Using XMM-Newton and Optical Photometry to Figure Out CVs

Paula Szkody
Lee Homer
Department of Astronomy, University of Washington, Seattle, WA 98195

Arne A. Henden
AAVSO, 25 Birch Street, Cambridge, MA 02145

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Abstract X-ray light curves from XMM-Newton combined with optical data from the satellite and ground-based observers provide distinctive shapes and periodicities that give information on the correct classification of cataclysmic variables. Our recent data on three SDSS sources with strong helium emission are used to identify a highly magnetic system (a polar), the spin of the white dwarf in an intermediate polar, and a typical disk accreting system.

1. Introduction

There are several ways of classifying cataclysmic variables (CVs) as reviewed in Warner (1995). One of the important methods invokes the magnetic field of the white dwarf, as this property has important implications for the way the mass transfer and accretion take place and ultimately on the amount of X-rays emitted. If the white dwarf has a low field (under 1 MG), the transferred mass accumulates in an accretion disk and X-rays are generated at the boundary layer, where the disk meets the white dwarf. For high fields (15–250 MG), the mass transfer goes directly to the magnetic poles of the white dwarf, forming an accretion column where copious X-rays are usually emitted (these systems are termed polars). For intermediate fields between these two cases, the material forms an outer disk ring while the area close to the white dwarf is funneled in wide accretion curtains to the magnetic poles, and these systems are called intermediate polars.

The following clues lead to the correct classification of magnetic and disk systems. For a polar, the optical and X-ray variations occur at the same (orbital) period, as the spin of the white dwarf is synchronized to the orbit by the magnetic field. The X-ray spectrum shows both a low temperature (30 eV) component from the heated white dwarf and a high temperature (30 keV) component from the accretion shock, and the absorption column is usually low (log of the hydrogen column density, n_H, is about 20). For intermediate polars, the optical and X-ray variations are at a shorter period than the orbital period, since the magnetic field is not high enough to synchronize the white dwarf spin and the X-rays are modulated at the spin period. The X-ray spectrum shows only a high temperature component, and the log hydrogen column density is high (log n_H ~22) due to absorption by the accretion curtains. Finally, for systems with an accretion disk, there is usually no periodic variability evident in the X-ray light curve, and the X-ray spectrum usually shows a component near 8–10 keV with low hydrogen column (log n_H ~20), as the X-rays originate from the boundary layer where the disk meets the white dwarf.

In the optical region of the spectrum, the distinguishing trait of magnetic systems is usually the presence of the high excitation line of HeII 4686Å. However, some nova-likes with high accretion rates and orbital periods between 3–4 hours (the SW Sex stars) can also produce strong HeII. Thus, when the Sloan Digital Sky Survey (SDSS, York *et al.* 2000) showed numerous CVs with strong HeII (Szkody *et al.* 2003), XMM-Newton observations were proposed in order to sort out their true identity. Here we report on the results for three systems: SDSSJ144659.95+025330.3, SDSSJ2050017.84–053626.8, and SDSSJ210131.26+105251.5, which we will abbreviate to SDSSJ1446, SDSSJ2050, and SDSSJ2101 throughout the rest of this paper.

2. The XMM-Newton Satellite

The XMM-Newton satellite is in a highly elliptical orbit (which enables long observations without earth occultation) and contains three X-ray mirror modules and one Optical Monitor (OM) that all operate simultaneously. The X-ray detectors consist of one high sensitivity CCD camera (EPIC-pn), two lower sensitivity cameras (EPIC-MOS), and a reflection grating spectrometer (RGS). Unfortunately, all our sources were too faint for any detections with the RGS, but the EPIC cameras have some energy resolution so they can be used to fit models and determine the temperature and column density of the sources. Further information on the XMM satellite and instruments can be obtained from the XMM website http://xmm.esac.esa.int/. The pictures of the mirrors on this site are especially interesting, as X-rays require grazing angles of reflection in order to be focussed, hence the telescopes consist of nested mirrors, rather than the single mirrors used in optical telescopes.

3. SDSSJ1446

This source was first identified as a potential polar in Szkody *et al.* (2003). Follow-up time-resolved spectroscopy of this source showed an orbital period that was near 4 hours. The XMM-Newton observations took place on 2004 Jan 30 and the X-ray light curves show a clear modulation with a period of 48.5 minutes, with increasing amplitude at lower energies. The OM and two ground-based observations obtained with the Naval Observatory Flagstaff Station (NOFS) 1-m telescope and CCD detector also showed a modulation at this period (Figure 1). The X-ray spectrum fits models with high temperature up to 60 keV and a high log column density of near 22. All these traits clearly point to the conclusion that SDSSJ1446 is an intermediate polar with a spin period of 48.5 minutes.

4. SDSSJ2050

Following the identification of this source as a CV (Szkody *et al.* 2003), the photometry of Woudt *et al.* (2004) revealed deep eclipses with an orbital period of 1.57 hours. Both the XMM-Newton (Figure 2) and optical NOFS data three days after the X-ray observation show eclipses with the same period, and the extended baseline could be used to refine the ephemeris. The X-ray spectrum can be fit with two components, one at 28 eV and the other at 41 keV with a log column density of 20.70. Thus, we conclude that this is a polar system.

5. SDSSJ2101

NOFS data were acquired five hours before the start of the XMM-Newton observations. The NOFS data (Figure 3) indicate variability near 107 minutes. A period of about 86 minutes is seen in the XMM data but the observation is very short (only 1.5 hours) so this is not confirmed. Optical spectra show no clear radial velocity variations so the inclination is likely low. The XMM spectra are fit with a 10 keV source with a low column. All these characteristics imply a low inclination disk system. However, since it has such a strong HeII emission line present in the SDSS spectrum, it is likely an SW Sex star. An orbital period remains to be determined.

6. Summary

Our combined optical and X-ray analysis of three SDSS-discovered CVs with prominent high excitation emission lines of HeII has resulted in the classification of SDSSJ1446 as an intermediate polar, SDSSJ2050 as a polar, and SDSSJ2101 as a likely low inclination SW Sex system. Although XMM-Newton has an optical monitor on board, the more extensive ground coverage is important for elucidating the periodicities and long term behavior of these systems.

Further details on these results (including the analysis of the light curves and spectra) can be found in Homer *et al.* (2006).

5. Acknowledgements

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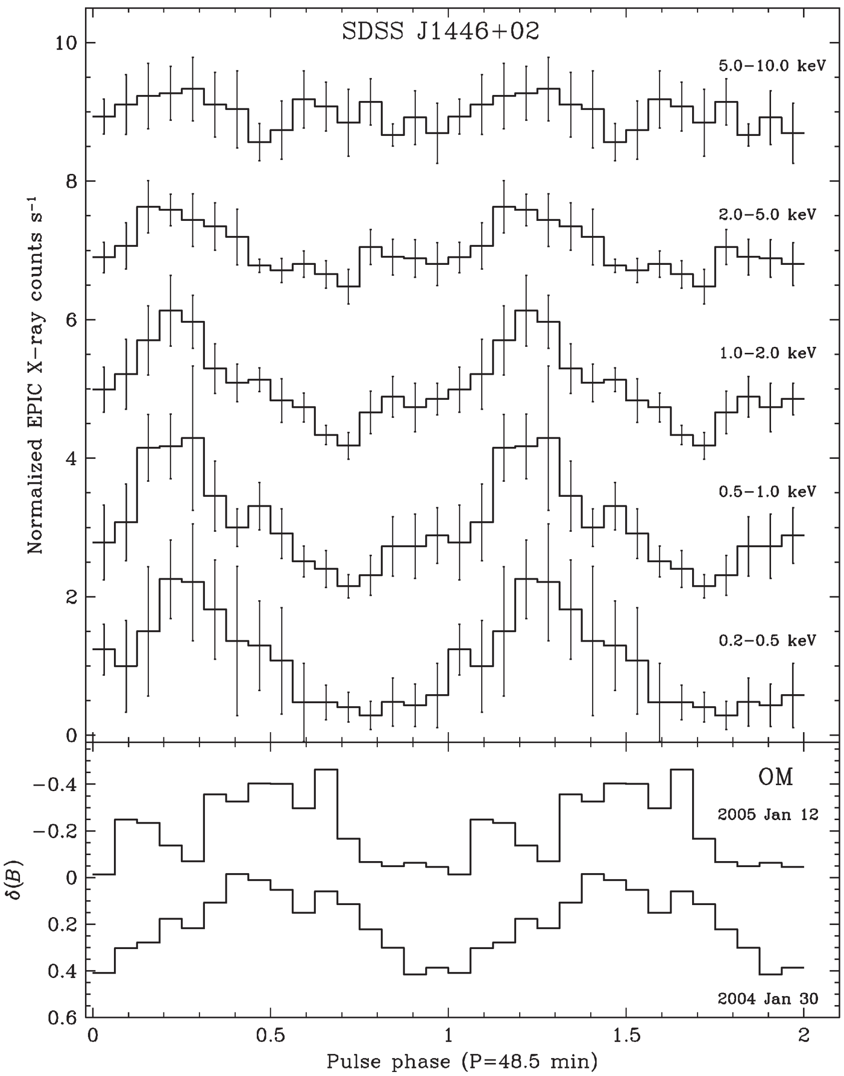

Figure 1. The X-ray and optical (OM with a B filter) light curves of SDSSJ1446 phased on the 48.5-minute spin period of the white dwarf, showing how the amplitude changes with different energies.

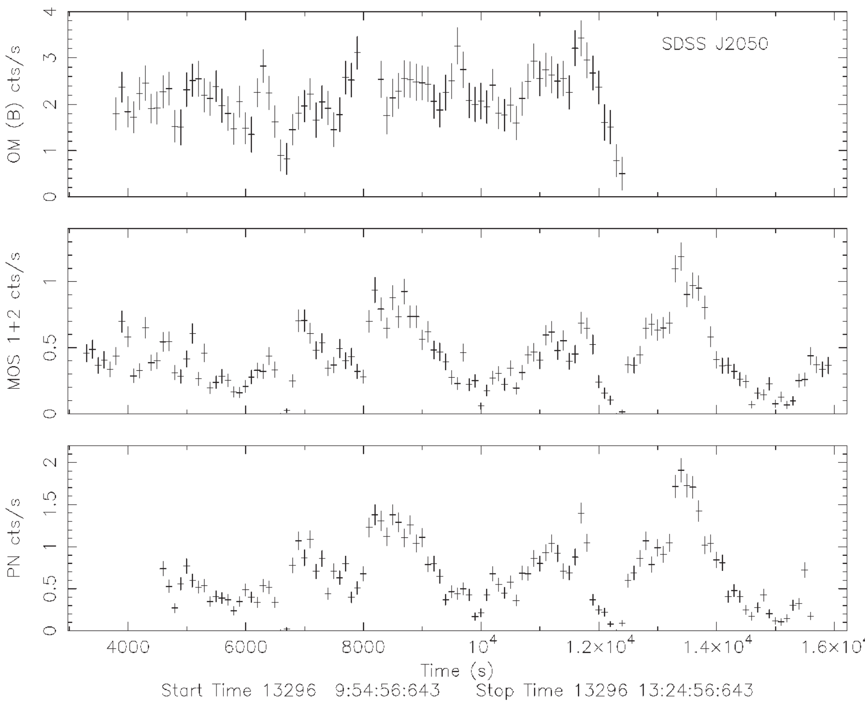

Figure 2. The XXM-Newton X-ray and optical (OM with B filter) light curves of SDSSJ2050 showing eclipses near 6800 and 12400s as well as large variability throughout the orbit at all energies.

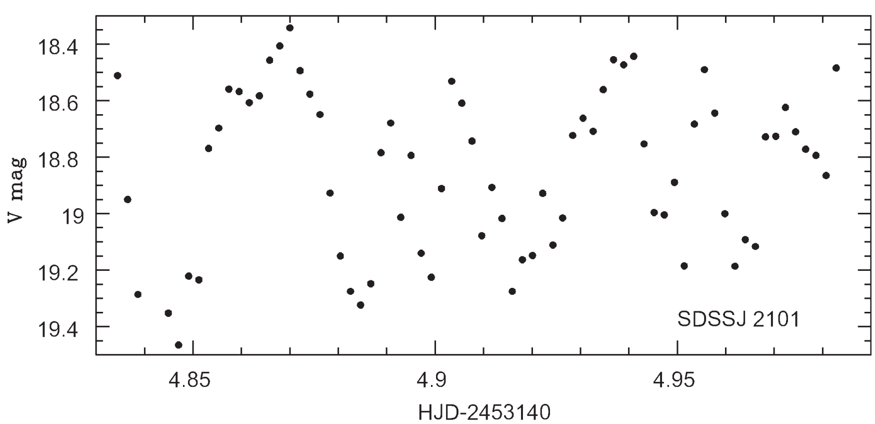

Figure 3. The NOFS light curve of SDSSJ2101 5 hours before the start of the XMM-Newton observations. While large variations are present, there is no clear periodicity found in these data.