ULTRAVIOLET OBSERVATIONS OF STELLAR CORONAE: EARLY RESULTS FROM HST

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1. Observing stellar coronae in the ultraviolet

Although coronae for stars other than the Sun have previously been detected only in the X-ray and radio portions of the spectrum, the HST and future spacecraft sensitive to ultraviolet (UV) and extreme ultraviolet (EUV) light will have the spectral resolution to study the dynamics and spectroscopic diagnostics of hot coronal plasmas. In the UV region accessible to HST, forbidden lines of FeXII at 1242 and 1349Å, of FeXXI at 1354Å, and other species seen in solar flares, are predicted to be present in the spectra of active stars. Upcoming observations with the Goddard High Resolution Spectrograph (GHRS) by S. Maran will search for these lines in the dM2e star AU Mic and other stars.

Stellar coronal studies with HST can, in principle, answer a number of questions that X-ray and radio studies cannot presently address. Among these questions are: (1) the nature of the systematic and random mass motions of hot plasma in both quiet and flaring stars, (2) the importance of mass motions in the energy balance of the corona, (3) the existence of coronal plasma at 10^5K and cooler temperatures in cool giants and other stars, (4) coronal densities from density-sensitive lines formed in the transition region, and (5) the location and size of active regions from Doppler imaging in transition regions lines.

I report here on observations of the spectroscopic binary system Capella (G0 III + G9 III) and the inactive K5 III star γ Draconis, which is a member of the class of hybrid-chromosphere stars (Hartmann, Dupree, and Raymond 1980) characterized by high-velocity blue-shifted features due to a cool wind and faint emission lines formed at temperatures up to 150,000K. The Capella UV emission line spectrum is dominated by the more rapidly rotating G0 III star in the system (Ayres and Linsky 1980).

2. Low resolution GHRS spectra of Capella and γ Draconis

We obtained low resolution spectra with the G140L grating of Capella on 15 April 1991 and of γ Dra on 6 April 1991. These spectra obtained through the Large Science Aperture (LSA) have a resolution of about 1,000 and high signal/noise. The spectrum of Capella is dominated by bright emissions, including the resonance lines of C II, Si IV, C IV, and N V formed at temperatures of 20,000–150,000K.

The low dispersion spectrum of γ Dra shows a very different appearance as both Lyman-α and the O I 1304 Å multiplet dominate over the high-temperature lines. The

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J. Bergeron (ed.), Highlights of Astronomy, Vol. 9, 657–658.

other prominent emission lines are from neutral species and the fourth positive bands of CO, all formed at temperatures below 8,000K. The high temperature resonance lines of C II to N V are all present but very weak.

The surface fluxes of the high-temperature lines for the G0 III component of Capella lie about a factor of 3 below the "saturated" limit, the maximum radiative emission from a star completely covered with "active regions" (Vilhu 1987). On the other hand, the surface fluxes for the high temperatures lines for γ Dra lie nearly a factor of 10,000 below the "saturated" limit. They are, in fact, the smallest surface fluxes ever measured on a cool star. A plausible heating mechanism is a stochastic distribution of acoustic wave periods which leads to the occasional coalescence of individual shocks into very strong shocks that produce high-temperature plasma (cf. Cuntz and Luttermoser 1990).

3. Moderate and high resolution GHRS spectra of Capella

We obtained moderate dispersion spectra of Capella through the LSA with a resolution of 10,000 or 30 km/s. The C IV resonance line profiles appear to be smooth Gaussians with no identifiable structure or splitting. The FWHM of the C IV 1548 Å line is 217 km/s, while for the 1550 Å line it is 186 km/s. These widths are much larger than the predicted thermal width, $\Delta\lambda_D$ = 14.4 km/s, and the instrumental width of 30 km/s, but are consistent with IUE observations at quadrature. The line flux ratio $f_{1548}/f_{1550} = 1.77$ is significantly smaller than the ratio of gf values which is 2.0. These data indicate that both turbulence and opacity broaden these lines, and that the 1548Å line is optically thick.

These spectra contain profiles of many intersystem lines that are important diagnostics of electron densities in the transition region. We were able to observe the Si III] 1892Å, C III] 1909Å, O III] 1660, 1660 Å, and the O IV] and S IV] intersystem lines near 1400Å. The S IV] have never been detected previously in a stellar spectrum, except for the Sun, while the other intersystem lines have been detected by IUE in a few stars but with poor signal/noise. The narrower width of the Si III] line compared to the C IV 1550 Å line is consistent with the Si III] line being turbulently broadened but with no opacity broadening, as is expected for intersystem lines that should be optically thin.

We discuss finally our beautiful echelle spectra of Capella obtained through the SSA, which have a spectral resolution (Wahlgren et al. 1991) of 87,000, corresponding to 3.4 km/s. Our objective was to determine the D/H ratio and the other properties of the interstellar medium along the 13 pc line of sight towards Capella.

The spectrum of the Mg II h (2803 Å) and k (2796 Å) resonance lines obtained with the Ech-B grating show the narrow interstellar absorption lines, which are spectrally resolved and do not go to zero flux after correction for scattered light. The analysis of the line profiles provides information on both the line opacity and broadening. One can also see the self-reversal of the emission line from the G9 III star, and to the left one can see a portion of the self-reversal of the emission line from the G0 III star.

This work is supported by NASA Grant S-56500-D to the N.I.S.T.

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