Chandra Observation of the Core of Abell 576

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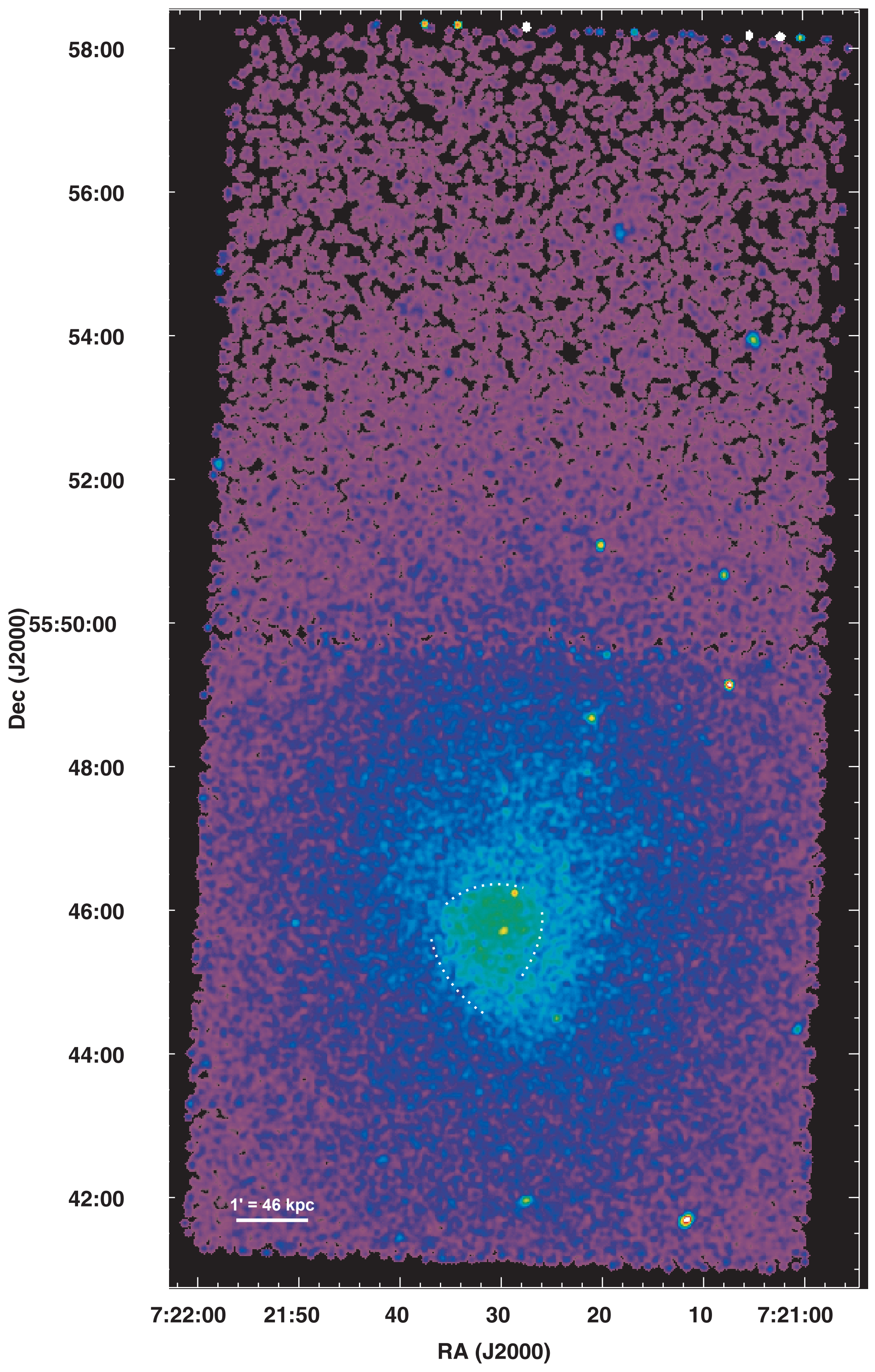
Introduction

We present a Chandra observation of the nearby (z = 0.0377) cool cluster Abell 576. The cluster shows multiple sharp edges in the central 50 kpc. The temperature gradients across the edges are relatively small, but both the density and the abundance change by significant amounts. The pressure gradient across the north edge indicates that the edge must be moving at nearly the sound speed. We measure a very small cooling rate inside the edges, and a slightly larger cooling rate at larger radii. We interpret the edges to be indicative of a merging subcluster that is settling into the center of the main cluster. We discuss the effect of this merger on the development of a cooling flow in this otherwise relaxed cluster. We find that the dissipation of the kinetic energy of the merging subcluster is capable of suppressing most cooling in the central 100 kpc or so of the main cluster, if that energy is efficiently thermalized.



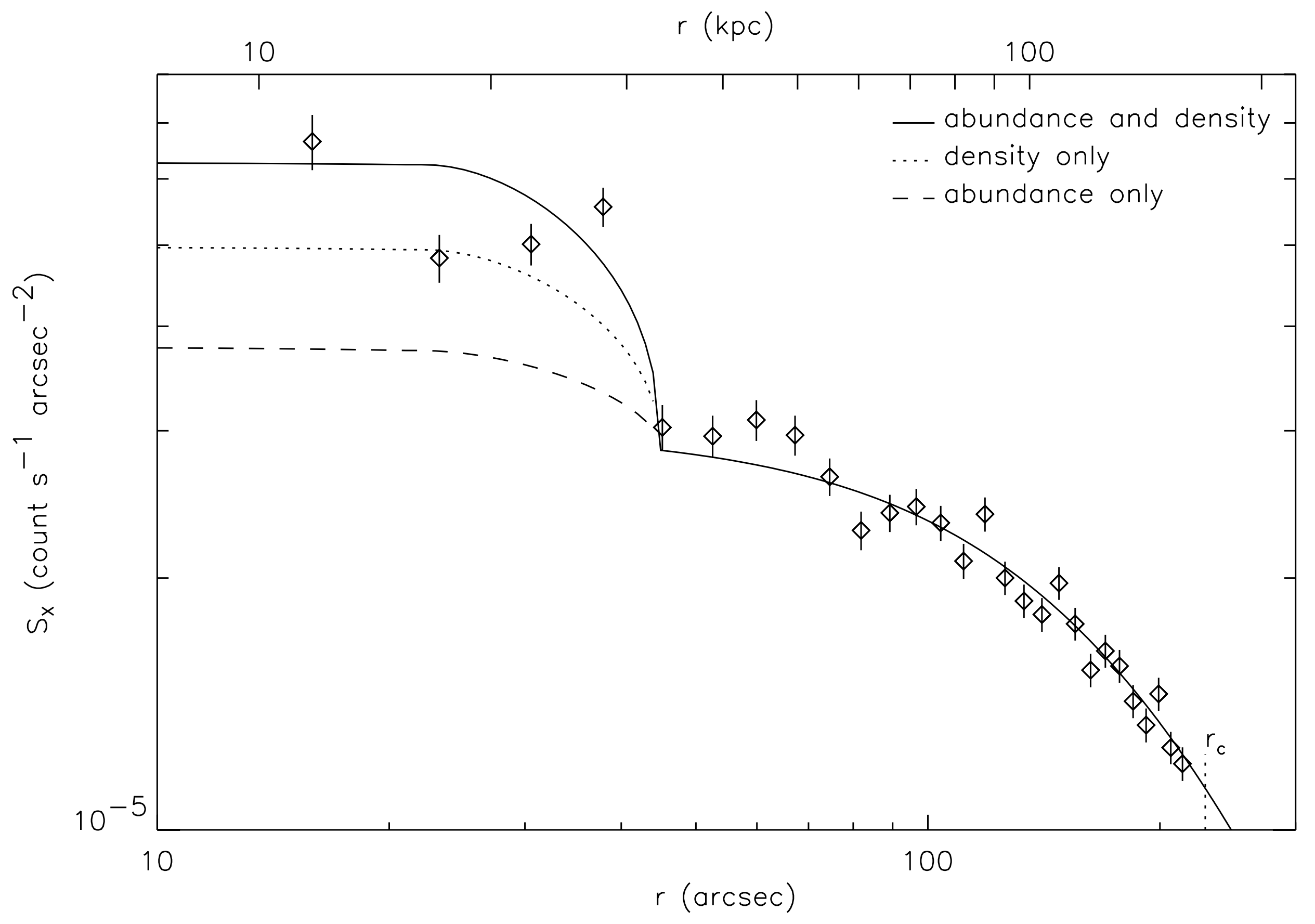
Gaussian smoothed, background- and exposure-corrected Chandra image of Abell 576. The S3 (bottom) and S2 (top) chips are shown. Approximate locations of the surface brightness edges are indicated by the dotted lines.

Imaging Spectroscopy

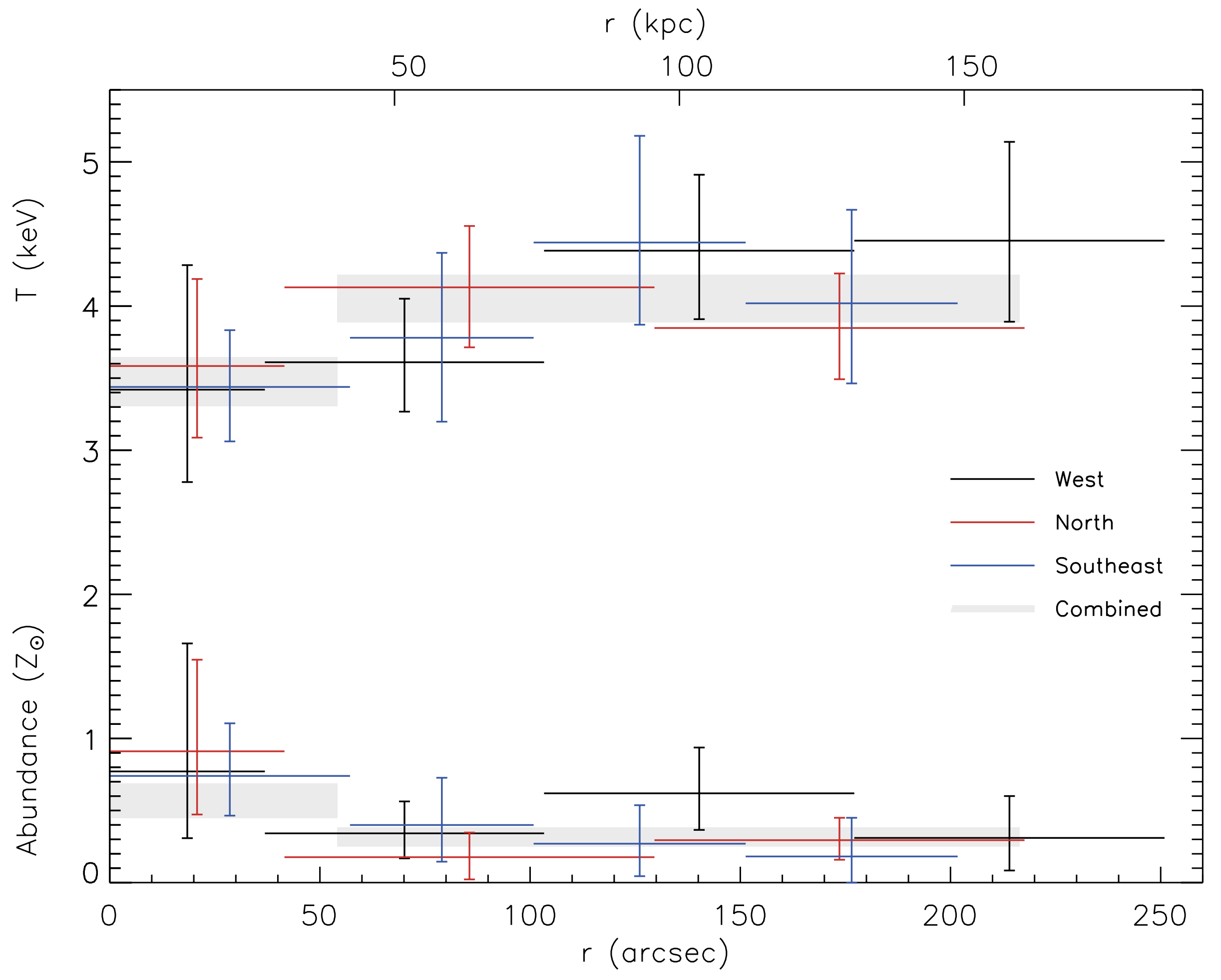
Much substructure is evident in the core of Abell 576, as is evident from the figure to the left. The dashed lines mark the approximate locations of three surface brightness edges. With the possible exception of the north edge, these differ from the cold fronts seen in merging clusters, in that the temperature jumps across them are not particularly large, and therefore the density jumps across them are small as well. However, the increased iron abundance combined with the small density increase can account for the sharp increase in surface brightness. The top figure to the right shows the measured surface brightness in a wedge across the north edge. Superposed on the data are curves indicating a beta-model fit to the data, with brightness increases due to a density increase only, an abundance increase only, and a combination of the two. Both effects appear to be necessary to account for the entirety of the observed brightness.

As the lower figure to the right shows, the abundance in the center of the cluster in significantly higher than that outside the edges, at greater than 90% confidence. There are two readily apparent possible explanations for this. The first is that the gas in the inner 100 or so kpc began with an abundance gradient, and that dynamical activity, such as AGN-induced boiling or a subcluster merger, has stripped or compressed the gas just outside the edges so the gradient has become a sharp jump. The other explanation, which we favor, is that the north edge is in fact the cool core of a merging or recently merged subcluster which started with a different abundance than that of the main cluster. This would imply that the other edges trace the tail of gas that has been stripped from the subclusters as it has fallen into the potential of the main cluster. Our data do not have enough counts to measure the [Si/Fe] ratios on either side of the edges to conclusively test for different origins of the gas, but we have applied for time with XMM to accomplish this.

This latter explanation has the attractive feature, which we discuss in more detail below, of injecting a large amount of energy into the center of Abell 576. This added energy, if efficiently thermalized, could provide enough heating to suppress the expected cooling flow. We measure a cooling rate of only 1.1±0.5 $M_\odot$ yr^{-1} inside the edges, and 5±1 $M_\odot$ yr^{-1} outside the edges. These cooling rates are for the regions indicated in gray in the figure to the right. Thus, cooling in the central 200 kpc or so must be suppressed, since the cooling times implied by the deprojected density profile and temperature profile would produce a couple hundred $M_\odot$ yr^{-1} accretion rate in the absence of some heating mechanism. There is no evidence in either the X-ray or the radio of any recent AGN activity in the cluster core at a level capable of suppressing cooling by the necessary amount.

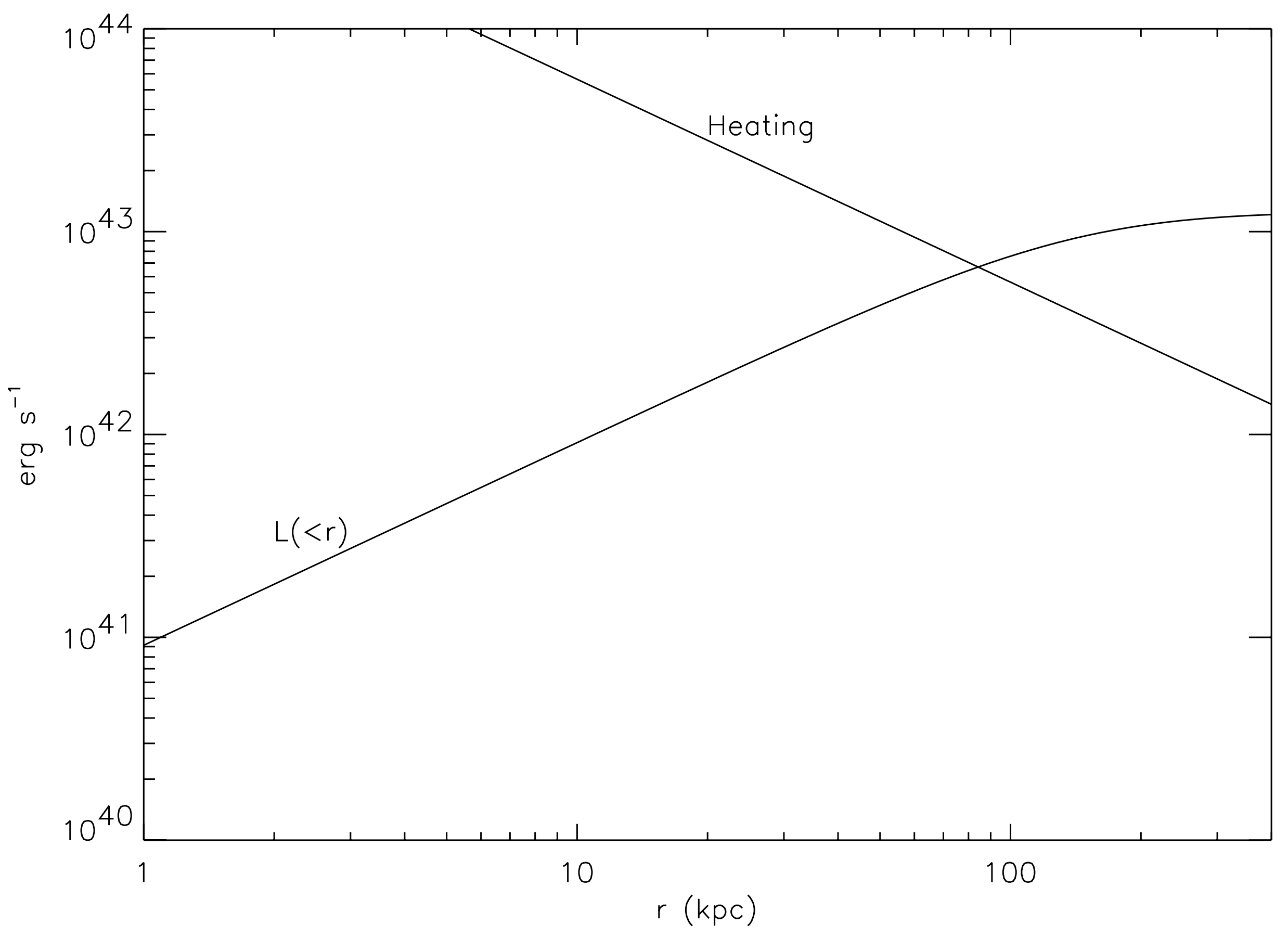


Surface brightness profile across the north edge. The curve is a beta-model fit to the data. The parameters for the model are taken from Mohr et al. (1996), renormalized to our data.



Spectral profiles across the three edges indicated in the figure to the left. Note the higher abundance and lower temperature in the center. The gray boxes show the best fit to the combined spectra. Error bars are 90% confidence.

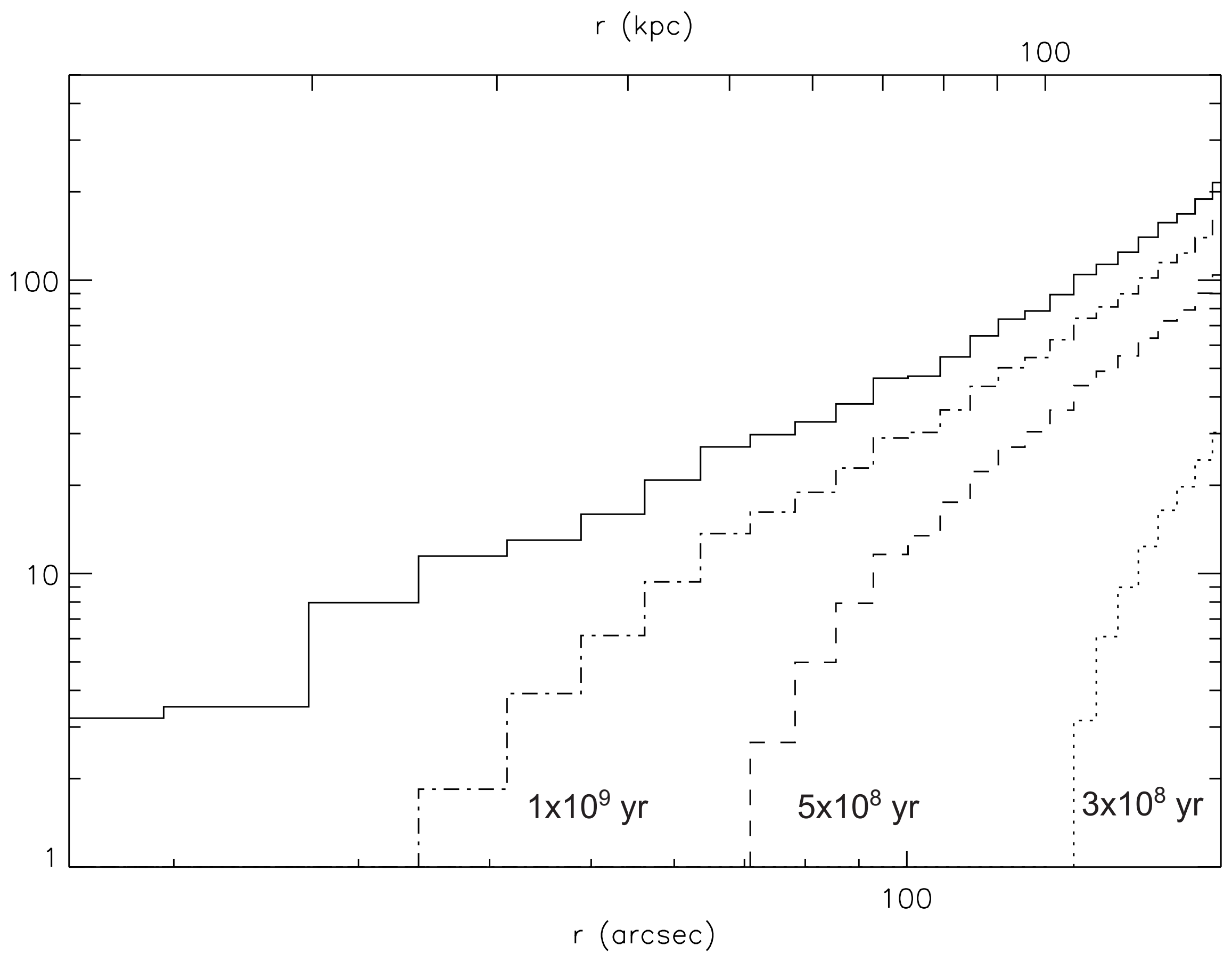
Can Heating from the Merger Counteract Cooling in the Center of the Cluster?



Integrated luminosity and energy from dynamical heating as a function of orbital radius of the subcluster. For reference, the sound crossing time from r = –200 kpc to r = 200 kpc is ~5x10^8 years, so the relevant timescale for heating out to that radius is 1.5 Gyr.

The cold core in the center of the cluster is measured to have a velocity of about 750 km/s, or Mach 0.9 (with about a 50% error) at the ambient temperature of the cluster as a whole. From this and its mass as determined by a deprojection analysis, we determined the currently available kinetic energy that can go into heating the surrounding ICM. To the left we show the integrated luminosity of the main cluster L(<r) and the heating provided by the motion of the cold core. The heating rate assumes that 3/4 of the current kinetic energy is dissipated over a timescale equal to 3 sound crossing times of the main cluster at the given radius. In this time, the cold core will have swept up its own mass in gas, and will therefore have reduced its velocity by half, dissipating 3/4 of its kinetic energy. This approximates the average velocity as Mach 1, which may be a slight overestimate. In addition, it ignores the effect that dark matter would have in driving the oscillation of the core, thereby increasing the average speed and increasing the heating rate. The heating curve should therefore be viewed as a lower limit.

The right panel shows the theoretical mass accretion rate both with and without the effects of heating. The dissipation timescale assumed is given for each curve. These curves are only rough approximations, since they assume perfect efficiency in thermalizing the kinetic energy of the subcluster, which would cause us to overestimate the rate of heating. This may, however, be a small effect compared to the driving effect of the dark matter mentioned above.



Theoretical mass accretion rate derived from density deprojection and projected temperature profile (solid line) and mass accretion rate after correction for dynamical heating from moving cold core.