eXtreme gravity with X-rays

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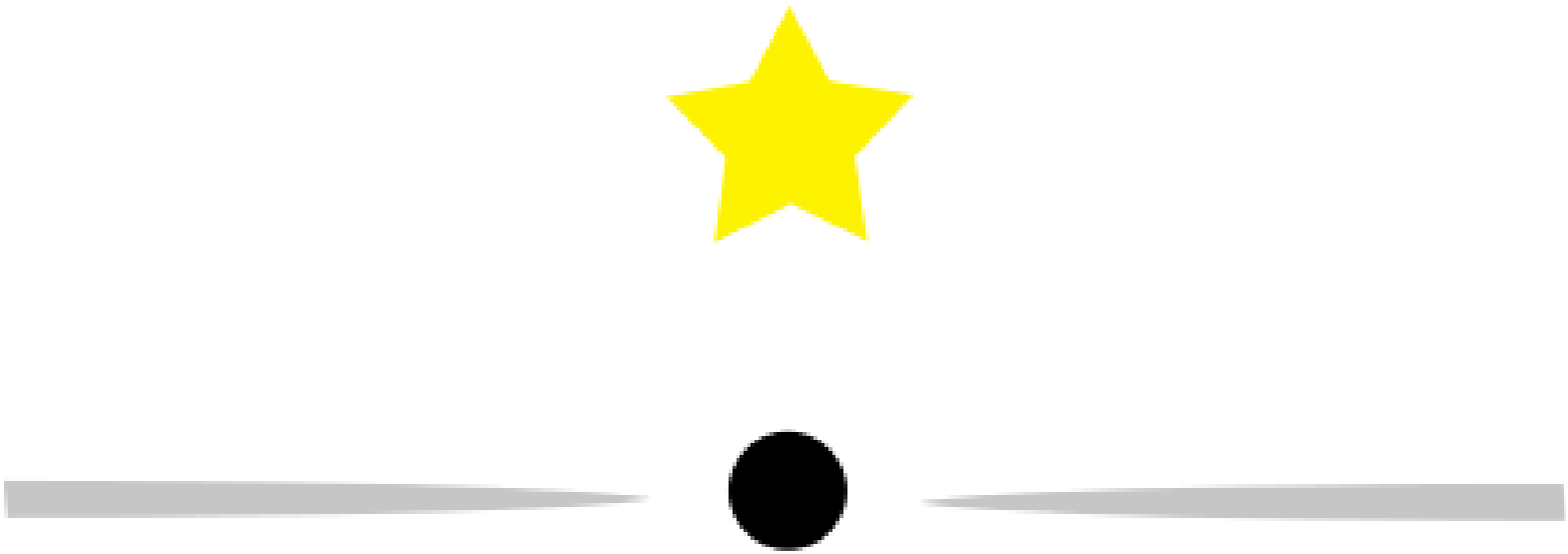
The playground



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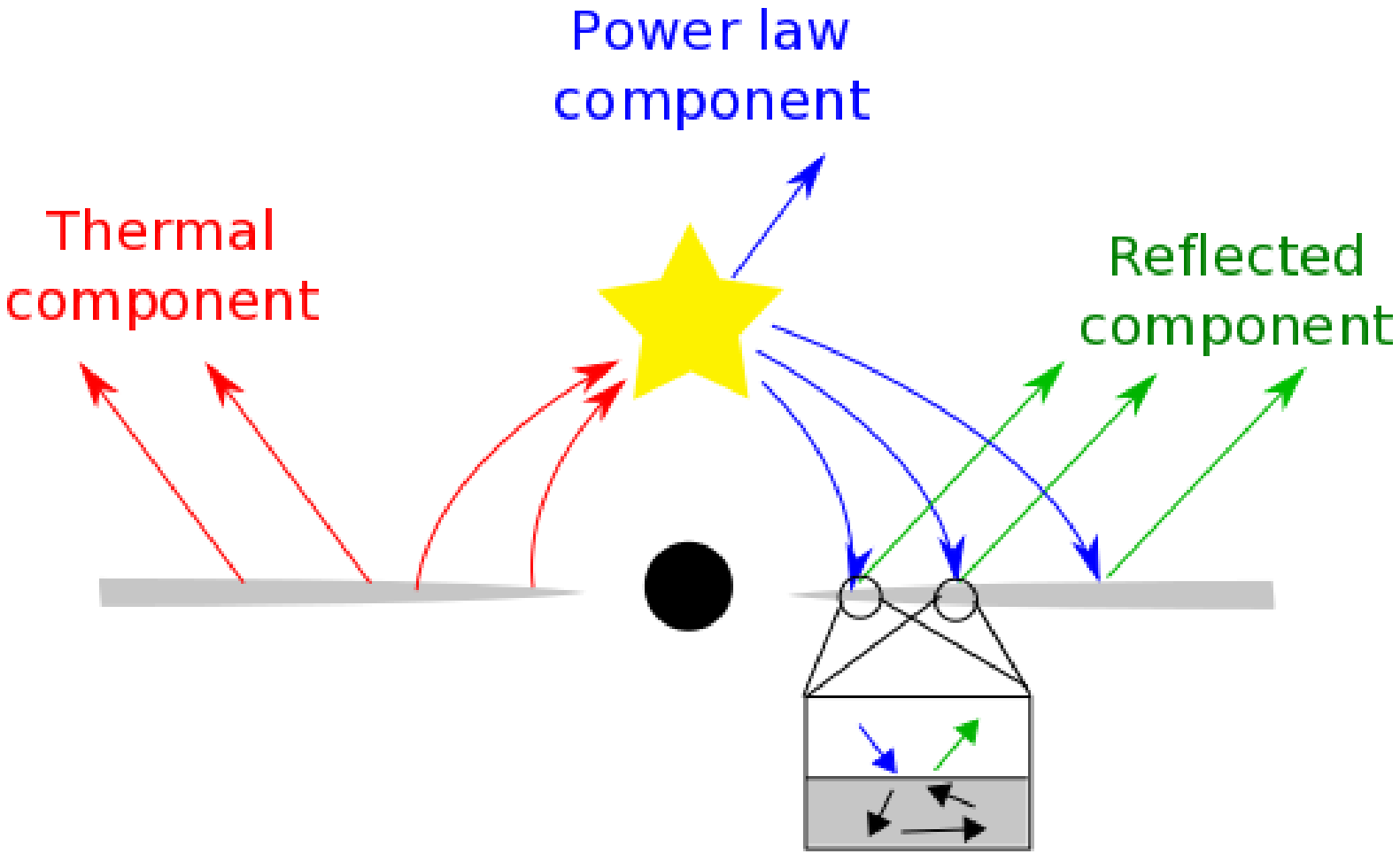


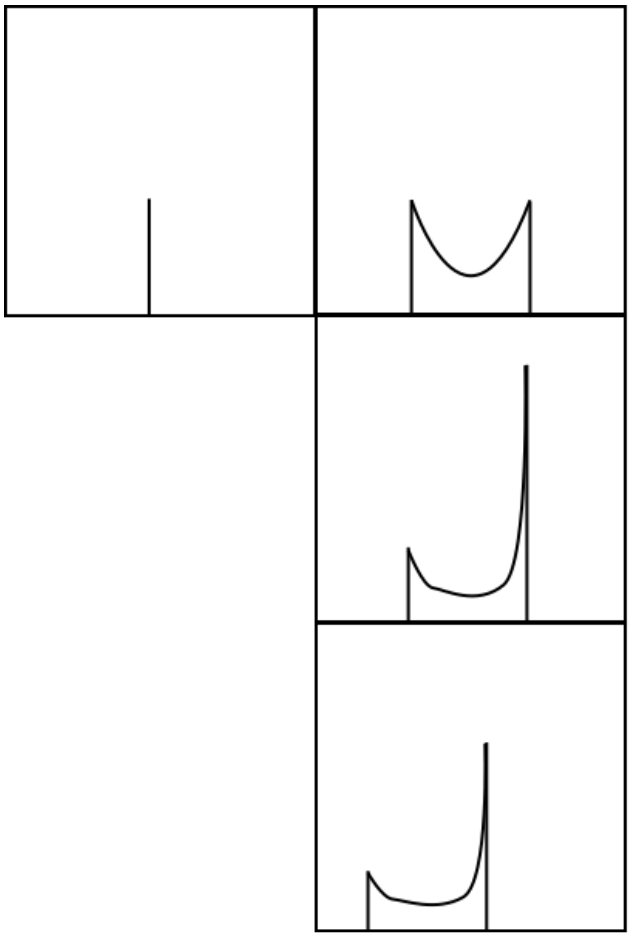
The thin disk

- Disk on the equatorial plane
- Nearly circular geodesics
- No magnetic fields
- No advection

For the next few slides:

- Inner edge at ISCO
- Disk made of ionized iron

Broadening of a line



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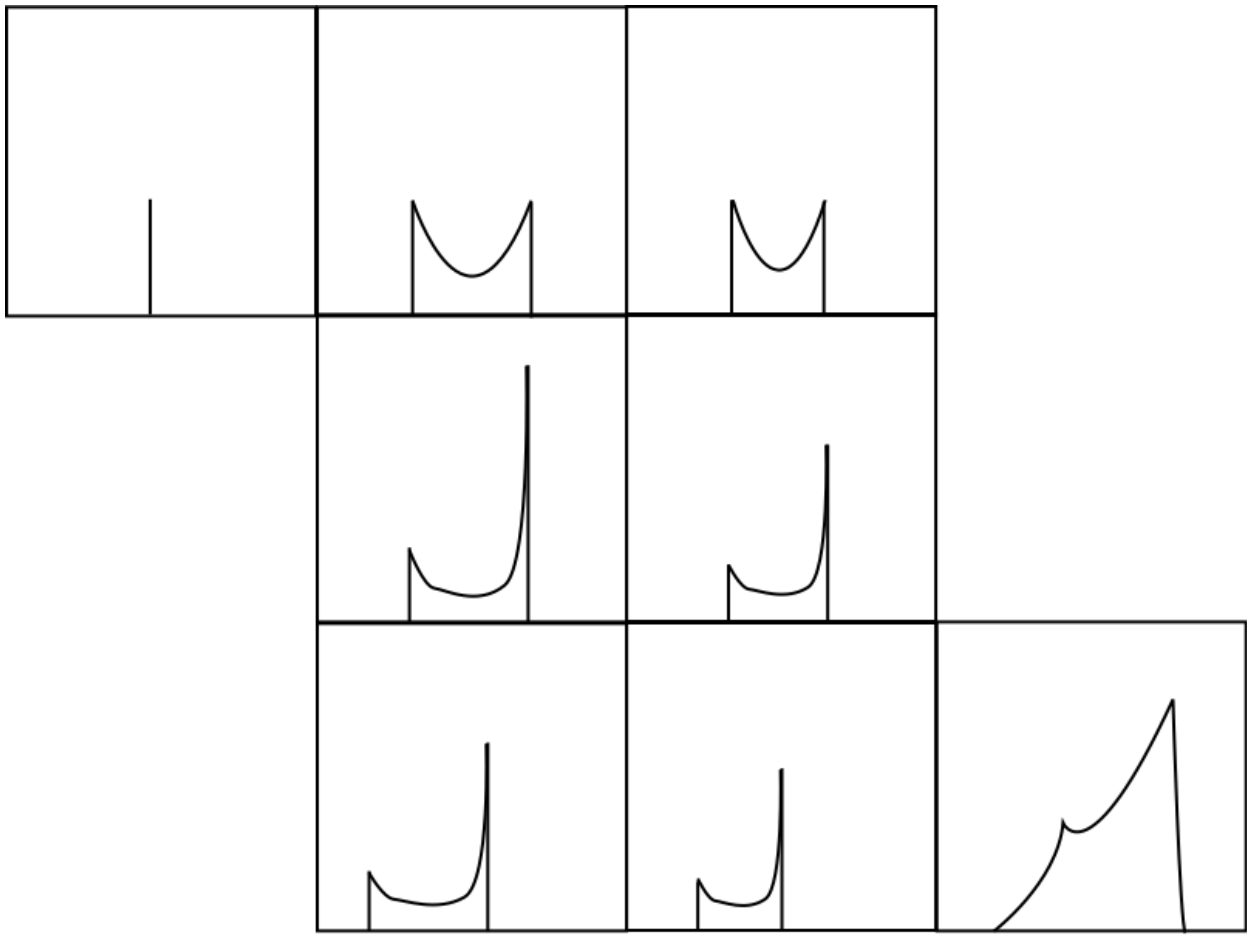
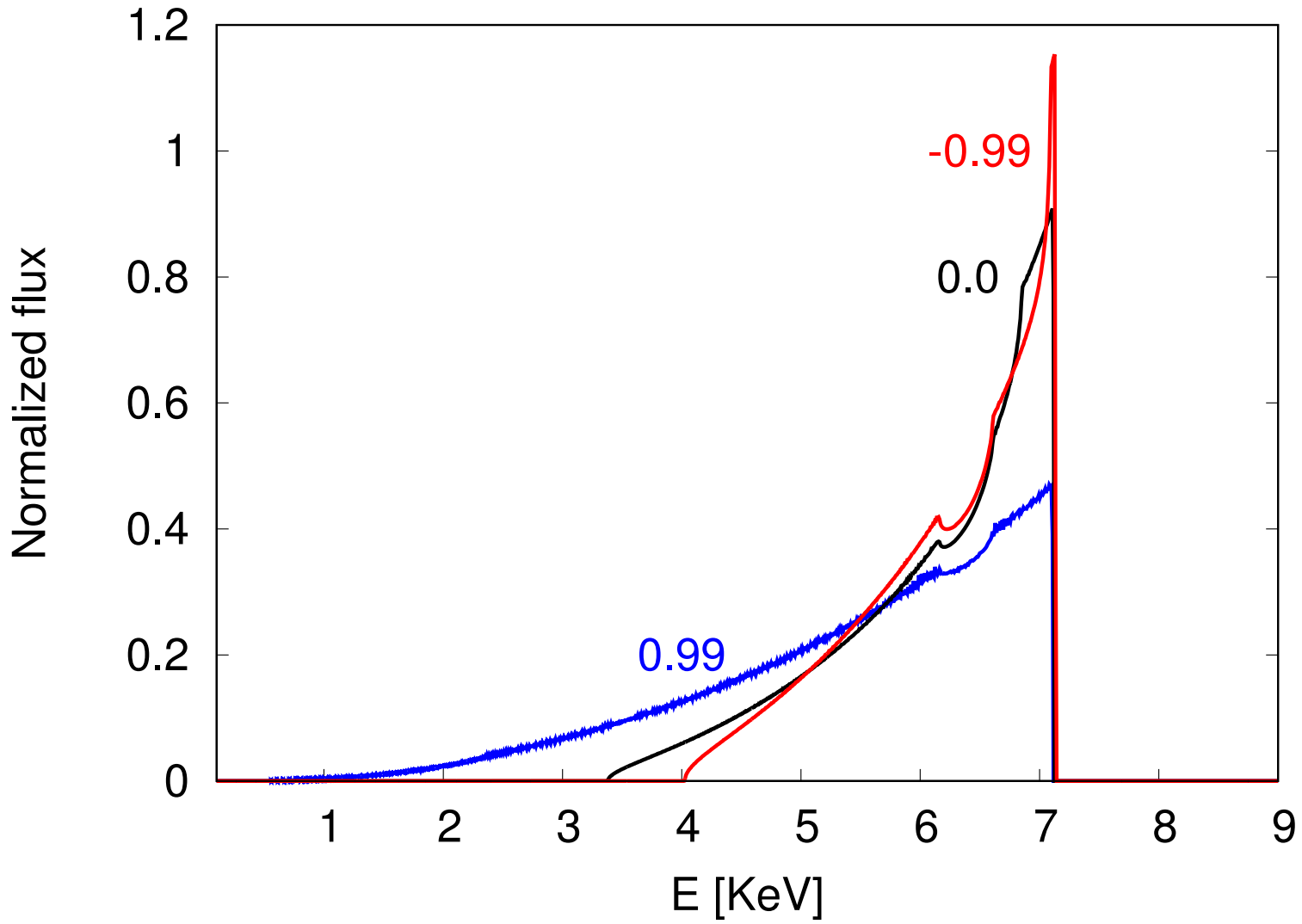


Kα lines: Kerr background



Hawking-Thorne bet

Black holes theory

- Within GR: Kerr metric.

Black holes theory

- Within GR: Kerr metric.
- Beyond GR:

Top-down	Bottom-up

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Top-down	**Bottom-up**
New theory $\rightarrow$ new BHs	Kerr metric $\rightarrow$ new BHs

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Complicated solutions	Spacetime pathologies

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Top-down	**Bottom-up**
New theory $\rightarrow$ new BHs	Kerr metric $\rightarrow$ new BHs
New theory of gravity!	Maps to other theories
Complicated solutions	Spacetime pathologies
EdGB	Johannsen
Kerr-Sen	Cardoso-Pani-Rico
Chern-Simons	Konoplya-Rezzolla-Zhidenko

Black holes beyond GR: bottom-up

- Johannsen metric:

$$
\begin{aligned}
g^{\alpha\beta}\frac{\partial}{\partial x^\alpha}\frac{\partial}{\partial x^\beta} = &-\frac{1}{\tilde{\Sigma}\Delta}\left[(r^2+a^2)A_1(r)\frac{\partial}{\partial t}+aA_2(r)\frac{\partial}{\partial\phi}\right]^2 \\
&+\frac{1}{\tilde{\Sigma}\sin^2\theta}\left[A_3(\theta)\frac{\partial}{\partial\phi}+a\sin^2\theta A_4(\theta)\frac{\partial}{\partial t}\right]^2 \\
&+\frac{\Delta}{\tilde{\Sigma}}A_5(r)\left(\frac{\partial}{\partial r}\right)^2+\frac{1}{\tilde{\Sigma}}A_6(\theta)\left(\frac{\partial}{\partial\theta}\right)^2 \qquad (1)
\end{aligned}
$$

where

$$\tilde{\Sigma} = r^2 + a^2\cos^2\theta + f(r).$$

Black holes beyond GR: bottom-up

- Johannsen metric:

$$g^{\alpha\beta}\frac{\partial}{\partial x^\alpha}\frac{\partial}{\partial x^\beta} = -\frac{1}{\tilde{\Sigma}\Delta}\left[(r^2+a^2)A_1(r)\frac{\partial}{\partial t} + aA_2(r)\frac{\partial}{\partial \phi}\right]^2 + \frac{1}{\tilde{\Sigma}\sin^2\theta}\left[A_3(\theta)\frac{\partial}{\partial \phi} + a\sin^2\theta A_4(\theta)\frac{\partial}{\partial t}\right]^2 + \frac{\Delta}{\tilde{\Sigma}}A_5(r)\left(\frac{\partial}{\partial r}\right)^2 + \frac{1}{\tilde{\Sigma}}A_6(\theta)\left(\frac{\partial}{\partial \theta}\right)^2 \quad (1)$$

where

$$\tilde{\Sigma} = r^2 + a^2\cos^2\theta + f(r).$$

$$A_1 = 1 + \alpha_{13}(M/r)^3 + \ldots, \quad A_2 = 1 + \alpha_{22}(M/r)^2 + \ldots$$
$$A_5 = 1 + \alpha_{52}(M/r)^2 + \ldots, \quad f = \epsilon_3(M^3/r) + \ldots$$

Johannsen, PRD, 88, 044002 (2013)

Mapping Johannsen

- Slowly rotating Chern-Simons [Yunes, Pretorius; PRD 79 (2009)]

In this case, the mapping is

$$\alpha_{24} = \frac{5}{8}\zeta_{\rm CS}, \tag{136}$$

$$\alpha_{25} = \frac{15}{14}\zeta_{\rm CS}, \tag{137}$$

$$\alpha_{26} = \frac{27}{16}\zeta_{\rm CS}. \tag{138}$$

- Static EdGB [Yunes, Stein; PRD 83 (2011)]

and the lowest-order coefficients are:

$$\alpha_{52} = -\frac{\alpha_3}{\kappa},$$

$$\alpha_{53} = -\frac{3\alpha_3}{\kappa},$$

$$\alpha_{54} = -\frac{70\alpha_3}{3\kappa}. \tag{134}$$

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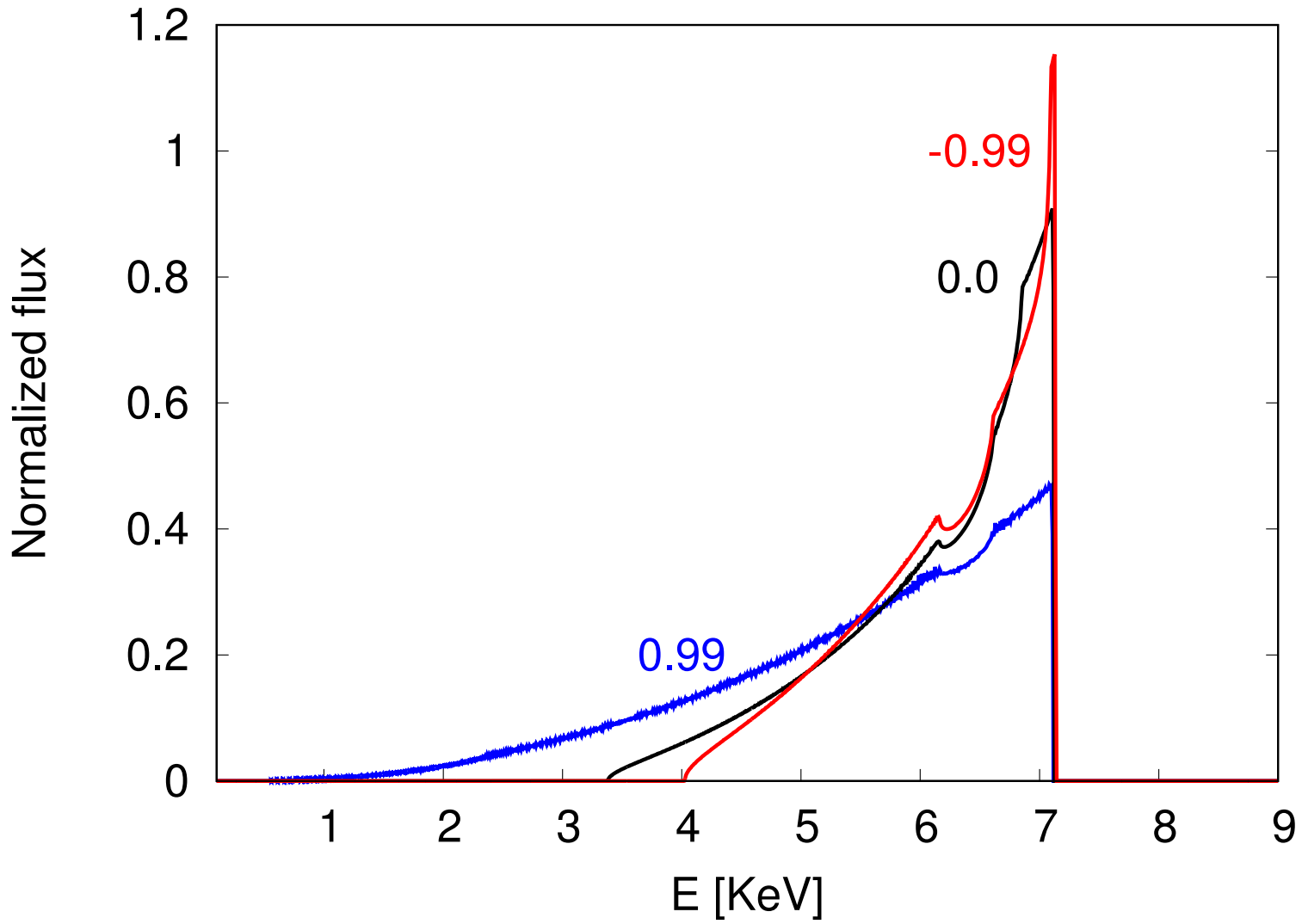
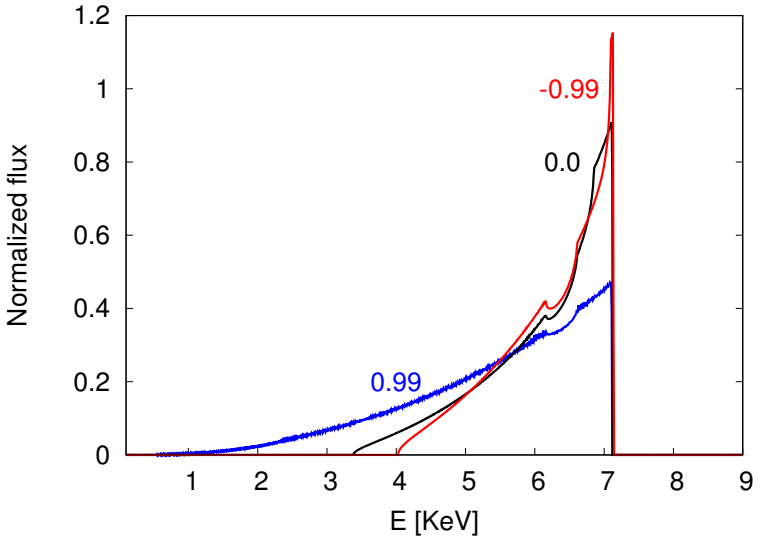
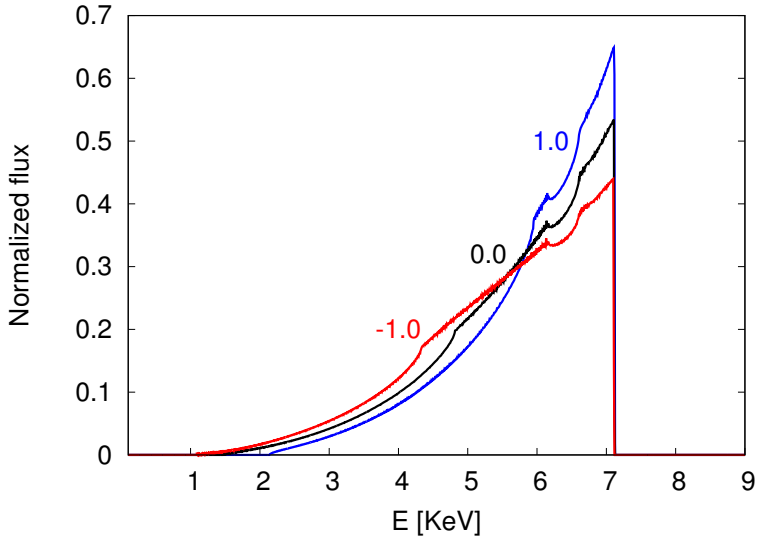
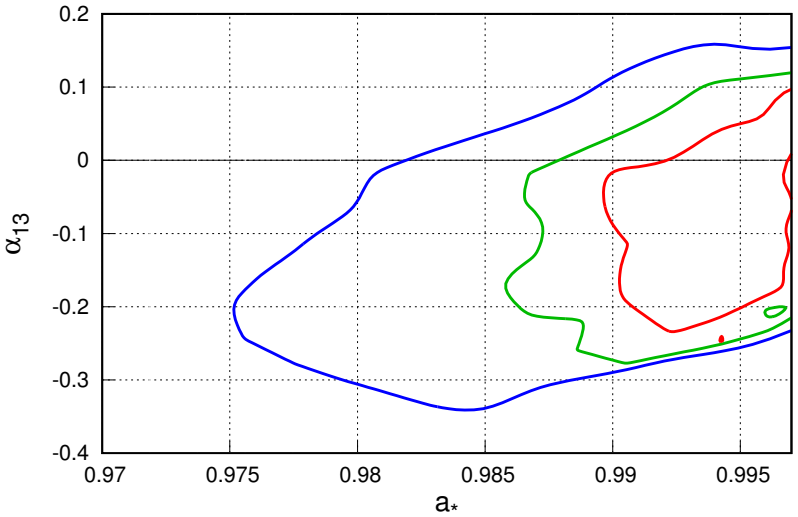


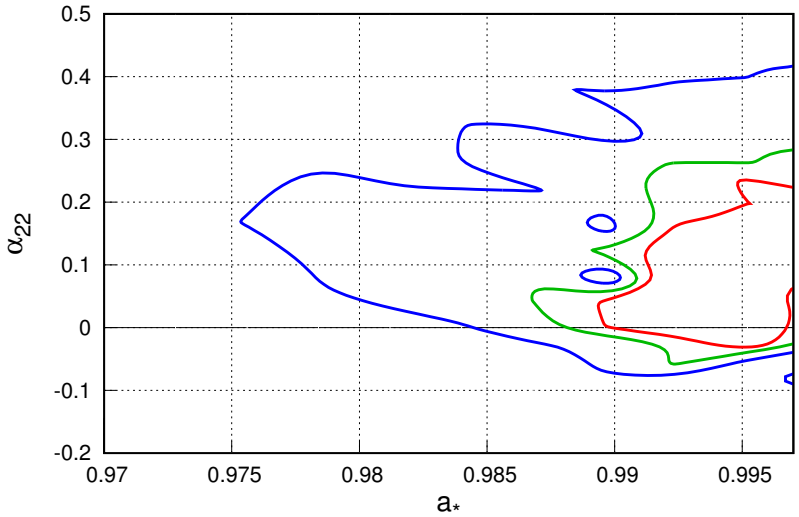
Iron lines: A comparison





Constraints: GS 1354-645





Xu, SN, et al., accepted in ApJ, arXiv:1807.10243

Conclusion

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  1. lamp post

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  2. thick disk

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  3. atomic data

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  1. more top down metrics

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Thank you!