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Morphology of Gamma-ray Halos around Middle-aged Pulsars: Influence of the Pulsar Proper Motion

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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 and diffuse in the surrounding medium. The diffusion coefficient is found to be significantly lower than the average value in the Galactic disk. If so, given a typical proper velocity of $400 - 500\,\mathrm{km/s}$ 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. We find that the morphology of the pulsar halo can be basically classified into three evolutionary phases, depending on the proper velocity, the cooling of the emitting electrons and the diffusion coefficient. Generally, the morphology would appear highly asymmetric at ≤ 1 TeV while keeps more or less spherical at ≥ 10 TeV for middle-aged pulsars. The proper motion can induce observable offsets between the position of the pulsar and the center of the halo from GeV up to a few TeV energies provided that the source is located within several kpc from Earth. It is more difficult to produce resolvable offset of the pulsar halo at higher energy due to more rapid cooling of emitting electrons. Our result can provide constraints on the origins of the observed extended sources at very high energies.

Keywords

Gamma-ray; TeV Halo; Pulsar

Collaboration

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Subcategory

Theoretical Results

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