An *EUVE* Detection of a Low-Mass X-ray Binary? AC211 in M15

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We have observed M15 with EUVE, in an attempt to detect AC211, the well know globular cluster Low Mass X-ray Binary (LMXB). Our observations are part of an attempt to characterize the *EUVE* properties of LMXBs by looking at those towards which the extinction is extremely low (as it is for M15): these observations are impossible for the vast majority of Galactic LMXBs. *EUVE* successfully detected this cluster, at a countrate of 0.002 counts s^{-1}. In this paper we discuss the association of this source with AC211, and alternative scenarios for *EUVE* emission from M15.

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1. Introduction

Low Mass X-ray Binaries (LMXBs) are systems where a neutron star or black hole primary accretes material (via an *accretion disk*) from a low mass ($M \leq 1 M_{\odot}$) secondary. As such, they provide a unique opportunity for the study of compact objects and their interaction with their companion stars (e.g., see Bhattacharaya & van den Heuvel 1991 for a review). Although they have been studied extensively from radio to ~MeV energies, little is known of their EUV (10–100 eV) spectral characteristics. This is primarily because most LMXBs are relatively distant (>1 kpc), and lie behind >0.5 magnitudes of optical extinction, dramatically reducing any EUV flux. It is only with the launch of *EUVE* that observations can be performed which even approach the required sensitivity, and even then only for the relatively unobscured systems.

2. The LMXB in M15

There is a class of LMXBs toward which the reddening is accurately known—the globular cluster LMXBs. Of these the clusters with the lowest reddening are M15 (E_{B-V} ~0.05) and NGC 1851 (E_{B-V} ~0.02; Djorgovski 1993). These are the lowest measured towards any LMXB and hence these systems provide a unique opportunity to study the EUV characteristics of LMXBs in general. Furthermore, the low metallicity of M15 (only 0.01 Solar) implies that the effects of photoelectric absorption within this system are likely to be substantially reduced, further increasing the chances of detecting any EUV component.

The optical counterpart of the M15 LMXB, AC211, is the best studied cluster LMXB at optical wavelengths (e.g., Ilovaisky 1989). The optical light curve of AC211 shows an eclipsing modulation strongly indicative of a high inclination system: however, the X-ray light curve is only weakly modulated at the orbital period of 17.1 hrs (Auriere et al. 1993). The large degree of X-ray heating inferred from the optical colors and luminosity, coupled with the relatively modest X-ray luminosity of $\sim 5 \times 10^{36}$ ergs s^{-1} (e.g., Hertz & Grindlay 1983), implies that most of the emitted radiation from this system is unobserved. This is either because it is obscured, or because the bulk of the emission lies in a hitherto

S. Bowyer and R. F. Malina (eds.), Astrophysics in the Extreme Ultraviolet, 431–435.

unobserved spectral region. Although the former hypothesis was favored initially (e.g., Fabian, Guilbert, & Callanan 1987), it has since been shown to be untenable (see Dotani et al. 1990 for more details).

Hence we conclude that circumstantial evidence exists for an unobserved spectral component: could this be in the form of EUV emission? We obtained an *EUVE* observation of M15 in an attempt to constrain the contribution of such a component to the overall energetics of the system.

3. Observations and Data Reduction

The *EUVE* instrumentation has been described in detail by Bowyer & Malina (1991) and by Welsh et al. (1990). In brief, the *EUVE* Deep Survey and Spectrometer telescope (DSS) feeds an EUV spectrometer, which covers the wavelength range from 70–760 Å in three bands, and the Deep Survey photometer (DS). About half of the on-boresight photons are not intercepted by the dispersive elements of the spectrometer and pass through a boron coated Lexan filter (Vedder et al. 1989) to a focus on the DS detector. This telescope, filter and detector combination has significant transmission between about 65 and 170 Å, peaking at approximately 83 Å with an effective area of approximately 12 cm^2. The effective area curve is illustrated in Bowyer et al. (1994).

M15 was acquired by the *EUVE* Deep Survey and Spectrometer telescope (DSS) on UT 1994 June 6 13:55, and was observed until UT 1994 June 8 06:08.

We reduced the data corresponding to satellite night-time, which comprises about 25 minutes or so of each *EUVE* 90 minute orbit. Although the DS and SW spectrometer detectors remained switched on throughout the observation (except for episodes of very high geocoronal and particle background when count rates exceeded detector safety thresholds), the higher daytime geocoronal background can dominate the relatively faint flux from M15, and the daytime data are not useful. M15 was detected in the DS instrument only after a significant fraction of the photons from the entire observation were co-added. The average count rate in the DS was approximately 0.0017 count s^{-1}. As expected, this count rate is much too low to yield any appreciable signal in the spectrometer.

In order to produce light curves from the DS data, we first constructed photon event lists from the satellite telemetry, mapped in celestial coordinates, in the QPOE format. The QPOE event lists included sufficient sky area so as to facilitate accurate background subtraction. Episodes of high geocoronal and particle background were first filtered out, and light curves were then calculated from the photon event lists using an "aperture photometry" method for time bin sizes of 10,000 s. Shorter time bins resulted in rather noisier data. The image is illustrated in Figure 1, and the light curve is plotted in Figure 2. The light curve appears to be variable, albeit only at the 96% confidence level. There is no obvious modulation on the orbital ephemeris of AC211, but this does not rule against an origin in the LMXB because of (a) the shallow nature of the 1–10 keV modulation and (b) the low signal-to-noise of our data.

4. Discussion

4.1. *AC211 As the EUV Source*

Assuming an effective temperature of 50–100 eV (the range for which the *EUVE* DS photometer is most sensitive for the reddening discussed above), the observed *EUVE* countrate corresponds to a luminosity of $\geq 10^{35}$ ergs s^{-1} (see Callanan et al. 1995 for further details).

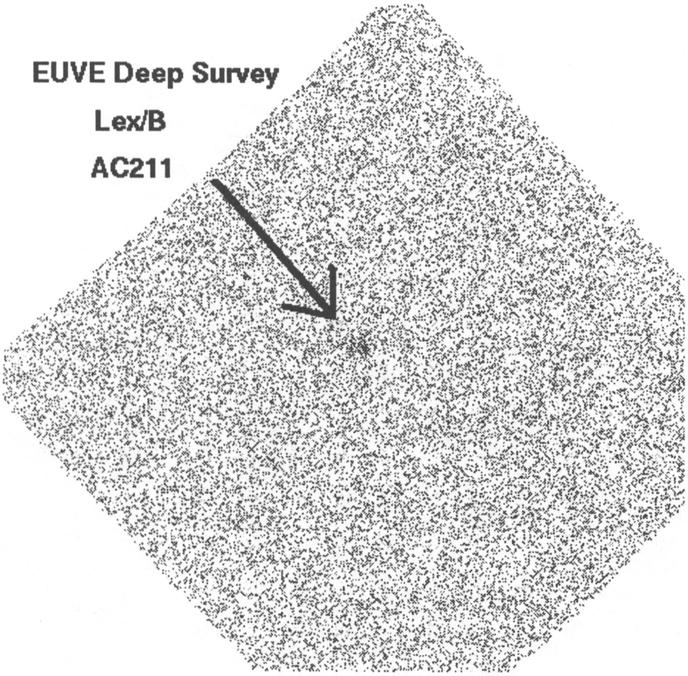

FIGURE 1.

If this flux originates from AC211, then the true EUV luminosity will be even higher because of the column intrinsic to the binary. For example, a column of $\sim 9 \times 10^{20}$ cm^{-2} (well within the range reported by Callanan et al. 1987) yields an intrinsic luminosity of $\sim 10^{38}$ ergs $^{-1}$. Hence, without a simultaneous measurement of EUV flux and X-ray column, we can only constrain the EUV flux of AC211 to be 10^{35}–10^{38} ergs s^{-1}.

EUV emission from accreting neutron stars has previously been observed from X-ray pulsars (e.g., Her X-1 and RX J0059.2-7138) and the so called "Extreme Ultra Soft" sources (Shulman et al. 1985: Hughes 1994; Hasinger 1994). The former may be explained by emission from the neutron star magnetosphere (McCray & Lamb 1976). The most plausible explanation for the latter may be steady thermonuclear burning on the surface of a white dwarf (van den Heuvel et al. 1992). However, as AC211 is a bursting neutron star (e.g., Dotani et al. 1990), neither of these explanations can be valid in this case. However, a more precise estimate of the AC211 EUV luminosity is probably required before more detailed modelling is warranted.

5. Alternative Scenarios

The central star ($L \sim 3000 L_{\odot}$) of the well known planetary nebula K 648 in M15 might be expected to be a significant EUV source. However, the effective temperature is thought to be 40,000 K (Adams et al. 1984) and as such the system is beyond the sensitivity limit of *EUVE* (given the 10.5 kpc distance to M15).

However, it is more difficult to exclude a population of optically faint planetary nebulae/post-AGB stars. For example, systems such as K1-16 (Fruscione et al. 1995)

https://doi.org/10.1017/S0252921100036344 Published online by Cambridge University Press

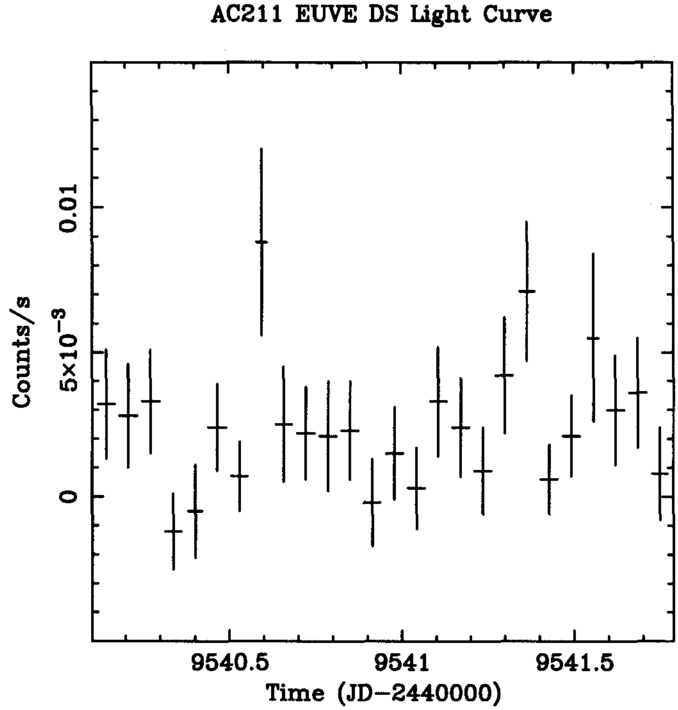

FIGURE 2.

would be detectable at the distance of M15, and could make a significant contribution to the EUV flux. However, preliminary calculations based on the current M15 mass function show that a sufficiently large number of such stars are unlikely exist in the cluster core (Callanan et al. 1995).

Conclusive evidence for the association of our EUV flux with AC211 is only likely to come if significant variability can be found in the EUV lightcurve: a longer observation is required to establish this with certainty.

6. Conclusions

We have detected EUV emission from the globular cluster M15. Although it is likely to be associated with AC211, we cannot as yet exclude the possibility that some of the emission is due to a population of post-AGB/planetary nebula stars. If the emission is indeed dominated by AC211, we can constrain the LMXB EUV luminosity to $\sim 10^{35}$–10^{38} ergs s^{-1}. It is clear that further observations of this and other low column LMXBs (i.e., that in NGC 1851) are required to establish the true origin of the M15 EUV emission, and the ubiquity of LMXB EUV emission in general.

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https://doi.org/10.1017/S0252921100036344 Published online by Cambridge University Press