

MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS BRICS Astronomy Working Group Oct 29, 2018

The BINGO radio telescope: an instrument to explore the Universe in the 21cm wavelength

Carlos Alexandre Wuensche and the BINGO Collaboration¹

ca.wuensche@inpe.br

¹www.bingotelescope.org



Talk outline

Cosmological relevance

The BINGO telescope

Current status

Era of precision cosmology

- Cosmology is now in a golden area (Planck, SDSS, DES and other large surveys) but there are still a few key questions to be answered!
 - □ Inflation (t<10⁻³² s) maybe CMB with B-mode polarization results
 - □ Dark energy DES, e-BOSS, EUCLID, HETDEX and others?





Image Credit: Dana Berry / SkyWorks Digital Inc. and the SDSS collaboration.

21 cm cosmology

- Universe is reasonably well understood from t ~ 10⁻⁶s to t ~ 380.000 years and then after Cosmic Dawn (t ~ 180 Myears)
- History of matter evolution can be traced via HI (and its disappearance) from z=20 to z=0
 - \Box 0 < z < 2 Dark energy
 - \Box 2 < z < 6 Curvature</th>For reference \Box 0 < z < 6 Primordial NG</td> \Box Z = 0.5=> t = 8,63 Gy \Box What's next??? \Box Z = 2=> t = 3,32 Gy \Box Z = 6=> t = 0.94 Gy \Box Z = 20=> t = 0,18 Gy
- HI bias related to the size of the hot dark matter halos. Too small => low density => low shield => H ionization



C. A. Wuensche (2018)

Baryon Acoustic Oscillations (BAOs)

- □ Acoustic waves imprinted on CMB 380,000 years after Big Bang
- □ Acoustic scale **D** set by distance light travelled at that time
 - Known precisely from CMB power spectrum
 - □ D=147.18±0.29 Mpc (Planck Collaboration 2018 VI)



Why BAO in radio?

- Complementary to optics, different systematics
- Decay time of HI hyperfine transition is ~ 10¹⁵ seconds, but 75% of visible matter in the Universe is made of H...
- Efficient alternative for measuring a large number of galaxies individually (plus integrating the signal "alla" CMB allows for the reutilization of a large background experinece in instrumentation and data analysis)
- Interferometers are excellent instruments for these measurements, but are expensive and hard to operate and maintain
- Approach: single-dish, many horns X single horn per dish



- Large collecting area (> 500 m²)
- Large covered area on the sky (care should be taken with leaving out very small scales, < 0.1 Mpc.h⁻¹)
- Low sidelobes and good (precise shape) beam
- Long observing time (> 1 year)
- Sensitivity to intermediate scales, where BAO is important (0 < z < 2)
- Redshift range: 0.1 < z < 1 (bias larger than 0.7 after that)</p>
- Frequency range:
 - □ 1300 MHz => z≈0.08
 - □ 100 MHz => $z \approx 0.93$ Lots of RFI in this frequency range

Adapted from Bull et al. 2015

The HI signal power spectrum

INPE

Cosmological HI signal is weak! (≈100 µK rms) and on degree scales



C. A. Wuensche (2018)

The BINGO Radio Telescope



BINGO concept (as of June 2018)

Instrument characteristics

- Dish diameter : 45m and 38m
- Resolution (°): ~ 0.67
- Horn opening (°): ~ 25
- Frequency range (MHz): 960 1260
- Channel resolution ~ 1 MHz
- Z interval: 0.13 0.48

Instrument characteristics

- Number of feeds : 50 (dual pol.)
- Horn largest diameter: 1.9m
- Horn length: 4.3m
- Focal plane size: 19m x 9,5m
- Estimated scan area: ~ 5000[□]
- No cryogenics : T_{sys} ≈ 50K

Fixed wire-mesh parabolas No moving parts Transit telescope Most components "off-the-shelf" Guiding principle : simplicity !

Project status

- BINGO is under construction
 - horn prototype completed
 - transitions, polarimeter, transitions and magic tee prototypes being completed in 2 weeks (November 10)
 - receiver waiting for components to arrive
 - RFI initial measurements on site completed => permanent monitor received from Swiss to be installed on site
 - □ Topography sorted out => optical design in preparation
 - Legal issues regarding property, electrical power, roads and silence protection zone being handled by collaborators in Paraiba
- About 80% completely funded
 - □ (total ~ R\$ 17.5 M => ~ US\$ 4,25 M)





Receiver status



Monitoring, power distribution



Polarimeters, transitions and magic tees



Horn status

- Aluminum horns (6060 T4 alloy)
 - Mass: 347 kg, not including screws and bolts, which may add ~ 30 kg to the unit
 - □ Number of rings (sectors): 127
 - Length: 4318 mm
 - 🗆 Mouth: 1900 mm
 - 🗆 Throat: 250 mm

Project:

- Eletromagnetics: Bruno Maffei (IAP, France)
- Mechanical: Luiz Reitano (INPE, Brazil)

Construction

Calfer (Brazil)



"BINGO: Horn design, fabrication and testing" (Wuensche et al. 2018, in preparation)



Site selection

S. Martinho, INPE's center, South of Brazil



Paraíba sites





Peel, Wuensche et al. (2018, Journ. of Astron. Instr., accepted)





© 2018 Google Data SIO, NOAA, U.S. Navy, NGA, GEBCO Image Landsat / Copernicus US Dept of State Geographer

eral Mountains

Brazil

Suncion

Bolivia

Google Earth

Imagery Date: 12/13/2015 2°47'21.40" N 42°11'44.56" W elev -4359 m eye alt 4094.82 km 🔘

C. A. Wuensche (2018)

Brasilia

20





PRODUCED BY AN AUTODESK STUDENT VERSION



PRODUCED BY AN AUTODESK STUDENT VERSION



Serra da Catarina, Vale do Piancó (PB) Lat: 07° 02' 57.1" S Long: 38°15' 46"W





Silence zone proposal

INPE



C. A. Wuensche (2018)

Additional science with BINGO

(We will have an ultra-deep large-area spectral survey at 960-1260 MHz)

1. BAOs contain additional information

□Matter density

Redshift distortions

Anisotropic BAOs...

- 2. Life history of hydrogen
- 4. Radio recombination lines
- 5. Galactic continuum

Main difficulties – as of October 2018

- Large telescope → need to find a company to fabricate the dishes
- Large horns → fabrication process understood, need to reduce costs for 50
- 1/f noise → Correlation receiver (needs to be reduced)
- Calibration and stability → use Moon and planets for additional calibration
- Sidelobe pick-up → careful optical design (horn testing showed quite good rejection for 1st/2nd lobe and front/back lobe rejection
- Radio Frequency Intereference
 Mobile quiet zone has been already requested to the state authorities
- Atmospheric fluctuations → not a serious problem for BINGO frequencies
- Bright foreground emission -> Component separation techniques (alla Planck)
 - □ Diffuse Galactic radio emission
 - □ Extragalactic point sources



BINGO



BAOs from Integrated Neutral Gas Observations



Thank you!

INPE

Please visit us at http://www.bingotelescope.org



Espelhos

Crédito: L. A. Reitano



Espelhos

INPE

Crédito: L. A. Reitano











C. A. Wuensche (2018)