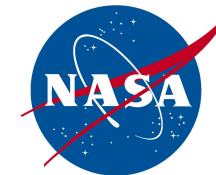
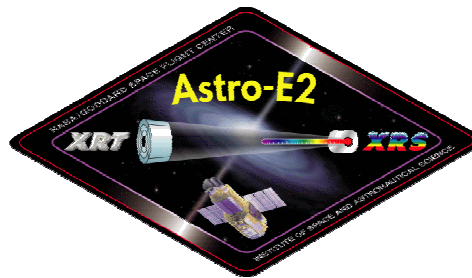
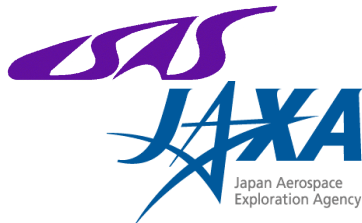


# High resolution X-ray spectroscopy with Astro-E2 XRS: Status and Prospects

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Institute of Space Astronautical Science,  
Japan Aerospace Exploration Agency



# Outline

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- Status of the Astro-E2 mission
  - Current X-ray observatories
  - Mission details
  - Tests/Results/Schedule
- Prospects for X-ray studies of clusters
  - New Chandra/XMM results
  - Scientific topics with XRS
  - Feasibilities of some clusters

# X-ray Observatories



## The Three Major Satellites

Chandra .. High spatial resolution

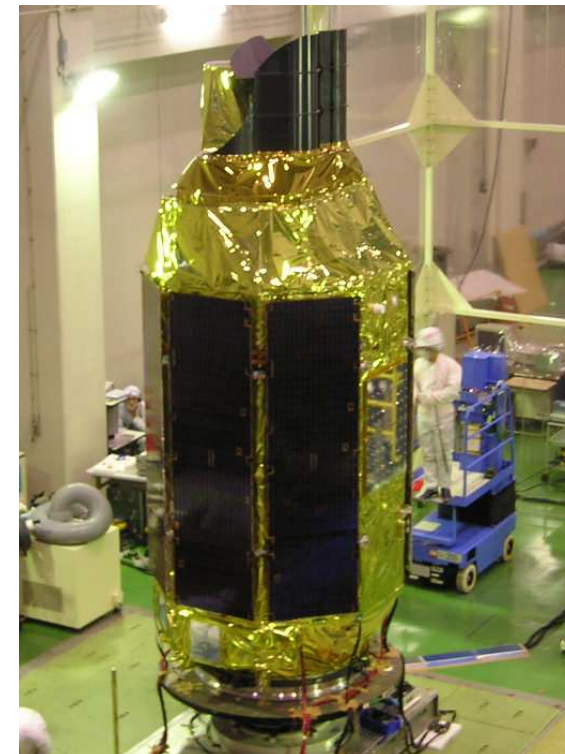
XMM-Newton .. Large effective area

Astro-E2 .. High spectral resolution

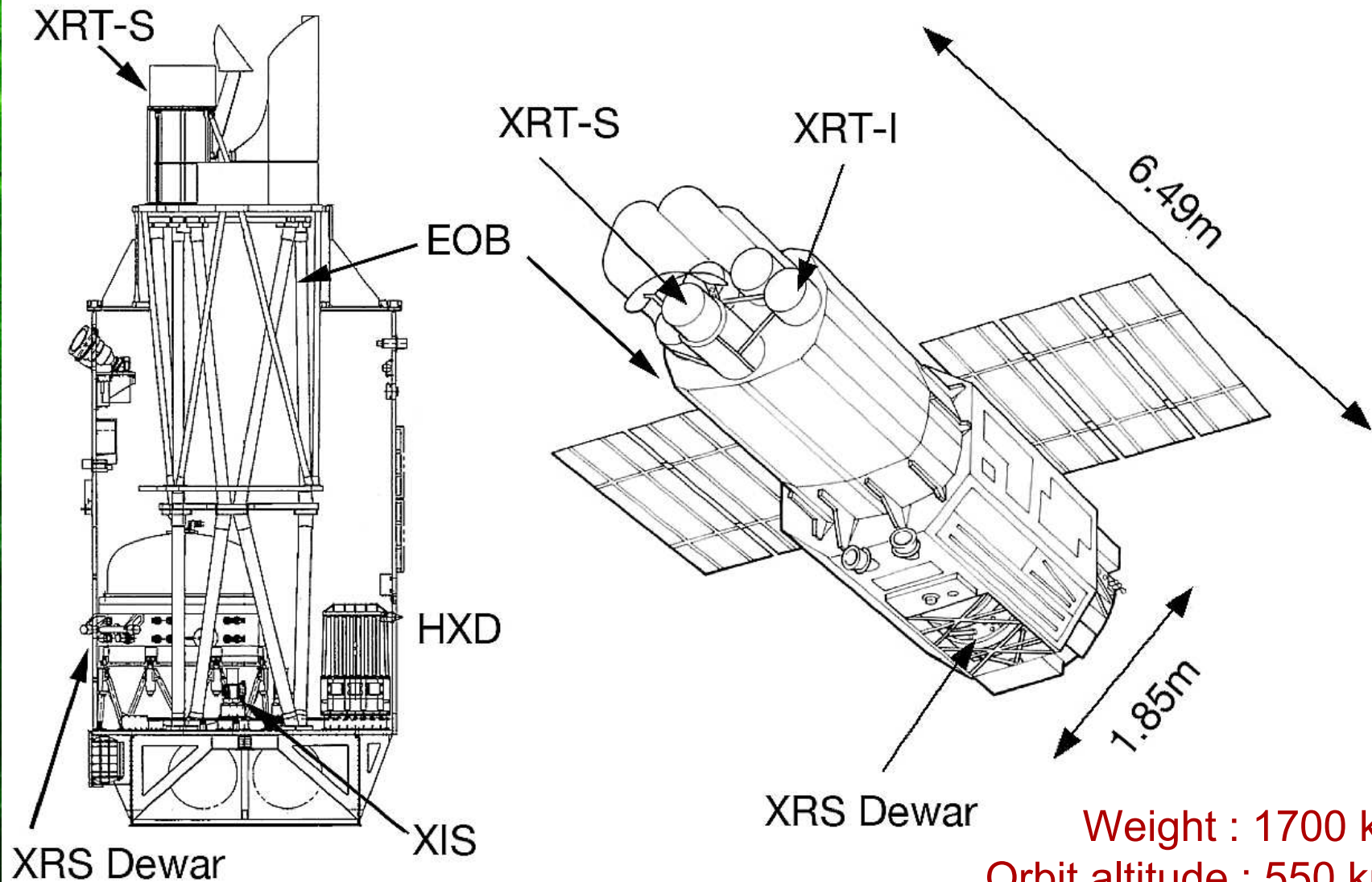
# The Astro-E2 Mission

Astro-E2 is a powerful X-ray observatory developed jointly by the Japan (ISAS/JAXA) and US (NASA/GSFC).

- High x-ray spectral resolution throughout energy band where bulk of astrophysically abundant elements exist (O - Ni)
- Non-dispersive spectrometers enable imaging spectroscopy of extended sources
- Large collecting area for high sensitivity
- *Very* large simultaneous bandwidth to enable disentangling complex, multi-component spectra

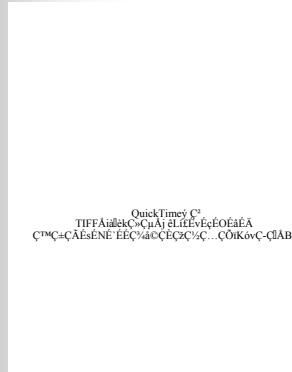


# The Spacecraft



Weight : 1700 kg  
Orbit altitude : 550 km  
Orbital period : 96 min

# Astro-E2 Instruments



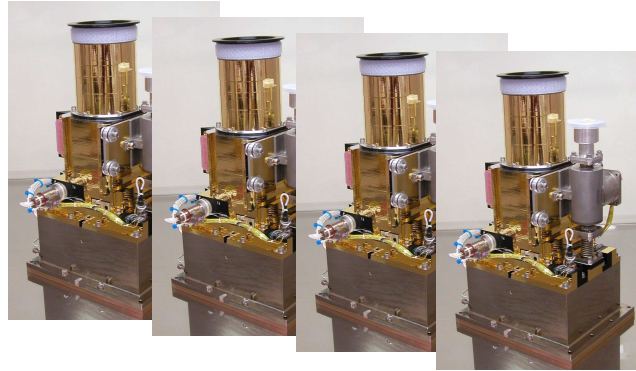
## XRS

X-Ray Spectrometer

X-ray calorimeter

Band: 0.3 - 12 keV

FOV: 2.9' x 2.9'



## XIS (x4)

X-ray Imaging Spectrometers

X-ray CCD cameras

0.2 - 12 keV

18' x 18'



## HXD

Hard X-ray Detector

Si PIN + Scintillators

10-40/30-600 keV

34'x34'/4.5°x4.5°

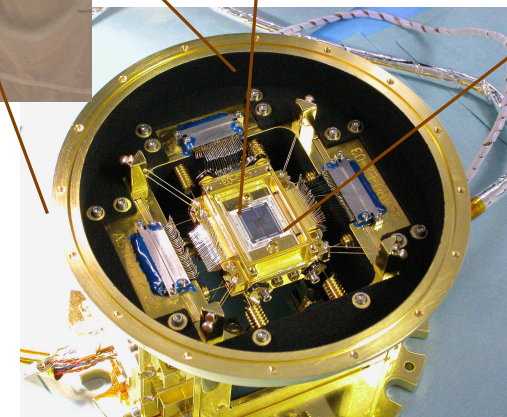
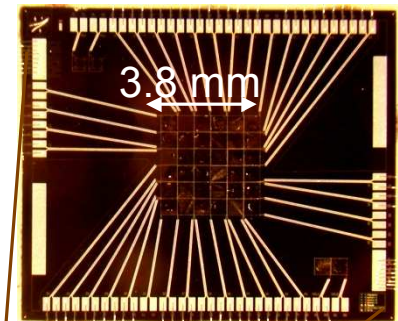
with XRT (x5)

X-Ray Telescopes

Angular resolution ~2 arcmin



# The X-Ray Spectrometer



QuickTime<sup>®</sup> C<sup>2</sup>  
TIFF Aialek C>CuAj ðLiEñEçEÖEáEÁ  
C™C=ÇAEsENE'EEC%a©CEÇZC%Ç...ÇÖIKöVÇ-çIAB

PI: R. Kelley (NASA/Goddard)

- 6x6 array with 30 available pixels
- Operate at 60 mK cooled by
  - solid Ne dewar (17 K)
  - liquid He cryostat (1.3 K)
  - the Adiabatic Demagnetization Refrigerator (60 mK)
  - the mechanical cooler
- Expected lifetime is 2-3 years

# Integration & Tests

Calibration at NASA/GSFC



03/Dec 04/Jan

Install the ensors & ADR into the He insert



Feb

Shipping from US to Japan



Mar

Install the He insert into the dewar at SHI



Apr

Attach MLI



May

Attach the aperture filters

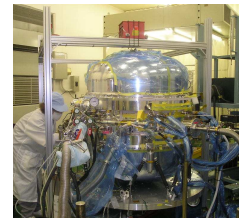


Jun

Mount the electronics onto the S/C panel at ISAS



Jul

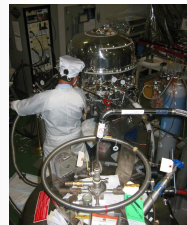


Aug

Shipping from SHI to ISAS Vib test at ISAS

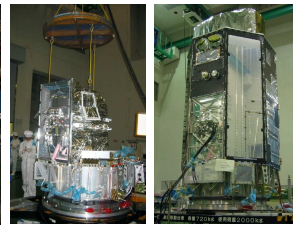


Ne100% fill



Sept

Mount onto S/C



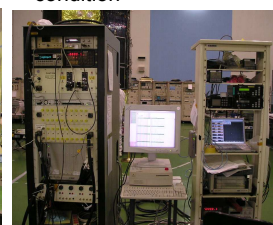
Oct

S/C vib test at ISAS



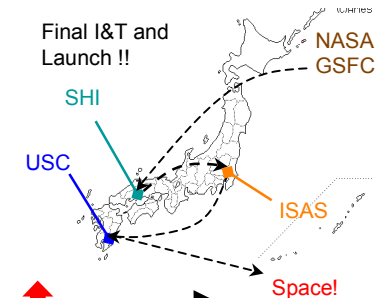
Nov

Maintain the temperature condition



Dec

Final I&T and Launch !!

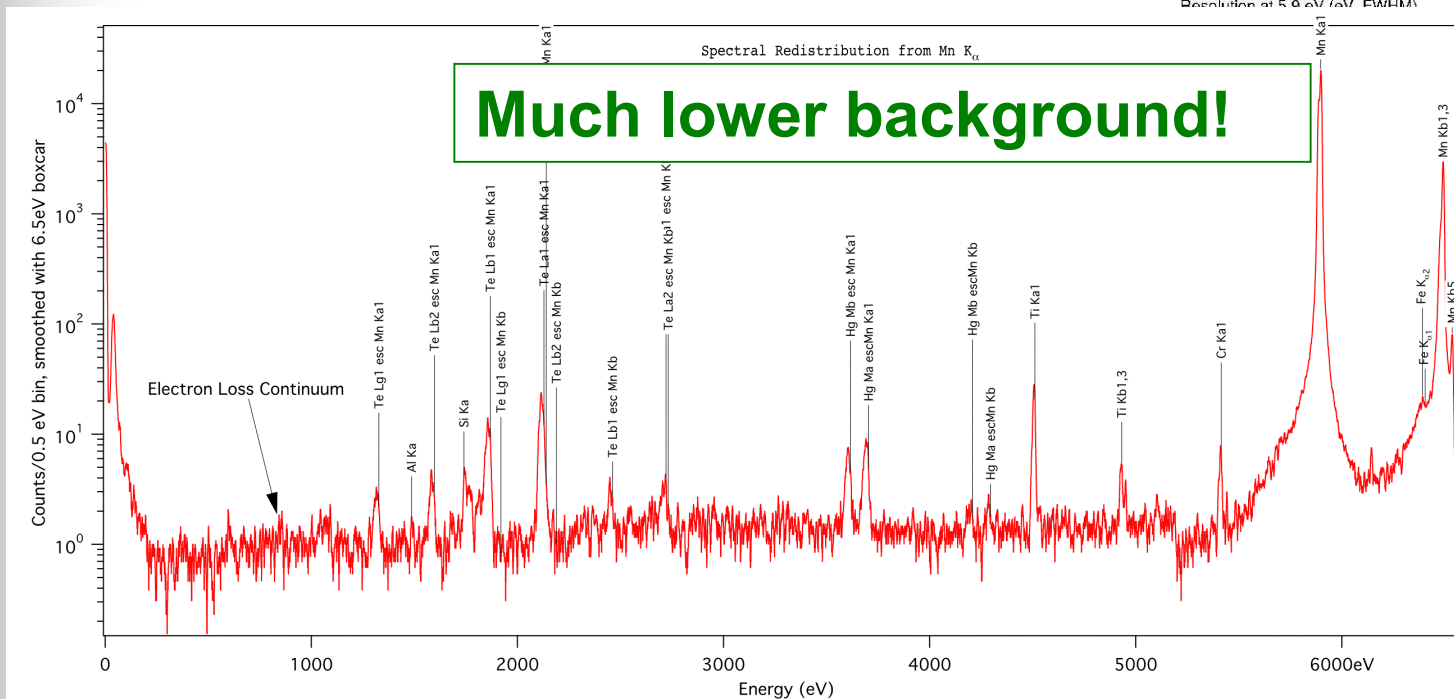
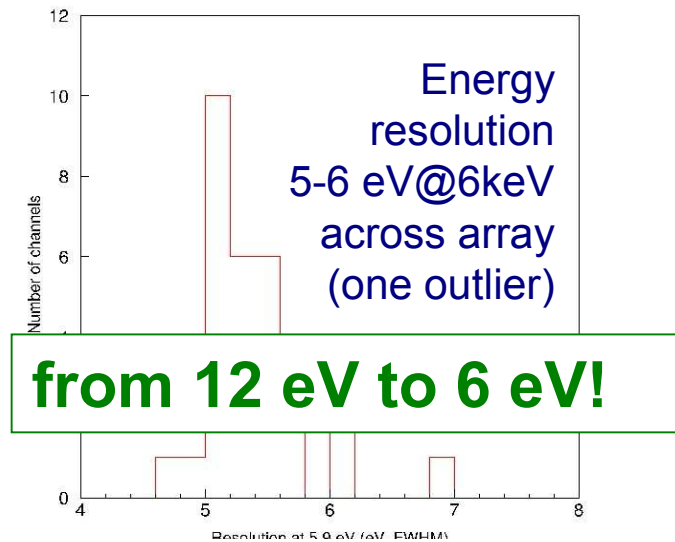
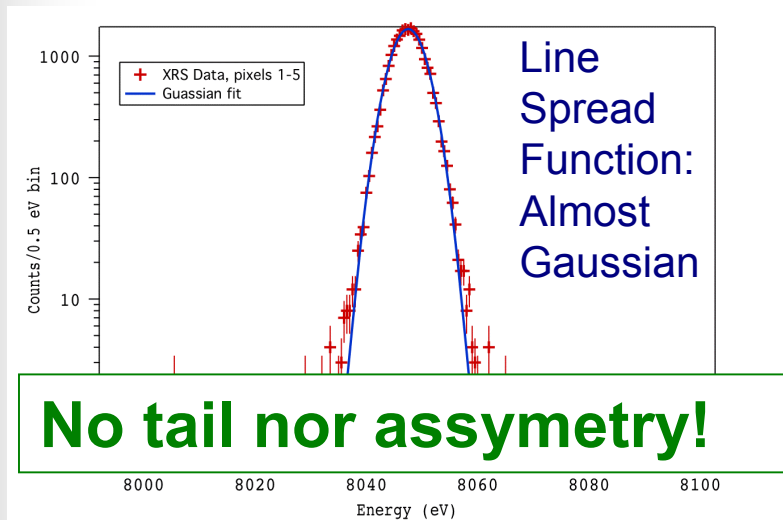


.. summer , 2005

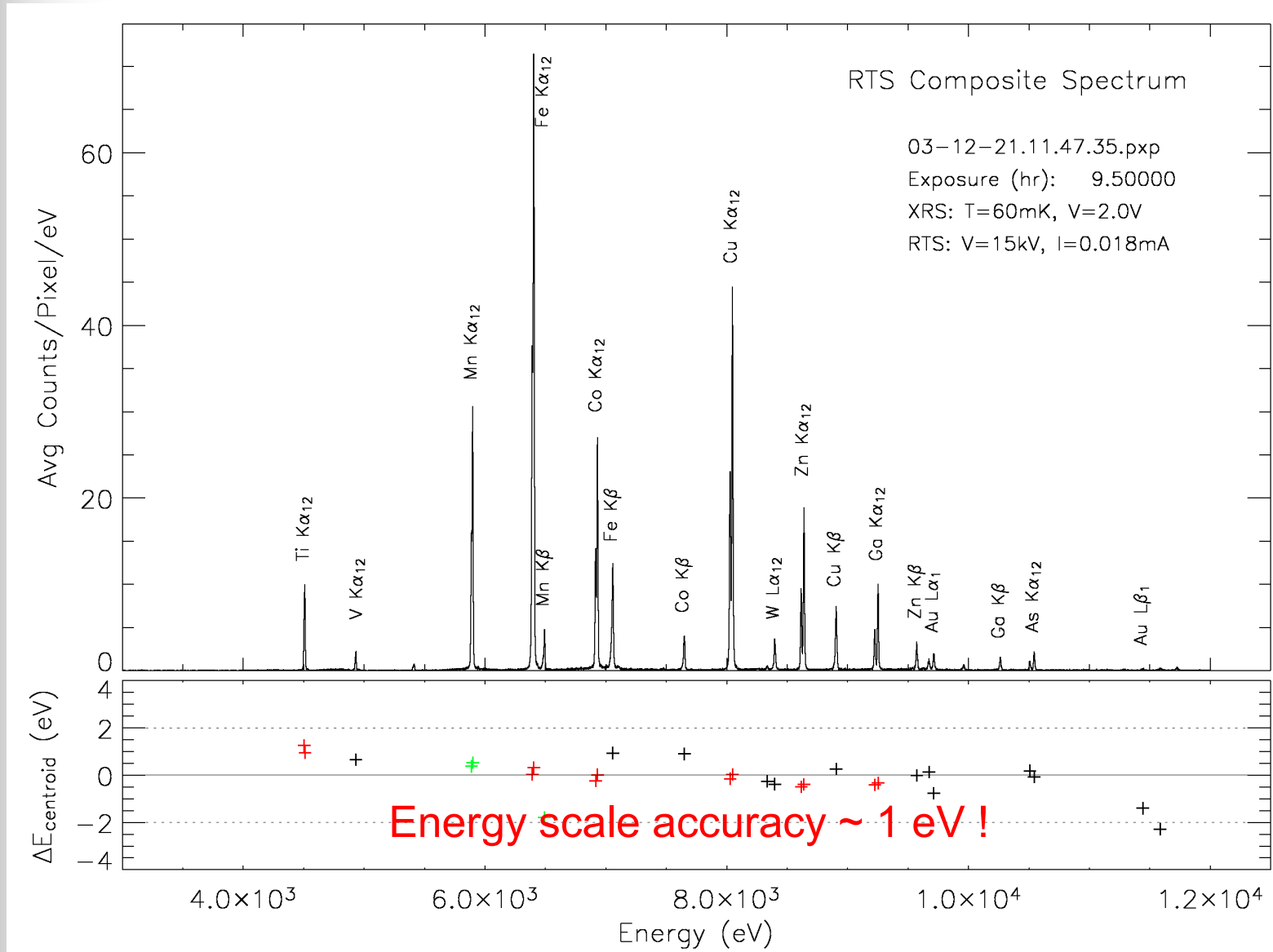
The launch date was in Jan, but delayed.



# Performance of XRS



# Energy Scale



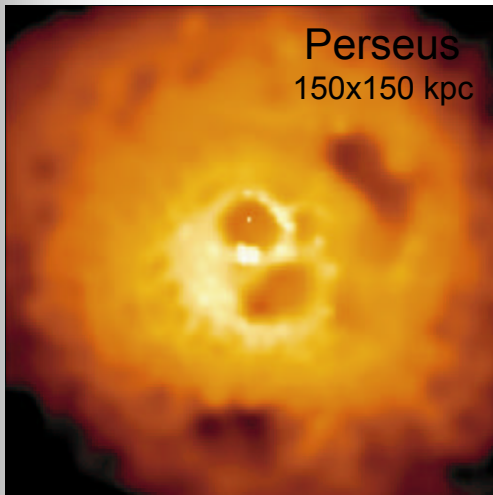
# Prospects for cluster studies with XRS

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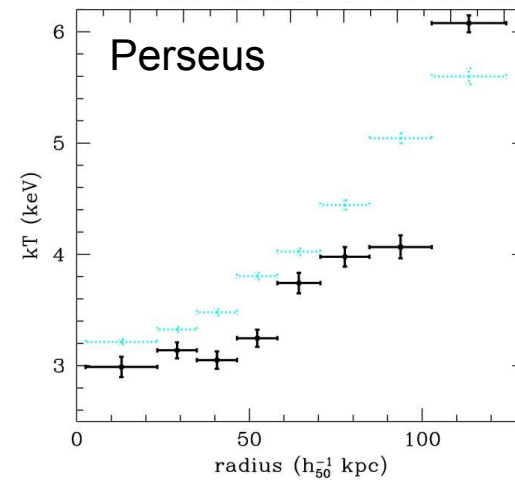
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# New Results by Chandra/XMM

## I. Complex cores

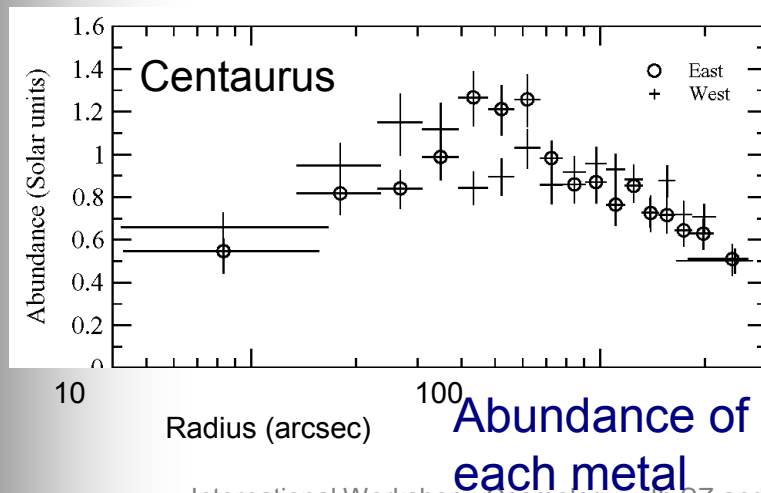


## II. Lack of very cool gas

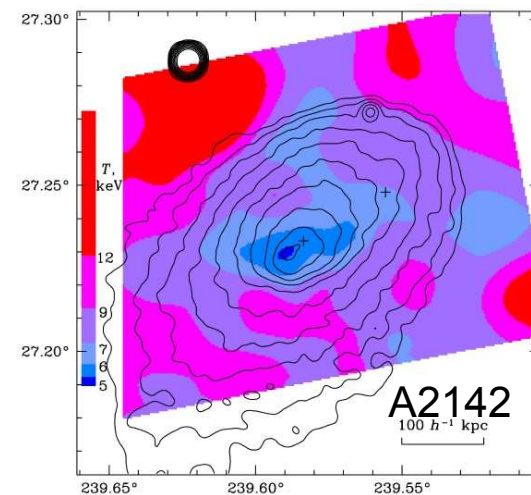


Emission lines from cold gas

## III. Metallicity ring, blobs, Si/Fe



## IV. Cold fronts / Shock fronts



Gas motion at  $v \sim 1000$  km/s

# Sciences in Galaxy Clusters with XRS

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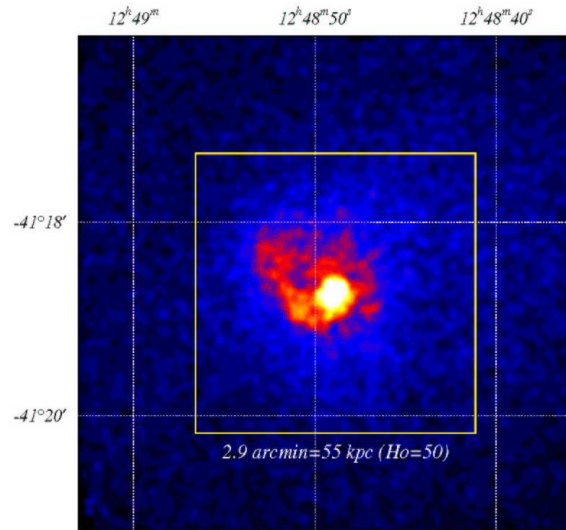
- Measure metal abundances from Oxygen to Nickel precisely more than ever
- Detect and measure line profiles resulted from gas motion such as turbulence, cold front, or subcluster merger
- Diagnose plasmas from line ratios.

Clusters in the Performance Verification Targets:

Perseus, Centaurus, A1795, A2199

A754, A2256, A3667, A2142, A520, A2218, A2597

# Abundance/Cooler gas (Centaurus)



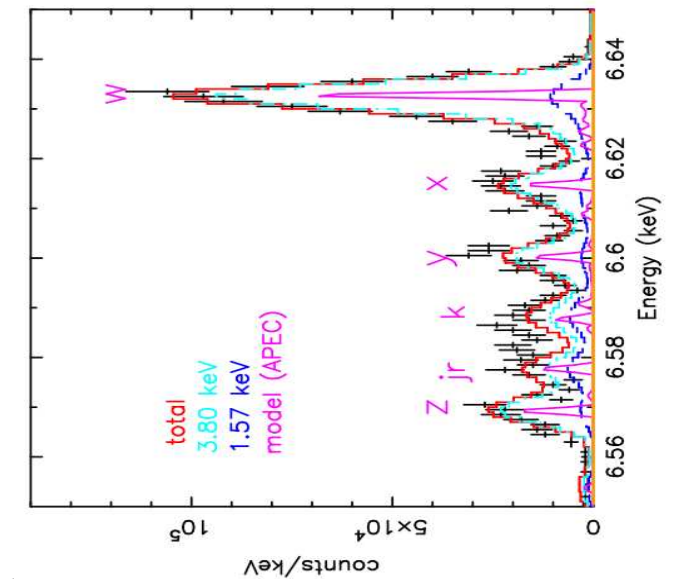
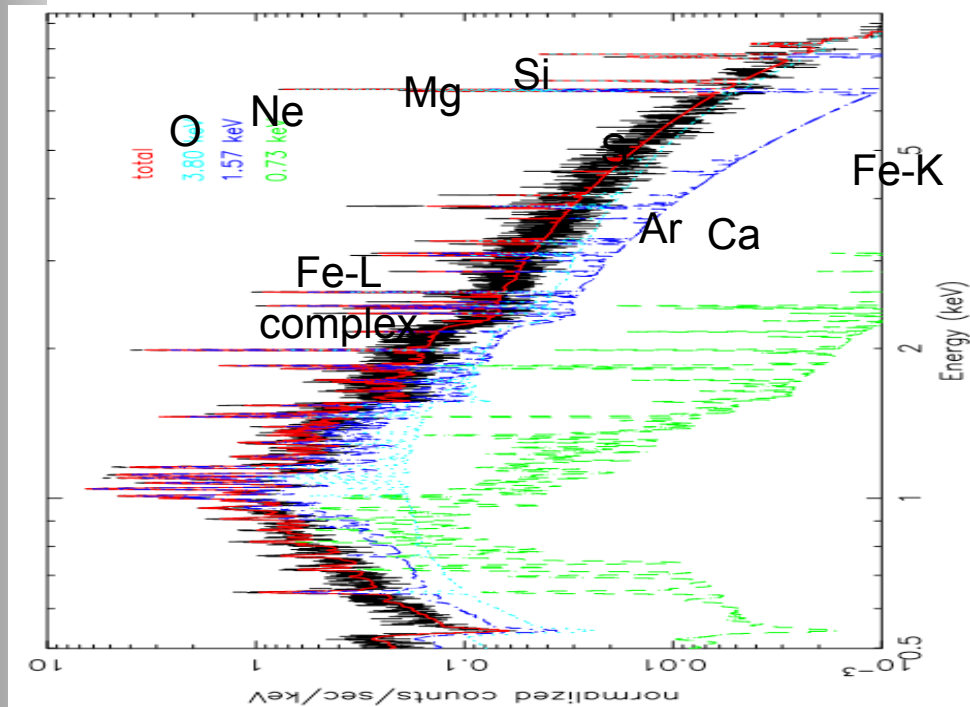
$z=0.011$ ,  $kT=1-3$  keV,  $Z=1-2$  solar

Strong emission lines → **line intensity**

Bright and complex core

2 or 3 temperature components?

Takahashi et al. In prep



# Dynamics - Core (Perseus)



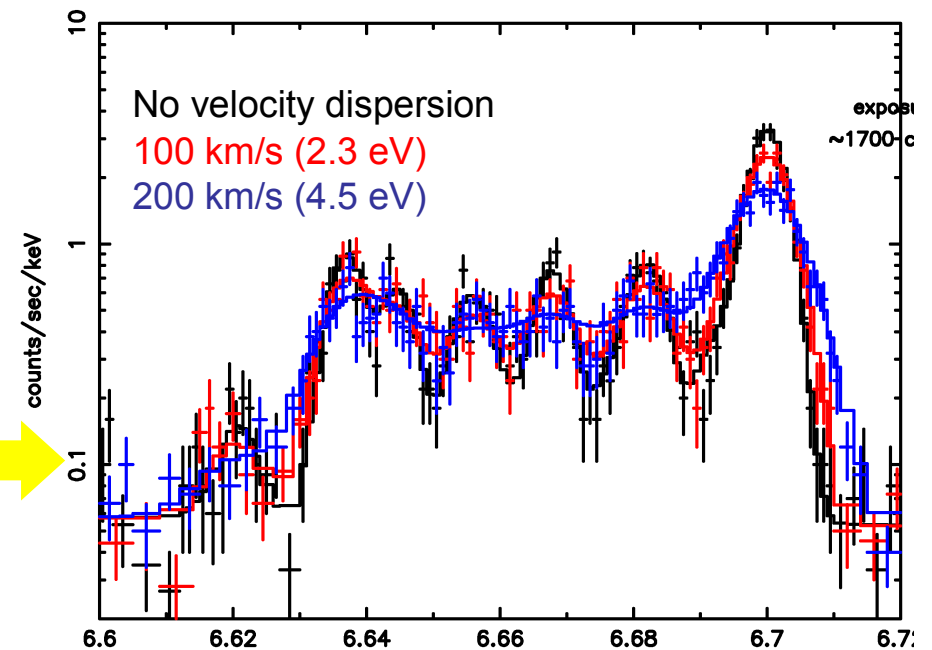
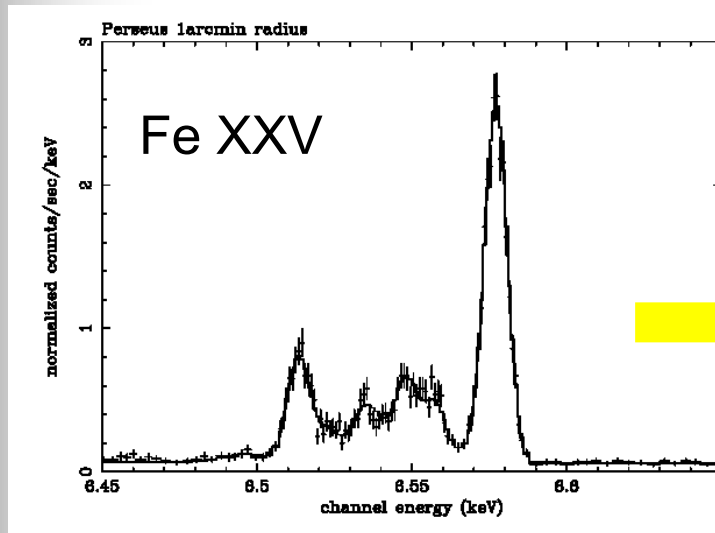
Fabian et al. 2003

$z=0.018$ ,  $kT=4-6$  keV,  $Z=0.5$  solar

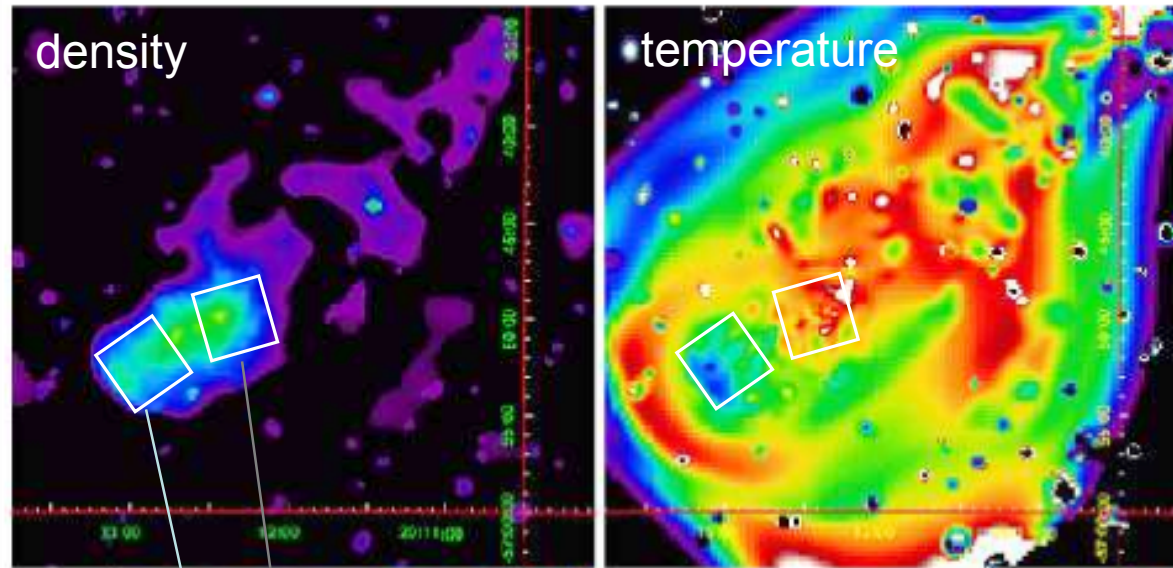
Brightest Fe-K line

Active gas motion → line broadening

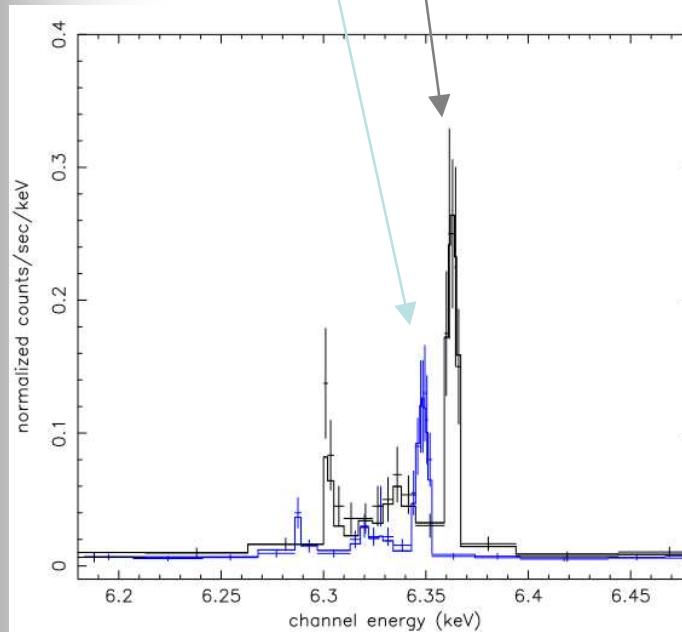
Resonance scattering



# Dynamics - Cold front (A3667)



Briel et al. 2004

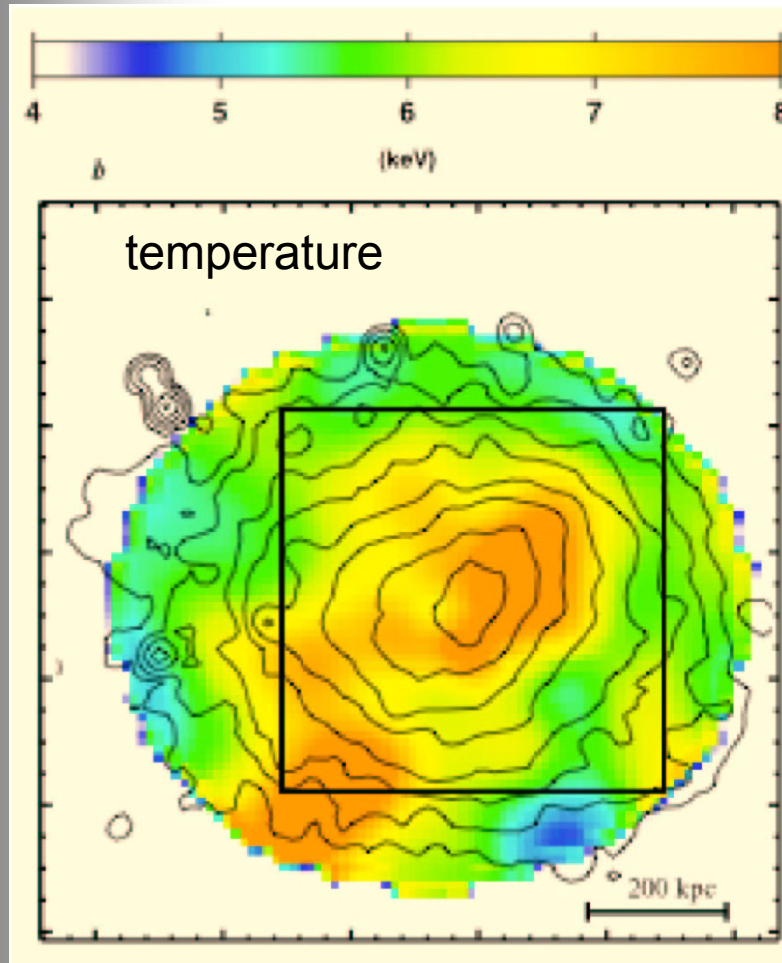


$z=0.055$ ,  $kT=6-7$  keV,  $Z=0.3$  solar

Remarkable cold front  
by a cool gas cloud moving  
at  $v \sim 1400$  km/s  $\rightarrow$  **line shift**



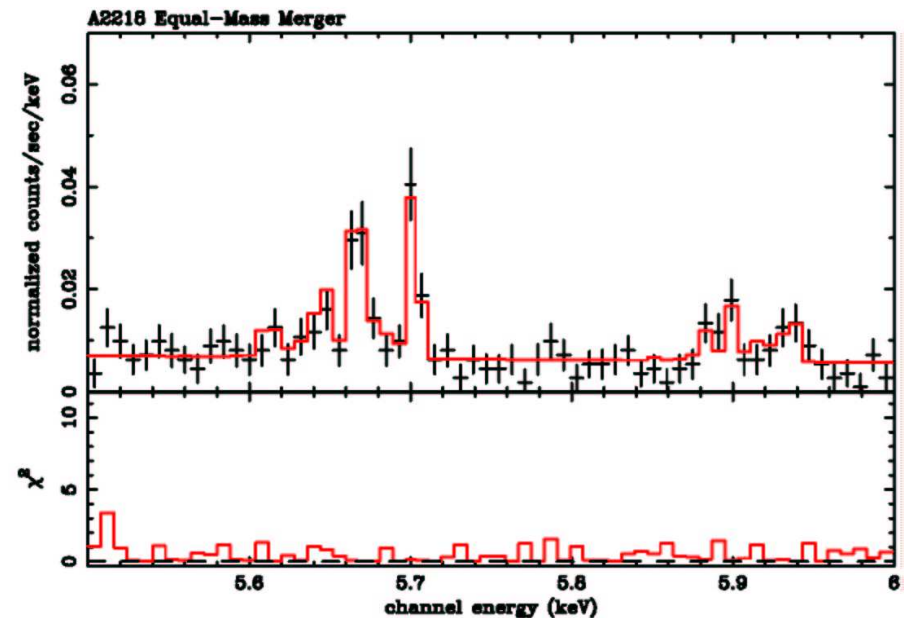
# Dynamics - LOS Merger (A2218)



Markevitch et al. 2003

$z=0.18$ ,  $kT=7$  keV,  $Z=0.2$  solar

Discrepancy in lens/X-ray mass  
Line of sight merger w/  $v \sim 2000$  km/s  
→ line shift

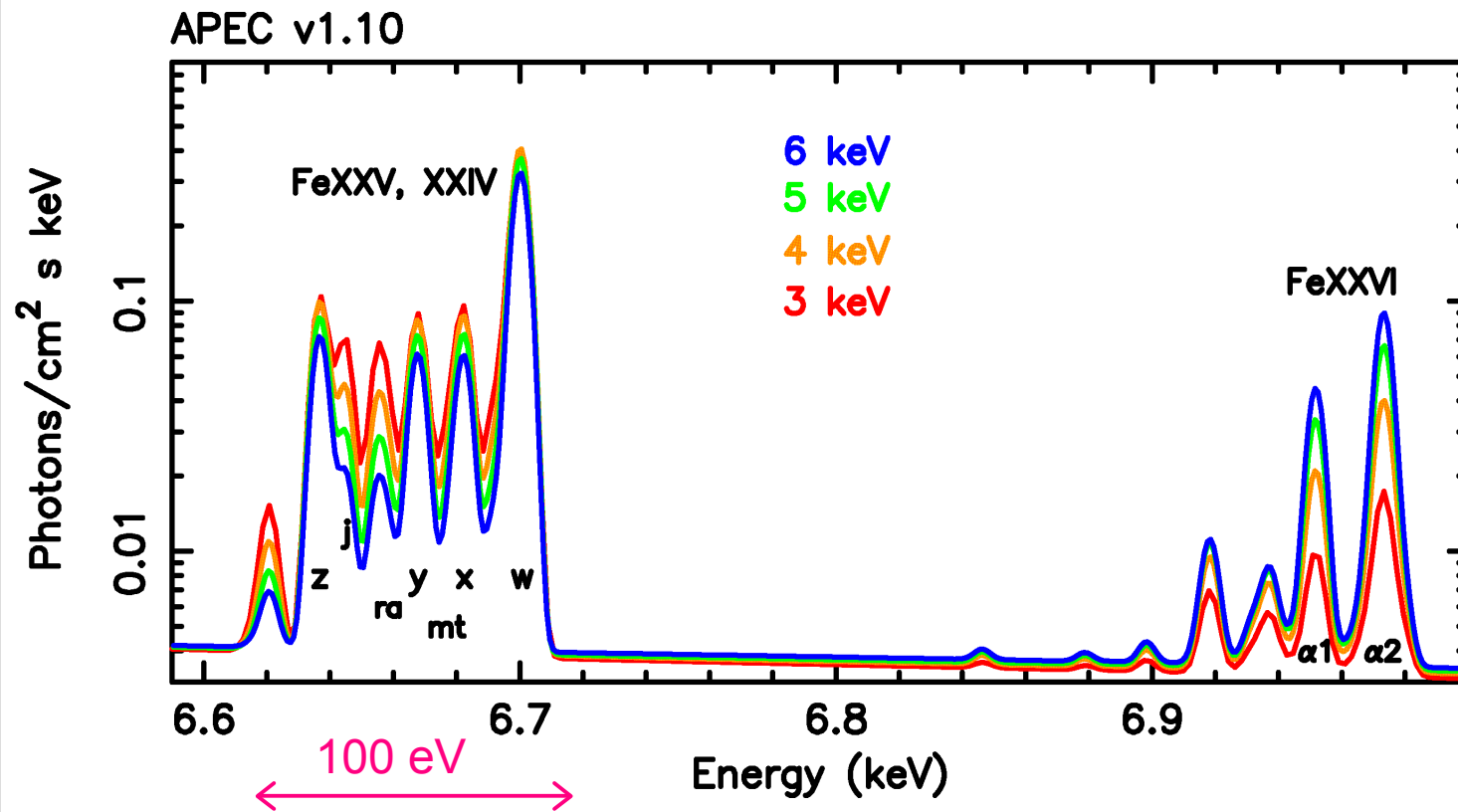


# Plasma Diagnostics

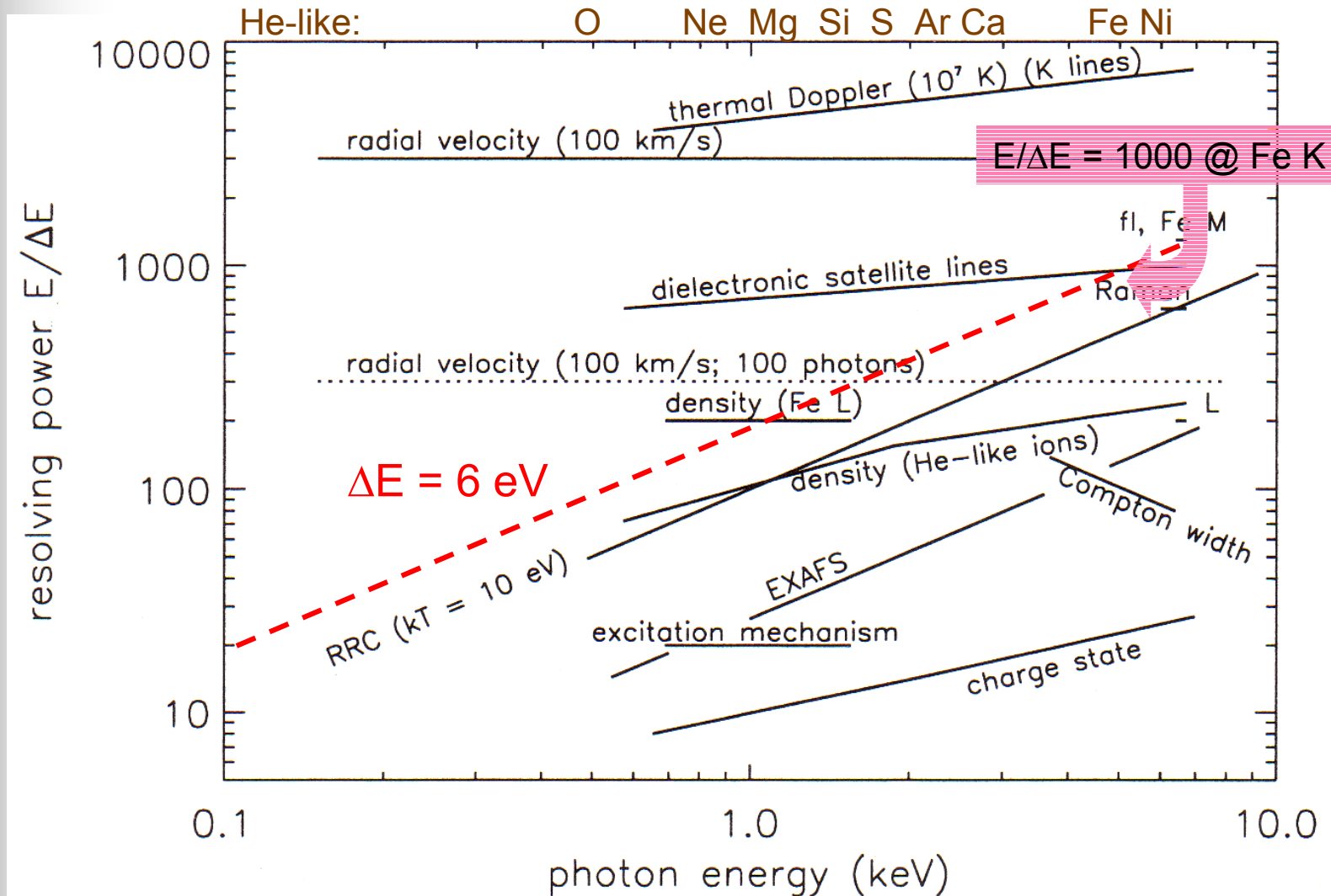
Line ratios give us physical parameters directly!

$j/w$  : electron temperature

$z/w$ : ionization level



# Spectral Diagnostic Thresholds and XRS Resolution



Spectral diagnostic thresholds and XRS resolution of 6 eV (diagram from F. Paerels)

# Time Allocation

<http://www.astro.isas.jaxa.jp/astroe/index.html.en>

Phase: PV	AO1	AO2	AO3?	AO4
SWG 100%	SWG 25%	SWG 15%	GO 100%	GO 100%
	GO 75%	GO 85%	Japan 42.0%	Japan 50%
	Japan 31.5%	Japan 35.5%		
	US 32.5%	US 37.5%	US 37.5%	US 30%
	ESA 6.0%	ESA 7.0%	ESA 8.0%	ESA 10%
	J-US 5.0%	J-US 5.0%	J-US 12.5%	J-US 10%
1 7/8	19/20	31/32	36?	months

Targets to be observed are already fixed

AO-1 clusters:

AWM7, A478, A496, A1689, A2029, A2052,  
A2319, A3571, A4059, 2A0335, ...

Depends on the  
lifetime of XRS

XIS & HXD only

# Summary

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- XRS has been improved, and achieved an ultimate energy resolution of 6 eV (FWHM) at 6 keV
- XRS observations of cluster emission line profiles (line intensity, shift, broadening, & symmetry) offer a “new window” on ICM:
  - Precise abundance values
  - Energy and gas flows during cluster growth
  - Signatures of turbulence in cores
- The launch will be soon! (in June or July)



International Workshop : Cosmology with SZ and X-ray Observatories at Sophia Univ, March 5-6, 2005