THE MAGNETIC Be STAR SIGMA ORIONIS E

C. T. Bolton
David Dunlap Observatory, Richmond Hill, Ontario L4C 4Y6

A. W. Fullerton
David Dunlap Observatory, Richmond Hill, Ontario L4C 4Y6

D. Bohlender
Department of Astronomy, University of Western Ontario
London, Ontario N6A 5B9

J. D. Landstreet
Department of Astronomy, University of Western Ontario
London, Ontario N6A 5B9

D. R. Gies
Astronomy Department, University of Texas, Austin, Texas
78712

Over the past two years, we have obtained high resolution high signal/noise (S/N) spectra of the magnetic Be star σ Ori E at the Canada-France-Hawaii Telescope and McDonald Observatory. These spectra, which cover the spectral regions 399-417.5 and 440-458.5 nm and the Hα line and have typical S/N>200 and spectral resolution ≃0.02 nm, were obtained at a variety of rotational phases in order to study the magnetic field structure, the distribution of elements in the photosphere, and the effects of the magnetic field on the emission envelope. Our analysis of these spectra confirms, refines and extends the results obtained by Landstreet & Borra (1978), Groote & Hunger (1982 and references therein), and Nakajima (1985).

The Hα emission is usually double-peaked, but it undergoes remarkable variations with the 1.19081 d rotational period of the star, which show that the emitting gas is localized into two regions which co-rotate with the star. Both regions pass in front of the disk of the star, and these passages coincide with the complete disappearance of the Hα emission, the appearance of shell absorptions in the higher Balmer lines, and deep minima in the light curve. The depths of the photometric minima are correlated with the strength of the emission from the region projected onto the stellar disk and the depth of the shell absorptions at the time of the minimum, which indicates that most of the light variations are produced by the effects of the circumstellar material. The photometric minima coincide with the magnetic nulls, which indicates that the emission regions lie above the intersections of the magnetic and rotational equator, since the projected rotation velocity (vsini=162±2 km s^{-1}) and rotation period indicate that i≃90°. Comparison of our profiles with published profiles from 1974, 1976 and 1979 suggests that the emission strength and variations have not changed over more than 3400 cycles.

The maximum width of the Balmer shell lines (≃0.4 nm) and the widths of

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the deep photometric minima in the light curve indicate that the emission regions subtend 18°-40° at the center of the star. When the emission regions are seen projected on the sky, the emission has a sharp inner boundary displaced about 285 km s^{-1} from the velocity of the star, and the primary emission region extends to about 1030 km s^{-1} (930 km s^{-1} for the secondary region). Thus the emission extends from 1.76 R_* to about 6.36 (or 5.74) R_*. The peak of the primary (secondary) emission occurs at 3.3 (3.6) R_*. If the magnetic energy density equals the mass energy density at this point, the electron density derived from the number of the last visible Balmer shell line corresponds to the density at this point, and the magnetic field is dipolar, then the surface magnetic field is about 1.5 T, which is in good agreement with the lower limit (1 T) derived from the magnetic field measures. The same assumptions and the unequal spacing of the photometric minima imply that $74° < i < 90°$ and $\beta \lesssim 53°$

Critics of the nonradial pulsation (NRP) model for the line profile and light variations commonly observed in Be stars frequently suggest rotating spoke and spotted star models as alternative explanations (Harmanec 1986). Since the two emission clouds around σ Ori E can fairly be described as "spokes", and it also has spectrum and light variations (after the effects of the circumstellar matter are taken into account) like those of spotted (Ap) stars, it can serve as a prototype for both models, and it is instructive to compare its line profile variations with those seen in the classical Be stars. The spokes produce striking effects in the Balmer lines of σ Ori E, but have no effect on the He I or metallic lines, where the variations are usually observed in Be stars. The profile variations of the weak He I lines superficially resemble those expected for a low order NRP, but they are 180° out of phase with those of the strong lines, which is not predicted by the NRP model. Furthermore, these profile variations are associated with equivalent width variations, which have not been reported in the Be stars. σ Ori E's metallic line profile variations are dramatically different from those of the He I lines because of the effects of Zeeman broadening and the rotating magnetic field of the star, while the He I and metallic lines of Be stars show similar profile variations. It would be useful to carefully search for the effects seen in σ Ori E in a small sample of Be stars, but the available observations suggest that neither the rotating spoke nor spotted star models are promising explanations for the absorption line profile variations seen in classical Be stars.

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