Characteristics of our neighboring A-stars

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Abstract

We have a project, under the aegis of the Nearby Stars (NStars) / Space Interferometry Mission Preparatory Science Program to obtain spectra, spectral types, and, where feasible, basic physical parameters for the 3600 dwarf and giant stars earlier than M0 within 40 parsecs of the Sun. There are 66 B-to-early-F stars among the first 664 stars analyzed in the northern hemisphere, and 37 of the same among a similar number of southern hemisphere stars. With these we can start looking at statistics of Ap, Am, λ Boötis, and other A-type stars for a volume-limited sample, and we can find out just how well we know our neighbors.

The project's data are available on our website, http://stellar.phys.appstate.edu

The Project

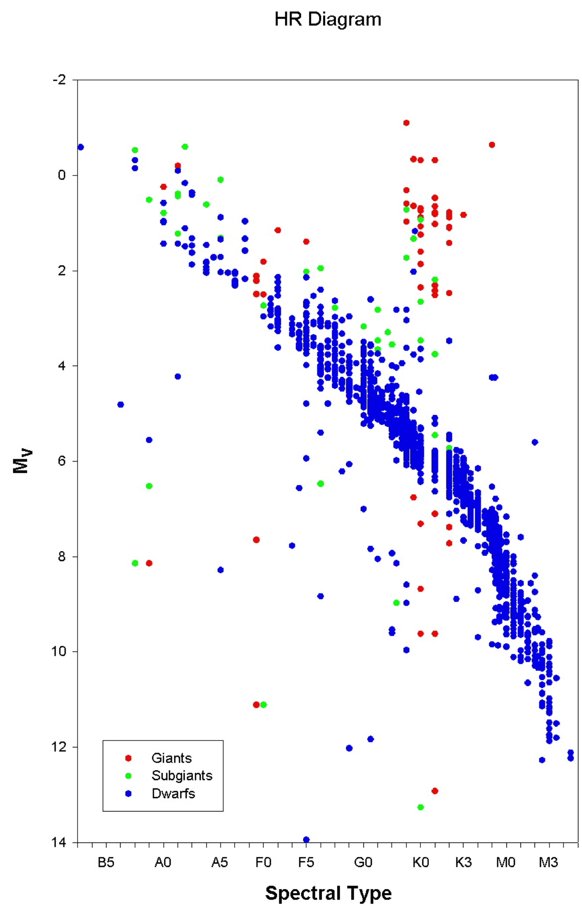
The Nearby Stars (NStars) Spectroscopy Project, carried out jointly at Appalachian State University, the Vatican Observatory and the David Dunlap Observatory is now in its final phases. In this project we have been engaged in obtaining spectroscopic observations of all 3600 dwarf and giant stars earlier than M0 within a radius of 40 parsecs (Gray *et al.* 2003). These blue-violet spectra, obtained at classification resolution, are being used to obtain homogeneous, precise MK spectral types.

In addition, these spectra are being used in conjunction with existing Strömgren *uvby* and Johnson-Cousins *BVRI* photometry and synthetic spectra to derive the basic astrophysical parameters for these stars (T_{eff}, log(g) and [M/H]). Our spectra include the Ca II K & H lines, which we are using to measure chromospheric activity on the Mount Wilson system (Baliunas *et al.* 1995).

Spectral Types

To date, we have determined over 2000 new spectral types for our program stars.

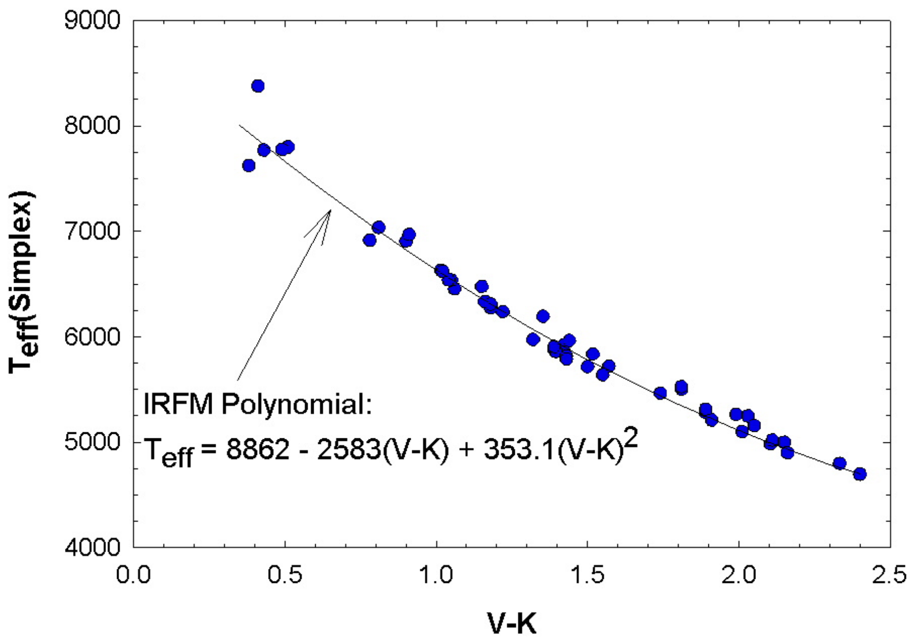
These spectral types are multi-dimensional and include not only the normal temperature and luminosity classes, but also dimensions related to abundance peculiarities and Ca II K & H emission.



The HR diagram to the right is based on our spectral types and Hipparcos parallaxes (ESA 1997). We are using this diagram to refine the census of stars within 40pc of the Sun. The stars that scatter below the main sequence all have, without exception, large parallax errors. Our spectral types confirm that these stars lie beyond 40pc.

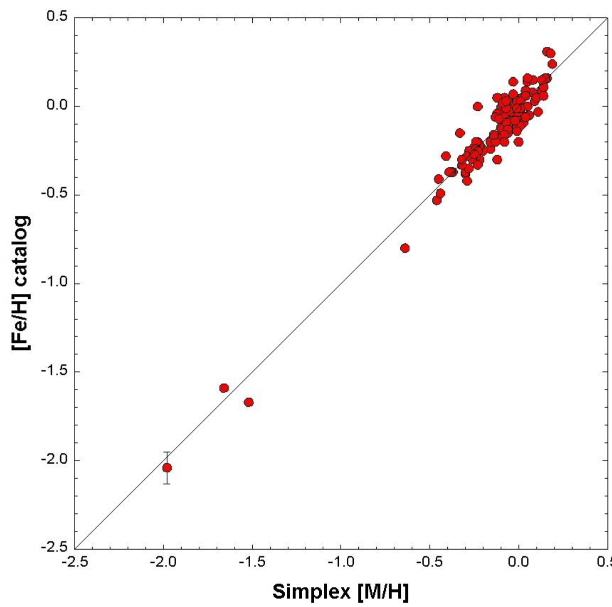
Basic Astrophysical Parameters

We are using our spectra in conjunction with already existing Strömgren *uvby* and Johnson-Cousins *BVRI* photometry to derive, from fits with synthetic spectra (using the *SIMPLEX* algorithm) the basic astrophysical parameters (T_{eff}, log(g) and [M/H]) for our program stars. The synthetic spectra are based on the spectral synthesis code *SPECTRUM* (Gray & Corbally 1994).



Our derived effective temperatures are in excellent agreement with the Infrared Flux Method (IRFM, Blackwell & Lynas-Gray 1994) as can be seen from the figure above.

As can be seen from the figure to the right, our [M/H] values are also in excellent agreement with the mean [Fe/H] values from the Cayrel de Strobel *et al.* (2001) [Fe/H] catalog.



We estimate errors of ±75K for T_{eff}, ±0.10 in log(g) and ±0.10 in [M/H]. Our comparison with the [Fe/H] catalog (see figure to the right) shows a scatter of only 0.09 dex, comparable to the scatter in the [Fe/H] catalog itself.

Statistics of the A-type NStars

The accuracy and homogeneity of our data make possible a number of astrophysical investigations. Here we look at just those with spectral types ranging from B8 to F2. Table 1 is for a northern set, derived from spectra from the 0.8-m telescope at the Dark Sky Observatory, North Carolina, and Table 2 is for a southern set from the CTIO 1.5-m telescope. Their statistics can be summarized as (percentages are of the total stars in the spectral range):

	Northern		Southern	
Ap	8	12%	4	11%
Am	8	12%	3	8%
λ Bootis	4		0	
metal weak	4		1	
normal	42		29	
Total	66		37	

These results, representing a little more than one third of the NStars in our survey, are preliminary. Even though the total number of stars in the two sets is about the same, we do expect the number of A-type stars to be larger in the northern set since (1) this included a "legacy" group, already observed at DSO, that reflected an author's interest in A stars, and

(2) Eric Olsen's preference in the southern, Strömgren set was for F- and G-type stars. However, the relative numbers of A-type stars in the four peculiar categories are not biased.

Johnson (2004) got 7% for the percentage of classical Ap/Bp to all equivalent main sequence stars. Like Wolff (1968), she found a sharp drop in percentage after A5, with the bulk occurring at late-B type. In our volume-limited survey we have very few stars in this peak of the Ap/Bp distribution.

Abt & Morrell (1995) make the point that the better the spectra (both in signal-to-noise and in dispersion), the easier it is securely to spot peculiarities. Though the northern spectra had both factors somewhat in their favor, these do not seem to be making a significant difference between the percentage of Ap stars detected in our northern and southern sample.

The four λ Boötis stars in the northern set are the <u>only</u> ones within 40 pc. That none within this volume of space should be southern stars must be due to the statistics of small numbers, always something to bear in mind.

The analysis of our survey of neighboring stars within 40 pc is not yet complete. Yet these preliminary results, just as those for metallicities and chromospheric activities (Paper I), are giving a tantalizing indication of what it will be like <u>really</u> to know our stellar neighbors.

References

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Table 1. DSO "Paper I" A-type Stars

HD	Hip #	SpecTyp	Note1	T_{eff}	log(g)	ξ	[M/H]	Note2/3
358	677	B8 IV-V Hg Mn		13098	3.91	2.0 f	0.0 f	*
1651	1663	kA7hA9mF0 III						
11636	8903	kA4hA5mA5 Va		8300	4.10	3.5	0.02	
13161	10064	A5 IV		8186	3.70	2.0 f	0.20	*
16970	12706	A2 Vn		8673	3.96	2.0 f	0.00	*
17094	12828	A9 IIIp	*	7225	3.90	3.2	0.04	
19356	14576	B8 V	*					
31295	22845	A3 Va λ Boo...	*	8611	4.15	2.0 f	-1.24	*
33111	23875	A3 IV		8377	3.29	2.0 f	0.08	*
40183	28360	A1 IV-Vp...	*	9024	3.71	2.0 f	0.00	*
256294	30362	B8 IVp...	*					
44769	30419	A8 V(n)		7732	3.69	2.0 f	-0.02	*
47105	31681	A1.5 IV+		8953	3.46	2.0	-0.18	*
48915	32349	A0mA1 Va		9580	4.20	2.0 f	0.30	*
+18 1563	35389	A5 V						
60178	36850	A1.5 IV+						
71155	41307	A0 Va		9556	3.95	2.0 f	-0.44	*
76644	44127	A7 V(n)		7769	3.91	2.0 f	0.00	*
78362	45075	kA5hF0mF5 II	*					
87696	49593	A7 V(n)		7839	4.07	2.0 f	-0.01	*
87901	49669	B8 IVn		11962	3.56	2.0 f	0.00 f	*
95418	53910	A1 IVps (Sr II)	*	9342	3.70	2.0	0.06	*
97603	54872	A5 IV(n)		8037	3.72	2.0 f	0.00	*
102647	57632	A3 Va		8378	4.22	2.0 f	0.00	*
103287	58001	A1 IV(n)		9272	3.64	2.0 f	-0.19	*
106112	59504	kA6hF0mF0 (III)	*					
106591	59774	A2 Vn		8613	3.70	2.0 f	-0.03	*
110411	61960	A3 Va λ Boo...	*	8671	4.03	2.0 f	-1.10	*
112185	62956	A1 III-IVp kB9		9020	3.23	2.0 f	0.00 f	*
112413	63125	A0 II-IIIp SiEuCr						
116656	65378	A1.5 Vas		9330	3.88	2.0	0.16	
116842	65477	A6 Vnn		7955	3.88	2.0 f	0.00	*
118098	66249	A2 Van		8633	3.77	2.0 f	-0.02	*
125162	69732	A3 Va λ Boo...	*	8512	3.95	2.0 f	-1.86	*
137909	75695	A8 V: SrCrEu		7624	3.99	2.0	0.50	*
139006	76267	A1 IV		9584	3.71	2.0 f	0.00	*
141795	77622	kA2hA5mA7 V						
156164	84379	A1 Ivn		8879	3.47	2.0 f	-0.04	*
-07 4419B	84581	A9 III						
161868	87108	A1 Vn kA0mA0		8951	4.03	2.0 f	-0.81	*
165777	88771	A5 V		8400	3.89	3.0	0.20	
172167	91262	A0 Va		9519	3.88	2.0 f	-0.43	*
177724	93747	A0 IV-Vnn		9190	3.74	2.0 f	-0.68	*
177756	93805	B9 IVp	*	11501	4.02	2.0 f	0.00 f	*
187642	97649	A7 Vn		7800	3.76	2.0 f	0.02	*
203280	105199	A8 Vn		7773	3.45	2.0 f	0.09	*
209845	109117	kA3 hA5 mF2 (IV)						
222603	116928	A7 V		7742	3.83	2.0 f	-0.05	*

HD	Hip #	SpecTyp	Note1	T_{eff}	log(g)	ξ	[M/H]	Note2/3
F0 - F2 Stars								
432	746	F2 III		6915	3.49	3.1	-0.02	
8723	6706	F2 V		6690	4.12	1.6	-0.26	
11171	8497	F2 III-IV		7087	4.10	2.4	0.15	
32537	23783	F2 V		7018	4.05	2.1	-0.12	
56986	35550	F2 V kF0mF0	*	6906	3.68	2.6	-0.27	*
56963	35643	F2 V kF1mF0	*					
58946	36366	F1 V		7035	4.06	1.9	-0.21	
91480	51814	F2 V		6972	4.22	2.1	-0.05	
110379/80	61941	F2 V	*					
112412	63121	F2 V		6969	4.17	2.0	-0.13	
112429	63076	F1 V mA7(n)	*	7129	4.01	1.9	-0.14	*
113139	63503	F2 V		6829	3.94	2.3	-0.10	*
164259	88175	F2 V		6771	4.01	1.9	-0.06	
187532	97650	F2 V		6782	4.07	1.5	-0.12	
202444	104887	F2+ V		6621	3.54	1.9	-0.20	
206043	106897	F1 V(n)		7145	3.93	2.3	-0.13	*
218396	114189	F0+ V (λ Boo)...	*	7424	4.22	2.0	-0.50	
219080	114570	F1 V		7176	3.93	2.7	-0.22	

Note (1): In some of these comments, the rotational broadening (v sin i) of the star is noted; these are visual estimates used in the simplex solutions and should not be taken as actual measurements of the v sin i.

HIP 677 = HD 358: Far-UV in the IUE spectra is very discrepant with respect to the model, probably because of excess metal blanketing in this chemically peculiar star. The simplex solution was carried out without IUE spectra and is suspect.
HIP 10064 = HD 13161: Rotational broadening = 100 km/s.
HIP 12706 = HD 16970: Rotational broadening = 150 km/s.
HIP 12828 = HD 17094: Strong metallic-line spectrum; some metals = F1.
HIP 14576 = HD 19356 = Algol.
HIP 22845 = HD 31295: A3 Va kB9.5mB9.5 λ Boo; rotational broadening = 100 km/s; IUE spectra used in the simplex solution.
HIP 23875 = HD 33111: Rotational broadening = 180 km/s; IUE spectra used in the simplex solution.
HIP 28360 = HD 40183: A1 IV-Vp kA1mA1.5 (Sr). Mild Ap star; rotational broadening = 100 km/s.
HIP 30362 = HD 256294: B8 IV kB9 helium-weak.
HIP 30419 = HD 44769: Rotational broadening = 100 km/s.
HIP 31681 = HD 47105: IUE spectra used in the simplex solution. See Fig. 2.
HIP 32349 = HD 48915 = Sirius: Only an SWP IUE spectrum was used in the simplex solution, as the LWP and LWR spectra were all defective or had large gaps. The simplex fit is excellent, except for the K line, which is too strong in the model. This is consistent with the Am nature of Sirius.
HIP 35550 = HD 56986: Rotational broadening = 100 km/s. Spectral type may also be written F2 V Fe-0.5.
HIP 35643 = HD 56963: Spectral type may also be written F2 V Fe-0.5.
HIP 41307 = HD 71155: Rotational broadening = 150 km/s.
HIP 44127 = HD 76644: Rotational broadening = 100 km/s; IUE spectra used in the simplex solution.
HIP 45075 = HD 78362: Anomalous luminosity effect.
HIP 49593 = HD 87696: Rotational broadening = 120 km/s; IUE spectra used in the simplex solution.
HIP 49669 = HD 87901: Rotational broadening = 250 km/s; IUE spectra used in the simplex solution.
HIP 53910 = HD 95418: Some sharp lines, Fe II λ4233 enhanced. May be mild shell star. IUE spectra used in the simplex solution.
HIP 54872 = HD 97603: Rotational broadening = 150 km/s; IUE spectra used in the simplex solution.

HIP 57632 = HD 102647: Rotational broadening = 120 km/s; IUE spectra used in the simplex solution.
HIP 58001 = HD 103287: Rotational broadening = 150 km/s; only SWP IUE spectrum available for the simplex fit.
HIP 59504 = HD 106112: Anomalous luminosity effect.
HIP 59744 = HD 106591: Rotational broadening = 180 km/s; IUE spectra used in the simplex solution.
HIP 61941 = HD110379/80: γ Vir AB.
HIP 61960 = HD 110411: A3 Va kB9.5mA0 λ Boo; rotational broadening = 150 km/s; IUE spectra used in the simplex solution.
HIP 62956 = HD 112185: Good fit except that the K line in the model is stronger than in the star, consistent with the spectral type.
HIP 63076 = HD 112429: Rotational broadening = 100 km/s. Spectral type may also be written F1 V(n) Fe-0.8.
HIP 63503 = HD 113139: Rotational broadening = 100 km/s.
HIP 65477 = HD 116842: Rotational broadening = 180 km/s; IUE spectra used in the simplex solution.
HIP 66249 = HD 118098: Rotational broadening = 180 km/s.
HIP 69732 = HD 125162: A3 Va kB9mB9 {lambda} Boo; rotational broadening = 100 km/s; IUE spectra used in the simplex solution.
HIP 75695 = HD 137909: The LWP IUE spectrum shows very broad, strong absorption due to metal blanketing. The fit was carried out without the IUE spectrum and thus is suspect.
HIP 76267 = HD 139006: Rotational broadening = 150 km/s; the LWP IUE spectrum is inconsistent with the two SWP spectra and was not used in the fit.
HIP 84379 = HD 156164: Rotational broadening = 250 km/s.
HIP 87108 = HD 161868: Rotational broadening = 200 km/s; IUE spectra used in the simplex solution.
HIP 91262 = HD 172167 = α Lyr = Vega: IUE spectra used in the simplex solution.
HIP 93747 = HD 177724: Rotational broadening = 300 km/s; IUE spectra used in the simplex solution.
HIP 93805 = HD 177756: Metals and helium slightly weak; rotational broadening = 150 km/s; He I lines strong in the model compared with the star, consistent with spectral type.
HIP 97649 = HD 187642: Rotational broadening = 200 km/s; IUE spectra used in the simplex solution.
HIP 105199 = HD 203280: Rotational broadening = 200 km/s; IUE spectra used in the simplex solution.
HIP 106897 = HD 206043: Rotational broadening = 120 km/s.
HIP 114189 = HD 218396: F0+ V kA5mA5 (λ Boo); see Gray & Kaye 1999.
HIP 116928 = HD 222603: IUE spectra used in the simplex solution.

Note (2):
f = Physical parameter was held fixed in the simplex solution.

Note (3): Where [M/H] = 0.00 refers to solar metallicity.

Table 2. CTIO "Stromgren" A-type Stars

HD	Hip #	Name	SpecTyp notes*	SpecTyp(AM95)
hd2262	2072	kap Phe	A5 IVn	A6 Vn
hd16754	12413		A1 Vb	A1 V
hd20320	15197	xi Eri	kA4hA9mA9 V	Am (A3/A6/A7)
hd25490	18907	nu Tau	A0.5 Va	A2 V
hd39060	27321	bet Pic	A6 V	A6 V
hd50241	32607		A8 Vn kA6	
hd74956	42913		A1 Va(n)	
hd78045	44382		kA3hA5mA5 V	
hd80007	45238		A1 III-	
hd83446	47175		A7 V	
hd88955	50191		A2 Va	
hd102249	57363		A7 V	
hd109536	61468		A7 V	
hd110304	61932		A1 IV+	
hd128898	71908	alp Cir	A7 Vp SrCrEu *	A9 p(SrEu St, Ca wk, K sn)
hd135379	74824	bet Cir	A3 Va	A3 V
hd144197	78914		kA3hA7mF3? III: *	
hd159876	86263	zet Ser	A9 Vp Sr *	Am (A7/A9/F3)
hd172555	92024		A7 V	
hd178253	94114	alp CrA	A2 V *	A2 Vn
hd181577	95168	rho1 Sgr	A9 V	A9 IV
hd210418	109427	tet Peg	A1 Va	A2 V
hd215789	112623	eps Gru	A2 IVn SB2	A2 Vn
F0 - F2 stars				
hd225003	194	32 Psc	F1 V	A9 III
hd6763	5346		F2 V	
hd12311	9236	alp Hyi	F0 IV	F0 IV
hd27290	19893		F1 V	
hd29875	21770		F2 V	
hd31203	22531	Pic A	F1 V Fe-0.4	F0 IV
hd40292	27947		F1 V	F0 III-IV
hd86629	48926		F1 V	
hd92139	51986		F0 Vp kA5 Sr	
hd105211	59072		F2 V	
hd109799	61621		F2 V	
BD-10 5142	96643		F2 V	
hd195627	101612	phi1 Pav	F0 V	F0 V
hd210853	110078	psi Oct	F0 IIp *	F0 III-IV

Notes (*)
HIP 71908: blue side of K-line broadened by Eu probably.
HIP 78914: noisy spectrum
HIP 86263: λ4178 strong also
HIP 94114: noisy spectrum
HIP 110078: noisy spectrum, but some lines, e.g. of Cr, Sr, and Ca, enhanced.