High ionization species in the nearby ISM from an exhaustive analysis of the IUE INES database :

the case of Ap-Bp stars

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High ionization species in the nearby ISM from an exhaustive analysis of the IUE INES database,

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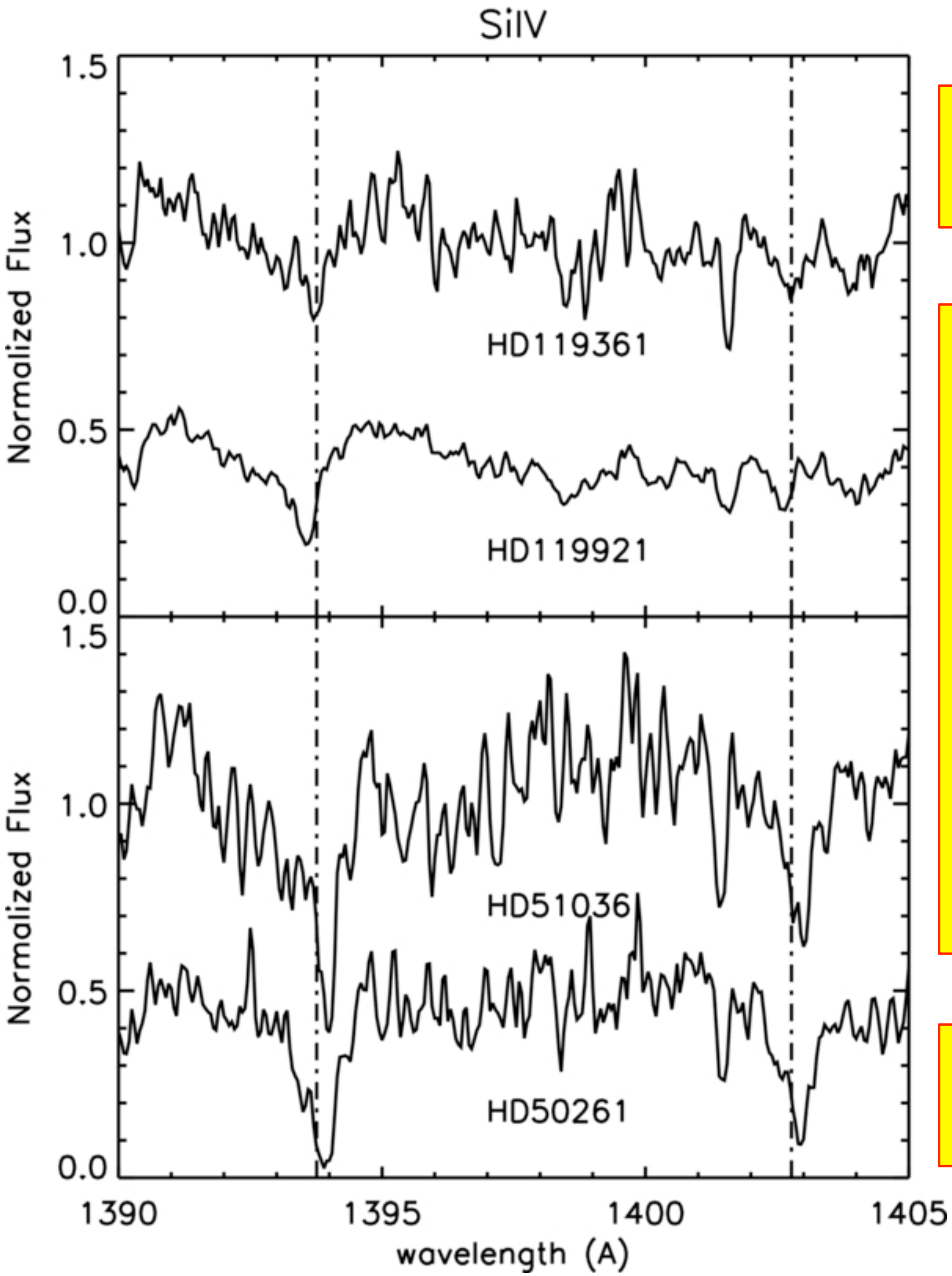
The spectra of normal late-B and early A stars do not show any trace of

- a shell,
- chromospheric lines (Freire Ferrero 1986) ,
- a transition zone (Freire Ferrero 1986) , or
- coronal lines

neither in the optical nor in the UV.

Many stars of these spectral types are nearby, in the local interstellar medium (LISM).

In fact, these stars, with stellar effective temperatures T_{eff} beyond 9000 K, could not develop the **subphotospheric H I convective zone** (like solar-type stars) necessary to produce a **non-radiative temperature rise** in outer atmospheric layers **(chromospheres, transition regions, and corona)**, in which any high ionized species lines, either in absorption or in emission, could be formed.



HD 119921 : AOV, l = 315.28 b = 25.28, 131 pc

HD 119361 : B8III, l = 313.20 b = 19.76, 488 pc

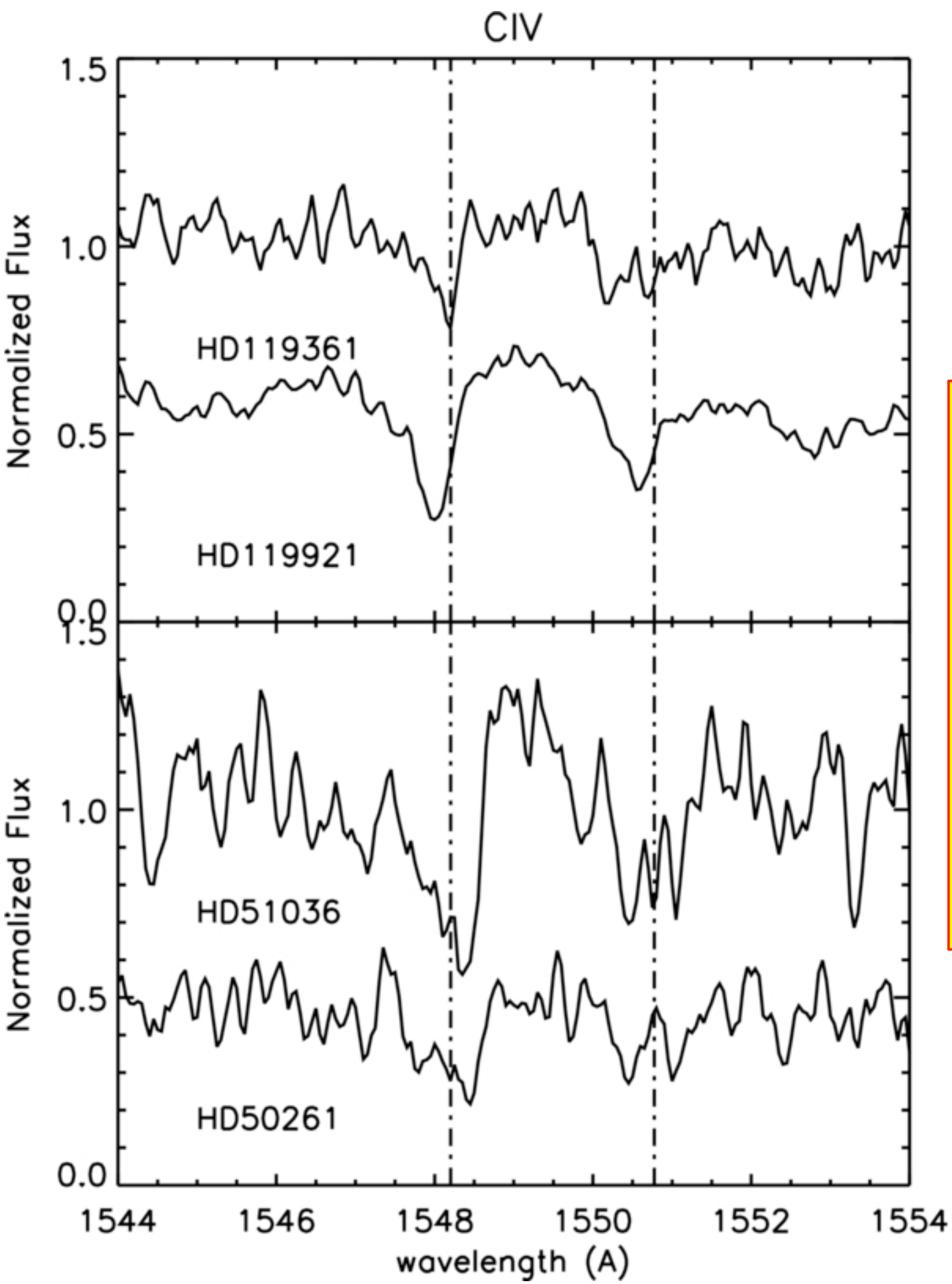
Comparison of Si IV spectral region of HD 119921 and HD 119361 (at the top), and HD 50261 and HD 51036 (at the bottom).

The flux is normalized to the mean flux in the interval shown (1390-1405 Å), with the bottom star displaced by 0.4 in flux.

Stellar weak spectral features ?

HD 50261 (B4/ B3, l = 235.8 b = −11.3, 286 pc)

HD 51036 (B5/B3, l = 235.2 b = −10.1, 5 kpc)



Comparison of C iv spectral region of HD 119921 and HD 119361 (at the top), and HD 50261 and HD 51036 (at the bottom).

The flux is normalized to the mean flux in the interval shown (1544-1554 Å), with the bottom star displaced by 0.4 in flux.

Therefore, nearby late-B and early-A stars of luminosity classes III, IV, and V (Freire Ferrero 1984; Freire Ferrero et al. 1984a) are the best stellar targets for searching for signatures of highly ionized species (like **Si IV and C IV**) in the nearby interstellar medium (ISM).

In this way we prevent to misinterpret the origin of weak lines observed on the spectra of the targets B or A stars, because IS lines superpose to stellar lines in the observed spectra.

Stellar Grouping (IUE INES database)

Our choice of normal late-B and early-A stars to search for signatures of Si IV and C IV in the nearby ISM is justified because normal MS and giant stars of these spectral types cannot produce these ions in their external atmospheric layers.

Nevertheless, in this spectral type range, there are other stars having special characteristics that eventually produce Si IV and C IV lines in their stellar or CS layers.

To avoid possible misinterpretations coming from these stars, we have revised all the spectral types in our sample. After that, we classified stars [558] into seven groups:

1 = normal (IV,IV-V,V) [227],

2 = peculiar (Ap,Bp,Am) [164],

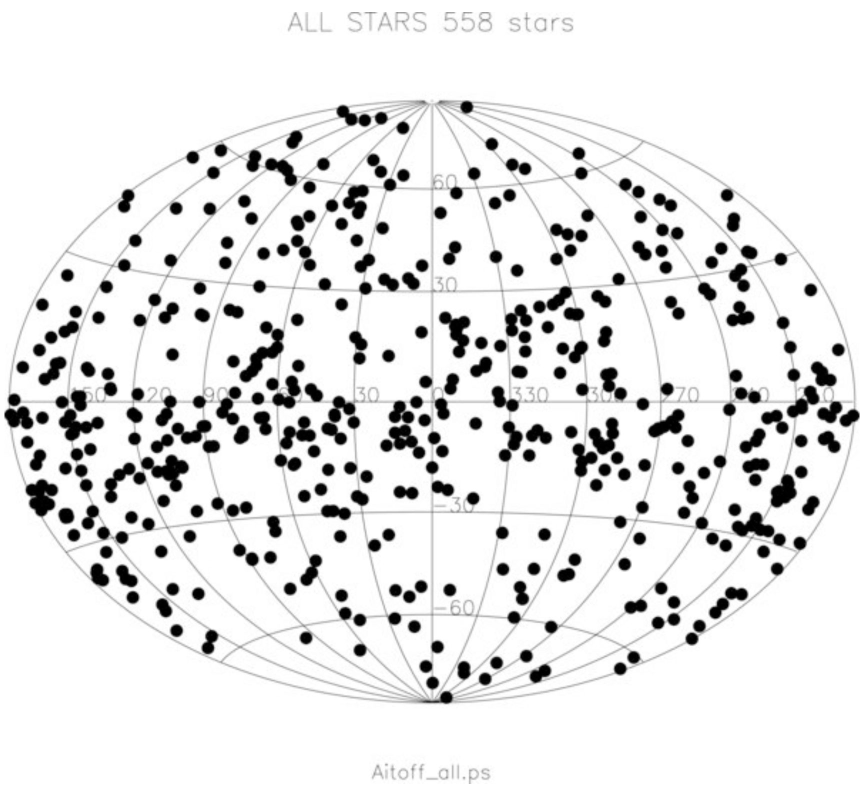
3 = giant (III) [42],

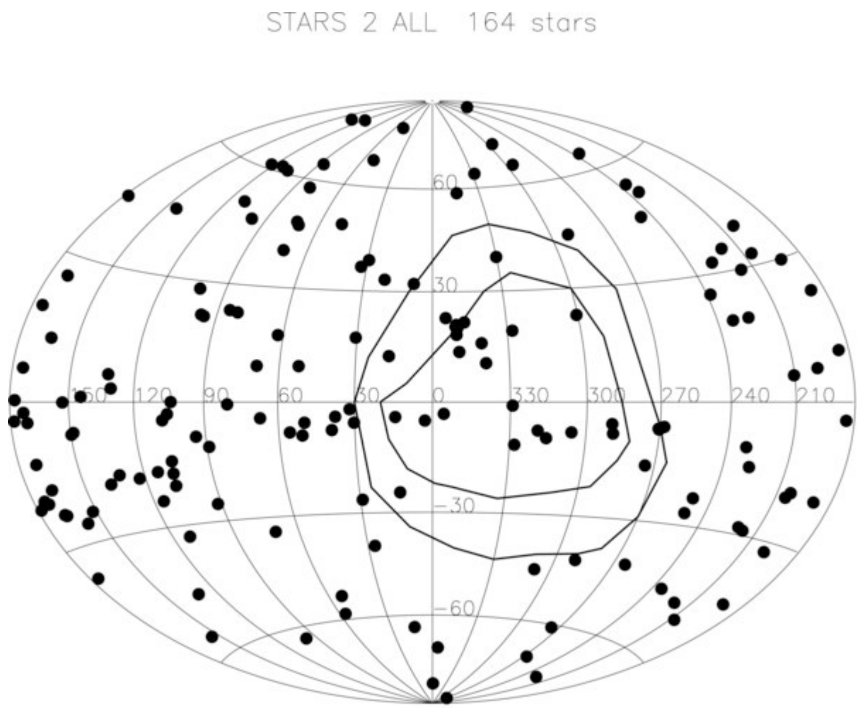
4 = emission-line (Ha, Balmer series,Fe II visible lines) [69]

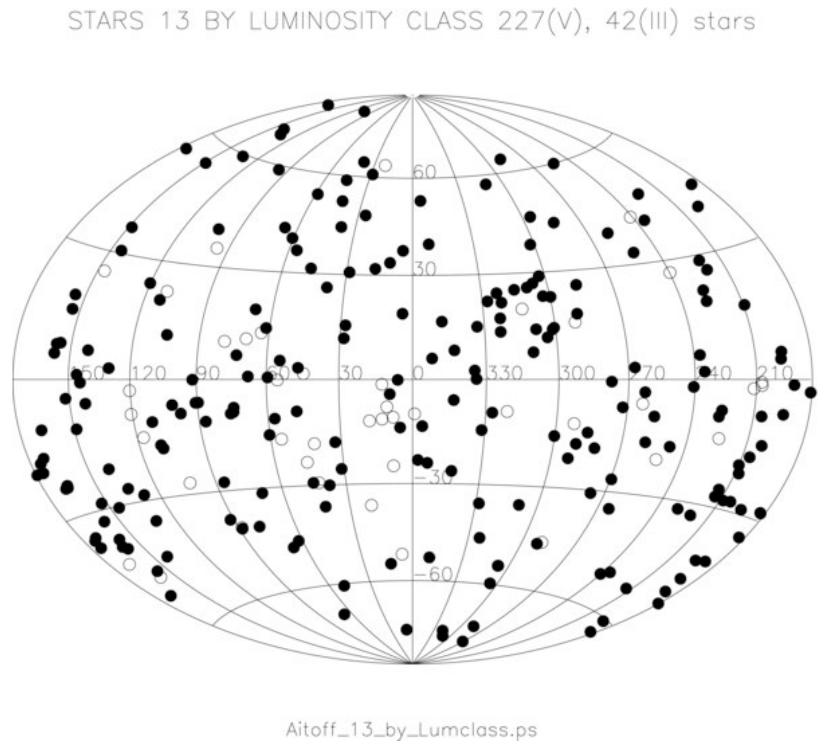
5 = Algol [25],

6 = pre-main sequence (PMS) or Herbig Ae/Be (HAEBE) [13],

7 = shell [18].







(a) Aitoff projection for all 558 stars
(B6-A9, luminosity classes III to V)

(b) Aitoff group 2

(c) Aitoff group 13

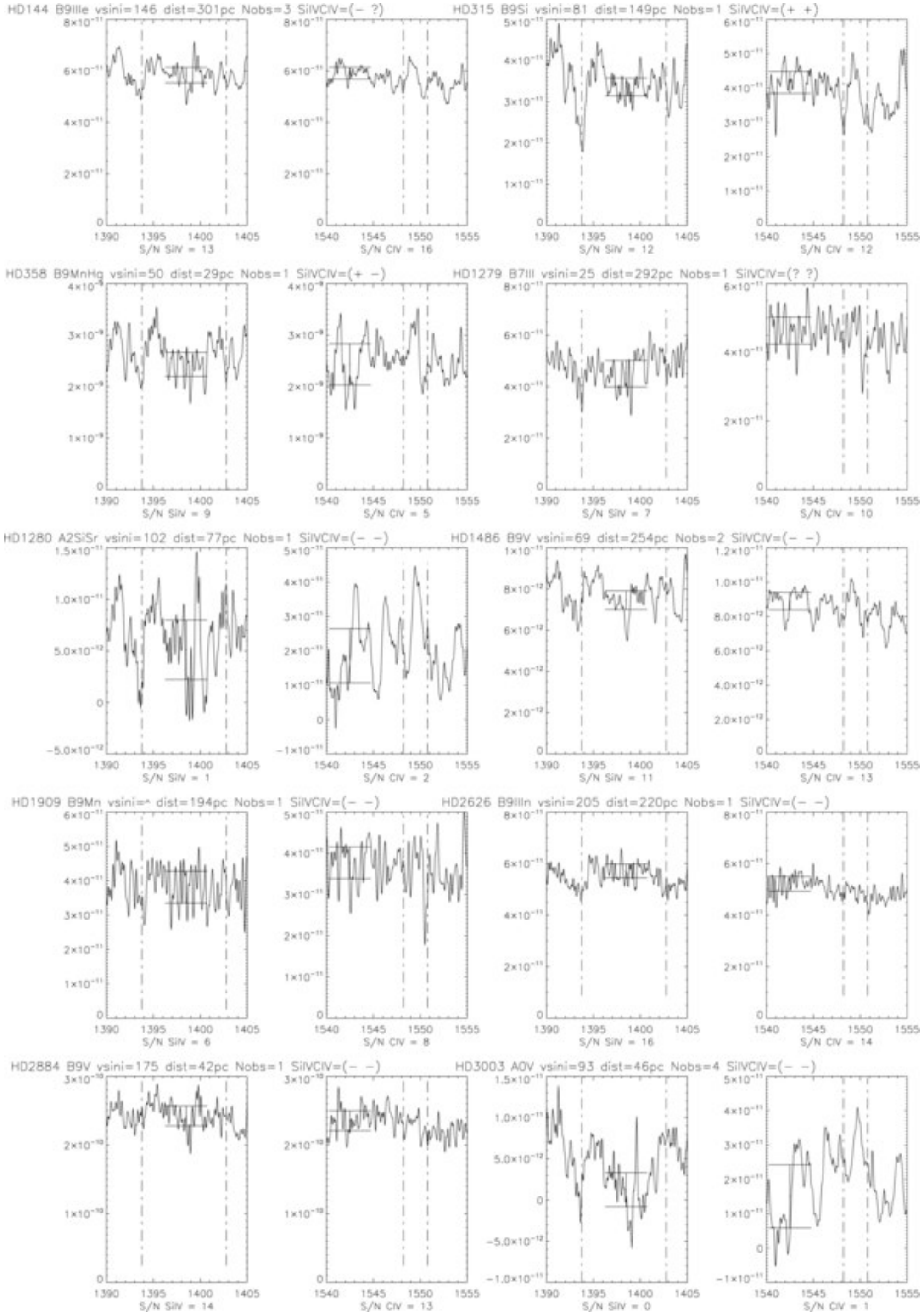
We characterized four independent categories of detection of possible IS line absorptions.

- ***Full positive detection***. Weak Si iv and C iv absorption features appear distinctly in the stellar spectra (indicated as "+ +," or positively detected).

- ***Partial positive detection***. Only the lines of one of the ions were detected in the stellar spectra (indicated with one "+" for one of the doublets and with a "–" or "?" for the other doublet).

- ***Ambiguous or doubtful detection***. A possible non-stellar spectral contribution (uncertain case) appears on one or both resonance lines of Si iv and/or C iv (one indicated with a "?" and the other with a "?" or "–").

- ***Negative detection***. We do not detect spectral features around the Si iv and C iv lines wavelengths (indicated as "– –").

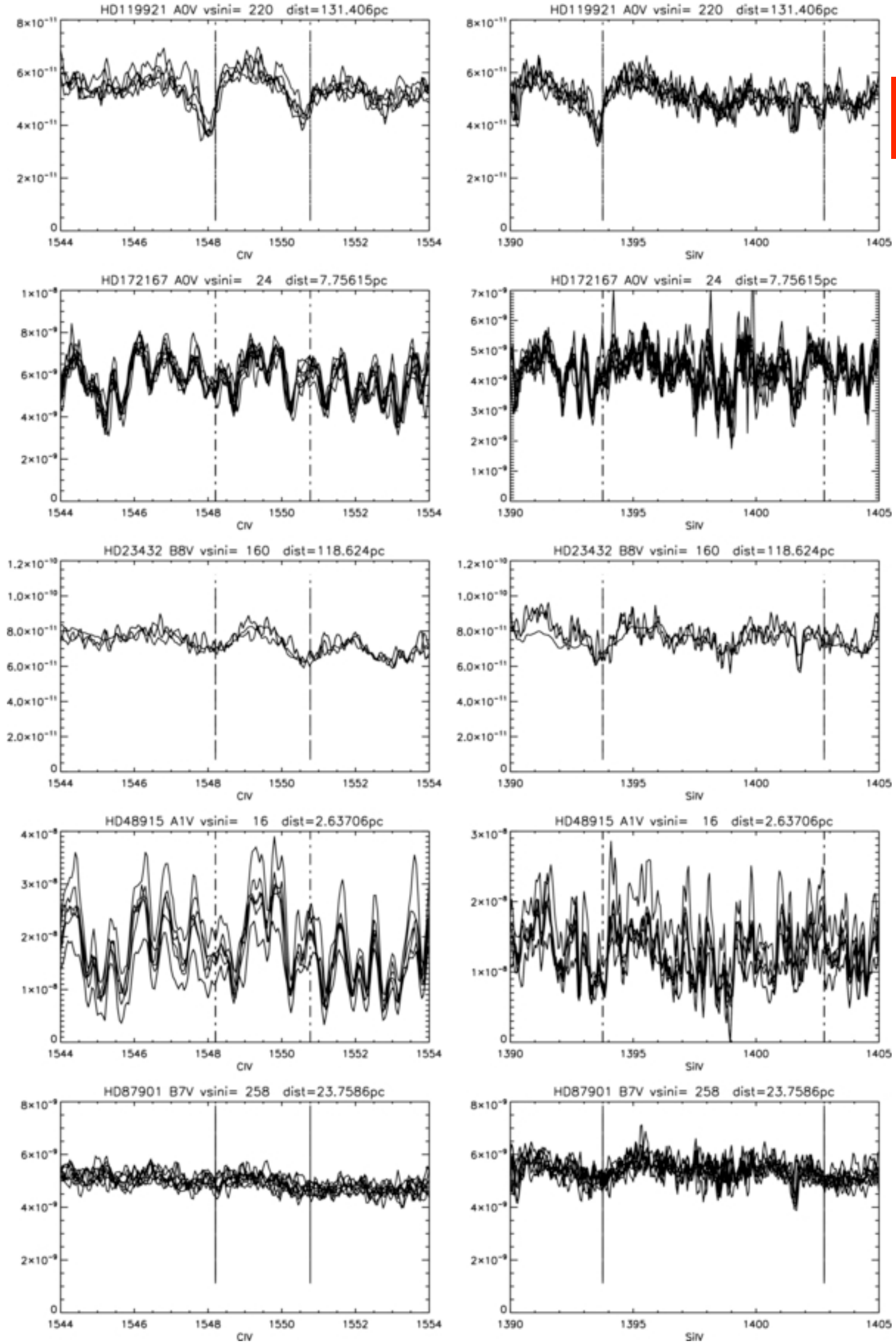


Median absolute deviation (MAD) from the median of the local continuum flux at the wavelengths of Si IV and C IV resonance lines.

Vertical lines indicate the central wavelengths of those lines.

MAD is plotted in the wavelength interval were it was calculated.

wavelengths (Å)	= abscissas
fluxes (erg/s/A/cm^2)	= ordinates



Has HD 119921 variable spectra ?

Superposition of *IUE* spectra taken at different times, of HD 119921 and HD 23432 and other stars, considered as normal or standards, like Vega (HD 172167) and Sirius (HD 48915).

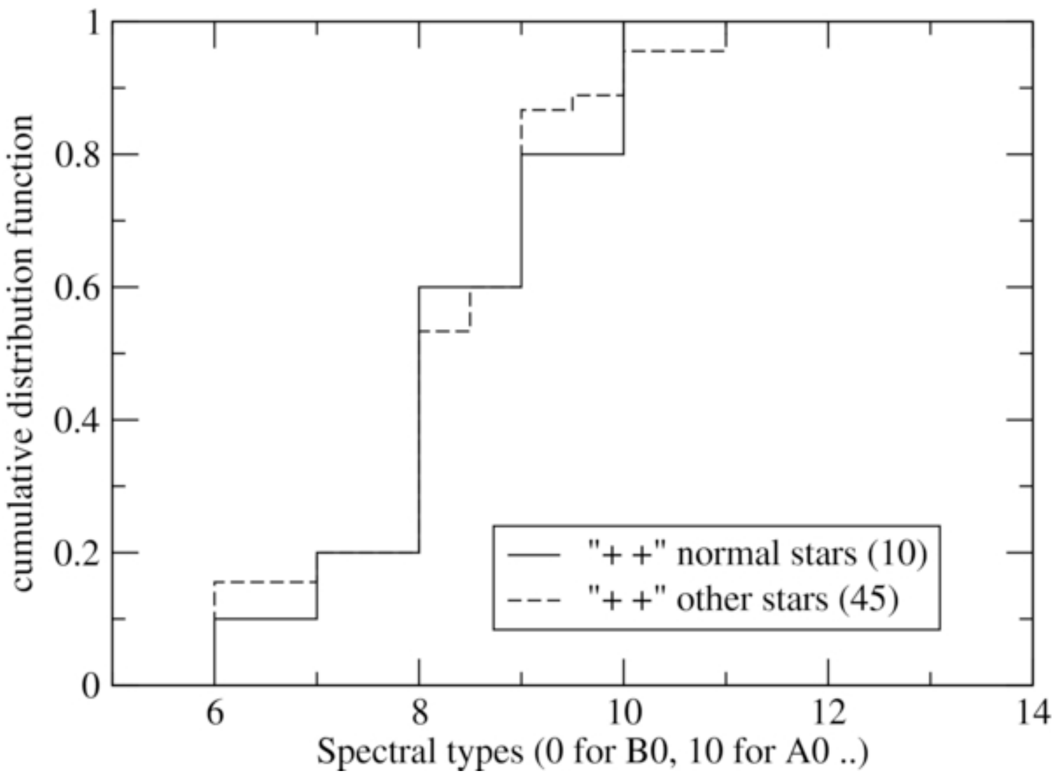
The apparent **spectral variability** can be explained by instrumental noise.

The C iv region (1544-1554 Å) is shown at the left, and the Si iv region (1390-1405 Å) at the right.

Comparison of the spectral type cumulative distribution functions (CDFs) of "+ +" stars of group 13 with all the other "+ +" stars.

With a Smirnov distance of 0.089 for so small sample, the agreement is indeed perfect (threshold: 94%). Plots are centered at spectral type A0.

In abscissas, each spectral type is divided into 10 subtypes beginning with 0 (0 = B0, ... , 6 = B6, ... , 10 = A0, ...).



Conclusions :

1. The weak UV absorptions of Si IV and C IV, observed in the spectra of nearby normal late-B and early-A stars, certainly have an IS origin.

2. The IS region responsible for the formation of these lines would be the **IZ between the expanding Local Bubble and the Loop I** (Egger & Aschenbach 1995; Egger 1998).

3. The positively detected “+ +” category is not a special stellar characteristic of normal stars and uniformly affects all stellar groups.

4. **Practically all “+ +” and “one +” stars are at distances larger than 90 pc** (53/55 “+ +”; 82/97 “one +”) and their number increases with distance.

5. Inside the IZ between the LB and Loop I, the percentage of “+ +” stars as well as that of “one +” stars is higher than that of the other stars, providing evidence that the IZ has particular IS properties. Our results are in agreement with those of Savage et al. (1997) who detected IS Si IV and C IV in the Sco-Cen direction.

Collission between the Loop I and the Local Bubble : the Interaction Zone (IZ)

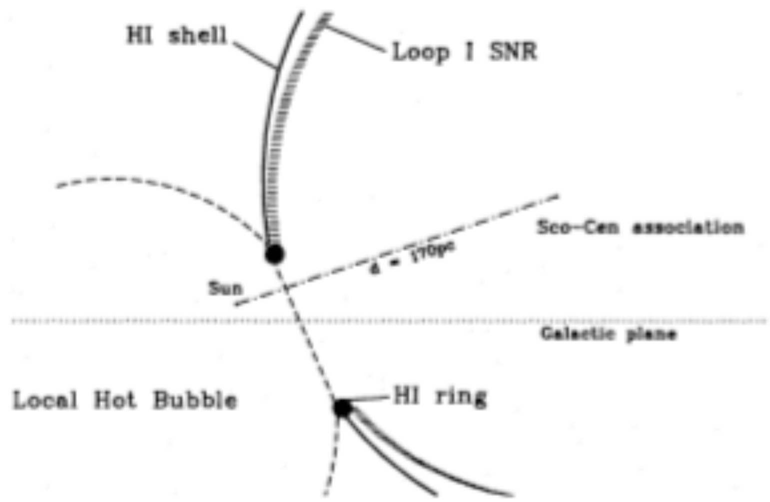
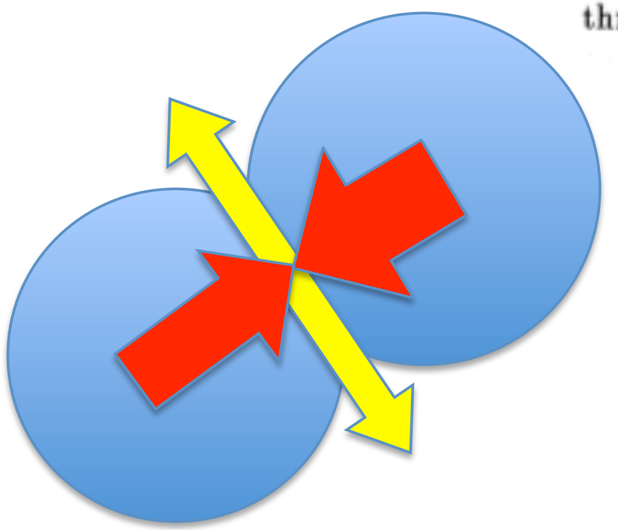


Fig. 5. Schematic vertical cut (normal to the Galactic plane) through the interaction area of Loop I and the LHB.

(Egger and Aschenbach, 1995, AA 294, L25).



Collission between the Loop I and the Local Bubble

In the IZ, the very hot (106 K) IS gas, coming from one direction slows down and cools when it collides with the gas coming from the opposite direction.

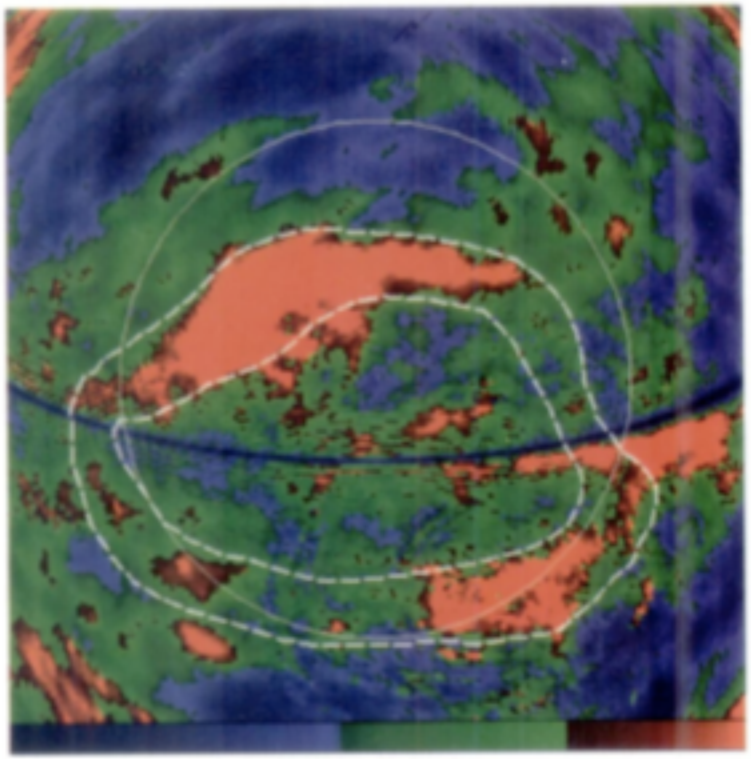


Fig. 3. Map of N_H values multiplied by $sin|b_{II}|$ (colour coded). The Sco-Cen supershell encloses the radio Loop I (solid circle). The dashed lines mark the annular H I feature in the interaction area of Loop I and the Local Hot Bubble.

The cooling could be important enough to produce intermediate hot (10^5 –10^4 K) IS matter with densities 20–30 times higher than those of the surrounding ISM, where no other major IS interactions occur.

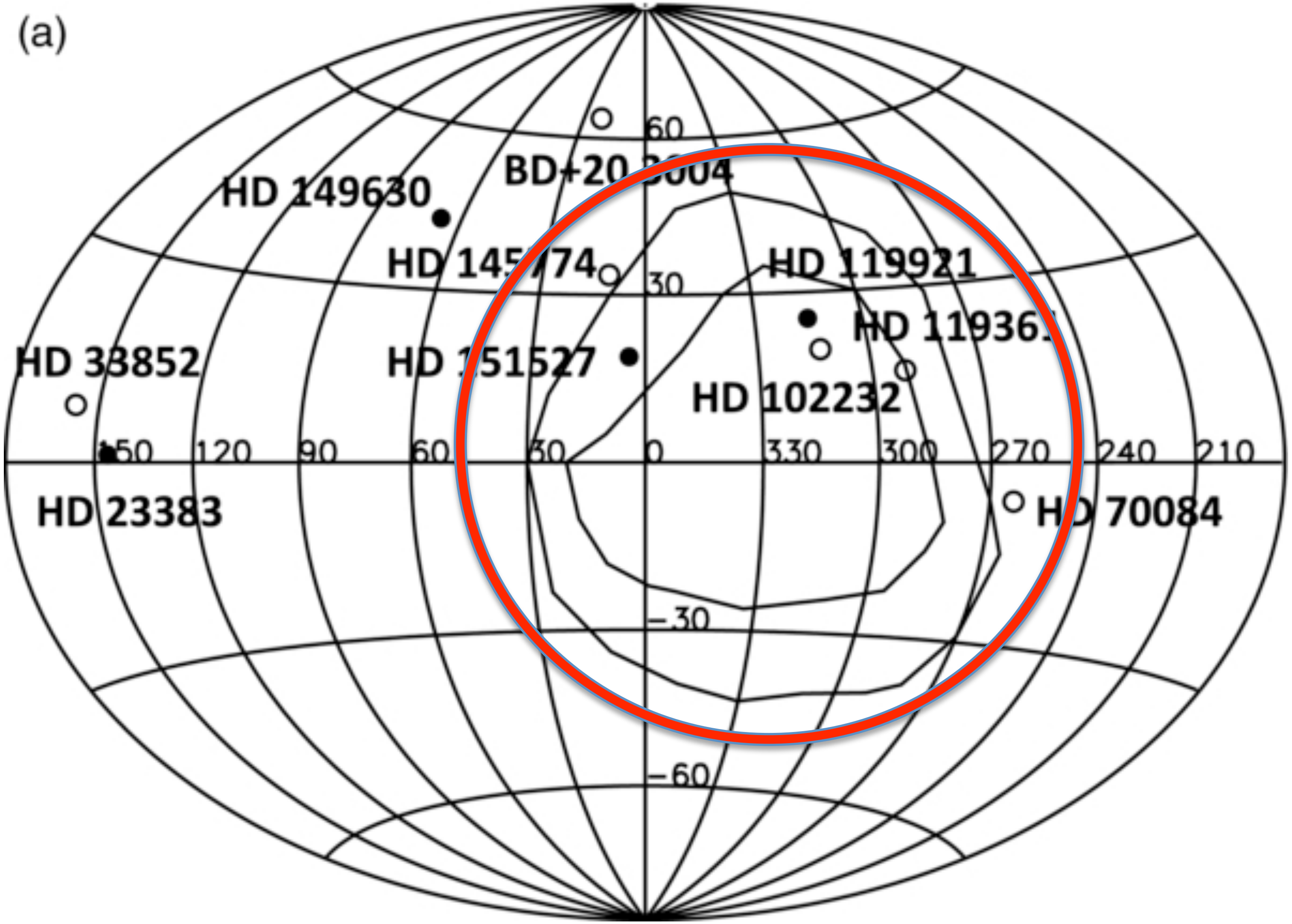
These temperatures are appropriate to locally produce cloudlets of Si IV and C IV whose signature we observed in the normal positively detected stars.

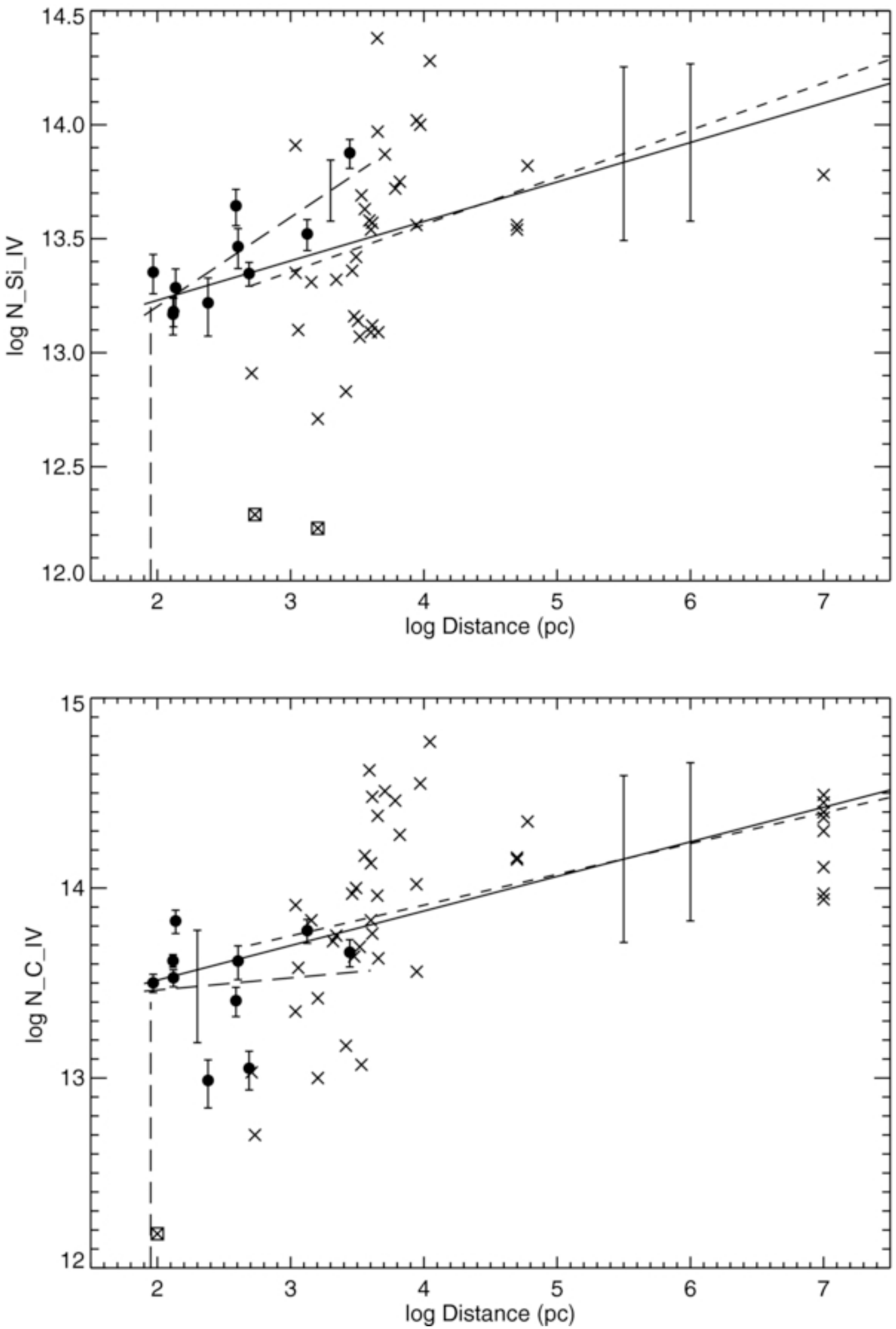
By contrast, for PMS, shell, and emission-line stars (groups 4, 5, 6, and 7) the origin of these weak absorptions could be IS, stellar, and/or CS.

(Egger and Aschenbach, 1995, AA 294, L25).

The 10 Normal and Giant + + stars

(a)





Correlation of **log *N*(Si IV)** and **log *N*(C IV)** with **log *D*** :
filled circles with error bars represent values of our positively detected stars (group 13) and crosses represent the Sembach et al. (1997) data).

Regression lines for our positively detected stars (long-dashed lines), for the Sembach et al. (1997) data (dashed lines), and for both data (solid lines).

Standard deviations of each regression line are indicated.

+ + *Ap and Bp stars* have a different behaviour of **+ + *normal late-B and early-A stars***

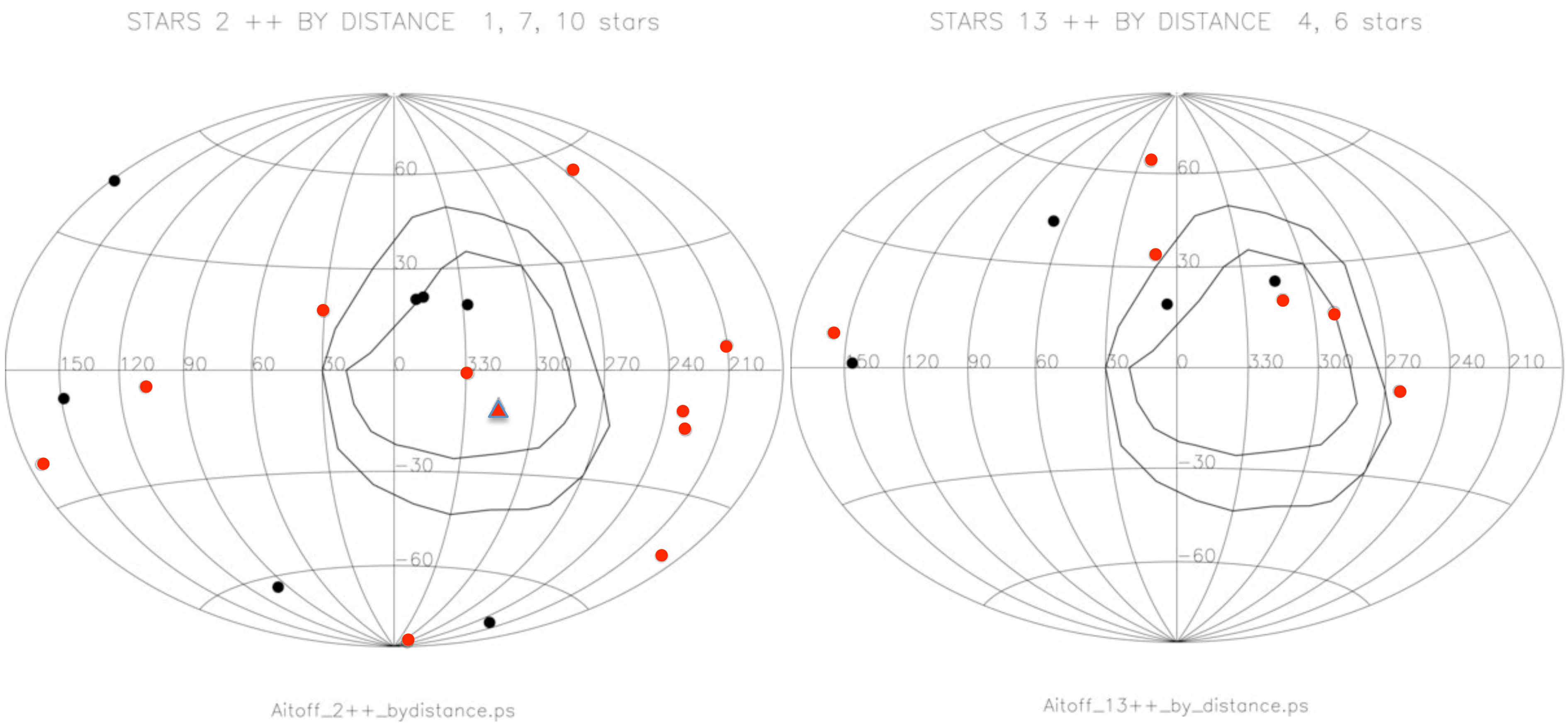


Table 17
Number of Positively Detected Stars by Group and by Distance Interval (Upper Part) and Percentage Ratios (Lower Part) with Errors Derived by the Binomial Distribution

Group	$d < 90$ pc	90 pc $< d <$ 200 pc	$d > 200$ pc	Total
13	94	106	69	269
13 (++)	0	4	6	10
2	45	83	36	164
2 (++)	1	7	10	18
All	151	240	167	558
All (++)	2	26	27	55
% 13(++)/13	$0.0^{+1.9}_{-0.0}$	$3.8^{+2.9}_{-1.8}$	$8.7^{+4.8}_{-3.4}$	$3.7^{+1.6}_{-1.1}$
% 2(++)/2	$2.2^{+4.9}_{-1.8}$	$8.4^{+4.2}_{-3.1}$	$27.8^{+9.4}_{-8.0}$	$11.0^{+3.0}_{-2.5}$

Table 18

Number of Positively Detected Stars by Group, by Distance Interval, and Being "Inside and Nearby" or "Outside" of the IZ and of the Gould Belt

Group	Interaction Zone (IZ)						Gould Belt	
	Total ++	$d < 90$ pc	90 pc $< d <$ 200 pc	$d >$ 200 pc	In/Out	In/Total (%)	In	In/Total (%)
13	10	0	2/2	4/2	6/4	$60.0^{+18.0}_{-20.5}$	9	$90.0^{+8.3}_{-19.4}$
2	18	1/0	3/5	2/7	6/12	$33.3^{+14.6}_{-12.3}$	13	$72.2^{+11.4}_{-14.4}$
4	17	0/1	2/7	1/6	3/14	$17.6^{+14.2}_{-9.5}$	13	$76.5^{+10.9}_{-14.7}$
5	5	0	1/1	1/2	2/3	$40.0^{+30.3}_{-25.3}$	4	$80.0^{+16.6}_{-32.4}$
6	3	0	2/0	0/1	2/1	$66.7^{+27.7}_{-41.4}$	3	$100.0^{+0.0}_{-45.9}$
7	2	0	0/2	0	0/2	$0.0^{+60.2}_{-0.0}$	1	$50.0^{+41.7}_{-41.7}$
All	55	1/1	10/17	8/18	19/36	$52.8^{+10.0}_{-10.0}$	43	$78.2^{+10.0}_{-10.0}$

Notes. The number of stars "inside/outside" (in/out) the IZ between the Local Bubble and the Loop I is indicated for each interval of distances. Column 8 indicates the number of stars projected over the GB and Column 9 the percentages of "inside" the IZ over total number of (+ +) stars of each group.

Table 19

Number of Stars for Each Interval of Distance Grouped by the Category of Detection Followed by the Percentage of Stars of Each Group Relative to the Total Number of "all stars" by Distance Interval

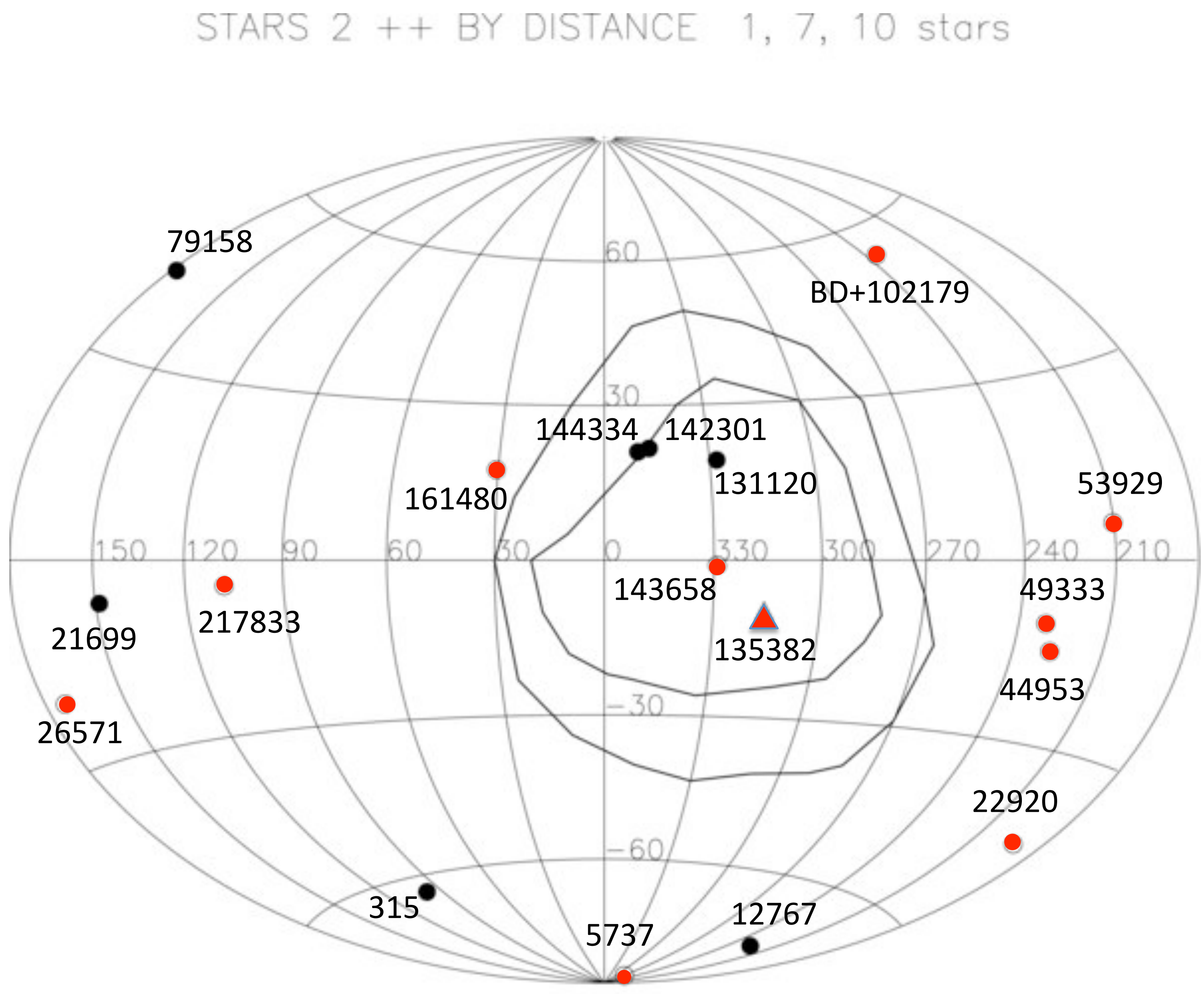
Distance	All					%			
Intervals (pc)	Stars	++	one +	−−	? or ??	++	one +	−−	? or ??
0 − − > 100	176	4	16	112	44	2.27	9.09	63.64	25.00
100 − − > 200	218	24	46	99	49	11.01	21.10	45.41	22.48
200 − − > 300	93	10	20	37	26	10.75	21.51	39.78	27.96
300 − − > 400	35	8	10	9	8	22.86	28.57	25.71	22.86
400 − − > 500	9	3	3	1	2	33.33	33.33	11.11	22.22
500 − − > ...	27	5	3	10	9	18.52	11.11	37.04	33.33

How to constrain the Ap conspiration ?

The new challenge is now :

(a) why several + + Ap stars are located outside the IZ, but

(b) anyway lying practically beyond 100 pc, except for HD 135382 ?


STARS 2 ++ BY DISTANCE 1, 7, 10 stars
60
30
-30
-60
150
120
90
60
30
0
330
300
270
240
210
79158
BD+102179
144334
142301
131120
161480
53929
143658
49333
21699
217833
135382
44953
26571
22920
315
5737
12767

HD 135382

A 1 V , V = 2.9 , d = 55 pc , R = 6 Ro , v sin i = 199 Km/s

has a debris disc (radius 481 AU),

ApJ 660, 1556-1571, 2007,
Characterization of Dusty Debris Disks : The IRAS and Hipparcos Catalogs,
Joseph H. Rhee, Inseok Song, B. Zuckerman and Michael McElwain)

but it is not a multiple star

ApJ 745, 147, 2012
Binaries among debris disk stars
David R. Rodriguez and B. Zuckerman

Ap and Bp stars = peculiar A and B stars = CP stars = chemically peculiar stars

Explanatory Theory :

- Ap and Bp stars are slow or medium rotators,
- some of them have a magnetic field **B** (for some of them very strong) with closed lines of field (oblique rotator theory),
- **B** empeaches convection to develop and also turbulence from rotation.

Result :

- The atmospheres are very stable and classical hydrodynamic are absent.
- Classical mixing of matter is not possible and chemical elements can be stratified by gravity (as in the high terrestrial atmosphere)
- But the action of weak radiative forces can modify the stratification of chemical elements : some will be pushed up, other will be not perturbed and finally other ones will fall in the atmospehre (diffusion).

But, in addition, Ap and Bp are not only CP.

Some ApBp stars are also :

- **X-ray emmitters,**
- **binaries,**
- **rapidly oscillating (atmospheres)**

Preliminary

analysis . . .

Ap stars	all	projected inside IZ	projected outside IZ	% (in/out)	Notes Fig.
d < 90 pc	45	5	40	12.50	4c / 8g
90 < d < 200 pc	83	23	60	38.33	4c / 8g
d > 200 pc	36	5	31	16.13	4c / 8g
all distances	164	33	131	25.19	1b
all "+ +"	18	5	13	38.46	8f
% ("+ +"/all)	10.98	15.15	9.92	- - - -	- - -
all "one +"	51	12	39	30.77	8u
"one ?" and "? ?"	81	10	71	14.08	8v

The pseudo-elliptical IZ (minor axis 45° and major axis 60°) can be approximated by a spherical cap of 50° or 55°, even though the observed region does not completely cover the cap. The ratio of this cap in steradians with the celestial sphere is 0.5 [1 − cos α], where α is the subtended angle of the cone limiting the cap from the center of the sphere. **For α 50° and 55°, the ratios are** respectively, **17.86% and 21.32%, which can be considered the random probabilities**.

HD	Sp. Type	Var	Period (day)	v.sin i (Km/s)	Bin	B field (10-4 T)	X-Ray	Teff (K)
315	B9 Si		-	81	-	1437.9	rassob	- - - -
5737	B6 Hew		21.65	20	R	324.0	X-ARXA	13 200
12767	A0 Si	a^2 CVn	1.89	45	-	242.1	rassob	12 900
21699	B8 HewkSi		2.49	35	? R	827.6	-	14 400
22920	B8 Si		3.95	39	-	307.1	-	13 900
26571	B8 Si		-	20	R	-	hyadesxray	-
44953	B8 Hewk		-	30	R	-	-	-
49333	B7 Hewk		2.18	65	? R	618.4	rassob	16 450
53929	B9 MnHg		-	25	-	215.9	-	-
79158	B9 Hewk		3.84	49	? R	636.3	-	12 500
131120	B7 Hewk		-	54	R	120.1	-	-
135382	A1 Eu		-	199	R	192.5	-	-
142301	B8 HewSi	Ro Ap	1.459	90	? R	2 103.6	XMM-SSC	15 700
143658	B9 Si		-	-	-	- - -	-	15 600
144334	B8 Hewk		1.495	55	HR	783.2	rassob	14 700
161480	B6 Hewk		-	25	RP	-	-	-
217833	B8 Hewk		-	30	R	3 648.7	CHANDRA	14 800
BD+ 102179	B6 p		-	-	-	-	-	-

Principal beast in the Ap fauna

• metallic-lined (Am),	or CP1,
• Ap,	or CP2,
• mercury-manganese (HgMn),	or CP3,
• helium-weak (He-weak)	or CP4,
• helium-rich (He-rich)	

Am	= CP1	weak lines of Ca II and/or Sc II, but enhanced abundances of heavy metals. Slow rotators ; Teff = 7000 - 10 000 K.
Ap	= CP2	show strong magnetic fields, enhanced abundances of elements (Si, Cr, Sr and Eu). Generally slow rotators. Teff = 8000 K - 15 000 K,.
HgMn	= CP3	also classically considered as Ap, **but do not show the strong magnetic fields** of classical Ap stars. High abundances of Hg and Mn (from Hg II and Mn II lines). Very slow rotators. Teff 10 000 K - 15 000 K.
He-weak	= CP4	show weaker He lines than would be expected classically from their observed Johnson UBV colours.
He-rich		From solar to a factor > 1 with respect to H. C Underabunt. Spectroscopic and photometric variabilityis explained by an abundance distribution across the stellar sur-face. Teff 15 000 K – 27 000 K. They are the most massive CP stars.

Ap variabilities

Alpha2 Canum Venaticorum variable = **α^2 CVn variable**.

CP MS stars B8p to A7p.
They have :strong magnetiic fields and strong Si, Sr, or Cr lines.
Brightness variability 0.01 to 0.1 magnitudes over periods of 0.5 to 160 days.

Continuum and line profiles vary, as do their magnetic fields with the same periods supposed to be the stellar rotational period.

Spectral and liuminosity variabilities caused by an inhomogeneous distribution of metals in their stellar atmospheres.
The surface of the star varies in brightness from point to point.

Rapidly Oscillating Ap stars = roAp

2007MNRAS376,615

Kochukhov, O.; Ryabchikova, T.; Weiss, W. W.; Landstreet, J. D.; Lyashko, D.

Line profile variations in rapidly oscillating Ap stars : resolution of the enigma

sharp-lined roAp stars / variations of Pr III, Nd II, Nd III and Tb III lines
prominent change of the profile variability pattern with height in the atmospheres of all studied roAp stars : at least one rare-earth ion is characterized by unusual blue-to-red moving features, as in the roAp star γ Equ.

Common behaviour in rapidly rotating non-radial pulsators but inexplicable in the framework of the standard oblique pulsator model of slowly rotating roAp stars.
This variation occurs in quadrature with the radial velocity changes, and its amplitude rapidly increases with height in stellar atmosphere.

Periodic expansion and compression of turbulent layers in the upper atmospheres of roAp stars. The line profile changes in slowly rotating magnetic pulsators should be interpreted as a superposition of **two types of variability: the usual time-dependent velocity field due to an oblique low-order pulsation mode and an additional linewidth modulation, synchronized with the changes of stellar radius**.

Stellar magnetoacoustic pulsations.

Thank you for

We acknowledge support from the Faculty of the European Space Astronomy Centre (ESAC).