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*Research Note*

# IUE Observations of Two Late Type Stars: R Aql and W Hya

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**Summary.** Ultraviolet spectra of two late type M stars R Aql and W Hya were obtained with the International Ultraviolet Explorer (IUE). Spectra were obtained of R Aql near maximum ($\phi=0.21$) and minimum ($\phi=0.65$) of the visible light curve. We find that the absolute flux intensity of the Mg II resonance doublet (2796 Å, 2803 Å) is essentially the same at these phases in the visible light curve. A nebular emission feature at 3133 Å is detected at minimum light in R Aql that is possibly due to O III. Mg II emission is totally absent in W Hya, which contradicts earlier predictions that this star has an 8000 K permanent chromosphere. These results are discussed as they pertain to the formation of silicate grains in cool M giant atmospheres.

**Key words:** stellar chromospheres – mass loss – stellar winds – long period variables

## Introduction

Ultraviolet observations of two late type stars W Hya and R Aql were obtained with the International Ultraviolet Explorer (IUE). UV spectral observations were made in low dispersion (~6 Å spectral resolution) between 1200 Å and 3200 Å using exclusively the large 10″×20″ entrance aperture of the IUE spectrometer (Boggess et al., 1978). This program was concerned mainly with detection of line emission from circumstellar nebulosity resulting from shock driven stellar winds interacting with the interstellar medium. Evidence for shock excited emission in the extended circumstellar shell in the UV was not found, although detection of chromospheric line emission in one star R Aql was detected.

Detection of chromospheric emission is particularly interesting in late type M giants because they are stars generally associated with mass loss and stellar winds. Radiation pressure acting on grains has been proposed as a mechanism for ejecting material from the cool M giant atmosphere (Kwok, 1975; Renzini, 1977). As such, the appearance of chromospheric line emission, suggestive of temperatures in the 6000 K to 8000 K range, places a number of constraints on grain formation models in cool M giant atmospheres.

## Observations and Analysis

UV observations of the Mira variable R Aql (M 5e–M 8e) obtained here show the resonance doublet of Mg II (2796 Å, 2803 Å) in emission. Only emission possibly attributed to O III (3133 Å) and several broad emission features that are possibly blends of low excitation metals were detected with two hour exposures in the long wavelength (2000 Å–3200 Å) camera. Weak UV continuum was detected at wavelengths $2500 < \lambda < 3200$ Å. However, the nature of the continuum observed is possibly the result of instrumental scattered light. This question is presently under investigation.

UV observations of R Aql (period = 293 d) were obtained on 29 July (62 d post-maximum light, $\phi=0.21$) and 25 November (3 d post-minimum light, $\phi=0.65$). Predicted times for maximum and minimum light were provided by Mattei of the AAVSO. The spectra are shown in Figs. 1a, b where the wavelength identifications of the strongest features are shown. The feature at 2200 Å is attributed to pixel noise. The spectrum obtained at $\phi=0.21$ (Fig. 1a) exhibits a number of emission features at 3029 Å, 3054 Å, 3096 Å, 3142 Å, and 3182 Å that are possibly blends of Fe II emission. In the UV spectrum obtained at $\phi=0.65$ (Fig. 1b) a prominent broad emission feature centered at $\lambda \sim 2300$ Å is tentatively identified here as a blend of Fe II multiplets (2), (3), (35), and (36) and Ni II multiplet (3) emission.

Table 1 shows the absolute flux in the Mg II resonance lines, for which the flux shown here represents the integrated intensity of both resonance doublets. As is evident from the table, the emission remained essentially constant within a factor ~2 over the declining phase of the visual light cycle of the star. Owing to the relatively weak signal overall in our spectra, we estimate absolute accuracy of line flux intensities to within 10–20%. The appearance of Mg II emission is suggestive of a warm chromosphere between 6000 K and 8000 K. Analysis of Mg II line formation by Basri and Linsky (1980) in late type supergiants such as α Ori generally indicates densities of $n_e \sim 10^5$ and $n_H \sim 10^6$–$10^7$ cm$^{-3}$ at the Mg II forming region of the stellar chromosphere. We expect that these densities should be scaled up by a factor of ≳10 for the more compact M type variables such as R Aql. As such, grain formation in this region of the atmosphere of R Aql is unlikely because the temperatures generally implied by the Mg II emission are far in excess of the phase transition temperature for grains (around 1000 K–1500 K). Models developed by Kwok (1975) for grain formation in cool M giant atmospheres and Lucy (1976) do not consider the existence of chromospheres. This result suggests that for at least one star here known to have extensive mass loss (Gehrz and Woolf, 1971), and microwave emission (Scharlach and Woolf, 1979), grain formation most likely occurs at the very outer periphery of the stellar atmosphere where temperatures and densities are conductive for this process.

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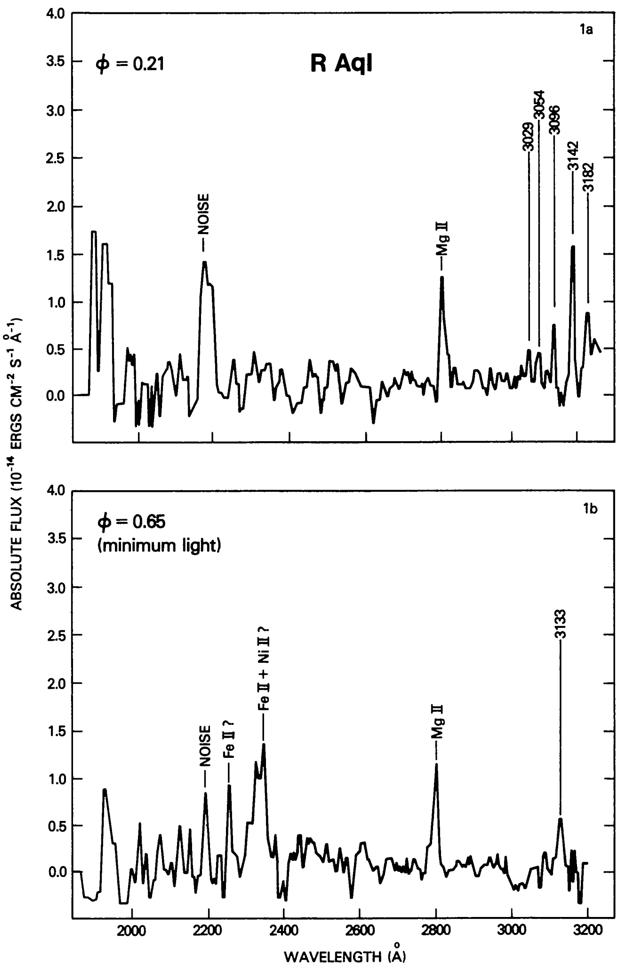


**Fig. 1a.** Long wavelength spectrum of R Aql obtained at $\phi=0.21$ in which the Mg II lines appear as an emission feature at 2800 Å. Exposures were 2 h in low dispersion. Long wavelength spectrum at $\phi=0.65$ where the Mg II resonance emission has essentially the same absolute flux within a factor ~2 as that observed at $\phi=0.21$. Prominent features are are seen at wavelengths around 3100 Å. Also, the low level continuum detected at $\phi=0.21$ in the range 2500 Å < $\lambda$ < 3200 Å was not detected at $\phi=0.65$ using the same exposure time and identical configuration of the IUE spectrometer

**Table 1**

| Observing date | Phase ($\phi$) | Absolute flux of Mg II (erg cm$^{-2}$ s$^{-1}$) |
|---|---|---|
| 29 July '80 | 0.21 (65 d post-maximum) | 1.6 $10^{-13}$ |
| 25 Nov. '80 | 0.65 (3 d post-minimum) | 1.4 $10^{-13}$ |

Near minimum visual light emission at 3133 Å is present that is possibly attributed to O III (Fig. 1b), where the measured absolute flux of this feature is $F_\lambda \sim 7.6\ 10^{-14}$ erg cm$^{-2}$ s$^{-1}$. At $\phi=0.21$ this line appears blended (Fig. 1a) with a stronger unidentified emission feature at ~3142 Å. O III emission is found typically in planetary nebulae spectra (cf. Kaler, 1976). This suggests the presence of high excitation emission in close proximity to R Aql. However, other high excitation emissions lines are not observed with IUE. In view of the fact the O III is likely excited through Bowen fluorescence photons derived from He II (304 Å), the absence of emission of N V, C IV, Si III] and C III] in the UV suggests that our identification of O III is dubious. More observations in high dispersion are required to resolve this question.

If formed in a stellar chromosphere the fact that Mg II resonance emission is essentially constant at two different phases in the variable light cycle of the star has implications for mechanisms concerned with acoustic energy generation in convection zones as a means for chromospheric heating. One would expect that the ionization and temperature structure of the outer convective envelope of the red giant undergoes physical changes during the pulsation cycle of the star and that some changes should be reflected in chromospheric emission. Constant chromospheric emission during the declining phase of the light cycle of R Aql here suggests that the energy source responsible for Mg II resonance emission is insensitive to the acoustic generation flux of the convection envelope. However, if Mg II line emission arises in a circumstellar shell, this might explain the fact that this medium excitation line appears seemingly insensitive to the physical changes that occur at very deep levels in the stellar envelope.

UV spectra obtained in the long wavelength camera of W Hya (M 8 e–M 9 e; SRc variable type) using two hour exposures shows a total absence of Mg II emission. Only continuum was detected in the wavelength range 2400 Å < $\lambda$ < 3200 Å, that again is possibly attributed to instrumental scattered light. The irregular light cycle characteristic of an SRc type variable prevents us from determining the exact point in the visual light curve when our observations were obtained. The visual monitor of IUE recorded a visual magnitude $m_V \sim 8$ at the time of our observations. However, owing to the red sensitivity of the onboard FES visual monitor on IUE, magnitudes for red stars tend to be overestimated by generally $\gtrsim 1$ mag. Including an approximate correction for this effect, W Hya was about $m_V \sim 9$ mag at the time of our observations, which places the star almost mid-range in its estimated light cycle [$m_V = 7.7$–$11.6$, Kukarkin et al. (1969)].

A lack of Mg II emission and other emission lines in the ultraviolet is not consistent with Lambert and Snell (1975), who find a chromospheric temperature $T_e \sim 8000$ K for this particular star by examining the excess infrared emission relative to black-body emission in the infrared bands at 10 and 35 μm. Their findings suggest that because veiling of absorption lines in the visible is not present in the spectrum of W Hya that the chrmomospheric emission dominates at wavelengths $\lambda \lesssim 3000$ Å. A total absence of emission in the UV between 2000 Å and 3200 Å here, however, suggests a lower state of excitation is present in the atmosphere of W Hya as compared to R Aql: W Hya appears to be a more likely candidate for grain formation in cool stellar atmospheres as has been suggested by Kwok (1975) and Lucy (1976), that could account for the circumstellar silicate emission observed in this star by Gehrz and Woolf (1971). Further observations in the UV and visible are necessary to identify the mechanism for mass expulsion from M giant atmospheres for particular late type stars, and as such possibly discern the mechanisms that are appropriate for the formation of circumstellar shells for particular catagories of M variables.

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