Chandra Observation of the Merging Cluster Abell 2065: An Unequal Mass Merger?

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ABSTRACT:

We present an analysis of a 41 ks observation of the merging cluster Abell 2065 with the ACIS-I detector. Previous observations with ROSAT and ASCA provided evidence for an ongoing merger, but also suggested that there were two surviving cooling cores, which were associated with the two cD galaxies in the center of the cluster. The Chandra observation reveals only one X-ray surface brightness peak, which is associated with the more luminous, southern cD galaxy. The gas related with that peak is cool and displaced from the position of the cD. The data suggest that this cool material has formed a cold front. On the other hand, in the higher spatial resolution Chandra image, the second feature to the north is not associated with the second cD, rather it appears to be a trail of gas behind the main cD. We argue that only one of the two cooling cores has survived the merger, which suggests that the cluster is undergoing an unequal merger. The data indicate that a shock front is propagating through the cluster's ICM, which we use to constrain the kinematics of the system.

INTRODUCTION:

Abell 2065 is a Type III, richness class 2, cluster of galaxies at a redshift of 0.072. The central region of the cluster reveals two cD galaxies whose line-of-sight velocities differ by 600 km/s (Postman et al. 1988). Peres et al. (1998) estimated a central cooling time of ~4.4 Gyr and a rate of ~13 $M_{\odot}yr^{-1}$. Data obtained with *ROSAT* suggested the presence of two surface brightness peaks, which coincided with the two cD galaxies found at the cluster center. Based on these data and on *ASCA* observations, Markevitch et al. (1999) argued that the two subclusters had already undergone a merger and they used the survival of the two cooling cores to constrain the gravitational potentials of the two clusters.

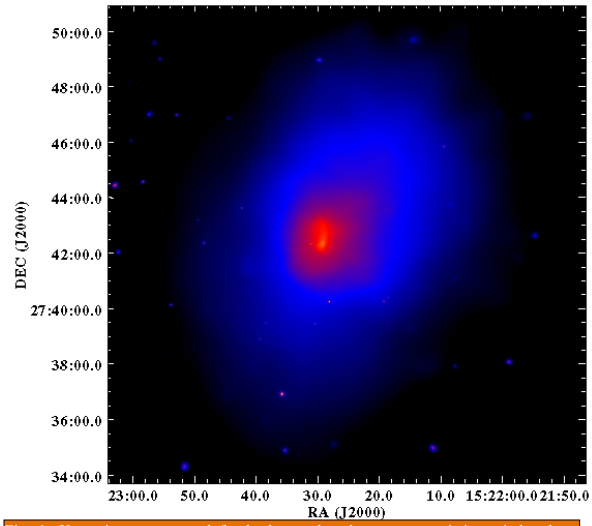

Fig. 1: X-ray image corrected for background and exposure variations; it has been adaptively smoothed to minimum signal-to-noise of 3. The compact, bright region at the center of the image consists of a steep, bright extension to the south. Also, a more diffuse tail extends to the north. A few arcminutes to the SE of the X-ray peak, there is evidence for a bow-shaped brightness discontinuity.

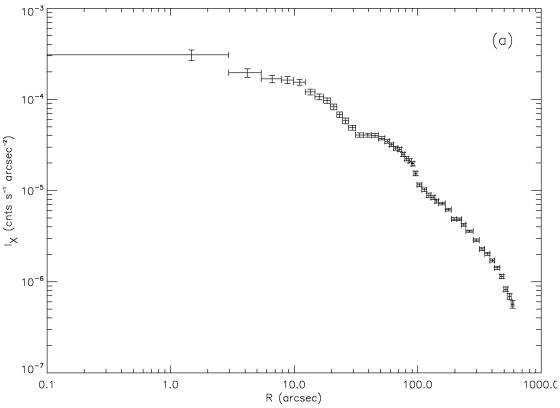

Fig. 4: Surface brightness profile of the region SE of the cD. Two discontinuities are striking in the profile; the inner at ~30" and the outer at ~100" from the center. The outer 500" are adequately fit with a β-model, suggesting that the gas concentration at that location has not been significantly disturbed by merger processes.

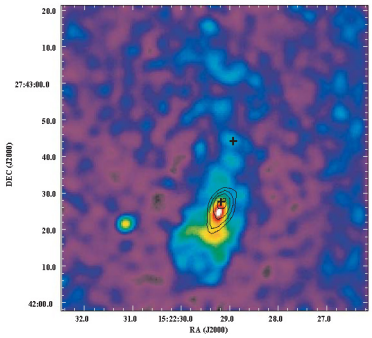

Fig. 2: DSS image of the central 4'x4' of the cluster, overlaid with the X-ray surface brightness contours. Only the southern cD is associated with the X-ray peak, whereas the northern galaxy is located along the dimmer, diffuse, northern tail. Notice the X-ray emission is extended immediately to the SE of the southern cD galaxy, in the direction of the brightness discontinuity.

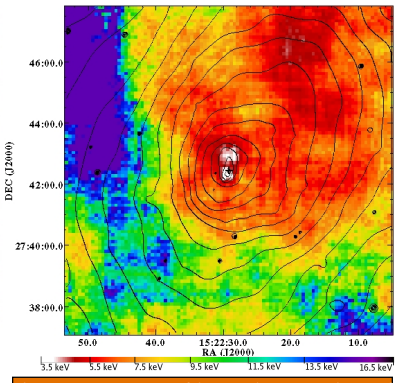

Fig. 3: Temperature map of the central 10'x10'. The SE of the cluster is much hotter than the global cluster temperature (5.52±0.14 keV). At the center, two cool regions are separated by a slightly warmer region. The spectral properties of these regions were investigated individually and the derived temperatures of these regions were found consistent with a monotonic increase. Thus, within the errors, the two cool regions are not two distinct gas concentrations.

NATURE OF SOUTHERN EXTENSION:

- Coolest cluster region.
- Center shifted by ~12" with respect to the potential peak, identified with the cD galaxy.
- Inner surface brightness discontinuity traces closely the southern cD extension.

These suggest that the southern extension is the displaced cool core of the southern cluster. The survival of the core suggests that the cloud is bound by a cold front at the southern end. Constrain the merger kinematics:

- The survival of the core can be used to set an upper limit of 1900 km s^{-1} to the merger relative velocity.
- By applying the stagnation condition, we obtain a value of the Mach number of the front of M=1.7±0.2 or a velocity of ~2000 km s^{-1}.

OUTER DISCONTINUITY:

- Temperature map supports a temperature increase across the front, but
- From projected temperature profile, the temperature across the discontinuity is consistent with either an increase or a decrease, within the errors.

Therefore, the discontinuity is consistent with being either a shock or a cold front. Both scenarios yield consistent kinematical results with each other and with the analysis of the inner cold front. The adopted Mach number, from the shock scenario, is then M = 1.7±0.3.

DYNAMICAL INTERPRETATION:

- Absence of northern cool core => southern cluster more massive, disrupted the northern cool core.
- Southern extension shifted to the SE of the cD, discontinuity 100" SE of cD => southern cluster moves to the SE.
- Temperature map structure reminiscent of Gómez et al. (2002), unequal mass merger simulation viewed 250 Myrs after core passage.
- Existence of cold front and northern cool tail can be explained by ram pressure stripping, followed by mass transportation to the low pressure stagnation point from the interior of the cool cloud (Heinz et al. 2003).

CONCLUSIONS:

Our data show that:

- Only one cool core has survived the merger.
- The cool core has formed a cold front at 30" from the southern cD galaxy.
- There is evidence for a discontinuity at 100" from the cD, but its nature cannot be determined at the accuracy of our data.
- Both structures are moving at the same velocity within the errors.
- We conclude that Abell 2065 is a case of an unequal mass merger, that we are viewing a few hundred Myrs after core crossing.

Support for this work was provided by the National Aeronautics and Space Administration primarily through Chandra award GO2-3159X, but also through GO2-3160X, GO3-4160X, GO4-5133X, GO4-5133X, and GO5-6126X, issued by the Chandra X-ray Observatory.

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