The nuclear structure of 3C 84 with Space VLBI (Radioastron) observations

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HST image of NGC 1275 with the red filter (F625W) contains the H alpha line (Fabian et al 2008). The image measures 140x150 arcsec in size.
3C84: A gamma-ray bright misaligned AGN

- BCG of the Perseus Cluster
- Prototypical cooling core cluster
- One of the strongest compact radio sources
- Extensively studied up to 87 GHz (radio)
- Nearby: $z=0.0176$, $1\ \text{mas} = 0.344\ \text{pc}$
- Central mass $3.4 \times 10^8$ solar masses
- $0.1\ \text{mas} = 10^3\ r_g$
At mas resolution 3C84 shows two symmetric 'lobes' with evidence of absorption in the Northern one.

At sub-mas 3C84 appears one-sided with slow proper motion (sub-luminal): $0.1 - 0.5 \, c$ in contrast with the sidness asymmetry and the high jet velocity required by the gamma-ray emission.

If the source is intrinsically symmetric it should have relativistic jets: $v = 0.9c$ if theta = 25 deg.

→ large deceleration expected because of jet interaction with a dense ISM (cooling cluster, Liuzzo et al. 2010)
From Asada et al. 2006, VSOP observations ➔ Lobe proper motion ➔ Lobe age: 1959 outburst
0316+413: 43 GHz
Epoch 1999.26

Core C1

C2

Romney et al. 1995
Activity related to C2 component

2003 ejection new component C3
VLBA at 43 GHz in the period of 2002–2008
Kenta Suzuki et al. 2012

Peak position of $C3$
VERA 43 GHz images from Nagai et al. 2012

New ejection C3, flux density increase
2009 August detected by Fermi-LAT
Abdo et al. 2009
Spectral index information suggest C1 as the radio core

No strong connection between gamma-ray flares and radio activity

C3 flux density is increasing -- it is the brightest component
January 2013 image VLBA at 43 GHz

Nagai et al. 2014
Radioastron: September 21, 2013

JVLA - phased array at 22 GHz, but observations also at different Frequencies:

JVLA only: unresolved nuclear structure:

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>Jy</th>
<th>5-15 GHz spectral index</th>
<th>self abs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>17.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>35.9</td>
<td>-0.65</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>42.3</td>
<td>-0.43</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>29.3</td>
<td>0.55</td>
<td></td>
</tr>
</tbody>
</table>
UV coverage Radioastron at 5 GHz after data editing and calibration
Ground only baselines

Ground + a few space bas. 2 ED
43 GHz image from Nagai et al. 2014 - HPBW: 0.24x0.13

5 GHz Radioastron image
0.9 x 0.5 mas
Spectral index between 5 and 43 GHz

-0.7

0.2

-1.4

HPBW=0.70x0.45
uv max 70x10^4
4.7 ED
1990 – 2000: source in a low flux density phase
   centrally peaked jet
   no VHE emission
C2  now relatively steep spectrum:  1990 – 2000 activity
   connection with 1959 lobes?

After 2005: nuclear activity + C3  ➔  increasing flux density
   new jet orientation
   limb-brightened jet

C3 self-absorbed - new ejection - connection with 1959 lobes?
C1 core self-absorbed

Tavecchio and Ghisellini 2014: the overall SED of 3C84 can be
   reproduced in the framework of the «spine-shear» model.
Radioastron results (only from 5 GHz data):

1) 3C 84 core self-absorbed - unresolved at about 0.4 - 0.3 mas

2) One-sided jet resolved in agreement with limb-brightened structure spectral index = 0.2

3) C3 compact and bright component surrounded by a diffuse emission

4) C2 emission diffuse and steep spectrum (1.1 = old emission)
   ➔ Previous activity misaligned by IGM not connected to lobes?

We need a better insight of the core and the C3 region
 ➔ radioastron 22 GHz data
Thank You