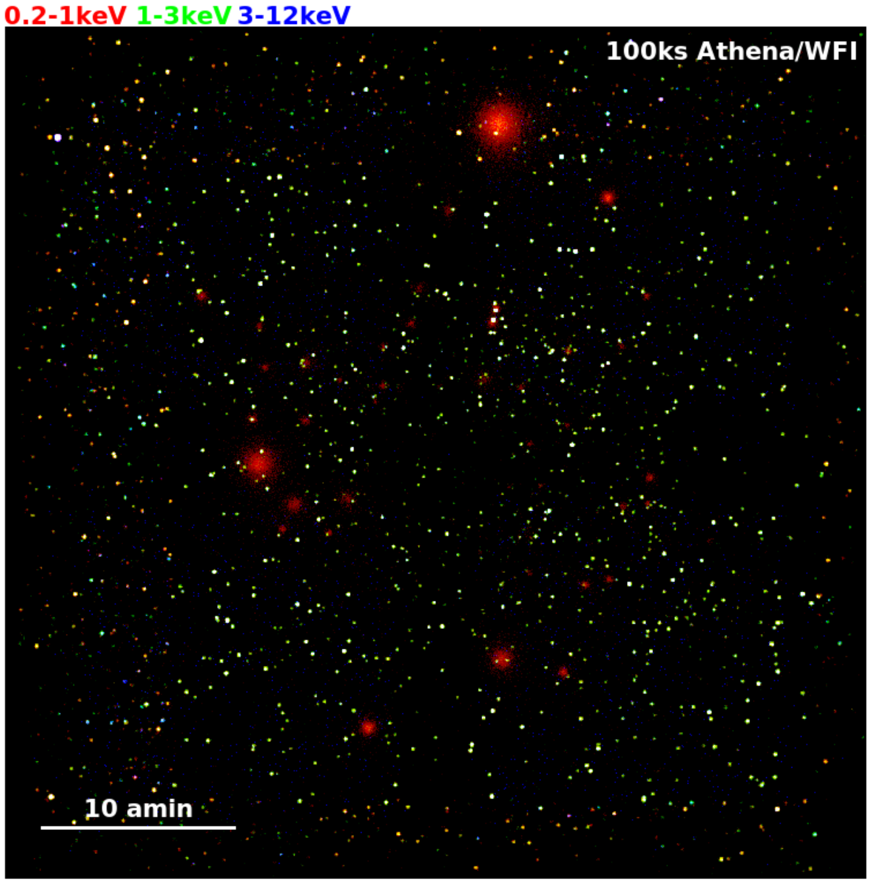
Unveiling the Hot, High Redshift Universe with the Athena WFI

Steven Allen and Adam Mantz (Stanford University)

Studies of galaxy groups and galaxy clusters, the largest objects in the Universe, have played an important role in helping to establish the standard model of cosmology, with a universe dominated by dark matter and dark energy and structure that grows in a hierarchical manner. Cosmological tests with groups and clusters have placed powerful constraints on the mean matter and dark energy densities, the dark energy equation of state, how gravity works over very large scales, and the masses of neutrinos. Equally important, astrophysical studies of groups and clusters have provided critical insights into the nature of dark matter, how environment impacts the evolution of galaxies, the interplay between supermassive black holes and their environments, and how and when the chemical enrichment of the intergalactic medium occurred.

The foundation of galaxy group and cluster science is provided by sensitive wide field surveys. With its ground-breaking capabilities, the *Athena* Wide Field Imager (WFI) will revolutionize these studies. By exploiting fully the exceptional grasp (product of collecting area and field of view) and spatial resolution of the *Athena* mirrors, and their exquisite sensitivity at soft X-ray energies, the WFI will open a new window onto the early universe, enabling us to find and characterize the first galaxy groups and clusters that formed, more than 10 billion years ago.

Most of the normal (baryonic) matter in the Universe is in the form of diffuse gas, which is typically very hard to see. However, galaxy groups and clusters are so massive that their gravity squeezes this gas, heating it to temperatures of millions of degrees and causing it to shine brightly in X-rays. The more massive the group or cluster, the brighter and hotter the X-ray emission.



SIXTE simulation of a single 100ks *Athena*/WFI pointing of the *Chandra* Deep Field South. Galaxy groups and clusters identified in the field are visible as extended red (i.e. soft) sources. Credit: WFI Team.

As well as determining when the first galaxy groups formed, WFI observations will show how they were then pulled together by gravity to form more massive galaxy clusters. Measurements of the rate of this growth will provide a sensitive probe of cosmology. By providing precise masses for the clusters and characterizing their dynamical states, WFI measurements will also enable a host of astrophysical studies. Working in coordination with observatories operating at other wavelengths, WFI observations will reveal the physics that drives galaxy evolution in groups and clusters, from the triggering and quenching of star formation to the activity of supermassive black holes, and the relations between these phenomena and the X-ray emitting group and cluster gas. WFI measurements will shed new light on the cycling of matter in and out of galaxy groups, being pulled by gravity and pushed by galactic winds, and the resulting chemical enrichment of the intergalactic medium.