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Tuning in to the feedback bassline: revealing the operation of AGNs in galaxy clusters with high-resolution radio observations

Timmerman, R.

Citation

Timmerman, R. (2023, November 22). *Tuning in to the feedback bassline: revealing the operation of AGNs in galaxy clusters with high-resolution radio observations*. Retrieved from <https://hdl.handle.net/1887/3663557>

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Note: To cite this publication please use the final published version (if applicable).

PUBLICATIONS

First author

1. *The first high-redshift cavity power measurements of cool-core galaxy clusters with the International LOFAR Telescope*
R. Timmerman, R. J. van Weeren, A. Botteon, H. J. A. Röttgering, L. K. Morabito and F. Sweijen
Submitted to *Astronomy & Astrophysics*.
2. *Measuring cavity powers of active galactic nuclei in clusters using a hybrid X-ray-radio method*
R. Timmerman, R. J. van Weeren, A. Botteon, H. J. A. Röttgering, B. R. McNamara, F. Sweijen, L. Birzan and L. K. Morabito
Astronomy & Astrophysics, 2022, 668, A65
3. *Origin of the ring structures in Hercules A*
R. Timmerman, R. J. van Weeren, J. R. Callingham, W. D. Cotton, R. Perley, L. K. Morabito, N. A. B. Gizani, A. H. Bridle, C. P. O’Dea, S. A. Baum, G. R. Tremblay, P. Kharb, N. E. Kassim, H. J. A. Röttgering, A. Botteon, F. Sweijen, C. Tasse, M. Brüggen, J. Moldon, T. Shimwell and G. Brunetti
Astronomy & Astrophysics, 2022, 658, A5
4. *Very Large Array observations of the mini-halo and AGN feedback in the Phoenix cluster*
R. Timmerman, R. J. van Weeren, M. McDonald, A. Ignesti, B. R. McNamara, J. Hlavacek-Larrondo and H. J. A. Röttgering
Astronomy & Astrophysics, 2021, 646, A38

Contributing author

1. *A novel radio imaging method for physical spectral index modelling*
E. Ceccotti, A. R. Offringa, L. V. E. Koopmans, **R. Timmerman**, S. A. Brackenhoff, B. K. Gehlot, F. G. Mertens, S. Munshi, V. N. Pandey, R. J. van Weeren, S. Yatawatta and S. Zaroubi
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- C. J. Riseley, N. Biava, G. Lusetti, A. Bonafede, E. Bonnassieux, A. Botteon, F. Loi, G. Brunetti, R. Cassano, E. Osinga, K. Rajpurohit, H. J. A. Röttgering, T. Shimwell, **R. Timmerman**, R. J. van Weeren
Monthly Notices of the Royal Astronomical Society, 2023, 524, 4, 6052
3. *VLBI imaging of high-redshift galaxies and protoclusters at low radio frequencies with the International LOFAR Telescope*
 C. M. Cordun, **R. Timmerman**, G. K. Miley, R. J. van Weeren, F. Sweijen, L. K. Morabito and H. J. A. Röttgering
Astronomy & Astrophysics, 2023, 676, A29
 4. *V-LoTSS: The circularly polarised LOFAR Two-metre Sky Survey*
 J. R. Callingham, T. W. Shimwell, H. K. Vedantham, C. G. Bassa, S. P. O'Sullivan, T. W. H. Yiu, S. Bloor, P. N. Best, M. J. Hardcastle, M. Haverkorn, R. D. Kavanagh, L. Lamy, B. J. S. Pope, H. J. A. Röttgering, D. J. Schwarz, C. Tasse, R. J. van Weeren, G. J. White, P. Zarka, D. J. Bomans, A. Bonafede, M. Bonato, A. Botteon, M. Brüggen, K. T. Chyży, A. Drabent, K. L. Emig, A. J. Gloudemans, G. Gürkan, M. Hajduk, D. N. Hoang, M. Hoeft, M. Iacobelli, M. Kadler, M. Kunert-Bajraszewska, B. Mingo, L. K. Morabito, D. G. Nair, M. Pérez-Torres, T. P. Ray, C. J. Riseley, A. Rowlinson, S. Shulevski, F. Sweijen, **R. Timmerman**, M. Vaccari and J. Zheng
Astronomy & Astrophysics, 2023, 670, A124
 5. *The LOFAR Two-metre Sky Survey – V. Second data release*
 T. W. Shimwell, M. J. Hardcastle, C. Tasse, P. N. Best, H. J. A. Röttgering, W. L. Williams, A. Botteon, A. Drabent, A. Mechev, A. Shulevski, R. J. van Weeren, L. Bester, M. Brüggen, G. Brunetti, J. R. Callingham, K. T. Chyży, J. E. Conway, T. J. Dijkema, K. Duncan, F. de Gasperin, C. L. Hale, M. Haverkorn, B. Hugo, N. Jackson, M. Mevius, G. K. Miley, L. K. Morabito, R. Morganti, A. Offringa, J. B. R. Oonk, D. Rafferty, J. Sabater, D. J. B. Smith, D. J. Schwarz, O. Smirnov, S. P. O'Sullivan, H. Vedantham, G. J. White, J. G. Albert, L. Alegre, B. Asabere, D. J. Bacon, A. Bonafede, E. Bonnassieux, M. Brienza, M. Bilicki, M. Bonato, G. Calistro Rivera, R. Cassano, R. Cochrane, J. H. Croston, V. Cuciti, D. Dallacasa, A. Danezi, R. J. Dettmar, G. Di Gennaro, H. W. Edler, T. A. Enßlin, K. L. Emig, T. M. O. Franzen, C. García-Vergara, Y. G. Grange, G. Gürkan, M. Hajduk, G. Heald, V. Heesen, D. N. Hoang, M. Hoeft, C. Horellou, M. Iacobelli, M. Jamrozy, V. Jelić, R. Kondapally, P. Kukreti, M. Kunert-Bajraszewska, M. Magliocchetti, V. Mahatma, K. Małek, S. Mandal, F. Massaro, Z. Meyer-Zhao, B. Mingo, R. I. J. Mostert, D. G. Nair, S. J. Nakoneczny, B. Nikiel-Wroczyński, E. Orrú, U. Pajdosz-Śmierciak, T. Pasini, I. Prandoni, H. E. van Piggelen, K. Rajpurohit, E. Retana-Montenegro, C. J. Riseley, A. Rowlinson, A. Saxena, C. Schrijvers, F. Sweijen, T. M. Siewert, **R. Timmerman**, M. Vaccari, J. Vink, J. L. West, A. Wołowska, X. Zhang and J. Zheng
Astronomy & Astrophysics, 2022, 659, A1
 6. *LoTSS Jellyfish Galaxies III. The first identification of jellyfish galaxies in the Perseus cluster*

- I. D. Roberts, R. J. van Weeren, **R. Timmerman**, A. Botteon, M. Gendron-Marsolais, A. Ignesti and H. J. A. Röttgering
Astronomy & Astrophysics, 2022, 658, A44
7. *A MeerKAT-meets-LOFAR Study of MS 1455.0+2232: A 590 kiloparsec 'Mini'-Halo in a Sloshing Cool-Core Cluster*
C. J. Riseley, K. Rajpurohit, F. Loi, A. Botteon, **R. Timmerman**, N. Biava, A. Bonafede, E. Bonnassieux, G. Brunetti, T. Enßlin, G. Di Gennaro, A. Ignesti, T. Shimwell, C. Stuardi, T. Vernstrom and R. J. van Weeren
Monthly Notices of the Royal Astronomical Society, 2022, 512, 3, 4210

CURRICULUM VITAE

I was born on August 6, 1996, in the city of Meppel in the Netherlands. Despite initial efforts from my father during my toddlerhood to guide me into a career as a carpenter, like most of my family, it quickly became clear that my career prospects lay elsewhere. However, I did not see myself pursuing a career in science during the majority of my childhood, even though science was something I had a keen interest in. During my childhood, one of my main interests was in computers, which I could imagine myself doing as a career whenever I failed to avoid thinking about my future. At the age of 12, I started my VWO at the Greydanus College in Meppel and later Zwolle. During this time, I thoroughly enjoyed following physics, chemistry, mathematics and computer science classes. I made friends with a few amazing people, whom I am still in contact with to this day, and found it incredibly helpful to have friends who were as passionate as I was in these topics. When the time came at the end of my VWO to find a university programme, I initially looked into going to Utrecht to pursue either computer science or game development together with a friend. However, I was also attracted to the physics and astronomy programme in Utrecht, and attended a few information days. To my disappointment, I discovered that the astronomy component was practically non-existent, which made me realize for the first time that I actually would be very interested in pursuing astronomy. Ironically, it was this lack of astronomy in Utrecht which revitalized the interest in astronomy I have had since I was a child. I subsequently attended a few information days at the Kapteyn Astronomical Institute in Groningen and was immediately hooked. I finished my VWO and enthusiastically moved to Groningen to join the BSc Sterrenkunde programme.

During my bachelor's, I passionately followed physics, mathematics and astronomy courses. Again, I made new friends who were equally invested in learning about the nature of our Universe, and together we attended classes, made homework and prepared for exams. I still consider these friends to be my best friends, and will always appreciate the support they've given me during my bachelor's. In my third year, I followed the radio astronomy course by Dr. John McKean, and fell in love with this area of astronomy. After having successfully broken my cum laude streak with a 6 for the radio astronomy exam, I approached John for a BSc project. John offered me an exciting project on a distant lensed quasar, which required me to process 80 hours of 22 GHz Very Large Array data divided over 42 separate observations. To give me the best training possible, he told me to download the data from the archive without the flags applied by the observatory, so I would have to manually go through the observations to spot erroneous data.

Thanks to extra help from Cristiana Spingola and Hannah Stacey, I reduced and imaged all 80 hours of data, and my love for radio interferometry was awakened. I also first tasted what it was like to do research, and also fell in love with this practical aspect of science. I remember being disappointed to discover it was Friday afternoon, meaning I had to wait till Monday before I got to work on my project again. Unlike during courses, when all the information was presented to you during organized lectures, research requires that you fight for knowledge and insight using your curiosity, persistence and attention to detail. It felt amazing to be curious again on a daily basis and look into the Universe to discover its secrets. After my BSc project, I continued with a master's programme at the Kapteyn Astronomical Institute in Groningen and did not hesitate to approach John again for a project. This time, we would be working on a distant lensed quasar using High Sensitivity Array (HSA) observations, which include the VLBA, VLA, Effelsberg, Arecibo and the Greenbank Telescope (GBT). Unfortunately, Arecibo was offline due to hurricane damage, robbing me of my only opportunity to work with this telescope before old age took it from us. Additionally, the Effelsberg data was lost and the VLA was phased up in A-configuration instead of D-configuration, making it rather useless for HSA purposes. Fortunately, I was still able to obtain my first VLBI experience, reducing and imaging the VLBA and GBT observations in AIPS. Again, I loved every moment of this observational radio astronomy project, which reinforced my desire to pursue a PhD in this direction.

After obtaining my MSc degree cum laude in 2019, I was fortunate enough to be able to continue my academic career with my #1 choice: the LOFAR-VLBI project on radio-mode feedback in clusters at Leiden Observatory under the supervision of Reinout van Weeren. The following four years became some of the best years of my life. I've been able to enjoy the company of some amazing people in the LOFAR group, the observatory and on my trips abroad. I've been able to visit the USA during the 7th VLA Data Reduction School. I attended the LOFAR KSP Meeting in Turin at the end of 2019 before COVID shut everything down, and I've more than compensated for the following lockdown with an observation trip to La Palma to assist with observations for Ian Roberts, LOFAR Family meetings in Cologne and Olsztyn, the IAU General Assembly in South Korea, the SPARCS meeting in South Africa, the VLBI anniversary in Bologna for an invited talk, and LOFAR Long Baseline Busy Weeks in Durham and Paris. During my PhD, I have gained extensive experience with the calibration of LOFAR-VLBI observations, and look forward towards a bright future of radio astronomy where we can make these observations more accessible to the general community. Additionally, the SKA and ngVLA are approaching rapidly, offering a lot to be excited for.

Following my PhD, I will proceed with a postdoc at Durham University in the United Kingdom, where I will be working with Dr. Leah Morabito. In Durham, I will continue in the same research direction, studying radio-mode feedback in galaxy clusters with LOFAR-VLBI observations, but then shifting my focus more towards the high-redshift regime where I started my academic career.

ACKNOWLEDGEMENTS

When I started my PhD in Leiden, I could not have imagined what a beautiful time was ahead of me. Even despite the COVID-19 pandemic, I have enjoyed some of the most amazing years I could have asked for. I am extremely grateful to all my friends, colleagues, and everyone else for this unforgettable experience.

I want to start with my supervisor, Reinout. You told me one should never thank their supervisor because they are simply doing the job they're supposed to do, but you did so much more than that. Not only were you the most knowledgeable, helpful, patient, and supportive supervisor, but you are also one of the nicest, humblest, and friendliest people I know. You will always be a role model to me and so many others. You have guided me smoothly through my PhD, helped me develop myself into an independent researcher and prepared me for the next exciting steps in my career.

Huub, you have been a great second supervisor for me. You have always been supportive, while also never failing to seize an opportunity to challenge my research. You have made me a better researcher, and I will frequently ask myself "what would Huub say?" in my future career. I have really enjoyed working with you.

To my friends of the LOFAR group, I cannot thank you enough. You have made the Leiden Observatory feel like home from the first day. We have traveled the world together and made memories I will cherish for the rest of my life. Erik and Anniek, you were like a brother and sister to me these past four years, and I have counted myself incredibly lucky many times that our paths crossed. I hope we will remain friends for a long time. Frits, my mentor, thank you for helping me understand even the most subtle details of low-frequency radio interferometry with LOFAR. Maria, thank you for your endless enthusiasm and for getting me involved in fascinating new projects. Jurjen, thank you for all the amazing help and for all the dances. Christian, thank you for dealing with the lowest frequencies so the rest of us don't have to. Joe, thank you for always being supportive and for all your wisdom. Andrea, thank you for all the help with the X-ray observations. Gabriella, thank you for taking the time to talk to me during my interviews and convincing me I should do a PhD with Reinout. I'm still planning to visit Hamburg one day... Finally, of course also a warm thank you to Sarah, Tim, Wendy, George, Martijn, Rafaël, Ian, HaoYang, Jit, Tong, Sai, Joshua, Xuechen, Raymond, and Kim.

To my collaborators of the LOFAR Surveys team, thank you for being such amazing colleagues. It has been a delight to work with you and learn from you. A

special thank you goes to the Long Baseline Working Group: Leah, Neal, Shruti, Emmanuel, Marco, Etienne, Alexander, Emmy, Gulay, Marcin, Martin, Pranav, Vijay, Shane, James, Jonny, Hrishikesh, Cyril, Matthijs, Deepika and Alexandra. Naturally, I am also very grateful to all the other members of the collaboration for all the support, amazing discussions, and experiences at our many scientific meetings: Alessandro, Annalisa, Aurora, Bernard, Bohan, Carole, Catherine, Corey, Dan, David, Duy, Francesco, Gianfranco, Giulia, Harish, Hiroki, Javier, Ken, Lara, Laura, Luca, Marco, Marco, Marco, Marcus, Marina, Marisa, Matthias, Nadia, Nika, Philip, Rohit, Thomas, Tiziana, Tom, and Volker.

To my dear friends of the Leiden Observatory, thank you for being such lovely people! You are a big part of the reason why I've enjoyed the past four years as much as I did. First of all, thank you to my office mates: Andrej, Kirsty, Marta, Josh, Mathilde, Leindert and Matus. You have always been amazing company. Also a big thank you to the Gnarrrllllyy committee for organizing the unforgettable PhSki trip: Juicing Joey "the Iceman" Braspenning, Roi "the Shredder" Kugel, Cool Chris "the PUNisher" van Buchem and Aperol Spritz Amy (first of her name) "loco loca" Louca. I could not have wished for a better first winter sports experience! Next, a very warm thanks for all the other lovely people who were always welcoming and helped make the observatory the warm place it is, including but not limited to Alessia, Andrew, Anna, Bas, Brigitte, Chloe, Ciaran, Dario, Dilo-van, Dora, Elia, Elina, Evgenii, Fedde, Folkert, Fraser, Gijs, Helgi, Hiddo, Ivana, Jeger, Jelle, Jeroen, Lammim, Lucie, Lukasz, Luna, Lýdia, Maaïke, Maite, Mantas, Margot, Marina, Markus, Martijn, Martje, Morgan, Natasha, Niccolò, Olivier, Orestis, Osmar, Patrick, Paul, Piyush, Pooneh, Rico, Rob, Roi, Ruslan, Samira, Sanjana, Shun-Sheng, Sid, Sill, Silvia, Stella, Stijn, Thijs, Thomas, Timo, Turgay, Verónica, Victorine, Willeke, William, Xiaoyuan, Yanling, Yapeng, Zephyr, Zhenlin and Zorry. Naturally, a special thank you also goes to the support staff of the observatory, who have always been friendly and helpful: Alexandra, Alina, Bram, Châtelaine, David, Eric, Erik, Evelijn, Hafize, Huib, Jacqueline, Liesbeth, Marjan, Monica, Nancy, Nuray, Robin, Somayeh, and Susanne. Finally, I want to thank the left coffee machine in the Kaiser Lounge, you always made the best (free) coffee. Finally finally, I want to thank the Big Dipper for blessing us with wonderful borrels.

To all the lovely people I met during my trips, thank you for making these trips some of my best memories! I hope I'll have the chance to meet many of you again. Thanks for making my trip to Socorro an absolute blast, Andrew, Annaliese, Anton, Cosima, Francesca, Gerrit, Kenzie, Tatiana, and Virginia. Thanks for joining me on my trip to Bologna and for being such lovely company that week, Célestin, Florian, Florian, and Jonas. Thanks for joining the Leiden gang on our trip to South Africa, Jonah and Shilpa. You made it an even better experience than I could have ever dreamed of.

To all my friends outside of my world of academia, thank you for being my support and providing me with a lot of "life" for my work-life balance. I first want to thank my dear friends, the Step Musketeers: Kevin and Reinier. I am super happy we stayed in touch so often despite going our separate ways in life after our master's in Groningen. You have been an incredible support. Next, I want

to thank the rest of the Kangoeroes: Hans, Gijsbert, Suzan, Marcel, and Daniël. You are the best Walibi-gang anyone could ask for. A special thank you goes to my medeowner: Bas. I have always admired your positive influence on everyone around you. Never stop being you. Naturally, I also want to thank the members of the Grote Oef: Bart, Bram, Calvin, Gerben, Hans, Lars, Maarten, Michael, and Timon. Who knows how I would have made it through the pandemic without you all. Also a big thank you to Bradley, Leander, Lisa, Martijn, and Richard for all the good times we've shared together. Almost finally, a special thank you to three lovely people who have made Leiden always a warm place for me: Tom, Tjissa, and Josefine. Finally, a big thank you to Rick for the incredible cover illustration.

The last thank yous go to two very special people to me: my parents. You have always supported me, from my first day till now. You have always been a loving home to me, and you mean the world to me. I would not have been here in life without your infinite support.

