Mem. S.A.It. Vol. 82, 662

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# Abell 2146: riding the wake of a merging galaxy cluster

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**Abstract.** The *Chandra* X-ray observation of the galaxy cluster Abell 2146 (Russell et al. 2010) has revealed the supersonic passage of a subcluster through the cluster center producing two Mach 2 shock fronts and a gas structure similar to the bullet cluster (Markevitch et al. 2002). We report on integral field observations of the brightest cluster galaxy located behind one of the shock fronts and in the wake of the ram pressure stripped core. Crawford et al. (1999) have detected the optical emission line gas surrounding the brightest cluster galaxy. The galaxy has a large H$\alpha$ luminosity above $10^{42}$ erg s$^{-1}$ and a large star formation rate (200 solar masses per year, O'Dea et al. 2008). The unique location of the brightest cluster galaxy behind the shock front and offset from the X-ray cool core allows us to investigate the effect of turbulence behind the shock front and disruption of the cooling core on the cool $10^4$ K gas in the system.

**Key words.** Galaxies: clusters: individual: Abell 2146 - Galaxies: interactions

## 1. Introduction

The galaxy cluster Abell 2146 (z=0.233) is in the process of a major merger event (Russell et al. 2010). In the hierarchical merger scenario the subcluster member galaxies are effectively collisionless particles and so should, along with the dark matter component, lead the baryonic gas, which is held up by friction, after the main collision event. This is observed in the Bullet cluster (Markevitch et al. 2002) however, while many of the subcluster member galaxies do appear to be in front of the X-ray peak, in Abell 2146 the brightest cluster galaxy (BCG) is located directly behind a Mach 2 shock front and in the wake of the ram pressure stripped cool cluster core (see Fig. 1).

X-ray observations of shock fronts are extremely rare, currently only a few other examples are known: the Bullet cluster, Abell 520 (Markevitch et al. 2005) and Abell 754 (Macario et al. 2010), as they require the interaction to be close to the plane of the sky, hence the unusual location of the BCG is unlikely to be due to a projection effect.

## 2. Emission line structure and kinematics

We report the discovery of a narrow plume of warm gas, 4 kpc wide and greater than 12 kpc long coincident with the soft X-ray emis-

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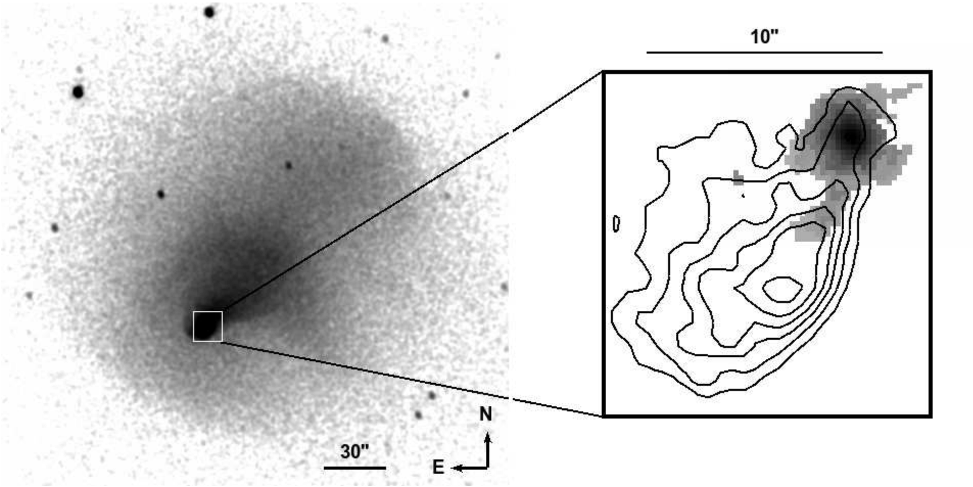


**Fig. 1.** Left: *Chandra* X-ray image of Abell 2146 in the 0.3-0.7 KeV energy band smoothed with a 2D Gaussian with $\sigma$ = 1.5 arcseconds. Right: H$\alpha$ emission above 3$\sigma$ overlaid with *Chandra* soft X-ray contours (0.5-1.0 KeV).

sion being stripped from the subcluster cool core. The total H$\alpha$ luminosity of the plume is $4.7\times10^{40}$ erg s$^{-1}$, which is 2 per cent of the total H$\alpha$ luminosity ($2.0\times10^{42}$ erg s$^{-1}$) of the BCG. This luminosity is consistent with the long slit observations of Crawford et al. (1999; $L_{H\alpha} = 1.8\times10^{42}$ erg s$^{-1}$). Using the mean electron density in the plume ($10^3$ cm$^{-3}$) calculated from the [S II] ratios and, assuming that the gas is fully ionised and that the plume is a cylinder of radius 2 kpc, we estimate the mass of hydrogen in the plume to be $2\times10^{10}$ $M_\odot$. The remaining gas in the core is very compact and extends to a radius of only about ~6 kpc. There is evidence of rotation in the central galaxy around the south-east axis and a smooth gradient in the line-of-sight velocity of the plume. The plume gas is either being stretched out or collapsing into the central galaxy depending on the orientation.

## 3. Summary

We report on a work in progress where we have discovered a narrow, massive H$\alpha$ plume either being dragged out behind the ram pressure stripped cool core or falling back onto the BCG. One possibility for the unique location of the BCG is that we are observing a late stage merger where the subcluster has already reached the apocenter of its orbit and the gas has rebounded in a 'ram pressure slingshot' (Hallman et al. 2004; Mathis et al. 2005; Ascasibar et al. 2006) and overtaken the galaxies. However the shock velocity ( = 2200 km s$^{-1}$) and projected distance from the center of the main cluster implies that the merger age is only 0.1-0.3 Gyr. The prominence of the two shocks and the intact subcluster core also suggest that the main merger event did not occur very long ago.

Combining our observations with lensing observations of the mass distribution (King et al. in prep) will allow us to understand further the stage of this merger and the unusual location of the BCG.

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