The SRT as a Science Facility

Astronomical Validation & Scientific Perspectives

Isabella Prandoni
Project Scientist SRT

INAF- Istituto di Radioastronomia
Bologna

I. Prandoni - 12th EVN Symp. - 08/10/2014
Team AV

- **PS:** Isabella Prandoni
- **Co-PS:** Matteo Murgia, Andrea Tarchi, Sandro Orfei, Gianni Comoretto

+ ~30 people covering various technical/astronomical expertises (8 IRA/Med; 24 OACa; 2 Arcetri)

- Pulsar; Galactic & Extra-galactic, etc.
- Continuum, Line, Mapping, VLBI, etc.
- SW, Receivers, Backends, etc.

[interface with commissioning team]

ASTROPHYSICAL VALIDATION TEAM

The SRT astrophysical validation team

1. **Isabella Prandoni**, i.prandoni@ira.inaf.it (Project Scientist)
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SARDINIA RADIO TELESCOPE

Largest (64-m) Italian radio telescope

Quasi-Gregorian system with shaped Surfaces

Multiple focal position (P, G, 4 BWG):
- up to 20 receivers, frequency agility

Active Surface: 1008 panels, 1116 electro-mechanical actuators with remote control

http://www.srt.inaf.it
PROJECT STATUS

Telescope Commissioning (end 2013)

Advanced technical activities/Precursors (from Jan 2014)
Fine-tuning, integration of sub-systems (derotator, f-track), backends commissioning (DFB, XARCOS, etc.), metrology, site monitoring, etc.

Astronomical Validation (running in parallel – 16h-24h time slot)
Astronomical Validation (AV) toward a radio observatory!

- Last phase before first astronomical observations (shared risk, early science)

- **Goal 1:** Tests on predefined sources to characterize the SRT astronomical performance in all standard observing modes; identification of technical problems and/or limitations

- **Goal 2:** Transforming the SRT into a real Observatory (HW/SW development, observing/analysis tools, cook-book, etc.);

- **Goal 3:** maximization of science exploitation since first light
AV - SW DEVELOPMENT

Observing with SRT:

- **ETC**: SRT Exposure Time Calculator  
  Zanichelli et al.
- **CASTIA**: Source Visibility  
  >30 telescopes (incl. EVN), on line  
  Vacca, Iacolina et al.
- **ScheduleCreator**: Righini et al.  
  Nuraghe SD Operations (TP/XARCOS)
- **SEADAS**: Corongiu et al.  
  Interface for Pulsar Obs. (DFB/ROACH)

Data Monitoring/Handling:

- **Cross Scan Quick Look/Reduction**: Righini et al.
- **SDI**: SD multi-feed Imager (OTF)  
  Pellizzoni et al.
- **RFI monitoring**: Melis et al.
- **RFI detection/excision**: Ricci et al.
- **Format Converter**: Trois et al.
  FITS to CLASS
SRT Single-Dish Imager (SDI): Early Applications at C-band

**SNR 3C157/IC 443**

VLA 330 MHz
64”x74” resolution

Calibrated 5 GHz image - Medicina Febr. 2013 – 6.4’ res.

Hewitt et al. 2006

Credits SDI Team: A. Pellizzoni, E. Egron, N. Iacolina, S. Righini, A. Trois, V. Vacca

SRT C Band TP vs ROACH2
June 2014 – 2.8’ res.

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1st GENERATION INSTRUMENTATION

**RECEIVERS**

- 310-420 MHz
- 1.3-1.8 GHz (Dual Band)
- 5.7-7.7 GHz (Mono-feed)
- 18-26 GHz (Multi-feed, 7 elements)

**BACK-ENDs**

- **DFB: Digital Spectrometer (pulsar)**
  (ATNF Pulsar Digital Filter-Bank)
  1 GHz BW, up to 16384 chan

- **ROACH: 2x512 MHz/1x1024 MHz**

- **DBBC2 (1 GHz, 4 IFs) + Mark5C (VLBI) + SW Corr (DIFX)**

- **TP: analog back-end Total Power**
  7x2 outputs, 2 GHz BW

- **XARCOS: Digital Spectrometer**
  8 outputs, 60 MHz BW, 4096 channels

I. Prandoni - 12th EVN Symp. - 08/10/2014
The SRT: INTERNATIONAL CONTEXT

• Single-Dish Operations: Competitors
  - 60/100m class radio telescopes: SRT, JB (70m), Eff (100m), GBT(100m), Parkes (64m)
  - Dishes with active surface: SRT, Effelsberg, GBT
    + Yebes (40m), Noto (32m), IRAM (30m), Onsala (25m), Metshaovi (14m)

  ➔ State-of-the-art RX, Back-end (multi-feeds, etc.)
  ➔ Ad hoc observing strategies/pipelines (large surveys, imaging SW, etc)
  ➔ Coordinated use of Italian antennas (exploit synergies)
  ➔ High frequency science (Dynamic scheduling, metrology, multi-feeds, etc.)

• Networks: Cooperation
  - EVN, eVLBI, Space-VLBI, mm-VLBI, Italian VLBI, AVN,…
  - PTAs/LEAP

  ➔ High priority for ad hoc RX, Back-ends (eg 43/86 GHz; ROACH, etc.)
  ➔ SW Correlation for Italian VLBI, AVN (DIFX)
The SRT: INTERNATIONAL CONTEXT

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  - Dishes with active surface: SRT, Effelsberg, GBT
    + Yebes (40m), Noto (33m), JRAM (20m), Ossola (35m), Metsahovi (14m)

Highest Priority:
• Include SRT in International Networks: EVN, LEAP
• SD Operations: Pulsars (dual-band RX)/Surveys (multi-feed)

• Networks: Cooperation
  - EVN, eVLBI, Space-VLBI, mm-VLBI, Italian VLBI, AVN,…
  - PTAs/LEAP

→ High priority for ad hoc RX, Back-ends (eg 43/86 GHz; ROACH, etc.)
→ SW Correlation for Italian VLBI, AVN (DIFX)
SRT as part of VLBI Networks

- **EVN → Medicina & Noto + SRT** from 2015
- **Space-VLBI (RadioAstron) → Medicina & Noto**, SRT test experiments ongoing
- **eVLBI**: Optic fibre connection to Medicina & Noto + SRT in 1-1.5 years
- **mm-VLBI** (7/3 mm) → high-ν capability Noto + SRT 43 GHz funded; 86 GHz IRAM
- **Italian VLBI → Medicina, Noto, SRT + SW correlator (DIFX)** – tests ongoing (talk by Stagni)

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**RadioAstron**

Orbital Period: 7-10 gg
Apogee: 310,000-390,000 km
Perigee: 300-7,000 km

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<thead>
<tr>
<th>Frequency band [GHz]</th>
<th>0.327</th>
<th>1,665</th>
<th>4.83</th>
<th>18 - 25</th>
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<td>Ang. Res. At 350,000 km baseline [microas]</td>
<td>540</td>
<td>106</td>
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AV – FIRST VLBI TESTS

Credits: VLBI tests involve experts at IRA, Medicina and Noto, who are not part of AV team Coordination M. Nanni

2013, Oct. 10 → First Italian VLBI test: Medicina-Noto-SRT + SW correlator
- Several unknowns (Scheduling, SW Corr., Mark5C)
- Synchronization problem with DBBC2-Fila10-MK5C

First fringes Med-SRT 27-01-2014!

Antenna Coordinates measurements (17/02/2014)

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AV – FIRST VLBI TESTS

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First Fringe:
27 Jan 2014
SRT-Medicina, K-band

First Fringe:
27 Jan 2014
SRT-Medicina, K-band

Courtesy
M. Nanni

I. Prandoni - 12th EVN Symp. - 08/10/2014
AV - EVN TESTS

First EVN tests February/March 2014 Session:
5 tests performed, 3 successful (2 L-band + 1 K-band)

Problems to be solved:
- fringe amplitude (DBBC conf)
- stability in synchronization

PLAN: get problems solved for May/June 2014 EVN run

I. Prandoni - 12th EVN Symp. - 08/10/2014

Credits:
C. Migoni
AV - EVN TESTS

First EVN tests February/March 2014 Session:
5 tests performed, 3 successful (2 L-band + 1 K-band)

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- fringe amplitude (DBBC conf)
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PLAN: get problems solved for May/June 2014 EVN run

C. Migoni

L-band Feb 2014
K-band Mar 2014
L-band May 2014
C-band June 2014

L-band May 2014

I. Prandoni - 12th EVN Symp. - 08/10/2014
First EVN tests February/March 2014 Session:
5 tests performed, 3 successful (2 L-band + 1 K-band)

Problems to be solved: fringe amplitude (DBBC conf)

PLAN:
get problems solved for May/June 2014 EVN run

I. Prandoni - 12th EVN Symp. - 08/10/2014

EVN May/June 2014 run:
1st L-band EVN experiment (29 May): PI Perez-Torres 6h
Data not correlated yet

SRT READY TO PARTICIPATE TO EVN RUNS (Shared-risk mode)
Mark5B+ ready to be installed in parallel
**AV – SRT & RadioAstron**

- **1st L-band RadioAstron Experiment** (4/5 June 14):
  13.5h - PI Sovolainen

- **Other RadioAstron Experiments**: K-band - July 17 & 26

  Data not correlated yet

Credits: C. Migoni

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**RadioAstron:**

**Medicina & Noto**

**SRT – tests ongoing**

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**Orbit:** 7-10 days
**Apogee:** 310,000-390,000 km
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L/P Dual Band
+ ROACH1

PULSAR STUDIES WITH SRT

- **Dual band** 20+90 cm receiver ➔ unique capability to remove interstellar medium effects

- **LEAP**: Large European Array for Pulsars
  (Westerbork, JB, Effelsberg, Nancay, SRT)

  **Phased Array**: ‘Coherent’ combination of the 5 major European telescopes
  ➔ **most sensitive telescope at L-band for timing** (~200m, ie ~ Arecibo-illuminated dish, but able to track sources, and observe larger region of sky)

  **Ultra-precision Pulsar Timing**: Searching for signature of space-time perturbations in pulsar timing residuals

**Leader experiment for detecting GW** from cosmological background or from local SMBH in merging systems

Courtesy A. Possenti
**AV – PULSARS: LEAP (ROACH)**

Pulsar Group OAC: Perrodin, Concu, Melis et al.

1. **First LEAP session** including SRT (5 telescopes):
   **2013, July 27th** (ROACH installed)

   ROACH tests limited to 16 MHz → Only brightest pulsars
   Goal: 128 MHz → LEAP; 500 MHz → EPTA

2. **Feb. 2014**: 8-node cluster available
   → **31/03/14**: First LEAP session with 8 bands (128 MHz)!

   → tests ongoing: SRT participate to all monthly 25th LEAP sessions (nearly all msec pulsars detected)

3. **May 9, 2014**: Correlation between SRT and Westerbork

4. **Sept. 2014**: data acquisition completely automatized
   (SEADAS+NURAGHE)

**Next Step:** **5 Telescope LEAP coherent addition**

**Main Issue:** Strong RFIs in L-band → Site + nearby radar (RFI up to 1460 in 1 pol)
AV – Single Dish

- Mainly C-band:
  - Continuum (TP)
  - Pulsars (TP/DFB)

Receiver

- K-single 18%
- K multi 4%
- None 3%
- L/P 19%

Linearity Test:
- <2000 counts

Confusion Noise:
- ~0.2 mJy

Monitoring Calibrator Campaign

Credits: Righini
C-Band - High Dynamic Range Imaging Test

ADVANCED TEST:
Observations with TP (C Band) to test/debug beam deconvolution procedures (based on Imaging SW SCUBE (Govoni et al.). 300 1x1 deg² maps of 3C147

• Beam reconstruction and shapelet modeling works fine
  ➔ DR~7000
• Need deep beam pattern measurements at fine El. steps

Credits:
M. Murgia, F. Govoni, S.Poppi, V.Vacca, P.Castangia, A.Tarchi

3C147: Dirty/Cleaned Image

Restoring beam FWHM=2.8’

3C147: Beam Model

• Beam reconstruction and shapelet modeling works fine
  ➔ DR~7000

I. Prandoni - 12th EVN Symp. - 08/10/2014
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C-Band - High Dynamic Range Imaging Test

Restoring beam FWHM=2.8'$

3C147: Dirty/Cleaned Image

I. Prandoni - 12th EVN Symp. - 08/10/2014
AV – PULSARS: SD (TP)

PSR J1745-2900, firstly detected as an X-ray flare from Sgr A* by Swift and then identified as a 3.76 s X-ray magnetar

2013, May 6th → First Observations with SRT (1 hour) @ C-band with TP thanks to long period + flat spectrum

Regularly re-observed in the following months:

2013 Nov. 9th: Magnetar observed in L Band with ROACH

TP not suited BUT produced First SRT publication!
ATEL#5053 – 14 May 2013 - Buttu et al.

Credits: M. Burgay + Pulsar Group OAC
Detection by Sardinia Radio Telescope of radio pulses at 7 GHz from the Magnetar PSR J1745-2900 in the Galactic center region

ATel #5053: Marco Buttu (INAF-Osservatorio Astronomico di Cagliari), Nichi D’Amico (INAF-OAC), Elise Egron (INAF-OAC), Maria Noemi Iacolina (INAF-OAC), Pasqualino Marongiu (INAF-OAC), Carlo Migoni (INAF-OAC), Alberto Pellizzoni (INAF-OAC), Sergio Poppi (INAF-OAC), Andrea Possenti (INAF-OAC), Alessio Triac (INAF-OAC), Gian Paolo Vargiu (INAF-OAC), on behalf of the Sardinia Radio Telescope Science Validation Team and the Commissioning Team on 7 May 2013; 19:19 UT

Credential Certification: Marta Burgay (burgay@oa-cagliari.inaf.it)

Subjects: Radio, Neutron Star, Soft Gamma-ray Repeater, Pulsar

Referred to by ATel #: 5058

During the Sardinia Radio Telescope (SRT) science verification phase, we observed...
AV – PULSARS: SD (DFB)

Credits: M. Burgay + Pulsar Group OAC

**PSR J1713+0747** Effelsberg (Kramer et al. 1999)

SRT: **6.1 GHz** (400 MHz BW, 512 channels)

→ one of highest frequency detection of MSP!

Intrinsic profile asymmetry disappearing with frequency

J1713+0747: one of the best for timing arrays (regular pulses)
PSR J1713+0747

Effelsberg

SRT: 6.1 GHz (400 MHz BW, 512 channels)

→ one of highest frequency detections

Data Format: standard psrfits

Psrchive suite to produce waterfall plots

Intrinsic profile asymmetry disappearing with frequency

J1713+0747: one of the best for timing arrays (regular pulses)
SUMMARY

VALIDATED - CLOSE TO VALIDATION:

- VLBI Operations: ready from technical point of view (EVN+RadioAstron) L, C, K
- LEAP Operations: L-band/Roach (close to ready)
- Single Dish: Pulsar C-band Observations: TP and DFP folding mode
  Continuum TP Observations: C-band, incl. imaging; K-band-single

IN PROGRESS I:

- Single Dish K-band-multifeed/imaging: Continuum TP
- Single Dish Spectroscopy: single/multi-feed: XARCOS
- Single Dish Pulsar search mode

CAVEAT: Logistics, technical support (shifts), man power

IN PROGRESS II:

- Single Dish L/P Band → spectropolarimetry with DFB or ROACH
- eVLBI → 1-1.5 years (optic fibre)
- mm-VLBI → 86 GHz + 43 GHz (under design); metrology

ToO → limited time available as DDT (see eg Magnetar)