Cosmic Ray Science Interest Group
status report
Co-Chairs: Igor Moskalenko and Jim Beatty

AMS-02
JEM:
ISS-CREAM
CALET

Jan 8, 2018
ISS constellation

- Alpha Magnetic Spectrometer (AMS-02), launched on May 19, 2011
  - Cosmic ray species: elements H-Fe, electrons, positrons, antiprotons
  - Energy range: $\sim 0.5 \text{ GeV} - >1 \text{ TeV}$

- Calorimetric Electron Telescope (CALET), launched in August 2015
  - Cosmic ray species: elements Z=1-40 (Zr), all-electrons
  - Rigidity range: $\sim 10 \text{ GV} - 800 \text{ TV}$

- ISS-CREAM, launched on August 14, 2017 (mostly US mission)
  - Cosmic ray species: elements Z=1-26, all-electrons
  - Energy range: $\sim 1 \text{ TeV} - >1 \text{ PeV}$
Low energies (current US missions)

• Provide separation of individual isotopes, excellent instruments, but fairly old (ACE – 20 y.o., V1,2 – 40 y.o. !)

• Voyager 1, 2 – first heliospheric boundary/interstellar probe
  • Launched in August 1977
  • Isotopes Z=1-28, all electrons
  • Energy range: ~1 MeV/n – 200-500 MeV/n

• Advanced Composition Explorer/Cosmic Ray Isotope Spectrometer (ACE/CRIS)
  • Launched on August 25, 1997
  • Isotopes Z=28
  • Energy range 100 – 500 MeV/n
Recent scientific highlights

- Flat all-electron spectrum with sharp cutoff at ~1 TeV
- Rising positron fraction
- Flat antiproton/proton ratio
- Breaks in p, He, Li, Be, B, C, N, O spectra at the same rigidity ~300 GV (and perhaps in heavier nuclei)
- Smooth falling B/C ratio up to 2 TV
- Primary $^{60}$Fe in cosmic rays (excess in $^{22}$Ne/$^{20}$Ne ratio)
- Puzzling A-dependences of volatile and refractory elements
- All of them sparked hot discussions in the literature
- Below are few examples from 2017
All-electron CR spectrum

- New LAT spectrum is ~10-30% higher at LE than the old one.
- Good agreement with AMS-02 data, but there is still a 1-2σ discrepancy at HE.

Geomagnetic cutoff correction + more precise simulation/selection

Break at $53 \pm 8$ GeV, index $-3.21 \pm 0.02 / 3.07 \pm 0.02$
Direct measurements of all-electron spectrum up to 5 TeV

- CALET & DAMPE are confirming the cutoff at ~1 TeV

Different behavior >100 GeV

Hint at a spectral feature at 700-800 GeV?

Clearly seen 2-3 components in the CRE spectrum (local sources?)

Hint for a long-awaited feature at a few TeV?
Breaks in C, N, O

- Breaks in C, N, O found at the same rigidity as earlier in p, He
- Surprisingly similar spectral shape of ‘primary’ nuclei!

AMS-02
Golden age of astrophysics of cosmic rays

• Cosmic ray missions provided many breakthroughs and discoveries over the last decade
• We are not done yet!
• Hot discussions in the literature, but it is clear that some local sources are influencing CR fluxes in the neighborhood of the Solar system
• Combined effort of astrophysicists and particle physicists around the globe, but the US scientists are missing this once-in-a-lifetime discovery hunt!
• Still missing:
  • Heavy elements/isotopes through Th/U at low and high energies (probes of local sources, explosive nucleosynthesis)
  • Measurements of radioactive species $^{10}\text{Be}$, $^{26}\text{Al}$, $^{36}\text{Cl}$, $^{54}\text{Mn}$ in the energy range 100 – 1000 MeV/n
  • Heavy calorimeters for PeV range
• So we have to participate!
• Precision, precision, precision! – the key to the new discoveries
BACKUP SLIDES
Asymptotically approaches a constant ~0.15 or drops?

Closely related to all electron spectrum and very puzzling positron excess

Fermi-LAT’12 (East-West effect)

Aguilar’13, Accardo’14

Asymptotically approaches a constant ~0.15 or drops?
• If excess positrons are produced in pulsars or DM decays why the $p/e^+$ ratio is flat?
• The flat $p/e^+$ ratio perhaps indicates a common origin of $p$ and $e^+$!
Some isotopes have anomalous abundances in CRs vs. Solar system
Excess in $^{22}\text{Ne}/^{20}\text{Ne}$ may indicate ~20% contribution from Wolf-Rayet winds (SN expansion in massive pre-SN stars winds)
Primary $^{60}\text{Fe}$!
ACE/CRIS: ~200 MeV/n
Puzzling A (Z?)-dependences

Super-TIGER, HEAO, CREAM

The elemental abundances are lining up forming puzzling A-dependencies of volatile and refractory elements when divided on 19% MSM + 81%SS mix

Look similar at low and very-high energies
“Discrepant hardening” breaks in p and He spectra

✧ First noticed in CREAM data, hints were present in earlier data

✧ Spectrum of He is flatter than spectrum of protons

✧ Perhaps similar breaks exist in spectra of heavier nuclei
PAMELA: definitive evidence of the breaks

- Breaks are at the same rigidity
- $p/\text{He}$ ratio is smooth
- Points to the same origin of the breaks
B/C ratio

- Contrary to expectations, the B/C ratio is monotonically falling up to ~2 TV
- The “structure” is not significant
- The dashed red line is a fit that yields an index 0.3333
- If C has the “break”, B should also have it!
- and the breaks in C and B must be the same!
- but B is 100% secondary...