LOFAR Observations of the Euclid Deep Field North

M. Bondi (INAF-IRA) & R. Scaramella (INAF-OARoma)
on behalf of the LOFAR Italian Consortium

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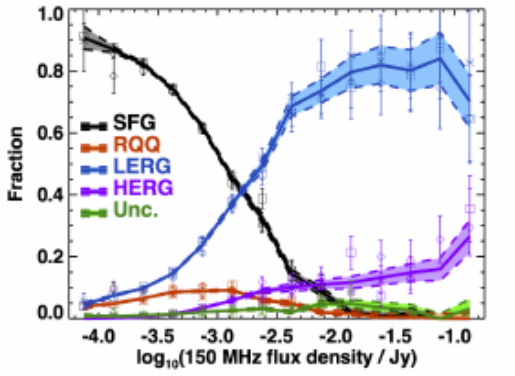
LoTSS Deep Fields:

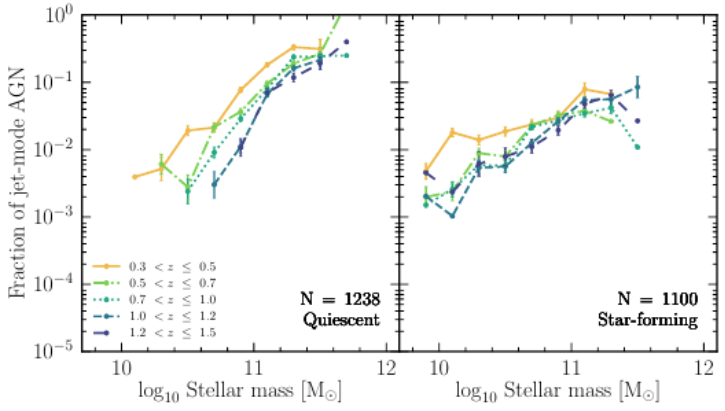
- **Deep LOFAR 150 MHz observations in some of the best-studied extragalactic fields. DR1 (Tasse+21, Sabater+21, Kondapally+21, Duncan+21, Mandal+21, Bonato+subm, Best+subm, Kondapally+subm, …..)**

Field	Area of best ancillary data	Observing time in LoTSS-Deep DR1	rms noise in LoTSS-Deep DR1	Number of sources in DR1	Data currentl in hand	Final proposed integration time	Target rms depth
ELAIS-N1	6.74 deg^2	164 hrs	19μJy/bm	84,862	460 hrs	500 hrs	11μJy/bm
Boötes	8.63 deg^2	80 hrs	32μJy/bm	50,112	144 hrs	312 hrs	16μJy/bm
Lockman Hole	10.28 deg^2	112 hrs	22μJy/bm	36,767	256 hrs	352 hrs	13μJy/bm
NEP	10.0 deg^2	–	–		72 hrs	400 hrs	13μJy/bm

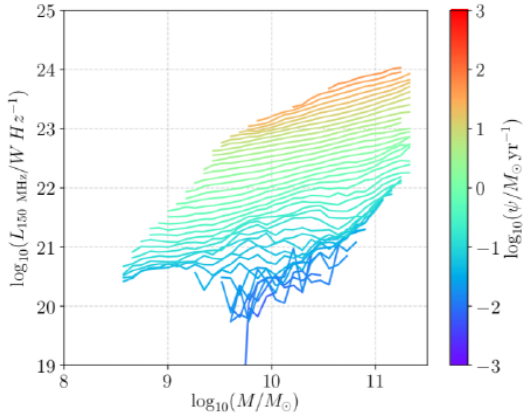
Radio source populations



Fraction of jet-mode AGN vs stellar mass



Radio luminosity vs stellar mass and SFR



Why a new deep field in North Ecliptic Pole (NEP) region ?

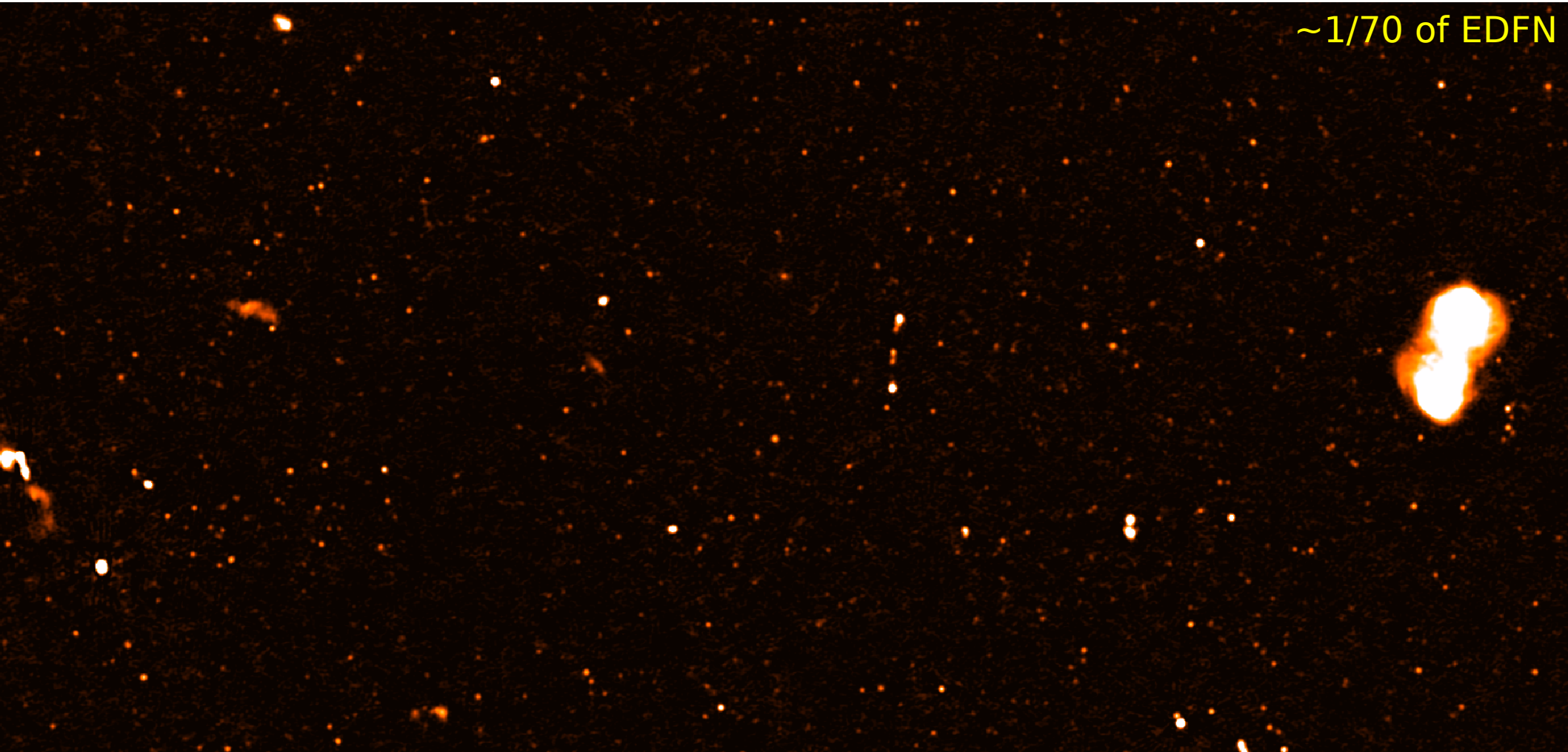
- **NEP is the location of the Euclid Deep Field North (EDFN):**
  - **Sub-arcsec NIR imaging down to H=26 mag over a 10 sq.deg. field**
- **Within the Continuous Viewing Zone (CVZ) for JWT and eRosita missions**
- **Growing range of complementary observations: e.g. Hawaii Two-0 (P.I. D. Sanders) and HEROES (P.I. G. Hasinger)**
- **Just a few degrees away from A2255 (Botteon+2020): two LOFAR beams can observe simultaneously EDFN and A2255**

LOFAR Data Reduction
(special thanks to F. Vitello and A. Botteon)

- **LOFAR-IT is in charge for the data reduction and analysis of the EDFN.**
- **Data reduced at SuperComputer OCCAM based in Turin and run by the Competence Centre for Scientific Computing (C3S), an interdepartmental research centre (University of Turin and INFN) specialized in high performance computing.**
- **We used lofar pipeline v2:**
  - Light Node for pre-factor
    - CPU: 2x Intel® Xeon® Processor E5-2680 v3, 12 core 2.5GHz
    - RAM: 128GB/2133MHz (8 x 16 Gb)
  - Fat Node for ddf-pipeline (takes 8 weeks...)
    - CPU: 4x Intel® Xeon® Processor E7-4830 v3 12 core/2.1Ghz
    - RAM: 768GB/1666MHz (48 x 16Gb) DDR4
  - Data storage: ~60 Tb

Data products: image and catalogue

- From the first 72 hrs of observations of EDFN we obtained:
  - 6” resolution image in a 20 sq.deg. field, central r.m.s 30 μJy/beam at 150 MHz



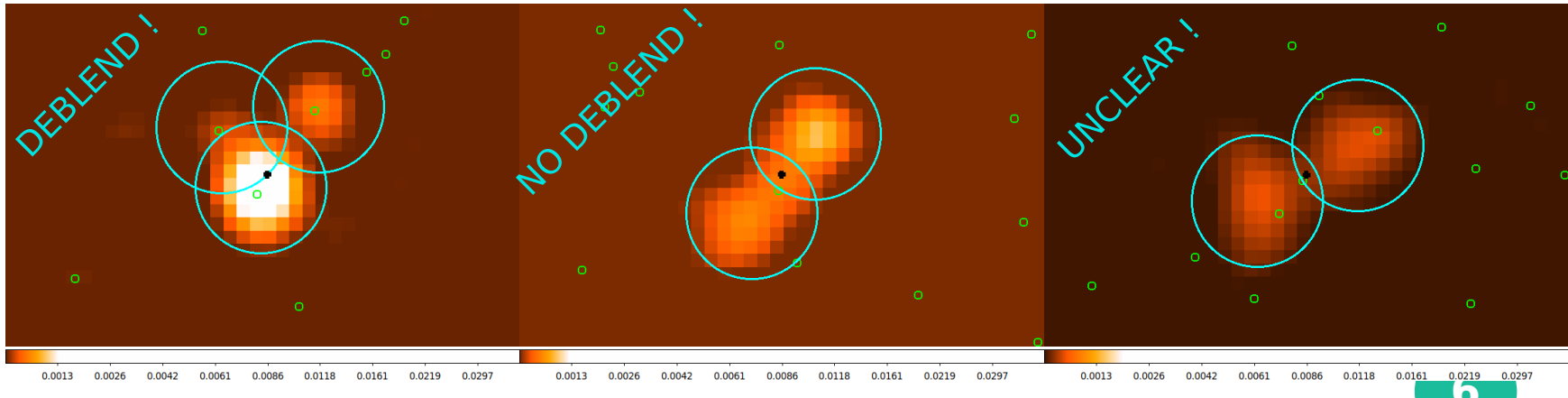
Data products: image and catalogue

- From the first 72 hrs of observations of EDFN we obtained:
  - 6” resolution image, central r.m.s 30 μJy/beam at 145 MHz
  - PyBDSF (Mohan & Rafferty 2015) catalogue of ~45,000 radio source (>5sigma), ~23,000 within the 10 sq.deg. EDFN region (thanks to M. Brienza)
  - Produced a catalogue v2.0
    - Removing artifacts: side-lobes near strong sources
    - Deblending of Gaussian components wrongly associated to the same radio source (using available NIR/optical images and catalogues)
    - Associate together separated components (i.e. lobes) that were classified as different sources by PyBDSF

Radio pos.

Gauss comp.

unWise source



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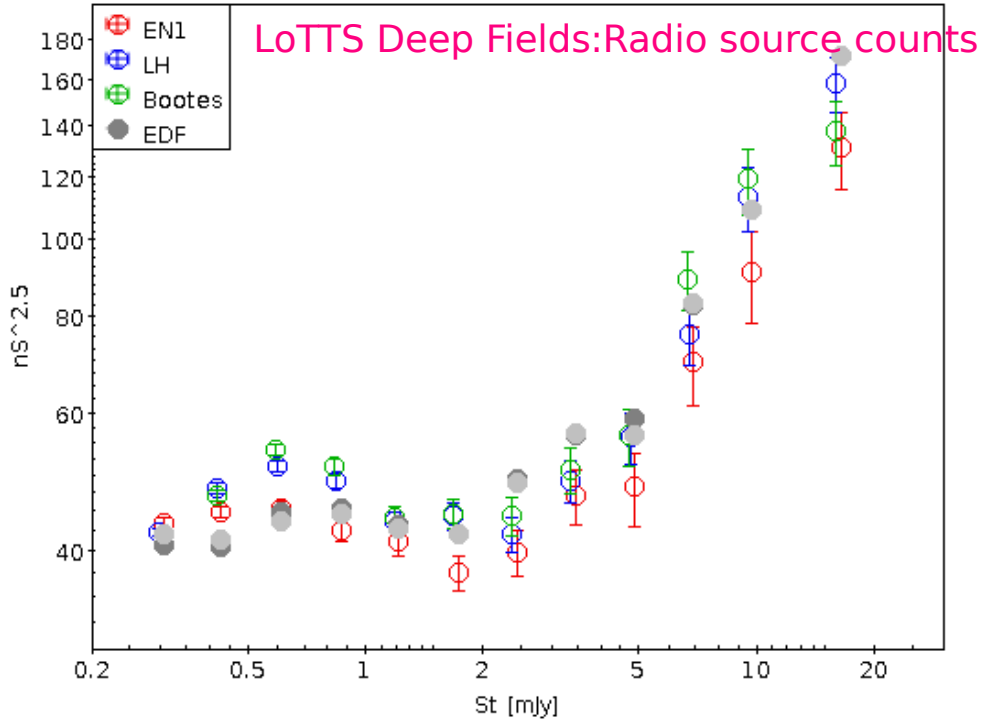
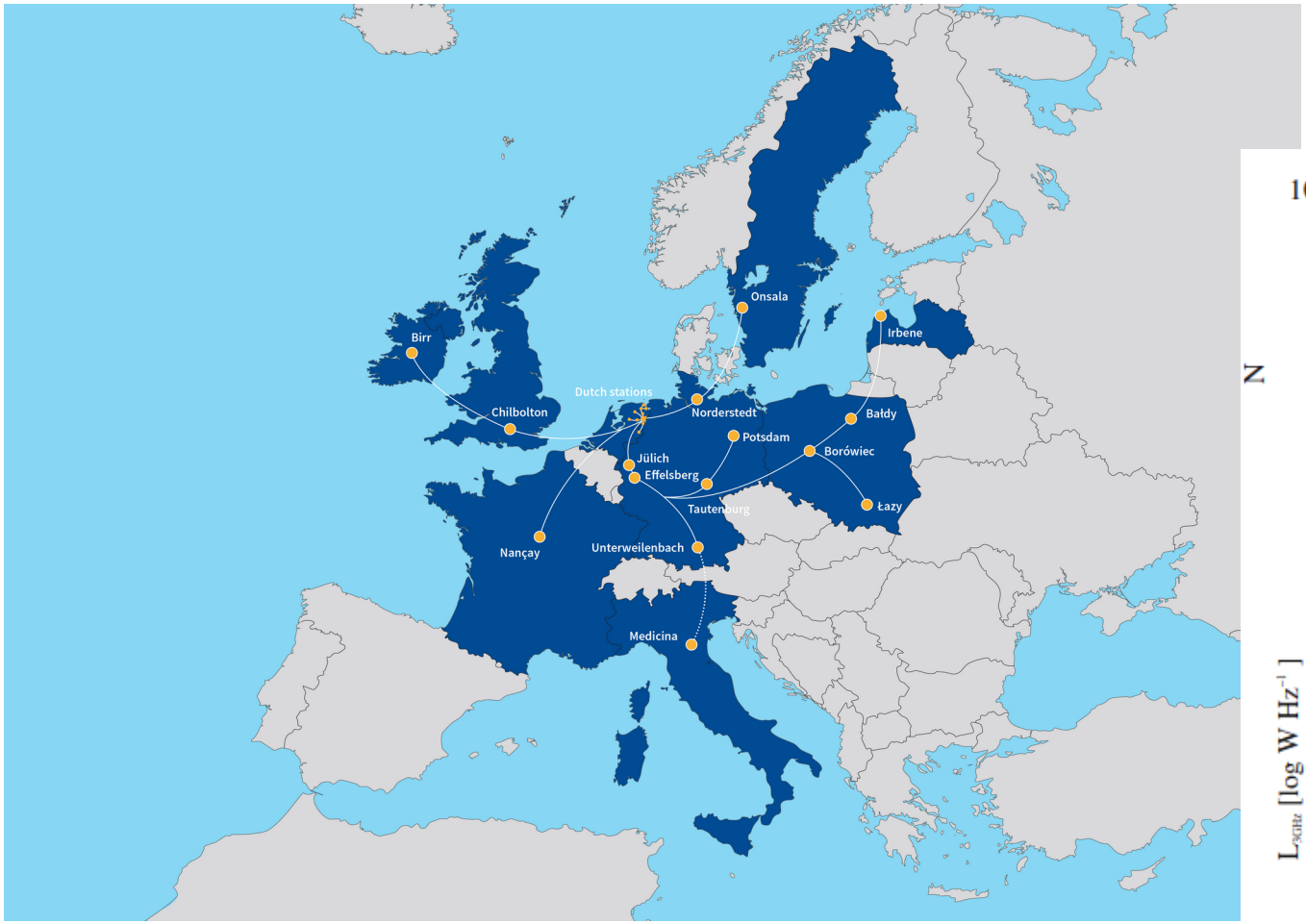


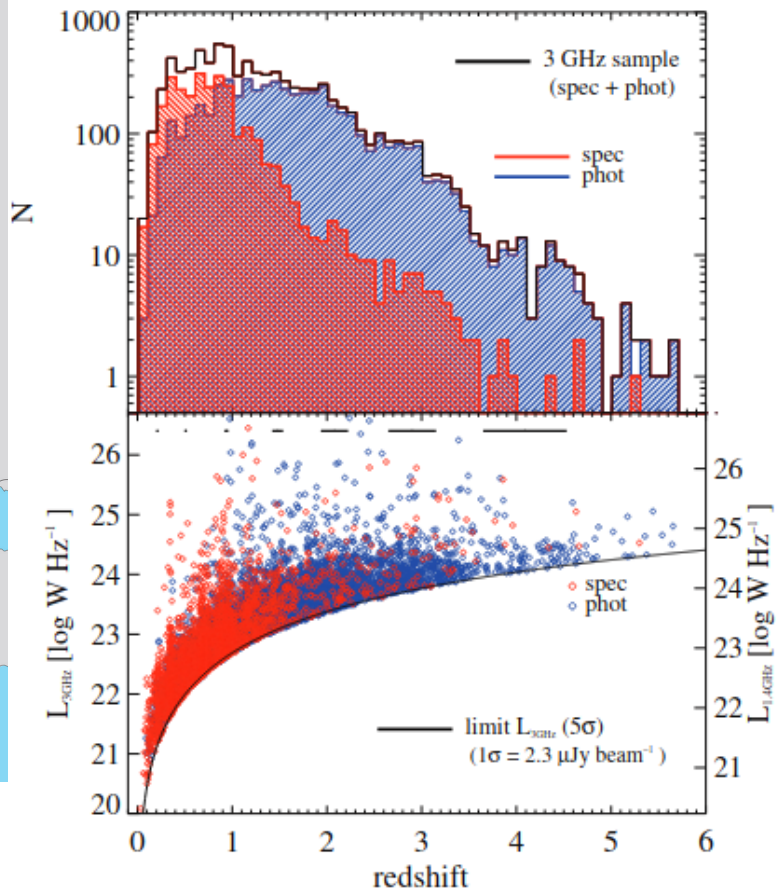
Bondi+ in preparation
(with G. Zamorani & P. Ciliegi).
Number counts for EN1, LH and Bootes are from Mandal+2021

Moving to unexplored territories:
LOFAR long baselines

International LOFAR Telescope (ILT)



- **Resolution from 6” (~50 kpc at z=1) to 0”.3**



48 stations in The Netherlands
14+1 international stations

Delvecchio+2017

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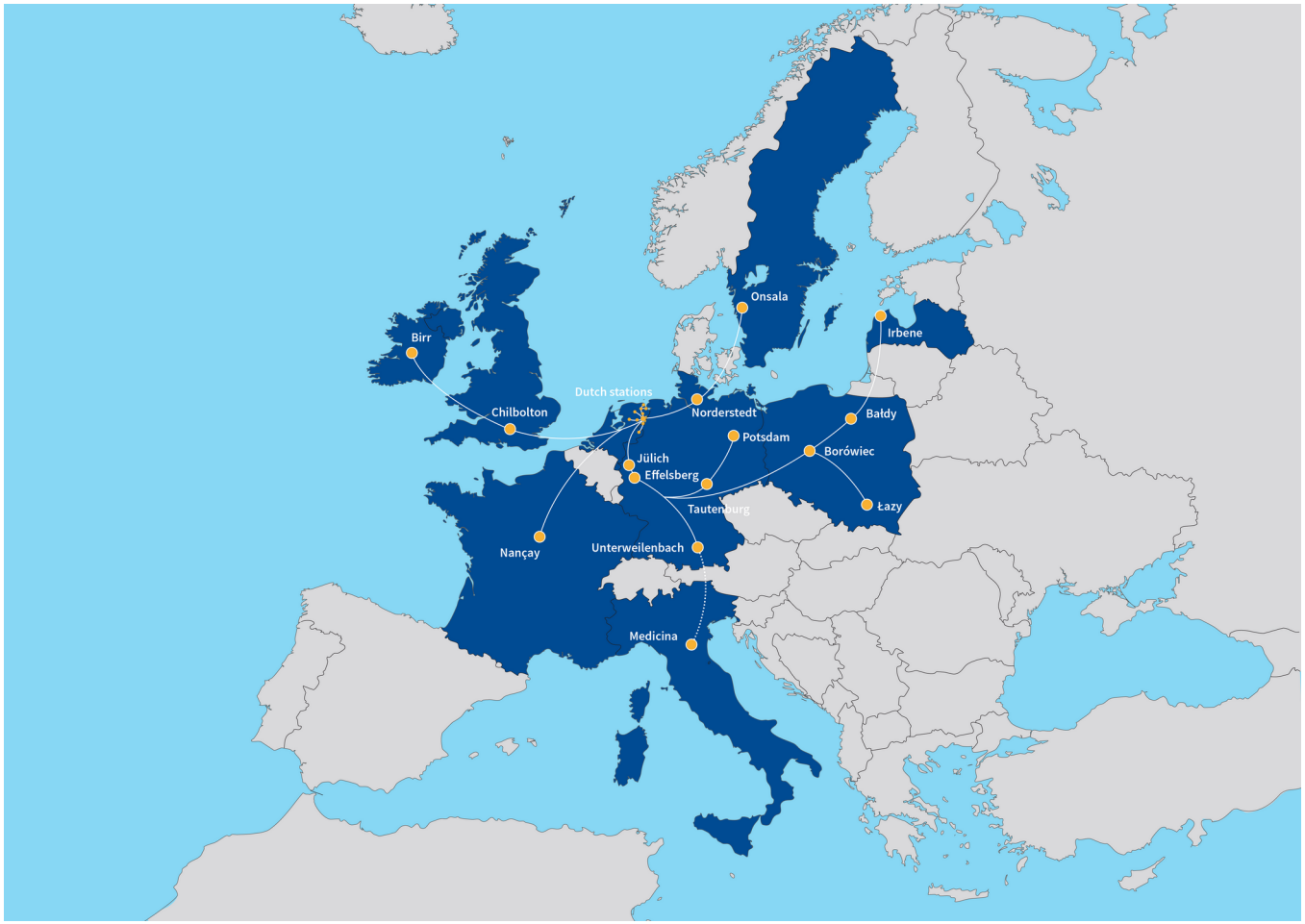
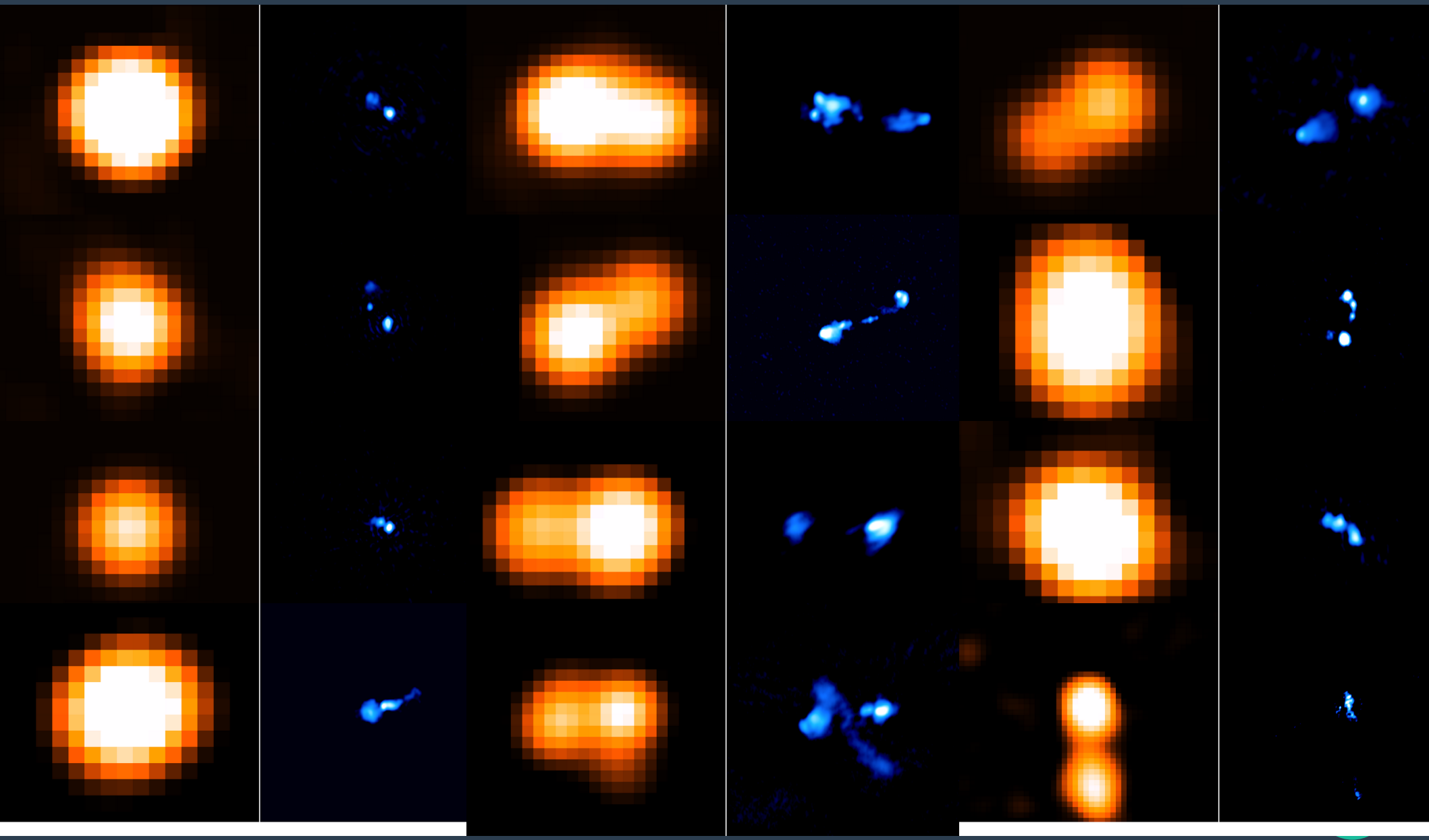


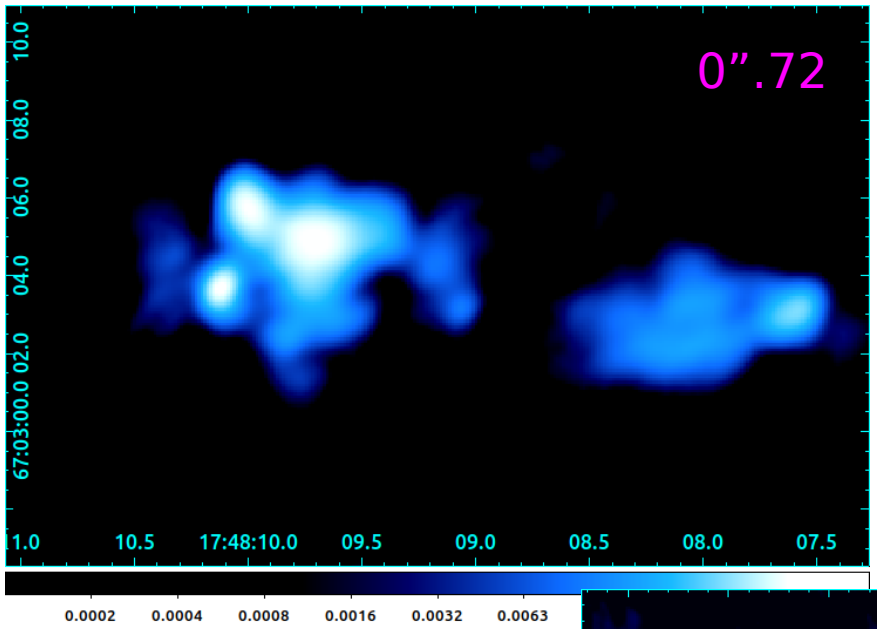
48 stations in The Netherlands
14+1 international stations

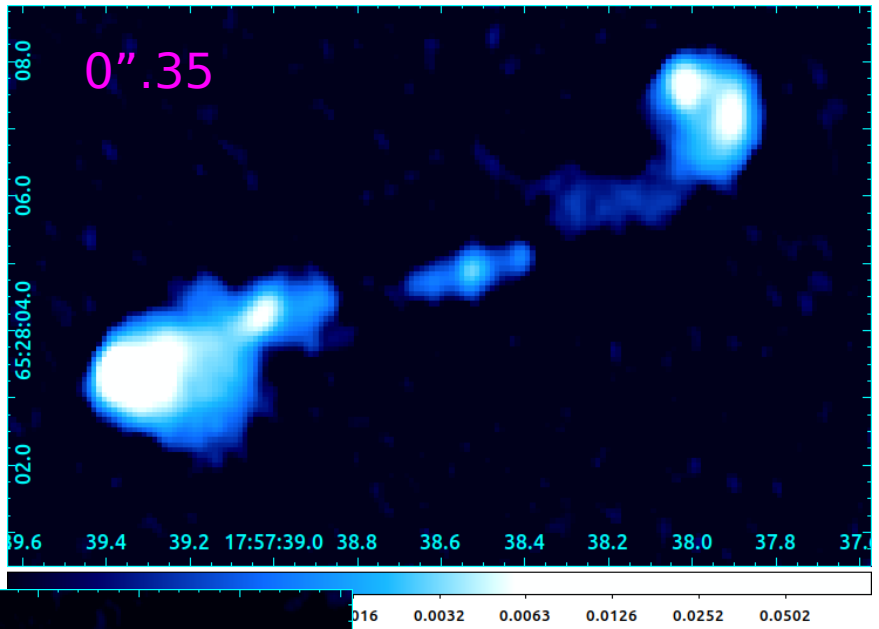
- **Resolution from 6” (~50 kpc at z=1) to 0”.3**
- **Further calibration steps are needed (black-belt experts)**
- **Morabito+ 2021: first step towards a standard and documented pipeline to include the international baselines in LOFAR data analysis**
- **First results from a single 8hrs night: not yet high-res wide field imaging but postage stamp technique**

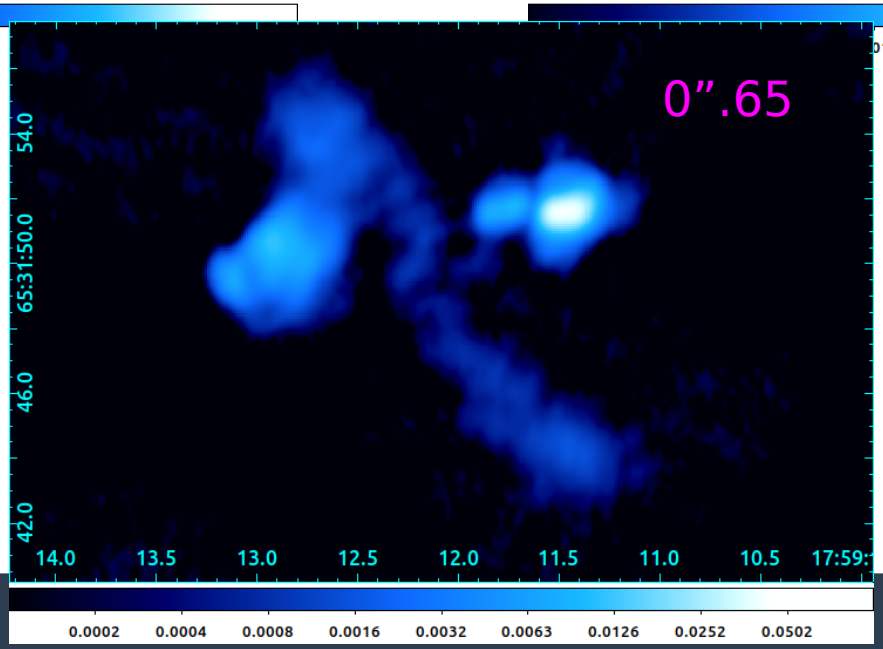
ILT images of galazies in the EDFN



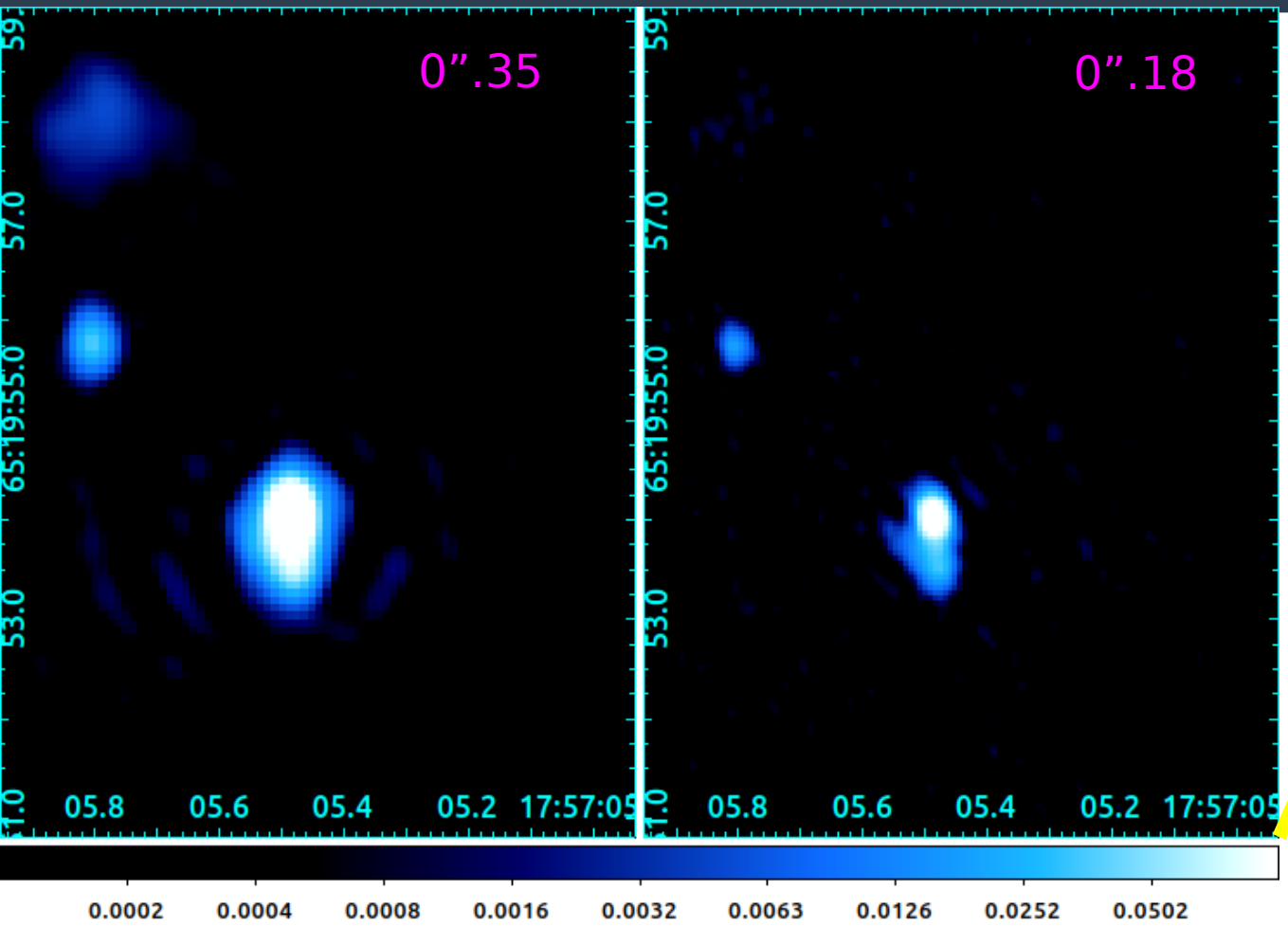
Radio galaxies at z~0.7

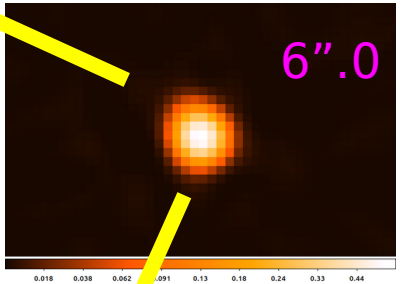


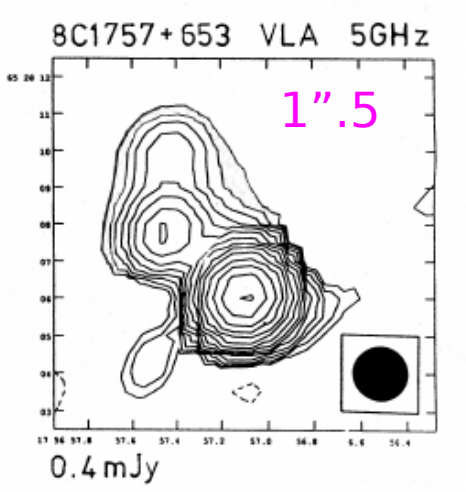




High-z radio galaxies at low frequencies 1/2







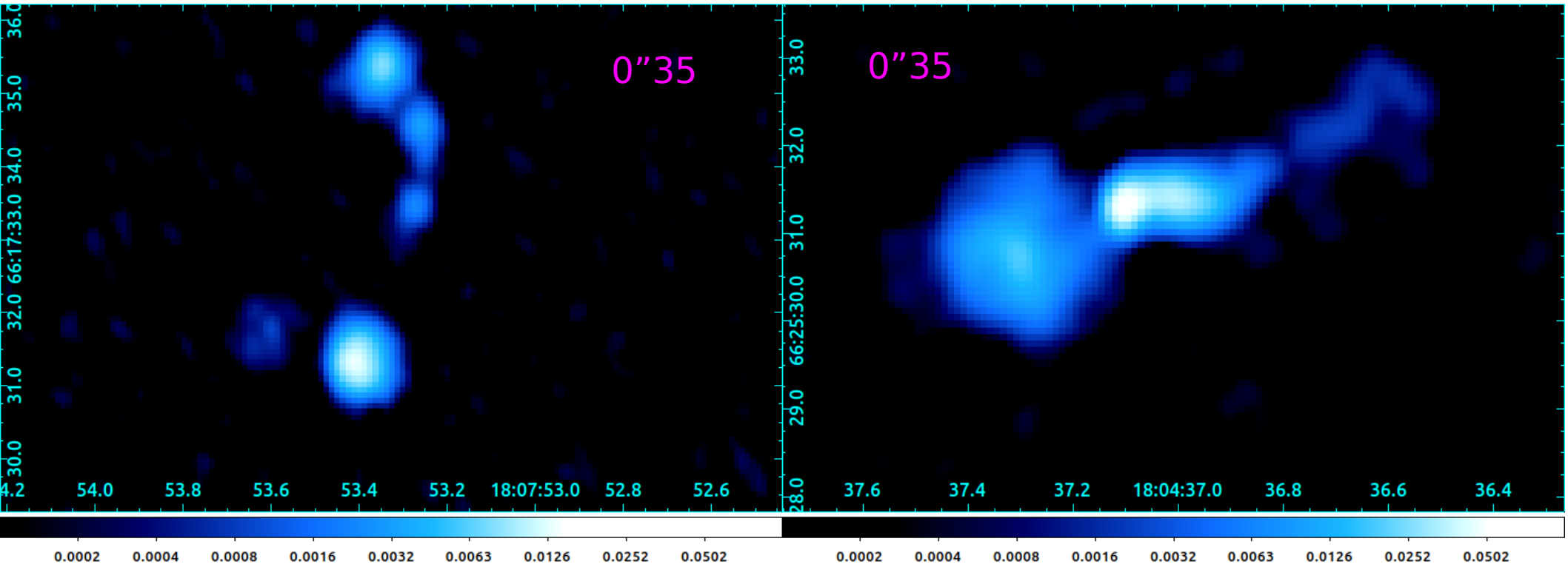
Lacy+ 1992

Agn at z=1.416 associated to high-redshift galaxy cluster (Galametz+2010, Casasola+2018)

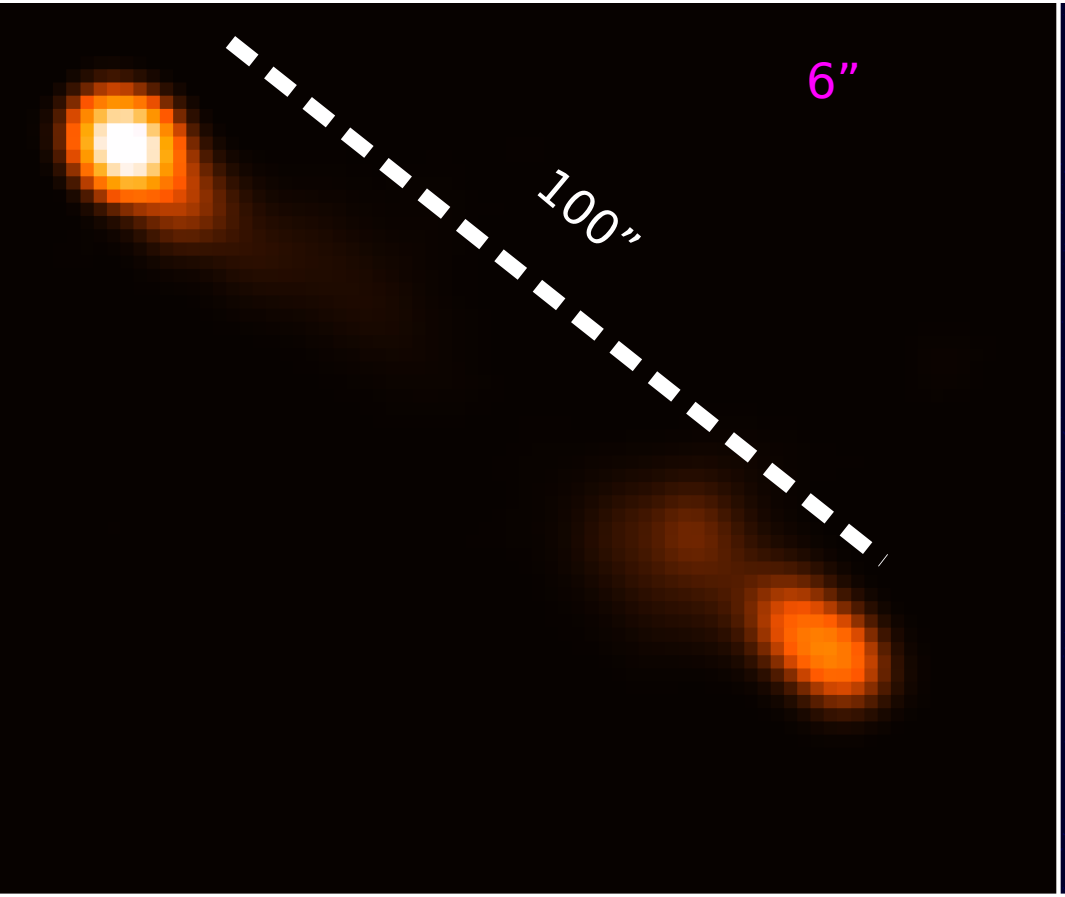
High-z radio galaxies at low frequencies 2/2

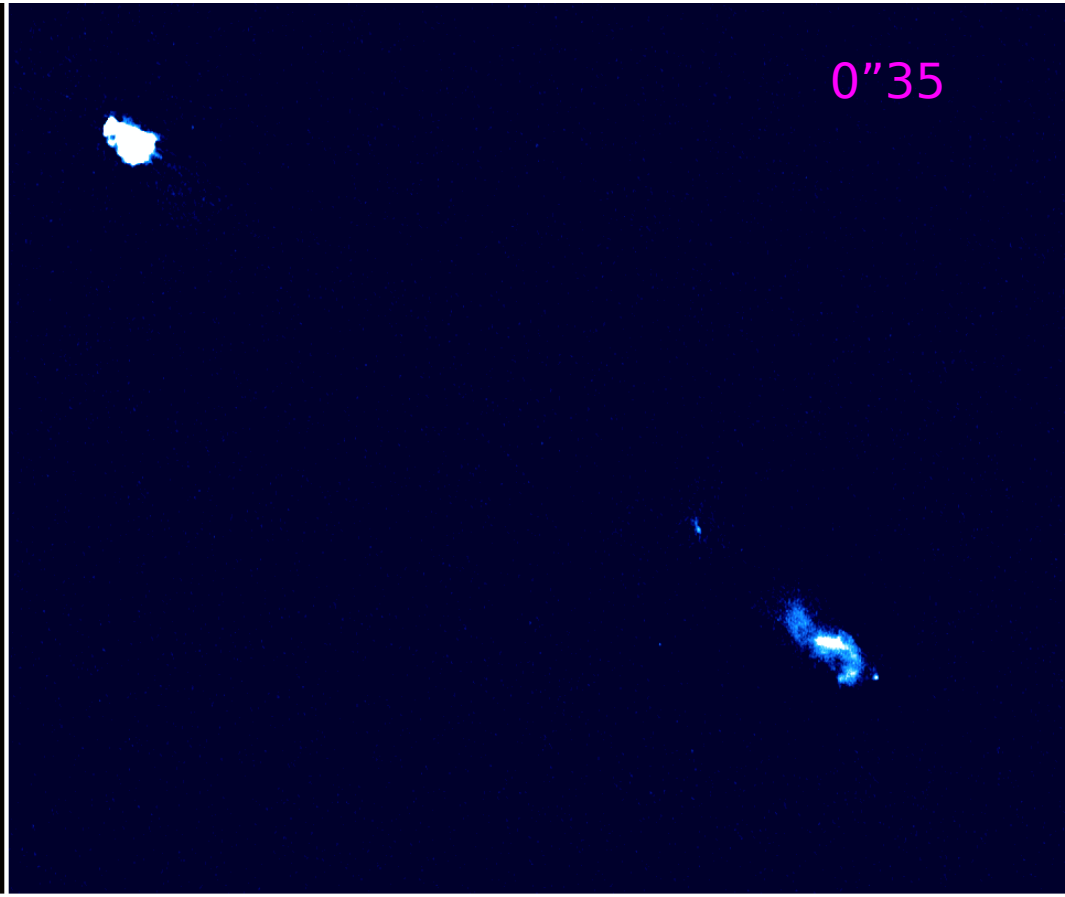
Lobe dominated RG at z=2.05

Core dominated RG at z=1.91



ILT in EDFN: Not just for compact sources





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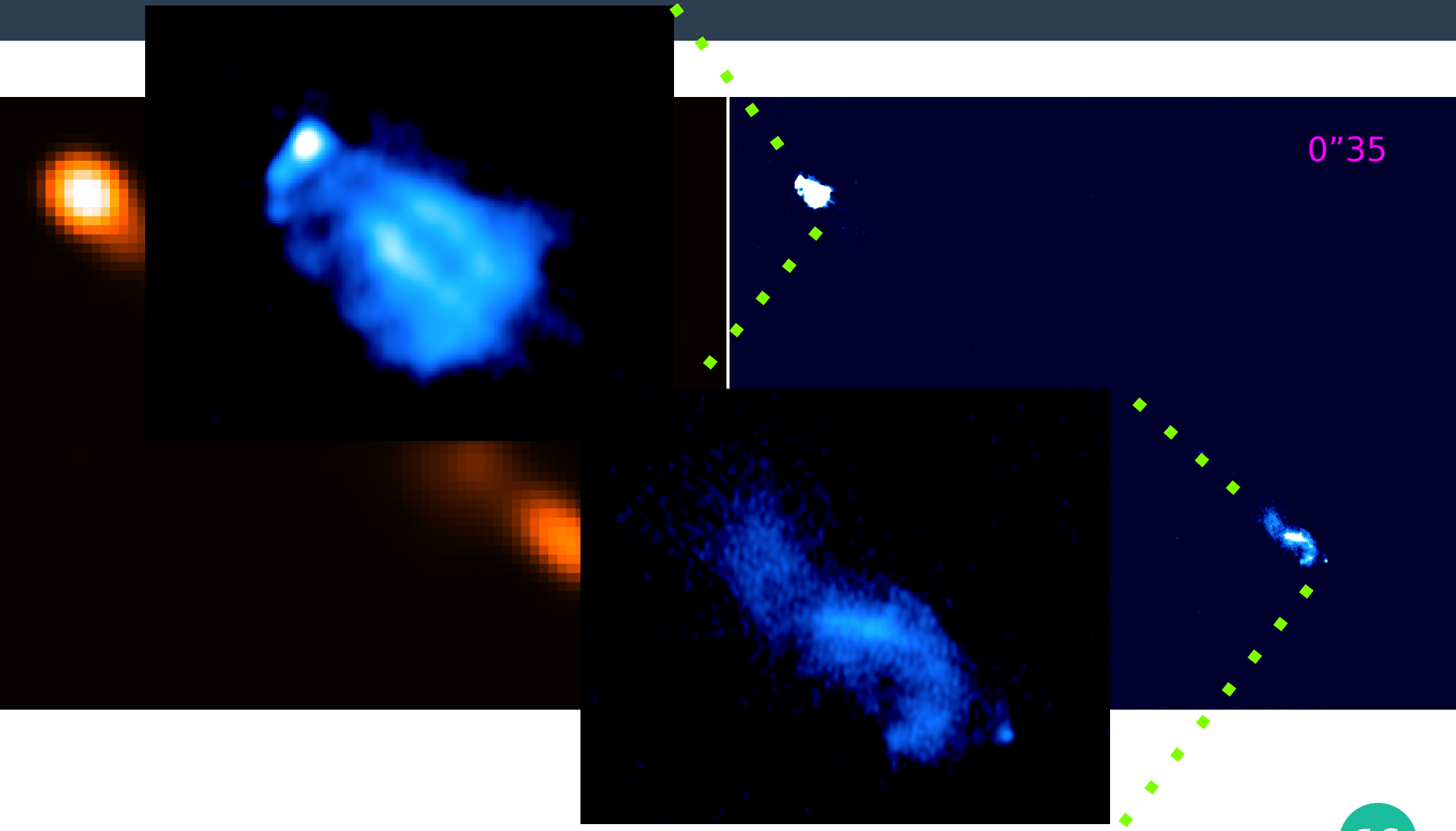

Summary

- **First LOFAR Deep Field processed and analyzed in Italy.**
  - Rms noise consistent with that obtained in Bootes (similar obs. time)
  - Derived a refined catalogue of ~23,000 radio sources over the 10 sq.deg. covered by EDFN
  - Radio source number counts are in agreement with those obtained from other LoTSS deep fields
  - LOFAR long-baseline will provide images with resolution comparable to that of Euclid NIR imaging, crucial to properly identify and study the population of galaxies at $z \geq 1$, and for detailed study of jets and hot-spots in lower redshift objects.

Thanks !