PART III

THE CRITICAL EVALUATION OF DATA

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THE CRITICAL EVALUATION OF STELLAR DATA

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ABSTRACT

Many catalogues of astronomical data appear in book form as well as in a machine-readable format. The latter form is popular because of the convenience of handling large bodies of data by machine and because it is an efficient way in which to transmit and make accessible data in books which are now out of print or very difficult to obtain. Some new catalogues are prepared entirely in a machine-readable form and the book form, if it exists at all, is of secondary importance for the preservation of the data.

In this paper comments are given about the importance of prefaces for transmitting the results of a critical evaluation of a body of data and it is noted that it is essential that this type of documentation be transferred with any machine-readable catalogue. The types of error sometimes encountered in handling machine-readable catalogues are noted. The procedures followed in developing the Goddard Cross Index of eleven star catalogues are outlined as one example of how star catalogues can be compared using computers. The classical approach to evaluating data critically is reviewed and the types of question one should ask and answer for particular types of data are listed. Finally, a specific application of these precepts to the problem of line identifications is given.

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I. INTRODUCTION

In recent years there has been a trend away from publishing catalogues in book form to preparing catalogues by computer and distributing them on magnetic tape with appearance in book form a secondary occurrence. For instance, Kelly and Palumbo (1973) assembled and cross-checked their compilation of atomic and ionic wavelengths shortward of 2000Å using punched cards. They then output the table on magnetic tape and finally prepared a tape to run a linotype machine for preparing the book. At present we have in machine-readable form catalogues that were prepared using a computer and catalogues which first appeared in book form and later were transcribed to a machine-readable format. A need exists for critical evaluation of all this data in order to find its machine-readable characteristics as well as the scientific validity of the data itself.

This need raises the following questions: How does one evaluate data and transfer the evaluation with the data? This concerns the documentation accompanying the data file. What is the best way to express an evaluation? Does one do this by means of a weighting system or does one prepare a written evaluation? What properties of a data file should be evaluated? Are there standard tests which should be applied and for what properties of files of astronomical data?

There are two types of catalogue: (i) a listing of data obtained by one method of measurement, for instance, a radial-velocity catalogue prepared from observations made at one observatory, and (ii) a compilation of a selected type of data from many sources, for instance, the U.S. Naval Observatory catalogue of UBV photoelectric photometry (Blanco, et al. 1968). If one is to use several machine-readable catalogues efficiently, one needs not only a cross index giving the ID's of the astronomical objects contained in the catalogues but also a preface describing what each item in the catalogue is and how it was obtained. Also one needs to know what accuracy may be expected, what systematic and random errors occur, and the completeness of the data.

In every catalogue selection rules have been applied. Thus, the Smithsonian Astrophysical Observatory Star Catalogue (Whipple 1966) lists only 4 to 6 bright stars per square degree. Not all bright stars in a crowded region are given. Other catalogues such as the radial-velocity or photometric catalogues prepared at certain observatories give data for stars of selected spectral types, within specified magnitude limits and within definite declination limits.

In evaluating a catalogue one needs to know what data are given and their sources as well as the selection rules which have been applied in making up the list of objects treated. When printed catalogues were the only sort available it was easy to obtain this

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type of information. It was usually printed as a preface to the catalogue. With machine-readable catalogues one does not always have the needed information. It should be mandatory to provide written documentation with each catalogue tape describing what was in the original preface in the case of old catalogues and documenting fully new catalogues which have been prepared entirely by machine. Many old catalogues are out of print, yet the data contained in them remain valid. These data frequently are now made accessible by means of machine-readable catalogues. A determined effort should be made to develop and distribute documentation for these machine-readable catalogues that preserves the information given in the original preface.

II. CATALOGUE PREFACES

A preface should be prepared and distributed by those who compile the catalogue or who distribute machine-readable copies of an old catalogue. This preface should:

(1) describe the observational data used to provide the tabulated characteristic,

(2) give a detailed description of the instrumentation used to obtain the data,

(3) describe the methods used to obtain the tabulated characteristic from the raw measurements,

(4) describe the selection rules used to define the group of objects studied, e.g. area of sky covered, magnitude limit, spectral distribution considered, atomic species studied, etc.,

(5) give sources for the material used when the results from a series of catalogues or papers have been collated,

(6) describe the weighting system used, if any, to express an evaluation of the data,

(7) describe the search for and evaluation of any systematic trends in the data,

(8) give a study of the random errors in the compilation,

(9) describe the statistics of the objects reported in the catalogue.

With many old catalogues no longer in print, it becomes urgent to reproduce in printed form the essential information given in the old prefaces. Should such information be published as one or more articles in a scientific journal or should it be published as a special publication of a government institution? Whatever happens, the information will slowly be lost. One might consider whether it is appropriate to transfer this needed descriptive material on a magnetic tape as a header record to the original catalogue.

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III. HANDLING ASTRONOMICAL CATALOGUES ON MAGNETIC TAPE

A general utility program can be used with a magnetic tape of a catalogue to dump the contents of the tape or to scan them. These initial reads will determine the properties of the data control block, the number of tracks on the tape, and the type of character code used. In addition they will count the number of physical records and the number of files on the tape. If documentation is available, this information can be verified; if it is not available, it may be possible to generate appropriate documentation by comparing with the original source.

The following procedure is followed when checking out an astronomical catalogue on magnetic tape in the Laboratory for Optical Astronomy at the Goddard Space Flight Center. First one logical record from each block is listed using a high-speed input/output routine. Also the last record is listed to ensure that the entire catalogue is present. This information serves as an index to the entire tape. Next a printout of the first one or two hundred sequential records is obtained to checkout the correspondence of the machine-readable version with the printed version of the tape and/or accompanying documentation. A visual scan of the printout is made to verify that given columns of information line up for subsequent records.

Next a check is made on quantities which should be increasing or decreasing, for instance catalogue identifier or right ascension. Then a check is made on columns which are typically numerical in nature, for instance, magnitude, to make sure that all entires are indeed numerical. Sometimes if a value is not available or is off scale, a substitute, such as asterisks, is given. Since reading these symbols with a numerical format will cause an error, the field is then changed to some large but readily distinguishable number, for instance, 99.9, so that a numerical format read will be valid.

A check on ranges of values to point out gross keypunching errors is made, such as:

$$0 \le \alpha^h \le 23$$
$$0 \le \alpha^m \le 59$$
$$0 \le \alpha^s \le 59$$
$$-90 \le \delta^o \le +90$$
$$0 \le \delta' \le 59$$
$$0 \le \delta'' \le 59$$
$$\sim -5.0 \le m_v \le \sim 20.0$$

spectral types
luminosity ranges
galactic coordinates

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If the catalogue which is being machine-checked has other identifiers, then a cross check with each identifier can be made to verify any common information. By this cross-checking technique, errors in either or both catalogues can be found. The greater the number of catalogues that are available (a definite advantage of a data center) the greater will be the reduction in the number of errors remaining in any given catalogue.

Minimum problems between computers are realized when a tape is written in either EBCDIC or external BCD. Otherwise, special techniques need to be employed which can be very time consuming. For instance, the IBM 360 series cannot represent in binary a -0, for zero will always be given with a + sign. If the record is written in EBCDIC, however, logical tests can be made to differentiate between the two cases.

Computer installations vary in their ability to handle magnetic tapes. Some can process only 7 or only 9 track tapes; not all density ranges can always be handled even if the computer can accommodate both track sizes. Some computers do not have FORTRAN-callable routines to process multifile tapes.

Older machine-readable catalogues often tried to limit information to that which could be carried on an 80-column computer card. In order to accomplish this, they would use overpunches in a given column or columns to represent different cases. Efforts to unravel these overpunches can be quite time consuming especially if the overpunches are not well documented.

In an effort to decrease the number of blank spaces in a given record, frequently only a small number of columns are allotted for a given class of information. An example of this is other catalogue identifiers. It would be more convenient for the user of each catalogue to have each major identifier in its own set of columns. One must keep in mind that the reason for having machine-readable catalogues is so that the machine can easily retrieve any given set of information.

IV. THE GODDARD CROSS INDEX

With the multitude of catalogues that exists in machine-readable form, it is necessary that a cross index exist relating the different identification numbers (ID's) of a star or other astronomical object to each other. At the Goddard Space Flight Center we have developed a cross index that accesses eleven star catalogues. It is the result of merging these star catalogues using the Mark IV File Management System. To use this technique, one first designs a framework into which each catalogue is arranged to fit. For each stellar entry, there is provision for right ascension, declination, visual magnitude, photographic magnitude, spectral type, proper motion and the ID from each catalogue to be merged. Not every one of these "spaces", or

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quantities, will be filled for every star, of course. The computer program is tailored to process each catalogue in order to copy and rearrange the catalogue data to fit this master plan or layout. We refer to any catalogue rearranged in this way as a Submaster.

For most catalogues, the common or linking ID is either the Henry Draper (HD) number or the Durchmusterung (DM) number. We have divided each catalogue according to these two basic ID's: stars having HD number; stars not having HD number, but which do have DM number; those having neither. The HD stars were then sorted by increasing HD, the DM stars were ordered by decreasing DM zones starting at the North Celestial Pole. Those stars having neither HD nor DM number have not yet been merged into the Cross Index.

Once each catalogue has been prepared to fit the required format, it must be ordered in the same sequence as all the other catalogues to be merged, and precessed, if necessary, to the same epoch. One is then ready to add the catalogues, or Submasters, one at a time, to the Master Cross Index. This step consists of matching and merging the Master and a Submaster, where there is a common ID of either HD number or DM number. If the computer finds a match between two HD's, it then tests the positions given by the two catalogues. If the two positions are separated by more than 0.1 degree of arc, the ID from the Submaster is not entered into the Master. Instead, the entire record for that star, as given in the Submaster, is copied into an error file and the Master for that entry is left unaltered. The stars in the error file are later hand-checked against the original catalogues and the key-punched version of the catalogue in an effort to uncover the cause of the discrepancy in position. Sometimes the HD number for one star has been punched incorrectly, and the computer attempts to treat two different stars as if they were the same since their HD numbers read the same. Sometimes a sign error in the declination or a punching error in the position is discovered in either the Submaster or Master.

When the Submaster does not find a match in the Master for its HD or DM number, the Submaster's entry is inserted in the proper sequence. Since there is no star available in the Master list at that point for a comparison check, such merged, or inserted, entries could possibly introduce errors. However, as subsequent Submasters are added, it is likely that such stars will show up in other catalogues to be matched against the Master and thus permit a check.

For ease of computer processing and to gain experience, we started the project with a small catalogue, namely the Yale Bright Star Catalogue (YBS) as our basic Master and then pulled in the Submasters. In each case, a catalogue reference code was carried to indicate the catalogue from which any piece of data

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was recorded. In addition, the computer was given a specific hierarchy of preferred sources for each of the following: position, magnitude, spectral class, and proper motion.

The catalogues included in the Goddard Cross Index at the moment are: the Smithsonian Astrophysical Observatory catalogue, the Henry Draper catalogue, the Boss General Catalogue, Jenkins Trigonometric Parallax catalogue, the U.S. Naval Observatory Photoelectric catalogue, the YBS, the Strömgren-Perry uvby catalogue, the Wackerling Emission-Line Objects catalogue, the Batten Spectroscopic Binaries catalogue, Jaschek's catalogue of Spectral Classifications and the Wilson Radial-Velocity Catalogue. Each of these catalogues has its own peculiarities. The more familiar we were with the machine-readable version of each catalogue, and the more it had been used previously, the fewer the difficulties usually caused by integrating that Sub-master into the system. This does not mean that there would necessarily be less stars in the error file of such a catalogue, since, as explained earlier, the errors could be due to catalogues merged into the Master at an earlier step. Obviously one of the spin offs of such an exercise is to uncover errors which might not have been detected without such comparison checks.

Working with the error files requires one's best sleuthing abilities, using all the information at hand including magnitude and spectral type as checkpoints. One must keep detailed records of where one has looked and what one did or did not find. Each error star has its own case history. Once we are convinced as to where the error is, we make a computer-edit run to correct the errors and to enter the correct catalogue ID's at that point.

Only the most basic data needed to identify each star has been retained in the Goddard Cross Index. These are position, visual magnitude, photographic magnitude, spectral type, proper motion, catalogue ID, HD or DM, and reference catalogue for each of the data items. Because the ID's themselves are preserved for each catalogue, one can retrieve the full catalogue entry for each star.

No weighting system for the data was used, only a hierarchy of preferred catalogues for selecting the data source, when there was more than one choice. Error ranges and critical remarks are not included in the Goddard Cross Index since the data which is preserved here is primarily for identification purposes.

Regarding the preface and explanatory notes we urge the user to examine this material for each catalogue prior to using a machine-readable version of the catalogue. If the preface or notes are provided to the National Space Science Data Center (NSSDC) with the catalogue tape, the Data Center sends out copies of this material when it distributes a copy of the tape. The NSSDC has agreed to act as a distribution center for North America.

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The generation of the Goddard Cross Index is still in progress. The principal difference between this Cross Index and the Catalogue of Stellar Identifications (CSI) prepared by the Strasbourg group is that we have retained all the catalogue ID's explicitly instead of retaining only a flag to indicate membership in a given catalogue, as Strasbourg has done for some of its entries. At present the CSI contains more catalogues and also more stars than does the Goddard Cross Index. Although the ultimate end products of the two endeavours have basic similarities, because the sequence in which the catalogues were merged differs between the two projects, there is a greater chance of uncovering errors than if the same sequence of combination had been followed. Furthermore, a computer comparison of the "final" versions of the two Cross Indices will be an excellent check on the identifications made by that point.

V. CRITICAL EVALUATION OF DATA

All responsible scientists know that the data compiled in catalogues should be evaluated critically. In the case of measured quantities, not only a specific quantitative description of the quantity measured is required, but also a detailed description of how the measurement was made and what care was taken to make the measurement repeatable. In addition, it is desirable to relate the new quantity to values published in older catalogues and to screen the whole body of data for systematic and random errors.

Manipulation of a large data base is greatly facilitated by the use of a computer. The fact that large bodies of data can nowadays be handled rapidly and with little stress on the astronomer makes it mandatory to consider the critical evaluation of data at the time of merging new and old data bases. We already possess a critical evaluation of many of the old sets of data. My concern is that we keep the old evaluations and develop evaluations of the new data.

To talk about systematic and random errors is to imply that there is some value which is, by definition, "correct" or "best". This leads to a philosophical discussion about the meaning of "best". In reference to what characteristic property is the quantity best? All critical evaluations of a body of data should address this question. For a measured quantity such as radial velocity, magnitude or proper motion, "best" is usually defined as the mean value of all available results. The deviation of an individual measure from the mean value is called an error. Sometimes weights are applied in forming the mean or best value. If so, one must ascertain whether the weights result in a bias. Ostensibly the weights are assigned to remove a bias or systematic effect believed to exist in the original data owing to some properties of the raw data or the measuring system. I think what

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one is trying to do by applying weights is to ensure that the total group of deviations from the mean value will follow the normal error function. However, in many astronomical studies one does not have a large enough body of data to justify the assumption that the errors (deviations from best value) will follow the normal error curve. Therefore, it is essential that the methods of obtaining the data and the selection of astronomical objects be well documented and that this documentation travel with the data whether it be machine-readable or not, so all factors affecting the data are known.

Before I deal with a specific case of critical evaluation, I shall review some of the characteristic properties to be considered when evaluating various types of astronomical data. Specialists in each field will recognize that what I mention here is in no way exhaustive. These possible sources of error, and more, are frequently discussed in the introductions to the older catalogues. It is somewhat disturbing that at present, information in these areas is frequently suppressed. I would like to see some way of preserving this information in machine-readable catalogues.

Spectral type
- What is the quality of the spectra? This may be determined from the width of the spectrum, the emulsion used, the dispersion and the level of exposure.
- What line ratios or other criteria were used for type and what for luminosity class?
- What are the standard stars for spectral type?

Colour classes
- How are they defined and what is their relation to spectral type?

Photometry
- How were the extinction corrections obtained? Are there any guiding errors indicating that perhaps all the light did not fall through the diaphragm or that other errors dependent on telescope attitude occurred?
- What were the standard stars used to tie into other photometric series? Were all these standards constant in light?
- How are the bandpasses and the zero point of the magnitude scale defined? Is the scale truly logarithmic over its whole range?
- Was any correction applied for light of the night sky, background or nearby stars or for emission nebulosity?
- How did the sensitivity of the detector degrade with time?
- What is the change in the effective wavelength of each bandpass with spectral type?

Positions
- How are the stellar positions tied to the

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fundamental system of right ascension and declination? What sort of measuring errors occur? Are any of them systematic?

Proper motions - What is the time base between several series of plates?
- What are the measuring procedures and how are the new results tied to old work?

Radio sources/ X-ray sources - What are the error boxes in position?
- What are the uncertainties in intensity?
- How is the bandpass defined and what is its effective frequency?

VI. AN APPLICATION OF THE TECHNIQUES OF CRITICAL EVALUATION

One of the first tasks to be done when one obtains a spectrogram of a new spectral region for a star or other object is to identify the spectral lines which are present either in absorption or emission. One compiles a list of the wavelengths of all apparent lines and compares this list with laboratory lists of the lines known in atomic and ionic spectra from all elements suspected to be present in the star or other object. If there are a sufficient number of coincidences with the key lines of any one species, one concludes that that species is probably present. However, the problem is not simple. On the one hand, all the measured lines may not be real and the list of observed features may be incomplete. There may be false indications of the presence of lines owing to noise in the spectrum record and some key lines may be missed owing to data drop outs. On the other hand, the laboratory lists may be incomplete, although they generally list all strong lines, and lines of the various species frequently fall at nearly the same wavelengths, causing blends. One bases a decision that a certain species is present not only on obtaining coincidence with many lines of the spectrum, particularly with the strongest lines, but also with a consideration of the multiplet structure shown and on the general level of ionization and excitation apparent in the stellar spectrum. Masking of the lines of one species by those due to another is a serious problem, because the spectral resolution of the observed spectrum is rarely better than 0.2Å with the result that the wings of an observed feature are at least 0.3Å wide, while the density of possible lines is frequently 3 per Å or more. When the spectrum of a selected species, such as Fe II, contains many lines, many coincidences should be found before that species is considered to be present. If, however, the species is believed to have a low abundance, such as that for boron, and its spectrum contains few lines in the spectral region under study, one must consider seriously whether the few observed coincidences may be due to chance. I have no quantitative rules to give for handling problems like these. The following example will, however, demonstrate the problem.

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I feel that computer matching of lists of observed lines with lists of lines known in the laboratory is too insensitive a technique for establishing what is present in the spectrum of an astronomical source. The spectroscopist must survey all possibilities for identifications and make a judgement based on the total evidence of degree of coincidence and possible masking. Wavelength coincidence means that the observed and laboratory wavelengths agree to within an amount $\Delta\lambda$, with $\Delta\lambda$ usually in the range $\pm$ 0.2 to $\pm$ 0.4Å.

The problem of identifying the lines in the ultraviolet spectrum of a B star as recorded from space presents a good example of the critical evaluation needed when interpreting ultraviolet spectra of stars.

The observations with OAO-3, Copernicus, are made as follows: In the Princeton experiment a narrow slit, behind which is a photomultiplier, steps through the spectrum travelling along the Rowland circle of the grating. This yields a set of points, nominally a constant $\Delta\lambda$ apart, which give the count per dwell time of 13.76 seconds. These intensity readings are arranged by computer in order of increasing wavelengths, they are corrected statistically for background counts due to corpuscular radiation encountered in orbit and they are corrected for the stray and scattered light in the optical system. They are then plotted as a function of wavelength, the wavelength being corrected for the motion of the star and of the earth and the satellite.

Figure 1 shows typical raw data for the star η CMa, spectral type B5 Ia. The observed points have been connected with straight lines. Lines have been drawn to represent the level of the continuous spectrum and to represent the smoothed level of stray light and noise originating in the detectors because of noise in the electronics and noise due to encounters in orbit with electrons and protons. The statistical uncertainty in a count of N is $N^{1/2}$. On this account alone one wonders whether small changes like the inflection appearing at 1048.2Å are real. These data have been taken with the U2 spectrometer which records intensities with a slit of 0.2Å wide at points separated by about 0.2Å. It is clear that there are many absorption lines which overlap each other in the ultraviolet spectrum of a B type supergiant. The spectrum of the B6 III star, ζ Dra, is similar although the lines are sharper.

Figures 2, 3 and 4 show regions of the spectrum of η CMa and ζ Dra normalized to an adopted continuum after the corrections for stray light, scattered light and particle noise have been made. There are many absorption lines and suggested identifications are noted above the spectrum record. It is clear that the resonance lines of abundant ions are stronger in the supergiant than in the giant star. One wonders how reliable are the series

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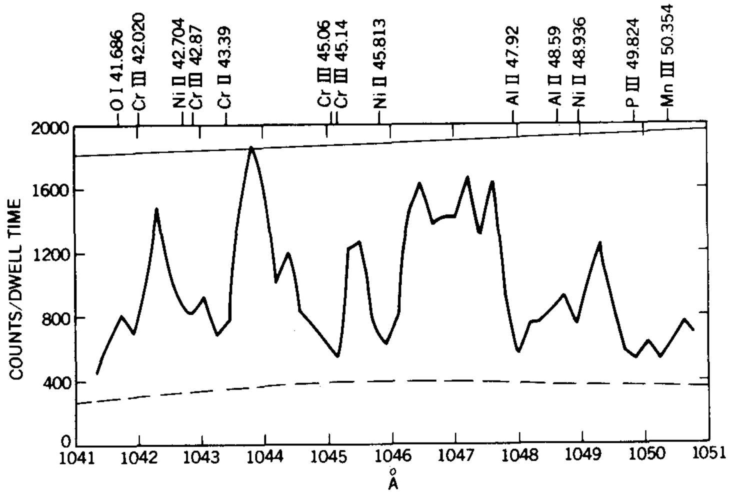

Fig.-1- Raw data in the ultraviolet spectrum of η CMa, B5 Ia, taken with the U2 spectrometer of the Copernicus satellite. The observational points have been joined by a continuous line. The upper thin line represents the continuum joining high points in the spectrum while the broken line gives an estimate of the level of counts due to background.

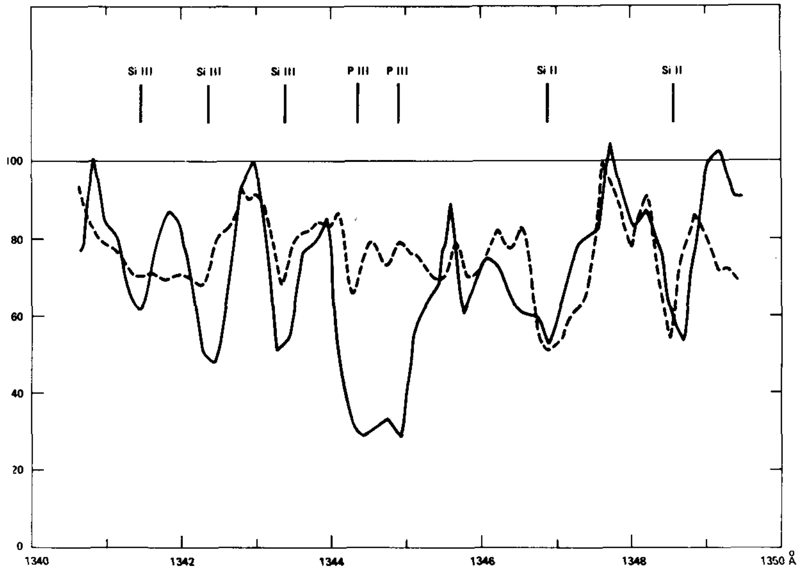

Fig. 2 - The normalized spectrum of η CMa (solid line) and of ζ Dra (broken line) in the vicinity of the P III resonance lines, derived from tracings made with the U2 spectrometer of the Copernicus satellite.

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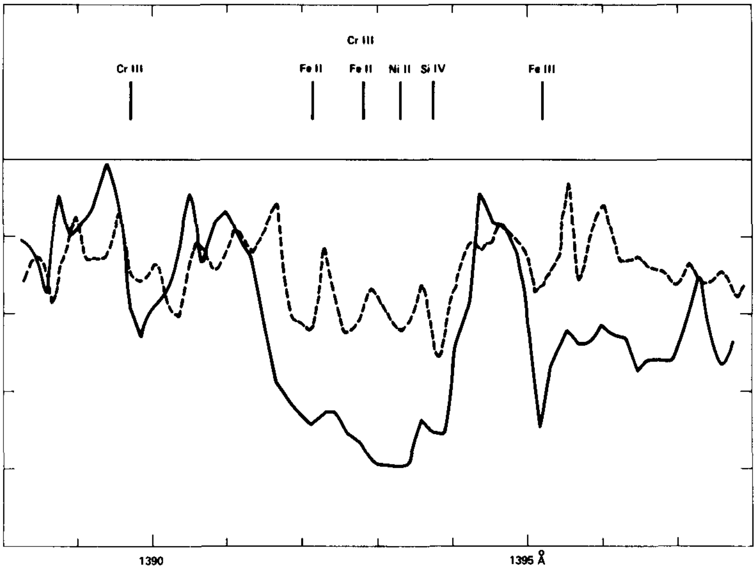

Fig. 3 - The normalized spectrum of η CMa (solid line) and of ζ Dra (broken line) in the vicinity of one Si IV resonance line, derived from tracings made with the U2 spectrometer of the Copernicus satellite.

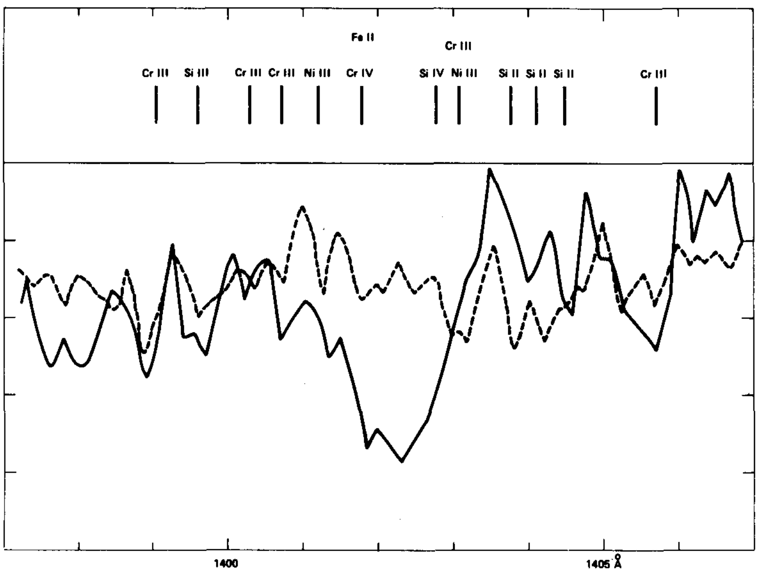

Fig. 4 - The normalized spectrum of η CMa (solid line) and of ζ Dra (broken line) in the vicinity of the other Si IV resonance line. The evidence for Si IV in ζ Dra is slight.

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of identifications that have been made. Each dip and shoulder was considered to indicate the probable presence of an absorption line. After a survey of all the material it was decided that no emission lines are present and that the high points indicate wavelengths in the continuous spectrum.

The average observed line density in the range 1035 to 1425Å is 1.7 lines per Å for ζ Dra. It is slightly less for η CMa. However, over part of the spectrum the count is low and the statistical uncertainty in the number of counts received is 5-10 percent of the maximum count. This uncertainty plus occasional noise spikes which are not eliminated by the statistical correction for noise means that some of the smaller dips and inflection points are false. Which are the false absorption lines?

The identifications were made by listing all lines from likely ions that fell within ± 0.3Å of an observed line. Since the third spectra of the metals (Ti, V, Cr, Mn, Fe) average 2.7 lines per Å in the observed spectral range (see the wavelength lists of Kelly and Palumbo 1973), and there are also many lines from the second, third and fourth spectra of the light elements in this range, most stellar lines have two or more possible identifications. One must consider more data than the number of possible coincidences in order to determine whether an atomic or ionic species is present.

Interesting spectra such as Be II and B II have a few lines in the observed range. Can one decide that these ions are present in ζ Dra? In the case of Be II, 8 lines are known between 1035 and 1425Å. All coincide within ± 0.2Å with stellar lines which are attributed to other ions. One must conclude that Be II could be present in ζ Dra, but that only a detailed spectrum-synthesis study will prove whether it is there or not. In the case of B II, 9 lines fall in the observed range, four of which coincide with lines attributed to other ions. In particular, the resonance line at 1362.461Å may contribute to the feature observed at 1362.40Å but it is certain that Si III λ 1362.366 will also contribute, for other Si III lines are strong in the spectrum of ζ Dra. Only spectrum synthesis will demonstrate if the contribution of B II is significant.

In ζ Dra there are 690 lines between 1035 and 1425Å, six percent of which are unidentified. Some of these are probably spurious. The list of probable and possible species present comes from an assessment of the amount of coincidence between laboratory and observed spectra, the amount of masking by other lines and a knowledge of what level of ionization and excitation occurs in the atmosphere of the star.

Spectra from the International Ultraviolet Explorer (IUE) satellite will be output as tracings which have been prepared by computer from the digitally read charge on the target of the SEC camera tube. This data will require careful evaluation to demonstrate what are true stellar or interstellar spectral features and

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what are spurious features due to noise in the system or to peculiarities of the detectors. Since the spectral element of resolution is about 0.12Å in the high resolution mode for IUE, it will not be possible to measure accurately the profiles of the very sharp interstellar absorption lines found by Copernicus. In the case of the low resolution spectra recorded by IUE, the spectral element of resolution is about 6Å. Clearly in this case every observed feature in the ultraviolet spectrum of a star will be a blend of a number of contributing spectral lines. It will be possible to determine the trends with varying spectral type of the blended strong features in ultraviolet stellar spectra, but it will not be possible to identify uniquely the individual lines contributing to each blend.

VII. SUMMARY

The critical evaluation of data is an activity that every responsible scientist engages in. In the past, when data was published chiefly in books, the results of the critical evaluation were usually presented in a preface. However, many old catalogues are now out of print although the data contained in them continue to have validity to some level. The problem of making old catalogues more widely available can be solved by transcribing the old catalogues into a machine-readable format. However, this action does not solve the problem of transferring with the catalogue either the original critical evaluation or a new evaluation made with reference to modern data. In addition, one must be alert to sources of error or difficulties of interpretation due to computer peculiarities.

New catalogues can be prepared efficiently by computer and the use of a computer will facilitate the intercomparison of various data sets to establish criteria which lead to an evaluation of the scientific value of the data. Although computers can be used to find and correct errors of format and of content, they cannot provide critical evaluation of the data. That is an activity which must be done by the scientist. Astronomers should see to it that adequate critical evaluations of computer-processed catalogues are published in the astronomical literature where they are accessible to all who would use the machine-readable catalogues.

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