Study of radio spectral index of radio galaxy DA 240

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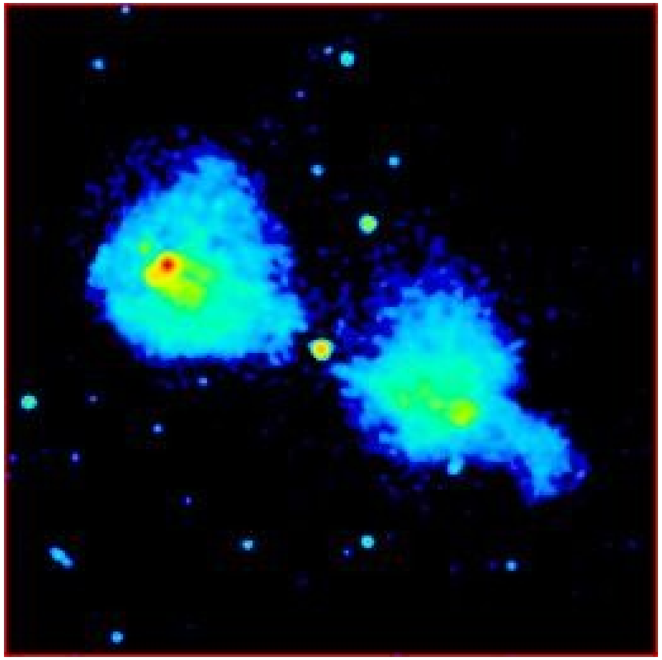
Outline of the talk

- DRAGNs
- DA 240 is DRAGN and GRG
- Data and method
  - WSRT radio telescope + CLEAN algorithm
  - Leahy et al. 2013, NED 2002
  - FITS data
- Flux densities
- Spectral index between 326 and 608 MHz
- Conclusions

(DRAGN - Double Radio sources Associated with Galactic Nucleus
(GRG - Giant Radio Galaxy)

Giant radio galaxy from Leahy’s Atlas: DA 240

- DRAGN: a radio source containing at least one of the following types of extended, synchrotron-emitting structures: jet, lobe, and hotspot complex (Leahy 1993)
- DRAGN DA 240 is one of the first GRGs recognized as such (larger than 1 Mpc), placing it at a distance of 215 Mpc.
- It consists of two radio clouds about 40' long, and a comparatively weak central core



Cross-identifications: DA 240;
CGCG 262-029;
CGCG 0744.6+5556;
MCG +09-13-057;
4C +56.16;
2MASX J07483682+5548591.

DA 240 at 608 MHz
(picture taken from "3CRR" sample
of Laing, Riley & Longair, 1983)

Data and method

- data are provided at:

  (1) J. P. Leahy, A. H. Bridle, R. G. Strom, An Atlas of DRAGNs (2013):
  http://www.jb.man.ac.uk/atlas/ (Leahy, Bridle & Strom, 2013),
  (2) NASA/IPAC Extragalactic Database:
  http://ned.ipac.caltech.edu/ (Mazzarella & the NED Team, 2002)

- WSRT observations:

  326 MHz (Willis & O'Dea, 1990) and 608 MHz (Willis et al., 1974)

- we use the calibrated data, which are processed using analysis techniques and programs like CLEAN algorithm

- the resolution: 20" at 326 MHz (92 cm) and 9.2" at 608 MHz (49.3 cm)

(NED - NASA/IPAC Extragalactic Database)
(WSRT - Westerbork Synthesis Radio Telescope)

Astrophysical data in FITS format

- data format with flexibility and storage efficiency
- it consists of one or more sets of a Header and Data Units
- Header is human-readable and contains keywords and values which describe the data (such as position or time of observation)
- Data Units are tables with *n*-dimensional data arrays
- long term archiving, i.e. all versions of the FITS format are backwards-compatible, with the latest version being 4.0 (adopted in 2016 and formally released in 2018).
- details at: https://www.loc.gov/preservation/digital/formats/fdd/fdd000317.shtml

(FITS - Flexible Image Transport System)

```
SIMPLE  =                    T / file does conform to FITS star
BITPIX  =                  -64 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                  128 / length of data axis 1
NAXIS2  =                   63 / length of data axis 2
EXTEND  =                    T / FITS dataset may contain exter
COMMENT   FITS (Flexible Image Transport System) format is defi
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 200
CONTENT = 'spectral index'     / file contains radio spectral i
CTYPE1  = 'R.A.     '          / type of data axis 1
CUNIT1  = 'DEG.     '          / units of data axis 1
CRPIX1  =                    1 / reference pixel of data axis 1
CRVAL1  =             227.9139 / coordinate of reference pixel
CDELT1  =        -0.0005555556 / increment (pixel size) along d
CTYPE2  = 'DEC.     '          / type of data axis 2
CUNIT2  = 'DEG.     '          / units of data axis 2
CRPIX2  =                    1 / reference pixel of data axis 2
CRVAL2  =             26.27667 / coordinate of reference pixel
CDELT2  =          0.001111111 / increment (pixel size) along d
ORIGIN  = 'P. Jovanovic (AOB)' / origin of FITS file
END
```

ORIGIN = 'P. Jovanovic (AOB)' / origin of FITS file

51	0.936519	1.36507
50	1.02748	1.0823
49	1.02661	0.754727
48	0.828574	0.445012
47	0.521536	0.457455
46	0.527394	0.519968
45	1.02868	0.723496
44	0.547804	0.356786
43	-0.40605	-0.747602
42	-0.118193	-0.931678
41	NULL	-0.285456
40	NULL	0.57741
39	-1.1705	0.0464566
38	-1.33724	-0.304674
37	-0.532189	0.183604
36	NULL	0.490755

Header

Data Unit (Table)

Example of FITS data

Method of calculation

- the area of the investigated radio source, as well as the flux densities, we determine in three ways (the most detailed explanation in Borka Jovanović 2012):

  I - brightness temperature contours (isolines Tb) or, in this case, flux density contours (isolines Sν),

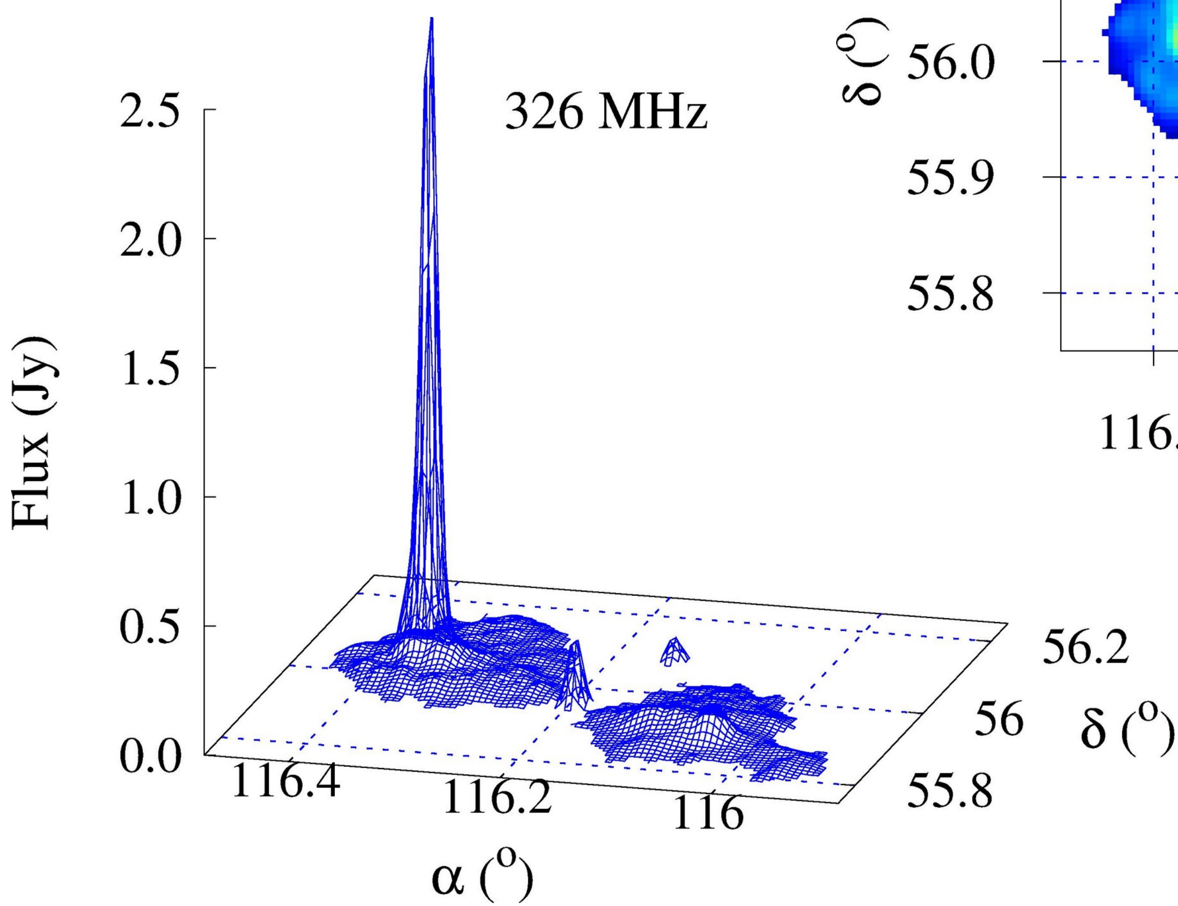
  II - flux density 2D profiles, for constant declination, to find out what would be min and max values of observed Sν,

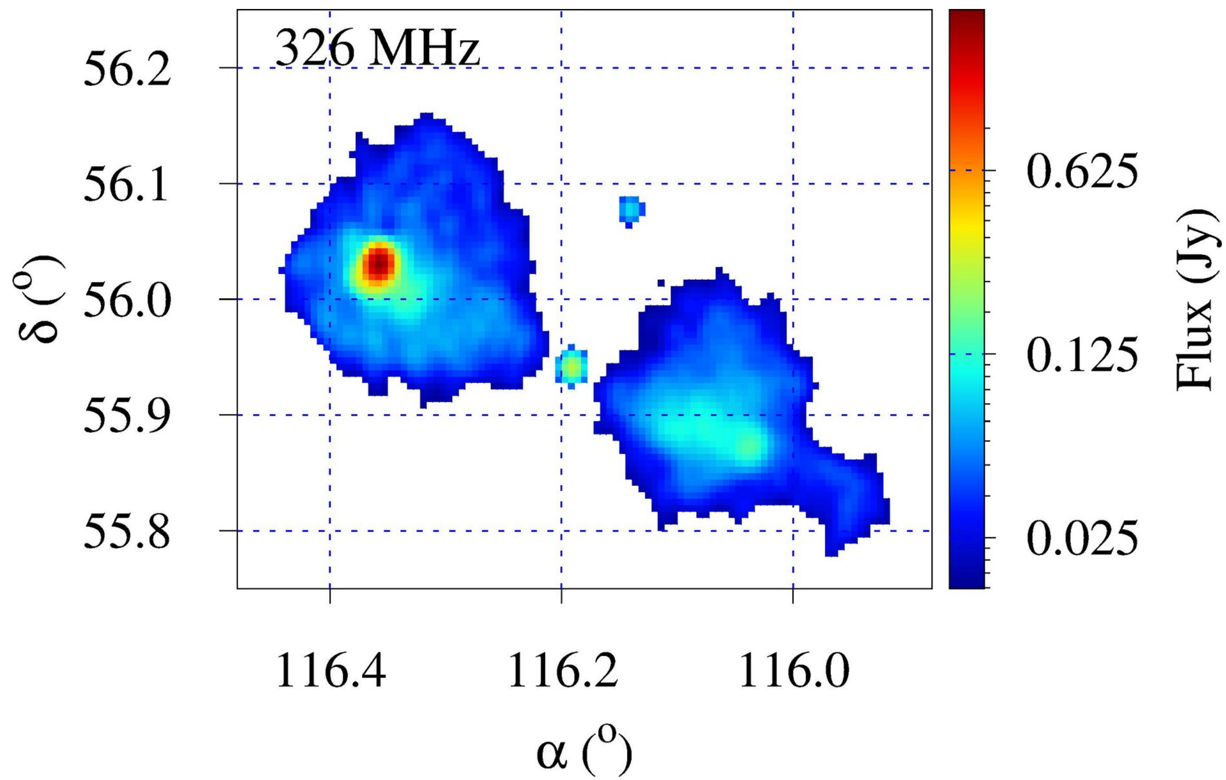
  III - 3D profiles give us also the possibility to estimate the area of the loop, and also it could be easily seen some superposed source.

(by doing the procedure in all three ways, we can check if the results are good)

The flux density distribution of giant radio galaxy DA 240 - at **326 MHz**

2D and 3D plot at **326 MHz**.



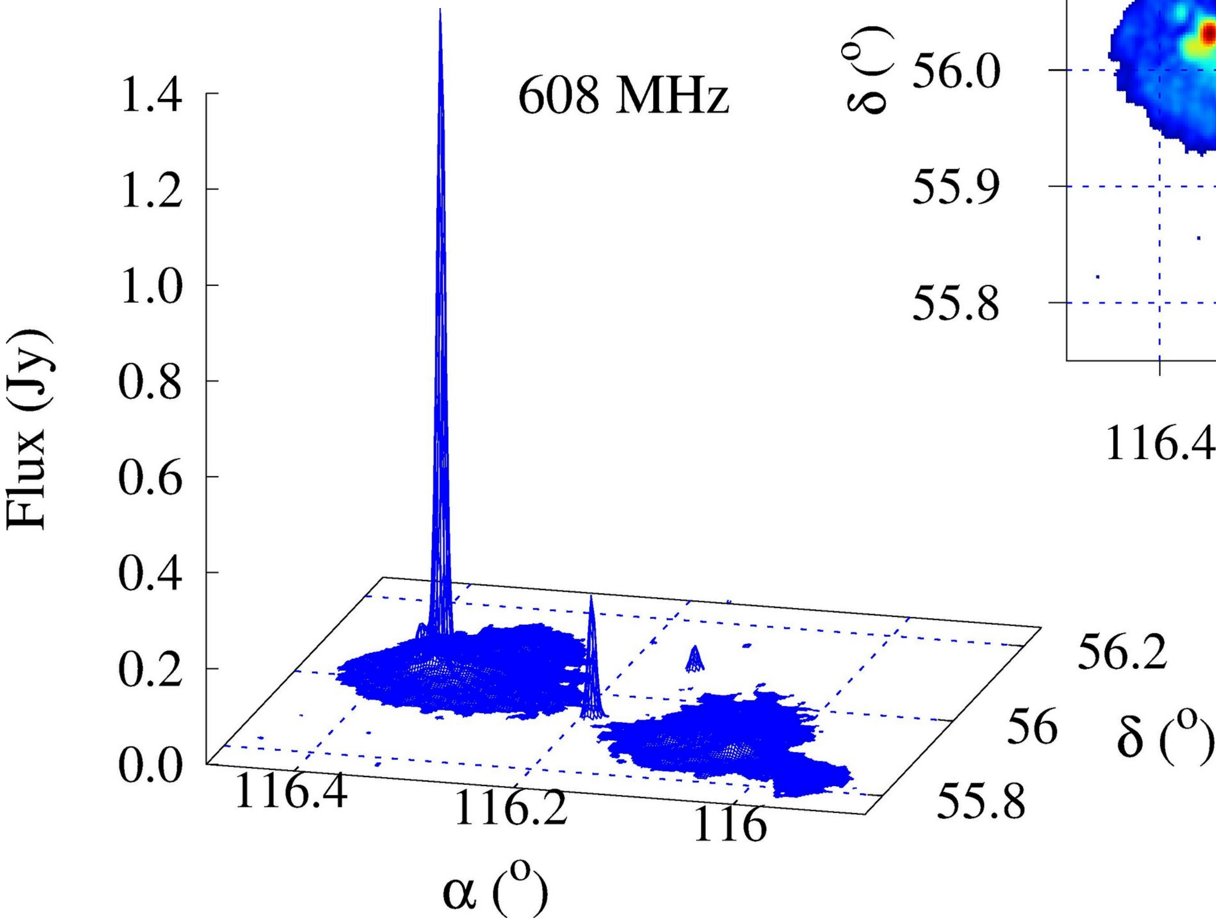


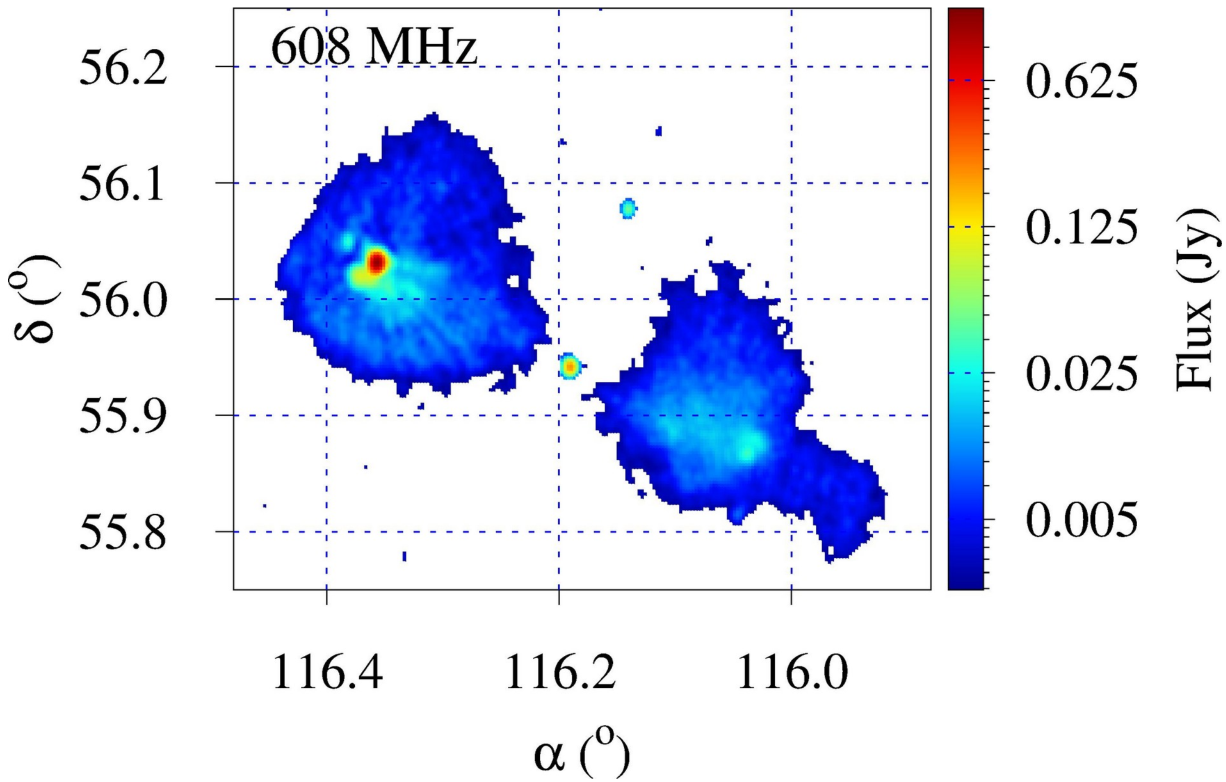
Smin = 0.016 Jy
Smax = 2.55 Jy

1 Jy = 10^{-26} W/(m^2 Hz)

The flux density distribution of giant radio galaxy DA 240 - at **608 MHz**

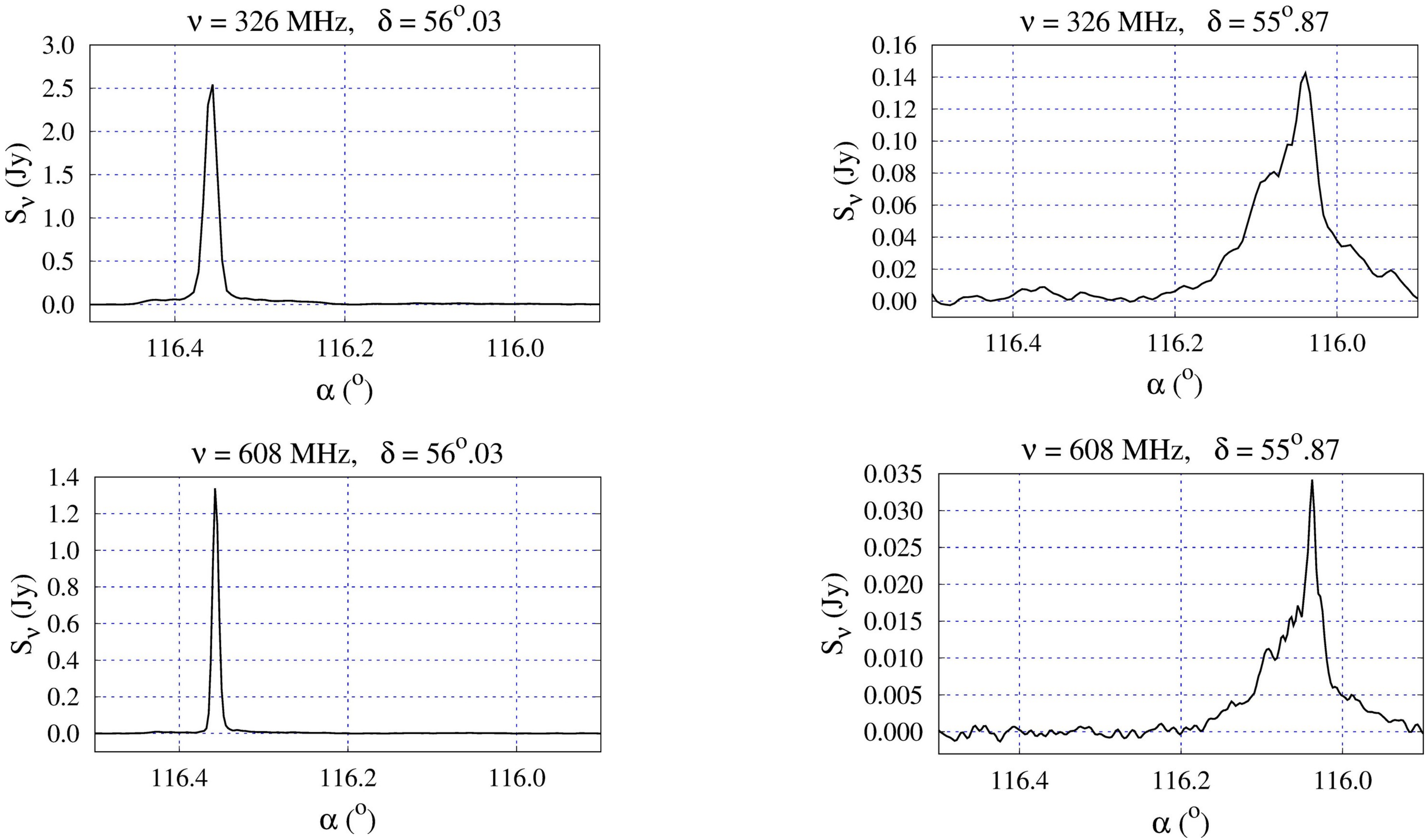
2D and 3D plot at **608 MHz**.





Smin = 0.0023 Jy
Smax = 1.38 Jy

Examples of flux profiles for constant declinations



- The 326 and 608 MHz flux profiles for constant declinations δ = 56°.03 (left) and δ = 55°.87 (right), containing northern and southern hotspots.

Radio spectral index

- If over some finite frequency range we can describe the amount of flux density $S\nu$ as a function of frequency ν by the formula:

$$S_\nu \sim \nu^{-\alpha},$$

where α is a constant, called the 'radio spectral index', we say that the flux has a 'power law dependence' on frequency.

- Radio spectral index α is negative value of coefficient of the line:

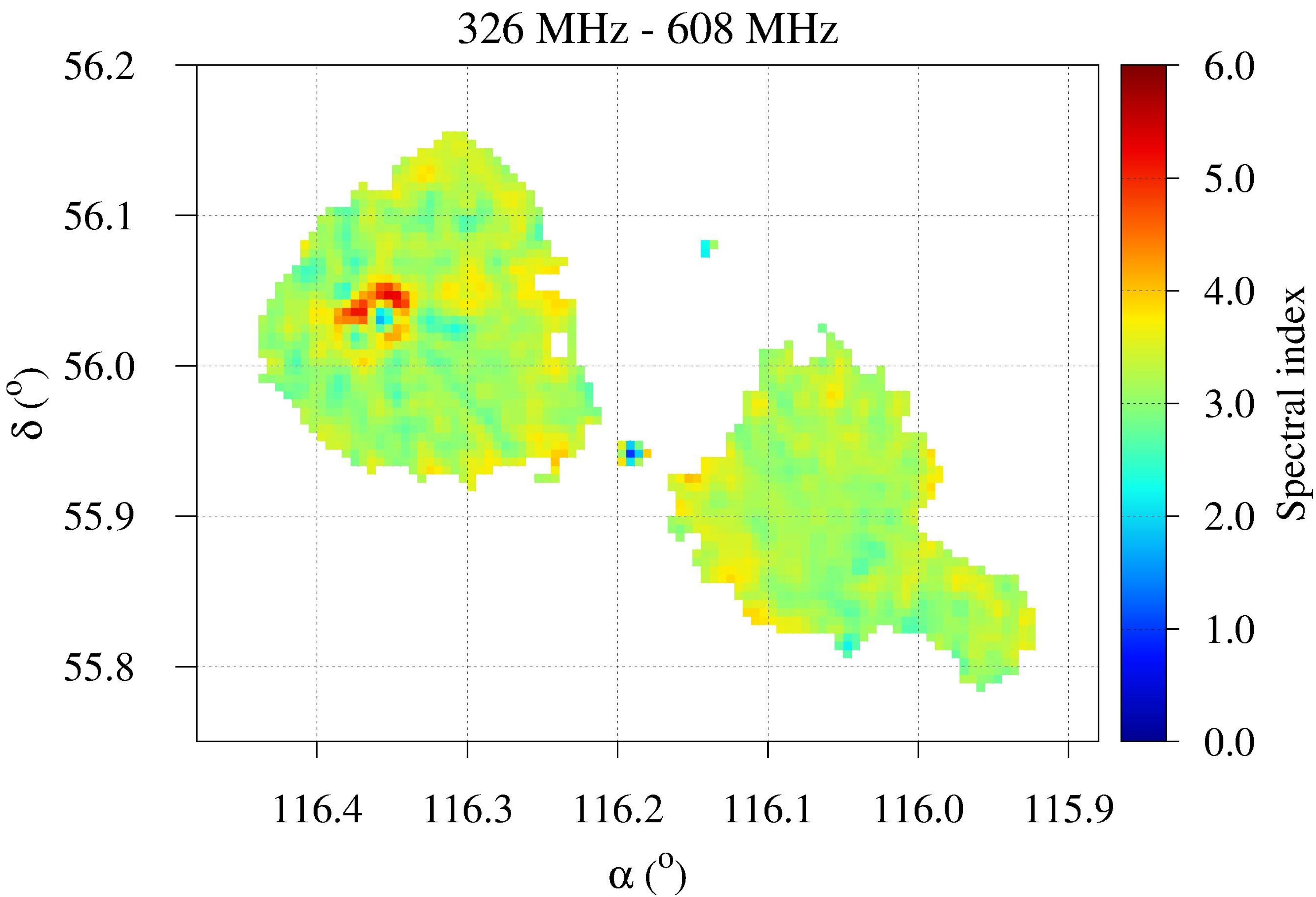
$$\alpha = -\frac{\log\left(\frac{S_{\nu_1}}{S_{\nu_2}}\right)}{\log\left(\frac{\nu_1}{\nu_2}\right)}.$$

- mechanisms of radiation:

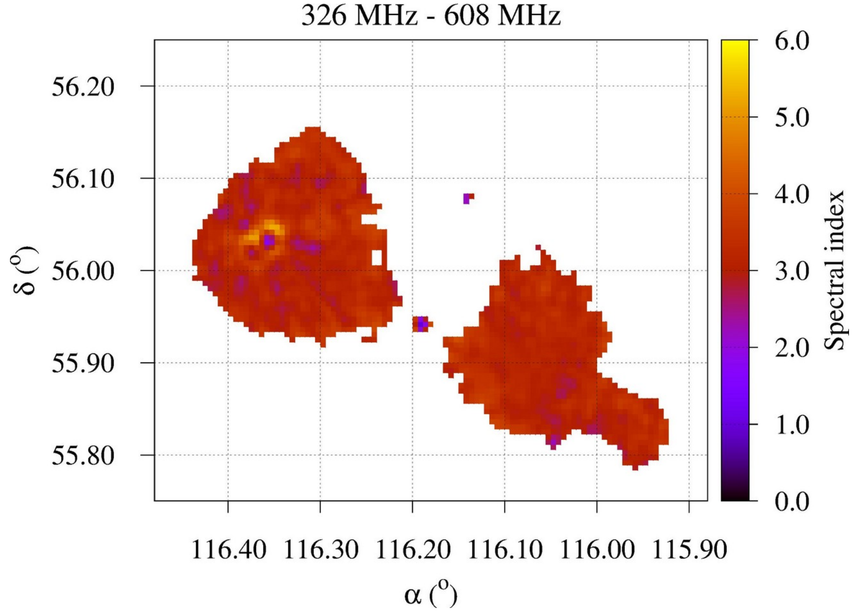
$\alpha < 0$ thermal

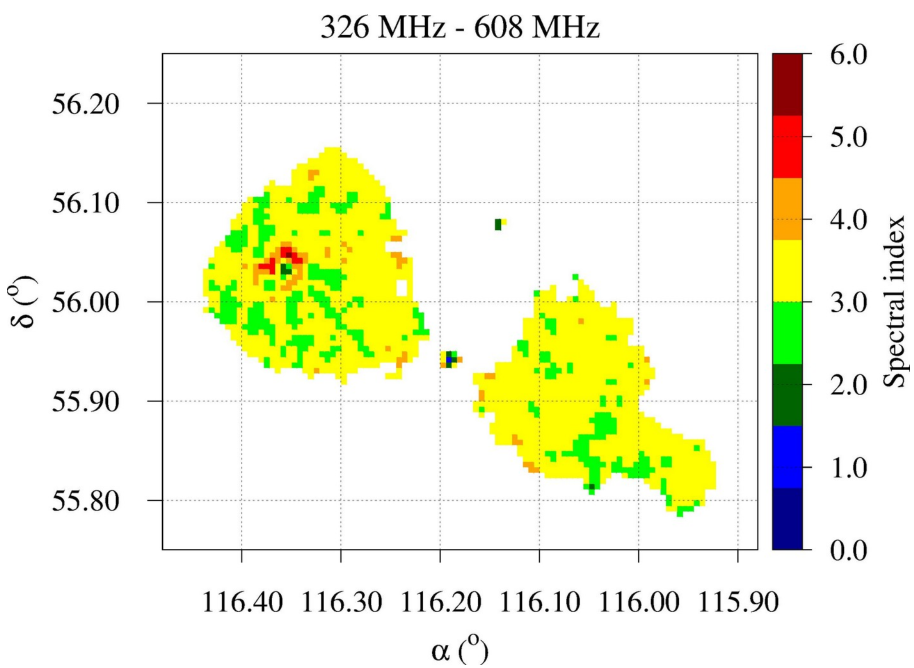
$\alpha > 0.1$ non-thermal

Spectral index distribution between 326 and 608 MHz



Spectral index distribution (for different colorbars)





- From the colorbar we can read the values of radio spectral index α, meaning this:
- α > 0 corresponds to non-thermal mechanism of radiation, and
- when the spectral index is zero, the flux density is independent of frequency, and the spectrum is said to be flat.
- We can notice a huge range of surface brightness over the intensity map, and the highest value is at the eastern component.

Discussion and conclusions

- We investigated the giant radio galaxy DA 240: the flux density and the spectral index distribution.
- A remarkable feature is the huge range of surface brightness over the intensity map, as well as the prominence of the eastern component.
- We used publicly available data: Leahy's atlas of double radio-sources (Laing, Riley & Longair 1983 and Leahy, and NED database.
- We used the available flux densities of DA 240 at 326 MHz (92 cm) and 608 MHz (49.3 cm).
- We provide the spectral index distribution derived between these two frequencies.
- We show that synchrotron radiation is the dominant emission mechanism over the whole area of the source.

References

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- V. Borka Jovanović, D. Borka, A. Arsenić, P. Jovanović, Adv. Space. Res. 71, 1227 (2023)

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Cygnus loop -> **Rev. Mex. AA** 2011
Galactic loops I-IV -> **Open Astron. J.** 2011
HB21 -> **Rev. Mex. AA** 2012
3C 349 -> **Publ. AOB** 2012
* **About our method** -> Publ. AOB 2012
* **Contribution to Green's Catalogue** of Galactic SNRs -> SPIG 2016:
https://www.mrao.cam.ac.uk/surveys/snrs/snrs.info.html
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Lupus loop -> **Rev. Mex. AA** 2017
3C 315 -> **Publ. AOB** 2022
3C 84 -> **Proc. of Sci.** 2023
4C 14.11 -> **Adv. Space Res.** 2023

Our method of calculation was developed for main Galactic radio loops, but it is applicable (and also rather efficient) to all SNRs, end to extragalactic radio sources, as well.

Thank you for attention!