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The Northern Cross Fast Radio Burst project: recent results and future perspectives

Gianni Bernardi (INAF-IRA) for the NC FRB collaboration;

special kudos: M. Pilia, G. Naldi, D. Pelliciari, A. Geminardi, P. Esposito



"FRB-Italy 2025", Bologna, May 7th - 9th 2025



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The Northern Cross radio 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;





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- Analogue beam former \rightarrow 16 dipoles (one receiver) are grouped together within each cylinder. 4 beams per cylinder;
- New LNAs installed on the focal line, signals sent RF over fibre to an acquisition board (digitisation and channelization);
- Calibration is by cross-correlating the signals from all the receivers and form the corresponding visibilities (i.e. interferometrically);
- FPGA channelization: 16 MHz bandwidth, 781.25 kHz channel width, 1 digital beam. Second channelization stage for a final: 134 µs time resolution, 14 kHz channel resolution.
- 8 cylinders till 2022, 16 cylinders now: <u>one $0.2^{\circ} \times 1.6^{\circ}$ beam; 1σ sensitivity: ~ 1 Jy ms.</u>











First FRB light in 2020



Trudu, Pilia, GB et al. (2022)

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 1σ sensitivity: ~ 1.2 Jy ms





Spinoff activities: FRB observations with Medicina and Noto radio telescopes



Pelliciari, GB et al. (2025), see Pelliciari's talk









Spinoff activities: FRB observations with Medicina and Noto radio telescopes



Geminardi et al., in prep.

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2320

ž 2300

2280

2260









- 2.3 GHz, 64 MHz bandwidth;
- 32 µs time resolution;
- 1σ sensitivity: ~ 1.8 Jy ms

edicina and Noto radio telescopes

- Luminous events are rare $10^{-2} 10^{-3}$ h⁻¹;
- Multiwavelengths observations need more on-sky time than sensitivity!
- Radio-optical simultaneous campaign to begin soon (see Ambrosino's tecnogrant/talk)



Geminardi et al., in prep.









Future outlook: the Next Generation Croce del Nord (NG-Croce)

- PNRR-funded project (PI: G. Bianchi);
- WP "FRB enabling" leader: M. Pilia:
 - WP leader "CHORD": A. Possenti (see Possenti's talks);
 - WP "Enabling Croce": G. Bernardi;
- Goals:
 - Restoration of the EW arm;
 - Multibeam capabilities for the NS and EW arm;
 - Installation of a 360 MHz receiver at the Noto radio telescope







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Hybrid Cavity-Planar P-band Illuminator developed for the primary focus of the 32-m Noto Reflector Antenna

- EM design: OA Arcetri & Sirio Antenne 0
- RX design: IRA 0
- Fabrication: Sirio Antenne Ο
- Frequency band ($\Delta f/fc$) = 300–420 MHz (33%)
- Polarization = Dual linear
- Aperture efficiency (expected) > 65%
- Very compact solution < 30 cm along the optical axis •









courtesy F. Perini



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New backend system

- 672 analogue inputs (256 NS + 416 EW) are digitized by newly designed FPGA boards;
- (Multi)beam forming and FRB search performed in real time by an 18 HPC node cluster. Each node is equipped with:
 - Dual multi-core CPU;
 - 2 NVIDIA L40S GPUs;
 - 2 TB RAM;
 - 2x SSD;
- A total of 8 PB disk storage is available although no long term raw data archive is planned











Future observing modes and capabilities

Large area case:

- Beamform 4 cylinders;
- Mechanically shift block of 4-cylinders
- <u>1 σ sensitivity: ~ 4 Jy ms;</u>
- 160 µs time resolution,
- 7.8 kHz frequency resolution;
 - \rightarrow <u>~1 burst every two days > 10 Jy ms</u>
- Poor localization: ~arcmin for ~100 Jy ms bursts
- Maximum sensitivity case:
- Beamform 64 cylinders in a single direction;
- <u>1σ sensitivity: ~ 250 mJy ms (~ 1 mJy ms</u> including the EW arm);





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Conclusions

- We made the Northern Cross telescope capable of observing FRBs. The Northern Cross is the only INAF-owned radio array. We built an enthusiastic research group (includes promising young researchers, technologists, collaborators from four different institutes);
- We can run long observing campaigns (> 1500 h on the sky so far); still limited instantaneous sky coverage; ~30 bursts detected so far
- Simultaneous multifrequency observations 0.408 2.3 GHz (Northern Cross, Medicina, Noto) of well-localized bursts unique in today's world landscape. Synergy with optical/high energy observations; (including 190 MHz when the LOFAR station will become operational in Medicina
- Current/future work (NG-Croce) will turn the NC into a CHIME-like telescope... looking forward to our own 500 burst catalogue;



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