Direct X-ray Spectral Deprojection of Galaxy Clusters

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Introduction

Temperature, density and abundance profiles of the hot intracluster medium (ICM) are important diagnostics of the complex interactions of gravitational and feedback processes in the cores of galaxy clusters. Deprojection of X-ray data by methods such as PROJCT, which are model dependent, can produce large and unphysical oscillating temperature profiles (eg. PROJCT Figure 1). Direct Spectral Deprojection (DSDEPROJ; Sanders & Fabian 2007; Russell et al. (submitted)) is a model-independent approach, assuming only spherical symmetry, which solves some of the issues inherent to model-dependent deprojection routines.

Method

DSDEPROJ starts with spectra extracted from a series of concentric annuli in a sector of the cluster and subtracts off suitable blank-sky background spectra. Assuming spherical symmetry and using appropriate volume scaling factors, DSDEPROJ subtracts projected spectra from each successive annulus to produce a set of deprojected spectra. Uncertainties on individual spectra were calculated using a Monte Carlo method.

The resulting deprojected count spectra were each fitted in XSPEC v11 with an absorbed single-temperature MEKAL model to produce the temperature, density and metallicity profiles. The projected spectra were also deprojected with the XSPEC model PROJCT for comparison.

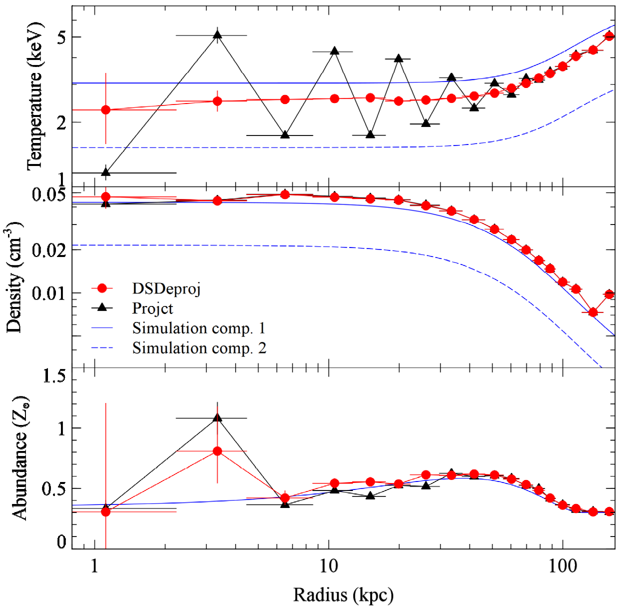
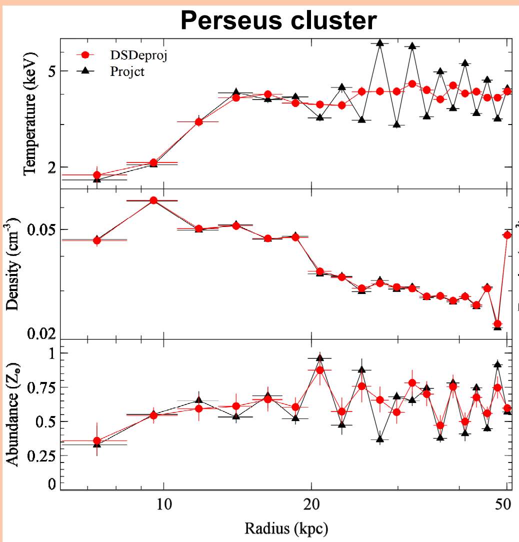
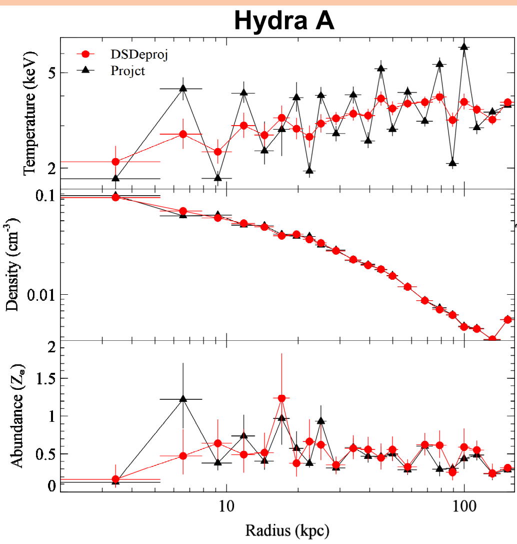


Figure 1: Deprojected temperature (top), electron density (centre) and metallicity (bottom) profiles for a two-temperature simulated cluster. The single-temperature PROJCT and DSDEPROJ results are overlaid on the true cluster profiles. Multiphase gas produces large and unphysical oscillations in the PROJCT temperature profile.

Results





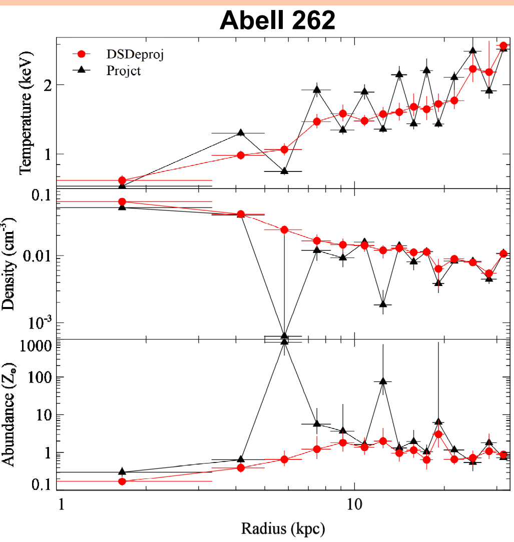


Figure 2: Deprojected temperature (top), electron density (centre) and metallicity (bottom) profiles for the Perseus cluster. Spectra were extracted from a sector of the cluster core containing a section of the weak shock that surrounds the inner bubbles (Graham et al. 2008). DSDEPROJ produced a stable temperature profile despite the presence of multiphase gas in the cluster core.

Figure 3: Deprojected temperature (top), electron density (centre) and metallicity (bottom) profiles for Hydra A. Spectra were extracted from complete annuli, excluding the central 1.5” of the cluster. There are significant quantities of cooler gas throughout the cluster core (Nulsen et al. 2002), which resulted in a particularly unstable PROJCT temperature profile.

Figure 4: Deprojected temperature (top), electron density (centre) and metallicity (bottom) profiles for A262. Spectra were extracted from a sector to the south of the nucleus. The sharp drop in density at ~6kpc was caused by the unphysically large value of the metallicity. The inner regions of A262 contain bright knots of cooling gas, which provide a challenge for any deprojection routine.

Conclusions

- **DSDEPROJ** is a model-independent deprojection method which produces a series of deprojected counts spectra. These deprojected spectra can be fitted with a suitable spectral model to produce stable radial profiles. Russell et al. (submitted) showed that when DSDEPROJ was applied to a set of simulated clusters the correct deprojected profiles were recovered. DSDEPROJ was also shown to produce stable results for elongated clusters and clusters containing sharp jumps in temperature and density.

- **PROJCT** fits spectra extracted from a series of concentric annuli simultaneously to account for projection. However, for a multiphase medium, a single-temperature PROJCT fit will tend to account for one temperature component in one shell and another in a neighbouring shell. The resulting temperature profiles oscillate and are unstable to changes in the radial binning.