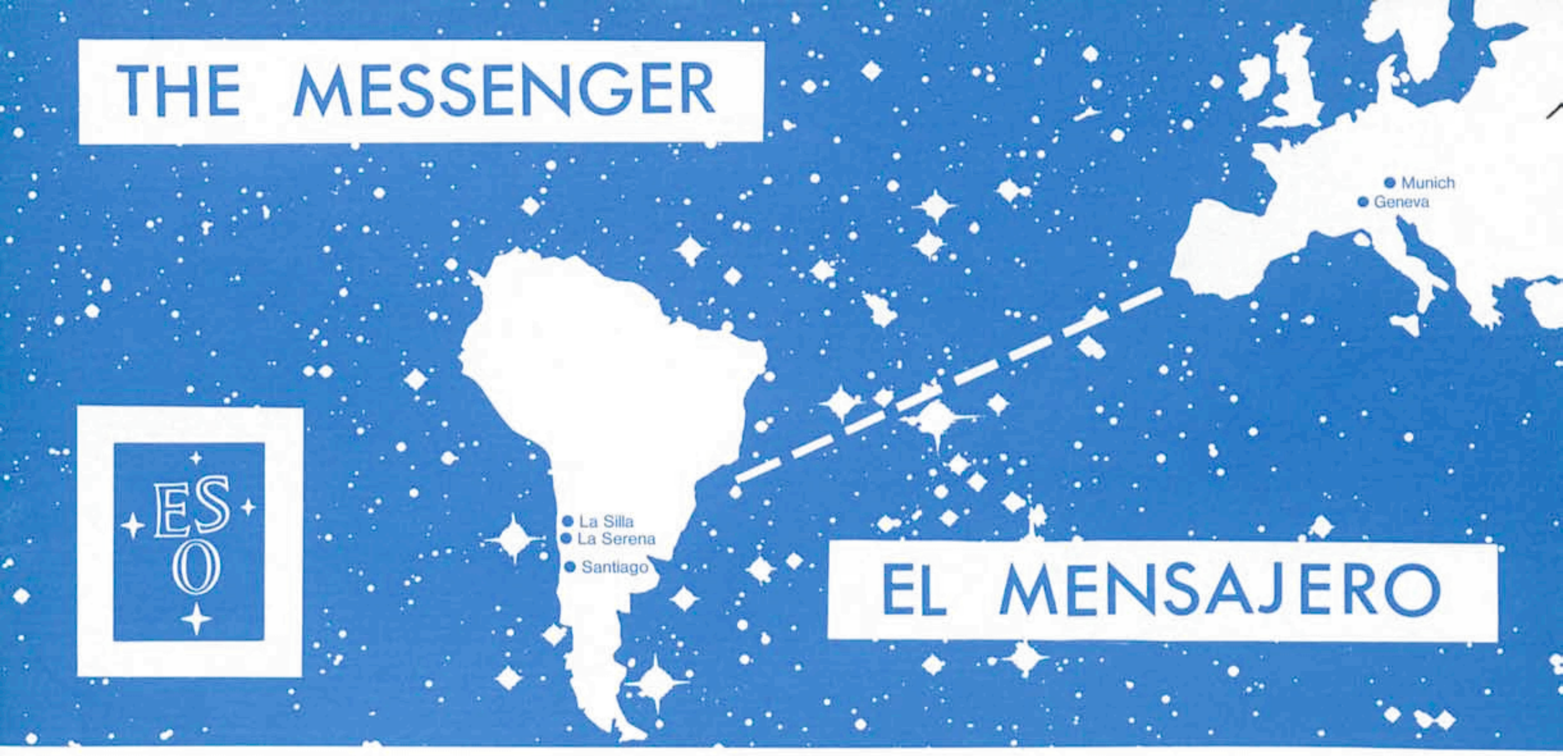
THE MESSENGER

EL MENSAJERO



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Radial Velocities of Visual Binaries

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> *In addition to the initial chemical composition, the mass of a star is a fundamental parameter; it determines the life of the star from its birth, through its long or short period of luminous glory and to its inevitable end as a compact object. And yet, few stars have actually had their mass accurately measured. The programme that has recently been undertaken by Dr. Edwin van Dessel of the Royal Observatory in Brussels, Belgium, is therefore of particular importance. By obtaining precise measurements of radial velocities of stars in double or multiple systems, Dr. van Dessel expects soon to add new, well-determined stellar masses to the present, all to short list.*

Observing visual binaries is one of the oldest arts in astronomy. Rather extensive series of observations of double stars have been published, e.g. by F. G. W. Struve (1837: Stellarum duplicum et multiplicium Mensurae Micrometriae, measures made at Dorpat; from 1839 on he observed in Pulkovo with a 15-inch refractor, then the largest in the world), by Mädler (also at Dorpat, Estland—now Tartu) or by Schiaparelli (1885, Milan). In his private observatory near Milan, later on in Gallarate, Baron Ercole Dembowski accumulated over 20,000 measures, published in collected form after his death (1881). Quite accurate measurements were performed with often very modest instrumentation.

With the observation of a double star we refer to the measurement of the position of the secondary star relative to the primary. The standard equipment has always been a filar micrometer attached to a long-focus refractor. The tradition is still being kept up, e.g. in Nice (Couteau, Muller, with two refractors of 74 cm und 50 cm aperture—the 74 cm has a focal length of 18 m), Washington (Worley, Walker—65 cm refractor), Sproul (Heintz—60 cm). Pairs separated by as little as $0\overset{''}{.}10$ have been measured.

The IDS catalogue of visual double stars contained some 64,000 stars when it was edited in 1963 by Jeffers and van den Bos; the discovery of visual pairs goes steadily on. For only about 800, however, enough observations have been collected to determine orbital elements.

As is well known, visual binaries are the only means of obtaining stellar masses, through Kepler's third law. The mass of a star being one of its basic parameters, it is clear that we would like to have as many of them determined as accurately as possible. Unfortunately, the formula which gives the total stellar mass

$$M_1 + M_2 = a^3/\pi^3 P^2$$

(*M* mass in solar units, *a* separation in arcsec, π parallax in arcsec, *P* orbital period in years) relies heavily upon the parallax. The observational parallax values are as a rule affected by too large errors to give a sufficiently precise mass determination. The quotient a^3/P^2 is in general much better determined, even if the observations do not cover an entire period (see e.g. Dommanget, 1971: *Astrophys. Space Sci.* **11**, 137). In most cases one resorts to statistical aid: the system is made to conform to the mass-luminosity relation; the corresponding parallax value is called the dynamical parallax. Individual masses M_1 and M_2 can be sufficiently well established, once the total mass is known, from the magnitude difference between the components. There is a way to obtain the complete set of information independently of statistical means, namely by combining visual and spectroscopic data.

All this is common knowledge, but there have been surprisingly few efforts so far to make spectroscopic observations of visual binaries and to acquire radial velocities of them with the aim of determining their mass. The main reason is probably that it is a rather ungrateful task, because of the slowness of orbital motion and consequently the long duration of such a programme. We may mention Victoria, Kitt Peak and, recently, Cambridge (England) as the most active observatories in the field.

The Programme: Mass Determination . . .

A programme of radial velocity observation of visual binaries was started by the author in 1977 at ESO. For practical reasons it would not be desirable to launch a programme that requires observations over one or more decades; but we shall try to show in the following that also on a shorter timescale (in the order of a few years time at a rate of 1 or 2 observing campaigns per year) very useful results may already be expected.

The ideal case is a binary for which the spectrum shows lines of both components. Even more ideal is the case where the star can be treated as a double-lined binary. There are but few examples—e. g. δ Equ or α Aur (Capella—actually a rather special case, because it ought to be called an interferometric binary rather than a visual one). However, for the purpose of mass determination one does not really need to cover the full radial velocity variation. If the visual orbit is known, one radial velocity value at the same instant for both components (or the radial velocity difference) suffices in principle to have an independent determination of the parallax and the total mass—but it pays, naturally, to have more measurements of the kind; the mass ratio between the components can be found independently from all other data if the velocity curves are well enough established to derive the amplitudes K_1 and K_2.

With the 152 cm telescope in coudé at a reciprocal dispersion of about 3 Å/mm, stars down to 6th–7th magnitude can be observed in a reasonable time. This gives us something like 10 double stars that ought to have, at present, a large enough radial velocity difference to be double-lined (Dommanget and Nys, 1967: *Catalogue d'Ephémérides*, Comm. Obs. Roy. Belg. No. B15; the new edition is expected in 1979). Some caution is indicated, because the predicted separation in radial velocity is based on the visual orbit; and of course the lines have to be sharp enough.

There are quite a number of visual binaries that during their orbital motion present a large radial velocity difference (Dommanget and Nys: 8 % has an amplitude $K > 20$ km/s). First of all the stars with relatively short period; typical values: P from 4 to 10 years, maximum velocity difference from 15 to 40 km/s. Another reason may be the large eccentricity: orbits with $e \approx 0.9$ are more common than is usually believed. Some stars have an uneventful radial velocity variation during decades and then go through a rapid phase near periastron. An example is shown in figure 1.

If the magnitude difference $\triangle m$ between the components is too large, say $\geq 0\overset{m}{.}8$, the binary will be single-lined. One then can still obtain the absolute dimensions of the system, combining the visual elements with the radial velocity measures, but the ratio M_2/M_1 will have to be derived from $\triangle m$ and the radial velocity variation one observes will be proportional to $M_2/(M_1 + M_2)$—i. e., will be small and hence subject to rather large relative errors. Our observing programme contains several systems going

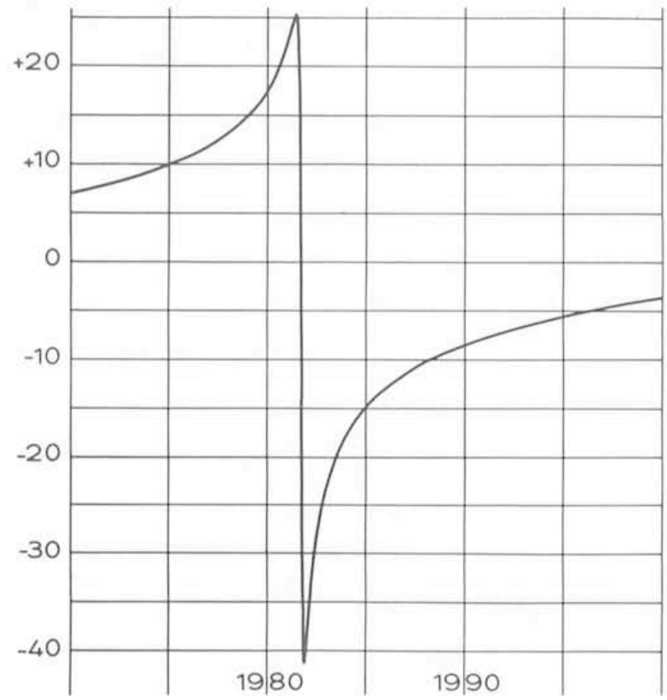

Fig. 1: *The radial velocity difference between the two components of the visual binary ADS 7662, which has an orbital period of 64.7 years and an eccentricity of 0.949 (Finsen, 1977).*

through a critical phase with peak radial velocity difference, as well as short-period pairs with marked radial velocity variation. These stars are observed at a reciprocal dispersion of 12 Å/mm, which is extremely well suited for accuracy and number of measurable lines.

. . . and Related Problems

The actual programme is not aimed at a long-duration observation. If it were, one would be able to combine radial velocity and visual measurements and compute combined spectroscopic-visual elements. The computational techniques are available (e.g. Morbey, 1975: *P. A. S. P.* **87,** 689), but the observational material is still lacking.

There are other purposes, though, that may be served on a shorter timescale. One concerns the identification of the node: the visual orbital elements yield the node $\Omega \pm 180°$. Given that the components are identified properly, a few radial velocity observations spaced sufficiently in time (and one can use older measurements for this purpose) may resolve the ambiguity in the plane of the orbit and allow us to decide whether the node is ascending or descending. This question may be of importance for statistical problems in our galaxy.

Another issue concerns the ambiguity that sometimes arises from visual measurements. Whenever the two components are of nearly equal magnitude, the visual observer is faced with an indetermination of quadrant and this frequently leads to two possible orbits. An example of such a case and the corresponding radial velocity curves are given in figure 2. It is clear that radial velocity observations ought to be able to decide between the two orbits.

Finally, there is an important subgroup among the visual binaries (of which we still consider only those with known orbital elements): those which are in fact triple or quadruple. In other words, visual pairs in which one component

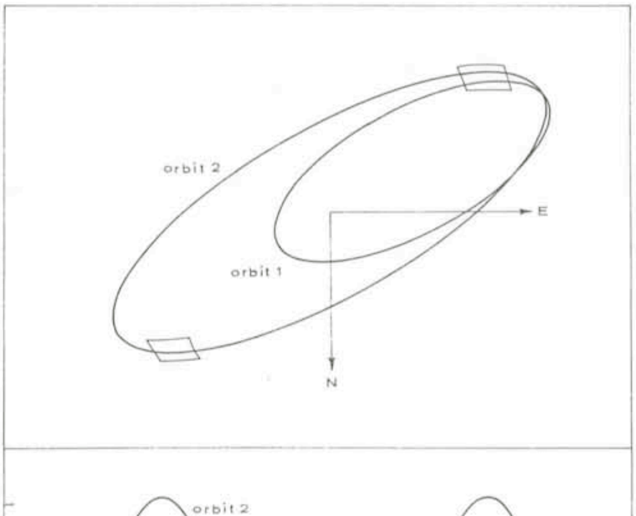

Fig. 2: *The case of B1909 (HR 108). Van den Bos calculated two equally possible orbits, the first with a period of 5.625 years (eccentricity 0.60), the second with a period of 11.25 years (e = 0). Both components are of magnitude 7.2. The two orbits as seen on the sky are shown in the upper part of the figure. A group of observations is indicated schematically by a quadrangle; because of the indetermination of quadrant (which star is the primary?) they are ± 180°. The relative radial velocity curves are shown in the lower part of the figure.*

or both are themselves spectroscopic binaries. These systems are interesting, because the statistics of their occurrence and their dimensions (mass and size) give us information about the formation of stars and stellar systems. In order to obtain a radial velocity curve for the visual pair, one has to determine the orbital elements, or at least v_o, of the spectroscopic binary at various epochs. In general, the systems are truly hierarchic ($P_{vis.} >> P_{spectr.}$), as is predicted by stability considerations. There are a few systems, though, that show lines of the three components and for which the hierarchy is less pronounced. The lines in such a case are intermingled in a complicated way. We have attacked two of those, which already have been described by Evans (see also Batten: Binary and multiple systems of stars), at a reciprocal dispersion of 3 Å/mm.

There are quite a number of systems with broad lines that are suspected of containing a spectroscopic binary, but the large scatter in radial velocity values will in many cases simply be due to the inevitable inaccuracy of the measurements. A few of the most striking cases have been added to the programme in order to bring, hopefully, some clarity.

All in all, the programme contains a rather large variety of interesting visual binary systems. The selection also has to count with the imminent putting to use of Coravel, i.e. radial velocity measurements by means of a mask. This method is faster, but there are certain limits to it (spectral type, angular separation of the components). On the other hand, the material of binaries for which visual data can be combined with radial velocities may well increase rapidly during the coming years. New, close pairs are discovered through occultation observations and can be measured with the speckle technique. Speckle observations can also deal with binaries that were hitherto only spectroscopic. We may at last be able in the coming years to arrive at a statistically significant number of stars with properly determined mass.

The plates are measured with the Grant machine of ESO, Geneva. It is a pleasure to compliment Jorge Melnick and Klaus Banse with the reduction facilities they have set up.

List of Preprints Published at ESO Scientific Group

June–August 1979

56. M. DENNEFELD and G. TAMMANN: Birthrate and Mass Function in the Magellanic Clouds. May 1979, *Astronomy and Astrophysics.*
57. O. M. KURTANIDZE and R. M. WEST: New Carbon Stars in Cygnus. May 1979, *Astronomy and Astrophysics.*
58. E. G. TANZI, M. TARENGHI, A. TREVES, M. C. W. SANDFORD, A. J. WILLIS and R. WILSON: Ultraviolet Observations of AM Herculis. June 1979, *Astronomy and Astrophysics.*
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60. E. B. HOLMBERG, A. LAUBERTS, H.-E. SCHUSTER and R. M. WEST. The ESO/Uppsala Survey of the ESO (B) Atlas of the Southern Sky—VII. June 1979, *Astronomy and Astrophysics Supplement Series.*
61. I. SEMENIUK: Photometry of V 436 Centauri during the Superoutburst in May 1978. July 1979, *Astronomy and Astrophysics.*
62. N. VOGT, W. KRZEMINSKI and C. STERKEN: Periodic and Secular Variations in the Lightcurve of Dwarf Nova ex Hydrae. July 1979. *Astronomy and Astrophysics.*
63. N. VOGT and J. BREYSACHER: The Dwarf Nova BV Centauri, a Spectroscopic Binary. Submitted to *Astrophysical Journal.*
64. PH. VERON, P. O. LINDBLAD, E. ZUIDERWIJK, M.-P. VERON, G. ADAM: On the Nature of the so-called Narrow Line X-ray Galaxies. Submitted to *Astronomy and Astrophysics.*
65. M. TARENGHI, W. G. TIFFT, G. CHINCARINI, H. J. ROOD, L. A. THOMPSON: The Hercules Supercluster I. Basic data. Submitted to *Astrophysical Journal* (Dec. 15, 1979).
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67. G. A. TAMMANN, A. YAHIL and A. SANDAGE: The Velocity Field of Bright Nearby Galaxies II. Luminosity functions for various Hubble types and luminosity classes. The peculiar motion of the local group relative to the Virgo cluster. August 1979, *Astrophysical Journal.*