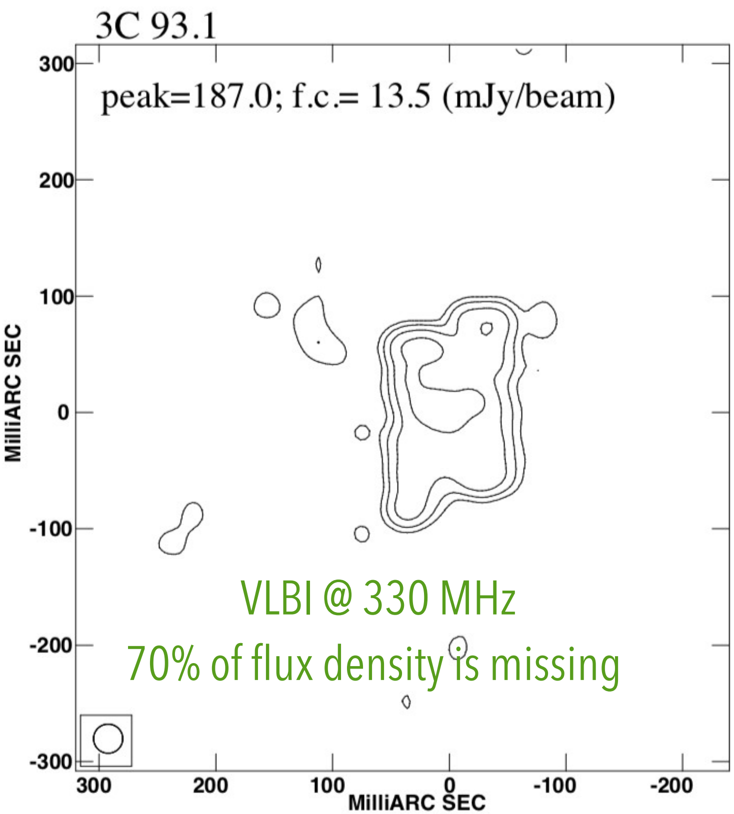
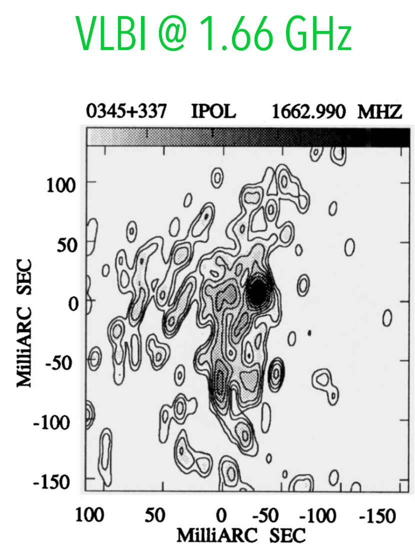
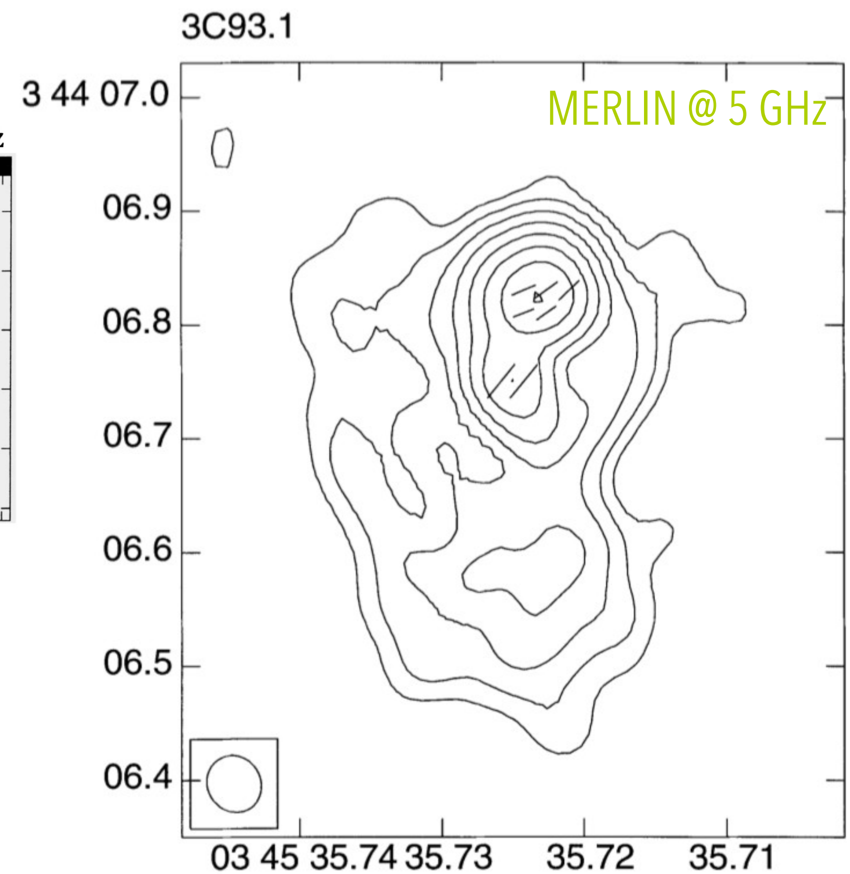
Bright Compact Steep-Spectrum Sources at Low Frequency







Daniele Dallacasa, Monica Orienti, Carla & Roberto Fanti
2021, MNRAS, 54, 2312

Bright ...

CSS Sources from 3CR +PW sample (Spencer et al. 1989, Fanti et al. 1990)

(G, SSQ, EF)

Classic sample of powerful CSS objects

'' radio source smaller than the host galaxy (EF < 4″) ''

'' radio spectrum peaking from ~ 100 MHz to ~ GHz ''

Spencer, Schilizzi, Akujor, Nan Rendong, Sanghera, Ludke, Stanghellini, Venturi, Garrington, Wilkinson+ many others

Are they still relevant? (to be studied at low frequencies)

Cores (and Jets)?

H – S ?

Lobes?

... and the turnover frequency

Sometimes, low frequency turn up in the radio spectrum (earlier activity?)

Faders ("radio steep", no core, no jets, no h–s)

Most properties are ~ understood (youth ~ ok, but...
Quasars .vs. galaxies; polarization & environment/size)

However, still working on them.... (e.g. interpretation in terms of a number of discrete components generally not satisfactory)

330 MHz observations, Mark II (3CR) and Mark III mode E (PW)

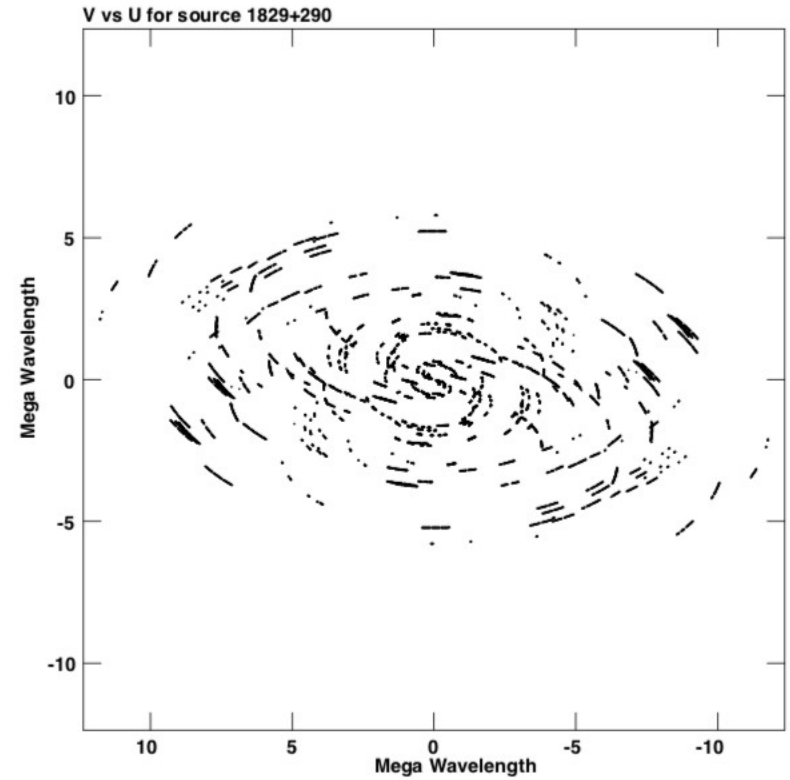
1992 November 4 and 1995 February 20.

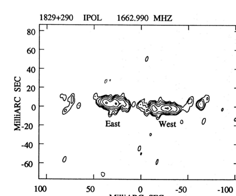
Snapshots

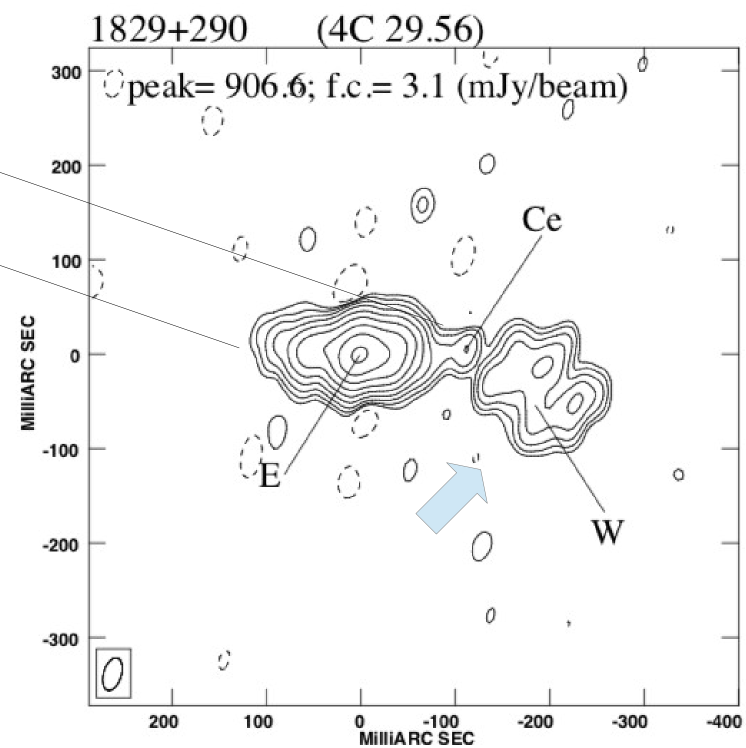
Resolution ~ 20mas

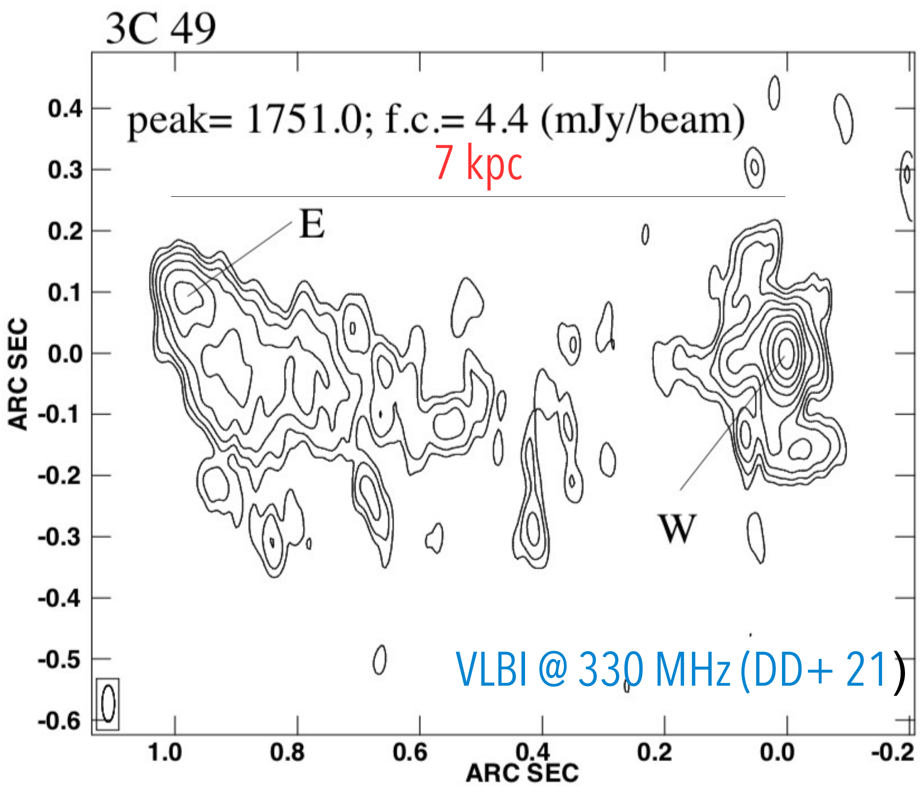
Noise ~ 2-5 mJy/beam

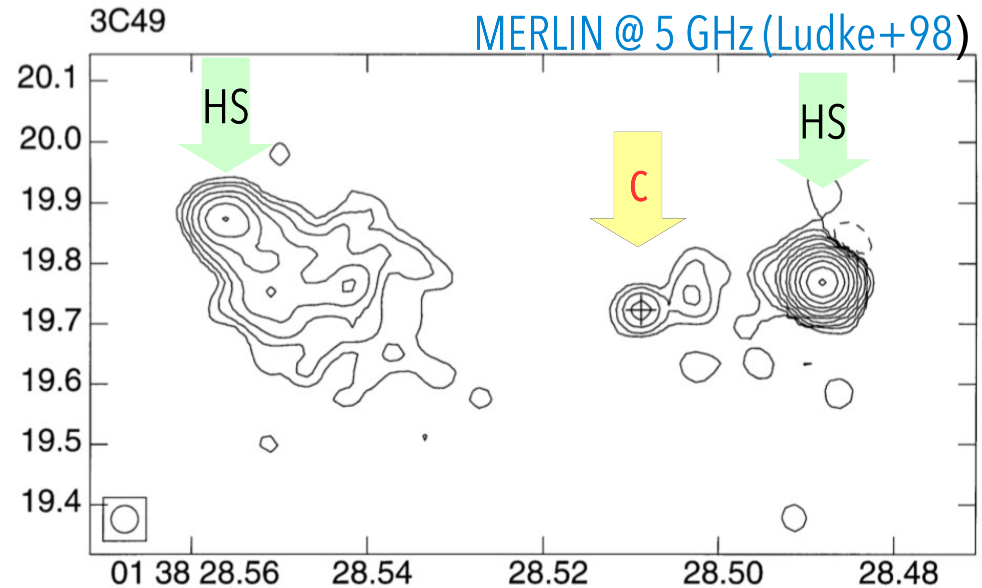
Sometimes, additional components are detected



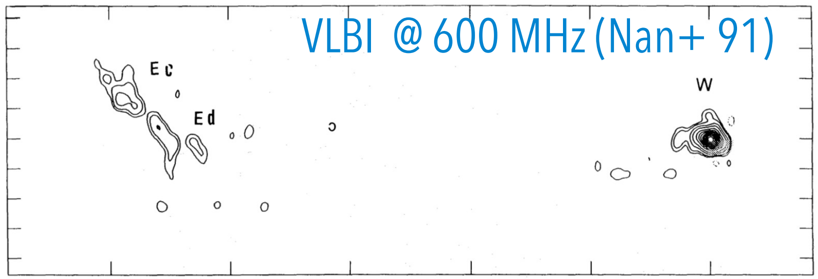


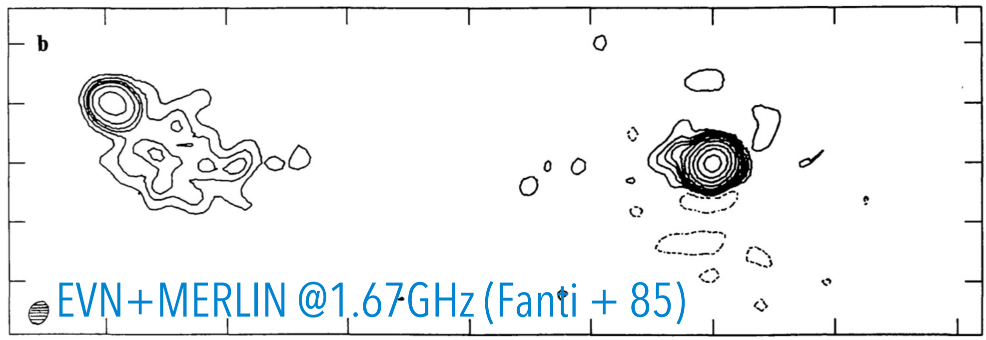


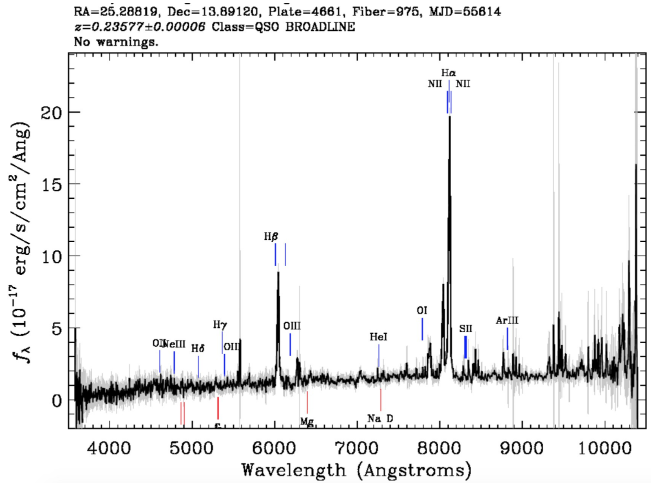


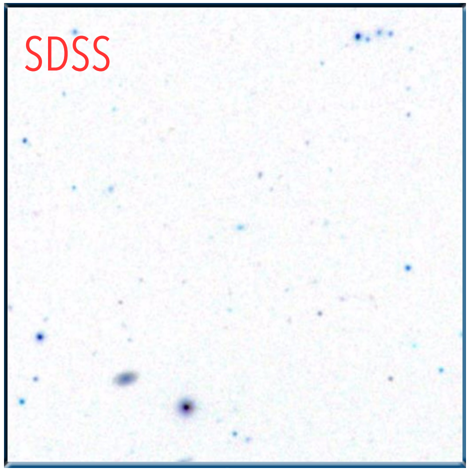


Asymmetry in the FD increases with frequency



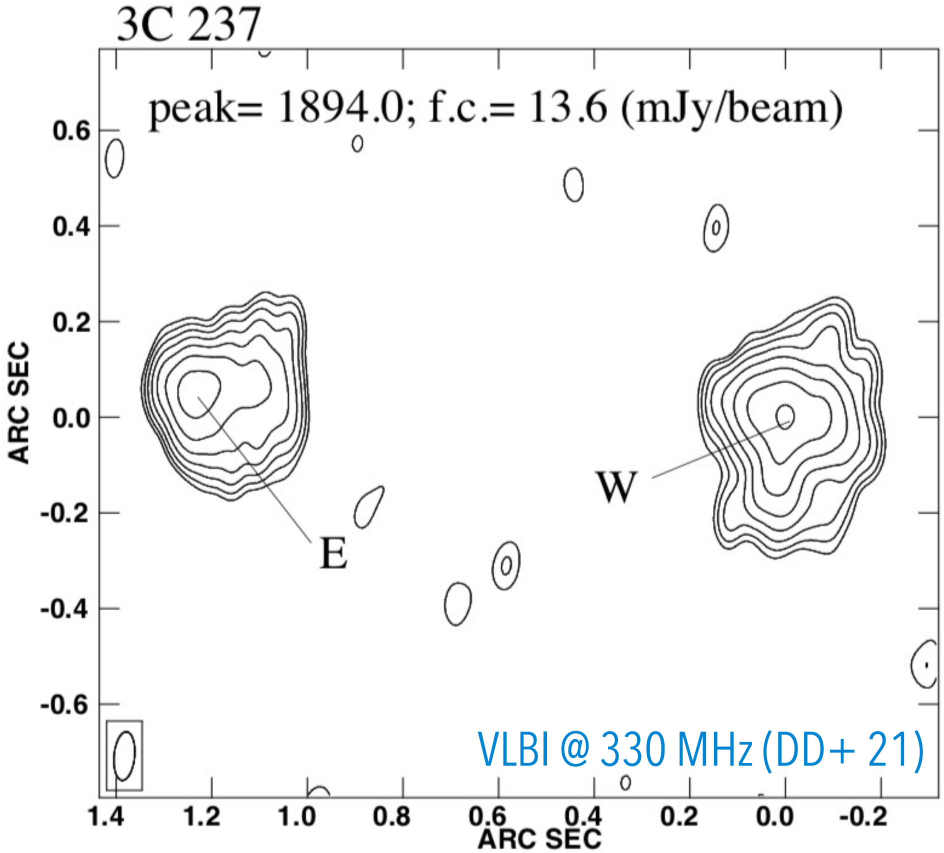






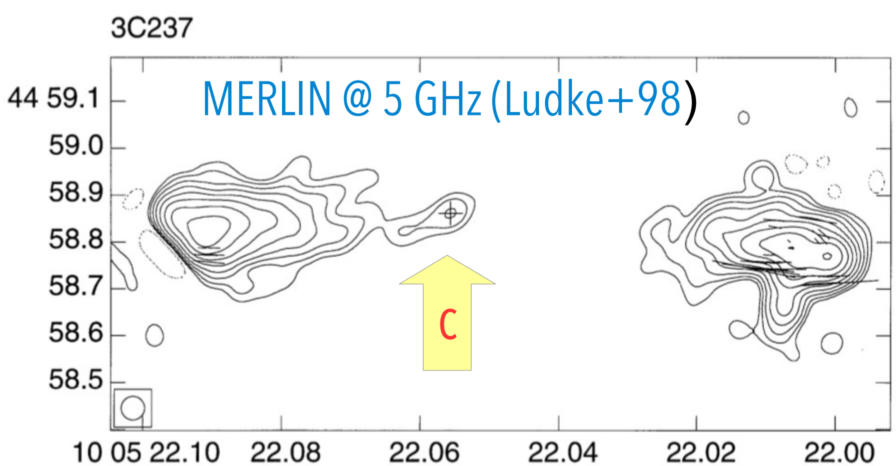
G 3C49, Z=0.621

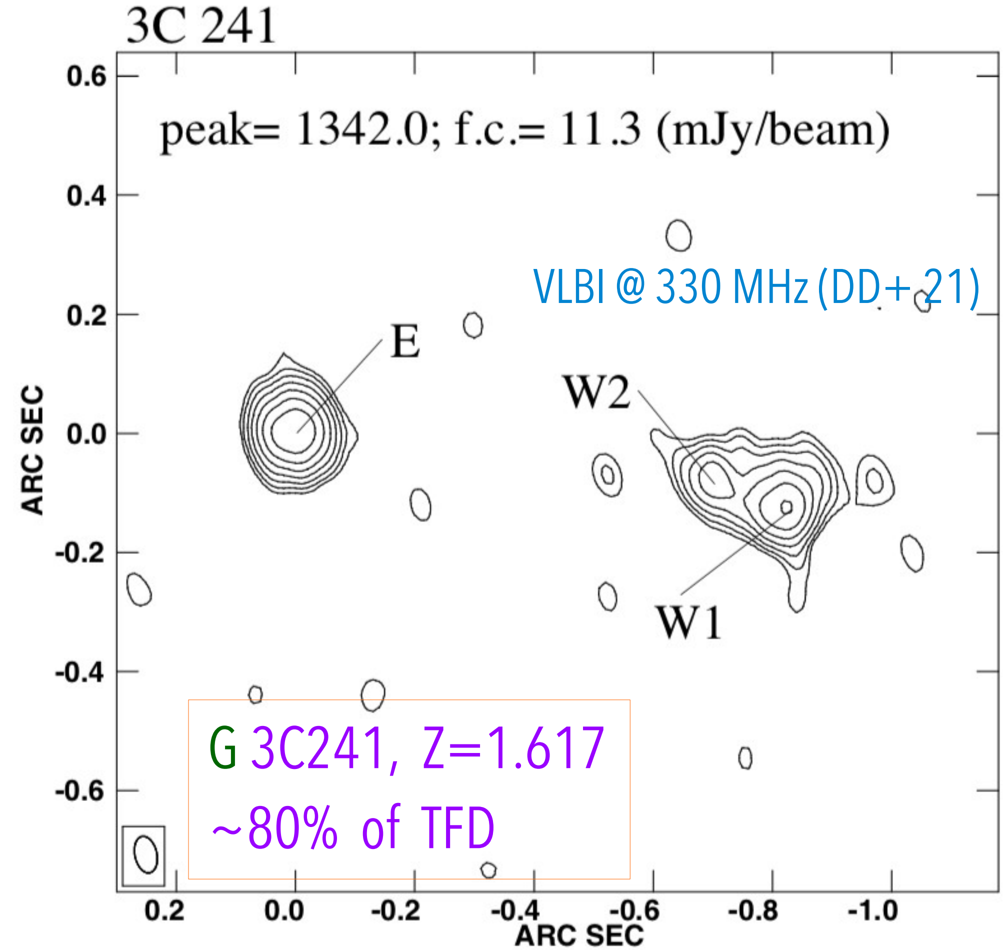
~100% of TFD

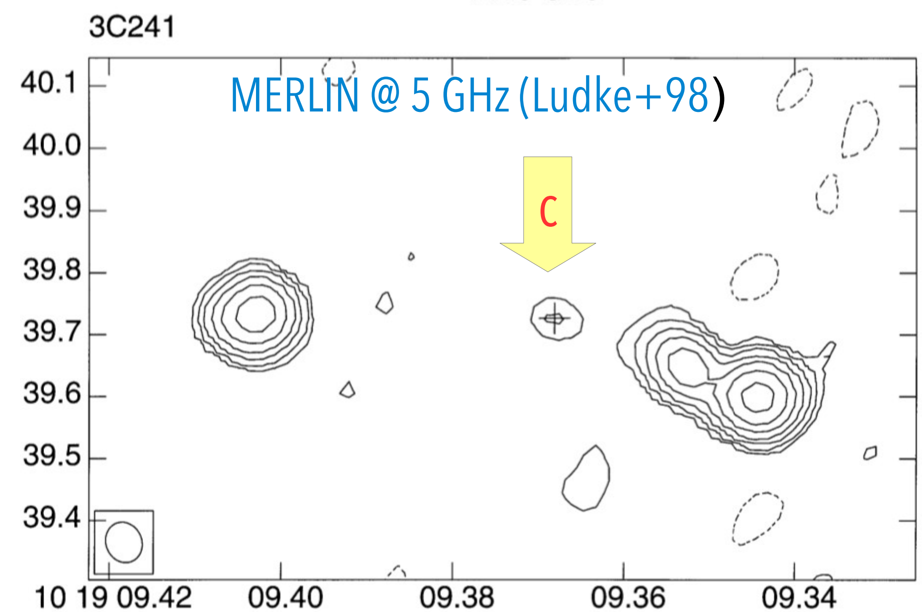


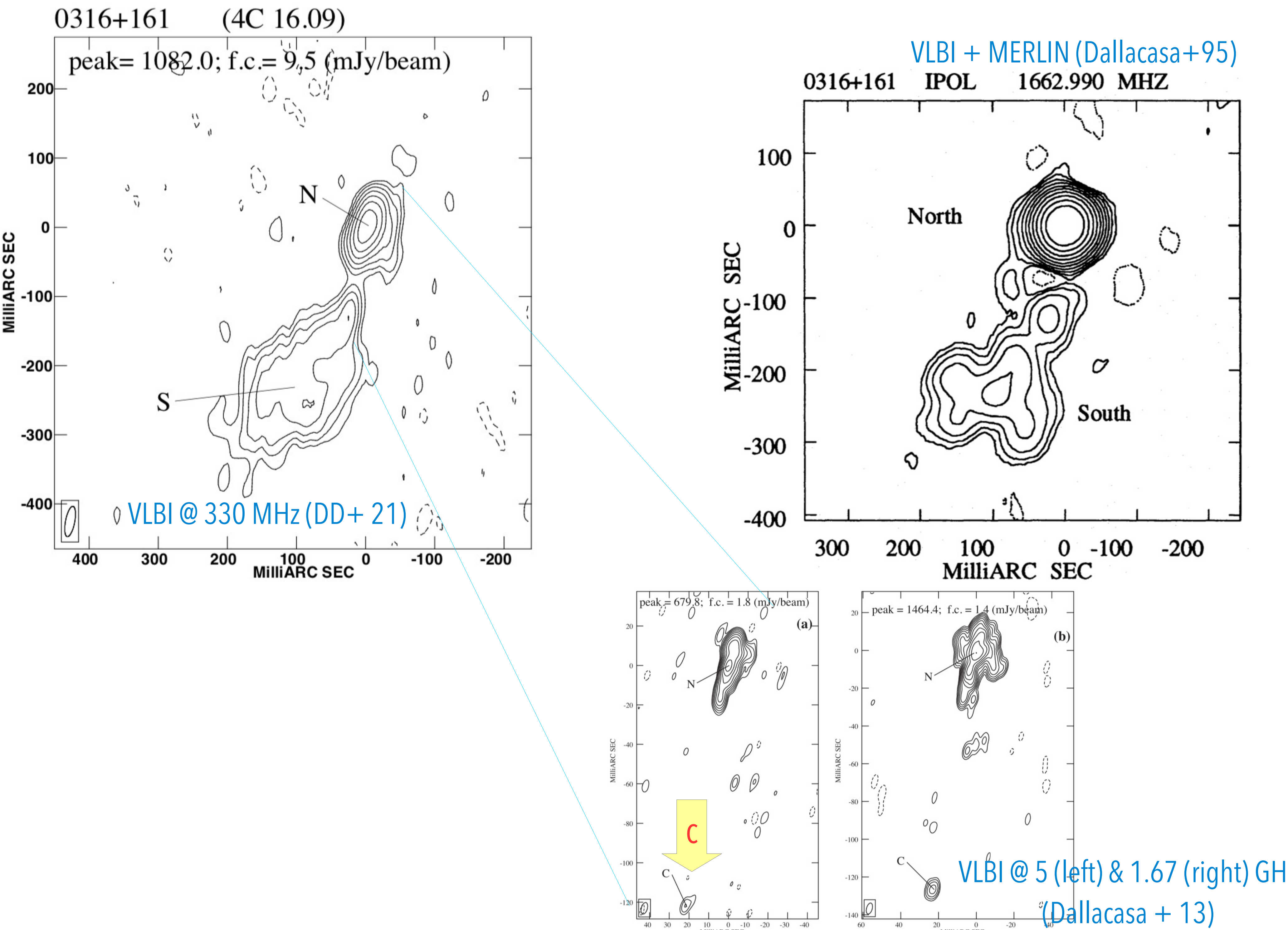
G 3C237, Z=0.877

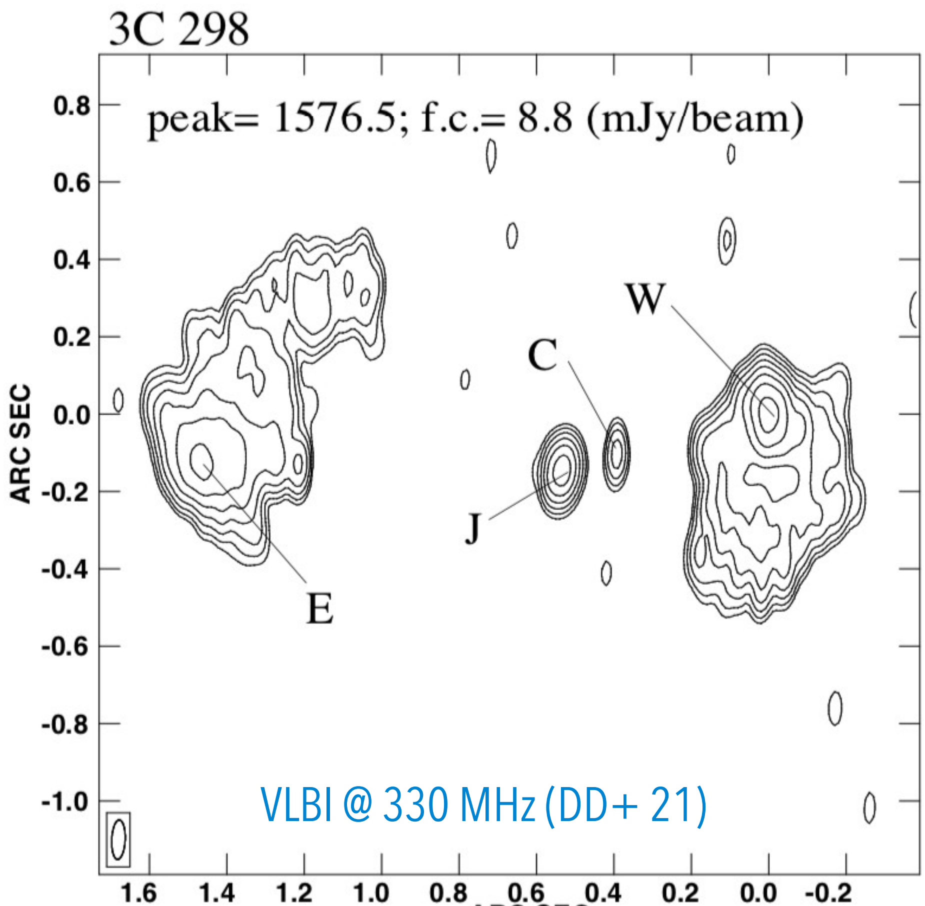
~100% of TFD

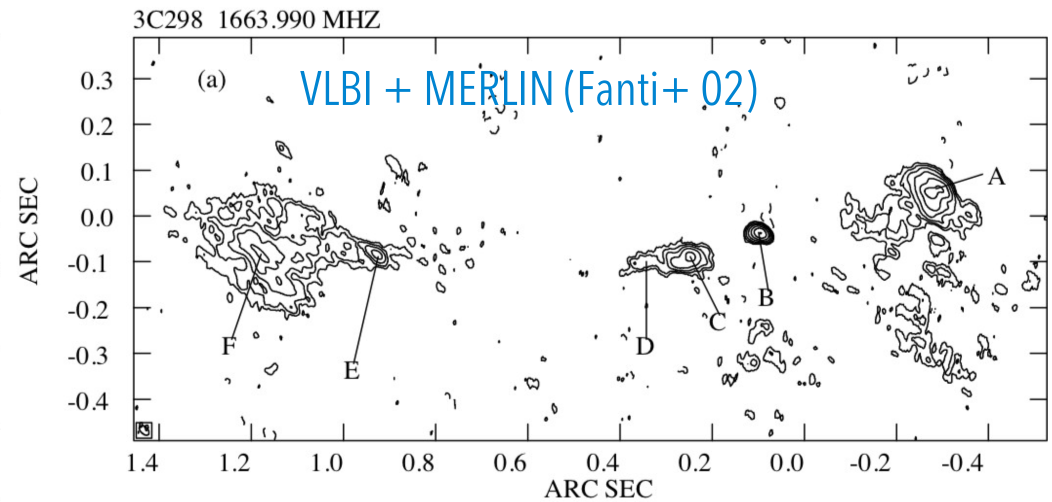


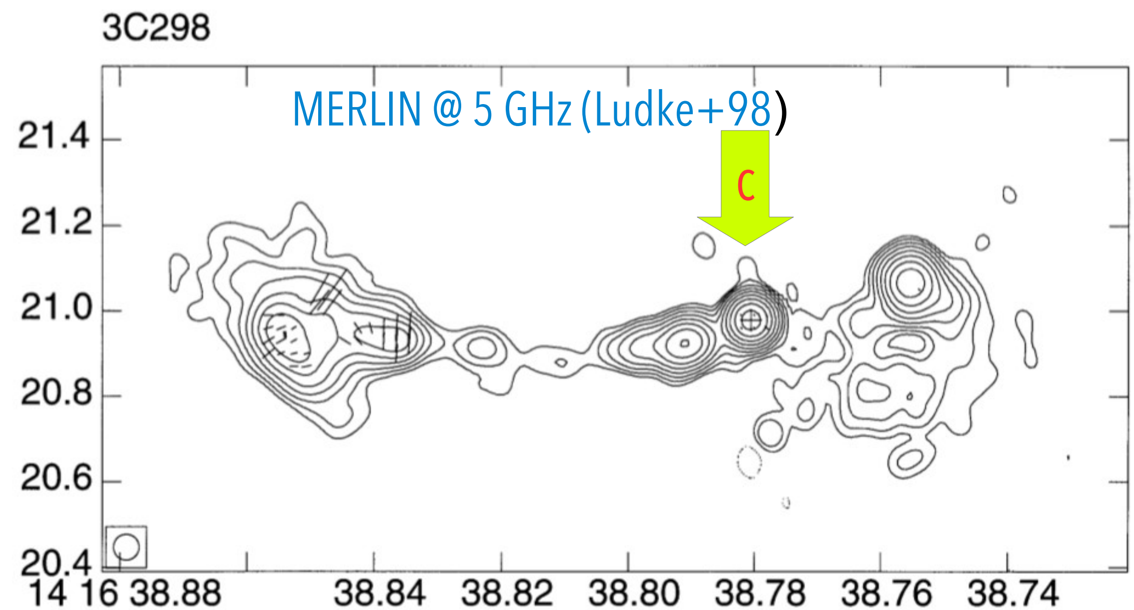


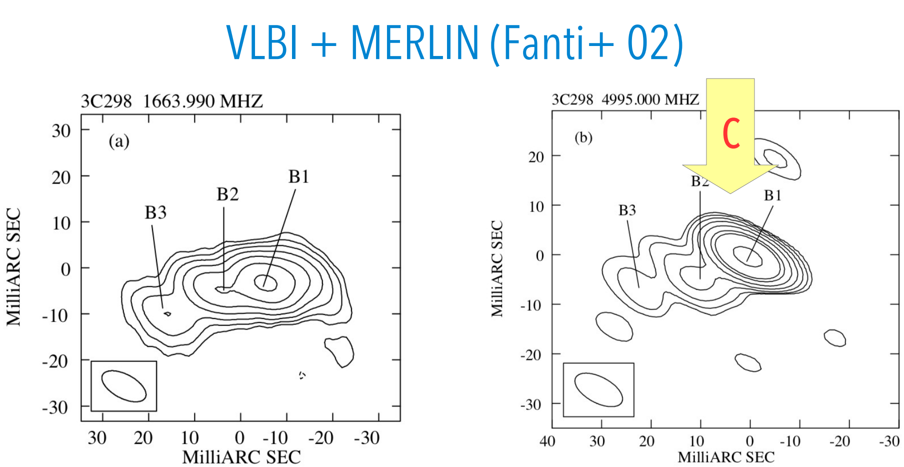



0316+161 (4C 16.09)
peak= 1082.0; f.c.= 9.5 (mJy/beam)
N
S
MilliARC SEC
VLBI @ 330 MHz (DD+ 21)
VLBI + MERLIN (Dallacasa+95)
0316+161 IPOL 1662.990 MHZ
North
South
MilliARC SEC
peak = 679.8; f.c. = 1.8 (mJy/beam)
(a)
peak = 1464.4; f.c. = 1.4 (mJy/beam)
(b)
N
C
MilliARC SEC
VLBI @ 5 (left) & 1.67 (right) GHz
(Dallacasa + 13)









Q 3C298, Z=1.437

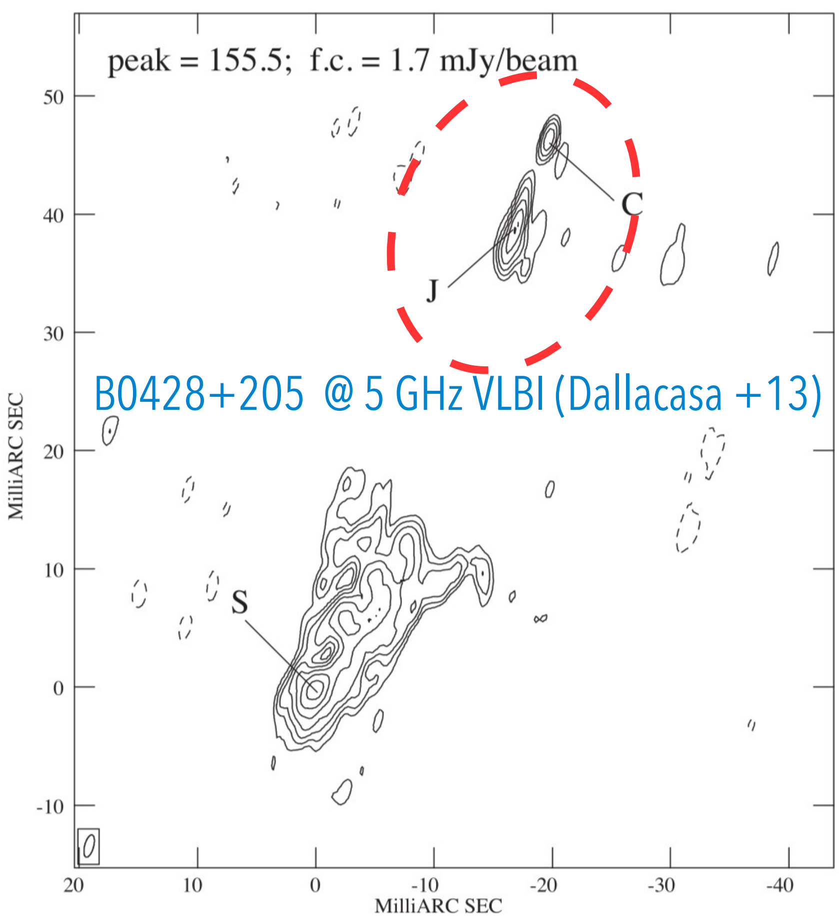
~60% of TFD

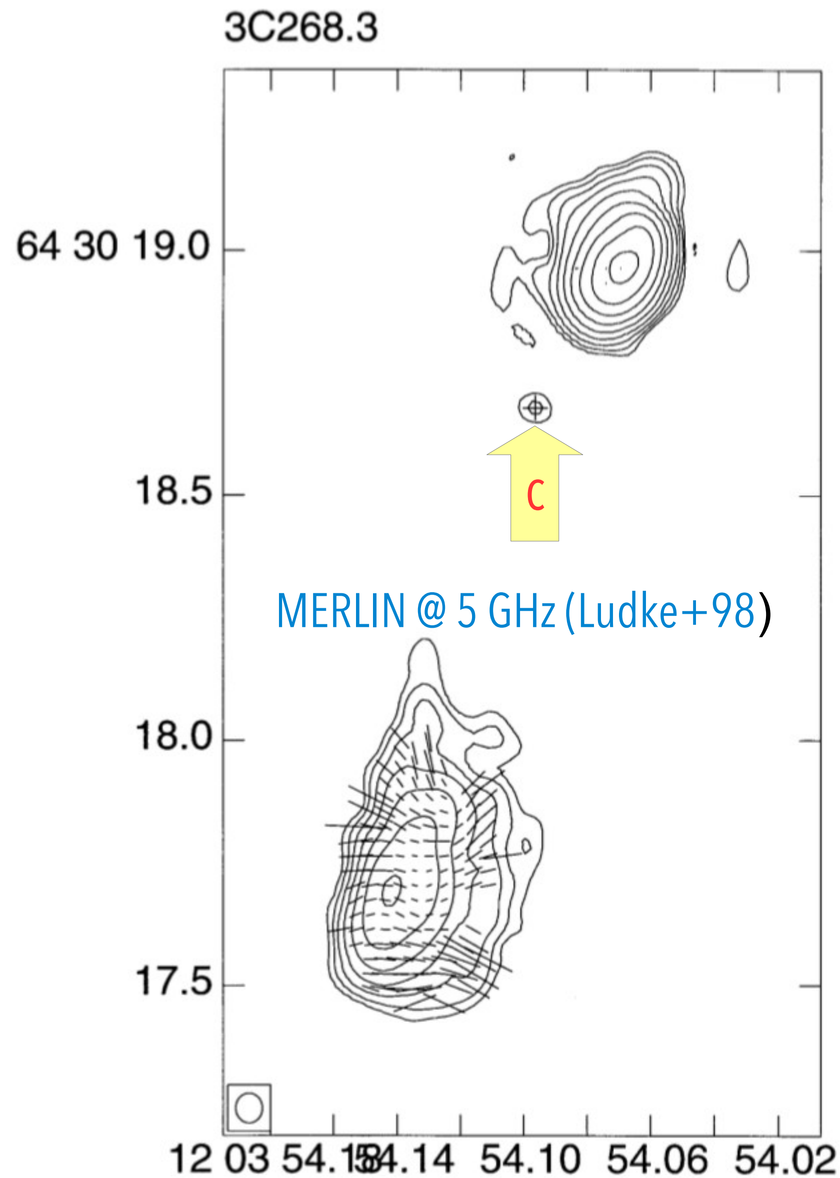
Cores:

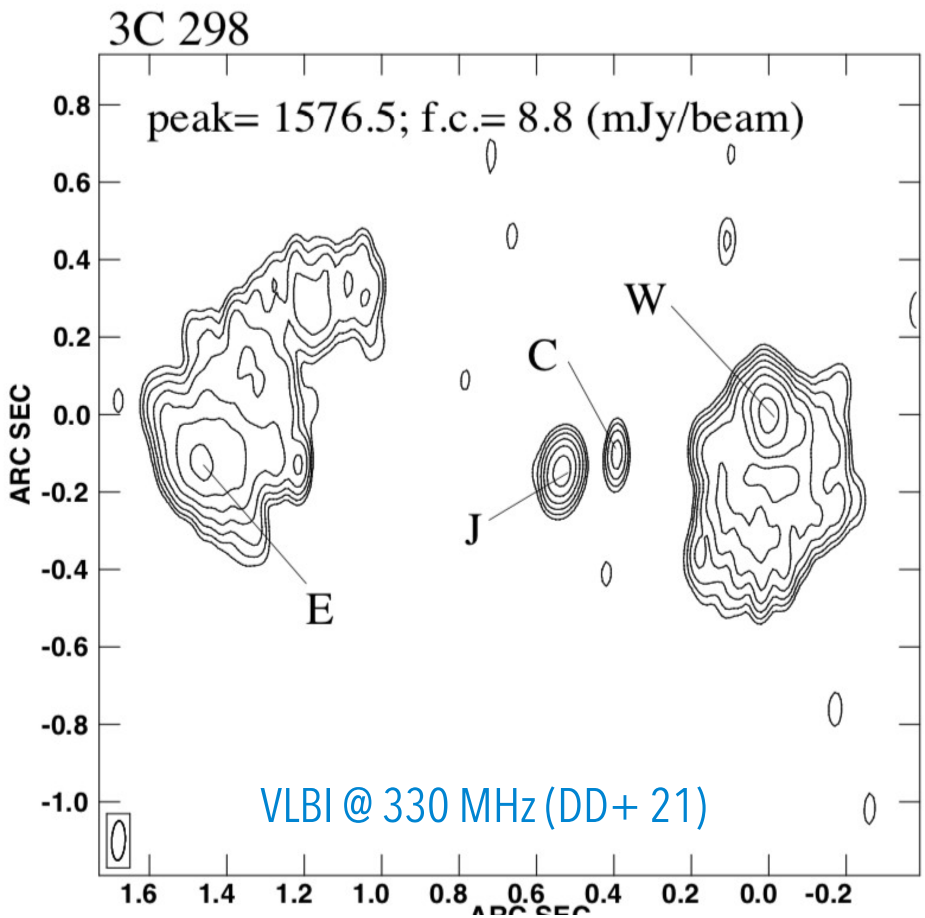
Best visible @ high frequencies

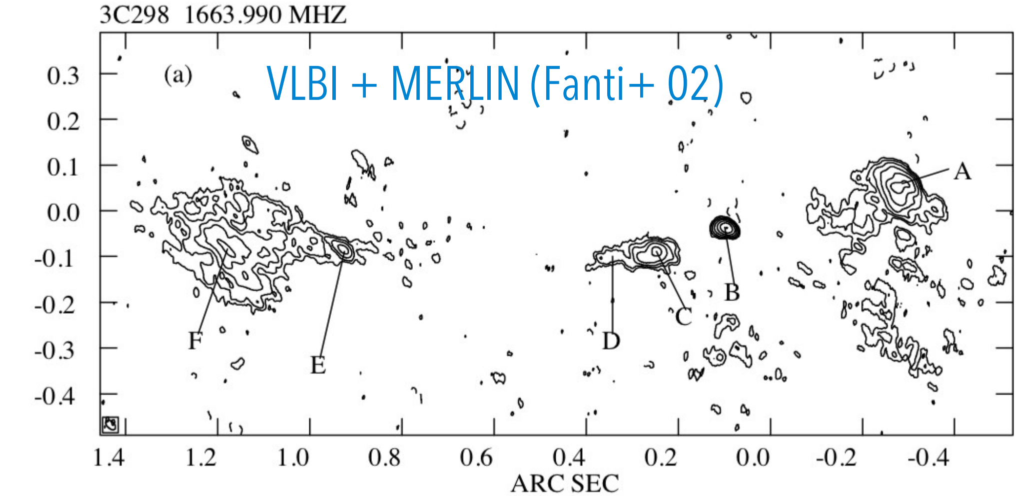
Often best described as "core region"

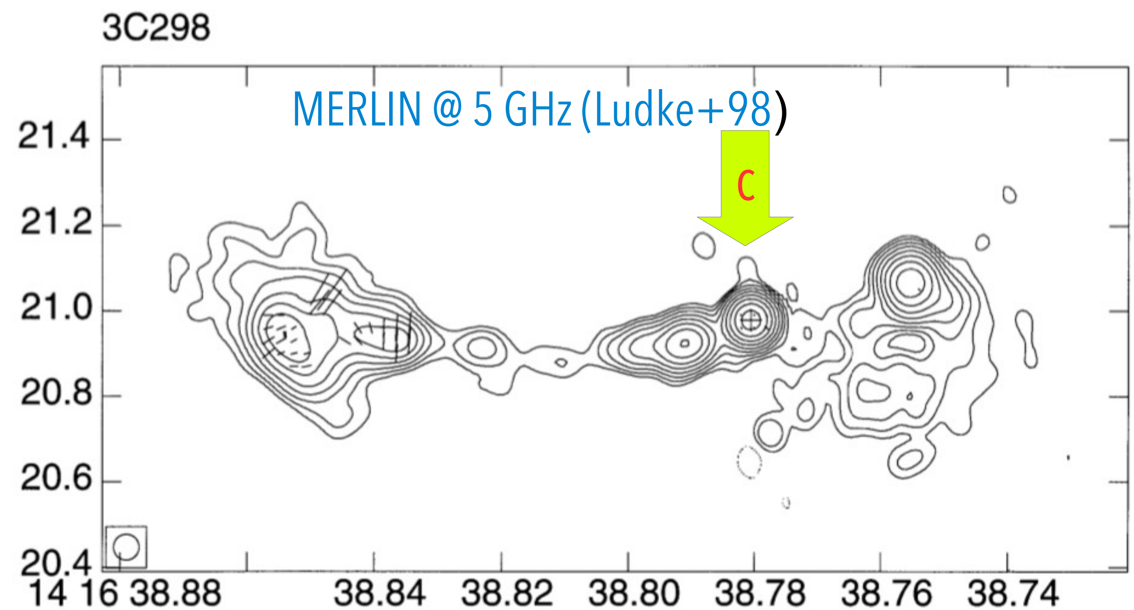
In general, they are not very bright (below 5 GHz)



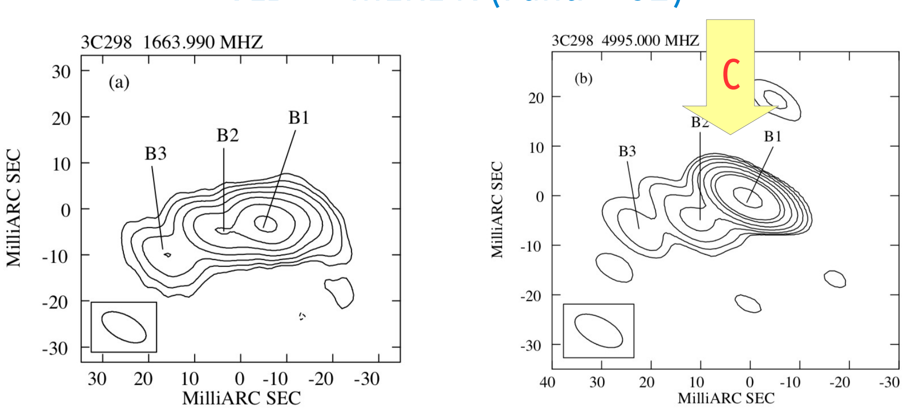








VLBI + MERLIN (Fanti+ 02)

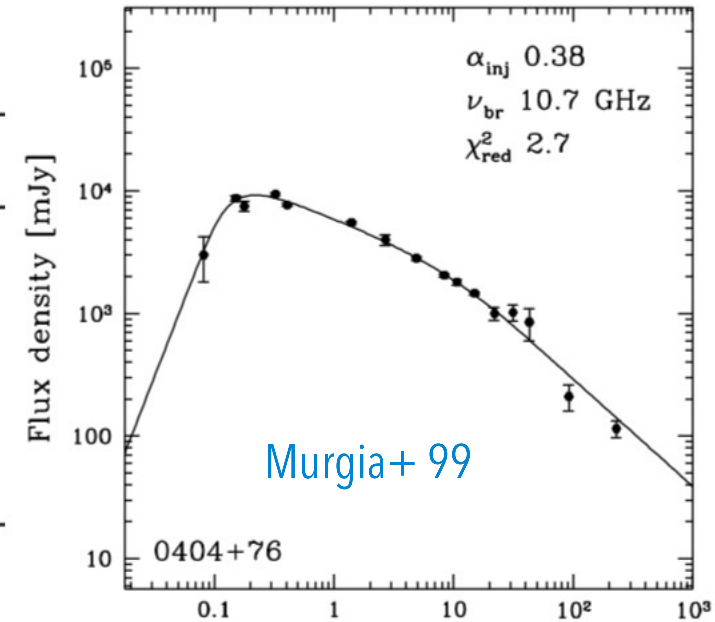


Jets: best visible @ high freq. (image sensitivity and fidelity)

Hot – spots: less prominent than lobes at 330 MHz

Table 4. Physical parameters for the hotspots and lobes.

	Hotspots	Lobes
L (erg s^{-1})	5×10^{43} - 3×10^{45}	10^{44} - 6×10^{45}
E_{min} (erg)	10^{56} - 10^{58}	10^{57} - 6×10^{59}
u_{min} (erg cm^{-3})	4×10^{-8} - 10^{-6}	10^{-9} - 3×10^{-7}
p_{eq} (dyne cm^{-2})	3×10^{-8} - 6×10^{-7}	2×10^{-10} - 2×10^{-7}
H_{eq} (mG)	0.3 - 1.5	0.1 - 0.8



$$\tau_{dyn} \sim \frac{2\,E_{lobe}}{c\,P_{eq}\,A}$$

in the range $2\cdot10^3 \rightarrow 5\cdot10^4$ yr

consistent with radiative age

from integrated radio spectrum

(constant jet energy flux assumed)

$$\tau_{syn} = 1610\,\frac{B^{0.5}}{B^2 + B^2_{CMB}}\,\frac{1}{[\nu_{br}(1+z)]^{1/2}}$$

Table 5. Source ages and magnetic fields. Column 1: source name; column 2: source component; column 3: dynamical age; column 4: equipartition magnetic field of the lobe; columns 5 and 6: radiative ages and equipartition magnetic field from Murgia et al. (1999).

Source	comp.	τ_{dyn} 10^4 yr	$H_{eq,lobe}$ mG	τ_{rad} 10^4 yr	H_{eq} mG (HS)
3C 49	W	2.4	0.2	0.1	7.0
	E	3.6	0.2	0.1	7.0
3C 138	E	3.0	0.4	1.7	1.0
3C 298	W	4.8	0.4	>5	1.6
	E	3.3	0.2	>5	1.6
1153+317	S	0.9	0.4	0.5	1.7
2342+821	W	0.2	0.5	⩽0.13	4.5

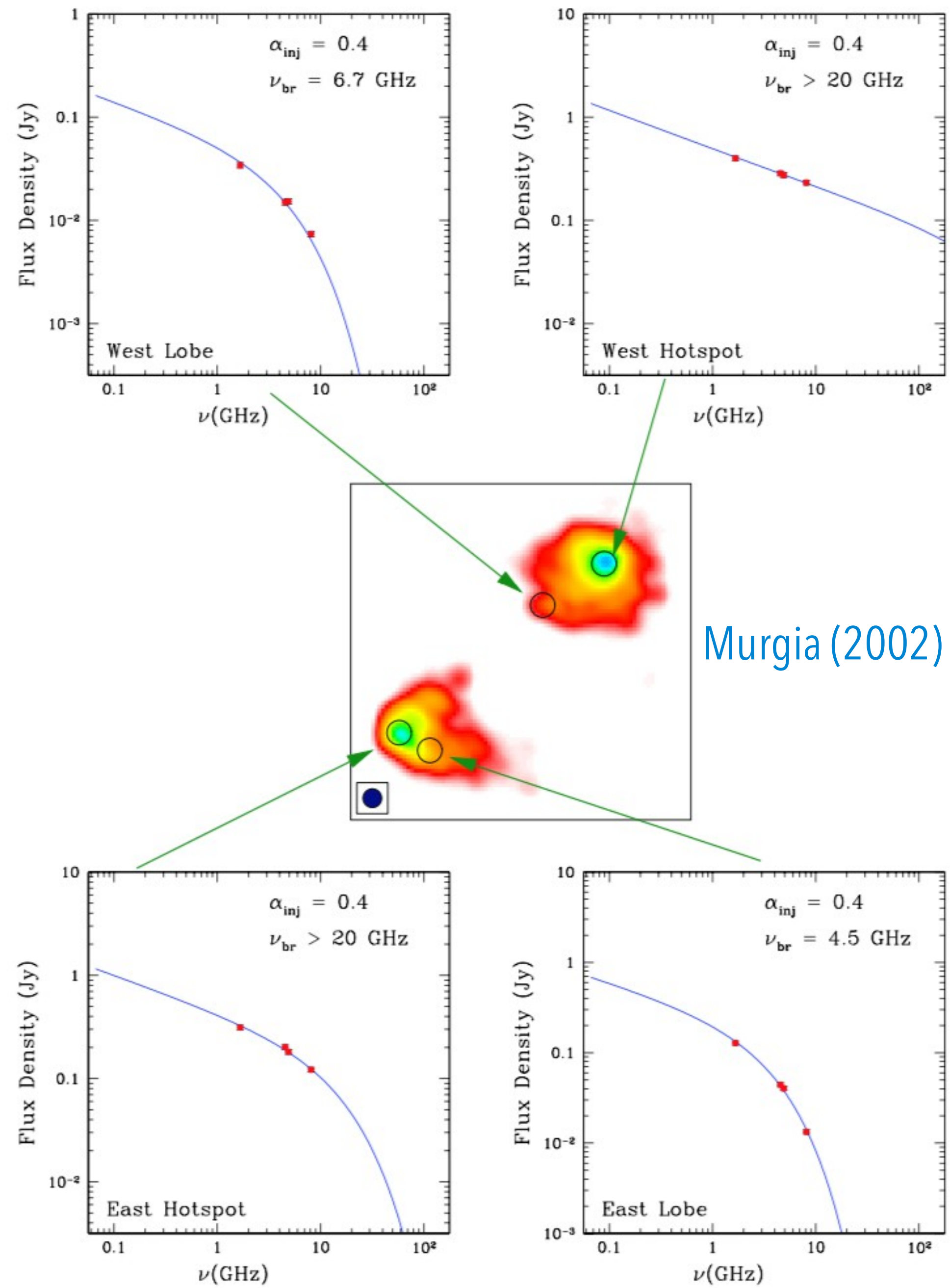
Best way to determine radiative age:

Multiple (VLBI) observations with high spatial resolution & sensitivity to search for the oldest electron population

Still alive at very low frequencies!

LOFAR LBs will be OK for objects with angular sizes of a few arcsec

VLBI would be ok for the smallest sources (a few kpc or less), but self/absorption makes them difficult targets



Murgia (2002)

Summary (some statements may have not been explained in detail)

100% of flux density could not be accounted for in ~2/3 of the sources

Additional brightness distribution = cocoons? partial detection of lobes?

Cores are rare @ 330 MHz (as well as jets!)

Best seen at 5 GHz (core region) – no surprise!

Hot-Spots & Lobes dominant

Energy content & "dynamical age" (~consistent with radiative age!)

Asymmetries

(less prominent than at GHz frequencies, decreasing with Linear Size)

What can we learn from “bright” CSS sources in a stream of (un)consciousness

Memento:

High magnetic fields & moderate gamma electrons imply synchrotron losses “faster” than in “extended” radio galaxies (quick ''faders'' if CE switches off)

The ''Cotton effect'' and the FFA contribution to self-absorption

Why are they brighter than the new population of fainter sources, e.g. Low power FR-II? (Low radio powers will be explored in the next decades)

There is a new population of astronomers entering at some level into the CSS-GPS field...