A Shot in the Dark: The Integrated H I Content of the Most Massive Structure Known

Background and Relevancy:

One of the prime observational astrophysical goals in the coming decades is the development of 21-cm instrumentation (e.g. the SKA) that will effectively probe the structure of H I emission during the so called "Dark Ages" – the time between recombination and the subsequent re-ionization of the Universe at z ~10. During this period it is presumed that the process of galaxy formation is well underway through halo building (assembly of dark matter into dense cores) and the subsequent capture of neutral hydrogen into these pre-existing halos which ultimately fuels the first generation of star formation. As shown in the SKA simulations:

(http://www.skatelescope.org/pages/science_key_Eor.htm)

There is considerable structure in the neutral and ionized phases of hydrogen as well as significant evolution of these structures. As a result of this structure and its evolution on various spatial scales as well as redshift scales, there should be a detectable signal associated with statistical fluctuations in what is essentially an "H I background", which is similar to the kind of surface brightness fluctuation signal used in stellar population analysis (e.g. O'Neil etal 1999). However, there currently is no observational experience on measuring the integrated H I signal on scales of a few Mpcs that may encompass several hundred/thousand discrete sources. Here we propose to make a pilot observation that, if successful, will allow SKA precursor facilities to have target (at z=0.89) in which to test and optimize any surface brightness fluctuation procedure to detect large H I structures.

In addition, at later times, Z~1, simulations show that a great deal of structure formation through hierarchical assembly is occurring. Observational confirmation of this is clearly available via both optical and X-ray surveys that have definitively detected rich clusters in the redshift range z=1-1.5. It is very likely that these virialized cores are producing a very large population of infalling galaxies much like what is currently observed in the Coma and Virgo clusters. From observations of these nearby clusters it has been well established that a substantial amount of H I from individual galaxies will be lost, either through ram pressure stripping or X-ray heating (evaporation) as the individual galaxy falls through the cluster/ICM for the first time. While this physical situation may be generic to any core+infalling population structure, at z~1 the individual galaxies likely contain much higher fractional H I contents than is the case at lower redshift. Thus the total amount of gas available to the virialized core is significant and its this gas, from infalling galaxies, that may ultimately be responsible for the large baryonic mass fractions observed for cluster cores. However, like the 21-cm surface brightness structure, this effect has never been observed. We are therefore proposing to observe a target of opportunity, afforded by this new spectral window, that can address both of these concerns.

The Target of Opportunity:

The galaxy cluster, CL J1226.9 +3332 was discovered by Ebeling etal (2000) from ROSAT pointed survey data. Follow up observations using XMM-Newton (e.g. Maughan etal 2004) reveal this cluster to be the hottest known cluster at $z > 0.6$ (12 Kev). This temperature is consistent with limited velocity data which suggests a dispersion of 1600 – 1800 km/s. The total X-ray mass has been measured to be 1.4×10^{15} solar masses –again amongst the highest ever measured. Ellis etal (2007) have constructed a CM diagram for the brightest members of this cluster and confirm that, although the fraction of early type galaxies in this cluster is much lower than in Coma, the brightest early type galaxies appear to be substantially old. Hence, by all observational accounts, CL J1226.9 +3332 is a massive, relaxed cluster at $z=0.89$ and shows that this process of cluster formation and subsequent virialization can occur at substantially higher redshifts than simulations predict. That makes this cluster and its environment rare.

We therefore propose to take advantage of the newly opened spectral window at 700-825 MHZ to observe CL J1226.9 +3332 in the redshifted line of 21-cm emission. At the distance of CL J1226.9 +3332 the beam size will project to several core diameters which thus allows the infalling population of gas rich galaxies to be detected. Consider the case of the Coma cluster and the associated Supercluster of infalling spirals. A beam size of approximately 5 core diameters for Coma would contain the bulk of the infalling population (see Bothun etal 1992) which consists of several hundred disk galaxies each with an average H I mass of approximately 5×10^9 solar masses spread out over approximately 3000 km/s of velocity space. This would be the generic signature of any H I beam which contained hundreds/thousands of infalling galaxies into an already existing virialized structure and we seek to attempt detection of this potential population around CL J1226.9 +3332. Clearly this is a high risk, high reward target and we are proposing to observe it here as the appropriate frequency space has now opened up. A detection of an integrated H I signal at $z = 0.9$ would clearly be a new scientific achievement in extragalactic H I and would provide valuable insight into the observational signatures of giant, integrated H I structures that are going to be associated with cluster formation.

Feasibility and Time Request

The declination of the source (+3332) will still allow for 2 hours on target per day. We therefore request 12 days for a total integration time of 24 hours as a preliminary integration time to probe whether or not there is a detectable signal. We have no clear way of showing whether or not detection is feasible as baseline and interference issues in this frequency range are unknown. If we scale up the Coma cluster and allow for a significant increase in the fractional H I content of the infalling galaxies, the expected total H I content would be in the range $10^{13} – 10^{14}$ solar masses, which is, in principle detectable at Arecibo (see Giovanelli 2007 white paper) using standard ON Source OFF Source mapping. Similar results hold if one scales up the $z = 0.28$ detection of H I in a single galaxy (H I mass approximately 10^{11} solar masses – see Catinella 2008). Hence, there is definitely a possibility that the integrated H I content of the infalling population around CL J1226.9 +3332 is detectable and we therefore propose to take advantage of this unique opportunity afforded us by the opening up of this new spectral window for redshifted H I observations.

References:

Bothun etal 1992 ApJ. 395, 347
Catinella, 2008 in The Evolution of Galaxies Through the Neutral Hydrogen Window
Ebeling etal 2000 ApJ. 548 L23
Ellis etal 2006 MNRAS 368,769
Giovanelli (2007) “Thoughts on the Future of H I Astronomy at Arecibo”
Maughan etal 2004 MNRAS 351,1193
O’Neil etal 1999 118, 1618