The cosmic ray content of superbubbles

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with S. Gabici and V. Tatischeff

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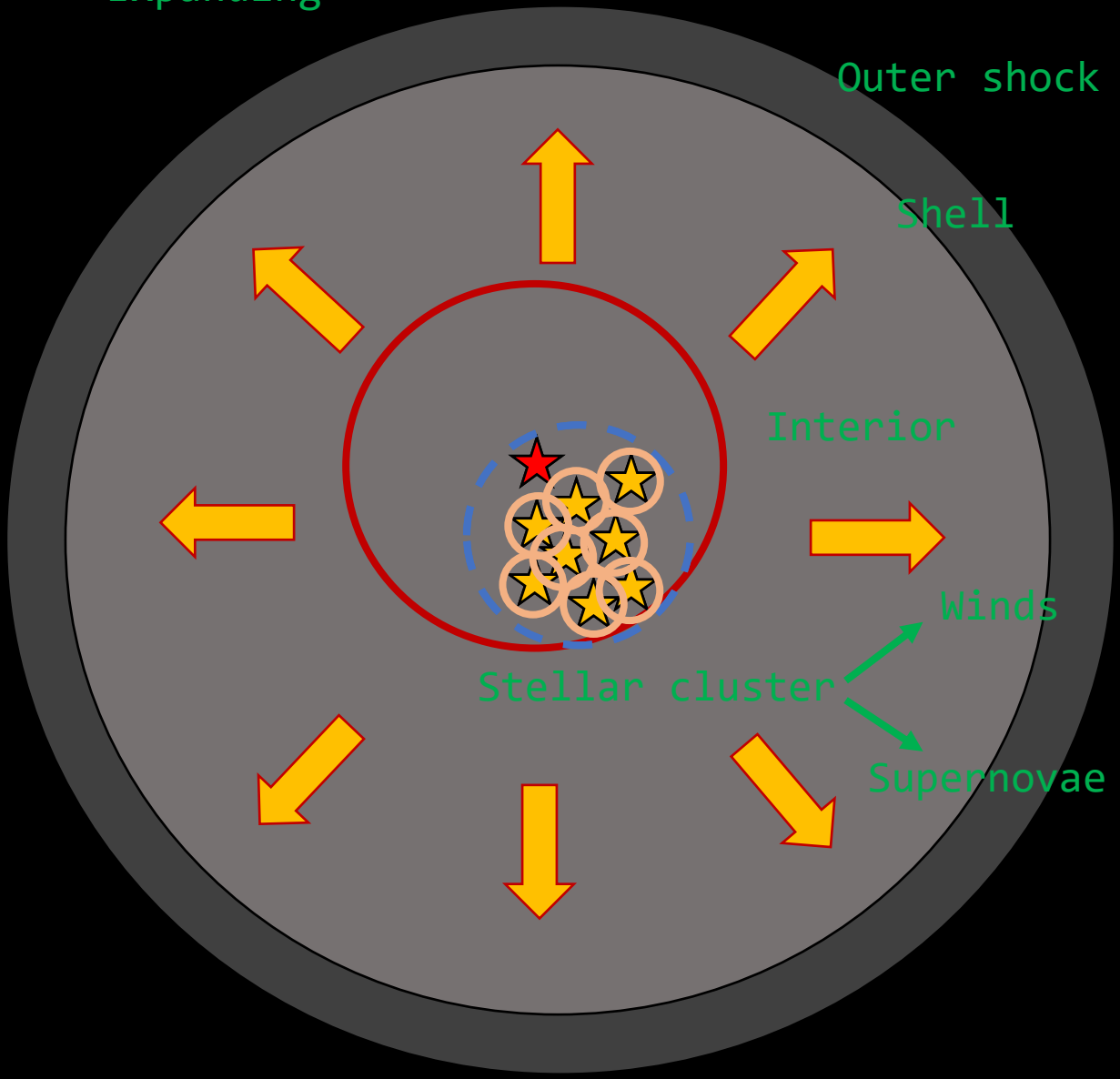
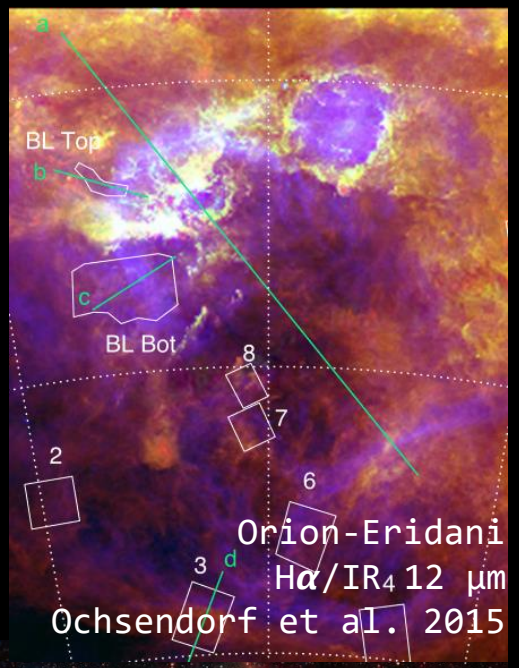
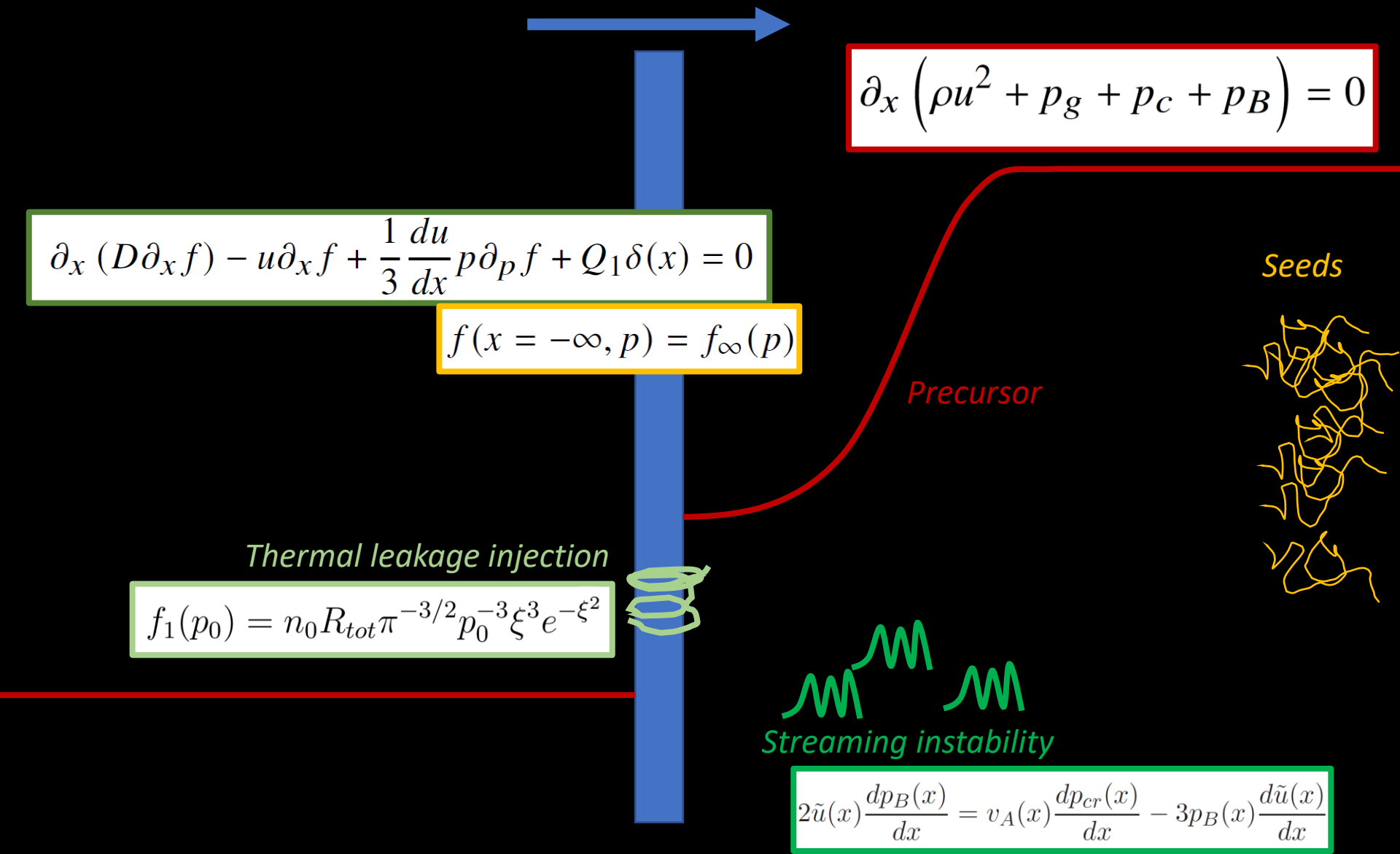
Superbubble
- Low density cavity
- Expanding

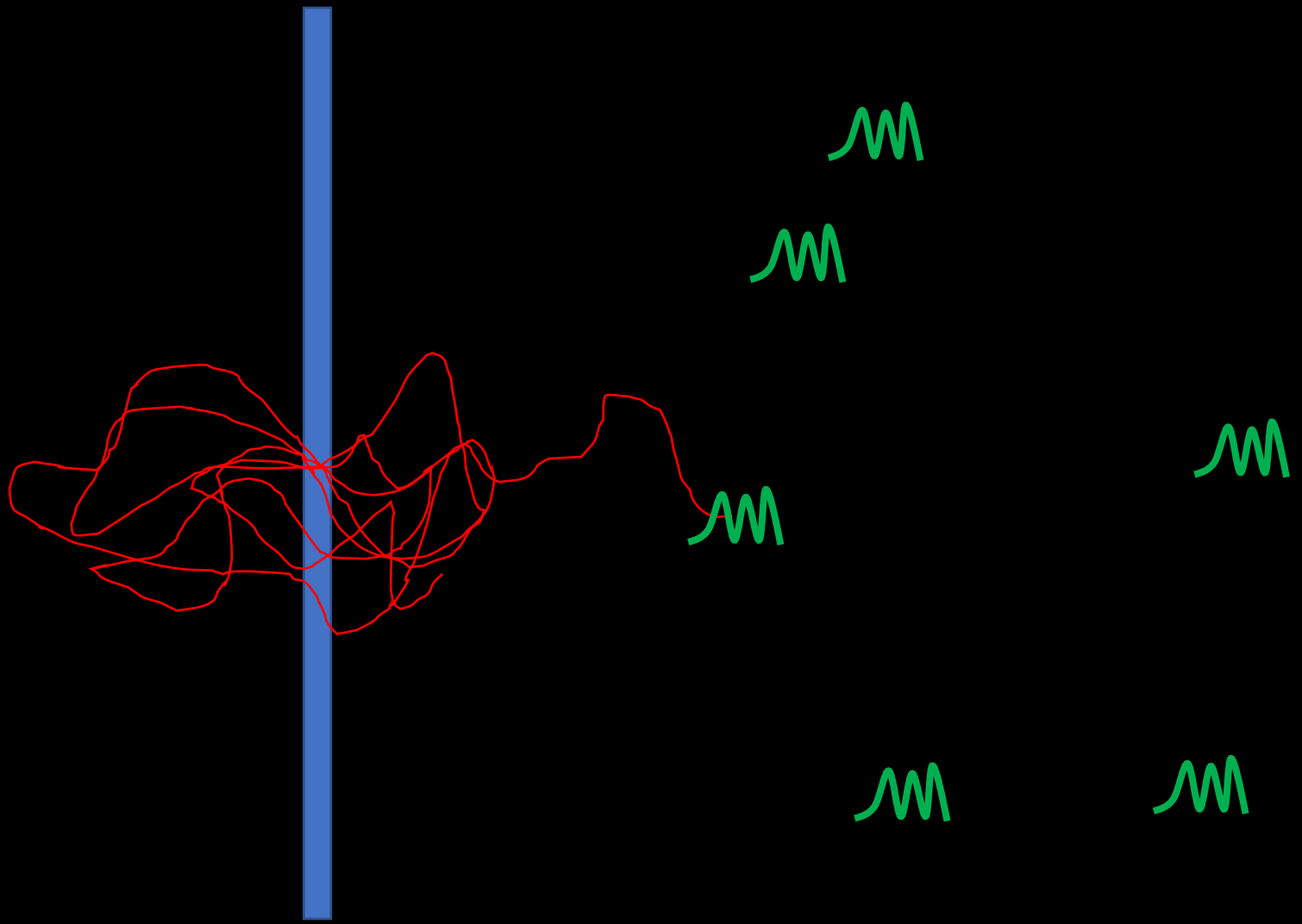




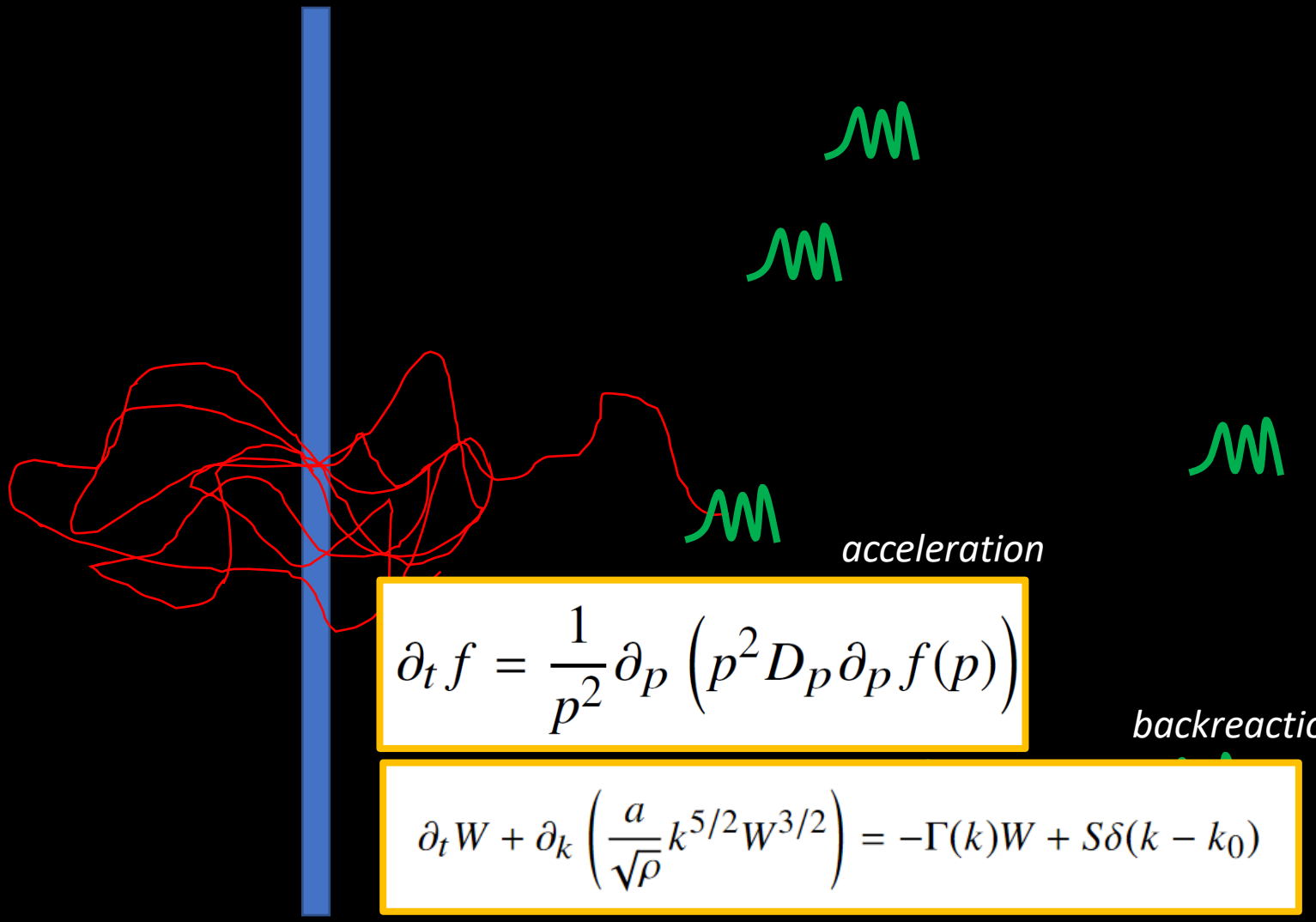
Nonlinear diffusive shock reacceleration



Nonlinear stochastic reacceleration



Nonlinear stochastic reacceleration



acceleration

$$\partial_t f = \frac{1}{p^2}\partial_p \left(p^2 D_p \partial_p f(p) \right)$$

backreaction

$$\partial_t W + \partial_k \left(\frac{a}{\sqrt{\rho}} k^{5/2} W^{3/2} \right) = -\Gamma(k) W + S\delta(k - k_0)$$

Shock (DSRA)

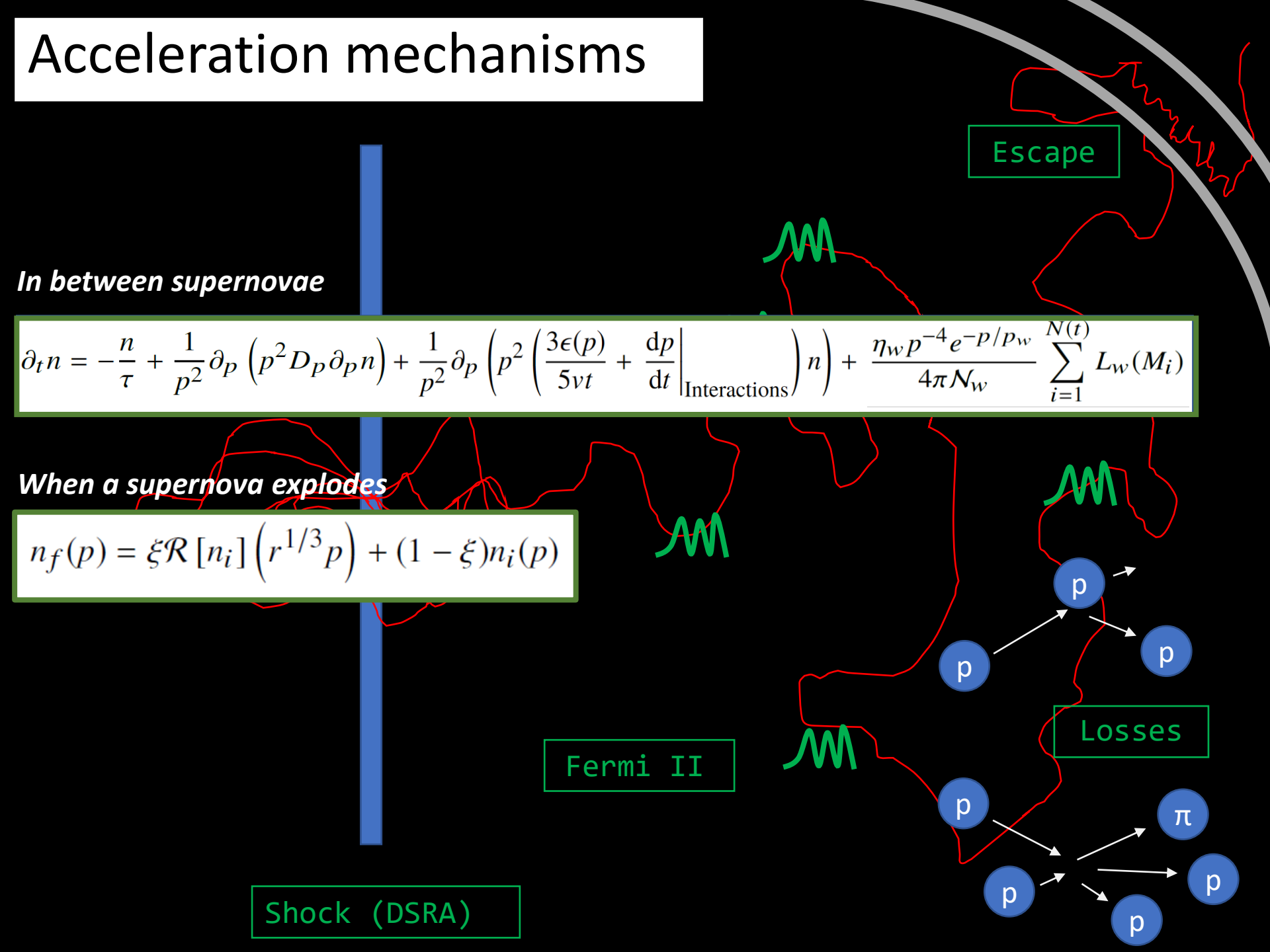
Acceleration mechanisms

In between supernovae

$$\partial_t n = -\frac{n}{\tau} + \frac{1}{p^2}\partial_p\left(p^2 D_p \partial_p n\right) + \frac{1}{p^2}\partial_p\left(p^2\left(\frac{3\epsilon(p)}{5vt} + \left.\frac{\mathrm{d}p}{\mathrm{d}t}\right|_{\text{Interactions}}\right)n\right) + \frac{\eta_w p^{-4} e^{-p/p_w}}{4\pi \mathcal{N}_w}\sum_{i=1}^{N(t)} L_w(M_i)$$

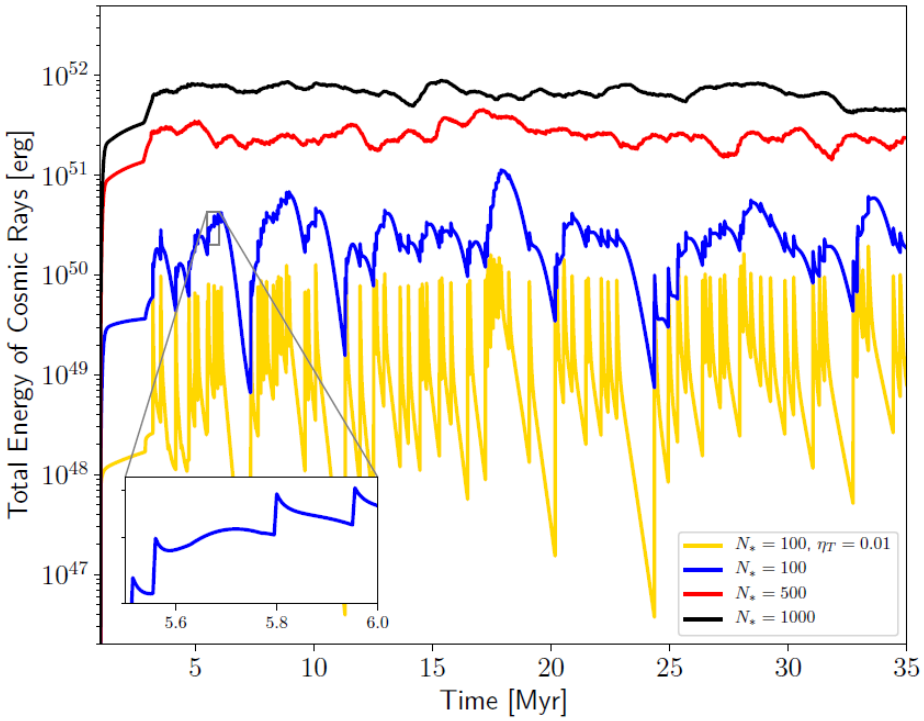
When a supernova explodes

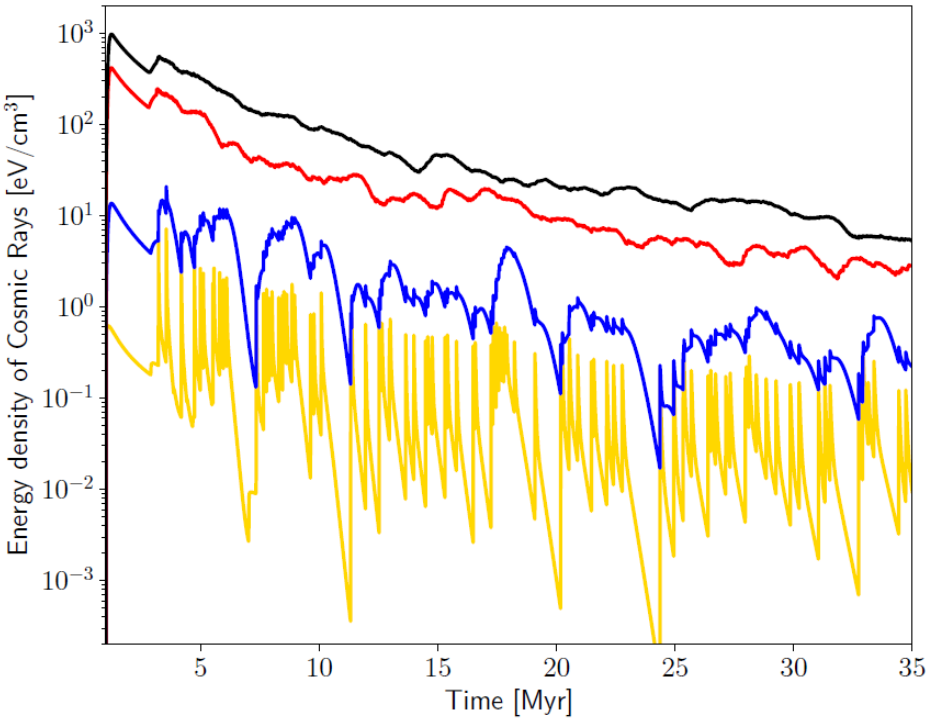
$$n_f(p) = \xi \mathcal{R}\left[n_i\right]\left(r^{1/3}p\right) + (1-\xi)n_i(p)$$



(Vieu et al. in prep.)

Selected results: Energetics





Acceleration in two steps:

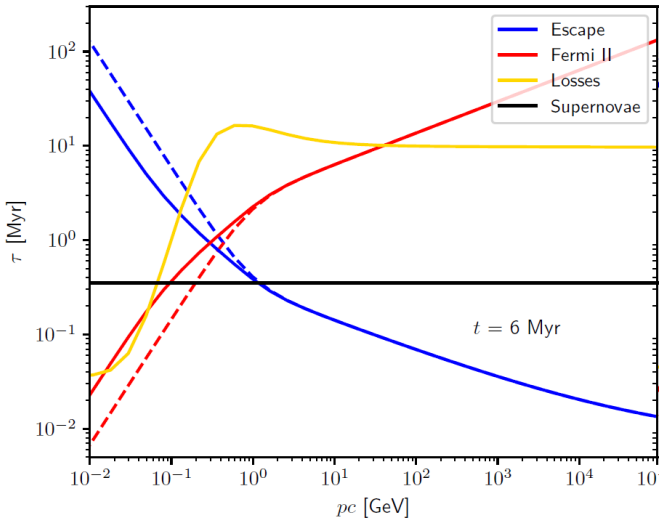
> supernova injection

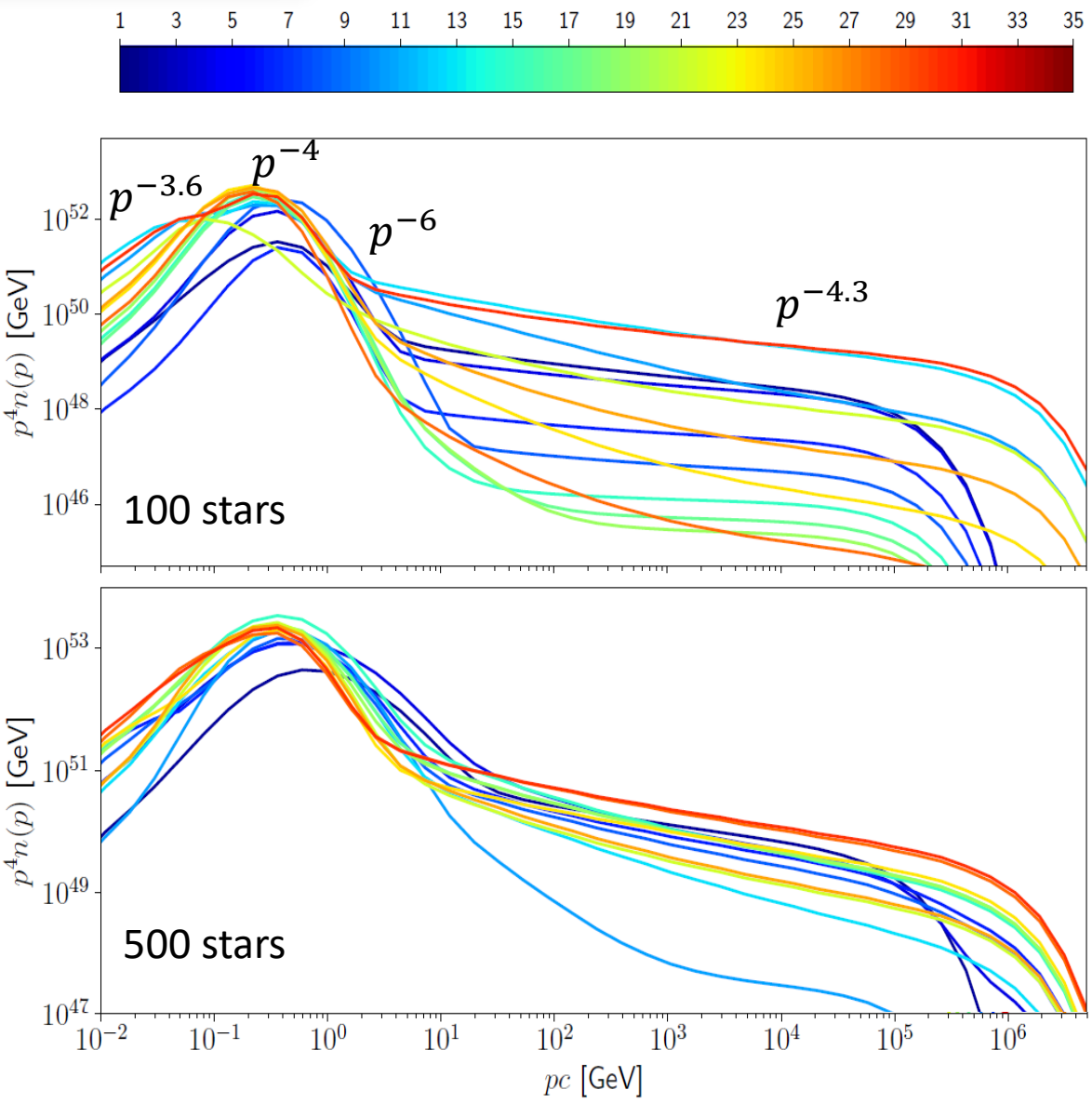
> Stochastic reacceleration

(Vieu et al. in prep.)

Selected results: Spectra

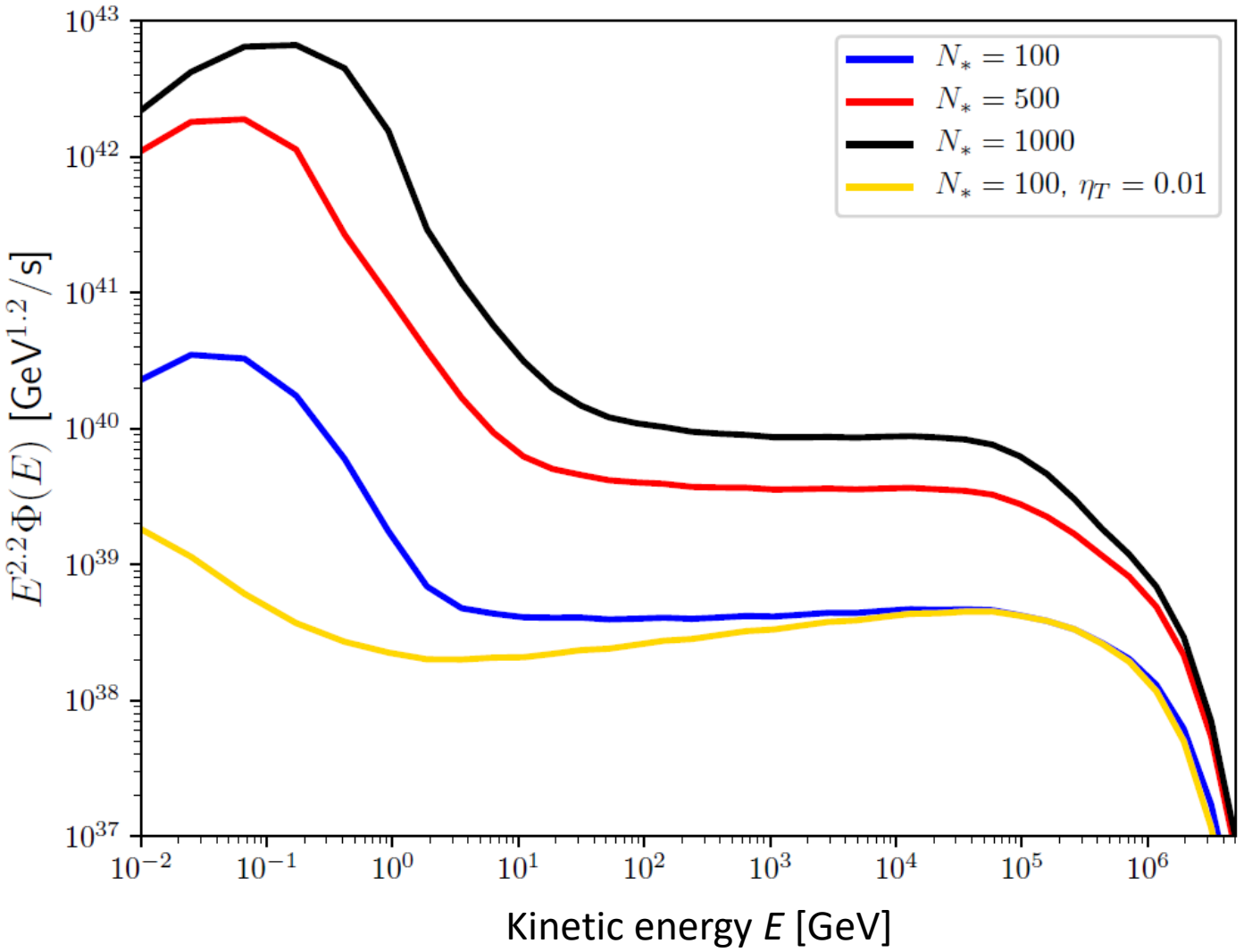
- Intermittency at small p
- Intermittency at high p
- Hard/Soft transition



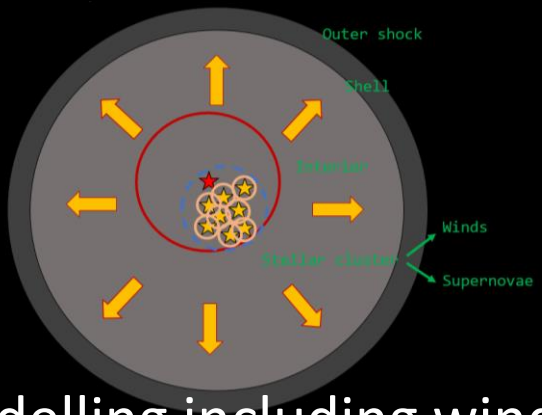


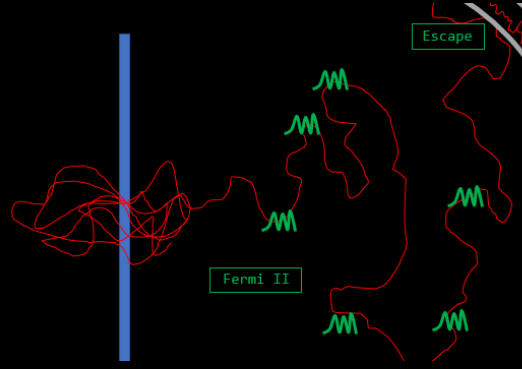
(Vieu et al. in prep.)

Selected results: Average escape spectra

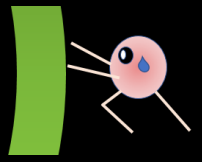


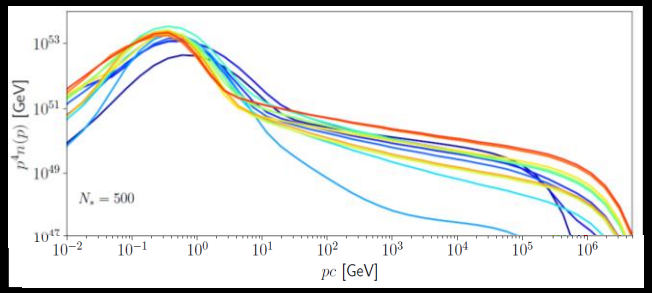
Summary



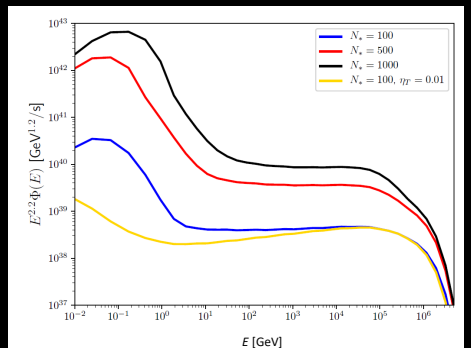


- Dynamical superbubble modelling including winds, SNR, turbulence
- Reacceleration => efficient energy transfer between stars and CR
- Nonlinear CR feedback must be taken into account





- 3 spectral regimes
- Steep escaping spectra ($E^{-2.2}$)



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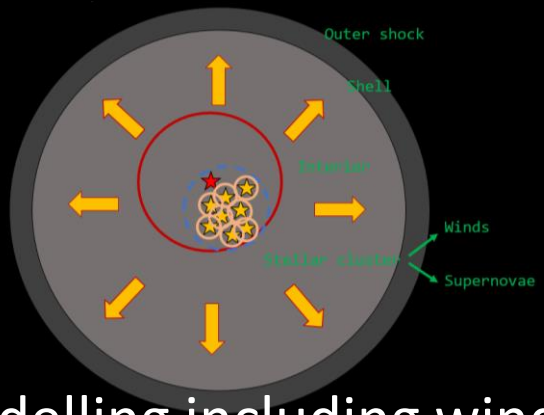

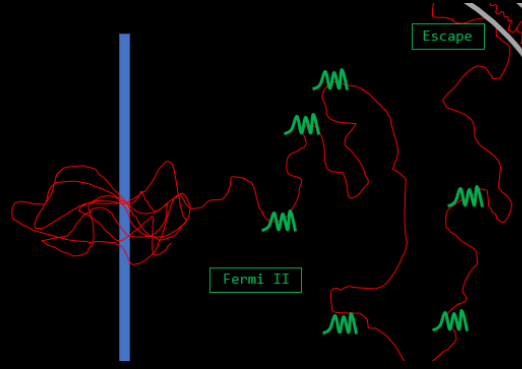

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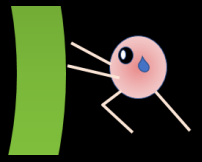

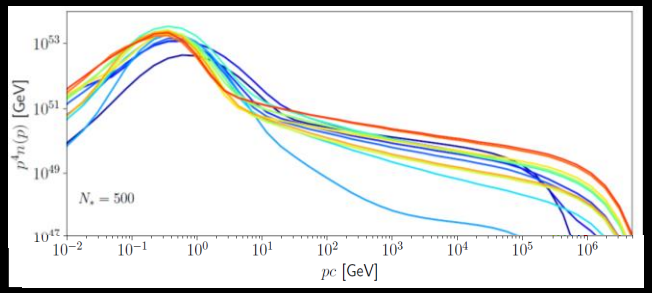

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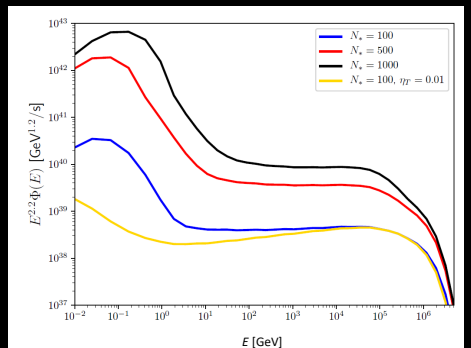

Thank you!