

# Contents

<i>Preface</i>	v
1. The Enigma of the Dark Night Sky	1
1.1 Why is the sky dark at night? . . . . .	1
1.2 “By reason of distance” . . . . .	4
1.3 Island Universe . . . . .	5
1.4 Non-uniform sources . . . . .	6
1.5 Tired light . . . . .	9
1.6 Absorption . . . . .	10
1.7 Fractal Universe . . . . .	12
1.8 Finite age . . . . .	13
1.9 Dark stars . . . . .	16
1.10 Curvature . . . . .	17
1.11 Ether voids . . . . .	19
1.12 Insufficient energy . . . . .	20
1.13 Light-matter interconversion . . . . .	21
1.14 Cosmic expansion . . . . .	22
1.15 Olbers’ paradox today . . . . .	25
2. The Intensity of Cosmic Background Light	29
2.1 Bolometric intensity . . . . .	29
2.2 Time and redshift . . . . .	32
2.3 Matter, energy and expansion . . . . .	33
2.4 How important is expansion? . . . . .	37
2.5 Simple flat models . . . . .	39
2.6 Curved and multi-fluid models . . . . .	41

2.7	A bright sky at night? . . . . .	44
3.	The Spectrum of Cosmic Background Light	49
3.1	Spectral intensity . . . . .	49
3.2	Luminosity density . . . . .	52
3.3	The delta function . . . . .	54
3.4	The normal distribution . . . . .	58
3.5	The thermal spectrum . . . . .	59
3.6	The spectra of galaxies . . . . .	62
3.7	The light of the night sky . . . . .	65
3.8	R.I.P. Olbers' paradox . . . . .	69
4.	Dark Cosmology	73
4.1	The four dark elements . . . . .	73
4.2	Baryons . . . . .	76
4.3	Dark matter . . . . .	80
4.4	Neutrinos . . . . .	84
4.5	Dark energy . . . . .	86
4.6	Cosmological concordance . . . . .	88
4.7	The coincidental Universe . . . . .	94
5.	The Radio and Microwave Backgrounds	97
5.1	The cosmological "constant" . . . . .	97
5.2	The scalar field . . . . .	98
5.3	Decaying dark energy . . . . .	102
5.4	Energy density . . . . .	105
5.5	Source luminosity . . . . .	108
5.6	Bolometric intensity . . . . .	113
5.7	Spectral energy distribution . . . . .	114
5.8	Dark energy and the background light . . . . .	115
6.	The Infrared and Visible Backgrounds	119
6.1	Decaying axions . . . . .	119
6.2	Axion halos . . . . .	123
6.3	Bolometric intensity . . . . .	125
6.4	Axions and the background light . . . . .	127
7.	The Ultraviolet Background	133

7.1	Decaying neutrinos . . . . .	133
7.2	Neutrino halos . . . . .	135
7.3	Halo luminosity . . . . .	137
7.4	Free-streaming neutrinos . . . . .	140
7.5	Extinction by gas and dust . . . . .	141
7.6	Neutrinos and the background light . . . . .	145
8.	The X-ray and Gamma-ray Backgrounds . . . . .	151
8.1	Weakly interacting massive particles . . . . .	151
8.2	Pair annihilation . . . . .	154
8.3	One-loop decay . . . . .	160
8.4	Tree-level decay . . . . .	162
8.5	Gravitinos . . . . .	166
8.6	WIMPs and the background light . . . . .	169
9.	The High-Energy Gamma-ray Background . . . . .	175
9.1	Primordial black holes . . . . .	175
9.2	Evolution and density . . . . .	178
9.3	Spectral energy distribution . . . . .	181
9.4	Bolometric intensity . . . . .	184
9.5	Spectral intensity . . . . .	187
9.6	Higher dimensions . . . . .	191
10.	The Universe Seen Darkly . . . . .	197
	<i>Bibliography</i> . . . . .	203
	<i>Index</i> . . . . .	217