LOFAR-IT: the user experience



Dipartimento di Fisica e Astronomia, Università di Bologna INAF – IRA

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June 18, 2019 - INAF Science Archives & the Big Data Challenge, Rome

LOw Frequency ARray



LOw Frequency ARray



LOw Frequency ARray



HBA 120-168 MHz

International LOFAR Telescope



International LOFAR Telescope



Key Science Projects









TRANSIENTS & PULSARS



EPOCH OF REIONIZATION



Science highlights

doi:10.1038/nature16976

A large light-mass component of cosmic rays at $10^{17} - 10^{17.5}$ electronvolts from radio observations

S. Buitink^{1,2}, A. Corstanje², H. Falcke^{2,3,4,5}, J. R. Hörandel^{2,4}, T. Huege⁶, A. Nelles^{2,7}, J. P. Rachen², L. Rossetto², P. Schellart², S. buttink^{er}, A. Corstanje^e, H. Facke^{er-mar}, J. K. Horander^{-*}, I. Hugge^e, A. Neileg^e, J. P. Kachen⁺, L. Kozsetto^{*}, F. Schellart^{*}, O. Scholten^{*}, S. ter Veen³, S. Thoudam², T. N. G. Trink³, J. Anderson¹⁰, A. Asgekar^{1,1}, I. M. Avruch^{1,13}, M. E. Bell¹⁴, M. J. Bentum^{3,15}, G. Bernardi^{16,17}, P. Best¹⁸, A. Bonafede¹⁹, F. Breitling²⁰, J. W. Broderick²², W. N. Brouw^{3,13}, M. Brüggen¹⁹, H. R. Butcher²², D. Carbone²³, B. Ciardi²⁴, J. E. Conway⁵⁵, F. de Gasperin¹⁰, E. de Geus³, Z. A. Deller³, R. J. Dettmar²⁷, G. van Diepen³, S. Duscha³, J. Bis/fiel⁷², D. Engels²⁹, J. E. Enriquez³, R. A. Fallows³, R. Fender³⁰, C. Ferrari¹³, W. Frieswijk³, M. A. Garrett^{3,32}, J. M. Grießmeier^{33,34}, A. W. Gunst³, M. P. van Haarlem³, T. E. Hassall²¹, G. Heald^{3,13}, J. W. T. Hessels^{3,23}, M. Hoeft²⁸, A. Horneffer⁵, M. Iacobelli³, H. Intema^{32,35}, E. Juette²⁷, A. Karastergiou³⁰, V. I. Kondratiev^{3,36}, M. Kramer^{5,37}, M. Kuniyoshi³⁸, G. Kuper³, J. van Leeuwen^{3,23}, G. M. Loose³, P. Maat³, G. Mann²⁰, S. Markoff²³, R. McFadden³, D. McKay-Bukowski^{39,40}, J. P. McKean^{3,13}, M. Mevius^{3,13}, D. D. Mulcahy²¹, H. Munk³, M. J. Norden³, E. Orru³, H. Paas⁴¹, M. Pandey-Pommier⁴², V. N. Pandey³, M. Pietka³⁰, R. Pizzo³, A. G. Polatidis³, W. Reich⁵, H. J. A. Röttgering³², A. M. M. Scaife²¹ D. J. Schwarz⁴³, M. Serylak³⁰, J. Sluman³, O. Smirnov^{17,44}, B. W. Stappers³⁷, M. Steinmetz²⁰, A. Stewart³⁰, J. Swinbank^{23,45}, M. Tagger³³, Y. Tang³, C. Tasse^{44,46}, M. C. Toribio^{3,32}, R. Vermeulen³, C. Vocks²⁰, C. Vogt³, R. J. van Weeren¹⁶, R. A. M. J. Wijers²³ S. J. Wijnholds³, M. W. Wise^{3,23}, O. Wucknitz⁵, S. Yatawatta³, P. Zarka⁴⁷ & J. A. Zensus⁵

> nature astronomy

Multiple regions of shock-accelerated particles during a solar coronal mass ejection

Diana E. Morosan ^{1,2*}, Eoin P. Carley^{1,3}, Laura A. Hayes^{1,3}, Sophie A. Murray ^{1,3}, Pietro Zucca⁴, Richard A. Fallows⁴, Joe McCauley¹, Emilia K. J. Kilpua², Gottfried Mann⁵, Christian Vocks⁵ and Peter T. Gallagher^{1,3}



A radio ridge connecting two galaxy

F. Govoni^{1*}, E. Orrù², A. Bonafede^{3,4,5}, M. Iacobelli², R. Paladino³, F. Vazza^{3,4,5},

M. Murgia¹, V. Vacca¹, G. Giovannini^{3,4}, L. Feretti³, F. Loi^{1,4}, G. Bernardi^{3,6,7},

C. Ferrari⁸, R. F. Pizzo², C. Gheller⁹, S. Manti¹⁰, M. Brüggen⁵, G. Brunetti³,

R. Cassano³, F. de Gasperin^{5,11}, T. A. Enßlin^{12,13}, M. Hoeft¹⁴, C. Horellou¹⁵, H. Junklewitz¹⁶, H. J. A. Röttgering¹¹, A. M. M. Scaife¹⁷, T. W. Shimwell^{2,11},

clusters in a filament of the

SCIENCE ADVANCES | RESEARCH ARTICLE

ARTICLES

https://doi.org/10.1038/s41550-019-0689-z

PHYSICAL SCIENCES

Gentle reenergization of electrons in merging galaxy clusters

Francesco de Gasperin,^{1,2}* Huib T. Intema,¹ Timothy W. Shimwell,¹ Gianfranco Brunetti,³ Marcus Brüggen,² Torsten A. Enßlin,⁴ Reinout J. van Weeren,^{1,5} Annalisa Bonafede,^{2,3} Huub J. A. Röttgering¹

LETTER

RESEARCH

RADIO ASTRONOMY

cosmic web

R. J. van Weeren¹¹, M. Wise^{2,18}

https://doi.org/10.1038/s41586-019-1086-6

Needle-like structures discovered on positively charged lightning branches

B. M. Hare¹*, O. Scholten^{1,2}*, J. Dwyer³, T. N. G. Trinh¹, S. Buitink^{4,5}, S. ter Veen⁶, A. Bonardi⁵, A. Corstanje⁵, H. Falcke^{2,6,7}, I. R. Hörandel^{5,7}, T. Huege^{4,8}, P. Mitra⁴, K. Mulrev⁴, A. Nelles^{9,10}, J. P. Rachen⁵, L. Rossetto⁵, P. Schellart^{5,11}, T. Winchen⁴, I. Anderson^{12,13}, I. M. Avruch^{6,14}, M. J. Bentum^{6,15}, R. Blaauw⁶, J. W. Broderick⁶, W. N. Brouw^{6,16}, M. Brüggen¹⁷, H. R. Butcher¹⁸, B. Ciardi¹⁹, R. A. Fallows⁶, E. de Geus^{6,20}, S. Duscha⁶, J. Eislöffel²¹, M. A. Garrett^{22,23}, J. M. Grießmeier^{24,25}, A. W. Gunst⁶, M. P. van Haarlem⁶, J. W. T. Hessels^{6,26}, M. Hoeft²¹, A. J. van der Horst²⁷, M. Iacobelli⁶, L. V. E. Koopmans¹⁶, A. Krankowski²⁸ P. Maat⁶, M. J. Norden⁶, H. Paas²⁹, M. Pandey–Pommier^{25,30}, V. N. Pandey^{6,16}, R. Pekal³¹, R. Pizzo⁶, W. Reich³², H. Rothkaehl³³, H. J. A. Röttgering²³, A. Rowlinson^{6,26}, D. J. Schwarz²⁴, A. Shulevski²⁶, J. Sluman⁶, O. Smirnov^{35,36}, M. Soida³⁷, M. Tagger²⁴, M. C. Toribio²³, A. van Ardenne⁶, R. A. M. J. Wijers²⁶, R. J. van Weeren²³, O. Wucknitz³², P. Zarka³⁸ & P. Zucca⁶

Technical highlights



1.4" x 1.0" res @54 MHz

> 0.2" x 0.3" res @150MHz



LOFAR-IT

On 16/04/18 INAF joined LOFAR and established the consortium LOFAR-IT

- Italy became *full member* of LOFAR with immediate access of INAF personnel to the KSPs *Guaranteed* time of observation (33 h/cycle)
- Italy is involved in the *technological development* leading the upgrade to LOFAR 2.0 and a LOFAR 2.0 station will be installed in Medicina (BO)
- The realization of an effective Italian e-infrastructure to support the analysis and archiving of LOFAR data is ongoing (Becciani+Taffoni talk)









 $FWHM=2.85^{\circ}$

2035

1993

1872

1969

1011

ection: None

2088



Calibration improvement







large FoV, **wide** frequency coverage (+freq. resolution), **high** angular resolution



large FoV, wide frequency coverage (+freq. resolution), high angular resolution COOL! But...





255

large FoV, wide frequency coverage (+freq.
 resolution), high angular resolution
 COOL! But...
 A specific e-infrastructure is needed



LOFAR Two-metre Sky Survey (LoTSS)
frequency 120-168 MHz
resolution 5"
rms 100 μJy/beam
FoV 6.4 deg² (Shimwell+17,19)



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LOFAR "raw data": 16 TB (8 hr obs)



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Pre-Factor Data volume ~ 300-400 GB RAM ~ 200 GB t ~ 12 hr

If co-observed with LoTSS, the Survey KSP can run it for you! (SURFsara, Juelich, Poznan)



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Initial-Subtraction

Pre- Data volume ~ 300-400 GB DD RAM ~ 300-400 GB t ~ few days

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Data volume ~ 300-400 GB
 RAM ~ 300-400 GB
 t ~ few days

Factor Data volume ~ few TB RAM ~ 50 GB t ~ weeks

Pre-DD

DD

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DD

Factor Data volume ~ few TB RAM ~ 50 GB t ~ weeks ddf-pipeline (DDFacet+killMS) Data volume ~ 3 TB RAM ~ 200 GB t ~ 1 week



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Tasse+15,18, van Weeren+16, Williams+16, de Gasperin+19

ddf-pipeline (DDFacet+killMS) Data volume ~ 3 TB RAM ~ 200 GB t ~ 1 week

LOFAR-IT computing power

Name	RAM	CPU	Cores			
lofar1	512G	Intel Xeon E5-2640 v4	2 x 10/20	OACT		
lofar2	384G	Intel Xeon Gold 6130	2 x 16/32	CPU Type	cores	RAN
lofar3	384G	Intel Xeon Gold 6130	2 x 16/32	4x Intel(R) Xeon(R) CPU E5-4627 v3 @ 2.60GHz	40	256 GB
lofar4	384G	Intel Xeon Gold 6130	2 x 16/32	4x Intel(R) Xeon(R) CPU	40	256 GB
lofar5	384G	Intel Xeon Gold 6130	2 x 16/32	E5-4627 v3 @ 2.60GHz		
lofar6	384G	AMD EPYC	2 x 24/48	4x Intel(R) Xeon(R) Gold 5118 CPU @ 2.30GHz	48	512 GE

OATS

Storage						
Name	RAM	CPU	Cores	Clock	Data Net	Storage Disk
lofarnas0	32G	Intel Xeon Silver 4108	1 x 8/16	1800/3000	10GbE	12 x 10TB RAID6

100% running

UniTO

3 FAT nodes on OCCAM 4 x Intel Xeon (12 core) RAM 768 GB DDR4, 1 SSD 800GB, 1 HDD 2TB, 2x10Gbit Ethernet 50 -> 150 TB NAS

CPU Type	cores	RAM
2 cpu INTEL Westmere E5620 @ 2.40GHz	16	256 GB
4x Intel(R) Xeon(R) CPU E5-4627 v3 @ 2.60GHz	40	256 GB
1x Intel(R) Xeon(R) GE5620 @ 2.40GHz	16	128 GB

Testing

LOFAR-IT computing power

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nafede's	lofar4	384G	Intel Xeon Gold 6130	2 x 16/32	4x Intel(R) Xeon(R) CPU	40	256 GB
	lofar5	384G	Intel Xeon Gold 6130	2 x 16/32	E5-4627 v3 @ 2.60GHz		
	lofar6	384G	AMD EPYC 7401	2 x 24/48	4x Intel(R) Xeon(R) Gold 5118 CPU @ 2.30GHz	48	512 GB

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UAIS		
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100% running

Testing

Current status



Notable computing power

Not many users at the moment

~1 user per node

nodes are not overloaded no queues

This doesn't mean that the computer power cannot be increased!!!

Different kind of use: science + benchmarks + developing

• All the software is installed in a **singularity image** maintained by F. Bedosti (IRA): easily portable, needs to be re-generated at each software update

• Clearly, only a fraction of the data can be backed-up

First LOFAR-IT school



~30 participants (students, Post-Docs, staff, new members of the KSP)

Scientific talks + hands-on sessions by LOFAR expert users









Bonafede+18



Botteon+, in prep





Bonafede+, in prep



Coma cluster



Coma cluster



Image size: 25900 x 25900 pixel²

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Intensive RAM usage (only lofar1@ira.inaf)

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t > 1 day

Image size: 25900 x 25900 pixel²

Intensive RAM usage (only lofar1@ira.inaf)



t > 1 day

This is *just imaging* (DDFacet)!

Galactic fields



Processing of LoTSS fields



LoTSS processing is done in *Herts*, *Leiden* and *Bologna*

"Pre-Factored" are retrieved from SURFsara/Juelich/Pozan

ddf-pipeline is run (t ~ 7-9 days)

Products uploaded in Leiden

ID 🔺	Status 👌	RA	Dec 🔶	Gal I 🗍	Gal b 🍦	User	Cluster 🛊	Node 🍦	Location \Leftrightarrow	Priority 🖨	Start 🝦	End 🔶
P021+26	Archived	21.9547	26.0955	133.046	-36.0607	botteon	Bologna	lofar3.ira.inaf.it	/local/work/botteon /LoTSS- DR2//P021+26	3	2019-05-19 01:27:46	2019-05-26 06:35:38
P024+19	Archived	24.0133	18.5829	137.458	-43.0269	botteon	Bologna	lofar3.ira.inaf.it	/local/work/botteon /LoTSS-DR2/P024+19	0	2019-04-12 02:06:59	2019-04-18 04:24:49
P035+34	Archived	35.3638	33.7394	143.58	-25.4975	botteon	Bologna	lofar2.ira.inaf.it	/local/work/botteon /LoTSS-DR2/P035+34	3	2019-03-29 20:37:52	2019-04-07 02:59:28
P177+17	Archived	177.421	17.1058	244.822	72.5629	botteon	Bologna	lofar2.ira.inaf.it	/local/work/botteon /LoTSS- DR2//P177+17	0		
P177+42	Archived	177.803	42.2069	158.234	70.551	botteon	Bologna	lofar2.ira.inaf.it	/local/work/botteon /LoTSS-DR2/P177+42	1	2019-03-29 14:57:33	2019-03-29 19:18:11
P180+22	Archived	180.436	22.1417	234.067	77.6642	botteon	Bologna	lofar3.ira.inaf.it	/iranet/home2 /dranoel/LOTSS /P180+22	0		
P200+37	Archived	200.333	37.3059	93.0132	78.0285	botteon	Bologna	lofar2.ira.inaf.it	/local/work/botteon /LoTSS-DR2/P200+37	1	2019-04-28 17:12:09	2019-05-11 06:22:39
P248+65	Archived	248.111	65.1831	96.6622	38.8135	botteon	Bologna	lofar2.ira.inaf.it	/iradata/irafs5 /dranoel/LOTSS //P248+65	0		2018-09-04 08:00:00
P320+23	Archived	320.593	23.0569	72.6872	-18.8184	botteon	Bologna	lofar2.ira.inaf.it	/iradata/irafs5 /dranoel/LOTSS //P320+23	0		2018-09-13 06:58:58
P354+01	Archived	354.778	0.757995	88.0523	-57.1328	botteon	Bologna	lofar1.ira.inaf.it	/local/work/botteon /LoTSS-DR2/P354+01	0	2019-05-13 23:45:00	2019-05-28 01:57:42

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- LOFAR is the *largest* pathfinder of SKA-LOW
 Scientific and *technical* highlights

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