

Contents

1	Introduction	1
1.1	Stellar evolution after the Main Sequence	1
1.1.1	Red Giant Branch	2
1.1.2	Early Asymptotic Giant Branch	4
1.1.3	Thermally Pulsing Asymptotic Giant Branch	4
1.1.4	Post-AGB	4
1.1.5	Massive stars	5
1.2	Characteristics of RGB, AGB and RSG stars	6
1.2.1	The photosphere	6
1.2.2	The extended atmosphere	6
1.2.3	The circumstellar envelope	7
1.3	This thesis	8
2	An introduction to optical/IR interferometry	11
2.1	Motivation	11
2.2	Principles of interferometry	13
2.2.1	Young’s slit experiment: point source	14
2.2.2	Young’s slit experiment: extended source	15
2.2.3	van Cittert-Zernike theorem	16
2.3	Common source morphologies	17
2.3.1	A point source	17
2.3.2	Circularly symmetric sources	17

2.3.3	Inclined structures	20
2.3.4	Multiple components	21
2.4	Interferometric FOV and wide-band visibilities	21
2.5	Phases	25
2.5.1	Closure phase	26
2.5.2	Differential phase	26
2.6	Facilities	27
2.6.1	FLUOR and TISIS on the IOTA	27
2.6.2	MIDI on the VLT-I	29
2.6.3	ISI	30
3	A new network of Mid-IR interferometric calibrators	33
3.1	Introduction	33
3.2	Sample selection	35
3.2.1	Specific requirements on the calibrators	36
3.3	Photometric observations	39
3.3.1	Literature photometry used	39
3.3.2	New JHKL observations	40
3.3.3	New Geneva photometry	40
3.3.4	Absolute calibration of the photometry	41
3.4	Modelling	42
3.4.1	Models	42
3.4.2	Interstellar extinction	43
3.4.3	SED fitting method	44
3.4.4	Error determination	45
3.5	Description of the catalogue	48
3.6	Discussion	49
3.6.1	Comparison angular sizes to literature values	49
3.6.2	Catalogue effective size	51
3.7	Summary and prospects	51
4	The photosphere of the K giant Arcturus	53
4.1	Introduction	53

4.2	The interferometric calibration process: the need for well-known calibrators . . .	54
4.3	The observations	55
4.3.1	The instrument	55
4.3.2	The calibrator star: HR 5512	56
4.3.3	Data reduction	56
4.4	Interpretation of the data: comparison with theoretical atmosphere models . . .	57
4.4.1	Arcturus atmosphere models and diameter determination	58
4.4.1.1	The atmosphere models	58
4.4.1.2	Diameter definitions	62
4.4.2	Discussion	65
4.4.2.1	Calibration problems	66
4.4.2.2	The photosphere of Arcturus	67
4.5	The binary hypothesis	68
4.5.1	Binary model	68
4.5.2	Discussion	69
4.5.2.1	Background star	72
4.5.2.2	Binary calibrator	72
4.5.2.3	The literature	73
4.5.2.4	Nature of the companion	75
4.5.2.5	The orbit	78
4.6	Conclusions and outlook	79
4.6.1	Implications for calibration	79
4.6.2	Prospects for Arcturus	79
5	Amorphous alumina in the extended atmosphere of α Orionis	81
5.1	Introduction	81
5.2	The observations	82
5.2.1	Spectroscopy	82
5.2.2	Interferometry	86
5.2.2.1	α Orionis	86
5.3	The modelling	89
5.3.1	The photosphere	89
5.3.2	The molecular layers	90

5.3.2.1	Opacities	92
5.3.2.2	Radiative transfer	93
5.3.3	The dust shell	95
5.4	Comparison with observations	95
5.4.1	The near IR	96
5.4.1.1	Comparing MARCS with ISO-SWS	96
5.4.1.2	Adding an H ₂ O layer	98
5.4.1.3	Comparison with the near-IR interferometric data	98
5.4.2	The mid IR	100
5.4.2.1	Excess emission and a larger apparent diameter	100
5.4.2.2	Explaining the mid-IR data	103
5.4.3	Discussion	109
5.5	Conclusions and prospects	111
6	The superwind of OH26.5+0.6 spatially resolved with MIDI	113
6.1	Introduction	114
6.2	Observations and data reduction	115
6.2.1	Images	116
6.2.2	Spectrum	119
6.2.3	Fringes	121
6.3	Modelling the circumstellar environment	122
6.3.1	Modelling strategy	123
6.3.2	SED fit of OH26.5+0.6 at minimum luminosity	125
6.3.3	Comparison with the MIDI data	126
6.4	Discussion	129
6.4.1	Nature of the large inner dust radius	130
6.4.2	A central disk embedded in an outflow	132
6.4.3	Asymmetry of the circumstellar environment	132
6.4.4	Envelope clumping	133
6.5	Conclusions and prospects	134
6.5.1	First results	134
6.5.2	Future work	134
6.5.2.1	Proposed VISIR observations	135

6.5.2.2	Proposed NAOS-CONICA observations	135
7	Conclusions and prospects	139
7.1	Results presented in this thesis	139
7.2	Plans for the near future	140
7.2.1	Molecules in the extended atmosphere of O-rich pulsating AGB-stars	140
7.2.2	Probing the upper atmosphere of cool carbon stars	144
7.3	Long-term plans	147
A	On the absolute calibration of Sirius	151
A.1	The Northern Hemisphere	151
A.2	The Southern Hemisphere	152
A.3	Vega versus Sirius	152
A.4	The near-IR excess of Vega	153
A.5	A fully consistent set of Geneva/SAAO zeropoints	154
A.6	Conclusions	156
	Samenvatting	157
S.1	Stellaire evolutie	158
S.1.1	De rode reuzentak	158
S.1.2	De asymptotische reuzentak	159
S.1.3	Post AGB en planetaire nevels	159
S.1.4	Massieve sterren	160
S.2	De vragen	160
S.3	Observationele uitdagingen	161
S.3.1	IR Spectroscopie	161
S.3.2	IR Interferometrie	162
S.3.3	Een kalibratienetwerk voor MIDI	162
S.4	Toepassingen	163
S.4.1	Arcturus: een binair systeem?	163
S.4.2	Betelgeuze: korrels alumina vlak boven de atmosfeer?	164
S.4.3	OH26.5+0.6: een schijf in de superwind?	165
S.5	Conclusies en vooruitzichten	167

Curriculum Vitae	169
List of acronyms	170
Bibliography	174