Simulated Cluster Archive: A Computational Catalog of X-Ray Clusters in a $\Lambda$CDM Universe

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Abstract. We have simulated the evolution of a large sample of X-ray clusters in a $\Lambda$CDM universe at high spatial resolution using adaptive mesh refinement and placed the results in an online archive for public access. The Simulated Cluster Archive website sca.ncsa.uiuc.edu provides tools for interactive 2D and 3D analysis of gas and dark matter fields, X-ray and SZ imaging, and data export. We encourage community use and solicit their feedback.

1 Why a Simulation Archive?

The creation of public archives of high-value observational data (e.g., NASA’s HSEARC) has been a great boon to astronomical research in the past decade. It has given rise to a new kind of astronomer—the archival astronomer—who is free to check the methods and results of the data’s authors, as well as to pursue independent, and sometimes novel, lines of inquiry. Archival astronomy is expected to grow in scope and importance in the coming decade. By creating this archive of simulated X-ray clusters, we hope to extend this concept into the computational realm where simulations are growing in size and complexity.

2 Science Goals

Our goal is to produce large, statistical catalogs of $\sim 100$ clusters simulated at high resolution for two cases: (1) with, and (2) without non-adiabatic physical processes, in order to:

- understand the role of non-adiabatic processes in X-ray clusters,
- make definitive predictions of the XLF evolution in both cases,
- compare degree of cluster substructure with observational samples,
- determine frequency of cooling flows as a function of $z$. 
We simulate a ΛCDM model with parameters $h = 0.7, \Omega_m = 0.3, \Omega_b = 0.026, \Omega_\Lambda = 0.7, \sigma_8 = 0.928$. The survey volume is $256h^{-1}\text{Mpc}$ on a side. We employ a new hydro+N-body code which uses Adaptive Mesh Refinement to place high resolution grids where needed. First, a survey calculation was performed with $256^3$ cells, $128^3$ particles, and two levels of refinement everywhere to locate the clusters in our sample. Then, each cluster is recomputed with up to 7 levels of refinement within the cluster environment. The DM mass resolution is $\sim 10^{10} h^{-1}M_\odot$; the L7 spatial resolution is $15.6h^{-1}\text{kpc}$.

The adiabatic (control) sample is near completion and being analyzed. Preliminary results focusing on the ten brightest clusters have been reported in and a second, more extensive paper is in preparation.

3 Archive Design and Tools

AMR simulation data structures are hierarchical and complex, and require specialized software for their manipulation and analysis. One of the design goals of the SCA was to shield the user from the complexity (and size) of AMR simulation data. We accomplished this by developing the SCA as a workbench-style system that lets users interact with the archived data over the Web. The user begins by selecting a cluster from a catalog list or a 3D VRML map. The server then retrieves the raw AMR data from NCSA’s mass storage system. Once the data is on the SCA web server, the user extracts from the AMR files particle data and field data sampled to a uniform grid of user-specified size and resolution. At this point, the user may export the extracted data as HDF files for local analysis or use the suite of analysis tools provided as a part of the SCA. The tools, which include 2D and 3D visualization tools, X-ray and SZ imager, and graphing tool, are implemented as thin Java applets in a client-server model. More detail can be found in.

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