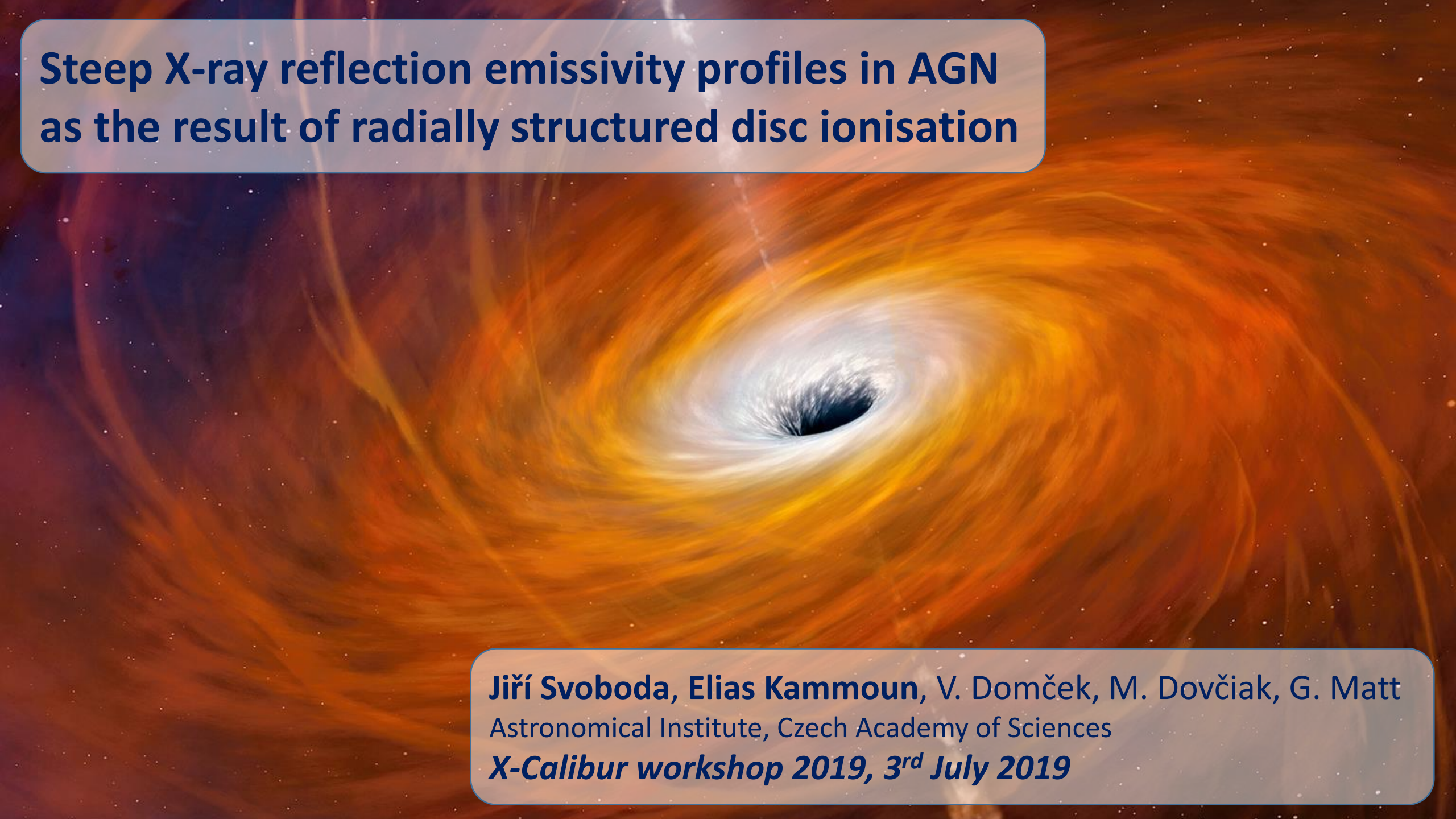
Steep X-ray reflection emissivity profiles in AGN as the result of radially structured disc ionisation



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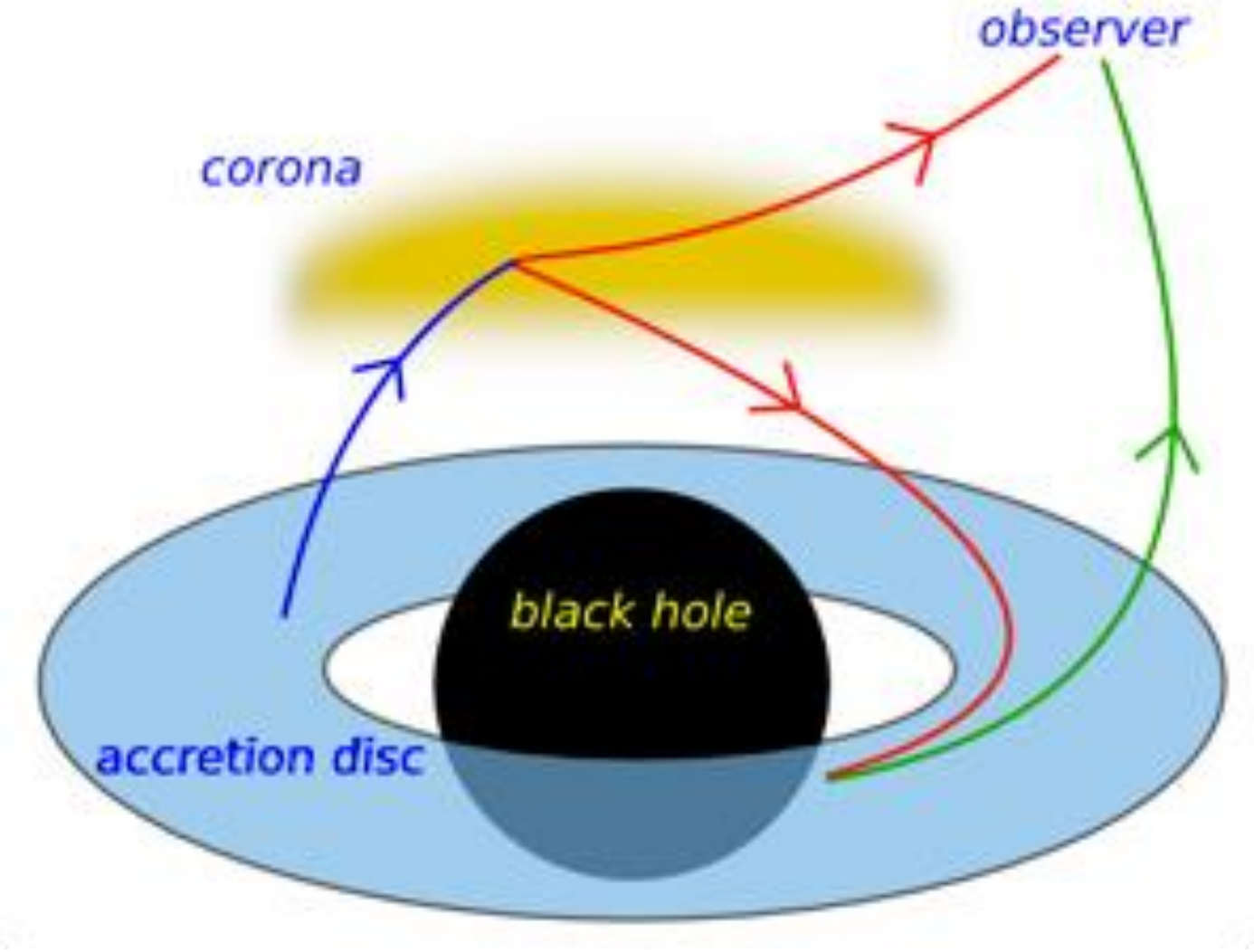
X-ray reflection



- X-ray reflection spectra contain information about:
  - **accretion disc** (ionisation, abundances)
  - **corona** (radial emissivity)
  - **black hole** (spin, relativistic effects)

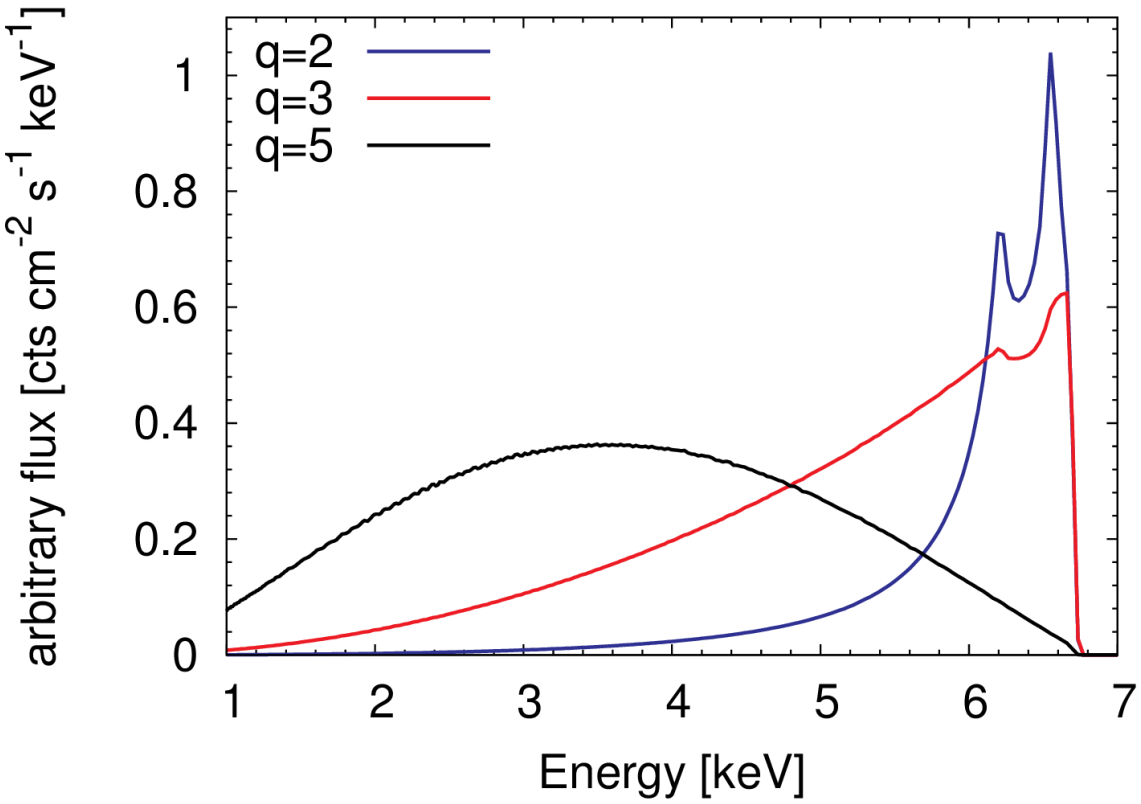
Radial emissivity

- approximated as a (broken) power law:

$$I \approx r^{-q}$$

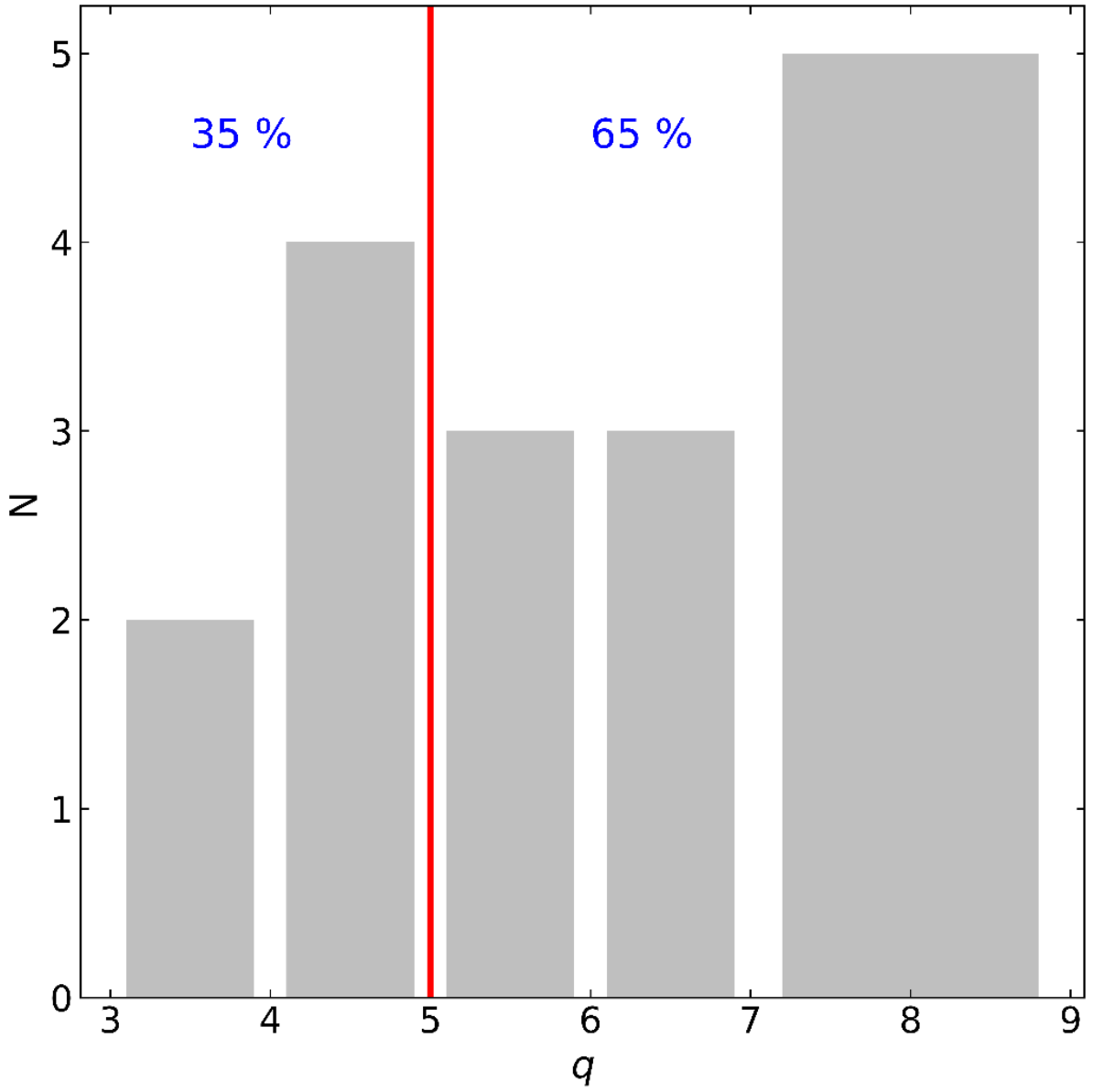
- standard value: $q = 3$
  - follows the local thermal dissipation of the energy $D \sim T^4(r) \sim r^{-3}$
  - corresponds to the irradiation from a source on the disc axis (lamp-post) in the Newtonian geometry
  - GR: if the corona is compact, light bending makes the radial dependence of the irradiation steeper
- compact corona also suggested from microlensing observations (Chartas+2009, Chen+2015)

Relativistic iron line profile for different radial emissivity:

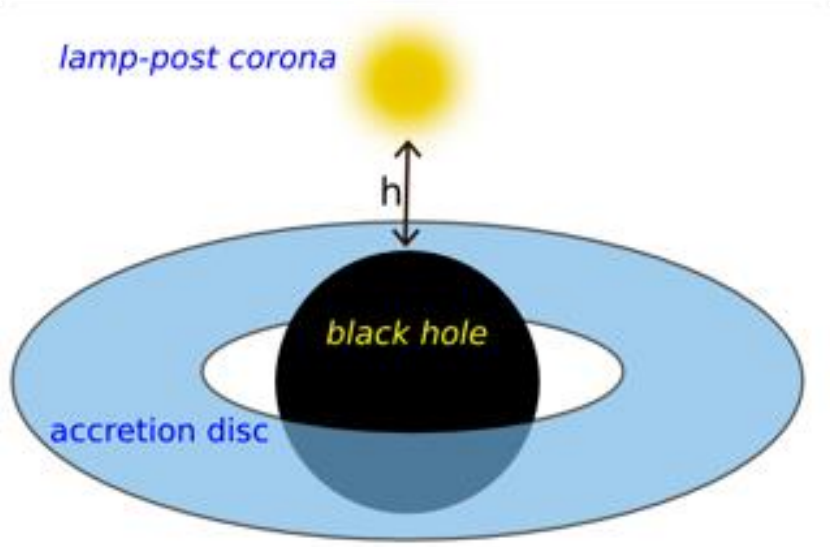


Steep radial emisivity in AGN observations

- several examples:
  - MCG -6-30-15: q ~ 5 (Fabian et al., 2002)
  - 1H 0707-495: q ~ 7.5 (Fabian+ 09, Wilkins+ 12)
  - IRAS 13224-3809: q ~ 7 (Ponti+ 10, Kara+ 13)
- compilation from Walton et al. (2013)
  - most of sources q>5

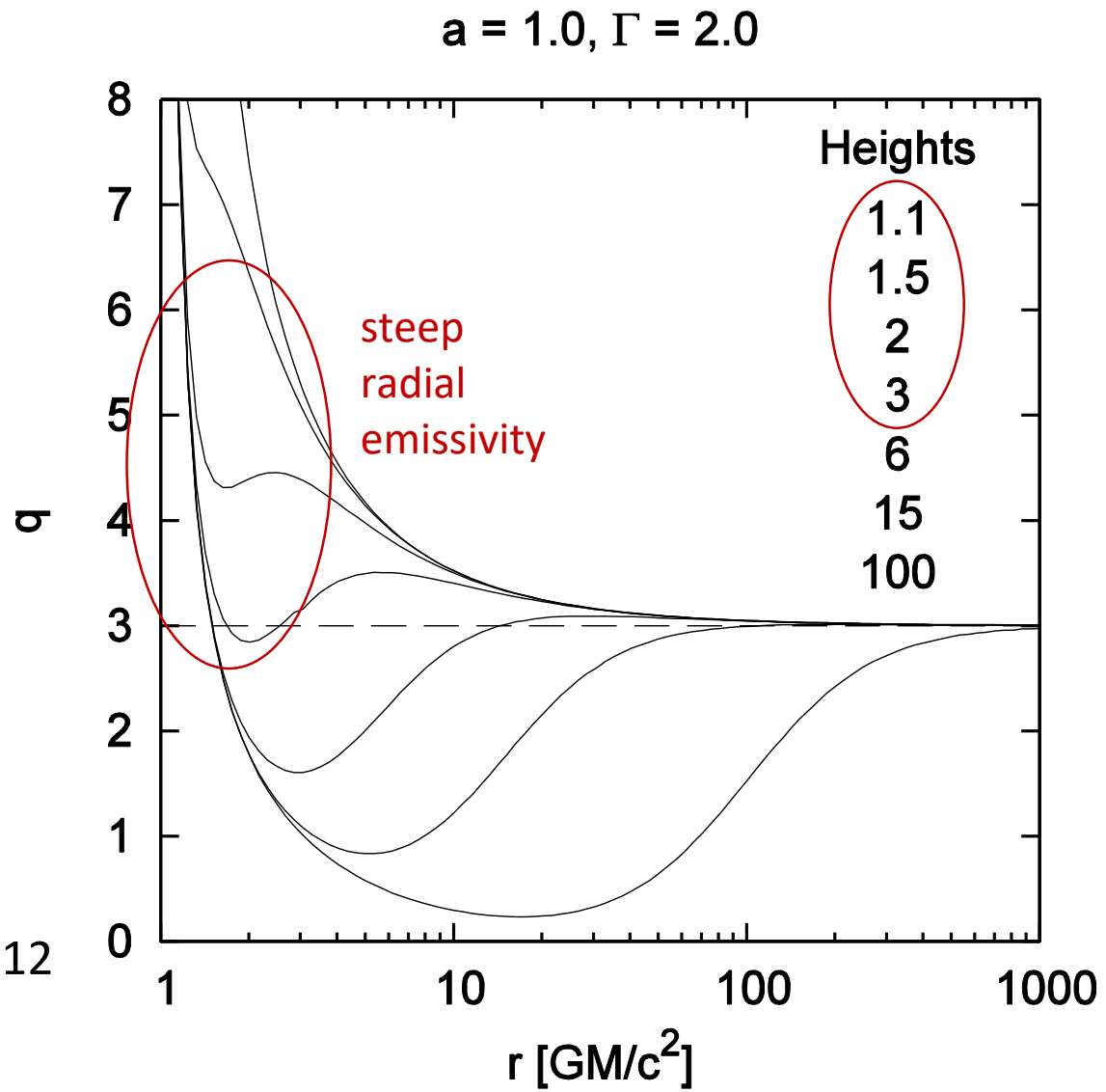


Steep radial emissivity due to light bending



→ requires very low heights

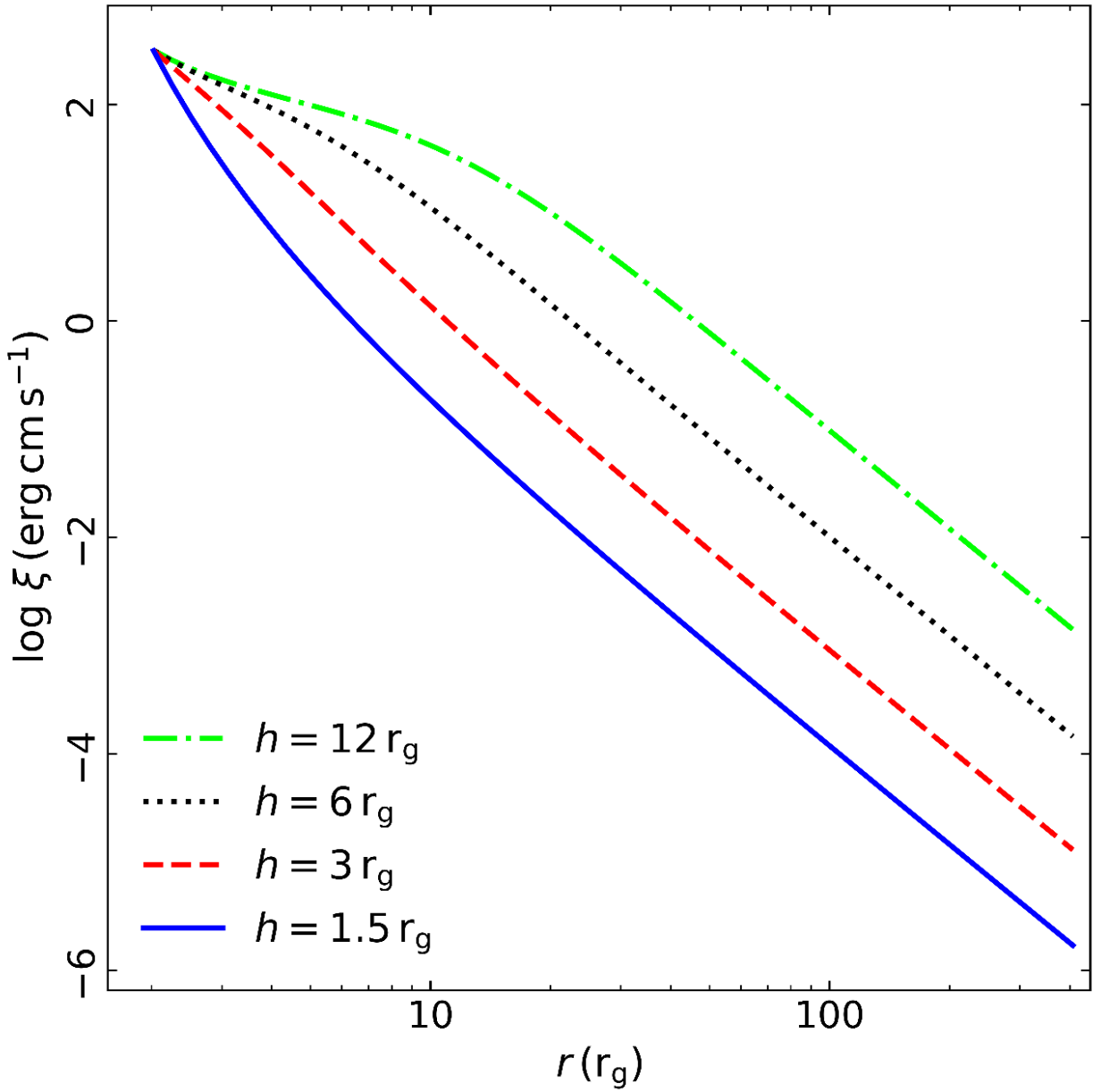
Dovčiak et al., 2012



Implication for disc ionisation

- a compact lamp-post source irradiates the disc at each radius with different power
- disc ionisation should be radially stratified and decreasing with the radius

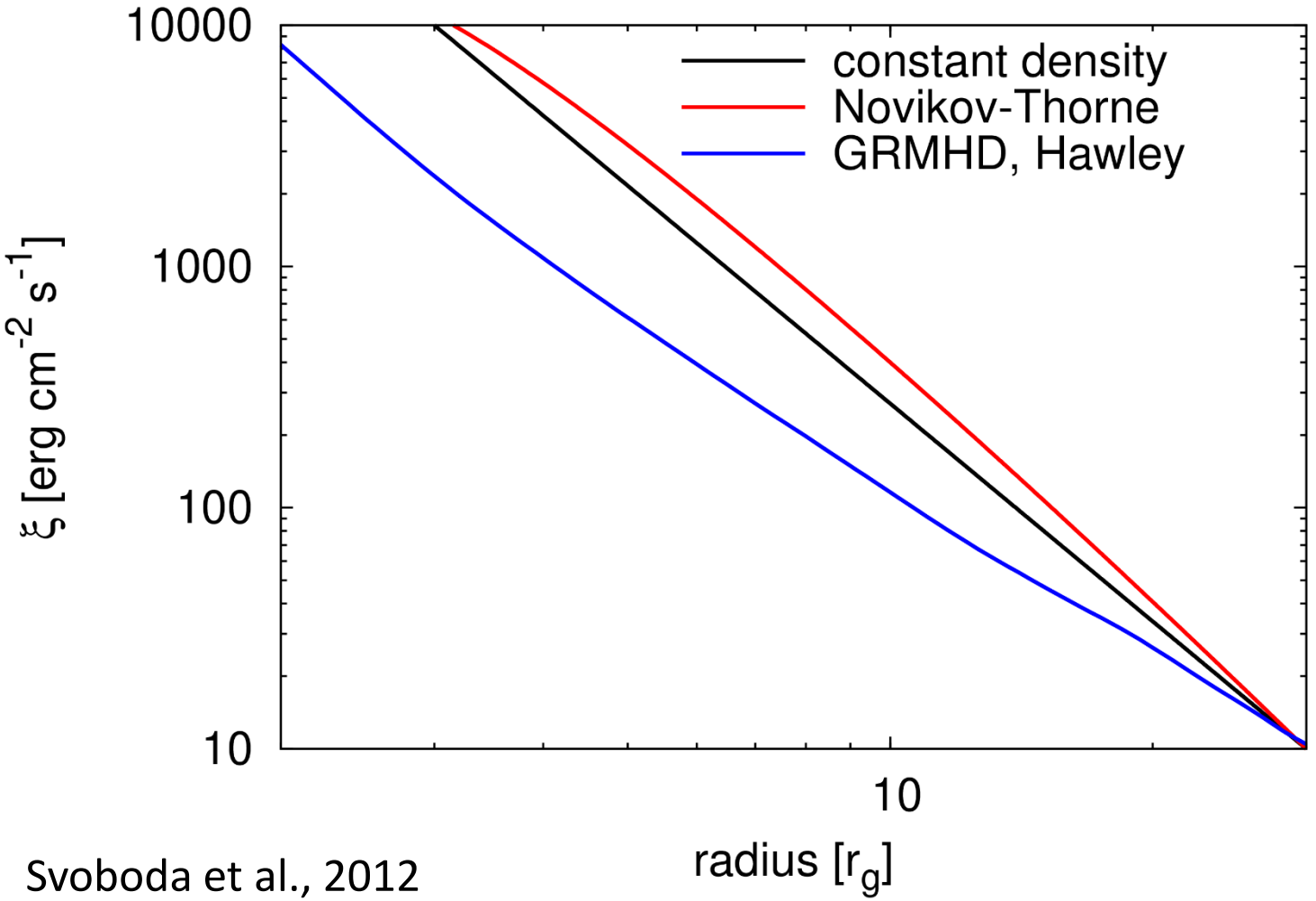
$$\xi(r) = \frac{4\pi F_{inc}(r)}{n_H}$$



Implication for disc ionisation

- radial decrease of ionisation also for standard q=3 and **different density profiles**

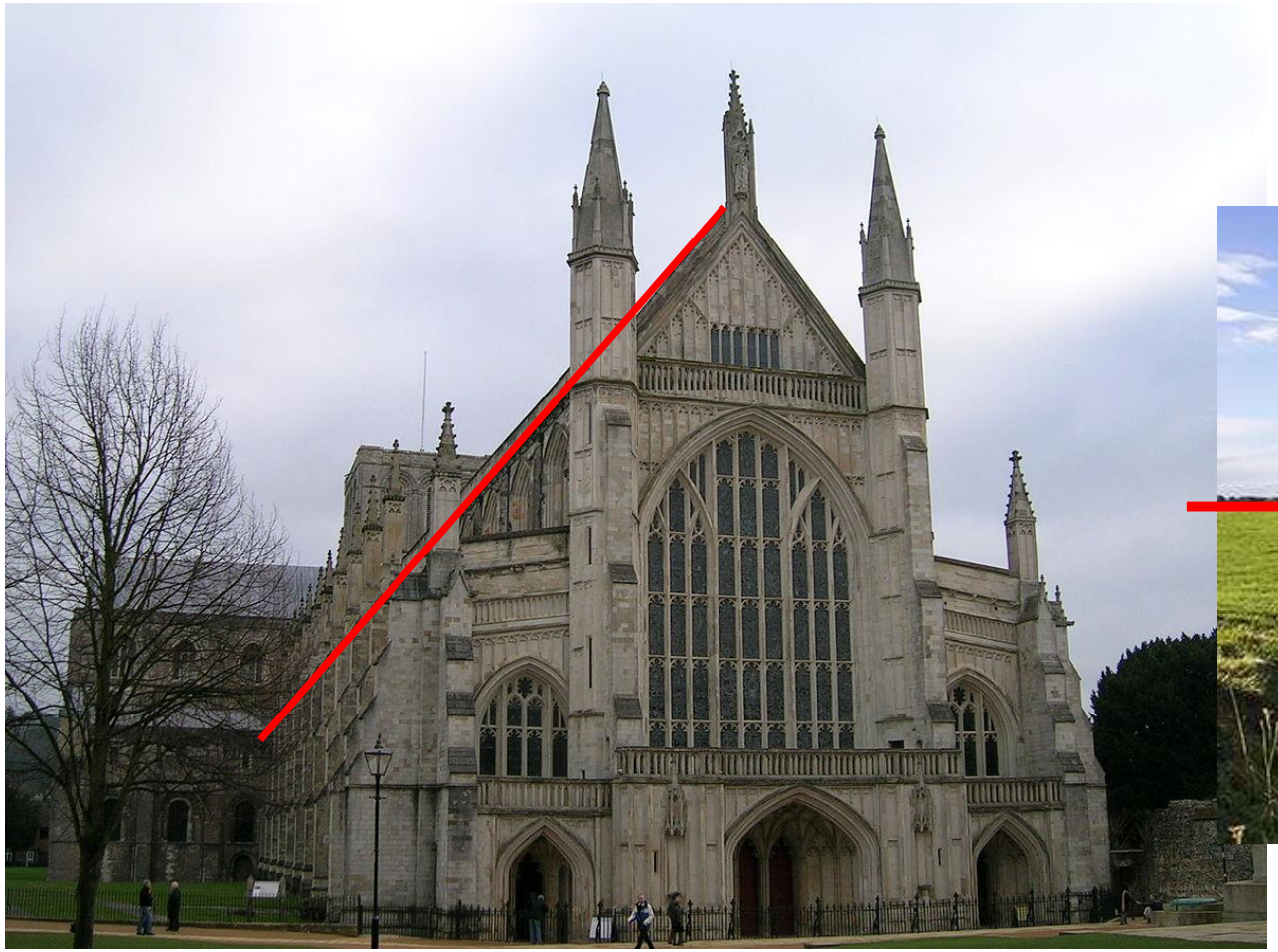
$$\xi(r) = \frac{4\pi F_{inc}(r)}{n_H(r)}$$



Svoboda et al., 2012

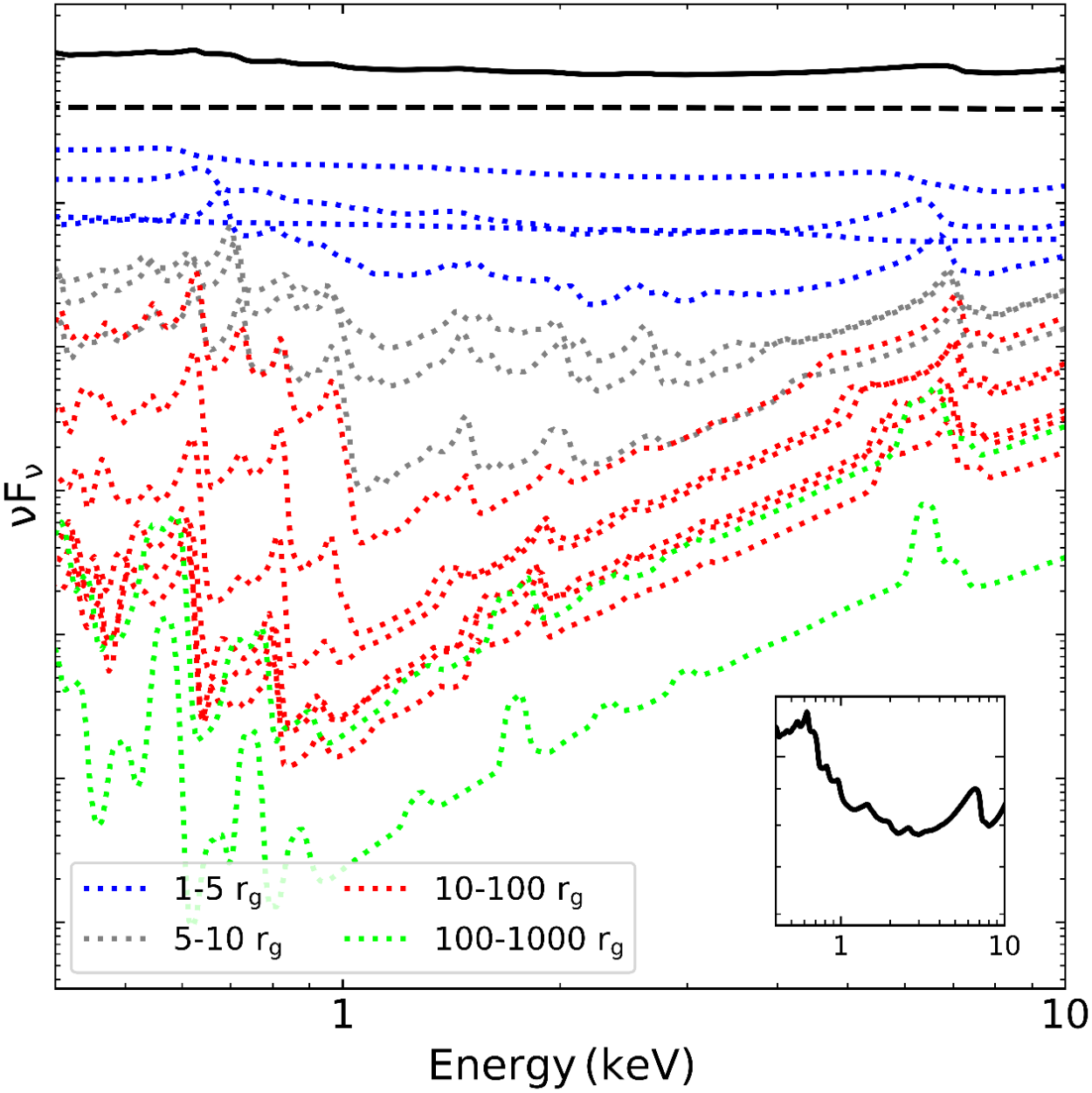
Radial profile of the disc ionisation

ξ (r)



Radially stratified X-ray reflection

- the innermost regions of the disc are highly ionised
- outer regions are not ionised
- resulting spectrum is the sum of contributions from each radius and can affect the radial emissivity parameter measurement



Study of relation between the ionisation structure and the radial emissivity

- idea first presented and discussed in Svoboda et al., 2012
- systematic analysis in our recent paper: Kammoun et al., 2019

Simulation

radially stratified ionisation in the disc

Fit

constant ionisation

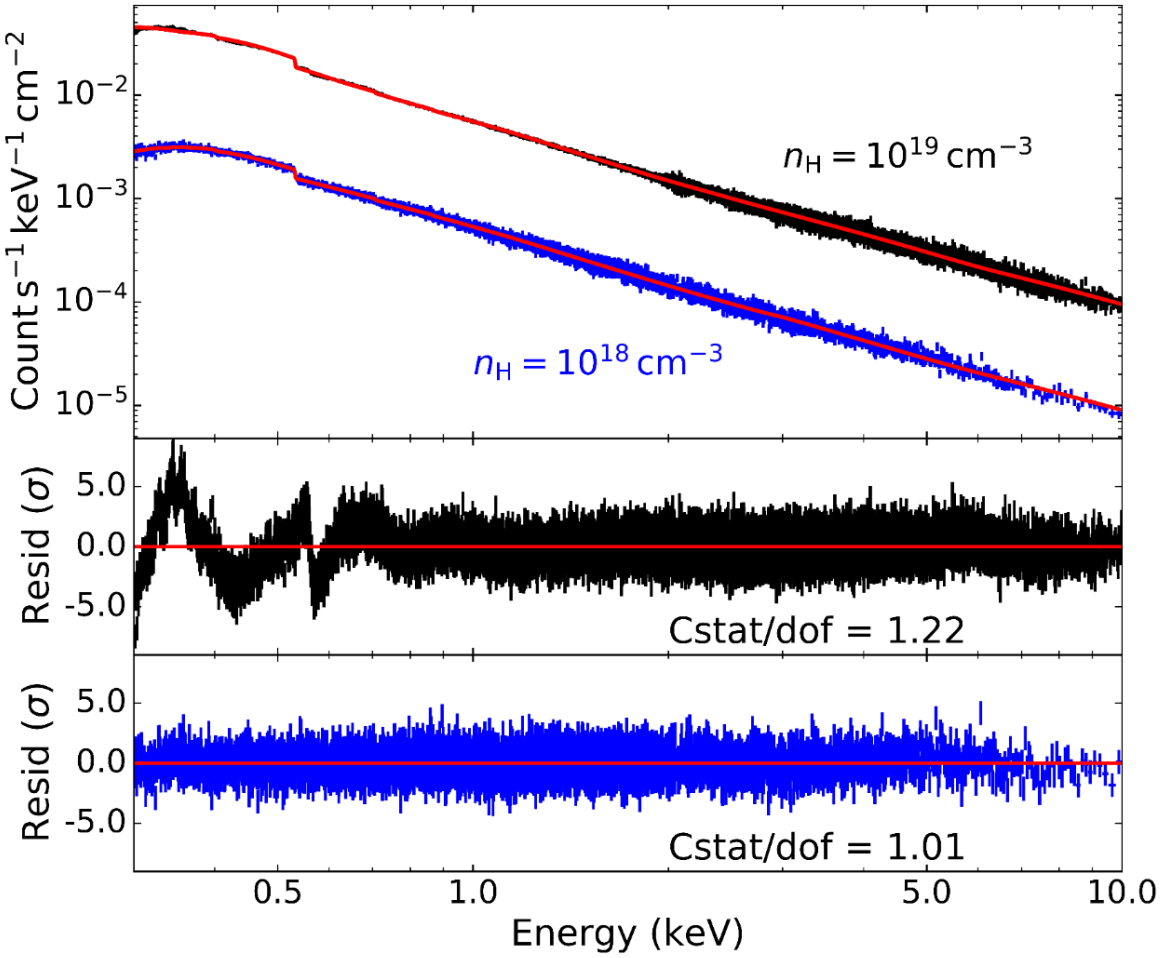
+ free radial emissivity parameter

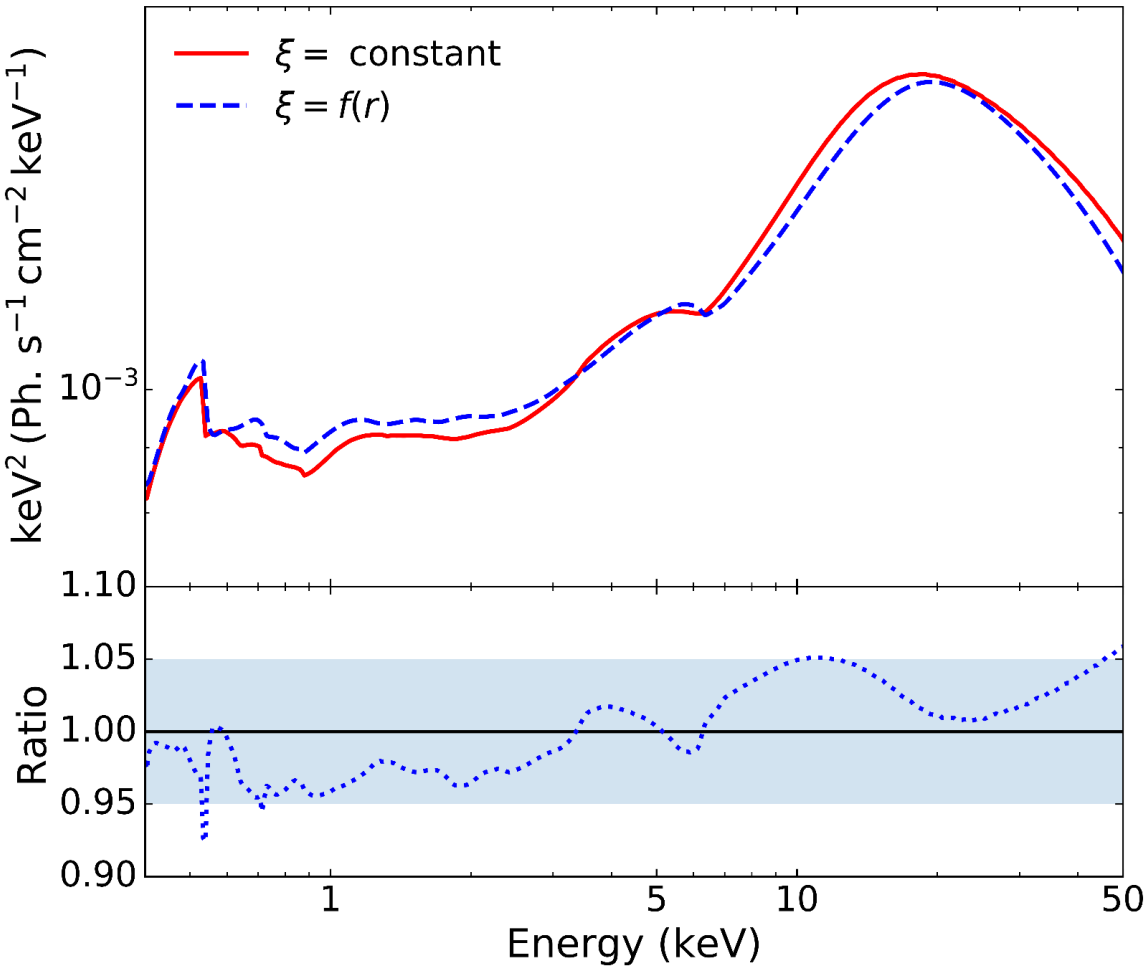
Simulation of the data

- model:
  - relativistic effects: code KY (Dovčiak et al., 2004)
  - ionised disc reflection: Xillver code (García et al., 2013)
- data simulation:
  - high-resolution X-ray spectroscopy Athena X-IFU (Barret et al., 2018)
    - why high resolution X-ray spectroscopy?
      - ➢ current low-resolution X-ray spectra do not allow to distinguish between radially-stratified ionization and constant ionization
      - ➢ major differences of the models are in the soft X-ray band
      - ➢ X-IFU will be well capable to measure relativistic effects in X-ray reflection spectra (Barret & Cappi, 2019)

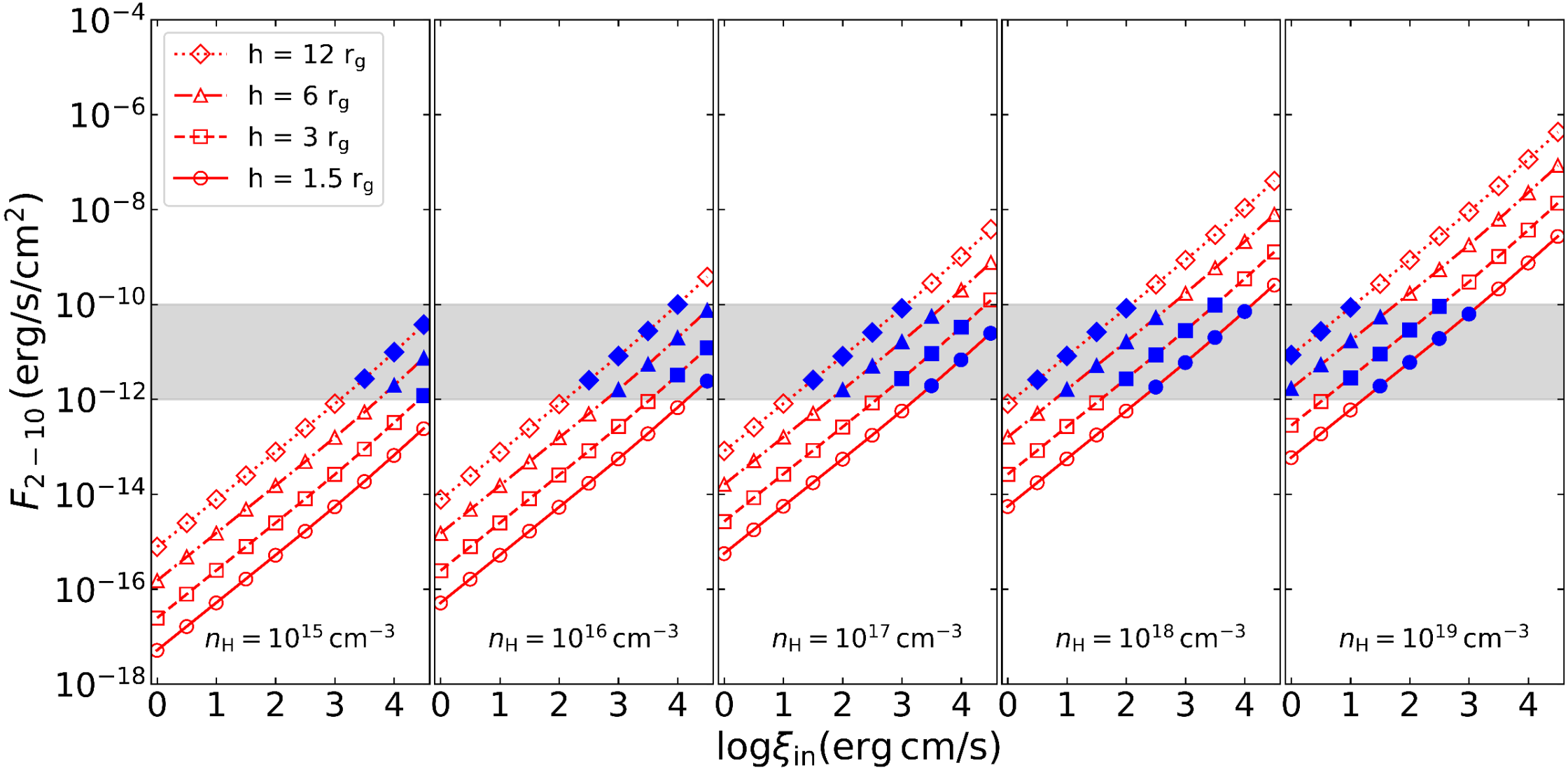
Simulation of the data and quality of the fit

- example of the simulated data and the best fit:

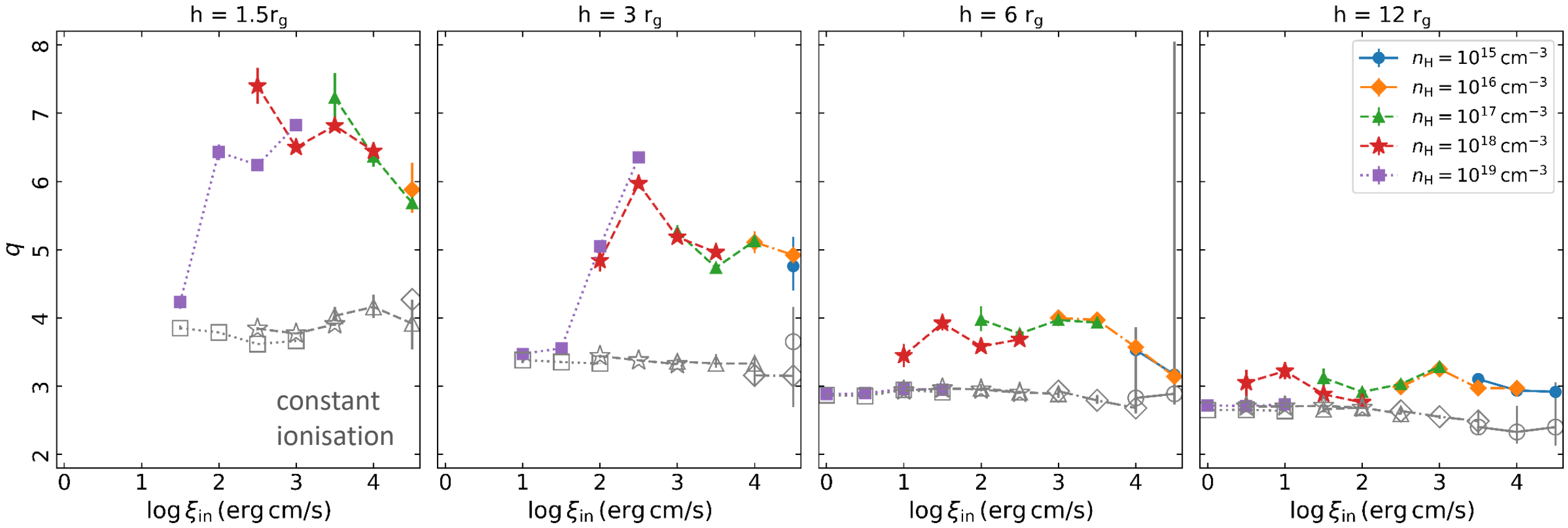




Selection of observable cases

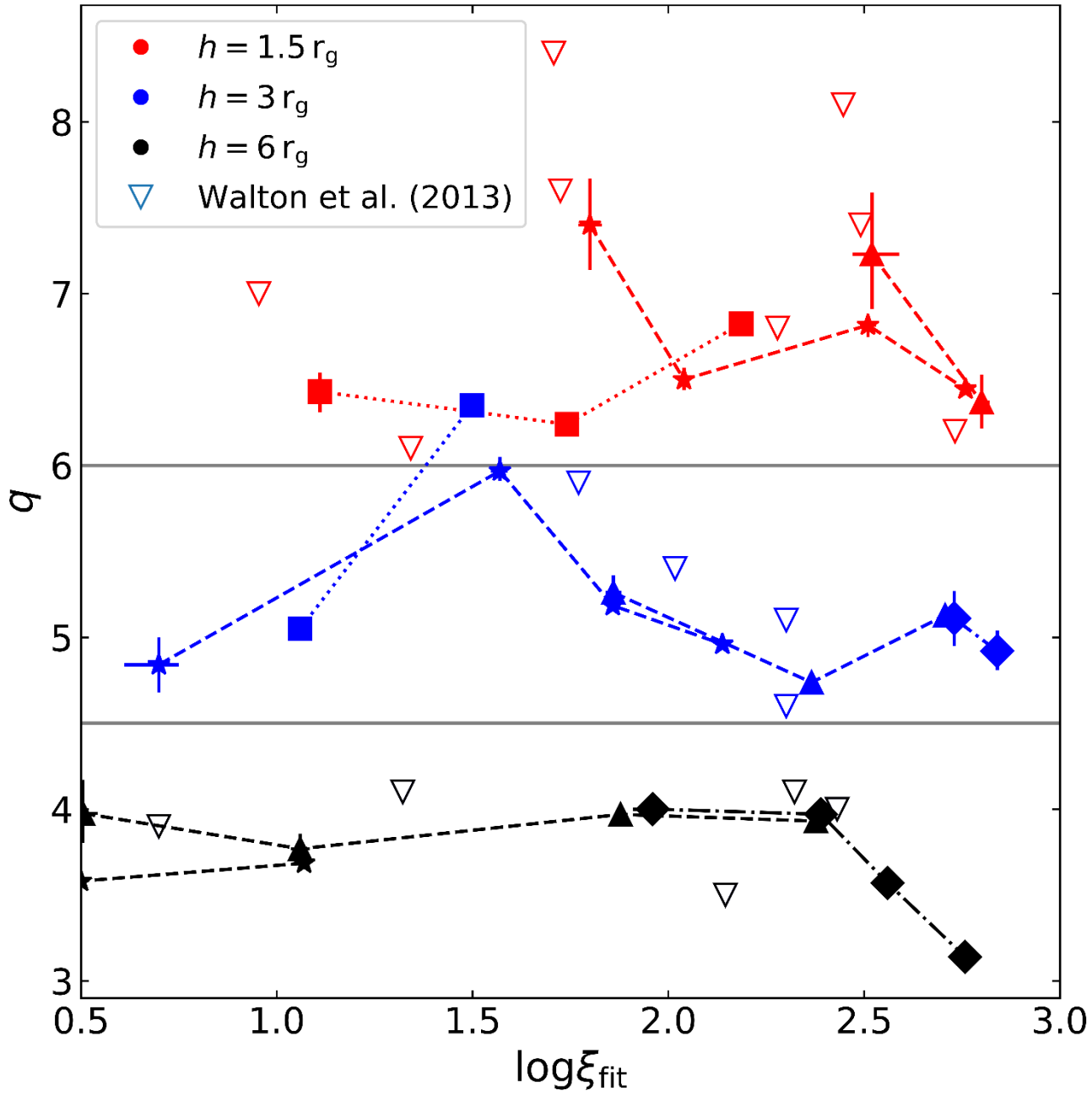


Results



- radially stratified ionisation can explain steep radial emissivity
- lamp-post geometry with constant ionisation hardly

Comparison with observations



Conclusions

- radially-stratified ionisation:
  - is a natural consequence of a compact lamp-post geometry
  - can well explain measured steep radial emissivity in the data
- in our simulations, we do not obtain steep radial emissivity with the lamp-post geometry only and constant disc ionisation
- see more details in Kammoun et al., 2019, MNRAS, 485, 239K

Conclusions

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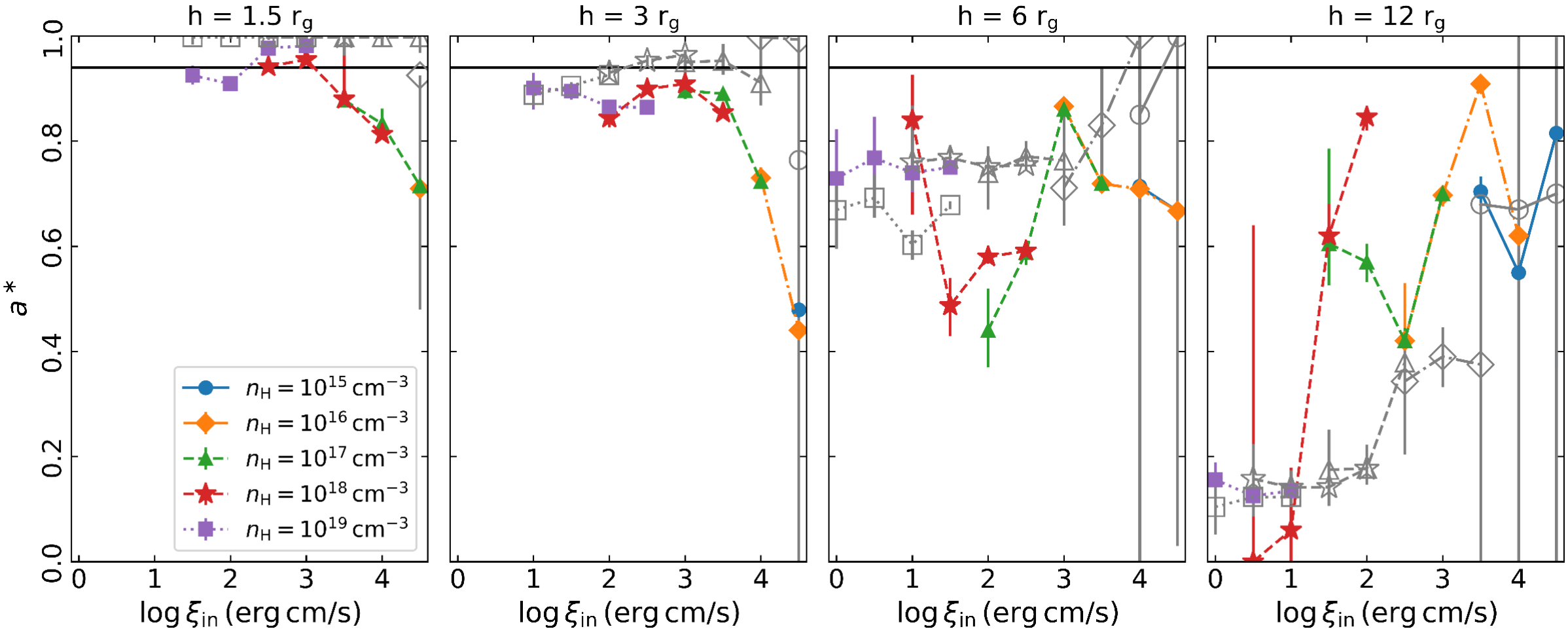
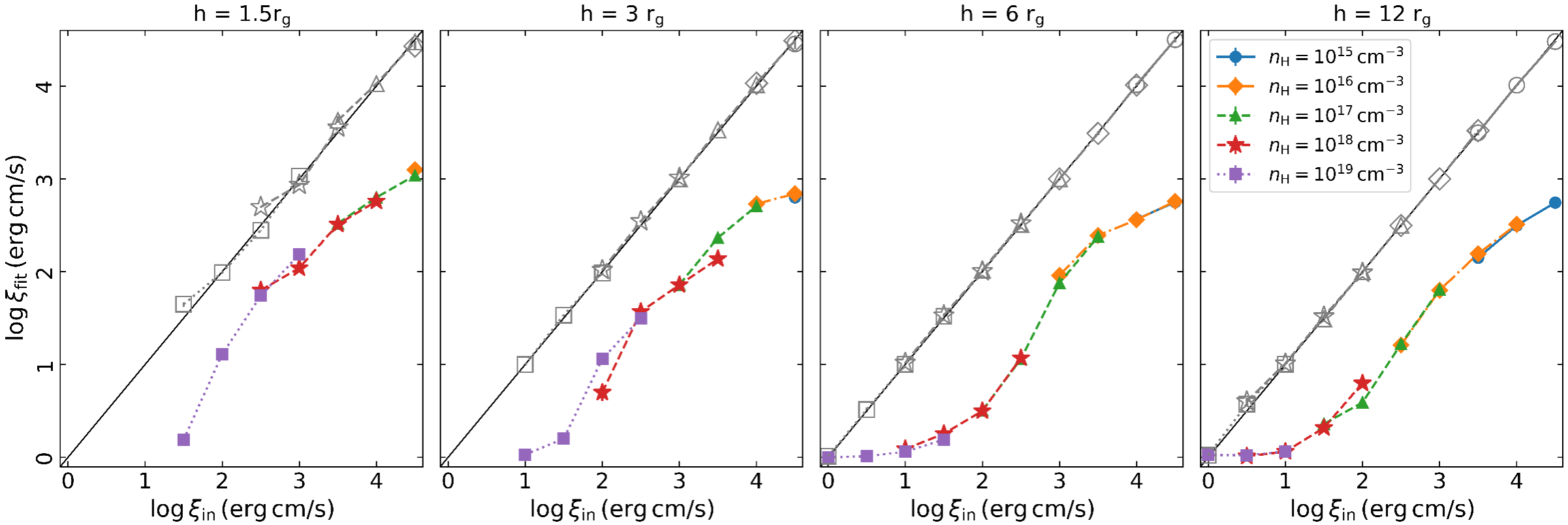
Thank you very much for your attention!!!

Additional materials

Effects on black hole spin



Relation between the ionisation at the innermost radius and the fitted value of the ionisation



Ionised reflection models for different density