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Neutral outflows in high-redshift dusty galaxies

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List of publications

First Author

1. *Angular Momentum of Dwarf Galaxies*
Butler, K. M., Obreschkow, D., Oh, S.-H.
The Astrophysical Journal, 834, L4 (2017)
2. *Resolved Neutral Outflow from a Lensed Dusty Star-forming Galaxy at $z = 2.09$*
Butler, K. M., van der Werf, P. P., Rybak, M., Costa, T., Cox, P., Weiß, A., Michałowski, M. J., Riechers, D. A., Rigopoulou, D., Marchetti, L., Eales, S., Valtchanov, I.
The Astrophysical Journal, 919, 5 (2021)
3. *Molecular Outflows in $z > 6$ Unobscured QSO Hosts Driven by Star Formation*
Butler, K. M., van der Werf, P. P., Topkaras, T., Rybak, M., Venemans, B. P., Walter, F., Decarli, R.
The Astrophysical Journal, 944, 134 (2023)
4. *Neutral Outflows in High- z QSOs*
Butler, K. M., van der Werf, P. P., Omont, A., Cox, P.
Astronomy and Astrophysics, 674, L5 (2023)

Contributing Author

1. *The bright extragalactic ALMA redshift survey (BEARS) I: redshifts of bright gravitationally lensed galaxies from the Herschel ATLAS*
Urquhart, S. A., Bendo, G. J., Serjeant, S., Bakx, T., Hagimoto, M., Cox, P., Neri, R., Lehnert, M., Sedgwick, C., Weiner, C., Dannerbauer, H., Amvrosiadis, A., Andreani, P., Baker, A. J., Beelen, A., Berta, S., Borsato, E., Buat, V., **Butler, K. M.**, Cooray, A., De Zotti, G., Dunne, L., Dye, S., Eales, S., Enia, A., Fan, L., Gavazzi, R., González-Nuevo, J., Harris, A. I., Herrera, C. N., Hughes, D., Ismail, D., Ivison, R., Jin, S., Jones, B., Kohno, K., Krips, M., Lagache, G., Marchetti, L., Massardi, M., Messias, H., Negrello, M., Omont, A., Perez-Fournon, I., Riechers, D. A., Scott, D., Smith, M. W. L., Stanley, F., Tamura, Y., Temi, P., Vlahakis, C., Weiß, A., van der Werf, P., Verma, A., Yang, C., Young, A. J.
Monthly Notices of the Royal Astronomical Society, 511, 3017 (2022)
2. *The Bright Extragalactic ALMA Redshift Survey (BEARS) II: Millimetre photometry of gravitational lens candidates*
Bendo, G. J., Urquhart, S. A., Serjeant, S., Bakx, T., Hagimoto, M., Cox, P., Neri, R., Lehnert, M. D., Dannerbauer, H., Amvrosiadis, A., Andreani, P., Baker, A. J., Beelen, A., Berta, S., Borsato, E., Buat, V., **Butler, K. M.**, Cooray, A., De Zotti, G., Dunne, L., Dye, S., Eales, S., Enia, A., Fan, L., Gavazzi, R., González-Nuevo, J., Harris, A. I., Herrera, C. N., Hughes, D. H., Ismail, D., Jones, B. M., Kohno, K., Krips, M., Lagache, G., Marchetti, L., Massardi, M., Messias, H., Negrello, M., Omont, A., Pérez-Fournon, I., Riechers, D.

A., Scott, D., Smith, M. W. L., Stanley, F., Tamura, Y., Temi, P., van der Werf, P., Verma, A., Vlahakis, C., Weiß, A., Yang, C., Young, A. J.

Monthly Notices of the Royal Astronomical Society, 522, 2995 (2023)

3. *Bright extragalactic ALMA redshift survey (BEARS) III: detailed study of emission lines from 71 Herschel targets*

Hagimoto, M., Bakx, T. J. L. C., Serjeant, S., Bendo, G. J., Urquhart, S. A., Eales, S., Harrington, K. C., Tamura, Y., Umehata, H., Berta, S., Cooray, A. R., Cox, P., De Zotti, G., Lehnert, M. D., Riechers, D. A., Scott, D., Temi, P., van der Werf, P. P., Yang, C., Amvrosiadis, A., Andreani, P. M., Baker, A. J., Beelen, A., Borsato, E., Buat, V., **Butler, K. M.**, Dannerbauer, H., Dunne, L., Dye, S., Enia, A. F. M., Fan, L., Gavazzi, R., González-Nuevo, J., Harris, A. I., Herrera, C. N., Hughes, D. H., Ismail, D., Ivison, R. J., Jones, B., Kohno, K., Krips, M., Lagache, G., Marchetti, L., Massardi, M., Messias, H., Negrello, M., Neri, R., Omont, A., Perez-Fournon, I., Sedgwick, C., Smith, M. W. L., Stanley, F., Verma, A., Vlahakis, C., Ward, B., Weiner, C., Weiß, A., Young, A. J.

Monthly Notices of the Royal Astronomical Society, 521, 5508 (2023)

Curriculum vitae

I was born on the 31st of May 1994 at Como Hospital in the Perth Metropolitan, Western Australia, to Carole May and Craig David Butler, giving Erica Emma and Rajah AL Butler a little sister and later, Sheba AL Butler a big sister.

Growing up in the suburb of Belmont on Noongar Whadjuk boodjar (country), I enjoyed digging holes in my backyard, looking for worms and stalking my cat. I attended Belmont Primary School until age 12 where I learnt first how to write Kirsty and later, Kirsty. My favourite lessons were Art but my aspiration was to become a Veterinarian. In the later years I partook in the Primary Extension and Challenge (PEAC) program organised by the Department of Education of Western Australia for children in public schools. I additionally received instrumental music lessons on the clarinet in the last two years through the School of Instrumental Music (SIM) program also provided by the West Australian Government. In these years I played in the Belmont City Combined Schools Band and the Belmont City College band.

With my new-found talents in the music world I auditioned for and received a specialist music scholarship to attend Churchlands Senior Highschool and learn the Horn (not French). It was not long until a typical week included at least six mornings of rehearsals including a Combined Choir, Chamber Maids (all female chorale), a mixed Chorale (SATB), Wind band and Symphony Orchestra. At more irregular intervals my time was also spent with the Marching Band, on School musicals (Fiddler on the roof and Joseph's Technicolour Dreamcoat) and a Wind Quintet.

Despite my dedication to music, it was clear that my real talents lay in science. My long standing dream of becoming a vet and playing with tigers quickly became challenged, however, as I moved into senior high school and discovered physics. Suddenly, there was a subject I felt could explain everything around me. Torn between three worlds, I eventually decided I would adopt a house cat, play the horn as a hobby, and enrol in a double major of Physics and Mathematics at the University of Western Australia (UWA) with intentions of joining the Royal Australian Air Force (RAAF).

Shortly after high school graduation in 2011 I landed a casual job at the local Readings Cinema and immediately took out a bank loan to buy a horn of my own. At university I continued to study music theory and aural skills at the UWA Conservatorium of Music and was a horn player in their Symphony Orchestra. Outside of University I was member of the Western Australian Youth Orchestra and played in numerous other ensembles and projects sporadically throughout the years.

In the final year of my undergraduate studies I followed the Astrophysics branch of my physics major and discovered the utopia that is the International Center for Radio Astronomy Research (ICRAR). Following my undergraduate degree in 2014, I completed a joint summer studentship between ICRAR and the Pawsey Supercomputing Centre under the supervision of ICRAR professors Prof. Simon Driver (UWA) and Prof. Carol Jackson (Curtin University). In this project I cross matched the Galaxy and Mass Assembly (GAMA) catalogue with the Murchison Wide-field Array Commissioning Survey (MWACS) to find extragalactic radio sources common to both. During this time I was accepted into the Masters of Physics program at UWA, specialising in Astronomy and Astrophysics at ICRAR.

During my Masters I worked with Dr. Danail Obreschow and Dr. Se-Heon Oh on a project measuring the total baryonic angular momentum of local dwarf irregular galaxies. This combined radio observations of neutral hydrogen gas in the LITTLE THINGS sample taken with the Very Large Array (VLA) and Infrared observations of the stellar components taken with the Infrared Array Camera (IRAC) on the Spitzer space telescope. During my masters I decided to run the Perth City to Surf fun run, injured my knee and eventually discovered both knees were, in fact, not made to order. With two knee operations and four big screws in my future it was clear that joining the RAAF was now out of reach.

In reality this made a difficult decision easy, as my love for astronomy had grown; applying for a PhD position was now clearly the next step. So, after receiving my Masters of Physics with distinction in 2016, I set my sights outside of Australia and accepted a position at the Sterrewacht Leiden with Prof. Paul P. van der Werf who I had on good account was 'pretty chill'. And so, in late 2017 my horn and I packed our things and moved to little wet Netherlands, which I could not have pointed out on a map one year earlier. Here, I worked on my thesis studying the cold neutral gas outflows from very distant star-forming and active galaxies using molecular absorption line observations from the Atacama Large Millimeter/submillimeter Array (ALMA).

Alongside my research I was a teaching assistant for the undergraduate level Galaxies in the Universe course and the masters level Interstellar Medium course. I supervised and co-supervised two masters student projects and was an active member of the Bonanza, Borrel, Social and Diversity and Inclusion committees. Outside of the Sterrewacht I continued to play the horn with the Collegium Musicum Symphony Orchestra.

In my fourth year in Leiden I was offered a Post Doctorate position at the Institut de Radioastronomie Millimétrique (IRAM) in Grenoble, France, to begin in January of 2022. Here I spend 50% of my time as a member of the Science Operations Group (SOG) for the Northern Extended Millimeter Array (NOEMA) and the French ALMA Regional Centre (ARC). The remaining 50% is dedicated to my independent research where I continue my work on massive galaxy outflows. Finally, after more than a year after leaving Leiden I am concluding my PhD thesis and putting the doc in my postdoc.

Acknowledgments

I am incredibly grateful to an enormous number of people, animals and inanimate objects that have supported me, taught me and brought me happiness into the last 5.5 years of my life.

Firstly, I would like to thank my supervisor, Paul, for employing me and subsequently putting up with me.

There are many people whose jobs it is to support us at the observatory to do the research that we do. This includes my friends across the hallway at the secretariat: Marjan and Monica who always let me know when there were snacks in the KL and Susanne and our institute manager Evelijn who checked in on me every day when I got myself stranded in Peru. I would like to thank the Eriks (who I bugged the most) and everyone else in the computer group for their continued support for the technologically challenged. I would like to thank all of the angels at ALLEGRO, in particular Carmen, Liz, Aida and Andrés who provided enormous support for my ALMA projects, proposals and problems over the years.

Starting somewhere new and very far from home is always difficult, but many of you in Leiden welcomed me with open arms. To my 11th-floor instrumentation friends: Maaïke and Steven thank you for introducing me to Alex, David, Sebastiaan, Emiel, Patrick, Rob and the other intruders Stijn, Leindert, and Leon. Thank you all for adopting a lonely extragalactic soul into your coffee and lunch breaks and teaching me more than I'll ever need to know about coronagraphs. Similarly, to my Italian (and honorary Italian) family members: Maria Christina, Tomasso, Eleonora, Jit, Christos, Gabriela, Valeriya and Gabriella, your parties were always the best mix of fun and food. Some notable others in the upper years were of course Arthur and Merel who brought \vspace{} into my life, for which me and my ALMA proposals are forever grateful. Łukasz for always being up for an adventure. Andrej for being 100% wholesome. Andrew for debating lamingtons with me. Sierk, Santiago, Alex, Mieke, Mike, Kim, Nastasha, and Christian, thank you for your kindness.

Oort office 464 was my crowded second home in Leiden but luckily I was gifted with the best office mates. Aayush, you will always be the wise final-year PhD candidate in my eyes. Themiya, thanks for laughing at my niche Australian jokes and sorry I bullied you out of your office spot. Leindert, my half-academic brother, thanks for always being enthusiastic and willing to check out a plot. Matus, super grateful for all your help as my go-to postdoc for all my problems as well as a supportive friend. Marta, my half-academic sister, thank you for all the hugs and all the Paella. Josh, I forgive you for killing the sage, keep embracing your inner Father Christmas. And finally, Roland and Rychard who probably spent the same amount of time in that office despite only Roland actually being a member of it.

To my fellow PhDs: Dilovan, my dude, there was nothing we could not talk about or lose our breaths laughing over. Hiddo and Dieuwertje, our post-conference trips were the thing of legends but I maintain: one week is the absolute maximum safe duration of our coexistence. Fraser, my most hiccuppy friend, you were my favourite borrel buddy, never stop sweeping. Anna, 10/10 would decorate a cake with again, 0/10 would not cook celeriac with again. Martijn, I hope the kids are doing well. Pooneh, you and your infectious laugh always cheered me up. Mantas, we're all a little madder because of you, thank you. Dario, you're a rock star, keep rupturing eardrums. Anniek, I would choose you to be my navigator/car DJ every time. Bas, thanks for all

the chats over tea, I've learnt a lot from you. Omar, Thank you for always speaking your mind, +10 entertainment points. Jeroen, you're a good kid. Patrick, you will always be plant-parent goals. Turgay, thanks for all the weird stories. Frits, Dug? And to so many others who I have known for long and short: Michał, Nicco, Roi, Ivana, Margot, Erik, Lydia, Christian, Christiaan, Thijs, Jurjen, Elia, Evgenni, Marina, Folkert, Sanjana, Lammim, Willeke, Andrew, Rob, Louise, Martijn, Morgen, Osmar, Stella, Dora, thank you all for the fun.

To the older, but not necessarily wiser postdocs: Christina, Matthieu, Sarah, Michael, Madusha, Ken, Wendy, Alice, Alex, James, Tiago, Aurora, Domenik, Alessandro, Joe, Ashley and Benoit, thanks for being cool, too. In fact, to everyone at the Sterrewacht mentioned or missed, especially if I forced you into a Halloween costume, thanks for making it a good time.

A further thank you to my two masters students, Brigitte and Teo, for teaching me in return and to the entire Dustmites group and Galaxies journal club for everything I have learnt in those meetings.

Outside of work, I was also a member of the Collegium Musicum Association's symphony orchestra. I had many great experiences on tour, in concerts and at rehearsals, particularly with my fellow horn players. Thank you for occupying my Monday nights and giving me a tour of Dutch churches. Similarly, to my basketball friends at LUSV who always knew how to play hard and party harder. I would also like to thank my K-straat family: firstly Maria Cristina and Tomasso my gardening buddies, and later Matteo, Elina and Reinier who didn't touch the garden once. You all kept me sane and insane in different ways.

Much of this thesis was done from my new home in Grenoble. I want to thank Alfred for making those first few months a little less lonely. Of course, to all my new friends and colleagues at IRAM, thank you for your support and encouragement over the past year and a half. I'd also like to thank my psychologist, Tanya, for being worth every penny and more.

An extra special mention must be made to every cat I have met over the course of my PhD in both Leiden (the Princess next door, Kitty from the neighbourhood, Nala, Alma, Koe, Kaatje and Lizzie (Lizard)) and Grenoble (Pinko and Salmiak). Special inclusions: Pünktchen and Anton the bunnies, and all the animal parents for trusting me with their children.

To Big Dipper of the Leiden Sterrewacht, Seventh of its Name (Destroyer of Borrelnootjes, Painter of the Blood Moon, Seducer of the Red Planet, Harbinger of the Summer Storm, Sailor on the Solar Winds, Banisher of Postdocs, Shnuffler of Shnufflewobbles, Provider of Infinite Merriment, Bestower of Delicious Prizes, Most Stable of Geniuses, Shedder of a Billion Tears, Creator of the Heavenly Spoon, Owner of a Lonely Heart, Blackest of all the Bodies, The Bump in the Night, Mentor of n00bz, Scaler of the Great Wall, Whacker of Spoons, Guzzler of Gravy, Inventor of Everything Useful Ever, Snatcher of Naughty Children, Baker of Pop III Treats, Crafter of the Glittery Void, Enforcer of All Resolutions, The Egg Layer, Collector of Toes, The 3rd Hemsworth Brother, The Silent but Deadly, Trying Asbestos We Can, @xXx420_theBIgDee_360n0sc0pexXx, Герой Красного Шторма, Dark, Sensitive with low self-esteem, The Left Trucknut of Democracy, The Most Ataractic of Glows, Friend to ALL Kitties, Feeling a Bit Shy, The Royal Snorange, The Hash-Slinging Slasher, The Womb With a View, The Chocolate Submarine, The Field of Wheat, The Stylish LEAP of Faith, Help I've Become a 🐝Bee🐝, Pickle Diiiiiiiiiiiiiiiiip, Never Gonna Give You Up), it was an honour serving you.

Now for some Australians: Luke, Sam and Lucy, who did not forsake me over the other side of the world, thanks for the online board games. To every other Aussie who made use of Kirsty's

European hostel or dragged me along parts of their own European adventures, thanks for joining in on discovering this weird continent.

Finally, to my parents, Carole and Craig and my sisters Erica and Sheba, thank you for the fashion advice half a world away, the supplies of Vegemite, and the family updates every week. Thank you for everything during and leading up to my PhD that got me here (and the weird sense of humour that got me through it). We didn't know when I left Australia just how little we would be able to see each other in person, but you always supported me no matter what, thank you.