Warm corona model for the soft X-ray excess of AGN

Observational and theoretical constraints

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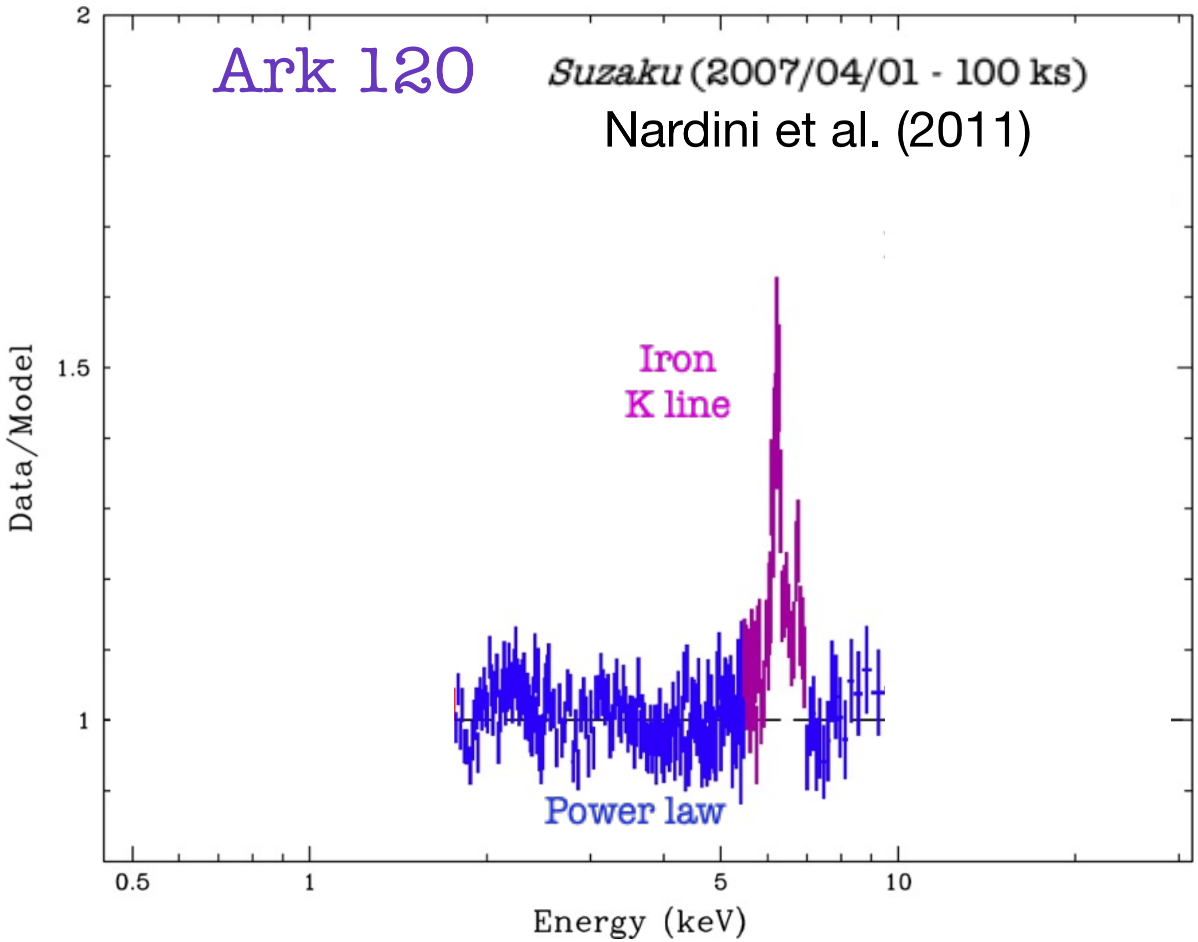
The soft X-ray excess



- Ubiquitous in AGN (Bianchi et al. 2009, Jin et al. 2012, Boissay et al. 2016, Gliozzi et al. 2020, …)
- Very few counter-examples…

Spectral characteristics

- Smooth and lack of strong spectral features

Spectral characteristics

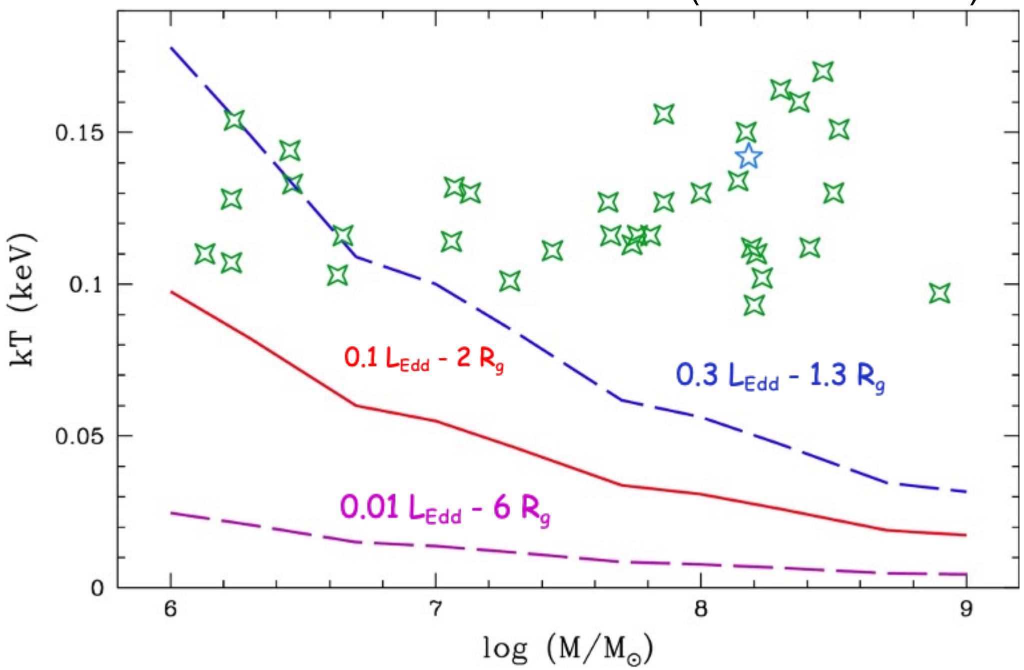
- Smooth and lack of strong spectral features

- Can be accounted for by thermal emission from the disc, BUT

➡ require way to high disk temperature

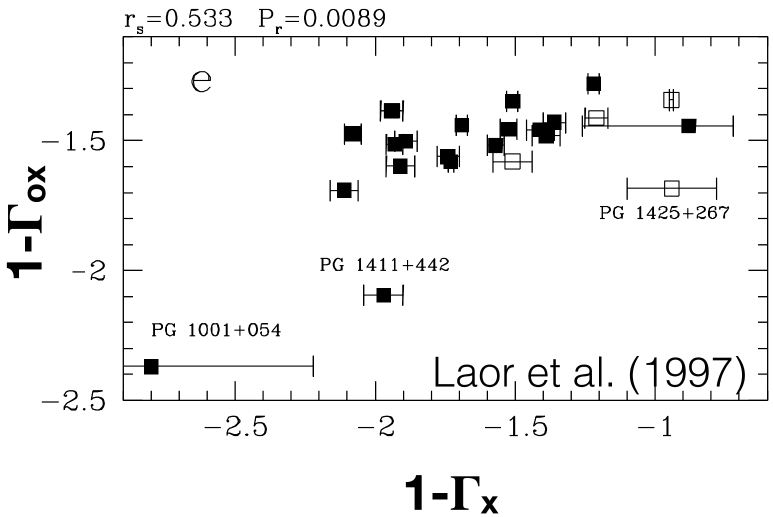
➡ similar disk temperature between objects of different BH mass and luminosity (Gierlinski & Done 2004, Bianchi et al. 2009, …)

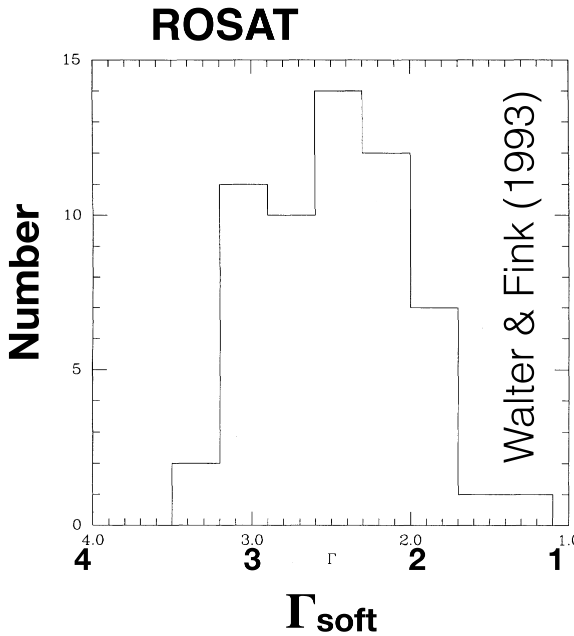
(From Nardini E.)

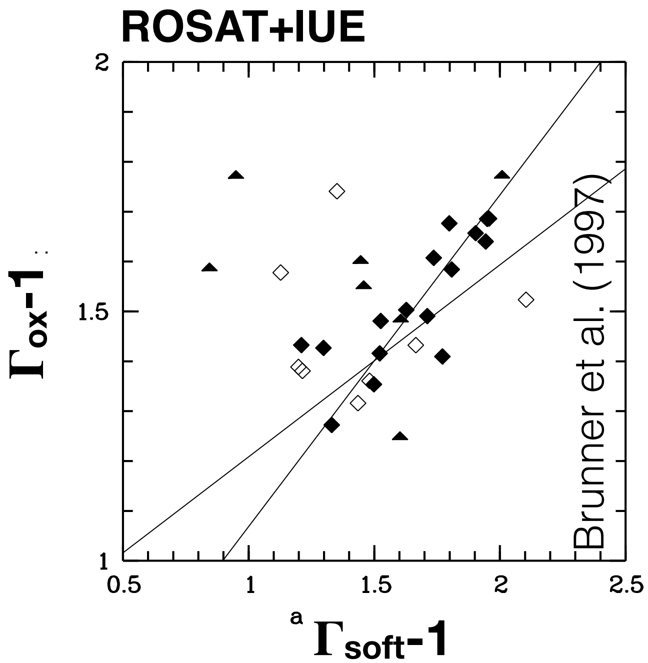


Spectral characteristics

- A fit with a power law gives $<\Gamma_{soft\ X}>\sim 2.5$



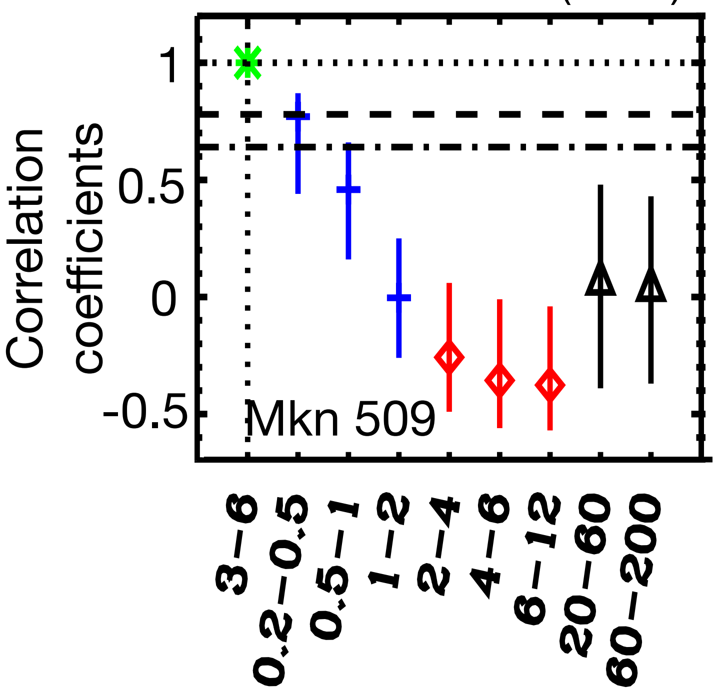




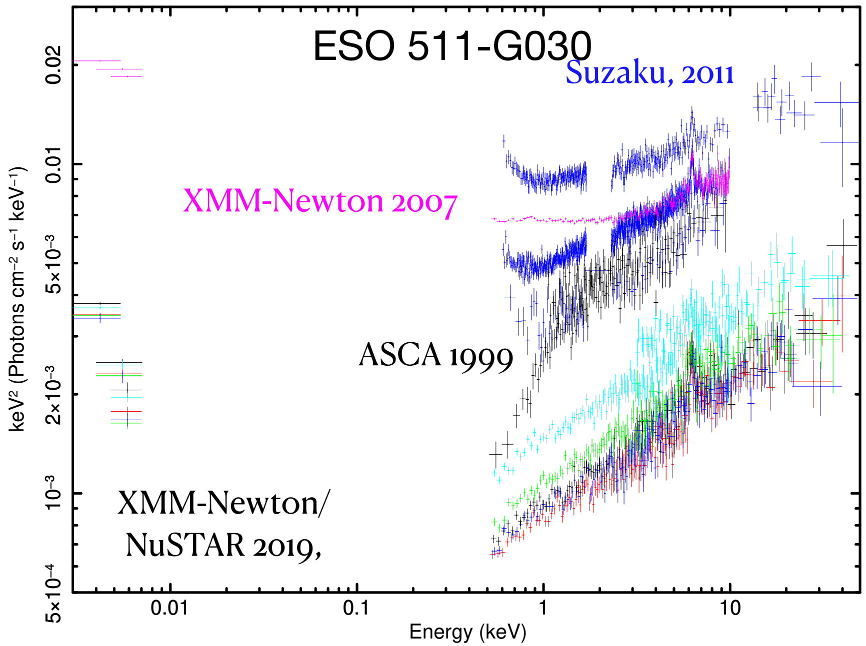
Timing characteristics

- Generally soft X correlates/behaves (on long timescale) with/like UV emission

Petrucci et al. (2013)



Middei et al. submitted (2022)

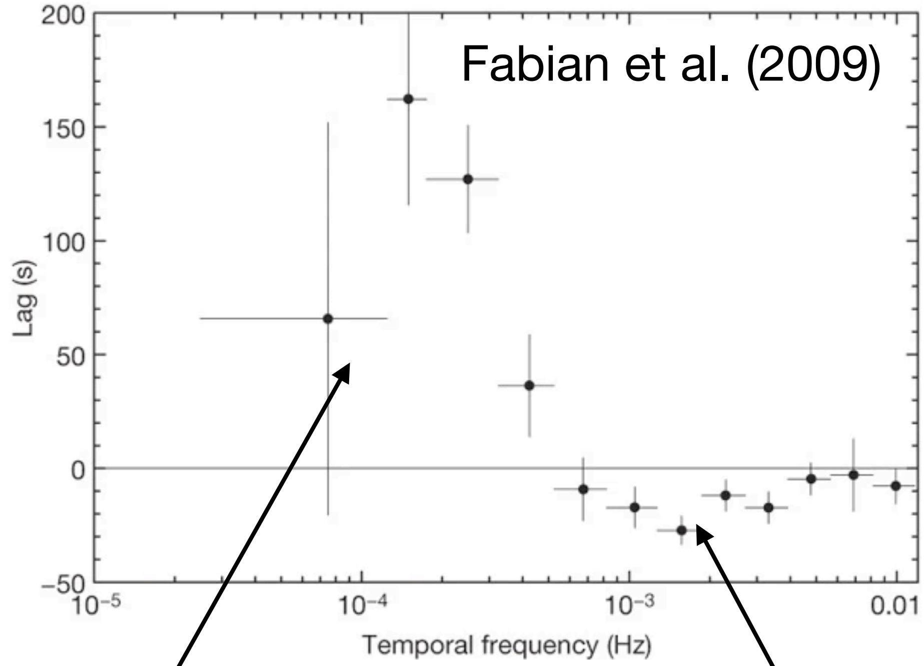


UV/Soft X-ray disappearance…

Very similar to Mkn 1018 (Noda & Done 2018)

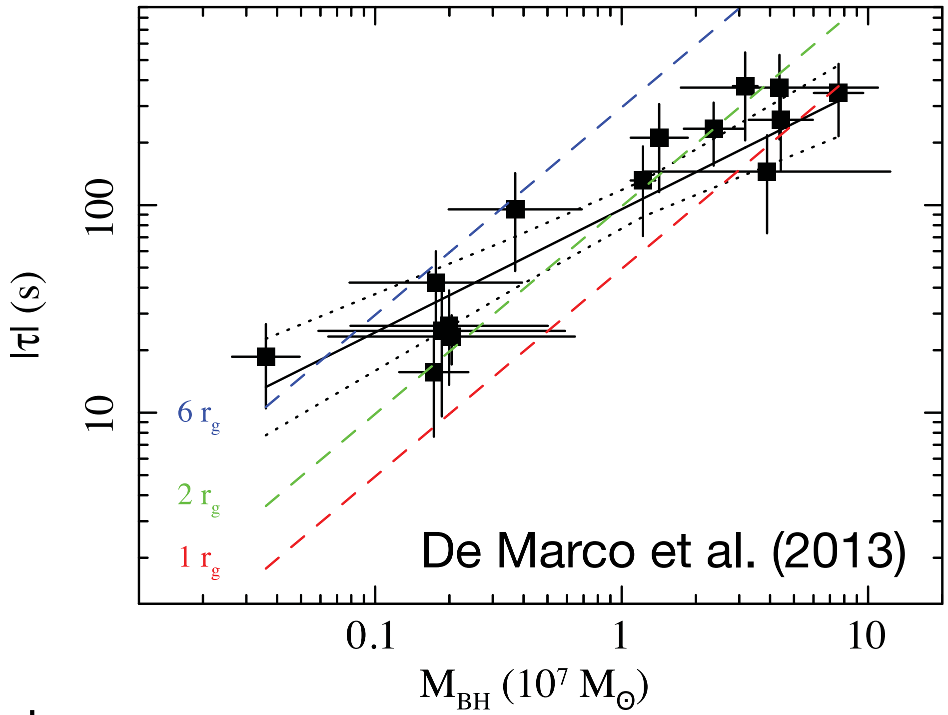
Timing Properties

Lag between soft (0.3-1 keV) and hard (1-5 keV)



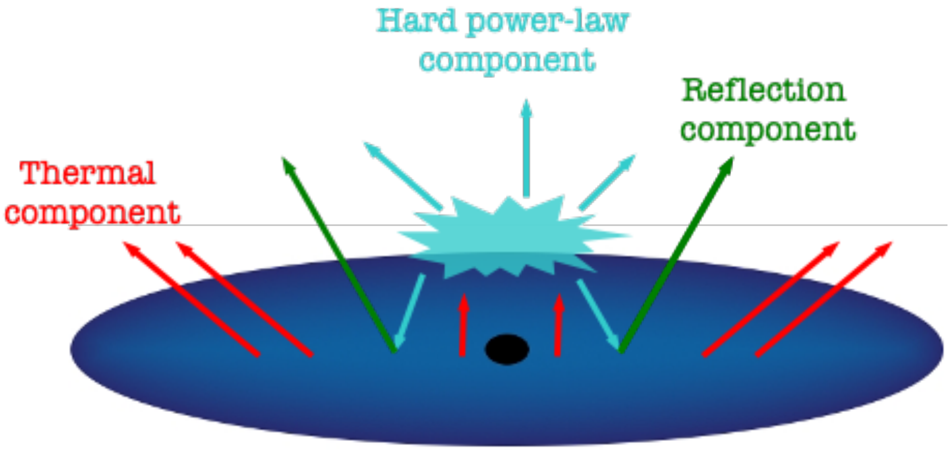
Soft lead on longer time scale: propagating fluctuation?

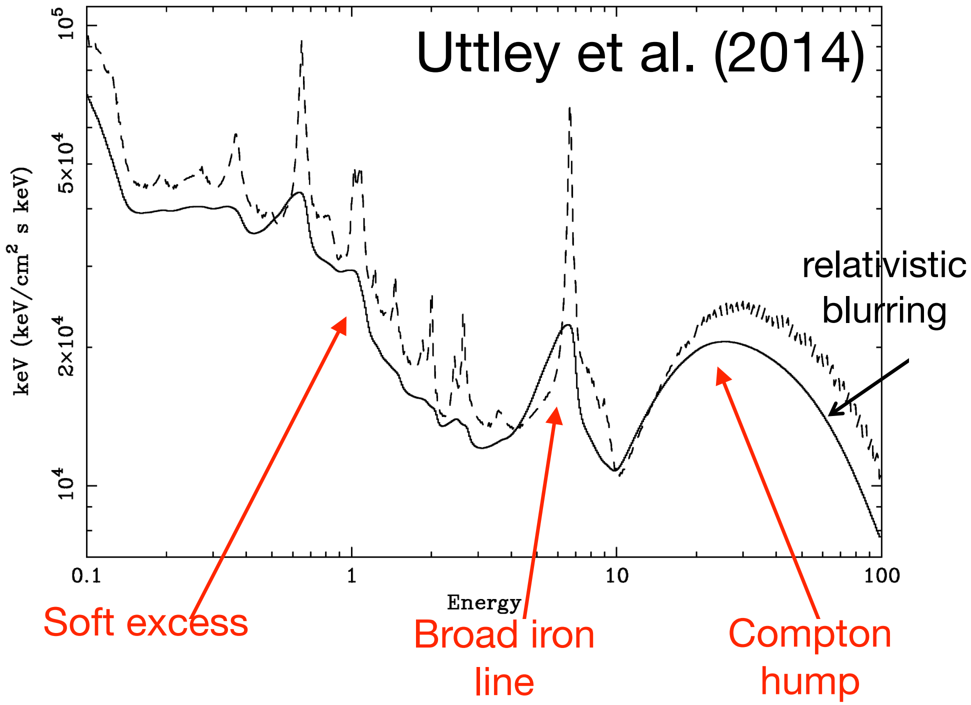
Soft lag on short time scale: reflection, reprocessing?



Main Models I

Blurred, ionized reflection (e.g. Ballantyne et al. 2001; Crummy et al. 2006; Walton et al. 2013; Garcia et al. 2019,…)





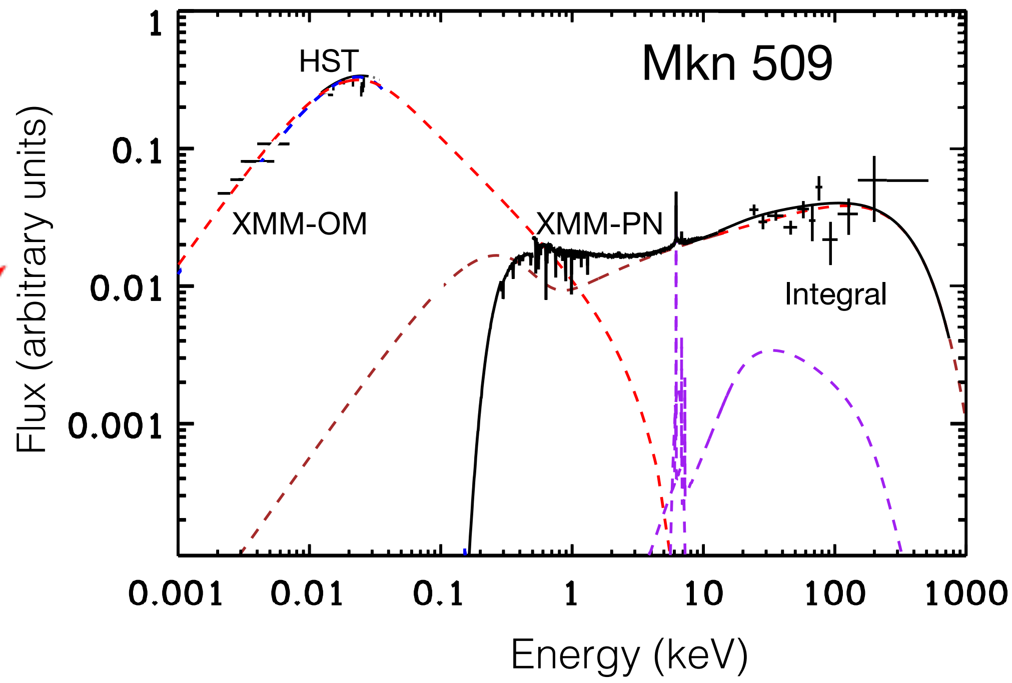
The relativistic motion of the inner accretion flow blurs the sharp atomic features into the smooth shape of the soft excess

Cons: Soft X-ray excess are observed in objects without broad Fe K line… Soft X not always correlated with hard X.…

Main Models II

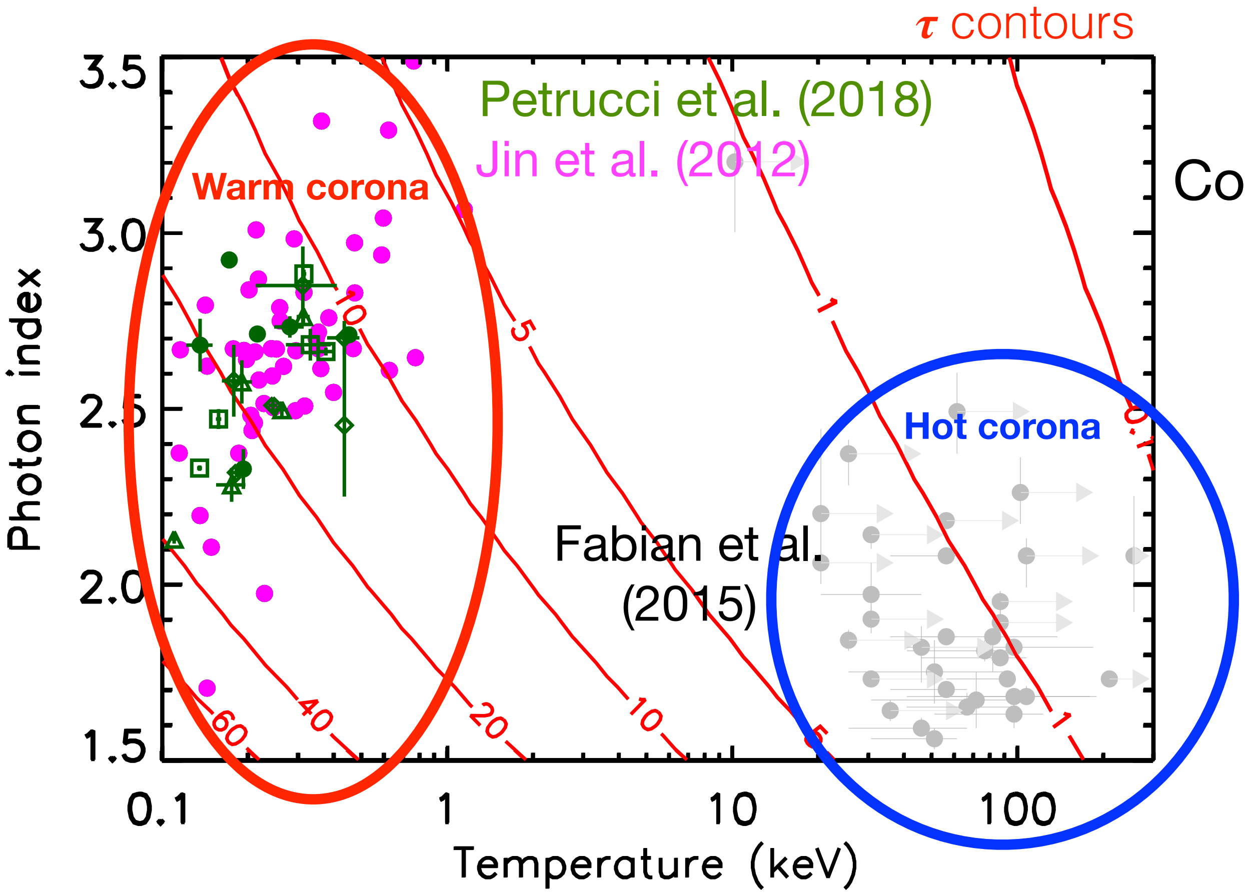
Two-coronae model (e.g. Magdziarzk et al. 1998, Jin et al. 2012, Done et al. 2012; Petrucci et al. 2013, 2018; Matt et al. 2014; Porquet et al. 2018; Ursini et al. 2018; Middei et al. 2019, …)

A 2nd corona covers part of the accretion flow and comptonized the UV emission to the soft X-rays



Cons: no clear origin of this warm corona… Fine tuning (kT_{wc}, τ_{wc})…

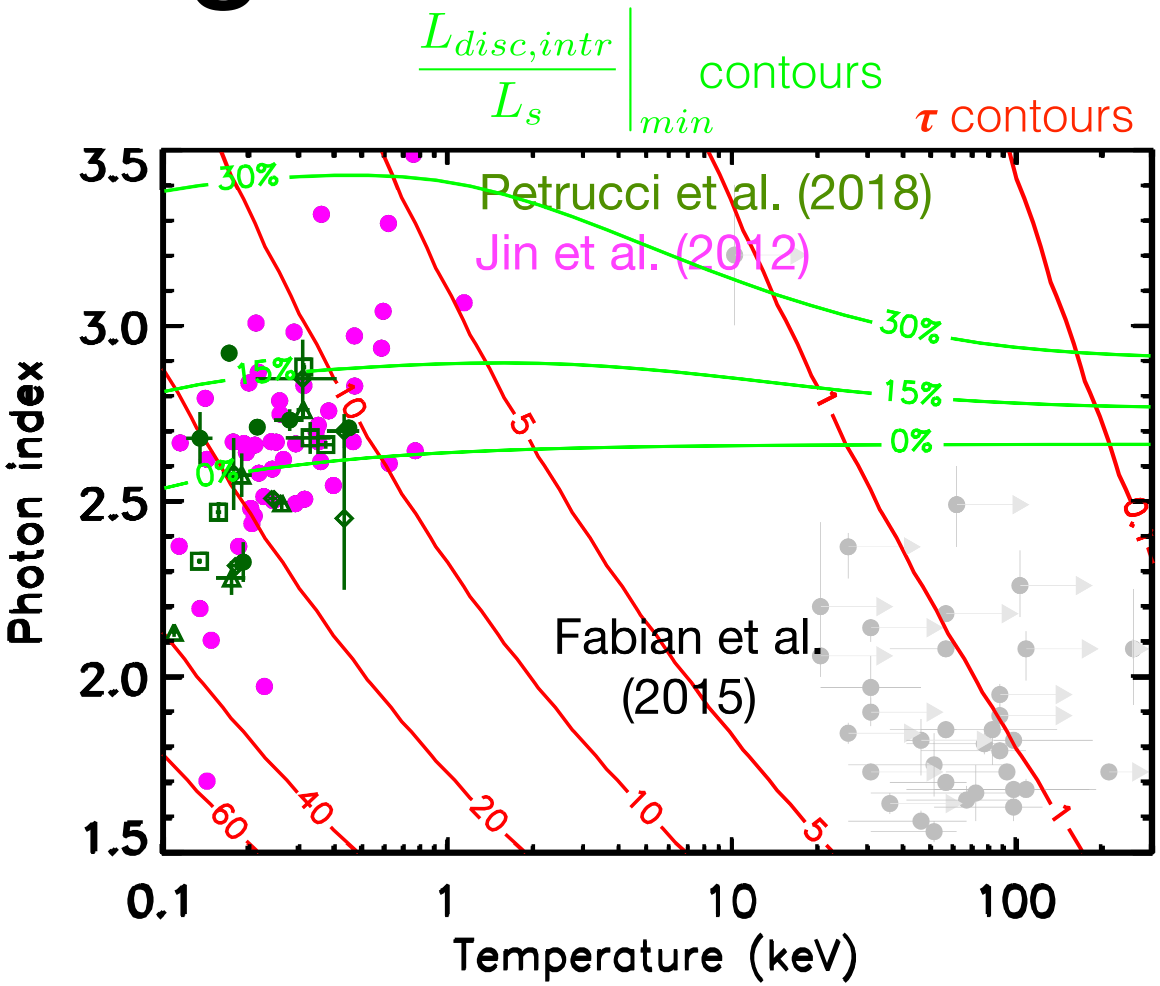
Testing the Two-Coronae Model



From Thermal Comptonisation physics
$\tau(\Gamma, kT)$

- A "hot" corona (kT~100 keV, tau~1) to fit the hard X-ray emission
- A "warm" corona (kT~1 keV, tau~10-30) to fit the UV to soft X-ray emission

Testing the Two-Coronae Model



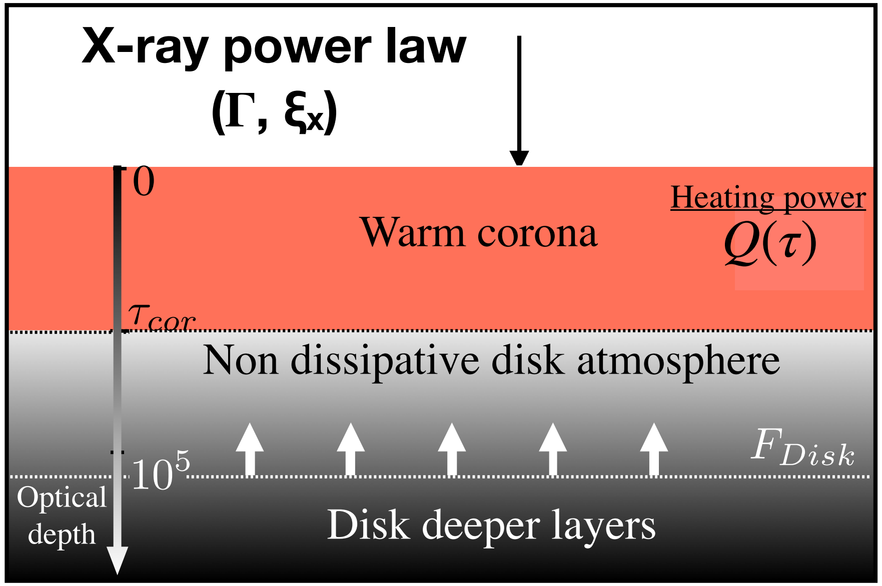
- A "warm" corona, where most of the accretion power is released, covering a non-dissipative disk

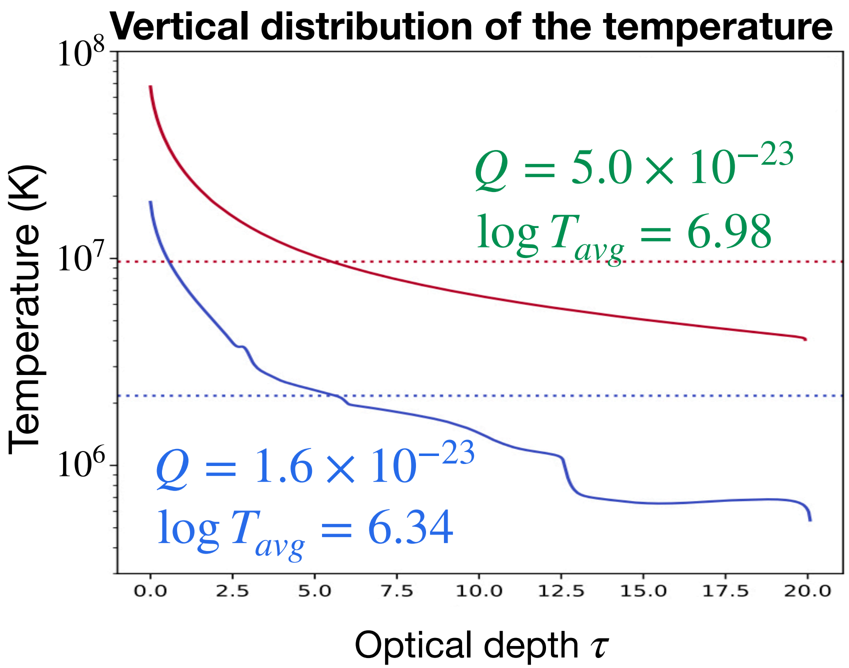
Numerical Simulations

- Photo-ionization code TITAN + Monte Carlo code NOAR   Dumont et al. (2003)
- Take into account heating due to external illumination, lines, edges, free-free…

See also Ballantyne (2020), Ballantyne & Xiang (2020) using the Ross Code

Rozanska et al. (2015)   Petrucci et al. (2020)





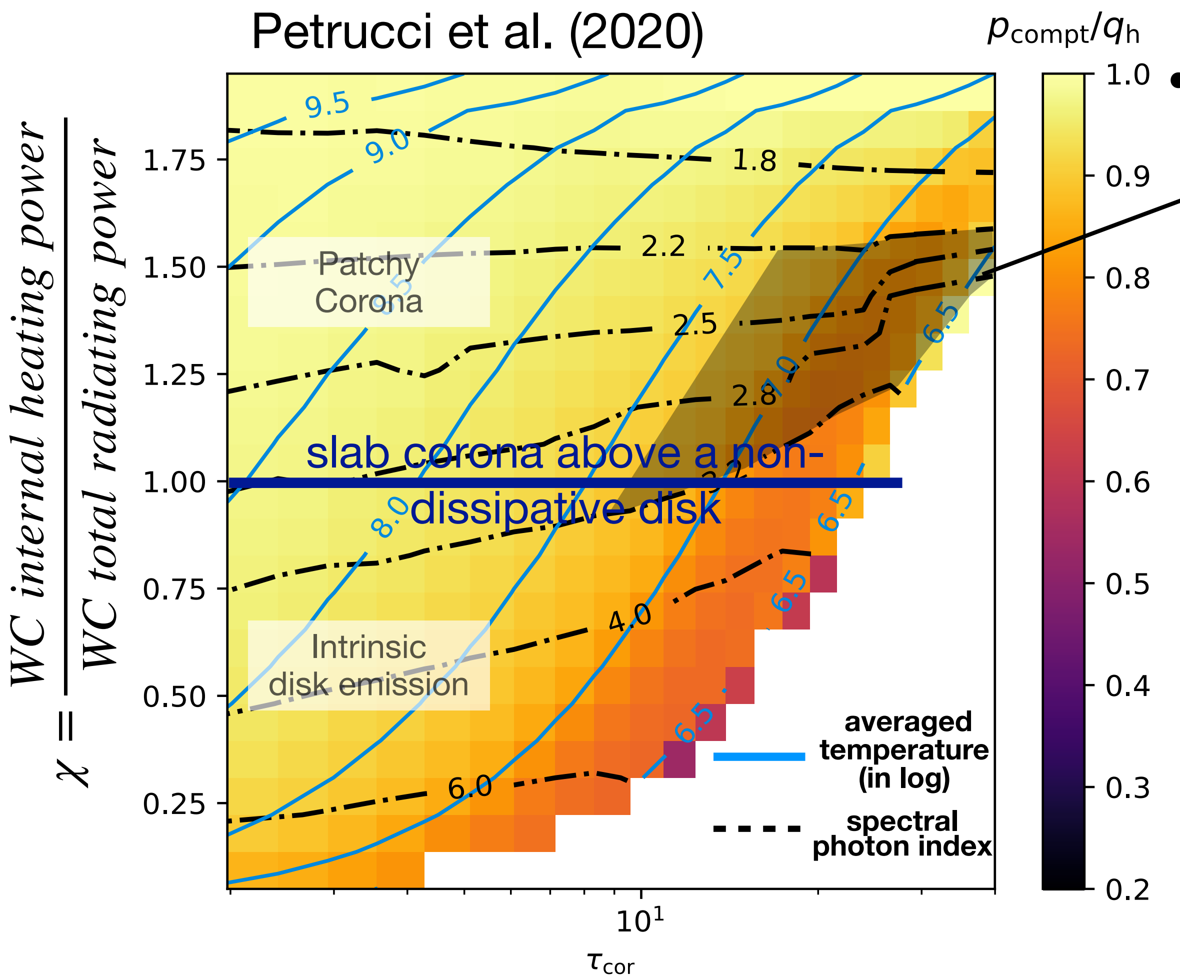
TITAN

τ =20, N_h=3x10^{25}cm^{-2} n_e=10^{12} cm^{-3}

T_{bb}=10^5 K Γ=1.8 ξ_x=10^3

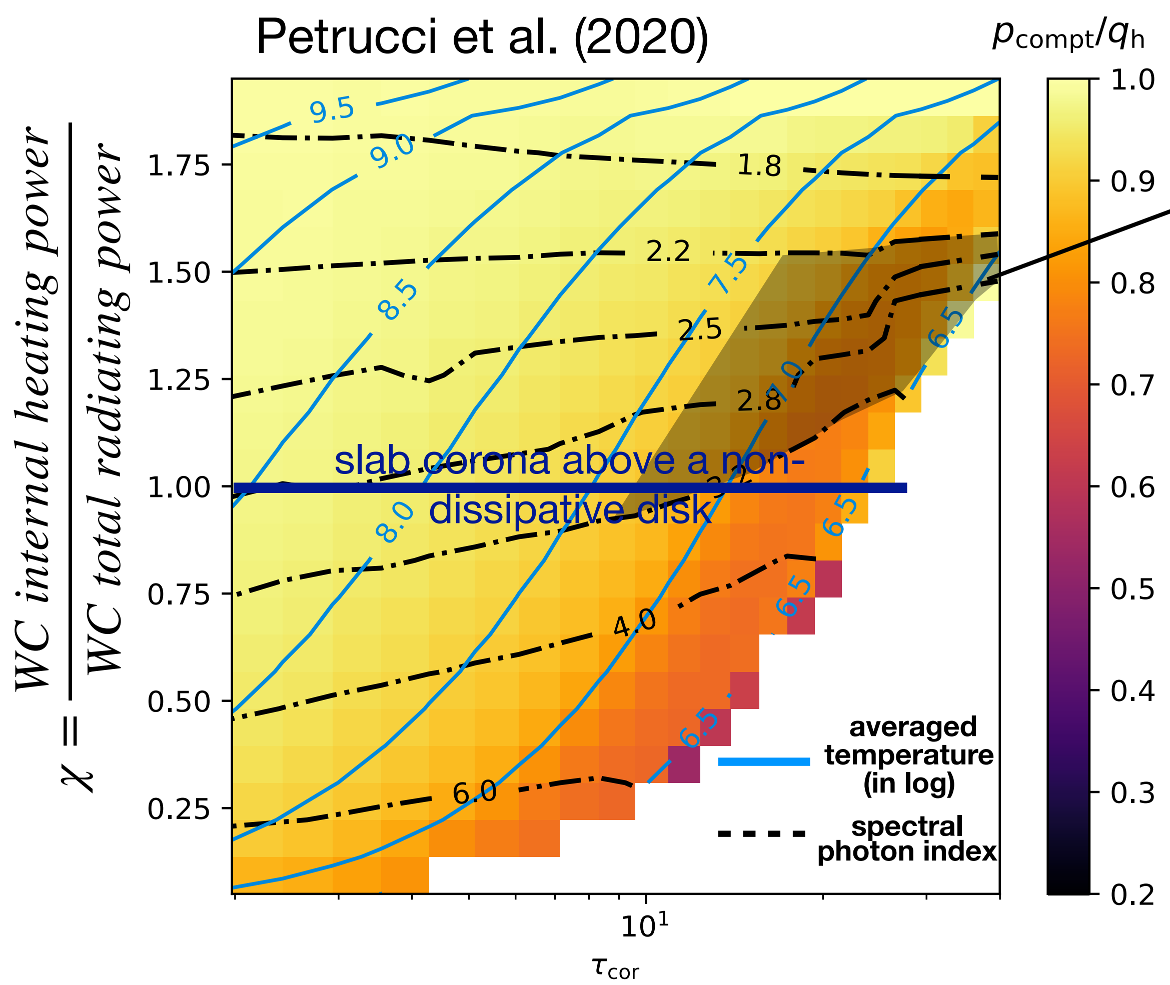
N.B.: $$Q_{Edd} = \frac{L_{Edd}}{4/3\pi R^3 n_e^2} = 2.4 \times 10^{-21} M_8^{-2} n_{e,12}^{-2} r_{10}^{-3} \mathrm{erg/s\ cm^3}$$

Numerical Simulations

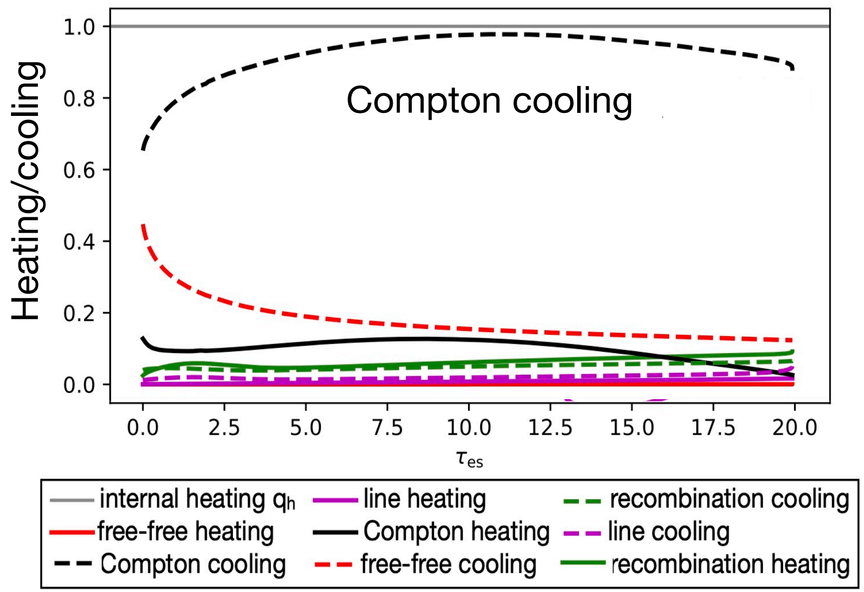


- In agreement with observational constraints (τ, kT, $\Gamma_{soft\ X}$)

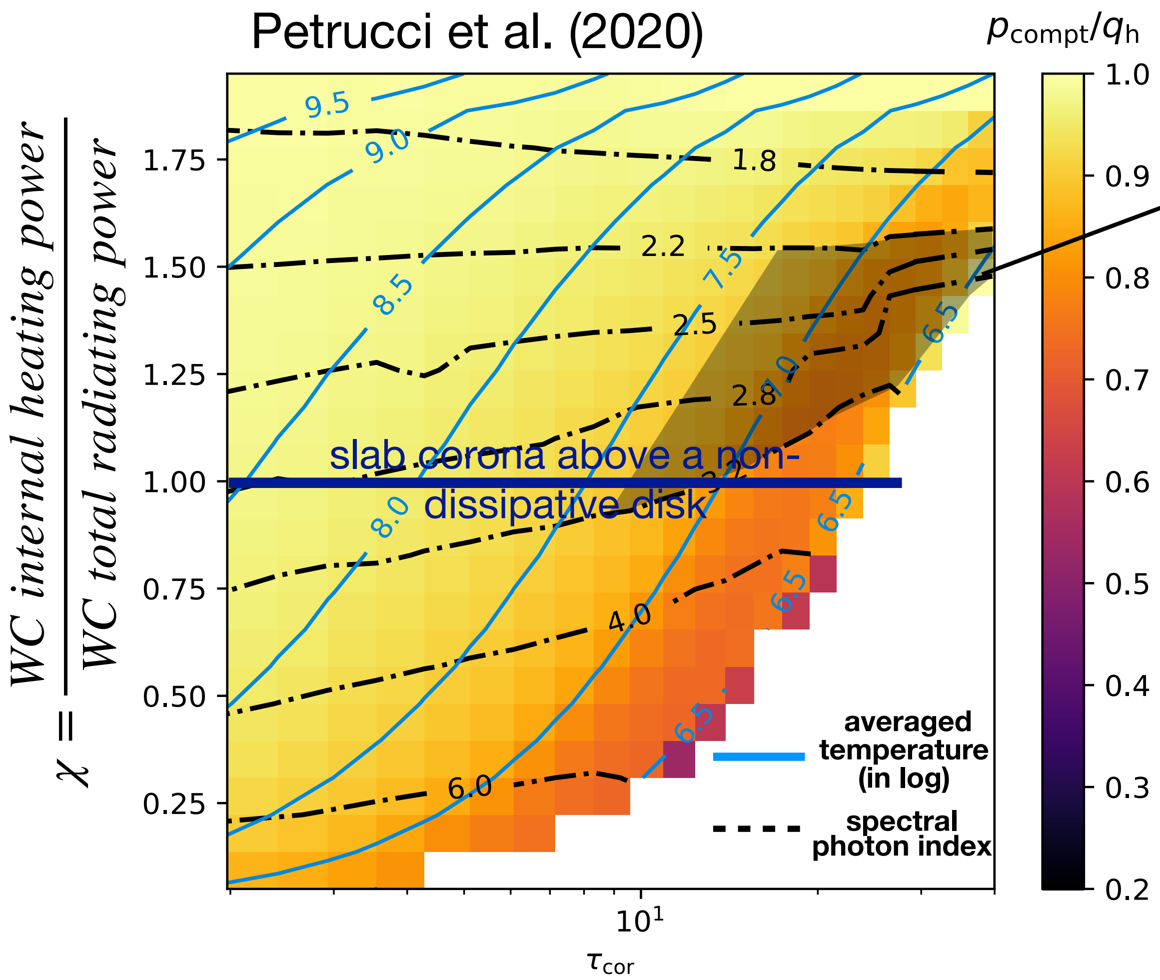
Numerical Simulations



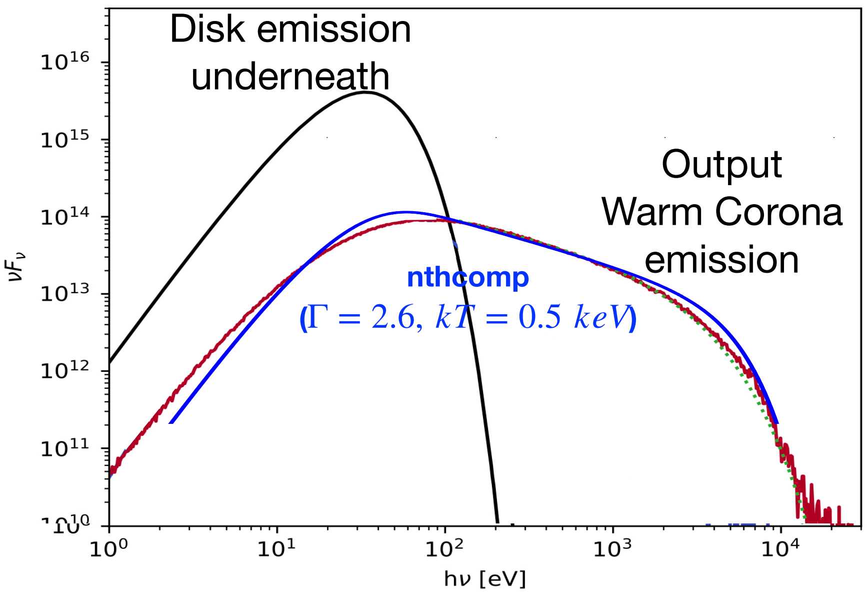
- In agreement with observational constraints (τ, kT, $\Gamma_{soft\ X}$)
- Dominated by Comptonisation



Numerical Simulations



- In agreement with observational constraints (τ, kT, $\Gamma_{soft\ X}$)
- Dominated by Comptonisation
- No (strong) emission/absorption lines



XSPEC tables

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========================================================================
Model    atable{/Users/petrucpi/Boulot/MODEL/ATABLE/TITAN/TITAN_C.mod}<1>
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   TITAN_C    logqh               -22.3963     +/-  0.0
   2    1   TITAN_C    tau                 16.4993      +/-  0.0
   3    1   TITAN_C    z                   0.0          frozen
   4    1   TITAN_C    norm                1.00000      frozen
________________________________________________________________________
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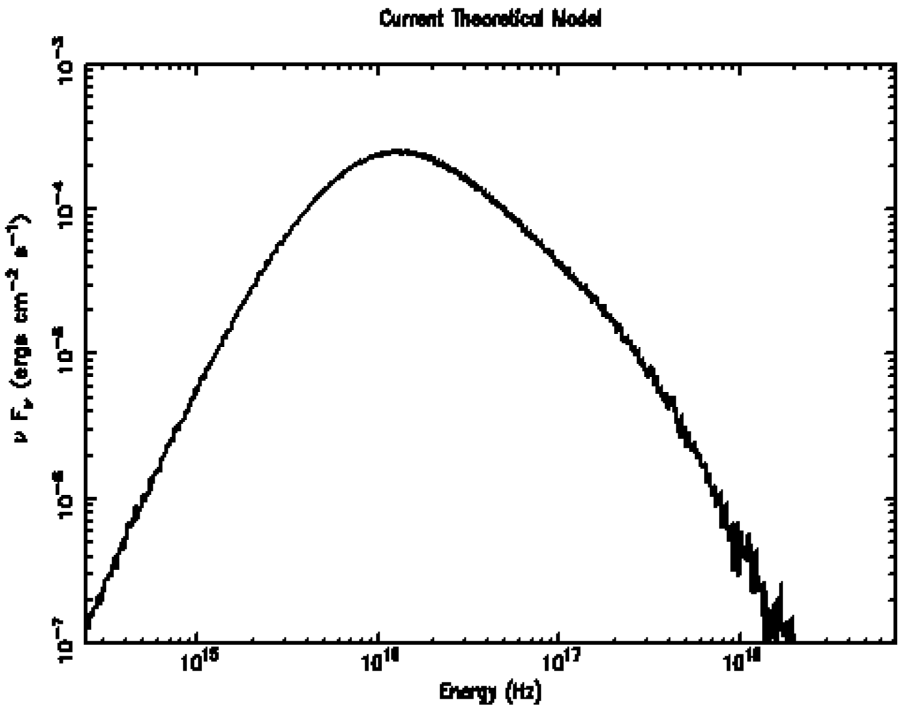


The table spectra are normalized by

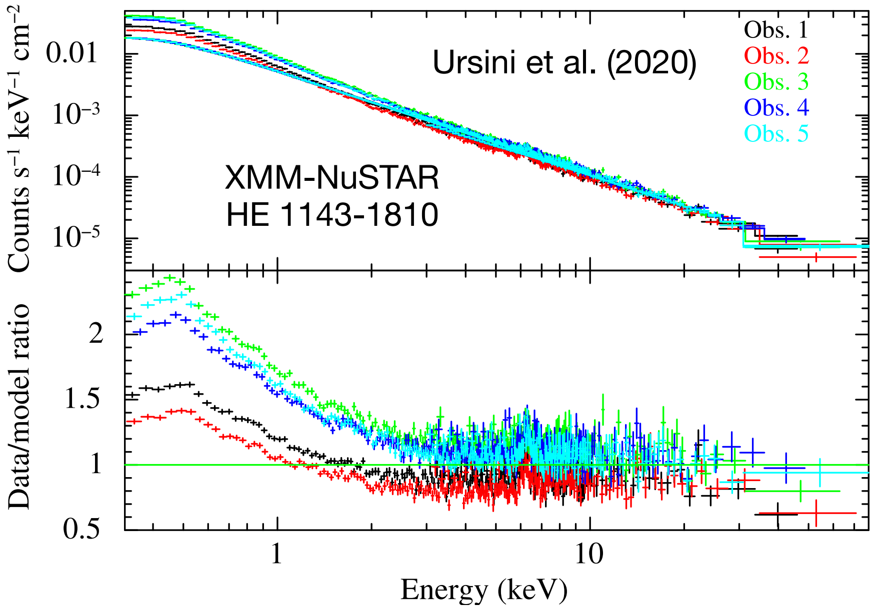
(10 Rg)**2./(4pi d10**2)

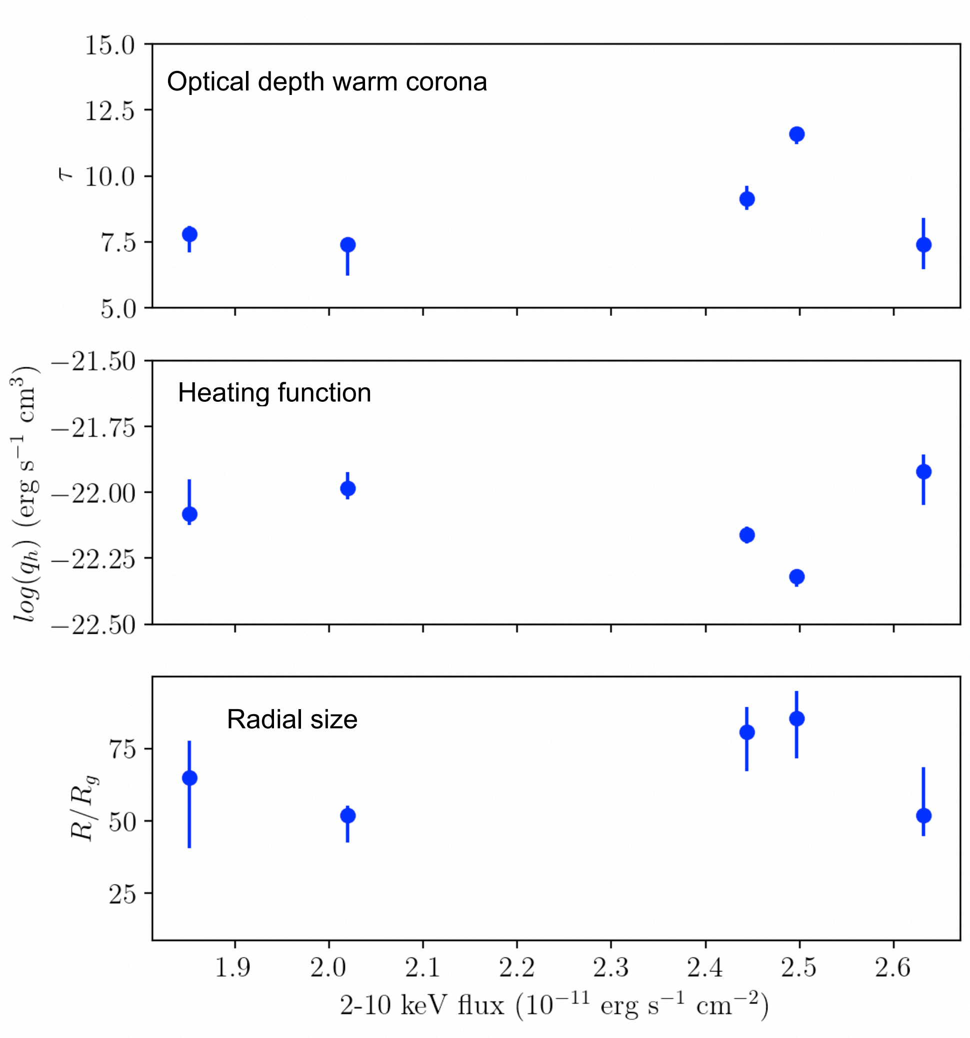
with Rg=1.5e13 cm and d10=10 kpc.

For a source at D (in 10 kpc units!) the best fit NORM of the table should give an estimate of the warm corona size

$$R_{WC} \simeq 8.5 \times 10^{13} \left(norm * D^2 \right)^{1/2} \; cm$$

Application to HE 1143-1810



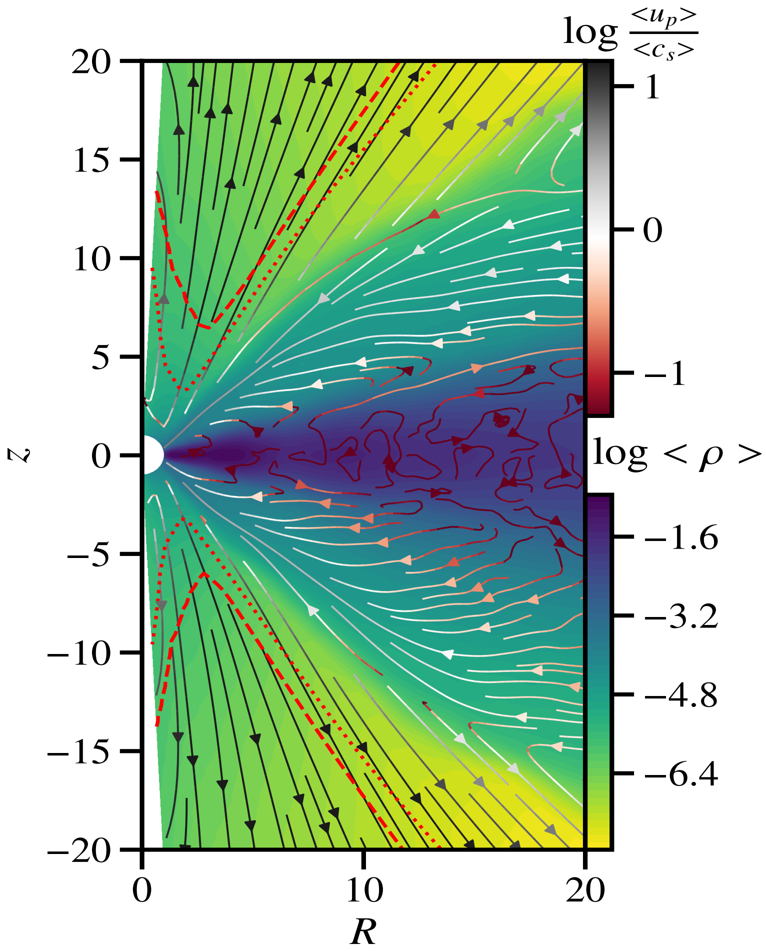


Work in progress….

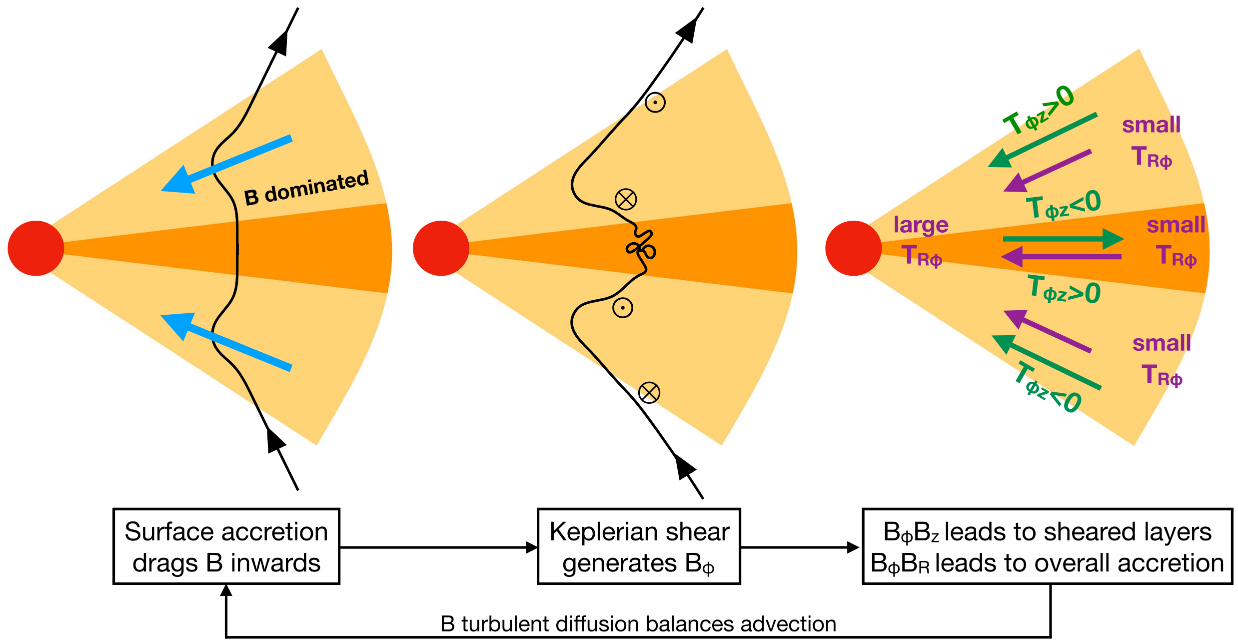
Conclusions

- Soft X-ray excess **ubiquitous** in AGN
- Origin of soft X-ray excess still unknown. **Blurred ionised reflection and warm comptonisation** fit well. Both have their own limitations but both could be present…
- Warm corona modelling with **local $Q_{heating}$ until large** τ_{wc} show that there is a parameter space area that agrees with observation, where **Compton dominates and no (strong) lines produced.**
- Limited parameter space with the right kT_{wc} and τ_{wc} and quite dependent on $Q_{heating}$ … Where $Q_{heating}$ comes from?

Local heating: « Coronal accretion »?



Jacquemin et al. (2021)



Zhu & Stone (2018)