COMMISSION No. 45

STELLAR CLASSIFICATION (CLASSIFICATION STELLAIRE)

Report of meetings in Baltimore, Maryland, USA, August 1988

President: R.F. Garrison   Secretary: D.J. MacConnell

Business Meeting, 8 August 1988

I. REPORT OF THE PRESIDENT:

A. IAU Reports on Astronomy:

There were new headings for the IAU reports this time, reflecting the increase in activity in the fields of automatic classification and classification of extra-atmospheric spectra.

It was decided that a given person should be asked to write a report for at least two terms, since it takes at least one term to learn how to do it efficiently and properly, but not much more than two, since it is a somewhat onerous task.

The IAU reports are very valuable, since not all of the references are accessible in the Astronomy and Astrophysics Abstracts under the obvious headings. The personal bibliographic files of an expert in the field usually contain much more. Of course, if the reporter uses only the abstracts, it is not worth the effort. Thus a compilation drawing on the two is more valuable than either separately.

B. Support of Colloquia, Symposia, etc. by Commission 45:

Past:

- Symposium #118 "Instrumentation and Research Programmes for Small Telescopes"
- Colloquium #93 "Physics of Be Stars"
- Colloquium #95 "Faint Blue Stars"
- Workshop "Astronomy with Large Databases"
- Colloquium #106 "Evolution of Peculiar Red Giant Stars"
- Colloquium #110 "Library and Information Services in Astronomy"

Proposed:

- "Evolution of Stars: The Photospheric-Abundance Connection" Bulgaria 1990 summer.
- "Astrophysics of the Galaxy through Precision Photometry" New York 1990 October.
- "WR and Luminous Blue Stars" Indonesia, 1990 June.
- "The Magellanic Clouds" Australia

II. MEMBERSHIP:

A. New Members: G.S.D. Babu (India), R. Coluzzi (Italy), G. Pizzichini (Italy), and Yamashita (Japan).

https://doi.org/10.1017/S0251107X00027607 Published online by Cambridge University Press

B. Resigning Members: D. Evans (USA), Osawa (Japan), B. Warner (South Africa), R. West (Germany), P. Hill (UK), R. Herman (France).

C. Deceased Members: Fracassini, Stromgren.

A suggestion was made that the list should be cleaned up by asking members in the next newsletter if they wish to remain on the list. At the same time, it was suggested that we co-opt new members by inviting people who are writing papers in the field, but who are not members. New IAU members can be proposed by the commissions as well as by member countries. In that way, we can remain an active commission of interested people.

III. OFFICERS:

A. President: M. Golay (Switzerland)

B. Vice President: D.J. MacConnell (USA) with E.H. Olsen (Denmark) as second

C. Scientific Organizing Committee:

1. Remaining:
   R.F. Garrison (Canada) as past president
   N. Houk (USA)
   T. Lloyd-Evans (South Africa)
   E.H. Olsen (Denmark)

2. Retiring:
   Claria (Argentina) - requested
   Heck (France) - after 2 terms
   Slettebak (USA) - after 4 terms!
   Straizys (USSR) - as past-past president

3. Proposed (and adopted) New Members of the S.O.C.:
   C. Corbally (Vatican)
   H. Levato (Argentina)
   N.R. Walborn (USA)
   R. Wing (USA)
   Zdanavicius (USSR)

IV. REPORT OF THE WORKING GROUPS:

After considerable correspondence with various people regarding guidelines for Working Groups, I was surprised to find that:

1) There is no "official status" for working groups; i.e. they don't exist as far as the IAU is concerned.
2) There are NO guidelines.
3) Any or no commissions are needed for "sponsorship," which in any case is not defined.
4) There is no IAU financial support to WG's or their newsletters.
5) There is no need to name a WG before proposing a meeting.

So, we set them up as we wish; they are merely a convenience for large commissions. However, the IAU Secretariat and the Executive Committee wish to be informed about the creation of a Working Group and the name of the chair-person.

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A. Ap Stars:

It was suggested that the name "Ap" stars continue to be used to describe the class, even though the class includes Bp and Fp stars, since "CP" implies a somewhat premature interpretation.

Two half-day sessions on Ap stars were held during the IAU, one on 3 August and the other on 5 August. The new Scientific Organizing Committee includes: K. Sadakane (Japan) (Chair), G. Michaud (Canada), D.W. Kurtz (South Africa), Lanz, and I. Hubeny (USA).

The working group was formed in 1979 jointly with Commissions 29, 36 and 45. Since Commission 29 is the "parent," it is assumed that the main report of the scientific sessions will be reported there.

B. Be Stars:

D. Baade reported that the Be Star Newsletter is published twice a year and 200 copies are mailed. There have been 6 issues totalling 160 pages. Gerry Peters will continue as editor and the newsletter is supported financially by ESO. There is regular updating of the bibliography, providing a good resource for workers in the field.

A scientific session was held on the morning of 6 August at the I.A.U. General Assembly in Baltimore.

A meeting is planned for 1991-2 as well as a workshop at an unspecified time. It was suggested that other stars, such as B stars with extended atmospheres, be included.

The Scientific Organizing Committee consists of Baade (Chair), Balona, Dachs, Doazan, Percy, Peters, Marlborough.

C. Standard Stars:

A. H. Batten reported that the working group on standard stars (Commissions 29, 30, and 45) has continued to operate during the last triennium, its most important function being the production, twice a year, of the Standard-Star Information Bulletin, under the capable editorship of L. Pasinetti.

Some members of the group have been involved in Commission 30's re-evaluation of the standard-velocity stars, which was discussed intensively at this Assembly. The Working Group met on 10 August, both for organizational matters and for scientific communications from Adelman, Andersen, Gerbaldi and Neckel.

The Scientific Organizing Committee is composed as follows: S. Adelman, J. Andersen, A. Batten (CHAIR) M. Gerbaldi, I. Glushneva, H. Neckel, and L. Pasinetti.

D. Peculiar Red Giants:

An IAU Colloquium on the "Evolution of Peculiar Red Giant Stars" (#106) was held in Bloomington, Indiana from 26-30 July 1988.

Suggested and informally organized at the Strasbourg meeting ("Cool Stars with Excesses of Heavy Elements") in 1984, the Working Group was formally constituted at the General Assembly in India (1985) under IAU Commissions 29 (Stellar Spectra) and 45 (Stellar Classification.

A twice-yearly newsletter is edited and mailed by C. Jaschek (Strasbourg). A new editor is needed.

Scientific reports were given by R. Foy ("Angular Diameter of Chi Cygni") and U. Jorgensen ("Effects of Polyatomic Molecules on Carbon Star Atmospheres").

The Scientific Organizing committee is composed of R. Foy, R. Garrison, H. Johnson (CHAIR), A. Renzini, R. de la Reza, V. Straizys, T. Tsuji, and R. Wing.

E. Photometric and Spectroscopic Data:

A.G.D. Philip reported that he and D. Egret are making a hard copy version of the standard star data available from the Strasbourg Data Center.

It was suggested during the meeting that Buscombe's catalogue of MK types would be useful if references were included; however, as is (without references), it is actually a disservice to the field of classification.

The Scientific Organizing Committee includes D. Hayes, C. Jaschek, Nandy, A.G.D. Philip (CHAIR) and W. Warren.

V. FUTURE MEETINGS:

I.A.U. General Assembly, Argentina in 1991; others in section I.

VI. RESOLUTIONS: (no resolutions were proposed)

VII. BY-LAWS:

The possibility of developing by-laws for our Commission was considered and rejected. Members present felt that by-laws are not necessary.

VIII. FUTURE SCIENTIFIC DIRECTIONS FOR COMMISSION 45:

Spectral classification is being done with digital detectors and the new methodology must be calibrated. One problem with tracings is that the eye is drawn to central depths in forming line ratios, but the bottom of a line is where the signal-to-noise ratio is the worst. There are several similar problems to be considered if we are to retain the level of discrimination that has been achieved by photographic techniques. (See report below on scientific session.)

N. Houk has just published volume 4 of the Michigan Spectral Catalogue. Work is in progress on volume 5, which will straddle the equator. Three-quarters of the northern hemisphere plates have been taken. The northern survey spectra go farther into the UV, so classifications may be slightly improved over the southern plates.

Automatic classification will be needed for any future projects involving extensions to the HD - e.g. the next 10 million stars. Work is underway by Kurtz and LaSala to develop sophisticated, pattern-recognition algorithms. See report below on scientific session.

The AAT multi-object spectrograph will provide lots of new digital data. Perhaps "quick-look" types could be provided automatically, followed by a more careful study of the most interesting stars.

Houk pointed out that good photometry is needed for the HD stars. The coverage is especially poor in the Southern Hemisphere, where the spectroscopic classifications are now complete. SAAO will probably not do it. Grenon suggested that Hipparcos will provide much new data, but it won't be of the highest precision because of the transformation necessary to obtain UBV data. The ST guide star program will also provide data, but of low precision. MacConnell suggested that qualified amateurs might be drafted to the project. Another possibility is a dedicated automatic photometric telescope. It is ironic that the difficult task of classification by eye is more than half finished, but the purportedly easier task of carrying out photometry is far from complete.

The IAU Traveling Telescope was mentioned. It has a small, uncooled photometer and a basic low-dispersion spectrograph.

Scientific Sessions, 9 August 1988: Baltimore

I. CLASSIFICATION USING DIGITAL DETECTORS:

Five papers were given during this session. A very brief summary of the main points is given hereinafter.

A. "Some Recipes for Classifying Digital Stellar Spectra" by C.J. Corbally

In the process of comparing digital spectroscopic specimens by eye, it is important to have a consistent "recipe" in order to get repeatable results. After catching the photons, the response of each pixel must be "flattened." It is then useful to convert the pixel numbers to wavelength, remove the effects of atmospheric extinction, and calibrate the counts/sec in terms of flux. The effect should be neutral for the same telescope/detector combination. After folding in the desired smoothing of pixels, the effect is a gain of information for a small number of pixels and a loss for a large number. Rectification may be desirable; while it tends to lose information on the continuum profile, it can gain information accessibility by standardization and readability.

The display of the spectrum on the screen (or tracing) can have a profound effect on the classification process. For example, the wavelength range covered for a given line depth affects whether it is the central depth of the line or the equivalent width which is most noticeable. A problem arises if there is too large a wavelength range along with too large a line depth, because the eye will notice the ratio of line depths more than the ratio of equivalent widths. The problem is that the S/N is poorest at the bottom of strong lines and can lead to serious discrepancies in classifications if the central depth is used.

The choice of signal-to-noise ratio is important. While the canonical value of S/N for IIa-O plates is said to be about 30, that is for an unwidened spectrum. Widening can increase the S/N to the equivalent of well over 100. A S/N of 300 or better is needed to carry out classifications which are equivalent in discrimination to the best photographic work.

Not mentioned above are spectrum subtraction, fourier noise reduction, automatic classification, and other manipulations. The advantages of digital spectroscopy are many and the disadvantages are few, but the pitfalls are many and some of them are very dangerous. It is sobering to remember the look of raw data. However, the appropriate consistent recipe can and will lead to classifiable spectrograms appropriate to the problem. The novice should beware the pitfalls.

https://doi.org/10.1017/S0251107X00027607 Published online by Cambridge University Press

B. "UV Spectral Classification: Why Do It?"
by C.D. Garmany

Is there a direct UV-optical correlation, and are there exceptions to the correlation? The answer is a definite yes to both questions.

It is neither cost effective nor time effective to use IUE strictly for spectral classification, but there are many uses for existing archived data.

The UV has certain very definite advantages. In particular, it is important to compare UV data with optical data to look for anomalies. One can examine different layers of a star's atmosphere in the UV. As a bonus, it is possible to observe extragalactic hot stars with this tiny 0.5-m telescope in about the same time as with a 4-m optical telescope.

The IUE gives digital spectra with resolution of either 6A or 0.25A covering 1170-2000A (SWP) or 2000-3200A (LWP). The S/N is only about 30, though spectra can be co-added. The archives are available to all astronomers and it is possible to carry out on-line searches of the catalogue of observations.

The archives contain a total of 34,000 SWP images and 25,000 LWR and LWP images. These figures can be broken down as follows:

TYPES	HI-DISP	LO-DISP
O V,I	1117	932
B0-B5 V	1710	1581
B0-B5 III-I	1049	766
B5-B9 V	438	362
B5-B9 III-I	208	213
A0-A9 V	305	491

(Multiple observations of the same star are included in these figures, but WR, Oe, Be, Ae, sdO, and sdB are not included.) Wu, et al. (1983 NASA-IUE Newsletter #22) published an IUE UV Spectral atlas of standard stars; Heck, et al. (1984 ESA SP-1052) produced an atlas of "normal" stars. Additional Atlases of hot stars have been published by Dean and Bruhweiler (1985 Ap.J.Suppl. vol.57, p.133), by Walborn, Nichols-Bohlin, and Panek (1985 NASA Ref. Publ. 1155) and by Faraggiana et al. (1986 Ap.J.Suppl. vol.61, p.719).

Walborn and Panek have published a series of papers on the correlation of UV spectra with optical types for O stars. Abbott (1978) showed a correlation of stellar escape velocity with wind terminal velocity. Hutchings (1982), and Bruhweiler, Parsons, and Wray (1982) noted a correlation of wind-line strength with the metallicity derived from the optical.

(This preliminary discussion was followed by the showing of a large number of IUE images to illustrate several interesting lines and correlations).

C. "Near-IR CCD Spectroscopy of Red Stars"
by M.S. Bessell

D. "Digital Spectral Classification of OB Stars"
by N.R. Walborn

Digital spectroscopy has come of age from the viewpoint of spectral classification. The quality is entirely comparable to that previously obtained photographically at 60 A/mm and 1.2 mm widening, permitting extension of the MK methodology to large numbers of faint

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objects. Examples of digital data from three different instruments compared with photographic spectrograms illustrate the point:

1) B supergiants observed by E. Fitzpatrick with the Shectman system at the CTIO 1-m telescope. Resolution 1.2A, 3800-5000A, S/N 50-60.

2) O3 and previously unobserved stars to 15th magnitude in the 30 Doradus central cluster observed by N.R.W. and C. Blades at the AAT with the IPCS and multiple-object, fiber feed. A system under development for the UK Schmidt will provide 400 objects in a single exposure.

3) Ofpe/WN9 spectra observed with the CTIO 4-m SIT vidicon.

An extensive OB digital atlas is planned by N.R.W. and E. Fitzpatrick.

E. "Comments on Classification of B Stars with IUE" by J. Rountree

The purpose of the project is to examine the applicability of the MK System in the ultraviolet region of the spectrum, to define a set of standard stars, and to establish UV classification criteria.

The sample includes 100 stars with "normal" MK types (no e, p, or n) in the range B0-B8, III-V. Most have also been classified at Strasbourg.

The data consist of high-dispersion IUE spectra taken with the SWP camera, rebinned to 0.25A and normalized. The spectra are plotted on a uniform scale and individually mounted.

The methodology is to group the spectra by existing MK spectral type, to define luminosity classes within the spectral range group, to select standards, and to move discordant stars into an earlier or later group. The process is then repeated until no further changes are needed.

Potential problems include: rotation, interstellar lines, stellar winds and variability.

The status of the project is that the material has been prepared, trends have been identified, and the B2 group has been classified. The target date for completion is December 1988 and publication by NASA of an Atlas will be sometime in 1989.

II. AUTOMATIC CLASSIFICATION

There were 4 papers originally planned for this session, but 2 of the authors were unable, at the last minute, to attend the IAU.

A. "Pattern Recognition Techniques Applied to a Homogeneous Data Set" by Jerry LaSala

1. Introduction

Houk, using traditional visual classification techniques, will take about 30 years to reclassify the 225,000 HD stars. Imagine trying to classify all the stars in the BD, CD, and CPD. The next 10 million will be impossible to do by traditional techniques.

The mean errors in Houk's subjective work are:

Houk-Houk	0.44	subtypes (for repeated classifications)
Houk-Garrison	0.63	subtypes
Houk-Cowley	1.3	subtypes

https://doi.org/10.1017/S0251107X00027607 Published online by Cambridge University Press

The goals of automatic spectral classification (see West 1973 in IAU Symposium #50) are: high speed, great endurance; homogeneity (elimination of personal errors); accuracy, detection of variability, and possibility of classification of higher dimension.

There are two approaches: criterion evaluation and pattern recognition. In the former, specified criteria (e.g. widths or strengths of specific lines) are automatically measured, then calibrated in terms of desired quantities (e.g. spectral type and luminosity class).

Pattern recognition, on the other hand, involves the comparison of the "total appearance" of the spectrum with spectra of standard stars and can include cross correlation and multivariate statistical methods.

Most of the previous work was reviewed by Kurtz in "The MK Process and Stellar Classification" (edited by Garrison, 1984).

The criterion evaluation approach has been used with up to 450 specified criteria, and gives mean errors comparable to the best visual classifiers at MK dispersion, but this approach is not practical for objective-prism spectra because of its dependence on absolute measurements.

Cross-correlation techniques give mean errors comparable to visual classifiers, but the metric distance method can give improved results. (See Kurtz in "The MK Process"). The latter also gives as bonuses: the resolution of the classification scheme it has developed, insight into possible higher dimensions, and a criterion for quantitative determination of peculiar features.

2. Application to a homogeneous data set

Plates from the Michigan Spectral Survey were borrowed from N. Houk. These were IIa-O plates with spectra widened to 0.8mm and a dispersion of 108 A/mm. A total of 3000 spectra have been scanned. (Previous studies have involved a maximum of 150 spectra).

The spectra were digitized on an APM, using a raster scan of each spectrum (offset to avoid overlap if necessary) of 128x1024 15-micron pixels. A median filter was used perpendicular to the dispersion to minimize plate defects; this gave 1024-element spectra. The spectra were rectified.

Cross correlation was performed to obtain initial classifications. These were compared with known Houk classifications. Then the metric distance algorithm was applied to classify the stars. This process flags as peculiar any spectrum farther than some maximum distance from <u>any</u> standard. It also flags as peculiar any feature which differs from the standard by more than 3 sigma. A measure of the quality of the classification is obtained from the metric distance.

Illustrations of spectra at all stages were presented for B stars. The beauty of this technique is that it "discovers" the criteria, based on the experience of previous classifications of standards, in much the same way as the visual classifier does. In fact, it is likely that the full development of the method will involve using Houk's 225,000 classifications to teach the machine to classify so it can automatically perform the next several million. In other words, it builds on and extends the traditional techniques rather than serving as a poor substitute.

https://doi.org/10.1017/S0251107X00027607 Published online by Cambridge University Press

B. "The Technique of Automatic Quantitative Stellar Spectral Classification Using Stepwise Linear Regression"
by V. Malyuto and T Shvelidze

Using objective-prism spectra with a dispersion of 166 A/mm, the authors have classified standard F-G-K stars. Criteria were selected from previous work at Abastumani and a linear regression model was adopted. A stepping procedure was introduced to choose the best subsets for independent variables.

Standard stars were classified using this mathematical technique and were compared with their standard values. The r.m.s. differences were found to be +/- 0.11 for spectral classes, +/- 0.5 for luminosity classes, and +/- 0.28 for [Fe/H]. Internally, for those spectra which were repeated, the r.m.s. differences were essentially zero. The only significant deviation was in [Fe/H] for the star HD 201251.

The conclusion is that there is general consistency between the calculated and the standard values of the main physical parameters for standard stars in the sample. The technique is well suited for large-scaled galactic structure investigations. A program is underway to study the main meridional cross-section of the Galaxy.