DIFFUSE CR, NEUTRINO AND GAMMA-RAY FLUXES FROM AGNs

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We investigate how the extragalactic proton component derived within the "escape model" [1] can be explained by astrophysical sources. We consider as possible cosmic ray (CR) sources **normal/starburst galaxies** and **radio-loud active galactic nuclei (AGN)**. We find that the contribution to the total **extragalactic proton flux** from normal and starburst galaxies is sub-dominant and does not fit the spectral shape deduced in the escape model. For radio-loud AGNs, **the complete extragalactic proton spectrum can be explained by a single source population, BL Lac/FR I**. We calculate the **diffuse neutrino and γ-ray fluxes** produced by these CR protons interacting with gas inside their sources. For a spectral slope of CRs close to $\alpha = 2.1 - 2.2$, **these UHECR sources can contribute the dominant fraction of both the isotropic γ-ray background and of the extragalactic part of the astrophysical neutrino signal observed by IceCube.**

METHOD AND ASSUMPTIONS

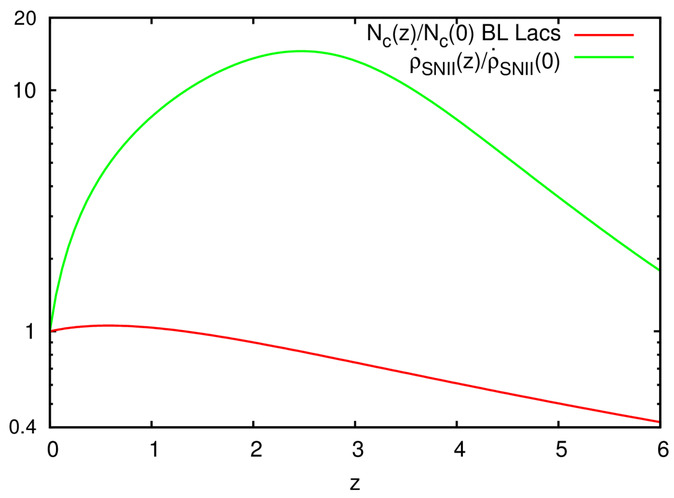
We try to fit the extragalactic CR proton flux derived within the "escape model" of [1]. Combining the KASCADE, KASCADE-Grande and Auger data suggests that the slope of the extragalactic proton spectrum is consistent with a spectral index $\alpha_p \sim 2.2$ at $E < 10^{18}$ eV, and $\alpha_p \sim 3$ at higher E.

We calculate the proton, neutrino and gamma-ray diffuse fluxes taking into account the distribution ρ(z) of sources and the interaction of protons/electrons/photons with EBL/CMB. We use the code [2] which solves the corresponding kinetic equations in 1D. We employ the EBL model of [3].

We implement *pp* interactions : For the spectrum of secondary photons and neutrinos, we use the cross sections tabulated from QGSJET-II-04 [4]. Secondaries from heavier elements are suppressed; their contributions are included adding a nuclear enhancement factor ε_M. Taking also into account the He component of the ISM, we set $\varepsilon_M = 2.0$.

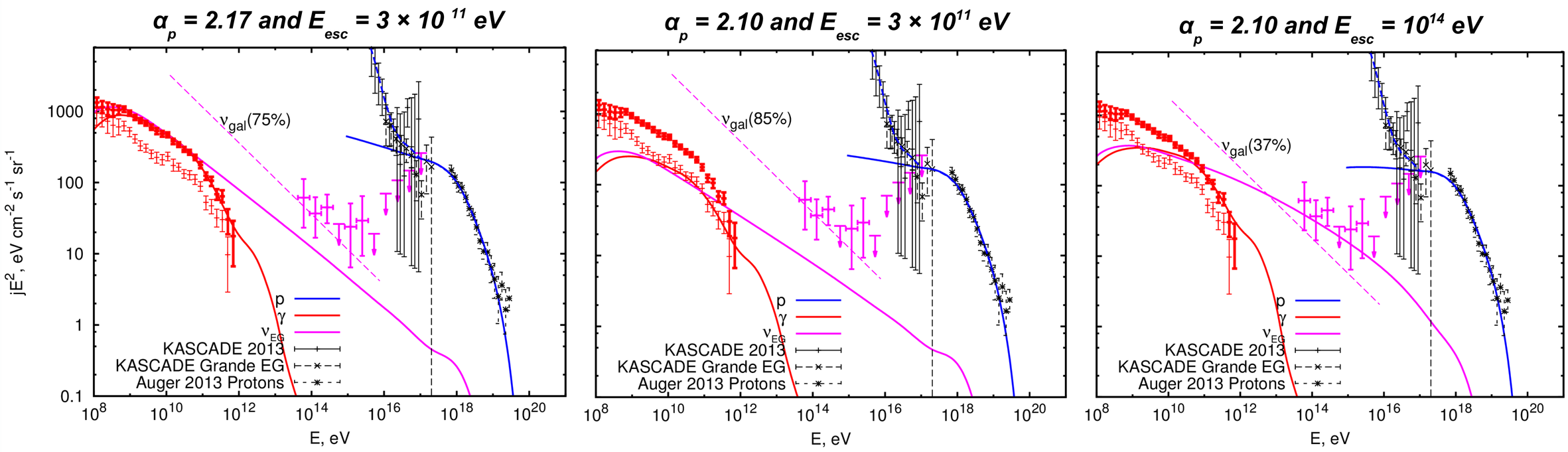
For radio-loud AGNs, we take for the grammage $X(E) \propto E^{-1/3}$ as expected for a turbulent magnetic field with a Kolmogorov spectrum. The normalization is fixed by setting the interaction depth $\tau_{pp} = 1$ at a reference energy E_{esc}. We assume a spectral index $\alpha_p = 2.0 - 2.5$ for the protons at the sources.

For $E_{max} = 10^{19}$ eV and sources with late-time evolution, we find that the diffuse extragalactic CR proton flux can be well fitted. For the evolution with redshift of BL Lacs, we take the parameters of [5], see red curve – right.



BL Lac, Type II SN evolution with redshift.

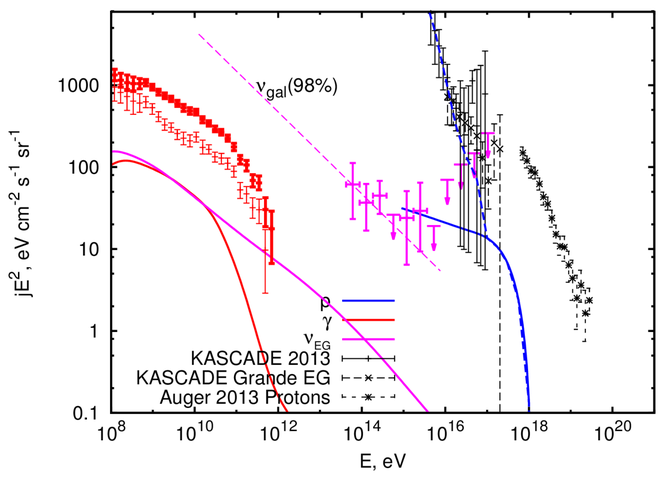
RESULTS : - DIFFUSE FLUXES FROM AGNs



Diffuse flux of CR protons from BL Lacs (thick blue line), Galactic proton flux in the escape model (dashed blue line). Resulting photon (red line) and neutrino (magenta) fluxes, for three different sets of α_p and E_{esc}. For all three panels, $E_{max} = 10^{19}$ eV. CR protons from KASCADE, KASCADE-Grande and Auger (black error-bars). IGRB and EGB from Fermi-LAT (red) and neutrinos from IceCube (magenta).

Acceleration close to the black hole satisfies the required conditions to produce secondary γ-ray and neutrino fluxes that can explain observations. For α_p close to 2.2, such UHECR sources would provide the dominant fraction of both the isotropic γ-ray background and of the extragalactic part of the astrophysical neutrino signal observed by IceCube. The difference of slopes between proton and neutrino fluxes is due to diffusion of primary protons in the turbulent magnetic fields of CR sources.

- DIFFUSE FLUXES FROM STARBURSTS



Star-forming galaxies give a sub-dominant contribution to the primary CR flux, *for the spectral index $\alpha_p = 2.2$* which is favoured by the escape model. By rescaling the grammage traversed by CRs in the Milky Way to starbursts, we find that they contribute ~ 30% at 10 GeV to the IGRB and ~ 10% of the IceCube neutrino flux below 10^{14} eV (see Fig. on the left). Taking into account the uncertainty in the grammage, they may contribute a non-negligible fraction to the IGRB and extragalactic part of the IceCube neutrinos, especially at low E.

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