PROBLEMS AND PROGRAMMING FOR ANALYSIS OF IUE HIGH RESOLUTION DATA FOR VARIABILITY

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ASTRACT

Observations of variability in stellar winds provide an important probe of their dynamics. It is crucial however to know that any variability seen in a data set can be clearly attributed to the star and not to instrumental or data processing effects. In the course of analysis of IUE high resolution data of α Cam and other O, B and Wolf-Rayet stars several effects were found which cause spurious variability or spurious spectral features in our data. Programming has been developed to partially compensate for these effects using the Interactive Data Language (IDL) on the LASP PDP 11/34 at the University of Colorado. Use of an interactive language such as IDL is particularly suited to analysis of variability data as it permits use of efficient programs coupled with the judgement of the scientist at each stage of processing.

INTRODUCTION

In order to extract the scientifically interesting information from a data set, it is necessary to be certain that any features in the data represent the object under study, and not the instrument studying the object, or the way in which the data has been reduced. This is applicable both to single observations of an object, or to a series of observations whose purpose is to search for temporal variability. During analysis of IUE high-resolution spectra of several O, B, and Wolf-Rayet stars a number of effects were found which cause either spurious variability or spurious spectral features in the data. This can considerably complicate analysis and interpretation of spectra. Not all of these effects can be easily seen in a cursory examination of the data provided by VILSPA and GSFC.

SIGNATURES OF PROBLEMS

The problems we have uncovered at the University of Colorado (C.U.) are more important in the hot stars surveyed than the ITF problem, or other problems addressed to date. Some can be identified quite quickly. These include improper zero levels in the centers of saturated absorption features, such as interstellar lines or strong P Cygni profiles. (This is more of a complication for analysis than a real stumbling block, since the true zero level is inferred directly.) A more serious problem is poor matching between adjacent orders (see Fig. 1), which rules out immediate interpretation and analysis of extended spectral features such as P Cygni profiles.

More subtle effects may not be as obvious. These include distortions of line profiles, which in extreme cases can cause a saturated line to appear unsaturated, for example. In other cases spectral features clearly present in the gross spectrum may be masked in the net spectrum. Spurious absorption features may also be introduced into the spectrum (see Fig. 2). Clearly, the absence of real spectral features, and the presence of spurious features can lead to significant misinterpretation of the data.

It is important to note that these problems are not peculiar to either VILSPA- or GSFC- processed data. They also can occur in data that has been processed with the new ITF as well as old ITF data. Data from some observing runs has up to 97% of the images affected. The problems are typically worst at the short wavelength end of the images, where the orders of the echellogram are most closely crowded together, but may affect the entire image. In many cases 50% of an image is rendered useless, which is an unfortunate waste of valuable observing time. These effects are not constant from exposure to exposure and can therefore introduce considerable spurious variability which can totally swamp any real variations present in a set of observations (see Fig. 3).

A PROBABLE CAUSE

Images having normal photowrites and gross spectra but showing these data problems have been found at C.U. to have background records which contain ghost spectral features and which are an appreciable fraction of the amplitude of the gross spectrum (up to 95%). This indicates that the gross and background scan lines have been misplaced perpendicular to the dispersion direction, with the background scan apparently obtained at a position very close to or within the stellar spectrum.

It is necessary to consider what physically might cause this misplacement. The IUE Image Processing Information Manual (Version 1.0) (1) notes that thermal effects in the spectrograph optical train can cause shifts of up to three pixels perpendicular to the dispersion direction in the geometrically and photometrically corrected image. The calibration exposures used in the automatic registration procedure are taken every two weeks normally, whereas thermal shifts are known to occur on time scales of a few hours.

Thus, if data are processed using the automatic registration procedure, the image may be incorrectly scanned for the gross spectrum and background. The gross appears to be less noticeably affected than the interorder scans, probably because use of a larger slit makes placement of the scan line less critical. Also, as the orders crowd together at short wavelengths in the echelle format, the problem becomes more severe. If the background scan line is to be placed on or very near to an order, a net spectrum results which bears very little resemblance to the true spectrum when the background scan is subtracted from the gross spectrum.

A PARTIAL SOLUTION

If any of these data problems appear in an image or set of images, it is essential to check the data in several ways. First, if the photowrite appears to be abnormal it is probably impossible to extract believable data from that image. If the photowrite seems normal, the problem may be related to improper extraction procedures and the gross spectrum and background record on the data tape should be examined order by order. If the gross spectrum, when ripple-corrected, shows poor matching between adjacent orders, or other distortions, reprocessing at VILSPA or GSFC is recommended.

There are situations, however, in which data having some of the problems described here can be salvaged without a need for reprocessing. Programs have been developed for this purpose on the LASP PDP 11/34 at C.U. using Interactive Data Language (IDL). Use of an interactive language such as IDL is particularly suited to reprocessing work or variability analysis as it permits use of efficient programs coupled with the judgement of the scientist at each stage of processing.

Our basic technique, following a suggestion by Heap (private communication) has been to repeatedly smooth the background tracing provided by VILSPA or GSFC with a running boxcar average until no spectral features remain. This is then subtracted from the gross spectrum, and the resulting spectrum is ripple corrected. This approach only works if the background is not too badly behaved and if it is not comparable to the gross in amplitude. Using these programs, we have been able to identify variability in several OB stars with confidence that the variability is stellar (2).

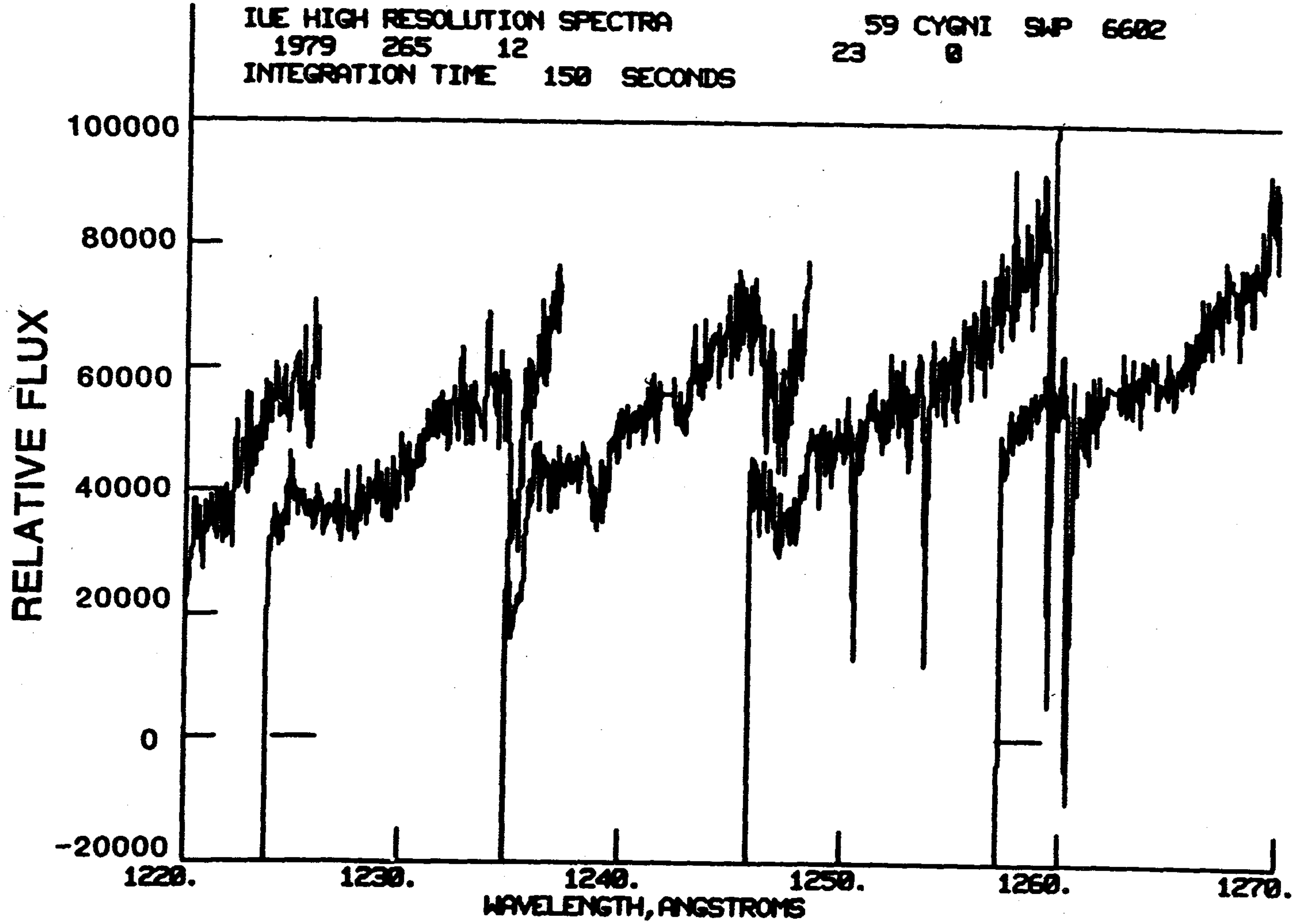
SUMMARY

The types of data-processing errors uncovered at C.U. in IUE high-resolution data indicate that IUE data should be thoroughly examined before analysis is attempted on any spectrum. Use of an interactive language such as IDL and programming similar to that developed at C.U. can make this a routine and relatively painless process. By taking such precautions much greater confidence can be placed in the results of any analysis and interpretation of IUE data whether from single images or as part of a search for temporal variability.

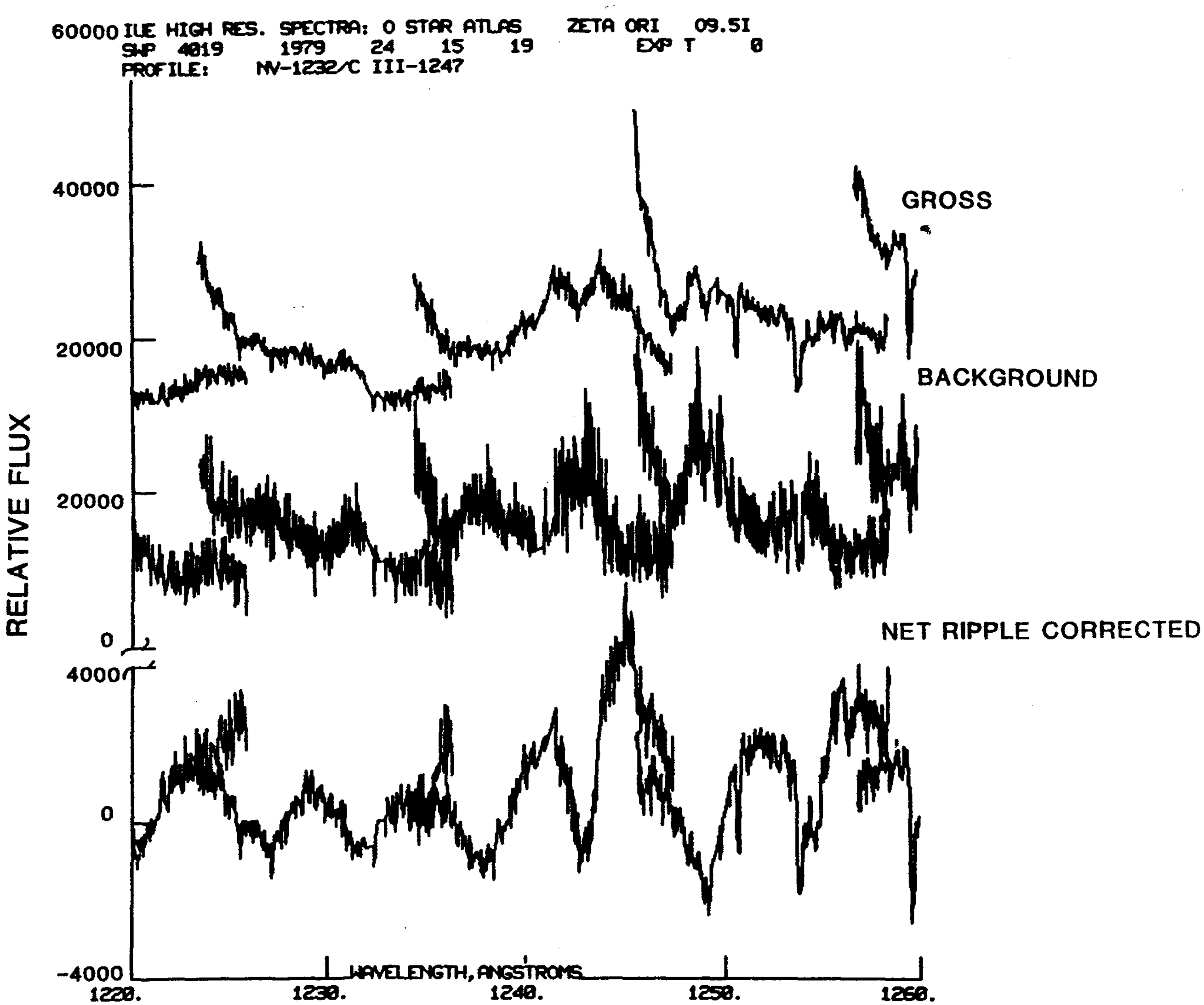
REFERENCES

1. International Ultraviolet Explorer Image Processing Information Manual. Version 1.0, Jan. 1980.

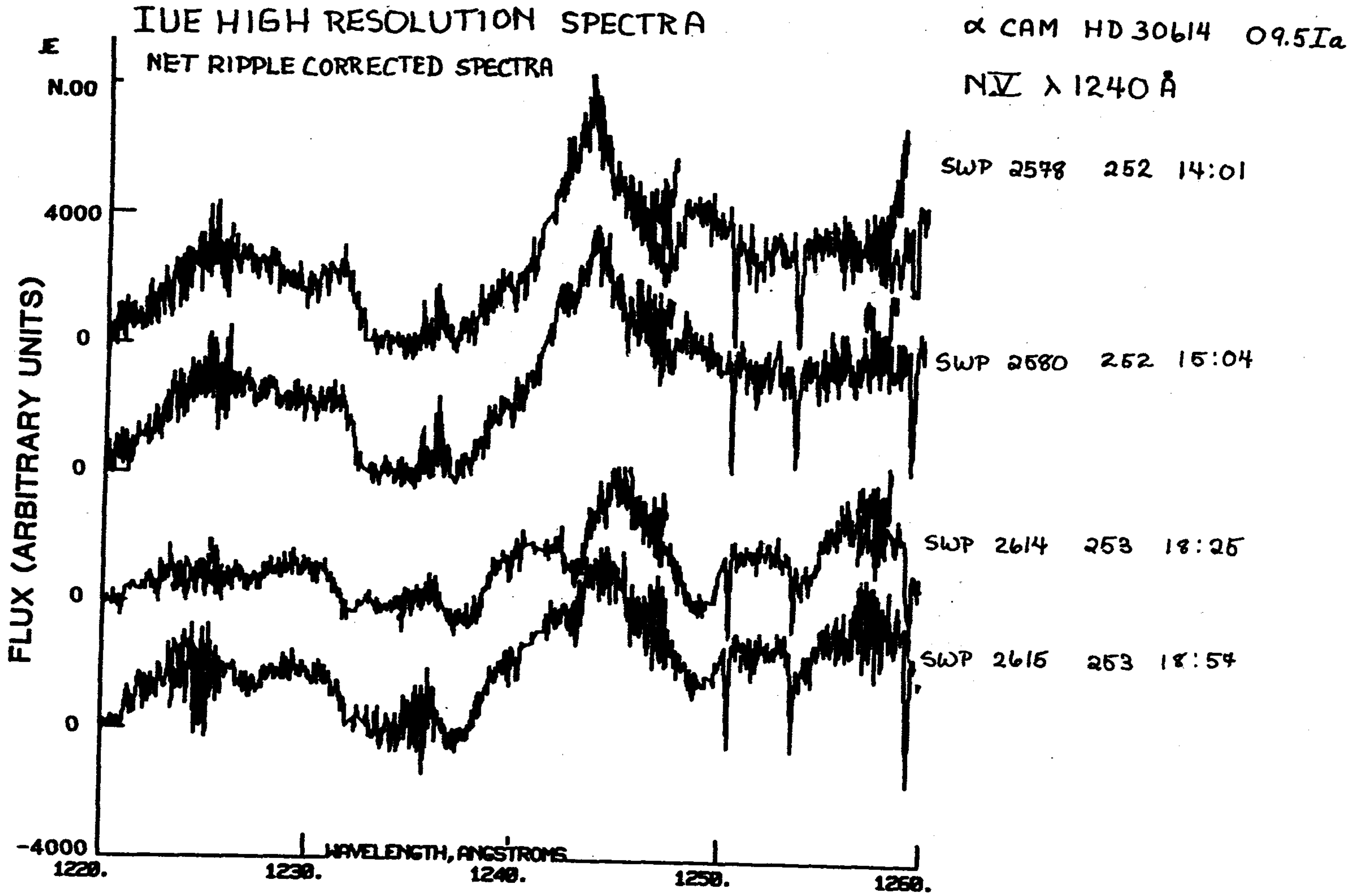
2. Grady, C.A. and Snow, T.P. Jr.: IUE Observations of Variability in Winds from Hot Stars. The Universe in Ultraviolet Wavelengths: The First Two Years of IUE. NASA CP-2171, 1980: this compilation.



1. NV λ1240 P Cygni profile region in 59 Cygni showing poor matching between orders. This image was processed with the new ITF.



2. NV λ1240 region in ζ Ori. All tracings have been ripple corrected for ease in viewing. Top tracing: gross spectrum. Middle: background. Note that amplitude is about the same as for the gross. Bottom: net obtained by subtracting the background from the gross. Note spurious absorption features which have replaced the NV P Cygni profile.



3. NV λ1240 in α Cam. These 4 tracings are the net ripple corrected spectra provided by VILSPA or GSFC. The gross spectra for these are essentially identical. Note the appearance and disappearance of CIII λ1247 absorption. Note also the considerable distortions in the P Cygni profile in SWP 2614, 2615. These changes are of the same order as real variations noted in OB stars, but in this case are completely spurious.