

$$F_A = F\{c_1, c_2\} := \bigcup_{w \in \{c_1, c_2\}^\infty} \phi(w)$$

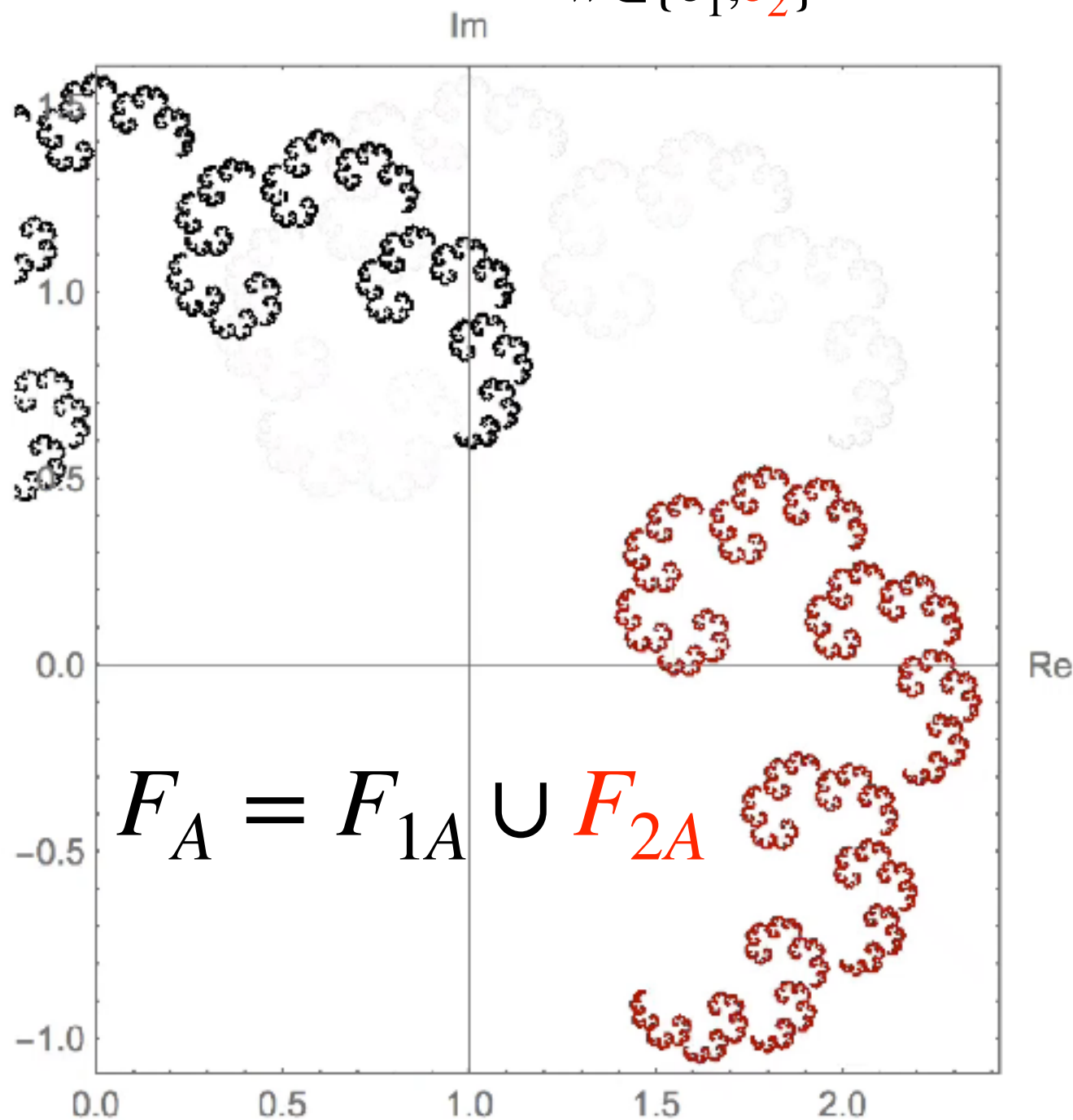
$$\{c_1, c_2\} = \{.3 + i.6, .5 - i.3\}$$

$$F_A = f_1(F_A) \cup f_2(F_A)$$

First-level pieces

$$F_{1A} := f_1(F_A) = 1 + c_1 \cdot F_A$$

$$F_{2A} := f_2(F_A) = 1 + c_2 \cdot F_A$$



$$r_2 = |c_2| \approx 0.58$$

$$\theta_2 = \arg(c_2) \approx -31^\circ$$

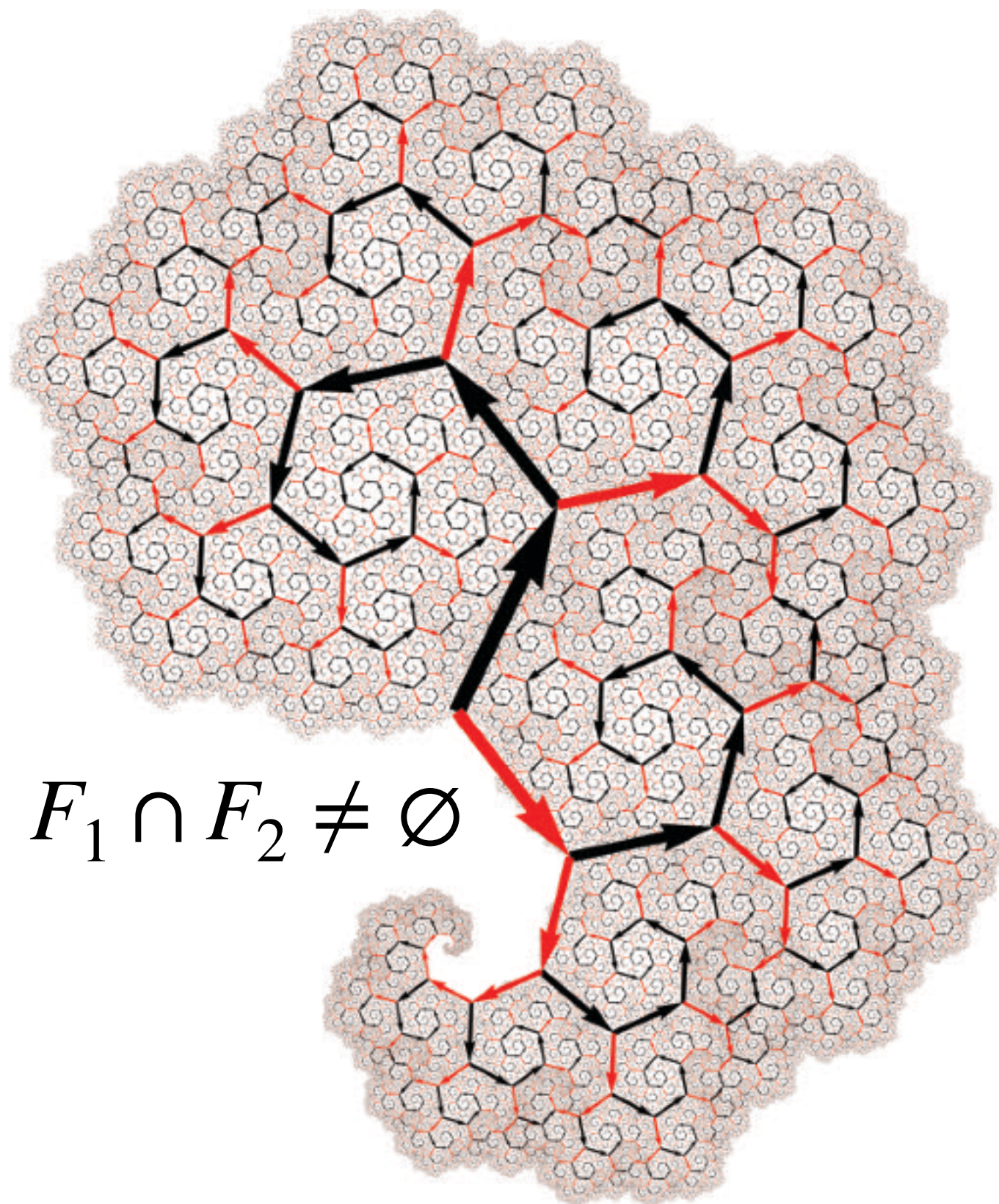
$$r_1 = |c_1| \approx 0.67$$

$$\theta_1 = \arg(c_1) \approx 63^\circ$$

The tipset is a self-similar set

$$F_{1A} \cap F_{2A} = \emptyset$$

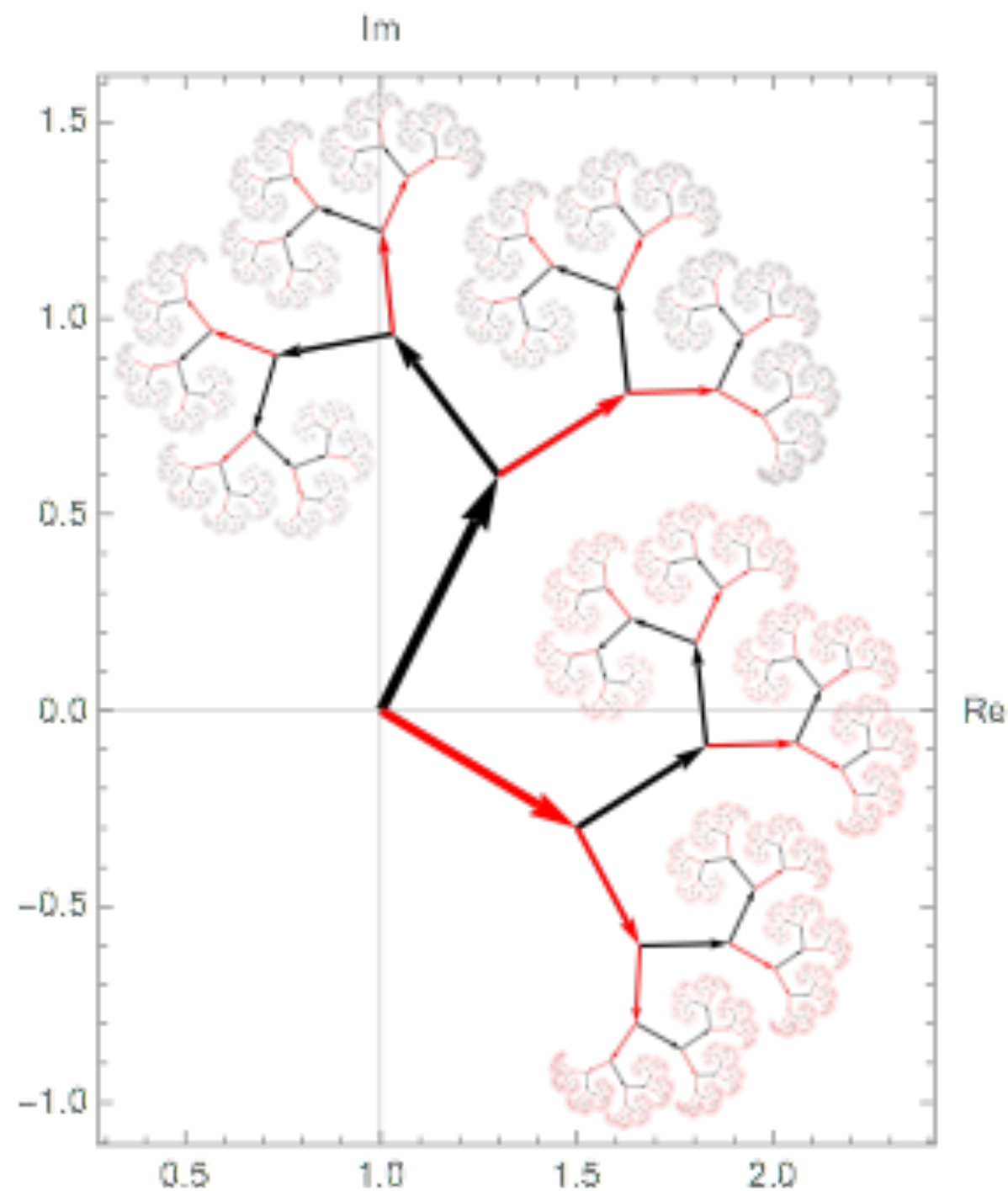
$$F_1 \cap F_2 = \emptyset$$



$$F_1 \cap F_2 \neq \emptyset$$

tipset connected

$$T\{0.352 + i0.720, 0.395 - i0.507\}$$



tipset disconnected

$$T\{0.3 + i0.6, 0.5 - i0.3\}$$

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References

- [1] Christoph Bandt. Geometry of self-similar sets. In *Fractals, Wavelets, and their Applications*, pages 21–36. Springer, 2014.
- [2] John E Hutchinson. Fractals and self similarity. *Indiana University Mathematics Journal*, 30(5):713–747, 1981.
- [3] Bernat Espigule. Families of complex trees related to the Sierpiński triangle and its reverse. *In Preparation*, 2019.
- [4] Jun Kigami. *Analysis on fractals*, volume 143. Cambridge University Press, 2001.
- [5] Gerald Edgar. *Measure, topology, and fractal geometry*. Springer, 2007.
- [6] Thierry Bousch. *Sur quelques problèmes de dynamique holomorphe*. PhD thesis, Orsay, 1992.
- [7] Christoph Bandt and Siegfried Graf. Self-similar sets 7. A characterization of self-similar fractals with positive Hausdorff measure. *Proceedings of the American Mathematical Society*, pages 995–1001, 1992.
- [8] William Thurston. Entropy in dimension one. *arXiv preprint arXiv:1402.2008*, 2014.

- [9] Araceli Bonifant, Misha Lyubich, and Scott Sutherland. *Frontiers in Complex Dynamics: In Celebration of John Milnor's 80th Birthday*. Princeton University Press, 2014.
- [10] Thierry Bousch. Connexité locale et par chemins holderiens pour les systemes itérés de fonctions. *preprint*, 1993.
- [11] Giulio Tiozzo. Continuity of core entropy of quadratic polynomials. *Inventiones mathematicae*, 203(3):891–921, 2016.
- [12] Harrison Bray, Diana Davis, Kathryn Lindsey, and Chenxi Wu. The shape of thurston's master teapot. *arXiv preprint arXiv:1902.10805*, 2019.
- [13] Danny Calegari, Sarah Koch, and Alden Walker. Roots, Schottky semigroups, and a proof of Bandt's conjecture. *Ergodic Theory and Dynamical Systems*, pages 1–69, 2016.
- [14] Michael F Barnsley and Andrew N Harrington. A Mandelbrot set for pairs of linear maps. *Physica D: Nonlinear Phenomena*, 15(3):421–432, 1985.
- [15] John Baez. The beauty of roots. *Available at: ucr.edu/baez/roots*, 2009.
- [16] Christoph Bandt. On the Mandelbrot set for pairs of linear maps. *Nonlinearity*, 15(4):1127, 2002.
- [17] Boris Solomyak and Hui Xu. On the Mandelbrot set for a pair of linear maps and complex Bernoulli convolutions. *Nonlinearity*, 16(5):1733, 2003.
- [18] MF Barnsley and DP Hardin. A Mandelbrot set whose boundary is piecewise smooth. *Transactions of the American Mathematical Society*, pages 641–659, 1989.
- [19] Stephen Wolfram. Implications for Everyday Systems *A New Kind of Science*. Wolfram Media Champaign, 2002. <http://www.wolframscience.com/nks/notes-8-6-parameter-space-sets/>
- [20] Benoît B Mandelbrot and Michael Frame. The canopy and shortest path in a self-contacting fractal tree. *The Mathematical Intelligencer*, 21(2):18–27, 1999.
- [21] Tara D Taylor. *Computational topology and fractal trees*. PhD thesis, Dalhousie University, 2005.
- [22] Tara D Taylor. Homeomorphism classes of self-contacting symmetric binary fractal trees. *Fractals*, 15(01):9–25, 2007.
- [23] Tara D Taylor. Topological bar-codes of fractals: a new characterization of symmetric binary fractal trees. *Banach Center Publications*, 84:181–216, 2009.
- [24] Tara D Taylor. A new classification of non-overlapping symmetric binary fractal trees using epsilon hulls. *Fractals*, 17(03):365–384, 2009.
- [25] Thibaut Deheuvels. Sobolev extension property for tree-shaped domains with self-contacting fractal boundary. *Annali della Scuola Normale Superiore di Pisa, Classe di Scienze*, 15(special):209–247, 2016.
- [26] Dušan Pagon. Self-similar planar fractals based on branching trees and bushes. *Progress of Theoretical Physics Supplement*, 150:176–187, 2003.
- [27] Bernat Espigule. Generalized self-contacting symmetric fractal trees. *Journal Symmetry*, 24(1–4):320–338, 2013.
- [28] Christoph Bandt and Nguyen Viet Hung. Fractal n-gons and their Mandelbrot sets. *Nonlinearity*, 21(11):2653, 2008.
- [29] Yutaro Himeki and Yutaka Ishii. M4 is regular-closed. *Ergodic Theory and Dynamical Systems*, pages 1–8, 2018.
- [30] Danny Calegari and Alden Walker. Extreme points in limit sets. *arXiv preprint arXiv:1811.07063*, 2018.
- [31] Víctor F Sirvent and Jörg M Thuswaldner. On the Fibonacci–Mandelbrot set. *Indagationes Mathematicae*, 26(1):174–190, 2015.
- [32] Bernat Espigule. A family of fern-like ternary complex trees. In *Proceedings of Bridges 2019: Mathematics, Music, Art, Architecture, Culture*. George Hart and Craig Kaplan, 2019.
- [33] Rüdiger Zeller. *Branching Dynamical Systems and Slices through Fractals*. PhD thesis, Greifswald University, 2015.
- [34] Christoph Bandt and Teklehaimanot Retta. Topological spaces admitting a unique fractal structure. *Fund. Math*, 141(3):257–268, 1992.
- [35] Casey Ryall Donovan. *Fractal, group theoretic, and relational structures on Cantor space*. PhD thesis, University of St Andrews, 2016.
- [36] Christoph Bandt, Nguyen Hung, and Hui Rao. On the open set condition for self-similar fractals. *Proceedings of the American Mathematical Society*, 134(5):1369–1374, 2006.
- [37] Kenneth Falconer. *Fractal geometry: mathematical foundations and applications*. John Wiley & Sons, 2004.
- [38] József Vass. *On the Geometry of IFS Fractals and its Applications*. PhD thesis, University of Waterloo, 2013.
- [39] József Vass. On the exact convex hull of ifs fractals. *Fractals*, 26(01):1850002, 2018.
- [40] RM Frongillo, E Lock, and DA Brown. Symmetric fractal trees in three dimensions. *Chaos, Solitons & Fractals*, 32(2):284–295, 2007.
- [41] Christoph Bandt, Mai The Duy, and Mathias Mesiing. Three-dimensional fractals. *The Mathematical Intelligencer*, 32(3):12–18, 2010.
- [42] Bernat Espigule. Generalized self-contacting symmetric trees in 3D. *Wolfram Science Summer School*, 2013.
- [43] Christoph Bandt and Karsten Keller. Self-similar sets 2. A simple approach to the topological structure of fractals. *Mathematische Nachrichten*, 154(1):27–39, 1991.
- [44] Kemal Ilgar Eroğlu, Steffen Rohde, and Boris Solomyak. Quasisymmetric conjugacy between quadratic dynamics and iterated function systems. *Ergodic Theory and Dynamical Systems*, 30(6):1665–1684, 2010.
- [45] Atsushi Kameyama. Julia sets of postcritically finite rational maps and topological self-similar sets. *Nonlinearity*, 13(1):165, 2000.
- [46] Michel L Lapidus and Machiel Van Frankenhuysen. *Fractal geometry, complex dimensions and zeta functions: geometry and spectra of fractal strings*. Springer Science & Business Media, 2012.
- [47] Valentina Benedetti, Valerio Brizi, Patrizia Guida, Susanna Tomasoni, Osele Ciampi, Elena Angeli, Ugo Valbusa, Ariela Benigni, Giuseppe Remuzzi, and Christodoulos Xinaris. Engineered kidney tubules for modeling patient-specific diseases and drug discovery. *EBioMedicine*, 2018.
- [48] Holly Dale. *An Exploration of the Emergence of Pattern and Form from Constraints on Growth*. PhD thesis, University of Calgary, 2014.

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