Fluorine in R CrB Stars

Why Fluorine?

- The astrophysical origin of fluorine is an unresolved issue.
- The element has only one stable, yet rather fragile, isotope, 19F.
- In stellar interiors it is readily annihilated 19F(p,α)16O, 19F(α,p)22Ne.
- A mechanism is required that enables F to escape from the hot stellar interior after it is created.

Scenarios proposed as the potential sources of F

- Explosions of Type II supernovae (SNe), by the process referred to as ν(nu)-process, can convert 20Ne into 19F (Woosley & Haxton 1988).
- Stellar winds from Wolf-Rayet (W-R) stars (Meynet & Arnould 2000).
- The third dredge-up of asymptotic giant branch (AGB) stars (Forestini et al. 1992).

- The reaction chain for F production in W-R stars and AGB stars is

  $^{14}N(\alpha,\gamma)^{18}F(\beta+)^{180}(p,\alpha)^{15}N(\alpha,\gamma)^{19}F$, where protons are liberated through $^{13}C(\alpha,n)^{160}$ followed by neutron captures, $^{14}N(n,p)^{14}C$.
- To discriminate between the three possible scenarios of F production accurate measurements of F abundances in these objects are needed.
- R CrB stars (RCB) are suggested to have gone through AGB phase in their earlier evolution, hence, F should be present in their atmospheres.
- Presence of F in RCB's atmosphere can serve as test bed for F production in AGB stars.

Measurements of F abundance

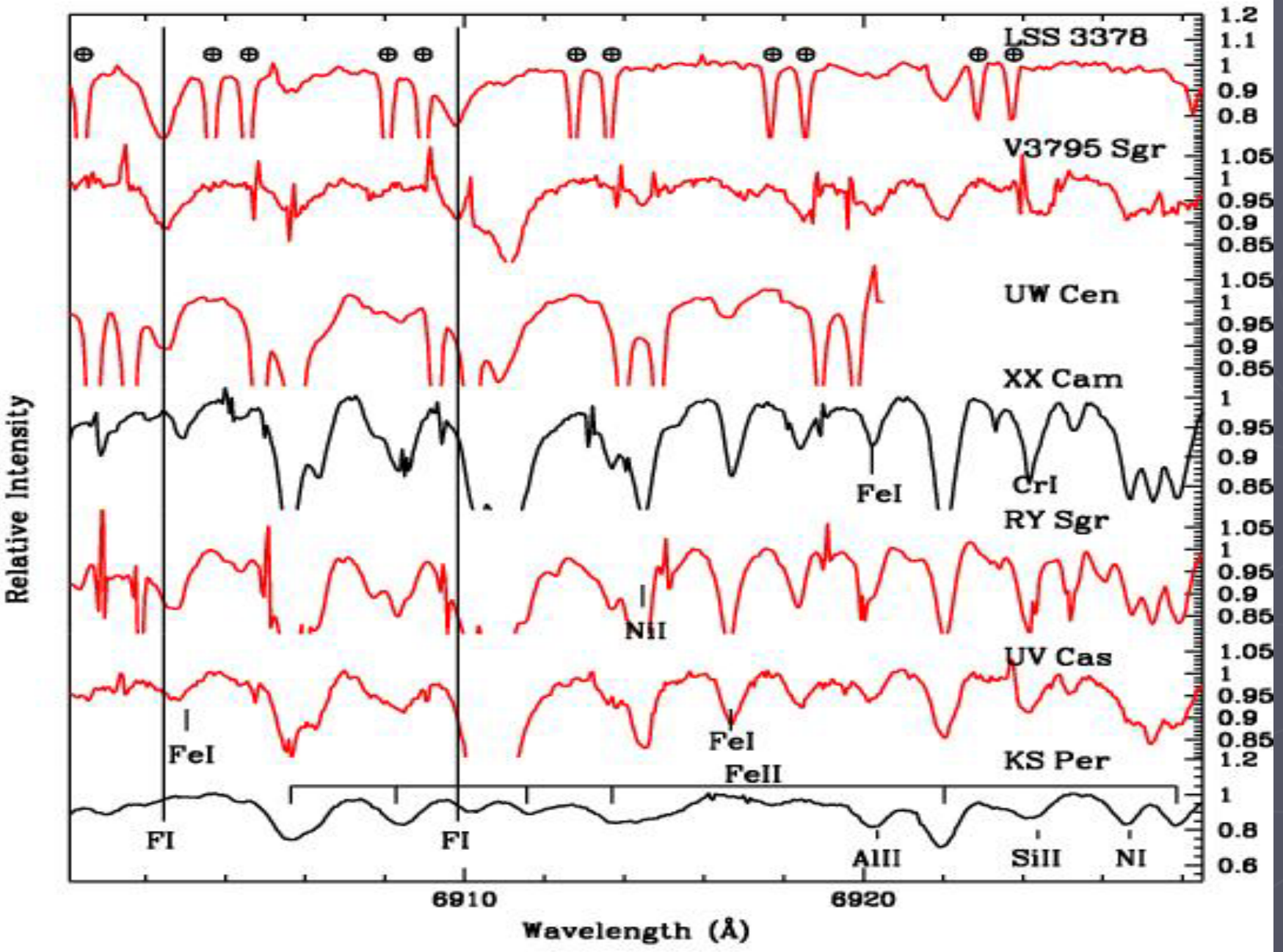
- Hall & Noyes (1969) measured F abundance from their identification of the fundamental vibration-rotation band of HF in sunspot spectra at 2.3μ .
- In red giants by Jorrissen et al. (1992), infrared HF vibration-rotation transition were used. They found enhanced F in C-rich stars, providing evidence of F production in AGB stars.
- Jorrissen et al's results were supported by observations of F V and F VI absorption lines in the far-UV spectra of hot post-AGB stars (Werner et al. 2005).

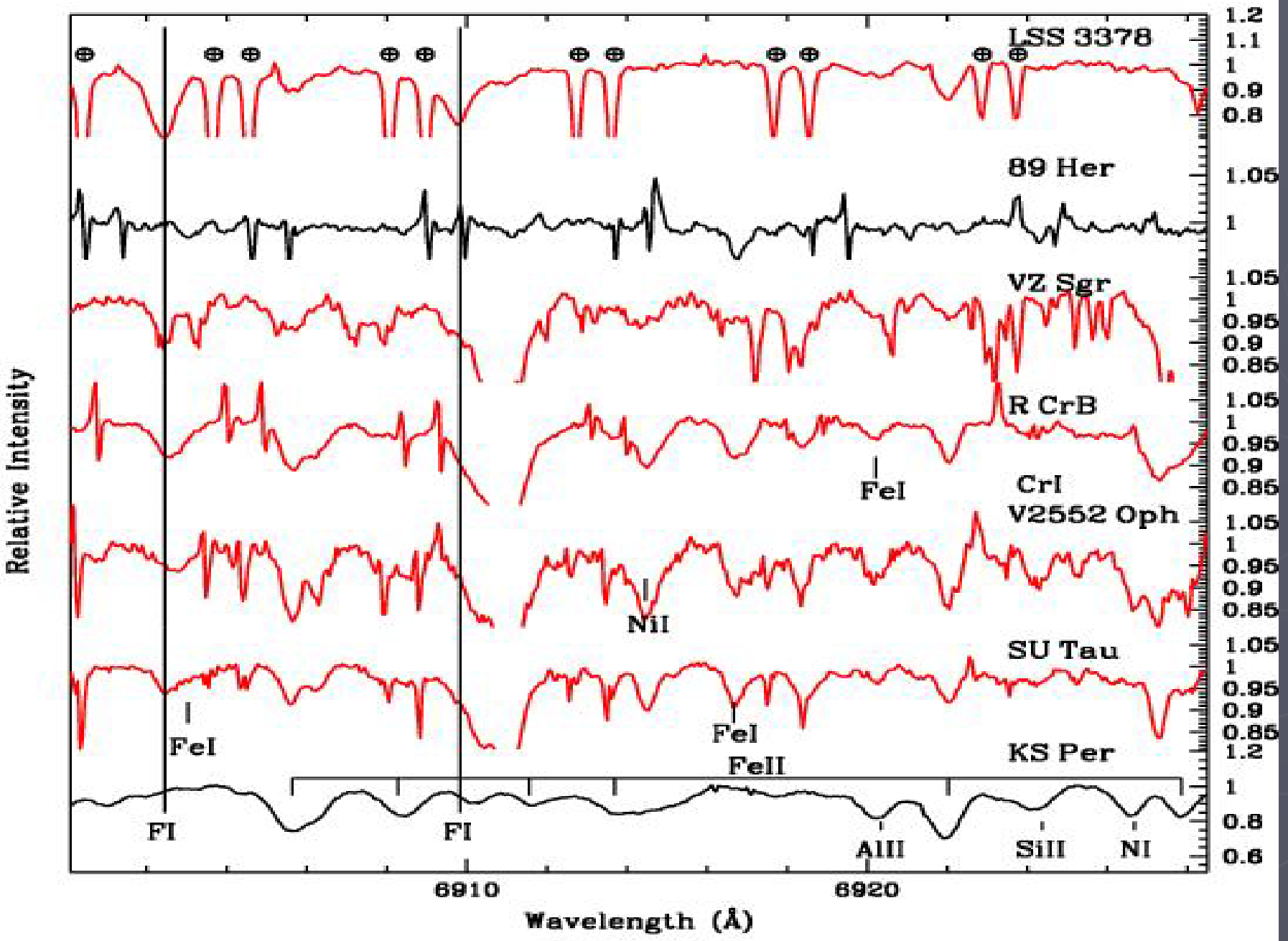
- F I λ955 interstellar absorption in two sight lines towards the Cep OB2 association using Far Ultraviolet Spectroscopic Explorer (Federman et al. 2005). No evidence of enhanced F resulting from the ν(nu)-process in Type II SNe.
- Zhang & Liu (2005) determine F abundances from the [F II] λ4789 and [F IV] λ4060 nebular emission lines for a sample of PNe. F is abundant in PNe – evidence of F synthesis in AGB stars.
- Pandey (2006) determine F overabundances in EHes from neutral fluorine lines - evidence of nucleosynthesis.

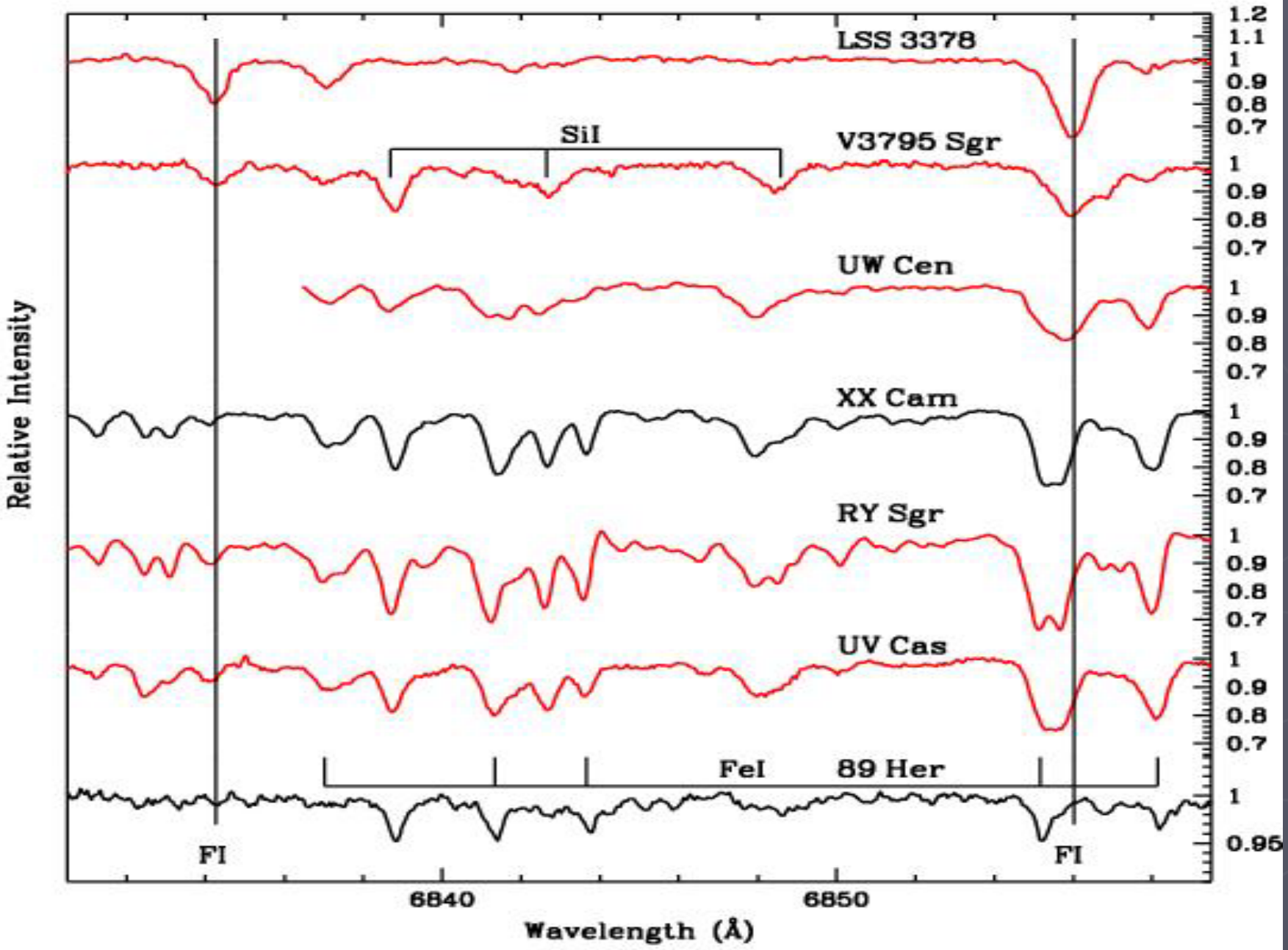
Searching For F I lines in RCBs

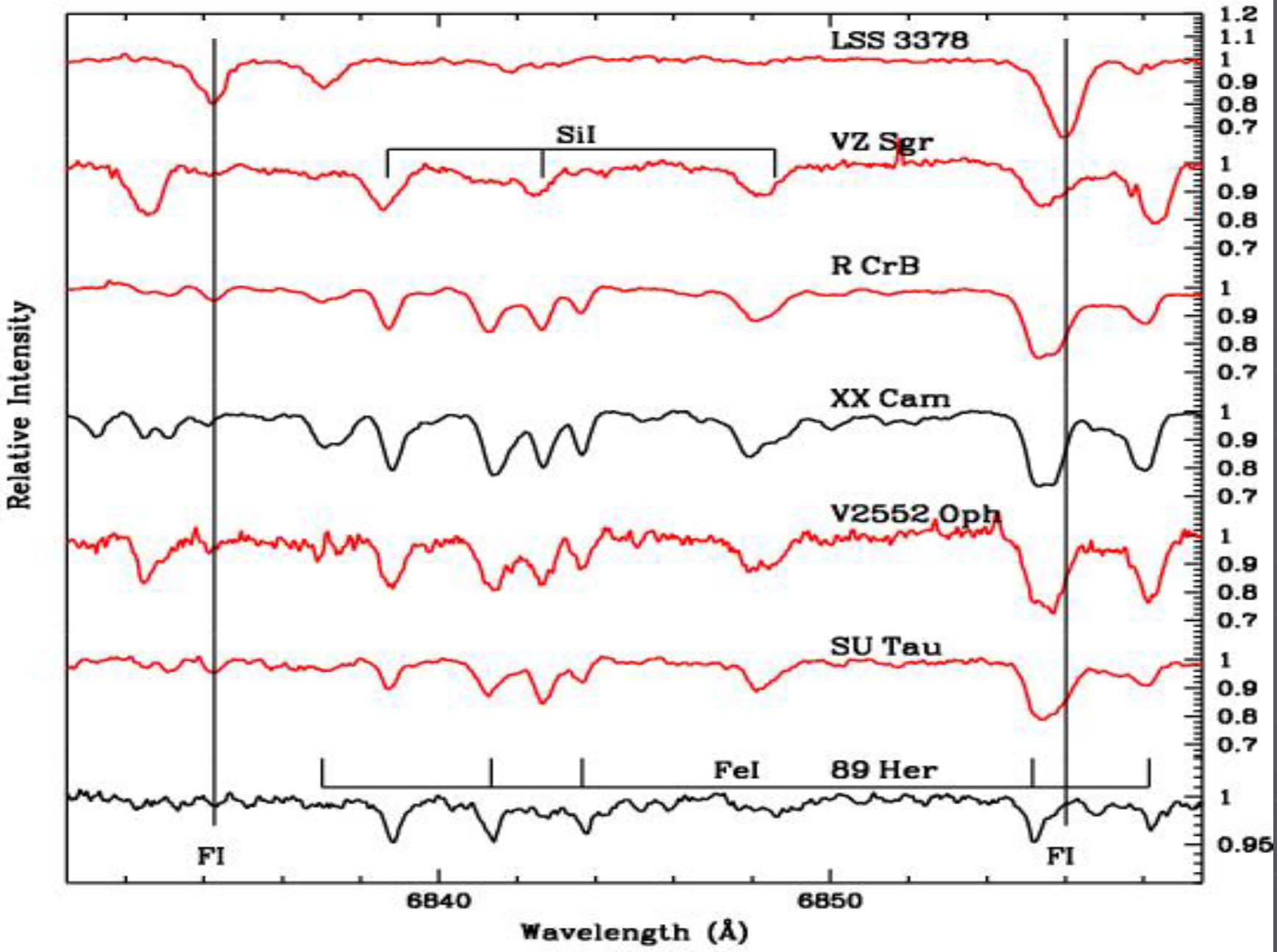
F I lines from 3s - 3p transition array detected in the spectra of the analysed stars. The F I lines used in abundance determination for all the analysed stars are shown in bold

RMT	λ (Å)	χ (eV)	log gf	Contributors
1	**7482.72**	12.73	−0.66	F I, C I λ7483.445Å (red wing), Fe II λ7482.777Å (weak)
	7514.93	12.75	−0.96	F I
	7331.95	12.70	−0.11	F I, Fe II λ7332.115Å
	7425.64	12.73	−0.19	F I, Fe II λ7425.095Å
	7552.24	12.73	−0.34	F I
	7573.41	12.75	−0.34	F I
2	**6856.02**	12.70	+0.44	F I, Fe II λ6855.646Å
	6902.46	12.73	+0.18	F I
	6909.82	12.75	−0.23	F I
	6773.97	12.70	−0.40	F I, Fe II λ6774.473Å (red wing)
	6834.26	12.73	−0.21	F I
	6795.52	12.73	−1.09	F I
4	**7754.70**	12.98	+0.24	F I, Ti II λ7755.751Å (red wing)
	7800.22	13.03	+0.04	F I, Si I λ7799.996Å (weak), Fe II λ7801.235Å (red wing)
6	**7037.45**	12.98	+0.10	F I
	7127.88	13.03	−0.12	F I
	6966.35	12.98	−1.01	F I
	7202.37	13.03	−0.33	F I, C I λ7202.267Å


LSS 3378
V3795 Sgr
UW Cen
XX Cam
RY Sgr
UV Cas
KS Per
Relative Intensity
FeI
CrI
NII
FeI
FeI
FeII
FI
FI
AlII
SiII
NI
6910
6920
Wavelength (Å)


LSS 3378
89 Her
VZ Sgr
R CrB
FeI
CrI
V2552 Oph
NiI
SU Tau
FeI
FeI
FeII
KS Per
FI
FI
AlII
SiII
NI
6910
6920
Wavelength (Å)
Relative Intensity


LSS 3378
SiI
V3795 Sgr
UW Cen
XX Cam
RY Sgr
UV Cas
FeI
89 Her
FI
FI
Relative Intensity
Wavelength (Å)
6840
6850
1.2
1.1
1
0.9
0.8
0.7
0.95


LSS 3378
SiI
VZ Sgr
R CrB
XX Cam
V2552 Oph
SU Tau
FeI
89 Her
FI
FI
Relative Intensity
Wavelength (Å)
6840
6850
1.2
1.1
1
0.9
0.8
0.7
0.95

Detection of F lines in RCBs implies enhanced F – synthesis of fluorine

V3795 Sgr	positive detection	McD
UW Cen	do	VBT
XX Cam	negative	VBT
RY Sgr	positive	VBT
UV Cas	do	McD
VZ Sgr	do	McD
R CrB	do	VBT
V2552 Oph	do	McD
SU Tau	do	VBT

Exploring RCB – EHe connection

- 19F is synthesized and then dredged upto the surface during the He-burning thermal pulses.
- 19F abundances can in principle be used to probe the neutron source , since 19F(α,p)22Ne did not destroy 19F.
- The rate for 19F(α,p)22Ne is about 20 times faster than 22Ne(α,n)25Mg in the $T_8 = 2.0 - 3.5$K temperature range, 19F cannot survive in layers where neutrons are being liberated by 22Ne(α,n)25Mg.
- Hence 22Ne(α,n)25Mg is not the source of neutrons, instead, 13C(α,n)16O is the neutron source.

THANK YOU