Franco Vazza (Jacobs University Bremen)

f.vazza@jacobs-university.de oppure vazza@ira.inaf.it

http://www.ira.inaf.it/~vazza/lezioni_bologna/

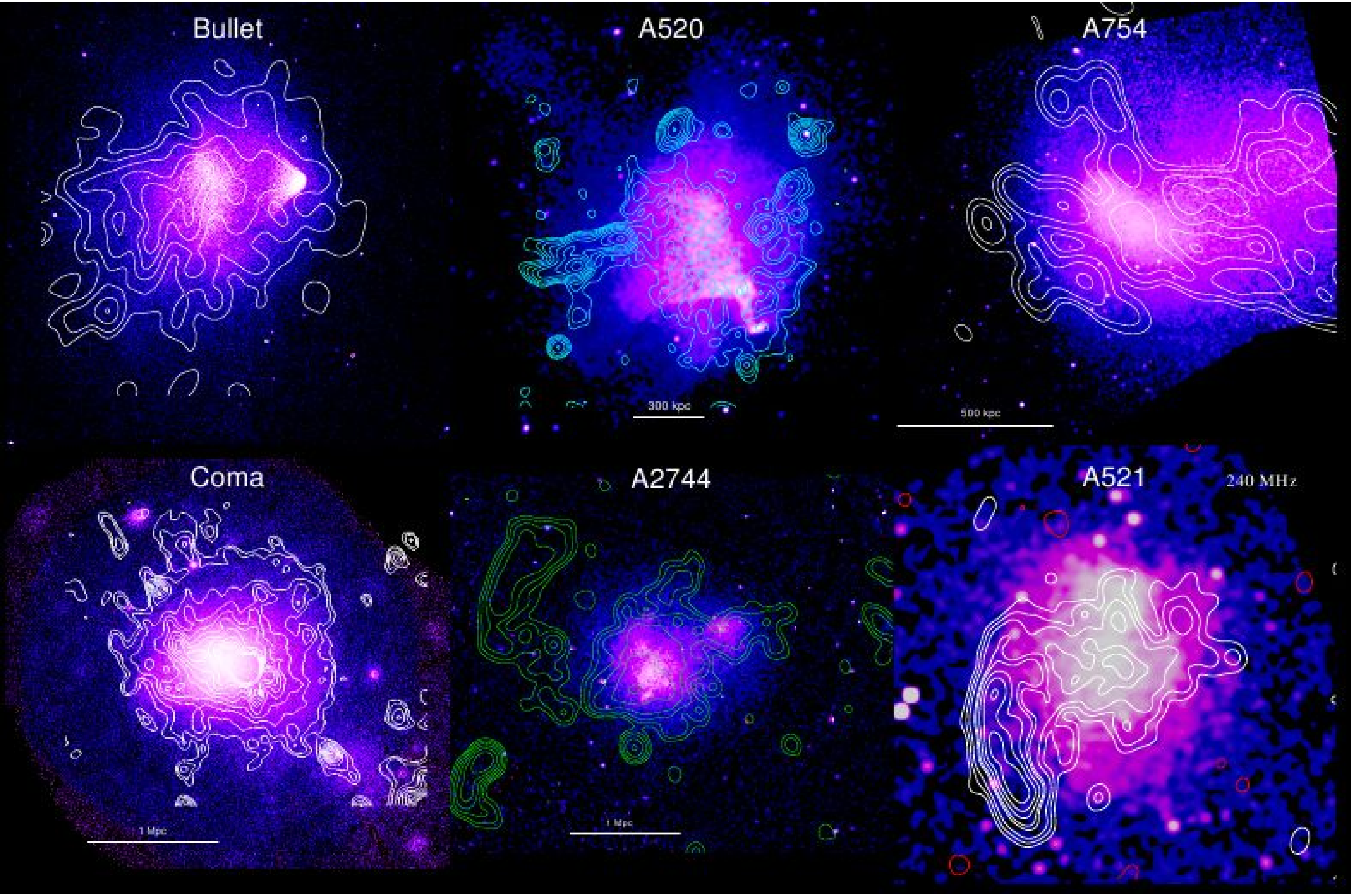
~

Il menù della settimana:

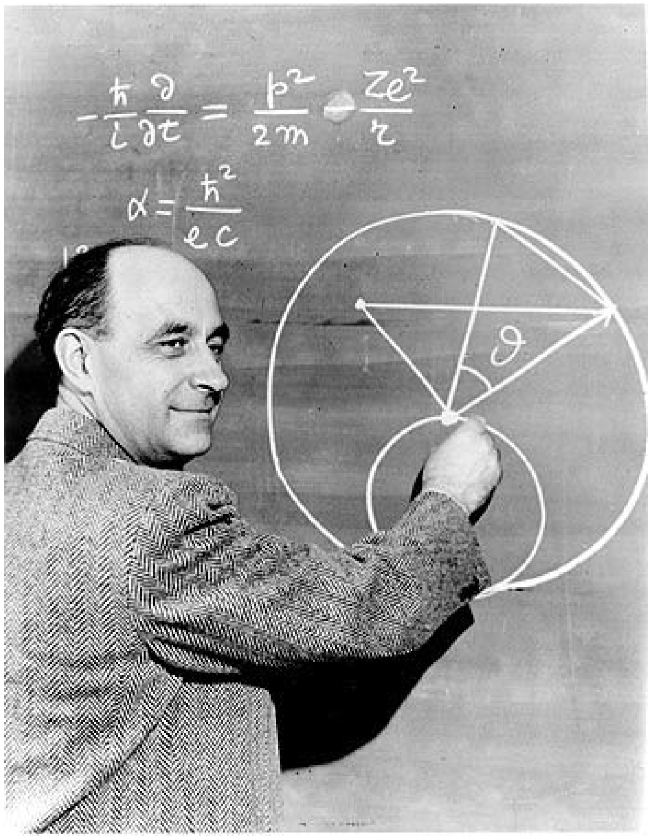
Oggi: processi di accelerazione di particelle "microscopici" [qualche conto, molta teoria]

Giovedì: modelli di accelerazione "macroscopici" per aloni e relitti [teoria/osservazioni, pochi conti]

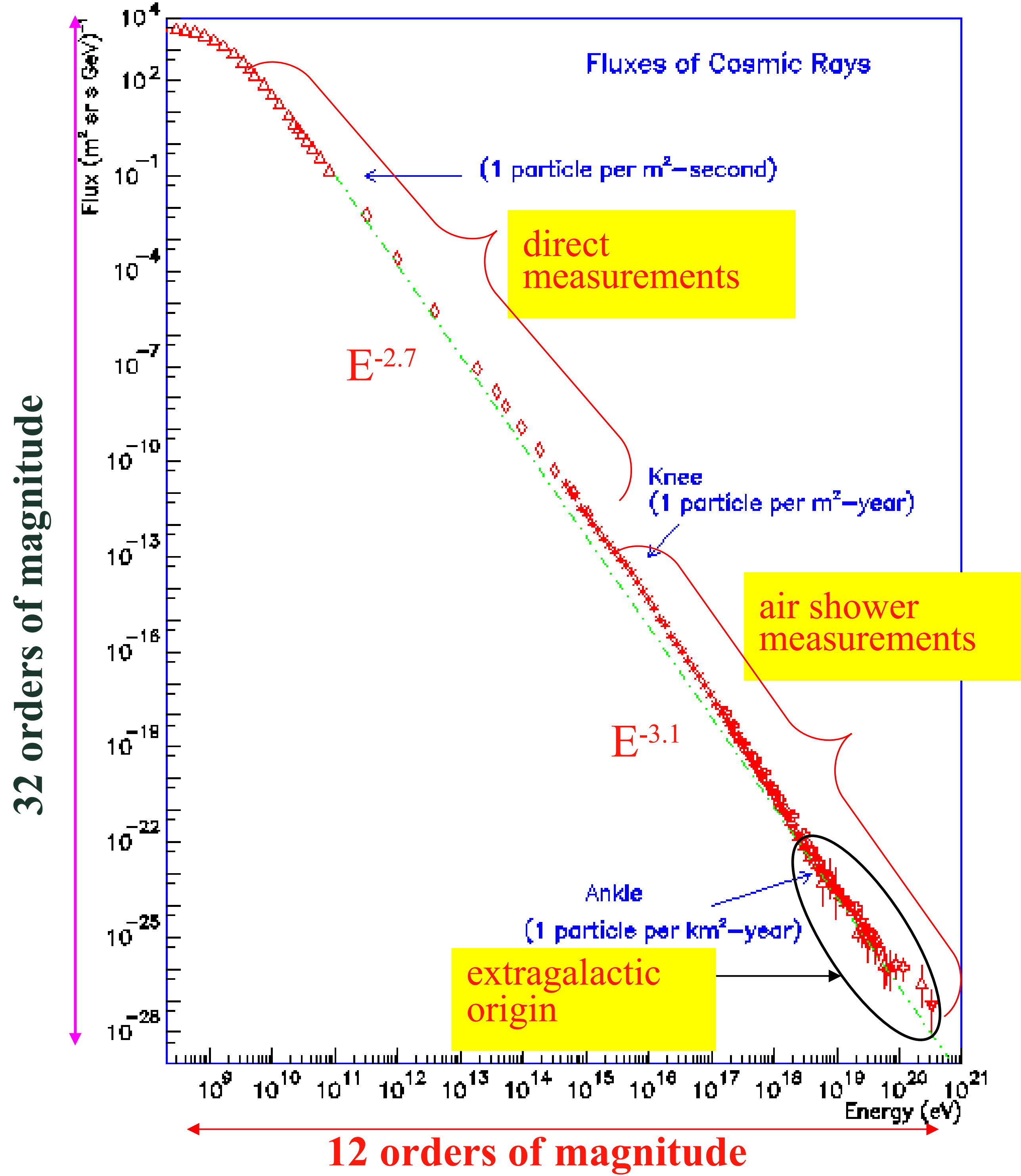
Martedì prox: simulazioni numeriche di processi non termici [molte immagini/video]

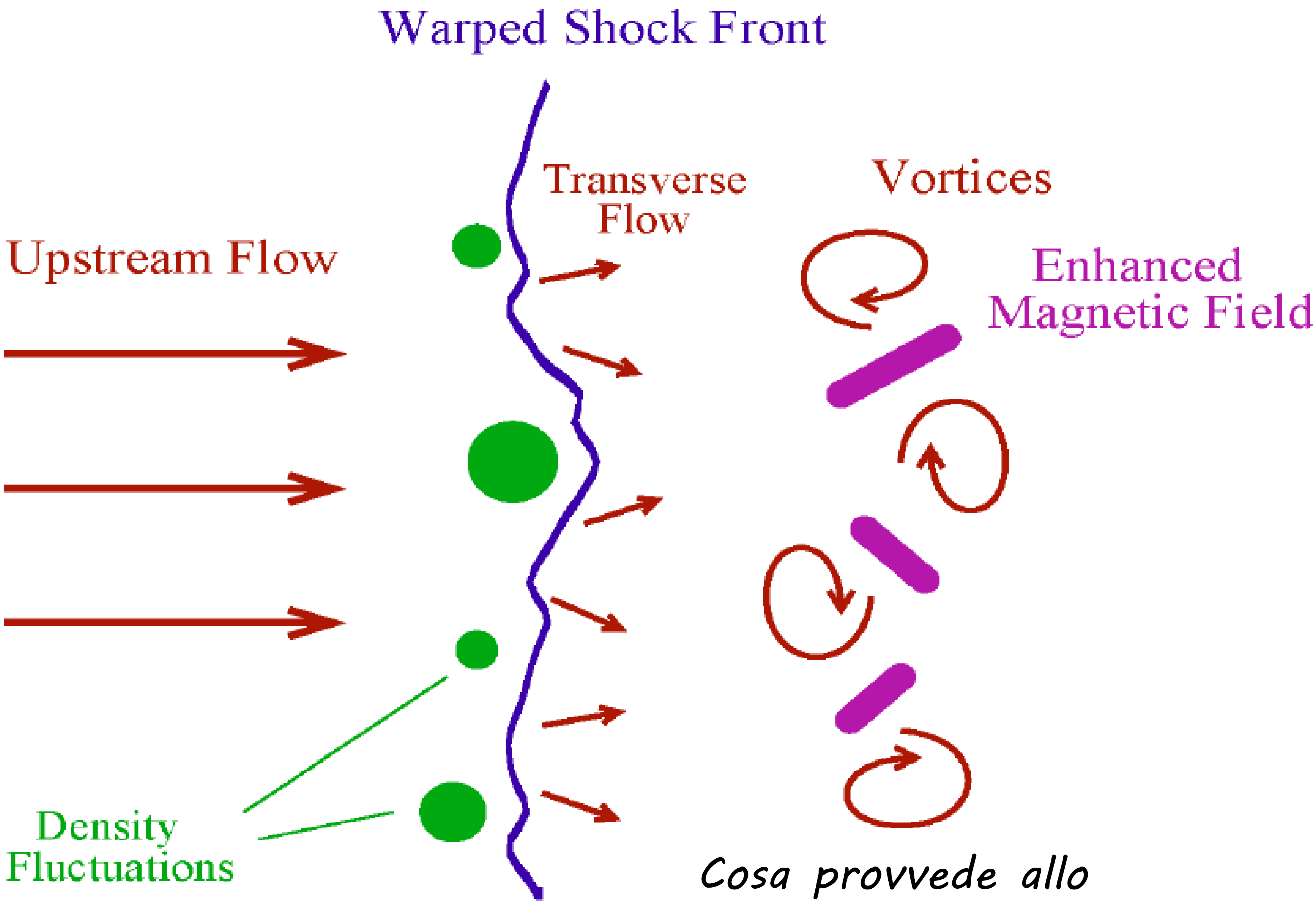


Bullet
A520
300 kpc
A754
500 kpc
Coma
1 Mpc
A2744
1 Mpc
A521
240 MHz



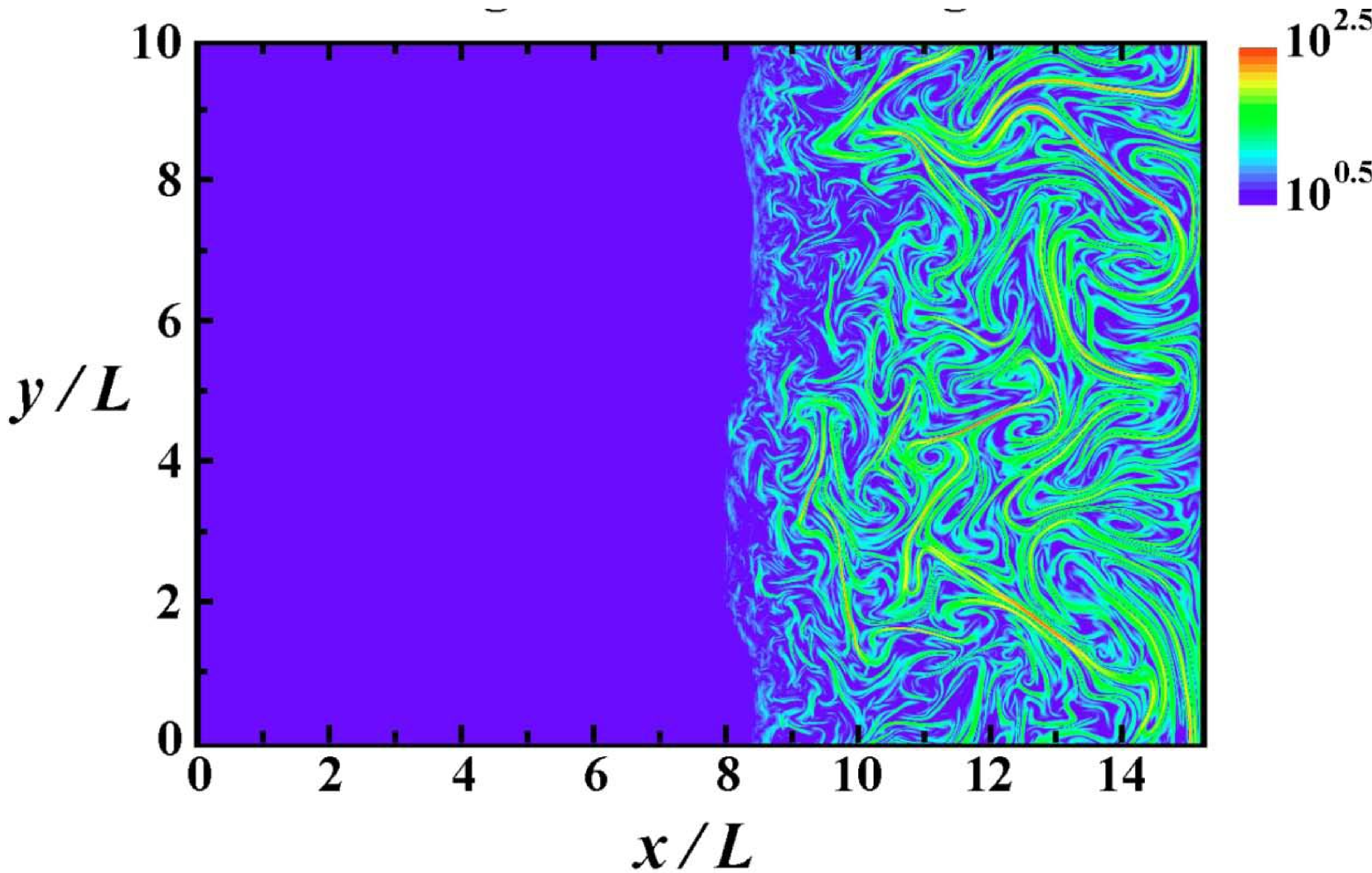
Enrico Fermi 1949:
"On the origin of cosmic radiation"





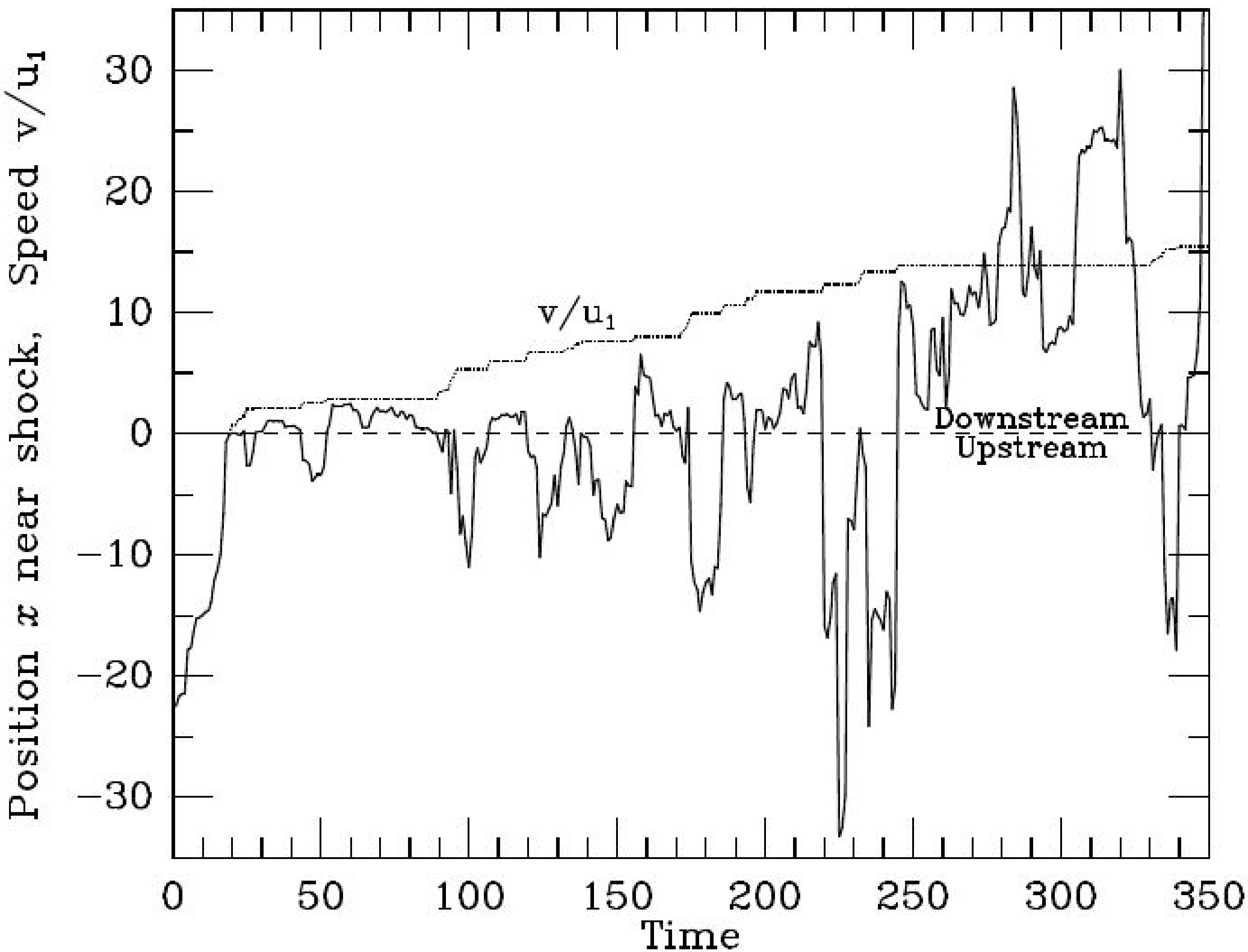
Cosa provvede allo scattering delle particelle attraverso lo shock?

Turbolenza MHD nel post-shock



Giacalone & Jokipii 2007

Accelerazione stocastica di una particella attraverso uno shock (simulazione)



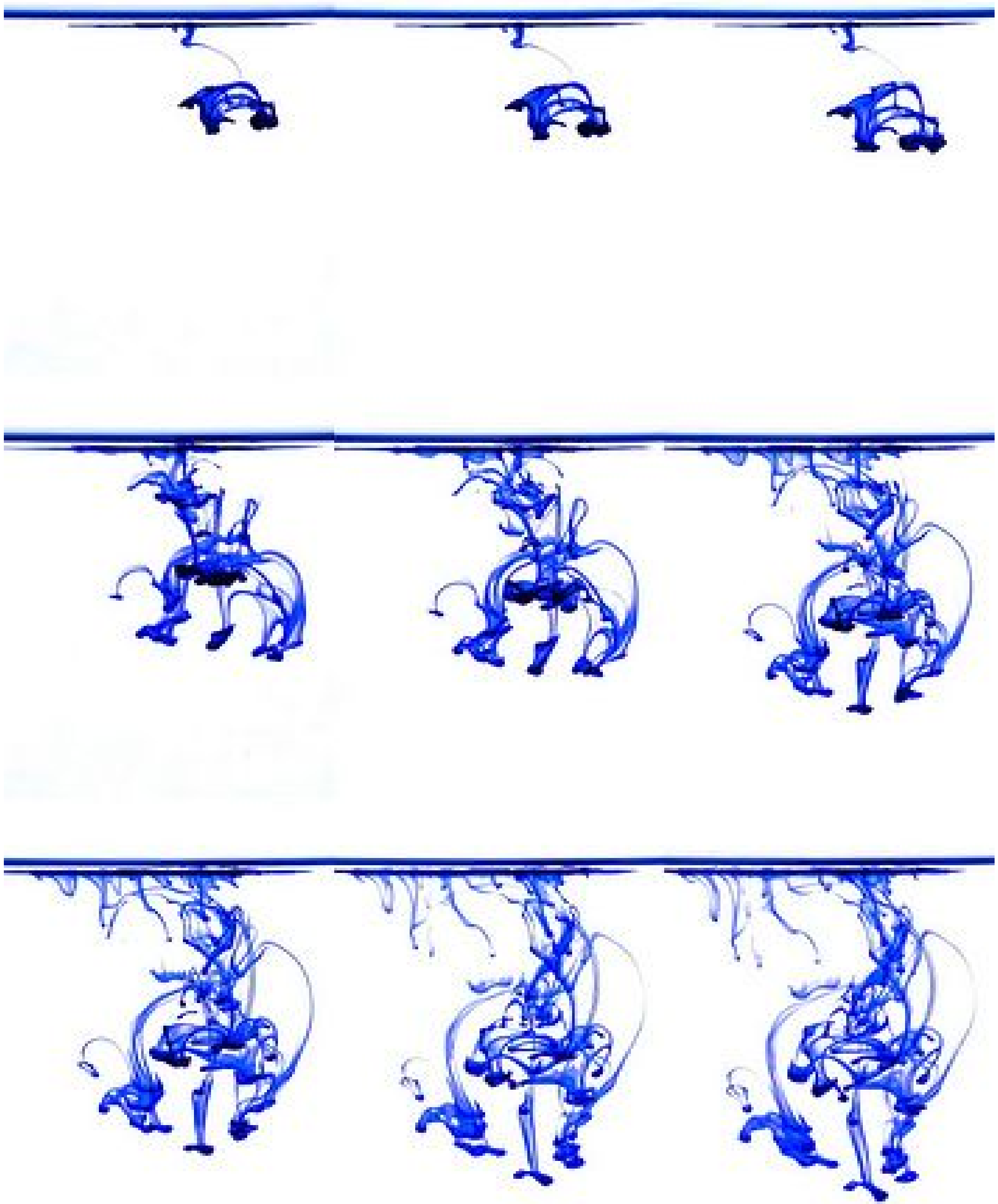
(Baring et al. 1993)

Nel limite di molti scattering

$v \gg |V_2 - V_1|$

La traiettoria delle particelle segue un comportamento "diffusivo"

$L = (t \cdot \kappa_{diff})^{1/2}$



DIFFUSIVE SHOCK ACCELERATION THEORY

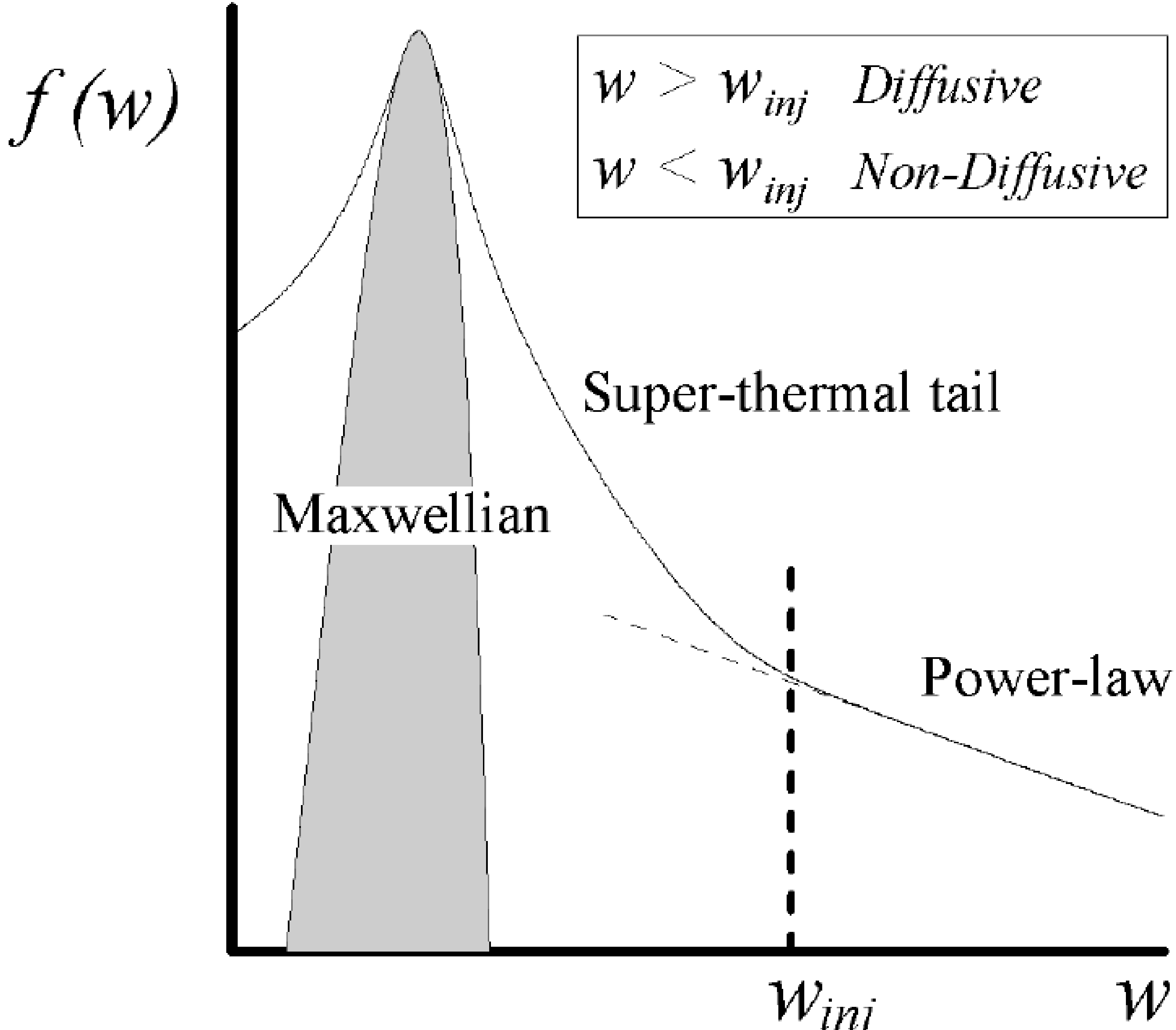
Bell 1978

Drury & Voelk 1981

Drury 1983

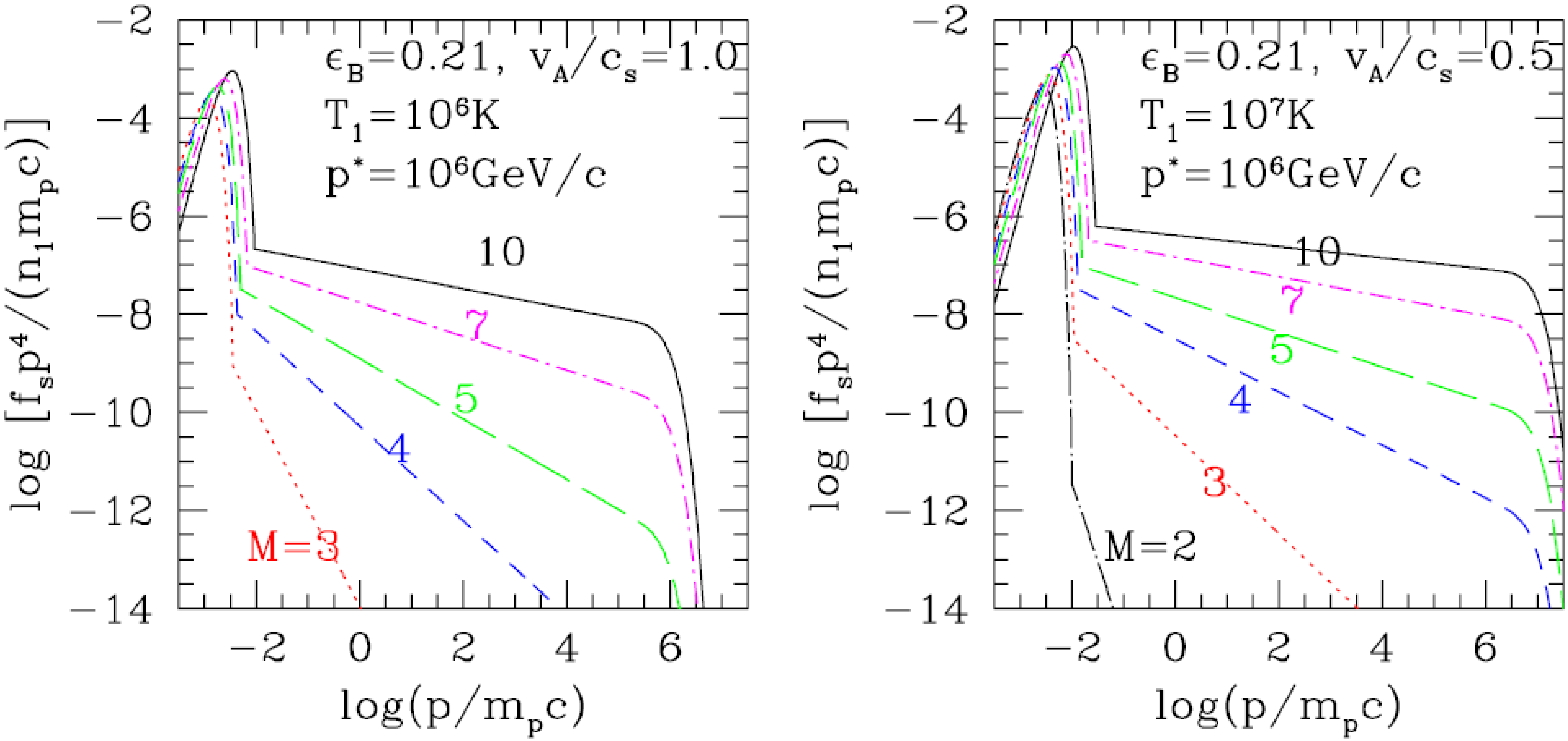
Blandford & Eichler 1987

etc....



f (w)
w > w_inj Diffusive
w < w_inj Non-Diffusive
Super-thermal tail
Maxwellian
Power-law
w_inj
w

Spettri di energia in funzione del numero di Mach



(Kang & Jones 2007)

Shock energy flux

$f_\phi = \frac{1}{2} \rho v_s^3$

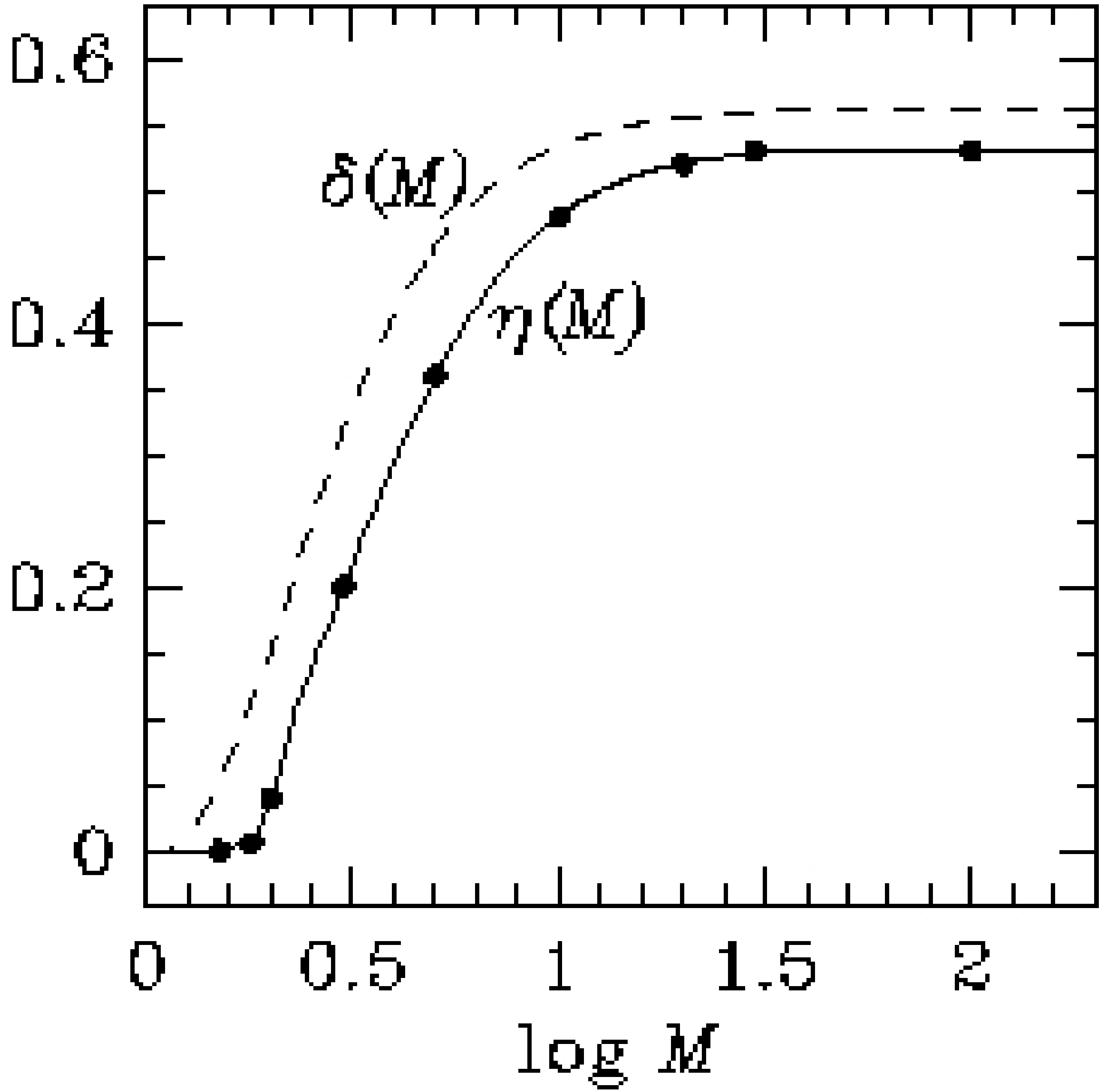
Flusso termico:

$f_{th} = \delta(M)\, f_\phi$

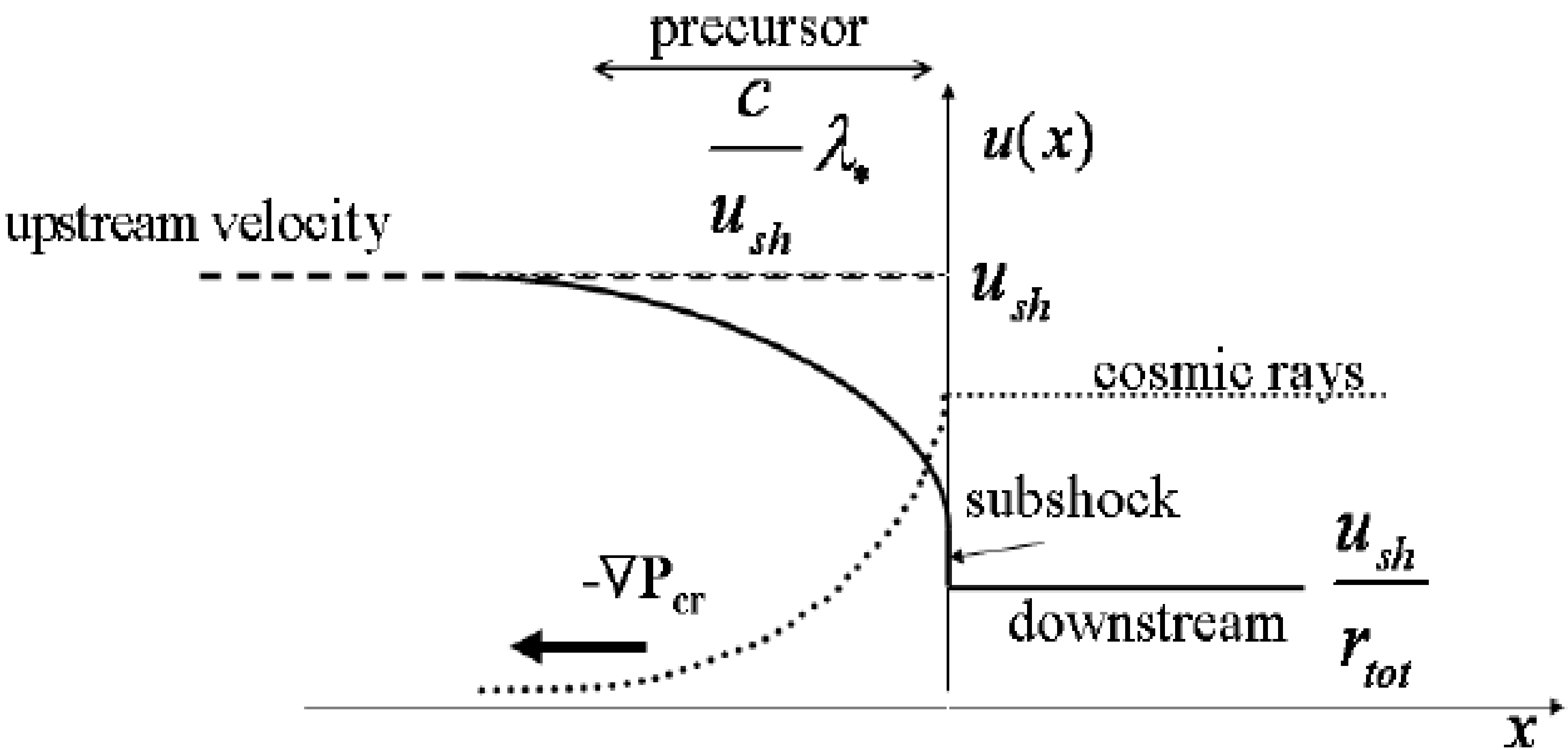
Flusso CR:

$f_{cr} = \eta(M)\, f_\phi$

$\delta(M) + \eta(M) < 1$

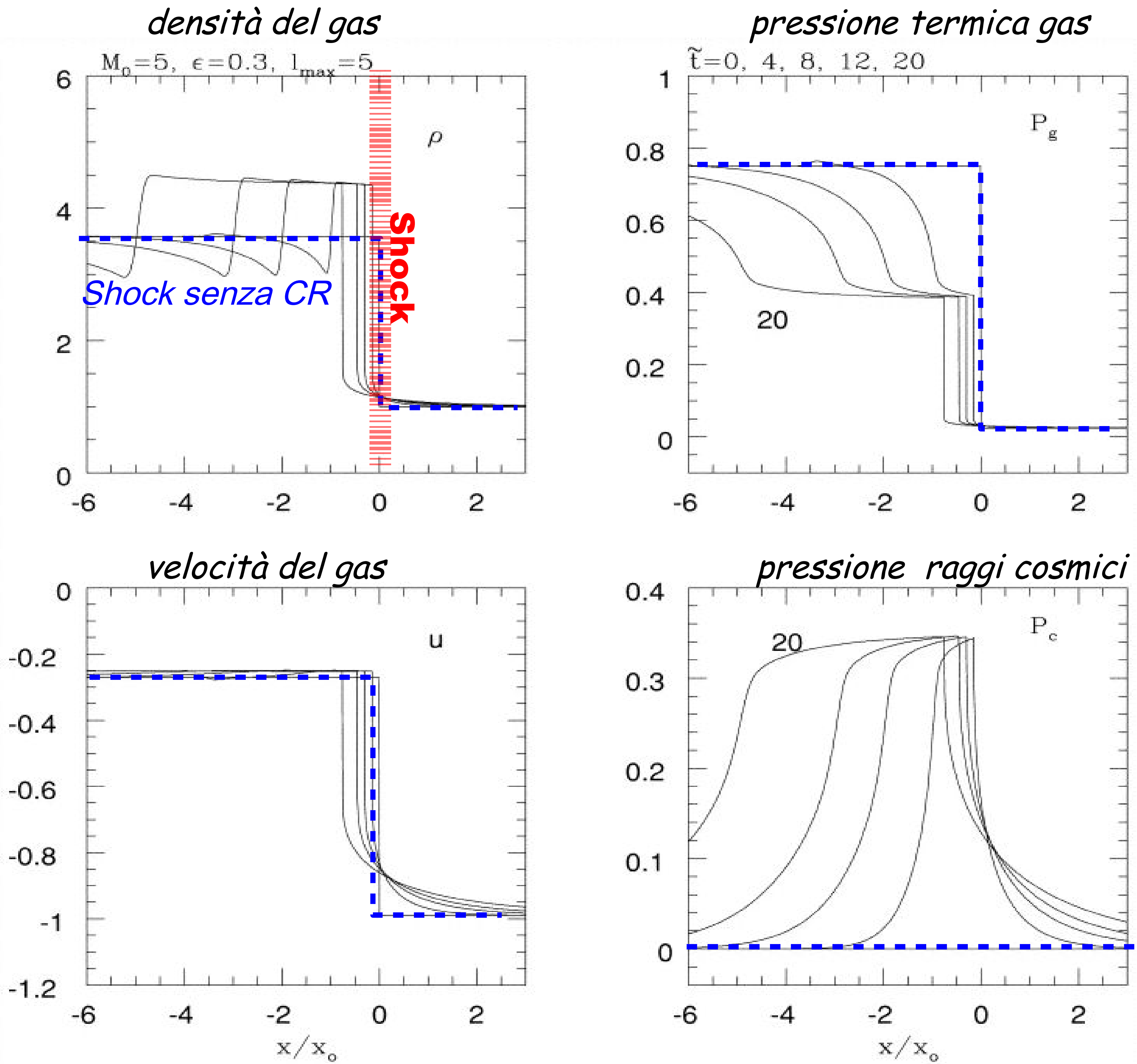


Shock modificati



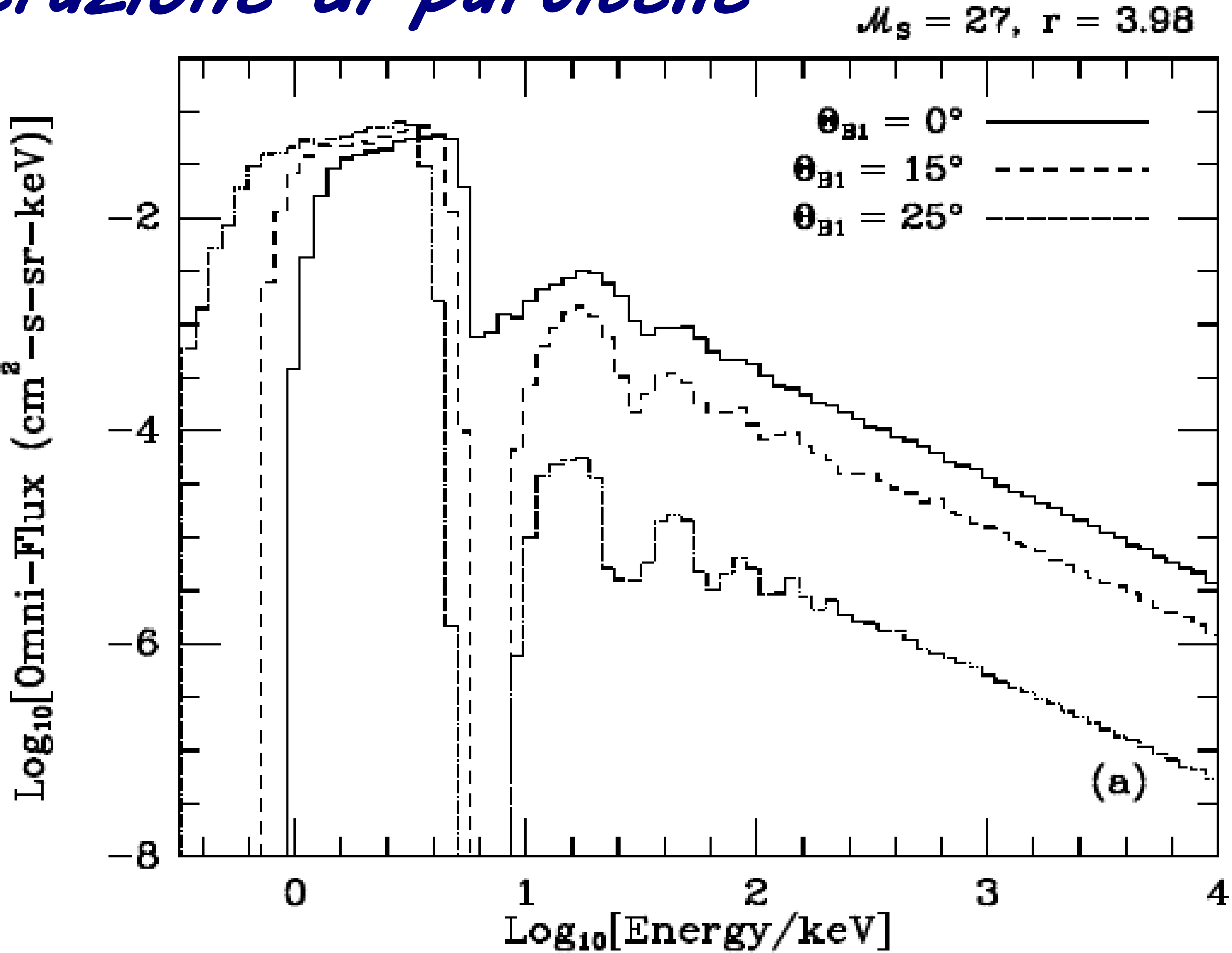
(da Bykov et al. 2006)

Shock “modificati”



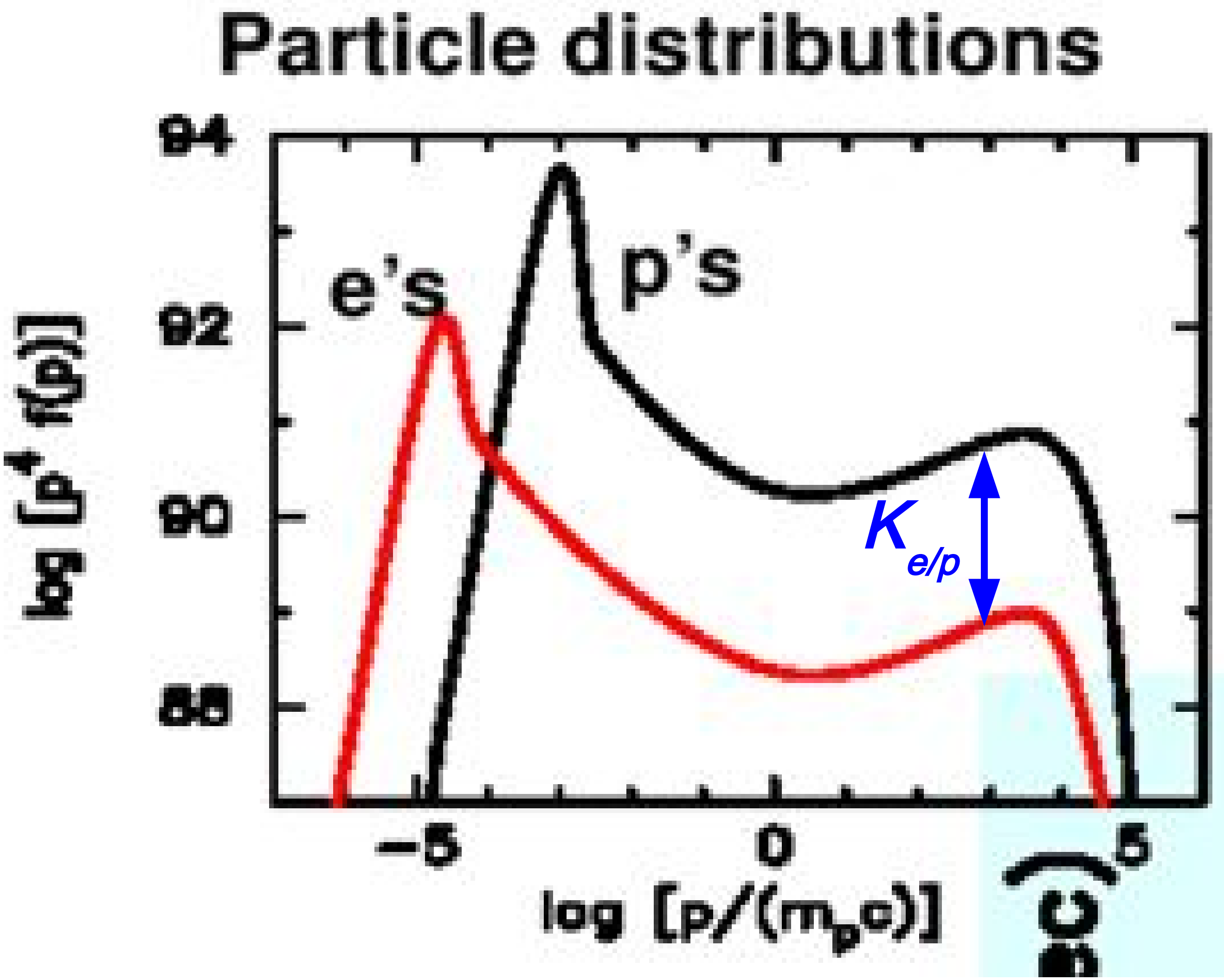
da Kang & Jones 2007

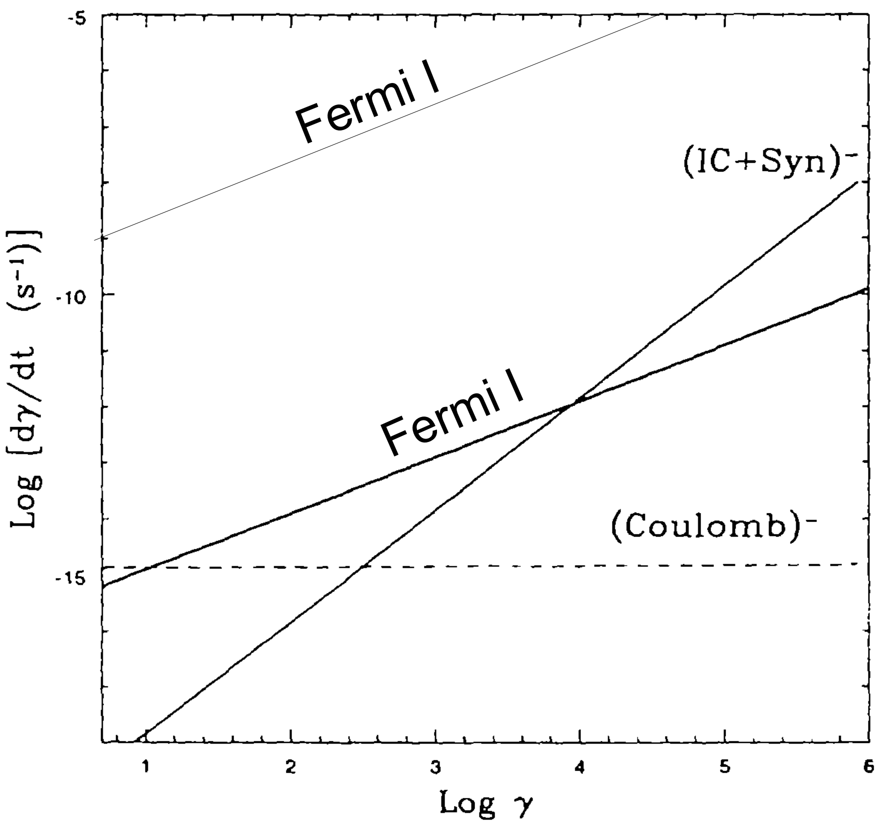
Effetto del campo magnetico sull'accelerazione di particelle

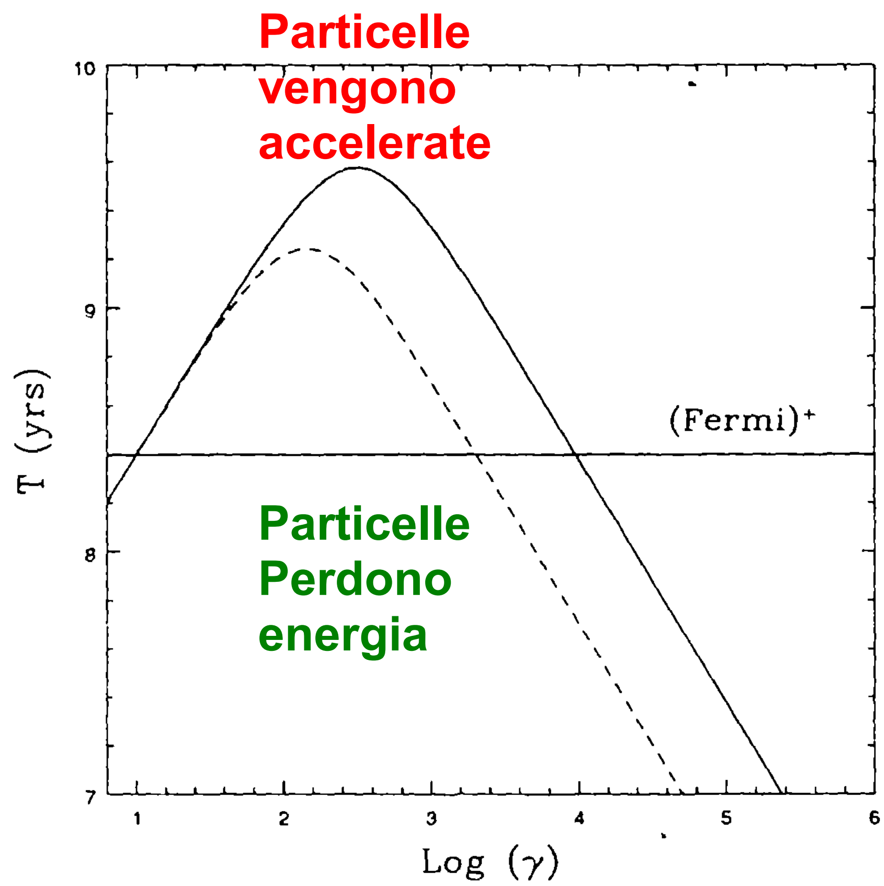


da Baring 1997

Spettri di protoni ed elettroni accelerati




Fermi I
(IC+Syn)⁻
Fermi I
(Coulomb)⁻
Log [dγ/dt (s⁻¹)]
Log γ


Particelle vengono accelerate
(Fermi)⁺
Particelle Perdono energia
T (yrs)
Log (γ)

Stochastic Particle Acceleration

Brunetti +al. 2004, Brunetti & Blasi 2005, Brunetti & Lazarian 2007...

D_p: momentum diffusion

Electrons/Positrons

$$\frac{\partial N_e(p,t)}{\partial t} = \frac{\partial}{\partial p}\left(N_e(p,t)\left[\left(\frac{dp}{dt}\right)_{rad} + \left(\frac{dp}{dt}\right)_i - \frac{2}{p}D_{pp}\right]\right) + \frac{\partial}{\partial p}\left(D_{pp}\frac{\partial N_e(p,t)}{\partial p}\right) + Q_e(p,t)$$

Q_e: "new" particles in the system

Protons

$$\frac{\partial N_p(p,t)}{\partial t} = \frac{\partial}{\partial p}\left(N_p(p,t)\left[\left(\frac{dp}{dt}\right)_i - \frac{2}{p}D_{pp}\right]\right) + \frac{\partial}{\partial p}\left(D_{pp}\frac{\partial N_p(p,t)}{\partial p}\right) + Q_p(p,t)$$

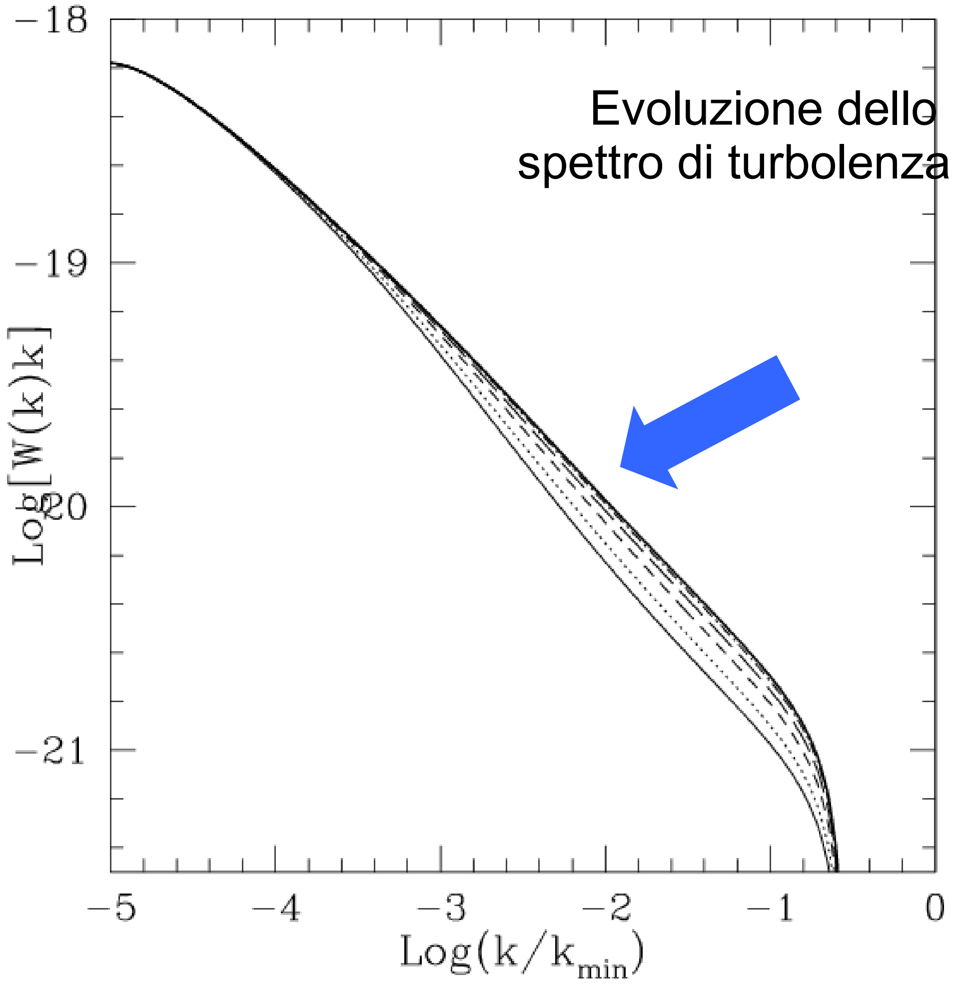
Waves

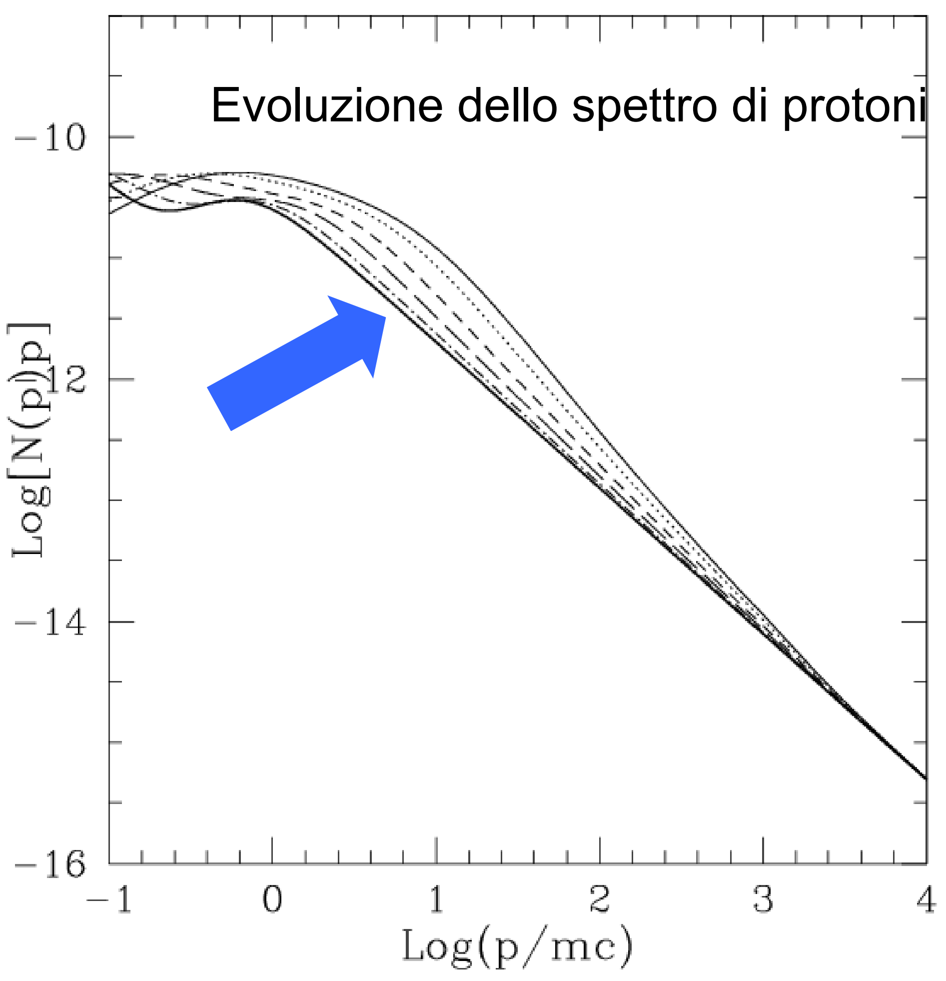
$$\frac{\partial \mathcal{W}(k,t)}{\partial t} = \frac{\partial}{\partial k}\left(k^2 D_{kk}\frac{\partial}{\partial k}\left(\frac{\mathcal{W}(k,t)}{k^2}\right)\right) - \sum_i \Gamma_i(k,t)\mathcal{W}(k,t) + I(k,t)$$

most could be with CR protons

n_{th}, T, B_o, $N_p(p,0)$, I(k)   quantità “macroscopiche”

$N_p(p,t)$, $N_e\pm(p,t)$, $W(k,t)$, $Q_e\pm(p,t)$,





QUALCHE REFERENZA (TOSTA)

-L.Drury 1995 "Particle Acceleration in Shocks"

- M.Baring 1997 "Diffusive shock acceleration: the fermi mechanism"

- G.Brunetti 2002 "Modelling the non-thermal emission from galaxy clusters"

- Bykov, Dolag & Durret 2008 "Cosmological Shock Waves"

n_{th}, T, B_o, $N_p(p,0)$, I(k) quantità “macroscopiche”

$N_p(p,t)$, $N_e\pm(p,t)$, $W(k,t)$, $Q_e\pm(p,t)$,