Non-LTE line formation for trace elements in stellar atmospheres,
July 30 – August 4, 2007, Nice, France

Resonance broadending and van der Waals broadening

Lyudmila Mashonkina
Institute of Astronomy, Russian Academy of Sciences

Introduction

The interaction atom A + atom A $\rightarrow$ resonance broadening.

The change in energy ~ r^{-3}.

- The only important interactions are H + H

in the atmospheres where hydrogen is largely neutral.

F and later type stars.

The interaction atom A + atom B $\rightarrow$ van der Waals broadening.

The change in energy ~ r^{-6}.

- The most important perturbing particles are H, He, and H_2.

Effect is significant in the atmospheres where both the absorbers and H, He, H_2 are mainly neutral.

F and later type stars.

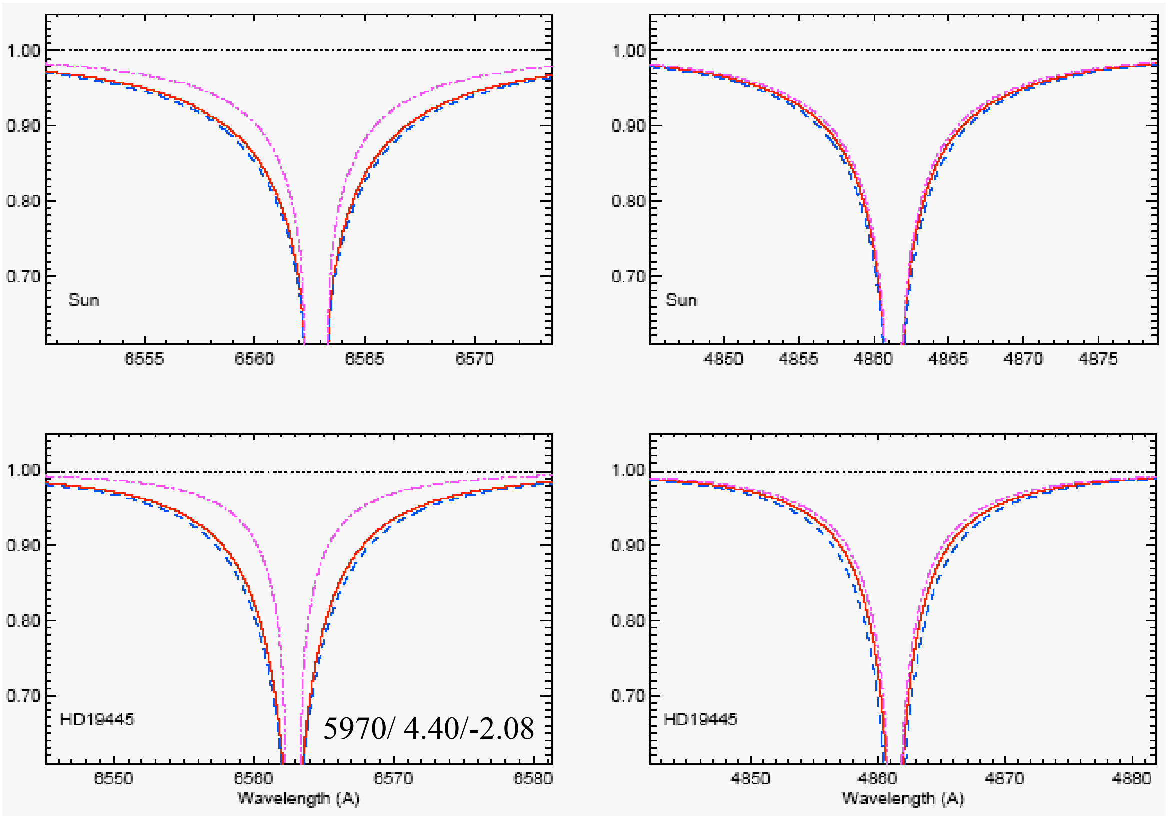
Self-broadening of hydrogen lines

H atoms undergo both resonance and van der Waals interactions. Their combined effect is referred to as self-broadening.

-·-·-·- linear Stark effect + natural damp. + Doppler,

—— + resonance broadening of *Ali&Griem* (1965),

- - - - self-broadening of *Barklem et al.* (2000).



Resonance broadening is more important for the first members of the series.

What is the effect of varying a self-broadening on a derivation of T_{eff} from fitting observed line wings of H_α and H_β?

Non-LTE line formation for H I
(*Mashonkina et al.* 2007b).

Sun

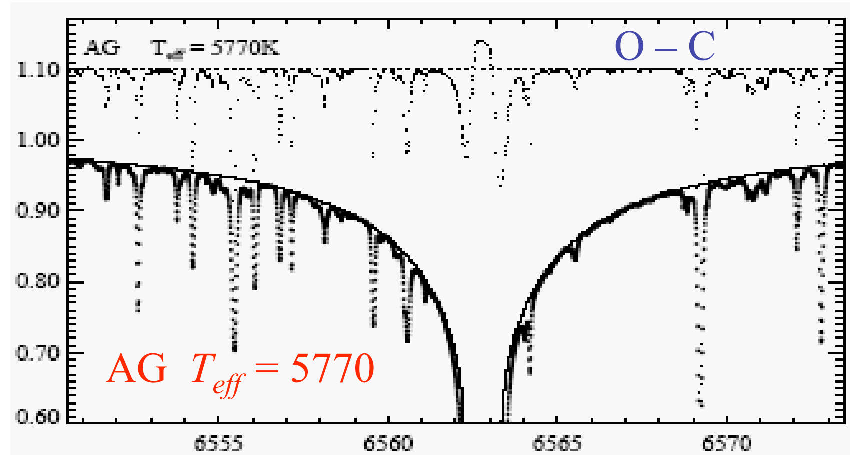
$T_{eff}(AG)$ = 5770 K,

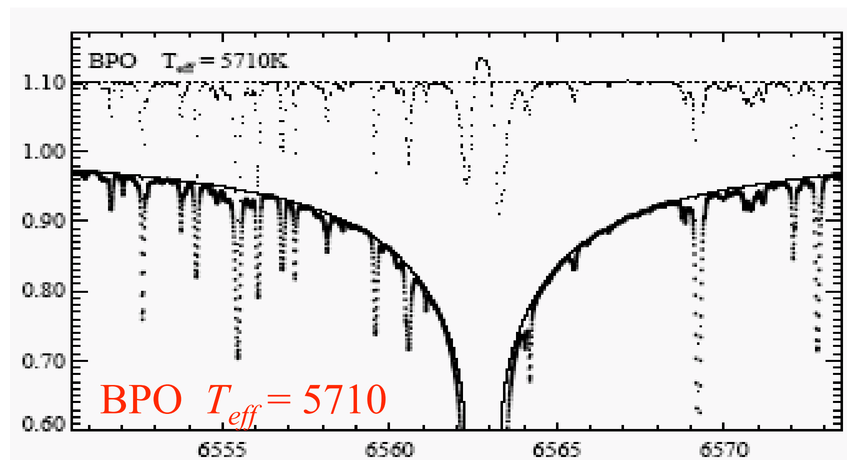
$\Delta T_{eff}(AG - BPO)$ = 60 K,

ΔT_{eff}(NLTE - LTE) = 20 K.

MAFAGS model atmospheres
(*Fuhrmann et al.* 1997).

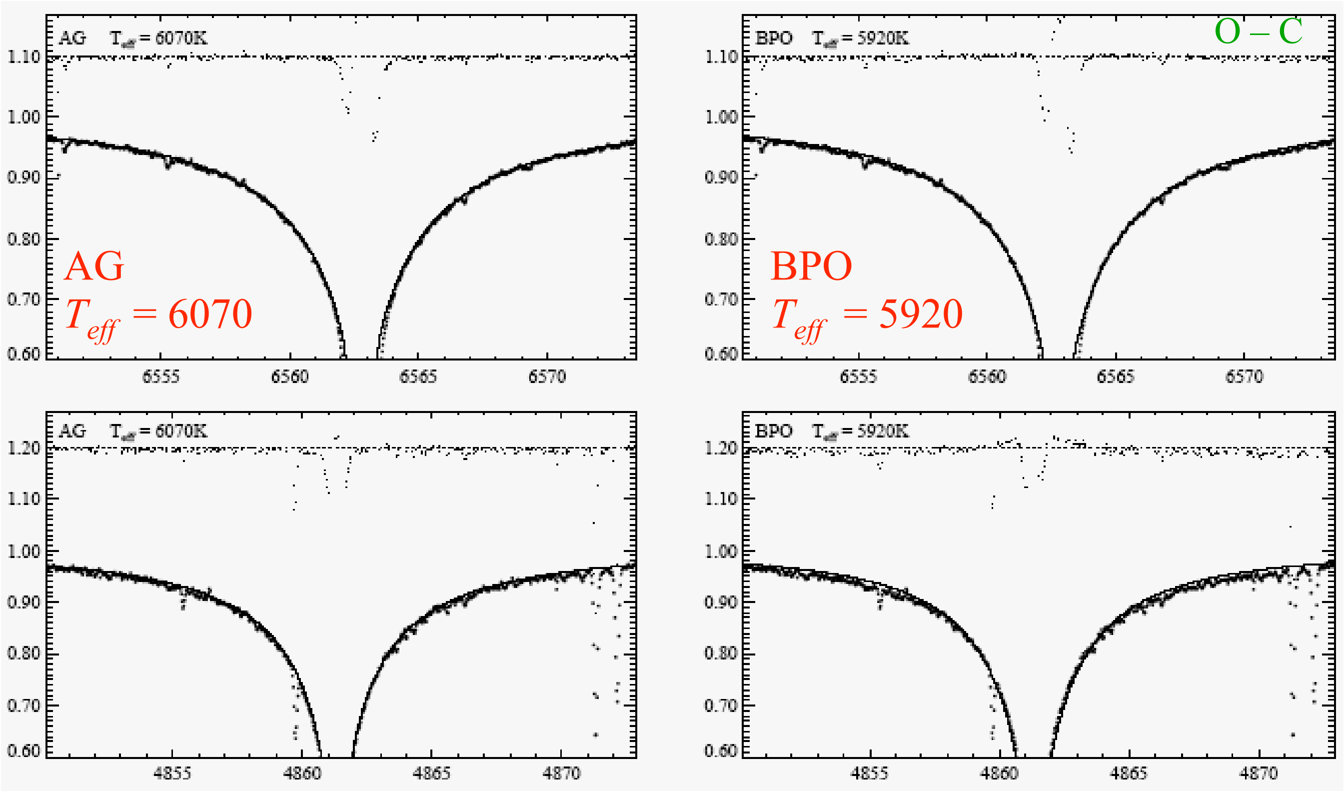
Barklem et al. (2002) deduce
T_{eff} = 5733 K (LTE).





The line core within ±1.1Å
is not included in the fit.

HD 19445 (log g = 4.40, [Fe/H] = -2.08)



FOCES observations by A. Korn, R ≈ 60000, S/N > 200 (red). ~ 100 (blue)

- ΔT_{eff} (*AG - BPO*) = 150 K,
- Non-LTE leads to consistent temperatures from H_α and H_β.

ΔT_{eff} (NLTE - LTE) = 100 K (H_α),

10 K (H_β).

Van der Waals broadening

A line absorption profile is described by the Lorentz profile.

- Experimental data are available for few spectral lines.
- The classical van der Waals description of *Unsöld* (1955) underestimates Γ_6, by ~ a factor 2.
- *Kurucz* (1992) modification of the Unsöld formula.
- The perturbation theory of *Anstee & O'Mara* (1991, 1995) developed for
  - neutral atoms (*Barklem & O'Mara* 1997; *Barklem et al.* 1998) and
  - the first ions (*Barklem & O'Mara* 1998; *Barklem & Aspelund-Johansson* 2005).

the *ABO* theory

The uncertainty of the predicted damping constants is estimated as 10% to 20%.

Comparisons among different methods

Experimental data vs. the ABO theory.

log C_6 (*ABO* – *Smith,* 1981)

≤ 0.16 dex for 4 common Ca I multiplets.

-0.43 dex for Ca I 5261.

Quantum mechanic computations vs. the ABO theory.

log C_6 (*ABO* – *Spielfiedel et al.* 1991) for Ca I 6122, 6162,

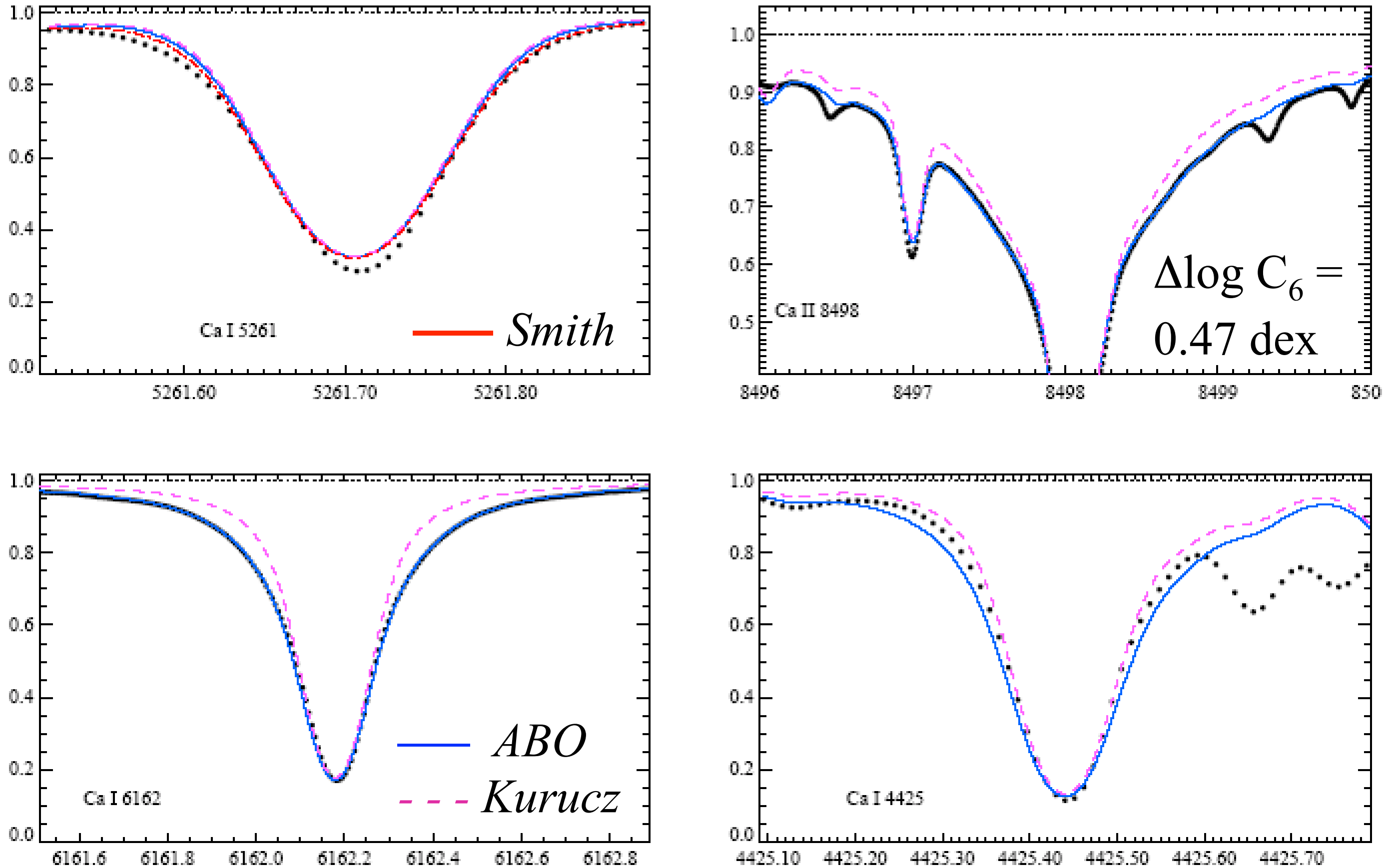
– *Kerkeni et al.* 2004) for Ca I 4226

≤ 0.1 dex.

The ABO theory vs. the Unsöld approximation as implemented by Kurucz (1992).

$\Delta\log C_6 =$ 0.34 dex

$\Delta\log C_6 =$ 0.83 dex



Solar flux profiles (KPNO, 1984, dots) of the Ca I lines compared to the non-LTE profiles

(*Mashonkina et al.* 2007a).

Concluding remarks

- The situation with atomic data on collisional broadening of spectral lines significantly improved for last decade.

- In precise analysis of line profiles (e.g. deriving surface gravity) and chemical abundance determinations,

  one still needs to check the available data using the Sun as a reference star and,

  if required, to estimate empirical corrections.