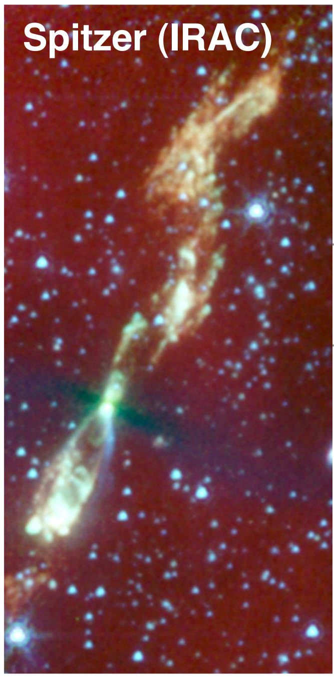
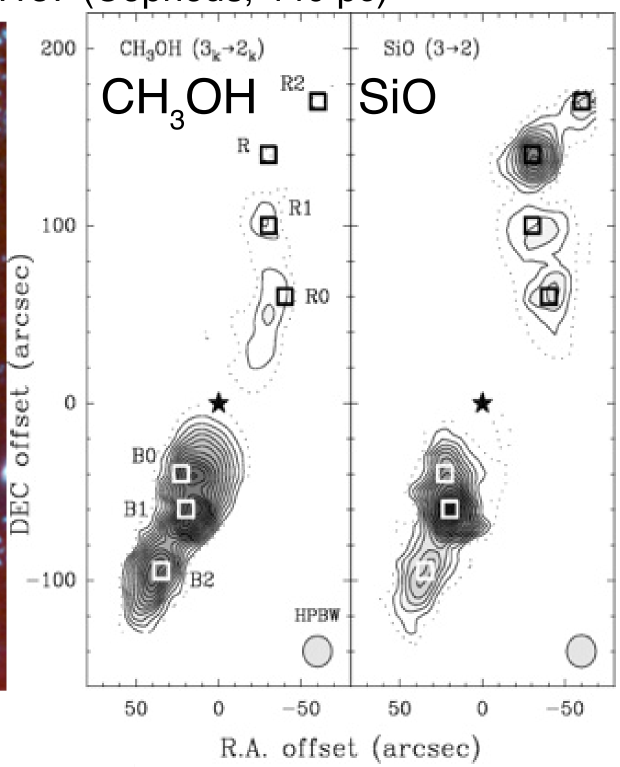
Modeling Dust Processing in Shocks in Dense Clouds

Molecular flow L 1157 (Cepheus, 440 pc)





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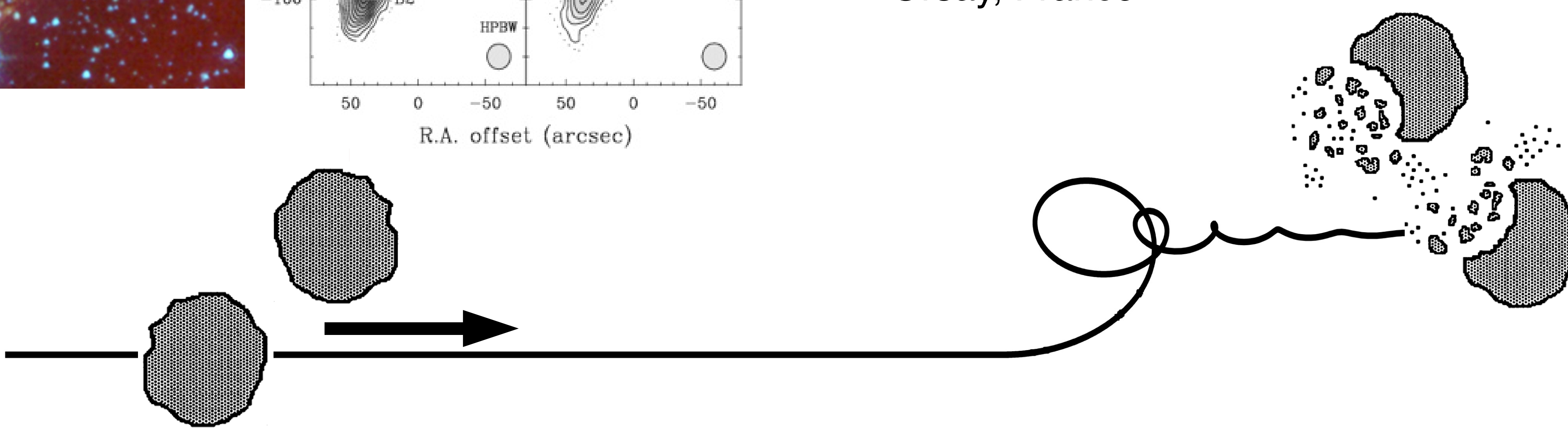
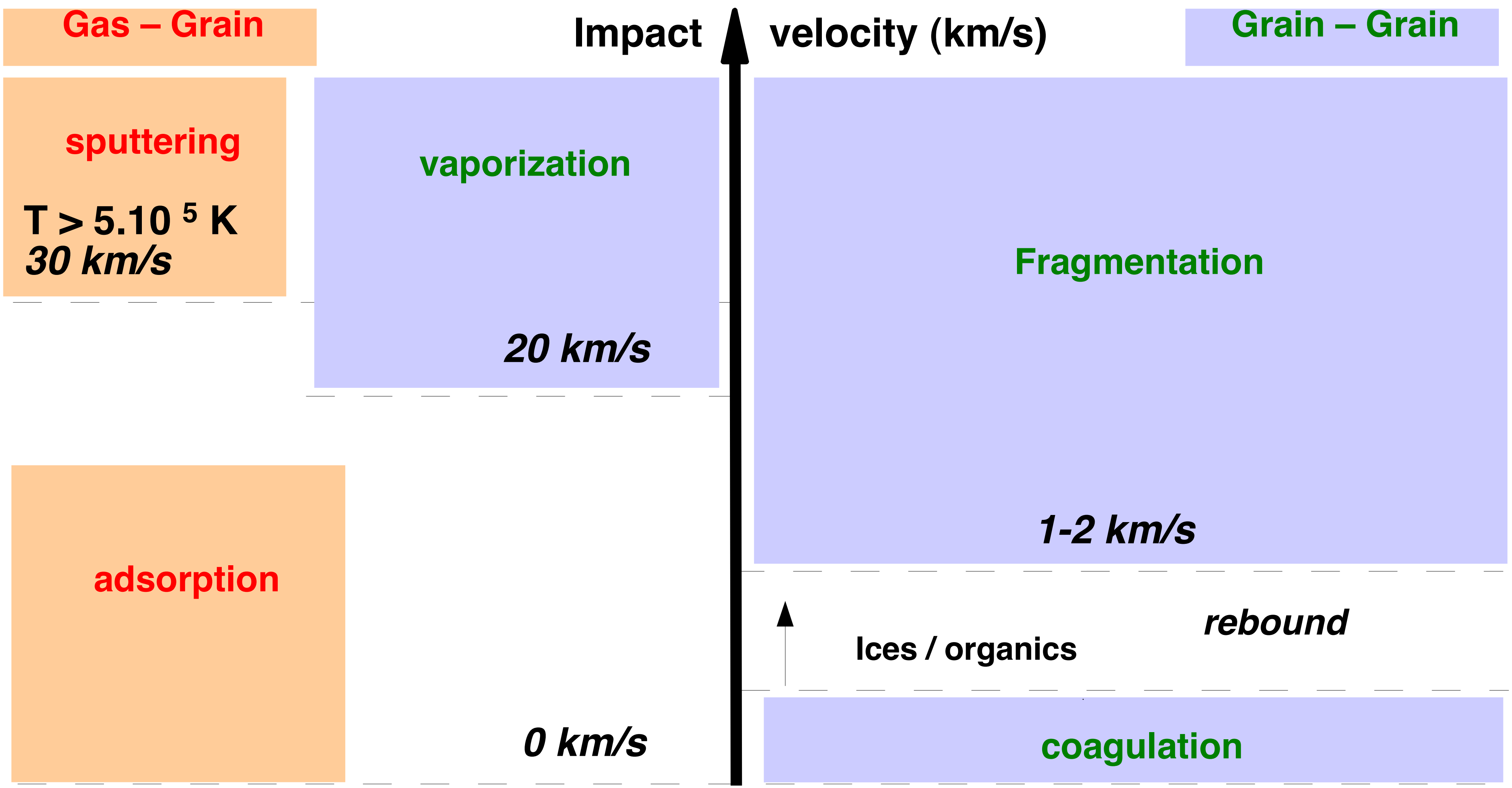


The impact of grain-grain collisions

Dust processing in gas-grain and grain-grain collisions



Destruction & formation
Total dust mass decreases/increases

Size redistribution
Total dust mass is conserved

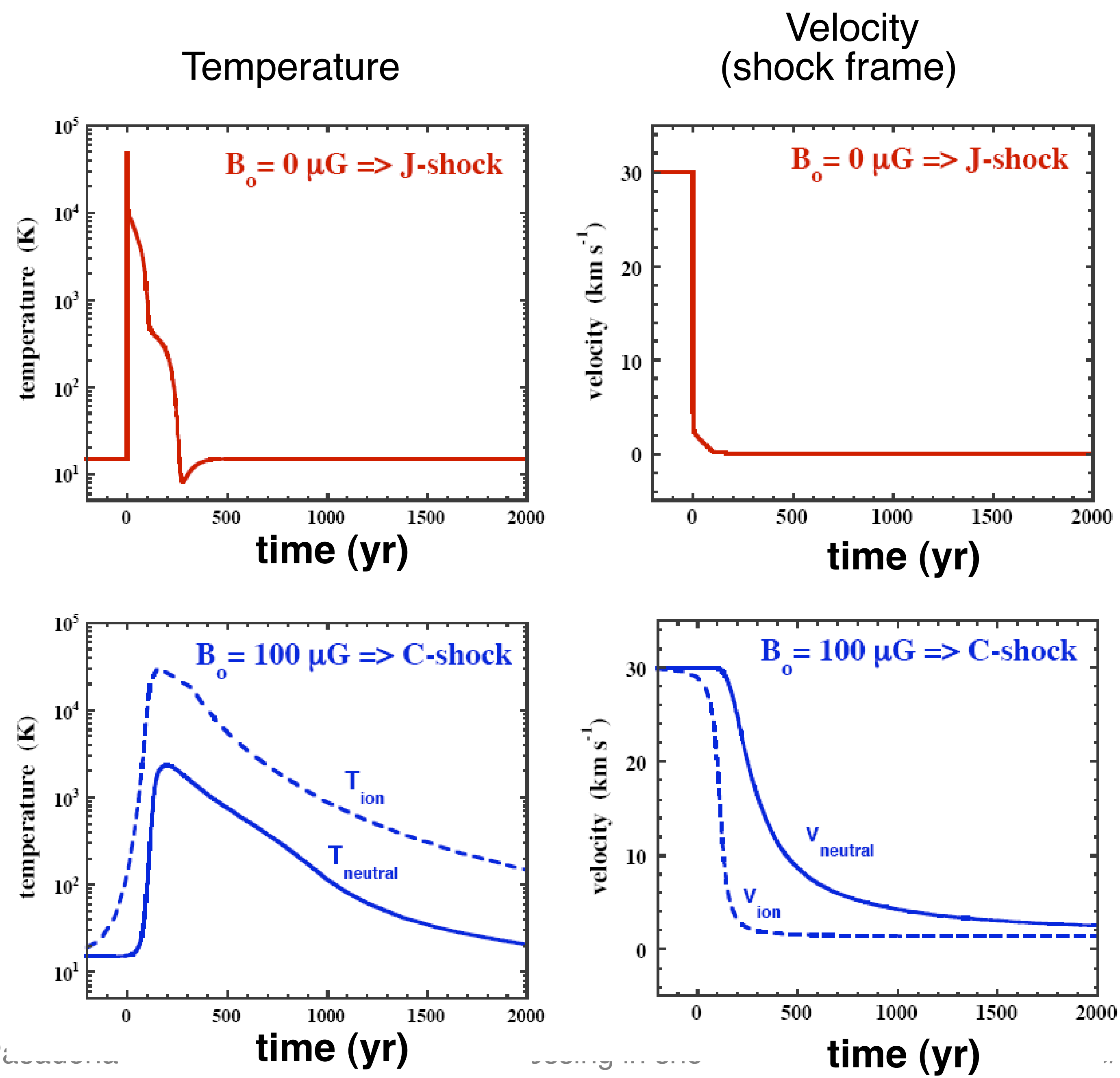
C shock & J shock of a same energy

30 km/s
10^4 cm^{-3}

J shock
$V_s > V_{critical}$

C shock
$V_s < V_{critical}$

ambipolar diffusion



Coupling the dust and shock physics

Full coupling & feedback
Out of equilibrium physics

Dust size distribution

- Charge distribution
- Dynamics
- Gas-grain collisions
- Grain-grain collisions

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Shocks

- Dynamics
- Temperature
- Ionization state
- Chemistry

Dust charging model

Draine & Sutin (1987)

Dust processing model :

Vaporisation: Tielens et al. (1994)

Shattering: Jones et al. (1996)

Sputtering:
- cores : May et al. (2000)
- mantles : Barlow (1978)

Shock model

Flower & Pineau des Forêts (2003)

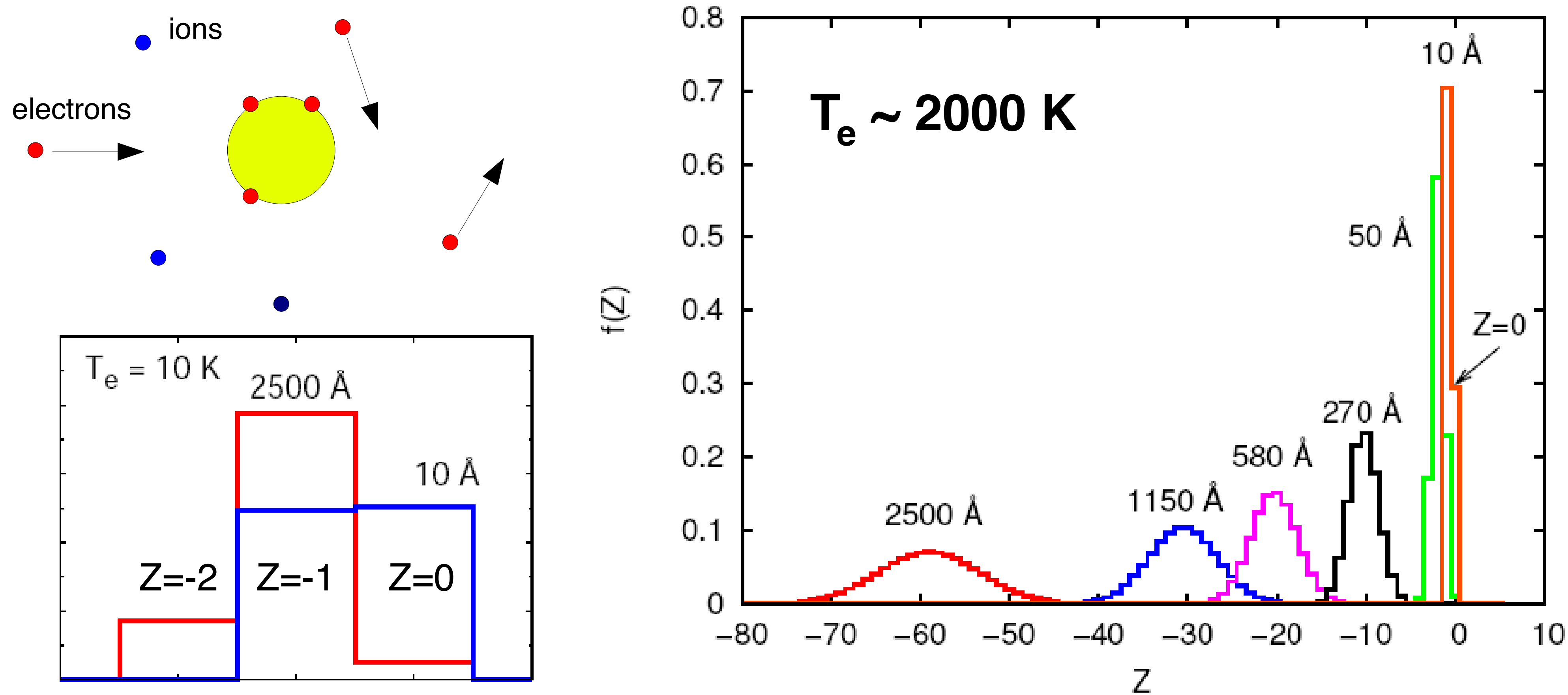
Grain charge at low temperatures (T < 10 eV)

Out of equilibrium charge distribution resulting from:

- Electron attachment (+ reflection)
- Ion recombination with electrons from the grain surface

(*Secondary electron emission is ignored : electron and ion temperature are too low)*

(photoemission are ignored : dense cloud are ~ screened from ISRF)

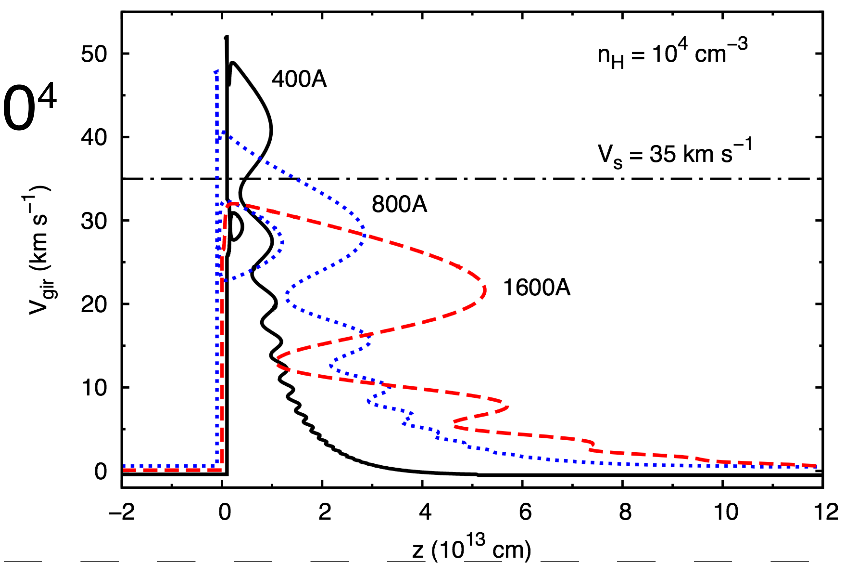


Dust dynamics without processing

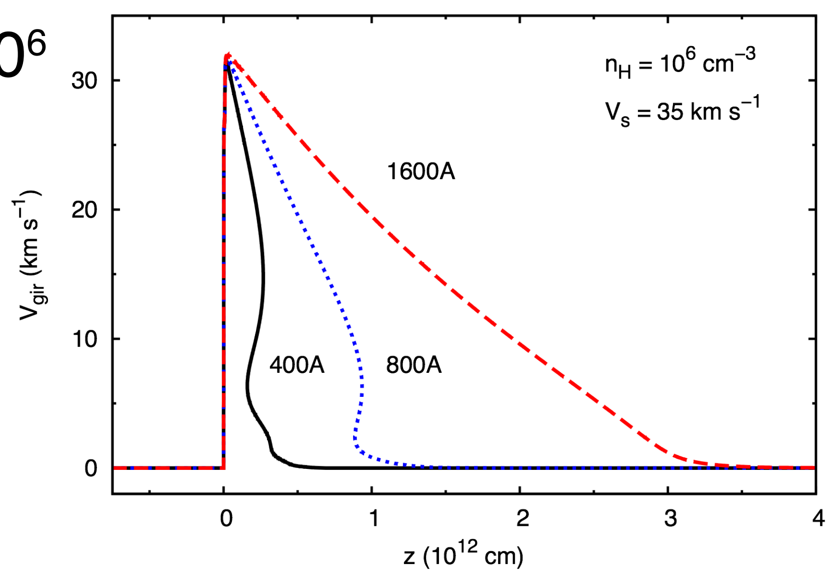
J shocks (Guillet et al. 2009)

Grain velocity relative to the gas = gyration velocity

$n_H = 10^4$



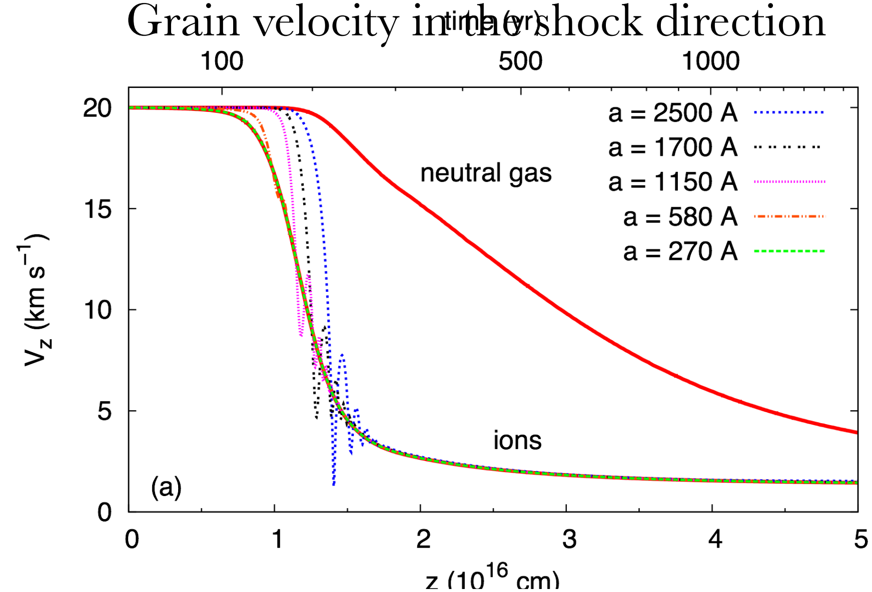
$n_H = 10^6$

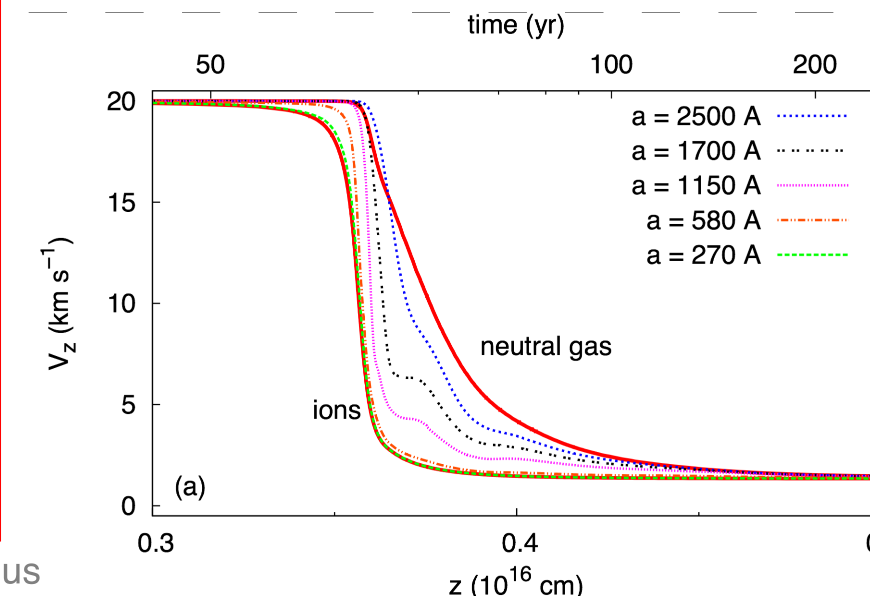


C shocks (Guillet et al. 2007)

(Results similar to Chapman & Wardle 2006)

Grain velocity in the shock direction

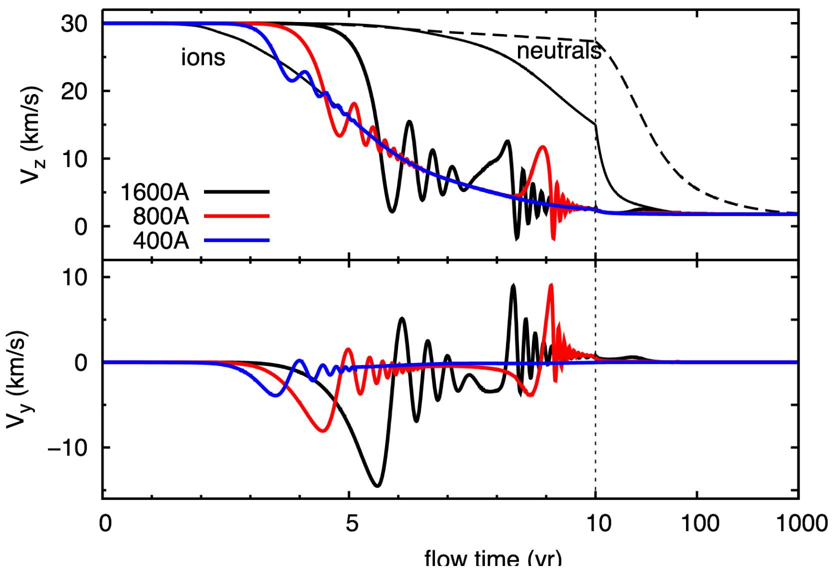


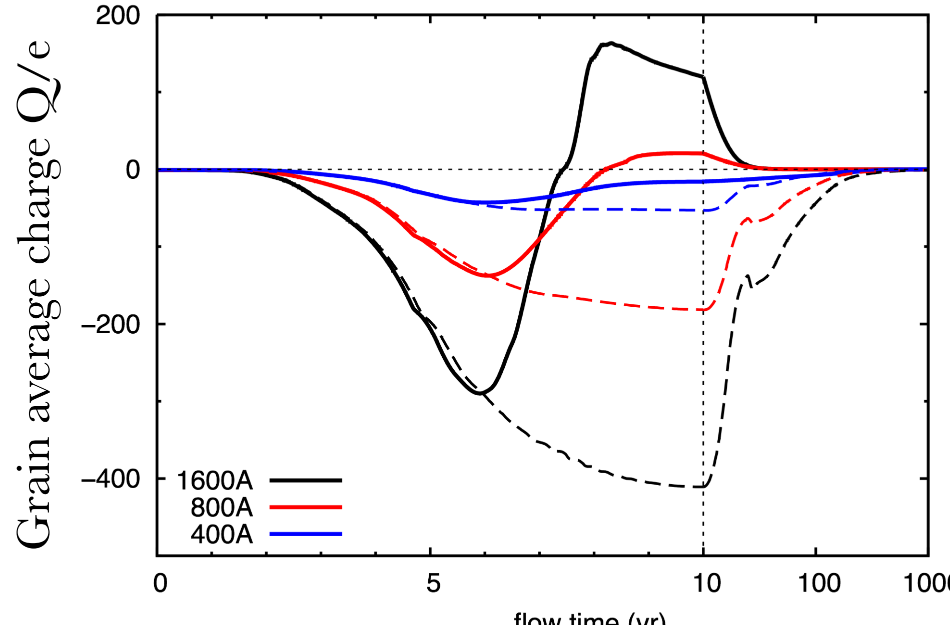


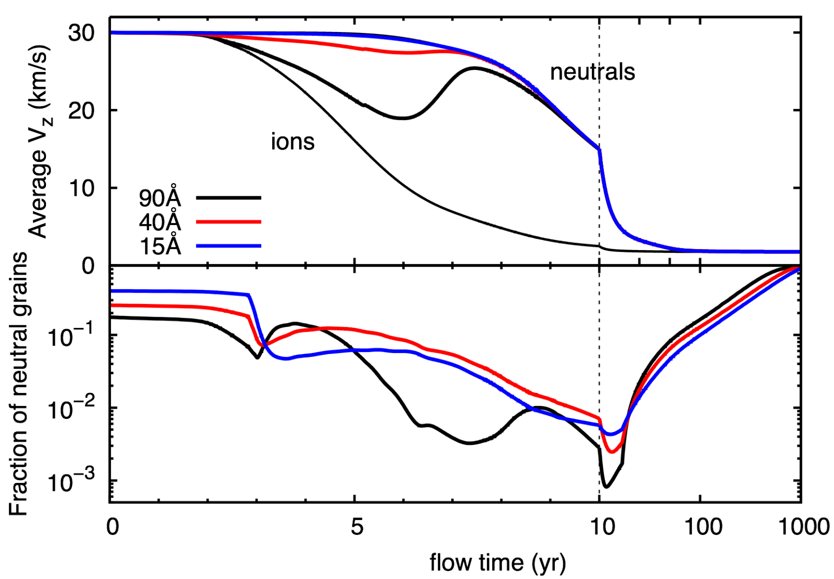
Dust charge and dynamics with processing

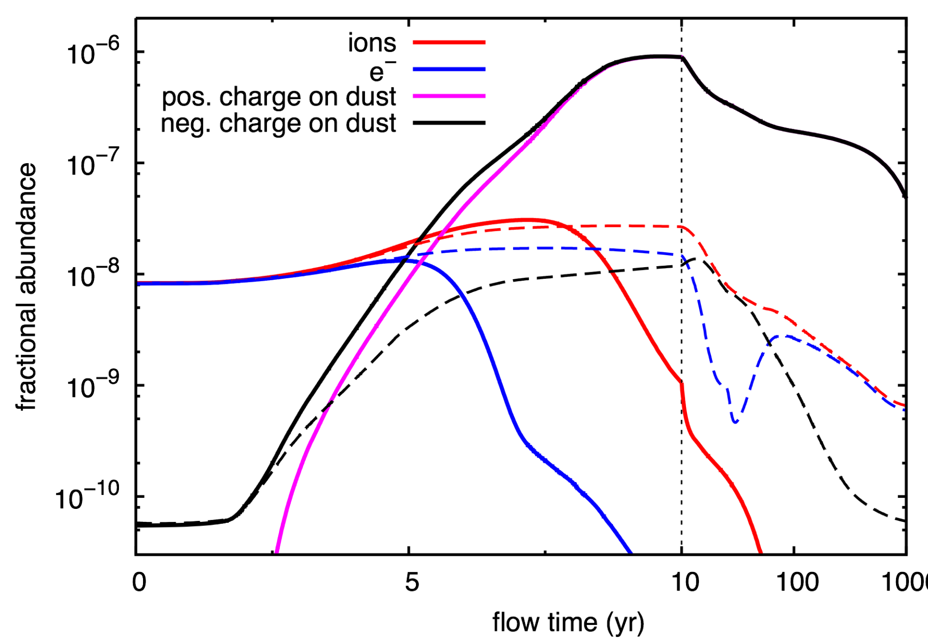
(Guillet, Pineau des Forêts & Jones 2011, accepted)

C shocks ($n_H = 10^5$ cm^{-3}, 30 km/s)







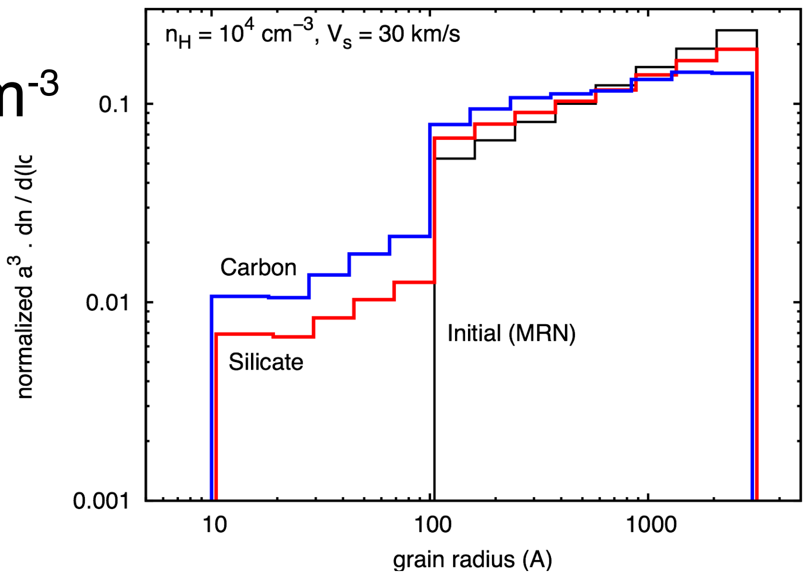


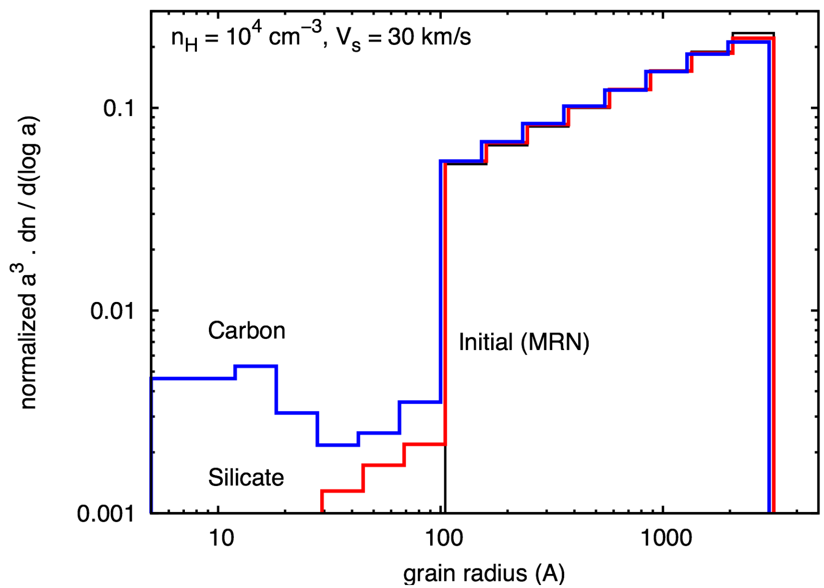
Dust size redistribution

(Guillet, Pineau des Forêts & Jones, submitted)

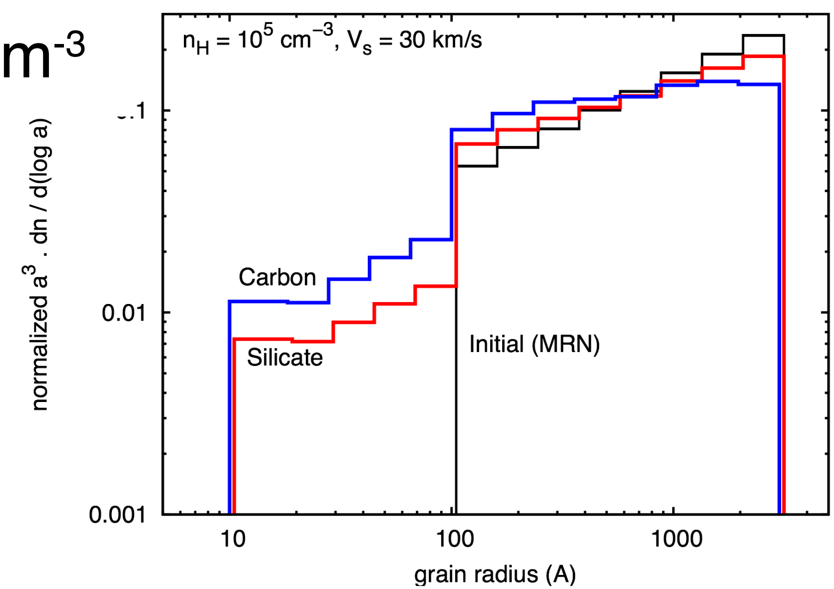
J shocks (30 km/s) | C shocks (30 km/s)

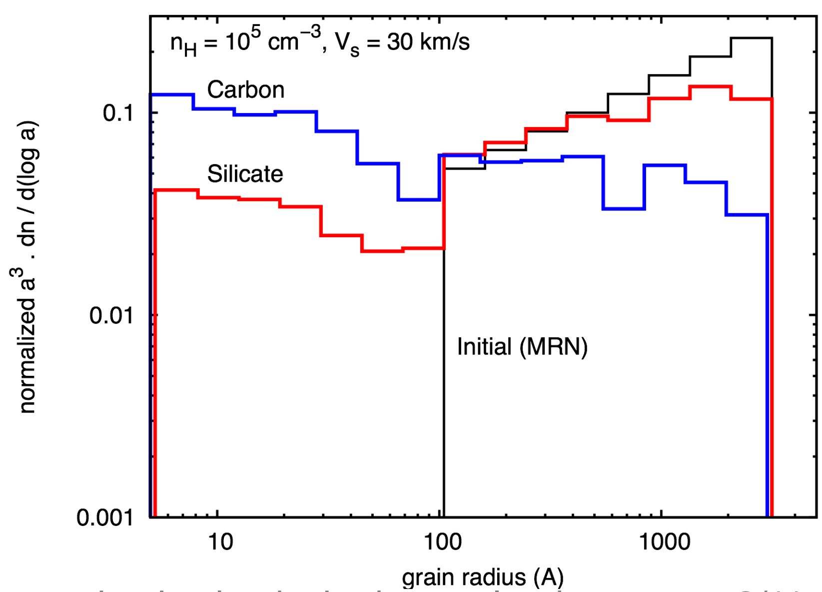
$n_H = 10^4\ cm^{-3}$





$n_H = 10^5\ cm^{-3}$

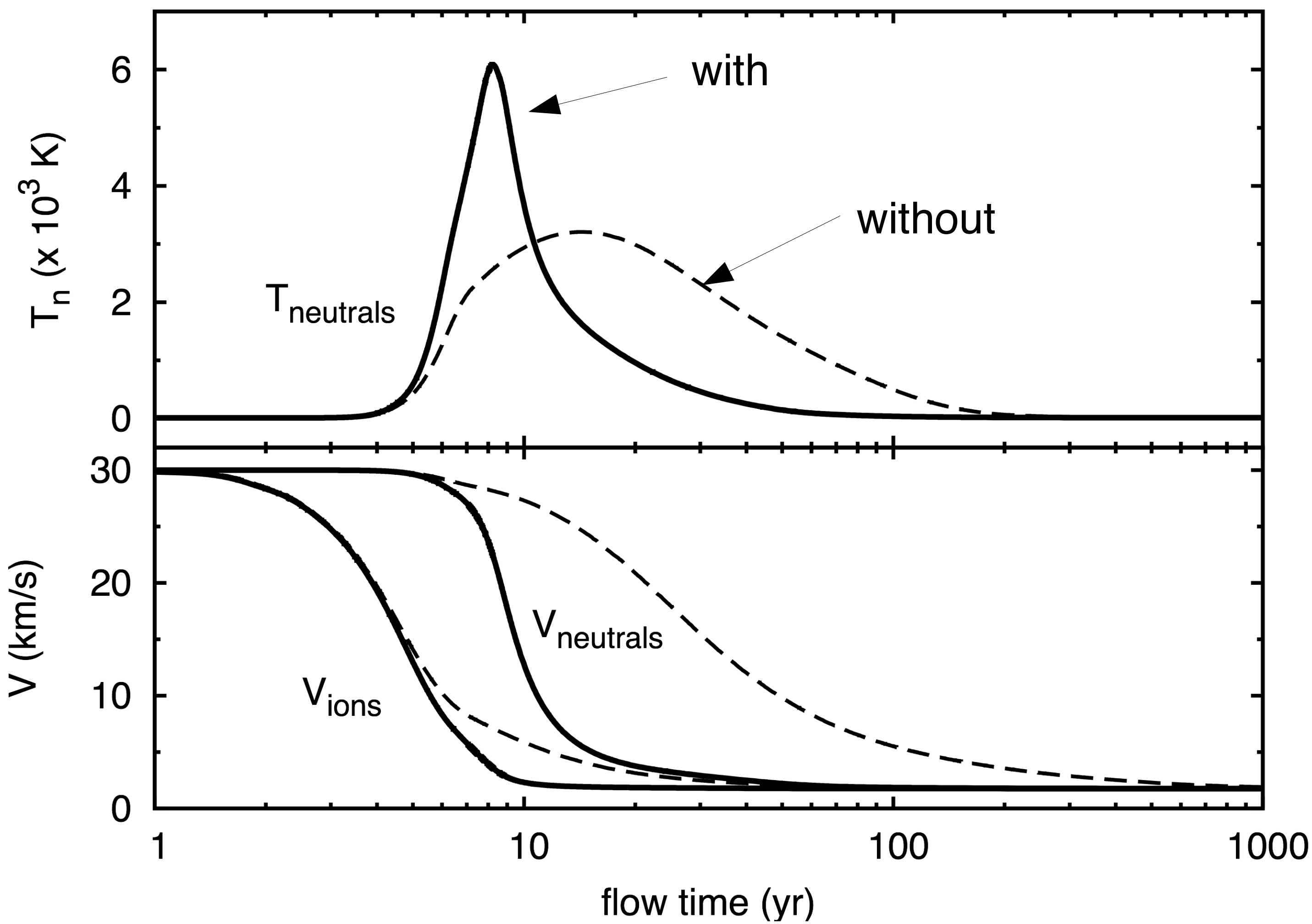




Feedback of shattering on the dynamics of C-type shocks

(Guillet, Pineau des Forêts & Jones, submitted)

C shock, 30 km/s, $n_H = 10^5$ cm^{-3}

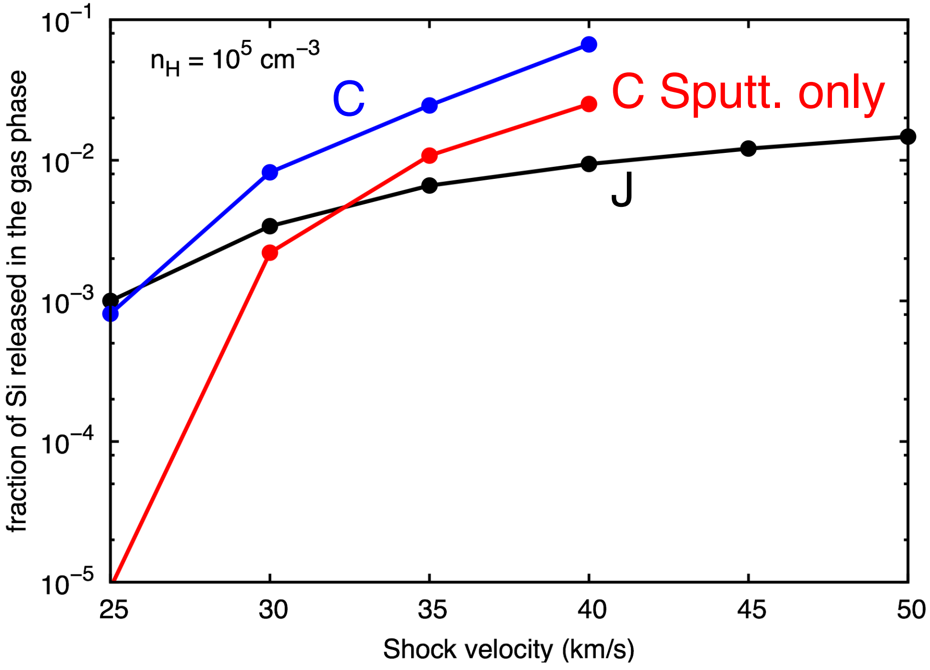


Dust destruction with and without grain-grain processing

(Guillet, Pineau des Forêts & Jones, submitted)

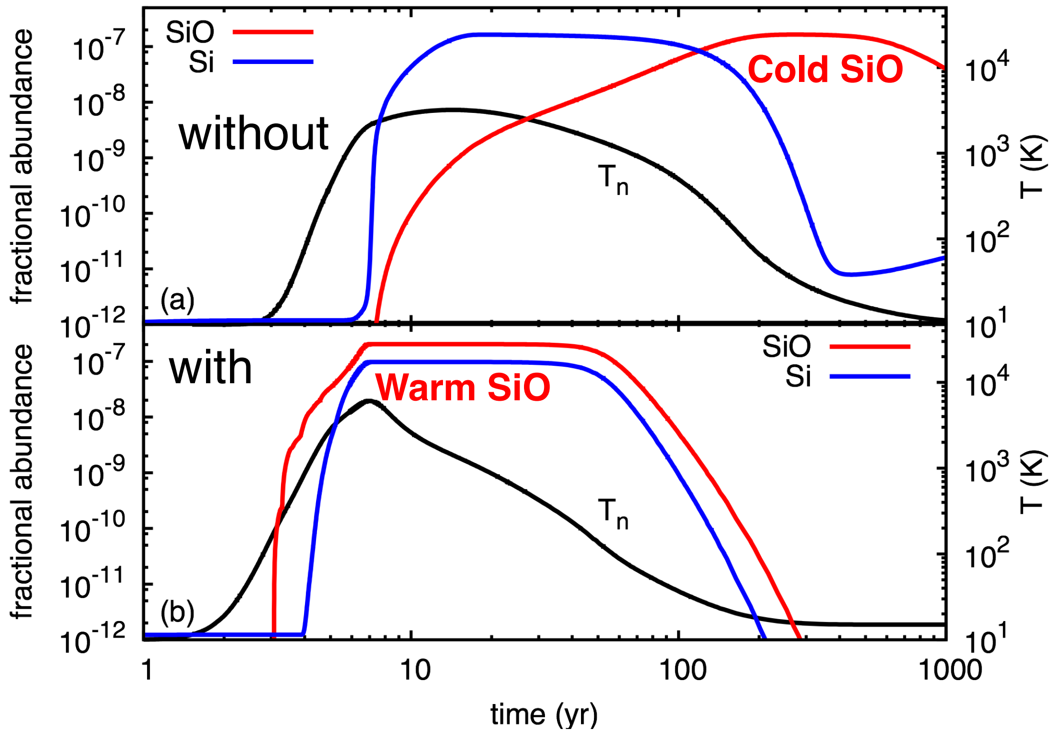
Comparaison C vs J shocks

Fraction of Si returned to the gas phase



SiO production in C shocks

with and without grain-grain processing



No sputtering in J shocks: only vaporisation

Vaporisation dominates sputtering in C shocks

Vaporisation => warm SiO

Sputtering + chemistry => cold SiO

Conclusions

SHOCKS IN MOLECULAR OUTFLOWS

- Slow shocks (< 50 km/s) => vaporisation can dominate sputtering
- High density (> 10^4 cm^{-3}) => low ionisation fraction

=> charged grains can be a dominant charge carrier (« dusty plasmas »)

VAPORISATION

- Dust can be destroyed by vaporisation in low-velocity (< 50 km/s) **J shocks: SiO, Fe^+**
- Vaporisation produce warm SiO in **C-type shocks: new SiO line profile**

SHATTERING IN C SHOCKS

- Shattering is negligible at low density(< 10^4), important at high density **(> 10^5 cm^{-3})**
- Feedback of shattering on shocks dynamics leads to **shorter and warmer shocks**.
- Coagulation in the shock is not able to compensate for shattering