XMM and MCVs

Cynthia H. James, Graziella Branduardi-Raymont, Mark Cropper and Gavin Ramsay
Mullard Space Science Laboratory, University College London, Holmbury St Mary, Dorking, Surrey, RH5 6NT, UK

ABSTRACT

In this paper we use ESA's SCISIM to simulate XMM spectra of PQ Gem, a Magnetic Cataclysmic Variable (MCV) of the Intermediate Polar (IP) class. The simulations are based on the parameter values for two different models which gave similar reduced χ^2 results when fitted to ASCA SIS data. These are representative of different levels of sophistication to the modelling of the physics of the postshock accretion flow. We compare these simulated spectra to those obtained from the ASCA observations and assess some of the diagnostic capabilities of XMM with respect to MCVs.

1. Introduction

Cataclysmic Variables (CVs) are binary systems in which the secondary is a main sequence star and the primary is a white dwarf. The secondary star fills its Roche lobe and donates its material to the primary star through the first Lagrangian point in the same basic process as for all CVs. However, in the case of MCVs, this process is modified in the vicinity of the white dwarf by its strong magnetic field which tends to counteract the formation of an accretion disc. It is the strength of the magnetic field which determines the extent of this modification and the location of the threading of the accretion column onto the magnetic field lines. In addition it also plays a significant role in the degree of synchronisation between the rotation period of the white dwarf and the orbital period of the system.

Those systems with the strongest magnetic fields, the Polars, show observational evidence which indicates the complete absence of an accretion disc so that the accretion stream impacts directly onto the white dwarf surface close to one or both of its magnetic poles. These systems are synchronised to within approximately 1%. Whereas, in IPs it is more complex with a lower field allowing the formation of a disk, but in some cases it maybe truncated and/or stream overflow of the disk occurs. These systems lack complete synchronisation which complicates the observed modulation of their light curves.

There is observational evidence to support the presence of hotspot(s) of around 10^8K due to the standing shock caused by the impact site(s) of the accretion onto the surface of the white dwarf, Cropper (1997). The extent of the modulation of the light curves of MCVs due to the accretion processes depends not only on the system parameters but also on the viewing angle of the observer. These effects with respect to PQ Gem are discussed by Potter et al.(1996) and by Mason (1997). One conclusion from this work is that spin phase showing maximum flux corresponds to the point where the post-shock region comes closest to face on to the observer.

In this paper we analyse ASCA archival data of the IP, PQ Gem, over the spin phase range showing maximum flux. Using XSPEC we obtain very similar reduced χ^2 for fits with two different models, which leads us to ask which is the more likely to be applicable. The surmise is that the match of two different models to the data will tend to diverge with increasing sensitivity of the instrumentation e.g. XMM-RGS. We use ESA's Science Simulator, SCISIM, to simulate PQ Gem RGS observations based on these two models. We then compare the resulting spectra both against each other and the original ASCA data and discuss the results.

2. ASCA Data Analysis

We extracted an average light curve for PQ Gem using the XSELECT package having reduced the ASCA SIS data in line with the recommendations issued by the ASCA Guest Observer Facility. We folded this light curve on the spin period using the spin ephemeris derived by Mason (1997), this is shown in Figure 1. From this folded light curve we assessed the spin phase which corresponds to face on to the observer as being between spin phases 0.12 to 0.54. We extracted a spectrum based solely on this part of the light curve, again using the XSELECT package and built response, auxiliary and background files to match.

We used XSPEC to fit this extracted spectrum with two models, based on a single temperature and a two-temperature optically thin Raymond-Smith plasma. We grouped the data by a factor of 3 across all 512 PHA channels and found that the resulting reduced χ^2s for the fit with the two models were very similar. We show the fitted ASCA SIS spectra in Figure 2, the models used for the fitting of the data in Figure 3 and the parameter values associated with the results from best fits in Tables 1 and 2.

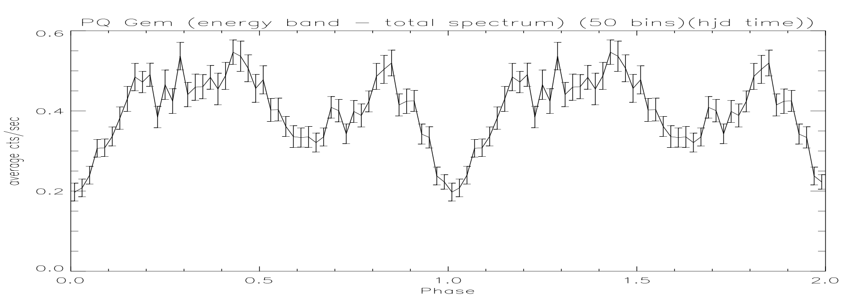

Fig. 1.— Light curve from ASCA SIS data for PQ Gem folded on the spin ephemeris of Mason (1997).

3. XMM Simulations

We used the SCISIM tool for the simulations. The details of the source were provided by the XSPEC models obtained from fitting the ASCA data of PQ Gem as we have detailed above. We created QDP files of both of the models using the QDP/PLT software package from within XSPEC. The parameter values matched those obtained from the fitting (see Tables 1 and 2) except for the column density which was set to zero. We used XSPEC to calculate the expected flux over the XMM band for both models.

We provided the column density and flux from the values already obtained using XSPEC and limited the energy bandwidth to lie between 0.25 and 12 keV. We configured SCISIM for an RGS and EPIC observation using the default instrument parameters with an exposure of 37,000 seconds in line with the ASCA exposure.

We used the FTOOLS, RGS Pipeline Processing and QDP/PLT in standalone mode to reduce the simulated RGS data, and produce spectra as shown in Figures 4 and 5. The first order spectra have been binned on wavelength such that the binning was approximately the resolution of the RGS instrument; whereas for the second order spectra the number of bins was halved to accommodate the reduced event rate.

4. Results

Significant differences between the simulations from the two models are apparent in their RGS spectra (Figure 4) and their "banana plots" (CCD PH distribution vs dispersed spectra, Figure 5). The simulated spectrum from a two temperature Raymond-Smith model (right hand plot of Figure 4) shows considerably more evidence of emission lines than does that from the single temperature Raymond-Smith (the left hand plot of Figure 4). The origin of these lines is due to the low temperature, 0.08 keV, component of the model. We can also see substantial differences

flux (2 -10 keV) ASCA	(photons cm^{-2} s^{-1})	2.81 x 10^{-3}
flux (.25 -12 keV) XMM	(photons cm^{-2} s^{-1})	7.12 x 10^{-3}
integration time	(s)	37000
Optically thin thermal plasma	1 temperature Raymond-Smith(keV)	18.71
	normalization	1.69 x 10^{-2}
metal abundance	solar	1.0
constant absorber	nH (10^{22} cm^{-2})	1.13 x 10^{-3}
partial absorber	nH (10^{22} cm^{-2})	4.20
	covering fraction	0.52
Reduced χ^2	data grouped by factor of 3	1.39

Table 1: Results from fitting ASCA SIS data of PQ Gem with a model which included one optically thin thermal plasma component with Galactic column and partial absorbers at the source

between the simulated RGS spectra shown in Figure 4 and the ASCA spectra shown in Figure 2. The emission lines in Figure 4 are markedly resolved in the plots of the order 1 spectra, while nothing could possibly be identified as an emission line in the ASCA data. We have demonstrated the correctness of our surmise that the two models would be clearly separated with the increased sensitivity of the XMM instrumentation.

5. Discussion

We have shown that we can distingush between two simple models of the post-shock region in MCVs using XMM-RGS. However, the physics of this region is more complex than either of these two models. We have to include effects such as a strong temperature gradient between the shock front and the surface of the white dwarf (a multi-temperature model). A strong magnetic field will also effect the cooling processes. These complexities have been explored by Cropper et al.(1998) and Cropper et al.(1999) who find that the emission spectrum is different to either the two simple models shown here. The inclusion of these effects will be vital in interpreting our XMM spectra.

Acknowledgements
We would like to thank Tim Harries, Jon Rainger and Phil Williams of the MSSL SSC team for their prompt and kind assistance in the reduction of the simulated RGS data and Steve Potter for the provision of the code to fold the light curve.

Flux (2 - 10 keV) ASCA	(photons cm^{-2} s^{-1})	2.77 x 10^{-3}
Flux (0.25 - 12 keV) XMM	(photons cm^{-2} s^{-1})	1.15 x 10^{-2}
integration time	(s)	37000
Optically thin thermal plasma	2 temperature Raymond-Smith (keV)	27.15, 7.94 x 10^{-2}
	normalisation	1.66 x 10^{-2}, 1.69 x 10^{-2}
Metal Abundance	Solar	1.0
Constant absorber	nH (10^{22} cm^{-2})	1.94 x 10^{-2}
Partial Absorber	nH (10^{22} cm^{-2})	4.07
	covering fraction	0.46
Reduced χ^2	data grouped by factor of 3	1.30

Table 2: Results from fitting ASCA SIS data of PQ Gem with a model which included two optically thin thermal plasma components with Galactic column and partial absorbers at the source

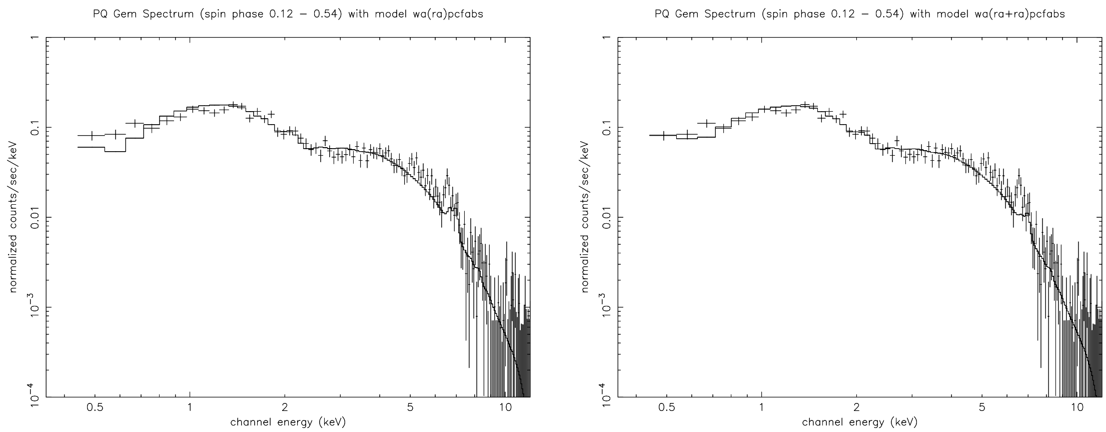

Fig. 2.— spectrum of ASCA data for IP PQ Gem for spin phase 0.12 - 0.54; LHS fitted to the single temperature model; RHS fitted to the two-temperature model.

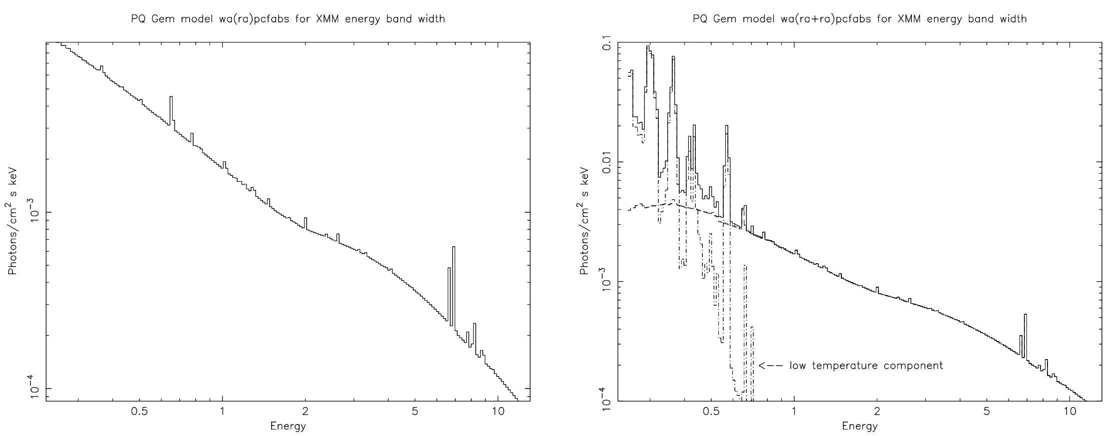

Fig. 3.— The spectral models and components from Figure 2; The details of the model on the LHS are given in Table 1 and those on the RHS are given in Table 2.

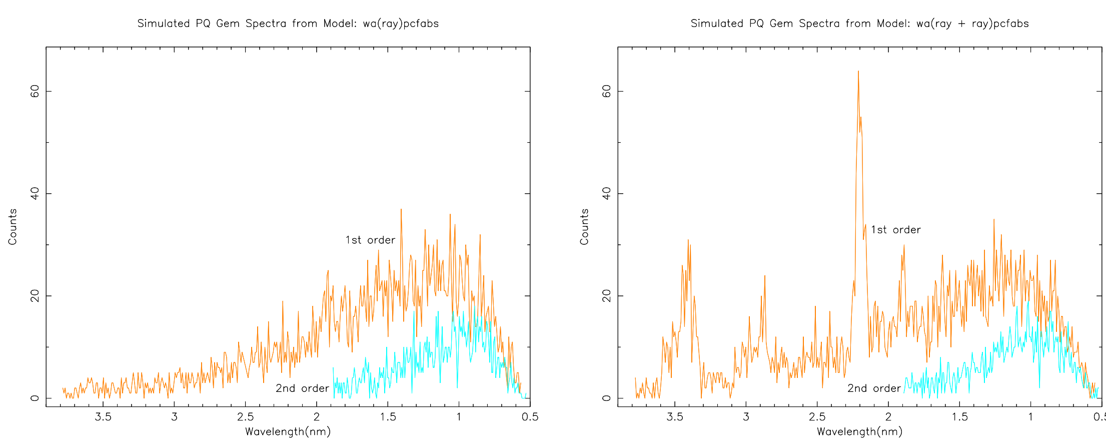

Fig. 4.— Simulated 1st and 2nd order RGS spectra. The LHS plot are the spectra obtained from the model detailed in Table 1; the RHS plot are the spectra from the model detailed in Table 2

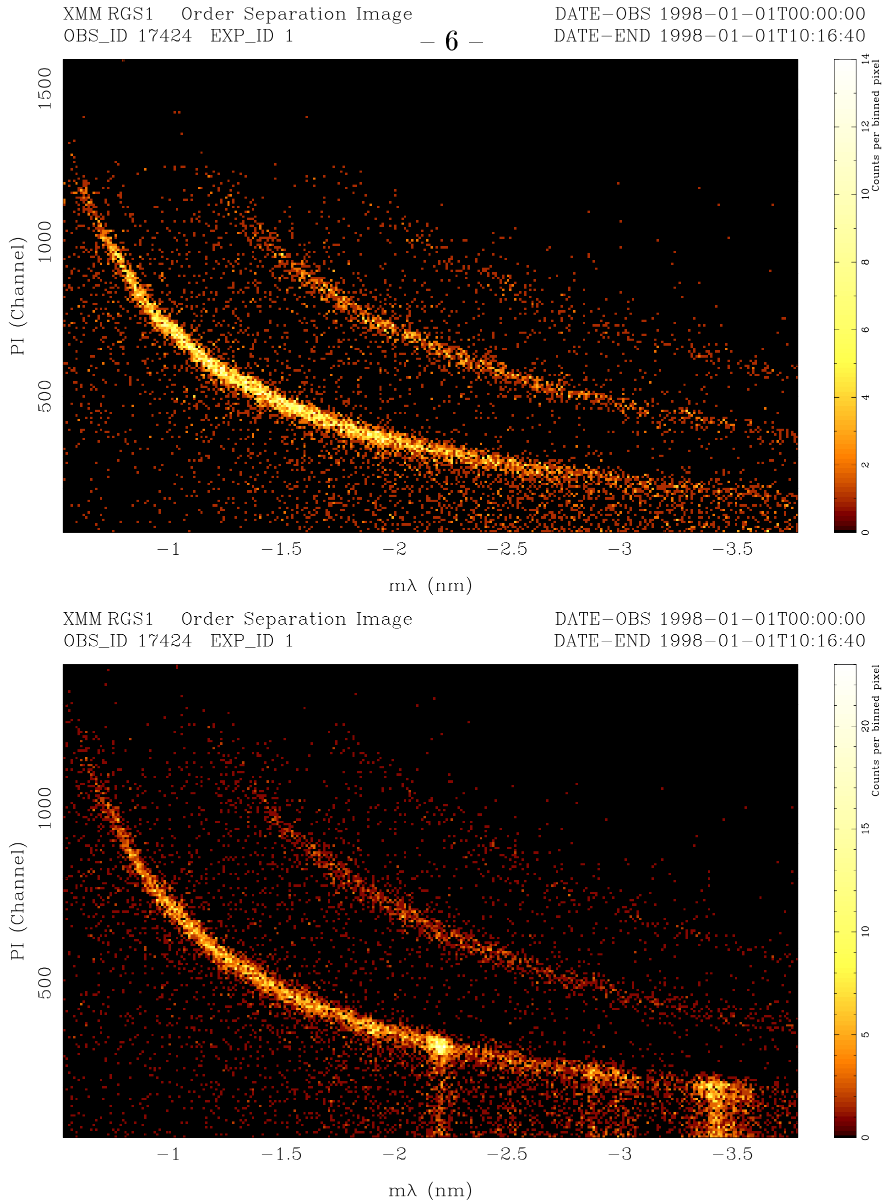

Fig. 5.— Energy-dispersion plot of RGS simulated spectra; LHS from the model detailed in Table 1 and on the RHS from the model detailed in Table 2.

References

Cropper, M., 1997, ASP Conference Series, Proc: of the 8th Annual Astrophysics Conference in Maryland.

Cropper M., 1998, these proceedings

Cropper, M., Ramsay, G., Wu, K., 1998, MNRAS, 293, 222

Cropper, M., Wu, K., Ramsay, G., Kocabiyik, A., submitted, MNRAS

Mason K.O., 1997, MNRAS, 285, 493

Potter S.B, Cropper M. Mason K.O., Hough J. & Bailey J., 1996, MNRAS, 285, 82

Raymond J.C., Smith B.W., 1977 ApJS, 35, 419