Evidence for GeV Cosmic Rays from White Dwarfs in the Local Cosmic Ray Spectra and in the Gamma-ray Emissivity of the Inner Galaxy

T. KAMAE, S.-H. LEE, K. MAKISHIMA, S. SHIBATA, and T. SHIGEYAMA

Input Data

- Hard X-ray obs → electrons to ~10-100 GeV in magnetic white dwarfs (WDs) → local el CR
- GeV γ-ray obs → protons to >100 GeV in novae (WDs) → local baryon CR
- Galactic g-ray obs → Glactic electron (brems) and proton (neutral pion decay) CR spectra

Assumptions

- CR at heliopause = Σ Galaxy (Galactic) + historic WD contri accumulated in loc bubble (local)
- All baryonic CRs from have one common spectrum
- All baryonic Galactic CRs approach single PL spectra for E > ~300-400GeV

Analysis Procedure

- Fit HE CR data and Voyager-1 data with polynomial regression of degree 6

Results

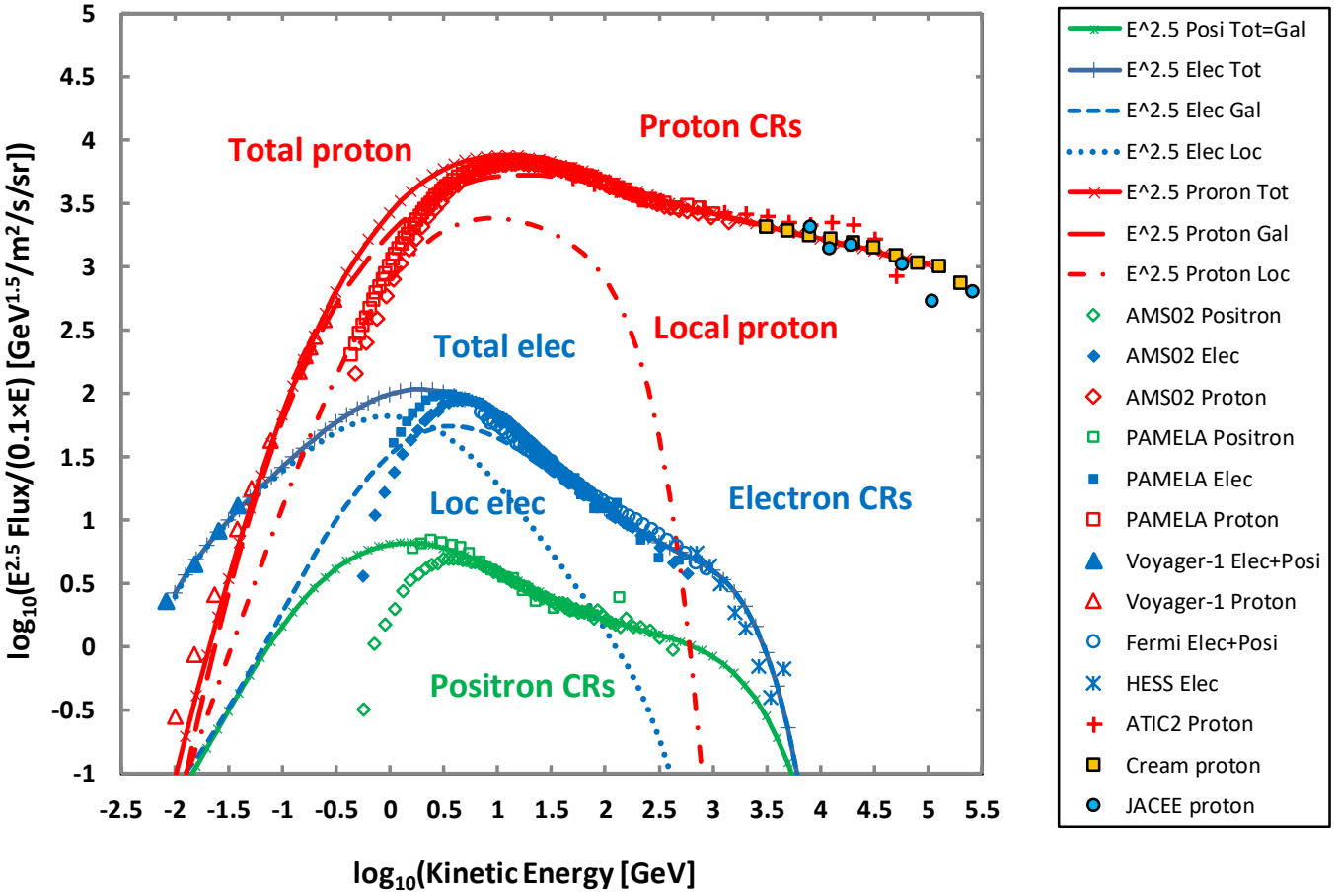
- Hardening of nuclear CRs = roll-down of soft loc CR from WDs ~300 GeV/n.
- WD contri make a "GeV-hump" in γ-ray emissivity e.g. in the inner Galaxy.

Total CR spectra for electrons and protons

The two sets of CR spectra:
=> polynomial formulae

Refitted again so that
the sum (total) will reproduce
the HE spectra and
Voyager-1 data

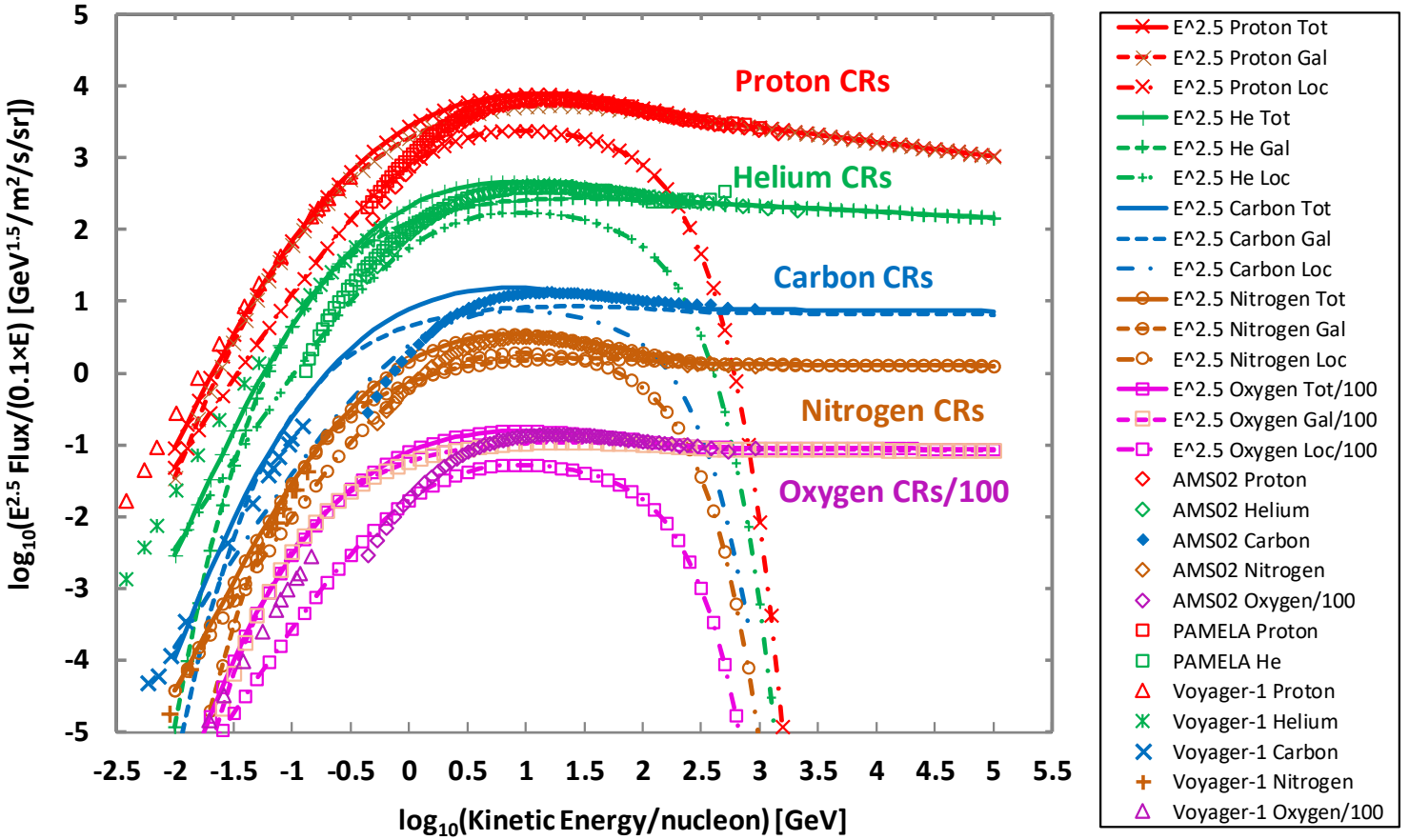
Note: Local proton and nuclear CR spectra show sharp drop-off or cut-off



Extension to nuclear CR spectra

Total, Galactic and local nuclear CR spectra shown with observed data.
Note that the spectra for Oxygen are scale down to 1/100

Note:
One common spectral shape for local proton and nuclear CRs



Conclusions

- **"Hardening" in nuclear CR spectra** is due to drop-off of CR spectra from WDs at E ~ 300GeV/n below harder Galactic CRs spectrum
  - **Common cooling mechanism** as proposed by Geng, Zhang, & Huang (2016) for el in mag WDs and by Vurm and Metzger (2016) for protons and nuclei in novae?

- **GeV humps in γ-ray spectra** due to interaction of low energy CRs from WDs with ISM
  - A hump is seen in the diffuse γ-ray spectrum from **the inner Galaxy (R < 1.5 kpc)**
    => high flux of low energy CRs injected from WDs in the region
    See Yuasa, Makishima, & Nakazawa (2012)

- The local electron CR flux $\approx$ the local proton CR flux when integrated over the spectra
  $\Rightarrow$ **electron/proton ratio is about two orders of magnitude higher** than in supernova remnants
  $\Rightarrow$ Magnetic induction is accelerating electrons to overcome the Coulomb barrier?

- Energy densities of the local electron and proton CRs ~10^{-3} eV/cc and ~10^{-2} eV/cc, respectively.