New results about the Accretion Flow in *Super-Eddington* NLS1s from *XMM-Newton* Observations

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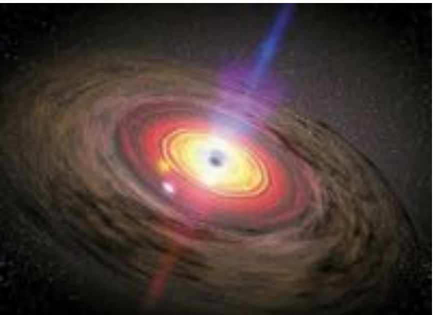
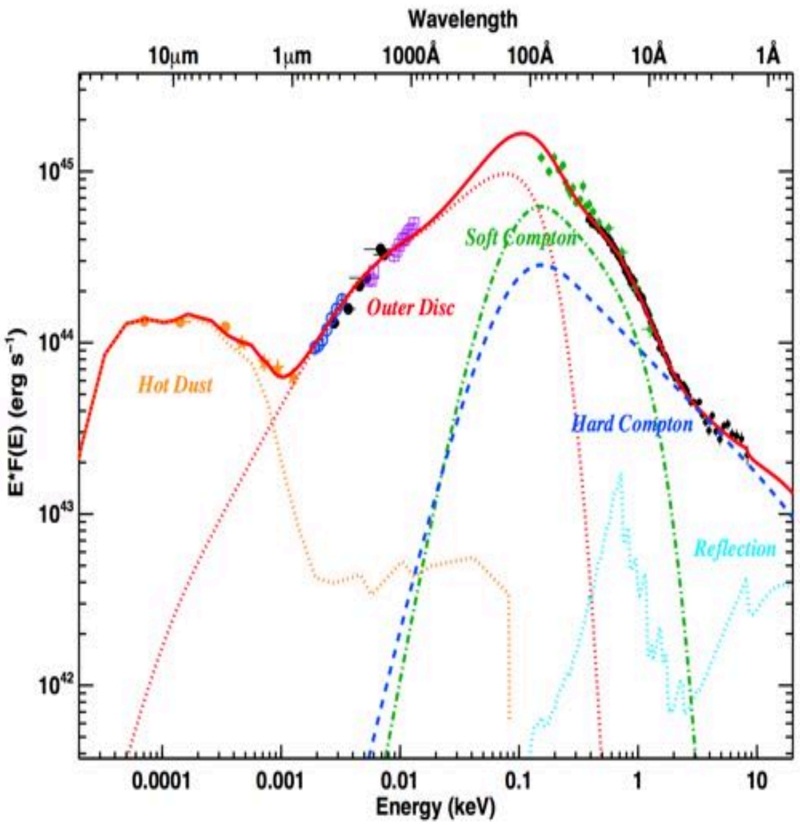


RX J0439.6-5311: the most robust super-Eddington 'Simple' NLS1

- Gallo et al. (2006): X-ray simple & X-ray complex NLS1s
- z=0.243
- Unobscured, clean line-of-sight
- Radio Quiet (no jet component)
- Very soft X-ray spectrum: $\Gamma \sim 2.2$
- Hβ FWHM ~ 700 km/s, single-epoch black hole mass 5×10^{6} $M_{\odot}$
- L/Ledd =12.9, highest among all 92 bright AGN in Grupe et al. (2010)

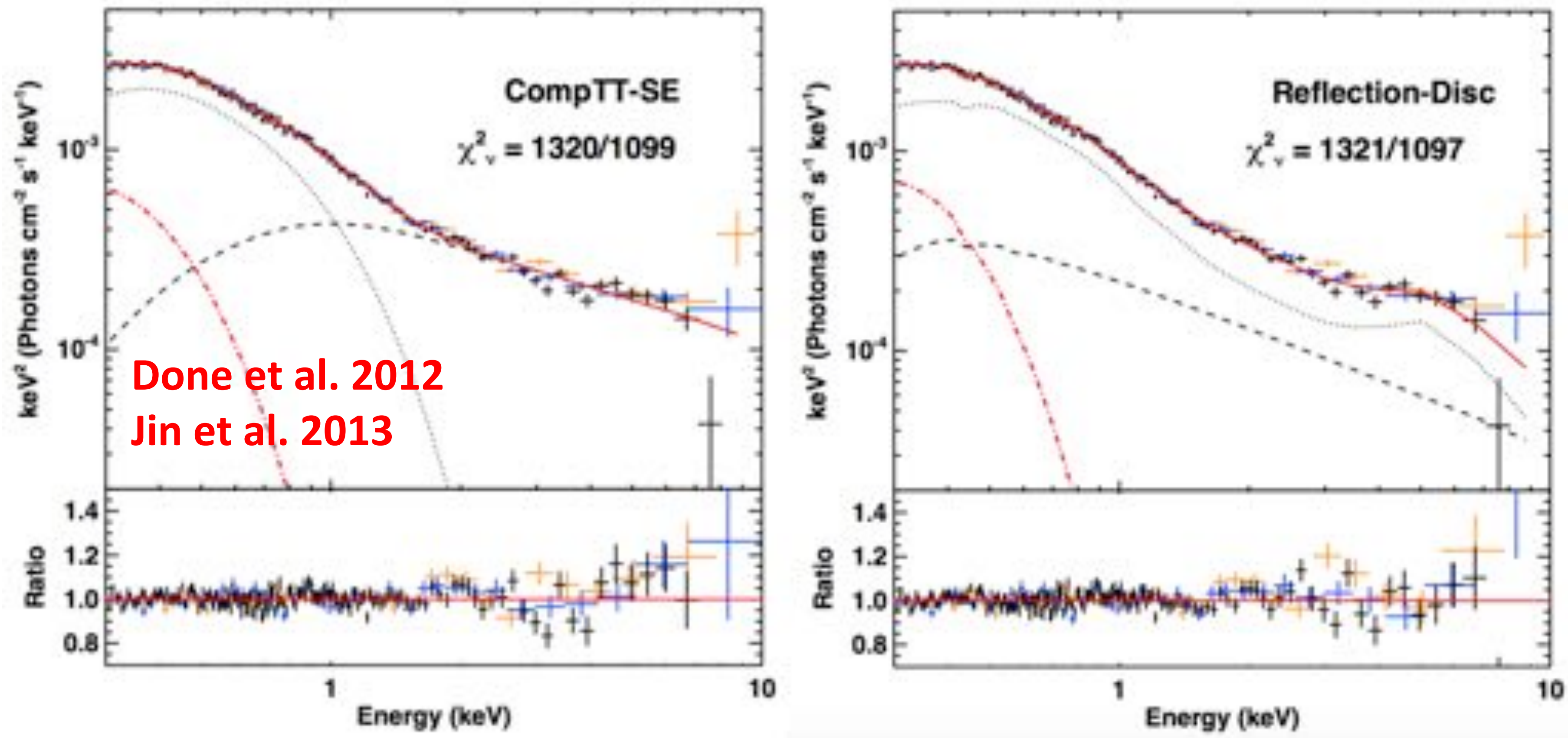


(Jin et al. 2017b, submitted)

RE J1034+396: first AGN QPO Detection, Alston's talk (a typical 'simple' super-Eddington NLS1)

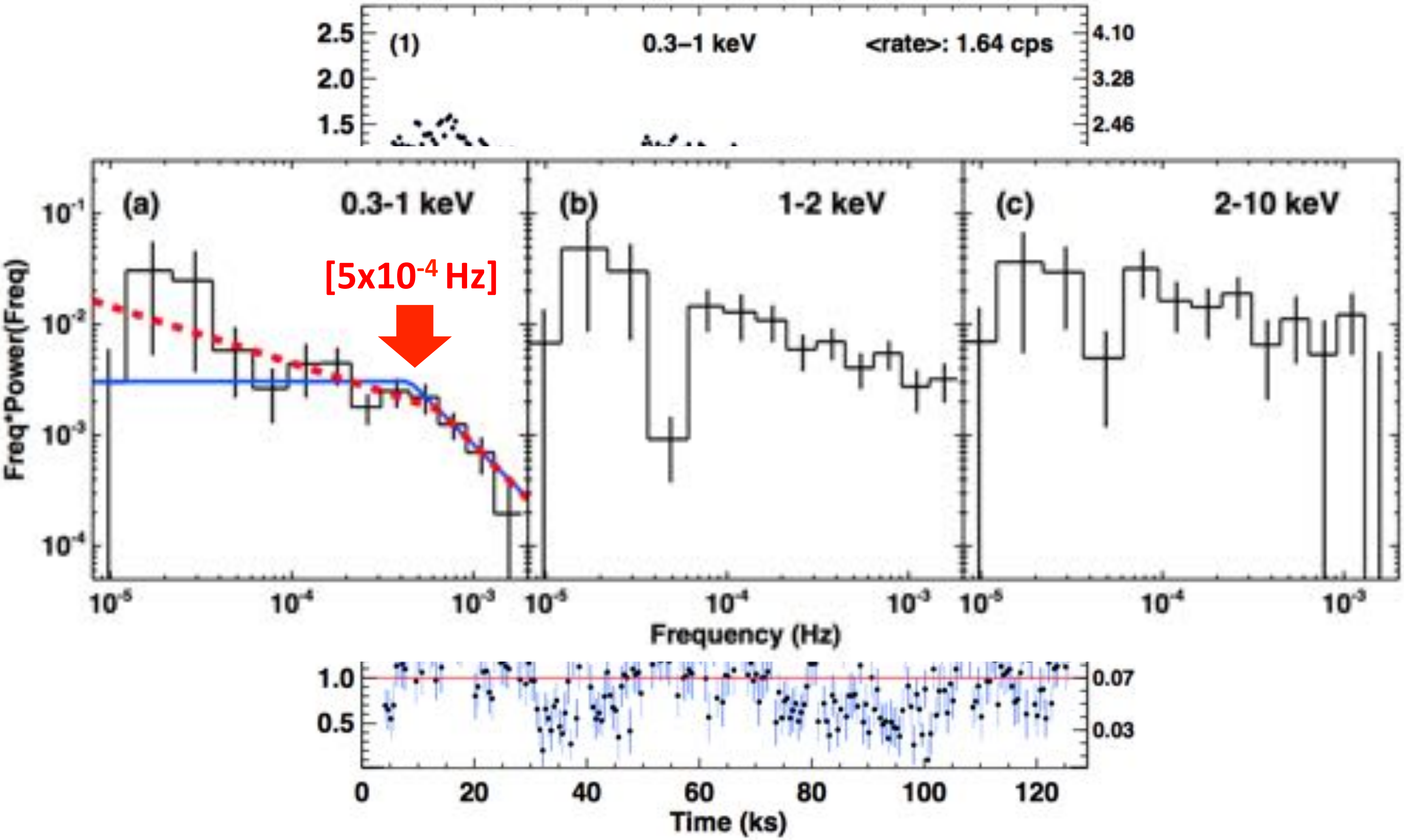
X-ray Properties

X-ray Spectral Fitting and Model Degeneracy



1. 'simple' X-ray spectra, but NOT less challenging to understand
2. We need variability to break the spectral degeneracy

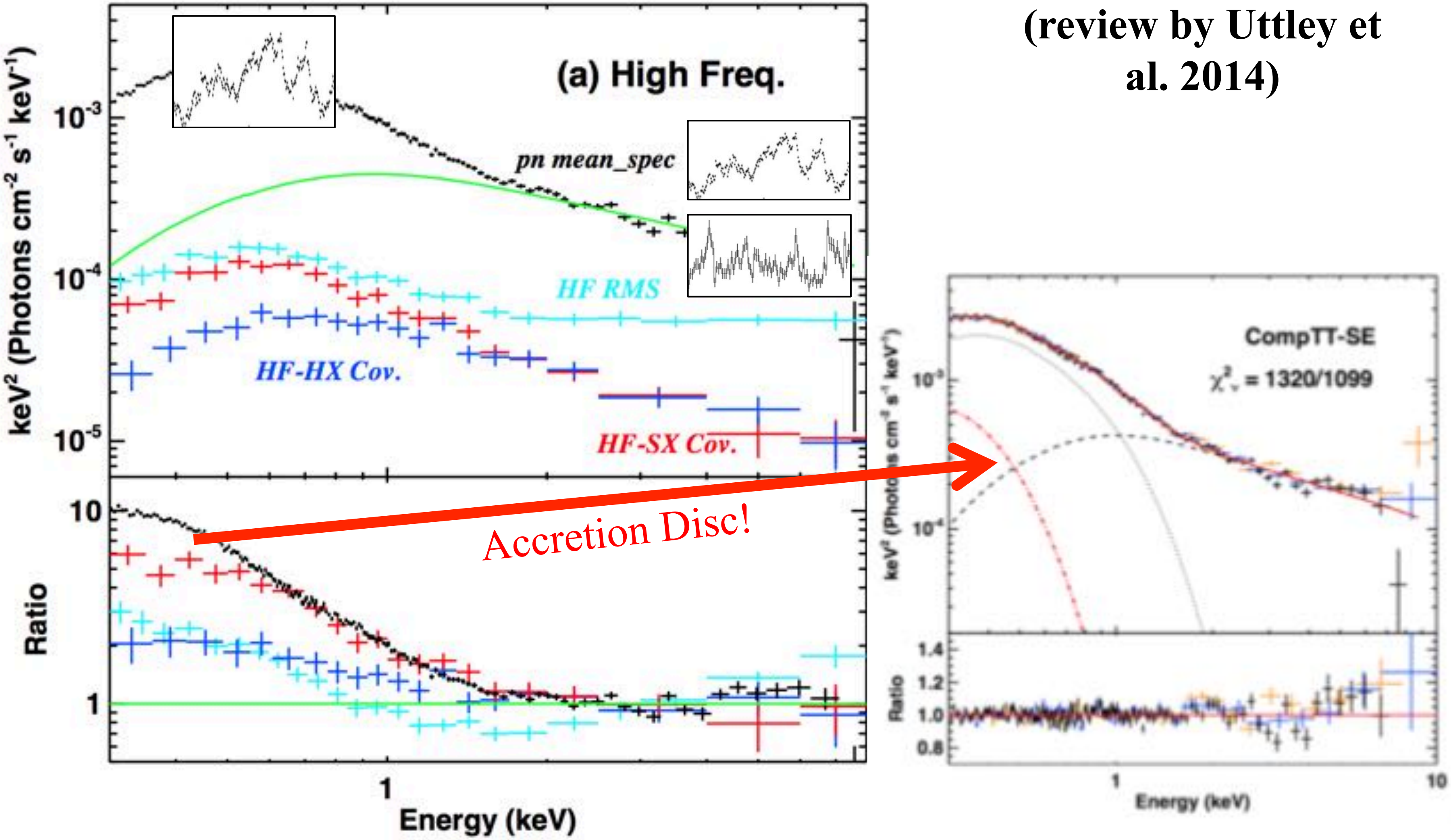
X-ray Variability – Energy Dependent



X-ray Variability Spectra

f-differentiated RMS spectra & Covariance Spectra

(review by Uttley et al. 2014)



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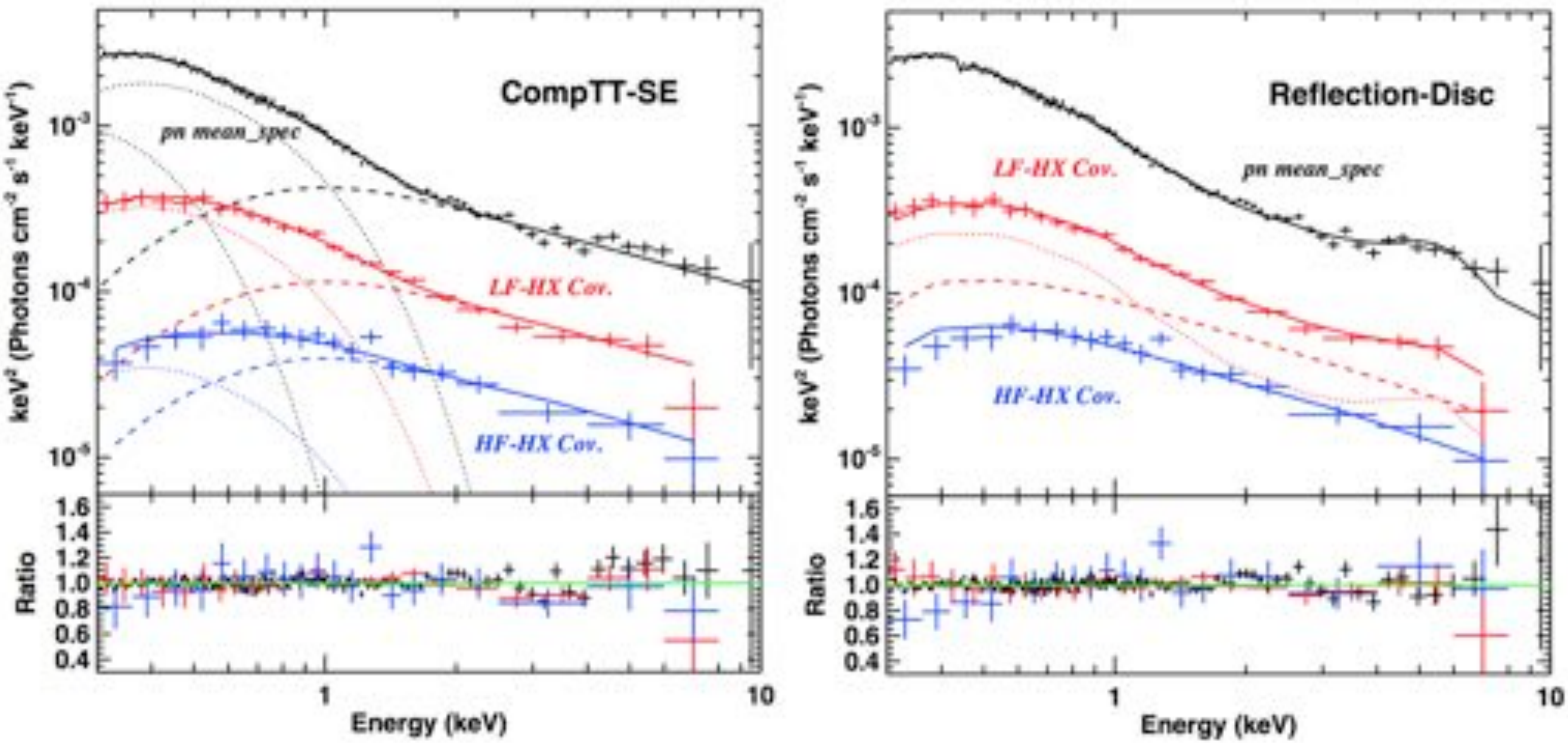
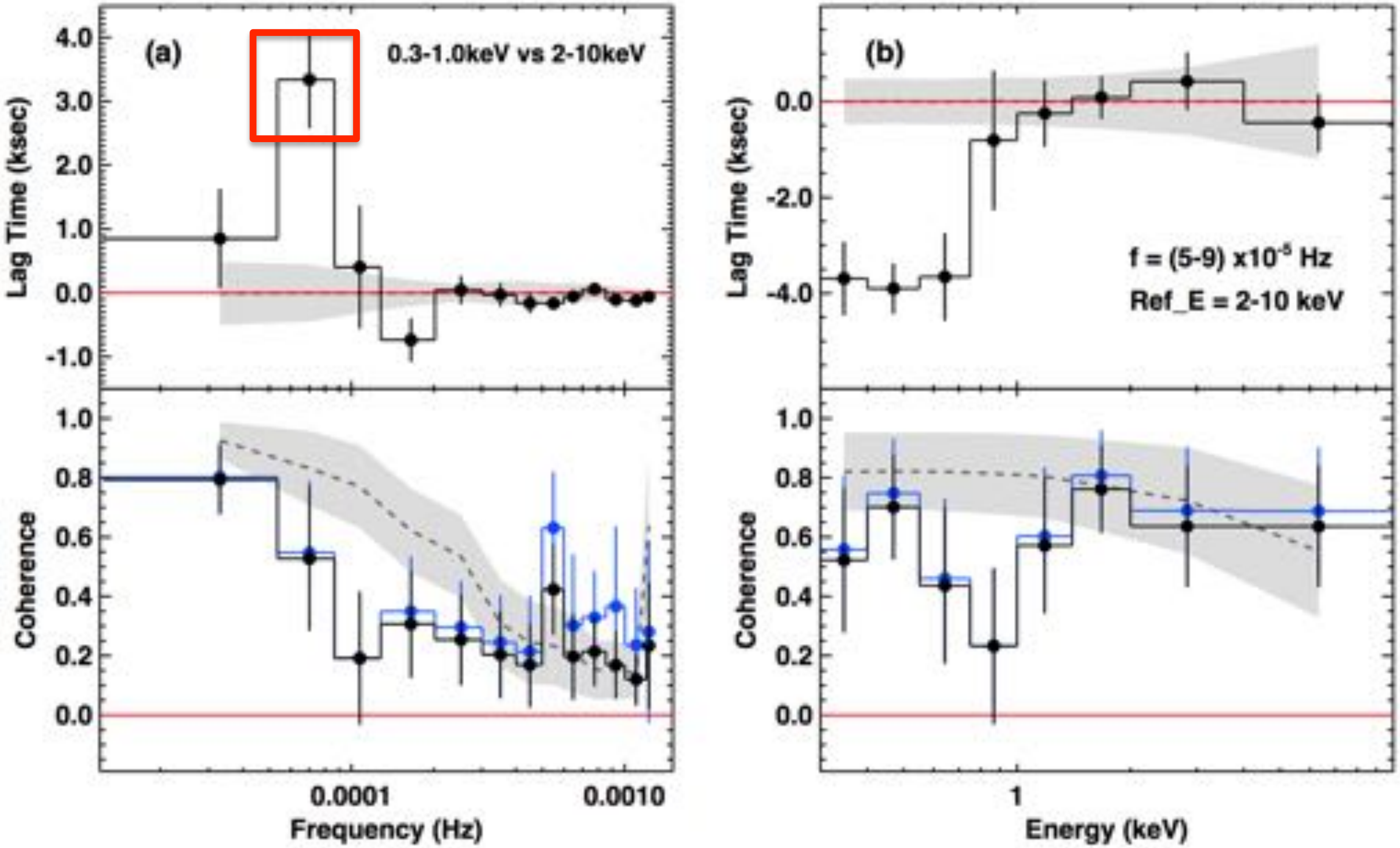
X-ray Variability Spectra

simultaneous fit to all the spectra



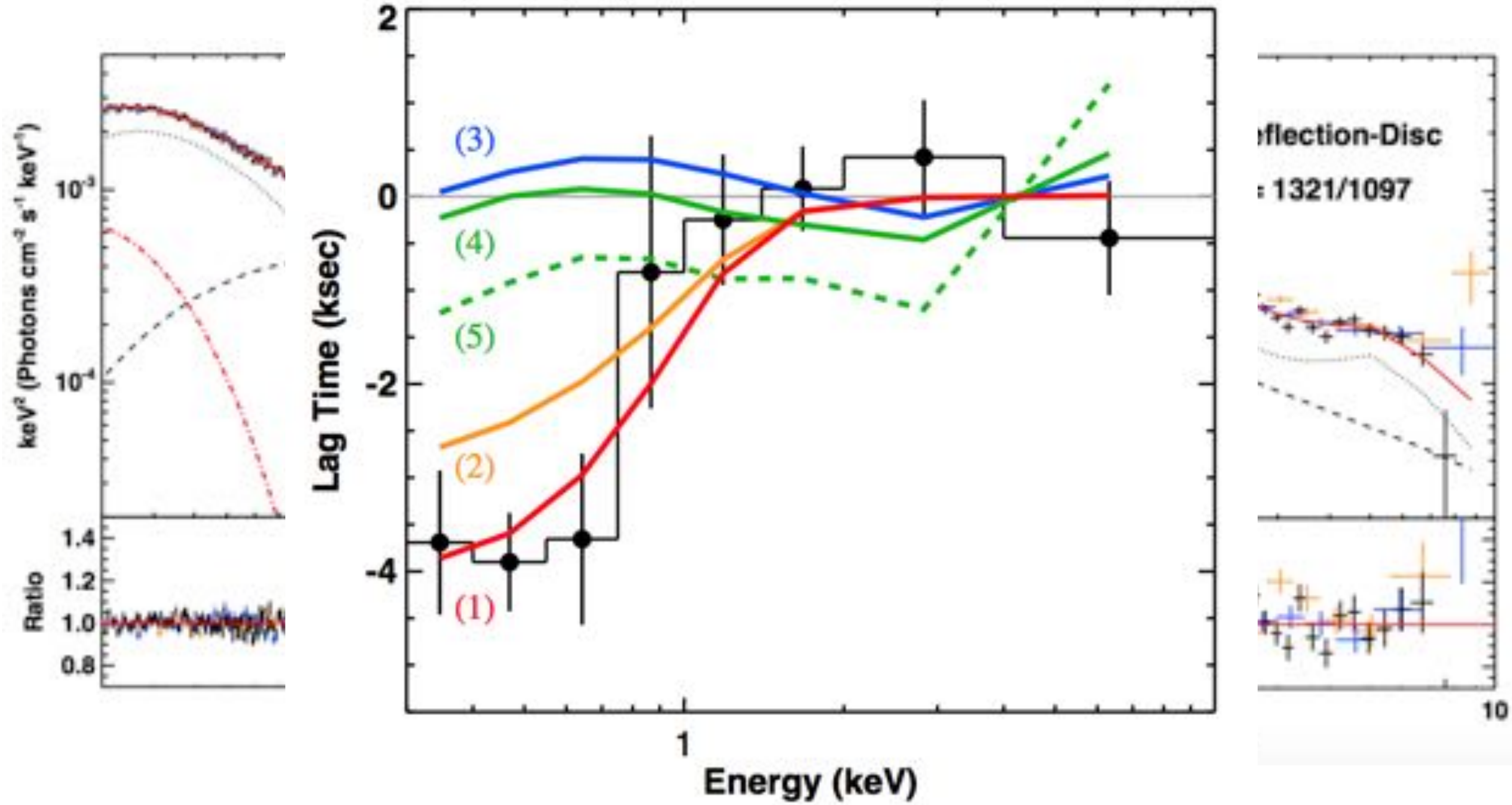
Cross-spectra & time-lag Analysis

soft X-rays leading hard X-rays with high coherence!



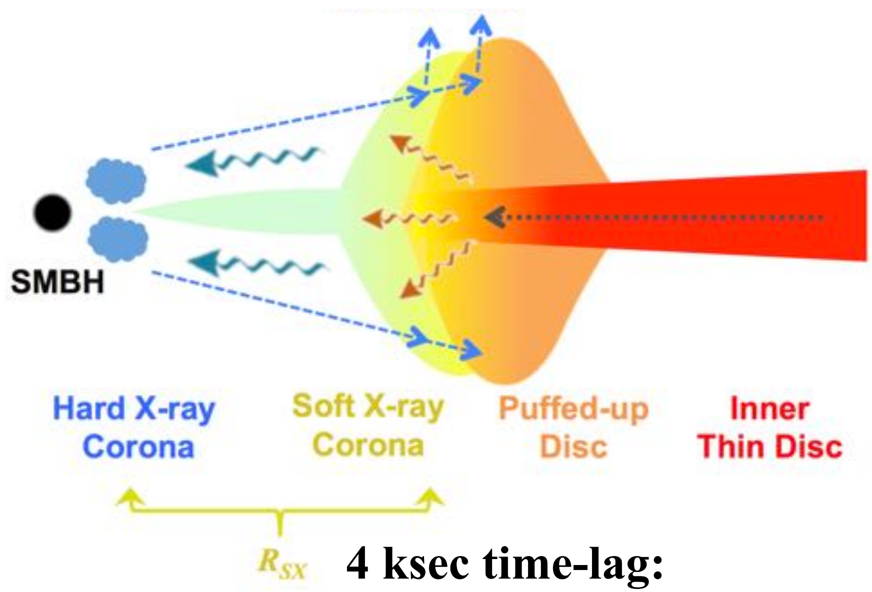
Cross-spectra & time-lag Analysis

low-f lag-spectrum also favors soft X-ray Comptonisation

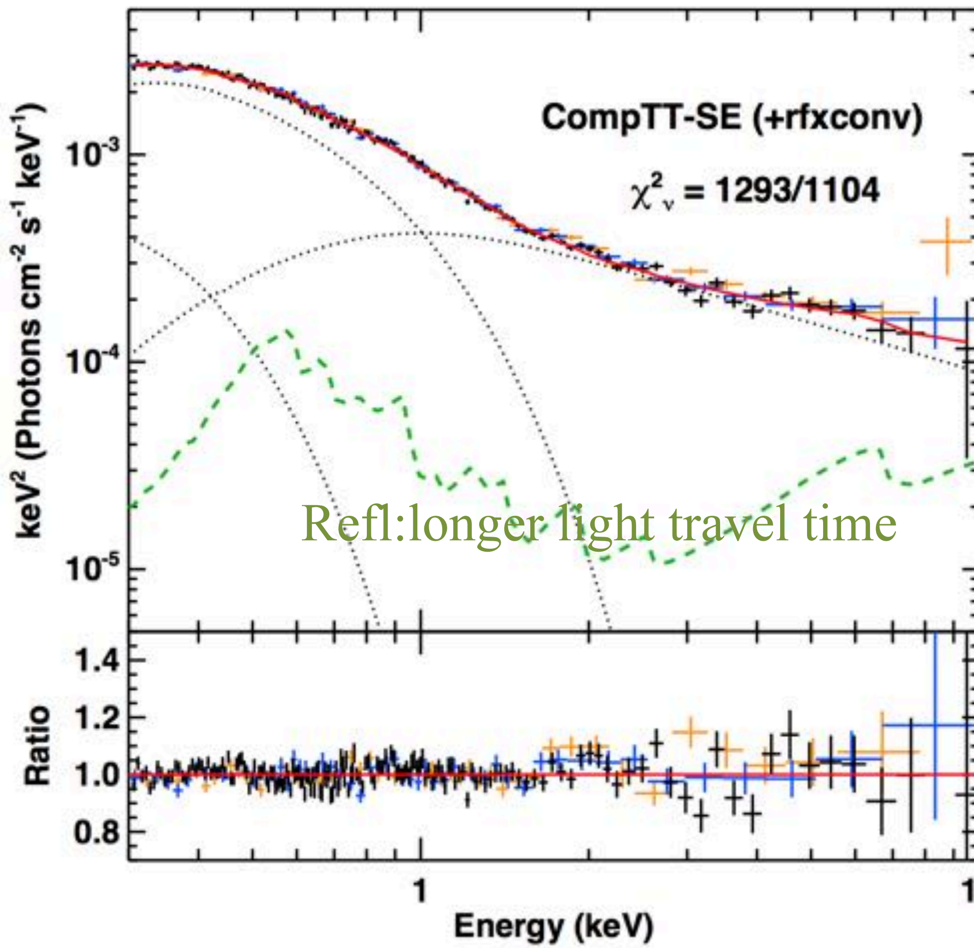


Best Inferred Geometry for the X-ray Emitting Region

disc + hard X-ray Compt + soft X-ray Compt + weak refl.



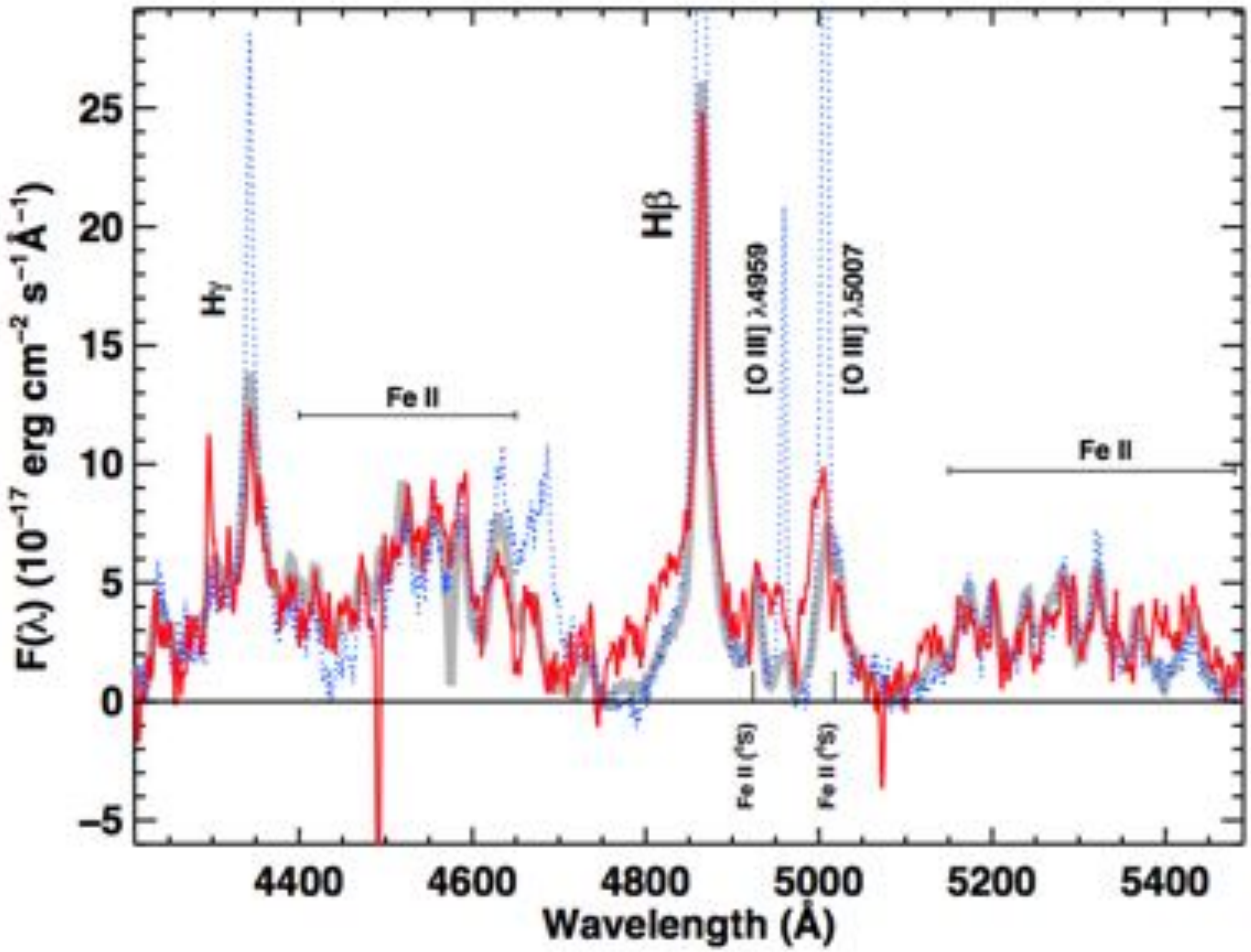
4 ksec time-lag:
80 Rg for $M=10^7 M_\odot$
200 Rg for $M=4\times10^6 M_\odot$



see Gardner & Done (2014) for a full spectral-timing modeling for PG 1244+026

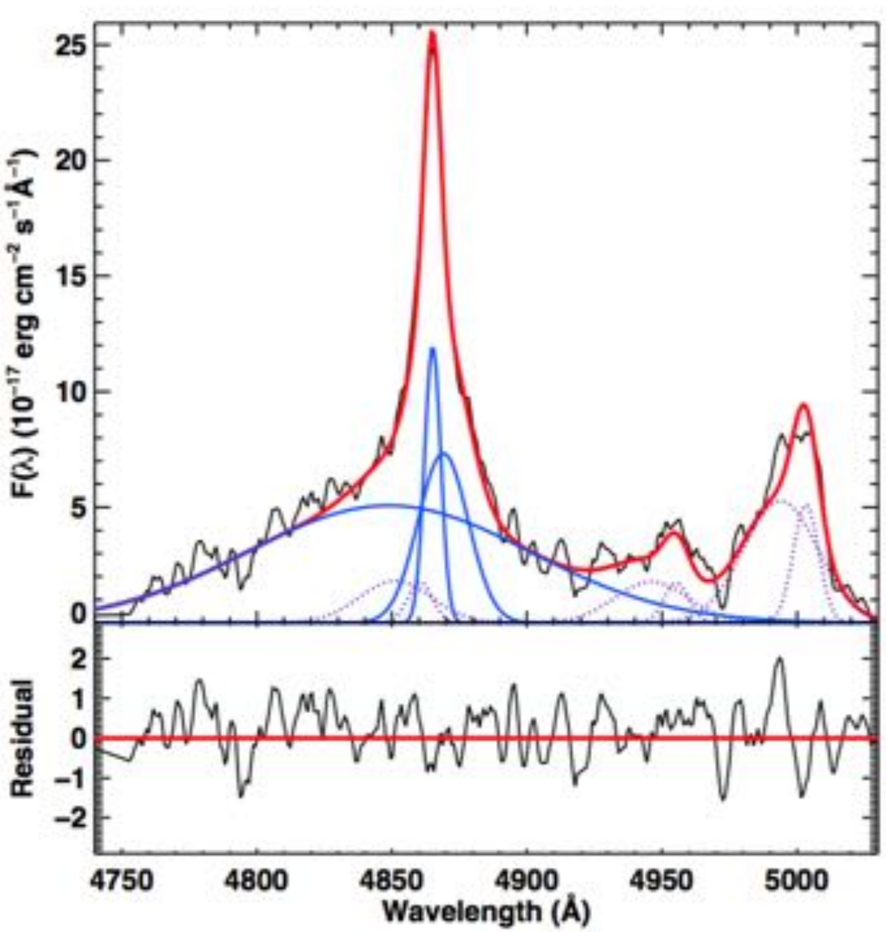
Multi-wavelength Properties

Outflows in BLR and NLR



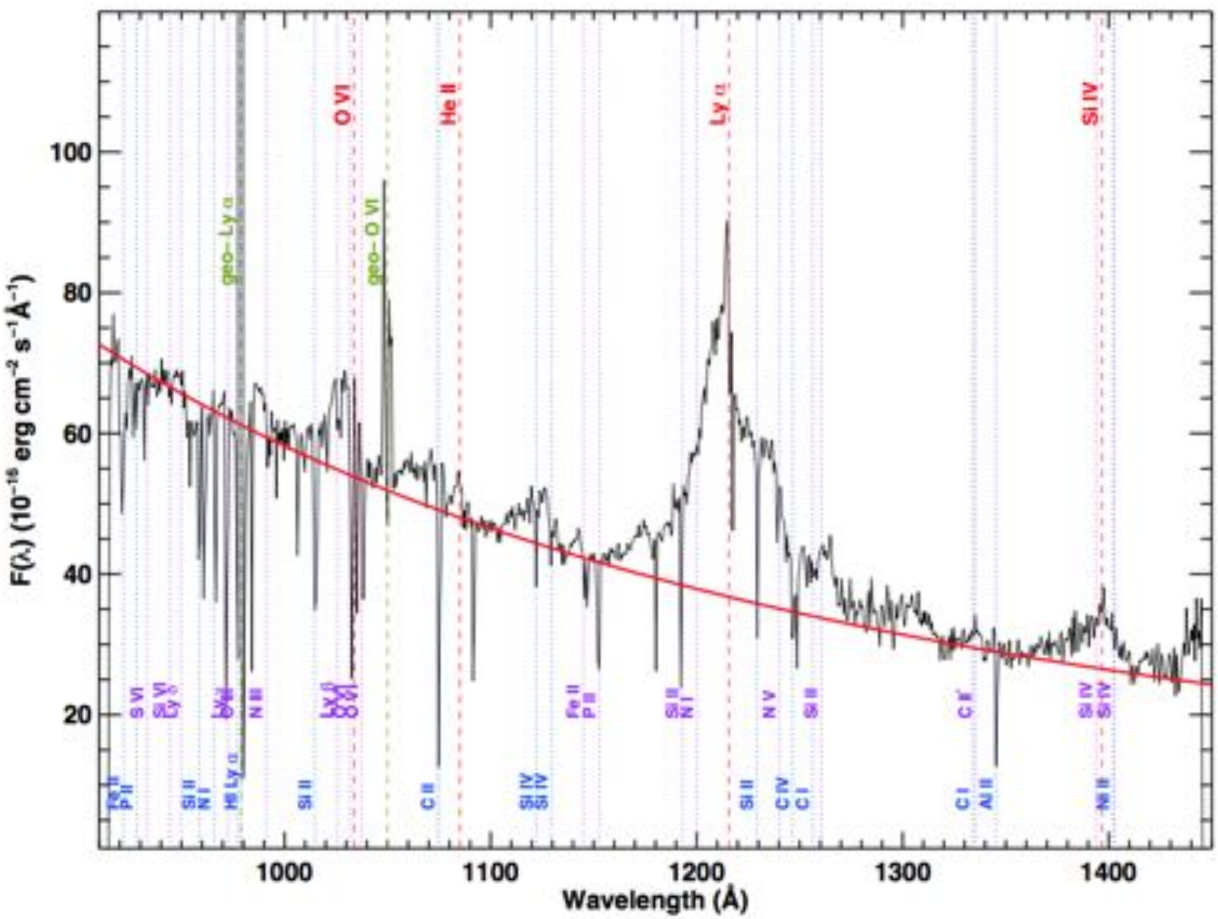
blue: PG 1244+026; gray: 1H 0707-495; red: RX J0439.6-5311

Outflows in BLR and NLR



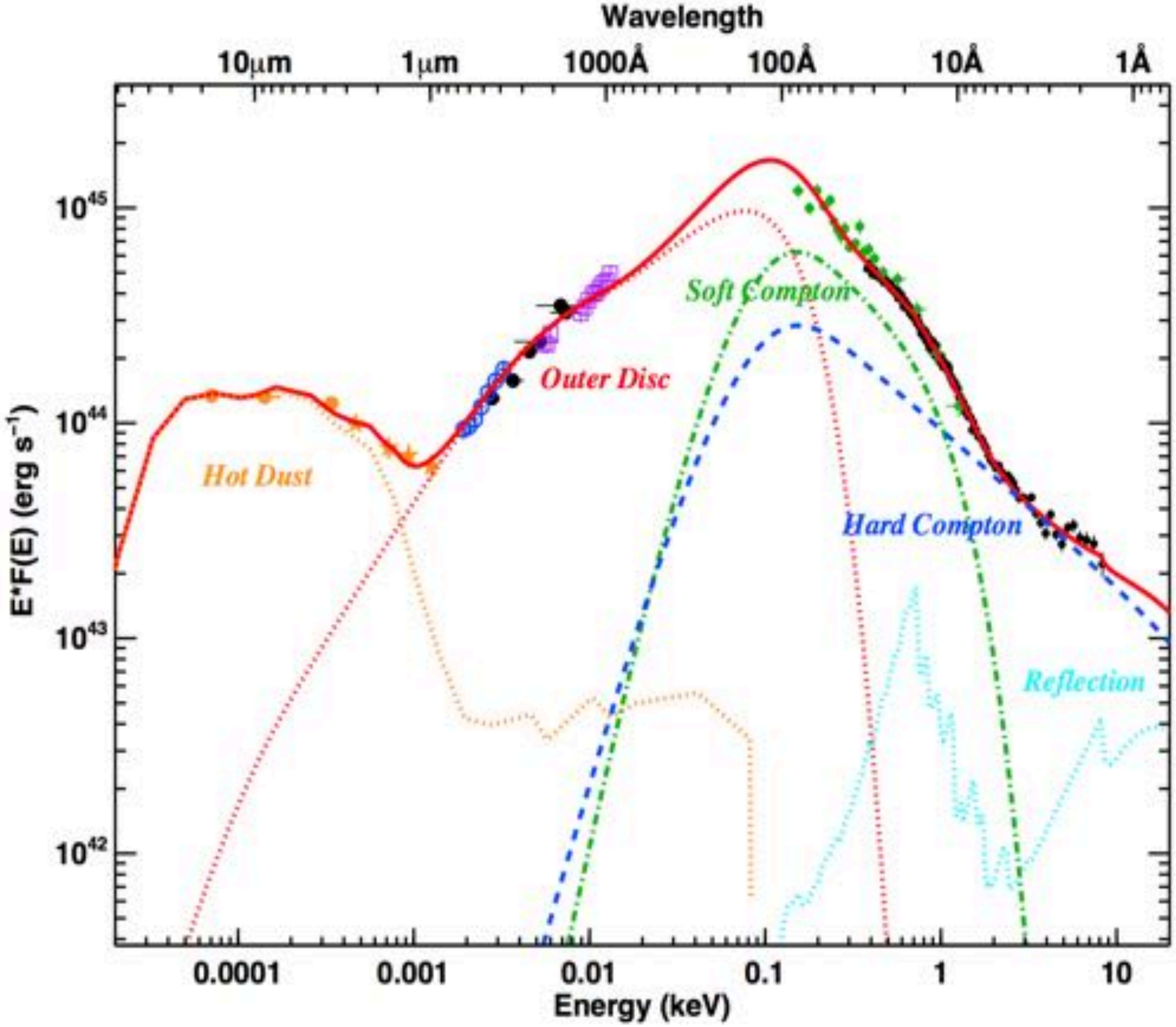
Component	Line-shift ($km\ s^{-1}$)	FWHM ($km\ s^{-1}$)	EW (Å)
	[O III]λ5007		
Gaussian-1	−290 ± 30	660 ± 80	2.0 ± 0.4
Gaussian-2	−860 ± 60	1940 ± 70	6.0 ± 0.4
total	–	1360 ± 180	8.0 ± 0.6
	Hβ		
Gaussian-1	150 ± 20	440 ± 60	2.8 ± 0.6
Gaussian-2	390 ± 110	1340 ± 140	5.2 ± 1.0
Gaussian-3	−860 ± 70	7580 ± 240	20.4 ± 0.5
NC	–	–	0.6 ± 0.3
total	–	850 ± 170	29.0 ± 1.3

Standard Geometrically Thin Outer Disc

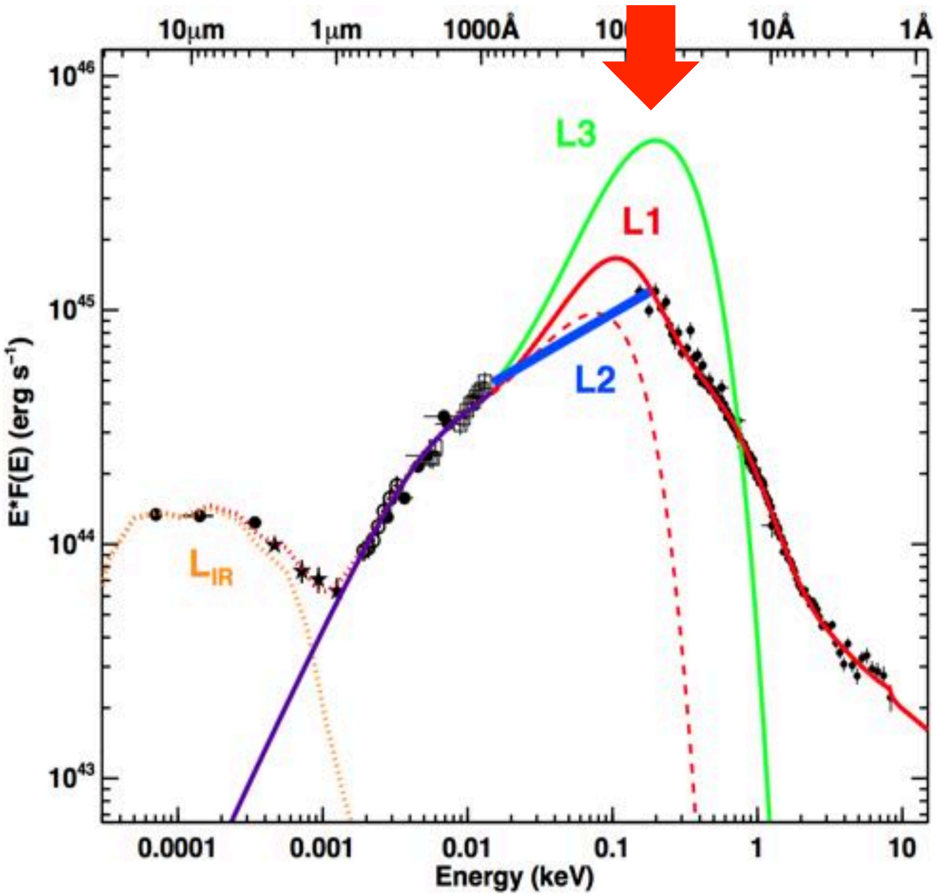


Standard accretion disc temperature profile down to 900 angstrom, or down to R ~ 190-380 Rg for $M=5\times10^{6}\sim10^{7}\ M_{\odot}$

Broadband SED of RX J0439.6-5311 – a robust super-Eddington NLS1



Broadband SED of RX J0439.6-5311 – a robust super-Eddington NLS1



$$F_{\rm opt} \propto \cos i\, (M\dot{M})^{2/3}$$

Davis & Laor (2011)

Table 3. Comparison of the mass accretion rate through the outer disc ($\dot{m}_{out}$) and the observed Eddington ratio (L_{bol}/L_{Edd}) for L_1 and L_2 in Fig. 7. We assume 30° inclination angle and zero spin. A higher spin or a larger inclination angle will further increase the $\dot{m}_{out}$ values (see DJ16).

BH Mass ($M_\odot$)	5×10^6	7×10^6	1×10^7	1.8×10^7
L_1/L_{Edd}	6.5	4.6	3.2	1.8
L_2/L_{Edd}	5.4	3.8	2.7	1.5
$\dot{m}_{out}$	23.8	12.1	5.9	1.8

$L_1 = 1.2\ L_2 = 0.4\ L_3 = 10.8\ L_{IR}$

A Global Picture of the super-Eddington Accretion Flow in RX J0439.6-5311

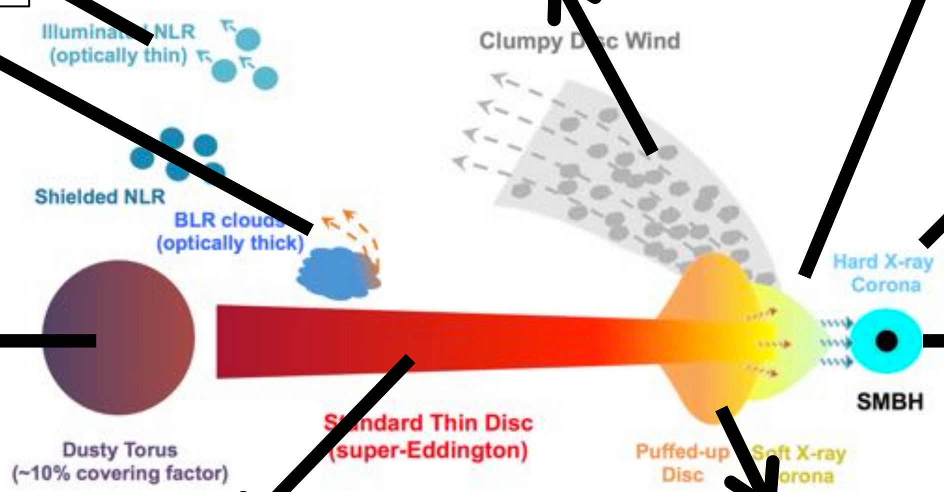
BLR and NLR Outflows:
Hβ and [O III]λ5007 line profiles

Clumpy Disc Wind:
Super-Edd mdot; outflow in NLR and BLR, Broadband SED – low radiative efficiency;

Extended Soft X-ray Corona:
X-ray Spectra, PSD, RMS/ Covariance/lag spectra

Compact Hard X-ray Corona:
X-ray Spec/Var.

Dusty Torus (10% covering factor):
Broadband SED in the IR



Black Hole Mass (10^6-10^7 $M_\odot$):
Optical-Spec, X-ray RMS

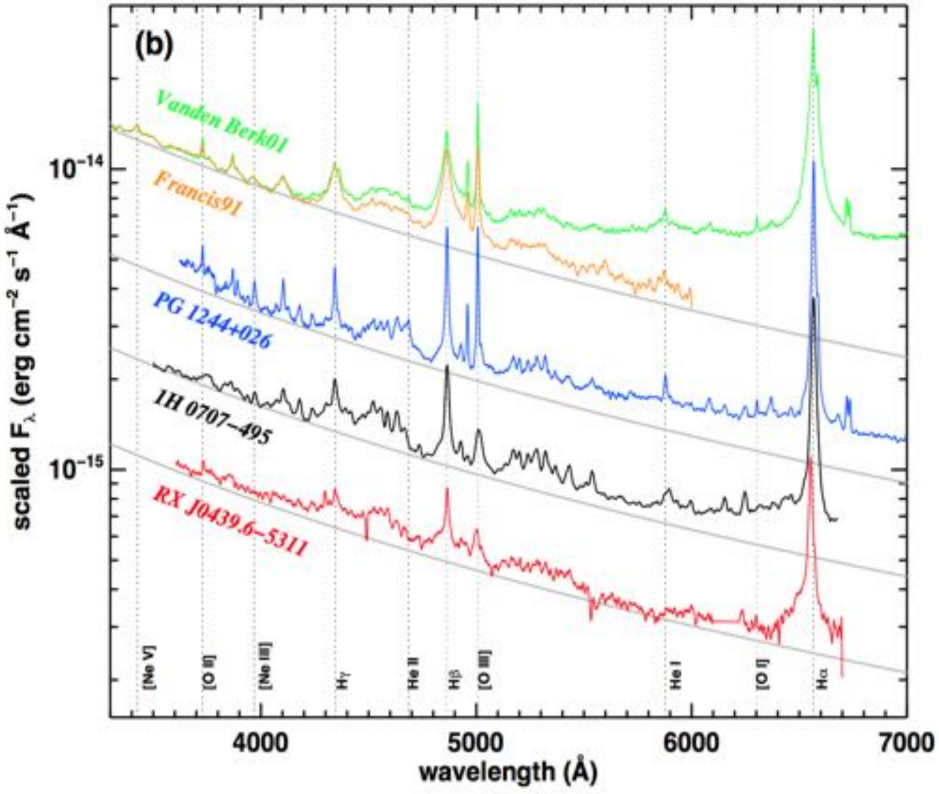
Standard Thin Outer Disc with super-Edd mdot:
UV/optical underlying Continua

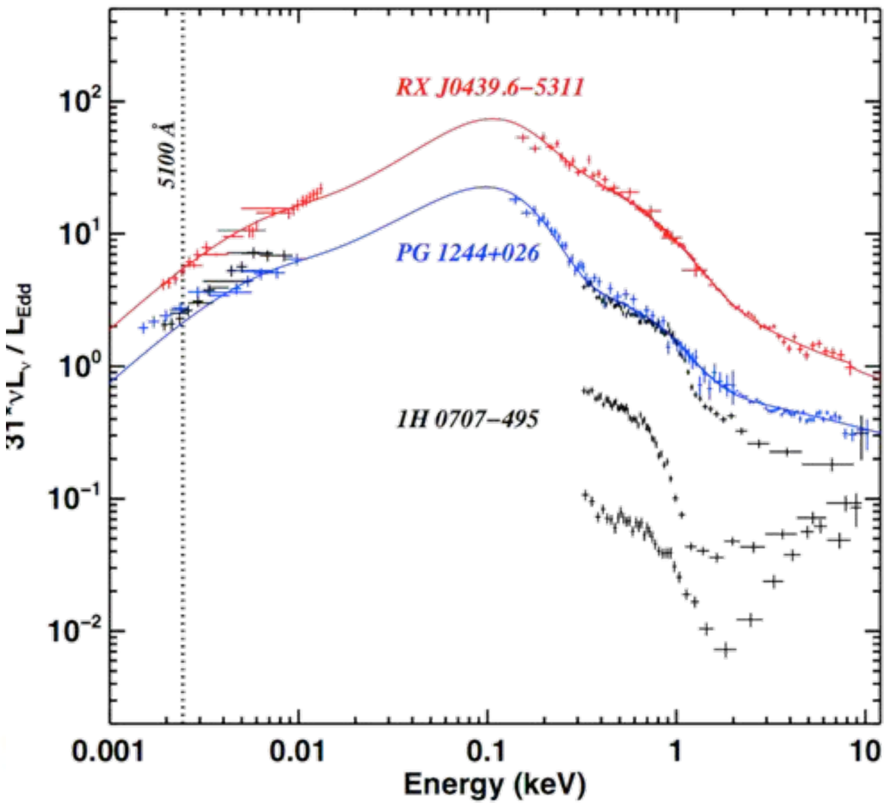
Puffed-up Inner Disc Region:
Super-Edd mdot; extended soft X-ray region vs. weak [O III] lines

Other ‘Simple’ *Super-Eddington* NLS1s:

- ✧ RE J1034+396 (e.g. Gierlinski et al. 2008; Middleton et al. 2009; 2011)
  first AGN QPO detection
- ✧ RX J0136.9-3510 (e.g. Grupe et al. 2004; Jin et al. 2009)
  Eddington Ratio ~13!
- ✧ PG 1244+026 (e.g. Jin et al. 2013; Kara et al. 2014; Alston et al. 2014)
  similar mass and mass accretion rate to 1H 0707-495, but with totally different X-ray spectral-variability (Done & Jin 2016)
- ✧ RX J1140.1+0307 (e.g. Miniutti et al. 2009; Ai et al. 2011; Jin et al. 2016)
  a super-Eddington IMBH, $M \sim 10^5\ M_\odot$
- ✧ RX J0439.6-5311 (e.g. Jin et al. 2017a, b)
  the so-far most extreme and robust super-Edd simple NLS1
- ✧ Others: Ton S180, Mrk 493, RBS 769, Mrk 142, etc.
  similar X-ray spectra and broadband SED

Broadband Comparison between ‘simple’ and ‘complex’ super-Eddington NLS1s



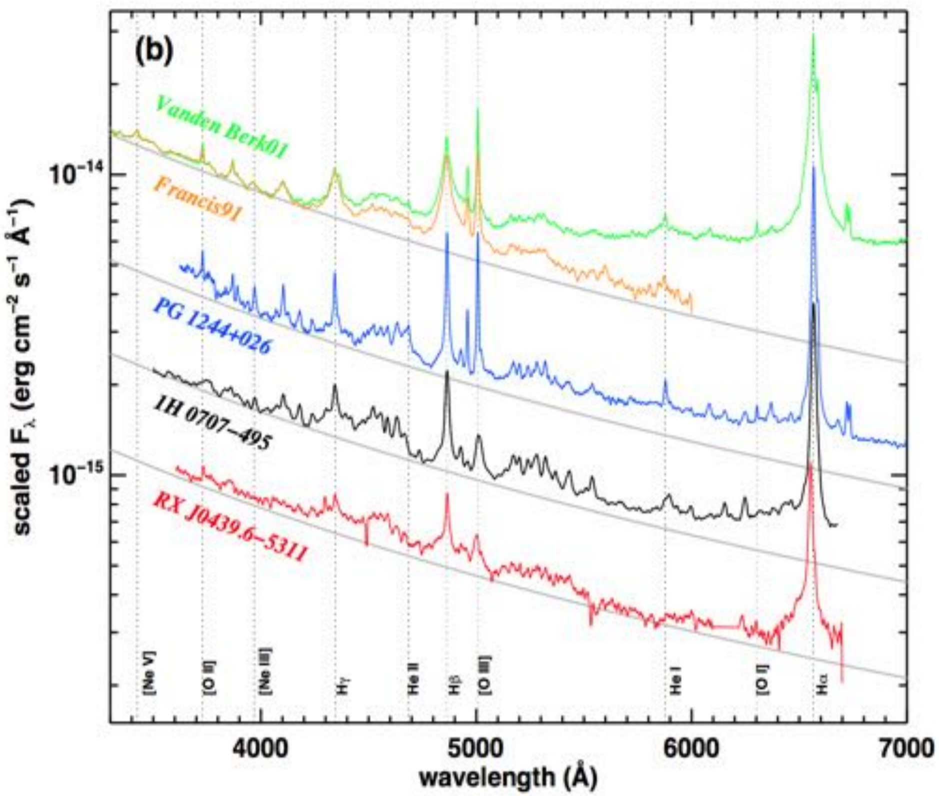


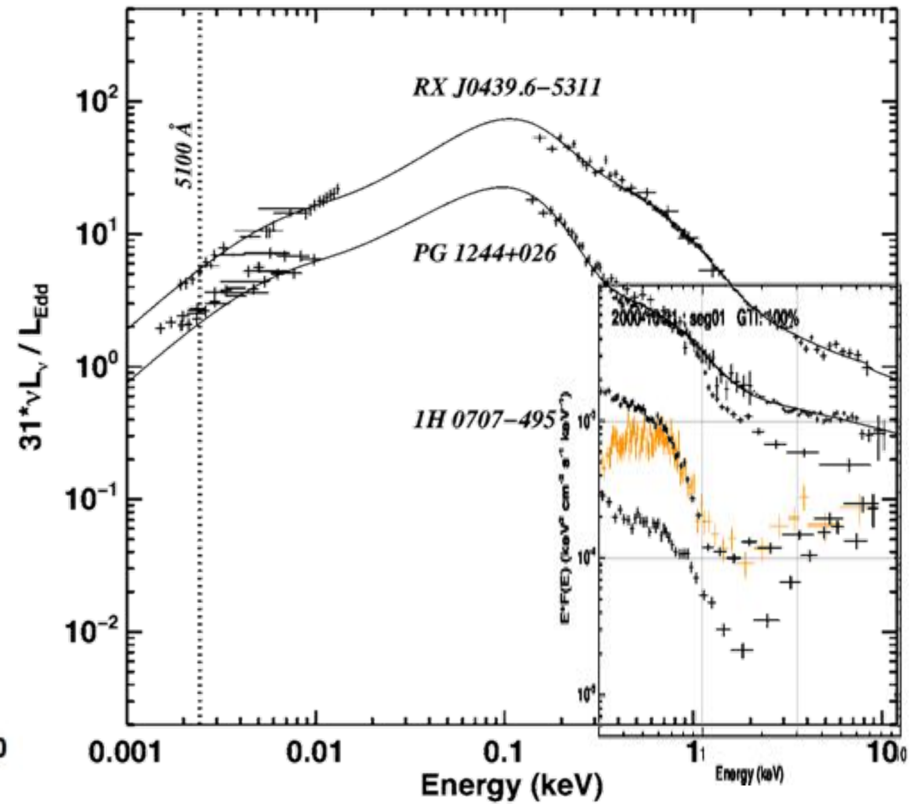
Broadband Comparison between ‘simple’ and ‘complex’ super-Eddington NLS1s

Similar black hole mass, mass accretion rate;

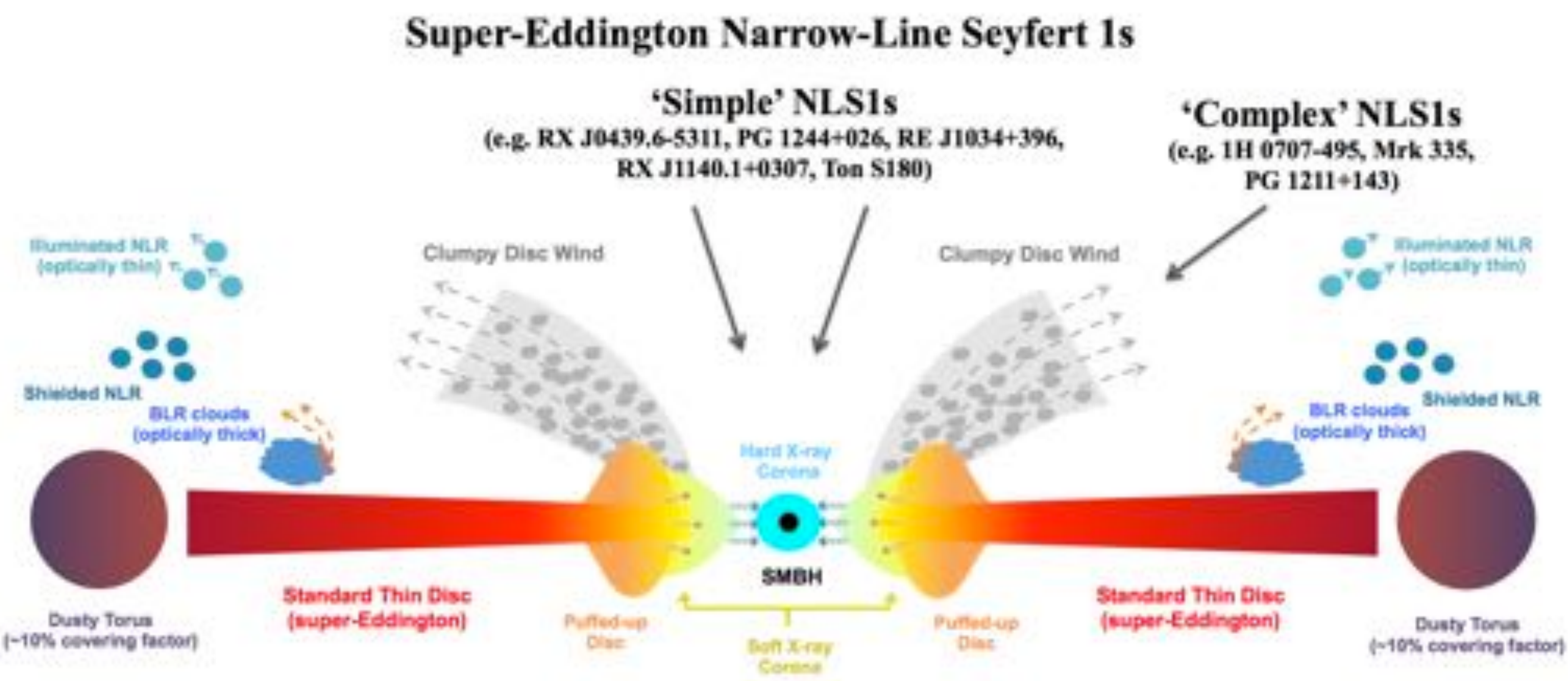
Similar optical/UV continuum and line emission;

but totally different X-ray spectral variability?! (viewing angle effect)





A Unified Picture for *All Super-Eddington* NLS1s

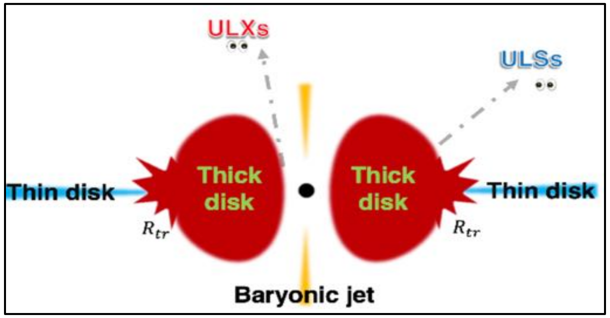


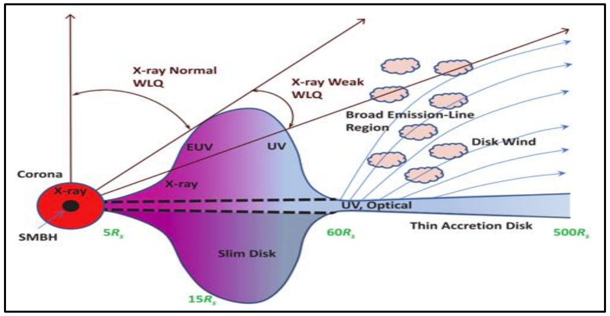
(Jin et al., 2017b, submitted)

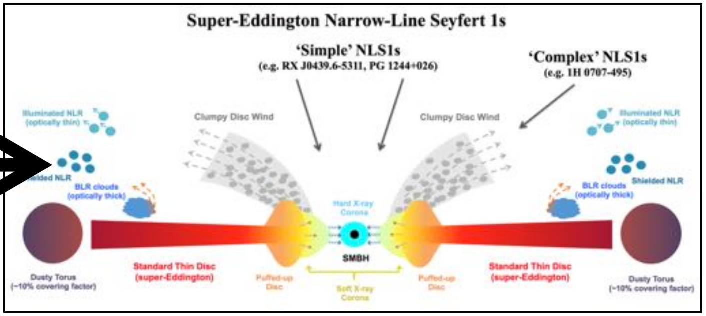
Similar Accretion Flow Geometry and viewing angle effect for ULX, NLS1, WLQs

Super-Eddington Accretion

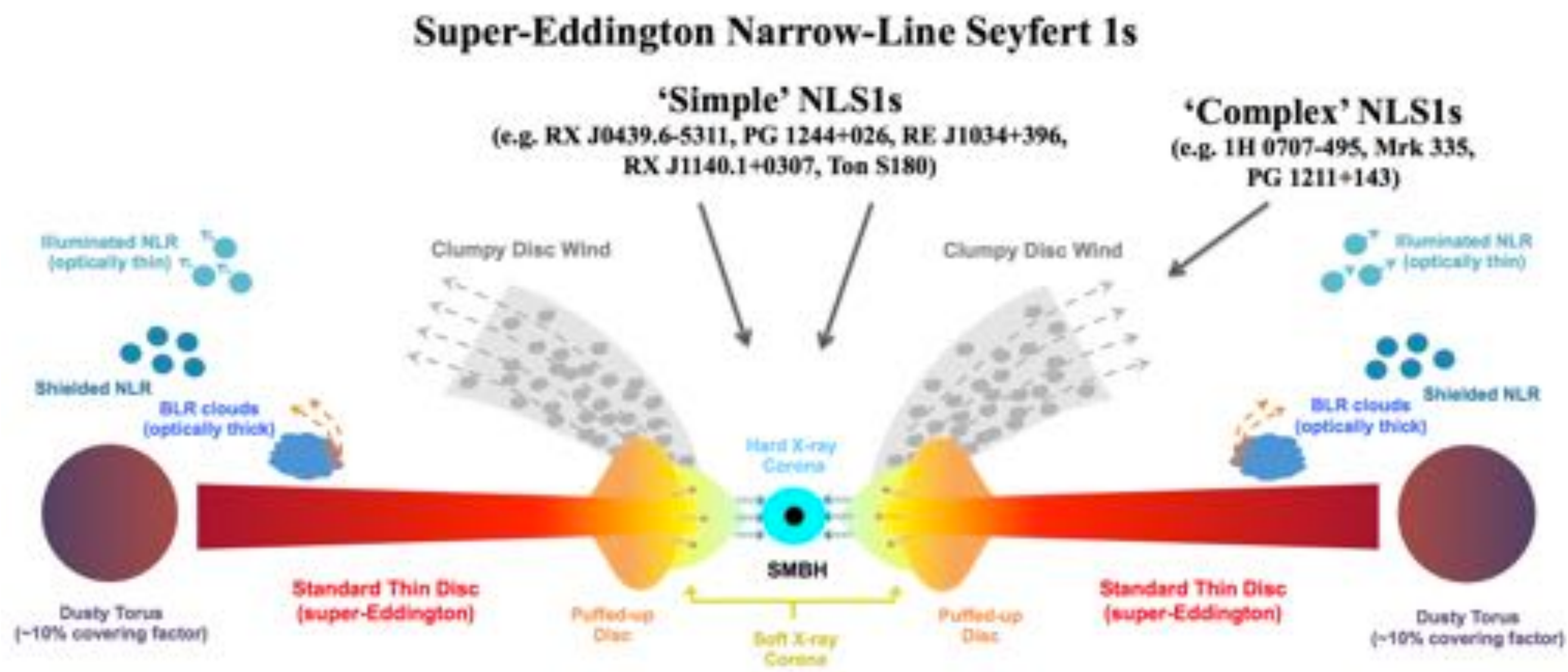
- Thin outer disc, puffed-up inner disc, disc wind
- Viewing angle effect relative to the puffed-up disc region and/or disc wind
- ULX vs. ULS (e.g. Gu et al. 2016)
- WLQ: X-ray normal vs X-ray weak (e.g. Luo et al. 2015)
- Super-Eddington NLS1: X-ray ‘simple’ vs ‘complex’, low-redshift analogs of WLQs (Jin et al. 2017b)







Conclusions:



- X-ray spectral-timing study and simultaneous multi-wavelength study are crucial to improve our understanding of these extreme accretion flows in SMBH:
- **Use deep XMM-Newton observations. Use OM.**

Thank you!

please contact C. Jin at chichuan@mpe.mpg.de