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Volume 2

Astronomy and Astrophysics

Extension and Supplement to Volume 1

Subvolume b

Stars and Star Clusters

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Astronomie und Astrophysik

Weiterführung und Ergänzung von Band 1

Teilband b

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L. H. Aller · I. Appenzeller · B. Baschek · H. W. Duerbeck
T. Herczeg · E. Lamla · E. Meyer-Hofmeister · Th. Schmidt-Kaler
M. Scholz · W. Seggewiss · W. C. Seitter · V. Weidemann

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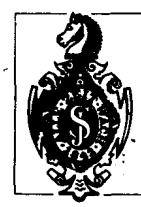

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Survey

Übersicht

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Vorwort

Nach dem kürzlich erschienenen ersten Teilband 2a des Bandes VI/2 „Astronomie und Astrophysik" wird hiermit der Teilband 2b vorgelegt. Auch für ihn gilt das im Vorwort zum ersten Teilband Gesagte ohne Änderung und Einschränkung.

Der letzte Teilband 2c wird so schnell wie möglich folgen.

Heidelberg und Göttingen, Oktober 1981 **Die Herausgeber**

Preface

This subvolume is the second part, 2b, of volume VI/2, "Astronomy and Astrophysics", the first part of which, VI/2a, has been published a short time ago. Since the preface of vol. VI/2a holds completely also for VI/2b, it will not be repeated here

The third part, 2c, will be published as soon as possible.

Heidelberg and Göttingen, October 1981 **The Editors**

List of abbreviations

Abbreviations, commonly used in Astronomy, and not always explained explicitly in this book.

AU	Astronomical Unit (= Distance Earth–Sun)
B.C.	Bolometric Correction
BD	Bonner Durchmusterung
CLV	Center-limb variation
CMD	Colour-magnitude-diagram
CNO	Carbon, Nitrogen, and Oxygen (*not* as molecule) e.g. CNO cycle, CNO anomalies
ESA	European Space Agency
ESO	European Southern Observatory
ET	or E.T. Ephemeris Time
EUV	Extreme ultraviolet
FWHW	Full Width of Half Maximum
HD	Henry Draper Catalogue
HR	Harvard Revised Catalogue
HRD	Hertzsprung-Russell Diagram
IAU	International Astronomical Union
IR	Infrared
ISM	Interstellar Matter
JD	Julian Date
KPNO	Kitt Peak National Observatory
LB, NS or LB	Landolt-Börnstein, Numerical Data and Functional Relationships in Science and Technology, New Series or: Landolt-Börnstein, NS
LC	Luminosity Class
LF	Luminosity Function
LMC	Large Magellanic Cloud
LTE	Local thermodynamic equilibrium
M	Messier Catalogue
MHD	Magneto-hydrodynamics
MMT	Multi-Mirror-Telescope
MPI	Max-Planck-Institut
NASA	National Aeronautics and Space Administration
NEP	Noise Equivalent Power
NGC	New General Catalogue
NLTE	Non-local thermodynamic equilibrium
NRAO	National Radio Astronomy Observatory, Green Banks, W. Va., USA
POSS	Palomar Observatory Sky Survey
RV	Radial velocity
SMC	Small Magellanic Cloud
Sp	Spectral type
URSI	International Union of Radio Science
UT	Universal time
UV	Ultraviolet
VLBI	Very Long Baseline Interferometry
XUV	X-ray and ultraviolet region
ZAMS	Zero Age Main Sequence

Abbreviations of further Star Catalogues: see 8.1.1
For abbreviations of special star types (e.g. WR stars), see "Spectralclassification" (4.1.1), "Variable stars" (5.1), "Peculiar stars" (5.2) and subject index.

Some important Astronomical Artificial Satellites, mentioned in this book

ANS	Astronomical Netherlands Satellite (The Netherlands NASA)
ATS	Applications Technology Satellite
COS	Cosmic Ray Satellite (ESA)
GIRL	German Infrared Laboratory
HEAO	High Energy Astrophysical Observatory (NASA)
HEOS	High Eccentricity Earth-Orbiting Satellite (ESA)
IMP	Interplanetary Monitoring Platform
IRAS	Infrared Astronomical Satellite
IUE	International Ultraviolet Explorer (NASA–UK–ESA)
OAO	Orbiting Astronomical Observatory (NASA)
OGO	Orbiting Geophysical Observatory
OSO	Orbiting Solar Observatory
MTS	Meteoroid Technology Satellite (NASA)
RAE	Radio Astronomy Explorer
SAS	Small Astronomy Satellite (NASA)

Contents

4 The stars

5 Special types of stars

6 Double stars and star clusters

4 The stars

4.1 Physical parameters of the stars

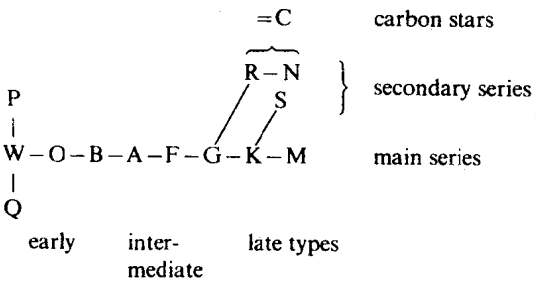
4.1.0 General remarks

The physical parameters given here are integral values which characterize the physical properties of a star as a whole, especially mass, luminosity, radius, effective surface temperature, age, spectral type, color, absolute magnitude, surface gravity, equatorial rotational velocity. Characteristic diagrams such as the luminosity-temperature (Hertzsprung-Russell) diagram enable us to describe the evolution of stars.

4.1.1 Classification of stellar spectra [1])

4.1.1.1 The (improved and extended) Harvard classification

The stars can be arranged in a linear sequence according to the general appearance of their line spectra. The essential parameter is the ionisation temperature of the stellar atmosphere. As the color temperature decreases from O to M, the stars become redder.



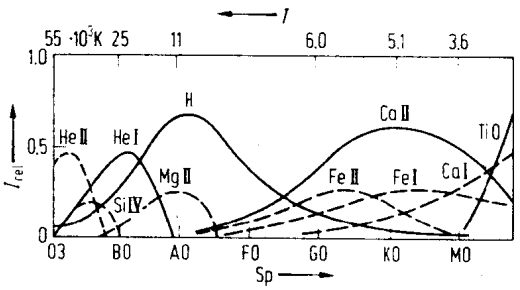


Fig. 1. The relative intensities I_{rel} of the most important lines in the spectra of the main series O···M (illustrated schematically).

99.95% of the stars brighter than $8^m.0$ (completeness limit of the Henry Draper Catalogue) belong to the main series O to M.

The spectral classes SP are given as decimals (e.g. O9, O9.5, O9.7, B0, B1, ...). Agreement is about ±0.6 of a subdivision [1]. The classification is made either based upon a summary description, or by determining the intensity ratios between certain (neighbouring) lines, or by comparison with the spectra of standard stars. The classification criteria may vary for spectra of different dispersions and wavelength regions.

Detailed descriptions of the line spectra of selected stars are referenced, e.g. in [2, 3, 4]. A selected list is given in Table 10, p. 7.

Table 1. Spectral classification of stars with predominant emission lines (hot stars) [5].

Sp	Standards	Spectral characteristics
P	NGC 7027, NGC 6720	Planetaries or planetary nebulae (see 5.4): many emission lines of very high excitation, including forbidden lines
Q	GK Per 1901 DQ Her 1934	Novae (see 5.1.3.2)
W	γ^2Vel (WC7 + O7)	Wolf-Rayet stars (=WR stars; see 5.2.1.2): very broad, intensive emission lines of H, He I, He II are superposed on a continuum which is especially intensive in the blue-UV region
WN	HD 192163 (WN6)	a) nitrogen sequence WN5···8 with strong emission lines of N III, IV, V
WC	HD 192103 (WC7)	b) carbon sequence WC5···8 with strong emission lines of C II, III, IV, O III···O VI

Details of subclasses of WR stars are given in Table 2, page 3.
See also 4.1.1.3, Table 9a.

[1]) In the following tables all wavelengths are given in [Å], if not stated otherwise.

For Table 2, see next page.

Table 3. Spectral types with predominant absorption lines (main series O···M).
For any two lines a and b in the third column:

a > b	line a stronger than line b
a = b	lines a and b have the same intensity
a: max	line a has maximum intensity at this spectral type
a ≈ 0.5 < A0 >	line a has half the intensity of the same line in spectral type A0
a ≈ 0.1 Hδ	line a has one tenth of the intensity of the line Hδ
a ≈ 2 ⊙	line a has twice the intensity as the same line in the solar spectrum

Sp	Standards	Spectral characteristics
O		Intensive (blue) continuum, predominant absorption lines of He II, additionally of C III, N III, Si IV [8]. If N III 4634/40/41 appears in emission the star is called Of (see 5.2.1.1), if He II 4686, it is Onfp. See [8].
O3	HDE 303308	He I 4471/He II 4541 = 0.1
O4 f	HD 190429 A	= 0.2
O5 (f)	HD 15558	= 0.3
O6 fp	λ^1 Cep	= 0.6
O7	HD 190864	= 0.9
O8	λ Ori	= 1.3
O9	ι Ori	= 1.8
B0	τ Sco, ε Ori	He I > He II; C III 4650 and Si IV 4089/4116: max; Hδ = 1.5 He I 4026.
B3	π^4 Ori	He I: max; H (Balmer lines) ≈ 0.5 < A0 >; O II and Si IV very weak.
B5	φ Vel	Si II 4128/4131 > He I 4121.
B8	β Per	He I 4471 = Mg II 4481; Hδ = 1.5 He I 4026; metal lines appear.
A0	α CMa	Balmer series dominating (H: max); Mg II 4481 most conspicuous after Balmer lines; K (Ca II 3934) ≈ 0.1 Hδ; Si II: max; depression of UV continuum by continuous Balmer absorption.
A5	β Tri, α Pic	Ca II (K) = 0.9 {Ca II (H) + Hε} and > Hδ; Fe I 4299/4303 and Ti II 4303 strong.
F0	δ Gem, α Car	Balmer series ≈ 0.5 < A0 >; Ca II (K) = Ca II (H) + Hε = 3 Hδ; many metal lines; G-band 4307 (Fe, Ti, Ca) appearing.
F5	α CMi, ϱ Pup	Balmer lines ≈ 2⊙; Ca I 4227 = 0.5 Hγ; G-band = 0.6 Hγ.
G0	α Aur, β Hyi	Solar-type spectrum (sun: G 2 or somewhat later); very intense metal lines; Ca I 4227 = Hδ; G-band = 2 Hγ = 3 Fe I 4325.
K0	α Boo, α Phe	Metal lines further enhanced, Balmer lines further weakened; Ca I 4227 = 2 Fe II 4172 = 3 Fe I 4383; Fe I 4325 = 2 Hγ; Ca II (H, K): max.
K5	α Tau	Similar to sunspot spectrum; Ca I and II dominating; G-band dissolved in lines; green TiO-bands appearing.
M0··· 2 (Ma)	β And (M0), α Ori (M2)	TiO-bands dominating (esp. 4762···4956, 5168···5445); Ca I 4227 strongest line.
M3··· 5 (Mb)	π Aur (M3)	Subclassification by increasing intensity of the green and red
M6···10 (Mc)	ϱ Per (M6)	(6651, 7054, 7589) band systems.
M0e···M10e (Md)	o Cet (M6e)	Balmer lines (at least Hα) in emission.