Sci-HI: First Upper Limits

Sonda Cosmológica de las Islas la Detección de Hidrógeno Neutro (Sci-HI)

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For the Sci-HI collaboration

Cosmology on Safari
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Isla Guadalupe NW Mexican Pacific Ocean
Sci-HI Collaboration

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- Aravind Nataranyan

- Marion Island group: Jon Sievers, Cynthia Chiang, UKNZ

- With future collaborators (pending funding) at IAC, IAUNAM, CINVESTAV, ININ, ESFM-IPN, UAC, UAS, IATE, GECI, INECOL, Reserva de la Biosfera de Mapimí, Reserva de la Biosfera de la Isla Guadalupe, SEGOB, & SEMAR.
21 cm All-sky Brightness Signal
The SCI-HI antenna design is a modified four-square we call the “Hibiscus” antenna.
Hibiscus Antenna: Simulate Design
Build Scale model
test scale model on antenna range...iterate
Experimental Design

[Diagram showing a circuit with components such as Antenna, Mechanical Switch, LNA #1, LNA #2, Attenuation & Band Pass Filter, Faraday Cage, Data Processor, ADC, LNA #3, 12 V Battery, and regulated power and control.]
To select the site, we evaluated current and potential experiment sites for their RFI environmental quality.
Site: Islands West of Mexico

Graph: Raw Signal (dB) vs Frequency (MHz)

- Red line: Green Bank, WV
- Blue line: Isla Guadalupe, MEXICO

Map: Island locations

Photo: Island and ocean view
Hibiscus Antenna on Isla Guadalupe, 2013
Use Milky Way Synchrotron Emission to calibrate
Sci-HI Scanning Paths in Galactic Coordinates

Isla Guadalupe

Isla Clarion
Measure Beam-Average Sky Temperature vs Sidereal Time
The best fit plot for

tion (2008). The top plot shows mean data from a single day of observa-
structure, but the larger residuals in the data make it
 mains in the residuals). The absence of a fitting process
fore, the
hand, the
ominal for extracting 21 cm information. On the other
signal remains in the residuals), making it less than op-
tral structure from the spectra (K
in the calibration and foregound fitting. The
als before and after addition of the simulated signal, we
process on the combined data. By comparing the residu-
umals are also lower than those predicted by Liu et al.
ionospheric ducting structure they describe. The resid-
quals are also lower than those predicted by Liu et al.

ing from 4.4 hours of integration regardless of calibration

0.4 0.5 0.6
 aides (de Oliveira-Costa et al. 2010) (see also Mesinger et al. (2011)). The

calibrated data (single day)
Johnson Noise Calibration

$$K_{JNC}$$ calibrated average of all calibration data taken over a single day.

![Graph showing temperature vs. frequency for different impedances (50 Ohm, 100 Ohm, Short).]
Antenna efficiency was calculated using reflectance data collected on-site for the antenna and first stage amplifier.
Even with this simple foreground model, residuals were dominated by system noise.
Results are significantly below foregrounds but still above model differentiation levels.
Improvements to SCIHI since first paper

- Plan to move to Isla Clarion and Marion Island – should allow observation in FM band
- Built second scaled antenna
- Operate on portable Generator rather than Battery—will allow multiple complete 24 cycles.
- Improved data taking efficiency from 10% to 33%
- Improved Faraday Cage by > 30 db.
- Will deploy to Marion Island very soon
Approved for deployment to Marion Island for the next three years!!
Base houses 13 winter-overs

Station may be a source of noise

Ship leaves April 6, 2015
Looking forward...more elaborate instruments

- Approach 1: use an external blackbody calibrator (like FIRAS)
  - Choose antenna that works well with the calibrator.

- Approach 2: use many extragalactic radio sources.
  - An aperture array can measure the spectrum using a digitally-formed frequency-independent beam, while simultaneously calibrating frequency response using bright radio sources.
Approach 1: Set of scaled corrugated horns, with external blackbody calibrators
Material with very low surface reflection is available.

- TDK IB-017
H-Plane measured antenna patterns
Tests of a blackbody calibrator
Blackbody Reflection Test

- Blue foam: microwave-absorbing foam
- Pink stryrofoam: not microwave-absorbing
Approach 2: Aperture Plane Array

Spacing: lambda/4
Size: 16x16

Use a wide apodization at low freq.
Point sources can be used to measure gain of each antenna.

LEDA at Owens Valley is testing this concept.
Conclusions

- SCI-Hi systematics at 10 kelvin level
- Isla Guadalupe west of Mexico is very quiet
- Marion or Clarion Island may be much quieter
- Even this ‘stage-1’ experiment may be capable of detecting the first-stars dip.
- Larger instruments have the potential to make a precise measurement