CALCULATED DIFFERENTIAL COLOR REFRACTION CONFRONTED WITH OBSERVED STELLAR POSITIONS

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ABSTRACT. We compare the calculations of differential color refraction with the observed effect found in some observed stellar positions. Special observations have been performed in a selected field where there are some Tycho-2 stars with well determined spectral types (from A to M). The observations cover the wide range of zenith distances from 72° to 27°. Our analysis demonstrates that differential color effects in refraction are significant.

1. INTRODUCTION

To determine the exact positions of celestial objects relative to reference stars it is necessary to include all the displacements and motions involved in the reference system. Among them the atmospheric color refraction should be taken into account. The best source for a comparison of calculated and observed color refraction are special observations in an area where there are some stars with available color information (covering a wide range of spectral types and/or color indices) as well as exact extraterrestrial stellar positions. Such observations and their treatment in the context of color refraction are the content of the present work.

2. OBSERVATIONS

Table 1: Data of the stars under study

No.	Tycho-2	V_T	$B_T - V_T$	$B - V^*$	Sp. Type
1	TYC 2665-0058-1	9.768	0.357	0.332	A7-F0IV-V
2	TYC 2665-0096-1	11.130	0.606	0.555	F5V
3	TYC 2666-0449-1	11.124	0.338	0.313	A5V
4	TYC 3134-1985-1	10.006	0.270	0.246	A7V
5	TYC 2666-1479-1	10.256	1.854	1.545	M0III
6	TYC 2665-0098-1	9.681	2.084	1.742	M0
7	TYC 2665-0678-1	11.876	0.350	0.325	
8	TYC 3134-1746-1	12.383	1.431	1.214	

*Transformed from $B_T - V_T$ to $B - V$ of the Johnson system (Bessell 2000).

For our observations we have chosen an area centered at NGC 6791 (Fig. 1). In our area there are eight stars, whose positions and $B_T - V_T$ are available in Tycho-2 catalog. For five of

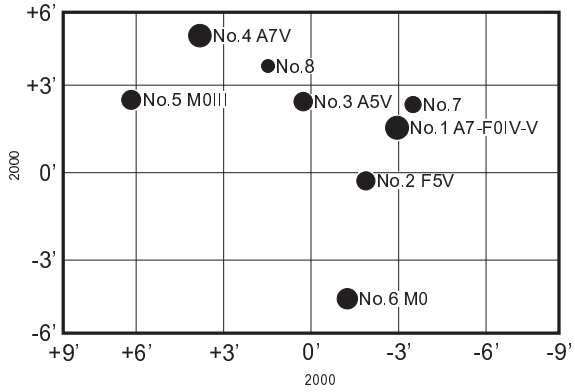

Figure 1: The star chart for the observed area ($18' \times 12'$). The center is $\alpha_{2000} = 19^h 21^m 00^s, \delta_{2000} = +37°27'00''$.

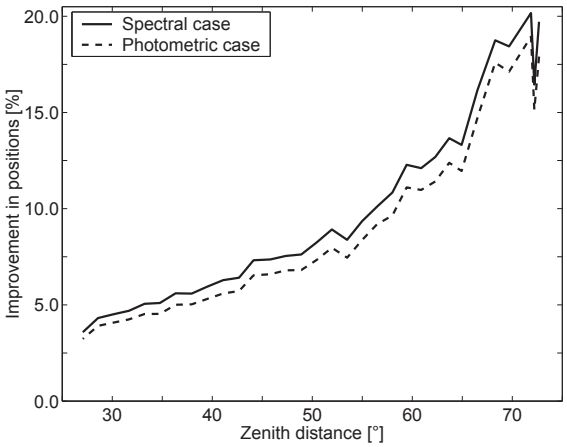

Figure 2: The positional improvement (as given in expressions 1) for spectral and photometric case, respectively, as function of the zenith distance for the area.

them there are spectral types derived from the color indices of the Vilnius photometric system (Cernis et al. 1997). For one further star (TYC 2665-0098-1) there is a spectral type (M0) in the Simbad database. All available information for the stars under study is summarized in Table 1.

We have performed our astrometric observations in Dresden during one night (April 24/25, 2001). The Meade LX200 telescope in combination with the SBIG ST-8 CCD detector leads to a frame which is $18'$ wide and $12'$ high. We started observations when the ascending area was at a zenith distance of about 72°. Then we were producing digital pictures every 10 minutes until the area reached a zenith distance of about 27°. In total we took 32 pictures. We did not use any filters. During observations we have registered the meteorological parameters: temperature, pressure and humidity.

3. DATA TREATMENT

To calculate refraction we used a computer program of Stone (1996) which was modified by Malyuto & Meinel (2000). Further modifications were carried out to be able to use the extended empirical library of energy distributions (Sviderskiene 1988) and to calculate refraction as a function of synthetic color indices ($B-V$, $V-R$ and $V-I$).

We have calculated the refraction values for every observation of the stars in Table 1. To compare different available possibilities, we distinguish two cases: (1) a photometric case where photometric color indices $B-V$ are used in the refraction calculations and (2) a spectral case where spectral types and luminosity classes are used in the refraction calculations.

Normally the refraction effects are subtracted from the observed stellar positions. However, the orientation of the CCD-matrix with respect to the celestial sphere is not known exactly from the beginning. To overcome this difficulty we modified the catalog positions by subtracting the refraction values from their calculated zenith distances. Then we determined the best transformation parameters of the observed and the modified catalog positions by least squares fit. From the residuals we calculated the standard deviation m_0.

As a result we have two values for m_0: the value $m_{0,sp}$ in the spectral case and the value $m_{0,phot}$ in the photometric case for every picture. To estimate the positional improvement in comparison with the case when there is no color information for stars, we have also calculated the value $m_{0,u}$ (when catalog coordinates are used without modifications). The improvement I in stellar positions is characterized by the following expressions (in percent for every picture):

$$I_{sp} = \left(1 - \frac{m_{0,sp}}{m_{0,u}}\right) \cdot 100, \qquad I_{phot} = \left(1 - \frac{m_{0,phot}}{m_{0,u}}\right) \cdot 100 \tag{1}$$

for the spectral and photometric case, respectively. This makes I rather independent of quality changes through the pictures series. The results are presented in Fig. 2.

4. CONCLUSIONS

Refraction calculations are necessary in order to extract accurate stellar positions from ground based observations at large zenith distances if an instrument without filters is used. The availability of broad-band indices is generally enough for accurate refraction calculations. The modified Stone refraction code will be inserted in the universal computer program for high precision position determination of minor planets on CCD frames (Langhans 2002).

5. REFERENCES

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