High-resolution imaging of SNR IC443 and W44 with the Sardinia Radio Telescope

E. Egron (INAF/OAC, Italy)

In collaboration with: A. Pellizzoni, S. Loru, M. N. Iacolina, M. Marongiu, S. Righini, M. Cardillo, A. Giuliani, S. Mulas, G. Murtas, D. Simeone...
SRT Location
San Basilio, Sardinia
Lat. 39°29'34" N - Long. 9°14'42" E, 700 m.a.s.l.
SRT Location

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Il Sardinia Radio Telescope
Un potente strumento per la radio astronomia in Sardegna

Presentation and observing perspectives with the Sardinia Radio Telescope

Elise Egron (SRT Science Validation Team)
A few words about SRT

- Dish dimension: 64-m diameter
- Active surface
- Frequency range: From 0.3 GHz to 110 GHz
- Visibility DEC: -40°, +90°
- First call ESP: Dec 2015
Radio observations of SNRs

* High-resolution maps of SNRs are lacking > 5 GHz
* Single dish and interferometry are complementary
* SRT maps of W44 and IC443 at 1.5 GHz, 7 GHz and 21.4 GHz

AIMS => to have precise measurements on flux density
=> to better understand the spectral index of SNRs

A. Pellizzoni’s talk
S. Loru’s poster
SRT observations

* On-The-Fly maps
* Beam oversampling
* Automatic RFI rejection
* Automatic baseline subtraction

\[
\text{Pixel size about } 1/4 \text{ HPBW}
\]
\[
\text{Single Dish Imager (SDI software)}
\]

\[\Rightarrow \text{Accurate flux density measurements and flux errors}\]
**W44 flux at 1.4 GHz?**

* Discrepancies in the literature (see Castelletti et al. 2007)

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<tr>
<th>Frequency (MHz)</th>
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<tr>
<td>1390.00</td>
<td>173 ± 35</td>
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<td>1414.00</td>
<td>274.7 ± 0.4</td>
<td>Altenhoff et al. (1970)</td>
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<td>1420.00</td>
<td>180 ± 36°</td>
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<td>210 ± 20</td>
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W44 at 1.5 and 7 GHz with SRT

\[
\text{F} = 214 \pm 6 \text{ Jy} \\
\text{beam: } 11.1' \\
14 \text{ maps of } 1.6\degree \times 1.4\degree \\
\text{eff time: } 4h10 \\
\text{rms} = 81 \text{ mJy/beam}
\]

\[
\text{F} = 96 \pm 5 \text{ Jy} \\
\text{beam: } 2.7' \\
7 \text{ maps of } 1.2\degree \times 1.0\degree \\
\text{eff time: } 6h50 \\
\text{rms} = 7 \text{ mJy/beam}
\]
**W44 flux at 1.4 GHz?**

* Discrepancies in the literature (see Castelletti et al. 2007)

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**SRT:** 1550....... 214 +/- 6 Jy  Egron et al. (submitted to MNRAS)
Figure 6. Comparison of the continuum maps of IC443 obtained with SRT at 7 GHz (left) with that obtained with the VLA and Arecibo at 21 cm (right) (Lee et al. 2008).

Figure 7. Left: contour map obtained by Effelsberg at 4.9 GHz (Altenhoff et al. 1979), middle: SRT observation at 7 GHz, right: intensity contours (indicated in green) obtained with the Urumqi at 4.8 GHz (Sun et al. 2011). The dotted rectangles indicate the same sky region.

The blue and green circles in the bottom corner of the maps show the beam size.

X-ray nebula associated with the pulsar (Petre et al. 2002; Frail et al. 1996) has a slight offset w.r.t. the pulsar and is consistent with a motion of the pulsar away from the SNR center.

5.2 IC443 and W44 continuum fluxes

We compared the values of the integrated flux densities we obtained with SRT at 1.55 GHz and 7 GHz with those presented in the literature. We note that no recent observations above 2 GHz were performed since the late 1970’s. Based on the values reported in Table 2 by Castelletti et al. (2011), we conclude that our measurements for IC443 ($S_{1.55\text{GHz}} = 133.7 \pm 4.0\text{ Jy}$ and $S_{7\text{GHz}} = 66.5 \pm 2.9\text{ Jy}$) are consistent with continuum fluxes obtained at 1.4 GHz ($S_{1.4\text{GHz}} = 130.13 \pm 13\text{ Jy}$ by Green 1986) and at 6.6 GHz ($S_{6.6\text{GHz}} = 70 \pm 15\text{ Jy}$ by Dickel 1971), within 1σ.

It is worth noting that typical continuum flux errors for IC443 in the literature are of the order of $\sim 10^{−15}$%, while we provided more accurate measurements. This is mostly due to our oversampled maps in which, for each pixel, tens of OTF baseline-subtracted scans are available, providing straightforward error measurements through standard deviation estimates. The SRT spectral index estimate for IC443.

Single-dish observations of W44

* Effelsberg at 4.9 GHz (beam: 2.6’)
* SRT at 7 GHz (beam: 2.7’)
* Urumqi at 4.8 GHz (beam: 9.5’)

Altenhoff et al. 1979

Sun et al. 2011
SRT and VLA maps of W44

* Advantage VLA => great details in the morphology
(see Castelletti et al. 2007: obs at 324 MHz)

* Advantage SRT => accurate flux measurements at 1.5 and 7 GHz
Single-dish observations of IC443

* Effelsberg at 868 MHz (beam: 14.5’)

* SRT at 7 GHz (beam: 2.7’)

* Urumqi at 5 GHz (beam: 9.5’)

(Reich et al. 2003)

(Gao et al. 2011)
IC443 at 1.5 and 7 GHz with SRT

**IC443 at 1.5 GHz:**
- Flux Density: $F = 131 \pm 4$ Jy
- Beam: 11.1' (1.1 arcminutes)
- Map Size: 2° x 2°
- Effective Time: 7h15
- rms: 76 mJy/beam

**IC443 at 7 GHz:**
- Flux Density: $F = 69 \pm 3$ Jy
- Beam: 2.7' (2.7 arcminutes)
- Map Size: 1.5° x 1.5°
- Effective Time: 5h30
- rms: 20 mJy/beam

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DISCUSSION

We obtained accurate images of W44 and IC443 probing the capabilities of the Sardinia Radio Telescope by operating single-dish OTF scans. Our results show reliable performances of the instrumentation over a two-year-long time span (gain stability $<5\%$) and provide self-consistency checks in measurements performed by simultaneous piggy-back observations with two different backends. On the other hand, this early SRT mapping of SNRs yielded challenging scientific results, providing the first spatially-resolved spectra in the 1.5−7 GHz range.

Our results are first compared with both low-frequency VLA interferometric data and existing 0.3−5 GHz single-dish maps (§5.1) and related integrated fluxes described in the literature (§5.2). In §5.3 we discuss the physical implications of the observed region-dependent spectral indices for IC443 and W44 and their correlation with the radio and gamma-ray intensity maps.
IC443 at 1.5 and 7 GHz with SRT

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<td>=&gt; 1400.00</td>
<td>146 ± 18</td>
<td>Wanner (1961)</td>
</tr>
<tr>
<td>=&gt; 1410.00</td>
<td>131 ± 13</td>
<td>Milne &amp; Hill (1969)</td>
</tr>
<tr>
<td>=&gt; 1419.00</td>
<td>130 ± 13</td>
<td>Green (1986)</td>
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Comparison with flux values at 1.4 GHz

- F = 131 +/- 4 Jy at 1.5 GHz
- F = 69 +/- 3 Jy at 7 GHz
- F = 131 +/- 4 Jy at 1.5 GHz

Extract from Castelletti et al. 2011

F = 69 +/- 3 Jy at 7 GHz consistent with Dickel 1971 F = 70 +/- 15 Jy at 6.6 GHz
SRT versus VLA/Arecibo

* Flux density at 1.5 and 7 GHz consistent with the literature

* Comparison of SRT map at 7 GHz with VLA and Arecibo at 1.4 GHz (Lee +2008)
Work in progress...

* High-resolution maps with - K-band receiver (18-26 GHz)
  - S-band receiver (3-4.5 GHz; under construction)

* W44 at 21.4 GHz
  (Loru et al. in prep)

* W44 at 4.4 GHz
  (Iacolina et al. in prep)
Conclusions

- High-quality maps => single-dish capabilities at 1.5, 4.4, 7, 21.4 GHz
- Flux measurements with precise error: 3% at 1.5 GHz, 5% at 7 GHz
  => integrated and local flux density
- Map of spectral index (talk A. Pellizzoni)
- Paper submitted to MNRAS (Egron et al.)

=> next steps: Analysis of spectral lines (Roach2 backend)
  Polarization maps
  Maps in Q-band (33 - 50 GHz)
Thank you for your attention!
**SNR W44**

*Comparison between SRT (64m) and Medicina (32m)*

- **Medicina at 5 GHz**
  - Beam size: 7.9'

- **SRT at 7.2 GHz**
  - Beam size: 2.7'

- **Medicina at 8 GHz**
  - Beam size: 4.9'

![Image of SNR W44 data](image-url)
Early Science Program

* First call for SRT proposals in Dec 2015

* Small number of large programs in shared-risk (15)
  http://www.srt.inaf.it/astronomers/early-science-program-FEB-2016/

* A program dedicated to imaging of supernova remnants (110h)

* Observations: 01 February - 31 July 2016