A search for signatures of **Preferential Heating** of heavy ions in the Low Solar Corona

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Can we detect a Signature of Preferential Heating of heavy ions by ion cyclotron resonance ?

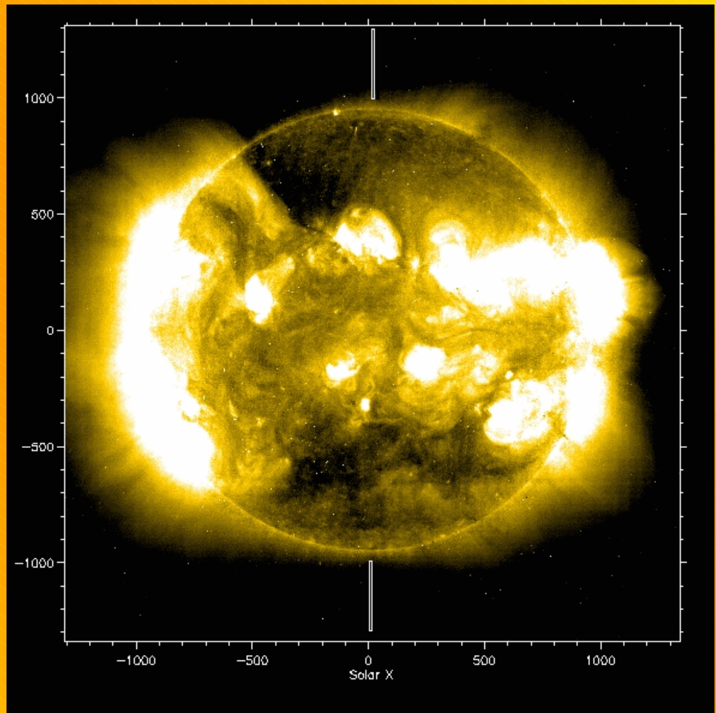
- Tu *et al.* Ap. J 503, 1998 : in coronal holes, ions can be heated by ion cyclotron waves (resonance with ions gyrating along the magnetic field lines)

  ⇒ Preferential heating : ions with the lower charge-to-mass ratios are heated more than the others

- Our observations :

  → May 2002 (MEDOC Campaign #9): EUV spectrometer SUMER/SoHO

  → **Correction of the line profils from the instrumental stray light contribution**, inherent to SUMER



Deriving Coronal Ion Temperatures from Linewidths (1)

- In coronal conditions, we can suppose the following **gaussian** contributions to the ion linewidth (Dere & Mason, *Solar Phys.*, **144**, 217-241, 1993) :

Thermal Doppler Effect

« Unresolved Velocity » (« non-thermal velocity »)

$$\sigma^2 = \overbrace{\frac{\lambda^2}{2c^2}\left(\frac{2kT}{M}\right.}^{\text{Thermal Doppler Effect}} \left. + \xi^2\right) + \sigma_I^2 .$$

Instrumental width

- **Unresolved Velocity** ξ : Turbulence, MHD wave, …? (any Doppler shift due to (symetric) plasma motion along the line of sight)

⇒ may be involved in coronal heating and fast solar wind acceleration :

C. Tu, E. Marsch, *Solar Phys.*, **171**, 363-391 (1997)

Y. Q. Hu, S. R. Habbal, and X. Li : *J. Geophys. Res.*, **104** (1999)

Deriving Coronal Ion Temperatures from Linewidths (2)

$$\sigma^2 = \frac{\lambda^2}{2c^2}\left(\frac{2kT}{M} + \xi^2\right) + \sigma_I^2.$$

One measured quantity, two unknowns (T and ξ) ! Two methods :

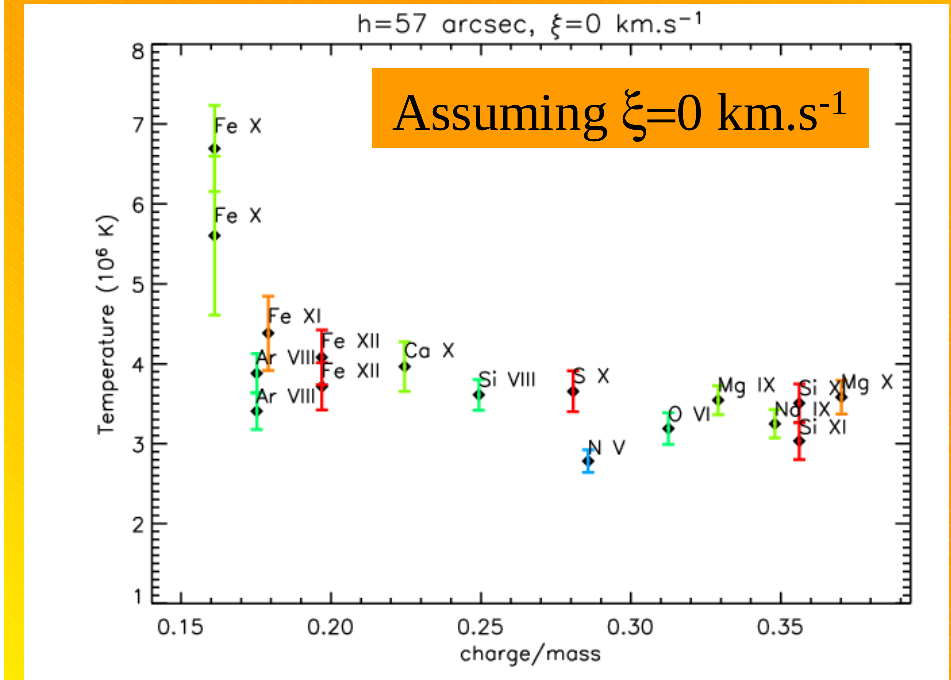
1) Assuming T = T(ionization equilibrium), and deduce ξ (historical method). BUT :

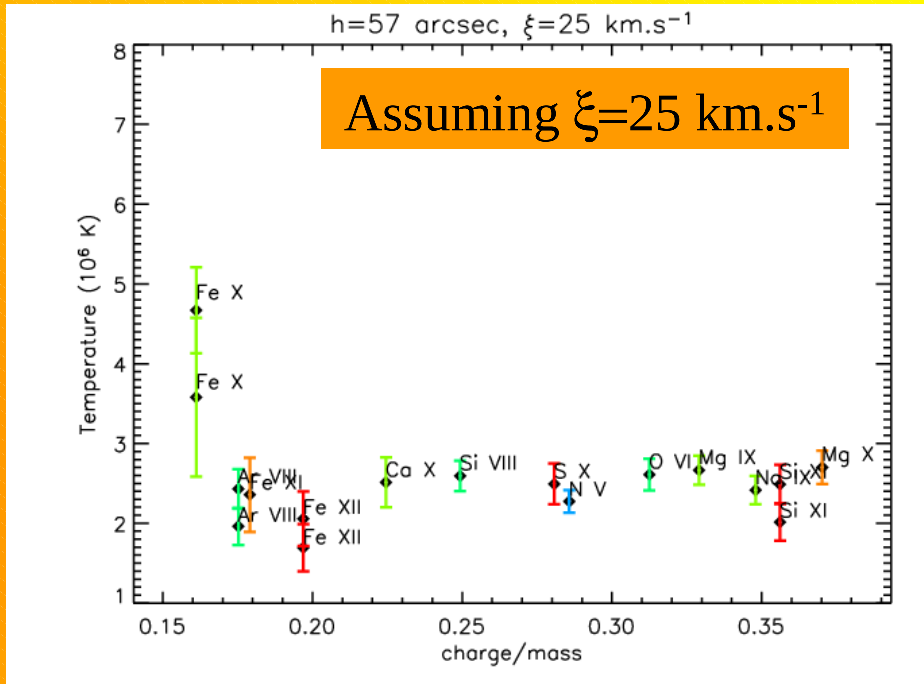
   → a ion can can be observed far from its temperature of maximum ionization equilibrium : ions of very different T(ionization equilibrium) are visible at a given altitude, and it yields a very wide range of values for ξ.

   → equilibrium of minor ions with the electrons may not be relevant (collision time : ~ 100 s, ion cyclotron time ~ 10^{-3} s)

2) Assuming the same value of ξ for every ion, and deduce the temperature of each ion specie.

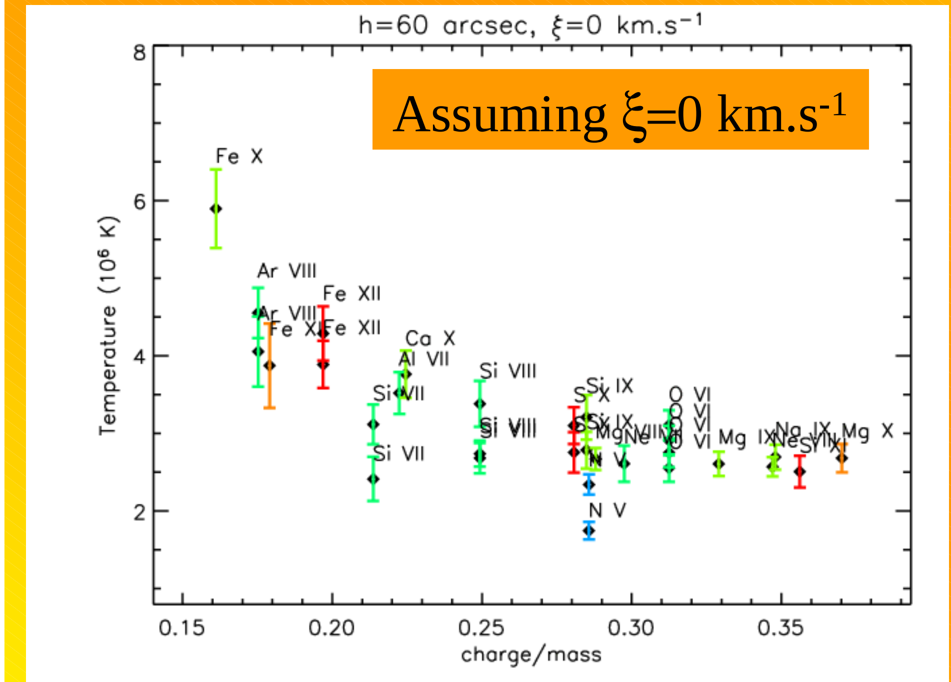
~ 42 000 km above the Coronal Hole

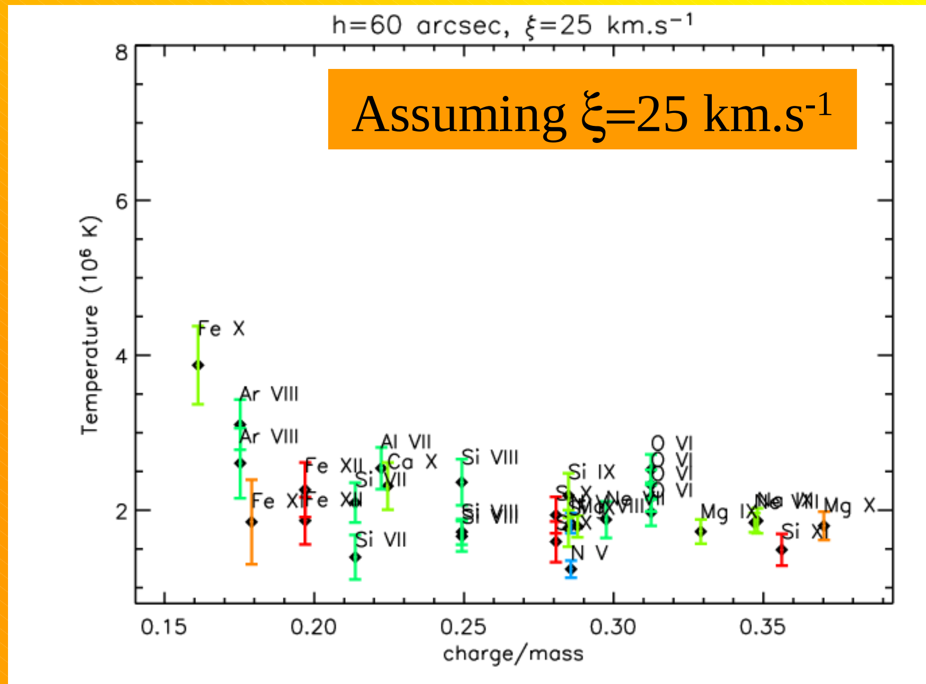




« **Preferential heating** » : are ions with lower charge-to-mass ratios hotter than the other ?

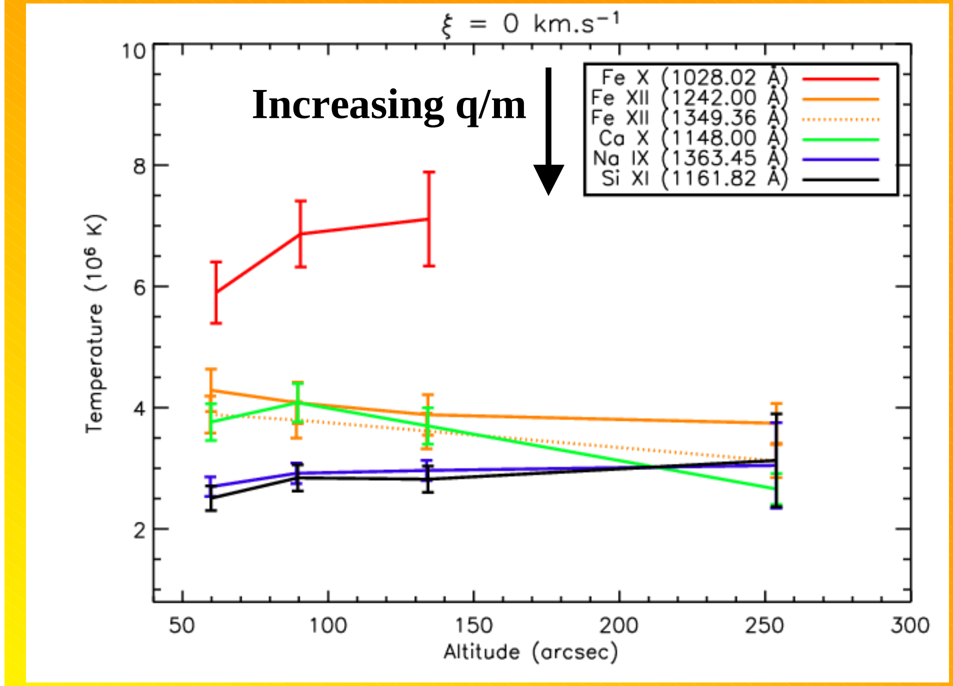
Comparison : same altitude over the South Pole



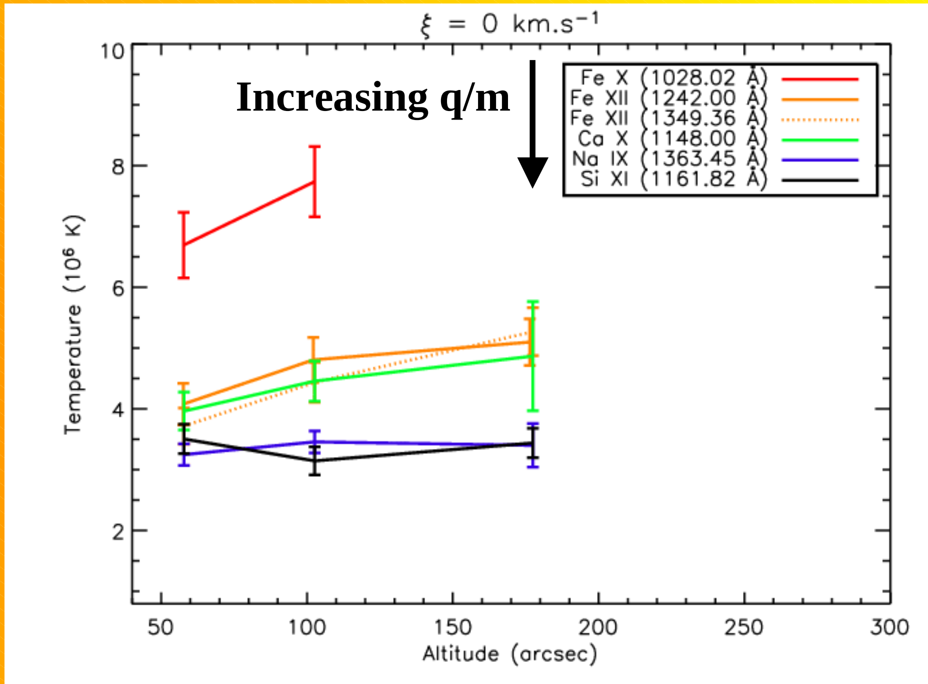


- Difficulty to conclude to a signature, due to :
  - → unkown value of ξ :dramatically affects the derived temperature of the heaviest ions ↔ the lowest charge-to-mass ratios
  - → Temperature results from balance between preferential heating (∝q/m) AND cooling by collisions with the protons (function of m/q^2)
  - → same trend above the coronal hole and the « quiet sun » region

Another approach :
Difference of line width with the altitude



Above the « quiet sun » region



Above the Coronal Hole

Interpretation of the variation in width

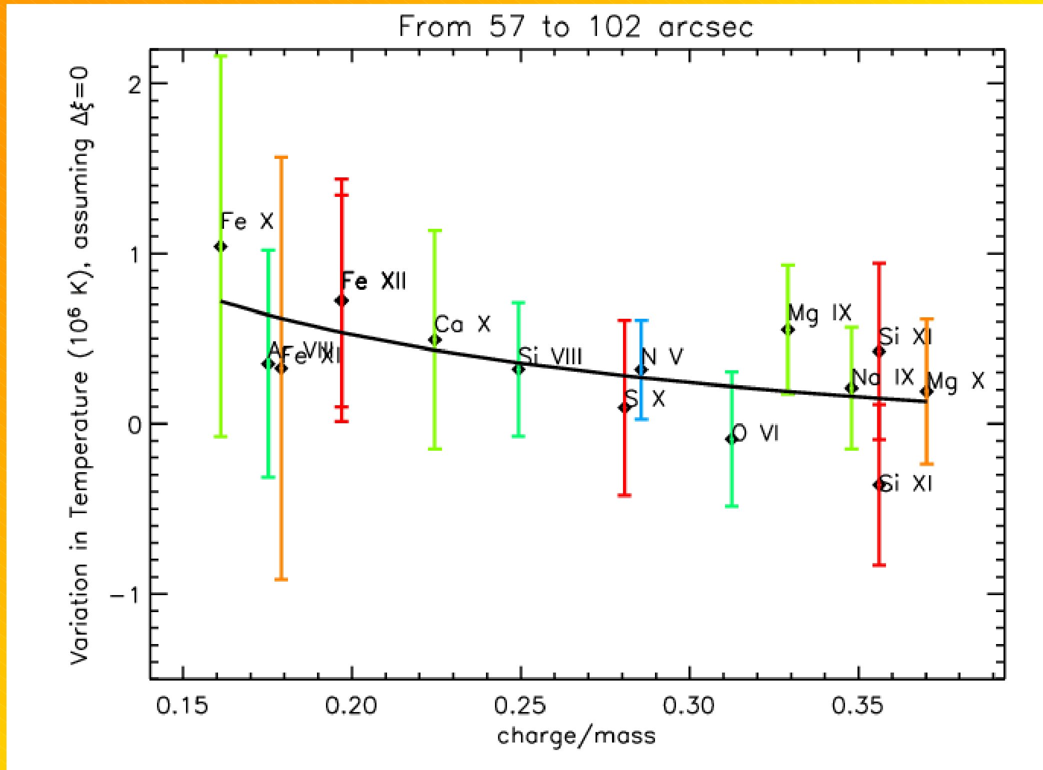
$$\Delta\sigma = \frac{\lambda^2}{2\sigma c^2}\left(\frac{k}{M}\Delta T + \xi\Delta\xi\right)$$

- Two extreme cases :

  $\rightarrow$ $\Delta\xi=0$: only ΔT, completely independant of absolute temperature or unresolved velocity ξ

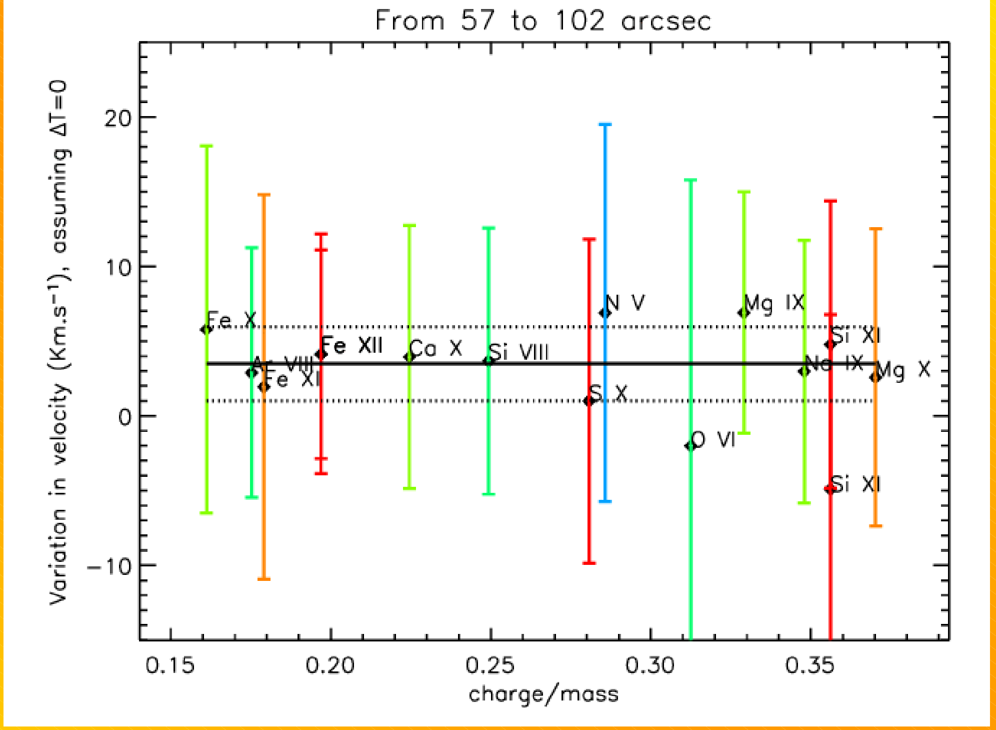
  $\rightarrow$ $\Delta T=0$: ξ only is varying : we must known about its initial value !

Case 1 : $\Delta\xi$=0



- **Interpretation** : signature of preferential heating, between 40 000 and 70 000 km

Case 2 : ΔT=0



- **Interpretation** : All ions experience the same increase of ξ :

Δξ ~ 4 km.s^{-1} from 40 000 to 70 000 km above the Coronal Hole, if ξ=25 km.s^{-1} at 40 000 km above the limb.

This may be the signature of an increase of Alfvén wave amplitude (e.g. due to density rarefaction in the adiabatique case).

The problem of line blending due to instrumental stray light

- Observation above the limb : SUMER is dazzled by the solar disc

  ⇒ **observed spectrum** =

  real coronal spectrum + instrumental stray light spectrum

  dominated by photosperic and chromospheric lines

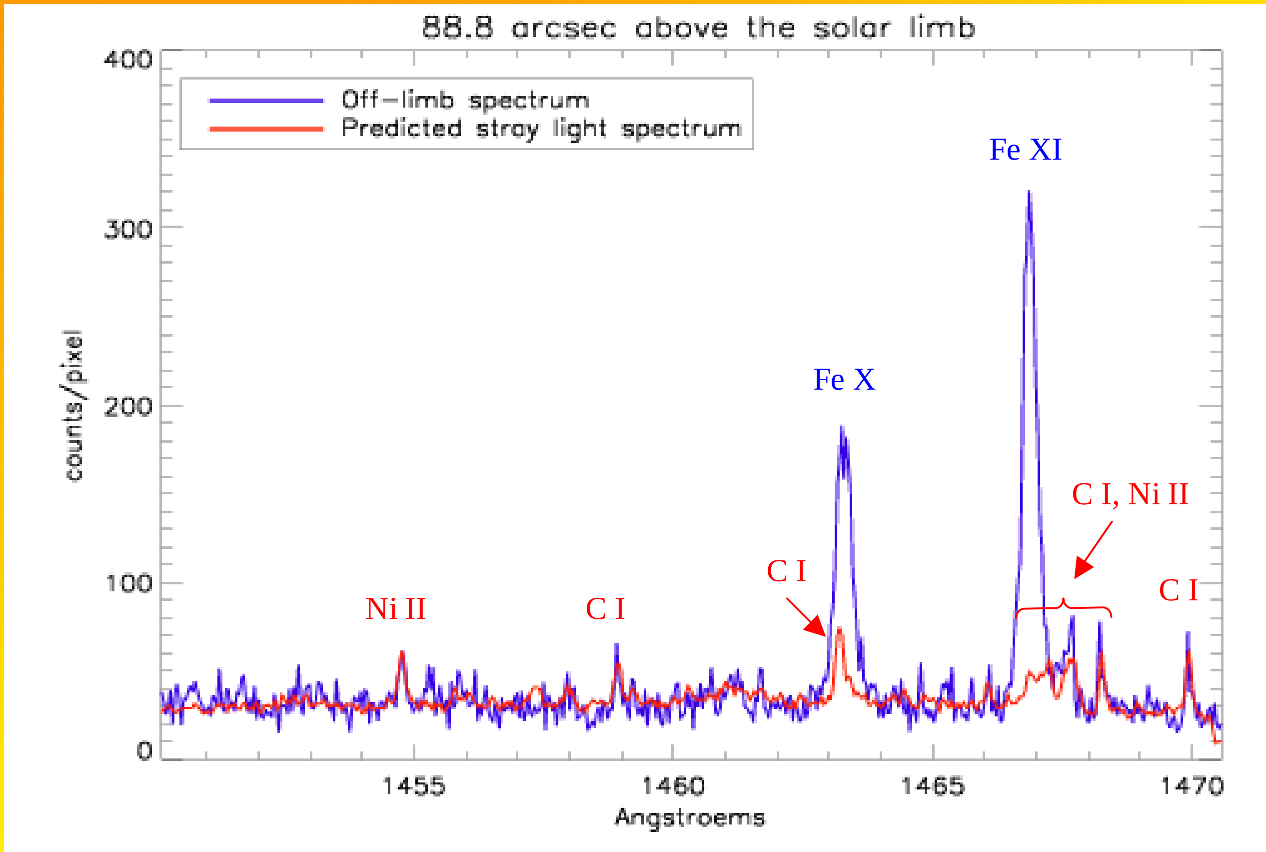
  ⇒ blending of some coronal lines with lines that should not be present in the Corona !

- To retrieve the coronal line profile, we have developped a method to predict the stray light spectrum

  Note that stray light contribution to the off-limb spectrum increases with altitude.

Stray light prediction : Example 1

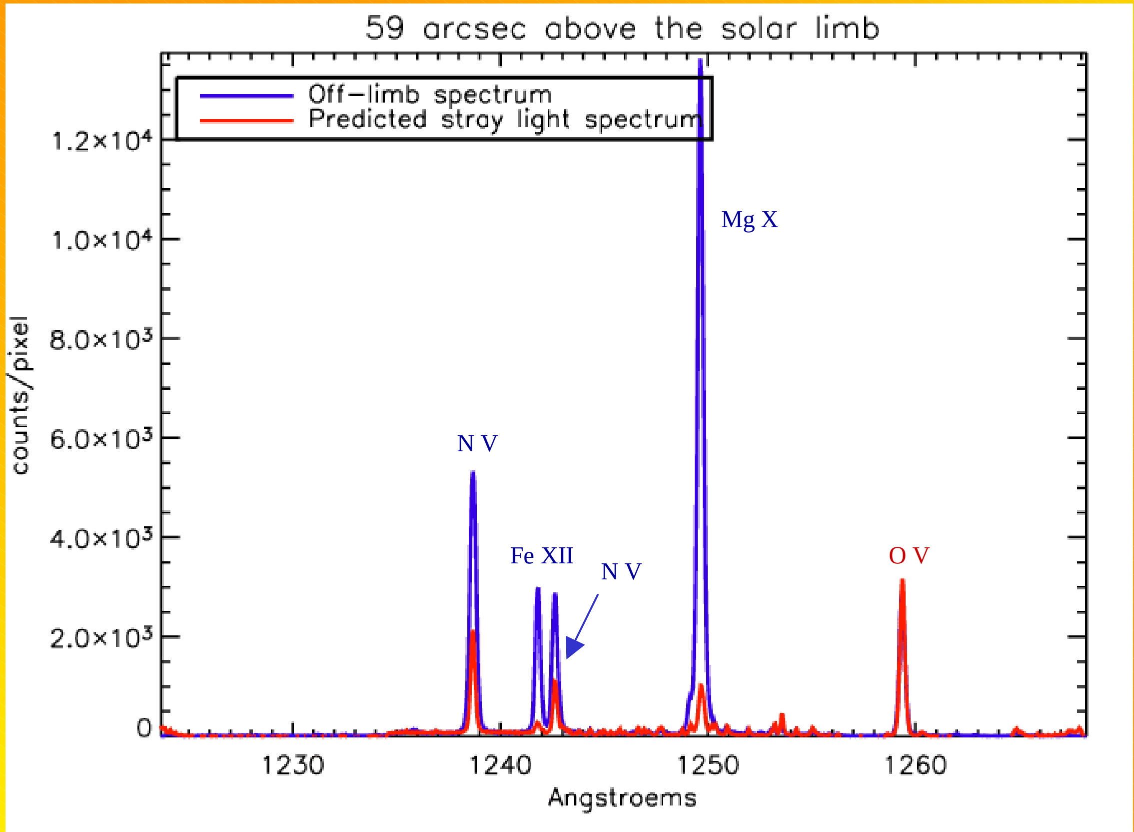
Blending by one or more « cold » ion lines of neighbouring wavelength :



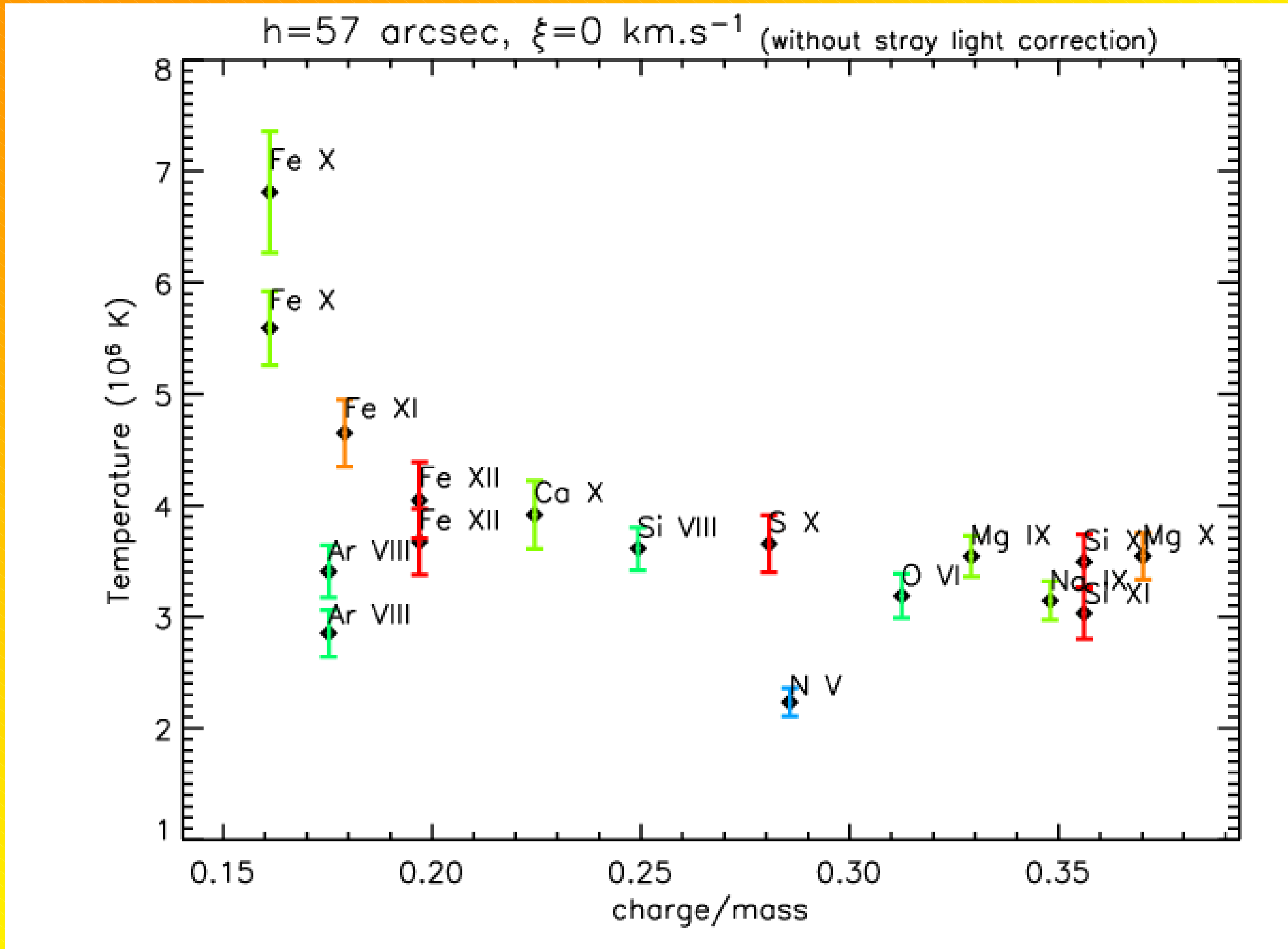
Stray light prediction : Example 2

- Blending by the same line, as seen on the disc

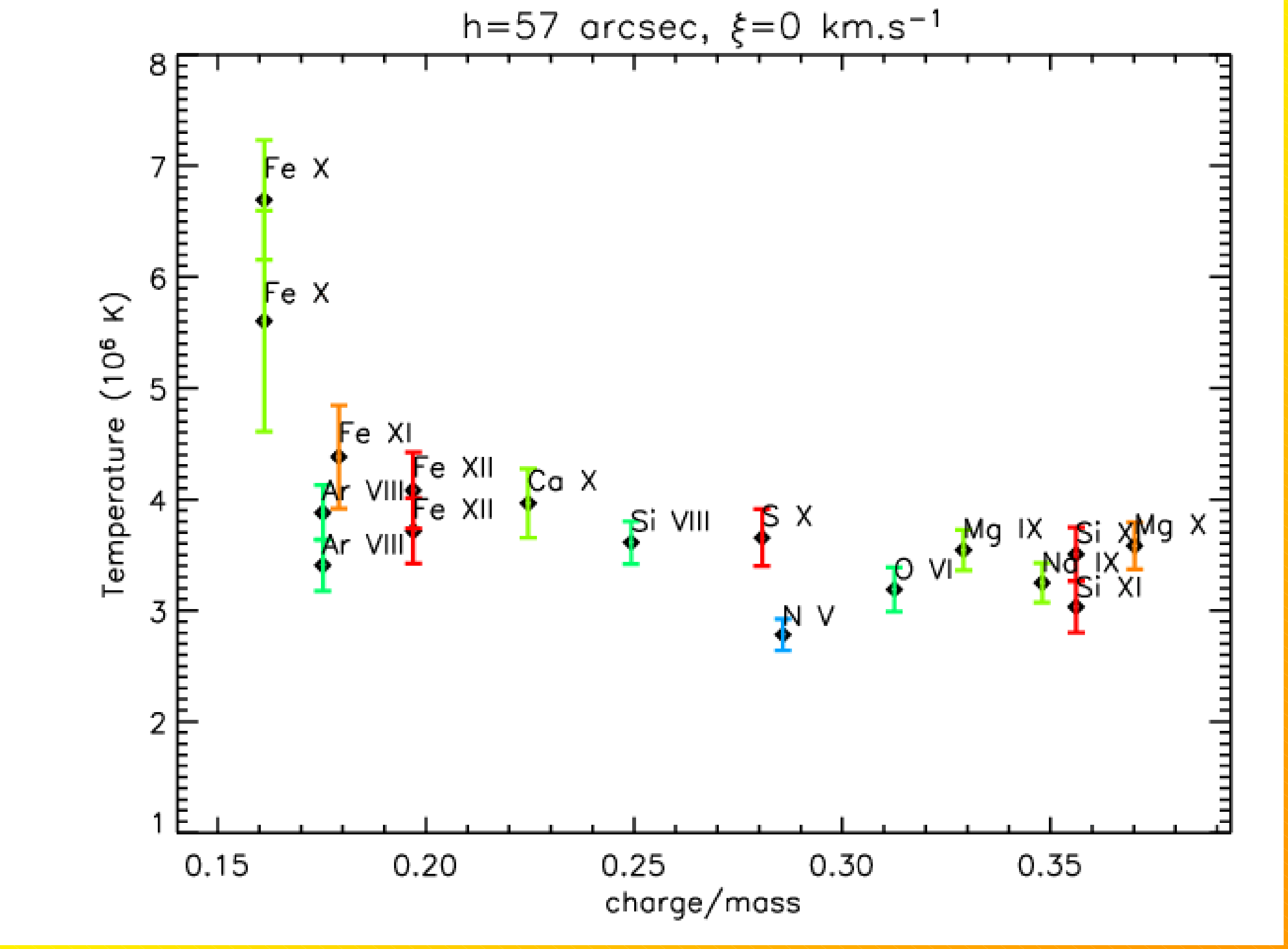
$\Rightarrow$ its line width is smaller (T chromosphere < T corona)



The effect of stray light correction : WITHOUT



The effect of stray light correction : WITH



Conclusions

- By measuring the difference of width between 2 altitudes, we are able to support the possibility of ion cyclotron preferential heating

- We cannot dismiss the interpretation of increasing unresolved velocity with the altitude. This increase is inversely proportional to the initial value of ξ

$\Rightarrow$ we need :

✓ to know more about the nature of the unresolved velocity,

✓ to constraint the value of ξ

✓ to constraint its variation with the altitude in the solar Corona

To be continued…