XMM-NEWTON X-RAY PROPERTIES of DISTANT PKS 0745-191 GALAXY CLUSTER

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INTRODUCTION

CLUSTERS OF GALAXIES

- The largest comprehensive samples of the universe.
- X-ray emission from intra-cluster medium (ICM) contains hot dilute gas provide information on:
 - The evolution of the cluster
 - chemical enrichment and,
 - processes causing the enrichment.
- By investigation of:
 - the temperature,
 - electron density,
 - pressure,
 - entropy of a cluster.



INTRODUCTION

PKS0745-191

- A well studied cluster at the outskirts and to the virial radius with Suzaku (Walker+ 2009,2012, George+ 2014).
- Chandra studies of the central region (Sanders+ 2014)
- Brightest distant cluster, z~0.1028
- Cool core, relaxed.
- Chen+ 2003: the temperature and abundance profiles with XMM-Newton 2000 data (one center and one off center observation) (total clean exposure time about 75ks.) BUT spectral fitting of MOS and PN was not simultaneous.



INTRODUCTION

PKS0745-191

This work;

- 2014 XMM-Newton observation of the cluster each EPIC camera <u>clean</u> exposure over 90ks!
- Focus on the central region of the cluster with much thinner annuli.



Observations	ID	Start Date	End Date	Pointing RA	Pointing Dec
(Center)	ID	yyyy-mm-dd	yyyy-mm-dd	(J2000)	(J2000)
Scheduled	0744340101	2014-10-07	2014-10-07	07h 47m 31.25s	-19d 17′ 40.3"
Unscheduled	0744340101	2014-10-09	2014-10-09	07h 47m 31.25s	-19d 17′ 40.3"

Principle Investigator: Sanders, Jeremy

Table 1. XMM Observations

OBSERVATION IDENTITY AND EXPOSURES

The unscheduled observations with prefixes **U002** were used for the analysis due to the longer exposure times to improve statistics.





XMM-NEWTON EPIC

EPIC: EUROPEAN PHOTO IMAGING CAMERAS





EPIC 2014 EXPOSURES OF PKS0745-191.

Notice The Missing CCDs!



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DATA PREPARATION & SPECTRAL ANALYSIS



DATA PREPARATION

- Cleaning of the raw data, queiscent particle background subtraction, image production, and annuli spectra production → ESAS package of SAS software, v16.0. with the latest calibration files and additional CalDB files were used.
- Due to ground problems during the observation, unscheduled observations of EPIC cameras (ID: U002) with exposure times longer than 100 ks were used (Table2).

Exposite ID	Instrument	Duration	Clean Exposure
Exposure ID	mstrument	(sec)	(sec)
S001	EMOS1	9039	Unprocessed
S002	EMOS ₂	9027	Unprocessed
S003	EPN	5334	Unprocessed
U002	EMOS1	106160	95670
U002	EMOS ₂	106157	97100
U002	EPN	107313	75930

Table 2: Scheduled and Unscheduled Exposures









SPECTRAL FITTING

- 10 annular regions from the center of the cluster to $\sim 0.5~R_{500}$
- Background estimation, ROSAT All Sky Survey (RASS) data for PKS0745-191.
- The galactic absorption column density → fixed (NED search): 4.2x10²¹ cm⁻².
- Spectral fits \rightarrow **XSPEC** v12.9.1 using chi-square statistics.
- Spectra \rightarrow a single temperature APEC model.

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- <u>Outermost</u> annulus → another cool temperature component model, requires a double temperature APEC model.
- DsDeproj code Russell et al. (2012) → to obtain the deprojected spectra,
 - and the best fit parameters of deprojected spectra were used to
 calculate the cluster's <u>pressure</u> and <u>entropy</u> profiles.



RESULTS

SPECTRAL FITS



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Figure 4 The temperature and abundance profiles by using 1T APEC model.

able 3: Simultaneous projected spectra fit of EPN and EMOS				
with a single temperature model. Errors represent 90				
per cent ($\Delta \chi^2$ = 2.71) confidence limits.				
Regions	Temperature	Abundance	χ^2	d.o.f.
(arcmin)	(keV)	(Z_{\odot})		

(arcmin)	(keV)	(Z _☉)		
0-0.25	$4.01^{+0.04}_{-0.04}$	$0.42^{+0.01}_{-0.01}$	1.54	1380
0.25-0.50	$5.05_{-0.04}^{+0.05}$	$0.37\substack{+0.01\\-0.01}$	1.43	1830
0.50-0.75	$5.54^{+0.08}_{-0.04}$	$0.36^{+0.01}_{-0.01}$	1.66	1655
0.75-1.00	$6.17\substack{+0.09\\-0.08}$	$0.35_{-0.02}^{+0.02}$	1.40	1477
1.00-1.50	$6.52\substack{+0.08\\-0.07}$	$0.34_{-0.02}^{+0.02}$	1.39	1893
1.50-2.00	$6.62\substack{+0.08\\-0.08}$	$0.34_{-0.02}^{+0.02}$	1.48	1660
2.00-2.50	$6.97^{+0.15}_{-0.15}$	$0.29^{+0.02}_{-0.02}$	1.43	1290
2.50-3.50	$7.36^{+0.16}_{-0.14}$	$0.28\substack{+0.02\\-0.02}$	1.39	1356
3.50-4.50	$6.68^{+0.14}_{-0.13}$	0.30+0.03	1.72	960
4.50-5.50	$6.45_{-0.10}^{+0.10}$	0.300 (fixed)	1.73	748

RADIAL TEMPERATURE AND ABUNDANCE PROFILES OF PROJECTED SPECTRA

NOTICE THE TEMPERATURE INCREASE BETWEEN 0'.0-3'.0



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Table 4: Simultaneous projected spectra fit ofEPN and EMOS, comparison of single temperature model and
two component temperature model for region 10.

Model	Regions	Temperature	Abundance	χ^2	d.o.f.
(1T vs. 2T)	(arcmin)	(keV)	(Z _☉)	$(\Delta\chi^2=2.71)$	
1T	4.50-5.50	$6.45\substack{+0.10\\-0.10}$	0.300 (fixed)	1.73	748
2T: T _{cool}	4.50-5.50	$2.17_{-0.46}^{+0.59}$	$0.14_{-0.08}^{+0.09}$	1.30	744
2T: T _{hot}	4.50-5.50	$10.19\substack{+0.56 \\ -0.68}$	$0.43\substack{+0.06\\-0.07}$	1.30	744

FOR THE OUTMOST ANNULUS, STATISTICS OF SINGLE TEMPERATURE & TWO TEMPERATURE **APEC** MODEL ARE COMPARED.

Improvement in resulted fits suggest that around 5'.0, there may exist a multi-phase gas.





Figure 5 :

Deprojected radial temperature and electron density profiles are obtained from single temperature apec model in 0.7 – 9.0 keV energy range. The statistical errors at 90% confidence level.

DEPROJECTION : FROM 2D TO 3D TEMPERATURE and DERIVED ELECTRON DENSITY PROFILES





RADIAL PRESSURE AND ENTROPY PROFILES ARE DERIVED

(drived from the deprojected spectra)



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CONCLUDING REMARKS

- The central radial temperature and abundance profiles are in good agreement with the work of Chen + 2003).
- Self consistent entropy profile up to $\sim 0.5 R_{500}$.

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- For the outmost annulus, we have compared the statistics of single temperature and two temperature APEC model.
 Improvement in resulted fits may suggest that around 5'.5, there is multi-phase gas existing → another structure?
- Temperature at the core is comparably lower than the neighboring regions pointing that PKS 0745-191 is a cool core cluster.
- The abundance profile shows a constant trend up to $\sim 0.5 R_{500}$.

