High resolution studies of Broad Absorption Line radio-loud quasars

Marcin Gawronski

Torun Centre for Astronomy
N. Copernicus University, Poland

Magdalena Kunert-Bajraszewska[1], Aneta Siemiginowska[2], Agnieszka Janiuk[3]

[1]Torun Centre for Astronomy, N. Copernicus University, Poland
[2]Harvard-Smithsonian Center for Astrophysics, Cambridge, MA
[3]N. Copernicus Astronomical Center, Warsaw, Poland

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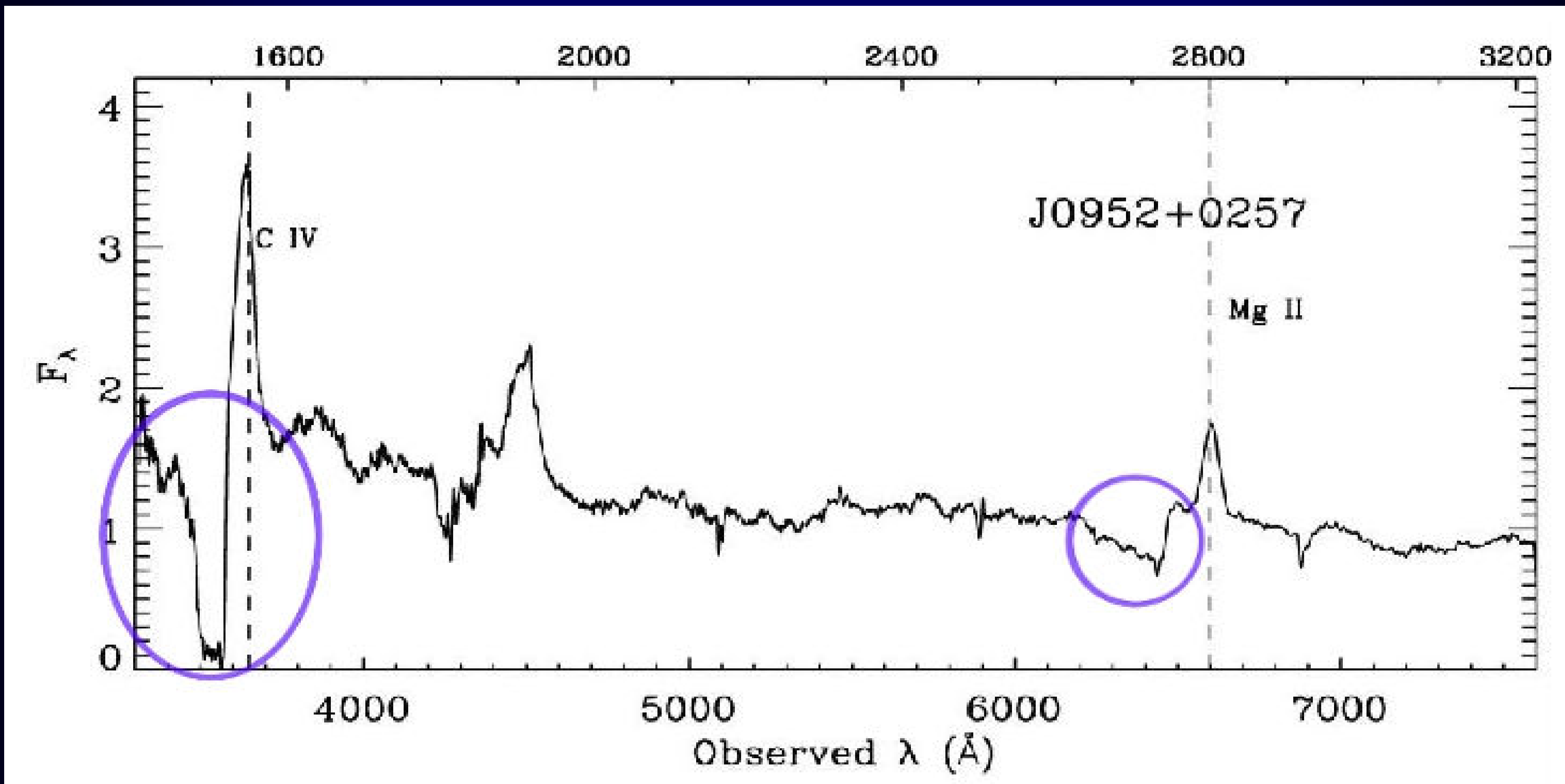
The INTRODUCTION to BAL quasars

Broad absorption lines (BALs) are seen in 10-30% of both the radio-quiet and radio-loud quasar populations. They are probably caused by the outflow of gas with high velocities and are a part of the accretion process.



The INTRODUCTION to BAL quasars

Origin of BALs

Orientation scenario

Weymann et al.,1991;
Elvis 2000

BAL regions exist in both BAL and non-BAL quasars, and the BAL quasars are normal quasars seen along a particular line of sight, e.g. a line of sight skimming the edge of the accretion disk or torus.

Evolution scenario

Becker et al.,2000;
Gregg et al.,2000, 2006
Brotherton et al., 2005

BAL QSOs are young or recently refuelled quasars. BALs may be associated with an evolutionary phase with a large BAL wind covering fraction, rather than orientation.

Selection criteria:

The balnicity index *BI>0* (Weymann et al., 1991):

The absorption index *AI>0* (Trump et al., 2006):

$$BI = \int_{3000}^{25000} [1 - \frac{f(\nu)}{0.9}] C d\nu$$

$$AI = \int_{0}^{29000} [1 - f(\nu)] C' d\nu$$

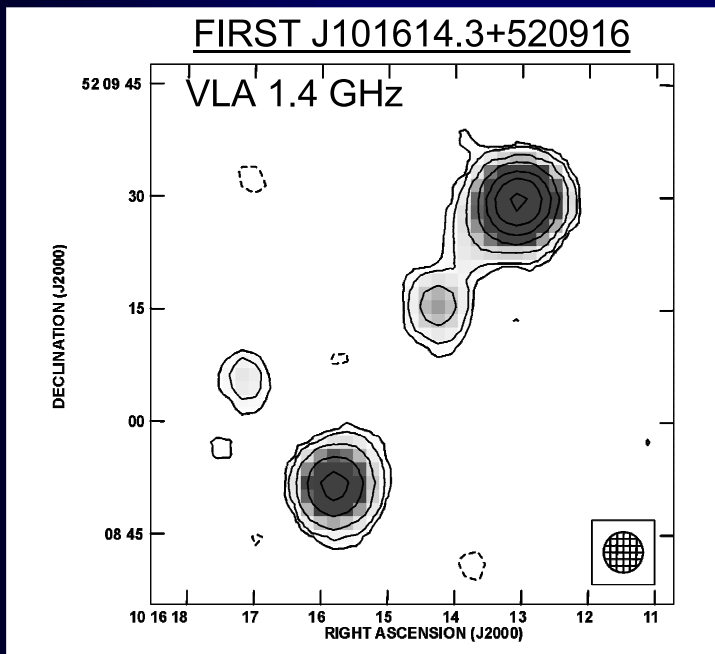
$f(\nu)$ – normalized flux;
C=1 whenever the quantity in brackets is continuously positive over an interval of 2000 km/s else C=0;
C'=1 in contiguous troughts which exceed the minimum depth (10%) and minimum width (1000 km/s) else C'=0.

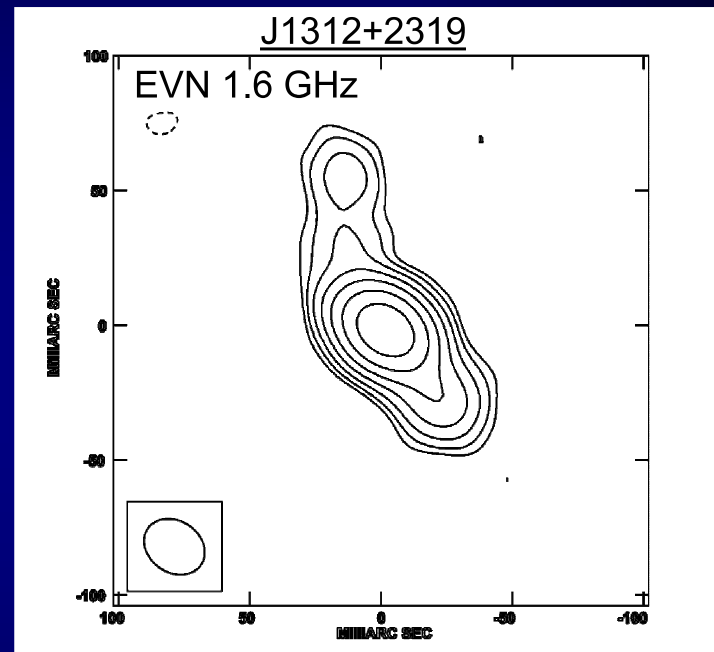
The *BI* criterium is much more conservative than the *AI*.

The *BI* quasars seem to have different radio properties than the AI objects (Shankhar et al. 2008).

The INTRODUCTION to BAL quasars

The radio morphologies of radio-loud BAL quasars provide important additional information about their orientation and the direction of the outflow. However, most of them are compact at radio frequencies, **so remained unresolved so far.**





large scale radio-loud BALQSOs

Gregg et al. 2000, 2006, Brotherton et al. 1998, Zhou et al. 2006

~ 10 objects

compact radio-loud BALQSOs

Jiang & Wang 2003, Liu et al. 2008
Kunert-Bajraszewska et al. 2007,2009
Montenegro-Montes et al. 2008, 2009

hundreds, but unresolved

The INTRODUCTION to BAL quasars

The complex picture of BALQSOs:

- LoBAL QSOs are in early evolutionary stage in the life time of a quasar (Urrutia et al. 2009, based on FIRST-2MASS survey of BALQSOs).

- Some of low-AI BALQSOs have different UV and X-ray properties than the „classical" BALQSOs (Giustini et al. 2008, Knigge et al. 2008)

- Low X-ray absorption is found in a small sample of radio-loud BALQSOs in comparison to the „classical" BALQSOs (Wang et al. 2008), a different wind launching mechanism needed?

- „AI" BALQSOs lack significant X-ray absorption, „BI" BALQSOs appear to be more X-ray absorbed and ionized (Streblyanska et al. 2010). „AI" BALQSOs may represent the late evolutionary state of the „classical" BALQSOs.

- On parsec scales radio-loud BALQSOs display core-jet morphology and also more complex double or multiple symmetric structures similar to structures observed in Compact Symmetric Object (CSOs) (Liu et al. 2008, Montenegro-Montes et al. 2008, 2009) which are known to be young. All orientation are allowed and it causes problems for the orientation scenario.

The GOALS of our PROJECT

- Study the origin of BALs. The high resolution radio observations of **the radio-loud compact BALQSOs** will allow us to resolve their structures and image the radio core and jets. This in turn will enable us to estimate the orientation of the jet axis, which is an important parameter in theory of the origin of BALs in quasars.

- Study the jets evolution and probable jet-cloud interactions. The BAL quasars can be still surrounded by the dense medium, since they fit in as a transition stage in the evolutionary hypothesis of Sanders et al.(1998), in which gas-rich mergers forming ultraluminous IR galaxies evolve into normal quasars (Gregg et al.2000).

- The polarisation information we got from the VLBA and EVN observations will increase our knowledge about BAL quasars environment by study the orientation of the magnetic field and Faraday rotation.

The SAMPLE and OBSERVATIONS

17 compact radio-loud BAL quasars

1

CSS quasar from FIRST survey
1045+352

MERLIN 5 GHz,
VLBA 1.7 GHz, 5 GHz & 8.4 GHz,
EVN+MERLIN 5 GHz
CHANDRA 0.5 - 7 keV

Kunert-Bajraszewska & Marecki, 2007
Kunert-Bajraszewska & Gawroński, 2009
Kunert-Bajraszewska et al., 2009
Kunert-Bajraszewska et al., 2010

2

16 BALQSOs from FIRST survey
and A Catalog of Broad Absorption
Line (BAL) Quasars from the SDSS
Third Data Release (Trump et al.,2006)
($F_{1.4GHz}$>150 mJy & F_{5GHz}>70 mJy)

VLBA 5 i 8.4 GHz
EVN 1.6 GHz
OCRA (Torun telescope) 30 GHz

data reduction in progress
frist results

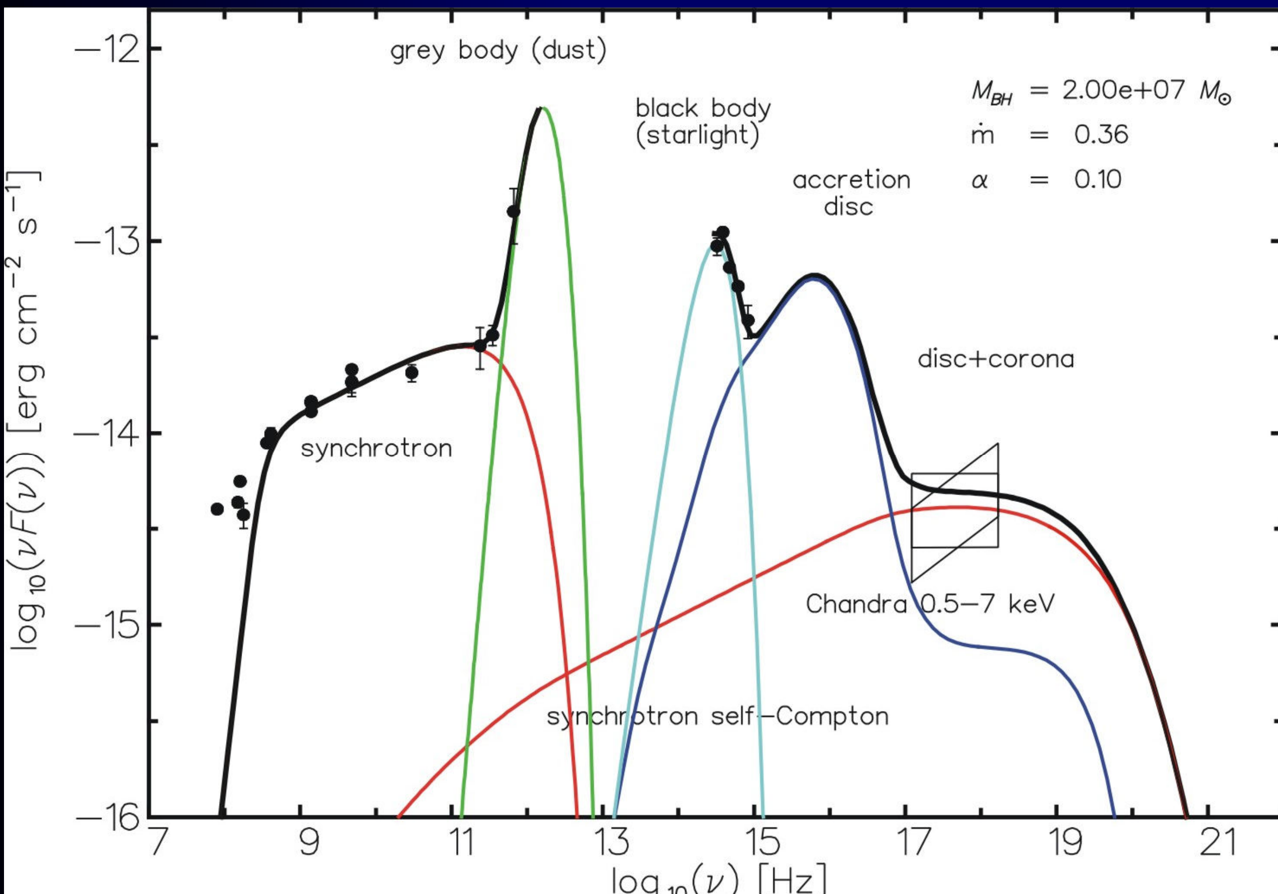
BAL quasar 1045+352

- CSS radio continuum
- z=1.604 (Willott et al. 2002), linear size ~4kpc
- one of the most radio-luminous BAL quasars (Log $L_{1.4GHz}$= 28.25 W/Hz)
- very luminous submillimeter object (Willott et al. 2002)
- HiBAL quasar

BAL quasar 1045+352

The Chandra X-ray observations

The X-ray emission of 1045+352 is very weak in comparison to other radio-loud BAL quasars, which together with the optical-X-ray index α_{OX}=1.88, suggests the presence of an X-ray absorber close/in the BLR region.



The SED modelling results:

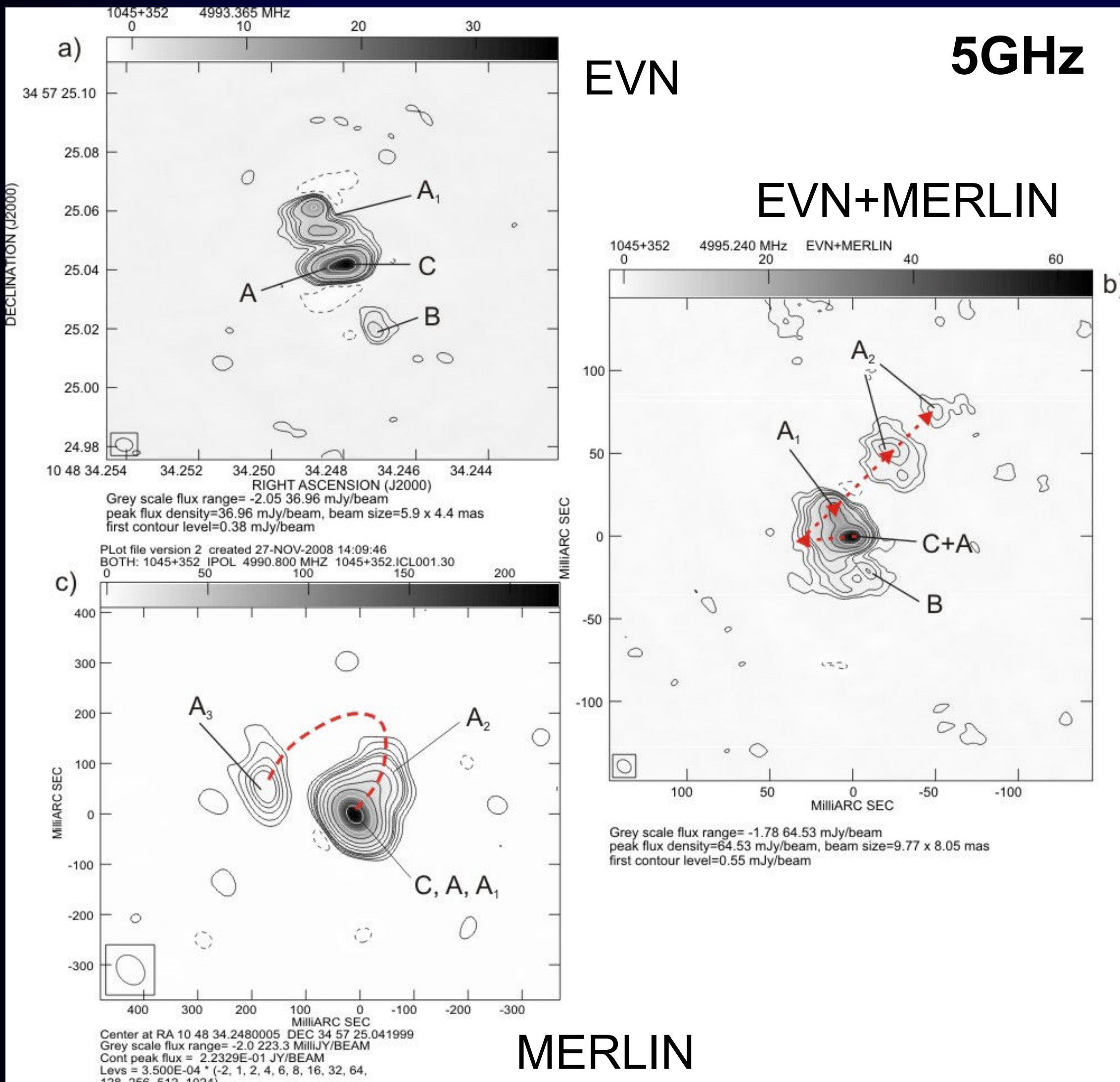
- observed X-ray emission mostly due to emission from the relativistic jet

- X-ray emission from the corona is absorbed in a large part

Kunert-Bajraszewska et al. 2009

BAL quasar 1045+352

Complex radio structure



The radio morphology is dominated by the strong radio jet resolved into many subcomponents and changing its orientation during propagation in the central regions of the host galaxy.

The observed radio morphology and changes of the jet direction may result from:

- a jet precession

- a merger

- jet-cloud interactions

Kunert-Bajraszewska et al. 2010

The new sample of radio-loud BAL quasars

Summary of new sample

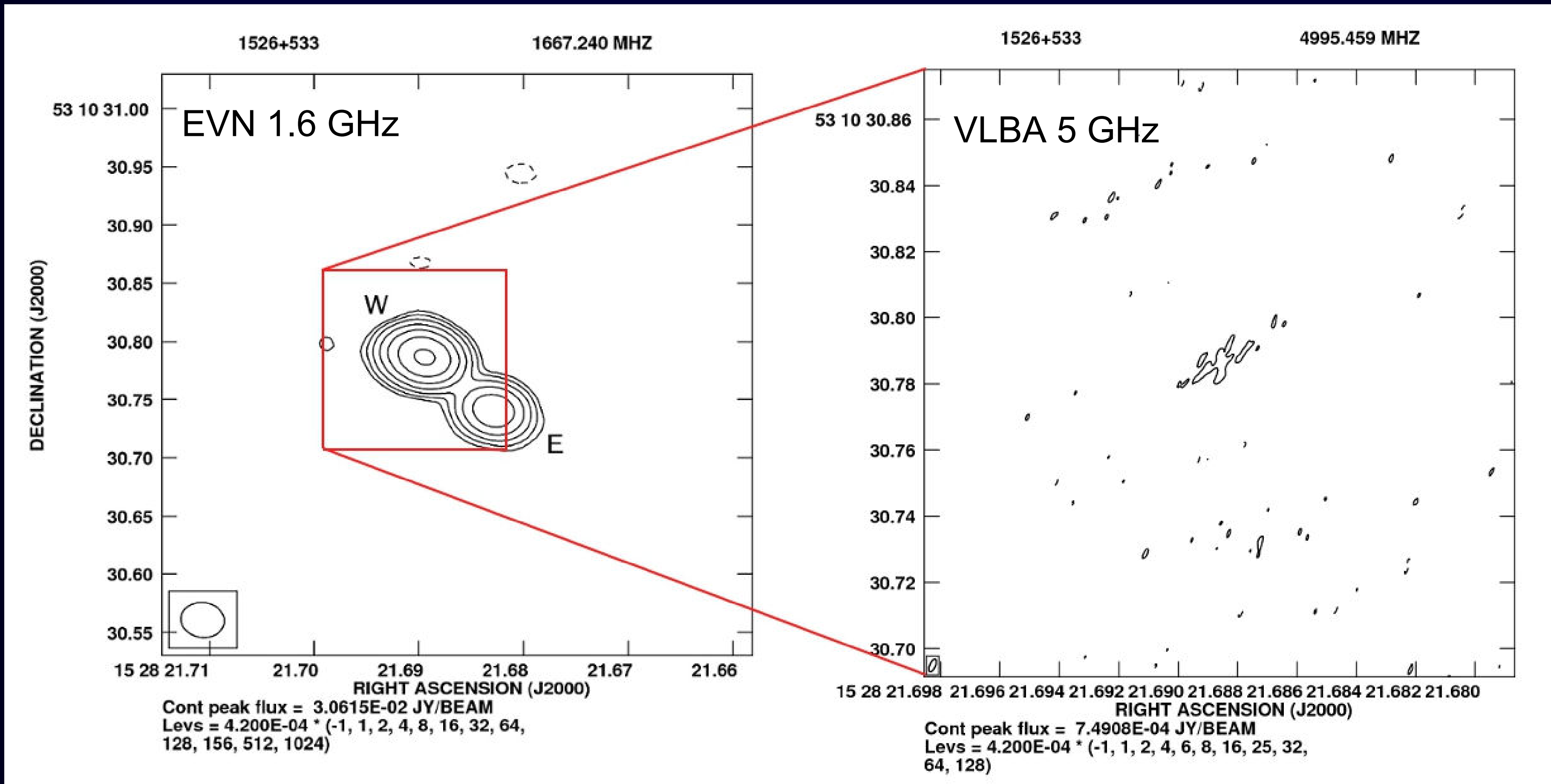
Source (1)	z (2)	Type (3)	Absorption index /AI/ (4)	$F_{1.4GHz}$ /mJy/ (5)	$\alpha_{4.8}^{1.4}$ (6)	Radio morphology (7)
0214-011	2.462	HiBAL	791	218.0	0.60	core-jet
0753+373*	2.514	HiBAL	841	247.3	0.04	core-jet
0756+406*	2.021	HiBAL	1114	199.6	0.87	core-jet
0812+332*	2.426	nHiBAL	747	342.5	0.94	core-jet
0925+450A*	1.904	nHiBAL	293	162.2	-0.35	unresolved
1002+483*	2.372	HiBAL	783	209.3	0.89	core-jet
1010+495*	2.201	nHiBAL	361	269.4	0.39	core-jet
1015+057	1.938	HiBAL	441	296.6	-0.09	core-jet
1040+080	2.665	HiBAL	1011	381.6	0.71	cj/gps**
1054+036	2.832	HiBAL	440	157.4	0.66	core-jet
J1103+0232	2.514	HiBAL	460	166.0	0.34	core-jet
1157+014	2.000	HiBAL	2887	268.5	0.64	unresolved
1221+509*	3.488	HiBAL	413	228.8	0.59	core-jet
1403+411*	1.993	HiBAL	780	214.0	-0.21	core-jet
1430+412*	1.970	nHiBAL	343	261.7	0.76	core jet
1526+533*	2.822	HiBAL	1701	182.6	0.71	dying?

Table 1: (2)- based on SDSS; (3)-(4) Trump et al., 2006; (5) - taken from FIRST; (6) - $S \propto \nu^{-\alpha}$, based on FIRST and GB6; * - EVN observations at 1.6 GHz; ** - no map at 4.8 GHz

Observed density fluxes of compact structures account only up to ~20% of total flux density at 5 GHz (~80% in the case of sources from Liu et al. 2008). There is a low brightness extended structure in objects from new sample.

The new sample of radio-loud BAL quasars

1526+533

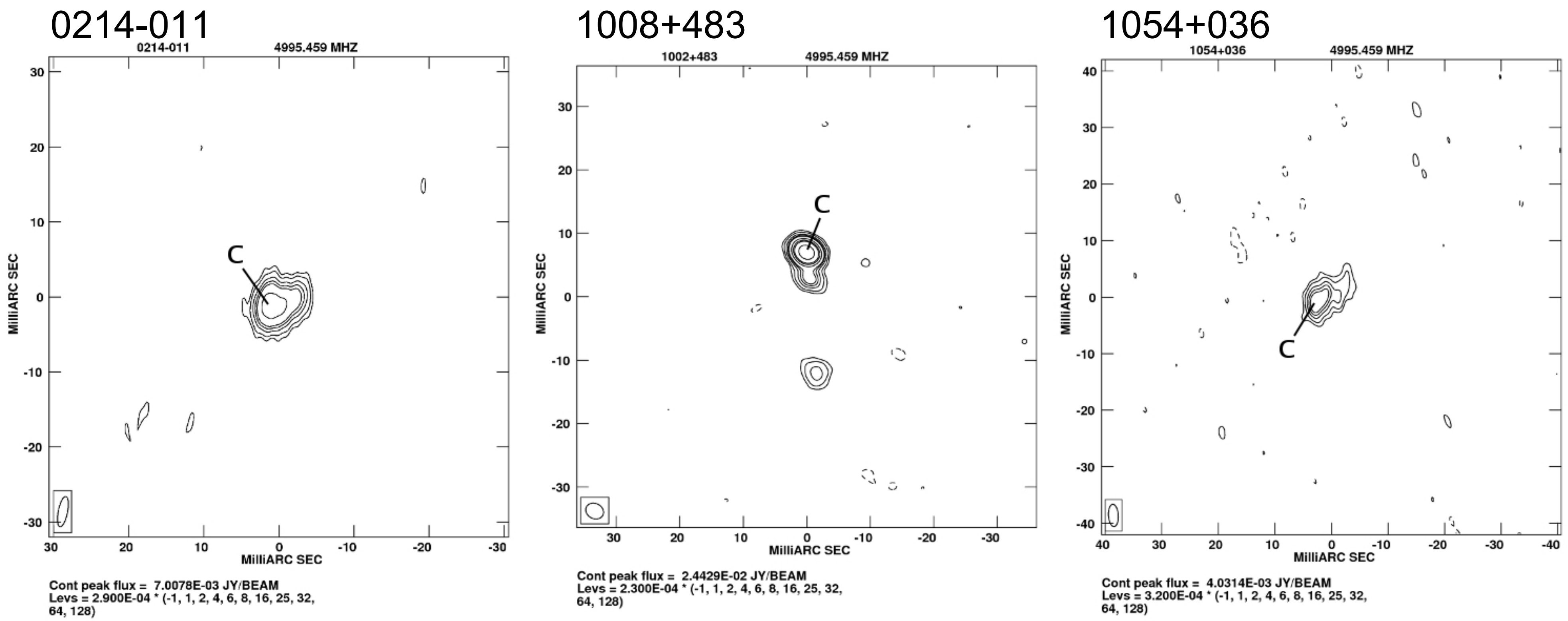


The source appears as a double object on EVN 1.6 GHz map. But we detected only a weak diffuse emission from W component on VLBA 5 GHz map.

Is 1526+533 a compact fader??

The new sample of radio-loud BAL quasars

12 (+1) from 16 sources have the core-jet radio morphology and show fainter emission from the jet compared to the core. This morphology suggest intermediate orientation between polar and equatorial geometries and support the orientation scenario .



VLBA 5 GHz

Conclusions:

- 1045+352 is a radio-loud BAL quasar with complex radio morphology
- observed X-ray emission mostly due to emission from the relativistic jet
- there is an X-ray absorber close/in the BLR region
- high-resolution radio observations of the new sample support the orientation scenario (in the opposition to previous results)

Still to do:

- polarization properties of sources from the new sample

Open questions:

- if 1523+533 is a fader how it fits into the evolutionary scenario?
- there are only the AI HiBAL quasars in our new sample
- what happens in the case of BI LoBAL quasars etc. ???
- what are the X-ray properties of sources from new sample ?

The BAL quasars chaos ←