9th EVN Symposium

"The role of VLBI in

*the **Golden Age** for Radio Astronomy"*

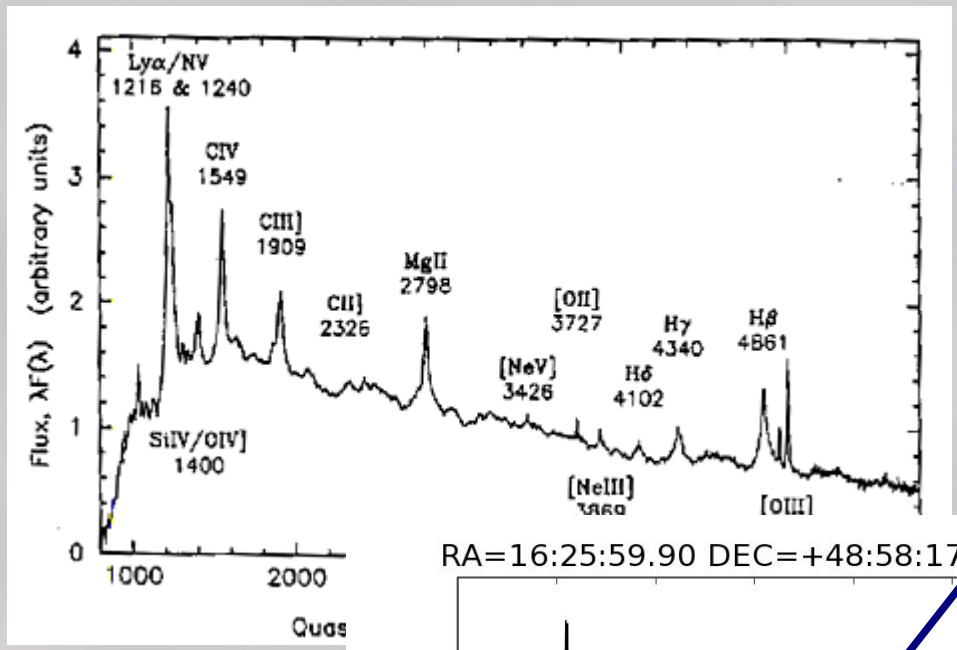
VLBI Imaging of radio-loud BAL QSOs

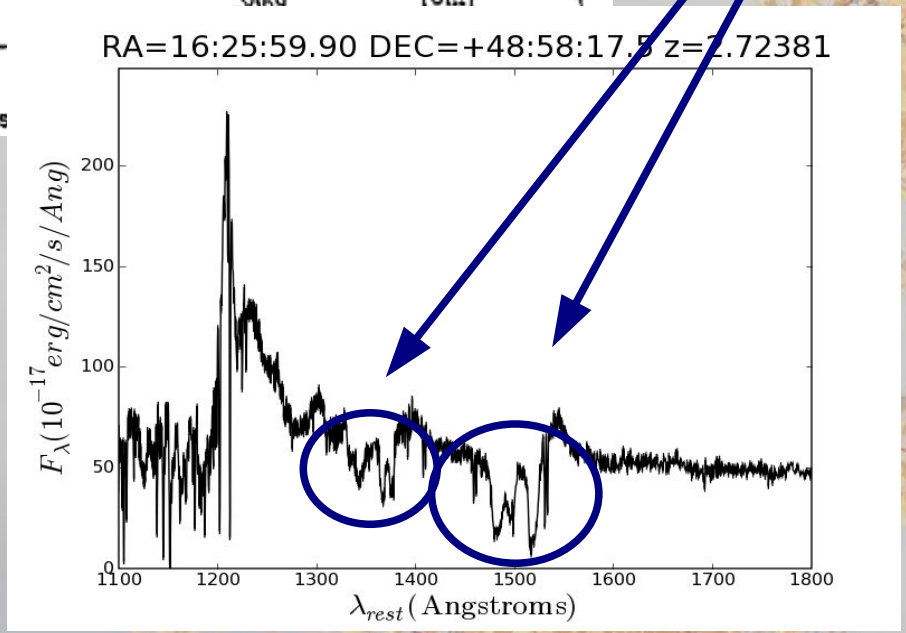
F.M. Montenegro-Montes, INAF-IRA

K.-H. Mack, INAF-IRA
C.R. Benn, ING
R. Carballo, Univ. Cantabria
D. Dallacasa, Univ. Bologna
J.I. González-Serrano, CSIC-IFCA
J. Holt, Univ. Leiden
F. Jiménez-Luján, CSIC-IFCA

Photo: Mark Elliott

Introducing BAL QSOs





Broad absorption towards the blue wing of some UV emission lines, shifted up to ~ 0.2 c

Most probably intrinsic

HiBALs, LoBALs, FeLoBALs.

BALs, mini-BALs, NALs

How many? ~ 20 %

BALs vs. non-BAL QSOs

- Similar in the optical but BAL QSOs more reddened
- BAL QSOs more highly polarised in the optical
- BAL QSOs X-ray weaker (because of higher extinction)
- Same mid-IR and sub-mm properties
- BAL QSOs compact radio morphologies & moderate power

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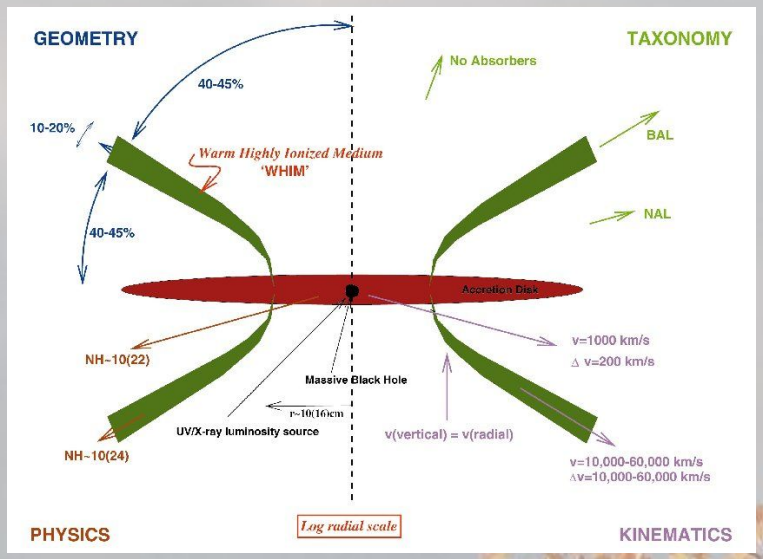
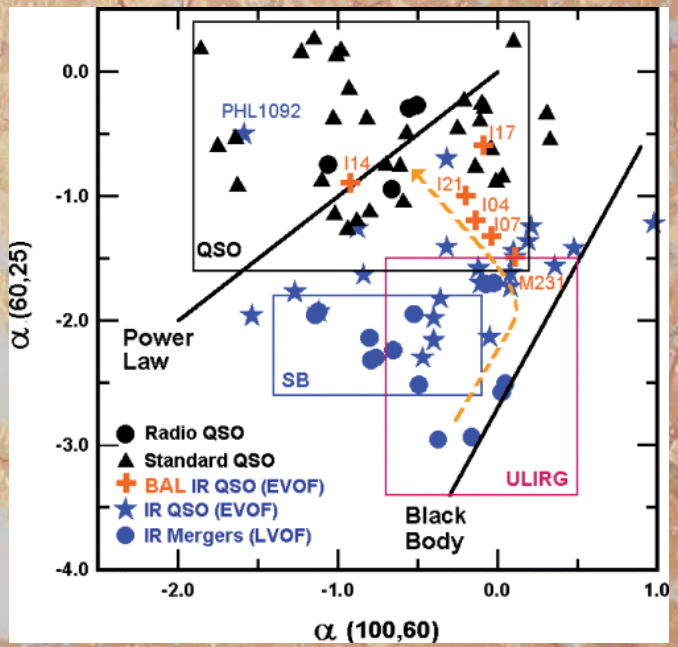


Elvis, 2000

Orientation

and /or

Evolution ?



Lípari & Terlevich, 2006

Radio BAL QSOs: Previous work

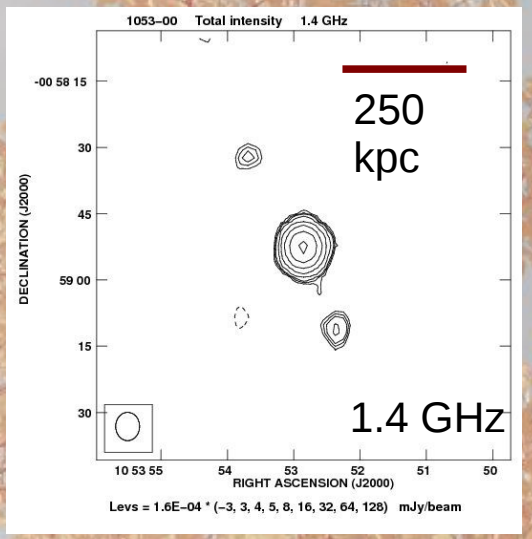
Characterisation of their radio properties

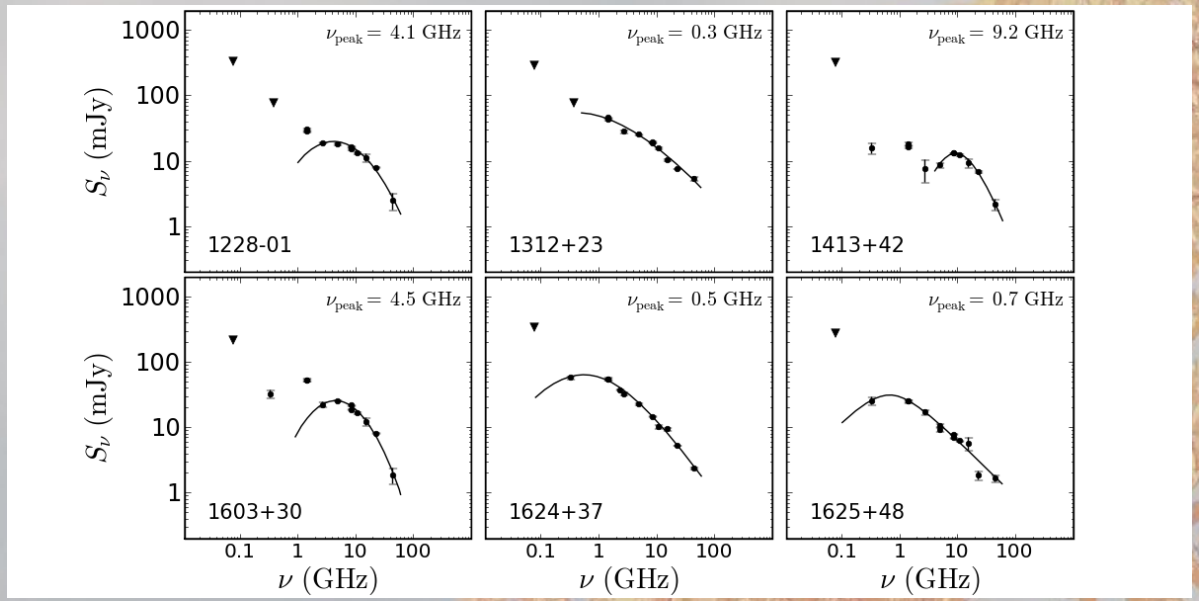
Montenegro-Montes et al., 2008 (MNRAS 388, 1853)

Compact at VLA resolution 8.4 - 22 GHz

80 % unresolved or slightly resolved @ 22 GHz (10 – 80 mas)

Convex spectral shape 1 - 40 GHz





Radio BAL QSOs: Previous work

Characterisation of their radio properties

Montenegro-Montes et al., 2008 (MNRAS 388, 1853)

No strong variability at 1.4 and 8.4 GHz

No polarisation at 8.4 GHz:

Some exceptions: 1159+01, 1624+37 $m_{8.4}$ (median) = 1.3 %

All these properties of CSS/GPS radio sources (e.g., O'Dea, 1998) which are probably young radio sources.

→ Favour Evolution

BAL and non-BAL QSOs have similar spectral index distribution

→ Against particular orientation

Why VLBI ?

BAL QSOs are compact. But... how compact? Can we resolve them? Are they intrinsically compact?

What is their pc-scale morphology?

Can we determine or constrain their orientation with respect to the line of sight?

What can we learn about the physics close to the central engine in these objects?

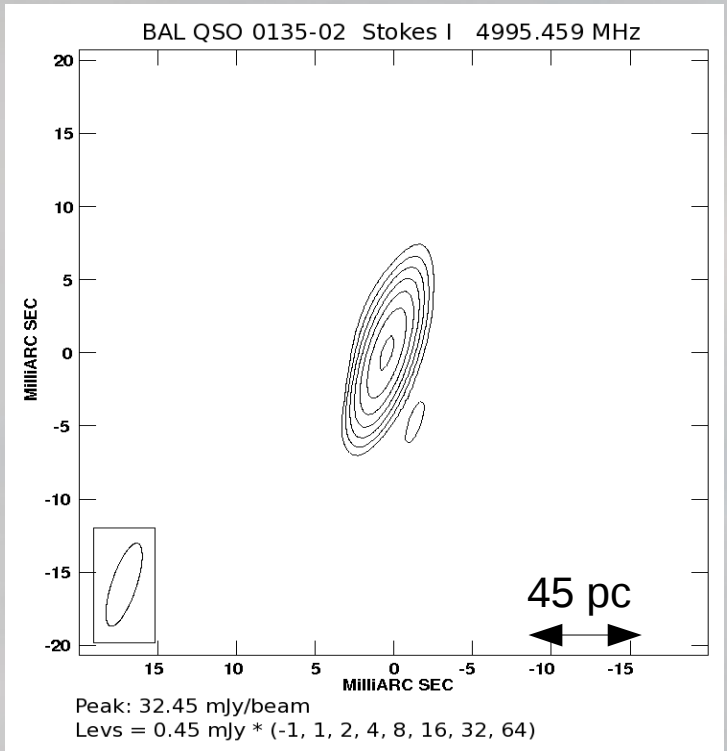
Where is the polarisation located in the few polarised radio BAL QSOs?

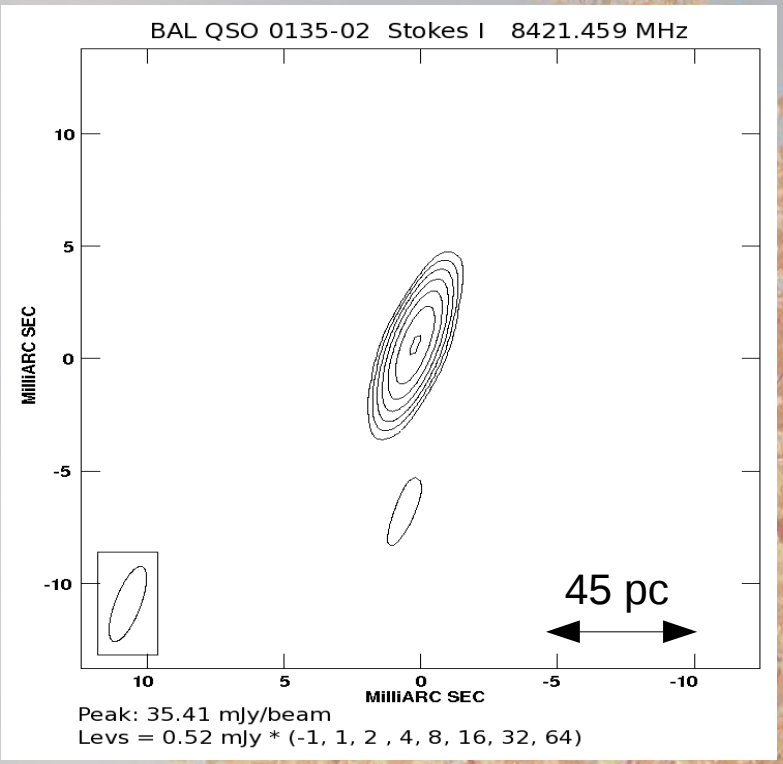
Pc-scale imaging of radio-loud BAL QSOs

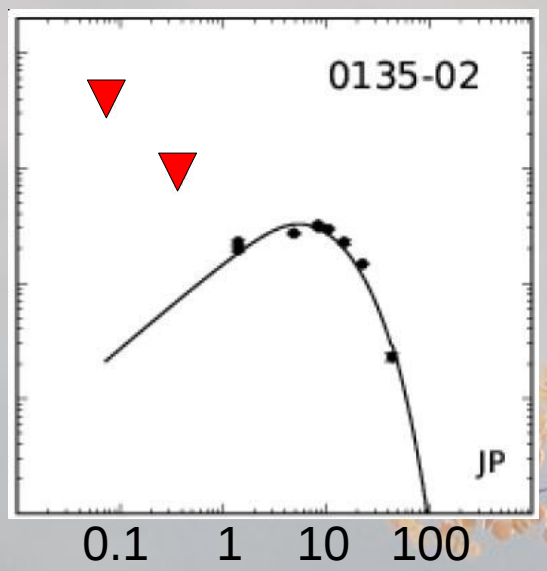
- Subsample of 6 BAL QSOs
- VLBA observations at 4.8 and 8.4 GHz (phased reference)

Source	z	Type	S(5 GHz) [mJy]	log L(5 GHz) [W/Hz]
0135-02	1.82	HiBAL	27.2 ± 0.6	26.3
0837+36	3.42	LoBAL	30.2 ± 2.3	26.7
1159+01	1.99	HiBAL	137.8 ± 1.7	27.3
1537+58	3.06	LoBAL	40.6 ± 0.8	27.3
1603+30	2.03	HiBAL	26.1 ± 0.7	26.6
1624+37	3.38	HiBAL	23.3 ± 1.1	27.1

Montenegro-Montes et al. 2008, (in prep.)

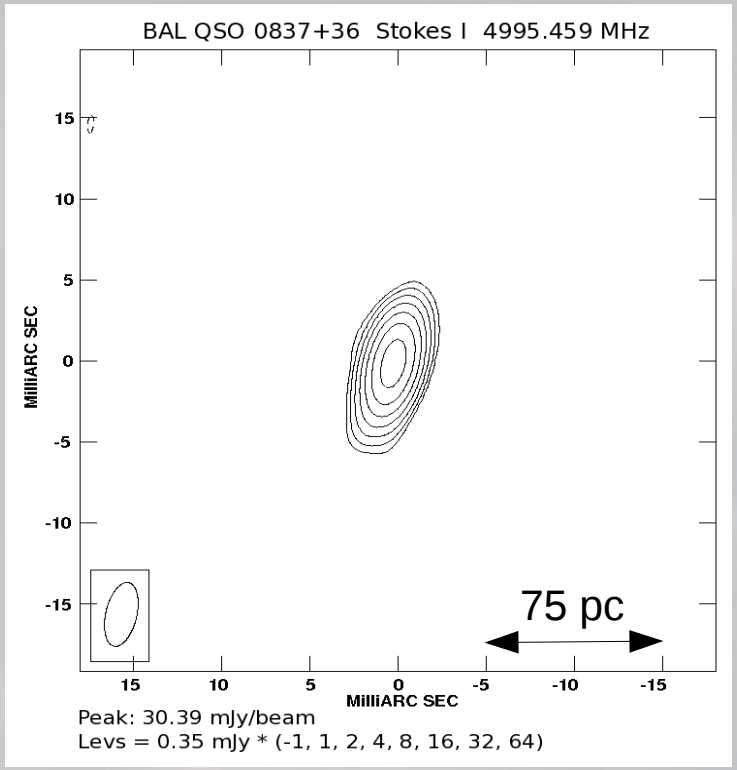


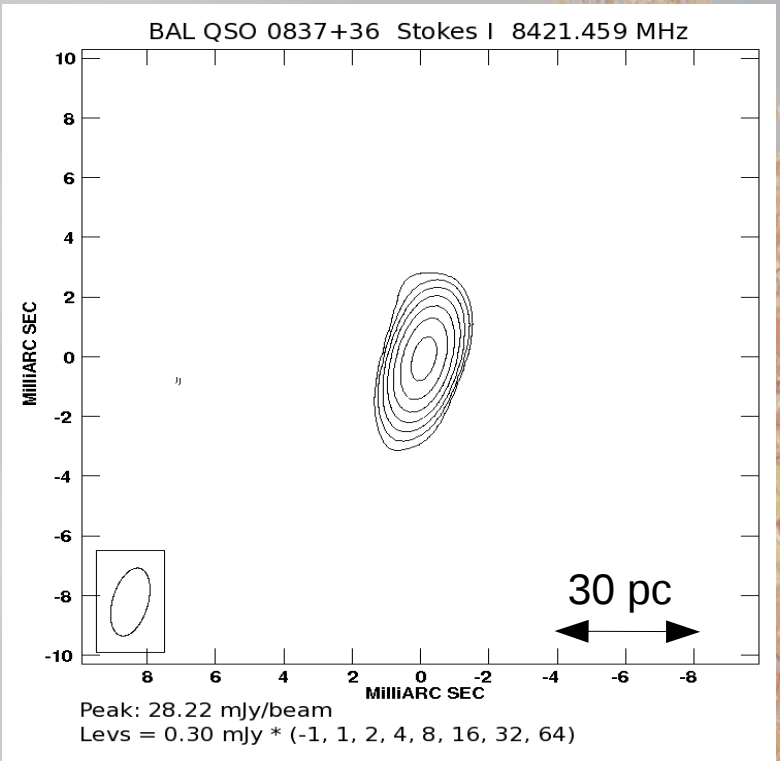


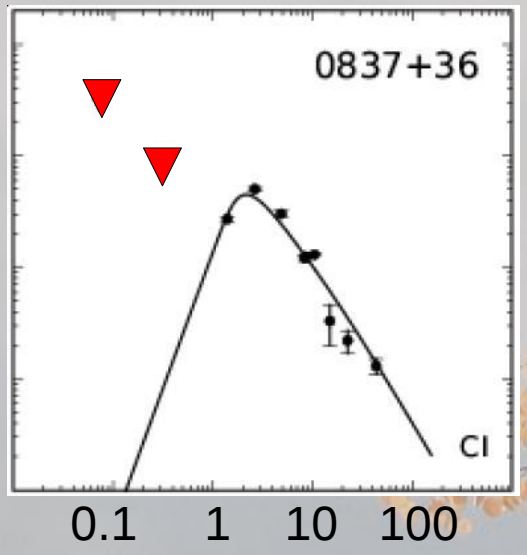


- Compact GPS / HFP quasar
- m(8.4 GHz) < 0.84%, m(22GHz) < 1.7%
- Maybe some variability but below 3-σ_{var}

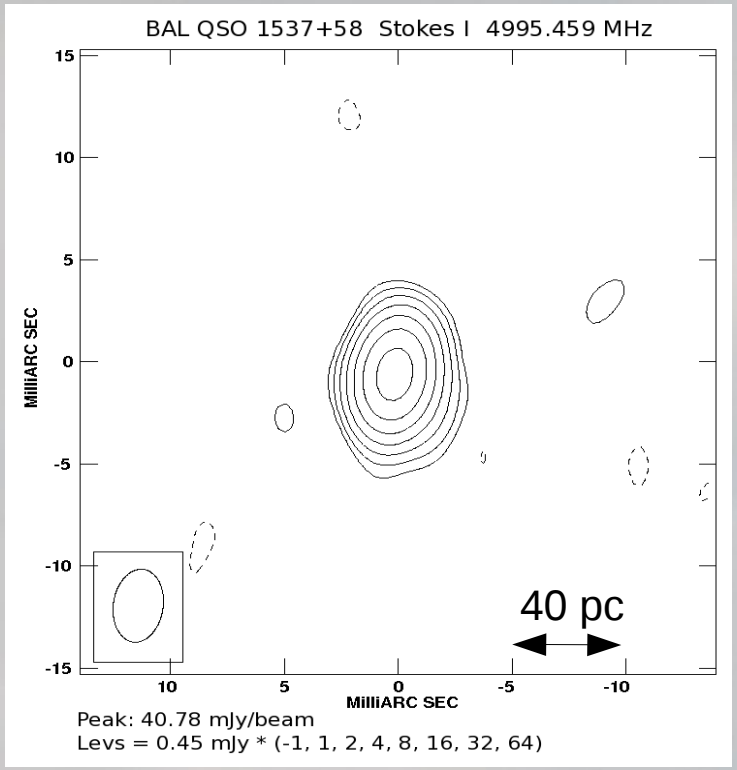
Further follow-up

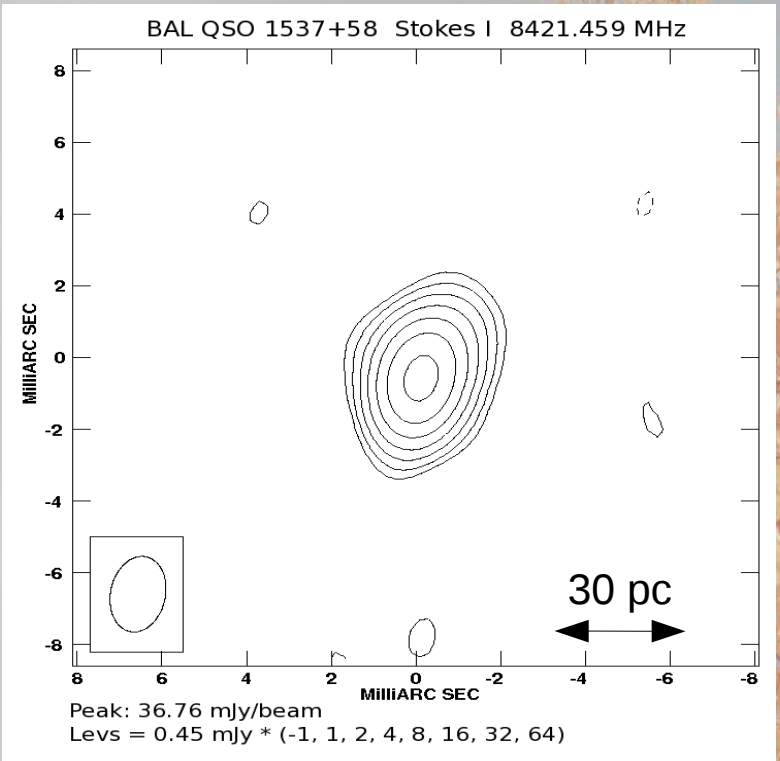


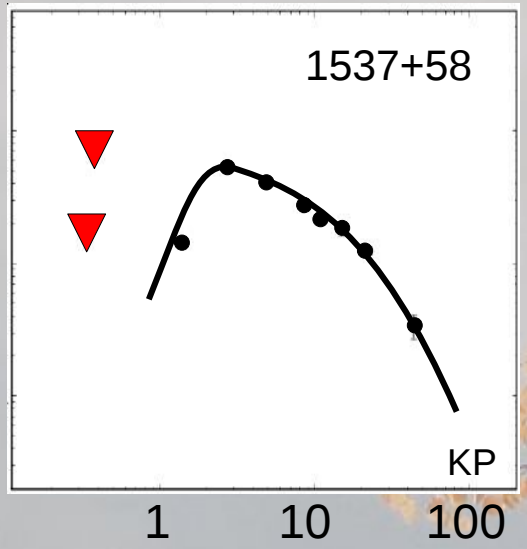




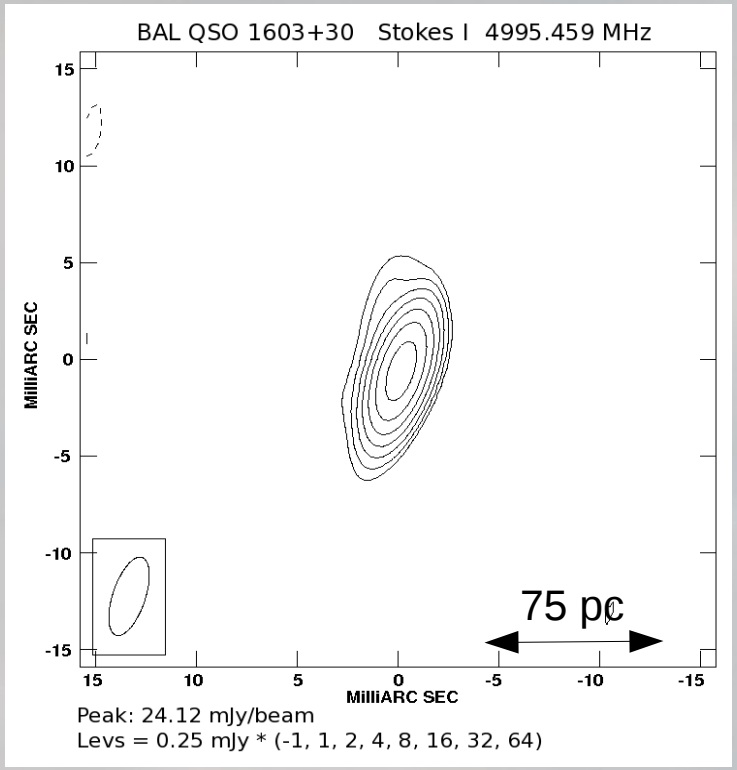
- Compact GPS quasar
- m(8.4 GHz) < 0.60%
- Variable at level ~ 5 σ_{var} Change in spectral shape?

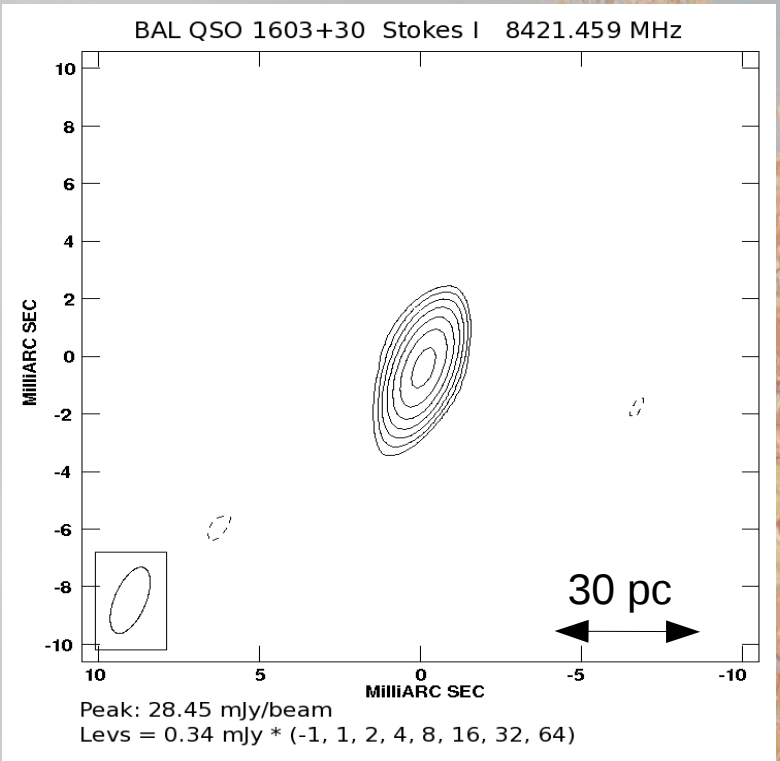


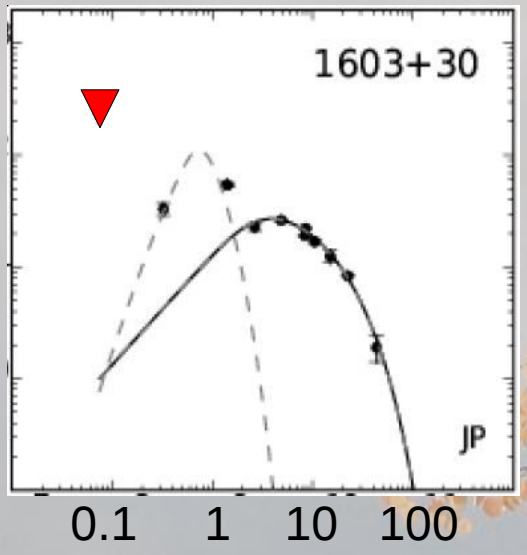




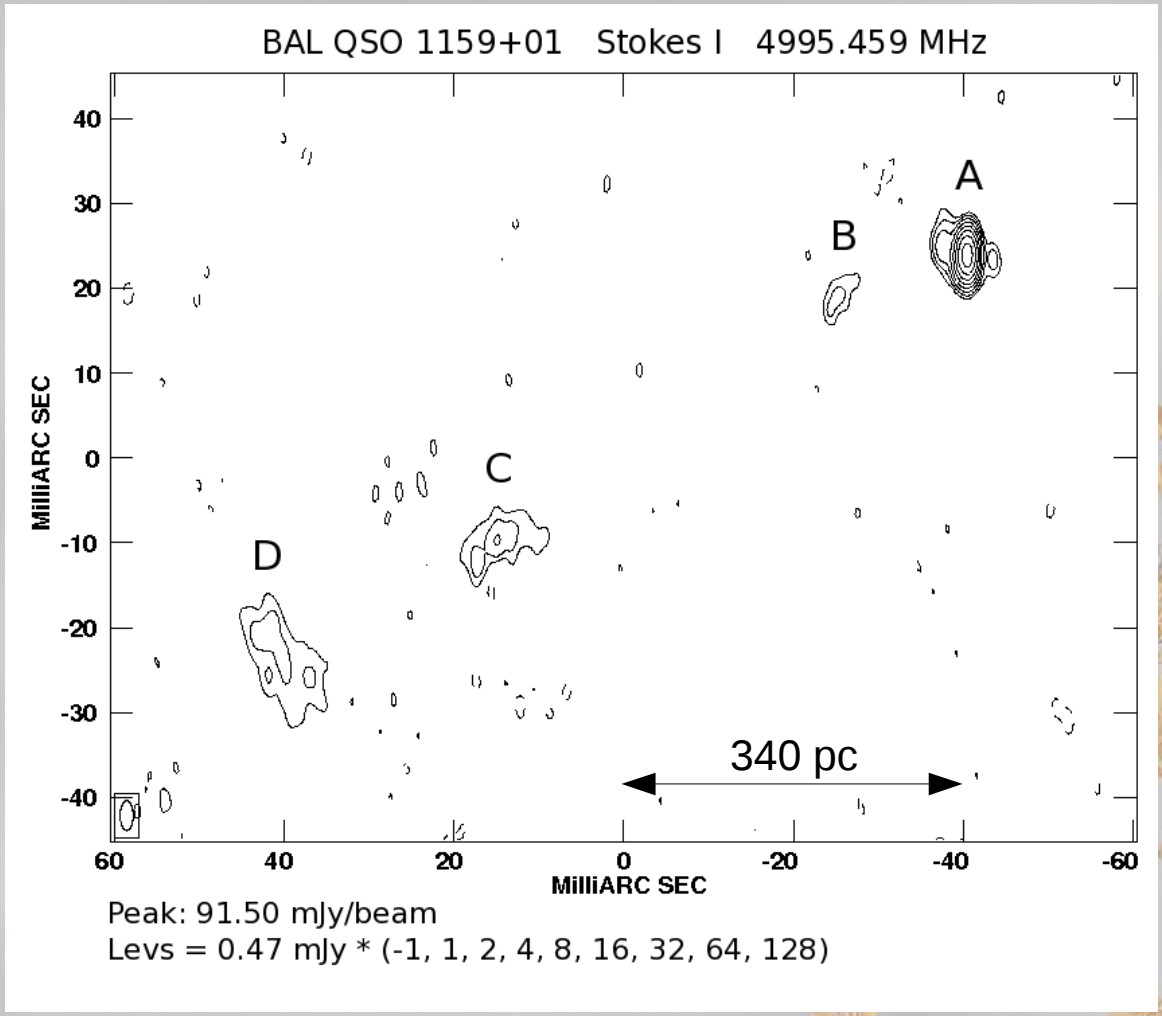
- Compact GPS quasar
- m(8.4 GHz) < 0.60%
- Variable at level ~ 3 σ_{var}



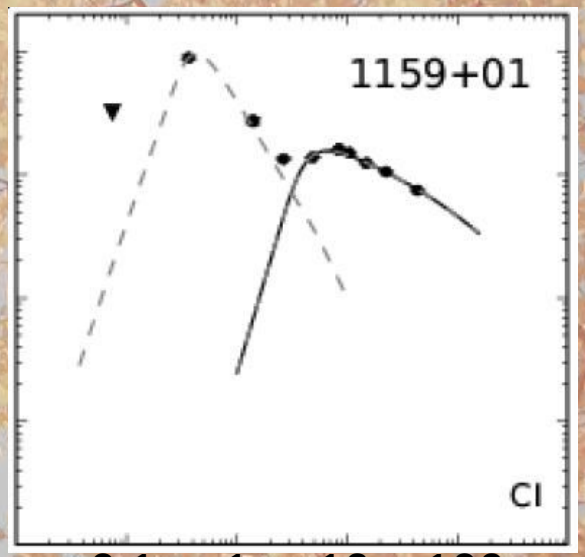


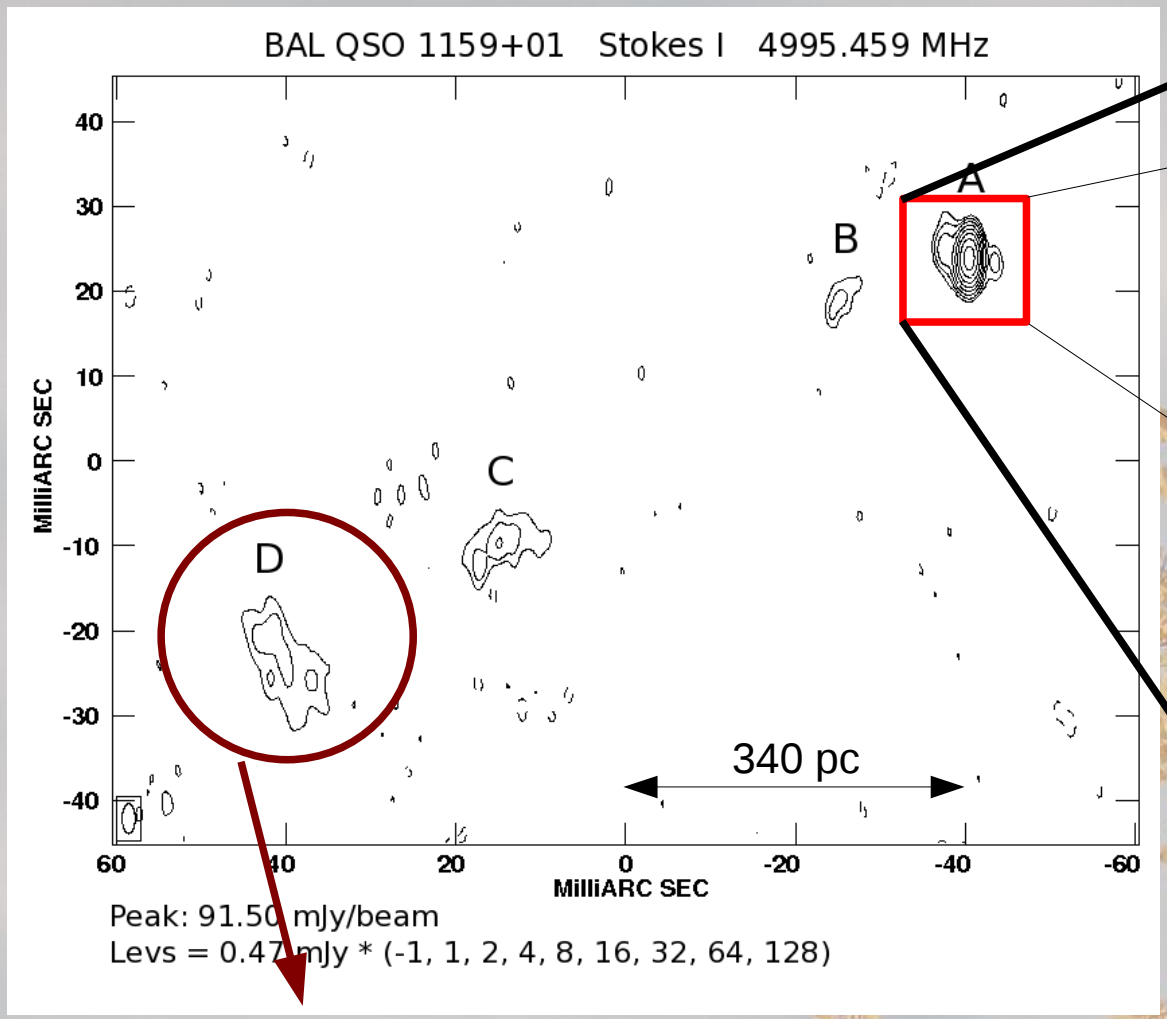


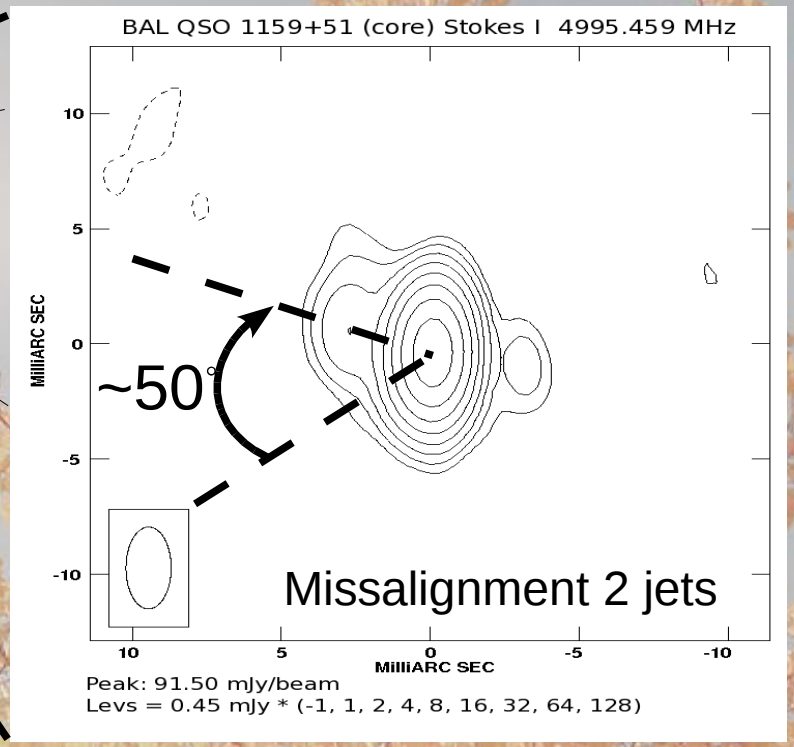
- Compact GPS quasar, 2 components?
- m(8.4 GHz) ~ 1.0 %; m(22 GHz) < 0.8 %
- No significant variability

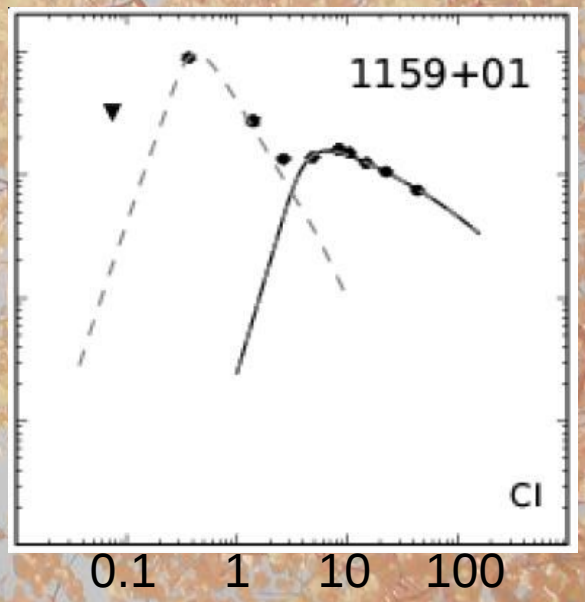


Much more interesting !!







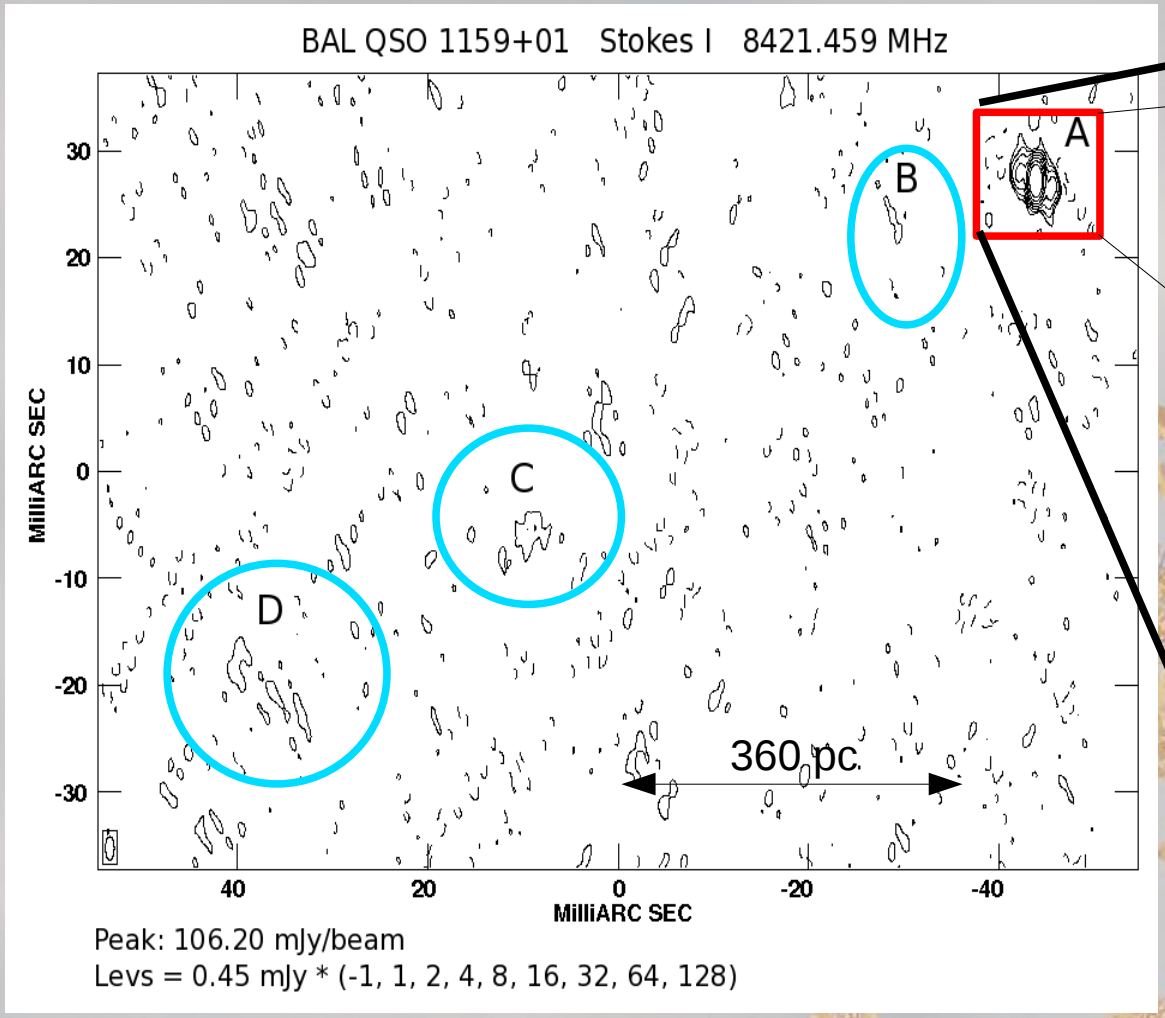


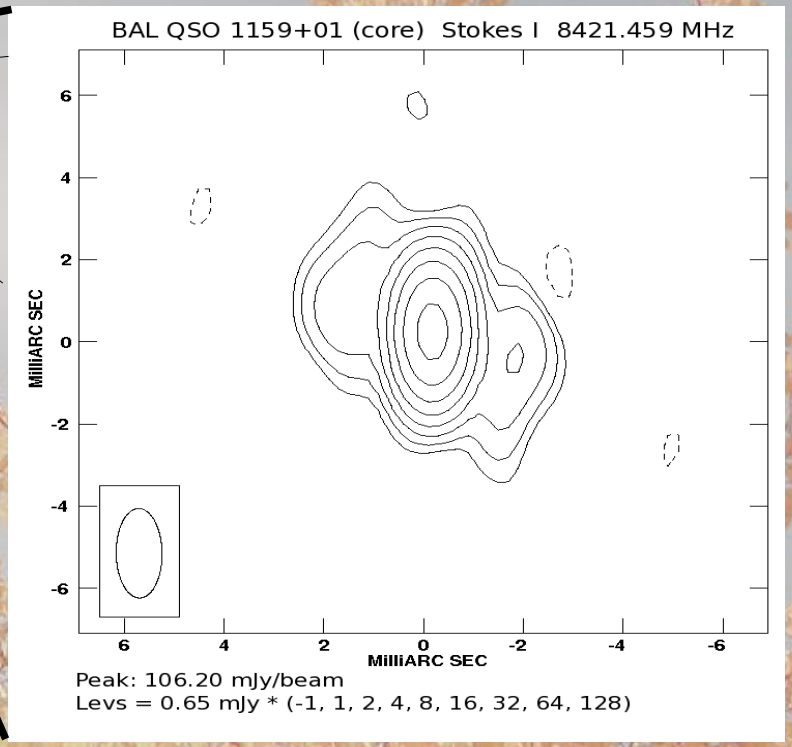
High polarisation m > 20%

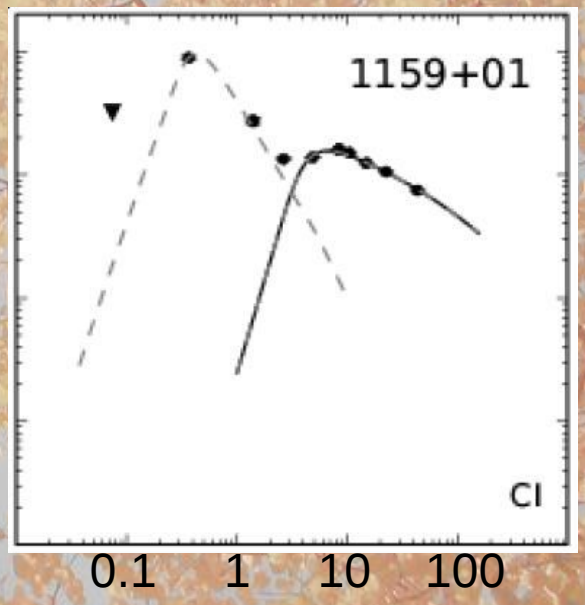
Residual/faint lobe emission (no hot-spot)

"Core": CSO morphology (?)

- Bright core
- Asymmetry in flux density







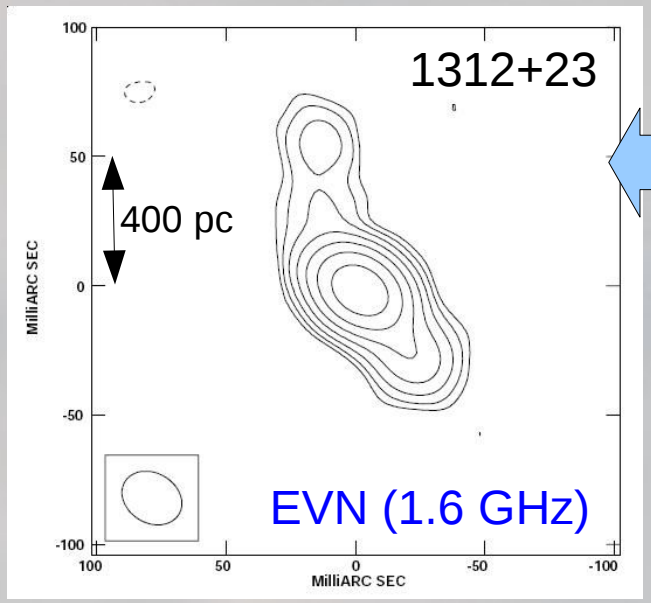
Very faint extended emission at 8.4 GHz

Spectral indices: "core" $\alpha = +0.3$ (inverted)

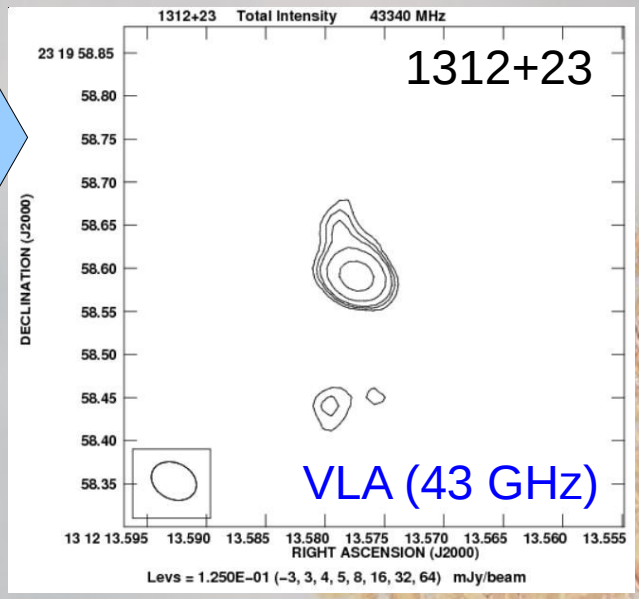
"extended (D+C)" $\alpha = -1.6$ (steep)

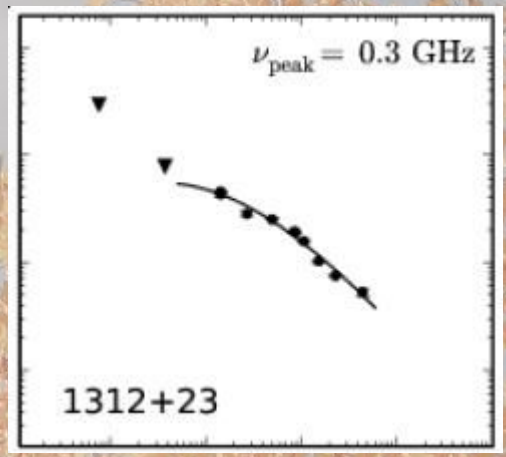
Other BAL QSOs with strange "CSO" shape

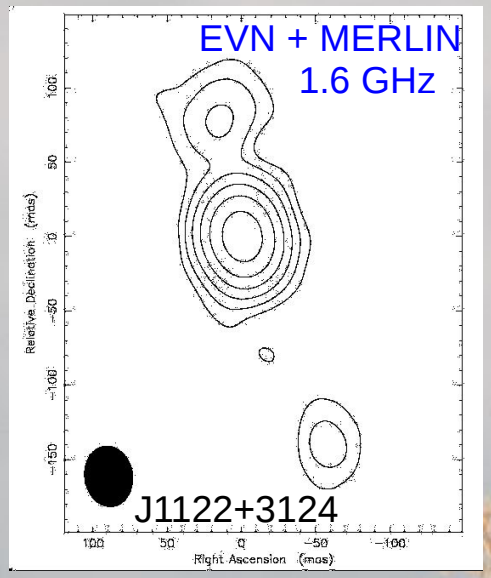
Jiang & Wang, 2003 (A&A 397, L13)

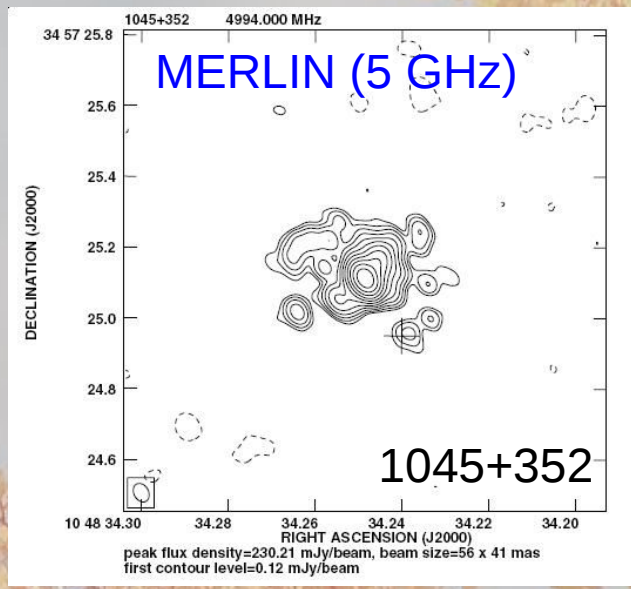


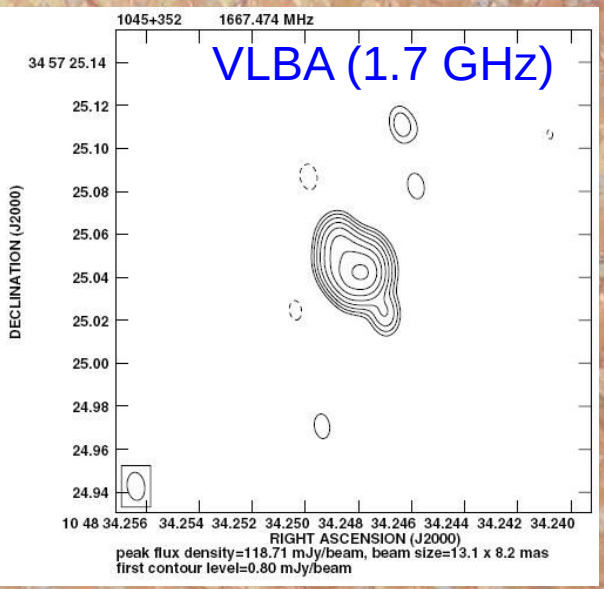
Montenegro-Montes et al., 2008 (MNRAS 388, 1853)





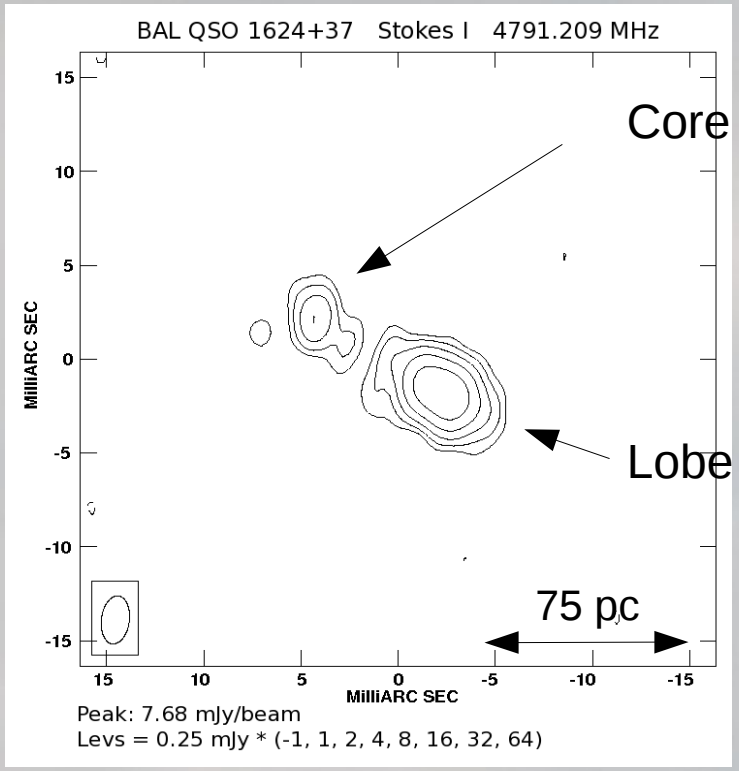


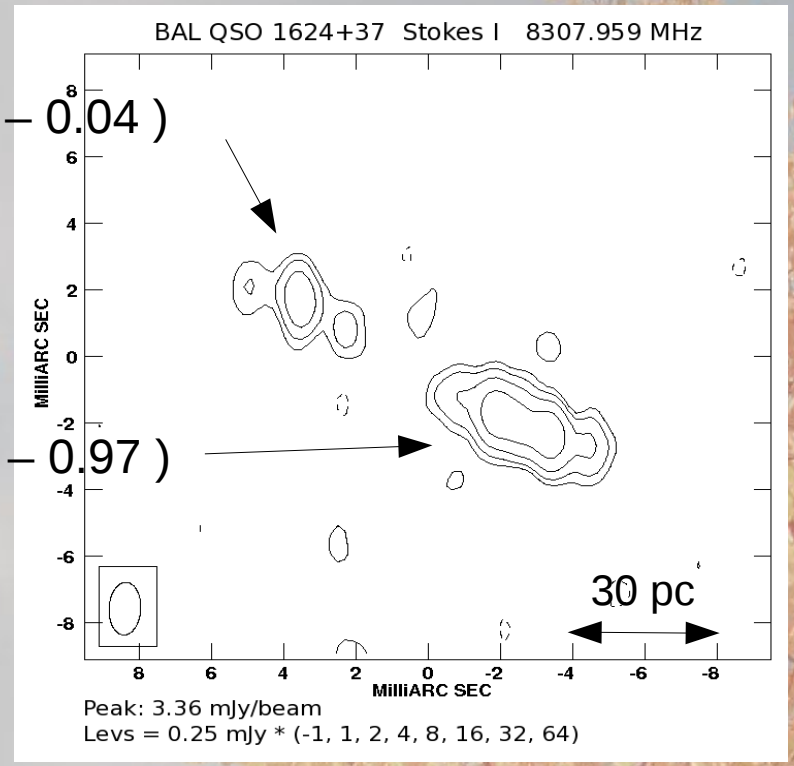


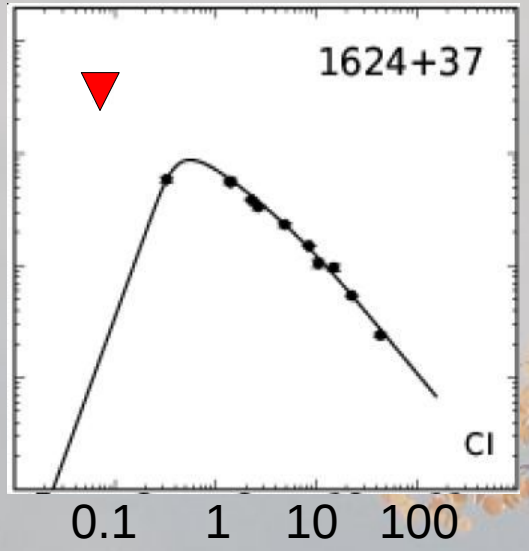


Liu et al., 2008 (arXiv:0808.2105)

Kunert-Bajraszewska & Marecki 2007 (A&A 469, 437)







- Unusual BAL QSO (Benn et al. 2005)
- CSS quasar: Core-jet morphology
- No polarisation detected in VLBA (?)
- Jet / counterjet gives $\theta < 37^{o}$

What are compact radio BAL QSOs? and future plans

Total of 17 BAL QSOs with VLBI in literature
(Jiang & Wang, 2003; Kunert-Brajraszewska & Marecki, 2007; Liu et al., 2008; This work)

- 9 unresolved (52%)
  Polar BAL QSOs / intrinsically compact / very faint jet-lobe
  Multi-epoch (variability) or deep VLBI (high dynamic range)
- 4 core-jet (24%)
  Intermediate orientation. If bright enough, θ can be determined
  Deep VLBI (constrain orientation)
- 4 strange “compact symmetric objects” (24%)
  Jet not aligned to the line of sight.
  Multi-epoch VLBI (expansion velocity) + high resolution (Space-VLBI)

2 with possible signs of restarting activity!
(Marecki et al. 2006 A&A 448, 479)


Thanks !
To the audience...
&
RadioNet
NRAO
EUROPEAN
vlbi
NETWORK