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Sent: Saturday, September 22, 2007 2:31 PM
To: richard.mccray@colorado.edu
Cc: jhewitt@mit.edu; futurescommittee@nrao.edu
Subject: Re: [FuturesCommittee] [Fwd: Re: Epoch of Reionization White Paper]

Hi Dick et al. -

I certainly agree that Dark Ages should be packaged as long-range. I would even be happy with a statement to the effect that to get this to work requires separating signal from background to one part in 10^6, and if the pathfinders cannot demonstrate the one part in 10^4 or 10^5 needed for reionization, then we quit. While we want to try these measurements from the ground, the moon really does offer the advantage that its ionosphere is negligible at these frequencies, and the Earth's ionosphere is nasty.
Plus RFI shielding of course. Joe, Jack, Chris, and I have already publicly argued that there is value in this approach! And as Chris said, the NAC came out with a report that a lunar dark ages survey is the highest priority topic for astrophysics from the moon. It certainly need not be done by astronauts - it could be done robotically - and the community should compare costs and benefits of all the astrophysics missions.

A few more comments.

Looking at calculations in Furlanetto et al review, the Dark Ages signal is 10 mK at z=40. The ratio of foreground to signal is about

F/S = 10^5 [(1+z)/10]^2.6

or F/S = 4 times 10^6 at z=40

Judd Bowman as part of his thesis work did a simulation of foreground subtraction at z=8 for which F/S = 8 times 10^4 according to our formula.
He assumed all point sources down to 10 mJy were subtracted from the uv data. Further foreground subtraction was done by fitting a smooth function to each image pixel and subtracting that. He simulated the sky by convolving it with FREQUENCY-DEPENDENT ANTENNA TILE BEAMS which have nasty, large frequency-dependent sidelobes. This is important as it vastly increases the noise in the image due to confusing sources. In a simulation with no thermal noise, the foreground was subtracted to the level of a tenth of a MICROKelvin. With thermal noise, the rms in the foreground- subtracted image was indistinguishable from the rms in an image modeled without the foregrounds. In other words, the indication is one can subtract the foregrounds when F/S = 8 times 10^4 if one pre-subtracts point sources to 10 mJy. We haven't yet done numerical experiments with F/S as large as the Dark Ages values - but since the foregrounds are "only" a factor of 100 larger, one would expect you "only" have to subtract point sources down to 100 microJy - not the nanoJy level that Nick said. If anyone would like to read Judd's thesis I can send it along. He is writing these results up for publication.

Using velocity effects to separate the primordial dark matter power spectrum from the reionization effects at smaller redshifts (like z=10):

This is an alternative to going to high redshifts to measure the uncontaminated (by star formation and other "gastrophysics") dark matter power spectrum. A reference is Barkana & Loeb 2005, ApJ, 624, L65.
The idea is based on the fact that the power spectra associated with different source terms have different

dependences on the angle to the line of sight.
So if you could get a nice big dataset that has information on k_x, k_y, k_z (as you should with 21cm since it is optically thin) you could in principle separate out the part of the power spectrum that reflects the dark matter distribution. Max Tegmark and an MIT graduate student are doing simulations of this and last time I talked to Max about this a couple of weeks ago he said it looks fairly promising. I haven't yet seen quantitative results.

As for our report - I think this is an issue of philosphy. I like to take small steps toward a large goal. There are a lot of examples of this.
Take LIGO for example. 15 years ago many people thought what the LIGO collaboration was proposing was impossible. Now they have reached Initial LIGO design senstivity, which is in itself remarkable. The upgrade to Advanced LIGO is only a factor of ten in amplitude sensitivity, and it will be accomplished by several factors of 2-3 improvements, none of which looks too difficult. With Advanced LIGO a failure to detect gravitational waves would be a real surprise. It is a good thing Bob Eisenstein was willing to take the risk and invest in LIGO. They reached their sensitivity level via a series of small improvements, and could have been halted if any of those failed.

CMB measurements have a similar history. I remember in the mid-80s when MIT theory graduate students were doing theses calculating the little bumps and wiggles in the CMB power spectrum I was amazed they could put so much effort into something that was so far away from being measurable. I'm glad they did. And the CMB sensitivities improved bit by bit until now the polarization people are working on detecting a signal that is one part in 10^9.

Similarly, I believe the EoR/DarkAges work will gradually improve and should be halted if we cannot overcome the obstacles along the way. But I also want to keep my eye on the most interesting goals, and I believe those goals should be a factor in our motivation to proceed.

Jackie
