Temperature estimation of EXDRA and SSUMI dwarf Nova systems from spectroscopic data

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Abstract

The seasonal behavior of the light curve for selected star SS UMI and EXDRA during outburst cycle is studied. This behavior describes maximum temperature of outburst in dwarf nova. The raw data has been mathematically modeled by fitting Gaussian function based on the full width of the half maximum and the maximum value of the Gaussian. The results of this modeling describe the value of temperature of the dwarf novae star system leading to identify the type of elements that each dwarf nova consisted of.

Key words
Dwarf Nova, Fourier Model, transform and mathematical modeling.

Article info.
Received: Jan. 2015
Accepted: Mar. 2015
Published: Sep. 2015

تخمين درجات الحرارة لأنظمة المستعرات القزمية SSUMI and EXDRA من بيانات التحليل الطيفي

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الخلاصة

تم دراسة المنحني الضوئي للنجوم من خلال دورة التوهج العظمى، هذا التغير له علاقة كبيرة مع درجات الحرارة خلال فترة التوهج. هذه الارصادات تم وضع معادلات رياضية لها من خلال تمثيلها بدوال كاوس معتمدة على عرضها الكلي عند منتصف المسافة وكذلك قيمتها العظمى. من خلال هذه الدوال تم تخمين درجات الحرارة لهذه المستعرات القزمية وعليه تم تحديد انواع العناصر الكيميائية الداخلة في تركيبها.

Introduction

Cataclysmic variables are binary stars in which a relatively normal star is transferring mass to its compact by orbiting so close to each other's [1]. The gas from secondary stars flows following magnetic field and or gravity field and falls on the white dwarf [2]. This material flow creates an accretion disk around the white dwarf star and from times to times, nuclear reaction starts and the system show an increase in brightness, this phenomenon called an outburst. Research will confederate on the spectroscopic properties of the main types of dwarf nova and discuss model of the outbursts by getting the effective temperature of humps in dwarf nova selected systems light curves. Cataclysmic variables are subdivided into several smaller groups, often named after a bright prototype star characteristic of the class. In some cases the magnetic field of the white dwarf is strong enough to disrupt the inner accretion disk. Magnetic systems often show strong and variable polarization in their optical light, and are therefore sometimes called polar these often exhibit small-amplitude brightness fluctuations at what's presumed to be the period of rotation of the white dwarf and CVs can be classified to: (Classical) novae, Recurrent novae, and Dwarf novae[3].

There are two models describe the outburst in dwarf nova systems;

A. mass transfer burst a sudden increase in the transfer of material from the companion star to the accretion disk causes the disk to collapse. The result is that matter is suddenly dumped onto the white dwarf releasing large amounts of gravitational energy the nova outburst [4].

B. Disk instability model (DIM): the cause of outburst are strongly depend on the instability that taking place in the accretion disk. This because the material is transferred from the secondary star at a constant rate. The rate is higher from the accretion disk then it could be transported through the disk by viscous interaction and the material would be pile-up in the disk. the pile-up may make the disk to become instable, boosting up the viscosity, highly increase the angular momentum and spreading out the excess material inwards and outward, the white dwarf leading to enhance the brightness of the star [5].

In this section the spectroscopic light curves of the following dwarf nova star are demonstrate

1. EX DRA dwarf Nova star burst

The cataclysmic variable EX DRA (formerly HS 1804 + 6753), was first detected in the Hamburger Quasar Survey in 1989 as shown in Fig. 1. The system turned out to be a double-eclipsing dwarf nova of the UGem class with a quiescence magnitude of about 14m, relatively small outburst amplitude of 1m–2.3m and an orbital period of 5.04 h [6].

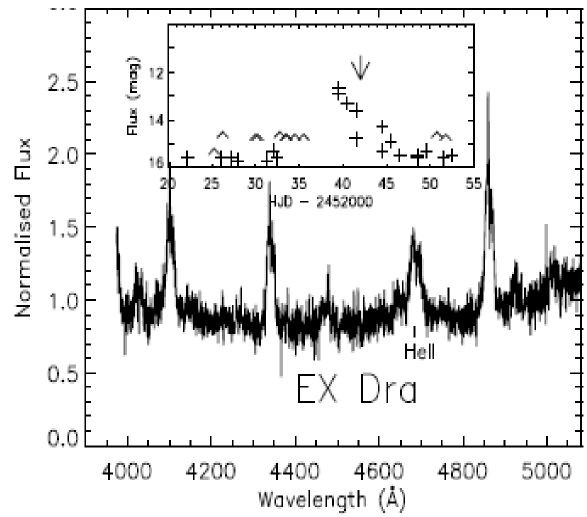

Fig.1: EX DRA spectroscopic light curve [7].

2. SSUMI Dwarf Nova star

The binary system SS UMI is in fact a U Gem type star. SS UMI was also obtained by Chen et al. (1991) who observed two outbursts of the star as shown in Fig. 2 [8]. Detection of the super humps .The variations in the positions of Hα emission lines allowed determination of the orbital period of the binary, which is equal to Porb = 0.06778 days (97.6 ± 1.5 min) [8].

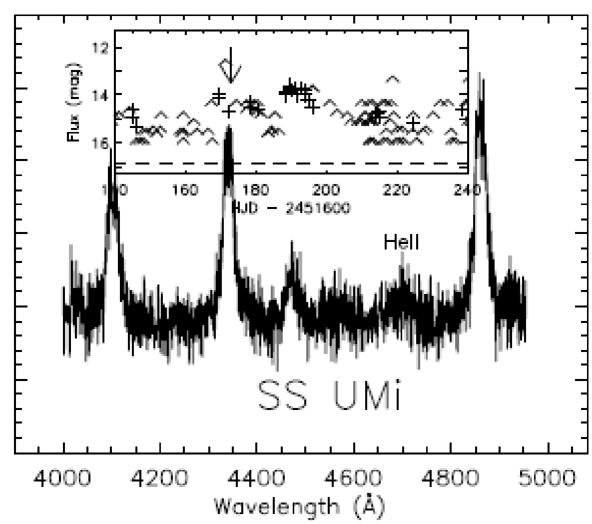

Fig.2: SS UMI spectroscopic light curve [7].

Thermal Line Width

The study of transitions in atomic spectra, and indeed in any type of spectroscopy, one must be aware that those transitions are not precisely sharp. There is always a finite width to the observed spectral lines. One source of broadening is the "natural line width" which arises from the uncertainty in energy of the states involved in the transition. This source of broadening is important in nuclear spectra, such as Mossbauer spectra, but is rarely significant in atomic spectroscopy [9]. A typical lifetime for an atomic energy state is about 10-8 seconds, corresponding to a natural line width of about 6.6 x 10-8 eV.

For atomic spectra in the visible and UV, the limit on resolution is often set by Doppler broadening. With the thermal motion of the atoms, those atoms traveling toward the detector with a velocity (v) will have transition frequencies which differ from those of atoms at rest by the Doppler shift. The distribution of velocities can be found from the Boltzmann distribution [10].

Since the thermal velocities are non-relativistic, the Doppler shift in the angular frequency is given by the simple form [9]:

$$\text{FWHM}= \Delta \lambda = 1.05\text{x } 10^{-6} \sqrt{\frac{T(\text{in } K)}{A}}\,\lambda \qquad (1)$$

Data analysis and interpretations

The EX DRA spectroscopic data has already been collected by taking a set of 137 spectra of EX DRA in an observing run at the (Calar Alto 3.5m telescope) with the Cassegrain Twin Spectrograph in 1992[7]. The chosen gratings per pixel in the red spectral range with a wavelength coverage between 4099 and 4337°A and 4679 and 4858 °A respectively during EX DRA outburst state in 1993.

The Gaussian function could be given by

$$G(x) = he^{-\frac{x^2}{2\sigma^2}} \qquad (2)$$

where h is the height and σ is the standard division of the Gaussian system.

Assuming h=1 and G(x) = 0.5, Eq. (2) will became.

$$0.5 = e^{-\frac{x^2}{2\sigma^2}} \qquad (3)$$

(x)is now defining as Half Width at Half Maximum (HWHM) of the Gaussian function by taking the logarithm of Eq. (3) we obtained the following equation.

$$H= 1.17\sigma \qquad (4)$$

The Gaussian fitting equation for the spectroscopic light curve data of EXDRA star that shown in Fig. 1 is given by:

$$\mathbf{G(\lambda)=0.9+0.77*}\, e^{-\frac{(\lambda-4101)^2}{2*10^2}} + 0.77\, e^{-\frac{(\lambda-4350)^2}{2*11^2}} + 0.5\, e^{-\frac{(\lambda-4700)^2}{2*15^2}} + 1.5\, e^{-\frac{(\lambda-4876)^2}{2*12^2}} \qquad (5)$$

This equation are achieved by fitting a Gaussian function for each peak the spectroscopic light curve and the normalization is taking place to adjust the fitted to the observed light curves. a MATLAB code is written to obtain these fitted data.

The value 0.9 describes the shifted constant value that added to Gaussian function (i.e background). The data shown in Fig.3 represents the real spectroscopic data in outburst before (faint line) and the fitting (dark line) fitting.

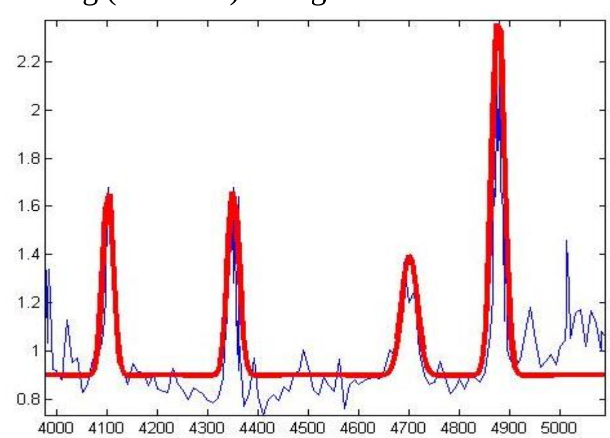

Fig. 3: Real spectroscopic data of EX DRA and its smoothed fitting data.

For SSUMI dwarf nova star the same processing is repeated and the equation became:

$$G(\lambda)=0.9+0.9\, e^{-\frac{(\lambda-4099)^2}{2*8^2}}+e^{-\frac{(\lambda-4334)^2}{2*15^2}}+1.2\, e^{-\frac{(\lambda-4851)^2}{2*16^2}} \quad (6)$$

Fig.4 demonstrates the spectroscopic data in outburst before and after fitting.

By estimating the result of the full width of the Gaussian (FWHM) = 2*(HWHM) the temperatures could be estimated from Eq (1). The result of HWHM, FWHM, and the estimated temperatures are presented in Tables1 and 2 for EX DRA and SSUMI stars respectively.

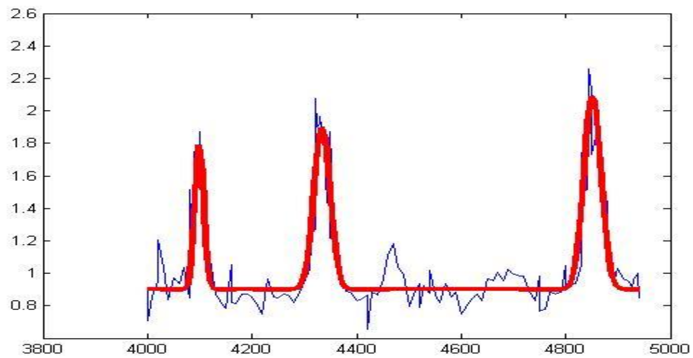

Fig.4: The Gaussian Fitting of SSUMI Star for the observed spectroscopic data.

Table 1: Estimating parameters and computing temperatures in dwarf nova stars EXDRA.

EXDRA Star						
sigma	HWHM	FWHM	λ At maximum peak (°A)	Element kind	Elements	T (Kelven)
10	11.774	23.548	4099.51	1	H	3.0E+07
11	12.951	25.9028	4337.47	16	O	5.2E+08
15	17.661	35.322	4679.52	2	He	1.0E+08
12	14.129	28.2576	4858.33	1	H	3.1E+07

Table 2: Estimating parameters and computing temperatures in dwarf nova stars SSUMI.

SSUMI Star						
sigma	HWHM	FWHM	λ At maximum peak (°A)	Element kind	Elements	T (Kelven)
8	9.4192	18.8384	4138.26	1	H	1.9E+07
15	17.661	35.322	4362.69	16	O	9.5E+08
18	21.1932	42.3864	4849.49	1	H	6.9E+07

Peak investigation

To verify our estimation for the pronounced peaks in the spectroscopic data it necessary to take a gradient of the fitted and real data. The gradient is defined as follows

$$F^{-}(x) = \frac{\partial}{\partial x} f(x) = \lim_{\Delta x \to 0} \frac{f(x+1)-f(x)}{\Delta x} \quad (6)$$

The results obtained from Eq. (6) on fitted and real spectroscopic data for both SSUMI and EX DRA are shown in Fig.5 and 6 respectively.

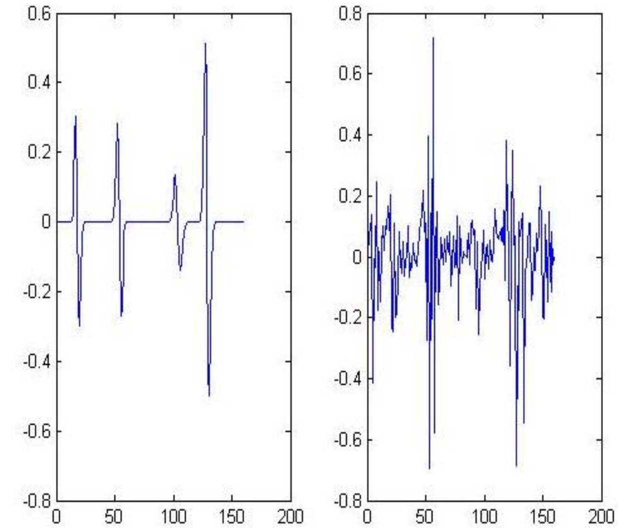

Fig.5: Derivate of Fitted and real data of EX DRA star.

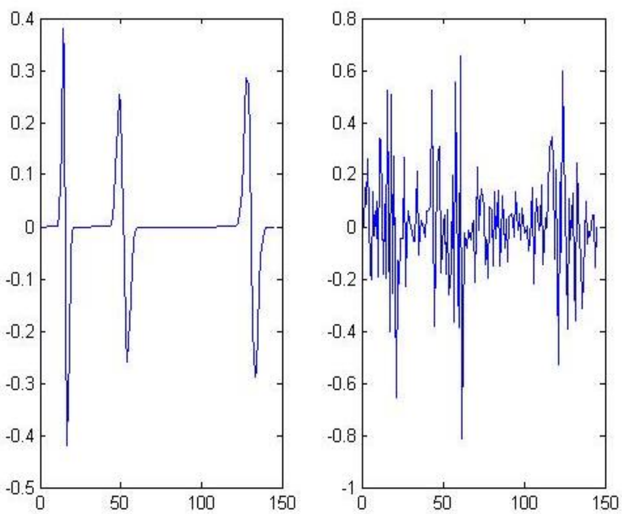

Fig.6: Derivate of fitted and real data of SSUMI star.

The result confirmed the exact location of the pronounced peaks and therefore the corresponding (λ) at the maximum value are identifying correctly.

Conclusions

The main conclusion that could be drawn from these analysis is that, the estimating temperature for both (EXDRA) and (SSUMI) stars at outburst is strongly depends on the width of each peak. The Gaussian function model shows a perfect correlation with the real data and shows better estimation.

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