THE EVOLUTIONARY STATE OF ZETA AURIGAE

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Ultraviolet studies, originally undertaken to ascertain the state of the atmosphere of the K-supergiant component of the zeta Aurigae system, have been sidetracked by the discovery of significant accretion effects. An analysis of the phase dependence of the profiles of resonance lines in Mg II and C IV has led to a qualitative model of the wind flow from the K star. At the position of the B star, the flow velocity is about 100 km/sec and the density is 3×10^{-6} cm^{-3}, leading to a mass loss rate of 2×10^{-8} solar masses per year. This wind interacts with the B star in a shock, which will be described, leading to accretion on the B star at a rate of 4×10^{-10} solar masses per year.

INTRODUCTION

Zeta Aurigae--the prototype for a group of eclipsing binary systems--consists of a K-type supergiant star ($R = 200\ R_\odot$, $M = 8.3\ M_\odot$) and a smaller, B-type companion ($R = 4\ R_\odot$, $M = 5.6\ M_\odot$). The system is interesting because, during partial eclipse phases, the light of the hot companion passes through the extended atmosphere of the supergiant, (see Wilson, 1960; Wright, 1970). The resulting atmospheric eclipse permits us to probe the stratification of the atmospheric layers of the K supergiant.

Spectra of zeta Aurigae have been obtained with the International Ultraviolet Explorer before, during and after the 1979 - 1980 eclipse. The high dispersion spectra have been obtained in both the short (1150 to 1950 A) and the long (1900 to 3200 A) wavelength regions. Preliminary descriptions of the spectra have been published by Chapman (1980, 1981a). More detailed discussions of the initial analysis of the spectra are given by Chapman (1981b) and Stencel and Chapman (1981).

NATURE OF THE WIND NEAR THE B STAR

The resonance doublet of Mg II is the only pair of lines in the zeta

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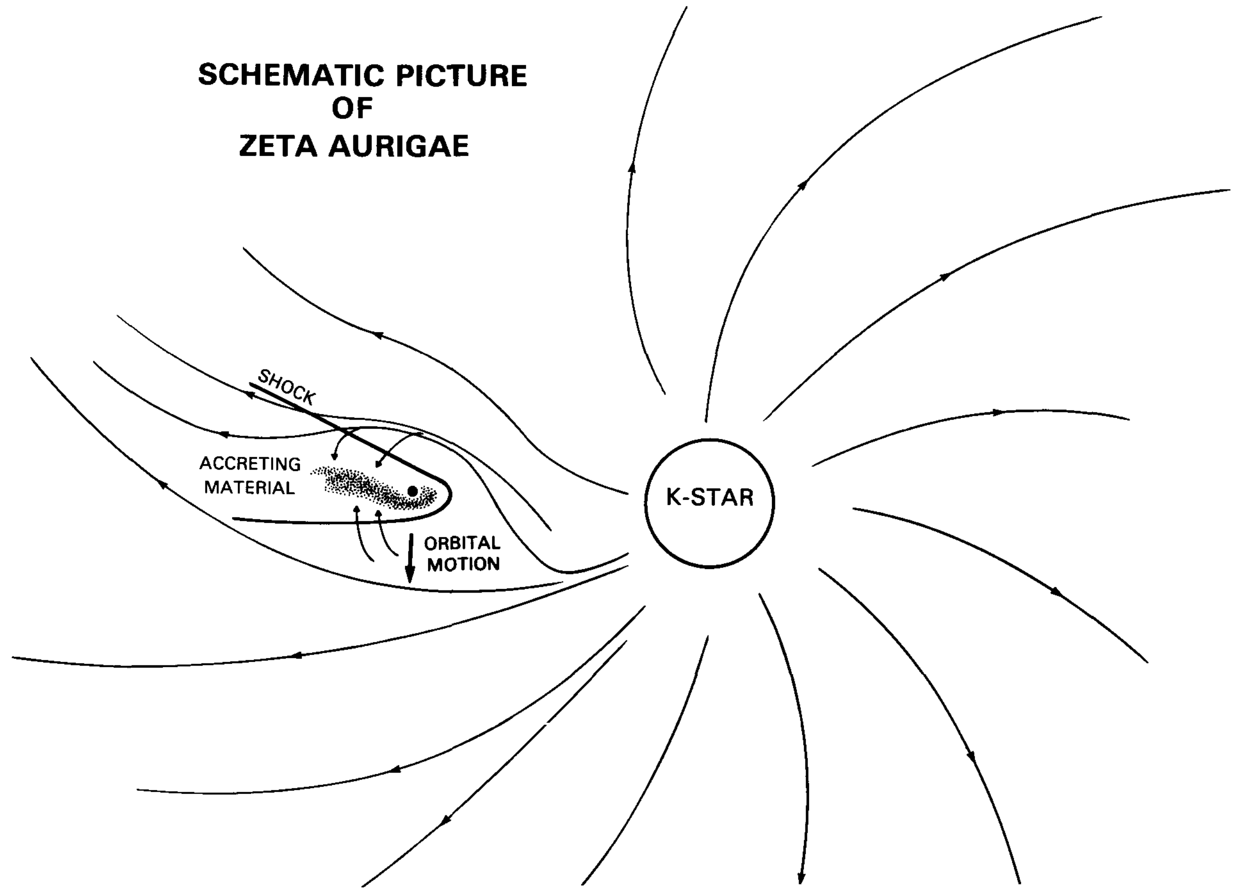

Figure 1. A schematic model of the zeta Aurigae system. The C IV absorption occurs in the accreting material, (dotted).

Aurigae spectra to show P Cygni profiles. We conclude from our analysis (Chapman, 1981b) that the lines originate entirely in the circumstellar material. Fitting Theoretical P Cygni profiles (Castor and Lamers, 1979) to the observed profiles leads us to conclude that the wind speed is approximately 100 km/sec and the matter density at the B star is about 3×10^{-6} cm^{-3}. The latter number was derived assuming that the wind plasma is not accelerated after it leaves the immediate vicinity of the K star.

The profiles of the C IV resonance lines are a strong function of orbital phase. Near primary eclipse, before atmospheric effects become significant, the lines are relatively weak, with a possible double profile. After primary eclipse, the profiles become significantly broader. Their shape indicates the presence of large amounts of turbulent material. This type of profile has persisted through observations made at and somewhat after secondary eclipse.

THE MODEL

The model of the zeta Aurigae system derived from the observations is described in detail by Chapman (1981b) and Stencel and Chapman (1981). The basic features of the model are summarized in Figure 1. The wind from the K star flows past the B star at roughly Mach 8.5, giving rise to a bow shock. Material passing through the shock is heated to high temperatures (250,000 K) as its kinetic energy is converted to internal energy. The material then flows into a dense, slowly moving column which accretes onto the B star. Using the Bondi and Hoyle (1944) accretion model, we find that the B star accretes 4×10^{-10} solar masses per year, or roughly 0.5 gm per cm^2 of surface each year. According to models calculated by Kurusz (1979), the mass per unit area above optical depth 2.5 in a B-star atmosphere is roughly 5.5 gm/cm^2. Thus the B star accretes a new photosphere every decade, and the material will probably remain there, since B stars have radiatively dominated photospheres. The B-star atmosphere is almost certainly composed primarily of material processed within the K star. The so-called dredge-up phases of red giant evolution (Becker and Iben, 1979), will affect the abundances in the surface layers of the K star and therefore in the wind and in the B-star atmosphere. The isotopes ^{4}He and ^{14}N should be enhanced while ^{1}H, ^{12}C and ^{16}O should be depleted. A careful study of abundances using the ultraviolet spectrum is in order.

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