Spectral analysis of LMXB Aql X-1 in soft and hard states with *Suzaku*

Soki Sakurai (University of Tokyo, Japan)
K. Nakazawa, K. Makishima (University of Tokyo, Japan)
& S. Yamada (Institute of Physical and Chemical Research, Japan)

(1) Introduction ~ Soft and Hard states of LMXBs ~

- **Soft state**
  - Well studied since the 1980’s.
  - (Mitsuda et al., 1984, White et al., 1988,)
  - High mass accretion rate.
  - Bright in energy below ~20 keV.
  - A firm picture has been established.

- **Hard state**
  - Researches have recently started (e.g., Barret et al., 2001, Lin et al., 2009a)
  - Low mass accretion rate.
  - Spectra with $\Gamma \approx 2$ power law shapes.

**Unsolved Problems**
- What is correct mission model? (the source of Compton seed photons?)
- What is the accretion geometry like? (disk, corona, neutron-star surface, ...?)

(2) *Suzaku* results on Aql X-1 in the Soft and Hard states (reanalysis of the archival data originally published as Raichur et al. [6])

<table>
<thead>
<tr>
<th>Seven <em>Suzaku</em> observations of Aql X-1 on the ASM light curve</th>
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<tbody>
<tr>
<td><strong>Soft state</strong></td>
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<tr>
<td><em>vFv</em></td>
</tr>
<tr>
<td>$R_{in} = 14\pm2$ km</td>
</tr>
<tr>
<td>compTT</td>
</tr>
<tr>
<td>$R_{bb} = 0.5\pm0.1$ km</td>
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| **Hard state** |
| *vFv* | compPS (seed=blackbody) |
| $R_{bb} = 10\pm2$ km |
| $R_{in} = 21\pm4$ km |

Our results on the **Soft state** reconfirm previous studies.
In the **Hard state**, the emission model and accretion geometry (above right) were successfully identified.

- **Model:** diskBB + compPS(seed = black body) + Gaussian($E=6.4$ keV)
- Seed photons of compPS are from the NS surface.
- The standard disk is truncated at $r \approx 20$ km.
- Most of the NS surface becomes hot ($kT = 0.51\pm0.02$ keV).
- Coronal parameters: $T_{e}=35\pm5$ keV, $\Gamma \approx 2.7$

(3) Discussion

A fully physical emission model in the **hard state** was determined for the first time, wherein the seed photons of compPS are identified with the *blackbody* from the neutron-star surface.

Geometrical features of the accretion flow in the **Soft/Hard states**

<table>
<thead>
<tr>
<th>Accretion Disk</th>
<th>NS surface</th>
<th>Flux ratio (corona+NS / disk)</th>
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<tbody>
<tr>
<td><strong>Soft state</strong></td>
<td>The disk inner edge is close to the NS surface.</td>
<td>Accretion/emission occurs mainly onto/from an equatorial zone. $F_{cor} / F_{disk} \sim 0.44$ (from the data) The disk is rather luminous.</td>
</tr>
<tr>
<td><strong>Hard state</strong></td>
<td>Truncated at $\sim 20$ km. At $&lt;20$ km, it becomes an optically-thin and geometrically-thick hot flow, to be identified with the Compton corona.</td>
<td>Matter accretes almost spherically, and the whole NS surface shines. $F_{cor} / F_{disk} \sim 6$ (from the data) The ratio is reversed from that in the soft state; the corona + NS much brighter.</td>
</tr>
</tbody>
</table>

(4) Conclusion

We analyzed archival *Suzaku* spectra of Aql X-1 in the **Soft/Hard states**. The **Soft state** results reconfirm previous studies. In the **Hard state**, we have for the first time identified major emission components and obtained a fully physical picture of the accretion geometry.

References