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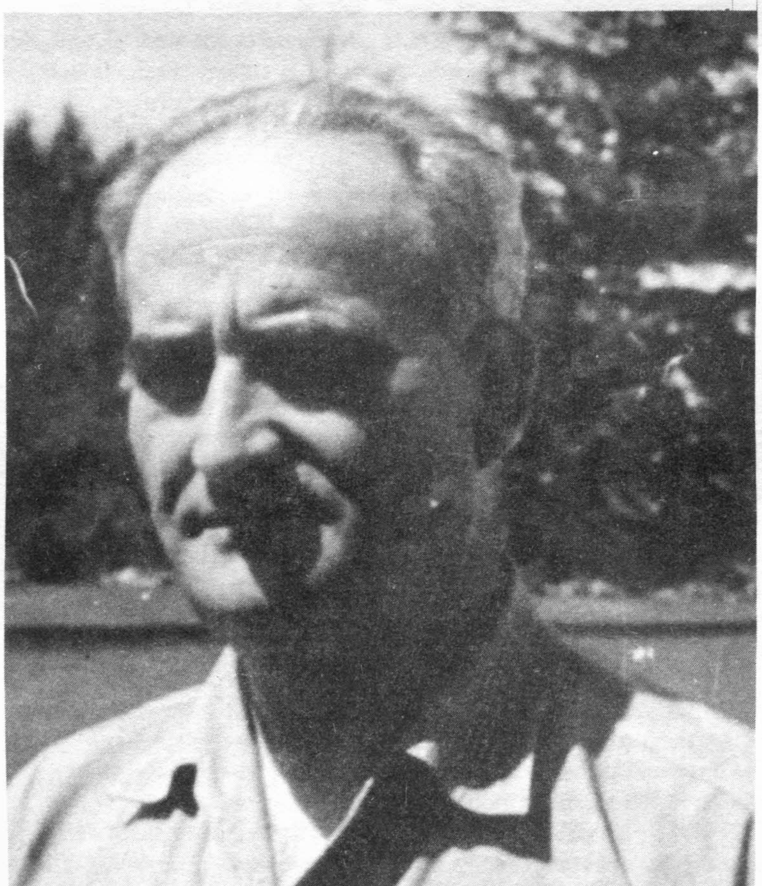
Obituary

Prof. Dr Zaharije M. Brkić

(1910–1979)

The fellows of the Belgrade Observatory are grieved at learning of the death of Prof. Dr Z. M. Brkić, who – – from 1938 to 1972 – was its very active collaborator. Professor Brkić contributed considerably to the formation of the Observatory. Particularly appreciated is his share in the creation and developing of the Time Service, headed by him for a long time. Thanks, obave all, to his infatiguable work, this Service took a successful course, which resulted in its inclusion into the International Time Service. Most of his scientific papers appeared in the Observatory's publications.

Belgrade astronomers are joined in their mourning by collegues throughout the country as by the death of Professor Brkić another of Yugoslav astronomy's pioneering workers is gone.



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NEW TENDENCIES OF THE RESEARCH INTO THE ASTRONOMICAL REFRACTION*

G. Teleki

SUMMARY:

A review is given of the more recent researches into the refractional influences, with special emphasis on those new tendencies in studying or eliminating the influence of the astronomical refraction (prevention, three-dimensional refraction, multi-wave methods, the use of the artifical satellites) of which it is expected to considerably promote our knowledge of this phenomenon.

I. INTRODUCTION

In more recent time an increased interest in the studying the atmospheric, among them the refractional, influences on the astronomical measurements is being felt. This is also evidenced by the number of the published papers: in the period 1976–1979 75 papers, dealing with this subject, are registered. An IAU/IAG Symposium on the refractional influences in astrometry and geodesy was held in 1978 (Tengström, Teleki, 1979a).

This increased interest in itself speaks clearly on the present-day needs of astrometry. A particularly strong need in astrometry is, namely, currently felt for more accurate observational data, whereby it becomes less and less possible to proceed in the same way as heretofore, when many of the outside factors were being treated as accidental and as such not accounted for. The things were the same in relation to more atmospherical influences, among others especially to anomalous refraction.

It is to be hoped that, as a result of this new approach, previously so frequent custom of proclaiming influences as refractional all those effects having whatever connection with the meteorological factors, will vanish. Such a wrong tendency can result in formalistic solutions of the analysis of astrometric results, which usually contribute nothing to the study of the problems of the astronomical refraction. There is a variety of atmospheric influences (Teleki, 1978a) and the refractional influences on particular astrometric measurements, most often, are not the most significant. Clearly, this necessitates a more studious approach to these researches. To illustrate this statement we refer to the recent paper of Solovieva (1978). She made investigation of the inclination variations of a pier in a basement and found these variations (more precisely: perturbations in the systematic inclination variations) to be dependent on the wind direction. Looking for an explanation she realized that the cause of the phenomenon lied in the sagging of the Earth's crust, produced by the variation fo the atmospheric pressure (the wind direction indicating the sense of the inclination; wind blowing proceeds always from the region of higher pressure; these inclination variations can surpass those conditioned by the Moon tides). With the wind effect on the star transit times established earlier (with the transit instrument), this author was able to derive the effect on the astrometric observations of these Earth crust inclination variations, originating from the air pressure. What is the reason of our quoting this paper? We did this because the refractional influences are, most often, the only ones referred to in connection with the wind effect; less talked on is the mechanical (gust) effect or the temperature effect of the level. These researches of Solovieva show, once again, that in studying the variations exhibited by the astrometric results one has to proceed very cautiously as we are facing a complex phenomenon.

In the present account those recently published papers will in the first instance be pointed out which testify of the new tendencies in the investigation or the elimination of the influence of the astronomical (optical) refraction (Sections 2 to 5) whereas the rest of them will be referred to only summarily.

One may say that the current researches in this field are dedicated to rather isolated problems and an important task is incumbent to syntetize our knowledge of refraction as an integral phenomenon (Teleki, 1979a). This is true not only of astrometry but of geodesy as well (Izotov, 1975).

* Presented to the IAU Commission 8, Montreal, August 1979.

2. PREVENTION

The prevention is a very important measure as it has been proved that it was impossible to account for, with a satisfying accuracy, various refractional and other atmospheric influences. Hence all the measures aimed at reducing or eliminating these influences must especially be acclaimed.

Recently, a very studious theoretical study by Høg (1978) of the thermal and aerodynamical effects associated with the meridian buildings was published. He points out the need of the thermal insulation and ventilation of the meridian buildings both by daytime and the night. A rather narrow slit is preferable (and not a wide one as hitherto believed). Høg considers his investigations incomplete as no correlation has been worked on with the results of astrometric measurements obtainable with a meridian building offering good conditions as regards the diminishing the refractional and other atmospheric influences. However, pending his completing his investigation in the above sense, something close to the conceptions he expressed in his paper has already been achieved with the pavilion of the Belgrade zenith telescope (Milovanović et al., 1980). In the period 1968–1970 this pavilion has been adjusted in such a way which is, in retrospect, in conformity with the principles formulated by Høg. Moreover, the instrument (Talcott levels inclusive) has been protected against the temperature effects by suitable thermal insulation and the dew cap prolonged up to the roof slit. These adjustments were vindicated by the results of observation: the accuracy of the observations has increased considerably. It is interesting that the internal accuracy has risen substantially more than the external accuracy. No complete explanation has as yet been found as to what is the cause of this. Possibly, the main cause should be sought in the position of the atmospheric layers close above the pavilion's roof. It is hard to say what the cited adjustments have brought about concerning the refractional influences, but it is indisputable that the overall atmospheric effects have been weakened, that is, their variability reduced.

In connection with the decisive influence of the pavilion we wish to cite here only two more papers: Kakuta et al.(1974) and Shcheglov (1976a).

It is necessary to indicate here the investigations of Kiryan (1975) bearing upon the thermal properties of a building in Pulkovo by which a considerable asymmetry of the temperature field was revealed. A particularly pronounced difference is stated between the states with the roof removed. Maximum temperature gradient measured was $0^{\circ}25$ C per meter. Concerning conditions within and around the building, the works should be cited of: Mogilin (1977), Shcheglov (1977), Kolshevnikov and Kalshanov (1978a) and Shamaev (1978). The temperature differences are, doubtless, the main cause of the atmospheric inhomogenity, affecting thereby dominantly the astrometric observations. To what extent could they be removed? It is hard to answer, but every effort should be exercised to have them at least (radically) reduced.

The building surroundings must also be taken care of. It is interesting to mention at this juncture the investigations of Pavlov (1978). He showed that the trees and bush around the building can be sources of considerable influence of the result of observations. The systematic effect of the clock corrections, originating from this vegetation can attain $0^{s}.02$. Pavlov's suggestion is that there should be neither trees nor bush, nor other similar sources of air distubance in the surroundings of the building.

Ever more acute is also the question of the correct choice of location for the (astrometric) stations. Concerning this subject several works could be cited: Barletti et al. (1977), Mao and Mohr (1976), Kolshevnikov and Kolshanov (1978b) and others. Detailed explorations of the climate of Mizusava (Sugava, 1978) show the complexity of the atmospheric factors on the astrometric data.

Refractional disturbances within the instrument can be reduced by adequate masures. One idea is, for instance, the filling of the astrolabe's interior with helium (Anonymous, 1975; Niemi, 1979).

3. THREE-DIMENSIONAL REFRACTION

Here we have to deal with a new tendency, having as its objective the interpretation of the influence of refraction as a spatial phenomenon, instead of its being interpreted as a phenomenon in a plane. To achieve this, previous thorough explorations in the optics are necessary (the problems involved: Fermat's principle, the laws of refraction, refractive index), which are to be supplemented by the investigations in the meteorology (meteorological fields, the local atmosphere characteristics), and, as a matter of fact, by investigations in the astrometry and the geodesy. Failing these additional investigations some of the three-dimensional methods can hardly be said to be any better than those two-dimensional (Hotine, 1969).

The constructions of the new tables of refraction (Teleki, 1977a) is just aimed at introducing into the „averaged" refractional influences spatial elements as well. The basic question concerned is the choice of the three-dimensional model of atmosphere. Curently engaged in this field are Saastamoinen (1978), Sergienko (1979) and others. According to Saastamoinen an atmospheric model, calculated as a function of latitude and elipsoidal height, the inclination of the isopycnic surfaces caused by the temperature distribution using standard values of vertical temperature gradients for troposphere and stratosphere and assuming the state of hydrostatic equilibrium, can give sensibile differences between the north and south refractional values (at 60° zenith distance of the order 0".01, and at 80° zenith distance of the order 0".1). According to earlier investigations of Sugawa and Kikuchi (1979), there is, in the north hemisphere, a stronger asymmetry of the refractional effects in the north-south direction (mean value for the zenith area is 0".003) than in the east-west direction (up to 0".0015).

However, whilst the refractional tables, giving pure refraction, depend upon the free atmosphere and the idealized surface atmospheric layers, the refractional anomalies have their main source in, let it be called, „perturbed" lower atmosphere: in the planetary (Ekman) boundary layer, particularly in its lowest, surface layer (100 to 200 m above the soil). It is in this part of the atmosphere that the study of the three-dimensional structure of the refractional influences acquires a particular significance. Among the more recent works, related to this aspect of the problem, is Hughes' (1979) study of the urban heat islands. This is a problem most observatories are, more or less, confronted with. The values of the refractional effects derived are not large – they vary within the range ±0".03 for the zenith distance $\pm 45^\circ$ – but, as can be gathered from this paper, they may be considerably higher. Indisputably, Hughes has pointed out the real influence, bearing a three-dimensional character, of the heat islands around the astrometric buildings and these studies should certainly be continued.

All the studies of the local refractional influences, relating to this problem, are of importance as they indicate the spatial character of these influences. Here are some of the recently published papers: Goto (1979), Archangel'skij and Kirichuk (1976), Archangel'skij (1977), Kirichuk and Olejnik (1977), Mikhajlov (1975), Shteins (1977), Vasilenko (1978), Bagildinsky et al. (1979), Stearns and Wesely (1974), and others.

In treating the refractional influences in general, notably if the influences in the planetary boundary layer, are concerned little attention is paid to the character of the meteorological, and especially of the temperature field. It is usually assumed that one has here to deal with such processes that allow functional representation. This, however, is not the case. The meteorological fields, and by this very fact the refractional influences, must by treated as non-stationary stochastic process. Such an approach has not found application in the astrometry – even though the influences in the boundary impose this – but it has been practiced in the geodesy in connection with the terrestrial refraction (Kahmen, 1977). A more real treatment of the atmospheric influences, especially in the lower layers, will certainly necessitate the use of the fundamental works on the wave propagation in a turbulent medium (Tatarsky, 1961; Gurvich et al., 1976; etc).

4. MULTI-WAVE METHODS

In geodesy, multi-wave methods are developed for the determination of the refractional influences in directions and distances, giving encouraging results (Tengström, Teleki, 1979c). Two or more wave lengths are used.

Proceeding from his basic idea (Tengström, 1967) for the determination of refraction at vertical angle measurements in geodesy, Tengström (1977) infers that the astronomical refraction α_D, in D-line, at observing the stars in two wave lengths, can be determined by the relation:

$$\alpha_D = k\,\delta + q \tag{1}$$

where: k – the value depending on the instantaneous state in the atmosphere (under terrestrial conditions this value amounts to $(n_D-1)/[n(\lambda_1) - n(\lambda_2)]$, where $\underline{n}$ are the the refractive indices corresponding to the given wave length λ in the vacuum),

$\delta = d_m - d_c$,

d_m – the measured dispersion between two lines in a star-spectrum,

d_c – the calculated dispersion for the given wavelengths,

q – the correction for humidity.

There is now the question of determining all the right-hand terms in the equation (1). The values of k and q ought to give a notion of the influence of the whole of the atmosphere through which the starlight ray is passing. It is a great problem how to calculate these values with the sufficient accuracy. Another great problem is the determination of δ, the more so if the radiation intensity in different wave lengths is sensibile different (under the terrestrial conditions δ should be determined within ±0".001 for α to be known within ±0".1).

In geodesy, by usint the two-wave method, it is possible to, more or less, eliminate the refractional influences for an atmosphere of constant composition. The main limiting factor is the variability of the humidity. Further improvement of the accuracy at using the multi-wave methods presupposes better atmospheric models (de Munk, 1979).

Currie (1979) is developing two-color refractometry prosecuting the same objective as Tengström: the determination of the anomalous refraction from star observation. The basic idea can be summarized as follows:

Denote by θ_λ the deviation of a ray, whose wavelength is λ, from its initial direction, and by ϕ the true zenith distance of the star. Suppose the observations were made in blue (B) and red (R) colors. Then, according to Currie, for the visual (V) range, the following basic relation is valid:

$$\theta_v = \Omega(\theta_B - \theta_R) \tag{2}$$

where: $\theta_B = (n_B - 1)$,
$\theta_R = (n_R - 1)$,
n – refractive indices, measured with two-color refractometer (TCR),

$$\Omega = \frac{n_v - 1}{(n_B - 1) - (n_R - 1)} = \frac{n_v - 1}{n_B - n_R}$$

If the effective wave lengths used are 3500 Å (B) and 6000 Å (R), then (for 15°C and 760 mmHg) $\Omega = 30.36$.

The first version of the instruments (telescope, TCR) is expected to yield an accuracy of 0".01 in the determination of the refractional influences.

Two relevant methods are currently being developed – the one at the Geodetic Institute at Uppsala, Sweden, and the other at the Maryland University, USA. It is quite understandable that supplementary researches must be carried out in order to solve various problems involved (Tengström, Teleki, 1979d). But one can safely claim, all fact considered, that the multi-wave methods are worth the work required.

5. THE USE OF THE ARTIFICIAL SATELLITES

The Earth artificial satellites can, in a direct and indirect way, contribute to the determination of the refractional influences.

The indirect methods imply high precision determination of the ESA Hipparcos Astrometry Satellite. These highly precise stellar positions are then used for direct determination of the refractional values through the ground based observations of the same stars (Teleki, 1969b). Here belong the meteorological measurements of the atmosphere density, used afterwards for determining the refractional influences. However, the density of the boundary layers cannot be determined by these methods (Tatarsky, 1968).

To the direct methods are counted those which imply the determination of the refractional effects by way of measurements from abroad the satellites. A suggestion of the kind was put forward at the IAU Symposium No. 89 (see.: Resolution No.9, Tengström, Teleki, 1979b).

6. OTHER RESEARCHES

These might be grouped following way:

6.1 The following works are dedicated to the general questions of the astronomical refraction: Nefed'eva (1976a), Kozik (1977), Sergienko (1978b) and Teleki (1977a, 1978b, 1979c).

6.2 The pure refraction and the tables of refraction are the subjects of several papers: Nefed'eva (1978a, 1978b, 1978c), Nefed'eva and Sokolova (1978), White (1975), Mikkola (1979), Saastamoinen (1979), Kolchinsky (1979). Teleki (1980) has analysed the prospective impact of the atmosphere's evolution in the course of time on the values of the pure refraction and has found that the existing (good) refraction tables will keep their validity over the whole span of human civilisation and beyond.

6.3 A problem of its own is the determination of the refraction at larger zenith distances. Vasilenko and Haritonova (1977) showed, by using a new method of refraction angle calculation advanced by Tatarsky and Haritonova (1974), that it was possible to give theoretically the values of refraction even up to 88° zenith distance (their agreement with the measured values is stated). Yatsenko (1978) found that Nefed'eva's tables give better values of refraction at zenith distances over 65° than the Pulkovo Tables. Johnson (1976) has investigated the refraction at the Arctic by making observations (usually the Sun) at large zenith distances.

6.4. Nefed'eva (1976b) has studied daily variations of the refraction within the optical range, while Altenhoff (1979) has made analogous investigations within the radio range.

6.5. The question of the chromatic refraction is the subject of these studies: Kiryan and Kiryan (1977), Lengauer (1977, 1978), Bagildinsky et al. (1979).

6.6. Ivanov et al. (1978) give the corrections due to humidity as a sum of two terms: the first depending of the humidity in the surface layer, and the second on the overall atmospheric humidity (determinable by spectral hygrometer). These corrections exceed 0".01 at larger zenith distances.

6.7. Kolchinsky (1978) suggests that at each astrometric station several atmospheric models, worked out on the assumption of a clear sky, should be ready-made and used in the calculating of the local refractional influences. Nefed'eva (1977), on the other hand, shows that the refractional characteristics of the atmosphere are almost unaffected by the cloudiness, being in fact dependent on the meteorological conditions on the sea level, the soil composition, the direction and the speed of wind and, to some extent, on the location's latitude. May it be remarked that the question of cloudiness, relating to the refraction, is currently being studied in more details at Belgrade Astronomical Observatory.

6.8. Sergienko (1978a) investigated the seasonal variations of the refractive index with differring altitudes above the sea level and showed that these variations preserve their character unchanged in all the layers apart from the surface layer. The variations bear a local character.

6.9. Ivanov (1979) analysed the effects of the turbulence on the astrometric observations and inferred that these effect should be taken into consideration at composing the observing programmes, in developing new instruments and methods of coordinate determination and their automatisation.

6.10. Scherer (1977) introduces the term „dynamical refraction" for the refraction variation occuring in the course of satellite tracking (such an effect is non-existing with a static camera). As these effects are not negligible it follows that they should be accounted for with the photographic astrometric observations.

6.11. Various questions of the anomalous refraction are dealt with these papers: Nefed'eva (1976a), Teleki (1977b) Kreinin and Tolchelnikova-Murry (1977), Yasuda and Fukaya (1979).

6.12. The measurements and the explorations of the temperature field within and around the observing building continue to be practiced (see references in Section 2), with the purpose of finding out the corrections to the astrometric observations. The temperature differences are, doubtless, dominant in producing the anomalous refraction. But the practice shows that the calculation of the true values of the anomalous refraction is impossible with nothing but temperature measuring confined to a few point. This is not only a consequence of the small number of places (points) of measurements but also on account of the atmospheric dynamical factors being ignored (Kakuta et al., 1974). Perfected methods of recognizing these anomalies are therefore requisite. A possibility is offered by the acoustic method (Bean, Teleki, 1974; Shcheglov, 1976b; Kornilov, 1979) of which at least the information on the sources of the more pronounced anomalous refractions might be expected (Bean, Teleki, 1974). It is an open question whether direct measurement of the refractive indices by several refractometers might secure a more complete insight into the field of the refractive index within and around the instrument building, enabling a better comprehension of the possible field of anomalies. Here again, the most valuable results are likely to be obtained by the multi-wave methods.

7. CONCLUSION

We find it most appropriate to restate the conclusion in our paper (Teleki, 1976c), confirmed and developed by the Resolution of the IAU Symposium on the Refractional Influences in Astrometry and Geodesy (Tengström, Teleki, 1979e). The conclusions are as follows:

7.1. Astrometry needs more accurately known refractional influences than we are nowadays able to offer;

7.2. Refractional tables, giving values for ideal and average conditions, must be brought closer to reality;

7.3. Not even improved refraction tables are capable of meeting presend-day needs, which necessitates special investigations of refractional effects at a given place and for a given time;

7.4. Preventive measures should be strictly observed: careful site selection, adequate pavilions, instruments, accessories and observing methods. Observations should not be made at zenith distances over 60^o–70^o, and meteorological data should cautiously be collected.

In our view it is necessary to intensify the work in the prospective fields of these investigations, pointed out in Sections 2 to 5 (prevention, three-dimensional refraction, multi-wave methods, the use of artificial satellites).

It should be remarked that the need exists for promoting the investigation of the refractional influences within other electromagnetic radiation ranges. Even though the refractional influences remain similar within, say, the radio and the optical ranges, they nevertheless, are not identical, thus needing separate treatment.

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INVESTIGATION OF THE LEVEL DIVISION INEQUALITIES WITH AN EXTRAFOCALLY ADJUSTED COLLIMATOR

L. A. Mitić

SUMMARY:

Graduation of two astronomical 1" levels has been investigated from close distance (4.7 m) with a collimator (8/100 cm) whose micrometer was adjusted extrafocally by 32 cm. High precision of settings of the level graduation lines (mean error of settings ranged from ±0".0020 to ±0".0014, permitted the inequalities in the division values to be firmly established. These inequalities, however, rarely exceed ±0".02.

INTRODUCTION

It is well known that the terrestrial objects, at even close distances, can also be observed with the astronomical telescopes, provided their eye-piece has been placed extrafocally. The extrafocality, that is, the distance of the eye-piece from the focal plane will, evidently, grow as the object under observation is nearing the instrument.

This possibility has been exploited for investigating the division irregularities of two astronomical 1" levels, used otherwise with the Vertical Circle of the Belgrade Observatory. The measuring tool was a collimator fitted with micrometer, only 4.7 m distant from the level.

However, interestaing as the results obtained may be concerning the actual quality of the level graduation, they were not our prime objective. The investigation had in fact to provide an answer as to the feasibility of pursuing the level indication, i.e. its bubble's position, from a few meter distance, by precise micrometer settings. Such a method of scanning the level indication should, conceivably, yield substantially superior results to those achievable by the ordinary naked eye estimates or by minuscule telescopes without micrometer. Clearly, this method is hardly practicable within the scope of standard astronomical observations for many reasons. The point, however, is that we, anyway, have a singular case in mind, where the suggested method seems quite workable: pursuing the inclination variations of a meridian mark pier by means of a level, fixed on it. The meridian mark concerned belongs to our Large Transit Instrument, currently engaged in observing a bright stars programme by absolute method. A thermostatic container of appropriate size in which the level is to be placed, should safeguard it, to the extent possible, against thermal effects. The reading of this level's indication, that is, of its bubble ends position, is to be performed with a collimator fitted with a micrometer, installed at a few meter distance, in full analogy to what is set forth hereafter.

TECHNICAL DETAILS

The level graduation investigation was excuted with the north collimator (Askania, 8/100 mm) of the Large Meridian Instrument of the Belgrade Observatory. This collimator, fitted with the micrometer, has its counterpart in the south collimator of the same optical parameters. The south collimator, having no micrometer, served for the level supporting gadget to be fastened on its object-glass end. As both collimators preserved their position in which they are regularly used with their principal instrument, it turned out that the investigated level was at such a close distance from the north, scanning collimator.

The fastening of the level supporting device on the south collimator's tube was achieved by a metallic ring, 3 cm wide. The level was placed on the supporting devices's holding plate in the east-west direction, thus perpendicularly to the optical axis of the north collimator, by whose movable wire the level graduation lines were set upon. The supporting device's level bearing plate is movable, within a grooved frame attached to the fastening ring, in the east-west direction. This east-west motion of the level holding plate is effected by a screw, incorporated in a grooved frame, the identical motion being thereby imparted to the level under investigation.

One of the levels, that graduated 0 to 40, was investigated in two variants: in the first, the level graduation was turned about its tube's axis by 90° from its normal, upwards, position so as to have it directly facing the north, scanning, collimator. Consequently, it was viewed in the scanning collimator without prior reflection from the level mirror. In the second variant the level graduation occupied its normal position, that is, it was turned toward the zenith. It could now be viewed only after its image had been reflected from the level mirror, the latter being inclined 45° with respect to the horizontal plane.

The second level, graduated 50 to 90, was investigated in only one variant: with its graduation turned toward the objective of the scanning collimator.

In both cases the illumination of the level graduation (more precisely, the illumination of that part of the graduation, comprising the particular division whose pair of lines, defining it, were at that time being set upon) was provided by two small electric bulbs, fixed at a few centimeter distance from the level. In the first variant, with the graduation turned toward the objective of the scanning collimator, the illuminating bulbs were, clearly, behind the level for the observer on the collimator's eye-piece. In the second variant, where the graduation image had first to be reflected from the level mirror, they were fixed under the level.

With the scanning collimator and the illuminating bulbs occupying a static position in the course of an investigation tour, while the level alone was submitted to a gradual east-west motion, it was achieved that division upon division, in succession, defiled over the vertical thread of the fixed cross-wire of the collimator's field of view, each one of the divisons illuminated in exactly the same way at the time of its two lines being set upon. This was an essential precaution measure against the errors which might have slipped into our results, had the illumination been different with different divisions along the level scale.

To achieve a sharp viewing of the level graduation in the scanning collimator, with the level only 4.7 m away, it was necessary to pull out the collimator's eye-end with micrometer by not less than 32 cm from its normal, that is, focal position, and have it fixed there. This was materialized by firmly screwing and additional metallic tube of that lenth into the collimator's tube, as illustrated in Fig. 1.

It took on the average 2.70 micrometer revolutions for the movable wire of the scanning collimator to cover a level division image, that is, the separation between two consecutive lines of the level scale image. As the linear pace of the movable wire, into which a micrometer screw revolution is turned, is 0.5 mm, and the level division true linear value being 2.3 mm, it follows that a convenient image-to-object ratio of 0.6 was attained by our arrangement, i.e. the linear separation of two consecutive division lines images in the collimator's field of view was over half that of their true separation on the level.

The mean division value varied, in fact, from one series of measurements to another from about 2.65 to about 2.75 revolutions, depending obviously on the temperature changes. This suggests a simpler way of determining the level division temperature coefficient being embodied in our procedure, than the conventional method, based on the use of examinator. An additional advantage of our procedure are its more accurate results.

The accuracy of settings of the graduation lines under the first variant (level graduation turned toward the objective of the scanning collimator) is ±0.0037 micrometer revolution. Curiously, exactly the same accuracy is otherwise routinely achieved in the regular use of this collimator's movable wire: the setting on the south collimator's fixed cross-wire within the observing programme being carried out with the Meridian Circle to which, as already stated, the two collimators belong.

Now the benefits of the fact that, owing to the close proximity of the level under investigation to the scanning collimator, the division image was as dilated as to require 2.70 micrometer revolutions ot be swept out by the movable wire from line to line, came into play. Assuming, for convenience, the angular division value to be exactly 1".000, it follows from the ratio 1.000/2.70 that the above quoted routine accuracy of ±0.0037 micrometer revolution, comuted into the level angular division units, is turned into quite an impressive accuracy of ±0".0014. This is 75 times as high a precision as the one associated with the naked eye reading of the level bubble position: ±0".1 (Drodofski, 1956). May it be noted in passing that an angle of 0".0014, subtended at the Earth's centre, would comprise an arc of no more than 4.2 cm on its surface.

The accuracy attained in the second variant (level graduation viewed upon reflection from the mirror) is somewhat lower. It amounts to ±0".0020, that is, still 50 times more precise than the naked eye reading of the level indication. The lower accuracy in this variant is, obviously, a consequence of the markedly poorer clarity of the graduation image, caused by the light being partially absorbed at its reflection from the mirror.

One is recalled at this juncture that the deviations of the vertical of a point on the Earth's surface, on account of the combined changing gravitational attractions of the Moon and the Sun, can attain about 0".05 (Melchior, 1966). The scattering of our settings on the level graduation (and on level bubble ends which have tentatively also been made), as stated above, being about 20 times narrower, it follows that these Earth's verticals inclination variations, produced by the luni-solar tidal action, would be, apart from the level itself, well within the measuring capabilities of the technics and method employed in our investigations. In view of the well known shortcomings of the astronomical level, it scarcely can be expected to duly respond to such minute inclination variations even if placed in totally thermostatic surroundings.

PROCEDURE OF INVESTIGATION

On putting the level on the movable plate of its supporting device, itself fastened, as indicated, on the south collimator's object-glass tube end, its graduation image is first sharpened in the field of view of the north, scanning, collimator. Thereupon, the level is brought, by revolving the driving screw of the supporting plate, to the position where one of its graduation endings, say the one comprising the line 0, occupied the middle of the field of view, marked by the vertical fixed wire of the scanning collimator. By appropriately manipulating the leveling screws of the collimator it is achieved that its horizontal fixed micrometer wire was bisecting the level scale image longitudinally. By this, the preparatory operations were finished and the investigation proper could be started. Two participants were needed in the proceeding: the observer at the north collimator and his assistant at the level supporting unit (south collimator).

Now, three settings are made by the movable wire of the scanning collimator on the graduation line 0, then as many on the line 1. This done, the movable wire is returned to the position where it coincided with the line 0. The assistant then displaces the level, by carefully turning the screw of the supporting gadget, by one division, so that the graduation line 1 is now exactly under the movable wire, kept menawhile in the position where it was covering the line 0. In executing this level transporting by exactly one division the assistant is guided by the observer on the scanning collimator, who closely watches the progressing of this sensitive operation in the field of view. In exactly the same way the lines 1 and 2 are now set upon. The movable wire is again returned to the position where it covered the line 1, which is, in fact, the position where it originally coincided with the line 0. The whole operation is reitered with the lines 2 and 3, 3 and 4 etc.

The difference of the micrometer readings of any two consecutive lines, defining a particular division, gives the value of that division in revolution units. As stated, this value amounted to about 2.70 revolutions on the average.

By ever returning the movable wire, upon completing the settings on any pair of lines, defining a division, so as to coincide with the line first set upon, the important principle was held that virtually one and the same part of the scanning micrometer screw should be used for settings on all 40 pairs of the graduation lines.

From what is stated above it follows:

– each one of the pairs of lines, defining a particular division, has been set upon quite independently from each other, accordingly, the values of all 40 divisions have been obtained independently, to;

– as one and the same part of the micrometer screw has been used in carrying out all the settings, which in itself means that those settings have been made at one and the same place of the field of view, the effects of the eventual screw irregularities, along with those of the curvature of the image, have automatically been eliminated.

On arriving gradually to the last pair of lines (say 39 and 40) the entire procedure of settings is repeated in the opposite sense, that is, beginning with the line 40 and ending with the line 0, observing, as a matter of fact, the same precaution rules as specified above. One complete series comprised two such semi-series. The division values from one series are, therefore, given by the means of two values, derived from each one of the semi-series, executed in opposite senses.

RESULTS OBTAINED

1. In Fig. 2 the deviations are illustrated of the individual division values from their general mean, taken as reference value, of the level graduated 0 to 40. These deviations are derived from two series of measurements, carried out on 6 and 7 June 1978. The accordance of the results of both series, with quite of number of them even completely coinciding, is in itself an evidence both of their reality and the expediency of the method employed.

As evident in Fig. 2, the deviations of individual division values do not, apart from rare exceptions, exceed $0''.02$, that is only 2% of the mean division value, as long as the latter is not grossly in excess of $1''.000$.

It is, however, surprising to find, with regard to the high precision of settings (m.e. $\pm 0''.0014$) that the diaccordance of, say, division value deviations between the lines 24 and 25, 35 and 36, 39 and 40, obtained on the first and the second date respectively, amount to $0''.01$, which is about 7 times the mean error. This is probably due to the not always adequate performance of the level supporting unit (the plate, holding the level and the driving screw to which it is attached). At any rate one could note that in the course of the gradual displacement of the level there was from time to time some rather gross lifting and dropping of its graduation image from its normal position (i.e. from the position in which the fixed horizontal wire of the scanning collimator was exactly bisecting the level scale longitudinally). There obviously must have been some irregularities in the shape of the driving screw of the transporting unit, causing the supproting plate attached to this screw, along with the level resting on it, to exhibit the lifting and dropping.

2. The next question we wanted to answer to, was whether the second level, the one graduated 50 to 90, had irregularities of the same order or, possibly, of quite a different order of magintude. The results of investigation of this second level are illustrated in Fig. 3.

As only the order of magnitude of this level's division irregularities was our objective we deemed it sufficient, with respect to the high precision of measurements, to make one single series of settings. This were carried out on 15 June 1978. The mean error of settings in this investigation turned out to be ±0".0016.

As evidenced by Fig. 3, the answer of our question lets no doubt: the graduation irregularities of this level are of the same order as that of the first level. This is what one could well have anticipated.

3. After investigating the level graduation by observing it directly, that is, without the intermediary reflection from the mirror, it was interesting to make an analogous investigation by viewing it indirectly, that is, by way of mirror. This because most of the levels used with the large meridian instruments are read via the mirror. The possibility was, namely, to be reckoned with of the mirror surface being uneven, producing thereby additional, if apparent, graduation distortions.

Two series of measurements, on 22 and 23 July 1978, were carried out. The investigation was extended to only first half of the graduation, from the line 0 to the line 20. The results are illustrated in Fig. 4.

We find there, first of all, the results of both series mutually accordant, thus dependable. But the crucial point is that these results are, in fact, a replica of those exhibited in Fig. 2, which have been obtained without the mirror. We, therefore, did not push our investigation further, that is, we did not extend them over the second half of the level graduation, nor made any of the second level (graduated 50 to 90). Presumably, most of the level mirrors are of similar quality.

Nevertheless, the presence of the level-mirrors in this experiment made itself tell, as earlier pointed out, through markedly poorer clarity of the level graduation image, even though the illumination had remained the same as in the two previous investigations. Evidently, a perceptible light precentage has been absorbed at its reflection from the mirror. The higher mean error (±0".0020) of settings in this investigation by about 30%, as compared with the one obtained at direct viewing of the graduation (±0".0014), is the tangible consequence of the reduced image sharpness caused by the light absorption.

CONCLUSIONS

This is, to our knowledge, the first investigation of the division inequalities of astronomical levels. Although one might have apriori been pretty sure that these inequalities, if existing, must be essentially below the error of the naked eye reading of the bubble end positions, rated, often optimistically, at ±0".1, our results, in demonstrating that the division values deviations do not, as a rule, exceed ±0".02, possess the force of evidence that the above presumption was a correct one.

The method of investigation, implying the use of the astronomical telescope fitted with micrometer for scanning a precision graduation, like that of an astronomical level, placed at only a few meter distance, proved highly efficient, having at the same time the advantage of simplicity.

Hence, as the most important result of our investigations we consider the demonstration of the feasibility in certain cases at least, of pursuing the level indicatio by the same method and technics as set out in thi paper. As mentioned in the introductory section, it i planed to fix a level on the south meridian mark pie of the Large Transit Instrument. The level is to b thermally insulated by a suitable containedr and kep temperature-steady by a thermostat. Ideally, therma effects on the level should thereby be annuled, the leve bubble kept, accordingly, constant all along, and it displacement down the scale should be due to the mar pier inclination variation exclusively. The reading o this thermally steadied level is to be performed by a astronomical instrument with micrometer, adjuste extrafocally and installed to the south of the meridia mark, a few meter away.

Even if the precision of settings on the level line and on the bubble ends proves a few times only highe than that attainable with the naked eye estimates, an not tens of times higher as has been achieved in ou investigations reported on here, even then interestin prospects seem open concerning the fine-structure ana lysis of the short-term and long-term inclination varia tions of the mark pier. If successful, as hoped, this stud will be a contribution to question of the absolut right ascension determinations: the azimuth of th instrument, more precisely, its relative componen the reference direction of which is defined by th meridian marks.

Quite independent from our study of the inclinatic variations of the meridian mark pier, the method adva ced here can be applied for some subtle investigatio of the level itself, beyond those described, as for ir tance the variability of the division value with tempe ture changes etc.

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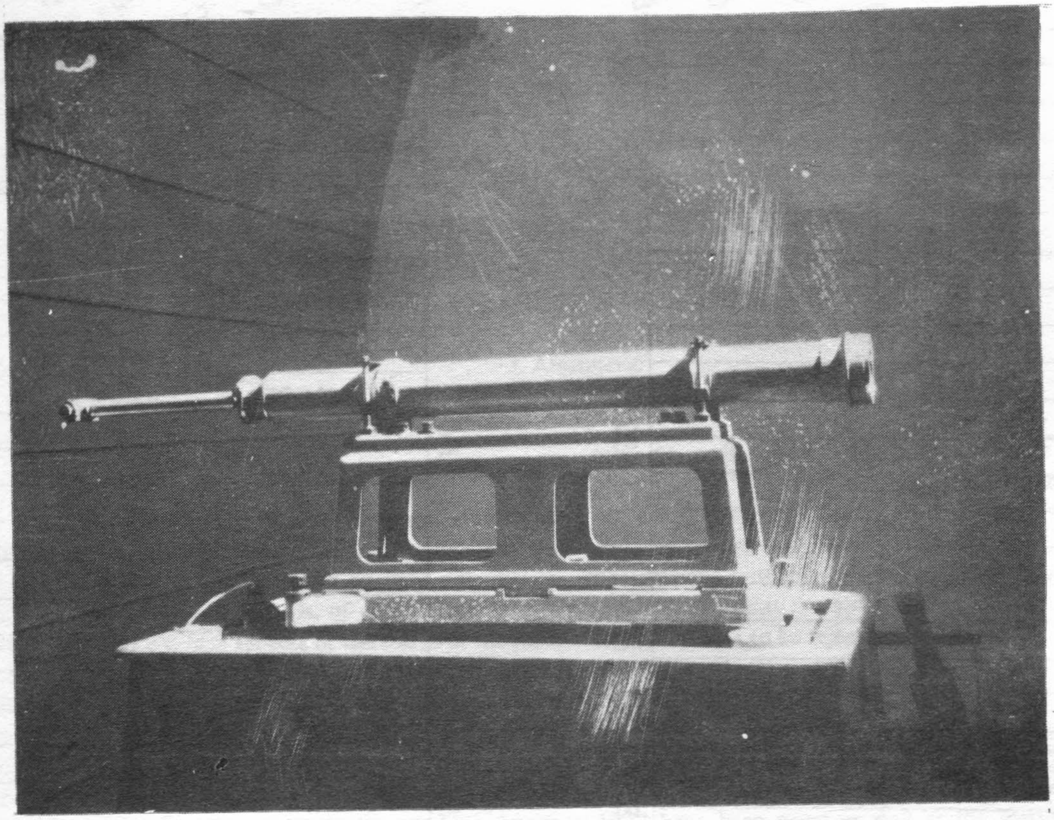

Fig.1

The north, scanning collimator, with its eye-piece micrometar fixed extrafocally by 32 cm.

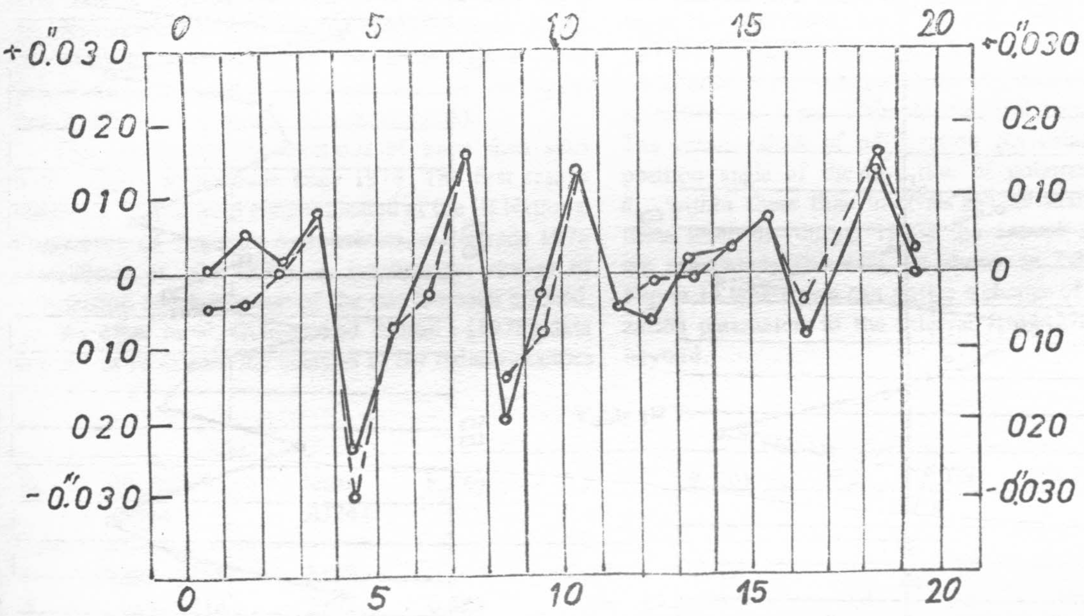

Fig.4

Division inequalities of the first half of the level graduated 0 to 40. The level graduation viewed indirectly, i. e. upon reflection from the mirror.

Solid line: Results obtained on 22 July 1978.
Dashed line: results obtained on 23 July 1978
Compare with the results of the first half of Fig. 2.

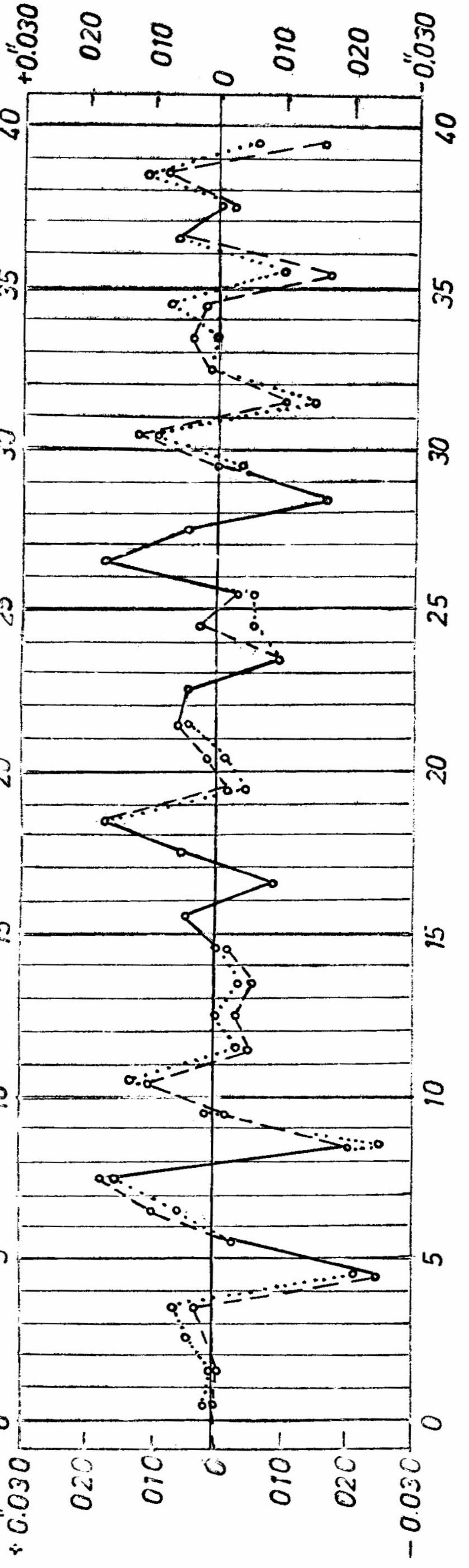

Fig.2

Division inequalities of the level graduated 0 to 40. The level graduation viewed directly (= mirror bypassed)

Dashed line: results obtained on 6 June 1978

Dotted line: results obtained on 7 June 1978

Solid line: results on both dates *identical*

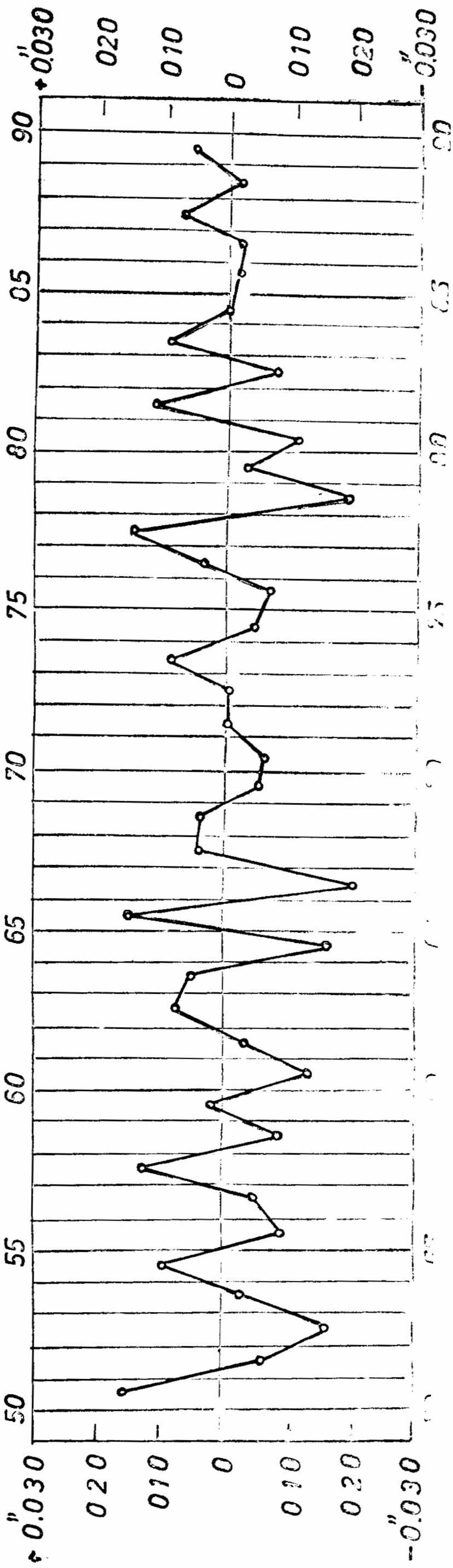

Fig.3

Division inequalities of the level graduated 50 to 90. Th
graduation viewed directly (= mirror bypassed)

Bull. Obs. Astron. Belgrade N° 131 UDC 523.82

SYNCHRONOUS CHANGES OF POLARIZATION, BRIGHTNESS AND RADIAL VELOCITIES OF o ANDROMEDAE

J. Arsenijević

INTRODUCTION

Intrinsic stellar polarization is being studied at Belgrade Astronomical Observatory through changes with time of parameters of linear starlight polarization in the V spectral region. This is, of course, only one of several possible physical aspects of the star, but the most accessible one regarding Belgrade instrumental and climatic limitations. Consequently, our observations of polarization are also limited to some classes of bright stars. On the other hand, the instrument (Zeiss refractor 65 cm) and the corresponding polarimeter (Kubičela et al., 1976) are capable of securing years-long homogeneous series of observations.

In order to realize a complex approach to the analysis of the physical processes responsible for changes with time of intrinsic polarization of some shell stars, our observational programme has been coordinated with photoelectric observations of the same stars at Hvar Observatory, initiated some years ago by colleagues from Ondrejov Observatory (Czechoslovakia).

The polarimetric observations of some shell stars is in progress at Belgrade since 1974. The first results bearing on o And were communicated at the III National Conference of Yugoslav Astronomers at Belgrade 1976 (Arsenijević et. al., 1979). A synchronous change of polarization and brightness of the star has been noticed. On the other hand, Gulliver and Bolton's (1978) data enabled us to extend the analysis to the radial velocities too. At present one can state the existence of complex photometric, polarimetric and kinematic stellar event.

Since the last appearance of the shell on o And in 1975, the star has been widely observed, with some observations probably not yet published. There is strong interest in eventual unpublished polarimetric observations of o And to be released.

POLARIZATION

In the mentioned Arsenijević's et al. (1979) paper polarimetric results related to o And from 1974 till 1977 have been given as well as the instrumental data and reduction procedure. Some fast and slow changes with time of the observed polarization have been noticed as well as one coincidence of the maximum of the observed polarization percentage with the brightness minimum. The observation has been continued in 1978.

The polarization changes in the interval JD2442700–800 deserve a detailed analysis. The data were grouped according to some characteristic polarization values. The mean values of polarization percentage, P_V, and position angle of the direction of polarization plane, θ_V, within these time intervals are calculated. Outside these intervals (during 1975) the annual mean values are calculated. The data are shown in Table I and in Figure 1a where one can notice a change of both polarization parameters in the interval JD2442700–800 and beyond.

Table 1

No	Interval JD244...	Mean JD244	P_V(%)	σp	θ_V (o)	$\sigma\theta$	N	ΔP_V	$\Delta\theta_V$
1	2292–2368	2330	0.44	±0.13	101.4	±9.0	23	–	–
2	2689–2714	2702	0.44	.06	99.6	4.1	5	0.03	48
3	2719–2720	2720	0.59	.13	104.7	6.3	6	0.16	114
4	2743–2776	2760	0.51	.09	116.2	5.1	8	0.25	146
5	3034–3077	3056	0.42	.12	128.3	8.2	14	0.39	161
6	3395–3402	3399	0.17	.10	118.2	16.9	59	0.32	3
7	3723–3755	3753	0.16	.03	123.5	5.7	6	0.34	2

In such an analysis the knowledge of the intrinsic stellar polarization is certainly needed. However, the interstellar polarization in the direction of o And has not been estimated yet. There is, to our knowledge, an upper-limit estimation of intrinsic polarization of o And in the vicinity of H-alfa line only, given by McLean and Brown (1978), amounting aproximately to 0.1%.

We didn't dare extrapolate this value to the visual spectral region. Instead of the unknown intrinsic polarization proper we decided to show the changes of the observed polarization taken as vectors which, on the assumption of constant interstellar polarization (which is certainly true), correspond to the changes of intrinsic stellar polarization vector (No.1 in Table 1) at the same time represents (besides the interstellar component) the stellar polarization before the last shell stage. The vectors representing the polarization change of the intrinsic polarization with respect to the polarization observed 1974 (interstellar plus some possible intrinsic component) are shown in Figure 2 in a polar (P,2θ) corrdinate system.

The measured polarization vectors are shown by dashed lines and the istatenous increments of the intrinsic polarization by heavy lines. The amounts of the corresponding percentage and position angle changes are given in Table 1 in the ΔP_v and $\Delta\theta_v$ columns.

Irrespective of the values of the interstellar and the original (1974) components of the intrinsic polarization we are in position to follow the changes of intrinsic polarization parameters ΔP_v and $\Delta\theta_v$, Table 1.In Figure 1b one can see that the polarization changes with respect to the 1974 data increase rapidly just in the interval JD2442700–800.

After JD2442800 the changes continued untill 1977 (arround JD244330) when a stabilisation throughout 1978 set in. It seems that the process initiating the changes of the intrinsic polarization of o And ended in 1977, but a new perhaps temporary, component of intrinsic polarization, different from 1974 probably remained.

PHOTOMETRY

Bossi et al (1977) published their photometric measurements of o And that are largely coincident with the intervals of our polarization measurements. They found some brightness changes but the most remarkable one was the change during JD2442711 (about 0.08 magnitude in the V region). The same brightness change has been independently observed by Arsenijević (unpublished) at Hvar, corroborating the former observation. Bossi's Values of ΔV averaged according to intervals corresponding to the intervals of polarization measurements are shown in Figure 1 (c) as a function of time. It is obvious that in the period JD2442700–800 characterized by remarkable changes of polarization, a minimum of brightness of o And has been observed. For the present we can state that a synchronous change of brightness and polarization took place.

RADIAL VELOCITIES

Taking the radial velocities data given by Gulliver and Bolton (1978) the mean velocity values have been found for approximately the same intervals already used in the grouping of the photoelectric and polarimetric data. The mean radial velocities are shown in Figure 1 (d). Here again a conspicuous change took place in the period JD2443700–800. The velocities changes are similar in all spectral lines (except for the interstellar Calcium) but the most striking change pertains to the He singlet (which is, accordint to Gulliver and Bolton, certainly a photospheric line) and possibly the MgII line, suspected to be a shell line.

CONCLUSION

It seems very likely that an event on o And having taken place in the interval JD2442700–800 was observed as synchronous changes of linear optical polarization, brightness and radial velocities. A complex quantitative analysis of the event has still to be done. One looks forward to the spectrophotometrical data anounced by Gulliver and Bolton (1978). The full interpretation of this complex event should engage a team of different specialists. We have been careful not to express any assumption about the physical mechanism involved in the event. We only believe that the present state of polarization of o And is a temporary one. We are going to continue the polarimetric observations using an improved automatic version of the Belgrade photoelectric polarimeter.

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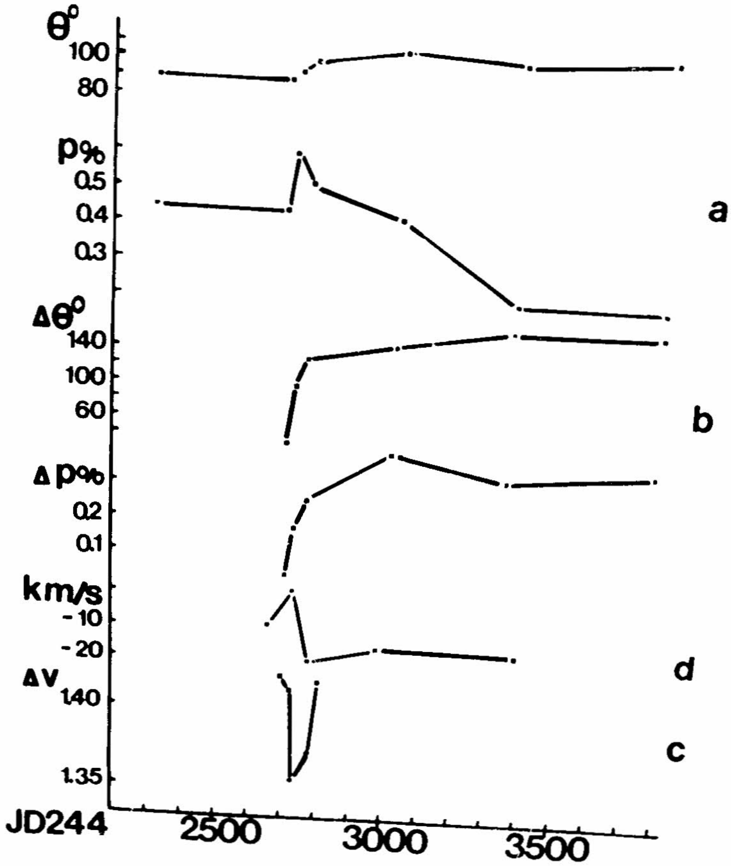
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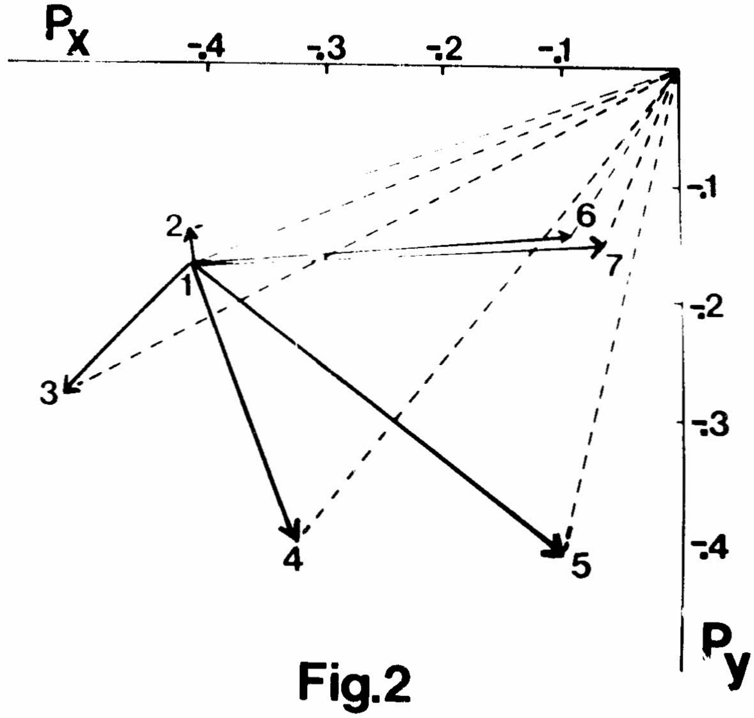
100
80
p%
0.5
0.4
0.3
a
Δθ°
140
100
60
b
Δ p%
0.2
0.1
km/s
-10
-20
d
ΔV
1.40
1.35
c
JD244
2500
3000
3500
Fig.1


P_x
-.4
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P_y
1
2
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Fig.2

ORBITS OF FIVE VISUAL BINARIES

D. J. Zulević

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SUMMARY:

Orbits and dynamical parallaxes are presented for five visual binary systems: ADS 1548, ADS 8145, ADS 10085, ADS 16131 and ADS 16368. Calculated positions are compared with observations and ephemerides are given for each system.

Orbits for five visual binaries have been computed using the methods of Thiele-Innes. Dynamical parallaxes were computed by the method of Baize and Romani (1946) with magnitudes and spectral types taken from the Lick Index Catalogue of Viaual Double Stars, 1961.0 (1963). The relevant information is given i Table I.

Table I

ADS 1548 = IDS 01513N3032 = A 819, 8.2–8.7, F5

P = 261.1	Ω = 161°.2	A = +0".4300
n = 1°.3788	ω = 180°.9	B = −0".1400
T = 1811.84		F = +0".1200
a = 0".45	$\pi_{dyn.}$ = 0".007	G = +0".3740
e = 0.24	Σ m AB = 3.9 ⊙	C = −0".0035
i = 29°.7	a = 64.3 AJ	H = −0".2293

Observations

T	P	ρ	mag.	n	Obs.	$(0-C)_P$	$(0-C)_\rho$
1904.83	131°.8	0".53	7.8–9.3	2	A	+0°.0	+0".02
1910.7	136.1	0.42		3	GrO	−0.9	−0.10
1917.26	143.0	0.50		2	A	+0.5	−0.03
1924.78	144.1	0.61		1	Bail	−4.4	+0.06
1938.28	158.1	0.64	7.9–9.4	4	VBs	−0.7	+0.08
1942.62	158.1	0.62		3	VOU	−4.0	+0.06
1954.80	170.0	0.55	7.9–9.4	3	VBs	−1.4	0.00
1956.02	163.8	0.63		3	B	−8.6	+0.08
1956.98	168.1	0.64	7.8–9.6	3	COU	−5.0	+0.09
1958.657	170.3	0.55	8.1–9.3	3	B	−4.1	0.00
1962.961	170.6	0.46		4	Wor	−7.2	−0.08
1969.00	188.2	0.52	8.1–9.3	3	Heintz	+5.4	−0.01
1970.945	181.2	0.60		3	WOR	−3.2	+0.07
1975.89	188.2	0.43		3	Heintz	−0.4	−0.09
1979.68	194.2	0.51		2	DZ	+2.2	0.00

Ephemerides

T	P	ρ	T	P	ρ
1980.0	192°.3	0".51	1985.0	197°.0	0".50
1981.1	193.2	0.51	1986.0	198.0	0.49
1982.0	194.2	0.50	1987.0	198.9	0.49
1983.0	195.1	0.50	1988.0	199.9	0.49
1984.0	196.0	0.50	1989.0	200.9	0.49

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ADS 8145 = IDS 11179N0441 = A 2776 AB, 8.8–8.8, F5

P = 97.54	Ω = 76°.6	A = −0".0365
n = 3°.6908	ω = 179°.8	B = −0".1515
T = 1910.05		F = +0".0810
a = 0".16	$\pi_{dyn.}$ = 0".005	G = −0".0200
e = 0.31	Σm_{AB} = 3.4 ⊙	C = +0".0000
i = 57°.6	a = 32 AJ	H = −0".1351

Observations and residuals

T	P	ρ	mag.	n	Obs.	$(0-C)_P$	$(0-C)_\rho$
1914.30	273°.9	0".17	8.9–8.9	2	A	−0°.1	+0".07
1921.	–	–		1	A	(313.8	0.08)
1923.	–	–		1	A	(329.9	0.07)
1927.31	41.	0.10	8.7–8.7	1	A	+37.5	+0.02
1929.32	–	–		1	A	(14.1	0.09)
1937.27	36.3	0.15	8.7–8.7	1	VBs	−8.9	+0.01
1944.25	55.7	0.16	8.7–8.7	2	VBs	−2.8	−0.01
1945.33	57.4	0.20	8.7–8.7	2	VBs	−2.8	+0.02
1950.33	65.3	0.16	8.7–8.7	2	VBs	−1.5	−0.03
1954.12	72.3	0.14		3	VBs	+1.1	−0.06
1957.64	78.2	0.15		4	VBs	+3.0	−0.05
1961.19	79.5+	0.22	m = 0.0	3	WOR	+0.5	+0.02
1962.08	81.0+	0.19	8.9–9.1	4	B	+1.0	−0.01
1963.94	69.2+	0.20	8.3–8.3	3	COU	−12.9	0.00
1969.23	90.3	0.18	m = 0.0	1	Walk	+1.8	−0.01
1969.28	88.6	0.18	m = 0.0	2	WOR	0.0	−0.01
1975.30	86.9	0.16		4	Heintz	−10.5	0.00

+ Quadrant reversed.

Ephemerides

T	P	ρ	T	P	ρ
1980.5	107°.8	0".14	1983.0	114°.6	0".16
1981.0	109.1	0.13	1983.5	116.2	0.12
1981.5	110.4	0.13	1984.0	117.9	0.12
1982 0	111.7	0.13	1984.5	119.6	0.11
1982.5	113.2	0.13	1985.0	121.4	0.11

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ADS 10085 = IDS 16263N3406 = HU 1173, 9.3–9.3, F5

P = 89.11	$\Omega = 65^\circ\!.8$	A = –0".0260
n = 4°.0400	$\omega = 207^\circ\!.7$	B = –0".1433
T = 1969.81		F = +0".0910
a = 0".16	$\pi_{dyn.} = 0''.006$	G = +0".0407
e = 0.68	$\Sigma m_{AB} = 2.4 \odot$	C = –0".0657
i = 62°.0	a = 26.7 AJ	H = –0.1251

Observations and residuals

T	P	ρ	mag.	n	Obs.	$(0-C)_P$	$(0-C)_\rho$
1905.38	69°.2	0".24	8.4–8.7	2	HU	+1°.2	+0".01
1921.92	80.8	0.24	8.8–9.0	4	VBs	+3.0	–0.01
1932.46	84.9	0.22	8.8–9.0	4	VBs	+0.6	–0.01
1944.28	88.6	0.16	8.8–9.1	1	VBS	–6.2	–0.01
1944.30	91.3	0.19	8.8–9.1	1	VBs	–3.5	+0.02
1945.30	100.4	0.17		4	VOU	+4.3	0.00
1948.62	90.4	0.15	8.8–9.1	1	VBs	–10.6	+0.01
1948.64	91.4	0.16	8.8–9.1	1	VBs	–9.6	+0.02
1953.52	116.	0.10		1	VBs	+4.2	–0.01
1955.63	–	< 0.23		1	Mul	(199.0	0.09)
1957.60	–	0.1		1	VBs	(128.2	0.08)
1958.58	140.6	0.10	8.7–8.9	4	B	+6.6	+0.03
1960.45	Simple	0.2		1	COU	(148.5	0.06)
1963.561	–	–		1	WOR	(183.2	0.05)
1967.43	Simple			1	COU	(229.9	0.06)
1968.541*	274.6	0.12	m = 0.0	1	WOR	+32.1	+0.07
1970.465	Ronde			1	COU	(272.1	0.04)
1975.48	32.9	0.14		3	Heintz	–1.4	+0.07

* unpublished

Ephemerides

T	P	ρ	T	P	ρ
1981.0	54°.0	0".14	1986.0	60°.9	0".18
1982.0	55.8	0.15	1987.0	62.0	0.19
1983.0	57.3	0.16	1988.0	62.9	0.20
1984.0	58.6	0.17	1989.0	63.8	0.20
1985.0	59.8	0.17	1990.0	64.7	0.21

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ADS 16131 = IDS 22334N0147 = HO 479, 8.2–9.7, GO

P = 188.60	Ω = 65°.2	A = +0".4430
n = 1°.9088	ω = 72°.6	B = –0".0030
T = 2037.20		F = –0".1300
a = 0".61	$\pi_{dyn.}$ = 0".015	G = –0".5830
e = 0.29	Σm_{AB} = 1.9 ⊙	C = –0.4187
i = 133°.7	a = 40.7 AJ	H = –0".1313

Observations and residuals

T	P	ρ	mag.	n	OBs.	$(0–C)_P$	$(0–C)_\rho$
1893.46	232°.0	0".62	7.5–9.0	3	HO	–6°.0	–0".02
1906.63	230.5	0.68	7.7–9.5	3	DOO	+6.9	+0.02
1937.175	192.7	0.53	8.6–9.2	2	B	+5.1	–0.05
1939.098	183.4	0.45	8.5–9.3	4	B	–1.6	–0.13
1945.28	177.2	0.44	8.8–9.9	2	B	+1.0	–0.12
1951.84	166.1	0.44	8.4–9.6	2	B	0.0	–0.11
1954.78	167.5	0.36		1	MUL	+6.2	–0.18
1954.84	159.0	0.61		3	COU	–2.2	+0.07
1955.20	158.3	0.44		2	MUL	–2.4	–0.10
1955.90	154.7	0.55		2	BAZ	–4.8	+0.01
1956.93	157.1	0.51	8.0–9.2	2	COU	–0.7	–0.03
1961.52	148.7	0.59	8.4–9.5	4	B	–1.5	+0.06
1961.56	149.5	0.55	7.5–9.9	3	COU	–0.7	+0.02
1961.86	155.7	0.55		3	Heintz	+6.0	+0.02
1963.318	143.8	0.53		4	WOR	–3.4	0.00
1968.92	140.	0.53		5	Heints	+2.0	0.00
1970.95	130.8	0.63		2	BAZ	–3.6	+0.10
1975.66	123.6	0.66		3	Heintz	–3.0	+0.13
1976.51	126.9	0.54		3	WOR	+0.3	0.00
1978.63	123.6	0.53		2	DZ	+1.9	–0.01

Ephemerides

T	P	ρ	T	P	ρ
1981.0	117°.8	0".54	1986.0	109°.9	0".55
1982.0	116.2	0.54	1987.0	108.3	0.55
1983.0	114.6	0.54	1988.0	106.7	0.55
1984.0	113.0	0.55	1989.0	105.2	0.55
1985.0	111.4	0.55	1990.0	103.6	0.55

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ADS 16368 = IDS 22507N5100 = HU 785, 9.8–10.2, –

P = 105.52	$\Omega = 69^\circ\!.0$	A = +0".0675
n = $3^\circ\!.4114$	$\omega = 0^\circ\!.1$	B = +o".1750
T = 1975.81		F = +0".0930
a = 0".19	$\pi_{dyn.}$ = 0".006	G = –0".0362
e = 0.54	$\Sigma m_{AB} = 2.8 \odot$	C = +0".0003
i = $122^\circ\!.1$	a = 31.7 AJ	H = +0".1609

Observations and residuals

T	P	ρ	mag.	n	Obs.	$(0-C)_P$	$(0-C)_\rho$
1902.53	$261^\circ\!.7$	0".25	9.4–9.8	1	HU	$-2^\circ\!.9$	+0".11
1903.58	260.4	0.25		2	HU	–2.6	+0.01
1922.74	250.3	0.23		3	VBs	+1.2	0.00
1946.4	227.6	0.19		4	VBs	–3.3	–0.03
1954.7	202.8	0.12		5	VBs	–15.9	–0.04
1976.81	63.8+	0.17		2	Heintz	+2.2	+0.08

+ Quadrant reversed.

Ephemerides

T	P	ρ	T	P	ρ
1981.0	$24^\circ\!.8$	0".07	1986.0	$328^\circ\!.4$	0".08
1982.0	13.5	0.07	1987.0	319.7	0.08
1983.0	1.7	0.07	1988.0	312.2	0.09
1984.0	349.7	0.07	1989.0	306.0	0.10
1985.0	338.5	0.07	1990.0	300.7	0.10

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LES ORBITES DE DEUX ETOILES DOUBLES VISUELLES (ADS 2301 = A 2414 et ADS 2531 = A 829)

V. Erceg

(Reçu le 15.02.1980)

RÉSUMÉ:

On donne les éléments des orbites, les masses, les magnitudes absolues e parallaxes dynamiques orbitalles de deux étoiles doubles visuelles, les éléments é determinés en utilisant la méthode de Thiele-Innes-Van den Bos. Pour la syst ADS 2531, D. Olević (1973) et P. Baize (1979) ont determiné les éléments orbi avec la période 249.67 et 120.6 ans.

ORBITE DE ADS 2301 = A 2414

Pos. (1950): $02^h59^m.4$; $+18°07'$ Mgns.: 10.2–10.9; Sp. G5;

Tableau I

Les éléments orbitaux, les quantités astrophysiques et les constantes

P = 125.379 ans		
n = 2°.8713		
T = 1883.25	A = −0".2450	$\pi_{dyn.orb.}$ = 0".010
e = 0.47	B = −0.0817	M_A = 5.1
a = 0".297	F = 0.0000	M_B = 5.8
i = 43°.89	G = −0.2600	$\mathfrak{M}_A = 1.02\ \odot$
Ω = 54°.80	C = ±0.1471	$\mathfrak{M}_B = 0.90\ \odot$
ω = 134°.39	H = ∓0.0144	a = 29.7 U.A.
T = 2014.04; 2086.88;		

Tableau II

Les éphémérides

t	θ°	ρ"	t	θ°
1980.0	56.0	0.34	1985.0	63.7
1981.0	57.4	0.33	1986.0	65.5
1982.0	58.9	0.33	1987.0	67.4
1983.0	60.4	0.32	1988.0	69.4
1984.0	62.0	0.31	1989.0	71.5

Tableau III
Les observations et les résidus

T	θ^o_o	$\rho^"_o$	Obs.	n	Références	$(O-C)_\theta$	$(O-C)^"_\rho$
1910.720	311.2	0.16	A	1	ADS	+ 6.5	+0.08
1912.820	319.8	20	A	2	"	+ 3.5	+ 5
1922.170	347.6	30	A	4	"	− 3.3	− 1
1930.780	2.3	31	VBs	1	La corr.pers.Obs.de Nice	− 3.3	+ 2
1930.780	9.6	34	A	2	"	−10.6	− 1
1936.784	12.2	37	V	3	"	− 4.8	− 2
1940.676	18.1	33	VBs	1	"	− 5.8	+ 3
1943.783	19.1	33	VBs	1	"	− 3.1	+ 4
1943.832	22.2	33	VBs	1	"	− 6.2	+ 4
1951.058	26.5	32	VBs	1	"	− 2.5	+ 7
1951.066	24.2	29	VBs	1	"	− 0.2	+ 10
1961.710	30.7	36	C	1	J. O. Vol. 50., Fasc. 1.	+ 4.3	+ 4
1961.818	35.3	42	Wor	3	La corr.pers.Obs. de Nice.	− 0.2	− 2
1965.960	38,0	48	C	3	J. O. Vol. 50, Fasc. 1.	+ 1.4	− 9
1976.940	51.0	0.40	Hz	3	La corr. pers. Obs. de Nice.	+ 0.9	−0.04

ORBITE DE ADS 2531 = A 829

Pos. (1950): $03^h23^m\!.4$; $+12^o19'$ Mgns: 8.3–9.8; Sp.GO;

Tableau I
Les éléments orbitaux, les quantités astrophysiques et les constantes

P = 87.660 ans		
$n = 4^o\!.1068$		
T = 1893.76	$A = -0''\!.2300$	$\pi_{dyn.orb.} = 0''\!.018$
e = 0.84	B = −0 .0100	$M_A = 4.6$
$a = 0''\!.445$	F = +0.1133	$M_B = 6.1$
$i = 119^o\!.02$	G = +0.4233	$\mathfrak{M}_A = 1.13 \odot$
$\Omega = 69^o\!.24$	$C = \mp 0.3809$	$\mathfrak{M}_B = 0.85 \odot$
$\omega = 258^o\!.23$	$H = \mp 0.0794$	a = 24.8 U.A.
T = 1983.61; 2067.82;		

Tableau II
Les
Les éphémerides

t	θ^o	ρ''	t	θ^o	ρ''
1980.0	251.9	0.12	1985.0	60.6	0.21
1981.0	224.2	0.06	1986.0	56.5	0.24
1982.0	104.9	0.06	1987.0	53.3	0.27
1983.0	75.8	0.12	1988.0	50.6	0.29
1984.0	66.3	0.18	1989.0	48.2	0.31

Tableau III
Les observations et les résidus

t	θ^{o}_{o}	ρ''_{o}	Obs	n	Références	$(0-C)^{o}_{\theta}$	$(0-C)''_{\rho}$
1904.85	40.5	0.33	A	2	ADS	+ 1.0	+0.03
1914.75	29.6	44	A	2	"	– 1.5	– 1
1922.05	18.2	42	A	2	"	+ 1.7	+ 2
1932.88	12.4	38	A	2	Lick Obs. Bull. N. 491	– 4.4	+ 5
1936.751	2.8	42	V	4	La corr. pers. Obs. de Nice	+ 0.7	0
1942.64	348.3	41	V	3	"	+ 7.9	0
1949.98	348.3	35	VBs	4	"	– 2.3	+ 3
1959.07	322.6	35	C	3	J. O. Vol. 42 N. 2.	+ 8.0	– 2
1961.848	322.9	30	B	4	Lick. Obs. Bull. N. 579	+ 2.1	+ 2
1964.00	322.4	32	C	3	La corr. pers. Obs. de Nice.	– 2.1	– 2
1965.437	318.1	22	Wor	4	"	– 1.2	+ 8
1968.54	300.5	25	VBs	5	"	+ 8.3	+ 3
1973.93	111.8*	30	Hz	3	"	– 0.6	– 7
1976.88	100.5*	0.19			"	– 2.8	+0.01

* Quadrant changé

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NEW DOUBLE STARS DISCOVERED IN BELGRADE WITH THE ZEISS REFRACTOR 65/1055 cm, SUPPLEMENT VI

G. M. Popović

SUMMARY:

Presented are position and 68 measures of 28 double stars discovered in Belgrade with the Zeiss refractor 65/1055 cm. The position are related to the epochs 1900, 1950 and 2000.

This Supplement is a result of the continuation of the systematic checking of duplicity of BD stars with the Belgrade Zeiss refractor 65/1055 cm. The form of this Supplement is identical to that in which the preceding one had appeared (Popović G., 1977). The distribution of pairs according to ρ in the previous supplements along with that in the present Supplement is given in Table 1.

Table I

Distribution of the pairs according to ρ

Suppl.	$\rho < 1''$	$1'' \leqslant \rho < 3''$	$\rho \geqslant 3''$	Σ
I – V	13	46	67	126
VI	5	6	17	28
I – VI	18(12%)	52(34%)	84(54%)	154(100%)

The bright BD +45°3152 ($5\overset{m}{.}8$), (which is the reference star for GP 144) has been recurrently observed on 6 occasions with the purpose to establish its duplicity (1977.811, 1977.819, 1978.532, 1978.696, 1979.780, 1979.785). On four occasions a certain elongation in the direction $\theta \sim 74^{\circ}$ has been stated. At the epochs 1978.696 and 1979.785 the duplicity could not be confirmed. On no occasion two separate nuclei have been clearly observed. The question of this bright star could easily be cleared in more favourable climatic conditions.

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Table II

New double stars

Double star	1900 α 1950 δ 2000	t	θ	ρ	m or Δm	Mgf.	W	BD Δα Δδ	Comm
GP 148	02033N4415	78.009	120°0	3″18	10,0–12,5	590	1+1	+43°434 (8ᵐ1)	
	02064N4430	79.701	121.4	3.79	10.0–13.0	500	1+1	Δα = +1 s, Δδ = +3'	
	02095N4444	**78.855**	**120.7**	**3.48**	**10.0–12.8**		**2n**		
GP 142	02153N4510	77.798	32.4	5.77	12.0–12.2	700	1+1	+45°601 (9ᵐ5)	
	02185N4524							Δα = +5 s, Δδ = –5'	
	02206N4538								
GP 147	03162N4307	78.006	336.0	3.02	11.0–13.0	590	1+1	+43°694 (9ᵐ5)	
	03195N4317							Δα = +14 s, Δδ = –6'	
	03229N4328								
GP 140	05073N3648	77.798	145.7	0.33	9.0– 9.0	880	3+2	+36°1049 (7ᵐ7)	
	05106N3652	77.812	155.0	0.32	8.5– 8.8	880	2+2		
	05140N3656	**77.804**	**149.8**	**0.33**	**8.8– 8.9**		**2n**		
GP 133	08047N3545	75.235	37.2	8.47	9.3–11.0	500	1+1	+35°1773 (9ᵐ3)	
	08079N3537	78.173	34.5	8.77	9.0–11.0	500	1+1		
	08112N3528	**76.704**	**35.8**	**8.62**	**9.2–11.0**		**2n**		
GP 146	09210N3357	77.182	322.2	6.57	9.0–11.0	590	1+2	+33°1861 (9ᵐ4)	
	09241N3344	78.170	318.4	6.82	10.0–12.0	500	1+2	Δα = –11 s, Δδ = +15'	
	09271N3332	**77.676**	**320.3**	**6.70**	**9.5–11.5**		**2n**		
GP 151	09503N4427	79.271	77.5	0.39	8.5– 8.5	880	3+3	+44°1931 (8ᵐ2)	
	09536N4414	79.279	75.6	0.45	0.2	700	2+2		
	09567N4400	**79.274**	**76.7**	**0.41**	**0.1**		**2n**		
GP 153	13495N4134	79.288	355.0	0.99	9.5– 9.6	880	2+1	+41°2438 (8ᵐ8)	
	13516N4119							Δα = –41 s, Δδ = –8'	
	13538N4104								
GP 131	17123N4446	77.573	136.8	3.35	10.0–10.2	590	2+2	+44°2678 (8ᵐ7)	
	17138N4443	77.576	139.2	3.08	10.0–10.5	590	1+2	Δα = –11 s, Δδ = +1'	
AB	**17153N4440**	**77.574**	**137.8**	**3.23**	**10.0–10.3**		**2n**		
AC		77.576	322.2	28.07	10.0–10.2	590	2+1		
GP 132	17268N4451	77.576	153.0	15.91	9.5– 9.6	590	1+2	+44°2720 (9ᵐ4)	
	17283N4447								
	17298N4444								

Double star	1900 α 1950 δ 2000	t	θ	ρ	m or Δm	Mgf.	W	BD Δα Δδ	C.I. UAI Comm.26
GP 134	18244N4351	77.672	62.6	6.28	9.0–10.0	590	1+1	+43°2980 (9ᵐ.4)	–
	18259N4353	77.677	64.3	7.05	9.5–12.0	590	1+1		
AB	18274N4354	**77.675**	**63.6**	**6.74**	**9.2–11.0**		**2n**		
AC		77.672	285.1	65.6	9.0– 9.8	590	1+1		
		77.677	285.0	65.3	9.5–11.0	590	1+2		
		77.675	**285.0**	**65.4**	**9.2–10.4**		**2n**		
CD		77.672	244.3	4.10	9.8–12.0	590	1+1		
		77.677	250.0	3.50	11.0–14.0	590	1+2		
		77.675	**247.7**	**3.74**	**10.4–13.0**		**2n**		
GP 130	18538N3459	77.412	125.4	55.5	9.5–12.0	700	1+1	+34°3369 (9ᵐ.5)	–
	18556N3502	77.571	124.9	55.5	9.5–10.5	500	1+2		
AB	18574N3505	**77.507**	**125.1**	**55.5**	**9.5–11.2**		**2n**		
BC		77.412	272.4	8.43	12.0–12.8	700	1+2		
		77.571	271.5	8.41	10.5–11.3	500	1+2		
		77.492	**272.0**	**8.42**	**11.2–12.0**		**2n**		
GP 135	19253N3456	77.677	40.2	1.83	10.8–11.5	590	1+2	+34°3568(9ᵐ.5)=GP 34	73
	19272N3502	77.767	33.7	1.83	10.0–10.5	700	1+2	Δα = +3 s, Δδ = –8'	
	19290N3518	**77.722**	**37.0**	**1.83**	**10.4–11.0**		**2n**		
		79.665	36.1	1.85	11.0–12.0	420	1+2		
		79.670	36.9	1.87	11.5–12.5	500	2+2		
		79.692	32.8	1.97	0.7	590	1+1		
		79.698	32.7	1.94	10.0–11.0	700	1+2		
		79.679	**35.0**	**1.90**	**1.0**		**4n**		
GP 154	19259N3329	79.698	226.4	3.94	12.0–12.0	500	2+2	+33°3475 (9ᵐ.4)	79
	19278N3335							Δα = –3 s, Δδ = +10'	
	19296N3341								
GP 155	19260N3458	79.665	95.8	3.29	10.0–12.0	420	2+2	+34°3572 (8ᵐ.5)	79
	19278N3505	79.670	96.2	3.85	10.0–12.0	420	2+2	Δα = +33 s, Δδ = –1'	
	19297N3511	79.692	93.8	3.83	10.0–12.0	500	1+1		
		79.698	95.8	3.00	–	500	1+1		
		79.677	**95.6**	**3.52**	**10.0–12.0**		**4n**		
GP 138	20107N4521	77.762	35.0	0.35	0.2	700	3+2	+45°3102 (9ᵐ.1)	73
	20123N4530	77.803	33.6	0.48	9.2– 9.4	500	3+2		
	20139N4539	**77.782**	**34.3**	**0.42**	**0.2**		**2n**		
GP 128	20152N3531	77.519	307.8	3.69	12.0–12.3	590	1+1	+35°4065 (9ᵐ.5)	77
	20171N3541							Δα = –19 s, Δδ = +1'	
	20190N3550								
GP 129	20172N3506	78.791	31.6	5.19	13.0–13.5	590	1+2	+34°3980 (9ᵐ.5)	
	20191N3516							Δα = –4 s, Δδ = +0'.3	
	20210N3525								
GP 144	20190N4527	78.532	120.2	5.10	12.0–12.3	700	1+2	+45°3152 (5ᵐ.8)	
	20206N4536	79.785	119.9	5.86	14.0–14.7	700	1+2	Δα = +10 s, Δδ = –1'	
	20223N4546	**79.158**	**120.0**	**5.48**	**13.0–13.5**		**2n**		

Double star	1900 α 1950 δ 2000	t	θ	ρ	m or Δm	Mgf.	W	BD Δα Δδ	C.I. UAI Comm.26
GP 156	20295N4626	79.791	311.9	2.60	11.0–13.0	700	1+1	+46°2971 ($9^m.4$)	80
	20311N4636							Δα = –45 s, Δδ = +2'	
	20327N4646								
GP 149	21264N4513	78.532	295.6	3.02	–	700	1+2	+45°3564 ($7^m.9$)	77
	21283N4526							Δα = +5 s, Δδ = +1'	
	21302N4540								
GP 137	21275N4429	77.760	101.3	1.30	11.5–11.5	590	1+1	+44°3848 ($9^m.4$)	73
	21296N4442							Δα = 0 s, Δδ = +1'	
	21313N4455	79.665	107.4	1.47	0.0	420	1+1		
		79.670	108.6	1.83	0.0	420	1+1		
		79.668	**108.0**	**1.65**	**0.0**		**2n**		
GP 150	21280N4452	78.532	~225	–	1.5	700	1	+44°3855 ($9^m.5$)	77
	21299N4505	79.665	221.7	3.57	9.0–12.0	500	2+1		
	21317N4518								
GP 136	21287N4409	77.803	249.3	22.7	9.0–10.2	500	3+2	+43°3962 ($9^m.5$)	73
	21306N4422								
A–BC	21325N4436								
BC		77.760	88.8	1.98	11.0–11.0	590	1+1		
GP 139	21332N4342	77.768	184.5	0.65	0.5	700	1+2	+43°3988 ($9^m.3$)	73
	21352N4356	77.803	185.3	0.82	9.5–10.2	500	3+2		
	21371N4409	**77.790**	**185.0**	**0.76**	**0.6**		**2n**		
		79.665	183.5	0.62	9.7–10.0	500	2+2		
		79.670	180.3	0.79	0.2	500	2+1		
		79.667	**182.1**	**0.69**	**0.2**		**2n**		
GP 145	22002N4604	77.820	101.7	1.56	10.0–10.5	880	2+2	+45°3785 ($9^m.2$)	77
	22022H4618	78.737	105.7	1.85	10.0–10.1	590	1+1	Δα = –43 s, Δδ = 0'	
	22041N4632	78.792	99.4	1.73	10.0–11.0	590	1+1		
AB		**78.292**	**102.1**	**1.68**	**10.0–10.5**		**3n**		
CD		77.820	30.5	1.41	10.2–10.5	880	1+2		
		78.737	29.5	1.53	10.0–10.1	590	1+1		
		78.792	31.0	1.26	11.0–11.5	590	1+1		
		78.360	**30.4**	**1.40**	**10.4–10.7**		**3n**		
AB–CD		78.737	92	30.6	–	590	1+1		
		78.792	95	29.8	–	590	1+1		
		78.764	**94**	**30.2**			**2n**		
GP 141	23265N4540	77.765	257.0	3.16	13.0–14.0	590	1+1	+45°4248 ($8^m.8$)	77
	23289N4556							Δα = +7 s, Δδ = –1'	
	23313N4613								
GP 143	23308N4747	77.812	283	~2.5	Δm = 3.0	880	2+1	+47°4199 ($9^m.5$)	77
	23331N4803	78.816	280	–	Δm = 4.0	590	1+1		
	23355N4820	**78.214**	**282**	**~2.5**	**Δm = 3.3**		**2/1n**		

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MICROMETER MEASURES OF DOUBLE STARS (SERIES 32)

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SUMMARY:

Presented here are 153 measures of 78 Double Stars made with 65/1055 cm refractor of Belgrade Observatory.

The present list is a continuation of the published series of measures of double stars in Belgrade, made in period 1979.09–1979.85. In the Table I of measures the columns give: ADS number, double star designation, multiple, position for 1900 (IDS), epoch omitting the century, position angle, separation, estimated magnitudes, number of nights and notes. An asterisk in the second column indicates that there is a note at the end of Table I.

In the present work the distribution of 152 measures of distances is as follows:

$\rho \leqslant 0''.50$	$0.50 < \rho \leqslant 1.00$	$1.00 < \rho \leqslant 1.50$	$1.50 < \rho \leqslant 2.00$	$\rho > 2.0$
10	73	37	20	12
6,5%	48,0%	24,3%	13,1%	7,9%

Table I
Micrometer measures of double stars

ADS	Disc. IDS	Mult.	Epoch 1900+	P	ρ	Est.Mag.	n	Notes
61	STF 3062		79.77	288°.4	1″.30	6.4–7.5	1	Baize, 1958: +1°.6, –0″.13
	00010N5753							
283	HJ 1018		79.79	87.5	1.32	8.6–9.2	1	Muller, 1956: +1°.2, –0″.12
	00154N6707							
963	BU 235	AP	79.67	125.6	0.87	7.5–7.9	1	Changed 51° since 1875.
	01047N5029							
1254	STF 138	AB	79.70	234.4	1.55	7.5–7.7	1	
	01308N0708		79.77	233.3	1.53		1	
			79.79	233.7	1.58		1	
			79.85	233.3	1.55		1	
			79.78	233.7	1.55		4	Changed 53° since 1830.
1538	STF 186		79.68	55.4	1.35	7.0–7.0	1	Freitas-Mourao, 1976: –1°.1, +0″.4
	01507N0121							
1548	A 819	AB	79.67	191.1	0.51	8.2–8.7	1	
	01513N3032		79.69	197.2	0.50		1	
			79.68	194.2	0.51		2	Zulević, 1980: +2°.2, 0″.00
2034	STT 43		79.69	10.0	0.94	8.3–9.9	1	
	02349N2612		79.70	7.4	0.97		1	
			79.85	8.9	0.95		1	
			79.75	8.8	0.95		3	Heintz, 1061: +0°.4, –0″.07
2377	STT 50	AB	79.85	169.1	1.25	8.5–8.5	1	Popović, 1972: +1°.7, +0″.17
	0.3027N7110							
2446	STT 53		79.70	259.7	0.82	7.7–8.5	1	Rabe, 1948: –6°.3, –0″.04.
	03113N3816							
2995	STT 531	AB	79.09	7.4	1.23	7.3–9.0	1	
	04009N3749		79.10	7.8	1.24		1	
			79.14	8.3	1.25		1	
			79.11	7.8	1.24		3	Rabe, 1956: +3°.8, –0″.18.
3390	STF 577		79.18	22.4	1.21	8.6–8.6	1	Hock, 1966; –0°.5, +0″.08
	04355N3719							
3956	STF 677		79.09	156.0	0.97	7.9–8.0	1	
	05153N3719		79.14	157.0	0.92		1	
			79.12	156.5	0.95		2	Heintz, 1962: –3°.4, –0″.08.
5871	STF 1037		79.14	323.6	1.18	7.2–7.2	1	
	07066N2724		79.18	325.1	1.33		1	
			79.16	324.3	1.26		2	Karmel, 1940: +3°.2, –0″.06.
6175	STF 1110	AB	79.14	104.1	1.94	2.0–2.9	1	Muller, 1955: +3°.3, –0″.31.
	07282N3166							
6650	STF 1196	AB	79.14	285.2	0.73	5.6–6.3	1	Gasteyer, 1954: –0°.6, –0″.10.
	08065N1757							
6650	STF 1196	AC	79.11	83.9	5.45	5.6–6.5	1	
	08065N1757		79.14	79.7	5.54		1	
			79.13	81.8	5.50		2	
7067	STF 1280	AB	79.14	112.6	1.21	9.3–9.4	1	Heintz, 1973: –1°.6, –0″.06.
	08460N7071							

7081	AG	79.25	189.9	1.55	9.3–9.4	1	Changed 47° since 1912.
	08491N1659						
7307	STF 1338	79.28	253.3	1.06	6.6–6.8	1	Starikova, 1966: −1°.0, +0″.12.
	09147N3837						
+75°403	KUI 47	79.28	102.7	0.98	10.6–10.7	1	Baize, 1965: +2°.8, −0″.21.
	10017N7537						
7685	STT 213	79.28	136.4	0.61	8.4–10.2	1	Heintz, 1962: +8°.6, −0″.21.
	10075N2755						
7704	STF 215	79.25	187.3	1.24	7.0–7.3	1	
	10108N1774	79.30	185.6	1.16		1	
		79.27	186.5	1.20		2	Zeara, 1957: +5°.2, −0″.18.
8032	A 1590	79.25	347.1	1.27	9.2–9.4	1	
	10576N5464	79.28	345.4	1.25		1	
		79.26	346.2	1.26		2	Heintz, 1963: +2°.6, +0″.05.
8119	STF 1523	79.20	107.5	2.86	4.4–4.9	1	
	11128N3166	79.25	108.6	2.91		1	
		79.30	107.4	2.85		1	
		79.25	107.8	2.87		3	Heintz, 1966: +1°.6, −0″.09.
8553	STF 1643	79.20	14.1	2.23	9.2–9.5	1	
	12222N2735	79.28	13.2	2.31		1	
		79.24	13.6	2.27		2	Hopmann, 1964: +0°.9, −0″.02.
8680	HU 640	79.28	142.6	0.60	10.1–10.1	1	Baize, 1973: +3°.8, −0″.16.
	12458N3065						
8887	HO 260	79.28	71.2	1.02	9.6–9.8	1	
	13189N2945	79.28	72.9	0.98		1	
		79.43	73.1	0.93		1	
		79.33	72.4	0.98		3	Ambruster, 1978: +1°.2, −0″.05.
9031	STF 1785	79.45	158.3	3.11	7.9–8.2	1	Strand, 1955: −0°.7, −0″.28.
	13445N2689						
9071	A 1614	79.43	133.9	0.98	9.4–9.5	1	
	13539N5229	79.45	135.3	1.06		1	
		79.44	134.6	1.02		2	Mourao, 1960, +0°.8, −0″.23.
9182	STF 1819	79.28	245.8	0.89	7.7–7.8	1	
	14103N0346	79.28	245.9	0.88		1	
		79.28	245.9	0.88		2	Baize, 1973: +5°.7, +0″.06.
9229	STF 1834	79.43	102.1	1.14	7.9–8.0	1	
	14166N4858	79.53	102.5	1.17		1	
		79.53	102.2	1.11		1	
		79.50	102.3	1.14		3	Van den Bos, 1938: −1°.4, −0″.08.
9418	STF 287	79.28	347.4	0.90	8.5–8.6	1	
	14478N4480	79.53	347.4	0.93		1	
		79.41	347.4	0.92		2	Heintz, 1962: +1°.8, −0″.17.
9425	STT 288	79.28	174.5	1.37	6.9–7.6	1	
	14487N1567	79.53	172.1	1.35	7.7–8.2	1	
		79.41	173.3	1.36	7.3–7.9	2	Heintz, 1955: +2°.0, +0″.10.
9578	STF 1932	79.28	249.1	1.39	7.1–7.6	1	
	15140N2672	79.45	250.2	1.29		1	
		79.45	249.8	1.28		1	
		79.54	247.9	1.28		1	
		79.44	249.2	1.30		4	Heintz, 1964: −0°.8, −0″.08.
9626	STF 1938 BC	79.54	16.8	2.07	7.2–7.8	1.	Baize, 1951: +0°.8; −0″.10
	15207N3742						

9716	STT 298	AB	79.54	214.2	0.68	7.4–7.7	1	Couteau, 1965: +2°.6, −0″.07.
	15325N3968							
9982	STF 2026		79.54	24.4	2.62	9.1–9.6	1	Heintz, 1963: +0°.6, −0″.16
	16111N0737							
10075	STF 2052	AB	79.28	137.1	1.30	7.8–7.8	1	
	16245N1837		79.44	134.9	1.15		1	
			79.53	135.6	1.22		1	
			79.42	135.6	1.26		3	Siegrist, 1952: +0°.5, −0″.15.
10235	STF 2107	AB	79.44	84.9	1.27	6.7–8.2	1	
	16479N2850		79.52	90.2	1.17		1	
			79.48	87.5	1.22		2	Rabe, 1927: 0°.0, −0″.14.
10.279	STF 2118		79.68	68.2	1.05	6.9–7.4	1	Giannuzzi, 1956: −0°.5, −0″.22.
	16559N6511							
10341	BU 823	AB	79.54	124.3	0.77	8.7–9.7	1	
	17015N0047		79.67	121.2	0.76		1	
			79.60	122.7	0.76		2	Arend, 1955: +5°.1, −0″.23.
10585	A 351	AB	79.53	236.2	0.40	9.7–10.1	1	Baize, 1954: +1°.7, +0″.06.
	17255N2929							
10786	AC 7	BC	79.70	36.3	0.87	10.2–10.7	1	
	17425N2747		79.70	36.4	0.87		1	
			79.70	36.4	0.87		2	Couteau, 1957: +2°.7, −0″.19.
11045	STT 534		79.70	270.2	2.15	7.2–8.5	1	
	18008N2126		79.70	272.4	2.08		1	
			79.70	271.3	2.11		2	No change since 1852.
11186	STF 2294		79.53	97.0	0.94	8.5–8.8	1	
	18094N0009		79.54	96.3	0.97		1	
			79.67	94.8	0.98		1	
			78.58	96.0	0.96		3	Wilson, JNR, 1935: +2°.2, −0″.05.
11334	STF 2315	AB	79.55	136.7	0.63	6.6–7.6	1	
	18210N2720		79.67	132.9	0.59		1	
			79.69	132.6	0.59		1	
			79.64	134.1	0.60		3	Heintz, 1959: +4°.6, −0″.08.
11483	STT 358		79.45	162.6	1.71	6.8–7.2	1	
	18314N1654		79.52	164.0	1.63		1	
			79.48	163.3	1.67		2	Hopmann, 1970: −1°.1, +0″.10.
11568	STF 2384	AB	79.54	312.9	0.58	8.6–9.1	1	
	18385N6702		79.67	315.2	0.57		1	
			79.68	310.3	0.57		1	
			79.69	314.0	0.54		1	
			79.70	313.4	0.57		1	
			79.66	313.2	0.56		5	Heintz, 1975: +1°.7, −0″.05.
11623	A 253		79.52	121.6	0.63	9.1–10.1	1	
	18400N3135		79.53	122.9	0.68		1	
			79.53	122.2	0.65		2	Muller, 1955: +1°.6, −0″.10.
11692	HU 937		79.70	321.8	0.51	8.9–9.3	1	Baize, 1979: −4°.7, −0″.02.
	18456N6405							
11897	STF 2438		79.52	5.4	0.76	6.8–7.4	1	
	18558N5805		79.53	4.1	0.76		1	
			79.68	3.6	0.79		1	
			79.58	4.4	0.77		3	Jastrzebski, 1959: +2°.0, −0″.11.
11956	STF 2437		79.67	28.5	0.57	8.2–8.4	1	
	18575N1902		79.67	27.4	0.59		1	
			79.68	28.1	0.58		1	
			79.67	28.0	0.58		3	Changed 52° since 1830.

12447	STT 2525	79.45	295.1	1.55	8.5–8.7	1	
	19225N2707	79.52	293.6	1.69		1	
		79.67	293.7	1.57		1	
		79.67	294.3	1.56		1	
		79.58	294.2	1.59		4	Tamburini, 1967: +1°.3, –0".24.
12889	STF 2576	79.67	358.3	1.94	9.1–9.1	1	
	19418N3322	79.67	358.1	1.98		1	
		79.68	359.3	1.84		1	
		79.70	358.1	1.83		1	
		79.68	358.5	1.90		4	Rabe, 1948: +1°.7, –0".12.
12972	STT 387	79.53	170.4	0.60	6.9–7.9	1	
	19450N3504	79.70	170.6	0.59		1	
		79.70	170.1	0.61	7.0–7.9	1	
		79.64	170.4	0.60		3	Baize, 1961, +2°.3, 0".00.
13665	A 1205	79.67	105.6	0.46	9.2–10.0	1	
	20141N2854	79.69	107.0	0.50		1	
		79.68	106.3	0.48		2	Heintz, 1978: +4°.1, –0".08.
13723	STT 406	79.70	119.4	0.55	7.4–8.3	1	Heintz, 1975: +3°.2, –0".04.
	20166N4503						
14238	BU 64 AB	79.52	167.3	0.68	9.1–9.1	1	
	20403N1222	79.53	164.3	0.53		1	
		79.55	162.8	0.68		1	
		79.53	164.8	0.63		3	Baiez, 1957: +1°.7, +0".08.
14296	STT 413 AB	79.70	18.0	0.78	4.8–6.1	1	Rabe, 1948: +2°.6, –0".06.
	20435N3607						
14333	J 194 AB	79.53	205.5	0.51	10.2–10.2	1	
	20446N1102	79.67	204.5	0.49		1	
		79.60	205.0	0.50		2	Baize, 1976: +3°.9, –0".05.
14424	BU 367 AB	79.53	120.0	0.40	8.6–9.0	1	
	20508N2743	79.67	117.7	0.47		1	
		79.69	119.3	0.44		1	
		79.63	119.0	0.44		3	Heintz, 1961: +0°.9, –0".06.
14499	STF 2737 AB	79.55	285.9	0.97	5.8–6.3	1	
	20541N0355	79.67	287.5	0.88		1	
		79.68	287.6	0.88		1	
		79.70	288.6	0.89		1	
		79.65	287.4	0.90		4	W. H. Bos, 1933: +1°.9, –0".15.
14573	STF 2744 AB	79.55	131.0	1.22	7.0–7.5	1	
	20580N0108	79.67	129.6	1.30		1	
		79.67	129.7	1.21		1	
		79.63	130.1	1.24		3	Popović, 1964: +4°.5, –0".03.
14766	A 884	79.69	132.9	0.39	9.4–9.5	1	Changed 54° since 1904.
	21098N4630						
14783	HI 48	79,53	256.8	0.60	71.–7.3	1	
	21117N6400	79.67	250.1	0.79		1	
		79.60	253.4	0.69		2	Baize, 1950: +2°.5, 0".00.
15270	STF 2822 AB	79.67	296.3	1.84	4.7–6.1	1	
	21397N2817	79.68	296.9	1.81		1	
		79.69	295.9	1.81		1	
		79.68	296.4	1.82		3	Heintz, 1965: –1°.3, +0".02.
15447	BU 75 AB	79.53	335.7	0.30	8.4–8.9	1	Baize, 1973: +9°.0, –0".04.
	21506N1025						
16185	STF 2934	79.69	74.3	0.86	8.7–9.7	1	
	22370N2054	79.69	76.4	0.87		1	
		99.69	75.4	0.87		2	Heintz, 1960: +5°.0, –0".08.

16326	A 632 AB 22480N5712	79.67 79.68 79.69 79.68	170.2 168.5 169.3 169.3	0.89 0.93 0.91 0.91	8.2–9.0	1 1 1 3	Heintz, 1962: +0°.1, +0".08.
16373	HU 987 22580N1115	79.70	90.7	0.86	9.1–9.3	1	Heintz, 1965: +2°.4, +0".20.
16785	A; 1487 23244N4009	79.67 79.67 79.67	165.9 164.9 165.4	0.88 0.89 0.88	9.0–9.5	1 1 2	Changed 23° since 1906.
1692	BU 858 AB 23363N3201	79.69	233.0	0.82	8.0–9.3	1	Changed 44° since 1881.
16951	A 1242 23380N1117	79.67 79.67 79.67	326.2 324.9 325.5	0.83 0.80 0.82	9.6–9.6	1 1 2	Zulević, 1977: +0°.6, +0".08.
17020	STT 507 AB 23438N6420	79.68	304.5	0.79	6.9–7.7	1	Zulević, 1977: +0°.8, +0".05.
17149	STF 3050 AB 23544N3310	79.68 79.69 79.69	307.5 309.8 308.6	1.49 1.61 1.55	6.6–6.6	1 1 2	Heintz, 1973: +0°.0, +0".01.
17178	HLD 60 23563N3905	79.67	182.3	0.89	9.2–9.6	1	Heintz, 1963: –0°.3, –0".15.
	GP 27 20552N3412	79.70	156.6	–	$\Delta m = 0.3$	1	
	GP 117 10123N4416	79.17	266.1	0.63	–	1	

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POSITIONS OF MINOR PLANETS OBTAINED IN 1979

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1. INTRODUCTION

This paper contains the results of photographic observations of minor planets performed by means of the Belgrade Observatory ZEISS Astrograph (160/800 mm; plate scale 258 "/mm). KODAK 130a0, ORWO

2. RESULTS

In Table 1 the results are shown of the observations of selected minor planets of the Leningrad Program. Columns headings denote: ordering number, observed object, epoch in UT, geocentric right ascension and