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1. Introduction

This report, like its predecessor, focuses on areas which have been especially active since the last General Assembly. A major development has been the appearance of the first data and results from such large-scale surveys as 2MASS and the Sloan Digital Spectroscopic Survey, as well as major projects conducted from the ground. We give, for the first time, electronic addresses for selected catalogues and atlases.

2. Working Groups

The following working groups all publish a newsletter, which may be accessed along with information on their activities from the Web page of Commission 45:
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3. Spectroscopy of Ultra-Cool Dwarfs

Kevin L. Luhman

Ultra-cool dwarfs have been defined as dwarfs with spectral types of M7 or later (Kirkpatrick, Henry & Irwin 1997) and thus include the new L and T spectral classes. Ultra-cool dwarfs are divided into two categories: old dwarfs in the field (> 1 Gyr) and their young progenitors in the nearest star-forming regions and open clusters (1 – 100 Myr). Because the former are nearby and the latter are young, these two groups are relatively bright and lend themselves to discovery and detailed study. Technically, the luminosity class of young ultra-cool objects is closer to subgiant than dwarf; nevertheless, I include them in this report on ultra-cool dwarfs.

3.1. The Field

Three years ago, L-type objects had been discovered in abundance ($\sim$ 100), while only a dozen T-type sources were known. Since then, 2MASS, SDSS, and other surveys have identified another 150 L dwarfs and 20 T dwarfs free-floating in the field (Cuby et al. 1999; Strauss et al. 1999; Kirkpatrick et al. 2000; Reid et al. 2000; Tsvetanov et al. 2000; Leggett et al. 2000; Burgasser et al. 1999, 2000b, 2002a; Hawley et al. 2002; Liu et al. 2002b). The first L and T dwarfs were discovered as companions, and companion searches have continued to reveal new members of these spectral classes. Ultra-cool dwarfs orbiting field stars have been found at wide angular separations through 2MASS images and follow-up spectroscopy by Kirkpatrick et al. (2001), Wilson et al. (2001), Gizis, Kirkpatrick & Wilson (2001), and Burgasser et al. (2000a). Companions that are likely to be ultra-cool have appeared at small angular separations in images obtained with HST and ground-based telescopes using adaptive optics (AO) (Martín et al. 2000b; Reid et al. 2001b; Els et al. 2001; Close et al. 2002a, 2002b), some of which have been observed with newly available AO spectroscopy (Potter et al. 2002; Goto et al. 2002; Liu et al. 2002a).

Spectral classification of ultra-cool dwarfs began with optical data for M and L types (Kirkpatrick et al. 1999; Martín et al. 1999b). Classification at these types has since been developed at IR wavelengths (Reid et al. 2001a; Leggett et al. 2001; Testi et al. 2001). The numerous discoveries of ultra-cool dwarfs have produced a well-sampled spectral sequence into late L and T types, enabling the definition of spectral subclasses in the T regime (Burgasser et al. 2002a; Geballe et al. 2002). To first order, the T spectral class was originally defined by the presence of methane absorption at IR wavelengths. However, under the accepted classification schemes for L and T types, late L dwarfs exhibit methane absorption at 3.3 μm (Noll et al. 2000), and possibly at 2.2 μm as well (McLean et al. 2001; Nakajima, Tsuji & Yanagisawa 2001). The temperatures below which methane absorption appears in each photometric band have been compared to theoretical predictions by Schweitzer et al. (2002). In addition to temperature, clouds are probably responsible for much of the variation in spectral features among L and T types (Burgasser et al. 2002b).

3.2. Open Clusters and Star-Forming Regions

Searches for ultra-cool dwarfs in nearby open clusters and star-forming regions have been motivated by the fact that brown dwarfs ($M \lesssim 0.075\ M_\odot$) are brightest and warmest when they are young, which enables their detection down to very low masses. For instance, objects near the hydrogen burning mass limit have spectral types of M6-7 when they are younger than 100 Myr, and eventually cool to mid-L types after several Gyr. In other words, a given ultra-cool spectral type corresponds to a much lower mass (by an order of magnitude) in a star-forming region than in the field.

The Pleiades open cluster (125 Myr) was the first site to prove fruitful in surveys for young ultra-cool dwarfs (Martín et al. 2000a). The emphasis has shifted to very young associations and star-forming clusters ($<$ 10 Myr), where the brown dwarfs should be even more luminous. Free-floating ultra-cool objects have been identified with optical and IR spectroscopy toward IC 348 (Luhman 1999), Chamaeleon I (Neuhäuser & Comerón 1999; Comerón, Neuhäuser & Kaas 2000), Ophiuchus (Wilking, Greene & Meyer 1999; Cushing, Tokunaga & Kobayashi 2000), Taurus (Martín et al. 2001a), the Orion Nebula Cluster (Lucas et al. 2001), σ Ori (Béjar, Zapatero Osorio & Rebolo 1999; Zapatero Osorio et al. 2000; Barrado et al. 2001), and the TW Hya association (Gizis 2002). In addition, companion searches have located late-type secondaries to young stars in the Taurus star-forming region (White et al. 1999) and in the associations of Tucanae (Lowrance et al. 2000; Guenther et al. 2001) and TW Hya (Lowrance et al. 1999; Neuhäuser et al. 2000). Most of these sources are late-M (0.01 - 0.1 $M_\odot$), while a smaller number of L-type objects (0.005 - 0.01 $M_\odot$) have been found toward Orion and σ Ori.

I now describe the spectral features that vary between ultra-cool dwarfs in the field and their young counterparts in clusters. Over time, the processes of convection and nuclear burning deplete Li at the surfaces of young low-mass stars and brown dwarfs. This depletion occurs faster for more massive objects, resulting in a boundary between non-Li and Li objects that evolves to lower masses, and thus fainter luminosities and cooler temperatures. For instance, the Li depletion boundary is near the hydrogen burning mass limit for an age of $\sim$ 100 Myr. Barrado et al. (1999) and Stauffer et al. (1999) have used this phenomenon to estimate ages for the Pleiades (125 Myr), IC 2391 (53 Myr), and α Per (90 Myr) open clusters. In star-forming clusters, ultra-cool sources are too young to have depleted their Li and thus exhibit strong absorption at 6707 Å (Martín, Basri & Zapatero Osorio 1999a). At M types, the presence of Li absorption can be used to distinguish young late-type members of a cluster from foreground field dwarfs. This breaks down for L-types, as the time scale for Li depletion is so long.

Youth and membership are more easily determined with the gravity-sensitive Na I and K I absorption lines, which are stronger than Li and reside at brighter regions of the optical spectrum. At late M types, these features are weaker in young stars than in field dwarfs which have higher surface gravity. However, at types later than $\sim$L0, these lines are difficult to use as diagnostics of youth because they become weaker and the optical flux continues to decrease. It is advantageous to work at infrared wavelengths. Steam absorption at each end of the H and K bands results in a plateau in the spectra of dwarfs, while for young sources this plateau is less apparent and the spectrum is instead more sharply peaked (Lucas et al. 2001).

L-type objects found toward star-forming regions are sometimes referred to as "objects of planetary-mass" (Lucas et al. 2001; Zapatero Osorio et al. 2000) because L0 corresponds roughly to the deuterium burning mass limit (0.013 - 0.015 $M_{\odot}$) for ages of $<$ 10 Myr. The relationship between the L types reported by Lucas et al. (2001) from IR spectra and the standard optically-based classifications for field dwarfs is unclear, however these objects are likely to be young because they show IR steam features unlike those of field dwarfs but consistent with the predicted dependence on surface gravity (Allard et al. 2001). The early L source found by Zapatero Osorio et al. (1999) towards the σ Ori cluster appears to have Na I and K I line strengths that are indicative of youth, but the remaining objects are too faint ($I > 21$) for such measurements, while the strong Hα emission found for some of them (Barrado y Navascués et al. 2001) is not convincing. The σ Ori objects (Martín et al. 2001b) lack the distinctive steam absorption bands found in Orion by Lucas et al. (2001), which suggests that they are foreground field dwarfs rather than cluster members.

For the spectral classification of young objects at late-M types, Luhman (1999) found that the various spectral features between 6000 and 9000 Å are best matched with averages of spectra for standard dwarfs and giants. Because some of the IR steam bands become stronger at a fixed temperature from dwarfs to young objects (Allard et al. 2001), optically-classified young sources are probably the appropriate standards when using IR spectra to measure spectral types for young late-type objects.

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4. Spectral Classification

4.1. Hot Stars

Shara et al. (1999) found 31 Galactic W-R stars by photometric means and confirmed 18 of them by spectroscopy. Walborn & Fitzpatrick (2000) presented an atlas of digital spectra of peculiar OB stars. Walborn et al. (2000) presented an atlas of ultraviolet and optical spectra of metal-deficient O stars in the SMC. They find it necessary to introduce far-ultraviolet criteria into the definition of spectral types for the first time. Walborn & Howarth (2000) obtained digital spectra of O3-5 and ON/OC supergiants in Cygnus. Walborn et al. (2002) define the new earliest spectral type of O2. Jaxon et al. (2001) classified 42 OB stars in the LMC. Herrero et al. (2001) found from HST UV spectra that the terminal velocity of stellar winds depended on spectral type in the range O3If-B1I in Cyg OB2. Vittamariz & Herrero (2000) studied the effect of microturbulence on the spectra of luminous OB stars. Eracleous et al. (2002) made a spectroscopic reconnaissance of stars discovered in fields near the Galactic plane by Lanning & Meakes (2000; 2001).

Williams & van der Hucht (2000) found two composite spectra in a search for companions to WC9 stars. Breysacher, Azzopardi & Tester (1999) present the fourth catalogue of Population I W-R stars in the LMC. Walborn et al. (1999) used HST/FOS to obtain blue spectra of 42 W-R or OB stars in four compact groups in the LMC. Massey, Waterhouse & DeGioia-Eastwood (2000) studied the upper main sequence of 19 OB associations in the Magellanic Clouds, to conclude that W-R stars have a minimum mass of 70 $M_\odot$ in the SMC but 30 $M_\odot$ in the LMC, while LBVs are over 85 $M_\odot$. A study of OB stars in 12 clusters and associations in the Galaxy indicated high minimum masses for W-R stars there also (Massey, DeGioia-Eastwood & Waterhouse 2001). Bartzakos, Moffat & Niemela (2001) found a low binary frequency among 24 WC/WO stars in the Magellanic Clouds. Heydari-Malayeri et al. (2002) found that O6-8 stars in N81 in the SMC are underluminous by up to 2 mag, so they are extreme examples of luminosity class Vz.

Kinman et al. (2000) make a spectroscopic study of field Blue Horizontal Branch (BHB) candidates. Moehler, Landsman & Dorman (2000) took spectra of 12 possible BHB members of 47 Tucanae and NGC 362. Behr et al. (1999) found that in BHB stars in M 13 which are hotter than 12 000 K, [He/H] is 0.1 to 0.01 solar, while some elements such as Fe are 3 times solar or about 100 times the expected value for the cluster. Even larger effects were found in M 15 (Behr, Cohen & McCarthy 2000). This is important for spectral typing. Grundahl et al. (1999) found a discontinuity on the horizontal branch such that stars with $(u\text{-}y)_o$ bluer than 1.0, or T_{eff} hotter than 11 500 K, are brighter than those to the red. Radiative levitation of elements heavier than C and N takes place, drastically altering the photospheric abundances of heavy elements. Hui-Bon-Hoa, LeBlanc & Hauschildt (2000) found that stratified model atmospheres, resulting from diffusion, can account for several features in the abundances and colour-magnitude diagrams of BHB stars. Peterson et al. (2001) found 37 BHB stars in the Galactic Bulge.

Morgan, Parker & Russeil (2001) found two new W-R central stars of planetary nebulae. Feibelman (1999) proposed CIII as a new classification parameter for [WC] central stars.

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4.2. Cool Stars

Ginestet et al. (2000) determined the absolute magnitudes of stars of types G-M using HIPPARCOS parallaxes. Gorgas et al. (1999) calibrated the 4000 Å break using spectra from the Lick IDS library. Munari & Tomasella (1999) studied the application of the MK system to high resolution spectra in the far red. Keenan & Barnbaum (1999) revised and calibrated the MK luminosity classes for G-K giant stars using HIPPARCOS parallaxes. Houdashelt et al. (2000a; 2000b) give synthetic spectra and deduce colour- T_{eff} relationships for late type stars. Alonso, Arribas & Martínez-Roger (1999a; 1999b) calibrate the temperature scale of F0-K5 giants as a function of colours and [Fe/H].

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4.3. λ Bootis Stars

Solano & Paunzen (1999) discuss the identification of λ Bootis stars on high-resolution IUE spectra. Paunzen et al. (2001) classified 708 possible λ Boo stars selected from uvbyβ photometry, using spectra of high resolution. Paunzen (2001) found that 2% of B8-F4 stars are of this type, including several in regions of recent star formation.

Faraggiana & Bonifacio (1999) noted that many λ Boo stars are known or suspected binaries. Manketti, Faraggiana & Bonifacio (2001) found that 2 out of 17 stars observed with speckle interferometry are close binaries with composite spectra. Faraggiana et al. (2001) found that HD 11786 has 5 components, while the double-lined binary HD 153808 has 3. Faraggiana, Gerbaldi & Bonifacio (2001) found that another star classified as a λ Boo, HD 174005, is a binary whose spectrum can simulate a weak-lined metal-poor star at some orbital phases.

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4.4. Infrared Classification

Blum, Conti & Daminelli (2000) and Blum et al. (2001) give spectra of three and five stars, respectively, in massive young clusters in the giant HII regions W 42 and W 31. Clark & Steele (2000) and Steele & Clark (2001) reported the run of feature strength with temperature class in K-band and H-band spectra of B stars. Clark et al. (1999) give IR spectra of candidate B[e]/X-ray binaries. Zaal, de Koter & Waters (2001) found criteria to classify stars of O9-B3 with ISO-SWS. Paumard et al. (2001) observed 16 helium stars near the Galactic centre with BEAR and concluded that these can be divided into LBV stars with velocities of 200 kms^{-1} in the P Cyg profiles and W-R stars with 1000 kms^{-1}. Wallace et al. (2000) describe J-band spectra of fundamental MK standards over the range O7-M6, luminosity class I-V. Ishii et al. (2001) obtained K-band spectra of 32 presumed precursors of Ae/Be stars. Smith & Houck (2001) found emission from circumstellar dust in a few, and atomic emission in most, mid-infrared spectra of W-R stars.

Forster Schreiber (2000) presents a library of moderate resolution K-band spectra of cool stars. Greene & Lada (2000) find that CO absorption is weak or veiled in K-band spectra of protostars. Kraemer et al. (2002) present a new classification scheme based on the spectral energy distribution and on spectral features such as silicate emission, using ISO SWS spectra covering 2.4 - 45.2 μm. Sylvester (1999) investigated the mid-infrared spectra of 18 late-type stars with unusual spectra according to IRAS. García-Hernández et al. (2002) found H_2 in the near infared spectra of 9 out of 30 planetary nebula precursors selected from IRAS. Frogel et al. (2001) established an abundance scale for globular cluster giants from K-band spectra.

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5. Surveys

5.1. Be Stars

Pigulski, Kopacki & Kolaczkowski (2001) found 22 Be stars in NGC 663 from BVRIHα photometry. Pigulski & Kopacki (2000) found 17 new Be stars in NGC 7419, bringing the total to 31. Grebel & Chu (2000) found 19 probable Be stars from a V-Hα/V-I diagram for stars in Hodge 301 in the 30 Dor region of the LMC. Keller, Bessell & Da Costa (2000) found 253 Be stars in four young star clusters in the Magellanic Clouds using the m(555)-m(656)/m(160)-m(555) diagram. Keller et al. (2001) found 33 Be stars in h and χ Persei. Murphy & Bessell (2000) found 218 emission line stars (113 previously known) in the SMC. Johnson et al. (2001) used VHα photometry to find many Be stars in the LMC clusters NGC 1805 and NGC 1818. Fabrika & Sholukhova (1999) found 81 emission line stars among 2330 OB stars in M 33, using Hα photometry. Gouliermis et al. (2002) found about 20 Be stars from BVRHα photometry of three associations in the LMC. Stevens, Coe & Buckley (1999) confirmed six and probably two more Be stars among X-ray binaries in the LMC, and Negueruela & Coe (2002) found that massive X-ray binaries in the LMC are mostly Be stars. Hummel et al. (1999) provide spectroscopic confirmation of 20 Be stars, identified photometrically, in NGC 330 in the SMC.

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5.2. Carbon Stars

Gigoyan et al. (2001) found 35 faint carbon stars from the First Byurakan Spectral Sky Survey; 22 have so far been confirmed with slit spectra. Liebert et al. (2000) used 2MASS data to find five cool, dust-enshrouded carbon stars out of the Galactic plane. One showed emission of C_2 bands and resonance lines of the alkali metals for a while. Christlieb et al. (2001) found 400 carbon stars at high Galactic latitude on the blue Hamburg/ESO Survey plates; recovery rate of dwarf carbon stars was poor.

Kontizas et al. (2001) found a large number of carbon stars on blue-green objective prism plates of the LMC. Cioni et al. (2001) found 7 S and 33 C stars by spectral classification of 126 AGB stars found from the DENIS and EROS surveys of the LMC. Albert, Demers & Kunkel (2000) used narrow-band CN and TiO filters as well as $(RI)_c$ filters to find 195 probable carbon stars in IC 1613 from their location in the CN-TiO, R-I diagram. Subsequently Battinelli & Demers (2000) found 40, 3 and 0 carbon stars in the Local Group dwarf galaxies Pegasus, DDO 210 and Tucana, Demers & Battinelli (2002) found 16 carbon stars in the Sagittarius dwarf irregular and 13 in Leo I, and Letarte et al. (2002) found 904 carbon stars and 341 possible bluer carbon stars in NGC 6822. Shetrone, Coté & Stetson (2001) found several carbon stars among new radial velocity members to the red of the giant branches of the Ursa Minor and Draco dwarf spheroidal galaxies. Demers, Dallaire & Battinelli (2002) extracted JHK_s photometry from 2MASS for a large sample of carbon stars found on blue-green objective prism spectra in the Magellanic Clouds, and used similar data for the Fornax dwarf galaxy to identify 26 C stars (most already known) from the appropriate colour range. The method is equivalent to their optical colorimetry. Nowotny et al. (2001) found 61 new carbon stars in M 31, using V, I, TiO and CN filters.

Aoki, Tsuji & Ohnaka (1999) studied HCN and C_2H_2 bands near 14 μmin carbon star spectra, using the ISO SWS. Knapp, Pourbaix & Jorissen (2001) used HIPPARCOS parallaxes to show that early R stars have luminosities appropriate to the red giant clump. Pollard & Lloyd Evans (2000) found the first known carbon star among the RV Tauri stars, in the Large Magellanic Cloud.

MacConnell, Wing & Costa (2000) found new S stars in the Southern Milky Way. Van Eck et al. (2000) obtained UBVJHKL and Geneva photometry, low resolution spectra and radial velocities for 205 S stars. Wang & Chen (2002) give JHK photometry of 161 S stars and find that those which are Tc-rich are relatively brighter in the mid-infrared.

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5.3. Special Survey Techniques

Pre-main sequence stars show distinctive features, notably emission lines and infrared excesses, which enable detection from material of low spectroscopic resolution.

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Valenti, Johns-Krull & Linsky (2000) provide an atlas of IUE spectra of 50 T Tau and 74 Ae/Be stars covering 1150 - 1980 Å at 6 Å resolution, from which Johns-Krull, Valenti & Linsky (2000) establish diagnostics of accretion in the far-UV.

Hα Emission Sung, Chun & Bessell (2000) used UBVRIHα photometry to find pre-main sequence members of the young cluster NGC 6530 by their R-Hα colours, Park et al. (2000) found PMS stars in NGC 2264 and Park & Sung (2002) found PMS stars in NGC 2244. Herbig & Dahm (2001), using grism spectra, found 25 faint emission line stars but confirmed only 4 of 40 supposed Ae/Be stars reported on the basis of slit spectra, a result also confirmed by Ogura, Sugitani & Pickles (2002) in a grism study of 28 bright rimmed clouds containing 460 emission line stars. Herbig & Dahm (2002) used grism spectra to find 90 Hα emitters, many of them with excess emission at K indicating the presence of disks, in the young cluster IC 5146. Li et al. (2002) identified four pre-main sequence stars from slit spectra of X-ray emitters found by ROSAT in NGC 2244. Spectroscopy and uvbyβ photometry of the young cluster NGC 1893 (Marco, Bernabeu & Negueruela 2001) revealed two Ae/Be and three PMS stars of type F. Wichmann, Schmitt & Krautter (2001) found the first spectroscopically-confirmed extragalactic T Tauri star, with intense Hα emission, in a dark cloud in the LMC.

Circumstellar Dust Disk Haisch, Lada & Lada (2000) find circumstellar disks in an L-band survey of the young embedded cluster NGC 2024. The excess emission from a disk shows up much more strongly at L than at K, while L is far more easily observed than the mid-infrared wavebands. The addition of the mid-infrared N band added only one probable disk, confirming the efficiency of L in the detection of disks (Haisch et al. 2001). Lada et al. (2000) found that the L-band was optimum for detecting disks around stars in the Trapezium cluster. Muench et al. (2001) found that 65% of brown dwarfs in the Trapezium cluster have excesses at K, indicating the probable presence of circumstellar disks. Stassun et al. (2001) obtained photometry at 10 μmfor 32 PMS stars without IR excesses in the near-IR; only three showed an excess indicating the possible presence of a truncated disk. The occurrence of disks is confined to stars of type later than G in the older cluster IC 348 (Haisch, Lada & Lada 2001). Rebull et al. (2002) obtained UBVRIJHK photometry for 5600 stars and classification spectra for 400 in NGC 2264, enabling the identification of circumstellar disks. Jayawardhana et al. (2001) used 2MASS and L and N imaging to find six stars with significant excesses, all also showing Hα emission, in MBM 12 which is the nearest star-forming cloud. Gómez & Kenyon (2001) found about 100 stars with excesses at K in the Cha I dark cloud. Koerner et al. (2000) show that the quadruple system HD 98800 contains a circumbinary disk which is detectable only in the mid infrared. Kobayashi & Tokunaga (2000) found six stars with excesses at K in a cloud near the rim of the Galaxy. Brandner et al. (2001) found 20 probable Ae/Be and T Tau stars by their excess at K in the 30 Dor nebula in the LMC.

Pezzuto et al. (2002) used mid-infrared ISO-LWS photometry to demonstrate a clear increase in colour temperature of circumstellar dust from PMS class 0 to II, where class II included 14 Ae/Be and 6 T Tau stars. Ivezić & Elitzur (2000) show that AGB stars may be distinguished from PMS stars because a different spatial distribution of circumstellar dust results in a different spectral energy distribution.

Enhanced Lithium Dolan & Mathieu (1999) found strong Li in 72 of 537 stars examined at 0.6 Å resolution in the λ Ori star-forming region. Preibisch, Guenther & Zinnecker (2001) found 98 new PMS stars, nearly all of M type, among 576 stars in Upper Scorpius.

X-ray Emission Torres et al. (2000) identify 10 - 16 young stars, first found by their X-ray emission, in a nearby cluster centred on ER Eri. MK types are given for 59 stars. Pozzo et al. (2000) used BVI_c photometry to show that X-ray sources around γ Vel form an association of low-mass PMS stars. Zuckerman et al. (2001) found six T Tau stars among

ROSAT sources near HR 4796. Berghöfer & Christian (2002) show that stars in NGC 2244 generally have Hα emission if they have a high ratio of X-ray output to visible luminosity.

Hess Diagrams Photometry of very large samples of stars in distant stellar systems cannot be analysed on a star-by-star basis. The CMD of a nearby comparison field may be subtracted first. The "cleaned" CMD may then be divided into regions corresponding to stars of a specific type or evolutionary stage such as OB stars or red giant clump stars, whose various distributions may be compared to make deductions about the evolution of the system. This type of classification, using optical wavebands, has been performed by Cole et al. (1999) for IC 1613, by Gallart et al. (1999) for Leo I, by Alcock et al. (2000) for the LMC, by Saviane, Held & Bertelli, 2000, for Fornax and by Momany et al. (2002) for SagDIG. Nikolaev & Weinberg (2000) used 2MASS to study stellar populations in the LMC and Alard (2001) investigated variations in metallicity within the Sgr dwarf spheroidal galaxy.

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6. Photometric Classification

Rubén A. Vázquez

6.1. Wide-Band Systems

Sekiguchi & Fukugita (2000) studied the relationship between B-V and T_{eff}. A new technique allowing the UBV Q-method to be used for the spectral classification of stars of the older spectral types A1-M5 as well as for the young O-A0 stars is described by Kuznetsov et al. (2000). Bonifacio, Caffau & Molaro (2000) present an intrinsic colour calibration for F-K stars using Johnson broadband colours together with line indices. Bessell & Germany (1999) calibrated the MACHO photometric system for V - R, T_{eff} and BC_V for metal poor giants. Ducati et al. (2001) obtain intrinsic colours in Johnson UBVRIJHKLMN from a large sample. Westera et al. (2002) discuss a metallicity calibration of UBVRIJHKL photometry. Castelli (1999) calculates synthetic UBV colour indices from model atmospheres and investigates their dependence on T_{eff}, gravity and microturbulent velocity.

Forbes (2000) obtained UBVRI photometry of 156 stars for a study of the OB association in Serpens. Reed (1999), Reed & Reed (1999, 2000), Moffat & Reed (1999) and Reed & Niemczak (2000) present CCD BVR photometry for a large number of stars drawn from the Case-Hamburg catalogue of Luminous Stars in the Northern Milky Way. Van Houten, Walraven & Walraven (1999) and van Houten (2001) report observations in the Walraven photometric system for many OB stars. Dolan & Mathieu (2002) identified pre-main sequence stars in the λ Ori region from VRI photometry of 320 000 stars.

A UBV photometric and proper motion survey of two intermediate-latitude fields was undertaken by Ojha et al. (1999). The South Galactic pole field SA 141 was investigated using the RGU photometric system by Karatas et al. (2001). Photoelectric UBV photometry for 2600 metal-poor dwarf and giant candidates selected from the HK survey of Beers are reported by Norris et al. (1999). Bonifacio, Monai & Beers (2000) give UBV data for 268 metal-poor candidates from the northern HK survey.

$UBV(RI)_c$ photometry for 51 cool stars detected in the EUV by the ROSAT Wide Field Camera is presented by Cutispoto et al. (1999). Williams, McGraw & Grashuis (2001) obtained BVRI photometry of sdO stars found in the PG survey; Williams et al. (2001) provide JK photometry for the same stars. BV photometry of 187 G, K and M0 field giants with suspected variability is reported by Henry et al. (2000).

BVRIJHK photometry have been secured for a sample of 152 white dwarfs by Bergeron et al. (2001). A catalogue of WULBV, $UBV(RI)_c$ and JHKLM observations for a sample of 162 southern emission line objects and shell stars is presented by de Winter et al. (2001). JHK photometry of 52 isolated Be stars of spectral types O9-B9 and luminosity classes III-V is presented by Howells et al. (2001). JHK photometry for 58 young binary systems using near-infrared speckle interferometry was obtained by Woitas et al. (2001). JHK photometry for 58 main sequence, mainly Vega-type, and pre-main sequence stars was carried out by Eiroa et al. (2001). Infrared J, H, and K band observations for T_{eff} and $\log g$ determination and abundance analyses were performed for 70 stars of spectral types B0-B5 by Lyubimkov et al. (2000). JHK photometry for some of the IRAS sources with SiO masers in the central part of the Galaxy was carried out by Deguchi (1999). UBV photometry for 878 luminous member stars of the Large Magellanic Cloud was undertaken by Schmidt-Kaler et al. (1999).

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6.2. Medium-Band Systems

Strömgren System Absolute magnitudes for 233 southern CP2 stars (covering the magnetic Ap stars) derived from Hβ photometry and existing uvby photometry are confronted with Hipparcos results for a common subset of 152 stars by Maitzen et al. (2000). Twarog, Anthony-Twarog & Tanner (2002) find that the uvby metallicity calibration for G dwarfs is wrong: the c_1 index becomes more metallicity-dependent as T_e declines, so that cool dwarfs of high metallicity would be classified as giants. Hilker (2000) has recalibrated the (b-y), m_1 diagram to determine the iron abundances of red giants.

uvby-β photometry of 116 X-ray flux-selected active stars in the directions of the Orion (40), Taurus-Auriga (58) and Scorpius OB2-2 (18) star forming regions is given by Chavarria-K et al. (2000). Mooney et al. (2000) reported uvby photometry for 31 high Galactic latitude stars selected from the Palomar-Green Survey. Kaltcheva, Olsen & Nielsen (2000) reported Strömgren (283) and Hβ (225) photometry of O and B type stars brighter than 9.5 mag in the field of the Carina Spiral Feature. Nielsen, Jønch-Sørensen & Knude (2000) report uvbyβ CCD photometry for more than 500 stars towards the cometary globules CG 30/31/38. Strömgren (127) and H-β (25) photometry of bright OB-stars in the Canis Major - Puppis - Vela region of the Milky Way is reported by Kaltcheva & Olsen (1999), while Kaltcheva & Hilditch (2000) analyse the data. Strömgren (343) and Hβ (213) photometry of O and B stars is presented for the fields of the Galactic OB associations Monoceros OB2, Canis Major OB1 and Collinder 121 by Kaltcheva, Olsen & Clausen (1999). Franco (2002) obtained uvbyβ photometry for 205 stars towards a void in the Lupus Dark Cloud. Strömgren photometry has been obtained by Schuster et al. (1999) for 140 very metal-poor stars. Anthony-Twarog et al. (2000) used uvby and Ca photometry to show that 42 of 52 metal-poor stars identified in the N Hemisphere HK Survey had [Fe/H]< -2.5.

Domingo & Figueras (1999) derived temperature, evolution and metallicity effects from Strömgren photometric indices for main-sequence late A-type stars with Hipparcos trigonometric parallaxes. Strömgren synthetic photometry from an empirically calibrated grid of stellar atmosphere models has been used to derive the effective temperature of each component for a sub-sample of 20 SB2 eclipsing binaries by Lastennet et al. (1999).

Cole, Smecker-Hane & Gallagher (2000) report abundance estimates using Strömgren photometry for 100 red giants in the Large Magellanic Cloud. Larsen et al. (2000) determined individual reddenings for B stars in two fields in the Small Magellanic Cloud and two fields in the Large Magellanic Cloud using uvby CCD photometry.

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Washington System Bessell (2001) has checked the passbands of the Washington (C, M, T1, T2) system using the Vilnius Spectrophotometric Atlas, followed by a comparison of observed and synthetic colour-colour relations. Washington photometry has been used by Morrison et al. (2000) to identify halo stars, as part of a wide-ranging survey. The use of the Washington photometric system, supplemented by the DDO51 filter, for identifying distant halo giants has been examined by Morrison et al. (2001). Piatti et al. (1999) carried out Washington C and T1 CCD photometry of 21 fields in the northern part of the LMC. Piatti et al. (2001) used similar photometry to obtain colour-magnitude diagrams for a series of clusters projected on to the outer parts of the Small Magellanic Cloud and to determine metallicities from the red giant branch. Dohm-Palmer et al. (2000) used the Washington

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filter system, which can distinguish between dwarfs and giants, to identify candidate halo stars. A simplified variant of the combined Washington/DDO51 four-filter technique was applied by Majewski et al. (2000) to carry out a survey of the structure of the Milky Way halo, as well as the halos of other Local Group galaxies.

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Vilnius System Straižys, Cernis & Bartasiute (2001) report Vilnius seven-color photometry for 238 stars down to 13 mag in the area of the California Nebula in Perseus. Zdanavicius & Zdanavicius (2002) use Vilnius photometry for 309 stars on the Cam and Per border to obtain photometric spectral type and luminosity class. Bartasiute (1999) has obtained photoelectric seven-color photometry in the Vilnius medium-band system for 374 stars in four MEGA proper-motion fields near the North Galactic Pole. Bartasiute, Ezhkova & Lazauskaite (1999) present seven-color photometry in the Vilnius system and hence derive spectral type, absolute magnitude and metallicity for 145 Hipparcos stars with accurate parallaxes. Progress on a new calibration of the Vilnius photometric system in terms of temperature and absolute magnitudes (based on temperatures of 450 stars determined by the infrared flux method or from angular stellar diameters and absolute magnitudes) of 2100 stars with Hipparcos parallaxes is given by Straižys, Kaslauskas & Bartasiute (1999). Straižys (1999) reviews some photometric systems currently in use including the broad-band system UBV and its extension RI, the revised WBVR system and the medium-band Vilnius and Strömvil systems.

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DDO System Observations in the BV and DDO systems have been obtained for 184 late-type stars in the Galactic antirotation direction by Westpfahl et al. (1999). Taylor (1999) derived metallicity calibrations with six sets of parameters (one of them is the DDO CN index, δ CN) calibrated for use with both evolved and dwarf G-K stars. Photoelectric photometry in the UBV, DDO and Washington systems for red giant candidates in the intermediate-age open cluster NGC 2354 is presented by Clariá et al. (1999).

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6.3. Other Systems

Transformations between the MACHO Bma and Rma passbands and standard Cousins V and R were derived in the field of Ru 149 by Bessell & Germany (1999). Stoughton et al. (2002) report photometry for 14 million and spectra for 54 000 objects in the Sloan Digital Sky Survey Early Data Release. Optical and infrared colours of stars matched in the 2MASS and the SDSS are discussed by Finlator et al. (2000). Yanny et al. (2000) used a sample of over 4000 stars with the colours of main sequence A stars in the SDSS data to trace substructure in the halo. Ultraviolet photometry from the Wisconsin Experiment Package on the Orbiting Astronomical Observatory 2 (OAO 2) is presented for 614 stars by Meade (1999).

Highly accurate photometric data in the three filter, narrow-band Δ a-system for five open clusters (NGC 2489, NGC 2567, NGC 2658, NGC 5281 and NGC 6208) allow the detection of apparent chemically peculiar stars (Paunzen & Maitzen 2001). Chemically-peculiar stars in NGC 1866 in the LMC were found by Δa photometry (Maitzen, Paunzen & Pintado 2001). Be stars in six fields in the young clusters NGC 330 and NGC 346 in the SMC, and NGC 1818, NGC 1948, NGC 2004 and NGC 2100 in the LMC were identified by differencing R band and narrow-band H-alpha CCD images by Keller et al. (1999). The ability of the Strömvil photometric system to identify peculiar stars of various types: F-M subdwarfs, G-M metal-deficient giants, cool carbon, barium and zirconium (S-type) stars, chemically peculiar B and A stars, emission-line stars (Be, Ae/Be, WR, T Tauri, etc.), white dwarfs, some horizontal-branch stars and many types of unresolved binaries is discussed by Straižys (1999).

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7. Catalogues and Atlases

Kirk D. Borne

Also see this: http://arXiv.org/abs/astro-ph/0208185 ... "Automated Stellar Spectral Classification..."

7.1. Atlases

ELODIE archive (Prugniel, P. et al. 2001)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/catalogs/3/3218/

Spectral Library of Galaxies, Clusters and Stars (Santos, J. F. C. et al. 2001)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/catalogs/3/3219/

CaII H&K to CaII IRT echelle spectra (Montes, D. et al. 2000)
http://adc.gsfc.nasa.gov/cgi-bin/adc/cat.pl?/journal_tables/A+AS/146/103/

https://doi.org/10.1017/S0251107X00001504 Published online by Cambridge University Press

Spectrophotometric atlas of symbiotic stars (Munari, U. & Zwitter, T. 2002)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/journal_tables/A+A/383/188/
http://www.edpsciences.org for Figs 4 - 256

7.2. Broad Catalogues

Michigan Catalogue of HD stars, Vol.5 (Houk, N. 1999)
http://adc.gsfc.nasa.gov/cgi-bin/adc/cat.pl?/catalogs/3/3214/

14th General Catalogue of MK Spectral Classification (Buscombe, W. 1999)
http://adc.gsfc.nasa.gov/cgi-bin/adc/cat.pl?/catalogs /3/3222/

15th General Catalogue of MK Spectral Classification (Buscombe, W. 2001)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/catalogs/3/3225/

Symbiotic stars catalogue (Belczyński, K. et al. 2000)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/journal_tables/A+AS /146/407/

7.3. Hot Stars

7th Catalog of Galactic Wolf-Rayet stars (van der Hucht, K. A. 2001)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/catalogs/3/3215/

Early-type stars towards the Galactic Centre (Dufton, P. L., Smartt, S. J., & Hambly, N. C. 1999)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/journal_tables/A+AS/139/231/

Early-type stars towards the Galactic Centre. II. (Dufton, P. L. et al. 2001)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/journal_tables/A+A/373/608/

7.4. Mid-Temperature Stars

Precise spectral types for 372 A, F and G stars (Gray, R. O., Napier, M. G., & Winkler, L. I. 2001)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/journal_tables/AJ/121/2148/

Basic parameters for 372 A, F and G stars (Gray, R. O., Graham, P. W., & Hoyt, S. R. 2001)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/journal_tables/AJ/121/2159/

7.5. Cool Stars

General Catalog of galactic Carbon stars, 3d Ed. (Alksnis, A. et al. 2001)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/catalogs/3/3227/

M stars in Cepheus region (Kazarian et al. 2001)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/journal_tables/other/Ap/44.335/

Library of FOE spectra of late-type stars (Montes, D., Ramsey, L. W., & Welty, A. D. 1999)
http://adc.gsfc.nasa.gov/cgi-bin/adc/cat.pl?/journal_tables/ApJS/123/283/

Teff and log(g) of low-metallicity stars - a three-dimensional classification using an automated neural network (Snider, S. et al. 2001)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/journal_tables/ApJ/562/528/

Revision of MK luminosity classes (Keenan, P. C. & Barnbaum, C. 1999)
http://adc.gsfc.nasa.gov/cgi-bin/adc/cat.pl? /journal_tables/ApJ/518/859/
and see http://www.astronomy.ohio-state.edu/MKCool/ for updated catalogue

Library of Spectra (0.5 to 2.5um) of Cool Stars (Lancon, A. & Wood, P. R. 2000)
http://adc.gsfc.nasa.gov/cgi-bin/adc/cat.pl?/journal_tables/A+AS/146/217/

Stellar-activity of late-type stars (Strassmeier, K. G. et al. 2000)
http://adc.gsfc.nasa.gov/cgi-bin/adc/cat.pl?/journal_tables/A+AS/142/275/

Effective temperatures of carbon-rich stars (Bergeat, J., Knapik, A., & Rutily, B. 2001)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/journal_tables/A+A/369/178/

7.6. Pre-Main Sequence Stars

Classification and vsini of Vega-type and PMS stars (Mora, A. et al. 2001)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/journal_tables/A+A/378/116/

7.7. Subdwarfs and White Dwarfs

Spectroscopically Identified White Dwarfs (McCook, G. P. et al. 1999)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/catalogs/3/3210/

UVES/VLT spectra of white dwarfs (Koester, D., et al. 2001)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/journal_tables/A+A/378/556/

7.8. IRAS Sources and Infrared Spectra

Spectra of T dwarfs. I. (Burgasser, A. J. et al. 2002)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/journal_tables/ApJ/564/421/

IR spectra of oxygen-rich evolved stars (Speck, A. K. et al. 2000)
http://adc.gsfc.nasa.gov/cgi-bin/adc/cat.pl?/journal_tables/A+AS/146/437/

O, B and Be stars equivalent widths (Lenorzer, A. et al. 2002)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/journal_tables/A+A/384/473/

Infrared properties of barium stars (Chen, P. S. 2001)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/journal_tables/A+A/372/245/

Properties of OH/IR stars with IRAS LRS spectra (Chen, P. S. et al. 2001)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/journal_tables/A+A/368/1006/

7.9. Ultraviolet Spectra

Merged Log of IUE Observations (NASA-ESA 1999)
http://adc.gsfc.nasa.gov/cgi-bin/adc/cat.pl?/catalogs/6/6099/

Tubingen Ultraviolet Echelle Spectrometer (Barnstedt, J. et al. 1999)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/catalogs/6/6107/

Mg II K line Wilson-Bappu relationship (Cassatella, A. et al. 2001)
http://adc.gsfc.nasa.gov/adc-cgi/cat.pl?/journal_tables/A+A/374/1085/

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