A New Map of Neutrino Emission in Our Galaxy with CRPropa

The properties of galactic neutrinos observed by our telescopes may encode new very-long-baseline physics.

We simulate the (3+1) dimensional production of neutrinos in our galaxy in cosmic ray collisions with gas clouds in order to enable future BSM searches using galactic neutrinos.

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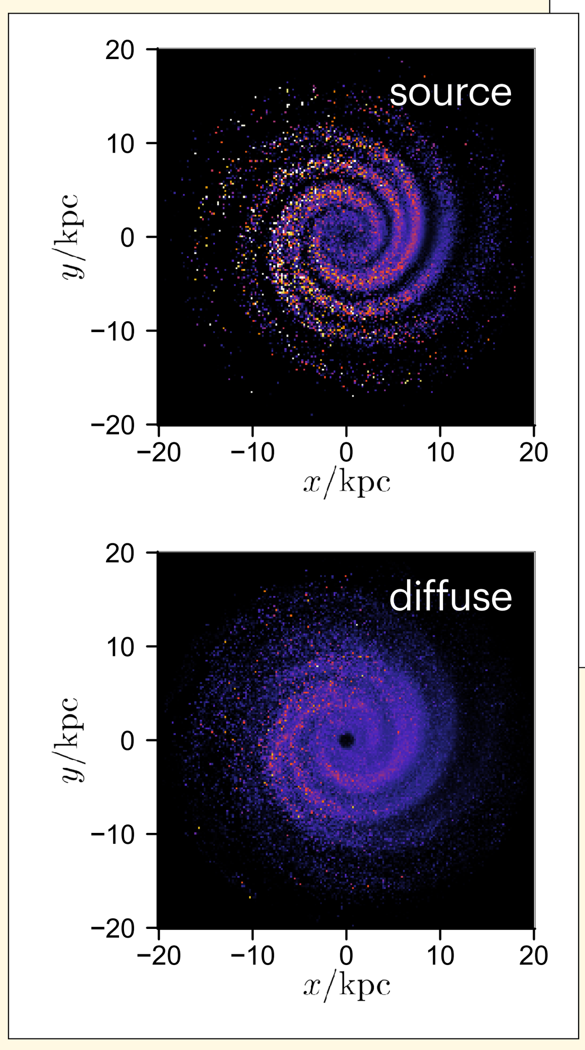
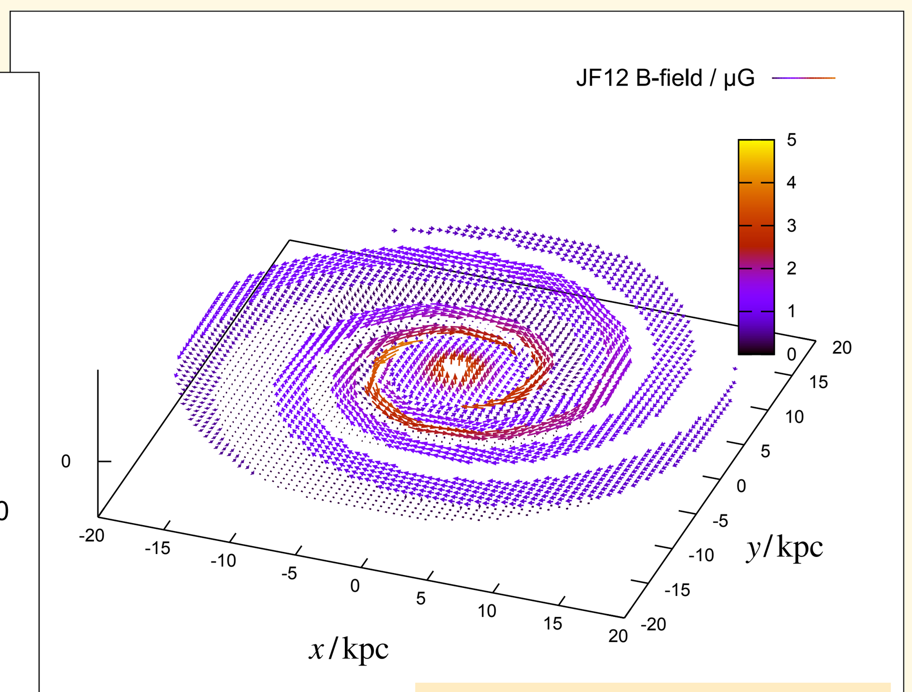
Method:

Simulate CR production and diffusion with CRPropa → Rescale the simulated CR flux by fitting to local observations → Integrate the CR flux against the $p-p$ cross-section and the target density.

$$\frac{dN_\nu^{\text{obs}}}{dA\, d\Omega\, dt\, dE_\nu} = \int dR\, \rho_{\text{target}} \left[\left[\int dE_{\text{CR}} \frac{d\sigma}{dE_\nu} \Phi_{\text{CR}} \right] \right]$$

Cosmic Rays: Sources + Diffusion





Jansson + Farrar **arXiv:1204.3662**

We assume cosmic rays are produced with random direction in the galaxy by sources in a spatial distribution following that of supernova remnants.

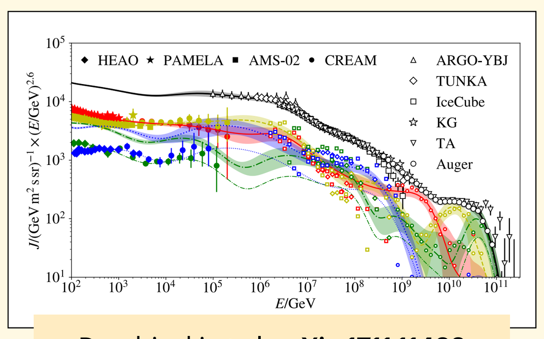
CRPropa solves the diffusive transport equation by time-integrating equivalent stochastic differential equations (SDE)s using an Euler-Maruyama scheme.

The diffusion of a particle is characterized by the axisymmetric, anisotropic diffusion tensor, which scales as a power-law in rigidity R and describes random motion in directions parallel / perpendicular to the local B-field.

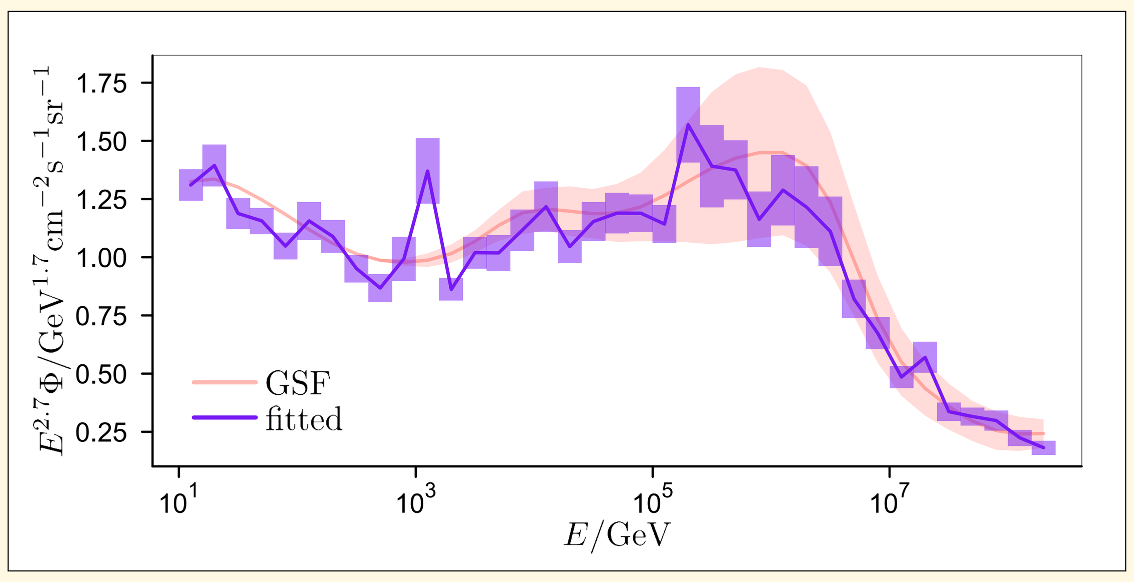
$$\hat{\kappa} = \begin{bmatrix} \kappa_\perp & & \\ & \kappa_\perp & \\ & & \kappa_\parallel \end{bmatrix} = (6.1 \cdot 10^{24} \text{m}^2\text{s}^{-1}) \cdot s \begin{bmatrix} \epsilon & & \\ & \epsilon & \\ & & 1 \end{bmatrix} \left(\frac{R}{R_0}\right)^\gamma$$

Cosmic Rays: Flux Modeling

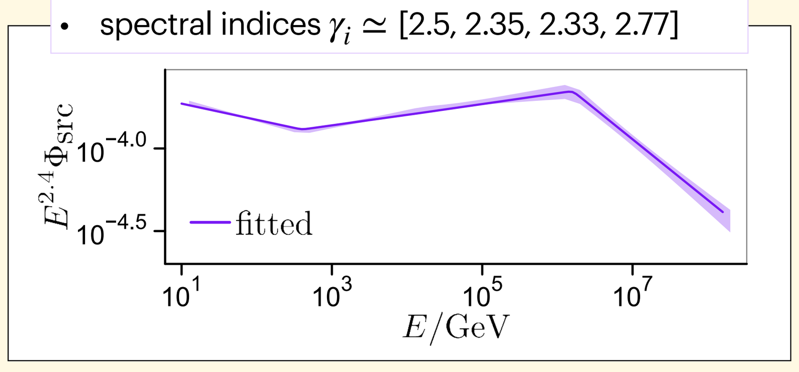
We assume the CR flux produced by every source is the same, and determine its normalization and shape by fitting the simulated diffuse flux in our local region to the GSF proton flux (Dembinski et al. **arXiv:1711.11432**).



Dembinski et al. **arXiv:1711.11432**

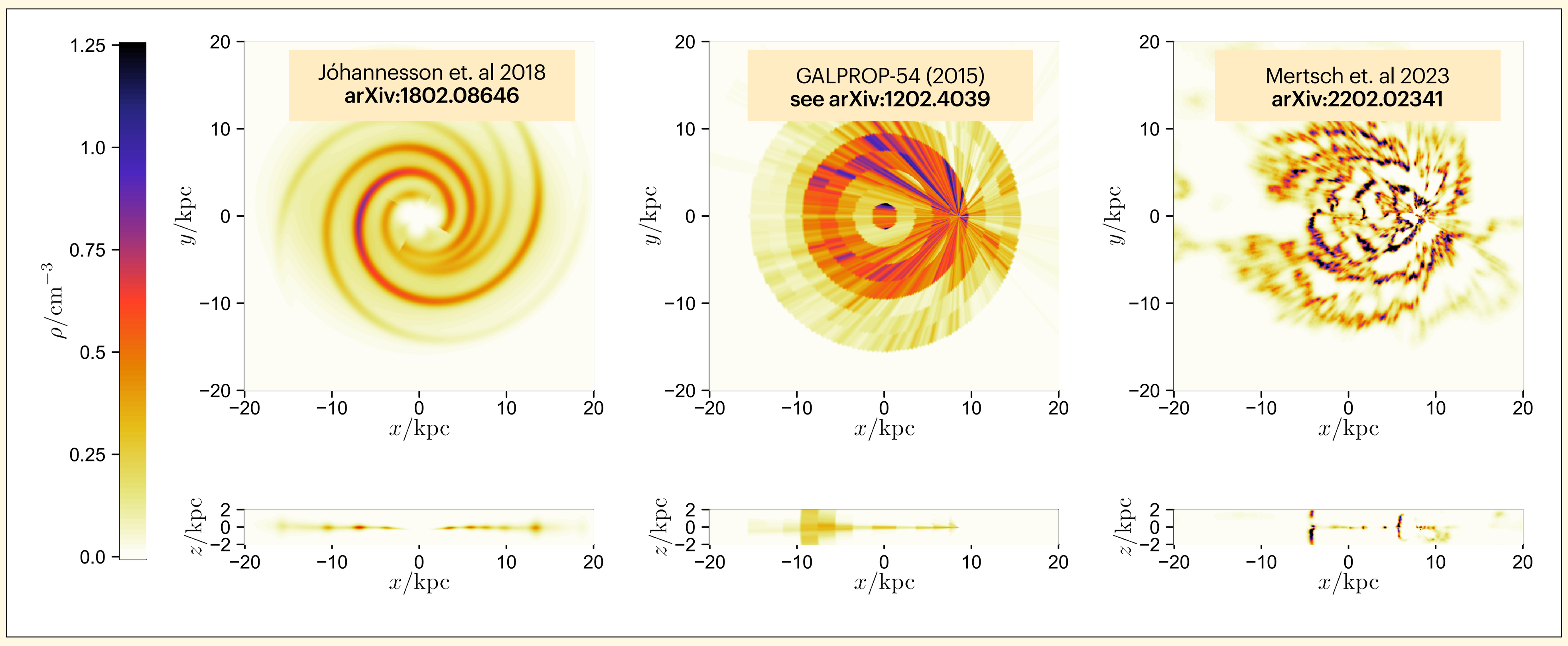


Source flux model: triply broken power law with:
- breaks at 0.4TeV, 16TeV, 16PeV
- spectral indices $\gamma_i \simeq$ [2.5, 2.35, 2.33, 2.77]



Galactic Gas Maps

3D maps of the galactic atomic hydrogen H_I gas distribution can be inferred from measurements of the frequency shift and brightness temperature of 21cm line by assuming a galactic rotation curve. However, degeneracies in the inverse map (frequency to radial distance) make this calculation technically challenging. We consider maps produced using three different techniques. The smoother, lower-resolution maps tend to spread out gas molecules over a wider area, resulting in lower densities.

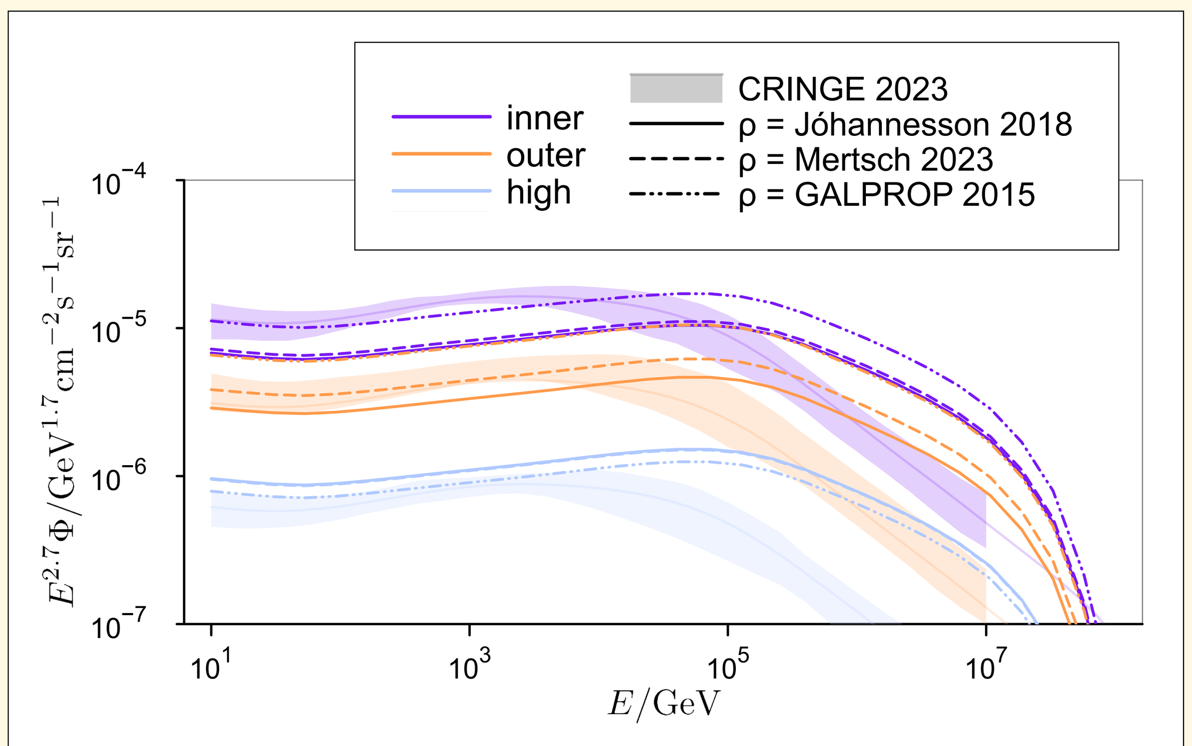


Results:

Neutrino Flux

We average the neutrino flux over different regions in the sky in order to visualize its large-scale properties:

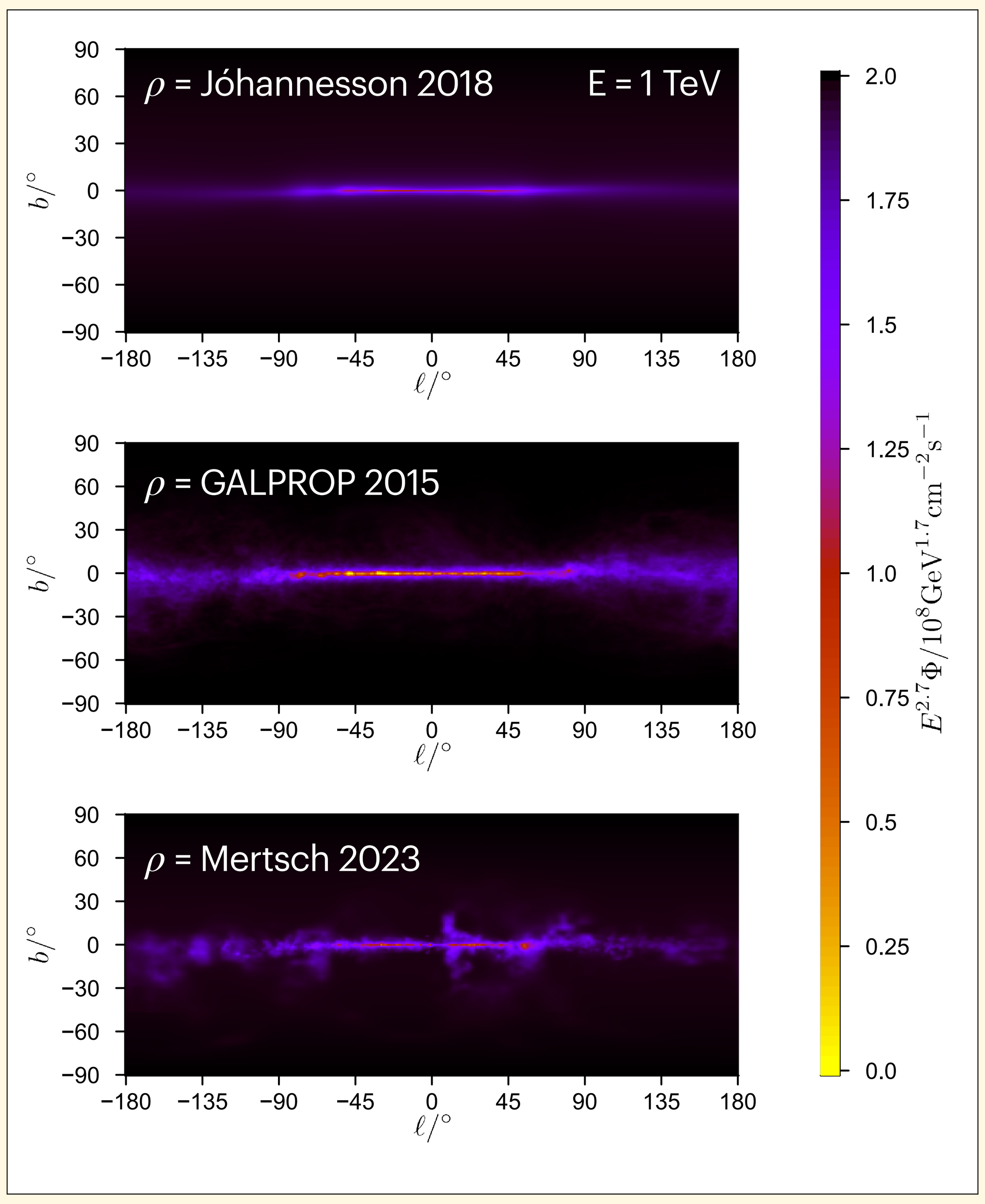
inner:	$\lvert l \rvert < 80^\circ$, $\lvert b \rvert < 8^\circ$
outer:	$\lvert l \rvert \geq 80^\circ$, $\lvert b \rvert < 8^\circ$
high-latitude:	$\lvert b \rvert \geq 8^\circ$



We find that the shape of the flux is mostly independent of the direction in the sky. The overall scale can vary by up to a factor of two depending on the gas model used.

We also plot the CRINGE model flux (Schwefer et. al **arXiv:2211.15607**) for comparison.

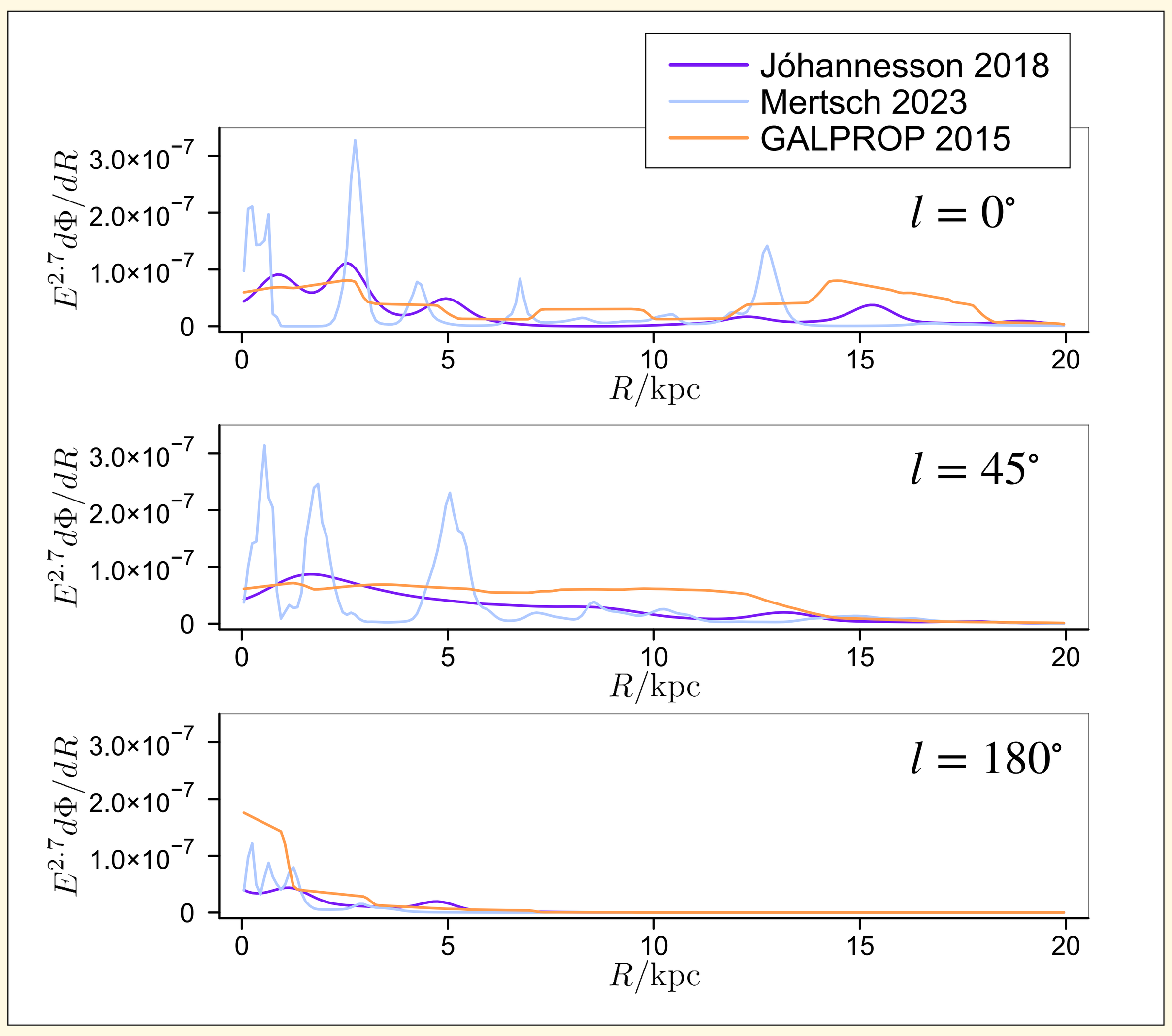
We also plot the neutrino flux over the whole sky:



Distance-Differential Flux

To compute the distance-differential flux, we integrate the neutrino emission in three dimensions along a LOS direction (l, b). We average the integral over a wide pixel of $10^\circ \times 10^\circ$, corresponding to the large typical angular uncertainty of a neutrino event.

Because neutrino production is approximately confined to a plane, the resulting $R-$distributions scale roughly as R^{-1}.



We find that the neutrino production along the line-of-sight depends significantly on the target gas distributions, which have large uncertainties in radial distance.