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

Arshed Ali Kadhem

Department of Astronomy & Space, College of Science, University of Baghdad, Iraq
E-mail: space_198@yahoo.com

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 nova 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.

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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 P =
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 $6.6 \times 10^{-8}$ 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]:

$$\text{FWHM} = \Delta \lambda = 1.05 \times 10^{-6} \sqrt{\frac{T \text{ (in K)}}{A}} \lambda$$  \hspace{1cm} (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

$$G(\chi) = h e^{-\frac{x^2}{2\sigma^2}}$$  \hspace{1cm} (2)

where $h$ is the height and $\sigma$ is the standard division of the Gaussian system.

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

$$0.5 = e^{-\frac{x^2}{2\sigma^2}}$$  \hspace{1cm} (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.

$$H = 1.17\sigma$$  \hspace{1cm} (4)

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

$$G(\lambda) = 0.9 + 0.77 e^{-(\lambda - 4101)^2 \cdot 2^{-10^2}} + 0.77 e^{-(\lambda - 4350)^2 \cdot 2^{-11^2}} + 0.5 e^{-(\lambda - 4700)^2 \cdot 2^{-15^2}} + 1.5 e^{-(\lambda - 4876)^2 \cdot 2^{-12^2}}$$  \hspace{1cm} (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.](image-url)
For SSUMI dwarf nova star the same processing is repeated and the equation became:
\[
G(\lambda) = 0.9 + 0.9 \left( e^{-\frac{(\lambda-4099)^2}{2 \cdot 8^2}} + e^{-\frac{(\lambda-4334)^2}{2 \cdot 15^2}} + 1.2 e^{-\frac{(\lambda-4851)^2}{2 \cdot 16^2}} \right) \tag{6}
\]
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 Tables 1 and 2 for EX DRA and SSUMI stars respectively.

![Fig.4: The Gaussian Fitting of SSUMI Star for the observed spectroscopic data.](image)

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

<table>
<thead>
<tr>
<th>Sigma</th>
<th>HWHM</th>
<th>FWHM</th>
<th>λ At maximum peak (°A)</th>
<th>Element kind</th>
<th>Elements</th>
<th>T (Kelven)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>11.774</td>
<td>23.548</td>
<td>4099.51</td>
<td>1</td>
<td>H</td>
<td>3.0E+07</td>
</tr>
<tr>
<td>11</td>
<td>12.951</td>
<td>25.9028</td>
<td>4337.47</td>
<td>16</td>
<td>O</td>
<td>5.2E+08</td>
</tr>
<tr>
<td>15</td>
<td>17.661</td>
<td>35.322</td>
<td>4679.52</td>
<td>2</td>
<td>He</td>
<td>1.0E+08</td>
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<tr>
<td>12</td>
<td>14.129</td>
<td>28.2576</td>
<td>4858.33</td>
<td>1</td>
<td>H</td>
<td>3.1E+07</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Sigma</th>
<th>HWHM</th>
<th>FWHM</th>
<th>λ At maximum peak (°A)</th>
<th>Element kind</th>
<th>Elements</th>
<th>T (Kelven)</th>
</tr>
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<tbody>
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<tr>
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<td>35.322</td>
<td>4362.69</td>
<td>16</td>
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<td>9.5E+08</td>
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<td>18</td>
<td>21.1932</td>
<td>42.3864</td>
<td>4849.49</td>
<td>1</td>
<td>H</td>
<td>6.9E+07</td>
</tr>
</tbody>
</table>

### 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

\[
F^{-}(x) = \frac{\partial}{\partial x} f(x) = \lim_{\Delta x \to 0} \frac{f(x + \Delta x) - f(x)}{\Delta x} \tag{6}
\]

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.

References