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# INTERFEROMETER OBSERVATIONS OF DOUBLE STARS[1]

By PAUL W. MERRILL

ABSTRACT

*Interferometer observations of double stars.*—(1) *Revised elements of the orbit of Capella* were obtained by combining the previously reported measurements of Anderson, slightly corrected, with observations made on ten nights from October, 1920, to April, 1921, using the rotating interferometer attached to the 100-inch telescope. The chief results are: $P=104.022$ days; $a=0''.05360$; $a_1+a_2=126.63\times10^6$ km; $\pi=0''.0632$; $m_1=4.2\odot$; $m_2=3.3\odot$. The average residuals are 1° for position angle and 0''.0007 for separation. (2) $\kappa$ *Ursae Majoris* was independently discovered as a double and was measured on five nights, March 1 to April 30, 1921. The separation decreased from 0''.0836 to 0''.0772, but the position angle changed only 2°. One component is brighter by perhaps half a magnitude. (3) $\nu^2$ *Boötis* was found to be difficult to measure as the fringes behaved abnormally, so only a rough measurement was possible. The system may be complex. (4) *Search for new measurable double stars.* Some spectroscopic binaries, stars with composite spectra, variable stars, and some bright stars taken at random—in all 85 stars, of varying magnitude down to 5.7 (Table IV)—were examined for duplicity, but with the exception of six doubtful cases, $\delta$ Cancri, 10 Leonis Minoris, $o$ Leonis, $\epsilon$ and $f$ Ursae Majoris, and $\upsilon$ Sagittarii, no changes in fringe visibility with position angle of the interferometer were observed.

Tests by Michelson at the Yerkes and Mount Wilson observatories[2] showed that even in poor seeing interference fringes can be observed in star images with slit separations ranging from 40 to nearly 100 inches. Following these results in an attempt to make the interference method sufficiently accurate and convenient to justify its extended use in the measurement of double-stars, Mr. Anderson devised a new type of stellar interferometer with which settings are made by rotating a pair of fixed slits. This instrument he applied with great success to the determination of the relative positions of the components of Capella.[3] His measures of distance, on five nights, ranged from 0''.0418 to 0''.0505, while the position angles were shown to be decreasing at a rate in keeping with a revolution period of 104 days. A double-star orbit was computed by him, using the spectroscopic elements previously determined at the Lick Observatory.

[1] *Contributions from the Mount Wilson Observatory*, No. 240.

[2] *Mt. Wilson Contr.*, No. 184; *Astrophysical Journal*, **51**, 257, 1920.

[3] *Mt. Wilson Contr.*, No. 185; *Astrophysical Journal*, **51**, 263, 1920.



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It is interesting to note that in 1900 J. Miller Barr called attention to the desirability of attempting the observation of Capella as a double star by interferometer methods.[1]

The present paper is a record of further applications of the rotating type of interferometer to known double stars, and to a search for new doubles of small angular separation. The 100-inch Hooker telescope was used in all the observations, and practically the same procedure as that described by Anderson was followed throughout.

The constants of the interferometer were re-determined independently. The factor which is used to reduce the actual separation of the slits to their corresponding separation in the Gauss plane was found by dividing the equivalent focal length of the telescope, 1606 inches, by 28.00 inches, the distance of the slits from the focus. The value thus obtained, 57.34, was checked by a direct determination. At the upper end of the telescope tube, on the struts supporting the secondary mirror, were placed two rectangular pieces of wood of the same shape as the slits, but with dimensions slightly smaller than those of the slits as projected in the Gauss plane. Thus, when the telescope was directed to a bright star, by removing the eye-piece and placing the eye at the focus, the blocks could be centered in the slits, leaving lines of light at the edges. The separation of the blocks, divided by the separation of the slits, gives the factor desired. This experiment yielded the value 57.2, which was thought to be a trifle small. The factor adopted for all the reductions was 57.3, which falls within the limits of uncertainty of both determinations.

## CAPELLA

R.A. 1900 = $5^h9^m.3$; Dec. 1900 = $+45°54'$; Mag. 0.2; Class G0.

Additional interference measures of Capella have been made by the writer on ten nights, and a revised orbit has been calculated.

As the series of observations was made during the winter months poor seeing was frequently experienced. Although the observing routine could usually be carried through in the regular way, on a few occasions the conditions became so bad that reliable settings

[1] *Astrophysical Journal*, 11, 248, 1900.

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could be made only by watching patiently and utilizing the best moments. The nights on which bad seeing prevents interferometer observations of Capella are quite rare. This is not true to the same extent of fainter stars.

The new measures of Capella appear in Table I, in which the third column, with the heading Slits, gives the separation (in the Gauss plane) of the slits; the fourth column, $\eta$, contains the

TABLE I

OBSERVATIONS OF CAPELLA

| Date | P.S.T. | Slits | $\eta$ | $\theta$ | $\rho$ | |
|---|---|---|---|---|---|---|
| 1920 Oct. 5.... | $16^h 15^m$ | 174.2 cm | 46°65 | 253°9 | 474 | |
| Nov. 3.... | 13 20 | 142.8 | 24.75 | 164.8 | 437 | |
| | 14 05 | 173.3 | 41.90 | 164.6 | 440 | |
| | 14 39 | 203.6 | 50.80 | 163.8 | 441 | |
| 1921 Jan. 14.... | 7 36 | 142.2 | 30.12 | 263.5 | 461 | |
| | 8 31 | 172.6 | 45.25 | 262.9 | 467 | |
| | 9 08 | 202.9 | 52.65 | 262.2 | 461 | |
| | 10 25 | 202.9 | 51.78 | 261.2 | 452 | Weight ½ |
| Jan. 31.... | 7 07 | 142.2 | 43.45 | 213.7 | 550 | |
| | 7 19 | 172.6 | 52.40 | 214.0 | 539 | |
| | 7 29 | 202.9 | 58.82 | 214.8 | 540 | |
| | 7 46 | 123.9 | 33.32 | 212.8 | 548 | |
| Feb. 2.... | 7 18 | 172.6 | 52.67 | 209.8 | 542 | |
| | 7 52 | 142.2 | 43.30 | 208.6 | 548 | |
| | 8 55 | 202.9 | 58.07 | 207.9 | 529 | Weight ½ |
| Mar. 1.... | 6 52 | 172.6 | 36.95 | 106.0 | 411 | |
| | 7 10 | 202.9 | 47.00 | 105.6 | 410 | |
| | 7 23 | 232.8 | 53.25 | 106.2 | 407 | |
| Mar. 2.... | 6 44 | 202.9 | 48.32 | 101.2 | 421 | |
| | 6 52 | 172.6 | 39.22 | 102.4 | 424 | |
| | 7 04 | 232.8 | 54.35 | 101.4 | 418 | |
| Mar. 3.... | 6 52 | 172.6 | 39.27 | 98.1 | 425 | |
| | 7 08 | 202.9 | 48.10 | 97.8 | 419 | |
| | 7 23 | 232.8 | 54.05 | 98.4 | 415 | |
| Mar. 31.... | 7 07 | 172.6 | 51.00 | 15.0 | 522 | |
| | 7 23 | 202.9 | 56.60 | 14.2 | 508 | |
| | 7 38 | 142.2 | 38.87 | 14.3 | 512 | |
| Apr. 1.... | 7 16 | 142.2 | 37.50 | 11.4 | 503 | |
| | 7 35 | 172.6 | 48.65 | 11.4 | 498 | |
| | 7 55 | 202.9 | 56.32 | 11.7 | 504 | |

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angle of projection for minimum fringe visibility;[1] the fifth column, $\theta$, the position angle of the components; and the sixth column, $\rho$, their separation in units of one ten-thousandth of a second of arc, i.e., 474 = 0."0474. The effective wave-length was taken to be 5500 A.

In Table II are collected the mean values for each night. The weights assigned depend principally on the number of complete individual observations. The total number of settings was increased during poor seeing in an attempt to give approximately standard accuracy to each complete observation. Since the factor 57.3 is somewhat smaller than that used by Anderson in the first observations, it was decided by mutual agreement between him and the writer that it would be better to change the original reductions. Hence the first five values of $\rho$ in Table II are larger by 2.4 per cent than the corresponding figures in *Contribution* No. 185.

TABLE II

MEAN CO-ORDINATES OF COMPONENTS OF CAPELLA

| G.M.T. | | | | $\theta$ | O−C | $\rho$ | O−C | Weight | |
|---|---|---|---|---|---|---|---|---|---|
| (1) | 1919 | Dec. | 30.65..... | ....... | ....... | 428 | +3 | ⅓ | Anderson |
| (2) | 1920 | Feb. | 13.63..... | 5.0 | +2.2 | 469 | −7 | ⅔ | Anderson |
| (3) | | Feb. | 14.65..... | 1.0 | +1.6 | 462 | −6 | 1 | Anderson |
| (4) | | Feb. | 15.66..... | 356.4 | +0.5 | 454 | −6 | 1 | Anderson |
| (5) | | Mar. | 15.63..... | 242.0 | +1.9 | 517 | +10 | ⅔ | Anderson |
| (6) | | Apr. | 23.63..... | 107.0 | +0.4 | ....... | ....... | ⅓ | Anderson |
| (7) | | Oct. | 6.01..... | 253.9 | +2.6 | 474 | −7 | ⅓ | .......... |
| (8) | | Nov. | 3.92..... | 164.4 | −1.6 | 439 | −4 | 1 | .......... |
| (9) | 1921 | Jan. | 14.70..... | 262.6 | −0.1 | 461 | +5 | 1 | .......... |
| (10) | | Jan. | 31.64..... | 213.8 | +0.6 | 544 | +11 | 1 | .......... |
| (11) | | Feb. | 2.66..... | 208.9 | +1.1 | 542 | +14 | 1 | .......... |
| (12) | | Mar. | 1.63..... | 105.9 | −0.9 | 409 | −11 | 1 | .......... |
| (13) | | Mar. | 2.62..... | 101.6 | −1.1 | 421 | −5 | 1 | .......... |
| (14) | | Mar. | 3.63..... | 98.1 | −0.4 | 420 | −12 | 1 | .......... |
| (15) | | Mar. | 31.64..... | 14.5 | −1.0 | 514 | +7 | 1 | .......... |
| (16) | | Apr. | 1.65..... | 11.5 | −1.0 | 502 | +2 | 1 | .......... |

The orbital elements deduced by Anderson gave a fair representation of the additional observations but it was found possible to make some slight improvements.

[1] The out-of-step appearance of the fringes shown in Anderson's laboratory experiments (see illustration in *Mt. Wilson Contr.*, No. 185) was not observable. Accordingly the sensitive method of fringe bisection could not be used, but settings were made for the minima of visibility.

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By comparing recent spectroscopic observations at Mount Wilson with those made at the Lick Observatory in 1900 Sanford[1] has found that the original figures for the period, 104.022 days, are very nearly correct. Accordingly this value has been used throughout the present computations.

Preliminary trials showed that the eccentricity is probably smaller than 0.016 as given by Reese. Hence it did not seem necessary to vary both $T$ and $\omega$. The date 2422596.79 was chosen for $T$ by trial and retained thereafter. This corresponds to a periastron time 0.8 days later than that adopted by Anderson. Corrections to $a$ and to ☊ were then found by direct algebraic processes. Finally a least-squares solution was carried through for the elements $\omega$, $i$, and $e$. This yielded very small corrections to the preliminary values.

The adopted elements follow:

$T$ = J.D. 2422596.79
$P$ = 104.022 days, angles decreasing.
$\omega = 114^\circ.30$
$i = -41^\circ.08$
☊ $= 38^\circ.70$
$e = 0.0086$
$a = 0''.05360$

To these may be added the following quantities found by combining the foregoing elements with the spectroscopic results:

$a_1 + a_2 = 126{,}630{,}000$ km  $m_1 = 4.2\odot$
$\pi = 0''.0632$  $m_2 = 3.3\odot$

The residuals from these elements are given in Table II. They are considerably larger than one might expect from the degree of accordance of the individual observations as shown by Table I. Moreover, observations made on successive nights exhibit a tendency toward similar residuals. This would seem to mean either that there are systematic errors in the observations, or that the best orbital elements have not been found, or that the orbit is not a true ellipse, or that there is present a combination of two or three of these causes.

[1] *Publications Astronomical Society of the Pacific*, **34**, 178, 1922.

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As to systematic errors it must be admitted there are possibilities of slight effects. For instance, no ready direct method was found of checking the position angle circle of the interferometer when attached to the telescope, so that the actual position angles of the slits may conceivably have differed by small amounts from the angles as read from the circle. Again, the condition of the telescope mirrors, the position of the struts supporting the secondary mirror, the settings of the compensator, the exact location of the focus, the condition and position of the observer's eyes, may have been responsible for small systematic errors. For the most refined results in an extensive investigation all these factors should receive attention.

In regard to the orbital elements it may be that a different set of values would give smaller residuals. Indeed it has been found by taking $T=2422563.76$, $\omega=0\overset{\circ}{.}0$, $e=0.01$, that the residuals in $\rho$ are considerably reduced while the $\theta$ residuals are somewhat increased. With a circular orbit the representation is also very good. This indicates that as far as the interferometer observations are concerned the eccentricity and the time of periastron are practically indeterminate. As compared with the spectroscopic orbit this condition doubtless arises from the flexibility of the double star orbit due to the inclusion of the element representing the inclination of the orbit plane. By varying the orbital elements *arbitrarily* a better set of residuals than those in Table II could probably be found, but in view of the spectroscopic data there would apparently be no physical justification for such procedure and it has been thought better to retain the elements given on page 44 until future observations shed more light upon the situation.

One curious feature appears with several different trial sets of orbital elements, namely, that the early observations persist in giving positive residuals for $\theta$ (O−C). This may be due either to a systematic difference between Anderson's observations and the writer's, or to perturbations causing the position angle of the real node to decrease with time at the rate of about $2\overset{\circ}{.}4$ per year, or about $0\overset{\circ}{.}6$ in one orbital revolution. The physical interpretation and probability of such a perturbation may be a matter of interest to mathematical astronomers.

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If, from the orbit adopted in this paper, we compute the position angles corresponding to the Greenwich observations[1] in 1900 (mean places), we find a fairly consistent set of residuals averaging $+18^\circ$. Compared with the interferometer observations, this residual would be removed by a motion of the node of $0^\circ.9$ per year in the same direction as that suggested by the residuals of the interference measures themselves.

Capella presents one of the very small number of cases in which a comparison of the visual and spectroscopic data leads to an accurate value of the parallax. The value found in the present investigation, $0''.063$, agrees well with the mean trigonometric determination, $0''.067$, and the spectroscopic value,[2] $0''.076$.

### $\kappa$ URSAE MAJORIS

R.A. 1900 = $8^h 56^m.8$, Dec. 1900 = $+47^\circ 33'$; Mag. 3.7; Class A0.

On the night of March 1, 1921, Mr. Anderson and the writer were engaged in making some tests in connection with the stellar interferometer attached to the Hooker telescope, of a special apparatus[3] devised by the former to produce an artificial double star of known separation by means of which the constants used in the regular reductions might be checked. It consisted of a quartz plate two and a half millimeters thick, cut at $45^\circ$ to the optic axis, which, when mounted in the converging beam, transformed a single star into a double star having a separation of 12 microns, which corresponds to $0''.06$ at the Cassegrain focus of the Hooker telescope. When the telescope was pointed toward $\kappa$ Ursae Majoris and the observations were begun, anomalous results were obtained. Instead of the usual *four* minima in a complete revolution, a larger number appeared. We recognized that the behavior corresponded to that of a quadruple star and surmised that the star would be measurable as a double without the quartz plate. Proceeding at once to verify this by removing the quartz plate and making settings in the ordinary manner, we determined the position angle and separation to be $251^\circ.9$ and $0''.0836$. It was not

[1] *Monthly Notices, Royal Astronomical Society*, **61**, 72, 1901.

[2] *Mt. Wilson Contr.*, No. 199; *Astrophysical Journal*, **53**, 34, 1921.

[3] *Mt. Wilson Contr.*, No. 222; *Astrophysical Journal*, **55**, 48, 1922.

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until a few days later that we learned that this star is a known double, A 1585, discovered by Aitken[1] in 1907 when its separation was about twice as great. This incident illustrates the fact that a close quadruple star can readily be detected by the interference method.

Subsequent interferometer measures made during March and April 1921 showed that the separation was decreasing at the rate of 0″.003 per month, and the position angle by about one degree per month.

TABLE III

MEASURES OF κ URSAE MAJORIS

| Date | Position Angle | Distance | |
|---|---|---|---|
| 1907.83 | 283°.2 | 0″.21 | Aitken, micrometer |
| 1909.33 | 281.4 | 0.25 | Aitken, micrometer |
| 1919.29 | 264.9 | 0.15 | Aitken, micrometer |
| 1921 Mar. 1 | 251.9 | 0.0836 | ........ |
| Mar. 2 | 252.5 | 0.0833 | ........ |
| Mar. 31 | 251.3 | 0.0801 | ........ |
| Apr. 1 | 250.7 | 0.0796 | ........ |
| Apr. 30 | 250.2 | 0.0772 | ........ |

In good seeing the fringes are quite distinct even at minimum visibility, showing that the components are not equal. The magnitude difference is perhaps two or three times as great as in Capella, but probably does not much exceed one-half of a magnitude.

## $\nu^2$ BOÖTIS

R.A. 1900 = $15^h28^m.2$; Dec. 1900 = $+41°14'$; Mag. 5.0; Class A2.

At the suggestion of Dr. Aitken the double star $\nu^2$ Boötis, A 1634,[2] was placed upon the observing list. This close double of separation 0″.1 or less had been found to be a difficult object to resolve with the Lick 36-inch refractor. His observations[3] indicate that the position angle has decreased from 237° in 1907 to about 213° in 1920.

Examination of this star with the interferometer showed that the visibility changed as the slits were rotated, but observations on

[1] *Lick Observatory Bulletin*, 4, 168, 1908.

[2] *Ibid.*

[3] Kindly communicated by letter.

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different nights, and with different slit separations, did not yield the consistent results obtained with Capella and $\kappa$ Ursae Majoris, and to be expected of any double star. The observations were rather difficult on account of the faintness of the image. The regular sized slits were employed although it might have been an advantage to use larger ones.

On the night of June 18, 1921, immediately following rather unsuccessful attempts at measurement, this note was written:

> Seeing and visibility are good but settings on $\nu^2$ Boötis seem almost impossible. Fringes are certainly visible in all position angles at 108.9, 142.2, 172.6, and 202.9 cm (slit separation). It is a question of *small* differences in visibility; these differences seem smaller tonight than previously. One must guard against the physiological factor that fringes appear more distinct when parallel to the line joining the eyes. This may cause some of the above readings to be illusory. However, I believe there are real variations in visibility. Perhaps the star is triple or complex. Sometimes there appear to be regions 20° to 30° wide of low visibility. There appear to be "shoulders" in the visibility curve; i.e., the visibility drops off on rotating 5°–10° but does not return at once on rotating further. Star is a puzzle so far. Perhaps a wide double with one star a close pair.

Mr. Humason also examined this star on the same evening, June 18, 1921, and thought the variations in visibility to be real.

If we assume the object to be a double star the most probable result deduced from all the settings appears to be $\theta = 192°$, $\rho = 0\overset{''}{.}061$. This depends very largely on observations with a slit separation of 142.2 cm. The mean epoch was May 1921.

## EXAMINATION OF STARS FOR DUPLICITY

A number of stars have been tested for evidences of duplicity by looking for variations in the visibility of the fringes as the slits were rotated. Slit separations up to 200 cm (80 inches) were used in nearly all cases. The stars in Table IV exhibited no appreciable variation of fringe visibility with position angle of the slits. If these stars are double, their components could not have been as much as $0\overset{''}{.}03$ apart on the date of observation, provided their magnitudes are nearly equal. If the difference in magnitude is greater than 0.5, changes in visibility might escape detection unless the circumstances were especially favorable. The stars

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examined include spectroscopic binaries, stars with composite spectra, variable stars, and some bright stars taken at random.

TABLE IV

STARS APPARENTLY SINGLE

| Star | Mag. | R.A. 1900 | Star | Mag. | R.A. 1900 |
|---|---|---|---|---|---|
| β Persei | var. | $3^h$ $1^m7$ | d Boötis | 4.8 | $14^h$ $5^m8$ |
| ζ Tauri | 3.0 | 5 31.7 | α Boötis | 0.2 | 14 11.1 |
| 51 Aurigae | 5.7 | 6 31.7 | A Boötis | 4.8 | 14 13.8 |
| $\psi^5$ Aurigae | 5.3 | 6 39.5 | θ Boötis | 4.1 | 14 21.8 |
| α Geminorum | 2.0, 2.8 | 7 28.2 | ρ Boötis | 3.8 | 14 27.5 |
| β Geminorum | 1.2 | 7 39.2 | ε Boötis | 2.7, 5.1 | 14 40.6 |
| 40 Lyncis | 3.3 | 9 15.0 | 109 Virginis | 3.8 | 14 41.2 |
| θ Urs. Maj. | 3.3 | 9 26.2 | β Boötis | 3.6 | 14 58.2 |
| ε Leonis | 3.1 | 9 40.2 | δ Boötis | 3.5 | 15 11.5 |
| η Leonis | 3.6 | 10 1.9 | ι Draconis | 3.5 | 15 22.7 |
| α Leonis | 1.3 | 10 3.0 | β Cor. Bor. | 3.7 | 15 23.7 |
| λ Urs. Maj. | 3.5 | 10 11.1 | ν Boötis | 5.2 | 15 27.3 |
| ζ Leonis | 3.6 | 10 11.1 | α Cor. Bor. | 2.3 | 15 30.5 |
| μ Urs. Maj. | 3.2 | 10 16.4 | κ Serpentis | 4.3 | 15 44.2 |
| ρ Leonis | 3.8 | 10 27.5 | α Scorpii | 1.2 | 16 23.3 |
| 46 Leo. Min. | 3.9 | 10 47.7 | β Herculis | 2.8 | 16 25.9 |
| ψ Urs. Maj. | 3.2 | 11 4.0 | α Herculis | 3.5, 5.4 | 17 10.1 |
| δ Leonis | 2.6 | 11 8.8 | δ Herculis | 3.2 | 17 10.9 |
| ξ Urs. Maj. | 4.4, 4.9 | 11 12.9 | π Herculis | 3.4 | 17 11.6 |
| ν Urs. Maj. | 3.7 | 11 13.1 | ο Herculis | 3.8 | 18 3.6 |
| χ Urs. Maj. | 3.8 | 11 40.8 | d Serpentis | 5.3 | 18 22.1 |
| 93 Leonis | 4.5 | 11 42.8 | α Lyrae | 0.1 | 18 33.6 |
| β Leonis | 2.2 | 11 44.0 | β Lyrae | Var. | 18 46.4 |
| β Virginis | 3.8 | 11 45.5 | 113 Herculis | 4.6 | 18 50.5 |
| γ Urs. Maj. | 2.5 | 11 48.6 | β Cygni | 3.2, 5.4 | 19 26.7 |
| δ Urs. Maj. | 3.4 | 12 10.5 | δ Sagittae | 3.8 | 19 42.9 |
| γ Corvi | 2.8 | 12 10.7 | η Aquilae | Var. | 19 47.4 |
| η Virginis | 4.0 | 12 14.8 | 31 Cygni | 4.0 | 20 10.5 |
| δ Corvi | 3.1 | 12 24.7 | 32 Cygni | 4.2 | 20 12.3 |
| 8 Can. Ven. | 4.3 | 12 29.0 | β Capricorni | 3.2 | 20 15.4 |
| δ Virginis | 3.7 | 12 50.6 | 47 Cygni | 4.8 | 20 30.0 |
| 43 Com. Ber. | 4.3 | 13 7.2 | α Equulei | 4.1 | 21 10.8 |
| 20 Can. Ven. | 4.7 | 13 13.1 | 14 Pegasi | 5.0 | 21 45.4 |
| ζ Urs. Maj. | 2.4, 4.0 | 13 19.9 | δ Cephei | Var. | 22 25.4 |
| 17 Can. Ven. | 5.0 | 13 30.3 | η Pegasi | 3.1 | 22 38.3 |
| τ Boötis | 4.5 | 13 42.5 | ο Androm. | 3.6 | 22 57.3 |
| η Boötis | 2.8 | 13 49.9 | | | |

NOTES

$7^h28^m2$, α Geminorum, both components, 2.0, 2.8.
11 12.9, ξ Urs. Maj., both components, 4.4, 4.9.
13 19.9, ζ Urs. Maj., both components, 2.4, 4.0.
14 40.6, ε Boötis, both components, 2.7, 5.1.
17 10.1, α Herculis, both components, 3.5, 5.4.
18 22.1, d Serpentis, brighter component, 5.3.
19 26.9, β Cygni, both components, 3.2, 5.4.

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Although the dates of observation, slit separations employed, the seeing, and notes on any apparent peculiarities were, of course, recorded in the observing book and will be made available to anyone interested in a particular star, these details do not seem worth publishing. For the most part the dates of observation lie between February 1 and June 17, 1921. Several stars observed by Anderson about a year earlier are included in Table IV. On a few nights Mr. Humason alternated with the writer in the examination of stars for duplicity.

Variations in visibility for *f* Ursae Majoris (R.A. 1900 = $9^h1^m.9$; Dec. 1900 = $+52°0'$; Mag. 4.5; Class A3p) were suspected on the night of April 30, 1921, but a complete set of minima as for a double star was not obtained and the variations were not definitely confirmed.

The following stars were also suspected of changes in visibility, but the reality of the changes is doubtful. They do, however, deserve careful re-examination, which it is hoped other observers will give them, as the double star work at the Mount Wilson Observatory has been discontinued.

| | Mag. | R.A. 1900 |
|---|---|---|
| δ Cancri | 4.2 | $8^h39^m.0$ |
| 10 Leo. Minor | 4.6 | 9 28.1 |
| o Leonis | 3.8 | 9 35.8 |
| ε Urs. Maj. | 1.7 | 12 49.6 |
| υ Sagittarii | 4.6 | 19 16.0 |

In searching for doubles with the interferometer, poor and, in particular, variable seeing is a great disadvantage and renders conclusions uncertain. To illustrate this the following quotations from the observing record may be of interest.

γ Boötis — R.A. 1900 = $14^h28^m.1$; Dec. 1900 = $+38°45'$; Mag. 3.0; Class F.

1921 April 1 — Seeing fair. "Several times suspected slight variations but cannot make any settings. Probably single."

June 16 — Seeing poor. "Visibility very low on account of poor seeing. Fringes seen only by rare glimpses."

June 18 — Seeing fair. "Round."

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| | |
|---|---|
| γ Lyrae | R.A. 1900 = $18^h55^m.2$; Dec. 1900 = $+32°33'$; Mag. 3.3; Class A. |
| 1921 April 30 | Seeing good but rather irregular. "Suspect slight variation but may not be real." |
| June 14 | Seeing poor and variable. "Followed around at 142 cm with some suspicion as to variability (doubtless due to variable seeing). Followed partly around at 173 cm but seeing turned very poor and fringes disappeared." |
| June 17 | Seeing poor. "About equally distinct in all position angles at 142 cm and 197 cm. Fairly well seen by waiting for best moments." |

While complete disappearance of the fringes, as for a close double of equal components, would be noticed in any except the very worst seeing, small variations in visibility cannot be recognized with certainty in poor and irregular seeing. Thus the suspected doubles noted in preceding paragraphs may be spurious, while some of the stars in Table IV may prove to have small variations in visibility, due to unequal components, which were overlooked by the writer. The brighter the star the less the difficulty caused by the seeing.

### GENERAL REMARKS

In the Mount Wilson interferometer the slits are separated by turning a divided head, the readings of which are calibrated in terms of the actual slit separation. For systematic double star observations it would probably be better to replace this design by a metal plate containing pairs of slits at several fixed separations so arranged that any pair could be easily moved to the center of the field, the others remaining covered. Time would be saved in observing and the possibility of errors in setting and reading the separations greatly reduced. The separations, moreover, would not be subject to change with time or with readjustment of the instrument, unless the distance of the plate from the focus were changed.

The accuracy of the results obtained by Anderson's method of rotating the apertures and the convenience with which it can be applied are so great as to make it probable that this method will become very important in the future of double star astronomy. The range in the separations and magnitude differences of the double stars to which it can be successfully applied is, of course,

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small, but the interferometer results would supplement the ordinary micrometer measures in a most desirable way, making it possible to follow some very close and especially interesting pairs with highly satisfactory precision. The new pairs discovered by the interferometer will not be numerous as compared to those now known through direct observations, but they are likely to be of very great individual importance.

The present investigation has been greatly facilitated by Mr. Anderson's kindness in placing his experience with the stellar interferometer in so far as possible at the disposal of the writer, and by considerable assistance in securing and recording the observations. This kindness is gratefully acknowledged, as well as that of Mr. Humason in aiding with the observations on several nights.

MOUNT WILSON OBSERVATORY
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