THE ROLE OF CURRENT AND FUTURE ITALIAN RADIO TELESCOPES

Federica Govoni

INAF - Osservatorio Astronomico di Cagliari

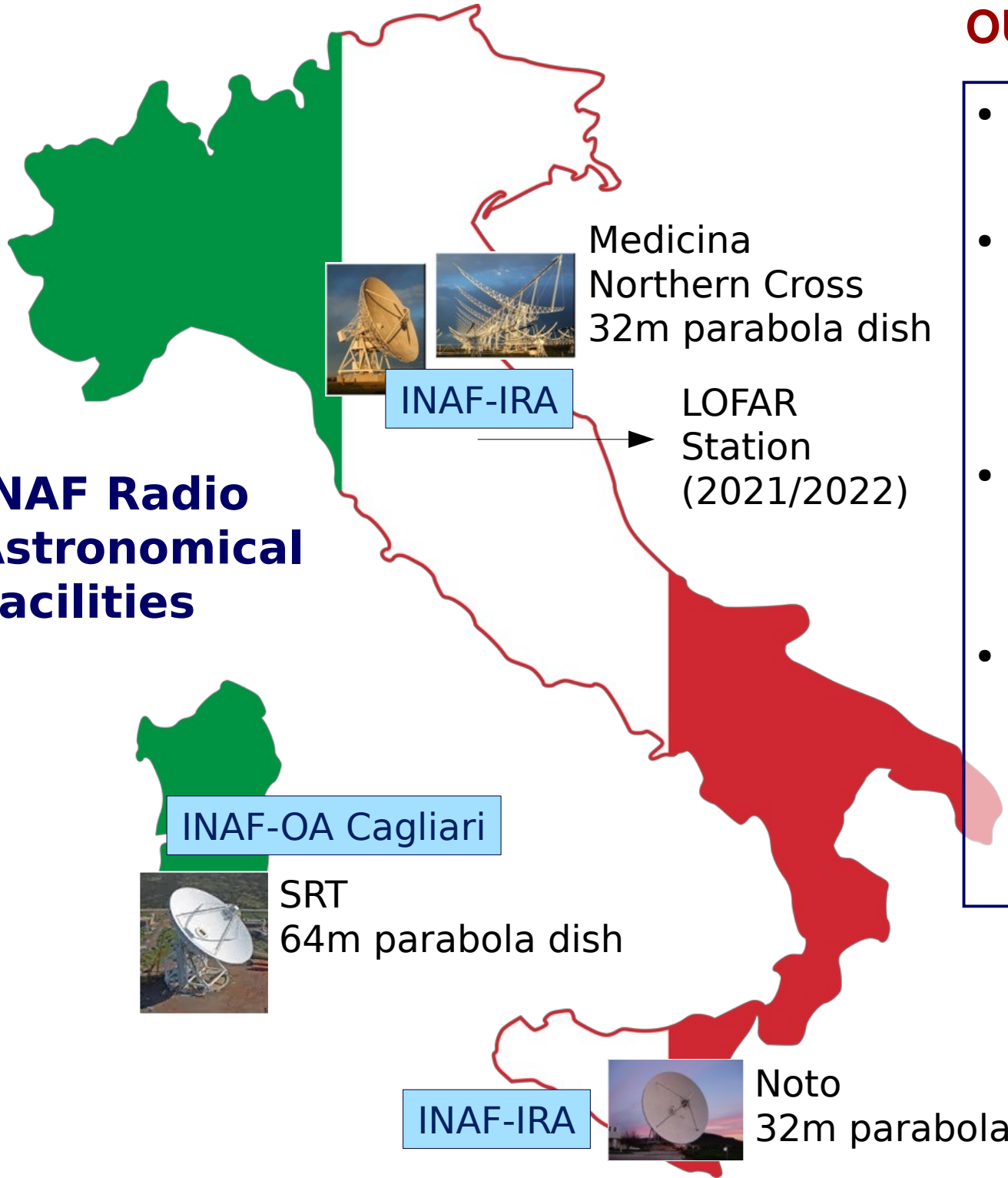
Coordinator of the Division II (Radio Astronomy) of the INAF Scientific Directorate

The era of collaborative multi-wavelength and multi-messenger astronomy:
science and technology

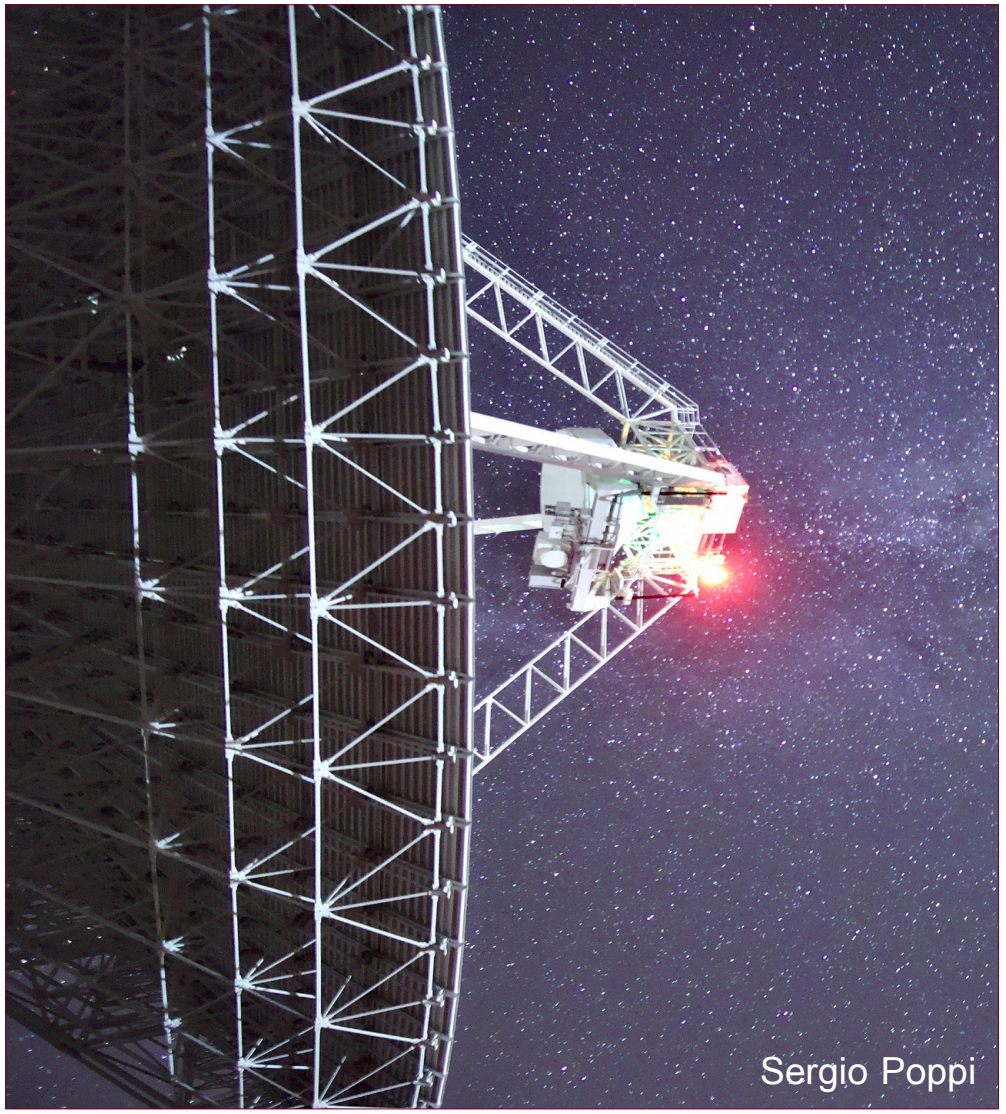
The 2nd Pietro Baracchi Conference, 22-24 October 2019
Firenze - Italy

OUTLINE OF THE TALK

- Status of the SRT, Medicina, and Noto
- SRT, Medicina, and Noto as single dishes and in the European VLBI Network (EVN)
- Multi-messenger era with the radio astronomical facilities
- Future perspectives for radio observations at high frequencies with the Italian radio telescopes



Status of the SRT, Medicina, and Noto



Timeline of the SRT

June 2012 – October 2013:
Technical commissioning

February 2012 - January 2016:
Astronomical Validation

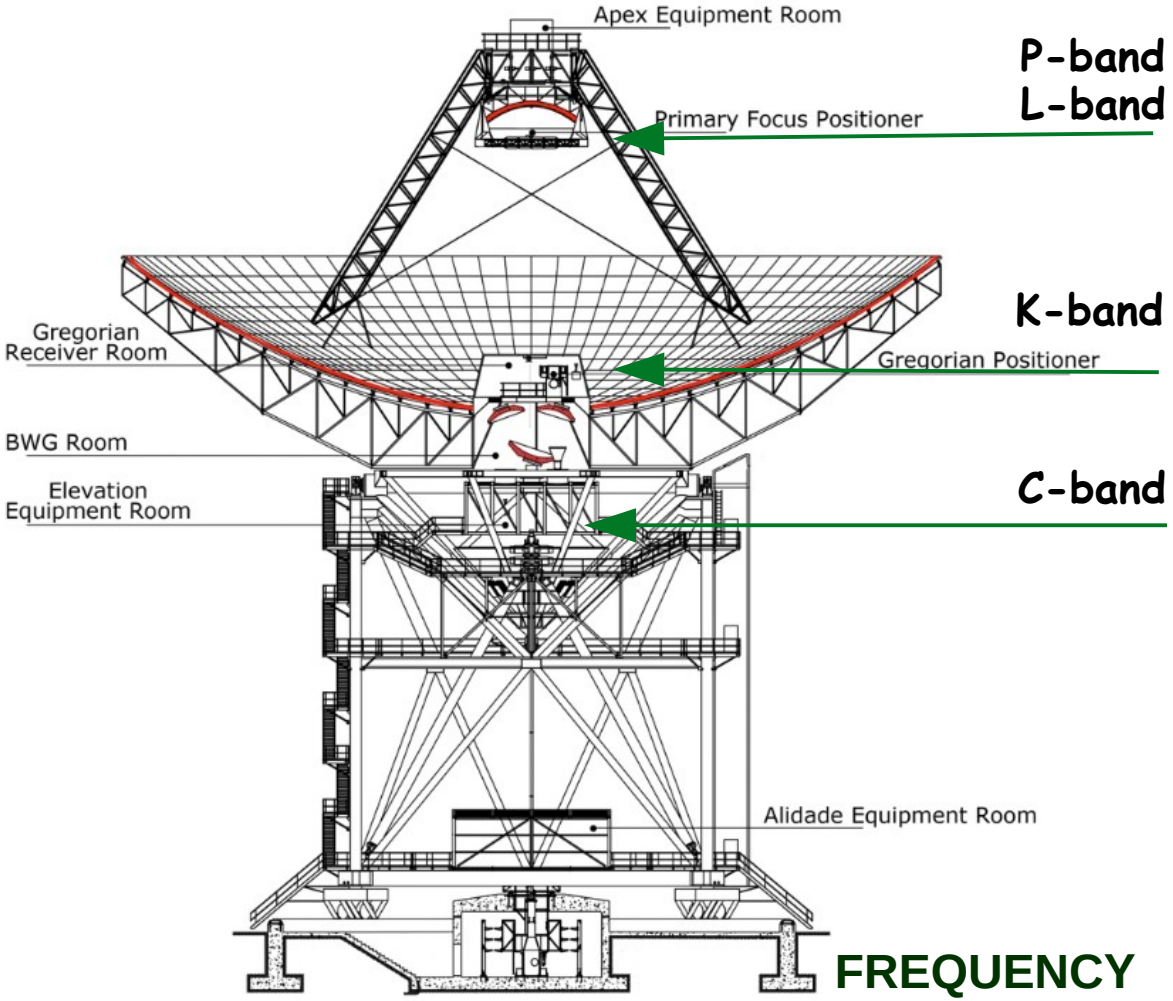
February - August 2016:
Early Science Program

2017
Refurbishment of active surface
Buildings and structures completed

2018
Re-commissioning
First open call

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 305-410 MHz
L-band 1.3-1.8 GHz
Coaxial

Chigh-band 5.7-7.7 GHz

K-band multibeam 18-26.5 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

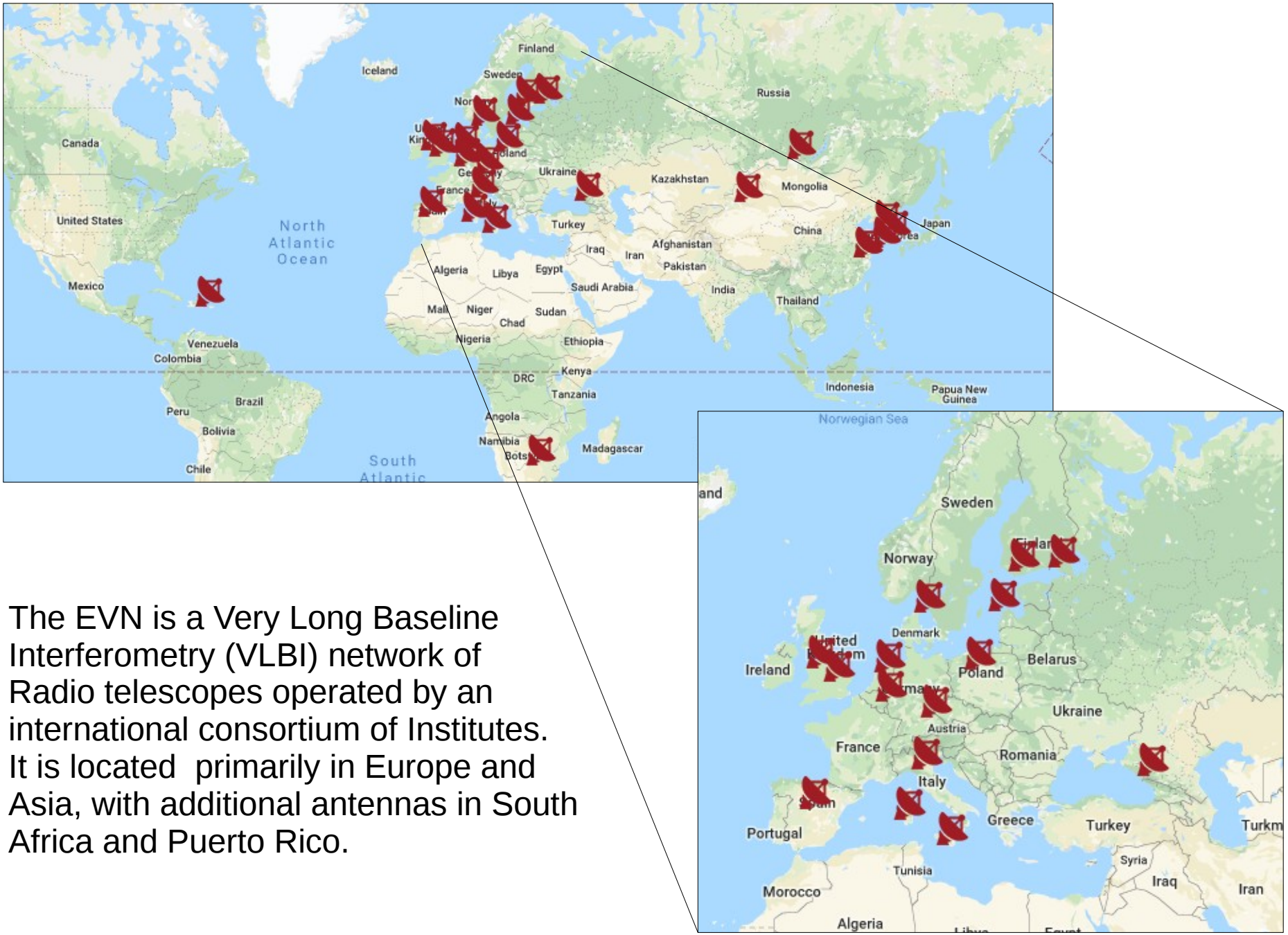
K-band 18-26.5 GHz

Ku-band 13.5-17.5 GHz

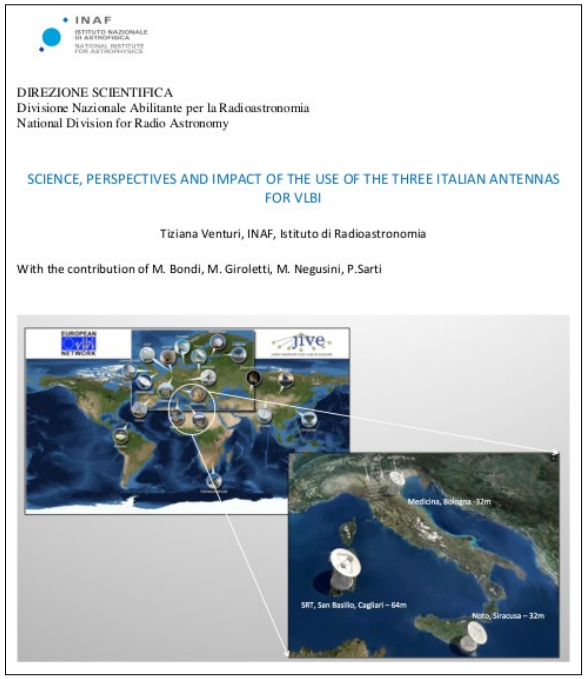
Medicina is the only Italian telescope without a facility for extending its operating frequencies up to 100 GHz; deformations due to gravity prevents good aperture efficiency at frequencies higher than the K-band.

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

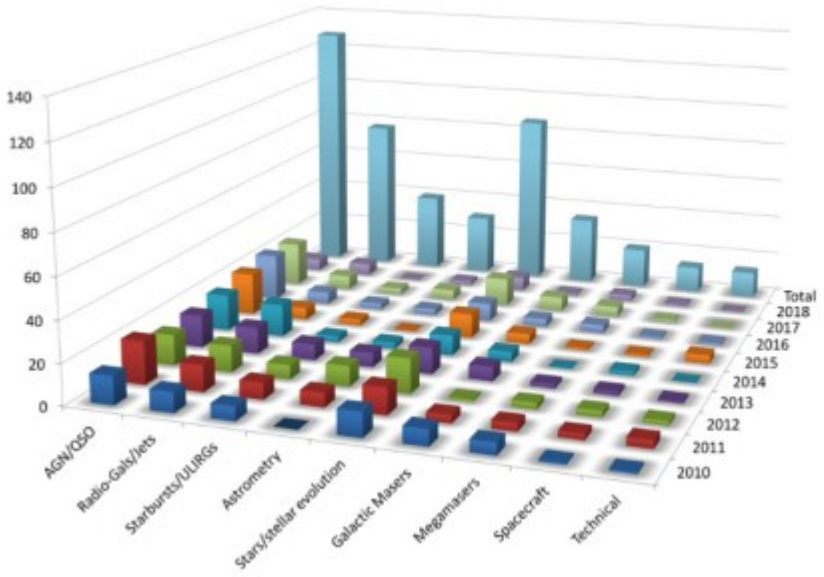
SCIENCE, PERSPECTIVES AND IMPACT OF THE USE OF THE THREE ITALIAN ANTENNAS FOR VLBI

Tiziana Venturi, INAF, Istituto di Radioastronomia

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

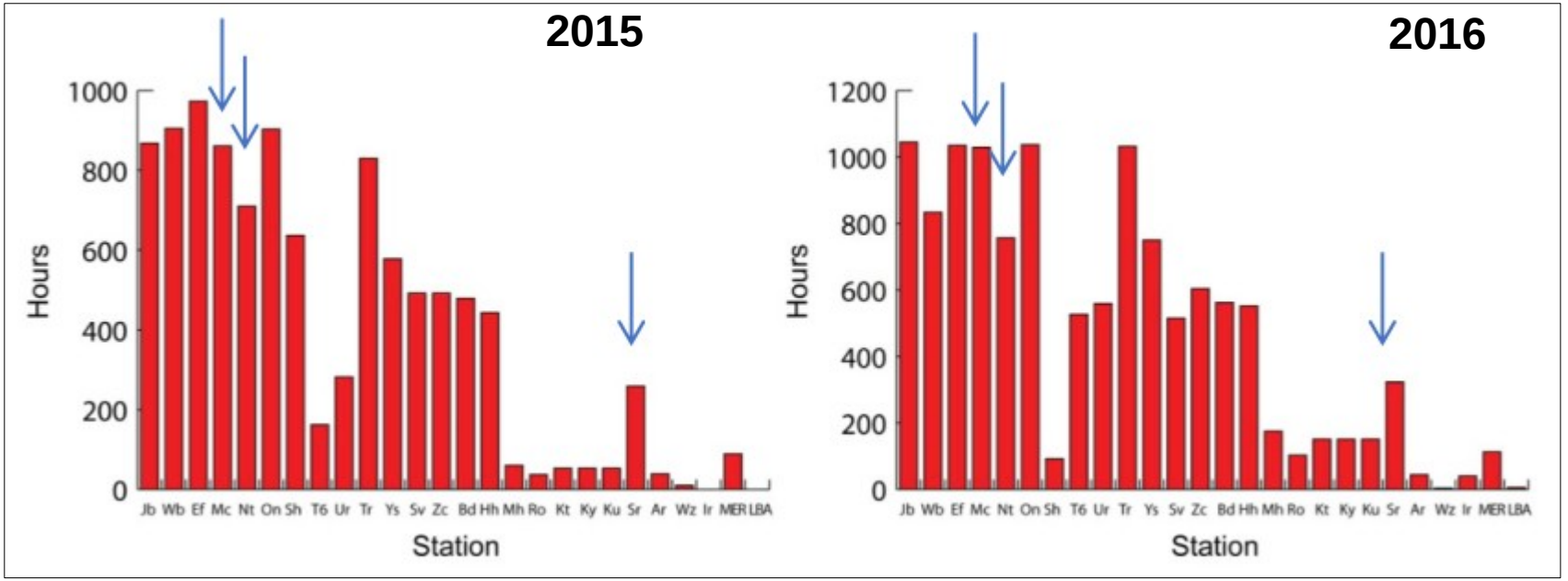
Report by Tiziana Venturi

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

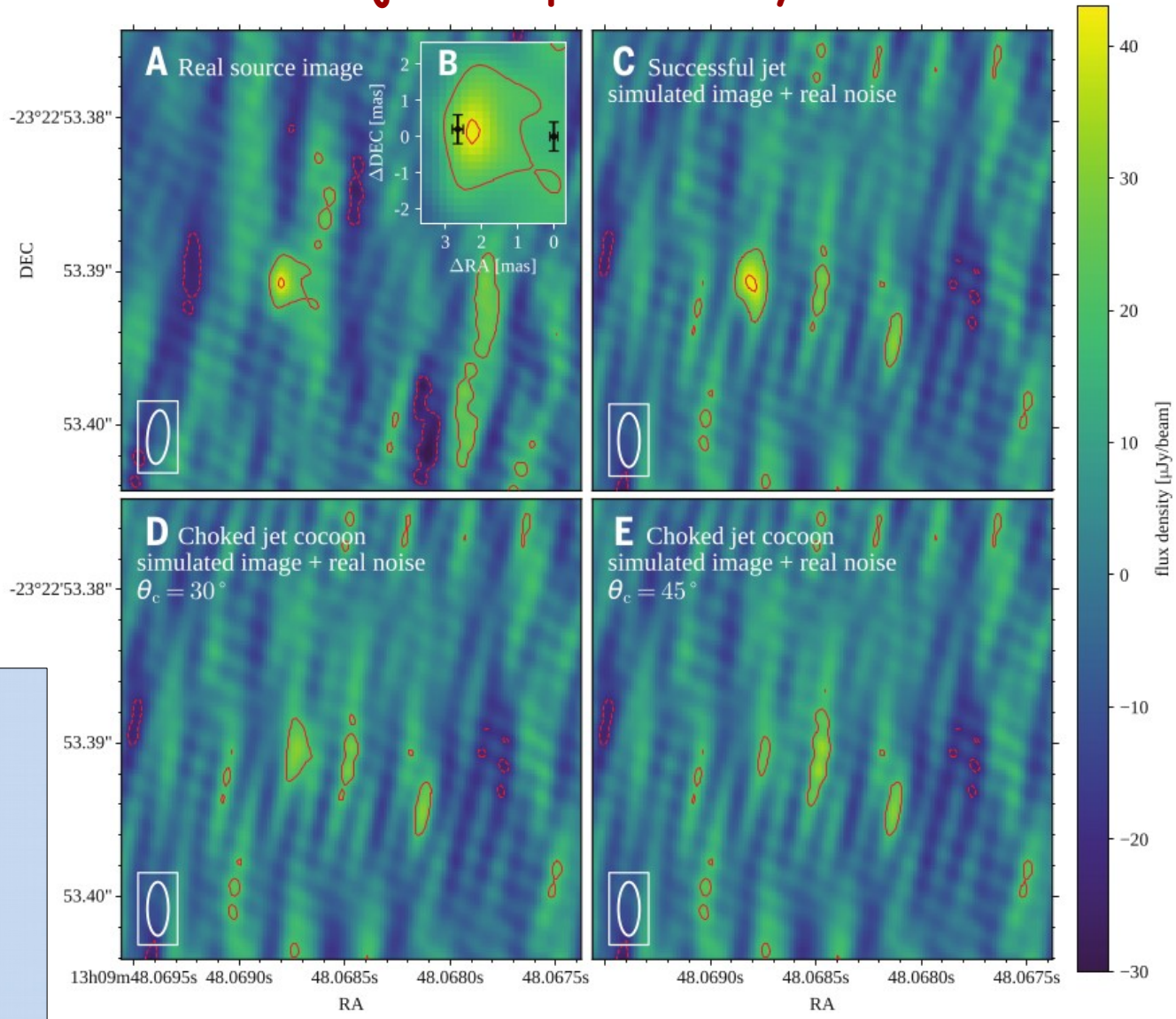
Number of hours for each EVN antenna (3 weeks – 3 times in a year)



Taken from EVN biennial report 2015-2016

Compact radio emission indicates a structured jet was produced by a binary neutron star merger

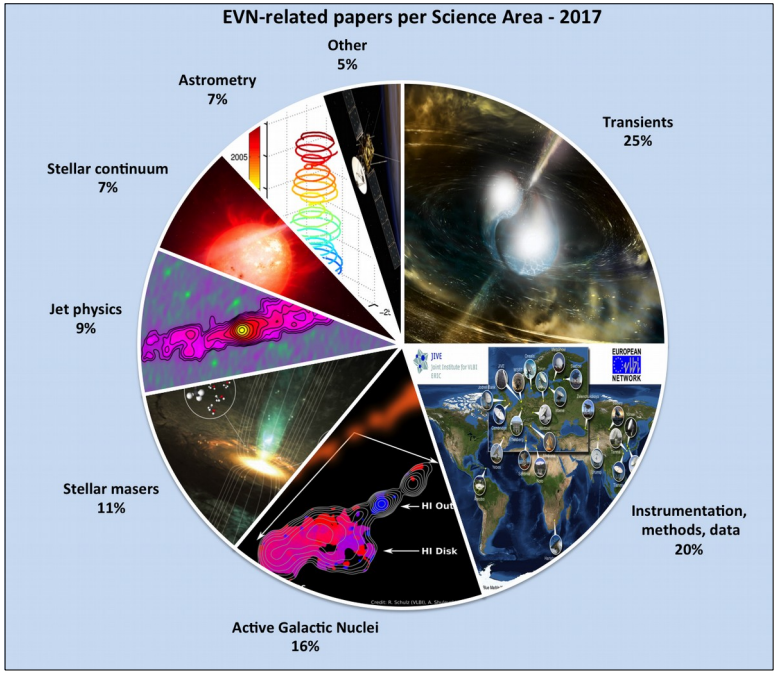
The gravitational waves signal detected by LIGO and VIRGO of the binary neutron star merger GW170817 was detected in both gravitational waves and electromagnetic emission



Ghirlanda et al. (2019, Science)

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

Credits: Z. Paragi



Requesting Observation Time at the Italian Radio Telescopes

http://www.radiotelescopes.inaf.it

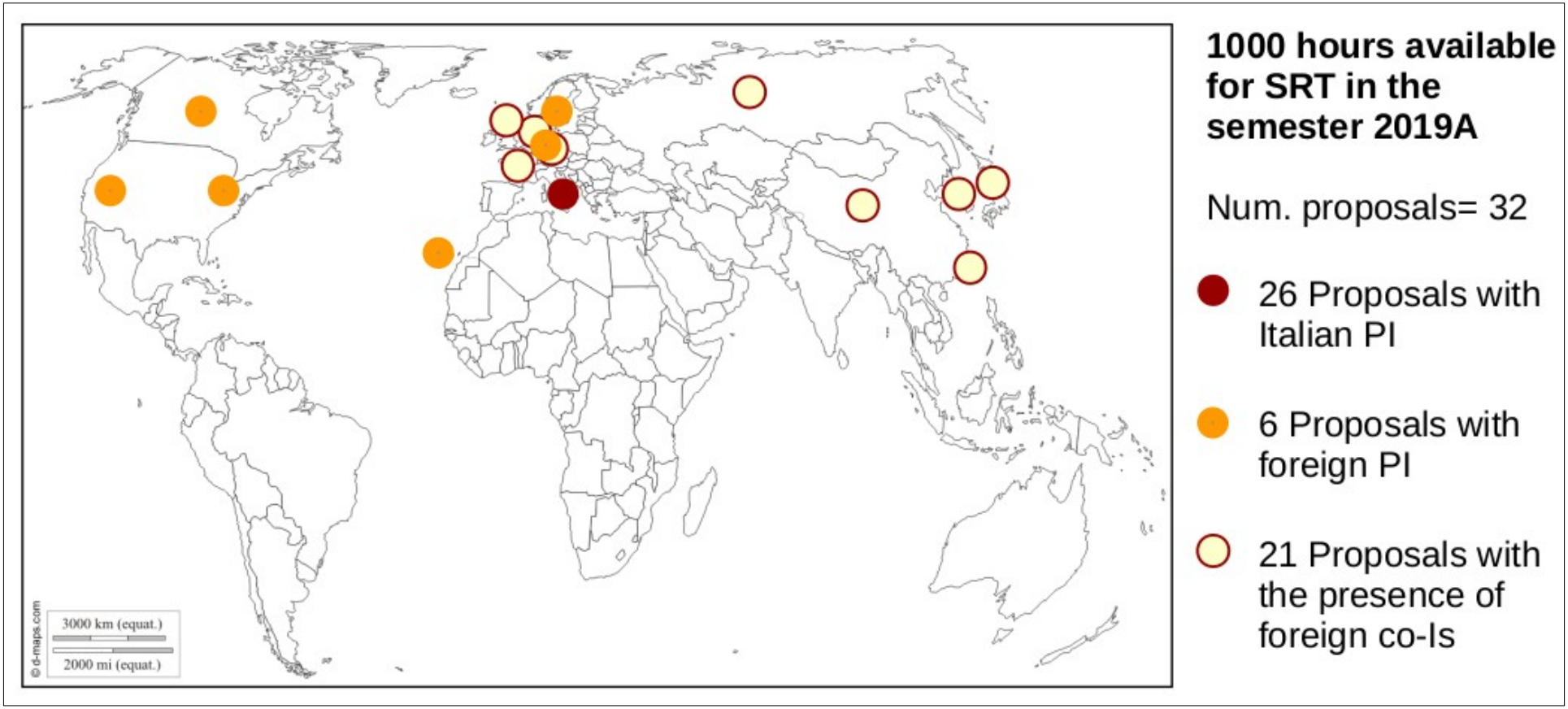
Semester 2020A; Deadline 3 October 2019

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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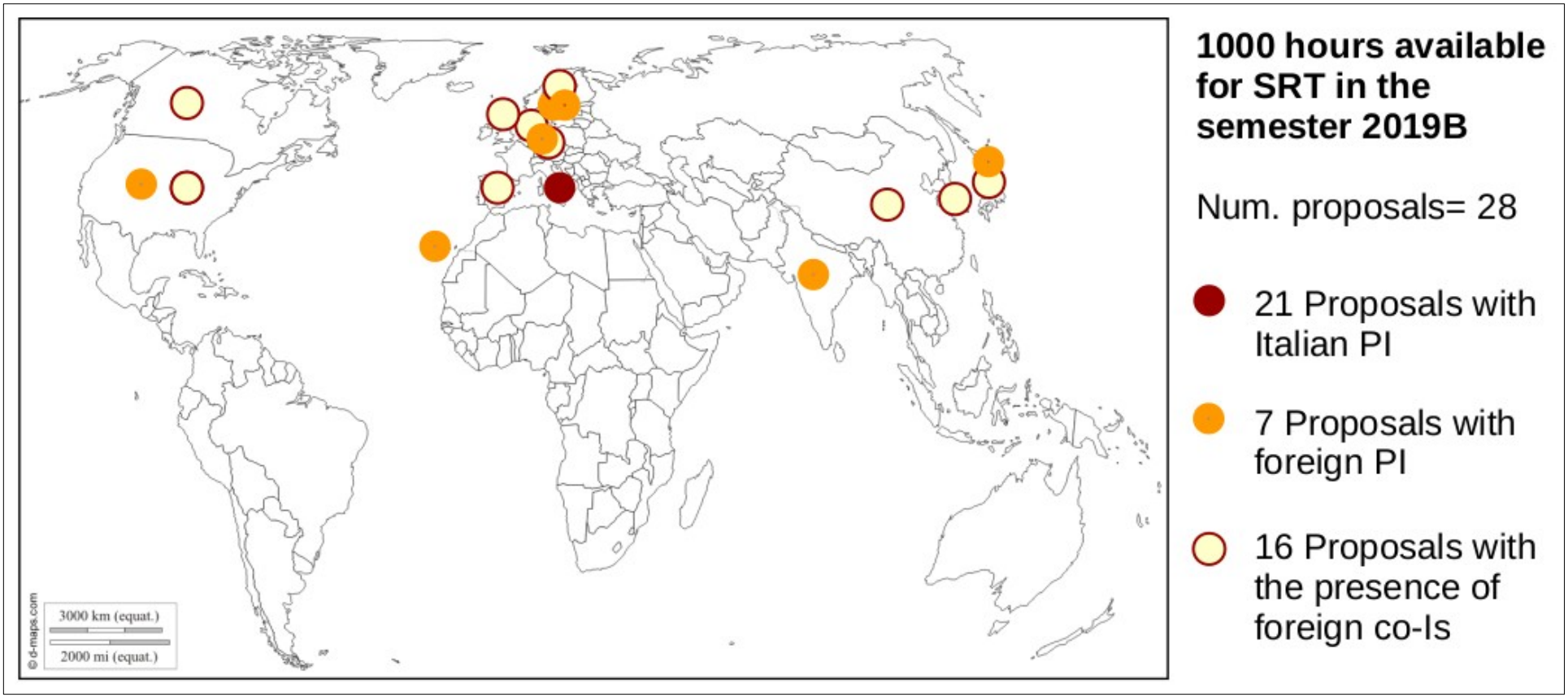
Semester 2019B (June 2019 – December 2019)

Report by Andrea Tarchi (chair of the TAC)



SINGLE-DISH and extra-EVN INTERFEROMETRIC OBSERVATIONS

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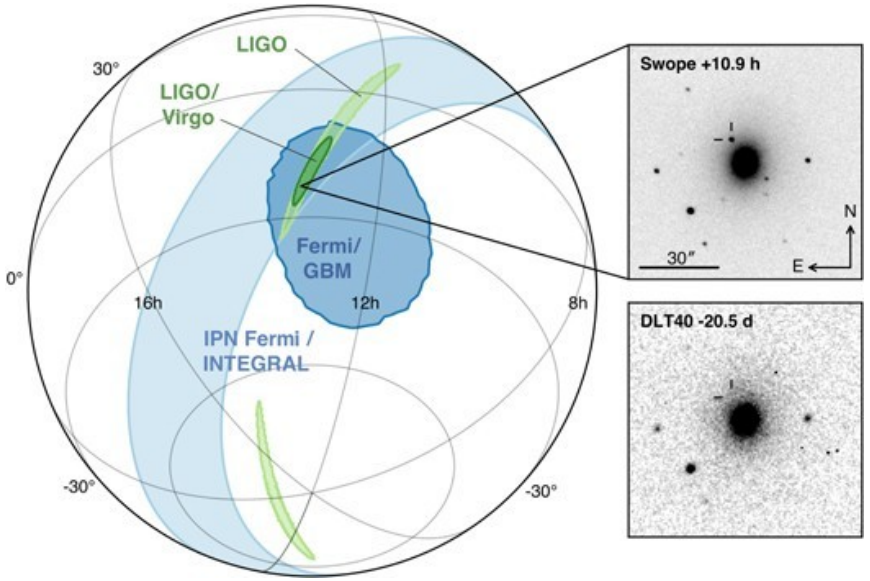
Multi-messenger observations of a binary neutron star merger



Abbott et al. (2017, ApJL)

Follow-up observations (7-19 Sept. 2017) with the SRT
Frequency 7.2 GHz
Bandwidth 0.68 GHz
Flux < 1.2 - 1.5 mJy

Telescope	UT Date	Time since GW Trigger (days)	Central Frequency (GHz)	Bandwidth (GHz)	Flux (μ Jy), 3σ	GCN
VLITE	Sep 7 19:09:43 UTC	21.36	0.3387	0.034	<8100	Hallinan et al. (2017a)
SRT	Sep 7 10:41:00 UTC	20.92	7.2	0.68	<1200	Aresu et al. (2017)
ATCA	Sep 8 12:00:00 UTC	22	17.0	···	<35	Wieringa et al. (2017)
ATCA	Sep 8 12:00:00 UTC	22	21.0	···	<35	Wieringa et al. (2017)
SRT	Sep 8 11:00:00 UTC	21.93	7.2	0.68	<1500	Aresu et al. (2017)
VLITE	Sep 8 19:05:35 UTC	22.37	0.3387	0.034	<6300	Hallinan et al. (2017a)
SRT	Sep 9 10:37:00 UTC	22.92	7.2	0.68	<1800	Aresu et al. (2017)
VLITE	Sep 9 18:52:45 UTC	23.36	0.3387	0.034	<4800	Hallinan et al. (2017a)
GMRT	Sep 9 11:30:00 UTC	23.0	1.39	0.032	···	Resmi et al. (2017), S. K
e-MERLIN	Sep 10 13:00:00 UTC	24	5.0	0.512	<126	Moldon et al. (2017b)
Effelsberg	Sep 10 13:10 UTC	24	5	2	<30000	Kramer et al. (2017)
Effelsberg	Sep 10 13:35 UTC	24	32	2	<90000	Kramer et al. (2017)
VLITE	Sep 10 18:36:48 UTC	24.35	0.3387	0.034	<6600	Hallinan et al. (2017a)
e-MERLIN	Sep 11 13:00:00 UTC	25	5.0	0.512	<151	Moldon et al. (2017b)
e-MERLIN	Sep 12 13:00:00 UTC	26	5.0	0.512	<113	Moldon et al. (2017b)
e-MERLIN	Sep 14 13:00:00 UTC	28	5.0	0.512	<147	Moldon et al. 2017b
e-MERLIN	Sep 15 13:00:00 UTC	29	5.0	0.512	<106	Moldon et al. 2017b
GMRT	Sep 16 07:30:00 UTC	29.8	1.39	0.032	···	Resmi et al. (2017); S. K
e-MERLIN	Sep 16 13:00:00 UTC	30	5.0	0.512	<118	Moldon et al. 2017b
ALMA	Sep 16 20:36:21 UTC	30.34	97.5	···		Alexander et al. (2017c)
MeerKAT	Sep 17 07:16:00 UTC	31	1.48	0.22	<60	Goedhart et al. (2017a)
e-MERLIN	Sep 17 13:00:00 UTC	31	5.0	0.512	<111	Moldon et al. (2017b)
e-MERLIN	Sep 18 13:00:00 UTC	32	5.0	0.512	111	Moldon et al. (2017b)
SRT	Sep 19 11:38:00 UTC	32.96	7.2	0.68	<1200	Aresu et al. (2017)
EVN	Sep 20 10:00:00 UTC	34	5.0	0.256	<84	Paragi et al. (2017b)
e-MERLIN	Sep 21 13:00:00 UTC	35	5.0	0.512	<132	Moldon et al. (2017b)
e-MERLIN	Sep 22 13:00:00 UTC	36	5.0	0.512	<121	Paragi et al. (2017b)
VLA	Sep 25 16:51:45 UTC	39.2	6.0 GHz		Detection	Alexander et al. (2017b)

Other scientific results with the SRT Radio Telescope
http://www.srt.inaf.it/astronomers/science_srt/

Multi-messenger and transient programs in progress at the italian radio astronomical facilities

GW → Radio follow-up of gravitational radiation sources with the SRT *(PI: A. Possenti)*
→ Exploring late-time pulsed radio emission fro the compact object as a left over of GW170817 *(PI: A. Possenti)*
→ Catching the radio counterpart of the afterglow of gravitational waves *(PI: M. Giroletti)*
→ Gravitational Wave detection using the European Pulsar Timing Array *(PI: D. Perrodin)*

LOOKING FOR LOW FREQUENCY GWs WITH THE PULSAR TIMING ARRAYS
(see talk by Andrea Possenti)

GRB → Broad band modelling of the afterglow emission from Gamma Ray Bursts: a strategy for short response radio follow-up with SRT *(PI: M. Marongiu)*

FRB → Shadowing FRB searches at MeerKAT: a pilot project *(PI: A. Possenti)*
→ Shadowing CHIME to localise repeating FRBs with EVN dishes *(PI: F. Kirsten)*
→ High frequency monitoring and follow-up observations of the repeter FRB121102 with SRT *(PI: M. Pilia)*
→ Localizing repeating Fast Radio Burst: a pilot project *(PI: M. Giroletti)*

THE NORTHERN CROSS FAST RADIO BURST PROJECT
(see talk by Gianni Bernardi)

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

Ministero dell'Istruzione dell'Università e della Ricerca

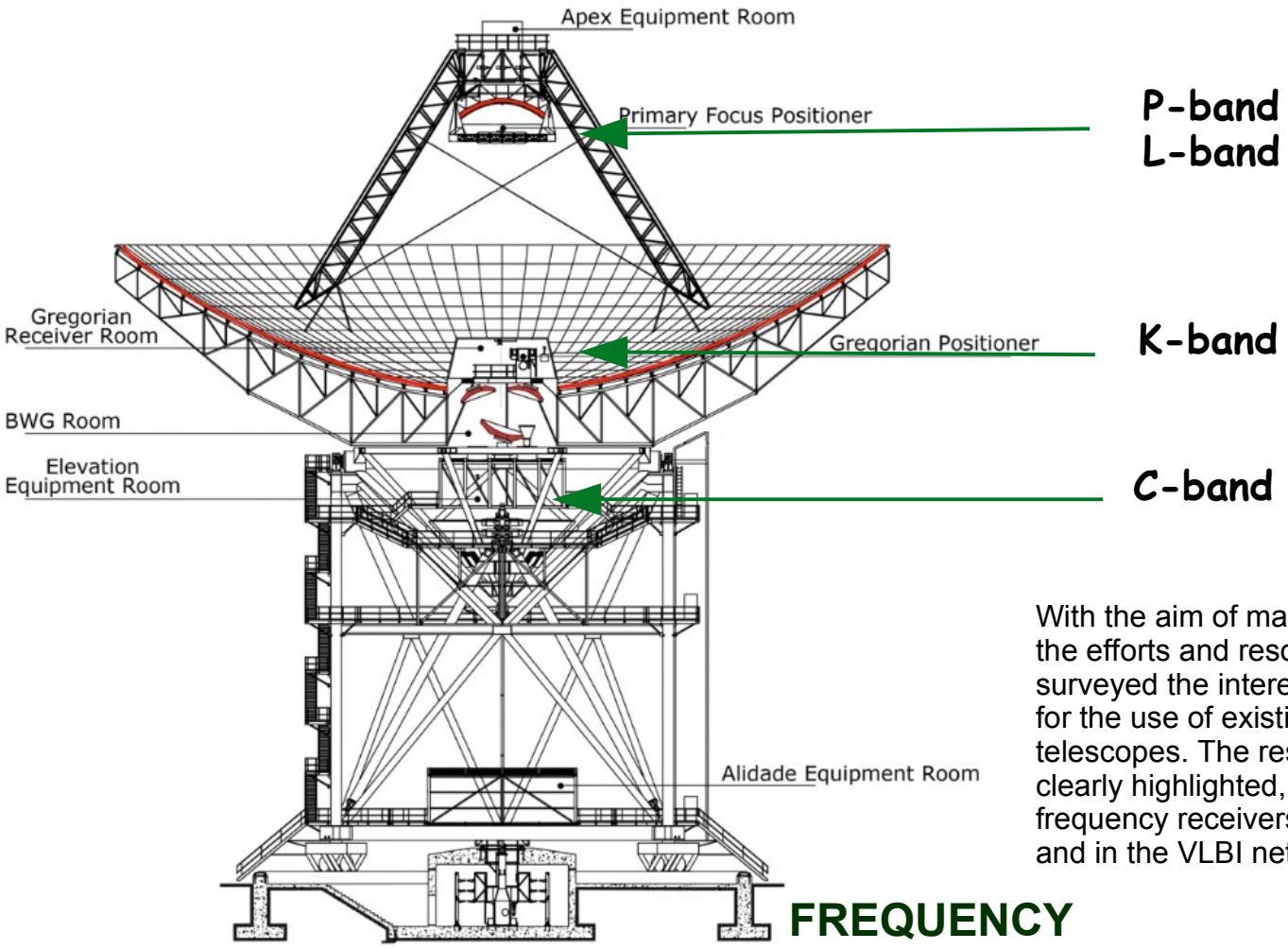
Dipartimento per la Formazione Superiore e per la Ricerca

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

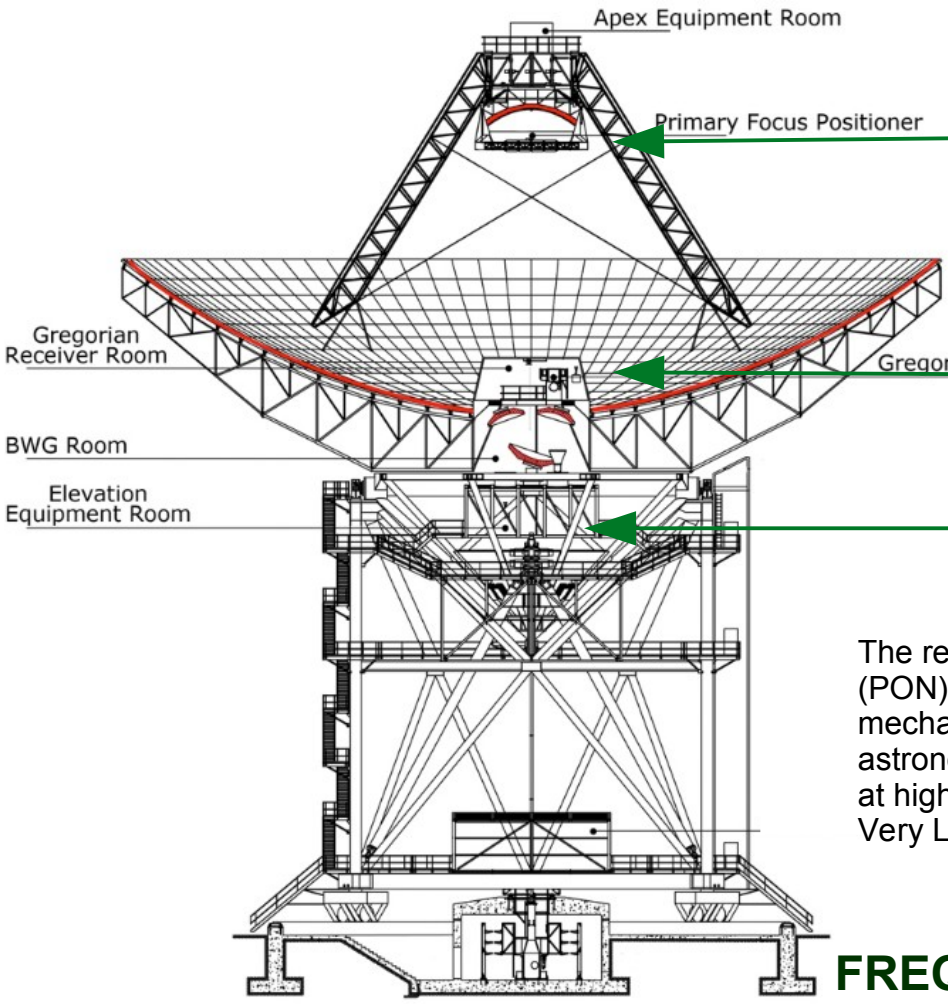
P-band 305-410 MHz
L-band 1.3-1.8 GHz

S-band 3.0-4.5 GHz

Clow-band 4.2-5.6 GHz

C-band 5.7-7.7 GHz

K-band multibeam 18-26.5 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 305-410 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 18-26.5 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

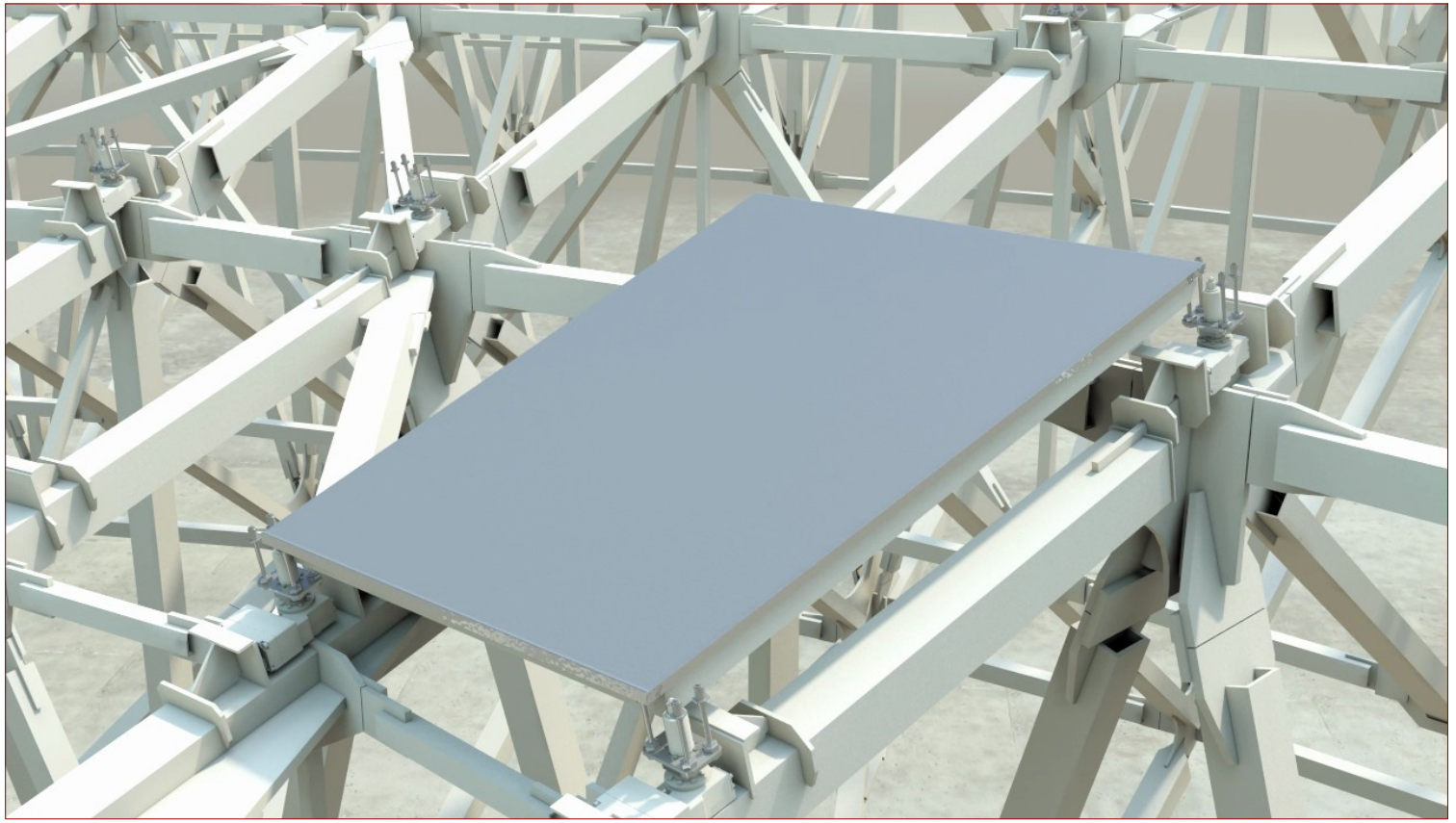
Supply of a millimeter chamber operating in the 80-116 GHz frequency band composed of an array of about 300 independent detectors (pixels) that simultaneously sample a wide field of view.

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

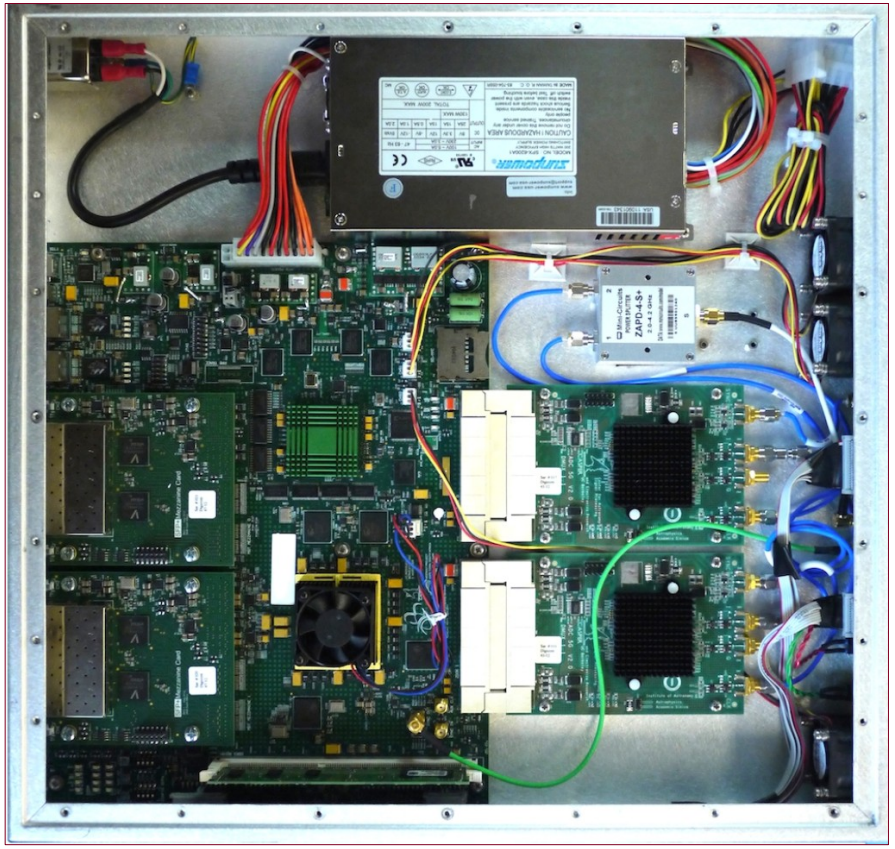
The aim is to optimize:
- Pointing performances
- Aperture efficiency and the gain of the antenna at all elevations
- Wind induced structural effects

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.

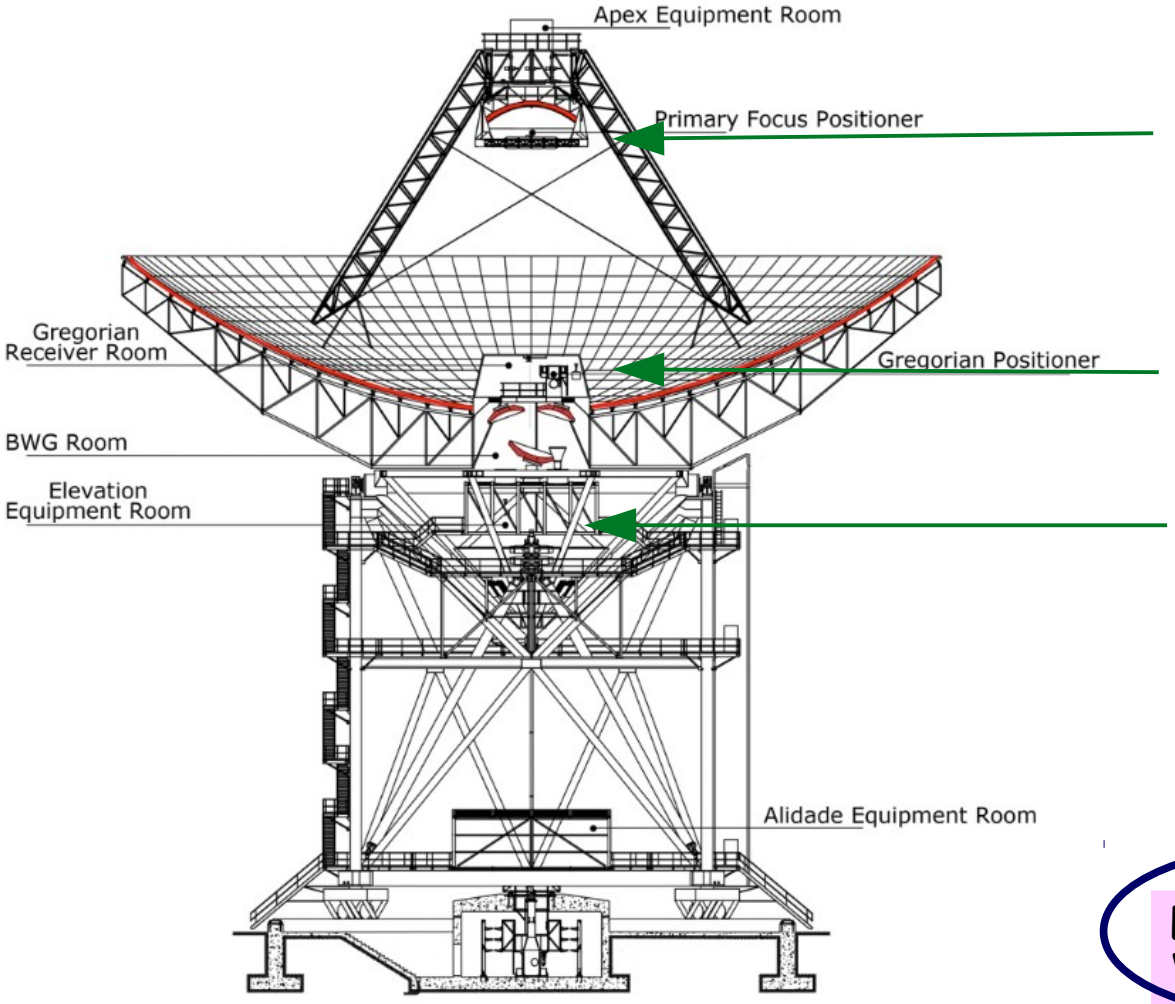
Particular attention has been paid to the purchase of instrumentation for laboratories, to guarantee that the effects of the upgrading of SRT will be mantained for at least ten years. In fact, such laboratories will permit not only to test and characterize the new backends and receivers that will enhance 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 305-410 MHz
L-band 1.3-1.8 GHz

C-band
5.7-7.7 GHz

K-band multibeam
18-26.5 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

INAF Radio Astronomical Facilities

Medicina
Northern Cross
32m parabola dish

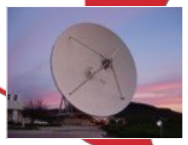
INAF-IRA

LOFAR
Station
(2021/2022)

INAF-OA Cagliari

SRT
64m parabola dish

INAF-IRA



Noto
32m parabola dish

THANK YOU!!!!

- Status of the SRT, Medicina, and Noto
- SRT, Medicina, and Noto as single dishes and in the European VLBI Network (EVN)
- Multi-messenger era with the radio astronomical facilities
- Future perspectives for radio observations at high frequencies with the Italian radio telescopes