Unveiling Systematic Uncertainties in X-ray Reflection Spectroscopy: Implications for Black Hole Spin Measurements

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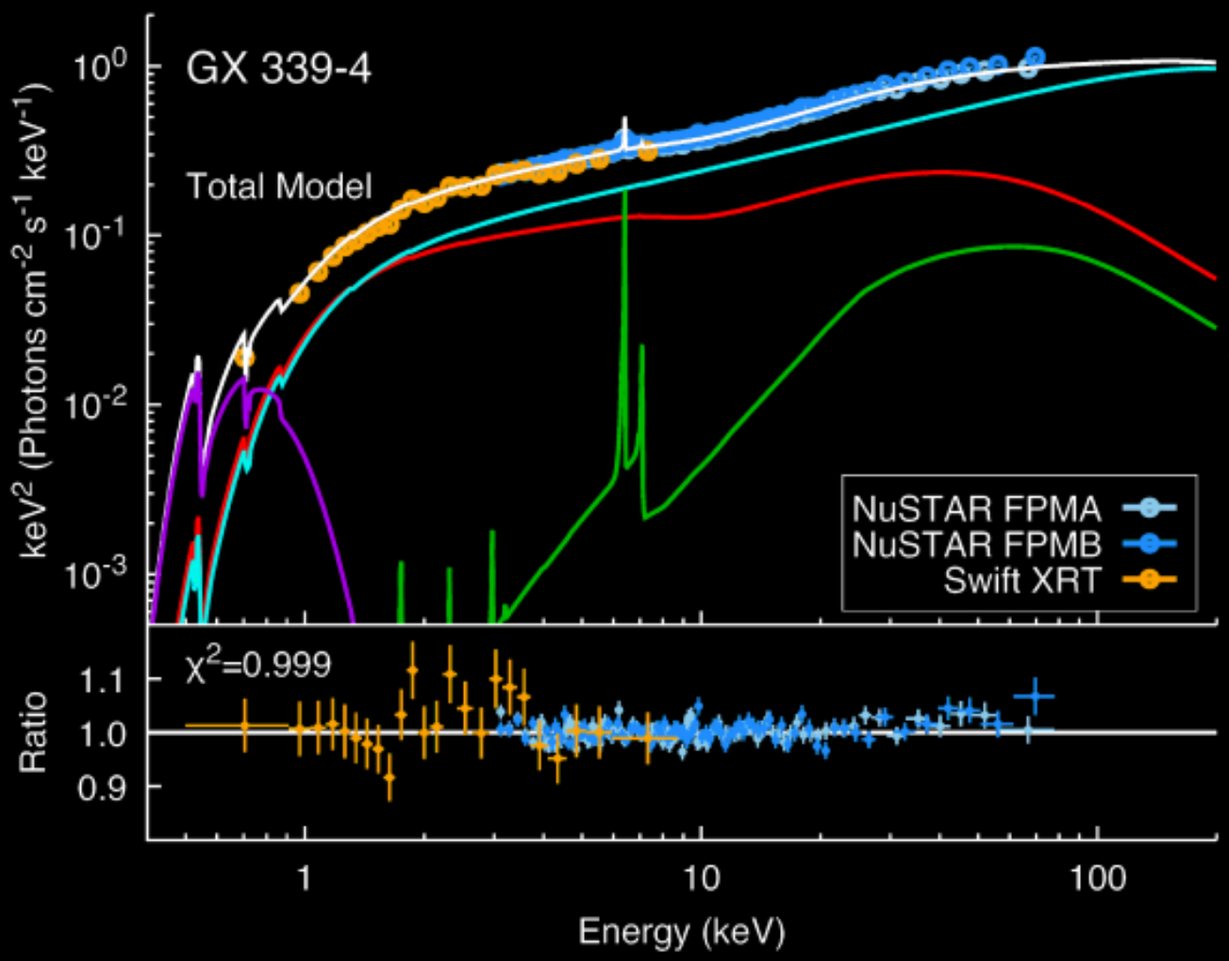
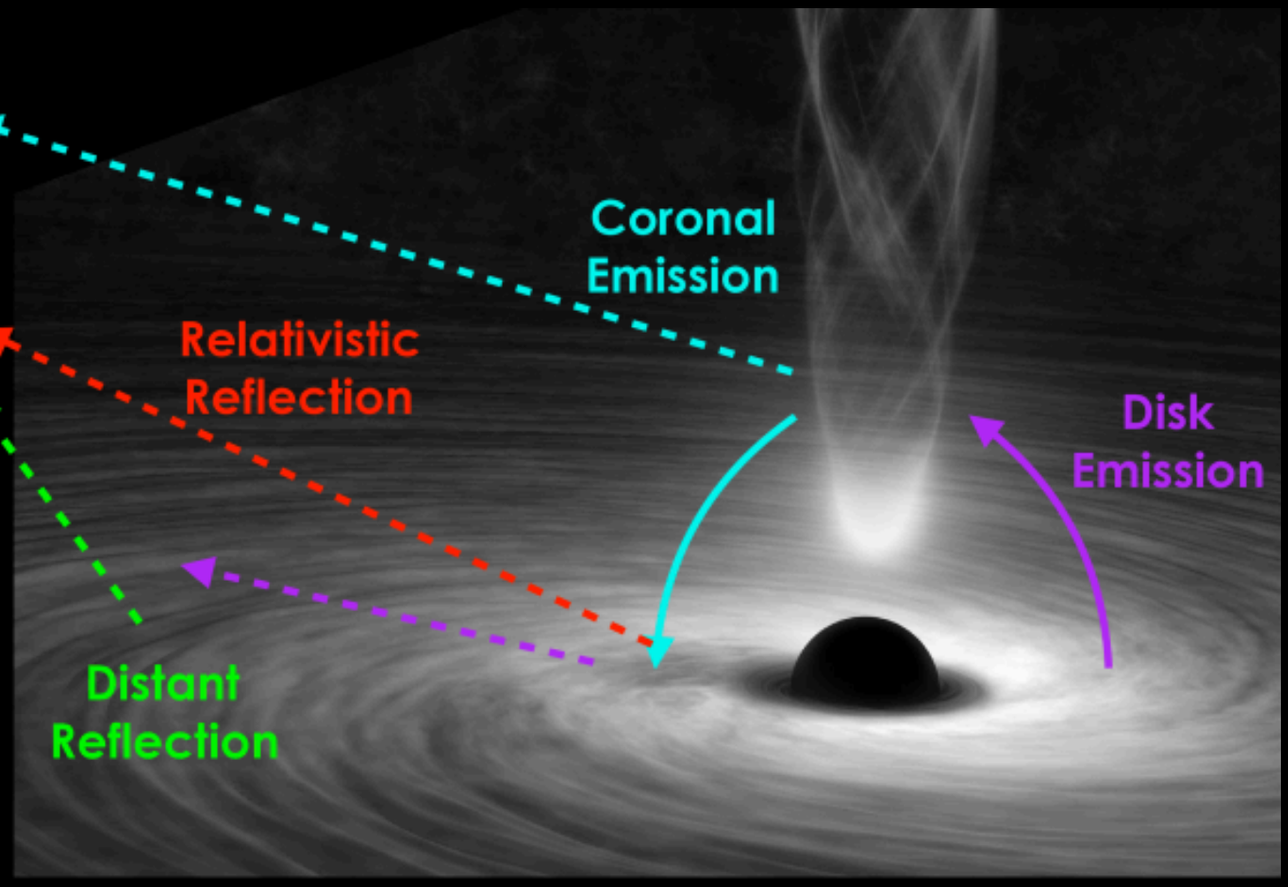
1. X-ray reflection spectroscopy

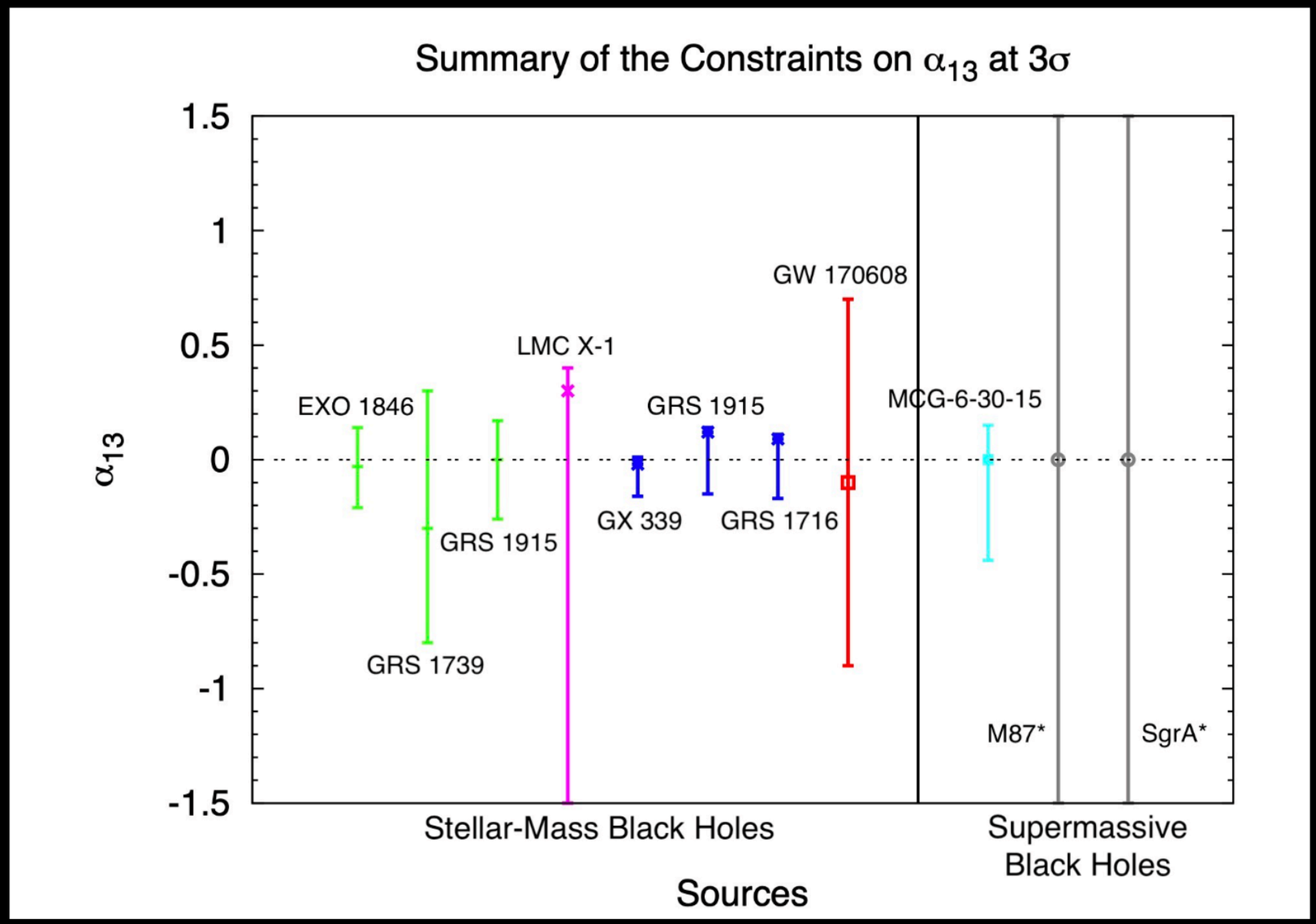




Credit: NASA/JPL-Caltech/R

2. Test of GR

Summary: X-ray, GWs, VLBI



Credit: Bambi et al. 2023

3. Systematic Bias

Model Simplifications

All the available relativistic reflection models assume a number of simplifications that introduce systematic bias/uncertainties in the final estimates of the parameters.

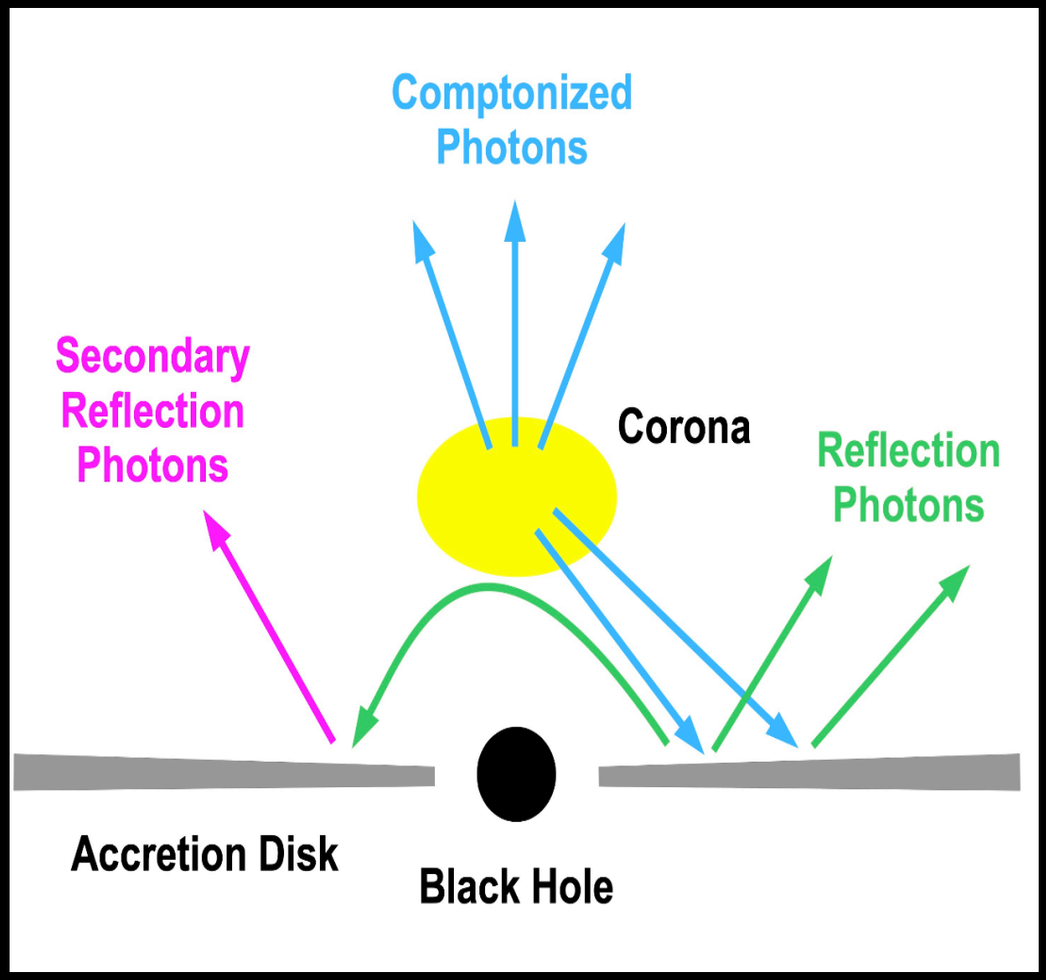
- **The calculation of the reflection spectrum in the rest frame of the gas in the disk**

- **The description of the accretion disk.**

- **Relativistic effects not taken into account (returning radiation)**

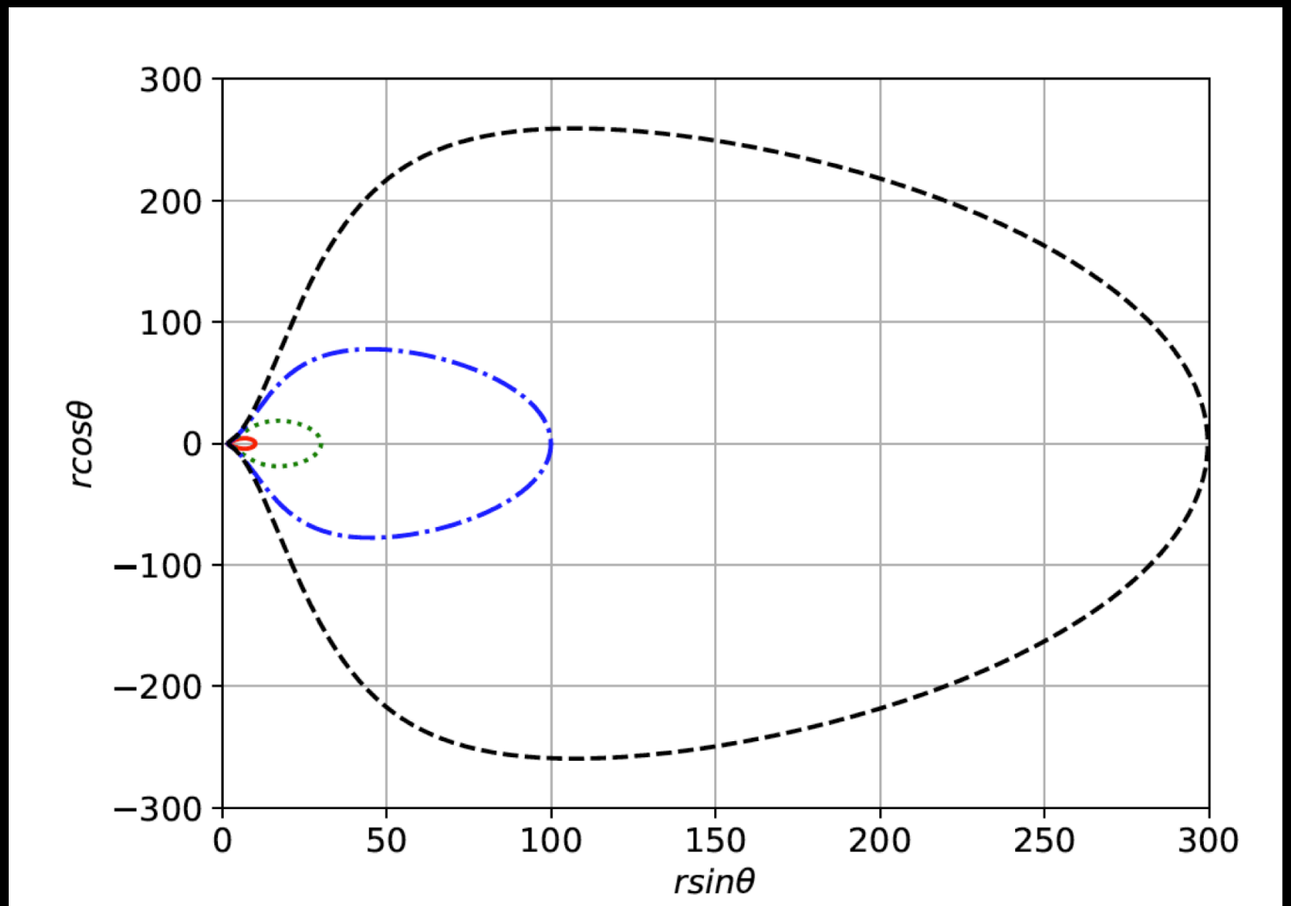
- **The description of the hot corona.**

Credit: Bambi+2021

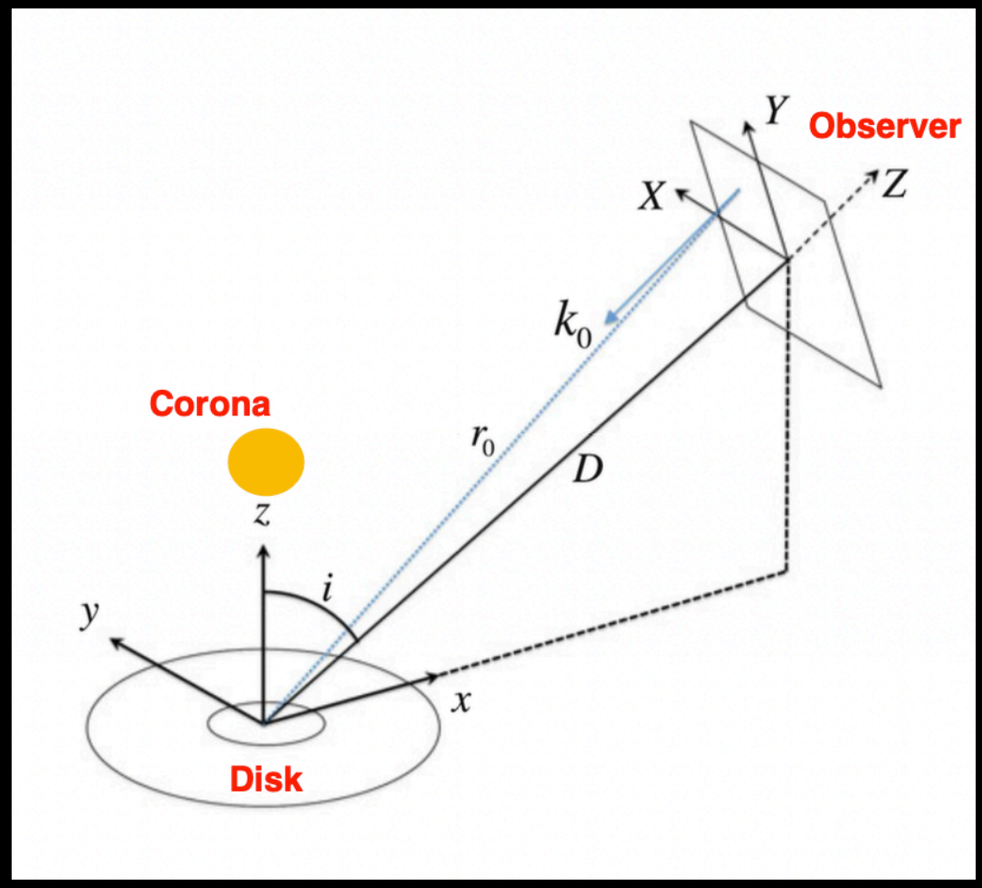


3. Systematic Bias

Model Simplifications: Disk Structure



(Abramowicz et al. 1978)



Credit: Bambi et al. 2023

$$F_o(\nu_o) = \int_{R_{\rm in}}^{R_{\rm out}} \int_0^1 \frac{\pi r_e g^2 f(g^*, r_e, \iota)}{\sqrt{g^*(1-g^*)}} I_e(r_e, \theta_e) dg^* dr_e,$$

$$f(g^*, r_e, \iota) = \frac{1}{\pi r_e} g \sqrt{g^*(1-g^*)} \left| \frac{\partial(\alpha, \beta)}{\partial(g^*, r_e)} \right|$$

$$g^* = \frac{g - g_{\rm min}}{g_{\rm max} - g_{\rm min}} \in [0, 1]$$

3. Systematic Bias

Model Simplifications: Disk Structure

Iron line for Polish donut disks

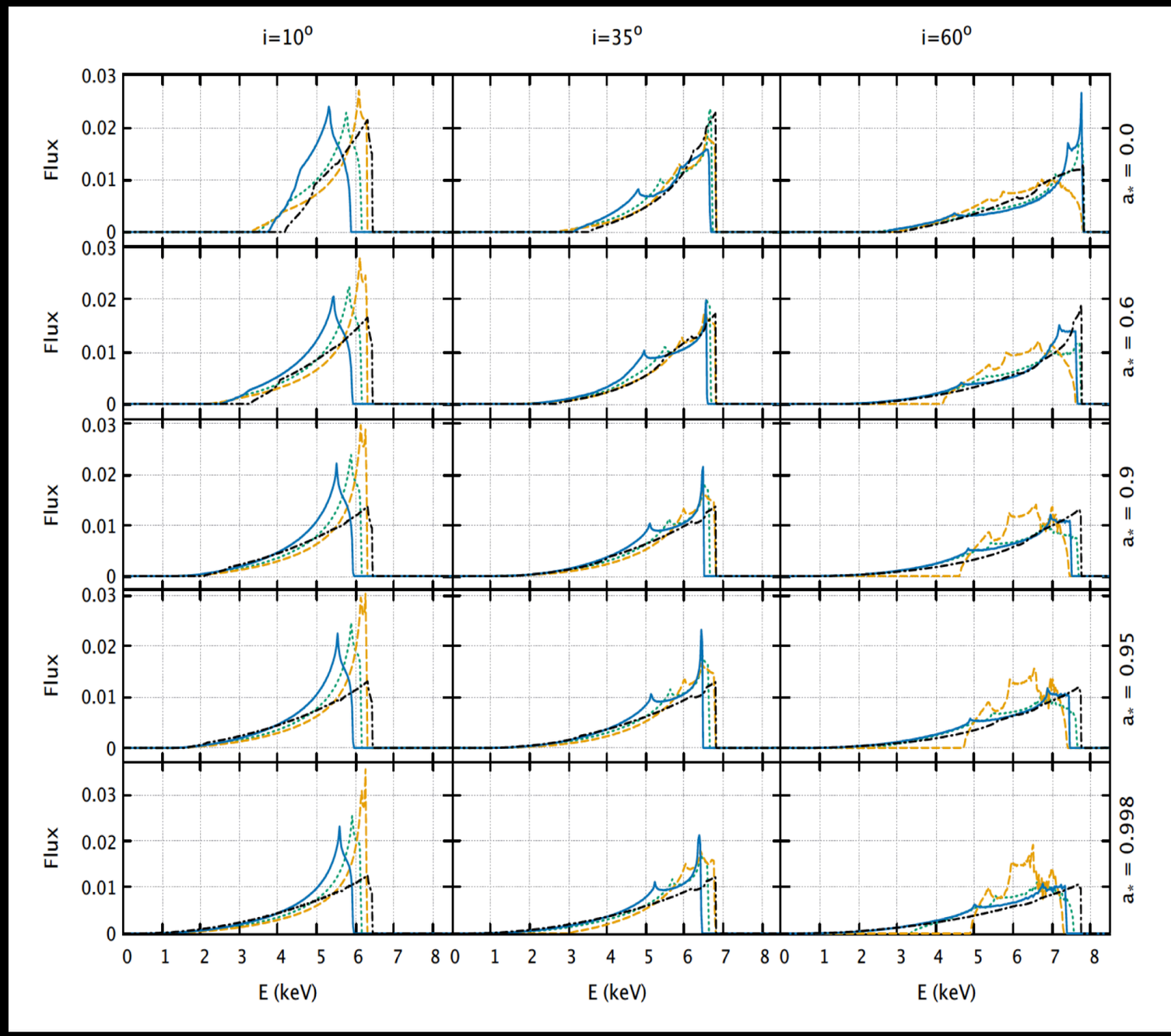
$q = 3$

Novikov-Thorne disk (black),

12 M,

20 M,

40 M.



Riaz et al. 2020

3. Systematic Bias

Model Simplifications: Disk Structure

Iron line for Polish donut disks

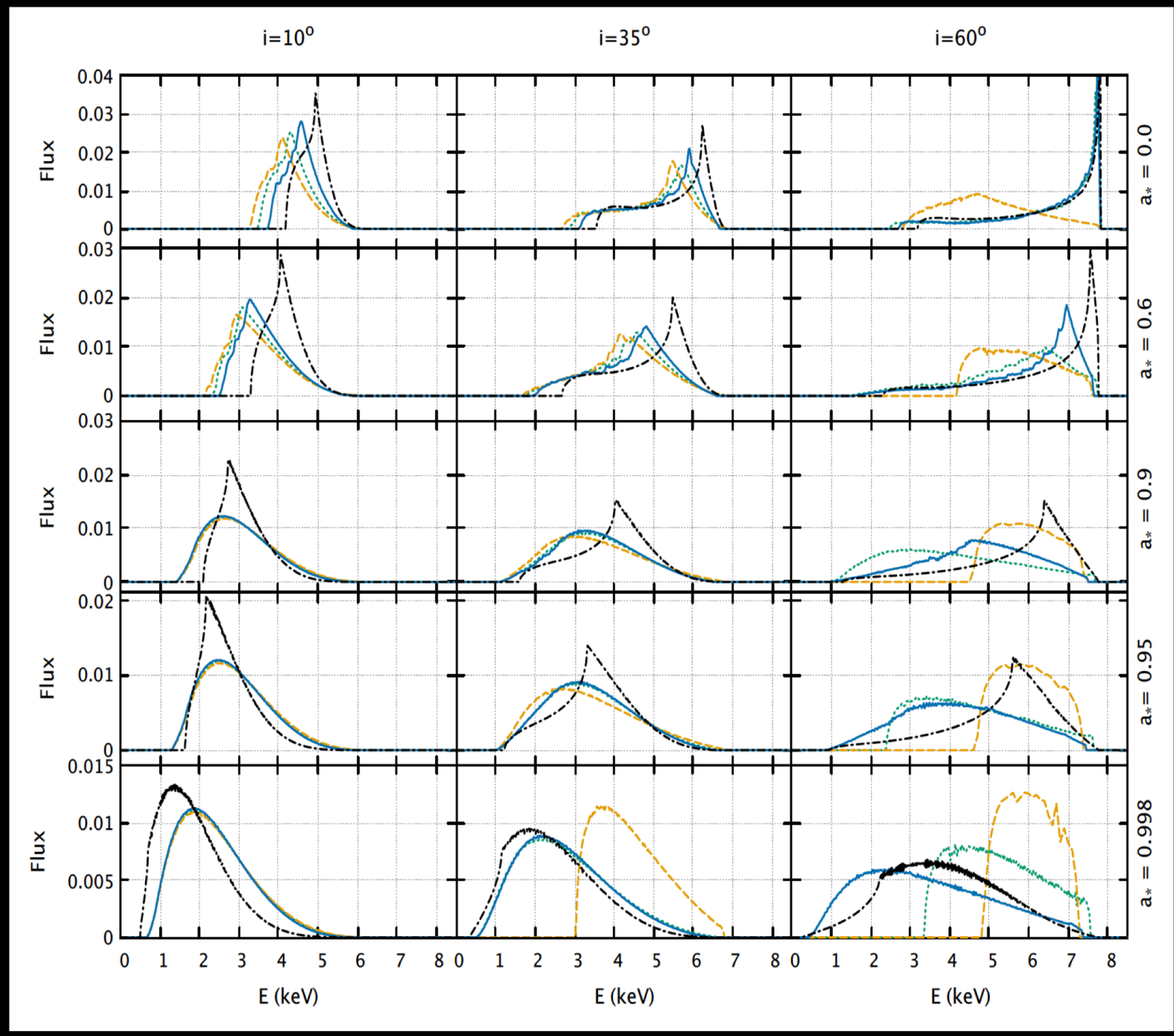
$q = 9$

Novikov-Thorne disk (black),

12 M,

20 M,

40 M.



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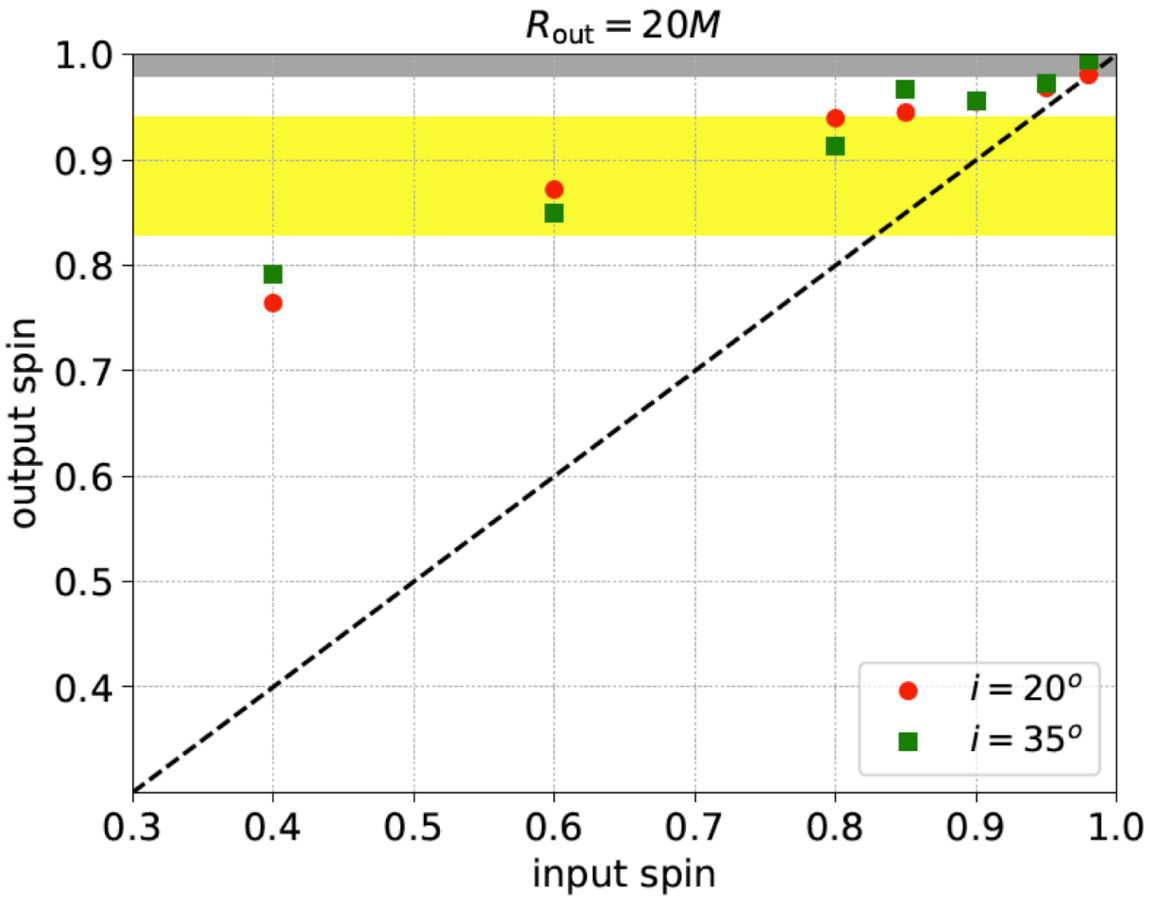

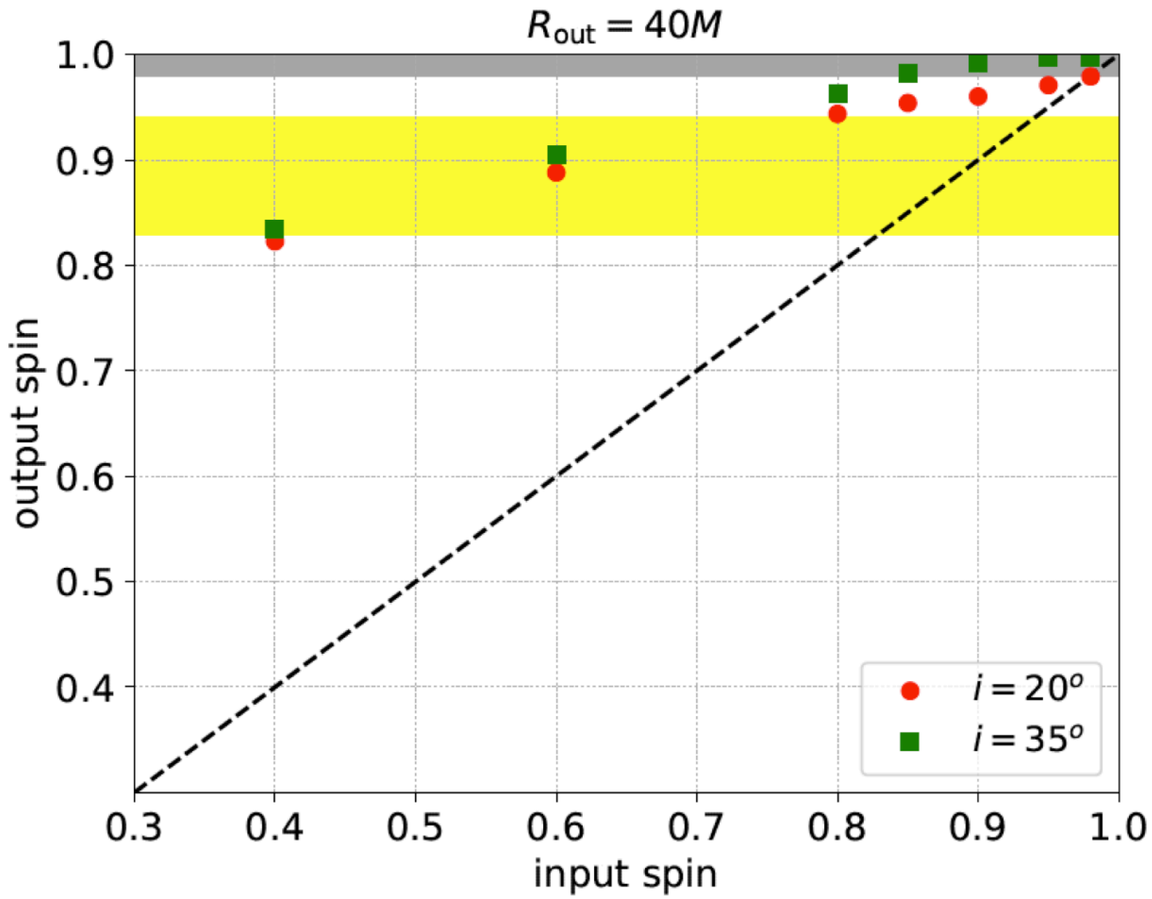

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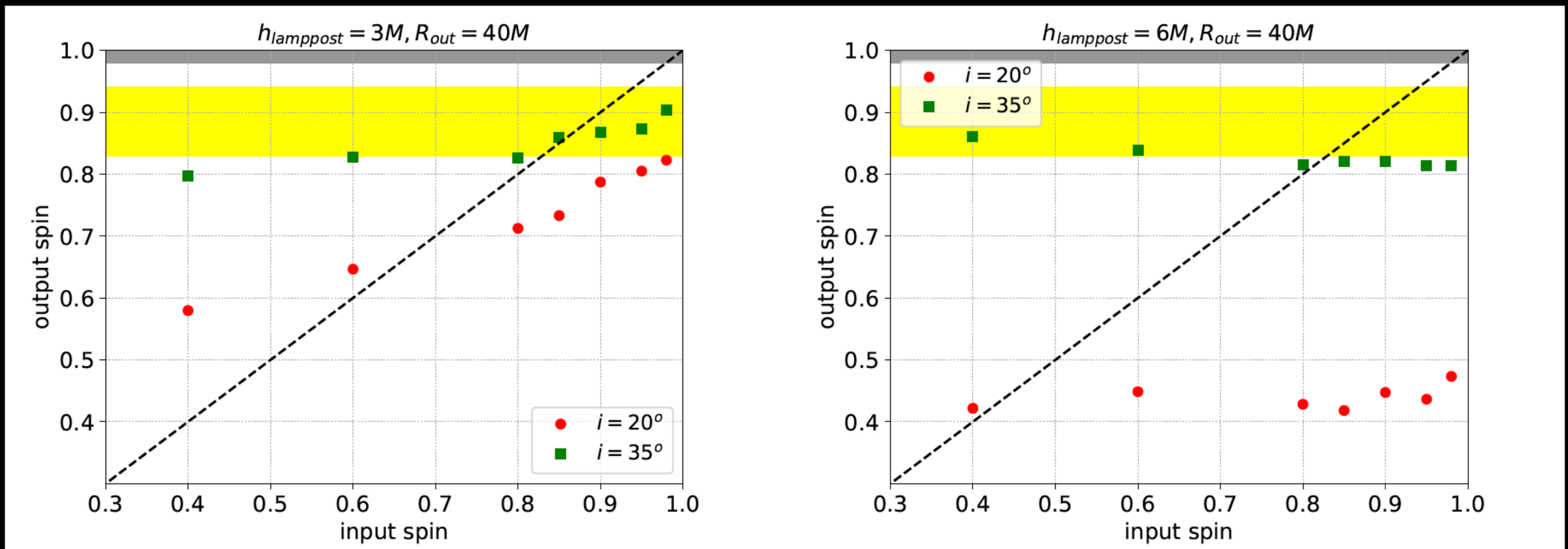
Grey horizontal region for 1H0707-495 (Zoghbi et al. 2010; Walton et al. 2013).Yellow horizontal region for Ton S180 (Walton et al. 2013).

3. Systematic Bias

Model Simplifications: Disk Structure



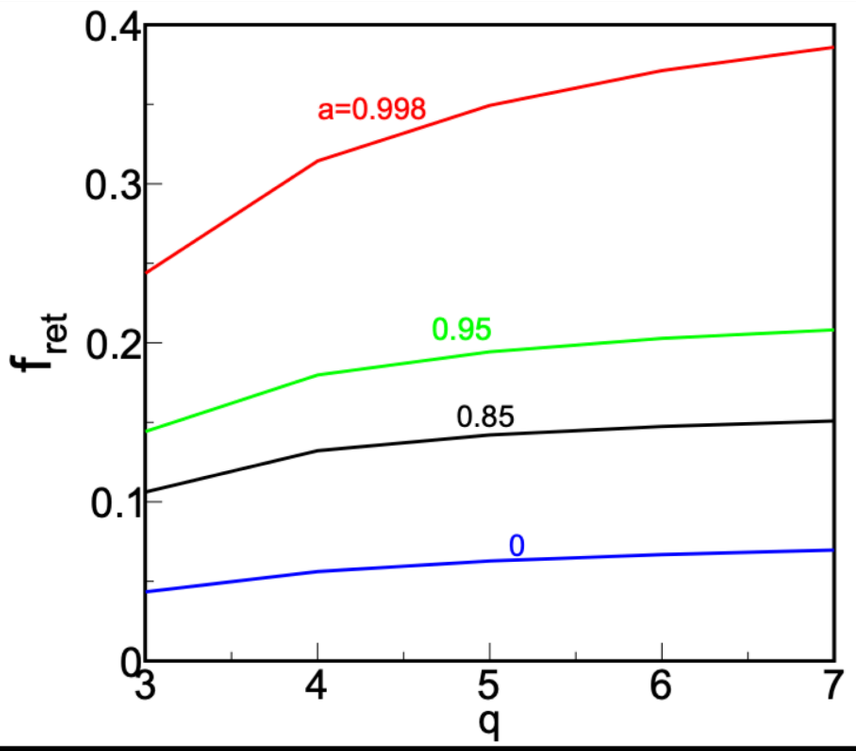
Riaz et al. 2020

Grey horizontal region for 1H0707-495 (Zoghbi et al. 2010; Walton et al. 2013).Yellow horizontal region for Ton S180 (Walton et al. 2013).

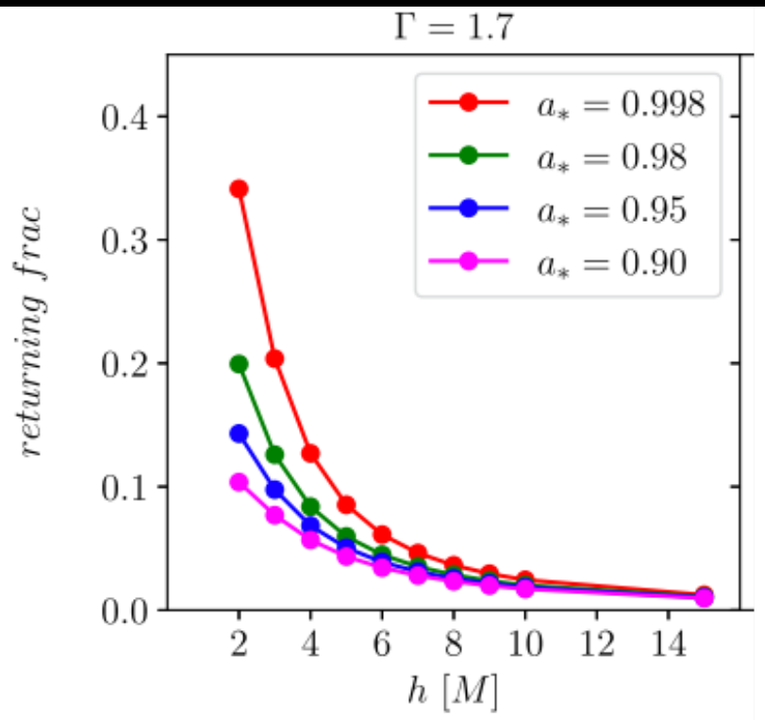
3. Systematic Bias

Model Simplifications: Returning Radiation

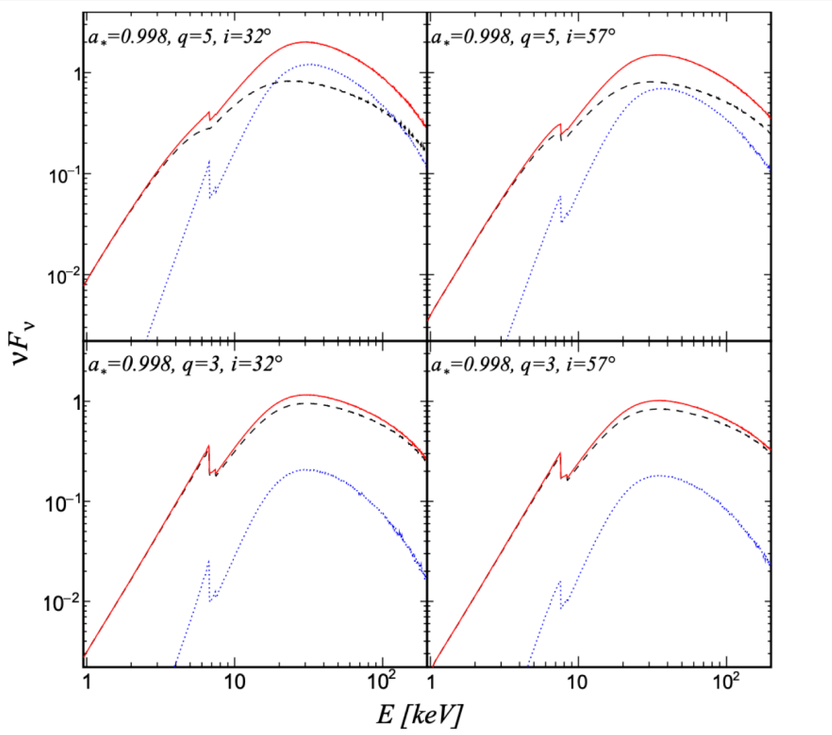
Riaz et al. 2021



Riaz et al. 2023



Riaz et al. 2021



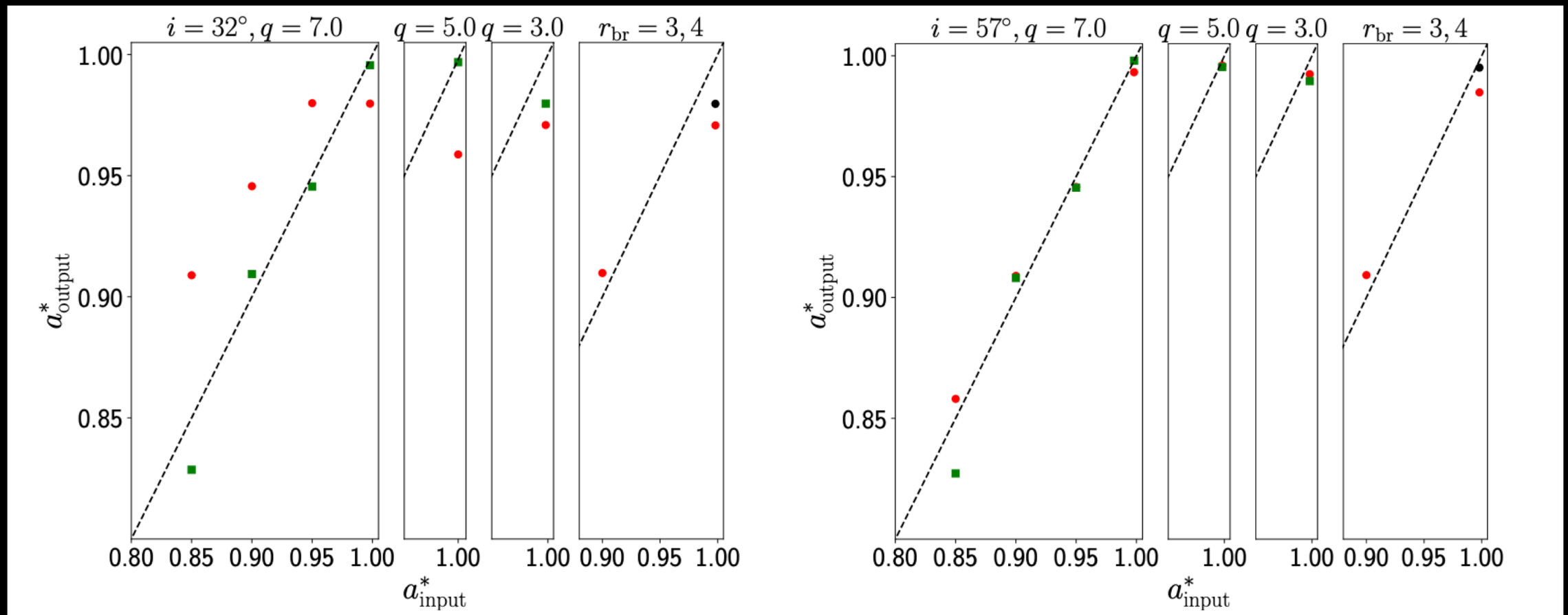
Returning radiation distorts the relativistic reflection spectra through two effects:

- Radial redistribution of the irradiating flux
- Contribution of reflection produced by radiation with energy distribution deviating from a power-law.

The over all effect of the returning radiation is to strengthen the emission and absorption features

3. Systematic Bias

Model Simplifications: Returning Radiation



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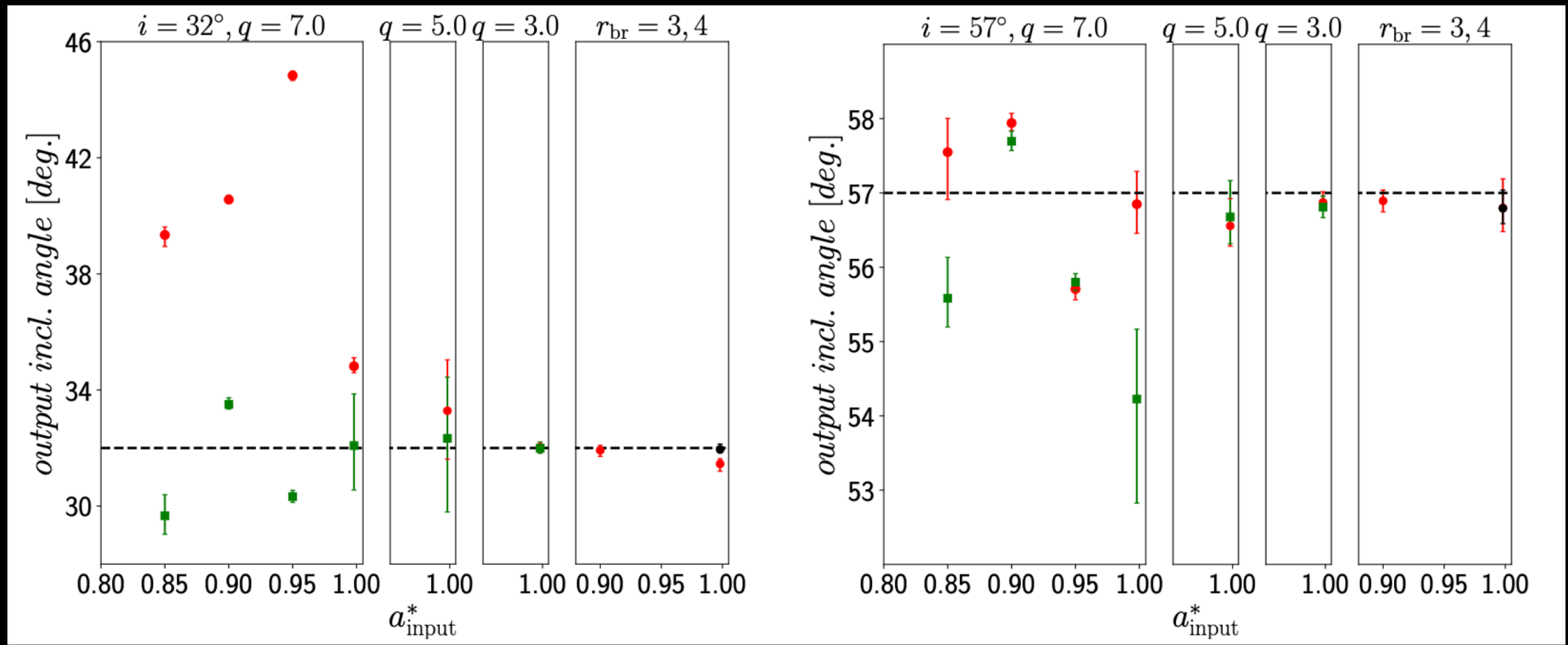

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4. Conclusion

The structure of the accretion disk:

- ➢ Current spin measurements of sources with high mass accretion rates are, therefore, not reliable.

The returning radiation:

- ➢ Spin tends to be overestimated for low viewing angle simulations.
- ➢ No clear bias is observed for high viewing angles.

Takeaway message:

- ➢ Systematic uncertainties in current relativistic reflection models are important issues. These models need further improvement to be ready for next-generation X-ray data analysis.