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ULTRAVIOLET SPECTROPHOTOMETRY OF ARCTURUS FROM A ROCKET

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ABSTRACT

Spectrophotometric observations of Arcturus were obtained at the resolution of about 7 Å in the wavelength region 2700–4000 Å from an Aerobee rocket. Although the payload was capable of obtaining observations shortward of 2700 Å, the stellar flux was too weak for meaningful measurements below that wavelength. The most significant feature in the ultraviolet shortward of the atmospheric cutoff is an emission feature at 2800 Å identified as the resonance line of the Mg II doublet.

I. INTRODUCTION AND OBSERVATION

Spectroscopic studies of Arcturus (α Boo) conducted thus far are summarized by Griffin (1968). In the ultraviolet spectral region, the work by Shaw (1936) reached the shortest wavelength, 3150 Å, but involved only identification of spectral lines. Work by others did not extend into the ultraviolet. The primary objective of this paper is to report the detailed spectral energy distribution of Arcturus in the ultraviolet in the hope of assisting other investigators in constructing models for the late type giant.

The observations to be discussed in this paper were obtained as a part of a rocket-borne ultraviolet experiment, in which Jupiter was the primary target (Kondo 1971). The telescope-spectrometer system, pointed and stabilized through the combined use of an inertial attitude control system and a star-tracker (STRAP III), had the capability to observe more than one target during a flight. Since there appeared to be sufficient time to observe another target, Arcturus was selected for observation in order to investigate the detailed ultraviolet spectral energy distribution of a late-type giant. It might be added that the choice of the secondary target was somewhat restricted by the star-tracker, which would not operate effectively for stars fainter than approximately the second magnitude. The 13-inch Cassegrain telescope was launched from White Sands Missile Range aboard an Aerobee 150 rocket at 04:32, 1968 May 17 (U.T.). The telescope was equipped with a scanning spectrophotometer and three photomultipliers that were capable of obtaining observations in the spectral range 1100–4100 Å. For further discussion of the instrumentation, the reader is referred to articles by Stecher (1970) and Kondo (1971).

The photomultipliers used in the experiment were calibrated against a phototube freshly coated with sodium salicylate. In the process of reduction, the quantum efficiency of the sodium salicylate coated photomultiplier was assumed constant. This assumption is a possible source of some error in the results. At wavelengths longward of about 3500 Å, sodium salicylate becomes increasingly transparent to photons. Consequently, for this wavelength region, the data provided by the manufacturer of the photomultiplier tube were adopted for the reduction. The uncertainty in the spectral energy curve shortward of 3500 Å has been estimated to be about 10 percent from the calibration data and the known instrumental characteristics. Longward of 3500 Å, the uncertainty is thought to be greater than this value.

II. RESULTS AND DISCUSSION

The spectral energy distribution of Arcturus in the wavelength region 2700–4000 Å is plotted in Figure 1. The flux scale has been arbitrarily chosen. Actually, two such scans were obtained, but since both scans agree reasonably well, only one is shown here. Because of the occasional slippages of the gear that drove the rotating grating, there are uncertainties in the wavelength determination. This made it impractical to take an average of the two scans. The spectral resolution of the observations, as determined from the known characteristics of the telescope-spectrograph system and also from the stability of the telescope estimated from the star-tracker telemetry recording, is about 7 Å. The spectral lines in Arcturus for the region longward of 3150 Å were identified by Shaw at much higher resolution. Because of the above-mentioned uncertainties in the wavelength determination, only very strong features that repeat themselves in both

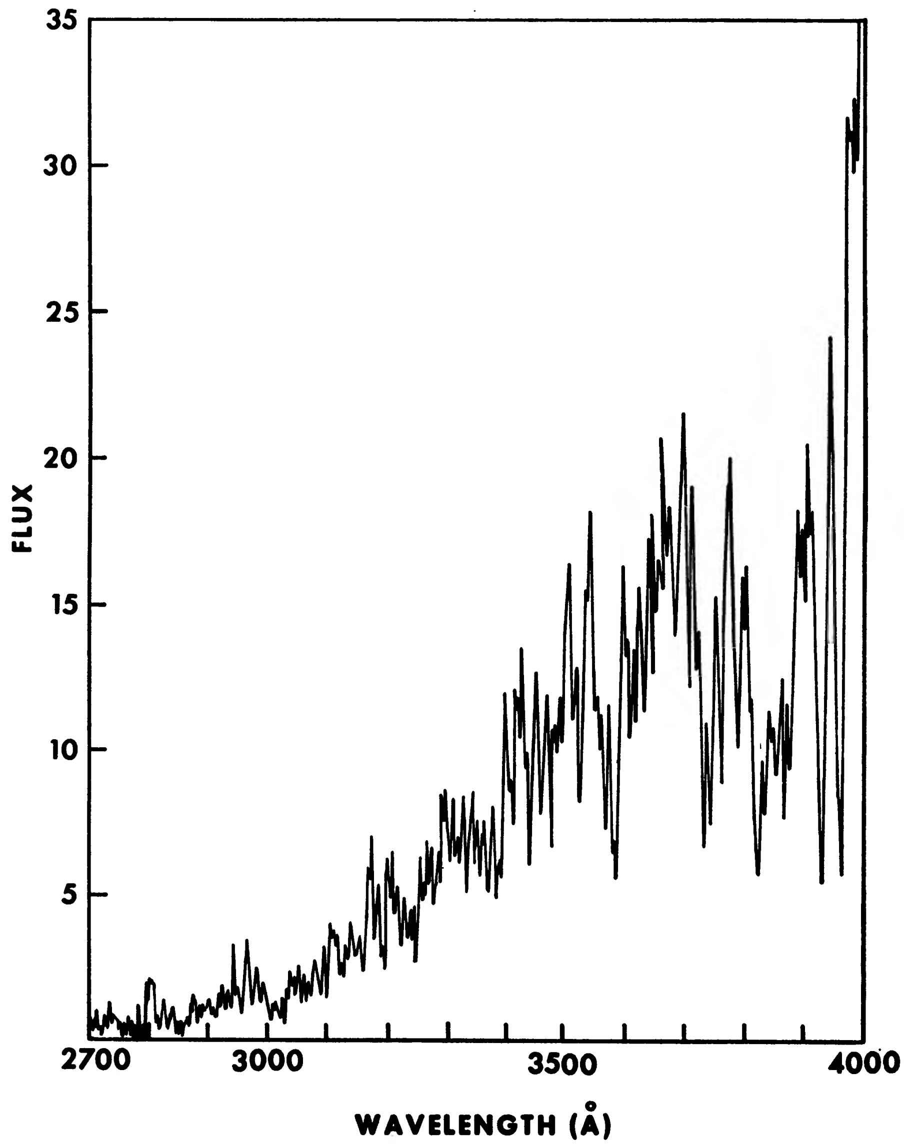

FIG. 1.—Spectral energy distribution of Arcturus (K2 IIIp) observed from a rocket. Flux scale is arbitrary.

scans may be identified reliably in the current observations. For the region shortward of 3150 Å, such a feature is the Mg II doublet emission at 2800 Å, which will be discussed later in more detail.

In Figure 1 we see spectral features that give appearances of emission lines. Many of these features are believed to be residual continuum with adjacent absorption features. Because of the highly uncertain level of the "true" continuum due to the severe line blanketing effect, no attempt is made in this paper to evaluate the equivalent widths of the absorption lines that are observed. The spectral features of Arcturus were compared with the ground-based spectra of α Ari (also a K2 III), which extended to about 3150 Å. The gross spectral features of Arcturus are in general agreement with those of α Ari in their corresponding wavelength region, although no comparison was possible for the spectral energy distribution. The observed spectral energy distribution of Arcturus was compared with the theoretical spectral energy output of a late-type giant by Carbon and Gingerich (1969). The line-blanketed theoretical model was computed for $T_e = 4000°$ K and $\log g = 3.0$. The effective temperature of 4000° K is perhaps a bit too low for Arcturus (Johnson 1966). The observed spectral energy distribution is basically in agreement with the theoretical model. However, the superposition could not be performed unambiguously because of the uncertainties in normalization.

The most significant feature beyond the atmospheric cutoff is an emission feature at about 2800 Å, which has been interpreted as being due to the Mg II doublet resonance lines at 2795 and 2802 Å. Sometimes a spurious noise, such as that due to cosmic-ray impacts, gives an appearance of an emission feature. It can also contaminate or fill up an otherwise present absorption feature. However, the emission feature at 2800 Å is quite distinct in both scans, and it is very likely to be a real feature. Figure 2 shows the spectral

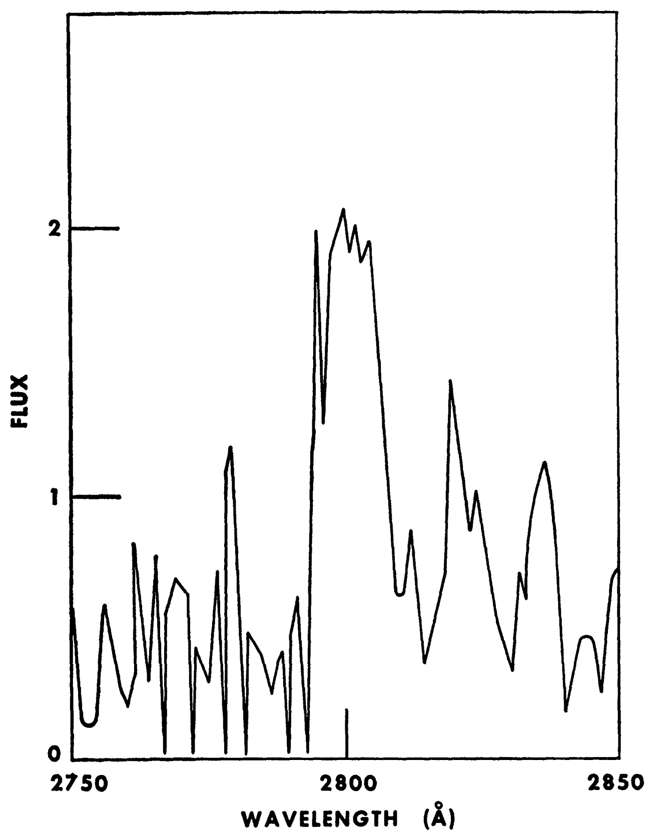

FIG. 2.—Spectral energy distribution of Arcturus in the region of the Mg II doublet emission in an expanded scale.

region 2750–2850 Å in an expanded scale. The OAO–A2 observations of Arcturus at resolution of about 25 Å, reported by Doherty (1970), also show an emission at about 2800 Å. This emission feature is an ultraviolet counterpart of the Ca II H- and K-doublet emissions at 3968 and 3933 Å, which have been interpreted as being due to an active stellar chromosphere. Wilson and Bappu (1957) give the intensity of the Ca II K emission feature in Arcturus as Class II, which makes it not a very strong feature, Class I being the weakest observable and Class V being the strongest, reaching the continuum level. At the resolution of some 7 Å in the current work, the Ca II emission must have served only to fill the bottom of the absorption feature. No evidence of the Ca II emission is seen in Figure 1, although the Ca II absorption line is clearly observed at about 3933 Å. In comparison, the Mg II doublet emission is about twice as intense as the "apparent" adjoining continuum. It is perhaps of interest to note that the Mg II doublet emissions have been observed in the solar spectrum from rockets and reported first by Durand, Oberly, and Tousey (1949), followed by others. The Mg II emissions in the Sun are typically an order of magnitude more intense than the Ca II emissions, which are detectable in the Sun only with extremely high dispersions. In view of their apparent relative strength, the Mg II doublet emissions may provide a powerful tool for investigation of the stellar "chromosphere."

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