FERO (Finding Extreme Relativistic Objects)

Statistics of Relativistic Fe K_α lines in Type1 AGN

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Abstract

Based on a large collection of 149 XMM-Newton archival data of un-obscured radio-quiet AGN, the FERO project is addressed to systematically study the properties of relativistic emission in type 1 active galaxies, both in individual objects and collectively as a sample. We will describe here the details of the analysis carried out and discuss briefly the main results and conclusions of the study, including, detection fractions, broad line average properties and dependence of line properties with physical parameters.

Key words: quasars: emission lines - galaxies: nuclei - galaxies: active - X-ray: galaxies - line: profiles

1. Introduction

The detection of a broadened and skewed Fe K_α line in AGN spectra is generally interpreted as an effect on X-ray photons due to the gravitational field of the central black hole. Measuring the parameters of broad Fe lines provides therefore a diagnostic of the accretion disc structure. The presence of this feature has been debated among the AGN community for a long time. Most studies of bright individual sources have shown that the detection of a broad line can be very dependent on the assumed spectral model. Recent works on large samples of AGNs converged to say that the broad line is more common in low luminosity AGN (Nandra et al. 1997, 2006, Streblyanska et al. 2005, Guainazzi et al. 2006) but there is no agreement on the fraction of detected broad Fe lines and on the average line intensity. The FERO project is designed to address these questions in a systematic way, by looking at the properties of relativistic emission in type 1 active galaxies, both in individual objects and collectively as a sample. Two papers are in preparation, one to report on the spectral analysis of the individual sources of the sample (de la Calle I. et al. in preparation), and a second one devoted to the analysis of the stacked spectra (Longinotti et al. in preparation), where full details of the work will be given. Here we only highlight the main aspects of the work.

2. The Sample

The FERO sample proceeds from the CAIXA sample (Bianchi et al. 2009), and consists of 149 radio-quiet type 1 AGN (67 are classified as Quasars (RQQs) and 82 classified as Seyfert 1s (Sy)). Only sources with $N_H \leq 2\ 10^{22}$ cm^{-2} are included in the sample to avoid heavily absorbed spectra in the 2 to 10 keV spectral region. No redshift restriction has been imposed to the sample selection (90% of sources with redshift $\leq$0.5). When needed, source properties are extracted from the CAIXA sample. The FERO sources were cross-correlated with the RXTE all-sky Slew Survey (Revnivtsev et al. 2004) sources having a count rate in the 3-8 keV energy band greater than 1 cts/sec. This defines a flux-limited sample of 31 sources that are used as a control sample.

3. Analysis

The data used for the FERO project comes from >200 XMM-Newton observations public up to April 2008. Individual observation exposure times range between 1 ksec and 400 ksec, with 90% of observations <100 ksec exposure. Where multiple observations of the same source were available, the individual spectra were combined and treated, for all purposes, as a single observation. Only EPIC-pn data, from different observing modes, has been used. The time-averaged spectra were re-binned with 25 background subtracted cts/channel, and >3 channels. For the spectral analysis, a pre-analysis cut is imposed: only source spectra with good

statistics are fitted (>17 d.o.f). The fit was restricted to the 2 to 10 keV energy rest frame, and the same model has been uniformly applied to the whole sample. In the stacked spectra analysis, only sources with broad line upper limits are considered. Stacked ratios are calculated as weighted means of individual ratio plots.

4. The Model

All spectra have been uniformly fitted with the following baseline model (9 components with a total of 14 free independently-fitted parameters): warm absorber (*absori*), Compton reflection from neutral material (*pexrav*), a series of five zero-width lines, 6.4 keV (neutral Fe I K_α), 6.7 keV (ionized Fe XXV), 6.96 keV (ionized Fe XXVI) and 7.06 keV (neutral Fe I K_β) and Fe I 6.4 keV Compton Shoulder, and last, a relativistic broad line (*kyrline*). During the fitting procedure some limitations are introduced to some model parameters as well as carrying out different *runs* to tests different model components. In particular, we tested ionized reflection (*pexriv*) and relativistic 6.7 keV Fe line. The results presented here come from a merge of the two runs, neutral and ionized reflection.

5. Results

The results presented are given based on the analysis of individual sources and in terms of the stacked spectra.

5.1. Fe Broad Line Detections

The fraction of relativistic Fe lines detected in the FERO sample is 7±3% (11/149). Considering only the sources from the flux-limited sample, the detection fraction rises to 36±14% (11/31). Figure 1 shows the equivalent width of the broad 6.4 keV Fe K_α line vs. hard X-ray counts (2-10 keV) for the FERO sources. Two caveats apply in the derivation of the detection fractions. First, the detections of 1H0707-495 and PG1211+143 are not considered. Second, these fractions include the detections from the neutral and ionized reflection runs. The neutral run yields 9 detections, and the ionized run yields two extra detections: Mrk766 and ARK120, and is favored over the neutral run for Mrk509.

The average broad line EW is of the order of 100 eV (never higher than 300 eV for any given source). The average system properties (as inferred from the kyrline model) are: $<\phi>\sim 28\pm5^\circ$ for the disk inclination angle and $<\beta>\sim 2.4\pm0.4$ for the disk emissivity. With only two spin measurements (MCG-6-30-15: 0.86 $(^{+0.01}_{-0.02})$ and Mrk509: 0.78 $(^{+0.03}_{-0.04})$) no mean value has been derived. In terms of correlations, no significant correlations have been found between the broad line EW and any of the source physical properties investigated: accretion rate, hard X-ray luminosity or Black Hole Mass.

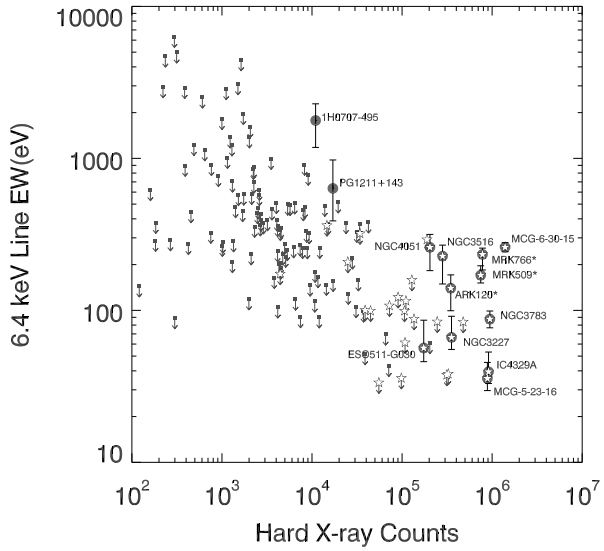

Fig. 1. Equivalent width of the broad 6.4 keV Fe K_α line vs. hard X-ray counts (2-10 keV) for the FERO sources. Filled circles indicate line detections at the 5σ confidence level (where error bars indicate the 90% c.l. intervals), while filled squares indicate line upper limits at the 90% c.l.. White stars indicate sources belonging to the flux-limited sample.

5.2. Stacked Spectra

Broad lines in the stack spectra are weak, being the line intensity never higher than 80 eV. There is tentative evidence of a trend with hard X-ray luminosity, where a broad line is favored in lower luminosity sources. Possible trends with physical property drivers are inconclusive, and those with source type are to be investigated (like Seyferts and Quasars or narrow line and broad line).

6. Conclusions

The main results of this work may be summarized as follows: a) Strong broad Fe lines are found only in AGN with spectra of extremely good statistical quality b) Stacking of the upper limits shows that the red wing is far less common than expected and that any broad line emission is nearly absent in sources at higher 2-10 keV luminosity.

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