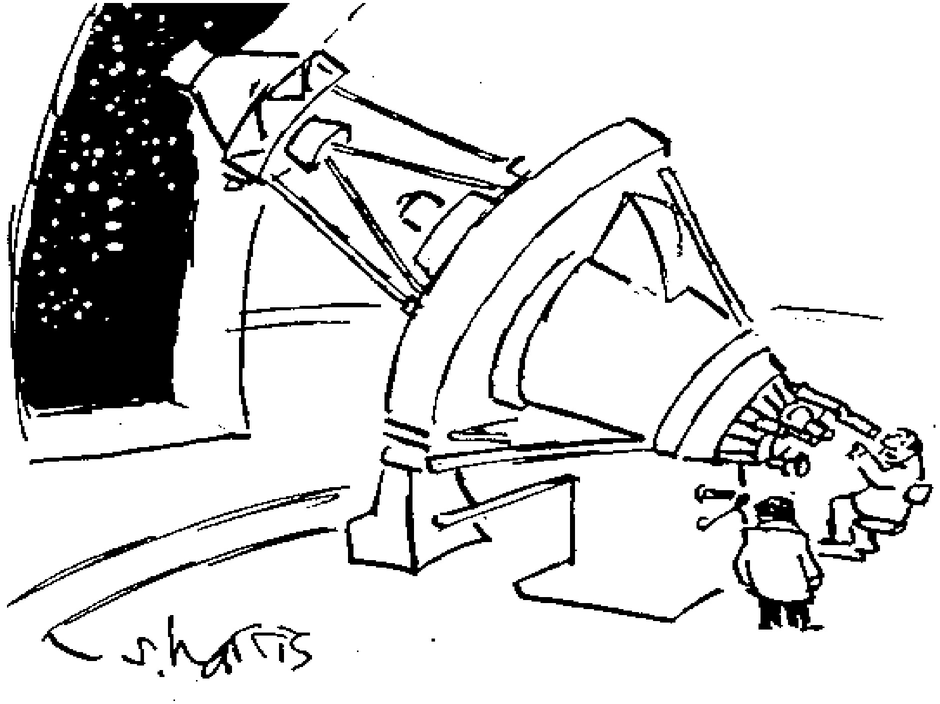
Planet Host Stars: Params & More

Lijiang – May 15th 2007



"Actually they all look alike to me."

Planet host stars, parameters and element abundances.

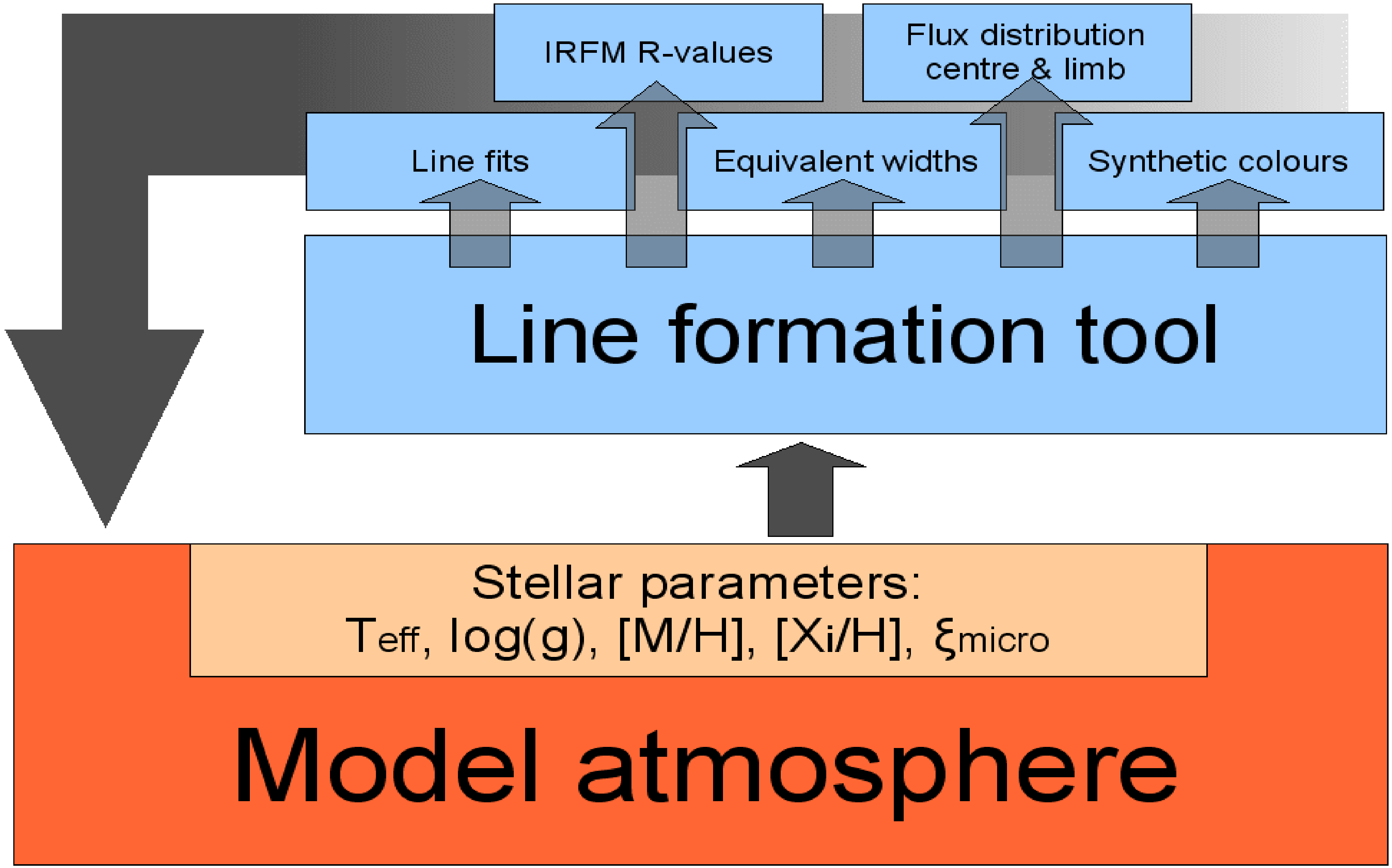
Our collaboration: The team

- Prof. ZHAO Gang and group:
  NLTE-element abundances
- Prof. Lyudmila MASHONKINA:
  *NLTE-element abundances, **Hydrogen in NLTE***
- Prof Thomas GEHREN:
  NLTE-element abundances
- Dr. Frank GRUPP:
  Model atmospheres, stellar parameters, instrument development

Planet host stars: Outline

- Model atmospheres – the **backbone** of it all
- Methods of determining stellar parameters
  - T_{eff}, log(g), [M/H], etc.
- Error sources:
  - Models: atmospheres
  - Line formation
- What can be done
- What should be improved

Model atmospheres: Backbone (1)



Model atmospheres: Backbone (2)

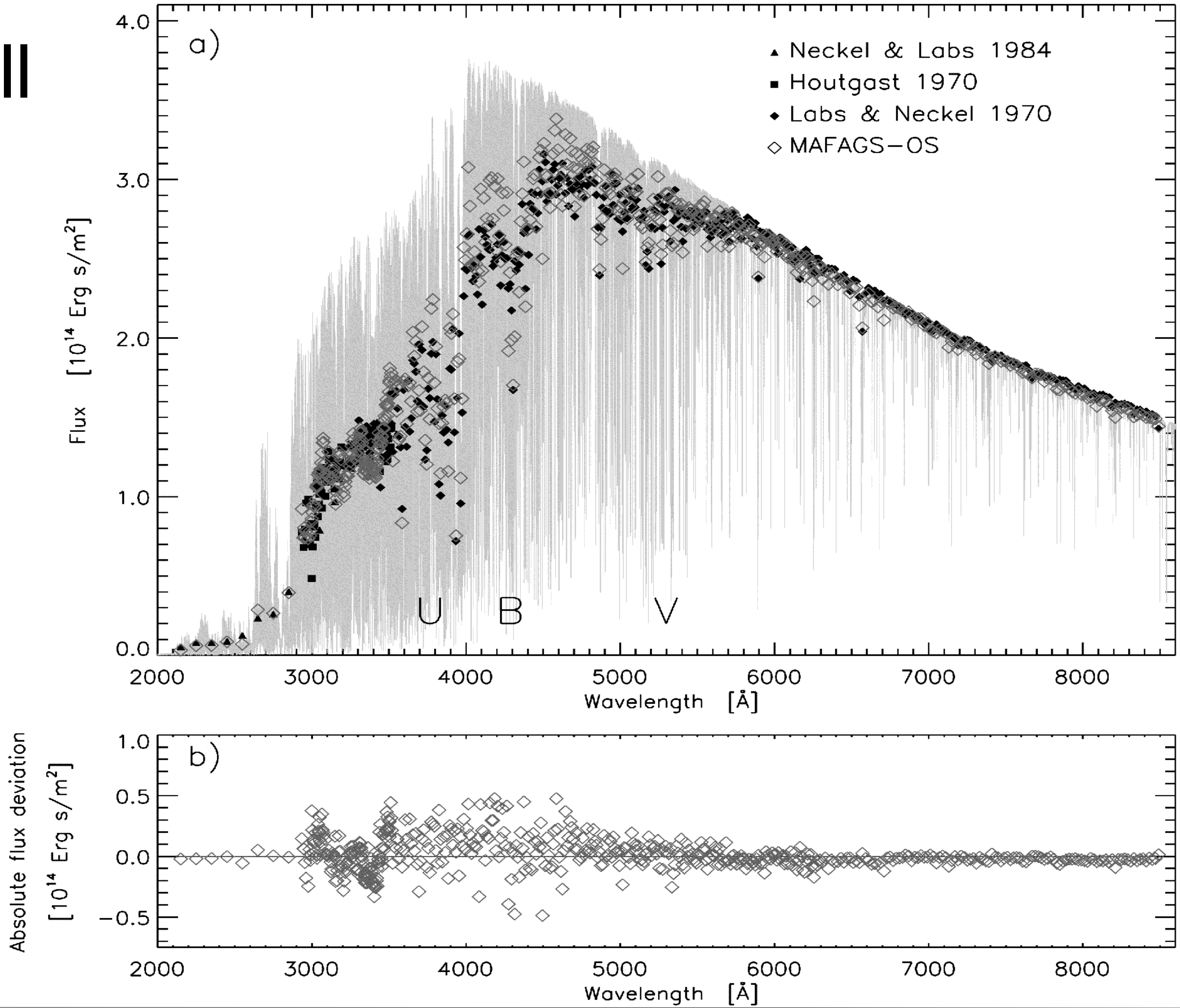
- There are different approaches to model atmosphere calculation:
  - 1D hydrostatic models: ATLAS, MARCS, MAFAGS
  - 3D hydrodynamic models: 3D (Nordlund)
  - Empirical models (for the sun): Holweger-Müller, Maltby ...
- In this talk: **1D, plane parallel, LTE, opacity sampling – MAFAGS-OS** (A&A 420, 289-305)
  - OS (MARCS, ATLAS12) ↔ ODF (ATLAS9)
- In this talk: **F & G-type stars**

Model atmospheres: Backbone (3)

- MAFAGS-OS
  - Optimized for A, F and G stars
  - Arbitrary element mixture possible due to OS
    - e.g. new CNO abundances of Asplund et al.
  - New, more accurate bound-free data for Fe I, Mg I & Al I (up to 1000 times larger than hydrogenic approx.)
  - 45' - 4h computation time

Model atmospheres: Backbone (4)

- Solar flux well reproduced
- Solar colors agree well



Stellar parameters: T_{eff}

- F and G-type stars
  - Infrared Flux Method, IRFM
  - **Balmer lines**
  - Theoretical colors
  - Empirical colors
  - Ionization equilibrium
  - Excitation equilibrium

Stellar parameters: T_{eff} - IRFM

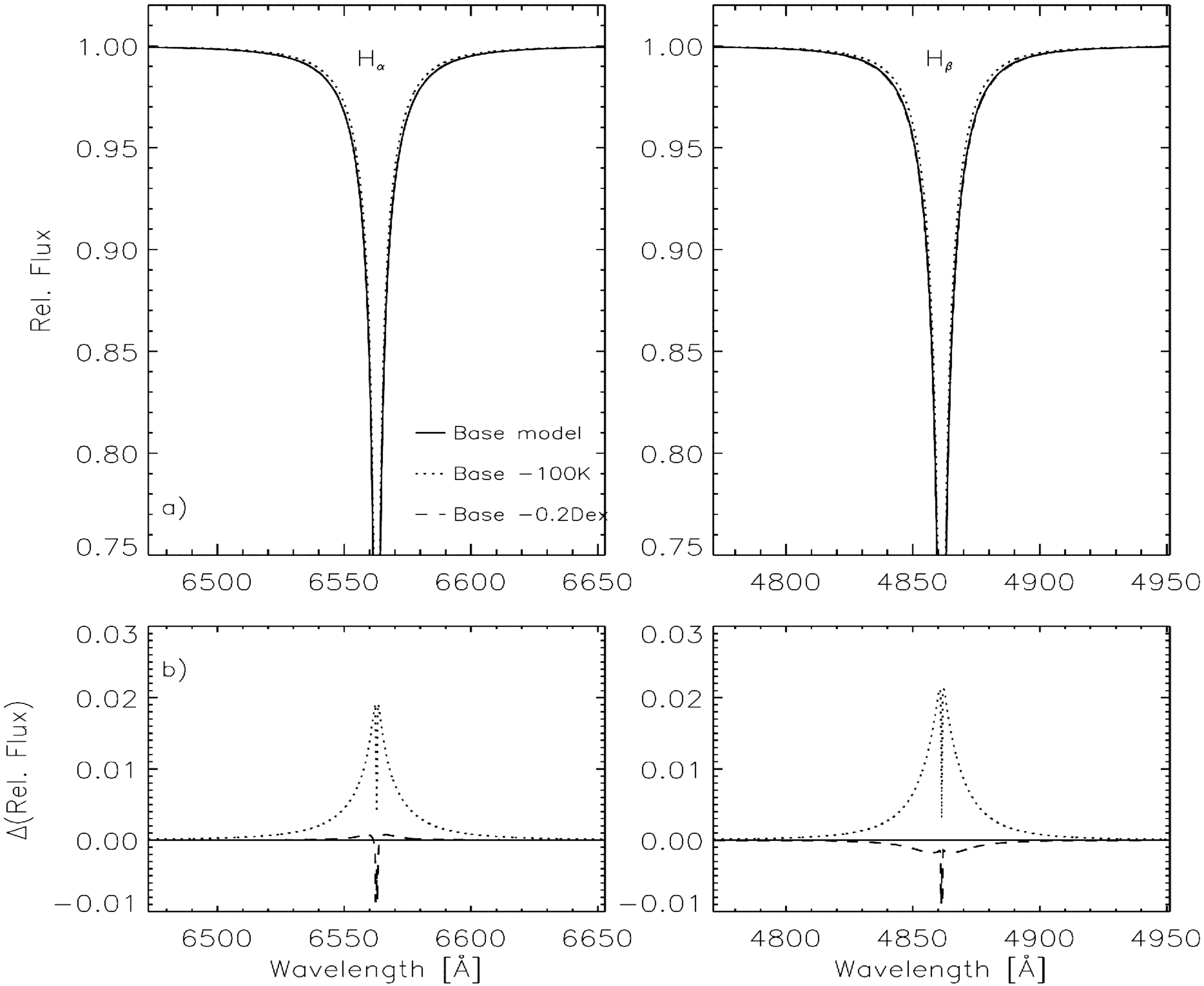
- InfraRed Flux Method
  - Comapres the ratio of IR-Colors to total flux between:
    - Theoretical model (model atmosphere flux distribution)
    - Measurement
  - As $F \approx T_{eff}^{\,4}$ this provides T_{eff}
  - Fewer opacity sources in the IR
    → often said to be ”model independent” ?!

Stellar parameters: Teff – Balmer lines

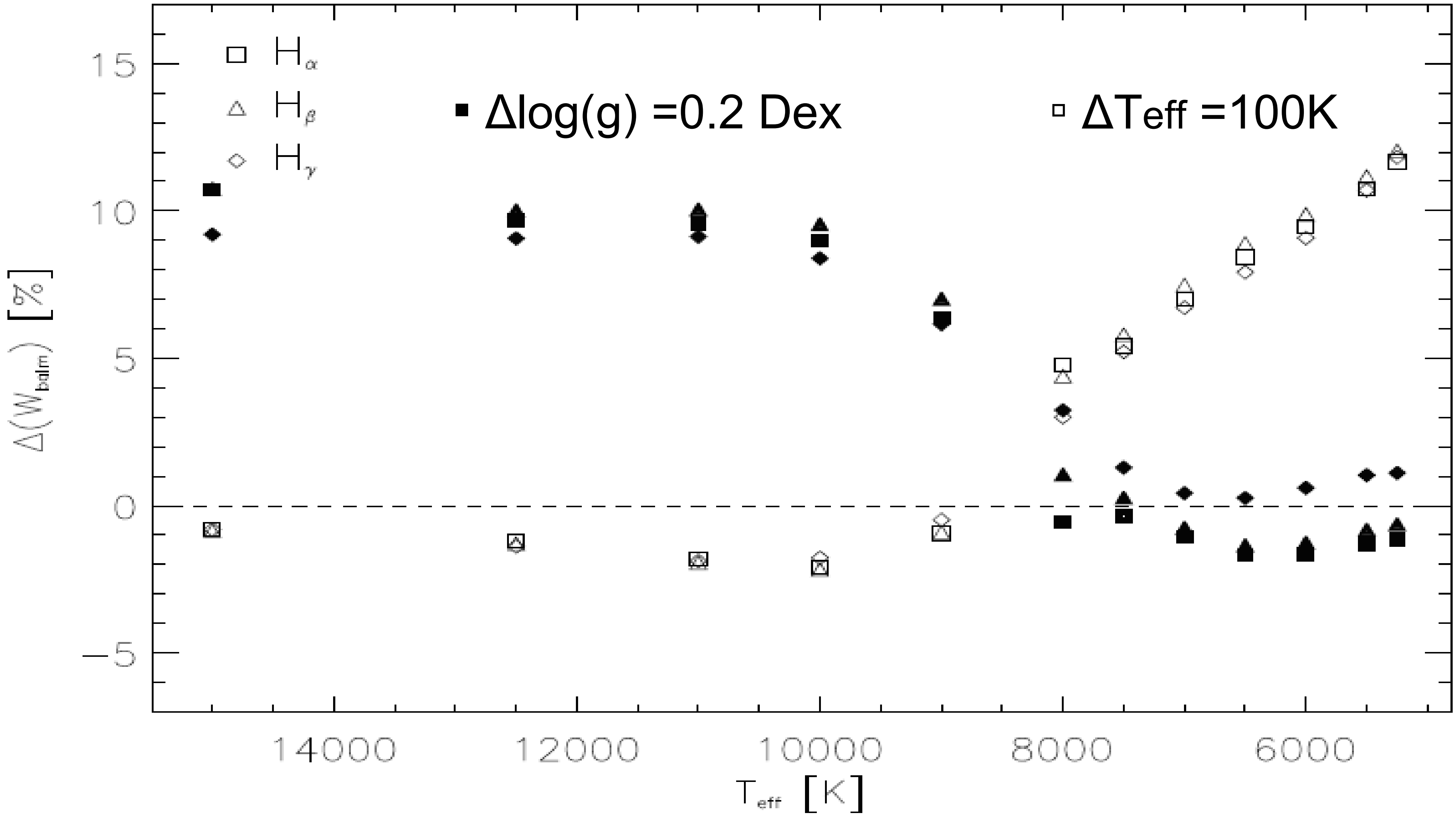
- Teff=6000K
- ΔTeff=100
- Δlog(g)=0.2

➔ Good Teff indicator

➔ Detailed spectral information

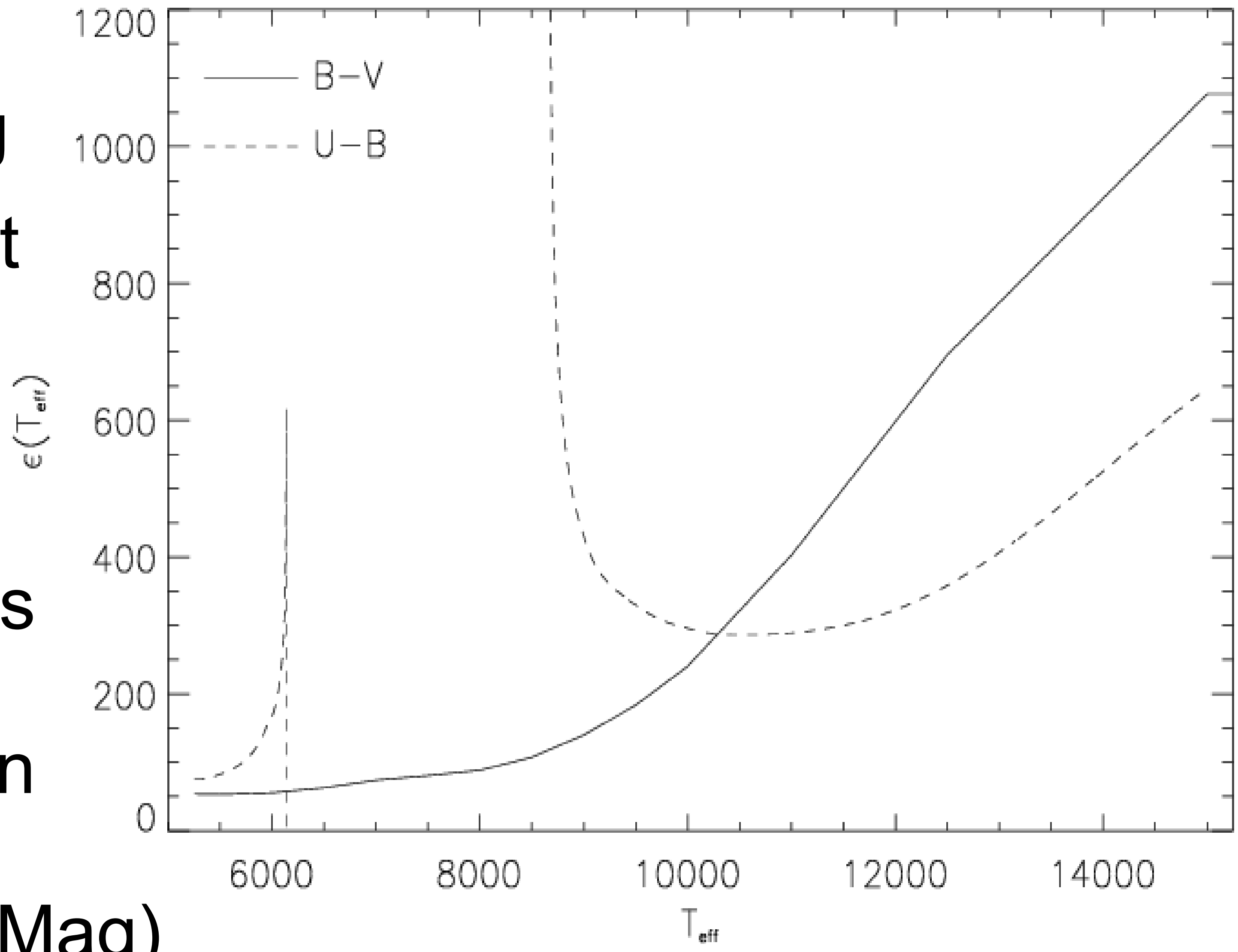


Stellar parameters: Teff – Balmer lines



Stellar parameters: Teff – Colors

- Colors: Δ=0.01Mag
- U-B can not be used for A & F-type stars
- Best models meet solar colors within 0.03 Mag... (ODF 0.08 Mag)



Stellar parameters: log(g)

- F and G-type stars
  - **Strong line method**
  - Ionization equilibria
  - Main sequence fitting
  - Colors

Stellar parameters: log(g) - Strong

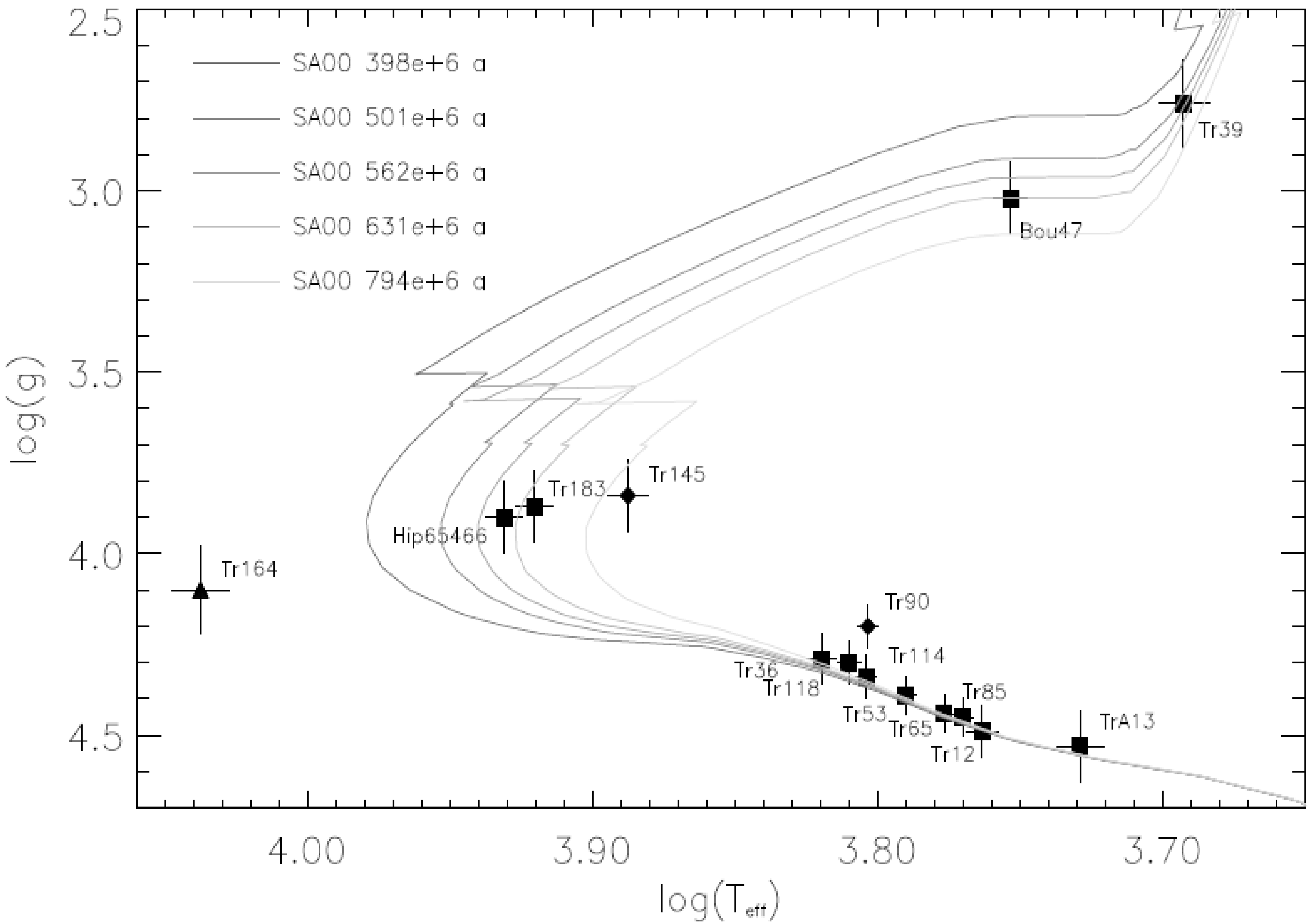
- Strong lines of eg. Mg, Fe, Ca are very pressure and therefore log(g) sensitive.
  - Measure element abundance using “weak” lines.
  - Use strong lines of the same element to measure log(g).
- Mg-b lines together with Mg 5711Å work well.
- If there is significant NLTE at work we are in trouble.

Stellar parameters: log(g) - IonEqui

- Ionization equilibria
  - Ionization equilibrium depends on electron pressure and therefore on log(g).
  - Very unequal partners, often 98% vs. 2%.
    Small changes in number → large changes in ratio.
  - Ionization is in most cases NLTE affected.
  - NLTE effects from other elements affect the test partners by their contribution to electron pressure.
  - In general: Results insecure by at least 0.2 Dex.

Stellar parameters: log(g) - Evolution

- Binarity?
- Membership?
- Field stars?

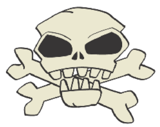


Stellar parameters: Abundances

- **Line fitting (LTE & NLTE)**
- Equivalent width (LTE & NLTE)

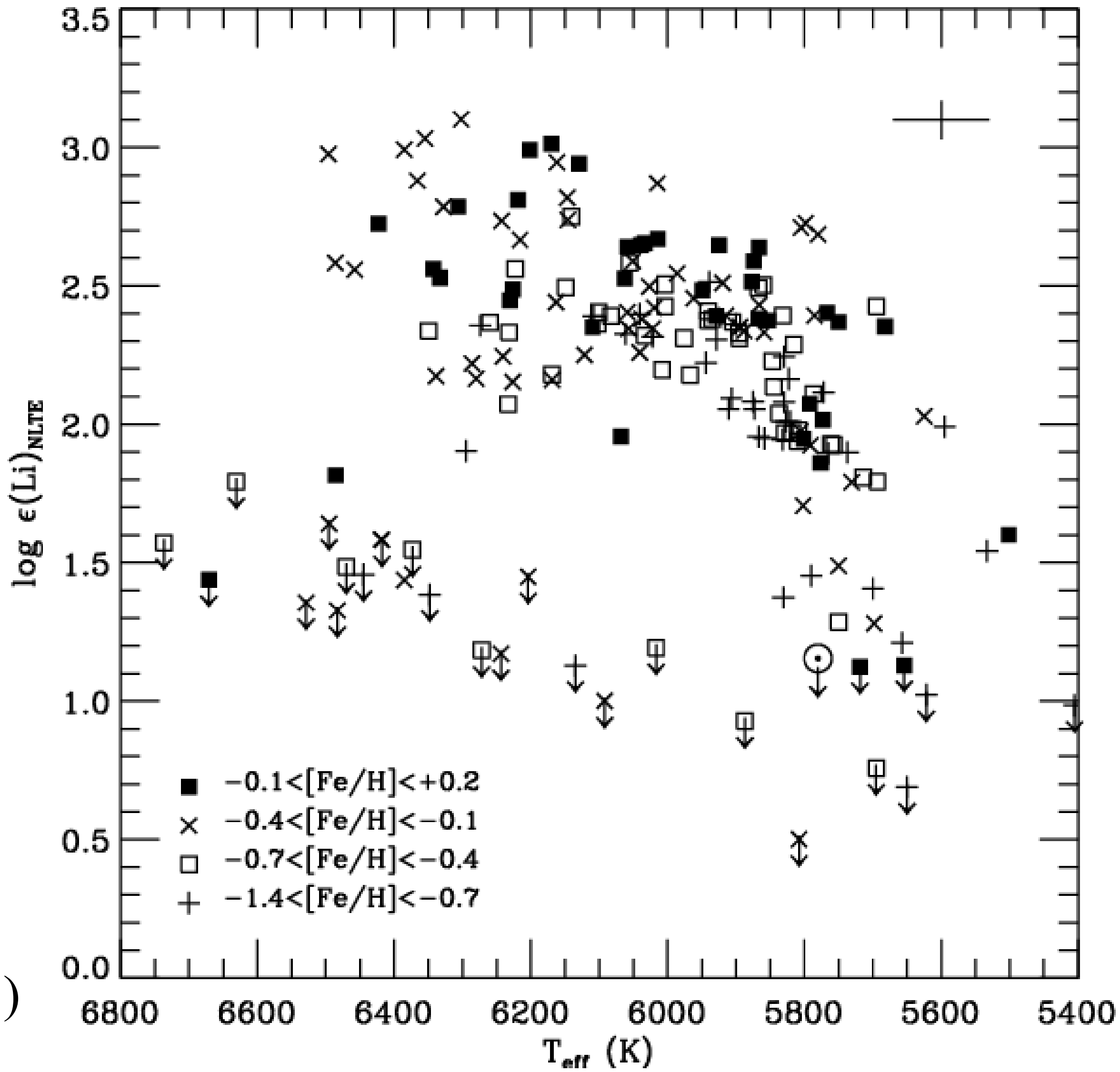
Stellar parameters: Abundances

- [Fe/H] often used as “general metalicity”
- [α/Fe] with α=O, Ne, **Mg**, Si, S & Ca overabundant in metal poor stars
  - O is important opacity contributor
  - α-elements are important electron donators
- Determined by individual line fits.
- EW is an integrated number that tells few about the quality of a fit.
- SME - “spectroscopy made easy” ...



Stellar parameters: Abundances

- Li (NLTE)
  - Significant "scatter"
  - Is this real?

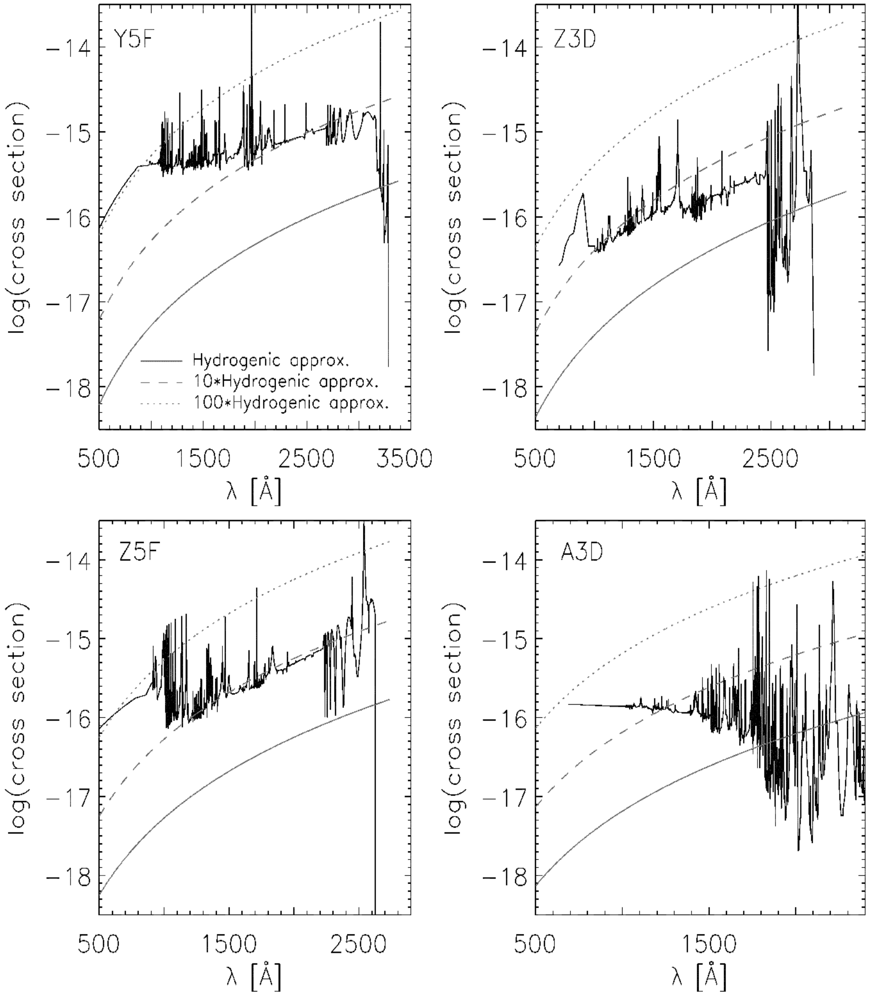


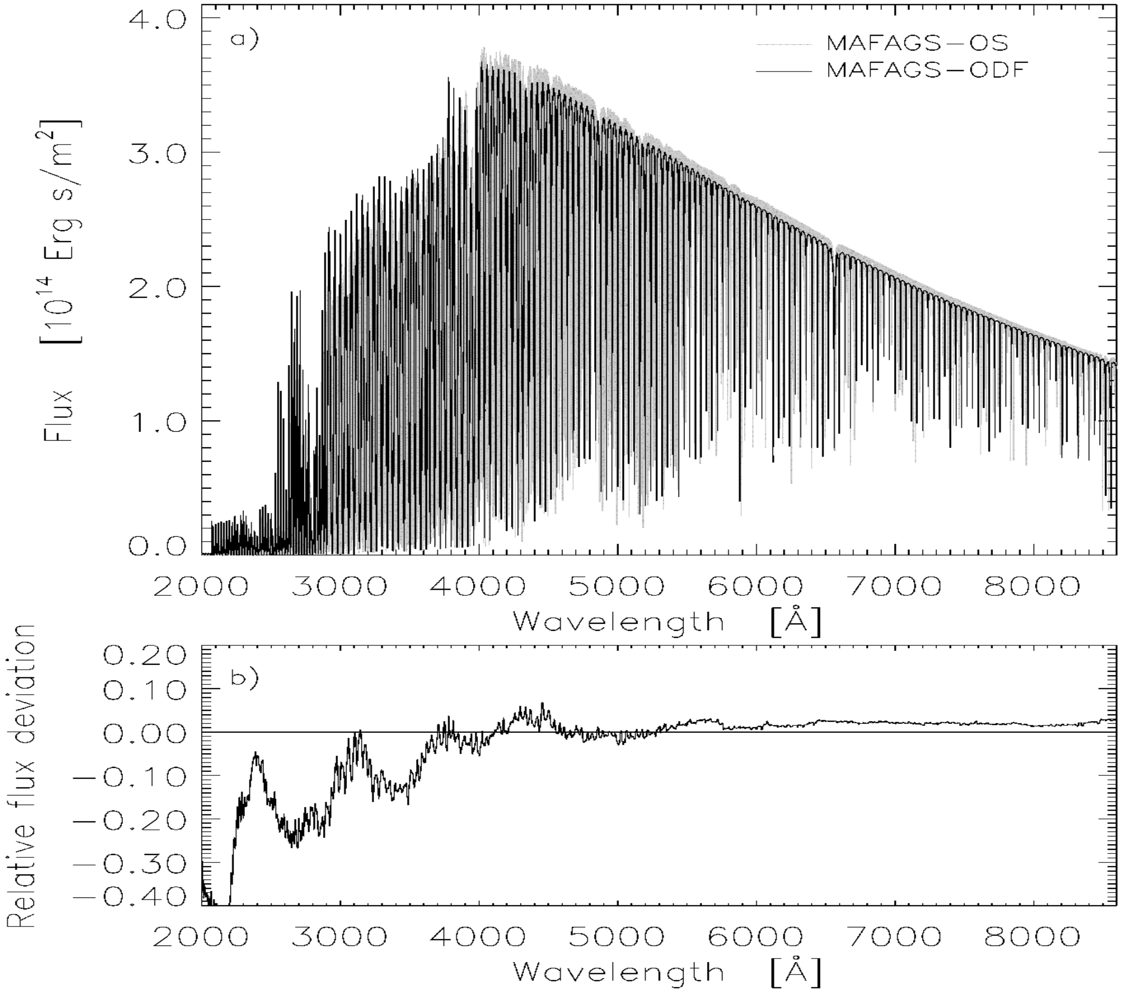
Chen, Nissen, Benoni, Zhao (2001)

Stellar parameters:Error sources

- Model
  - Computational limitations (≈10K for 1D models)
  - **Opacity data**
  - Treatment of convection
  - Solar element abundances (C,N,O, .. Ne,..Fe)
  - **Balmer line broadening**
  - **LTE vs. NonLTE**
  - ...
- Observation
  - High resolution spectroscopy (noise, normalization)
  - Photometry (standards, system transformation ...)

Error sources: Model atmospheres

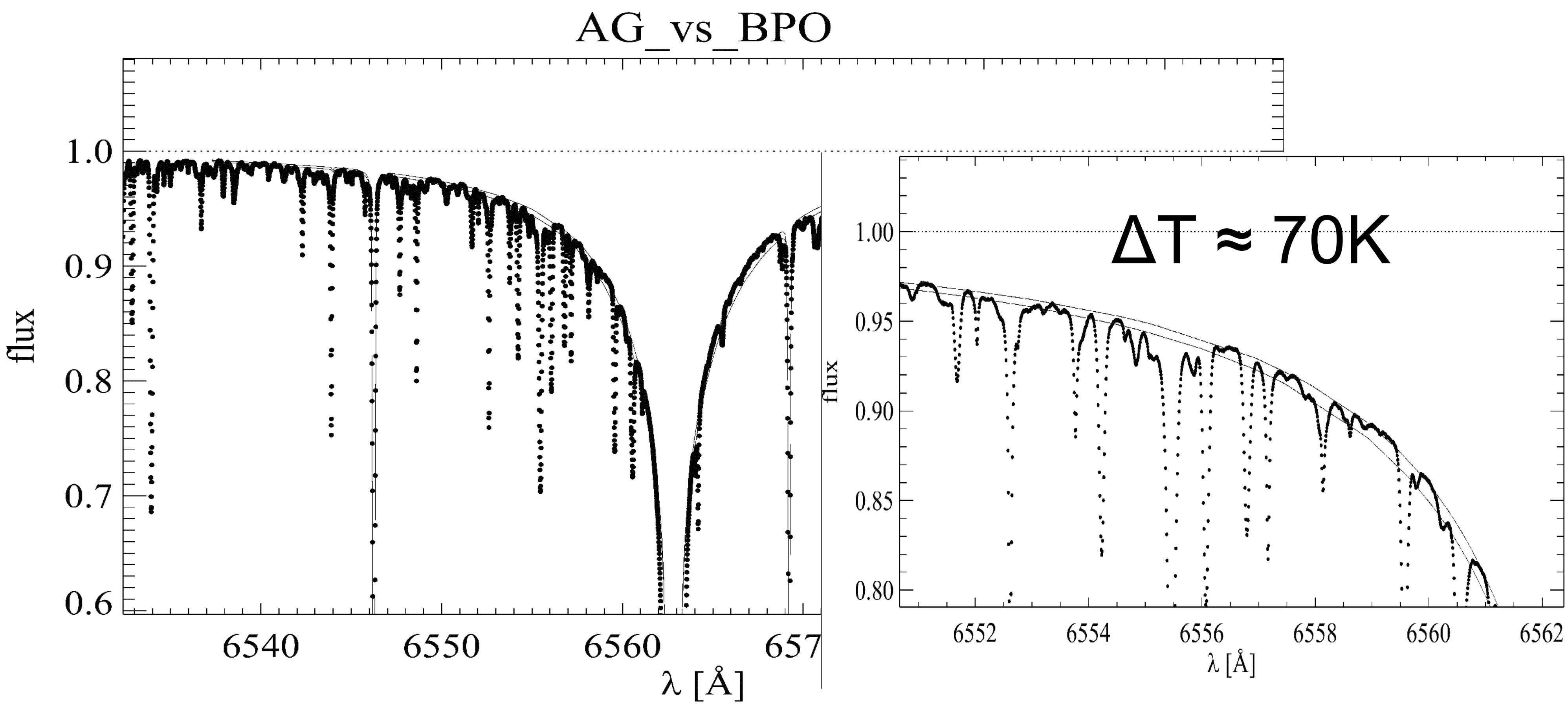




More UV-opacity → Flux redistribution to the red

Error sources: Resonance broad.

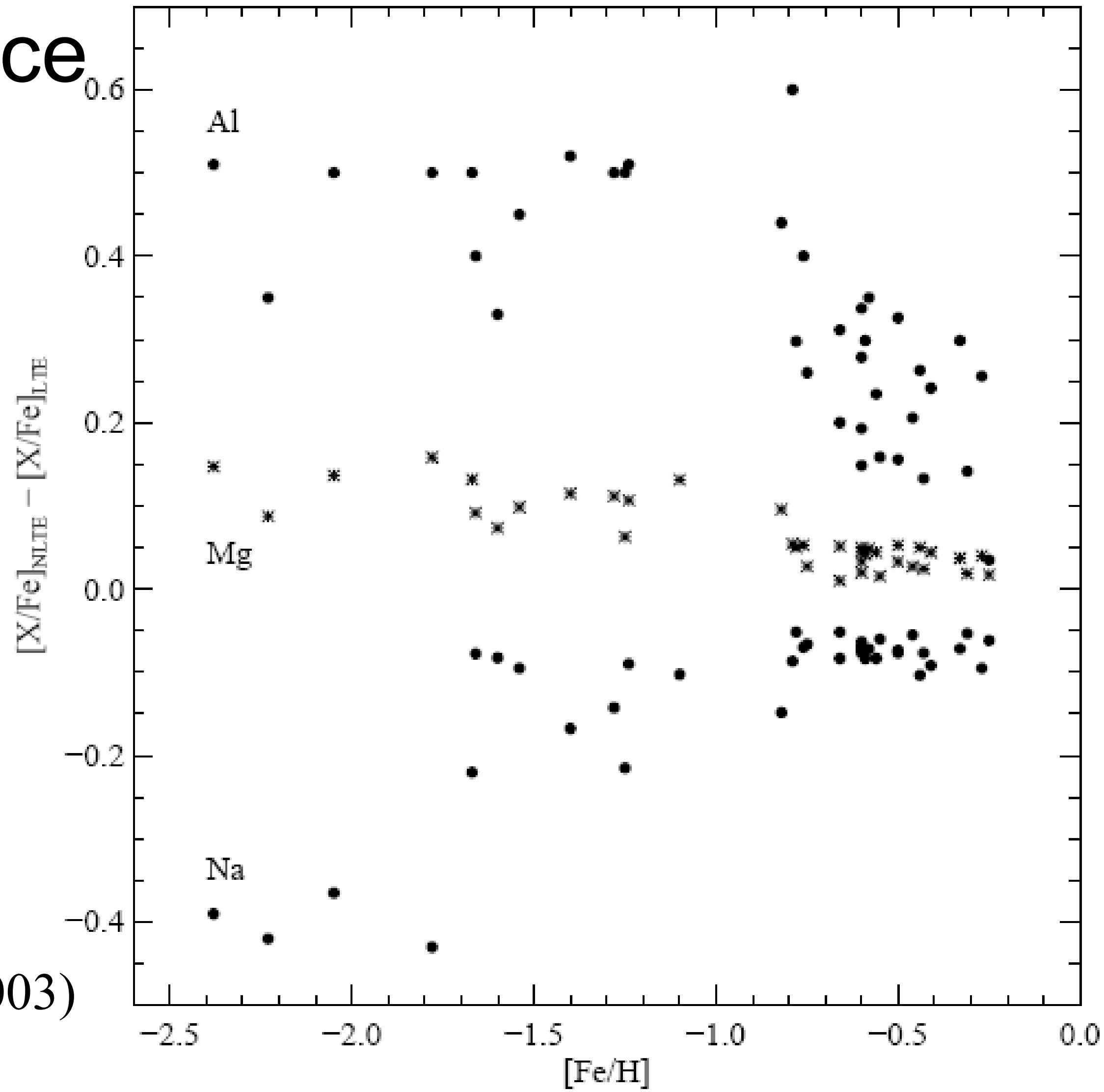
- There are concurrent theories of resonance broadening for Balmer lines



Error sources: LTE vs. NLTE (1)

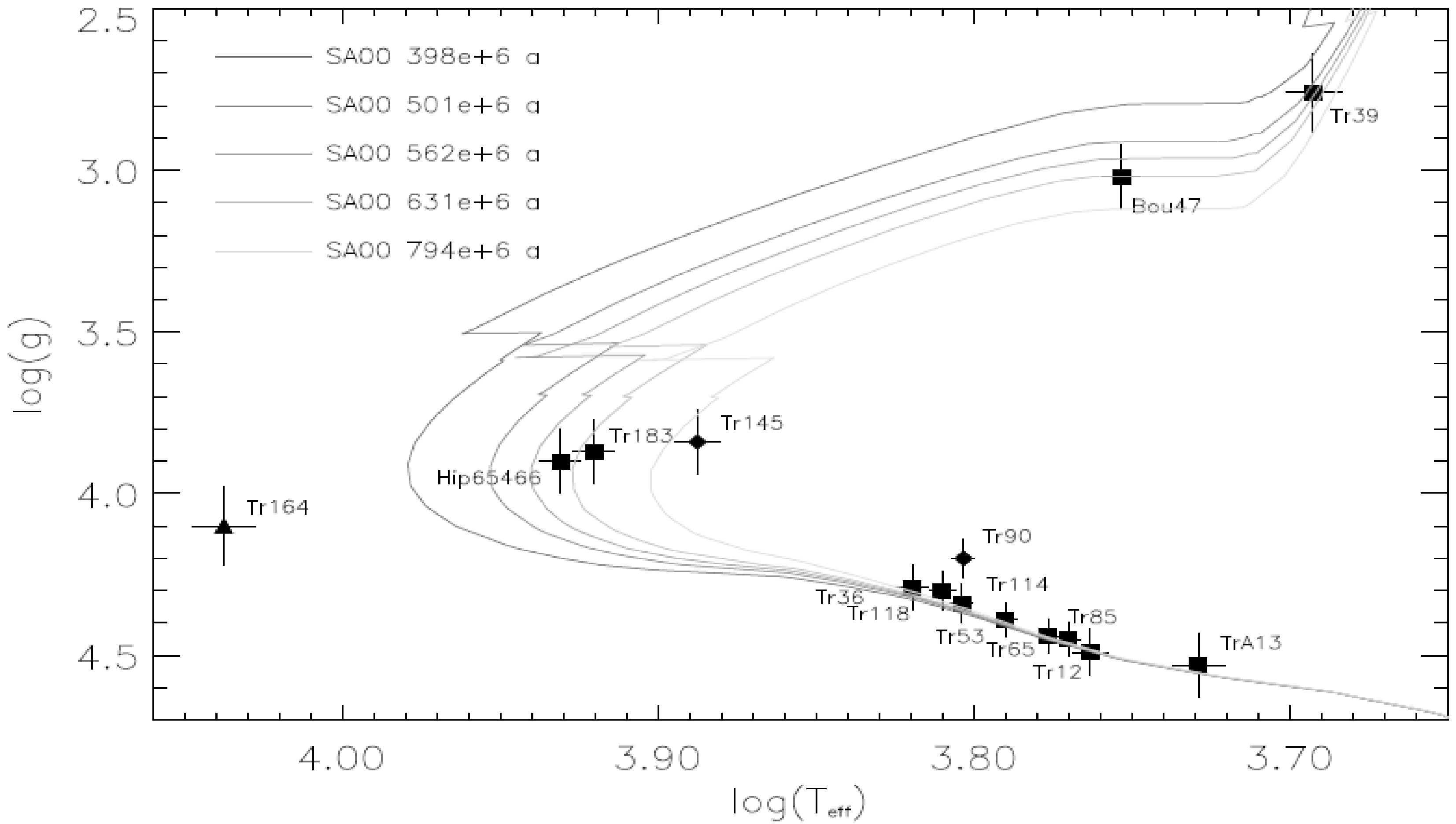
- NLTE / LTE difference
- As large as 0.5 Dex
- Too large to tell anything about chemical evolution

Gehren, Liang, Shi, Zhang, Zhao (2003)



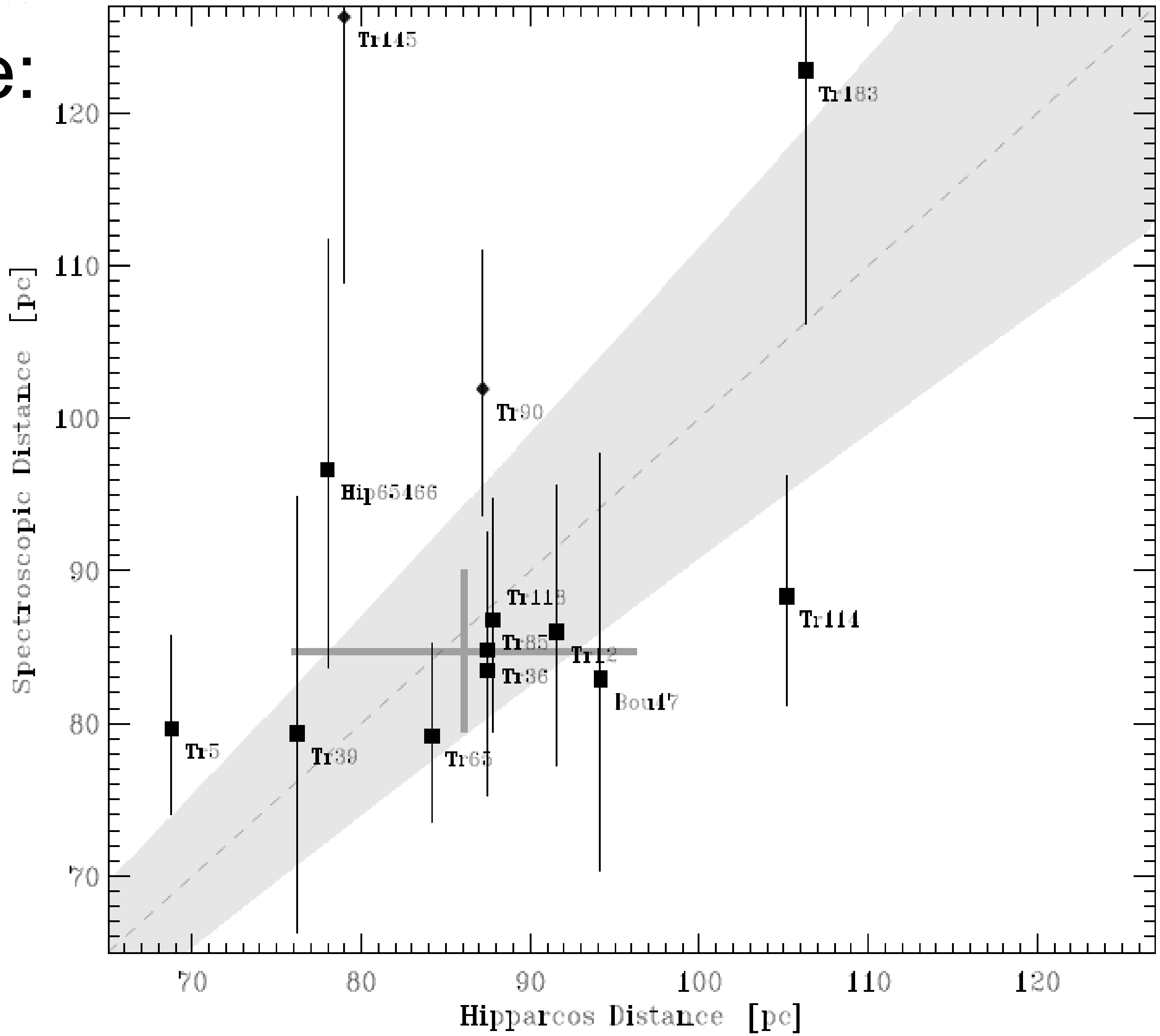
What can be done (1)

- Mel111, age determination



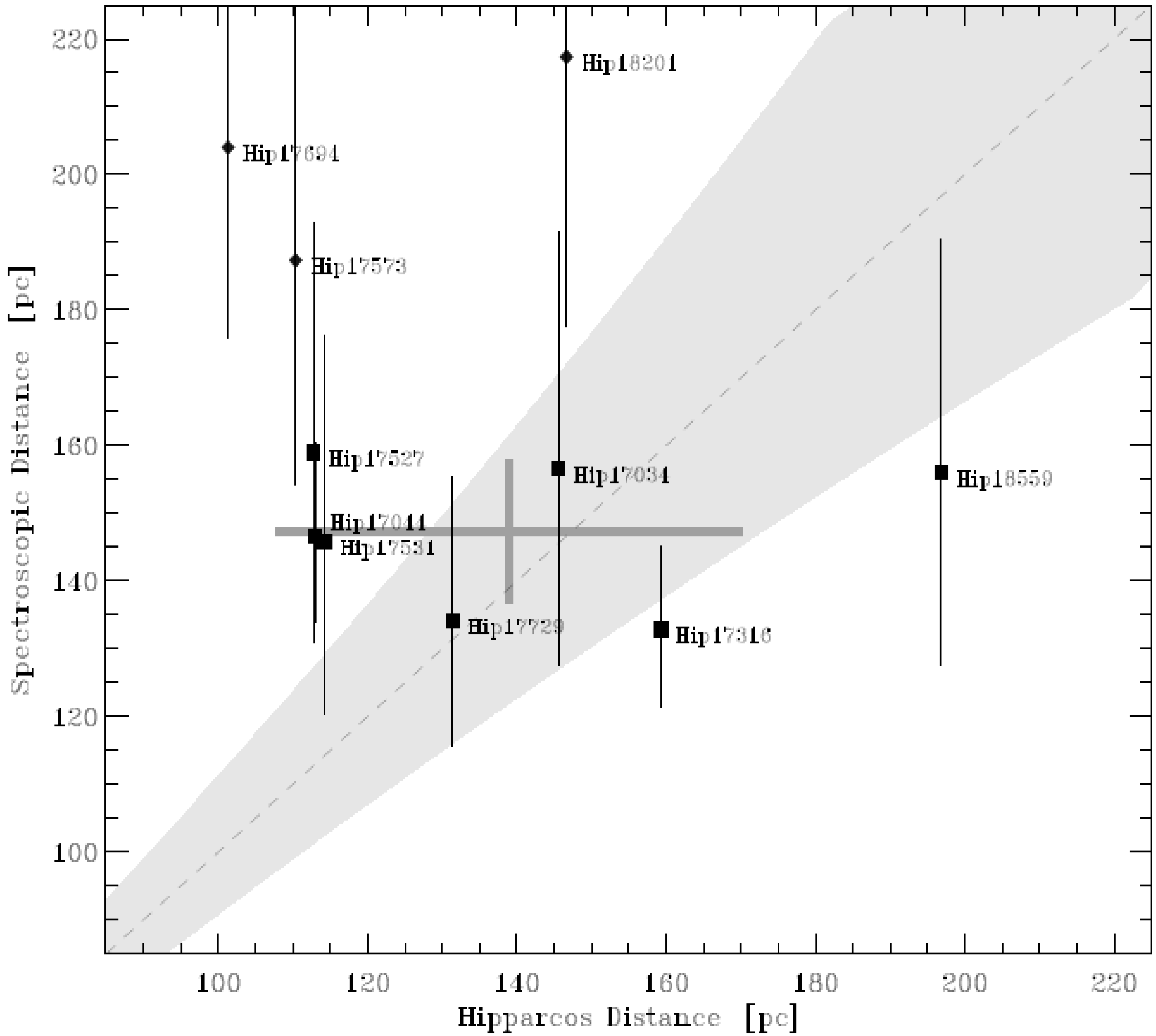
What can be done (2)

- Mel111 distance: Hipparcos vs. spectroscopic
- Note the error-bars



What can be done (3)

- Pleiades distance: Hipparcos vs. spectroscopic
- Now spectro. is even better!

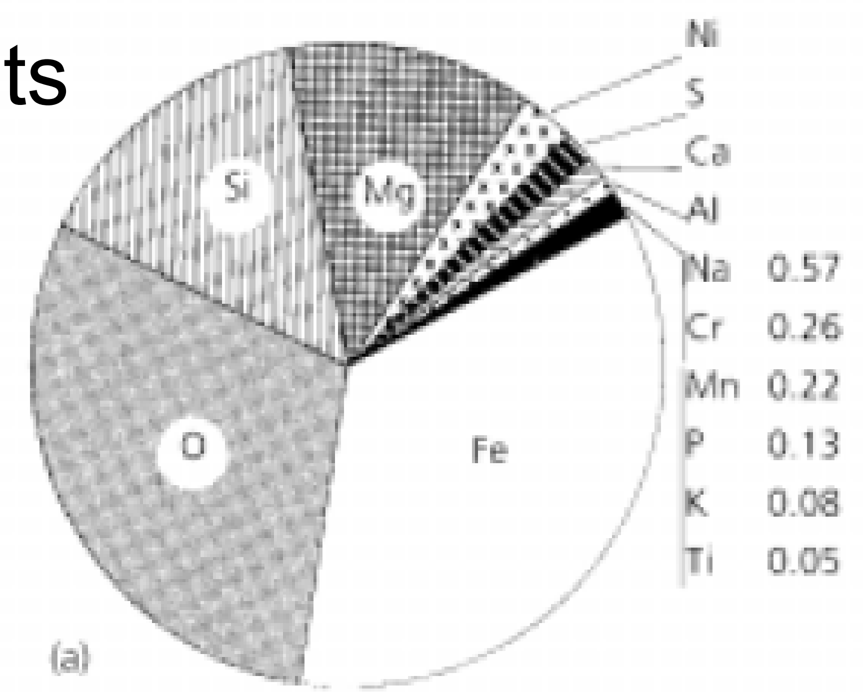


Summary:

- We are able to determine stellar parameters with reasonable accuracy
  - Using Balmer lines for effective temperatures
  - Broad lines (Mg-b) for log(g)
  - Fe for metalicity
  - Mg for α-element enhancement
- We can determine good NLTE abundances
- LTE is a real danger – remember, Δ(LTE,NLTE) may reach 0.5 Dex

Planet host stars: Rocky planets

- Rocky planets consist of Fe, O, Si, Mg, ...
- So these elements should miss in the stars that have formed rocky planets
- Very precise measurements needed (effect is small)
  - Best parameters
  - NLTE analysis
  - Main-sequences of OC



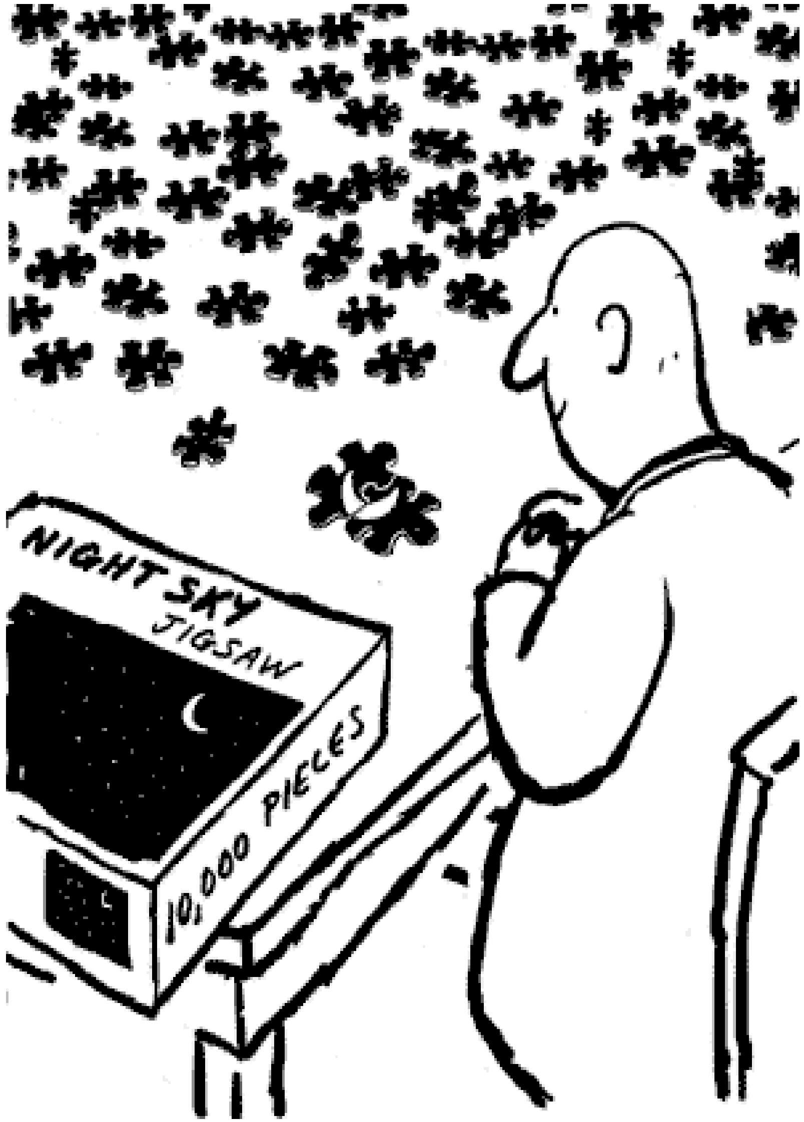
What should be improved

- Modern telescopes and spectrographs increased observational quality dramatically.
- Model insecurities today level observational errors → need to improve on theory!
- Theory needs to keep pace with >VLT projects.
  - NLTE for hydrogen Balmer lines
  - NLTE for Mg-b lines (and all other elements)
  - Better tests of the atmospheric models
  - Better instruments that allow for good continuum rectification and continuous spectra

Planet host stars: Parameters

- Thanks to the organizers of the conference!
- If anybody needs MAFAGS atmospheric models, feel free to contact me.
- We need large telescopes dedicated to spectroscopy!

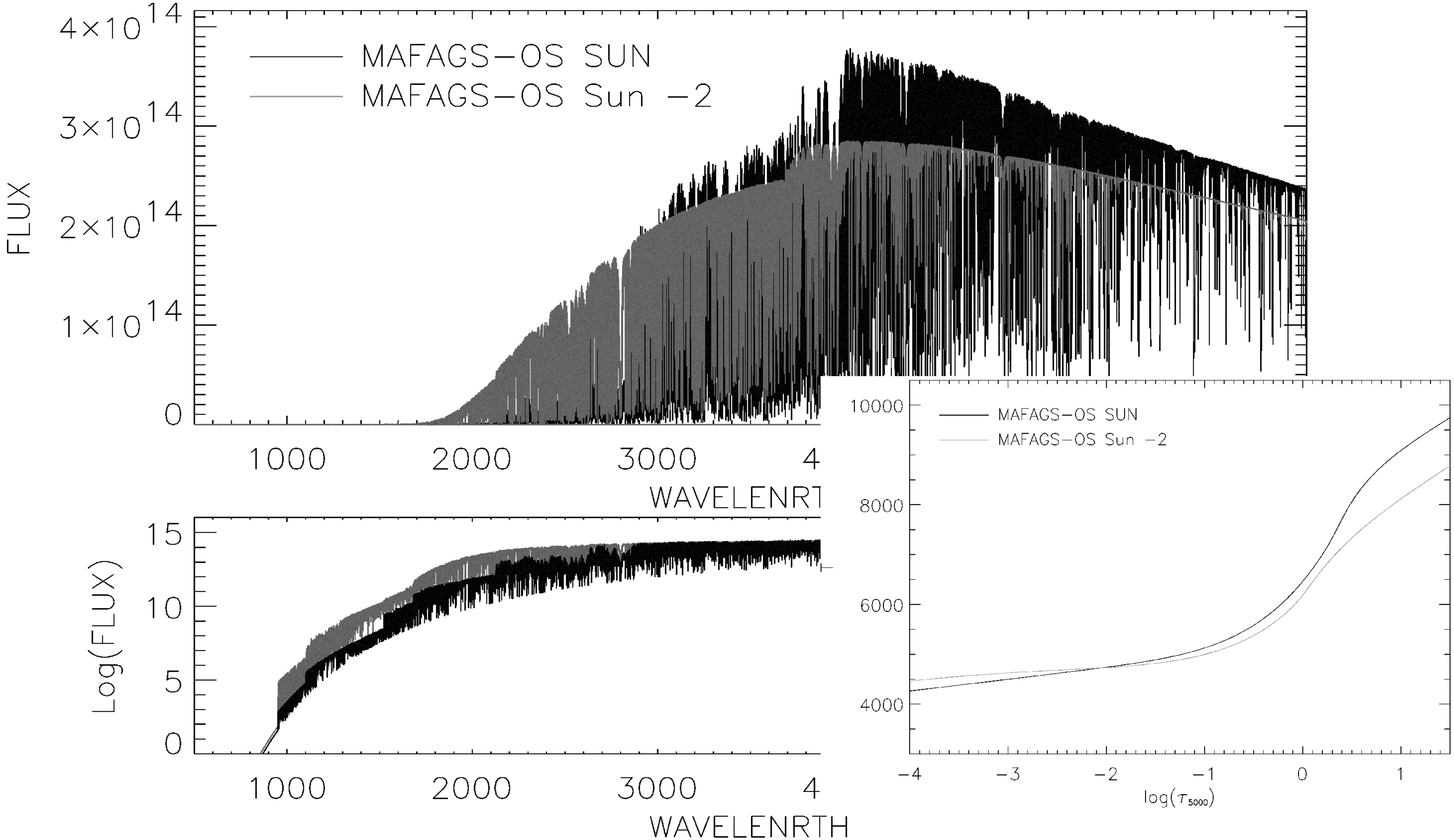
Thank you for your attention!



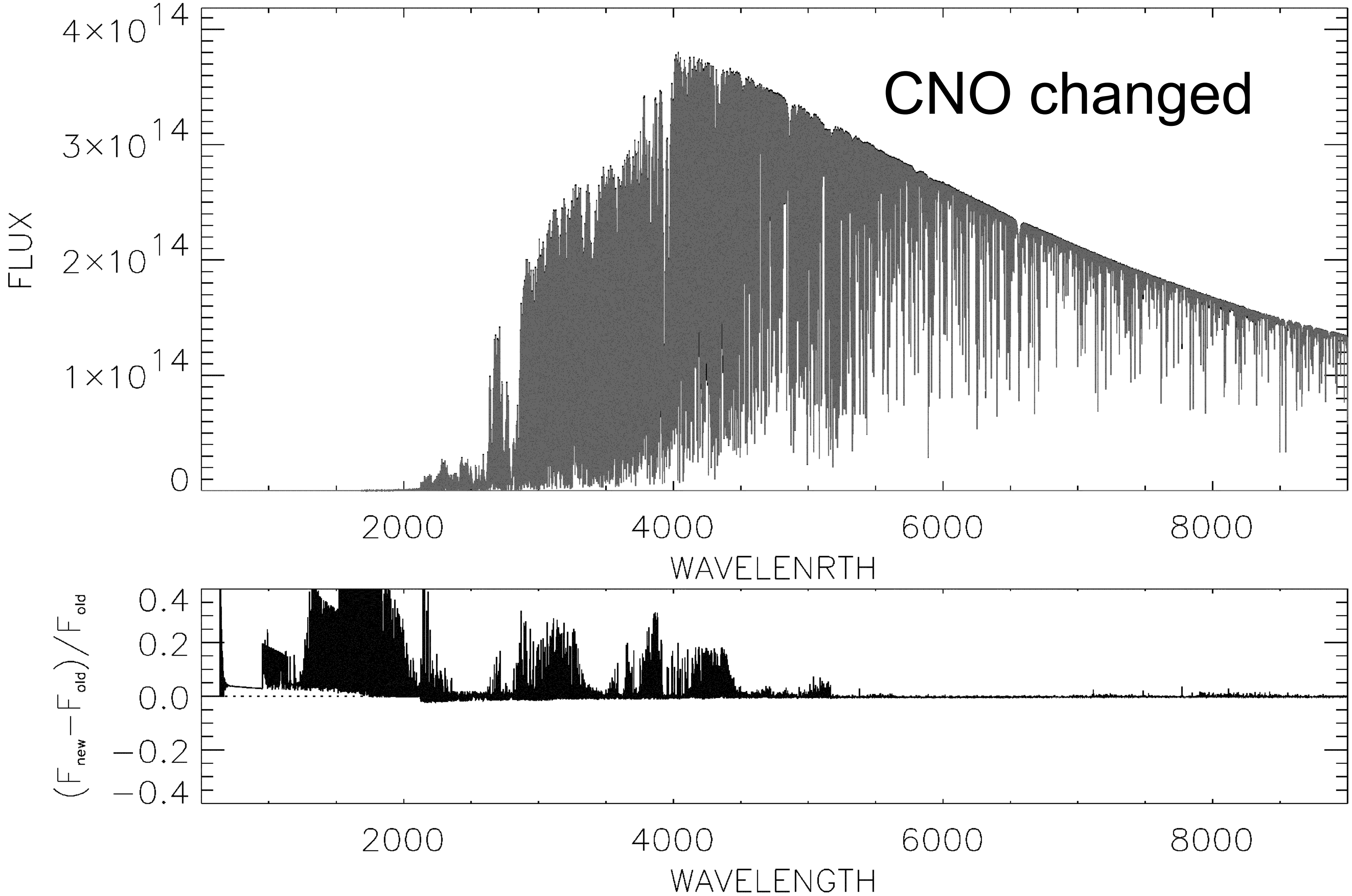
A few words on differential analysis...

- Differential analysis require:
  - Comparable physics throughout the model
    - Comparable temperature structure
    - Comparable pressure structure
    - Comparable flux structure (photo-ionization)
    - Comparable convective structure

A few words on differential analysis...



Error sources: Solar abundances



Total error budget: Contributers (Sun)

	IRFM	U-B	B-V	Balmer
Computation	10	10	10	10
ODF→OS(bf-cross)	60	170	55	50
Convection (1D)	10	10	5	30
CNO	15	40	20	15
Fe	30	30	25	25
Balmer				60
Observation	50			

Total error budget: The T_{eff} error bar

Neither Gaussian error propagation nor total sum are the real thing! (e.g. Balmer line broadening)

It is a "budget" and it depends on the science how much you "spend".

	Quadratic	Total
IRFM	±70 K	±125 K
U-B / B-V	±180/65 K	±260/115 K
Balmer	±90 K	±190 K

Model insecurities ≥ observational insecurities.
Better observations VLT/ELT need better models!