Mariner 9 Ultraviolet Spectrometer Experiment: Stellar Observations

Abstract. *Photoelectric spectra have been obtained for a number of early-type stars in the 1100- to 2000-angstrom region with the Mariner 9 ultraviolet spectrometer. The resonance lines of H I, Si IV, and C IV are easily identified, as are features due to C II, C III, Si III, Fe II, N IV. The absolute energy distribution derived from the data lie about 20 percent below those of OAO-2 in the 1200- to 2000-angstrom region.*

Although the Mariner 9 ultraviolet spectrometer was designed to measure emissions from the sunlit atmosphere of Mars (*1*), it has demonstrated a significant capability for the observation of stars. The first stellar measurements were made en route to Mars during a spacecraft sequence designed to calibrate the pointing mechanism for the instrument scan platform. Good spectra were obtained for δ Cet, ϵ Per, and α Lyr (Vega). Weak signals were recorded for several other stars. Since orbital insertion, stars have been observed on a continuing basis. The quality of these observations is comparable to that obtained with sounding rockets (*2*) and the Orbiting Astronomical Observatory OAO-2 (*3*).

In addition to providing information on the temperature, composition, and atmospheric structure of hot stars, these observations are important to the Mariner mission: they provide a check on the preflight calibration of the instrument, permit the instrumental sensitivity to be monitored throughout the period of orbital operations, and should eventually provide an in-flight calibration which is more accurate than the laboratory calibration.

The instrument used for these measurements is a 250-mm Ebert-Fastie spectrometer with a 3-inch (7.62-cm) occulting slit telescope and extensive baffling to eliminate stray light. Wavelength scanning is accomplished by moving the grating with a cam drive which completes a cycle every 3 seconds. Two photomultiplier tubes measure the spectrum simultaneously; the 100- to 1900-Å region is measured with a cesium iodide photocathode, while the 1500- to 3400-Å region is measured with a cesium telluride photocathode. The electronics provide an analog output which is sampled every 5 msec or 4.5 Å in first order. The resolution of the instrument is about 15 Å in first order and 7.5 Å in second order. The instrument is similar to the spectrometer used in the Mariner 6 and 7 experiments (*4*).

In a typical 3-second scan, only a few photoelectric events per sample may be recorded, so it is necessary to add a large number of scans to achieve good statistical accuracy. Figure 1 shows the results of adding 144 scans of γ Ori recorded with the short-wavelength detector during the 28th orbit. The sky background Lyman alpha emission has not been removed.

The strongest features in this spectrum are the resonance lines of Si IV at 1400 Å and C IV near 1550 Å, and a series of Si III lines at 1300 Å and Fe II lines near 1620 Å. In the second order the resonance line of interstellar hydrogen at 1216 Å is apparent, as are the lines of C III at 1247 Å and C II at 1334 Å. The higher resolution of the second-order spectrum is demonstrated by the separation of the Si IV lines at 1393.8 Å and 1402.8 Å. This resolution makes it possible to identify lines which are blends in the OAO-2 data.

The spectra of several other stars are shown in Fig. 2. The first-order spectra have been corrected for sky background and placed on a relative flux scale by using the preflight laboratory calibration.

The Lyman alpha line at 1216 Å is the strongest feature in these spectra; it is primarily due to interstellar hydrogen, except for α Lyr where the stellar H I line is saturated. A progression of line strengths with spectral type can be seen for Si III, Si IV, and C IV. If a smooth continuum is drawn for these stars severe line blanketing in the 1400- to 1800-Å region becomes apparent, increasing with effective temperature and reaching a maximum of nearly 0.6 magnitude in ϵ Per near 1600 Å. This effect may also be seen in data from OAO-2. The effect of temperature variations on the ultraviolet continua of stars may be seen by comparing the spectra of δ Cet and α Lyr, whose effective temperatures are 21,900° and 9,650°K, respectively (*5*).

In Fig. 3 we compare the absolute energy distribution for ϵ Per as determined from the Mariner 9 ultraviolet spectrometer data with the flux measured by the Wisconsin experiment on OAO-2, based on an interim calibration for spectrometer No. 2 (*6*). The

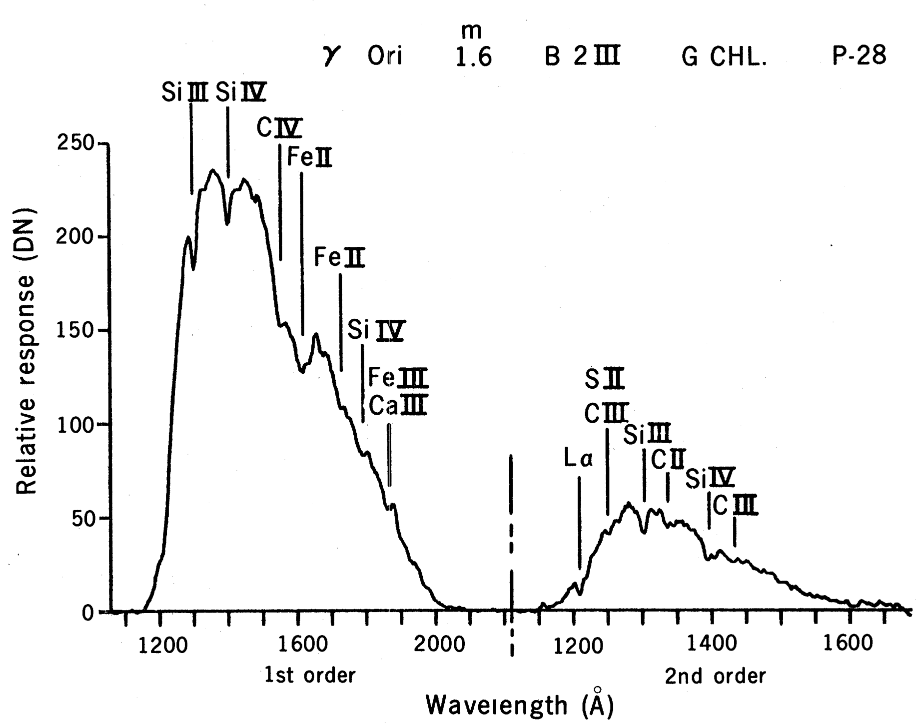

Fig. 1. The spectrum of γ Ori in the 1100- to 2000-Å region observed during the 28th orbit. It is the sum of 144 3-second scans, smoothed once with a three-point running average, and with the dark current subtracted. The sky background Lyman alpha emission has not been removed. The graph is a plot of instrumental response in data numbers (*DN*) versus wavelength in angstroms.

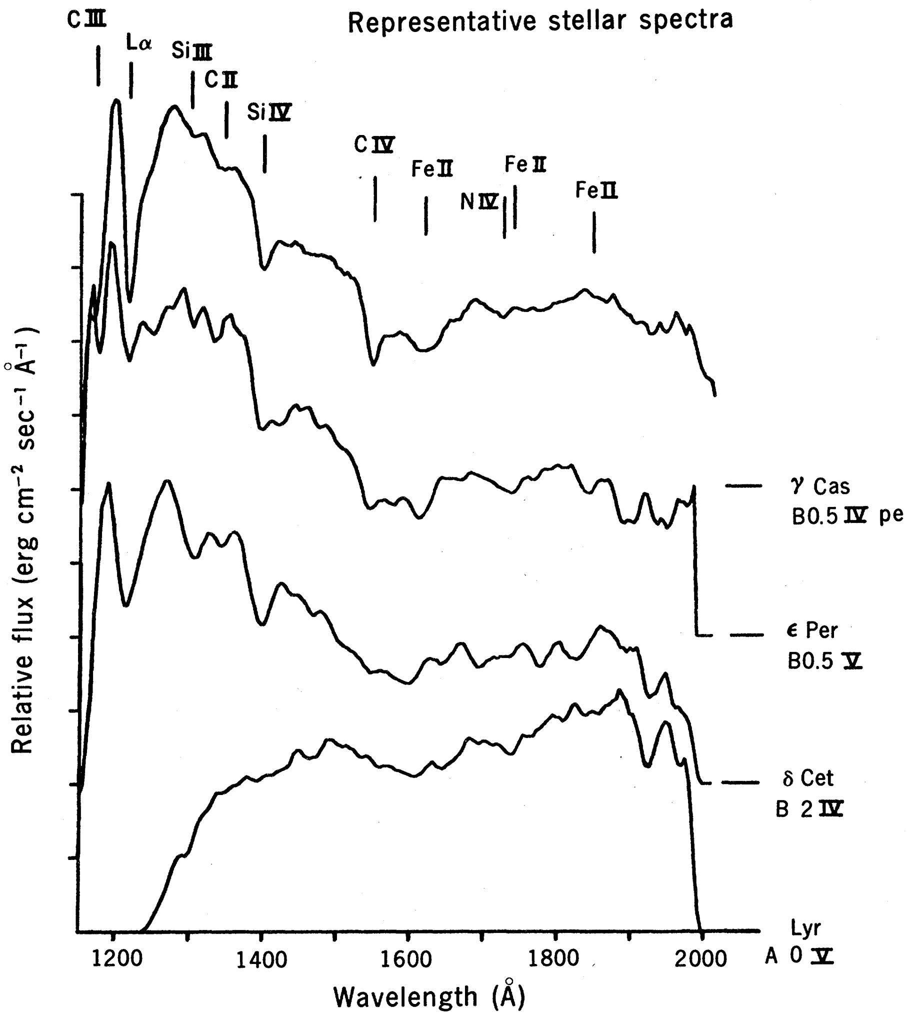

Fig. 2. A comparison of four stars observed with the Mariner ultraviolet spectrometer. The first-order spectra have been corrected for sky background and placed on a relative flux scale by using the preflight laboratory calibration. The zero level for each star is indicated by the horizontal line at the right.

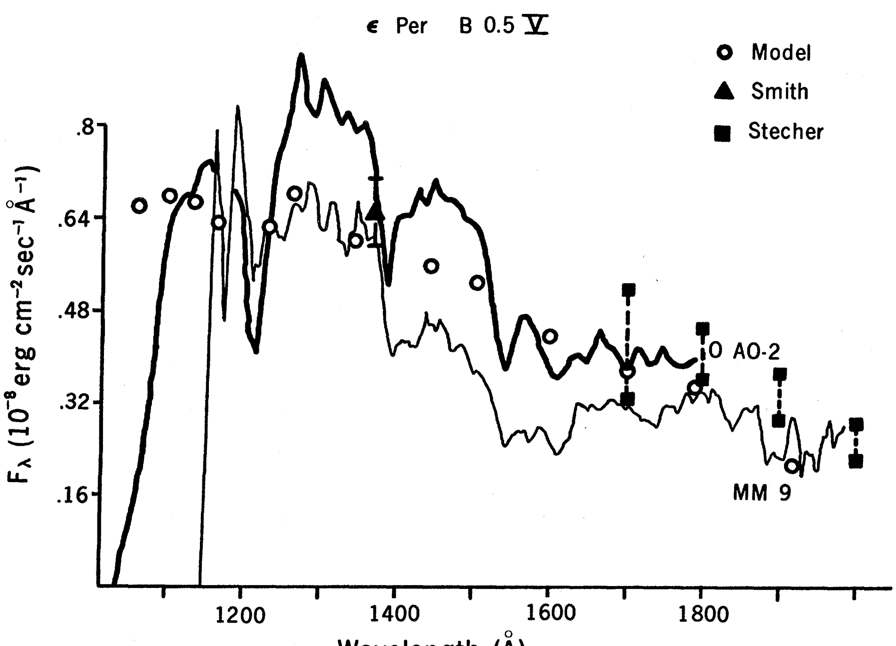

Fig. 3. The absolute energy distribution for ε Per as determined by Mariner compared with the flux (F_λ) measured by OAO-2. The observations of Stecher and Smith, and the model of Van Citters and Morton ($T_e = 25{,}200$°K) are shown.

observations of Stecher (*7*) and Smith (*8*), and the model atmosphere of Van Citters and Morton (*9*) ($T_e = 25{,}200$°K) are also shown. The observations all agree with one another within the accuracy of their absolute calibrations (± 20 to 30 percent) although the Mariner 9 data fall about 20 percent below the OAO-2 observations and are in better agreement with the model calculations. A more rigorous comparison with models must await a more accurate inflight calibration, based on the observation of stars whose flux is known to ± 10 to 15 percent from rocket observations.

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References and Notes

1. C. W. Hord, C. A. Barth, J. B. Pearce, *Icarus* **12**, 63 (1970); C. A. Barth, C. W. Hord, A. I. Stewart, A. L. Lane, *Science* **175**, 309 (1972).
2. T. P. Stecher, *Astrophys. J.* **159**, 543 (1970).
3. A. D. Code, T. E. Houck, J. F. McNall, R. C. Bless, C. F. Lillie, *ibid.* **161**, 377 (1970).
4. J. B. Pearce, K. A. Gause, E. F. Mackey, K. K. Kelly, W. G. Fastie, C. A. Barth, *Appl. Opt.* **10**, 805 (1971).
5. R. Schild, D. M. Peterson, J. B. Oke, *Astrophys. J.* **166**, 95 (1971).
6. A. D. Code, private communication.
7. T. P. Stecher, *Astron. J.* **74**, 98 (1969).
8. A. M. Smith, *Astrophys. J.* **147**, 158 (1967).
9. G. W. Van Citters and D. C. Morton, *ibid.* **161**, 695 (1970).
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