Particles Acceleration in Converged Shocks

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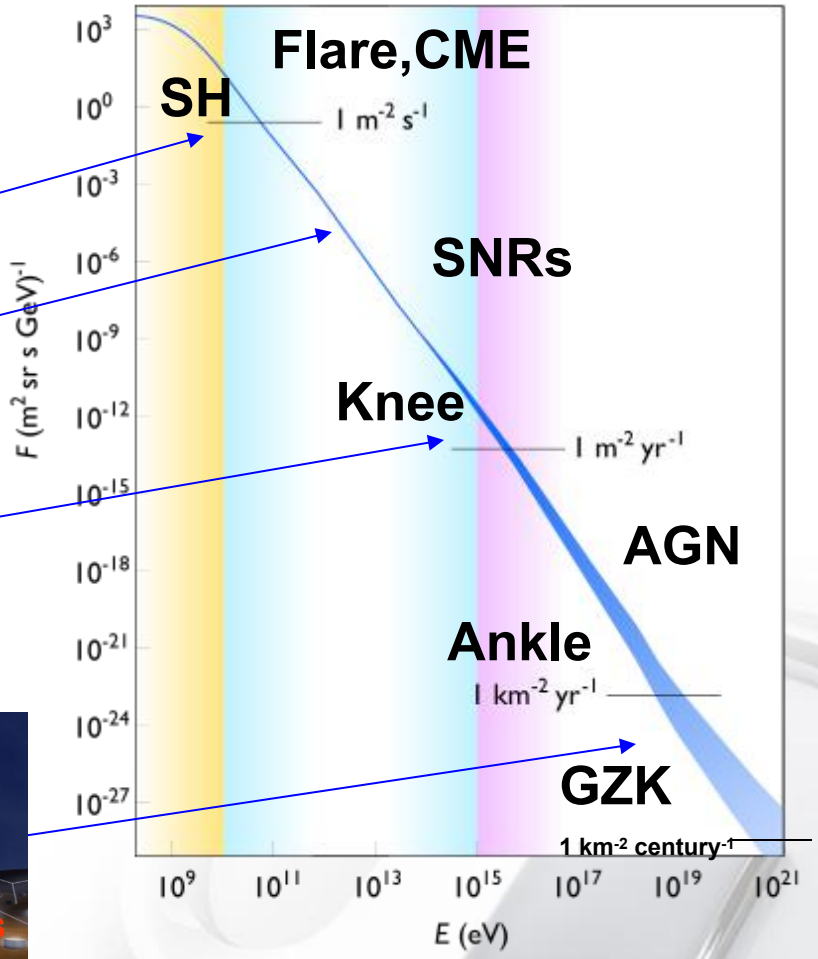
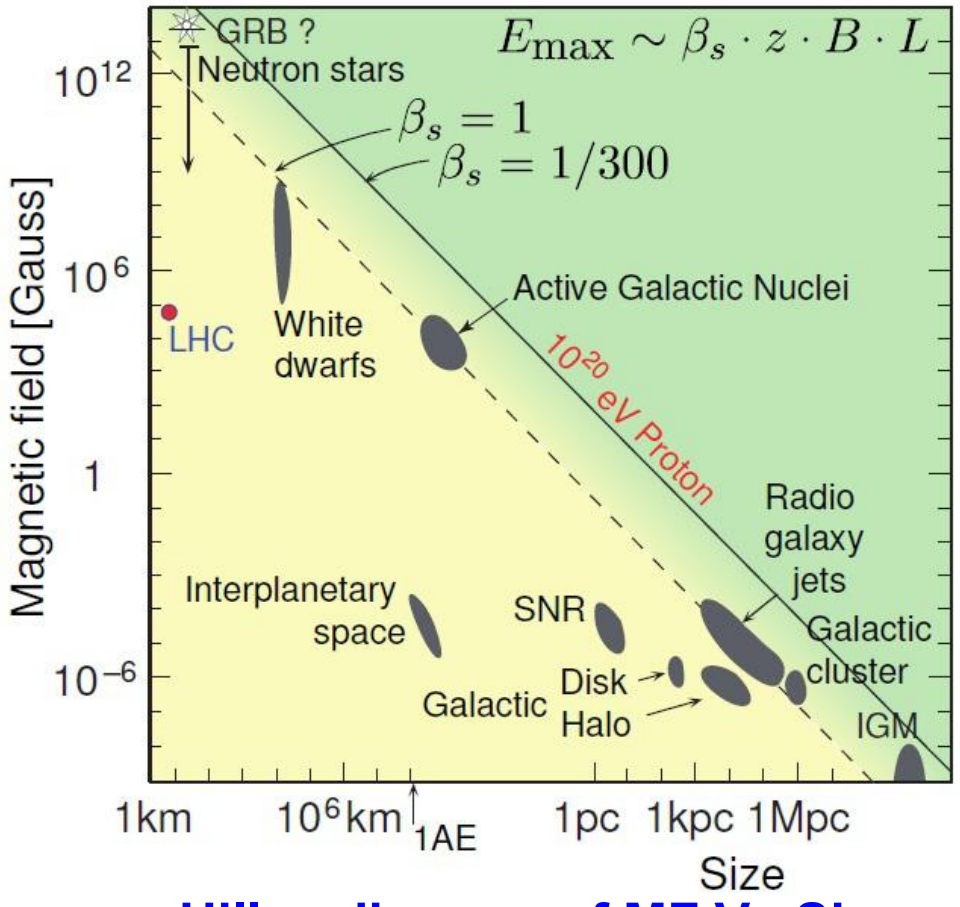
Observations of Cosmic rays



Cosmic Ray Theory

- CR Origin
- Composition
- Propagation
- Acceleration

DSA (1980's)

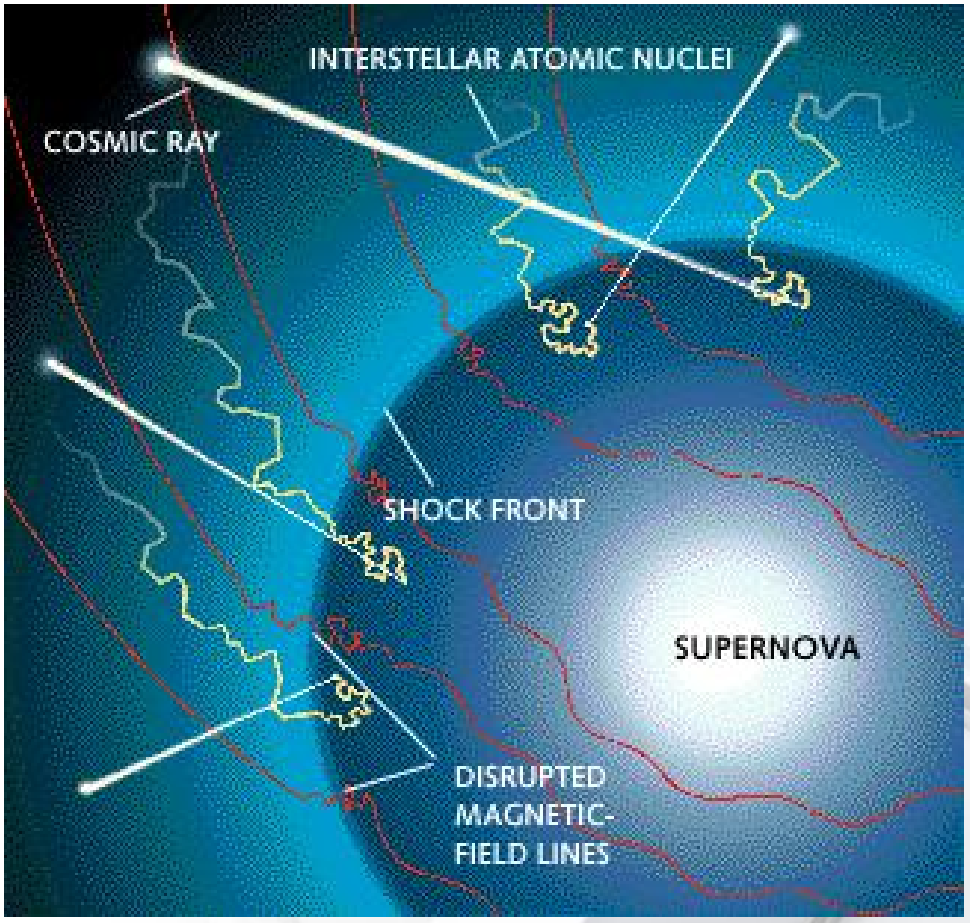


Hillas diagram of MF Vs Size

(Olinto,2011)

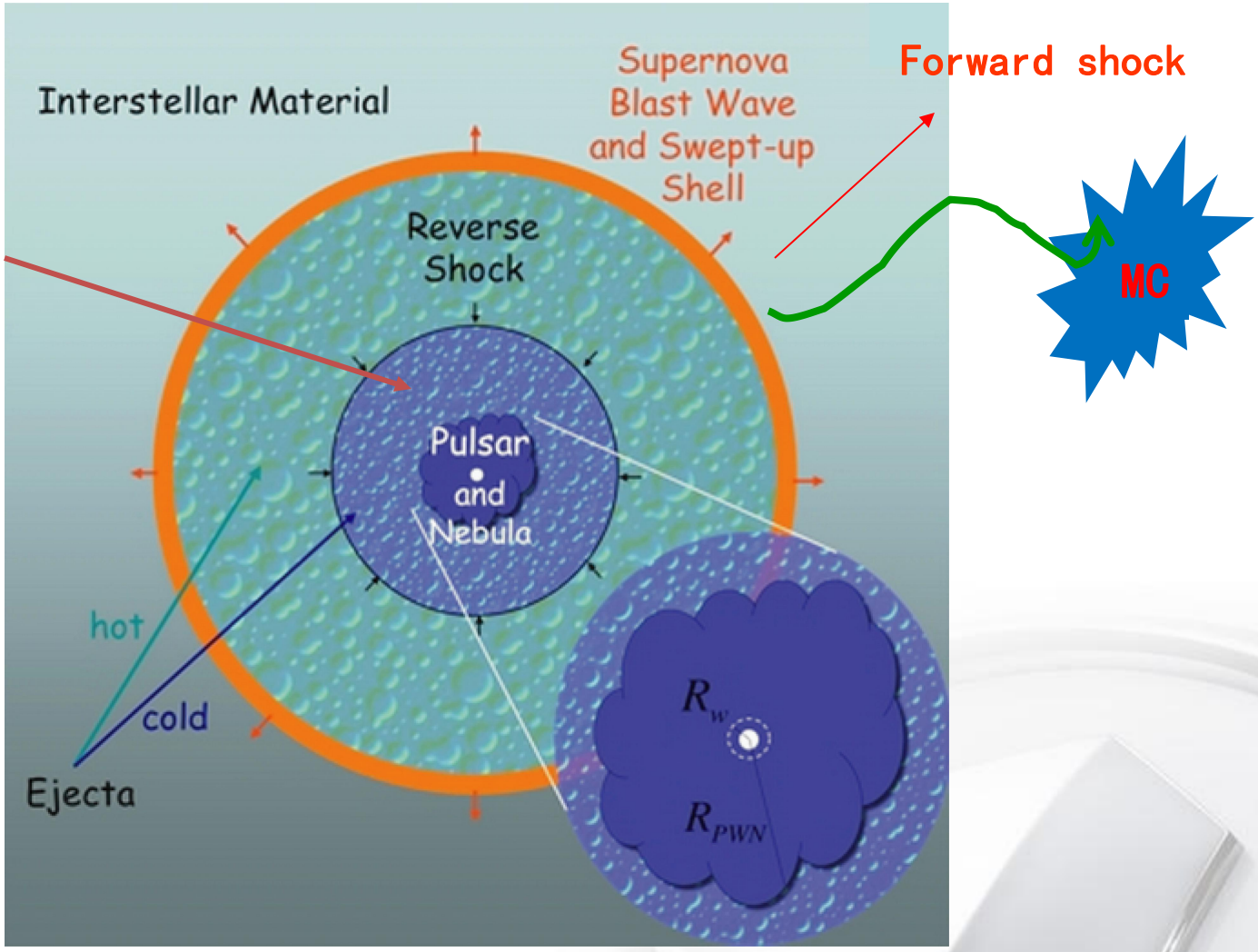
SNR Shock

- Pinpointing a direct source is impossible
- Individual CR move along random paths in the turbulent magnetic fields.
- Indirect methods indicate that most CR < 3×10^{15} eV are from shock waves driven by SNR explosions.



SNR 1006 – Chandra

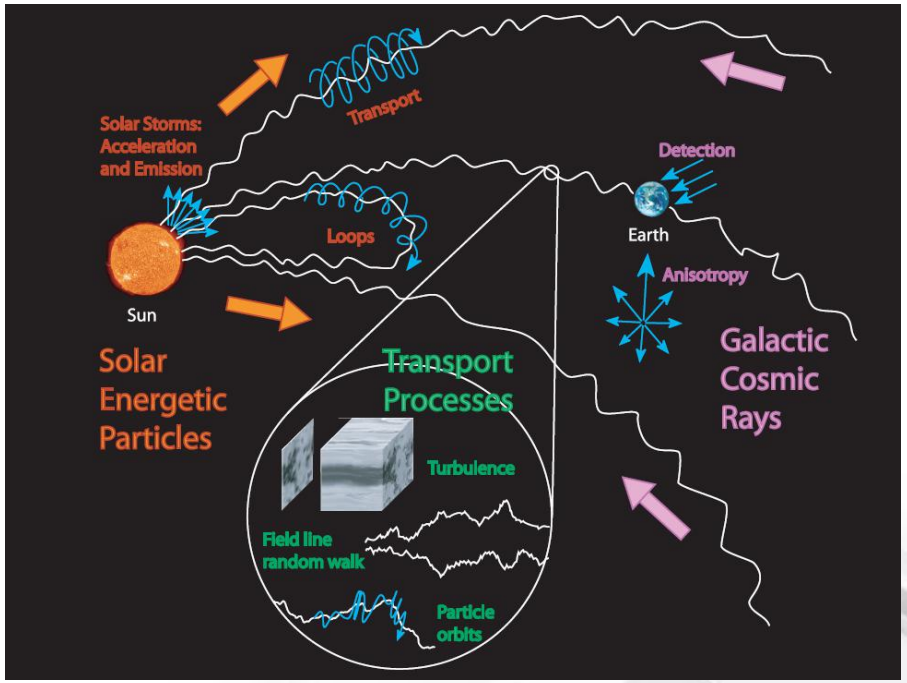
WPNE Shock



G21.5-0.9, Metheson+, 2005

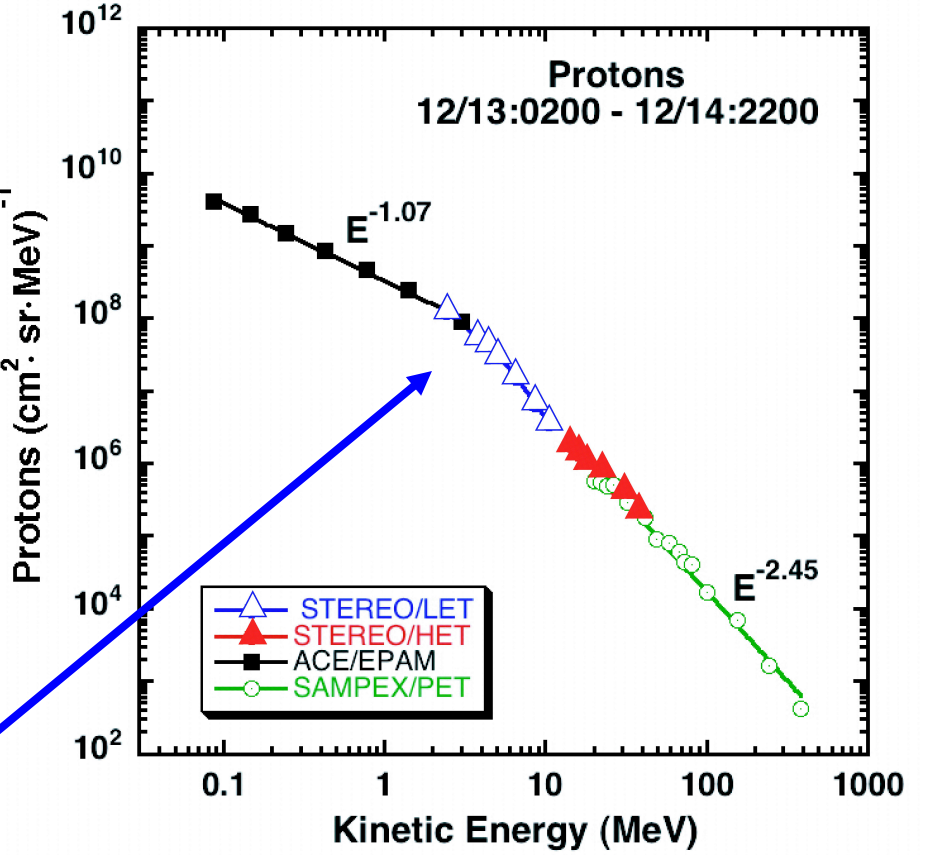
Interplanetary Shock

- Manetic field turbulence provide the site for particles diffusion processes in the interplanetary shock.
- Diffusive shock acceleration (DSA) can be applicated in CME-driven shock.



Obs: Energy Spectral ``Break'' (I)

1. Heliosphere
2. Break
3. CME
4. LHAASO?

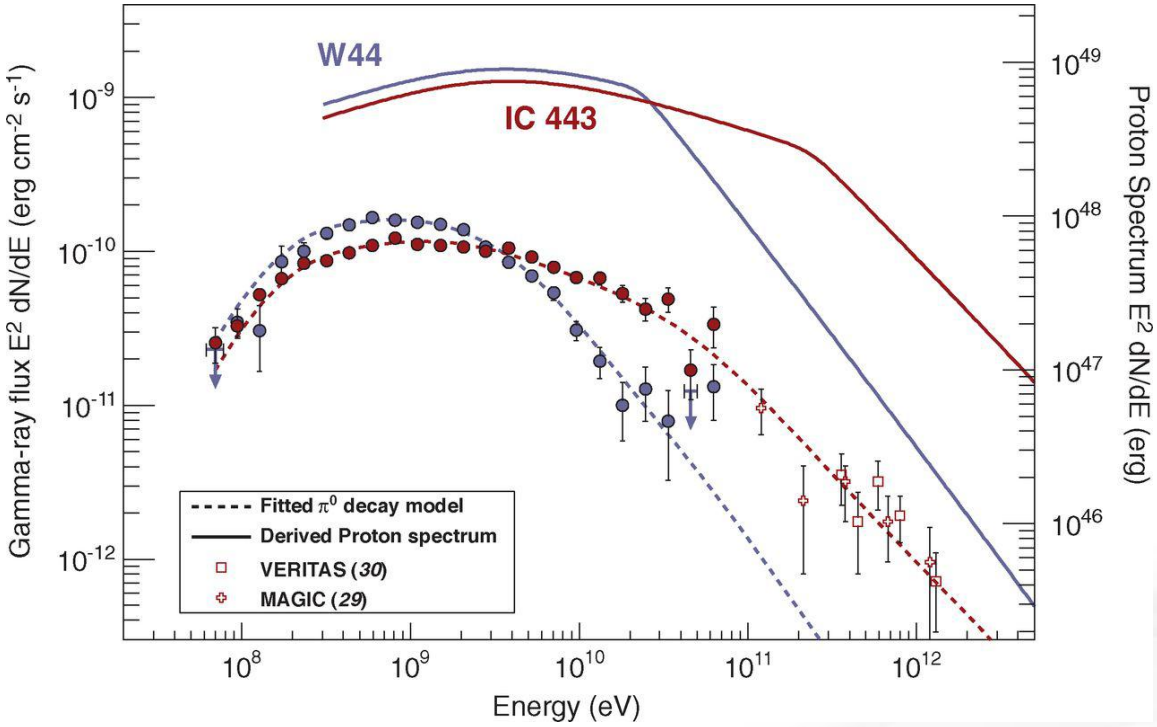


2006-DEC-13 SEP

Break (1-10MeV)

Mewaldt, et al. ICRC,2008

Obs:Energy Spectral ``Break'' (II)



SNR: IC443 & W44, Ebr =250MeV for gamma-ray, Sci. Ackermann et al. (2013)

Previous Studies: Single Shock Model

1, The dynamical shock structures, AA, Wang et al, 2011

2, Injection rate, ApJS, Wang et al, 2013

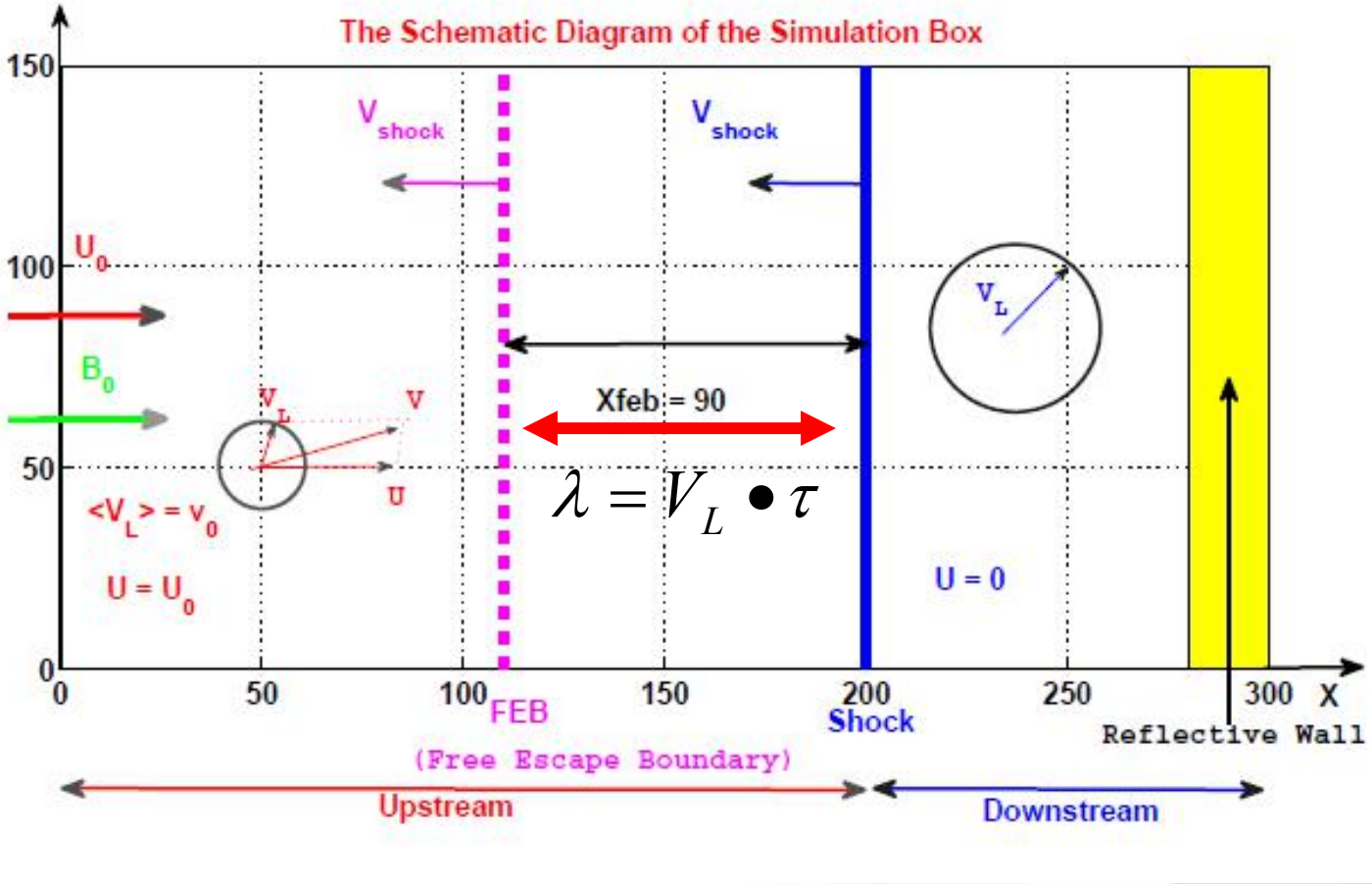
3, CME-driven shock, RAA, Wang et al, 2012

4, E_{max} in CME shock, RAA, Wang, et al, 2016

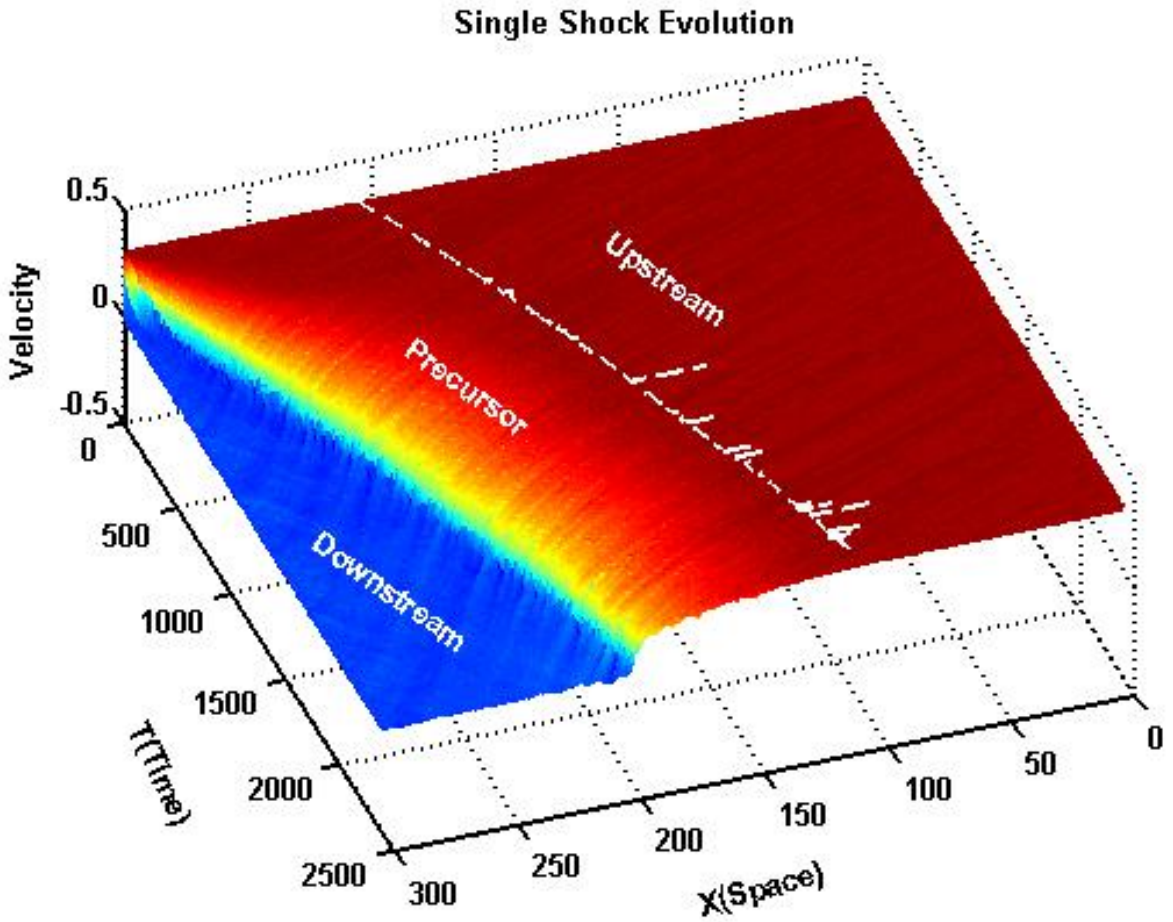
Present work: Double Shocks Model

5, Energy spectral ``break'' in converged two shocks, ApJ, submittted, Wang, et al, 2016

1，Single Shock Model

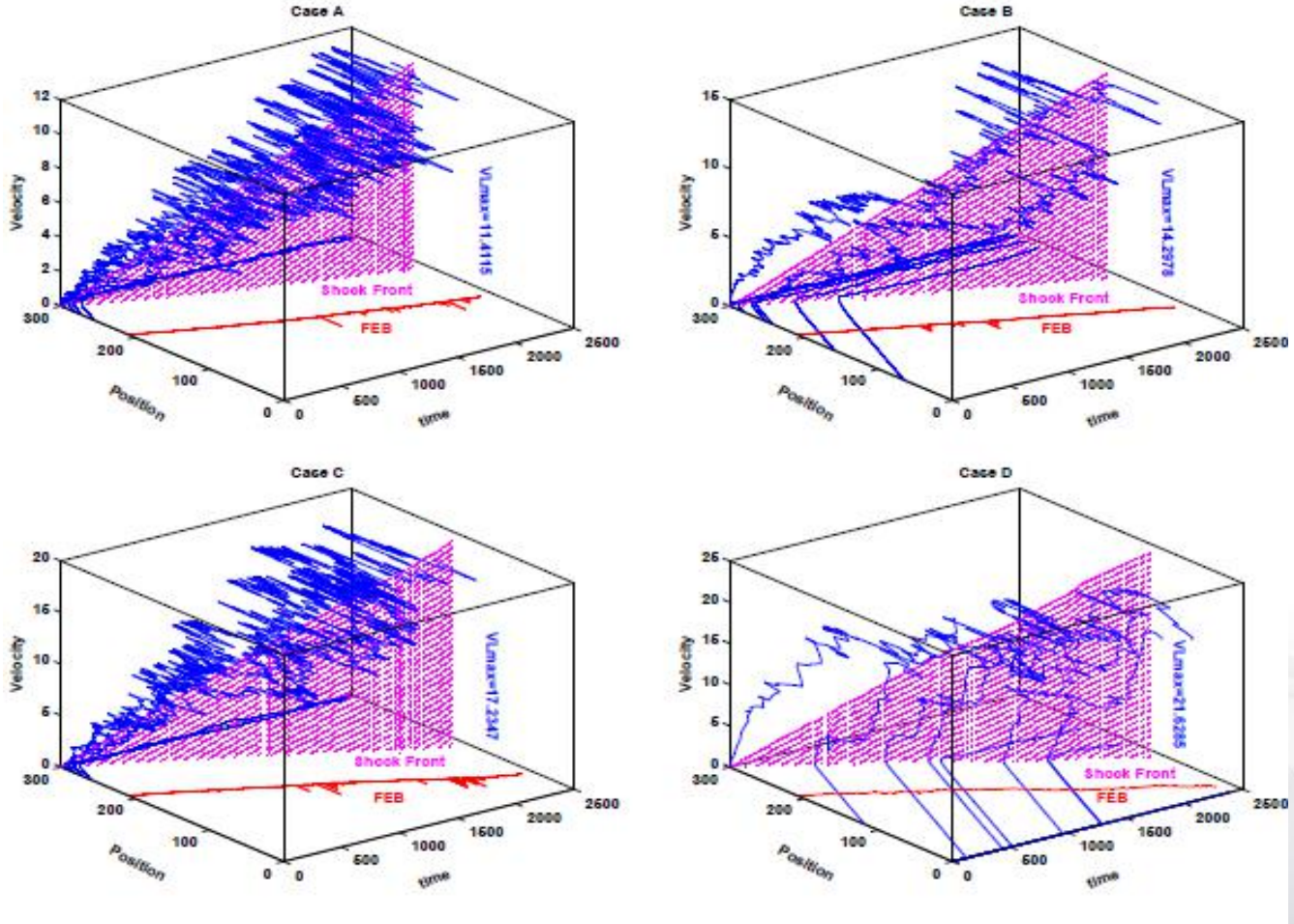


a, Shock Evolution



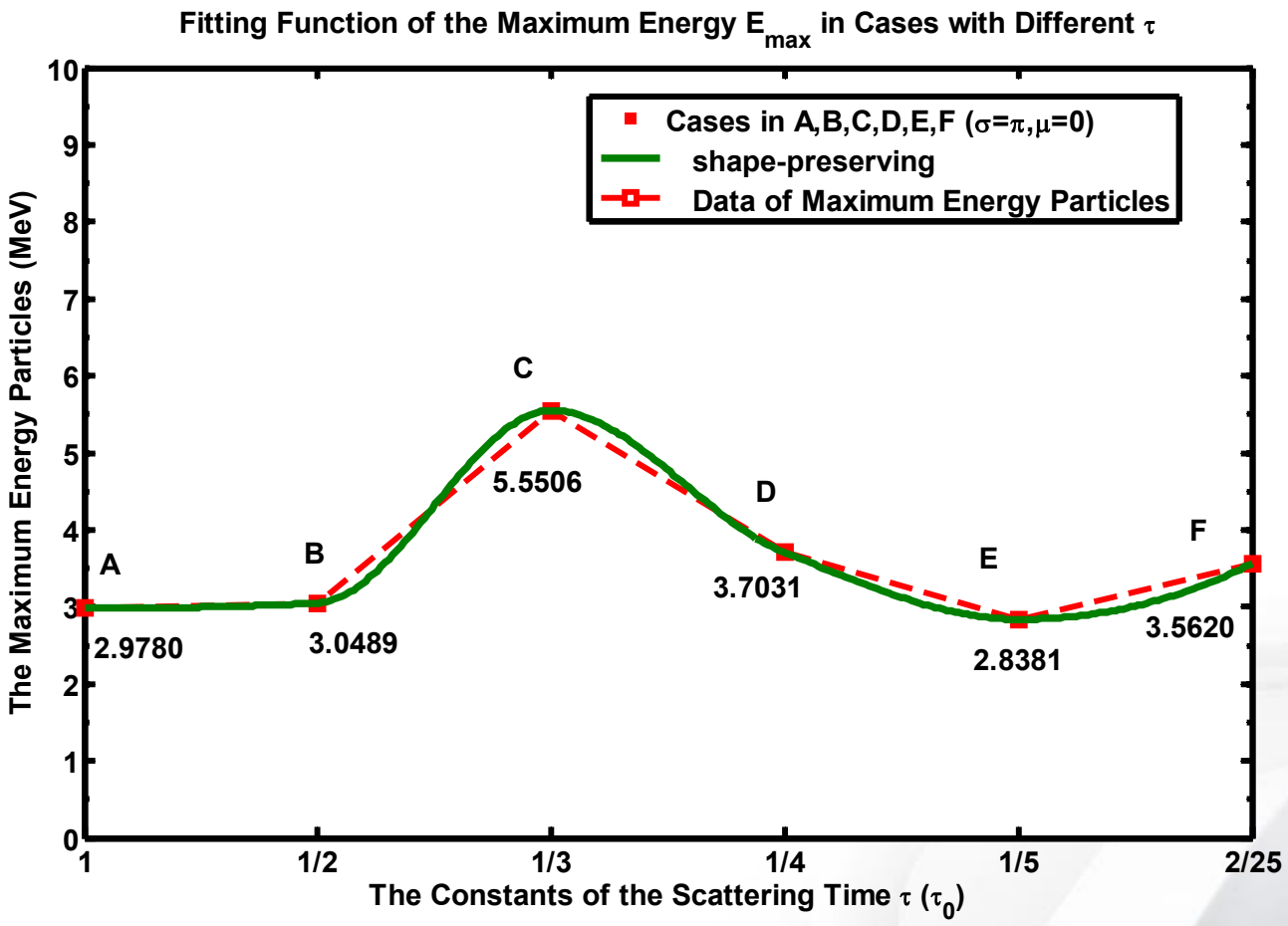
(Wang+, ApJS, 2013)

b, Particle Injection & Acceleration



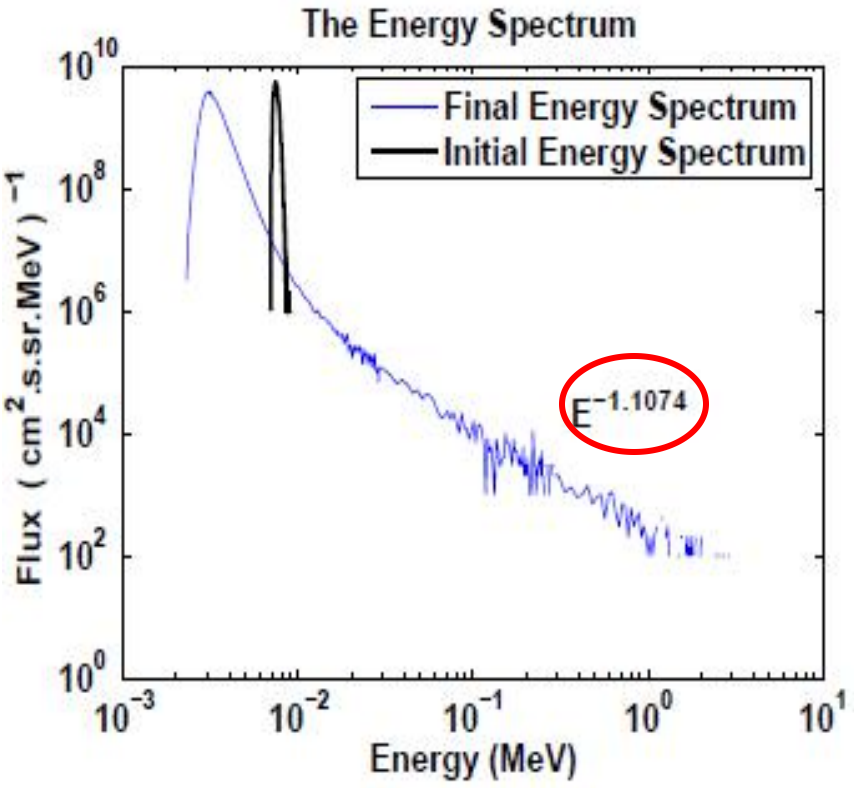
Injection rate (Rinj from 3%~10%)

c, Saturation of E_{max}

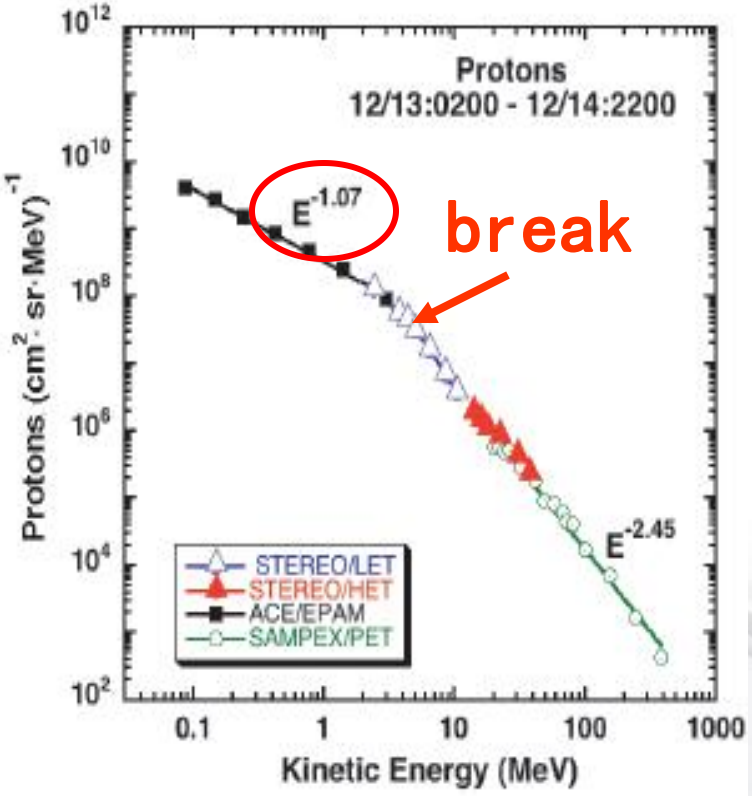


（Wang+, ICRC, 2013）

d, Energy spectral ``cut-off"

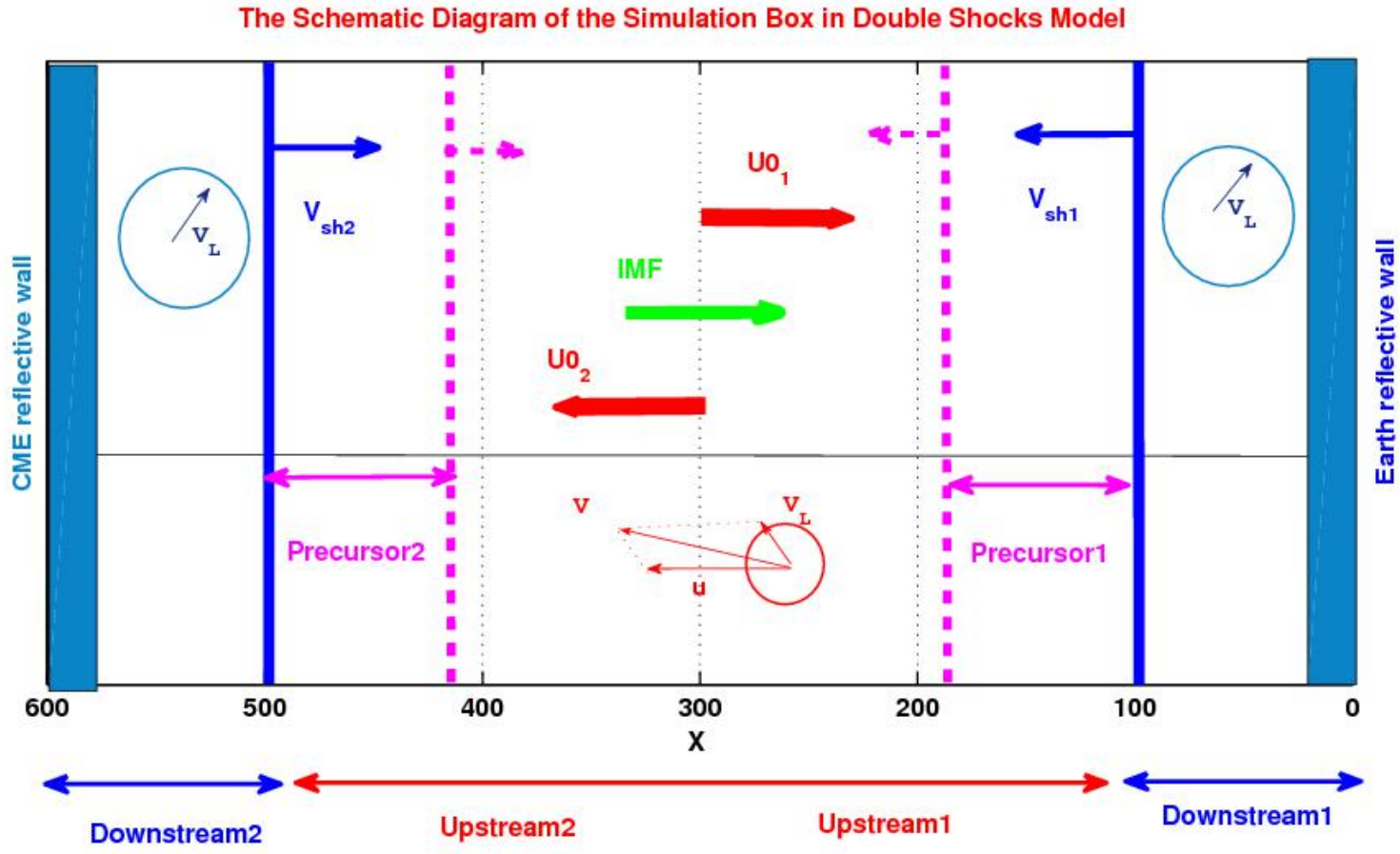


Simulated results
(Wang+, RAA,2012）

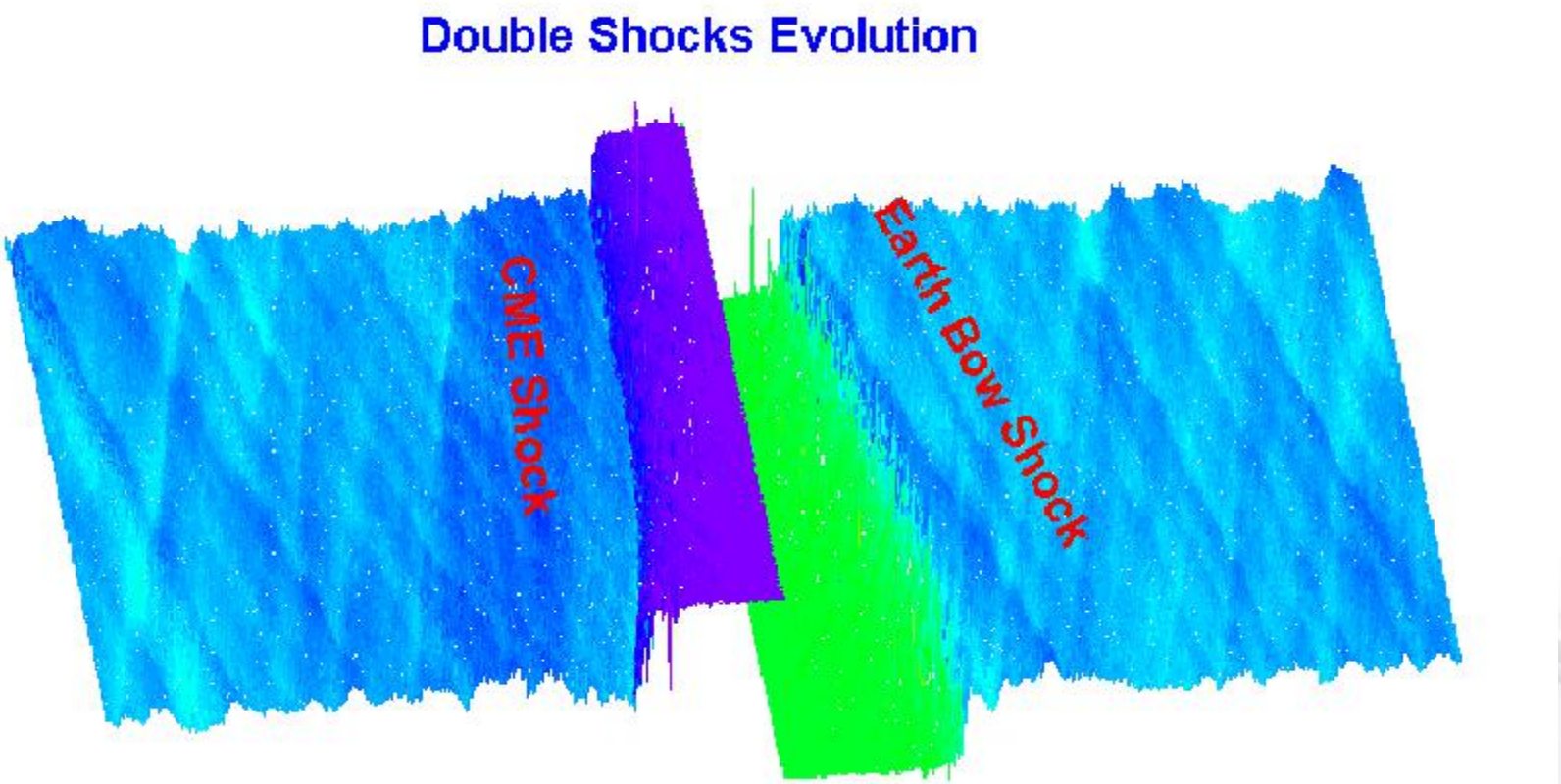


Observed results
Mewaldt+, (2008）

2，Double Shocks Model

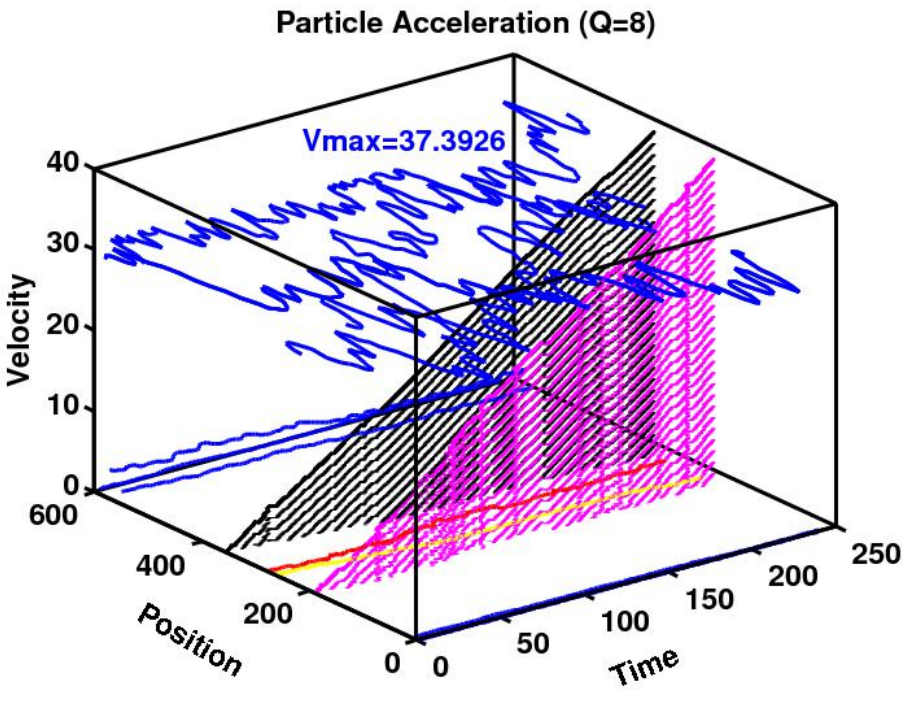


a, Double Shocks Evolution



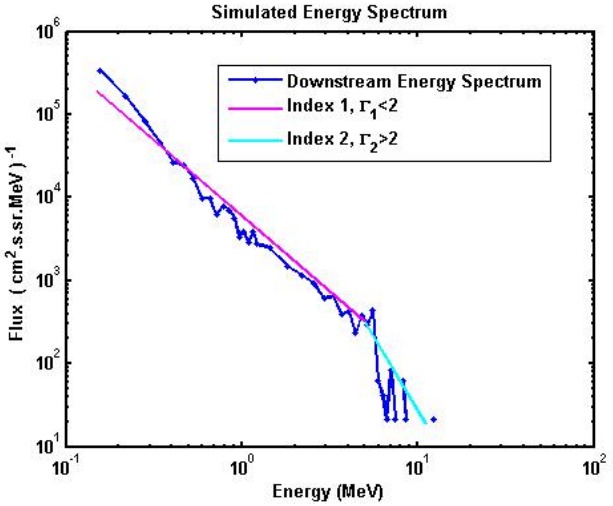
b, Particle Acceleration on Double Shocks

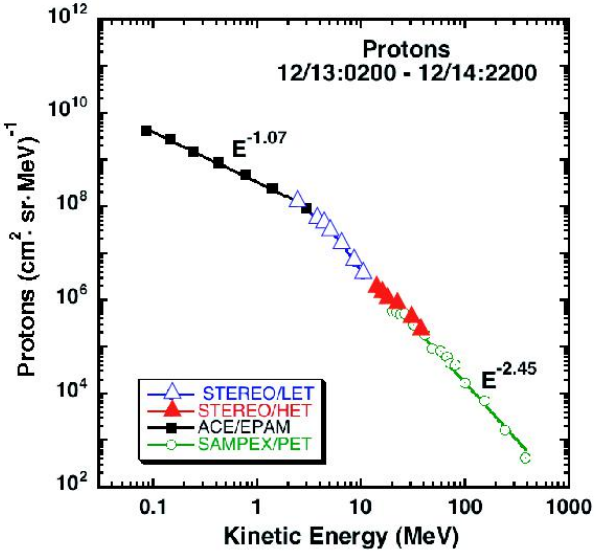
We propose the double shocks model: CME shock interacts with the bow shock. Particles obtain the acceleration on the double shock fronts, which can provide more energy gains than single shock.



c, Comparison of Energy Spectra

Comparing the simulated results of the 2006 Dec 13 events with the observations, we find the consistent enenrgy spectral ``break'' at near 5MeV.





Conclusions

- **Obtained E_{max}>10MeV**
- **Find a ``break'' at 5MeV**
- **Verified the SNR-MC system!**

Discussions

- **Magnetic field generation:**
- **Weibel instability, Alfven instability (DSA).**
- **Non-resonant hybrid (NRH) instability(Bell 2004).**
- **Long scalelength instability (Bykov 2011).**

- **Modification:**
- **Probably, apply NRH to obtain higher energy tail up to 1GeV, which would be well consistent with the observations.**

Collaboration with LHAASO

- **CME shadow Obs vs Simulation**
- **SNR-MC system Obs vs Simulation**
- **IMF Obs vs Simulation**

Thanks !