Intensity Mapping of 21-cm line

Lessons learned from GBT

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- "Intensity Mapping" (IM): measurement of spatially diffused spectral line, in the confusion-limited regime
 - brightness temperature fluctuations on the sky - just like CMB, but in 3D
 - low angular resolution redshift survey

 without spatially resolving down to
 galaxy scales
 - Economical z-survey, but depending on the scales of interest.

- IM applications to 21-cm line
 - EoR experiments (z~10): measure HI power spectrum; probing scales of the ionized regions (20-50 Mpc) (?)
 - LSS/BAO measurements (z~1): probing BAO scales (150 Mpc); measure collective emission from HI clumps (DLAs).

Large-scale structure IM 21-cm measurement with GBT



Large-scale structure IM 21-cm measurement with GBT

- 21-cm: ground-state spin-flip hyperfine transition of neutral hydrogen. Weak.
- Previous 21-cm in emission: direct detection at z=0.2 (Verheijen et al. 2007), stacking technique at z=0.24 (Lah et al. 2007)

- Green Bank Telescope 100 meters in diameter; largest steerable single dish
- Observed at 670-910 MHz at two of the DEEP2 fields (2x 2x0.5 deg²) for ~25 hrs in total
- Probing 0.53 < z < 1.1
- Beam FWHM ~ $15' => 9 h^{-1}Mpc$ at z~0.8
- Spectral resolution ~ 24 kHz, rebinned to ~500 kHz => 2 h⁻¹Mpc
- Resolution element ~ $(9 h^{-1} Mpc)^3$

Calibration, RFI, foregrounds, etc.

- Calibration: noise-source injection
- Localized in frequency (line RFIs): flagging. Use cross-polarization correlation as a threshold. HI is non-polarized while RFI is.
- Smooth in frequency (everything else: broad-band RFI, foregrounds, gain variations): SVD eigenmode projection
 - Assume temperature field a separable function in space and frequency, T(x, f) = g(x) h(f)
 - Project out a few modes with largest eigenvalues.
 - On per drift scan time-scale (8-min; 2x0.25 deg²)
 - On observation time-scale (~12 hr; 2x0.5 deg²)

RFI, foregrounds, etc. Removal

- 21-cm signal: ~200 microK expected.
- Localized in frequency (line RFIs): dominant. Cross-polarization flagging removed 5% of data, reduced rms fluctuation to ~150 mK
- Smooth in frequency (everything else): rms fluctuation ~ 450 microK after SVD eigenmode projection
- 21-cm signal loss due to SVD method: quantified by simulations

Cross-correlating GBT HI & DEEP2 optical galaxies at $z \sim 0.7$ -1.1





Next Step: HI auto-correlation fn at z=0.8

Auto- and cross-correlating GBT HI & zCOSMOS optical galaxies at z ~ 0.5 -1.1



21cm at z~1: current status

- HI cross-correlation (with DEEP2 optical galaxies): measured at z~0.8
- HI auto-correlation at z~0.8: GBT on zCOSMOS field
- HI LSS redshift-space distortion (Masui et al. 10): 50 deg², 300 hrs at GBT, starting this June
- BAO measurement (e.g., Chang et al. 08, Wyithe & Loeb 08): CRT, CHIME ?

IM thoughts

- Intensity Mapping is feasible and useful
 - Enable HI detection at z=0.8
 - Foregrounds and RFIs at ~700 MHz are challenging but not showstoppers (yet)
- IM of other lines, e.g. CO, [CII], possible?
 - probing... LSS, astrophysics?
 - high frequencies small FoV, small structure; smaller dish, less sensitivity