Suzaku Observation of Anomalous X-ray Pulsar 4U 0142+61

T. Enoto (Tokyo Univ.)
K. Nakazawa, M. Kokubun, N. Shibasaki, M. Morii, M. Kawaharada, K. Makishima
Anomalous X-ray Pulsars

• Young rotating isolated NS
  – $P \sim 5\text{–}12$ s, $P\dot{\nu} \sim 1\times 10^{-11}$ s/s
  – $L_{\text{X-ray}} \gg L_{\text{SpinDown}}$
  – $B > 1\times 10^{14}$ G (Magnetar?)
  – 8 AXPs + a few candidates

• X-ray observations
  – Pulsed steep spectra below 10 keV
  – Extremely hard emission discovered in $>10$ keV
    by INTEGRAL/RXTE (~4 AXPs)
    [Molkov 2004; Kuiper 2004]

• Hard X-ray properties are still unknown.
AXP 4U 0142+61

- Hard X-ray Emitting AXP with $P \sim 8.7$ s, $D = 3.6$ kpc

[Durant 2006]

COMPTEL
Upper limit
> 750 keV

- Cutoff, photon index, time variation of the hard emission
- 4U 0142+61 is a good-aimed object for Suzaku

### Diagram

**Energy (keV)**

- **Swift**
- **INTEGRAL**
- **Suzaku**

**$E^2F$ (keV$^2$cm$^{-2}$s$^{-1}$keV$^{-1}$)**

- **Soft X-ray (Steep)**
- **Unexpected Hard X-ray ($\Gamma \sim 1$)**
4U 0142+61 was observed with Suzaku on 2007 August 13-14 for a 100 ks exposure.

- XIS SUM (0.4-10.0 keV) NXB/CXB subtracted
- HXD-PIN (10-70 keV) NXB subtracted

CXB level

Time (sec)
Suzaku clearly detected the Hard X-ray Emission at least up to \(~100\) keV, possibly higher.
Photon index and flux are consistent with those from INTEGRAL/RXTE 
($\Gamma=1.05+/-0.11, L=8.1E+34$ erg/s @ 20-100 keV)

Hard X-ray emission appears to be long-term stable
• Pulsations were detected by XIS/HXD at $P = 8.6888 \pm 0.0001$ s, which is consistent with a previous ephemeris. [R.Dib 2007]

• $3\sigma$ detection with HXD-GSO (80-150 keV)
Folded Pulse Shape

- Folded pulse shape is strongly energy dependent.

\[ \Delta t = 2 \text{ sec for XIS} \]

- XIS 0.4-1.7 keV
- XIS 1.7-4 keV
- XIS 4-10 keV
- PIN 10-20 keV
- PIN 20-70 keV
- GSO 80-150 keV

Counts/sec vs Phase
Short-term folded pulse shape

- Pulse folded for a short term,
- In low energy, a pulse shape is stable
- In high energy, pulse shape and pulsed fraction appear to change from epoch to epoch

Epoch 1
- XIS SUM (0.4-10.0 keV)
- HXD-PIN (10-70 keV)

Epoch 2
- XIS ~13% pulsed fraction

Epoch 3
- XIS SUM (0.4-4.0 keV)
- HXD-PIN (10-70 keV)

NXB+CXB level
Summary

• AXP 4U 0142+61 was observed with Suzaku for a 100 ks.

• Hard X-ray emission was clearly detected at least up to $\sim 100\text{ keV}$ with photon index 1.0, which is consistent with previous observations.

• Pulse shape is stable in low energy band, but in high energy it appears to change in a short-term during $\sim 2$ days.
Appendix
Multiband Spectra

Opt/IR Fall back disk?

Soft X-ray ($kT \sim 0.4$ keV)

Unexpected Hard X-ray ($\Gamma \sim 1$)

COMPTEL Upper limit $> 750$ keV

[P.R. den Hartog 2007]
Wideband spectra

Thermal comp. (kT ~ 0.4 keV)

$\epsilon = 1.0 + 0.5 - 0.3 + 0.3 - 0.3$

$F = 2.0 \times 10^{-11}$ erg/s/cm$^2$

@15–50 keV

$L = 6.9 \times 10^{34}$ erg/s

@20–100 keV

d = 3.6 kpc