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ORIGINAL ARTICLE

Investigation of X-ray cavities in the cooling flow system Abell 1991

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Abstract We present results based on the systematic analysis of *Chandra* archive data on the X-ray bright Abell Richness class-I type cluster Abell 1991 with an objective to investigate properties of the X-ray cavities hosted by this system. The unsharp masked image as well as 2-d β model subtracted residual image of Abell 1991 reveals a pair of X-ray cavities and a region of excess emission in the central ∼12 kpc region. Both the cavities are of ellipsoidal shape and exhibit an order of magnitude deficiency in the X-ray surface brightness compared to that in the undisturbed regions. Spectral analysis of X-ray photons extracted from the cavities lead to the temperature values equal to $1.77^{+0.19}_{-0.12}$ keV for N-cavity and $1.53^{+0.05}_{-0.06}$ keV for S-cavity, while that for the excess X-ray emission region is found to be equal to $2.06^{+0.12}_{-0.07}$ keV. Radial temperature profile derived for Abell 1991 reveals a positive temperature gradient, reaching to a maximum of 2.63 keV at ∼76 kpc and then declines in outward direction. 0.5–2.0 keV soft band image of the central 15″ region of Abell 1991 reveals relatively cooler three different knot like features that are about 10″ off the X-ray peak of the cluster. Total power of the cavities is found to be equal to $\sim 8.64 \times 10^{43}$ erg s^{-1}, while the X-ray luminosity within the cooling radius is found to be 6.04×10^{43} erg s^{-1}, comparison of which imply that the mechanical energy released by the central AGN outburst is sufficient to balance the radative loss.

Keywords Galaxies: active · Galaxies: clusters · X-rays: galaxies: clusters · Cooling flows: intergalactic medium

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1 Introduction

High-resolution X-ray observations of bright cool-core galaxy clusters with *Chandra* and *XMM-Newton* telescopes have shown that, even in the cores of clusters with high cooling rate, the observed quantum of gas cooled below $T \leq 1$ keV is significantly small (ZuHone 2011). Further, the rate at which mass is being deposited in the cores of the dominant cooling flow clusters is found to be an order of magnitude smaller than that estimated using standard models (Peterson et al. 2003; Peterson and Fabian 2006). This means some compensatory steady heating mechanism must be operative in the cores of such clusters (McNamara et al. 2006). A variety of mechanisms have been proposed to compensate the radiative losses, that include, the magnetic field re-connection (Soker and Sarazin 1990), thermal conduction due to electron collisions (Narayan and Medvedev 2001), turbulent conduction (Voigt and Fabian 2004) and heating by cosmic rays (Colafrancesco and Marchegiani 2008). However, the most promising source of heating for replenishing the radiative loss of the hot gas in clusters and groups of galaxies is the energy input from the super-massive black hole (SMBH) that is residing at the core of such cluster (Boehringer et al. 1993; Binney and Tabor 1995; McNamara et al. 2006; Fabian et al. 2006). One of the early clues explaining role of the active galactic nucleus (AGN) in reheating of the inter-galactic medium (IGM) was the high detection rate (∼70 %) of radio activity in the central galaxy of the X-ray bright clusters relative to the X-ray faint clusters (Burns 1990).

X-ray deficient cavities detected in numerous groups and clusters of galaxies provided with the direct evidence for the AGN feedback in such systems (Bîrzan et al. 2004; David et al. 2009; Dong et al. 2010; Randall et al. 2011). Often such cavities are seen near the center of clusters in about