Figure 1: An artist's rendition of a galaxy surrounded by stellar streams. Credit: James Josephides and S^5 Collaboration [**?**].

This thesis investigates stellar streams originating from globular clusters in the Milky Way. Stellar streams are long, thin structures composed of stars that have escaped a host stellar system, forming coherent tails that can span large regions of the sky. Globular clusters are dense gravitationally bound systems containing hundreds of thousands to millions of stars. They are one source of stellar streams. In Chapter 4, I present our study in which we simulated the expected distribution of stellar streams originating from the entire Milky Way globular cluster system. This study was the first of its kind. Stellar streams have high hopes for being inferential tools for inferreing the presence of dark matter sub halos within the Galaxy. These halos may perturb the stellar streams leaving "gaps" in their wake. In Chapter 5, we explored how the collective gravitational influence of all globular clusters can also perturb produce such gaps.

The structure of the thesis is as follows. The remainder of the introduction provides background on stellar streams, globular clusters, and their astrophysical context, as well as an overview of the current state of the field. Chapter 2 outlines the physical framework used to model stream formation and interpret their morphology. Chapter 3 describes the numerical methods employed in the simulations, including convergence tests and estimates of computational cost. Chapters 4 and 5 present two published studies, with the final chapter discussing these results in the broader context of the literature and highlighting future directions.

1   General context

Before explaining why Milky Way globular clusters and stellar streams are scientifically interesting, it is important to first set the scene. This thesis fits neatly within the field of galactic astronomy, which, at its core, studies the current state of our galaxy and the processes that shaped its formation within the broader context of the universe.

If we start this narrative from the beginning and place stellar streams and globular clusters in the timeline of cosmic history, their importance becomes clearer. The story begins best at the very start. The Lambda Cold Dark Matter (ΛCDM) cosmological model is currently the leading theory of the universe, successfully unifying a variety of observational evidence—from the Cosmic Microwave Background Radiation and the large-scale distribution of galaxies to the accelerating expansion of the universe [**??**].

Shortly after the Big Bang, conditions allowed protons, neutrons, and electrons to form and interact. For a few minutes, these particles collided and fused into heavier elements in a process known as Big Bang Nucleosynthesis [?]. When this phase ended, the universe's composition was mostly hydrogen, deuterium (^{2}H), helium-4 (^{4}He), and trace amounts of helium-3 (^{3}He) and lithium-7 (^{7}Li). By mass, hydrogen made up roughly 75%, and helium about 25% of the primordial universe [??].

Dark matter, which accounts for about five times more mass than ordinary matter, played a critical role in structure formation [?]. In the early universe, dark matter was distributed nearly uniformly but developed gravitational instabilities that caused it to collapse into a cosmic web of filaments and nodes. These massive nodes created deep gravitational wells that attracted ordinary matter [?]. The infalling gas subsequently cooled and formed stars. The resulting complex of stars, gas, and dark matter constitutes a galaxy [??].

Galaxies contain stars that are born, fuse hydrogen and helium into heavier elements, and eventually die, often as supernovae, enriching the interstellar medium with these heavier elements [?]. This process is a strong function of cosmic time as the chemical evolution of the universe becomes more metal rich. For example, the first generation of stars, known as Population III (Pop III) stars[1], formed in a very different environment, one devoid of metals [???].

The chemical composition of the gas is crucial since it influences the initial mass function (IMF) of stars. Stars formed from pristine, metal-free gas tend to have a top-heavy IMF, favoring the formation of massive stars [??]. In contrast, even small amounts of metals introduced into the gas can dramatically shift the IMF toward the formation of lighter stars [?].

Globular clusters are, to first approximation, single-stellar populations: their constituent stars formed from the same molecular cloud over a timescale shorter than the internal dynamical time [???]. Owing to their uniform chemical composition, stellar evolution within a cluster proceeds along the color-magnitude diagram as a function solely of initial mass [?]. This property enables precise age determinations from photometric observations, a method that historically provided the first robust lower limits on the age of the Universe [????]. With their low metallicities and advanced ages, globular clusters are dominated by Population II stars, indicating that they formed in environments enriched exclusively by the earliest generations of stars [?]. They thus constitute valuable fossil records of the initial phases of star formation and chemical evolution in the Universe.

Globular clusters are among the most ubiquitous stellar systems in the Universe [??]. They are found in virtually all galaxy types, from dwarfs to giant ellipticals, and their total number correlates with global properties of their host galaxies such as mass and luminosity [e.g., ??]. In the local Universe, we can directly observe the formation of massive bound stellar systems—so-called young massive star clusters—which may represent present-day analogs of the GC formation process [e.g., ??], though whether all such systems will evolve into globular clusters remains an open question.

Globular clusters serve as unique astrophysical laboratories, offering insights into stellar dynamics, stellar evolution, and galaxy assembly. Their evolution involves stellar structure and evolution, gravitational dynamics, and relativistic effects in dense environments. For instance, close stellar encounters and binary interactions—such as mass transfer or mergers—are common in such environments and significantly shape cluster evolution [???]. Additionally, globular clusters are suspected to be a pathway for forming intermediate-mass black holes [??]. The origin of IMBHs remains uncertain, as their masses are too large to be explained by isolated stellar evolution, yet too small to fall into the supermassive category [?].

Moreover, while traditionally considered as single stellar populations—homogeneous in age and chemical composition—decades of spectroscopic and photometric evidence have revealed the presence of multiple stellar populations in most GCs [???]. The origin of these multiple populations remains debated, with proposed explanations ranging from self-enrichment to accretion of external material, but no consensus has yet emerged.

A striking property of many GC systems is the bimodality in their metallicity distribution, with one population of metal-poor GCs and another of metal-rich GCs [e.g., ??]. This bimodality is now widely interpreted as evidence for multiple formation channels: metal-rich GCs likely formed in situ within the main progenitor galaxy during intense star-formation episodes, whereas metal-poor GCs were predominantly accreted from lower-mass satellites. The persistence of this bimodality across a wide range

---

[1]Stellar populations are named in reverse order of discovery. Population I stars are the youngest, metal-rich stars (including the Sun), Population II stars are older and metal-poor, and Population III stars are the very first, metal-free stars.

of galaxies suggests that hierarchical accretion has been a fundamental process shaping GC systems.

From the perspective of galaxy formation, the hierarchical model of structure growth posits that galaxies assemble through repeated mergers and accretion of smaller systems [**?**]. In this framework, GCs can form in situ within the main progenitor or be accreted from satellite galaxies [e.g., **?????**]. Consequently, the spatial distribution, kinematics, chemical abundances, and metallicity substructure of a galaxy's GC system retain valuable information about its merger history and assembly pathways. This makes GCs not only tracers of early star formation, but also fossil records of the build-up of their host galaxies.

? wrote a solid review about different globular cluster formation path ways and summarized some that work in predicting the currently observed number distirbution and statistics . . . **?** talks about cluster formation in the cosmological context with galactic assembly. **?** is one study that looked at how the presence of a dark matter subhalo could *influence* the observed kinematics of a cluster today.

Stellar streams — formed by stars gradually escaping from globular clusters due to tidal forces — are especially valuable. These streams preserve dynamical information about both their progenitor clusters and the gravitational potential of the host galaxy. The timing and properties of escaping stars can reveal the recent internal evolution of the cluster itself [**??**].

Moreover, as stellar streams trace arcs across the sky, they serve as natural probes of the Galactic gravitational field. Their coherent kinematics allow constraints on the mass distribution and substructure of the Milky Way [**??**]. This dual insight into cluster dynamics and galactic environment makes streams a uniquely powerful tool for modern galactic archaeology and dynamics.

2   The state of the art

? showed that streams can also be used to get at the accretion history of the Milky Way.

References

S. J. Aarseth, D. N. C. Lin, and J. C. B. Papaloizou. On the Collapse and Violent Relaxation of Protoglobular Clusters. ApJ, 324:288, January 1988. doi: 10.1086/165895.

Tom Abel, Greg L. Bryan, and Michael L. Norman. The Formation of the First Star in the Universe. *Science*, 295(5552):93–98, January 2002. doi: 10.1126/science.1063991.

Angela Adamo, Peter Zeidler, J. M. Diederik Kruijssen, Mélanie Chevance, Mark Gieles, Daniela Calzetti, Corinne Charbonnel, Hans Zinnecker, and Martin G. H. Krause. Star Clusters Near and Far; Tracing Star Formation Across Cosmic Time. Space Sci. Rev., 216(4):69, June 2020. doi: 10.1007/s11214-020-00690-x.

Manuel Arca Sedda, Albrecht W. H. Kamlah, Rainer Spurzem, Mirek Giersz, Peter Berczik, Sara Rastello, Giuliano Iorio, Michela Mapelli, Massimiliano Gatto, and Eva K. Grebel. The DRAGON-II simulations - I. Evolution of single and binary compact objects in star clusters with up to 1 million stars. MNRAS, 528(3):5119–5139, March 2024. doi: 10.1093/mnras/stad3952.

Nate Bastian and Carmela Lardo. Multiple Stellar Populations in Globular Clusters. ARA&A, 56:83–136, September 2018. doi: 10.1146/annurev-astro-081817-051839.

Vasily Belokurov and Andrey Kravtsov. In-situ versus accreted Milky Way globular clusters: a new classification method and implications for cluster formation. MNRAS, 528(2):3198–3216, February 2024. doi: 10.1093/mnras/stad3920.

Ana Bonaca, Rohan P. Naidu, Charlie Conroy, Nelson Caldwell, Phillip A. Cargile, Jiwon Jesse Han, Benjamin D. Johnson, J. M. Diederik Kruijssen, G. C. Myeong, Joshua S. Speagle, Yuan-Sen Ting, and Dennis Zaritsky. Orbital Clustering Identifies the Origins of Galactic Stellar Streams. ApJ, 909 (2):L26, March 2021. doi: 10.3847/2041-8213/abeaa9.

Philip G. Breen and Douglas C. Heggie. Dynamical evolution of black hole subsystems in idealized star clusters. MNRAS, 432(4):2779–2797, July 2013. doi: 10.1093/mnras/stt628.

Jean P. Brodie and Jay Strader. Extragalactic Globular Clusters and Galaxy Formation. ARA&A, 44 (1):193–267, September 2006. doi: 10.1146/annurev.astro.44.051905.092441.

Volker Bromm. Formation of the first stars. *Reports on Progress in Physics*, 76(11):112901, November 2013. doi: 10.1088/0034-4885/76/11/112901.

Sean M. Carroll. The Cosmological Constant. *Living Reviews in Relativity*, 4(1):1, December 2001. doi: 10.12942/lrr-2001-1.

Sunmyon Chon, Kazuyuki Omukai, and Raffaella Schneider. Transition of the initial mass function in the metal-poor environments. MNRAS, 508(3):4175–4192, December 2021. doi: 10.1093/mnras/stab2497.

Lia C. Corazza, Oswaldo D. Miranda, and Carlos A. Wuensche. Potential contributions of Pop III and intermediate-mass Pop II stars to cosmic chemical enrichment. A&A, 668:A191, December 2022. doi: 10.1051/0004-6361/202244334.

Richard H. Cyburt, Brian D. Fields, Keith A. Olive, and Tsung-Han Yeh. Big bang nucleosynthesis: Present status. *Reviews of Modern Physics*, 88(1):015004, January 2016. doi: 10.1103/RevModPhys. 88.015004.

Melvyn B. Davies, Giampaolo Piotto, and Francesca de Angeli. Blue straggler production in globular clusters. MNRAS, 349(1):129–134, March 2004. doi: 10.1111/j.1365-2966.2004.07474.x.

Annibale D'Ercole, Enrico Vesperini, Francesca D'Antona, Stephen L. W. McMillan, and Simone Recchi. Formation and dynamical evolution of multiple stellar generations in globular clusters. MNRAS, 391 (2):825–843, December 2008. doi: 10.1111/j.1365-2966.2008.13915.x.

M. Fellhauer, M. I. Wilkinson, and P. Kroupa. Merging time-scales of stellar subclumps in young star-forming regions. MNRAS, 397(2):954–962, August 2009. doi: 10.1111/j.1365-2966.2009.15009.x.

Duncan A. Forbes and Rhea-Silvia Remus. Metallicity gradients in the globular cluster systems of early-type galaxies: in situ and accreted components? MNRAS, 479(4):4760–4769, October 2018. doi: 10.1093/mnras/sty1767.

Duncan A. Forbes, Nate Bastian, Mark Gieles, Robert A. Crain, J. M. Diederik Kruijssen, Søren S. Larsen, Sylvia Ploeckinger, Oscar Agertz, Michele Trenti, Annette M. N. Ferguson, Joel Pfeffer, and Oleg Y. Gnedin. Globular cluster formation and evolution in the context of cosmological galaxy assembly: open questions. *Proceedings of the Royal Society of London Series A*, 474(2210):20170616, February 2018a. doi: 10.1098/rspa.2017.0616.

Duncan A. Forbes, Justin I. Read, Mark Gieles, and Michelle L. M. Collins. Extending the globular cluster system-halo mass relation to the lowest galaxy masses. MNRAS, 481(4):5592–5605, December 2018b. doi: 10.1093/mnras/sty2584.

Mirek Giersz, Nathan Leigh, Arkadiusz Hypki, Nora Lützgendorf, and Abbas Askar. MOCCA code for star cluster simulations - IV. A new scenario for intermediate mass black hole formation in globular clusters. MNRAS, 454(3):3150–3165, December 2015. doi: 10.1093/mnras/stv2162.

Simon Glover. The Formation Of The First Stars In The Universe. Space Sci. Rev., 117(3-4):445–508, April 2005. doi: 10.1007/s11214-005-5821-y.

R. G. Gratton. Deep photometry of globular clusters. V. Age derivations and their implications for galactic evolution. A&A, 147:169–177, June 1985.

Raffaele G. Gratton, Eugenio Carretta, and Angela Bragaglia. Multiple populations in globular clusters. Lessons learned from the Milky Way globular clusters. A&A Rev., 20:50, February 2012. doi: 10.1007/ s00159-012-0050-3.

Jenny E. Greene, Jay Strader, and Luis C. Ho. Intermediate-Mass Black Holes. ARA&A, 58:257–312, August 2020. doi: 10.1146/annurev-astro-032620-021835.

Carl J. Grillmair, K. C. Freeman, M. Irwin, and P. J. Quinn. Globular Clusters with Tidal Tails: Deep Two-Color Star Counts. AJ, 109:2553, June 1995. doi: 10.1086/117470.

William E. Harris, Gretchen L. H. Harris, and Matthew Alessi. A Catalog of Globular Cluster Systems: What Determines the Size of a Galaxy's Globular Cluster Population? ApJ, 772(2):82, August 2013. doi: 10.1088/0004-637X/772/2/82.

William E. Harris, Gretchen L. Harris, and Michael J. Hudson. Dark Matter Halos in Galaxies and Globular Cluster Populations. II. Metallicity and Morphology. ApJ, 806(1):36, June 2015. doi: 10.1088/0004-637X/806/1/36.

F. Hoyle. The ages of Type I and Type II subgiants. MNRAS, 119:124, January 1959. doi: 10.1093/mnras/119.2.124.

Rudolf Kippenhahn, Alfred Weigert, and Achim Weiss. *Stellar Structure and Evolution*. 2013. doi: 10.1007/978-3-642-30304-3.

J. M. Diederik Kruijssen. The Formation of Globular Clusters. *arXiv e-prints*, art. arXiv:2501.16438, January 2025. doi: 10.48550/arXiv.2501.16438.

J. M. Diederik Kruijssen, Joel L. Pfeffer, Mélanie Chevance, Ana Bonaca, Sebastian Trujillo-Gomez, Nate Bastian, Marta Reina-Campos, Robert A. Crain, and Meghan E. Hughes. Kraken reveals itself - the merger history of the Milky Way reconstructed with the E-MOSAICS simulations. MNRAS, 498(2): 2472–2491, October 2020. doi: 10.1093/mnras/staa2452.

Mark R. Krumholz. The big problems in star formation: The star formation rate, stellar clustering, and the initial mass function. Phys. Rep., 539:49–134, June 2014. doi: 10.1016/j.physrep.2014.02.001.

Mark R. Krumholz, Christopher F. McKee, and Joss Bland-Hawthorn. Star Clusters Across Cosmic Time. ARA&A, 57:227–303, August 2019. doi: 10.1146/annurev-astro-091918-104430.

T. S. Li, S. E. Koposov, D. B. Zucker, G. F. Lewis, K. Kuehn, J. D. Simpson, A. P. Ji, N. Shipp, Y. Y. Mao, M. Geha, A. B. Pace, A. D. Mackey, S. Allam, D. L. Tucker, G. S. Da Costa, D. Erkal, J. D. Simon, J. R. Mould, S. L. Martell, Z. Wan, G. M. De Silva, K. Bechtol, E. Balbinot, V. Belokurov, J. Bland-Hawthorn, A. R. Casey, L. Cullinane, A. Drlica-Wagner, S. Sharma, A. K. Vivas, R. H. Wechsler, B. Yanny, and S5 Collaboration. The southern stellar stream spectroscopic survey (S^5): Overview, target selection, data reduction, validation, and early science. MNRAS, 490(3):3508–3531, December 2019. doi: 10.1093/mnras/stz2731.

R. Maiolino and F. Mannucci. De re metallica: the cosmic chemical evolution of galaxies. A&A Rev., 27 (1):3, February 2019. doi: 10.1007/s00159-018-0112-2.

Houjun Mo, Frank C. van den Bosch, and Simon White. *Galaxy Formation and Evolution*. 2010. doi: 10.1017/CBO9780511807244.

Stephen D. Murray and Douglas N. C. Lin. Globular Cluster Formation: The Fossil Record. ApJ, 400: 265, November 1992. doi: 10.1086/171993.

Jacob Nibauer, Ana Bonaca, and Kathryn V. Johnston. Constraining the Gravitational Potential from the Projected Morphology of Extragalactic Tidal Streams. ApJ, 954(2):195, September 2023. doi: 10.3847/1538-4357/ace9bc.

G. Pagnini, P. Di Matteo, S. Khoperskov, A. Mastrobuono-Battisti, M. Haywood, F. Renaud, and F. Combes. The distribution of globular clusters in kinematic spaces does not trace the accretion history of the host galaxy. A&A, 673:A86, May 2023. doi: 10.1051/0004-6361/202245128.

G. Pagnini, P. Di Matteo, M. Haywood, A. Mastrobuono-Battisti, F. Renaud, M. Mondelin, O. Agertz, P. Bianchini, L. Casamiquela, S. Khoperskov, and N. Ryde. Abundance ties: Nephele and the globular cluster population accreted with ω Cen: Based on APOGEE DR17 and Gaia EDR3. A&A, 693:A155, January 2025. doi: 10.1051/0004-6361/202450264.

P. J. E. Peebles. Primordial Helium Abundance and the Primordial Fireball. II. ApJ, 146:542, November 1966. doi: 10.1086/148918.

L. Perivolaropoulos and F. Skara. Challenges for ΛCDM: An update. New A Rev., 95:101659, December 2022. doi: 10.1016/j.newar.2022.101659.

Planck Collaboration, N. Aghanim, Y. Akrami, M. Ashdown, J. Aumont, C. Baccigalupi, M. Ballardini, A. J. Banday, R. B. Barreiro, N. Bartolo, S. Basak, R. Battye, K. Benabed, J. P. Bernard, M. Bersanelli, P. Bielewicz, J. J. Bock, J. R. Bond, J. Borrill, F. R. Bouchet, F. Boulanger, M. Bucher, C. Burigana, R. C. Butler, E. Calabrese, J. F. Cardoso, J. Carron, A. Challinor, H. C. Chiang, J. Chluba, L. P. L. Colombo, C. Combet, D. Contreras, B. P. Crill, F. Cuttaia, P. de Bernardis, G. de Zotti, J. Delabrouille, J. M. Delouis, E. Di Valentino, J. M. Diego, O. Doré, M. Douspis, A. Ducout, X. Dupac, S. Dusini, G. Efstathiou, F. Elsner, T. A. Enßlin, H. K. Eriksen, Y. Fantaye, M. Farhang, J. Fergusson, R. Fernandez-Cobos, F. Finelli, F. Forastieri, M. Frailis, A. A. Fraisse, E. Franceschi, A. Frolov, S. Galeotta, S. Galli, K. Ganga, R. T. Génova-Santos, M. Gerbino, T. Ghosh, J. González-Nuevo, K. M. Górski, S. Gratton, A. Gruppuso, J. E. Gudmundsson, J. Hamann, W. Handley, F. K. Hansen, D. Herranz, S. R. Hildebrandt, E. Hivon, Z. Huang, A. H. Jaffe, W. C. Jones, A. Karakci, E. Keihänen, R. Keskitalo, K. Kiiveri, J. Kim, T. S. Kisner, L. Knox, N. Krachmalnicoff, M. Kunz, H. Kurki-Suonio, G. Lagache, J. M. Lamarre, A. Lasenby, M. Lattanzi, C. R. Lawrence, M. Le Jeune, P. Lemos, J. Lesgourgues, F. Levrier, A. Lewis, M. Liguori, P. B. Lilje, M. Lilley, V. Lindholm, M. López-Caniego, P. M. Lubin, Y. Z. Ma, J. F. Macías-Pérez, G. Maggio, D. Maino, N. Mandolesi, A. Mangilli, A. Marcos-Caballero, M. Maris, P. G. Martin, M. Martinelli, E. Martínez-González, S. Matarrese, N. Mauri, J. D. McEwen, P. R. Meinhold, A. Melchiorri, A. Mennella, M. Migliaccio, M. Millea, S. Mitra, M. A. Miville-Deschênes, D. Molinari, L. Montier, G. Morgante, A. Moss, P. Natoli, H. U. Nørgaard-Nielsen, L. Pagano, D. Paoletti, B. Partridge, G. Patanchon, H. V. Peiris, F. Perrotta, V. Pettorino, F. Piacentini, L. Polastri, G. Polenta, J. L. Puget, J. P. Rachen, M. Reinecke, M. Remazeilles, A. Renzi, G. Rocha, C. Rosset, G. Roudier, J. A. Rubiño-Martín, B. Ruiz-Granados, L. Salvati, M. Sandri, M. Savelainen, D. Scott, E. P. S. Shellard, C. Sirignano, G. Sirri, L. D. Spencer, R. Sunyaev, A. S. Suur-Uski, J. A. Tauber, D. Tavagnacco, M. Tenti, L. Toffolatti, M. Tomasi, T. Trombetti, L. Valenziano, J. Valiviita, B. Van Tent, L. Vibert, P. Vielva, F. Villa, N. Vittorio, B. D. Wandelt, I. K. Wehus, M. White, S. D. M. White, A. Zacchei, and A. Zonca. Planck 2018 results. VI. Cosmological parameters. A&A, 641:A6, September 2020. doi: 10.1051/0004-6361/201833910.

M. Plionis, O. López-Cruz, and D. Hughes. *A Pan-Chromatic View of Clusters of Galaxies and the Large-Scale Structure*, volume 740. 2008. doi: 10.1007/978-1-4020-6941-3.

Simon F. Portegies Zwart, Stephen L. W. McMillan, and Mark Gieles. Young Massive Star Clusters. ARA&A, 48:431–493, September 2010. doi: 10.1146/annurev-astro-081309-130834.

William H. Press and Paul Schechter. Formation of Galaxies and Clusters of Galaxies by Self-Similar Gravitational Condensation. ApJ, 187:425–438, February 1974. doi: 10.1086/152650.

A. Sandage. Main-sequence photometry, color-magnitude diagrams, and ages for the globular clusters M3, M13, M15 and M92. ApJ, 162:841, December 1970. doi: 10.1086/150715.

R. Schneider, A. Ferrara, P. Natarajan, and K. Omukai. First Stars, Very Massive Black Holes, and Metals. ApJ, 571(1):30–39, May 2002. doi: 10.1086/339917.

Raffaella Schneider, Ruben Salvaterra, Andrea Ferrara, and Benedetta Ciardi. Constraints on the initial mass function of the first stars. MNRAS, 369(2):825–834, June 2006. doi: 10.1111/j.1365-2966.2006.10331.x.

Rachel S. Somerville and Romeel Davé. Physical Models of Galaxy Formation in a Cosmological Framework. ARA&A, 53:51–113, August 2015. doi: 10.1146/annurev-astro-082812-140951.

Gary Steigman. Primordial Nucleosynthesis in the Precision Cosmology Era. *Annual Review of Nuclear and Particle Science*, 57(1):463–491, November 2007. doi: 10.1146/annurev.nucl.56.080805.140437.

Alar Toomre and Juri Toomre. Galactic Bridges and Tails. ApJ, 178:623–666, December 1972. doi: 10.1086/151823.

A. Varghese, R. Ibata, and G. F. Lewis. Stellar streams as probes of dark halo mass and morphology: a Bayesian reconstruction. MNRAS, 417(1):198–215, October 2011. doi: 10.1111/j.1365-2966.2011.19097.x.

Eduardo Vitral and Pierre Boldrini. Properties of globular clusters formed in dark matter mini-halos. A&A, 667:A112, November 2022. doi: 10.1051/0004-6361/202244530.

Long Wang, Rainer Spurzem, Sverre Aarseth, Mirek Giersz, Abbas Askar, Peter Berczik, Thorsten Naab, Riko Schadow, and M. B. N. Kouwenhoven. The DRAGON simulations: globular cluster evolution with a million stars. MNRAS, 458(2):1450–1465, May 2016. doi: 10.1093/mnras/stw274.