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Chandra Observation of the WAT Radio Source/ICM Interaction in A623

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Abstract

Galaxy clusters are important objects for studying the physics of the intracluster medium (ICM), galaxy formation and evolution, and cosmological parameters. Clusters containing wide-angle tail (WAT) radio sources are particularly valuable for studies of the interaction between these sources and the surrounding ICM. These sources are thought to form when the ram pressure from the ICM caused by the relative motion between the host radio galaxy and the cluster bends the radio lobes into a distinct wide-angle morphology. We present first results from the analysis of a Chandra observation of the nearby WAT hosting galaxy cluster Abell 623. A clear decrement in X-ray emission is coincident with the southern radio lobe, consistent with being a cavity carved out by the radio source. We present spectral fits to the overall cluster emission, as well as a temperature profile derived from the emission in concentric annuli. Future work on this data set will involve creating density and pressure profiles. Based on the X-ray pressure in the vicinity of the radio lobes and assumptions about the content of the lobes, we will estimate the relative ICM velocity required to bend the lobes into the observed angle. Since ICM velocities are very difficult to measure directly, future Chandra observations of such systems will be important probes of the dynamics of the ICM.

Acknowledgements

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Introduction

Radio galaxies with a wide-angle tail (WAT) morphology are frequently found in clusters of galaxies. These sources are thought to form when the ram pressure from the ICM caused by the relative motion between the host radio galaxy and the cluster bends the radio lobes into their distinct wide-angle structure. Abell 623 is a galaxy cluster located at z=0.0891 that is host to a WAT radio source. We present a preliminary analysis of the interaction between the WAT radio source and the ICM in Abell 623.

Observations and Images

Our observations were completed in two separate exposures, totaling 48.2 ks. After cleaning for flares, we were left with a total of 46.0 ks worth of observations. The data were processed for VFAINT mode and merged to create a single image in the 0.3-10 keV energy range. This was corrected for both the background (using blank-sky background files) and the exposure time variance using the exposure map. Using the *csmooth* script in CIAO, we created an adaptively smoothed image to highlight the overall X-ray emission. Contours of this emission, along with a 20 cm radio observation of the WAT radio source are shown overlaid on an r-band SDSS image in Figure 1 below.

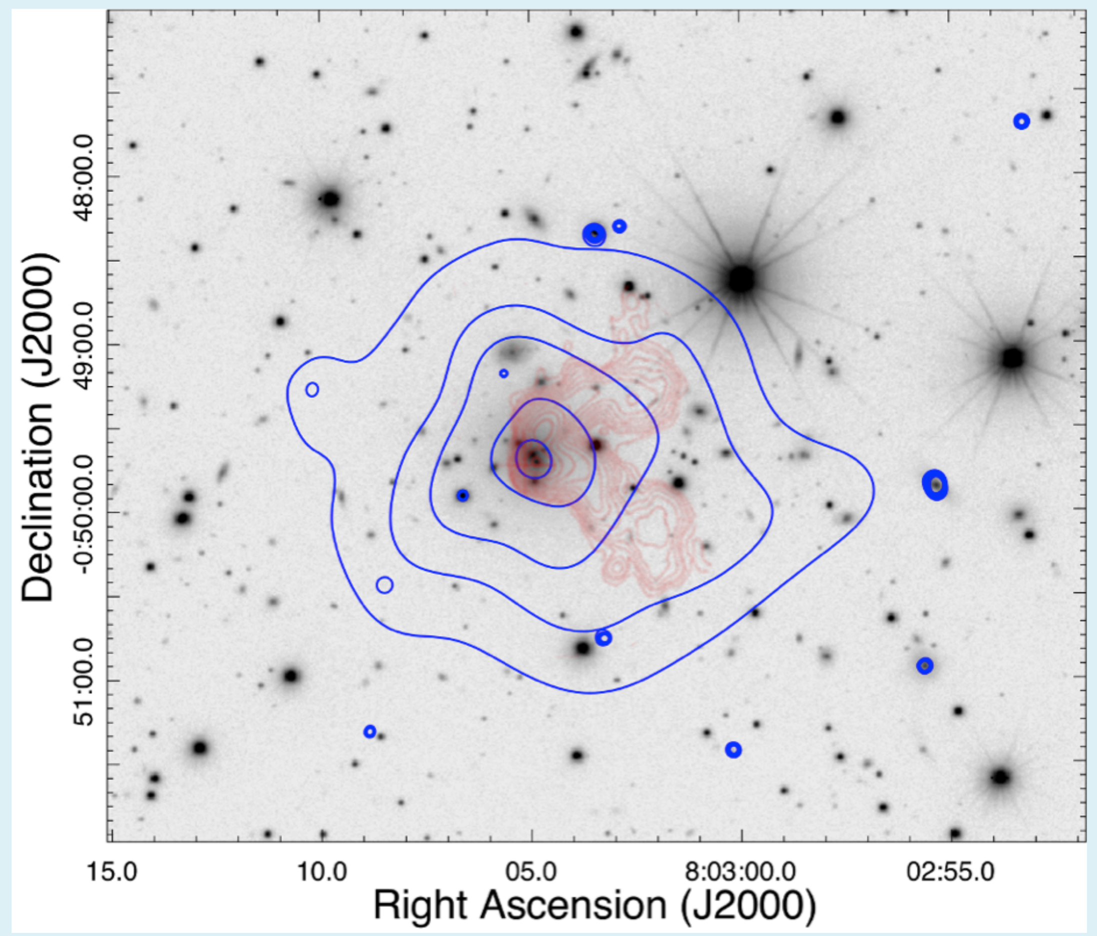

Figure 1. An r-band SDSS image of A623. The blue contours are from our Chandra X-ray observations of the cluster emission, and the red contours show the WAT radio source emission at 20 cm.

WAT/ICM Interaction

The adaptively smoothed image, along with an overlay of the 20 cm radio contours is shown below in Figure 2. The southern radio lobe is coincident with a clear decrement in X-ray emission, which is consistent with a cavity being carved out by the WAT radio source. The northern lobe is also located near a region of lower X-ray surface brightness, though not as apparent as its southern counterpart.

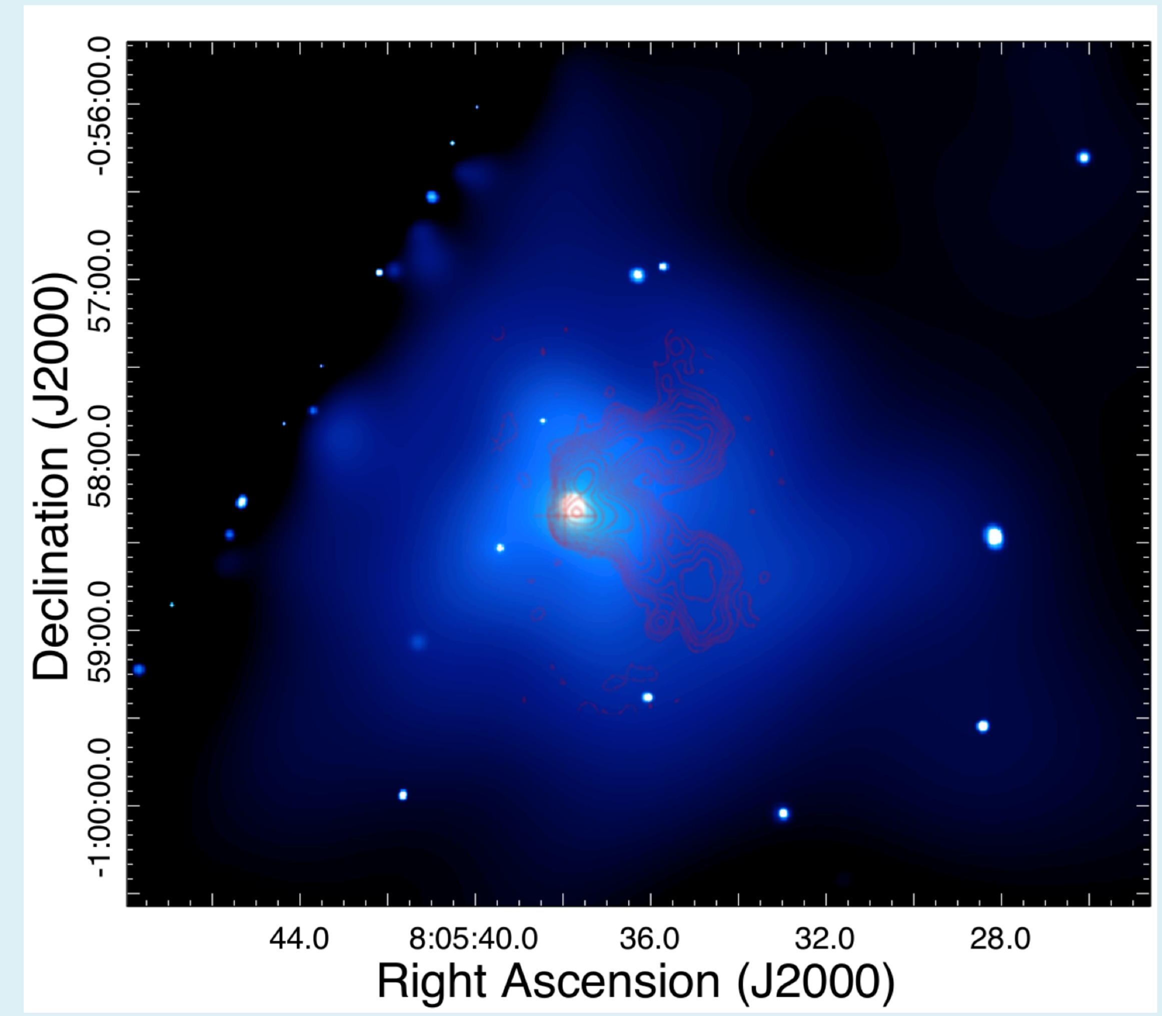

Figure 2. An adaptively smoothed 0.3-10 keV image of the Chandra X-ray observation of A623. Contours of 20 cm radio emission are overlaid in red.

Beta Model Fitting

In order to determine several cluster parameters, we fit a 2D beta model to the overall cluster emission. These parameters and their associated errors are shown below in Table 1. Of particular interest are the core radius and the value for β, which are lower than that of the typical cluster. Since β (typically ≈0.6) represents the ratio of specific energy in galaxies to that in cluster gas, A623 appears to have a larger than typical amount of specific energy contained within the cluster gas than usual.

Parameter	Value
Core Radius	$60.5^{+5.6}_{-5.4}\ kpc$
Ellipticity	$0.187^{+0.028}_{-0.029}$
Position Angle	$7.7^{\circ}{}^{+4.6}_{-4.6}$
β Value	$0.408^{+0.011}_{-0.010}$

Table 1. 2D Beta model fit parameters to the 0.3-10 keV cluster emission. Errors were calculated using Cash statistics. The position angle is measured in degrees, from north to east.

Spectral Fitting

We performed spectral fits in the 0.3-5 keV energy range to determine the overall temperature and abundance in the cluster. The models used and their output parameters are shown below in Table 2.

Spectral Models	N_H	kT	$Z_\odot$	χ^2/d.o.f.
APEC (fixed absorption)	3.73	$4.63^{+0.53}_{-0.49}$	$0.30^{+0.26}_{-0.19}$	1.00
APEC (thawed absorption)	$2.95^{+3.71}_{-2.95}$	$4.76^{+0.89}_{-0.74}$	$0.31^{+0.30}_{-0.20}$	1.00
APEC+APEC (thawed abs.)	$24.2^{+21.7}_{-15.8}$	$0.36^{+0.25}_{-0.15}$ / $3.72^{+0.97}_{-0.60}$	$0.48^{+0.38}_{-0.25}$	0.99

Table 2. Outputs of spectral modeling fits using APEC models. Parameters shown are Galactic absorption (in 10^{20} cm^{-2}), abundance (in $Z_\odot$), temperature (in keV), and reduced chi-squared.

Temperature Profile

We created a temperature profile of the cluster by fitting single APEC models to six annuli centered on the central AGN. The Galactic absorption and abundances were set to what was found in the single APEC model with fixed absorption. An interesting feature is the sudden jump in temperature for the second region- this suggests the possible presence of a shock, which will be examined further.

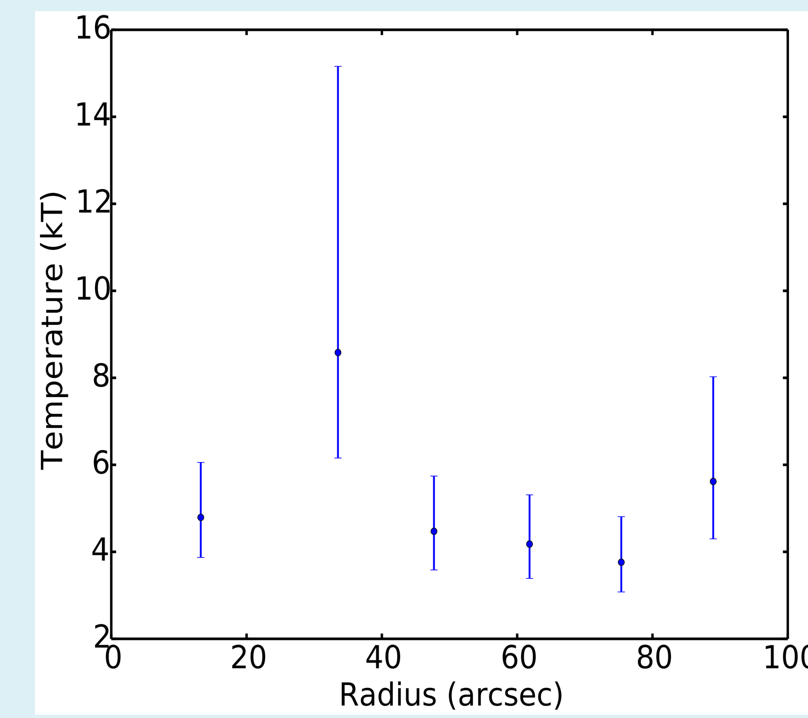

Figure 3. A temperature profile created from single APEC model fits made from six annuli centered on the central AGN.

Future Work

Our next steps include creating density and temperature profiles in the same regions as the above temperature profile. Based on the X-ray pressure near the radio lobes and assumptions about the content of the lobes, we can estimate the ICM velocity needed to bend the lobes into the angles seen. Since ICM velocities are hard to probe, future Chandra observations of systems hosting WAT radio sources will prove to be important to understanding the dynamics of the ICM.