THE FIRST EUV SURVEY: WHITE DWARFS AND COOL STARS

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ABSTRACT. Preliminary results from the survey carried out with the Wide Field Camera (WFC) on ROSAT are presented. 732 sources were detected, of which 230 were observable in both the S1 and S2 filters. The distribution of sources with galactic longitude, near the galactic plane, shows the greatest number in the quadrant where H I absorption is least. The identifiable sources include a high proportion of hot white dwarfs and 'normal' late-type stars. The optical follow-up programme has identified over 40 new white dwarfs and over 60 late-type stars including RS CVn systems and cataclysmic variables. Emission from some A stars detected appears to come from white dwarf companions. Individual sources of particular interest are discussed. The systematic analysis of a sample of late-type stars has begun.

1. INTRODUCTION

The characteristics of the WFC have been described by Sims et al. (1990). Briefly, it consists of a grazing incidence telescope with a set of three, nested, Wolter-Schwarzschild Type I mirrors, and a microchannel plate detector at their common focus. A filter can be selected from six available for scientific use, viz. two redundant pairs of 'survey' filters (S1a/S1b and S2a/S2b), with a 5^{o} field of view, and two pointed phase filters (P1 and P2), with a 2.5^{o} field of view. Following preliminary in-orbit checks to verify the system (Wells et al. 1990) and a short pre-survey test phase, during which 35 new EUV sources were detected (Pounds et al. 1991), the main survey began on 30 July 1990 and continued, with few interuptions, until 25 January 1991. About 96% of the sky was covered with exposures of ~ 1000 to 2000 s, in each of the S1a (65 – 140 Å) and S2a (112 – 200 Å) filter bands. The initial processing of the WFC survey data was completed within one month of the end of the survey.

2. RESULTS FROM THE SURVEY

2.1. The Number and Distribution of Sources

Pounds (1991) has presented some early results from the WFC survey. The preliminary list includes 732 sources that pass stringent acceptance criteria, 230 of

J. Bergeron (ed.), Highlights of Astronomy, Vol. 9, 241–245.

which were detected in both survey filters. As expected, most of the sources can be identified with hot white dwarfs and late-type stars. Several extragalactic sources (active galactic nuclei) and several cataclysmic variable binary systems were detected, and the Vela and Cygnus supernova remnants were mapped.

Figure 1 shows a preliminary map of the 732 sources, plotted in Galactic coordinates. The source diameter is proportional to the logarithm of the observed flux.

A polar diagram of the number of sources detected in each quadrant of galactic longitude, for latitudes $b < \pm 30^{o}$, superimposed on the contour of $N_H = 5 \times 10^{19}$ cm^{-2} from interstellar absorption (Paresce 1984), (this value corresponding to an optical depth of order one in the survey wavebands), shows the most sources in the quadrant ($180^{o} < l < 270^{o}$) where H I absorption is least.

2.2. Known Catalogue Sources

Optical counterparts to the EUV sources have been found using the major catalogues available on the Starlink STADAT system, the CDS Strasbourg SIMBAD database and the Hubble Space Telescope Guide Star Catalogue. Some 280 probable identifications have been made, including about 150 late-type stars likely to have coronae and about 42 objects such as hot white dwarfs (T > 25,000 K), central stars of planetary nebulae and subdwarfs.

About 20 sources have been identified with A stars, despite the non-detection of the bright A stars β Car (A0 III) and β Leo (A3 V) in the calibration observations. Five of these are amongst the brightest sources seen in the survey. Several pieces of evidence, including the S2/S1 count ratios, suggest that the emission may be coming from an optically unresolved white dwarf companion. (See below also). If all the A star EUV emission is shown to originate from white dwarfs this would significantly change our view of the local white dwarf population. However, since stars as early as A7 V (Altair) are known to have X-ray emission (Schmitt et al. 1985), any late A V stars should be examined carefully in view of their importance in the context of the onset of dynamo action.

2.3. The Optical Follow-up Programme

An optical follow-up programme is being carried out on sources for which the identification is ambiguous or unconvincing. This involves a team from the WFC consortium and other UK institutions, using the 2.4m Isaac Newton Telescope on La Palma and a collaboration with Buckley and colleagues at the University of Capetown, using the South African Astronomical Observatory. The identification process is based on low (~10 A) and/or intermediate dispersion (~1 A) spectroscopy of objects within the error-circle of the WFC source. Sky survey material digitised with the APM and COSMOS measuring machines at Cambridge and Edinburgh is also used.

The results of four weeks observing have been presented by Mason et al. (1991). Figure 2 shows the classes of objects identified, including the results of further optical observations in May 1991. It can be seen that white dwarfs form the largest single category, followed by 'normal' late-type stars and dMe stars. Some new RS CVn systems have also been discovered, e.g. RE0481+23.

2.3.1. *Individual Sources.* Although not a survey observation the WFC 'First light' image revealed a new bright source, RE1629+781. The details of this discovery have been reported by Cooke et al. (1991). The source is one of the seven brightest detected by the WFC. The optical properties of the candidates in the error circle

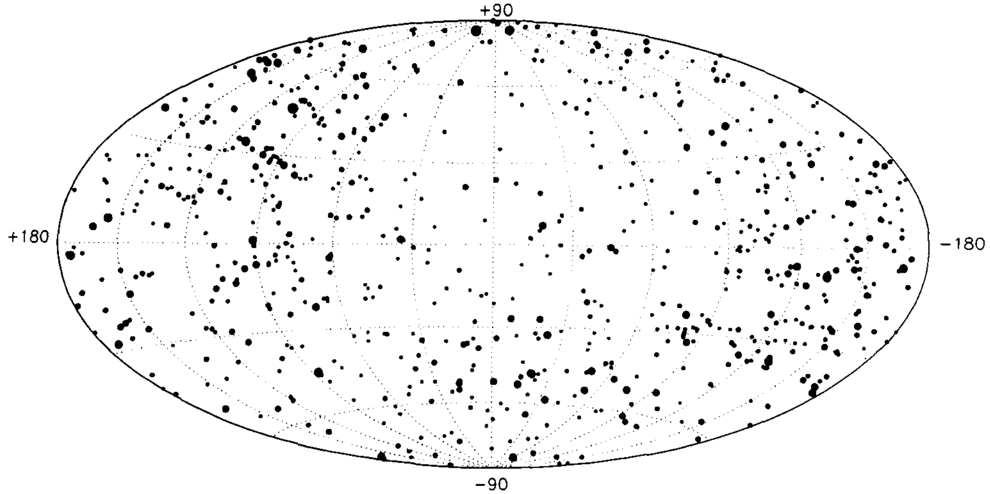

Fig. 1. The WFC map of EUV sources, in galactic coordinates. The source diameter is proportional to the logarithm of the observed flux.

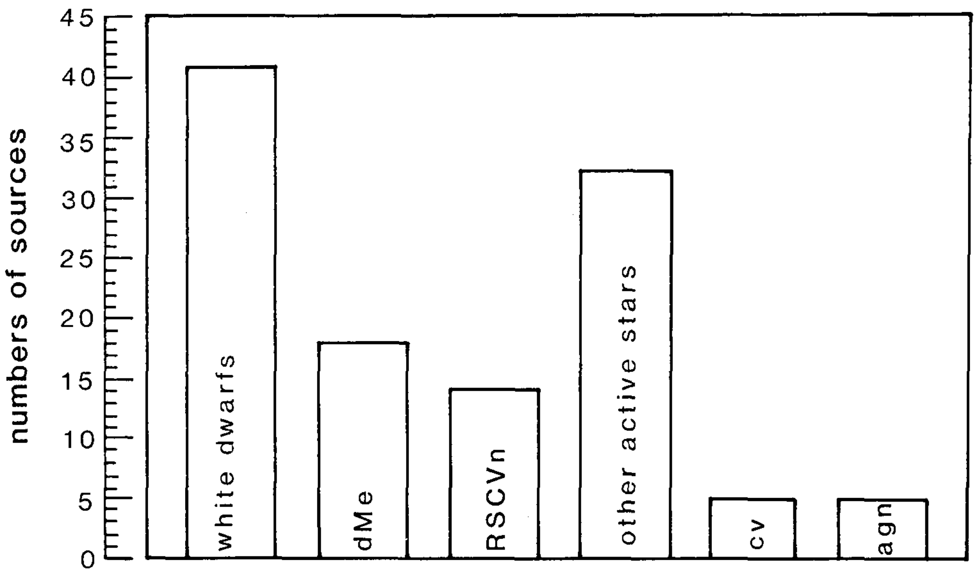

Fig. 2. A histogram of the types of objects identified in the optical follow-up programme to the WFC survey.

show that one is located close to the DA white dwarf HZ43 in a colour–magnitude plot. Optical spectroscopy with the William Herschel Telescope and the Intermediate–dispersion Spectroscopic Imaging System shows broad H absorption lines and TiO bands, charateristic of a DA white dwarf with an M dwarf companion. Narrow H α emission is present, probably formed by reprocessing of the EUV emission from the white dwarf on the surface of the M star. The optical spectrum is similar to that of Feige 24, a DA + dM1–2 binary (Leibert and Margon 1977; Margon et al. 1976). Although the apparent magnitudes of Feige 24 and RE1629+781 are similar, the S1a flux of RE1629+781 is larger, in spite of it having a lower temperature (~35,000 – 40,000 K). This suggests that the composition of the two white dwarfs is significantly different, with RE1629+781 having a much lower opacity in the EUV.

A second Feige 24 type system has been discovered during the survey. This is RE1016–05, whose optical spectrum also shows the characteristics of a white dwarf, an M2 dwarf, and again a narrow emission feature in H α.

The system RE0751+14 is among the most interesting cataclysmic variables discovered so far in the WFC survey. The optical spectrum shows a blue continuum and strong emission lines of H and He. Fast photometry, carried out in the K band on the UKIRT telescope, shows a double peaked modulation of about 4% with a period of 12.8 min. RE0751+14 appears to be an intermediate polar (IP) magnetic cataclysmic variable, with a spin period of 12.8 min. The orbital period of the system is thought to be about 6 hours. Since EX Hya is the only known IP to be detected in the WFC survey the low column density in the direction of RE0751+14 may be a factor in its detection.

One of the A stars detected in the survey with the WFC and the Position Sensitive Proportional Counter (PSPC) is β Crt (A2 IV) (Fleming et al. 1991). Very few single A stars have been detected by previous X–ray instruments (Golub et al. 1983) and the new observations would imply a very high luminosity if interpreted in terms of a stellar corona. Instead, Fleming et al. (1991) suggest that the emission originates from an optically unresolved white dwarf companion. They use early radial velocity measurements (Campbell 1928) and the PSPC pulse height distribution, which is similar to those of the known DA white dwarfs GD 50 and PG 1658+441, to support this conclusion. They use white dwarf atmosphere models to show that β Crt B is similar to Sirius B.

2.4. A Sample of Late–Type Stars

Jeffries et al. (1991) have made an initial analysis of a sample of 102 late–type stars with well known values of B–V, including dwarfs, sub–giants and giants. Many of the stars appear in the Strassmeier et al. (1988) catalogue of chromospherically active binary stars. Ca II H and K line fluxes, Einstein X–ray fluxes and IUE C IV fluxes are available for a large proportion. Stellar surface fluxes in the WFC bands have been found for stars for which N_H is estimated to be $< 2 \times 10^{19}$ cm^{-2}. The S1/S2 flux ratio alone does not allow a sensitive determination of temperature above 10^6 K and a fixed value of 5×10^6 K was used. The results are similar to those obtained by Vilhu and Walter (1987) in their studies of X–ray emission from cool stars. At a given B–V there is a spread of surface fluxes, limited by the stellar rotation rate and the instrumental sensitivity. The WFC flux quoted over the (rather wide) band of 0.05 – 0.3 keV, correlates well with the Einstein X–ray flux (0.15 – 0.4 keV). The correlations between C IV and X–ray fluxes found previously (e.g. Montesinos and Jordan 1988) are essentially correlations between emission measures in the transition region and the corona because the fraction of the power emitted in the Einstein IPC band has a dependence on T_e that cancels that of the total power loss. The temperature, power loss and fraction emitted in the WFC band must be determined before meaningful correlations with C IV and other fluxes can be made.

3. CONCLUSIONS

The analysis of the EUV survey is at an early stage. However it is already clear that it will substantially add to our knowledge and understanding of the local interstellar medium, the properties and statistics of local white dwarfs, the coronae around a wide variety of late type stars and of the plasma emitting in binary systems.

ACKNOWLEDGEMENTS

The success of the EUV sky survey, the primary aim of the UK Wide Field Camera project, is due to the combined skills and efforts of a large number of people, both in producing the WFC instrument and operating it successfully in orbit. C.J. appreciated the opportunity to present the results, and is grateful to all those who provided material. The WFC project was supported by the SERC.

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