

ROSAT X-Ray Analysis of Galaxy Clusters

Aileen A. O'Donoghue

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I. Obtain your ROSAT data

Go to HEASARC Browse page (<http://heasarc.gsfc.nasa.gov/cgi-bin/W3Browse/w3browse.pl>)

Under number 1 enter coordinates,

Under number 2 click "ROSAT"

Click "Start Search"

A Browse Query Results page will pop up:

● Browse Tip: Do you know how to plot Browse results? [Learn more on this topic](#) or [See all tips](#)

Table Name/Row Count Summary: 79 tables queried. A total of 13 rows returned.

WATCH TO SEE WHEN THE QUERY IS FINISHED

Click on "Query Results" tab at top

CLICK ROW

UNCLICK "All"

CLICK "Derived ROSAT Data Products"

Click on “Data Products Retrieval” tab at top

Click “Preview and Retrieve”

A new tab will open, click the images, background images and exposure image

[Archive](#)
Data Products for selected rows
Tip Archive [HELP](#)

[Choose Tables](#) > [Choose Data Products](#) > Retrieve Data Products

- Do you want to view a data product? Click on its hyperlinked data format.
- Do you want to retrieve data products in a tarfile? Check the boxes beside each product and click one of the buttons at the bottom of the page.

Select all products for all rows

[ROSAT Archival Data \(rosmaster\)](#) [FTOOLS](#) [ROSAT FTOOLS](#)

seq_id	instrument	exposure	ra	dec	name	_link_ror	_link_rday_begin	_link_rday_end	_link_proposal_number
RP700345N00	PSPCB	7494	14 04 09.6	+09 37 48	E1401+098 700345	604	605	602	

Select all products in this row

Derived ROSAT Data Products

- Energy-Coded Image (rp700345n00_ime.fits.Z) [FITS](#) 106 kB updated: 1996/05/09 18:00:23
- Exposure Map Image (rp700345n00_mex.fits.Z) [FITS](#) 240 kB updated: 1996/05/09 18:00:26
- Hard Band Background Image (rp700345n00_bk2.fits.Z) [FITS](#) 82 kB updated: 1996/05/09 18:00:07
- Hard Band Image (rp700345n00_im2.fits.Z) [FITS](#) 32 kB updated: 1996/05/09 18:00:17
- Lightcurve (rp700345n00_ltc.fits.Z) [FITS](#) 25 kB updated: 1996/05/09 18:00:24
- Screened Source List (rp700345n00_qsrc.fits.gz) [FITS](#) 54 kB updated: 2001/07/18 00:18:34
- Soft Band Background Image (rp700345n00_bk3.fits.Z) [FITS](#) 96 kB updated: 1996/05/09 18:00:09
- Soft Band Image (rp700345n00_im3.fits.Z) [FITS](#) 43 kB updated: 1996/05/09 18:00:20
- Total Band Background Image (rp700345n00_bk1.fits.Z) [FITS](#) 103 kB updated: 1996/05/09 18:00:05
- Total Band Image (rp700345n00_im1.fits.Z) [FITS](#) 52 kB updated: 1996/05/09 18:00:14

TAR selected products

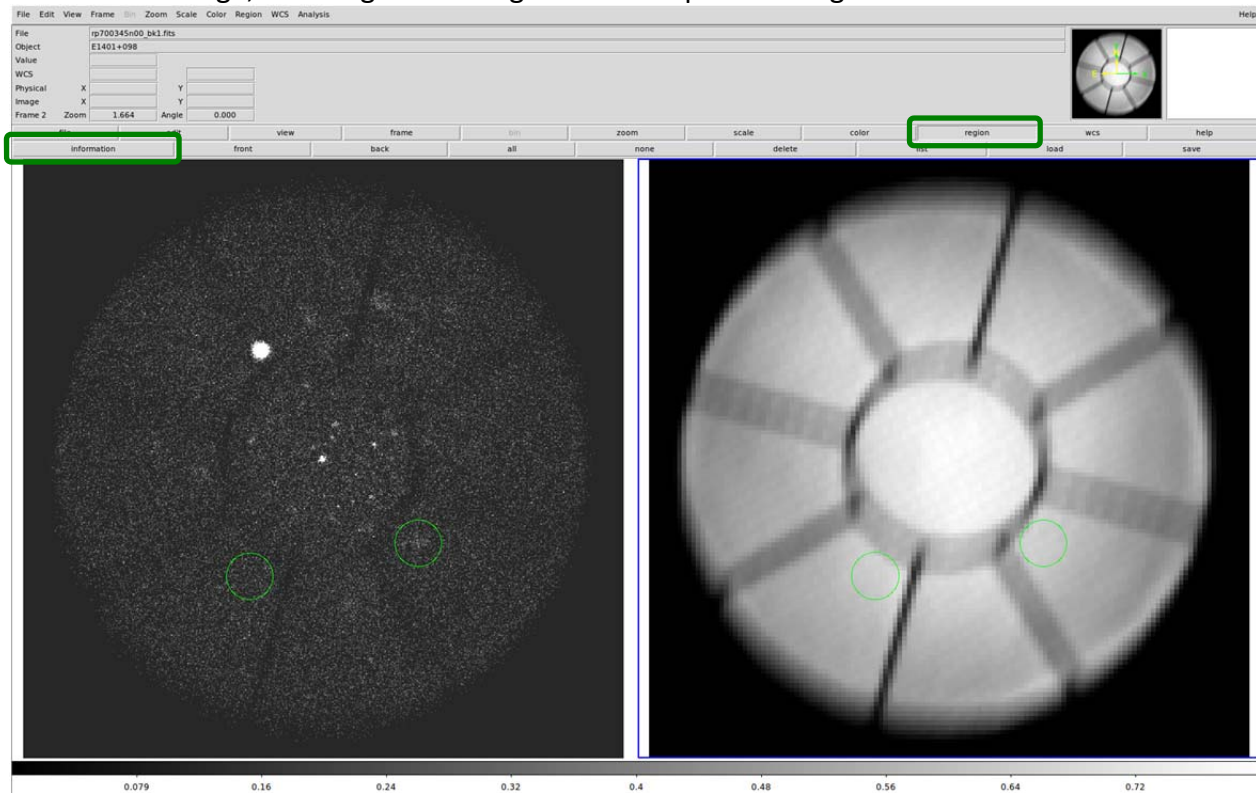
Click “TAR Selected Products”

Click “TAR Selected Products”

Download the TAR ball, unTAR it and unzip the files.

II. Analysis using ds9 (aka SAOimage)

Load an image, its background image and the exposure image into ds9 and tile the frames



```
File Edit Font
# source
# data_file: /home/aod/X-Ray/ZW1.400/700345/rp700345n00_i1.fits
# arcsec/pixel: 15
# background
# constant_value: 0.000000
# column units
# area: arcsec**2
# surf_bri: cnts/arcsec**2
# surf_err: cnts/arcsec**2
# background-subtracted results
reg net_counts error background berror area surf_bri surf_err
-----
1 821.000 28.653 0.000 0.000 281925.03 0.003 0.000
2 916.000 30.265 0.000 0.000 281925.03 0.003 0.000
# source_region(s):
# physical:circle(5803.1009,4674.1488,599.99994);circle(10111.141,5520.6406,599.99994)
# source_data
reg counts pixels
-----
1 821.000 1257 OFF SOURCE
2 916.000 1253 ON SOURCE
```

BROAD BAND

```
File Edit Font
# source
# data_file: /home/aod/X-Ray/ZW1.400/700345/rp700345n00_bk1.fits
# arcsec/pixel: 15
# background
# constant_value: 0.000000
# column units
# area: arcsec**2
# surf_bri: cnts/arcsec**2
# surf_err: cnts/arcsec**2
# background-subtracted results
reg net_counts error background berror area surf_bri surf_err
-----
1 797.220 28.235 0.000 0.000 281925.03 0.003 0.000
2 805.105 28.374 0.000 0.000 282825.03 0.003 0.000
# source_region(s):
# physical:circle(10111.141,5520.6406,599.99994);circle(5803.1009,4674.1488,599.99994)
# source_data
reg counts pixels
-----
1 797.220 1253 ON SOURCE
2 805.105 1257 OFF SOURCE
```

BROAD BAND

```
File Edit Font
# source
# data_file: /home/aod/X-Ray/ZW1.400/700345/rp700345n00_mex.fits
# arcsec/pixel: 15
# background
# constant_value: 0.000000
# column units
# area: arcsec**2
# surf_bri: cnts/arcsec**2
# surf_err: cnts/arcsec**2
# background-subtracted results
reg net_counts error background berror area surf_bri surf_err
-----
1 7184525.350 2680.396 0.000 0.000 281925.03 25.484 0.010
2 6926103.659 2631.749 0.000 0.000 282825.03 24.489 0.009
# source_region(s):
# physical:circle(10111.141,5520.6406,599.99994);circle(5803.1009,4674.1488,599.99994)
# source_data
reg counts pixels
-----
1 7184525.350 1253 ON SOURCE
2 6926103.659 1257 OFF SOURCE
```

ON THE EXPOSURE MAP, "COUNTS" ARE SECONDS OF EXPOSURE IN THE ENTIRE REGION:

$$\frac{\text{exposure seconds}}{\text{pixel}} = \frac{7184525 \text{ s}}{1253 \text{ pixel}} = 5734 \frac{\text{s}}{\text{pixel}}$$

```
File Color Width Property Font
Number 22 ON SOURCE
Text
Center 14:02:48.000 +09:19:40.00 fk5
Radius 5 arcmin
Apply Close
```

```
File Color Width Property Font
Number 21 OFF SOURCE
Text
Center 14:05:13.500 +09:12:37.00 fk5
Radius 5 arcmin
Apply Close
```

```
File Edit Font
# source
# data_file: /home/aod/X-Ray/ZW1400/700345/rp700345n00_im2.fits
# arcsec/pixel: 15
# background
# constant_value: 0.000000
# column units
# area: arcsec**2
# surf_bri: cnts/arcsec**2
# surf_err: cnts/arcsec**2
# background-subtracted results
reg net_counts error background berror area surf_bri surf_err
-----
1 322.000 17.944 0.000 0.000 281925.03 0.001 0.000
2 254.000 15.957 0.000 0.000 282825.03 0.001 0.000
# source_region(s):
# physical:circle(10111.141,5520.6406,599.99994);circle(5803.1009,4674.1489,599.99994)
# source_data
reg counts pixels
-----
1 322.000 1253 ON SOURCE
2 254.000 1257 OFF SOURCE
HARD BAND
```

```
File Edit Font
# source
# data_file: /home/aod/X-Ray/ZW1400/700345/rp700345n00_bk2.fits
# arcsec/pixel: 15
# background
# constant_value: 0.000000
# column units
# area: arcsec**2
# surf_bri: cnts/arcsec**2
# surf_err: cnts/arcsec**2
# background-subtracted results
reg net_counts error background berror area surf_bri surf_err
-----
1 223.181 14.939 0.000 0.000 281925.03 0.001 0.000
2 243.020 15.589 0.000 0.000 282825.03 0.001 0.000
# source_region(s):
# physical:circle(10111.141,5520.6406,599.99994);circle(5803.1009,4674.1489,599.99994)
# source_data
reg counts pixels
-----
1 223.181 1253 ON SOURCE
2 243.020 1257 OFF SOURCE
HARD BAND
```

```
File Edit Font
# source
# data_file: /home/aod/X-Ray/ZW1400/700345/rp700345n00_im3.fits
# arcsec/pixel: 15
# background
# constant_value: 0.000000
# column units
# area: arcsec**2
# surf_bri: cnts/arcsec**2
# surf_err: cnts/arcsec**2
# background-subtracted results
reg net_counts error background berror area surf_bri surf_err
-----
1 540.000 23.238 0.000 0.000 282825.03 0.002 0.000
2 555.000 23.558 0.000 0.000 281925.03 0.002 0.000
# source_region(s):
# physical:circle(5803.1009,4674.1488,599.99994);circle(10111.141,5520.6406,599.99994)
# source_data
reg counts pixels
-----
1 540.000 1257 OFF SOURCE
2 555.000 1253 ON SOURCE
SOFT BAND
```

```
File Edit Font
# source
# data_file: /home/aod/X-Ray/ZW1400/700345/rp700345n00_bk3.fits
# arcsec/pixel: 15
# background
# constant_value: 0.000000
# column units
# area: arcsec**2
# surf_bri: cnts/arcsec**2
# surf_err: cnts/arcsec**2
# background-subtracted results
reg net_counts error background berror area surf_bri surf_err
-----
1 527.130 22.959 0.000 0.000 281925.03 0.002 0.000
2 511.024 22.606 0.000 0.000 282825.03 0.002 0.000
# source_region(s):
# physical:circle(10111.141,5520.6406,599.99994);circle(5803.1009,4674.1489,599.99994)
# source_data
reg counts pixels
-----
1 527.130 1253 ON SOURCE
2 511.024 1257 OFF SOURCE
SOFT BAND
```

III. Calculate the source flux in counts/sec/pixel in each energy band

Find the counts per second

a) Subtract the backgrounds & calculate uncertainties

$$\text{Signal} = \text{On Source Counts} - \text{Off Source Counts}$$

$$\text{Uncertainty} = \pm \sqrt{\text{Signal}}$$

Band	Region	Image	Counts	Pixels	Signal	Uncertainty
Broad: 0.1 – 2.4 keV	On Source	im1	916.000	1253	im1 _{On Source} – im1 _{Off Source}	√Signal
		bk1	797.220	1253		
	Off Source	im1	821.000	1257	916 – 821 = 95 counts	9.75
		bk1	805.105	1257		
Hard: 0.4 – 2.4 keV	On Source	im2	322.000	1253	im2 _{On Source} – im2 _{Off Source}	√Signal
		bk2	223.181	1253		
	Off Source	im2	254.000	1257	322 – 254 = 68 counts	8.25
		bk2	243.020	1257		
Soft: 0.1 – 0.4 keV	On Source	im3	555.000	1253	im3 _{On Source} – im3 _{Off Source}	√Signal
		bk3	527.130	1253		
	Off Source	im3	540.000	1257	555 – 540 = 15 counts	3.87
		bk3	511.024	1257		

b) Find the exposure times from the mex image

$$\text{Exposure} = \frac{\text{Counts}}{\text{Pixels}}$$

Band	Region	Image	Counts	Pixels	Counts/pixel
All	On Source	mex	7184525.350	1253	5733.859
	Off Source	mex	6926103.659	1257	5510.027

Find the Flux Count Rate from the values in a) and b)

$$\text{Source Flux} = \frac{\text{Signal}}{\left(\frac{\text{Counts}}{\text{Pixel}}\right)}$$

Band	Signal	Counts/Pixel	Flux Count Rate
Broad: 0.1 – 2.4 keV	95	5733.859	0.01657 counts/second/pixel
Hard: 0.4 – 2.4 keV	68		0.01186 counts/second/pixel
Soft: 0.1 – 0.4 keV	15		0.00262 counts/second/pixel

IV. Find the neutral hydrogen density in the Milky Way

Select nH Column Density from the HEASARC tools (heasarc.gsfc.nasa.gov/docs/tools.html)

Enter the source coordinates & take the Leiden/Argentine/Bonn (LAB) Average

eg. 2.03×10^{20} atoms/cm² for Zwicky 1400+0949



Calculate the Total Galactic H I Column Density
(Powered by HEASoft)

Input Equatorial coordinates:
[210.7000°, 9.3278°], equinox J2000
Cone Radius: 1.00°

```
>> Leiden/Argentine/Bonn (LAB) Survey of Galactic HI
LII , BII 349.715228 65.490720
Requested position at X and Y pixel 248.01 212.38
Search nH in 4 X 4 box
Each pixel is 0.675 deg X 0.675 deg
nH calculated using all points within
1.0000 deg from input position
RA DEC Dist nH
211.3626 9.5154 0.6802 2.11E+20
210.9399 9.1291 0.3091 2.18E+20
210.5109 8.7502 0.6070 1.94E+20
210.7424 10.0432 0.7167 1.91E+20
210.3205 9.6592 0.5000 2.07E+20
209.8921 9.2827 0.7984 2.00E+20
LAB AVERAGE LAB >> Average nH (cm**2) 2.03E+20
LAB >> Weighted average nH (cm**2) 2.06E+20
```

V. Find the Energy flux

Select WebPIMMS from the HEASARC tools

Under “Convert From”, choose
ROSAT/PSPC Count Rate

Under “Into”, choose “FLUX”

Input the energy range for each band in keV for
both “Input” and “Output” energy ranges

Type in the Flux Count Rate (above),
the galactic nH and redshift, leaving the
“Intrinsic nH” as zero.

Choose the APEC model with
0.4 Solar Abundance and
7.65 | 3.8492

Click “Estimate Count Rate” to get the flux



Access the multiple component model interface.

Convert From: ROSAT/PSPC Count Rate
Into: FLUX

ROSAT 0.1-2 keV 6.2-124 A

Input Energy Range (low-high): 0.1-2.4 keV
Output Energy Range (low-high): 0.1-2.4 keV

Source: Flux / Count Rate 0.01657 (erg/cm²/s)
(counts/s)

Galactic nH: 2.03e20 (cm⁻²)
Redshift: 0.02
Intrinsic nH: none (cm⁻²)

Model of Source: APEC
Model Parameters: 0.4 Solar Abundance, 7.65 | 3.8492

Buttons: Estimate Count Rate, Reset

The output page gives a measured flux (FLUX) and a calculated value of what the flux would be if there were no neutral hydrogen absorption by the Milky Way galaxy

Band	Flux Count Rate	Flux
Broad: 0.1 – 2.4 keV	0.01657 cts/sec/pix	1.976×10^{-13} erg/cm ² /s
Hard: 0.4 – 2.4 keV	0.01186 cts/sec/pix	1.652×10^{-13} erg/cm ² /s
Soft: 0.1 – 0.4 keV	0.00262 cts/sec/pix	1.334×10^{-14} erg/cm ² /s

Band	Flux Count Rate	Unabsorbed Flux
Broad: 0.1 – 2.4 keV	0.01657 cts/sec/pix	2.461×10^{-13} erg/cm ² /s
Hard: 0.4 – 2.4 keV	0.01186 cts/sec/pix	1.756×10^{-13} erg/cm ² /s
Soft: 0.1 – 0.4 keV	0.00262 cts/sec/pix	4.022×10^{-14} erg/cm ² /s

VI. Calculate the Luminosity

Using the flux and the distance (r) in km

$$\text{Luminosity} = 4\pi r^2 (\text{Flux})$$

To find the distance from the recessional velocity use

$$r = \frac{\text{velocity}}{H_0}, H_0 = 72 \text{ km/s/Mpc}$$

For 6000 km/s (z = 0.02)

$$r = \frac{6000}{72} = 83.3 \text{ Mpc}$$

$$= 272 \text{ million ly} = 2.57 \times 10^{26} \text{ cm}$$

Band	Unabsorbed Flux	Luminosity
Broad: 0.1 – 2.4 keV	2.461×10^{-13} erg/cm ² /s	2.045×10^{41} erg/s
Hard: 0.4 – 2.4 keV	1.756×10^{-13} erg/cm ² /s	1.459×10^{41} erg/s
Soft: 0.1 – 0.4 keV	4.022×10^{-14} erg/cm ² /s	3.342×10^{40} erg/s

Input Parameters:

Model #1: apec04_765 Model #2: Model #3: Model #4:

P_1keV #1: apec04_765 P_1keV #2: P_1keV #3:

Galactic n_H: 2.03e20 cm⁻²

Intrinsic n_H: 0.0 // cm⁻²

Redshift: 0.02

From: rosat pspc open 0.1-2.4

Output Flux energy range: 0.1-2.4 keV;

Count Rate: 0.01657 cps

Internal model normalization = 2.608E-04

Redshifted with z= 0.0200 and a Galactic Nh= 2.030E+20

Useful mission related information may be found at:

<http://heasarc.gsfc.nasa.gov/docs/rosat/rosat3.html>

BROAD BAND

FLUX

PIMMS predicts a flux (0.100- 2.400keV) of 1.976E-13 ergs/cm/cm/s

Unabsorbed FLUX

PIMMS predicts an unabsorbed flux (0.100- 2.400keV) of 2.461E-13 ergs/cm/cm/s

FLUX

HARD BAND

PIMMS predicts a flux (0.400- 2.400keV) of 1.652E-13 ergs/cm/cm/s

Unabsorbed FLUX

PIMMS predicts an unabsorbed flux (0.400- 2.400keV) of 1.756E-13 ergs/cm/cm/s

FLUX

SOFT BAND

PIMMS predicts a flux (0.100- 0.400keV) of 1.334E-14 ergs/cm/cm/s

Unabsorbed FLUX

PIMMS predicts an unabsorbed flux (0.100- 0.400keV) of 4.022E-14 ergs/cm/cm/s