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COMMISSION 45: STELLAR CLASSIFICATION

(CLASSIFICATION STELLAIRE)

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1. INTRODUCTION

This report does not intend to give a complete review of all the papers that appeared since the previous General Assembly but to focus on a few subjects only.

For the XXIVth General Assembly, Commission 45 initiated the venue of a Joint Discussion (JD13) on "HIPPARCOS and the Luminosity Calibration of the Nearer Stars". A session of this JD13 is devoted to "Hipparcos and the MK standards".

The subject of spectral classification of dwarf stars cooler than the M spectral type is new. A Report on this topic is given. Presently two new letters are used to classify those ultra-cool dwarfs : the letter " L" and the letter "T ". These letters should not be considered as an "official" classification scheme endorsed by the Commission 45 of the IAU nor as a "natural" extension of the Harvard Spectral Classification Scheme. The XXIVth General Assembly will be the right place to discuss new systems.

New instruments make their mark and stellar classification is now feasible in nearby galaxies. Large surveys have been completed or are foreseen. New instrumentation allows the observation of a very large number of stars at low resolution, so we stress, in this Report, the importance of the methods directed to automated spectral classification.

2. WORKING GROUPS

Four Working Groups are related to Commission 45.

All of them publish a Newsletter. Information on their activities as well as links to the Newsletters can be obtained from the Web page of Commission 45:

http://www.iap.fr/com45uai/index.html

- Working group on Standard Stars
chairperson : Bob Garrison
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editor of the Newsletter : Pierre North
- Working Group on Active B Stars
chairperson : D. Baade
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- Working Group on Peculiar Red Giant Stars
chairperson : Bob Wing
editor of the Newsletter : Sandra Yorka

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3. SPECTROSCOPY OF ULTRA-COOL DWARFS

(J. Davy Kirkpatrick)

Because the classification of ultra-cool dwarfs is a fairly new topic to this commission, I have included some background information describing how ultra-cool dwarfs are defined and why they are important as a class of objects in their own right. Following the background material, I list the spectral characteristics of each class comprising the ultra-cool dwarfs (M, L, and T), single out the papers in which their classifications are defined, and cite from the last three years other important publications discussing spectra of these objects. In the final section I give brief overviews of two recent meetings relevant to this topic.

3.1. Background

"Ultra-cool dwarfs" are generally defined as those dwarfs having spectral types of M7 or later (Kirkpatrick et al. 1997b). Consider the mass measurements for the components of these cool binary systems:

- Gl 65A, type M5.5 V, M=0.101±0.012 $M_{\odot}$ (Kirkpatrick et al. 1991; Geyer et al. 1988);
- Gl 234B, type M5.5 V, M=0.083±0.023 $M_{\odot}$ (Chance & Hershey 1998; Henry & McCarthy 1993);
- Gl 623B, type ~M5.5 V, M=0.081±0.014 $M_{\odot}$ (Marcy & Moore 1989); and
- Gl 65B, type M6 V, M=0.099±0.012 $M_{\odot}$ (see references above for Gl 65A).

Note that all four objects, the least massive dwarfs *having* robust dynamical mass measures, lie just above the hydrogen-burning minimum mass of ~0.075 $M_{\odot}$. Since these are field objects, they likely have ages of a few Gyr. For objects in the Pleiades (age ~125 Myr), Stauffer et al. (1998) have shown, using the lithium test (Rebolo et al. 1992), that the lowest mass stars have spectral types of ~M6.5 V. Cooler Pleiads all show the presence of lithium in their spectra, indicating that the core temperatures in these fully convective objects are insufficiently hot ($< 2.5 \times 10^6$K) to ignite thermonuclear burning. These cooler Pleiads are believed to be brown dwarfs. Extending this observation to older field objects implies that ultra-cool dwarfs represent a mixture of both stably burning, very low mass stars and ever cooling brown dwarfs.

However, it is incorrect to assume that spectroscopy can definitively determine the nature of an object as either star or brown dwarf. Theory indicates that for ultra-cool objects older than the Pleiades, the absence of lithium does not provide a "yes" answer to the question "Is this object a hydrogen-burning star?" For older objects, even the higher mass brown dwarfs ($0.060 < M < 0.075 M_{\odot}$) will burn lithium as core temperatures eventually exceed 2.5×10^6K, yet these temperatures are still not sufficient to ignite hydrogen thermonuclear reactions.

Spectroscopically, then, stars and brown dwarfs are not always distinguishable. For these objects, spectral classification has been established based on morphology alone, without any underlying physical interpretation attached, and over a broad spectral region observed at low resolution — just the same as the rest of the MK system. As detailed below, ultra-cool dwarfs are now divided into three different spectral types: (late-)M, L, and T.

3.2. Definition of Spectral Classifications — Types M, L, and T

Late-M Dwarfs These objects are dominated in the optical far red by strong oxide bands (TiO and VO). In the near-infrared, bands of H_2O, TiO, CO, and FeH are prominent. Strong atomic lines of K I and Na I are seen in both regions.

The first ultra-cool M dwarf, vB 10, was discovered by van Biesbroeck (1944), although it was over thirty years later that the very cool nature of its spectrum was first revealed (Liebert et al. 1978). Although only 20 ultra-cool M dwarfs were identified (Kirkpatrick et al. 1995) in the fifty years following the original discovery, the last few years have witnessed the discovery of many dozens of additional examples in the field, in nearby star clusters, and in regions of active star formation.

Dwarf spectral standards of type M7, M8, and M9 were first established by Boeshaar & Tyson (1985). Those classifications were quantified by Kirkpatrick et al. (1991) over the spectral region 6300-9100 Å using a variety of spectral ratios to measure the strengths of atomic lines and molecular bands. The classification was further refined in Kirkpatrick et al. (1995). Ultra-cool M dwarfs can have types of M7, M7.5, M8, M8.5, M9, or M9.5. These classifications were first extended into the near-infrared by Jones et al. (1994).

In the last three years, numerous papers have been written on late-M dwarf spectroscopy. The reader is asked to consult Kirkpatrick et al. (1997a,b; and references therein) for optical spectral classification and Delfosse et al. (1999; and references therein) for near-infrared classification.

L Dwarfs L dwarfs are characterized in the optical far red by hydride bands (CrH, FeH, and CaH) and H_2O. TiO and VO are weaker than in M dwarfs and in fact vanish completely at low resolution by mid-L types. The hydride bands themselves even begin to vanish by late-L. Ground-state transitions of the alkali elements (Na, K, Rb, Cs, and sometimes Li) are also strong. The most dramatic features in the far red are the *wings* of the ground-state Na I and K I doublets, which are hundreds of Angstroms wide at mid- and late-L types. In the near-infrared, bands of H_2O, FeH, CrH, and CO are prominent, as are atomic lines of K I and, at the latest types, collision-induced absorption by H_2.

The first L dwarf, GD 165B, was discovered by Becklin & Zuckerman (1988), although it was not until five years later that the unique character of its far red spectrum was revealed (Kirkpatrick et al. 1993). Beginning with three discoveries by Delfosse et al. (1997), many more L dwarfs have now been discovered – over 100 at the time of this writing.

The L dwarf classification system was quantified by Kirkpatrick et al. (1999a) using spectral ratios which measure the strength of oxide bands, hydride bands, and alkali lines as well as the broadening of the K I doublet. This classification has been defined over the wavelength regime 6300-10000 Å and will soon be extended to the near-infrared. Classifications are currently defined for each half-integer subtype from L0 to L8.

Among the important papers published on L dwarfs in the last three years are Ruiz et al. (1997), Delfosse et al. (1997), Tinney et al. (1997), Martín et al. (1997), Tinney et al. (1998), Martín et al. (1998), Rebolo et al. (1998), Tokunaga & Kobayashi (1999), Delfosse et al. (1999), Kirkpatrick et al. (1999a), and Kirkpatrick et al. (1999b).

T dwarfs T dwarfs are defined as those objects exhibiting CH_4 absorption in low resolution, K-band spectra (Kirkpatrick et al. 1999a). Between 6000-10000 Å they are strongly influenced by the broadening of the K I and Na "D" doublets and have a strong ground-state Cs I doublet as well as strong H_2O bands. The hydrides FeH, CrH, and CaH — hallmarks of L-dwarf spectra — are non-existent or very weak at low resolution. In the near-infrared, T dwarfs are dominated by bands of CH_4, H_2O, and H_2 (collision-induced absorption).

The first T dwarf, Gl 229B, was discovered by Nakajima et al. (1995). Its near-infrared spectrum was first presented in Oppenheimer et al. (1995). Beginning in mid-1999, a flurry of other T dwarf discoveries was made, bringing the total number of T dwarfs known to 12.

A T-dwarf classification system has yet to be quantified because full spectra from 6000 Å to 2.5 μm are still being acquired for the newest discoveries. Burgasser et al. (1999) have made the first attempt at a spectral ordering based on the strength of the CH_4 bands in the near-infrared. Two challenges facing the quantification of a classification system are finding more T dwarfs to build up a continuum of types and uncovering examples cooler than those already identified.

Additional information on the spectra of T dwarfs can be found in the following references: Oppenheimer et al. (1995), Geballe et al. (1996), Noll et al. (1997), Oppenheimer et al. (1998), Schultz et al. (1998), Strauss et al. (1999), Burgasser et al. (1999), Leggett et al. (1999), and Cuby et al. (1999).

3.3. Scientific Meetings

Conveniently, two very important meetings on ultra-cool dwarfs roughly bracket the period covered in this report. The first was "Brown Dwarfs and Extrasolar Planets" held in Puerto de la Cruz, Tenerife, Spain, on March 17-21, 1997 (ASP Conf. Ser. 134, ed. R. Rebolo, E. Martín, & M. R. Zapatero-Osorio; San Francisco: ASP). At the time of this conference, a handful of ultra-cool objects were known in the Solar Neighborhood. However, the majority of success in the brown dwarf realm had come through the discovery of ultra-cool dwarfs in nearby open clusters such as the Pleiades and Praesepe and in star formation regions such as ρ Ophiuchi and the Taurus Molecular Cloud. This success is credited to photometric identification of candidate targets in deep, pointed observations of these selected areas of the sky. Despite this success, only a half dozen objects were recognized as having types cooler than the coolest M dwarfs, and spectral classifications for these were just being discussed.

The second meeting was "From Giant Planets to Cool Stars" held in Flagstaff, Arizona, USA, on June 8-11, 1999 (ASP Conf. Ser., in press). At this meeting, the emphasis on ultra-cool spectra shifted from clusters and star forming regions to the field, where dozens of nearby ultra-cool objects had been discovered. The shift in emphasis can be largely credited to target identification by large-area photometric surveys: the 2-Micron All-Sky Survey (2MASS), the Deep Near-Infrared Survey of the Southern Sky (DENIS), and the Sloan Digital Sky Survey (SDSS). Observations of these field objects showed that a continuum of spectra existed between late-M dwarfs and the very cool methane brown dwarf Gl 229B.

A comparison of these two conference proceedings vividly illustrates how far the study of ultra-cool dwarfs has come in just the last two years.

References

Becklin, E. E., & Zuckerman, B., 1988, Nature, 336, 656.
Boeshaar, P. C., & Tyson, J. A., 1985, AJ, 90, 817.
Burgasser, A. J., et al., 1999, ApJ, 522, L65.
Chance, D. R., & Hershey, J. L., 1998, PASP, 110, 425.
Cuby, J. G., et al., 1999, A&A, 349, L41.
Delfosse, X., et al., 1997, A&A, 327, 25.
Delfosse, X., et al., 1999, A&AS, 135, 41.
Geballe, T. R., et al., 1996, ApJ, 467, L101.
Geyer, D. W., Harrington, R. S., & Worley, C. E., 1988, AJ, 95 1841.
Henry, T. J., & McCarthy, D. W., Jr., 1993, AJ, 106, 773.
Jones, H. R. A., et al., 1994, MNRAS, 267, 413.
Kirkpatrick, J. D., Beichman, C. A., & Skrutskie, M. F., 1997a, ApJ, 476, 311.
Kirkpatrick, J. D., et al., 1999a, ApJ, 519, 802.
Kirkpatrick, J. D., et al., 1999b, ApJ, 519, 834.
Kirkpatrick, J. D., Henry, T. J., & Irwin, M. J. 1997b, AJ, 113, 1421.
Kirkpatrick, J. D., Henry, T. J., & Liebert, J., 1993, ApJ, 406, 701.
Kirkpatrick, J. D., Henry, T. J., & McCarthy, D. W., Jr. 1991, ApJS, 77, 417.
Kirkpatrick, J. D., Henry, T. J., & Simons, D. A., 1995, AJ, 109, 797.
Leggett, S. K., et al., 1999, ApJ, 517, L139.
Liebert, J. W., Kron, R. G., & Spinrad, H., 1978, PASP, 90, 718.
Marcy, G. W., & Moore, D., 1989, ApJ, 341, 961.
Martín, E., et al., 1997, A&A, 327, L29.

Martín, E., et al., 1998, ApJ, 507, L41.
Nakajima, T., et al., 1995, Nature, 378, 463.
Noll, K. S., Geballe, T. R., & Marley, M. S., 1997, ApJ, 489, L87.
Oppenheimer, B. R., et al., 1995, Science, 270, 1478.
Oppenheimer, B. R., et al., 1998, ApJ, 502, 932.
Rebolo, R., et al., 1998, Science, 282, 1309.
Rebolo, R., Martín, E., & Magazzù, A., 1992, ApJ, 389, L83.
Ruiz, M. T., Leggett, S. K., & Allard, F., 1997, ApJ, 491, L107.
Schultz, A. B., et al., 1998, ApJ, 492, L181.
Stauffer, J. R., Schultz, G., & Kirkpatrick, J. D. 1998, ApJ, 499, L199.
Strauss, M. A., et al., 1999, ApJ, 522, L61.
Tinney, C. G., Delfosse, X., & Forveille, T., 1997, ApJ, 490, L95.
Tinney, C. G., et al., 1998, A&A, 338, 1066.
Tokunaga, A. T., & Kobayashi, N., 1999, AJ, 117, 1010.
van Biesbroeck, G., 1944, AJ, 51, 61.

4. SURVEYS AND AUTOMATED SPECTRAL CLASSIFICATION

(Ted von Hippel and Coryn Bailer-Jones)

Modern spectroscopic surveys and automated classifiers are becoming so inextricably linked that it is difficult even to summarize one without discussing the other. Some of the automated classifiers are being built because of current analysis needs, though with a clear anticipation of future, larger surveys. Other automated classifiers are being designed specifically for future surveys. Automated classifiers may be applied to databases already in hand, to real-time analysis at the telescope, or one day to on-board satellite analysis where the raw data are too bulky to save and transmit. In addition, many current spectroscopic surveys target galaxies. These surveys may contain stars either by accident or by a purposeful, but minority, assignment of input slits or fibers to stars. Nonetheless, these surveys still represent vast sources of stellar spectral data. Our review embarks by discussing current work, both on automated stellar classification and surveys, and then finishes with plans and portents for the future.

4.1. Automated Spectral Classification

A large part of the effort in automating stellar spectral classification has focused on automating the MK system, and most of this effort has concentrated on the application of supervised feed-forward neural networks. The earliest refereed work can be found in papers by Gulati et al. (1994), von Hippel et al. (1994), Weaver & Torres-Dodgen (1995), and Vieira & Ponz (1995). These authors focused primarily on spectral type classification of intermediate to low resolution spectra (1-15 Å) in the optical and UV. They all used similar methods (namely training and testing on two separate pre-classified sets of spectra), although specific network architectures, optimization, and regularization techniques differed.

In the past few years, these groups have developed their work further. Weaver & Torres-Dodgen (1997) used a set of ~ 250 low resolution (15 Å) O–M, I–V spectra (5800–8900 Å) to produce median classification precisions of 0.5 spectral subtypes and 0.2 luminosity classes. Bailer-Jones et al. (1998) used a database of over 5000 optical (3800–5200 Å) spectra at intermediate resolution ($\simeq$3 Å) and achieved a spectral type classification error of $\sigma = 0.8$ subtypes across the full range of spectral types present (B2–M7). They used a probabilistic network for luminosity class determination, and achieved correct high confidence dwarf/giant discrimination across this range for over 95% of cases. Their work also shows how Principal Components Analysis can be used to identify unusual spectra and compress

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the data by a factor of 30 without any loss of classification accuracy. Singh et al. (1998) trained their networks on 55 spectra (3500–8900 Å, $\Delta\lambda$ = 11 Å) in the range O–M and report a global classification error of $\sigma = 2.2$ subtypes, also using PCA-compressed spectra. In the UV, Vieira & Ponz (1998) used 229 IUE low dispersion spectra (1150–3200 Å, $\Delta\lambda$ = 2 Å) of O3 to K0 stars in both a feed-forward neural network (achieving $\sigma = 1.10$ spectral subtypes) and an unsupervised Self-Organizing Map ($\sigma = 1.62$). Results in the UV were also reported by Mukherjee et al. (1996).

Spectral classification is a means to an end, namely the determination of physical stellar parameters. Two groups have focused on automated methods of determining physical parameters directly. Katz et al. (1998); also see Soubiran et al. 1998) have developed a minimum distance method (a generalization of χ^2 minimization, e.g. Takeda 1995) to parametrize spectra in terms of T_{eff}, [M/H], and log(g) by finding the most closely matching template spectrum. The template grid consisted of 211 spectra (3900–6800 Å, $\Delta\lambda \simeq 0.1$ Å) with 4000 K $\leq T_{eff} \leq$ 6300 K, $-0.29 \leq$ [M/H] $\leq +0.35$, and log(g) for main sequence and evolved stars. At SNR=100, the *internal accuracy* of the method (obtained by parametrizing each template spectrum by removing it from the grid) is 86 K, 0.16 dex, and 0.28 dex for T_{eff}, [M/H], and log(g), respectively. Bailer-Jones et al. (1997) used a neural network trained on synthetic spectra to determine T_{eff} for real spectra of different luminosity classes. This also gave rise to a T_{eff}–SpT calibration across the range B2–M7 accurate to 3–6% and showed evidence for metallicity sensitivity. Gulati et al. (1997a) used this approach and a χ^2 minimization method to obtain a T_{eff}–SpT calibration for G and K dwarfs to within $\pm$250 K.

In the context of optimizing the photometric/spectroscopic system for the GAIA mission (see below), Bailer-Jones (2000) has assessed the accuracy with which T_{eff}, [M/H], and log(g) can be obtained from spectra at a range of SNRs (1000, 50, 20, 10, 5) and (two pixel) resolutions ($\Delta\lambda = 25, 50, 100, 200, 400$). He generated a set of 3500 synthetic spectra over a large wavelength coverage (3000-10000 Å) with T_{eff}, [M/H], and log(g) in the ranges 4000 to 30000, -3.0 to $+1.0$, and 2.0 to 5.0, respectively. Using feed-forward neural networks, the $\Delta\lambda = 100$ Å spectra at a SNR of 10 permitted T_{eff} determination to better than 2%, and average errors for [M/H] and log(g) of 0.24 and 0.37 dex, respectively. As these values are similar to the finest sampling of the parameters in the training data grid, the performance is almost certainly data (rather than model) limited. He has also assessed the relative performance of several newly proposed multi-band filter systems for determining physical parameters.

Readers will note that over the past few years there has been considerable progress in automated classification and physical parametrization. It is clear that good quality two or even three dimensional parametrization/classification is now possible. However, some general points about the recent research should be highlighted. In all of the work discussed above, the quoted accuracies are averaged across a large range of physical parameters: The quality of performance typically varies markedly, with some regions of parameter space being considerably better or worse than others. Moreover, the above studies have usually only looked at 'normal' stars, and then only at the well defined parameters of T_{eff}, [M/H], and log(g) (or SpT and LC on the MK system). The true value of automated methods will be in their application to large surveys, such as SDSS and GAIA. Thus the method must be able to cope with the additional complications of unselected targets, such as binarity, extinction, and variable abundance ratios. In practice, therefore, survey classification methods will have to be somewhat more sophisticated and robust than those currently available. Some work has been done on extinction (e.g. Gulati et al. 1997b) and binarity (Weaver 1999). Equally important is the fact that many future surveys will probe populations very different from those on which the MK system was developed. It is therefore vitally important that classification/parametrization systems are adopted which maximize the scientific return from the survey. The determination of physical parameters directly from spectra is clearly desirable. A past criticism of this approach has been that reparameterization will be required as new models are developed. However, since modeling astrophysical phenomena

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is the goal of our profession, and since the current generation of high speed computers and storage media make this reparameterization relatively easy, we should proceed with physical parameterization undaunted.

References

Bailer-Jones, C. et al. 1997, MNRAS, 292, 157.
Bailer-Jones, C. et al. 1998, MNRAS, 298, 361.
Bailer-Jones 2000, in preparation.
Gulati, R. et al. 1994, ApJ, 426, 340.
Gulati, R. et al. 1997a, A&A, 322, 933.
Gulati, R. et al. 1997b, PASP, 109, 843.
von Hippel, T. et al. 1994, MNRAS, 269, 97.
Katz, D. et al. 1998, A&A, 338, 151.
Mukherjee, S. et al. 1996, Ap&SS, 239, 361.
Soubiran, C. et al. 1998, A&AS 133, 221.
Singh, H. et al. 1998, MNRAS, 295, 312.
Takeda, H. 1995, PASJ, 47, 287.
Vieira, E.F. & Ponz, J.D. 1995, A&AS, 111, 393.
Vieira, E.F. & Ponz, J.D. 1998, ASP Conf. Ser. 145, 508.
Weaver, W.B. & Torres-Dodgen, A.V. 1995, ApJ, 446, 300.
Weaver, W.B. & Torres-Dodgen, A.V. 1997, ApJ, 487, 847.
Weaver, W.B. 1999, in preparation.

4.2. Surveys

In the category of ongoing surveys, Balayan (1997), Abrahamyan (1997), Gigoyan (1998), and their colleagues have published a number of papers (see references) on the stars and their classifications from the First and Second Byurakan Sky Survey. Their survey contains more than 1700 starlike objects with photographic magnitudes brighter than 19.5.

A survey of similar size, the Hamburg/ESO Objective-Prism survey (Wisotzki et al., 1996) was primarily organized to find QSOs in the range $12.5 \leq B \leq 17.5$, but there are also a significant number of stars in this survey. Christlieb et al. (1999) are developing an automated search for metal-poor halo stars from this database. Their catalog should reach ~ 1 magnitude deeper and cover 4.5 times the volume as the very successful HK Survey of Beers and collaborators.

The survey of Beers and collaborates (1992) is currently being actively followed up (e.g. Beers and collaborators 1999), rather than enlarged. Work is underway to automate the parameter determination and analysis of these data (Rhee, Beers & Irwin, 1999).

An innovate survey using a transit telescope with a liquid mirror primary and 33 intermediate (200 to 400 Å) band filters has already reported (Hickson & Mulrooney, 1998) initial results. While not strictly a spectroscopic survey, the large number of passbands allow the survey team to convert the multi-band imaging into low resolution spectroscopy for QSOs, galaxies, and a few hundred thousand Galactic stars.

Surveys of a few thousand stars may benefit from automated classification techniques. Automated techniques will be essential, however, for the largest surveys. Perhaps the largest survey undertaken to date, the Sloan Digital Sky Survey (SDSS, http://www.sdss.org/), will obtain spectra for over one million objects to $R \sim 18$ with a spectral range of 3900 - 9100 Å, R=2000, and SNR ≥ 13 per Å for the faintest objects. Although this survey targets galaxies, it will aid work on automated stellar classification both by the large number of stars accidentally observed and by the development of automated galaxy classification techniques.

Looking towards the future there are many more surveys in the development stages. While most are targeted towards galaxies, ESA's GAIA, for example, will be a very impressive example of bringing multiple, extremely high precision instruments and automated techniques together to determine the type, distance, and radial velocity for ~ 1 billion Galactic stars. Automated techniques are here so essential that the satellite is being built around expert systems and much of the data processing may be done on-board, with results transmitted to Earth. Automated techniques are expected to show their greatest strength when tuned to a particular survey, and GAIA should be an outstanding example of this approach.

References

Abrahamyan H.V., et al. 1997, Astrophysics 40, 131

Balayan, S.K., 1997 Astrophysics 40, 413

Beers, T. et al. 1992, AJ, 103, 1987.

Beers, T. et al. 1999, The Third Stromlo Symposium: Galactic Halo, eds. Gibson, B.K., Axelrod, T.S. & Putman, M.E., ASP Conf. Ser., 165, 202.

Christlieb et al. 1999, The Third Stromlo Symposium: Galactic Halo, eds. Gibson, B.K., Axelrod, T.S. & Putman, M.E., ASP Conf. Ser., 165, 259.

Giogoyan, K.S., et al. 1998, Astrophysics 41, 356.

Hickson & Mulrooney, 1998, astro-ph/9710044.

Rhee, J., Beers, T.C., & Irwin, M.J. 1999, BAAS, 194, 8411.

Wisotzki, L. et al. 1996, A&AS, 115, 227.

5. CLASSIFICATION IN THE UV

(Nolan R. Walborn)

5.1. Scope

This report is based on a survey of the following journals for the years 1996-1999: A&A, A&AS, AJ, ApJ, ApJS, MNRAS, PASP. The ADS and personal compilations for OB stars were used. If the report were limited to papers specifically addressing classification, it would be quite brief. However, many current advances in spectral morphology are produced by astrophysically oriented investigations. They may contain systematic information for a class of stars, or extensive coverage at an atlas level for one or a few stars. Accordingly, many of the latter types of papers are included here. Their coverage may be more representative than complete, but it should provide a useful guide for interested readers. In general, studies primarily directed toward spectral variability have not been included.

5.2. OB Stars

A major developmental study based on IUE high-resolution data for O stars was presented by Penny, Gies, & Bagnuolo (1996, 1997a). The results were applied to tomographically resolved components of spectroscopic binaries by Bagnuolo & Barry (1996, Plaskett's Star = HD 47129, showing enhanced nitrogen); Penny, Gies, & Bagnuolo (1997b, DH Cephei = HD 215835); and Penny, Gies, & Bagnuolo (1999, HD 152248). Cross-correlation studies of similar data for 177 O stars were carried out by Penny (1996), and for 373 OB stars by Howarth et al. (1997). All hot components of composite binary spectra observed with IUE at low resolution were classified by Parsons & Ake (1998). An atlas of 10 Lacertae, O9 V, from HST/GHRS data was presented by Brandt et al. (1998). A library of IUE high-resolution data for B stars was compiled as a spectral-synthesis tool by de Mello, Leitherer, & Heckman (1999), following on the analogous work for O stars by Leitherer, Robert, & Heckman (1995). An EUVE atlas (70-760 Å) was prepared by Craig et al. (1997); Cohen et al. (1998) observed ϵ Canis Majoris (B1.5 II) in the EUV with ORFEUS; and an atlas of the best Copernicus data (1000-1200 Å) for OB stars was presented by Walborn & Bohlin (1996).

A significant methodological investigation of IUE low-resolution data for OB stars in the SMC and LMC was carried out by Smith, Neubig & Bruhweiler (1997, 1999, respectively). De Koter, Heap, & Hubeny (1998) and Crowther & Dessart (1998) analyzed the brightest stars in R136a with HST/GHRS data; the former study found that all of them have O V stellar-wind profiles, showing that they are all of spectral type O3, independently confirming the HST/FOS optical results of Massey & Hunter (1998). UV classification studies of OB stars in other LMC clusters were done by Wilcots, Hodge, & King (1996, NGC 1770 and 2014); Will et al. (1996, NGC 1948); Olsen et al. (1997, LH 72); and Will, Bomans, & Dieball (1997, LH 47). Stellar winds in Local Group galaxies were investigated by Bianchi, Hutchings, & Massey (1996) and by Prinja & Crowther (1998).

5.3. Peculiar Hot Stars

The UV spectra of the LBVs AG and HR Carinae were investigated with IUE by Shore, Altner, & Waxin (1996), and that of the WN star EZ Canis Majoris with ORFEUS by Mandel et al. (1996). Zickgraf et al. (1996) observed B[e] supergiants in the Magellanic Clouds with IUE; Szeifert et al. (1996) studied LBVs in M31 and M33 with HST; and Pasquali et al. (1997) surveyed Ofpe/WN9 spectra in the LMC with HST/FOS. The composite UV wind morphology of η Carinae was investigated with HST/GHRS by Ebbets, Walborn, & Parker (1997) and Lamers et al. (1998).

The EUVE atlas of Craig et al. (1997) includes WDs and CVs, while Hoare et al. (1996) presented the first EUV observation of a PNN (NGC 1360). Zweigle et al. (1997) studied the wind of the PNN in NGC 6543 with ORFEUS. Holberg, Barstow, & Sion (1998) surveyed hot WDs with IUE echelle data. Kruk & Werner (1998) observed PG 1159 stars in the FUV with HUT. Feibelman (1999a,b) investigated O VII λ1522 in PNN and PG 1159 stars, and C III λ2297 as a classification criterion for [WC] PNN, respectively, in IUE data.

5.4. A Stars

Verdugo, Talavera & Gómez de Castro (1999) presented a UV and visible atlas of A-supergiant spectra. A detailed, long-term study of the Ap star χ Lupi with HST/GHRS was summarized by Leckrone et al. (1999). Chromospheric emission lines in late-A spectra were investigated by Simon & Landsman (1997) and Simon & Ayres (1998).

5.5. Late-Type Stars

The EUVE atlas of Craig et al. (1997) emphasizes F-M spectral types. Dupree & Brickhouse (1998) observed luminous cool stars with ORFEUS. The UV spectra of cool giants were investigated by Ayres et al. (1998) and Robinson, Carpenter, & Brown (1998). Carpenter & Robinson (1997) observed α Orionis (M2 Iab) with HST/GHRS, while Carpenter et al. (1997) studied the carbon star TX Piscium similarly.

References

Ayres, T. R., Simon, T., Stern, R. A., Drake, S. A., Wood, B. E., & Brown, A. 1998, ApJ, 496, 428.

Bagnuolo, W. G., Jr. & Barry, D. J. 1996, ApJ, 469, 347.

Bianchi, L., Hutchings, J. B., & Massey, P. 1996, AJ, 111, 2303.

Brandt, J. C. et al. 1998, AJ, 116, 941.

Carpenter, K. G. et al. 1997, ApJ, 486, 457.

https://doi.org/10.1017/S0251107X00002984 Published online by Cambridge University Press

Carpenter, K. G. & Robinson, R. D. 1997, ApJ, 479, 970.
Cohen, D. H., Hurwitz, M., Cassinelli, J. P., & Bowyer, S. 1998, ApJ, 500, L51.
Craig, N. et al. 1997, ApJS, 113, 131.
Crowther, P. A. & Dessart, L. 1998, MRAS, 296, 622.
de Koter, A., Heap, S. R., & Hubeny, I. 1998, ApJ, 509, 879
de Mello, D. F., Leitherer, C., & Heckman, T. M. 1999, ApJ, in press
Dupree, A. K. & Brickhouse, N. S. 1998, ApJ, 500, L33
Ebbets, D. C., Walborn, N. R., & Parker, J. Wm. 1997, ApJ, 489, L161.
Feibelman, W. A. 1999a, PASP, 111, 221.
Feibelman, W. A. 1999b, ApJ, 519, 726.
Hoare, M. G., Drake, J. J., Werner, K., & Dreizler, S. 1996, MNRAS, 283, 830.
Holberg, J. B., Barstow, M. A., & Sion, E. M. 1998, ApJS, 119, 207
Howarth, I. D., Siebert, K. W., Hussain, G. A. J., & Prinja, R. K. 1997, MNRAS, 284, 265.
Kruk, J. W. & Werner, K. 1998, ApJ, 502, 858.
Lamers, H. J. G. L. M., Livio, M., Panagia, N., & Walborn, N. R. 1998, ApJ, 505, L131.
Leckrone, D. S., Proffitt, C. R., Wahlgren, G. M., Johansson, S. G., & Brage, T. 1999, AJ, 117, 1454.
Leitherer, C., Robert, C., & Heckman, T. M. 1995, ApJS, 99, 173.
Mandel, H. et al. 1996, A&A, 310, 239.
Massey, P. & Hunter, D. A. 1998, ApJ, 493, 180.
Olsen, K. A. G., Hodge, P. W., Wilcots, E. M., & Pastwick, L. 1997, ApJ, 475, 545.
Parsons, S. B. & Ake, T. B. 1998, ApJS, 119, 83.
Pasquali, A. et al. 1997, ApJ, 478, 340.
Penny, L. R. 1996, ApJ, 463, 737.
Penny, L. R., Gies, D. R., & Bagnuolo, W. G., Jr. 1996, ApJ, 460, 906.
Penny, L. R., Gies, D. R., & Bagnuolo, W. G., Jr. 1997a, ApJ, 482, 1085.
Penny, L. R., Gies, D. R., & Bagnuolo, W. G., Jr. 1997b, ApJ, 483, 439.
Penny, L. R., Gies, D. R., & Bagnuolo, W. G., Jr. 1999, ApJ, 518, 450.
Prinja, R. K. & Crowther, P. A. 1998, MNRAS, 300, 828.
Robinson, R. D., Carpenter, K. G., & Brown, A. 1998, ApJ, 503, 396.
Shore, S. N., Altner, B., & Waxin, I. 1996, AJ, 112, 2744.
Simon, T. & Ayres, T. R. 1998, ApJ, 500, L37.
Simon, T. & Landsman, W. B. 1997, ApJ, 483, 435.
Smith Neubig, M. M. & Bruhweiler, F. C. 1997, AJ, 114, 1951.
Smith Neubig, M. M. & Bruhweiler, F. C. 1999, AJ, 117, 2856.
Szeifert, Th. et al. 1996, A&A, 314, 131.
Verdugo E., Talavera, A., & Gómez De Castro, A. I. 1999, A&AS, 137, 351.
Walborn, N. R. & Bohlin, R. C. 1996, PASP, 108, 477.
Wilcots, E. M., Hodge, P. W., & King, N. 1996, ApJ, 458, 580.
Will, J.-M., Bomans, D. J., Vallenari, A., Schmidt, J. H. K., & De Boer, K. S. 1996, A&A, 315, 125.
Will, J.-M., Bomans, D. J., & Dieball, A. 1997, A&AS, 123, 455.
Zickgraf, F.-J., Humphreys, R. M., Lamers, H. J. G. L. M., Smolinski, J., Wolf, B., & Stahl, O. 1996, A&A , 315, 510.
Zweigle, J. et al. 1997, A&A, 321, 891.

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6. PHOTOMETRIC CLASSIFICATION

(Hugo O. Levato and Juan Claria)

A good number of contributions to the classification of stars through photometry have been published during the triennium. The results derived from Hipparcos photometry produced a big impact in the field. We will mention in this summary papers that include a relatively large number of stars in order to keep the length of this summary within the space allowed. As usual we will divide the contributions according to the band width of the photometric system used.

6.1. Wide-band systems

van der Blik et al. (1996) described the infrared photometric system for the single channel photometers at ESO, which have been used from 1983 until 1994. Redd & Vance (1996) reported UBV photometry of 284 stars listed in Stephenson and Sanduleak's Luminous Stars in the Southern Milky Way catalog. Menzies et al. (1996) reported UBV(RI)c observations of 37 standard stars in IC 4996. Weis (1996) published multicolor broadband photometry for 1194 stars with large proper motion. Worthey & Fisher (1996) established a purely empirical UBVRIJHK color-T_{eff} calibration for multi-metallicity isochrones and population models. Stone (1996) presented fluxes for 103 stars which were observed for HST calibration. Winkler (1997) derived red and infrared colours of 257 early-type stars from observations through the UBV(RI)cJHK and Hβ filters. Using V and I passbands Vallenari et al. (1997) derived photometric data for 36,000 stars down to V = 22 mag in a field of the Baade window. Lee et al. (1997) presented JHK magnitudes for 202 high proper motion stars. Strassmeier et al. (1997) published 9250 differential UBV and/or V(RI)c observations for 23 chromospherically active stars, single and binary, pre-main sequence and post-main sequence, taken between 1991 and 1996. Pavlovski et al. (1997) reported results of the systematic UBV monitoring of Be stars between 1972 and 1990. Percy et al. (1997) reported long-term UBV observations of 23 bright, active Be stars. Carrasco et al. (1997) presented UBVRI photometry in the Kron-Cousins system for 272 stars of the FK5 Extension Catalogue stars. Reed et al. (1998) published UBV CCD photometry of 90 stars listed in the Case-Hamburg Catalogue of Luminous Stars in the Northern Milky Way. von Braun et al. (1998) published new UBVRI photometry of giants in globular clusters. They combined the results with JHK photometry to produce color sequences. Sinachopoulos & Van Dessel (1998) published UBV photometry of visual binaries. Davidge (1998) published near infrared photometry (JHK) of bright giants in the central regions of the Galactic Bulge. Patterson et al. (1998) published (V)RI photometry of 73 nearby star candidates in the southern hemisphere. van Houten et al. (1999) published five color photometry in the Walraven color system of OB stars in the southern hemisphere.

References

van der Blik, N.S., Manfroid, J., & Bouchet, P. 1996, A&AS, 119, 547.

von Braun, K., Chibouvas, K., Minske, J.K., Salgado, J.F., & Worthey, G. 1998, PASP, 110, 810.

Carrasco, G., Ledoux, C., & Loyola, P. 1997, A&AS, 126, 311.

Davidge, T.J. 1998, AJ, 115, 2374.

van Houten, C.J., Walraven, Th., & Walvaren, J.H. 1999, A&S, 137, 113.

Lee, S.G., Carney, B.W., & Probst, R. 1997, J. Korean Astr. Soc., 30, 1.

Menzies, J.W., & Marang, F. 1996, MNRAS, 282, 313.

Patterson, R., Ianna, P.A.,& Begam, M.C. 1998, AJ, 115, 1648.

Pavlovski, K. et al. 1997, A&AS, 125, 75.

Percy, J. et al. 1997, PASP, 109, 1215.

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Redd, B.C., & Vance, S.J. 1996, AJ, 112, 2855.
Reed, B.C., Carmody, P.M., & Landy, D.H. 1998, PASP, 110, 27.
Sinachopoulos, D., & Van Dessel, E. 1998, A&AS, 130, 299.
Strassmeier, K.J., Bartus, J., Cutispoto, G., & Rodonó, M. 1997, A&AS, 125, 11.
Stone, R.P.S. 1996, ApJS, 107, 423.
Vallenari, A., Chiosi, C., Bertelli, G., & Ng, Y.K. 1996, ASP Conf. Ser. 102, 320.
Weis, E.W. 1996, AJ, 112, 2300.
Winkler, H. 1997, MNRAS, 287, 481.
Worthey, G., & Fisher, B. 1996, BAAS, 28, 1366.

6.2. Medium-band systems

Strömgren system Morale et al. (1996) presented results of a uvbyβ photometric study of a sample of X-ray active late-type stars. Using the uvby system, Arellano Ferro & Mantegazza (1996) obtained a reddening-free calibration for [Fe/H] valid for giants and supergiants of intermediate temperature. Gray et al. (1996) determined T_{eff} log(g) and [M/H] for a set of 56 field HB candidates using Strömgren photometry. Clausen et al. (1997) published accurate standard uvby indices for 73 southern B, A, F and G stars with V magnitudes between 8.2 and 10.9. Eggen (1997) derived heavy element abundances of 61 RHB and early AGB stars from Strömgren photometry. Adelman (1998) published differential uvby photometry for four magnetic chemically peculiar stars. Jordi et al. (1997) analyzed the currently available calibrations in Strömgren photometry by using open clusters. Massana et al. (1998) studied the capacity of the ubvyHβ system for detecting CP stars. Katcheva (1998) published Strömgren and Hβ photometry of 130 stars in the Carina section of the Milky Way.

Vilnius system Forbes et al. (1997) defined a new set of 60 standard stars in the E-regions for the Vilnius system. Tautvaisiené (1996) carried out three-dimensional classification in the Vilnius system for a set of RHB stars of the thick disk. Cernis et al. (1997) established 73 new standard stars of magnitudes 9-13 in the Vilnius system.

DDO system Cousins & Caldwell (1996) discussed several problems in the DDO photometry that have implications for precision photometry in general. Claria et al. (1996) derived DDO metal abundances of high-luminosity late-type stars in 23 open clusters.

6.3. Narrow-band systems

Damineli et al. (1997) described a photometric system designed for detection of WR stars in the near infrared region using narrow-band filters.

6.4. Other systems

Vreux et al. (1996) presented the first tests of a five-filter photometric system aimed at WR classification. Kunzli et al. (1997) presented calibration of Geneva photometry for B to G stars in terms of T_{eff}, log (g) and [M/H]. Straizys (1997) applied the Stromvil system for a search of solar-type stars. Maitzen et al. (1997) reported the first CCD measurements carried out in the three filter Δa system for detecting CP2 stars. Marchenko et al. (1998) studied the results of the Hipparcos photometry for 141 O and WR type stars. Maitzen et al. (1998) observed 131 Ap and Am stars in the Δa system with the purpose of contributing to the study of the 5200 feature in CP stars. Straizys et al. (1997) published the project for classifying peculiar stars with the GAIA-type satellite. Roger et al. (1998) discussed a new system for classifying WR stars. Vogt et al. (1998) published an extensive Δ a-photometric survey of 803 southern A and B type stars. Krisciunas et al. (1998) presented results with a 5 color filter photometry identical to the system used by the Sloan Survey, for almost 2,000 objects, mostly stars. Alcock et al. (1998) published mean colors and magnitudes of 1800 RR Lyrae stars of the Galactic Bulge produced by the MACHO project. Adelman (1998) discussed the Hipparcos photometry of chemically peculiar B,A, and F stars.

References

Adelman, S.J. 1997, A&AS, 125, 65.

Adelman, S.J. 1998, A&AS, 132, 93.

Alcock, C. et al. 1998, ApJ, 492, 190.

Arellano Ferro, A., & Mantegazza, L. 1996, A&A, 315, 542.

Cernis, K., Bartasiūtė, S., Straizys, V., & Janulis, R. 1997, Baltic Astron., 6, 573.

Claria, J.J., Piatti, A.E., & Osborn, W. 1996, PASP, 108, 672.

Clausen, J.V., Larsen, S.S., Garcia, J.M., Giménez, A., & Storm, J. 1997, A&AS, 122, 559.

Cousins, A.W.J., & Caldwell, J.A.R. 1996, MNRAS, 281, 522.

Damineli, A., Jablonski, F., de Freitas, L.C., & de Freitas-Pacheco, J.A. 1997, PASP, 109, 633.

Eggen, O.J. 1997, AJ, 114, 1666.

Forbes, M.C., Dodd, R.J., & Sullivan D.J. 1997, Baltic Astron. 6, 371.

Gray, R.O., Corbally C. J., & A.G.D., Philip 1996, AJ, 112, 2291.

Jordi, C., Masana, E., Figueras, F., & Torra, J. 1997, A&AS, 123, 83.

Kaltcheva, N.T., 1998, A&AS, 128, 309.

Krisciunas, K., Margon, B., & Szkody, P. 1998, PASP, 110, 1342.

Kunzli, M., North, P., Kurucz, R.L., & Nicolet, B. 1997, A&AS, 122, 51.

Massana, E., Jordi, C., Maitzen, & Torra, J. 1998, A&AS, 128, 265.

Maitzen, H.M., Pauzen, E., & Rode, M. 1997, A&A, 327, 636.

Maitzen, H.M., Pressberger, R., & Pauzen, E. 1998, A&AS, 128, 573.

Marchenko, S.V. et al. 1998, A&A, 331, 1022.

Morale, F., Micela, G., Favata, F., & Sciortino, S. 1996, 119, 403.

Royer, P., Vreux, J.M., & Manfroid, J. 1998, A&AS, 130, 407.

Straizys, V. 1997, IAU Coll. 161, Publisher: Bologna, Italy, p. 375.

Straizys, V., Hog, E., & Philip, A.G.D. 1997, ESA SP-402, 761.

Tautvaisienė, G. 1996, ASP Conf. Ser., 109, 547.

Vogt, N., Kerschbaum, F., Maitzen, H.M., & Faúndez-Abans, M. 1998, A&AS, 130, 455.

Vreux, J.M., Manfroid, J., & Royer, P. 1996, 33rd Liège Coll., 31.

7. CATALOGS AND ATLASES

(Nancy G. Roman)

7.1. Atlases

Gray is preparing a Digital Spectral Classification Atlas that will soon be available, probably on the Web at http://www.phys.appstate.edu/spectrum/. This will be along the lines of the MAT atlas and the Keenan and McNeil atlas but will use CCD spectra. Valdes et al. (1998) are preparing a CCD atlas of approximately 500-800 stars at about 1 Å resolution over most of the optical region (3750-9400 Å). It will cover a wide range of temperature, gravity, and metallicity. Hopefully, the data will be released about the end of 1999. Pickles (1998) has compiled a Stellar Spectral Flux Library of observed spectra for the region 1150-10620 Å with coverage of 10620-25000 Å for about half of the entries. The 131 flux-calibrated spectra include all normal spectral types for solar abundance, metal-weak, and metal-rich F-K dwarfs and G-K giants. The spectra are given as flux versus wavelength in steps of 5 Å. Montes et al. (1997) have compiled a library of 170 high and mid-resolution spectra of F, G, K, and M stars in the regions of CaII H & K, Hα, Hβ and NaI D and HeI D3 lines. Although intended as templates for studies of chromospherically active stars, the library can also be used for spectral classification purposes. Montes is maintaining a www page (http://www.ucm.es/info/Astrof/spectra.html) of libraries of stellar (including the Sun) spectra, with links to much other spectroscopic information.

Hanson et al. (1996) have compiled a 2 μ (K-band) atlas of spectra of 180 well studied, optically visible, luminous stars. Most are O or B stars. They develop classification criteria for this spectral region. The atlas serves as a standard for classification of spectra from heavily reddened regions. Kerton et al. (1999) have prepared an atlas of O stars in the yellow green region as an aid to classifying heavily reddened stars. Wu et al. ((1996); the full atlas will be available soon on the Web) have produced an ultraviolet spectral atlas (covering the region 1150-3200Å) of approximately 550 standard stars selected from the final IUE archive. Barnbaum et al. (1996) have compiled a moderate-resolution spectral atlas of carbon stars on the 1993 Revised MK system as refined and extended. Spectra of 39 stars are presented in detail and a catalog of 119 carbon stars is given. Verdugo et al. (1999) presented an atlas of profiles of lines in 41 A-supergiants observed at high and medium resolution in the visible and ultraviolet. Drilling et al. have established an MK-like system for classifying hot sub-dwarfs including "spectral class", "luminosity class", and "helium class". An atlas (in The Kth Reunion, L. Davis Press, Schenectady, NY) of spectra for each class is in press.

References

Barnbaum, C., Stone, R.P.S., & Keenan, P. 1996, ApJS, 105, 419.

Hanson, M.M., Conti, P.S., & Rieke, M.J. 1996, ApJS, 107, 281.

Kerton, C.R., Ballantyne, D.R., & Martin, P.G. 1999, AJ 117, 2485.

Montes, D.,Martin, E.L., Fernandez-Figueroa, M.J., Cornide, M., & De Castro, E. 1997, A&AS, 123, 473.

Pickles, A.J. 1998, PASP, 110, 863.

Valdes et al. 1998, Stand. Star Newsletter #24.

Verdugo, E., Talavera, A., & De Castro, A.I.G. 1999, A&AS, 137, 351.

Wu, C., Schiffer, F.H., & Crenshaw, D.M. 1996, BAAS, 188, 5510.

7.2. Broad Catalogs

Houk reports that volume 5 ($\sim$ 34000 stars between 12° and +5°) is now finished and being proofread. Buscombe has completed his 14th General Catalogue of MK Spectral Classifications. This will be available from the astronomical data centers, as are most of the earlier ones. Many of the entries are previously unmatched infrared sources. Balayan (1997a, 1997b) has classified 626 stars and objects with continuous spectra from the Second Byurakan Spectral Sky Survey. The objects have right ascensions 7h45m to 17h15m, declinations +49° to +61°, and $10.12 \leq m_{pg} \leq 19.5$.

References

Balayan, S.K. 1997a, Astrofizika, 40, 153.

Balayan, S.K. 1997b, Astrofizika, 40, 327.

7.3. Hot Stars

Smith et al. (1999) have developed a three-dimensional classification for WN stars with which they have classified all of the WN stars in the Galaxy and two thirds of those in the LMC. Breysacher et al. (1999) have compiled a catalog of 134 WR stars in the LMC including equatorial coordinates, photometric data, spectral classification, binary status, and correlation with OB associations and HII regions. Figer et al. (1997) have compiled an atlas of K-band spectra (R 525) of 38 northern galactic WR stars. Steele et al. (1999) have provided spectral types and rotational velocities for 58 Be stars of luminosity classes III to V.

Lennon (1997) devised a new classification system for B-supergiants in the SMC on which he classified 64 stars. He then linked the system with the MK system by requiring that the stars in the same class have similar physical characteristics, other than metal abundance. Neubig and Bruhweiler (1997), Smith Neubig (1999) have classified 133 O and B stars in the SMC and 143 stars in the LMC from low resolution IUE spectra. The classification system, that is independent of the MK system, is designed to be applicable to O and B stars in other galaxies with comparable metallicities. Walborn & Blades (1997) have classified 106 OB stars within the 30 Doradus Nebula. Massey & Hunter (1998) have classified 65 HST spectra of the bluest, most luminous stars in R136. Walborn et al. (1999) have classified compact OB Groups in the Large Magellanic Cloud.

Kilkenny et al. (1997) are engaged in a survey of blue stellar objects at high galactic latitudes in the southern hemisphere. Spectra of 675 blue objects have been published. These are in the northern Galactic Cap (more than $\sim 30°$ from the plane) south of $-12.3°$ Parsons & Ake (1998) classified from their far UV IUE spectra the hot companions of more than 100 middle- and late-type giants and supergiants. Craig et al. (1997) have prepared an atlas of extreme ultraviolet spectra (70 - 760Å) of 95 bright sources. The atlas is grouped by optical type.

References

Breysacher, J., Azzopardi, M., & Testor, G. 1999, A&AS, 137, 117.

Craig, N. et al. 1997, ApJS, 113, 131.

Figer, D., McLean, I.S., & Najarro, F. 1997, ApJ, 486, 420.

Kilkenny, D., O'Donoghue, D., Koen, C., Stobie, R.S., & Chen, A. 1997, MNRAS, 287, 867.

Lennon, D.J. 1997, A&A, 317, 871.

Massey, P., & Hunter, D.A. 1998, ApJ, 493, 180.

Neubig. M.M.S., & Bruhweiler, F.C. 1997, AJ, 114, 1951.

Smith, L.F., Neubig. M.M., & Bruhweiler, F.C. 1999, AJ, 117, 2856.

Parsons, S.B., & Ake, T.B. 1998, ApJS, 119, 83.

Smith, L.F., Shara, M.M., & Moffat, A.F.J. 1996, MNRAS, 281, 163.

Steele, I.A., Negueruela, I., & Clark, J.S. 1999, A&AS, 137, 147.

Walborn, N.R., & Blades, J.C. 1997, ApJS, 112, 457.

Walborn, N.R., Drissen, L., Parker, J.Wm., Saha, A., MacKenty, J.W., & White, R.L. 1999, AJ, 118, in press (October issue, STScI Preprint 1369)

7.4. A-type stars

Wilhelm et al. (1999) have used medium-resolution spectroscopy and UBV photometry to classify 1121 stars, mainly A-type stars and mainly in the halo of the Galaxy. Gray & Corbally (1998) has classified 38 Herbig Ae stars and 22 pre-main sequence stars in three young clusters on the basis of an extension to the MK system.

Paunzen et al. (1997) have produced a catalog of 45 λ Boo stars. Gray has established a Web page:http://www.phys.appstate.edu/spectrum/lamboo.html on λ Boo stars

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and including an up-to-date bibliography. Corbally & Gray (1996) have classified 67 stars whose photometry makes them field horizontal branch candidates. Ten λ Boo-like stars are included.

References

Corbally, C.J., & Gray, R.O. 1996, AJ, 112, 2286.
Gray, R.O., & Corbally, C.J. 1998, AJ, 116, 2530.
Paunzen, E., Weiss, W.W., Heiter, U., & North, P. 1997, A&AS, 123, 93.
Wilhelm, R. et al. 1999, AJ, 117, 2329.

7.5. Cool Stars

Keenan is working on revised MK standards for all late-type stars. The completed portion (first nine hours) is available on the Web (http://www.astronomy.ohio- state.edu/MKCool/). Malyuto et al. (1997) have developed classification criteria for red supergiants in the wavelength range 4800 to 7700 Å based on the strength of individual features. They present classifications for 47 southern stars that are available in the astronomical data centers. Bartkevicius & Lazauskaite (1997) have classified 848 stars suspected to be Population II stars. Not all were. Pesch & Bidelman (1997), Bidelman & MacConnell (1998), Loth & Bidelman (1998), have classified various groups of late type stars including stars on the USNO parallax program, large proper motion stars, northern peculiar stars, and variable stars in the IRAS Point-Source catalog.

Skrutskie et al. (1997) have classified $1.6\,\mu$ spectra of bright stars observed in the prototyping phase of the 2MASS survey. Most are AGB, M, C, and S stars. Bartkevicius (1996) has produced a catalog of 261 CH and related stars. Mürset & Schmid (1999) has derived the spectral types of the cool giants in about 100 symbiotic systems and added types for about 70 additional systems from the literature. Sloan & Price (1998) have published infrared spectral classifications for 635 optically identified oxygen-rich variables.

References

Bartkevicius, A. 1996, Baltic Astron., 5, 217.
Bartkevicius, A., & Lazauskaite, R. 1997, Baltic Astron., 6, 499.
Bidelman, W.P., & MacConnell, D.J. 1998, IBVS, 4612, 1.
Loth, A.L., & Bidelman, W. 1998, PASP, 110, 270.
Malyuto, V., Oestreicher, M.O., & Schmidt-Kaler, Th. 1997, MNRAS, 286, 500.
Mürset, U., & Schmid, H.M. 1999, A&AS, 137, 473.
Pesch, P., & Bidelman, W. 1997, PASP, 109, 643.
Skrutskie, M.F., Lysaght, M.G., & Weinberg, M.D. 1997, ApSpSc Lib. Ser. 210, 117.
Sloan, G.C., & Price, S.D. 1998, ApJS, 119, 141.

7.6. Subdwarfs and White Dwarfs

McCook & Sion (1999) have produced a catalog of 2249 white dwarfs that presents a variety of information on each star including spectral types on the expanded system that he describes in detail. This is the fourth edition of the Villanova Catalog of spectroscopically-identified White Dwarfs. Gizis (1997) classified 50 late-type with metal abundances ranging from those that are similar to Population I to those that are significantly more metal poor. Devising new criteria in red spectra, he was able to divide his sample into M-subdwarfs and extreme M-subdwarfs.

References

Gizis, J.E. 1997, AJ, 113, 806.

McCook, G.P., & Sion, E.M. 1999, ApJS, 121, 1.

7.7. Clusters

Shi & Hu (1999) provided MK types for 263 stars in the young clusters IC 1805, NGC 654, and NGC 6823. Levato et al. (1998) have classified 526 stars in the Ori OB1 association included by Warren and Hesser in their photometric study of the association. Abt & Corbally (1997) have classified primaries within Trapezium systems. Sears & Sowell (1997) have classified apparent post-main-sequence stars in 8 intermediate-age open clusters. Only a few stars appear to be cluster members. Hanson et al. (1997) have classified a population of high mass young stellar objects in M17. Bosch et al. (1999) have classified 175 stars in the 30 Doradus cluster.

References

Abt, H.A., & Corbally, C.J., 1997, in Visual Double Stars: Formation, Dynamics and Evolutionary Tracks, Eds. J.A. (Dordrecht: Kluwer), 127.

Bosch, G., Terlevich, R., Melnick, J., & Selman, F. 1999, A&AS 137, 21.

Hanson, M.M., Howarth, I.D., & Conti, P.S. 1997, ApJ, 489, 698.

Levato, H.O., Malaroda, S., & Morrell, N. 1998, IX Latin American Regional IAU Meeting, Rev. Mex. AAp, to be published.

Sears, R.L., & Sowell, J.R. 1997, AJ, 113, 1039.

Shi, H.M., & Hu, J.H. 1999, A&AS 136, 313.

7.8. IRAS Sources and Infrared Spectra

Kwok et al. (1997) have classified spectra of 11,224 IRAS sources on the basis of the presence of emission and absorption features and on the shape of the continuum. The spectra were divided into 10 classes but no attempt was made to correlate them with optical types. The latter are presented when available. Iyengar & McConnell (1998) have classified a large number of unidentified IRAS Point Sources.

Meyer et al. (1998) have compiled a catalog of H-band spectra for 85 stars of approximately solar abundance in a broad range of types and luminosities observed at a resolving power of 3000. Ginestet et al. (1997, 1999) classified near infrared spectra of 317 supposedly composite stars, of which 235 proved to be true composites.

References

Ginestet, N., Carquillat, J.M., Jaschek, C., & Jaschek, M. 1997, A&AS, 123, 135.

Ginestet, N. Carquillat, J.M., & Jaschek, C. 1999, A&AS, 134, 473.

Iyengar, K.V.K., & McConnell, D.J. 1998, A&AS 133, 2011.

Kwok, S., Volk, K., & Bidelman W.P. 1997, ApJS, 112, 557.

Meyer, M., Edwards, S., Kinkle, K.H., & Strom S.E. 1998, ApJ, 508, 397.

7.9. X-Ray Sources

Martin et al. (1998) classified 106 candidate optical counterparts of 77 X-ray sources in the ρ Ophiuchi star-forming region. Metanomski et al. (1998) have used photometry and low resolution spectra to estimate spectral classifications for a sample of F, G, and K stars in selected areas of the ROSAT all-sky survey. Li & Hu (1998) have searched for weak-line T Tauri stars (WTTS) in the outskirts of the Taurus-Auriga molecular cloud. They provide

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classifications of 75 WTTS and one classical T Tauri stars. Martin et al. (1999) classified 35 stars in this region reported to be WTTS from mid resolution spectra. They find that most of the sources discovered in the ROSAT all-sky survey are not WTTS.

References

Li, J.Z., & Hu, J.Y. 1998, A&AS, 132, 173.

Martin, E.L., Montmerle, T., Gregorio-Hetem J., & Casanova, S. 1998, MNRAS, 300, 733.

Martin, E. L., & Magazzú, A. 1999, A&A 342, 173 173.

Metanomski, A.D.F., Pasquini, L., Krauter, J., Cutispoto, G., & Fleming, T.A. 1998, A&AS, 131, 197.

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President of the Commission