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

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1. INTRODUCTION

- AVAILABLE 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 XMM2 is not still well reproduced...

NEUTRAL ABSORBER:
Suzaku $\rightarrow$ UNABSORBED $C_{f} \leq 0.1$
XMM2 $\rightarrow$ ABSORBED $N_H \sim 10^{22}\text{cm}^{-2}$ $C_{f} \approx 0.4$

disc-reflection component ✔
black body ✗
2. X-RAY DATA

- X-RAY DISC REFLECTION COMPONENT: relativistic parameters

Very rapidly spinning Kerr Black Hole

\[ a \geq 0.92 \text{ at } 99.99\% \text{ conf. level} \]

\[ q = 4.3^{+0.8}_{-0.6} \text{ at } 90\% \text{ conf. level} \]

\[ i = 53^\circ \pm 5^\circ \text{ at } 90\% \text{ conf. level} \]

Very high inclination
2. X-RAY DATA

• SOFT TIME LAG

Soft X-Ray Excess = Partially Ionized X-ray Reflection of the inner accretion disc

\[ |\tau| = 658 \pm 342 \text{ s} \quad \text{at} \quad \nu \sim 1.7 \cdot 10^{-4} \text{ Hz} \]

\[ M_{BH} = (4.5 \pm 1.5) \times 10^7 \, M_\odot \Rightarrow M_{best} = 4.5 \times 10^7 \, M_\odot \]

\[ \text{dist.} = (3.0 \pm 1.5)r_g \]

\[ \tau \sim 1600 \, \text{s} \quad \text{dist.} = 7 \, r_g \]

Wilkings & Fabian (2013) → Dilution Effects

SHORT TIME DELAYS between Disc-reflection Band (0.3–0.6 KeV) and Power Law Continuum (0.8–3 KeV)

ONLY IF LAGS are interpreted like LIGHT-CROSSING TIME
2. X-RAY DATA

• JOINT ANALYSIS: Results

VARIABILITY due to the COLD ABSORBER

Swift
\( N_H \sim 5 \times 10^{21} \text{ cm}^{-2} \)
\( C_f \sim 0.5 \)

XMM1
\( N_H \sim 3 - 4 \times 10^{23} \text{ cm}^{-2} \)
\( C_f \geq 0.94 \)

63 days

Disc reflection component detected in all observations

<table>
<thead>
<tr>
<th>Variable components</th>
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</thead>
<tbody>
<tr>
<td>Obs.</td>
</tr>
<tr>
<td>( N_{H_{\text{cold}}} )</td>
</tr>
<tr>
<td>Swift</td>
</tr>
<tr>
<td>XMM1</td>
</tr>
<tr>
<td>Suzaku</td>
</tr>
<tr>
<td>XMM 2</td>
</tr>
<tr>
<td>Chandra 1</td>
</tr>
<tr>
<td>Chandra 2</td>
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<tr>
<td>Chandra 3</td>
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<tr>
<td>Chandra 4</td>
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<tr>
<td>Chandra 5</td>
</tr>
</tbody>
</table>

\( \chi^2/\text{dof} = 3075/2028 \)

\( \chi^2/\text{dof} = 1248/1218 \)
3. UV DATA

- ABSORBER FROM THE CLUMPY TORUS OR FROM BLR?

<table>
<thead>
<tr>
<th>Filter</th>
<th>Swift (^a) (unabsorbed)</th>
<th>XMM 1 (^b) (absorbed)</th>
<th>XMM 2 (^b) (unabsorbed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UVW2</td>
<td>13.5 ± 0.6</td>
<td>7.9 ± 0.4</td>
<td>−</td>
</tr>
<tr>
<td>UVM2</td>
<td>12.2 ± 0.4</td>
<td>8.5 ± 0.4</td>
<td>12.4 ± 0.5</td>
</tr>
<tr>
<td>UVW1</td>
<td>11.8 ± 0.7</td>
<td>10.6 ± 0.5</td>
<td>9.9 ± 0.5</td>
</tr>
<tr>
<td>U</td>
<td>10.0 ± 0.5</td>
<td>10.7 ± 0.5</td>
<td>8.8 ± 0.4</td>
</tr>
</tbody>
</table>

- BLR → within \(R_{\text{dust}}\) (dust-free)
- CLUMPY TORUS → outer \(R_{\text{dust}}\) (dust content)

- ABSORBER from the DUSTY CLUMPY TORUS → UV Variability

- XMM1 (X-ray absorbed)
  - UVW2 Flux: 40% absorbed
  - UVM2 Flux: 30% absorbed

- ABSORBER from the DUSTY CLUMPY TORUS + high inclination \((i = 53° ± 5°)\)
4. X-RAY AND UV DATA

X-RAY EMITTING REGION

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

\[ \Delta T \leq 63 \text{ days} \]

\[ v_c \leq v_{Kep} \text{ at the } R_{dust} \]

\[ R_{dust} \approx 0.4 L_{Bol,45} = 0.14 \text{ pc} \]

\[ L_{Bol} = 1.3 \times 10^{44} \text{ erg s}^{-1} \]

Nenkova et al. (2008)

\[ n_c \leq 6.7 \times 10^8 \text{ cm}^{-3} \]

for BLR \( n_c \geq 10^9 \text{ cm}^{-3} \)

ABSORBER from the DUSTY CLUMPY TORUS
5. CONCLUSIONS

- ESO 362-G18 midly absorbed by
  Most remarkable event between:
    Swift
    \( N_H \sim 5 \times 10^{21} \text{ cm}^{-2} \)
    \( C_f \sim 0.5 \)
  x
  XMM1
  \( N_H \sim 3 - 4 \times 10^{23} \text{ cm}^{-2} \)
  \( C_f \geq 0.94 \)
- Strong Soft Excess
  Fe K energies excess
  20-30 KeV excess
- THE DETECTION OF A SOFT TIME LAG
- 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) ← ABSORBER from the DUSTY CLUMPY TORUS → Seyfert 1 (18/09/2004)
**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 $\Gamma$ and normalization as the nuclear continuum
  - Free column Density
  - Multiplied by a factor (0–1)