CORONAL AND CHROMOSPHERIC STRUCTURE IN AR LAC. II. PHYSICAL CHARACTERISTICS OF THE ATMOSPHERE

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In this series of papers we report on an effort to deduce the morphology of the chromosphere and corona of AR Lacertae, an eclipsing RS CVn system (Hall 1976), via observations at UV, radio, and X-ray wavelengths during a complete orbital cycle. In another paper (Gibson, Walter and Basri 1982, Paper I), we present the observational data and general constraints on the morphology of the coronae. The full study will be published elsewhere (Walter, Gibson, and Basri 1982).

In modeling the corona of AR Lac, we have tried to keep the model simple, yet realistic. We have drawn upon solar analogy except that, in light of the much larger observed coronal emission measures, we model the corona as a volume of uniform volume emissivity rather than as individual loops. Our model is symmetric about the equator, and confines the emission to within a band in latitude.

Because of the rapid X-ray egress from primary minimum the G star corona must be small, with a slab height of $\lesssim 0.02\ R_*$. Conversely, the corona about the K star must be extended. Both must be asymmetric in longitude, and the extended component of the K star corona must be highly confined in latitude. There is also a small, poorly constrained coronal component ($R_c \sim 0.01\ R_*$) on the K star. Figure 1 shows the projected X-ray surface brightness contours as observed for the two stars.

From the observed emission measure N_e^2V, the coronal temperatures (Paper I), and the emitting volume V inferred from the model, we can compute mean densities N_e and pressures $P = 2N_ekT$; these are given in Table 1 and are not model dependent. The derived pressure scale heights are much larger than the observed extent of the corona, implying the necessity of active confinement of the gas. The deduced pressures and densities are large, but are comparable to that of a hypothetical Sun covered with small flares (Vaiana and Rosner 1978). Transition region pressures appear to be significantly lower.

The simultaneous Einstein MPC data strongly suggest that during egress from primary eclipse we observed either a small flare somewhere in the system or the emergence from eclipse of a flaring region. If the latter, we can compute an upper limit to the size of the region ($<2 \times 10^{10}$ cm), and a lower limit of $\sim 10^{11}$ cm^{-3} on the particle density. At this density the plasma frequency is ~18 GHz, which may explain the lack of a radio flare.

The asymmetries in the X-ray and UV light curves require that the coronae be highly asymmetric. Figure 2 is a sketch to scale of the

P. B. Byrne and M. Rodonò (eds.), Activity in Red-Dwarf Stars, 445–446.

system at this epoch. The leading (spotted) hemisphere of the G star contributes most of the X-ray and UV luminosity. The inner (substellar) trailing hemisphere of the K star is bright in the UV, while the inner leading quadrant is brightest in X-ray. We infer surface flux differences of more than a factor of three in the chromosphere and suggest that chromospheric models based upon homogeneous atmospheres may be unacceptable for highly active stars.

Table 1. AR Lac Coronal Parameters

Component	G	$K_{extended}$	K_{inner}	Flaring Sun
Coronal radius (R_*)	1.0-1.02	1.5-2.0	1.0-1.01	---
$\overline{Ne}_{corona}$ (cm^{-3})	5.9×10^{10}	2.9×10^{9}	7.1×10^{10}	5×10^{10}
$\overline{P}_{corona}$ (dynes cm^{-2})	96	24	67	140
$\overline{Ne}_{Tr}$ (cm^{-3})	$>2\times10^{11}$	---	10^{11}	
P_{Tr} (dynes cm^{-2})	>3	---	1.7	

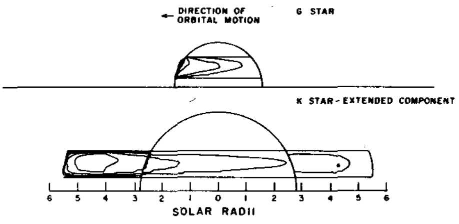

Figure 1. Contour plot of the projected X-ray surface flux at Earth. The contour levels are 0, 0.25, 0.5, 1.0, 2.0, 4.0, and 8.0×1.4E-33 ergs cm^{-2} s^{-1} for the G star, and 0, 0.5, 1.0, 2.0, 4.0×1.1E-33 ergs cm^{-2} s^{-1} for the K star.

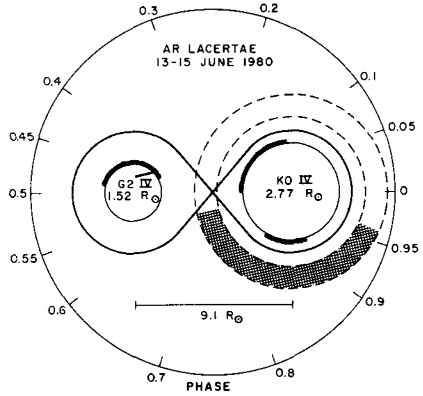

Figure 2. The state of the coronae of AR Lac. The dark highlighting on the stellar surface indicates bright coronal and chromospheric emission. The cross-hatched region indicates the extended component of the K star's corona. Orbital phases are indicated.

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https://doi.org/10.1017/S0252921100096469 Published online by Cambridge University Press