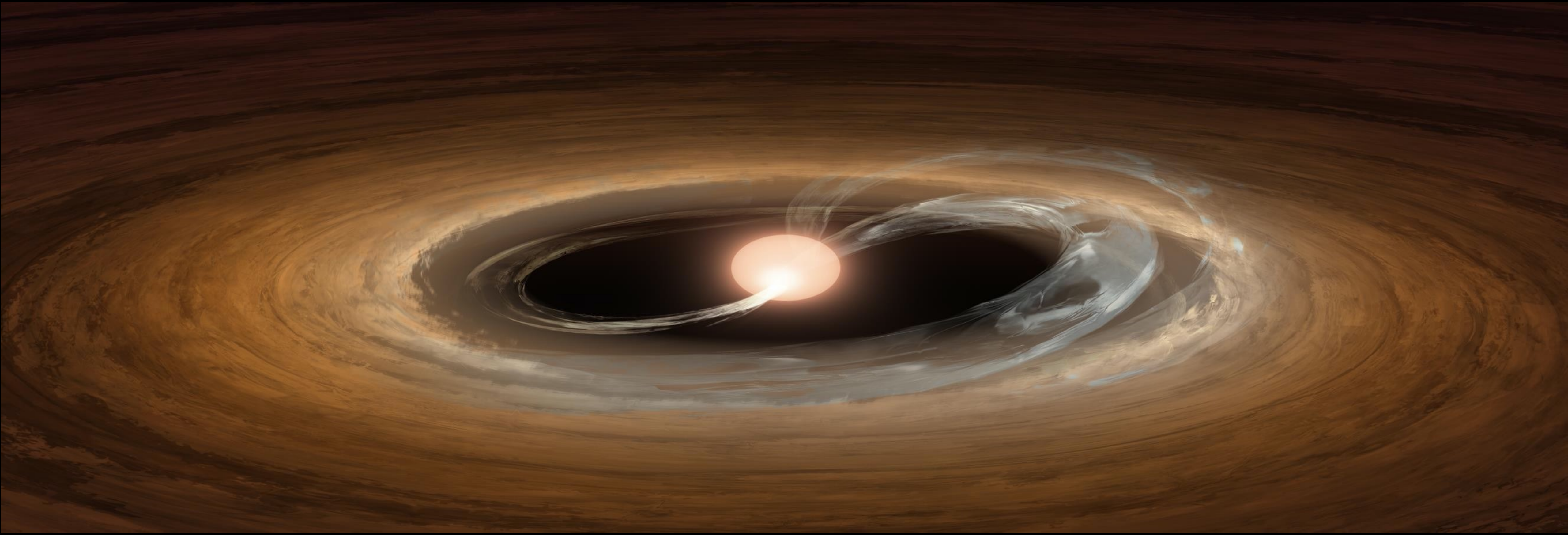
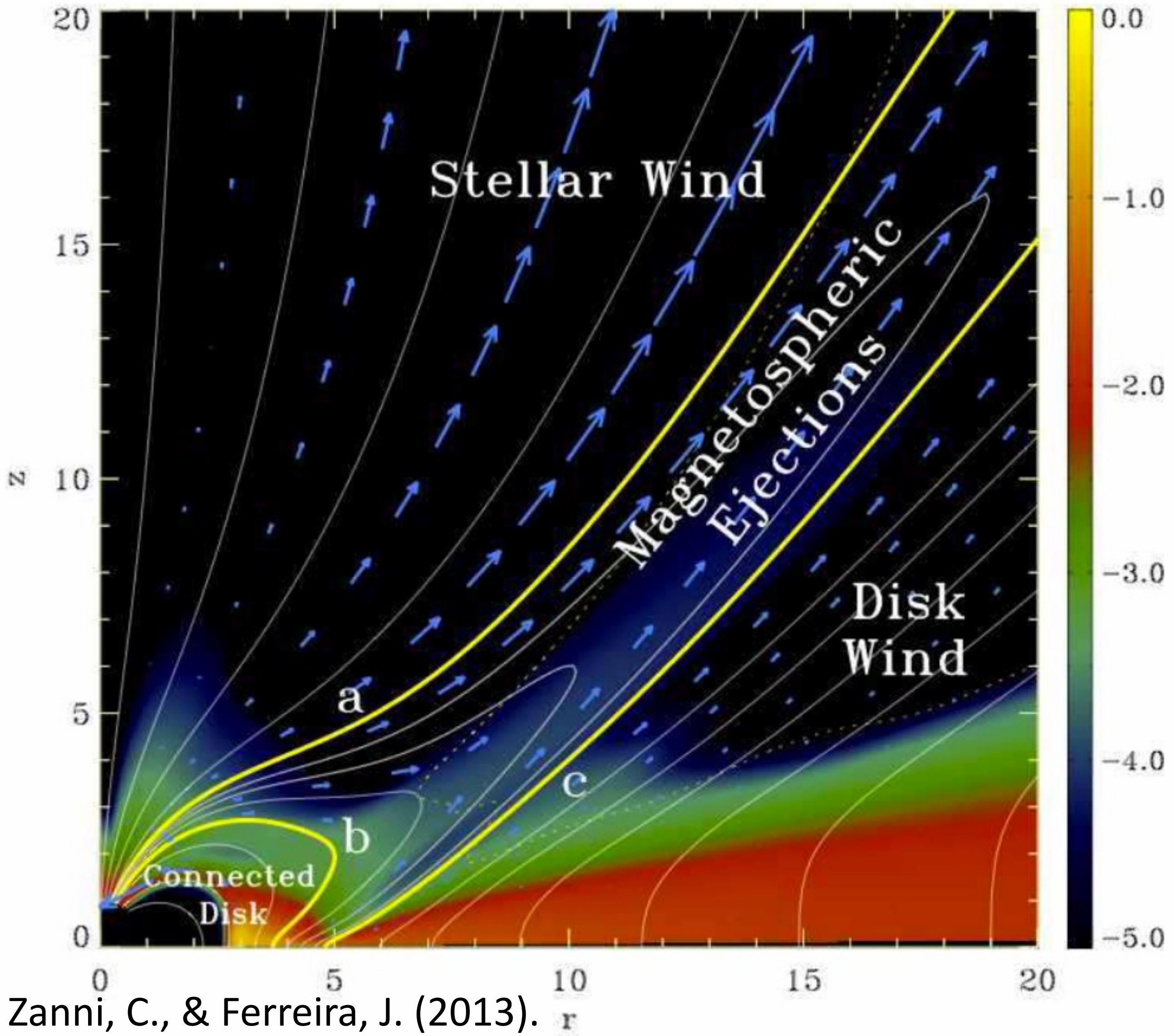
Ionisation by magnetic reconnection events in T Tauri discs



Valentin Brunn

I. Context

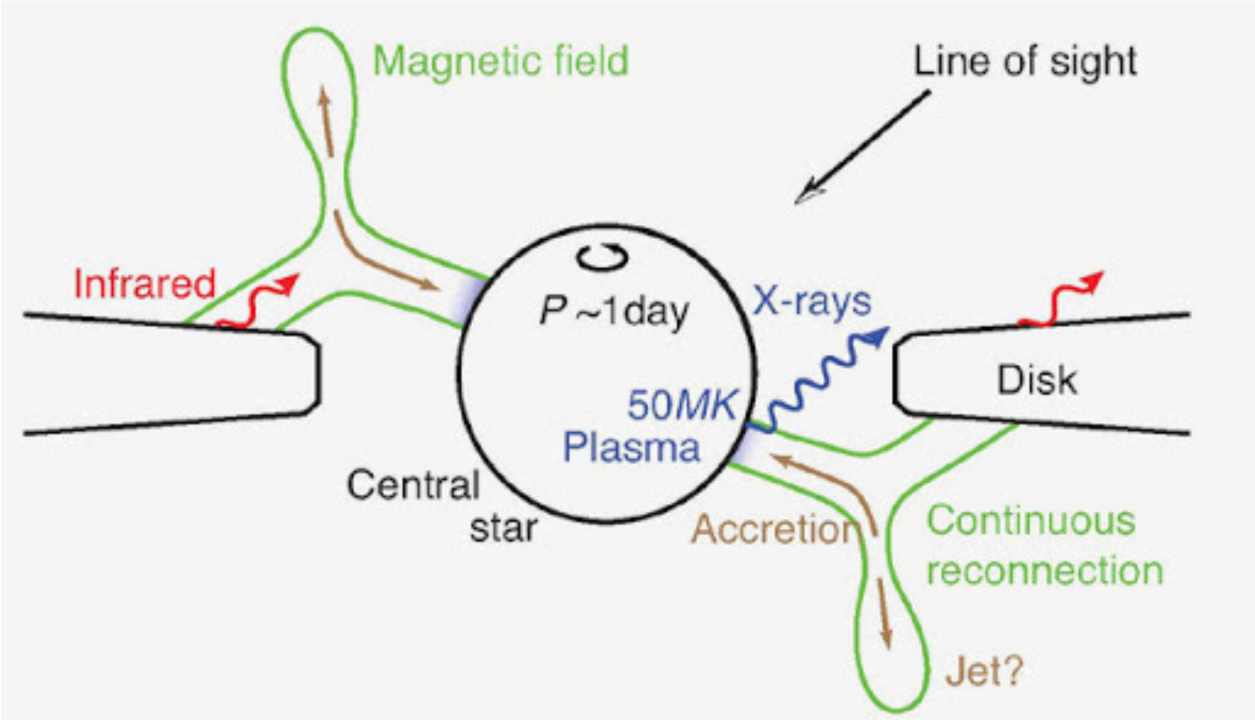
Regions of interest



Zanni, C., & Ferreira, J. (2013).

Interaction region between **star** magnetic field and **disc** magnetic field

Reconnection regions



Energetic particles are produced that will **ionise** the inner disc

Interests of ionisation in protoplanetary discs

Source of **heating** of disc and jet
Initiate disc (prebiotic) **chemistry**
Controls **accretion**

The study :

Ionisation rates in

T Tauri discs due to

magnetic

reconnection events

Procedure

$$\zeta(N) = 2\pi \int_{E_{ion}}^{\infty} j(E,N)\sigma_{ion,k}(E)dE \quad (s^{-1})$$

$j(E,N)$: the propagated spectrum

$$j(E) = j_0(E_0)\frac{L(E_0)}{L(E)}$$

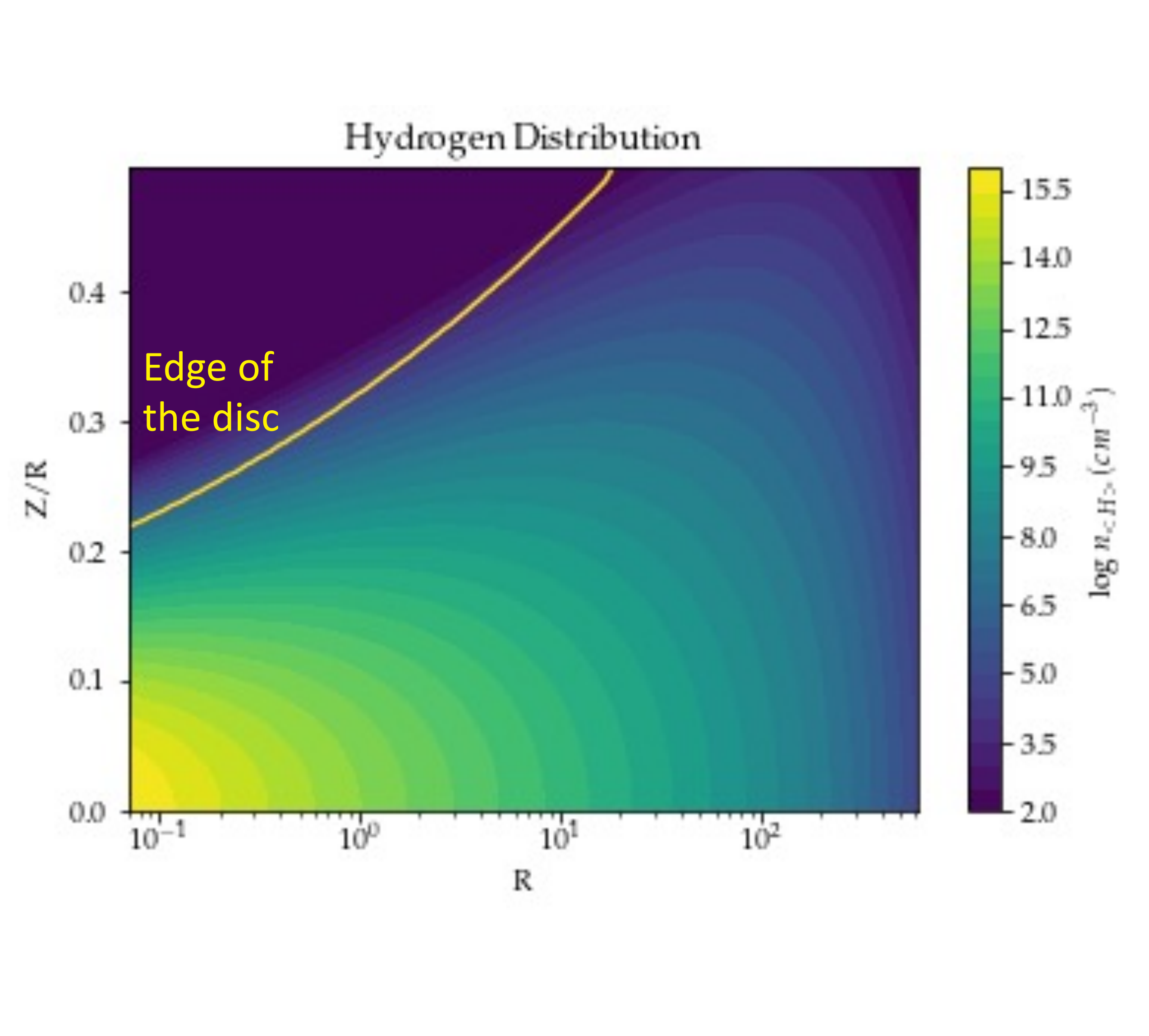
Injection model

Particle – Disc interaction

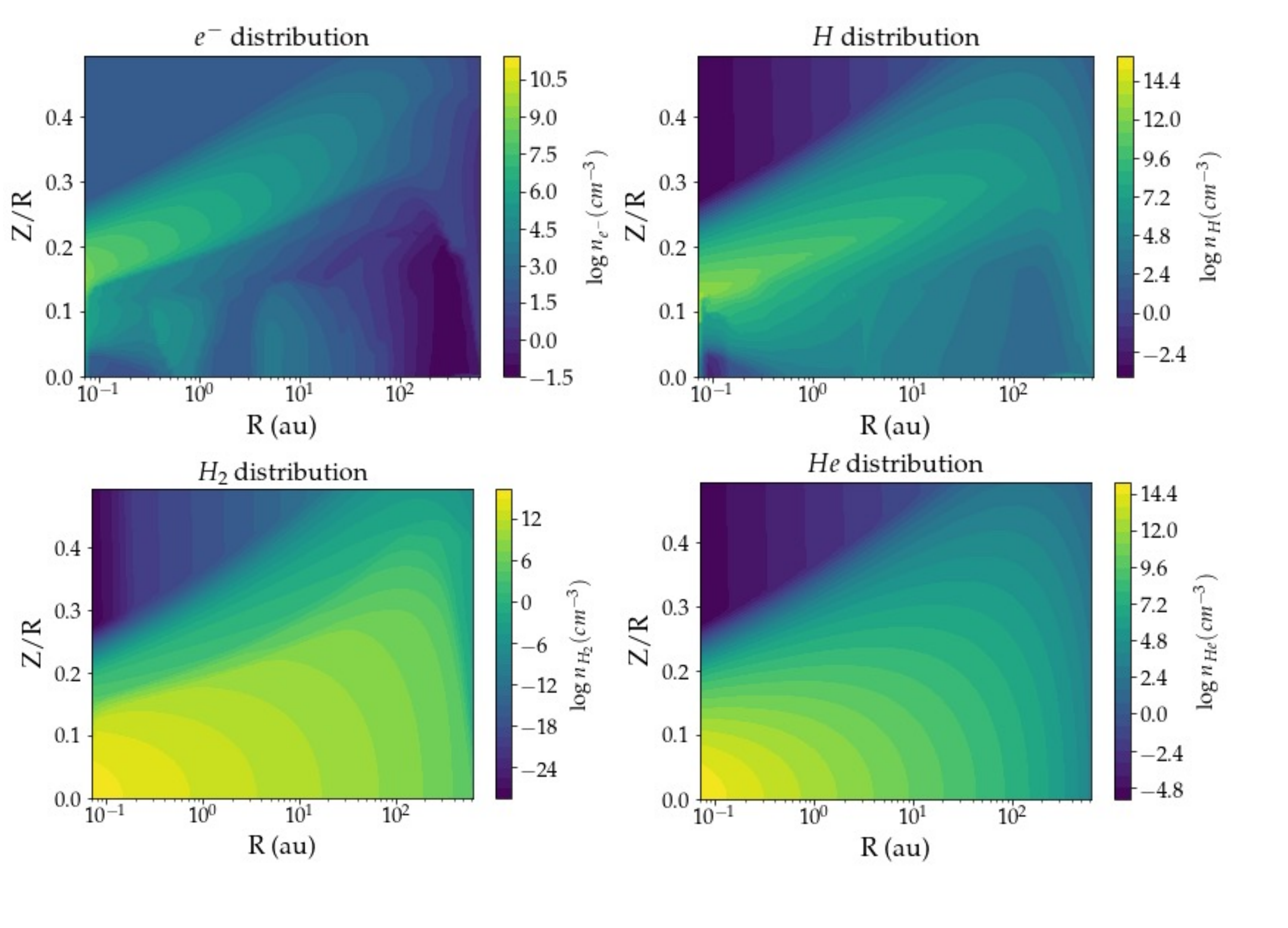
Padovani et al. 2009

Structure :

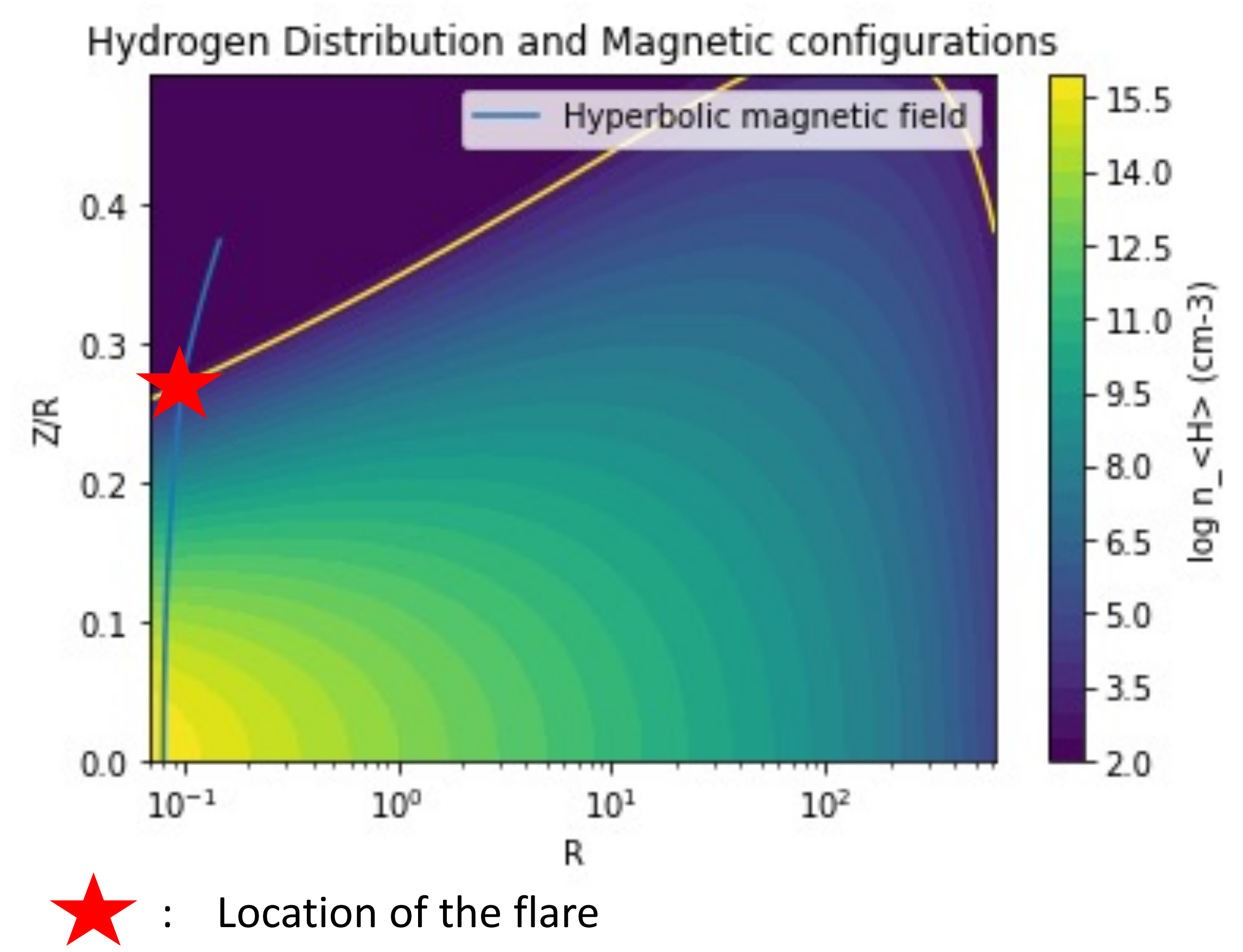
II. Protoplanetary Disc Model



Chemical Model: ProDiMo (Woitke P. 2009)

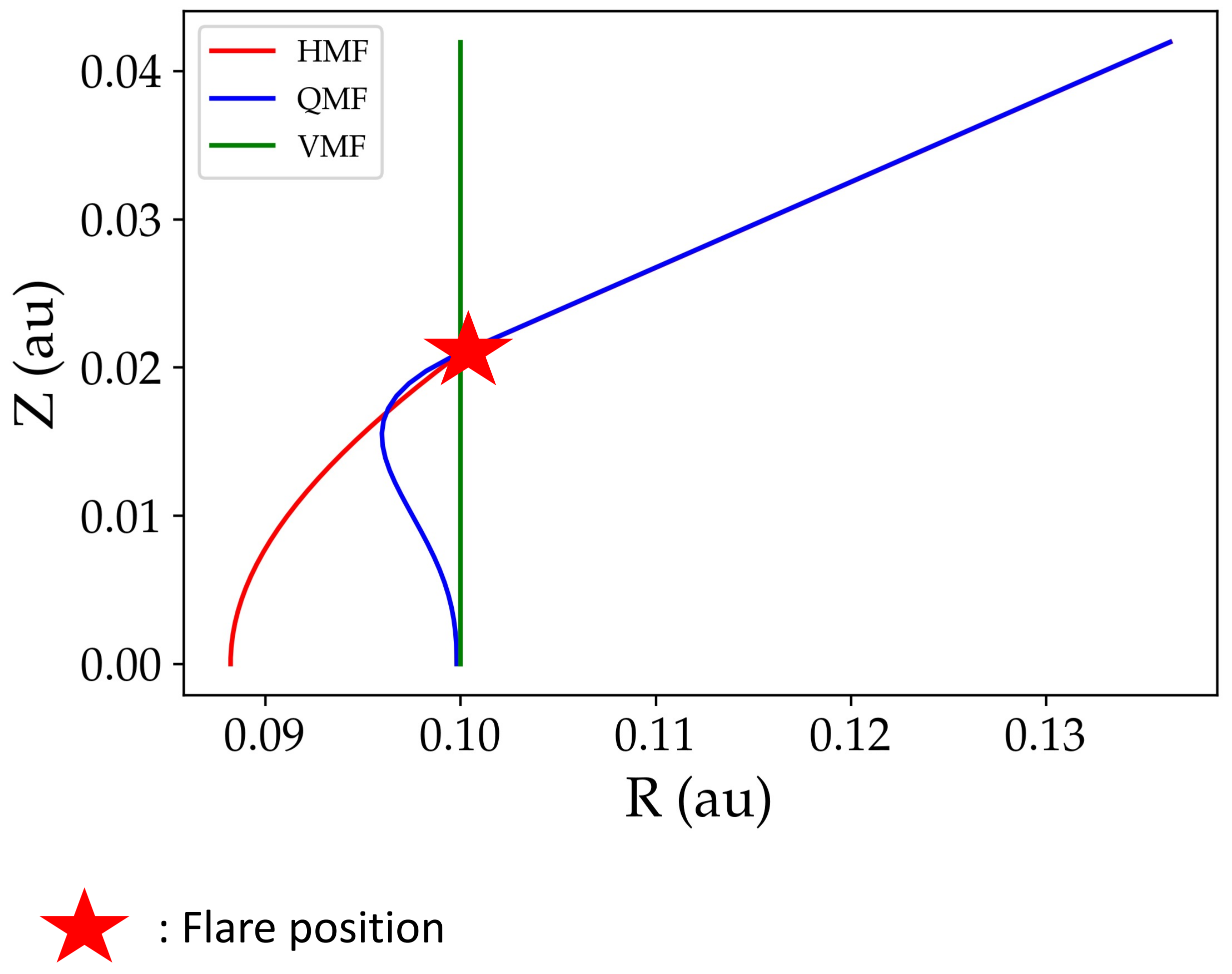


Composition:
Plasma, **H**,
H_2 and **He**



Flare append at the **disc edge**

Magnetic Configurations

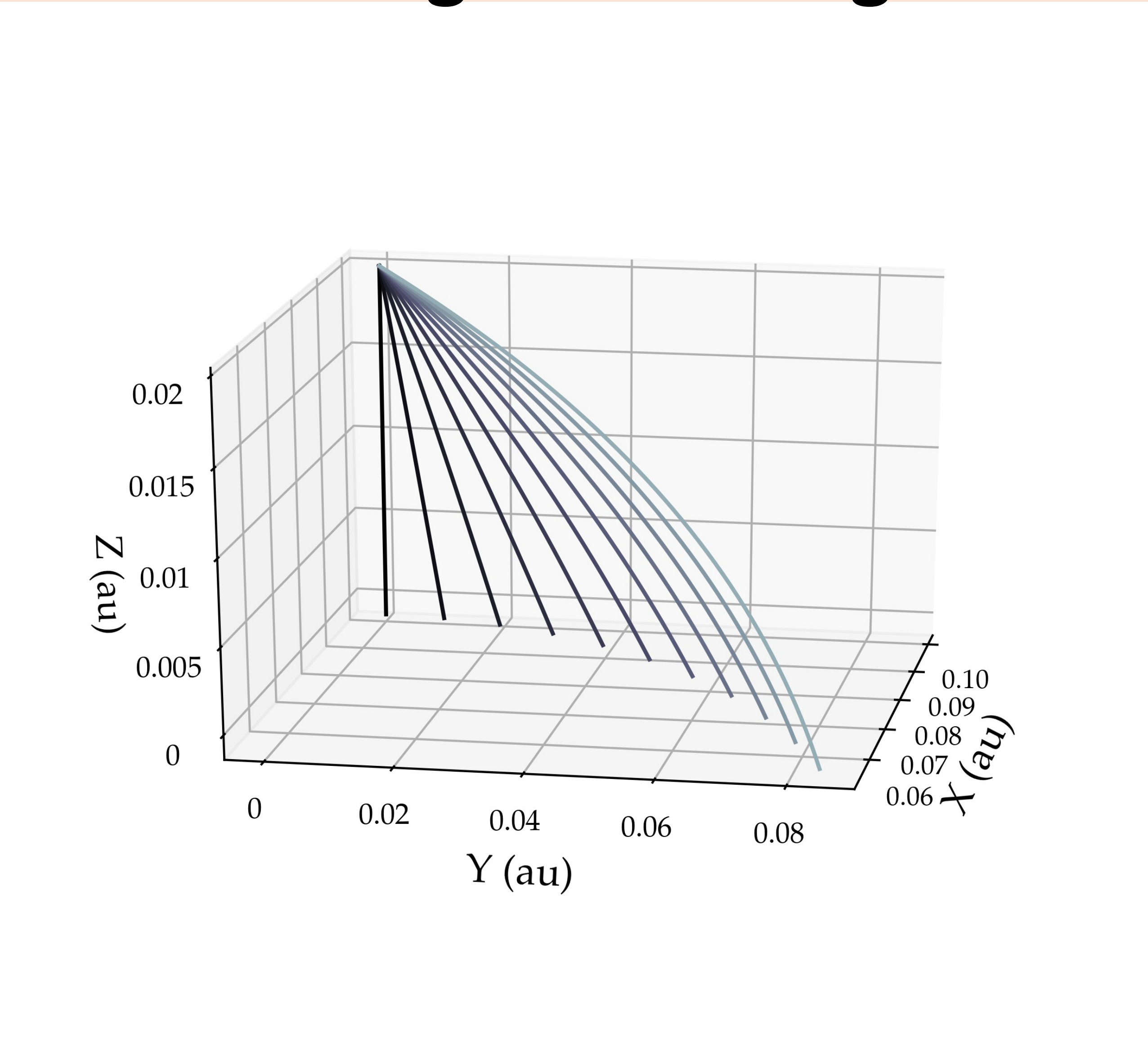


Vertical : Référence

Hyperbolic : Disque standard (Blandford, R. D., & Payne, (1982))

Quartic : Differential accretion in the disc

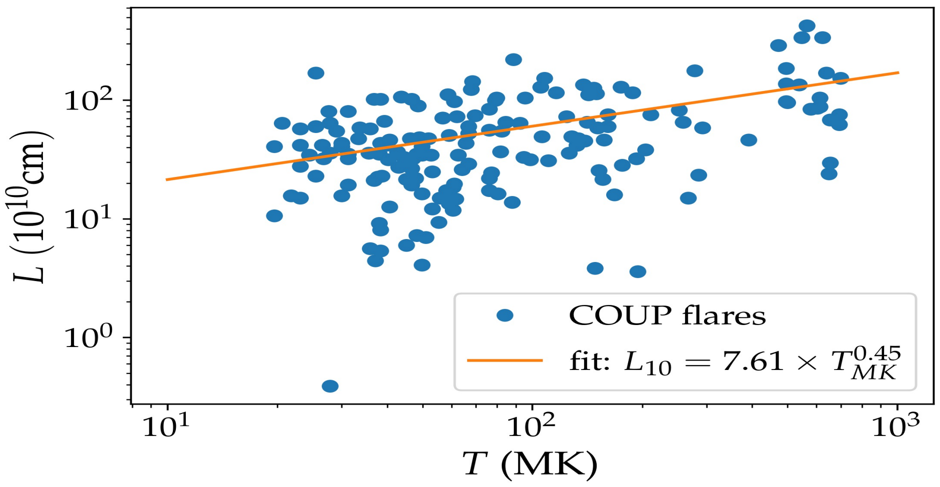
Toroidal Magnetic Configurations



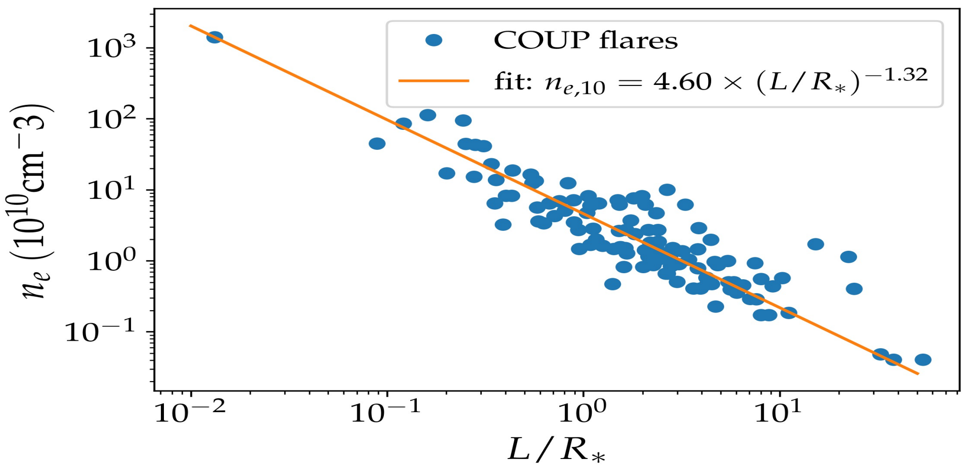
Particles explore **different** column densities for each configuration

III. Particle and Radiation Model

Flare size as a function of temperature



Density as a function of flare size



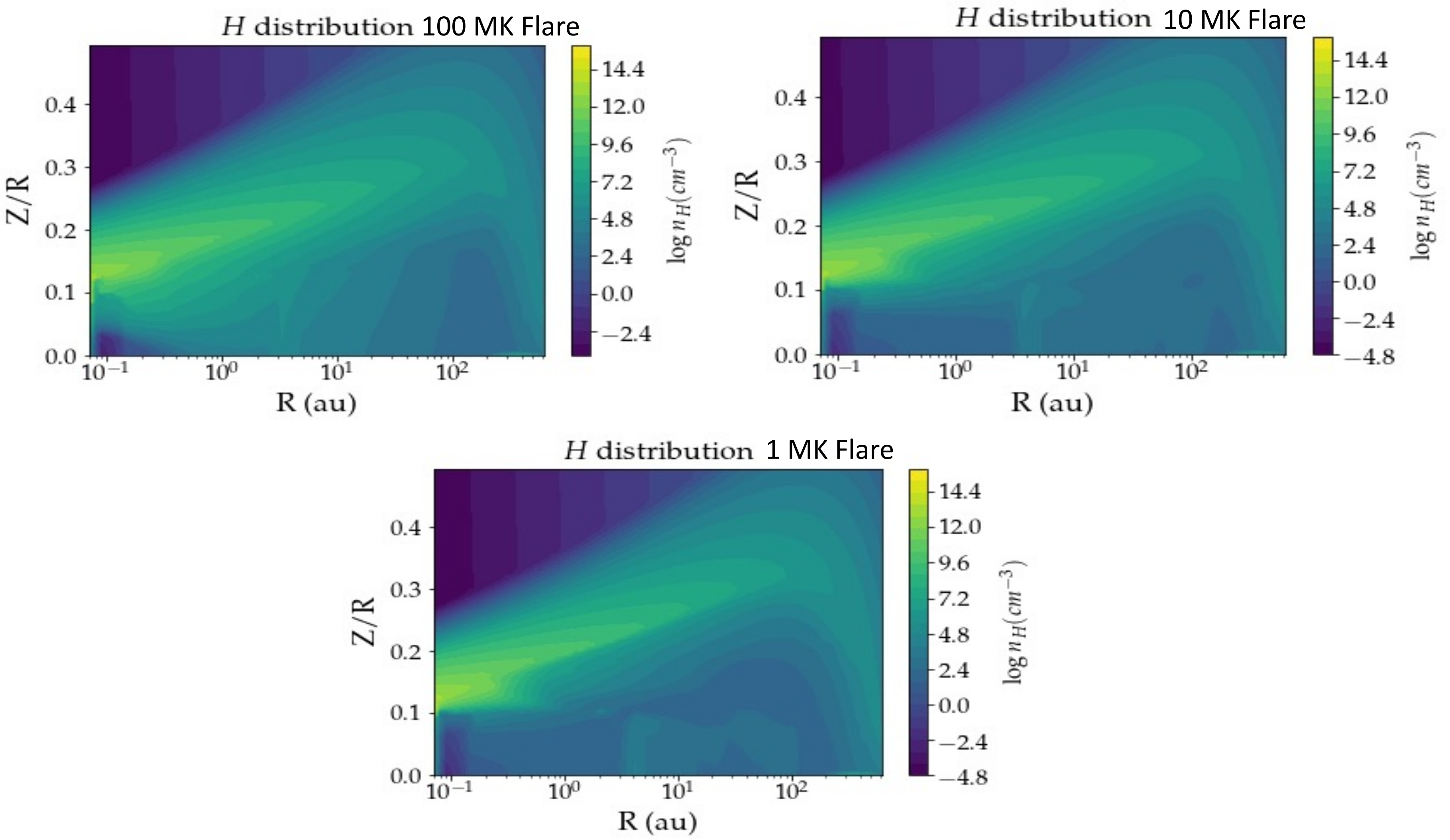
Getman, K. et al. (2008) *The Astrophysical Journal*.

Bremsstrahlung **Luminosity** (erg/s):

$$L_X = 1.4 \times 10^{26} L_{10}(T)^3 n_{e,10}(T)^2 T_6^{1/2} g_B$$

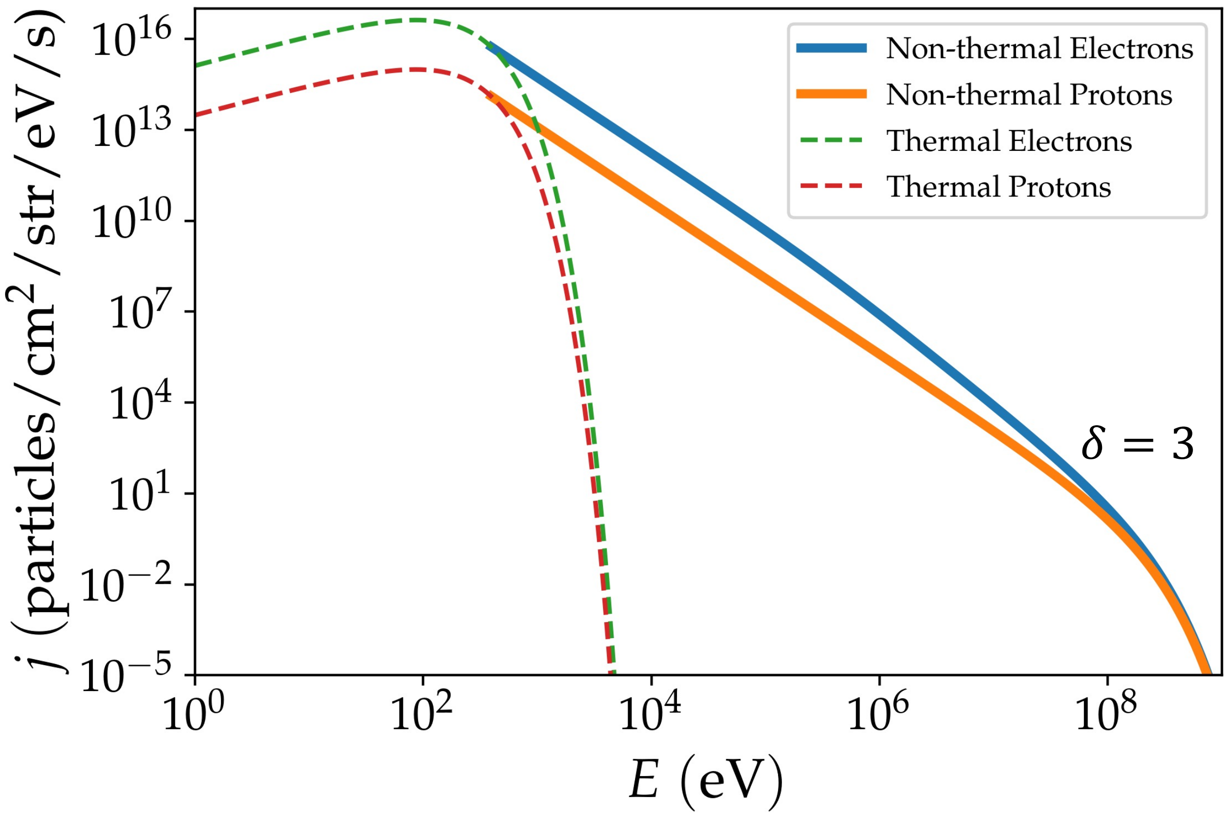
L_{10} : size of the flare over 10^{10}cm
$n_{e,10}$: electron density over $10^{10}\mathrm{cm}^{-3}$
T_6 : temperature over 10^6K
g_B: Bolometric Gaunt factor

ProDiMo computes the chemical structure of the disc for different flare temperatures



Atomic hydrogen is present **deeper** in the disc for hot flares with **strong X-ray** emission

Particle Injection



Power law spectrum as in solar flares

$$j_0(E, T_F) \sim \left(\frac{E}{E_{inj}(T_F)}\right)^{-\delta} \exp(-\frac{E}{100\ MeV})$$

n_{NTh} : density of non-thermal particles
E_{inj}: injection energy
T_F: temperature of the flare

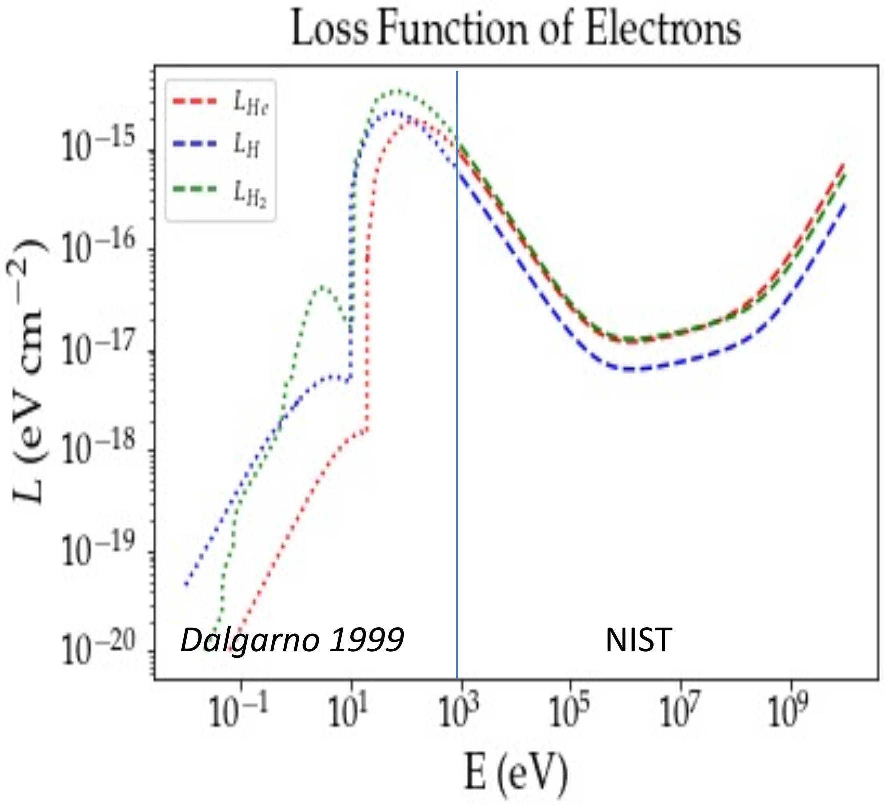
IV.
Disc Ionisation Model

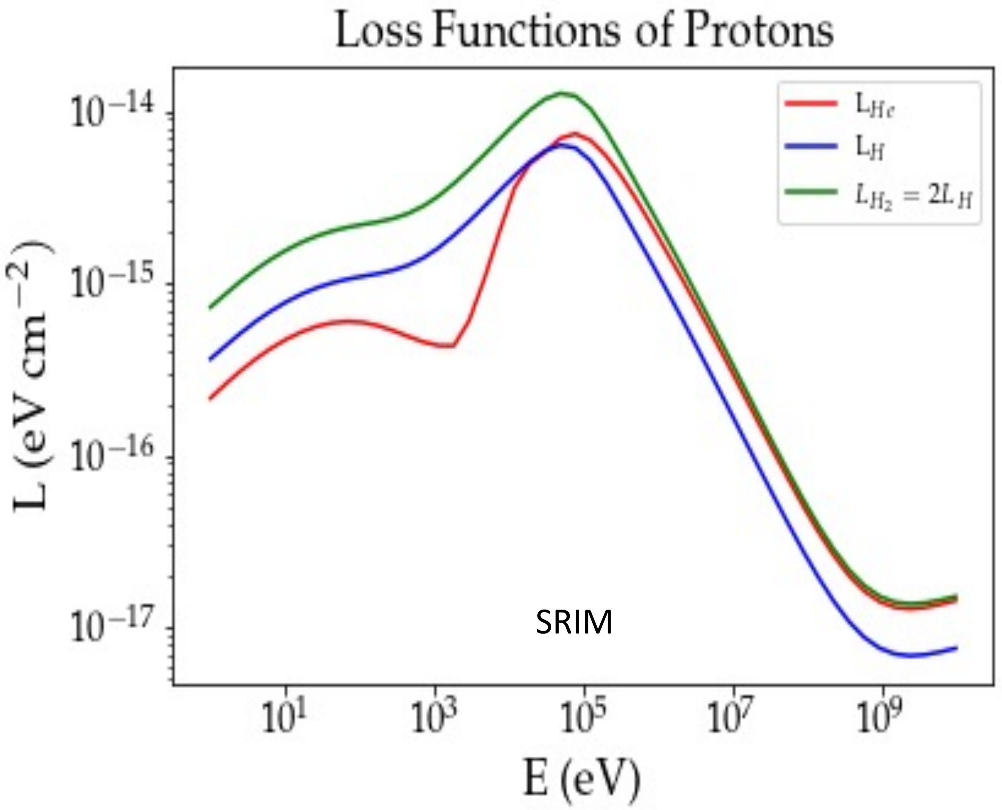
The loss function

$$\frac{dE}{dN} = -L(E)$$

The loss function describes a maximum of **interaction processes**

Loss functions





Loss function depends on the **particle** and the **medium** crossed

Mean Loss function

$$\bar{L}(E,s) = \sum_i f_i(s)\, L_i(E) \quad i = H, H_2, He$$

$$f_i = \frac{1}{s}\int_0^s \frac{n_i(s')}{n_{tot}(s')}\,ds'$$

We build a mean loss function at **each position**

$$j(E,N) = j_0(E_0)\frac{\bar{L}(E_0)}{\bar{L}(E)}$$

Padovani, M. et al (2009) *Astronomy & Astrophysics*.

Continuous slowing down approximation gives the **propagated spectrum**

$$\zeta(N) = 2\pi \int j(E, N)\big(1 + \phi(E)\big)\sigma_{ion}(E)dE$$

σ_{ion} : ionisation cross section
$\phi(E)$: ionisation by secondary particles

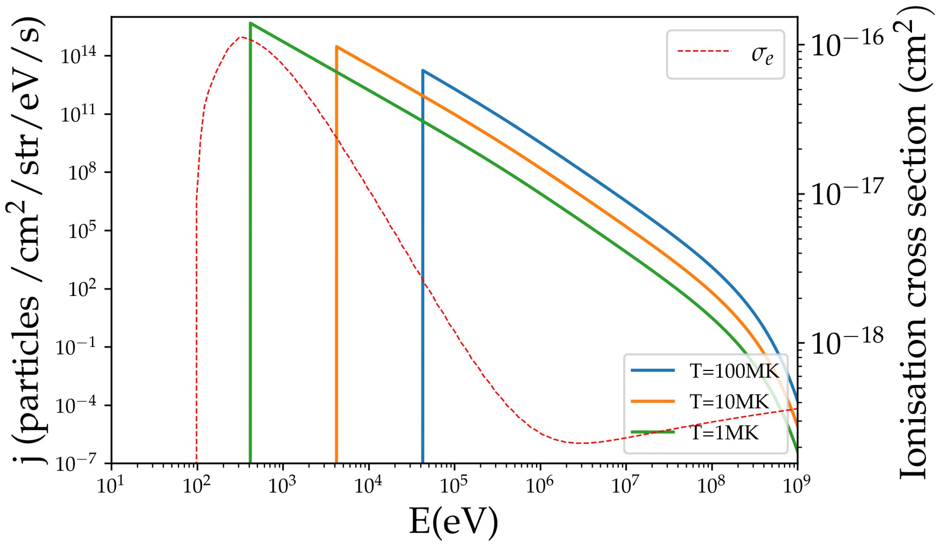
Ionisation rates obtained from **propagated** spectrum

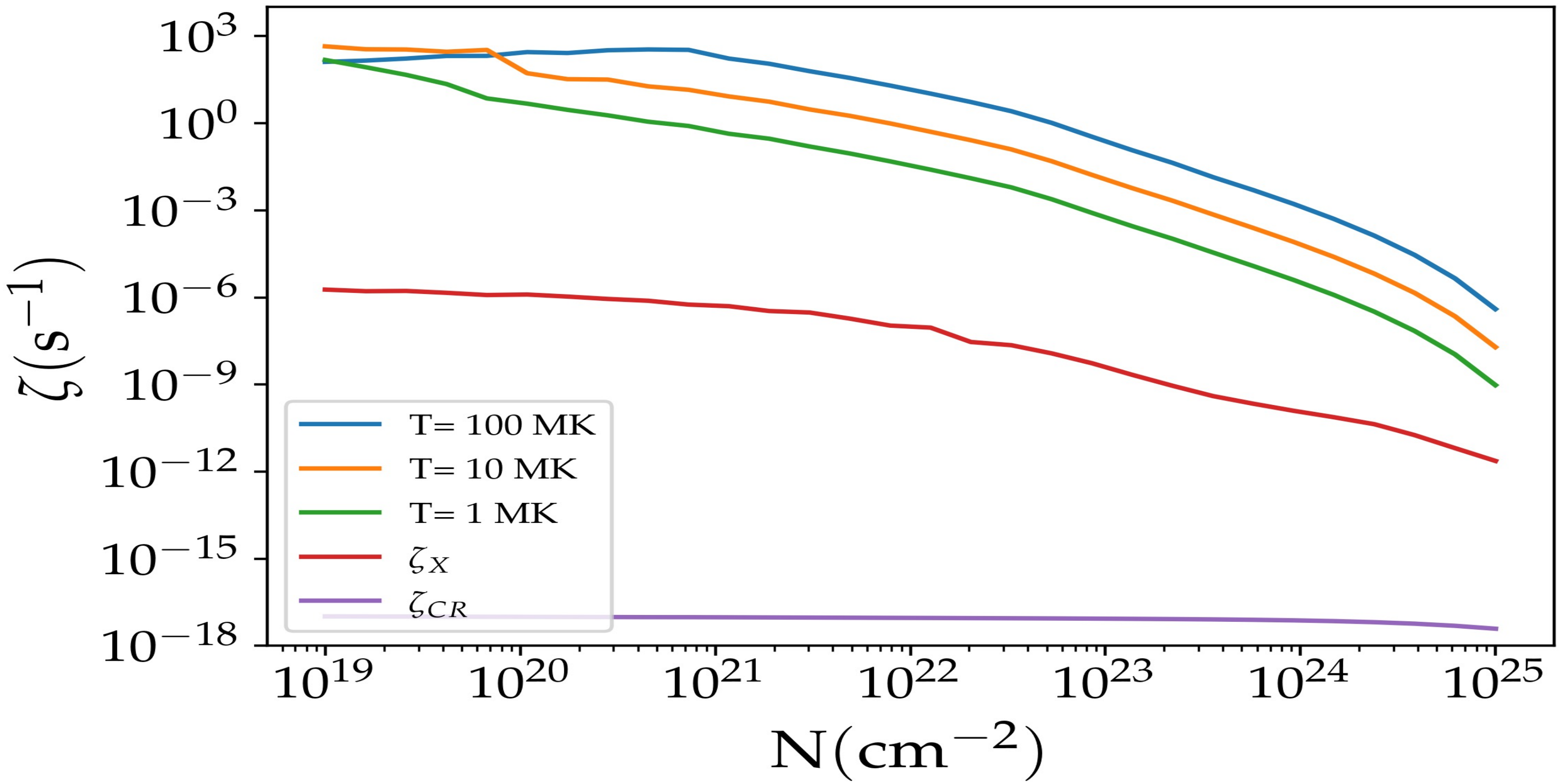
V. Results

Parameters explored

Magnetic configuration
Physical properties of plasma → **Power law index** of injection spectrum

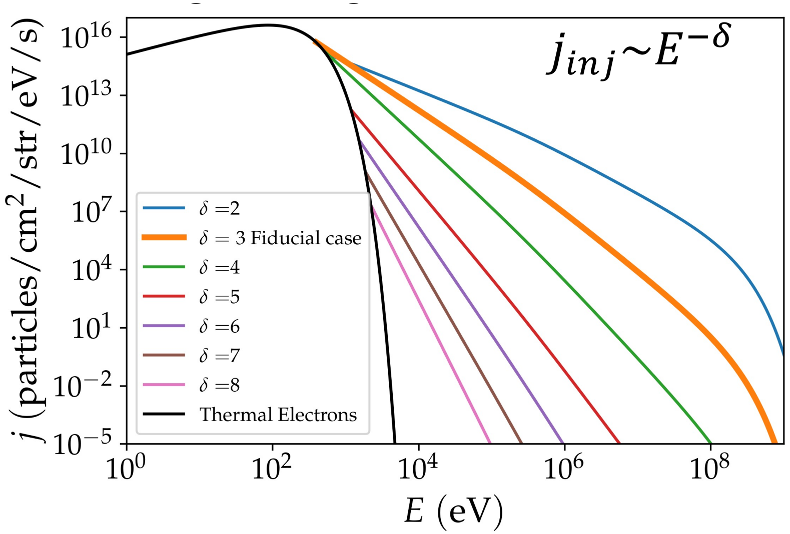
Flare's temperature → **Normalisation** of the injection spectrum

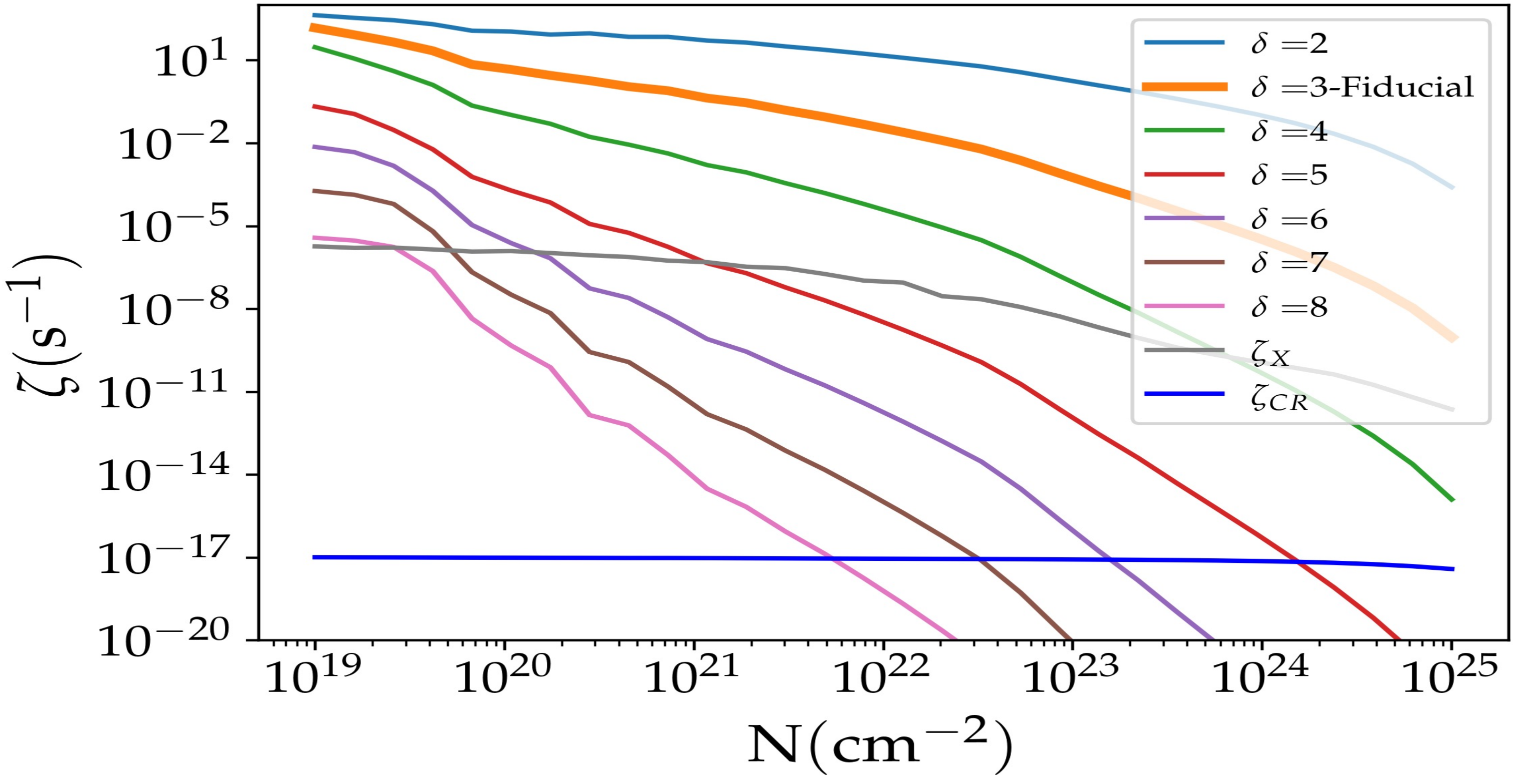




Hotter flare, higher ionisation rate

Even **weak flares** are a **dominant** source of **ionisation**





Lower index, higher ionisation rate

Dominant source of ionisation for $\boldsymbol{\delta < 5}$

Toward a more Predictive Model

Ionisation rate are overestimated due to very localised results

↓

Need of a spatial and time averaged model