UHECR Spectrum And Composition In Two-Population Model

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One-population model

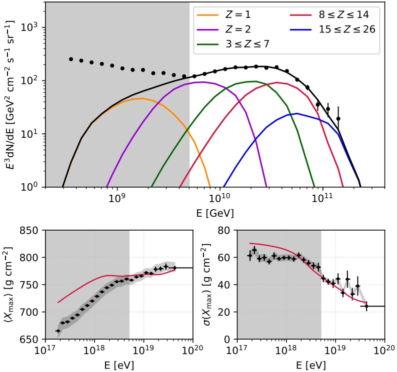

Figure: UHECR spectrum and composition for the best-fit parameters of a single population model.
Image: S. Das, S. Razzaque, N Gupta; Eur. Phys. J. C **81** (2021) 59

1. Single population of extragalactic sources injecting H, He, N, Si, Fe
2. Random energy between 0.1-10^3 EeV – power law, with $R_{\rm cut} = 10^{18.2}$ eV
3. Spectral cutoff due to diminishing ^{56}Fe flux – local extragalactic sources
4. Simulated $X_{\rm max}$ slope – addition of light component may improve the fit

Two-population model

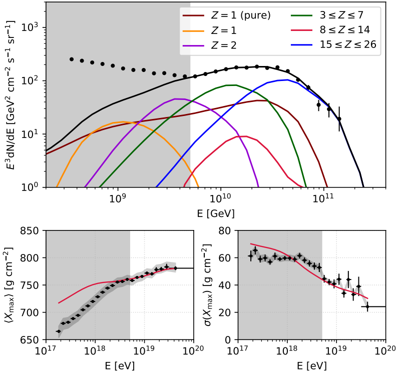

Figure: UHECR spectrum and composition for the best-fit parameters of a single population model. Image: S. Das, S. Razzaque, N Gupta; Eur. Phys. J. C **81** (2021) 59

1. Discrete source population injecting ^{1}H only – spectral index $\alpha_1 = 2.6$
2. High value of $E_{\max} \approx 10^{19.6}$ eV – 2% contribution at highest-energy bin
3. Significant improvement in composition fit $\langle X_{\max} \rangle$ and $\sigma(X_{\max})$ at ROI
4. Injection spectral index of Pop-II becomes positive, but "hard" ($\alpha_2 \approx 1$)

Cosmogenic components

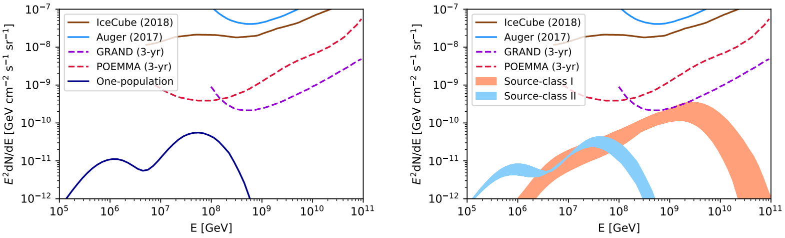

Figure: Cosmogenic neutrino spectrum for the best-fit parameters of a single population (**left**) and two-population (**right**) model. Image: S. Das, S. Razzaque, N Gupta; Eur. Phys. J. C **81** (2021) 59

- One-population model yields a typical neutrino flux expected for high abundances of heavy nuclei – out of reach for current & future detectors.
- $1-20\%$ contribution of pure proton component at the highest energy bin is shown. Neutrino flux for corresponding best-fits of heavy nuclei is also shown.
- A small fraction of protons can yield large number of neutrinos via $\Delta-$resonance

Summary

1. Composition fit of one-population model improves greatly on addition of a pure proton component extending upto the highest observed energies
2. Composition studies at the highest energies is restricted by low event rates, $\langle X_{\mathrm{max}} \rangle$ is linear in $\ln A$, $\sigma(X_{\mathrm{max}})$ – no one-to-one correspondence with mean log mass
3. We constrain the maximum allowed proton fraction at 3.5σ C.L. at the highest energies – comes out to be $12.5 - 17.5\%$ for all α values considered
4. Redshift evolution of sources – AGNs, GRBs: candidates for Pop - I accelerating protons to ultrahigh energies. TDEs: heavy nuclei injection at sources