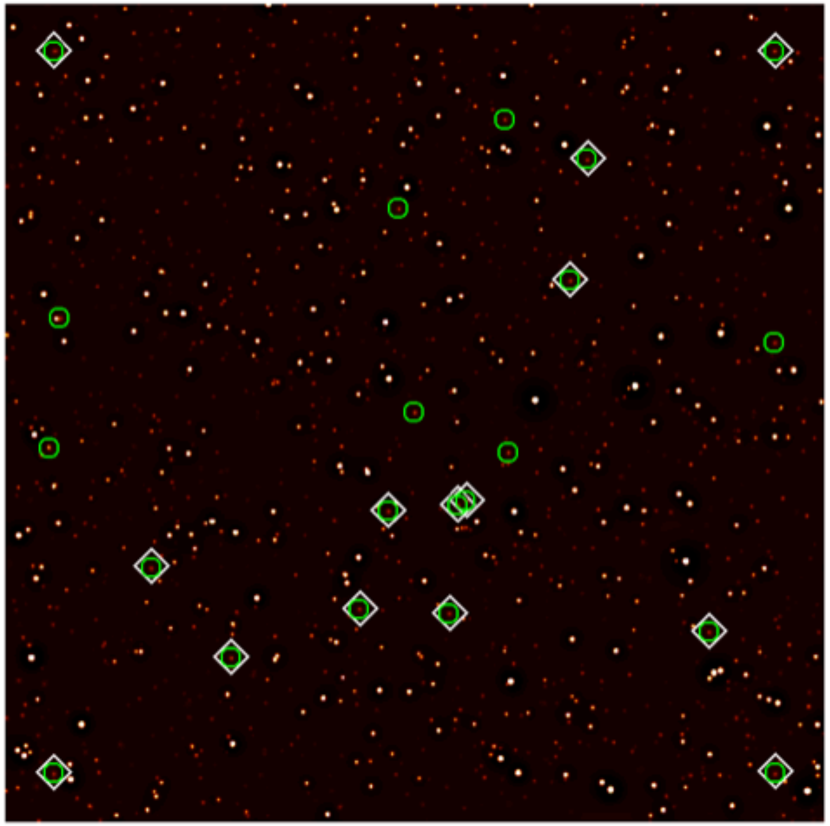
Athena's discovery potential for early galaxy groups

Thomas H. Reiprich, Chaoli Zhang, Miriam Ramos-Ceja, and Florian Pacaud, Argelander-Institut für Astronomie (Bonn, Germany)

Astronomers love to search for distant objects because distant means old. Or rather it means these objects existed when the Universe was very young. For instance, the first stars have not been found, yet; when did they exist and did they really have the huge masses expected theoretically? Do the highest redshift gamma-ray bursts provide insight here? When did the first galaxies and their supermassive black holes form? Are their mass distributions and number densities as expected by current models? This passion for the remote and distant is not only due to astronomers' intrinsic curiosity but these early objects indeed hold important clues about processes that affect their formation and evolution. *Athena* will be instrumental in answering these questions.

The biggest objects in the Universe are galaxy groups and clusters. Within the current cosmological paradigm they should have formed bottom up; i.e., smaller ones formed first, then growing bigger with time through accretion and mergers. So, when did the first groups – massive enough to bind >10^7 Kelvin hot plasma – come into existence? The answer to this question depends on many astrophysical and cosmological known unknowns, and likely on unknown unknowns, too. E.g., it is currently unclear which process – on top of gravity – predominantly shapes the gas density and temperature structure of groups: stellar feedback, or feedback from active supermassive black holes? At high redshift, the model predictions for these scenarios differ strongly. Possibly, the upcoming dark energy observatories eROSITA, Euclid etc. will completely solve all of these cosmology questions. It seems more likely, though, that they will turn up new questions, uncover new riddles. Observations of high-redshift groups will be crucial in answering those unknown questions related to cosmological structure formation.

Athena is the ideal mission to study those early galaxy groups. On the one hand, *Athena* will follow-up high-redshift groups and clusters detected before its launch by other means, e.g., with eROSITA in X-rays, with Euclid and LSST in the optical/infrared, with CMB-S4 in the sub-mm/mm, and/or with SKA in the radio waveband. The unique contributions of *Athena* will then include, e.g., the detailed characterization of their density and temperature structure, of their heavy element abundance, and of their internal gas velocity structure. *Athena* will also discover and characterize new very distant (redshift > 2) galaxy groups with a deep survey of 10s of square degrees within the first four years of the mission (see Figure). In later phases of the mission there is the potential for shallower but much larger area surveys, holding the promise to discover ~10,000 groups above redshift 1.



Simulated wavelet filtered image of an 80 ks Athena/WFI observation. Cosmic X-ray background, galactic foreground, and particle background are included as well as telescope vignetting and PSF degradation with off-axis angle. The green circles correspond to the input groups at z=2.5 with M_{500} = 5×10^{13} Msun and the white squares to the detected sources through the wavelet filtering source and maximum likelihood detection algorithms: it can be clearly seen that moderate exposures with Athena/WFI processed with state-of-the-art software can detect very distant groups to uncover the mysteries of their origin and evolution. Credit: Chaoli Zhang, Miriam Ramos-Ceja, Florian Pacaud, Thomas H. Reiprich, and also the SIXTE team.