

# Intermediate Scale Structures in BL Lac Objects

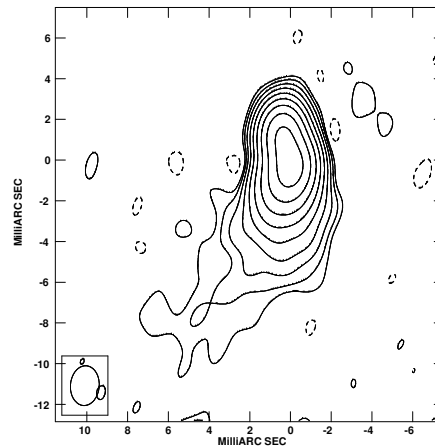
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# Introduction

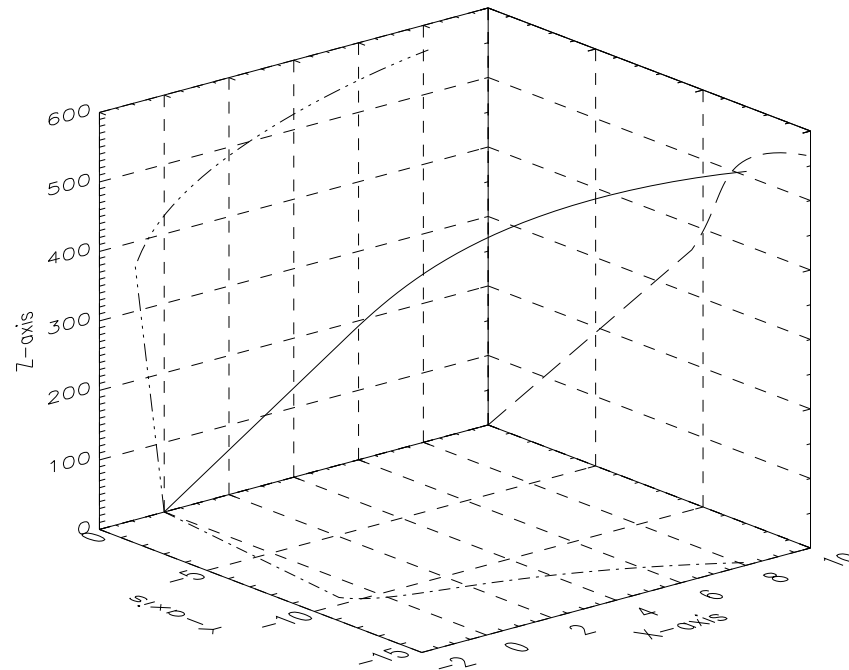
BL Lac objects:

- Are blazars - rapidly variable polarized radio emission
- Have low emission line luminosities
- It has been suggested that they are beamed counterparts to low luminosity FR 1 radio galaxies.
- Show complicated VLBI structure, but are often approximately point sources to the VLA.



# Parsec-scale Jets

- Initially relativistic.
- Often do not survive on to arcsecond scales.
- e.g., 3-D trajectory modelling of BL Lac suggests deprojected scales of  $\sim 1$  kpc.



# Intermediate Scale Emission



- A number of the most famous BL Lacs appear as (near) point sources to the VLA.
- But the flux density recovered in VLBI images is less than seen by the VLA.
- $\Rightarrow$  emission on intermediate scales.
- The luminosity in the inferred intermediate scale structure can be quite high.
  - This may have implications for BL Lac/FR I unification schemes.
- Attempt to image the intermediate scale emission by going to low frequency.
  - Is likely to be steep spectrum.
- VLBA observations at 2.3 GHz, 1.7 GHz, 600 MHz, 300 MHz.

# Source Selection



Based on previous simultaneous VLBI and VLA images.

Intermediate scale (I.S.) flux densities.

Source	Inferred I.S. $I/(\text{Jy})^a$	Inferred I.S. $p/(\text{Jy})^a$	Inferred I.S. $\chi/(\text{deg})^a$
1219+285	0.22	0.011	-88
1803+784	0.59	0.058	58
BL Lac	0.43	0.019	37
0735+178	0.87	0.020	85
0954+658	0.21	0.033	-50

<sup>a</sup> Gabuzda et al. (1992, 1994)

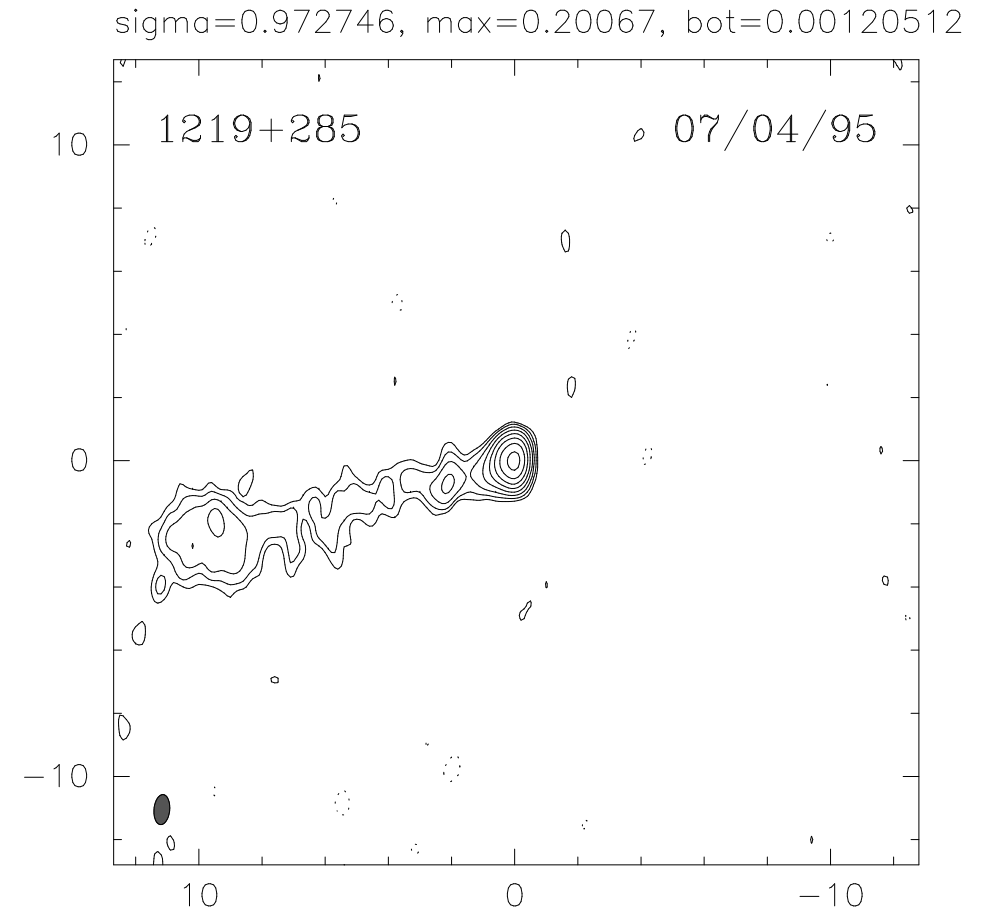
The intermediate scale flux density has luminosity above the FR I/FR II division.

Here we present the first two sources: 1219+285 and 0735+178.

# 1219+285

## Source details:

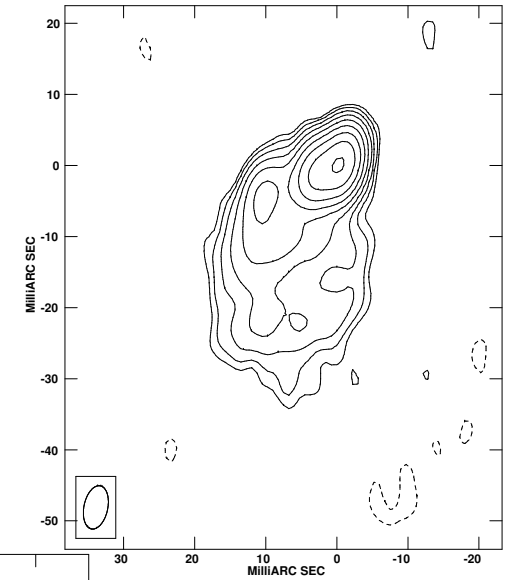
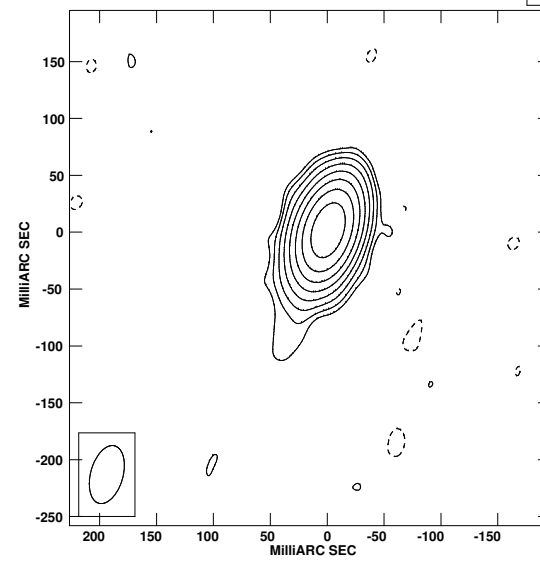
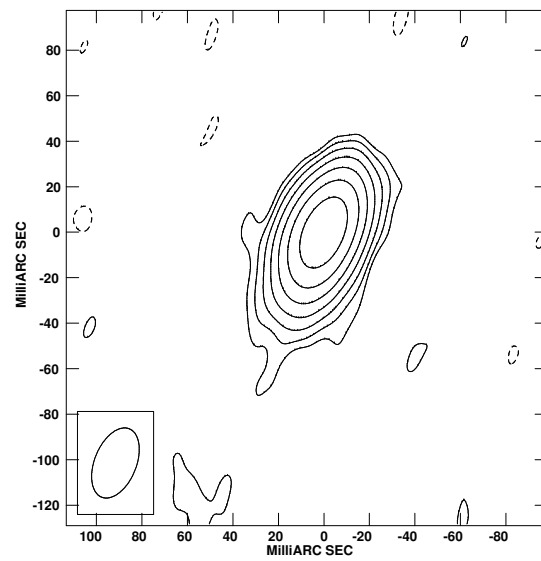
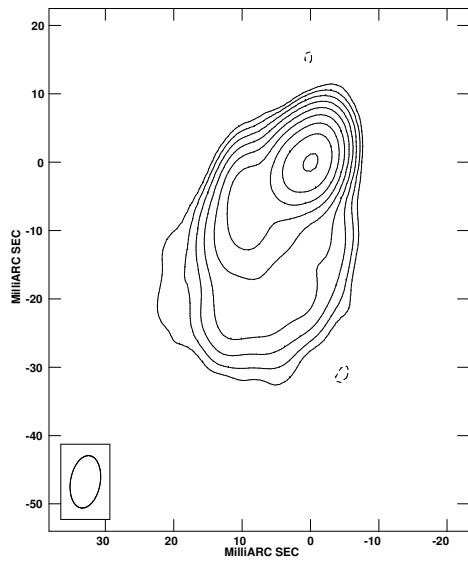
- $z = 0.102$
- VLBI jet extends to east of the core, then turns south (e.g. Mantovani poster)
- Superluminal components.
- Unresolved to VLA D-array (Kollgaard et al. 1992).



from VLBA 2 cm survey: “A long thin jet terminates in a prominent extended component.”

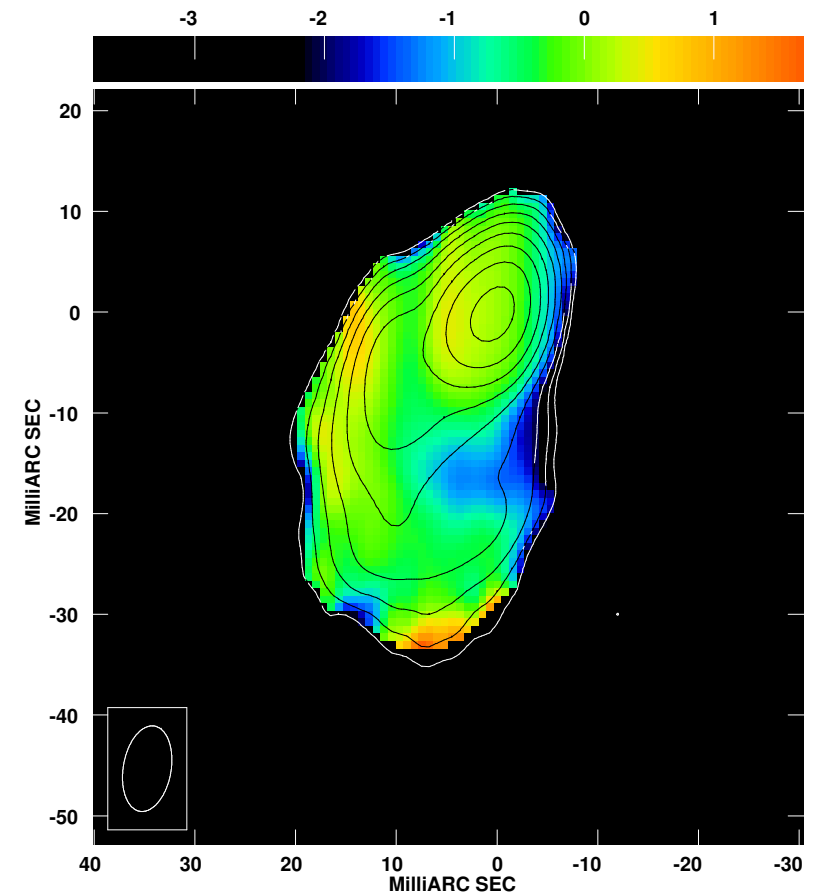
# 1219+285 – Images

Peak emission at  
0.38, 0.38, 0.66 and 0.68 Jy/beam,  
respectively.



# 1219+285 – Results

- Diffuse emission to south,  $\perp$  to known VLBI jet.
- Jet appears to change direction sharply.
- Increased brightness and flatter spectral index (see right) at point where jet begins to bend.
- Less than 50% of the expected I.S. flux is detected.
- No evidence for additional extended emission at the lowest frequencies.
- Luminosity in the intermediate scale structure  $\sim 2.2 \times 10^{24} \text{ W Hz}^{-1}$



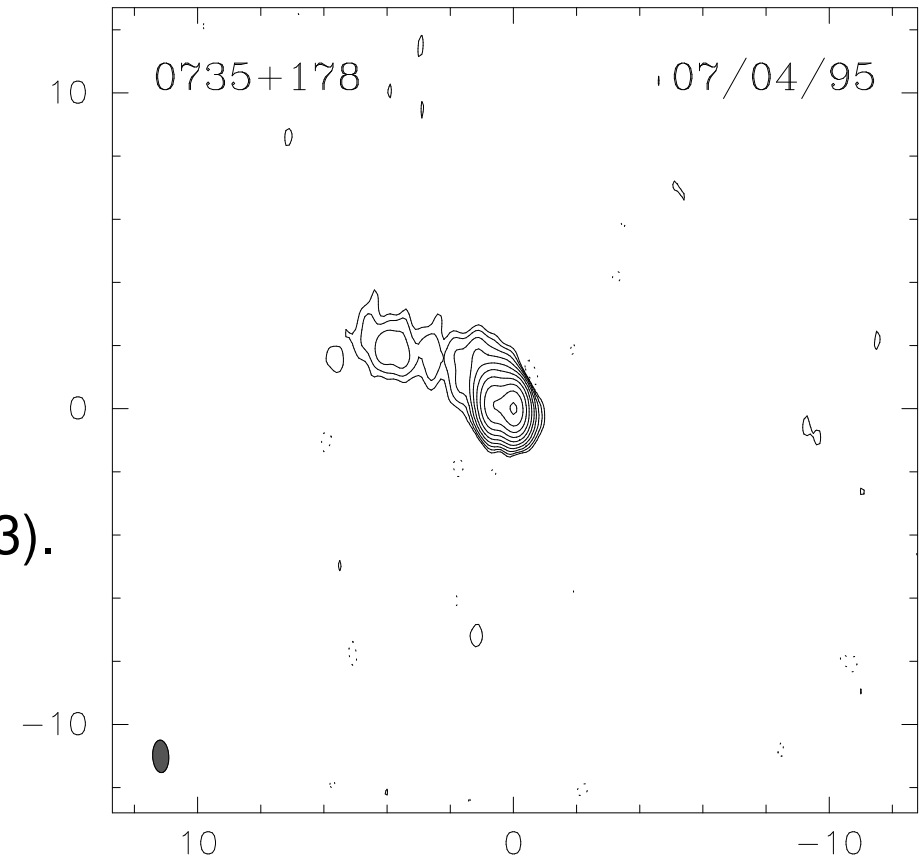


# 0735+178

## Source details:

- $z \geq 0.424$  (absorption lines)
- VLBI jet extends to northeast of the core.
- Superluminal components, and apparent bends of  $90^\circ$ .
- Unresolved to VLA (Kollgaard et al. 1992, Ulvestad et al., 1983).

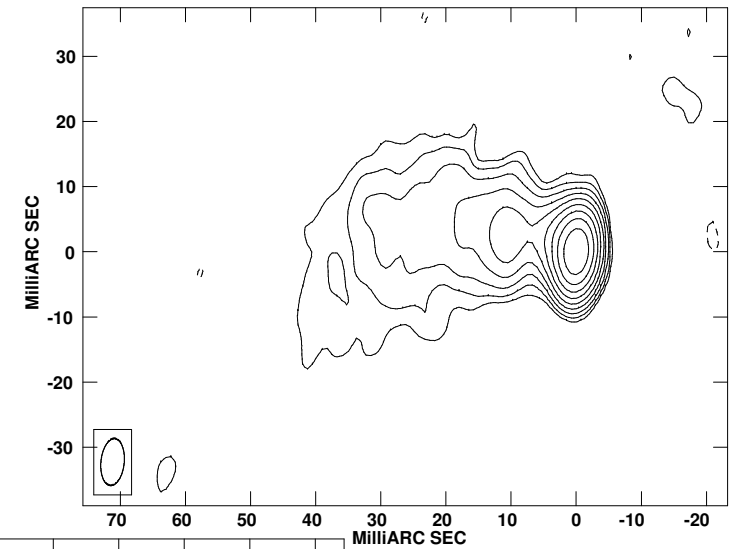
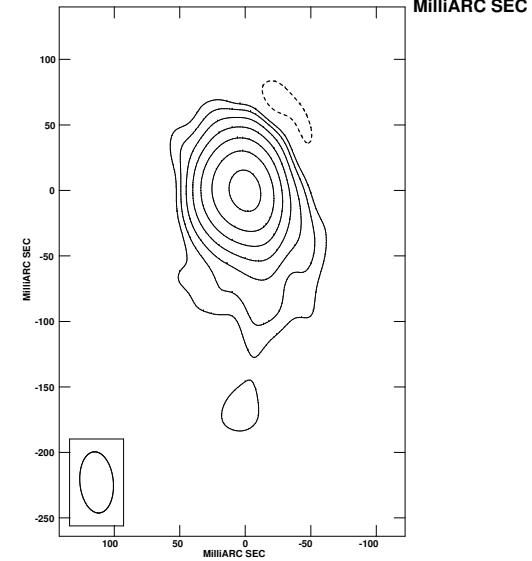
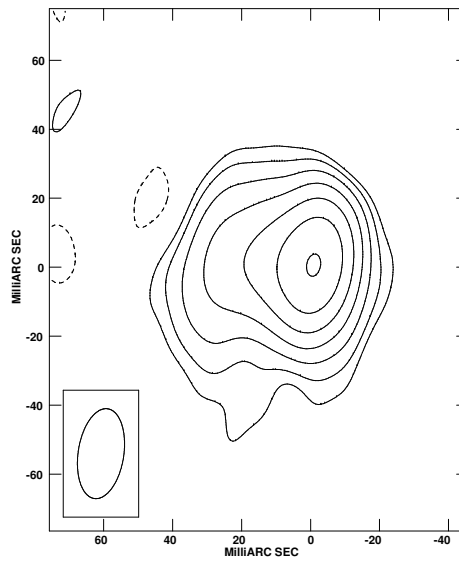
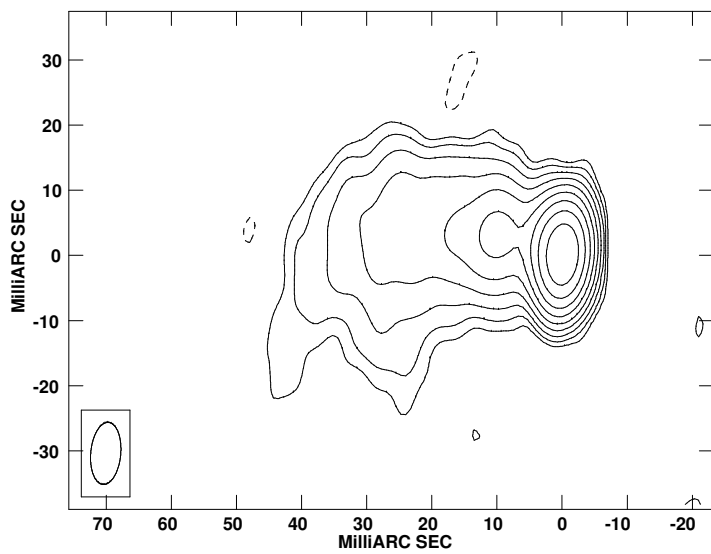
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from VLBA 2 cm survey: “The jet has multiple sharp curves”.

# 0735+178 – Images

Peak emission at  
0.78, 0.79, 0.65 and 0.43 Jy/beam, respectively.



# 0735+178 – Results



- Jet beginning to turn towards south.
- Most of the expected I.S. flux is detected.
- Again, no firm evidence for additional emission at the lowest frequencies.
- Luminosity in the intermediate scale structure  $\sim 6.1 \times 10^{25} \text{ W Hz}^{-1}$

# Summary



- Coherent structures are detected in 1219+285 and 1803+784 on scales of  $\sim 30$  pc from the core.
- In 0735+178, almost all of the predicted I.S. flux is detected.
  - The new structures appear to be associated with a well-collimated jet.
- In 1219+285, a reasonable ( $\sim 50\%$ ) fraction of the predicted I.S. flux is detected.
  - Diffuse – possibly plume-like – emission is detected in 1219+285.
  - The luminosity in the diffuse structures in 1219+285 is at the lower end of the FR I/FR II divide.
  - The remaining “missing flux” has a power above the FR I/FR II divide.
- The polarization may provide information on interactions with the IGM (Faraday rotation, shear interactions, etc.).
- 3 more sources are available in the current sample. EVN/MERLIN data to come...