The Catalog of Galaxy Clusters from an Adaptive Matched Filter (AMF) Method Applied to SDSS DR9

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Abstract

We use an Adaptive Matched Filter (AMF) finder on Sloan Digital Sky Survey Data Release 9 (SDSS DR9, Ahn et al. (2015)) to select galaxy clusters. The galaxy clusters are found using a method that relies on the fact that clusters have, on average, a typical color distribution, and we use the SDSS DR9 catalog. By removing known objects from the catalog, we have built the catalog containing clusters from the Northern Hemisphere, but we set to remove objects. Although the initial data is selected to reduce the number of false galaxy detections, anomalous objects with photometric data that differ from the expected values, we use a slightly different SQL routine to identify potential non-clusters. We compare our catalog with other optical galaxy cluster catalogs to identify potential non-clusters.

What are Galaxy Clusters?

Galaxy clusters are the most massive gravitationally bound systems in the Universe. They have been found to be massive, dark matter dominated structures that correspond to the densest objects we observe today. Clusters of galaxies are the densest objects we observe today and hence are excellent laboratories for studying galaxy evolution. The mass function of galaxy clusters allows for the determination of several cosmological parameters, including the mass density, Ω_m, and the matter power spectrum normalization to WMAP (Komatsu et al. 2011). The mass function also allows for the determination of the dark energy equation of state (Wang et al. 2008) and neutrinos masses (Riess et al. 2005). A cluster is defined as a group of galaxies in which the density of galaxy members is higher than the local background density. A cluster radial surface density profile (NFW profile), a galaxy luminosity function (Schechter luminosity function), and redshift information are used to construct the cluster catalog. In the NFW profile, the density of dark matter as a function of radius is given by:

\[ \rho(r) = \frac{\rho_s}{(r/r_s)(1 + r/r_s)^2} \]

where \(\rho_s\) is the characteristic density, \(r_s\) is the scale radius, and \(r\) is the radius from the center of the cluster. The Schöffer luminosity function provides a parameterization of the spatial density of galaxies as a function of their luminosity:

\[ L_\ddot{f}(r) = \frac{1}{\sqrt{2\pi}} \int \exp \left( -\frac{m - m_*}{2\sigma^2} \right) \frac{d^2n}{dm} \frac{dm}{dm_*} \]

where \(L_\ddot{f}(r)\) is the characteristic galaxy luminosity where the power-law form of the function cuts off. The cluster finding algorithm correlates the likelihood on a grid whose points are centered on the positions of galaxies. After the clusters have been identified, it is necessary to relax the hypothesis that clusters are centered on a galaxy and refine the center position as well as the characterization of the clusters. The richness of a cluster is defined as the number of member galaxies within a fixed radius, typically 0.5 or 1.0 Mpc.

Looking forward

We are currently in the process of finishing the catalog construction, after which we will compile the validation process and check for systematics (such as artifacts we may flagging as clusters). This should be a very reliable and robust catalog once it is completed.

However, in future versions of the AMF catalogs, there is plenty of scope for refinements. The current catalog is constructed using a binary search algorithm, although the code could be extended to make use of information in all bands. Our catalog is truncated at an r-band magnitude of 22, because above this the behavior of the Schechter luminosity function is not well understood. This can be investigated in future catalogs.

Because the matched-filter algorithm uses both a cluster galaxy luminosity function and a field galaxy luminosity function which are expected to be different due to the morphology-density relation (Dressler 1982) and the observed dependence of the luminosity function on galaxy overdensity (Christiansen et al. 2005, Mo et al. 2004; Croton et al. 2005), it would be desirable to model these separately.

Validating the Catalog

One of the major tasks after building the catalog is to validate it, i.e., comparing it to other published catalogs (X-Ray, optical and X-posure). How many clusters from one catalog occur in the other and vice-versa? How well the richness and redshifts of the respective cluster catalogs correlate? How many clusters from one catalog occur in the other and vice-versa? How well do the richness and redshifts of the respective cluster catalogs correlate? To validate the AMF DR9 Northern Galactic Cap catalog with the XMM database of X-Ray clusters.

References