The Westerbork Synthesis Radio Telescope (WSRT)

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The WSRT is operated by ASTRON
It originally began as the Stichting Radiostraling Zon en Melkweg (SRZM)

- (or the Netherlands Foundation for Radio Astronomy, NFRA)
- Founded by Jan Oort, Henk van de Hulst, Marcel Minnaert and others in 1949
- Purpose: study radio emission from the Sun and Milky Way
SRZM's first instrument was a 7.5 m radar dish borrowed from the PTT.
7.5 m Würzburg was at Kootwijk (⊕), the “new” 25 m dish at Dwingeloo (✗)

- Kootwijk was the PTT station for long distance radio communication, which began in the 1920s.
- It soon became clear that this was not the best location for a radio telescope!
- Hence the move in 1955 to Dwingeloo
Opened in 1956, the first 25 m radio astronomy antenna
The Joint Institute for VLBI in Europe is also in Dwingeloo.
The WSRT is an east-west array for earth-rotation aperture synthesis

- Elements: $14 \times 25$ m parabolic reflectors
- 10 fixed elements on 1296 m baseline
- 2 elements on 300 m rail track at east end
- 2 elements on 180 m rail track 1.3 km further east
- Basic spacing $n \times 72$ m
25 m dishes have 8 mm mesh surface, lightweight construction

- Equatorial mount
- HA range -90.5° to +90.5°
- Dec range: horizon to \( \delta = +90° \)
- Slew rate: 18°/min
- \( f/D = 0.35 \), prime focus operation
## Observing bands and interferometer properties

<table>
<thead>
<tr>
<th>Wavelength (cm)</th>
<th>Aperture efficiency</th>
<th>Field of view (°arc)</th>
<th>Synth. beam (”arc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LFFE 260-170</td>
<td>0.30</td>
<td>8-5</td>
<td>160-104</td>
</tr>
<tr>
<td>UHF(_{lo}) 120-65</td>
<td>0.39</td>
<td>3.1-2</td>
<td>72-39</td>
</tr>
<tr>
<td>92</td>
<td>0.59</td>
<td>2.6</td>
<td>55</td>
</tr>
<tr>
<td>49</td>
<td>0.59</td>
<td>1.4</td>
<td>30</td>
</tr>
<tr>
<td>UHF(_{hi}) 40-25</td>
<td>0.39</td>
<td>1.11-0.83</td>
<td>26-15</td>
</tr>
<tr>
<td>L-band 27-17</td>
<td>0.54</td>
<td>0.8-0.5</td>
<td>15-11</td>
</tr>
<tr>
<td>13</td>
<td>0.54</td>
<td>0.37</td>
<td>7.8</td>
</tr>
<tr>
<td>6</td>
<td>0.48</td>
<td>0.17</td>
<td>3.7</td>
</tr>
<tr>
<td>3.6</td>
<td>0.35</td>
<td>0.1</td>
<td>2.2</td>
</tr>
</tbody>
</table>
### Sensitivities of the bands

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>Freq. range</th>
<th>System</th>
<th>r.m.s. in 12^h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(cm)</td>
<td>(MHz)</td>
<td>Temp. (K)</td>
</tr>
<tr>
<td>LFFE 260-170</td>
<td>117-175</td>
<td>700-400</td>
<td>5-3</td>
</tr>
<tr>
<td>UHF_{lo} 120-65</td>
<td>250-460</td>
<td>250-120</td>
<td>≈ 0.5</td>
</tr>
<tr>
<td></td>
<td>92</td>
<td>125</td>
<td>≈ 0.25</td>
</tr>
<tr>
<td></td>
<td>49</td>
<td>75</td>
<td>≈ 0.15</td>
</tr>
<tr>
<td>UHF_{hi} 40-25</td>
<td>750-1200</td>
<td>180-120</td>
<td>0.085</td>
</tr>
<tr>
<td>L-band 27-17</td>
<td>1150-1750</td>
<td>27-31</td>
<td>0.012</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>60</td>
<td>0.021</td>
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<tr>
<td></td>
<td>6</td>
<td>65</td>
<td>0.023</td>
</tr>
<tr>
<td></td>
<td>3.6</td>
<td>110</td>
<td>0.042</td>
</tr>
</tbody>
</table>
Strong points of the WSRT

- Wide frequency range, from 0.12-8.6 GHz
- Nearly continuous coverage, 0.12-1.7 GHz
- Rapid switching (≤ 1 min) between bands
- HI mapping, 0 ≤ z ≤ 0.25
- Highly flexible spectrometric capability, up to 8 × 20 MHz instantaneous bandwidth
- Wide-field imaging, mosaicing
- Polarization synthesis mapping
- Pulsar backend, tied array capability
Beams and grating lobes

1-D response: series of grating lobes

WSRT interferometer pairs generate 38+ concentric $u,v$-ellipses, equally spaced.

The antenna response produces is a narrow central lobe with concentric rings.
Cleaned map of extended source, with some residual artefacts
WSRT data reduction, and some limitations of the instrument

Data reduction packages:
- NEWSTAR (WSRT-specific features)
- AIPS; AIPS++; MIRIAD – via UVFITS

WSRT limitations:
- No ‘snapshots’ (one-dimensional array)
- Beam elongated N-S, \( \propto 1/\sin \delta \) (E-W array)
- Poor 2-d imaging for \( \delta < 0^\circ \) (cannot measure large ‘wedge’ in \( u,v \)-plane)
Example of HI mapping
Very extended radio galaxies like $3C\ 236$ and DA 240
The presumed supernova remnant CTB80 at $\lambda$49 & 3.6 cm

This flat spectrum PWN contains a 40 ms pulsar
Pulsar observing is done with the PuMa backend

PSR 1937+21, P=1.6 ms

![Graph showing pulsar signals over time]
In tied array mode (pulsars, VLBI) the WSRT has collecting area of 94 m dish.

Things to keep in mind when the WSRT is used as a VLBI element:

- Equatorial mount, not alt-az
- Allowed HA range (-6h – +6h) means any source can only be observed for 12 h
- The tied-array response is a fan-beam, ~12" arc wide at L-band. It can be broadened by dropping elements, with some loss of sensitivity
New project to produce multiple beams in each WSRT element for survey work
Thanks!