OAO-2 OBSERVATIONS OF
C III] 1909 Å LINE IN
GAMMA^2 VELORUM

Donald K. West
National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland

ABSTRACT

The C III] 1909 Å emission line in Gamma^2 Velorum was observed over a period of 24 hours in an attempt to find short period time variability. Analysis of this data found no periods in the range of 0.5 to 200 minutes, and placed an upper limit of 3% on the amplitude of the stellar pulsations. Improved spectral resolution data for this line was obtained by offsetting the OAO-2 pointing in steps of 15 seconds of arc. The line profile derived by combining this offset data with the slit function shows a definite asymmetry. Although the improved resolution gives results which are barely sufficient for comparison with the prediction from model envelopes, some information concerning the abundance of carbon and the physical conditions of the envelope can be gained.

I. INTRODUCTION

Gamma^2 Velorum is a binary with a period of 78.5 days, containing a Wolf-Rayet star WC8 and an O9 star. The ultraviolet spectrum has been observed from a rocket and by the OAO-2 in regions from 1100 to 4000 Å. Figure 1 shows an OAO spectrum at 10 Å resolution. This scan was made with a spacecraft offset of 13 arc min in order to shift 1909 Å into spectrometer 2 (Code _et al_. 1970). The offset introduces an uncertainty in the wavelength scale between 1600 and 2000 Å of about ±10 Å.

One of the strongest lines in the spectrum has been identified from rocket spectra by Stecher (1970) as an intercombination line of C III] $2s^{2}\,{}^{1}S-2s2p\,{}^{3}P$ at 1909 Å. The strength of

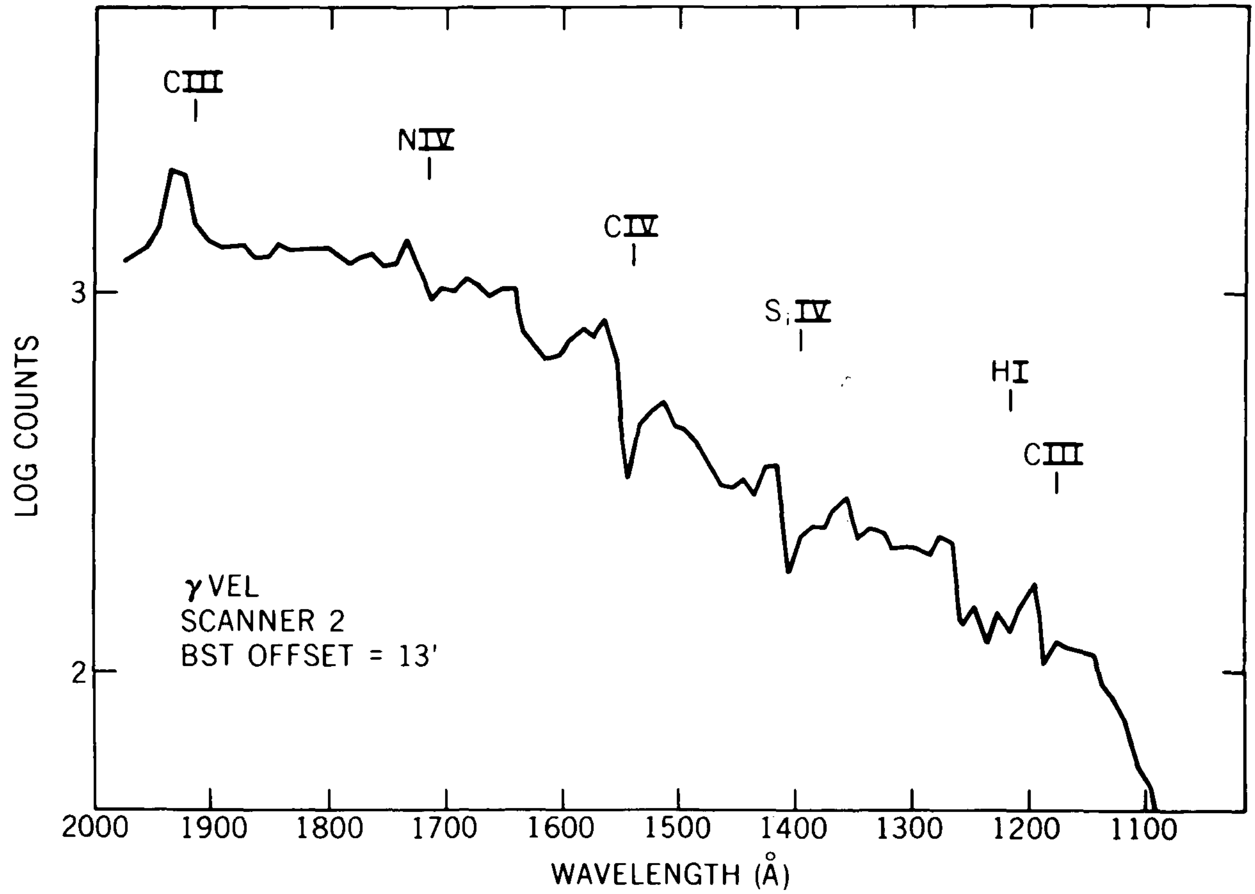

Figure 1.—OAO-2 spectral scan of γ^2 Velorum. Counts are raw data with 10 Å slit. Six prominent features have been identified.

this emission feature is most surprising because its transition probability is one million times smaller than a C III line of equal strength at 2297 Å, not shown in this figure.

The extent of excitation in this line has been investigated by Stecher and West (1968 and 1971) with the intent to determine if the population ratio was large enough to produce laser action. Model envelopes assumed spherically symmetric distribution of radially ejected mass and velocity. Equivalent widths resulting from these models were compared with the observed value of 15 Å for 1909 Å. A detailed profile fit was not possible because the rocket profile, although defined by about 40 points, was subject to instrumental rise and decay times. The OAO scans did not have this problem but the number of data points defining the core of the line was never more than 3.

The models were able to match the observations without requiring laser action, but it was necessary to increase the normal abundance of carbon by factors of 10 to 30. Additional and more detailed observations with higher resolution were required to answer questions of laser action, abundance anomalies, and model envelope choices.

Further observations of γ^2 Velorum were made as part of the Goddard guest observer program with the intent to search for periodic light variation in the line which might be associated with laser discharges in the envelope or with pulsational instabilities in the star. In addition, more closely spaced data points in the core of 1909 Å could be used with a knowledge of the instrumental slit function to deconvolve the profile to better than 10 Å resolution.

II. PERIODIC VARIABILITY

The amplitude of the line was monitored by offsetting the spacecraft optical axis by 13 arc min, which shifted 1909 Å into the far ultraviolet spectrometer. The slit of the spectrometer was then stepped in real time until a maximum output signal was observed near the peak of the line. Stellar photometer 1 was used as a background monitor. All data were taken under the best pointing stability obtainable with OAO, i.e. with the boresight startracker control. Readouts of the line and background were taken at 8 second time-intervals throughout the 20 minutes of spacecraft darkness for every orbit throughout 24 hours. Except for those orbits in which the South Atlantic Anomaly background saturated the detectors, all data were of high quality.

The data were analyzed for periodic amplitude variations in the range 0.5 to 200 minutes by T. M. Kelsall of Goddard, who supplied the computer programs and the interpretation of the output. The search was limited to only those amplitude changes which were outside of the noise band, because power spectrum analysis programs for periods hidden in noise require continuous data with equally spaced sample times.

The results of the analysis showed very strong periodic variations in the line and in the background, with a period of 100 minutes. Of course, this is the orbital period of OAO. Variability in the background was due to the anomaly and the small variation in the line was probably caused by thermal cooling distortions during the 20 minutes of night. No other periods were found.

III. LINE PROFILE

Figure 2 illustrates how a highly resolved profile $P(\lambda)$ is smeared by the slit function $S(\lambda)$ to produce the degraded ob-

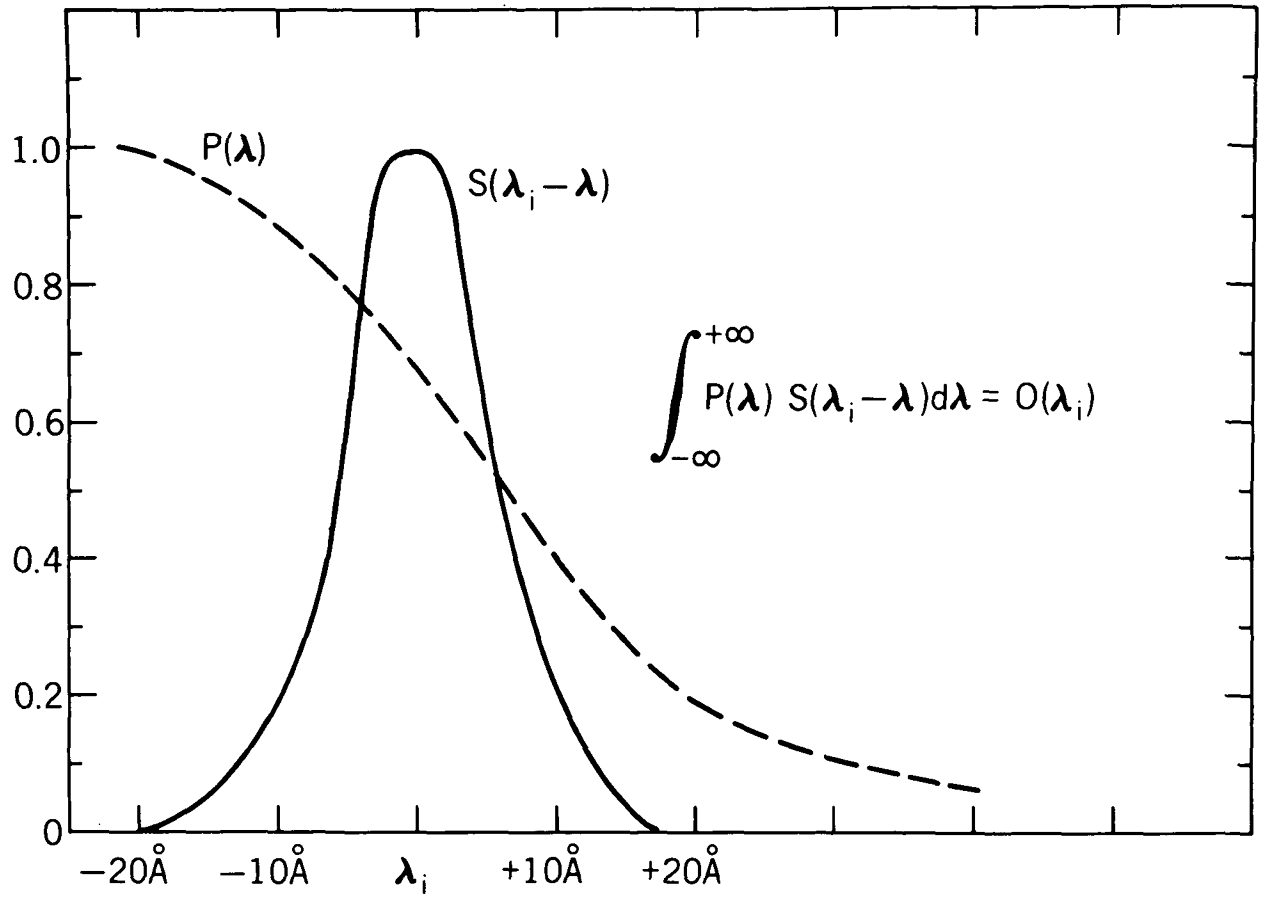

Figure 2.—The relative response of the instrumental slit function as a function of wavelength.

served profile O(λ). The slit function was provided by B. D. Savage of Wisconsin. The shape is nearly Gaussian with a half-width at half-maximum of 6 Å. The slit function is known with an accuracy no better than 10 percent and it is thus not suited for an analytic inverse Laplace transform solution for S(λ). This accuracy, however, is good enough to use the slit function to degrade an assumed or theoretically determined profile and then compare the result with the observed profile.

Line-profile data spaced at about 2.5 Å intervals were obtained by offsetting the spacecraft pointing in small increments of 15 arc sec. The spacecraft was stabilized at each position while about 30 readouts of the line and the background were taken over a period of 6 minutes. All data were taken in spacecraft darkness, in low background, and under boresight startracker control. A total of 12 data points on the line were obtained over a 5 hour period. This data produced the observed profile O(λ) shown on the left side of Figure 3. The long wavelength side of the line is closely Gaussian in shape but the short wavelength side appears to be depressed in a manner suggestive of an absorption component. No systematic effects in the observing procedures which might produce this kind of asymmetry at 1909 Å were uncovered.

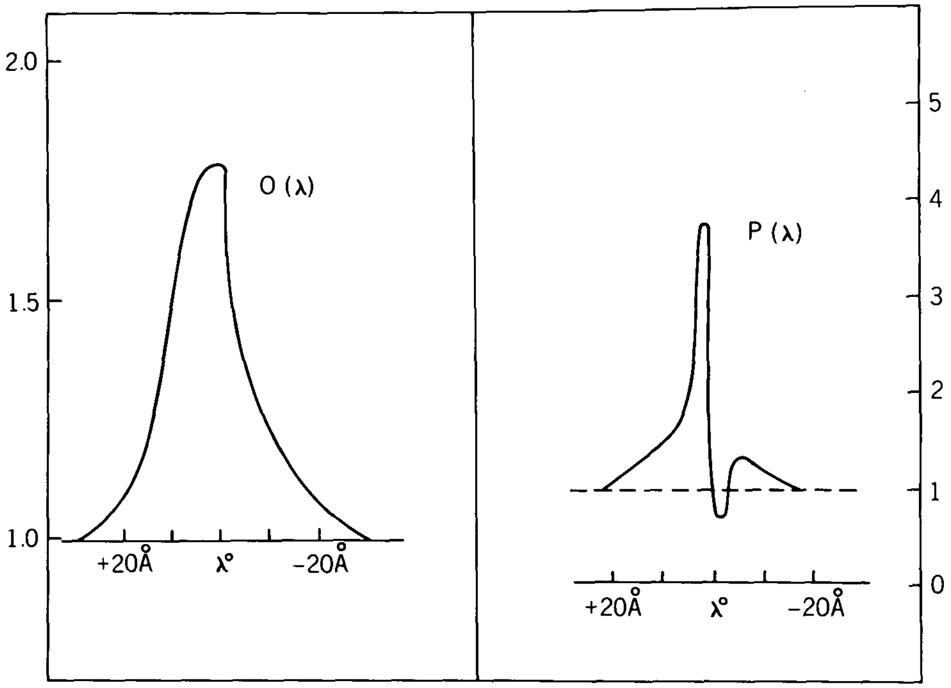

Figure 3.—The observed profile at 1909 Å, O(λ), and the iterative solution profile, P(λ).

The next step was to find a profile which when smeared by the slit function produced the observed profile. An iterative correction method was used in which the integration over the slit function, placed at λ_i, was carried out for an assumed starting profile of Gaussian shape. The result was compared with the observed $O(\lambda_i)$ and a correction was applied to the starting profile. This was done for 50 wavelengths spaced 1 Å apart.

The process was repeated until the difference between the observed profile and the iterated one converged to a small value. Several starting profile shapes were tried, but all converged to about the same shape with the difference between the observed profile and the final iterated profile being about 10 percent. At this point the solution began slowly to diverge with the emission peak growing higher and the absorption component growing deeper. A typical example of a best-fit profile is shown on the right side of Figure 3. Considering the uncertainties involved in this analysis and the uncertain uniqueness of the solution, the uncertainty on the depth of the absorption and the height of the emission is about 20%. One can be fairly certain, however, that the long wavelength side of the profile must be steeper than the short wavelength side in order to fit the observations.

IV. DISCUSSION

The results of the line variability analysis show no periods in the range of 0.5 to 200 minutes. If periodic amplitude variations exist, they are small, with amplitudes less than ±3%.

An alternative to increased carbon abundance may be found in models with non-spherically symmetric envelopes. The presence of the O star companion could, by the influence of its gravitational field and ultraviolet radiation, perturb non-uniformly the velocity field and the ionization of C III in envelopes of the WR star. Such an effect should be an observable function of phase. The phase of γ^2 Vel was determined from the zero point given by Ganesh and Bappu (1967) and the 78.5 day period. At the time of these observations the phase was found to be 0.90 which places the WR star almost completely behind the O star. In the simple picture of an expanding envelope atoms producing the short wavelength side of the line are located in the hemisphere of the envelope which is facing the observer. At the time of the observation this hemisphere was also facing the O star and could have experienced an increase in the ionization of C III to C IV due to the radiation field of the O star. This would decrease the number of C III atoms producing the short wavelength side of the line and produce the observed asymmetry. Although γ^2 Vel shows some light variability in the visible, it is not known to be an eclipsing variable.

Observations by OAO-2 at different phases could determine if there is a 78.5 variability in the ultraviolet. More detailed geometric models including gravitation and radiative effects of the companion star are needed before we can completely answer important questions of abnormal abundances in γ^2 Vel and other WR stars.

I wish to express my appreciation to A. D. Code for the generous grant of guest observer time on OAO-2. I thank T. E. Houck, M. Molnar and A. Holm for their help in obtaining the observations. I am most grateful to T. M. Kelsall of Goddard for his valuable help in the analysis of time dependent data. I am also very appreciative of T. P. Stecher for his initial suggestions for the observations. Finally, one must acknowledge the tireless work of the OAO ground crews and project staff at Goddard without whom observations of this type would not be possible.

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