Workshop "Heavy elements nucleosynthesis and galactic chemical evolution"
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Testing spectroscopic methods of stellar parameters determination for cool stars.

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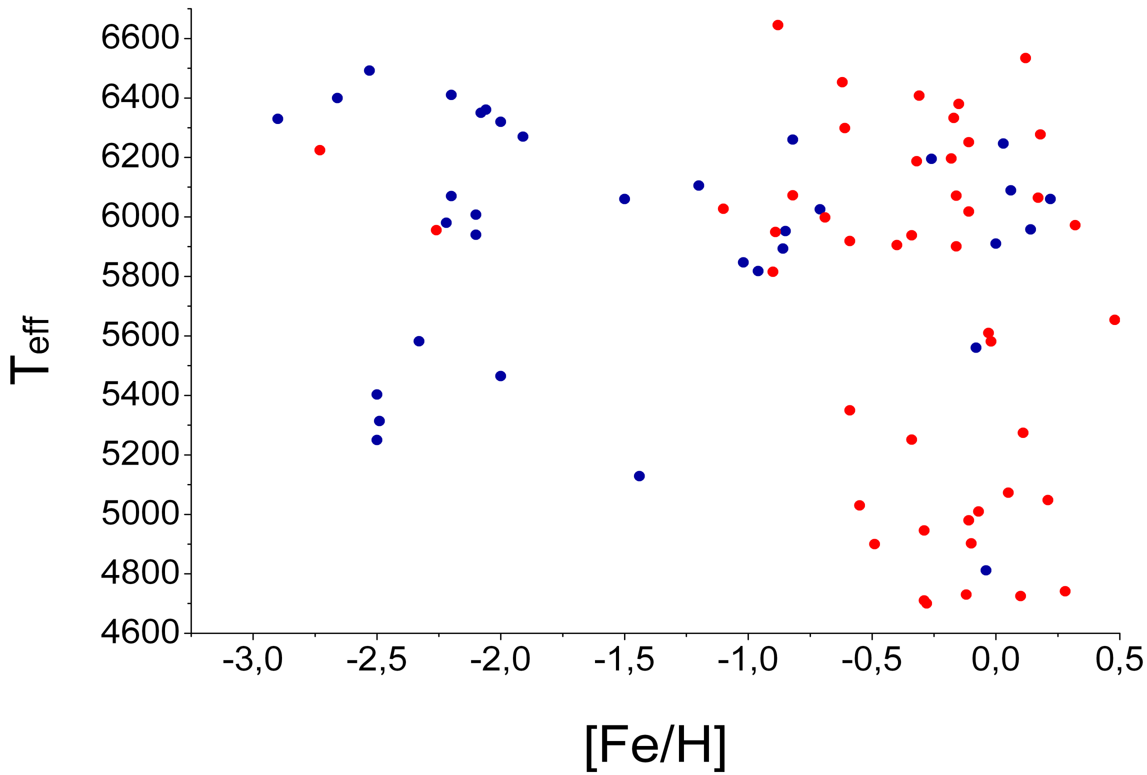
A systematic study of NLTE abundance of nearby dwarfs

80 stars, -3 < [Fe/H] < 0.5
Observations: Lick 3.0m/Hamilton (R~40 000, S/N~200)



Aims:
- ♦ Accurate determination of stellar parameters
- ♦ Abundances for elements from Sr to Eu (NLTE)

● stars with reliable Teff, log g

Testing spectroscopic method of log g, [Fe/H], V_{mic} determination using 12 stars with well determined parameters

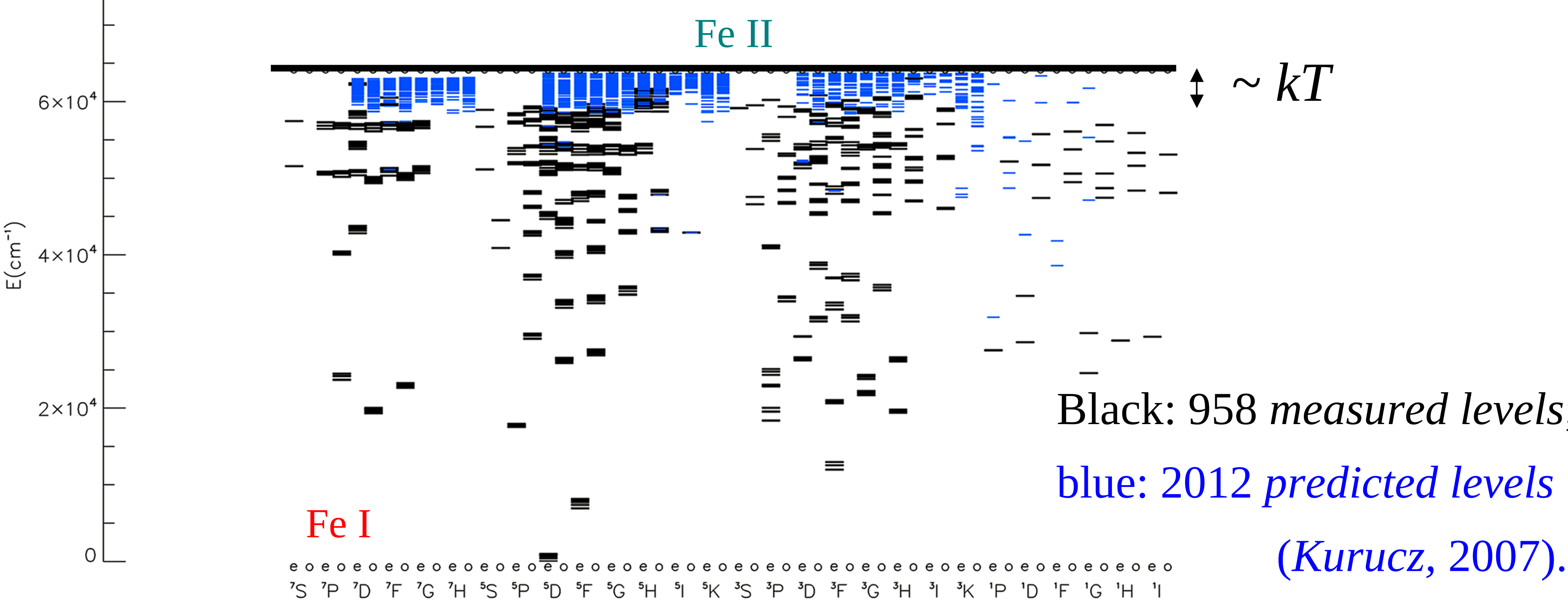
NLTE +
reliable list of iron lines

Input	Output ?
Reliable parameters from literature	Determined parameters
T_{eff} (IR flux method), $\sigma \approx 100$ K	is fixed. Check excitation equilibrium of Fe I. Abundances must not depend on E_{exc}.
log g (Hipparcos), $0.03 \le \sigma \le 0.2$ dex	Check ionization equilibrium Fe I, Fe II. Average abundances from Fe I and Fe II lines must coincide.
V_{mic}, $\sigma \approx 0.1$ km/s	Log ε_{Fe} vs. EW. Abundances must not depend on the line EW.
[Fe/H] = log ε_{Fe} star - log ε_{Fe} sun, $\sigma \approx 0.1$ dex	Simultaneously with log g and V_{mic}

The treated method will be applied to the remaining stars of the sample

Comprehensive model atom for Fe I — Fe II

was produced and tested with cool stars by Mashonkina et al. 2011

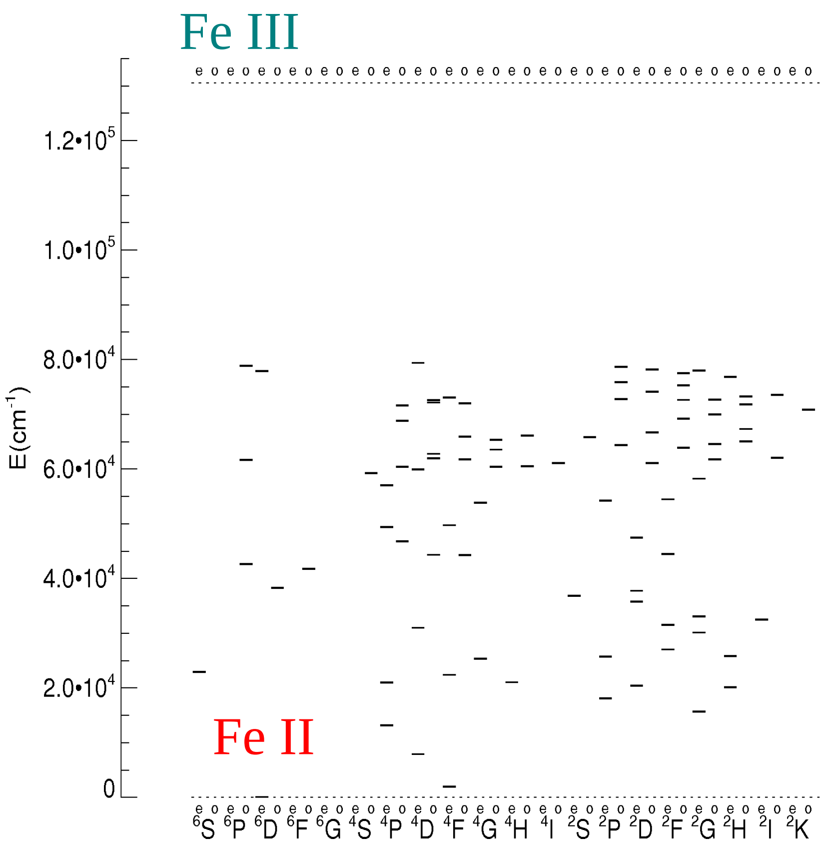


Term structure of Fe I below the ionization limit

Fe I is minority species, n(Fe I)/n(Fe) << 1

- low-excitation levels are subject to UV overionization,
- high-excitation levels provide collisional coupling to Fe II.

Fe II is majority species, n(Fe II) ≈ n(Fe)



Fe II terms below10 eV.

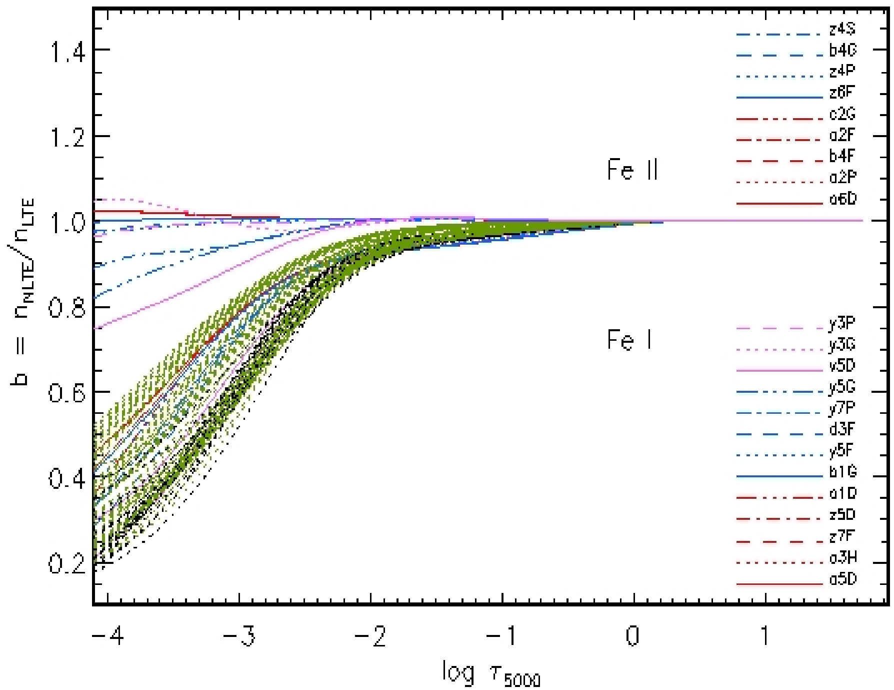
Fe I: 233 terms
+ 6 super-levels,
11958 *b*-*b* transitions,

Fe II: 89 levels ($E_{exc} \leq 10$ eV),
1523 *b*-*b* transitions,

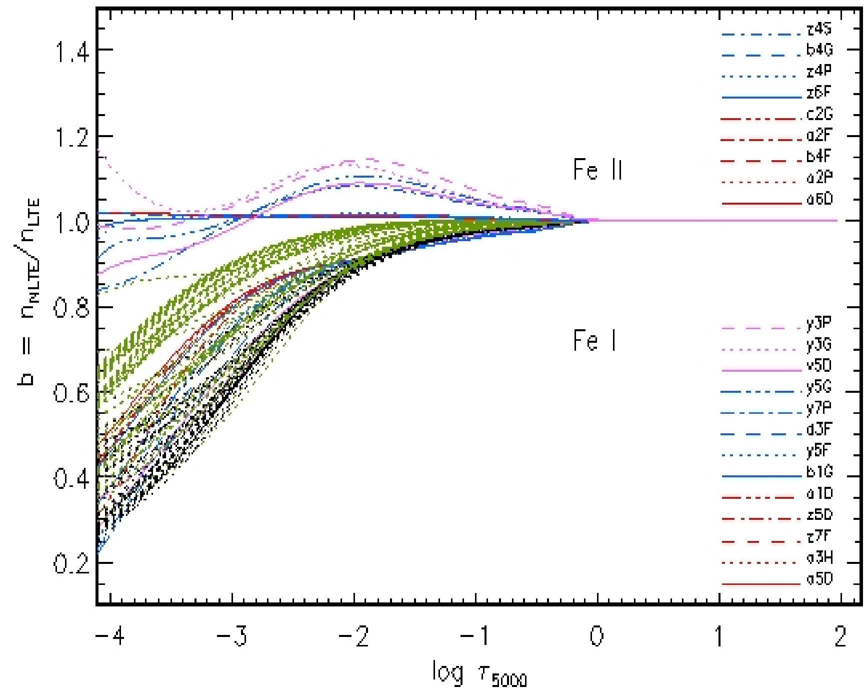
Fe III: the ground state.

Departure coefficients for Fe I and Fe II levels

5960/4.10/ 0.14



5280/4.51/ -2.0



Δ_{NLTE} = NLTE - LTE abundance

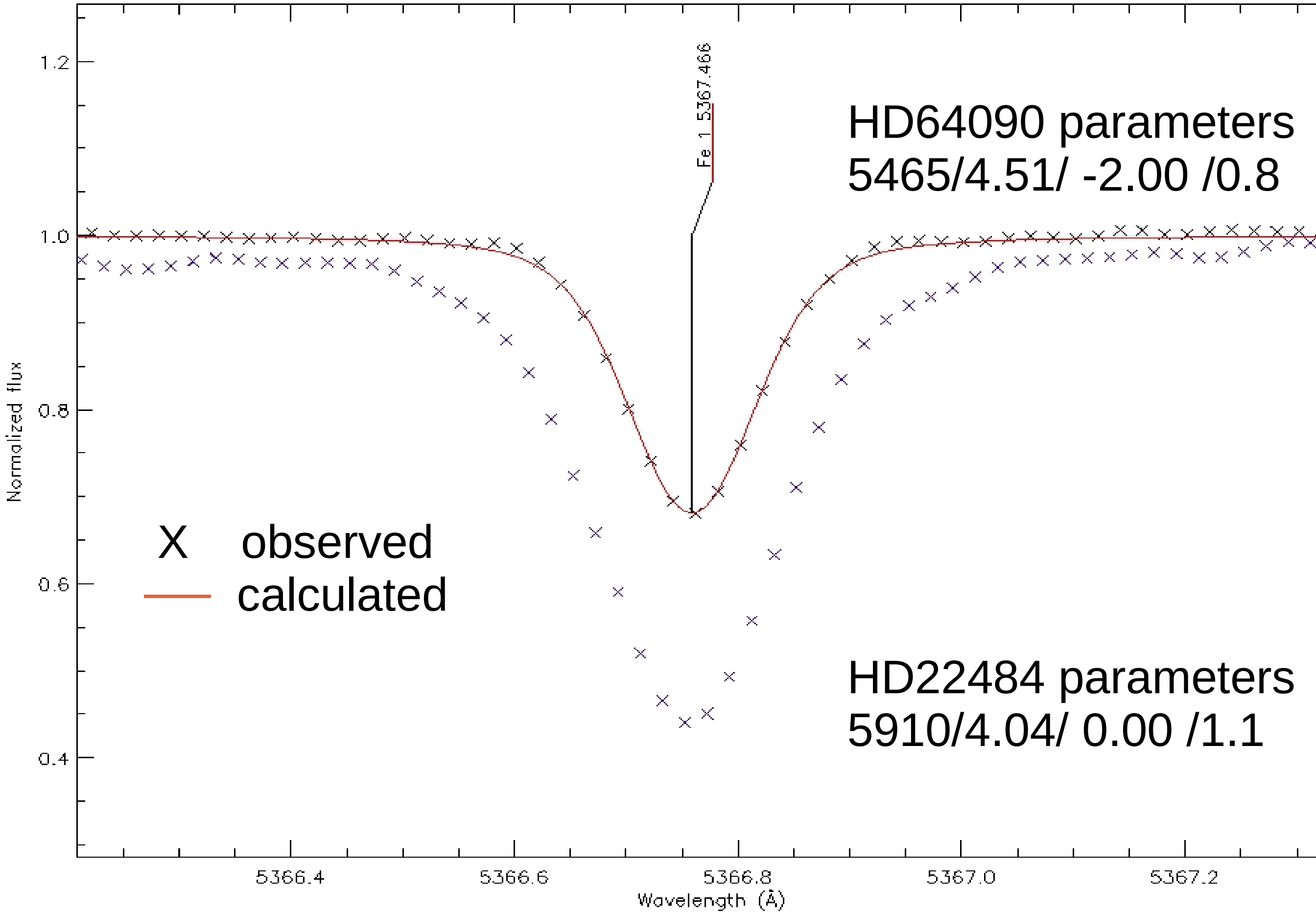
Fe I : NLTE leads to weaker lines, $\Delta_{NLTE} > 0, \leq 0.25$ dex
Fe II : deviations from LTE are negligible

NLTE level populations from DETAIL (Butler, 1985)

Synthetic spectra calculation

MARCS atmosphere models (Gustafsson et. al., 2008)

- synthV_NLTE (V. Tsymbal, private communication)
- binmag3 (O. Kochukhov, private communication)



Selected lines

N(Fe I) = 32
N(Fe II) = 28

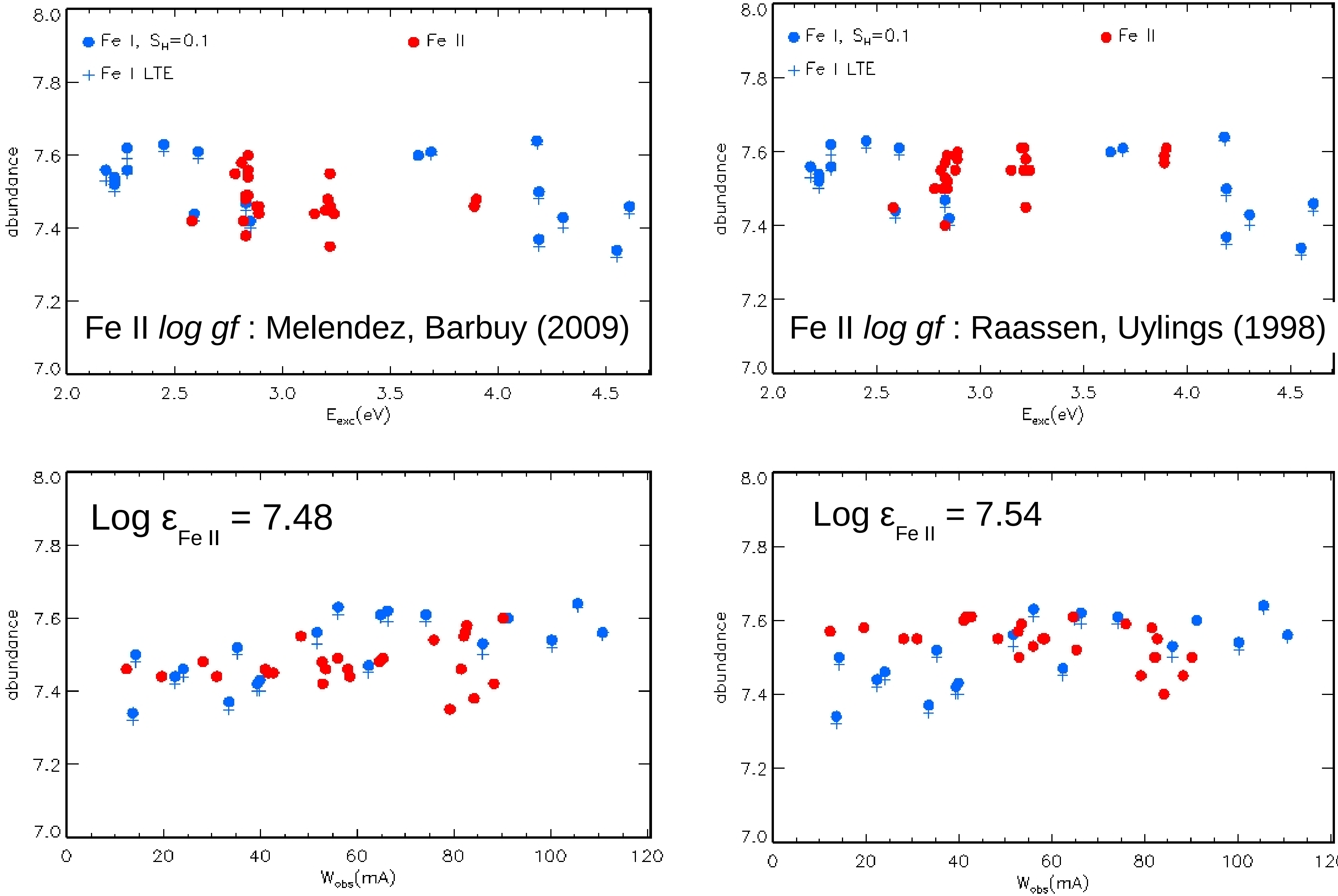
EW < 160 mÅ
(saturated lines are not sensitive to abundance changing),

E_{exc} > 2 eV
(to avoid possible 3D effects)

For metal poor stars

N(Fe I) ≥ 15
N(Fe II) ≥ 7

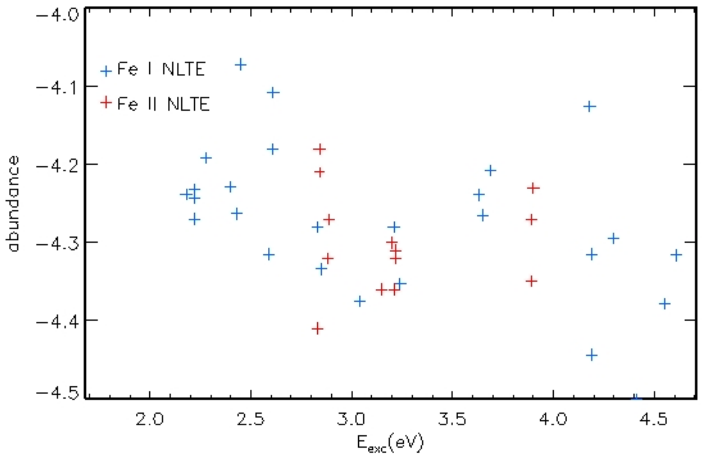
Sun 5780/4.44/ 0.00 /0.9

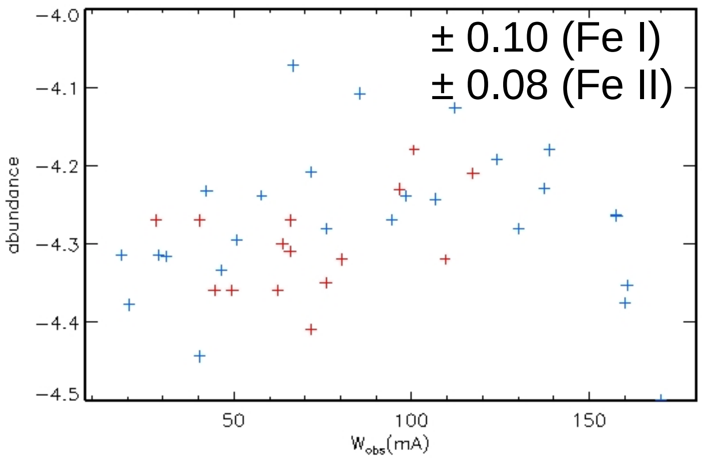


Fe II : two sets of oscillator strengths → 0.06 dex in abundance difference → 0.10 uncertainty in log g → Differential method

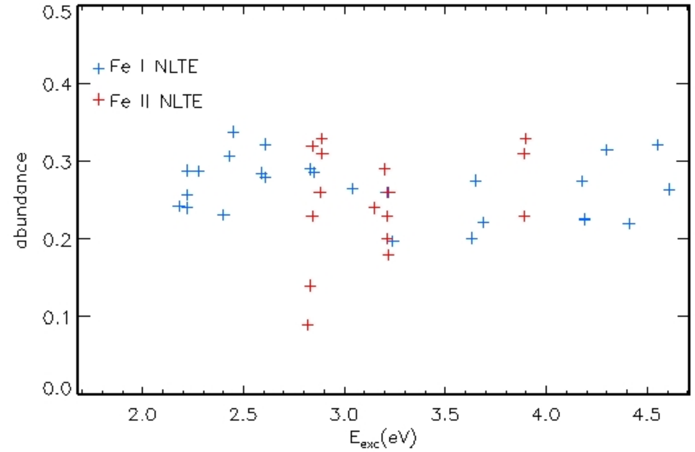
HD 30562 5960/4.10/ 0.24 /1.1

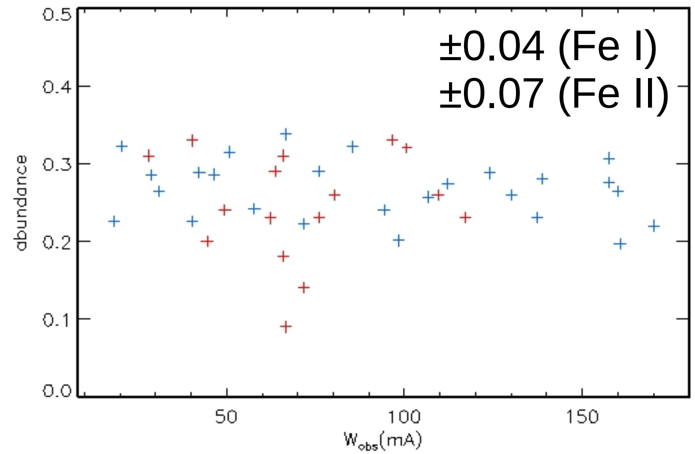
Absolute abundances





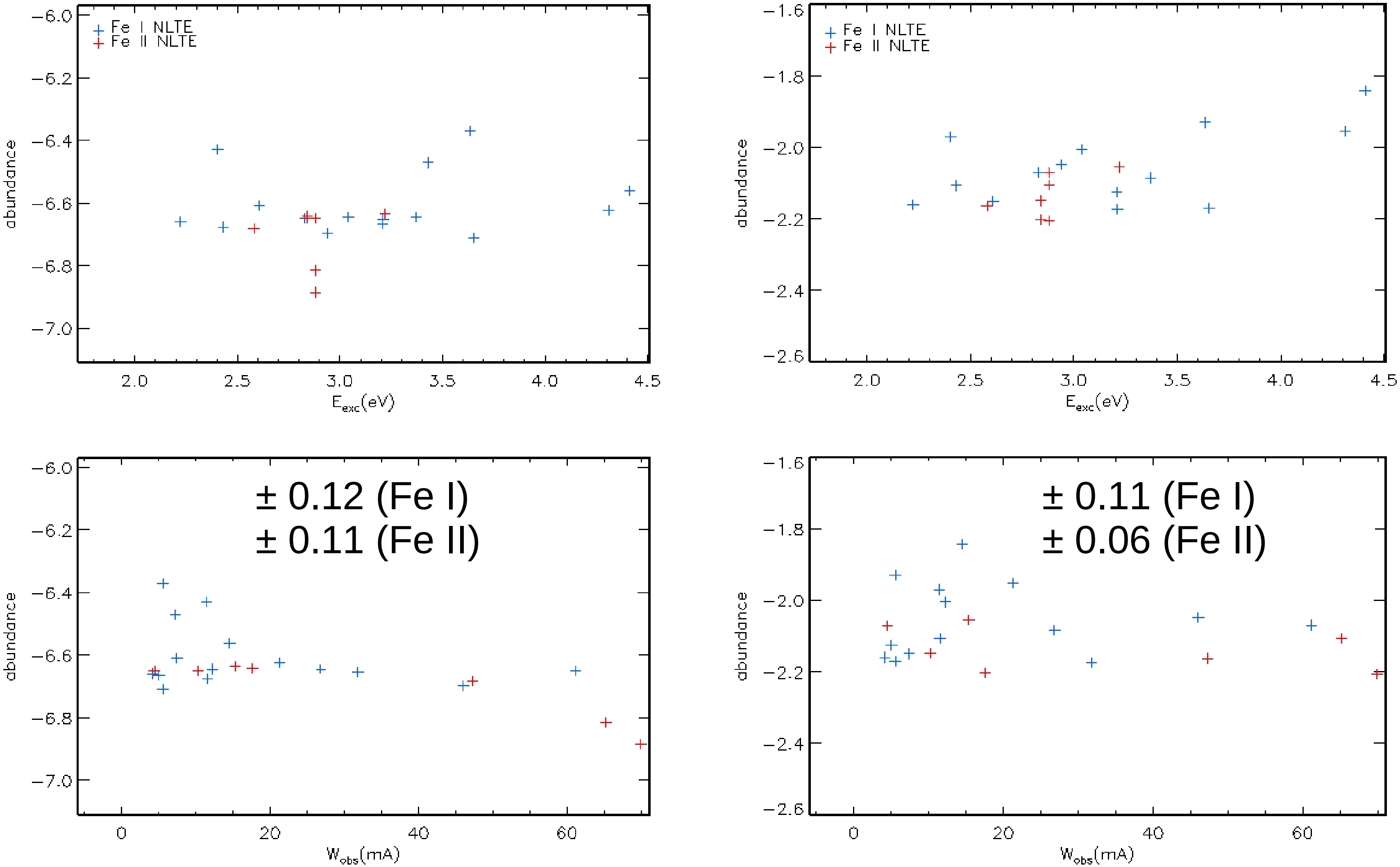
Abundances from differential method (line by line difference between stellar and solar abundances)





Scatter reduces, Fe I-Fe II agreement is better
Does this method work for metal-poor stars?

HD84937 6350/4.09/ -2.08 /1.7



Small reduction of scatter. Uncertainty in oscillator strength is removed, but uncertainty in VdW damping constants remains.

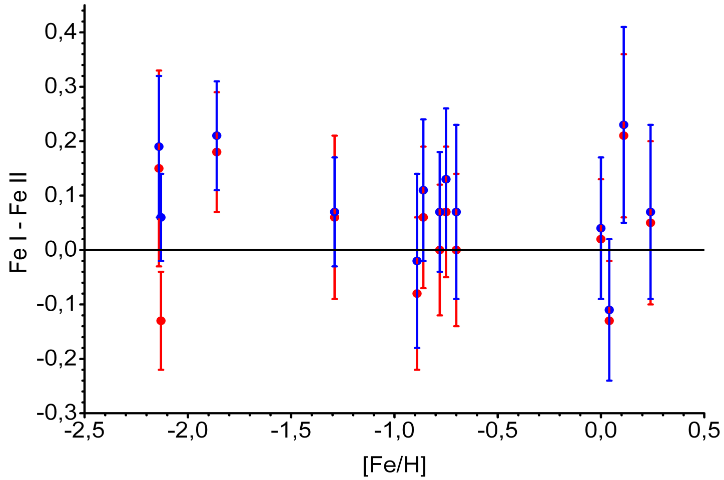
Fe I — Fe II abundance difference

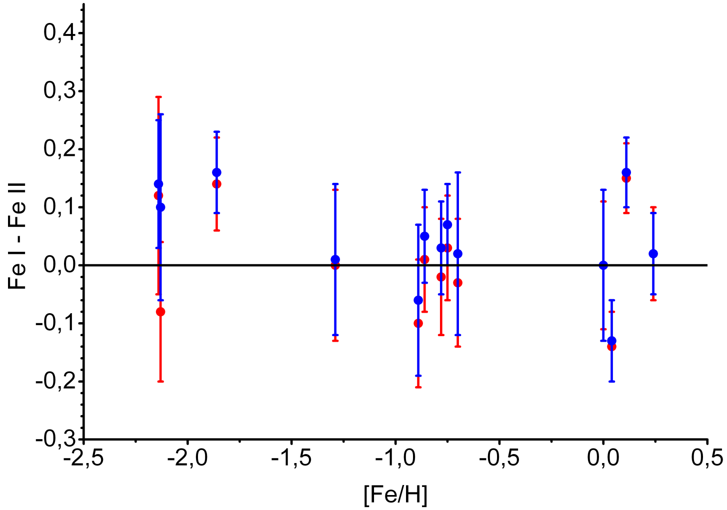
for 12 stars of the sample
with the most accurate parameters from literature

Absolute values

Differential values (relative to Sun)

● NLTE
● LTE





9 stars: agreement of log g from spectroscopic method and from Hipparcos measurements.
3 stars: disagreement, which is not possible to remove by any variations of the method.

Conclusions

♦ Iron abundances were obtained for 12 stars from Fe I and Fe II lines taking into account non-LTE effects

♦ Differential method
- avoids uncertainty in oscillator strengths,
- works well for stars close solar metallicity
- for metal-poor stars line-to-line scatter does not reduce due to uncertainty in VdW damping constants.

♦ 9 stars - agreement of log g from spectroscopic method and from Hipparcos measurements.
3 stars - disagreement, which is not possible to remove by any variations of the method.

The study will be continued.

♦ There are 15 more stars with log g from Hipparcos, which will be investigated by the same way.

♦ The method will be applied to the total sample of stars.