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# The Astrophysics of Emission-Line Stars

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Library of Congress Control Number: 2007922569

ISBN-10: 0-387-34500-0  
ISBN-13: 978-0-387-34500-0

e-ISBN-10: 0-387-68995-8  
e-ISBN-13: 978-387-68995-1

Printed on acid-free paper.

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# Contents

<b>Preface</b>	<b>xiii</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Emission-line stars	1
1.2 Early history of stellar spectroscopy	3
1.2.1 Early days of stellar spectroscopy	3
1.2.2 Early discoveries of emission-line stars	4
1.2.3 Spectral classification and emission-line stars	5
1.2.4 Additional discoveries of emission-line stars	6
1.3 Development of theoretical approach	9
1.3.1 Formation of emission lines	9
1.3.2 Hydrodynamic approach	12
<b>I Stellar Atmospheres and Formation of Emission Lines</b>	
<b>2 Stellar Spectra and Radiation Fields</b>	<b>19</b>
2.1 Basic properties of stars	19
2.1.1 Photometric system	19
2.1.2 Stellar parallax and stellar luminosity	20
2.1.3 Spectral classification	22
2.1.4 HR diagram and stellar parameters	26
2.2 Atomic spectrum	28
2.2.1 Hydrogen and ionized helium	28
2.2.2 Spectra of general atoms	33
2.2.3 Emission and absorption processes in atoms or ions	38
2.2.4 Line intensities in spectral sequence	39
2.3 Thermodynamic equilibrium and black-body radiation	41
2.3.1 Planck function	41
2.3.2 Boltzmann's law and Einstein coefficients	42
2.4 Concepts of spectral-line formation	44
2.4.1 Equations of radiative transfer	44
2.4.2 Absorption versus emission	44
2.4.3 Source function and black-body radiation	46

2.5	Stellar atmospheres and formation of absorption lines . . . . .	47
2.5.1	Radiation fields of stellar atmospheres . . . . .	47
2.5.2	Radiative transfer and limb darkening . . . . .	49
2.5.3	Radiative flux and effective temperature . . . . .	51
2.5.4	Radiative equilibrium and temperature gradient . . . . .	52
2.5.5	Formation of absorption lines . . . . .	55
2.6	Spectral-line profiles . . . . .	58
2.6.1	Profiles of absorption lines . . . . .	58
2.6.2	Line broadening by the stark effect . . . . .	60
2.6.3	Line broadening by turbulence . . . . .	62
2.6.4	Line broadening by stellar rotation . . . . .	63
2.7	Absorption lines and model atmospheres . . . . .	66
2.7.1	Curve of growth . . . . .	66
2.7.2	Model atmosphere . . . . .	70
<b>3</b>	<b>Dynamic Processes in Stellar Atmospheres</b> . . . . .	<b>79</b>
3.1	Convection layers and atmospheric structure . . . . .	79
3.1.1	Convection layers and the Schwarzschild criterion . . . . .	79
3.1.2	Convective instability . . . . .	80
3.1.3	Convection layers and mechanical energy . . . . .	82
3.1.4	Stellar evolution and chromospheric activities . . . . .	85
3.2	Stellar winds . . . . .	87
3.2.1	Basic concepts of stellar winds . . . . .	87
3.2.2	Radiation-driven winds in early-type stars . . . . .	89
3.2.3	Magnetic rotator model of the solar wind . . . . .	92
3.2.4	Stellar winds in late-type stars . . . . .	96
3.2.5	Stellar winds and mass-loss rates . . . . .	104
3.3	Accretion flows and accretion disks . . . . .	108
3.3.1	Spherically symmetric accretion flows . . . . .	108
3.3.2	Accretion disks of protostars . . . . .	110
3.3.3	Accretion disks of close binaries . . . . .	113
3.4	Shock waves . . . . .	117
3.4.1	Basic properties of shock waves . . . . .	117
3.4.2	Shock waves in stellar atmospheres . . . . .	122
3.4.3	Stellar atmospheres and shock waves . . . . .	127
<b>4</b>	<b>Formation of Emission Lines</b> . . . . .	<b>135</b>
4.1	Theories of static envelopes . . . . .	135
4.1.1	Dilution effect and the Rosseland cycle . . . . .	135
4.1.2	Nebular approximation and recombination lines . . . . .	138
4.1.3	Generalization of nebular approximation and escape probability by scattering . . . . .	141
4.1.4	Radiation field of the envelopes of early-type stars . . . . .	146
4.1.5	Balmer decrements of emission-line stars . . . . .	153
4.2	Theories of moving envelopes . . . . .	155

4.2.1	Escape probability by motion . . . . .	155
4.2.2	Escape probability and formation of emission lines . . . .	160
4.2.3	Method of velocity zones . . . . .	163
4.2.4	Other methods . . . . .	166
4.3	Formation of forbidden lines . . . . .	171
4.3.1	Nebular-type forbidden lines . . . . .	171
4.3.2	Formation of forbidden lines and critical electron density	172
4.3.3	Semiforbidden lines (intersystem lines) . . . . .	175
4.4	Nonthermal atmospheres . . . . .	175
4.4.1	Late-type stars and basal atmospheres . . . . .	175
4.4.2	Models of chromosphere . . . . .	176
4.4.3	Formation of emission lines . . . . .	180
4.4.4	Chromospheric activities of A-type stars . . . . .	182

## II Emission-Line Stars

<b>5</b>	<b>Early-type Emission-line Stars</b>	<b>189</b>
5.1	Wolf-Rayet stars . . . . .	189
5.1.1	Spectral classification and basic stellar parameters . . .	189
5.1.2	Spectral features of WR stars . . . . .	193
5.1.3	Time variations . . . . .	202
5.1.4	Spectroscopic binaries and mass of WR stars . . . . .	208
5.1.5	Spectroscopic models and chemical composition . . . . .	212
5.2	O-Type Emission-line stars . . . . .	215
5.2.1	Of stars . . . . .	215
5.2.2	Oe stars . . . . .	219
5.2.3	Central stars of planetary nebulae (PNCSS) . . . . .	220
5.3	B-Type Emission-Line stars (Be stars) . . . . .	224
5.3.1	What are Be stars? . . . . .	224
5.3.2	Basic types and catalogues . . . . .	225
5.3.3	Statistical properties . . . . .	228
5.3.4	Balmer line spectrum . . . . .	233
5.3.5	Other spectroscopic properties . . . . .	246
5.3.6	Time variations . . . . .	260
5.3.7	Peculiar Be stars . . . . .	274
5.4	Supergiant Emission-line stars . . . . .	275
5.4.1	Luminous blue variable . . . . .	275
5.4.2	P Cygni and P Cyg-type stars . . . . .	280
5.4.3	Supergiant B[e] stars . . . . .	287
5.4.4	Hubble-Sandage stars . . . . .	290
5.5	Evolutionary status of early-type emission-line stars . . . . .	292
5.5.1	Evolution of massive stars and emission-line stars . . . . .	292
5.5.2	Evolution of Be stars . . . . .	296
5.5.3	Evolution of binary systems . . . . .	299



<b>6</b>	<b>Late-Type Stars and Close Binaries</b>	<b>317</b>
6.1	Late-type stars and chromospheric activity	317
6.1.1	Emission-line intensities	317
6.1.2	Emission-line width	321
6.1.3	Excitation degree of emission lines	323
6.2	Emission-line red-dwarfs and flare stars	323
6.2.1	The emission-line red-dwarf stars (dMe)	323
6.2.2	Flare stars	328
6.3	Red giants and long-period variables	340
6.3.1	Red giants	340
6.3.2	Long-period variables	343
6.4	Eclipsing binary systems	351
6.4.1	Algol-type eclipsing binary systems	352
6.4.2	Formation of emission-lines in Algol type systems	353
6.4.3	Binary system with an atmospheric eclipse	356
6.5	RS Canes Venatici (RS CVn) type stars	360
6.6	Cataclysmic variables and novae	366
6.6.1	Cataclysmic variable stars	366
6.6.2	Classical novae (CNe)	367
6.6.3	Recurrent novae (RNe)	378
6.6.4	Dwarf novae (DNe)	385
6.6.5	Nova-like variables (NL)	389
6.6.6	Balmer decrements of cataclysmic variables	393
6.7	Symbiotic stars	397
6.7.1	Symbiotic stars and classification	397
6.7.2	Spectral features	399
6.7.3	CH Cygni, spectrum and its variation	404
6.7.4	Symbiotic novae	404
6.7.5	Binary nature and evolutionary state of symbiotic stars	408
<b>7</b>	<b>Pre-main Sequence Stars</b>	<b>423</b>
7.1	Herbig Ae/Be stars	423
7.1.1	Definition and catalogues	423
7.1.2	Spectral features	424
7.1.3	Rotational velocities and binarity	434
7.1.4	Variability	438
7.1.5	Toward the models of envelopes	444
7.1.6	Optical jet flows	446
7.2	T Tauri type stars	448
7.2.1	What are T Tauri type stars	448
7.2.2	Spectroscopic features	450
7.2.3	Chromospheric structures	464
7.2.4	Rotational velocities and binary systems	466
7.2.5	Variabilities and activities	469
7.2.6	FU Orionis and YY Orionis type stars	473

<i>Contents</i>	xi
7.3 Pre-main sequence stars and hydrogen spectra . . . . .	477
7.3.1 Emission-line intensities and Balmer decrements . . . . .	477
7.3.2 Hydrogen infrared emission lines and mass-loss rates . .	484
7.3.3 Shell absorption lines . . . . .	487
7.3.4 Magnetospheric accretion models and line profiles . . . . .	489
7.4 Evolution of pre-main sequence stars . . . . .	492
<b>Supplement</b>	<b>503</b>
<b>Author Index</b>	<b>511</b>
<b>Subject Index</b>	<b>519</b>
<b>Index of Stellar Objects</b>	<b>529</b>

# Preface

Many types of stars show conspicuous emission lines in their optical spectra. These stars are broadly referred to as emission-line stars, but, in the past, they were considered a type of peculiar stars, because emission lines were thought to be an indication of behaviors “peculiar” from the normal stellar atmospheres. Prior to 1950s, early-type emission-line stars such as Wolf-Rayet stars, Be stars, and P Cygni stars were called the early-type peculiar stars. With the advance in theories of emission-line formation, the name “emission-line stars” has been widely adopted to include both early- and late-type stars, and the name of “peculiar-stars” has been only used for chemically peculiar stars. Some stars that have no particular names as emission-line stars, such as cataclysmic variables and Mira variables, are also included in the category of emission-line stars. In closer examination most of stars on the Hertzsprung–Russell (HR) diagram show somehow evidence of emission lines formed in a less-developed form as in case of the Sun. In this book, however, we confine our examination of emission-line stars to the stars having strong lines in the optical region.

In the later half of the twentieth century, the physics of emission-line stars has been surprisingly developed under collaborations between ground-based and space observations. Wide wavelength observations have opened a new era of understanding the active stellar envelopes in various forms, such as stellar winds, accretion flows, flare activities, and binary interaction.

In this book an attempt is made to outline the physics of emission-line stars that are widely located on the HR diagram. Particular attention is paid to the spectral analysis of emission lines mainly in the optical region.

Although intended mainly for the use of graduate student and teachers of stellar astronomy, the present work should also provide a useful reference for practicing astronomers, particularly, for small-telescope users in institutions and public or private observatories. For these observers, emission-line stars may be an attractive choice to observe/monitor by their mysterious and often violent variable behaviors.

This book consists of a brief historical review in Chapter 1 followed by two major parts.

In Part I, first two chapters review the basic concepts on the spectroscopic processes (Chapter 2) and gas dynamical processes (Chapter 3) in stellar atmospheres. Chapter 4 is devoted to the mechanisms of emission-line formation in static and moving envelopes and in nonthermal atmospheres. Readers who

are already familiar with basic astrophysics can skip Chapters 2 and 3 and move to Chapter 4.

In Part II, broad overviews of emission-line stars are given in three chapters. Chapter 5 deals with the early-type emission-line stars (WR, Of, Oe, Be, LBV), mostly forming developed expanding envelopes. Chapter 6 yields the late-type stars (dMe, flare stars, Mira variables) and close binary systems (Algol, RS CVn, cataclysmic variables, symbiotic stars), where the nonthermal processes are prevailing. In Chapter 7 the pre-main sequence stars (HES and TTS) are considered as activities in the contracting phase of stellar evolution. Thus Part II as a whole will show an amazing variety of emission-line stars.

Though we have confined the topics to the stars in this book, there are numerous objects showing strong and active emission-line phenomena in and out of the Galaxy. This book is expected to be useful for these related fields. Considering remarkable progress in the field of the physics of emission line stars since submission of the manuscript, we have added a self-contained Supplement at the end of the book to bring it up to 2006.

For further reading, books, and review articles are prepared for each chapter. The cited references are also given. It should be noticed that this book owes a great debt to the numerous works cited for their thoughts, data, and figures. The authors express sincere gratitude to those who have gone before. "We stand on the shoulders of giants." One of the authors (T.K.) published a book entitled *Emission Line Stars* (2002) written in Japanese. The present book is realized on the basis of this original book. On this occasion T.K. expresses his thanks to the late Mr. Mitsuo Goto, who encouraged him for a long time and passed away just before the publication of the original book. K-C.L. would like to thank Professor Sun Kwok for the invitation to spend a semester at the Institute of Astronomy and Astrophysics, Academia Sinica, R. O. C., Fall, 2006. He would also like to acknowledge the support of the Department of Physics and Astronomy, University of Nebraska for releasing him from teaching to complete the manuscript of this book. The authors are grateful to Yvonne Norton Leung for her editing assistance.

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