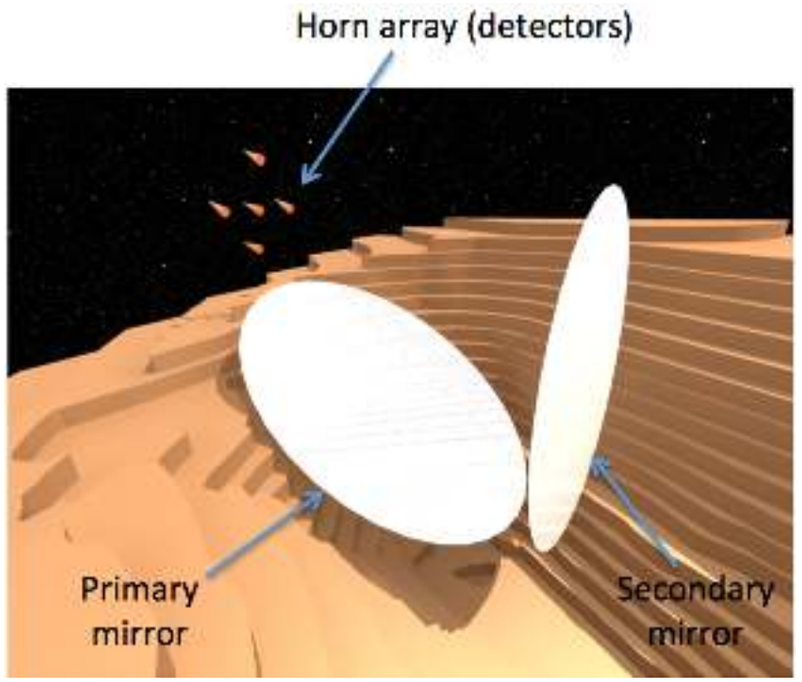
BINGO BAOs from Integrated Neutral Gas Observations

M.-A. Bigot-Sazy for the BINGO collaboration

National Astronomy Meeting 2015

BINGO telescope



Credit: Bruno Maffei, Adrian Galtress, Clive Dickinson

BINGO BAOs from Integrated Neutral Gas Observations

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BINGO BAOs from Integrated Neutral Gas Observations

Static radio telescope

2 mirrors compact range design with an offset focus

Crossed-dragone design (2 mirrors of similar size)

– Compact system

– Excellent beam

– Low sidelobes

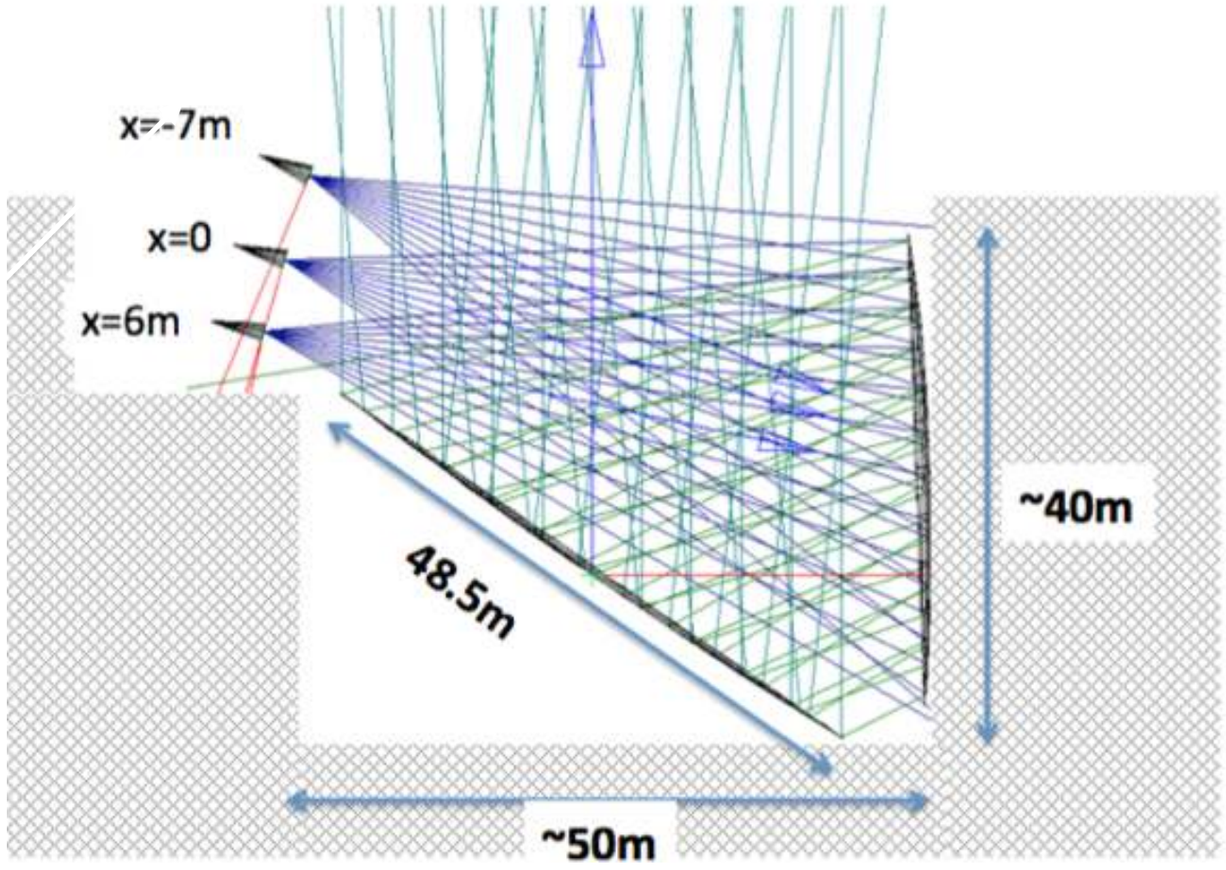
– Excellent cross-polarization response

– Favoured design for many CMB polarization experiments

- Design
  - feed horn array with 70 receivers
  - 15 deg x 200 deg field of view

Crossed-Dragone configuration

2 mirrors design with a flat focal plane



Credit: Bruno Maffei

BINGO BAOs from Integrated Neutral Gas Observations

Instrument parameters

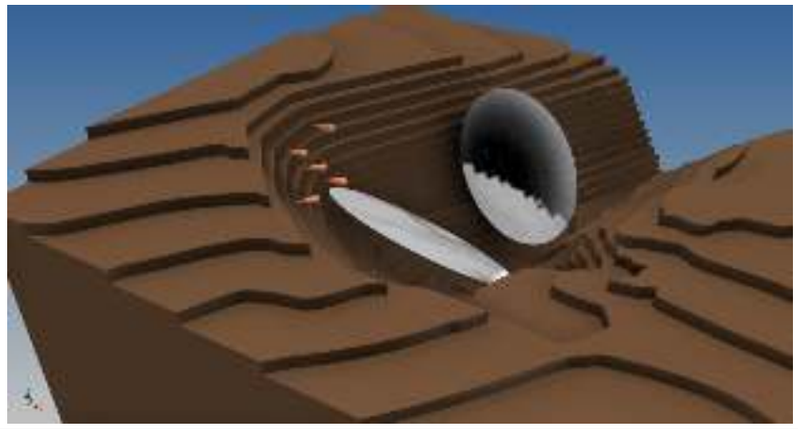
Frequency range 0.96 GHz to 1.26 GHz
(z =0.13-0.48)
1 MHz frequency channel
FHWM 40 arcmin at 1GHz
Survey Design (drift scan)
Observation time: 2 years of integration time
Declination: -5 deg
Area: 15 deg x 200 deg

Guiding principle : simple design

Location Uruguay (Castrillon Quarry an abandoned gold mine near Minas Corrales)

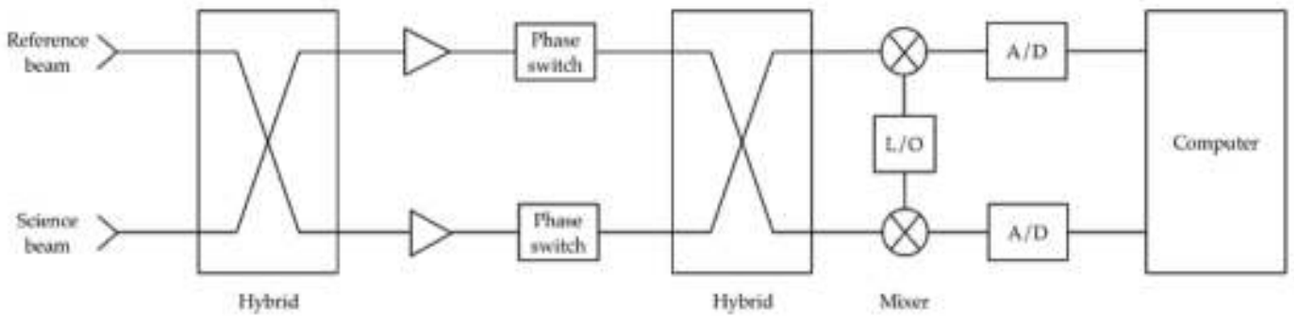
A clear view of the South Galactic Pole for the reference feed horns

- A low RFI environment.
- A topography that can easily support the two mirror design.



Credit: Bruno Maffei

Pseudo correlation receiver



No cryogenics: Tsys approx 50 K
rms noise level = 87 microK

Conical corrugated feedhorns

1.7 m in diameter and 4.2 m in length ⟶ large horns
Challenge: low cost and low weight
Idea: low-cost metalized foam sheets (Ian Browne)

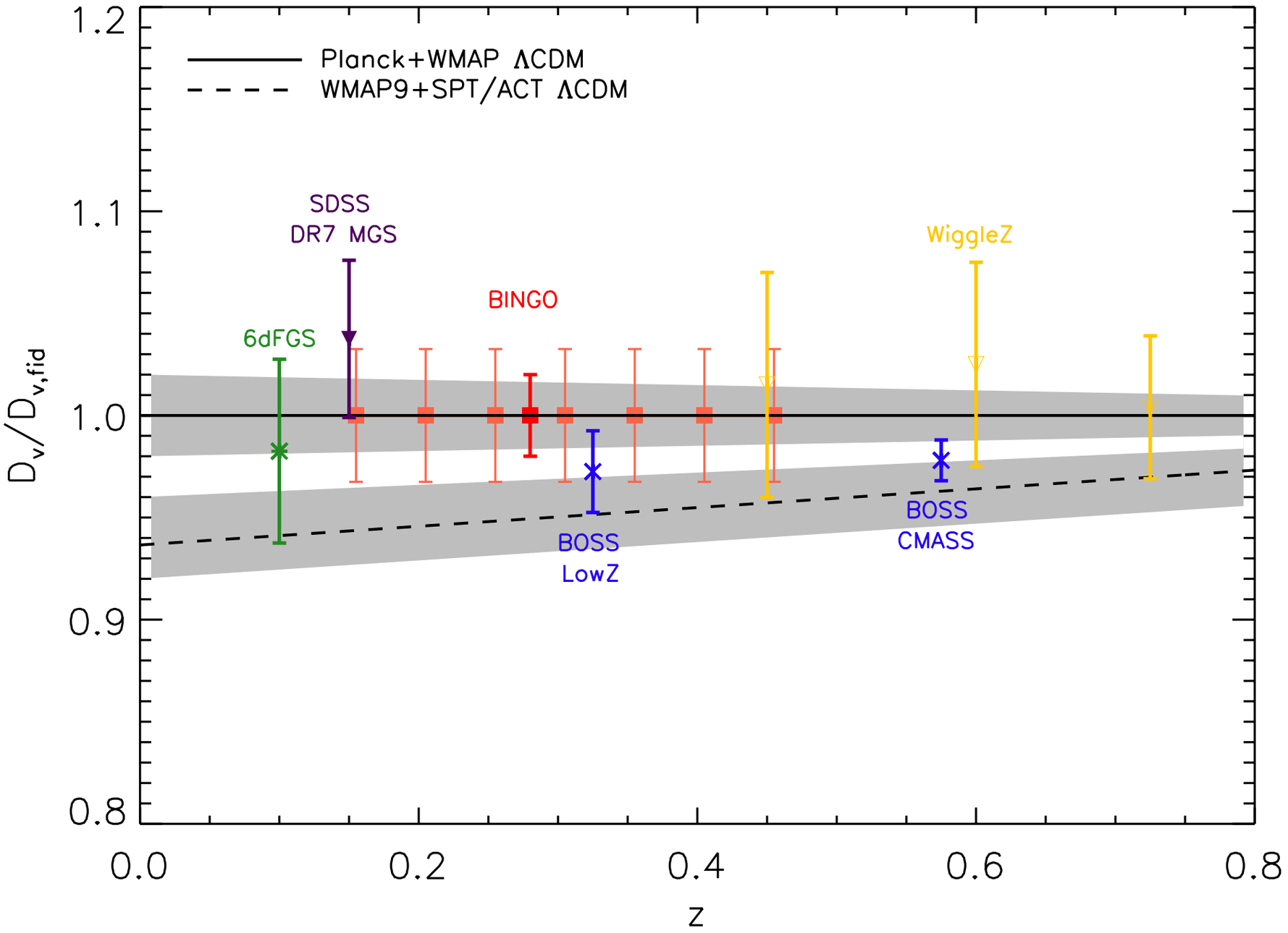
Construction of a 2 m horn

Credit: Ian Browne

Number of feeds: 70 (dual polarization)

Performance of the BINGO telescope

BAO "Hubble diagram" for the volume averaged distance



- Detection of BAOs at ~5σ - Measurement of acoustic scale to $\delta k_A/k_A \sim 2.2\%$
- Complementary in terms of redshift range with optic surveys and add to the possibility of measuring the cosmic distance scale only from BAOs

Challenges with intensity mapping data

- foreground component separation (intensity up to five orders of magnitude higher than the HI signal)

  Brightness temperature of the HI signal T ~100 microK

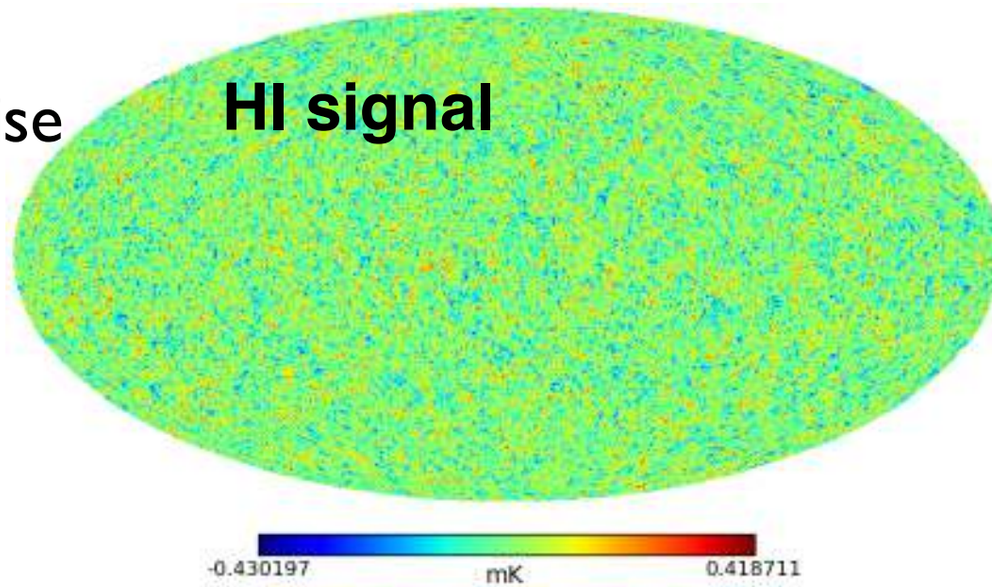
  Galactic Synchrotron emission T = 1 K (fluctuations 100 mK)

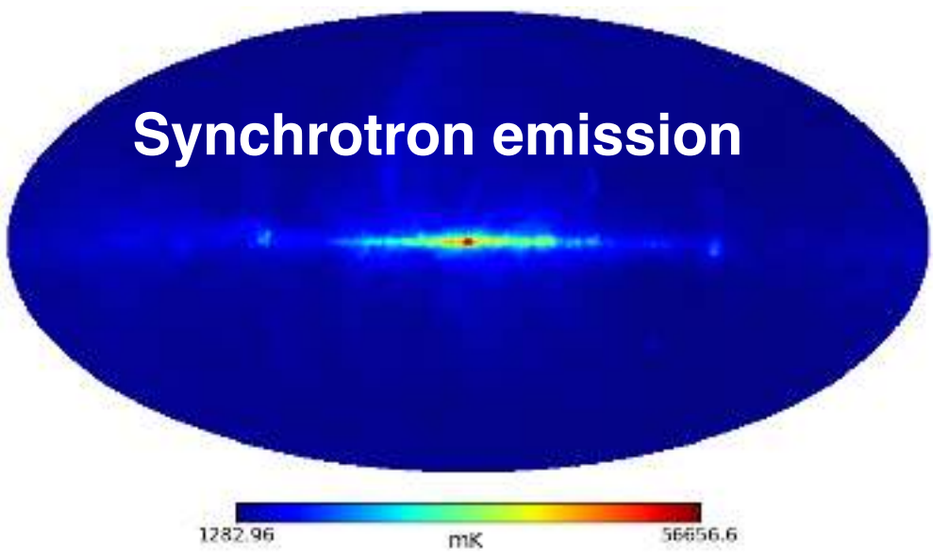
- noise
  - uncorrelated noise white noise
  - correlated noise in time and frequency 1/f noise
  - atmospheric 1/f noise
- systematics effects
  - sidelobes: near, intermediate, far (mode mixing)
  - bandpass calibration
  - cross polarisation
  - beam ellipticity ….

Careful design of the instrument and accurate calibration

otherwise

- systematic effects that can result in leakage of the continuum background into the HI signal
- addition of spectral features in the sky spectrum





Simulation of a single dish experiment

Sky emissions

Synchrotron *Remazeilles et al. 2015*

Background of unresolved point sources (S< 100 mJy)
Planck Sky Model (Delabrouille 2013)

HI emission CORA *Shaw et al. 2014*

Free-Free Planck Sky Model (Delabrouille 2013)

Simulation of a single-dish experiment

Redshift range $[z_{\rm min}, z_{\rm max}]$	[0.13, 0.48]
Frequency range $[\nu_{\rm min}, \nu_{\rm max}]$ (MHz)	[960, 1260]
Channel width $\Delta\nu$ (MHz)	15
FWHM (arcmin) at 1 GHz	40
Number of feed horns $n_{\rm f}$	70
Sky coverage $\Omega_{\rm sur}$ (deg^2)	3000
Observation time $t_{\rm obs}$ (yr)	1
System temperature $T_{\rm sys}$ (K)	50
Sampling rate (Hz)	0.1

- beams of the horns are given by a circular gaussian
- drift scan strategy (dec=-5 deg)

Other possible systematics

non-ideal beams (non-Gaussian beams, sidelobes, cross-polarization), ground spillover, mis-calibration, atmospheric 1/f noise…

Time-ordered data $d = As + n$

Instrumental noise

White noise

$$\sigma_t = \frac{T_{\rm sys}}{\sqrt{\Delta\nu t_{\rm pix}}}$$

system temperature = 35 K

1/f noise (**flat frequency spectrum!!!!**)

$$P(\nu) = \frac{\sigma^2}{f_s}[1 + \frac{f_{knee}}{f}]^{\alpha}$$

knee frequency = 1.0e-3 Hz
slope index = 1
sampling period = 30 min

Map-making

$$\hat{s} = (A^\dagger N^{-1} A)^{-1} A^\dagger N^{-1} d$$

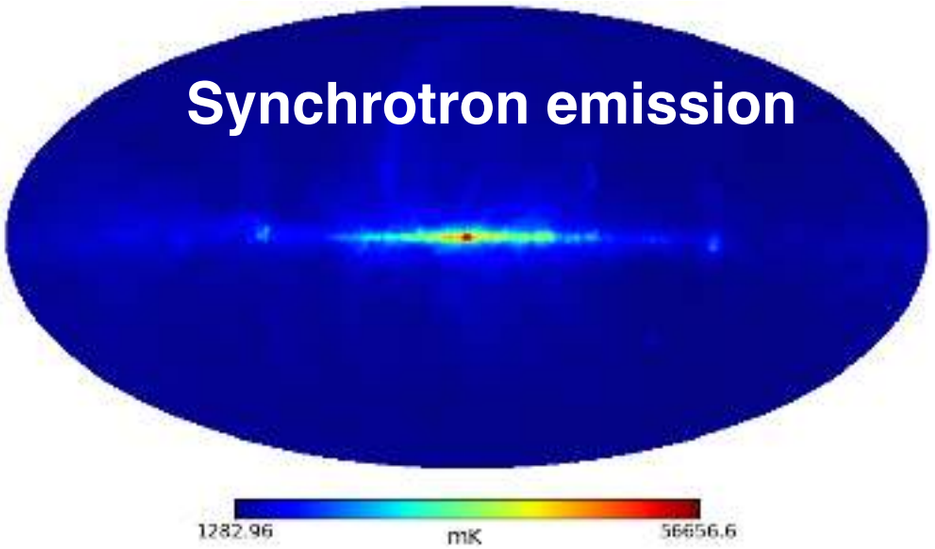
maximum likelihood map-making algorithm

Cantalupo et al. (2010)

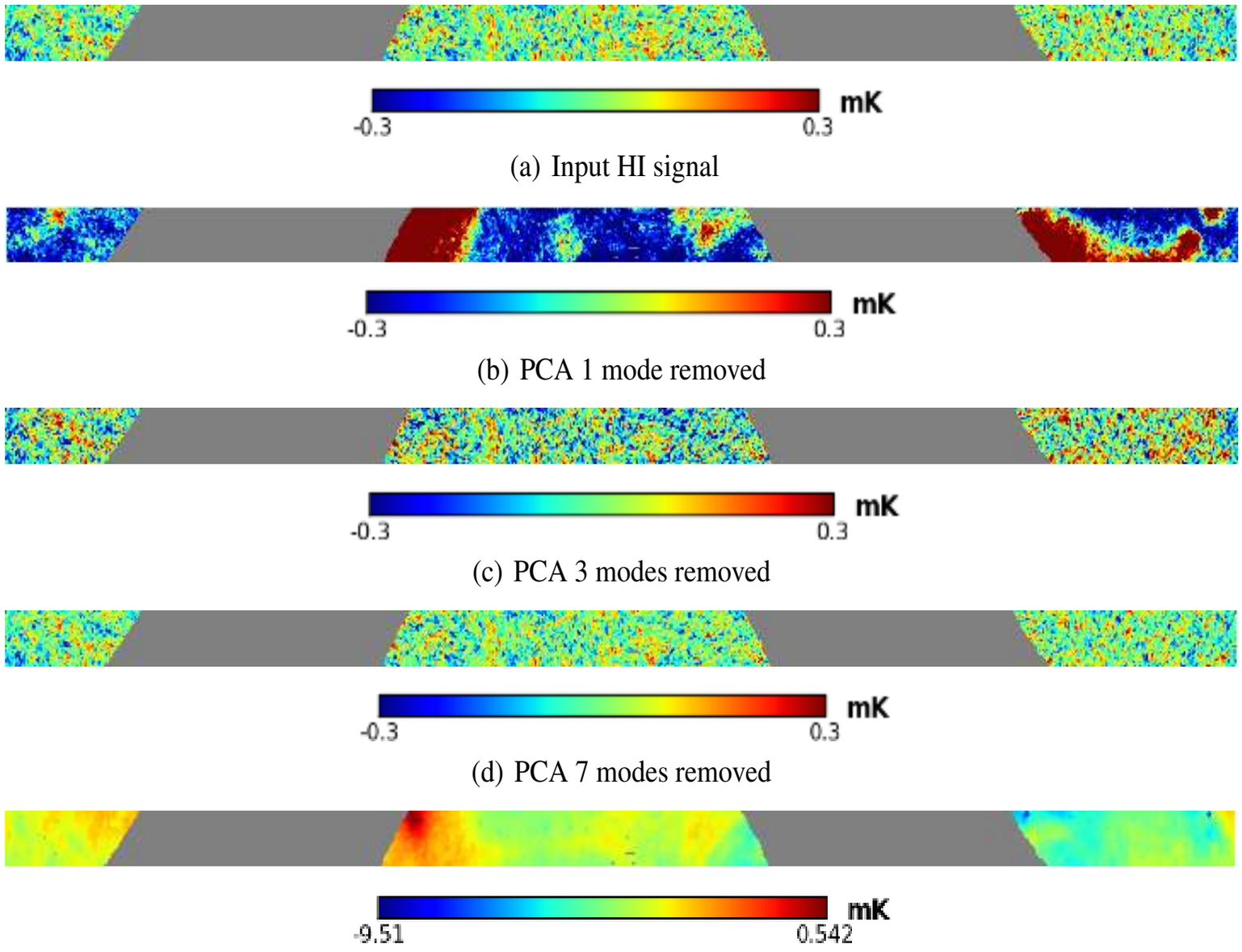
Foreground component separation

Property of the Galactic foreground

- Spectrally smooth



Assumption: perfect calibration



(a) Input HI signal

(b) PCA 1 mode removed

(c) PCA 3 modes removed

(d) PCA 7 modes removed

(e) Parametric fitting

Investigation of new methods using frequency and spatial information (Olivari et al., in prep.) **see Poster Lucas Olivari**

Conclusion

BINGO BAOs from Integrated Neutral Gas Observations

- with PCA, it is feasible to extract the HI signal from a highly contaminated foreground map (Alonso et al. 2014)

  → ~5% of the cosmological signal but a modification of the global shape of the power spectrum will not modify the BAOs wiggles

- investigate - more complex foreground cleaning methods

  - critical aspects of the calibration: the beam response and the instrument bandpass

Project status

- Receiver prototyping on-going
  - Already in the testing phase
- Basic mechanical design ready
  - Foam metalised sheets easy to make and seem to work
- FAPESP proposal being evaluated

  Estimated total cost ≈ 3M US dollars
- If funding appears in 2015, construction 2016, first science observations in 2017

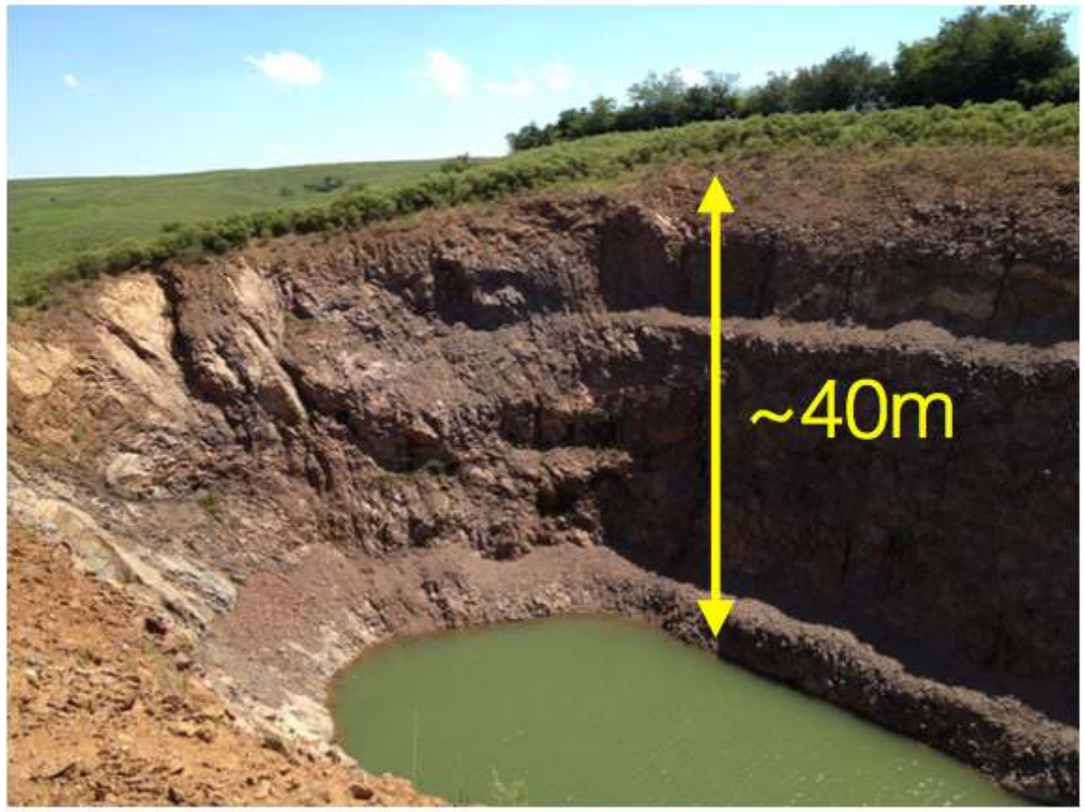
Thank you.

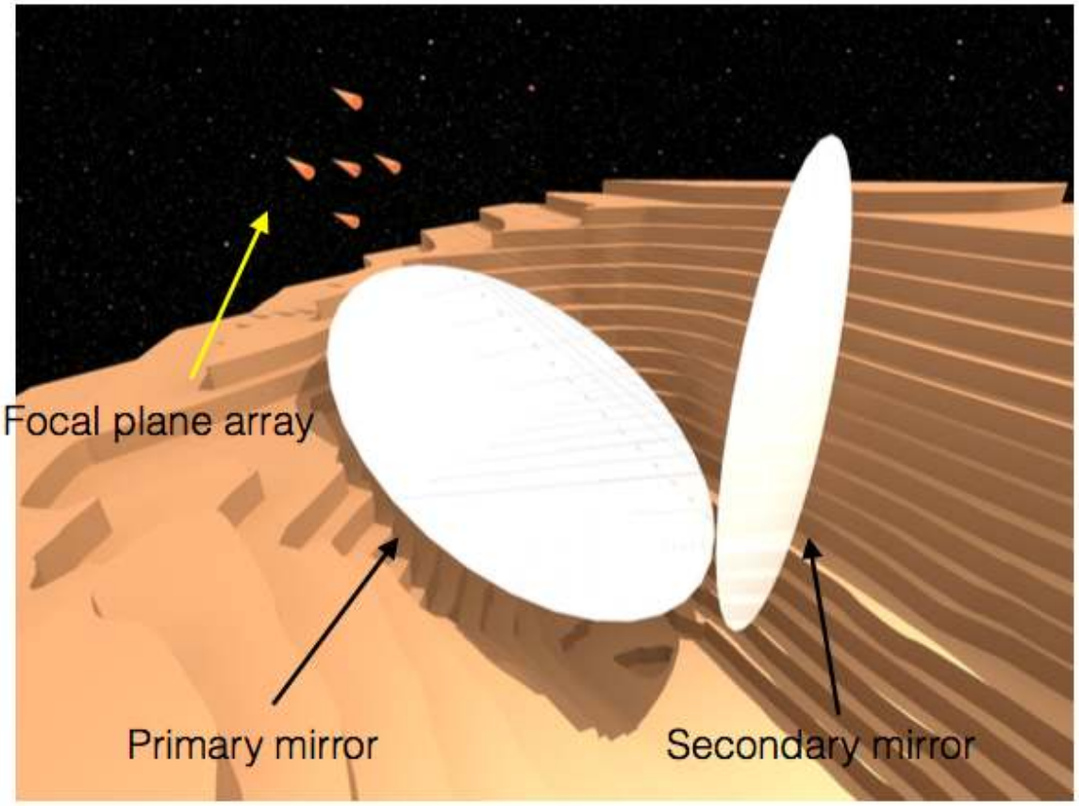
Site selection

Quary Castrillon in Northern Uruguay

stable walls in order to accommodate the telescope

correct orientation





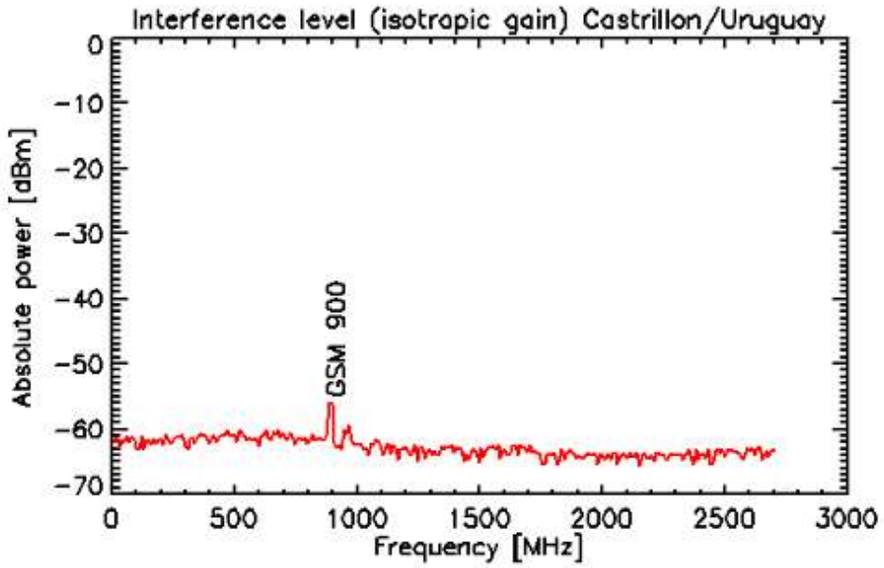
RFI testing

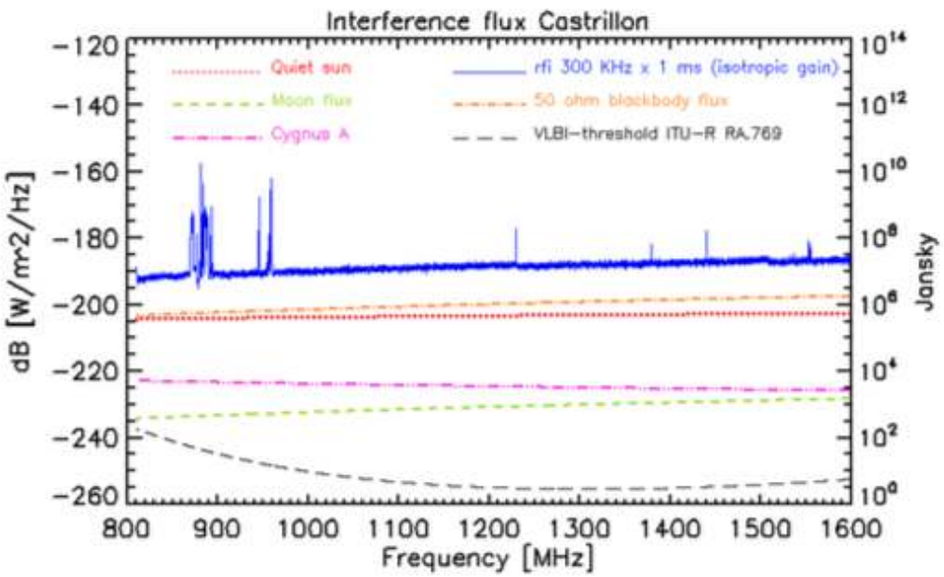
led by Christian Monstein (ETH, Zurich)

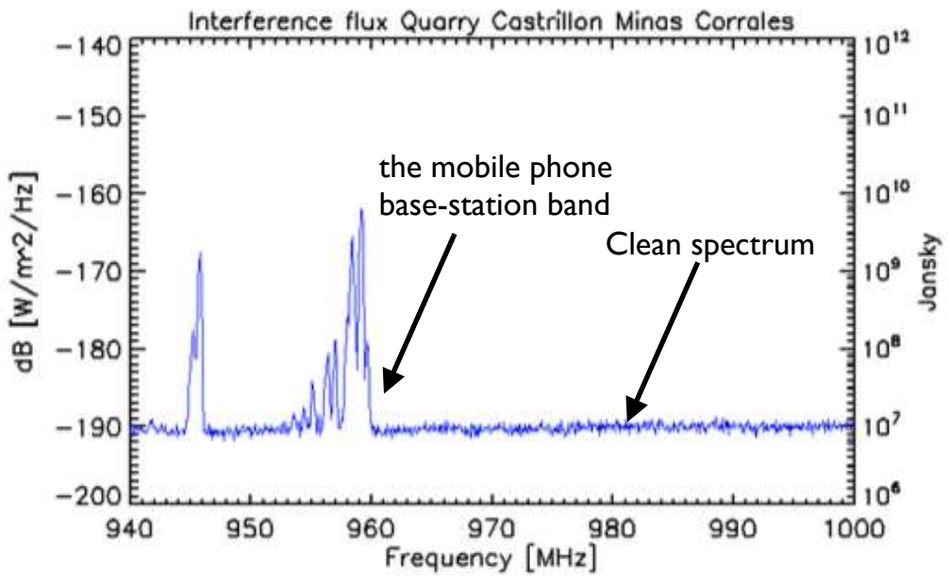
seven sites were visited

two frequency scans made

- a first one in absolute power from 10 MHz to 2700 MHz measured with an omnidirectional antenna
- a second narrow band one going from 800 MHz to 1600 MHz covering the BINGO band of interest.







Gold mine Castrillon in Minas Corrales

BINGO horns

Conical corrugated feedhorns

large feed horns : 1.7 m in diameter and 4.2 m in length

Idea : low-cost metalized foam sheets (Ian Brown)

Tests

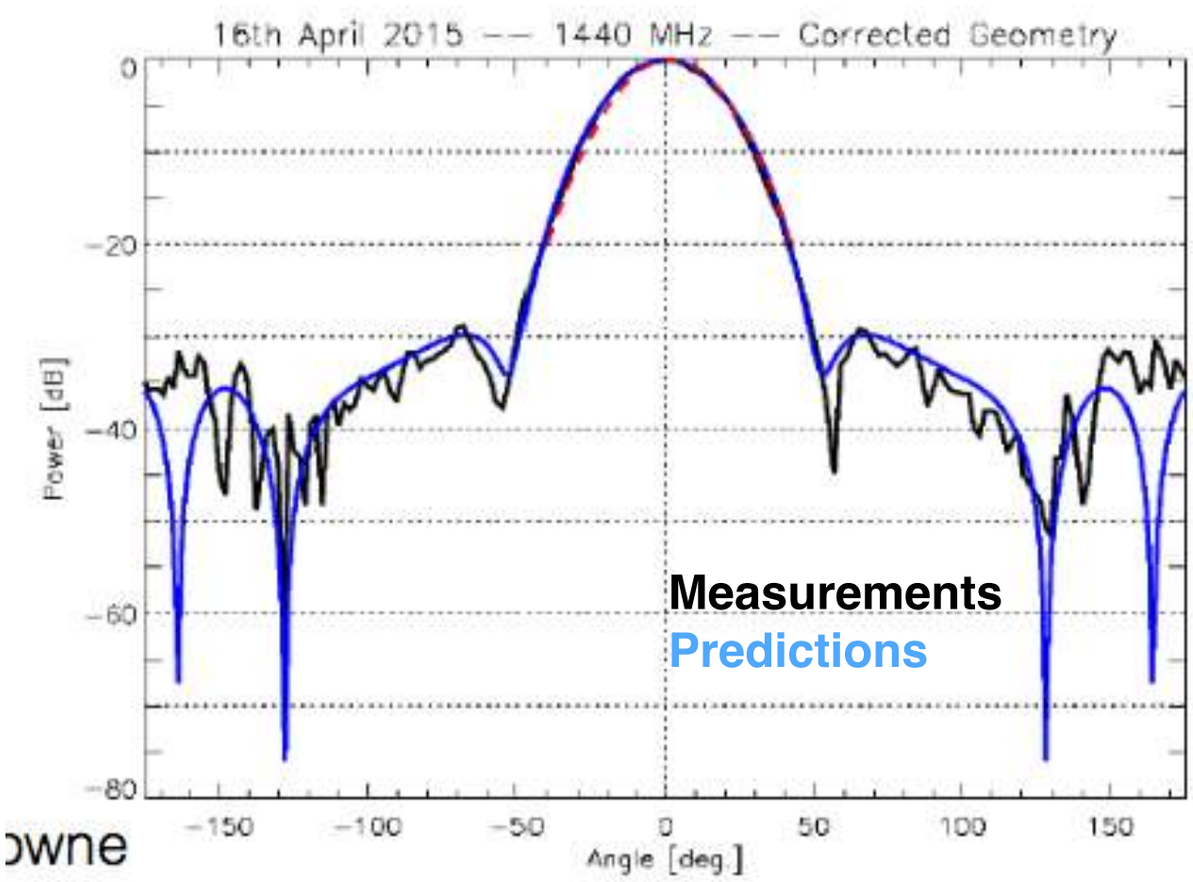
- Tests of the electrical properties of the horn performed with the VNA
- Polar diagram measurements

2 m horn with 78 sheets of 25 mm thick foam

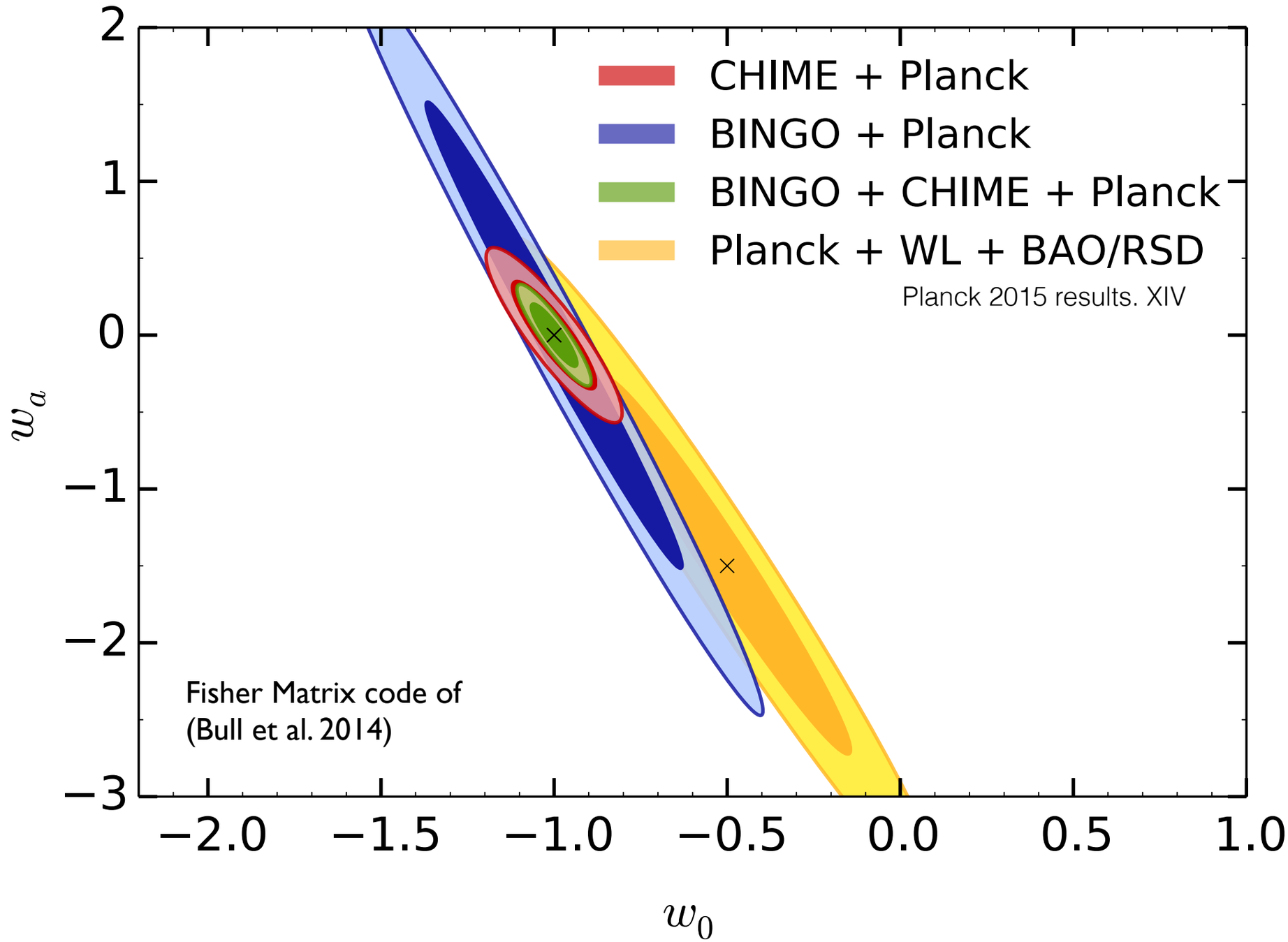
Results

- main beam with the predicted FWHM and of Gaussian shape, at least down to -30dB
- sidelobes and back lobe are around -40 dB
- on-axis polarization purity is better than -25 dB

Foam plate manufacturing technique works!!



BINGO constraints on Dark Energy



- improvement obtained with the combination of the IM experiments
- tight constraints can be made with radio BAO data (plus Planck) alone
  a completely independent measurement from optical surveys