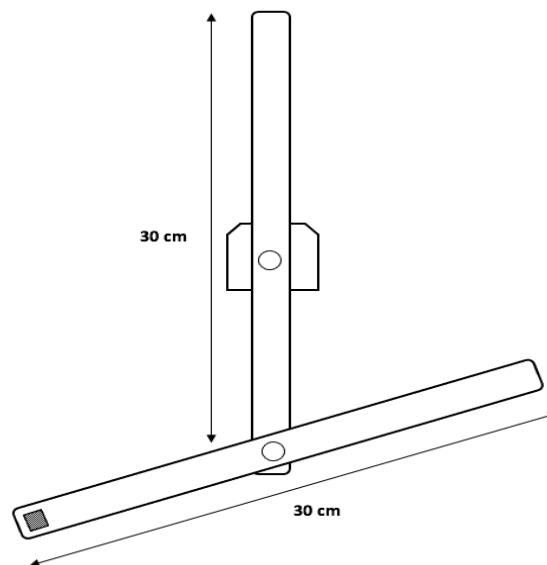


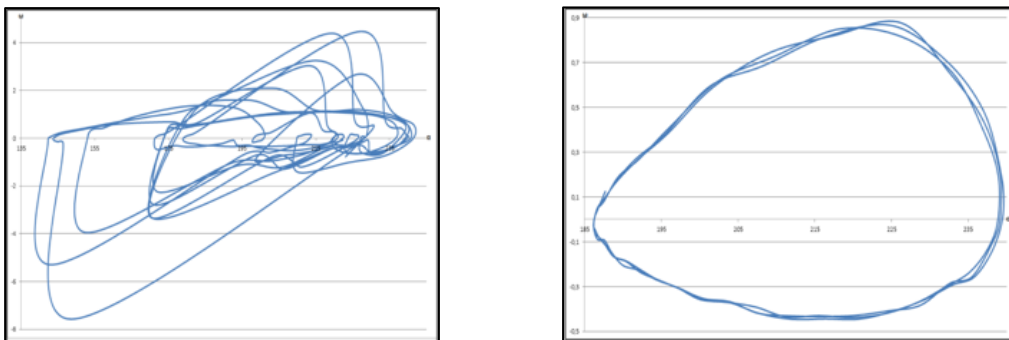
## Acknowledgements

I would like to thank the supervisors of Schülerforschungszentrum Nordhessen (SFN) for their help in providing the necessary equipment, mathematic literature on chaos physics and computer-technical help in creating the research simulation.

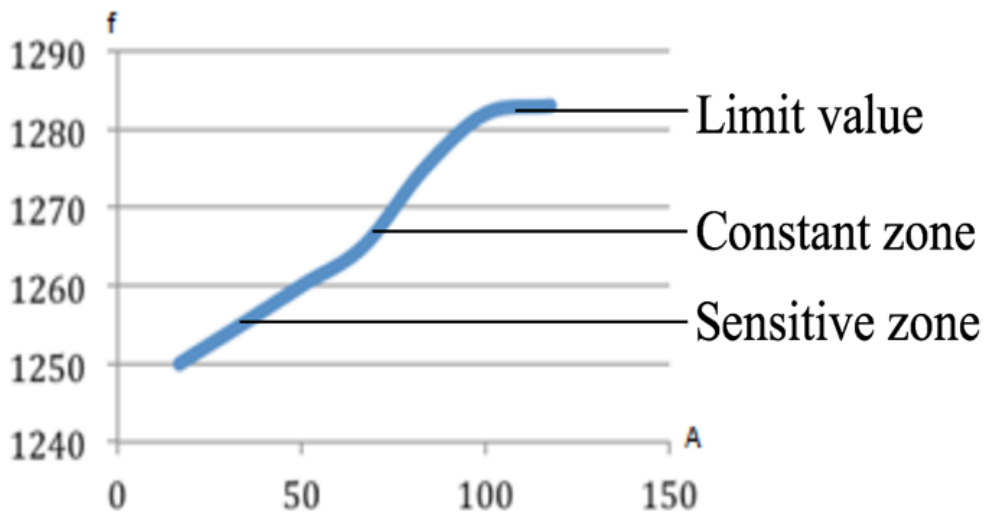
## Supplementary Material



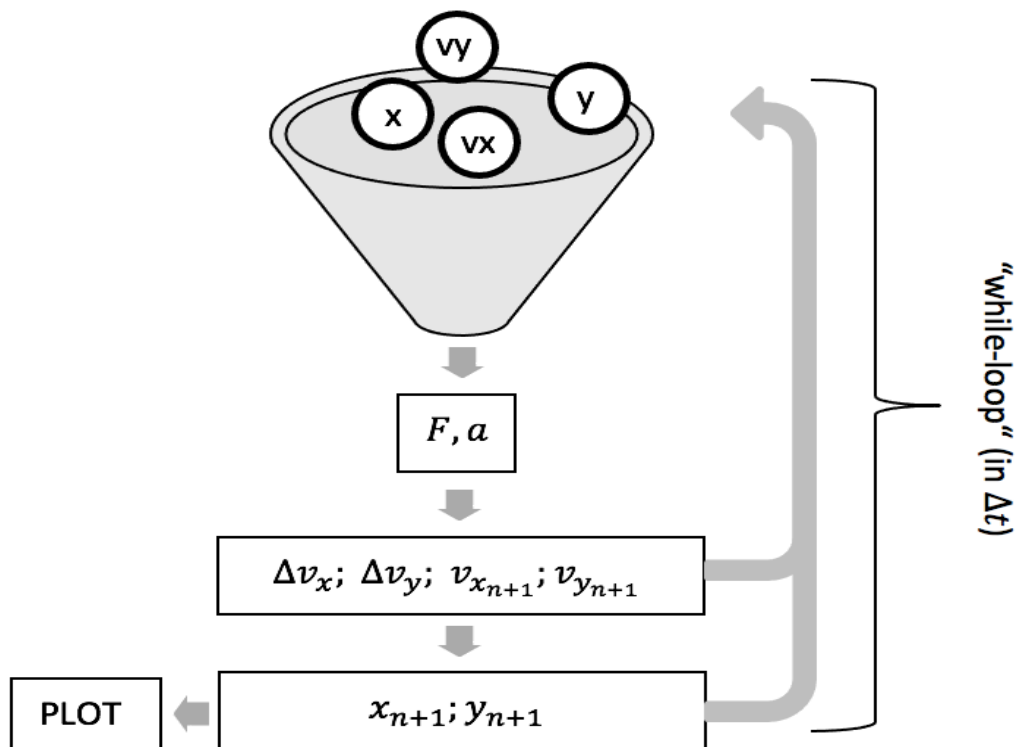
**FIGURE 1:** Chaos Pendulum Scheme



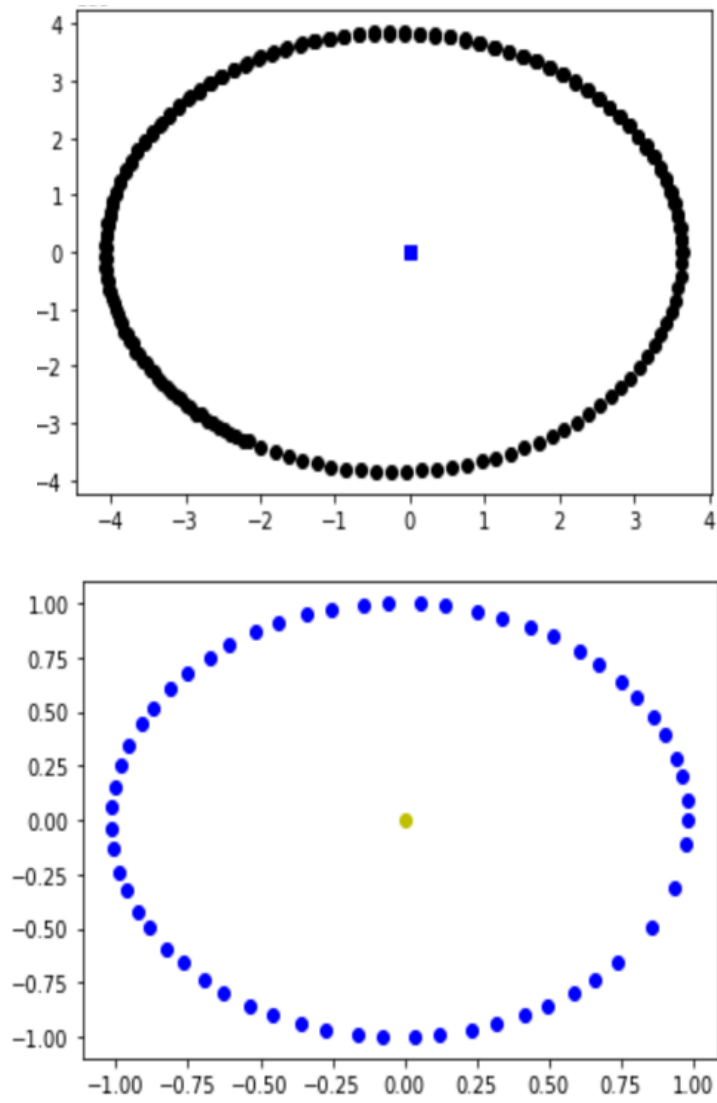
**FIGURE 2:** First (l.) and last (r.) 100 measuring points plotted in phase space



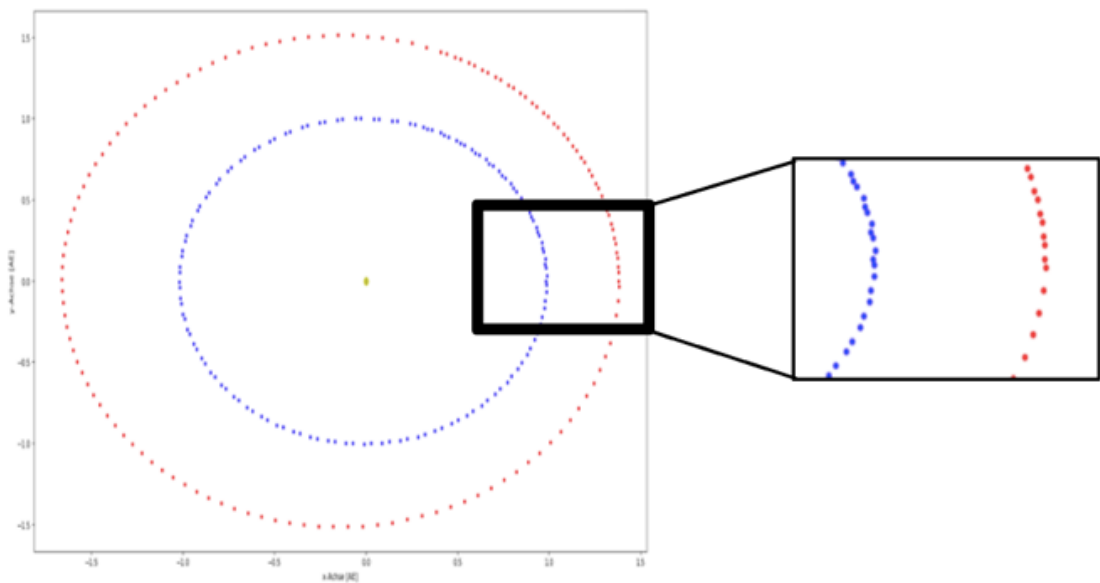
**FIGURE 3:** The CEF plotted against the calculated damping factor



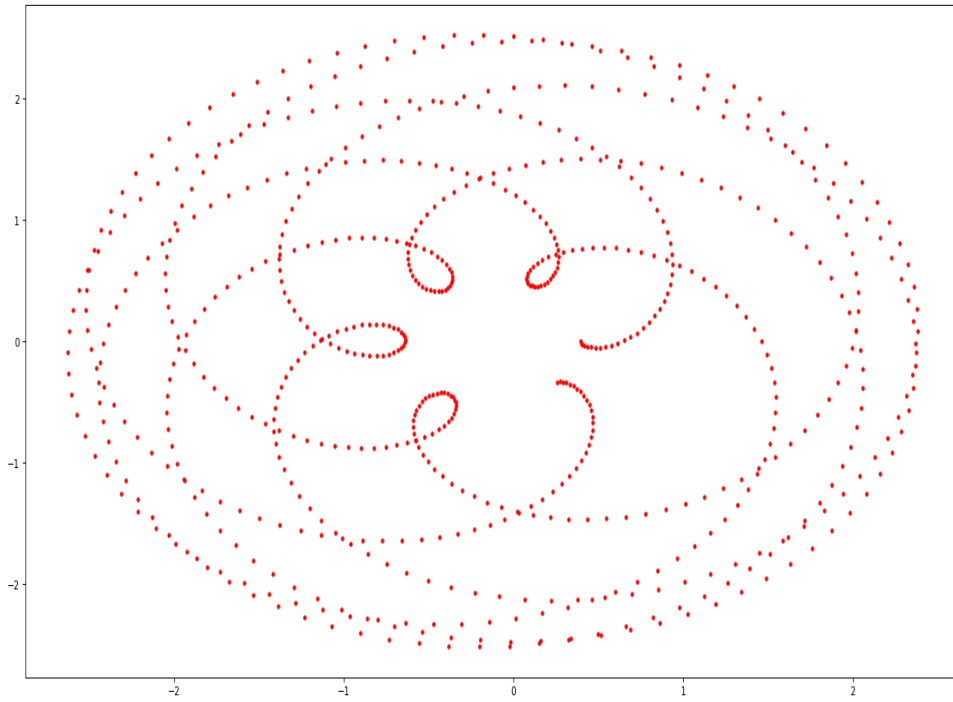
**FIGURE 4:** Scheme of my Program



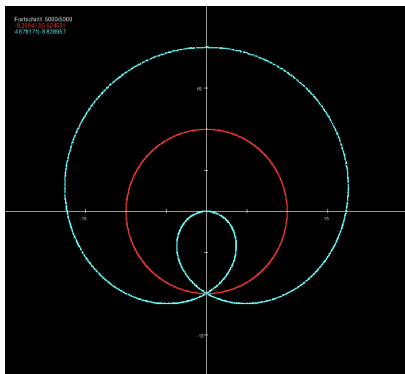
**FIGURE 5:** Two-body problems Earth-Moon and Sun-Earth



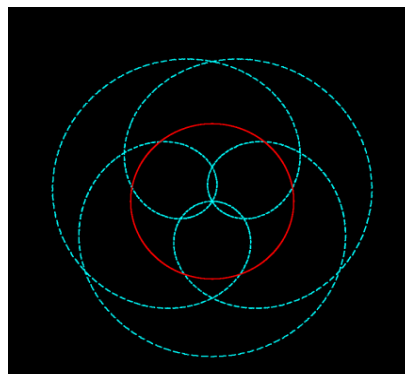
**FIGURE 6:** Non-linear three-body problem Sun-Earth-Mars



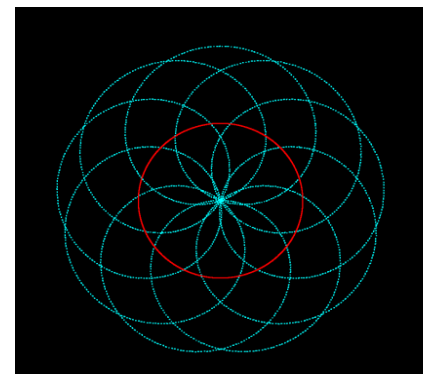
**FIGURE 7:** Movement of Mars in a non-linear three-body problem Sun-Earth-Mars with coordinate's origin on the position of Earth



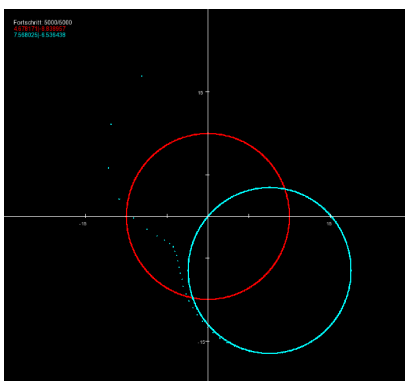
**FIGURE 8:** Coupled circular motions with  $\frac{f_2}{f_1} = 1$



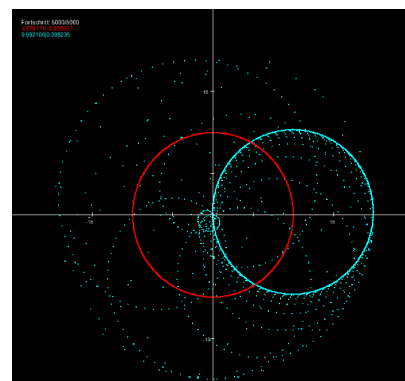
**FIGURE 9:** Coupled circular motions with  $\frac{f_2}{f_1} = 4$



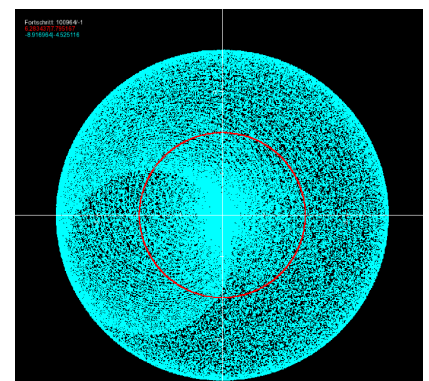
**FIGURE 10:** Coupled circular motions with  $\frac{f_2}{f_1} = 10$



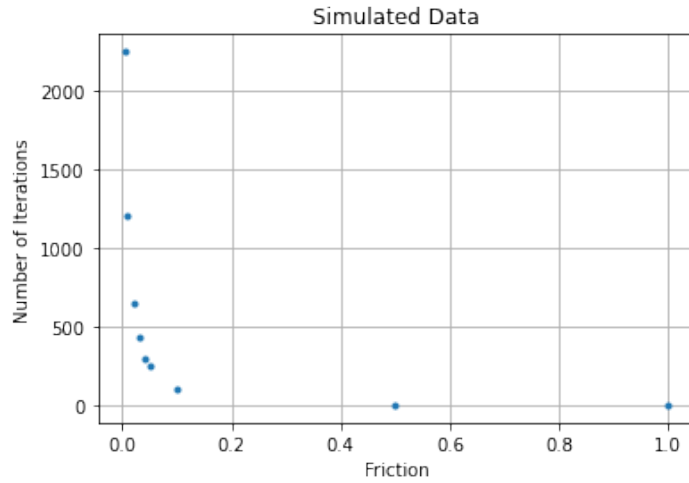
**FIGURE 11:** Damped circular motions with  $\mu = 0.1$



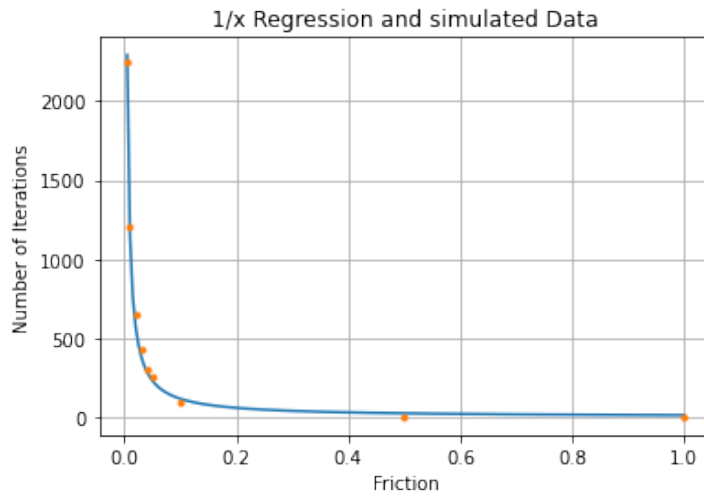
**FIGURE 12:** Damped circular motions with  $\mu = 0.05$



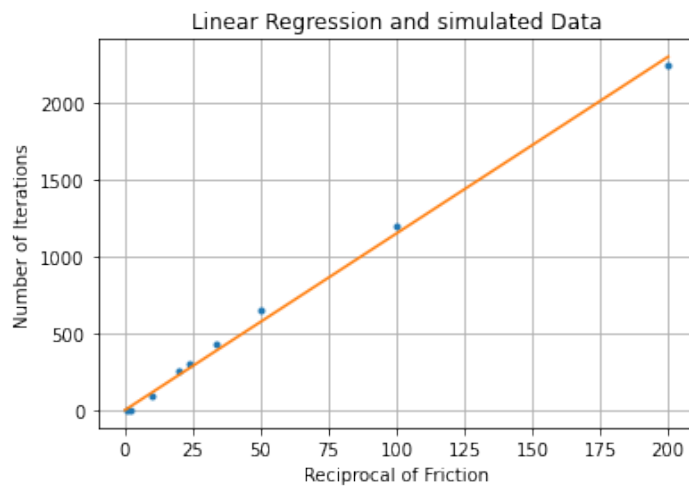
**FIGURE 13:** Damped circular motions with  $\mu = 0.05$



**FIGURE 14:** The friction factor plotted against the number of iterations to quasi-periodicity



**FIGURE 15:** Regression of simulated data to a first-degree hyperbola



**FIGURE 16:** Regression of linearized data to a straight

- [1] Maskawa, Toshihide and Nakajima, Hideo (1974): *Spontaneous Breaking of*
- [2] Kobayashi, Makoto; Maskawa, Toshihide and Kondo, Hiroki (1971): *Symmetry Breaking 6en6he Chiral  $U(3) \oplus U(3)$  and the Quark Model*, Nagoya University, Saga University, Kyoto University
- [3] Yoichiro, Nambu (2008): *Spontaneous Symmetry Breaking in Particle Physics: A Case of Cross Fertilization*, Enrico Fermi Institute, University of Chicago.
- [4] Bolz, Joachim (1998): *Die Suche nach dem "einfachsten" chaotischen System*.
- [5] anonymous: *Phasenraum*, accessed via <https://de.wikipedia.org/wiki/Phasenraum> on 15<sup>th</sup> Jan. 2021 at 6 PM.
- [6] University of Stuttgart (2018): *Was schwingt denn da? Phänomene rund um Pendel und Schwingungen*, p. 9.
- [7] Sugihara G, Hastings H.M. (1996): *Fraktale: Ein Leitfaden für Anwender*, ISBN 9783860253373.
- [8] F.G. Gauß: *Vierstellige logarithmische und trigonometrische Tafeln*, Stuttgart 1953
- [9] Briggs, John and Peat, F. David (1999): *Die Entdeckung des Chaos: Eine Reise durch die Chaos-Theorie*, ISBN 9783446159662.
- [10] anonymous: *Forces on a Falling Object with air resistance*, accessed via <https://www.grc.nasa.gov/www/k-12/airplane/falling.html> on 20<sup>th</sup> Jan. 2021 at 8.32 AM.
- [11] Jürgler R. (2004) Attraktor, Grenzykel. In: *Maschinendynamik*. VDI-Buch. Springer, Berlin, Heidelberg. [https://doi.org/10.1007/978-3-642-18706-3\\_12](https://doi.org/10.1007/978-3-642-18706-3_12)
- [12] Peitgen, Heinz-Otto (1989): *Chaos and Fractals: New Frontiers of Science*, ISBN 9780387202297
- [13] Feldmann, David P. (2012): *Chaos and Fractals: An Elementary Introduction*, ISBN 9780199566440. <https://de.wikipedia.org/wiki/Attraktor> on 16<sup>th</sup> Jan. 2021 at 9.58 PM.
- [14] Freistetter, Florian (2015): *Unlösbar und faszinierend: Das*

*Dreikörperproblem*, accessed via <https://scienceblogs.de/astrodicticum-simplex/2015/06/09/unloesbar-und-faszinierend-das-dreikoerperproblem/> on 17<sup>th</sup> Jan. 2021 at 4.01 PM.

[15] Deutsches Zentrum für Luft- und Raumfahrt (2020): *Mars in Opposition*, accessed via [https://www.dlr.de/content/de/artikel/news/2020/04/20201012\\_mars-in-opposition.html](https://www.dlr.de/content/de/artikel/news/2020/04/20201012_mars-in-opposition.html) on 23<sup>rd</sup> Jan. 2021 at 11.04 AM.

[16] Iseler, Albrecht (2002): *Grundbegriffe der Vektor- und Matrixalgebra*, p.9, Freie Universität Berlin.

[17] Frerichs, Stefan (2000): *Bausteine einer systemischen Nachrichtentheorie*, accessed via <https://www.stefre.de/html/chaostheorie.html> on 22<sup>nd</sup> Jan. 2021 at 8.39 PM.

[18] Bohn, John L. (2018): *A Student's Guide to Analytical Mechanics*, Cambridge University Press, ISBN 978-1-316-50907-4.

[19] College Algebra: *Equations of Hyperbolas*, accessed via

<https://courses.lumenlearning.com/waymakercollegealgebra/chapter/equations-of-hyperbolas/> on 2<sup>nd</sup> April 0.17 AM.

[20] (2005) *Die Linearisierung einer Funktion in einem Punkt*. In: *Angewandte Analysis in einer Unbekannten*. Springer-Lehrbuch. Springer, Berlin, Heidelberg. [https://doi.org/10.1007/3-540-26710-7\\_17](https://doi.org/10.1007/3-540-26710-7_17)

[21] Falconer, Kenneth (2014): *Fractal Geometry*, University of St. Andrews, ISBN 978-1-119-94239-9.

[22] Feldmann, David P. (2021): *Chaos and Fractals: An Elementary Introduction*, ISBN 9780199566440.