Comparison of relativistic iron line models II.

Fitting simulated data for the future satellite mission XEUS

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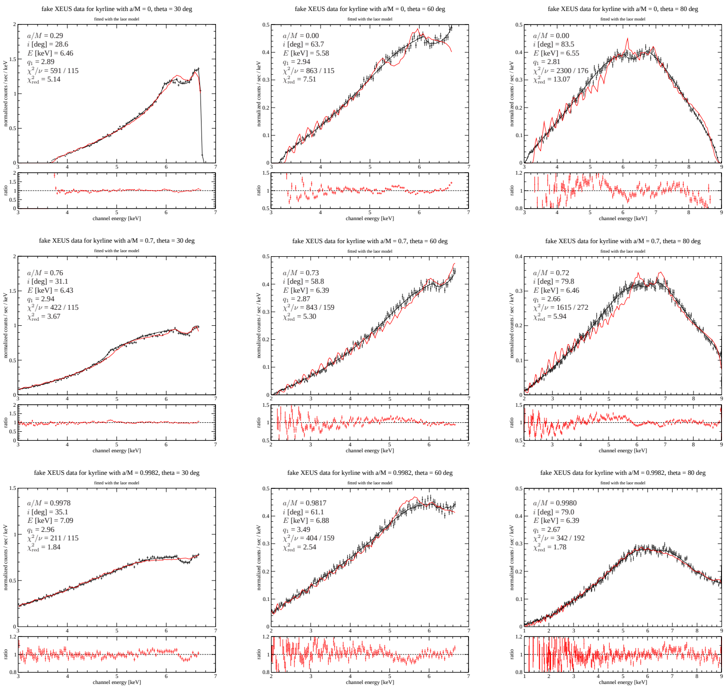
As a follow-up to poster I, we compare the *laor* and *kyrline* XSPEC models with simulated data for the planned X-ray satellite mission XEUS. The *laor* model always assumes the same metric of a maximally rotating black hole. The black hole spin is then constrained from the lower boundary of the broad iron line, assuming the inner edge of the accretion disc to be at the marginally stable orbit. In the more up-to-date *kyrline* model, different spin states of the black hole are intrinsically included in the metric. We study whether XEUS data could distinguish between the two models.

Simulated XEUS data for different values of the spin and inclination

We examine simulated data for the spin values $a/M = 0.$, 0.7 and 0.9982 and the observer inclinations $i = 30°$, $60°$ and $80°$. We simulate data for a *kyrline* model with a radial disc luminosity that follows a power law with index $q_1 = 3$ and with a rest energy $E = 6.4$ keV of the line. The simulated data were binned to a resolution of 30 eV per bin. We then fit the data with the *laor* model using the same initial values of the fitting parameters as for the data simulation. The inner disc radius is set to the marginally stable orbit for a given spin ($R_{\rm in} = R_{\rm ms}(a/M)$). In the set of figures below we show the simulated data with the expected errors (black crosses), the *kyrline* model from which the data were generated (black curve), and the *laor* model fit (red curve). The graphs of the data/model-ratio and the fitted parameters are also shown (for the *laor* model, a/M is computed from the inner disc radius).



Discussion and conclusions

We compare modeling of the broad iron line by the two relativistic XSPEC models *laor* and *kyrline*. The *laor* model always assumes an extreme Kerr metric ($a/M = 0.998$), and is used for the fitting of different spin values by identifying the inner edge of the disc with the marginally stable orbit. The spin is then estimated from the lower boundary of the broad line.

In the *kyrline* model, on the other hand, the spin itself is a fitting parameter and the metric is adjusted to the actual value of a/M. The discrepancies in the shape of the line are clearly seen especially for low values of a/M (left panel). They are apparently distinguishable in the simulated XEUS data that have sufficient statistics and energy resolution. A significant problem with *laor* appears at the high-energy edge of the broad line. Due to insufficient resolution, *laor* gives unacceptable results. Therefore, we excluded the higher-energy drop of the lines from the analysis so that the differences in the overall line shape are more visible.

We created simulated data for the objects examined on poster I (right panel). As suggested by previous analyses, *laor* slightly overestimates the values of the spin. For MCG 6-30-15 we get $a_{\rm laor} = 0.955$–0.964, while the data were simulated with $a_{\rm intrinsic} = 0.94$; for GX 339-4 we obtain $a_{\rm laor} = 0.72$–0.76 and $a_{\rm intrinsic} = 0.70$. The discrepancies are distinguishable for XEUS data. The overall fits of the data by *laor* are unacceptable with $\chi^2_{red} \approx 1.6$ for the MCG 6-30-15 simulations and with $\chi^2_{red} \approx 2.6$ for the case of GX 339-4. This is mainly caused by the insufficient resolution of the *laor* model.

Simulated XEUS data for MCG-6-30-15 and GX 339-4

We produced simulated XEUS data for the Seyfert galaxy MCG-6-30-15 and the black hole binary GX 339-4 using simplified models of the best data fits shown in poster I. For MCG-6-30-15 we used a power law model absorbed by neutral hydrogen and a broad iron line: phabs*(powerlaw + kyrline). The parameters of the continuum are the column density $n_{\rm H} = 0.4 \times 10^{21}$, the photon index $\Gamma = 1.9$ of the power law, and its normalization $K_\Gamma = 5 \times 10^{-3}$. For GX 339-4 we also added a multicolour disc component: phabs*(diskbb+powerlaw+kyrline) with $n_{\rm H} = 0.6 \times 10^{22}$, a disc temperature at the inner radius of $kT_{\rm in} = 0.87$, $K_{\rm kT} = 1.4 \times 10^3$, and $\Gamma = 3$, $K_\Gamma = 5.6$. The values of the line parameters are summarized in the *KY value* column of the table below. The value for the spin in the *kyrline* model was transfered to the value of the inner disc radius (marginally stable orbit) in the table.

Before the spectral analysis, we rebinned the data to have approximately a 5eV resolution, as it is planned for the XEUS instrument (see Parmar et al. 2006, proceedings of the SPIE, 6266, pp. 62661). We did some tests for different grouping. The discrepancies between the two models increase with larger grouping, but we can see apparent differences already for the most moderate rebinning.

MCG-6-30-15
exposure time: 220ks
counts (2-10keV): 1.4×10^7cts
flux (2-10keV): 1.5×10^{-11}erg cm^{-2} s^{-1}

Results of *laor* fit in 3-9keV

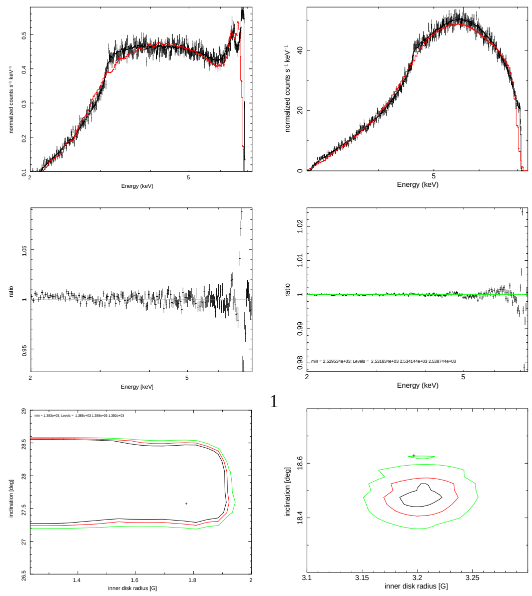
parameter	KY value	fitted value
$R_{in}[G]$	2.0	$1.85^{+0.04}_{-0.05}$
$i[deg]$	26.7	$25.4(3)$
E_{line}	6.7	$6.71(1)$
q_1	4.9	$4.51(3)$
q_2	2.8	$2.76(2)$
r_b	5.5	$6.2(1)$
$K_{\rm line}$	8.7×10^{-5}	9.0×10^{-5}
χ^2/ν		$1364/873$

GX 339-4
exposure time: 75ks
counts (2-10keV): 1.5×10^9cts
flux (2-10keV): 9.3×10^{-9}erg cm^{-2} s^{-1}

Results of *laor* fit in 3-9keV

parameter	KY value	fitted value
$R_{in}[G]$	3.39	$3.20^{+0.05}_{-0.05}$
$i[deg]$	19	$18.6(2)$
E_{line}	6.97	$6.94(5)$
q_1	3.45	$3.2(1)$
$K_{\rm line}$	6.5×10^{-3}	6.6×10^{-3}
χ^2/ν		$2298/873$

The following graphs illustrate the *laor* fits to the simulated data. The red curves correspond to the best fit of the *laor* model with the values listed in the tables above. The data/model ratios are also shown. The bottom graphs are confidence contours for the inner disc radius and the inclination angle.



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