NLTE analysis of spectra I: Departures from LTE for A-type stars

Inga Kamp

- Why A-type stars
- Carbon, Nitrogen, Oxygen, …
- Astrophysical results

Why A-type stars ?

- A type stars are excellent physics laboratories

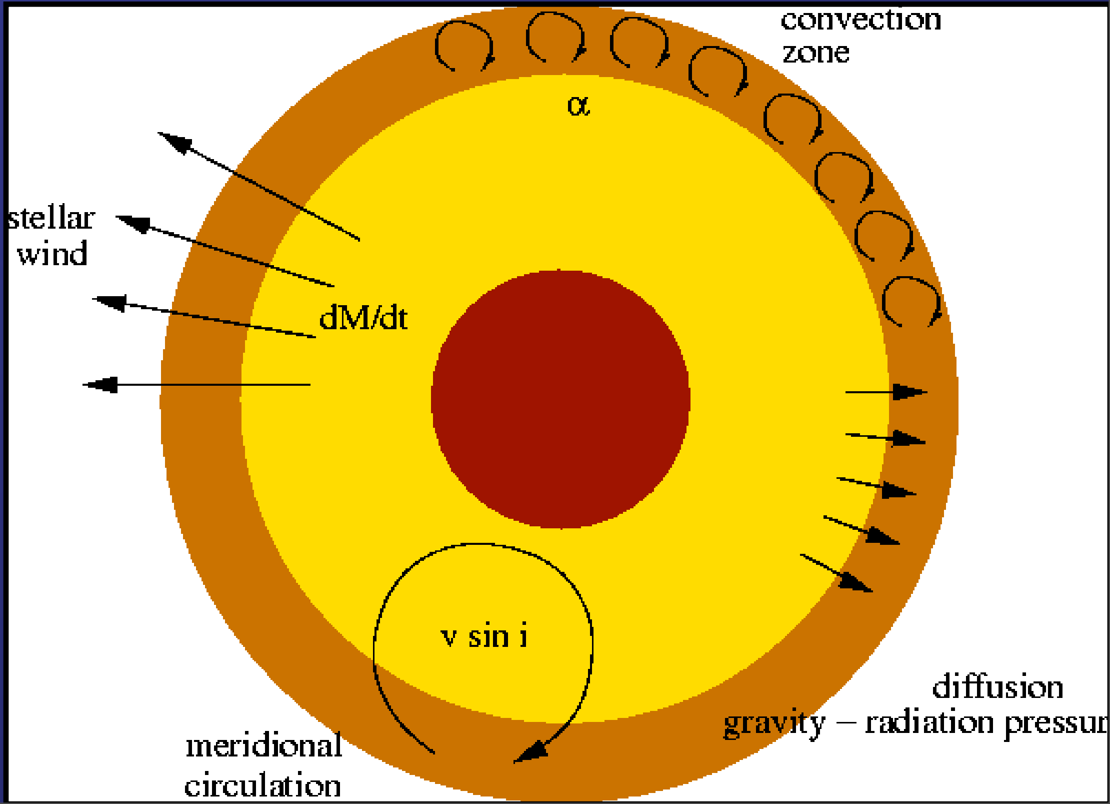
no (or weak) stellar winds to compete with diffusion

$v_{diffusion}$ <~ 1 cm/s

shallow convection zones

$M_{convection} \sim 10^{-8} M_{star}$

$v_{convection} \ll 1$ km/s



[e.g. Landstreet 2004]

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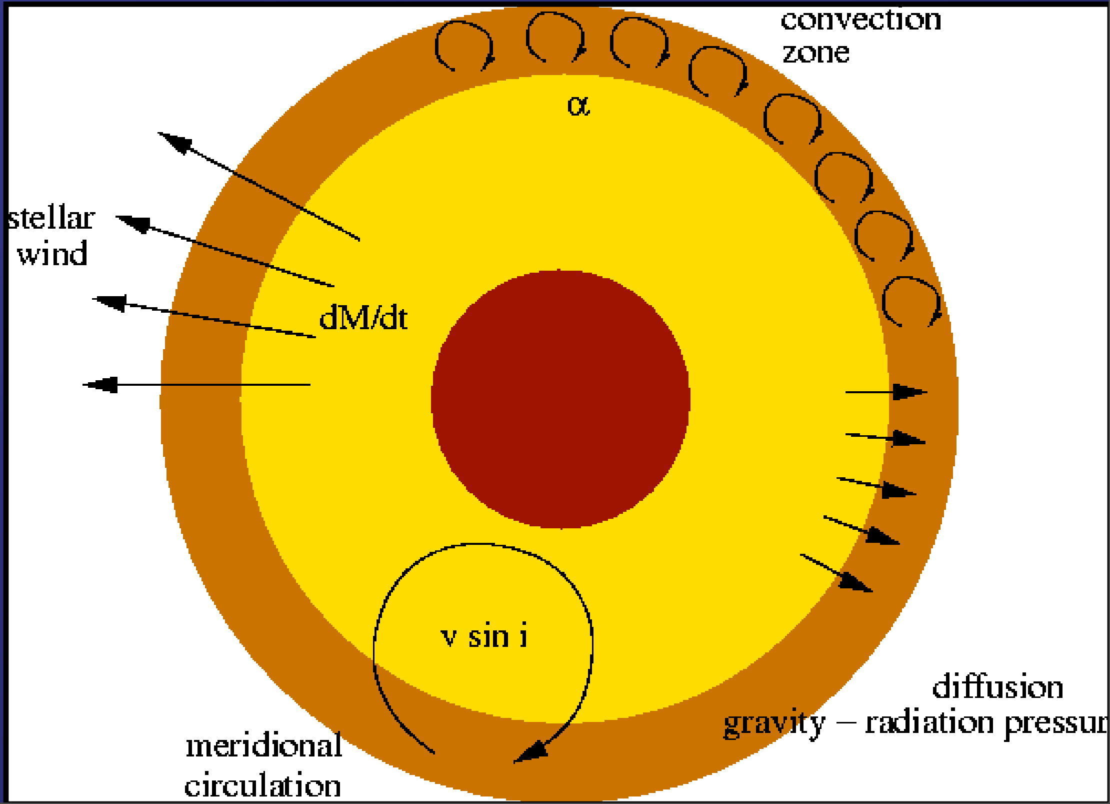
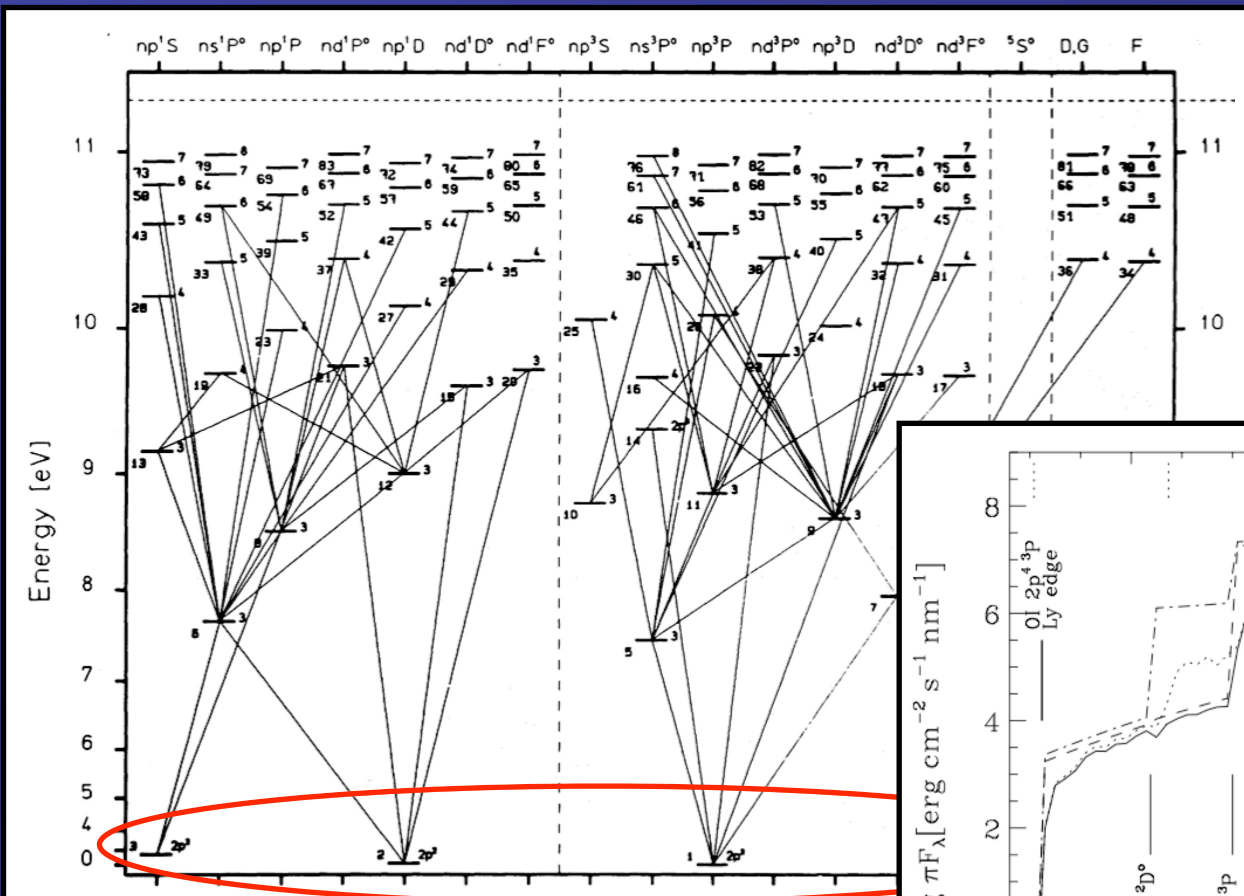


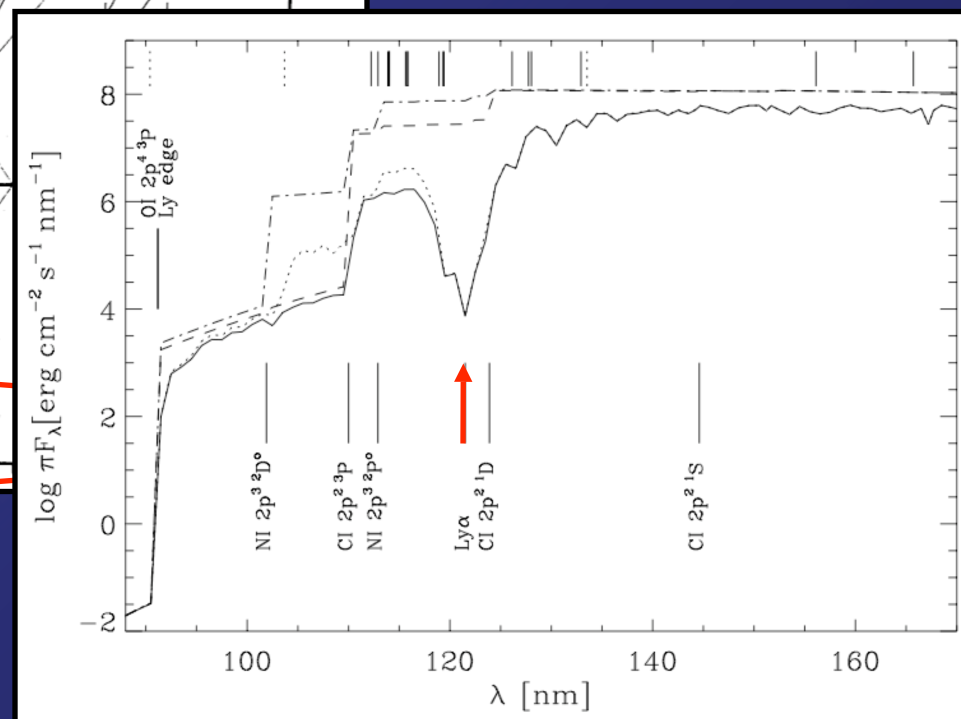
Model atoms published with Kiel code

• HeI	Lemke (1989)
• LiI	Steenbock & Holweger (1984)
• CI/II	Stürenburg & Holweger (1990)
• NI/NII	Rentzsch-Holm (1996)
• OI	Paunzen et al. (2003), Hempel & Holweger (2003)
• SiI/II	Wedemeyer (2001)
• AlI	Steenbock & Holweger (1992)
• BaII	Lemke (1990)
• CaI/II	Watanabe & Steenbock (1985)
• MgI	Lemke & Holweger (1987)
• FeI/II	Steenbock (1985), Gigas (1986)
• NeI	Graf (2002) -> Hempel & Holweger (2003)

Carbon

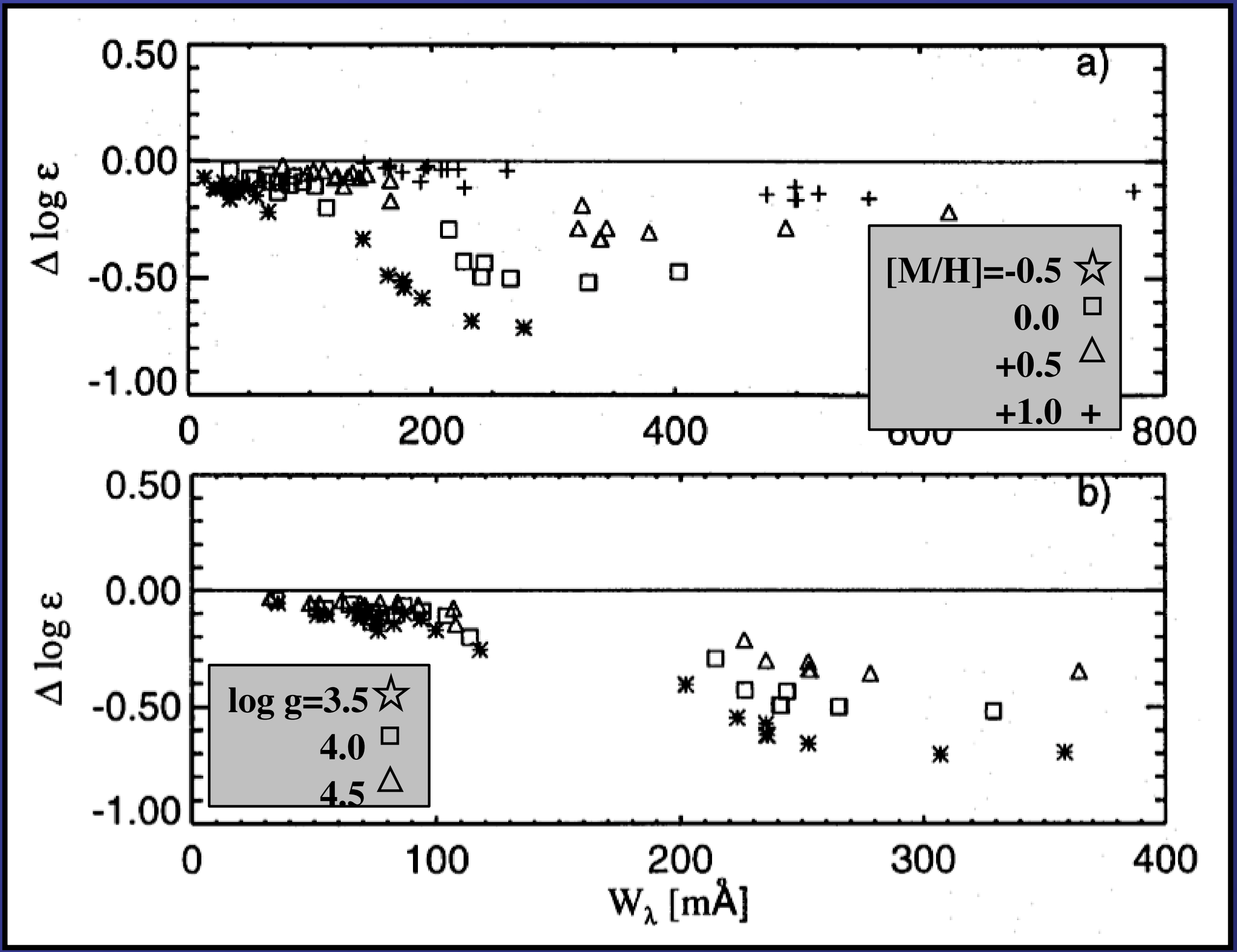


- Large depopulation of lowest four levels through photo-ionization



[Stürenburg & Holweger 1990;
Przybilla, Butler, Kudritzki 2001]

Carbon



- Large non-LTE corrections of -0.75 dex

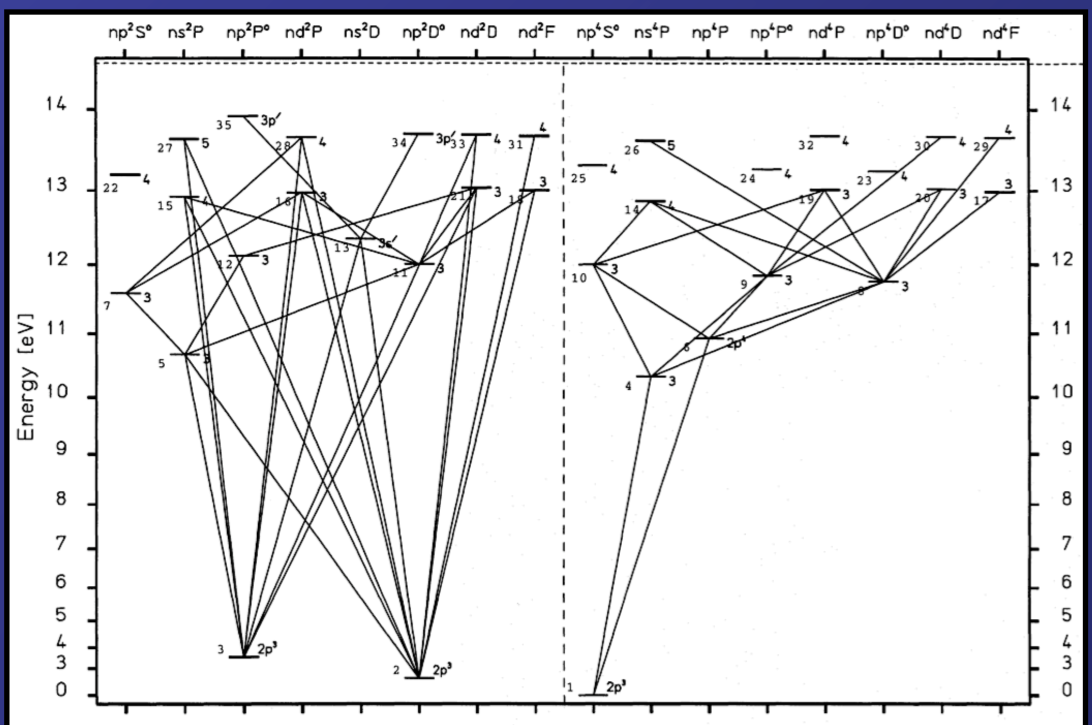
  at low metallicity
  &
  at low gravity

- Weak lines have smaller corrections

[Rentzsch-Holm 1997; Fabbian et al. 2007]

Nitrogen

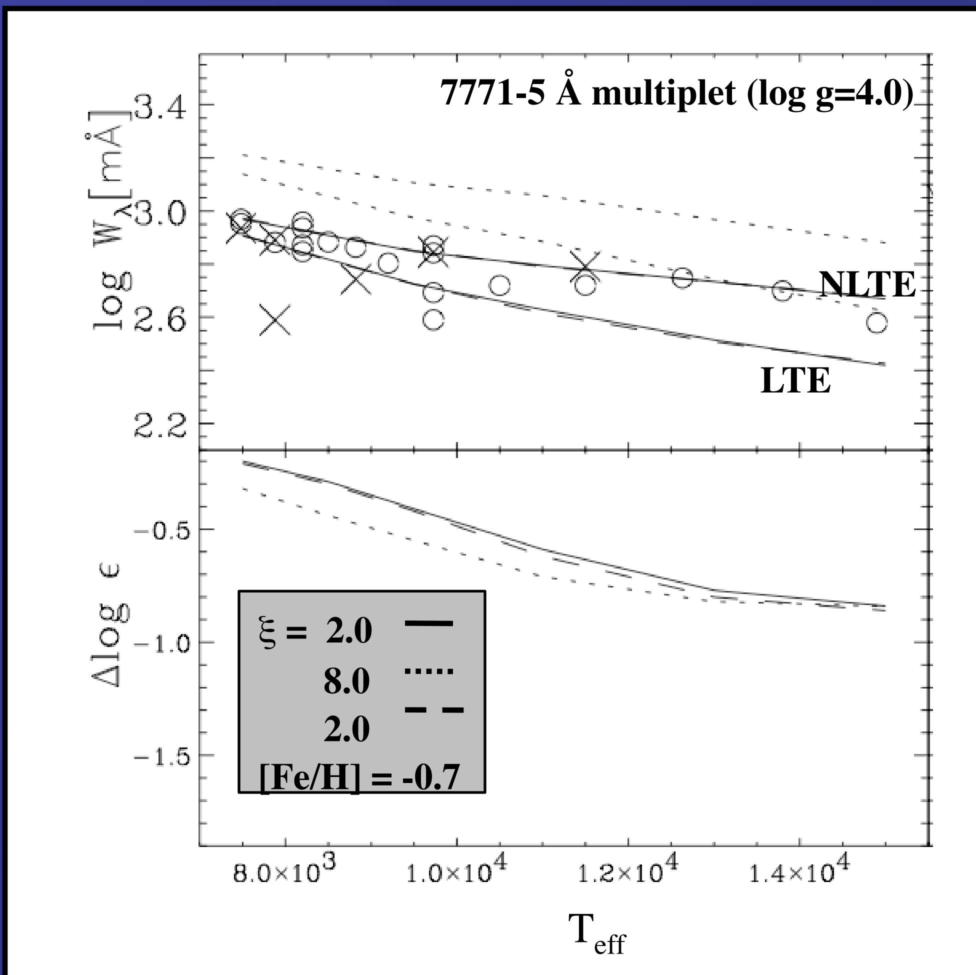
- NLTE abundance corrections grow with increasing T_{eff}
  diminish with increasing log g
- Strong impact of carbon abundance through UV bf continua
- Ground state strongly coupled to lowest two doublet levels

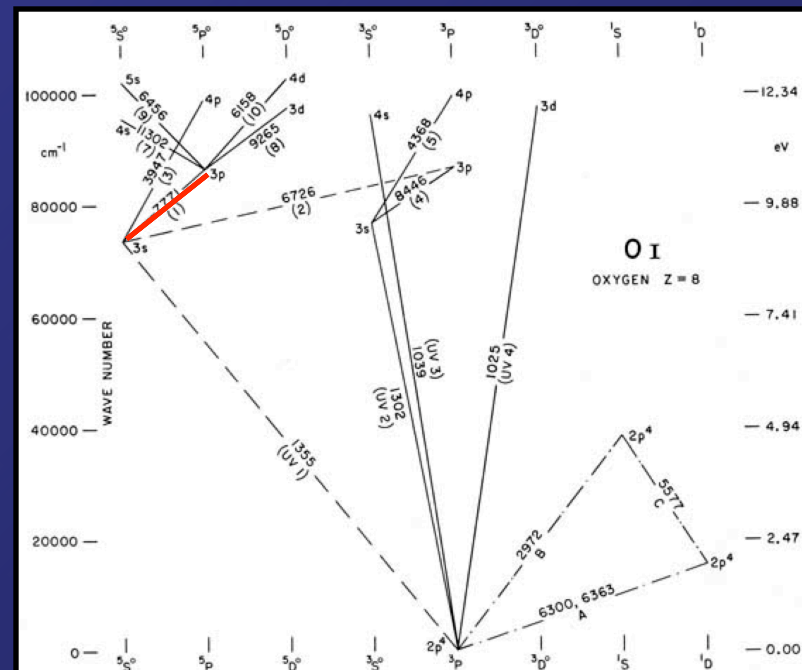


[Rentzsch-Holm 1997,
Przybilla & Butler 2001]

Oxygen

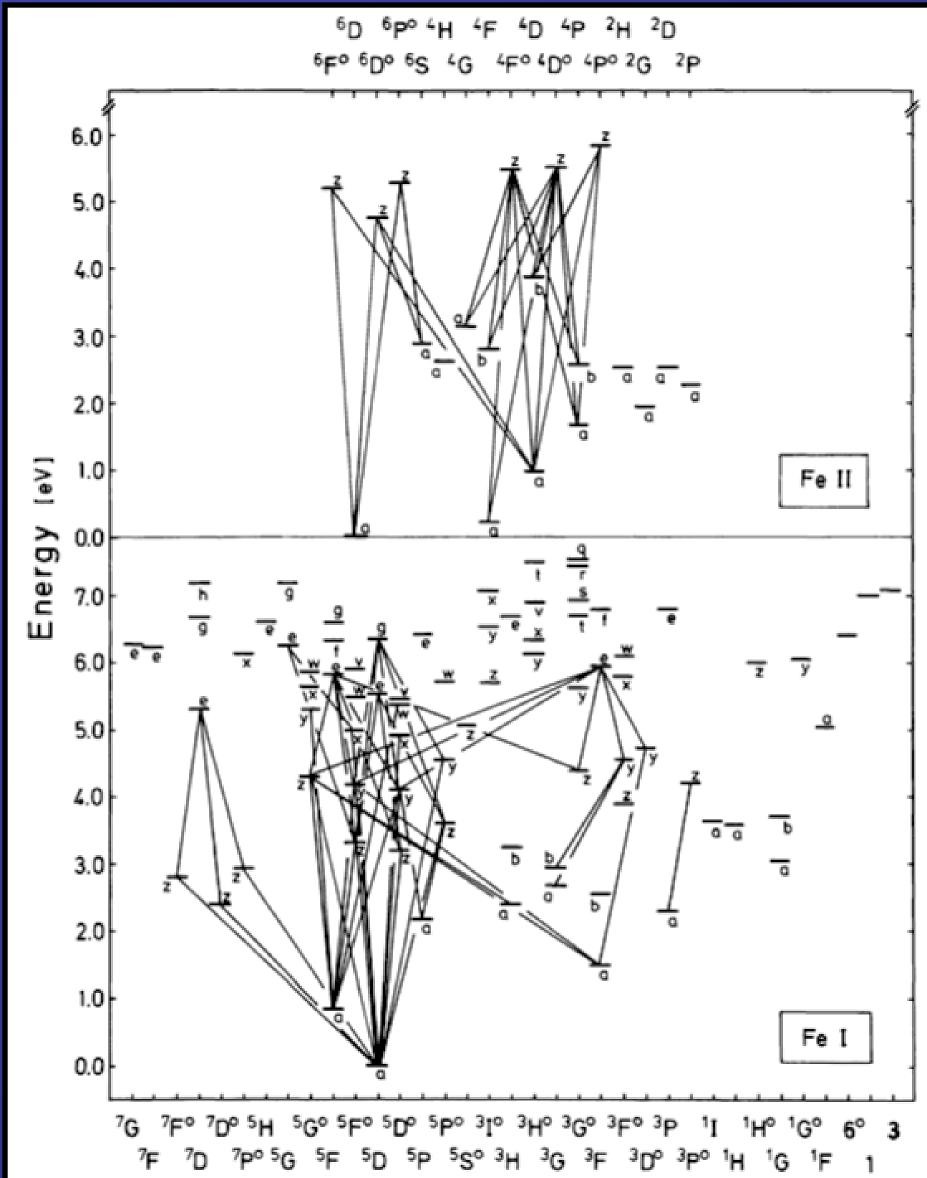
- Non-LTE abundance corrections typically ~ -0.5 dex





[Paunzen et al. 1999; Przybilla et al. 2000]

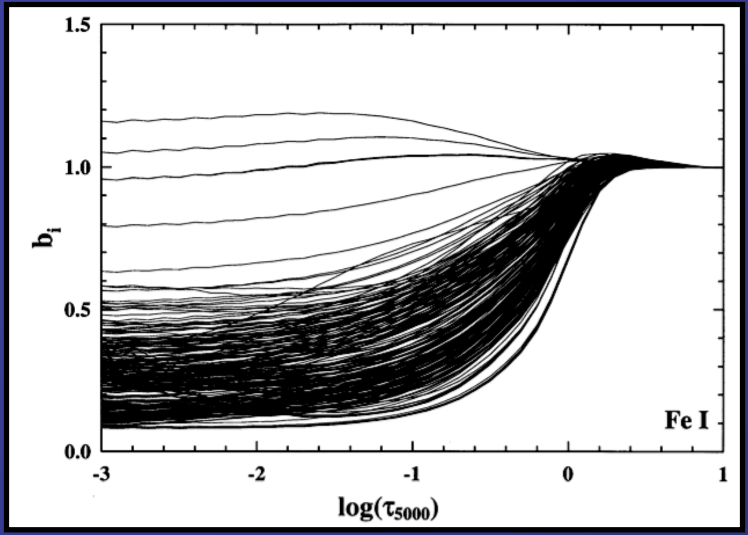
Iron



- Fe I non-LTE corrections ~ +0.2 … 0.3 dex
- Fe I overionized with respect to LTE
- Fe II generally in LTE except strong UV lines

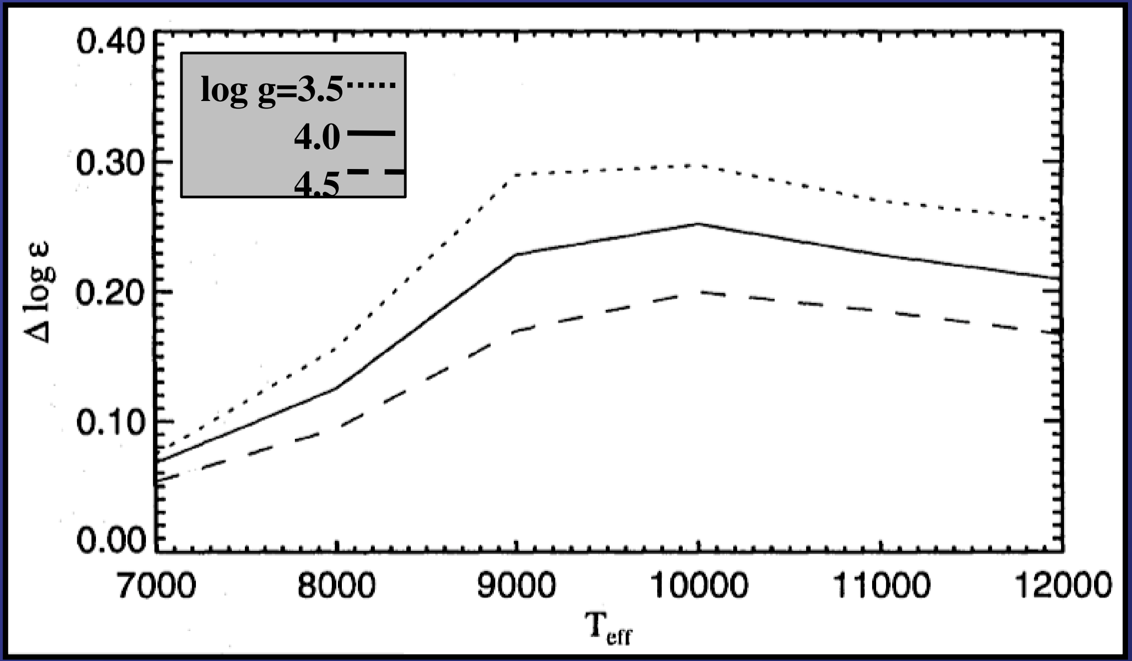
[Gigas 1986; Rentzsch-Holm 1996]

Iron



- overionization of FeI indicated by strong underpopulation for all levels

[Thevenin & Idiart 1999]



- average FeI non-LTE correction peak for A-type stars

[Rentzsch-Holm 1996]

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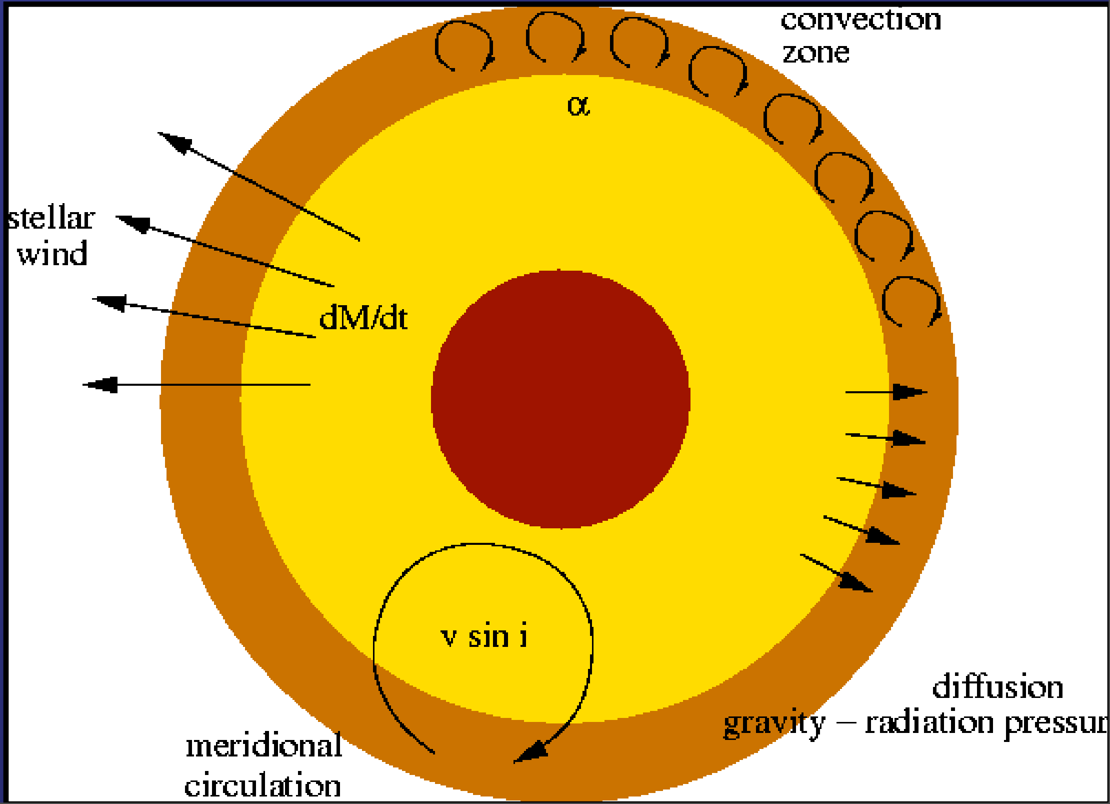
$v_{convection} << 1$ km/s



[e.g. Landstreet 2004]

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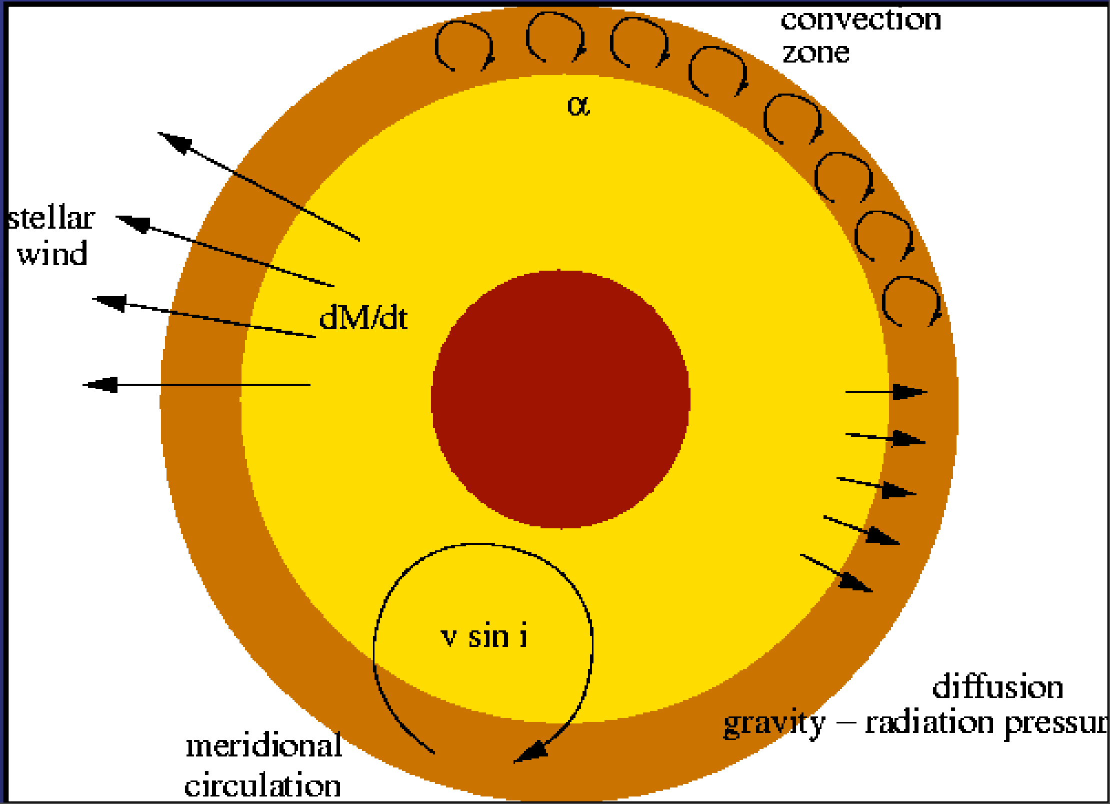

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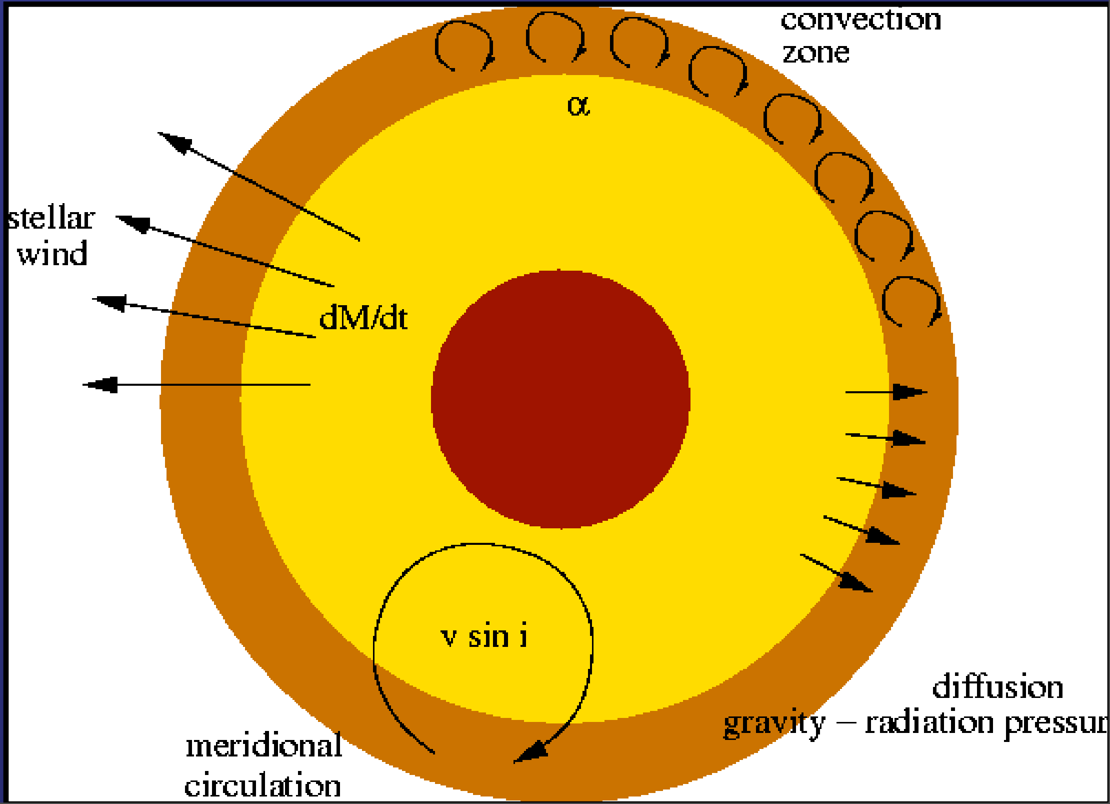
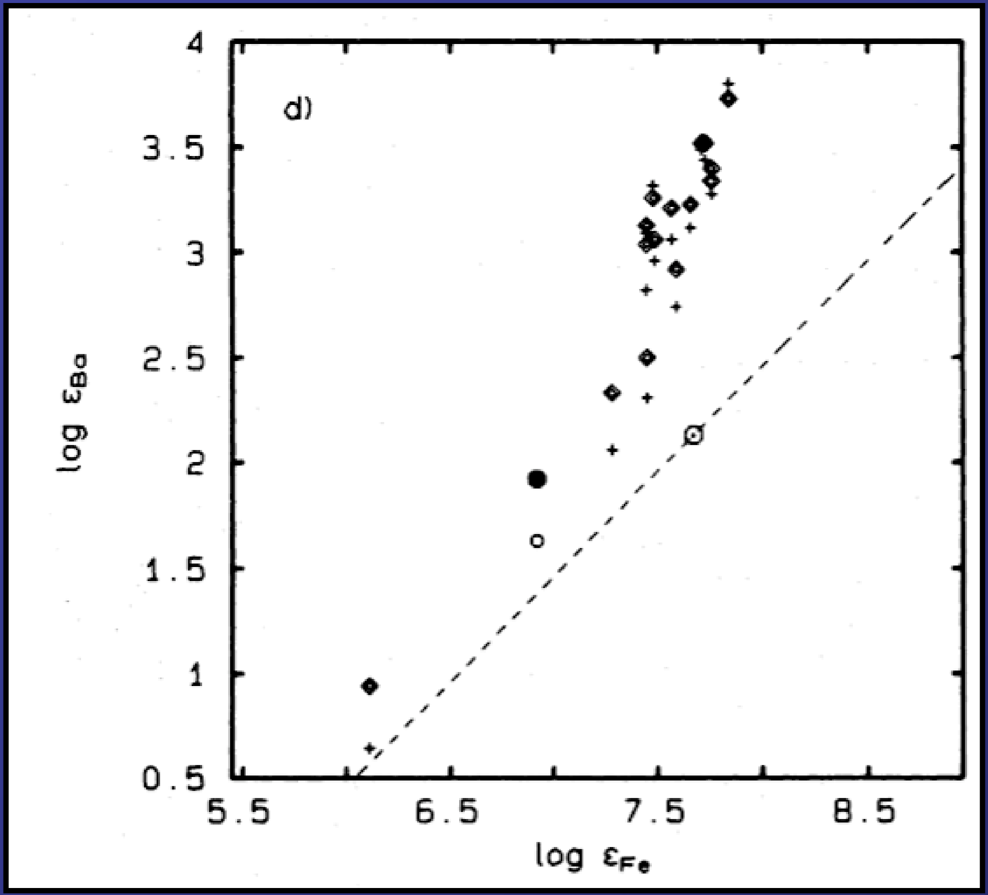


Diffusion pattern in A-type stars



[Lemke 1990]

- Sr and Ba increase strongly for [Fe/H] > 0

Ü evidence for selective radiative and gravitational forces in metal-rich stars

[papers by e.g. Michaud, Charbonneau]

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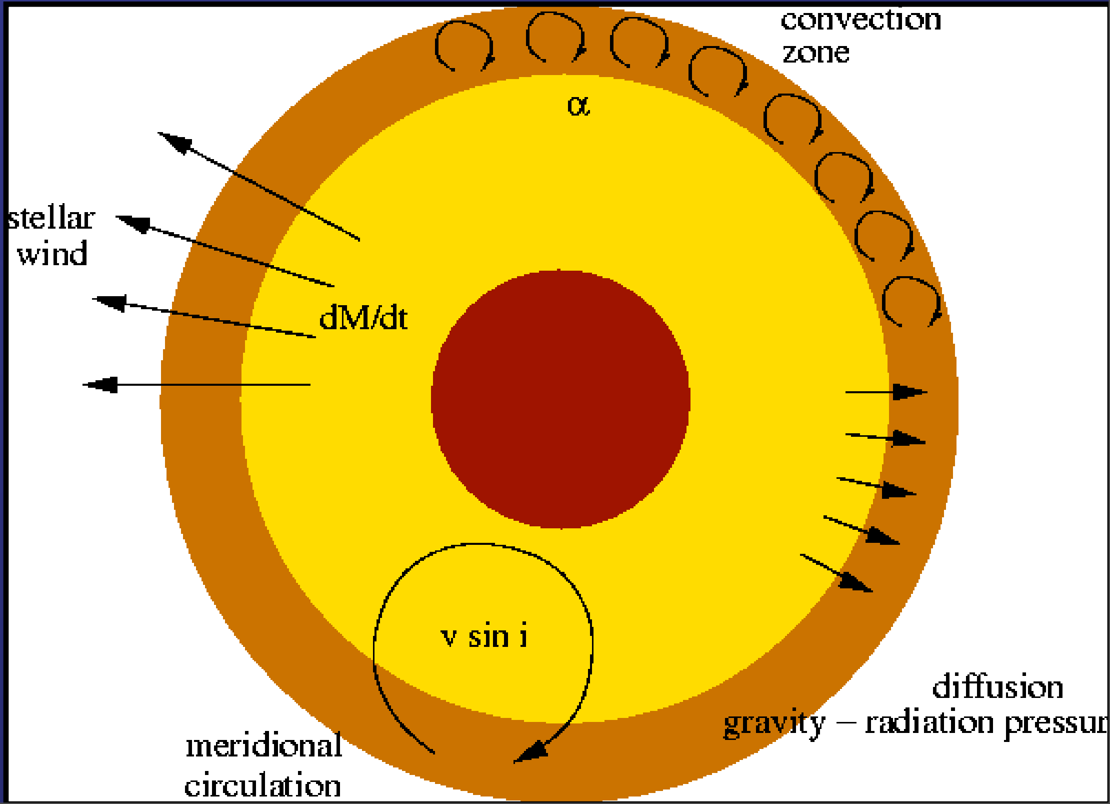
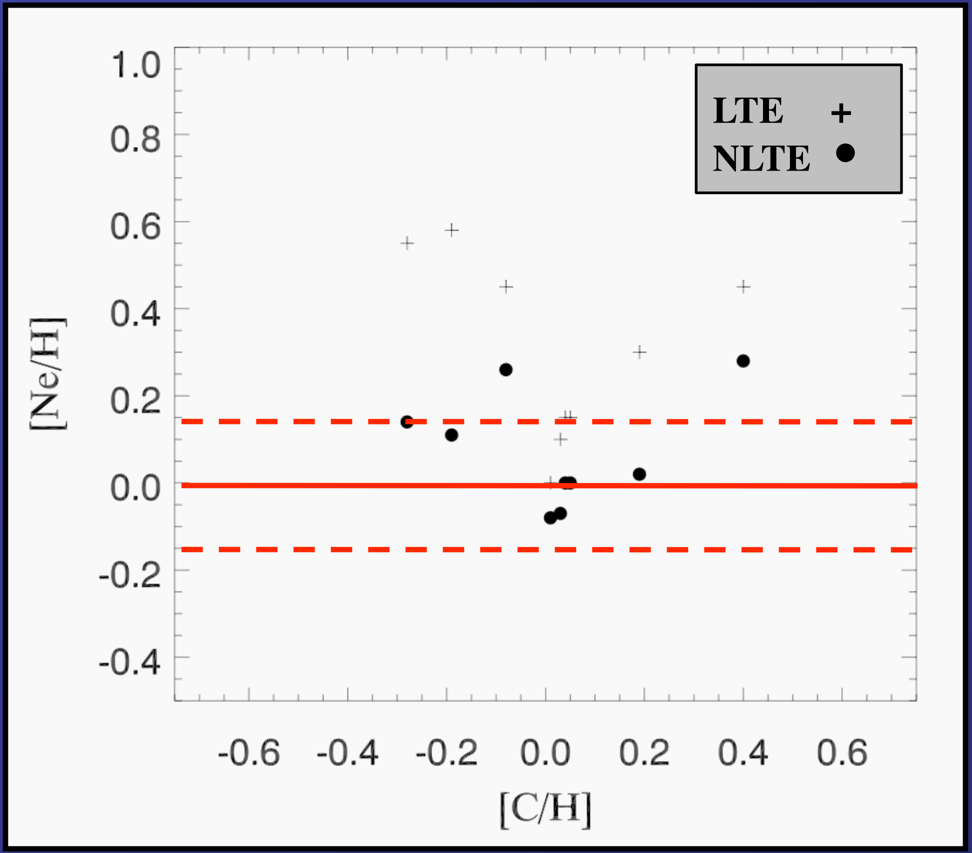


Weak stellar winds in late B-type stars



[Hempel & Holweger 2003]

- Strong Ne overabundances are expected in the presence of weak winds
- non-LTE brings the Ne abundances down to solar values

Ü wind mass loss rates are below 10^{-14} M_{sun}/yr

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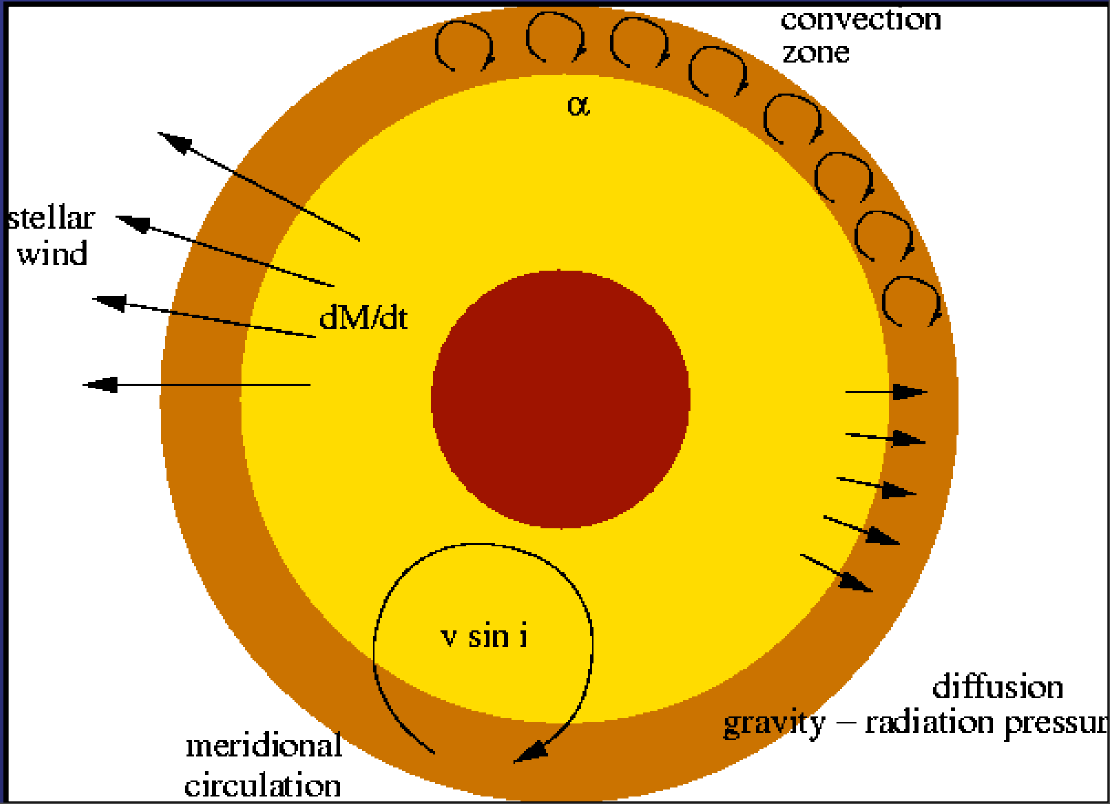
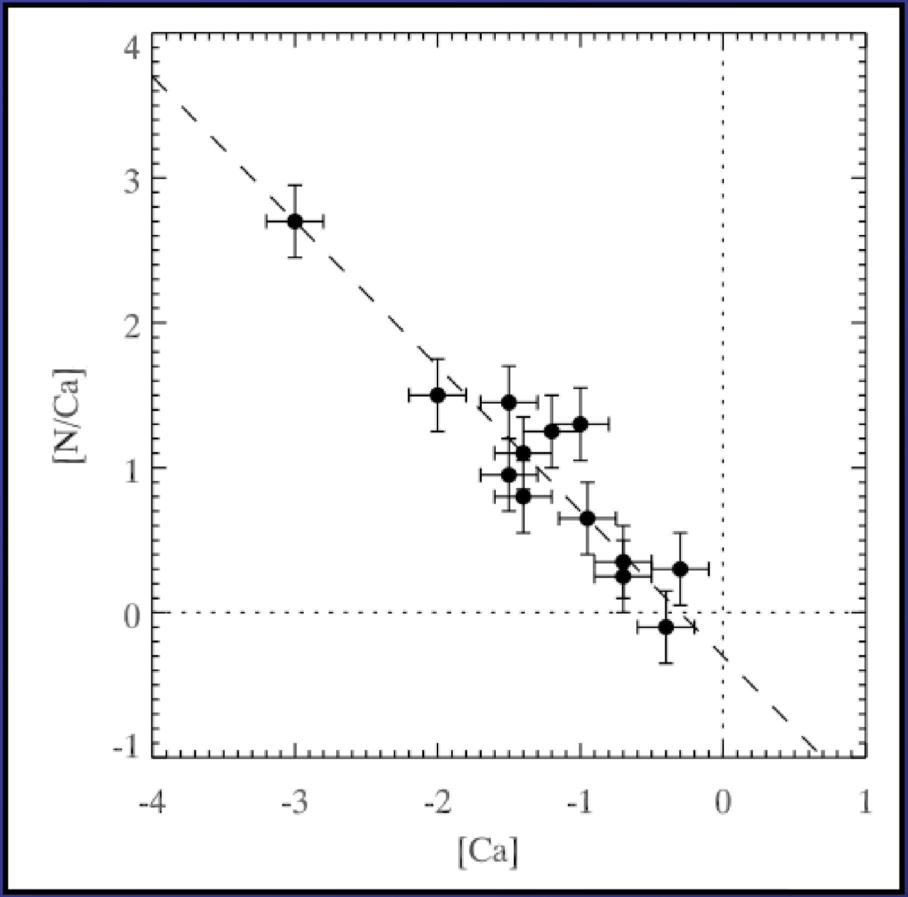
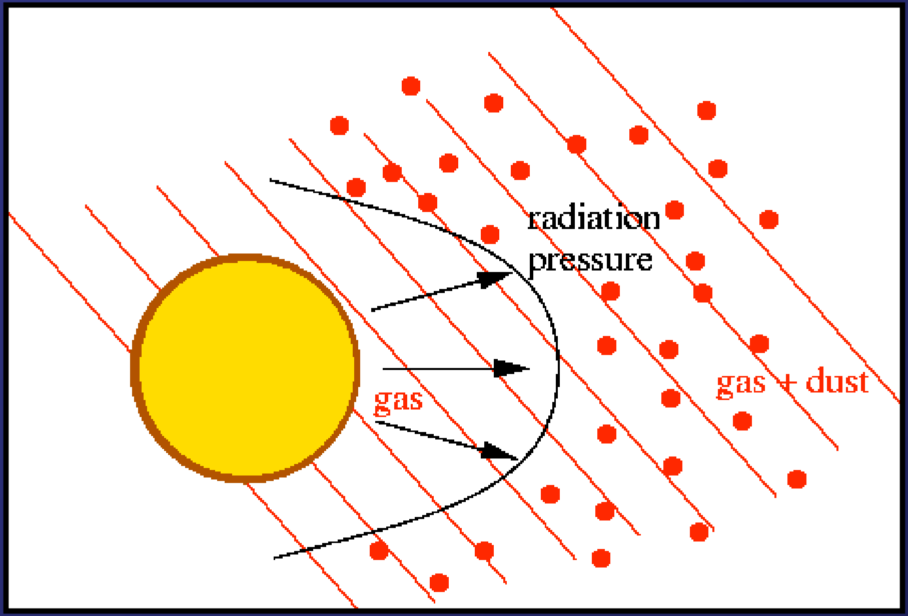


Accretion pattern in A-type stars



[Paunzen et al. 1999, Kamp et al. 2001, Kamp & Paunzen 2002]

- λ Bootis stars are F/A-type stars with strong metal underabundances and solar abundances of light elements



Summary

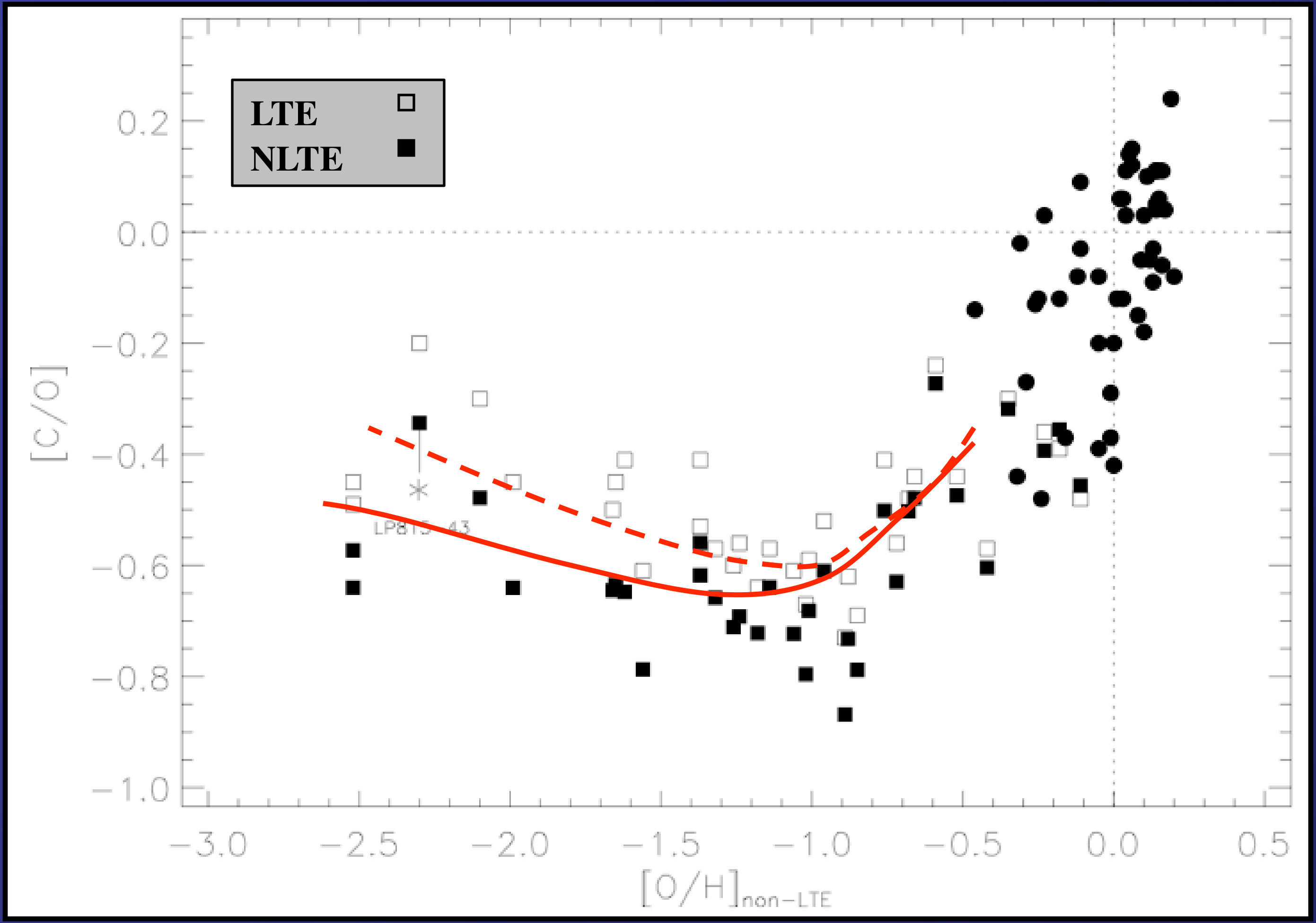
- NLTE effects in A-type stars can be important

  Ü check your favorite atoms/lines !

- A-type stars are excellent physics laboratories IF accurate abundances are known

  Ü need for NLTE calculations

Chemical evolution of our galaxy



- Evidence for enrichment by zero-metallicity Pop III stars

[Akerman et al. 2004, Fabbian et al. 2006]

Sulphur

Line	$\log \varepsilon_{\rm NLTE}$	$T_{\rm eff}$ (K)				
Å		8000	9000	10000	11000	12000
S I (6)8693.98 } S I (6)8694.70 }	7.71	(182.1, −0.19)	(105.0, −0.18)	(41.0, −0.09)	(16.8, −0.05)	(10.2, −0.05)
	7.21	(106.2, −0.12)	(51.6, −0.15)	(15.6, −0.09)	(5.5, −0.03)	(3.3, −0.04)
	6.71	(49.5, −0.09)	(21.6, −0.17)	(5.3, −0.09)	(1.8, −0.02)	(1.0, −0.05)
	6.21	(19.5, −0.09)	(8.1, −0.21)	(1.7, −0.08)	(0.56, −0.01)	(0.34, −0.04)

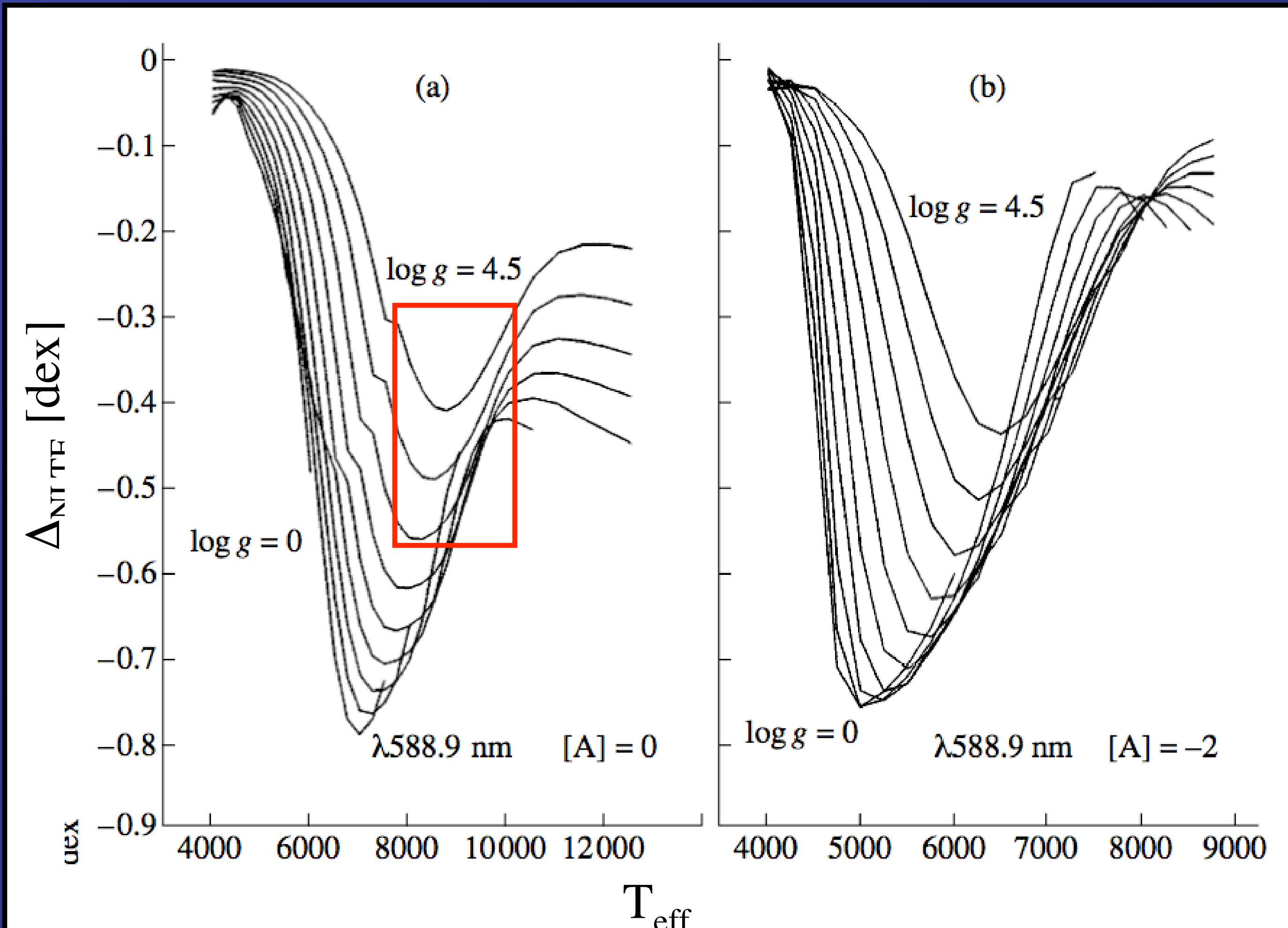
Note: Two values given in the parentheses are ($W_{\rm NLTE}$, $\Delta \log \varepsilon$), where $W_{\rm NLTE}$ is the theoretical NLTE W_λ in mÅ calculated for each $\log \varepsilon_{\rm NLTE}$, and $\Delta \log \varepsilon$ is the NLTE correction.

[Takada-Hidai & Takeda 1996]

- Near-IR lines show small negative abundance corrections ~ -0.1 … -0.2 dex

Sodium

- F/A-type stars have typical corrections of ~ -0.3 … -0.6 dex for the NaD doublet



[Mashonkina, Shimanskii, Sakhibullin 2000]