Far-UV spectroscopy of white dwarfs

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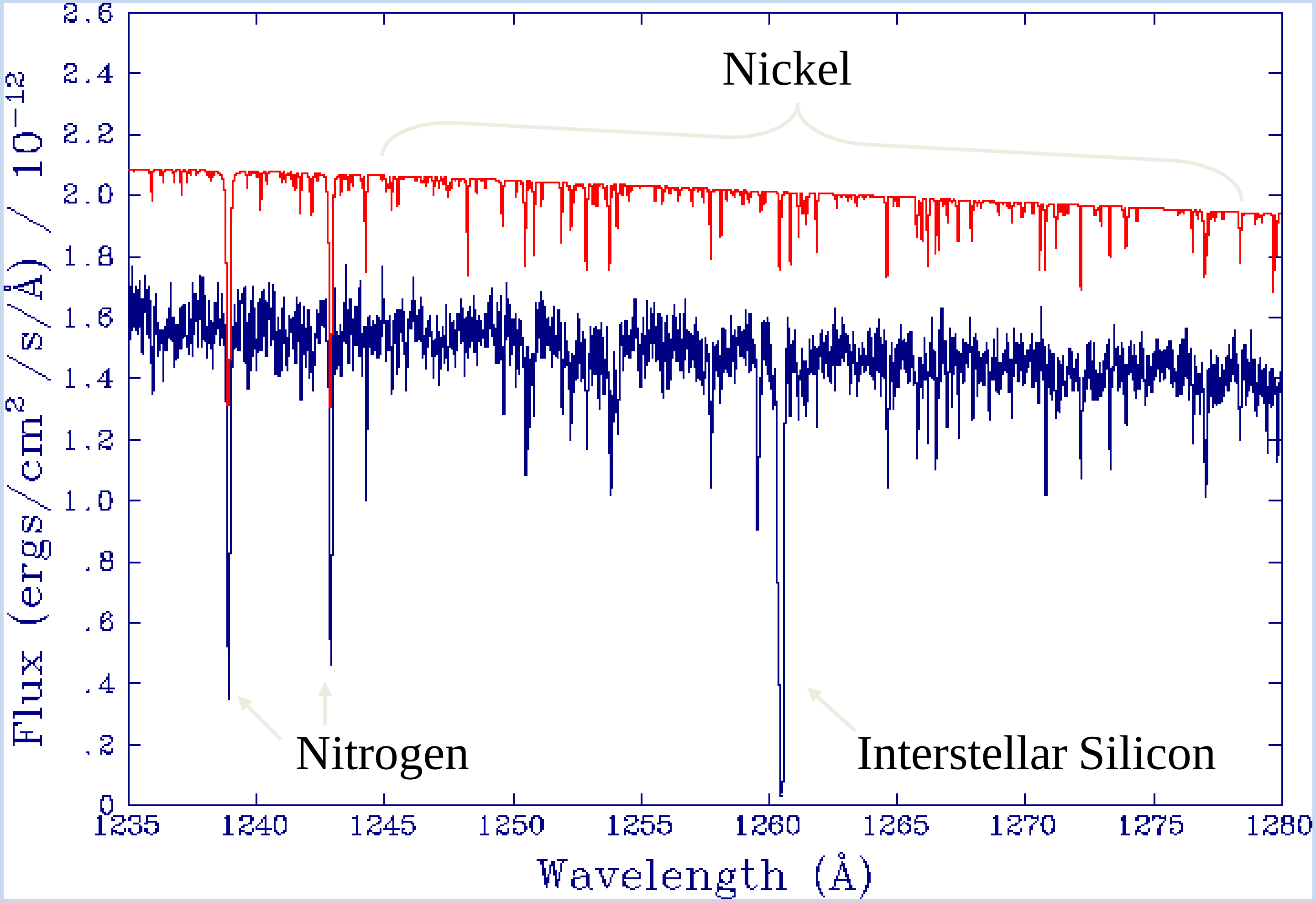
Introduction

- Hot white dwarfs contain significant quantities of metals, including Fe and Ni
- The far-UV is the best (only) spectral range for their study
- High resolution, S/N HST/STIS studies of the fine structure constant
- A large FUSE survey of photospheric abundances

A typical hot H-rich white dwarf



G191-B2B (H-rich DA)

- Best-studied DA with S/N~50-100
  - Preval et al. 2013, MNRAS, in press
- T_{eff}= 52,500 ± 900K, log g = 7.53 ± 0.09
- Rich (for a white dwarf) in metals – C, N, O, Al, Si, P, S, Fe, Ni, Ge
- ~950 lines present in FUSE & HST/STIS spectra

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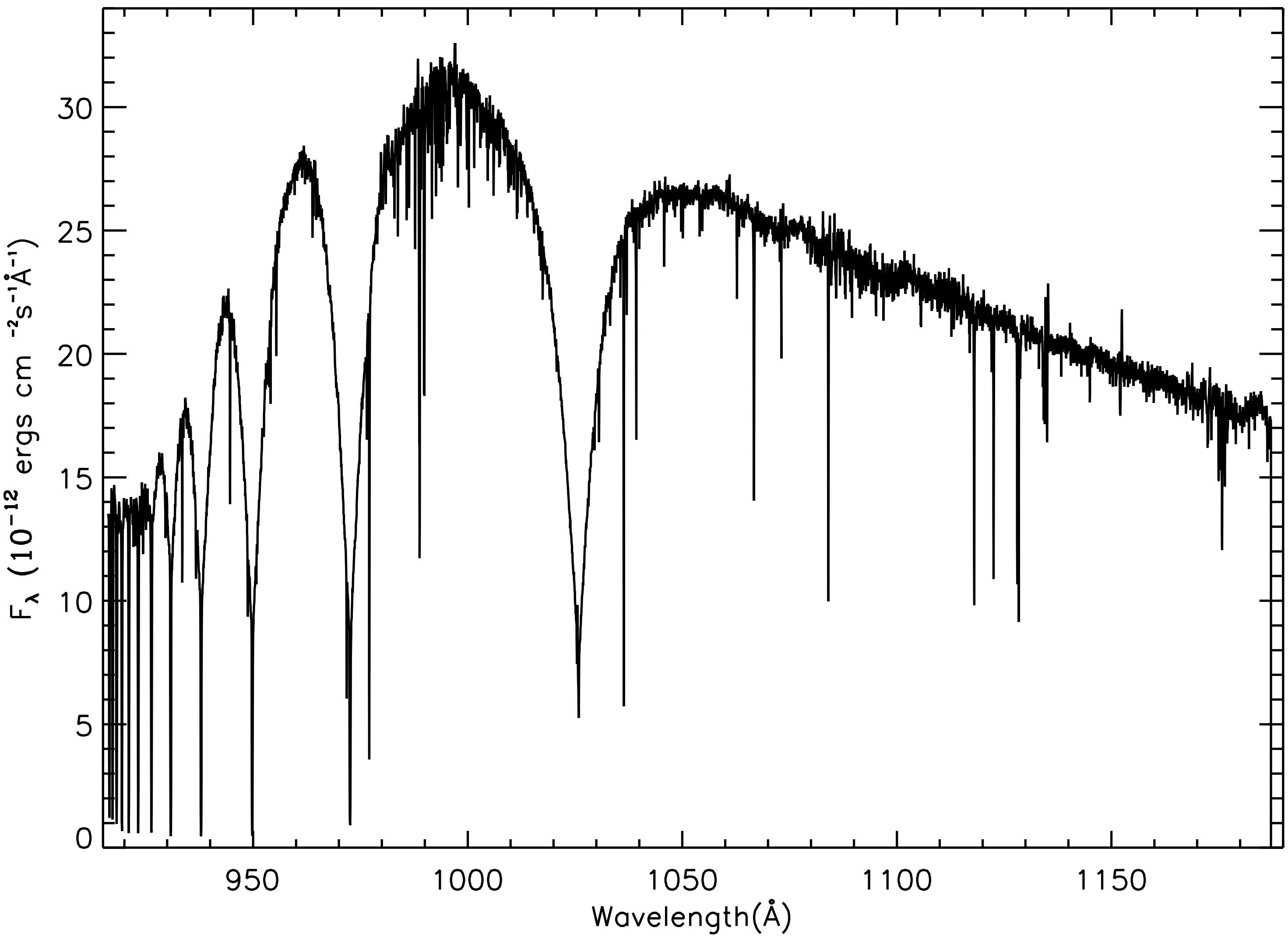

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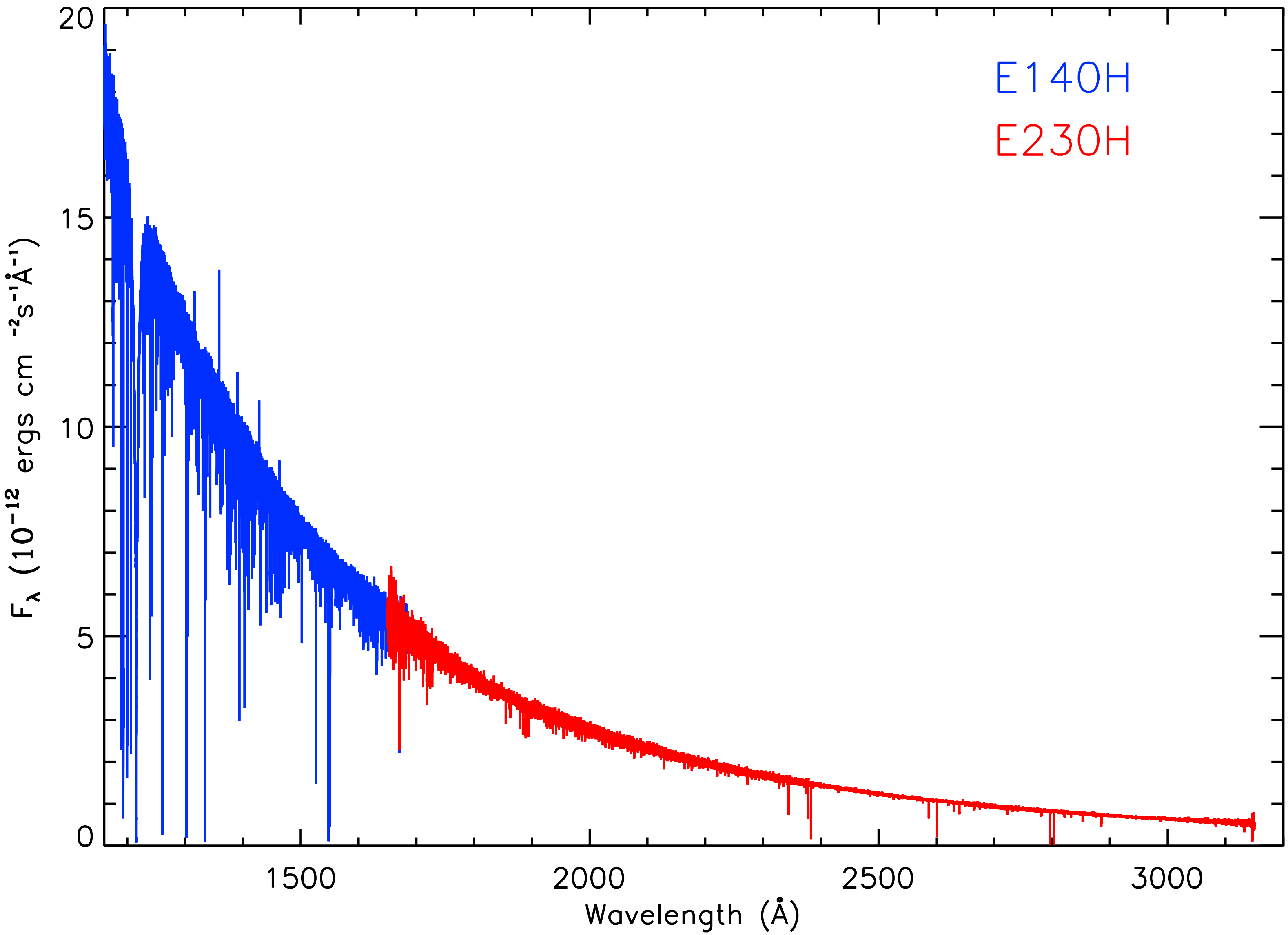

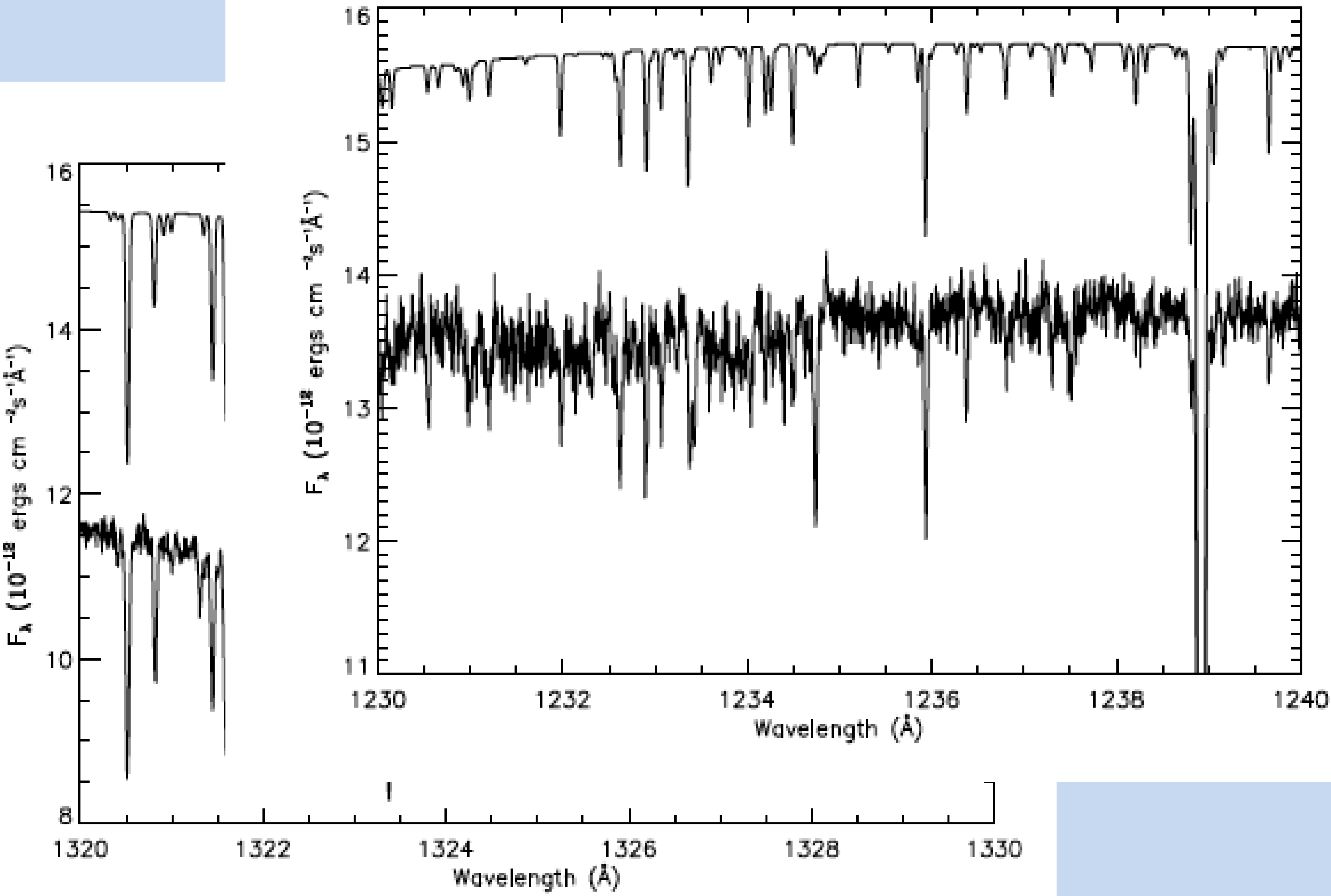

16
14
12
10
8
F_λ (10^{-12} ergs cm^{-2}s^{-1}Å^{-1})
1320
1322
1324
1326
1328
1330
Wavelength (Å)
16
15
14
13
12
11
F_λ (10^{-12} ergs cm^{-2}s^{-1}Å^{-1})
1230
1232
1234
1236
1238
1240
Wavelength (Å)

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Fine structure constant (α) variation

- Coupling constant characterising strength of the electromagnetic interaction
- High gravitational field of white dwarf results in very small (but potentially detectable) shift in wavelength
- Effect larger for high Z atoms (i.e. Fe, Ni!)

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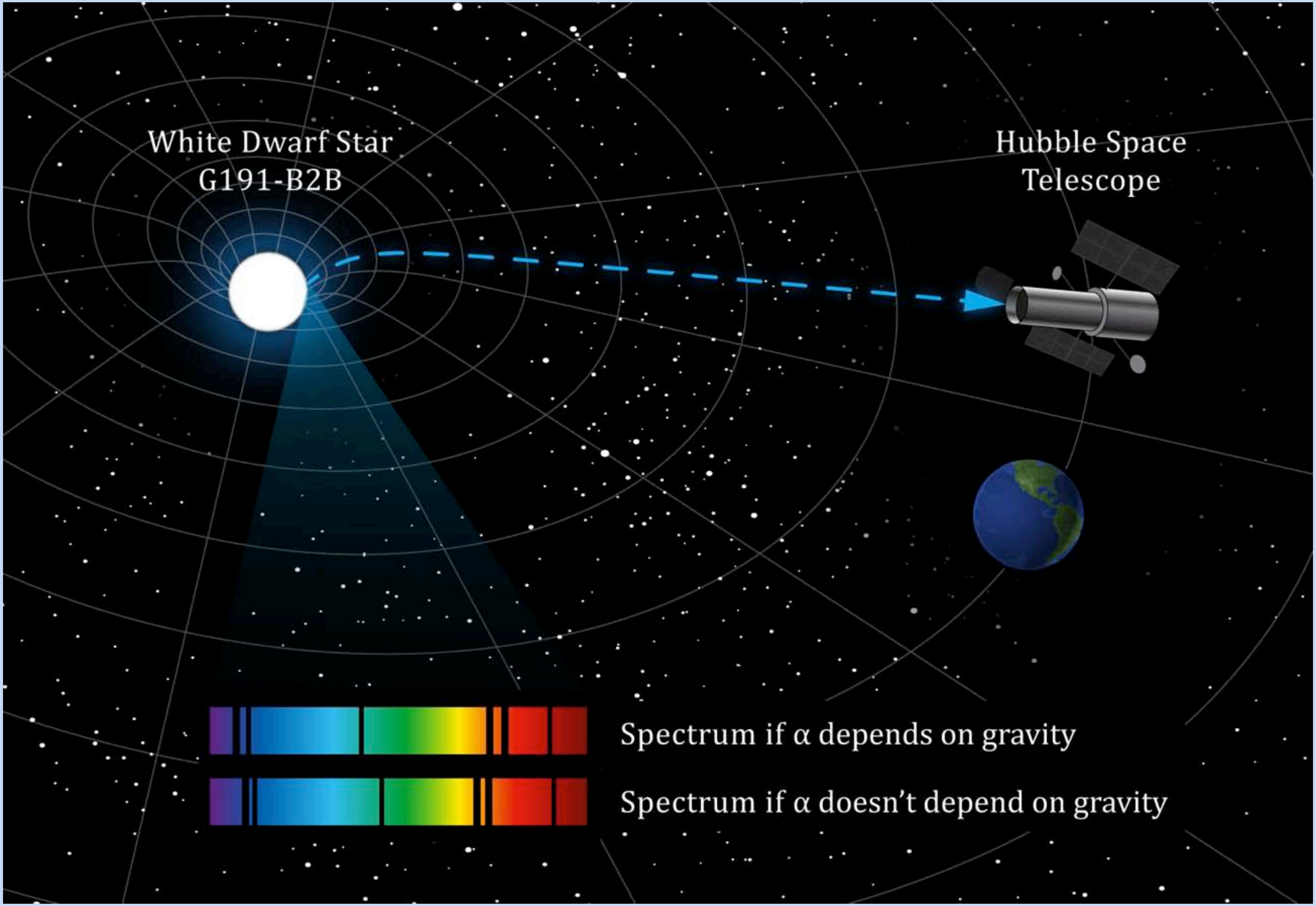
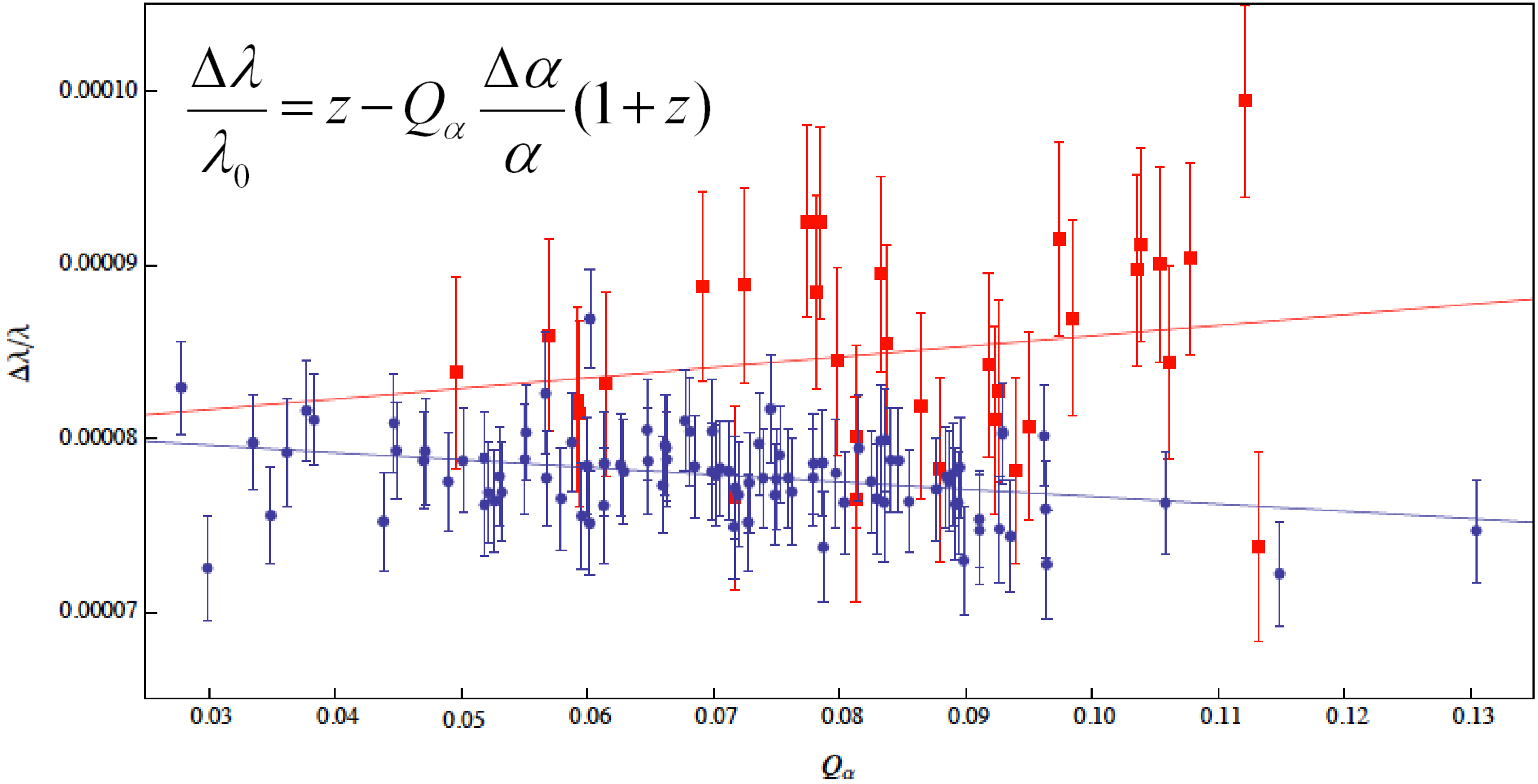


Berengut et al. Phys Rev Letters (2013)



$$\left.\frac{\Delta\alpha}{\alpha}\right|_{Fe} = (4.2 \pm 1.6)\times 10^{-5}$$

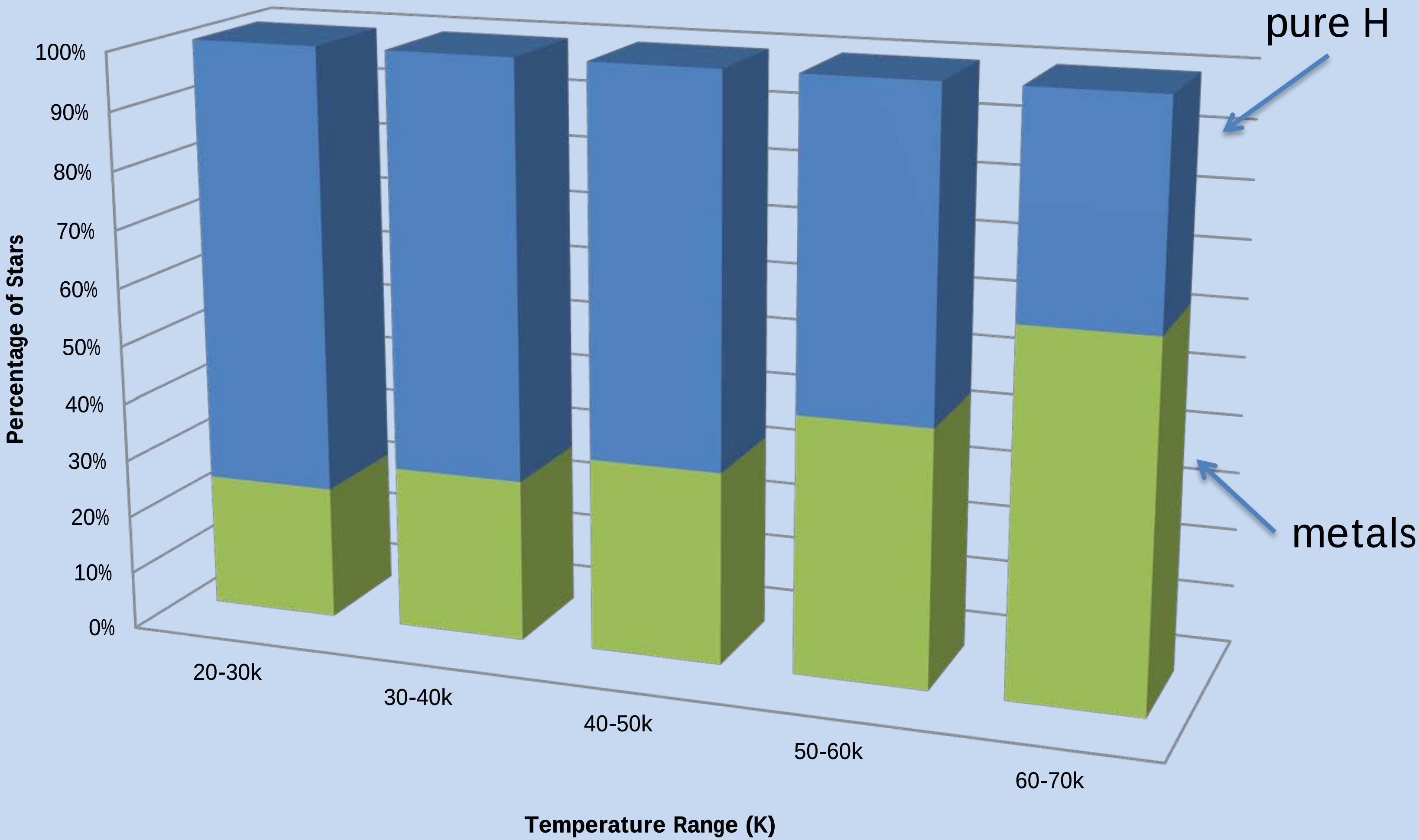
$$\left.\frac{\Delta\alpha}{\alpha}\right|_{Ni} = (-6.1 \pm 5.8)\times 10^{-5}$$

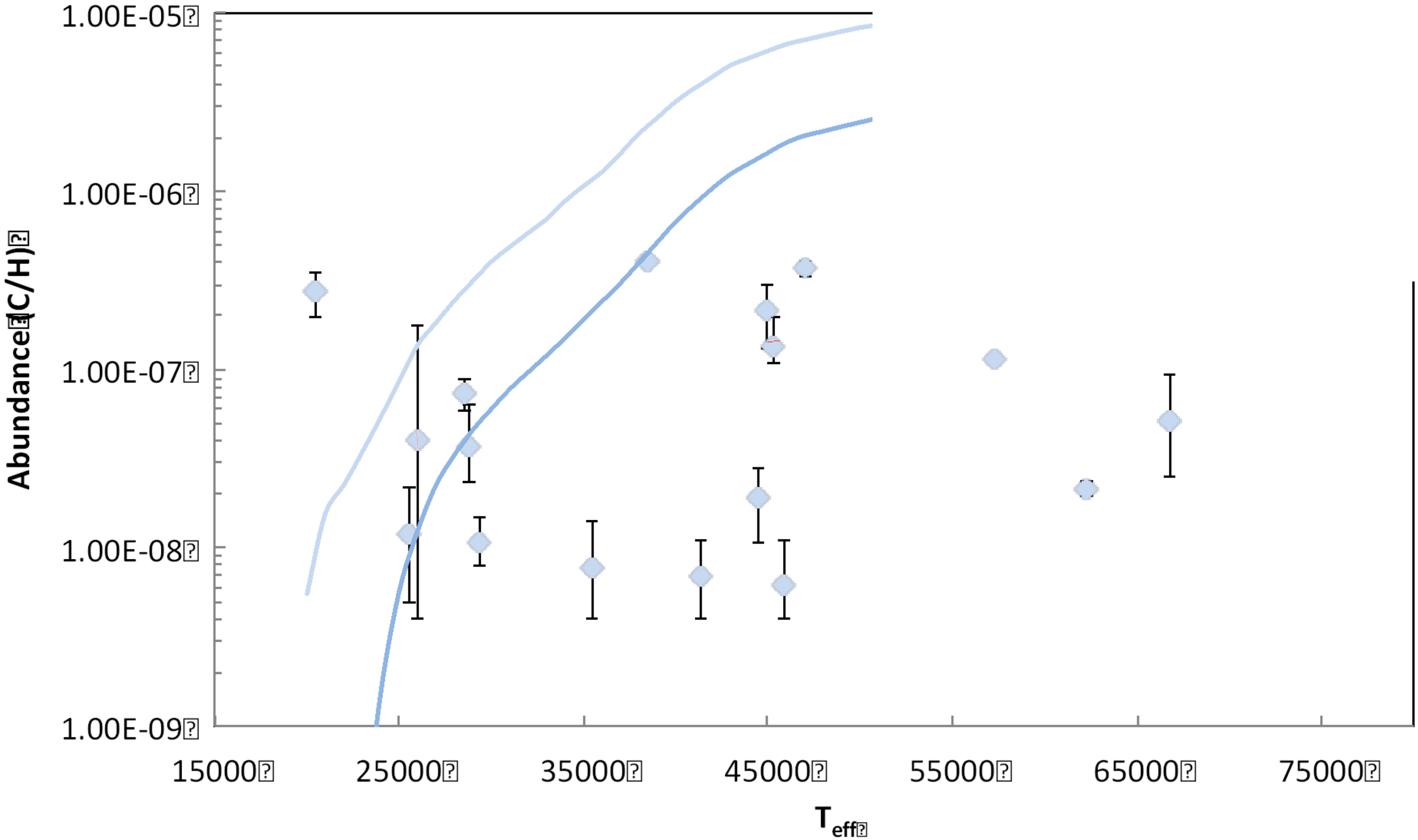
Blue Circles: Fe V
Red Squares: Ni V

Star	Teff	C	Si	P	S
WD0310-688	16181	U	U	U	U
WD1635+529	20027	U	U	U	U
WD1337+701	20435	D	D	D	U
WD0512+326	22750	U	D	U	U
WD0041-092	24900	U	U	U	U
WD0905-724	25398	U	U	U	U
WD0457-103	25540	U	U	U	U
WD2043-635	25971	U	U	U	U
WD2014-575	26579	U	U	U	U
WD0106-358	28580	D	D	D	U
WD2020-425	28597	U	U	U	U
WD1734+742	28795	D	D	U	U
WD1041+580	29016	U	U	U	U
WD0252-055	29120	U	D	D	U
WD1019-141	29330	D	U	D	D
WD0830-535	29330	U	U	U	U
WD0147+674	30120	U	U	U	U
WD1620+647	30184	U	U	U	U
WD0809-728	30585	U	U	U	U
WD1844-223	31470	U	U	U	U
WD0235-125	32306	U	U	U	U
WD0549+158	32780	U	U	D	U
WD0320-539	32860	U	U	U	U
WD0353+284	32984	U	U	U	U
WD1917+509	33000	U	D	D	U
WD0603-483	33040	U	U	U	U
WD1942+499	33500	U	D	D	U
WD0236+498	33822	U	U	U	U
WD0050-332	34684	U	U	D	D
WD2124+191	35000	U	U	U	U
WD0416+402	35227	U	U	U	U
WD1021+266	35432	D	D	D	D
WD0937+505	35552	U	U	U	U
WD1636+351	36056	U	U	U	U
WD1603+432	36257	U	U	U	U
WD1109-225	36750	U	U	U	U
WD1845+683	36888	U	U	U	U
WD1648+407	37850	U	U	U	U
WD2257-073	38010	U	U	U	U
WD1615-154	38205	U	U	U	U
WD1254+223	38205	U	U	U	U
WD1611-084	38500	D	D	D	U
WD2111+498	38866	U	D	D	D
WD1057+719	39555	U	U	U	U

Star	Teff	C	Si	P	S
WD1550+130	39910	U	U	U	U
WD1302+597	39960	U	U	U	U
WD0659+130	39960	U	U	U	U
WD1950-432	41339	U	D	U	U
WD1024+326	41354	U	U	U	U
WD0346-011	42373	U	U	U	U
WD1440+753	42400	U	U	U	U
WD1800+685	43701	U	U	U	U
WD2004-605	44200	U	U	U	U
WD0715-704	44300	U	U	U	U
WD2000-561	44456	D	D	D	D
WD1631+781	44559	U	U	U	U
WD0131-164	44850	U	D	D	U
WD1029+537	44980	U	U	U	U
WD1819+580	45330	D	D	D	D
WD0802+413	45394	U	U	U	U
WD2152-548	45800	U	U	U	U
WD2321-549	45860	U	D	D	D
WD0001+433	46205	U	U	U	U
WD1528+487	46230	U	U	U	U
WD2011+398	47057	D	D	D	D
WD1040+492	47560	U	U	U	U
WD0004+330	47936	U	U	U	U
WD2124-224	48297	U	D	D	U
WD1314+293	49435	U	U	U	U
WD0226-615	50000	U	U	U	U
WD2309+105	51300	U	D	D	D
WD1921-566	52946	U	U	U	U
WD0354-368	53000	U	U	U	U
WD2116+736	54486	U	U	U	U
WD1725+586	54550	U	U	U	U
WD1234+481	55570	U	U	U	U
WD2331-475	56682	U	D	D	D
WD0501+524	57340	D	D	D	D
WD0455-282	58080	U	D	D	D
WD0027-636	60595	U	U	U	U
WD1711+668	60900	U	U	U	U
WD0621-376	62280	D	D	D	D
WD0232+035	62947	U	D	D	D
WD0229-481	63400	U	D	D	D
WD2211-495	65600	U	D	D	D
WD1342+442	66750	D	D	D	D
WD2146-433	67912	U	D	D	D
WD1056+516	68640	U	U	U	U
WD2350-706	69300	U	D	D	D

FUSE survey of composition (89 stars)




1.00E-05
1.00E-06
1.00E-07
1.00E-08
1.00E-09
Abundance (C/H)
15000
25000
35000
45000
55000
65000
75000
Teff

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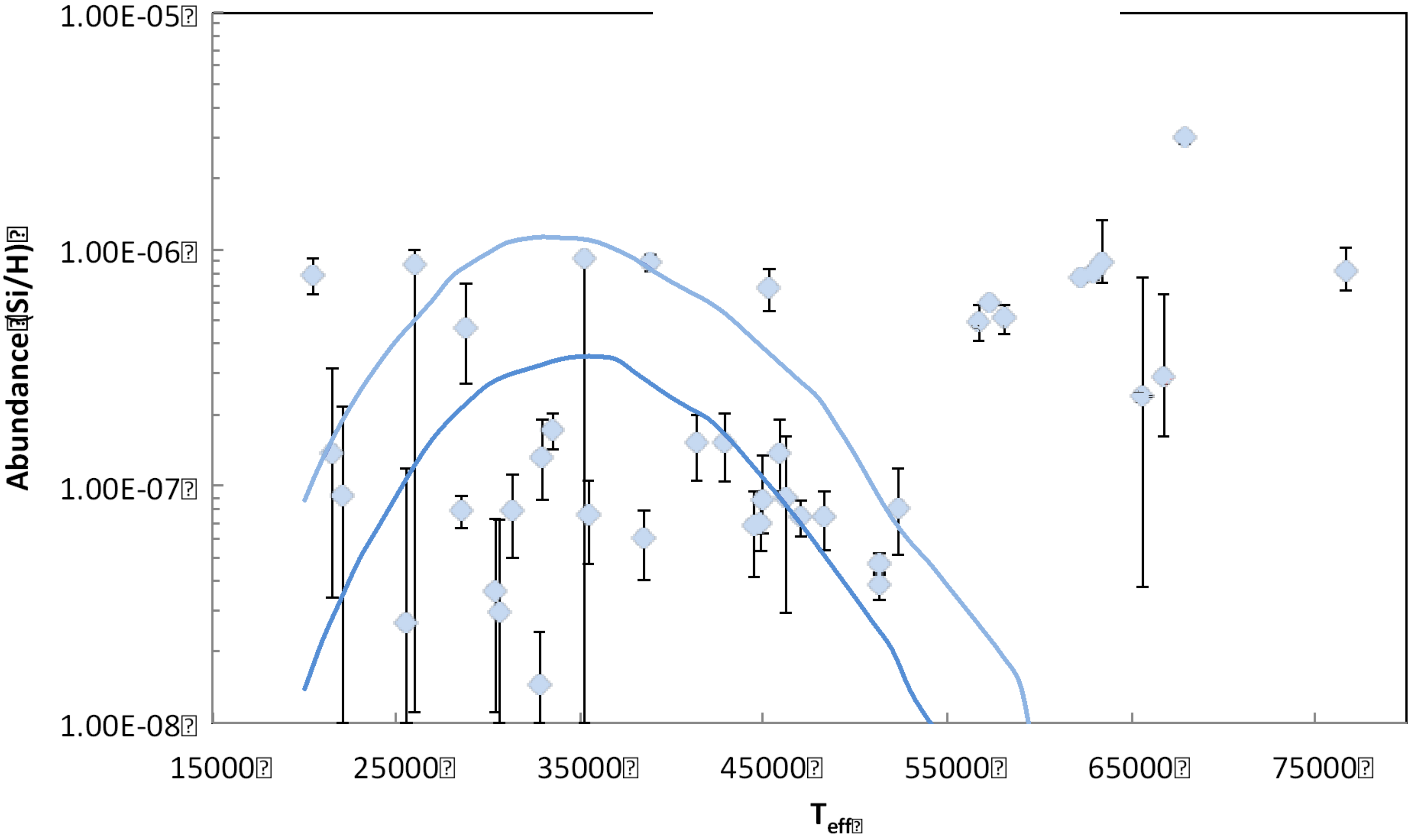

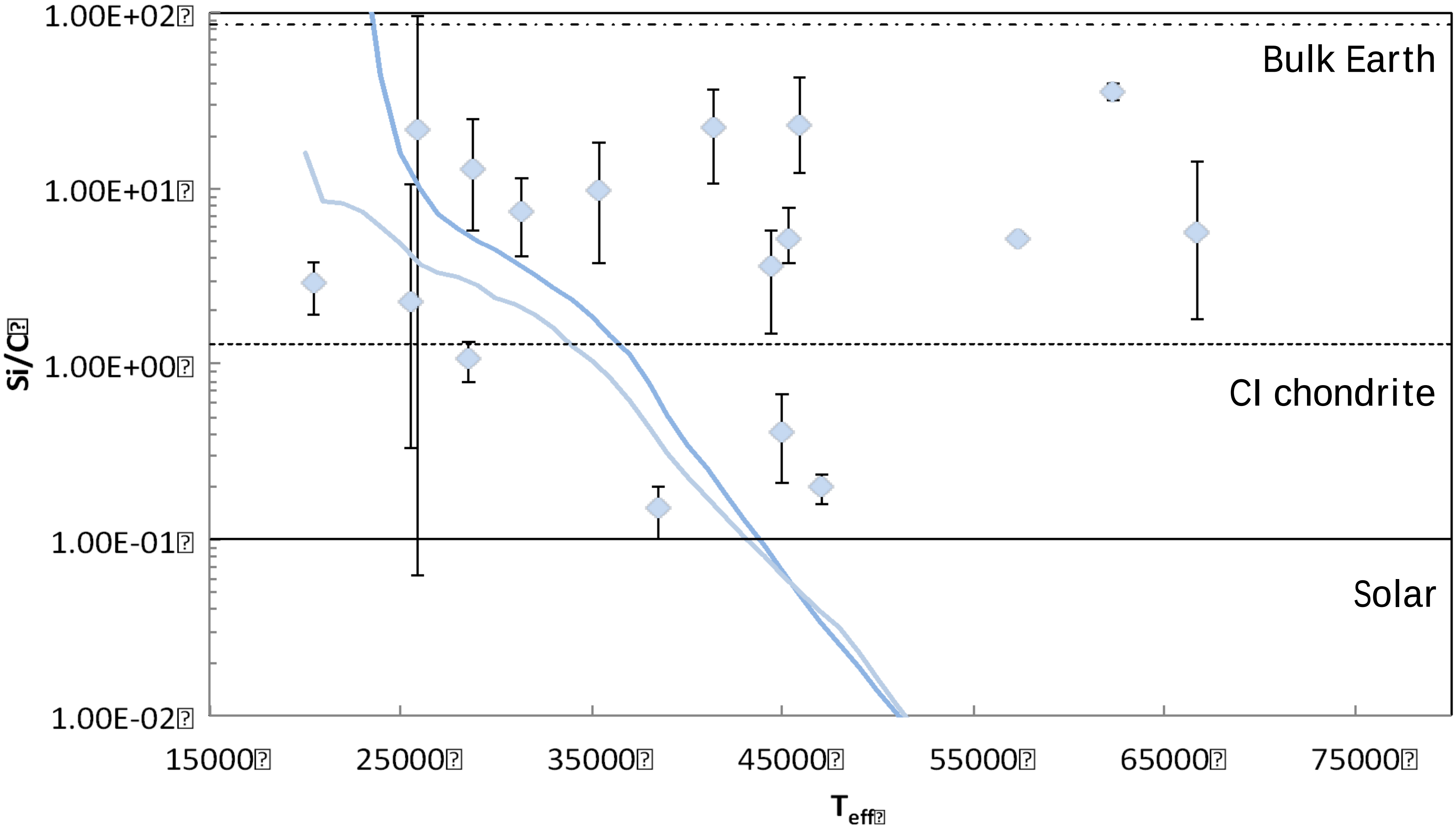
1.00E+02
1.00E+01
1.00E+00
1.00E-01
1.00E-02
Si/C
15000
25000
35000
45000
55000
65000
75000
T_{eff}
Bulk Earth
CI chondrite
Solar

Conclusions

- Fine structure constant
  - Need improved λλ accuracy
  - More high S/N spectra... range of gravities
- White dwarf abundances
  - Metals present in some WDs at all T_{eff}
  - C is depleted cf. Si... rocky material?
  - Radiative levitation is **not** dominant effect
  - WDs accreting from debris