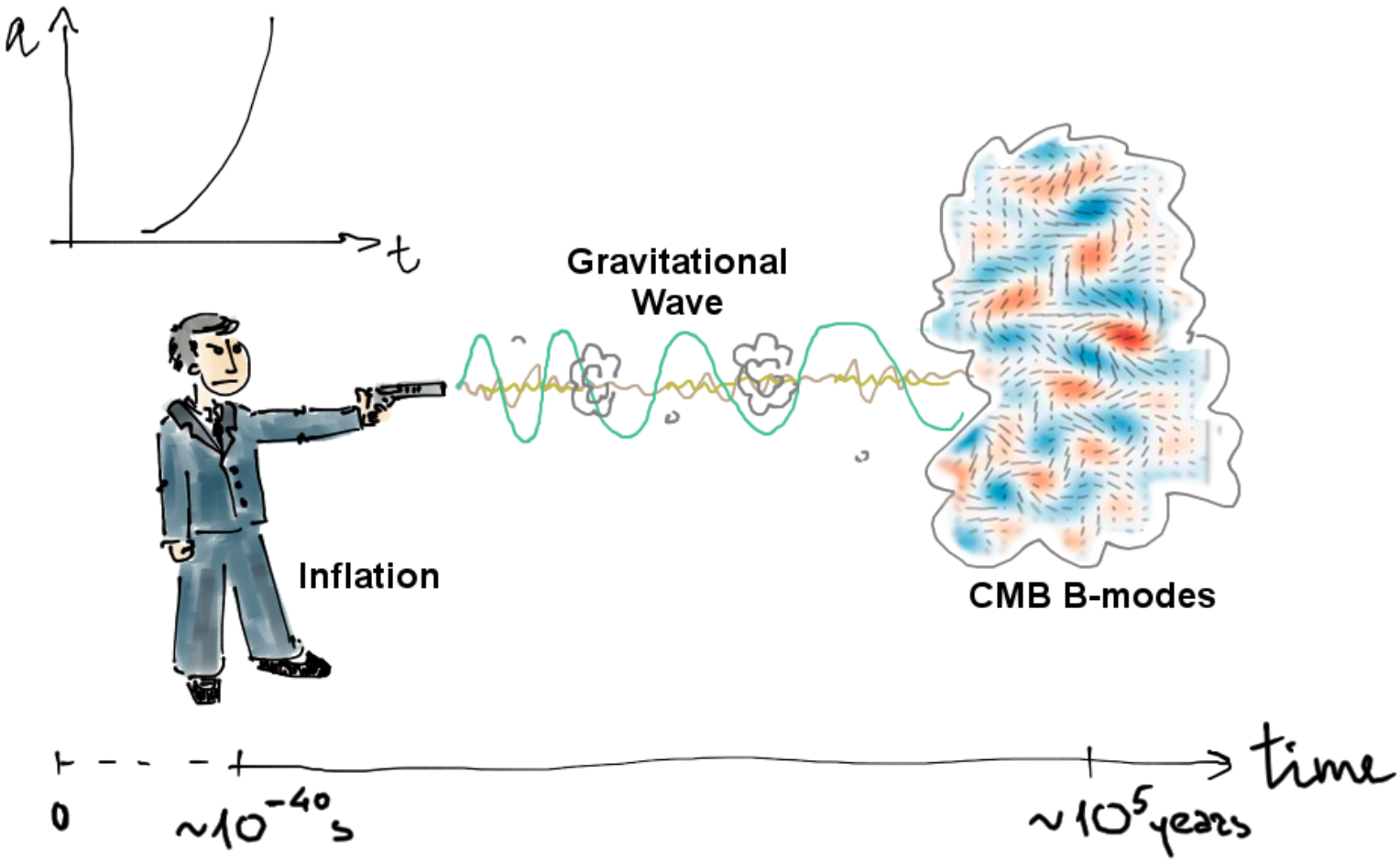
# QUBIC experiment

## Rencontres de Blois, 2016

Mikhail Stolpovskiy, APC

1.06.2016

# Inflation and B-modes



# What is QUBIC?

## Q and U Bolometric Interferometer for Cosmology

QUBIC is a ground-based cryogenic experiment, in construction phase, dedicated to measure primordial B-modes of CMB.

- Backgound limited bolometric detectors for the focal planes $\rightarrow$ **High sensitivity: r $<$ 0.02 @ 95% C.L. including foregrounds!**
- Interferometer with 400 elements $\rightarrow$ **Good systematics control.**
- Dual band $\rightarrow$ Two focal planes operating on 150 and 220 GHz. **Dust contamination control.**

# Who is QUBIC?

Qubic white paper: arXiv:1010.0645v1 [astro-ph.IM] 4 Oct 2010
Technical Design Report: coming soon on arXiv!

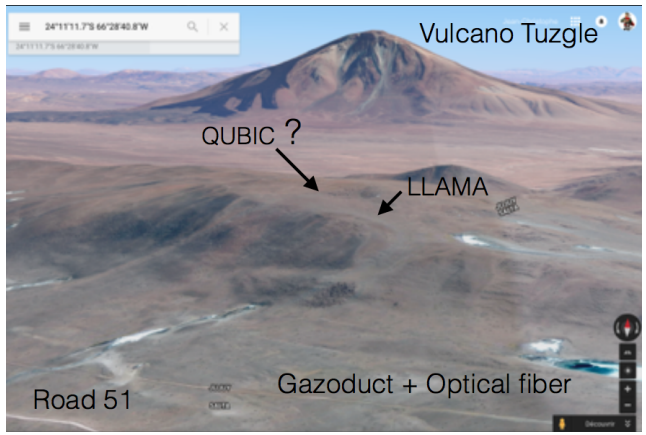
- APC Paris, France
- Brown University, USA
- Cardiff University, UK
- CSNSM Orsay, France
- IAS Orsay, France
- IEF Orsay, France
- IRAP Toulouse, France
- LAL Orsay, France
- University of Manchester, UK
- Universita di Milano-Bicocca, Italy
- Universita degli studi di Milano, Italy
- Maynooth University, Ireland
- Richmond University, USA
- Universita La Sapienza, Roma, Italy
- University of Wisconsin, USA

# Where and when is QUBIC?

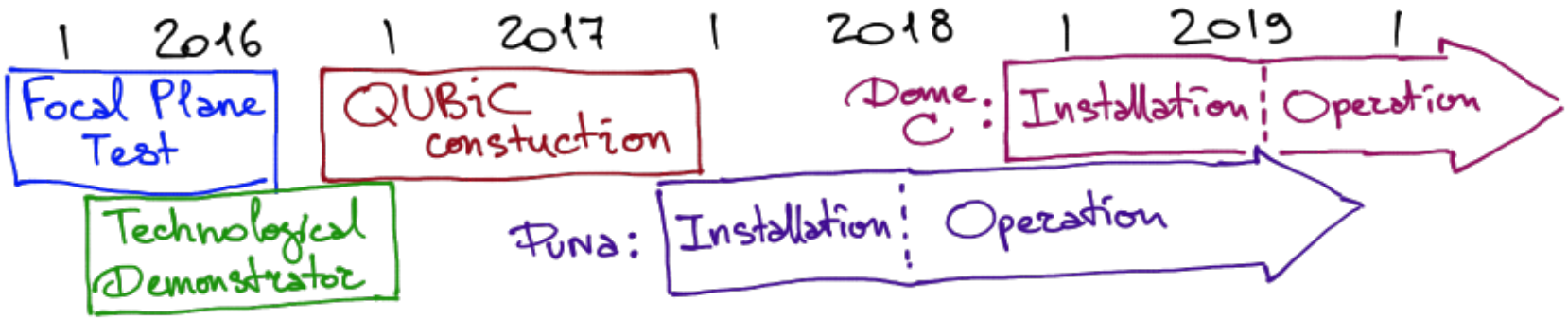
## Antarctic, Concordia station: baseline site


- Good atmospheric conditions for CMB observations.
- Hard logistics ($\sim +1$ year to the timeline).

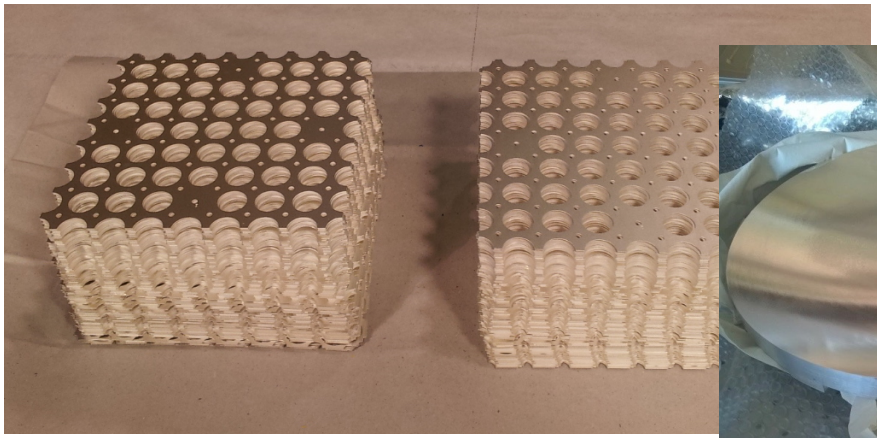
## Argentina, Puna desert: alternative site

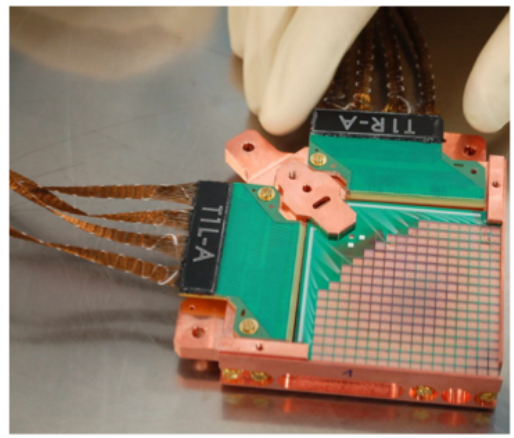


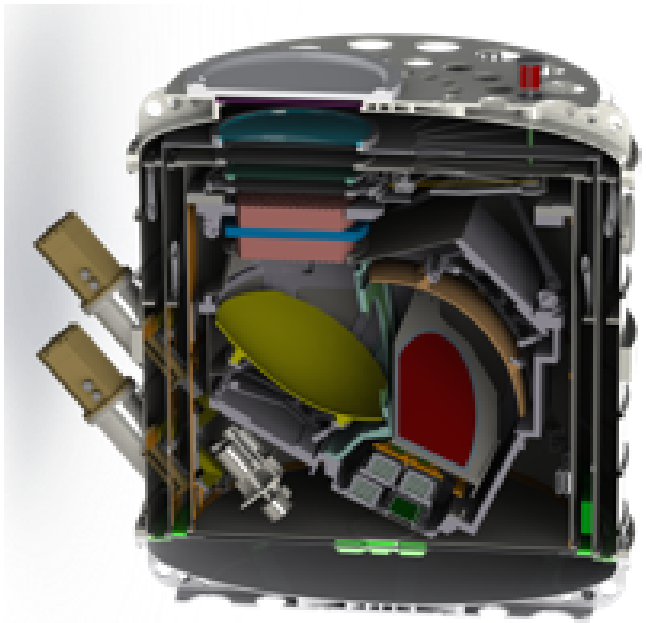

- The atmospheric conditions are not as good (factor 2-3 higher emissivity than Dome C $\rightarrow$ factor 1-3 on r sensitivity)
- But logistics is much easier.



# Instrument fully designed

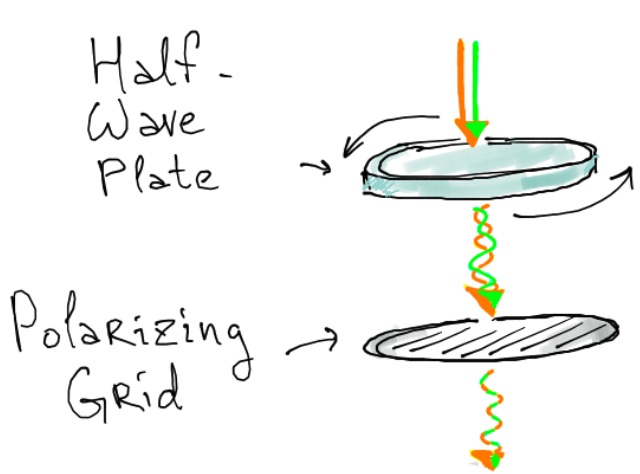




- 1.547m high
  1.42m diameter
  About 800 kg.
- 2 arrays of 992 NbSi TES
  Measured NEP $\sim 4 \times 10^{-17} WHz^{-1/2}$
  128 multiplexing per ASIC.

# QUBIC sketch




$$\begin{pmatrix} E_x \\ E_y \end{pmatrix} \Rightarrow \begin{pmatrix} Q \\ U \end{pmatrix} \begin{matrix} + \\ \times \end{matrix}$$

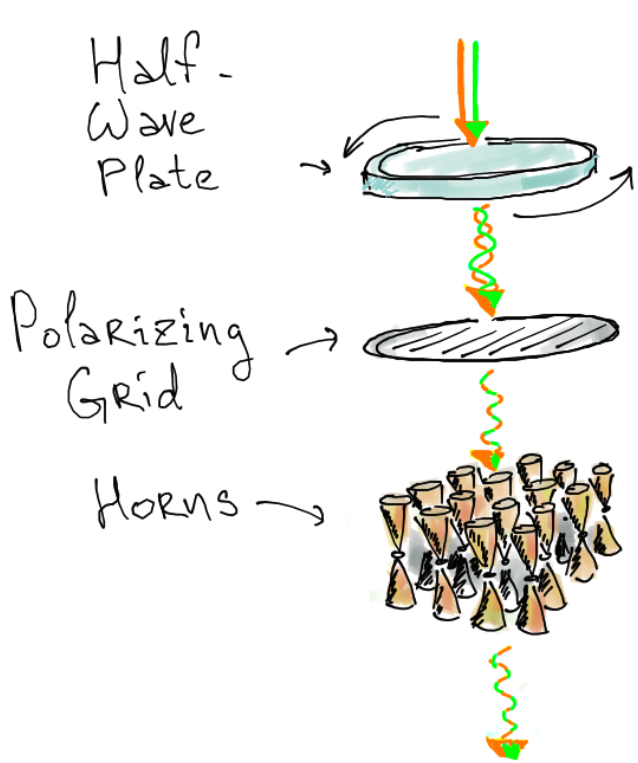
$$\begin{pmatrix} E_x \cos 2\varphi(t) + E_y \sin 2\varphi(t) \\ E_x \cos 2\varphi(t) - E_y \sin 2\varphi(t) \end{pmatrix}$$

$$\begin{pmatrix} E_x \cos 2\varphi(t) + E_y \sin 2\varphi(t) \\ 0 \end{pmatrix}$$

$$\Downarrow$$

$$S = I + Q \cos 4\varphi(t) + U \sin 4\varphi(t)$$

# QUBIC sketch




$$\begin{pmatrix} E_x \\ E_y \end{pmatrix} \Rightarrow \begin{pmatrix} Q \\ U \end{pmatrix} \begin{matrix} + \\ \times \end{matrix}$$

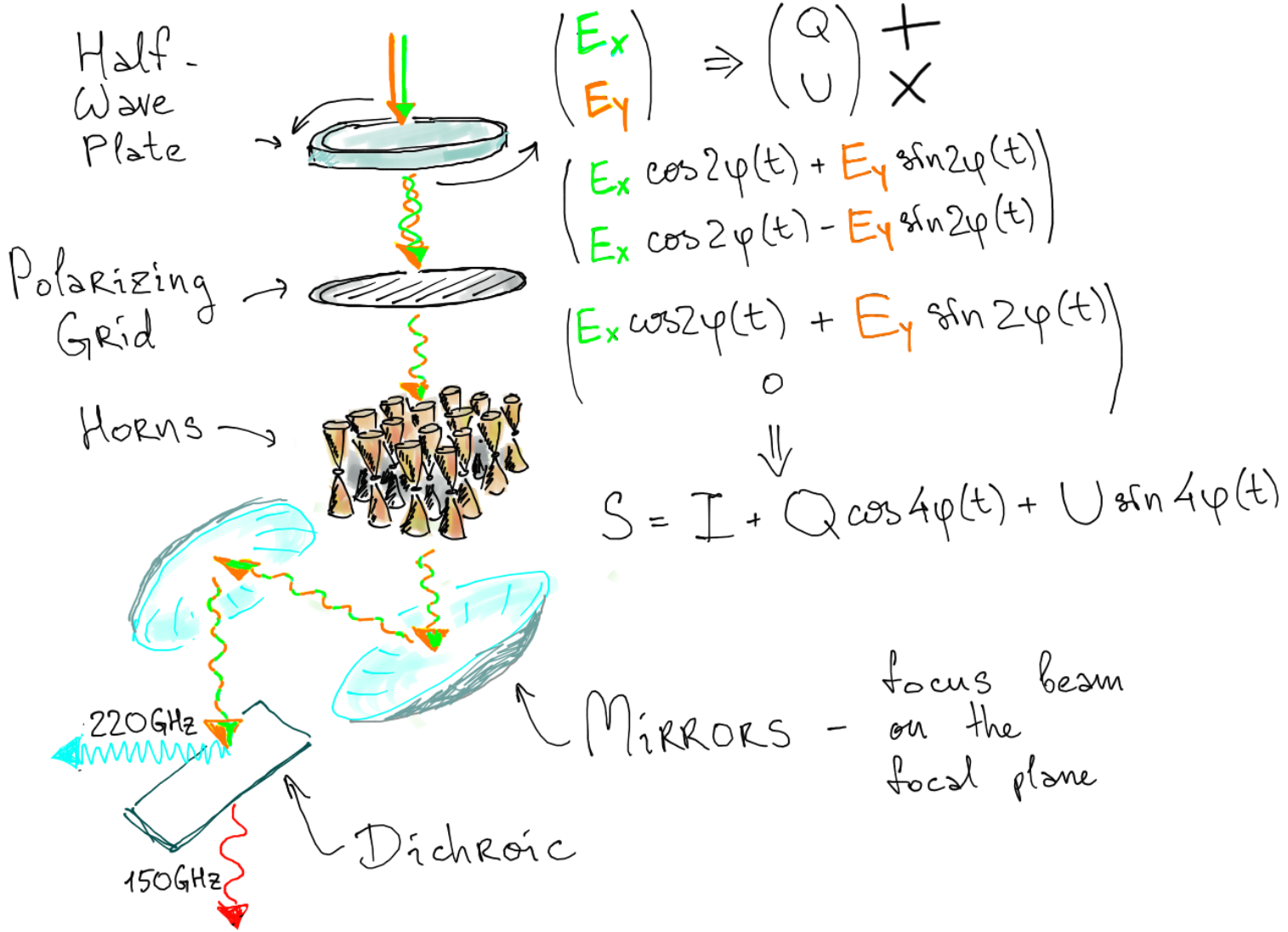
$$\begin{pmatrix} E_x \cos 2\varphi(t) + E_y \sin 2\varphi(t) \\ E_x \cos 2\varphi(t) - E_y \sin 2\varphi(t) \end{pmatrix}$$

$$\begin{pmatrix} E_x \cos 2\varphi(t) + E_y \sin 2\varphi(t) \\ 0 \end{pmatrix}$$

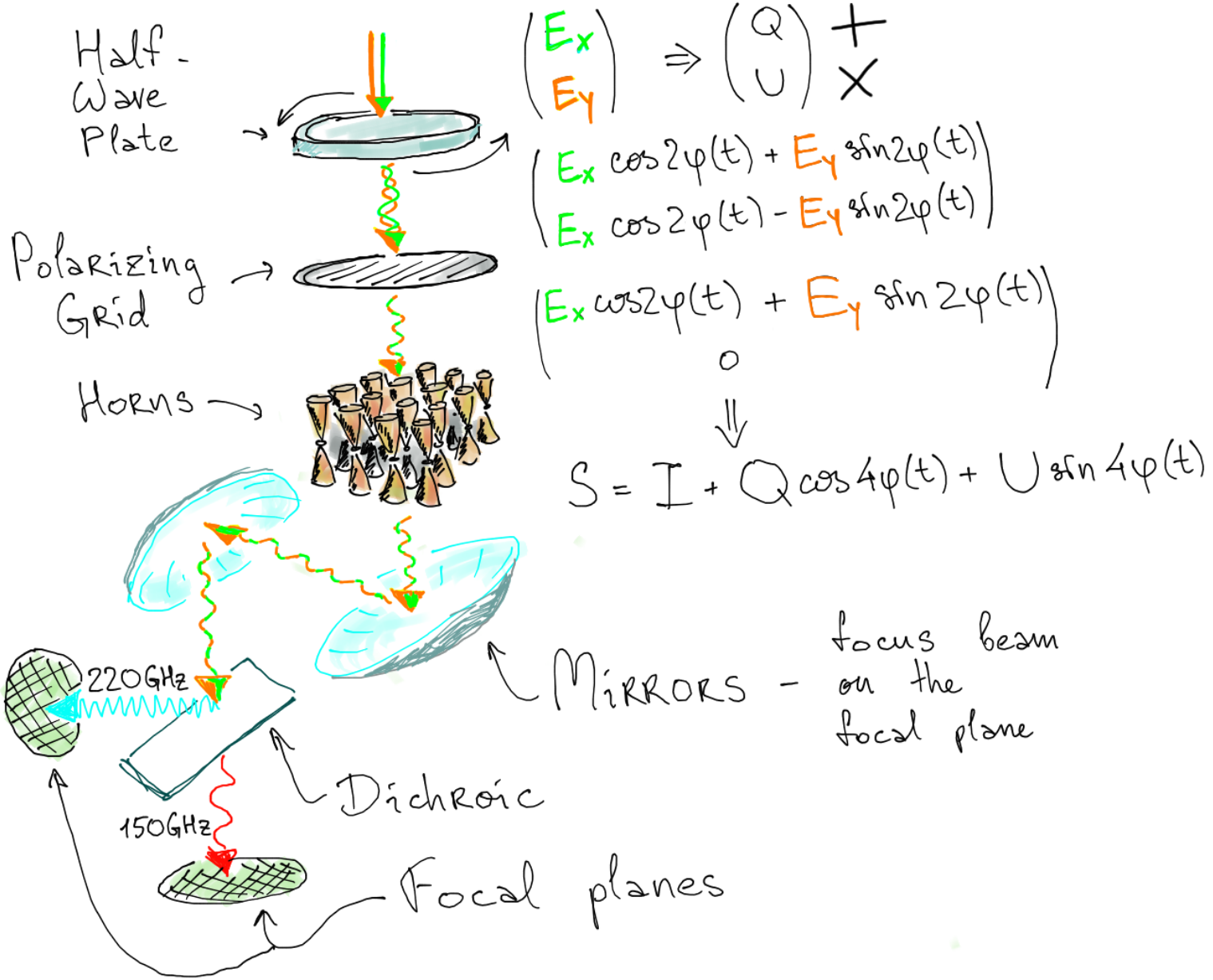
$$\Downarrow$$

$$S = I + Q \cos 4\varphi(t) + U \sin 4\varphi(t)$$

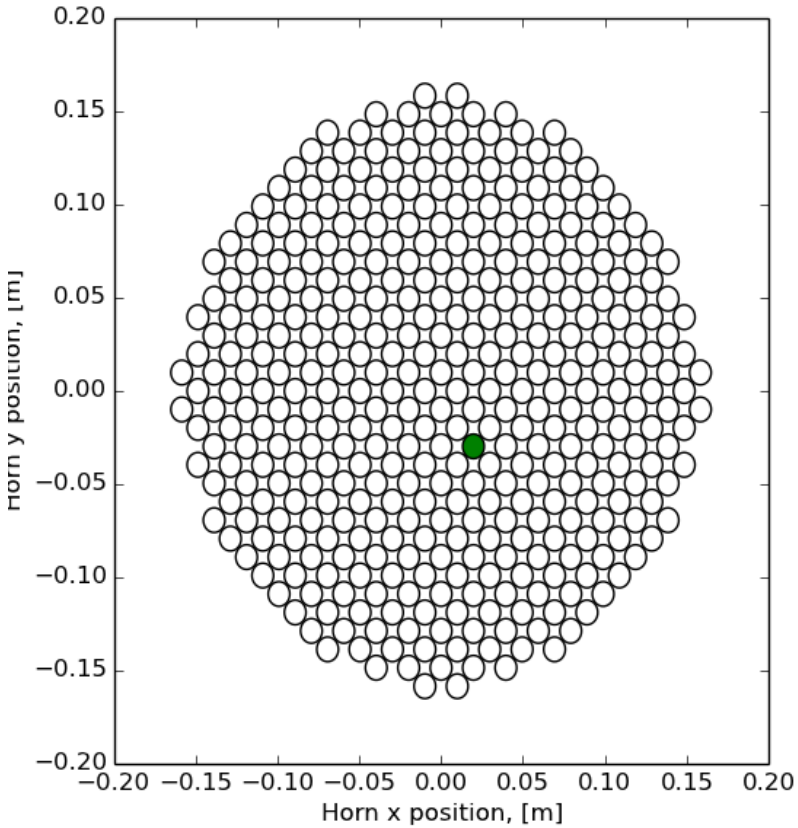
# QUBIC sketch

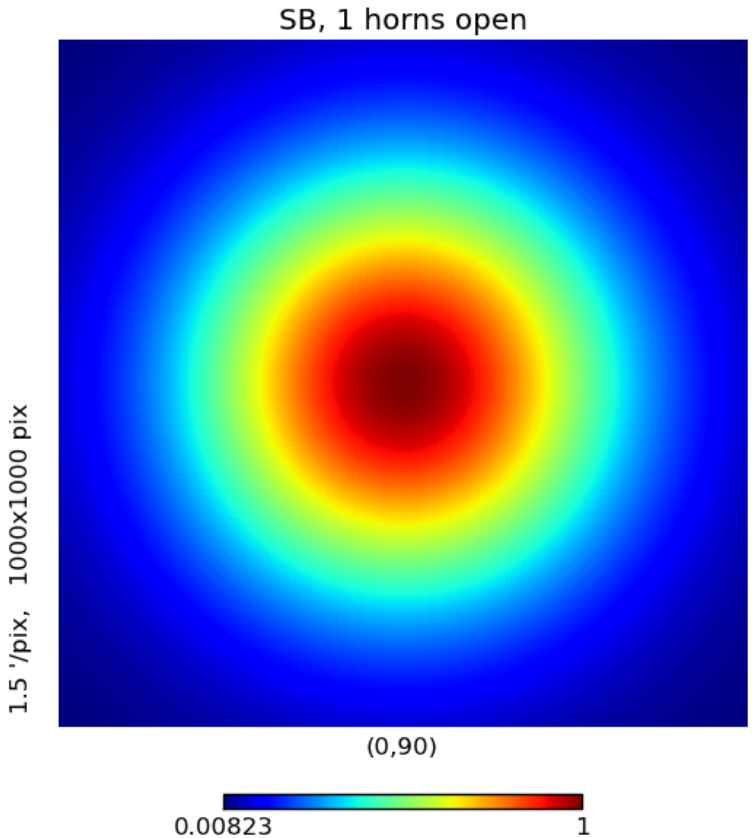


# QUBIC sketch



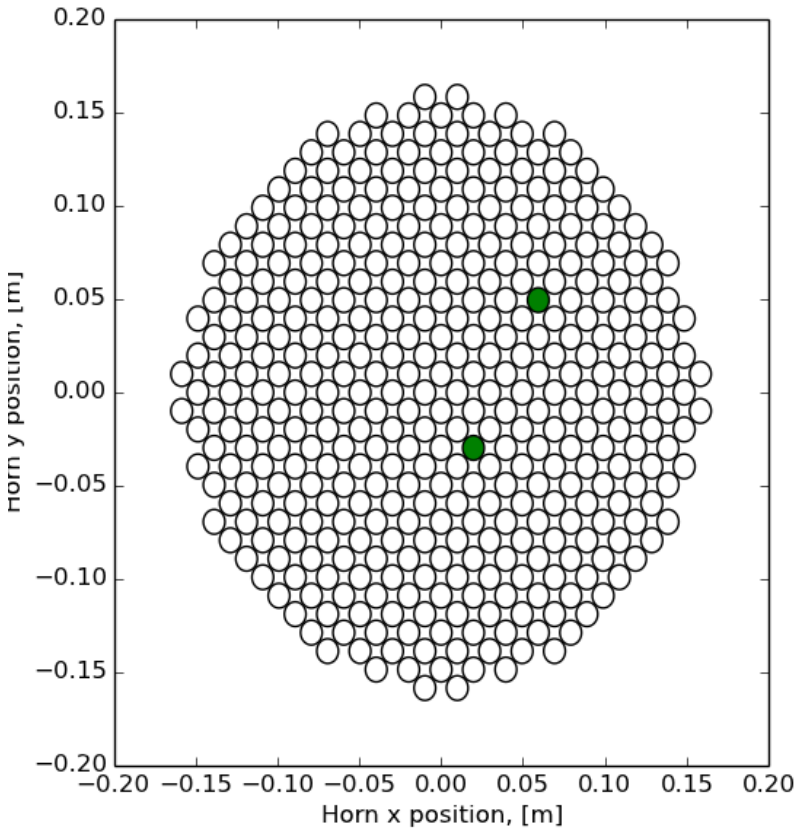
# Synthesized beam

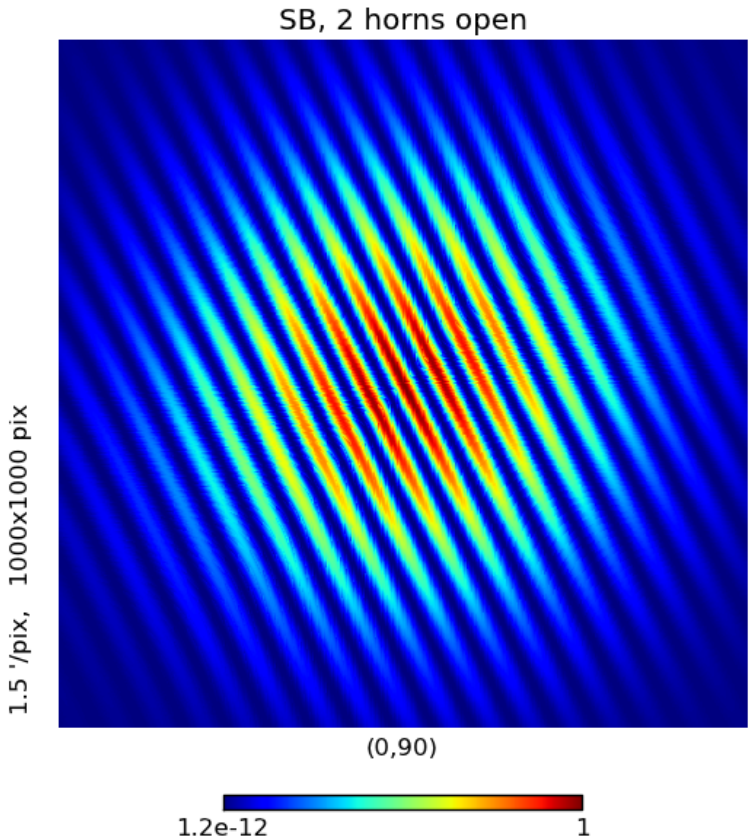


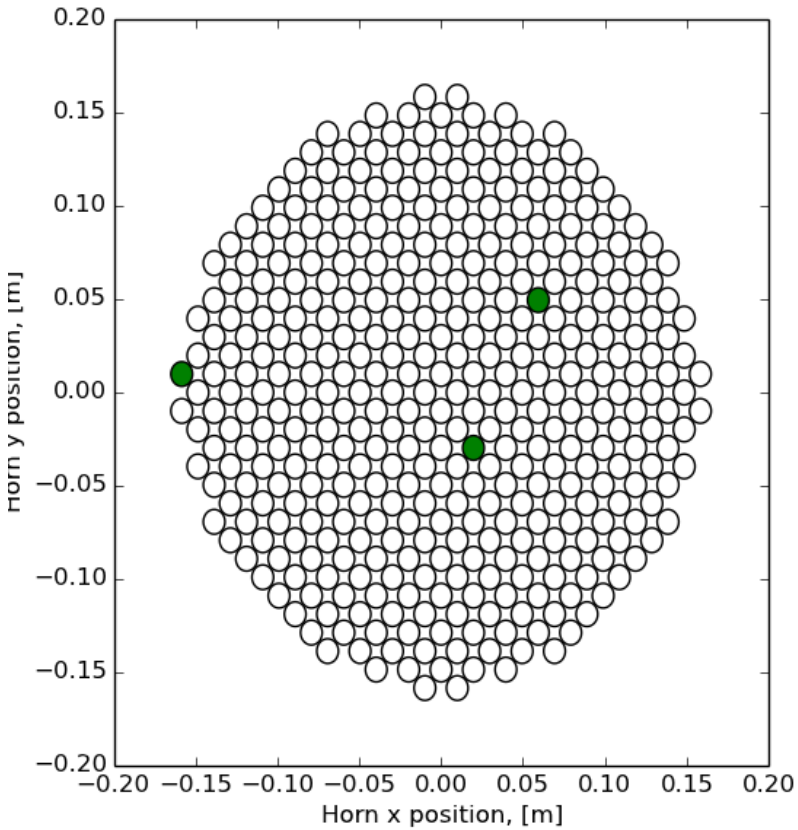

$\sigma$ of the input beam is 13 deg

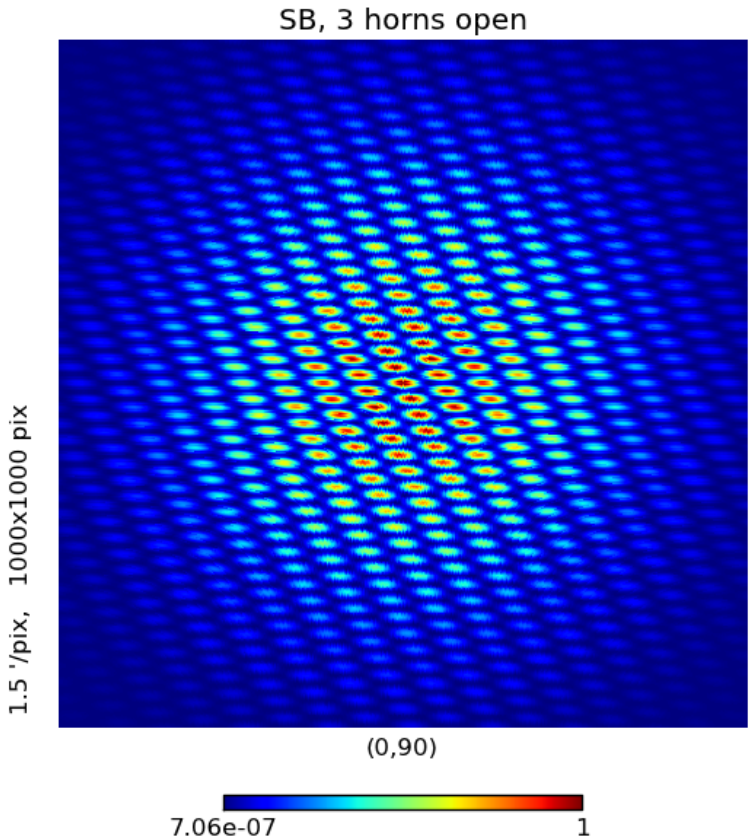
# Synthesized beam



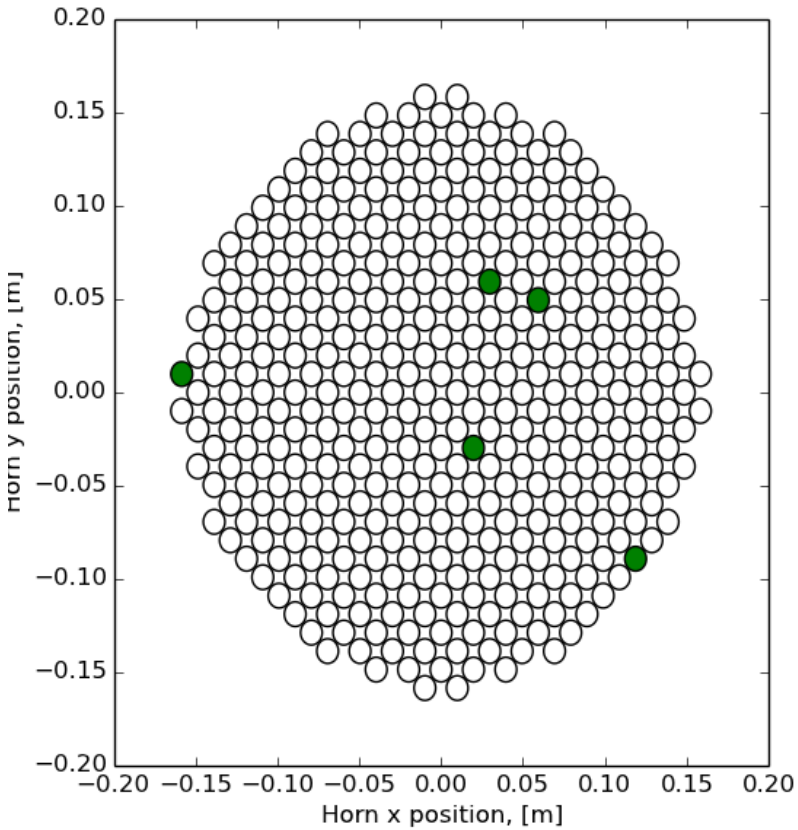



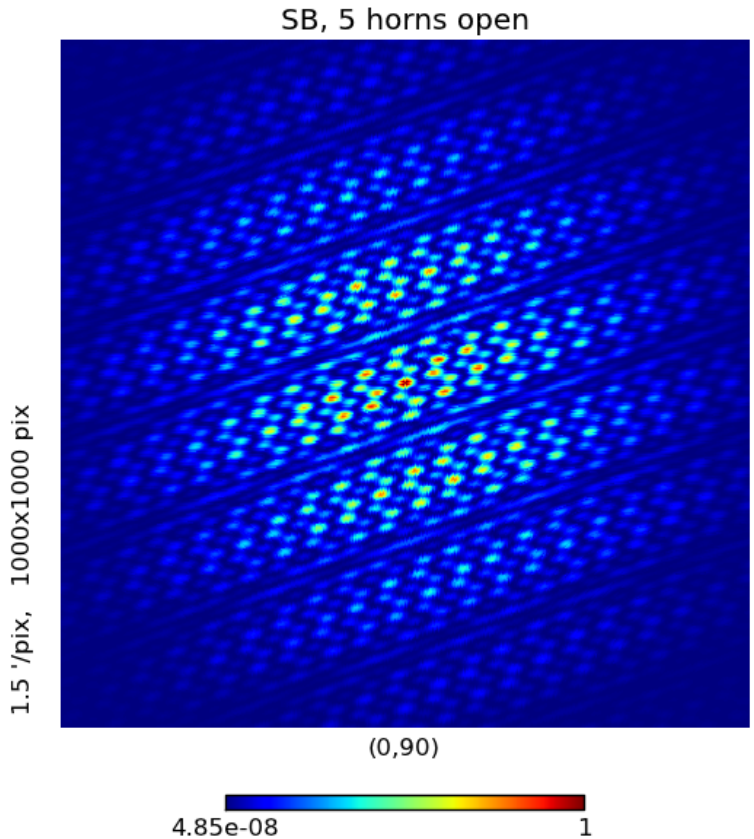
# Synthesized beam



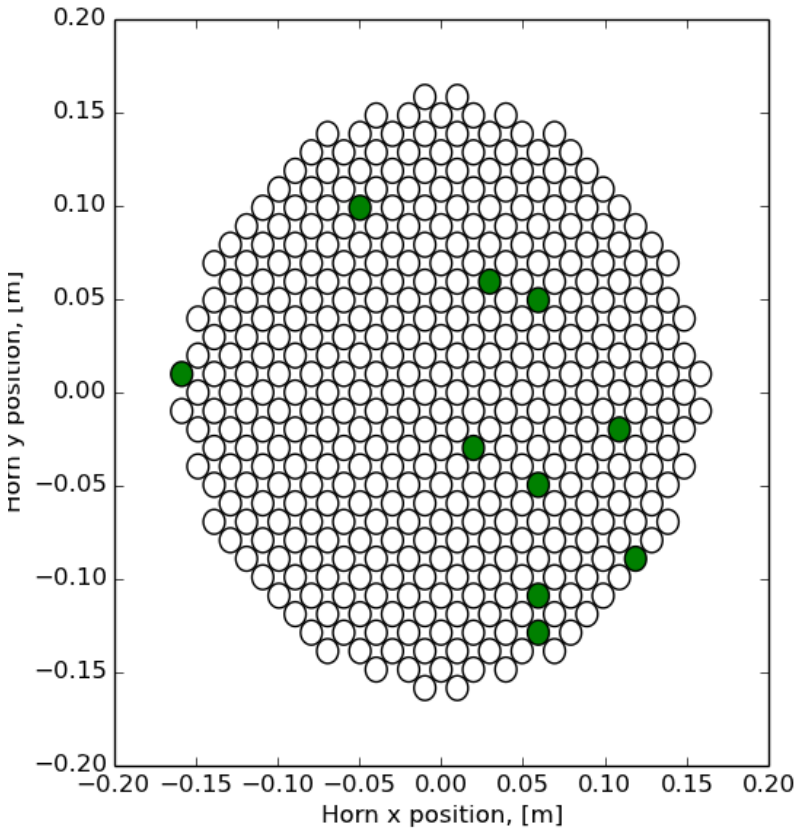



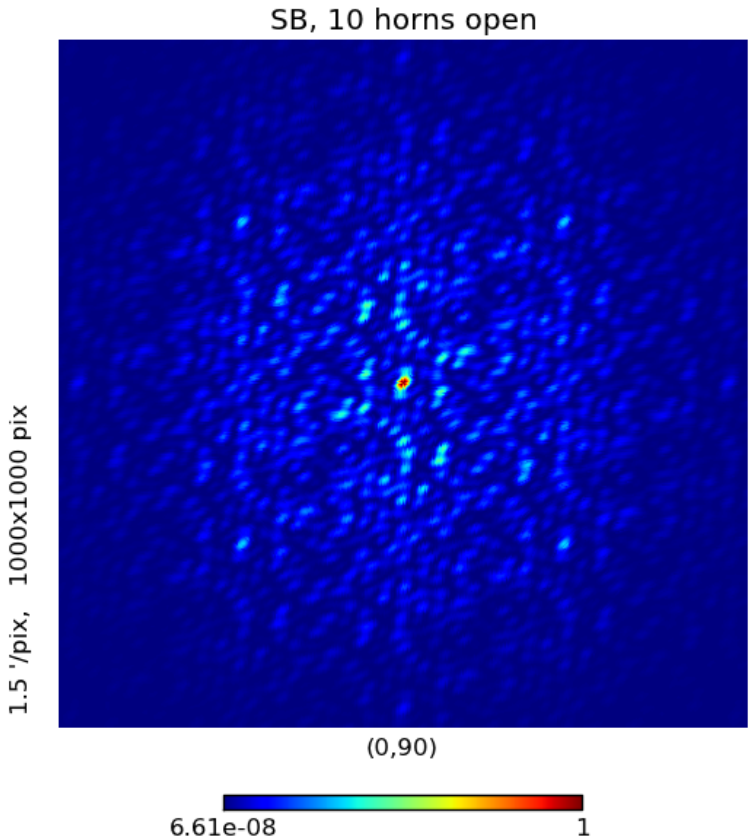
# Synthesized beam



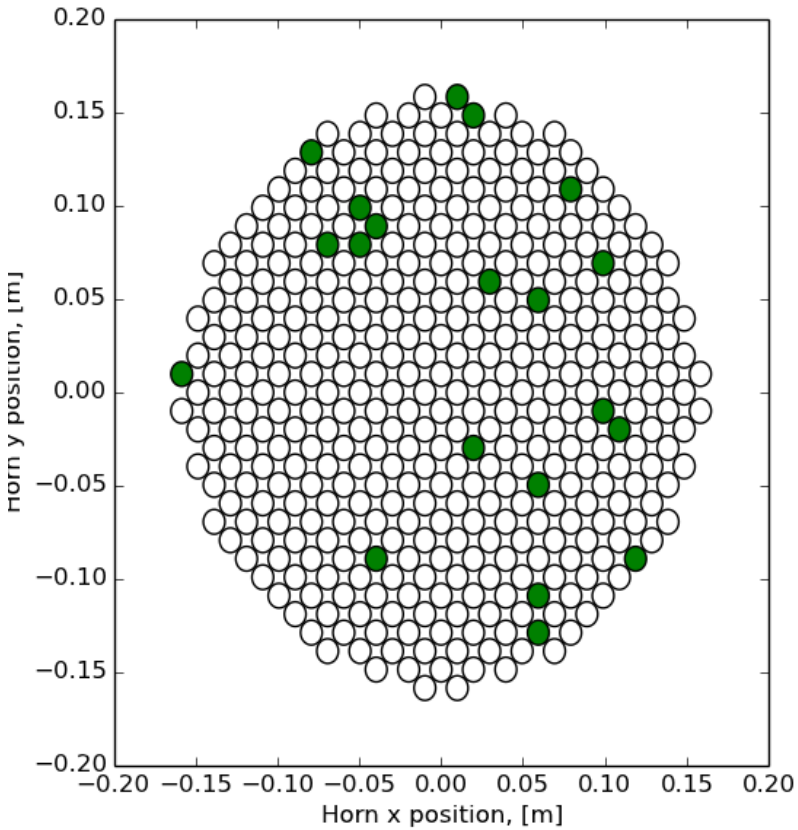



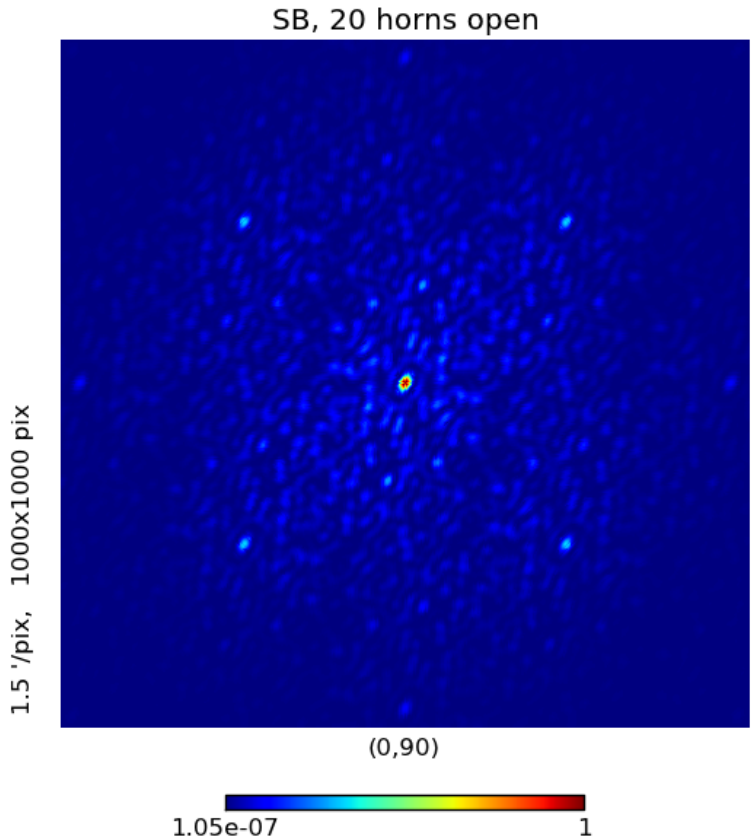
# Synthesized beam



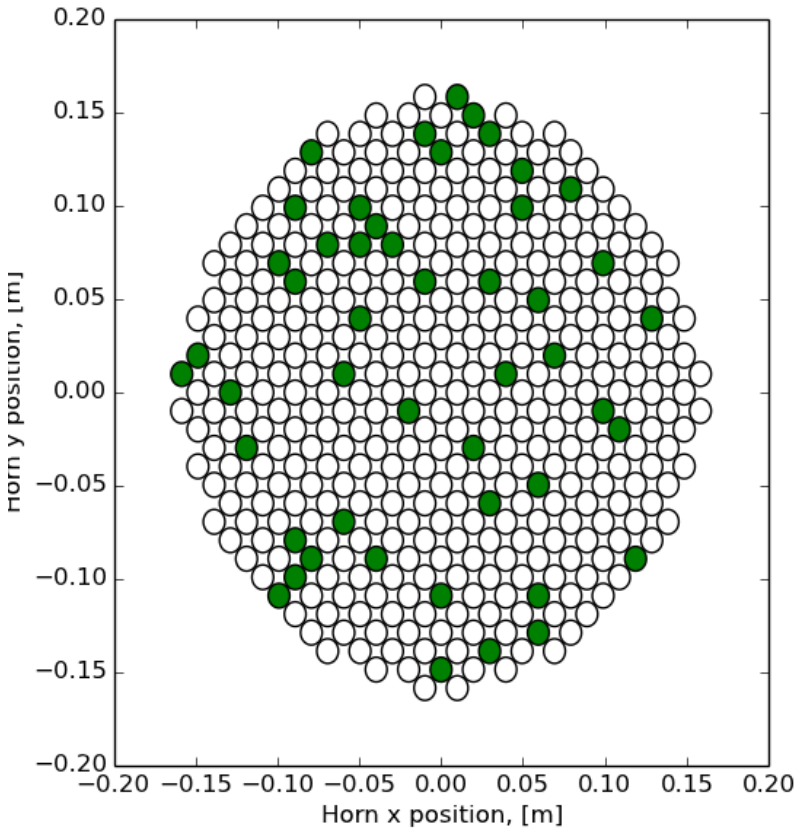



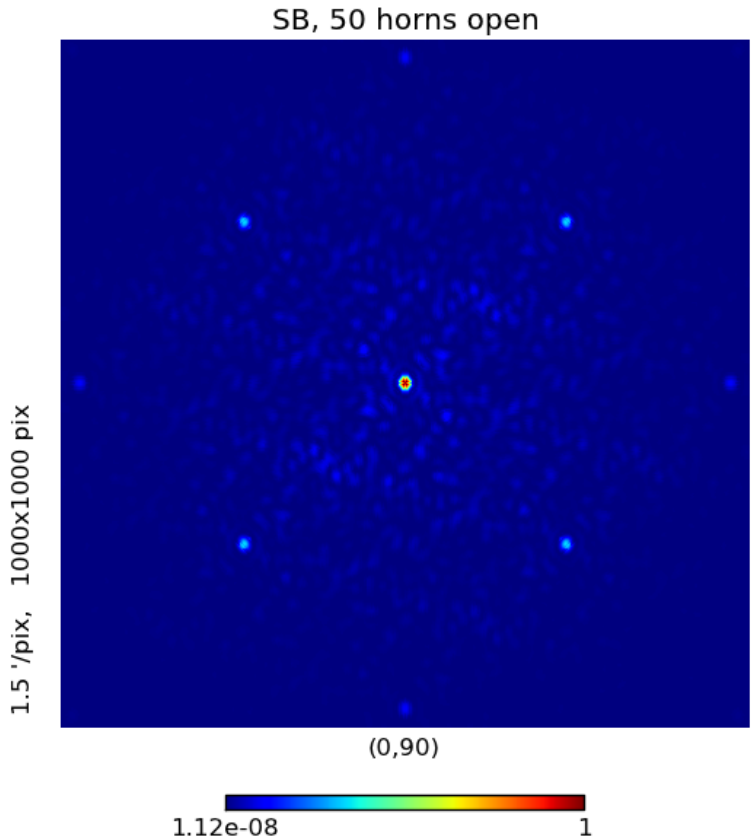
# Synthesized beam



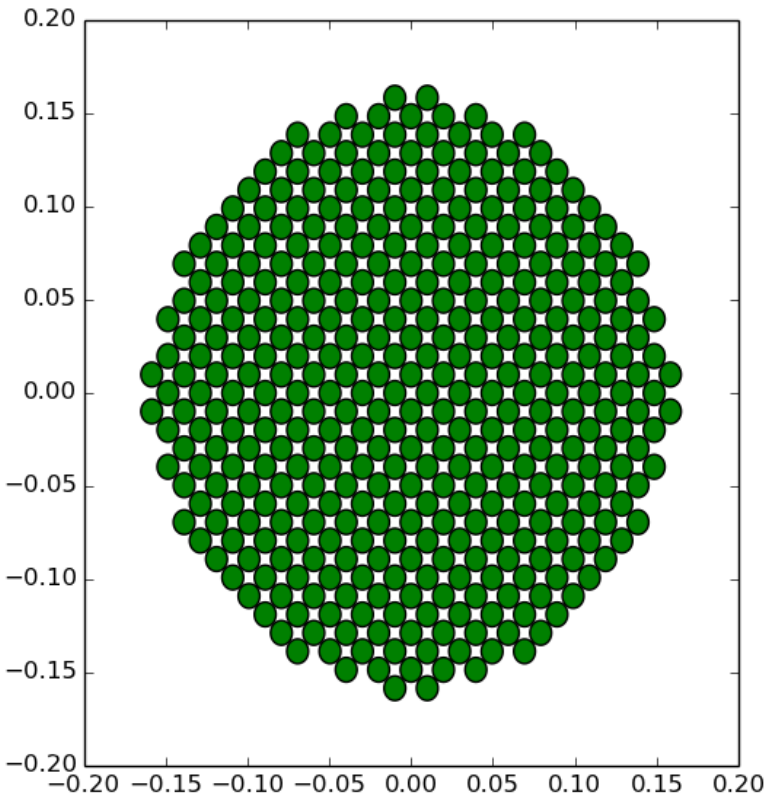



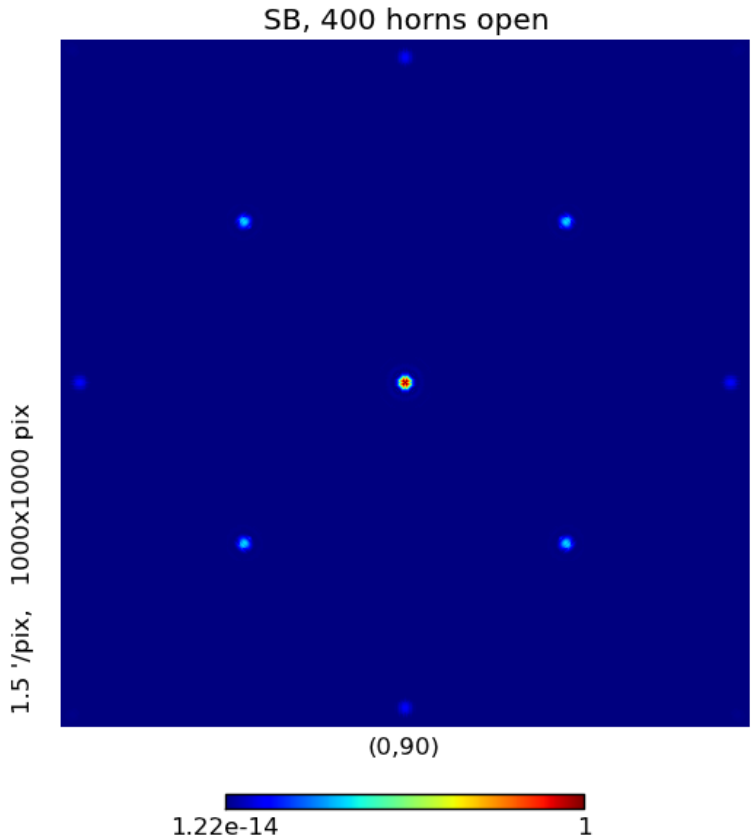
# Synthesized beam



# Synthesized beam

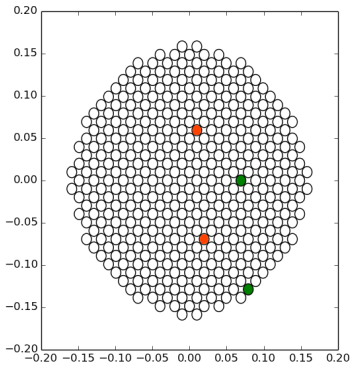


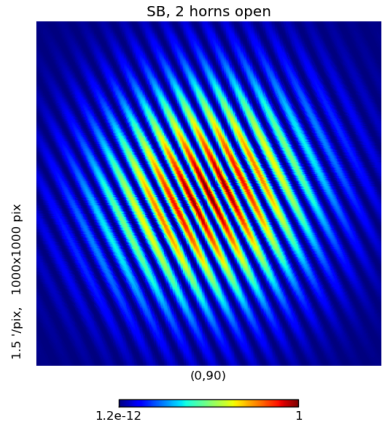




FWHM of the primary peak is 23.5 arcmin.

Fraction of power on secondary peaks is around 70%

# Self-calibration

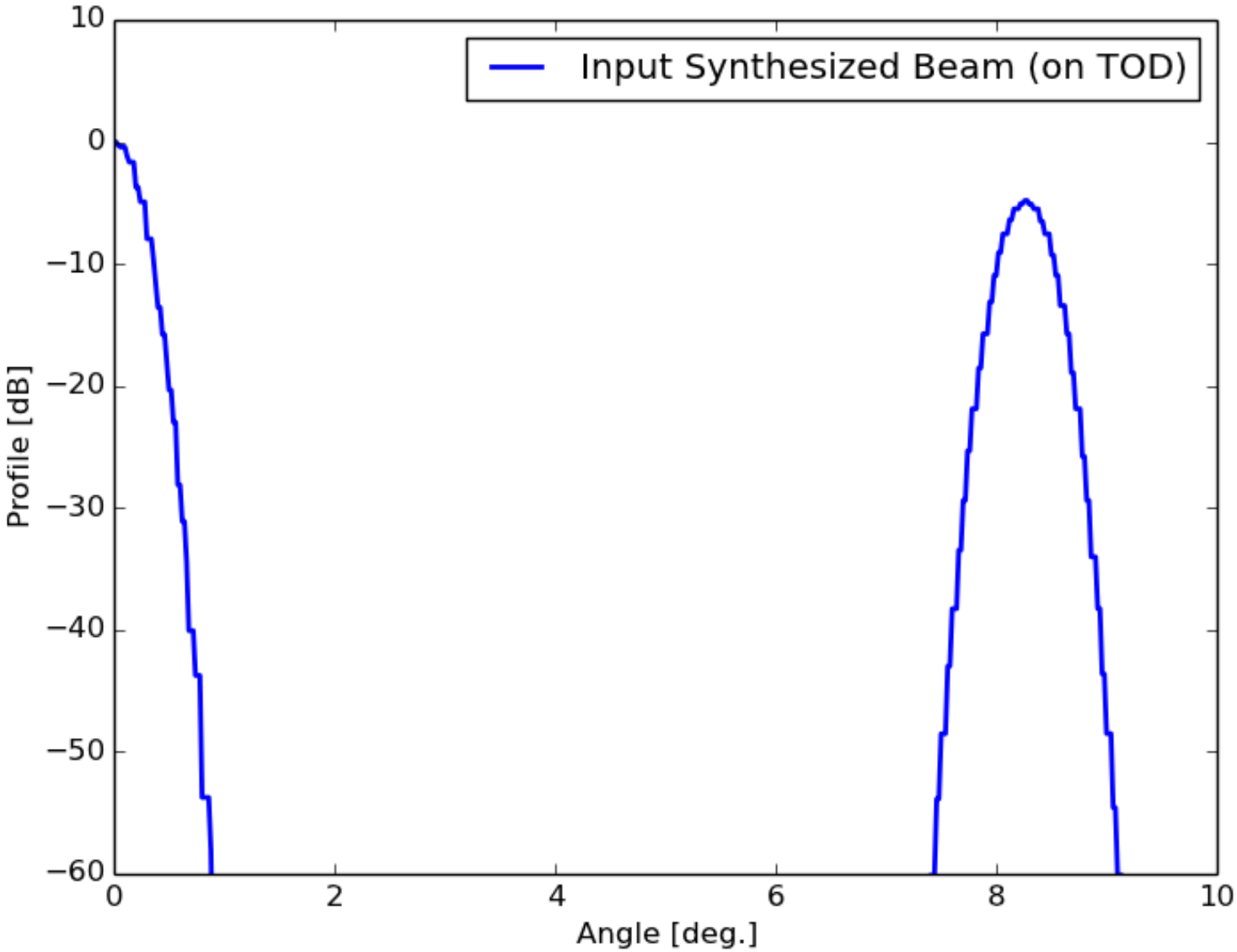


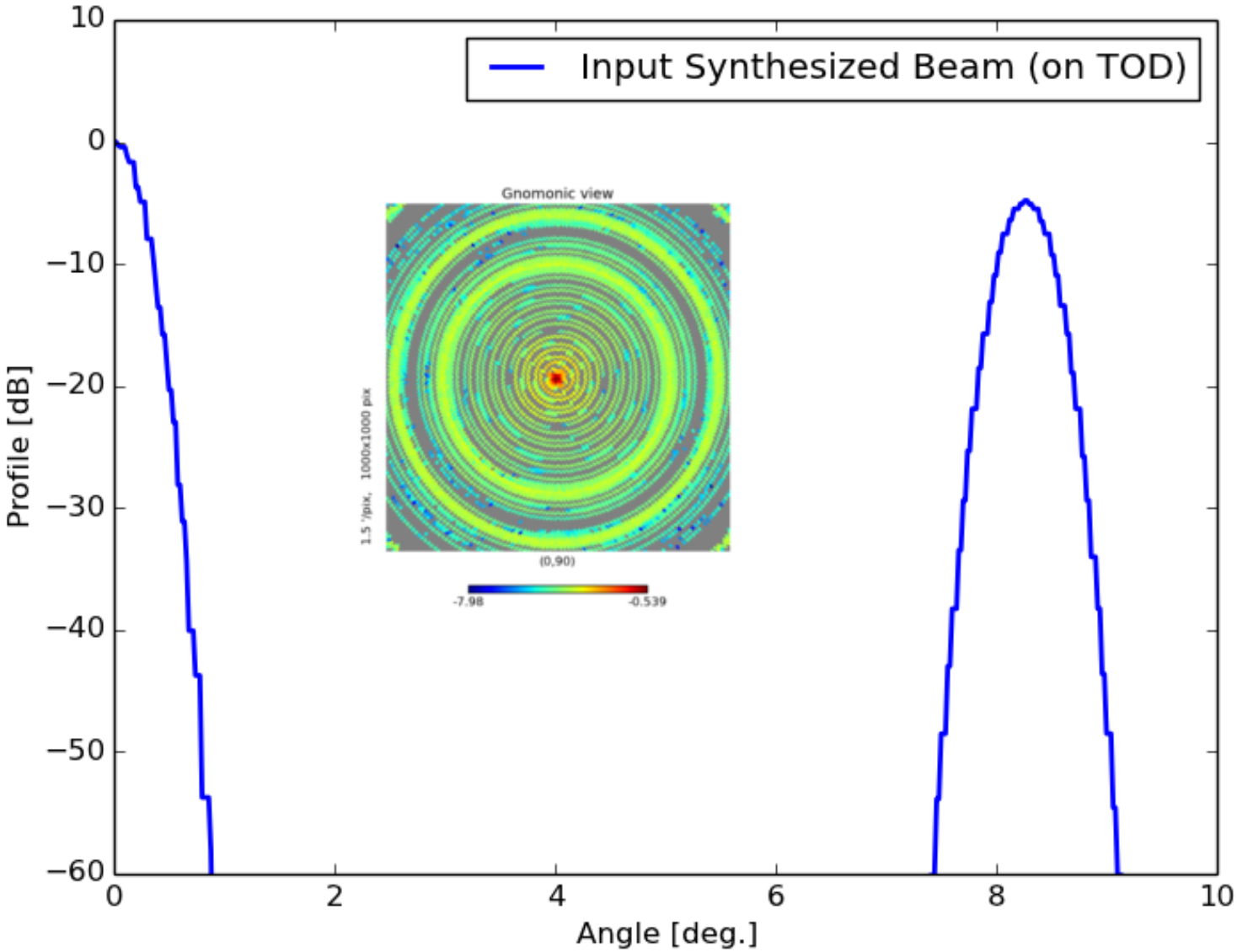

- For a perfect instrument all the redundant baselines should give the same interferometric pattern.
- If they don't, it tells us about systematics.
- Using an external point source we can run self-calibration and thus fit and control systematics effects.

| parameter | No Self Cal. | 1 day / year | | 100 days/year | |
|---|---|---|---|---|---|
| | $\sigma_{nominal-real}$ | $\sigma_{real-recovered}$ | ratio | $\sigma_{real-recovered}$ | ratio |
| Horn location error | $100. \times 10^{-6}$ | $5.86 \times 10^{-5}$ | 17 | $2.27 \times 10^{-8}$ | 4402 |
| Horn transmission | 0.0001 | $1.36 \times 10^{-6}$ | 73 | $1.22 \times 10^{-8}$ | 8182 |
| Horn cross-polarization | 0.0001 | $1.09 \times 10^{-6}$ | 92 | $1.20 \times 10^{-8}$ | 8280 |
| HWP transmission | 0.01 | $1.18 \times 10^{-4}$ | 84 | $7.27 \times 10^{-6}$ | 1375 |
| HWP cross-polarization | 0.01 | $1.24 \times 10^{-4}$ | 80 | $5.81 \times 10^{-6}$ | 1722 |

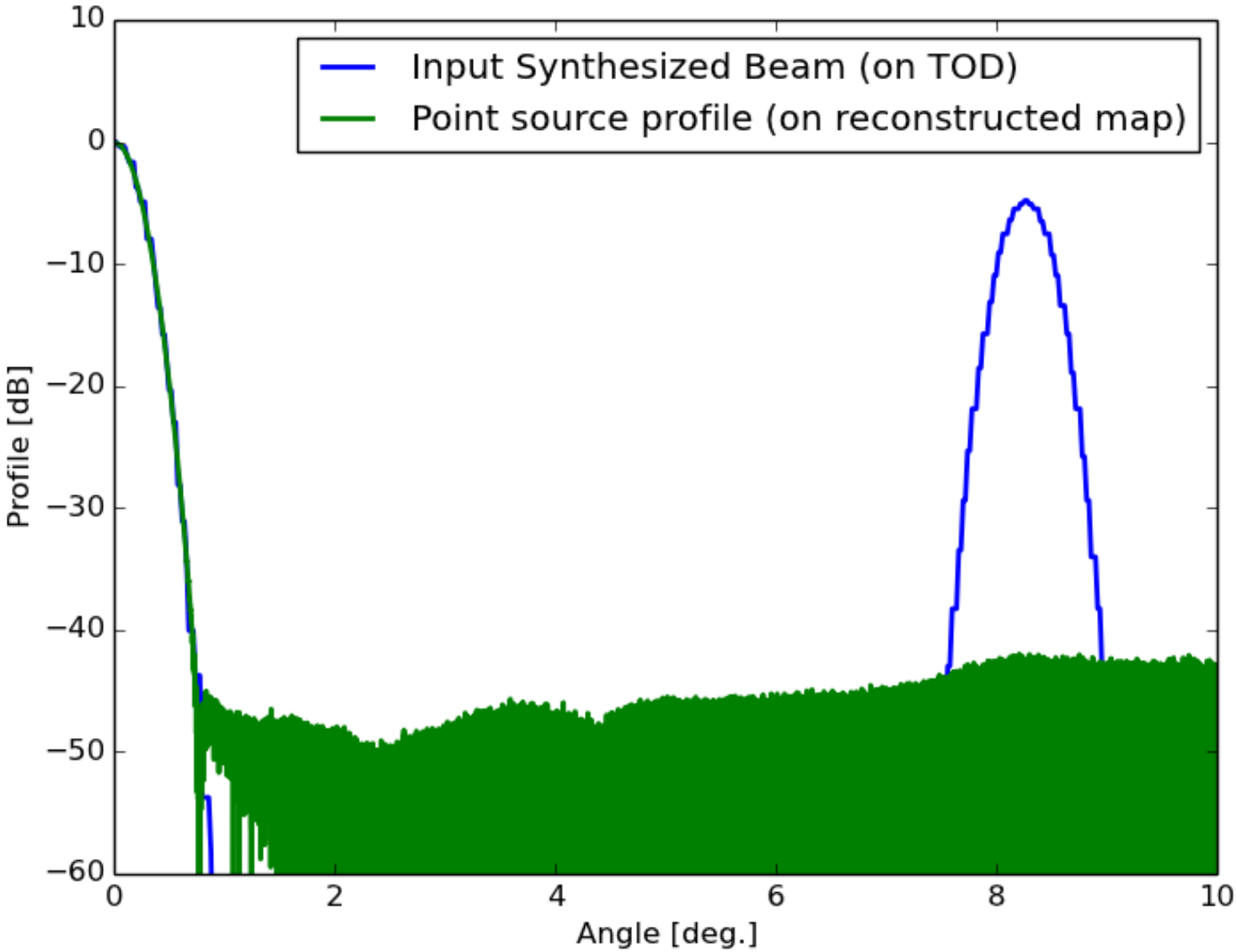
# Map-making


Input Synthesized Beam (on TOD)
Profile [dB]
Angle [deg.]
10
0
−10
−20
−30
−40
−50
−60
0
2
4
6
8
10

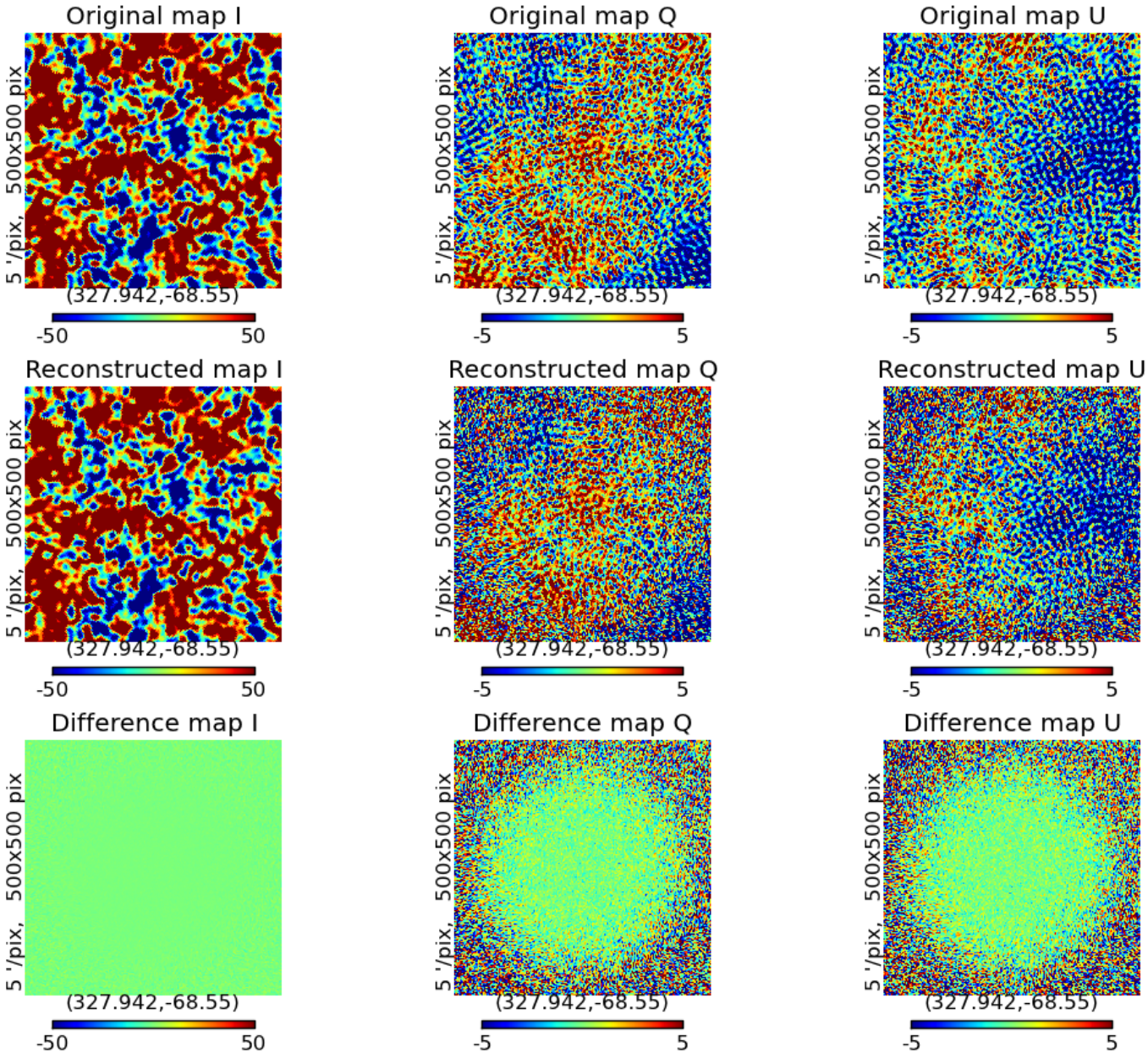
# Map-making


Input Synthesized Beam (on TOD)
Profile [dB]
Angle [deg.]
10
0
−10
−20
−30
−40
−50
−60
0
2
4
6
8
10
Gnomonic view
1.5 '/pix, 1000x1000 pix
(0,90)
-7.98
-0.539

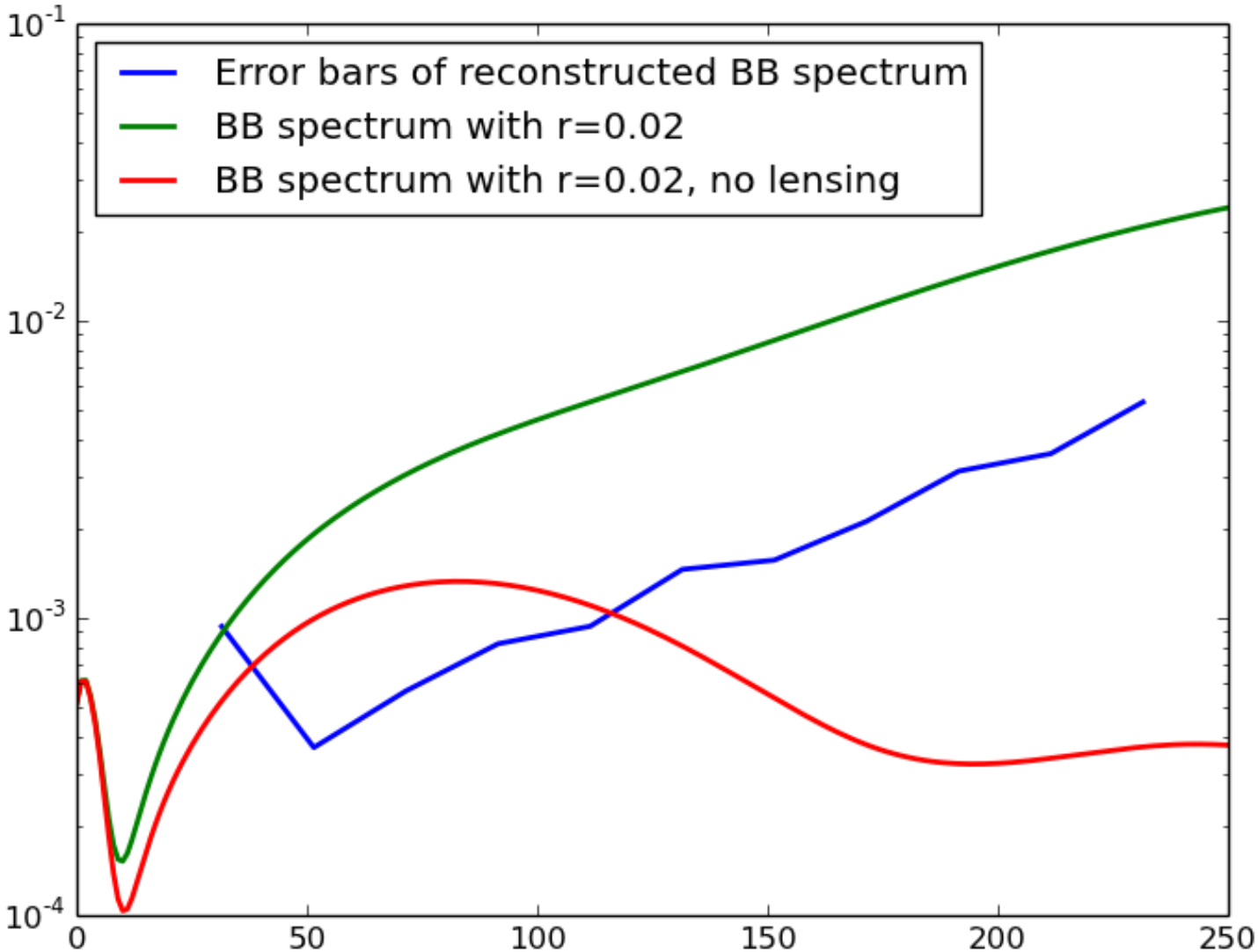
# Map-making


Input Synthesized Beam (on TOD)
Point source profile (on reconstructed map)
Profile [dB]
Angle [deg.]
10
0
−10
−20
−30
−40
−50
−60
0
2
4
6
8
10

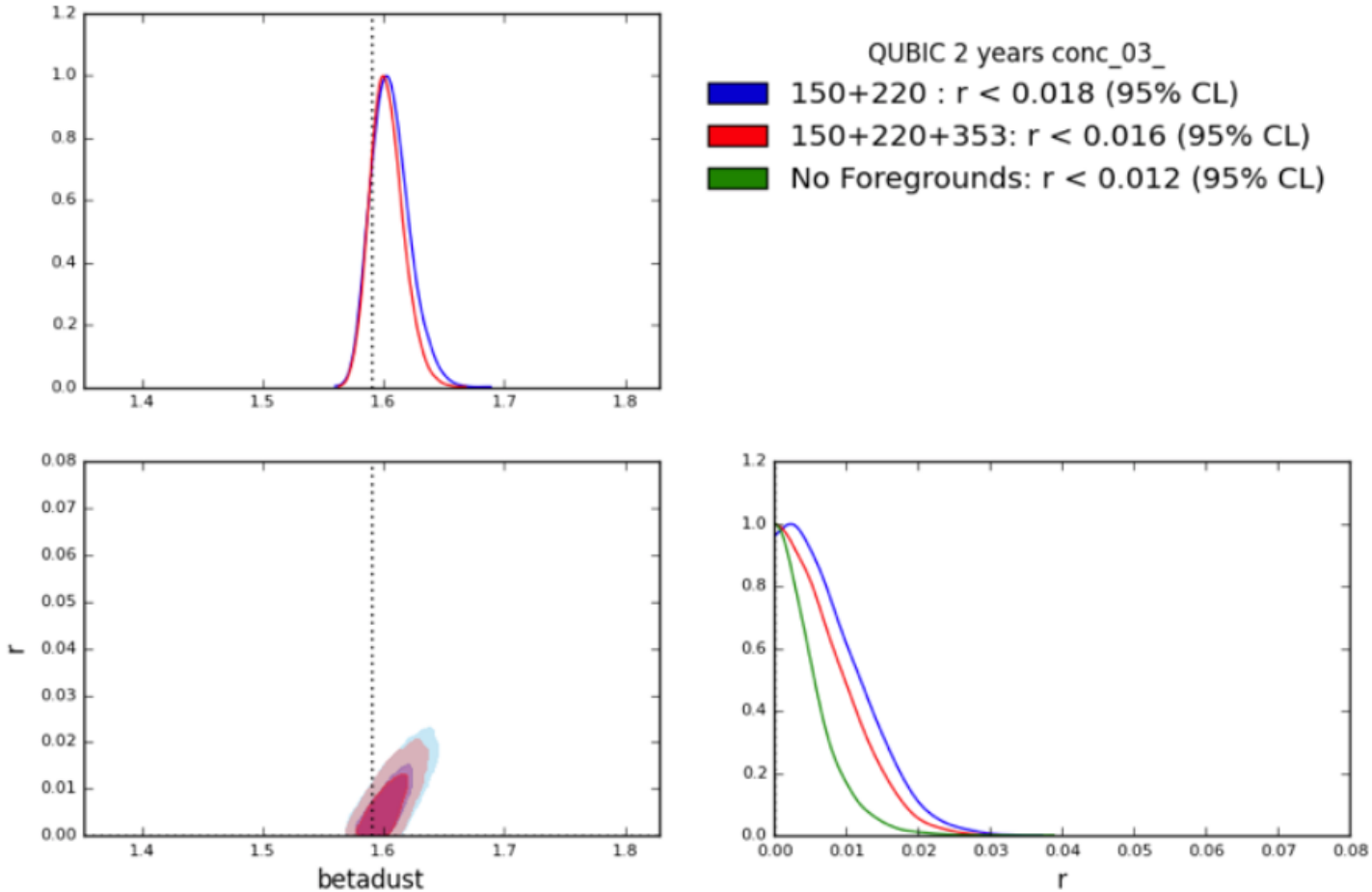
# Map-making


Original map I
Original map Q
Original map U
Reconstructed map I
Reconstructed map Q
Reconstructed map U
Difference map I
Difference map Q
Difference map U
5 '/pix, 500x500 pix
(327.942,-68.55)
-50
50
-5
5

# QUBIC sensitivity



# QUBIC sensitivity



# Conclusions

- QUBIC is a ground-based experiment for CMB primordial B-modes using the novel bolometric-interferometer configuration.
- Depending on the site we expect to get the first light in 2018 (Argentina) or in 2019 (Antarctica).
- Currently the instrument is fully designed. Parts of the instrument are under construction.
- QUBIC will be able to measure B-modes with high precision, down to $r < 0.02$ @ 95% C.L. in two years of operation.

**Thank you!**