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The Dynamics of Abell 2634

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Abstract

We have amassed a large sample of velocity data for the cluster of galaxies Abell 2634 which contains the wide-angle tail (WAT) radio source 3C 465. Robust indicators of location and scale and their confidence intervals are used to determine if the cD galaxy, containing the WAT, has a significant peculiar motion. We find a cD peculiar radial velocity of 219 ± 98 km s^{-1}. Further dynamical analyses, including substructure and normality tests, suggest that A2634 is an unrelaxed cluster whose radio source structure may be bent by the turbulent gas of a recent cluster-subcluster merger.

Introduction

Abell 2634 is a nearby rich cluster of galaxies which is an excellent setting for the study of environmental effects on galaxies. It contains a cD galaxy, NGC 7720, which is home to the prototypical wide-angle tail (WAT) radio source, 3C465. The bright radio core coincides with the optical nucleus and also the peak in the X-ray emission (Eilek et al. 1984). Diffuse X-ray emission asymmetrically surrounds the cD, which is roughly centered on the galaxy distribution. The cD also contains a companion projected about 12″ (7.2 h_{75}^{-1} kpc) away from the cD nucleus.

Most of the above features of A2634 can play a role in an underlying question of this project: what determines the structure and creation of the radio source 3C465? The WAT radio structure includes two straight jets eminating from the powerful core in opposite directions. The jets decollimate into tails at hot spots roughly equidistant from the core. The diffuse tails bend at or after these decollimation points and extend great distances (about 200 kpc in the case of 3C465). The tails of 3C465 are rather symmetrically bent forming an $\approx$ 90 degree angle with each other. This symmetry has suggested that the WATs are the slower analog of the NAT phenomenon, where motion of the galaxy through the intracluster medium (ICM) bends back the tails via ram pressure (Fanti 1984). Eilek et al. (1984) looked carefully at the physics involved in bending and disrupting the jets at the hot spots and found that galaxy velocities of $\approx$ 1000 km s^{-1} with respect to the ICM would be required for the ram pressure model. O'Donoghue et al. (1992) have recently reexamined the bending phenomenon and found that if another mechanism can be employed to disrupt the jets, lower velocities would be required to shape the tails. They found for tails that emit without *in situ* energization (the *adiabatic* model), the tails will bend by ram pressure even with low galaxy velocities (100 km s^{-1} was used). Their *kinetic* model, which is the opposite extreme where all energization occurs by *in situ* processes, did not allow the ram pressure bending. The true case is probably somewhere between these two models, so a lower limit on the required velocity is uncertain.

There are several reasons for opting for a bending mechanism which does not require the central dominant galaxies (CDGs) to move in WAT clusters. Few of the WATs in the O'Donoghue et al. sample (1990) show as symmetrically bent tails as 3C465, and one (Abell 690) even shows the two tails bending in opposite directions. Thus, it appears that more than simple galaxy motion through an ICM is required to create the structures. Moreover, observations of the central locations of CDGs (relative to both optical and X-ray centroids), as well their radial velocities (e.g. Quintana & Lawrie 1982) have set upper limits for their true velocities around 300 km s^{-1}. The lack of tidal truncation of extended cD envelopes puts even stricter limitations on the velocity of the CDG in their oscillations about the cluster center (Merritt

1984).. We thus became interested in carrying out a study of the dynamics of A2634. In particular, does the cD have a radial peculiar motion and is the cluster relaxed?

Results

We used the MX multifiber spectrometer and 90-inch telescope at Steward Observatory for redshift observations of 126 galaxies in Abell 2634 (i.e. $6000 < V < 14000$ km s^{-1}). This membership criterion reveals a central concentration of galaxies which is elongated with the same position angle as the cD galaxy and the asymmetric extension of X-ray gas. The companion galaxy to the cD is moving at 920 km s^{-1} with respect to the cD; it is not bound. The difference between the cD velocity and the cluster velocity centroid is -219 $\pm$ 98 km s^{-1} . The error for this peculiar motion suggests a 3% probability that the cD shares the radial velocity of the cluster. The velocity distribution can be rejected as Gaussian at the $\approx$ 93% level. It suffers from asymmetry and a long tail both due to high-velocity outliers. We looked for substructure using the δ-test (Dressler & Shectman 1988) and found that the East side of the cluster contained most of the velocity outliers. We did not find significant substructure in the sense of obvious spatial/velocity subgroups.

Discussion

A scenario which may explain the available observations is one of a progressed cluster-subcluster merger. Evrard (1990) has run an N-body, hydrodynamic simulation of cluster formation with a special emphasis on the appearance of the cluster in X-ray over time. The simulation includes a subcluster merger and he finds that the gas oscillates for a few crossing times (10^9 yr) before becoming blended into the general cluster distribution so that an elongation of gas along the direction of merger persists when the galaxies are fairly well mixed. This may explain the long X-ray extension in the core of A2634. The residual gas motion could also provide the ram pressure needed to shape the tails of a stationary WAT (since the infall velocity reaches 800 km s^{-1}).

We can account for the small peculiar motion of the cD using the merger idea in several ways. Our velocity sample may be contaminated and skewed by the presence of the subcluster so that the cluster velocity centroid no longer possesses the original cluster centroid. This contamination effect has been observed by Beers et al. (1991) in clusters with more pronounced substructure. More directly, the cD may have been given an impulse by a passing galaxy of the subcluster. We find that the net velocity change of the cD can be $\approx$ 170 km s^{-1} for a galaxy passing with an initial speed of $\approx$ 900 km s^{-1} , an impact parameter of 8 kpc and a mass of $.1M_{cD}$. It is also conceivable that the cD could have an induced oscillation in the cluster potential well due to the disturbance by the entire subcluster mass. For typical core radii and cluster potentials, however, the extent of the cD's oscillation is restricted by its lack of tidal stripping. Finally, the differences between our velocity distribution and a Gaussian, and the substructure results are both consistent with a progressed state of merger - where the galaxies may be dispersed but still do not have velocities characteristic of a relaxed cluster.

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