⊙
1925 - Spec. bin.	⊙ ⊙○	⊙
1950 - Broad-line cpt.	⊙ ⊙○	⊙○ ⊙
1960 - Eclipses	⊙ ⊙⊙ ○	⊙○ ⊙
1980 - Speckle	⊙ ⊙⊙ ○	⊙○ ⊙
1990 - LBI	⊙ ⊙⊙ ⊙	⊙○ ⊙
1995 - Planet 1	○⊙ ⊙⊙ ⊙	⊙○ ⊙
1999 - RV in triple	○⊙ ⊙⊙ ⊙	⊙○ ⊙
2003 - Planet 2	○○⊙ ⊙⊙ ⊙	⊙○ ⊙
Component nos.	**1 2 3 4 5 6**	**7 8 9**

2. The brighter of the two is resolved into two visual components in 1900, as they approach apastron. (We shall assume that the separation does not decrease again for at least another century, which will facilitate the discoveries to be discussed below.) They are labeled A and B. Since the common-proper-motion companion's physical connection to AB is confirmed at about the same time by the discovery that it has the same radial velocity as A, it is referred to as component C.

3. B is found to be a spectroscopic binary in 1925, despite having its spectral lines broadened severely by (synchronous) rotation. The discovery is made possible by its short period and large radial-velocity amplitude.

4. C is found in 1950 to show, in addition to its sharp-lined spectrum, a broad-lined one with radial-velocity variations indicative of binarity. The

sharp-lined spectrum does not show variations with the same period, so it is concluded that the system is triple.

5. In 1960, B is found by photoelectric photometry to show shallow eclipses. But even after stray light from A is carefully eliminated, their analysis requires the assumption of 'third light', strongly suggesting, but not proving, that that system is also triple. The eclipsing pair is listed as a variable star.

6. In 1980, speckle observations resolve C into two components of similar brightness. Thus it isn't obvious which of them is the broad-lined binary subsystem and which is its sharp-lined companion.

7. In 1990, long-baseline interferometry reveals the component of B that contributes the third light. That component, correctly described as a companion to the eclipsing pair, is significantly fainter than their combined light, as expected from the eclipse solutions, and is indeed a difficult object to detect by that technique. This of course also explains its absence from the combined spectrum.

8. In 1995 a planet is discovered around A, which is now sufficiently well separated from B to permit its spectrum to be observed uncontaminated, and its radial velocity to be measured very precisely.

9. In 1999, a slow variation in the velocity of the sharp-lined component of C is detected, along with a corresponding one in the velocities of the center of mass of the subsystem containing the broad-lined one. The latter has a smaller amplitude than the former, as might be expected since two stars are usually more massive than one of comparable luminosity. But careful work on equivalent widths of lines reveal that the sharp lined one is slightly the less luminous. Reanalysis of the speckle observations in the light of this information resolves numerous ambiguities of quadrant in the early (1980's) data and permits the derivation of a three-dimensional solution for the orbit.

10. In 2003, a second planet is found in orbit around A, by analysis of the residuals from the velocity curve due to the first, as a slow drift up and down.

11. We note that in the near future, high signal-to-noise spectroscopy should lead to the detection of the faint spectrum of the eclipsing pair's companion (the one that gave the third light and was seen by long baseline interferometry); measurement of its radial velocity variations would yield a similar solution for B.

3. Discussion

In this scenario, whose sequence of events I regard as much more plausible than the original one, in view of when the various techniques became available, components 4 and 5 were discovered before 6, and it is not obvious which of 9 and the combination of 7 and 8 should be called the primary of C. (The distant, sharp-lined companion, which dominates the spectrum, is 9.) We note, however, that if the eclipses of 4-5 were not shallow, the 4-5 pair would almost certainly have been first discovered by photometry rather than spectroscopy, a pattern normal for eclipsing systems. The presence of star 6, the third light, helps to make the eclipses shallow, but that could also be caused by the fainter component of the eclipsing binary being both cooler and smaller than the brighter one; note that it is not seen in the spectrum. Note also that we could instead have made the eclipsing pair a double-lined binary, while still retaining the above discovery sequence, provided that its orbital inclination was low enough to make the eclipses grazingly partial, and hence shallow, as required.

In this scenario too, C is a hierarchical triple, in contrast to the original scheme, which I regarded as implausible. But it isn't obvious whether 7 and 8 together should be the primary, Ca1 and Ca2, with 9 being Cb, or whether the a's and b's should be interchanged. Note that 7-8 is considerably more massive than 9, and slightly more luminous, but that 9 was discovered first in the sense that its spectrum was the first component to be seen in the combined spectrum, before it was realized that more than one star was present in the C system. Moreover, since the 4-5 pair was found before 6, on discovery 4 and 5 would have been called Ba and Bb respectively. But after 6 was found they would have to be renamed Ba1 and Ba2, while 6 becomes Bb in a hierarchical scheme. In the end, too, when A and B have been followed through a significant fraction of their orbit, it would be evident that the whole system was hierarchical; should the components then be renamed so that C becomes B, and A and B become Aa and Ab respectively, with all the consequent changes to the nomenclature of the smaller subsystems?

Thus this scenario required changes to any hierarchical nomenclature as a result of new discoveries. However in 2000 the rival sequential scheme corresponded very poorly to the hierarchical structure and thus revealed little about it. Indeed I would not find it easy to put the nine objects in order of discovery at all. For example note that the spectroscopic systems 4-5 and 7-8 are both single-lined binaries, with 4-5 eclipsing and 7-8 not. Indeed components 1, 2 and 8 have never been seen at all; their presence is inferred from their effects on the radial velocities of the stars nearest to them. And since the combination 7-8 is slightly brighter than 9, whose spectrum, being sharp, was detected first, was 7-8 the object first seen as C or was 9?

Thus for such a nightmare system as this, no scheme then, or now, under consideration can wholly satisfy the stringent demands initially proposed by IAU Commission 5. I did not then believe, nor do I now, that any physically useful system of nomenclature can be set in stone as the IAU appeared to wish. Instead I believe we must accept that useful designations correspond to the physical structure of the systems and that new discoveries of components will cause designations to be revised; all we can reasonably expect of those active in the field is that they do not rename objects unnecessarily. It follows therefore that we should set a good example, and not rename the objects in the WDS. We should thus adopt the revised version of the WDS scheme, expanded to cope with unresolved systems, and continue to ensure that it remains flexible enough to permit newly discovered components to be readily incorporated. As an example of such discoveries, see Patience et al. (2002).

In the example, several of the subsystems are 'discovered' by more than one technique, in the sense that it isn't immediately obvious whether, for example, a component found by speckle is the same as one seen previously in the spectrum of the combined light of a system. This may also be true in the real world. I have not gone into the situation where components are seen in only one spectral region, such as occurs for the IUE discoveries of companions to Cepheids, for example. The presence of a companion may have been inferred from variations in the mean radial velocity of the cepheid, but is the ultraviolet companion the one that causes that variation? In some cases we still don't know. Thus any scheme that tries to set designations in stone will be outdated in time, and will have to be abandoned. Flexibility is the key to a system that retains its usefulness.

4. Another point of view

Let me now briefly present another point of view, presented to me in correspondence with Jean Dommanget, and based upon his experiences in preparing the CCDM Catalogue. He is firmly convinced that designations should not change once they are established in the literature, a view divergent from my own. But he would achieve this stability by not basing a catalogue on *systems* of stars, but by listing the individual objects as separate entries. He would note their mutual relationships as a secondary matter. In a sense he would not produce a catalogue of binary and multiple systems at all, but instead one that listed the objects that are the components of such systems. This may in fact be the solution to the dilemma of making designations permanent in the face of new discoveries. It would leave hierarchical information out of the cataloging process altogether, except as a secondary matter. It was applied to resolved systems, and I do not know whether it could be extended to those not yet resolvable. For this reason at least, I am not convinced that this is the best way to proceed, but it does have some advantages.

References

Patience, J. et al. 2002, ApJ, 581, 654

1. Discussion

DICKEL: Designating by position only may be a problem if you don't know what the object is, i.e., can't see it.

SCARFE: That would be true of any designation that is simply a code, without astrophysical information included. The position is perhaps the minimum possible amount of that kind of information.