ASTRONOMICAL REFRACTION INVESTIGATIONS TODAY

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SUMMARY

In the light of Harzer's ideas, the author analyses the recent requirements for the astronomical refraction investigations. The basic conclusion is: refractional influences are mostly local in character, and for this reason we need local theories and tables. The role of the Study Group on Astronomical Refraction is accentuated.

1. Reffering to his own refraction tables, Harzer (1924) wrote the following: „Die vorliegenden Tabellen zur Berechnung der Ablenkungen der Lichtsrahlen in der Atmosphäre der Erde sind zum ersten Male mit den Ergebnissen der neueren Erforschung der Atmosphäre auf rein meteorologischer und physikalischer Grundlage und ohne die Benutzung astronomischer Beobachtungen hergestellt worden. Sie gelten in Strenge nur für die Beobachtungen am grossen Kieler Meridiankreise; mit demselben Rechte oder vielmehr Unrechte, wie die bisher veröffenlichten ähnlichen Tabellen können sie aber auch für einen anderen Beobachtungsort und ausserhalb des Meridianes benutzt werden, und zwar um so unbedenklicher, je geringer die Entfernung des Beobachtungsortes von Kiel ist".

So, he underlined the importance of the use of recent meteorological and physical knowledge as well as he declared that he had not used the astronomical observational data (the use of these data was needful before Harzer) and it follows that his tables are valid for the determined place only. After these strict statements, there is a compromise at the end all the same: the tables can be used on the other places too — with the same justification as other tables. Unfortunately, Harzer (1922—24) admits one compromise more: he considered that the errors in his tables can be determined — with sufficient accuracy — from the astronomical data.

Harzer's tables were criticized justifiably, but his basic idea on the necessity of establishing local refraction tables is still actual. Today much more than five decades ago, when Bakhuyzen (1915) and Emden (1923) declared similar ideas in the same way.

We wish to demonstrate the present need for the establishment and use of local refraction tables — starting from Harzer's basic assumptions.

2. We use observations of the same stars in upper and lower culmination for the partial elimination of systematical errors at the absolute declination determinaions. We employ the next relation (Podobed, 1968a):

$$2\Delta\varphi + E(z_l) \pm E(z_u) = \delta_l - \delta_u \qquad (1)$$

where are:

$\Delta\varphi$ — the correction of the mean latitude,
$E(z)$ — some function of zenith distance,
l — index for lower culmination,
u — index for upper culmination,
δ — declination calculated with known values.

The minus before $E(z_u)$ is related to the upper culmination when it is southern from the zenith.

Bessel has still proposed to substitude $E(z)$ for the function $\Delta k \tan z$, where Δk is some coefficient. In this manner from (1) we obtain the next relation, which is employed today too:

$$2\Delta\varphi + (\tan z_l \pm \tan z_u)\,\Delta k = \delta_l - \delta_u \tag{2}$$

Seeing that the refractional influences are proportional with tan z and because the refraction constant (the coefficient of the first refraction term with tan z) was known by insufficient accuracy in past, therefore for the value Δk gradually the term „refraction constant correction" has come in use. We also use this name at present time.

By means of the relation (2) — or formulas similar to this — from greater number of observations the values $\Delta\varphi$ and Δk can be calculated.

From 78 observations, Courvoisier (1904) determined Δk with the mean error of $\pm$ 0,"037. This fact speaks about the great dispersion of the basical data. The situaction is the same at other determinations too. Related to Δk the systematical influences are especially important. At different stations we have obtained different values of Δk (Bauschinger, 1898), but this value is not constant at the same particular station yet: Orlov (1945) showed that the refraction constant in the eleven absolute catalogs, observed with the Pulkovo Vertical Circle, changed within the range of 0,"26. Schmeidler (1970), after a careful discussion of vertical circle observations made at Pulkovo, Odessa, Munich and Canberra, has proved the existence of an annual variation of the refraction constant with an amplitude of about 0,"1.

For these variations, generaly speaking, we have no explanations. One part of the value Δk is caused by the real error in the calculation of refraction — this is supported by the fact that from the analysis of refraction constant it is possible to show, with low accuracy indeed, the dependence of the refractional influence on the spectral class of stars (Orlov, 1955) — but it involves also other influences (especially the flexion component), the nature of which is unknown to us. For this reason fully justifiable is the statement (Zverev, 1950; Schmeidler, 1956; Podobed, 1968b and others) that the smooting equation of (2), or any similar type is formal only, unreal, without any physical basis. This is why Harzer's basic statement on the elimination of the astronomical data at the calculation of refractional influences is acceptable. Astronomical observations cannot give real corrections for the calculation of the pure refraction (we use Δk for the purpose of this), above all for the anomalous refraction determination (Teleki, 1972).

The refraction constant is the function of the refractive index, accordingly of one physical parameter. For the calculation of this value we have formulas, the accuracy of which is in the order of 10^{-8}, and that means the error at the calculation of refraction of $\pm$ 0,''002 tan z. At the application of these formulas there are some difficulties, and thus the real accidental error is the order of $\pm$ 0,''02 tan z. The possible influence of systematic factors is the order of hundredth parts of a second of arc (Teleki, 1973). From these facts it seems, that the physics gives the markedly surer implement for the calculation of refraction then the values determined from astronomical observations.

3. The refraction investigations need the knowledge on the characteristics of the Earth atmosphere, the medium through which is propagated a light ray. Relevant to the determination of the refraction, the following can be concluded on the meteorological factors (Teleki, 1973):

a) There is no mathematically exact and universal model of atmosphere valid for all places on the Earth;

b) The free atmosphere (the part of atmosphere which is practically independent of the influence of Earth surface) can be approximately demonstrated with a composition of concentric layers which, however, doesn't satisfy the present requirements in full;

c) The atmosphere is not a quiet medium: the circulation is general characteristic of the atmosphere, the nature of which we don't know with a satisfactory accuracy;

d) The planetary boundary layer (the thickness of which is 1—2 km above Earth surface), and especially its lowest part, the surface layer (to 100—200 m above surface), cannot be really represented by mathematical models;

e) The field of meteorological elements around astronomical instruments and observing houses is very complicated and rather unknown for the time being (Kakuta et al., 1973).

What conclusion can be drawn from it? It is visible that the character of three--dimensions and non-stability are the general features of air physical parameters field. The atmospheric characteristics depend on observer's place and observation time. It was the reason why Harzer tried to get the mean feature of atmosphere above Kiel, and its variation in function of seasons, hour of the day and wind speed. His effort was based on evidence.

4. Harzer was the first who put in the correction for spectral class of stars in the refraction tables. It was completely justified, because the refractive index also depends on the wavelength of radiation; for stars of differing colours the refraction influence varies: for white-blue stars is greater than for yellow-red stars. Such an influence can be called chromatic refraction.

In refraction tables there are usually the corrections for the mean spectral class of stars. Mel'nikov (1956) is of the opinion that this practice leads to significant errors. For the same spectral class, the chromatic refraction varies from 0,''01 to 0,''07 in comparison with the mean value. Therefore the spectral class is no uniform criterion, with special regard to the fact that the variation of the effective wavelength from one spectral class to another is not sufficiently well determined (Socher, 1952; Orlov, 1955). For this reason Mel'nikov has proposed the calculation of the chromatic refraction separately for each star and every observation. Instead of spectral class he suggested the using of spectral photometric gradient as a basis.

Relevant to the chromatic refraction calculation, Kolchinskij (1948, 1954) underlined the influence of the optic of used instruments and of observer's eye. Löser (1957) analysed the variation of the chromatic refraction in the humid atmosphere (for the Sun light the refraction constant can be changed for 0,3%).

On the basis of Kolchinskij's and Mel'nikov's investigations, the main conditions for the correct determination of the chromatic refraction can be summarized in this way:

a) determination of the Earth atmosphere transmission factor for the observation time and place (in function of zenith distance);

b) determination of the employed instrument transmission factor;

c) calibration of the observer's eyes (for night and daytime conditions), and

d) determination of the spectral photometric gradient of observed stars.

All these points to the importance of certain factors which were not considered.

5. Depending on need we select the astronomical refraction tables. For observations of higher accuracy we must use such theories and tables which take into consideration local characteristics of atmosphere, instrument and observer — this statement results from above-mentioned facts. To be sure that it is not easy to put into execution all these requirements, but it is needful if we want to increase the accuracy of our astrometrical data. We need additional meteorological measurements, we must be very careful at the selection of observation places and at the building of pavilions, it is desirable to eliminate all the factors which provoke the variation of density fields, etc. (Teleki, 1969a).

If we observe on the small zenith distances — which is really the best prevention — then the pure refraction values slightly depend on the atmosphere structure above observation places. Teleki (1969b) analysed the dependence of the pure refraction values from changes of the atmosphere model. From the Belgrade aerological data, he obtained these variations: for $z = 45°$ approximately 0,″01—0,″02, and for $z = 60°$ approximately 0,″1. These variations really are not negligible.

The anomalous refraction (which can be treated as the difference between the true and the pure refraction) has still more the local character, because it dominantly depends on the planetary boundary layer and especially its lovest layer in the immediate wicinity of instruments. The field of meteorological elements is very complicated, and for this reason it is very hard — currently impossible — to calculate the real anomalous refraction corrections. This is why the prevention is very important in this case, in order to decrease the anomalous refraction values.

Let us come back to Harzer. His ideas, in some different forms, are valid nowadays too. That is to say: the refractional influences are mostly local in character and this fact must be considered especially at the observations of high accuracy. The smoothing of astronomical data doesn't contribute to progress, all we shall get in this way is that the basic difficulties will be masked.

There is some opposition against the using of local theories and tables in the astrometrical practice. The reason is not only because of the need of organisation of new measurements, which will be a great trouble to observers, but primarily because at this moment we have no clear conception on the new methods of this procedure. In this respect the Study Group on Astronomical Refraction, established in 1971 by the Commission on Positional Astronomy of the International Astronomical Union, must render help. The importance of these investigations is great, especially at this moment when we have new astrometrical methods, fundamentally different from the classical ones, and we must compare the old and the new data. At this comparison it is wanting to know different sorts of influences with higher accuracy than nowadays — among them refractional influences too.

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