References and Notes

Abbreviations used:

EHA = ESO Historical Archives (see *The Messenger* of December 1988).

FHA = Files Head of Administration at ESO Headquarters.

EHPA = ESO Historical Photographs Archives.

Heckmann Sterne = O. Heckmann, *Sterne, Kosmos, Weltmodelle,* Verlag Piper and Co., München–Zürich, 1976.

[1] Wykeham Publications Ltd., London–Winchester 1975.

[2] Heckmann Sterne, p. 323.

[3] For reports on work by Baranne, Köhler, and Paul of the years 1962 and 1963, see EHA-I.C.1.9.m.

[4] See page 118 of the Symposium Report.

[5] FHA, Minutes 28th meeting of the IC, p. 9/10.

[6] FHA, Doc. IC-26 = BG-16.

[7] FHA, Doc. IC-18 = BG-15.

[8] FHA, Minutes of the 12th Cou Meeting, p. 13.

[9] FHA, Doc. IC-24.

[10] For reports of these meetings, see FHA Docs. IC-27 and IC-29.

Observations of Visual Double Stars at La Silla

M. SCARDIA, Osservatorio Astronomico di Brera, Merate, Italy

Introduction

Of the many types of observing programmes made at La Silla with the most sophisticated equipment provided by modern techniques, one in particular distinguishes itself because it utilizes for the observations only the human eye, the oldest and most traditional of detectors used in astronomy. This research is the micrometric observation of visual double stars.

The concept of a visual double star is a relative one: by a visual double star we mean the whole of two or more stars, angularly close, which can be distinguished from each other through the eyepiece of the telescope. It is then evident that, when increasing the diameter of the telescope, ever more narrow double stars should become visible as distinct objects. However, there exists a lower limit, introduced by the earth's atmosphere, which is of the order of 0″.1. This limit to visual observations can sometimes be overcome by observers of great experience, on sites of particularly good seeing (Couteau, 1987).

The astronomy of visual double stars is by now over two centuries old. In 1778, W. Herschel, following one of Galileo's ideas, began systematic observations of visual double stars with the purpose of determining stellar parallaxes. He did not manage, comprehensibly, to determine any parallax, because the quantities to be measured were too small for the coarse micrometers of that period, but in 1803, with a publication that has made history (Herschel, 1803), he proved that physical binary stars were a reality and that the law of universal gravitation was valid also outside the solar system.

More than 600 astronomers after Herschel have measured visual double stars with various techniques, leaving a patrimony of about 1,000,000 individual measurements, summarized for practical purposes in over 410,000 annual averages.

This enormous task of observation has led to the discovery of over 70,000 double visual stars in the entire sky, of which about 900 have today a known orbit.

The history of the visual double star astronomy is a fascinating chapter in the history of Astronomy; for those who would like to examine it more closely, there are many articles and books that deal with it in detail (Baize, 1930 – Heintz, 1978 – Couteau, 1988).

The Method

The first "modern" measurements, by quality and accuracy, date back to 1828, and were made by F.G.W. Struve who used a refractor with a diameter of 24 cm at Dorpat in Esthonia. It was built by J. Fraunhofer and was at the time the greatest and the first conceptually modern instrument in the world. Struve discovered and measured 3134 double stars on the basis of a specific research programme.

We also owe to Struve the method of measurement of separations with the filar micrometer, known as the double distance method, commonly utilized even nowadays. The filar micrometer (utilized for over 80 % of visual measurements) is a very simple instrument: it is made up of a reticle of spider threads, placed in the focal plane of the telescope, two of which are fixed and perpendicular to each other. The third is mobile (by means of a micrometric screw) and is parallel to one of the fixed lines. The entire device can rotate around the optical axis of the telescope (Fig. 1).

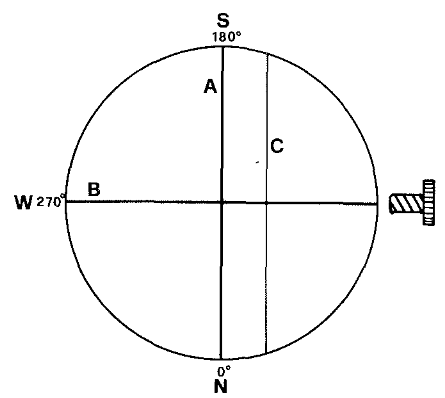

Figure 1: *Scheme of a filar micrometer: A and B are fixed wires, while C is the mobile wire whose movement is commanded by the rotation of the micrometric screw.*

The measurement of a visual double star consists in the determination of three fundamental parameters:

(a) the date of observation expressed in years and decimal fraction;

(b) the position angle ϑ, or the angle between the line that connects the two stars and the north direction, taking as the origin the "main" star (usually the brightest) (Fig. 2);

(c) the separation ϱ between the two stars, expressed in arcsec (Fig. 3). For this it is necessary to know the scale of the instrument in arcsec/mm.

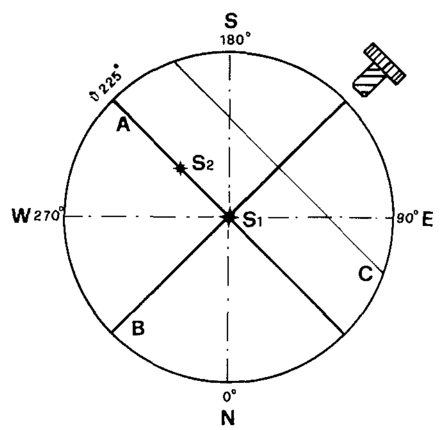

Figure 2: *The measure of the position angle ϑ is made by rotating the micrometer around the optical axis of the instrument so that the fixed wire A bisects the two stars S1 and S2. The most luminous star S1 is, by custom, considered the principal star and is chosen as the origin of the coordinates.*

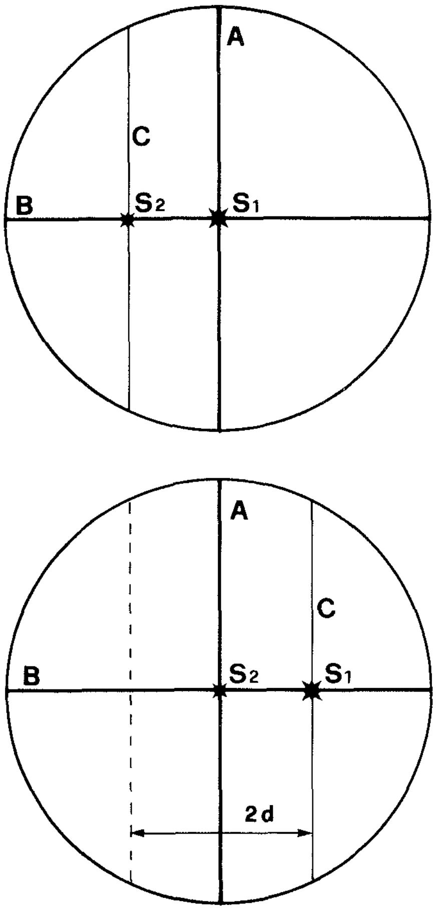

Figure 3: *The double distance method. To measure the separation, the micrometer is rotated in such a way that the fixed wire A and the mobile wire C are perpendicular to the line S1–S2. By means of the fine motion of the instrument the fixed wire A is superimposed exactly on the star S1 and by moving the micrometric screw the mobile wire C is brought to bisect the star S2 and a first reading of the micrometric screw is done. The operation is then repeated, bringing the fixed wire over the star S2 and the mobile one over S1. The difference between the two readings (2d), expressed in fractions of a millimetre, multiplied by the scale of the instrument expressed in arcsec/mm, gives us the double of the distance (ϱ) between the two stars in arcsec.*

An estimate of the difference in magnitude between the two stars is often added to these main quantities. Some brief comments on the measurement (the difficulty, the aspect of the couple, the state of the seeing, etc.) may be useful later, for a possible weighting. An essential condition however is that the seeing must be good.

"To measure well, you must see well": this principle, always valid, by Otto Struve, son of F.G.W. Struve and like his father a great observer of double stars, should never be forgotten by observers of visual double stars.

The Precision

The best instrument for this kind of high resolution observations is the traditional refractor, which was very common throughout the last century. Its long focus allows high magnification factors, which are essential in order to clearly examine the diffraction image provided by the lens. Experience teaches that an magnification which is 3–4 times the resolving magnification (the minimum magnification needed to see the diffraction image at the limit of visual acuity) is sufficient for this purpose. Also reflectors are currently used for such observations, but their use is more delicate because of the obstruction by the secondary mirror, of the less stable focus and of the higher sensibility to the air turbulence.

The precision which a good double star observer can reach is considerable; if the observing conditions are optimal, he can measure the separation of a large double star or estimate the one of a very narrow double (below the resolving power of the instrument used) with an uncertainty of only a few hundredth of an arcsec. For the position angle, the matter is different, because the uncertainty depends on the separation: from a few tenths of a degree for a well separated double star, to few degrees in case of a double star whose separation is just a bit more than half the resolving power of the objective used. In these conditions he will not see two distinct images anymore; the double star will appear like a slightly oval image (Fig. 4).

The final purpose of the observation of visual double stars is the calculation of the orbital elements which, once known by means of the third law of Kepler, make it possible (if the parallax is known) to determine the sum of the masses of the system.

The visual double stars, in conclusion, are indispensable for the determination of stellar masses, this fundamental parameter of astrophysics, which other types of binary known are not able to provide, except in particular cases. Few astronomers are aware of how modest the number of the accurately measured masses really is. The astronomical community usually uses the mass-luminosity relationship, but this empirical law is obtained experimentally starting from a few dozens of masses known.

The Patience

The observation of visual double stars necessarily implies long periods of time, because the huge majority of them has periods of hundreds, thousands and even tens of thousands of years. To obtain the orbital elements of a binary star, even only relatively reliable, it is necessary to observe at least half of its orbit. Hence the necessity for systematic and continuous observations and for a new generation to take the place of each generation of observers that passes. The astronomy of double stars is the branch of astronomy in which the ties between past, present and future are the closest. Today we are able to calculate an orbit only because earlier generations of astronomers have observed this star, and similarly our observations will be indispensable for the astronomers of the future. The unrelenting flow of time, instead of condemning these measurements to oblivion, makes them precious and indispensable.

It could be objected that astronomers don't have the patience to wait all this time to obtain more information about stellar masses, and that a sensible choice of the systems to be observed could shorten the waiting time. The problem has been dealt with and it has been proved (Couteau, 1978), on the basis of a hypothesis about the work which is very close to reality, that the rapidity with which information on masses can be obtained, grows as $D^{1.5}$, where D = diameter of the instrument. The large apertures allow the observation of narrower doubles, which have a higher probability of being short-period binaries and therefore give us information on their masses in few decades.

New techniques of observation, like the speckle interferometry, were implemented during the last twenty years, but are still little used. The potential of this technique, which was introduced by A. Labeyrie (Labeyrie, 1970) is great, especially for the very narrow double stars ($\varrho < 0\farcs2$), where the efficiency and the precision of the visual observation are lower. However, it is rather complicated and, for the time being, quite expensive in men and material, which is the opposite of the visual observation

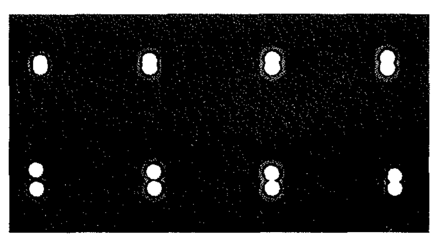

Figure 4: *The aspect of a double visual star for different values of the distance between the components. The distance is expressed in function of the radius of the first dark ring of the diffraction image (r = 1.22 λ/D).*
0.5 0.75 1.0 1.25
2.25 2.0 1.75 1.5
(taken from "Lunettes et Télescopes").

whose cost and complexity are very low. A comparison between the speckle measurements and the visual ones shows that they match very well, especially in the position angle (which is the most important parameter for the calculation of the orbital elements). However, as far as the separation is concerned, one sometimes gets the impression that the speckle measurements are systematically shorter than the visual ones, which on the whole, nevertheless, appear to have a higher dispersion. The observers of double stars are becoming progressively rarer: their number can already be counted on our fingertips. This speciality, which requires years of tough apprenticeship, suffers from the disaffection of the young who, dazzled by astrophysics, prefer theoretical researches or shorter, experimental ones requiring less observing engagement, which are able to offer secure funds and fast careers, because it is "fashionable". The indifference and, sometimes, the incomprehension of the astronomical community also contributes to making the work of the few who still devote themselves with passion to this type of research more difficult.

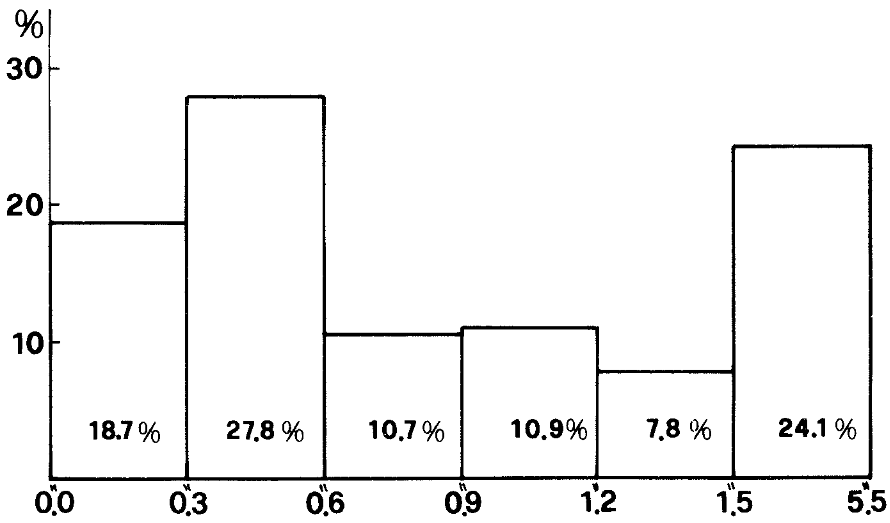

Figure 5: *Percentage of the measurements made at La Silla for each class of separation.*

Observations at La Silla

The southern hemisphere, which in the first half of this century was in a leading position, owing to the energetic activity of some great observers like Innes, Finsen, Van den Bos, Rossiter, etc., has been suffering for many years of complete neglect, because no astronomer is permanently observing any double star there, and the survey of the southern sky relies on the observing activity of only three astronomers, two North-Americans, Heintz and Worley, and the writer, the only European.

Only a few months ago the working group C.H.A.R.A. from Atlanta (U.S.A.), headed by H. McAlister, began to observe the double stars of the southern sky, using the 4-m telescope of Cerro Tololo and speckle interferometry.

At La Silla, the systematic observation of visual double stars of the southern sky began in 1986. The choice of the instrument fell on the GPO astrograph for very simple reasons: First, the GPO is a refractor with a diameter of 38 cm, whose limit of observation is close to 0″18. Its diameter, which is not very large, guarantees a good result, because it is hardly affected by the air turbulence; therefore, there is a high probability of having a good number of utilizable nights during each observing mission. It represents an excellent compromise between resolution power and yield. It is a simple instrument, robust and extremely reliable. This means no time wasted because of instrumental breakdowns. Second, the GPO is relatively little requested by the European astronomical community; it is therefore possible to obtain a reasonable number of nights in each observing period, thus optimizing the relative number of measurements/cost of the mission.

Small changes have been necessary to adapt the GPO astrograph to the visual observation of double stars. The correcting lens for astigmatism near the focal plane has been removed, because the observations are made on the optical axis. The original focal length, which is only 4 metres, has been increased to 9.5 metres, with a barlow lens; the examination of the image is made with a magnification of 760 times (4 times the resolving magnification). It was necessary to correct the chromatism of the objective, which has the minimum of the secondary spectrum close to 4300 Å, instead of the traditional 5600 Å, with a yellow filter GG 495 (initially a filter OG 530 had been used). In this way the troublesome blue halo around the bright stars which makes difficult the observation of fainter companions has been considerably reduced. The mounting, because of the position of the finder, prevents observation south of $\delta = -70°$, and the observation of objects near zenith is rather uncomfortable, because of the insufficient distance between the eyepiece and the floor of the dome. The ninth magnitude is the limit at which stars can be observed with reliability. But in spite of these restrictions, thousands of doubles of every separation are accessible for observation. The diffraction image provided by the lens is of good quality: it presents itself round and without defects. The observing programme foresees the observation of all the double stars, orbital and not, which satisfy the following conditions: (1) $\delta < 0°$, (2) $m < 9$, (3) $0''18 < \rho < 5''5$.

Each measurement of the position angle is an average of 8 or more set-

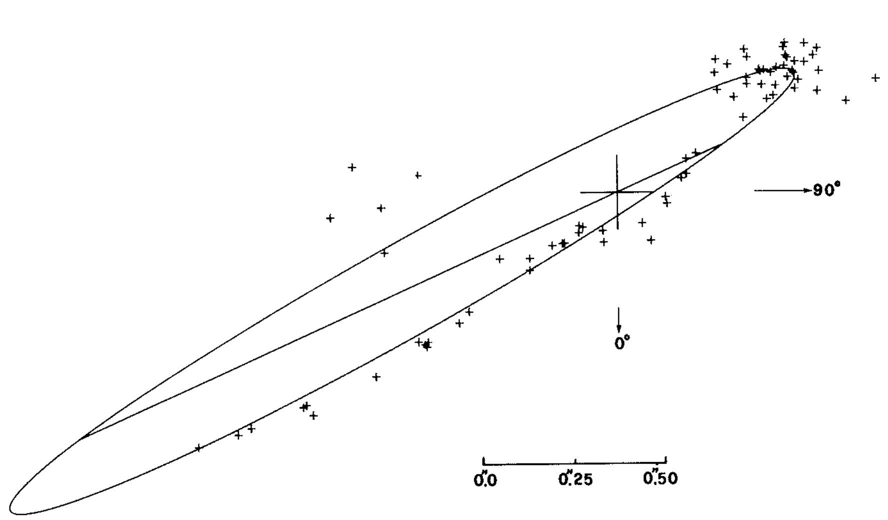

Figure 6: *Orbit of the binary star BU 738 (P = 305 years) obtained, utilizing also the measurements made at La Silla in the last few years.*

tings, while each measurement of separation is an average of 4 measures of the double distance.

It is possible now, after nearly four years and seven observing missions at La Silla, to make the first conclusions on the work done.

Regarding the air tranquillity, La Silla is largely superior to the average of European sites of which I have direct observing experience. 51% of the nights have been completely utilizable or in part (26% "good quality" nights and 25% "sufficient quality" nights), while during the remaining 49% of nights, bad seeing or covered sky have prevented the observations. A comparison with the seeing measurements made at Cerro Vizcachas has allowed to establish that, when the value measured there is better than 0″.7, generally, the images at the GPO can be considered good; in these conditions the diffraction image presents itself as stable and the "turbulence" is less than 0″.14 (for the definition of "turbulence", see Danjon and Couder, 1935, or Texereau, 1958).

Up till now, a total of 1840 measurements of 432 systems, down to separations of 0″.18, have been made at La Silla. Figure 5 shows the histogram of the percentages of the measurements made by class of separation.

From these first results, it is my firm belief that La Silla is a very valid site for the observation of visual double stars. The contribution that a good observer (who could rely full time, for this kind of observations, on the GPO astrograph, or on an instrument of superior class) could give to the astronomy of visual double stars and to the knowledge of stellar masses, would be fundamental.

A Final Plea

It is exactly because of the validity of the arguments exposed above that the voices heard in recent times "on the arid mountain" regarding the future of the small instruments are a cause of worry. They contribute to make even more uncertain the future of this branch of astronomy with great traditions, still scientifically valid, and which has lost none of its reasons of existence.

References

Baize, P., 1930, *L'Astronomie* **44,** 268.

Couteau, P., 1978, *L'observation des étoiles doubles visuelles,* Flammarion, Paris.

Couteau, P., 1987, *Astron. Astrophys. Suppl. Ser.* **70,** 193.

Couteau, P., 1988, *Ces astronomes fous du ciel,* Edisud, Aix-en-Provence.

Danjon, A., Couder, A., 1935, *Lunettes et télescopes,* Editions de la Revue d'Optique Théorique et Instrumentale, Paris.

Heintz, W. D., 1978, *Double Stars,* Reidel Publ. Company, Dordrecht.

Herschel, W., 1803, *Account of changes . . . in the relative situation of double stars,* Philos. Transactions, II part.

Labeyrie, A., 1970, *Astron. Astrophys.* **6,** 85.

Scardia, M., 1989, *Astrophys. Journ. Suppl. Ser.* **71,** 647.

Struve, F. G. W., 1837, *Stellarum duplicium et multiplicium mensurae micrometricae . . .,* Typographia Academica, Petropoli.

Texereau, J., 1961, La construction du télescope d'amateur, Société Astronomique de France, Paris.

Long-term Photometry of Herbig Ae/Be Stars in the Strömgren System

P. S. THÉ and E. BIBO, Astronomical Institute "Anton Pannekoek", University of Amsterdam, the Netherlands

Introduction

Our working group on the study of Herbigt Ae/Be stars has joined Sterkens group of Long-term Photometry of Variables from the beginning on. The photoelectric photometry is based on Strömgren's system and is done with the small ESO telescopes at La Silla. Since the magnitude limit for accurate measurements is about 9, in this long-term photometry we have monitored only the brighter 27 members of the Herbig Ae/Be stellar group. When after some time a star turned out to be non-variable we have discontinued observations of it. The study of Herbig Ae/Be stars, which usually are varying irregularly, is done for giving a better explanation of the complex problems connected with the variability of these ob-

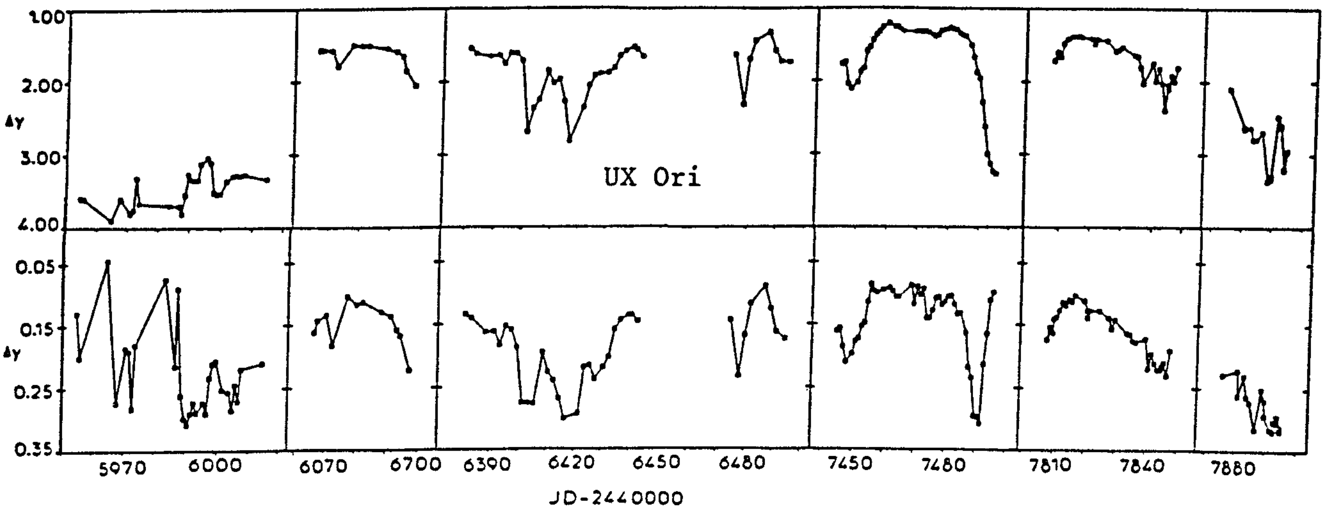

Figure 1: *The light curve of UX Ori. The star remains quite a long time at maximum brightness, but can leave it, and stay many days close to its minimum brightness.*