Katja Fahrion

Title

How do nuclear star clusters form?

Abstract

Nuclear star clusters (NSCs) are extremely dense stellar systems that reside in the centres of ~70% of galaxies, including our Milky Way. This nucleation fraction even reaches > 90% for
galaxy masses ~ 10^9 M_sun. NSCs have similar sizes to globular clusters (GCs), but are even more massive and dense. NSCs often co-exist with supermassive black holes and follow distinct scaling relations with properties of the host galaxy, but it is still debated how NSCs form and grow. Generally, two main scenarios are discusse: in-situ from gas at the galactic centre or via the dissipationless accretion of GCs that spiral inwards due to dynamical friction. Most likely, a mixture of both pathways is realized in nature, but the dominant channel nor how it relates with the host galaxy are known.

Constraining NSC formation in galaxies requires a complete view of both the kinematics and chemical properties of the host galaxy, the NSC, and the GC system.
Such a study is challenging, but possible with modern day integral-field spectroscopy. I will present how MUSE can be used to determine the dominant NSC formation channel for individual galaxies, in conjunction with a semi-analytical model of NSC formation. These complementary approaches reveal for the first time how the NSC formation depends on properties of the host galaxy and show a transition of NSC formation via GC-inspiral to in-situ star formation with increasing NSC mass.

Katja Fahrion, M.Sc.

kfahrion@eso.org
@KatjaFah
http://eso.org/~kfahrion
http://www.linkedin.com/in/kfahrion

Education

2018 – 2021
- **Ph.D. in Astronomy, European Southern Observatory, Garching, Germany.**
  Thesis title: *The Build-up of Galactic Nuclei*.
  Supervisor: Mariya Lyubenova.
  Participation in the International Max-Planck Research School (IMPRS).
  Expected graduation: August 2021

2016 – 2018
- **M.Sc. Physics, Ruprecht-Karls University, Heidelberg, Germany.**
  Grade: 1.0 (A+)
  Thesis title: *Globular Cluster Systems and the Connection to Nuclear Star Cluster Formation* at the Max Planck Institute for Astronomy, Heidelberg.
  Supervisors: Glenn van de Ven, Mariya Lyubenova.

2012 – 2016
- **B.Sc. Physics, Ruprecht-Karls University, Heidelberg, Germany.**
  Grade: 1.4 (A)
  Thesis title: *Deciphering Star Formation at low Metallicity - New SOFIA Observations of the Dwarf Galaxy NGC4214* at the Institute of Theoretical Astrophysics.
  Supervisors: Diane Cormier, Frank Bigiel.

Experience

Research Internships

2017
- **ESO Research Internship**, European Southern Observatory. Three months internship as part of Master project.

2015
- **RISE Worldwide Project**, McGill University, Montreal, Canada. Three months internship under a DAAD RISE Worldwide stipend. "DHCAL Calibration Using Track Segments".

Observing experience and proposals

2019
- **Scientific assistant** at the ESO Observing Programmes Committee P105.
- **ESO observer at APEX telescope**, 14-night observing run at the APEX telescope in Chile. Functions included deciding on the observing schedule, carrying out the observations and basic data reduction with CLASS.

2017
- **PI of MUSE Science Verification programme 60.A-9192**. "Has the nucleus of FCC47 been feasting on globular clusters?".

Science management

2019 – · · ·
- **Student representative**, European Southern Observatory. Functions include welcoming new students, organising trainings, mediating between students and the Office for Science.
- **Organiser of weekly social events**, European Southern Observatory.

2019 – 2020
- **Member of the Student Selection Committee**, European Southern Observatory. Functions include the review of applications, participation in interviews and the selection of candidates.

Experience (continued)

Teaching

2017 • **Teaching assistant**, Ruprecht-Karls University Heidelberg.
"Introduction into Astronomy & Astrophysics II"

2016 – 2017 • **Teaching assistant**, Ruprecht-Karls University Heidelberg.
"Introduction into Astronomy & Astrophysics I"

2014 • **Teaching assistant**, Ruprecht-Karls University Heidelberg.
"Beginner's Lab Course"

Training and Courses

Schools

2019 • **Vienna Dynamics Workshop**, Institute for Astronomy, Vienna. One week workshop on dynamical modelling of galaxies with triaxial orbit-superposition models.

• **Third ASTERICS-OBELICS International School**, advanced software programming for astrophysics and astroparticle physics in Annecy, France. Included lectures on data analysis with Python (numpy, astropy, pandas, seaborn, matplotlib, scipy), machine learning (Keras, tensorflow).

Training

• **Communication skills**. Training session at European Southern Observatory.

2018 • **Avoiding & Challenging harassment**. Training session at European Southern Observatory.

Courses

2020 • **Physics of the Cosmic Microwave Background**. IMPRS advanced course.

• **Stellar populations**. IMPRS advanced course.

• **Galaxy Formation**. IMPRS advanced course.

• **Astrobiology**. IMPRS advanced course.

2019 • **Cosmic Structure Formation**. IMPRS advanced course.

• **Astrophysics of Black Holes**. IMPRS advanced course.

• **High Resolution Astrophysics**. IMPRS advanced course.

Talks and Posters

Conference Talks

2020 • **Origin, growth and feedback of black holes in dwarf galaxies**, virtual meeting by Donostia International Physics Center, San Sebastian.
"Nuclear star cluster formation in dwarf and massive galaxies"

• **Dynamical Reconstruction of Galaxies**, Lorentz Workshop, Leiden, Netherlands.
"Globular clusters as tracers of galaxy assembly"

2019 • **Multi-Spin Galaxies**, Asiago, Italy.
"Revealing the multi-spin nature of kinematically decoupled components with Schwarzschild orbit-based models"

2018 • **Milky Way Streams**, Heidelberg, Germany.
"Globular cluster systems and the connection to nuclear star cluster formation beyond the Milky Way"

Talks and Posters (continued)

Posters

2020 • **RAS Early Career Poster Exhibition**, online.
"Globular clusters as tracers of galaxy assembly".

2019 • **IAU Symposium 351/MODEST19**, Bologna, Italy.
"Constraining nuclear star cluster formation using MUSE-AO observations of the early-type galaxy FCC47". Proceeding: arXiv:1908.00774

Seminars

2020 • **Galaxy Coffee**, remotely, Max Planck Institute for Astronomy, Heidelberg, Germany.
"Globular clusters as tracers of galaxy properties and mass assembly".

• **Astro Lunch**, remotely, Strasbourg Observatory, France,
"Globular clusters as tracers of galaxy assembly".

• **Journal Club**, remotely, John Moores University, Liverpool, UK.
"Globular clusters as tracers of galaxy assembly".

• **Galaxy Coffee**, Max Planck Institute for Astronomy, Heidelberg, Germany.
"Nuclear star clusters in dwarfs and massive galaxies".

2019 • **Lecture**, Vienna Dynamics Workshop, Institute for Astronomy, Vienna, Austria.
"Unveiling the origin of kinematically decoupled components with Schwarzschild modelling".

• **Thirty Minutes Talk**, European Southern Observatory, Santiago de Chile.
"Constraining the formation of the large Nuclear Star Cluster of FCC47 with MUSE + AO"

• **Lunch Talk**, Institute for Astrophysics, Pontificia Universidad Catolica de Chile, Santiago de Chile.
"Constraining the formation of the large Nuclear Star Cluster of FCC47 with MUSE + AO"

2017 • **Lunch Talk**, European Southern Observatory, Garching, Germany.
"Globular cluster systems and the connection nuclear star cluster formation".

Skills

Coding • **Python:** Advanced (data analysis and visualisation)
IDL: Working knowledge, data analysis
C++: Basics

Data analysis • **Numerical methods:** numpy, scipy, emcee
Astronomy related: astropy, pPXF, MGE, imfit, iraf

Data visualisation • **Plotting:** matplotlib, seaborn
Type setting: LaTeX, MS Office
Graphic design: Inkscape, Gimp

Data reduction • MUSE & SINFONI esoreflex, ZAP, CLASS

Languages • **German:** Native speaker
English: Fluent (C1 DAAD language certificate)
French: Basic knowledge

Outreach

Dec. 2019 • **ESOBlog**, "Astronomer on tour – The story of a trip to Chile to observe with the APEX telescope" (available here).

2018 – · · · • **Tour guide**, ESO Supernova Visitor Centre. Weekly tours through the exhibition.

Sept. 2019 • **Public talk (in German)**, Researcher's night, ESO Supernova Visitor Centre.
Title: "Sternhaufen".

Ongoing collaborations

- Fornax3D - A magnitude-limited survey of galaxies within the virial radius of the Fornax Cluster (Website)
- Michael Hilker, European Southern Observatory, Germany - Star clusters, galaxy evolution
- Glenn van de Ven, University Vienna, Austria - Dynamical modelling, galaxy evolution
- Ryan Leaman, University Vienna, Austria - Semi-analytical modelling, galaxy evolution
- Oliver Müller, Strasbourg Observatory, France - Dwarf galaxies
- Marina Rejkuba, European Southern Observatory, Germany - Dwarf galaxies, stellar populations

References

Dr. Mariya Lyubenova
Faculty astronomer
European Southern Observatory,
Karl-Schwarzschild-Straße 2,
85748, Garching bei München, Germany
mlyubeno@eso.org

Prof. Glenn van de Ven
Chair of Theoretical Extragalactic Astrophysics,
Department of Astrophysics, University of Vienna,
Türkenschanzstrasse 17,
1180 Vienna, Austria
glenn.vandeven@univie.ac.at

Dr. Michael Hilker
Faculty astronomer,
European Southern Observatory,
Karl-Schwarzschild-Straße 2,
85748, Garching bei München, Germany
mhilker@eso.org

Publications

Submitted and in preparation

1. **Fahrion, K.**, R. Leaman, M. Lyubenova and G. van de Ven (2020). *Disentangling the formation mechanisms of nuclear star clusters in the local Universe*. submitted to A&A., (available here).
2. Poci, A., R. M. McDermid, M. Lyubenova, L. Zhu, G. van de Ven, E. Iodice, L. Coccato, E. M. Corsini, J. Falcón-Barroso, D. A. Gadotti, **Fahrion K.**, I. Martín-Navarro, F. Pinna, M. Sarzi, S. Viaene and P. T. de Zeeuw (2020). *The Fornax3D project: the Assembly Histories of Lenticular Galaxies from a Combined Dynamics and Population Orbital Analysis*. submitted to A&A.
3. **Fahrion, K.** and M. Lyubenova (in prep.). *Stellar population properties of nuclear star clusters and globular clusters*.

Refereed papers

1. Müller, O., M. S. Pawlowski, F. Lelli, **K. Fahrion**, M. Rejkuba, M. Hilker, J. Kanehisa, N. Libeskind and H. Jerjen (Dec. 2020). 'The coherent motion of Cen A dwarf satellite galaxies remains a challenge for ΛCDM cosmology'. In: *arXiv e-prints*, arXiv:2012.08138.
2. Müller, O., **K. Fahrion**, M. Rejkuba, M. Hilker, F. Lelli, K. Lutz, M. S. Pawlowski, L. Coccato, G. S. Anand and H. Jerjen (Nov. 2020). 'The properties of dwarf spheroidal galaxies in the Cen A group: Stellar populations, internal dynamics, and a heart-shaped Halpha ring'. In: *arXiv e-prints*, arXiv:2011.04990.
3. **Fahrion, K.**, M. Lyubenova, M. Hilker, G. van de Ven, J. Falcón-Barroso, R. Leaman, I. Martín-Navarro, A. Bittner, L. Coccato, E. M. Corsini, D. A. Gadotti, E. Iodice, R. M. McDermid, F. Pinna, M. Sarzi, S. Viaene, P. T. de Zeeuw and L. Zhu (May 2020). 'The Fornax 3D project: Non-linear colour-metallicity relation of globular clusters'. In: *A&A* 637, A27, A27.

4. **Fahrion, K.**, M. Lyubenova, M. Hilker, G. van de Ven, J. Falcón-Barroso, R. Leaman, I. Martín-Navarro, A. Bittner, L. Coccato, E. M. Corsini, D. A. Gadotti, E. Iodice, R. M. McDermid, F. Pinna, M. Sarzi, S. Viaene, P. T. de Zeeuw and L. Zhu (May 2020). 'The Fornax 3D project: Globular clusters tracing kinematics and metallicities'. In: *A&A* 637, A26, A26.

5. Leaman, R., T. Ruiz-Lara, A. A. Cole, M. A. Beasley, A. Boecker, **K. Fahrion**, P. Bianchini, J. Falcón-Barroso, J. Webb, A. Sills, A. Mastrobuono-Battisti, N. Neumayer and A. C. Sippel (Mar. 2020). 'Globular cluster ejection, infall, and the host dark matter halo of the Pegasus dwarf galaxy'. In: *MNRAS* 492.4.

6. **Fahrion, K.**, O. Müller, M. Rejkuba, M. Hilker, M. Lyubenova, G. van de Ven, I. Y. Georgiev, F. Lelli, M. S. Pawlowski and H. Jerjen (Feb. 2020). 'Metal-poor nuclear star clusters in two dwarf galaxies near Centaurus A suggesting formation from the in-spiraling of globular clusters'. In: *A&A* 634, A53, A53.

7. **Fahrion, K.**, M. Lyubenova, G. van de Ven, R. Leaman, M. Hilker, I. Martín-Navarro, L. Zhu, M. Alfaro-Cuello, L. Coccato, E. Corsini, J. Falcón-Barroso, E. Iodice, R. M. McDermid, M. Sarzi and T. de Zeeuw (Aug. 2019). 'Constraining nuclear star cluster formation using MUSE-AO observations of the early-type galaxy FCC 47'. In: *A&A* 628, A92, A92.

8. **Fahrion, K.**, I. Georgiev, M. Hilker, M. Lyubenova, G. van de Ven, M. Alfaro-Cuello, E. M. Corsini, M. Sarzi, R. M. McDermid and T. de Zeeuw (May 2019). 'Single metal-poor ultra compact dwarf galaxy at one kiloparsec distance from the low-mass elliptical galaxy FCC 47'. In: *A&A* 625, A50, A50.

9. Sarzi, M., E. Iodice, L. Coccato, E. M. Corsini, P. T. de Zeeuw, J. Falcón-Barroso, D. A. Gadotti, M. Lyubenova, R. M. McDermid, G. van de Ven, **Fahrion, K.**, A. Pizzella and L. Zhu (Aug. 2018). 'Fornax3D project: Overall goals, galaxy sample, MUSE data analysis, and initial results'. In: *A&A* 616, A121, A121.

10. **Fahrion, K.**, D. Cormier, F. Bigiel, S. Hony, N. P. Abel, P. Cigan, T. Csengeri, U. U. Graf, V. Lebouteiller, S. C. Madden, R. Wu and L. Young (Mar. 2017). 'Disentangling the ISM phases of the dwarf galaxy NGC 4214 using [C II] SOFIA/GREAT observations'. In: *A&A* 599, A9, A9.

Conference Proceedings

1. **Fahrion, K.**, M. Lyubenova, G. van de Ven and M. Hilker (Aug. 2019). 'Using MUSE-AO observations to constrain the formation of the large nuclear star cluster in FCC47'. In: arXiv:1908.00774.