Velocity Fields and Spectrum Peculiarities in Beta Cephei Stars

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I. Introduction

The purpose of this project is to obtain high-resolution, short-wavelength IUE spectra of a number of Beta Cephei variable stars at frequent phase intervals during their pulsation cycles (typical periods are 4 to 6 hours), and to study the profile variations in several ultraviolet spectral lines in order to determine the velocity fields in the stellar atmospheres. This study is intended to point the way to answers to questions like the following:

1) Are these stars radial or nonradial pulsators? Can the actual pulsation mode be determined? Does the specified mode support or eliminate any candidate for the instability mechanism?

2) Are these stars losing mass at a significant rate (as evidenced by an accelerating velocity gradient)? If so, does this affect the stability or the future evolution of the star?

A secondary objective is to compare the mean spectra of the variable stars with those of nonvariable stars of the same spectral type, to see if some of the anomalies indicated by ultraviolet photometry and low-dispersion spectroscopy are borne out when the spectra are examined at high dispersion. In particular, anomalous luminosity indicators have been reported in a few cases.

II. Completed Work

Nine 8-hour shifts of observing time with the IUE satellite were scheduled for this project, in the second year of operations. All of these observing shifts were used profitably in May 1979, to obtain a total of 122 images of

10 variable stars and 3 comparison stars. The complete list of targets observed, and the number of images obtained for each one, is given in the table below. All the images were observed in the high-dispersion mode, through the small aperture. Most of them are well-exposed and usable.

Object	Type	SWP Images	LWR Images
Xi[1] CMa	Variable	11	2
Sigma Sco	Variable	12	2
Alpha Pyx	Comparison	1	1
Alpha Vir	Variable	11	2
Beta Cru	Variable	9	1
Tau[1] Lup	Variable	3	1
V986 Oph	Variable?	10	1
Gamma Peg	Variable	12	1
Zeta Cas	Comparison	3	2
Beta CMa	Variable	13	3
16 Lac	Variable	8	1
1 Cas	Comparison	2	1
12 Lac	Variable	9	1

Thirty-three Guest Investigator tapes, containing raw images, geometrically and photometrically corrected images, and extracted spectra were received by the Principal Investigator in June through September 1979. Photowrites and 10 Å/in tracings, as well as a

selection of 1 Å/in tracings, were also received. The extracted spectra were read from the GO tapes and written, in order of observation, on a set of four more closely packed, merged tapes. This work was performed using the minicomputer facility at the Goddard Space Flight Center.

Just as the merging of the spectra on the original GO tapes was being completed, it was discovered that all the spectra obtained for this project had been reduced with the incorrect Image Transfer Function. Since we are looking for small variations in the spectral line profiles, the type of distortion introduced by the incorrect Image Transfer Function would have invalidated our results. Therefore all analysis of the spectra was stopped pending receipt of the reprocessed images. These were received over a period of several months from June through September 1980. The re-merging of the reprocessed spectra was completed by the end of October 1980.

Meanwhile, with the help of Richard Fahey, we composed a set of FORTH words (subroutines) to perform the desired operations on our IUE spectra, again using the GSFC minicomputer. In an interactive mode, the routines enable one to locate and identify selected spectral lines, draw in the continuum, rectify the line profiles, and compute the central depth, half-width, equivalent width, and asymmetry parameter (a measure of the relative steepness of the red and violet wings.

A FORTRAN program, which had been previously written to reduce ground-based and Copernicus spectra, was adapted for use with the IUE data.

This program also rectifies the profiles and computes central depths, half-widths, equivalent widths, and asymmetry parameters, as well as the radial velocity associated with the deepest point in the line. The FORTRAN program runs on the GSFC 360-91 computer, in the batch mode. Its advantage over the FORTH program (in addition to speed) is that it consistently sets the continuum at exactly the same wavelengths in each spectrum. However, since the observer does not see the spectrum as the computation is being made, he has no opportunity to correct for instrumental artifacts and other possible errors without a second iteration.

Both the FORTH and the FORTRAN program were tested on a few of the original spectra, while we were waiting for the reprocessed spectra to be delivered. In spite of its disadvantages, the FORTH program appears to give better results, because it allows one to compensate for anomalies both in the instrument (shifts in the wavelength scale, reseaux, etc.) and in the star (real changes in the spectral line width) in a realistic manner.

III. Work in Progress

Because of the late arrival of the reprocessed spectra, little analysis was completed on our data before the end of the grant period. A preliminary examination of the spectra does not reveal any gross changes in the equivalent widths, such as were reported by Fischel and Sparks for the C IV and N V lines in Beta Cephei ("The Universe in Ultraviolet Wavelengths: The First Two Years of IUE," Goddard Space Flight Center, 1980). However, since Fischel and Sparks did not find any such anomalies for any of the other

stars in their program, it is beginning to appear that Beta Cephei is a unique object in this respect.

A comparison of the 1 Å/in tracings of Gamma Peg (a variable star) and Zeta Cas (a nonvariable star of the same spectral type, B2 IV), which were obtained in this program, was made by Anne Underhill for inclusion in a Book she is co-editing with the Principal Investigator ("B Stars With and Without Emission Lines," NASA and CNRS, in press). There were surprising differences in the line widths in the two spectra -- differences that may be greater than we can account for on the basis of rotation alone. This result is unexpected, since previous low-dispersion work (Lesh and Bohlin, PASP 87, 587, 1975) has indicated that the ultraviolet spectra of these two stars are nearly identical. This point will be pursued, to see if it has any connection with the pulsation of Gamma Peg.

We intend to complete our plan of measuring the central depths, half-widths, equivalent widths, and asymmetry parameters of selected lines in all the spectra obtained for this program, both of variable stars and non-variable stars. The FORTH routine on the minicomputer will probably be used for this purpose, since it apparently gives more reliable results. These parameters will then be plotted against phase for the variable stars, and the mean values for the variable stars will be compared with the values for the nonvariable stars.

It is anticipated that this phase of the project will be completed by August 1981. Subsequent analysis will depend upon the nature of the variations detected. If consistent results are obtained, they will be compared with the predictions of radial and nonradial pulsation theory.