X-ray Flaring in the Contact Binary KIC 9832227

Dirk Pandel[1], Lawrence Molnar[2]

[1]Grand Valley State University, Grand Rapids, MI, USA

[2]Calvin College, Grand Rapids, MI, USA

Email: pandeld@gvsu.edu

Introduction

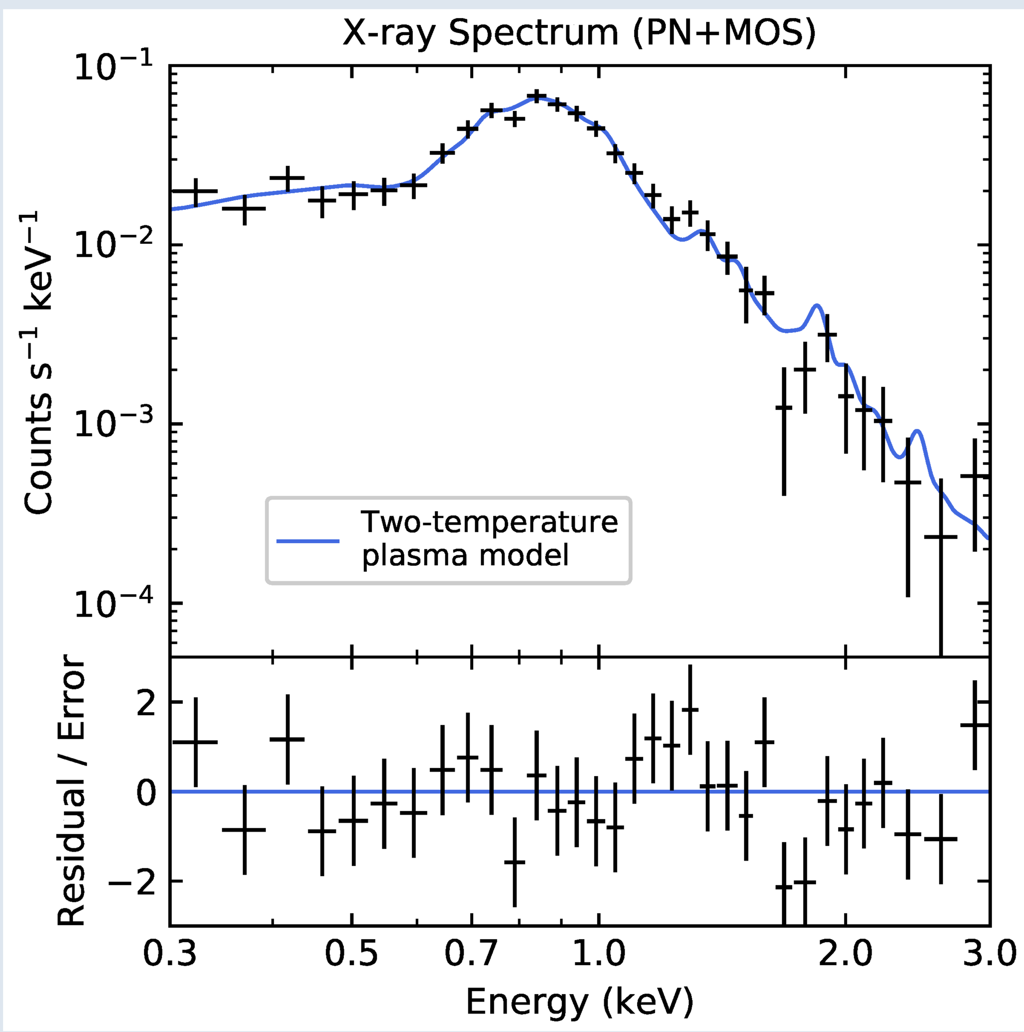
Contact binaries or W UMa stars are pairs of non-degenerate stars orbiting so closely that they share a common envelope and exhibit rapid stellar rotation. This results in high levels of chromospheric and coronal activity, making these stars strong sources of X-ray radiation. The specific origin of the X-ray emission remains uncertain. While some observations indicate that the X-rays arise from an extended corona encompassing both stars, other observations suggest that the corona is compact and predominantly above the polar regions of the primary star. We analyzed *XMM-Newton* data of the eclipsing contact binary KIC 9832227 to investigate the properties and origin of its X-ray emission. We also simulated the photospheric UV emission using stellar atmosphere models. The system parameters of KIC 9832227 are shown in the table to the right (see Molnar et al. 2017, ApJ, 840:1).

System Parameters of KIC 9832227

Orbital Period	0.4579331 days
Inclination	53.19°
Mass Primary	1.395 M_{Sun}
Mass Secondary	0.318 M_{Sun}
Temperature Primary	5800 K
Temperature Secondary	5920 K
Distance	633 pc

X-ray Spectrum

The binary was observed with *XMM-Newton* for 44 ks, slightly longer than one orbital cycle. We analyzed X-ray data from the two EPIC MOS cameras and the EPIC PN camera. KIC 9832227 is found to be a soft X-ray source with emission limited to energies below 3 keV originating from a multi-temperature plasma with temperatures up to 1 keV. The X-ray luminosity of 3.3×10^{30} erg/s is comparable to that of other W UMa stars with a similar orbital period. The X-ray spectrum is well fit by a two-temperature plasma model with a cooler 0.47-keV component and a hotter 0.94-keV component.

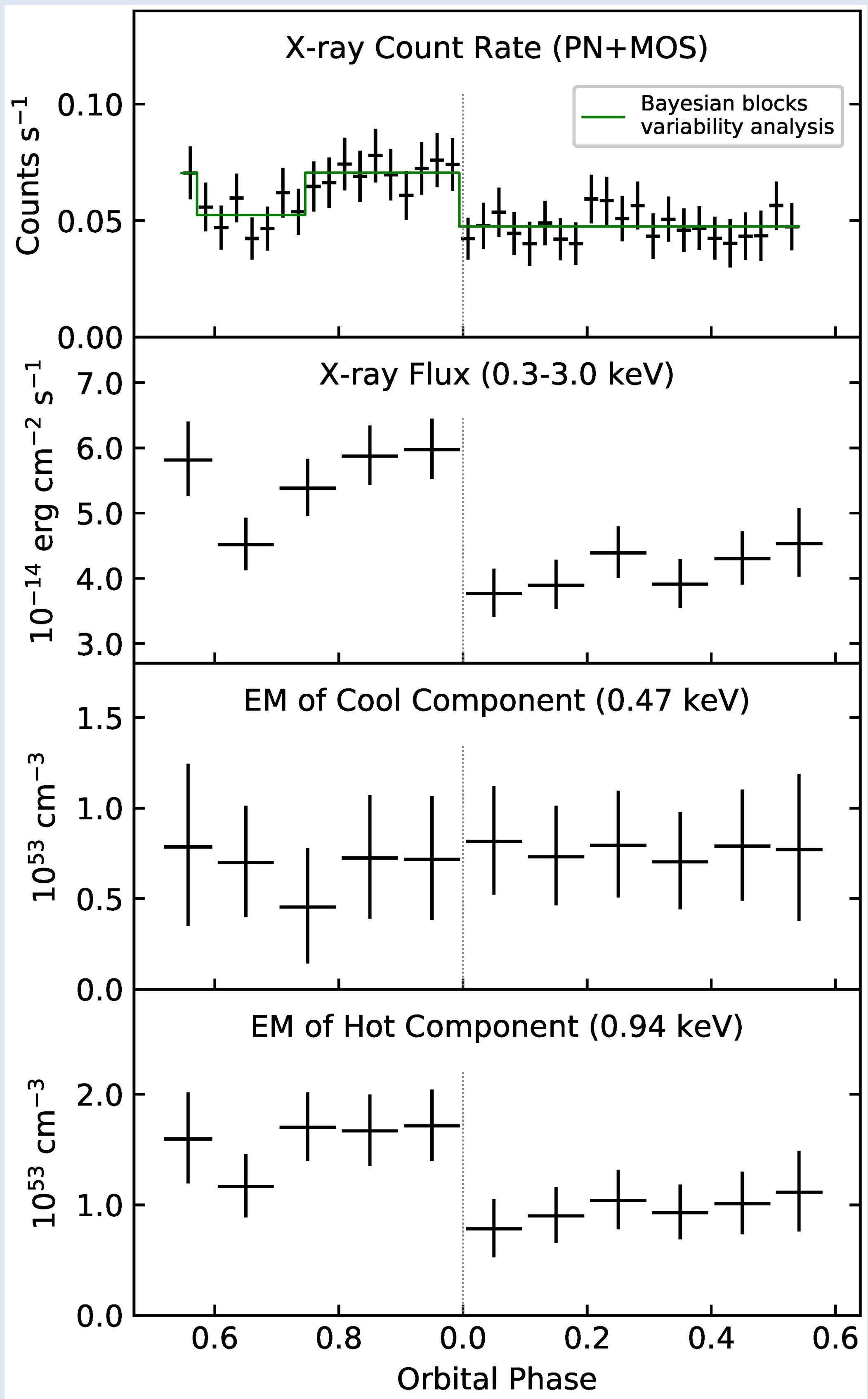


Best-fit Parameters for a Two-temperature Plasma model

Component 1:	
Temperature	0.47 keV
Emission Measure	0.9×10^{53} cm^{-3}
Component 2:	
Temperature	0.94 keV
Emission Measure	1.5×10^{53} cm^{-3}
Elemental Abundance	0.38 solar
Hydrogen Column Density	4.1×10^{20} cm^{-2}
Flux (0.3 – 3.0 keV)	4.7×10^{-14} erg/cm^2/s
Luminosity (>0.1 keV)	3.3×10^{30} erg/s
C Statistics	89.5 (72 d.o.f.)

X-ray Light Curve

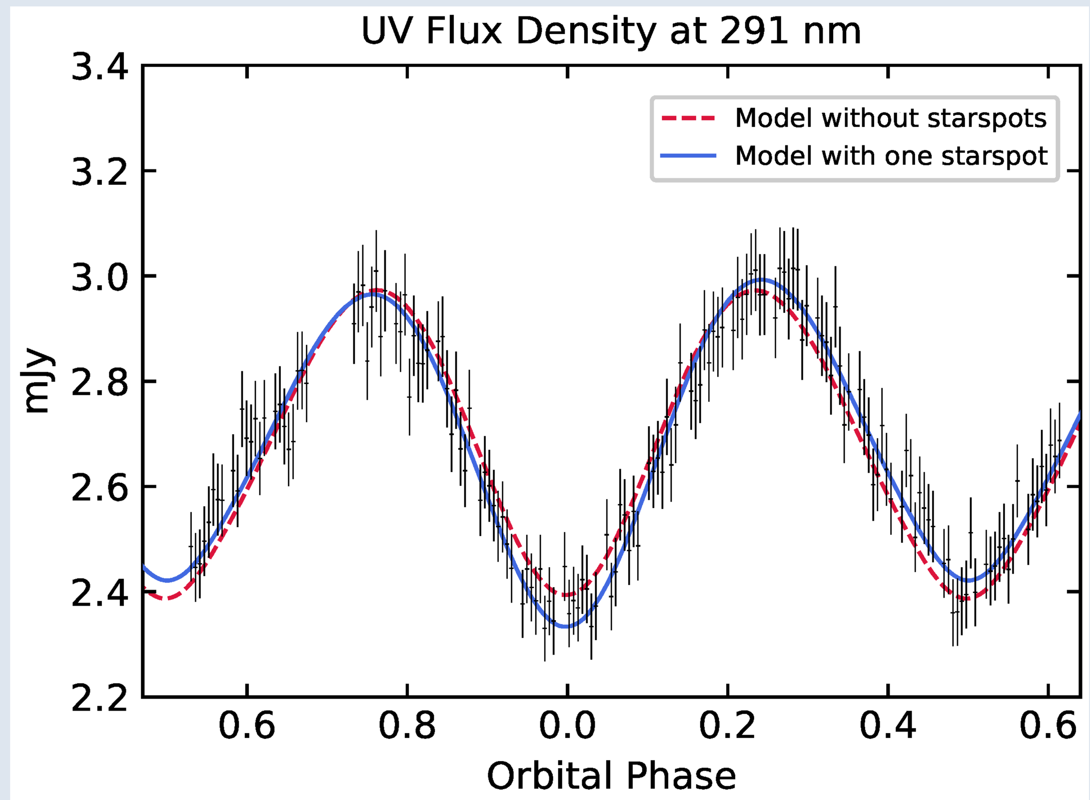
The X-ray light curve exhibits strong variability during the first half of the observation and no significant variability during the second half. A Bayesian Blocks variability analysis finds two distinct features in the light curve, a broad dip at phase 0.6–0.7 and a sudden drop at phase 0.0. The variability was predominantly caused by a larger emission measure (EM) of the hotter component in our two-temperature model, suggesting that the excess emission during the first half originated from a distinct region with a higher plasma temperature.



The rising X-ray flux at phase 0.6–0.7 and the drop at phase 0.0 was likely caused by a compact flare that moved over the limb of the primary and was then eclipsed by the secondary. From the light curve we deduced that the X-ray flare was located near the contact region between the two stars, and we constrained the size of the flare to less than 15° or 3×10^{10} cm. The non-flaring X-ray emission is not eclipsed and could originate from the polar region on the primary star or an extended corona.

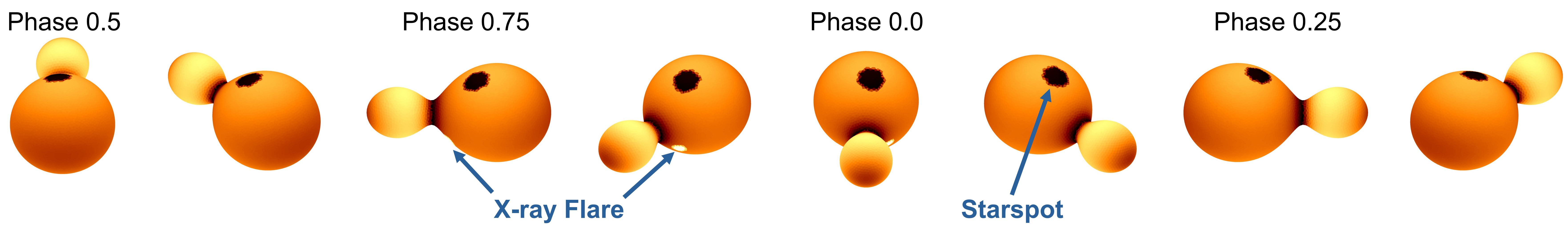
UV Light Curve

The binary was also observed with the *XMM-Newton* Optical Monitor using the UVW1 filter (wavelength 291 nm). The UV emission exhibits the same sinusoidal modulation at half the orbital period that is seen at longer wavelengths and which is due to the mutual eclipsing of the binary components. Because both component stars share a common envelope and have nearly identical temperatures, the two eclipses have almost the same depth. We simulated the UV light curve with the PHOEBE eclipsing binary modeling software which uses stellar atmosphere models to generate spectra at different orbital phases (Prša et al. 2016, ApJS, 227,29).



Although a simple model of the contact binary provides a reasonable fit to the data, we find a small difference between the depths of the two eclipses. This is likely caused by the presence of one or more starspots. We extended our model to include a single starspot and deduced that it must be located near the polar region of the primary. The observed UV flux is only 89% of that predicted by our model. This is likely due to interstellar extinction. Taking into account extinction, we find that all of the observed UV emission at 291 nm can be attributed to the photosphere and there is no evidence of significant chromospheric emission.

MJD of Superior Conjunction	57861.8544
UV Flux Scale Factor	0.89
Starspot on Primary:	
Colatitude	25°±15°
Longitude	15°±15°
Relative Temperature	0.88
Radius (fixed)	15°
χ^2 Statistics	951 (875 d.o.f.)



Conclusion

We found that the X-ray emission originates from a two-temperature plasma with the hotter component exhibiting significant variability. The source of the variable emission appears to be a compact flare near the contact region between the two stars that is being eclipsed by the secondary.

The UV emission at 291 nm predominantly originates from the photosphere and exhibits a nearly sinusoidal modulation due to the mutual eclipsing of the two stars. A small asymmetry between the two eclipses indicates the presence of a starspot near the polar region of the primary.