The BINGO radio telescope and 21 cm Cosmology

C.A. Wuensche on behalf of BINGO Consortium

The BINGO radio telescope and 21 cm Cosmology

C.A. Wuensche on behalf of BINGO Consortium

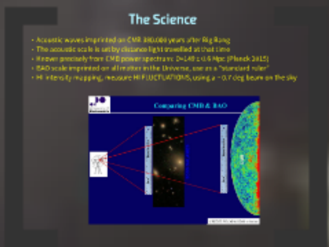
What's BINGO???

- BINGO stands for **B**AO from **I**ntegrated **N**eutral **G**as **O**bservations
- A "single" dish, multiple horns, radio telescope to measure Baryon Acoustic Oscillations (BAO)
- Also measure other astrophysical phenomena
- It will perform an intensity mapping of HI at redshifts $0.13 < z < 0.48$
- Constraints on Dark Energy parameters

- Cross-Dragone off-axis configuration
- 50 horns (1,8 m open x 4,7 m long)
- 2 dishes (~ 42 m diameter)
- Tsys ~ 50 K
- No moving parts

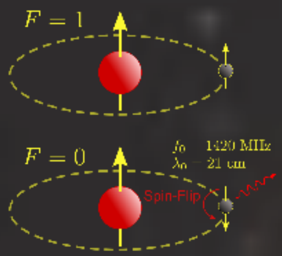
- Low side lobe / Compact / feasible structure
- Technology similar to CMB experiments
- Almost flat focal plane
- No cryogenics!!!
- **Nominal site in Serra do Urubú (Paraíba)**

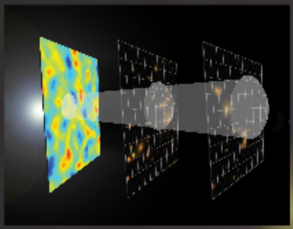
Science

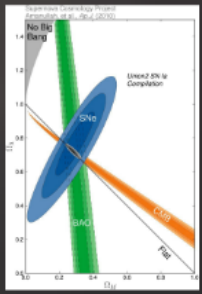


Motivation

- Use HI intensity mapping to search for **B**aryon **A**coustic **O**scillations (**BAO**)
- Follow up structure formation with matter power spectrum measurements
- Measure Dark Energy properties
- Static telescope, excellent for looking after other astrophysical transient phenomena







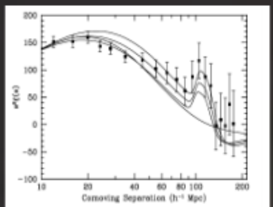


***Figure 1:** Large scale redshift space correlation function of the SDSS LRG sample (Eisenstein et al. 2005). Bumped curves reflect different amounts of $\Omega_m h^2$ (0.12, 0.13, 0.14 from top to bottom) and $\Omega_b h^2$=0.024. Flat curve represents a pure CDM model with $\Omega_m h^2 = 0.105$.*

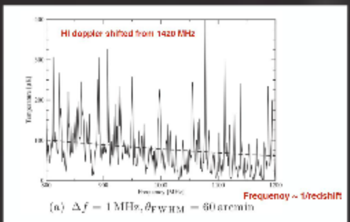


***Figure 3:** Simulated HI spectrum as seen by BINGO beam resolution and frequency bin.*

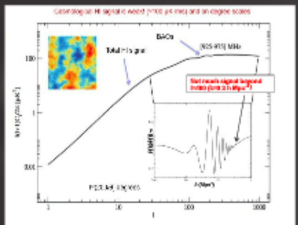


***Figure 4:** HI power spectrum, obtained from 2D neutral HI distribution. Subplot highlights the BAO oscillations.*

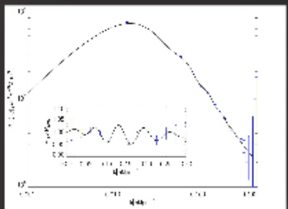


***Figure 5:** Projected power spectrum sensitivity for a full 1-year of BINGO observations, with 50 horns and 15° FOV (Battye et al. 2016). The subplot highlights the BAO features after dividing out the smoothed spectrum.*

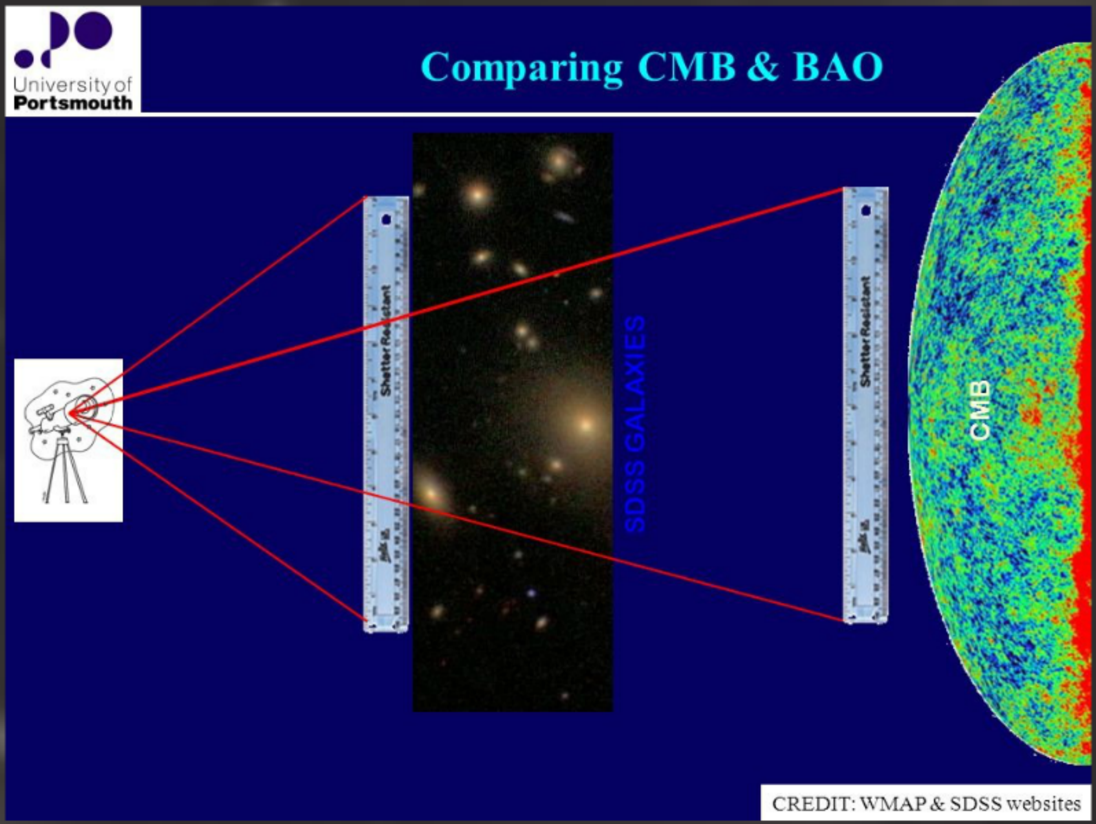
Figures from Eisenstein et al (2005) and Battye et al. (2013)

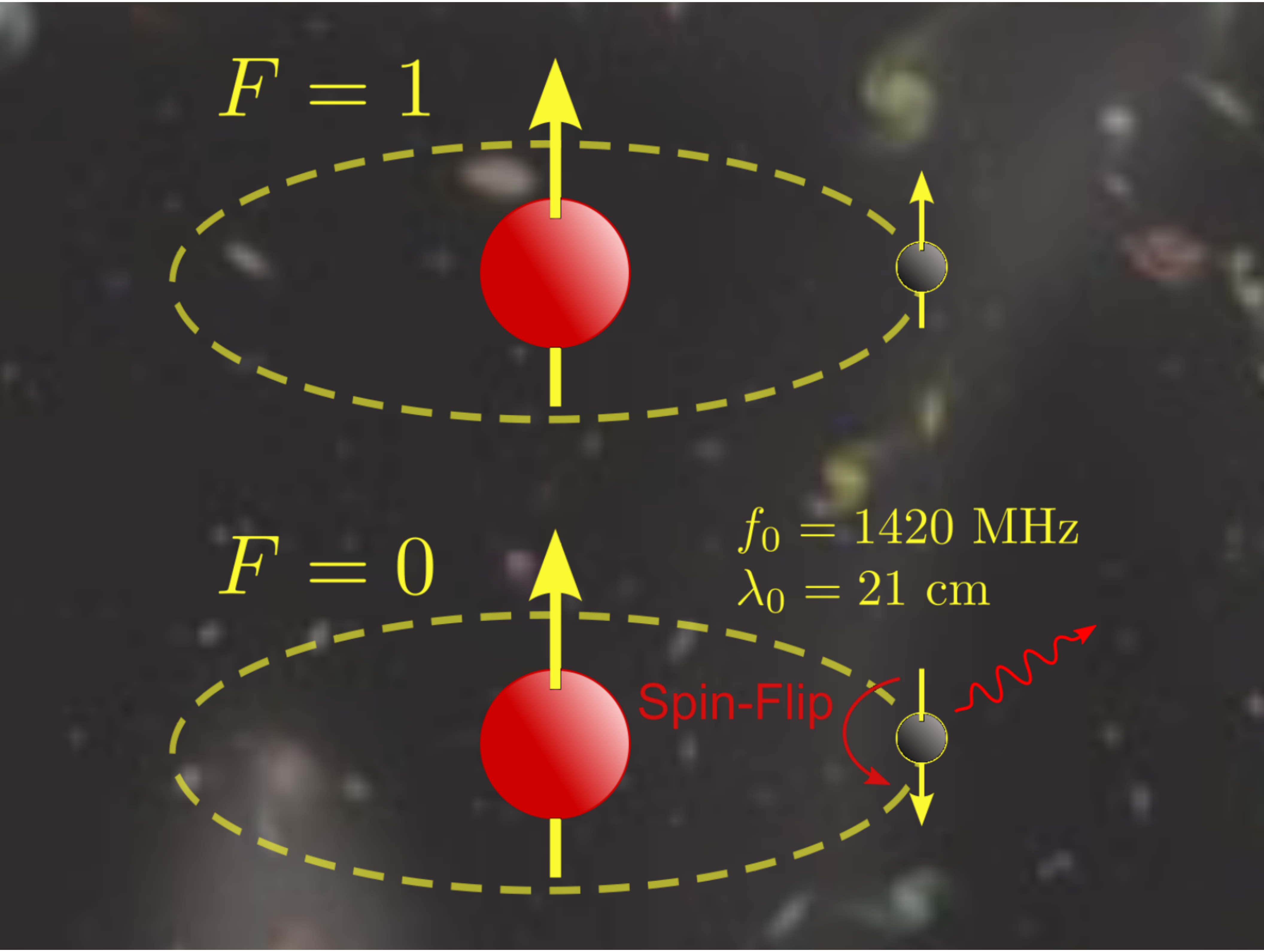
Motivation

- Use HI intensity mapping to search for **B**aryon **A**coustic **O**scillations (**BAO**)
- Follow up structure formation with matter power spectrum measurements
- Measure Dark Energy properties
- Static telescope, excellent for looking after other astrophysical transient phenomena

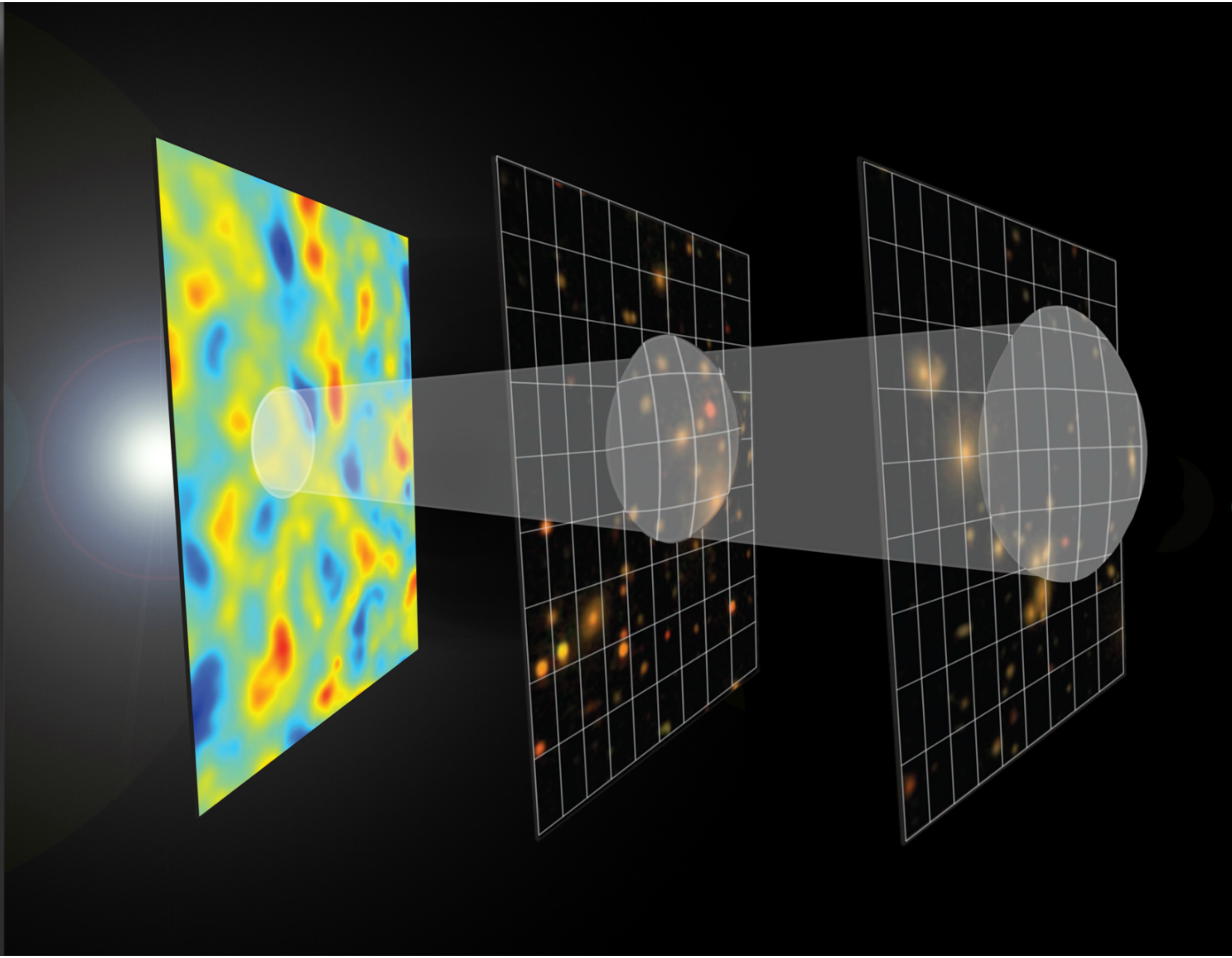
The Science

- Acoustic waves imprinted on CMB 380,000 years after Big Bang
- The acoustic scale is set by distance light travelled at that time
- Known precisely from CMB power spectrum: D=149 ± 0.6 Mpc (Planck 2015)
- BAO scale imprinted on all matter in the Universe, use as a “standard ruler”
- HI intensity mapping, measure HI FLUCTUATIONS, using a ~ 0.7 deg beam on the sky





$F = 1$
$F = 0$
$f_0 = 1420$ MHz
$\lambda_0 = 21$ cm
Spin-Flip



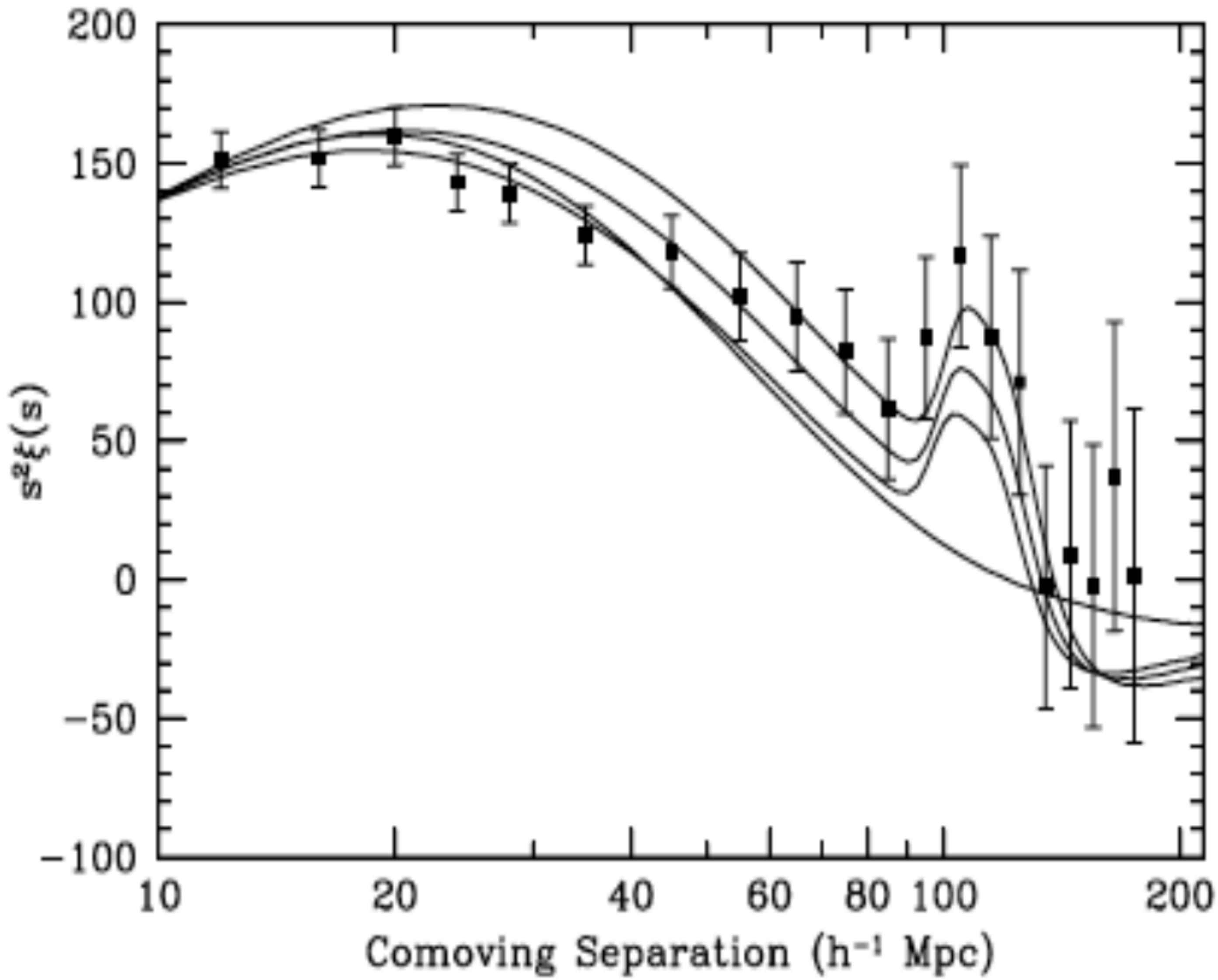


Figure 1: *Large scale redshift space correlation function of the SDSS LRG sample (Eisenstein et al. 2005). Bumped curves reflect different amounts of* $\Omega_m h^2$ *(0.12, 0.13, 0.14 from top to bottom) and* $\Omega_b h^2$*=0.024. Flat curve represents a pure CDM model with* $\Omega_m h^2 = 0.105$.

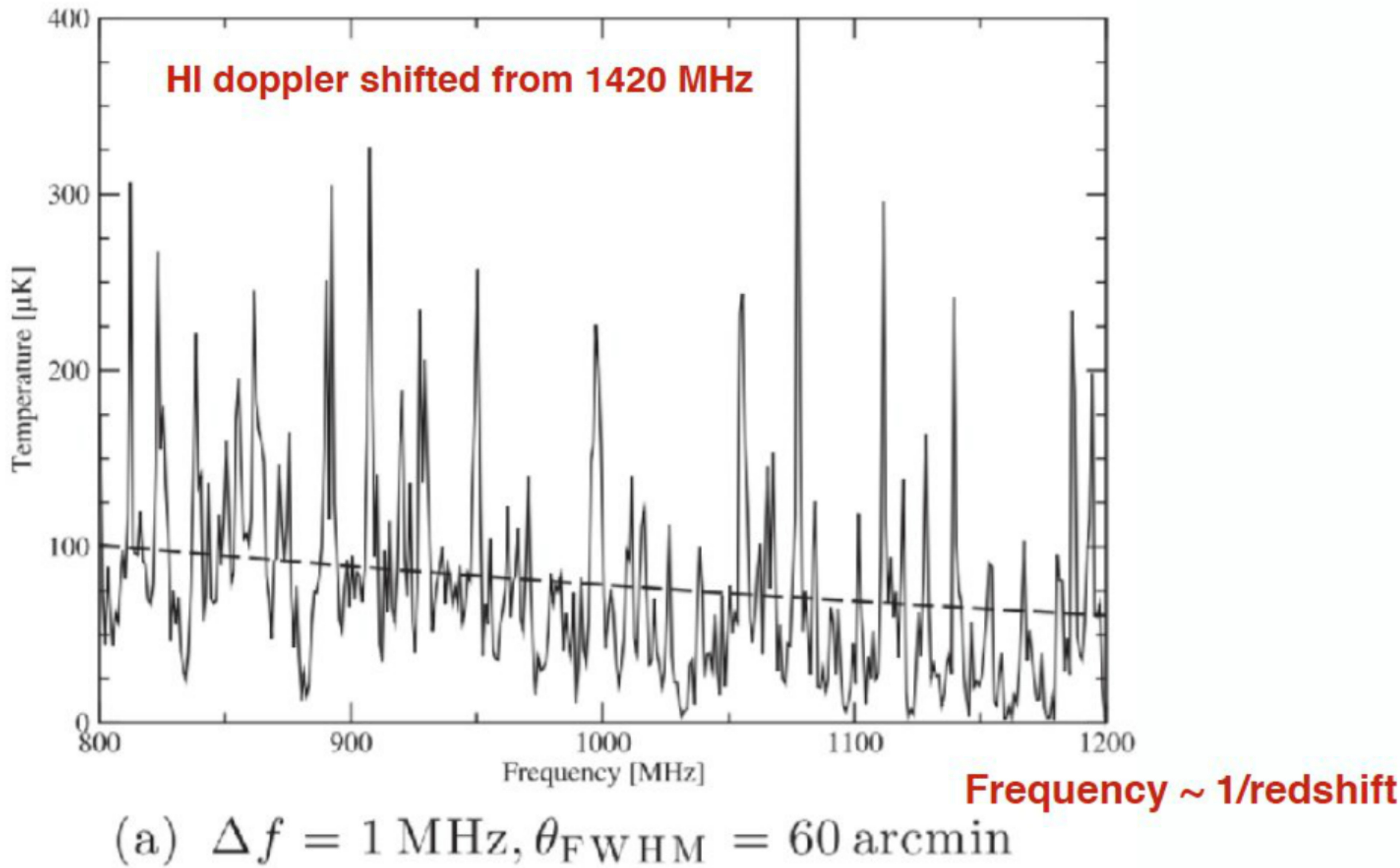


Figure 3: *Simulated HI spectrum as seen by BINGO beeam resolution and frequency bin.*

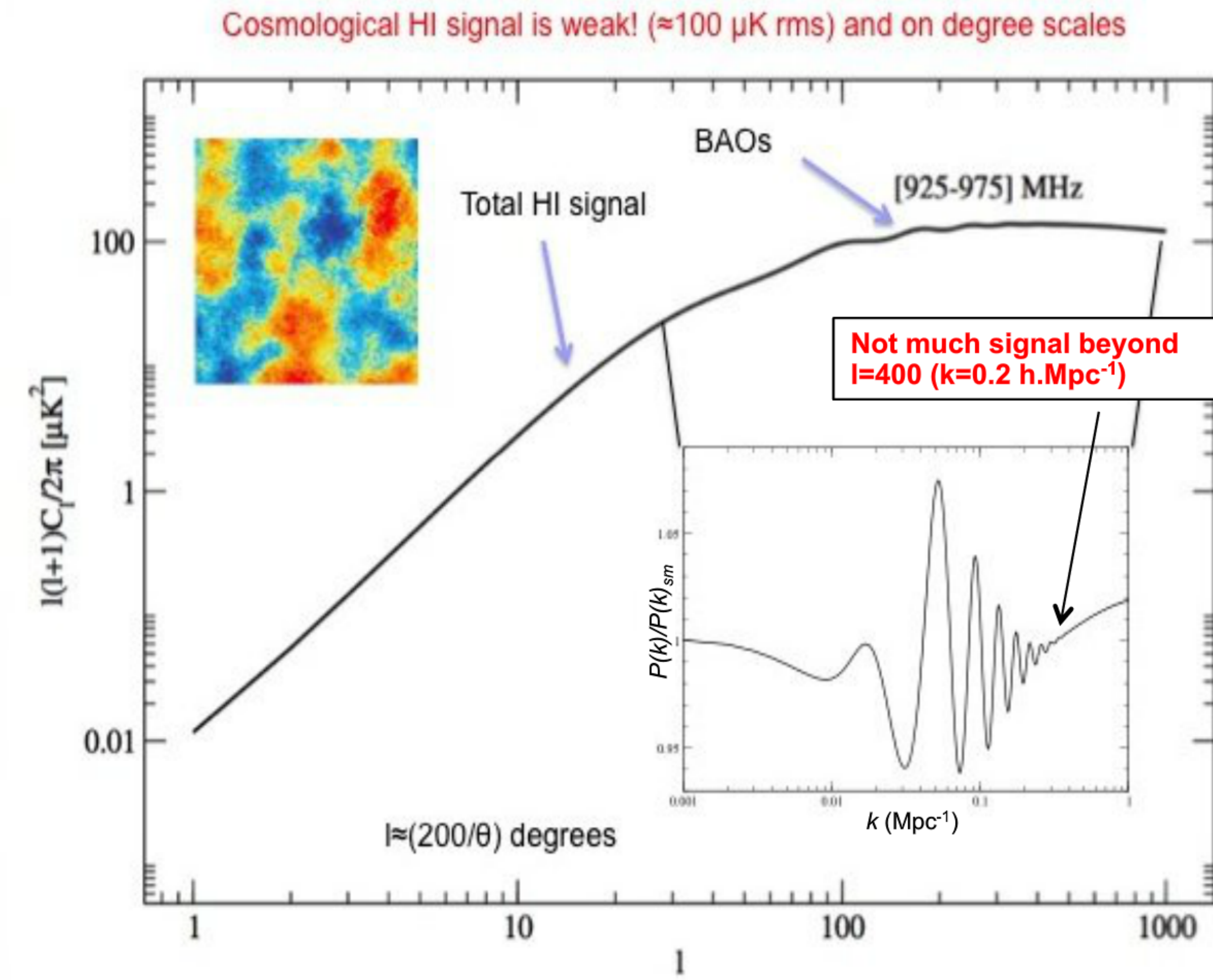


Figure 4: *HI power spectrum, obtained from 2D neutral HI distribution. Subplot highlights the BAO oscillations.*

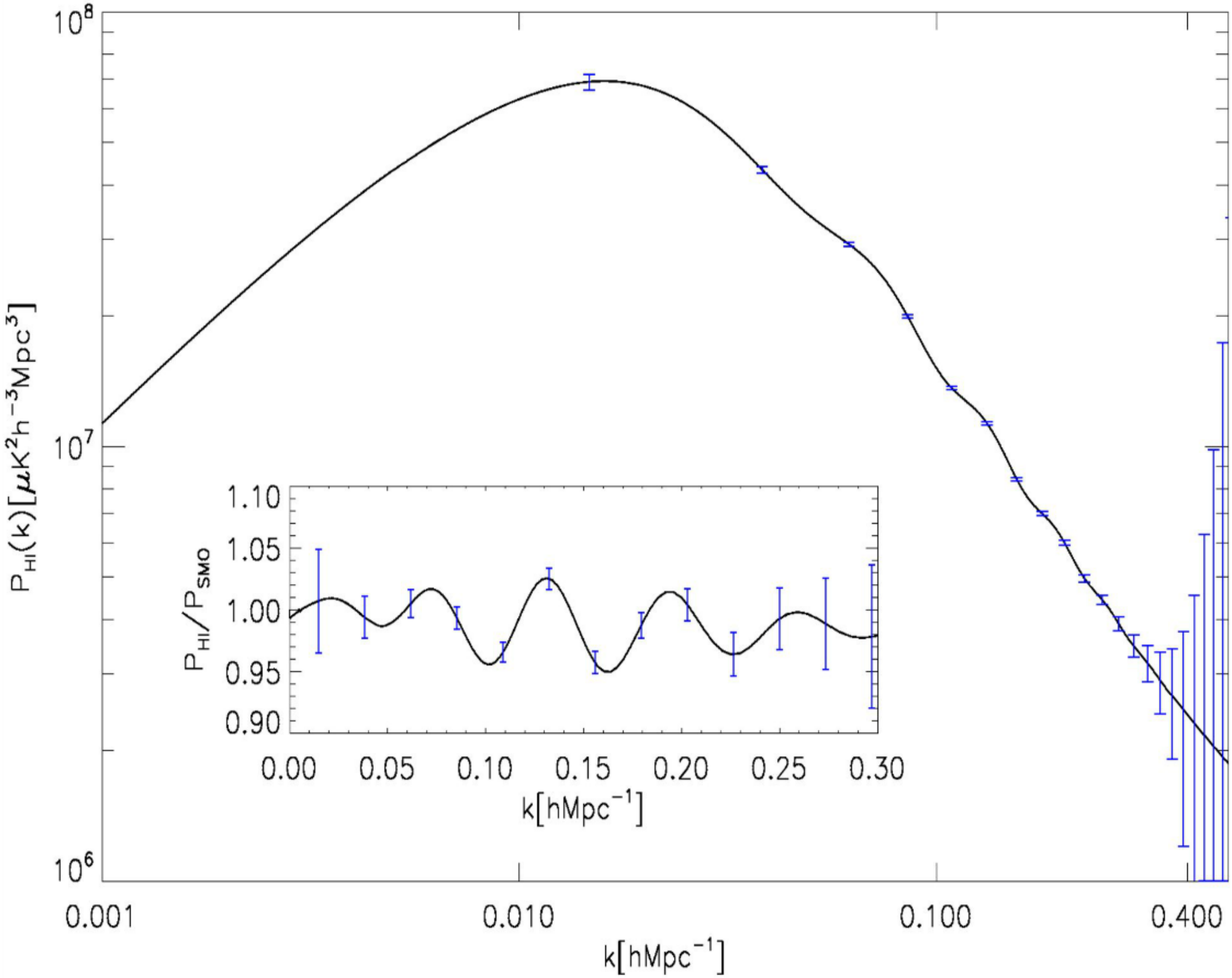


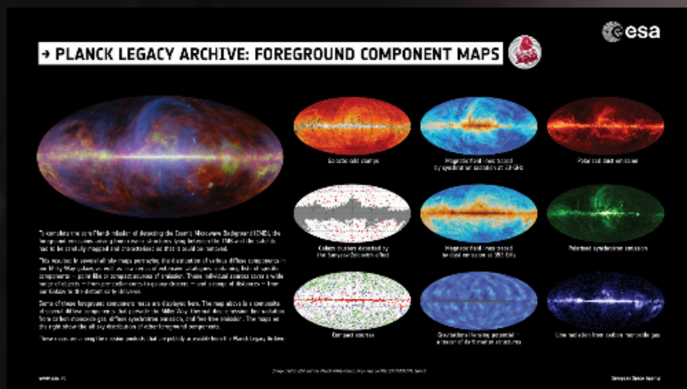
Figure 5: *Projected power spectrum sensitivity for a full 1-year of BINGO observations, with 50 horns and 15° FOV (Battye et al. 2016). The subplot highlights the BAO features after dividing out the smoothed spectrum.*

Why measuring BAO in the radio band?

- Complementary to optics, different systematics
- 21 cm intensity mapping: T(Theta, Phi, freq) directly measured “alla CMB”
- Efficient alternative for measuring a large number of galaxies individually
- Interferometers are excellent instruments for these, but are expensive
- Single-dish instruments have been used recently, but with no results
- Approach: single-dish, many horns X single horn per dish

Some scientific challenges

Foregrounds ~ 10000 stronger than BAO signal!!!!



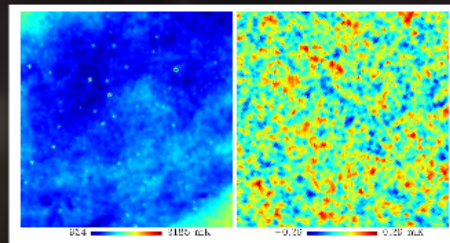
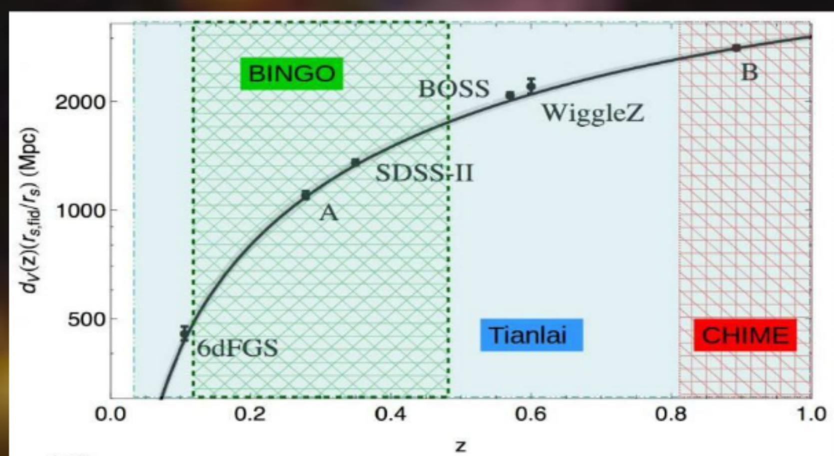
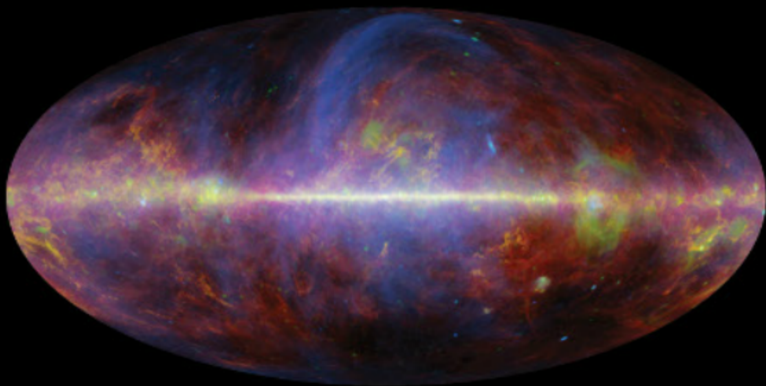


Figure 6: *. Astrophysical emissions (Galactic synchrotron, Galactic free-free, and extragalactic point sources) (left) and HI emission (right) at 1 GHz. The maps are centred at Galactic coordinates (30; 120). The maps resolution is 40 arcmin. Astrophysical emissions are ~ 10^4 brighter than HI emission.*



→ PLANCK LEGACY ARCHIVE: FOREGROUND COMPONENT MAPS

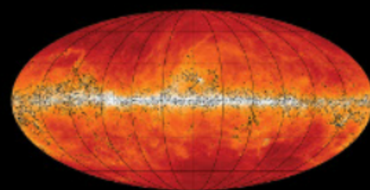


To complete the core Planck mission of detecting the Cosmic Microwave Background (CMB), the foreground emissions arising from cosmic structures lying between the CMB and the satellite had to be carefully mapped and characterised so that it could be removed.

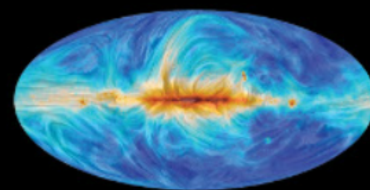
This resulted in several all-sky maps portraying the distribution of various diffuse components in our Milky Way galaxy, as well as in a series of extensive catalogues containing lists of specific components — point-like or compact sources of emission. These individual sources cover a wide range of objects — from pre-stellar cores to galaxy clusters — and a range of distances — from our Galaxy to the distant early Universe.

Some of these foreground component maps are displayed here. The map above is a composite of several diffuse components that pervade the Milky Way: thermal dust emission, line radiation from carbon monoxide gas, diffuse synchrotron emission, and free-free emission. The maps on the right show the all-sky distribution of other foreground components.

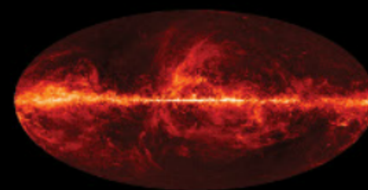
These maps are among the mission products that are publicly accessible from the Planck Legacy Archive.



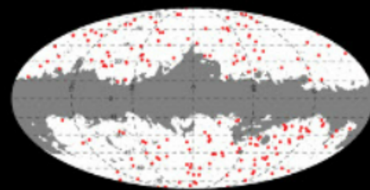
Galactic cold clumps



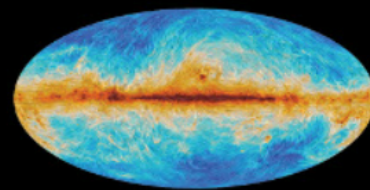
Magnetic field lines traced by synchrotron radiation at 30 GHz



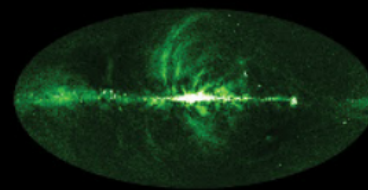
Polarised dust emission



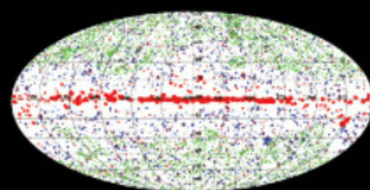
Galaxy clusters detected by the Sunyaev-Zeldovich effect



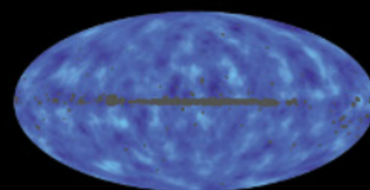
Magnetic field lines traced by dust emission at 353 GHz



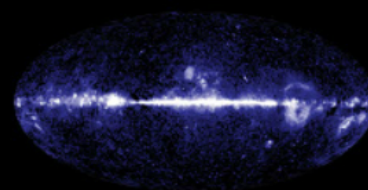
Polarised synchrotron emission



Compact sources



Gravitational-lensing potential — a tracer of dark matter structures



Line radiation from carbon monoxide gas

Image credits: ESA and the Planck Collaboration; large map credits: ESA/NASA/JPL-Caltech

www.esa.int

European Space Agency

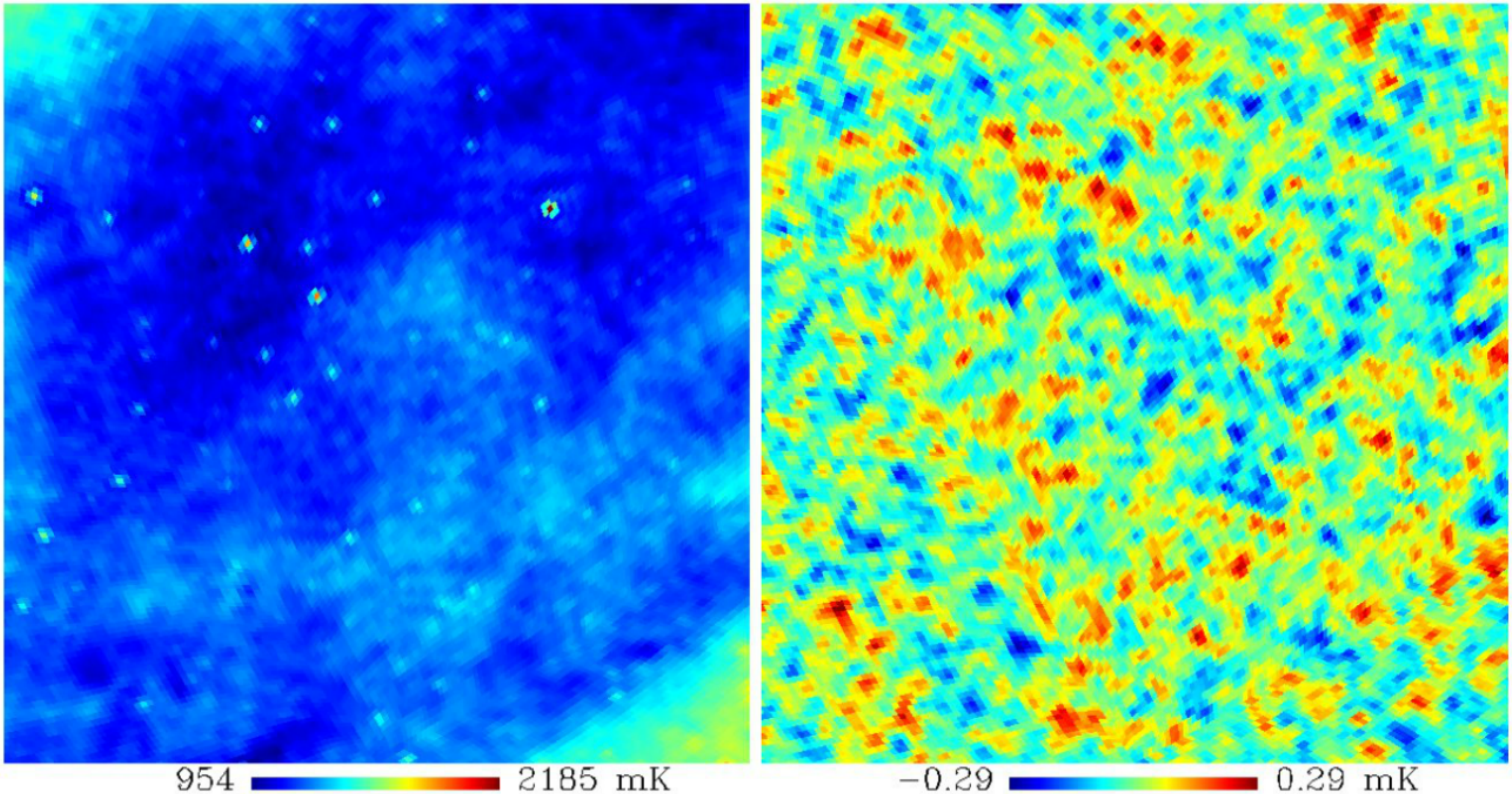
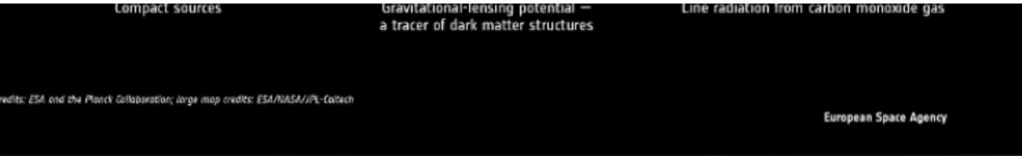
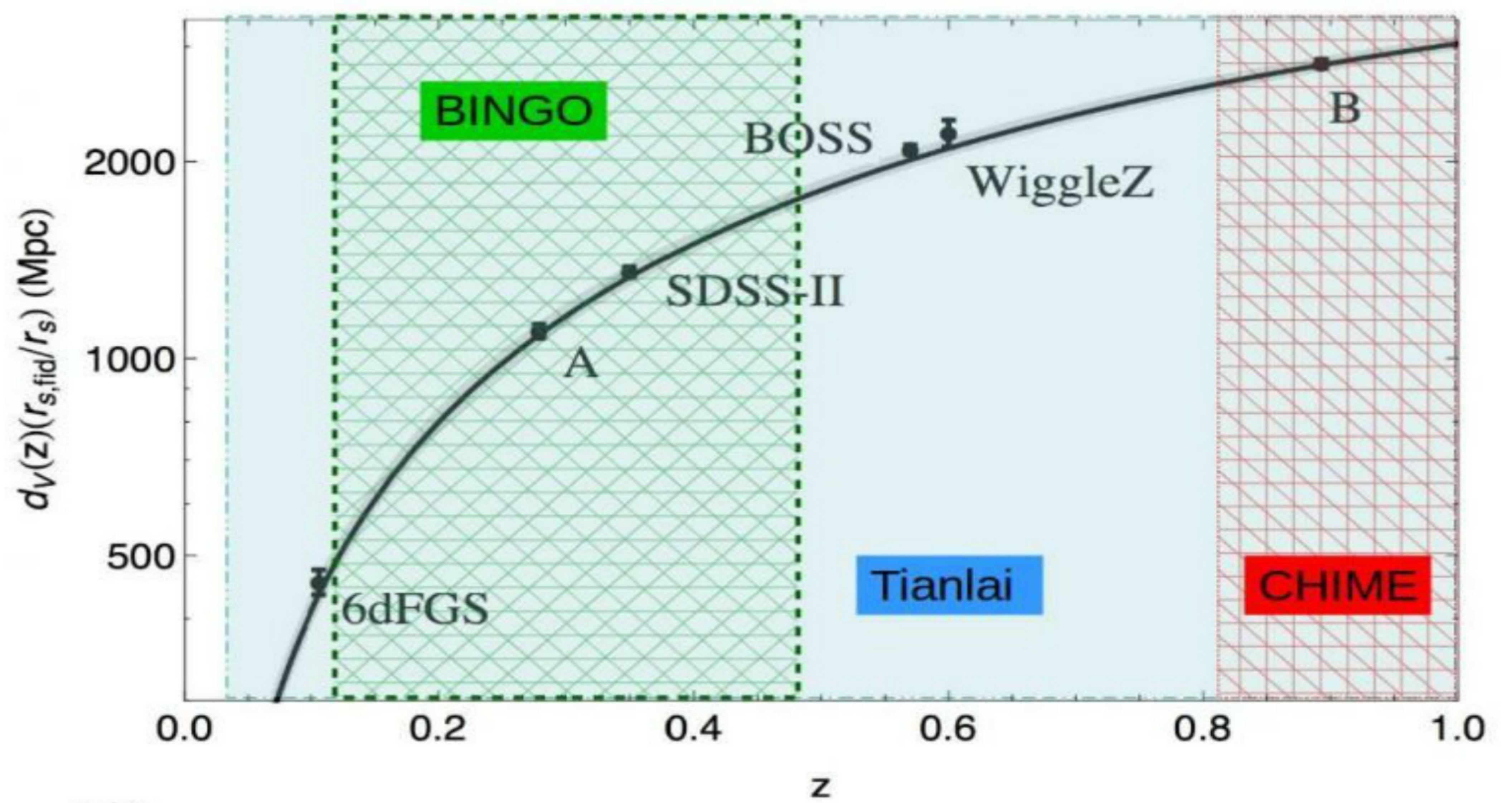


Figure 6: *. Astrophysical emissions (Galactic synchrotron, Galactic free-free, and extragalactic point sources) (left) and HI emission (right) at 1 GHz. The maps are centred at Galactic coordinates (30; 120). The maps resolution is 40 arcmin. Astrophysical emissions are ~ 10^4 brighter than HI emission.*



Galactic coordinates (30
arcmin. Astrophysical en
emission.



Technological challenges

Some of the challenges BINGO will have to deal with:

- Build the 50, ~ 4.8 x 1.8 m, horns to a 0.5 mm precision
- Transport to and build the 2, ~ 40 m dishes in "Sertão da Paraíba"
- Same thing for the horns
- Data stewardship of the 50 horns
- RFI from mobile phones, airplane routes, radio links and microwave ovens are a permanent threat to the quality of BINGO data!!!!
- Continuously monitor the radio environment around BINGO

Additional Science

- Life history of HI
- Fast Radio Bursts
- Pulsar timing
- Recombination lines
- Galactic science

Fast Radio Bursts

- First detected in 2007 (Lorimer et al., Science 2007)
- Duration: ~ millisecs to ~ 10s of millisecs
- Extragalactic origin, unknown causes (magnetar flares, short GRB bursts)

RESEARCH LETTER

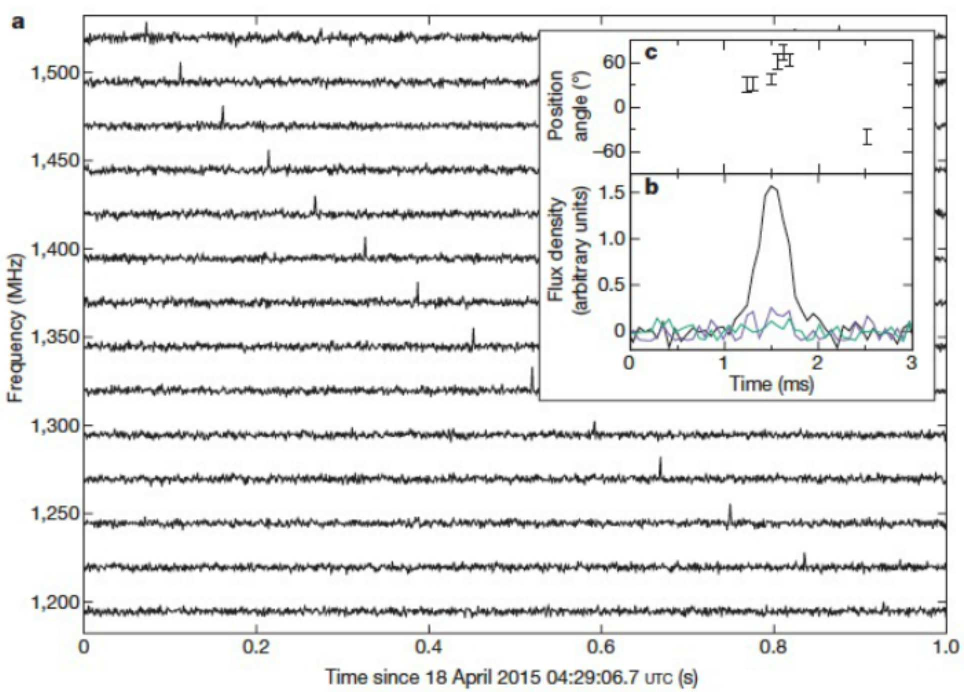


Figure 1 | The FRB 150418 radio signal. **a**, A waterfall plot of the FRB signal with 15 frequency sub-bands across the Parkes observing bandwidth, showing the characteristic quadratic time–frequency sweep. To increase the signal-to-noise ratio, the time resolution is reduced by a factor of 14 from the raw 64-μs value. **b**, The pulse profile of the FRB signal with the total intensity, linear and circular polarization flux densities shown as black, purple and green lines respectively. **c**, The polarization position angle is shown with 1σ error bars, for each 64-μs time sample where the linear polarization was greater than twice the uncertainty in the linear polarization.

flares, short GRB bursts)

RESEARCH LETTER

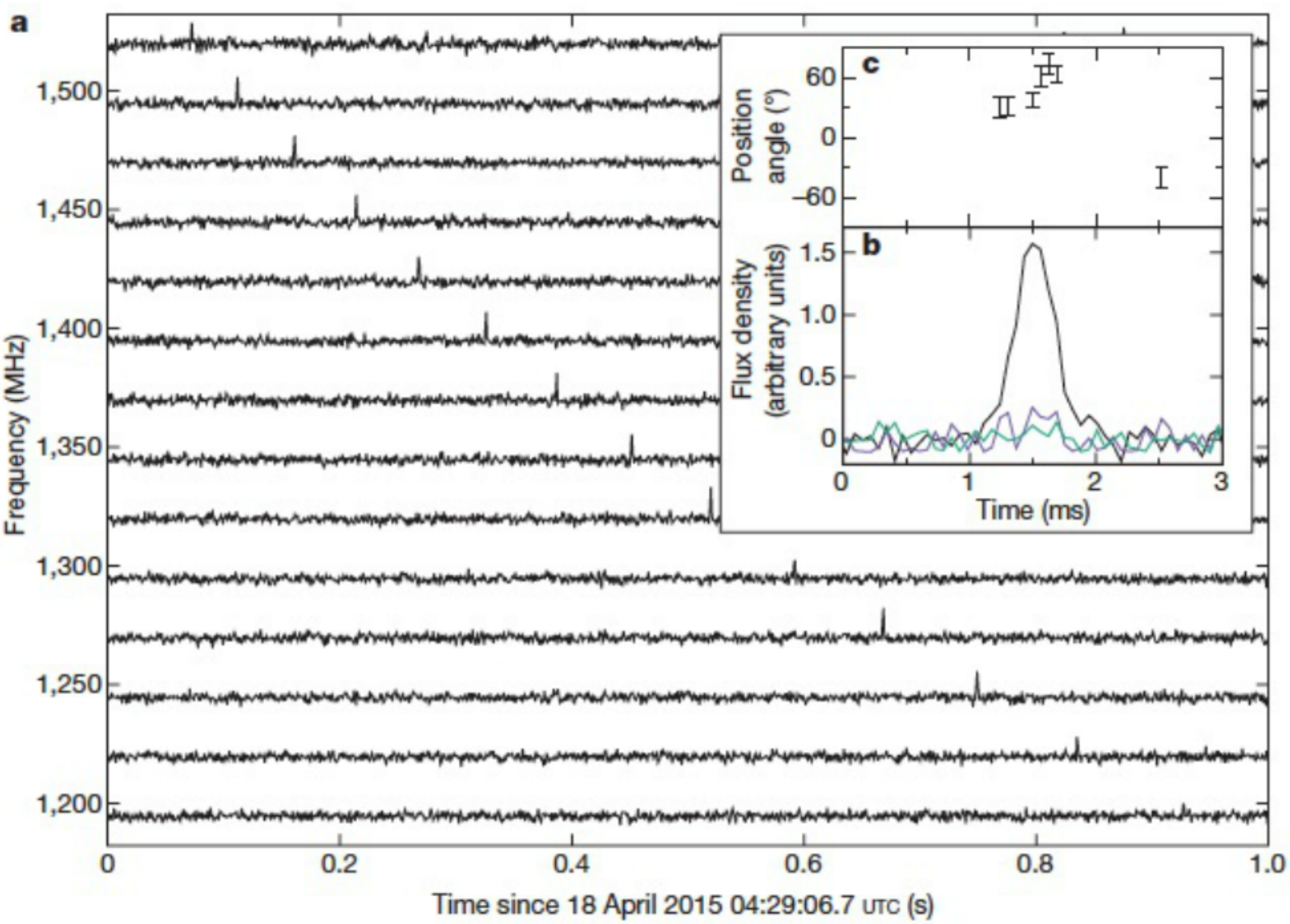
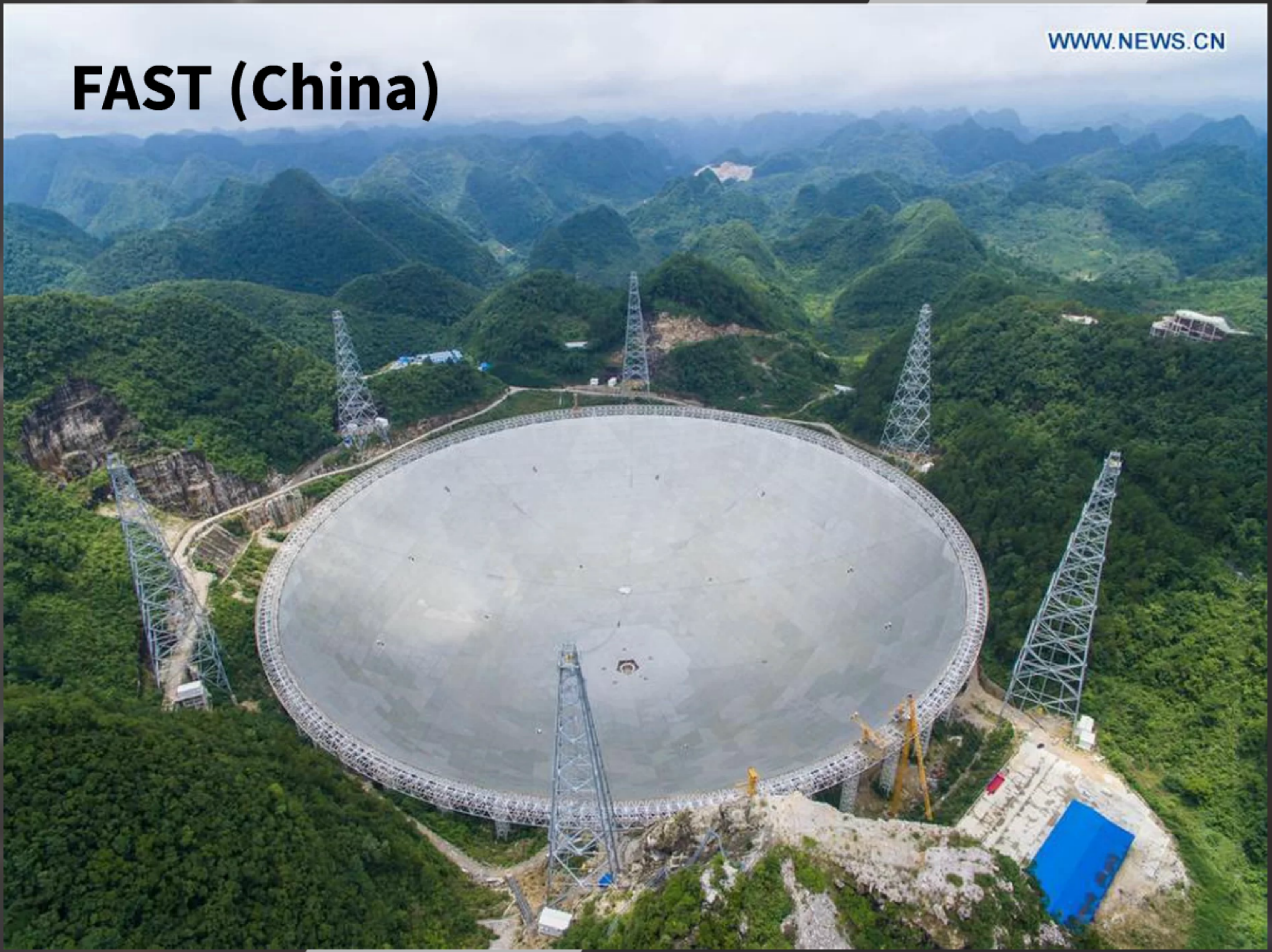


Figure 1 | The FRB 150418 radio signal. **a**, A waterfall plot of the FRB signal with 15 frequency sub-bands across the Parkes observing bandwidth, showing the characteristic quadratic time–frequency sweep. To increase the signal-to-noise ratio, the time resolution is reduced by a factor of 14 from the raw 64-μs value. **b**, The pulse profile of the FRB signal with the total intensity, linear and circular polarization flux densities shown as black, purple and green lines respectively. **c**, The polarization position angle is shown with 1σ error bars, for each 64-μs time sample where the linear polarization was greater than twice the uncertainty in the linear polarization.

BINGO competitors today

MeerKat (South Africa)

FAST (China)



Chime (Canada)


Not before ~ 2022, though...
SKA (South Africa/ Australia)
SPDO / Swinburne Astronomy Productions

Groenlândia
Islândia
Suécia
Noruega
Finlândia
Rússia
Irlanda
Dinamarca
Bielorrússia
Polônia
Ucrânia
Romênia
Itália
Grécia
Turquia
Cazaquistão
Mongólia
Uzbequistão
Quirguistão
Turquemenistão
Síria
Iraque
Irão
Afeganistão
Paquistão
Nepal
Índia
Myanmar
Tailândia
Vietname
Filipinas
Malásia
Indonésia
Coreia do Sul
Japão
Estados Unidos
México
Cuba
Porto Rico
Guatemala
Nicarágua
Venezuela
Guiana
Suriname
Colômbia
Equador
Peru
Bolívia
Paraguai
Chile
Argentina
Marrocos
Argélia
Tunísia
Líbia
Egito
Mauritânia
Mali
Níger
Chade
Sudão
Nigéria
Gana
Etiópia
Sudão do Sul
Somália
Quênia
República Democrática do Congo
Tanzânia
Angola
Zâmbia
Moçambique
Namíbia
Zimbábue
Botsuana
Madagáscar
África do Sul
Arábia Saudita
Iémen
Omã
Austrália
Oceano Atlântico Norte
Oceano Atlântico Sul
Oceano Índico
Mar Mediterrâneo
Golfo do México
Mar das Caraíbas
Mar Arábico
Baía de Bengala
Mar da China Oriental
Mar do Japão
Mar das Filipinas
Baía de Hudson
2.000,00 km
4.000,00 km
6.000,00 km
8.000,00 km
10.000,00 km
14.000,00 km
16.000,00 km
18.000,00 km
21.728,88 km
Google
The BINGO Consortium

Brazil

USP

Elcio Abdalla
Michael Peel
Andreia de Souza
Raul Abramo
Marcos Lima
Many students

INPE

C. A. Wuensche
Luiz Reitano
Cesar Strauss
Alan Cassiano
Renato Branco
Karin Fornazier
Thyrso Villela
Students

UFCG

SUPRA OMNES LUX LUCIS

Luciano Barosi
Franscisco Brito
Other professors
Many (potential)
students

UK

MANCHESTER 1824
The University of Manchester

Ian Browne, Richard Battye,
Clive Dickinson
P. Wilkinson
Stuart Harper
Sambit Raychaudury
Lucas Olivari
Tyanue Chen
Jodrell Bank technical staff

UCL

Filipe Abdalla

Other collaborators from the UK

Swiss

ETH Zürich

Alex Refregier
Adam Amara
Christian Monstein

Uruguay

UNIVERSIDAD
DE LA REPÚBLICA
URUGUAY

Gonzalo Tancredi
Manuel Caldas

Emilio Falco (USA)
Ana Mosquera (USA)

France, China and S. Africa

IAS Orsay

Bruno Maffei

Yangzhou University

Bin Wang

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

Yen-Zhe Ma

THANK YOU!

Please visit our web site:

http://www.bingotelescope.org