eEVN monitoring of M87

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Background: M87, or 3C274, or Virgo A

- Nearby FR1 radio galaxy, hosting massive black hole:
  - $d=16.7\ \text{Mpc}$,
  - $M_{\text{BH}}\sim 6\times 10^9\ \text{M}_\odot$
  - Scale: $1\text{mas} = 0.081\text{pc} = 140R_s$
  - Radio power $\sim 10^{25}\ \text{W}\ \text{Hz}^{-1}$ (@408 MHz)
M87: radio jet

- Inner jet shows limb brightened structure, no well defined proper motion

- Superluminal motions are detected downstream the jet with HST/VLA/VLBA
  - eg feature HST-1 ~0.8” (~70pc) from core

Courtesy of C. Walker
M87 at high energy

- Only resolved in X-rays by Chandra
- Detected -- not resolved -- by Fermi-LAT and TeV observatories (MAGIC, VERITAS, HESS)
- 2008: TeV flare, radio core flux density increase, quiescence in HST-1 (Acciari et al. 2009)
How to solve this?! 

- Need a coordinated TeV+radio monitoring 
- In radio, high sensitivity, good resolution, large field of view are needed 
  - EVN (with Shanghai, Arecibo) at 6cm 
  - in eVLBI mode to get good time sampling and prompt results 
- 6-8 hours observations on 2009 Nov, 2010 Jan, Feb, Mar
Clean I map. Array: EVN
M87 at 5.004 GHz 2010 Jan 27

EVN images

Map center: RA: 12 30 49.396, Dec: +12 23 28.244 (2000.0)

core
1.8 Jy/bm

inner jet
~250 mas long

HST-1
total flux ~20 mJy
EVN images, zoom
Radio-VHE, the campaign

• As we had hoped, TeV flares are detected! February 9th (ATel #2431), April 8-10 (ATel #2542)

• First flare is almost simultaneous (within 24hr) to our 2nd EVN epoch - core and HST-1 well behaved

• Additional observations extend monitoring until June
No significant increase of flux density in either core or HST-1, so far

<table>
<thead>
<tr>
<th>Epoch</th>
<th>Core (Jy)</th>
<th>HST-1 Peak (mJy/beam)</th>
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</thead>
<tbody>
<tr>
<td>Nov 19 - 2009</td>
<td>1.81 ± 0.03</td>
<td>3.5 mJy/beam</td>
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<tr>
<td>Jan 27 - 2010</td>
<td>1.81</td>
<td>2.7 VHE activity</td>
</tr>
<tr>
<td>Feb 10 - 2010</td>
<td>1.80</td>
<td>3.0</td>
</tr>
<tr>
<td>Mar 6 - 2010</td>
<td>1.89</td>
<td>4.6</td>
</tr>
<tr>
<td>Mar 28 - 2010</td>
<td>2.01</td>
<td>3.4</td>
</tr>
<tr>
<td>May 18 - 2010</td>
<td>1.93</td>
<td>2.8</td>
</tr>
<tr>
<td>Jun 9 - 2010</td>
<td>1.93</td>
<td>2.6</td>
</tr>
</tbody>
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Radio-VHE sum up

- Episodes of very high energy activity detected in 2005, 2008, 2010
- Simultaneous lower energy activity reported in jet feature (HST-1, 2005), core (2008) or none (2010)
- Coincidence or different mechanisms
- What is HST-1 anyway?
HST-1 kinematics

- Superluminal proper motion well measured in HST-1
- Different orientation wrt to inner jet and older observations
- Worth continuing to monitor
Additional data on HST-1 kinematics

- Additional observations available in the literature/archives:
  - Cheung et al. 2007: VLBA @1.6 GHz
  - Chang et al. 2010: VLBA @15 GHz
  - VLA archives at 15-22 GHz
  - Post-2005 apparent speed ~2.7c
Take home notes

- eEVN imaging beautifully suit coordinated studies of M87
- Two competing models: neither is confirmed
- Need more data!!!