Effect of κ-distributions on the Temperature Structure of the Prominence-Corona Transition Region

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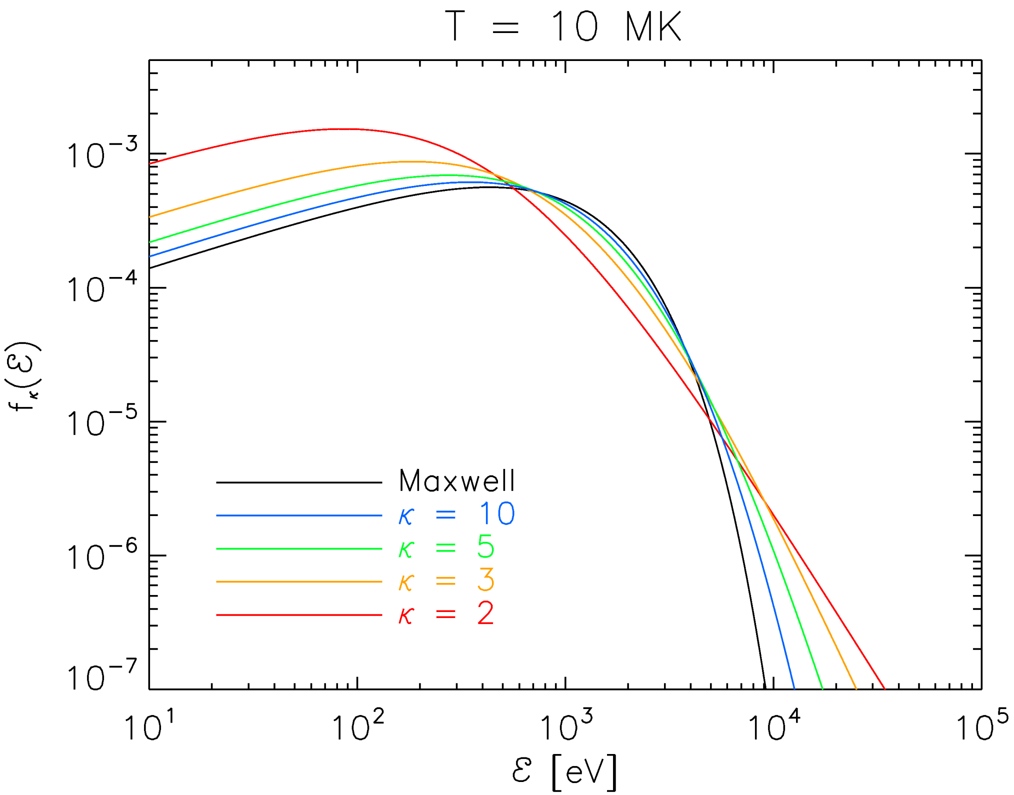
Motivation

- we study the emission – we need to know the microphysics
- supra-thermal component ("high-energy tail") observed in flares and solar wind
- Maksimovic et al. (1997): solar wind velocity distribution is well approximated by a κ–distribution
- Collier (2004): if the mean particle energy is not held constant, the entropy is *not* maximalized by a Maxwellian, but by a κ–distribution
- Dzifčáková & Kulinová (2011): relative intensities of Si III in the solar transition region correspond to the κ–distribution (why not in PCTR?)
- a distribution with an enhanced high energy tail can be formed in corona due to heating (e.g. by micro flares)
- shape of the distribution affects the ionization and excitation equilibrium

Non-thermal Electron κ-distribution

$$f_\kappa(E) = A_\kappa \frac{2E^{1/2}}{\pi^{1/2}(kT)^{3/2}}\left(1+\frac{E}{(\kappa-1.5)kT}\right)^{-(\kappa+1)}$$



$$A_\kappa = \frac{\Gamma(\kappa+1)}{\Gamma(\kappa-0.5)(\kappa-1.5)^{3/2}}$$

$$\langle E \rangle = 3kT/2$$

$$p = NkT$$

$$E \to \infty, \quad f(E) \approx const. \times E^{-(\kappa+1)}$$

Line Intensities

level population

ion abundance

Emissivity:
$$\varepsilon_{ij} = \frac{hc}{\lambda_{ij}} A_{ij} \frac{N_E^{+k,i}}{N_E^{+k}} \frac{N_E^{+k}}{N_E} \frac{N_E}{N_H} \frac{N_H}{N_e} N_e$$

Intensity:
$$I_{ij} = \frac{hc}{4\pi\lambda_{ij}} A_{ij} \int \frac{N_E^{+k,i}}{N_e N_E^{+k}} \frac{N_E^{+k}}{N_E} \frac{N_E}{N_H} \frac{N_H}{N_e} N_e^2 dl$$

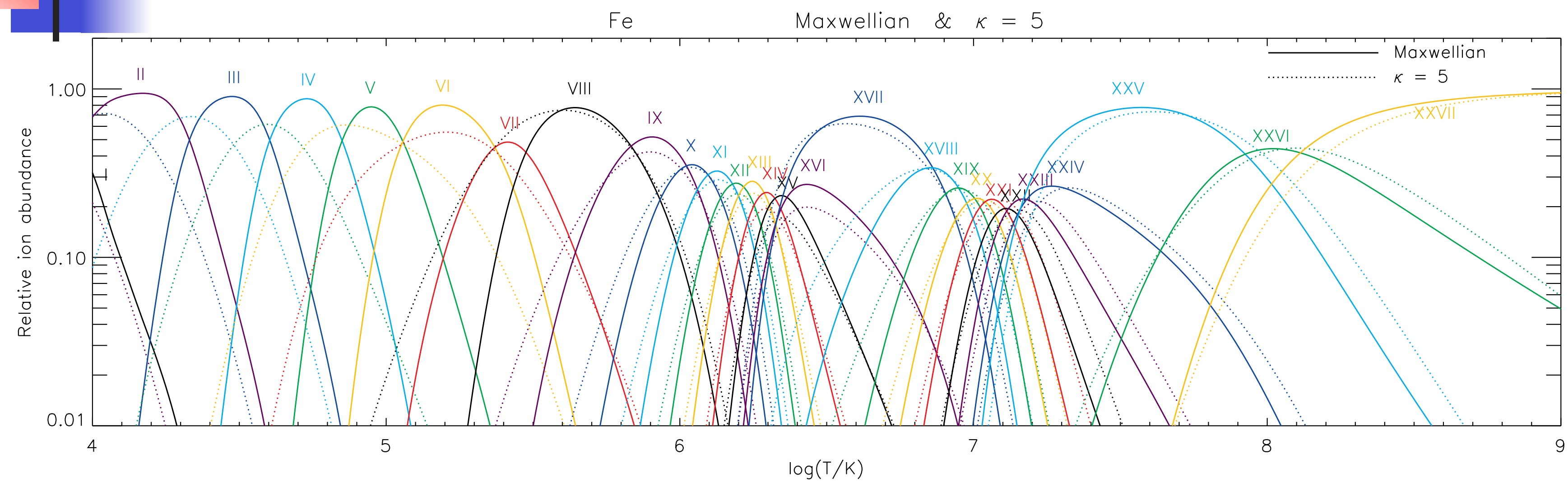
Multi-thermal plasma:
$$I_{ij} = \frac{hc}{4\pi\lambda_{ij}} A_{ij} A_E \int \frac{N_E^{+k,i}}{N_e N_E^{+k}} \frac{N_E^{+k}}{N_E} \frac{N_H}{N_e} DEM \; dT$$

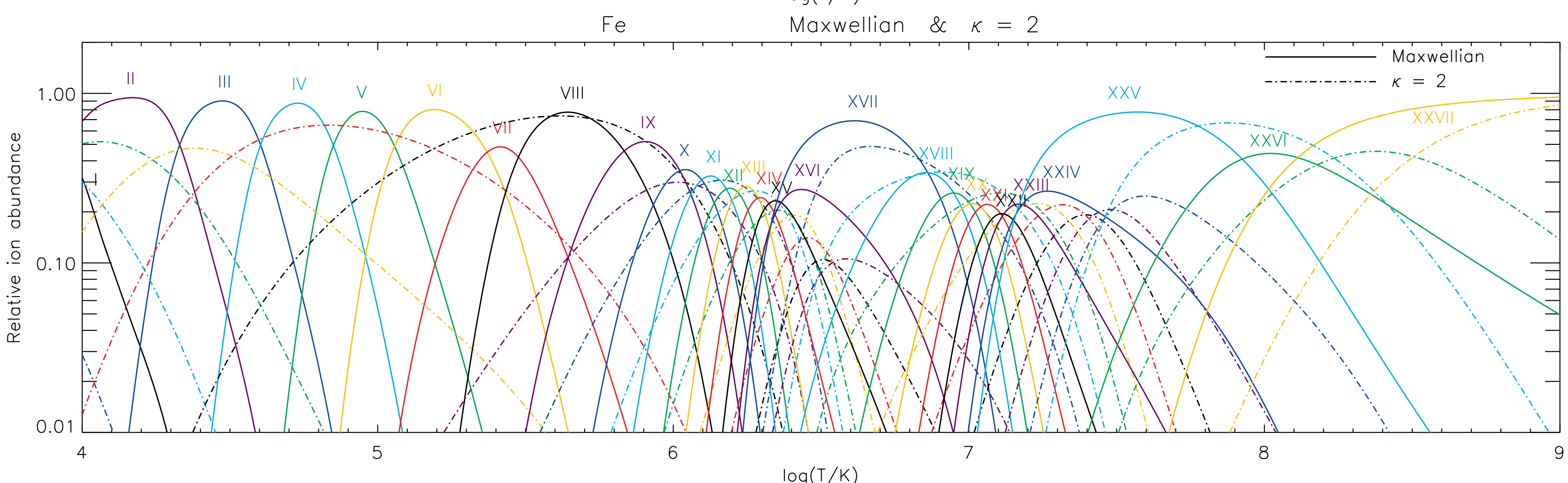
$$I_{ij} = \int G(T) \times DEM \; dT \qquad DEM = N_e^2 \frac{dl}{dT}$$

Ionization Equilibrium: κ-distribution

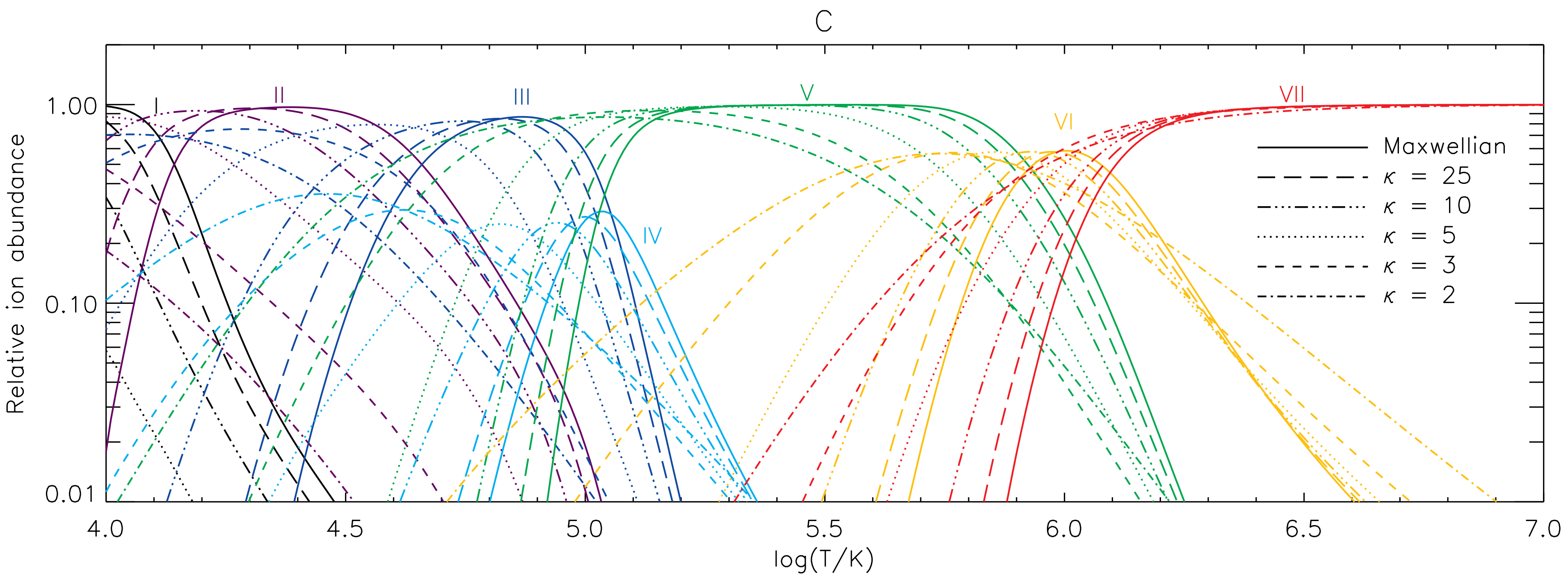
- new calculation of the ionization equilibrium for the Maxwellian distribution (chianti7.ioneq - Dere, 2007)
- new calculations of the ionization equilibrium for the $\kappa-$ distributions: Dzifčáková & Dudík, 2013, all elements up to Z=30

Ionization Equilibrium: κ-distribution





Ionization Equilibrium: κ-distribution



Excitation Equilibrium for the κ-distributions

level population

Intensity: $$I_{ij} = \frac{hc}{4\pi\lambda_{ij}} A_{ij} \int \frac{1}{N_e} \frac{N_E^{+k,i}}{N_E^{+k}} \frac{N_E^{+k}}{N_E} \frac{N_E}{N_H} \frac{N_H}{N_e} N_e^2 dl$$

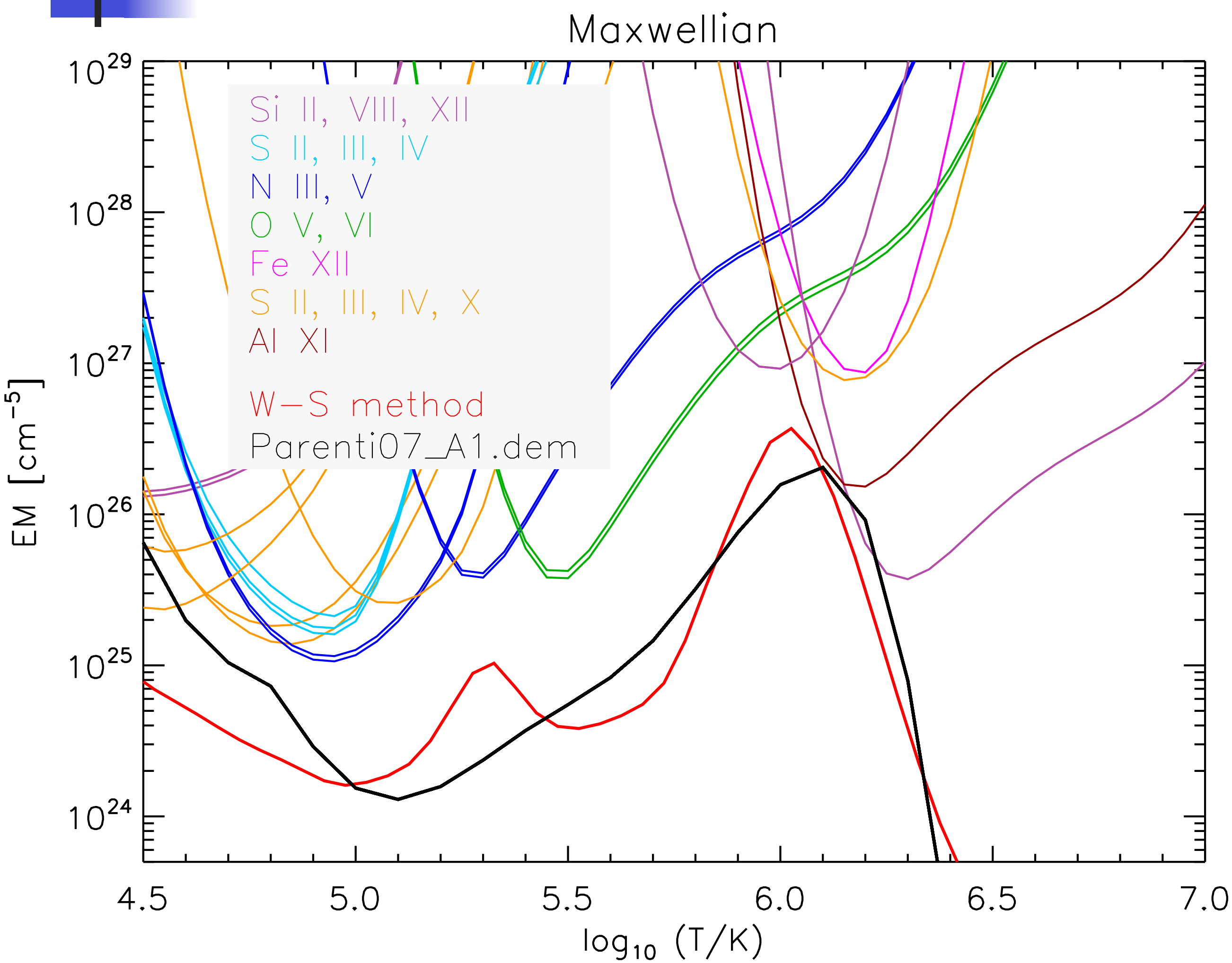
❖ The presence of the κ-distributions changes the electron excitation rates. The effect depends on the type of the atomic transition and ratio of the excitation energy to temperature.

❖ Databases usually contain only the collision strengths averaged through the Maxwellian distribution.

❖ Approximations for the cross sections were derived using method of Dzifčáková (2006) and tested in Dzifčáková & Mason (2008).

❖ Own modification of CHIANTI software and newly updated extended database (corresponds to version 7.1) allows relatively quick calculations of the line intensities for the κ-distribution

DEM of PCTR



DATA – SUMER observation Parenti et al. (2005)

Withbroe – Sylwester method (*Sylwester et al., 1980*)

Constant pressure:

$n_e T = 10^{14}$ cm^{-3} K

- our calculation – red line
- Parenti & Vial (2007) –black

Differences:

➢ ionization equilibrium (Mazzotta et al. 1998 – Dere, 2007)

➢ excitation equilibrium (database CHIANTI 6 – CHIANTI 7.1)

➢ calculation method

Abundance:

coronal – Parenti07_a1.dem (CHIANTI)

DEM of PCTR

With lower κ

EM-loci curves are

❖ much wider

❖ shifted to lower T in TR

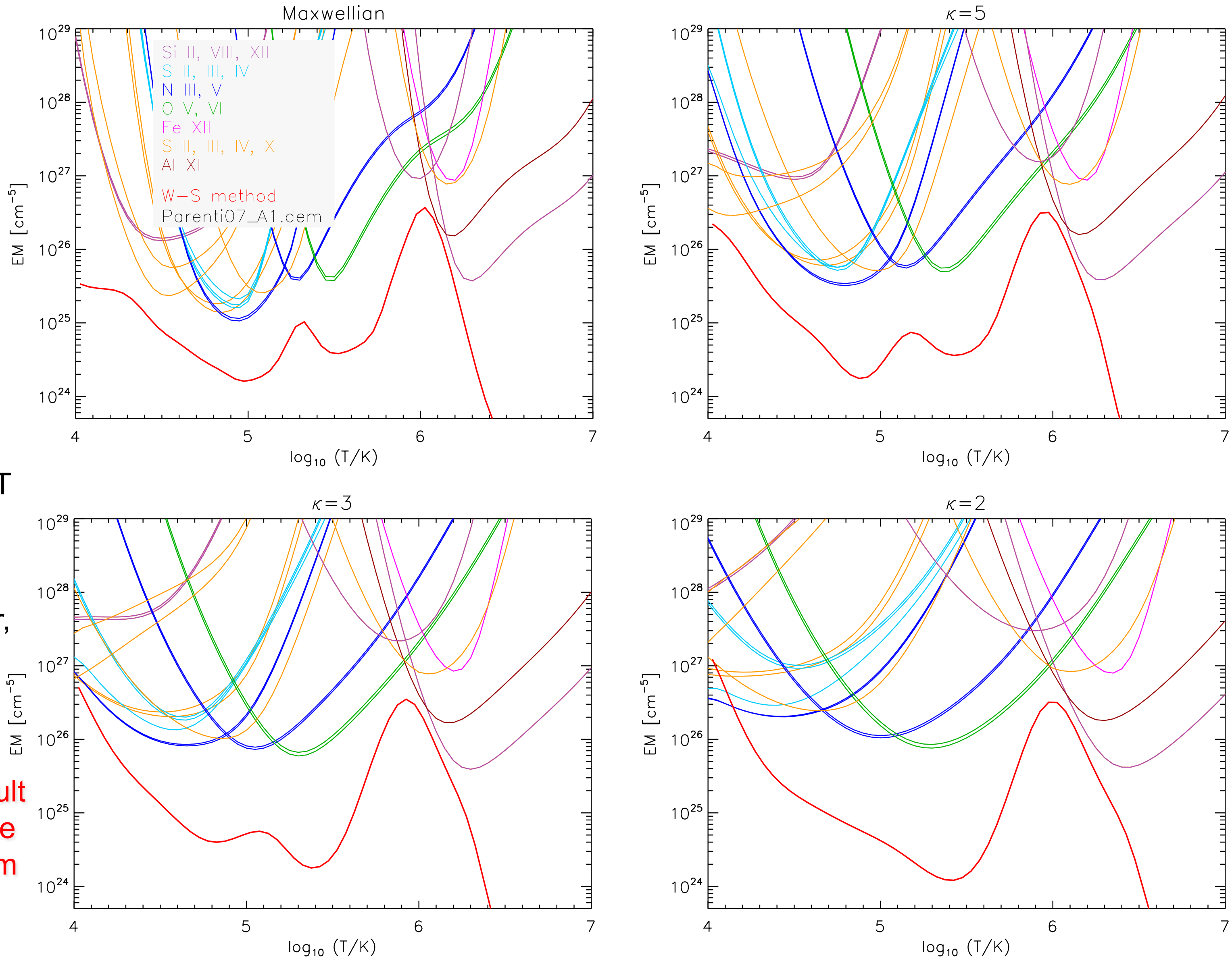
❖ shifted to higher T in corona

DEM's

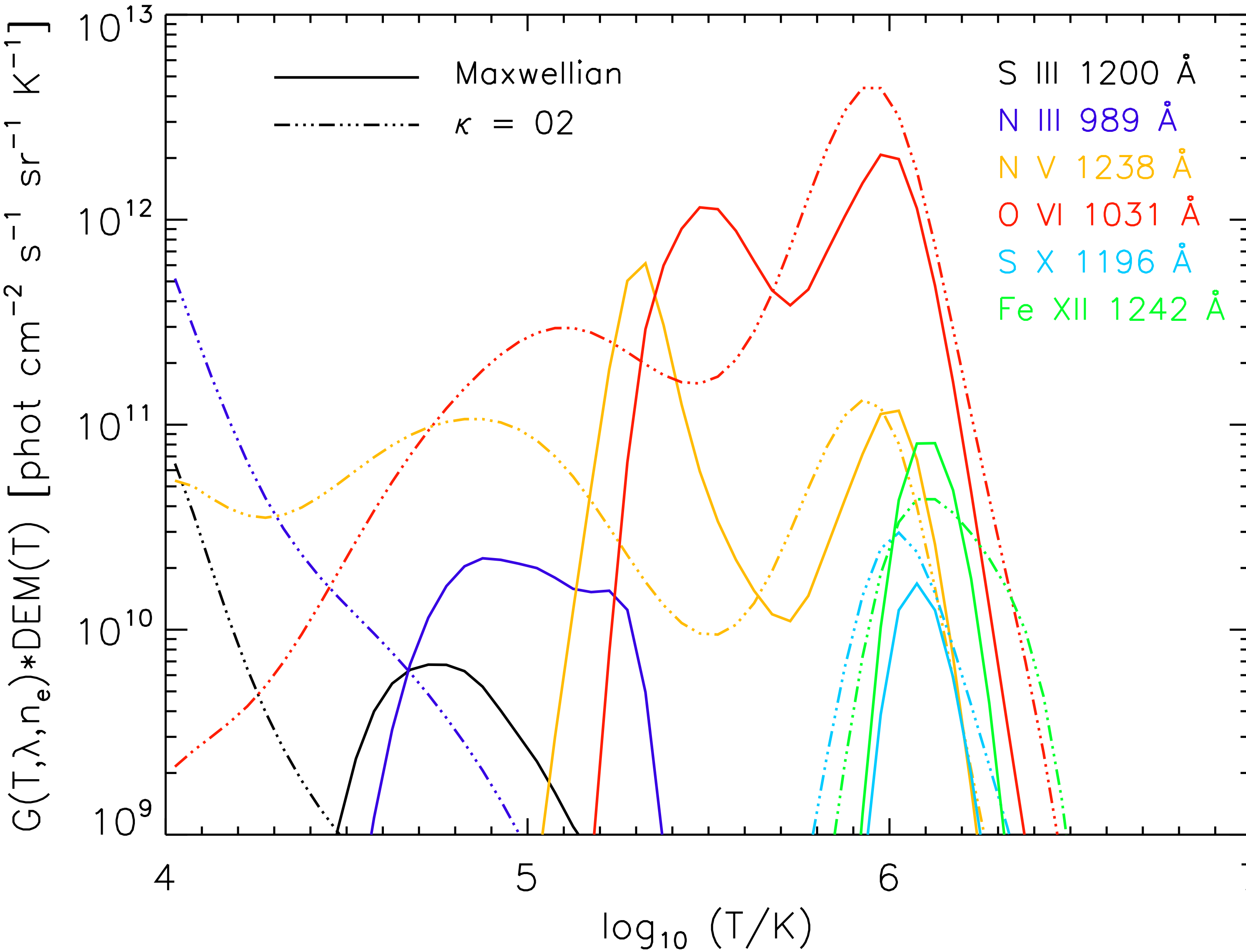
❖ have wider, lower, and shifted peaks

❖ are flatter

This is mainly a result of the changes in the ionization equilibrium



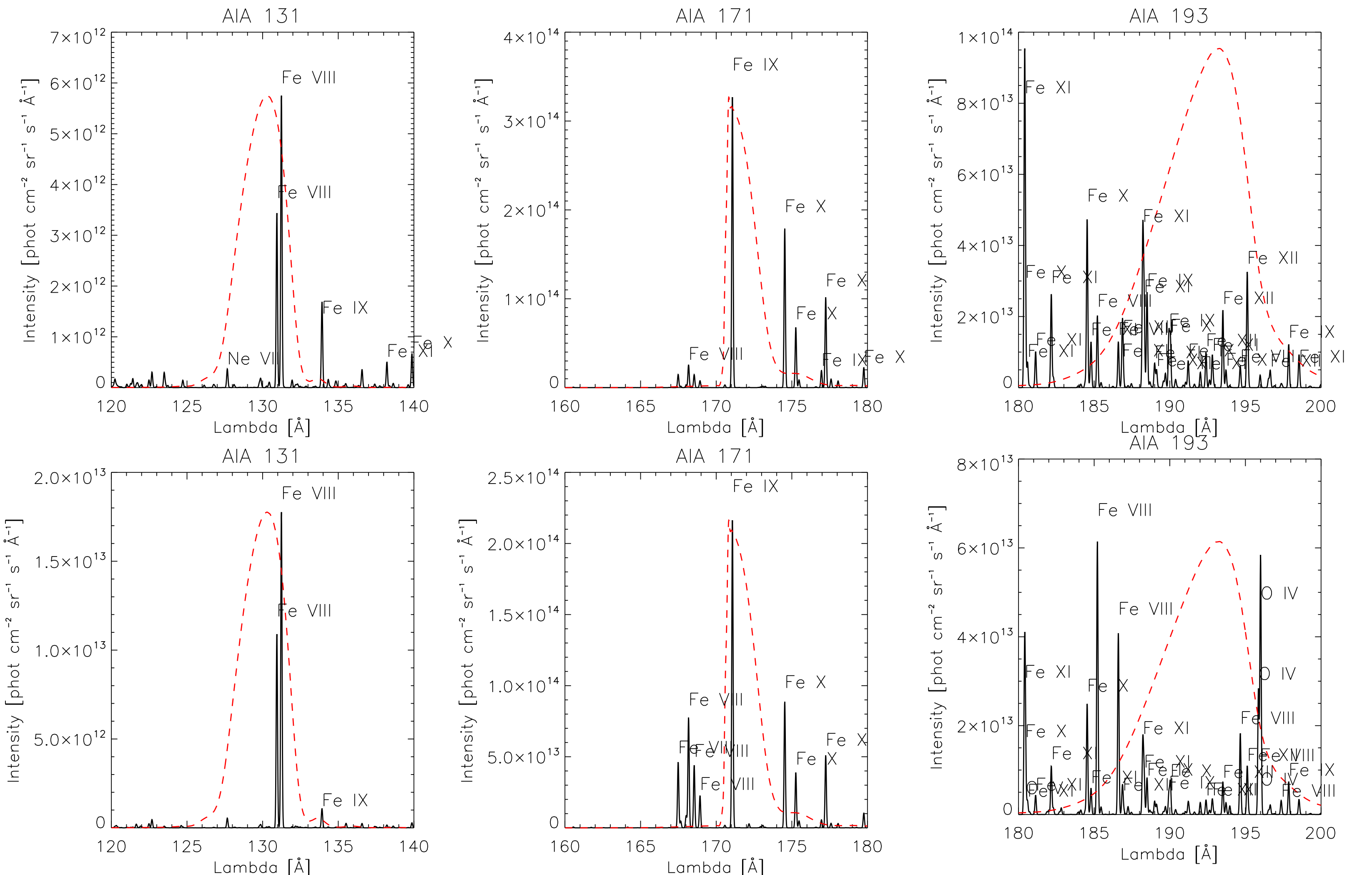
Temperature range of the line formation SUMER



Spectra in AIA filters

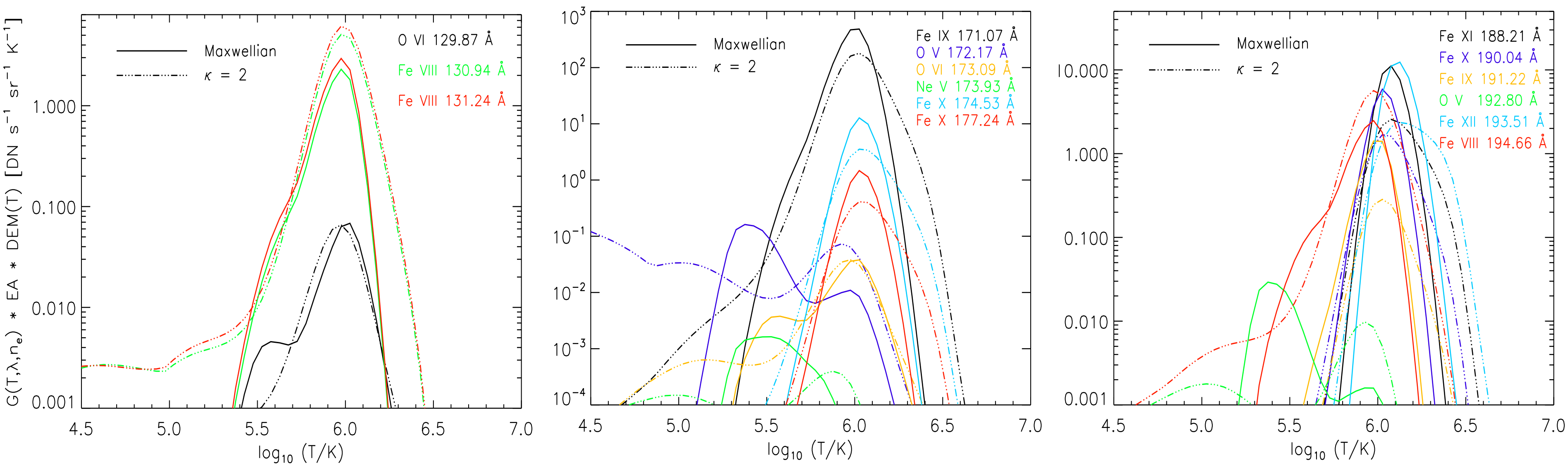
Maxwell

$\kappa = 2$



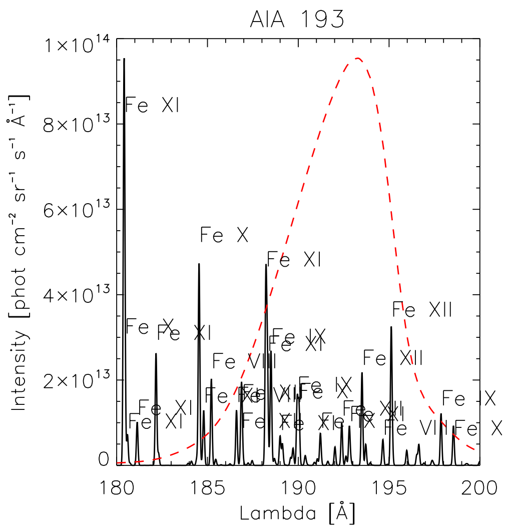
Temperature range of the line formation in AIA filters

131 171 193

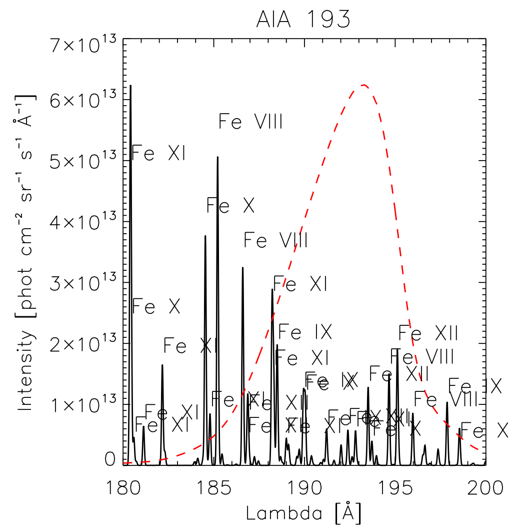


193 AIA

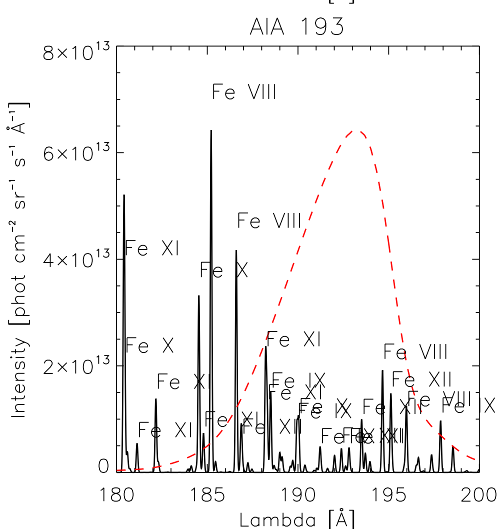
Maxwell



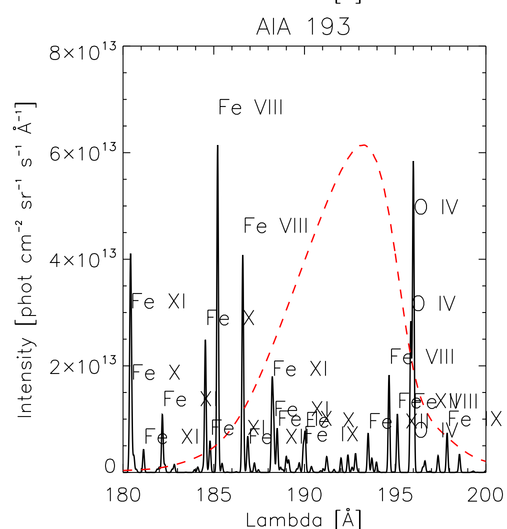
κ = 5



κ = 3



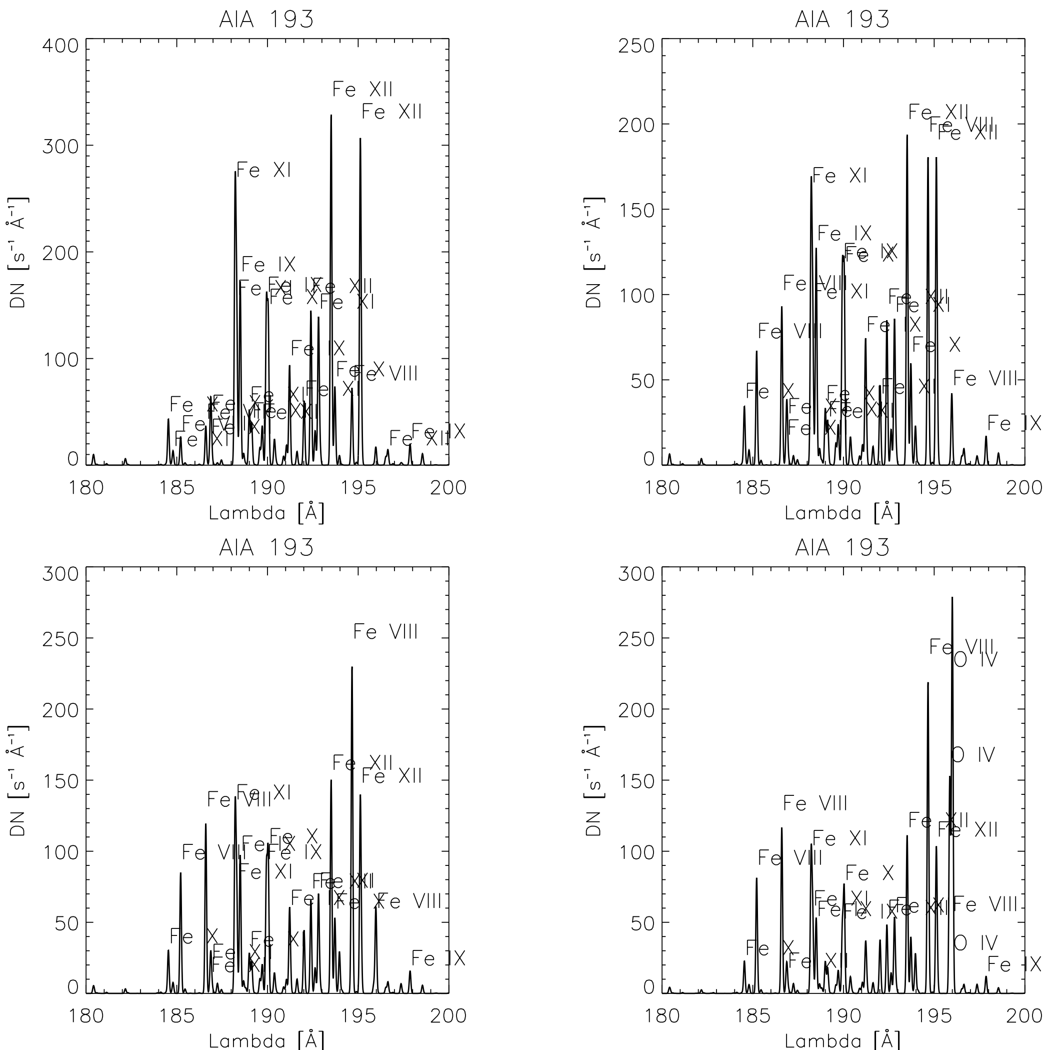
κ = 2



193 AIA

Maxwell

κ = 5



κ = 3

κ = 2

Summary

- for the κ-distributions, contributions to the line intensity can come from much wider temperature range than for the Maxwellian distribution
- this behaviour is mainly a result of changes in the ionization equilibrium with κ
- DEM's for κ-distributions have usually wider, lower, and flatter peaks that for the Maxwellian distribution
- peaks can be shifted to lower T (transition region) or higher T (corona) in comparison with a Maxwellian DEM
- κ-distributions can change temperature response in some of the AIA filters


Thank you very much
for your attention!