Intensity Mapping Baryon Acoustic Oscillation Experiments

Using 21-cm, Lyman Alpha and CII (158 micron) emission

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By Jeff Peterson CMU, March 11, 2012

CMU Cylinder Telescope Prototype
Outline

• Baryon Acoustic Oscillations
• 21- cm Intensity Mapping
• GBT Results
• Planned 21 cm intensity mapping experiments
• Lyman-alpha IM with Galex
• 158 micron IM with ALMA or JCMT
The History of Hydrogen Gas

GBT
Tianlai
CHIME
BINGO

LOFAR
MWA
PAPER
GMRT
PaST/21CMA

Lunar or Antarctic Array

Image: Scientific American 2006
Alfalfa redshift survey

Large scale structure matches optical surveys
Baryon Acoustic Oscillations – Dark Energy Probe

• CMB acoustic oscillations: imprinted standard ruler, 400 Mly.
Baryon Wiggles
Detected by
SDSS, 2df, WiggleZ

Eisenstein et al. 2009
21 cm Intensity Mapping

• 21-cm Intensity Mapping, JP, etal (arXiv:0902.3091)
• Chang, Pen, JP, McDonald PRL 100, 091303(2008)
Alfalfa 21-cm redshift survey
Green Bank Telescope
West Virginia

• 50 hours observation at z=1
• 10 hours at z=1.5

• DEEP2 Fields 2,4 deg x 0.5 deg fields

• 15 arcmin angular resolution at z=1
21cm – DEEP2 cross correlation

Current program

- Attempt to detect 21 cm structure without use of optical survey

- Sweep Horizontally across Wigglz fields, rising, setting and transit

- Use CMB cross linked imaging algorithm

- Use SVD to remove modes with common Freq. structure.

- Residual rms about 40 microK, about the expected amplitude of 21 cm signal.
21 cm <> optical cross correlation

21 cm Auto-correlation

Proposal under review for 9 feeds on GBT (and 3000 Hours)
Fast 21-cm Intensity Mapping Telescope concepts

- Many feeds on single dish (BINGO, GBT x 9)
- 100 close-packed dishes (Tianlai?)
- 2000 feeds on a cylindrical telescope (CHIME)
- 1,000,000 dipole in a filled aperture

Figure k shows a possible configuration for the complete HSz dark energy survey telescope. Optimization of the design is described in [k]e who have investigated the effect of array design on the standard ruler test with BzOe using the Dark Energy Task Force Figure of Merit as a benchmark. They also perform simulations of foreground removal assuming the foreground spectra are smooth compared to that of the HI signal. They optimize the survey parameters and present a fiducial example of an HSz BzO survey that is competitive with other Stage III dark energy experiments.

4.2 Experience with the Pittsburgh Cylinder Telescope (PCT) as a first step toward developing a dedicated cm intensity mapping telescope. Peterson led an international team including Uros Seljake UefLi, Pene Kris Sigurdsone and their students to assemble the PCT. The purpose of this prototype instrument was to examine cylinder telescope construction methods, cost, feed technologies, LNzse correlation technology, image artifacts, calibration techniques and more generally, to examine the issue of continuum foreground subtraction.

The PCT consists of two cylinders each 1 m wide and kn m long, with a separation of kn m between centers. The cylinders are oriented N-S. PCT is a transit telescope and uses FFT beamforming to create a fan of beams spanning most of the meridian. Each cylinder currently has lk dipoles installed along the focus. Jo dipoles of each linear polarization, which feeds a channel software correlator. So far we have used dipoles for each polarization that are spaced λ so for beams near the zenith there are n
The Tianlai Consortium

- Jeff Peterson (CMU)
- Kevin Bandura,
- Bruce Taylor
- Jim McGee
- Florence Liu
- Deena Kim
- Bruce McWilliams
- Ue-LI Pen (CITA)
- Uros Seljak (U. C Berkeley)
- Hee Jong Seo
- Peter Timbie (U. Wisc.)
- Scott Dodelson (FNAL)
- John Marriner
- Dave McGinnis
- Albert Stebbins
- Tzu-Ching Chang (IAA Taipei)
- Kris Sigurdson (UBC)

- Chen Xuelei (NAOC)
- Shi Huli
- Wang Yougang
- Wu Fangquan
- Li Yichao
- Chen Zhiping (Hangzhou Dianzi University)
- Rui Lui
- Christophe Yeche (Irfu - CEA)
- Christophe Magneville, Jim Rich
- P. Abbon, C.Flouzat, H. Deschamps (~ 1 FTE)
- Reza Ansari (LAL – CNRS/IN2P3, U. Paris Sud)
- Jean-Eric Campagne, Marc Moniez, Anna-Sofia Torrento
- D. Charlet, C. Beigbeder, T. Caceres, B. Mansoux, C. Pailler, M. Taurigna, (~2 FTE)
- Observatoire de Paris:
  - Pierre Colom, Jean-Michel Martin
  - J. Pezzani, …
- Jon Bunton (CSIRO)

Carnegie Mellon

IN2P3

CITA

ICAT

ECC

CSIRO

NAOC

the David & Lucile Packard Foundation
Commercial satellite
Dishes, individual mounts

Realisations at
LAL
Broad-band feed

- Dipole
- Conical Reflector
- Disk
- Ferrite
- 180 degree hybrid

0 dB = 9.42 dBi
Directivity = 9.91 dB

- 720.000 MHz  0.0 deg.
- 960.000 MHz  0.0 deg.
- 1200.000 MHz  0.0 deg.
- 1440.000 MHz  0.0 deg.

/Users/jeffreypeterson/Desktop/research/reionization/sky-temp/cone-dipole-both-discs-1GHz.nc
Thursday 27 Oct 2011 12:01
LNA Noise and gain

mga_amp_test_3 Noise Measurements

- n1 Gain
- n1 Noise

Gain (dB)

freq (Hz)
Sky Brightness Valleys
Lyman Alpha Intensity Mapping with GALEX

Redshift 0.5 – 1.3

Slit-less spectroscopy
Rotate satellite to create a CAT scan of cosmic structure
Lyman Alpha cross correlated with C+(158 micron)

Subaru LAEs at $z \sim 6$

Make 3-d image of SDF at 1 mm
With ALMA or CSO or JCMT
Conclusions

- 21 cm intensity mapping at z~1 is succeeding
- Many 21-cm BAO instruments proposed or under construction
  - Bingo, Tianlai, Chime, GBT nine-element etc.
- Intensity mapping with Ly Alpha, 158 micron line also promising.
- One year of observations with Galex could produce an IM BAO surveys