Improving the analysis methods in spectroscopic surveys of late-type stars

Karin Lind MPA Garching

Science with 4most,

Potsdam, 13-15 Nov. 2012

Motivation I

- A major science goal of 4most and other large spectroscopic surveys is Galactic archaeology by chemical tagging of FGK stars
  - **Statistics** : Soon > 10^6 stars
  - **Precision** (S/N, wavelength range) :
    $\sigma_{[X/H]}$<0.1dex, σ_{Teff}<150K, $\sigma_{log(g)}$<0.3dex
  - **Accuracy** (assumptions: 1D, LTE, atomic data) :
    $\sigma_{[X/H]}$< 0.5 dex, σ_{Teff}<400K, $\sigma_{log(g)}$< 1 dex

Motivation II

- 3D hydrodynamical modelling now cover most of the relevant FGK star parameter space.
- Very large differences in atmospheric structure at low [Fe/H]

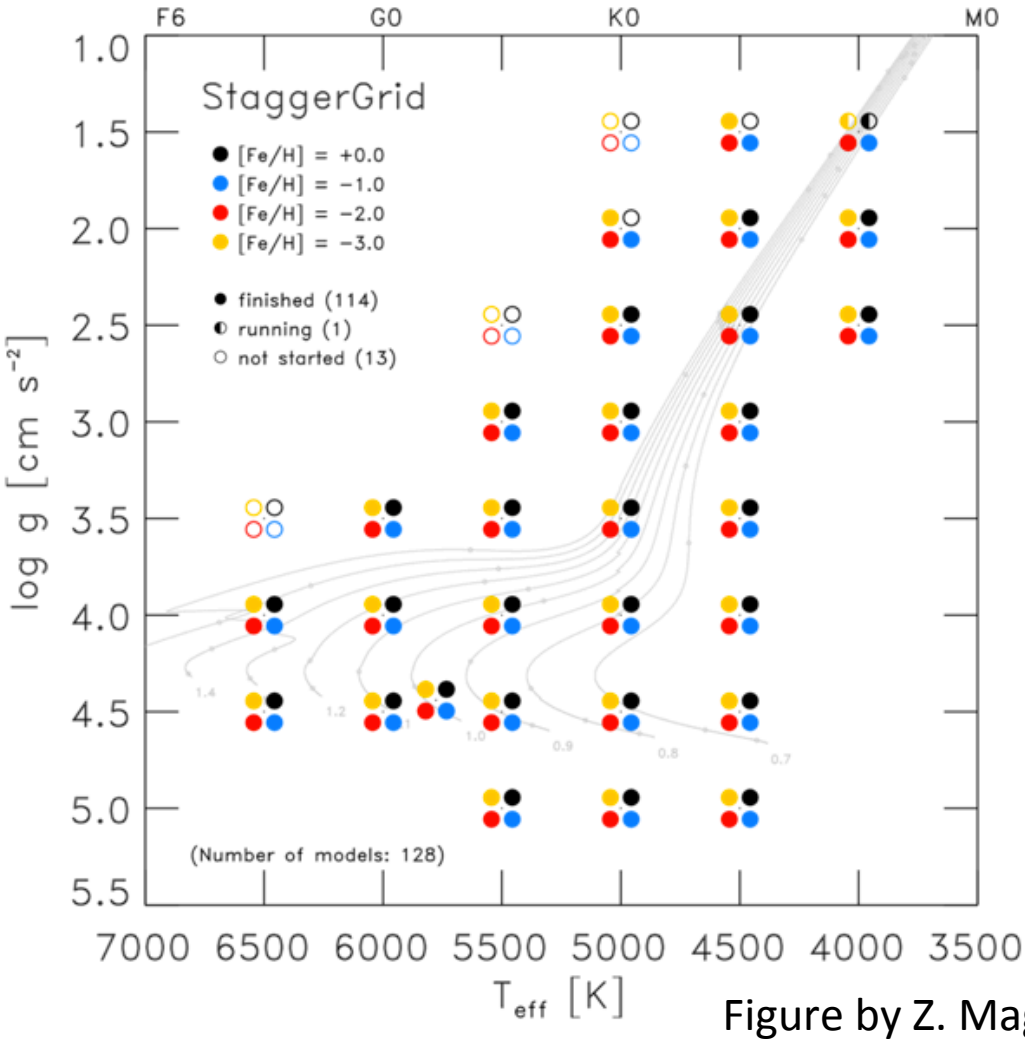
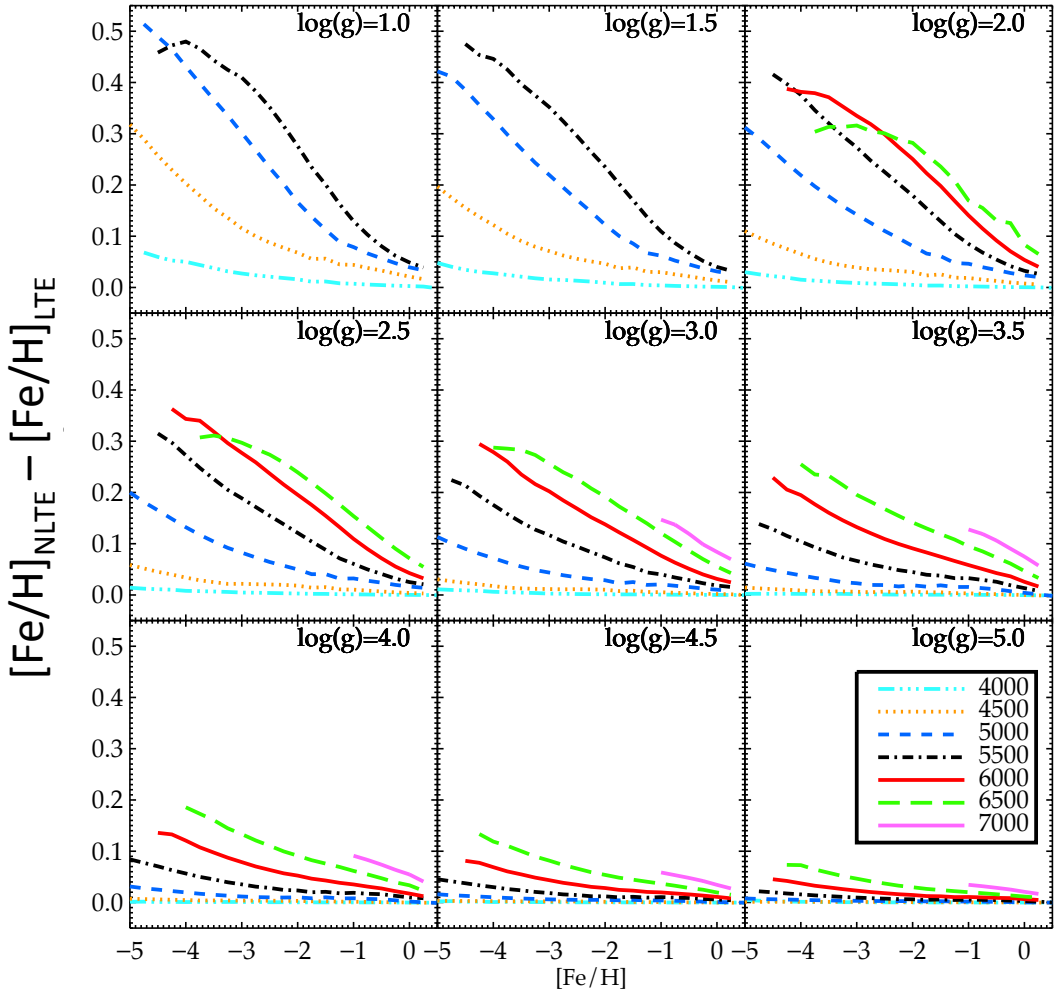


Figure by Z. Magic

Motivation III

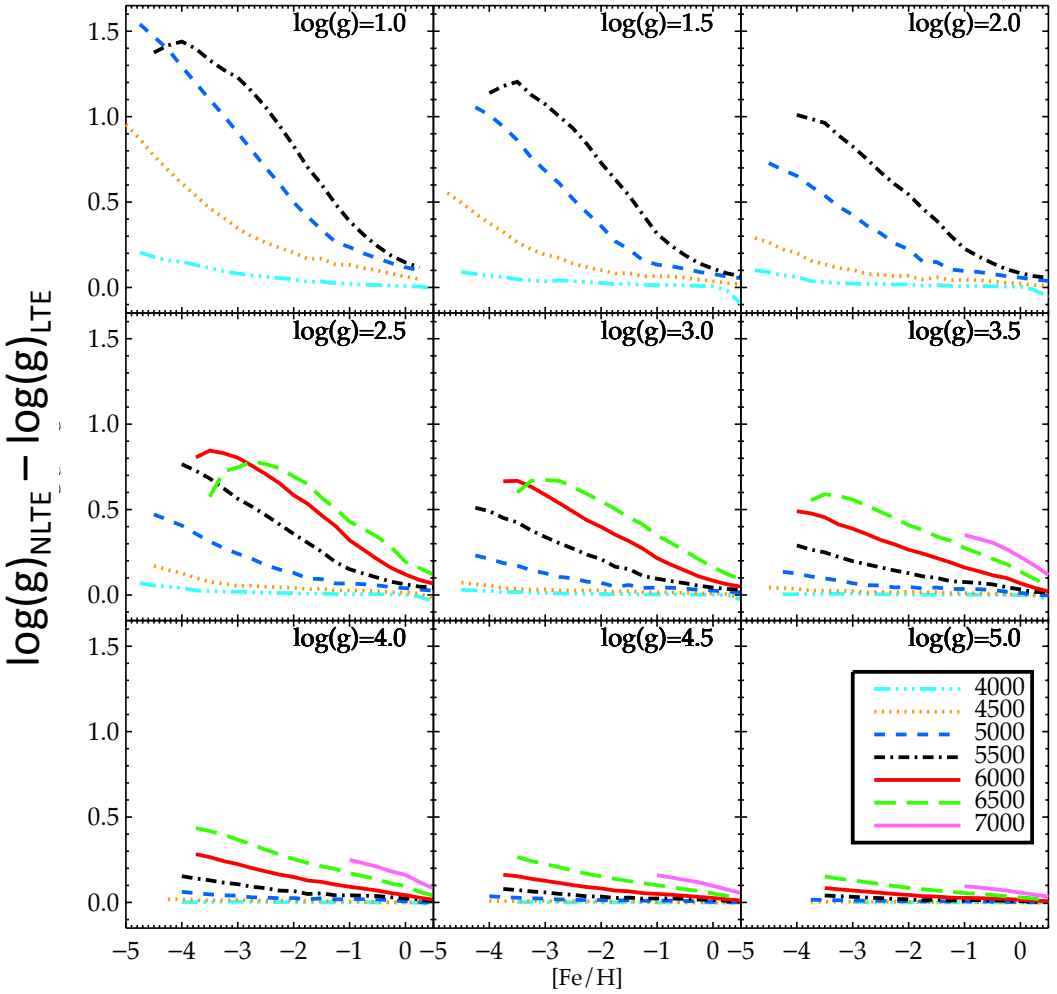
- Well-constrained NLTE modelling in 1D can be performed for most interesting elements (light, alpha, iron-peak, neutron capture)
- Uncertain atomic data calibrated using benchmark stars



Lind et al. (2012)

Motivation III

- Well-constrained NLTE modelling in 1D can be performed for most interesting elements (light, alpha, iron-peak, neutron capture)
- Uncertain atomic data calibrated using benchmark stars



Lind et al. (2012)

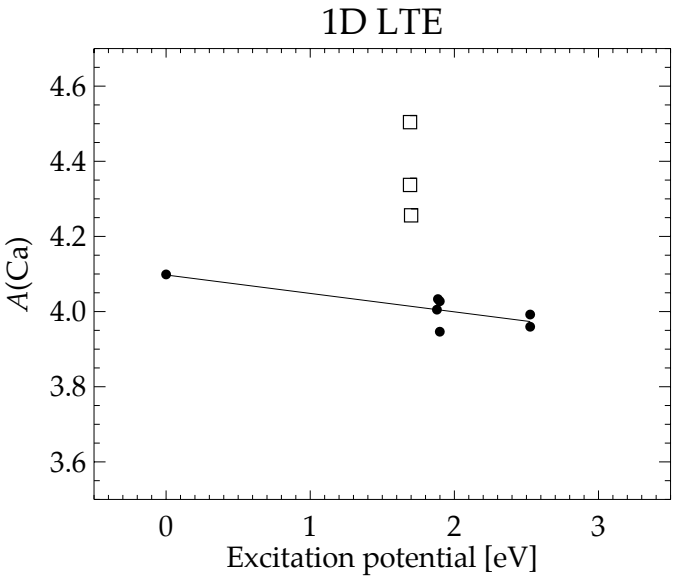
Ways forward

Model	LTE/NLTE	Time*	Performance for Ca lines (next slides)
1D	LTE	0.03s	
1D	NLTE	30s	
3D	LTE	30h	
3D	NLTE	3000h	The ultimate goal, reference point
<3D>	LTE	0.03s	
<3D>	NLTE	30s	

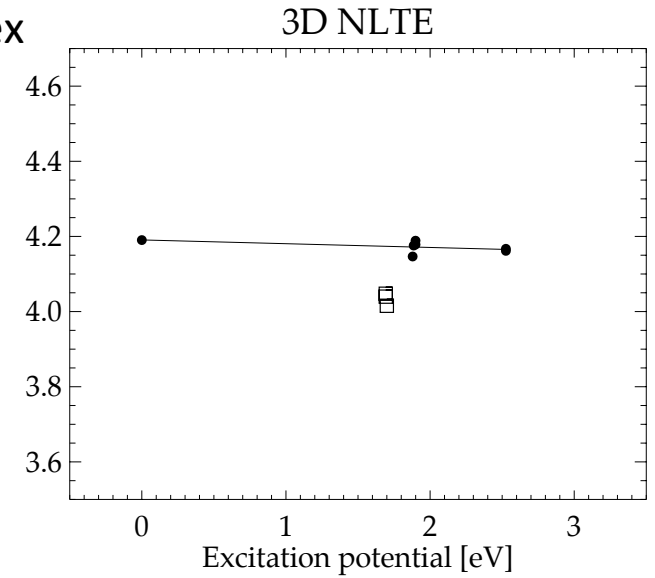
* CPU time to compute 10 spectral lines for one star

Example: Ca in metal-poor stars

Start ? Goal



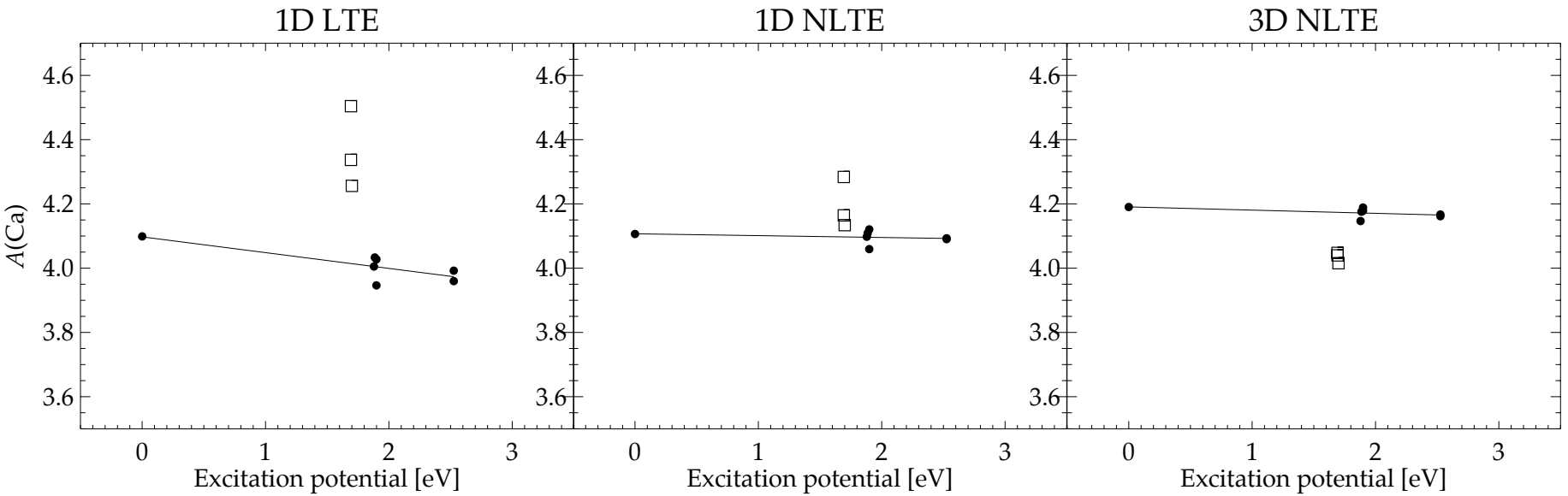
$\Delta(A(Ca)_{II} - A(Ca)_{I}) = 0.5$dex



Bullets: Optical CaI lines
Squares: NIR CaII triplet

Example: Ca in metal-poor stars

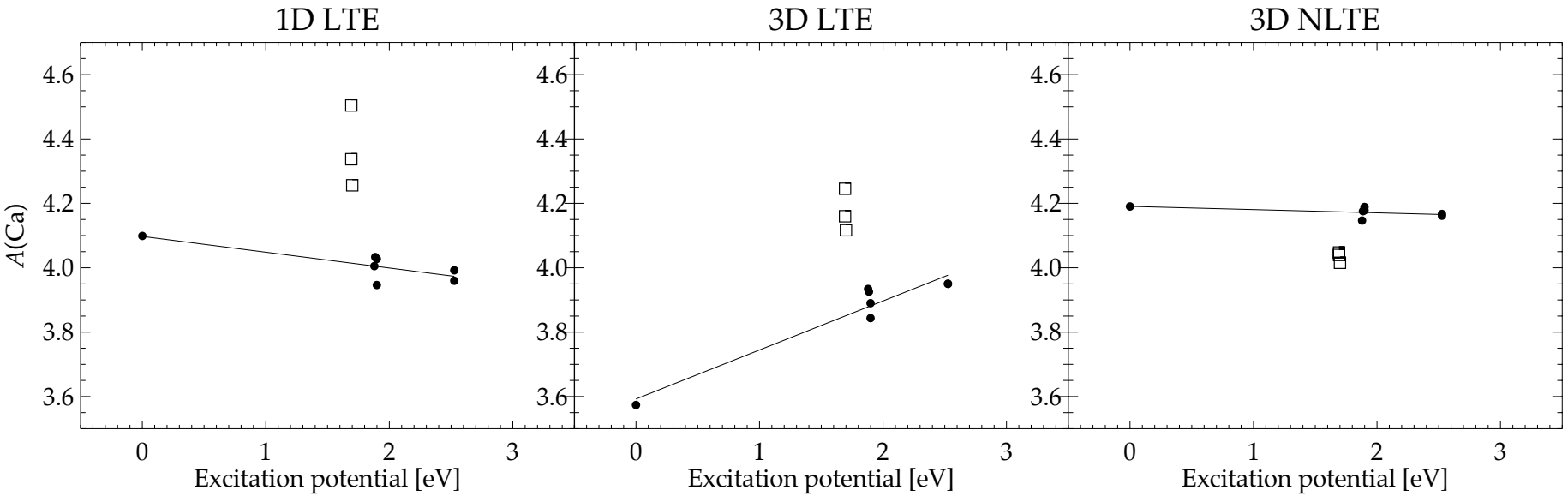
Start ? Goal



Bullets: Optical CaI lines
Squares: NIR CaII triplet

Example: Ca in metal-poor stars

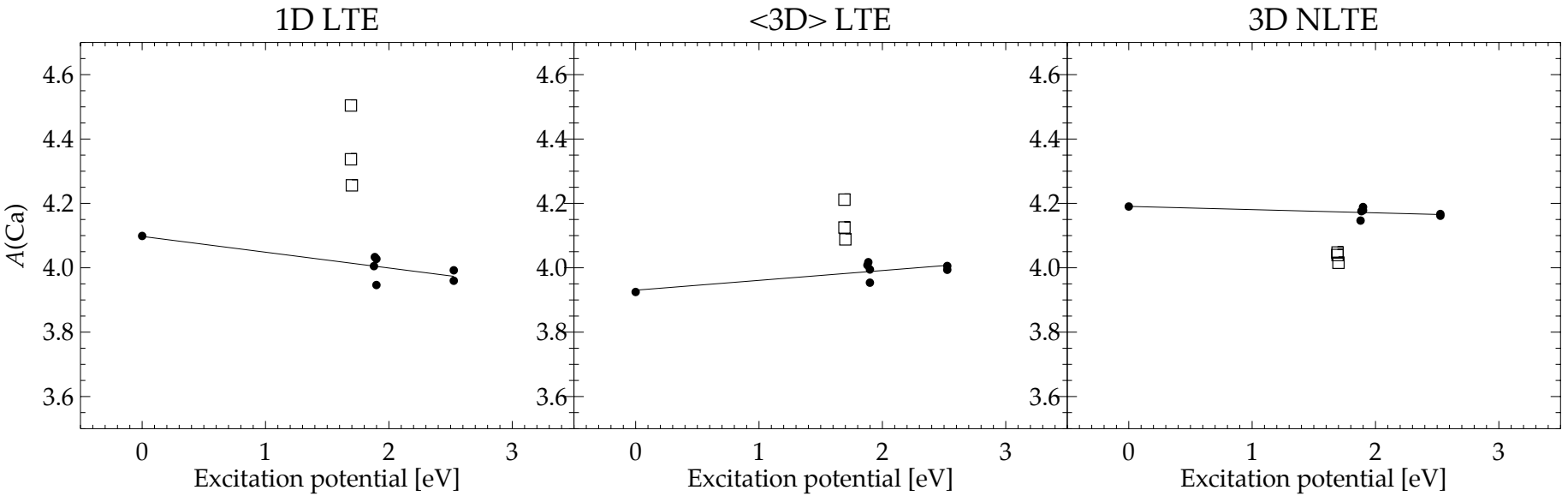
Start ? Goal



Bullets: Optical CaI lines
Squares: NIR CaII triplet

Example: Ca in metal-poor stars

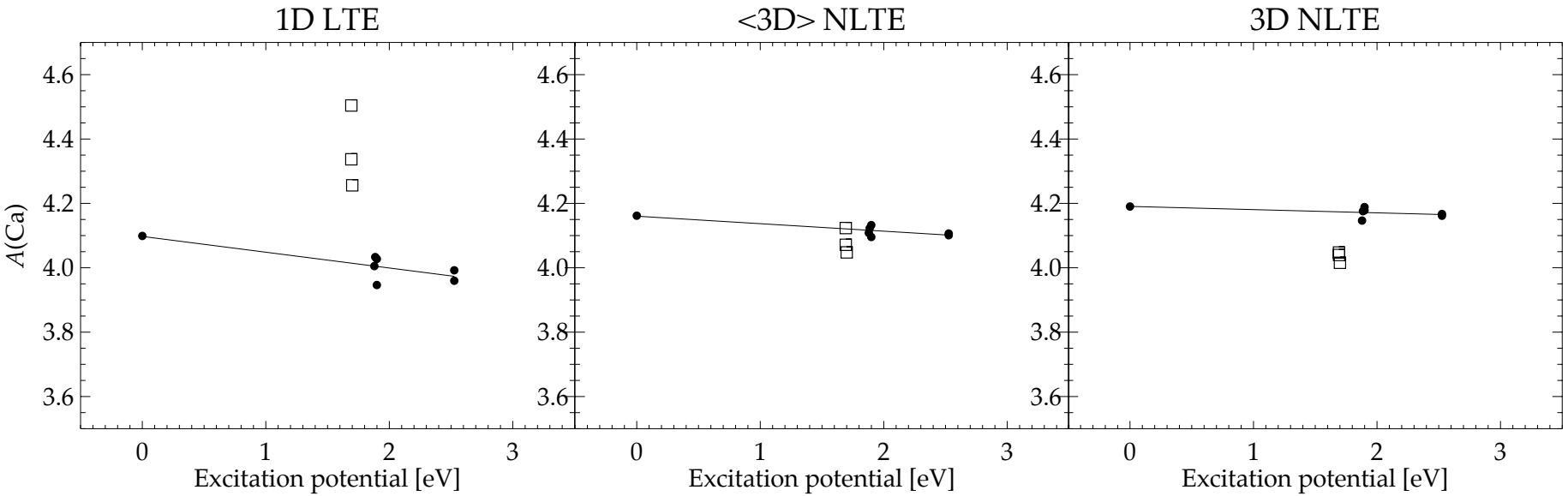
Start ? Goal



Bullets: Optical CaI lines
Squares: NIR CaII triplet

Example: Ca in metal-poor stars

Start ? Goal



Bullets: Optical CaI lines
Squares: NIR CaII triplet

Ways forward

Model	LTE/NLTE	Time*	Performance for Ca lines
1D	LTE	0.03s	Poor
→ 1D	NLTE	30s	Improvement for CaI and CaII
3D	LTE	30h	Improvement for CaII, not CaI
3D	NLTE	3000h	The ultimate goal, reference point
<3D>	LTE	0.03s	Improvement for CaII, not CaI
→ <3D>	NLTE	30s	Big improvement for CaI and CaII

* CPU time to compute 10 spectral lines for one star

Conclusions

- Spectroscopic parameters of FGK stars are affected by departures from LTE and 1D, hydrostatic equilibrium.
- NLTE analysis greatly improves in particular the ionisation balance of important elements (Ca, Fe)
- 1D NLTE and eventually <3D> NLTE analysis are feasible alternatives for analysis of large scale data sets.
- These will be implemented in the analysis of data from Gaia-ESO (SME, on-the-fly NLTE synthesis) and HERMES/Galah (Moog+NLTE corrections)

The INSPECT project

www.inspect-stars.net

Interpolate in grids of NLTE calculations to given stellar parameters and line strength