
Appendix A: MK Standard Stars

ANCHOR POINT STANDARDS—ROBERT F. GARRISON

The table of Anchor Points for the MK System is taken from a paper by the author in the book *The MK Process at 50 Years*, edited by Corbally, Gray, and Garrison (ASP Conference Series, vol. 60, 1994), pp. 3–14.

The “Anchor Points” is the subset of standard stars that have survived through the years with no change and therefore represent the most stable points in the System. They do not form a complete grid. I am working on defining the set of “Primary Standards” that are the best current standards to use in terms of accessibility and suitability and will represent a complete grid.

The first three columns in Table A.1 are self-explanatory. Column four is a list of classifications from the tables in the introductory booklet of the MKK Atlas (Morgan, Keenan, & Kelleman 1943). In parentheses are listed types from the Atlas that were not listed in the tables (only one star in this subset: HR 617), or differed slightly from the types in the tables (only one star in the final list: HR 5191 and the only difference is that an “n” was added in the Atlas).

Column five is a list of classifications from Morgan’s table of MK standard stars given in the UBV definition paper by Johnson & Morgan (1953). The types in the parentheses are from Morgan (1951).

Column six is a list of types from the 1973 Annual Reviews in Astronomy and Astrophysics article by Morgan and Keenan.

The types listed in columns seven, eight, and nine are taken from several modern lists. The seventh and eighth columns include types for stars cooler than the Sun, from various publications by Keenan and his associates. The ninth column includes types for GK stars by Morgan from an unpublished list as well as Walborn’s (1973) types for O stars and Gray’s (1987, 1989a, b, and 1994) types for B8–F2 stars.

Finally, all the types were checked for consistency with my own plate file. Thus, the Anchor Points represent the MK System as it was in 1943, as it was in 1953, 1973, 1978, 1989, and as it is now. The Anchor Points are the *de facto* standards, though they may not be the best ones or the ones we wish were standards. However, because of its long history, the MK System now has a life of its own. Instead of trying to manipulate it and distort it, we must listen to it.

Note by Gray and Corbally: We have added a tenth column to this table giving the recommended spectral type for the standards listed in this table. We also note that Walborn has recently found that 15 (S) Mon is a likely spectrum variable, with mean type near O7.5. We also suggest users avoid the star α Ori (Betelgeuse) as it is a spectrum variable. To date, Garrison has not finished his selection of primary standards. We offer the following tables of standards (Tables A.2–A.7) from a number of sources as recommended primary and secondary standards.

Table A.1 MK Standard Stars: Anchor Points September 1993

HR or other HD	Star Name	MKK43 Table (Atlas)	MK53 Table 1 (Michpub1951)	MK73 Table 1,2 (K76M78 Atlases)	KY88 (KM89)	KY85 (KP80)	WWM GK STD 86 Walborn OB, GRAY BAF	Recommended Type
47839	15 S Mon.	O7	(O7)	O7 (V)			O7 V(f)	var?
214680	10 Lac	O9 V	O9 V	O9 V			O9 V	O9 V
36512	ν Ori	B0 V	B0 V	B0 V			B0 V	B0 V
37128	ϵ Ori	B0 I	B0 Ia	B0 Ia (B0 Ia)			B0 Ia	B0 Ia
41117	χ^2 Ori	B2 I	B2 Ia	B2 Ia (B2 Ia)			B2 Ia	B2 Ia
206165	9 Cep	B2 I	B2 Ib	(B2 Ib)			B2 Ib	B2 Ib
120315	η UMa	B3 V(n)	B3 V	B3 V			B3 V	B3 V
32630	η Aur	B3 V	B3 V	B3 V			B3 V	B3 V
53138	σ^2 CMa	B3 I	B3 Ia	B3 Ia (B3 lab)			B3 Ia	B3 Ia
58350	η CMa	B5 I	B5 Ia	B5 Ia (B5 Ia)			B5 Ia	B5 Ia
34085	β Ori	B8 Ia	B8 Ia	B8 Ia			B8 Ia	B8 Ia
103287	γ UMa	A0 V	A0 V	A0 V			A0 V	A0 V
172167	α Lyr	A0 V	A0 V	A0 V (A0 Va)			A0 V	A0 V
87737	η Leo	A0 Ib	A0 Ib	(A0 Ib)			(A0 Ib)	A0 Ib
21389	+58° 607	A0 Ia	A0 Ia	(A0 Ia)			(A0 Ia)	A0 Ia
197345	α Cyg	A2 Ia	A2 Ia	A2 Ia (A2 Ia)			A2 Ia	A2 Ia
216956	α PsA	A3 V	A3 V	A3 V			A3 V	A3 V
89025	ζ Leo	F0 III	F0 III	F0 III (F0 III)			F0 III	F0 IIIa
36673	α Lep	F0 Ib	F0 Ib	F0 Ib (F0 Ib)			F0 Ib	F0 Ib
113139	78 UMa	F2 V	F2 V	F2 V (F2 V)			F2 V	F2 V
20902	α Per	F5 Ib	F5 Ib	F5 Ib (F5 Ib)			F5 Ib	F5 Ib
30652	π^3 Ori	F6 V	F6 V	F6 V			F6 V	F6 V
194093	γ Cyg	F8 Ib	F8 Ib	(F8 Ib)(WWM)			(F8 Ib)(WWM)	F8 Ib
54605	δ CMa	F8 Ia	F8 Ia	(F8 Ia)(WWM)			(F8 Ia)(WWM)	F8 Ia
109358	HR 4785	β CVn	G0 V	G0 V (PCK)			G0 V	G0 V
121370	HR 5235	η Boo	G0 IV	(G0 IV)(PCK)			G0 IV	G0 IV
204867	HR 8232	β Aqr	G0 Ib	G0 Ib(PCK)(G0 Ib)			G0 Ib	G0 Ib

WALBORN'S OB PRIMARY STANDARDS

Table A.2 Walborn's Early O-type standards

O2 If*	O3 If*	O3.5 If*	O4 If ⁺
HD 93129A	Cyg OB2-7 Cyg OB2-22A	Pismis 24-1 (HDE228766) (NGC 2044W-9A) (MH 14)	HD 190429A Sk -67°166 Sk -67°167
O2 III(f*)	O3 III(f*)	O3.5 III(f*)	O4 III(f ⁺)
HDE 269810 Sk -68°137 LH 10-3061 LH 64-16 LH 114-7 NGC 346-3 (Sk -66°172 [+OB])		Pismis 24-17	ST 2-22 W28-23
O2 V((f*))	O3 V((f*))	O3.5 V((f ⁺))	O4 V((f ⁺))
BI253 (P871)	HD 64568 LH 10-3058 (Sk -71° 51) (P1163) (P1311) (ST 5-52[+OB])	HD 93128 HD 93129B (HD 93205) (HD 93250)	HD 46223 HDE 303308 W28-5

Table A.3 Walborn's Late O-type standards

HD 46150	O5 V((f))	HD 15558	O5 III(f)	Cyg OB2-11	O5 If ⁺
HD 93204	O5 V((f))			HD 14947	O5 If ⁺
HD 101190	O6 V((f))	Sk -66°100 HD 93130	O6 II(f) O6 III(f)	Sk -65°22 Sk -69°104 λ Cep	O6 Iaf ⁺ O6 Ib(f) O6 I(n) fp
HD 93146	O6.5 V((f))	HD 190864	O6.5 III(f)	HD 163758	O6.5 Iaf
HD 165052	O6.5 V(n)((f))			HD 150958	O6.5 Iaf
LH10:3128	O6.5 Vz			HD 69464	O6.5 Ib(f)
LH10:3073	O6.5 Vz				
HD 91824	O7 V((f))	HD 151515	O7 II(f)	Sanduleak 80	O7 Iaf ⁺
LH10:3102	O7 Vz	HD 93222 ξ Per	O7 III((f)) O7.5 III(n)((f))		
HD 48279	O8 V	HD 175754 λ Ori	O8 II((f)) O8 III((f))	HD 151804 HD 112244 HD 225160	O7.5 Iaf O8 Iaf O8 Iab(f) O8 Ib(f)
HD 46149	O8.5 V				
10 Lac	O9 V	ι Ori	O9 III	HD 148546	O9 Ia
HD 93028	O9 V			HD 210809	O9 Iab
HD 46202	O9 V			HD 207198	O9 Ib-II
AE Aur	O9.5 V	HD 189957	O9.5 III	α Cam	O9.5 Ia

Table A.3 Continued

HD 93027	O9.5 V	HD 16429	O9.5 II((n))	19 Cep	O9.5 Ib
		δ Ori	O9.5 II	HD 152249	OC9.5 Iab
		HD 10125	O9.7 II	HD 195592	O9.7 Ia
				Sk $-66^{\circ}169$	O9.7 Ia ⁺
				μ Nor	O9.7 Iab
				HD 152003	O9.7 Iab
				HD 47432	O9.7 Ib
				ζ Ori	O9.7 Ib
				HD 152147	O9.7 Ib
				HD 152424	OC9.7 Ia
				HD 104565	OC9.7 Ia
				HD 194280	OC9.7 Iab
				HD 269896	ON9.7 Ia ⁺
				BD $+36^{\circ}4063$	ON9.7 Iab
				HD 191781	ON9.7 Iab
				HD 123008	ON9.7 Iab

Table A.4 Walborn's B-type standards

ν Ori	B0 V			HD 48434	B0 III	ϵ Ori	B0 Ia
				HD 150041	B0 III	HD 122879	B0 Ia
						HD 91969	B0 Ia
						HD 156134	B0 Iab
						HD 164402	B0 Ib
τ Sco	B0.2 V	ϕ^1 Ori	B0.2 IV	HD 108639	B0.2 III		
				HD 6675	B0.2 II		
HD 36960	B0.5 V	λ Lep	B0.5 IV	1 Cas	B0.5 III	κ Ori	B0.5 Ia
						HD 152234	B0.5 Ia
HD 201795	B0.7 V	ξ^1 CMa	B0.7 IV	ϵ Per	B0.7 III	HD 154090	B0.7 Ia
						κ Cas	B0.7 Ia
						HD 152235	B0.7 Ia
						HD 109867	B0.7 Ib
						HD 190919	B0.7 Ib
ω^1 Sco	B1 V			β Cen	B1 II-III	HD 169454	B1 Ia ⁺
				$-57^{\circ}3506A$	B1 II	HD 148688	B1 Ia
				σ Sco	B1 III	HD 13854	B1 Iab
						ρ Leo	B1 Iab
						ζ Per	B1 Ib
						HD 86606	B1 Ib
HD 36959	B1.5 V			ϵ CMa	B1.5 II	ζ^1 Sco	B1.5 Ia ⁺
HD 154445	B1.5 V			HD 96159	B1.5 II	HD 190603	B1.5 Ia ⁺
				12 Lac	B1.5 III		
HD 42401	B2 V	γ Peg	B2 IV	HD 141318	B2 II	χ^2 Ori	B2 Ia
				γ Ori	B2 III	9 Cep	B2 Ib
22 Sco	B2.5 V			π^2 Cyg	B2.5 III	HD 92964	B2.5 Ia
HD 214432	B2.5 V					55 Cyg	B2.5 Ia
						3 Gem	B2.5 Ib
η Hya	B3 V			HD 21483	B3 III	σ^2 CMa	B3 Ia
η Aur	B3 V					κ Cru	B3 Ia
η UMa	B3 V					ι CMa	B3 Ib
						η CMa	B5 Ia
						β Ori	B8 Ia

Table A.5 Morgan and Keenan's Late B-type Revised (1973) MK Standards

ρ Aur	B5 V	18 Tau	B8 V
τ Her	B5 IV	27 Tau	B8 III
η CMa	B5 Ia	β Ori	B8 Ia
19 Tau	B6 IV	α Del	B9 IV
η Tau	B7 III		

Source: Morgan & Keenan (1973).

GRAY AND GARRISON'S LATE-B, A AND EARLY-F STANDARDS

In a series of four papers, Gray & Garrison (Gray & Garrison (1987, 1989a, b; Garrison & Gray 1994) defined parallel sequences of late B, A and early F-type standards. These two sequences (reproduced in Table A.6) are for low- $v \sin i$ and high- $v \sin i$ standards, to reduce systematic trends in spectral classification caused by differing rotational velocities.

Table A.6 Gray and Garrison's Late-B, A and Early-F Standards

Spectral Type	low- <i>v</i> sin <i>i</i> Standards	high- <i>v</i> sin <i>i</i> Standards
B7 V	(HR 1029) ¹	
B8 V	HR 9050	18 Tau
B8 III		27 Tau
B8 II	HR 3571	
B9 Va	ω For A	HR 2328
B9 IV	134 Tau	α Del
B9 III	HR 4712	ϵ Tuc
B9 II	HR 7245	
	(HR 5898)	
A0 Vb	HD 225047	
A0 Va	α Lyr	γ UMa
	(HR 3314)	(HD 201184)
A0 IV	HR 7211	HR 8451
A0 III	α Sex	HR 2969
	(α Dra)	
A0 II	HR 6478	
A0 Ib	η Leo	
A0 Ia	HR 1040	
A1 Va	HR 520	HR 2324
	(48 Cet)	
A1 IV	ρ Peg	δ Hya
A1 III	HR 2925	γ Tra
A1 II	HR 3487	
A2 Va	HR 4023	HR 2758
A2 IV	β Crt	β Ser
A2 III		HR 2751
A2 Ia	α Cyg	
A3 Vb	β Cir	
A3 Va	α PsA	HD 23643
	β Leo	
A3 IV	HR 4293	β Eri
A3 III	HR 3514	
A5 V	HD 23194	HD 23886
A5 II	o Sco	
A6 II	HR 3426	
A7 V	2 Hyi	21 LMi
A7 IV	HR 3270	ι UMa
A7 III	θ^2 Tau	
A9 V		44 Cet
A9 IIIb		γ Her
F0 V	HD 23585	
F0 IV	57 Tau	HR 8895A
F0 IIIb	η CMi	
F0 IIIa	ζ Leo	
F0 II	HR 292	
	HD 96898	
F0 Ib	α Lep	
F0 Ia	ϕ Cas	
F2 V	78 UMa	
	μ Vir	
F2 IV	32 Tau	
F2 III	β Cas	
F2 Ib	ν Aql	

¹ Suitable secondary standards in parentheses.

LATE-TYPE STANDARDS

The best source for late-type standard stars, especially, G and K-type stars and M giants is Keenan's Perkins catalog (Keenan & McNeil 1989). M-dwarf standards are listed in Chapter 9, and L- and T-dwarf standards in Chapters 9 and 10. The large number of standards in the Perkins catalog makes a full listing impossible here. Instead, we offer a table of standards (Table A.7), largely, but not exclusively drawn from the Perkins catalog that we have used in the Nearby Stars Program (Gray et al. 2003, 2006). Please also consult Table 9.1 for the primary M-dwarf standards, Table 9.2 for the primary L-dwarf standards, and tables in Chapter 10 for the primary T-dwarf standards.

Table A.7 Standards Used for the NStars Project

HR 1279	F3 V	HR 1566	F3 IV				
HD 27524	F5 V	Procyon	F5 IV-V	HR 7495	F5 II-III	HD 10494	F5 Ia
HR 5634	F5 V			HR 2706	F5 III-IV	α Per	F5 Ib
				(60 UMa)	F5 III		
γ Ser	F6 V	α Tri	F6 IV	HR 6577	F6 III-IV		
HD 27808	F8 V			HR 8905	F8 III	δ CMa	F8 Ia
						γ Cyg	F8 Ib
HR 506	F9 V						
β CVn	G0 V			81 Psc	G0 III	β Aqr	G0 Ib
λ Ser	G0- V						
16 Cyg A	G1.5 V						
Sun	G2 V					α Aqr	G2 Ib
				37 LMi	G2.5 IIa		
16 Cyg B	G3 V			HR 4742	G3 III		
70 Vir	G4 V	24 UMa	G4 IV			HR 8752	G4 0
κ Cet	G5 V	ω Sgr	G5 IV	HR 7788	G5 IIIa	9 Peg	G5 Ib
HR 5209	G5 V	μ Her	G5 IV				
61 UMa	G8 V	β Aql	G8 IV	κ Gem	G8 III	ϵ Gem	G8 Ib
				ϵ Vir			
				71 Oph	G8 III		
				δ Phe	G9 III		
				β LMi	G9 III		
54 Psc	K0 V			η Cyg	K0 III		
HD 224618	K0 V			19 Pup	K0 III		
				δ Cnc	K0 III		
HR 637	K1 V			90 Her	K1 IIIb		
ϵ Eri	K2 V			β Ret	K2 III		
HD 184467	K2 V			κ Oph	K2 III		
HR 753	K3 V						
Gl 570A	K4 V			κ Pyx	K4 III		
						ξ Cyg	K4.5 Ib
61 Cyg A	K5 V			γ Dra	K5 III		
Gl 529	K6 V						
61 Cyg B	K7 V			α Lyn	K7 III		
				υ Aur	M0 III		
Gl 846	M0.5 V						
Gl 411	M2 V			χ Peg	M2+ III	μ Cep	M2- Ia
						HD 10465	M2 Ib
Gl 752 A	M3 V						
Gl 725 B	M3.5 V						
				HR 3577	M4+ III		
Gl 166 C	M4.5 V					EV Car	M4.5 Ia
				BK Vir	M7- III		
				R Leo	M9: III		

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Appendix B: Calibrations of the MK System

ABSOLUTE MAGNITUDE CALIBRATION

Table B.1 Averaged Absolute Visual Magnitude Calibration for the Early-type Stars

SpT	V	IV	III	II	Ib	Iab	Ia
O2-3	-5.6	...	-6.0	...	...	...	-6.8
O4	-5.5	...	-6.4	...	...	...	-7.0
O5	-5.5	...	-6.4	...	...	...	-7.0
O6	-5.3	...	-5.6	...	-6.3	...	-7.0
O6.5	-5.3	...	-5.6	...	-6.3	...	-7.0
O7	-4.8	...	-5.6	-5.9	-6.3	...	-7.0
O7.5	-4.8	...	-5.6	-5.9	-6.3	...	-7.0
O8	-4.4	...	-5.6	-5.9	-6.2	-6.5	-7.0
O8.5	-4.4	...	-5.6	-5.9	-6.2	-6.5	-7.0
O9	-4.3	-5.0	-5.6	-5.9	-6.2	-6.5	-7.0
O9.5	-4.1	-4.7	-5.3	-5.9	-6.2	-6.5	-7.0
O9.7	...	...	...	-5.9	-6.2	-6.5	-7.0
B0	-4.1	-4.6	-5.0	-5.6	-5.8		-7.0
B1	-3.5	-3.9	-4.4	-5.1	-5.7		-7.0
B2	-2.5	-3.0	-3.6	-4.4	-5.7		-7.0
B3	-1.7	-2.3	-2.9	-3.9	-5.7		-7.0
B4	-1.4	-2.0	-2.6	-3.9	-5.7		-7.0
B5	-1.1	-1.6	-2.2	-3.7	-5.7		-7.0
B6	-0.9	-1.3	-1.9	-3.7	-5.7		-7.1
B7	-0.4	-1.3	-1.6	-3.6	-5.6		-7.1
B8	0.0	-1.0	-1.4	-3.4	-5.6		-7.1
B9	0.7	-0.5	-0.8	-3.1	-5.5		-7.1
A0	1.4	0.3	-0.8	-2.8	-5.2		-7.1
A1	1.6	0.3	-0.4	-2.6	-5.1		-7.3
A2	1.9	0.5	-0.2	-2.4	-5.0		-7.5
A3	2.0	0.7	0.0	-2.3	-4.8		-7.6
A5	2.1	1.2	0.3	-2.1	-4.8		-7.7
A7	2.3	1.5	0.5	-2.0	-4.8		-8.0
A9	2.5	1.6	0.6	-2.0	-4.8		-8.3
F0	2.6	1.7	0.6	-2.0	-4.7		-8.5
F1	2.8	1.8	0.6	-2.0	-4.7		-8.5

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EFFECTIVE TEMPERATURE CALIBRATION

Table B.3 Effective Temperature (K) Calibration for the Early-type Stars

SpT	Dwarfs	Giants	Supergiants
O3	44852	42942	42233
O4	42857	41486	40422
O5	40862	39507	38612
O5.5	39865	38003	37706
O6	38867	36673	36801
O6.5	37870	35644	35895
O7	36872	34638	34990
O7.5	35874	33487	34084
O8	34877	32573	33179
O8.5	33879	31689	32274
O9	32882	30737	31368
O9.5	31884	30231	30463
B0	29000	29000	
B1	24500	24500	
B2	19500	21050	18000
B3	16500	16850	
B5	15000	14800	13600
B7	13000	13700	
B8	11500	13150	11100
B9	10700	11731	
A0	9800	10000	9900
A1	9500	9500	
A2	8900	9000	9000
A3	8520	8500	8400
A5	8150	8000	8100
A7	7830	7750	7800
A9	7380	7450	

Table B.3 Continued

SpT	Dwarfs	Giants	Supergiants
F0	7250	7350	7200
F1	7120	7200	7050
F2	7000	7050	6960
F3	6750	6840	6770
F5	6550	6630	6570
F7	6250	6330	6280
F8	6170	6220	6180
F9	6010	6020	5980

Table B.4 Effective Temperature (K) Calibration for the Late-type Stars

SpT	Dwarfs	Giants	Supergiants
G0	5900	5800	5590
G1	5800	5700	5490
G2	5750	5500	5250
G5	5580	5200	5000
G8	5430	4950	4700
G9	5350		
K0	5280	4810	4500
K1	5110	4585	4200
K2	4940	4390	4100
K3	4700	4225	
K5	4400	3955	
K7	4130		3840
M0	3759	3845	3790
M1	3624	3750	3745
M2	3489	3655	3660
M3	3354	3560	3605
M4	3219	3460	
M5	3084	3355	3450
M6	2949	3240	
M7	2814	3100	
M8	2679	2940	
M9	2544	2755	
L0	2409		
L1	2274		
L2	2139		
L3	2004		
L4	1869		
L5	1734		
L6	1599		
L7	1464		
L8	1329		

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