Summary

Title: Morphology of Gamma-Ray Halos around Middle-Aged Pulsars: Influence of the Pulsar Proper Motion

Abstract: Recently, gamma-ray halos of a few degree extension have been detected around two middle-aged pulsars, namely, Geminga and PSR B0656+14, by the High Altitude Water Cherenkov observatory (HAWC). The gamma-ray radiation arise from relativistic electrons that escape the pulsar wind nebula, diffuse in the surrounding medium and interact with the background photon field. The diffusion coefficient is found to be significantly lower than the average value in the Galactic disk. If so, given a typical transverse velocity of 300-500 km/s for a pulsar, the displacement of the pulsars due to the proper motion could be important in shaping the morphology of the pulsar halos.

Motivated by this, we study the morphology of pulsar halos considering the proper motion of pulsar. We divide the evolution of the pulsar halo into three characteristic phases, that can categorize its morphological features and help to interpret the origin of the pulsar halo.

We quantitatively define two kinds of offsets between the pulsar halo and the pulsar. The maximum separation angle induced by pulsar proper motion can be given by $\Theta_{max}=3^{\circ}(E_{\gamma}/1TeV\})^{0.77}(v_{tr}/400km\ s^{-1})(d/2kpc)^{-1}$ empirically, assuming B=3μG.

We discuss whether the extended sources observed by HAWC and LHAASO can be associated with pulsar. Generally, above 10\,TeV, the offset between extended sources and candidate pulsar is hard to be explained by pulsar proper motion. Our result can help to interpret the origins of the observed extended sources at very high energies.