

Contents

Preface XI

List of Contributors XV

1	Hot White Dwarfs	1
	<i>Edward M. Sion</i>	
1.1	Introduction	1
1.2	Remarks on the Spectroscopic Classification of Hot White Dwarfs	2
1.3	The Hot DA Stars	6
1.3.1	DAO White Dwarfs	9
1.4	The PG 1159 Stars	11
1.5	DO White Dwarfs	14
1.6	DB White Dwarfs	17
1.6.1	DBA White Dwarfs	18
1.7	Hot DQ White Dwarfs	19
1.8	Conclusion	20
	References	21
2	Cool White Dwarfs	25
	<i>Mukremir Kilic</i>	
2.1	White Dwarf Cosmochronology	25
2.2	Cool White Dwarf Atmospheres	29
2.2.1	Collision Induced Absorption	29
2.2.2	The Missing Opacity Source in the Blue: Lyman- α Absorption	31
2.2.3	Model Atmospheres Versus Observations	32
2.3	Identification of Large Samples of Cool White Dwarfs	34
2.3.1	Photometric Selection	34
2.3.2	Proper Motion Selection	35
2.4	Observational Properties of Cool White Dwarfs	37
2.4.1	Color-Color Diagrams	37
2.4.2	Pure Hydrogen and Pure Helium Atmosphere White Dwarfs	38
2.4.3	Mixed H/He Atmosphere White Dwarfs	40
2.4.4	Ultracool (or Infrared-Faint) White Dwarfs	41
2.5	Spectral Evolution of Cool White Dwarfs	42

2.6	Ages for Individual White Dwarfs	44
2.7	The White Dwarf Luminosity Function	46
2.8	Halo White Dwarfs	48
2.9	Conclusions and Future Prospects	50
	References	51
3	Stars with Unusual Compositions:	
	Carbon and Oxygen in Cool White Dwarfs	53
	<i>Patrick Dufour</i>	
3.1	Introduction	53
3.2	DQ White Dwarfs	54
3.2.1	Historical Introduction and General Properties	54
3.2.2	Formation Mechanism	59
3.2.3	Relation Between Carbon Abundance and Temperature: An Overview	61
3.2.4	DQ White Dwarfs with Oxygen	64
3.2.5	The Peculiar (“C ₂ H”?) DQ White Dwarfs	65
3.3	Carbon and Oxygen in DBQ White Dwarfs	70
3.4	Hot DQ White Dwarfs	72
3.4.1	Historical Introduction and General Properties	72
3.4.2	Magnetism	76
3.4.3	Oxygen	78
3.4.4	Pulsations	78
3.4.5	Formation and Origin	81
3.4.6	Concluding Remarks on the Hot DQ Stars	83
3.5	Conclusion	84
	References	87
4	Planets Orbiting White Dwarfs	89
	<i>Rosanne Di Stefano</i>	
4.1	Introduction	89
4.2	Expectations	92
4.3	Detecting Radiation from the Planets	94
4.4	Evidence for Minor Planets	97
4.4.1	Survivability	97
4.4.2	Metal Enrichment and Disks	100
4.4.3	Transits of Asteroids	102
4.5	Timing	102
4.6	Mesolensing	105
4.6.1	Gravitational Lensing Basics	105
4.6.2	Nearby Lenses	107
4.6.3	Planet Detection via Lensing	108
4.6.4	Identifying White Dwarfs in the Lens System	109
4.7	Transits	111
4.7.1	Basics	111
4.7.2	SuperWASP	111

4.7.3	Wide-Field Monitoring	112
4.8	Prospects for the Future	112
	References	113
5	White Dwarf Circumstellar Disks: Observations	117
	<i>Jay Farihi</i>	
5.1	Introduction	117
5.2	History and Background	118
5.2.1	Early Searches	118
5.2.2	The Discovery of Infrared Excess from G29-38	118
5.2.3	The Polluted Nature of Metal-Rich White Dwarfs	120
5.2.4	Interstellar or Circumstellar Matter	122
5.2.5	G29-38 and the Asteroid Accretion Model	123
5.3	Pre-Spitzer and Ground-Based Observations	124
5.3.1	Photometric Searches for Near-Infrared Excess	124
5.3.2	Metal-Polluted White Dwarf Discoveries	125
5.3.3	The Spectacular Case of GD 362	126
5.3.4	Spectroscopic Searches for Near-Infrared Excess	127
5.3.5	Spectroscopy at Longer Wavelengths	129
5.4	The Initial Impact of Spitzer	129
5.4.1	Infrared Capabilities of Spitzer	129
5.4.2	First Results	130
5.4.3	The First Spitzer Surveys of White Dwarfs	134
5.5	The Next Wave of Disk Discoveries	138
5.5.1	The Second Class of Polluted White Dwarfs	138
5.5.2	A Highly Successful Spitzer Search	139
5.5.3	The Detection of Gaseous Debris in a Disk	141
5.5.4	Dust Deficiency of DAZ Stars – Collisions?	142
5.5.5	Expanding Searches to the DBZ Stars	143
5.5.6	Additional Disks with Gaseous (and Solid) Debris	145
5.6	Studies and Statistics	147
5.6.1	Spectroscopic Confirmation of Rocky Circumstellar Debris	147
5.6.2	First Statistics and the Emerging Picture	151
5.6.3	Dust-Deficiency in DAZ Stars – Narrow Rings?	153
5.6.4	The Composition and Masses of Asteroids around GD 362 and GD 40	158
5.6.5	Evidence for Water in Debris Orbiting White Dwarfs	161
5.6.6	A Last Look at the Interstellar Accretion Hypothesis	162
5.7	Related Objects	164
5.7.1	White Dwarfs Polluted by Companions?	164
5.7.2	Dust in the Helix?	165
5.8	Outlook for the Present and Near Future	166
	References	168

6	The Origin and Evolution of White Dwarf Dust Disks	173
	<i>John H. Debes</i>	
6.1	Introduction	173
6.2	Orders of Magnitude around a White Dwarf	174
6.3	Structure and Evolution of a White Dwarf Dust Disk	178
6.3.1	Optically Thin Dust Disks?	182
6.3.2	Subsequent Evolution of the Dust Disk	182
6.4	Origins of White Dwarf Dust Disks	185
6.4.1	The Unstable Planetary Perturbation Model	185
6.4.2	Dust and Accretion, or Just Accretion?	190
6.4.3	The Mean Motion Perturbation Model	192
6.4.4	Observability of Ring Progenitors	196
6.5	Conclusion	198
	References	200
7	Planetary Nebulae around White Dwarfs: Revelations from the Infrared	203
	<i>You-Hua Chu</i>	
7.1	Introduction: Expectations of Nebulae around White Dwarfs	203
7.2	Planetary Nebulae around White Dwarfs	204
7.3	High-Excitation Nebulae around Hot White Dwarfs	208
7.4	Mid-Infrared Emission from Circumstellar Nebulae of White Dwarfs	209
7.5	Conclusion	212
	References	215
	Index	217
	Object Index	223