Showing AGN spectral variability by Principal Analysis Component (PCA)

Agís-González, B*[1]., Risaliti, G*[2,3]. & Miniutti, G*[1].

[1]Centro de Astrobiología (CSIC/INTA); ESA P.O. Box: 78, E-28691, Villanueva de la Cañada, Madrid, Spain. [2]Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138, USA.[3]INAF-Osservatorio Astrofisico di Arcetri, Largo Enrico Fermi 5, I-50125,Firenze, Italy.

Introduction

The AGN spectra can be very complex, with multiple different models providing acceptable fits to the same data, meaning that spectral fitting alone cannot discern between alternative physical models. Principal component analysis (PCA) is a powerful tool for distinguishing different patterns of variability in AGN. It reduces the dimensionality of the data without loosing information and yields the directions that maximize the variance of the data. It works transforming a data set where variables correlate among each other into a new coordinate system, defined by a smaller number of uncorrelated variables called principal components or eigenvectors. Namely, it consists in a coordinate rotation so that one axis in the rotated system lies in the direction for which the distribution has the largest variance. This direction is known as the first principal component. The second principal component is orthogonal to the first one and is the axis along which the distribution has the next largest variance. The same is valid for a third component and so on. In this way, the variability is summed up in as few principal components as possible. And these principal components can be linearly combined to reconstruct the initial data set.

Need for Simulations

The advantage of this method is that it produces detailed spectra of each variable component in a model independent way. Calculating the RMS spectra can show the total variability as a function of energy, but cannot be used to determine how many variable components of the initial spectrum contribute to the variability.

But there is a small disadvantage: the interpretation of these variable components. As they need not to correspond to physical components, since there is no requirement for the true physical components to vary independently. Thus, a same principal component can be generated by more that one parameter or physical process varying. To solve this inconvenience and keep the independence from the models we turn to simulations. This technique was introduced by Koljonen et al. (2013) and it consists in creating simulated spectra based on physical models that are allowed to vary within given parameter ranges. Then, the PCA is applied to these spectra of models and produces the corresponding principal component. From these PCs, patterns from each spectral model can be detected. Then, they can be matched to the PCs found from the data for each source.

Method

To carry out the PCA we must first divide the data or simulations into timesliced spectra binned in energy. In order to maximize the spectral information we adapt the bin size so that the lower flux timesliced spectrum has at least 25 counts at high energies.

The resulting components show the strength of the correlation between energy bins, so a positive (or negative, the sign of the y axis is arbitrary) component shows that all bins vary equally, whereas a component that is positive at low energies and negative at high energies represents a pivoting effect.

Errors on the resulting component spectra are obtained by a Monte-Carlo method, in which the observed photon counts binned in energy and time are perturbed by a random amount proporcional to a poisson photon noise following a normal distribution and the PCA redone on the perturbed data set. This process is repeated 50 times.

NGC 4051: Previous Analysis

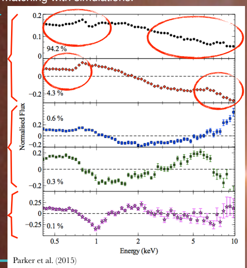
Parker et al. (2015) (hereafter, P15) classified our target source in their general classification of 26 AGN according to the patterns of the principal components (PCs), matching with simulations.

14 observations - ~40ks each one
10ks timeslicing

VARIABLE POWER LAW
+
CONSTANT REFLECTION COMPONENT
suppressing the spectral variability at energies of the soft excess and iron line.

VARIATIONS FROM THE RELATIVISTIC REFLECTION
and display the correlated soft excess and broad iron line

ABSORPTION EDGE at 1KeV



Source showing variable relativistic reflection

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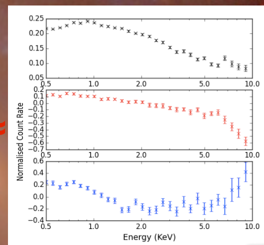
NGC 4051: Another Observation

We analyzed another observation of NGC 4051. As the results are equivalent to those found by P15, we decided to have a look to the 14 individual observations analysed by them.



1 observation - ~120ks

Fourth and fifth principal components are lost beacuse of the minor amount of data

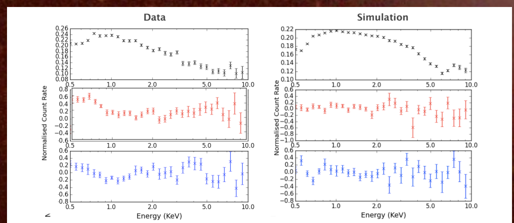
Also the first three principal components are softened

SAME INTERPRETATION OF THE PCs

Source showing variable relativistic reflection

NGC 4051: Highest Flux Observation

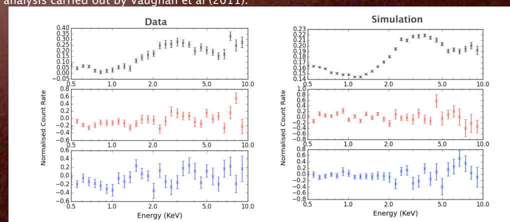
These are the principal component from the greatest flux observation of NGC4051 analysed by P15. It is a observation around 40ks, so sliced in 4 small spectra. As it is a short time we only take into account the first PC as the second and the third one can be dominated by noise. The principal resultant components are again matched with the interpretation of a varying power law with a relativistic reflection component found by P15.



SIMULATION → Power law varying in normalization
+
constant relativistic reflection component

NGC 4051: Lowest Flux Observation

However, the lowest flux observation analysed by P15 shows another different first principal component, where the variability is suppressed at low energies and arises at high energies. These changes can be simulated from the greatest flux simulation simply dropping the flux of the reflection component and adding a constant soft excess with a black body which suppresses the variability at low energies. Besides, this constant soft excess is also suggested in the analysis carried out by Vaughan et al (2011).



Power law varying in normalization
+
constant relativistic reflection component
+
Soft Excess ✓ Vaughan et al. (2011)

CONCLUSIONS & FUTURE WORK

In this work in progress we have confirmed the PCs intrepretation from Parker et al (2015) in another observation and at another time-slicing with a main conclusion: there is a

EVOLUTION OF THE PRINCIPAL COMPONENTS WITH THE FLUX

Besides, this has allowed us to corroborate the model proposed by Vaughan et al (2011) for NGC4051.
Now, we have to check the PCs at intermediate flux and be able to reproduce the evolution of flux with simulations. And, of course check this evolution in other sources

REFERENCES: [1] Parker, M.L., Fabian, A. C., Matt, G., et al. 2015, MNRAS, 447, 72 [2] Koljonen, K. I. I., McCollough, M. L., Hannikainen, D. C., & Droulans, R. 2013, MNRAS, 429, 1173 [3] Vaughan, S., Uttley, P., Pounds, K. A., Nandra, K., & Strohmayer, T. E. 2011, MNRAS, 413, 2489