EP Performance Verification (PV) Targets Recommendation Form

Submission Due Date: 15th October 2023

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1. TITLE

Verifying the timing capability of FXT by observing QPOs of the neutron-star low-mass X-ray binary 4U 1636-536

2. ABSTRACT *(< 250 words)*

We propose to take advantage of the capabilities of the Einstein Probe (EP) to study in depth the quasi-periodic oscillations (QPOs) in a neutron star binary system. The high time resolution and sensitivity of EP make it ideal for studying QPOs and using them as a probe of the neutron star accretion process. We recommend 36 ks of EP FXT observations of the source 4U 1636-536. The new timing and spectral data will be analysed to investigate its possible QPO phenomena and spectral features, such as spectral indices. These observations during the PV phase are essential to verify the capabilities of FXT and ensure its optimal performance in detecting the extreme properties associated with accreting compact objects.

3. RECOMMENDERS' INFORMATION

Principal Recommender	
***Recommender' Name**	Rong-Feng Shen
***Recommender' Email Address**	shenrf3@mail.sysu.edu.cn
***Recommender' Expertise**	Dr. Shen works in the area of black hole-related transient sources, such as gamma-ray bursts, tidal disruption events, and ultra-luminous X-ray sources.
***Recommender' STP(s)**	1, 2
Co-Recommenders	
***Recommenders' Names**	Guo-Ying Zhao
***Recommenders' Email Addresses**	zhaogy28@mail2.sysu.edu.cn
***Recommenders' Expertise**	A 2nd-year doctoral student, Guo-Ying Zhao works on GRB phenomena and XRB timing and spectral properties. In her

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	master thesis work (Zhao et al. 2022), she analysed the X-ray spectral of the binary 4U 1636-536, trying to understand how the high-energy X-ray photons released in a photosphere-expansion burst interact with the surrounding accretion disc.
***Recommenders' STP(s)**	Not a member or associate member yet

4. TARGET FORM

- **TARGET 1** ***(mandatory)***

***Target Name**	4U 1636-536			
***Target Type**	NS Low Mass X-ray Binary			
***Target Coordinates**	***RA:**	16:40:58.1	***DEC:**	-53:45:40.4
***Expected Flux in 0.3-10 keV**	1e-9 erg/cm^2/s			
***Primary Instrument**	FXT			
FXT Configuration ***(mandatory if the primary instrument is FXT, optional if the primary instrument is WXT)***	**FXT-A**	timing mode, medium	**FXT-B**	timing mode, medium
***Exposure Time**	Six exposures, each lasting 6 ks			
Suggest Joint Observation with Other X-ray Telescopes	N/A			
Other remarks	N/A			
*Note: * mandatory items*				

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5. SCIENTIFIC AND TECHNICAL JUSTIFICATION

(< 2 pages in total for this session, including figures, tables and references)

- **Scientific Motivations and Values**

We propose to use EP to observe one neutron star X-ray binary source 4U 1636-536, which will allow us to study the QPO in detail and thus better understand the structure of the accretion disc, the motion of the material, and the gravitational interactions, which are essential for understanding the process of accretion by compact objects.

By analysing the frequency, amplitude and spectral properties of the QPO, we can infer the mass, rotational speed, size and other parameters of the object, thus providing important data for astrophysical studies (Miller et al. 1998).

These research goals are included in the EP validation programme because QPO studies may require higher quality, more frequent or longer observations, and EP, with its high temporal resolution and long detection times (Yuan et al. 2022), can validate that the instrument is capable of delivering the required performance.

- **EP Capabilities to be Verified**

This target source observation will verify the high time resolution performance of the FXT (Yuan et al. 2022). We will observe QPO phenomena at different frequencies to test the performance of the FXT at high time resolution.

- **Immediate Objectives**

We propose to conduct EP observations of the neutron star binary 4U 1636-536 to achieve the following near-term goals:

1) Observe the QPO frequency and intensity of this target source (Lin et al. 2010).
2) Study the time-domain and energy-spectrum properties of the QPO phenomenon and the variation of the QPO frequency and amplitude with energy to understand the physical mechanisms.
3) Explore the relationship between the QPO phenomenon and other parameters of neutron star binary systems (e.g., mass, rotation speed, and orbital radius) to study their formation mechanisms and evolutionary processes.
4) Track the variation of the QPO phenomenon with time to detect potential periodic variations or instabilities (Lyu et al. 2010).

- **Technical Justification (e.g. target visibility during the PV phase)**

1) Our target 4U 1636-536 is a very bright X-ray source with a flux of ~10^{-9} erg/cm^2/s (Mondal et al. 2022), which is within the sensitivity range of the FXT and therefore available for detailed observations in the X-ray band.
2) The target has a good visibility for the EP FXT during the PV phase (~ 2024 March) of EP.
3) Our target source has been extensively studied and it shows QPO phenomena (Hsieh et al. 2020 & Lyu et al. 2014). Previous observations have identified QPO frequencies and observed their frequency and intensity to vary with time. This makes these target sources ideal candidates for an in-depth study of the nature and mechanism of QPO. In order to achieve the goal of studying the QPO phenomenon in neutron star low-mass X-ray binaries in depth, we need an instrument with high temporal resolution, which is exactly what the FXT provides.

- **References**

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[4] Lin Y F, Boutelier M, Barret D, et al. Studying Frequency Relations of kHz QPOs for 4U 1636-53 and Sco X-1: Observations Confront Theories. 2011, ApJ, 726, 74.

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[8] Lyu M, Méndez M, Altamirano D. Discovery of a correlation between the frequency of the mHz quasi-periodic oscillations and the neutron-star temperature in the low-mass X-ray binary 4U 1636–53. 2014, MNRAS, 445: 3659-3668.