CAPELLA: STRUCTURE AND ABUNDANCES

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This grant covers the analysis of ASCA spectra of the cool star binary system Capella. This project, as proposed, also involves the analysis of simultaneous EUVE data. We have obtained and reduced both data sets (ASCA: 1996 Mar 3-4; EUVE: 1996 Mar 3-7) and applied standard analyses. The need for new model calculations was made clear by the inability to obtain a good fit to the ASCA data. Liedahl & Brickhouse (1997) have performed these calculations. We have applied them to the ASCA spectrum, and found signficantly improved fits. The final paper is now in preparation. The results thus far are:

EUVE analysis. Emission line fluxes with error estimates have been extracted from the EUVE spectrum. An emission measure distribution (EMD) is constructed from the line intensities of highly ionized Fe over the temperature range $10^{6} to 10^{7.2}$ K. The absolute scale of the emission measure depends on the Fe/H abundance, which can be estimated quite roughly from the EUV line-to-continuum ratio. The summed spectra from previous observations allow a more precise determination, which we use.

ASCA analysis. The ASCA SIS and GIS spectra have been extracted and reduced in the usual way. Because this observation was also used to check the soft X-ray calibration of simultaneous XTE data (Ayres, PI), the processing received more than the usual degree of oversight from the ASCA team at Goddard. Initial spectral analysis with two-temperature, variable abundance XSPEC models failed to produce any acceptable fits to the data, as had been the case with the Performace Verification phase ASCA spectrum of Capella.

Application of EUVE model to ASCA analysis. As stated in the proposal, the EMD derived from EUVE gives the shape of the continuous distribution up to the temperature of the limiting ion (Fe XXIV). The EUVE-derived EMD model was applied directly to the ASCA spectrum. With minor normalization adjustment, the high energy component of the spectrum was well fit by the EUVE-derived model, and no additional higher temperature components were needed. Also, the X-ray spectral peak intensity, corresponding to Fe XVIII and XIX line emission, agreed well with the line fluxes of the EUV Fe XVIII and XIX lines. However, there was a noticeable problem

either around 1.0 keV (too much flux predicted) or 1.2 KeV ("missing flux").

Uncertainty Analysis. An uncertainty analysis was performed on the combined data sets. Raymond-Smith and MEKAL models were tested, but most of the analysis was done with MEKAL, which we considered to be the most updated model available in XSPEC, albeit with some known limitations. Consideration was given to instrument calibration issues, atomic physics uncertainties, and the possibility that the source did not follow the simplifying assumptions, such as ionization equilibrium and negligible optical depth. This required the construction of table models to be used in XSPEC in order to separate the model components, by element and by ionization state. The SPEX line list was used to generate these tables. We developed a new model for Ni ionization balance in order to bring the ionization balance into consistency with the Fe ionization balance in MEKAL. No simple explanations within the context of existing models appeared to resolve the problem with the ASCA data set. These results were reported in a poster at the AAS meeting (Winston-Salem 1997).

Benchmarks for the MEKAL model. Although we did not have the MEKAL model as a line list, the SPEX table was compared with solar observations in order to ascertain problems with emission line ratios that might have been previously noted, or to evaluate the possibility of missing lines. Indeed the solar spectra included flux around 1.2 keV from lines not calculated with SPEX (or MEKAL or Raymond-Smith).

New Atomic Physics. New calculations have been performed with the HULLAC code at Lawrence Livermore by Duane Liedahl, who independently realized that significant flux was missing in the MEKAL code. The new calculations predict line intensities for lines originating on principal quantum numbers from n=6 to n=10.

Current Status. The new calculations are being refined and written up to be submitted the Ap. J by Liedahl & Brickhouse. We have added these new lines to the Capella ASCA models and found significantly improved fits. Calibration adjustments are still required, but they are within reasonable limits. The results were reported in a poster at the AAS HEAD meeting (Estes Park 1997) and are in preparation now for submission to the Ap. J. by Brickhouse, Dupree, Edgar, Liedahl, Drake, White, & Singh. The abundances of Mg, Si, and S are now determined with good reliability and are close to their [solar] photospheric values. The abundance of Ne appears

lower than the cosmic abundance, but since this is not a well determined quantity, the astrophysical significance is unclear.

Implications. These results have widespread implications, e.g. flux around 1.2 keV appears missing in M87 (Hwang et al. 1997), PKS 1404 (Fabian et al. 1997) and MSH 11-62 (Harris, Hughes, & Slane 1997) as well as other stellar targets.

Publications

The Effect of Missing Lines on Models of the ASCA Spectra of Capella, N. S. Brickhouse, A. K. Dupree, R. J. Edgar, S. A. Drake, N. E. White, D. A. Liedahl, & K. P. Singh 1997, *A.A.S. HEAD Meeting*, poster

EUVE Observations of the W UMa Contact Binary 44i Boo: Coronal Structure and Variability, N. S. Brickhouse & A. K. Dupree 1997, *Ap. J.*, submitted

High Minor Ion Outflow Speeds in the Inner Corona and Observed Ion Charge States in Interplanetary Space, R. Esser, R. J. Edgar, & N. S. Brickhouse 1997, *Ap. J.*, submitted

A SAX/LECS X-ray Observation of the Active Binary Capella, F. Favata, R. Mewe, N. S. Brickhouse, R. Pallavicini, & Dupree, A. K. 1997, *A&A*, **324**, L37

Simultaneous ASCA and EUVE Observations of Capella, N. S. Brickhouse, A. K. Dupree, R. J. Edgar, S. A. Drake, N. E. White, D. A. Liedahl, & K. P. Singh 1997, *B.A.A.S.*, **29**, 808

Spectroscopic Preparation for AXAF and XMM, N. S. Brickhouse 1997, *Proceedings of the Tenth Cool Stars Workshop*, submitted

EUVE Observations of 44i Boo: Evidence for Localized Emission, N. S. Brickhouse, & A. K. Dupree 1997, *Proceedings of the Tenth Cool Stars Workshop*, submitted

High Resolution X-ray Spectroscopy with AXAF Transmission Gratings, John Houck & Nancy Brickhouse, *AXAF Newsletter*, **Issue 4**, in press

Atomic Processes in Astrophysics, J. C. Raymond & N. S. Brickhouse 1996, *Astrophysics and Space Science*, **237**, 321