ELUCIDATING THE NATURE OF NEW SLOAN DIGITAL SKY SURVEY ”CVS” WITH XMM-NEWTON

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ABSTRACT

We report follow-up XMM-Newton and optical observations of the two stars identified as candidate intermediate polars from their Sloan Digital Sky Survey spectra: SDSS J102347.67+003841.2 = FIRST J102347.6+003841 and SDSS J093249.57+472523.0. We also include a brief summary of the overall results from our on-going XMM-Newton follow-up programme of candidate magnetic cataclysmic variables (mCVs) found in SDSS.

Key words: individual: (SDSS J093249.57+472523.0, SDSS J102347.67+003841.2) — novae, cataclysmic variables — stars: magnetic — X-rays: stars.

1. INTRODUCTION

The Sloan Digital Sky Survey (SDSS) has proven highly effective in the identification of new accretion-powered binaries; its five colour photometry plus high quality follow-up spectra have revealed > 100 cataclysmic variables (CVs) and related objects (Szkody et al 2002-2005). This large sample facilitates the optical selection of candidate magnetic (m)CVs, thus potentially probing to lower accretion rates than available with earlier X-ray identification/selection methods. In an on-going programme of XMM-Newton observations we are obtaining X-ray measures, such as basic spectral parameters and fluxes to further improve our understanding of these systems, and confirm their magnetic classifications (or not).

2. OBSERVATIONS AND DATA REDUCTIONS

For each target we have obtained low-resolution spectra from the EPIC cameras, with count rates (pn) ranging from 0.08 to 0.4 cps. Our spectral and lightcurve extractions followed the standard procedures from the ABC guide and Vilspa help pages; however we always reextracted event lists from the ODF files to incorporate the latest calibration products. In the optical we obtained spectroscopy, spectro-polarimetry and time-series photometry, often simultaneous or contemporaneous with the X-ray observations. In most cases, we also obtained B-band imaging from the OM and performed custom extractions from the ODFs to produce binned lightcurves with time-resolutions comparable to our ground based data.

3. MOST RECENT RESULTS

Here we provide brief details on our results for SDSS J0932 and J1023; full details including figures appear in Homer et al 2006a.

3.1. SDSS J093249.57+472523.0

Two epochs of photometry show 7 deep and narrow eclipses; the $O - C$ analysis yields a best fit ephemeris: $\mathrm{HJD(TT)} = 2453122.2324(1) + E * 0.0661618(4)\mathrm{d}$. In addition, during May there was evidence for a periodic, non-eclipse modulation with P=1.04*Porb: perhaps a superhump?

A blue, high-excitation emission line spectrum, indicative of a magnetic CV, was seen in both the SDSS survey, and contemporaneously with our X-ray observations. Given our low S/N, the X-ray spectral fits allow for either a hard bremsstrahlung or power law emission model, but in each case a partial covering model with low Galactic column + high local $N_H = 1 \times 10^{23}\mathrm{cm}^{-2}$ and fraction 0.9 was needed; this suggests either an accretion curtain or (time-averaging over) X-ray dipping. Overall, observations suggest an intermediate polar nature: the X-ray/optical spectra are consistent with mCV or high-i active LMXB, but an F_X/F_{opt} comparable to other intermediate polars (IPs), and more than $100\times$ too low for an LMXB. However, the absence of additional photometric periodicities leaves its IP candidacy in doubt; more optical photometric monitoring needed.

Table 1. Summary of results from our XMM-Newton and optical follow-up programme on SDSS "CVs"

SDSS J	Class	P^a (h)	$V_{\rm avg}$	$f_X{}^b$ (erg s^{-1} cm^{-2})	Description
072910.68+365838.3	Polar	2.5	20.6	4×10^{-13}	Single-pole accretor, unusual 0.57 keV line during "flare"[1]
075240.45+362823.2	Polar	2.74	18.3	4×10^{-12}	Single-pole accretor,$L_{\rm BB}/L_{\rm br} = 0.35 - 0.5$[1]
170053.30+400357.6	Polar	1.94	18.7	1×10^{-12}	Anti-phased X-ray and optical orb. modn.– 2-pole accretor?[1]
015543.40+002807.2	Polar	1.45	16.5-18.5	3×10^{-12}	Shortest $P_{\rm orb}$ eclipsing polar, exhibits low/high states[2]
132411.57+032050.5	LARP^c	2.6	17.6	$< 6 \times 10^{-15}$	X-rays only from M dwarf secondary[3]
155331.12+551614.1	LARP	4.39	18.8	7×10^{-14}	As for 1324, long-term avg. $\dot{M} < 3 \times 10^{-12}$ $M_\odot$/yr[3]
144659.95+025330.3	IP	3.8/.8	18.0	2×10^{-12}	Large amp. spin modn. in opt./X-ray. $P_{\rm orb}$ from radial vels.[4]
093249.57+472523.0	IP?	1.59/?	18.8	2×10^{-13}	X-ray/opt. spectra suggest IP, but no spin modulation seen[5]
102347.67+003841.2	LMXB	1.94	16-17.5	6×10^{-13}	Only one (small) outburst to date, variable[5] X-ray emission dominated by non-thermal component

Notes: ^{a}For IPs both orbital and spin periods given, others $P_{\rm orb}$, ^{b}Unabsorbed X-ray flux in 0.01-10 keV band, ^{c}LARP=Low accretion rate polar. References: [1]Homer et al 2005, [2]Schmidt et al 2005, [3]Szkody et al 2004b, [4]Homer et al 2006b, [5]Homer et al 2006a

3.2. SDSS J102347.67+003841.2

First observed in a rare high state, when it exhibited: (i) radio emission (detected in FIRST survey, Bond et al 2002); (ii) a high excitation emission line spectrum (Szkody et al. 2003); (iii) a blue continuum with $V \approx 16$. Hence, a highly magnetic CV was suggested. In its more usual low state (as for our observations), one sees: (i) a red mid-G V stellar spectrum, with $V \approx 17.5$; (ii) a smooth optical modulation on the P=4.75 h orbit. Moreover, lightcurve modelling, and radial velocities imply $M_{acc} > 1.4\,M_\odot$ (Thorstensen & Armstrong 2005 - TA05), making SDSS J1023 an LMXB (usually observed in quiescence)

Our optical minimum phases well with TA05, giving a refined ephemeris: $\rm HJD(TT) = 2453081.8546(3) + E * 0.198094(1)d$. The X-ray lightcurve shows 60% (peak-peak) variation, possibly periodic on 1.66 h. If this were the white dwarf spin in an IP, it would require a unique $P_{\rm spin}$ to $P_{\rm orb}$ ratio.

Approximating the X-ray emission of a CV as a thermal plasma, we find an acceptable fit for a 40 keV MEKAL, with (fixed) low column $N_H = 1 \times 10^{19}{\rm cm}^{-2}$. Or for LMXB in quiescence, fitting a power law (+ optional neutron star atmosphere), we find good fits for the PL alone with $\Gamma = 1.3$, and $N_H = 9 \times 10^{19}{\rm cm}^{-2}$; the NSA contribution is negligible.

In summary, our observations support the LMXB hypothesis of TA05: (i) for d=2 kpc, $L_X = 10^{32.4}$ erg/s – typical for LMXBs in quiescence; (ii) X-ray emission dominated by power law (>97%) – fits with anti-correlation for low L_X systems (see Jonker et al 2004); (iii) X-ray variability akin to that of both Cen X-4 and EXO 1745-248, but origin of hard X-rays still a mystery; (iv) only one outburst known to date– implies large quiescent intervals, consistent with faint, low temperature NSA component. In contrast, many characteristics do not fit with a magnetic CV interpretation: (i) activity behaviour unlike any CV subclass – infrequent and low amplitude outburst(s); (ii) MEKAL spectrum fine for active CV, but what of its origin in absence of substantial mass transfer, it cannot be the chromospheric emission of the donor star, being both too hard and bright.

4. CONCLUSIONS

The XMM-Newton and optical follow-up of candidate magnetic CVs from SDSS has proven highly successful. Out of the 9 systems studied to date, only one has not turned out to be an mCV, and this a probable transient LMXB! We have added 1 or 2 IPs to their small numbers, as well as 2 polars with extremely low accretion rates, possibly pre-polars. The new eclipsing system SDSS J0155 has already yielded detailed constraints on the nature of its accretion flow, along with full binary parameters; it is ripe for further phase-resolved spectroscopy on 10m-class telescopes. Together with the other 3 polars, we find no evidence for the so-called soft X-ray excess; in agreement with the results of the latest XMM-Newton survey of the brighter polars by Ramsay, Cropper and co-workers.

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