SIMULTANEOUS, MULTI-FREQUENCY VLA OBSERVATIONS OF INVERTED SPECTRUM RADIO SOURCES

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Riccione GPS Conference
GPS and Inverted Spectrum Sources as a Problem, not a Pleasure

Radio sources confuse Cosmic Microwave Background (CMB) observations on small scales (<10′)

*Inverted spectrum* sources are a major problem.

- If spectrum close to thermal, hard to differentiate from CMB fluctuations.
- Such sources less likely to appear in low-frequency all-sky surveys

Hence my interest in GPS sources

Problem worse if sources are

- variable
- polarized.

Blind source counts at high frequency are hard.

- Total observing time, \( t \propto \nu^{-2} \) for fixed \( A_e \) and \( T_{syst} \).
- Australian 18 GHz survey (AT20G) will be very valuable (see following talk by Hancock)
Alternative to Blind Survey: A “Worst Case” Scenario

Explore sources known to have inverted spectra at higher frequencies.

Source selection

- cross correlated FIRST (1.4 GHz) and GB6 (4.9 GHz)
- required $\alpha > 0.4$ (with $S \propto \nu^\alpha$) (stronger criterion than Stanghellini et al. faint sample)
- used conservative flux thresholds (& dropped confused sources)
- selected $\sim 400$ sources
- observed $\sim 250$ of these, selected by sky position

- Highly *inhomogeneous* sample.
- New features: substantial numbers and *fainter fluxes* ($\sim 10-100$ mJy)
VLA Multifrequency Observations

Early round:

• simultaneous 1.4, 4.9, 8.5 and 22 GHz observations of ~250 inverted-spectrum sources
  – *simultaneous* to control for variability
  – (also have *some* multi-epoch observations)

• resolution issues: if source solid angle exceeds VLA beam size, flux density is underestimated

  $\alpha$ could be *overestimated* (loss of flux at low $\nu$) if steep-spectrum lobes are present

  $\alpha$ could be *underestimated* (loss of flux at high $\nu$) if cores are resolved at high frequency

  – therefore, regard these spectral indices as $\alpha$ for the *core*
Second VLA Observing Run

Follow-up VLA program ~17 months later:

- Re-observe at 8.5 GHz to control for variability
- Deeper 22 GHz observations
- 43 GHz fluxes for ~40 sources.

- Sources selected to have spectra flat or inverted to 22 GHz.
  So again, highly inhomogeneous sample.

- Polarization measured.
# Image Parameters

<table>
<thead>
<tr>
<th>Frequency, GHz</th>
<th>Epoch</th>
<th>Beam*</th>
<th>RMS, mJy*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.46</td>
<td>09/2001</td>
<td>50'' x 20''</td>
<td>~2</td>
</tr>
<tr>
<td>4.86</td>
<td>09/2001</td>
<td>15'' x 12''</td>
<td>0.18</td>
</tr>
<tr>
<td>8.46</td>
<td>09/2001</td>
<td>8'' x 6''</td>
<td>0.35</td>
</tr>
<tr>
<td>8.46</td>
<td>02/2003</td>
<td>10'' x 8''</td>
<td>0.4</td>
</tr>
<tr>
<td>22.4</td>
<td>09/2001</td>
<td>3'' x 2''</td>
<td>--</td>
</tr>
<tr>
<td>22.4</td>
<td>02/2003</td>
<td>4'' x 3''</td>
<td>0.25</td>
</tr>
<tr>
<td>43.3</td>
<td>02/2003</td>
<td>1.6'' x 1.2''</td>
<td>0.40</td>
</tr>
</tbody>
</table>

*Both approximate; HA, confusion and weather dependent.*
Results: Two-color Diagrams

~240 sources detected; ~160 in all bands.

Fluxes ~10-100 mJy.
Results: “False” Inverted Sources

Flaring during 5 GHz GB6 observations
“Normal” $\alpha < 0$ during our observations

Only $\sim 8\%$ of total

So most of sample has some spectral inversion.
Extension to 43 GHZ

~40 sources re-observed at 8, 22 & 43 GHz (excluding two strongly variable sources)

~8% turn over at \( \nu > 22 \text{GHz} \)
Related Observations: Radio Sources in Clusters

Lin, Partridge et al., astro-ph 0805-1750
140 sources in low-redshift X-ray clusters

Note shift in axes
Results: Spectral Variability

As pointed out by Merja Tornikoski, an issue for GPS sources ~5% of sources varied strongly (>15%) at 8 GHz; ~20% at 22 GHz. Given spectral variability, perhaps better to describe as Gigahertz Peaked Behavior.
Results: Spectral Variability

1446+173 (AP450: 0206, AG617: 0914,15–Sep–01)
Results: Polarization

Polarization measured at 8.5, 22 and 43 GHz
Mostly upper limits (especially at 22 & 43 GHz)
polarization < 4%
some trend for increase with $\nu$

1407+284 not shown: pol. = 0.6%
Preliminary Results: Optical IDs

60% optically identified to $21^m$
Of these $\sim 1/2$ galaxies, $1/2$ quasars

Of the GPB sources, $1/2$ quasars, $1/3$ galaxies, $1/6$ unidentified based on Palomar Survey

(Need to re-do using SDSS).