EP Performance Verification (PV) Targets Recommendation Form

Submission Due Date: 15th October 2023

NOTE: Please do not change or delete the words marked in blue.

1. TITLE

Probing the Accretion Disk-Feeding Inflow for Unique Redshift-Balmer-BAL AGN with EP-FXT

2. ABSTRACT *(< 250 words)*

A fundamental question about AGN is how the accretion disc is fed with external gas. Zhou et al. (2019) presented the first compelling evidence from optical redshifted BALs for the long-sought inflow directly feeding the disc, and propose a global scenario including both inflow and outflow. X-ray observations, which so far have been lack of, will provide crucial verification of the inflow/outflow scenario by tracing the expected absorption of the continuum and characteristic features due to the inflow/outflow gas. Here we propose EP PV observations of 2 archetypal sources carefully selected from the sample of Zhou et al. with variable redshifted Hydrogen Balmer BALs. This program will provide, for the first time, high-quality X-ray data for investigating X-ray properties directly related to the inflow/outflow materials, verifying AGN disc-feeding inflow scenario, exploring the geometry and kinematics of the inflows, and thereby allowing us to better understand the AGN fuelling mechanism. It can also be used to verify the performance of FXT, especially the energy resolution at soft X-rays.

3. RECOMMENDERS' INFORMATION

Principal Recommender	
***Recommender' Name**	Zhou Hongyan
***Recommender' Email Address**	zhouhongyan@pric.org.cn
***Recommender' Expertise**	AGN emission/absorption line studies; high-energy astrophysics
***Recommender' STP(s)**	STP1, STP2
Co-Recommenders	
***Recommenders' Names**	Yuan W., Jin C.

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***Recommenders' Email Addresses**	wmy@nao.cas.cn, ccjin@bao.ac.cn
***Recommenders' Expertise**	high-energy astrophysics; AGN multi-wavelength study
***Recommenders' STP(s)**	STP1, STP4

4. TARGET FORM

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

***Target Name**	SDSS J103620.58+121734.8			
***Target Type**	AGN			
***Target Coordinates**	***RA:**	10:36:20.58	***DEC:**	+12:17:34.8
***Expected Flux in 0.3-10 keV**	2.1e-12 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**	full-frame, thin filter	**FXT-B**	full-frame, thin filter
***Exposure Time**	10 ks			
Suggest Joint Observation with Other X-ray Telescopes	Swift/XRT			
Other remarks				

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*Note: * mandatory items*	

- **TARGET 2**

***Target Name**	SDSS J094859.47+433518.9			
***Target Type**	AGN			
***Target Coordinates**	***RA:**	09:48:59.47	***DEC:**	+43:35:18.9
***Expected Flux in 0.3-10 keV**	5.6e-13 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**	full-frame, thin filter	**FXT-B**	full-frame, thin filter
***Exposure Time**	10 ks			
Suggest Joint Observation with Other X-ray Telescopes	Swift/XRT			
Other remarks				
*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**

Quasars are believed to be powered by the gravitational potential energy of accreted matter falling onto a super-massive black hole (SMBH). A fundamental question remains unanswered as to whether and how the accretion disk is supplied with external matter. A major progress was made by Zhou et al. (2019, Nature, 573, 83), who reported the discovery of the first compelling evidence for fast inflow directly feeding the outer accretion disc in a small sample of quasars (Fig.1 left panel). The inflows reveal themselves as highly redshifted broad absorption lines (BALs) of neutral H and He atoms in the optical spectra. Their absorption troughs show a broad range of Doppler velocities from zero extending continuously inward to 5000 km s^-1 (Fig.1 middle panel), comparable with the free-fall velocity at thousands of gravitational radii (Rg). With detailed photo-ionisation, the fastest part of the in-falling gas was found to partially overlap with the outer accretion disk at radii of 10^{3-4} Rg. These streams of cold external gas, with large inflowing velocities accelerated by the gravity of the SMBH (Fig.1 left panel) and predicted column densities typically 10^23 cm^-2, are feeding the accretion discs at an estimated rate comparable to the quasar radiative energy output, assuming an axis-symmetric geometry of the in-falling gases.

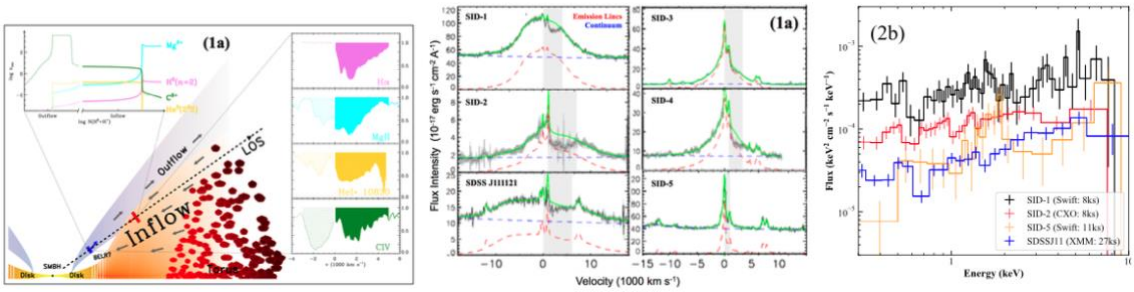

Figure1. Left: Schematic view of the central engine of quasars with both inflow and outflow, and the special LoS of the redshift-BAL AGN; Middle: fitting the optical spectrum around Ha line for some representative redshift-BAL AGN. A redshifted Ha-BAL is clearly identified in every sources as indicated by the grey region. Right: the X-ray spectra of 4 sources in the archive, where the possible signature of OVII K edge can be found at ~0.6 keV (AGN rest-frame).

However, this finding is based solely on analysis of the optical spectra and photo-ionisation modeling, and needs to be confronted with observations in X-rays, as the X-ray emission must also carry information as it passes through the inflowing and outflowing materials along the LOS (Fig.1 left panel). First of all, the predicted absorbed X-ray spectra can be tested straightaway. More meaningful is a quantitative comparison of the measured column density N_H from X-ray data with the model prediction. Since the redshifted BALs measures only the H and He atoms, which are only very small fractions of the H and He species in lowly ionised inflow gas, and the bulk of the gas is not directly measured and its properties are only derived based on the photo-ionisation modeling. An independently measured N_H from X-ray can provide

additional constraints to the Hydrogen density of the gas, which may help disentangle the degeneracy between N_H and the distance of the inflow to the black hole. Unlike the BAL of neutral H and He, the X-ray spectra are also sensitive to absorbing gas of warm ionisation, and thus they may probe different components of the inflows from the H/He BAL, and render us a more holistic view of the inflow.

Here we propose to observe 2 archetypal redshift-BAL AGN for EP PV observations with the following advantages.
(1) these 2 AGN show unambiguous redshifted BALs in the Balmer lines of neutral H and He, which correspond to the inflow speed of up to 8000 km s^-1.
(2) a physical scenario consisting of both inflow and outflow has been proposed. This scenario leads to predictions of physical conditions along the LOS, which can be directly tested with new X-ray observations.
(3) they are the brightest among the original sample. A possible O VII K-edge feature is also present in their X-ray spectra. It is promising that new EP-FXT observations can reveal these features with higher S/N.
(4) in comparison with previous snapshot X-ray observations, (non-)detection of the expected O VII absorption variabilities will shed new light on the geometry and kinematics of the inflows, considering the fact that dramatic variabilities already detected in hydrogen Balmer BALs (see Figure 2).

- **EP Capabilities to be verified**
  - **Spectral resolution of FXT:** The proposed targets will be used to verify the spectral performance of FXT, especially the spectral resolution at soft X-rays as some absorption features (e.g. OVII K-edge) is expected to be observed.
  - **Effective area and energy response of FXT:** with joint observation by Swift/XRT, the effective area of FXT and energy response can also be verified.
  - **WXT sensitivity:** the first AGN SDSS J1036 has an X-ray flux close to the sensitivity of WXT. Considering potential long-term AGN variability, there is possibility that its flux is above the detection limit of WXT during the EP observation, and so can be detected by both FXT and WXT.
- **Immediate Objectives**
  - Verifying and characterizing inflows from their absorption imprints in X-rays
  - If the no X-ray absorption found with FXT, the clouds would then obscure the BLR but not the X-ray emitting corona
  - If X-ray absorption found, the total gas column density will be measured
  - Test the spectral quality and resolution of the two FXT modules.
- **Technical Justification (e.g. target visibility during the PV phase)**

Both AGN have good visibility during the whole month of next March, so they should be easy to scheduled. Their expected X-ray fluxes as observed previously by XMM-Newton and Swift are all well above the detection limit of FXT, and should not

introduce significant pileup, so we choose full-frame mode with thin filter for both FXT modules.

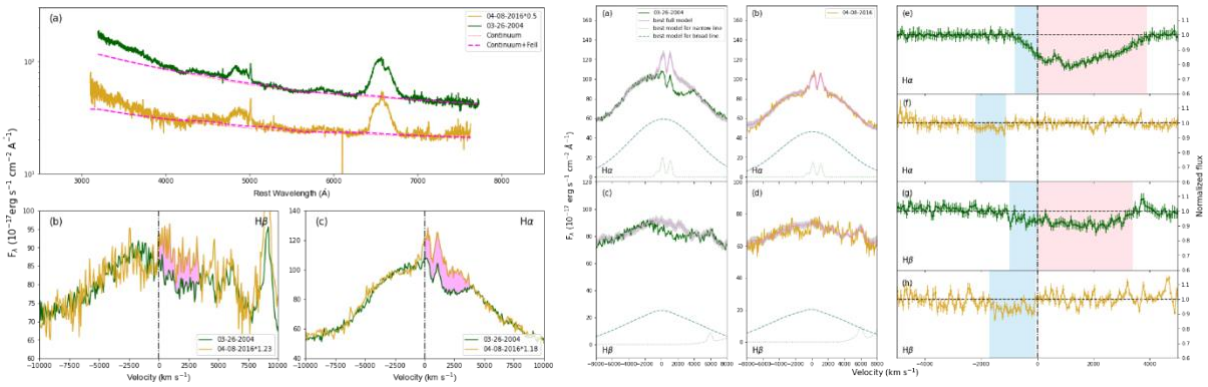

Fig. 2. Dramatic variabilities of the redshifted Balmer BALs detected in SDSS J103620.58+121734.8. Left. Direct comparison of two-epoch optical spectra (the latter epoch data scaled by a factor of 0.5 for clarity; variable H\alpha and H\beta BALs are filled with pink). Middle. Recover of the absorption-free spectra of the H\alpha and H\beta regimes. Right. Normalized H\alpha and H\beta BAL spectra.

- **References**

  - Zhou H., et al., 2019, Nature, 573, 83, Fast Inflow Directly Feeding Black Hole Accretion Disk in Quasars
  - Jin C. et al., 2017, MNRAS, 471, 706, Super-Eddington QSO RX J0439.6-5311 - II. global structure of the accretion flow;
  - Shi X., et al., 2016, ApJ, 829, 96, The Redshifted Hydrogen Balmer and Metastable He I Absorption Line System in Mini-FeLoBAL Quasar SDSSJ112526.12+002901.3: A Parsec-scale Accretion Inflow?