Escape of PeV particles from stellar wind termination shocks

Very energetic charged particles (mainly protons) coming from different places in the Milky Way and other galaxies finish their journey across the interstellar medium (ISM) by reaching the Earth's atmosphere where we can detect them: they are called Cosmic rays (CRs). They have a crucial role in the galactic ecosystem: they impact space plasma and magnetic fields, they have effects on the gas dynamics, drive the evolution of molecular clouds and regulate the stars formation. However, the way they are accelerated to such tremendous energies and transported across the ISM is still not very well understood. In particular, PeV CRs are very intriguing since they mark the limit of acceleration of galactic sources and can therefore constitute a very important tool to push the acceleration models to their limits.

CRs are pretty difficult to detect directly since they are diffused in the ISM. Hence, the detections methods are mostly indirect and based on the photons that are produced when CRs interact with ambient matter (mainly in X rays and gamma rays). Up until very recently, the available data on multi-PeV CRs were very poor as the detection band of corresponding photons (>0.1 PeV) was not well probed by the already existing detectors. But in 2021, the Large High Altitude Air Shower Observatory (LHAASO) has been completed. It is the most sensitive instrument probing the sky in the ultra-high-energy (>0.1 PeV) gamma-ray domain and has already detected tens of sources whose spectra extend to PeV energies, that have been tentatively associated with three classes of galactic sources: pulsar wind nebulae, supernova remnants, and stellar wind from massive stellar clusters. Therefore, LHAASO gamma-ray data can be used to constrain galactic particle acceleration models, and to identify the contribution from each class of sources mentioned above to the observed cosmic ray flux in the PeV domain.

In order to do that, we must first study the escape and transport of protons from their source to molecular clouds, where a lot of p-p interactions producing gamma rays (then detectable by LHAASO) occur. In my work, I am focusing on the case where the source is a massive star cluster, hence the particles are accelerated in stellar wind termination shocks before escaping. And I try to determine in a semi-analytical approach the parameters needed (distance between cloud and source, time, slope of injection, number of stars, etc) to produce an excess of gamma ray flux corresponding to PeV CRs that could be detectable by LHAASO. That enables first to construct a model for transport that will be needed to make the link between LHAASO data and the constraints for acceleration parameters, and that would also enable to tell where do we have to point LHAASO to have big probabilities to observe PeVatrons, to have more data and better constraints.