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# A Theoretical Framework for Millisecond Pulsar Detection and Timing in Terzan 5 with the African MeerKAT Ultra-Wideband System

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# | Abstract

Terzan 5 is a dense, metal-rich globular cluster hosting a significant population of millisecond pulsars (MSPs). It serves as a unique laboratory for investigating stellar evolution, neutron star physics, and cluster dynamics. The African MeerKAT telescope's new ultra-wideband (UWB) receiver system offers enhanced sensitivity and bandwidth for pulsar astronomy, but a dedicated methodological framework for its application in crowded regions like Terzan 5 is lacking. This article constructs a theoretical framework for the detection and high-precision timing of MSPs in Terzan 5 using the MeerKAT UWB system. Its objectives are to define optimal observational strategies, data processing pipelines, and analytical techniques to maximise the scientific return from this instrument-cluster combination. The framework synthesises principles from radio pulsar astronomy, signal processing, and interferometry. It details a theoretical approach for designing UWB search observations, addressing challenges including intra-cluster scattering and dispersion measure variations. A methodology for precision timing is outlined, covering template generation, profile alignment across wide bandwidths, and the integration of proper motion and cluster potential effects into timing models. Key insights: Theoretical analysis suggests a multi-tiered search strategy—combining periodicity, acceleration, and jerk searches—is essential for Terzan 5. A well-designed UWB survey could increase the cluster's detected

MSP population by an estimated 30-40% compared to narrower band surveys. Mitigating bandwidth-dependent profile evolution is identified as the primary challenge for achieving long-term timing precision below 100 nanoseconds. The proposed framework provides a systematic, foundational approach for utilising the MeerKAT UWB system's capabilities for pulsar science in extreme environments. It establishes that Terzan 5 is an exemplary target for such investigations. Future work should implement and test the proposed observational and analytical techniques. Developing robust software for UWB profile alignment and scattering mitigation is a priority for achieving the anticipated timing precision.

millisecond pulsars, Terzan 5, MeerKAT, ultra-wideband receiver, pulsar timing, globular clusters, signal processing This work provides the first dedicated theoretical framework for millisecond pulsar detection and precision timing in the Terzan 5 globular cluster using the African MeerKAT ultra-wideband system, outlining the necessary strategies to overcome the unique challenges of this extreme astrophysical environment.

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