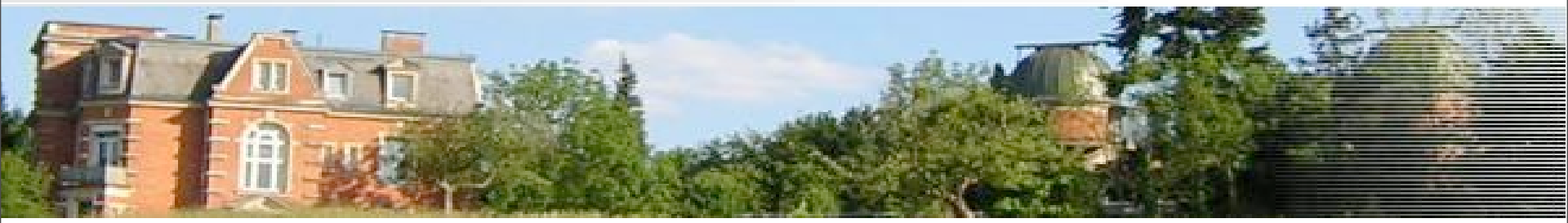
Dr. Remeis-Sternwarte Bamberg
Astronomical Institute of the
University of Erlangen-Nuremberg



Non-LTE effects in Hot Stars

N. Przybilla

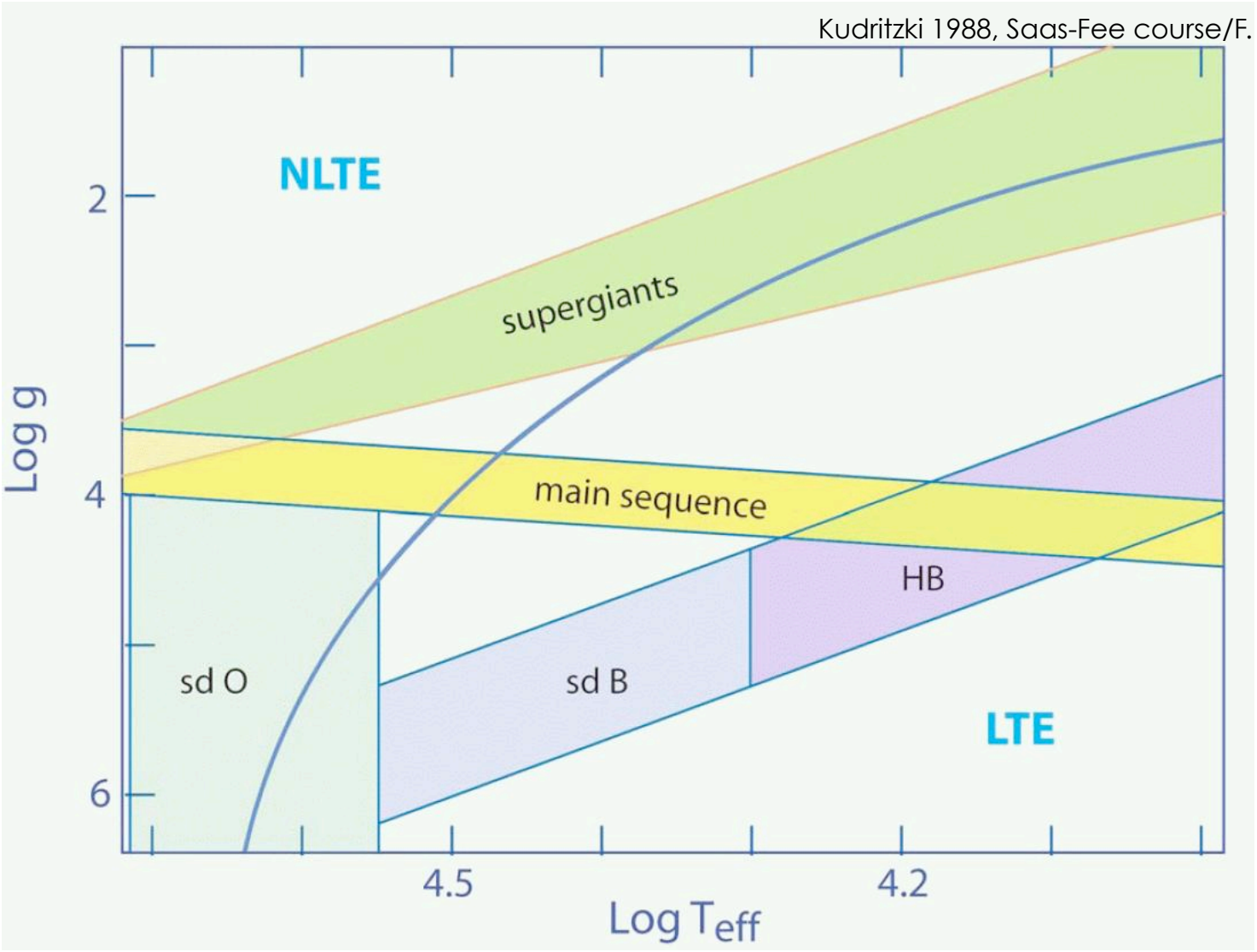
Why to study Hot Stars

- ‘laboratories‘: radiative atmospheres
  → testing stellar atmosphere techniques, model atoms

- highly luminous: spectroscopy over large distances

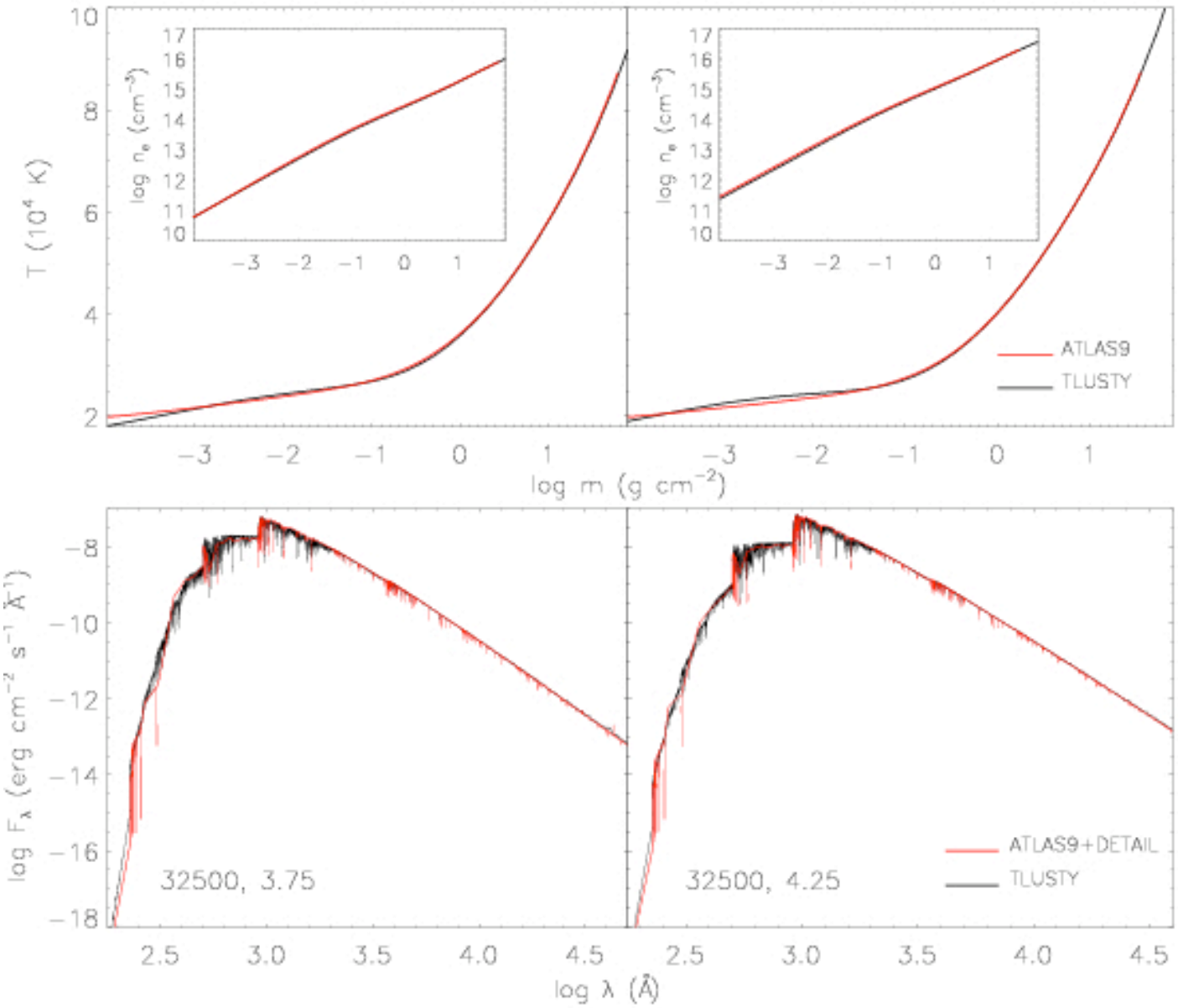
- observational constraints on
  - stellar evolution
  - galactochemical evolution } stellar parameters, abundances
  - cosmic distance ladder

Model atmospheres for Hot Stars



- stellar winds must not be neglected

Similarity of LTE and NLTE atmospheres ...

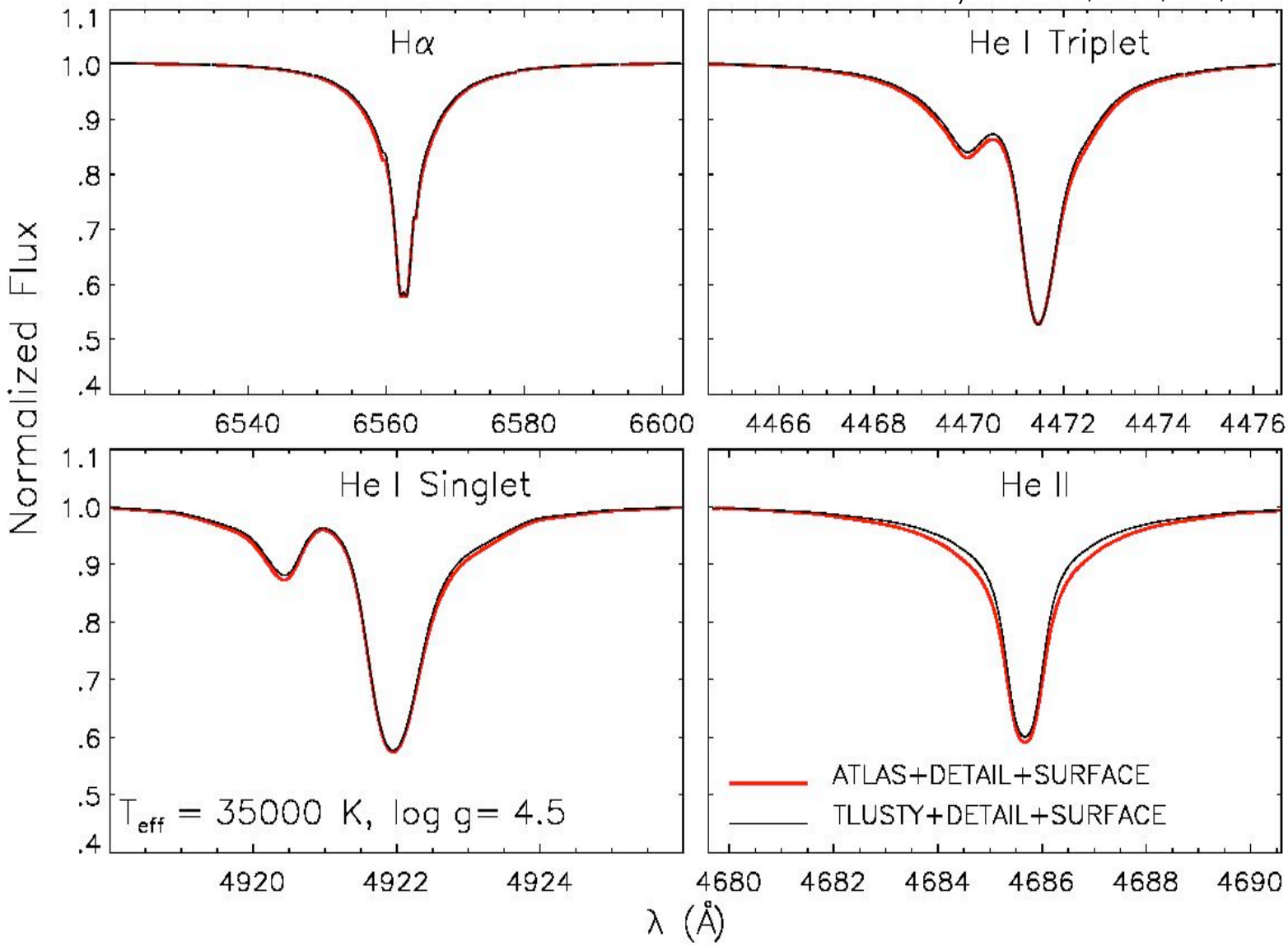


Nieva & Przybilla 2007,

A&A, 467, 295

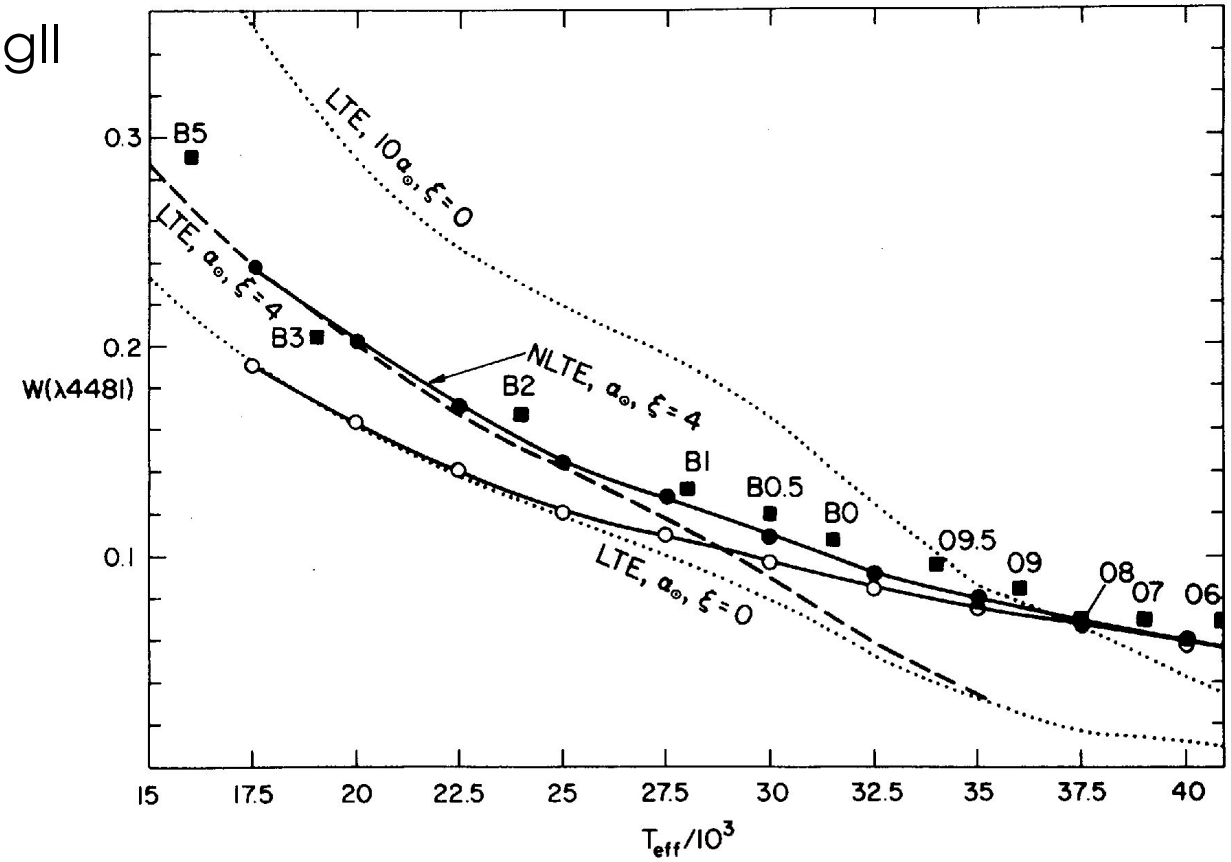
... and resulting line profiles

Nieva & Przybilla 2007, A&A, 467, 295



NLTE line formation: the early days

e.g. MgII



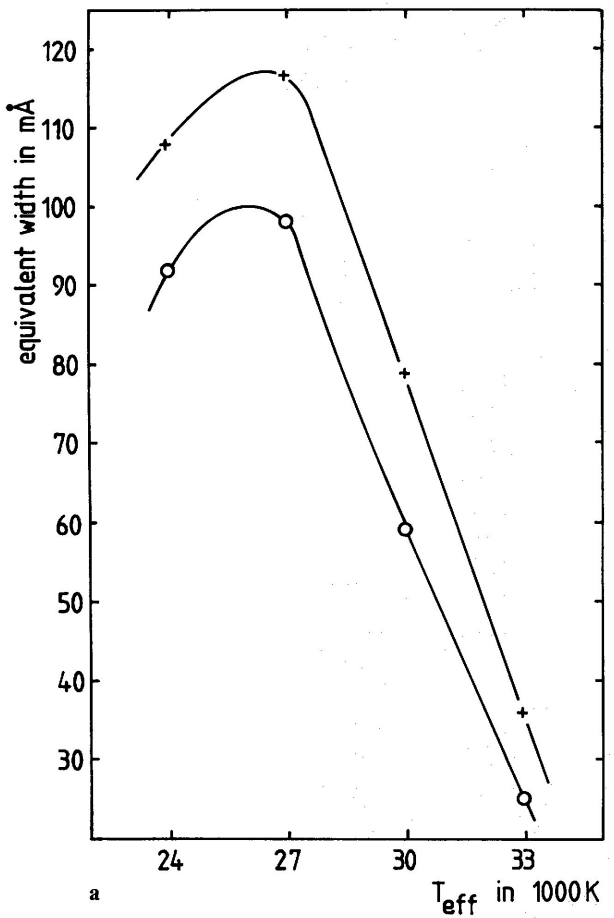
Mihalas 1972, ApJ, 177, 115

NLTE required to match observation consistently

FIG. 3.—Equivalent width of Mg II λ4481 (in Å) versus effective temperature in thousands of degrees. *Squares*, mean observed relation. *Dotted curves*, LTE equivalent widths assuming $\xi = 0$ and solar abundance (*lower curve*) or 10 times solar abundance (*upper curve*). *Dashed curve*, LTE equivalent widths assuming $\xi = 4$ km s^{-1} and solar abundance. *Solid curves*, non-LTE equivalent widths assuming solar abundance and $\xi = 0$ (*open symbols*) or $\xi = 4$ km s^{-1} (*filled symbols*). Note serious discrepancy between observations and LTE predictions at B0 and earlier, in contrast to good agreement between observations and non-LTE predictions over entire range.

NLTE line formation: the breakthrough

e.g. NII



Becker & Butler 1989, A&A, 209, 244

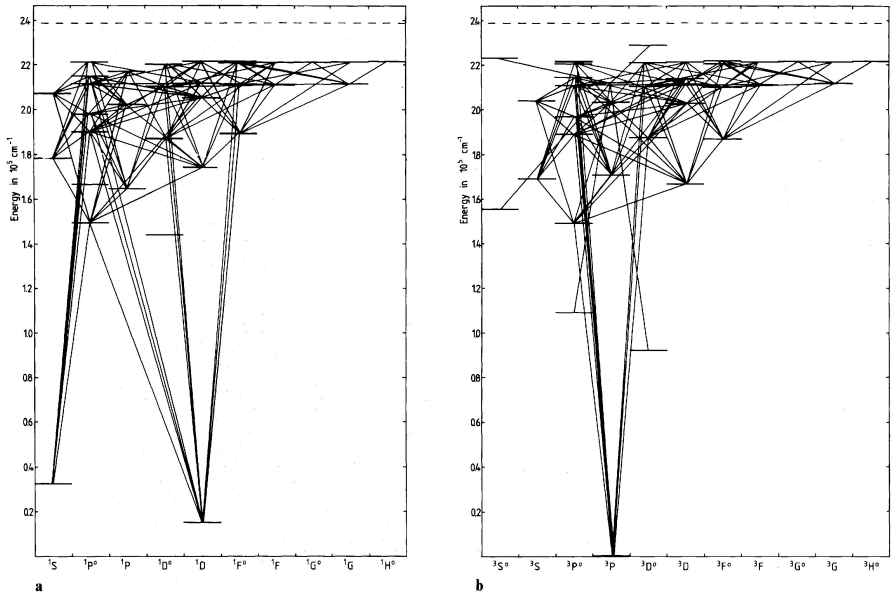
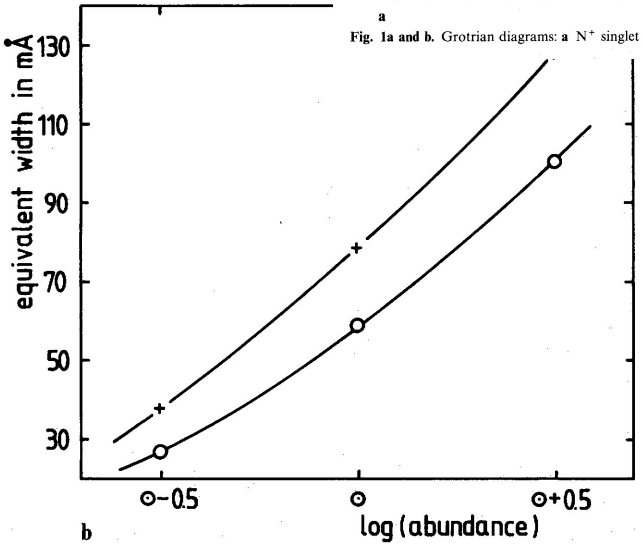


Fig. 1a and b. Grotrian diagrams: **a** N^+ singlet system and **b** N^+ triplet system. Note that singlets and triplets are treated simultaneously



- extensive model atoms
- accurate atomic data
- comparison with observation

Fig. 2. a Equivalent width versus effective temperature and **b** versus abundance for non-LTE (+) and LTE (o) calculations of the line at 4630.47 Å. **a** v_{turb}: 5 km s^{-1}, log g: 4.0, log ε: −4.051, **b** v_{turb}: 5 km s^{-1}, log g: 4.0, T_{eff}: 30000 K, abundances: log ε; ε number density relative to total number density

Becker & Butler 1988, A&A, 201, 232

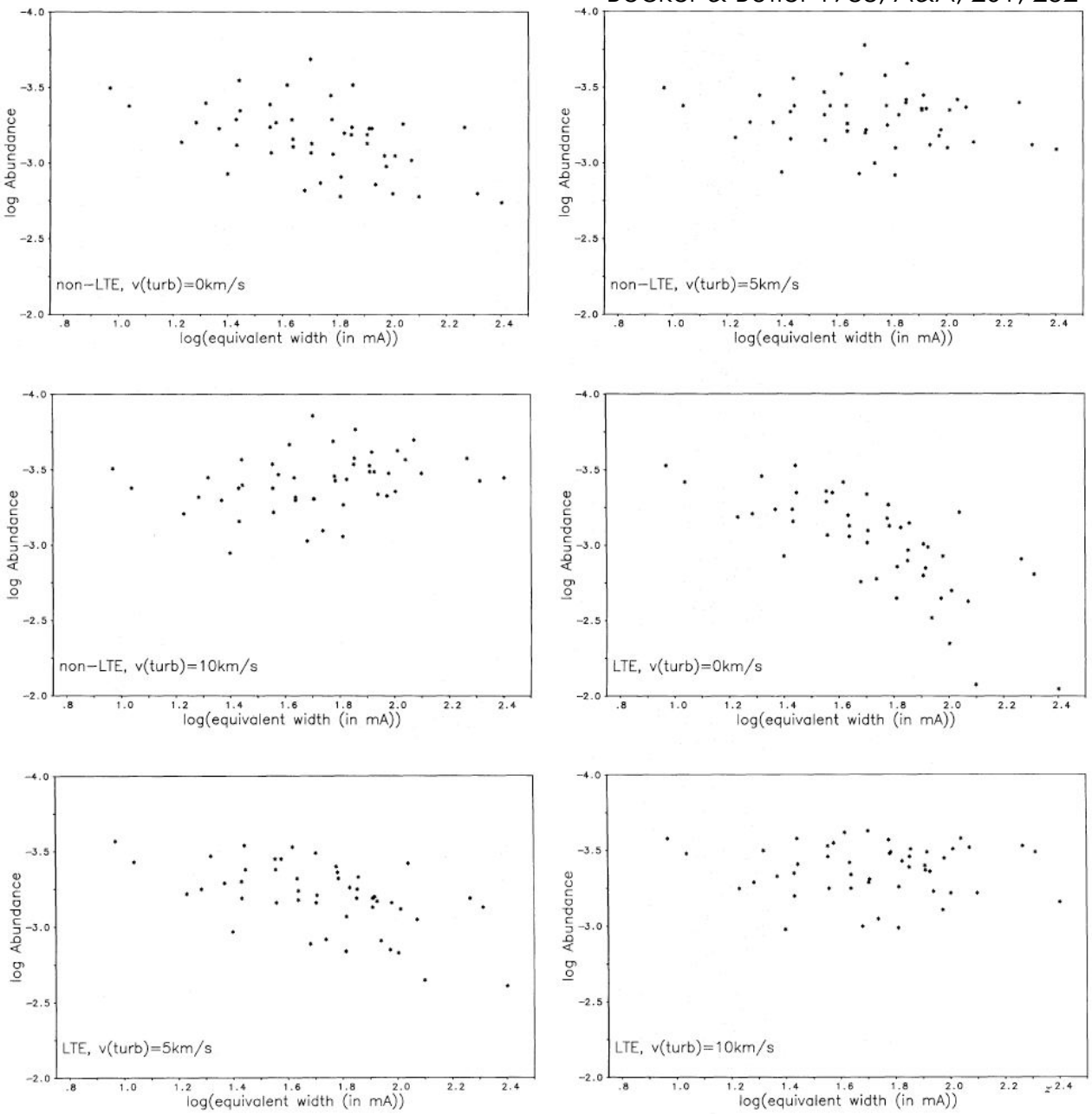


Fig. 10. Calculated abundances versus observed equivalent widths for τ Sco. Non-LTE and LTE, v_{turb}: 0 km s^{-1}, 5 km s^{-1}, 10 km s^{-1}

e.g. OII

- reduction of microturbulence values in NLTE

NLTE effects on abundance determinations in B-type stars

Kilian 1994, A&A, 282, 867

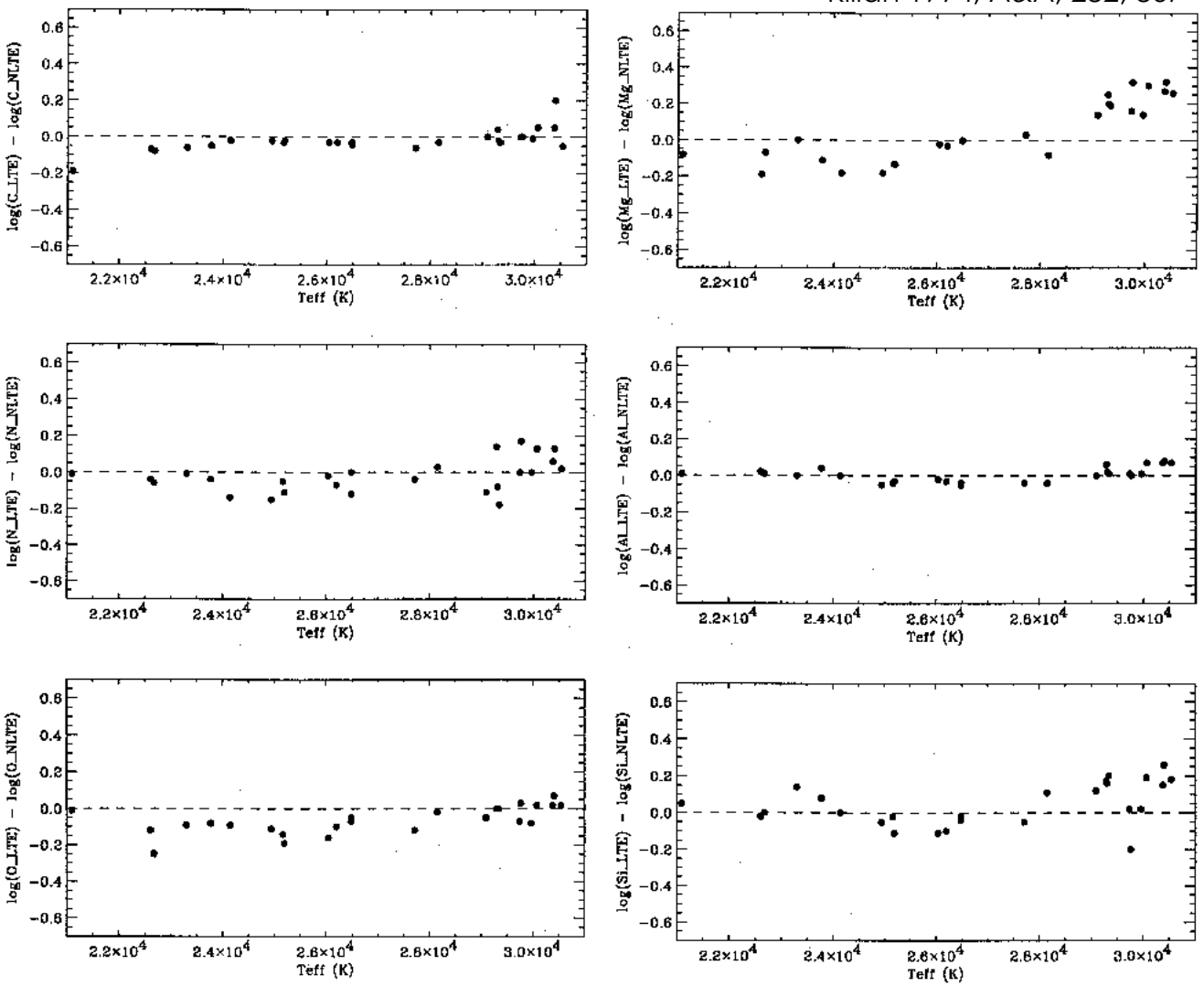


Fig. 4. Difference between LTE and NLTE abundance determination for carbon, nitrogen, oxygen, silicon, magnesium and aluminium

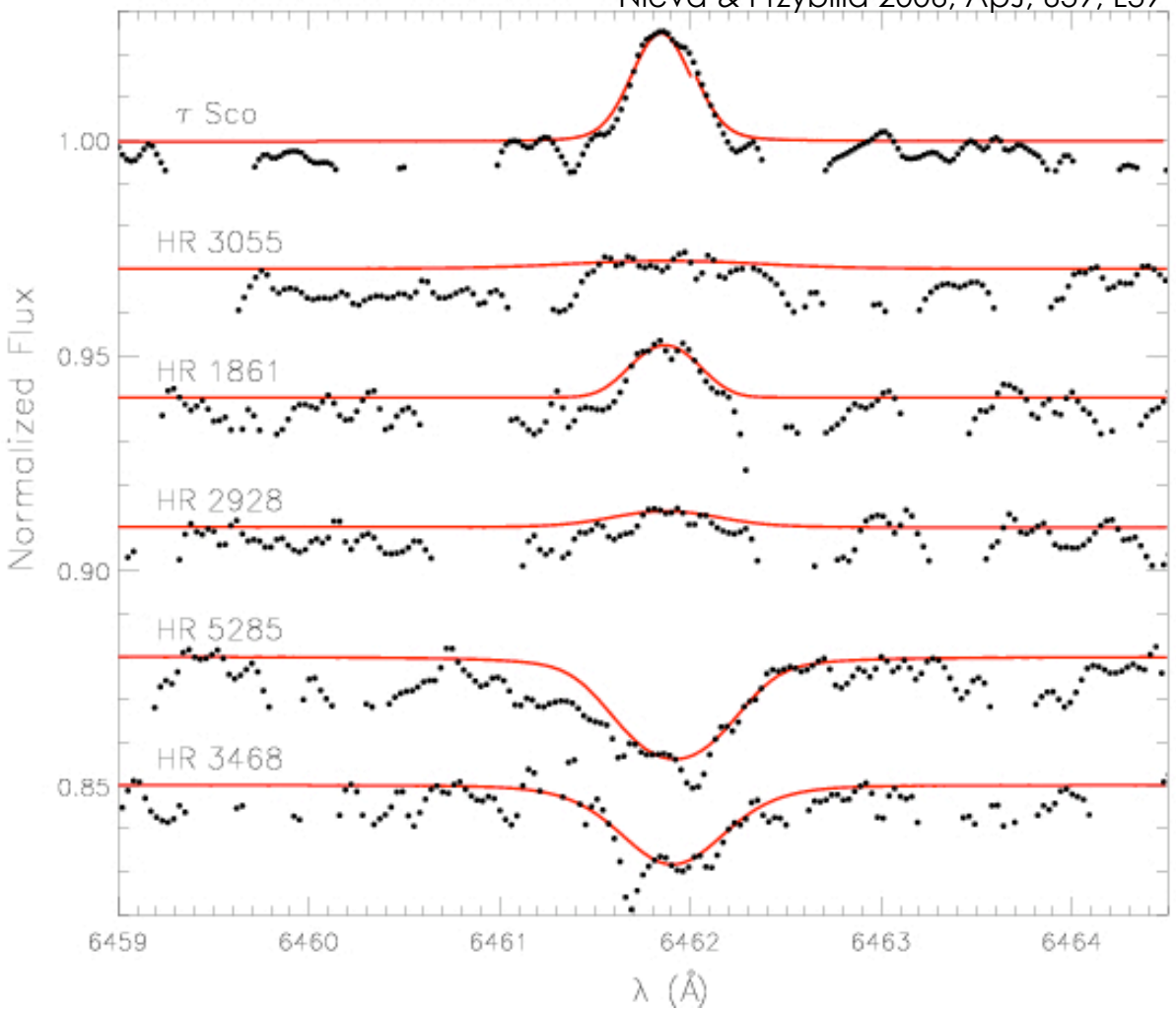
- NLTE effects ubiquous
- need to be accounted for if high accuracy is desired

Applications

- properties of stellar classes
- study of rotational mixing in course of stellar evolution: He, CNO
- abundances in stellar clusters: (in)homogeneities
- Galactic abundance gradients
- . . .

NLTE line formation: further refinements

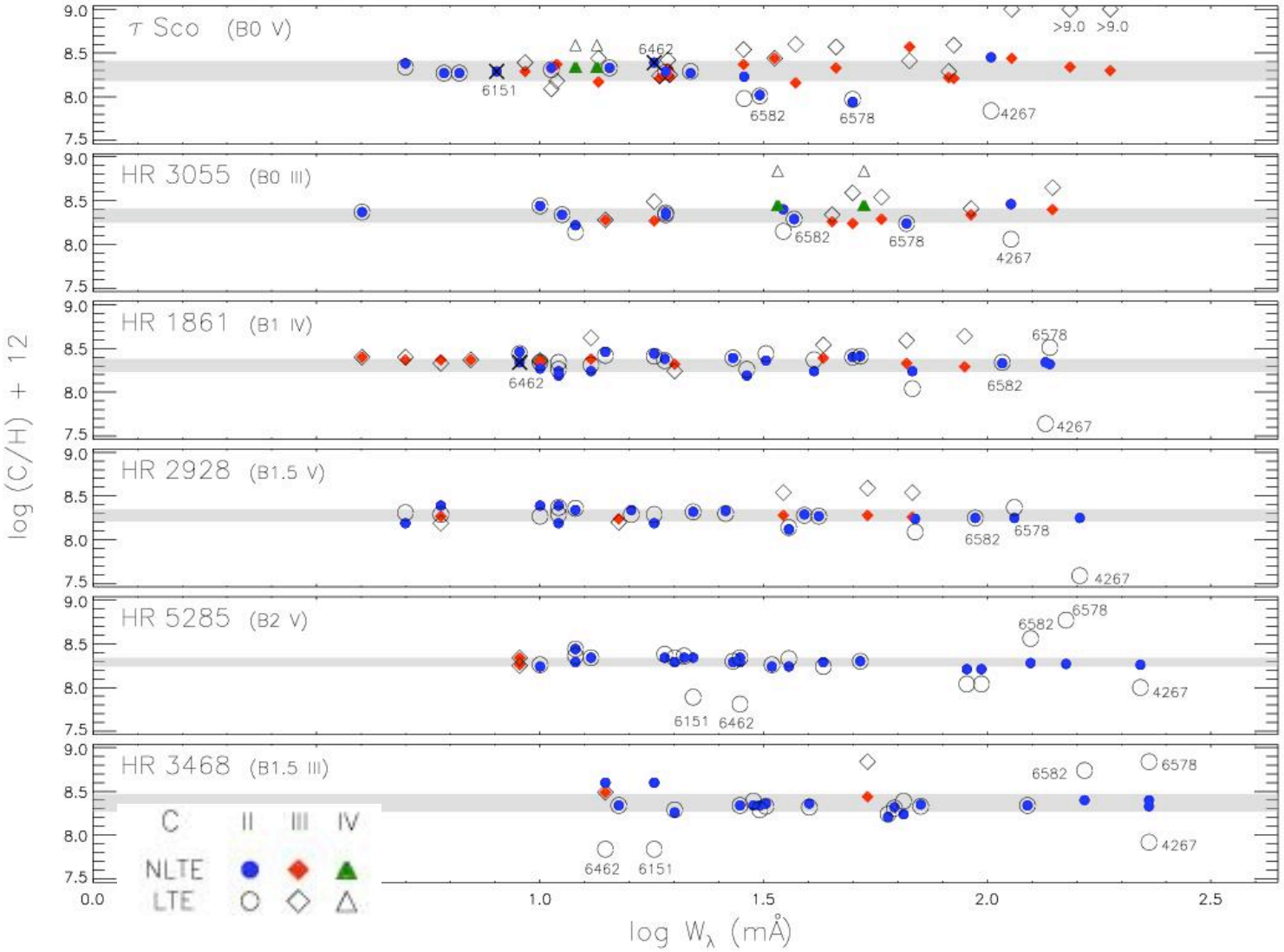
Nieva & Przybilla 2006, ApJ, 639, L39



- extended model atoms – more data from ab-initio calculations
- improved spectra: more observational constraints

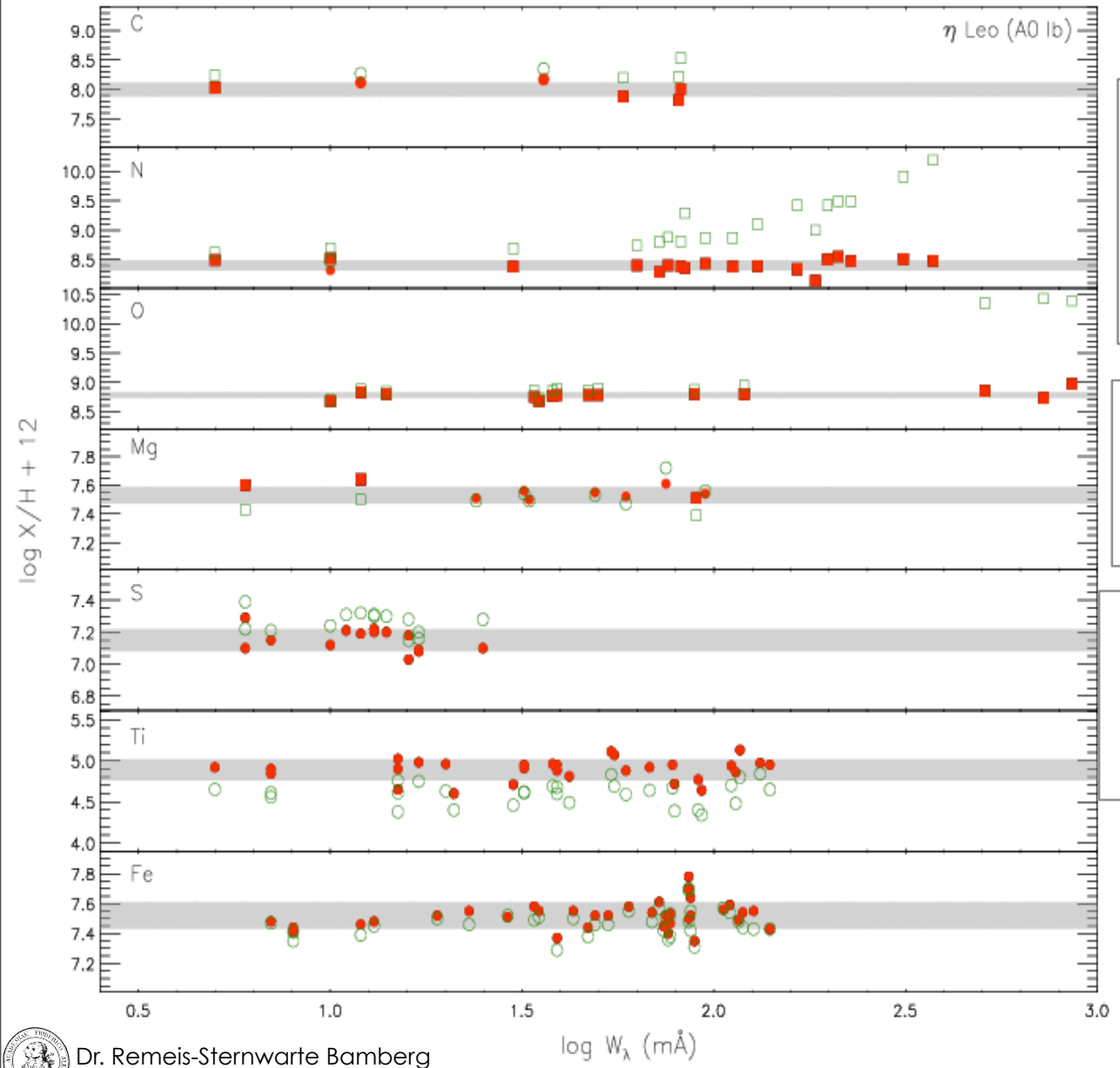
Quantitative spectroscopy at high precision 1

Nieva & Przybilla 2007, A&A, subm.



Quantitative spectroscopy at high precision 2

Przybilla et al. 2006, A&A, 445, 1099



NLTE:
absolute abundances
&
reduced statistical &
systematic uncertainties

Δ log ε :
1σ-stat.: ~ 0.05…0.10 dex
1σ-syst.: ~ 0.07…0.12 dex

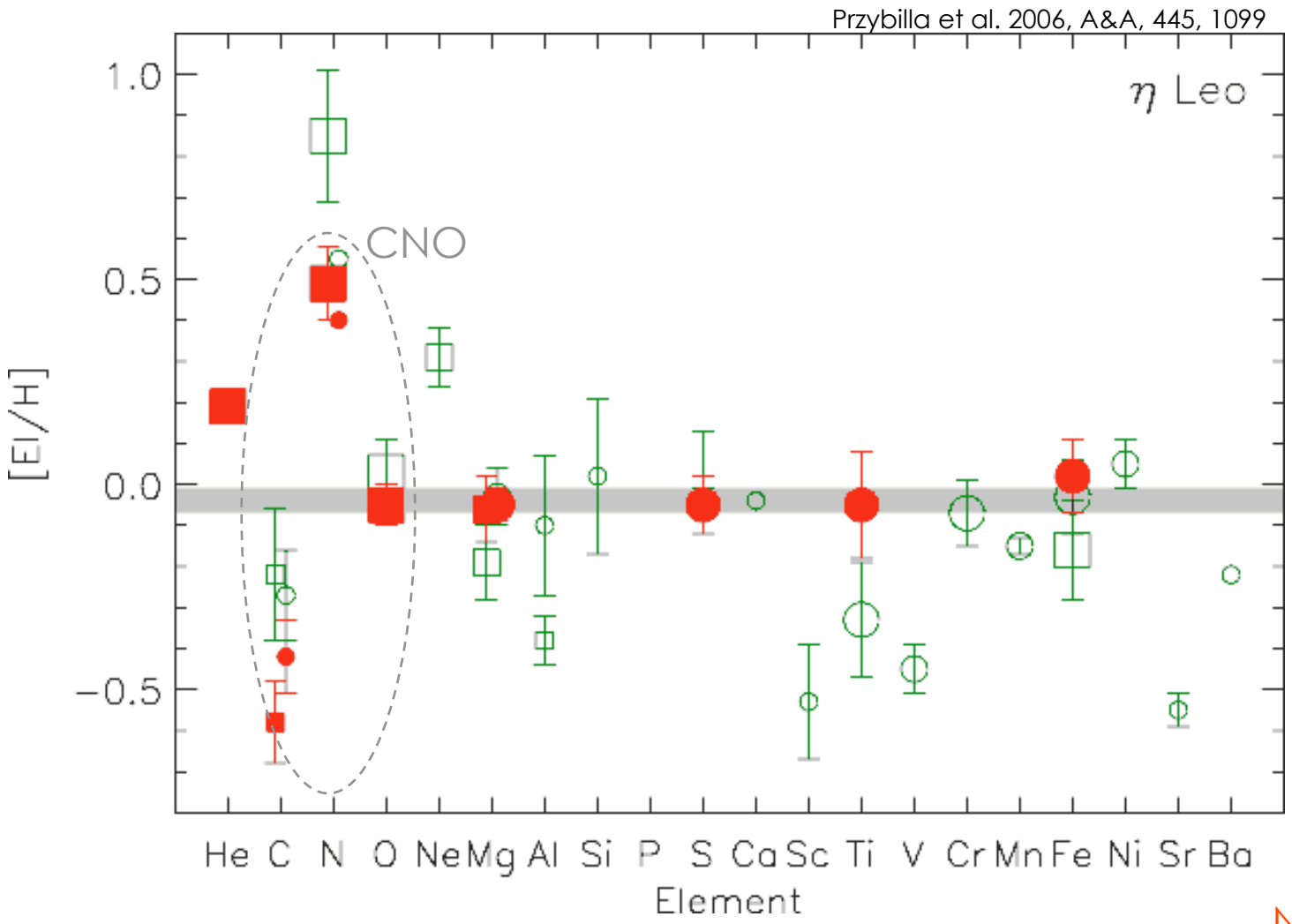
typical uncertainties
in literature (LTE): x ~2-3
+ unknown systematic
errors

NLTE/LTE

neutral

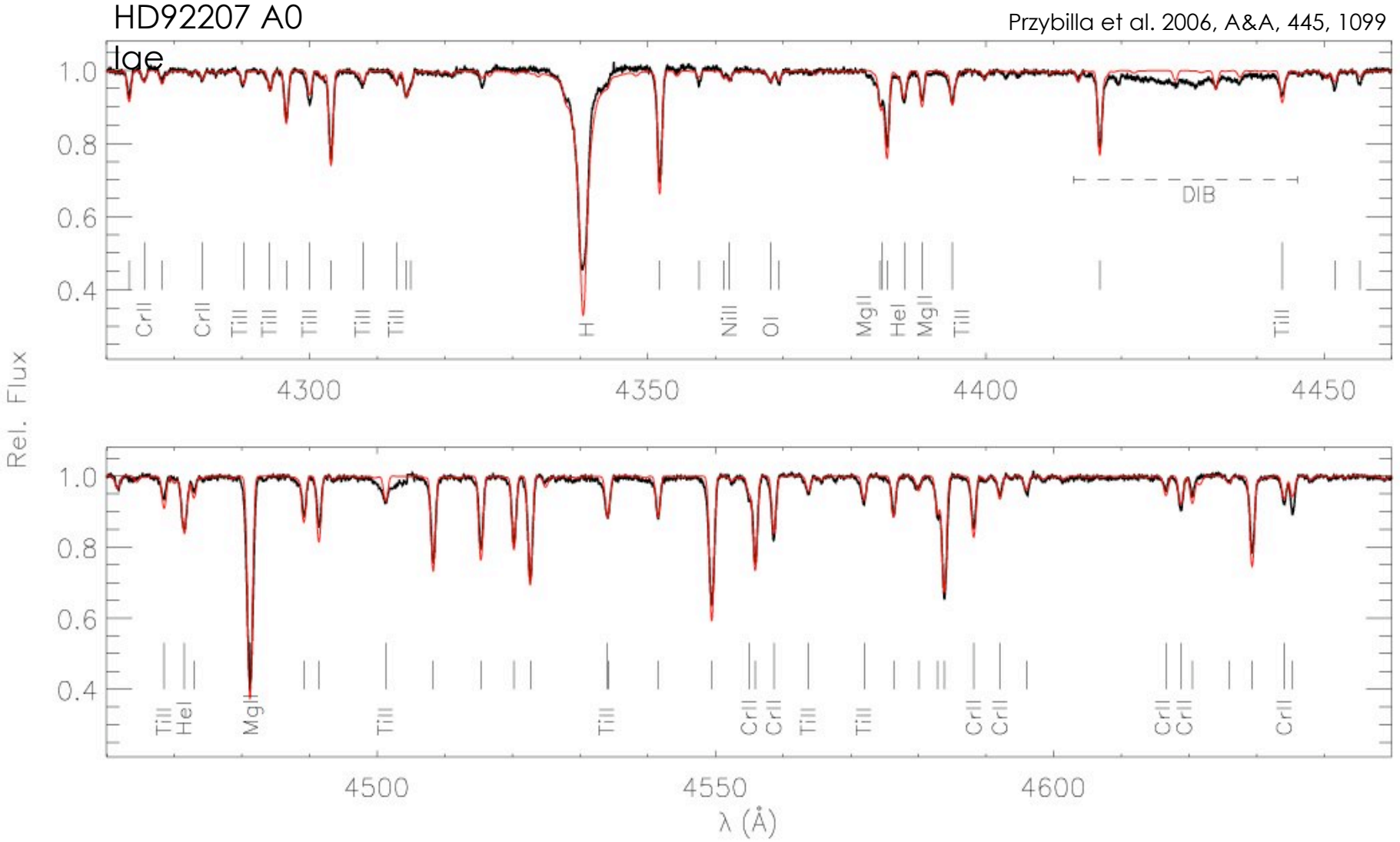
ionized

NLTE line formation: the larger context



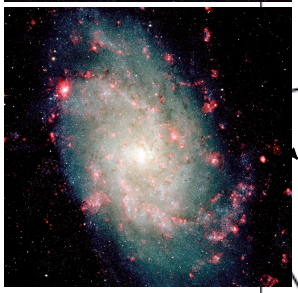
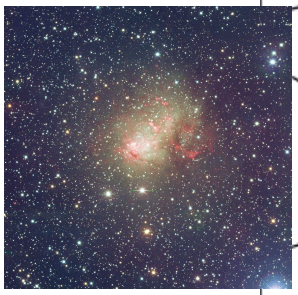
- elimination of systematic trends
- reduced uncertainties

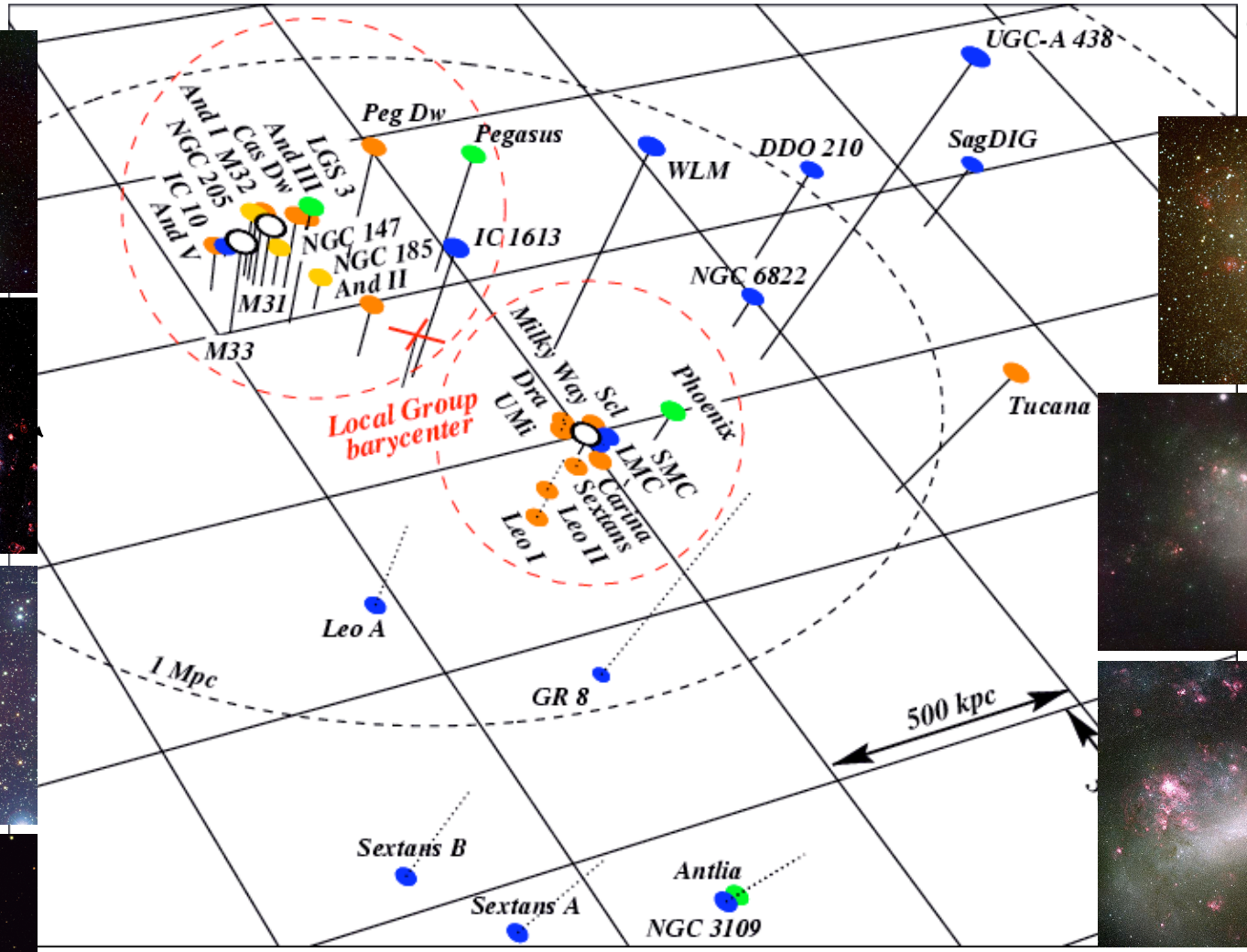
NLTE line formation: global spectrum synthesis

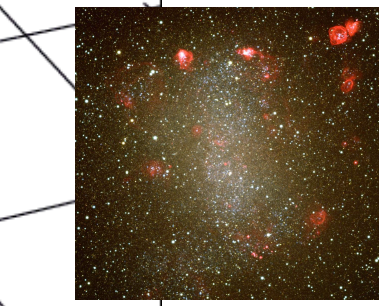
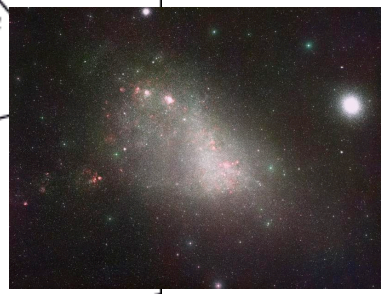
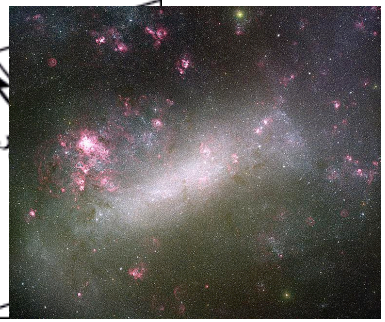


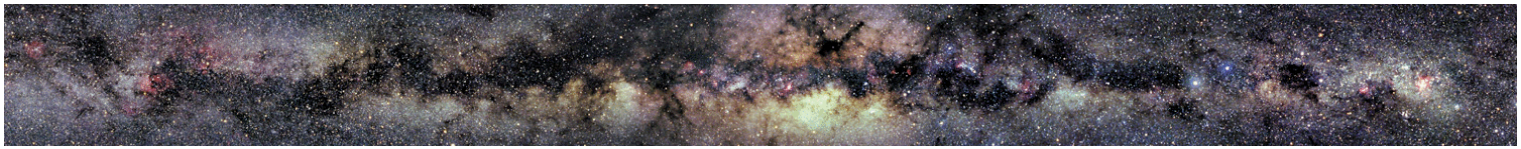
- good agreement may be obtained in global and in detail

Extragalactic Stellar Astronomy: The Local Group...

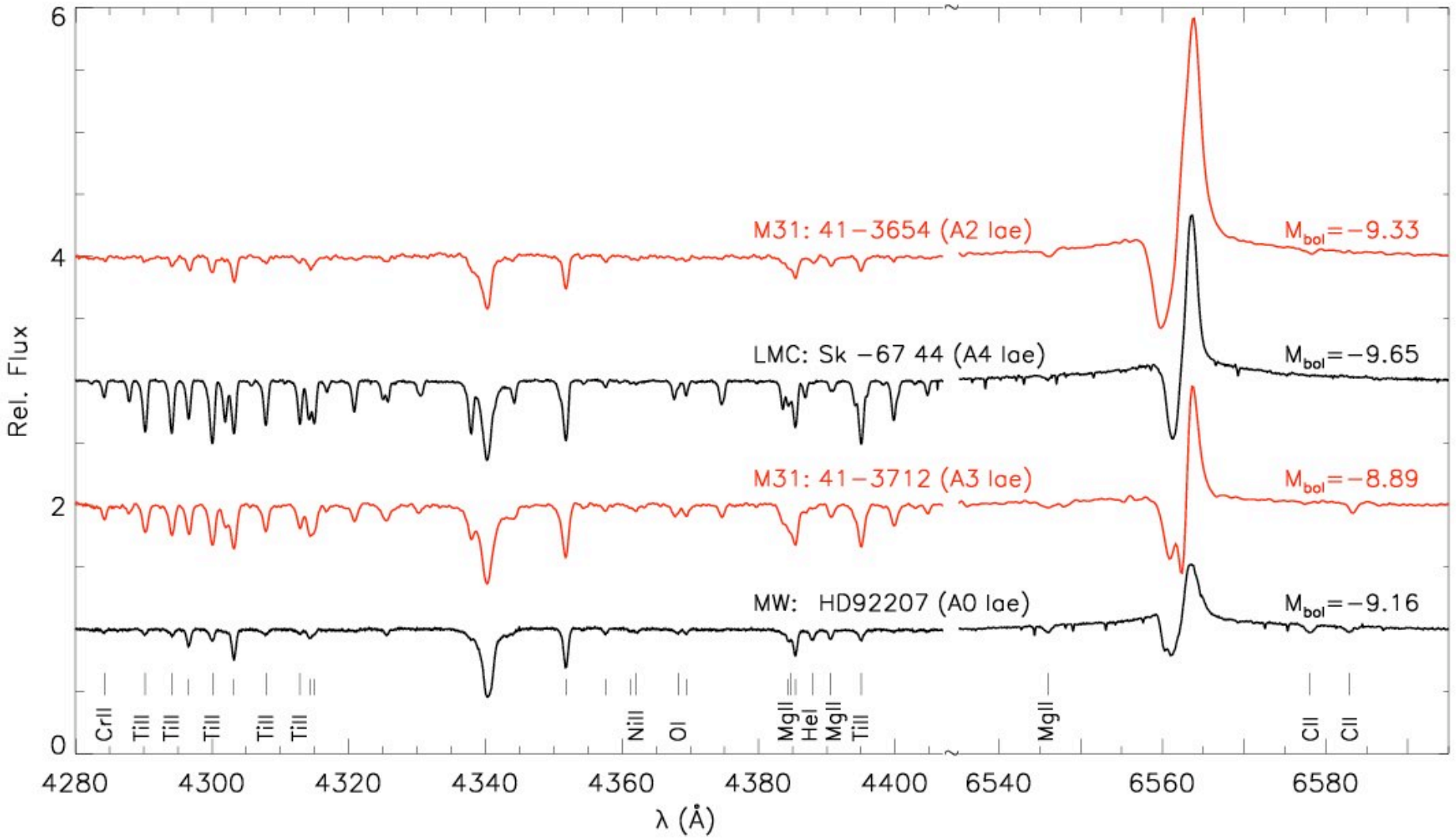




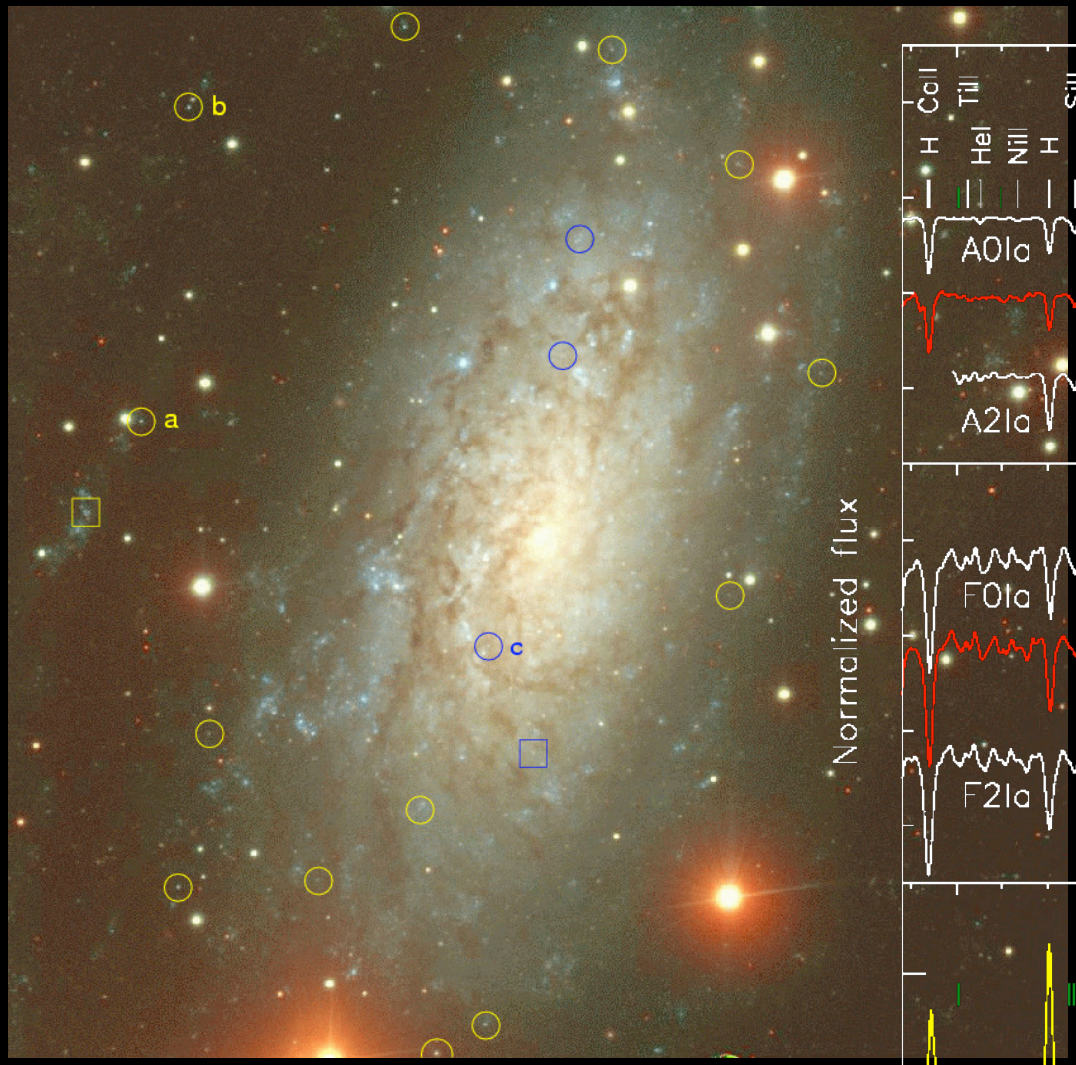



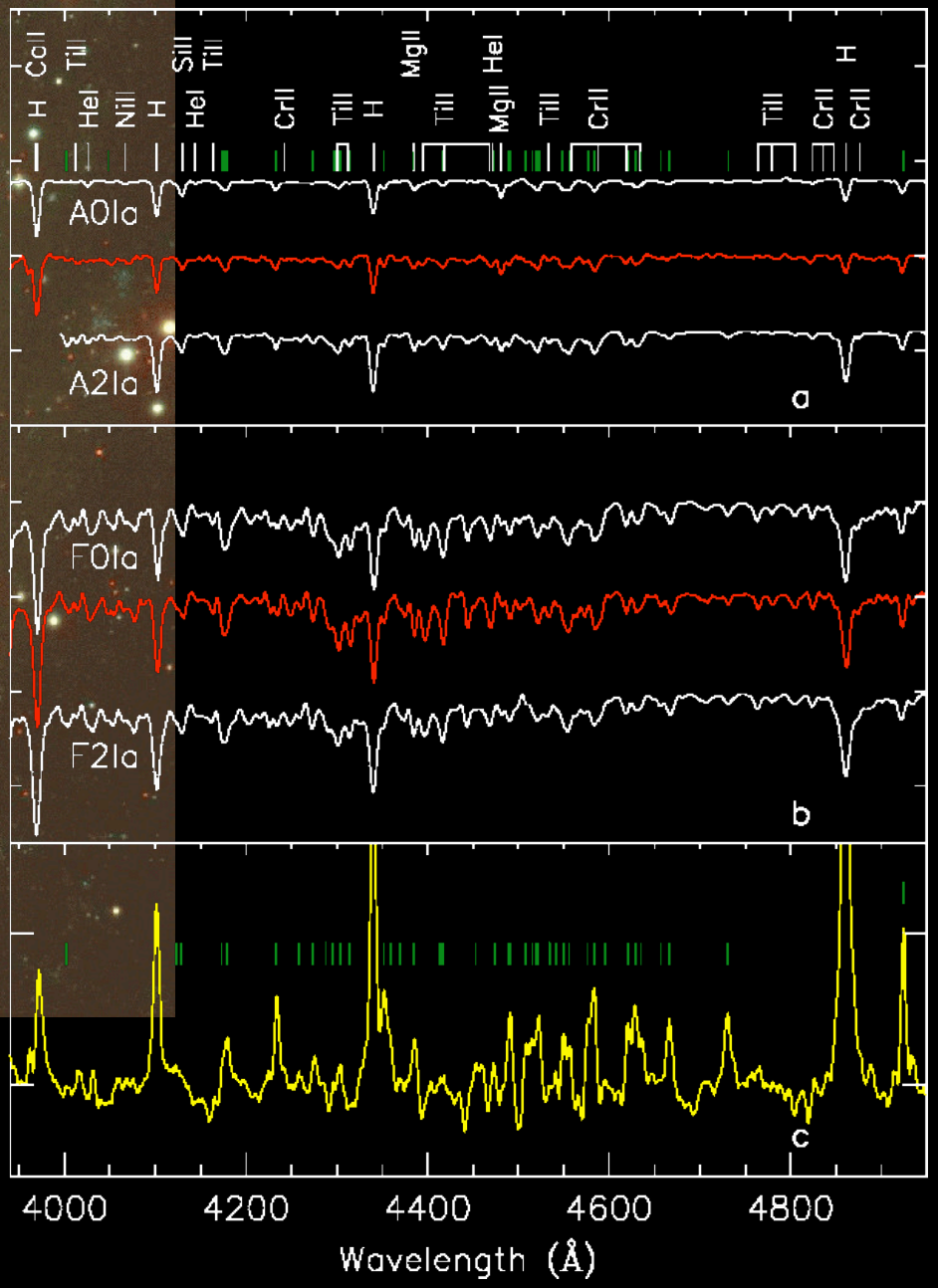






High-resolution spectroscopy in the Local Group







... and beyond

NGC 3621

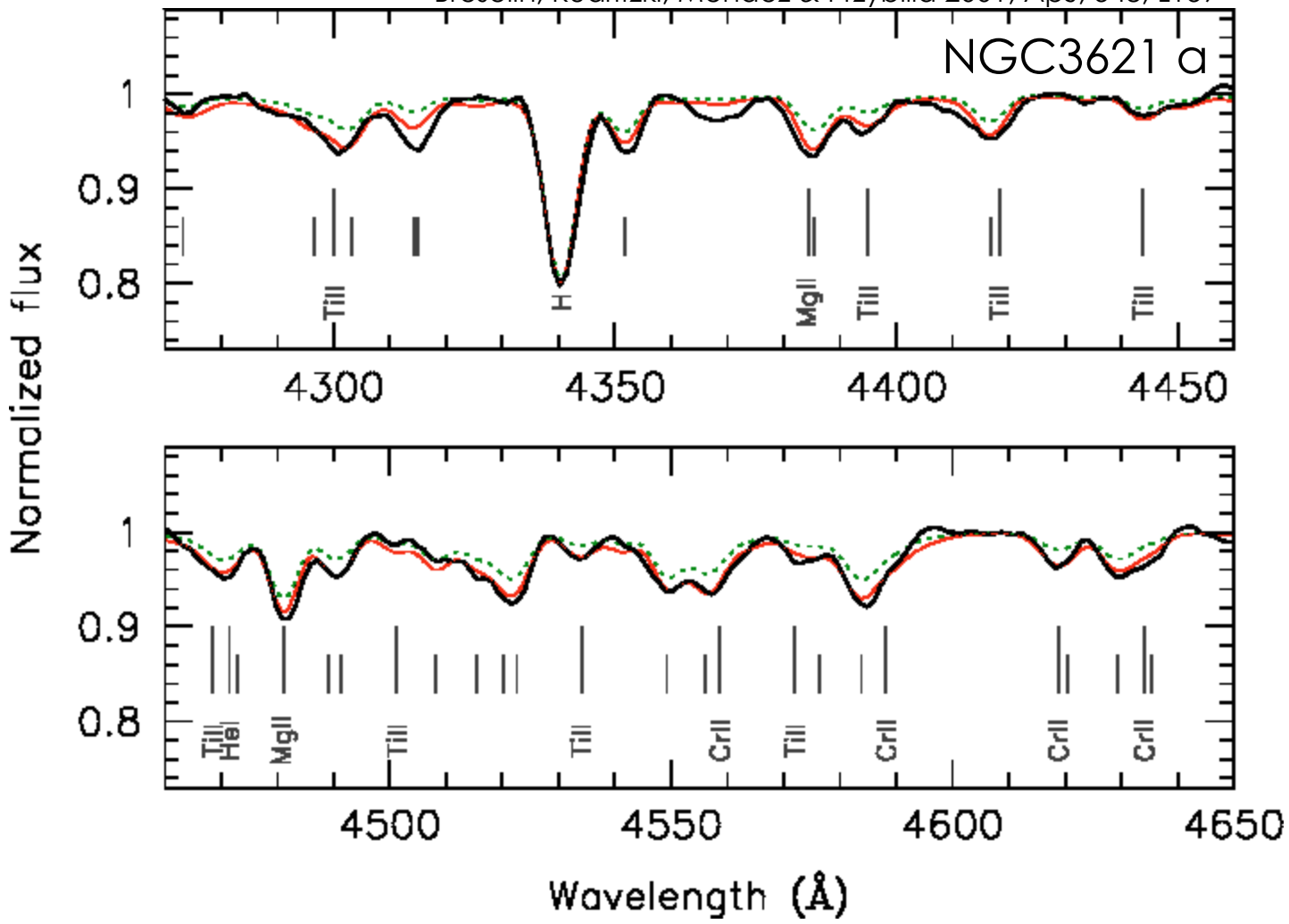
VLT/FORS1

d ~ 6.6 Mpc

Bresolin, Kudritzki, Méndez & Przybilla 2001, ApJ, 548, L159

Extragalactic Stellar Astronomy: Metallicities @ med-res

Bresolin, Kudritzki, Méndez & Przybilla 2001, ApJ, 548, L159



spectrum synthesis for 0.5 and 0.2 solar metallicity