STATUS OF THE RADIO ASTRONOMICAL FACILITIES IN ITALY

Federica Govoni

INAF - Osservatorio Astronomico di Cagliari

Coordinator of the Division II (Radio Astronomy) of the INAF Scientific Directorate

OUTLINE OF THE TALK

- Status of the SRT, Medicina, and Noto
- SRT, Medicina, and Noto in the European VLBI Network (EVN)
- Italian scientific highlights with the VLBI technique
- Future perspectives for radio observations at high frequencies with the Italian radio telescopes
- Status of the LOFAR project in Italy

INAF Radio Astronomical Facilities

Medicina
Northern Cross
32m parabola dish

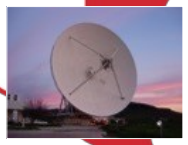
INAF-IRA

LOFAR
Station
(2021/2022)

INAF-OA Cagliari

SRT
64m parabola dish

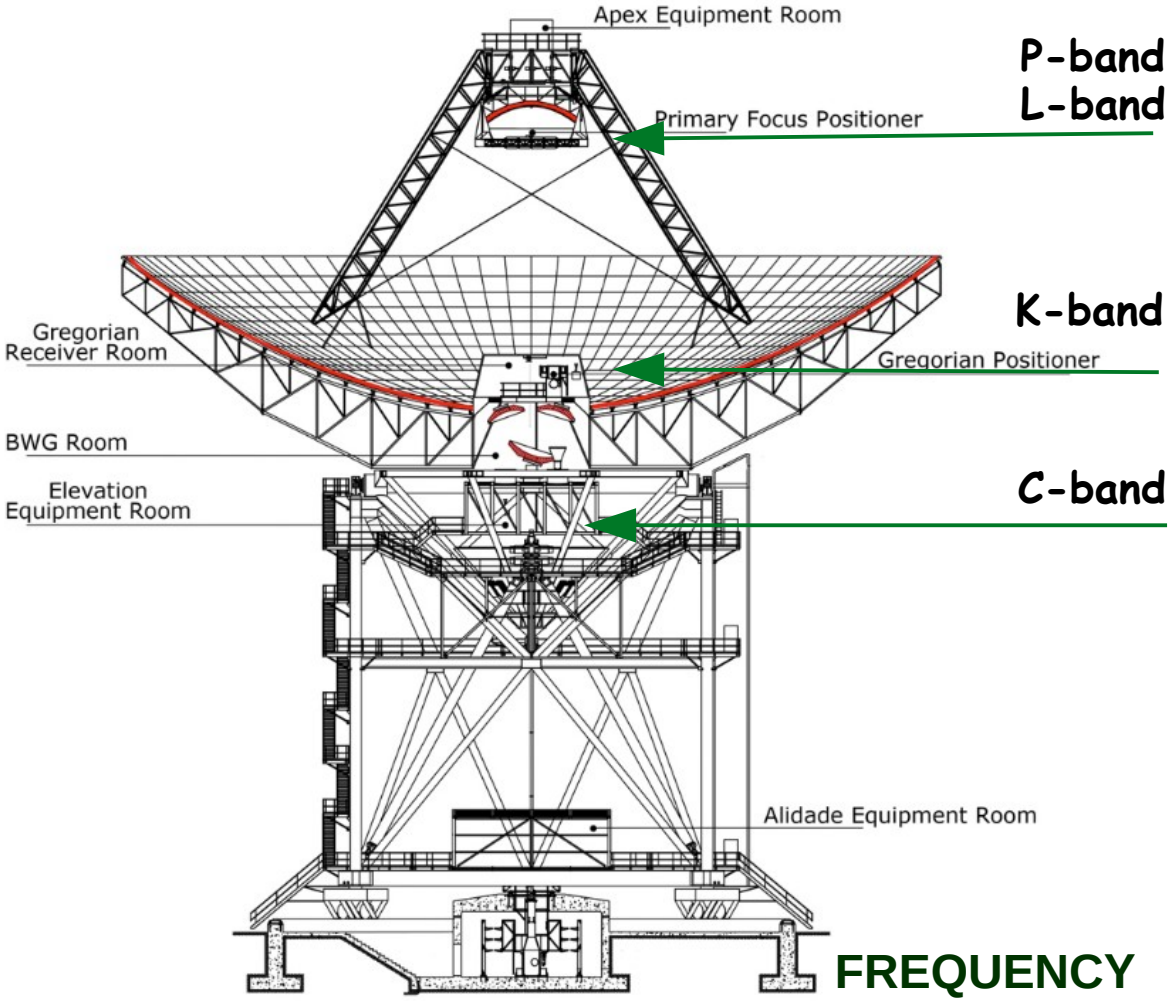
INAF-IRA



Noto
32m parabola dish

Status of the SRT, Medicina, and Noto

SRT - Receivers



SRT is equipped with a 7-beam receiver operating in K-band, with a single-beam receiver in Chigh-band, and with a dual frequency receiver in P/L band. Furthermore, two new S-band and Clow-band receivers are being finalized.

FREQUENCY

P-band 305-425 MHz
Coaxial

L-band 1.3-1.8 GHz

Chigh-band 5.7-7.7 GHz

K-band multibeam 18-26 GHz

S-band 3.0-4.5 GHz

Clow-band 4.2-5.6 GHz

Noto - Receivers

S-band 2.20-2.36 GHz coaxial

Clow-band 4.62-5.02 GHz

Chigh-band 5.1-7.25 GHz

X-band 8.18-8.98 GHz coaxial

K-band 21.5-23 GHz

Q-band 39-43.5 GHz

L/S/X band 1.3-1.8 GHz 2.2-2.36 GHz 8.18-8.98 GHz

FREQUENCY →

Medicina - Receivers

L-band 1,35-1.45 1.595-1.715 GHz

S-band 2.20-2.36 GHz coaxial

Clow-band 4.3-5.8 GHz

Chigh-band 5.9-7.1 GHz

X-band 8.18-8.98 GHz coaxial

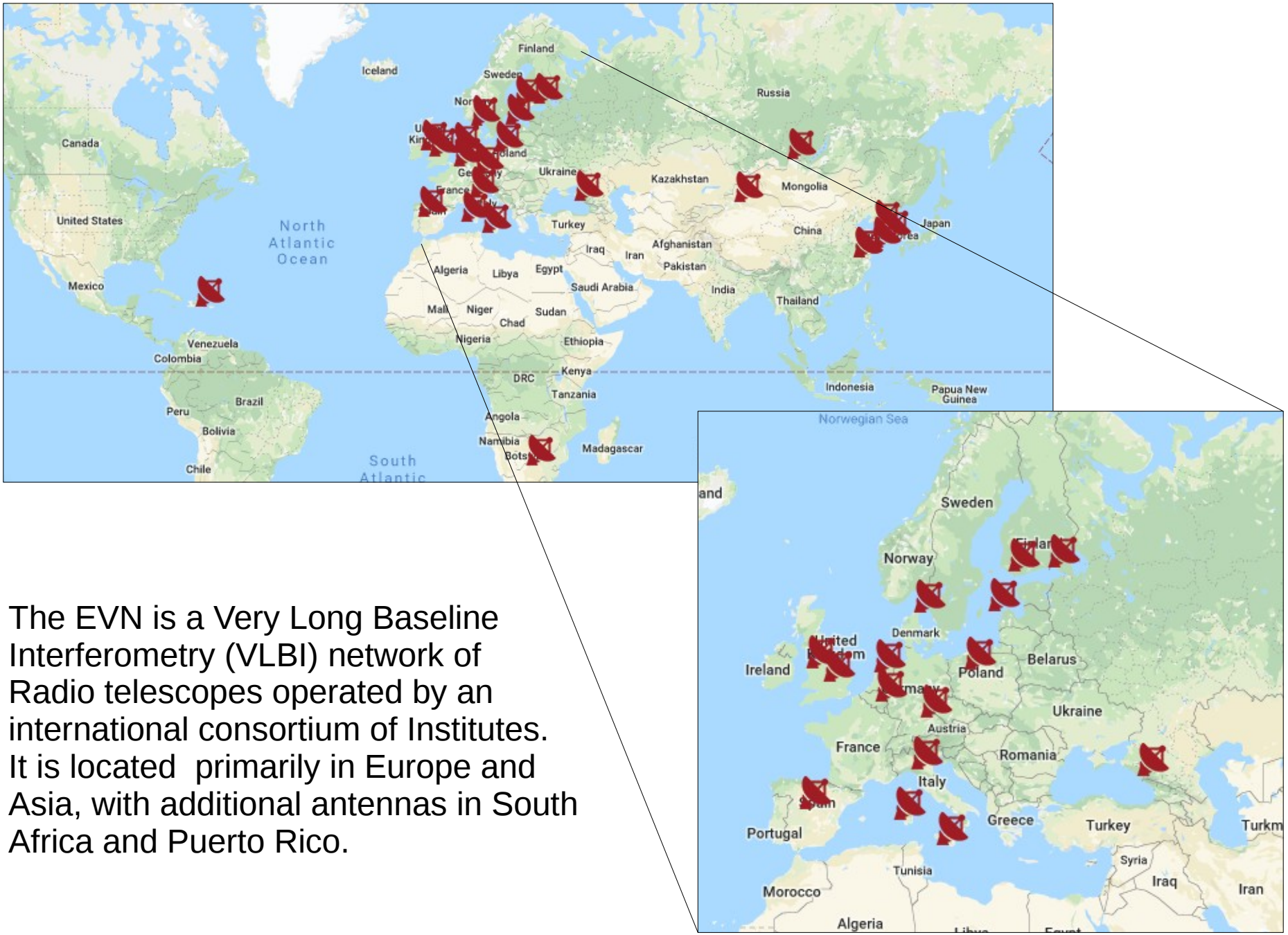
K-band 18-26.5 GHz

Ku-band 13.5-17.5 GHz

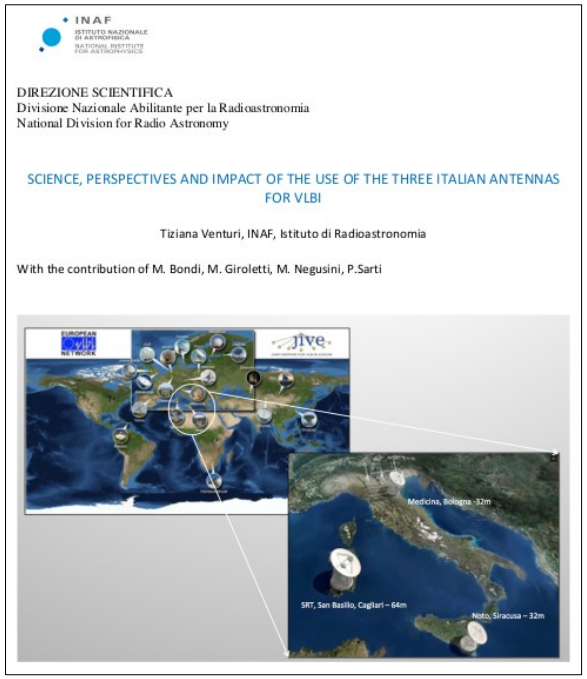
Medicina is the only Italian telescope without a facility for extending its operating frequencies up to 100 GHz; deformations due to gravity prevents good aperture efficiency at frequencies higher than the K-band.

MEDICINA → **Installation of the active surface**

SRT, Medicina, Noto in the European VLBI Network (EVN)



The EVN is a Very Long Baseline Interferometry (VLBI) network of Radio telescopes operated by an international consortium of Institutes. It is located primarily in Europe and Asia, with additional antennas in South Africa and Puerto Rico.



INAF
ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

DIREZIONE SCIENTIFICA
Divisione Nazionale Abilitante per la Radioastronomia
National Division for Radio Astronomy

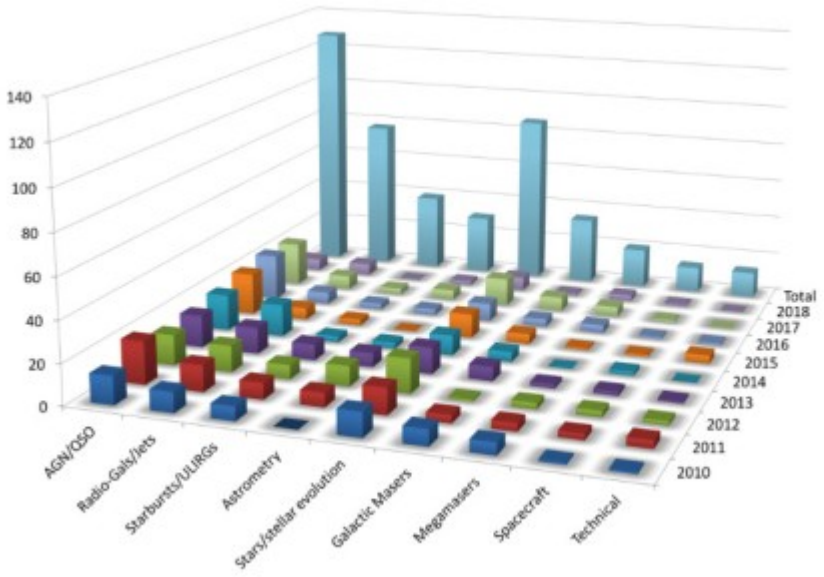
SCIENCE, PERSPECTIVES AND IMPACT OF THE USE OF THE THREE ITALIAN ANTENNAS FOR VLBI

Tiziana Venturi, INAF, Istituto di Radioastronomia

With the contribution of M. Bondi, M. Giroletti, M. Negusini, P.Sarti

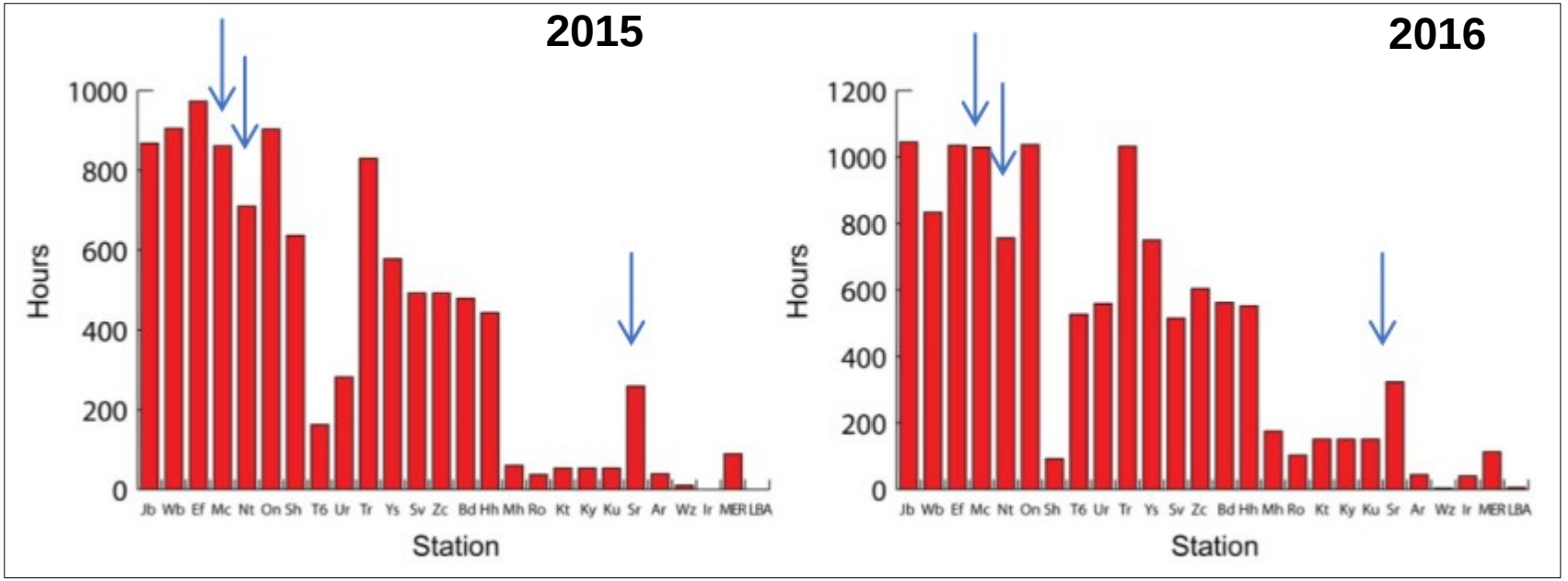
Report by Tiziana Venturi

EVN proposals: Topics and nationality of the PIs



2010 – 2017:
58 Italy
51 Germany
49 The Netherlands
42 China
34 Spain
32 Poland
31 UK
28 USA
21 Russia
16 Sweeden

Number of hours for each EVN antenna (3 weeks – 3 times in a year)

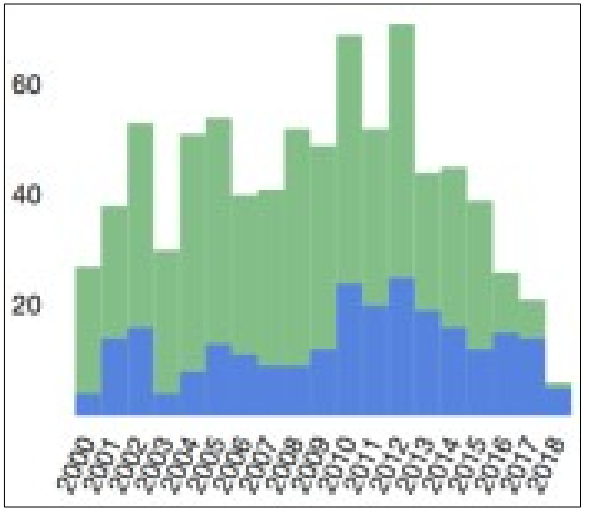


Taken from EVN biennial report 2015-2016

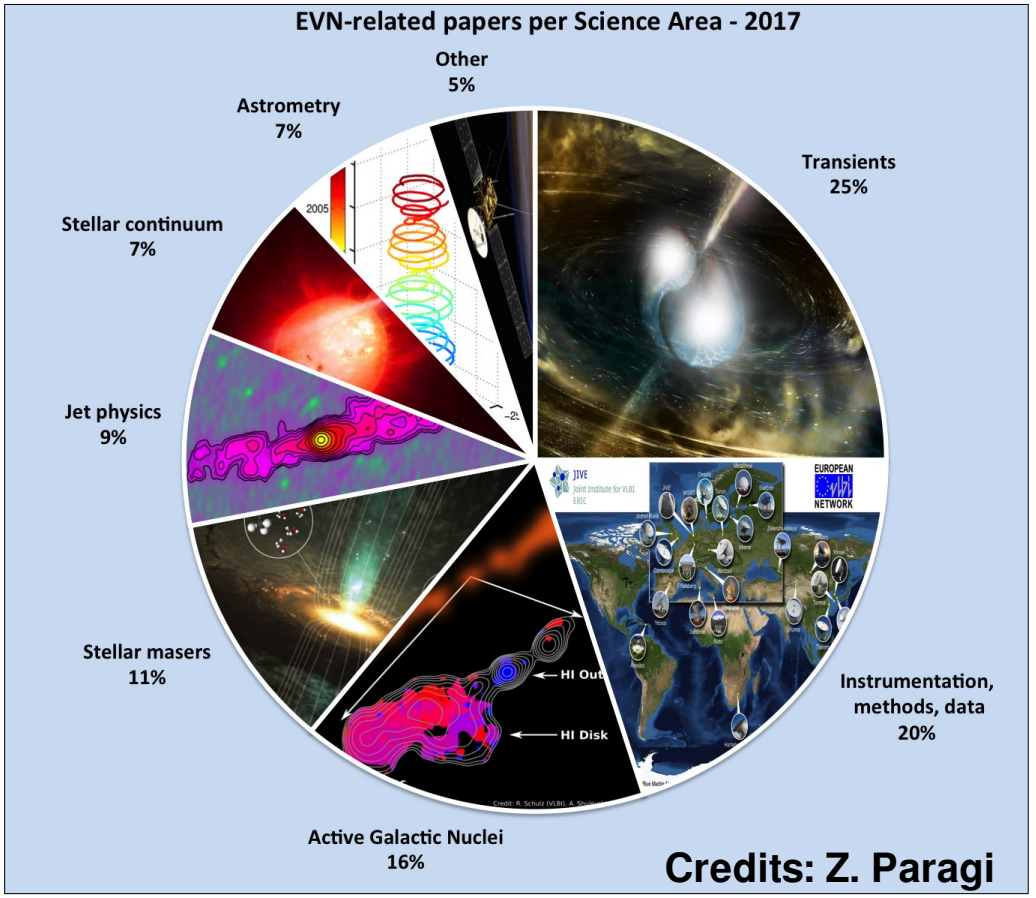
NUMBERS OF PUBLICATIONS IN THE PERIOD 2000 – MARCH 2018

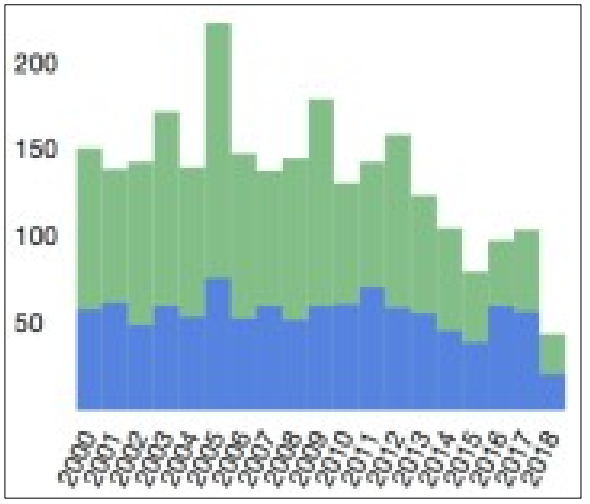
Refereed

Non Refereed



EVN





VLBA (observing time 3.5 times higher than EVN)

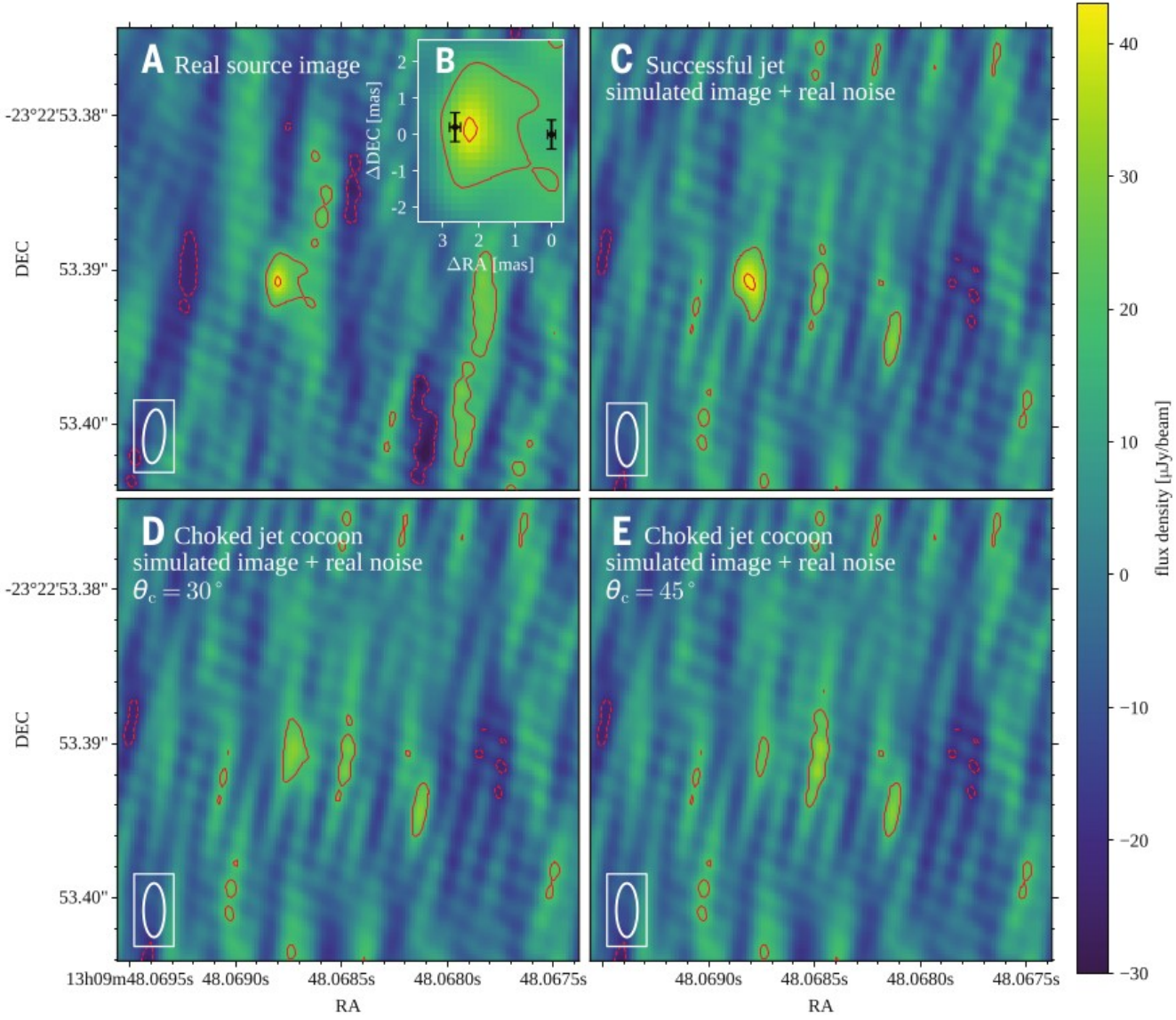
Report by Tiziana Venturi

Italian scientific highlights with the VLBI technique

Ghirlanda et al. (2019, Science)
" Compact radio emission indicates a structured jet was produced by a binary neutron star merger "

The gravitational waves signal detected by LIGO and VIRGO of the binary neutron star merger GW170817 was detected in both gravitational waves and electromagnetic emission

VLBI observations
Medicina/Noto
Frequency 4.8 GHz
Resolution 3.5x1.5 mas.

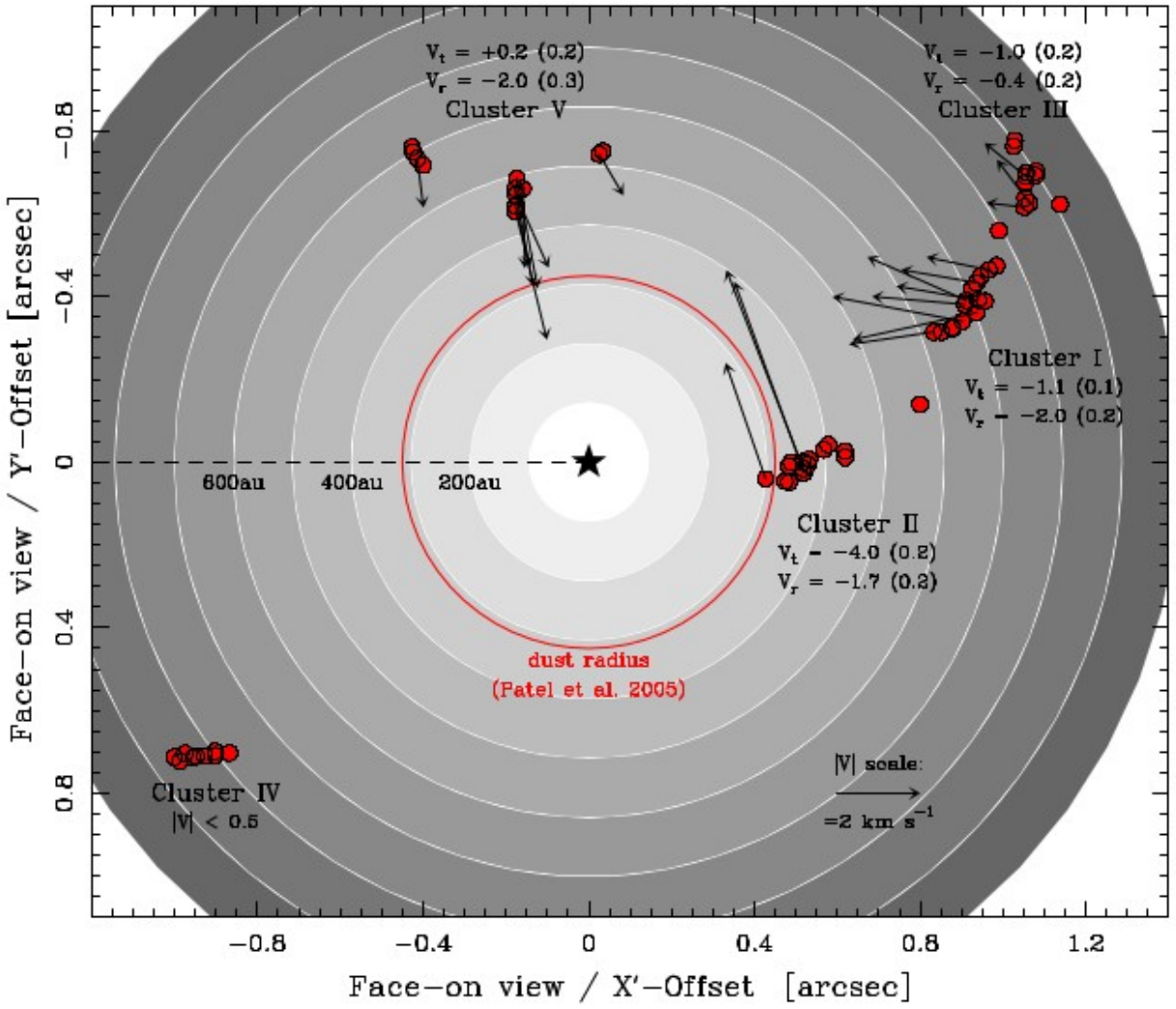


Italian scientific highlights with the VLBI technique

Sanna et al. (2017, A&A)
"Planar infall of CH3OH gas around Cepheus A HW2 "

Cepheus A HW2 is a protostellar object located in Cepheus A, the second nearest high-mass star-forming region.

Test the nature of an accretion disk in the vicinity of Cepheus A HW2 by measuring the three-dimensional velocity field of the CH3OH maser spots, which are projected within 1000 au of the HW2 object, with an accuracy on the order of 0.1 km/s.

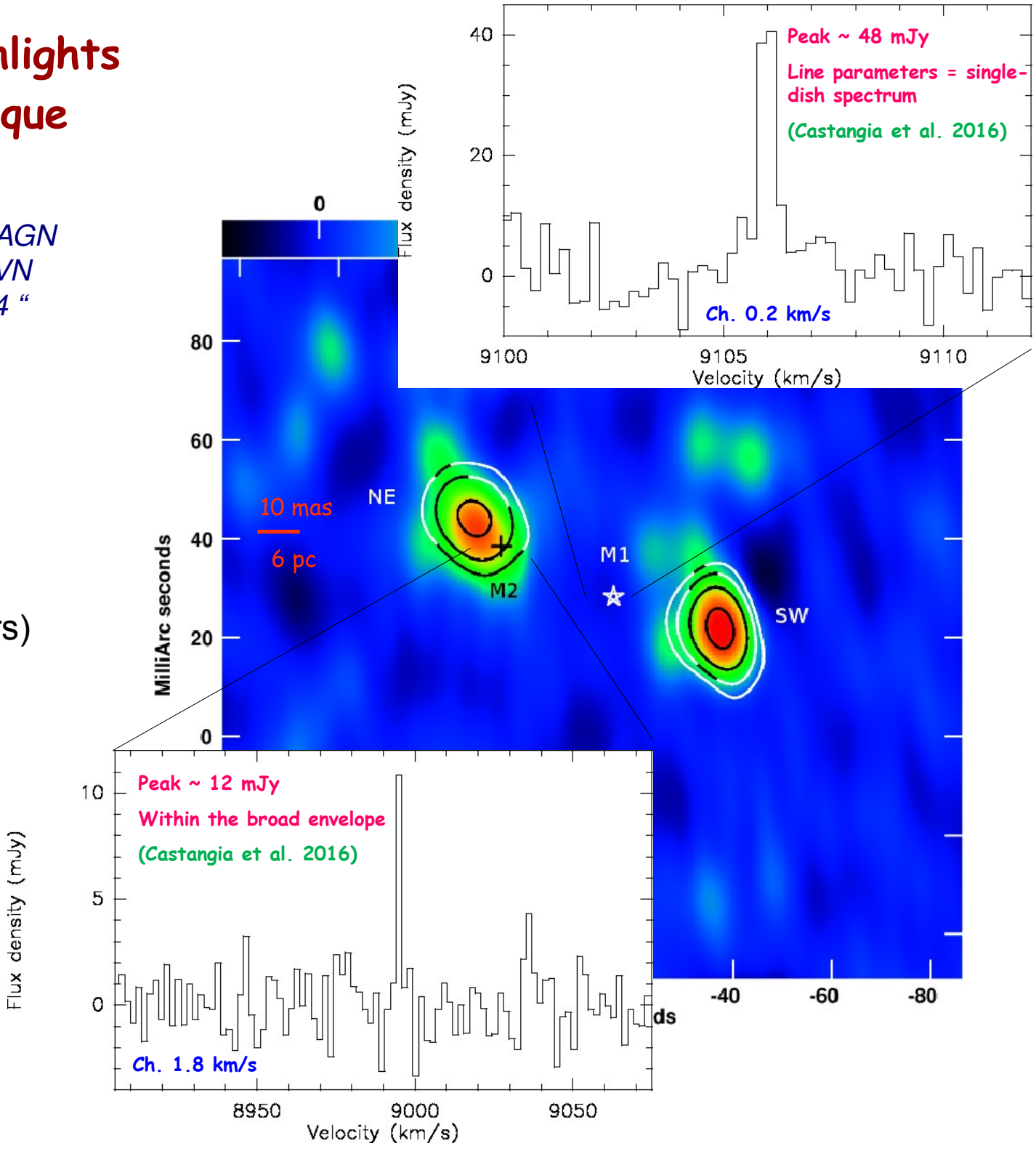


EVN Observations
(SRT/Medicina/Noto)
Frequency 6.7 GHz to image CH3OH (methanol) maser emission toward Cepheus A HW2 with 4.5 milliarcsec resolution.

Italian scientific highlights with the VLBI technique

Castangia et al. (2019, A&A)
" Water masers in compton-thick AGN II - The high detection rate and EVN observations of IRAS 15480-0344 "

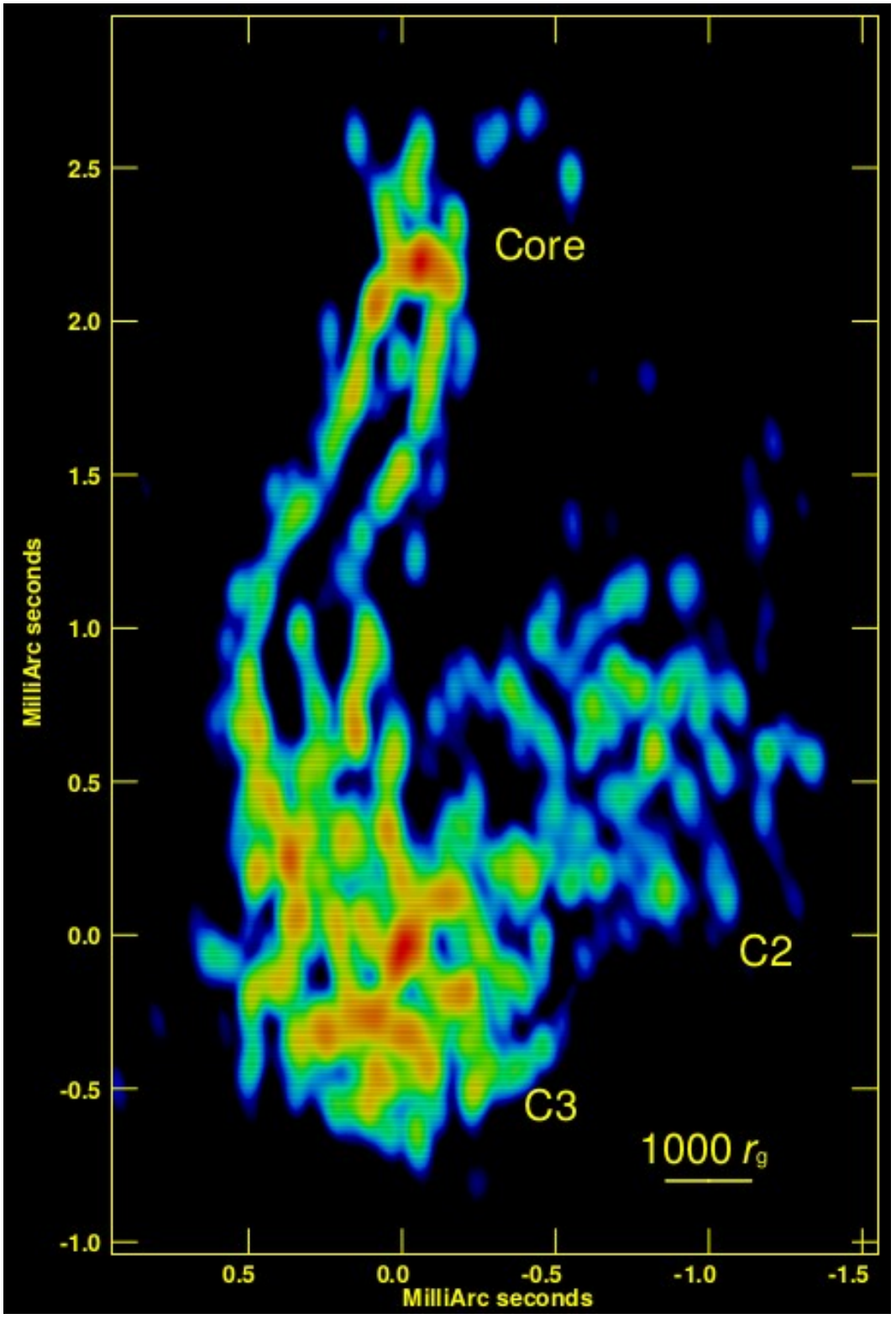
EVN observations
(SRT/Medicina/Noto)
Frequency 1.7GHz (colors)
Frequency 5.0 GHz (contours)
resolution ~10 mas.



Italian scientific highlights with the VLBI technique

Giovannini et al. (2018, Nature Astronomy)
"A wide and collimated radio jet 3C84 on the scale of a few hundred gravitational radii"

3C84 (Perseus)
Space-VLBI (Medicina)
Frequency 22 GHz
Resolution 0.1X0.05 mas



Requesting Observation Time at the Italian Radio Telescopes

http://www.radiotelescopes.inaf.it

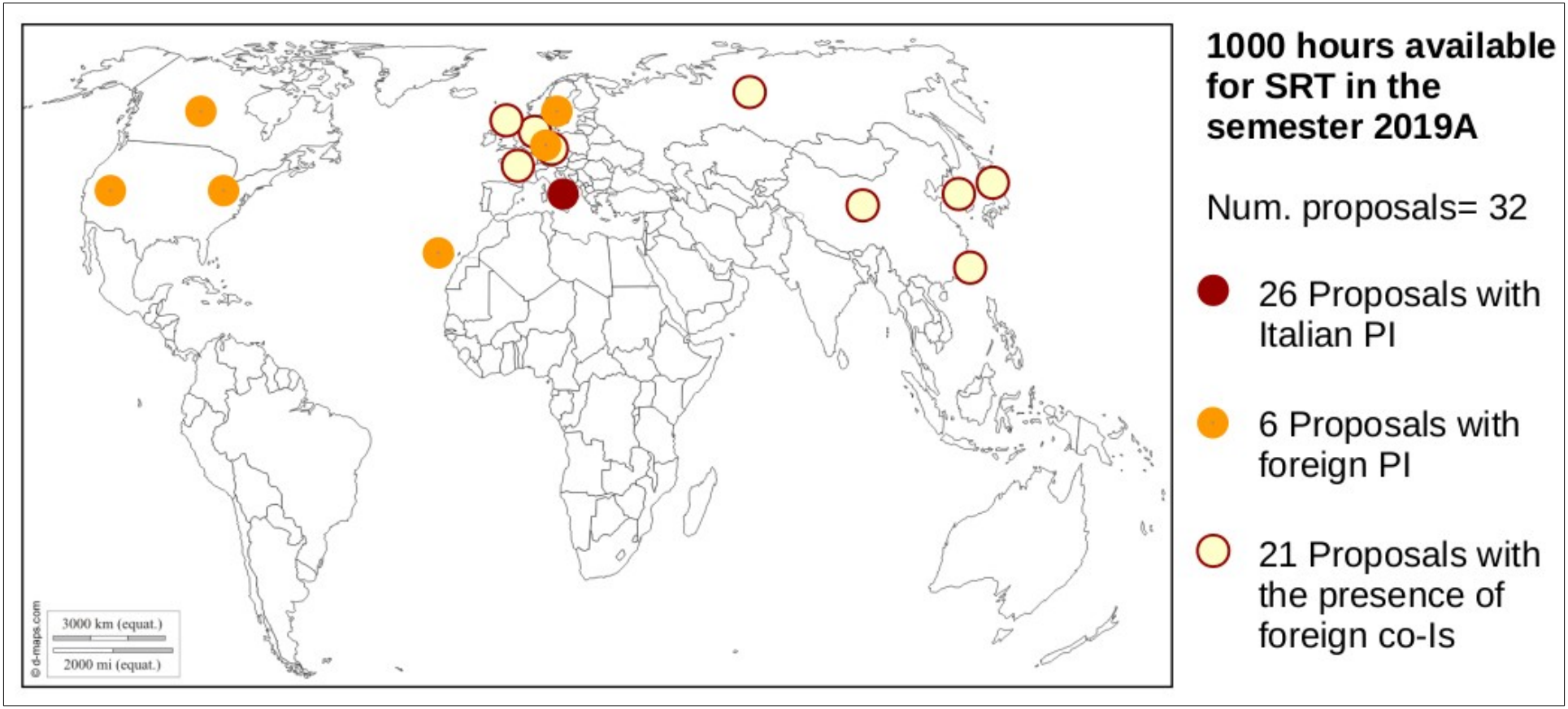
Next Deadline is 3 October 2019

SINGLE-DISH and extra-EVN INTERFEROMETRIC OBSERVATIONS

SRT, Medicina, and Noto are "**open sky facility**" :
Observational infrastructures that grants scientists of the international community access to the telescopes through calls for proposals every six months. The observations will be assigned on a competitive basis, by scientific merit, by a TAC of experts.

Semester 2019A (December 2018 – May 2019)

Report by Andrea Tarchi (chair of the TAC)



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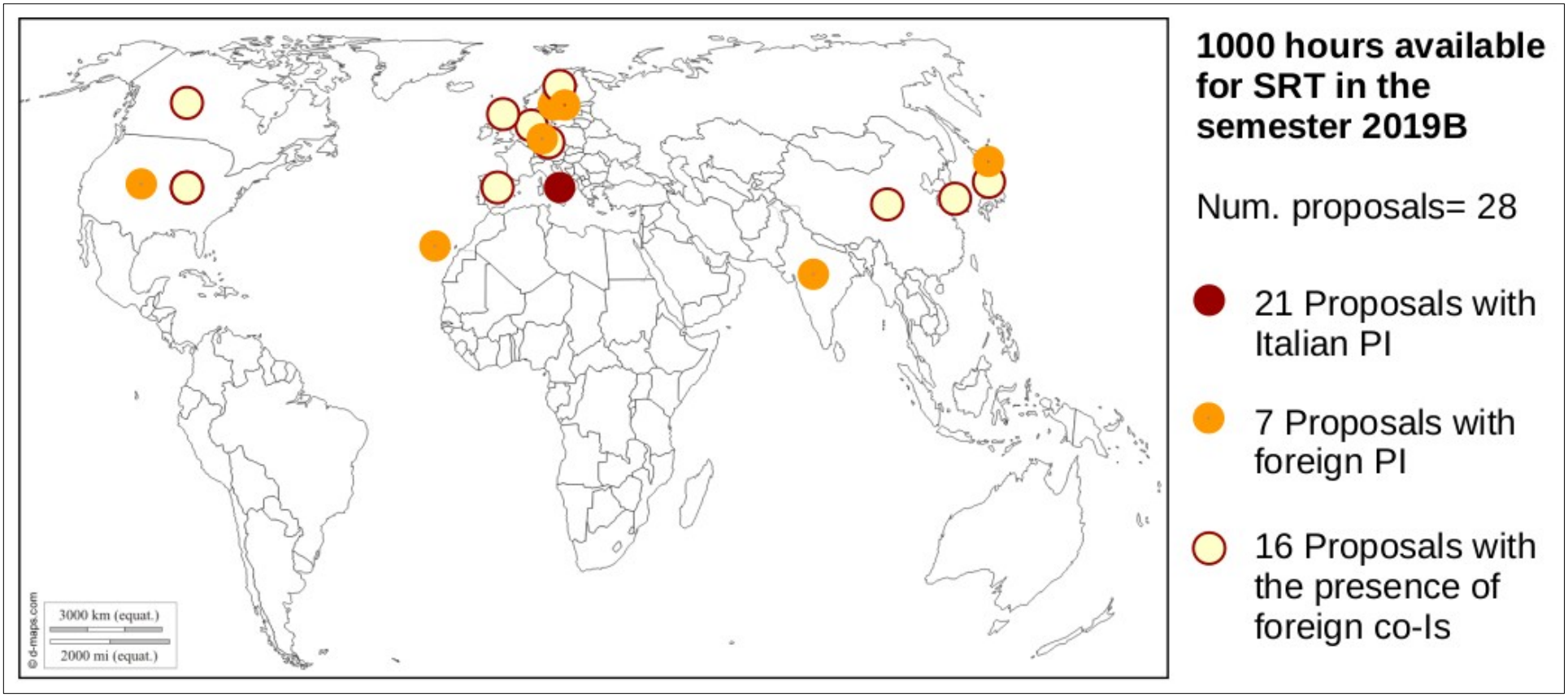
Semester 2019B (June 2019 – December 2019)

Report by Andrea Tarchi (chair of the TAC)



SINGLE-DISH and extra-EVN INTERFEROMETRIC OBSERVATIONS

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Future perspective for radio observations at high frequencies with the Italian radio telescope

Ministero dell'Istruzione dell'Università e della Ricerca

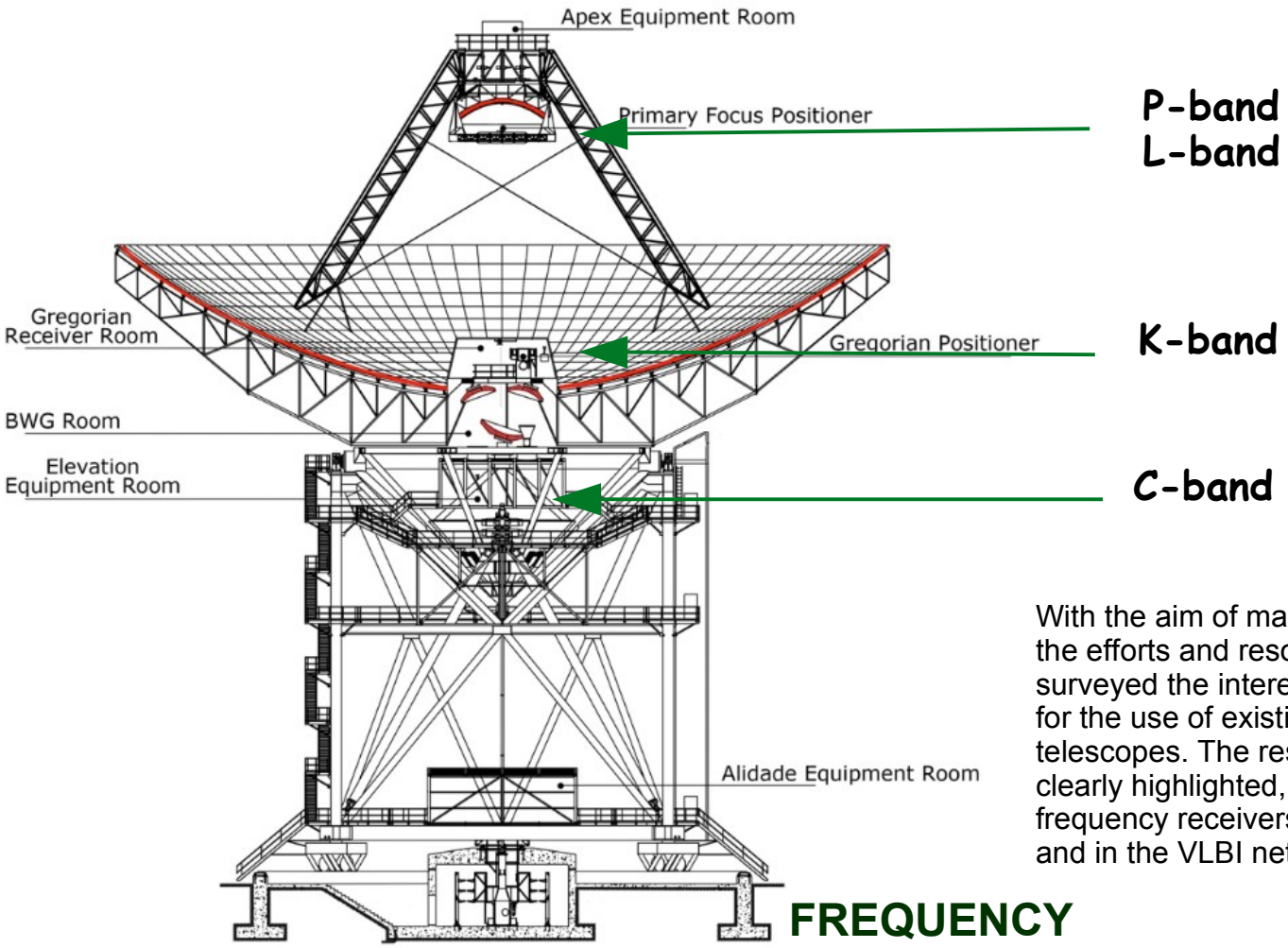
Dipartimento per la Formazione Superiore e per la Ricerca

Direzione Generale per il coordinamento, la promozione e la valorizzazione della ricerca

PON Ricerca e Innovazione 2014-2020

(CCI: 2014IT16M2OP005)

Call for proposals for grants aimed to enhance research infrastructures
National Operative Programme – Research and Innovation 2014-2020



P-band
L-band

K-band

C-band

With the aim of maximising the scientific return and harmonising the efforts and resources of the Institute, INAF has recently surveyed the interest of the Italian radio astronomical community for the use of existing and future receivers for italian radio telescopes. The result of this survey (Bolli et al., 2017), has clearly highlighted, for SRT, the interest in the use of high frequency receivers (> 20 GHz), both for single dish applications and in the VLBI network.

FREQUENCY

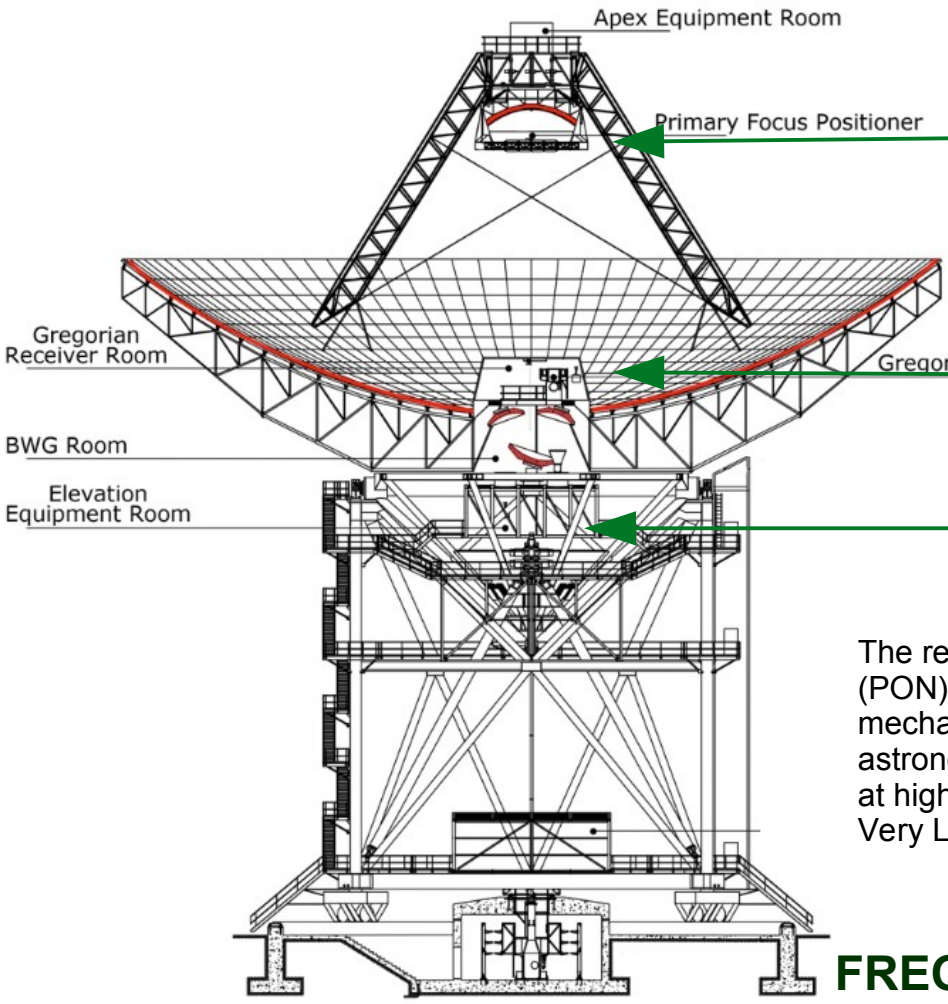
P-band 305-425 MHz
L-band 1.3-1.8 GHz

S-band 3.0-4.5 GHz

Clow-band 4.2-5.6 GHz

C-band 5.7-7.7 GHz

K-band multibeam 18-26 GHz



P-band
L-band

K-band

C-band

The recent upgrade of the active surface and the National Operative Program (PON) represent a great opportunity to equip SRT with all the electronic, mechanical and software systems necessary to allow the observation of radio astronomical sources at the highest radio frequencies. The contribution of SRT at high frequency will involve the use of SRT as a single dish and in the Very Long Baseline Interferometric (VLBI) network.

FREQUENCY

P-band 305-425 MHz
L-band 1.3-1.8 GHz

S-band 3.0-4.5 GHz

Clow-band 4.2-5.6 GHz

C-band 5.7-7.7 GHz

K-band multibeam 18-26 GHz

K/Q/W band VLBI

Q-band multibeam 33-50 GHz

W-band multibeam 75-116 GHz

W-band Camera 80-116 GHz

GOAL OF THE PROJECT

Enhancement of the SRT for the study of the Universe at high radio frequencies

ORGANISATIONAL STRUCTURE OF THE PROJECT

Operating Units directly involved in the project
The project is organized in 9 Work Packages (WP)

- Legal representative
  Nichi D'amico (INAF President)
- Scientific coordinator of the project
  Federica Govoni
- Financial officer in charge of the project
  Renata Schirrù

TIME SCALE OF THE PROJECT

32 months starting from Ministry Notification

BUDGET OF THE PROJECT

18.7 Meuro (15% outside Sardinia)
(the total amount must be spent within 32 months)
INAF cannot use the requested budget to hire personnel, for this reason we are investigating the interest of other Institutes in participating in calls for tender

WP1 - WP4 RECEIVERS

Acquiring, installing, and bringing in the operational phase high frequency radio astronomical receivers.

Multi-beam cryogenic receiver in W Band for SRT (75-116 GHz)

Coordinator: Alessandro Navarrini

Acquisition of a cryogenic receiver operating in the 75-116 GHz frequency band and composed of at least 9 double circular polarization beams.

Multi-beam cryogenic receiver in Q Band for SRT (33-50 GHz)

Coordinator: Alessandro Orfei

Development of a cryogenic receiver operating in the 33-50 GHz frequency band and composed of 19 double circular polarization beams.

Millimetre camera for SRT (80-116 GHz)

Coordinator: Matteo Murgia

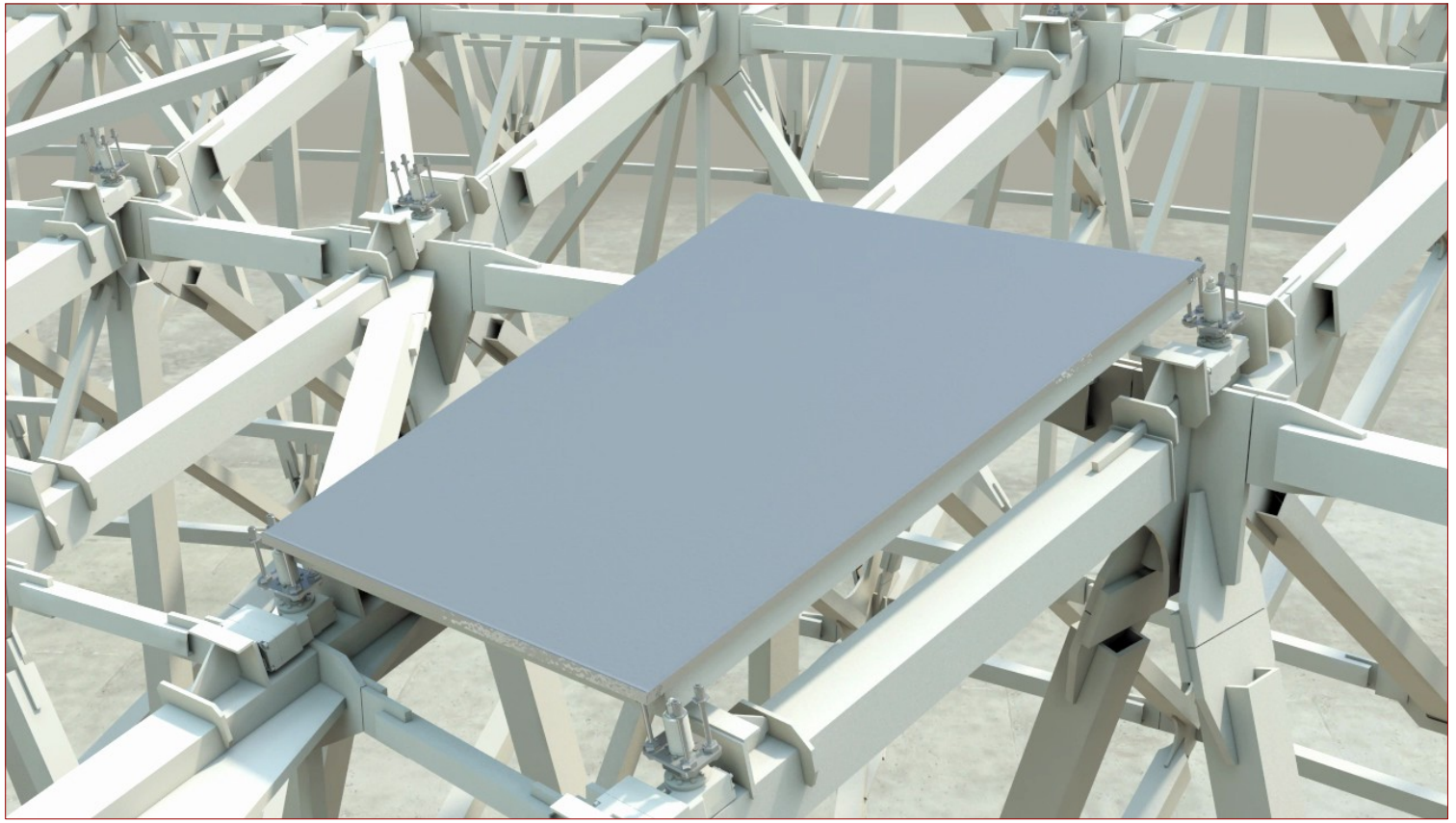
Supply of a millimeter chamber operating in the 80-116 GHz frequency band composed of an array of about 300 independent detectors (pixels) that simultaneously sample a wide field of view.

Simultaneous microwave compact triple-Band receiving system for the three Italian radio telescopes (18-26 ; 35-50; 85-116 GHz)

Coordinator: Pietro Bolli

Acquisition of a three-band microwave receiver system to be installed on SRT, Medicina and Noto. The acquisition of this system at the radio telescopes of Medicina and Noto is part of the activities carried out outside the Programme Area. This will have repercussions on the Program Area since adding the antennas of Medicina and Noto to the potential offered by SRT it will be possible to create a national VLBI interferometric network. Furthermore, the inclusion of the three Italian antennas in the millimeter global network will result in a significant expansion of the scientific potential of the VLBI.

WP5 – METROLOGY



ACTIVE SURFACE

Upgrading of SRT with a Metrological System

Coordinator: Sergio Poppi

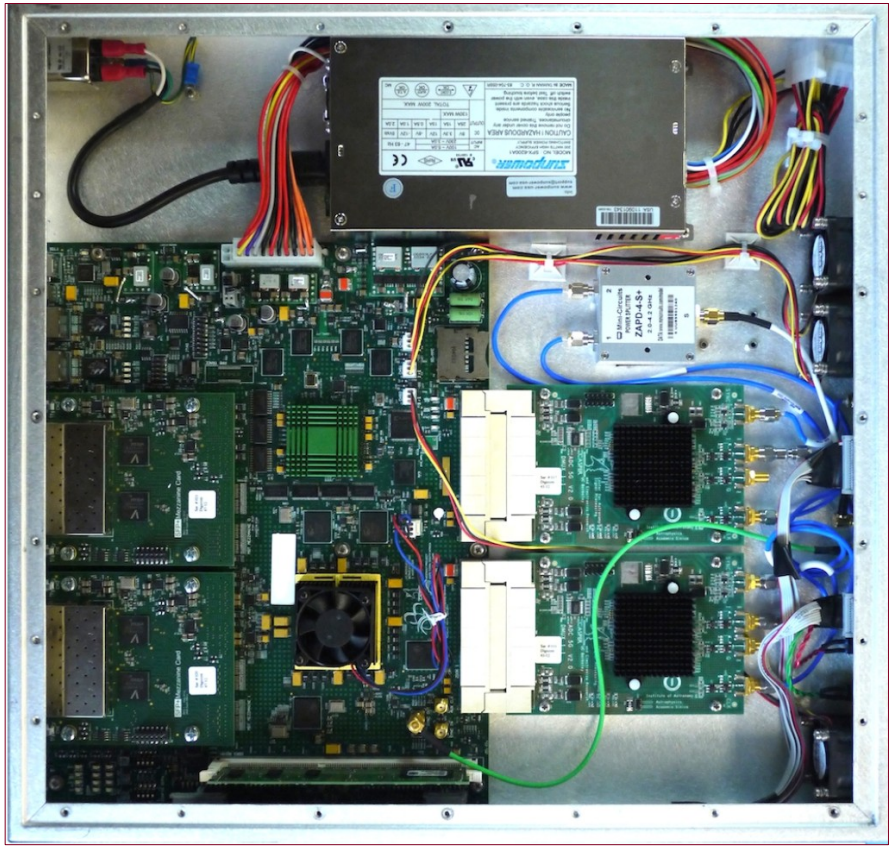
The aim is to optimize:
- Pointing performances
- Aperture efficiency and the gain of the antenna at all elevations
- Wind induced structural effects

The upgrade of the metrology system must contribute to reach the following key performance indicators:
- Surface accuracy (rms) of 150 micron
- Pointing error within 1 arcsec

WP6 - BACKENDS

State of the art Backend at the SRT:
SARDARA SArdinia Roach2-based Digital Architecture for Radio Astronomy up to 2500 MHz and 16k-channels, seven beams

Melis et al. (2018)



Upgrade of SRT Backends

Coordinator: Gianni Comoretto

The new high frequency receivers will be complemented by a backend system with a reconfigurable digital architecture capable of processing the signal for high resolution spectro-polarimetric observations over a wide range of frequencies and in multi beam mode.

WP7 – INTEGRATION OF THE SYSTEM

System Integration with new devices

Coordinator: Andrea Orlati

The set of acquired devices that will include new receivers, new backends and the metrology system will be integrated through a "turnkey" supply of electronic and mechanical interfaces, allowing the radio telescope as a whole to operate at high frequencies, optimizing the frequency agility.

WP8– HIGH PERFORMANCE COMPUTING (HPC)

New HPC and storage systems for the archival and the use of the SRT data

Coordinator: Andrea Possenti

Supply of ICT resources, in particular for data storage and processing, necessary for the archiving and analysis of data obtained with SRT. The data, which will become public after one year from the observation, will be archived and in the long term will constitute a mine of information that will allow to produce further science at high level.

WP9 – LABORATORIES

Upgrade of laboratories for the development of microwave technologies

Coordinator: Tonino Pisanu

Upgrade of the instrumental equipment of the three laboratories (mechanical, electronics, and microwaves) at the Astronomical Observatory of Cagliari.

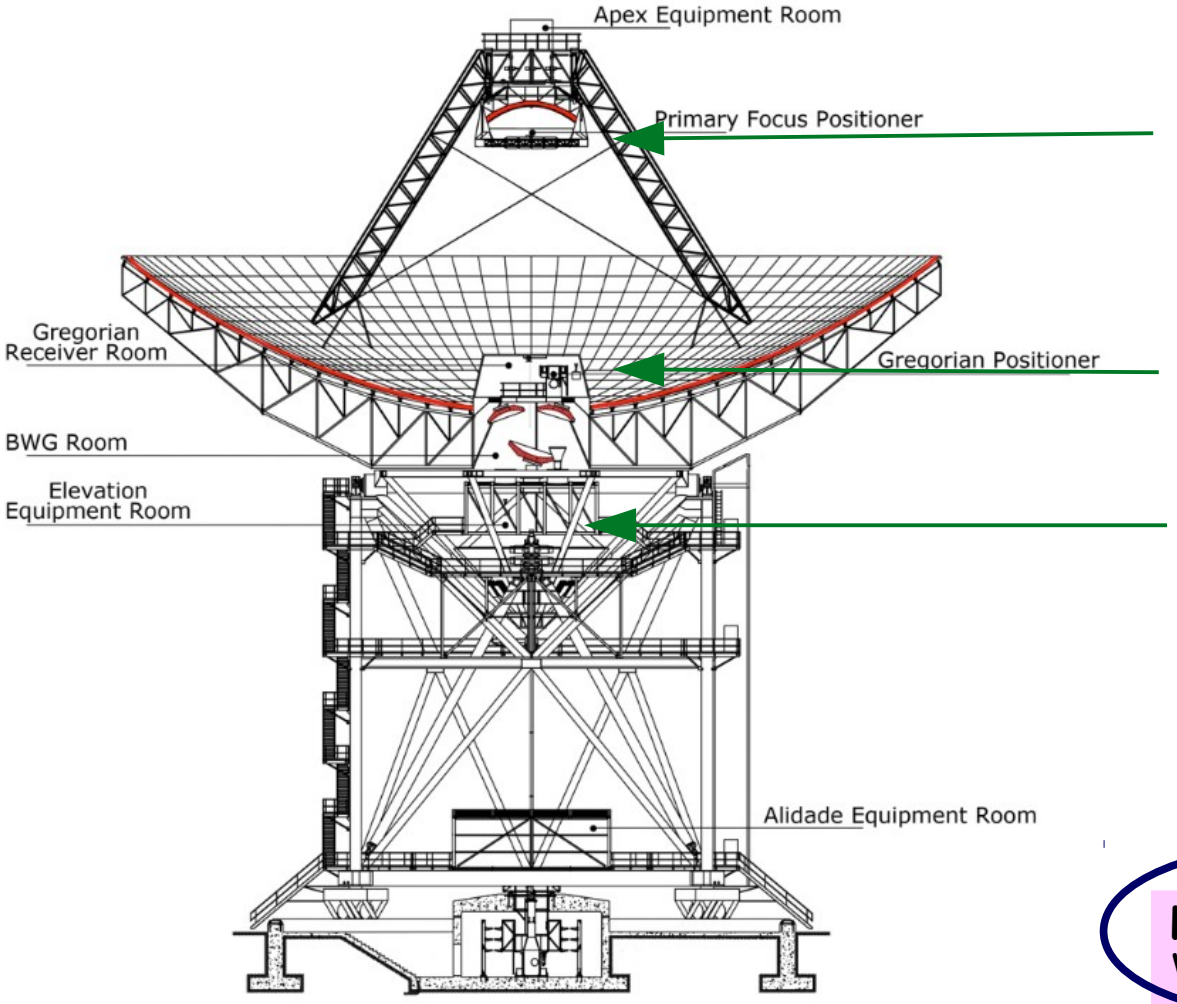
Particular attention has been paid to the purchase of instrumentation for laboratories, to guarantee that the effects of the upgrading of SRT will be mantained for at least ten years. In fact, such laboratories will permit not only to test and characterize the new backends and receivers that will enhance the scientific performance of the radio telescope, but at the same time will allow the monitoring, maintenance and updating of the various radio telescope devices.

Timeline and Budget of the 9 Work Packages

	OR / Mese	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	
WP1	Ricevitore criogenico multi-beam in Banda W (3mm) per SRT	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	2.850
WP2	Ricevitore criogenico multi-beam in Banda Q per SRT	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■				1.035
WP3	Camera millimetrica per SRT	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			2.700
WP4	Sistema ricevente a microonde compatto e simultaneo a tre-bande per i tre radio telescopi Italiani	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■				3.000
WP5	Sistema metrologico per SRT			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		2.300
WP6	Backends per SRT													■	■	■	■	■	■	■	■	■												1.555
WP7	Fornitura delle interfacce elettroniche e meccaniche per l'integrazione dei nuovi sistemi				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	2.498
WP8	HPC e sistemi di archiviazione per raccolta ed uso dati SRT																		■	■	■	■	■	■										1.400
WP9	Potenziamento dei laboratori per lo sviluppo di tecnologie a microonde																				■	■	■	■	■	■	■	■	■					1.345

18.683 (MEuro)

SRT AFTER ITS ENHANCEMENT FOR THE STUDY OF THE UNIVERSE AT HIGH FREQUENCIES



P-band
L-band

K-band

C-band

SRT
MEDICINA
NOTO

VLBI Backends for SRT, Medicina, and Noto

K/Q/W band
VLBI

W-band
Camera
80-116 GHz

P-band 305-425 MHz
L-band 1.3-1.8 GHz

C-band
5.7-7.7 GHz

K-band multibeam
18-26 GHz

S-band
3.0-4.5 GHz

Clow-band
4.2-5.6 GHz

Q-band
multibeam
33-50 GHz

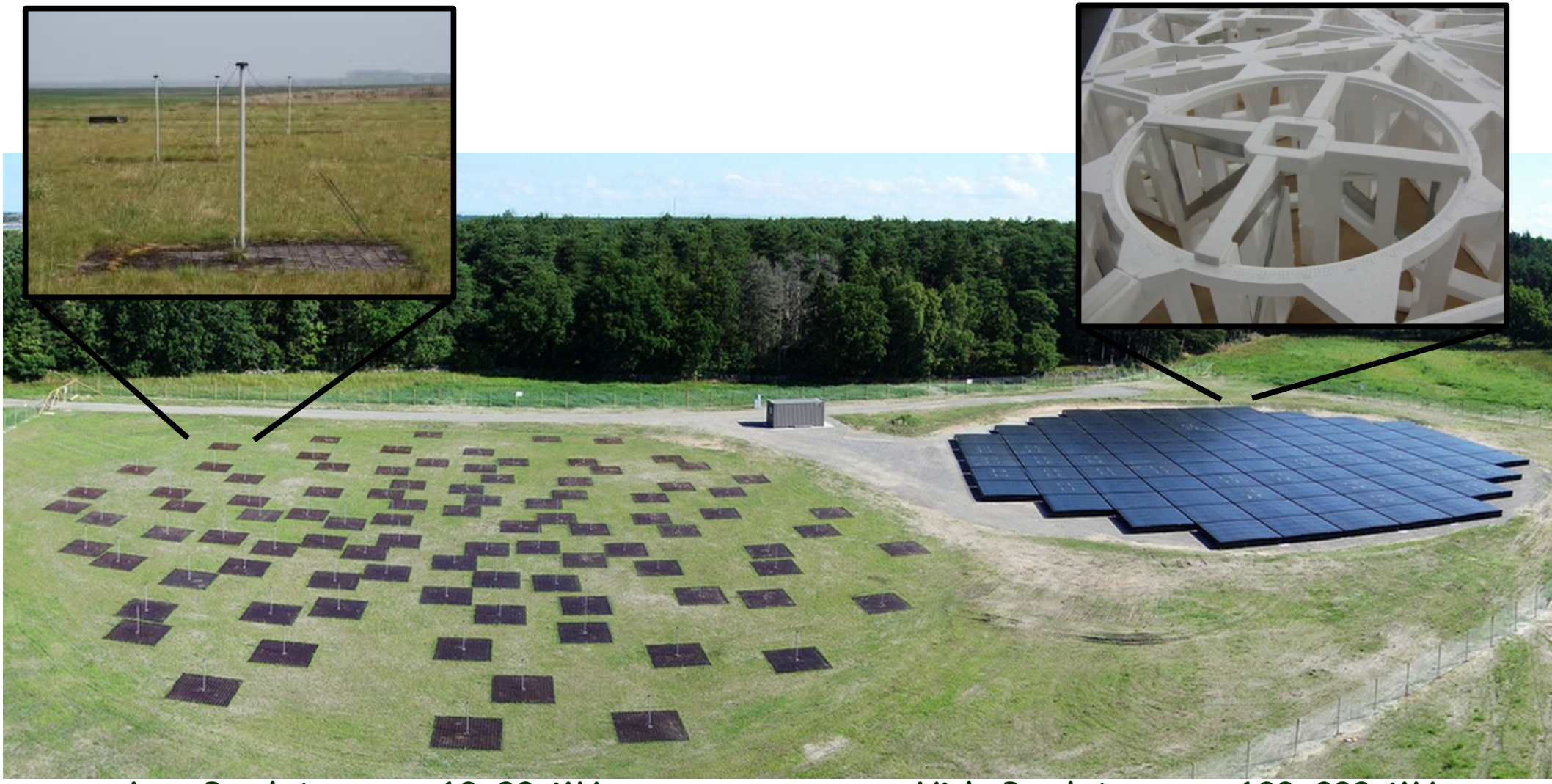
W-band
multibeam
75-116 GHz

LOFAR (LOw Frequency ARray)

(1) CORE – 24 Stations (arcmin resolution)
(2) REMOTE NL – 14 Stations; 10-100 Km baselines; 5-10 arcsec resolution
(3) INTERNATIONAL – 13 stations; 100 – 1000 Km; sub-arcsec resolution

LOFAR (LOw Frequency ARray)

Giant digital aperture array opening up a new window in the electromagnetic spectrum at low radio frequencies.



Low-Band Antennas 10-90 MHz

High-Band Antennas 120-200 MHz

The largest (collecting area and data flow) pathfinder toward the SKA.

LOFAR

Direzione Scientifica
Divisione Nazionale Abilitante per la Radioastronomia
National Division for Radioastronomy

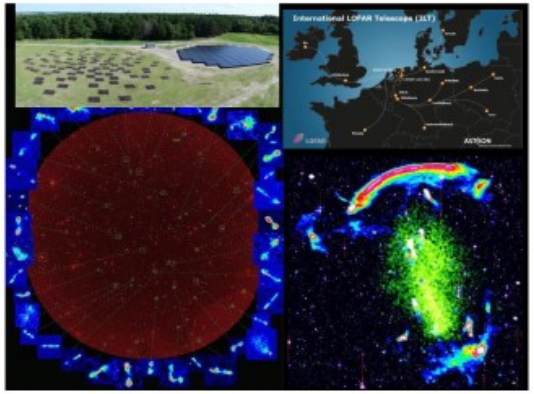
INAF
ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

ROADMAP PER LA PARTECIPAZIONE DI INAF AL LOW FREQUENCY ARRAY (LOFAR)

G. Brunetti, F. Govoni

con il contributo del Working Group WG-F03-01

U.Becciani (INAF Osservatorio Astrofisico Catania)
P.Bolli (INAF Osservatorio Astrofisico Arcetri)
A.Bonafede (INAF IRA Bologna)
J.Monari (INAF IRA Medicina)
M.Nanni (INAF IRA Bologna)
F.Perini (INAF IRA Medicina)
G.Taffoni (INAF Osservatorio Astronomico Trieste)



- Italy is in the ILT Board

- LOFAR station v2.0 in 2021/2022 (Medicina – Bologna)

- Scientific Involvement (about 30 staff members in KSPs, guarantee time 30h per semester)

LOFAR

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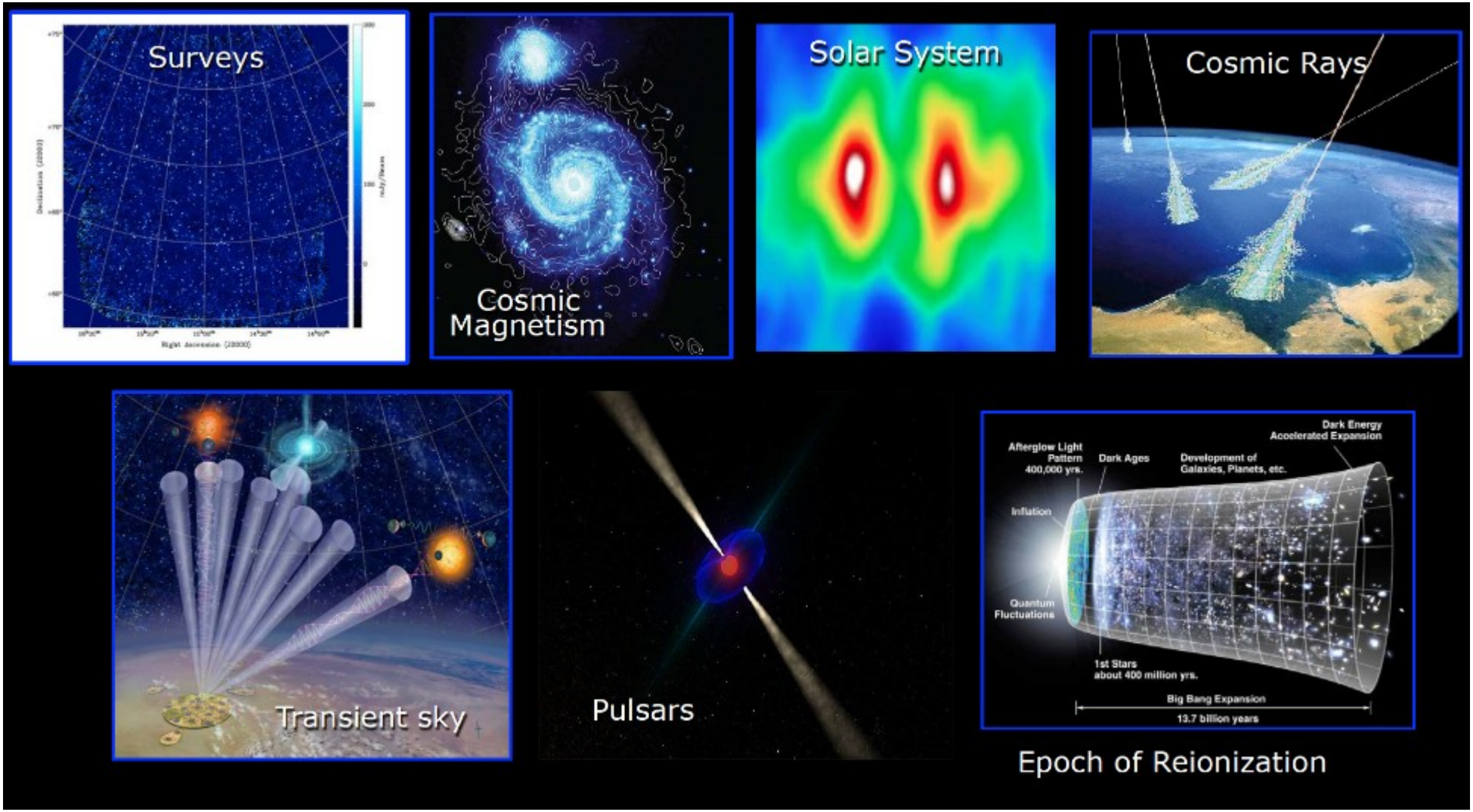
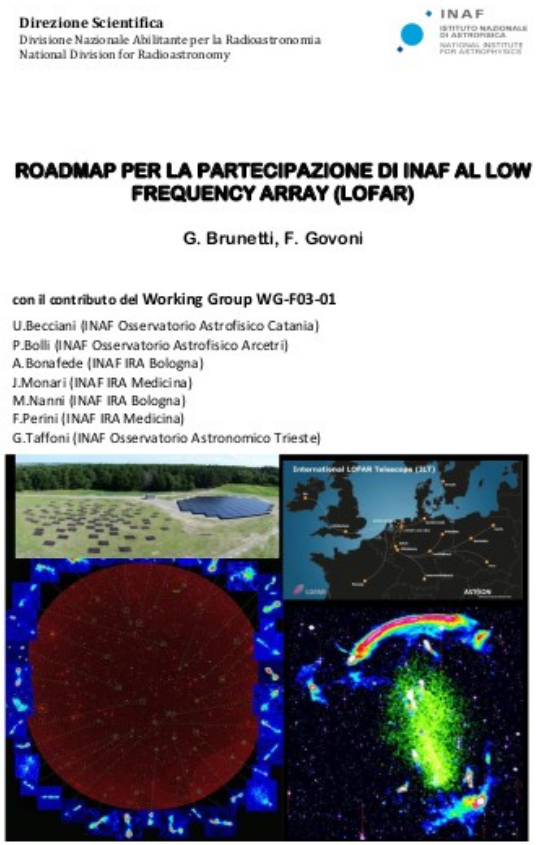
- Scientific Involvement (about 30 staff members in KSPs, guarantee time 30h per semester)



LOFAR


Direzione Scientifica
Divisione Nazionale Abilitante per la Radioastronomia
National Division for Radioastronomy

INAF
ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

ROADMAP PER LA PARTECIPAZIONE DI INAF AL LOW FREQUENCY ARRAY (LOFAR)

G. Brunetti, F. Govoni

con il contributo del Working Group WG-F03-01

U.Becciani (INAF Osservatorio Astrofisico Catania)
P.Bolli (INAF Osservatorio Astrofisico Arcetri)
A.Bonafede (INAF IRA Bologna)
J.Monari (INAF IRA Medicina)
M.Nanni (INAF IRA Bologna)
F.Perini (INAF IRA Medicina)
G.Taffoni (INAF Osservatorio Astronomico Trieste)

- Italy is in the ILT Board

- LOFAR station v2.0 in 2021/2022 (Medicina – Bologna)

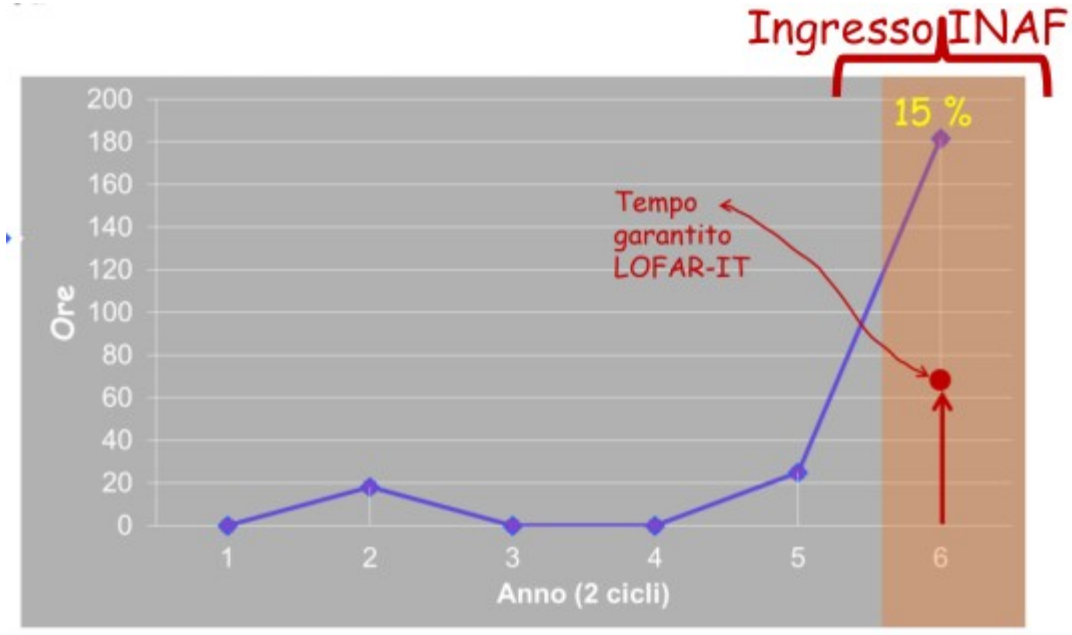
- Scientific Involvement (about 30 staff members in KSPs, guarantee time 30h per semester)

- Technological involvement (upgrade LOFAR stations v2.0 RCU + possible involvement in data reduction pipelines)

- Italian LOFAR data analysis Infrastructure (Trieste – Catania – IRA – Univ. Torino)

- The first italian LOFAR school (11-14 June 2019) and 3 post doct positions in the next future

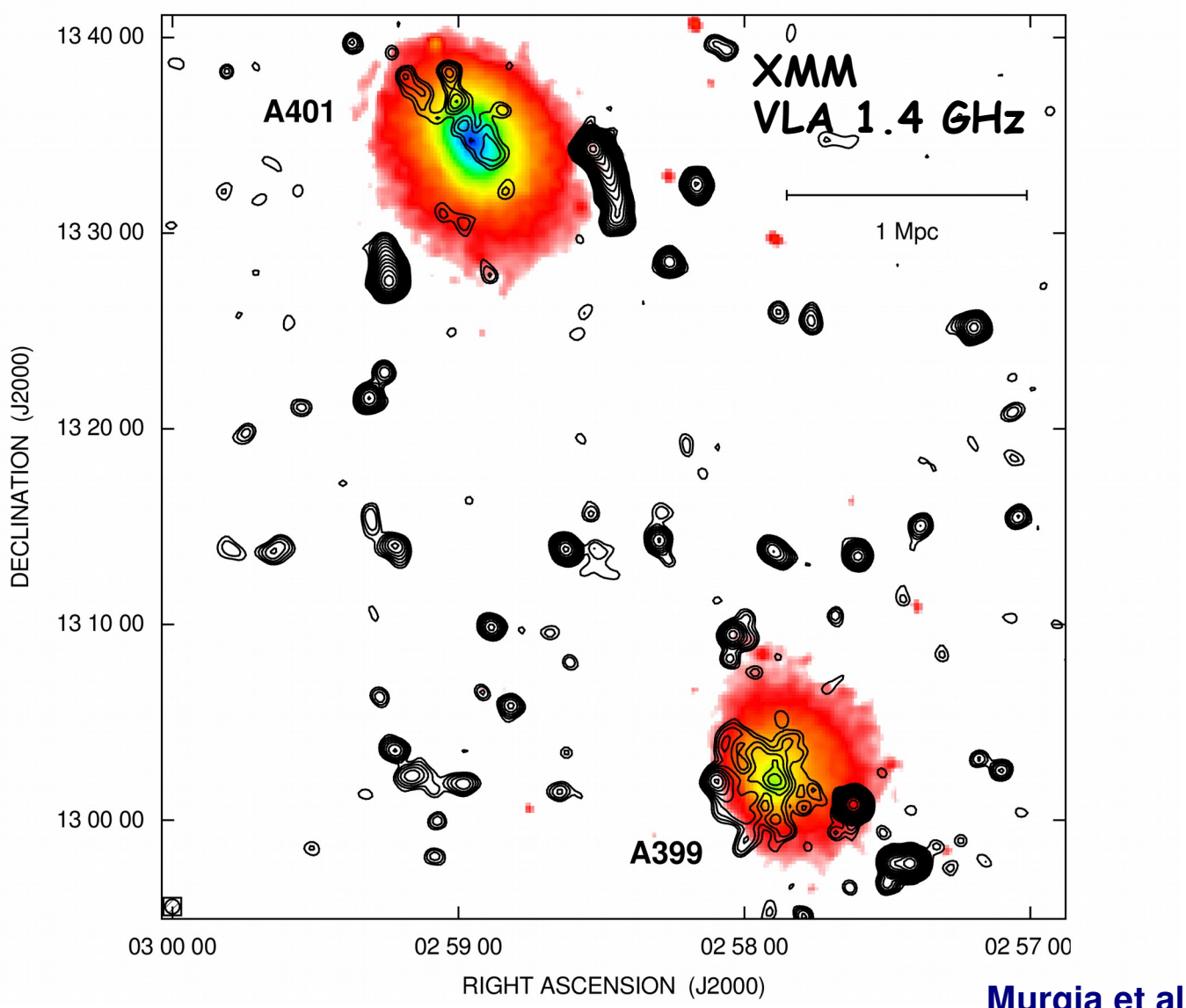
DEVELOP A COMMUNITY THAT IS ABLE TO WORK WITH LOFAR DATA



http://www.lofar.inaf.it

Magnetic fields beyond galaxy clusters

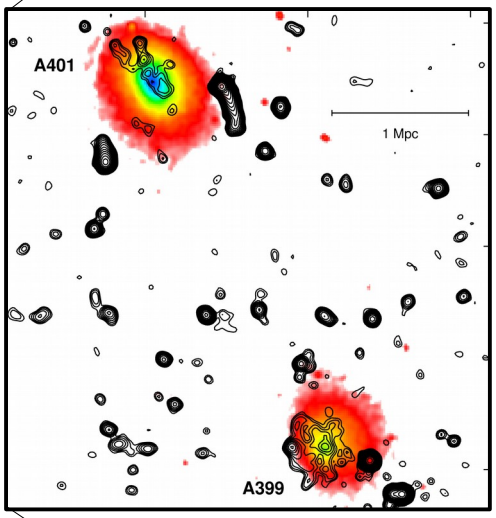
→ POSSIBLE COLLABORATION BETWEEN ITALY AND UKRAINE

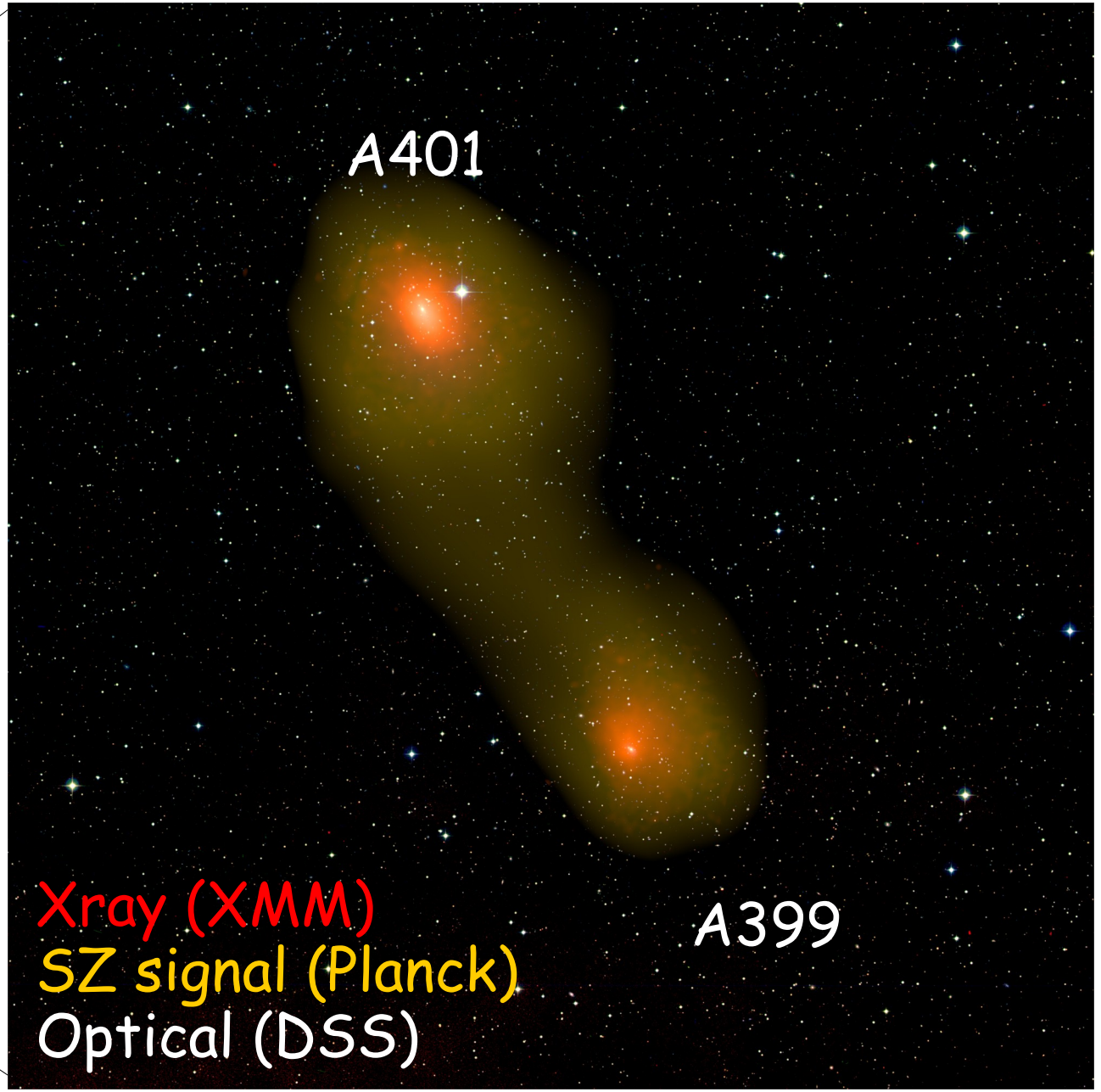


Murgia et al. (2010)

Pre-merging system A399-A401 at z~0.07
Galaxy clusters at a projection distance of ~3Mpc
Double radio halo discovered with the VLA at 1.4 GHz

Magnetic fields beyond galaxy clusters

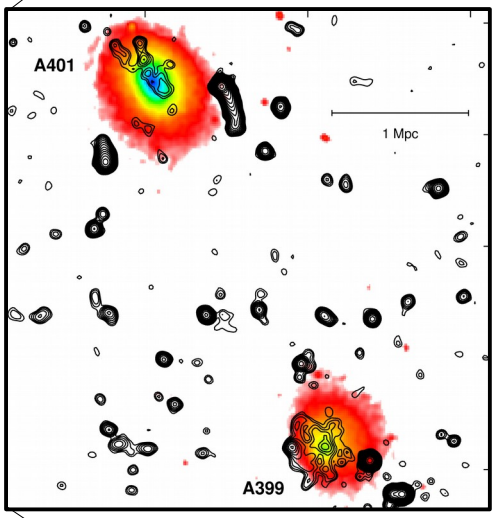




Isothermal filament of weak plasma detected by Planck between A399-A401

Planck Collaboration et al. (2013, 2016)

Magnetic fields beyond galaxy clusters

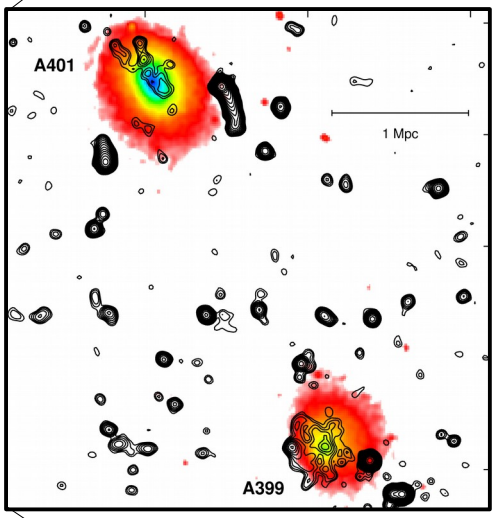


LOFAR
140 MHz
50" resolution
0.8 mJy/beam

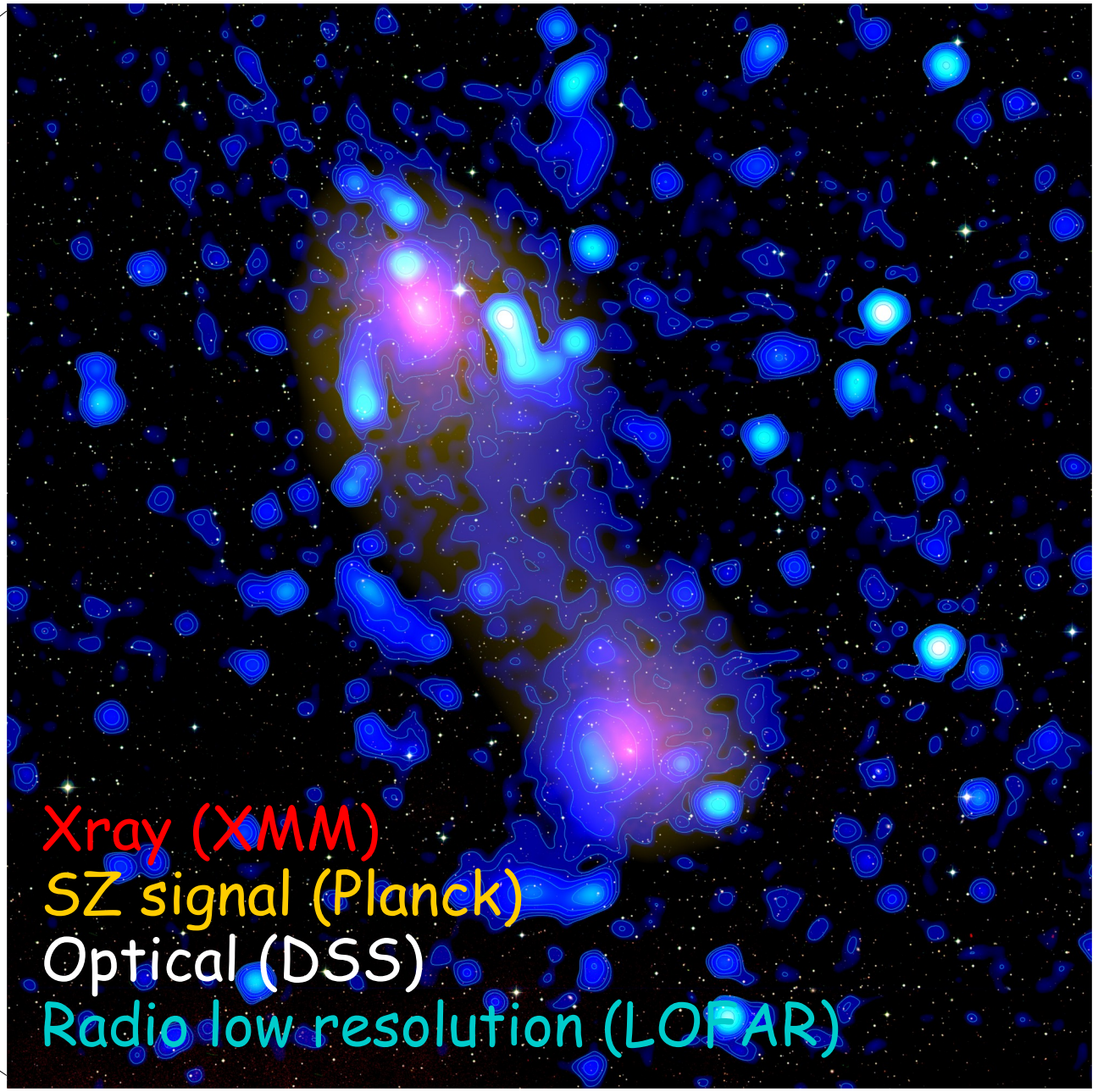
Xray (XMM)
SZ signal (Planck)
Optical (DSS)
Radio high resolution (LOFAR)

Govoni et al. (2019)

Magnetic fields beyond galaxy clusters

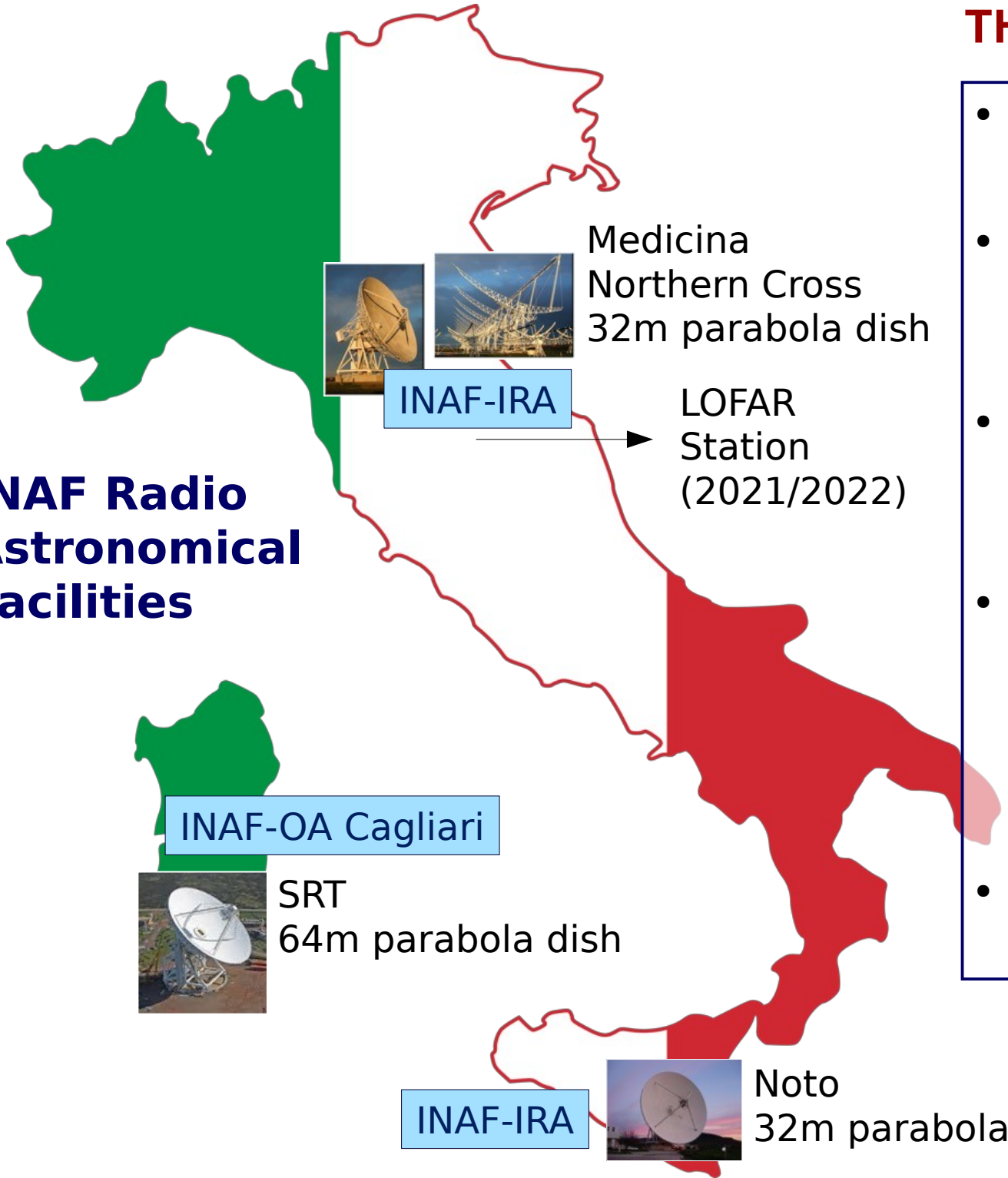


LOFAR
140 MHz
80" resolution
1 mJy/beam



Science AAAS

Govoni et al. (2019)



THANK YOU!!!!

- Status of the SRT, Medicina, and Noto
- SRT, Medicina, and Noto in the European VLBI Network (EVN)
- Italian scientific highlights with the VLBI technique
- Future perspectives for radio observations at high frequencies with the Italian radio telescopes
- Status of the LOFAR project in Italy