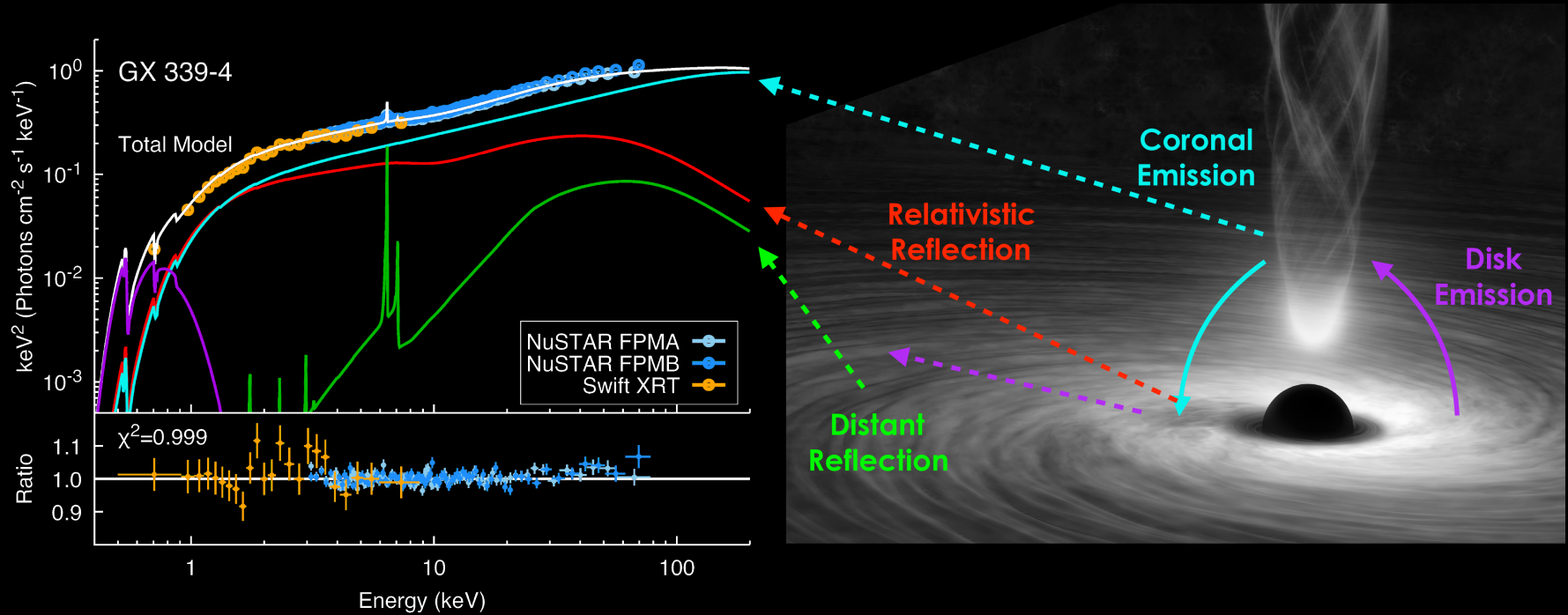


Constraining the corona by relativistic reflection modeling

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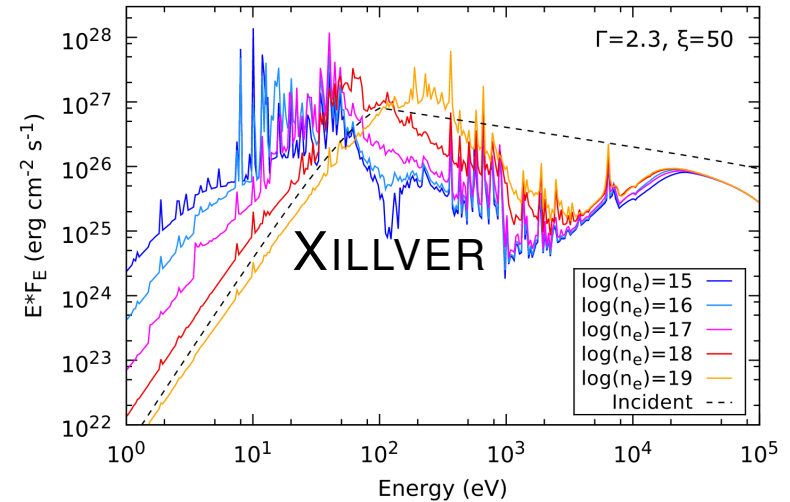
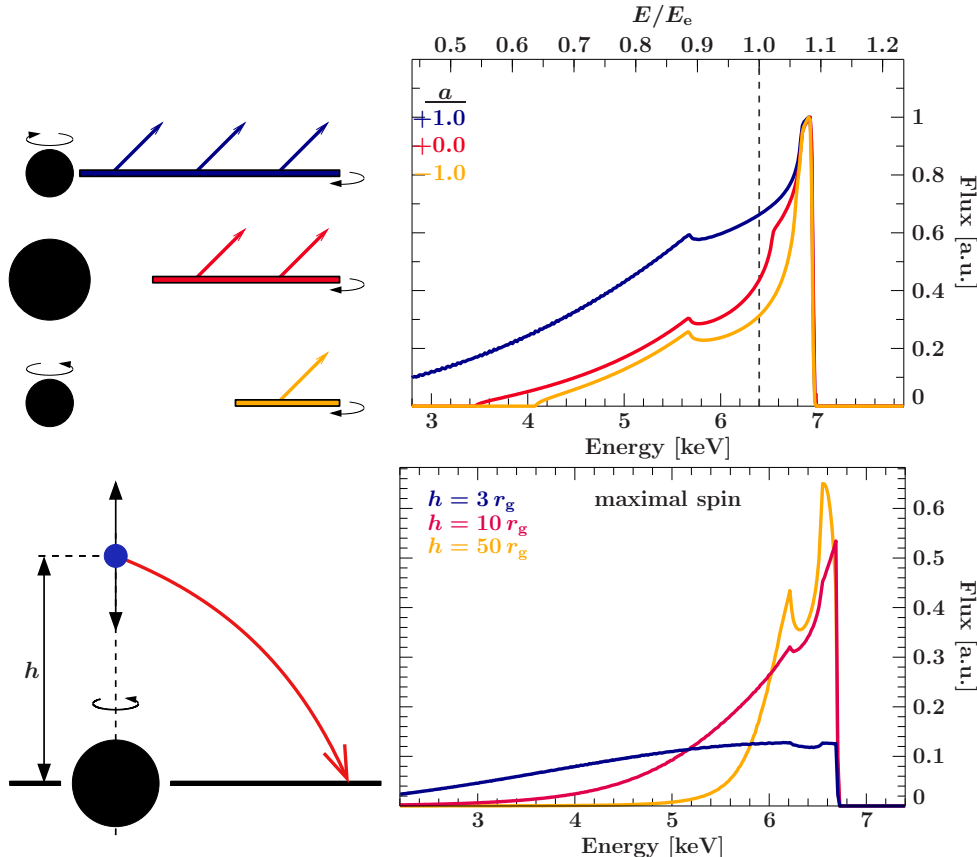
Broad band (relativistic) reflection spectroscopy



(Garcia et al., 2019)

Current baseline relativistic reflection modeling

Spectral fitting models: broad band reflection, ionization and density gradient, primary source, returning radiation



RELXILL (Dauser et al., 2010, 2013, 2014, 2016, 2022; García et al., 2013, 2014, 2016)

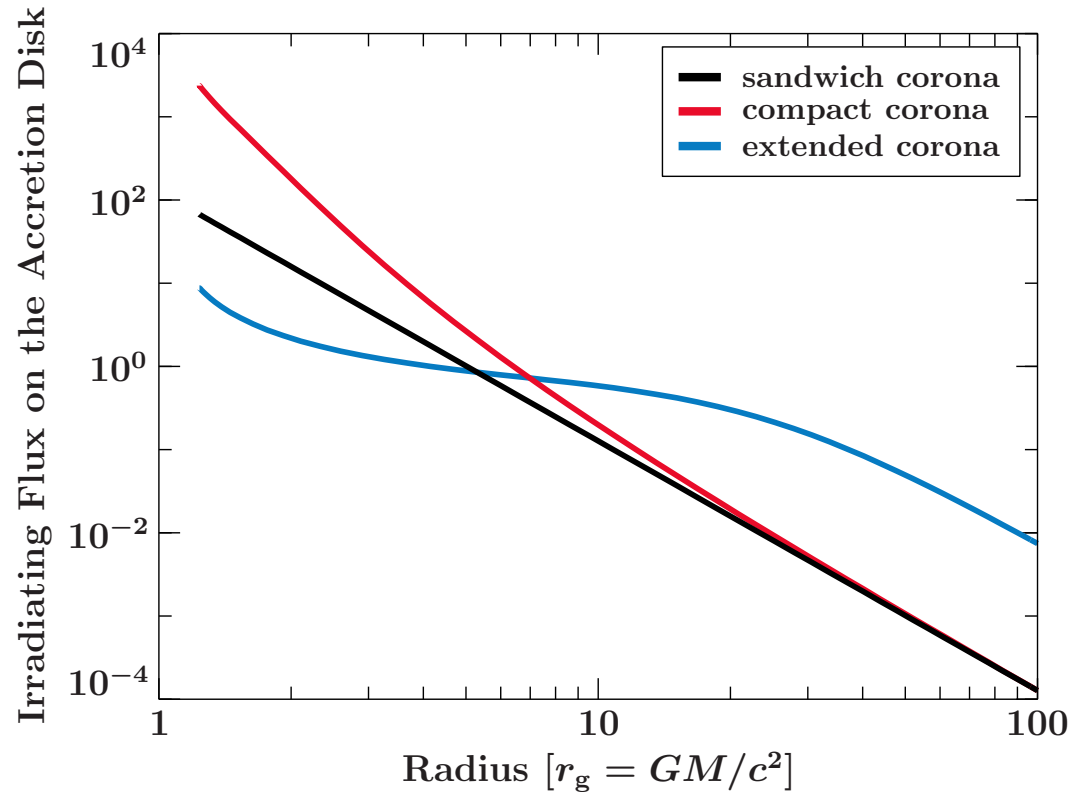
RELTRANS (Ingram et al., 2019), KY-models (Dovciak et al., 2004), REFLKERR (Niedzwiecki et al., 2019) , . . .

⇒ lacking a simple model with a **radially extended corona**

(previous studies/models: Gonzalez et al., 2017; Szanecki et al., 2020; Krawczynski et al., 2022; Zhang et al., 2024; Feng et al., 2025; Uttley & Malzac, 2025, , . . .)

How does the corona influence relativistic reflection?

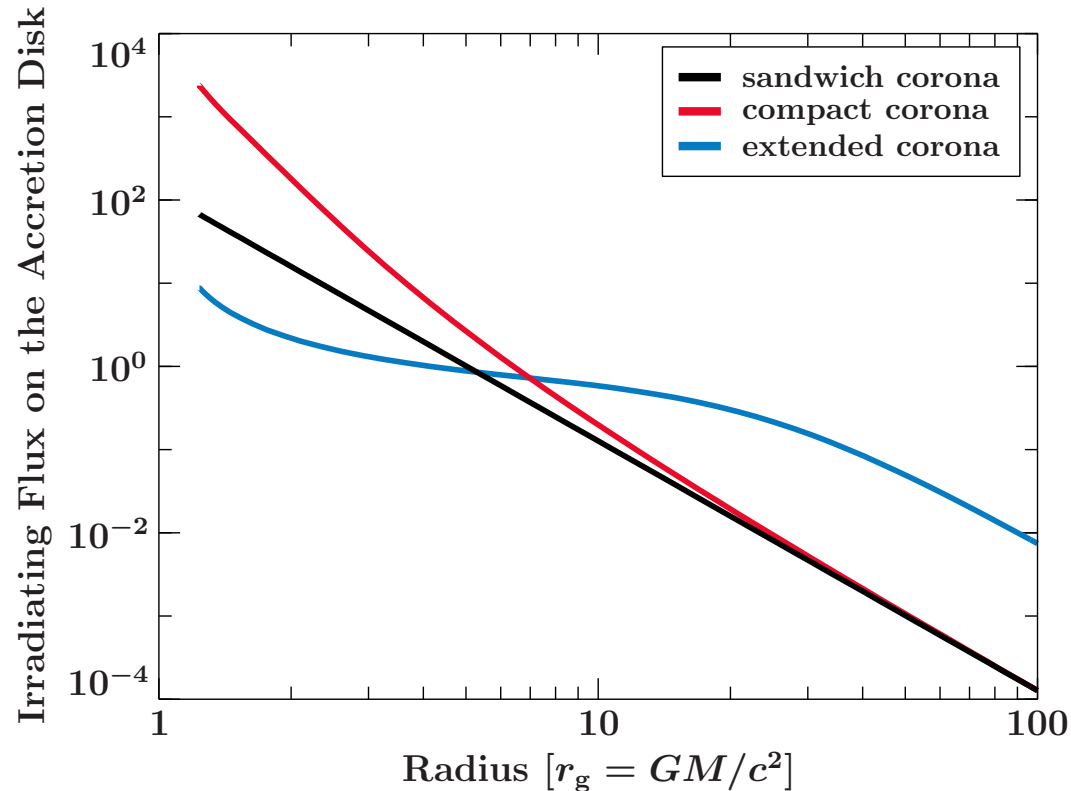
broad reflection lines require most photons to be reflected at the inner disk



the corona determines the **irradiation of the accretion disk**

How does the corona influence relativistic reflection?

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the corona determines the **irradiation of the accretion disk**

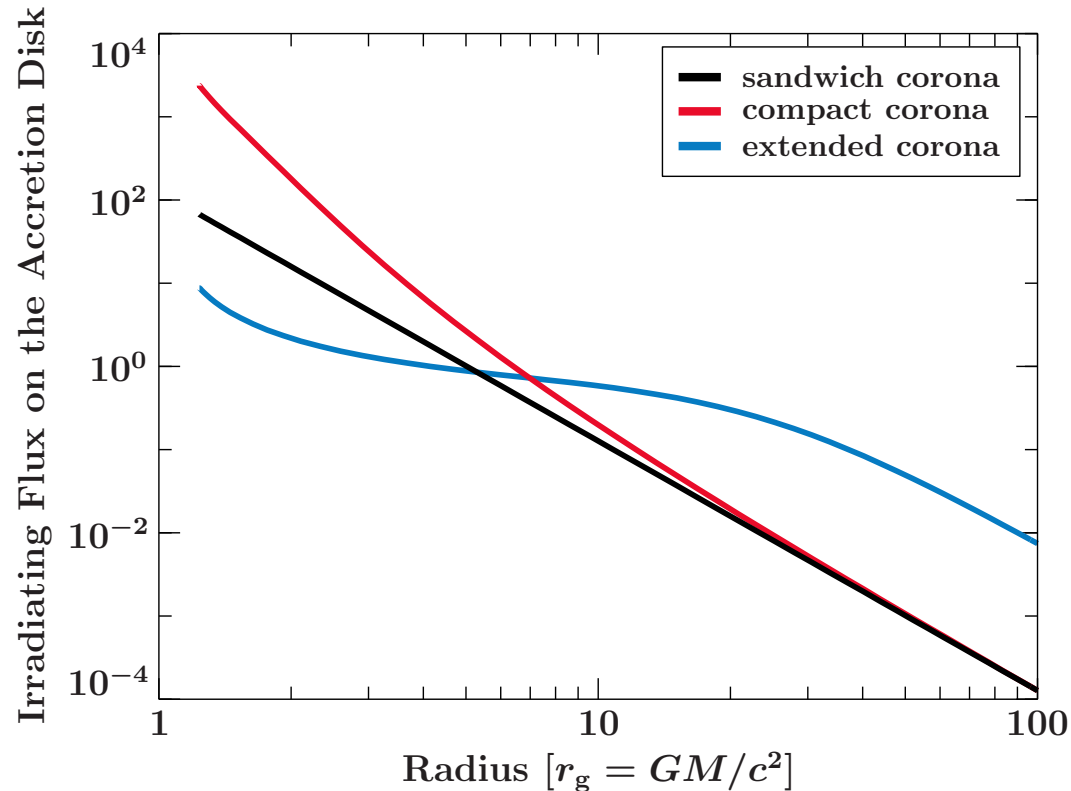
→ **strong, broadened relativistic reflection requires steep emissivities**

(Dauser et al., 2013; Parker et al., 2014; Duro et al., 2016; Walton et al., 2021, ...)

⇒ **compact corona close to the black hole**

How does the corona influence relativistic reflection?

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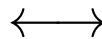
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general approach: use **point-like lamp post** as model of a **compact corona**



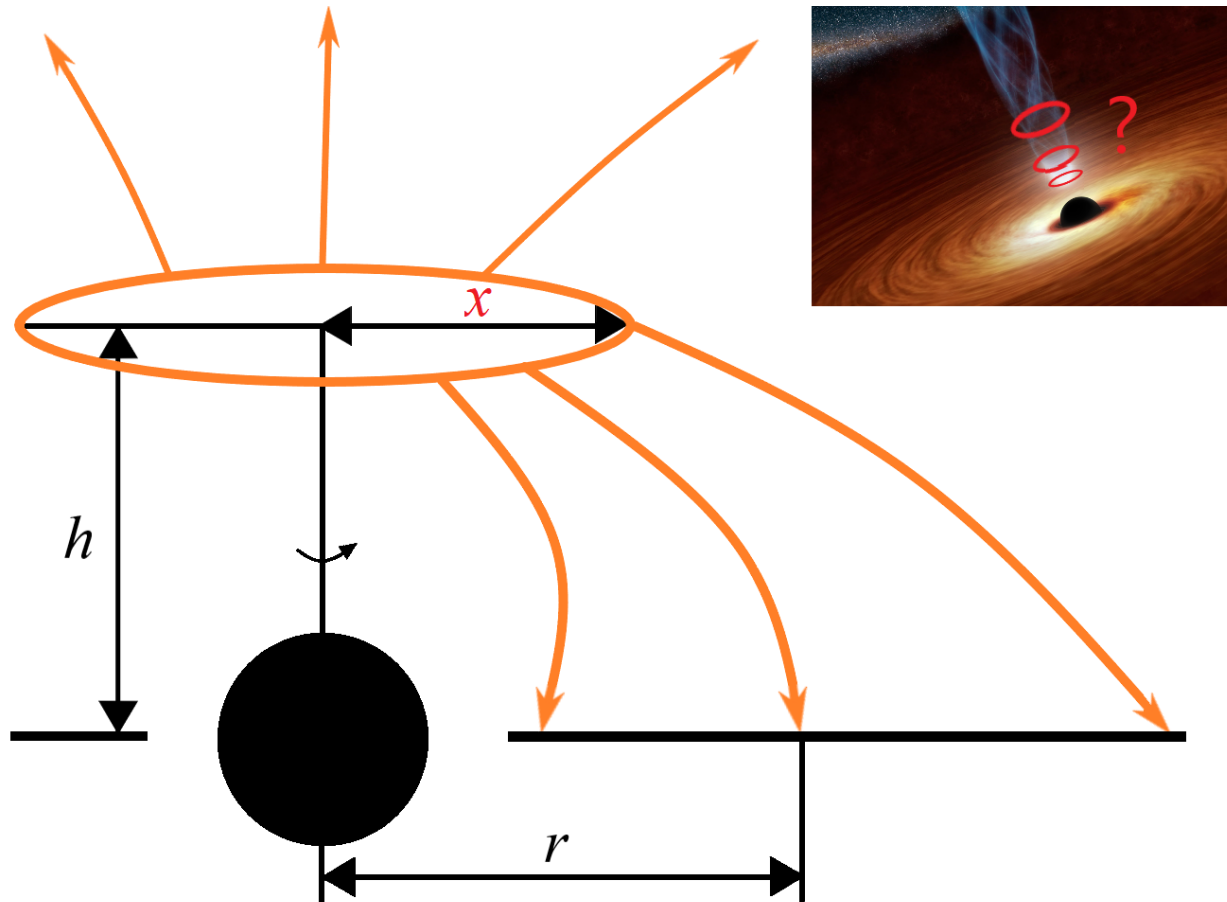
polarization measurements: favoring a **horizontally extended** corona?

(see, e.g., Krawczynski et al., 2022; Gianolli et al., 2023; Ingram et al., 2023, ...)

Extending the Lamp Post

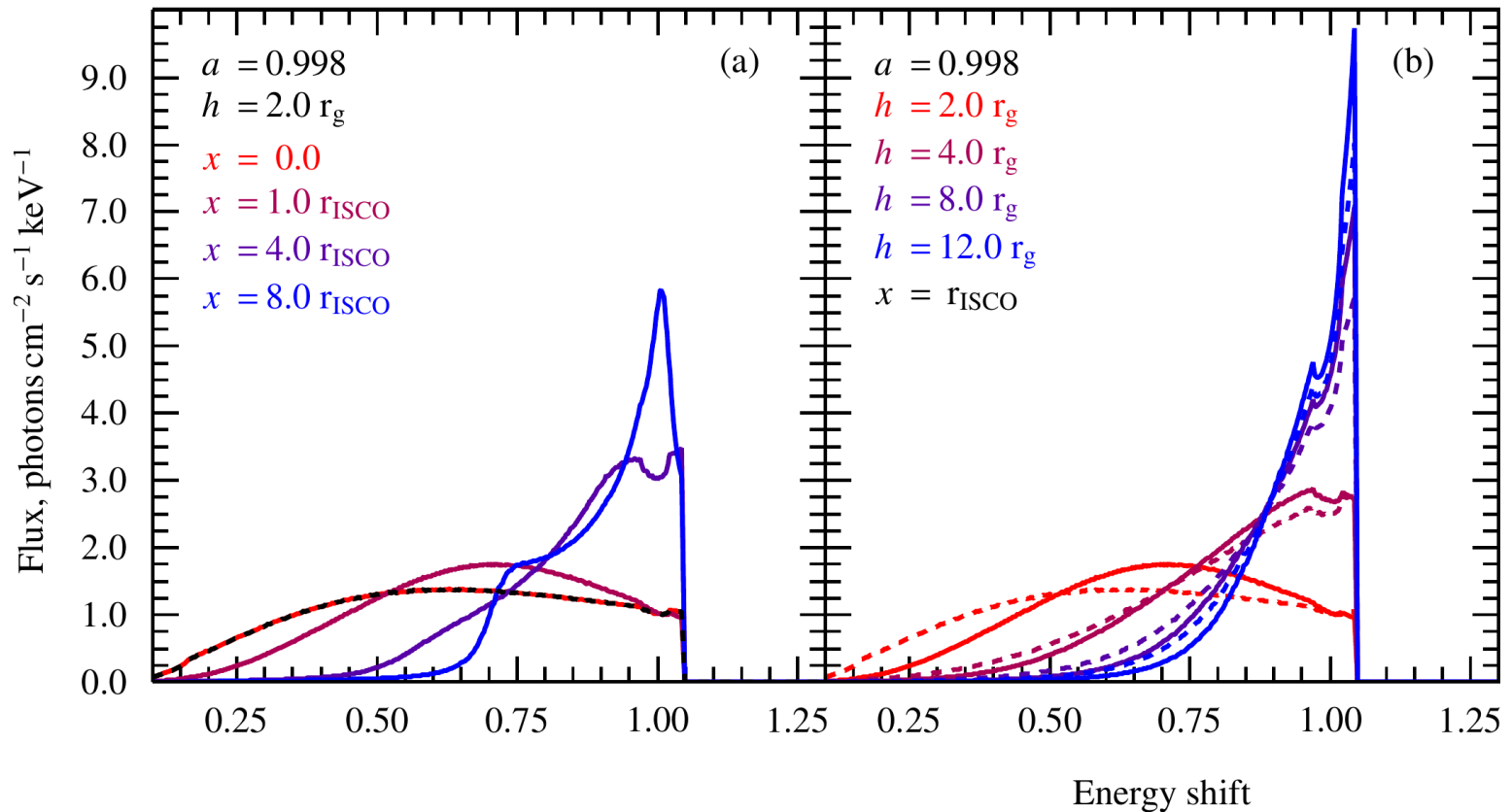
new RELXILL model based on ring-like extended sources (v2.6)

→ model any axi-symmetric source



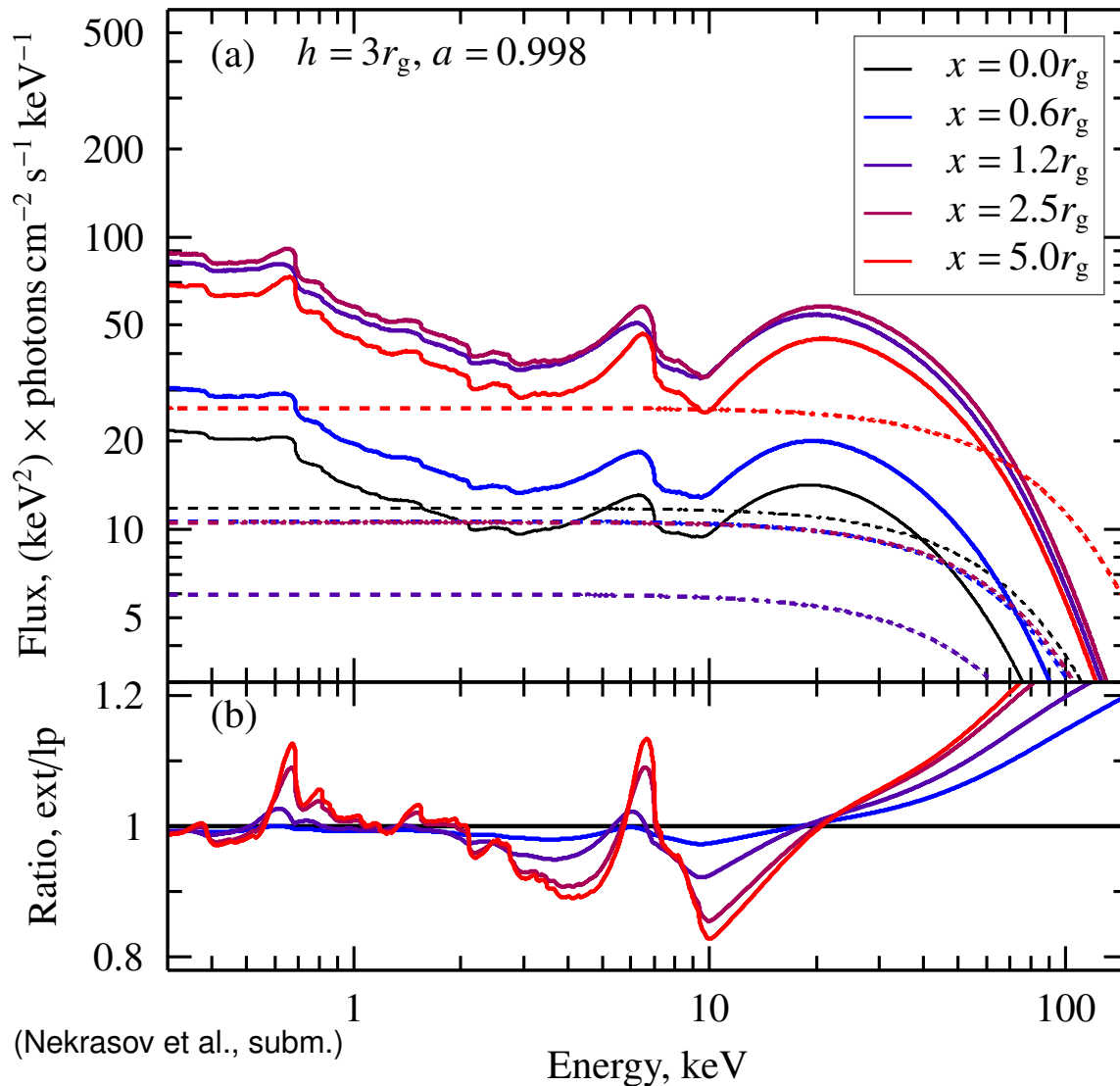
(Nekrasov et al., subm.)

Extending the lamp post: ring-like RELXILL model



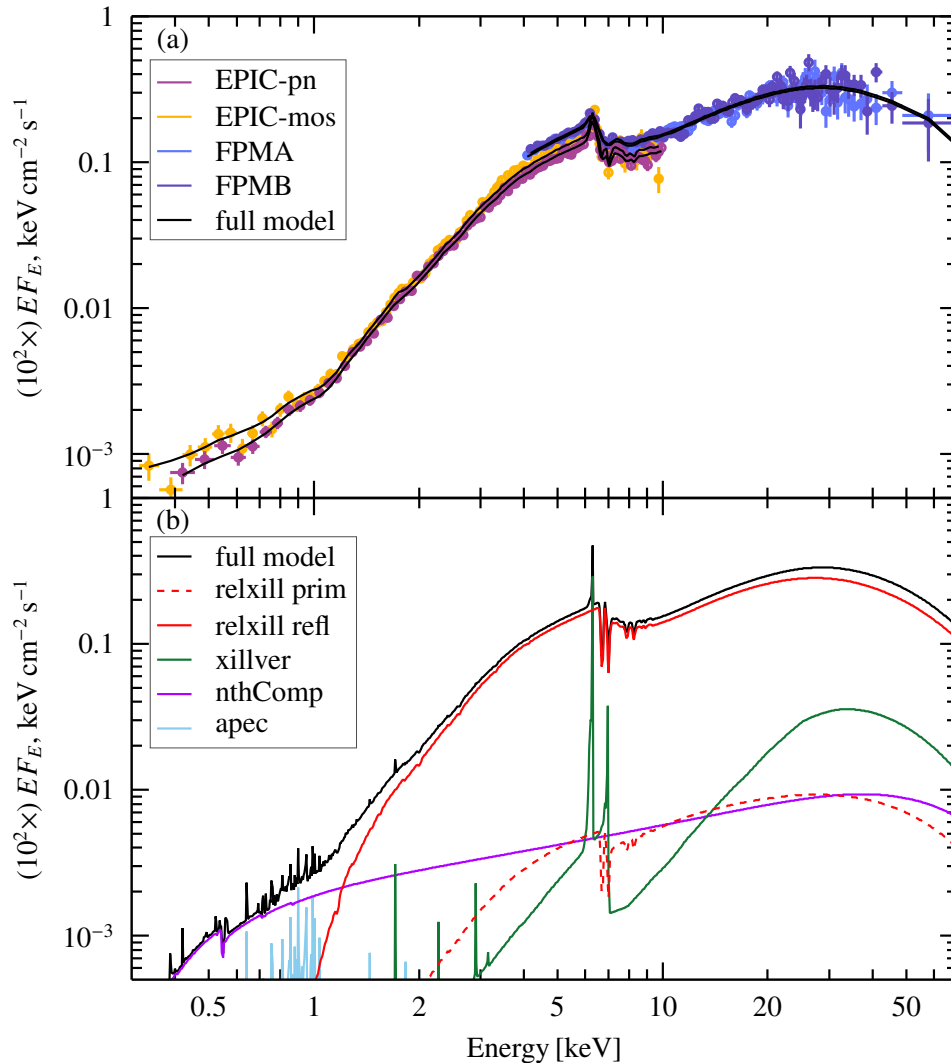
- narrower line shape for larger ring
- $x = 0$ to $x = R_{\text{ISCO}}$ has only a minor effect on the line shape

Extending the lamp post: ring-like RELXILL model



- similar shape for small ring size ($x < r_{\text{ISCO}}$)
- largest reflected flux for $x \approx r_{\text{ISCO}}$

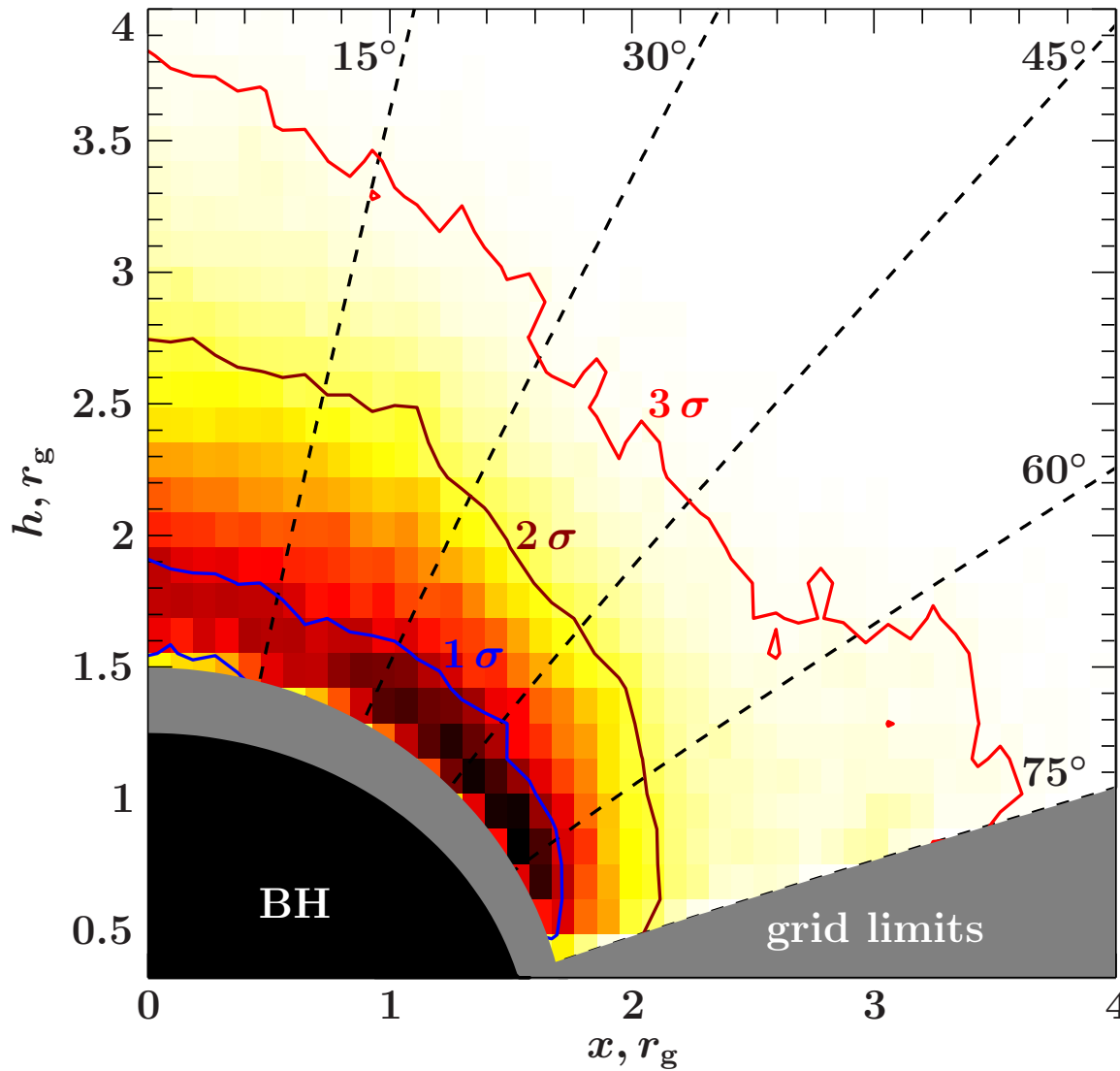
Relativistic Reflection in ESO 033-G002



(Nekrasov et al., subm.)

- *XMM-Newton* & *NuSTAR* spectra of Seyfert galaxy ESO 033-G002 shows very strong reflection (Walton et al., 2021)
 - compact LP corona ($h < 3 r_g$), high spin ($a > 0.93$)
- ⇒ **apply ring-like RELXILL model**

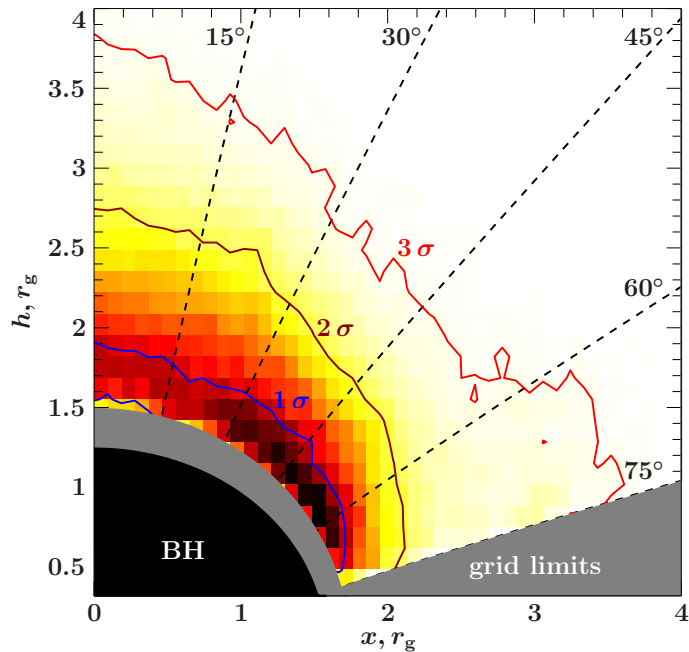
MCMC contours for ESO 033-G002 (extended RELXILL)



Any ring source at distance $r < 2r_g$ fits the data equally well than a LP with $h = 2r_g$

Conclusions: Lamp Post vs. Ring/Slab Corona

What does this mean for all other (low height) lamp post fits?

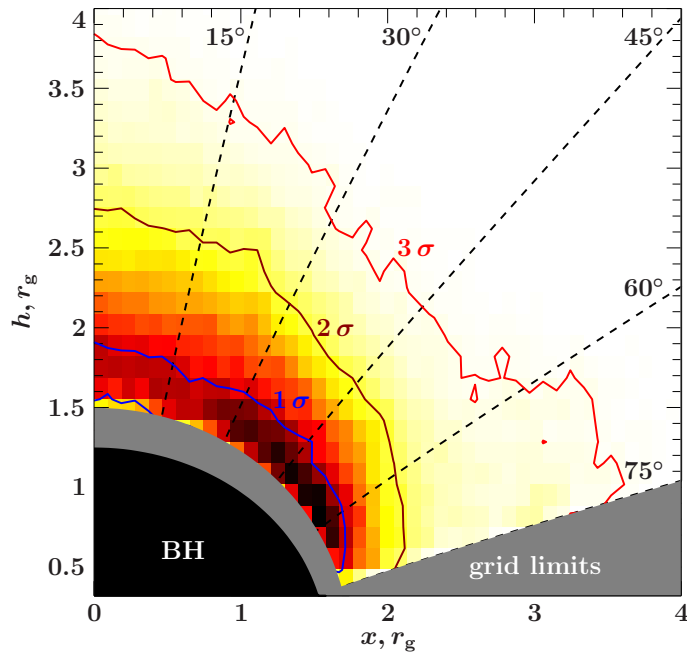


low height LP fit ***likely*** does not require corona on the rotational axis, but only a compact corona

- close distance to the BH
- can be extended or point-like

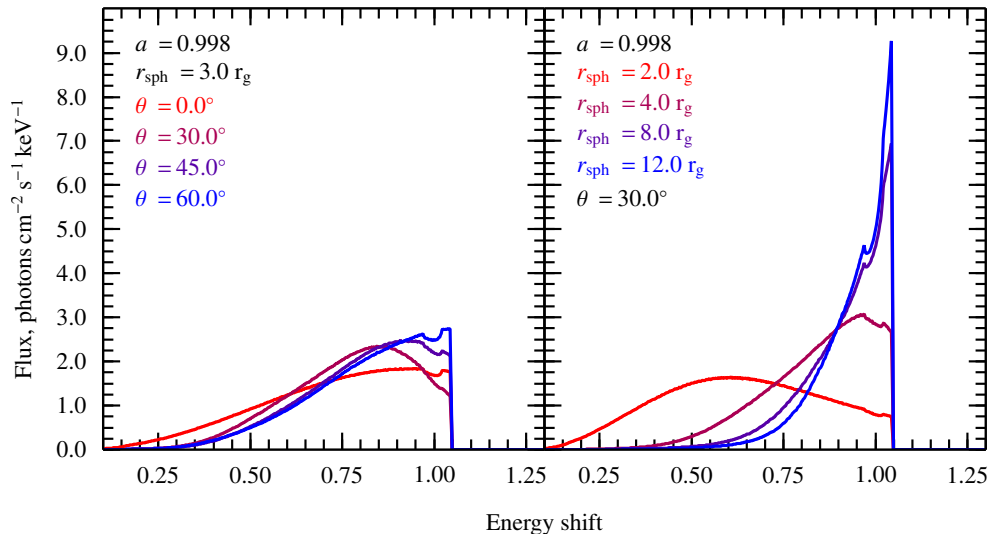
Conclusions: Lamp Post vs. Ring/Slab Corona

What does this mean for all other (low height) lamp post fits?



low height LP fit *likely* does not require corona on the rotational axis, but only a compact corona

- close distance to the BH
- can be extended or point-like



line shape sensitive to:

- distance to BH
- only weakly on θ

Summary & Conclusions

- implemented a new RELXILL model with **ring-like** corona to model any axi-symmetric corona (v2.6, available as of today)
- application to the reflection dominated AGN ESO 033-G002 shows that **the corona is close to the black hole ($< 2 r_g$), but not constrained in azimuth**

What does this mean for the (apparent) tension with polarization measurements favoring radially extended or cone-like coronae?

Due to the weak azimuthal dependency: *low height lamp* post fit compatible with radial/cone geometries?! → needs to be tested!

download RELXILL v2.6 here: www.sternwarte.uni.erlangen.de/research/relxill/

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Energy shift for an off-axis source

