The Northern Cross Fast Radio Burst project

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with N. Locatelli, G. Bianchi, A. Magro, G. Naldi, M. Pilia, G. Pupillo, A. Ridolfi, & G. Setti
The Epoch of Reionization

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(thanks to the HERA, LEDA and PAPER collaborations)

“The first Pietro Baracchi conference: Italo-Australian Radio Astronomy in era of the SKA”,
Perth, November 1-4, 2016
Once upon a time…

“We should do something with the Northern Cross”
Once upon a time…

“We should do something with the Northern Cross”

“Can we do something with the Northern Cross?”
“Remember to look beyond your horizon line everyday”
“Remember to look beyond your horizon line everyday”

Patrizio Paoletti

OMM®
the One Minute Meditation

A practical guide to know yourself and live a happy life

Pulsars!
“Remember to look beyond your horizon line everyday”
Fast Radio Bursts

the Adam of FRBs (Lorimer et al. 2008)

See talks by Bhandari’s and Ryder’s talks

(Farah et al. 2018)
$DM = \int_0^Z n_e dl > 10^2 \text{ pc cm}^{-3}$

well in excess of the Galactic contribution
Most are unique events... some repeats... some are localized!

\[ z = 0.32 \]

Bannister et al. (2019)
The Northern Cross Telescope

- T-shape array operating at 408 MHz;
- NS arm: array of 64 cylinders, 640 m × 23.5 m (11200 m² vs 8000 m² for CHIME), 64 dipoles per cylinder;
- EW arm: array of single dipoles, 564 m × 35 m;
- used for continuum observations: the Bologna catalogue (>13000 sources > 100 mJy; Ficarra et al., 1985)
The Northern Cross FRB project: hardware upgrade
The Northern Cross FRB project: hardware upgrade

- Analogue beam former → 16 dipoles (one receiver) are grouped together within each cylinder;
- New LNAs installed on the focal line, signals sent RF over fibre to an acquisition board (digitisation and channelization);
The Northern Cross FRB project: hardware upgrade

- FPGA channelization: 16 MHz bandwidth, 781.25 kHz channel width;

- Digital beam forming:
  - 6 cylinders, 1 beam: $0.75\degree \times 1.5\degree$; 1.08 $\mu$s time resolution;
  - 6 cylinders, 4 simultaneous beams: $0.75\degree \times 1.5\degree$ resolution, 124 $\mu$s time resolution;
  - 4 cylinders, $6\degree \times 6\degree$ FoV, 20 simultaneous beams: $(1\degree \times 1.5\degree)$; 276 $\mu$s time resolution; 3 kHz channel width;
System calibration

Instrumental amplitudes and phases are calibrated via interferometric observations of a calibration source (Cas A).

Locatelli, GB et al. (in prep.)
System characterization

B0329+54:
- 1.5 Jy @ 400 MHz;
- 714 ms period;
- DM ~ 27 pc cm$^{-3}$

$SEFD = \frac{S_v\sqrt{B\tau}}{S/N} = 426.5$ Jy

Locatelli, GB et al. (in prep.)
The Northern Cross Fast Radio Burst project roadmap

- **Blind survey:**
  - 2 × 4 cylinders;
  - 6° × 6° (element) FoV, 4 simultaneous (1° × 1.5°) beams;
  - 127 μs time resolution; 781.25 kHz channel width;

- **Targeted follow up of known repeating FRBs:**
  - 8 cylinders,
  - 1 beam: 0.6° × 1.5°;
  - 1.08 μs time resolution; 781.25 kHz channel width;

- **Blind survey (2.0):**
  - N × 4 cylinders;
  - 6° × 6° (element) FoV, 20 simultaneous (1° × 1.5°) beams;
  - 276 μs time resolution; 3 kHz channel width;

- **Localization;**
38° instantaneous field of view covered with 2 6°× 6° pointings

The field of view is tiled with 4 1°× 1.5° pointings

Locatelli, GB et al. (in prep.)
Blind survey forecasts

CHIME FRB rate equalized in ~1500 hours

Locatelli, GB et al. (in prep.)
Moving forward: blind survey 2.0 & localization

- New acquisition system $\rightarrow$ 3 kHz channel width;

- New digital beamformer $\rightarrow$ 20 simultaneous beams;

- Full restoration of the NS arm;

- Simultaneous observation at 150 MHz with the upcoming LOFAR station in Medicina (?)

- Localization: leveraging on the Italian VLBI network infrastructure?
Blind survey 2.0

306° instantaneous field of view covered with 13 6°× 6° pointings

The field of view is tiled with 20 1°× 1.5° pointings

Locatelli, GB et al. (in prep.)
Blind survey 2.0 forecasts

CHIME FRB rate equalized in ~34 hours

Locatelli, GB et al. (in prep.)
Conclusions and future outlook

1) FRBs are cool, exciting, the biggest surprise of the last decade (they are as old as my eldest daughter)… you name it!

2) The field changes on turkey life time scales (ASKAP, CHIME, UTMOST, MeerKAT + …);

3) Our goal is to add the Northern Cross to the FRB world map;

4) Did we spark the interest of our “Australian FRB colleagues”?
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