Contribution of Young Massive Star Clusters to the Galactic neutrino emission

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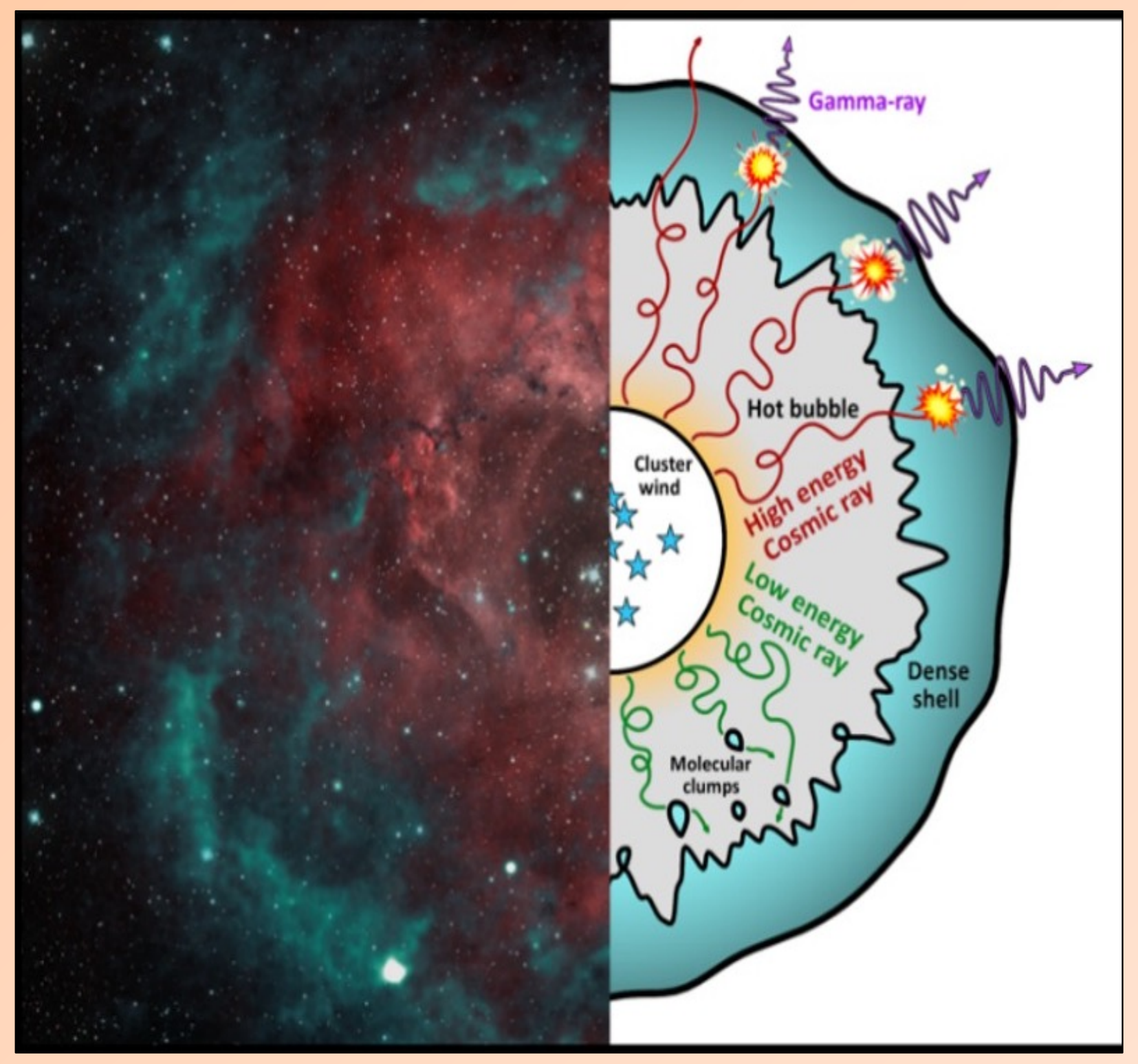
Cosmic-ray acceleration up to knee energies and beyond has been suggested to take place in ***young massive star clusters (YMSCs)****, as indicated by the detection of PeV photons in such system, e.g. the Cygnus region. Promising locations where efficient particle acceleration might take place in compact clusters are the strong termination shock driven by the* ***collective action of stellar winds****, combined with the action of* ***supernovae*** *occurring in their cores. Subsequent hadronic collisions of the* ***accelerated particles*** *result into* ***gamma-ray and neutrino*** *production, contributing to the* ***diffuse emissions observed in the Galactic Plane****.*

We here compute the expected very-high-energy neutrino signal by the entire ***star cluster population*** *of the Galaxy, via synthetic realizations based upon observed properties of the local population. We further provide a qualitative comparison to current Galactic Plane neutrino measurements by IceCube and present novel* ***neutrino template maps*** *which we encourage to test in future data analyses of large volume Cherenkov telescopes, as* ***IceCube and KM3NeT****.*

1. Particle acceleration in young and massive star clusters

YMSCs are **continuous accelerators** with lifetimes of several **million years**. The collective action of stellar winds in compact clusters can sustain the formation of a strong Wind Termination Shock (WTS), where **efficient particle acceleration** might take place, possibly up to PeV energies [1]. A schematic representation of the **wind excavated bubble** surrounding a compact YMSC is depicted in the figure.



The adiabatic wind-driven bubble consists of [2]:

- the **central core**, where the cluster stars are located;
- the **cold wind**, extending up until the collective WTS radius;
- the **low density bubble** of radius R_{fs}, filled with the shocked wind material up until the so-called contact discontinuity;
- the **shell** of compressed interstellar medium.

After 2-3 Myr of evolution, **supernova (SN) explosions** will start to occur and become the dominant power source in YMSCs [3], altering the simple spherically symmetric wind-blown bubble depicted above. Core-collapse SNe will remain active site of cosmic-ray (CR) production until ~30 Myr, corresponding to the lifetime of a 8 M_{sun} star in its main sequence evolution.

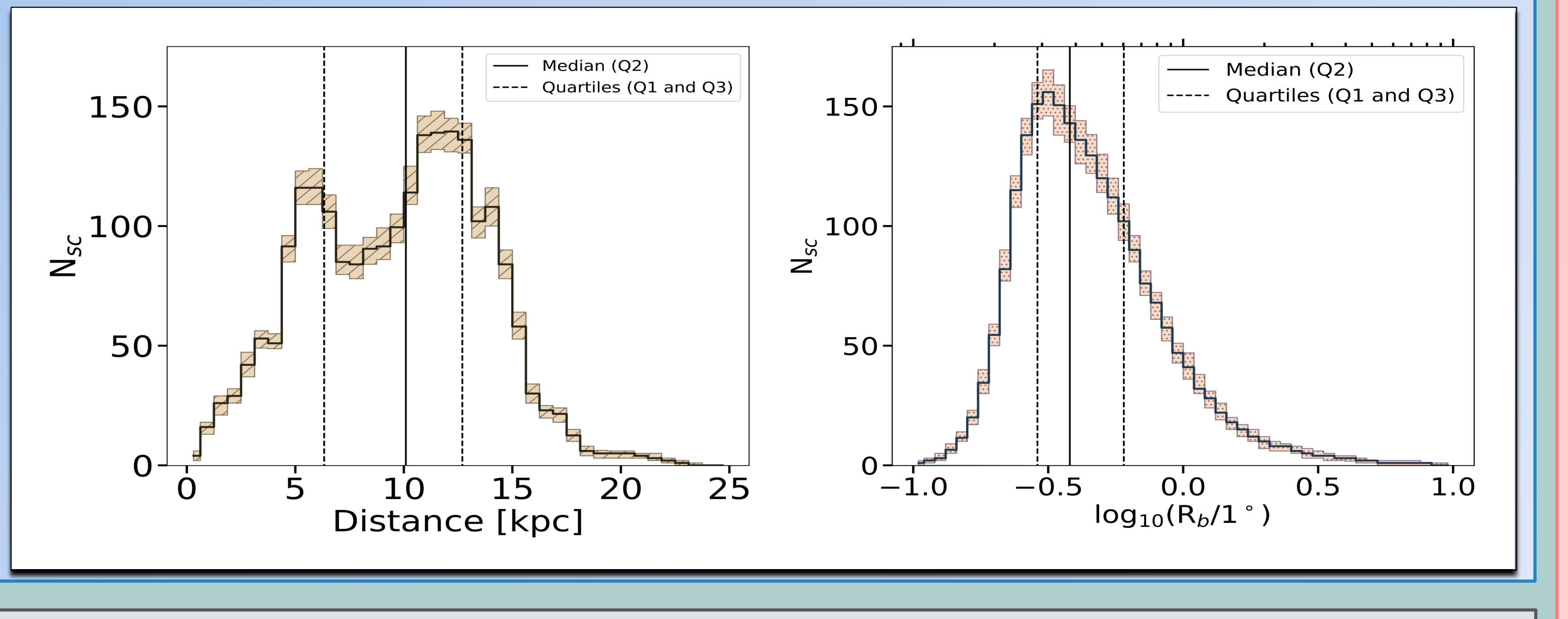
Inside of the bubble, the competition between diffusion and advection determines the particle transport [1].

2. The simulated cluster population of the Milky Way

The Milky Way population of YMSCs is known to completeness only in the ~2 kpc neighborhood of the Sun [4]. Therefore, in order to evaluate the cumulative neutrino emission from hadronic collisions occurring in the entire YMSC population of the Milky Way, we build a **synthetic sample of YMSCs** resembling their local observed properties. The expected number of clusters with age in [0, t_{max}], mass in [M_{min},M_{max}] and galactocentric radius up to R_{MW} is:

$$N_{\rm sc} = \int_{M_{\rm min}}^{M_{\rm max}} \int_0^{t_{\rm max}} \int_0^{R_{\rm MW}} f(M_{\rm sc})\psi(t)\Sigma(r)\, dM_{\rm sc}\, dt\, dr$$

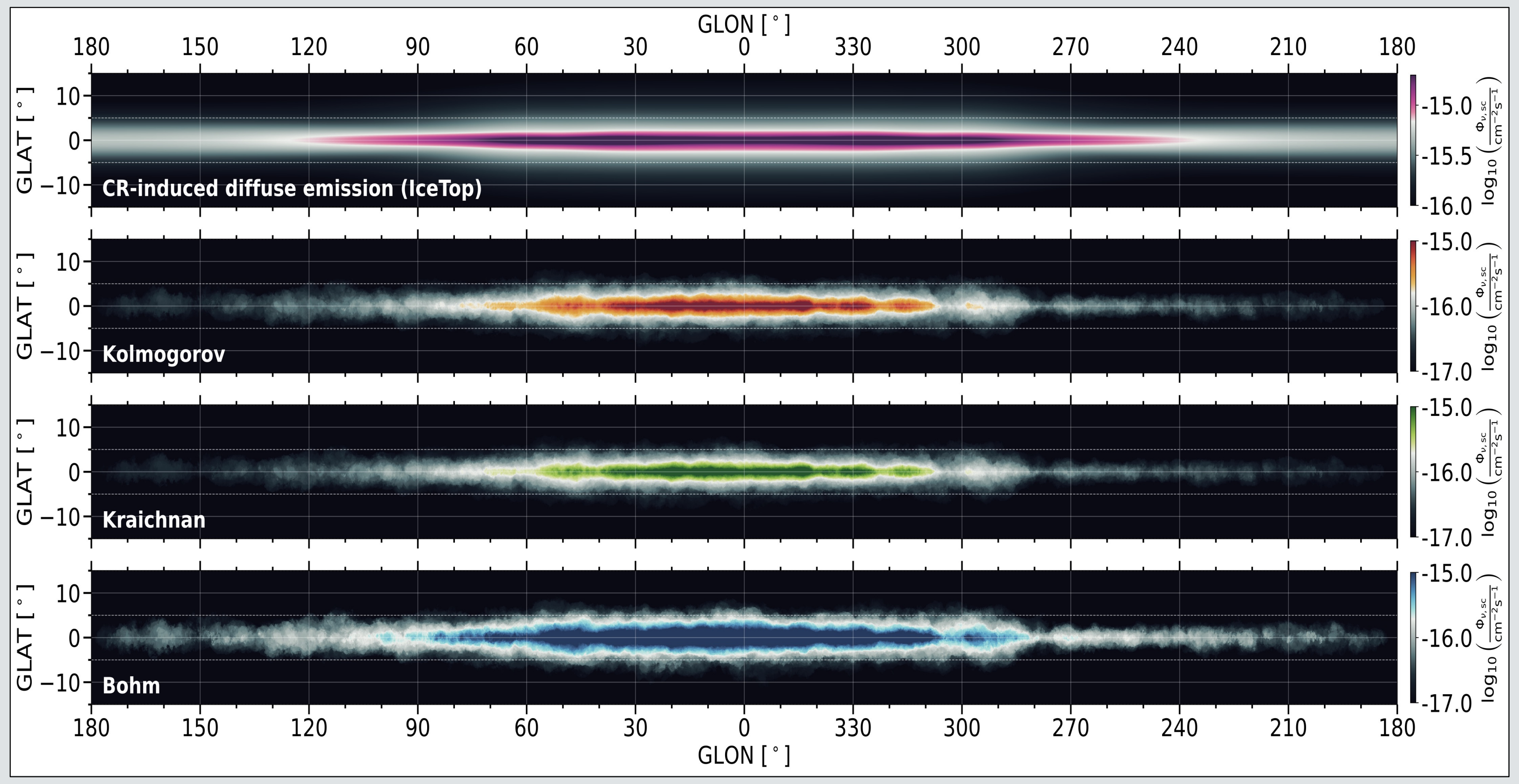
where f(M) represents the cluster initial mass function in M_{min}=1000 M_{sun}, M_{max} = 63000 M_{sun}; ψ(t) is the cluster formation rate, approximatively constant within the last t_{max}=30 Myr; and Σ(r) is the cluster spatial distribution up to R_{MW}=18 kpc. We obtain a total of **2243 YMSCs** and simulate their stellar properties in order to compute their **mechanical luminosities**. We thus perform **100 different realizations** per cluster, whose resulting distributions of heliocentric distances and bubble sizes are shown below.



4. Novel Galactic neutrino templates

Our study indicates that **the YMSC Milky Way population contribution to Galactic neutrinos amounts up to ~40% at neutrino energies of 10 TeV**. Interestingly, non-thermal emission by YMSCs has also been suggested to non negligibly contribute to the **gamma-ray diffuse emission** observed in the inner Galactic Plane region at energies above 100 GeV [9].

We encourage future data analyses of large volume neutrino telescopes to test our model, fitting simultaneously the source and the purely diffuse component as to **constrain the hadronic efficiency** of YMSCs. Therefore, we provide **spectral and spatial templates** of the expected Galactic neutrino emission calculated within the different scenarios here investigated, shown in the right panel for the case of Kolmogorov transport. Other templates will be made available via the online material associated to the publication [5] or upon request to the authors.

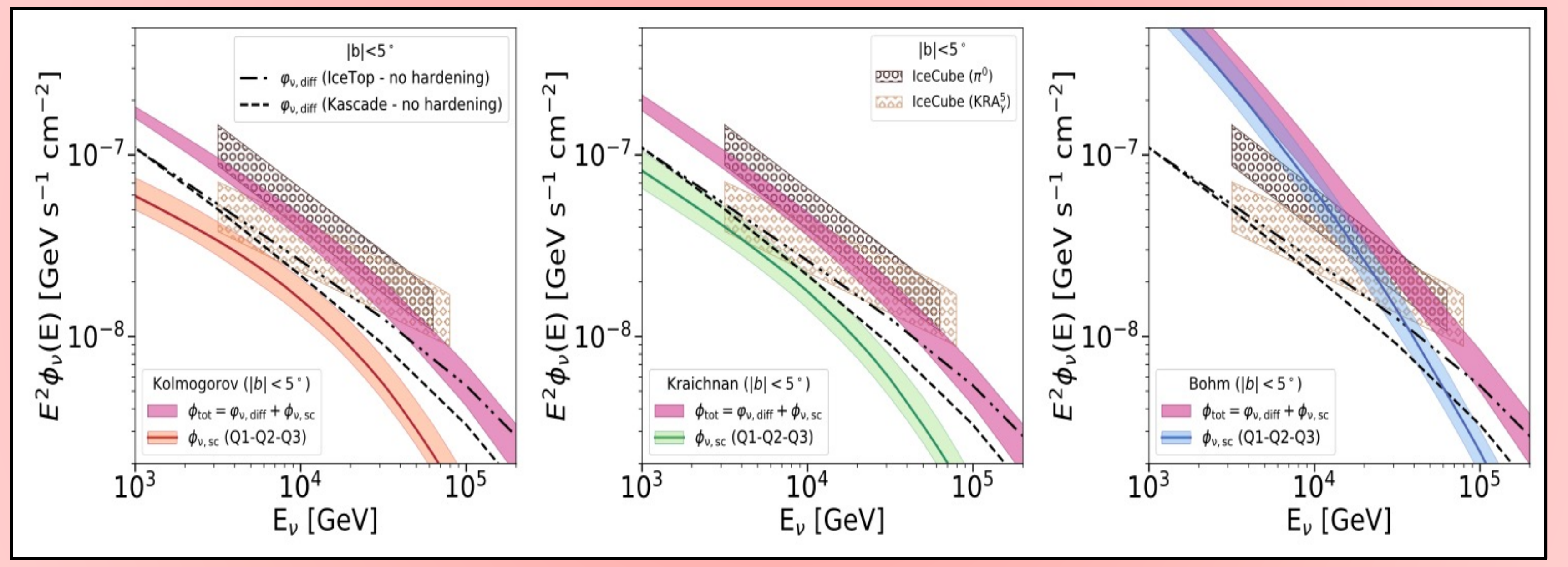


3. The Galactic Plane neutrino emission

For each realization of the YMSC Galactic population, we calculate the radial and energy dependent distribution function of **accelerated particles in both winds and supernova remnants** [5], considering different particle diffusion domains within the bubble itself. We then compute the expected neutrino flux from **proton-proton collisions** in each cluster as:

$$\phi_{\nu,\rm sc}(E_\nu) = \frac{c}{4\pi d_{\rm sc}^2} \sum_{i=e,\mu,\tau} \int_{E_\nu}^{\infty} \int_0^{R_{\rm b}} 4\pi r^2 f_p(r, E_p) n(r) \frac{d\sigma_{\nu_i}(E_p, E_\nu)}{dE_\nu}\, dr\, dE_p$$

The **cumulative neutrino fluxes** from the simulated Milky Way population of YMSCs are shown in the following panels via colored bands (orange, green, and blue, respectively for from Kolomogorov, Kraichnan, and Bohm, as indicated in the legend), assuming a standard 10% CR conversion efficiency.



IceCube observations of the Galactic Plane neutrino emission [6] are also shown in the **latitude range |b|<5 deg** for a qualitative comparison, given that the tested templates (KRA_γ and π^0) are different from the one here presented. The latter in fact only model the **CR-induced neutrino component**, produced by hadronic collisions among CRs and gas along the Galactic Plane. We further include this additional purely diffuse Galactic neutrino component, adopting the model by [7] for **CRs** while taking the **target gas profile** from GALPROP [8].

The total neutrino fluxes from both YMSCs and the diffuse CR-induced component is shown in each panel in magenta. While the most effective confinement domain of particles (i.e. Bohm diffusion) tends to overshoot IceCube data below neutrino energies of 10 TeV, **both Kolmogorov and Kraichnan appear consistent with current measurements.**

References:

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The content of this poster is contained in a manuscript currently under submission, more details can be found in [5].

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