



Minimum X-ray source size for a lamppost corona in light-bending models for AGN

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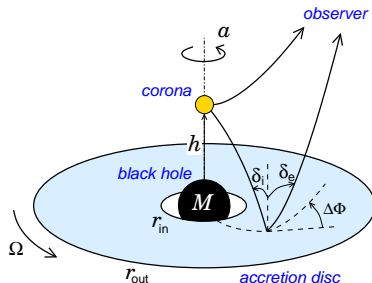
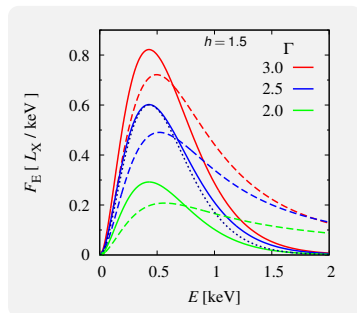
The Extremes of Black Hole Accretion
ESAC, Villafranca del Castillo, Madrid, Spain
8th–10th June 2015

Scheme of the lamp-post geometry

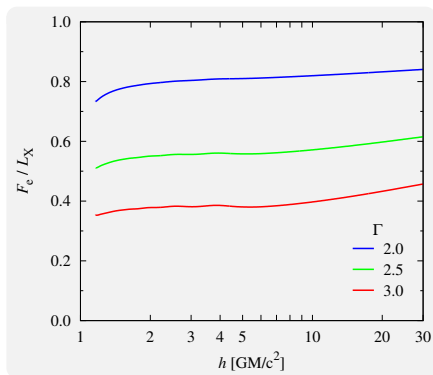
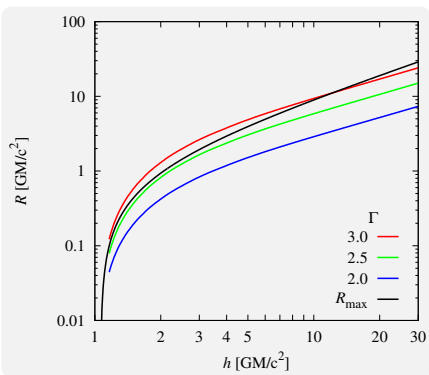
- ▶ **central black hole** – mass, spin
- ▶ **accretion disc**
 - Keplerian, geometrically thin, optically thick
 - Novikov-Thorne thermal emission ($T_{\text{NT}}, M, \dot{M} = \frac{L_b}{\eta c^2}, a, f_c$)
- ▶ **compact corona** with isotropic emission
 - height, luminosity, size (radius), optical depth (h, L_X or L_{obs}, R, τ)
- ▶ **up-scattering** in the corona
 - `nthcomp`($E; \Gamma, E_c, T_{\text{BB}}$)
- ▶ **relativistic effects**:
 - Doppler and gravitational energy shift
 - light bending (lensing)
 - aberration (beaming)

$$M = 10^7 M_{\odot}, L_b = L_{\text{Edd}},$$

$$a = 0.998, \eta = 32.4\%, f_c = 2.4$$



Size of the corona – constant intrinsic luminosity



$$L_X = 0.031 L_{\text{Edd}}$$

$$(L_{\text{obs}} = 0.02 L_{\text{Edd}} \text{ at } h = 10 \text{ GM}/c^2)$$

$$\Sigma_e = \frac{\tau}{\sigma_t} \sim 10^{23} - 10^{24} \text{ cm}^{-2}$$

$$n_e = \frac{\Sigma_e}{l} \sim 10^9 - 10^{12} \text{ cm}^{-3}$$

Γ	τ
2	0.85
2.5	0.4
3	0.2

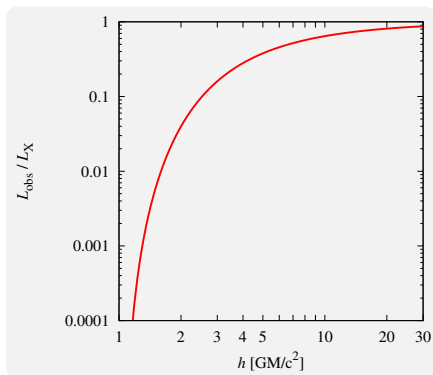
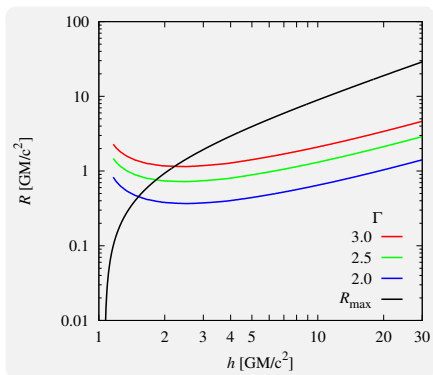
computed with
compps

$$\frac{F_e}{L_X} = 1 - \frac{F_{\text{in}}}{L_X} \frac{f_{\text{out}}}{f_{\text{in}}}$$

$$(1 - e^{-\tau}) f_{\text{in}} dS_L = f_{\text{out}}$$

$$R = \sqrt{\frac{1}{\pi} \frac{g_L}{1 - e^{-\tau}} \frac{f_{\text{out}}}{f_{\text{in}}}}$$

Size of the corona – constant observed luminosity

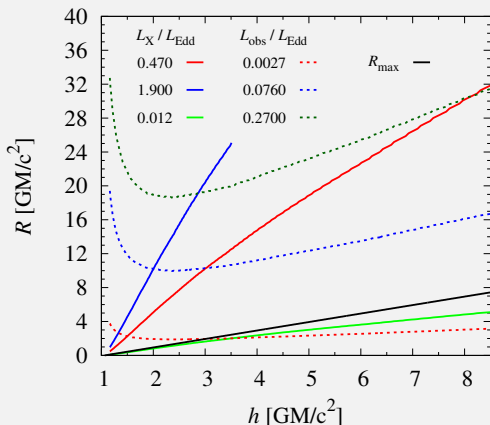


$$L_{\text{obs}} = 0.001 L_{\text{Edd}}$$

$$\frac{L_{\text{obs}}}{L_X} = g_L^2 \frac{d\Omega_L}{d\Omega_o}$$

What size of the corona is needed for the given observed luminosity if the corona is at height h ?

Application to 1H0707-495



- ▶ **dotted red** → size for the minimum L_{obs}
- ▶ **solid red** → size for the light bending scenario, L_X set from the minimum L_{obs} at $h = 1.5$
- ▶ **dotted dark green** → size for the maximum L_{obs}
- ▶ **dotted blue** → size for the average L_{obs}
- ▶ **solid blue** → size for the light bending scenario, L_X set from the average L_{obs} at $h = 2$
- ▶ **solid green** → size for the light bending scenario, L_X set from the minimum L_{obs} at $h = 3.5$ → pure light bending scenario cannot reach maximum L_{obs}

$$F_o(0.3 - 10\text{keV}) = 2 \times 10^{-13} - 2 \times 10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1}$$

$$L_{\text{obs}} = 4\pi D^2 F_o(0.3 - 10\text{keV}) \frac{\int_0^{\infty} E \text{nthcomp}(E; \Gamma, E_c, T_{\text{BB}}) dE}{\int_{0.3/g_L}^{10/g_L} E \text{nthcomp}(E; \Gamma, E_c, T_{\text{BB}}) dE}$$

Conclusions

General conclusions:

- ▶ for reasonable assumptions the corona is not tiny but still may be quite small (even of the order of $1 - 10 r_g$),
- ▶ in light bending scenario with inverse Compton the corona has to change size (geometry), it scales with height,
- ▶ for larger Γ we need smaller τ and both increase R ,
- ▶ point-source approximation is not valid, **3D** computations with **non-spherical** geometry and corona **rotation** are needed for more accurate corona size (and shape) estimation.

Conclusions

Conclusions on 1H0707-495:

- ▶ due to high observed flux in 1H0707-495, in the pure light bending scenario the small spherical patch of corona does not fit above the horizon,
- ▶ **Wilkins & Fabian (2012)** reproduce the steep radial emissivity with an extended corona (up to $30R_g$) at low height ($2R_g$),
- ▶ such an extended corona probably cannot change its emissivity to $100\times$ larger luminosity either through light bending scenario or by extending it even further outside,
- ▶ thus could the inner accretion have higher temperature to produce more photons? (the disc in our assumptions already shines at L_{Edd}),

Conclusions

- ▶ however, the steep decrease of radial emissivity might be artificial due to wrong assumptions on local emission directionality and radial decrease of ionisation, see **Svoboda et al (2012)** and his **poster A20**,
- ▶ thus the extension may be much smaller ($2 r_g$ at height $2 - 3 r_g$) and maybe the maximum flux could be explained by changing corona size and geometry, e.g. by extending it further outside ($20 r_g$ at height $2 - 3 r_g$)?
- ▶ **3D** computations with **non-spherical** geometry and corona **rotation** are needed for more accurate estimations.