The contribution of galactic sources to the diffuse high-energy neutrinos signal

GRAN SASSO SCIENCE INSTITUTE
CENTER FOR ADVANCED STUDIES INFN

G. Pagliaroli and F. L. Villante

UNIVERSITÀ DEGLI STUDI DE L'AQUILA

GOAL AND METHODOLOGY

The existence of non vanishing diffuse galactic contribution is guaranteed by hadronic interactions of HE Cosmic Rays (CR) with the gas contained in the galactic disk, through the production of charged pions (and kaons) that subsequently decays to neutrinos. In addition to this, HE neutrinos may be also produced by freshly accelerated hadrons colliding with the ambient medium within or close to an acceleration site. **Hadronic interactions** produce a roughly equal number of charged and neutral pions which decay to gamma rays. If photons are not absorbed by the intervening medium, we thus expect that the HE neutrino sky is strongly correlated with the HE gamma sky. This correlation provides us an handle to perform a detailed multi-messengers study of the galactic plane. The results of HE gamma observatories can be combined with the data collected by neutrino telescopes in order to test their consistence in a coherent scenario.

Total observed gamma sky

$$\varphi_{\gamma,\rm tot} = \varphi_{\gamma,\rm diff} + \varphi_{\gamma,\rm S} + \varphi_{\gamma,\rm IC}$$

$$\varphi_{\nu,\rm tot} = \varphi_{\nu,\rm diff} + \varphi_{\nu,\rm S}$$

HESS Background subtraction 95% reduction of the IC

Sources Terms

GOAL=Total Neutrino sky

$$\varphi_{\gamma,\rm S} = k_\gamma \left(\frac{E_\gamma}{\rm TeV}\right)^{-\alpha_\gamma} \exp\left(-\sqrt{\frac{E_\gamma}{E_{{\rm cut},\gamma}}}\right)$$

$$\varphi_{\nu,\rm S} = k_\nu(\hat n_\nu) \left(\frac{E_\nu}{\rm TeV}\right)^{-\alpha_\nu} \exp\left(-\sqrt{\frac{E_\nu}{E_{{\rm cut},\nu}}}\right)$$

Kappes et al., Astrophys. J. 656, 870 (2007)

$$\alpha_\nu = \alpha_\gamma$$

$$E_{{\rm cut},\nu} = 0.59\, E_{{\rm cut},\gamma}$$

$$k_\nu(\hat n_\nu) = (0.694 - 0.16\alpha_\gamma)\, k_\gamma(\hat n_\gamma = \hat n_\nu)$$

Free parameters

THE DIFFUSE GALACTIC COMPONENTS

$$\varphi_{i,\rm diff}(E_i,\hat n_i) = A_i \left[\int_{E_i}^{\infty} dE\, \frac{\sigma(E)}{E}\, F_i\left(\frac{E_i}{E},E\right)\right] \int_0^\infty dl\, \varphi_{\rm CR}(E,\mathbf{r}_\odot + l\,\hat n_i)\, n_{\rm H}(\mathbf{r}_\odot + l\,\hat n_i)$$

$i = \gamma,\ \nu$

1 o 1/3

CRs Inelastic Cross Section and spectra of secondary

Gas density distribution

Galactic Differential CRs flux

$$\varphi_{\rm CR}(E,\mathbf{r}) = \begin{cases} \varphi_{{\rm CR},\odot}(E) & \textit{Case A} \\ \varphi_{{\rm CR},\odot}(E)\, g(\mathbf{r}) & \textit{Case B} \\ \varphi_{{\rm CR},\odot}(E)\, g(\mathbf{r})\, h(E,\mathbf{r}) & \textit{Case C.} \end{cases}$$

- **Homogenous in the Galaxy**
- **Follows the SNRs distribution**
- **Variable Spectral index**

CR flux at Sun position

$$h(E,\mathbf{r}) = \left(\frac{E}{\bar E}\right)^{\Delta(\mathbf{r})} \qquad \bar E = 20\ \rm GeV$$

$$\Delta(r,z) = 0.3\left(1 - \frac{r}{r_\odot}\right)$$

Pivot energy of Fermi-LAT observations

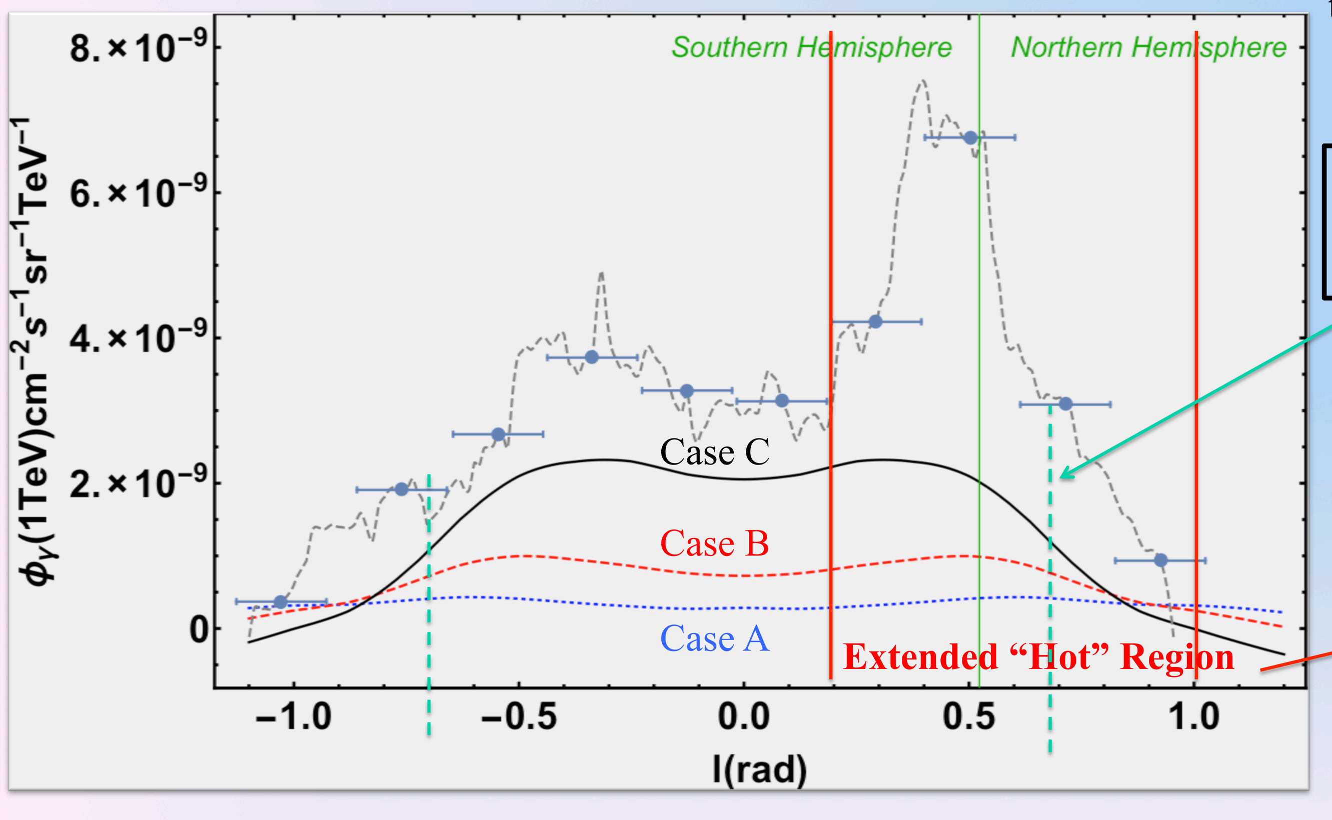
variation of the CR spectral index

CR density increases of a factor ~4 for Case B with respect to Case A

Case C is equivalent to the KRA model of Gaggero et al. PRL 119 (2017)

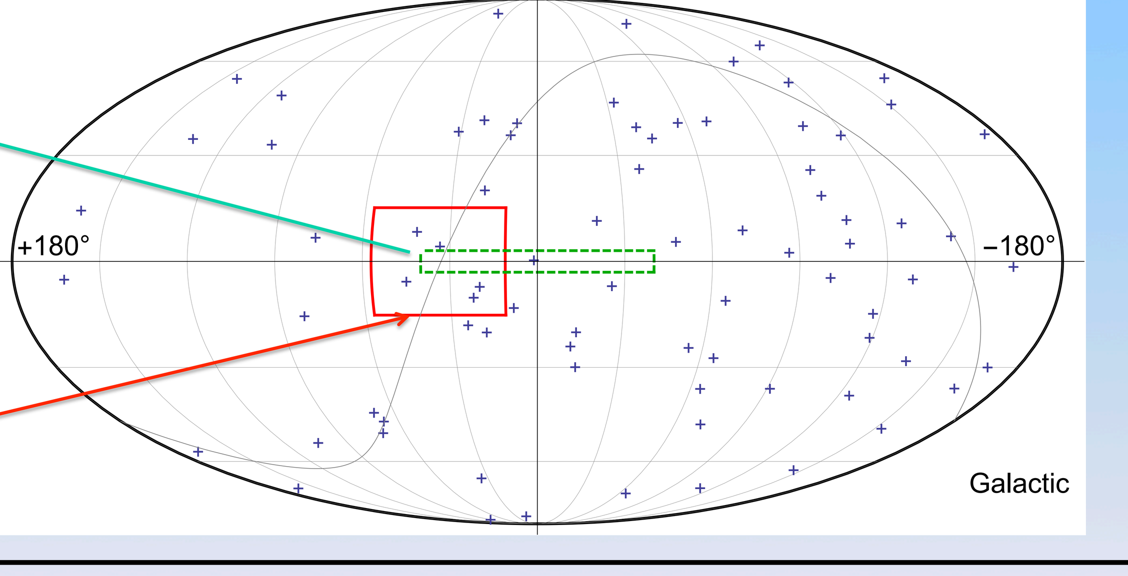
THE EXTENDED "HOT" REGION OF HESS

The HESS Galactic Plane Survey provided on 2014 the longitudinal and latitudinal profiles of the observed gamma flux at 1 TeV in the region $-75^\circ < l < 60^\circ$ and $-2^\circ < b < 2^\circ$. We re-binned the data with ~15º of bin (HESE showers resolution) and we take into account the background subtraction performed by HESS in order to compare the predicted diffuse gamma emission with the total observed gamma sky. Diffuse emission is compatible/below the total observed for all the Cases. The Sources contribution dominates the 1 TeV gamma sky and is the the 89%, 76% or 50% of the total galactic emission in Case A, Case B and Case C respectively.



Region of the Antares upper limit

HESE data provided by IceCube in 2078 days of data-taking



The 50% of the sources emission is concentrated in the Extended "Hot" Region with $11^\circ < l < 57^\circ$

In the Red box compatible with the EHR of HESS 5 HESE showers are observed.
The expected background in the same region is 0.3 showers due to atmospheric neutrinos.
The isotropic best-fit flux of IceCube can add 1.4 showers due to extragalactic emission.
The 5 observed showers represent a 1.5 sigma excess with respect to the 1.7 expected.

THE HEN SOURCES CONTRIBUTION

The sources contribution to the gamma sky can be obtained by subtraction of the diffuse emission from the total observed emission. The neutrino sources contribution can be derived by the gamma sources one under the hadronic production hypothesis and is a function of the two source parameters: spectral index and energy cutoff.

$$\frac{dN_{\rm Sh}(\hat n)}{d\Omega} = T \int dE_\nu \int d\Omega_\nu\, G_{\rm Sh}(\hat n,\hat n_\nu)\varphi_{\nu,tot}(E_\nu,\hat n_\nu)\left[A_e(E_\nu,\hat n_\nu) + A_\mu(E_\nu,\hat n_\nu)(1-\eta) + A_\tau(E_\nu,\hat n_\nu)\right]$$

0.8

Observation Time

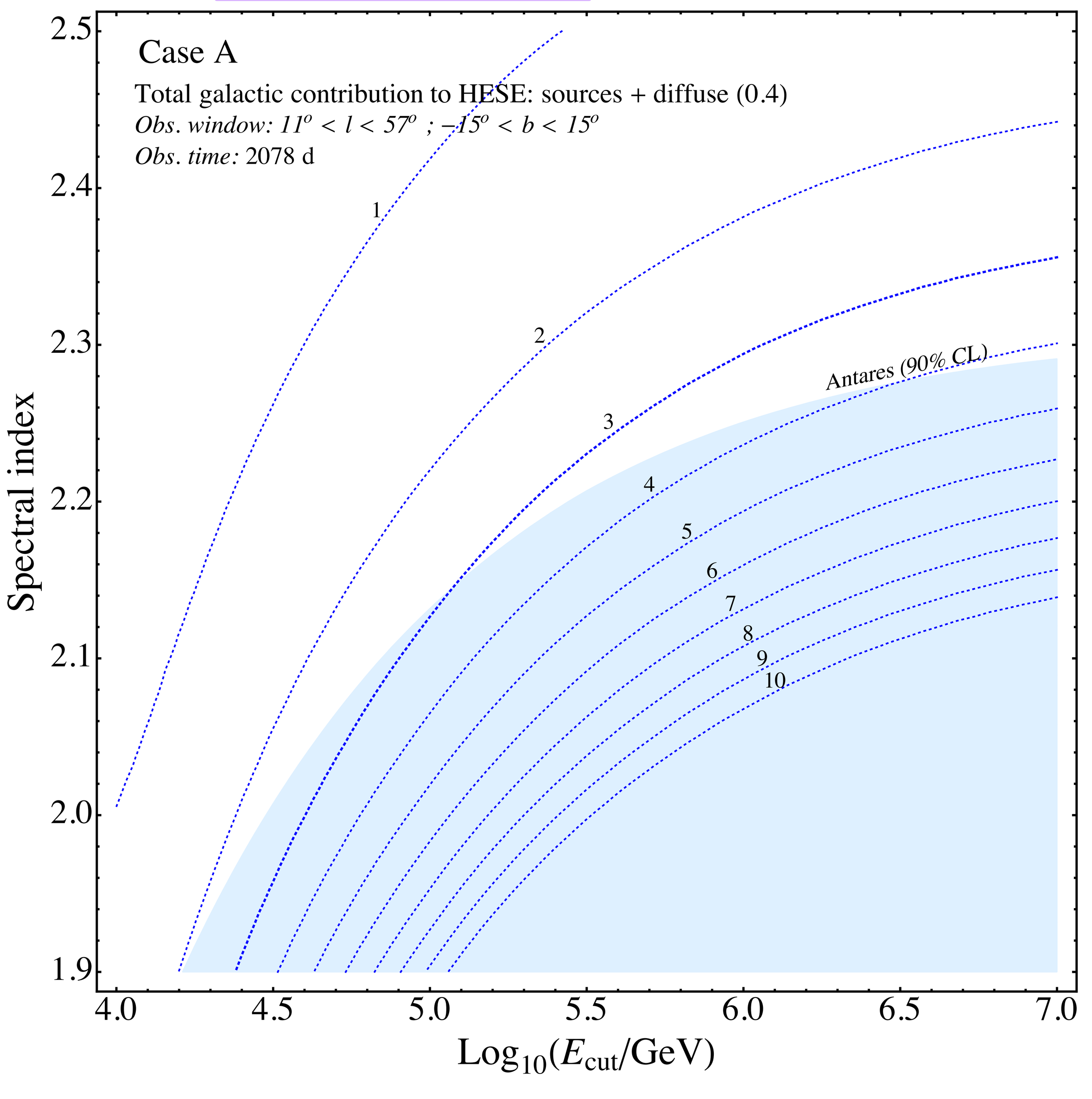
HESE Effective Areas

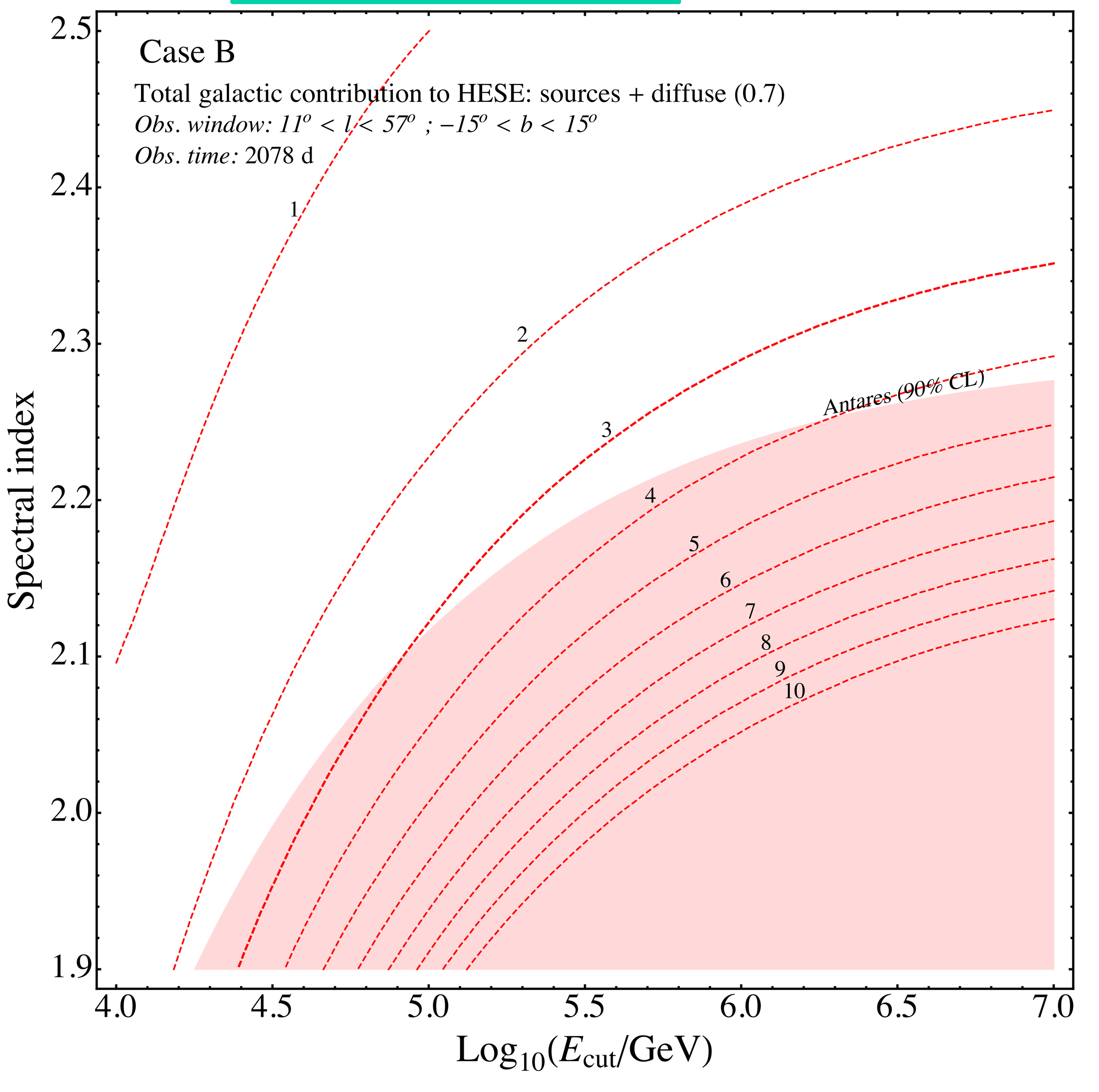
$$G_{\rm Sh}(\hat n,\hat n_\nu) = \frac{m}{2\pi\delta n_{\rm Sh}^2}\exp\left(-\frac{1-c}{\delta n_{\rm Sh}^2}\right)$$

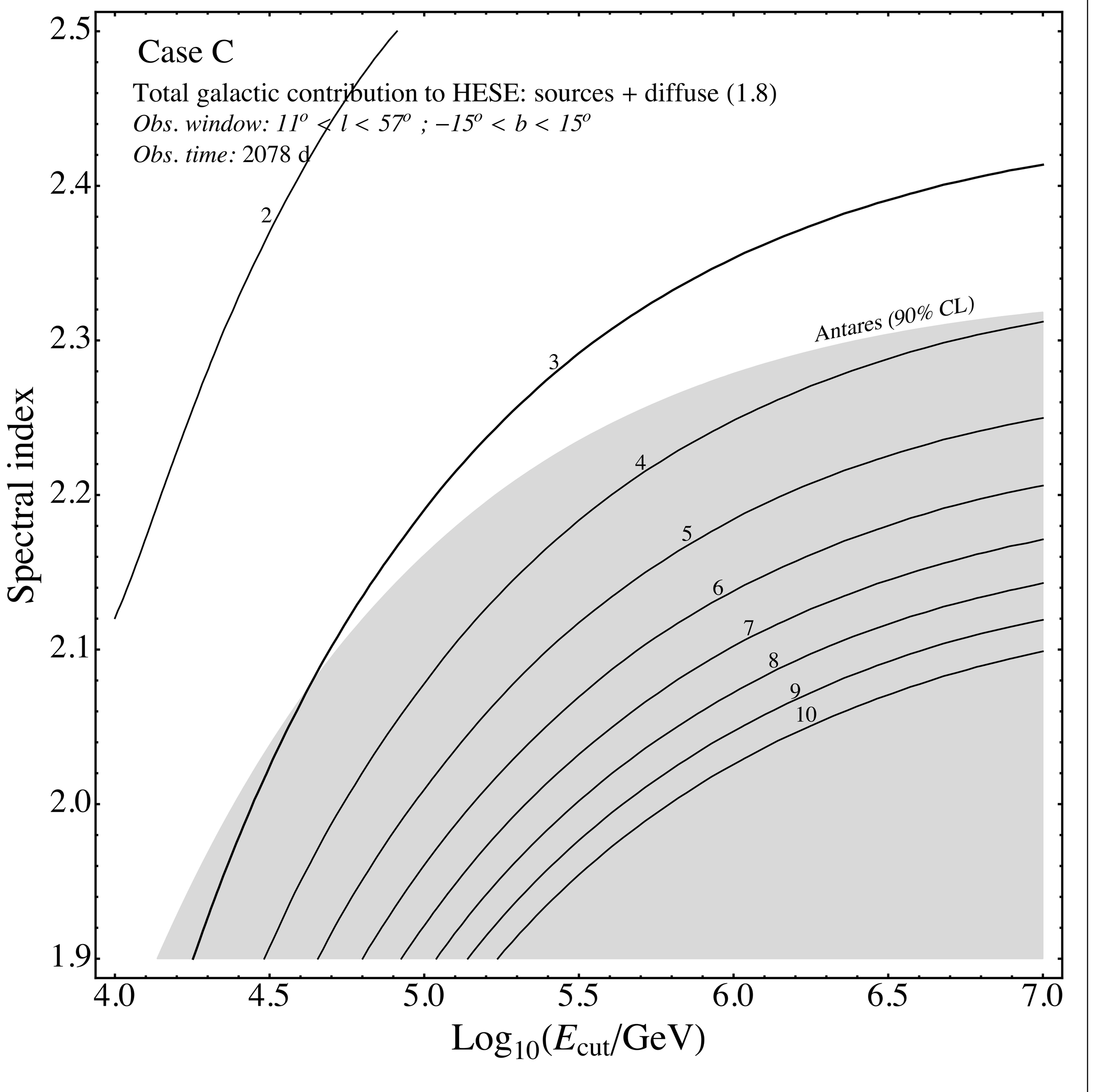
$c \equiv \cos\theta = \hat n\,\hat n_\nu$

Showers Angular Resolution

$\theta \leq 15^\circ$ At 68.3% of C.L.







The shaded areas show excluded regions in the parameters space α_ν and $E_{cut,\nu}$ provided by the Antares upper limit (S. Adrian-Martinez et al., Phys. Lett. B760, 143 (2016))
Lines correspond to a specific number of IceCube HESE showers events from the EHR region for Case A(blue dotted), Case B (red dashed) and Case C (black solid).
The observed HESE excess from the EHR (3.3 events) is compatible with the Antares exclusion regions for all the cases considered.
The Antares upper limit provides relevant constraints for neutrino emission parameters space for spectral index <2.3; e.g. an=2.0 and Ecut>30 TeV is excluded for all the Cases considered.

Perspectives in Astroparticle physics from High Energy Neutrinos (PAHEN) 2017
25-26 September 2017 – Naple, Italy