On the close correspondence between the stellar magnitude difference and the relative light flux in the range 0.05–0.30 mag

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Abstract. The main particularities of the correspondence, noted in the title, are represented by formulas and graphs. These formulas and graphs may be used for converting of small magnitude differences into relative light fluxes and vice versa. It is shown that while magnitude difference or relative flux belong to the range 0.05-0.30 the relative corrections for converting from one to other system of data rest in the interval ± 0.06.

Key words: astronomy – general; astronomy – education

Върху близкото съответствие между разлики на звездни величини и относителни светлинни потоци в интервала 0.05-0.30 mag

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Главните особености на съответствието, отбелязано в заглавието, са представени чрез формули и графики. Формулите и графиките могат да бъдат използвани за превръщане на малки разлики на звездни величини в относителни светлинни потоци и обратно. Показано е, че докато разликите на звездни величини или относителните потоци са в интервала 0.05-0.30, относителните поправки за преход от едната към другата система данни остават в границите на ± 0.06.

Introduction

The use of stellar magnitudes and their differences is wide spread in the astronomical photometry. Besides, (i) because of the definition of the stellar magnitude the number of a magnitude difference Δm in the range 0.05-0.30 mag corresponds well to the number of the relative light flux $\delta F = \Delta F/F$, especially in the same range of numbers, 0.05-0.30. By this reason (ii) small light variation of variable stars or active galactic nuclei are characterized preferably by difference of stellar magnitudes.

Though, regarding for example the results in the papers of Bachev et al. (2011) and Georgiev et al. (2012) about the variability of the cataclysmic binary star KR Aur, as well as in the papers of Zamanov et al. (2015) and Georgiev et al. (2018) about the variability of the recurrent nova RS Oph, expressed in magnitudes, the question "How many both data systems (magnitude differences and relative fluxes) differ?", arises. As an answer to this question in the present paper we juxtapose by formulas and graphs the numbers of the small magnitude differences and the respective relative light fluxes.

Graphs and table of the correspondence

The difference of stellar magnitudes Δm and the relative flux $\delta F = \Delta F/F$ follow the basic astronomical formulas (Zombeck 1990):

$$(1) \qquad \Delta m = -2.5 \log(1 + \delta F) \qquad \text{or} \qquad \delta F = \text{dex}\,(-0.4\Delta m) - 1,$$

(for $\Delta m \leq 0$ and , $\delta F \geq 0$).

Let us to express the magnitude difference in hundredths of the magnitude, cmag, and the relative fluxes in percentages [%]. Then the formulas (1) may be written formally as functions:

$$(1') \qquad \Delta m = \Phi(\delta F) \qquad \text{or} \qquad \delta F = \Psi(\Delta m).$$

The dependences (1') are represented in Fig.1. If $\Delta m > 30$ cmag or $\delta F > 30\%$, both systems of numbers differ more and more (Table 1).

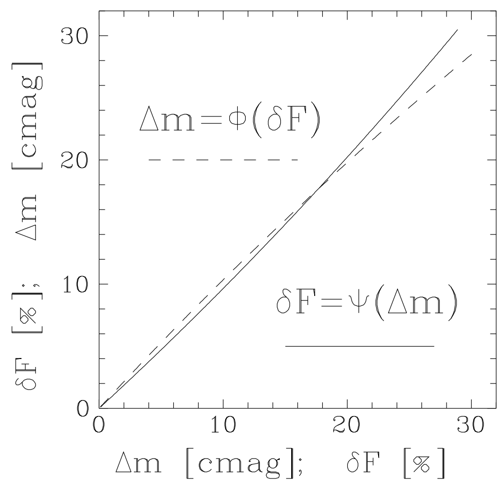

Fig. 1. Close correspondence between the magnitude differences Δm in the interval 5-30 cmag and the relative fluxes δF in the range 5–30% (Eq.1; Eq.1')

Figure 1 does not show how much both systems of numbers are really close. Therefore, let us to introduce the differences:

$$(2) \qquad \varepsilon(\Delta m) = \delta F - \Delta m \qquad \text{and} \qquad \varepsilon(\delta F) = \Delta m - \delta F.$$

Then the differences (2) may be written formally as functions:

$$(2') \qquad \varepsilon(\Delta m) = \Phi(\delta F) \qquad \text{or} \qquad \varepsilon(\delta F) = \Psi(\Delta m).$$

The dependences (2') are represented in Fig.2.

Figure 2 shows how both systems of numbers are close by their differences, in absolute sense. (Both graphs are curves which are not just symmetric in respect to the zero level.) So, when Δm or δF tends to 0, the differences (Eq.2, Eq.2') come near to 0. When Δm or δF are close to 8, the difference reaches local extremum with value about ± 0.35. When Δm or δF are close to 17.6, the differences become close to 0. Further the differences increases with reverse signs. However, the behavior of the relative differences are more sophistical, see Fig.3.

Figure 2 supplies graphic tools for estimation of the corrections $\varepsilon(\Delta m)$ or $\varepsilon(\delta F)$ for converting from one data system to the other. These corrections should be added by means the formulas, implemented in Fig.2.

For example, if $\Delta m = 5$ cmag, $\delta F \approx 4.7\%$ and if $\delta F = 5\%$, $\Delta m \approx 5.3$ cmag. Also, if $\Delta m = 20$ cmag, $\delta F \approx 20.2\%$ and if $\delta F = 20\%$, $\Delta m \approx 19.8$ cmag.

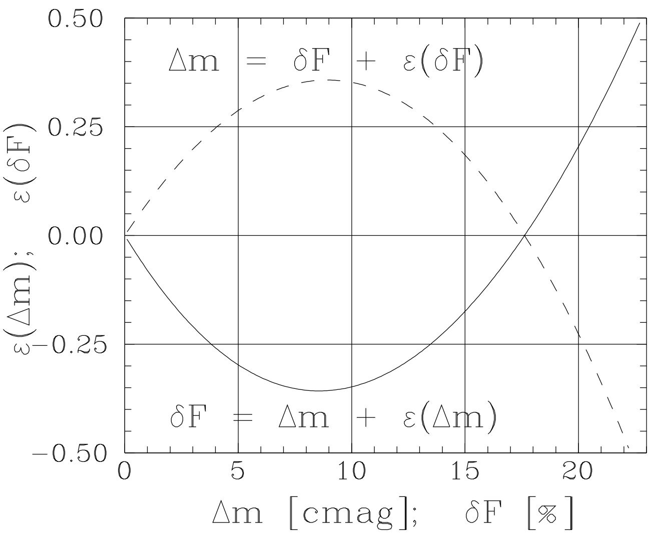

Fig. 2. Graphs of the magnitude differences Δm or the relative fluxes δF (Eq.2) in dependence on δF or Δm, respectively (Eq.2'), plus rules for data transform by addition of absolute corrections.

However, Fig. 2 does not show the relative value of the correction. Therefore, let us to introduce also the coefficients:

$$(3) \qquad \alpha(\Delta m) = \varepsilon(\Delta m)/\Delta m \qquad \text{and} \qquad \alpha(\delta F) = \varepsilon(\delta F)/\delta F.$$

The coefficients (3) also may be written formally as functions:

$$(3') \qquad \alpha(\Delta m) = \Phi(\Delta m) \qquad \text{and} \qquad \alpha(\delta F) = \Psi(\delta F).$$

The dependences (3') are represented in Fig.3.

Figure 3 shows the closeness of the numbers of both systems in relative sense. (The graphs are not just straight lines.) When Δm or δF decreases toward 0, the coefficients (Eq.3) increase by absolute value, i.e the relative differences between both systems grow up. When Δm or δF are close to 17.6, the coefficients are close to 0. Further the differences increase with reverse signs.

Figure 3 supplies graphic tools for transition from one data system to the other by addition of relative correction. The respective formulas are implemented. More important is that Fig.3 shows visually how much the relative corrections grow up towards the bounds of the regarded intervals of magnitude difference and relative flux.

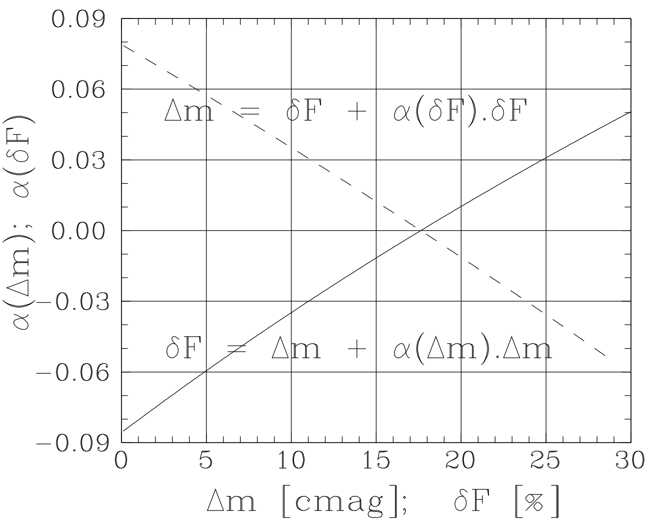

Fig. 3. Graphs of the coefficients $\alpha(\Delta m)$ and $\alpha(\delta F)$ (Eq.3) in dependence on Δm or δF, respectively (Eq.3'), plus rules for data transform by addition of relative corrections

According to Fig.3 while Δm or δF decreases below 5 or increases over 30 the relative correction grows up over ± 0.06 δF or ± 0.06 Δm, respectively. For example, for $\Delta m = 2$ cmag, the solid line shows coefficient about -0.08. Therefore, $\delta F \approx 2 - 0.08 \times 2 \approx 1.84\%$. Also, for $\delta F = 10\%$, the dashed line shows coefficient about 0.03. Therefore, $\Delta m \approx 10 + 0.03 \times 10 \approx 10.3$ cmag.

Table 2 contains the numerical correspondences. Often used magnitude differences (in mag) and relative fluxes (in parts of fluxes) in the range 0.01-1.00 are included.

Table 1. Row 1: Magnitude differences (in magnitude) or relative fluxes (in part of fluxes); row 2: respective relative fluxes; row 3: magnitude differences.

$-\Delta m$ or δF	0.01	0.02	0.05	0.10	0.15	0.20	0.25	0.30	0.50	1.00
δF	0.009	0.019	0.047	0.096	0.148	0.202	0.253	0.330	0.585	1.512
$-\Delta m$	0.011	0.022	0.053	0.103	0.151	0.198	0.242	0.286	0.440	0.752

Conclusions

Figure 2 and 3 visualize correspondence between the numbers of magnitude differences and the numbers of relative light fluxes in absolute and relative sense, respectively. These figures also supply tools for converting of data $\Delta m- > \delta F$ or $\delta F- > \Delta m$ by additive or relative corrections.

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