Gamma-ray halos in the HE and VHE Galactic landscape

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Abstract

The recent discovery of long-lived and large-size gamma-ray emission structures around a handful of middle-aged pulsars (Abeysekara et al. 2017) raised the question of their actual place in the high-energy (HE) and very-high-energy (VHE) Galactic landscape. If most pulsars develop such gamma-ray halos over several 100 kyr, harnessing the gamma-ray observations of our Galaxy might become challenging, especially at the highest energies: source confusion along the plane, observational/analysis strategies to allow safe background estimates, disentangling halos from larger-scale interstellar emission,… We have developed a Galactic halo population model in order to assess the possible contribution of halos to the gamma-ray emission of the Milky Way. In this poster, we present preliminary results focusing on two questions: 1) How many halos may/will be in reach of VHE instruments? 2) How do they relate to the larger-scale diffuse emission?

Halo population models

Individual halos are modeled following Tang et al. 2019, with reduced pair diffusion within 50 pc of the pulsar calibrated to match the Geminga halo profile. This is then included in a randomly generated SNRs+PWNe+halos population model for our Galaxy, in which halos are assumed to be the evolution of PWNe past about 60 kyr (Giacinti et al. 2019). Values/distributions for some key halo parameters, such as particle injection efficiency or spectrum, are calibrated to match the flux distribution of known sources, as illustrated in Fig. 1. One realization of the halo population of this model is referred to as Model A. An alternative Model B is computed with the same halo parameters but starting from known pulsars with ages <1 Myr and distances <10 kpc extracted from the ATNF catalog (Manchester et al. 2005). Model B is useful in identifying halo candidates, while model A compensates for biases in the known radio pulsar population and is useful in assessing the total population emission.

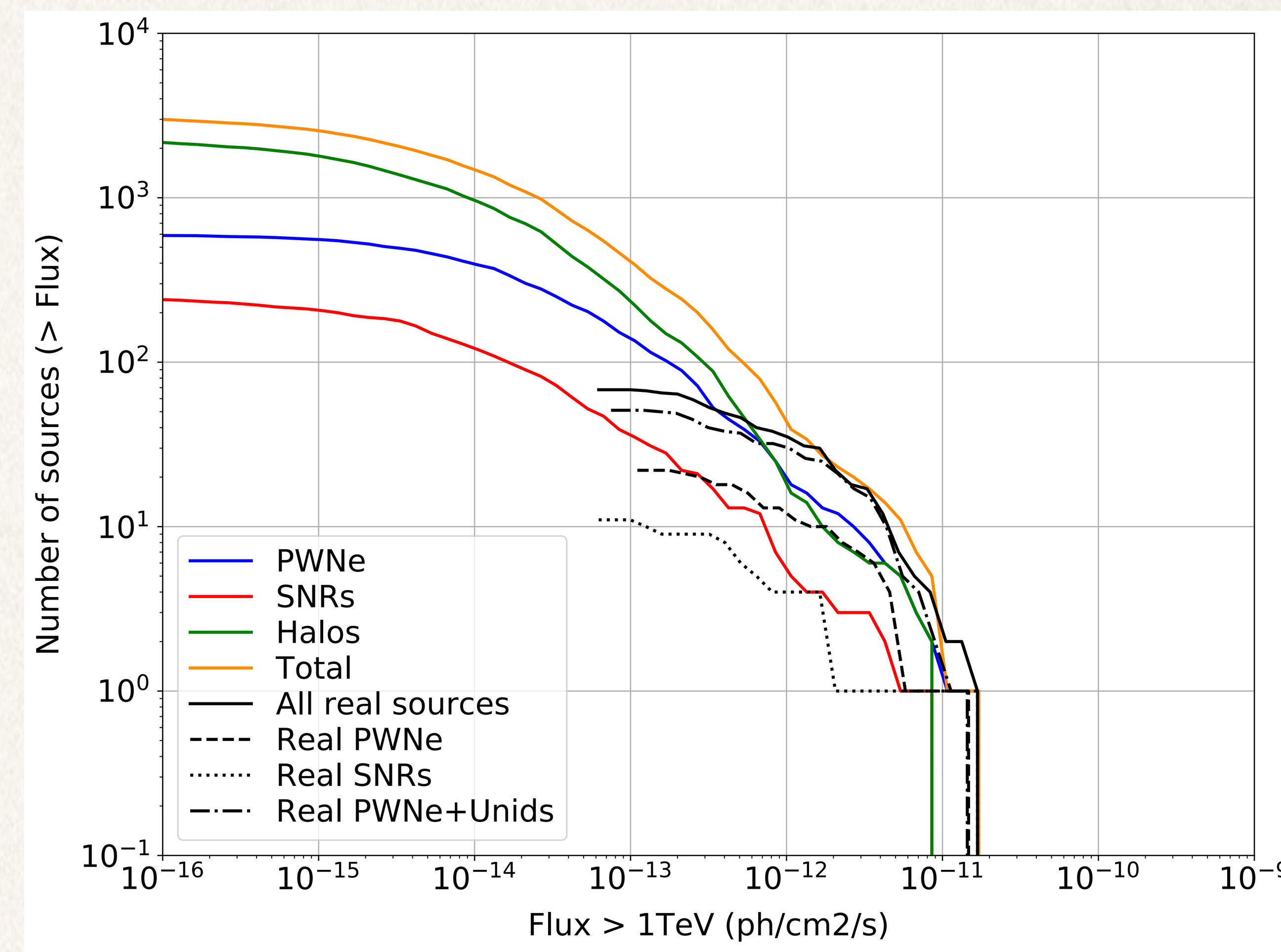

Fig. 1: Flux distribution of one realization of the SNRs+PWNe+halos source population (model A), compared to sources listed in the gamma-cat catalog.

Prospects for halo detectability

We focus on detection in the VHE range with IACTs. In Fig. 2, we compare the predicted halos emission to point-source sensitivities of 1,10,100 mCrab in the 1-10 TeV range, assuming sensitivity to extended sources degrades with source size (Hinton&Hofmann 2009). Given the current level of sensitivity in the Galactic plane, about 1 Crab for H.E.S.S., both models A and B indicate that a dozen objects should be in reach of existing instruments based on flux level only, but some have a degree-scale size and may be challenging to extract, not to mention source confusion in crowded regions. Model B suggests that going down to ~1mCrab sensitivities may triple the pool of accessible halos around know radio pulsars,. In addition, the mock population of sources in model A suggests that dozens of more distant and smaller-size halos could become detectable. A case-by-case investigation in underway to evaluate the potential of targets around known radio halos.

Relation to the galactic interstellar diffuse

From the detection prospects presented in Fig. 2, we have assessed the diffuse emission level from the remaining unresolved halo population in model A, as illustrated in Fig. 3. The total emission from halos is at best comparable or exceeds a baseline minimal model for the galactic diffuse in the plane above 100 GeV. As sensitivity improves down to 1mCrab, a larger fraction of sources is resolved out but the unresolved contribution remains high above 1TeV.

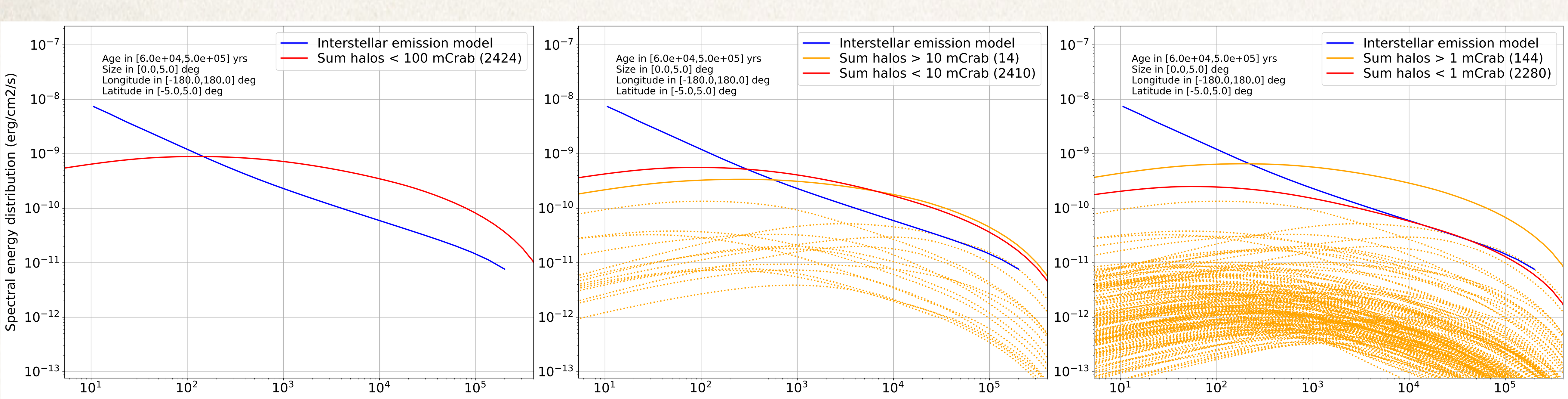

Fig. 3: Total resolved and unresolved halo emission along the plane in model A, for sensitivities of 100, 10, and 1mCrab from left to right, compared to a minimal model for the larger-scale Galactic diffuse emission. Individual spectra for detected halos are plotted as orange dotted lines.

We thank D. Gaggero for providing the interstellar emission model, a slightly modified version of the KRA model presented in Gaggero et al. (2015, ApJL, 815, L25) that will be presented in a forthcoming paper by Dundovic et al. « Simulating the Galactic Multi-messenger Emissions with HERMES ».

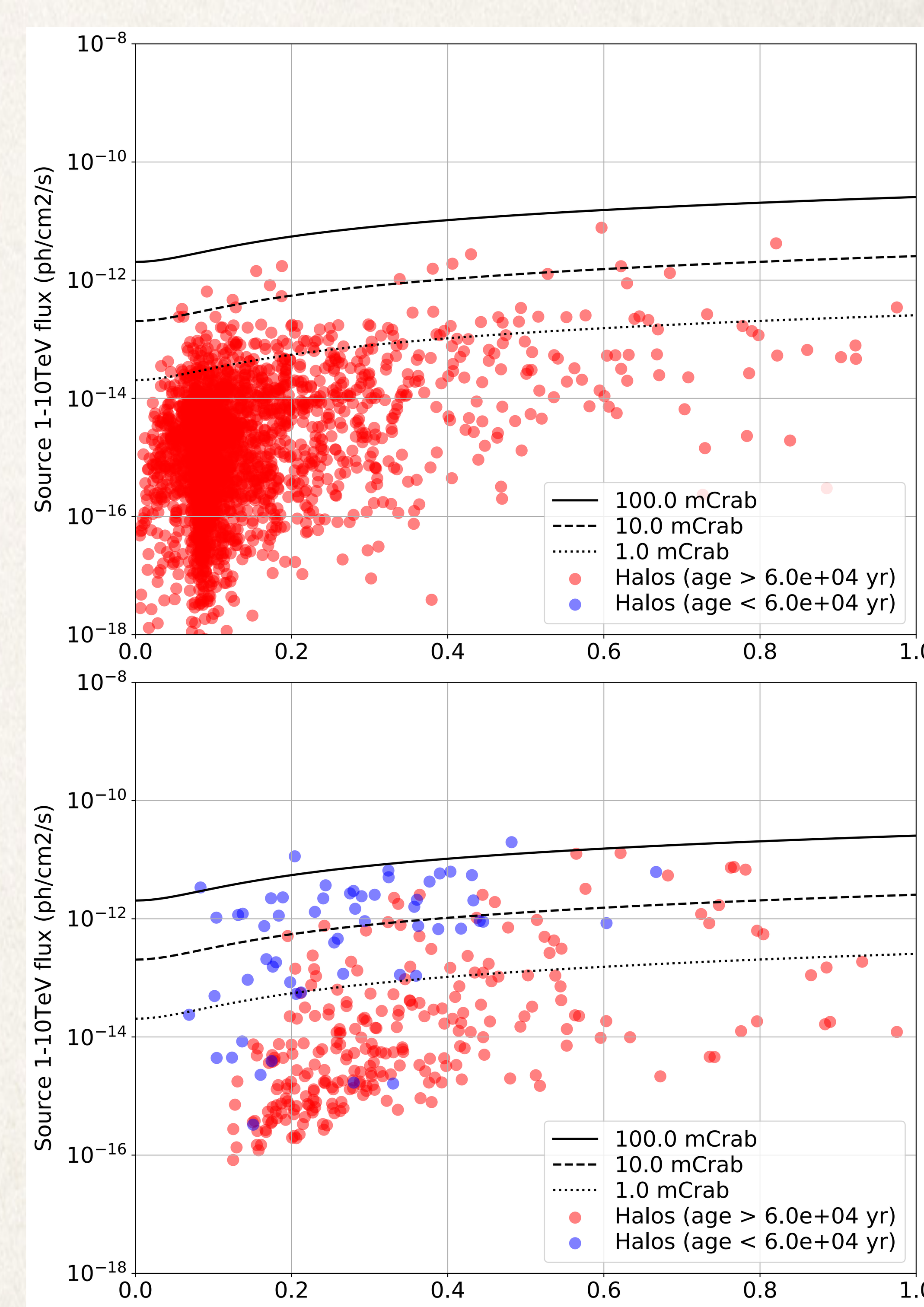

Fig. 2: Detectability of the halo populations in models A and B (top and bottom) for different levels of sensitivities. In model B, pulsars younger than 60 kyr are marked in blue as they may be associated with PWNe rather than halos

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- gamma-cat (see https://github.com/gammapy/gamma-cat)
- Naima (see https://naima.readthedocs.io/en/latest/ and Zabalza 2015)