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On the potential of bright, young pulsars to power ultra-high gamma-ray sources

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The recent discovery of a new population of ultra-high-energy gamma-ray sources with spectra extending beyond 100 TeV revealed the presence of Galactic PeVatrons - cosmic-ray factories accelerating particles to PeV energies. These sources, except for the one associated with the Crab Nebula, are not yet identified. With an extension of 1 degree or more, most of them contain several potential counterparts, including Supernova Remnants, young stellar clusters and Pulsar Wind Nebulae (PWNe), which can perform as PeVatrons and thus power the surrounding diffuse ultra-high energy gamma-ray structures. In the case of PWNe, gamma rays are produced by electrons, accelerated at the pulsar wind termination shock, through the inverse Compton scattering of 2.7 K CMB radiation. The high conversion efficiency of pulsar rotational power to relativistic electrons, combined with the short cooling timescales, allow gamma-ray luminosities up to the level of $L_\gamma \sim 0.1\dot{E}$. The pulsar spin-down luminosity, $\dot{E}$, also determines the absolute maximum energy of individual photons: $E_{\gamma\ \mathrm{max}} \approx 0.9\dot{E}_{36}^{0.65}$ PeV. This fundamental constraint dominates over the condition set by synchrotron energy losses of electrons for young PWNe with typical magnetic field of ≈100~μG with $\dot{E} < 10^{37}$ erg/s. We will discuss the implications of $E_{\gamma\ \mathrm{max}}$ by comparing it with the highest energy photons reported by LHAASO from a dozen of ultra-high-energy sources.

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