Transactions IAU, Volume XXIXA
Proc. XXIXA IAU General Assembly, August 2015
Thierry Montmerle, ed.

doi:10.1017/S1743921316000934

DIVISION G
COMMISSION 45

STELLAR CLASSIFICATION
CLASSIFICATION STELLAIRE

PRESIDENT	**Richard Gray**
VICE-PRESIDENT	**Caroline Soubiran**
PAST PRESIDENT	**Birgitta Nordström**
ORGANIZING COMMITTEE	**Adam Burgasser, Ranjan Gupta, Margaret Hanson, Sandy K. Leggett Caroline Soubiran, Harinder P. Singh Birgitta Nordström**

HISTORY AND HIGHLIGHTS

C.J. Corbally & R.O. Gray

1. Pre-history

Commission 45 is solidly anchored in the beginnings of the IAU. It evolved out of Commission 29, which was one of the original commissions and whose title and emphasis was the Spectral Classification of Stars (Transactions of the IAU, Volume I, 1922). C29 was formed with W.S. Adams (Pasadena) as president. Its first members were Miss Cannon, R.H. Curtiss, A. Fowler, A. de Gramont, M. Hamy, H.F. Newall, J.S. Plaskett, H.N. Russell, all very much part of the history of stellar spectroscopy. In the 1922 Transactions report it was recognized the Harvard System of spectral classification "has already been adopted by international agreement. . . "

The Transactions Volume V (1935) shows that under President H.N. Russell C29's name changed to the broader *Stellar Spectra*, though classification still dominated the discussions of its members. Indeed, Russell, still C29's president, reported in the 1938 Transactions Volume VI that "Most of [the members of the Commission who replied to the survey] are in general well satisfied with the existing system of classification and nomenclature." The "existing system" of course would change after the 1943 publication of the MKK Spectral Atlas, but in these WW II years the IAU did not meet in General Assembly.

When the IAU next met in 1950, the president, M.O. Struve, who was working at Yerkes Observatory and so in regular contact with W.W. Morgan, recorded some interesting reflections on the relationship between stellar classification and astrophysics.

> "When the I.A.U. was founded this problem [of classification] was the only one which came within the scope of Commission 29. Since that time the name of the Commission has been changed several times depending upon whether the principal task was to deal with the technical problem of classification or with the physical interpretation of the spectra. . . It may be desirable, now or in the future, to discuss whether a separate commission would be organized to deal with classification problems alone. But while many persons engaged in spectral classification could probably get along quite well without the astrophysical interpretations, the astrophysicist cannot get along without the help of his colleague who is interested in classification.

> Hence, for the immediate future the Commission believes that the present arrangement would be continued and that later, if there should be a sufficient desire for more detached deliberation of classification problems, a sub-committee be formed for this purpose." (Transactions of the IAU VII, p.289).

The arrangement of keeping astrophysics and classification together did continue for a while. The president of C29, M.J.L. Greenstein, reported significantly in the 1955 Transactions IX (p.388): "The Yerkes system developed by Morgan, Keenan and Kellman (MKK) provides a moderate- and low-dispersion, two-dimensional classification which has been extensively used. It is now redefined as the MK system (ApJ 117, 313, 1953)." But spectral classification was being broadened, for in the same report there was also a reference to work of Morgan with Johnson (UBV) and Stebbins (6-color) on photometry. Further, Roman was including a "third parameter, the division by kinematical properties, as shown by spectral peculiarities", denoting "presumably old population I and mild II stars."

All this work helped pave the way for the Vatican conference on Stellar Populations, held in 1957. Indeed, the 1958 Transactions X reported an urgency to extend MK standards to fainter stars to accommodate galactic research with objective-prism surveys. It also proposed an atlas for the southern sky and ones at different dispersions. Interestingly, the merging of C36, *Spectrophotometry*, with C29 was discussed.

The distinction between the more general, stellar spectra and the more specific, classification grew in 1961 when a Sub-Commission of C29, *Stellar Classification*, was formed, with W.P. Bidelman presiding (Transactions XI). It was primarily concerned with spectral classification, while including multi-color photometry (e.g., the Strömgren system) and spectral atlases. Members included, Buscombe, Mlle Divan, D.S. Evans, Keenan, Morgan, Petrie, Ramberg, Mlle Roman, Strömgren, Thackeray.

2. The Commission Established

Finally, in 1964 Commission 45, *Spectral Classification and Multi-band Colour Indices (Classifications spectrales et indices de couleur à plusiers bandes)*, was formally constituted at the Hamburg General Assembly, with W.P. Bidelman as president (Trans.XII), with vice president Ch. Fehrenbach, and an Organizing Committee consisting of W.W. Morgan, R.O. Redman, B. Strömgren, Th. Walraven, B. Westerlund. There were 62 other members reported in 1967 (Trans.XIIIA). Besides spectral classification, their work spanned spectrophotometric methods, catalogues, and spectral atlases, all detailed in 529 papers published in the period 1964 to 1967.

Then followed fifty years of contributions to astronomy by C45 members, under the leadership of its presidents and organizing committees. Its presidents have been, with their year of taking office: Ch. Fehrenbach (1967), B.E. Westerlund (1970), C. Jaschek (1973), B. Hauck (1976), A. Slettebak (1979), V. Straižys (1982), R.F. Garrison (1985), M. Golay (1988), D.J. MacConnell (1991), O.H. Levato (1994), Michèle Gerbaldi (1997), T. Lloyd Evans (2000), C. Corbally (2003), S. Giridhar (2006), R.O. Gray (2009), B. Nordström (R.O. Gray) (2012). The variety in expertise of these presidents, whether this was in spectroscopy, photometry, data bases, or atlases, has been reflected in the variety of the tasks and achievements of C45.

3. Meetings

A major work of any Commission is the running or sponsoring of scientific meetings. Among those with significant participation of C45 have been:

- 1971, IAU Symp 50, Spectral Classification and Multicolour Photometry, Córdoba

https://doi.org/10.1017/S1743921316000934 Published online by Cambridge University Press

• 1972, IAU Symp 54, Problems of Calibration of Absolute Magnitudes and Temperatures of Stars, Geneva
• 1974, Conference, Multicolor photometry and the Theoretical HR Diagram, Albany
• 1975, IAU Symp 72, Abundance Effects in Classification, dedicated to WW Morgan, Lausanne-Dorigny
• 1976, IAU Colloq 32, Physics of Ap Stars, Wien
• 1977, IAU Symp 80, The HR Diagram, dedicated to H.N. Russell, Washington DC
• 1978, IAU Colloq 47, Spectral Classification of the Future, dedicated to A. Secchi, Vatican City
• 1979, IAU Symp 85, Star Clusters, Victoria
• 1979, Colloq, Problems of Calibration of Multicolor Photometric Systems, Dudley Obs.
• 1981, IAU Symp 98, Be stars, Mnchen
• 1981, IAU Symp 99, Wolf-Rayet Stars: Observations, Physics, Evolution, in Cozumel
• 1981, IAU Colloq 64, Automated Data Retrieval in Astronomy, Strasbourg
• 1981, IAU Colloq 68, Astrophysical Parameters for Globular Clusters, Schenectady
• 1983, IAU Colloq 76, The Nearby Stars and the Stellar Luminosity Function, Middletown
• 1983, IAU Colloq 78, Astronomy with Schmidt-Type Telescopes, Asiago
• 1983, Colloq, The MK Process and Stellar Classification, Toronto
• 1984, IAU Symp 111, Calibration of Fundamental Stellar Quantities, Como
• 1984, Colloq, Cool Stars with Excesses of Heavy Elements, Strasbourg Obs.
• 1990, Conf, Evolution in Astrophysics: IUE in the Era of New Space Missions, Toulouse
• 1990, Colloq, The Infrared Spectral Region of Stars, Montpellier
• 1990, Colloq, Precision Photometry: Astrophysics of the Galaxy, Schenectady
• 1992, IAU Colloq 138, Peculiar vs. Normal Phenomena in A-Type and Related Stars, Trieste
• 1993, Colloq, The MK Process at 50 Years: A Powerful Tool for Astrophysical Insight, Tucson
• 1994, IAU Colloq 148, Future Utilisation of Schmidt Telescopes, Bandung
• 1996, IAU Symp 177, The Carbon Star Phenomenon, Antalya
• 2003, Conf, The Garrison Festschrift, Tucson
• 2006, IAU JD 13, Exploiting Large Surveys for Galactic Astronomy, Prague
• 2006, Colloq, The Future of Photometric, Spectrophotometric and Polarimetric Standardization, in Blankenberge

4. Research Highlights

This has to be a very selective list of highlights, while noting that the best place to find one's favourite topic(s) remains the reports of C45 within the Transactions of the IAU themselves. Early in C45's history (1970) its president, Ch. Fehrenbach, again affirmed that the Harvard system had been replaced in practice, for the most part, by the MK system, though now it had a third parameter of metallicity plus a refined ability to classify Am and Ap stars. At this time the photometric systems of Johnson & Morgan, Geneva, Strömgren & Crawford, Walraven, and van den Berg also flourished, each suited for different tasks.

A very significant collaboration was to establish a Working Group with Commission 25 (Photometry and Polarimetry) for the Collection of Photometric and Spectroscopic Data. This was directly connected with the Stellar Data Center (CDS, later named the

Strasbourg astronomical Data Center), which was created in 1972 under C.O. Jaschek and W.P. Bidelman, with director J. Jung. The CDS is best known for hosting the SIMBAD astronomical database, while the VizieR catalogue service and the Aladin interactive sky atlas followed and are also invaluable resources.

In the 1976 Transactions reporting on the progress and work of automated spectral classification merited a separate category, coinciding with the increased computing power available at the time. Work has continued on finding how best to approach this "holy grail" of classification, some concentrating on "criterion evaluation" to estimate the desired astrophysical parameters of stars, others using "pattern recognition" to distinguish the normal from the peculiar stars. A recent success has been the expert program, MK-CLASS, of R.O. Gray and C. Corbally (2014, AJ 147, 80).

During the IAU General Assembly in 1979 the name of C45 was changed to *Stellar Classification (Classification Stellaire)*, on a proposal by R. Wing, since this more comprehensively referred to a subject area in astronomy rather than just to techniques. The meetings sponsored by C45 around this time (see previous section) reflected this decision and showed the power of classification in tackling astrophysical problems.

The remark in the 1988 Transactions report by the then president, R.F. Garrison, that stellar classification provides "systems" for comparison between new types of stars was later borne out by the discovery and definition of the L, T, and Y classes of ultracool dwarfs. This exciting development regarding L and T dwarfs was discussed in a C45 session during the XXIV IAU GA in Manchester (2000). Research on these classes expanded rapidly so that by 2006 the T-dwarf standards became unified. In 2012 R.O. Gray's report recorded that Y-dwarfs had been discovered as distinct from T-dwarfs, and that low-gravity L0-L5 dwarfs had been defined. Developments in near-IR spectral surveys and libraries were crucial to these discoveries.

A very significant contribution to the integrity of stellar classification was announced in the Transactions report of 2003. B.A. Skiff had started producing the General Catalogue of Stellar Spectral Classifications, which critically included classifications derived from spectra, as collected from the literature. Citations were given for every entry, so that the "pedigree" of any classification became obvious. In the 2012 report this General Catalogue had reached a remarkable 452,890 entries.

Another significant contribution to the documentation and preservation of stellar spectral classifications in the literature was made with the publication of an encoding system to represent stellar classes in archival databases and archives (M.A. Smith *et al.* 2011, arXiv:1112.3617). This encoding system is now used in the MAST archive.

5. Working Groups

In 1982 the WG on *Standard Stars* was formed, with L.E. Pasinetti as chair and newsletter editor. It included members from Commissions 29, 30, 45 initially, and those from 25 were added in 1997. The programme proposed was (1) to maintain lists of standards in spectroscopy, photometry and polarimetry, radial velocity determination, flux measurements, as well as atlases, (2) to revise and improve these, (3) to consider the spectral type of the sun and candidates for solar analogues, (4) to address the distribution of standard stars around the sky, and (5) to plan specific observations. This ambitious programme continued through a good number of years under the subsequent chairs R.F. Garrison and C.J. Corbally. Its newsletter had wide distribution to near 50 libraries and more than 100 individuals. M.F. McCarthy and Corbally took over its editorship in 1992, Corbally was the sole editor from 1995, and R.O. Gray became the editor in 2000. The WG became Interdivisional in 2007 (Divisions IV, V, and IX). After the 44$^{\text{th}}$ issue of the

https://doi.org/10.1017/S1743921316000934 Published online by Cambridge University Press

Standard Star Newsletter in April 2008, the conversation on work involving standards lapsed.

The 2000 Transactions report also listed these Working Groups as including C45 participation: Ap and Related Stars (chair: Masahide Takada-Hidai); Active B Stars (chair: D. Baade); Peculiar Red Giant Stars (chair: R. Wing).

The lifespan of C45 included the dramatic transition in stellar spectroscopy from photographic to digital detectors. This transition brought with it the challenge of having data, whether photographic or digital, that are properly calibrated, used, and archived. To meet this challenge the Working Group for Spectroscopic Data Archives was established under C29, having C45 members in active participation, with R.E. Griffin as its vigorous chair.

6. The Future

Deep Galactic photometric and spectroscopic surveys, like Pan Starrs, LSST, SDSS, and Gaia, will all shape the future of stellar classification. So will the large spectroscopic arrays such as the 4000 fibers in LAMOST. Automatic classification will prove to be essential for these surveys. Just what the needs these have for the kind of coordination an IAU Commission or Working Group can supply is not yet obvious. Once it is, the morphing of C45 into a new working group or commission can start. What is clear is that "classification" remains a powerful tool in stellar and galactic astrophysics.

https://doi.org/10.1017/S1743921316000934 Published online by Cambridge University Press