QUASISYNTHETIC PHOTOMETRY

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ABSTRACT. The brief description of new ideas for the flux calibration of stellar spectra are presented. Described approach lets us to produce a lot of reference stars both for ground and space observations. The metodology also opens possibilities to determine the angular diameters from high resolution stellar spectra and analyze the interstellar medium in the direction of a star.

Key words: Stars: absolute spectrophotometry: angular diameters; stars: individual: Vega, Procyon.

1. Introduction

One of the problems in stellar observational astrophysics is the calibration of observed quantities into physical energy units. The usual approach to make this is to choose the set of the reference stars, calibrate their magnitudes or spectra and use these quantities for calibration of other observed stars. The main problem here is a calibration of reference stars. For the first time this was done using Vega as a primary reference star for ground-based observations while observing the secondary reference stars. But such way is impossible in preparation of the set of reference stars for GAIA project, for instance, because the satellite cannot observe stars brighter than magnitude 10. To calibrate the observed stellear spectra from the ground with high resolution we need to have the flux spectra with same one. The basic idea of the proposal is not totally new. Similar approach is being used in so-called Synthetic Photometry (see, for example, Colina et.al., 1996). In this approach one can use the synthetic spectra for given stellar atmosphere model with calibrational purposes. But in this case we have a lot of problems with accuracy of this data: atmosphere models differ from the real stellar atmospheres, the spectral lines data are incomplete and not accurate either etc.

In this article I propose a simple way to eliminate all those problems: 1) we use the high dispersion, continuum normalized spectra of reference stars; 2) in a usual way we determine for these spectra T_{eff}, log g and [A]; 3) using stellar atmosphere model we calculate the continuum flux spectrum; 4) multiplying a theoretical flux spectrum by the observed normalized one we receive the energy flux spectrum coming from the stellar surface; 5) using this spectrum we calculate the photometric colors, compare them with so-named zero-point observed colors and receive the stellar angular diameter. Comparison of the angular diameters at different colors can help us to estimate the effect of reddening and find the dependence of the radius on wavelengths (for cool giants); 6) having the angular diameters we can tie (move) energy flux spectrum to the orbit of Earth. This proposal based on that we know: 1) the depth of stellar continuum formation differs negligibly for different atmosphere models; 2) in visible spectral region continuum fluxes depend practically only on effective temperature; 3) in visible region the theoretical description of stellar continuum (opacity sources) is well-studied; 4) all this cannot be said about usual Synthetic Photometry.

2. Approach testing

Recently I have tried to perform this procedure for two stars: Vega (HD 172167) and Procyon (HD 61421).

2.1. Vega

For the basic observations I used normilized high resolution Vega atlas (Takeda et.al., 2007). This spectrum was multipled by the theoretical continuum of a synthetic spectrum, computed using Kurucz's model atmosphere for Vega (*http://kurucz.harvard.edu/*). After this I have calculated the B color from surface flux spectrum that comes from the Vega and compared it to the observed B magnitude, using zero-point from (Colina et.al., 1996). In this way I received the angular diameter of Vega $\theta = 3.24$ mas, what number is close to the observed value $\theta = 3.202$ mas (Absil et.al., 2008). Using calculated value, I reduced quasi-synthetic spectrum to the orbit of Earth and compared with Vega energy flux spectrum, compiled by Hayes (Hayes, 1985).

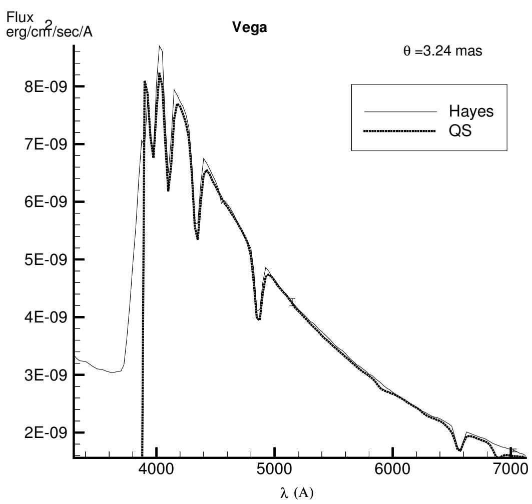

Figure 1: Quasi-synthetic spectrum of Vega, compared with flux spectrum from (Hayes, 1985).

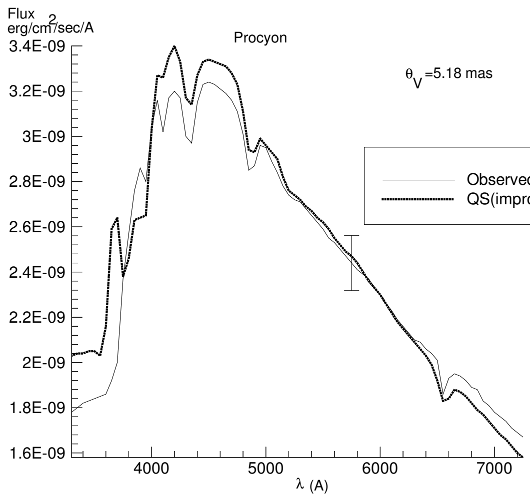

Figure 2: Quasisynthetic spectrum of Procyon, compared with flux spectrum from (Komarov et.al., 1979).

For comparision purposes Vega's quasi-synthetic spectrum was convolved with Gaussian of resolution R = 110. The result is shown on Fig.1.

As we can see, agreement of both flux spectra is perfect, excluding the cores of Hydrogen lines. This is caused by the rough description with the instrumental profile. The small features in the red part of QS spectrum are blends of telluric lines in Vega atlas.

2.2. Procyon

For this star I took the famous Procyon atlas of Griffin (Griffin, 1979), did all what is described above and compared obtained highly dispersed flux energy spectrum of Procyon, convolved with the Gaussian instrumental profile (R=52) with observed flux spectrum from (Komarov et.al., 1979) catalogue. Results are presented on Fig.2 below. The error bar indicates the authors estimated accuracy of observed flux spectrum in region V (5%). This estimated accuracy is degrading (up to 10%) towards the end of the spectrum. The same will happen if one tries to compare the data from different catalogues. There is one distinction in procedure: comparision of Griffin atlas with synthetic spectrum of Procyon shows that continuum normalization of atlas in Hydrogen lines regions, especially in a region of the Balmer jump, was done badly. More than, since the wavelength region of high resolved spectrum of atlas is wide, the telluric spectrum starts influecing strongly the results in a red part of the spectrum. I have roughly corrected the Procyon atlas both for continuum and telluric lines.

For this star the agreement between QS and observed flux spectra still inside error bars. The difference is caused by continuum normalization of atlas and telluric features, which was not removed completely. The angular diameter of Procyon, found from comparision the QS and observed V magnitudes - θ = 5.18 mas is close to the values from interferometric measurements (see table in article Kervella et.al.,2003). For example, the angular diameter at wavelength 7400 Å is: $\theta = 5.19 \pm 0.04$ mas.

3. Discussion

The idea of proposed method is very simple and can be realized very easy. But possible results look very promissing. Let me briefly describe the possible projects. 1) The catalogue of flux spectra for reference stars in visible region both for space and ground-based observations. Practically all stars for which we have high resolution spectra can be used. 2) The measurement of angular diameteres for all stars observed with high resolution. In combination with known parallaxes we can even determine the radii of these stars. 3) From comparison of the QS and observed colors at different wavelengths we can analyze the structure of interstellar medium. 4) The flux calibrated high dispersion spectra open new horizons in the field of stellar atmospheres analysis. For example, we can develop new approaches, based on the Vertical Inverse Problem (VIP) solutions. The reason is that we can directly use the formal solution of transfer equation instead of the LSQ technique that is being used now.

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