NGC 4051: low state XMM-Newton observation and modelization via the Cloudy code

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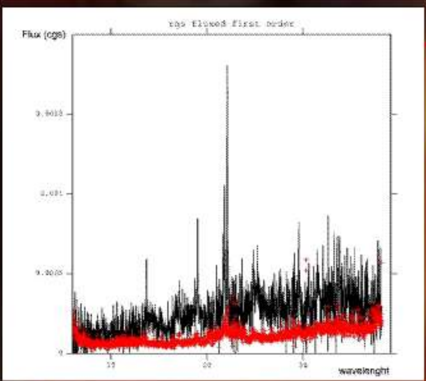
ABSTRACT:

The physical properties of the line emitting material in AGNs can be derived from well known line ratio diagnostics related to H-like and He-like ion transitions. Here, we show how to get this information (U, ne, nH, size, location and geometry of the emitting clouds) by a fit procedure of the overall observed spectrum with theoretical models developed by using the photoionization code CLOUDY. Application to NGC 4051 in its low flux state is shown.

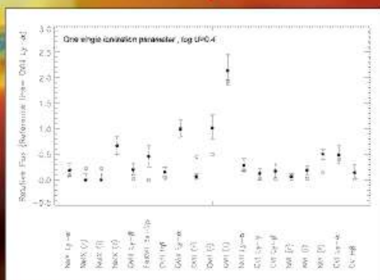
According the well established standard model for AGNs, the main properties of the energy output from the central part of an active galaxy is driven by the accretion on a SMBH. The characteristics of the observed radiation depend on the SMBH surrounding regions, i.e. geometry of the accretion flow, density and nature of matter, and on the presence of an accretion torus, an halo, an accretion disk and gas clouds spread around. The view of sight plays here a crucial role since, depending on it, different signatures are seen (e.g. Sy 1and Sy 2 galaxies). A detailed analysis and Cloudy models may help in undestanding the overall scenario.

X-rays collected by XMM-Newton allow to study these regions with unprecedent resolution. It is the case of NGC 4051. RGS study. Previous similar study: NGC 1068 (Kinkhabwala et al. 2002), Mrk 335 (Longinotti et al. 2008)

XMM-Newton observation (Nov. 2002): low state of the Galaxy. RGS spectra reduced...



From the XMM-Newton observation (EPIC and OM data) of the high state (May 2001), several observables can be obtained, i.e. α_{ox}=-1.14, Γ=-1.96. All this information enters the CLOUDY code producing grids of models depending on U, n_e and n_H, i.e. the (dimensionless ionization parameter, the electron density and the matter column density). The resulting grid and a comparison with the observed lines allow a fit to the data (one single gas component as a first approx.)



We searched for the best model that fits our data. A comparison between the observed and expected CLOUDY lines is shown to the left

In the following the contours plot of the solution at 68% and 99% confidence level.

...and several emission lines (H-like and He-like transitions) identified.

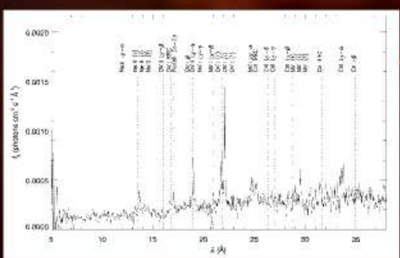
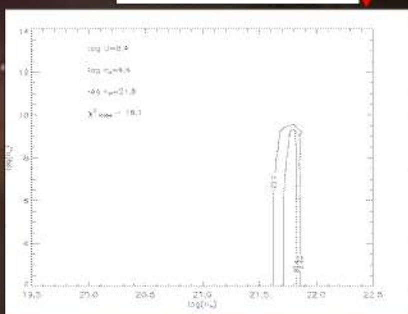
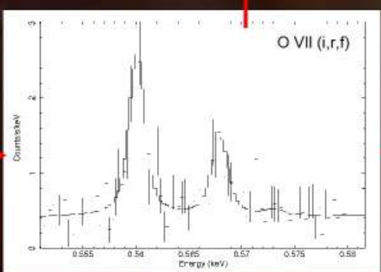


Table 1: NGC 4051 properties of the observed emission lines

Line ID	λ_{lab}(Å)	λ_{obs}(Å)	v (km s^{-1})	Flux ($\times10^{-14}$ cgs)	ΔC
$NeX_{L\alpha}$	12.132	12.207	1850	1.36	2.6
NVI_r	28.787	---	---	$\lesssim$0.92	0.9
NVI_i	29.082	29.074	−80	1.33	6.3
NVI_f	29.534	29.524	−110	3.55	38.3
$OVIII_{L\delta}$	16.006	15.902	−1950	1.43	11.3
$FeXVII_{3s2p}$	17.097	17.065	−556	3.26	20.7
$OVII_{H\delta}$	18.627	18.535	−1480	1.13	3.4
$OVIII_{L\alpha}$	18.967	18.978	180	7.01	135.2
$NVII_{L\gamma}$	19.826	---	---	---	---
$NVII_{L\beta}$	20.910	20.985	1080	2.14	9.6
$OVII_r$	21.602	21.585	−230	0.47	0.5
$OVII_i$	21.804	21.804	−4	7.16	74.0
$OVII_f$	22.101	22.103	30	15.04	237.9
$NVII_{L\alpha}$	24.779	24.797	220	2.02	16.9
CVI_{Ld}	26.357	---	---	---	---
CVI_{Lg}	26.990	26.957	−370	0.89	2.6
$CVI_{L\delta}$	28.465	28.324	−1490	1.22	5.6
$NeIX_r$	13.447	---	---	$\lesssim$0.76	0.0
$NeIX_i$	13.550	---	---	$\lesssim$0.80	0.1
$NeIX_f$	13.699	13.698	−24	4.68	49.8
$CVI_{L\alpha}$	33.734	33.762	250	3.46	28.8
$CV_{H\beta}$	34.973	35.261	2475	1.03	3.5



Standard diagnostic (e.g. R,G and L ratios) gives and idea of the gas properties. Here, we measuered G=12±1 corresponding to an electron density lower than 10^{10} cm^{-3} (see Porquet et al. 2003). **The gas is photoionised!**



When consideration on the recombination time-scales are done (the low state$_1$ observation was made 20 days after NGC 4051 switched off), an electron density lower than 10^5 cm^{-3} can be estimated.

One single ionization component fits quite well. The next step is a fit of the overall predicted model to the data. From the best fit parameters, information about both the size and location of the emitting clouds can be obtained...