ESO 362-G18: black hole spin and the size of the X-ray emitting region

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THE X-RAY UNIVERSE 2014, 16th June 2014

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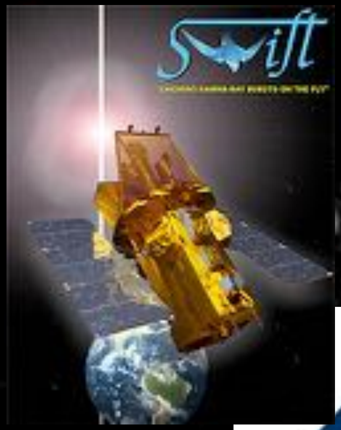
• I. INTRODUCTION

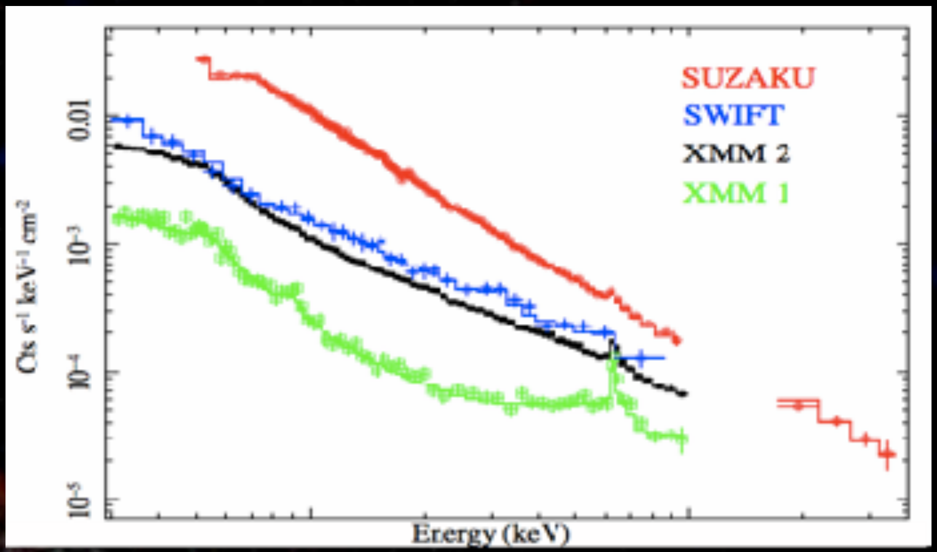
- AVALIABLE OBSERVATIONS & OUR MONITORING CAMPAIGN



2005-11-26

~2 months

(XMM1) 2006-01-28

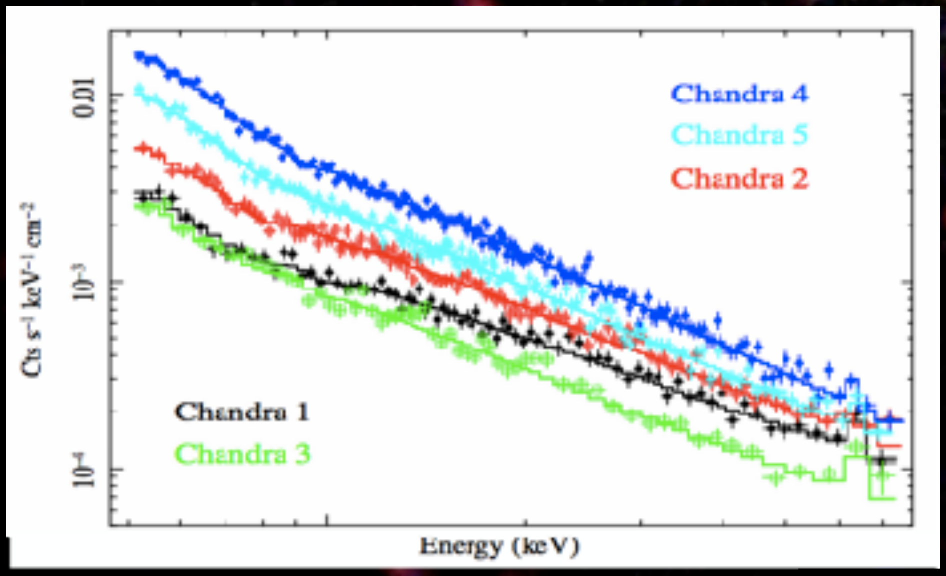


~2 years

2008-04-11

~2 years

(XMM2) 2010-01-29

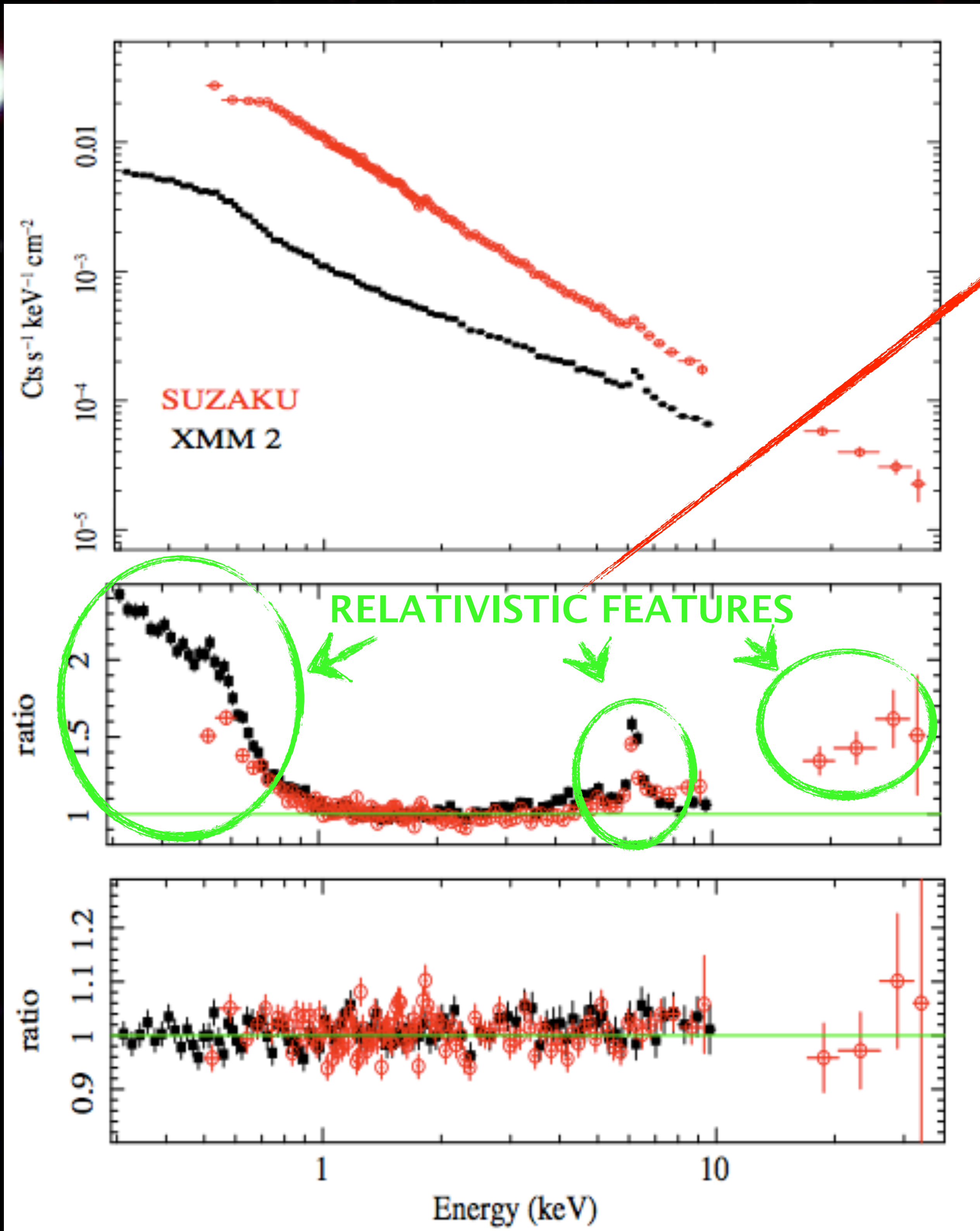


SHORTIME SCALES

x 5 observations
- along 15 days
- 2010-05

• 2. X-RAY DATA

- SOFT EXCESS & X-RAY DISC REFLECTION COMPONENT



DISC REFLECTION COMPONENT

+

WARM ABSORBER
with fixed N_H

...but XXM2 is not still well reproduced...

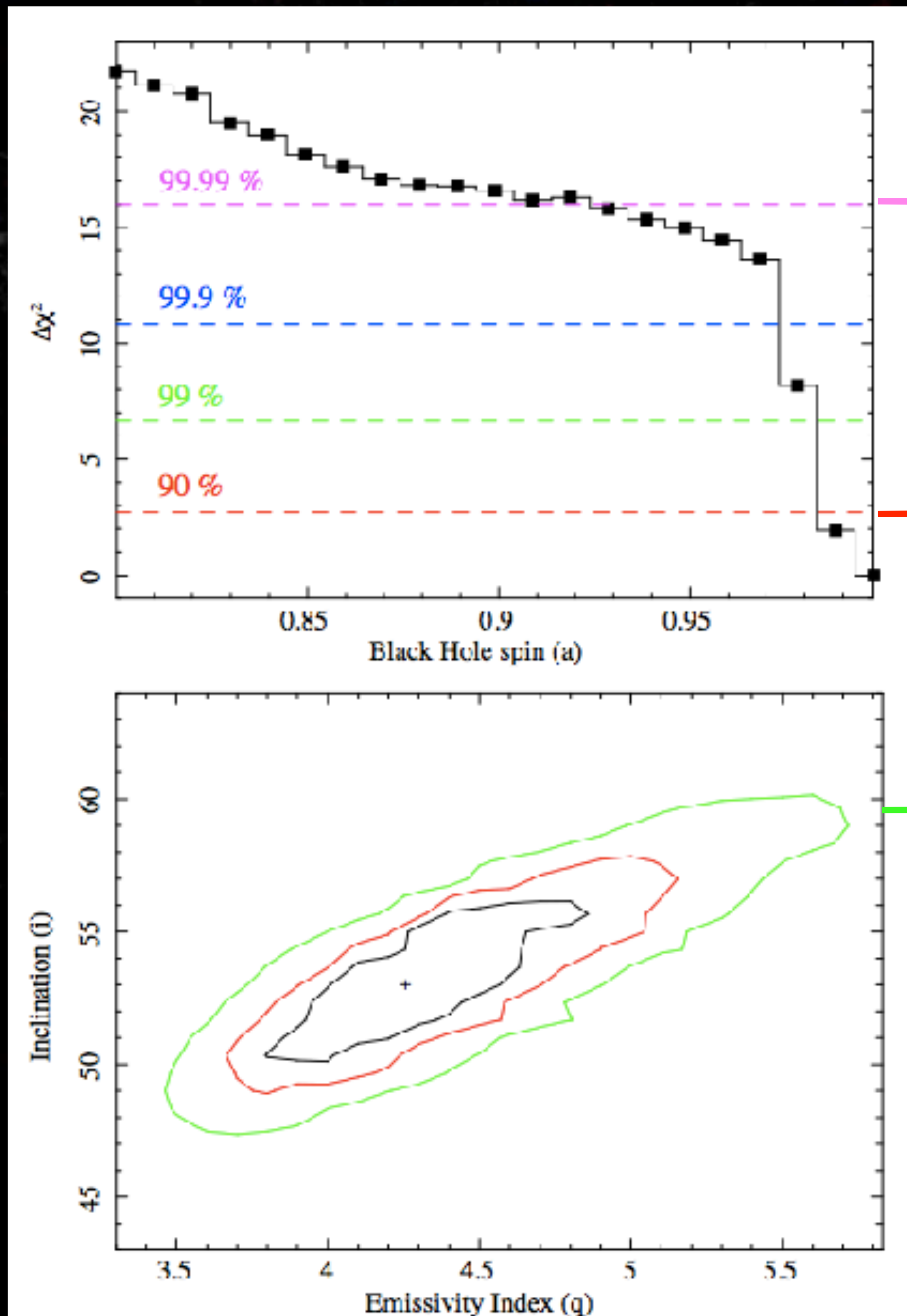
+

NEUTRAL ABSORBER:
Suzaku → UNABSORBED
$C_f \leq 0.1$
XMM2 → ABSORBED
$N_H \sim 10^{22} cm^{-2}$ $C_f \approx 0.4$

disc-reflection component ✓
black body ✗

• 2. X-RAY DATA

- X-RAY DISC REFLECTION COMPONENT: relativistic parameters



$a \geq 0.92$ at 99.99% conf. level

Very rapidly spinning Kerr Balck Hole

$a \geq 0.98$ at 90% conf. level

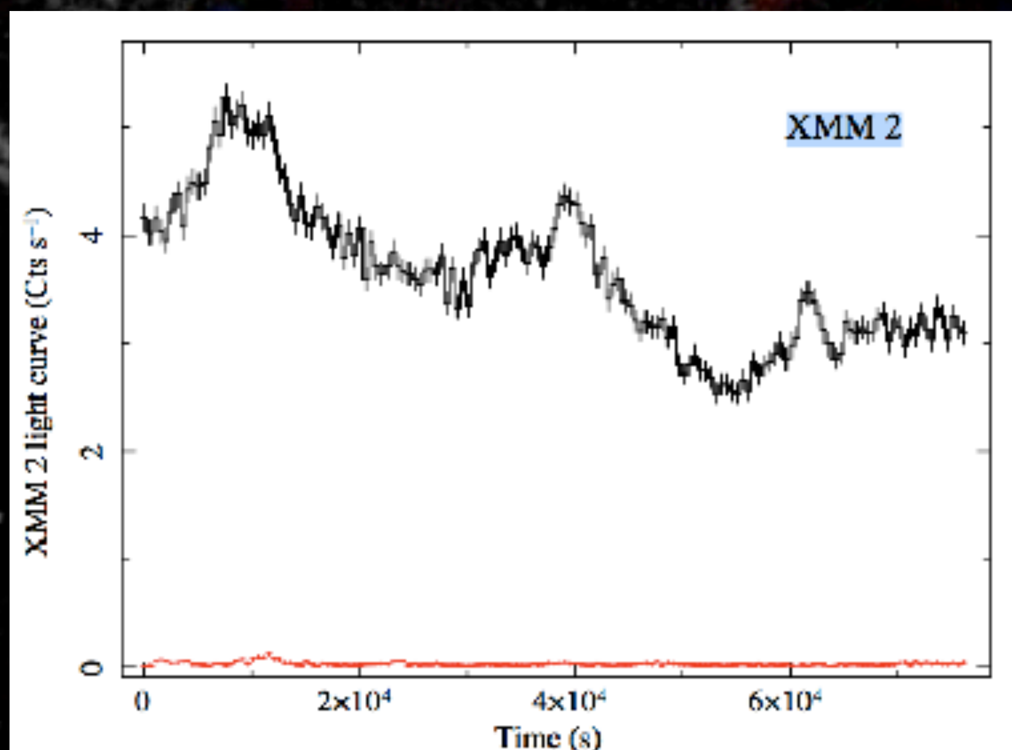
$q = 4.3^{+0.8}_{-0.6}$
$i = 53° \pm 5°$
at 90% conf. level

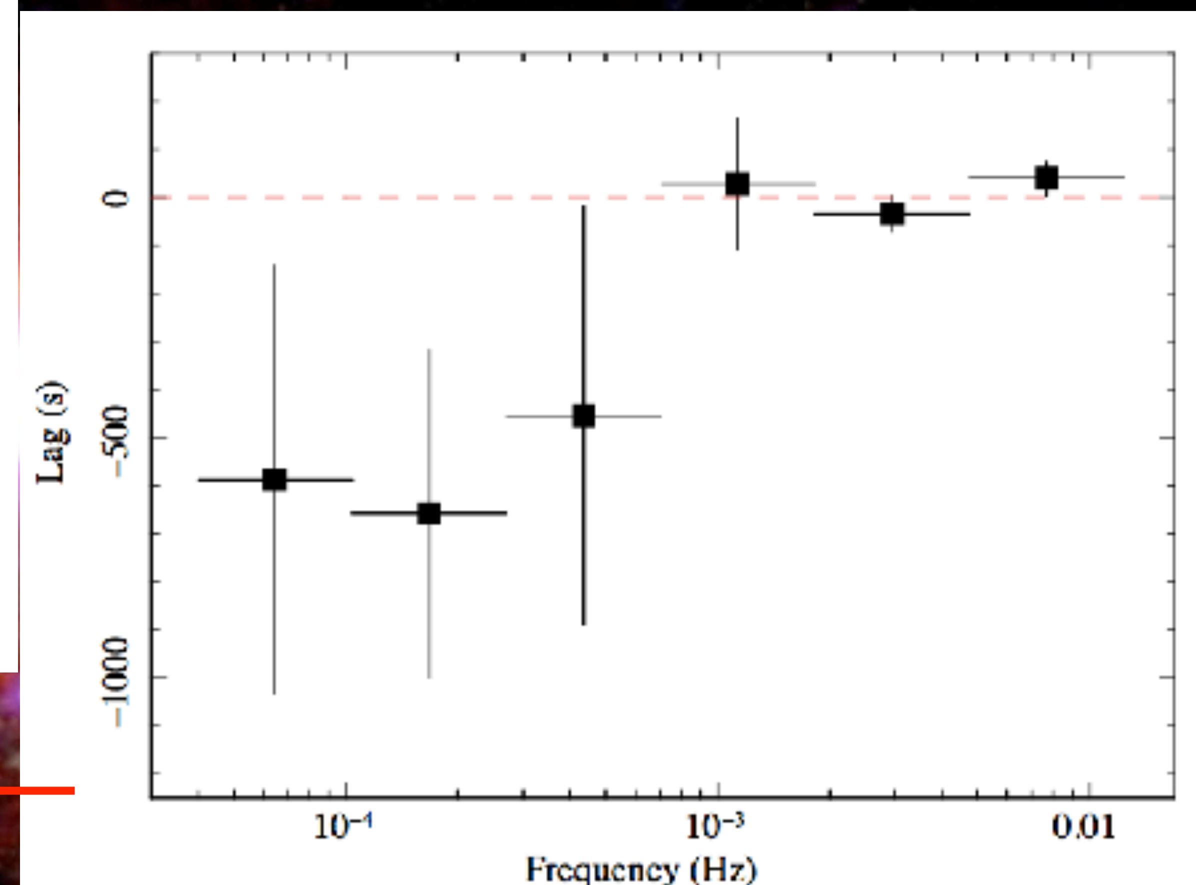
Very high inclination

• 2. X-RAY DATA

- SOFT TIME LAG

Soft X-Ray Excess = Partially Ionized X-ray Reflection of the inner acrcetion disc → **SHORT TIME DELAYS** between Disc-reflection Band (0.3-0.6 KeV) ⟷ Power Law Continuum (0.8-3 KeV)





$|\tau| = 658 \pm 342$ s at $\nu \sim 1.7 \cdot 10^{-4}$ Hz ←

$$M_{BH} = (4.5 \pm 1.5) \times 10^7 \ M_\odot \rightarrow M_{best} = 4.5 \times 10^7 \ M_\odot$$ → dist.= $(3.0 \pm 1.5) r_g$

Wilkings & Fabian (2013) → Dilution Effects → { $\tau \sim 1600$ s, dist. = $7 \ r_g$ }

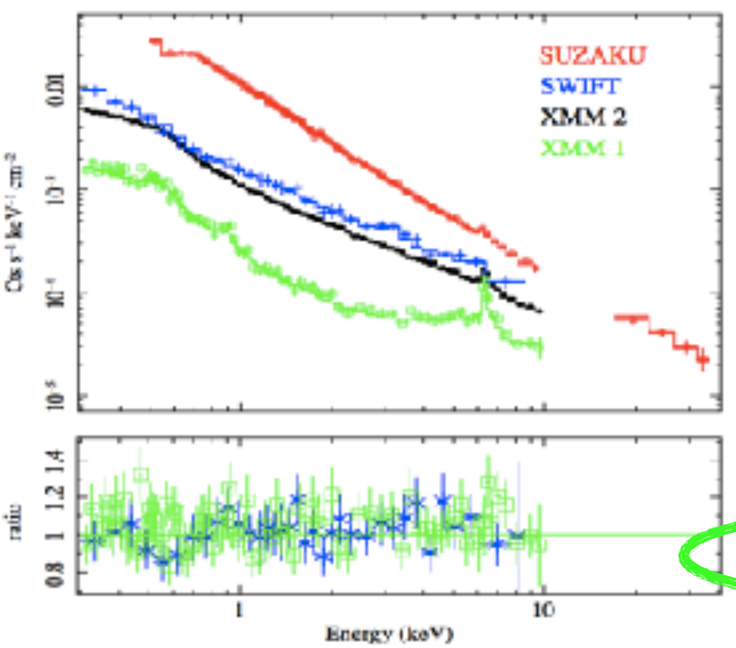
ONLY IF LAGS are interpreted like LIGHT-CROSSING TIME

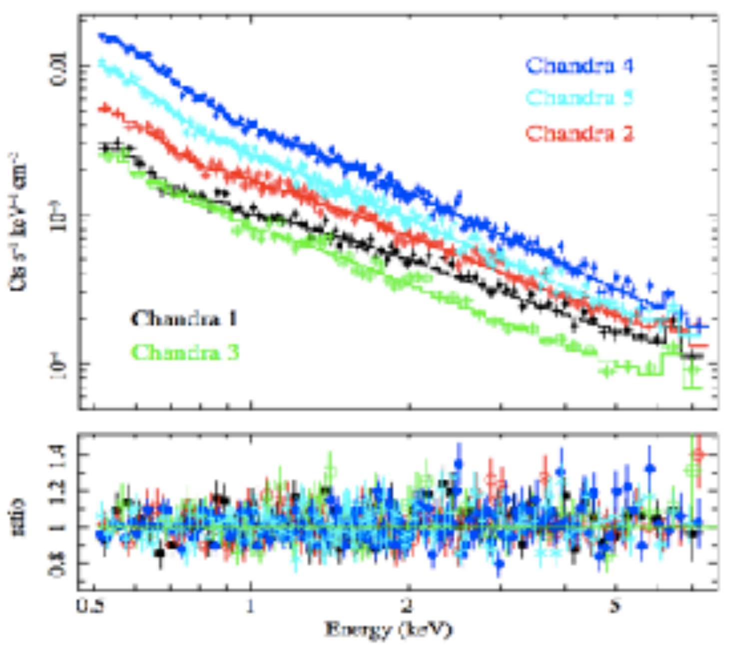
2. X-RAY DATA

- JOINT ANALYSIS: Results

- VARIABILITY due to the COLD ABSORBER → **Swift**: $N_H \sim 5x10^{21}$ cm^{-2}, $C_f \sim 0.5$ ← 63 days → **XMM1**: $N_H \sim 3-4x10^{23}$ cm^{-2}, $C_f \geq 0.94$

- Disc reflection component detected in all observations





Variable components

Obs.	Cold absorber		Warm absorber		Continuum		Disc–reflection	
	$N_H^{(cold)}$	$C_f^{(cold)}$	$N_H^{(ion)}$	$\log \xi$	Γ	$L_{2-10}^{(nuc)}$	$\xi^{(ref)}$	$L_{2-10}^{(ref)}$
Swift	0.5 ± 0.4	0.5 ± 0.3	0.15 ± 0.04	$2.0^{(XMM2)}$	2.0 ± 0.4	2.0 ± 0.3	$\leqslant 25$	$\leqslant 2.0$
XMM 1	35 ± 8	$\geqslant 0.94$	"	$2.0^{(XMM2)}$	1.90 ± 0.09	2.3 ± 0.2	$\leqslant 32$	$0.9^{+0.5}_{-0.7}$
Suzaku	$\leqslant 3$	$\leqslant 0.1$	"	2.4 ± 0.2	2.12 ± 0.03	8.35 ± 0.08	16 ± 12	1.9 ± 0.2
XMM 2	1.3 ± 0.2	0.42 ± 0.04	"	2.0 ± 0.3	1.80 ± 0.04	1.95 ± 0.06	$\leqslant 8$	0.9 ± 0.1
χ^2/dof = 3075/2928								
Chandra 1	0.8 ± 0.2	0.6 ± 0.1	0.20 ± 0.08	2.0 ± 1.1	1.7 ± 0.2	2.3 ± 0.2	$\leqslant 26$	0.7 ± 0.5
Chandra 2	"	0.4 ± 0.1	"	1.9 ± 0.6	1.8 ± 0.2	3.1 ± 0.1	$\leqslant 25$	0.9 ± 0.4
Chandra 3	"	0.5 ± 0.2	"	2.5 ± 1.3	1.8 ± 0.3	1.2 ± 0.4	$\leqslant 35$	$\leqslant 1.6$
Chandra 4	"	0.48 ± 0.06	"	2.5 ± 0.4	2.1 ± 0.1	4.9 ± 0.1	7 ± 6	1.3 ± 0.3
Chandra 5	"	0.4 ± 0.1	"	2.1 ± 0.4	2.0 ± 0.1	3.4 ± 0.1	$\leqslant 19$	1.1 ± 0.2
χ^2/dof = 1248/1218								

• 3. UV DATA

- ABSORBER FROM THE CLUMPY TORUS OR FROM BLR?

BLR → within R_{dust} (dust-free)

CLUMPY TORUS → outer R_{dust} (dust content)

ABSORBER from the DUSTY CLUMPY TORUS ⟷ UV Variability

Filter	Swift[a] (unabsorbed)	XMM 1[b] (absorbed)	XMM 2[b] (unabsorbed)
UVW2	13.5 ± 0.6	7.9 ± 0.4	–
UVM2	12.2 ± 0.4	8.5 ± 0.4	12.4 ± 0.5
UVW1	11.8 ± 0.7	10.6 ± 0.5	9.9 ± 0.5
U	10.0 ± 0.5	10.7 ± 0.5	8.8 ± 0.4

E ↑

XMM1 (X-ray absorbed)

UVW2 Flux 40% absorbed ⟷ UVM2 Flux 30% absorbed

→ ABSORBER from the DUSTY CLUMPY TORUS ✓

+ high inclination ($i = 53° \pm 5°$)

4. X-RAY AND UV DATA

- X-RAY EMITTING REGION SIZE

Fully covered X-ray emitting region during XMM1 → $D_X \leq D_C$

$$D_X = \Delta T v_c$$

Swift and XMM1 observations are 63 days apart → $\Delta T \leq 63\ days$

$v_c \leq v_{Kep}$ at the R_{dust} → $v_c \leq 1180\ km\ s^{-1}$

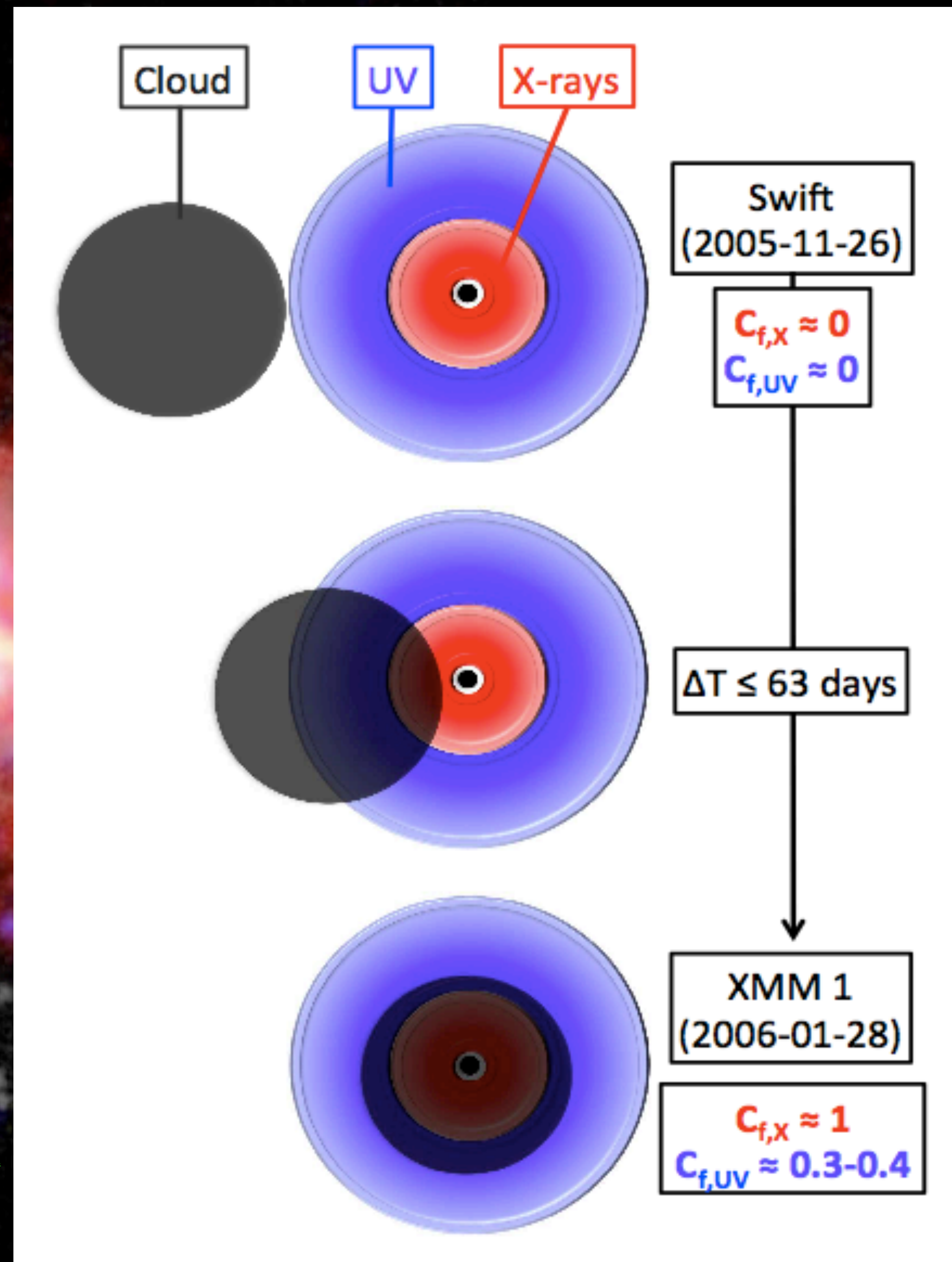
{ $R_{dust} \sim 0.4 L_{Bol,45}^{0.5} = 0.14$ pc Nenkova et al.(2008)
$L_{Bol} = 1.3 \cdot 10^{44}$ erg s^{-1} }

$$D_X \leq 96\ r_g\ M_{best}/M_{BH}$$

$$n_c \leq 6.7 \times 10^8\ cm^{-3}$$

for BLR $n_c \geq 10^9$ cm^{-3}

→ ABSORBER from the DUSTY CLUMPY TORUS ✓



• 5. CONCLUSIONS

- ESO 362-G18 midly absorbed by
  - WARM absorber (constant)
  - &
  - COLD absorber (VARIABILITY)

Most remarkable event between:

Swift	63 days	XMM1
$N_H \sim 5 \times 10^{21}$ cm^{-2}		$N_H \sim 3\text{-}4 \times 10^{23}$ cm^{-2}
$C_f \sim 0.5$		$C_f \geq 0.94$

- Strong Soft Excess
  Fe K energies excess
  20-30 KeV excess
  → DISC-REFLECTION COMPONENT (with relativistic effects):

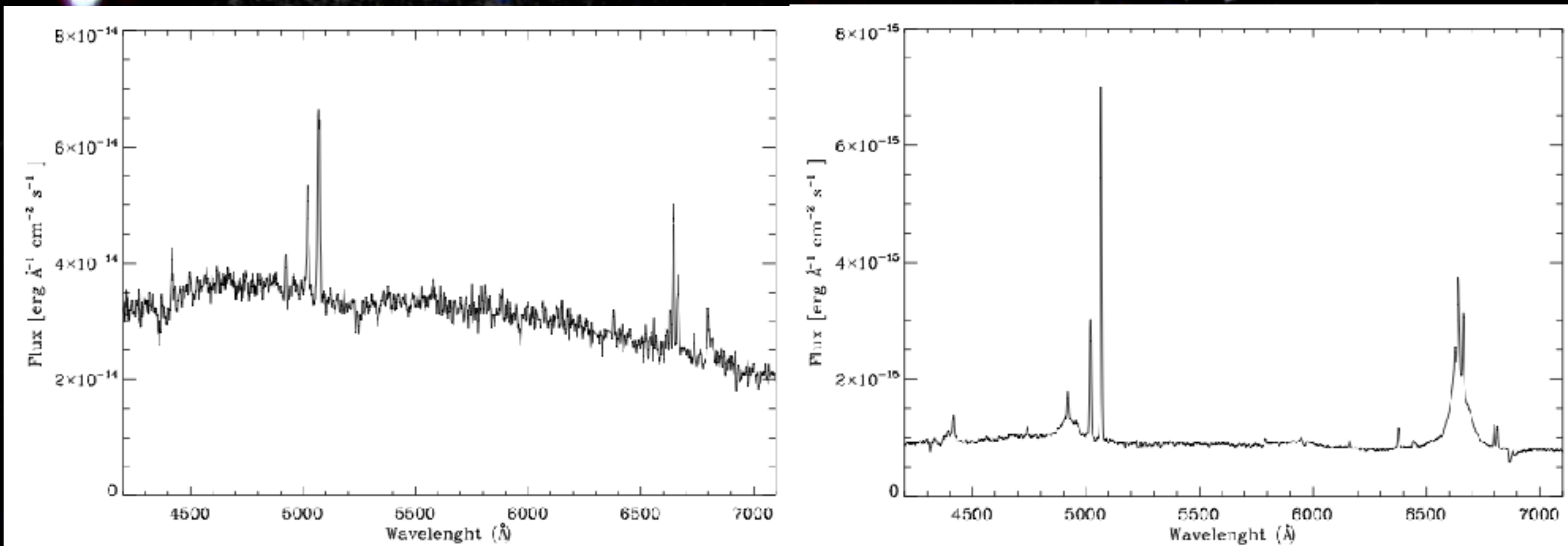
$$a \geq 0.92 \quad q = 4.3^{+0.8}_{-0.6} \quad i = 53^{\circ} \pm 5^{\circ}$$

- THE DETECTION OF A SOFT TIME LAG → Continuum Band ↔ $7\ r_g$ ↔ Soft-excess Band

- ABOSORBER FROM THE CLUMPY TORUS supported by:
  - High Inclination*
  - UV data

- BOTH X-RAY CONTINUUM AND SOFT EXCESS ORIGINATE IN A COMPACT REGION WITHIN $\sim 50\ r_g$

• FUTURE WORK



Seyfert 2 (30/01/2003) ⟷ Seyfert 1 (18/09/2004)

→ **ABSORBER** from the **DUSTY CLUMPY TORUS** ✓

• JOINT ANALYSIS: Scattered components

Extended Photoionized Gas →

SOFT SCATTERED COMPONENT:
Soft Power Law only absorbed by Galactic Column Density

Absorption due to a clumpy structure ↔

HARD SCATTERED COMPONENT:
phenomenological model used by Minutti et. al (2013) →

ABSORBED POWER LAW:
- Same Γ and normalization as the nuclear continuum
- Free column Density
- Multiplied by a factor(0-1)