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# Cataclysmic variable stars: photometry of V893 Sco star and spectroscopy of HS 0220+0603 star

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Abstract. Differential photometry was applied on V893 Sco star, observed from the Astronomical Observatory of the Universidad Nacional de Ingeniería in Peru. From its light curve it was measured an orbital period of 0.076 days approximately. Moreover, spectroscopic analysis was performed on the HS 0220+0603 star, which data was acquired from a database. A fitting program was written in Python to find, out of several synthetic spectra of white dwarf and templates of red dwarf, the combination of a white dwarf and a red dwarf spectrum that fits best the HS 0220+0603 spectrum, thus we found that this spectrum is a composition of a white dwarf spectrum of 30000 K and surface gravity  $(\log g) = 8.0$ , and a M5.5 type red dwarf star.

## 1. Introduction

Cataclysmic variable (CV) stars are binary systems composed of a white dwarf (WD) and a red dwarf (RD) orbiting each one around the center of mass of the system, where there is mass transference from the red one to the white one through the first Lagrangian (L1) point of the system, as the red dwarf has filled its Roche lobe [1]. The WD is called primary star and the RD secondary star.

If the WD has a weak magnetic field the system is called non-magnetic CV and the transferred mass forms an accretion disk around the WD, and subsequent mass flux collides with this disk producing a bright point, called "hot spot", that is sometimes the strongest source of light of the system. However, when the WD has a strong magnetic field, the flow is driven through the magnetic field lines to its poles, preventing the formation of the accretion disk, such stars are called "polar" CV stars. If the magnetic field is not so strong the disk is partially formed far from the WD, these systems are called "intermediate polar" CVs. Both polar and intermediate polar CVs are called magnetic CV.

When the orbital plane of the system is aligned to our line of sight we can observe periodic changes of the brightness caused by alternate eclipses between the stars and, eventually, the hot spot. That system is called a eclipsing system.

However, there are other characteristics related to the dynamics of the system that produce an abrupt increasing of its brightness. These increments in some cases are really big, orders of hundreds, thousands and millions in the brightening of the system have been observed. That is the reason why these systems are called cataclysmic. Such dynamical characteristic and the resulting change of brightness are used to classify to the CV stars.

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Between non-magnetic CV stars, we have the following three types [2]: A Nova, classic or recurrent, is a CV that has presented at least one eruptive phenomenon caused by thermonuclear explosion on the WD surface, where external shells of the WD are ejected to high velocities. Conditions for thermonuclear explosions are reached by increasing in the accretion rate over the WD surface. The brightness raises in a range from six to nineteen magnitudes. A Dwarf Nova (DN) is a CV that presents quasi-periodic increments of brightness, they are not produced by thermonuclear explosions but by instabilities in the disk related to increasing in the mass flux rate through the disk. No mass is ejected. The brightness raises in a range from two to five magnitudes. A Novalike (NL) is, basically, a CV that has not presented changes of its brightness with the characteristics of a Nova or a DN. They present irregular changes in its brightness.

Moreover, many types of CVs present states where its brightness diminishes between three to five magnitudes owing to decreasing in the mass flux from the secondary through the L1 point, which lighten the density of the disk, making it colder and less bright, thus the hot spot is extincted or insignificant. This "low state" can last days, months or years, after that the brightness return to its normal high state.

In this paper we present the first observation of a CV star from the Astronomical Observatory of the Universidad Nacional de Ingeniería (OAUNI, from its Spanish initials) [3, 4], we registered images of V893 Sco dwarf nova star [5] to measure its orbital period by differential photometry technique. Furthermore, we downloaded spectroscopic data of HS 0220+0603 eclipsing Novalike SW Sex class star [6] in low state from the European Southern Observatory (ESO) archive facility web page<sup>1</sup> to find the characteristics of its components with our empirical fitting method, which consists of finding the best combination of a WD synthetic spectrum and a M type (RD) template that fits to a spectrum of HS 0220+0603 star. Our method is assessed here for the first time.

### 2. Data acquisition

### 2.1. Photometric data

Observations of the V893 Sco dwarf nova star were carried out at OAUNI. OAUNI is located in the Junín region at Peruvian central Andes (see table 1 for geographical coordinates). This observatory has a 0.51 m RCOS telescope, a Paramount MEII mount, and a SBIG STXL-6303 CCD. The images were taken on June 30th, 2017. 275 frames with 20 s exposure time and filter V were acquired (see table 2). Furthermore, *darks* and *flatfields* were taken.

Longitude	Latitude	Altitude
75° 19' 14.11" W	12° 02' 28.69" S	3314 masl

 Table 1. Geographical coordinates of OAUNI.

<b>Table 2.</b> Photometric observations a	it OA	AUNI.

Date	Star	Coverage	# frames	Exp.	Filter
2017/06/30	V893 Sco	$123 \min$	275	$20 \mathrm{~s}$	V

<sup>1</sup> http://archive.eso.org/cms.html

## 2.2. Spectroscopic data

We acquired data of HS 0220+0603 eclipsing SW Sex star from the ESO Science Facility web page. This star was observed on November 20th, 2004, from ESO Paranal observatory with the Very Large Telescope - Unit 1 (ESO-VLT-U1)<sup>2</sup>, called Antu, and the second version of the instrument FOcal Reducer and low dispersion Spectrograph (FORS2), with the grism 600RI. Four draw spectra of this star with 600 s of exposure time were downloaded (see table 3), as well as *bias*, *flats*, *arcs*<sup>3</sup> and a spectrum of a standard star<sup>4</sup> (with its respective *flats* and *Arcs*).

Table 3. Spectroscopic data from ESO Science Archive Facility, observed with VLT-U1.

Date	Star	Instrument	Exp.	# frames
2004/11/20	HS 0220+0603	FORS2, GRIS_600RI	$600 \mathrm{~s}$	4

## 3. Reduction and analysis

## 3.1. Photometry: V893 Sco

The data (see table 2) was reduced with the software system IRAF (Image Reduction and Analysis Facility)<sup>5</sup>. The images were corrected by *overscan*, *dark* and *flatfield* with tasks from NOAO.IMRED.CCDRED package, then aligned with *imalign* task from IMAGES.IMMATCH package, and to calculating the magnitudes it was used the NOAO.DIGIPHOT.DAOPHOT package.

Figure 1 shows a reduced and aligned image, the V893 Sco star is pointed by the two red lines, while the two comparison stars, used for the differential photometry technique, by Comp1 and Comp2 labels, respectively.

Magnitudes of V893 Sco, Comp1 and Comp2 stars were measured, then the differences between them over each reduced and aligned image. Figure 2 shows light curves with errorbars built with Gnuplot<sup>6</sup> from these differences. First, on top of the figure a virtual horizontal line is shown, obtained from differences between the two comparison stars. This indicates that the two comparison stars have constant brightness, which makes them good comparison stars. The other two curves, light curves, have been built with the differences between the V893 Sco star and each comparison stars. They have similar form because, as was already said, the comparison stars have uniform brightness. For this reason, the light curves differ approximately just by a constant value.

From the light curves it is possible to infer the orbital period of the system. The figure 2 shows that the light curves have deep falls in x values of 0.516 and 0.592 approximately. These values indicate approximately the times of mid-eclipses of the primary eclipses in Julian days, i.e. the maximum eclipse of the WD by the RD. The difference between these primary eclipses is the orbital period, that is 0.076 d approximately, similar to 0.075961 d from Ritter and Kolb catalog [5].

<sup>6</sup> http://www.gnuplot.info/

 $<sup>^{2}\</sup> http://www.eso.org/public/teles-instr/paranal-observatory/vlt/$ 

 $<sup>^3\,</sup>$  Spectra of a combination of lamps (He, HgCd and Ar), for wavelength calibration.

 $<sup>^4\,</sup>$  Spectrum of LTT 377 star, for flux calibration.

 $<sup>^5</sup>$  IRAF is written and supported by the National Optical Astronomy Observatories (NOAO) in Tucson, Arizona. NOAO is operated by the Association of Universities for Research in Astronomy (AURA), Inc. under cooperative agreement with the National Science Foundation.



Figure 1. Field of vision of a reduced and aligned image. The V893 Sco star is in the intersection of red lines and the comparison stars are above "m" character in labels "Comp1" and "Comp2", respectively. This star was observed from OAUNI on 2017/06/30.



Figure 2. Light curves with errorbars of the V893 Sco star, built by differential photometry with data registered at OAUNI on 2017/06/30. Approximate orbital period of 0.076 d can be calculated from approximate positions of mid-eclipse of the primary eclipses.

## 3.2. Spectroscopy: HS 0220+0603

Spectra of HS 0220+0603 star, standard star and Arcs were corrected by overscan and flatfield in similar way to that of photometric data. Then spectra of the target star, calibrated on wavelength and flux, were extracted by doslit task from NOAO.IMRED.SPECRED, where extinction values and the directory of standard stars of Cerro Tololo Inter-American Observatory were used. Finally, the spectra were corrected by interstellar reddening with the task deredden from NOAO.ONEDSPEC package for E(B - V) = 0.047, corresponding to  $A_v = 0.145$  [6]. In figure 3, an example of this procedure is shown.

It is known that a spectrum of a CV in low state has contributions of basically the WD and the RD. A fitting program in Python was written to find out the combination of a synthetic spectrum of a WD and a template of a M type star that fits best to this spectrum.

From the Spanish Virtual Observatory web page<sup>7</sup> was downloaded synthetic spectra of WD made by Koester [7] with temperatures from 10000 K through 90000 K with interval of 5000 K, all of them with log g = 8.0. From this web page, it was also downloaded templates of M type classified under the system defined by Kirkpatrick *et al.* [8] from M4.5 through M9.5 with interval of 0.5.

A program that combines a synthetic spectrum of a WD and a M type star template was made. Seven points between wavelengths of 6300 and 8300 Å were set for fitting. The best fitting is that composed by a synthetic spectrum of 30000 K and log g = 8.0, and a template of M5.5 type star, similar to a WD of 30000 K and log g = 8.35, and a M5.5 type star from Rodríguez *et al.*, 2015 [6].



Figure 3. Spectrum of HS 0220+0603 star wavelength and flux calibrated and corrected for interstellar reddening .

<sup>&</sup>lt;sup>7</sup> https://svo.cab.inta-csic.es/main/index.php



Figure 4. Observed spectrum of HS 0220+0603 (light blue), synthetic spectrum of a white dwarf of 30000 K and log g = 8.0 (green) and M5.5 type template (red). This combination is the best fit to the observed spectrum according the fitting program.

### 4. Conclusion

An orbital period of 0.076 d was inferred for the dwarf nova V893 Sco and it was found that the components of the novalike HS 0220+0603 star in low state are a white dwarf of 30000 K and log g = 8.0, and a red dwarf M5.5 type star. Both, orbital period inferred and components found are similar to what we can find in literature as it was said in section 3.1 and 3.2, respectively. We are confident that our program has the potential for being useful in the study of cataclysmic variable stars. However, much more tests would be necessary to confirm the efficiency of our fitting method. Moreover, in this paper it has been demonstrated the suitableness of the OAUNI for the study of cataclysmic variable stars by photometry.

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