Non-ideal MHD and chemistry in star formation

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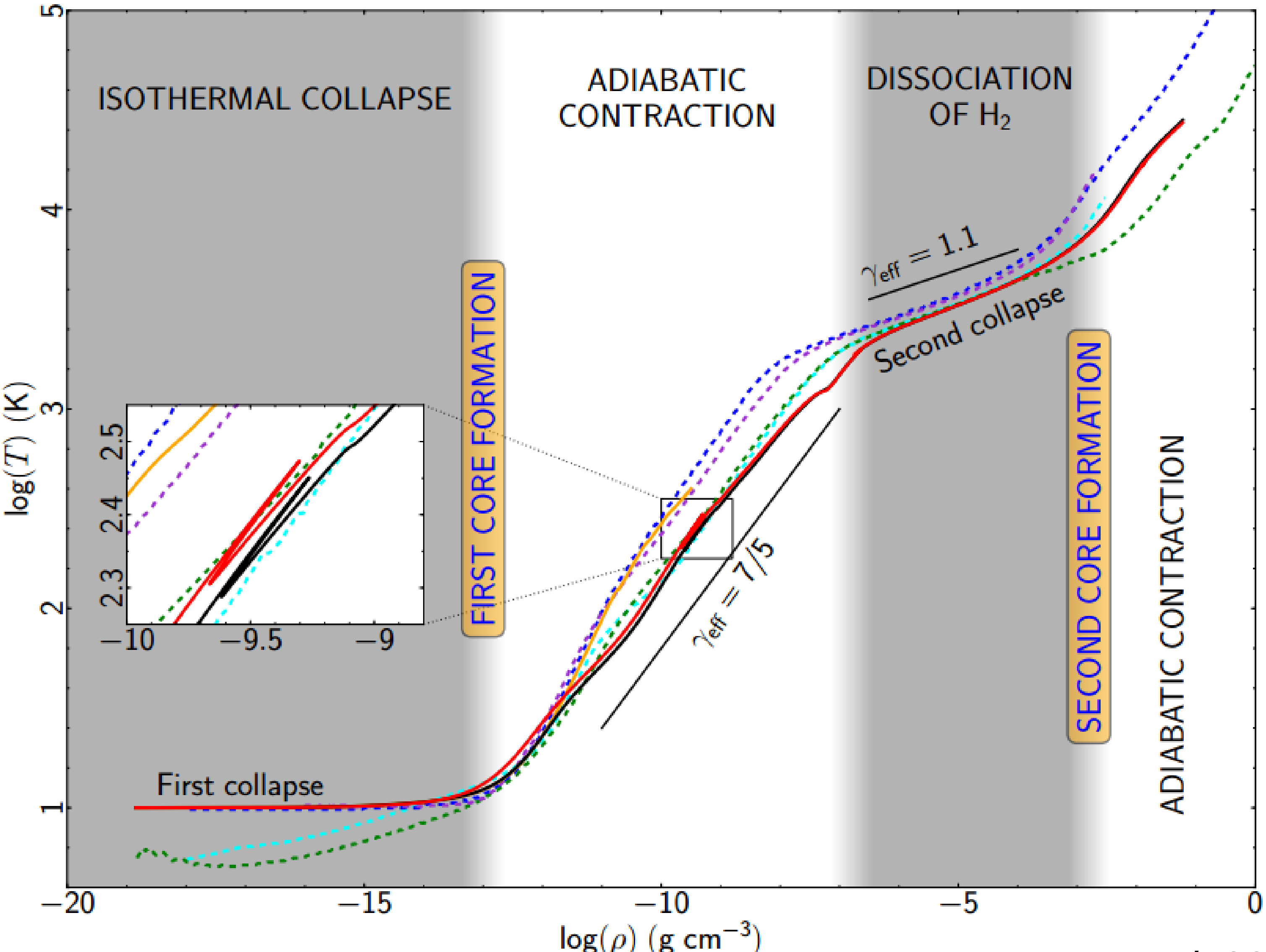
Outline

1. Context

2. Non ideal MHD

3. Chemistry

Collapsing core conditions



Vaytet et al. 2013

Non ideal MHD

Ohmic diffusion

$$\frac{\partial \mathbf{B}}{\partial t} - \nabla \times (\mathbf{v} \times \mathbf{B}) = -\frac{c^2}{4\pi} \nabla \times \left[\underbrace{\eta_\Omega (\nabla \times \mathbf{B})}_{\text{Ohmic diffusion}} \right.$$

$$\underbrace{+\eta_{\mathrm{H}} \left\{ (\nabla \times \mathbf{B}) \times \frac{\mathbf{B}}{||\mathbf{B}||} \right\}}_{\text{Hall effect}}$$

$$\left. \underbrace{+\eta_{\mathrm{AD}} \frac{\mathbf{B}}{||\mathbf{B}||} \times \left\{ (\nabla \times \mathbf{B}) \times \frac{\mathbf{B}}{||\mathbf{B}||} \right\}}_{\text{Ambipolar diffusion}} \right],$$

Hall effect

Masson et al. (2012) for RAMSES
Marchand et al. (in prep) for RAMSES

Ambipolar diffusion

Road to the resistivities

Resistivities

$$\eta_\Omega = \frac{1}{\sigma_\parallel},$$

$$\eta_H = \frac{\sigma_H}{\sigma_\perp^2 + \sigma_H^2},$$

$$\eta_{AD} = \frac{\sigma_\perp}{\sigma_\perp^2 + \sigma_H^2} - \frac{1}{\sigma_\parallel}$$

Conductivities

$$\sigma_\parallel = \sum_i \sigma_i,$$

$$\sigma_\perp = \sum_i \frac{\sigma_i}{1 + (\omega_i \tau_{in})^2},$$

$$\sigma_H = -\sum_i \frac{\sigma_i \omega_i \tau_{in}}{1 + (\omega_i \tau_{in})^2}$$

$$\sigma_i = \frac{n_i q_i^2 \tau_{in}}{m_i}, \ \omega_i = \frac{q_i B}{m_i c}$$

$$\tau_{in} = \frac{1}{a_{i\mathrm{He}}} \frac{m_i + m_{\mathrm{H}_2}}{m_{\mathrm{H}_2}} \frac{1}{n_{\mathrm{H}_2} \langle \sigma_{\mathrm{coll}} w \rangle_i}$$

Road to the resistivities

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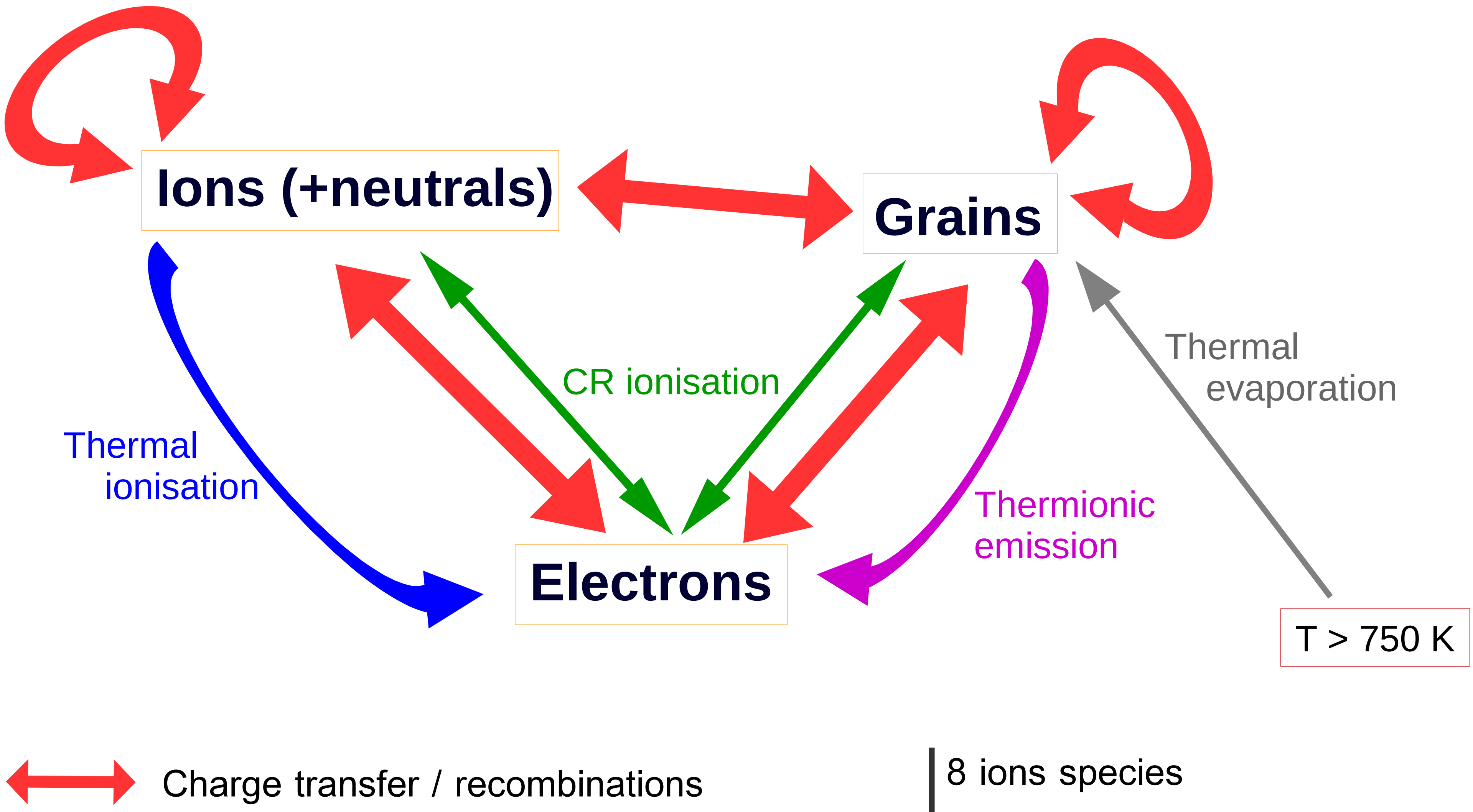
Chemical composition

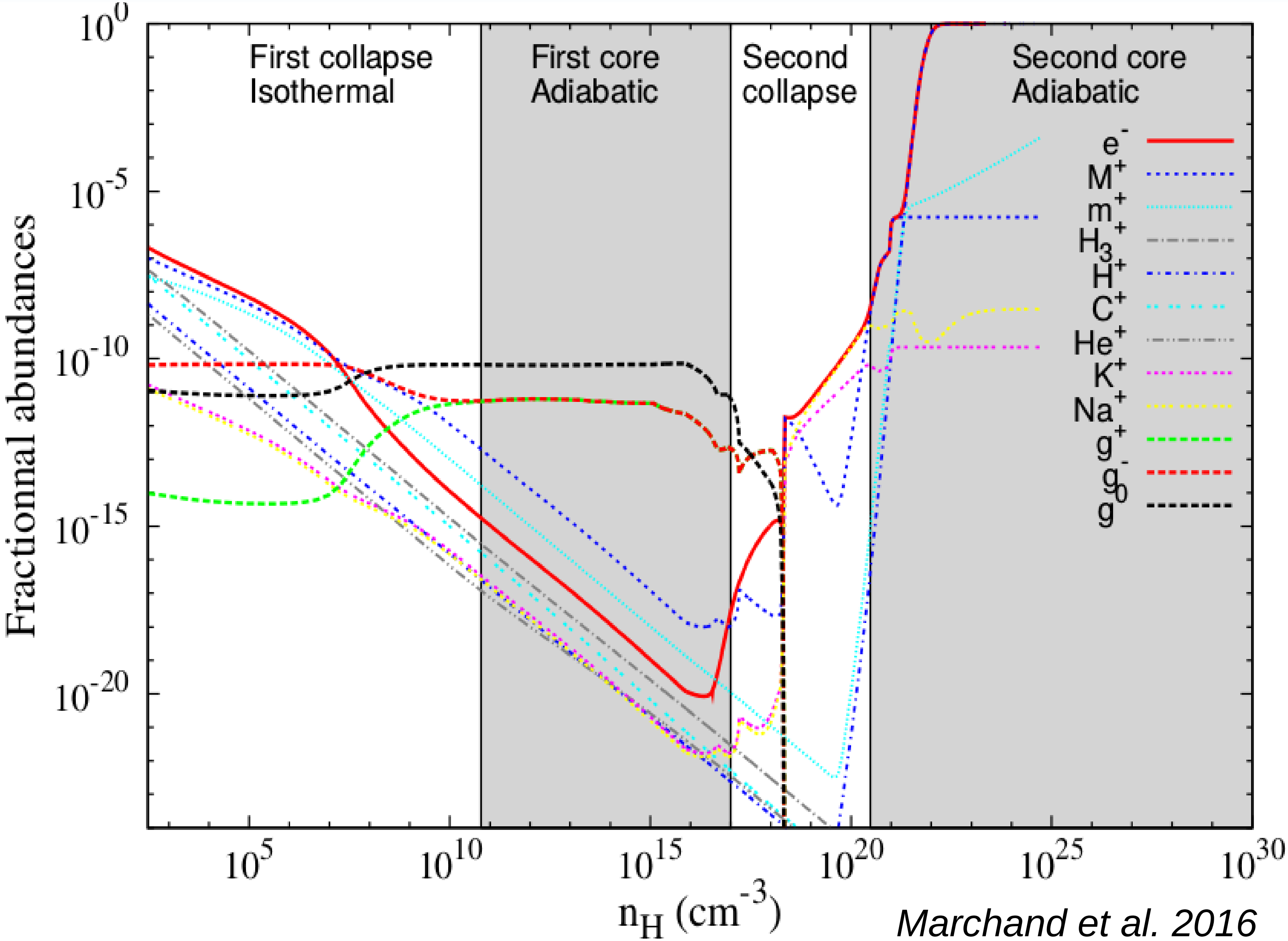
Chemical model



8 ions species

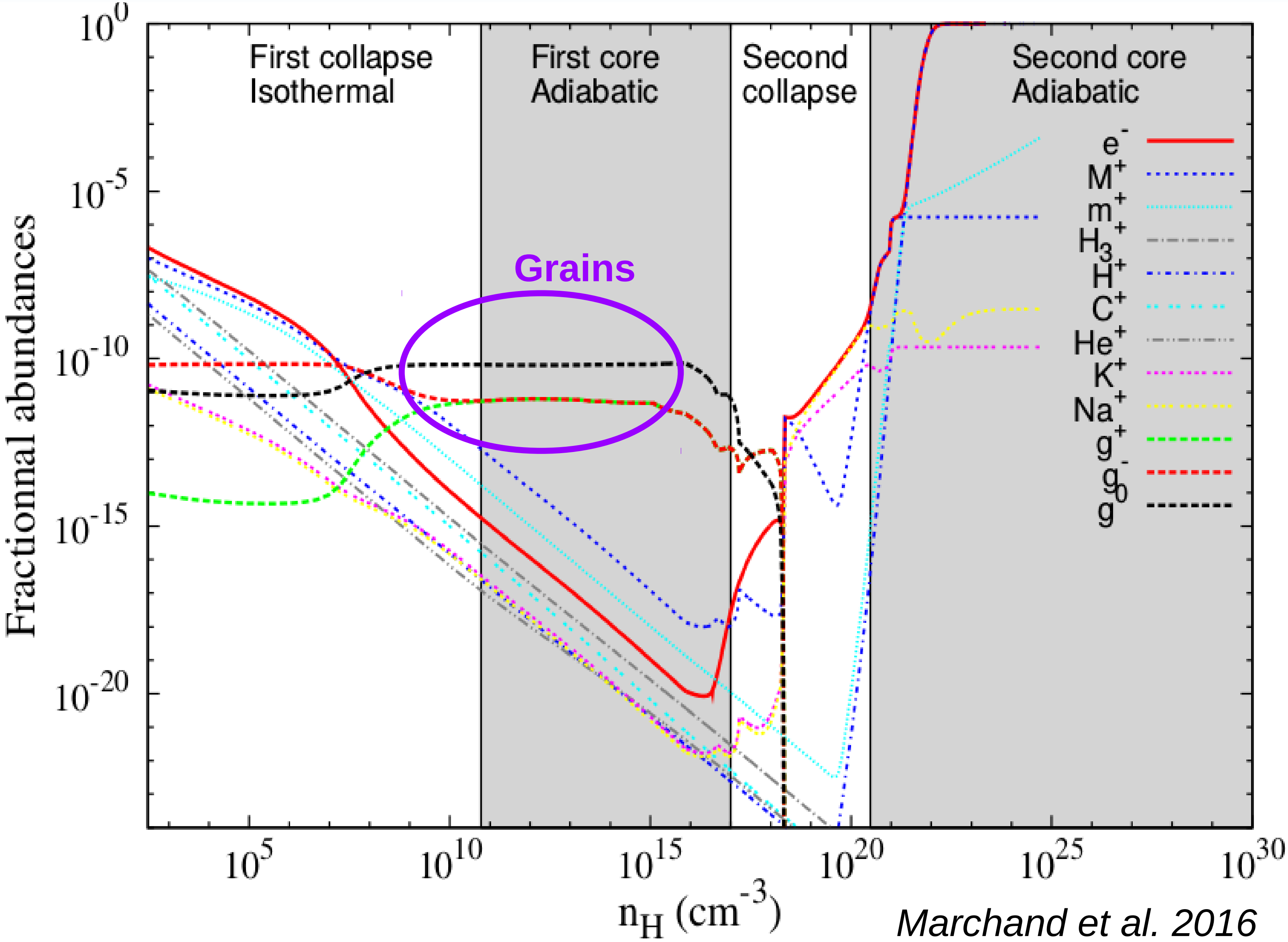
5-10 size bins of grains

Abundances



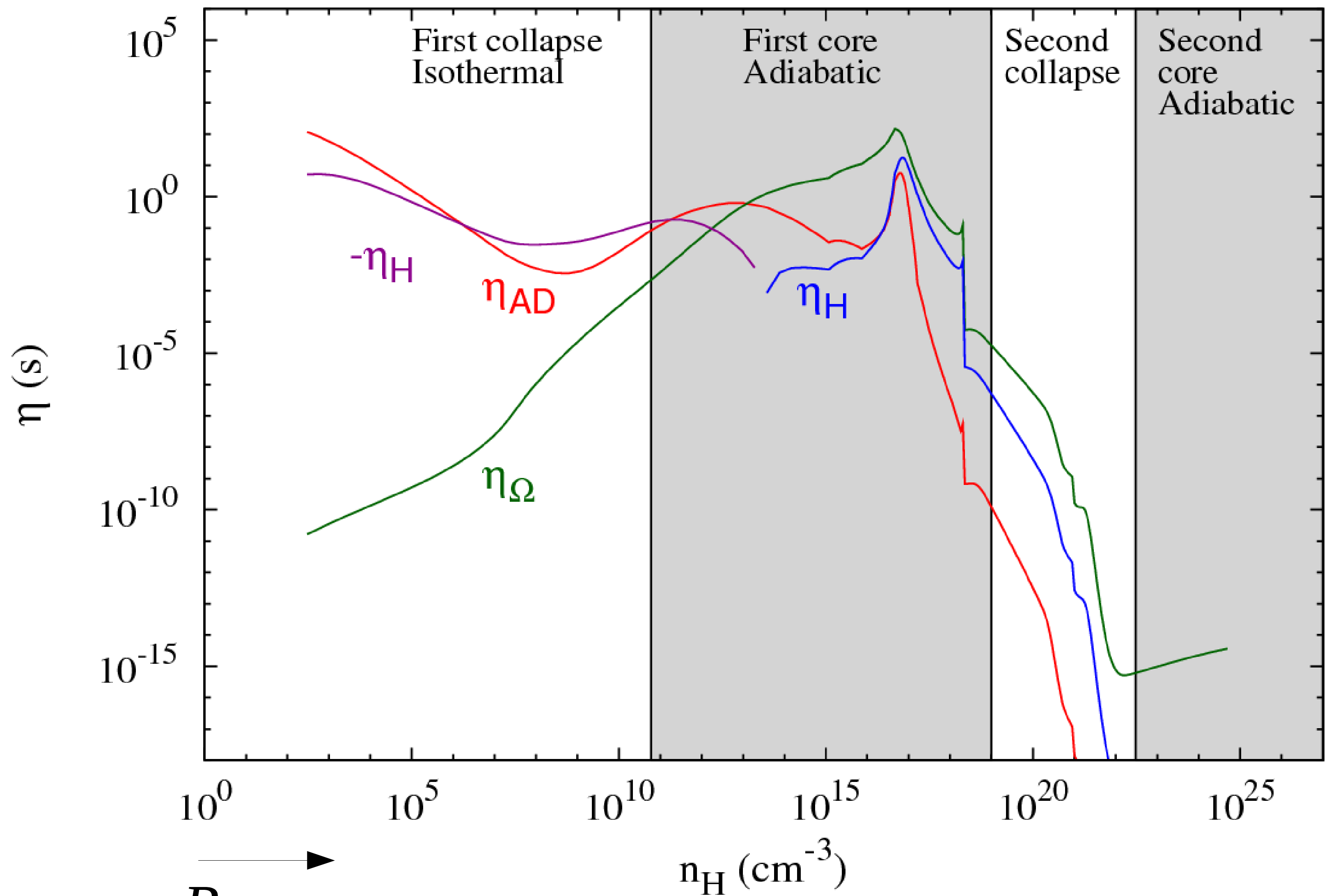
Marchand et al. 2016

Abundances



Marchand et al. 2016

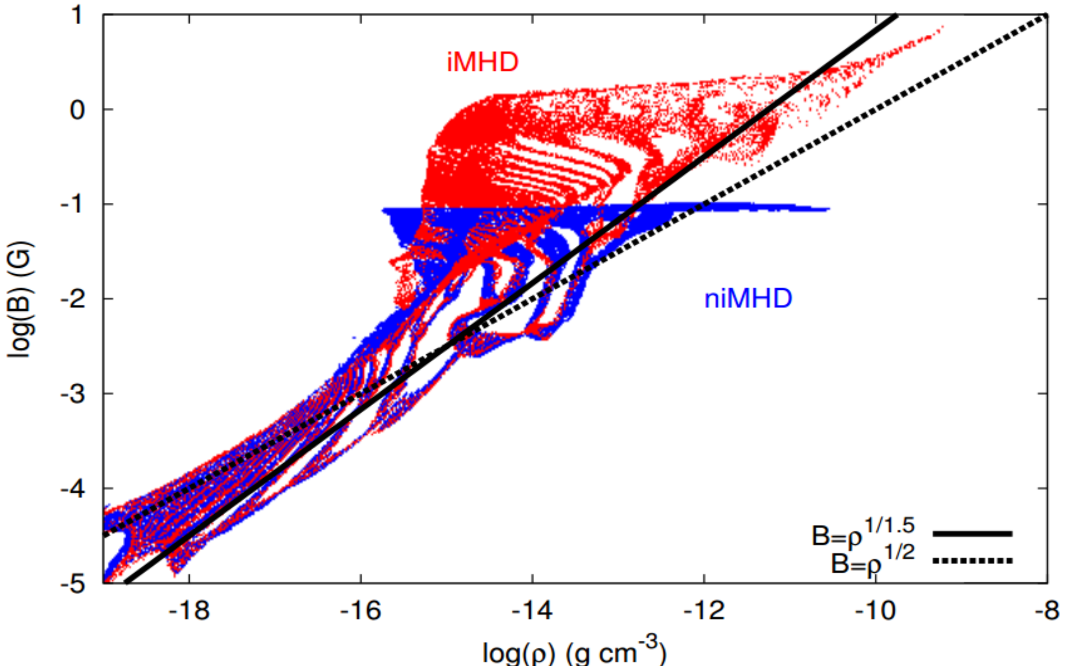
Resistivities

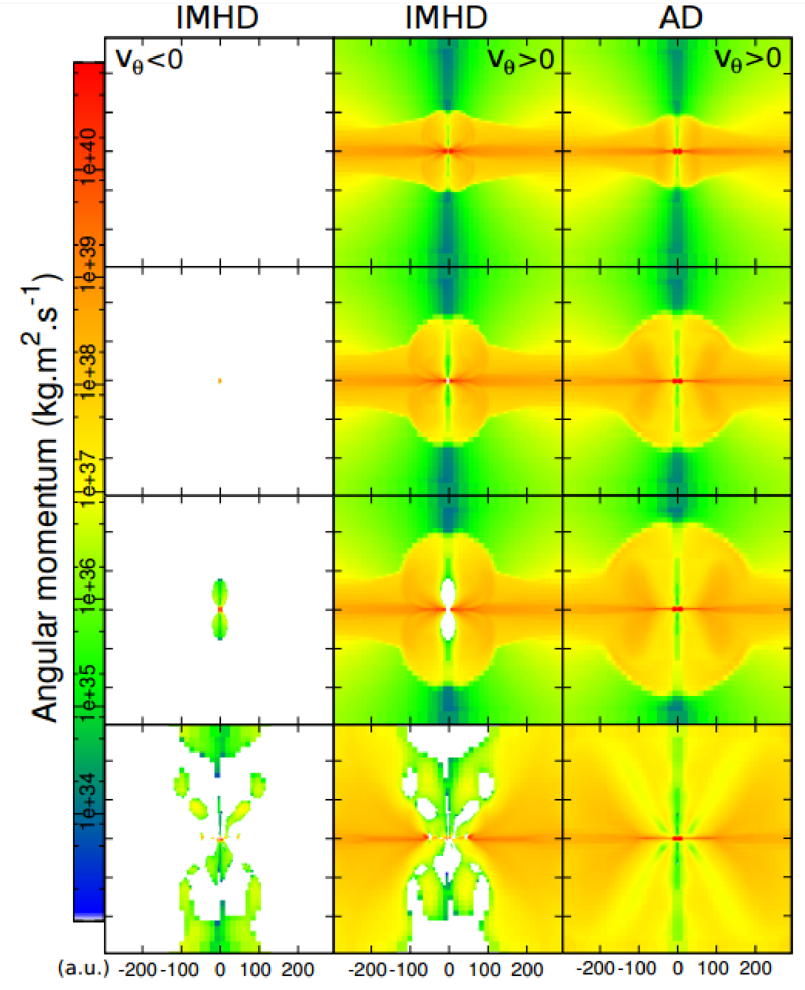


$B \propto \sqrt{\rho}$

Marchand et al. 2016

Influence on star formation





Masson et al. 2016

Conclusion

- Sizable impact of non-ideal mhd on star formation.
- Resistivities determined by the chemistry at stake.
- Grains dominant species in first core
  - Grain-grain chemistry important
  - 5-10 size-bins necessary
- Computation of a multidimensional (ρ, T, ξ) abundance table : https://bitbucket.org/pmarchan/chemistry (see Marchand et al. 2016)

Thank you !