SPECTRAL ANALYSIS OF ANNIHILATION EMISSION

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- Goals & method
- Modelling the annihilation spectra
- Preliminary results
- Conclusions

Goals & method

Spectral analysis e^+e^- emission (line characteristics, Ps continuum) provide the physical conditions of ISM where annihilation is taking place

=> Hints to determine the origin of positrons

Spectral characteristics depends only on the ISM conditions (T, ionization,...)
We neglect Doppler shift due to :
- Galactic rotation in the GC region (< 0.02 keV)
- turbulence of the ISM ($v_{turb.} < v_{therm.}$)

The ISM is characterized by 5 phases

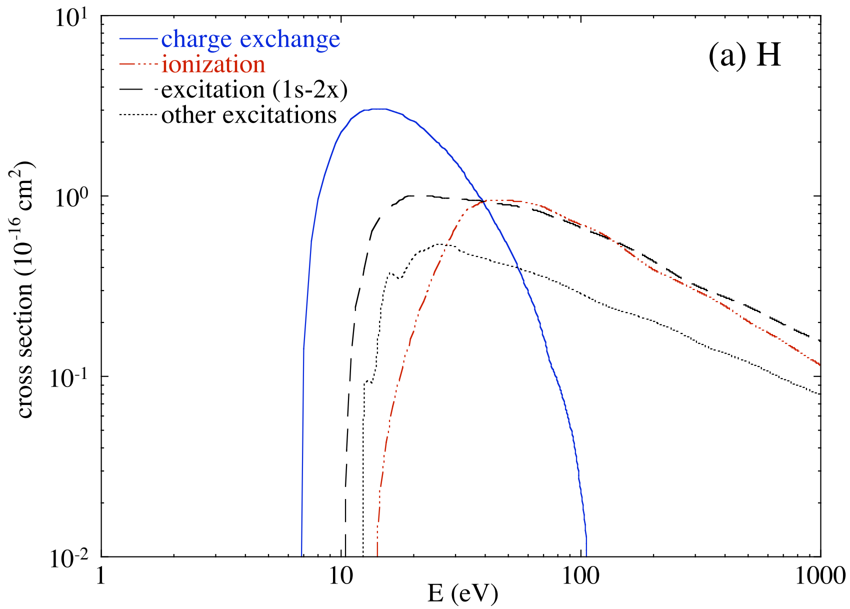
Phase	T (K)	Ion. Frac.	density (cm^{-3})
Molecular	80	0.	42
Cold	100	0.	42
Warm Neutral	8000	0.	0.37
Warm Ionized	8000	1.	0.25
Hot	10^6	1.	0.004

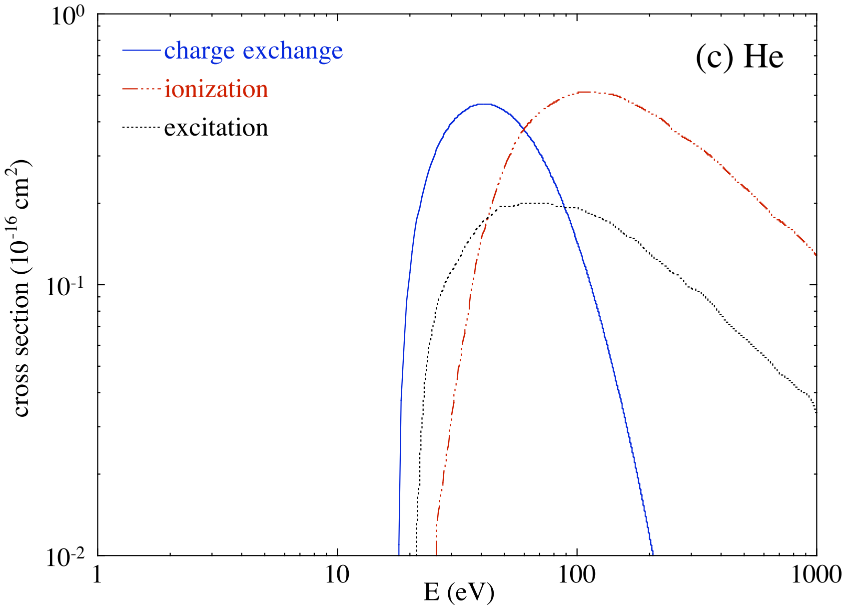
The method consist in (1) modelling the e^+e^- spectrum in each phases and (2) search for the fractions of phase which fit the measured spectra

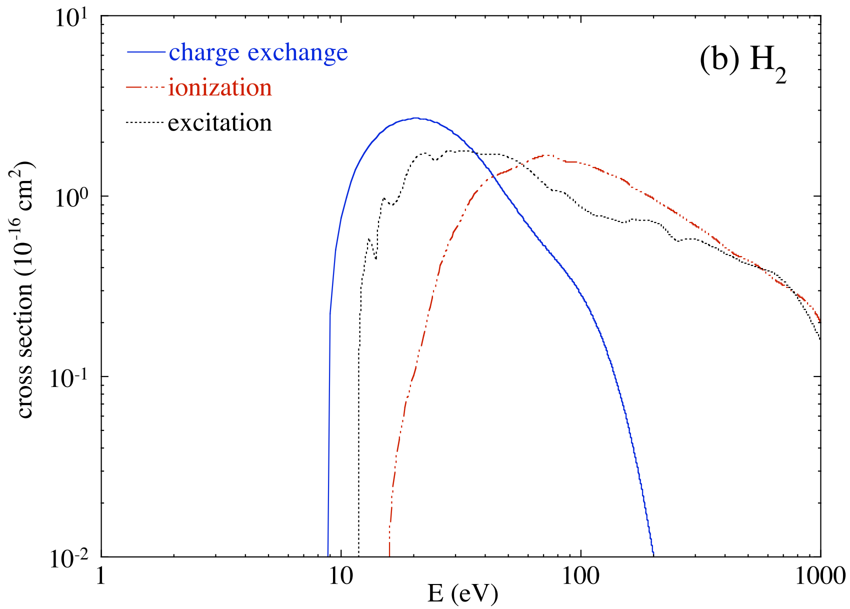
Modelling the annihilation spectra

Guessoum, Jean & Gillard, 2005, accepted in A&A

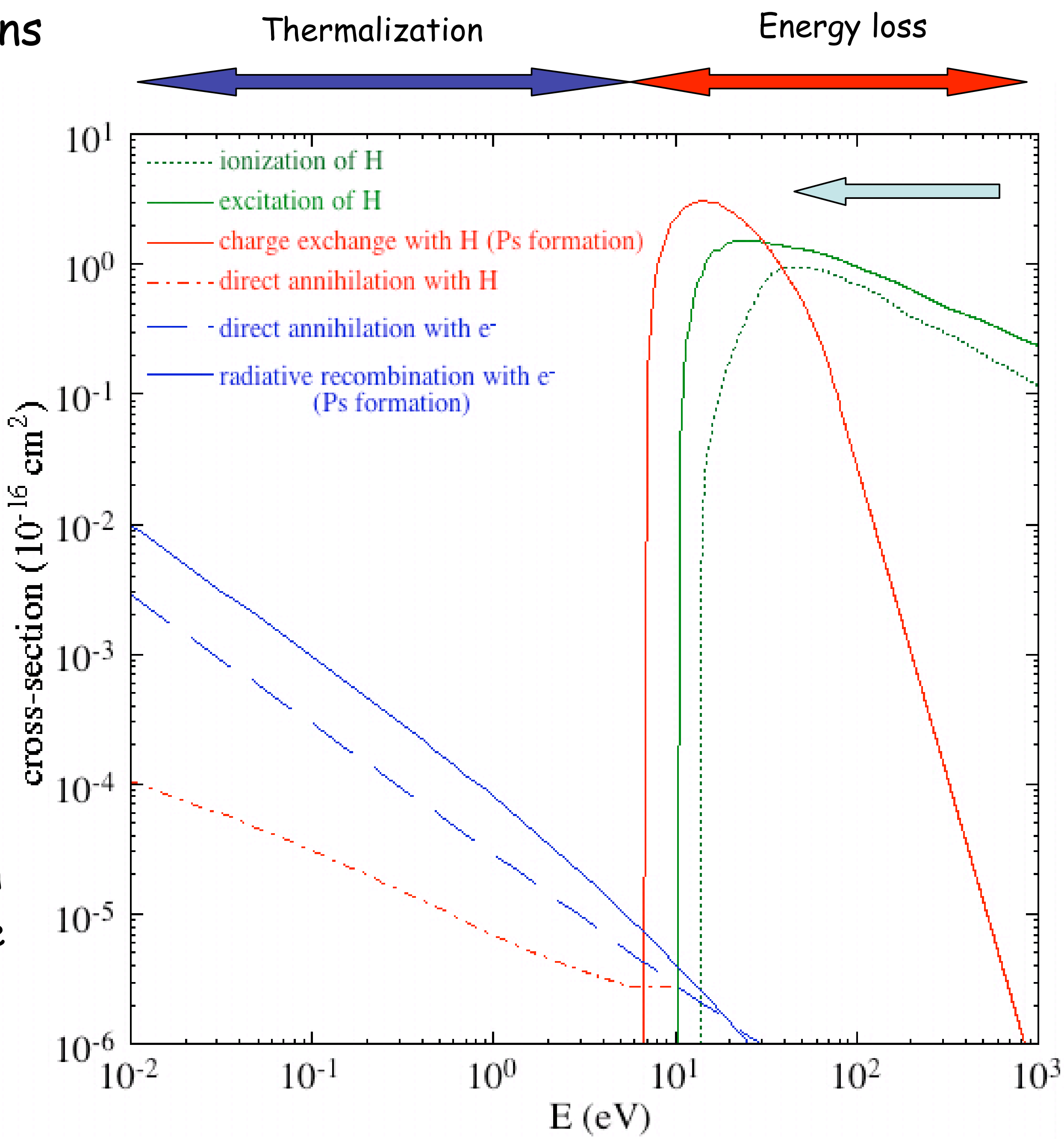
-> Update of cross sections for e^+ interactions with H, H_2 and He







-> Slowing down of positrons



f_1 : fraction of Ps formed in flight by charge exchange

$e^+ + X \rightarrow Ps + X^+$

-> Thermalized positrons

R_i : annihilation rate
function of T

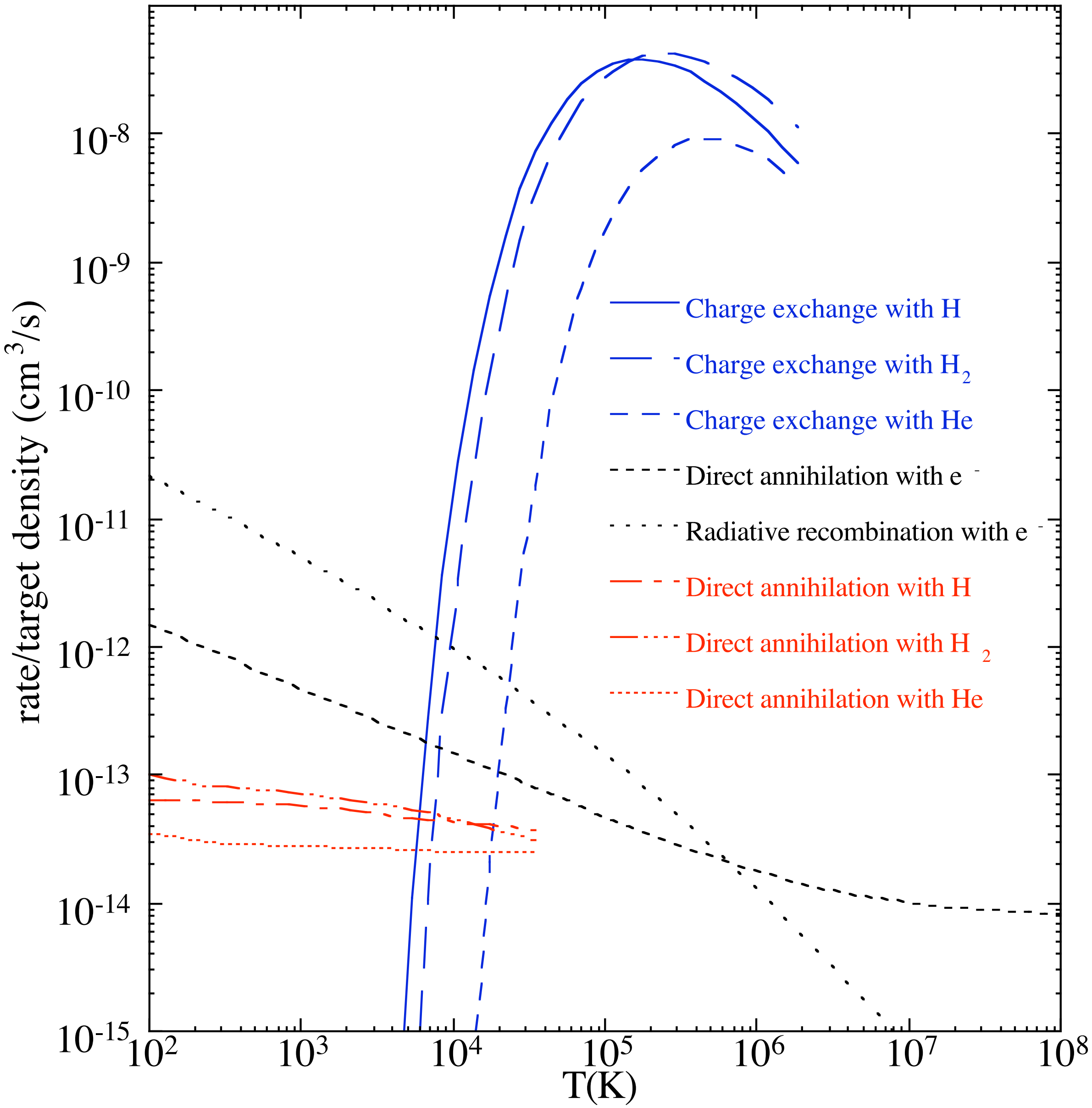
f_2 : fraction of Ps formed
by thermal e^+

$e^+ + X \rightarrow Ps + X^+$

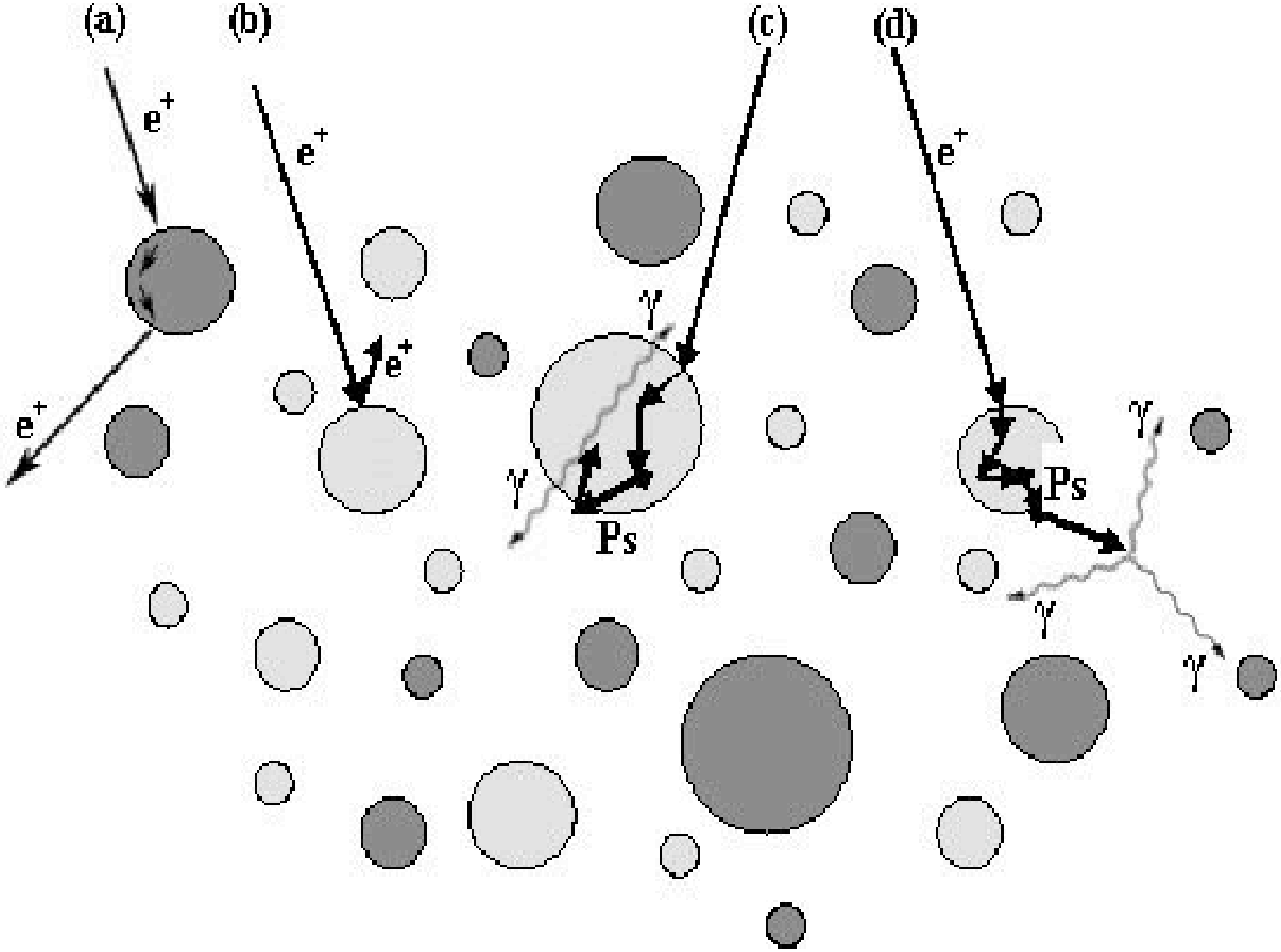
$e^+ + e^- \rightarrow Ps + \gamma$

=> Total fraction of Ps

$f_{Ps} = f_1 + (1-f_1)\, f_2$



-> interaction of thermalized positrons with grains



Grains : 0.6% of the total mass gaz but large cross-section (~radius^2)

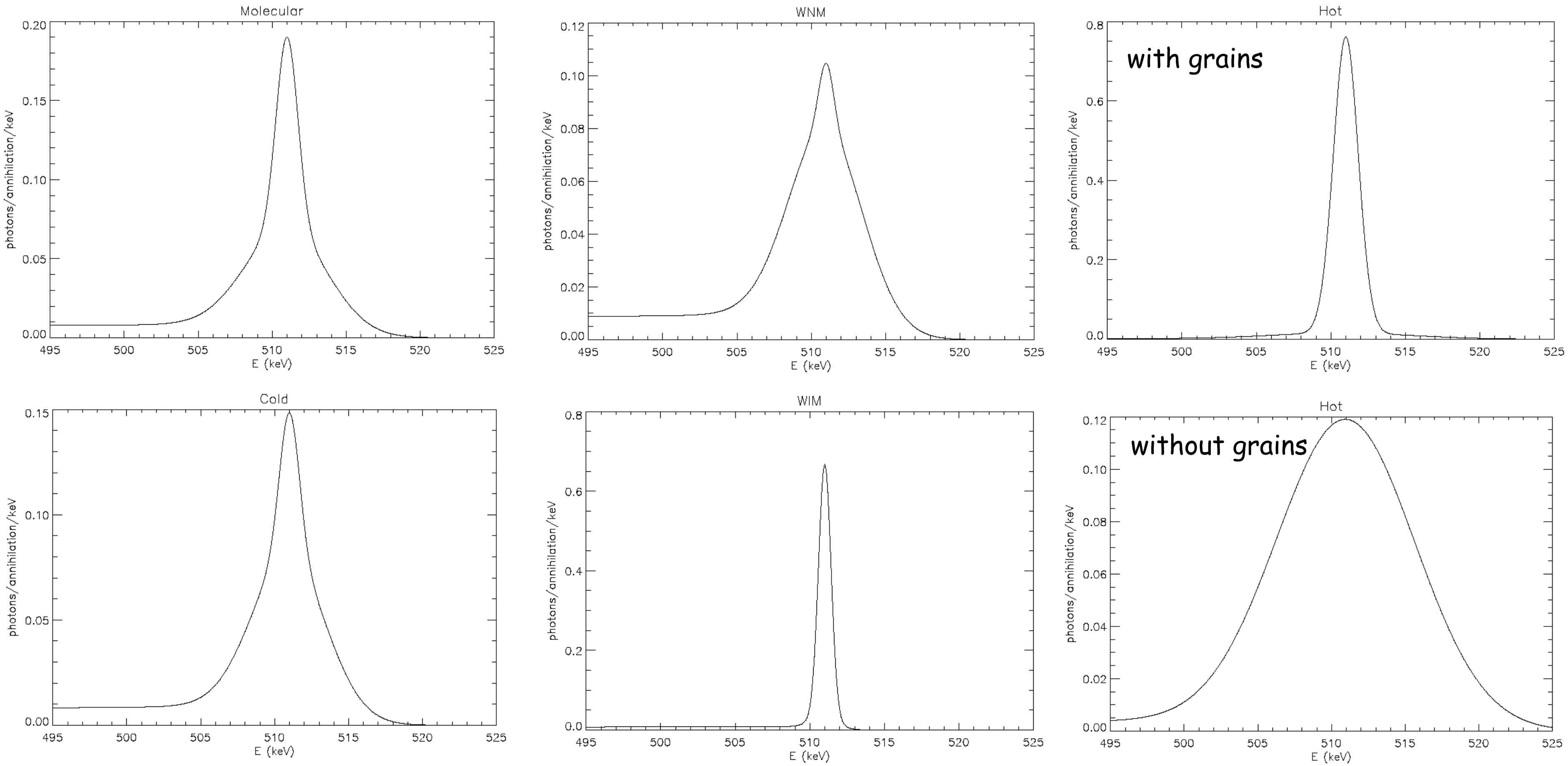
Annihilation rate of thermal e^+ in the different ISM phases

Process / Medium	Molecular ($T \approx 10$ K)	Cold ($T \approx 80$ K)	Warm Neutral ($T \sim 8000$ K)	Warm Ionized ($T \sim 8000$ K)	Hot ($T \sim 10^6$ K)
Charge Exchange with H	--	--	1.8×10^{-12}	--	--
Charge Exchange with H_2	--	--	--	--	--
Charge Exchange with He	--	--	9.0×10^{-21}	9.0×10^{-21}	--
Direct Annihilation with H	--	6.5×10^{-14}	4.4×10^{-14}	--	--
Direct Annihilation with H_2	4.3×10^{-13}	--	--	--	--
Direct Annihilation with He	1.5×10^{-13}	3.7×10^{-14}	2.6×10^{-14}	2.6×10^{-14}	--
Radiative Combination	--	--	--	1.2×10^{-12}	1.3×10^{-14}
Direct Annihilation with electrons	--	--	--	1.7×10^{-13}	1.8×10^{-14}
Capture by grains	2.4×10^{-16}	6.8×10^{-16}	6.5×10^{-15}	4.6×10^{-14}	2.4×10^{-13}

FWHM (keV) of the 511 keV line in the different ISM phases

Process / Medium	Cold & Molecular ($T < 100$ K)	Warm Neutral ($T \sim 8000$ K)	Warm Ionized ($T \sim 8000$ K)	Hot ($T \sim 10^6$ K)
Charge Exchange with H in flight	5.8	5.8	--	--
Charge Exchange with H_2 in flight	6.4	--	--	--
Charge Exchange with He in flight	7.4	7.4	8.7	--
Charge Exchange with H after thermalization	--	1.16	--	--
Charge Exchange with H_2 after thermalization	--	--	--	--
Charge Exchange with He after thermalization	--	1.22	1.22	--
Direct Annihilation with H	1.56	1.56	--	--
Direct Annihilation with H_2	1.71	--	--	--
Direct Annihilation with He	2.50	2.50	2.50	--
Radiative Combination	--	--	0.98	11
Direct Annihilation with electrons	--	--	0.98	11
Positronium from grains	1.4	1.4	1.4	1.4
Annihilation in grains	2.0	2.0	2.0	2.0

-> Spectra in different ISM phases



$F_{model}(E) = \sum f_i F_i(E)$

f_i fitted with spectral data

-> fit the measured spectra

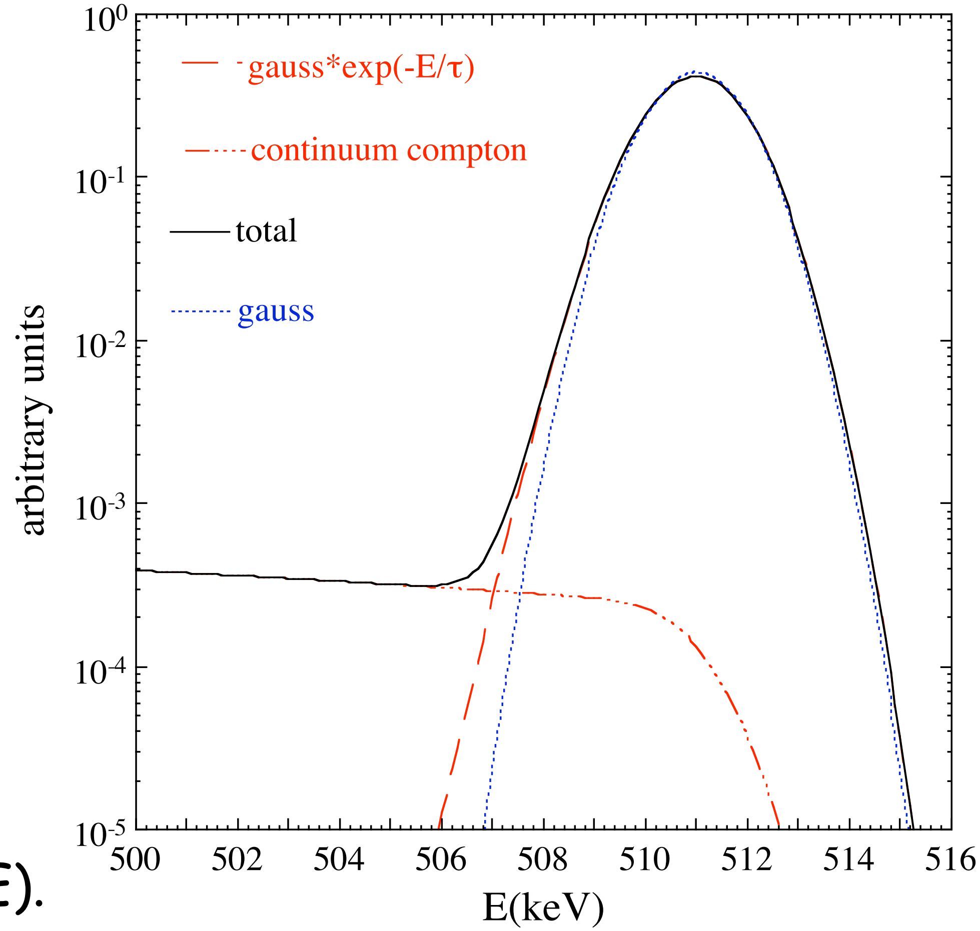
To be compared with data, models have to be convolved with the instrument response

$S(E) = F_{model}(E) * R(E)$

with

R(E) : spectral response

$R(E) = Gauss(E,FWHM) * e^{-E/\tau} + C(E).$



$e^{-E/\tau}$: term due to incomplete charge collection (radiation damage)

C(E) : Compton continuum (mean value extracted from RMFs and IRFs)

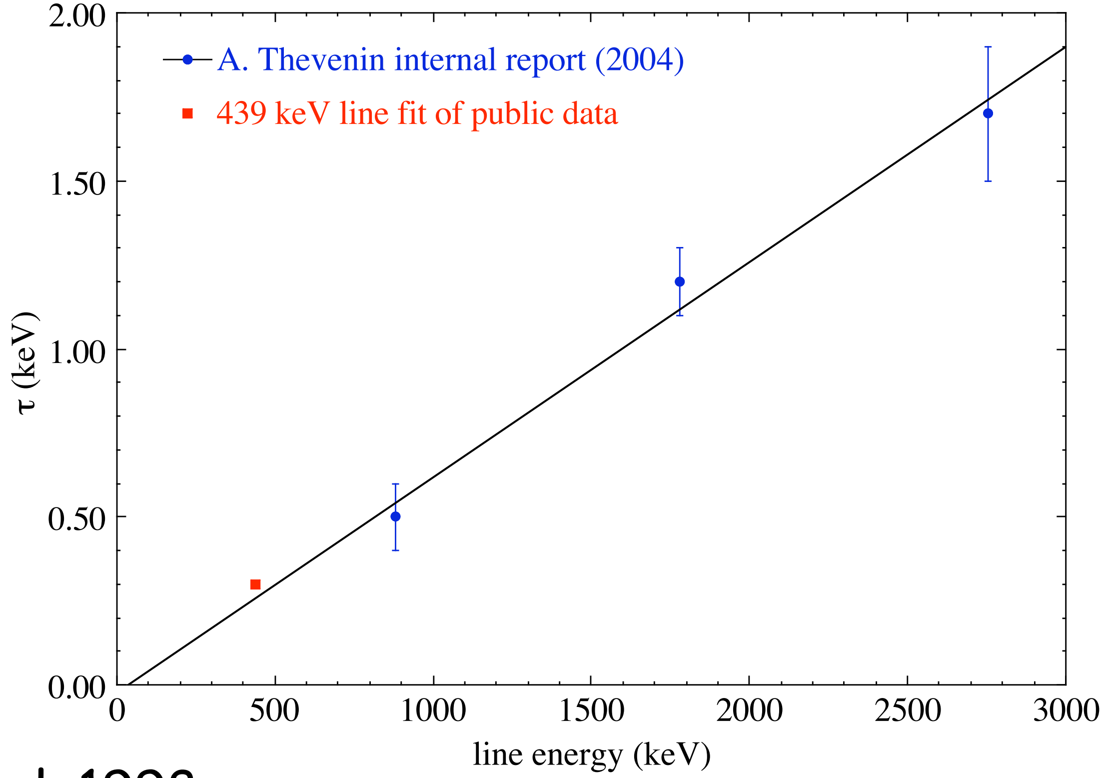
-> estimation of parameters for the spectral response

- SPI data : using neighbour background lines

=> $FWHM_{instr.}$ = 2.12 keV

=> τ (degradation parameter) :

439keV line: τ ~ 0.31 keV



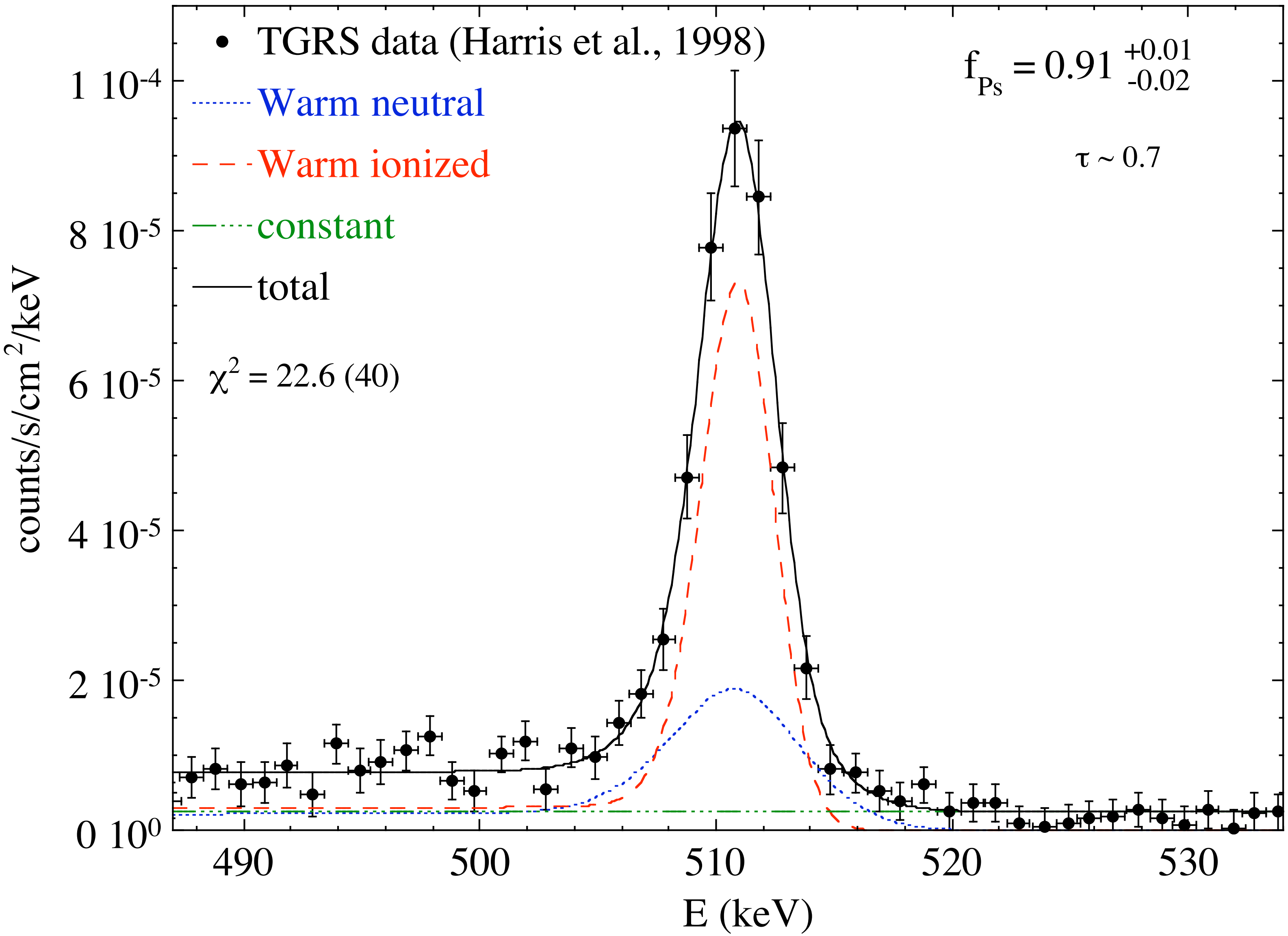
- TGRS data

Estimation based on Harris et al. 1998

=> $FWHM_{instr.}$ ~ 3.5 keV

=> τ ~ 0.7 keV

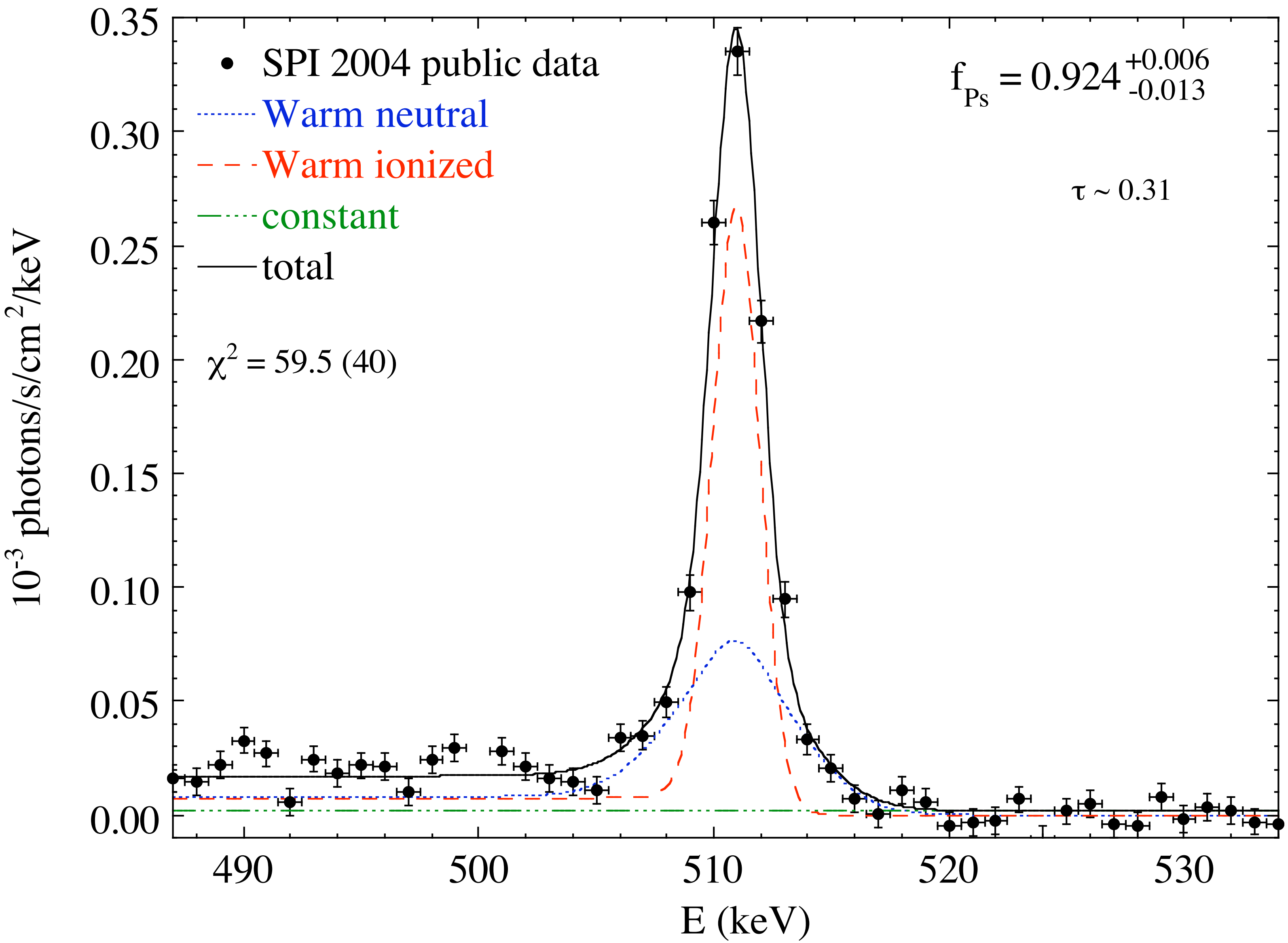
-> fit model to data



-> fit model to data

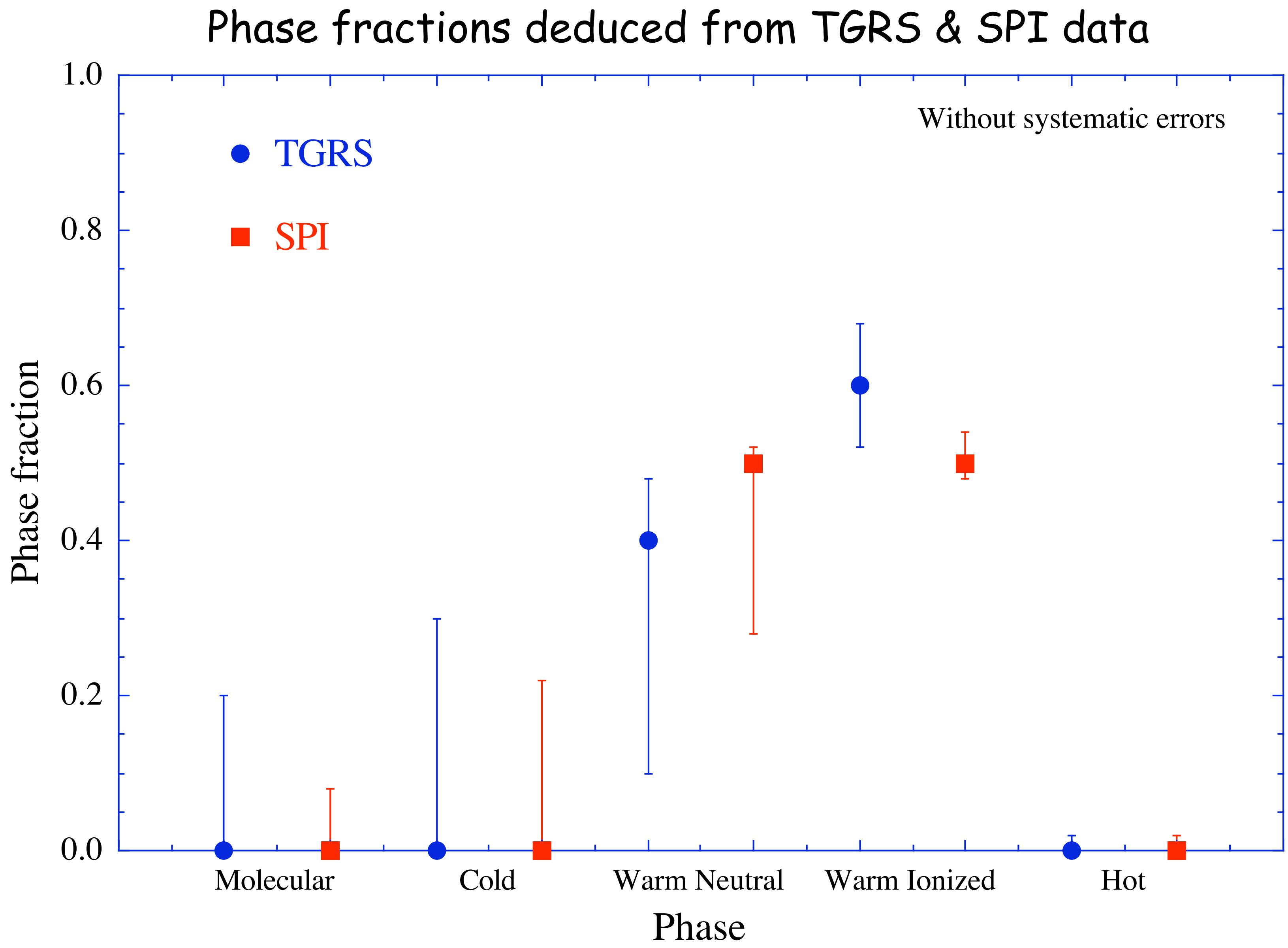
PRELIMINARY RESULTS

Preliminary SPI measured spectrum (model fitting Gauss. 8x7deg)



-> fit model to data

PRELIMINARY RESULTS



Conclusions

- Preliminary results :
  - -> annihilation seems to take place in warm media
  - -> agreement between TGRS and SPI data

    f_{Ps}(model)~0.92±0.01 vs. 0.94±0.04 (Harris et al., 1998)

- Systematic errors :
  - -> effect of radiation damage => $\Delta f_{Ps} \sim 0.01$

    => $\Delta f_{phase} \sim 0.02$

    need a better characterization
  - -> possible uncertainties in spectral response
  - -> background (continuum, lines…)

- near future :
  - -> spectro-imaging analysis