STRONGGRAVITY
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SEVENTH FRAMEWORK PROGRAMME

Relativistic reflection from accretion disc ionised due to illumination from on-axis compact corona

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Why to study toy model of lamp-post geometry?

- Astrophysical motivation:
  - observational evidence of a rather compact X-ray source (variability, micro-lensing) – corona size of tens of $R_\mathrm{g} = GM/c^2$
  - base of an aborted jet?
- Useful simplification:
  - many effects should be qualitatively similar with this simple geometry
  - it can give us certain limits on the model
    (e.g. limits on possibility of spin measurements)
  - we can easily explore the dependence on many parameters
    (height of the corona, ionization of the disc, ...)
  - if we want to study the dependence on geometry, we should know how other parameters influence the results

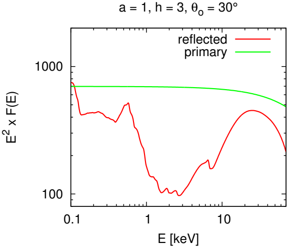
    (e.g. *Is the idea of measuring geometry of the corona via reverberation feasible?*)

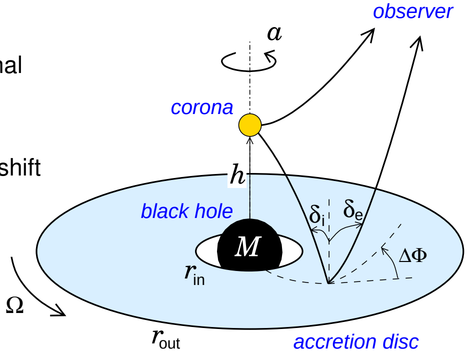
Short and incomplete basic list of references

- Miniutti & Fabian (2004) MNRAS, 349, 1435
- Niedźwiecki & Miyakawa (2010) A&A, 509, A22
- Dovčiak et al (2011) ApJ, 731, 17
- Dauser et al (2013) MNRAS, 430, 1694
- Cackett et al (2014) MNRAS, 438, 2980
- Fabian et al (2014) MNRAS, 439, 2307

Scheme of the lamp-post geometry

- central black hole – mass, spin
- compact corona with isotropic emission
  → height, photon index
- accretion disc
  → Keplerian, geometrically thin, optically thick
  → ionisation due to illumination
  (L_p, h, M, a, n_H, q_n)
- local re-processing in the disc
  → REFLIONX with different directional emissivity prescriptions
- relativistic effects:
  → Doppler and gravitational energy shift
  → light bending (lensing)
  → aberration (beaming)
- KYREFLIONX





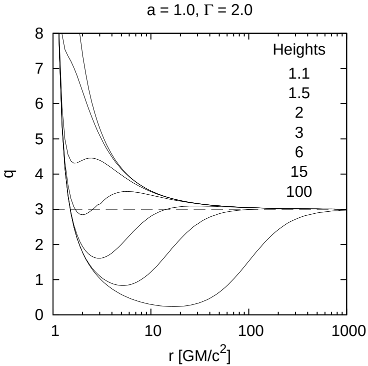
Parameters of the model

- BH mass → ionisation
- BH spin → amount of reflection, ionisation, incident and emission angles
- intrinsic luminosity → primary emission, amount of reflection, ionisation
- photon index → shape of primary and reflected emission, ionisation
- height → primary emission, amount of reflection, ionisation, incident angle
- radial density profile → ionisation
- observer inclination → emission angle

- ionisation → illumination, disc's density

- reflection ratio → height, spin, ionisation, observer inclination
- shape of the reflection → ionisation, emission directionality, relativistic blurring, photon index

Radial illumination profile



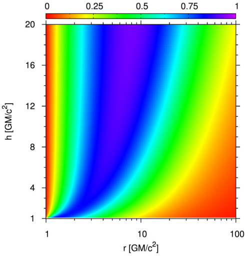
$$q(r) \equiv \frac{\mathrm{d}\log N_{\mathrm{inc}}(r)}{\mathrm{d}\log r} = -r\frac{\mathrm{d}}{\mathrm{d}r}\ln N_{\mathrm{inc}}(r)$$

- to be compared with simpler broken power-law radial dependence r^{-q}
- high q (≈ 7) in some sources (MCG-6-30-15, 1H0707-495, IRAS13224-3809)
- lamp-post geometry alone cannot explain high q in observations

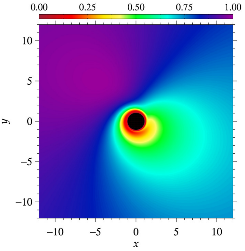
- Dovčiak et al (2011)
- Wilkins & Fabian (2012)
- Svoboda et al (2012)
- Dauser et al (2013)

Emission directionality

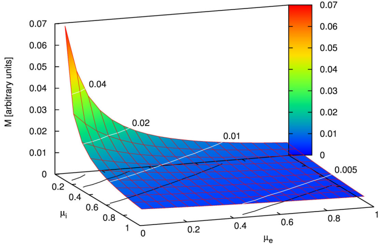
Cosine of the incident angle



Cosine of the emission angle



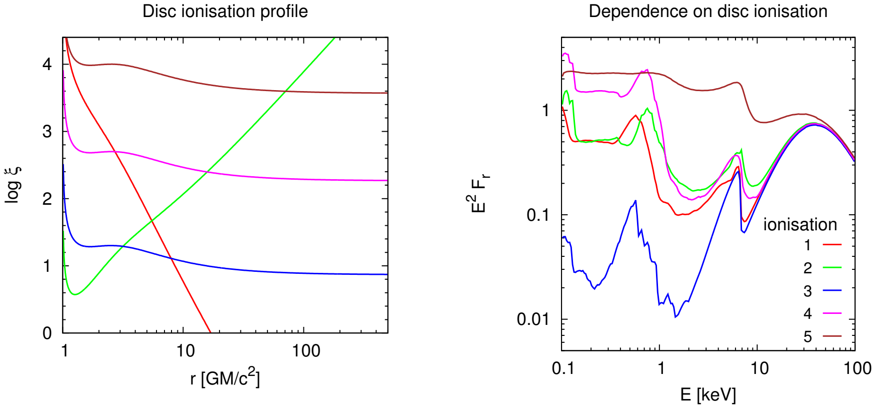
Emission directionality



- $K\alpha$ line emission directionality re-processing numerically computed for neutral disc with Monte Carlo multi-scattering code `NOAR` (Dumont, Abrassart & Collin, 2000)
- enhanced emission close to the black hole due to limb brightening and small incident and emission angles near the horizon – another reason for steeper emissivity

- Svoboda et al (2009)
- García et al (2014)

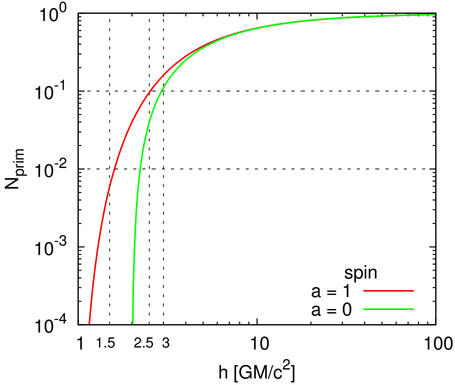
Radial ionisation profile



- Svoboda et al (2012):

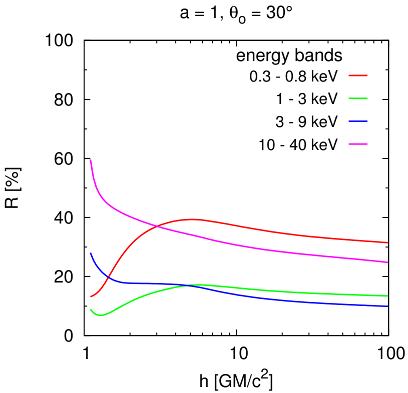
  $\rightarrow$ source at height $1.5\,R_g$ with limb brightening and changing radial ionisation profile may be fitted with isotropic emission, constant ionisation and radial broken power-law emissivity with $q \approx 7$

Primary luminosity



- the intrinsic primary must by much more luminous if the height of the source is small to observe the same flux at infinity

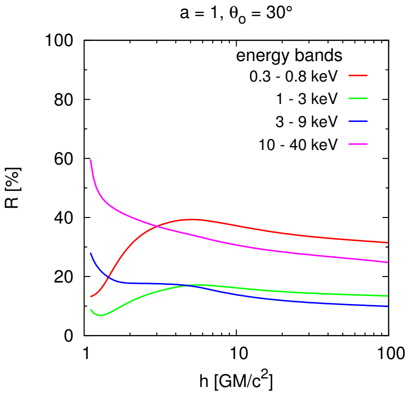
Reflection ratio

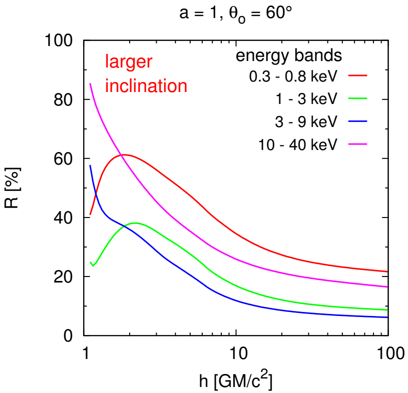


$$R \equiv \frac{F_r}{F_r + F_p}$$

- KYREFLIONX model predictions
- higher R for
  - larger inclinations
  - high spin
  - high ionisation

Reflection ratio





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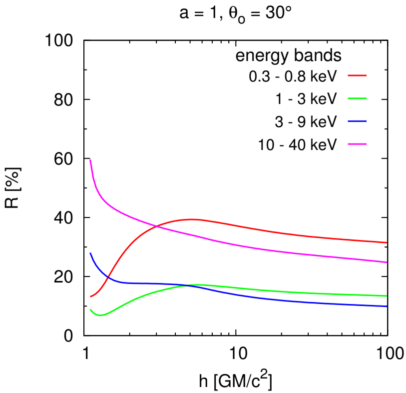

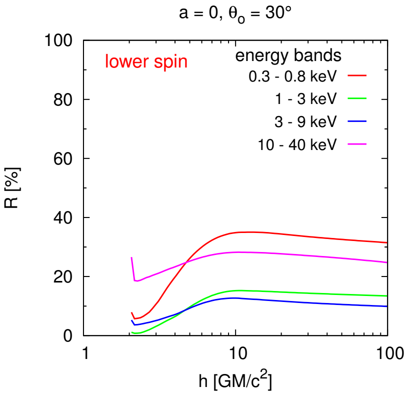

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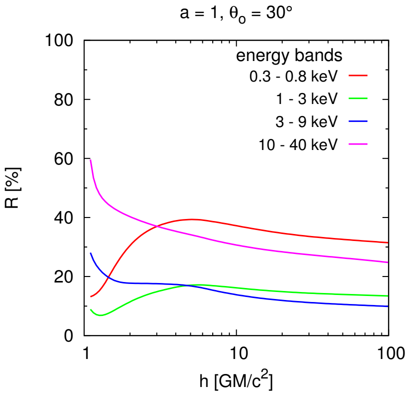

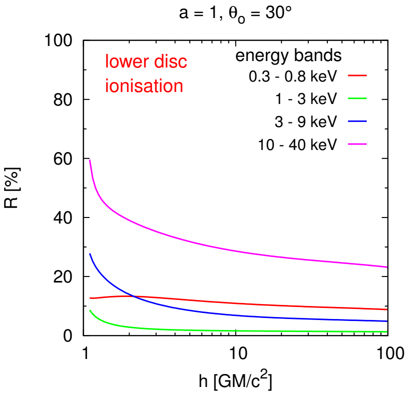

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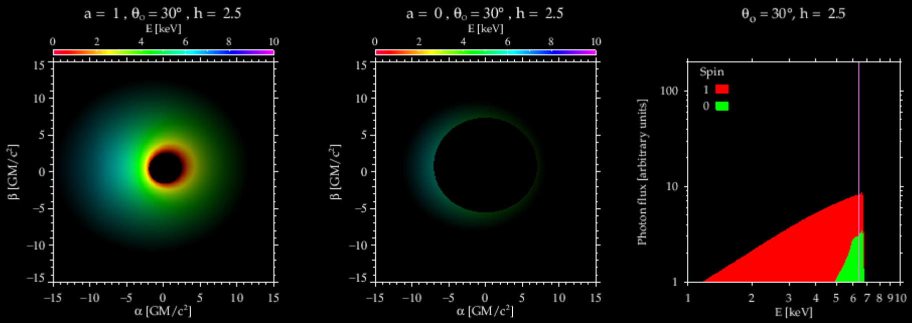
Spin measurements



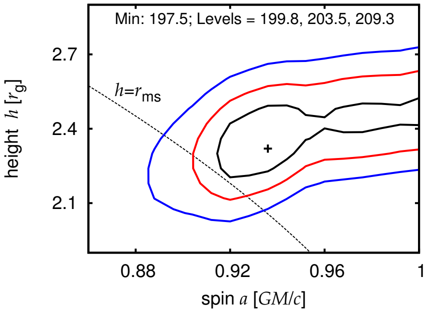
- spin measurements possible only for very compact corona situated very close to the black hole
- Miniutti & Fabian (2004)
- Dauser et al (2013)
- Fabian et al (2014)

Height of the primary source in MCG-6-30-15

`phabs(powerlaw + kyrline + zgauss + zgauss)`

$a = 0.94$, $\theta_o = 21.5^\circ$, $h = 2.3$, $\Gamma = 1.9$

fit to XMM-Newton data



Summary

The lamp-post geometry:

- to be able to measure the spin of the black hole the corona:
  - has to be located very close to the black hole (several $R_{\rm g}$)
  - has to be very compact
- for very low sources the intrinsic primary source luminosity has to be much larger than the observed one (10-times for height 2.5, more than 100-times for height 1.5)
- ionisation radial profile changes the spectrum substantially
- observed reflection ratio in KYREFLIONX is $\lesssim 60\%$ of the total emission for 30° in extreme Kerr case ($a = 1$)
- observed extreme steep radial emissivity could be explained by very low height ($q \approx 7 \Rightarrow h \approx 1.5$)

Poster advertisements

F11 X-ray polarization in the lamp-post model of non-smooth black-hole accretion discs

K01 Reverberation mapping in the lamp-post geometry of the compact corona illuminating a black-hole accretion disc in AGN