Research report, Ricarda Beckmann, Easter 2023

This report covers the timeframe from April 2022 to March 2023

Research projects

My research explores the co-evolution between massive black holes and their host galaxies across cosmic time. Every massive galaxy hosts a supermassive black hole in their centre whose properties show a remarkably strong correlation with that of their host galaxy. This strongly suggests that black holes evolve differently in different galaxies, but also that the galaxies are influenced by their black holes over time. My research probes both of these aspects of black holes in galaxies, with some projects more focused on the evolution of black holes itself, while others are more focused on how black holes influence their environment. In the last year, I have particularly extended my work to look at less massive black holes and their equally less massive host galaxies, and focused on advanced black hole physics such as black hole dynamics and black hole spin evolution.

Intermediate mass black holes

While supermassive black holes and their massive galaxies are well studied and comparatively well understood, until recently we had little evidence on whether there are black holes that are more massive than a few solar masses but less massive than about a million solar masses. With new observations of such objects now coming in, I have extended my research to study such lower but still massive black holes and their potential coevolution with their dwarf galaxy hosts. This year, I submitted a first-author paper on the subject, with two further publications in progress, and started a new collaboration with colleagues at the University of Surrey to extend this study to even lower masses.

The first supermassive black holes

One of the key scientific questions in astrophysics today is the origin of the first supermassive black holes. These objects are frequently seen in observations, but the rapid growth required to make these extreme objects challenges our understanding of how they could have come to be. For this fellowship, I am working on unravelling the mysteries surrounding these objects by running simulations of the very early Universe to understand when and how the first supermassive black holes began their evolution. This ambitious project has significantly advanced this year, with a publication on the subject in preparation.

Bridging the gap between simulations and observations

Simulations and observations are highly complementary tools to understanding the Universe: while observations can tell us how the Universe, and anything in it, really looks at a given point in time, simulations can show how individual objects evolve over long cosmic time periods. Comparing data from both approaches is key to building a holistic understanding of the Universe, but requires specific skills as the quantities that can be studied with observations are not easily accessible in simulations and vice versa. This year I collaborated with observational astronomer Dr. Becky Smethurst at the University of Oxford on a project that combined simulations with observations to understand if the evolution history of the host galaxy influences the observable properties of their central black holes.

Working with students & Teaching

Part III project

This year, I worked in conjunction with Dr. Vid Irsic and Dr. Anastasia Fialkov, and Part III student Adithya Nandakumar to see how the impact of an alternative dark matter model (so called axion dark matter) could influence the distribution of black hole spins we expect to observe. The project yielded interesting theoretical insights that we aim to extend using simulations next academic year.

Conferences talks & seminars

1. 2022/04 - “Computational galaxy formation” - invited conference talk
2. 2022/07 - "AGN feeding and feedback” - invited conference talk
3. 2022/09 - “Origin, growth and feedback of black holes in dwarf galaxies” - conference talk
4. 2022/10 - University of Edinburgh - invited colloquium
5. 2022/11 - University of St Andrews - invited colloquium
6. 2023/01 - Multi-messenger signals of early Universe black holes - invited conference talk
7. 2023/04 - RamsesUserMeeting2023 - contributed conference talk

Funding & Resources

One of the main requirements for my research is adequate access on supercomputers, which are obtained by applying for a certain number of usage hours to national computing centres during open calls. Proposals are commonly submitted by groups of researchers, led by a senior academic. In the last six months I contributed projects to both British and French resources on proposals lead by Prof Debora Sijacki in Cambridge and by Dr Yohan Dubois at the Institute d’Astrophysique de Paris. My contributions were awarded their resources on both proposals, so I am now well supplied with the resources I need to conduct my research. I have also submitted several grant applications to national and international funding bodies that will hopefully support my research in years to come. The evaluation process is ongoing.

Publications since April 2022

First author publications

1. **Beckmann, R. S.**, Dubois, Y., Pellissier, A., Olivares, V., Polles, F. L., Hahn, O., Guillard, P., & Lehnert, M. D. (2022), Cosmic rays and thermal instability in self-regulating cooling flows of massive galaxy clusters Astronomy and Astrophysics, 665, A129, 10.1051/0004-6361/202142527oi.
2. **Beckmann, R. S.**, Dubois, Y., Pellissier, A., Polles, F. L., & Olivares, V. (2022), AGN jets do not prevent the suppression of conduction by the heat buoyancy instability in simulated galaxy clusters Astronomy and Astrophysics, 666, A71, 10.1051/0004-6361/202243873oi.
3. **Beckmann, R. S.**, Dubois, Y., Volonteri, M., Dong-Páez, C. A., Trebitsch, M., Devriendt, J., Kaviraj, S., Kimm, T., & Peirani, S. (2022), Population statistics of intermediate mass black holes in dwarf galaxies using the NewHorizon simulation arXiv e-prints, arXiv:2211.13301, 10.48550/arXiv.2211.13301oi.
4. **Beckmann, R. S.**, Smethurst, R. J., Simmons, B. D., Coil, A., Dubois, Y., Garland, I. L., Lintott, C. J., Martin, G., Peirani, S., & Pichon, C. (2022), Supermassive black holes in merger-free galaxies have higher spins which are preferentially aligned with their host galaxy arXiv e-prints, arXiv:2211.13614, 10.48550/arXiv.2211.13614oi.

Publications lead by my students

1. Lescaudron, S., Dubois, Y., **Beckmann, R. S.**, & Volonteri, M. (2022), Dynamical friction of a massive black hole in a turbulent gaseous medium arXiv e-prints, arXiv:2209.13548, 10.48550/arXiv.2209.13548oi.
2. Massonneau, W., Dubois, Y., Volonteri, M., & **Beckmann, R. S.** (2023), How the super-Eddington regime affects black hole spin evolution in high-redshift galaxies Astronomy and Astrophysics, 669, A143, 10.1051/0004-6361/202244874oi.
3. Massonneau, W., Volonteri, M., Dubois, Y., & **Beckmann, R. S.** (2023), How the super-Eddington regime regulates black hole growth in high-redshift galaxies Astronomy and Astrophysics, 670, A180, 10.1051/0004-6361/202243170oi.
4. Jennings, F., **Beckmann, R. S.**, Sijacki, D., & Dubois, Y. (2023), Shattering and growth of cold clouds in galaxy clusters: the role of radiative cooling, magnetic fields, and thermal conduction Monthly Notices of the Royal Astronomical Society, 518, 5215, 10.1093/mnras/stac3426oi.
5. Dong-Páez, C. A., Volonteri, M., **Beckmann, R. S.**, Dubois, Y., Trebitsch, M., Mangiagli, A., Vergani, S., & Webb, N. (2023), Black hole mergers as tracers of spinning massive black hole

and galaxy populations in the Obelisk simulation arXiv e-prints, arXiv:2303.00766, 10.48550/arXiv.2303.00766oi.

6. Dong-Páez, C. A., Volonteri, M., **Beckmann, R. S.**, Dubois, Y., Mangiagli, A., Trebitsch, M., Vergani, S., & Webb, N. (2023), Multimessenger study of merging massive black holes in the Obelisk simulation: gravitational waves, electromagnetic counterparts, and their link to galaxy and black hole populations arXiv e-prints, arXiv:2303.09569, 10.48550/arXiv.2303.09569oi.

Collaborative publications

1. Volonteri, M., Pfister, H., **Beckmann, R.**, Dotti, M., Dubois, Y., Massonneau, W., Musoke, G., & Tremmel, M. (2022), Dual AGN in the Horizon-AGN simulation and their link to galaxy and massive black hole mergers, with an excursus on multiple AGN Monthly Notices of the Royal Astronomical Society, 514, 640, 10.1093/mnras/stac1217oi.
2. Olivares, V., Salomé, P., Hamer, S. L., Combes, F., Gaspari, M., Kolokythas, K., O'Sullivan, E., **Beckmann, R. S**., Babul, A., Polles, F. L., Lehnert, M., Loubser, S. I., Donahue, M., Gendron-Marsolais, M.-L., Lagos, P., Pineau des Forets, G., Godard, B., Rose, T., Tremblay, G., Ferland, G., & Guillard, P. (2022), Gas condensation in brightest group galaxies unveiled with MUSE. Morphology and kinematics of the ionized gas Astronomy and Astrophysics, 666, A94, 10.1051/0004-6361/202142475oi.
3. Smethurst, R. J., **Beckmann, R. S.**, Simmons, B. D., Coil, A., Devriendt, J., Dubois, Y., Garland, I. L., Lintott, C. J., Martin, G., & Peirani, S. (2022), Evidence for non-merger co-evolution of galaxies and their supermassive black holes arXiv e-prints, arXiv:2211.13677, 10.48550/arXiv.2211.13677oi.