What to expect from cosmic accelerators

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Introduction

Below 10^{20} eV, cosmic rays loose memory
of their point of origin,
but not of the chemistry at their origin

Can we fully model the composition changes
during propagation and inside the sources

to pinpoint cosmic-ray sources?

Introduction

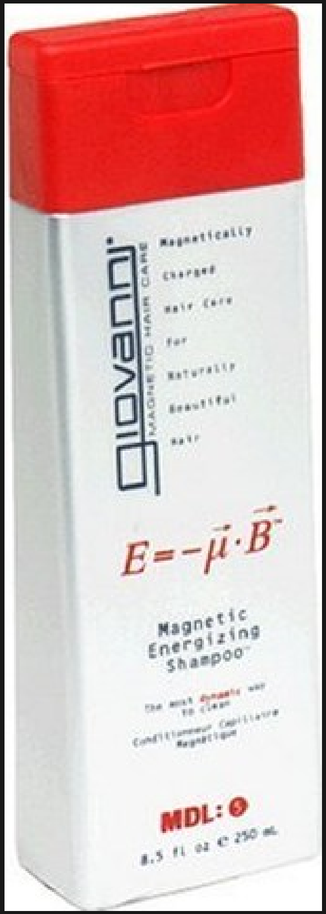
Fairly good calculations are available for propagation

So there remains the acceleration efficiency

and the escape problem.

Introduction

It‘s the magnetic field, stupid!



Escape

We need to get particles out of the sources

a) Diffusive escape

$$R = \frac{p}{q} \propto \sqrt{\gamma^2 - 1}\ A/Z$$

Standard rigidity dependence

In-source spallation and dissociation (e.g. Fang et al.)

Need to know the geometry

Need spatial transport in the model

b) Neutron escape

Works for protons only

Acceleration

Acceleration should also scale with rigidity,

But …

1. What is the composition of the environment?
2. What is the Z-dependence of the injection efficiency?
3. Is there VIP treatment for heavy elements during acceleration?

Environment

ISM composition:

AGN, GRB afterglow phase,

SNR forward shock in normal galaxy

Heavy composition

SNR reverse shocks, starbursters, SNOBs

GRB prompt phase? Neutron stars?

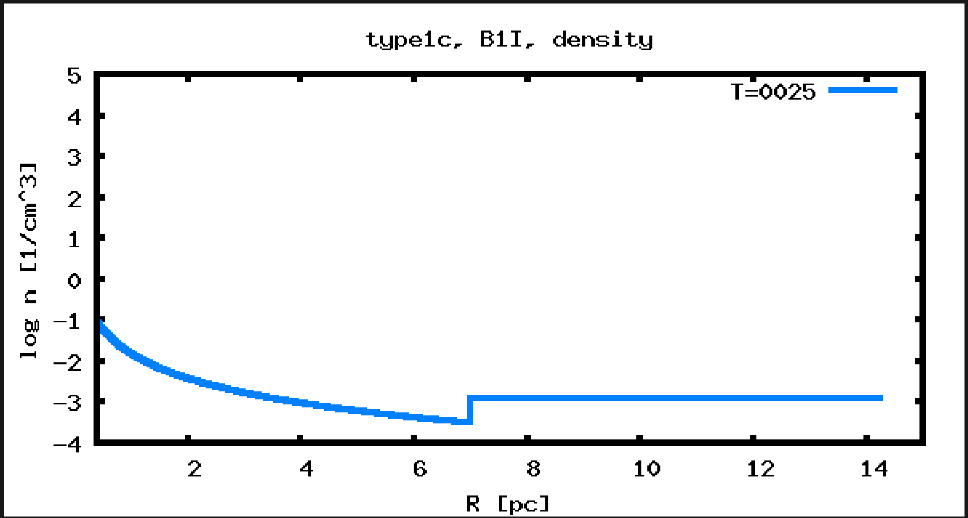
Environment

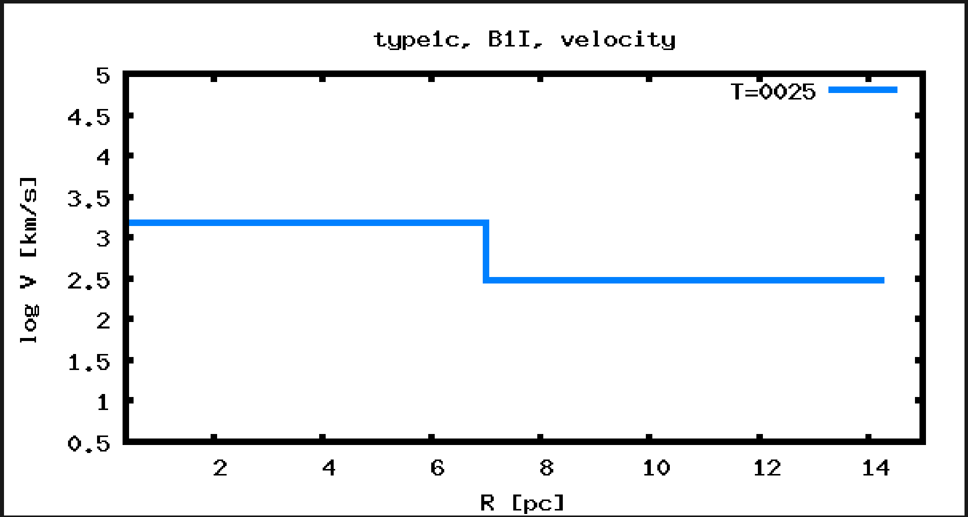
Type-Ic SNR

Wolf-Rayet progenitor

Forward shock,
normal composition

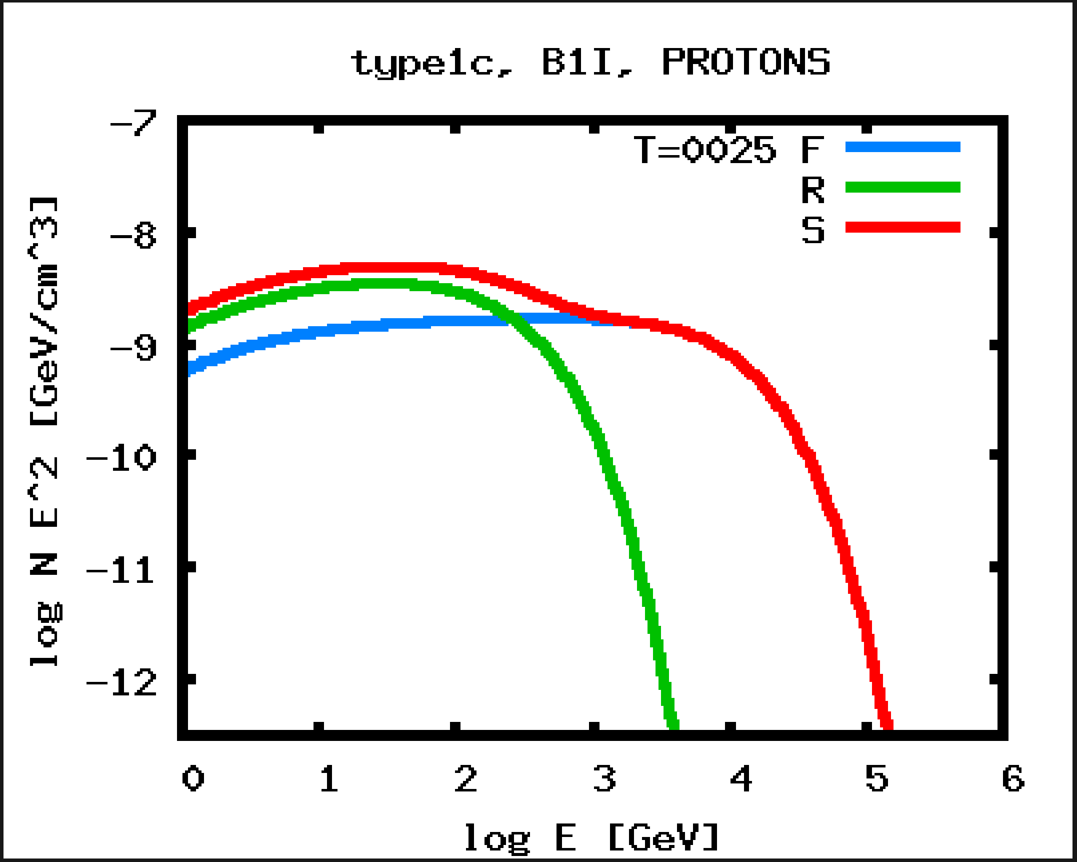
Reverse shock:
Ejecta,
heavy composition





Environment

Interplay of injection and acceleration rate



Telezhinsky et al. (2013)

Injection (for DSA)

Produce power law in rigidity

$$Q = q_o\, R^{-s} \qquad R > R_0$$

Total number of particles

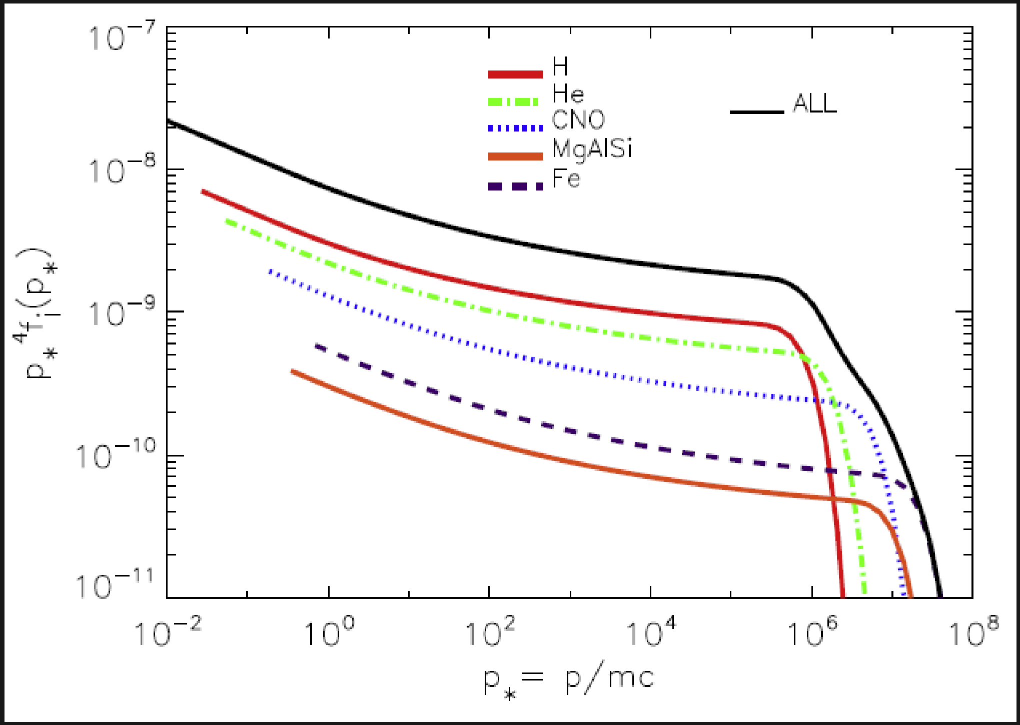
$$N = \frac{q_0}{s-1} {R_0}^{1-s}$$

Flux at high total energy, E=cZR

$$F(E) \propto N(cZR_0)^{s-1} E^{-s}$$

Injection (for DSA)

Example: Caprioli et al. (2011)



R_0=const. is assumed

Abundance pattern is assumed

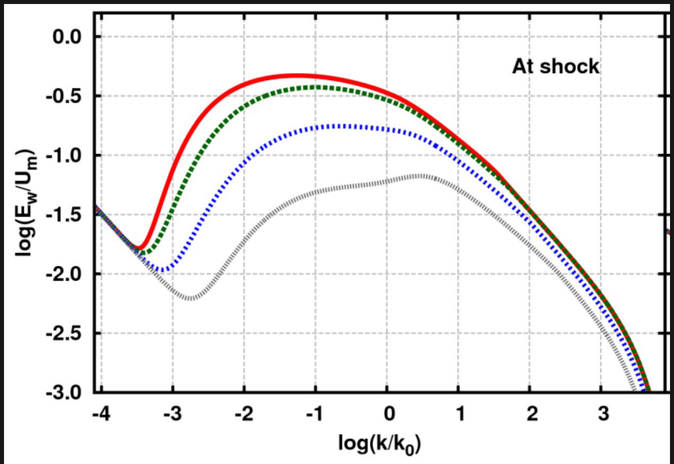
Includes nonlinear corrections to acceleration

Injection (for DSA)

Stronger non-linearity than by cosmic-ray feedback

New: Models with temporally and spatially evolving turbulence?

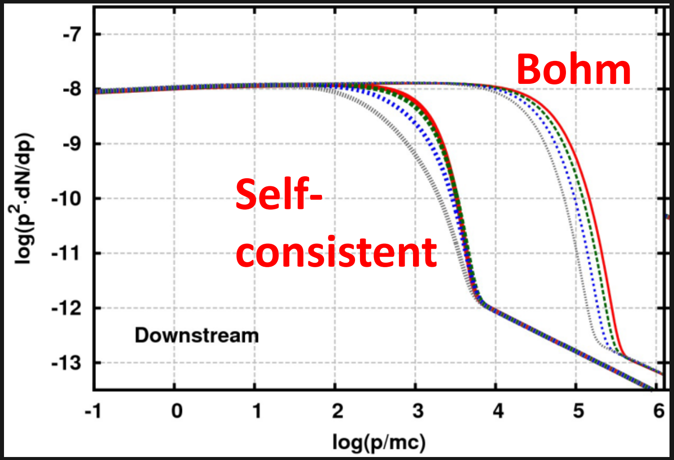
Transport equation covering growth, damping, cascading, advection, …



Power spectrum of turbulence

Type Ia
Sedov phase

No steady state!



Particle spectrum

Injection

Consider cosmic-ray isotope ratios

Large deviations from solar-system ratios (Binns et al. 2007)

for $^{22}Ne/^{20}Ne$ and $^{58}Fe/^{56}Fe$

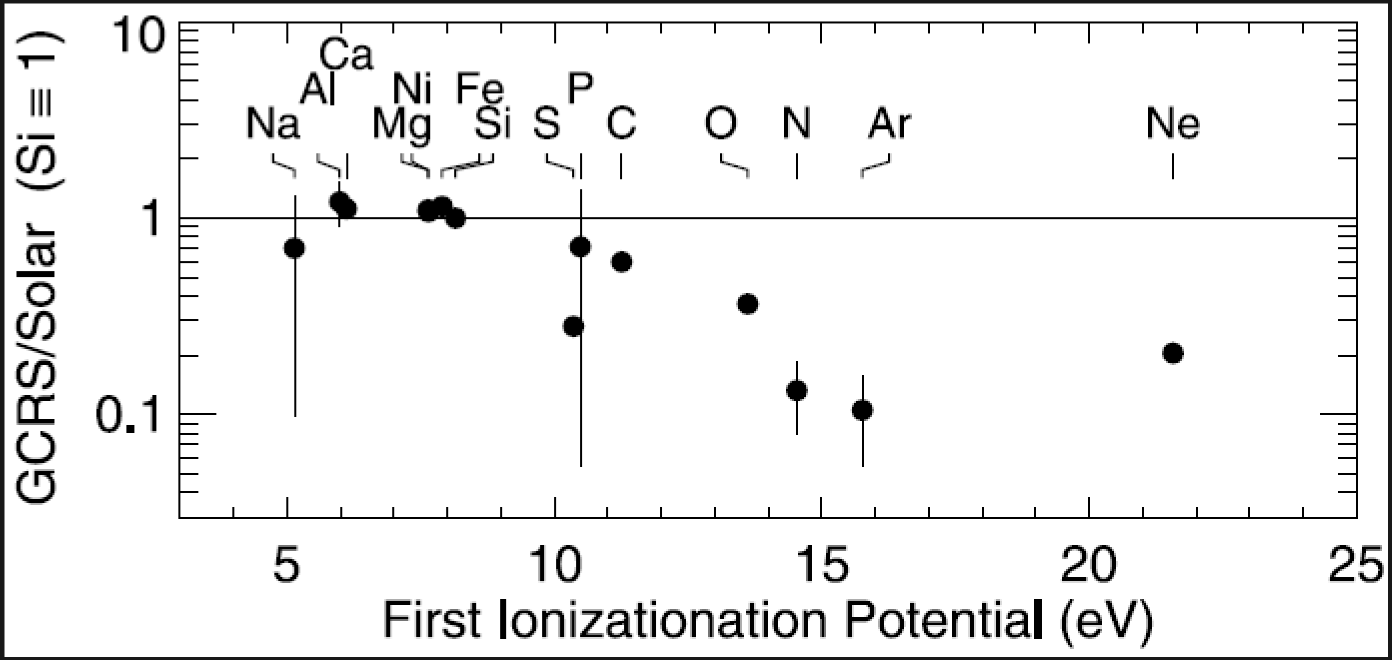
but similar to Wolf-Rayet models → OB associations?

Reverse-shock action or local enrichment?

Injection

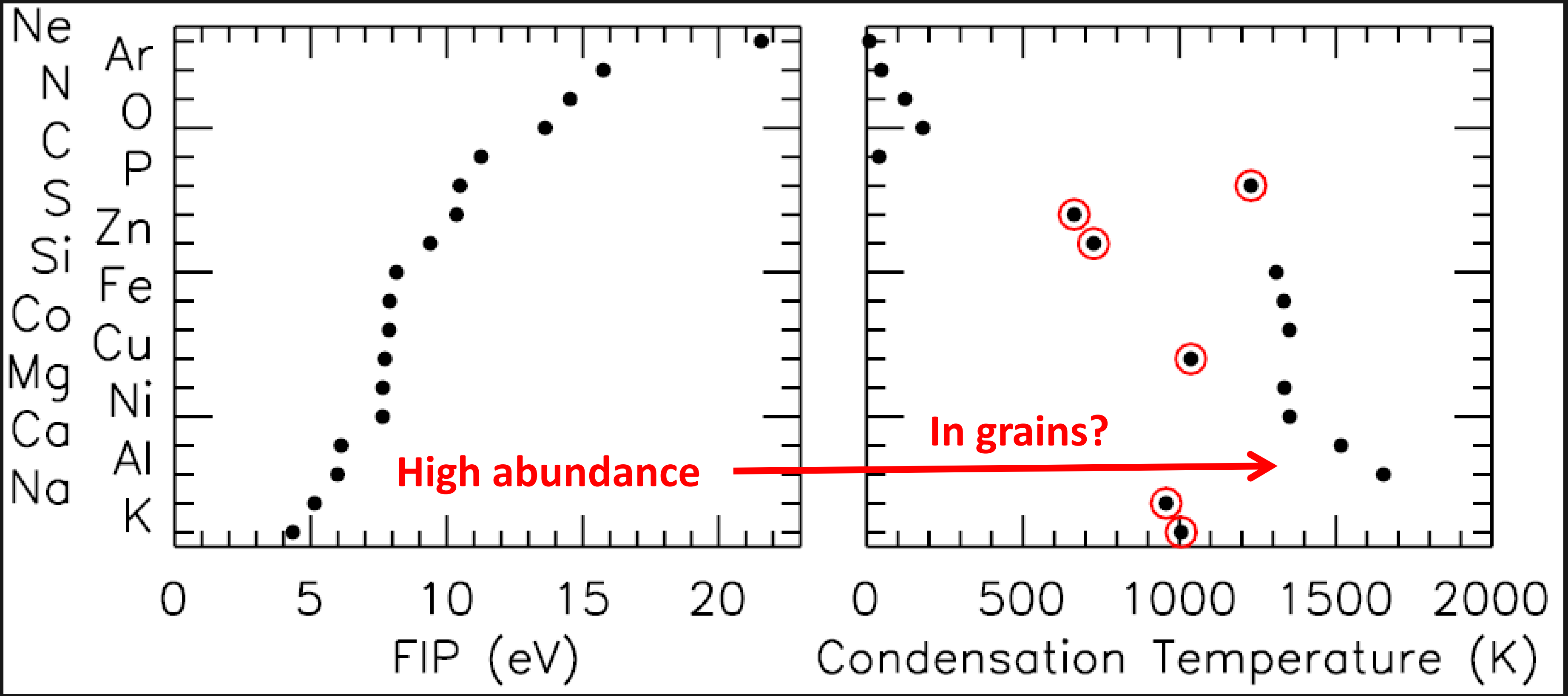
Elemental abundances at GCR sources

thought to correlated with first ionization potential



Injection

Possibly better correlation with volatility (Meyer et al. 1997)



Injection

Injection of grains and subsequent sputtering?

Pro:

Larmor radius is large → Easy injection

Con:

Larmor radius is large → Slow acceleration

Conclusion

Predicting the source composition is extremely difficult

… but we haven‘t tried very hard.

Many aspects are tied to details of
source structure and acceleration process,
and can be modeled in parallel.

Location and injection play the dominant role.