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Constraining emission and scattering properties of the Crab pulsar through VLBI

Robert Main[(1)], Marten van Kerkwijk[(1)], Ue-Li Pen[(2)]
(1) University of Toronto, Toronto, ON
(2) Canadian Institute for Theoretical Astrophysics, Toronto, ON

Extended Abstract

The crab pulsar has a striking radio profile, with two pulse components comprised of giant pulses - randomly occurring pulses which extend to extraordinary energies (see [1] for a review). The Crab, like many pulsars, exhibits scintillation – a pattern in frequency and time arising from interfering scattered images. The scattered images can be mapped through VLBI [2], and changes in the scintillation pattern can be used to measure physical separations at the pulsar surface on ~km scales [3]. The Crab pulsar is a unique scattering system; the majority of temporal scattering is induced by its surrounding nebula [4], while the angular broadening measured through VLBI requires scattering much closer to us along the line of sight [5]. The resolution of the scintillation pattern depends on where the scattering occurs; for the Crab pulsar, the nebular scattering gives a resolution smaller than the Crab's light cylinder, essentially putting the pulsar under a microscope. This means it is possible to distinguish between physical locations for the different components of the Crab pulsar's emission through its scintillation properties. Specifically, the Crab's radio profile consists of two phase windows where giant pulses originate, the main pulse and interpulse. A comparison of their scintillation spectra can tell whether they share a physical origin, and set observational constraints on the emission mechanism responsible for them.

The largest uncertainties in this method arise from the unknown location of the scattering screens. To this end, we have undertaken VLBI campaigns across a large range of frequencies. This includes observations with existing VLBI infrastructure of the European VLBI Network (EVN) with Arecibo at high frequency (1650MHz), as well as wide-band 400-800 MHz observations between the Algonquin Radio Observatory and the Dominion Radio Astronomical Observatory, and a 150MHz observation between the Murchison Widefield Array (MWA) and the Giant Metrewave Radio Telescope (GMRT). The high frequency observations can directly measure the scintillation pattern, revealing differences between the main pulse and interpulse; in cases of heightened scattering, even the scintillation pattern of main pulse pairs do not correlate. This implies a large physical separation between the two components, and an emission origin far from the pulsar's surface. At lower frequencies, the scattering screens are much larger, and can be resolved with ground based VLBI. The visibilities in conjunction with the scintillation properties both have measurable imprints relating to the scattering geometry. This allows us to constrain the source of the nebular scattering, and quantify the positional differences in the pulsar's emission, allowing us to determine the full scattering geometry.

References

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