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J/A+A/648/A9 Lockman Hole Apertif map at 1.4GHz (Morganti+, 2021)

The best of both worlds: combining LOFAR and Apertif to derive resolved radio spectral index images.

Morganti R., Oosterloo T.A., Brienza M., Jurlin N., Prandoni I., Orru E., Shabala S.S., Adams E.A.K., Adebahr B., Best P.N., Coolen A.H.W.M., Damstra S., de Blok W.J.G., de Gasperin F., Denes H., Hardcastle M., Hess K.M., Hut B., Kondapally R., Kutkin A.M., Loose G.M., Lucero D.M., Maan Y., Maccagni F.M., Mingo B., Moss V.A., Mostert R.I.J., Norden M.J., Oostrum L.C., Roettgering H.J.A., Ruiter M., Shimwell T.W., Schulz R., Vermaas N.J., Vohl D., van der Hulst J.M., van Diepen G.M., van Leeuwen J., Ziemke J.

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Abstract:

Supermassive black holes at the centres of galaxies can cycle through periods of activity and quiescence. Characterising the duty cycle of active galactic nuclei (AGN) is crucial for understanding the impact of the energy they release on the host galaxy. For radio AGN, this can be done by identifying dying (remnant) and restarted radio galaxies from their radio spectral properties. Using the combination of the images at 1400MHz produced by Apertif, the new phased-array feed receiver installed on the Westerbork Synthesis Radio Telescope, and images at 150MHz provided by LOFAR, we have derived resolved spectral index images (at a resolution of 15 arcsec) for all the sources within an approximately 6 deg^2 area of the Lockman Hole region. In this way, we were able to select 15 extended radio sources with emission (partly or entirely) characterised by extremely steep spectral indices (steeper than 1.2). These objects represent cases of radio sources in the remnant or the restarted phases of their life cycle. Our findings confirm that these objects are not as rare as previously thought, suggesting a relatively fast cycle. They also show a variety of properties that can be relevant for modelling the evolution of radio galaxies. For example, the restarted activity can occur while the remnant structure from a previous phase of activity is still visible. This provides constraints on the duration of the 'off' (dying) phase. In extended remnants with ultra-steep spectra at low frequencies, the activity likely stopped a few hundred megayears ago, and they correspond to the older tail of the age distribution of radio galaxies, in agreement with the results of simulations of radio source evolution. We find remnant radio sources with a variety of structures (from double-lobed to amorphous), possibly suggesting different types of progenitors. The present work sets the stage for exploiting the powerful tool of low-frequency spectral index studies of extended sources by taking advantage of the large areas common to the LOFAR and the Apertif surveys.

Description:

The launch of imaging surveys with the APERture Tile In Focus (Apertif) phased-array feed (PAF) system, recently installed on the Westerbork Synthesis Radio Telescope (WSRT) and working at 1400MHz has provided an ideal complement to the surveys done with LOFAR at frequencies centred on 150 and 54 MHz.

The Apertif observations of the Lockman Hole were done on April 28, 2019, during the Apertif commissioning phase.

Objects:

RA (2000)	DE	Designation(s)
10 45 00.0	+58 00 00	Lockman Hole = NAME Lockman Hole

File Summary:

FileName	Lrecl	Records	Explanations
ReadMe	80	.	This file
list.dat	125	1	Information of fits map
fits/*	0	1	Fits map

See also:

J/A+A/329/482 : ROSAT Deep Survey in the Lockman Hole (Hasinger+, 1998)
J/PASJ/53/445 : ASCA Deep survey in Lockman Hole Field (Ishisaki+, 2001)
J/A+A/393/425 : Spectral analysis of Lockman Hole (Mainieri+, 2002)

J/A+A/398/901 : VLA survey at 6 cm in the Lockman Hole (Ciliegi+, 2003)
J/AJ/125/2521 : 2MASS6x survey of the Lockman Hole (Beichman+, 2003)
J/A+A/413/843 : Far IR survey in the Lockman Hole (Kawara+, 2004)
J/A+A/427/23 : 14.3um survey in the Lockman Hole (Fadda+, 2004)
J/A+A/427/773 : ISOCAM 14.3µm Deep Survey in Lockman Hole
(Rodighiero+, 2004)
J/A+A/479/283 : XMM observations of the Lockman Hole (Brunner+, 2008)
J/MNRAS/387/1037 : 610-MHz survey of Lockman Hole with GMRT (Garn+, 2008)
J/MNRAS/397/281 : Radio imaging in Lockman Hole (Ibar+, 2009)
J/ApJS/185/433 : SWIRE/Chandra survey in Lockman Hole Field (Wilkes+, 2009)
J/ApJS/198/1 : Photometry catalogs for the Lockman Hole (Fotopoulou+, 2012)
J/other/BASI/38.103 : 6Lockman Hole 10-MHz survey with GMRT. II. (Garn+, 2010)
J/A+A/551/A97 : Lockman Hole/XMM VLBI observations (Middelberg+, 2013)
J/MNRAS/462/2934 : Lockman Hole North 3GHz catalogue (Vernstrom+, 2016)
J/MNRAS/463/2997 : Lockman Hole low-frequency radio sources (Mahony+, 2016)
J/MNRAS/429/2080 : Lockman Hole 10C sources radio spectral indices
(Whittam+ 2018)
J/ApJ/856/67 : Lockman Hole VLA 3GHz radio source catalog (Cotton+, 2018)
J/MNRAS/495/4084 : Lockman Hole region 325MHz source catalog (Mazumder+, 2020)

J/A+A/622/A1 : LOFAR Two-metre Sky Survey DR1 source catalog
(Shimwell+, 2019)

J/A+A/648/A2 : LOFAR Two-metre Sky Survey Deep Fields DR1 (Sabater+, 2021)
J/A+A/648/A3 : LOFAR Two-metre Sky Survey Deep Fields DR1 (Kondapally+, 2021)
J/A+A/648/A4 : LoTSS Deep Fields DR1 photometric redshifts (Duncan+, 2021)

https://lofar-surveys.org/releases.html : LOFAR Home Page

Byte-by-byte Description of file: list.dat

Bytes	Format	Units	Label	Explanations
1- 9	F9.5	deg	RAdeg	Right Ascension of center (J2000)
10- 18	F9.5	deg	DEdeg	Declination of center (J2000)
20- 23	I4	---	Nx	Number of pixels along X-axis
25- 28	I4	---	Ny	Number of pixels along Y-axis
30- 50	A21	"datime"	Obs.date	Observation date
52- 58	F7.5	GHz	Freq	Observed frequency
60- 64	I5	Kibyte	size	Size of FITS file
66- 85	A20	---	FileName	Name of FITS file, in subdirectory fits
87-125	A39	---	Title	Title of the FITS file

Acknowledgements:
Raffaella Morganti, morganti(at)astron.nl

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Jurlin et al., 2020A&A...638A..34J, The life cycle of radio galaxies in the LOFAR Lockman Hole field
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Tasse et al., Paper I 2020A&A...248A...1T
Sabater et al., Paper II 2020A&A...248A...2S, Cat. J/A+A/648/A2
Kondapally et al., Paper III 2020A&A...248A...3S, Cat. J/A+A/648/A3
Duncan et al., Paper IV 2020A&A...248A...4D, Cat. J/A+A/648/A4
Mandal et al., Paper V 2020A&A...248A...5M
Smith et al., Paper VI 2020A&A...248A...6S
Gloudemans et al., Paper VII 2020A&A...248A...7G
Wang et al., Paper VIII 2020A&A...248A...8W
Hardcastle et al., Paper X 2020A&A...248A..10H
Osinga et al., Paper XI 2020A&A...248A..11O
Herrera Ruiz et al., Paper XII 2020A&A...248A..12H
Callingham et al., Paper XIII 2020A&A...248A..13C

(End) Patricia Vannier [CDS] 29-Oct-2020

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