

# The high mass accretion rate spectra of GX 339-4: Black hole spin from reflection?

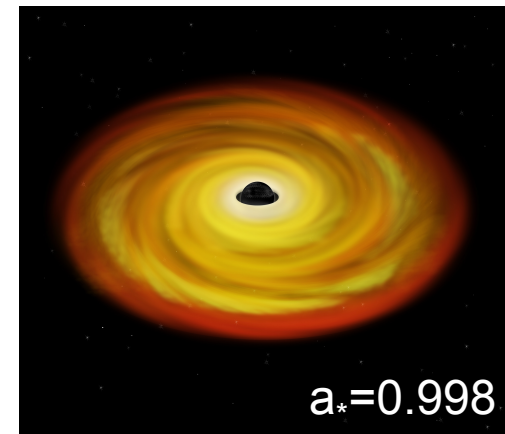
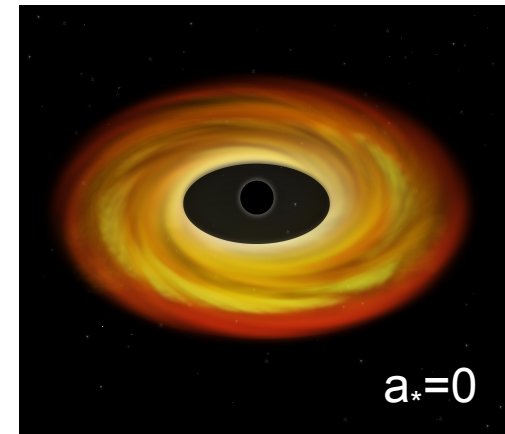
Mari Kolehmainen & Chris Done,  
Durham University  
Maria Diaz Trigo, ESO



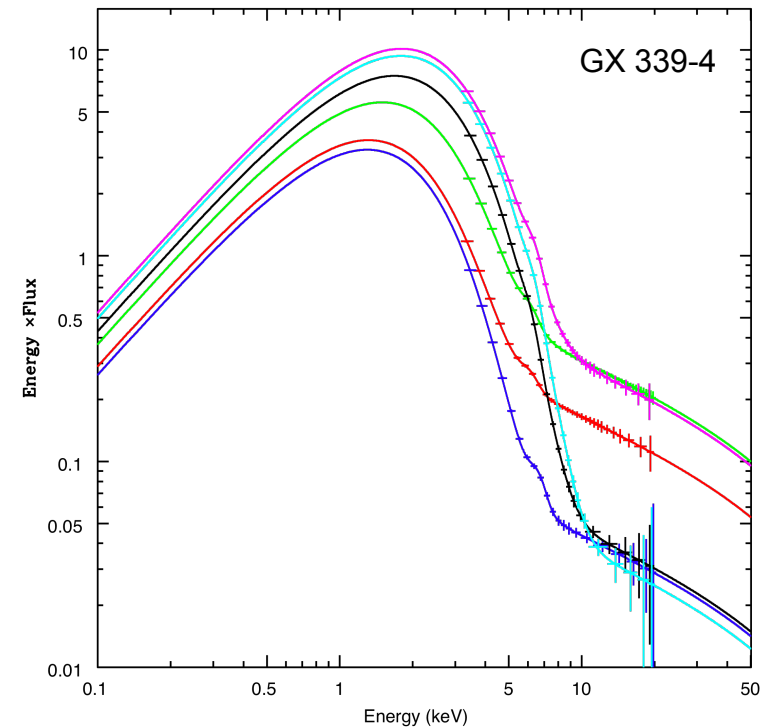
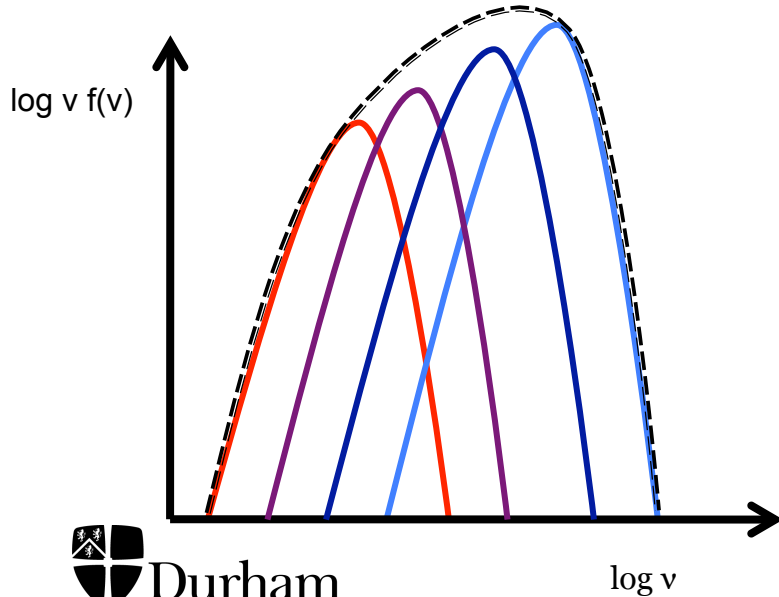
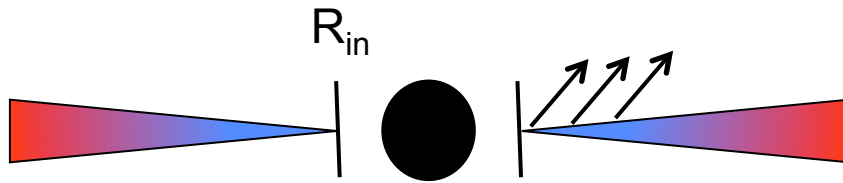
**Black Hole Astrophysics**  
**Winchester**  
**18 - 22 July 2011**

# Black hole spin

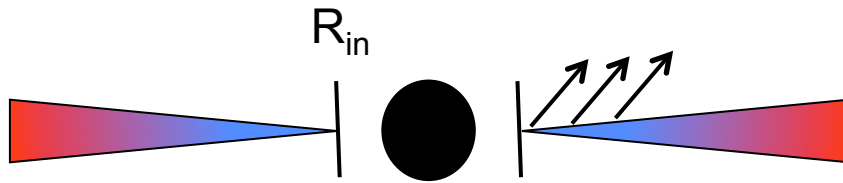
- Specific angular momentum
  - $a_*$  : 0 - 0.998
  - $R_{\text{in}}$  : 6 - 1.24  $R_g$
- currently 2 ways to determine
  - disc fitting
  - Fe line



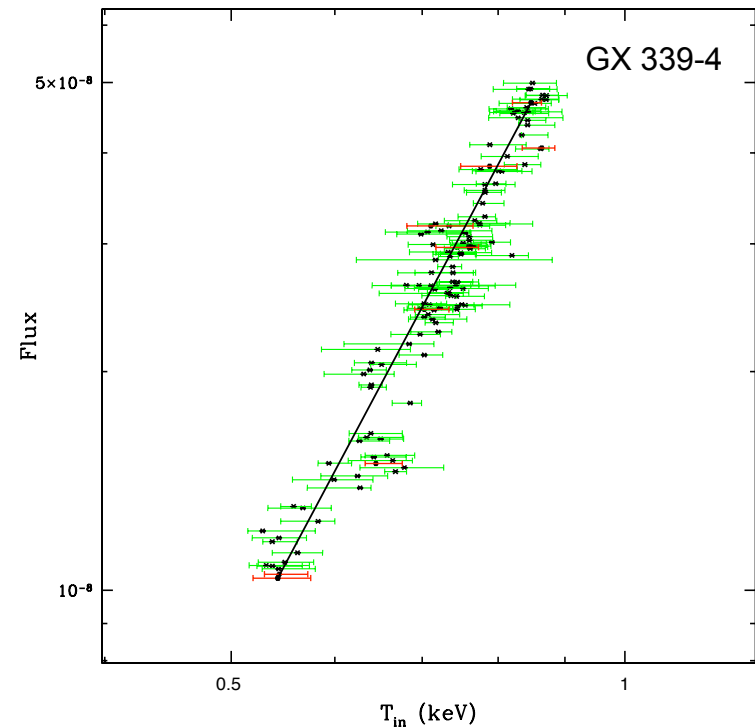
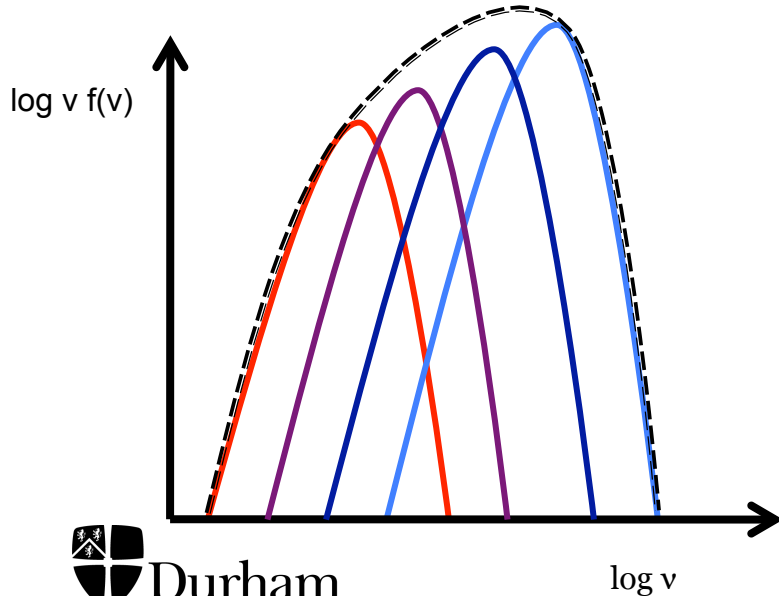
# Black hole spin: disc fitting



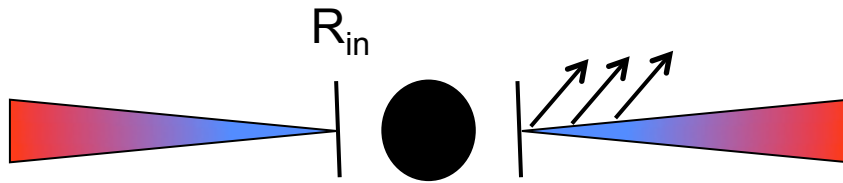
# Black hole spin: disc fitting



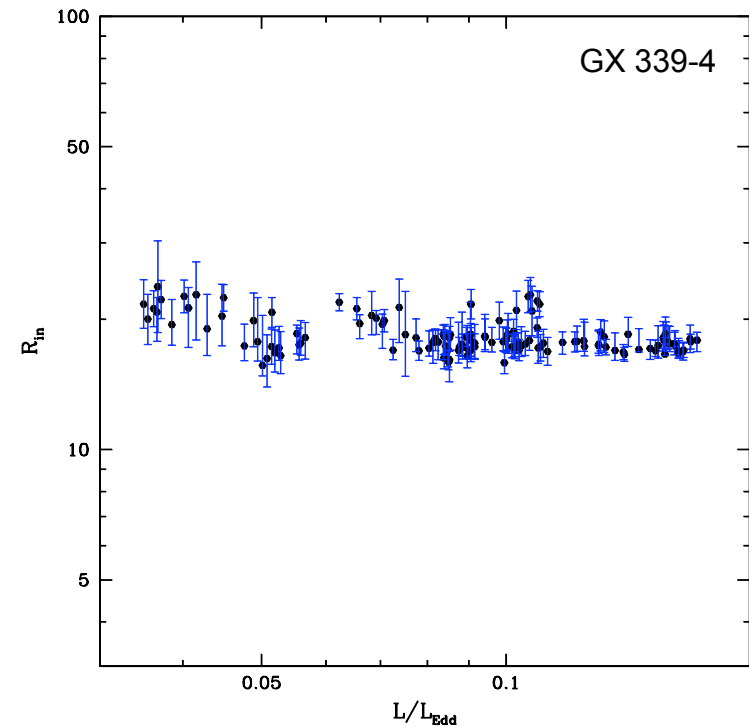
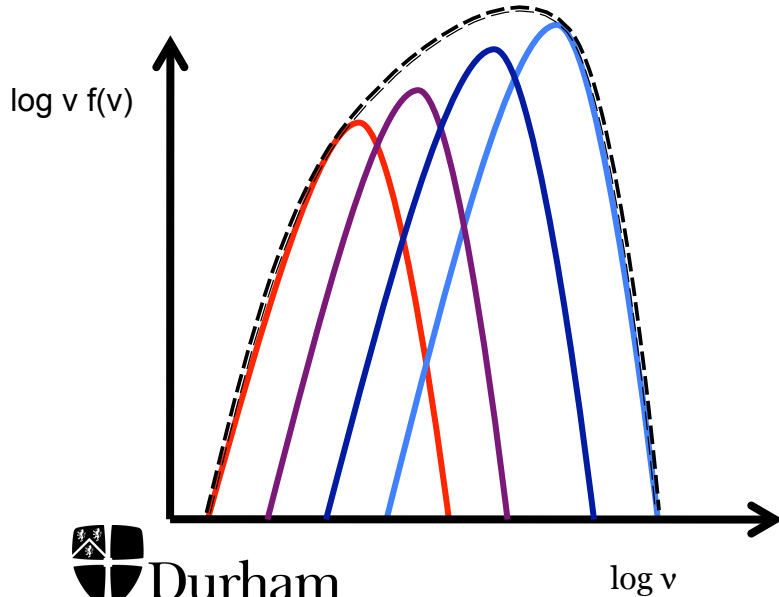
$$L \propto 2\pi D^2 F / \cos i \propto AT_{disc}^4$$



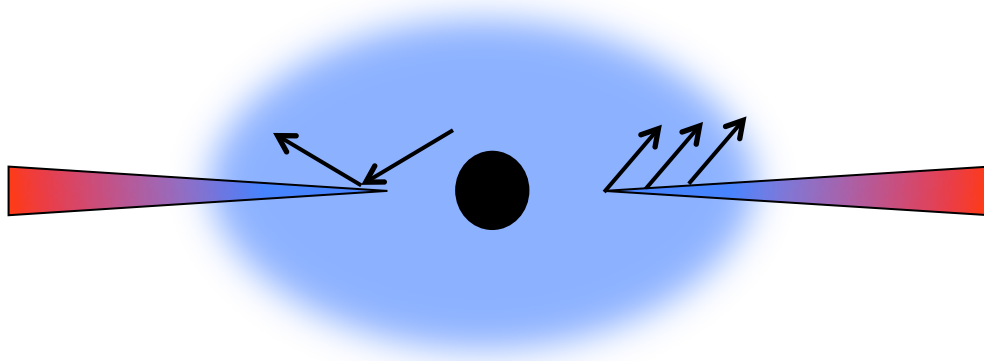
# Black hole spin: disc fitting



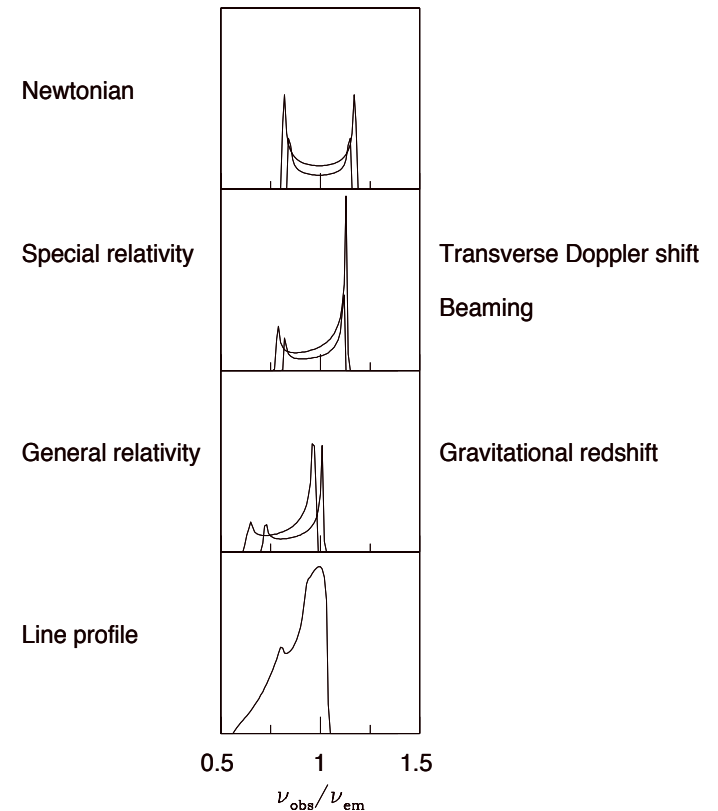
$$r_{in}^2 \propto D^2 / (M^2 \cos i)$$



# Black hole spin: Fe-line profile



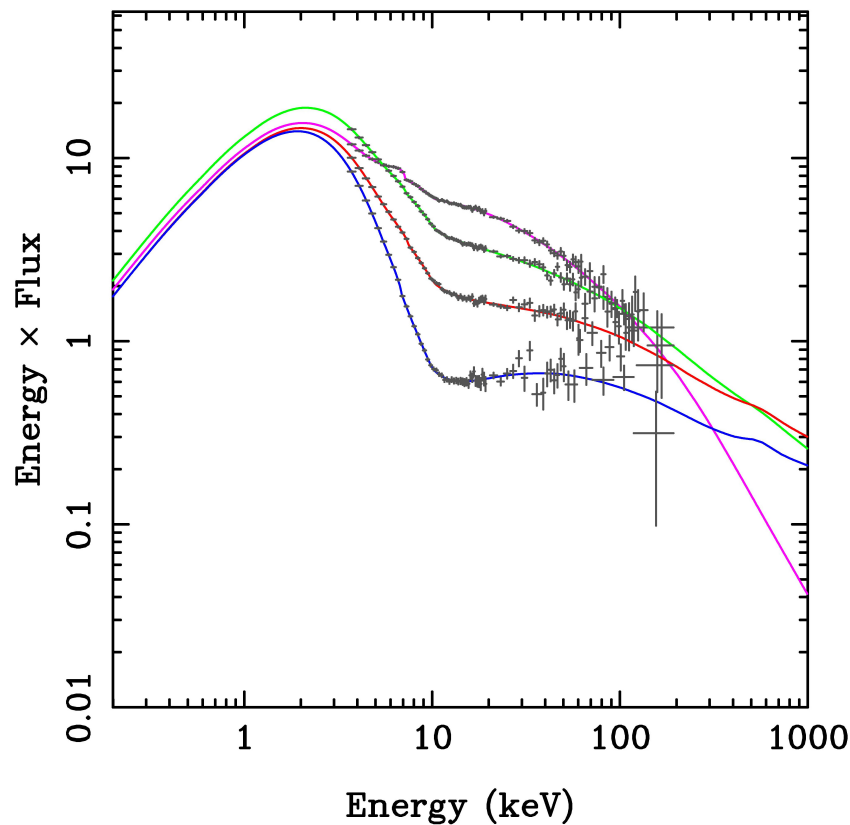
- Iron emission line at 6.4 keV from reflected emission



Fabian et al. 2000

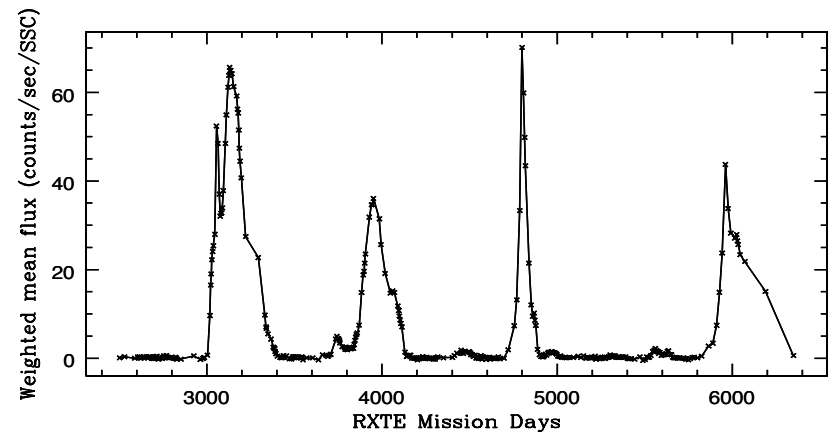
# Comparing spin measurements: High mass accretion rate spectra

- Disc continuum fitting
  - disc dominated spectra
  - classical high/soft state
- Fe line profile
  - strong hard X-ray tail
  - very high/soft intermediate states



# Comparing spin measurements: GX 339-4

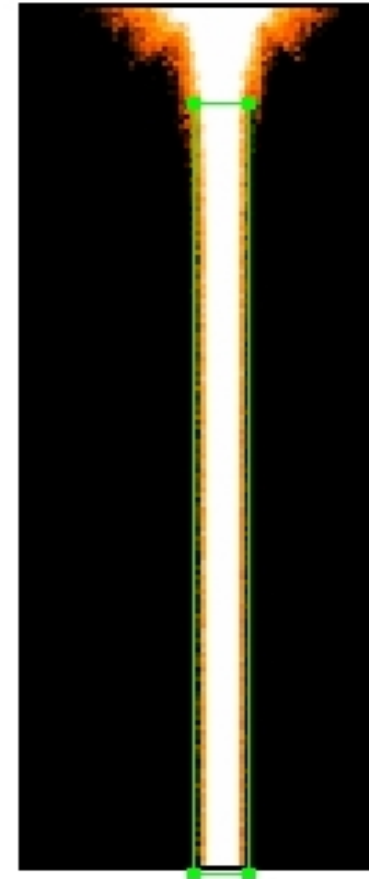
- Disc fitting gives upper limit
  - $a_* < 0.9$  from RXTE spectra  
(Kolehmainen & Done 2010)
  
- Fe line values higher
  - $a_* \approx 0.94$  from XMM-Newton  
Burst mode soft intermediate state (Miller et al. 2004)
  - $a_* \approx 0.89$  from Suzaku intermediate state  
(Miller et al. 2008 vs. Yamada et al. 2009)
  - $a_* \approx 0.94$  from XMM-Newton LHS  
(Reis et al. 2008 vs. Done & Diaz Trigo 2010)





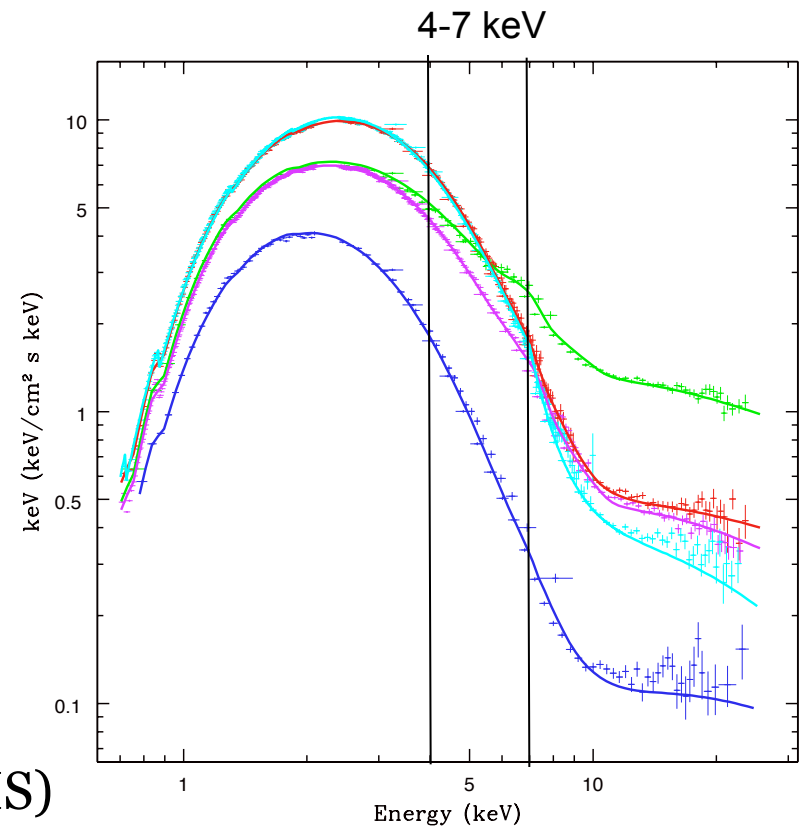
# XMM-Newton EPIC pn Burst mode

- Time resolution  $7\mu\text{s}$ 
  - Pileup limit 60,000 counts/s
  - Timing mode  $30\mu\text{s}$  (800 counts/s)
- Duty cycle 3 %
  - photon collecting time/readout time



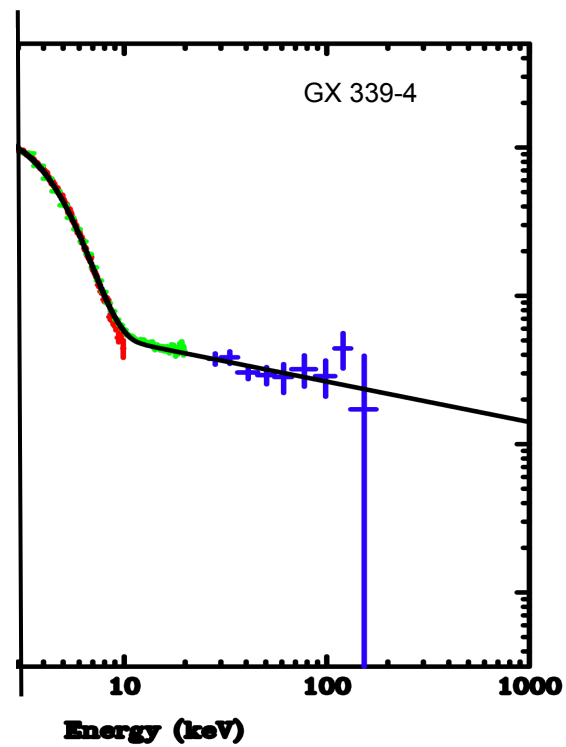
# High mass accretion rate spectra of GX 339-4

- Joint EPIC-pn/RXTE observations (0.7-25 keV)
- Fast timing mode data, not piled up!
- 3 disc dominated states
- 2 soft intermediate states (SIMS)



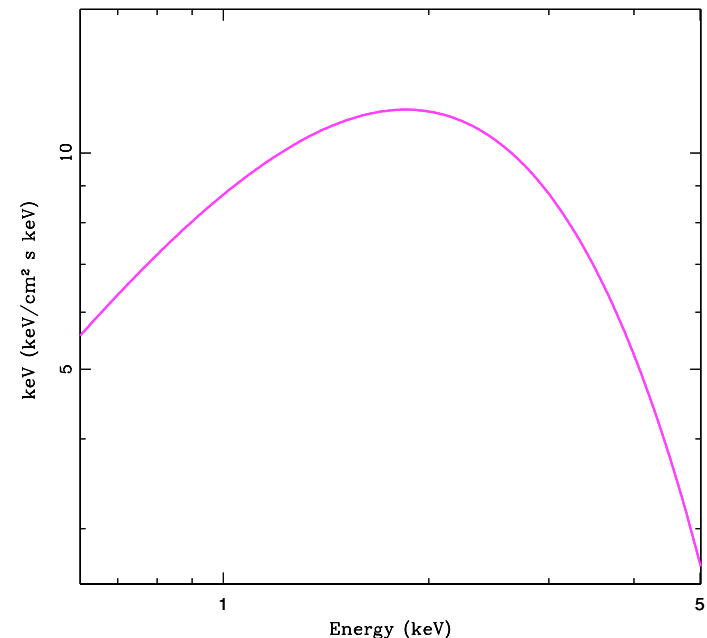
# Below the RXTE energy band

3 keV



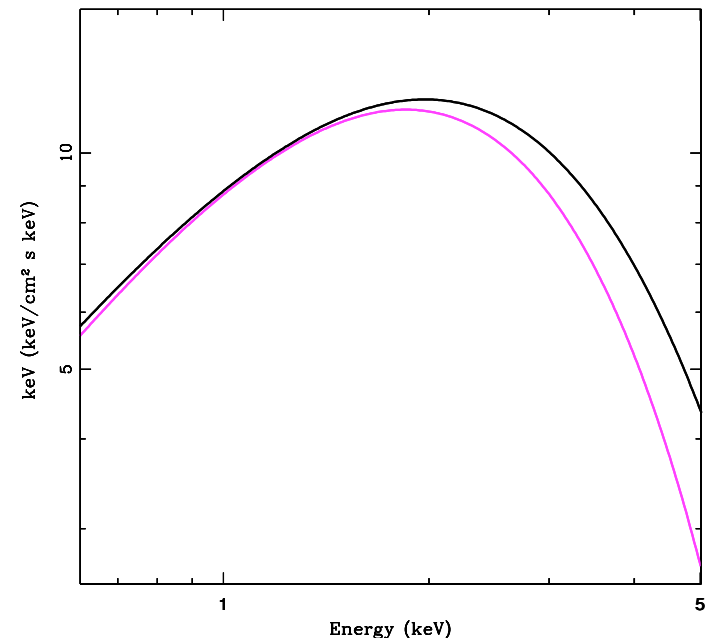
# Continuum fitting below 3 keV: Disc dominated state

- **DISKBB**
  - simplest multi-colour disc blackbody
- **KERRBB**
  - stress-free inner boundary condition, colour- temperature correction and relativistic smearing
- **BHSPEC**
  - calculates radiative transfer through each disc annuli
  - includes all the relativistic corrections
  - assumes  $R_{\text{in}} = R_{\text{ISCO}}$



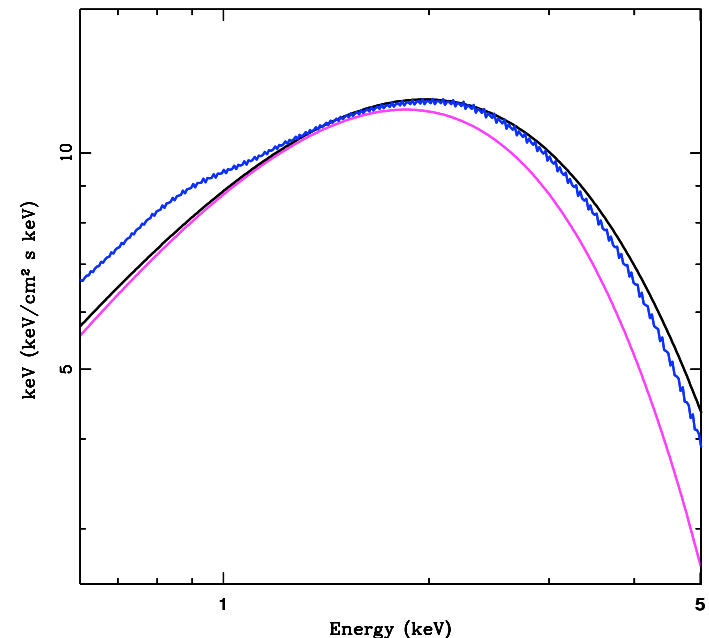
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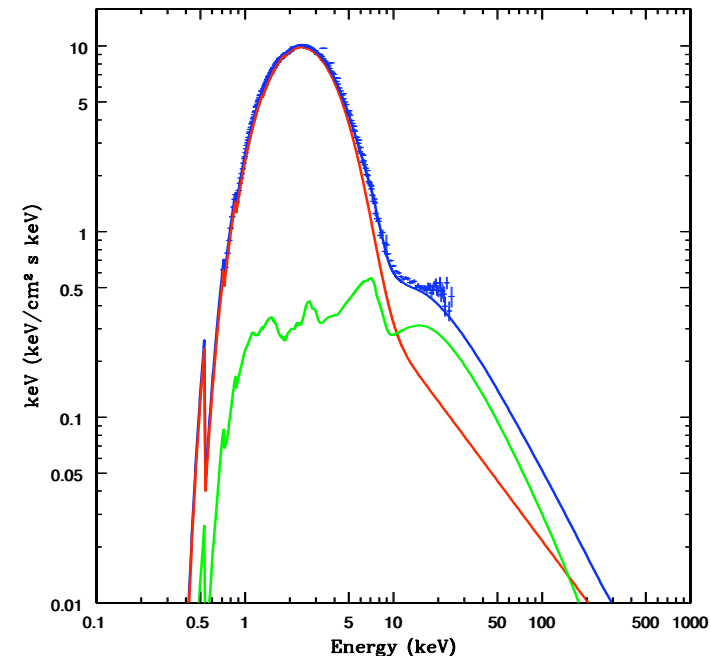
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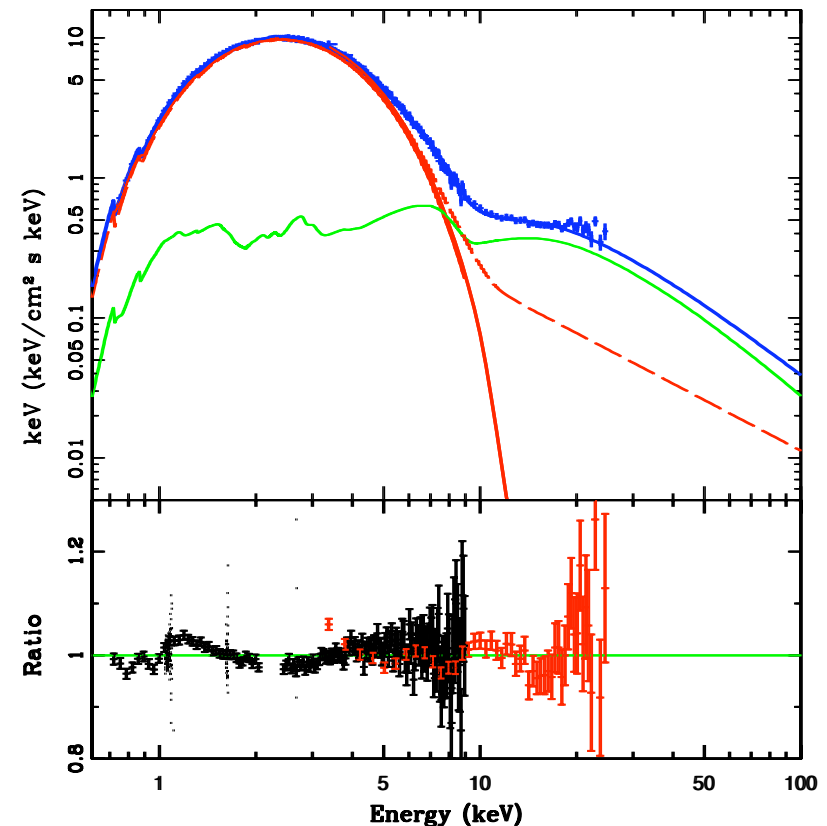
# Continuum fitting below 3 keV: Disc dominated state

- **Disc** model
  - use this as seed photons for Comptonisation to make X-ray tail (convolved with **Simpl** (Steiner et al. 2009))
- **Reflection** of Comptonised continuum using ionised reflection models of Ross & Fabian
- Relativistic smearing (**kdblur**)



# Continuum fitting below 3 keV: Disc dominated state

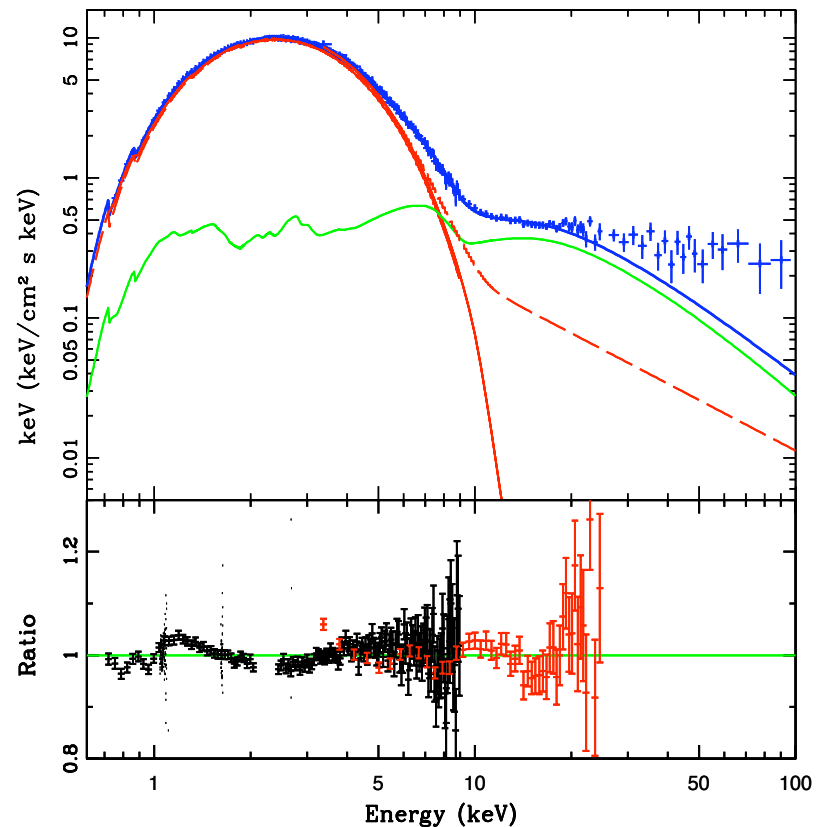
- BHSPEC+reflected continuum
  - very steep continuum to make disc broader
  - high reflection fraction
  - misses high energies
  - residuals around 1 keV





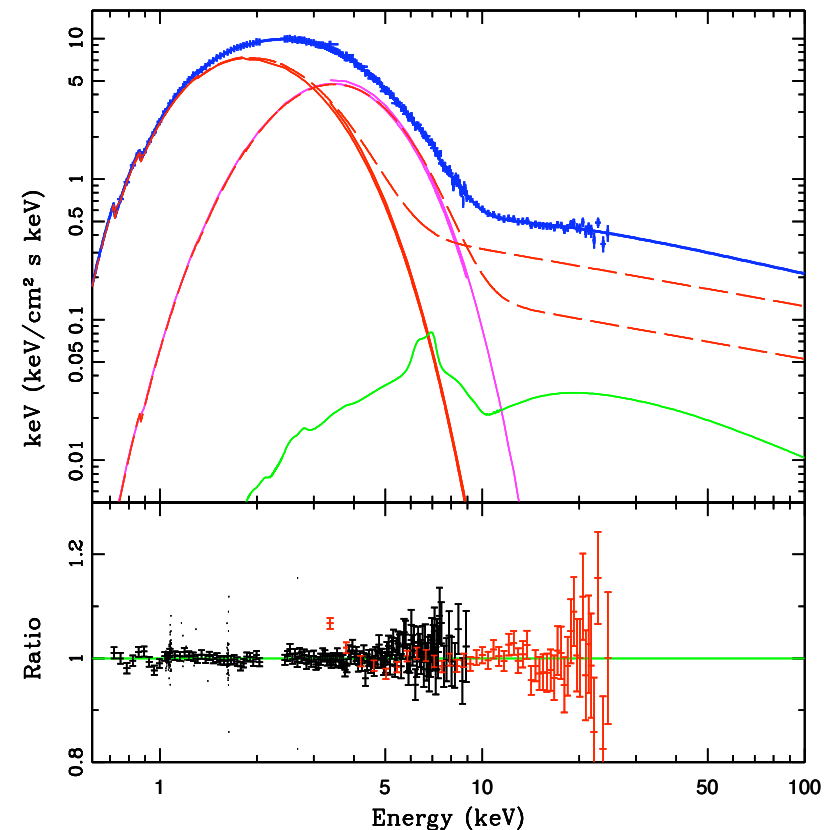
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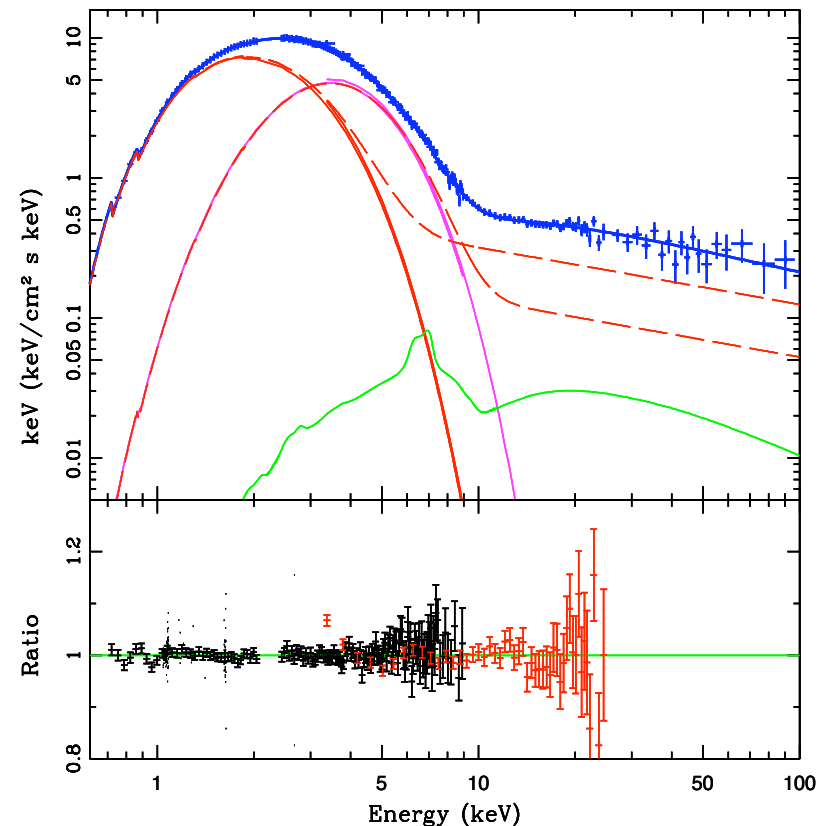
# Continuum fitting below 3 keV: Disc dominated state

- (diskbb+compTT)  
+reflected continuum
  - reasonable reflection fraction+continuum
  - extrapolates to high energies
- fit for different mass accretion rates



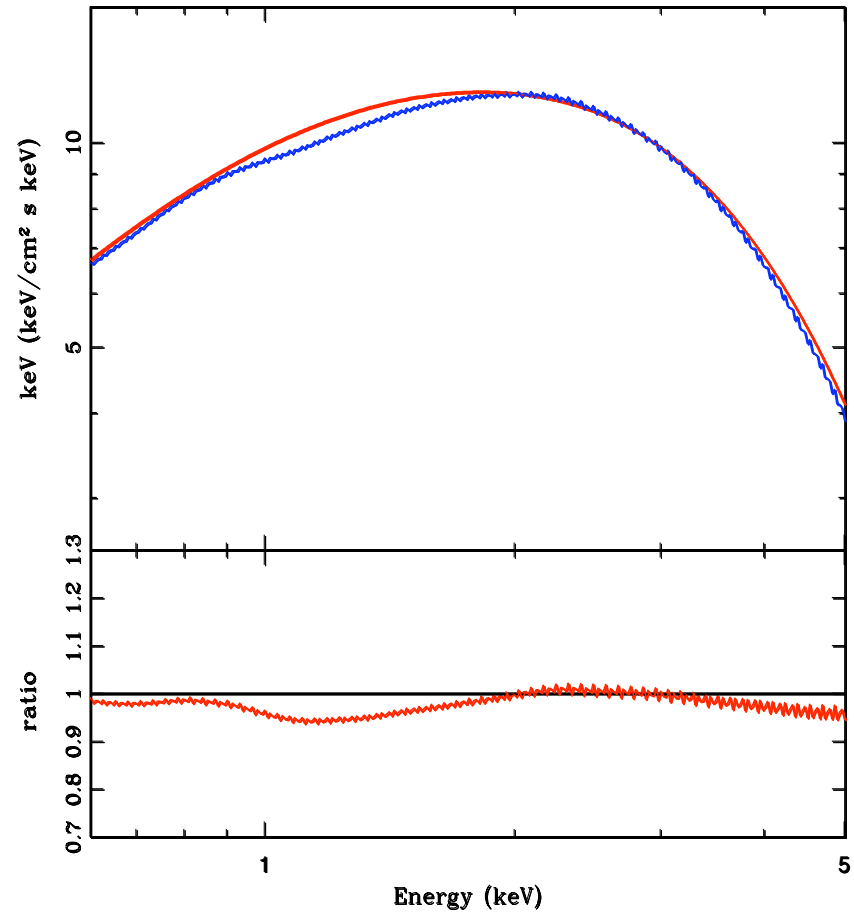
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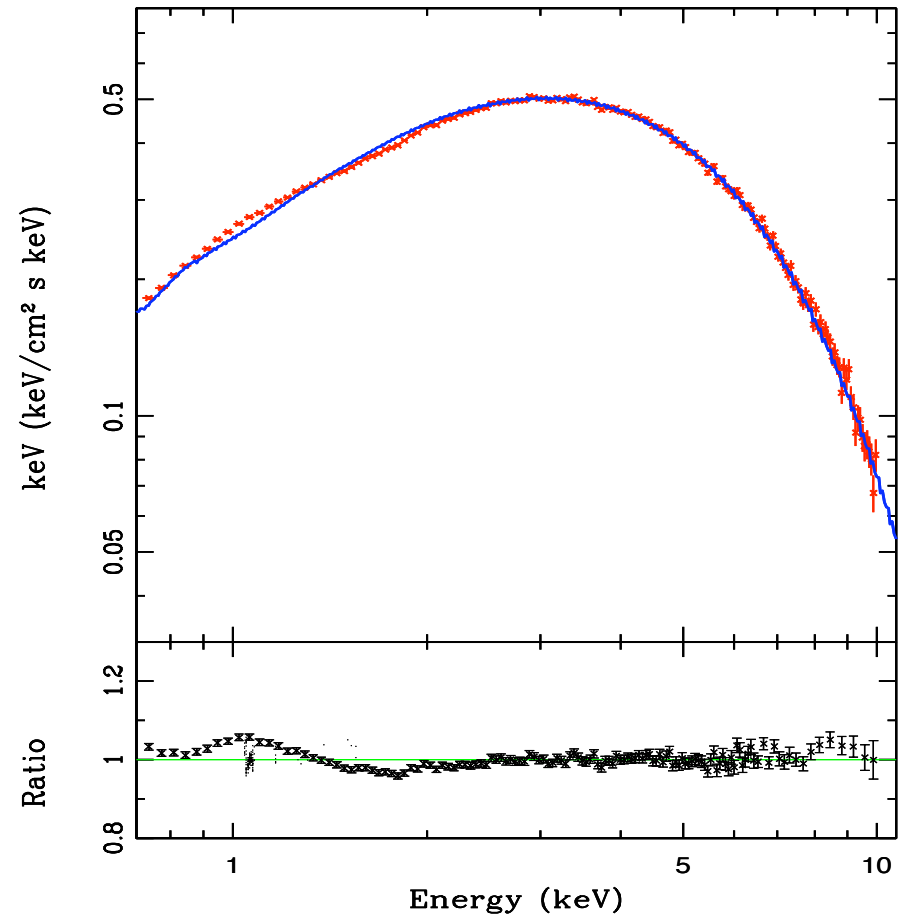
# Continuum fitting below 3 keV: Disc dominated state

**DATA**  
VS.  
**BHSPEC**



# Continuum fitting below 3 keV: LMC X-3

**DATA**  
VS.  
**BHSPEC**



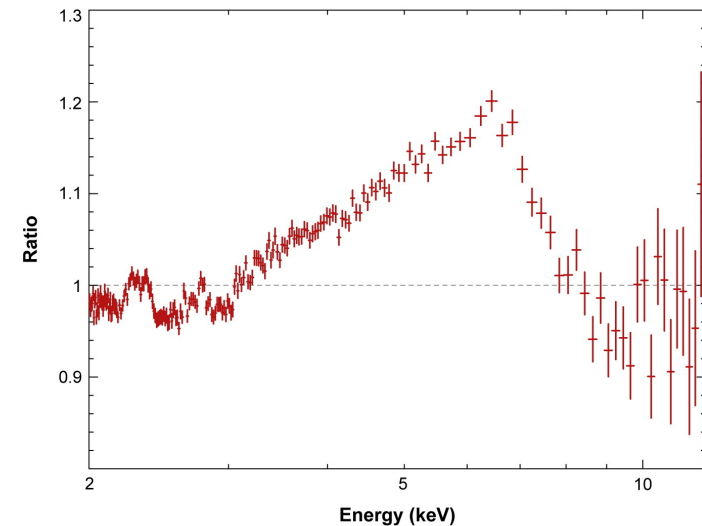
# Soft intermediate state: the Fe line

Previously derived a strict upper limit for the spin in GX 339-4 from continuum fitting of disc dominated RXTE spectra (Kolehmainen & Done, 2010)

- $a_* < 0.9$  for any reasonable mass ( $< 15M_{\odot}$ ), distance ( $> 6$  kpc) and inclination ( $i > 45^\circ$ )

GX 339-4 widely studied in terms of Fe-line

- burst mode spectrum gave  $a_* = 0.935$  (e.g. Miller et al. 2004; Reis et al. 2008)

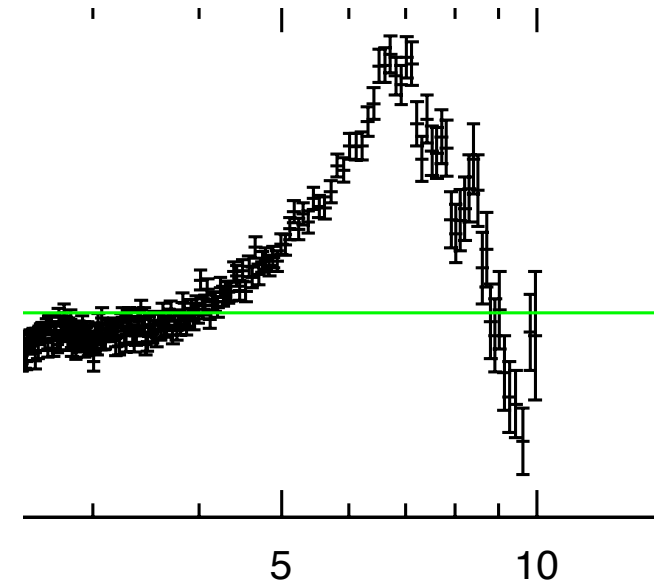


Miller et al. 2004

# Soft intermediate state: the Fe line

## diskbb+po

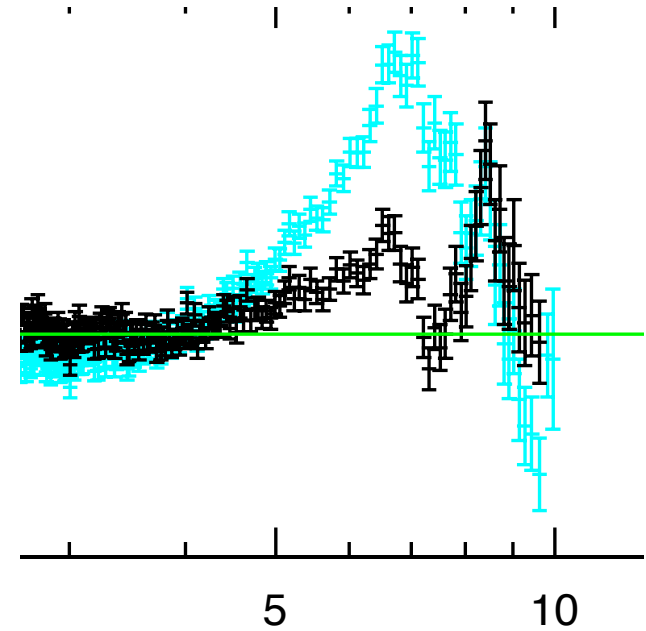
- disc, power law tail
- continuum modelled by ignoring 4–7 keV



# Soft intermediate state: the Fe line

(diskbb+compTT)+reflected  
continuum

- convolved disc+thermal  
Comptonisation, ionised  
smeared reflection





# Conclusions

- Real disc spectra seem broader than diskbb or even BHSPEC
- Changing the continuum model changes the shape of the iron line (and the BH spin)