INTRODUCTORY REMARKS ON THE SYMBIOTIC STAR AG DRACONIS

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AG Draconis contains a relatively early cool component. Quoted spectral types range from dG7 (Wilson 1943) to K3III (Boyarchuck 1969). Most recently Smith and Bopp (1981) adopt G7IIIe. The optical spectrum shows in emission the permitted lines of hydrogen and helium, both neutral and singly ionized. At various times the spectrum of the late type component has been heavily veiled by a blue continuum and numerous lines of various stages of ionization of iron have been seen, including the 6830 A feature which Allen (1980) attributes to Fe VI. On the other hand, on a KPNO echelle spectrum taken by one of the current authors (CMA) in 1977 August, the late giant spectrum was very sharp and no iron or forbidden lines were present. The lack of the forbidden lines identifies AG Dra as a high density case and thus it conforms to the spectral type-density correlation found by Allen (1980).

The Hα profile of AG Dra has a shape which is typical of many of the symbiotic stars. The strong, sharp central peak is bordered by wings of unequal strength. The blue wing of the emission is decidedly stronger than the red wing, a situation commonly referred to as a "blue assymetry". Occasionally, as shown in figure 1, the blue wing developes a distinct shoulder and perhaps even a reversal or separate blue shifted component. Similar phenomena have been reported by Smith and Bopp (1981). They show that the blue component is most pronounced at photometric minimum and suggest that it comes from a wind off the hot component which at that time is less dominated by the redward component which originates around the cool component. Our spectra in which the continuum is well detected and which are linear and unsaturated over their entire intensity range, show that the red peak remains nearly constant relative to the continuum while a distinct absorption cuts into the blue wing.

Anderson, Cassinelli and Sanders (1981, and, with Oliversen, elsewhere in this conference) have reported the detection of AG Dra by the HEAO 2 Imaging Proportional Counter. AG Dra is a remarkably strong source of soft X-rays.

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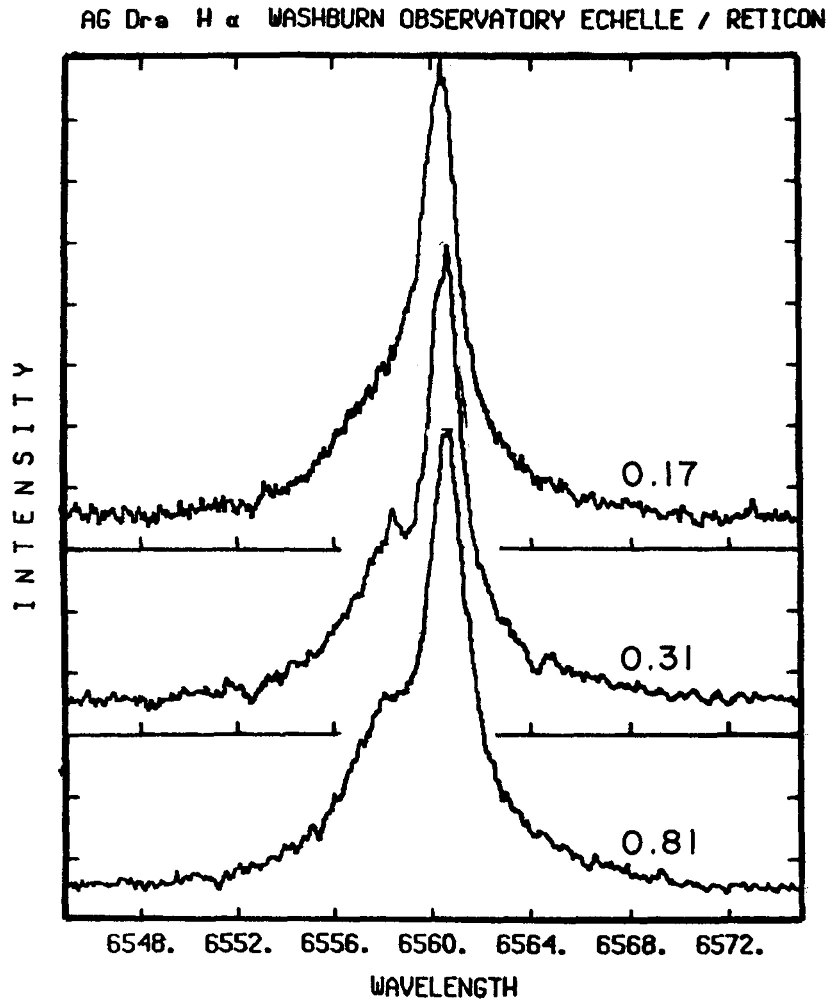

Figure 1. The H-alpha profile of AG Dra at three different phases. Photometric maximum defines phase zero. A shoulder or reversal on the blue wing appears from phase .3 to .8, i.e. during times of depressed U-brightness.

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Meinunger (1979) has shown that AG Dra exhibits variations in the U-band of about one magnitude with a period of 554 days. Variations in the B- and V- bands are also present but their amplitudes are much smaller and there are no deep minima obviously correlated with the deep and unmistakeable U-minima. On the other hand, the most recent maximum , which was an unusually high one, shows up as an obvious outburst in the visual data of the AAVSO. Meinunger's data have been considerably augmented by Kaler (private communication). In figure 2 we show the combination of these two data sets, phased according to the Meinunger ephemeris. Although there is considerable scatter, it is clear from the figure that there is an underlying consistency to the light curve which would not be suspected in Meinunger's plot. The light curve is characterized by somewhat rounded maxima, sharp minima and a rise to maximum which is slightly faster than the decline to minimum.

If one ignores the slight asymmetry in the light curve, the shape of the curve is similar to that of a close, eclipsing binary. However the long period and the relatively small size of the cool component makes such a geometry highly unlikely. If an eclipse is to produce a continuous variation, the size the eclipsed object must be of the same order of size as the orbit. Clearly such a component can not be stellar or it would dominate the spectrum of the entire system. An extended disk might be such a component.

An alternate model for AG Draconis is a star with active regions of enhanced surface brightness. Rotation of the star produces the modulation in the U-magintude. In order to produce continuous variations the active region must cover a substantial fraction of the stellar surface. The erratic nature of the light curve would occur if the average lifetime of an active region or part thereof is less than or comparable to the rotational period of the star. Models with differing spot characteristics were calculated by following a generalized version of the method of Bopp and Evans (1973). A region symmetric in latitude about the equator and covering a large extent in longitude (about 220 deg) reproduces the rounded shape of the U light curve. A U amplitude of about .9 magnitude was produced with a region having a brightness enhancement of 1.4 times over the non-enhanced region and covering 43% of the stellar surface. It was found that a symmetric region is unable to reproduce the slight asymmetry in the U light curve. An asymmetry can be introduced by allowing for longitudinal variations in region size and/or for surface brightness gradients. Figure 3 illustrates symmetric and non-symmetric active region models. No attempt was made to find a 'best fit' model since the solution is by no means unique. We conclude that if the U light curve is due to a rotating mottled star, then the active region must cover a large part of the star and that it is probably non-uniform in size and/or brightness.

Models which utilize the Planck function for surface brightness

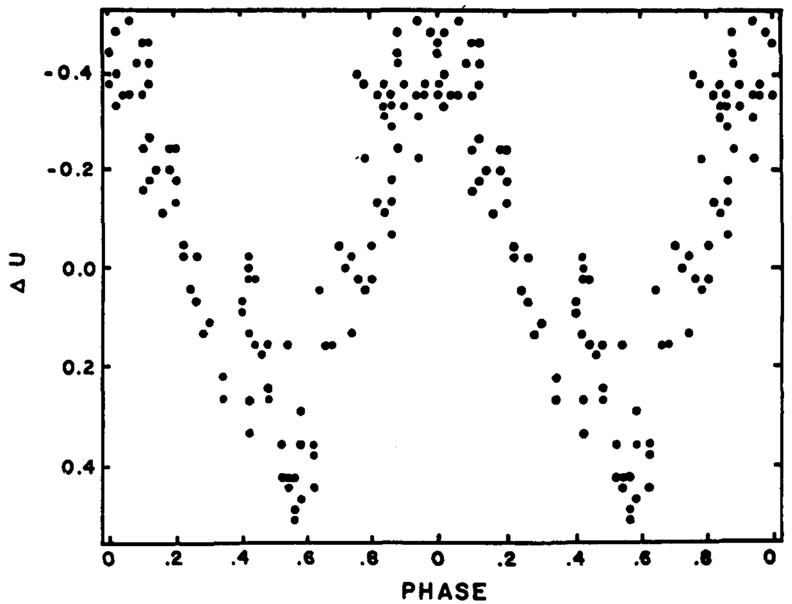

Figure 2. Composite light curve of AG Dra

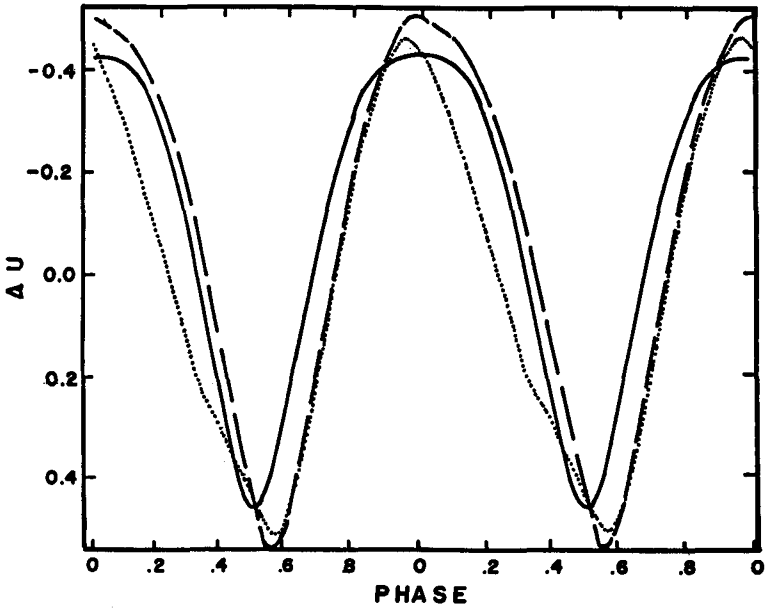

Figure 3. Active region models: T_B=brightness temperature, Δl=longitude extent, $\Delta\beta$=latitude extent, Normal surface T_B=3275K
Solid line: single region T_B=3525, Δl=220, $\Delta\beta$ =$\pm$40.
Dashed line: 2 regions T_B=3525, Δl=100, $\Delta\beta$ =$\pm$40 leading, $\Delta\beta$=$\pm$ 70 trailing. Dotted line: 3 regions, Δl=120, $\Delta\beta$ =$\pm$50, T_B=3400 leading, T_B=3600 trailing.

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and which yield the appropriate U-magnitude amplitude uniformly predict V-magnitude amplitudes near .6 magnitudes whereas the observed variations are of the order of 0.3. A simple thermal emission model, i.e. hot "spots", can not be the physical mechanism producing the surface brightness enhancement.

Enhanced Balmer line and continuum enhancement is often associated with stellar activity. The Hβ equivalent width is observed to be correlated with the light curve reaching a maximum at about the same time as does the U-band brghtness. Thus we suggest that the photometric behaviour of AG Dra may be the result of chromospheric activity modulated by rotation.

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