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Studying the flaring emission of the Crab pulsar wind nebula system in high-energy gamma-rays

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The Crab system, composed of a bright pulsar wind nebula (PWN) powered by the young energetic central pulsar PSR B0531+21 , has been observed across the electromagnetic spectrum for decades of investigation. Its emission in the gamma-ray band has challenged our understanding of the radiation and particle acceleration processes at play for such systems. In addition to the steady-state synchrotron emission from the PWN, sporadic flares have been observed in the energy range from a few hundreds of MeV to a few GeV.

By analysing available Fermi-LAT data across a fourteen-year-long monitoring, we study the energy-dependence and time-variability of the high-energy flares. Using a sample of flaring epochs derived by Bayesian-block analysis, we investigate the short and longer term effects on the steady-state emission of the system, while attempting characterising the significantflares in terms of their spectral evolution with time. Finally, we discuss the extent to which our latest results can place constraints on particle acceleration in the pulsar wind.

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1. Astrophysical context

The Crab composite system encompasses several directly and inderectly observable components. Its central power engine, the young and energetic pulsar PSR B0531+21 , a fast-rotating neutron star, generates a magnetised pulsar wind of predominately ultra-relativistic electron-positron pairs. The bulk energy of the cold and relativistic upstream plasma dissipates at a given spatial boundary, defined by the equalisation of the unshocked wind ram pressure with the shocked wind pressure in the expanding bubble of relativistic leptons : the termination shock (TS) of the PW. At this shock-driven boundary, a bright extended pulsar wind nebula is formed and is ex- panding at early evolutionary stages within a larger and also initially freely-expanding shocked and unshocked ejecta-filled nebula.

The Crab pulsar has a uniquely broadband emission, from radio to VHE gamma-ray ranges. Its observed radio pulsations provide derived characteristics such as a period of 33 ms and spin-down power of 5.10^{38} erg.s^{-1}.

In order to explain the emission associated with its pulsar wind nebula, in a conventional evolution scenario, the acceleration region size would be bounded by the shock of the pulsar wind. The deposited accelerated electrons and positrons at the TS, will then radiate via synchrotron and inverse Compton scattering processes, rendering a bright extended region seen also from radio to the ultra-high-energy gamma-ray band.

2. Data analysis

2.1 Gating the pulsar emission

2.2 Fermi-LAT

3. Synchrotron emission

3.1 Spectral energy distributions

3.2 Light-curves

4. Time-variability

4.1 Flares

4.2 Emission states

4.3 Power spectra

5. Outlook

References

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