Reverberation in a narrow relativistic line Seyfert galaxy

S Kalli 1 2 and A Zoghbi3
1 Departement of Physics, University Mohamed Boudiaf, M'sila, ALGERIA
2 Laboratoire LPMS, University Constantine1, ALGERIA
3 Departement of Astronomie, Michigan University, Michigan, USA
E-mail: k.sihem@gmail.com

Abstract. Seyfert galaxy NGC 5506 is an excellent target for X-rays reverberation, since its spectrum shows both narrow and broad components of the Kα Iron line, and its AGN shows strong X-rays variability. Using different XMM-Newton satellite observations, we study the spectrum in the energy band 2-10 keV.

1. Introduction
Seyfert galaxies are active galactic nuclei (AGN) with a spiral shape and intense emission lines spectra. There exists two subclasses of Seyfert galaxies, type I with a spectrum containing both narrow emission lines and broad emission lines, and type II with a spectrum containing only narrow emission lines. Observations have shown that most of X-rays are emmited in the vicinity of the black hole. In the accretion disc corona, a power law X-rays specrum is produced from multiple inverse Compton scattering of optical/UV photons by hot thermal electrons. Part of the produced X-rays will be reflected in different regions of the accretion disc. This will imply a reverberation time lag between the direct and reflected emissions. A first detection of time lag has been done at soft energy, below 1 keV [1]. A more important time lag has been first detected in the Kα Iron band of the bright Seyfert galaxy NGC4151, between reflected emission (5-6 keV) and direct emission (2-3 keV) and (7-8 keV)[2].

The final observed spectrum is composed of the direct power law emission and reflected emission with a special signature. We will study the spectrum of the Seyfert galaxy NGC 5506 using data from XMM-Newton satellite. NGC 5506 is a nearby (z = 0.0061) narrow line Seyfert I galaxy [3], and it is X-ray obscured [4]. It has been observed by many X-rays satellites, and its spectrum was studied using NuSTAR data by [5]. In this paper, we first describe the part of spectrum containing the broad Iron line in Section 2, then we present the observations and our data analysis in Section 3. The results will be presented in Section 4, and we end by a discussion and a conclusion.

2. Broad Iron line
The observed spectrum from Seyfert galaxies contains both the direct power law emission and the reflected emission. The reflection spectrum has a special shape due to relativistic effects [6], since emission lines are broaden and distorted due to relativistic effects like transverse Doppler and gravitationnel redshift as shown in figure 1. The distorsions are stronger when the photons
are emitted close to the black hole. This gives a broad shape to the Iron line predicted by [7], and first clearly observed by [8].

![Figure 1](image1.png)

**Figure 1.** The profile of the broad iron line due to relativistic effects. The upper panel shows the Newtonian effect, the second panel shows beaming and transverse Doppler effect due to high velocity. The third panel shows the gravitational redshift effect. The total effect is shown in the last panel, the Iron line is broaden and distored [6].

3. Observations and Data Analysis
To study the Seyfert galaxy NGC 5506, we are using observations from XMM-Newton satellite (X-ray Multi-Mirror Mission, an X-ray space observatory launched by the European Space Agency in December 1999).

There are many short observations, 20 ks each, and two longer observations taken in 2008-2009, one dominated by background flares and the other of duration of 90 ks. New observations were taken in 2015-2016. Data were obtained from the XMM-Newton archive.

We will compare the NGC 5506 spectra from two sets of data (figure 2), the old data from the long observation taken in July 27th 2008 and the new data from the long observations taken in July 7th 2015.

![Figure 2](image2.png)

**Figure 2.** The spectra of NGC5506 from XMM-Newton long observations taken in July 27th 2008 (old data) and in July 7th 2015 (new data).

1 https://www.cosmos.esa.int/web/xmm-newton/xsadownload
We used HEASOF T v6.19 to reduce data and extract the spectra. For spectral fitting, we use the public package XSPEC\(^2\) which contains several spectral models.

To fit data, we start by including a model for the photoelectric absorption ‘phabs’, that accounts for galactic hydrogen density, and its redshifted variant ‘zphabs’. Then we add a power law for the direct emission. Then to fit the shape of the broad iron lines we use gaussians, characterized by a norm, a line width and a line energy. We compare the best fit parameters from old data and new data as shown in Table 1. Plots of spectra and models for old data and new data are shown in figure 3.

Table 1. Comparaison between best fit parameters for the model composed of power law and two gaussian from old data and new data.

| Model  | Parameter       | Old data    | New data    |
|--------|-----------------|-------------|-------------|
|        | \( N_H (10^{22} \text{cm}^{-2}) \) | 2.88 ± 3.22E-02 | 2.82 ± 3.49E-02 |
|        | \( \Gamma \) (Photon Index) | 1.79 ± 9.07E-03 | 1.65 ± 9.68E-03 |
| gaussian 1 | \( E_1 \) (keV) | 6.39 ± 9.82E-03 | 6.40 ± 6.88E-03 |
| gaussian 1 | \( \sigma \) (keV) | 0.14 ± 1.18E-02 | 9.58E-02 ± 8.90E-03 |
| gaussian 2 | \( E_2 \) (keV) | 6.89 ± 8.74E-02 | 6.94 ± 1.82E-02 |
| gaussian 2 | \( \sigma \) (keV) | 7E-04 ± 3.05E-02 | 9.83E-02 ± 2.33E-02 |

Figure 3. Spectra and folded model with the data/model ratio, using a model composed of power law and two gaussians. *Left:* for the old data, the best fit corresponds to the third column of Table 1. *Right:* for the new data, the best fit corresponds to the last column of Table 1.

4. Results

After fitting the NGC 5506 spectra using old data and new data, we obtained the best fit parameters as shown in Table 1. For the new data, the statistic test \( \chi^2 \) gives 1798.91 using 1599 PHA bins, corresponding to reduced \( \chi^2 = 1.13139 \) for 1590 degrees of freedom, which is an acceptable result. For the old data, we obtained a best fit, where the statistic test \( \chi^2 \) gives 1451.72 using 1413 PHA bins, it corresponds to reduced \( \chi^2 = 1.03399 \) for 1404 degrees of freedom. Comparing to best fit values found in [5], where \( N_H \) was found \( 3.10^{+0.21}_{-0.20} 10^{22} \text{cm}^{-2} \), the \( N_H \) value from old data best fit equal to 2.88 ± 0.03 is closer than the value from new data.

\(^2\) https://heasarc.gsfc.nasa.gov/xanadu/xspec/
best fit. Same note for the power law photon index $\Gamma$, where the best fit value from old data $\Gamma = 1.79 \pm 0.01$ is closer to $\Gamma = 1.91 \pm 0.03$ found in [5], than the best fit value from new data $\Gamma = 1.65 \pm 0.01$. However the fit parameters for the gaussians seem to be more realistic for the new data.

5. Discussion an Conclusion
In this work, two sets of data from XMM-Newton satellite observations are analysed in order to fit the NGC 5506 spectra. We used several mathematical and physical models from the Xspec package. We compared best fit parameters from old data and new data. We found that physical parameters as Hydrogene density and photon index are approaching the values found using data from NuSTAR observations [5]. Since the aim is to proof the reflection of X-rays in the accretion disk implying a broad iron line, we have to replace gaussians using physical models containing reflection. This is part of a paper in preparation.

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