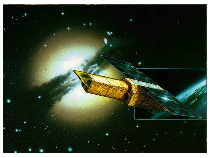
# Fe-rich ejecta in the northeast shell of RCW86 revealed with Suzaku



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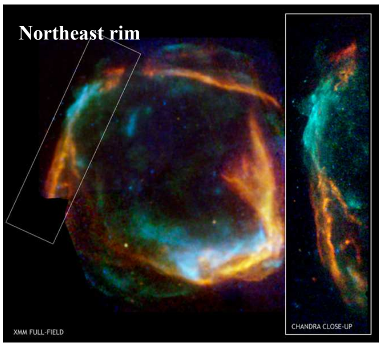
*Abstract:* We present the results of the Suzaku observation of RCW86, one of the historical Galactic supernova remnants (SNRs). By the imaging analysis, we revealed for the first time the morphology of the Fe-K emission in the northwestern shell of this SNR. The emission has no spatial correlation with the non-thermal X-ray filament, but is enhanced at the inward region with respect to the thermal emission from the blast-shocked dense interstellar medium. With the spectral analysis, we found that the Fe-K line (E ~ 6.42 keV) was reproduced by the thermal plasma with an extremely low ionization age of $n_et \sim 2 \times 10^9$ cm$^{-3}$ s. These results suggest that the origin of the Fe-K emission is Fe-rich ejecta heated by reverse shock very recently.

## 1. Introduction

**RCW86 (G315.4 -2.3)**
One of the historical Galactic SNRs
A possible remnant of SN in AD 185
→ Age ~ 1800 yr
Distance = 2.8 kpc (Rosado+1996)

**Previous X-ray observations**
ASCA : Discovered synchrotron X-rays (Bamba+2000, Borkowski+2001)
Chandra, XMM-Newton : Revealed detailed structure (right figure)

**Northeast rim** : soft-thermal and non-thermal emission filament join smoothly along the outer shell (Vink+2006).




Red : 0.5-1 keV (thermal plasma)
Blue : 2-6 keV (synchrotron X-rays)
Vink+2006

・6.4 keV Fe-Kα line (corresponding to emission from Fe I) detected by ASCA
→ Fluorescence caused by supra-thermal electrons ? (Vink+1997)
→ Fluorescence caused by synchrotron X-rays ? (Tomida 1999)
⇒ Chandra and XMM-Newton failed to detect Fe-Kα from this region. Therefore, the origin of Fe-K emission is still unknown.

**Scientific goal of the Suzaku observation**
∴ To reveal the origin of Fe-Kα emission
⇒ It is necessary to investigate the morphology and ionization state of Fe emission.

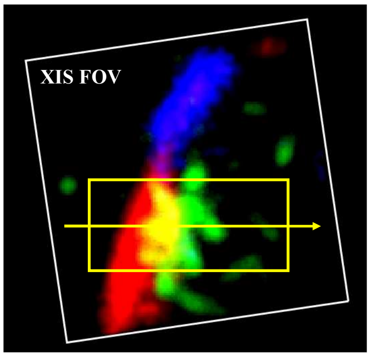
**The merit of Suzaku** : the highest sensitivity for diffuse sources and good energy resolution in the 5-10 keV range, which includes Fe-K lines.

## 2. Suzaku Image

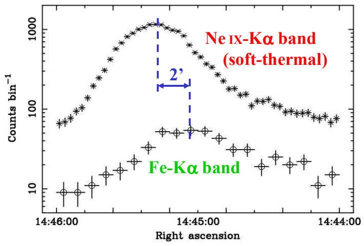
The effective exposure time of the Suzaku observation was obtained to be ~ 53 ksec.

Suzaku/XIS image
Red : 0.5-1 keV (thermal plasma)
Blue : 3-6 keV (non-thermal X-ray)
Green : 6.3-6.5 keV (Fe-Kα emission)

We revealed the morphology of Fe-K emission in this region, for the first time!



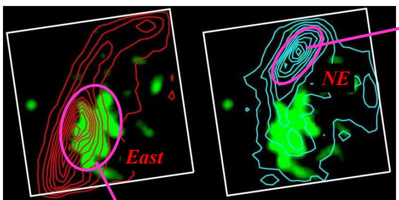

Projection profiles for the rectangular region shown in the right figure

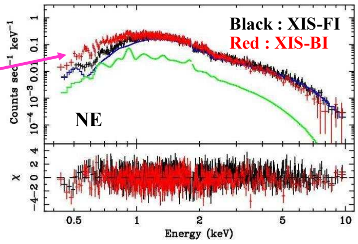


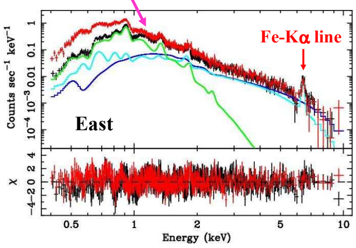

・No spatial correlation between the Fe-Kα and hard X-ray emissions.
・Fe-K peak is significantly shifted to the inner region from the soft emission.

⇒ The origins of these emissions are different from each other?

## 3. Spectrum




**Fe-Kα energy : 6424 (6404-6444) eV**
⇒ Ionization state of Fe = +8 ~ +16
⇒ Low ionized thin-thermal plasma origin ! (NOT fluorescence)

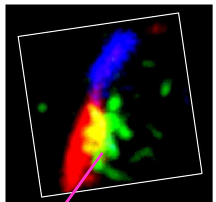
**East** : NEI plasma × 2 + power-law
low-kT: ~0.3 keV, metal abundance : sub-solar
high-kT: ~1.8 keV, Fe-rich ( >14 solar) plasma age < 380 yr ( << 1800 yr)

**NE** : low-kT component + power-law (power-law dominant)

## 4. Discussion

### 4.1 Origin of the components

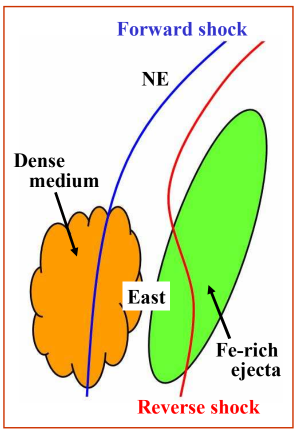
**Power-law** (Γ ~ 2.8)
・Spatially connected from East
⇒ Synchrotron emission from TeV electrons accelerated at the forward shock front
NE : high shock velocity
$V_s$ = 2700 km/s (Vink+2006)

**~ 0.3 keV plasma**
・Sub-solar metal abundance
・Spatially coincident with Hα filament (Smith 1997)
⇒ ISM heated by forward shock
East : high ISM density

**~1.8 keV plasma (Fe-Kα)**
・Fe abundance : over-solar
・Enhanced at the inward region
・Plasma age < 380 yr
⇒ Fe-rich ejecta heated by reverse shock very recently
$M_{Fe}$ = 0.07 (0.06 – 0.6) $M_\odot$
⇒ A portion of the Fe Ejecta?

### 4.2 Unified picture




Schematic view of the interpreted structure of RCW86 northeast region

Possible scenario to explain the present morphologies and spectra of each component.

The East and NE rims were expanding with same high velocity until a few hundred years ago.

<<East rim>>
Collided with a dense medium very recently.
⇒ Forward shock decelerated rapidly.
At the same time, reverse shock began to move inward to the interior of the SNR.
⇒ Fe-rich ejecta was heated.

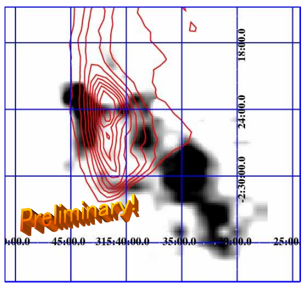
<<NE rim>>
Forward shock is still expanding in a tenuous region, and hence keeps a high shock velocity.
⇒ Efficient cosmic-ray acceleration is maintained.
⇒ Strong synchrotron emission.
Reverse shock also expand with high velocity. Therefore, it has not yet reached the Fe-rich ejecta layers ⇒ Fe-K emission at NE is absent.

## Preliminary Result of ASTE CO Observation

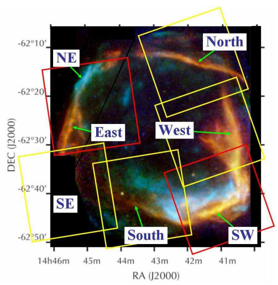
**Search for the shocked molecular gas**

Since RCW86 is an SNR in the OB association (Westerlund 1969), a candidate for the "dense medium" is either a wind-blown wall surrounding the SNR (suggested by Vink+1997) or a molecular cloud.

We recently performed CO observations of the surrounding of the RCW86 northeast region with ASTE (Atacama Submiliimeter Telescope Experiment), and found the molecular cloud interacting with the East rim of RCW86 !




Gray scale : ASTE CO (J3-2) map
Contour : Suzaku 0.5-1.0 keV




## Future Suzaku Observations

The mapping observations on entire RCW86 had been approved as the target of the Suzaku AO-3 cycle observations. It will be carried out soon!

The FOVs of approved Suzaku observations are shown with the yellow frames in the left figure.