The X-ray continuum and soft excess emitting region sizes from occultation events

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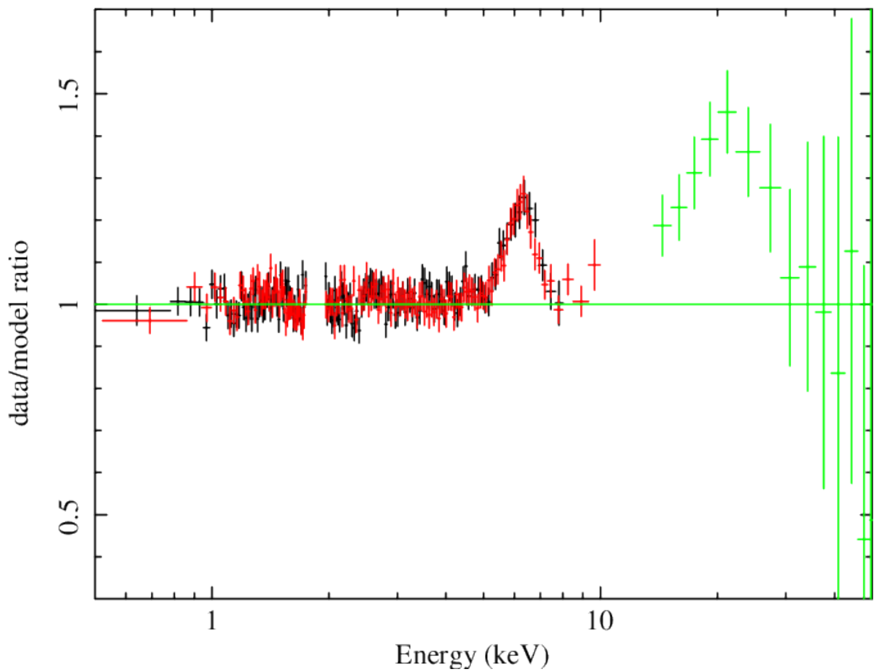
with special thanks to Beatriz Agís and Mario Sanfrutos

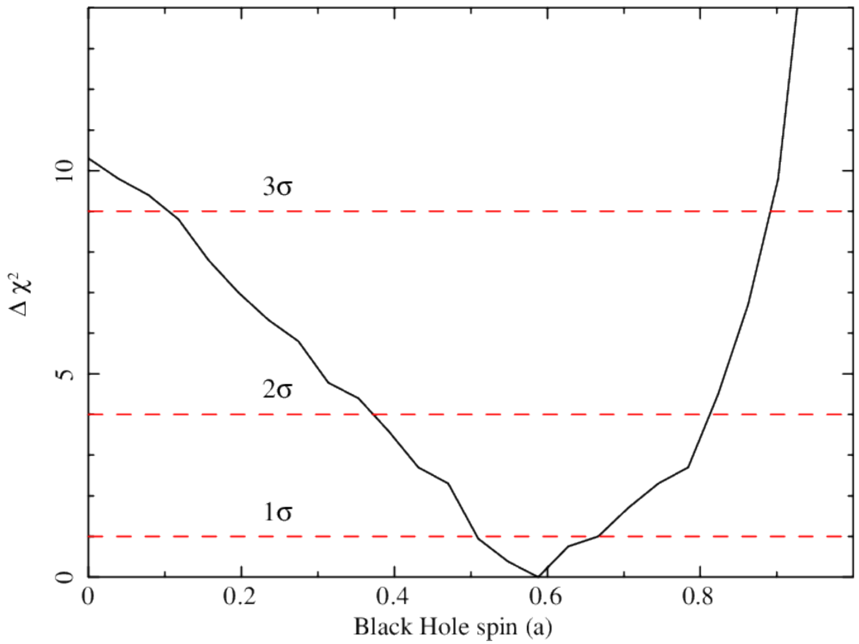
The X-ray Universe 2014 - Dublin

Source #1: SWIFT J2127.4 (Sanfrutos et al. 2013)

Narrow Line Seyfert 1 → Suzaku reveals a broad Fe K line (Miniutti et al. 2009) and an intermediate BH spin (a≈0.6)

This result was then confirmed with XMM+NuSTAR (see Marinucci's talk tomorrow)





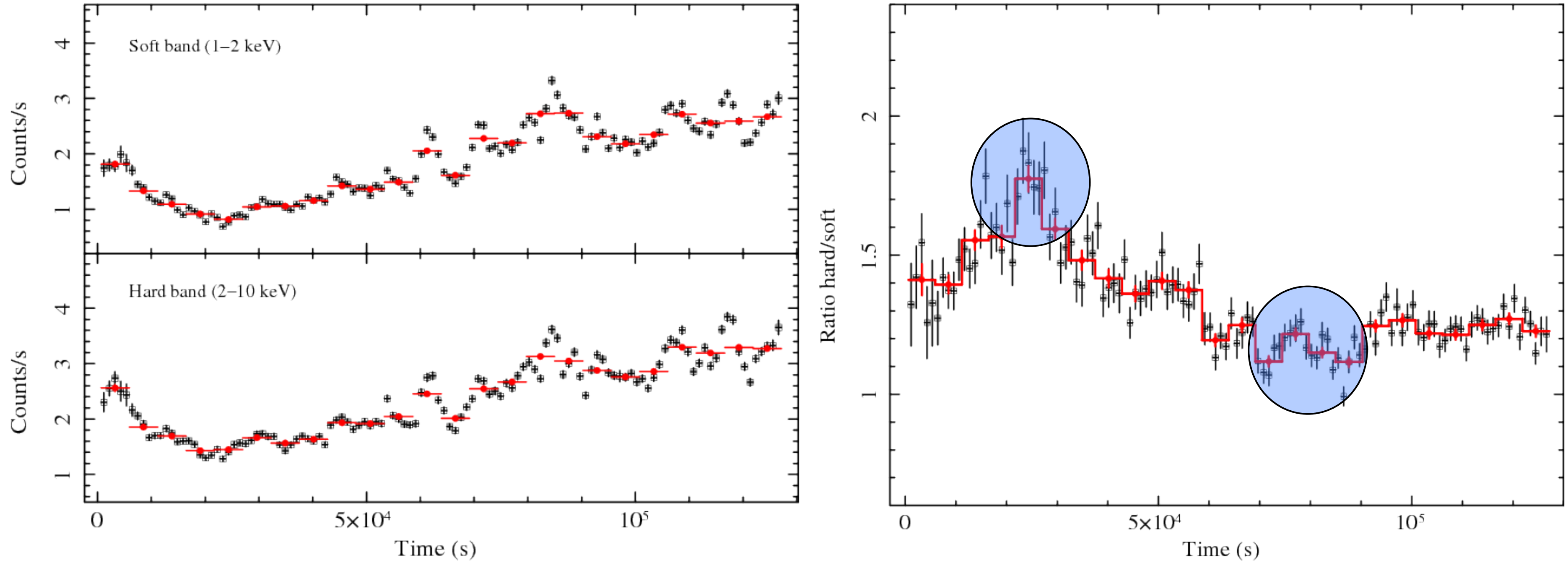
The Suzaku analysis also suggests a relatively high inclination (from the broad Fe line) of 45°

→ our LOS may intercept some obscuring gas (outlflows/BLR/torus)

Source #1: SWIFT J2127.4 (Sanfrutos et al. 2013)

We then re-observed the source with XMM

→ investigating in some more detail any short timescale spectral variability



The hard-to-soft ratio (HS) light curve suggests the presence of an event during the first half of the obs

To investigate its nature, we accumulate two spectra during the high and low HS intervals

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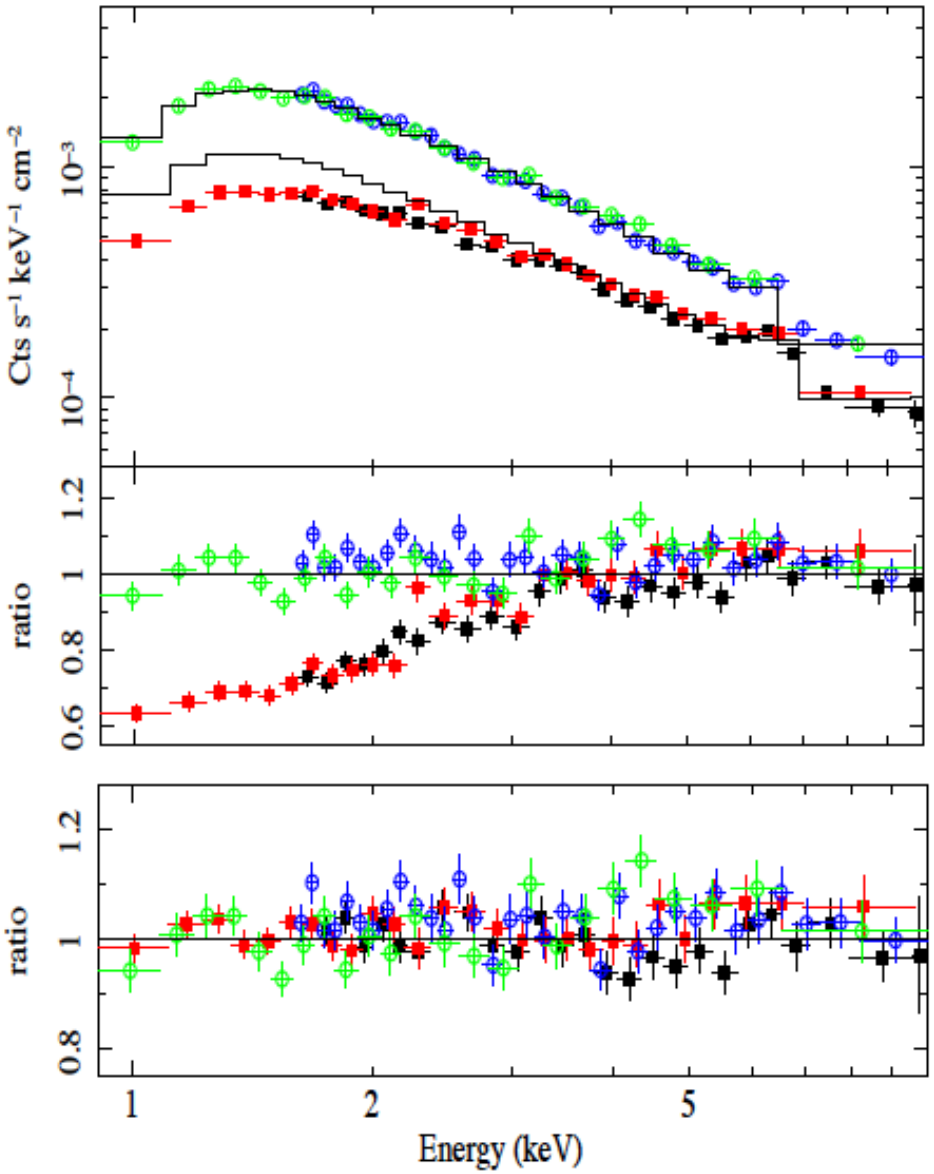

Clear signs of extra absorption are seen (both PN and MOS) during the high HS Interval

→ Likely occultation event

Spectral analysis indicates a layer of absorbing gas with $N_H \approx 2\times10^{22}$ cm^{-2} with variable covering fraction

→ $C_f \approx$ 30-40% in the high HS state

$C_f \approx$ 0 % in the low HS state

We then consider a fully time-resolved spectral analysis (24 intervals of about 5 ks each) to track the variable absorber

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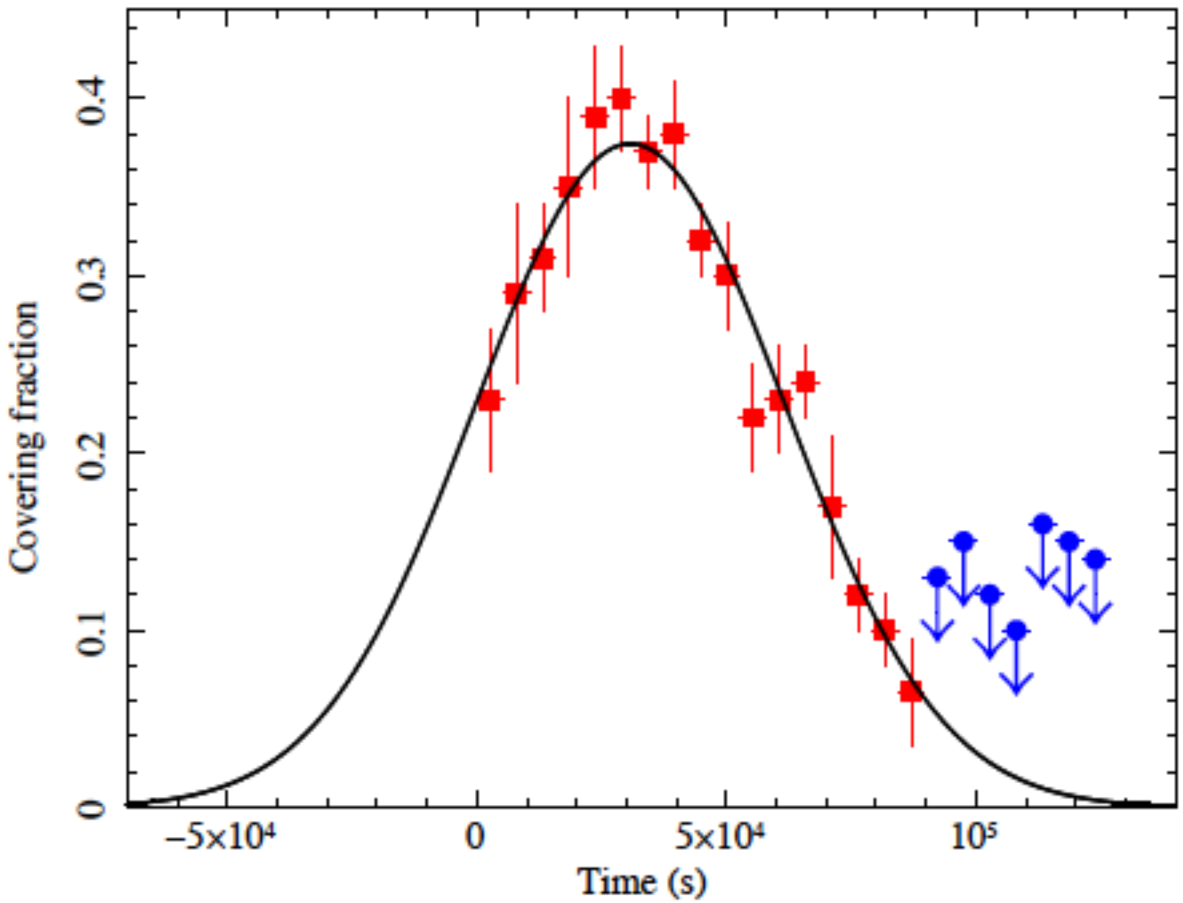

The C_f evolution is smooth and clearly demonstrates the passage of a discrete cloud into our LOS to the X-ray emitting region

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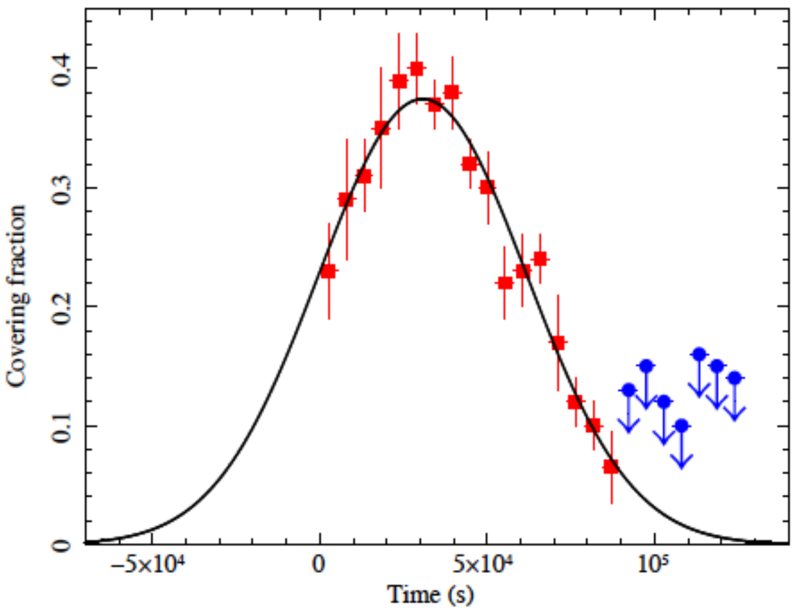
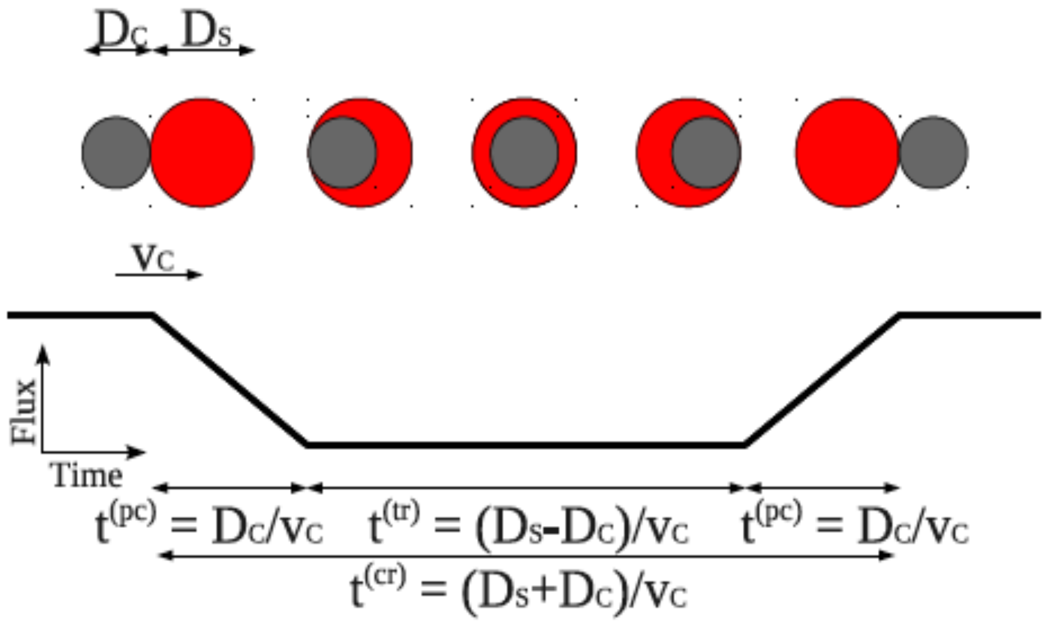




RESULTS

→ Cloud number density $n_c \geq 1.5 \times 10^9$ cm^{-3}

→ Cloud size (diameter) $D_c \leq 1.5 \times 10^{13}$ cm

→ Cloud distance $R_c \geq 4.3 \times 10^{16}$ cm

→ Cloud velocity $v_c \approx 2100$ km/s

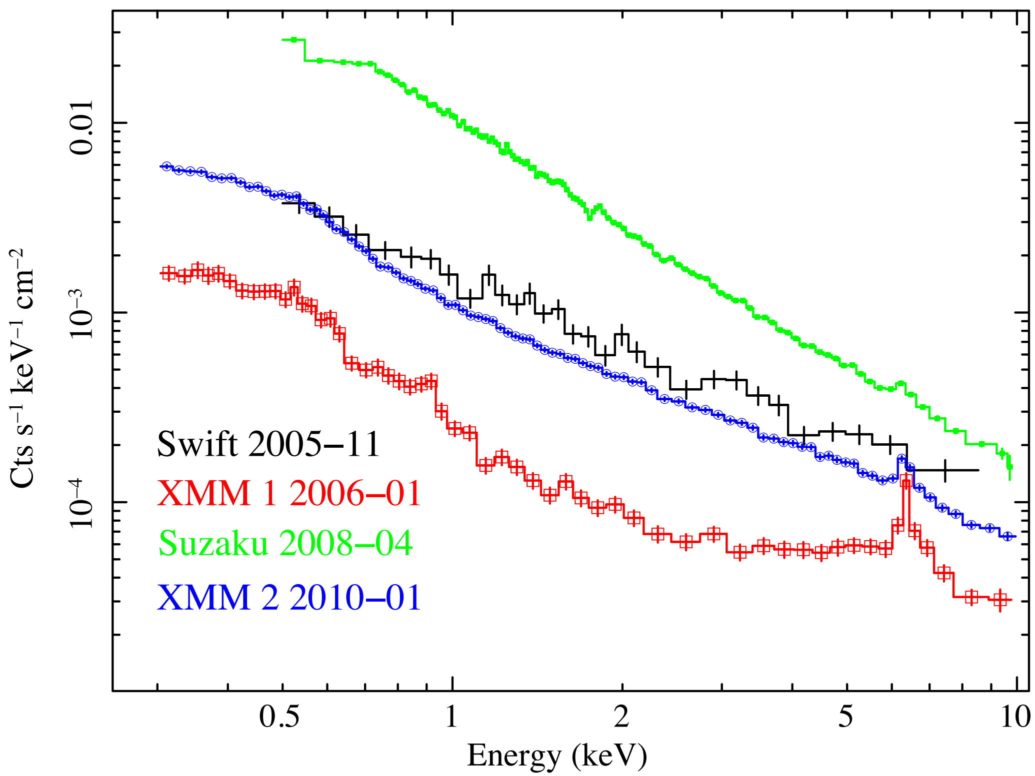
BLR cloud

Then, since the maximum C_f is about 40 % we have that

→ X-ray source size (diameter) is $D_s \leq 2.3 \times 10^{13}$ cm $\approx 10.5\ R_g$ (single-epoch BH mass)

Source #2: ESO 362-G18 (Agís et al. MNRAS submitted & Miniutti et al. 2014, almost there)
[already presented by Beatriz Agís in her talk on Monday]

Seyfert 1.5 galaxy with huge spectral variability on months/years timescales



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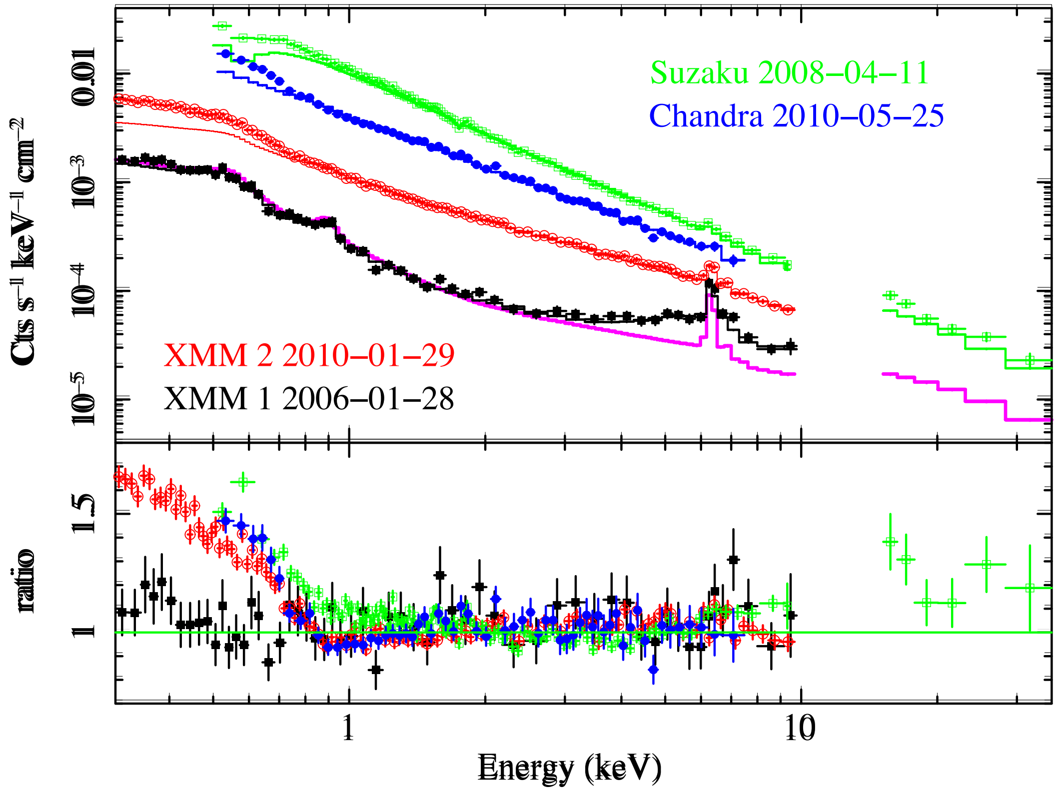


All unabsorbed observation exhibit a strong SOFT EXCESS while the absorbed XMM1 observation does not

→ The soft excess is also absorbed

→ We may have a chance of deriving the size of the soft excess emitting region

Source #2: ESO 362-G18 (Agís et al. MNRAS submitted & Miniutti et al. 2014, almost there)

As discussed by Beatriz Agís in her talk, the variability of the absorber between a Swift and a XMM observation separated by two months allows us to place an upper limit on the size of BOTH the X-ray corona and soft excess emitting region, namely

$D_s \leq 96\ R_g$

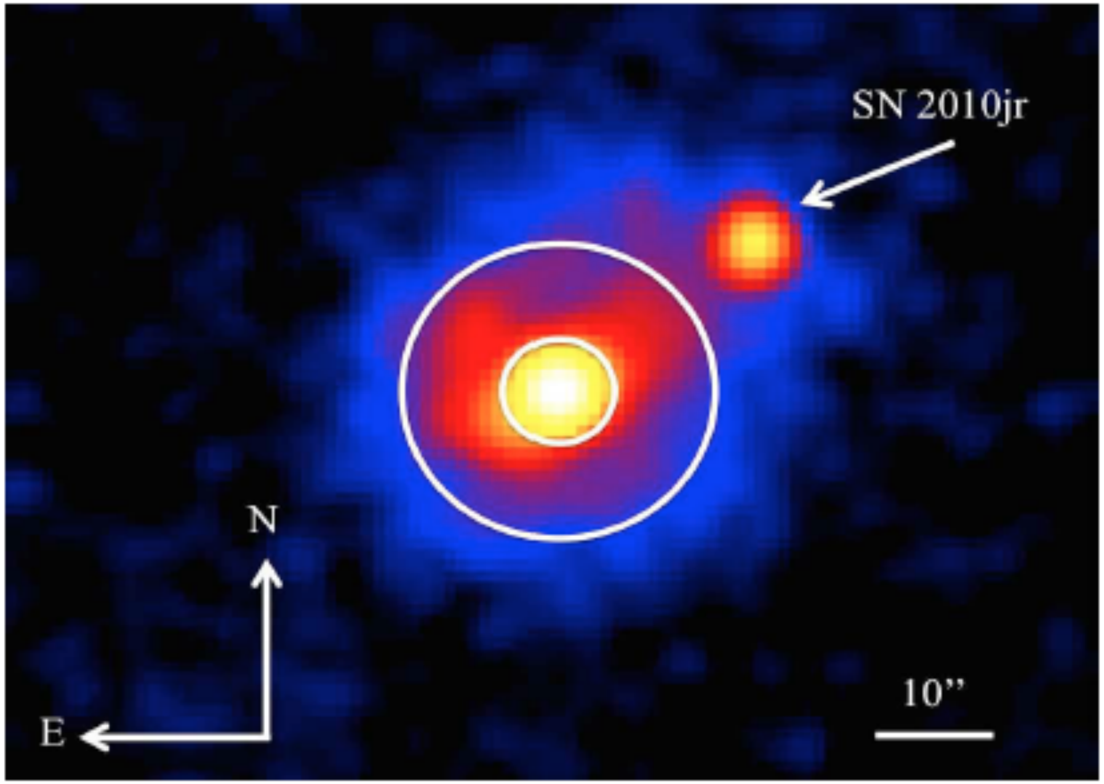
In order to refine this limit, we would need to track an occultation event as we did in SWIFT J2127.4

no short timescale event was seen during any of the obs

→ consistent with the fact that we identified the variable absorber with the dusty clumpy torus (long timescales + UV correlated variability/reddening)

However, something happened on 2010 November the 11th in this galaxy …

Source #2: ESO 362-G18 (Agís et al. MNRAS submitted & Miniutti et al. 2014, almost there)



… and Swift followed up the SN evolution with UVOT (and XRT) with 36 short observations (1-2 ks) over the following 2.5 months

Source #2: ESO 362-G18 (Agís et al. MNRAS submitted & Miniutti et al. 2014, almost there)

The quality of the individual observations is low, so to see whether further absorption variability events took place during the Swift monitoring, we consider appropriate hardness ratios

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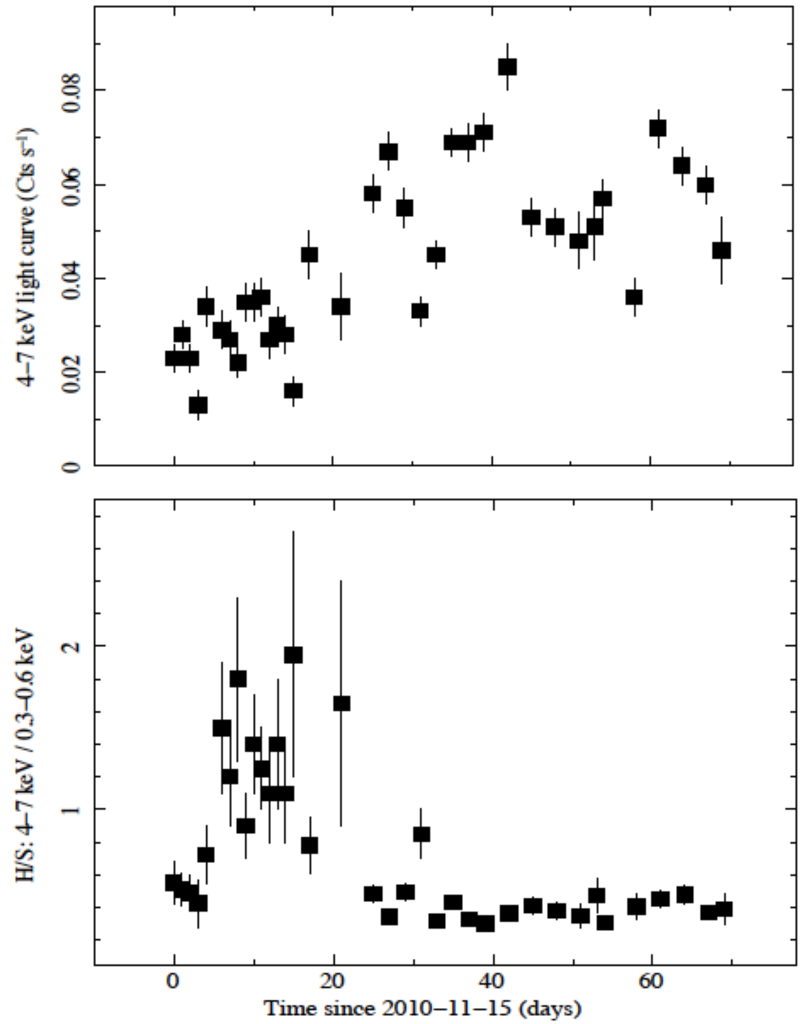

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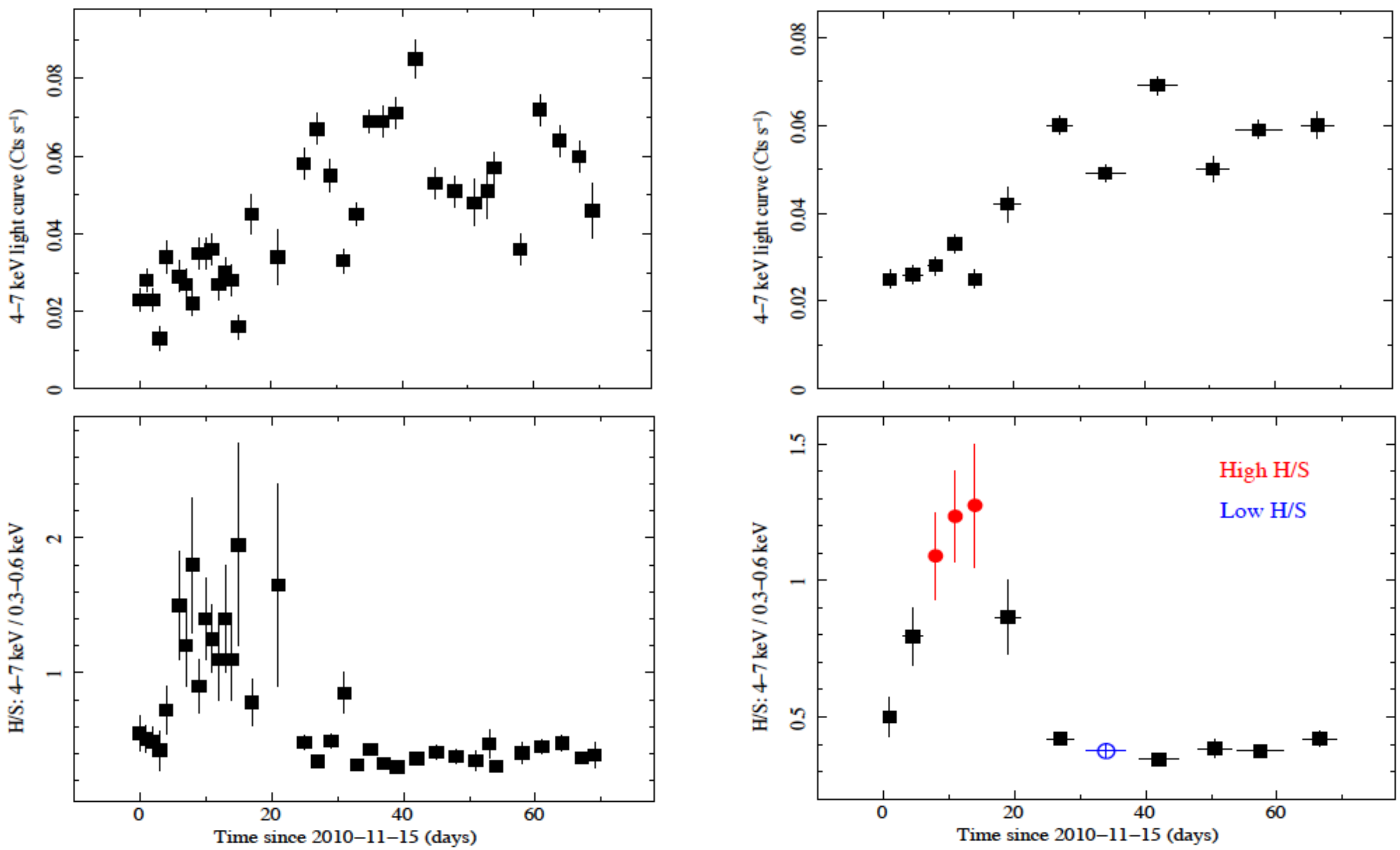
We then combine each three consecutive Swift obs to reduce error bars



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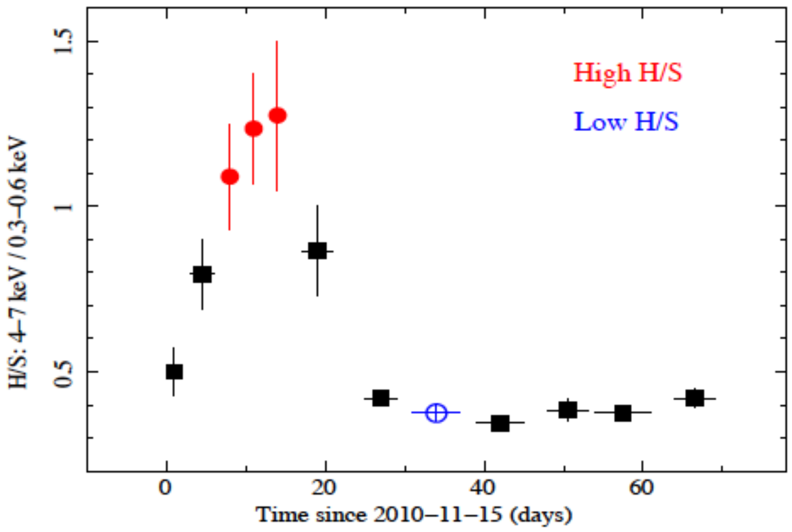
Having combined three Swift obs, the data quality is now also sufficient to perform spectral analysis



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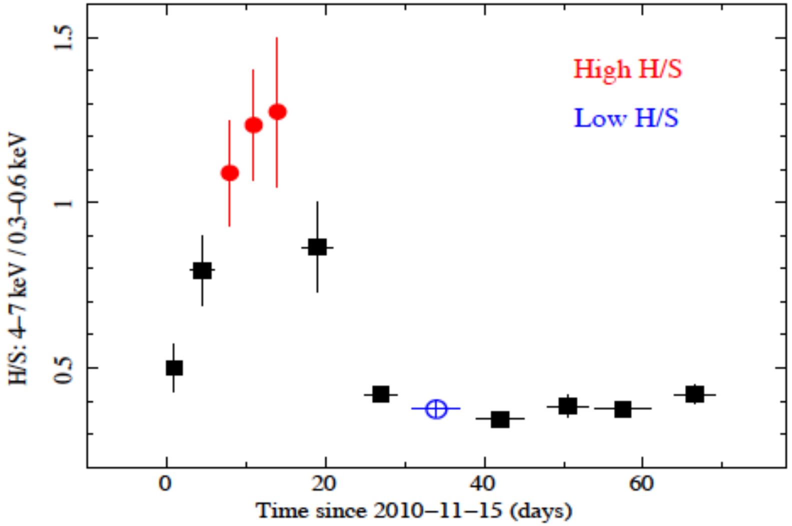

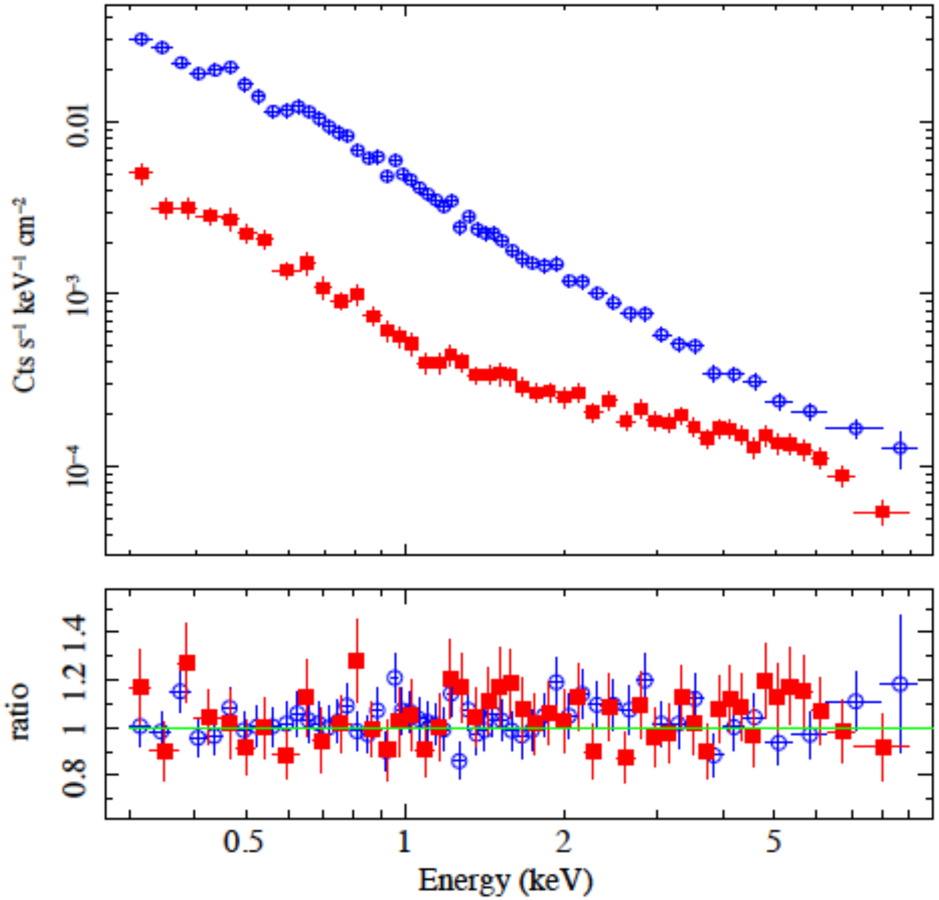

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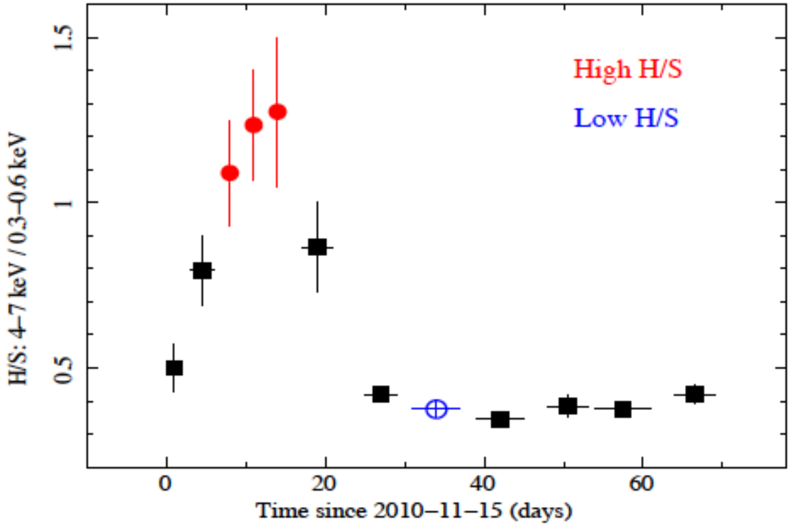
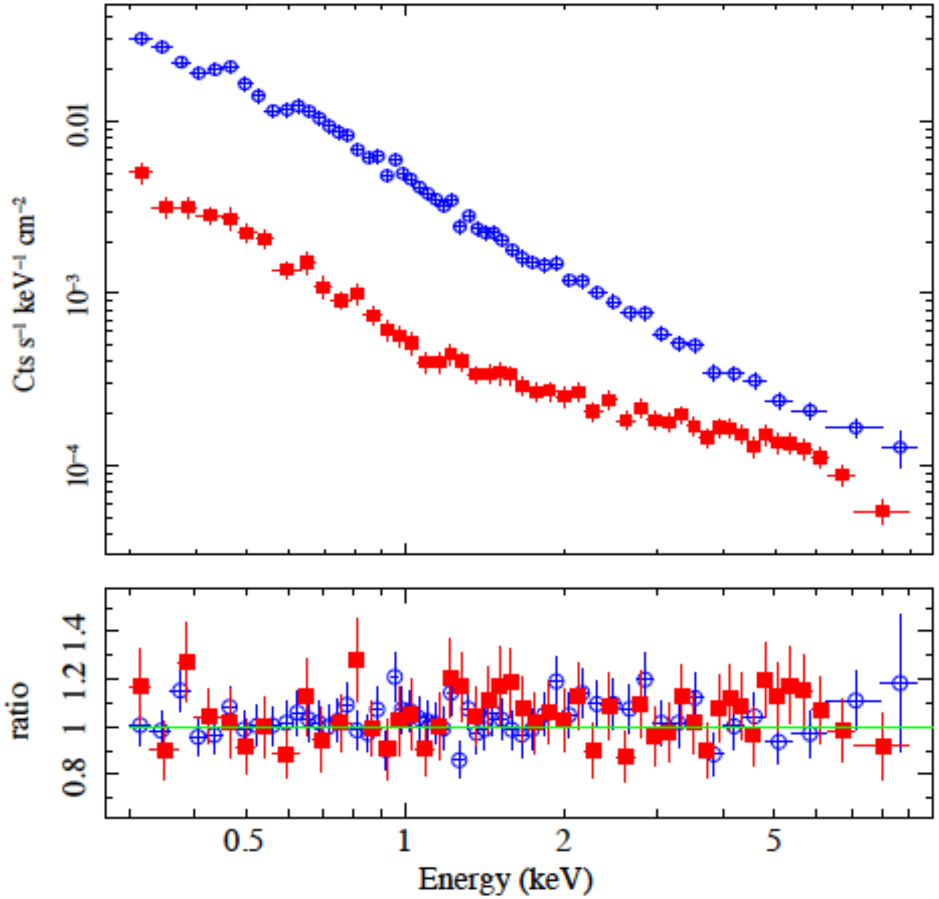


Parameter	High H/S	Low H/S
Γ	1.9 ± 0.1	2.03 ± 0.06
$L^{\rm PL}_{2-10}$	1.7 ± 0.0	3.2 ± 0.0
$\xi_{\rm ref}$	$\leqslant 30$	$\leqslant 35$
$L^{\rm ref}_{2-10}$	0.9 ± 0.0	1.7 ± 0.0
$N_{\rm H}$	5 ± 2	–
$\log \xi$	1.0 ± 0.3	–
$C_{\rm f}$	0.84 ± 0.6	$\leqslant 0.09$
$\chi^2/{\rm dof} = 376/341$		



Source #2: ESO 362-G18 (Agís et al. MNRAS submitted & Miniutti et al. 2014, almost there)

1) C_f evolution by absorbing both the power law and the disc-reflection (soft excess)

2) C_f evolution for the power law (black) and the disc-reflection component (red) allowed to have different C_f (i.e. different size)

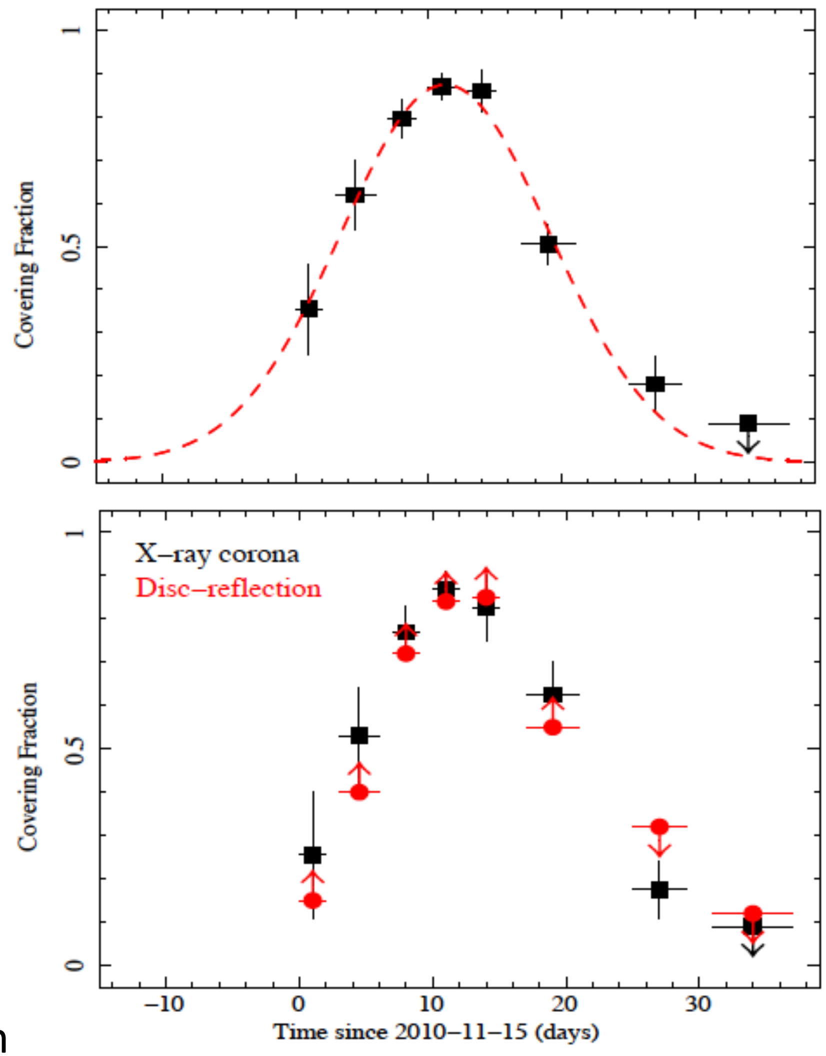
→ The X-ray corona and the disc-reflection emitting regions are consistent with having the same geometrical size

BUT

As the C_f of the disc-reflection emitting region could be higher than that of the continuum

$D_{reflection} \leq D_{corona}$

The question is now to estimate this size from Within which BOTH components must come from



Source #2: ESO 362-G18 (Agís et al. MNRAS submitted & Miniutti et al. 2014, almost there)

By using the same methods applied to SWIFT J2127.4, we have that

RESULTS

→ Cloud number density $n_c \geq 1.1\text{-}2.5 \times 10^8$ cm^{-3}
→ Cloud size (diameter) $D_c \leq 1\text{-}3 \times 10^{14}$ cm
→ Cloud distance $R_c \geq 0.2\text{-}2 \times 10^{18}$ cm
→ Cloud velocity $v_c \leq 500\text{-}1200$ km/s

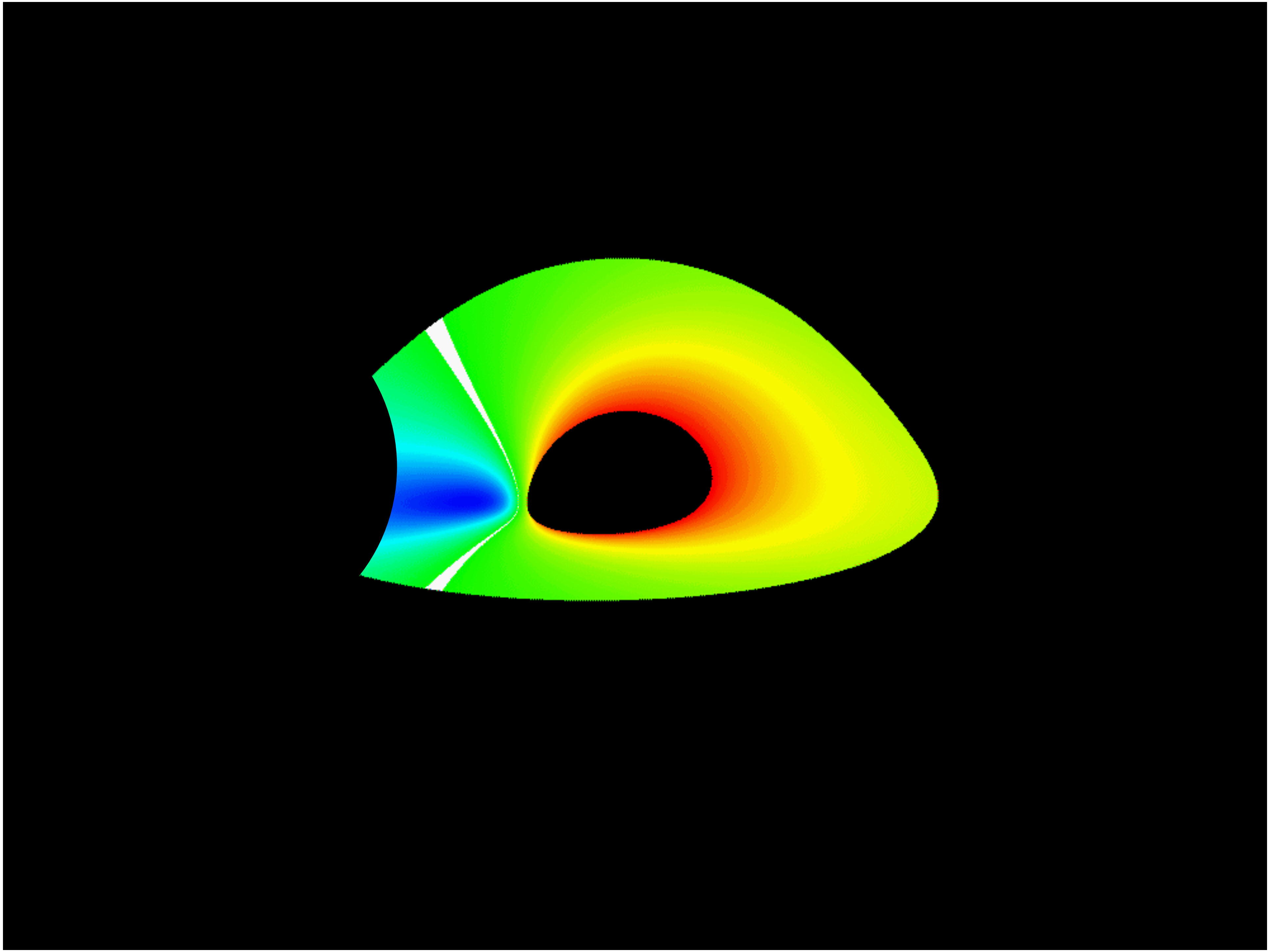
CLUMPY TORUS cloud
(as in previous 2-months event by Agís et al.)

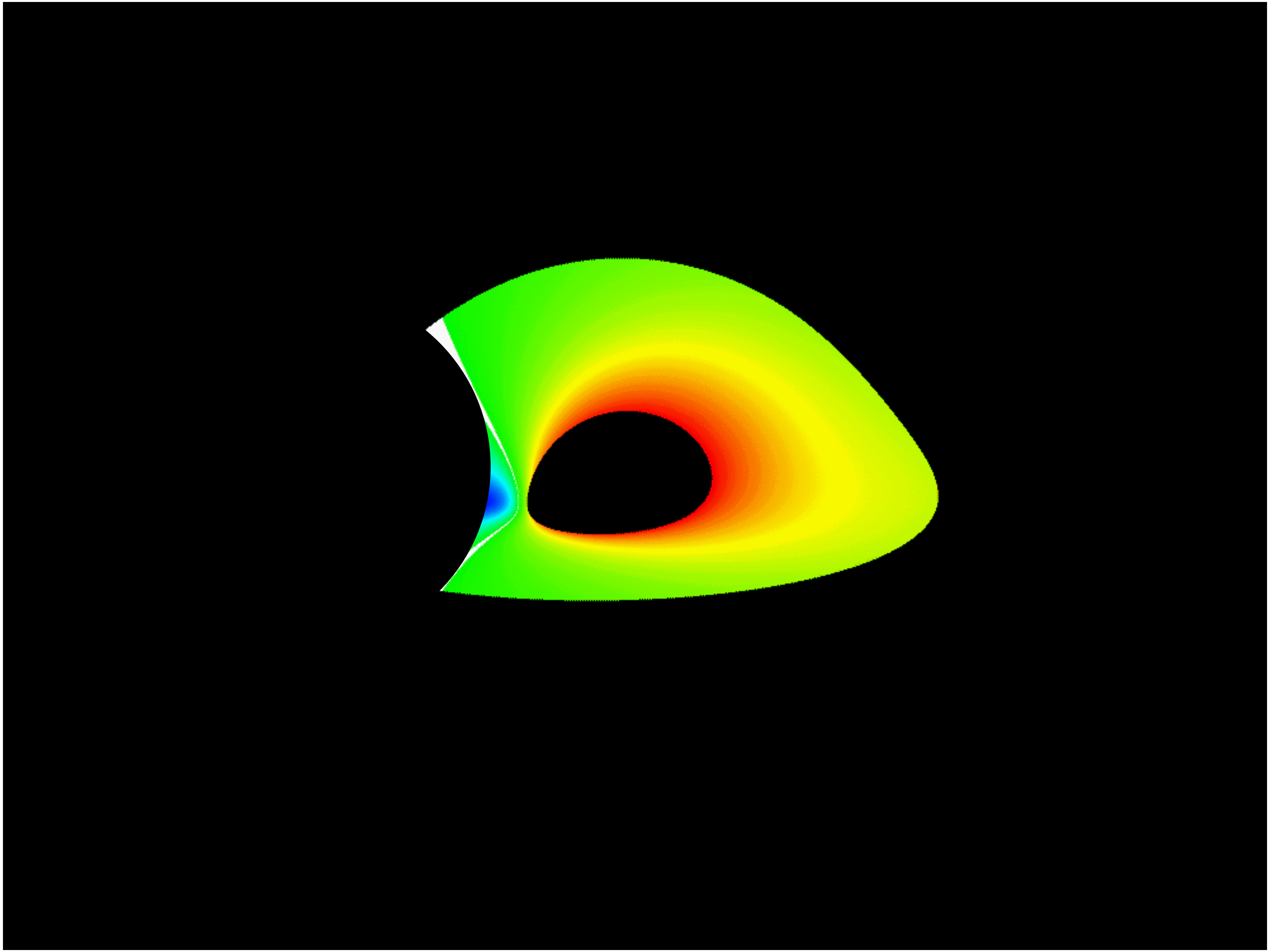
Then, since the cloud maximum C_f is about 80 % we have that

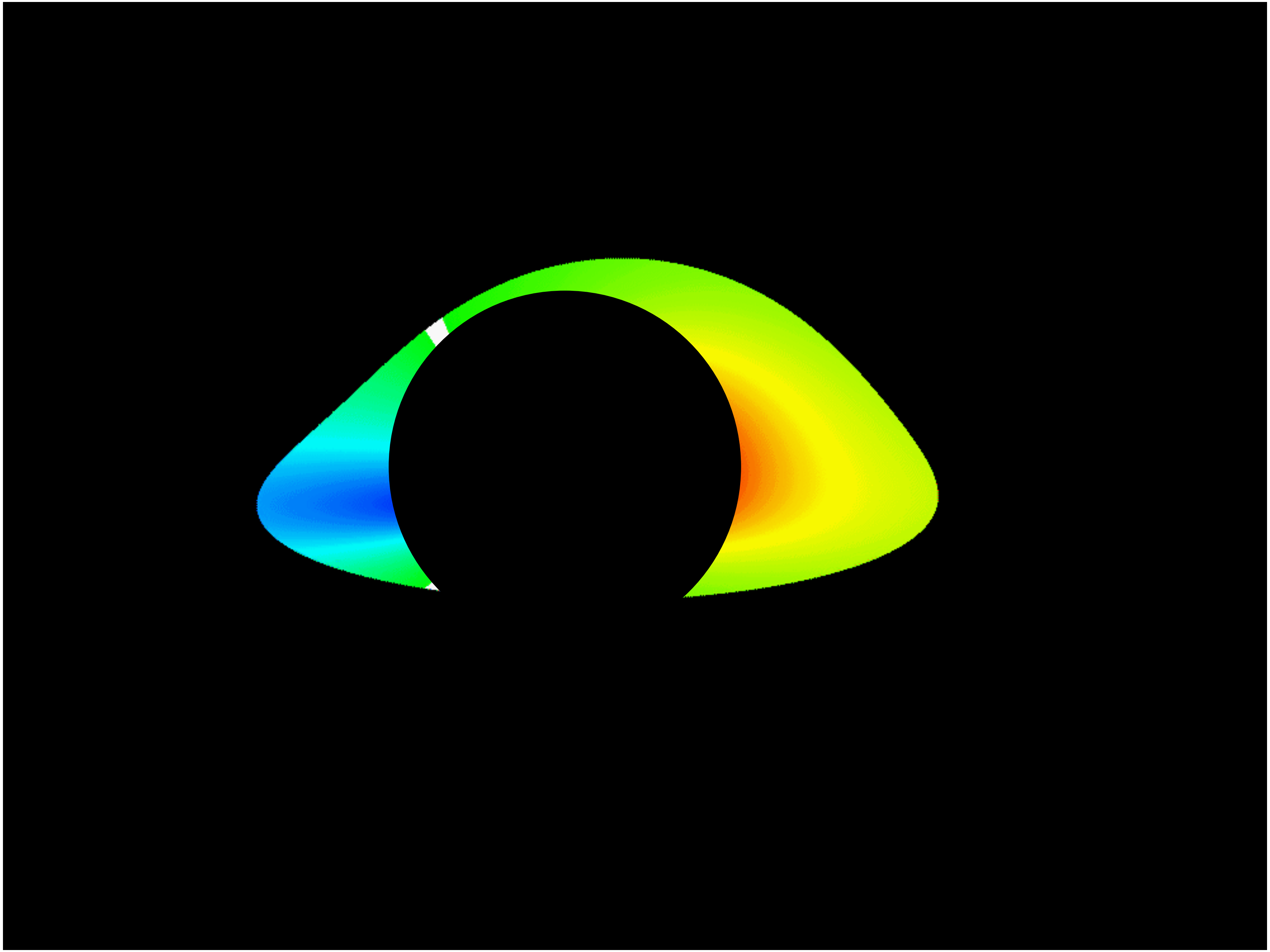
→ X-ray source size (diameter) is $D_s \approx 20\text{-}50\ R_g$

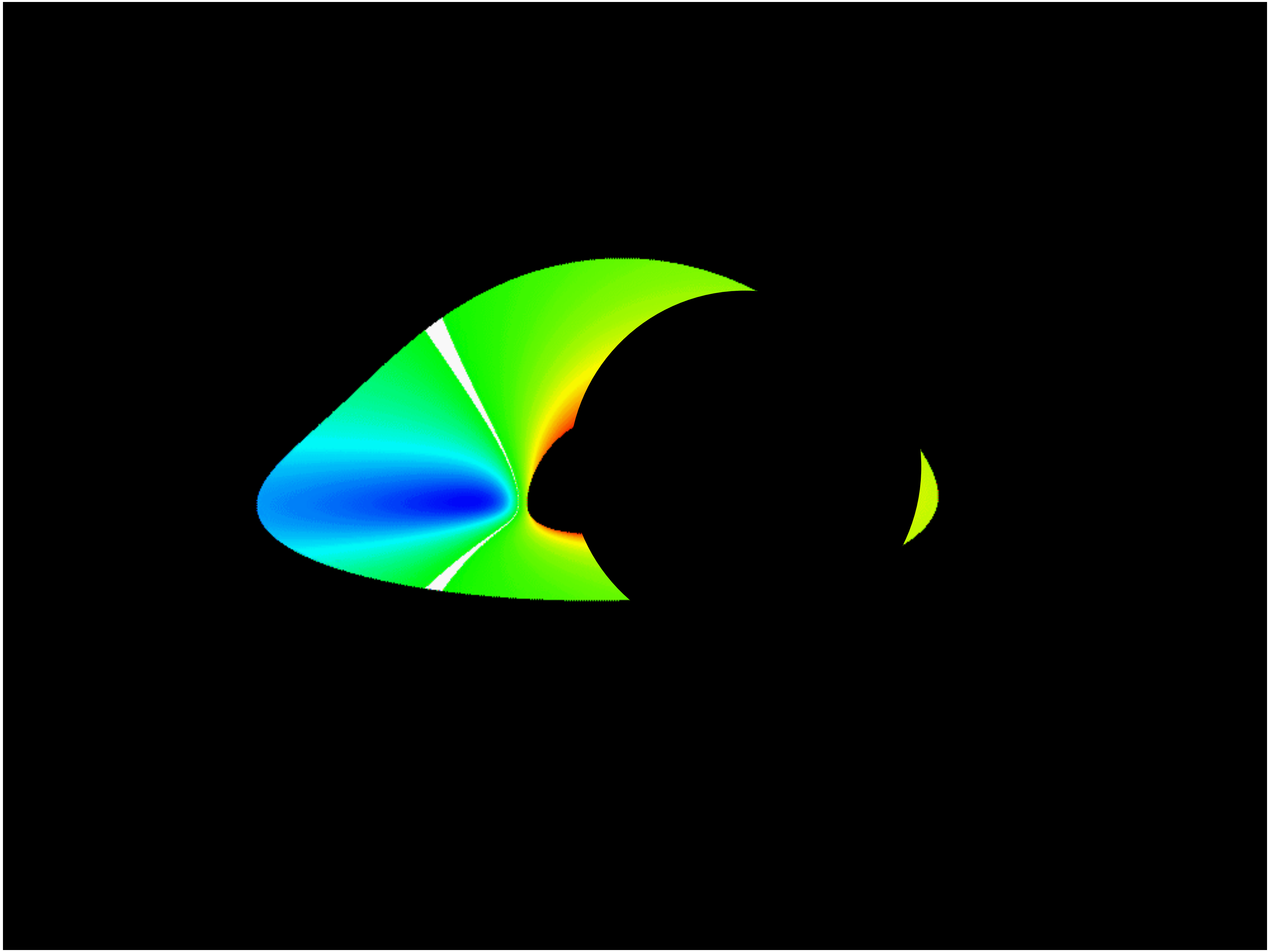
Assuming the natural symmetry, BOTH the X-ray corona and the soft-excess emitting region are confined within 10-25 R_g from the central BH, the soft excess being possibly slightly more compact than the corona

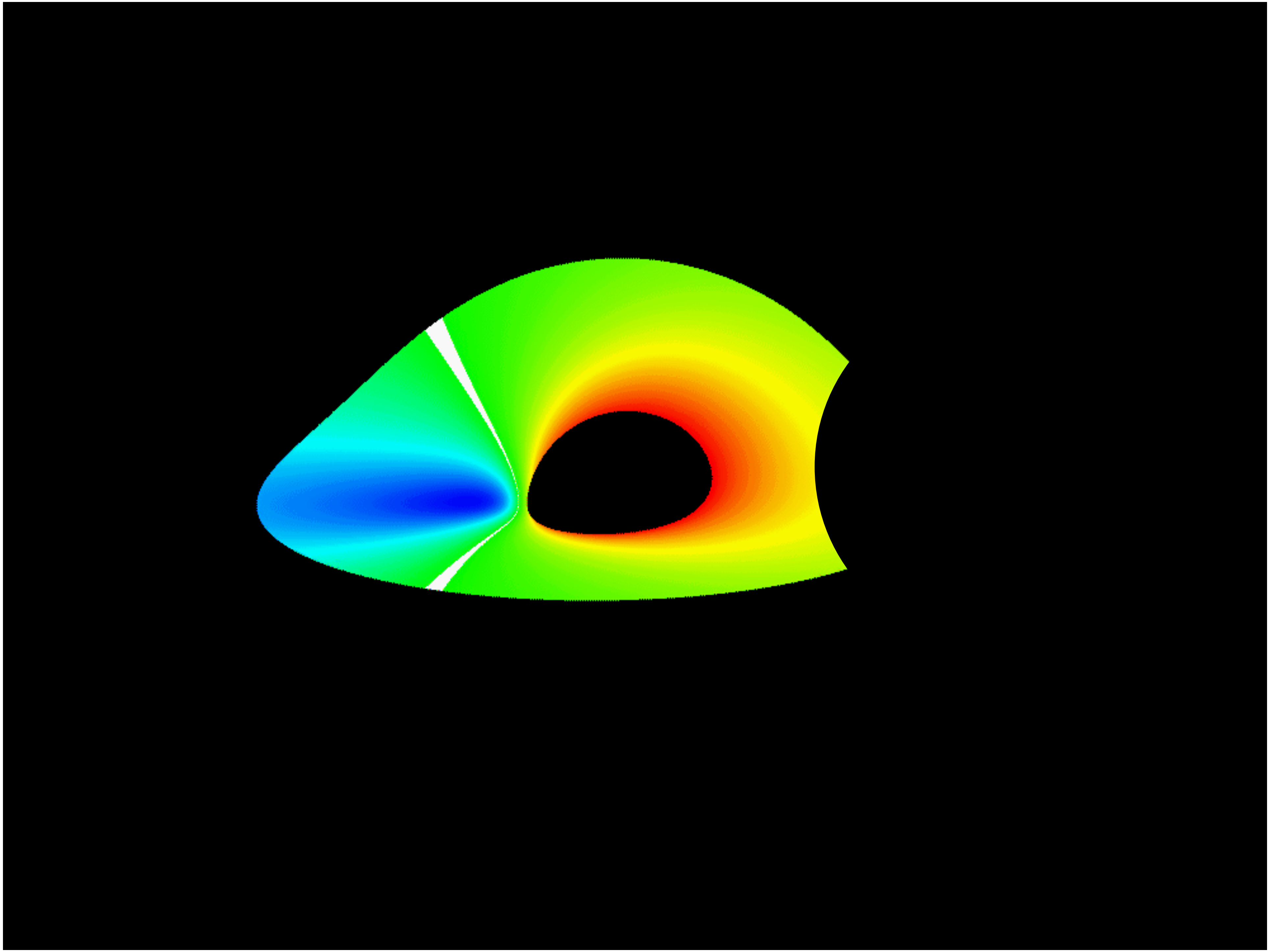
The occultation of the soft excess, if due to disc-reflection, may be used to test GR in the strong field regime

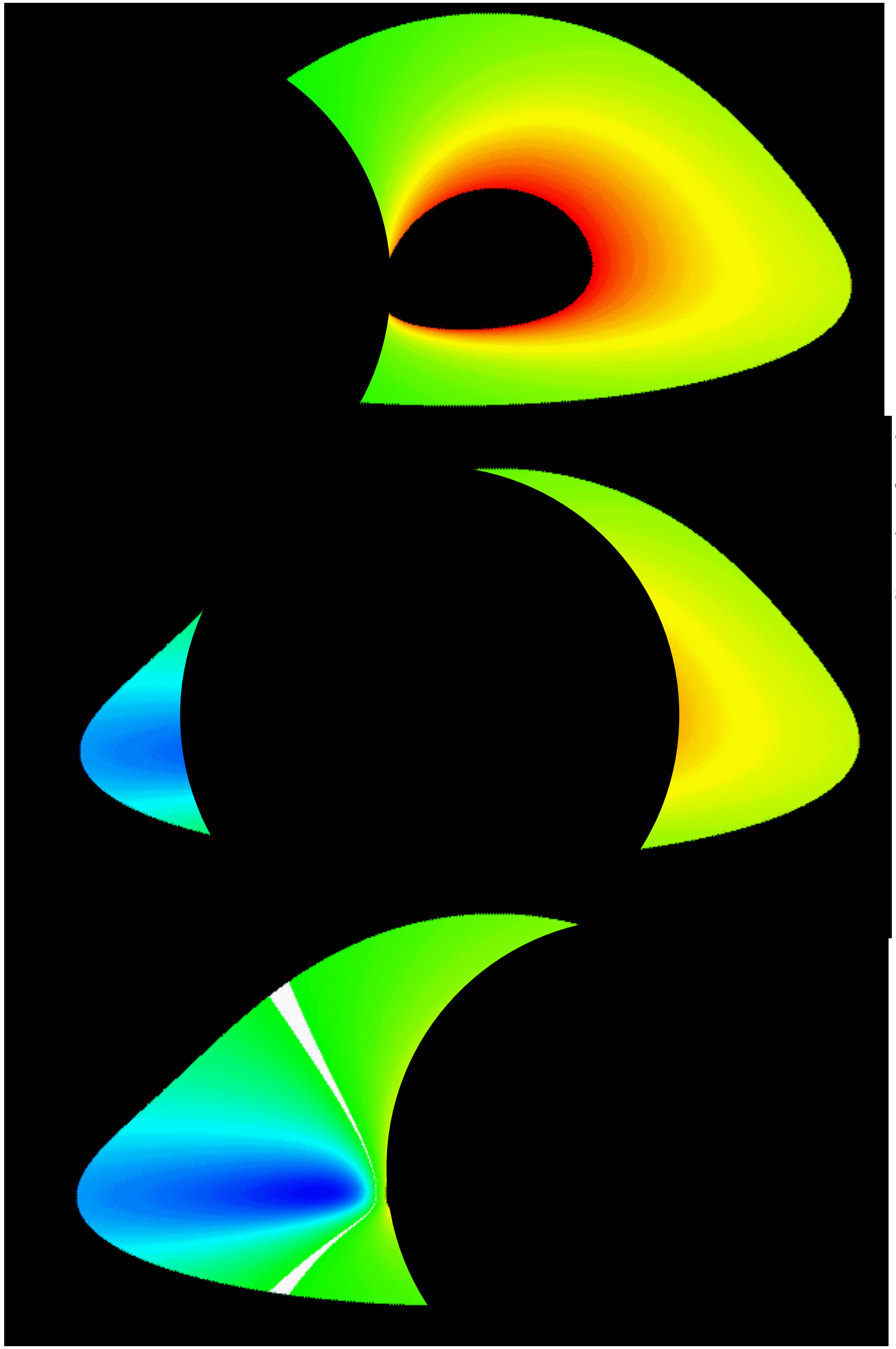


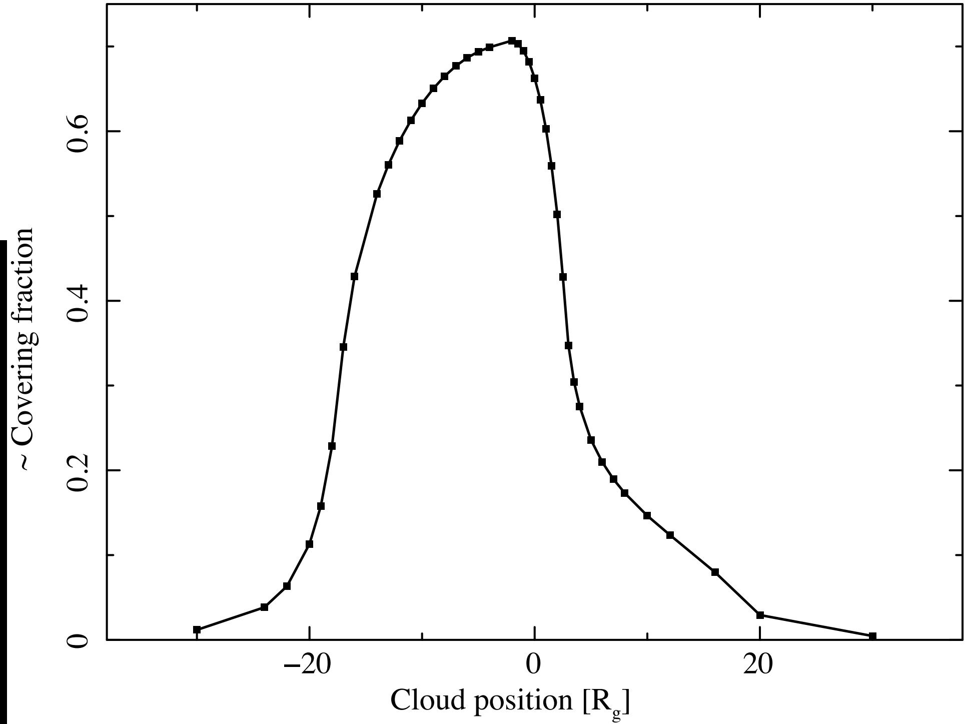




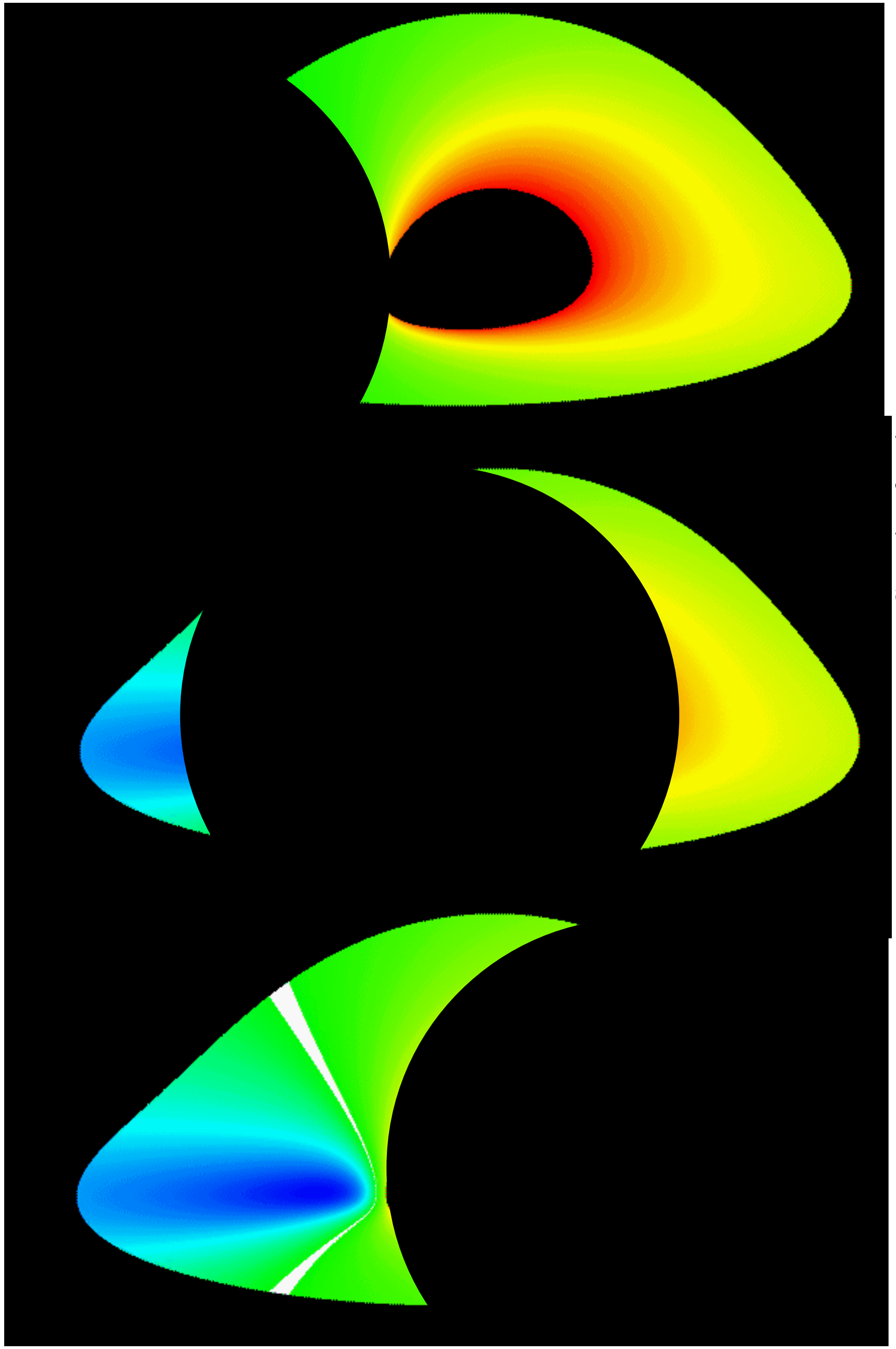


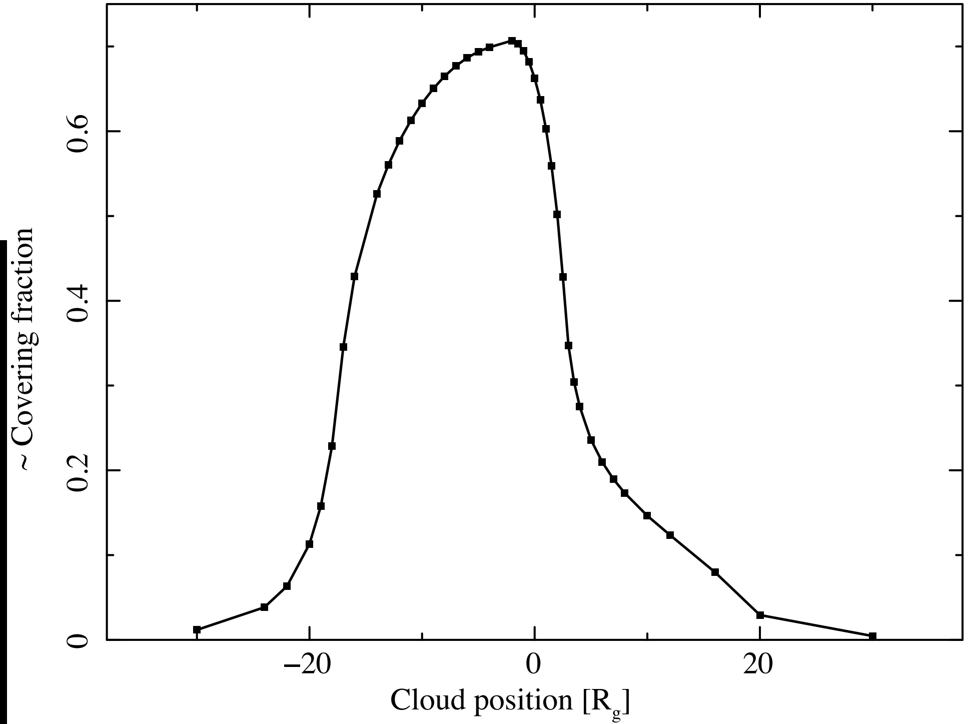






As the cloud size is comparable or larger than the emitting region, we have an almost symmetric evolution





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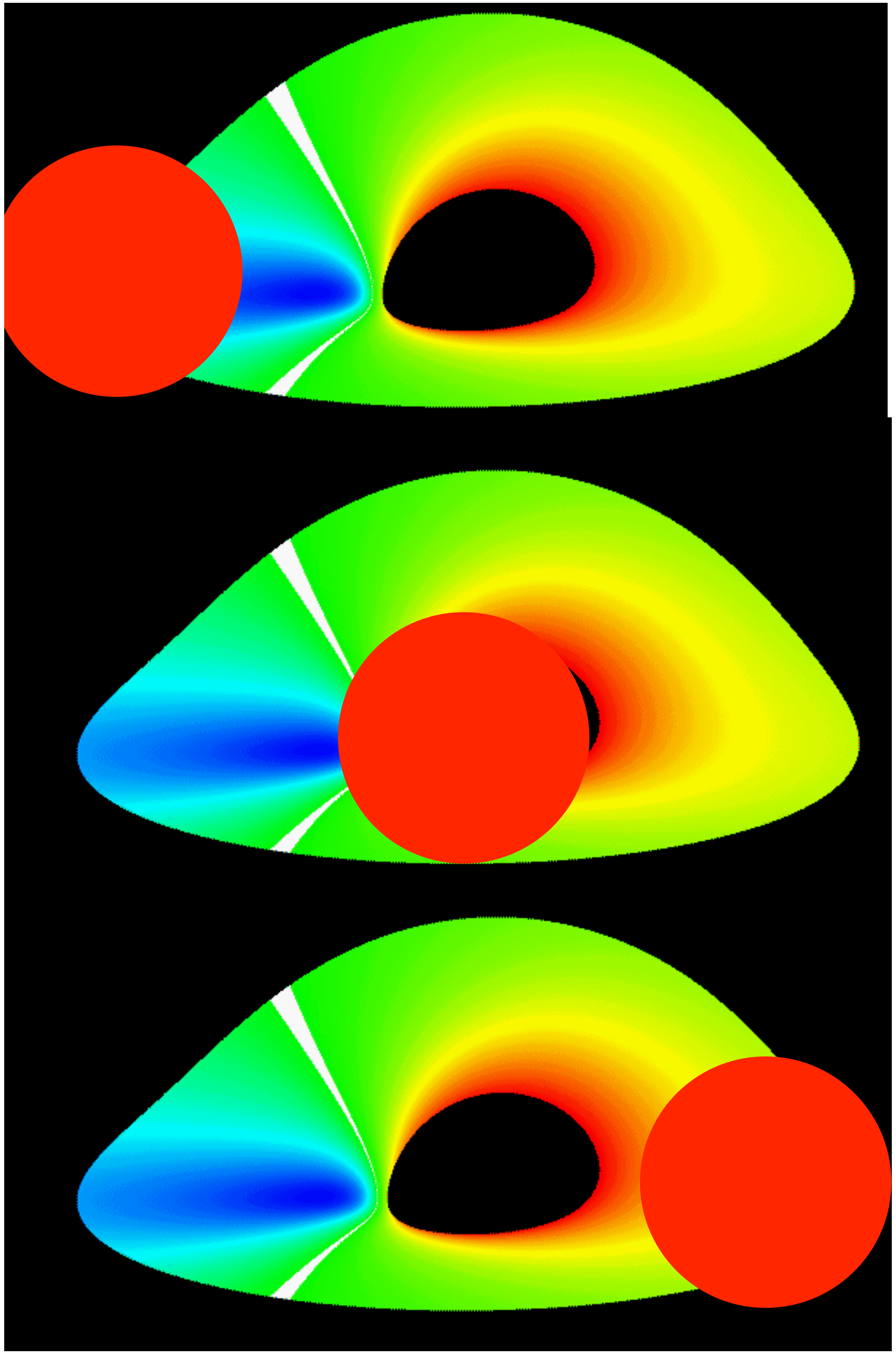
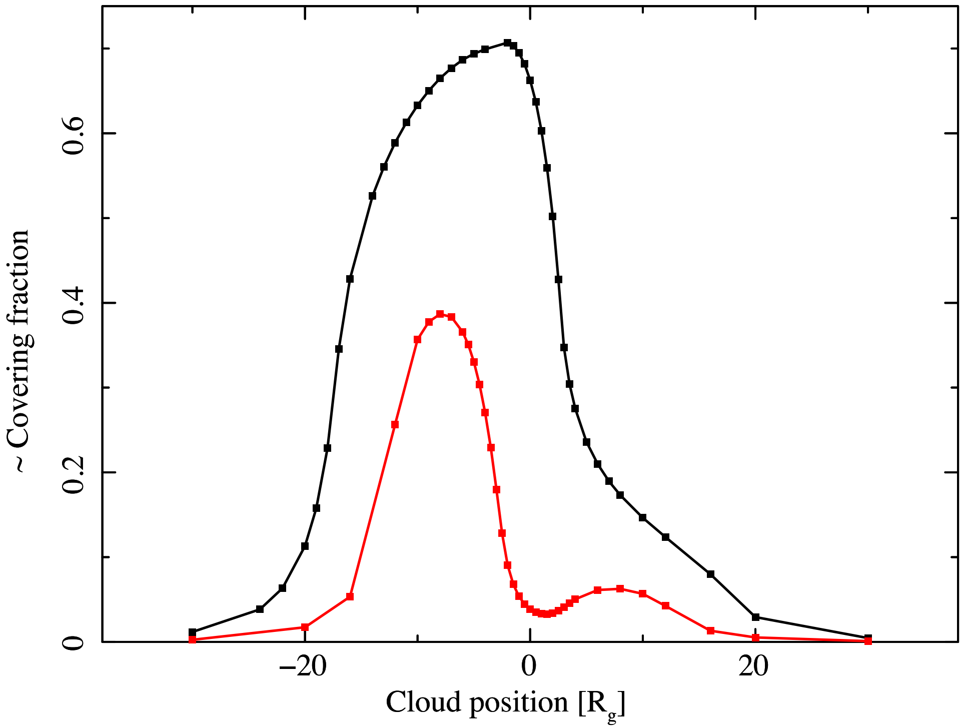
However, if it becomes comparable with the ISCO (1 to 6 R_g depending on BH spin) one starts to see BLUE and RED parts, as well as the ISCO iself





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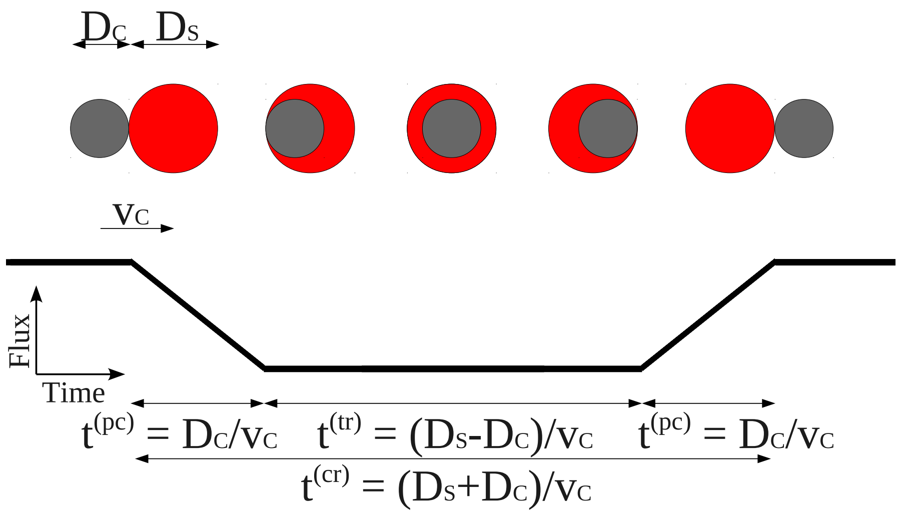
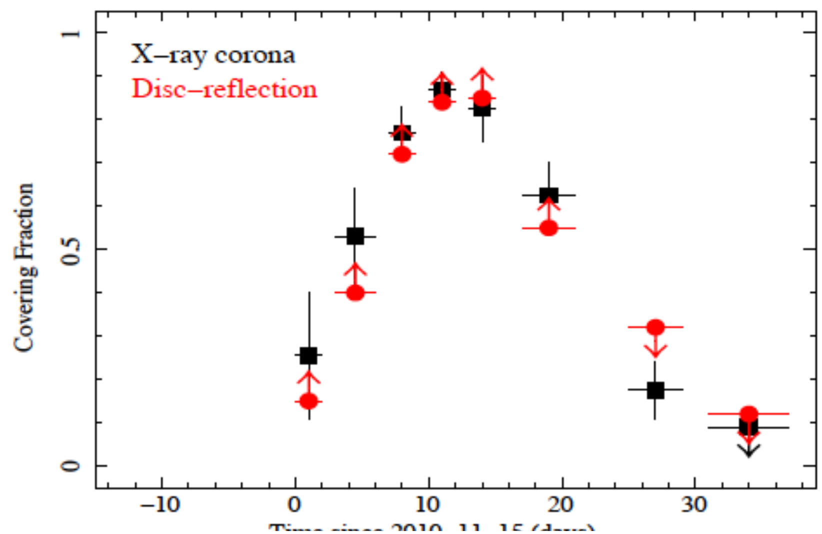
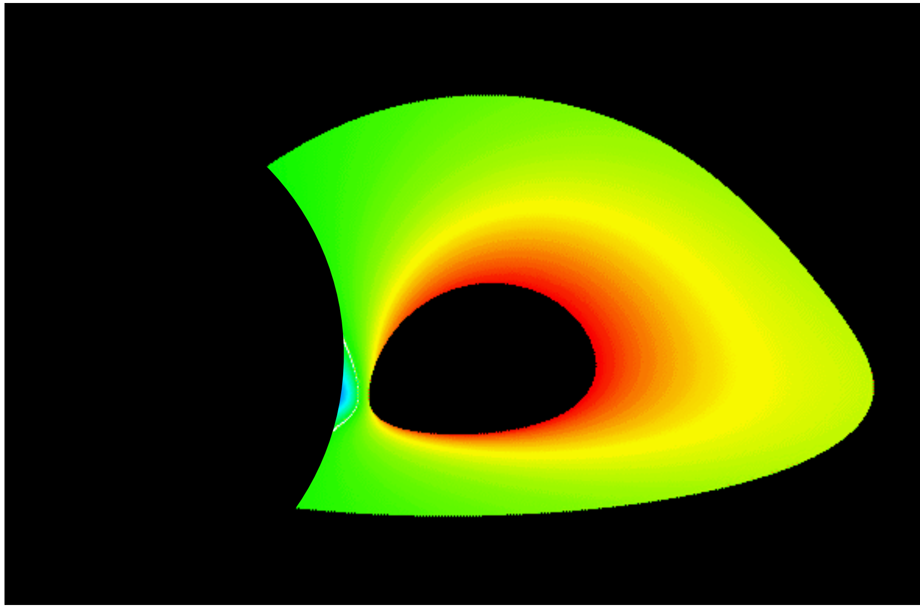
X-ray eclipses enable us to map the innermost regions of the accretion flow close to BHs
[also Miniutti et al. 2013; Sanfrutos et al. 2013; Agís et al.sub; Miniutti et al. in prep.]







THANK YOU