H_2 emission in dynamical environments

P. Lesaffre,

F. Levrier, B. Godard

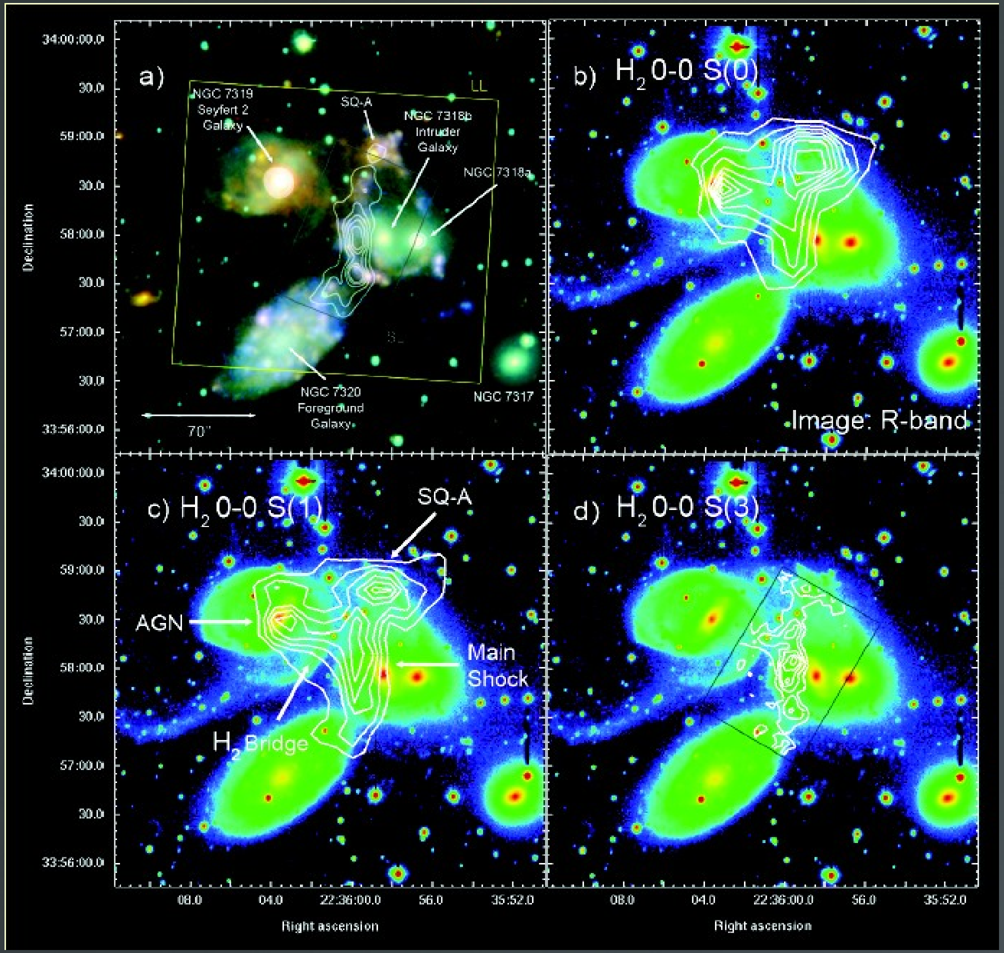
V. Valdivia, N. Dziourkevitch,

A. Gusdorf, M. Gerin

G. Momferratos, E. Falgarone, G. Pineau des Forêts

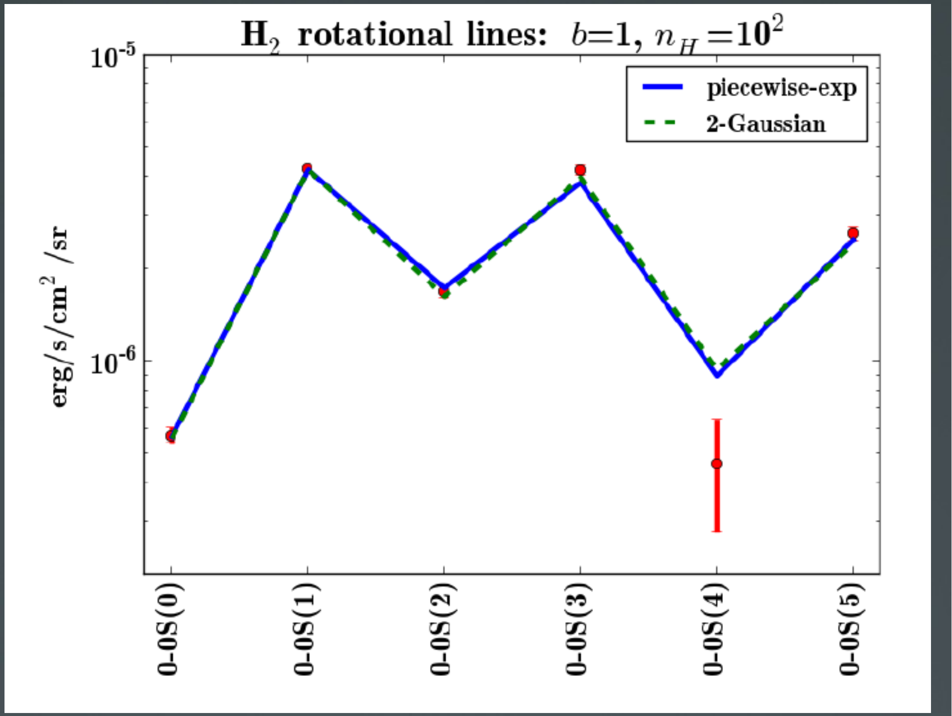
Atelier H2

In the Stefan's Quintett: a galactic shock 3 times as bright in H2 as in X.



Data: Cluver, Appleton et al. (2010)

Guillard et al. (2009, 2010)

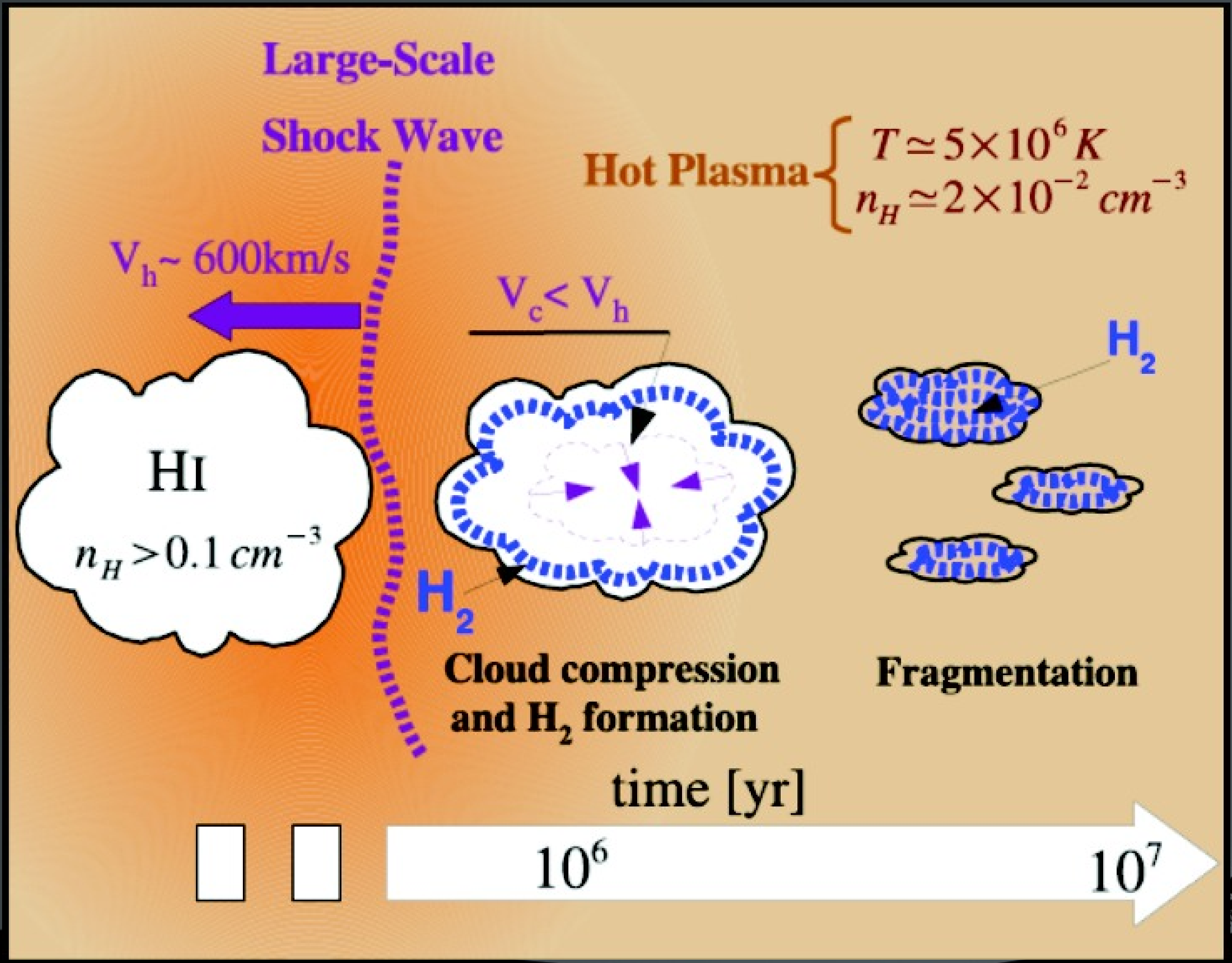


Models: a distribution of shocks

Lesaffre et al. (2013)

Shock driven turbulence

Guillard et al. (2010)



Dissipation in decaying turbulence.
Isothermal 3D MHD (Mach 4, ABC)

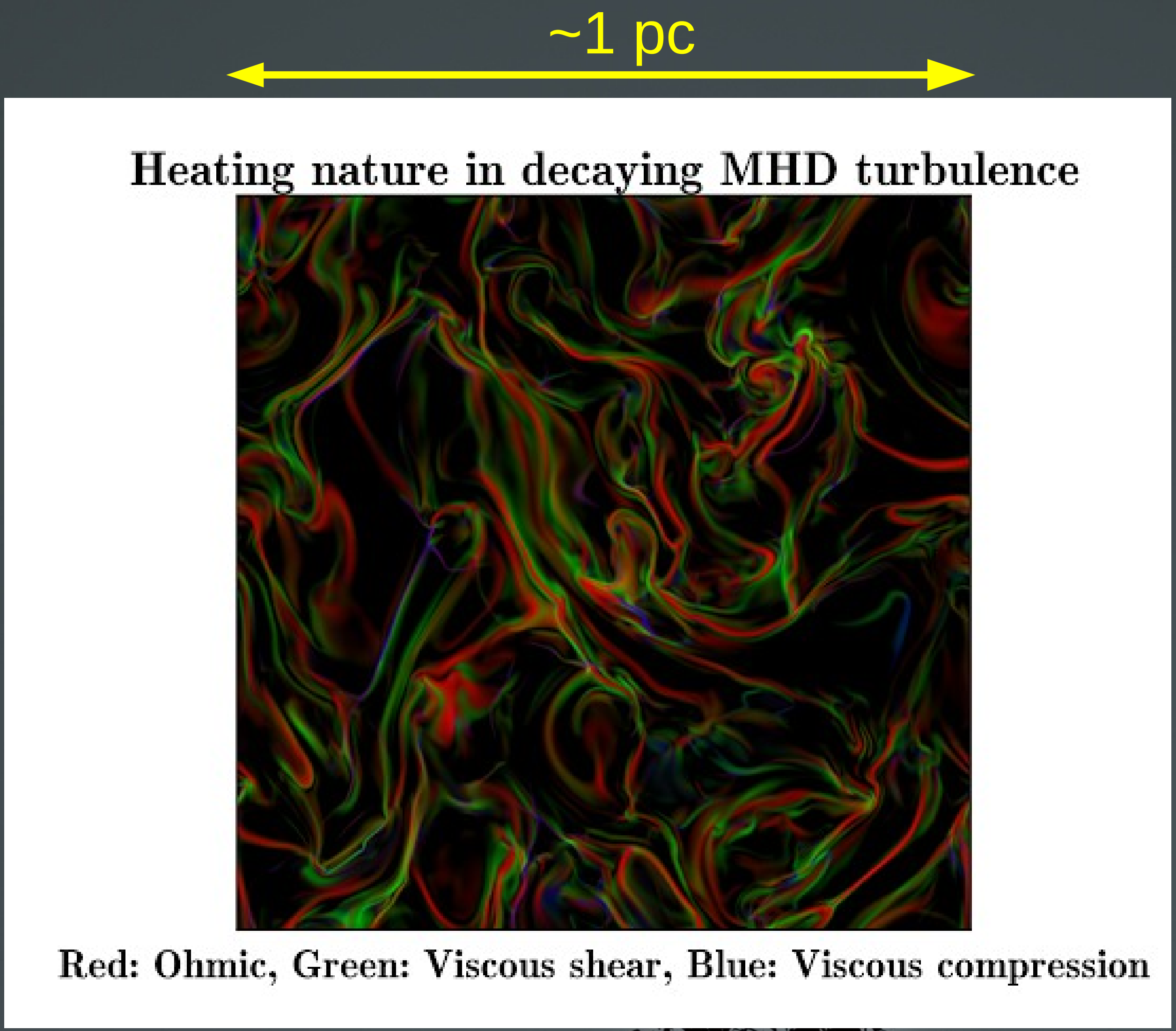
$n_H \sim 100/cm^3$

$<u^2> \sim <b^2/\rho>$

$Re = LU/\nu \sim$ ~~2.10^7~~ 10^3

$Re_m = LU/\eta \sim$ ~~2.10^{17}~~ 10^3

(1020^3 pixels)



(Momferratos PhD thesis:
DUMSES simulations with careful treatment of vicous and resistive dissipation)

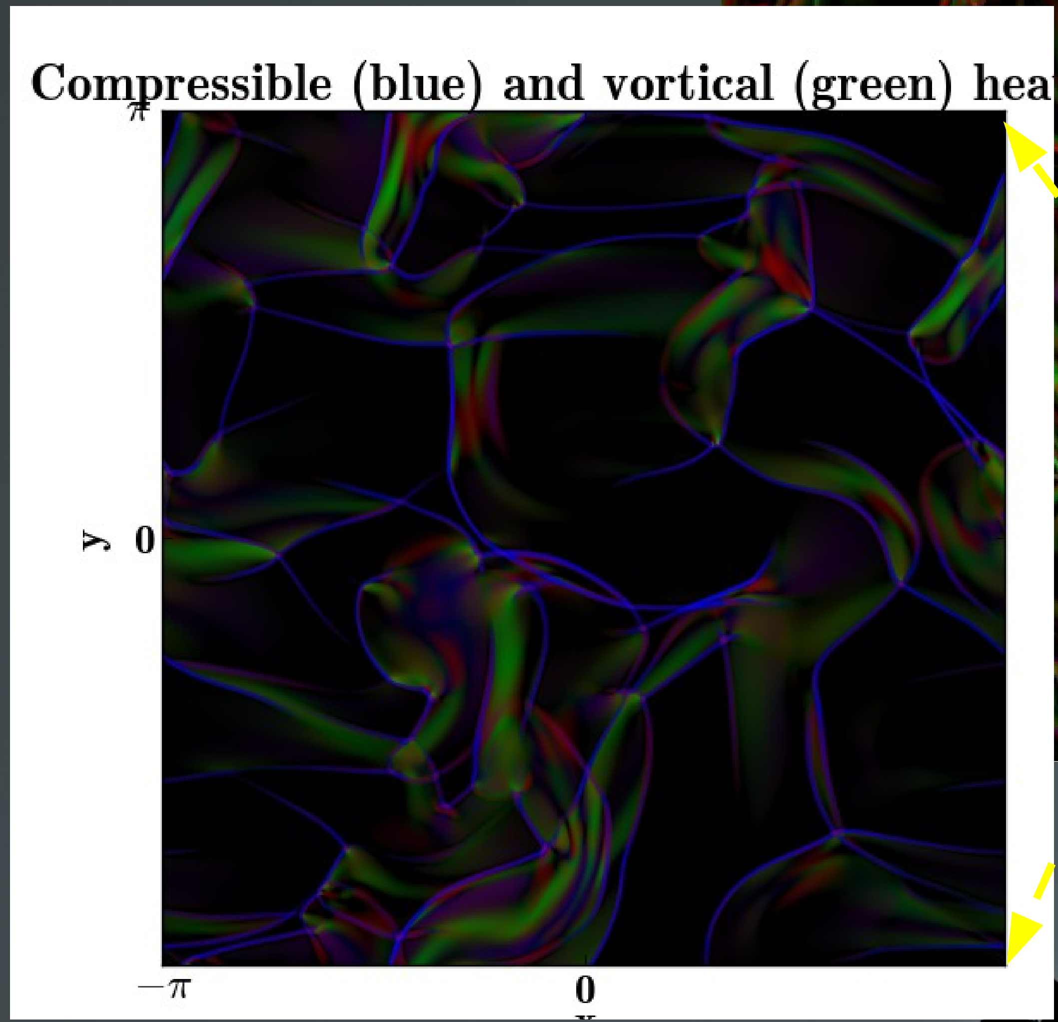
Decaying turbulence (2D runs)

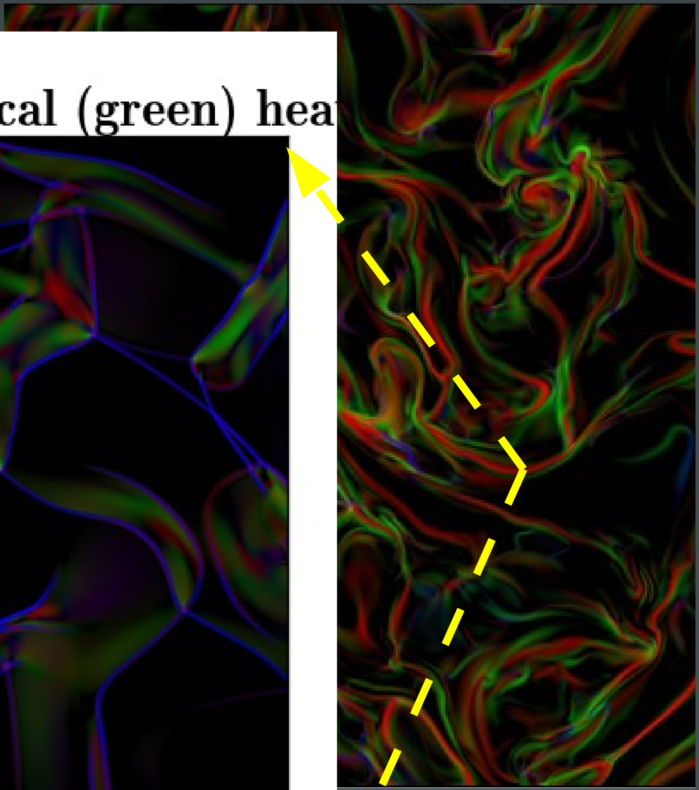
$n_H \sim 100/cm^3$

ACTUAL ν

No B field.

10^{16} cm





Decaying 2D turbulence from U_{rms} ~2 km/s
(way above average, But think intermittency)

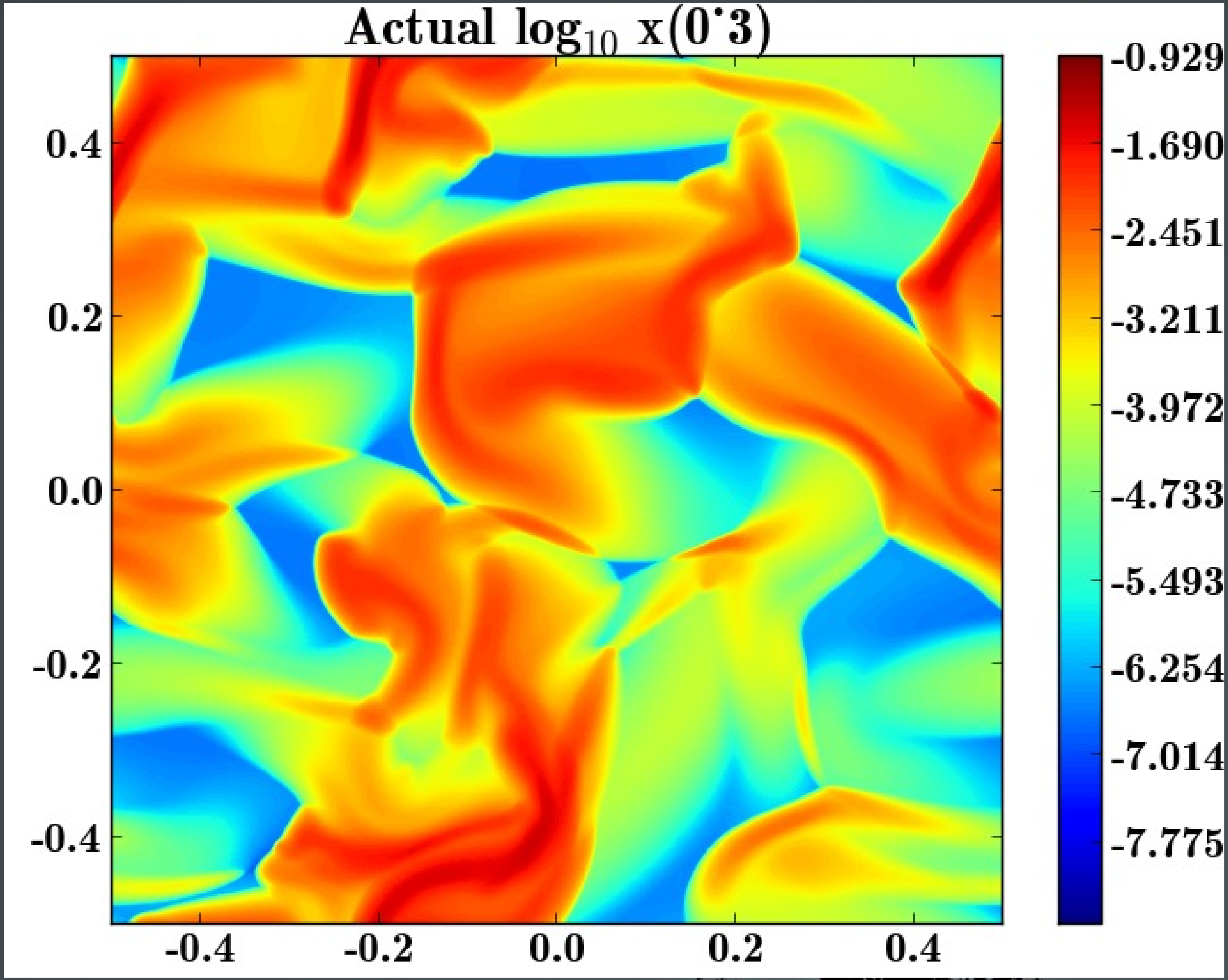
Coupling chemistry and MHD: CHEMSES = DUMSES + Paris-Durham

<u>**ACTUAL**</u>
viscous dissipation

32 species,
7 H_2 levels
1024^2 pixels,

<u>Uniform Irradiation:</u>
G_0=1, Av=0.1
$n_H \sim 100/cm^3$
=> molecular, but without CO.

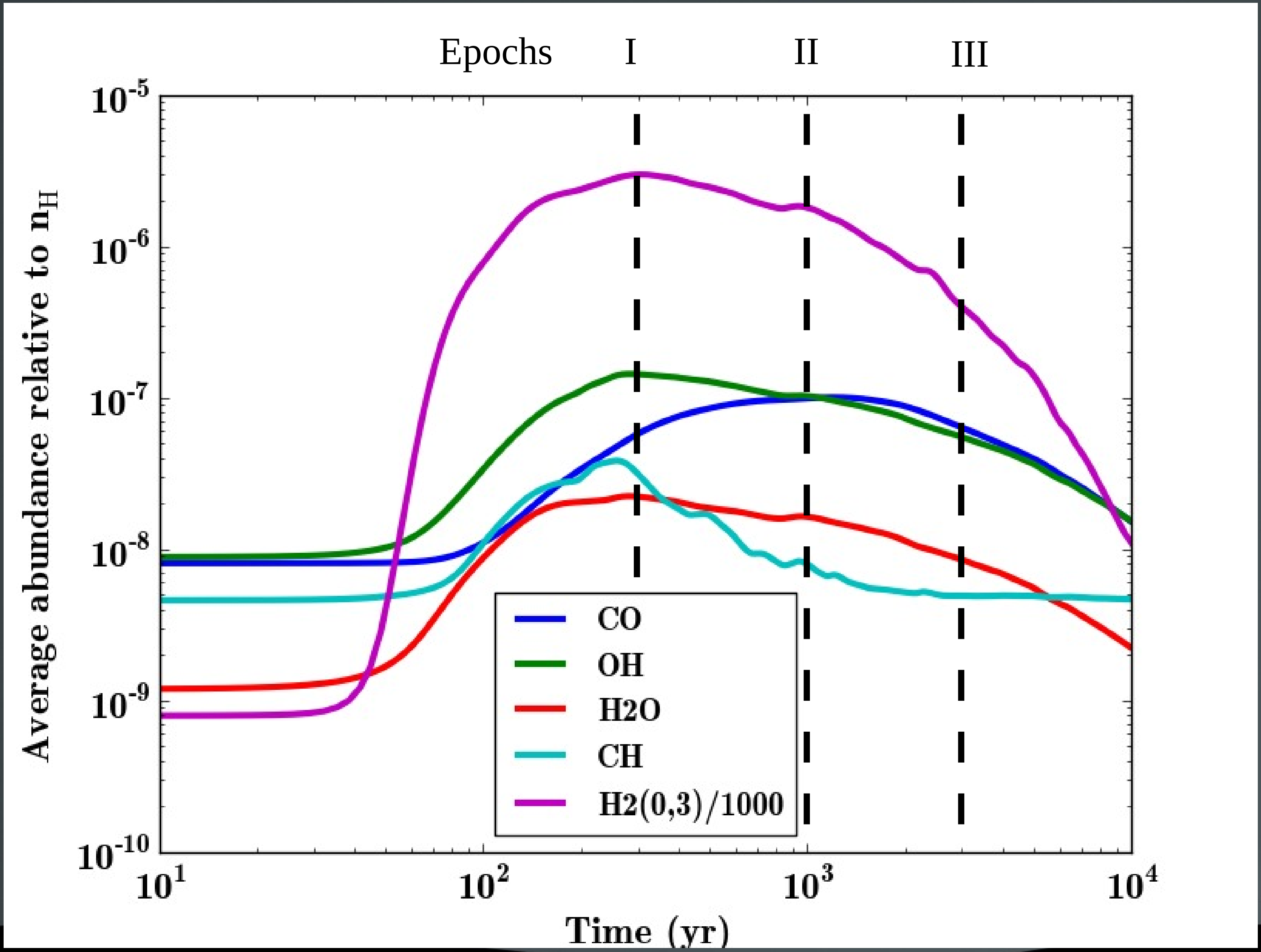
10^{16} cm



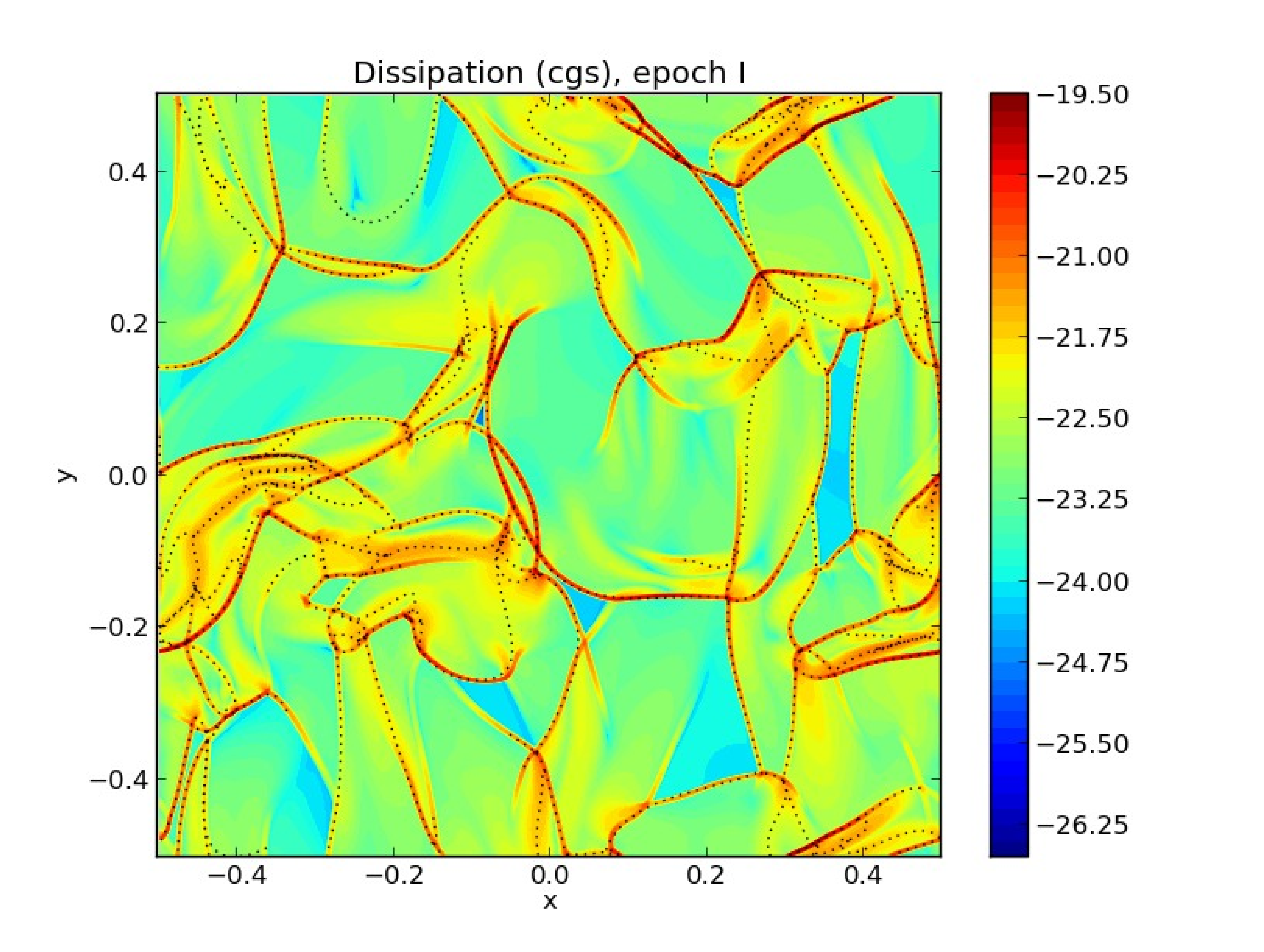
Map of H_2 v=0 J=3

H_2 excited and molecules produced by dissipation of 2D turbulence

$G_0=1$
Av=0.1

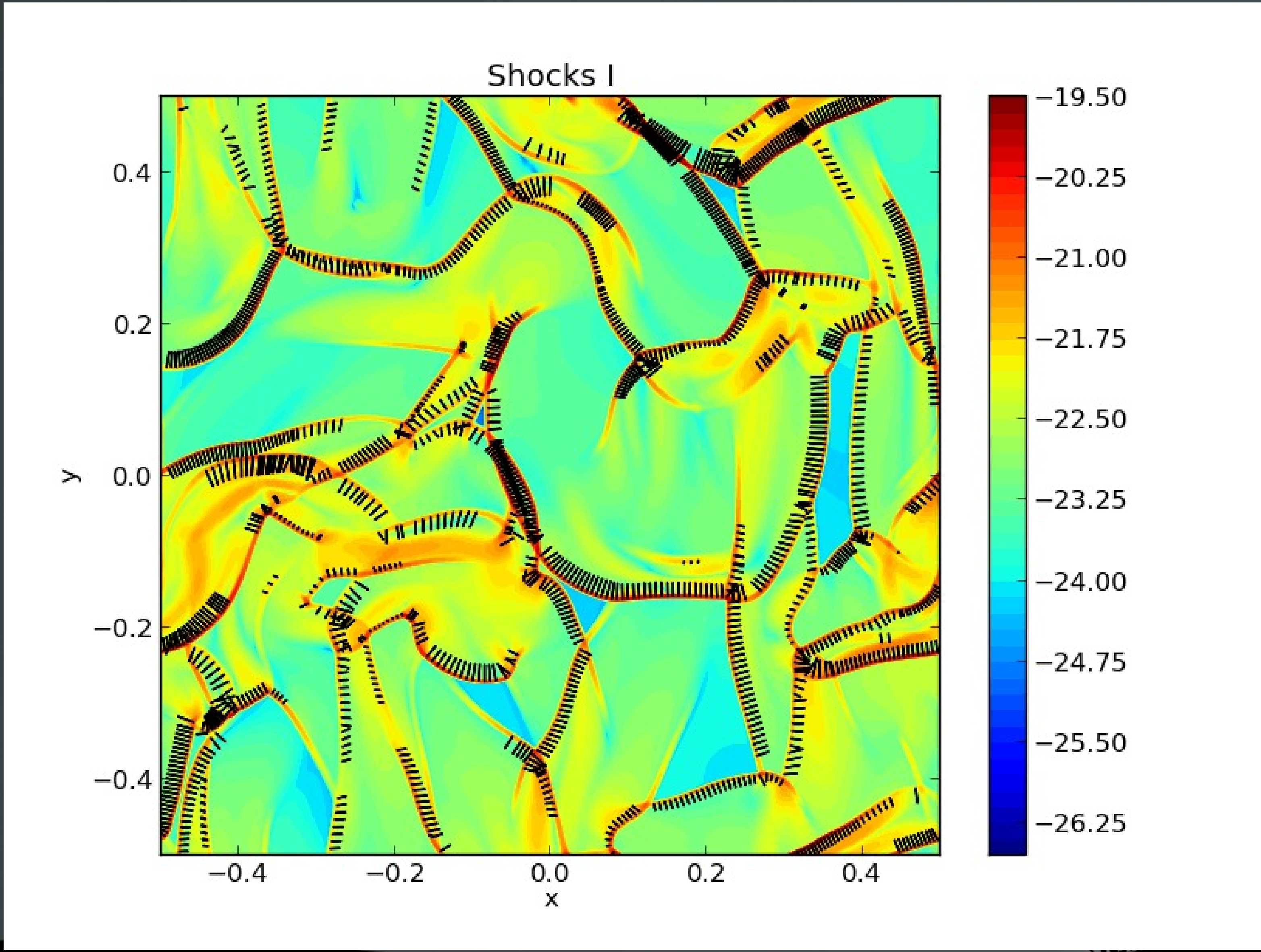


Find the ridges of dissipation
(using DISPERSE, by Thierry Sousbie)

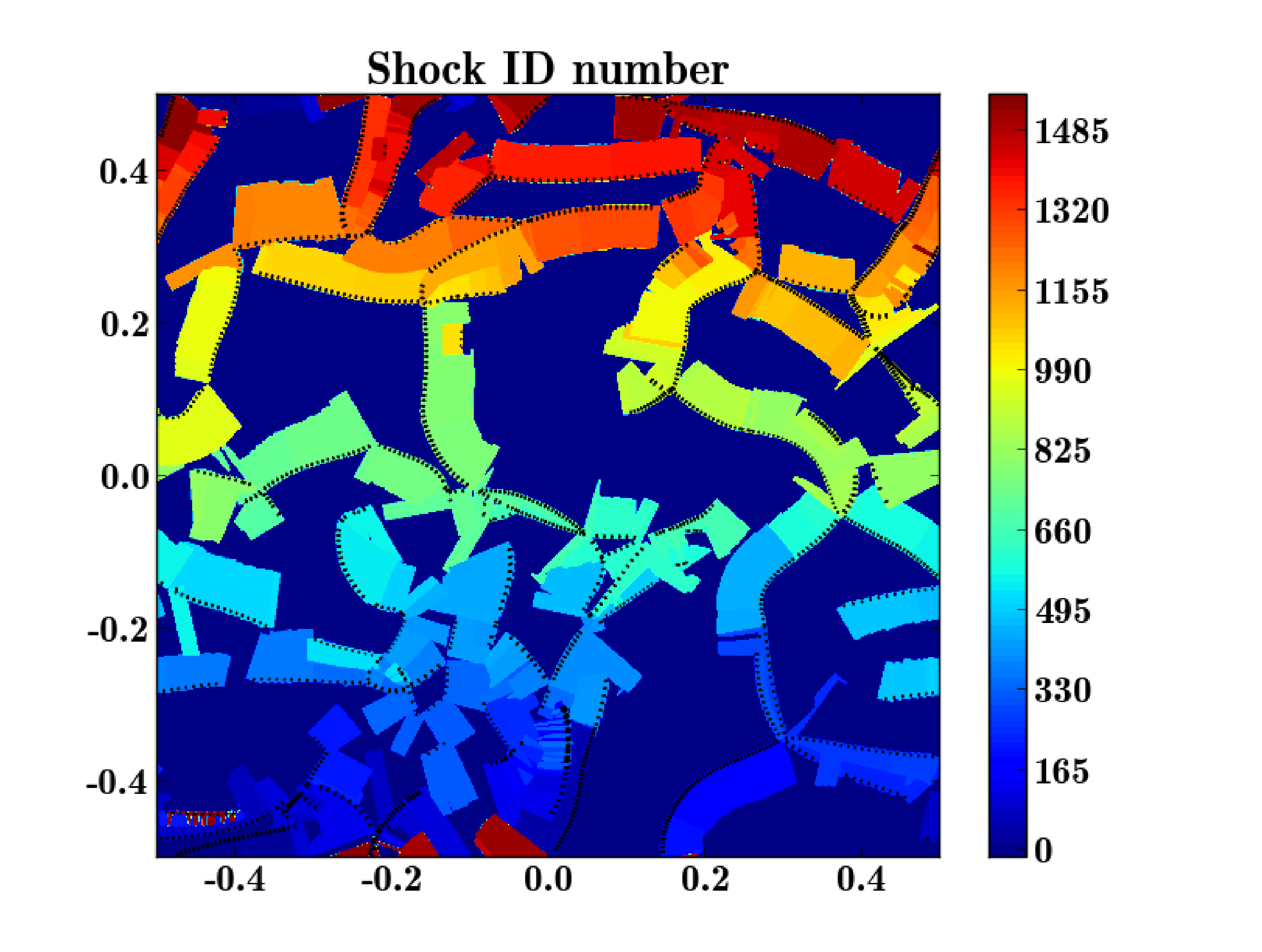


Find steady-state shocks

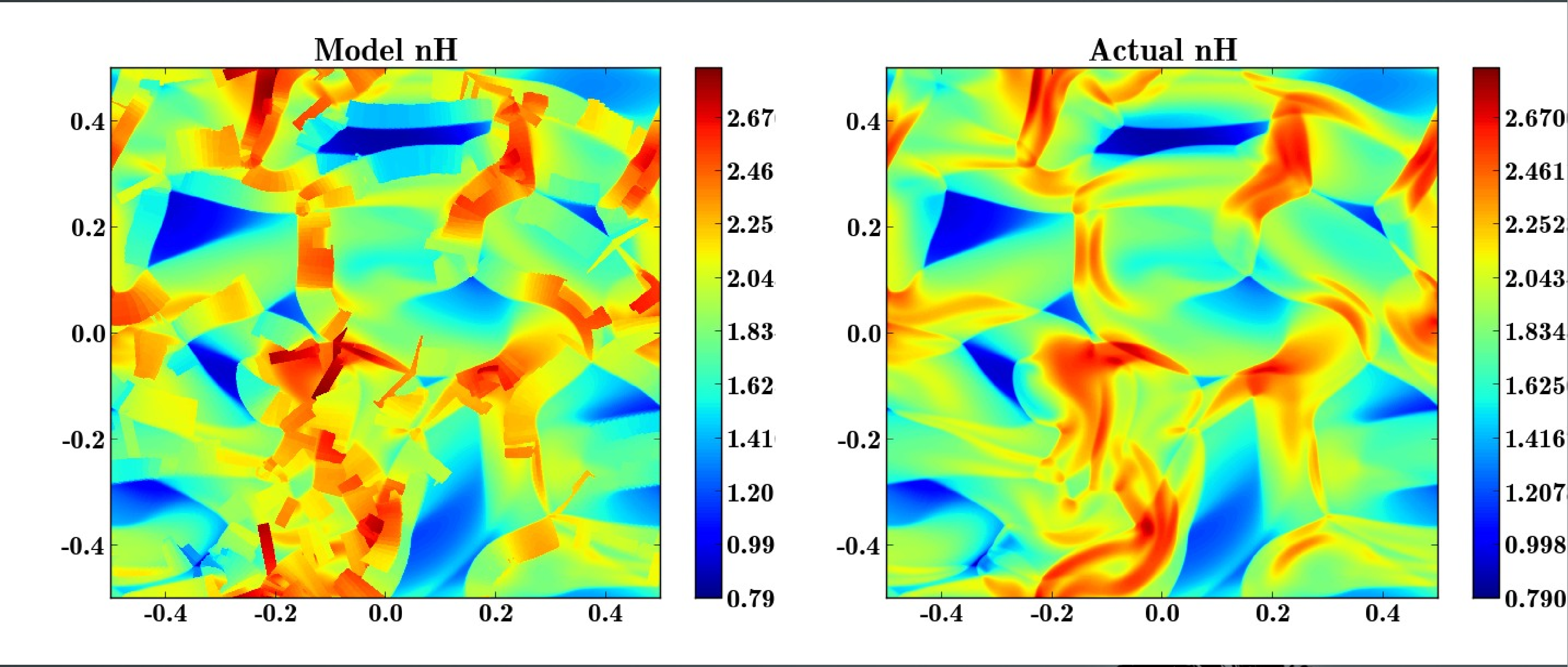
(by fitting locally)



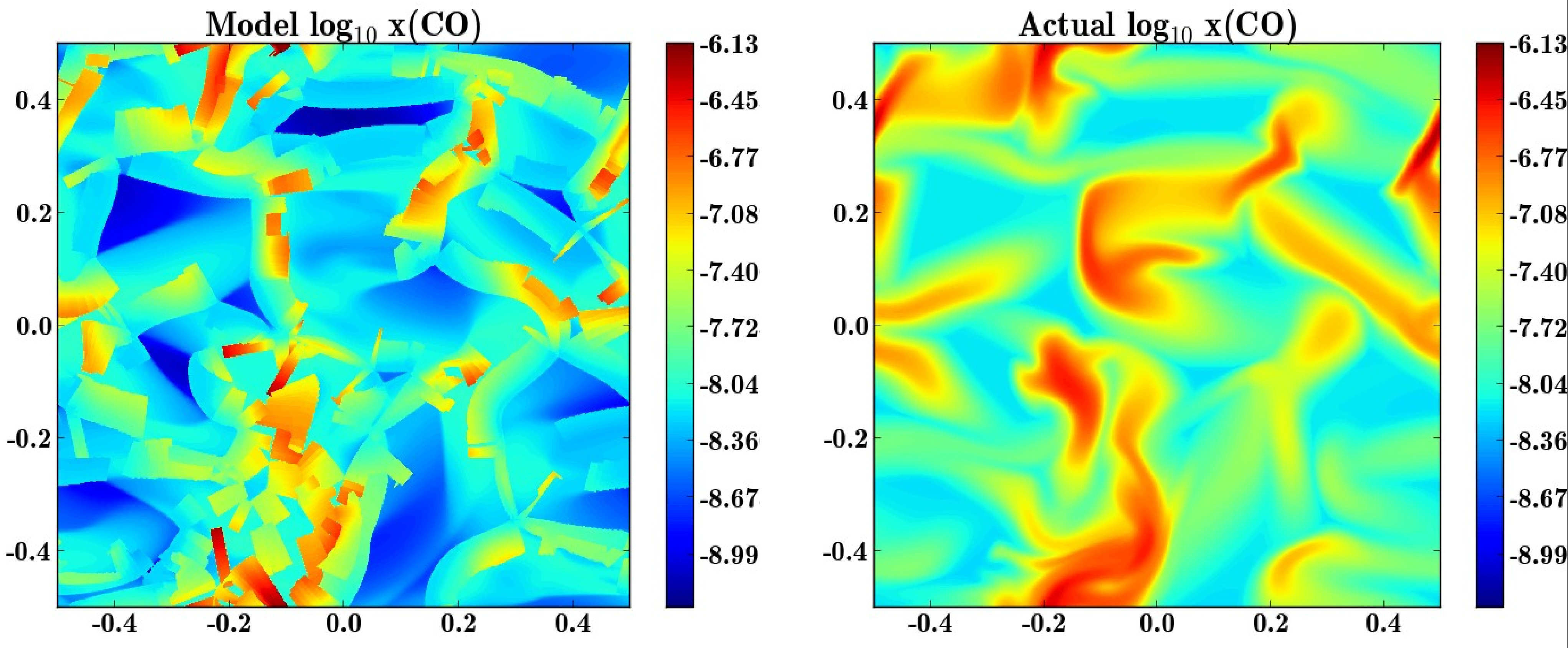
Affect each point to a shock
(=> define background and shocked regions)



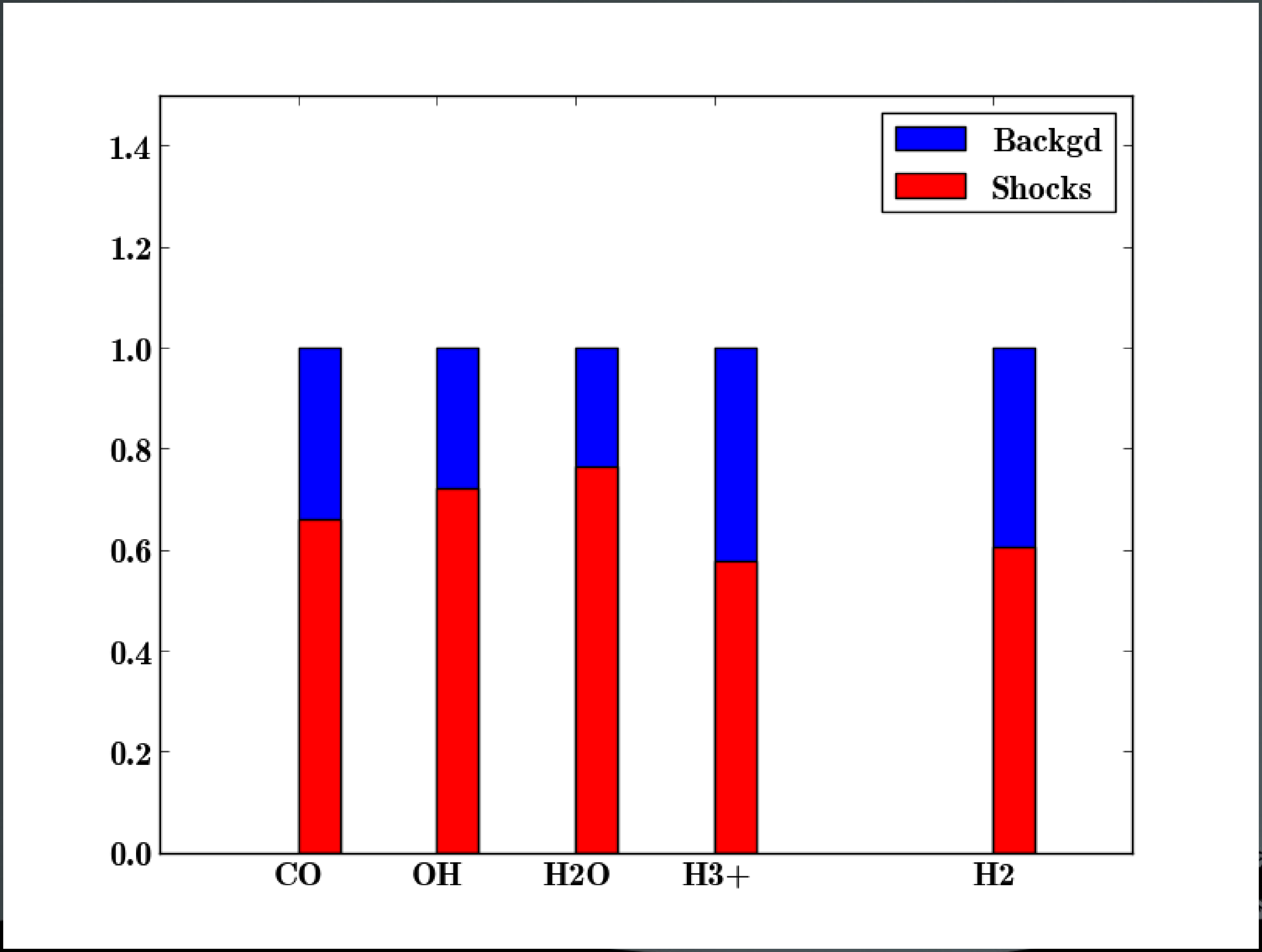
Use steady shock models in the shocked region e.g. here: mass density ($\log_{10} n_H$)



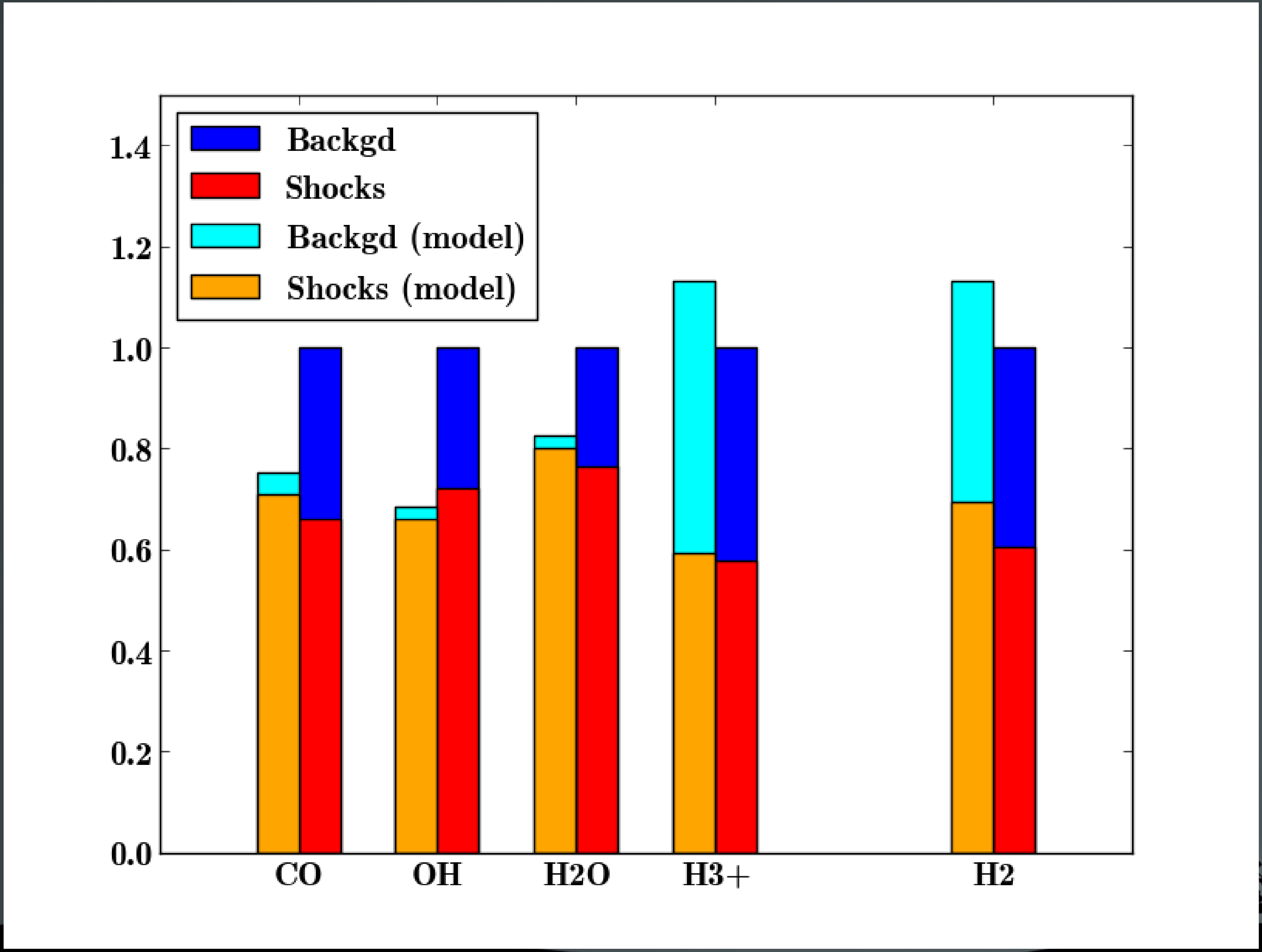
The map of CO relative abundance (chemical equilibrium used outside shocks)



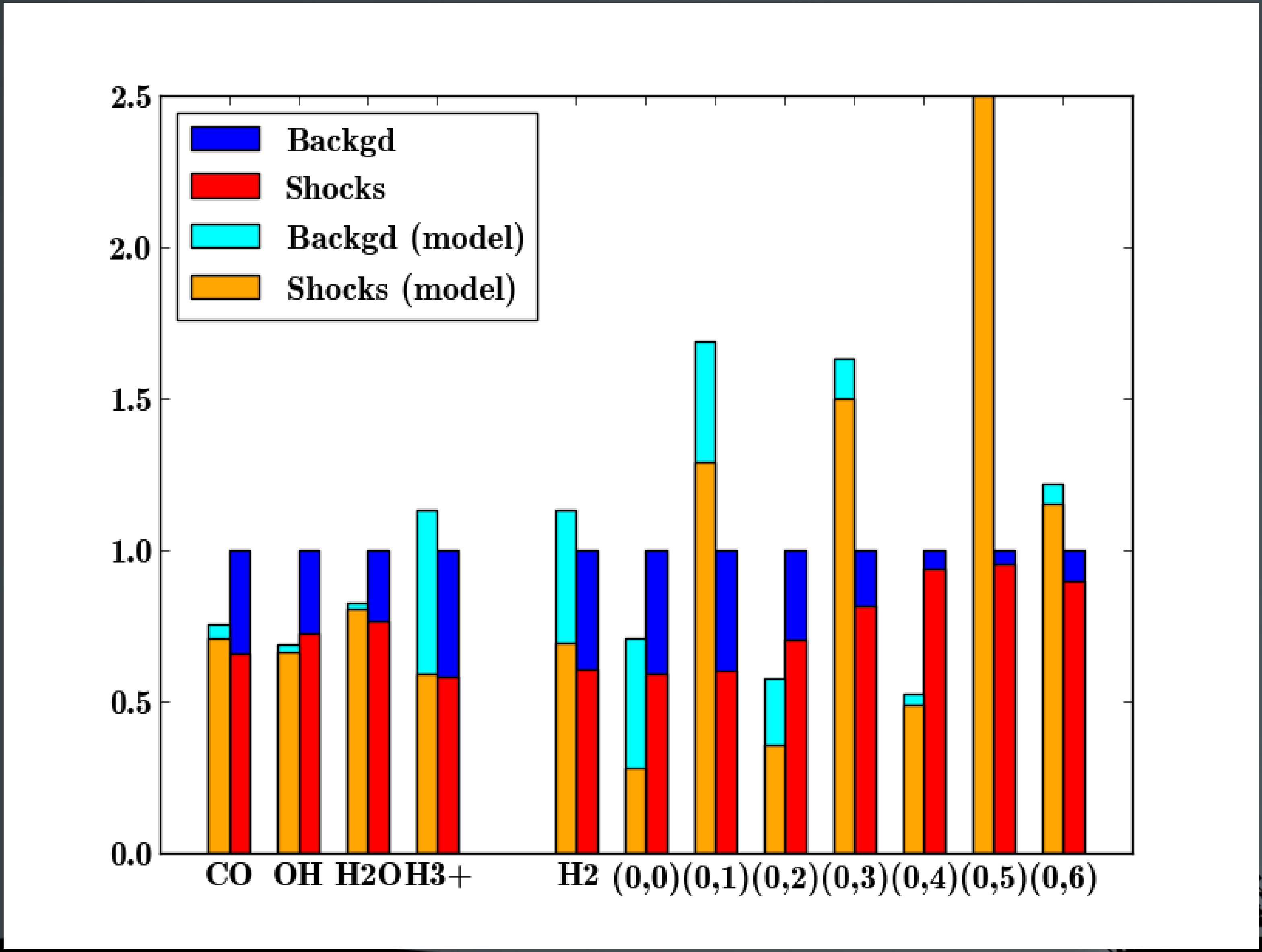
Fraction of molecules in background and shocked region



Model performance on average for chemistry

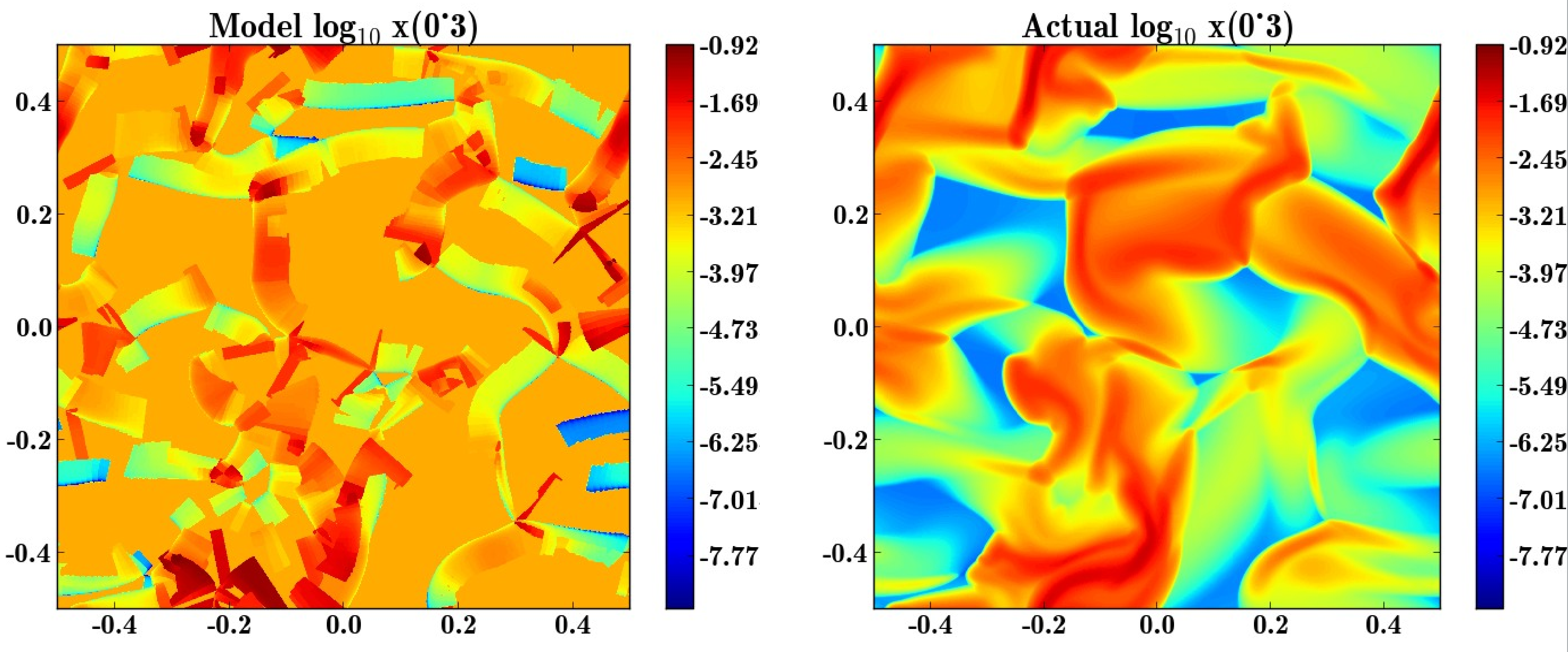


Performance on H2 levels

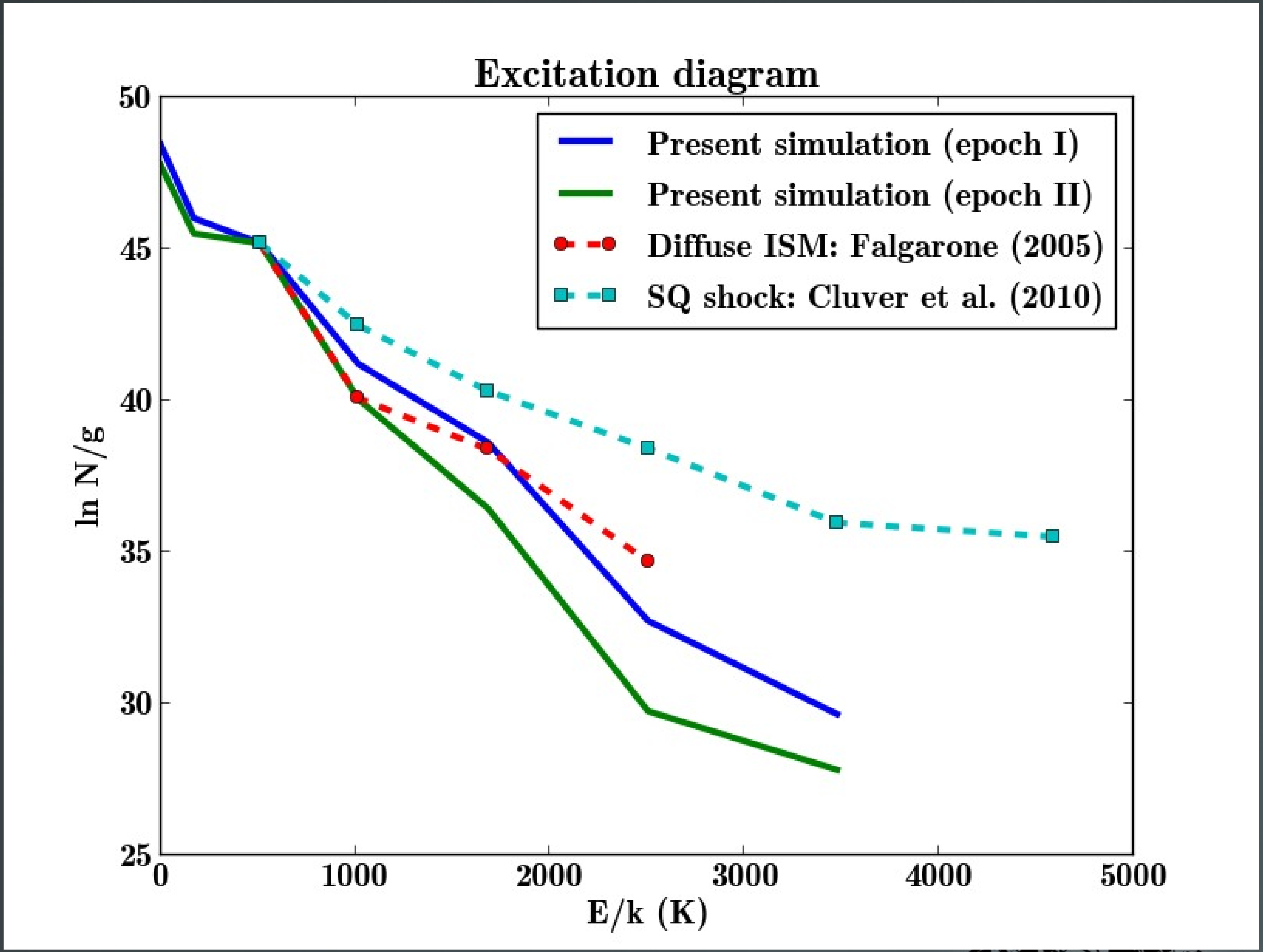


The map of the 0-0 S(1) upper level (actual average used in the background region) H_2 excitation records past shocked history:

- sensitive to entrance conditions
- old shocks are still visible



Average H_2 Excitation diagram



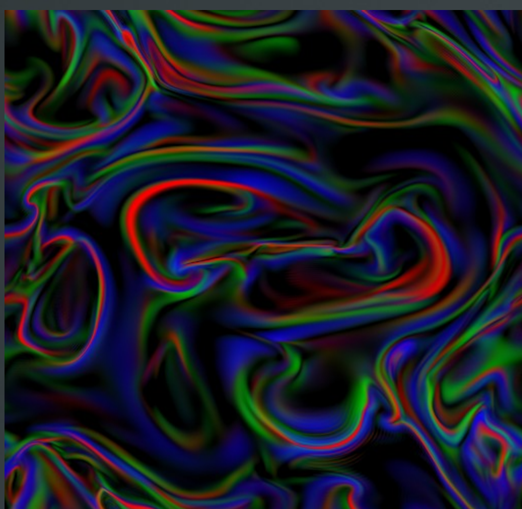
Conclusions

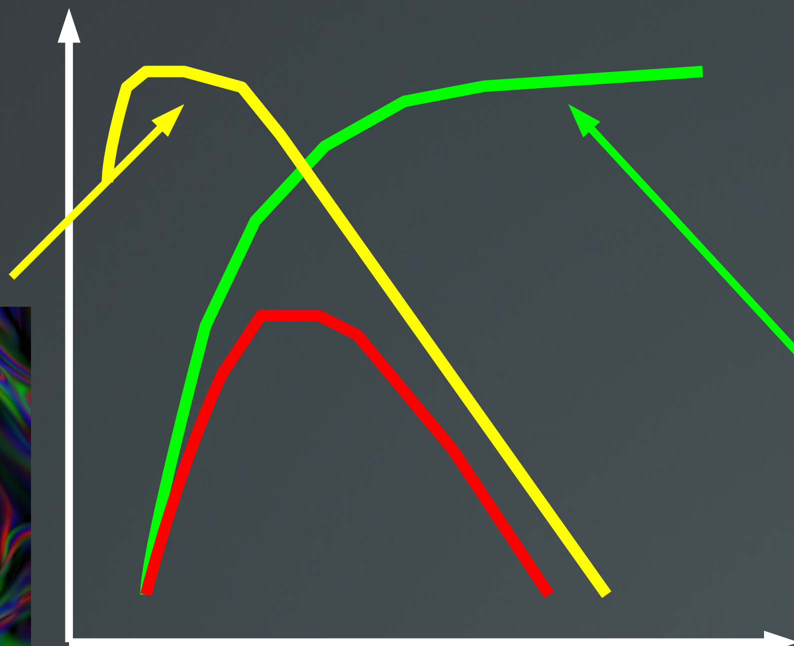
- Many molecules are sensitive to dissipation (amongst others, H_2 and CO).
- This chemistry requires extreme spatial resolution, and is absent from current large scale simulations.
- A distribution of steady-shocks is not too bad as sub-grid model for the molecular chemistry.
- H_2 excitation is slower to react, and will keep track of dynamical history for a longer time than chemistry.
- Prospects:

check B field and ambipolar diffusion.

Prospects

Intermittent statistics of the dissipation

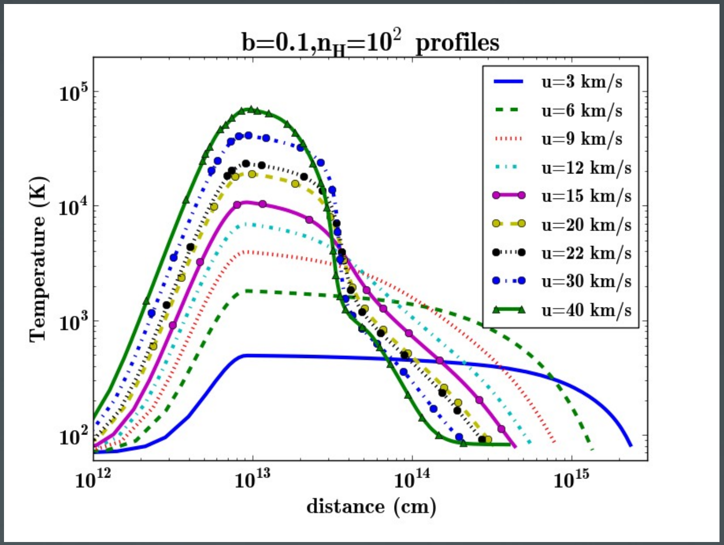




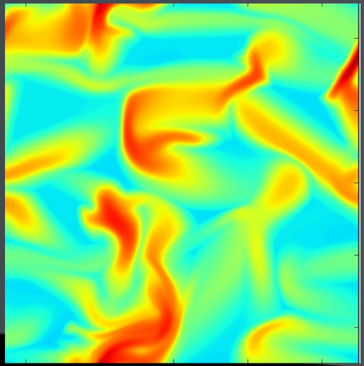
3D simulations

=> Molecules
Formation + excitation

Molecular yields from Shocks (for example)



1D simulations

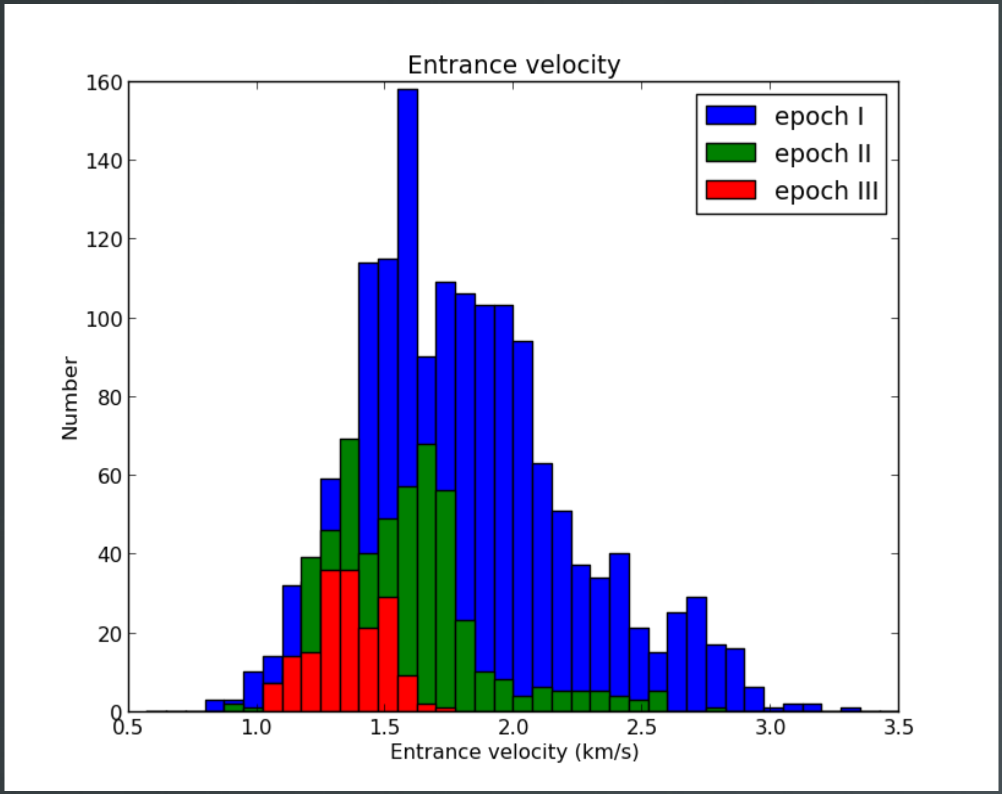


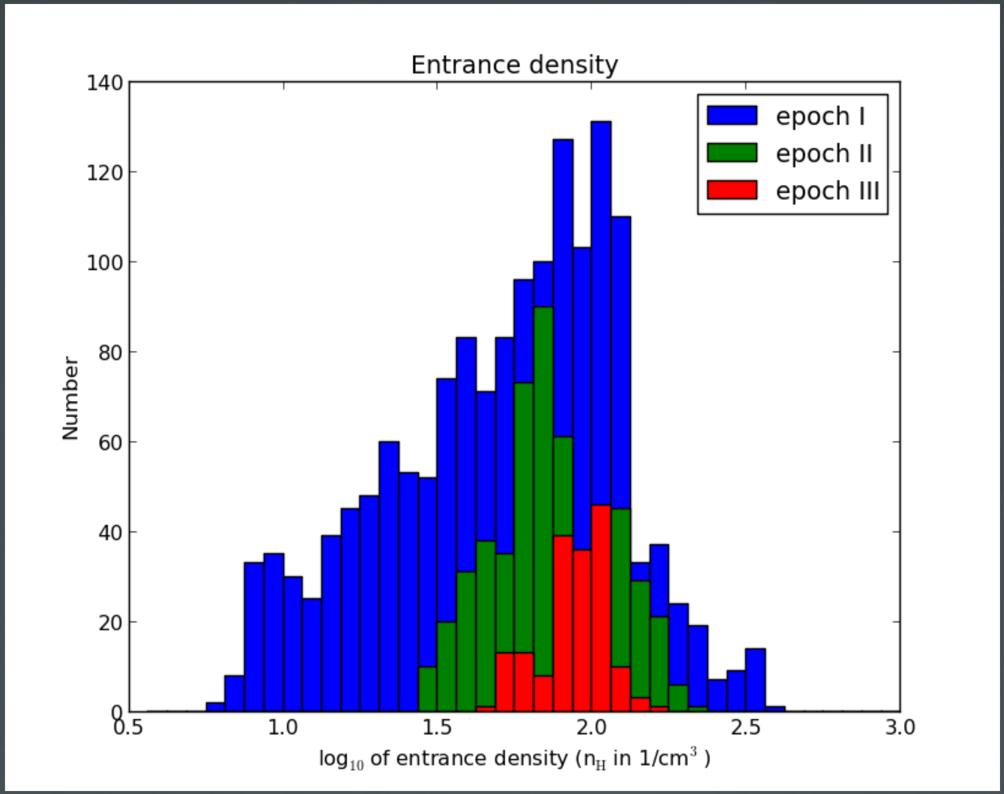
CO map

Validation with 2D simulations

Turbulent dissipation is localised

Shock statistics

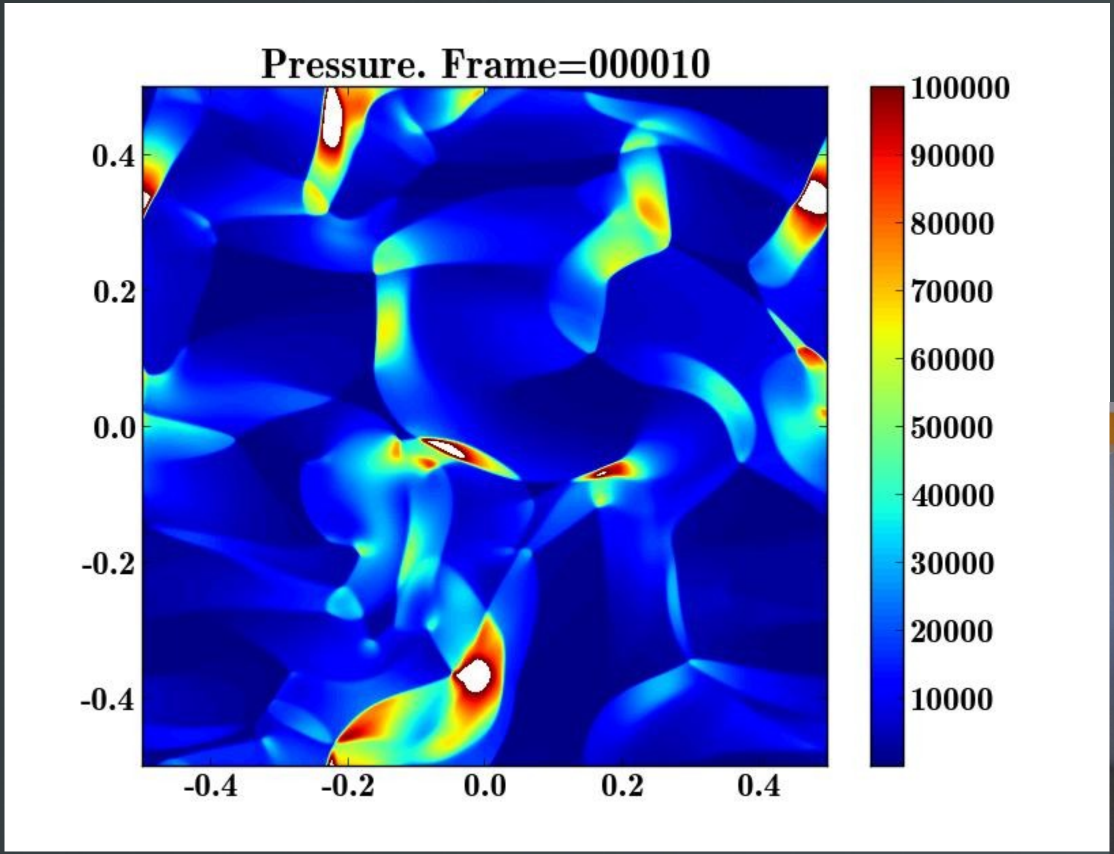




Distributions are skewed:
- to high velocities (intermittency ?)
- to low densities (mass conservation ?)

Dans une simulation, on secoue un petit morceau de gaz insterstellaire.

~ 3 jours-lumière



Temps de calcul:
50 000 h à l'IDRIS (1 jour sur 2000 processeurs)

Temps simulé: 10 000 ans.

Lesaffre et al. (In prep)

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