Highlights on Spanish Astrophysics IX, Proceedings of the XII Scientific Meeting of the Spanish Astronomical Society held on July 18 – 22, 2016, in Bilbao, Spain. S. Arribas, A. Alonso-Herrero, F. Figueras, C. Hernández-Monteagudo, A. Sánchez-Lavega, S. Pérez-Hoyos (eds.)

Searching for Cataclysmic Variables in the J-PLUS Survey

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Abstract

Cataclysmic Variables (CVs) are binary systems made of a white dwarf which is accreting mass from a less evolved companion. Depending on the physical properties of the system, the observational characteristics of CVs can be very diverse. Nevertheless, as we learned from projects like the Sloan Digital Sky Survey, CVs occupy the same locus of quasars in color-color diagrams, hence their discovery can be quite challenging. In this paper, we expose how the filter set of the J-PLUS project can help to efficiently separate CVs from other objects (mostly quasars) and even get their type. Through simulations and real data, we explain how accurate the method is and identify the following steps to finally get the first complete unbiased magnitude-limited sample of Cataclysmic Variables to date, a fundamental data set to be able to study the evolution of this type of objects.

1 Introduction

Cataclysmic Variables are close interacting binaries made of a white dwarf accreting mass from a companion (the secondary star) which is filling its Roche-lobe and forming an accretion disc (for a review, see [9]). The secondary star is typically a low-mass late-type main sequence star. The simple structure of both stellar components makes CVs one of the best classes to study and test our understanding of the evolution of compact, interacting binaries and its application to more complex astrophysical phenomena, such as black hole binaries, short gamma-ray bursts, X-ray transients, milli-second pulsars and Supernovae Ia, our yardsticks for measuring distances, to resolve the still discrepancies between current populations models and observations. Although we have over 40 years of extensive research on CVs and more than 1100 systems known (see [7]), there are still many questions to answer and a larger and well known population of CVs becomes necessary.

The search for CVs has largely benefited from serendipitous discoveries based on the variability properties of these objects (for a recent example, see [2]). With the advent of large field surveys, CVs have often been found as by-products of quasar searches, since CVs and quasars tend to occupy the same place in colour-colour diagrams based on broad-band filters (for a review, see [5]).

The Javalambre Auxiliary Survey Telescope (JAST/T80) located at the Observatorio Astrofísico de Javalambre (OAJ) in Teruel has been designed for stellar classification with a combination of broad and narrow band filters (for a review on the scientific use of these filters, see [3]). This article explains how this filter set can be used to efficiently recover CVs and separate them from other objects. The observations to be carried out at the OAJ will provide the best magnitude limited complete sample of CVs to date.

2 Deriving Color-Cuts

In general terms, depending on the mass transfer rate, a CV spectrum can be blue and/or red and it can show H_α emission due the accretion disk. When observed in broad band filters, quasars at low redshifts are mostly blue while they become red at high redshift. In function of the redshift of the quasar, some line may be at the same wavelength of H_α at rest frame (e.g. H_β at z ~0.4). Keeping this in mind, we have developed a three-steps methodology to separate CVs from quasars.

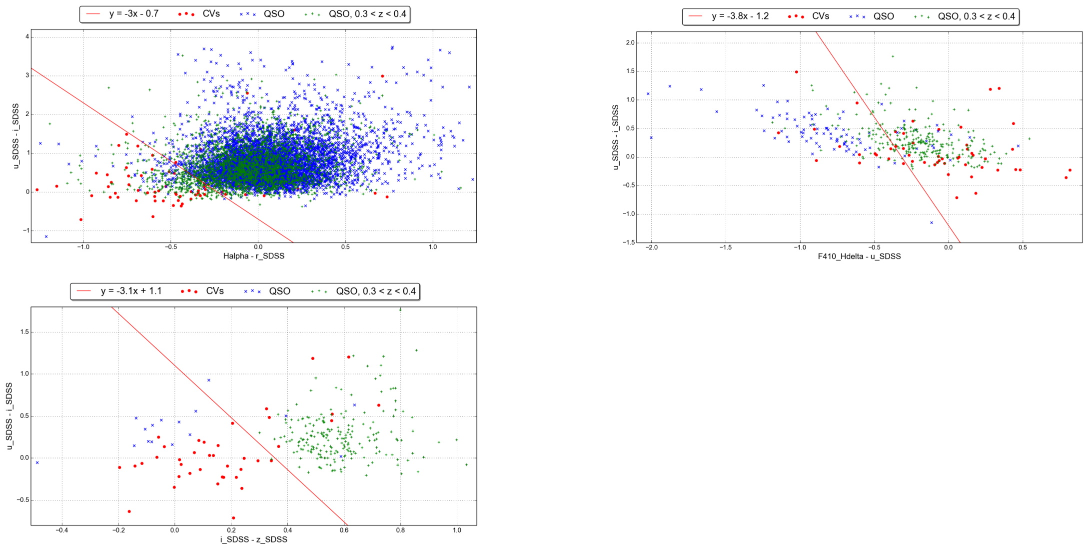

Figure 1: Three color-cuts devised to disentangle CVs from quasars, the red dots are the CVs, the green are Quasars with redshifts between 0.3 and 0.4 and in blue the rest of the Quasars. Top-left panel shows the color-color diagram J0660-rSDSS vs uJAVA-iSDSS, most of the CVs are below the cut and most of the Quasars fall above it. Top-right, J0410-uJAVA vs uJAVA-iSDSS with the remaining objects below the cut in the top-left panel. Bottom-left, iSDSS-zSDSS vs uJAVA-iSDSS with the remaining objects above the cut in the top-right panel.

The three-step method is displayed in Figure 1. The top-left panel shows the color-color diagram J0660-rSDSS vs uJAVA-iSDSS and its purpose is to distinguish the CVs from quasars with no emission line in J0660. Since H_α at rest frame is located in this filter, most of the CVs are found below the cut. The uJAVA-iSDSS is used to trace the continuum, which can be red or blue for both CVs and quasars as explained above, and therefore is used for reference in all the diagrams. The top-right panel shows that quasars in a series of redshifts can be separated from CVs using the J0410-uJAVA colour in combination with the uJAVA-iSDSS. In the bottom-left panel, the green dots emphasize the quasars with redshifts between 0.3 and 0.4. These quasars have H_β in the J0660 filter and are particularly challenging. Nevertheless, for these objects, the H_α line is shifted between the iSDSS and zSDSS filters, at around 8600 Å, hence the color iSDSS-zSDSS, in the bottom-left panel, places these quasars around values 0.5 and CVs around 0 and allows for discrimination.

3 Science Verification Observations

During the science verification phase of T80Cam (see [4]), three fields were observed to test the methodology described in the previous section. Figure 2 shows the result for one of these three fields mentioned (field J1730).

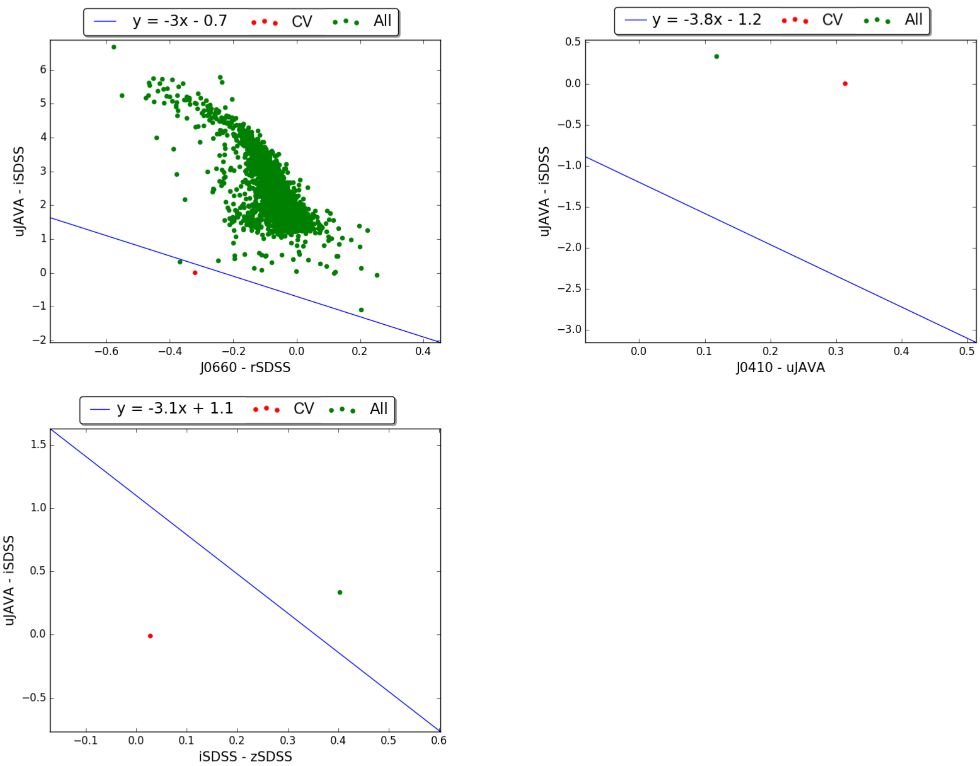

Figure 2: Real J-PLUS observation for field J1730. The red dot is the known CV used to test the methodology applying the three color-cut. The known CV is retrieved.

This is a real J-PLUS observation, and we mark in red the known CV (J173008.36+624754.6, a dwarf nova), and in green the rest of the objects classified as point source (including quasars). The known CV is the only object which passes the three cuts. It is worth mentioning that there is another object passing the first and second cut. This is a quasar with a Mg line emission located in J0660 which implies that OII and NeIII lines are shifted around 8800Å. That, combined with a relatively blue spectrum, makes the difference in the color-color diagram iSDSS-zSDSS vs uJAVA-iSDSS and therefore is not classified as CV.

In another field observed during science verification, we could test our method on the star J171145.08+301319.9. The object was not successfully identified as CV (left panel Figure 3). Analyzing the field, we noted that the CV is much brighter than it was when it was observed by SDSS (see table 1).

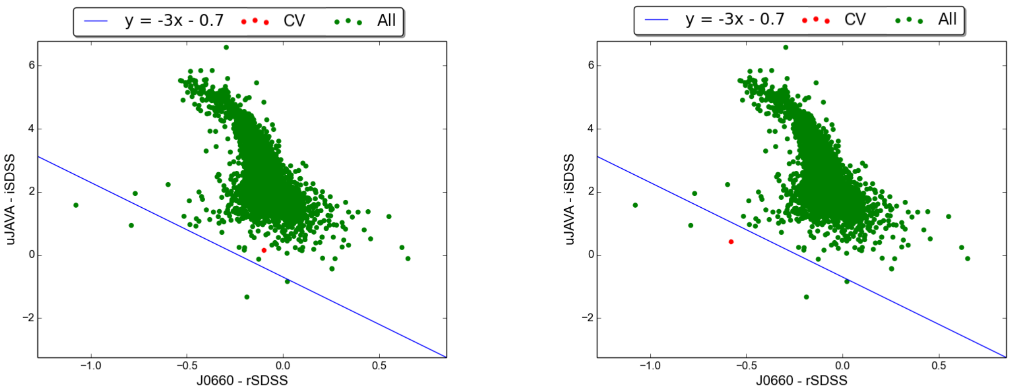

Figure 3: Real J-PLUS observation for field V1247Her. Both panels are color-color diagrams facing J0660-rSDSS vs uJAVA-iSDSS. The left one shows the CV as found in the J-PLUS observation, it wasn't retrieved. The right one represents the CV convolving the SDSS spectrum to the J-PLUS filters of it during the SDSS observation. It would have passed at least the first cut.

	uSDSS	gSDSS	rSDSS	iSDSS	J0660
SDSS Photometry	20.43	20.19	20.12	20.15	NoData
SDSS Synthetic Photometry	20.14	20.26	20.14	20.25	19.61
J-PLUS Photometry	18.59	18.81	18.16	18.29	18.06

Table 1: Table comparing the SDSS photometry, the SDSS Synthetic photometry and the J-PLUS photometry.

We believe that what we are seeing is that the system had low mass accretion rate during the SDSS observation, while it had high mass accretion rate during the J-PLUS observations. Convolving the SDSS spectrum of the CV with the J-PLUS filters and applying the first color-cut, the CV is recognized as such.

4 Summary and Conclusions

We have presented a new methodology, based on the J-PLUS filter set, to identify CVs in wide field surveys. The methodology is based on cuts in colour-colour diagrams and it has a completeness of 36% (i.e. recovers 31 out of 86 CVs in our test sample) and a purity of 76%. Since we expect to have about 1000 quasars for each CV in the J-PLUS survey, both completeness and purity are still small (in particular the latter) for our main goal, which is to provide an unbiased magnitude-limited sample of CVs for evolutionary studies. We have embarked on a new approach (see [1]) based on machine learning algorithms which we expect to improve our selection.

Acknowledgments

Funding for the J-PLUS Project has been provided by the Governments of Spain and Aragón through the Fondo de Inversiones de Teruel, the Spanish Ministry of Economy and Competitiveness (MINECO; under grants AYA2015-66211-C2-1-P, AYA2015-66211-C2-2, AYA2012-30789 and ICTS-2009-14), and European FEDER funding (FCDD10-4E-867, FCDD13-4E-2685). The Brazilian agencies FAPESP and the National Observatory of Brazil have also contributed to this project.

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