THE TEMPERATURE DETERMINATION FROM THE VOYAGER FUV SPECTRA

S. Štefl
Astronomical Institute of the Czechoslovak Academy of Sciences,
251 65 Ondřejov, Czechoslovakia

Abstract

The far ultraviolet spectrophotometers aboard the Voyager spacecrafts provided also many observations of stellar objects. An easy method of determining the effective temperature by fitting the energy distribution gradient in the region 900 - 1100 Å can be applied to Voyager spectra of B-type stars. It is suitable particularly for Be stars, the spectrum of which is modified by a radiation field of circumstellar envelope.

1 The Voyager far ultraviolet spectrophotometers

The Voyager 1 and 2 interplanetary spacecrafts have been lunched in August and September 1977. Their primary goal was to investigate the outer planets of the solar system. Besides other instruments, they carry also two nearly identical far ultraviolet spectrophotometers (UVS), which were designed to determine the composition and the structure of the atmospheres of planets and their satellites. During the periods of interplanctary cruise these instruments are used for other astronomical purposes, mainly for the spectrophotometric observations of stellar objects.

The UVS are objective grating spectrometers covering the wavelength range of 525 – 1650 Å with 18 Å resolution. An mechanical collimator restricts their fields of view to 0.°10 × 0.°87. The photon counting detector utilizes a 128 element linear anode array to collect the output of a dual microchannel plate electron multiplier. The Cu I photocathode deposited on a MgF_2 filter plate enables to extend the response of the detector to 1700 Å. The integration times of the self scanned anode array are of 3.84 or 576 seconds. Limiting flux at 1000 Å is $5 \cdot 10^{-13}$ erg/cm^2.sec.Å. The reliability of the absolute calibration of the Voyager spectra has been challenged recently. The calibration should be reliable within 10 – 15 % according to the published description of the experiment. However, the observations of Spica by a rocket-borne spectrograph (Cook et al. 1989) indicate a need of a Voyager-calibration revision.

The archive of the Voyager observations – located at the Lunar and Planetary Laboratory, University of Arizona, Tucson – contains over 600 observations of more than 300 separate targets of different classes (bright O and B stars, hot luminous objects, variable stars and extragalactic sources). Because of a permanent lack of financial support, only part of Voyager stellar observations have been processed in the standard way. So far no funds have been allocated for a planned guest program, which would enable to people coming to Tucson to process the chosen observations. The Voyager UVS are assumed to provide regular observations till 1995.

2 Temperature determination using Voyager spectra

A determination of the effective temperature of Be stars and its variations can provide one of the most important keys to the studies of Be-star phenomena and to a testing of the available models. Unfortunately, deriving T_{eff} of Be stars, we usually meet serious difficulties. Interaction of the circumstellar matter with the radiation from the envelope can, sometimes very drastically, modify both line and continuous radiation of the studied B-type star. Consequently, the standard methods using photometric observations, energy distribution or exact line profiles can yield inaccurate or rather misleading results for some Be stars. So far the most extended method is based on the flux integration. However, the method is very sensitive to the absolute calibration of the spectrophotometric instrument and to the interstellar reddening correction. The interstellar extinction curve is less reliable just in the region, in which B-type stars radiate most of their energy. Besides, for a given Be star, part of the corresponding colour excess E(B-V) found in the optical region could be of circumstellar origin. Because we have no idea on circumstellar extinction curves, we may apply then a wrong correction for the interstellar reddening in the far UV region.

The extended archive of the Voyager observations allows us to derive the effective temperature of Be stars using the gradient of their energy distribution in the spectral region 900 – 1200 Å. The method is based on the simple fact that the energy distribution of B-type stars has the highest gradient, which is very sensitive to their photospheric temperature, in the region 900 – 1100 Å. Because this gradient is much less influenced by the processes in the circumstellar envelope than the absolute values of the UV flux, continuum or line visual radiation, the method is particularly suitable for Be stars.

We applied the method to the Be stars *o* And and KX And. The data have been processed using the standard LPL software package and dereddened using the extinction curve extended to FUV region by Longo et al. (1989). The correction for the absorption of molecular hydrogen derived in the same paper has been applied to the spectra of KX And. We set a grid of Voyager spectra of B-type standard stars of the luminosity classes IV and V with known temperatures, mostly derived by Underhill et al. (1989). Before fitting the spectra of a Be star we scaled those of standard stars in the wavelength interval, in which a Be-star spectrum is modified as less as possible by shell lines. An accuracy of our procedure should be given practically by the errors of standard stars temperatures – it is less than 5 %. Nevertheless, analyzing the spectra of a given Be star, we must take into account some effects which do not allow a straightforward application of our method and which are sources of additional errors of our results. *o* And is a multiple system with at least one more component of a close spectral type and we must guess, how the other components contribute to the total energy distribution of the brightest component. As to KX And, it is supposed to be a strongly interacting binary surrounded by an optically thick accretion disk. The circumstellar matter may contribute to the colour excess E(B-V) by as much as half of its value and consequently to introduce a wrong interstellar correction. Moreover, we do not know any extinction curve for the circumstellar extinction. The correction for the absorption of molecular hydrogen in the optically thick disk must be carried out, although the H_2 - column density can be only roughly estimated. The background radiation must be examined very carefully for a weak source as KX And.

Because we have used the spectra of standard stars obtained with the same instrument as those of studied stars, our results are not significantly influenced by the above mentioned uncertainty in the Voyager UVS absolute calibration. Detailed results of the analyses of *o* And and KX And Voyager spectra are being prepared for the publication.

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