MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

PUMA Workshop 2020

The BINGO Telescope

an instrument to investigate the Universe through the 21 cm neutral hydrogen line

C. A. Wuensche

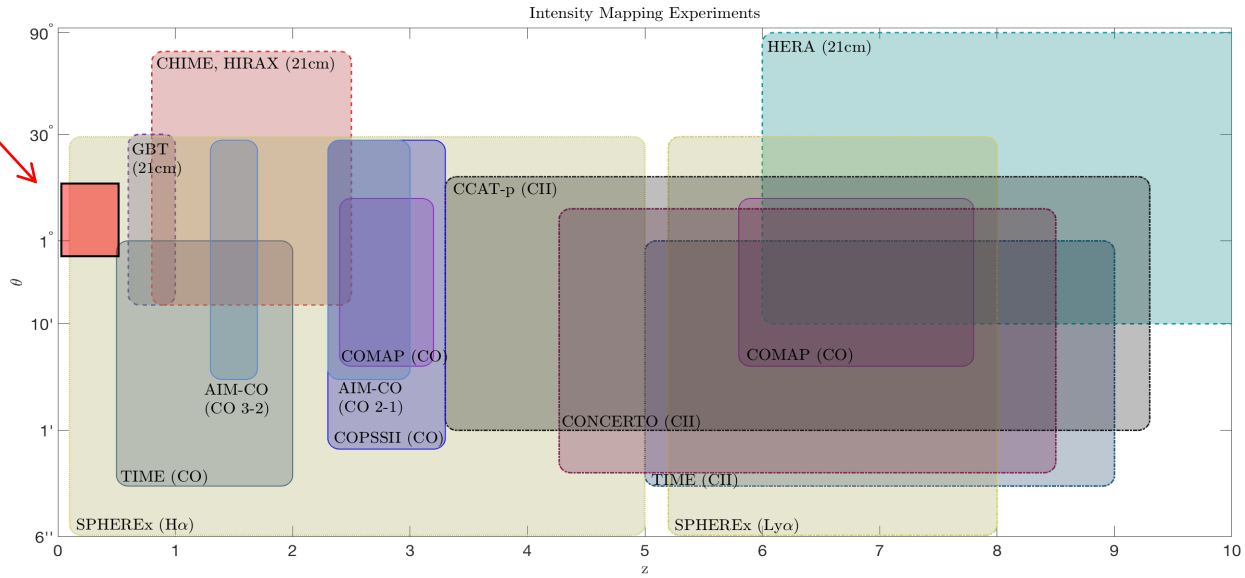
on behalf of the BINGO Collaboration

ca.wuensche@inpe.br

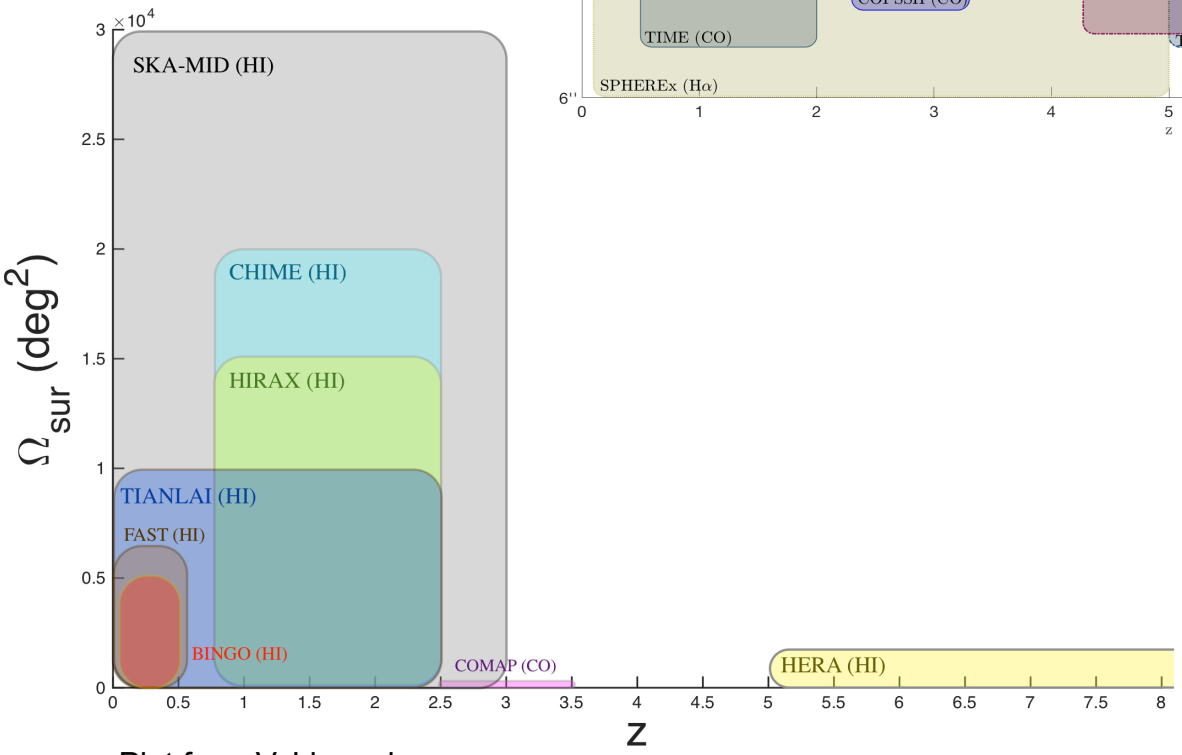
BINGO Science goals

- Measure BAO on top of the 21 cm HI spectrum
- HI intensity mapping can be used as mass tracer, probing distortions in redshift space and checking BAO anisotropy
- **Additional science**
  - Life history of hydrogen
  - Radio recombination lines
  - Galactic continuum
- And, of course, **FRBs**, which will be delivered for free due to the nature of BINGO observational strategy

BINGO fits here (our update of pag. 44 of Kovetz et al (2017)



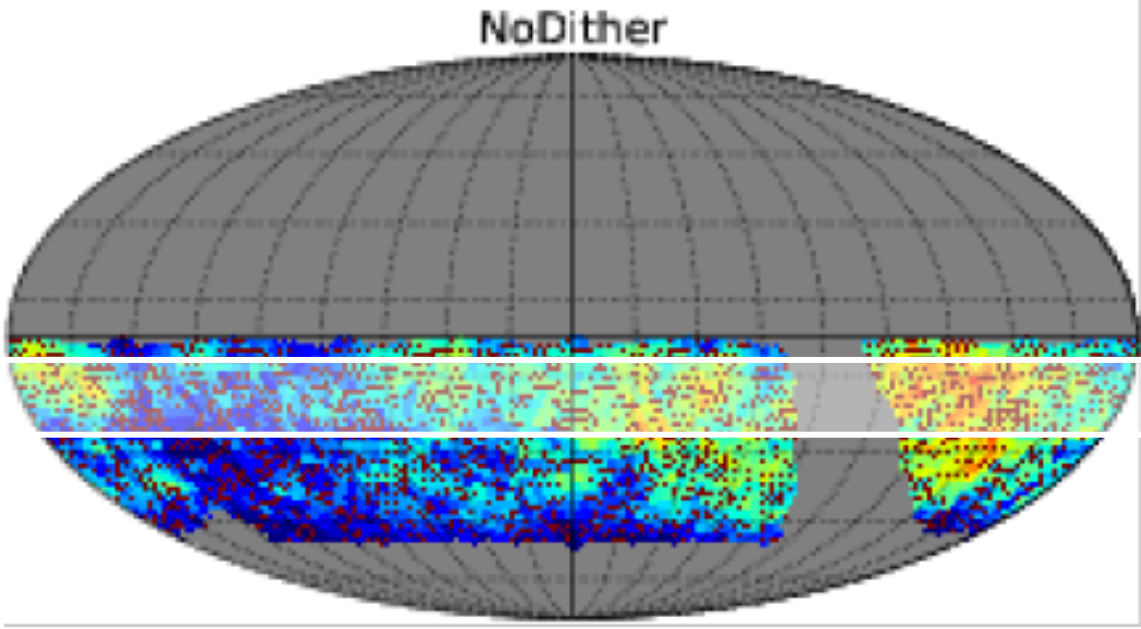
Kovetz et al, (arXiv:1709.09066)

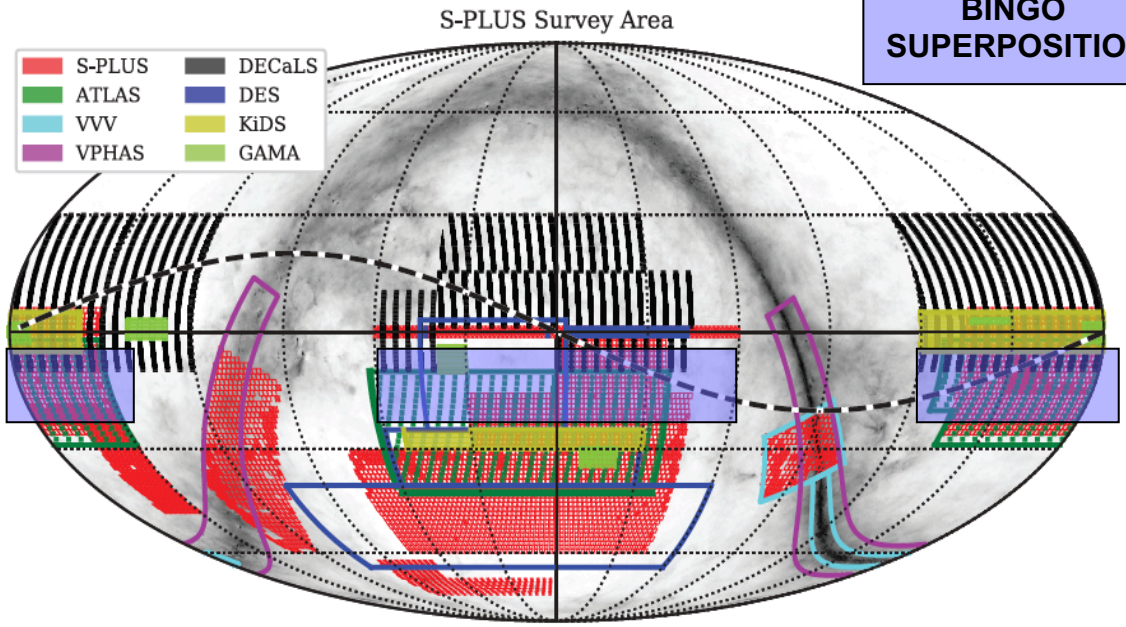


Plot from V. Liccardo

C. A. Wuensche (2020)

LSST Cosmology map (simulated).
arXiv:1708.04058, chap. 9, fig. 9.3.
BINGO coverage area in white





BINGO SUPERPOSITION

The “FIDUCIAL” BINGO (May 2020)

FIDUCIAL BINGO	
T_sys (K)	70
Frequency band (MHz)	280
#channels	30
Channel resolution (MHz)	9.3
Sampling time (Hz)	10
Min frequency (MHz) / Redshift	980 / 0,45
Max frequency (MHz) / Redshift	1260 / 0.13
Redshift band (for 40 channels)	0.008
Instrument noise (mK, 1 second)	22

Site coordinates (Aguiar, PB)	
7° 2’ 27.6" S	38° 16' 4.8" W

FIDUCIAL BINGO	
Focal length (m)	63.2
Primary mirror: off-axis paraboloid	
M	20.0 /
M	
Pi	
Optics FWHM (deg)	0.67
Survey area (square deg)	6000
Horns	28

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

	1 year	2 years	5 years
Integration time/pixel	2,54E+05	5,07E+05	1,27E+06
Sensitivity/pixel (microK)	45,49	32,17	20,34

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FIDUCIAL BINGO	
Focal length (m)	63.2
Primary mirror: off-axis paraboloid	
Major/minor semi-axis (m)	20.0 / 20.0
Secondary mirror: off-axis hyperboloid	
Major/minor semi-axis (m)	18.3 / 17.8
Pixel solid angle (sr)	0.35
Optics FWHM (deg)	0.67
Survey area (square deg)	6000
Horns	28

	1 year	2 years	5 years
Integration time/pixel	2,54E+05	5,07E+05	1,27E+06
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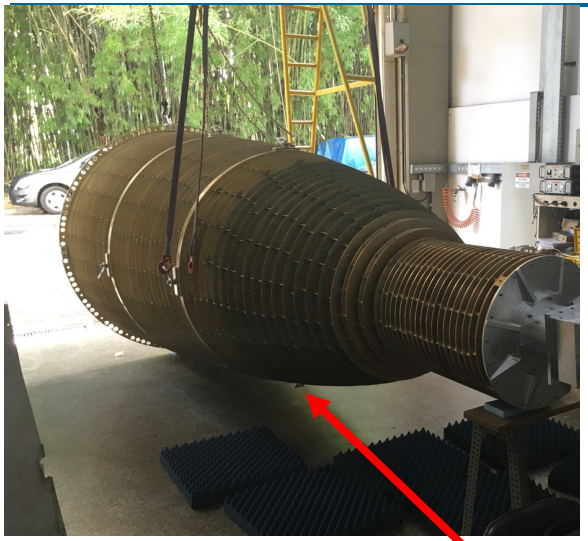
Project management status

- Most of the funding (> 80%) is already granted
  - FAPESP: main funding agency.
  - General coordination: Elcio Abdalla (IF/USP)

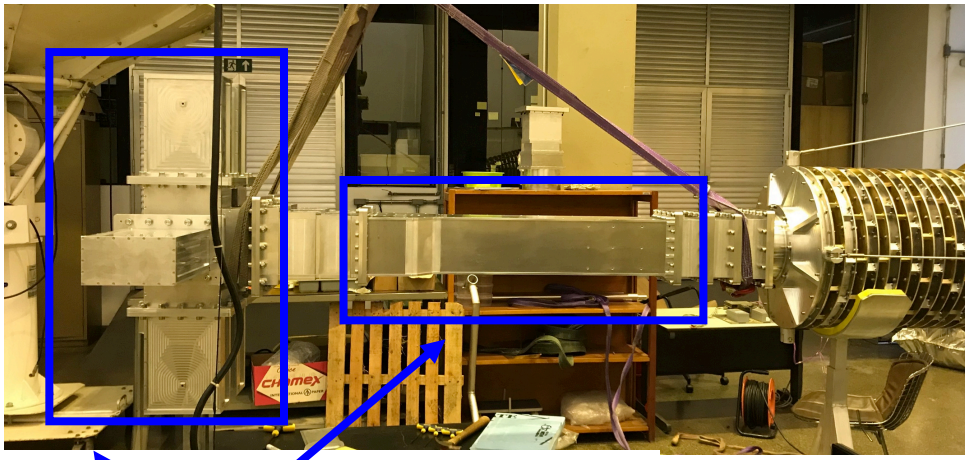
- BINGO construction proceeds…
  - Site defined => RFI initial measurements on site completed
  - Site waiting for return to normal conditions to start road work and cleaning
  - Horn, transitions, polarizer, and magic tee prototypes completed and successfully tested
  - main receiver components (first stage LNAs and filters, secondary LNAs and filters) successfully tested
  - Major Project Review 2019 → **green light to proceed to Phase 2.**
  - "Antenna" to be integrated and tested at INPE (no sky measurements)
  - "Antenna" to be integrated and tested in Paraíba (sky measurements)
  - Optical design completed
  - Engineering projects near completion
  - Dish fabrication in discussion with Brazilian company

Challenges (July 2020)

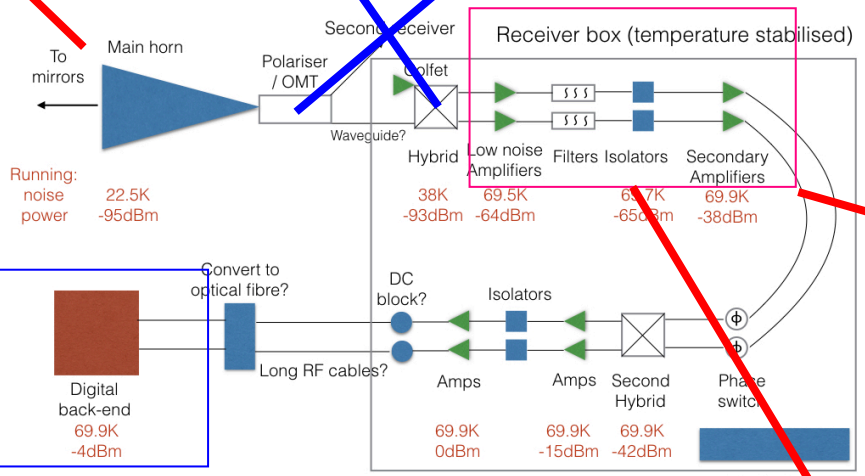
- Large telescope: **discussions ongoing with the company to produce the dishes**
- Large horns: **fabrication process understood, discussions ongoing with the company to produce the horns**
- Optical design: **optics simulations indicate very small distortions of the beams for the current horn array. Final array will have 28 non-aligned horns.**
- Calibration and stability: **use colfets and a CW source as internal calibration. Noise and stability for both are under investigation**
- Receiver stability: **has to be tested with internal cooling and later, under the hot environment temperature in Paraíba**
- Digital backend: **SKARAB boards, mass purchase is subject to current dollar exchange rate being more favorable. Advances in programming slow due to Covid-19 restricted access to INPE's labs. Needs to be integrated to the receiver in the lab in the upcoming months**
- Radio Frequency Interference → **Mobile quiet zone has already been requested to the state authorities (both to State agencies and ANATEL). Discussions are advancing.**



Testing completed



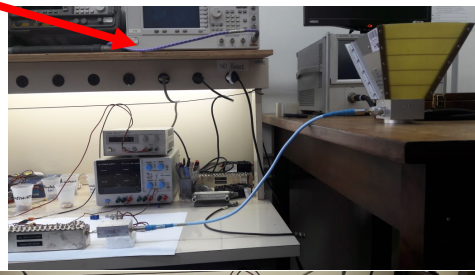
Testing completed

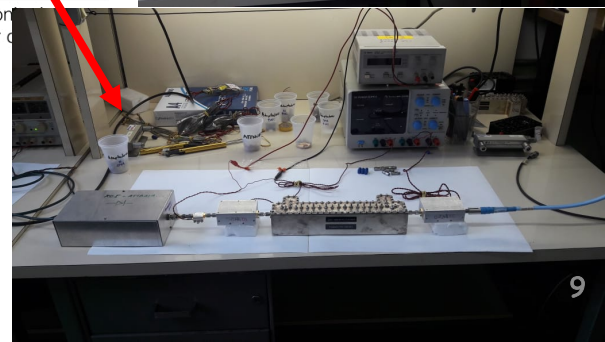


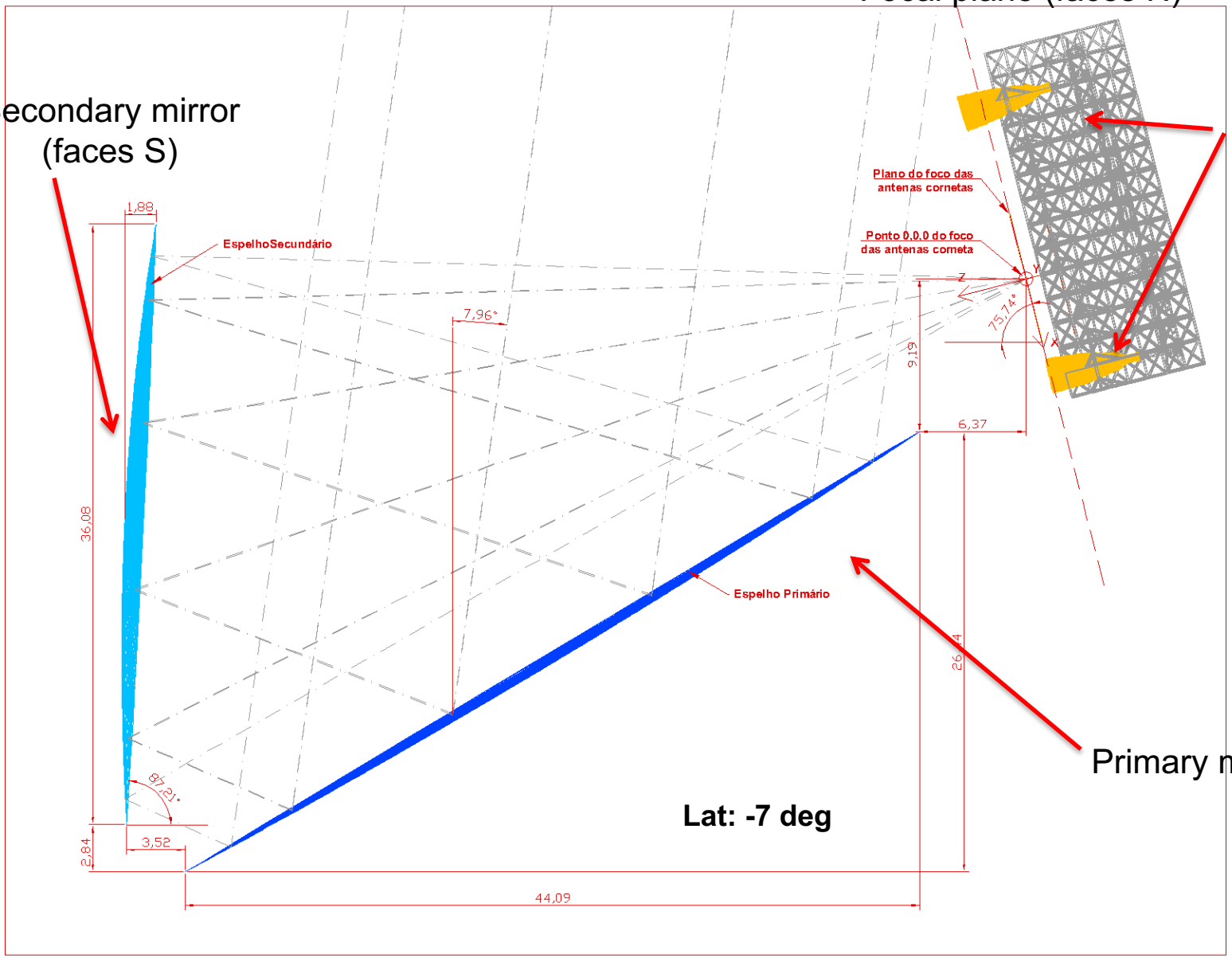
Setup ongoing



Testing completed



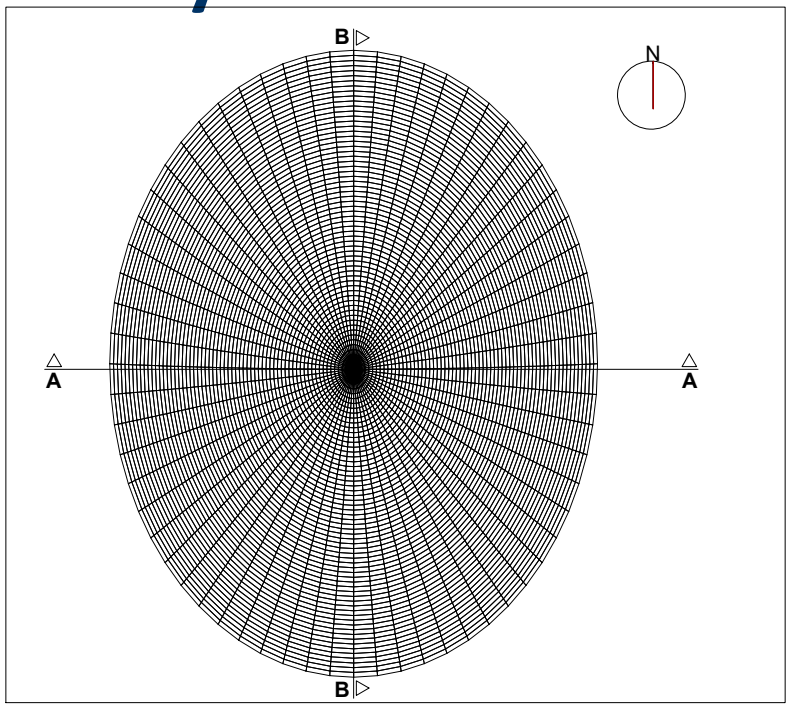




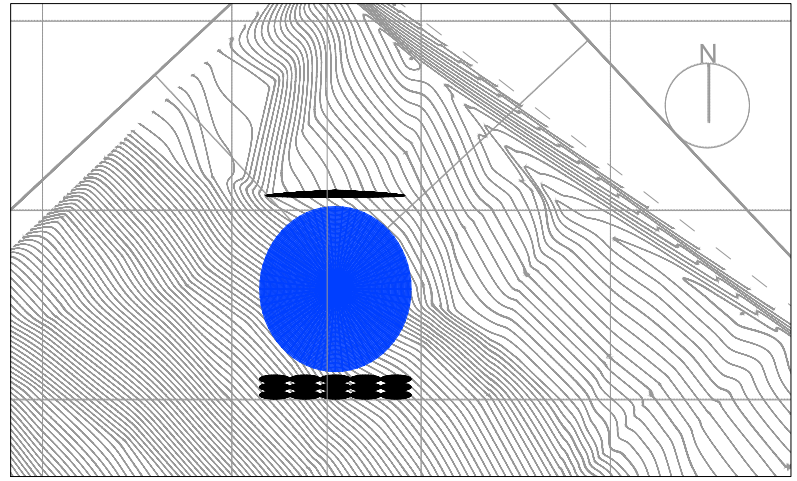
Contributions of Maffei, Ferreira, Abdalla, Souza

C. A. Wuensche (2020)

Primary dish



01 Vista em Planta - Espelho Primário
1:250

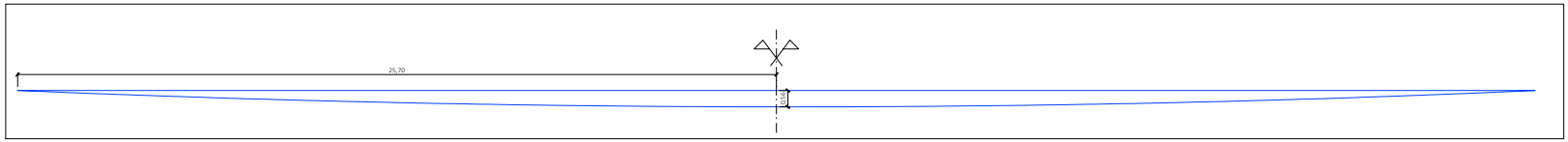


04 Planta-chave - Espelho Primário

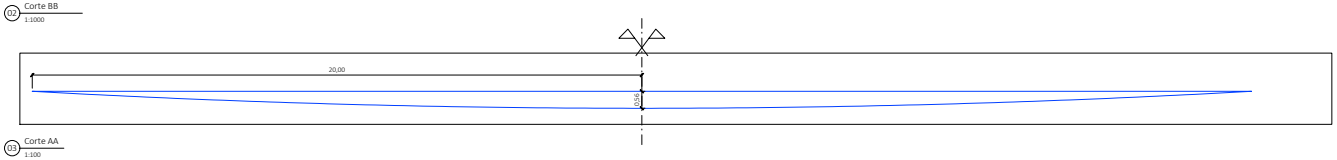
Documentos de referência:

1.DXFBingo_bis.DXF

2.BINGO_50.gxp



02 Corte BB
1:1000



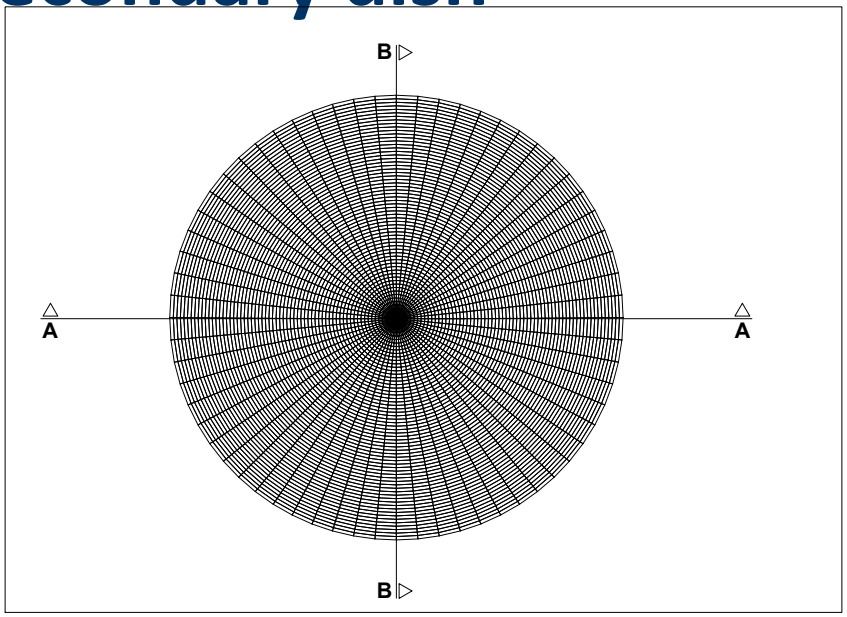
03 Corte AA
1:100

Rev. nº	Descrição	Data	Resp.
Empreendimento:	RADIOTELESCÓPIO BINGO		
Localização:	ZONA RURAL DO MUNICÍPIO DE AGUIAR – PB		
Edificação:	ESPELHO PRIMÁRIO		
Título da Folha:	PLANTA E CORTES		Folha nº 01/01
Área Técnica:	ARRANJO	Estágio: PROJETO BÁSICO	Escala INDICADA
Desenho:	APS	Verificação: FBA / BM / CAW	Nº Des. 002
Arquivo:	BINGO-03-DRW-0001-A-ESPELHO_PRIMARIO.DWG		Data OUT/2019

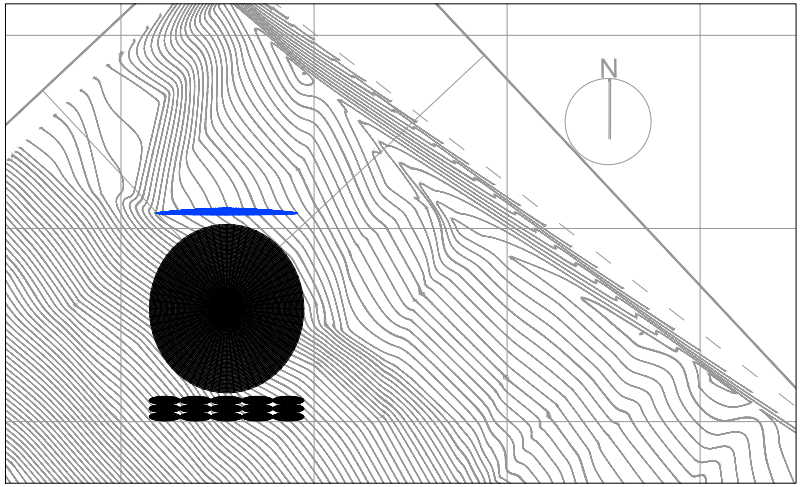
From A. P. de Souza

C. A. Wuensche (2020)

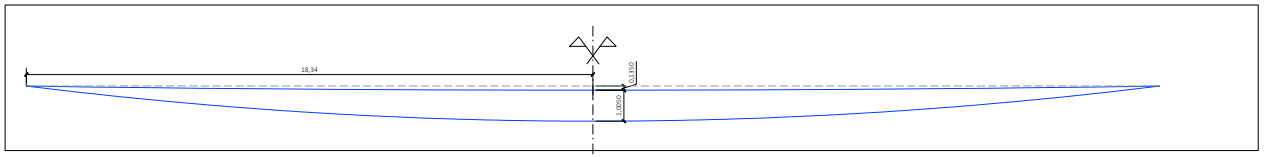
Secondary dish



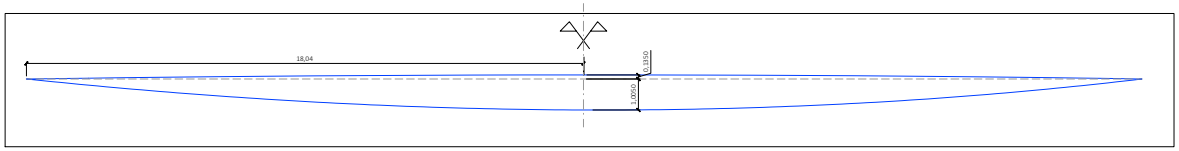
01 Vista Frontal - Espelho Secundário
1:250



04 Planta-chave - Espelho Secundário



02 Corte AA - Horizontal
1:1000



03 Corte BB - Vertical (perpendicular ao solo)
1:100

Documentos de referência:

1.DXFBingo_bis.DXF

2.BINGO_50.gxp

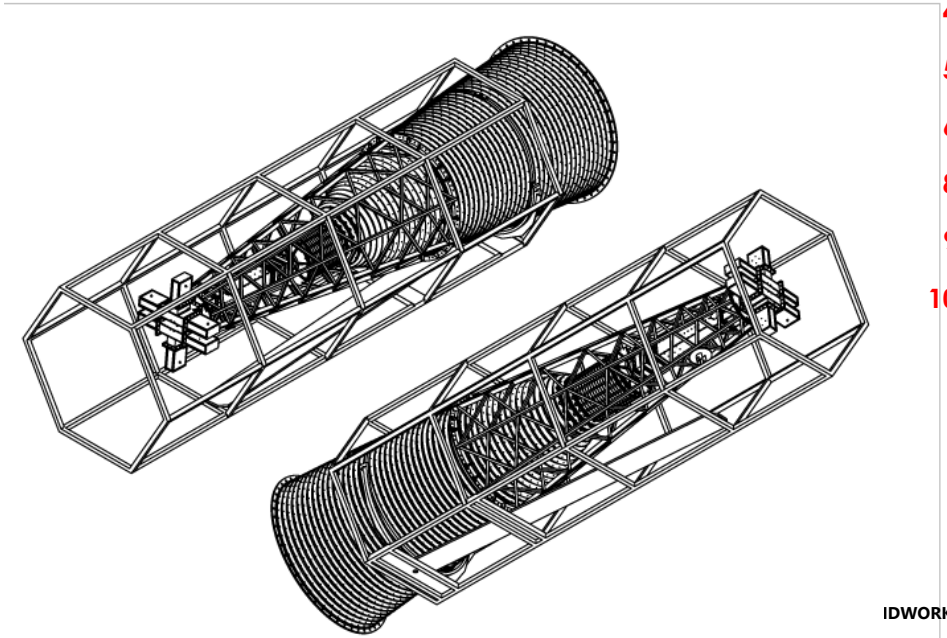
Rev. nº	Descrição	Data	Resp.
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Localização:	ZONA RURAL DO MUNICÍPIO DE AGUIAR – PB		
Edificação:	ESPELHO SECUNDÁRIO		
Título da Folha:	PLANTA E CORTES		Folha nº 01/01
Área Técnica:	ARRANJO	Estágio: PROJETO BÁSICO	Escala INDICADA
Desenho:	APS	Verificação: FBA / BM / CAW	Nº Des. 003
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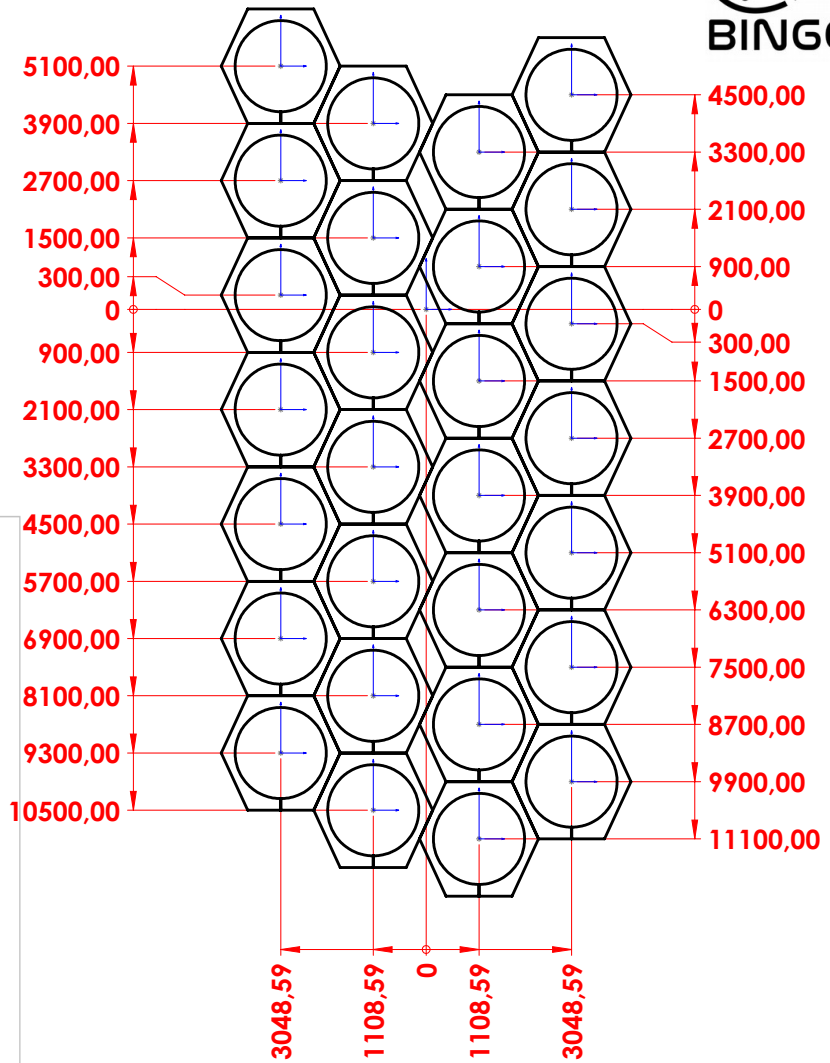
From A. P. de Souza

C. A. Wuensche (2020)

Horn fabrication and testing in
Wuensche et al. (Exp. Astron., 2020)

From L. A. Reitano





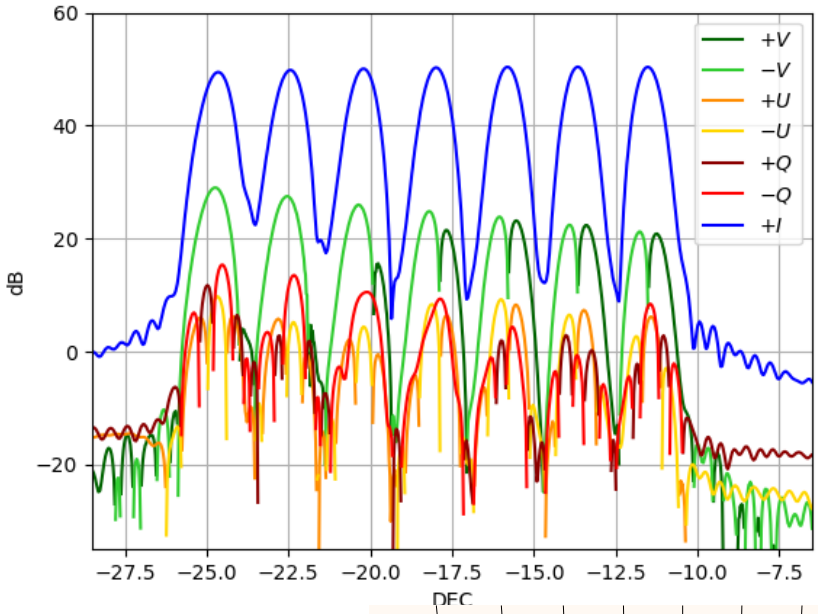
IDWORKS. Somente para fins de instrução.

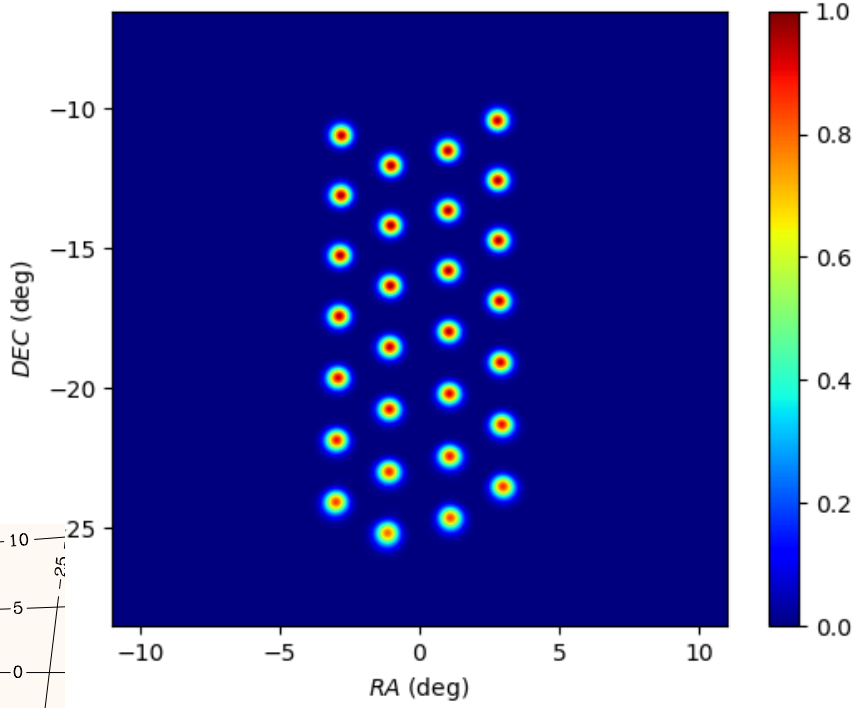


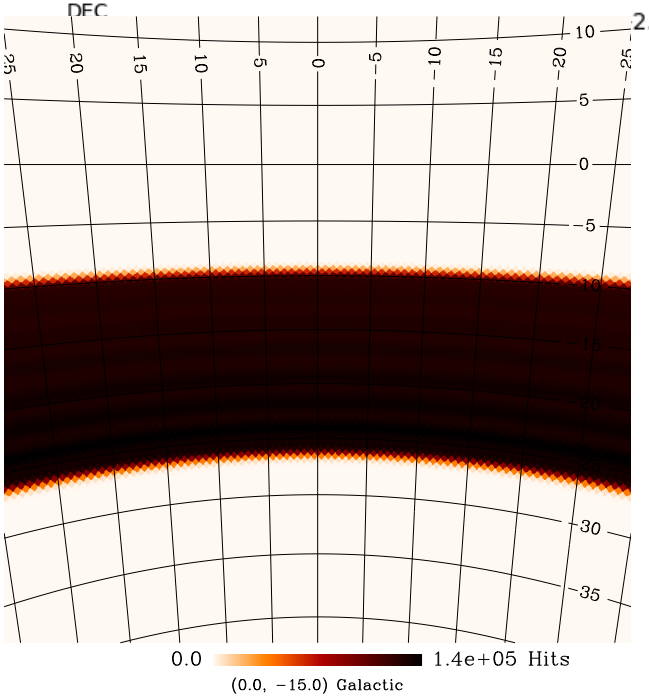
ational Product. For Instructional Use Only.

C. A. Wuensche (2020)

BINGO

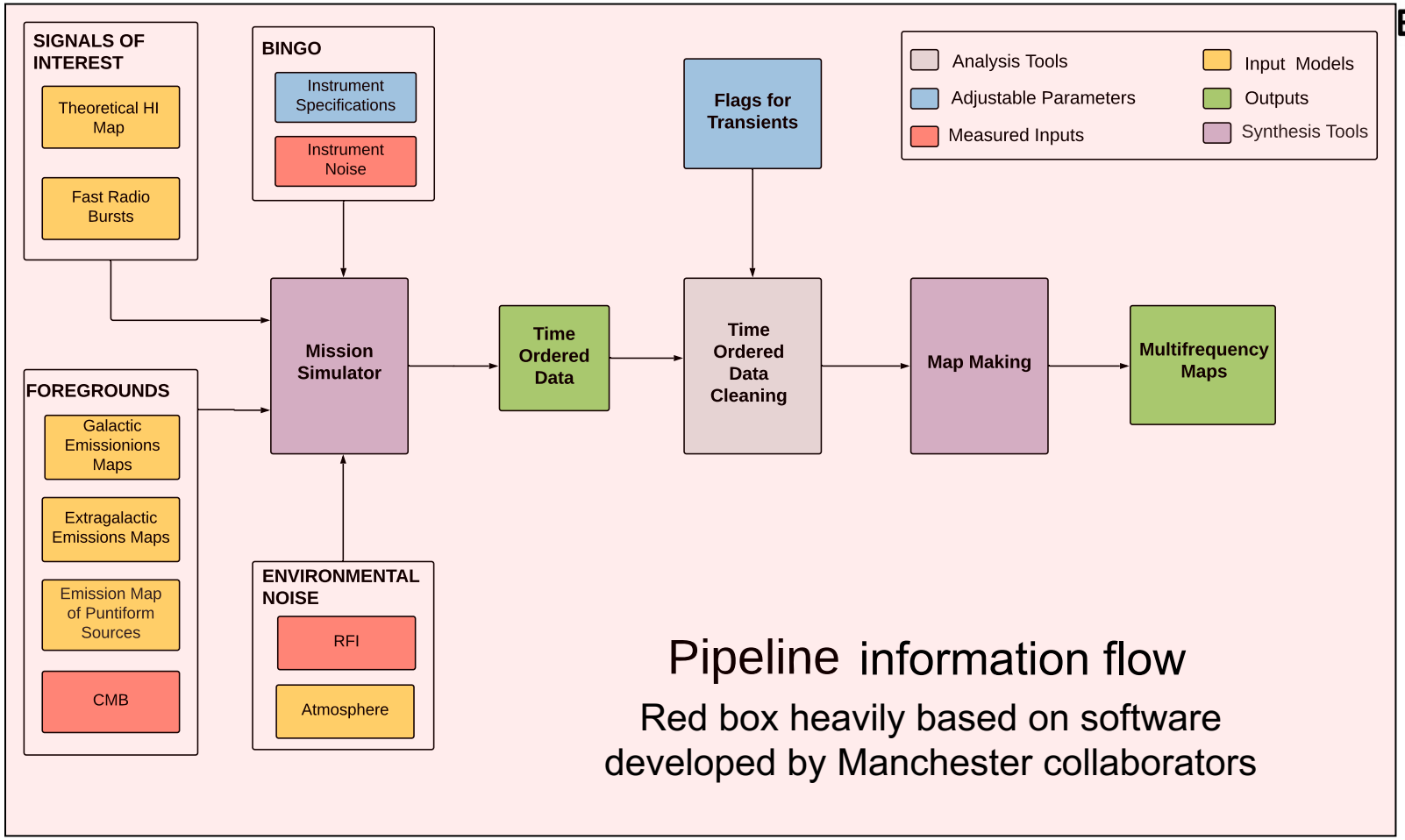


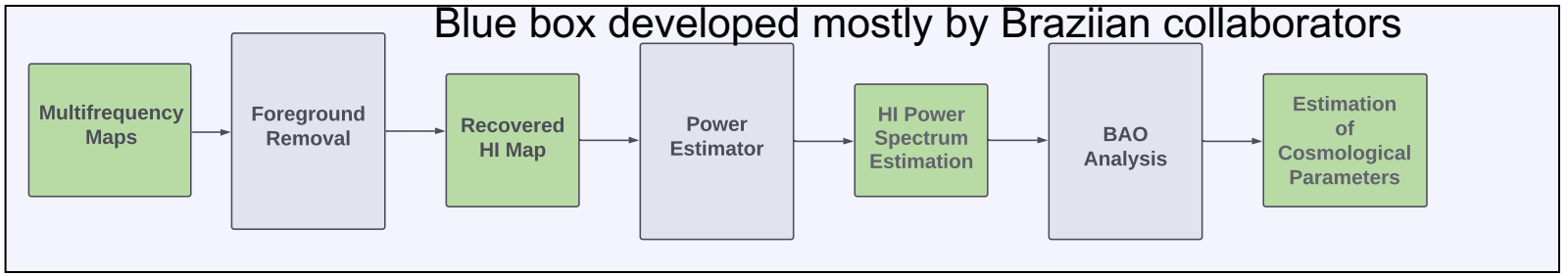




Abdalla, Marins, Mota et al., in preparation

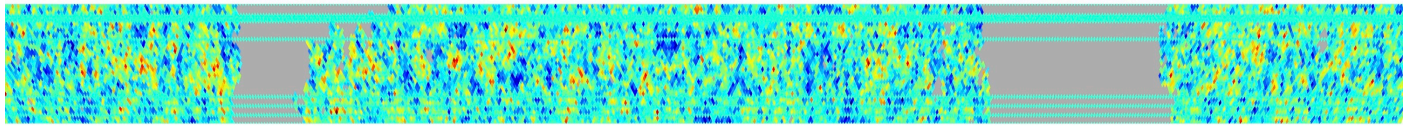
C. A. Wuensche (2020)



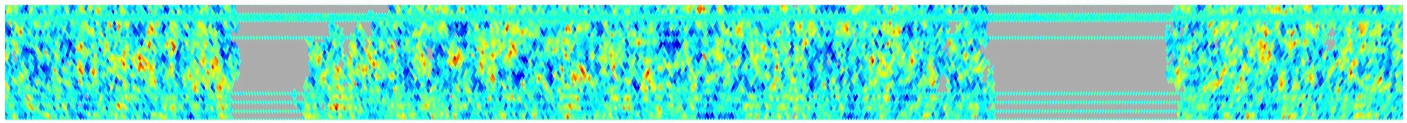


From E. Merícia

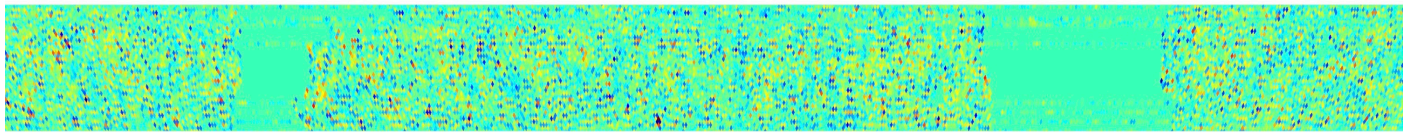
C. A. Wuensche (2020)



BINGO simulated input map @ 1100 MHz

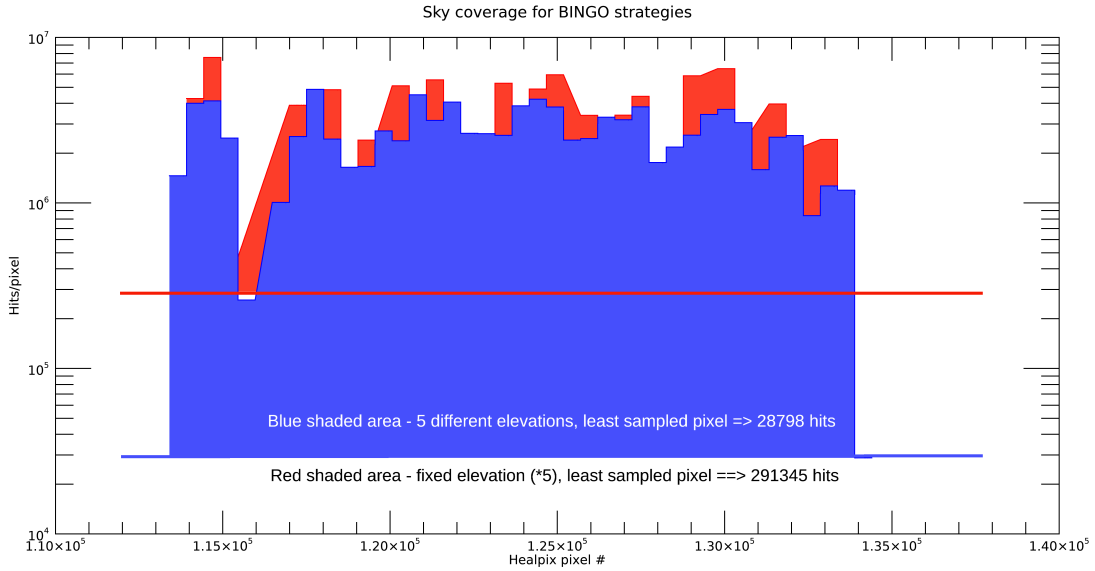


BINGO reconstructed map @ 1100 MHz



Residuals −0.18 0.25 mK

From V. Liccardo



C. A. Wuensche (2020)

- FRB is not BINGO main science, but serendipitous detections are expected
- Outriggers for interferometric pinpoint of the progenitor are being planned
- Needs ADDITIONAL FUNDING!

M.Sc. thesis from F. Vieira (2020) presented a preliminary analysis performance regarding FRB detections

For ~ 1.5 Jy (SNR = 5) BINGO will likely see about 1 event every 2.84 days…

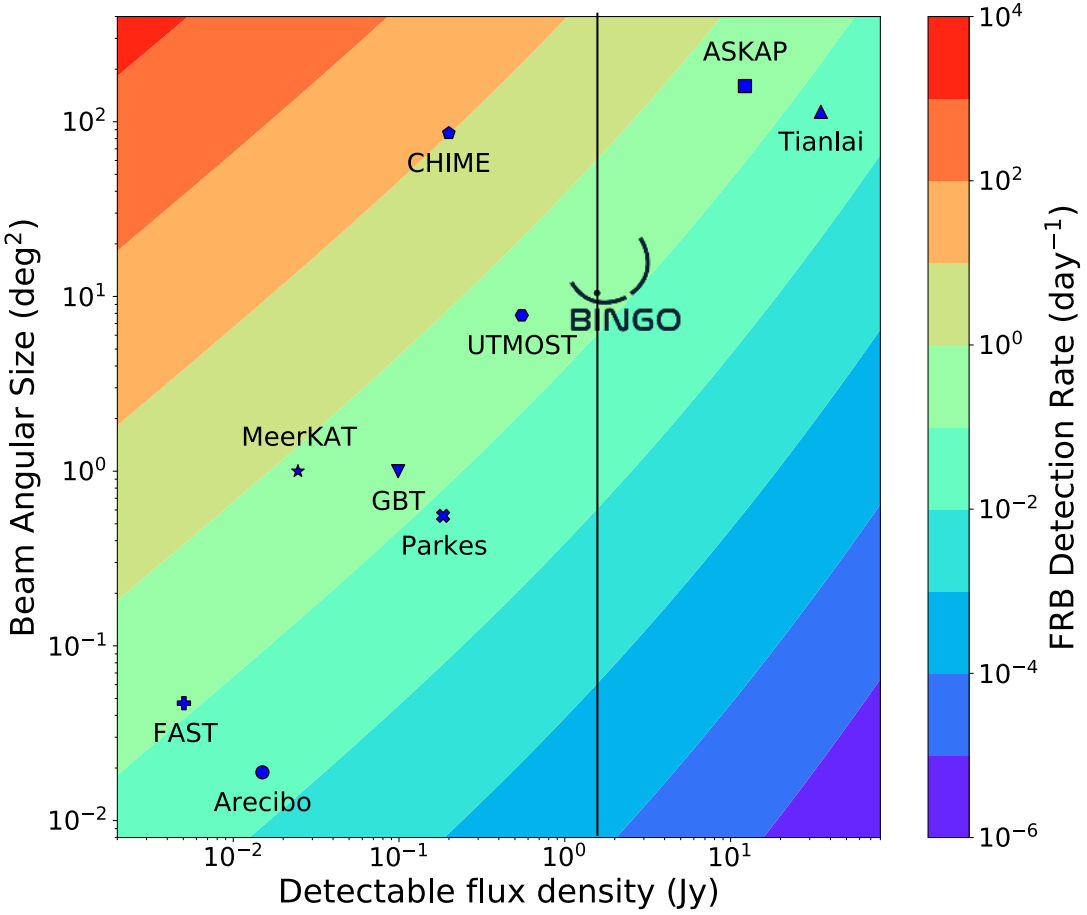
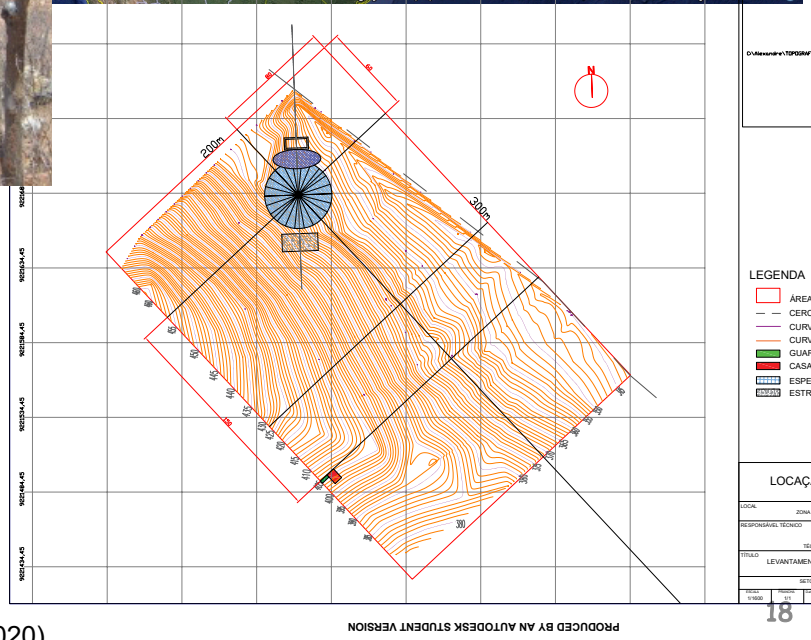


Figure from Luo et al., arXiv:2003.04848

Landim, Vieira, Vargas et al.: estimates for BINGO ongoing





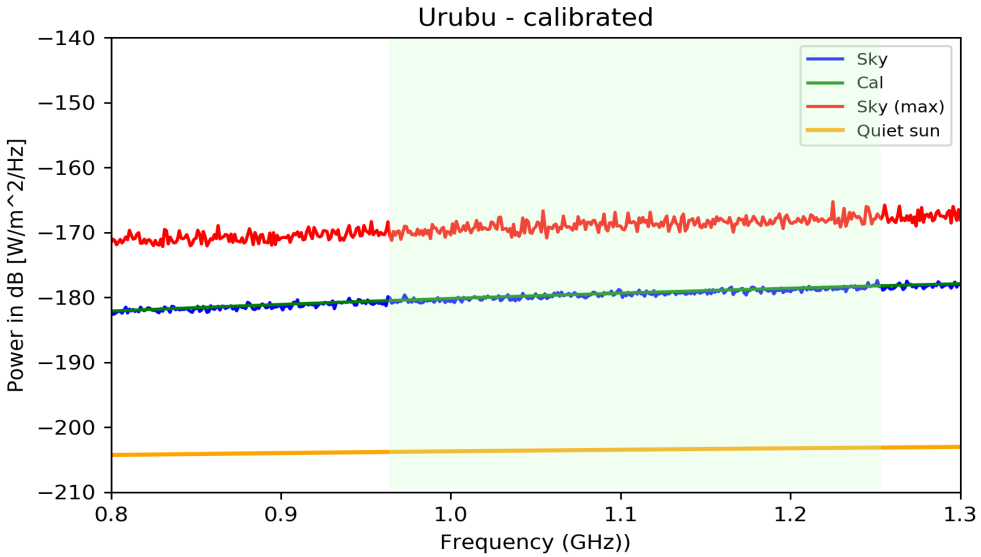


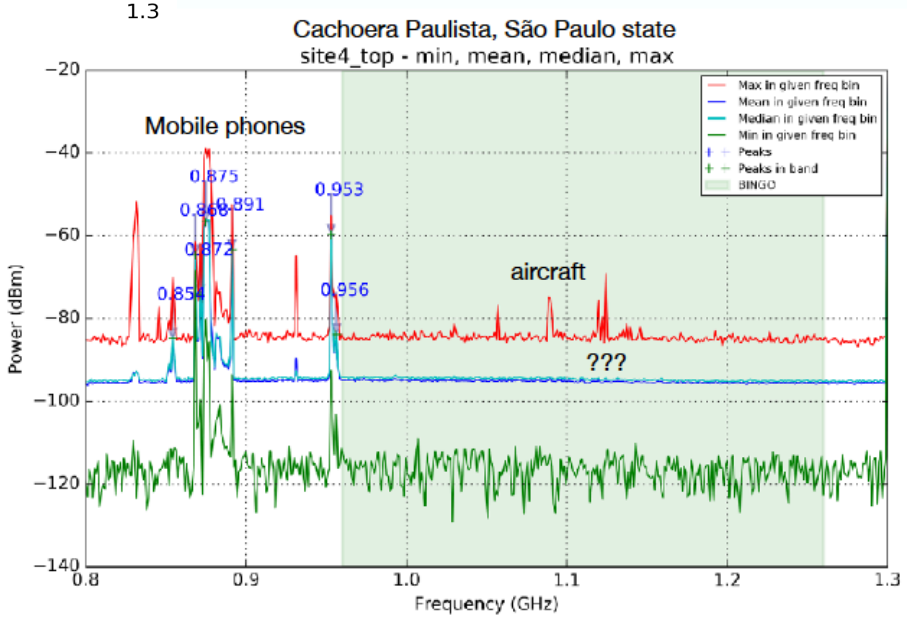
Serra da Catarina, Vale do Piancó (PB)

7° 2' 27,6" S; 38° 16' 4.8" W

C. A. Wuensche (2020)

Paraíba site is VERY CLEAN in the radio band





C. A. Wuensche (2020)

BINGO papers

- BINGO horn fabrication – C. A. Wuensche et al. (Exp. Astronomy, 2020 – arxiv:1911.13188)
- BINGO Site selection and RFI measurements – M. Peel et al. (Journ. Astron. Instrum. 2019 – arvix:1811.09464)
- The BINGO Telescope update – C. A. Wuensche et al. (J. of Physics Conf. Series, 2019 – arxiv:1803.01644)
- Papers near completion phase, planned to be submitted to A&A by October 2020
  - BINGO Project description – E. Abdalla et al.
  - BINGO Instrument description - C. A. Wuensche et al.
  - BINGO Mission simulations performance – V. Liccardo et al.
  - BINGO optical design – F. Abdalla et al.
  - BINGO 21cm Intensity Mapping Mock. I. HI Halo Occupation Distribution and Mock Building – J. J. Zhang et al.
  - BINGO componente separation – K. Fornazier et al.

BINGO

BAOs from Integrated Neutral Gas Observations





















Visit us at http://portal.if.usp.br/bingotelescope/

THANK YOU