Otto Rössler
1970-79

FROM CHEMICAL REACTIONS
TO
THE TOPOLOGY OF CHAOS

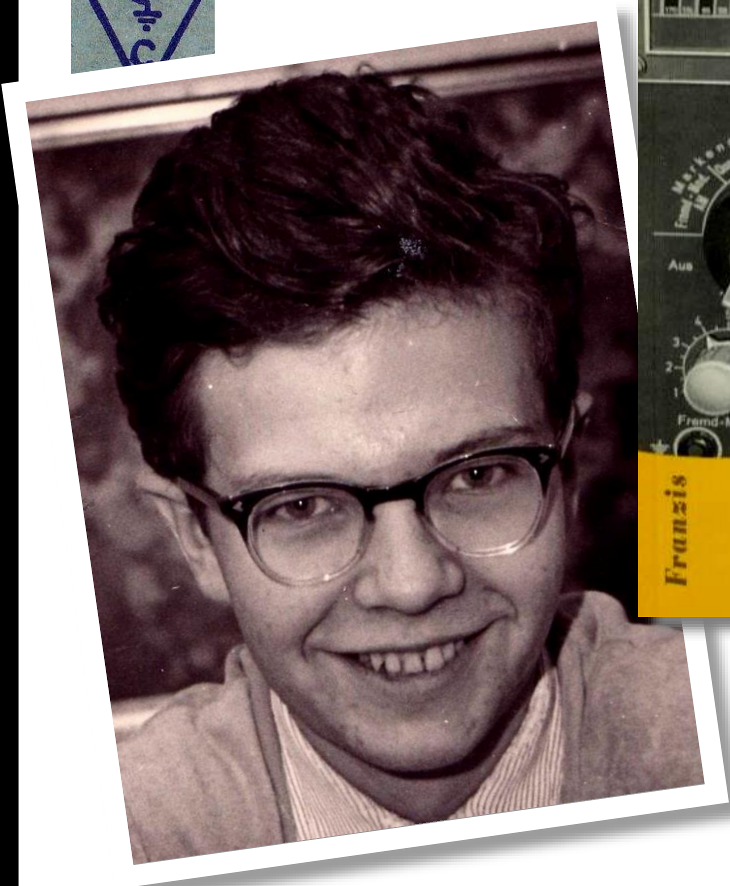
Conducted by

Christophe Letellier

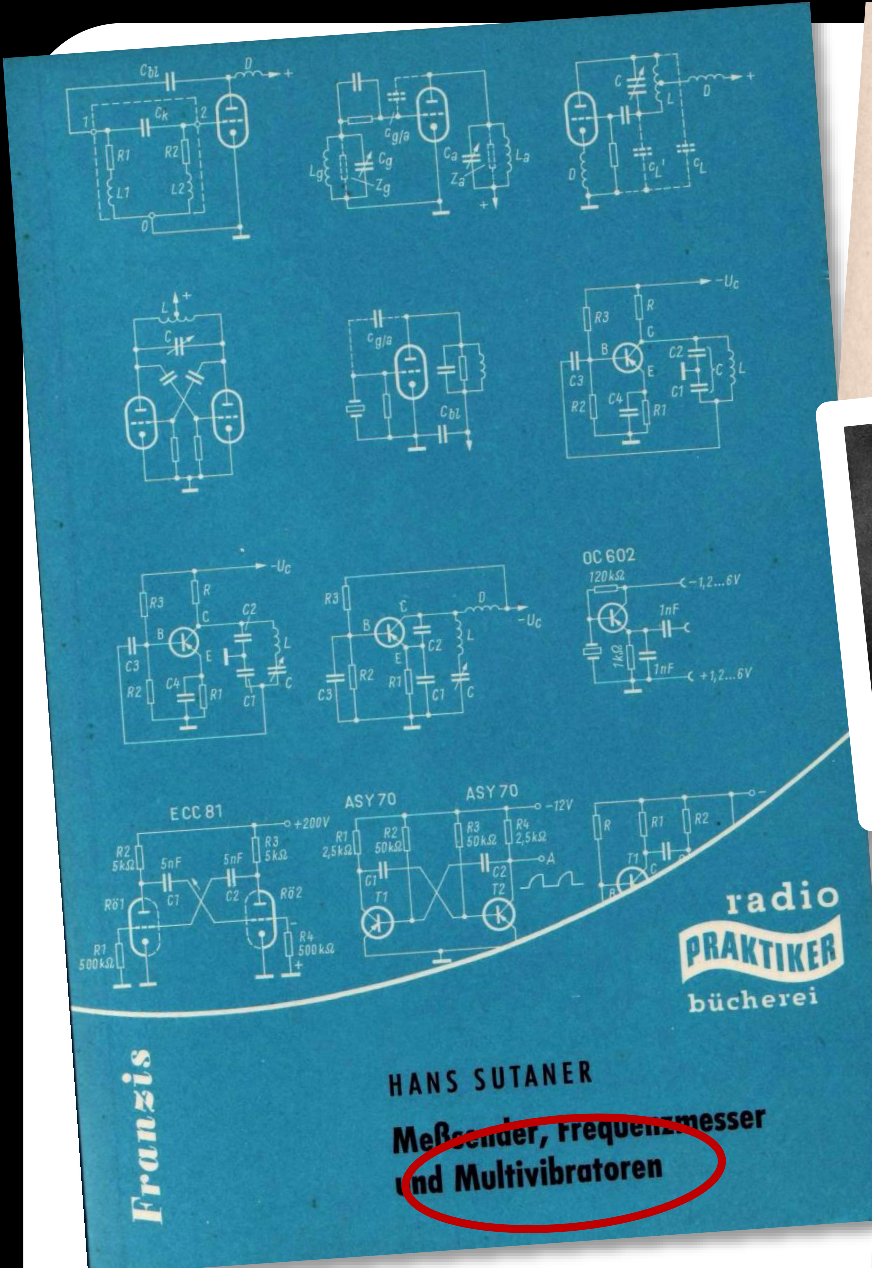
University of Rouen

Born on May 20, 1940

Deutscher Amateur Radio Club



DL9: Individual licences with full privileges



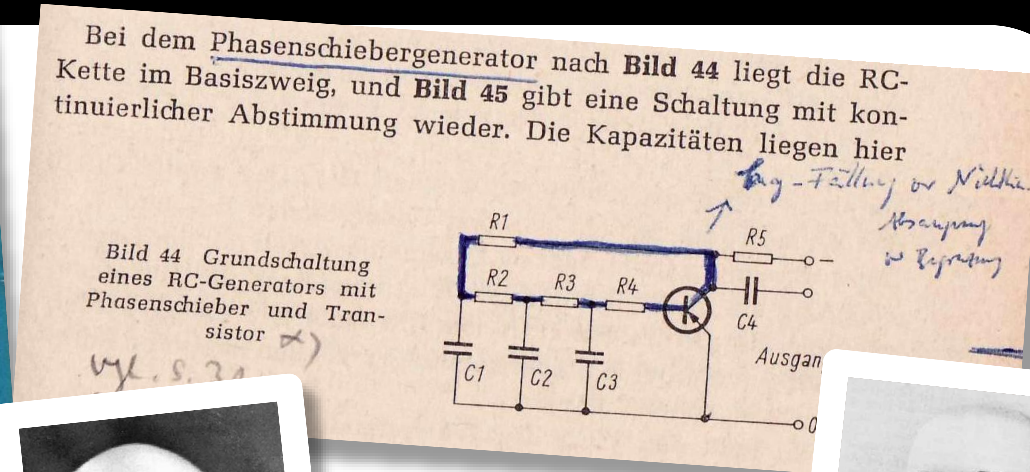
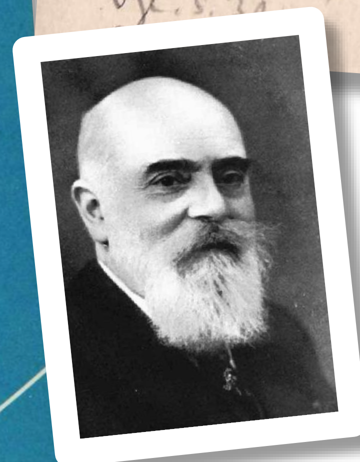
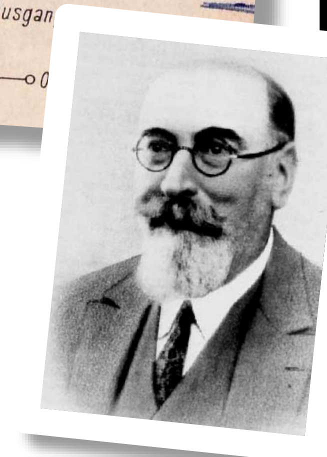

Bei dem Phasenschiebergenerator nach **Bild 44** liegt die RC-Kette im Basiszweig, und **Bild 45** gibt eine Schaltung mit kontinuierlicher Abstimmung wieder. Die Kapazitäten liegen hier

Bild 44 Grundschaltung eines RC-Generators mit Phasenschieber und Transistor

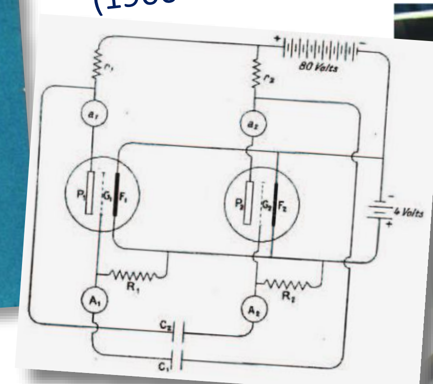
Abraham & Bloch's multi-vibrator



Henri Abraham
(1900-1984)



Eugène Bloch
(1878-1944)



1970: Assistant (working with Friedrich Seelig)

Department for Theoretical Biology, University of Tübingen

REPETITIVE HARD BIFURCATION IN A HOMOGENEOUS REACTION SYSTEM

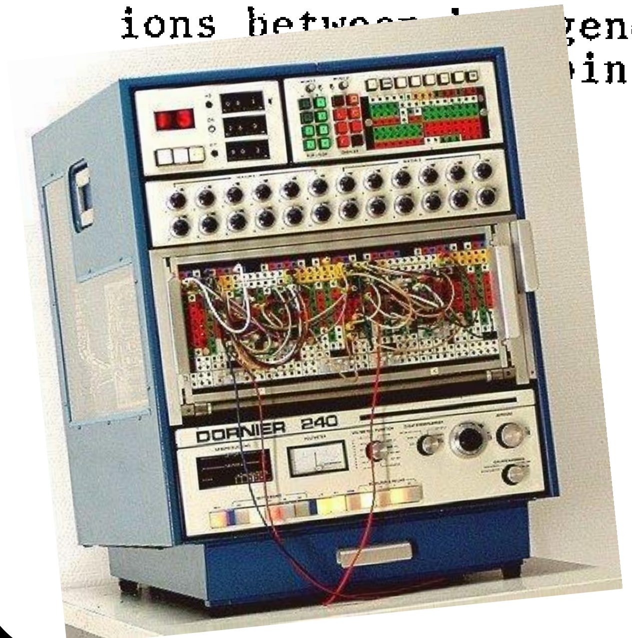
O. E. RÖSSLER and D. HOFFMANN
Division of Theoretical Chemistry, University of Tübingen,
West Germany

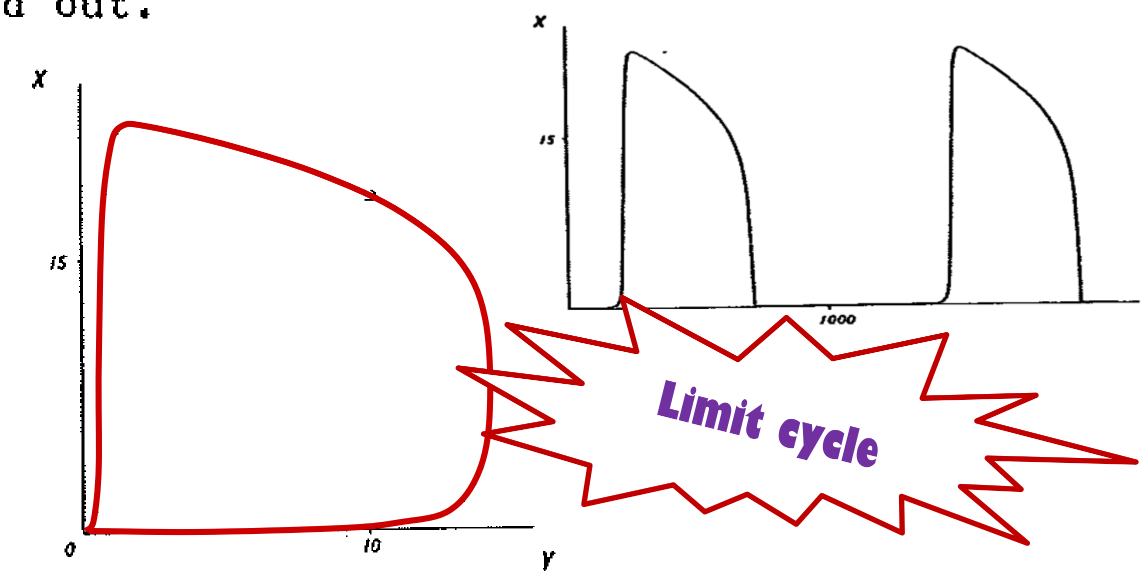
Analysis and Simulation of Biochemical Systems, 91-102, 1972

1972

Dietrich Hoffmann

This paper consists of three parts. First, theoretical evidence that the Belousov-Zhabotinsky reaction (BZR) is a Bonhoeffer oscillator, i.e. a special type of chemical hysteresis oscillator, is presented. Second, a brief account of the qualitative theory of chemical relaxation oscillators is given, centering around the notion of hard bifurcation. Finally, some connections betw… geneous and nonhomogeneous chemical bifurcat- … inted out.

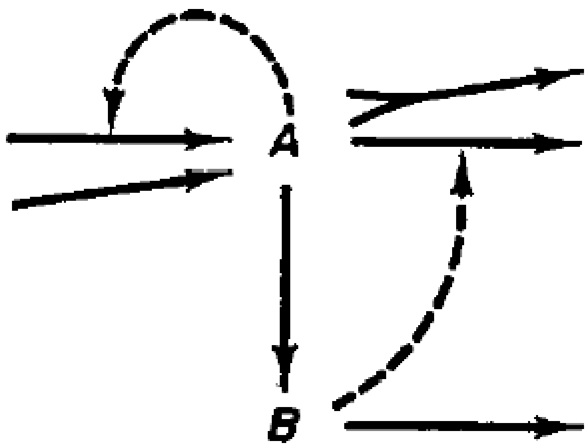




J. theor. Biol. (1972) 36, 413–417

1972

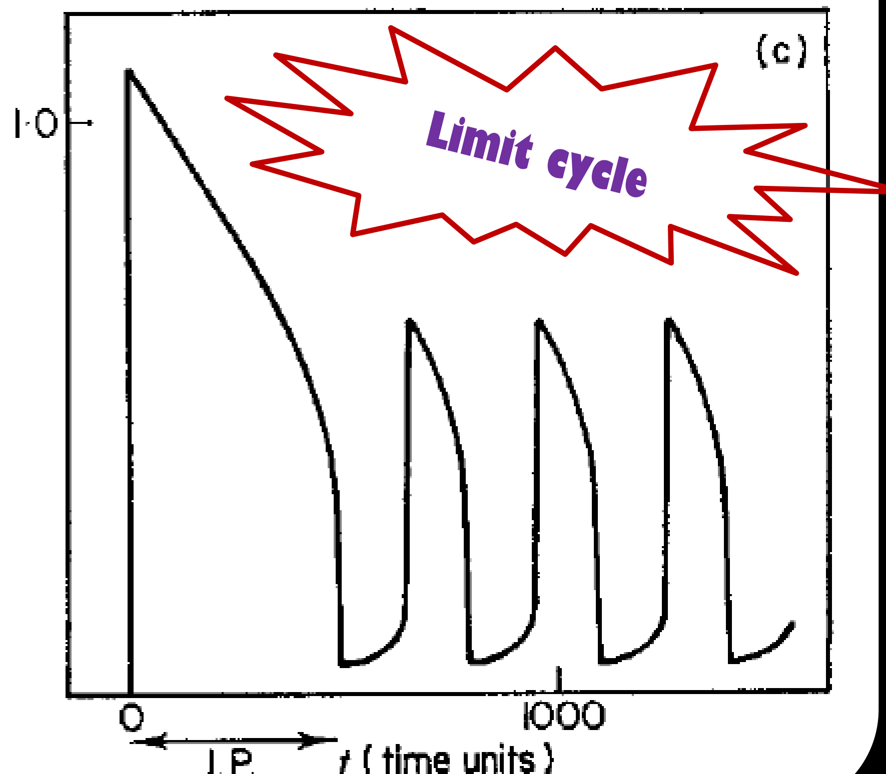
A Principle for Chemical Multivibration



Prototype reaction scheme

$$\dot{a} = k_1 a - k_2 b \frac{a}{a+K} - k_3 a^2 + k_4$$

$$\dot{b} = k_5 a - k_6 b,$$



1975

INTERNATIONALER KONGRESS ÜBER
„RHYTHMISCHE FUNKTIONEN IN BIOLOGISCHEN SYSTEMEN“

INTERNATIONAL CONGRESS ON
“RHYTHMIC FUNCTIONS IN BIOLOGICAL SYSTEMS”

CONGRES INTERNATIONAL SUR
“LES FONCT… S RYTHMIQUES DANS DES SYSTEMES BIOLOGIQUES”

Wien/Vienna/Vienne, 8.—12. 9. 1975

Vienna, September 12,1975

This is to certify that

Dr. RÖSSLER .... participated in the International Congress on "Rhythmic Functions in Biological Systems" and paid the registration fee amounting to

AS 300.— ....

KONGRESSBÜRO
der W. med. Akademie
für ärztliche Fortbildung
Wien IX. Alserstraße

Vienna, September 8-12, 1975

Frau Veith

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Elektro-Radio-Fernsehen
Sämtliche
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Haushalts-
und Freizeitartikel
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October 7, 1975

PURDUE UNIVERSITY
DEPARTMENT OF BIOLOGICAL SCIENCES
WEST LAFAYETTE, INDIANA 47907

RS. 9.10., Ah. 14.10.75

7 October

... literature much better than I do.... a development I would like to encourage by sending along a few choice reprints + preprints (coming separately)

Yes I also have been intrigued by the possibility that "core meander" betrays a deterministic "strange attractor".

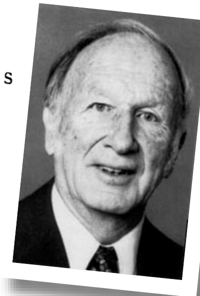
And John Guckenheimer is following up the conjecture you also came to, that periodic forcing of an limit-cycle oscillator → "strange attractor". Actually it turns out a bea "strange repellor", but

« *Your insight amazes me. I think you will understand **this literature** much better than I do... A development I would like to encourage by sending along a few choice of reprints + preprints* »

130 JOURNAL OF THE ATMOSPHERIC SCIENCES

Deterministic Nonperiodic Flow[1]

EDWARD N. LORENZ



SIAM J. APPL. MATH.
Vol. 32, No. 1, January 1977

PERIODIC SOLUTIONS OF A LOGISTIC DIFFERENCE EQUATION*

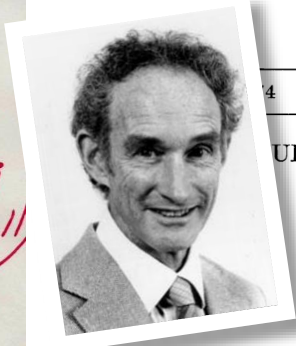
F. C. HOPPENSTEADT AND J. M. HYMAN†

J. Math. Biology 4, 101—147 (1977)

The Dynamics of Density Dependent Population M

Journal of Mathematical Biology © by Springer-Verlag 1977

J. Guckenheimer, Santa Cruz, California,
G. Oster and **A. Ipaktchi**, Berkeley, California

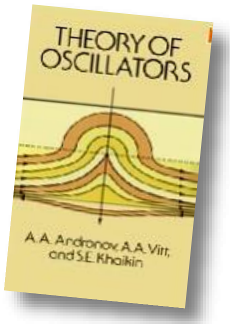


4 The American Naturalist July–August 1976

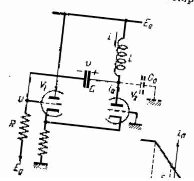
URCATIONS AND DYNAMIC COMPLEXITY IN SIMPLE ECOLOGICAL MODELS

ROBERT M. MAY AND GEORGE F. OSTER

The universal circuit

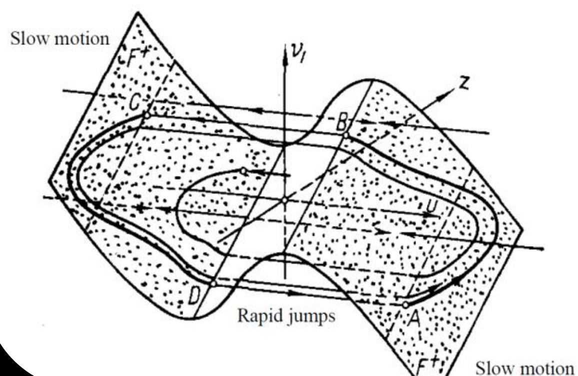


Alexandre Andronov (1901-1952)

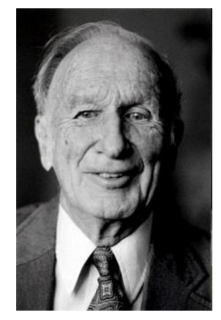

§9. A MULTIVIBRATOR WITH AN INDUCTANCE IN THE ANODE CIRCUIT

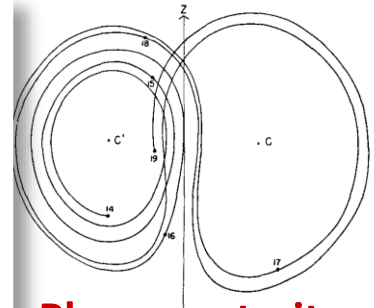
We have now seen that the investigation of a self-oscillating system is considerably simplified if one of the important oscillation parameters is small, so that the motions can be split into comparatively simple "rapid"

$$
\begin{cases}
\mu\dot{u} = E_a - Ri_a(u) - \left(1 + \dfrac{R}{\beta r}\right)u + (1-\beta)\dfrac{R}{\beta r}z - v_1 \\
\dot{v}_1 = z \\
\dot{z} = \dfrac{C_1}{\beta(1-\beta)C_2}n - \left(1 + \dfrac{C_1}{\beta C_2}\right)\dfrac{z}{1-\beta}
\end{cases}
$$

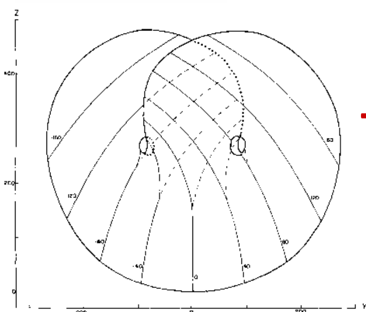


Lorenz 1963



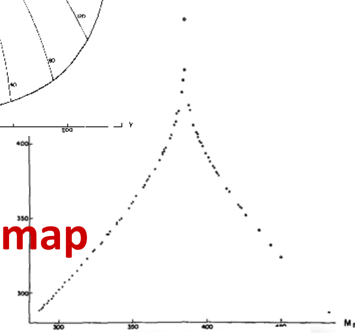


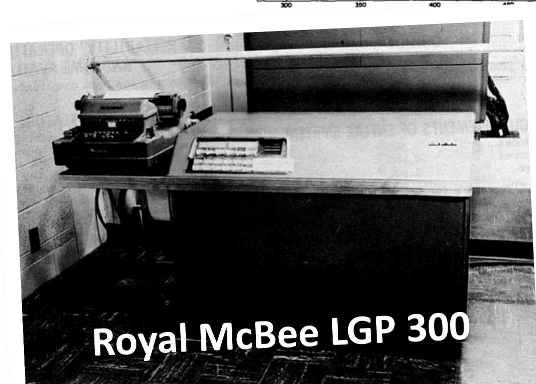
Phase portrait



Topology

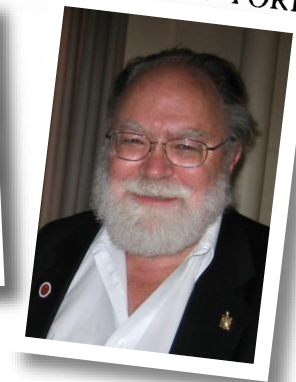
First-return map





PERIOD THREE IMPLIES CHAOS

TIEN-YIEN LI AND JAMES A. YORKE



THEOREM 1. *Let J be an interval and let $F: J \to J$ be continuous. ... which the points $b = F(a)$, $c = F^2(a)$ and $d = F^3(a)$, satisfy*

$$d \leqq a < b < c \text{ (or } d \geqq a > b > c).$$

Then

T1: *for every $k = 1, 2, \cdots$ there is a periodic point in J having*

Furthermore,

T2: *there is an uncountable set $S \subset J$ (containing no periodic ... the following conditions:*

(A) *For every $p, q \in S$ with $p \neq q$,*

$$\limsup_{n\to\infty} |F^n(p) - F^n(q)| > 0 \tag{2.1}$$

and

$$\liminf_{n\to\infty} |F^n(p) - F^n(q)| = 0. \tag{2.2}$$

(B) *For every $p \in S$ and periodic point $q \in J$,*

$$\limsup_{n\to\infty} |F^n(p) - F^n(q)| > 0.$$

REMARKS. Notice that if there is a periodic point with period 3, th... will be satisfied.

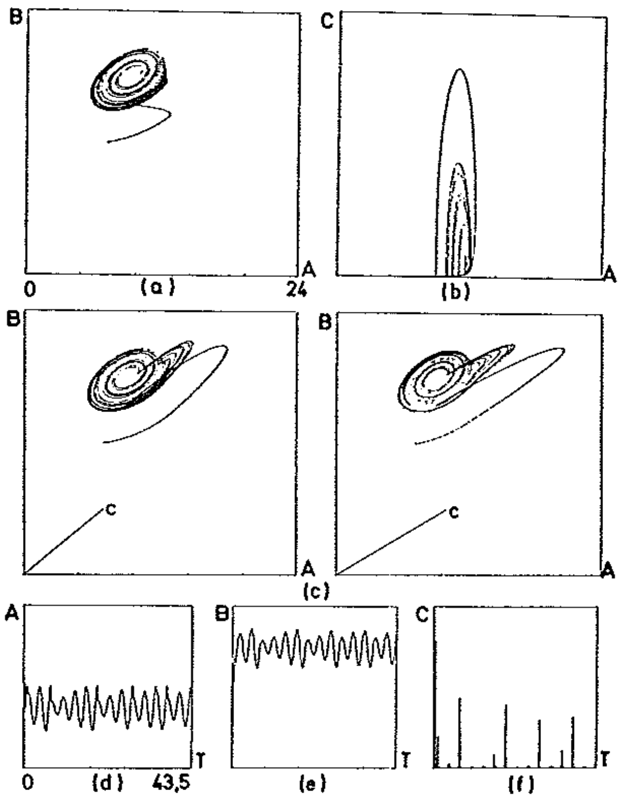
Chaotic Behavior in Simple Reaction Systems

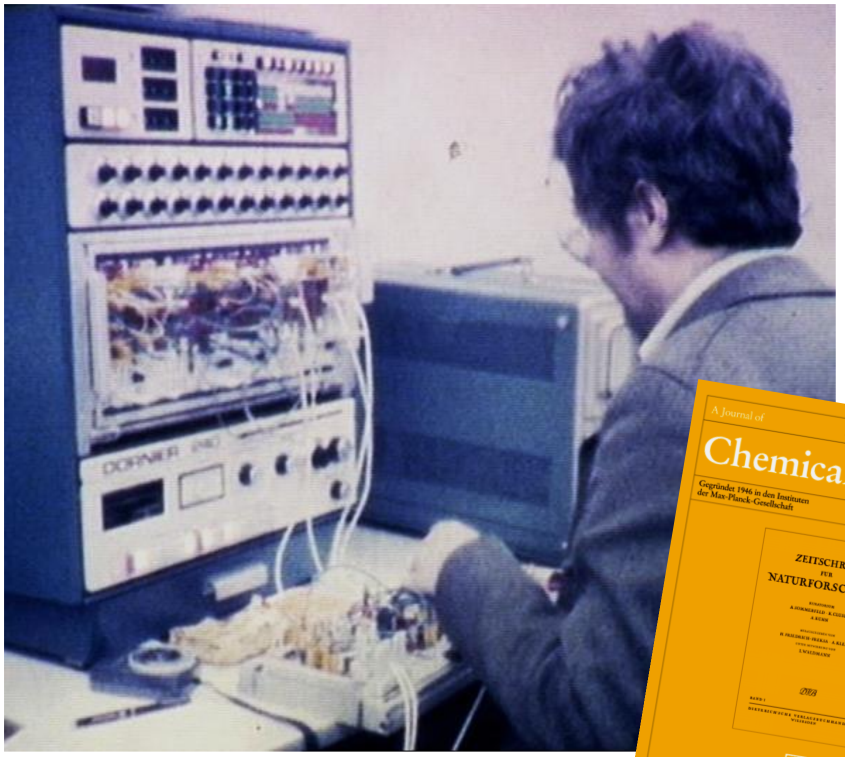
Otto E. Rössler

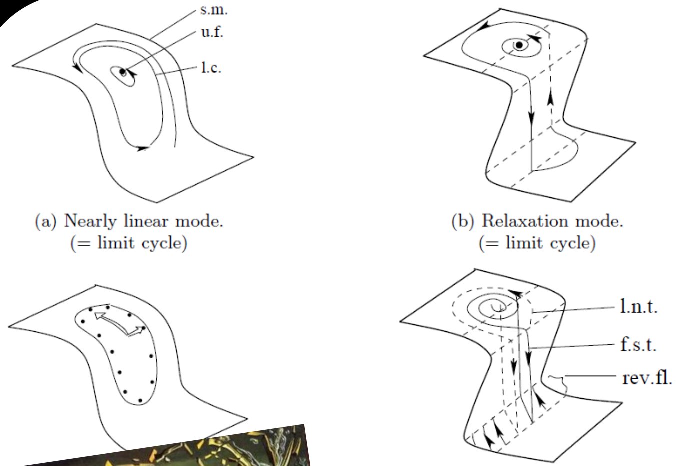
Institut für Physikalische und Theoretische Chemie der Universität Tübingen

(Z. Naturforsch. 31 a, 259—264 [1976]; received January 5, 1976)

Chemical system theory, exotic kinetics, nonperiodic oscillation, 3-variable dynamical systems, strange attractors





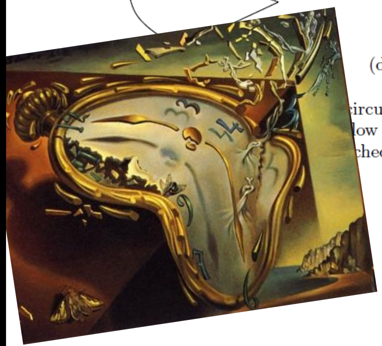


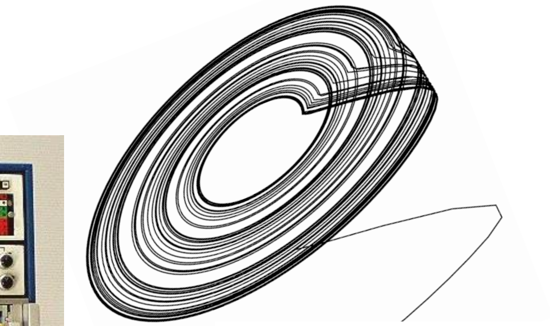
(a) Nearly linear mode.
(= limit cycle)

(b) Relaxation mode.
(= limit cycle)

(d) Chaos-producing mode (see text).

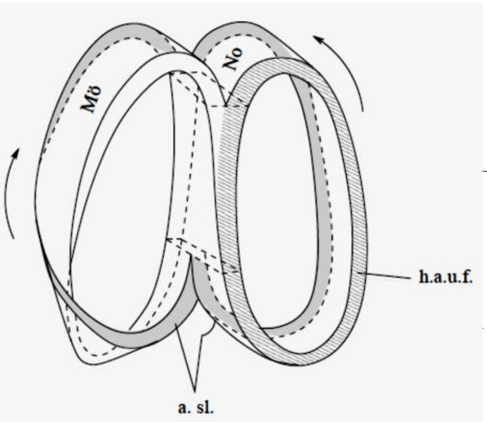
ircuit. s.m.= slow manifold, u.f.= unstable
low manifold in (b) and (d) is unstable, f.s.t.
ched trajectory", rev.fl.= reversed direction

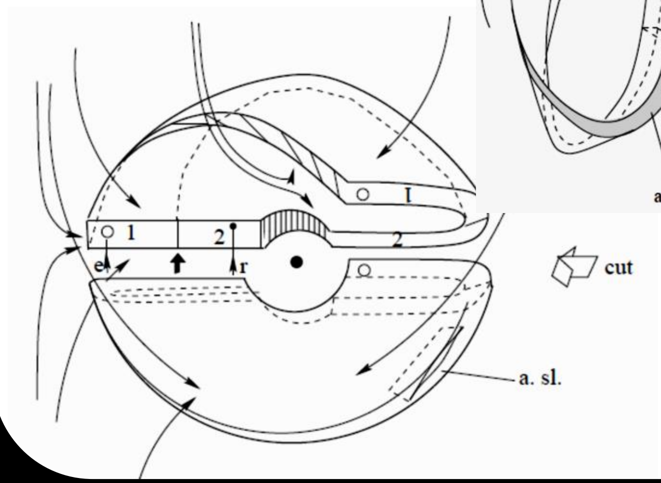


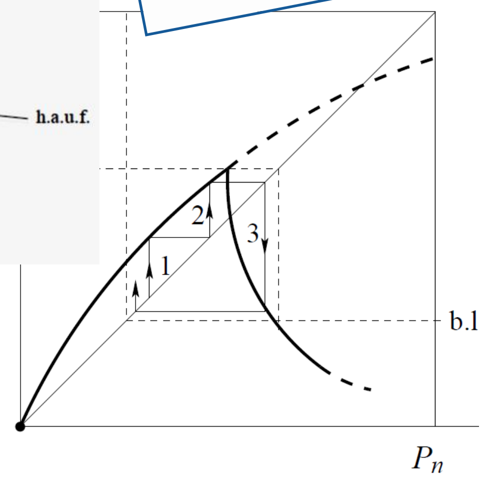


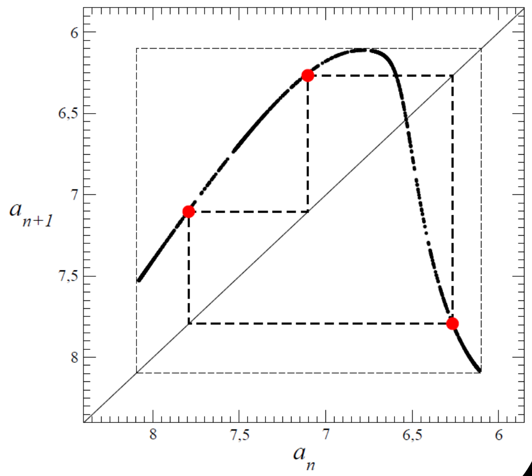
$$
\begin{cases}
\dot a &= k_1 + k_2 a - \dfrac{(k_3 b + k_4 c)a}{a+K}\\
\dot b &= k_5 a - k_6 b\\
\mu \dot c &= k_7 a + k_8 c - k_9 c^2 - \dfrac{k_{10} c}{c+K'}
\end{cases}
$$

PERIOD THREE IMPLIES CHAOS







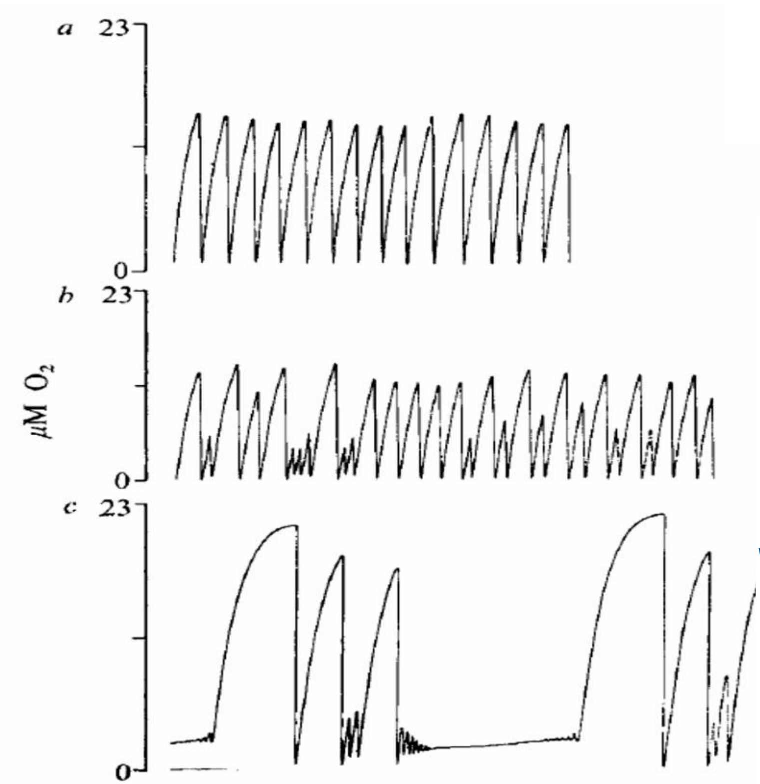


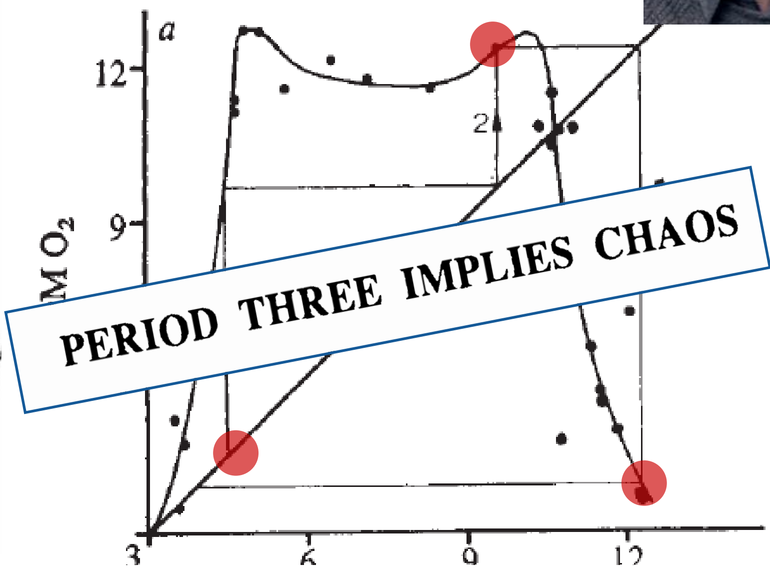
Chaos in an enzyme reaction

Lars Folke Olsen
Hans Degn

*Institute of Biochemistry,
Odense University,
Odense, Denmark*





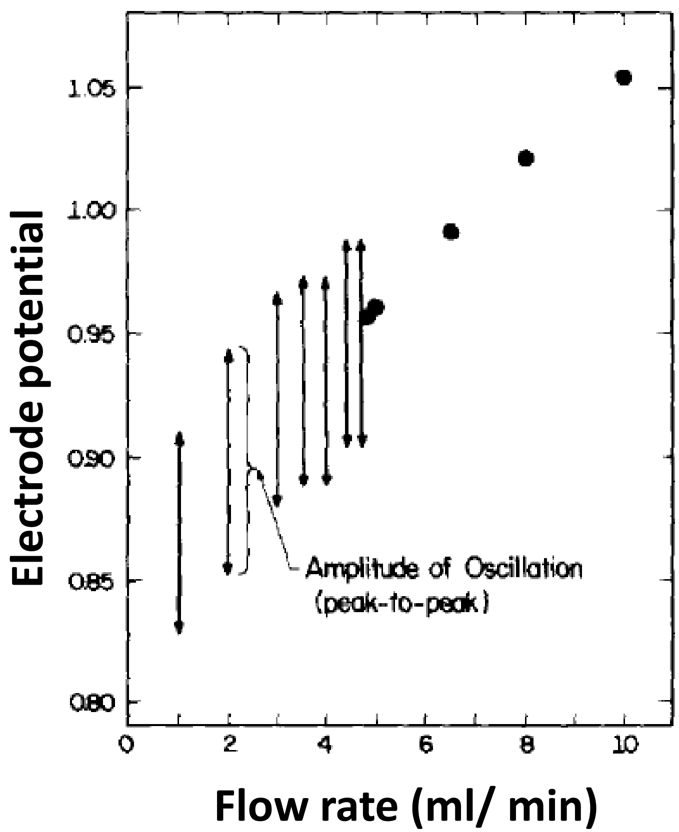
solutions. The argument is based on a theorem by Li and Yorke[3]. Here we report the finding of chaotic behaviour as an experimental result in an enzyme system (peroxidase). Like Rössler[2] we base our identification of chaos on the theorem by Li and Yorke[3].

Nature Vol. 267 12 May 1977

The Chemical Engineering Journal, 12 (1976) 9–21

The Belousov–Zhabotinskii Reaction in

K. R. GRAZIANI*, J. L. HUDSON** and R.



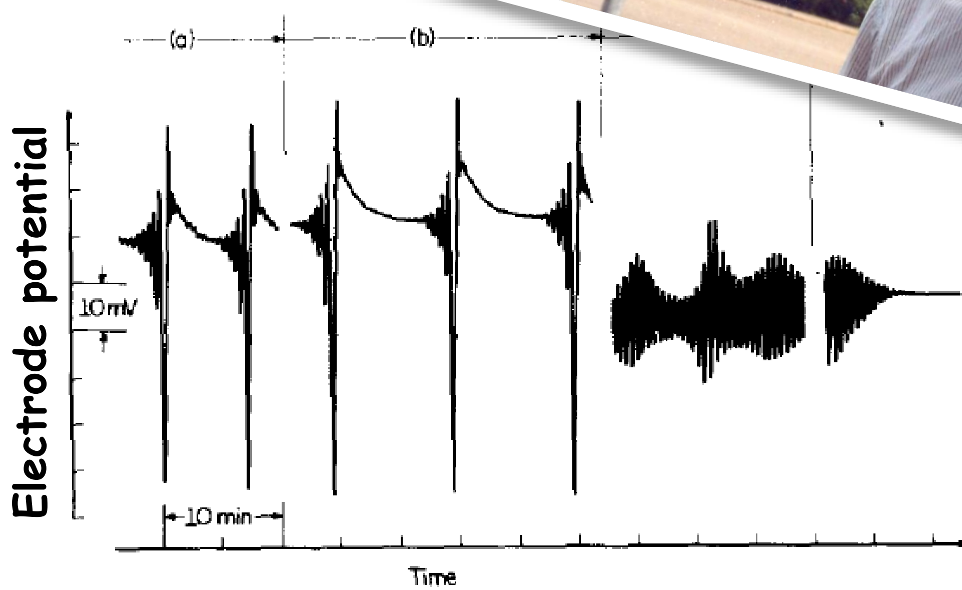


Fig. 3. Effect of sodium bromate feed rate on oscillations: (a) 1.28 ml min^{-1}; (b) 1.32 ml min^{-1}, the normal flow rate of bromate for a total flow of 4.7 ml min^{-1}; (c) 1.33 ml min^{-1}; (d) 1.36 ml min^{-1}.

Peak-to-peak fluctuations for sustained oscillations

1977

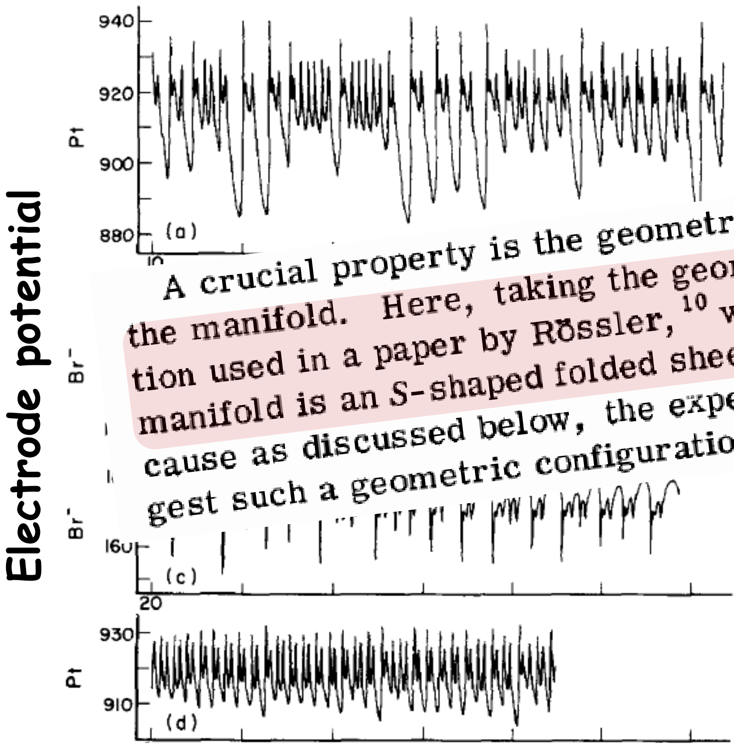
Experimental evidence of chaotic states in the Belousov–Zhabotinskii reaction

R. A. Schmitz, K. R. Graziani,[a] and J. L. Hudson[b]

Department of Chemical Engineering, University of Illinois, Urbana, Illinois 61801

(Received 3 May 1977)

Experimental results are reported which show strong evidence that the Belousov–Zhabotinskii reaction proceeds in an intrinsic chaotic (sustained time-dependent, nonperiodic) manner over a range of residence



A crucial property is the geometric configuration of the manifold. Here, taking the geometric representation used in a paper by Rössler,[10] we suppose that the manifold is an S-shaped folded sheet (see Fig. 4), because as discussed below, the experimental results suggest such a geometric configuration.

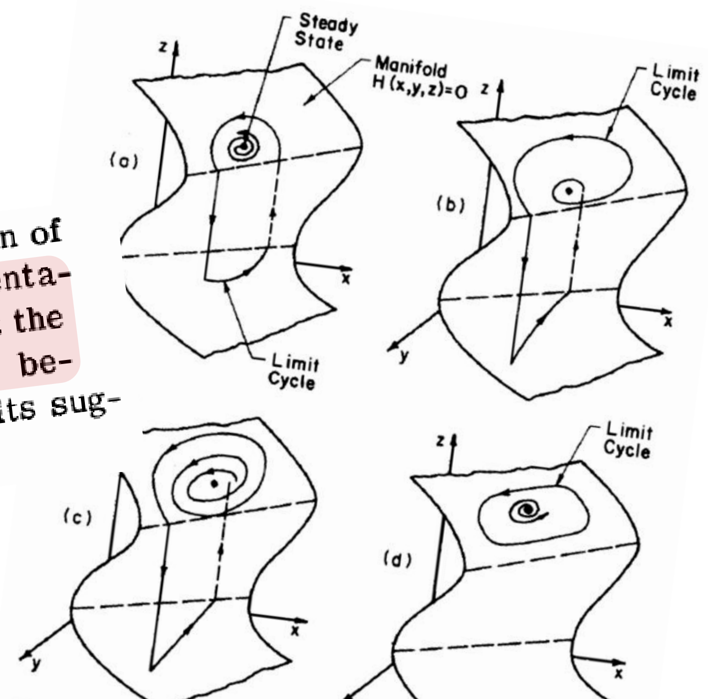


FIG. 4. Suggested theoretical state space trajectories.

1978

Chaos in the Zhabotinskii reaction

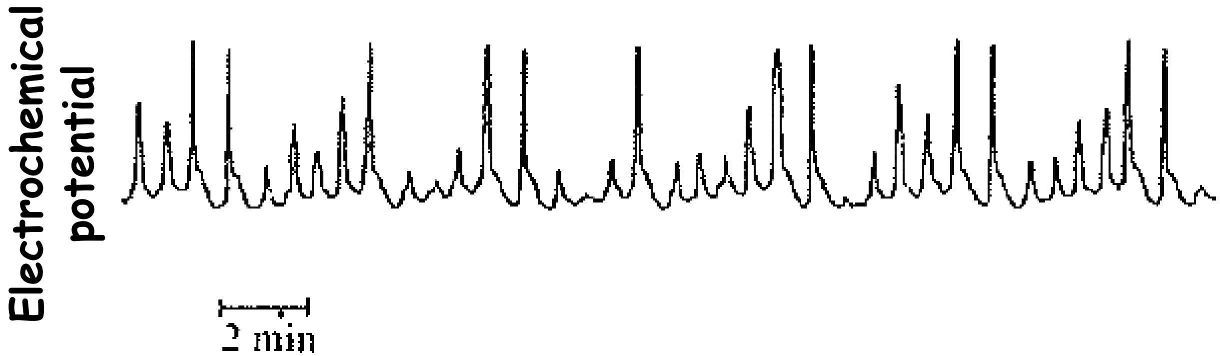
THE Belousov–Zhabotinskii reaction is a chemical Bonhoeffer–van der Pol circuit, that is, a relaxation oscillator that can be run as both an astable and a monostable 'flip-flop'[1–3]. Apparently

OTTO E. ROSSLER
sical and Theoretical Chemistry,
bingen,
Theoretical Physics,
ttgart

KLAUS WEGMANN
mical Plant Physiology,
bingen, 7400 Tübingen, FRG

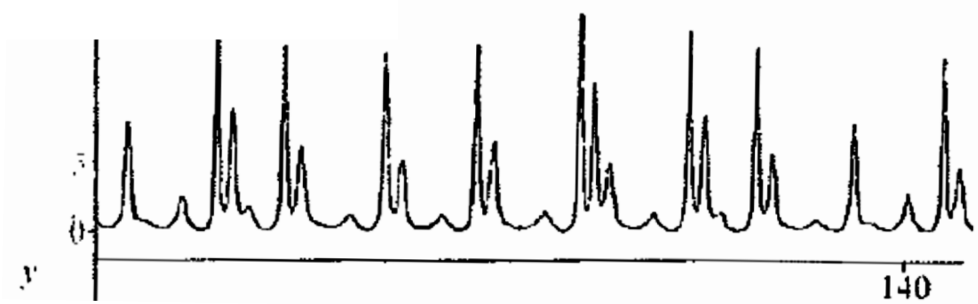
type' chaos[20] are possible in such systems. We present here preliminary evidence for the occurrence of screw-type chaos in the Zhabotinskii reaction.

0.1 V



compared to

$$\begin{cases} \dot{x} = -y - z \\ \dot{y} = x + 0.55y \\ \dot{z} = 2 - 4z + xz \end{cases}$$



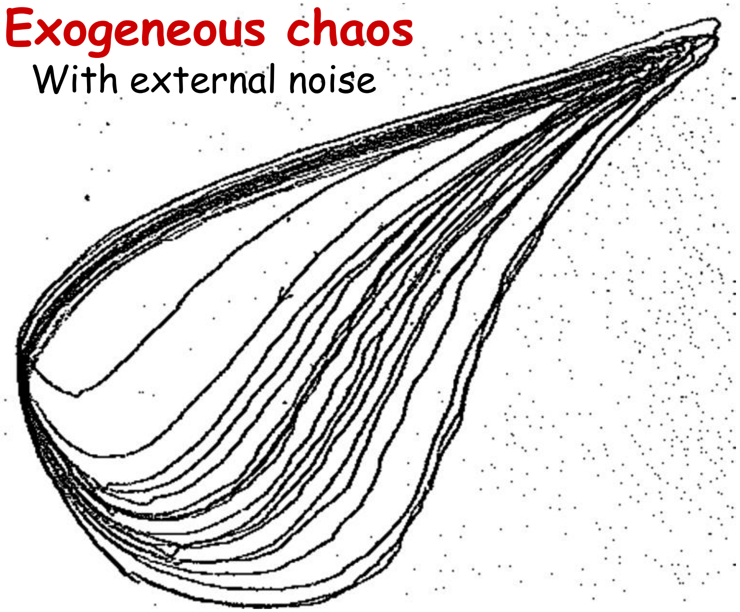
Different Kinds of Chaotic Oscillations in the Belousov-Zhabotinskii Reaction

Klaus Wegmann
Institut für Chemische Pflanzenphysiologie der Universität

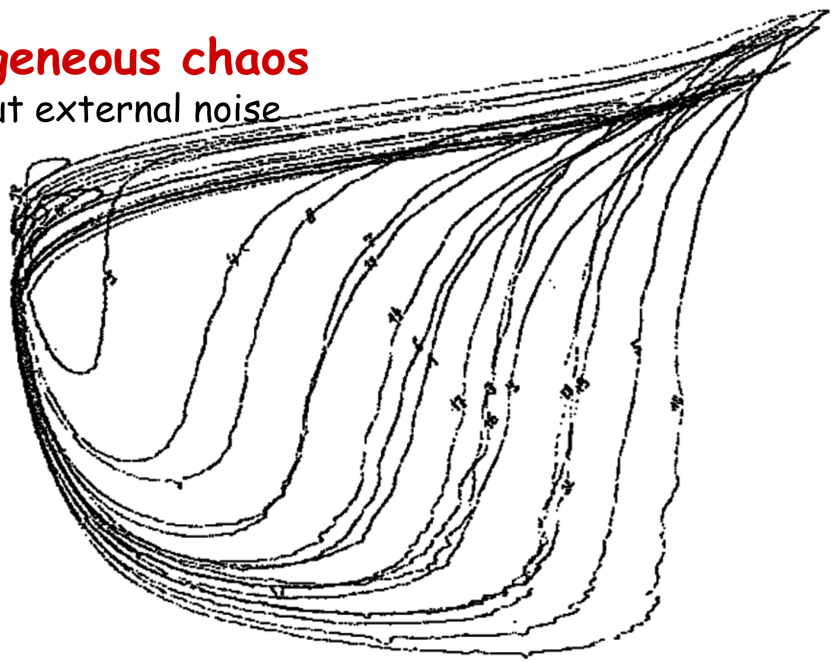
and

Otto E. Rössler
Institut für Physikalische und Theoretische Chemie der Ur
Institut für Theoretische Physik der Universität Stuttgart

Exogeneous chaos
With external noise

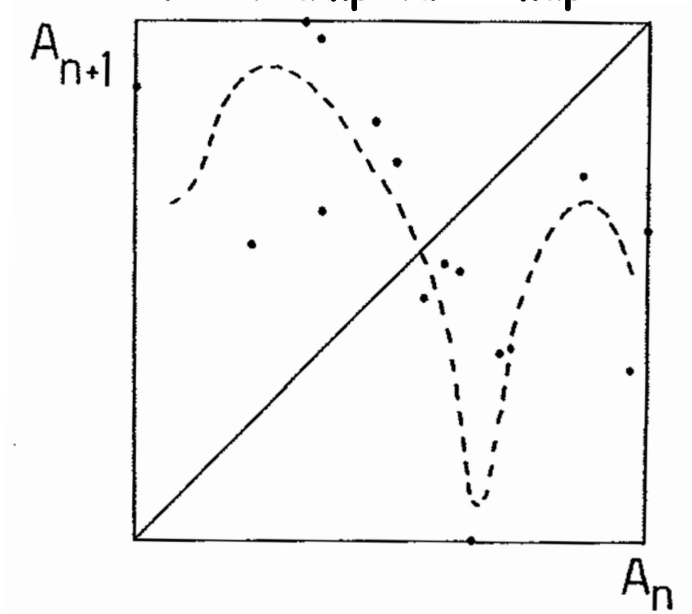


Endogeneous chaos
without external noise



Potential of bromide ion sensitive electrode

Next-amplitude map



Z. Naturforsch. 33a, 1179—1183 (1978); received July 19, 1978

Different Types of Chaos in Two Simple Differential Equations*

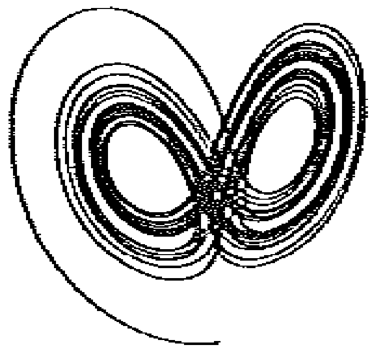
Otto E. Rössler

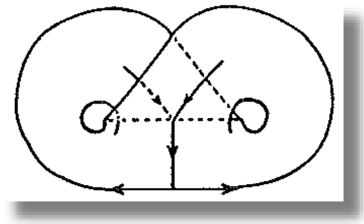
Institute for Physical and Theoretical Chemistry, Division of Theoretical Chemistry, University of Tübingen

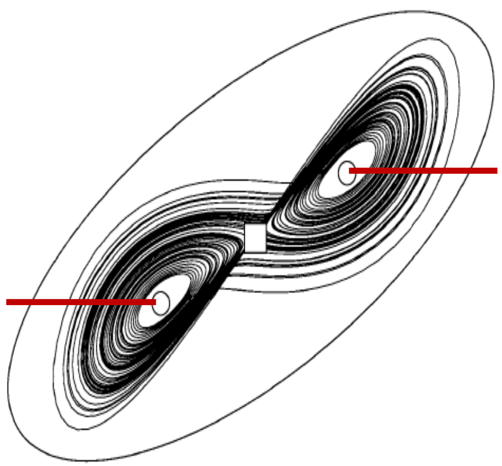
(Z. Naturforsch. 31 a, 1664—1670 [1976]; received November 10, 1976)

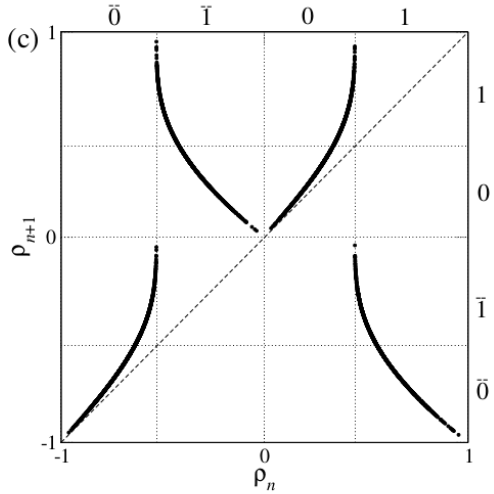
1976

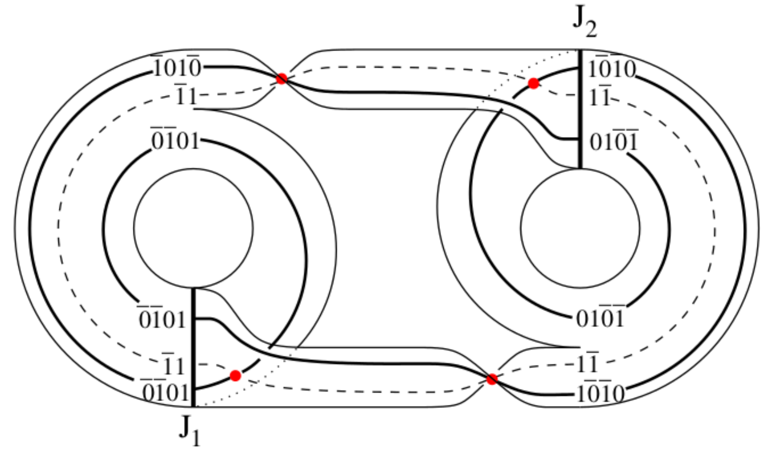
Lorenzian chaos











Different Types of Chaos in Two Simple Differential Equations*

Otto E. Rössler

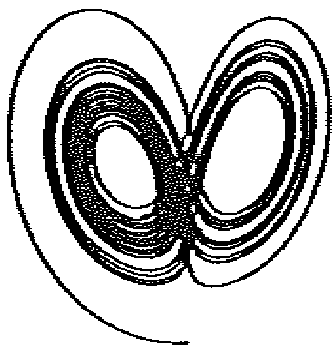
Institute for Physical and Theoretical Chemistry, Division of Theoretical Chemistry, University of Tübingen

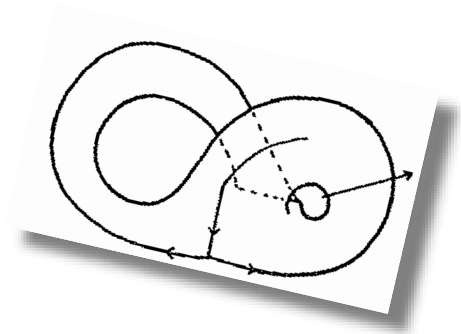
(Z. Naturforsch. 31 a, 1664—1670 [1976]; received November 10, 1976)

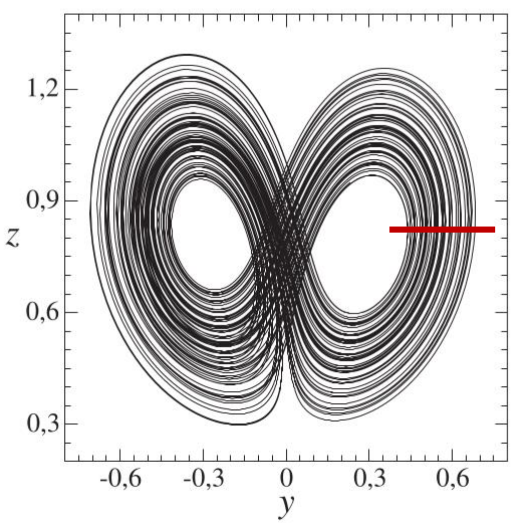
1976

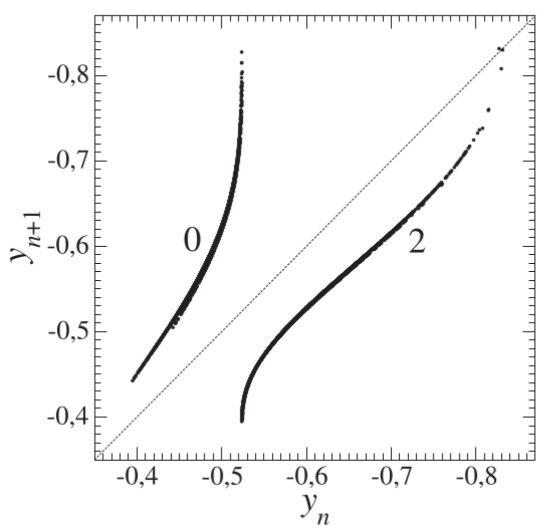
Sandwich chaos

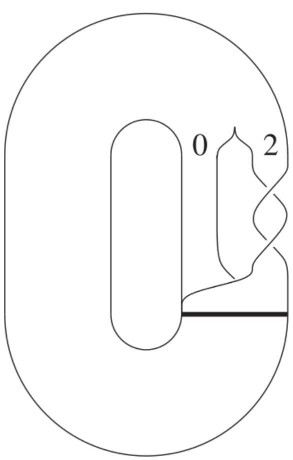
$$\begin{cases} \dot{x} = -cx + by + d \\ \dot{y} = -x + y - yz \\ \dot{z} = -az + y^2 \end{cases}$$











Different Types of Chaos in Two Simple Differential Equations*

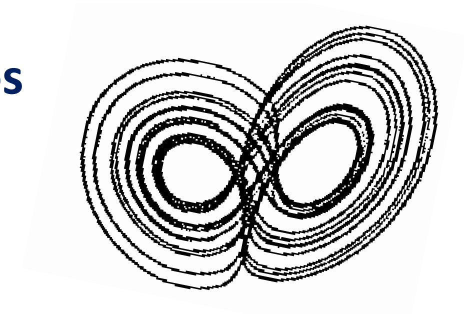
Otto E. Rössler

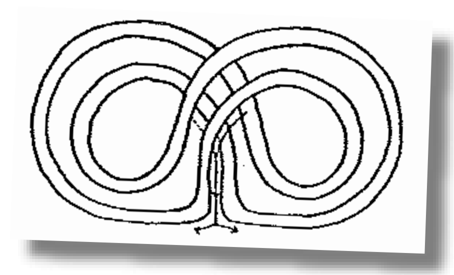
Institute for Physical and Theoretical Chemistry, Division of Theoretical Chemistry, University of Tübingen

(Z. Naturforsch. 31 a, 1664—1670 [1976]; received November 10, 1976)

1976

Horseshoe chaos





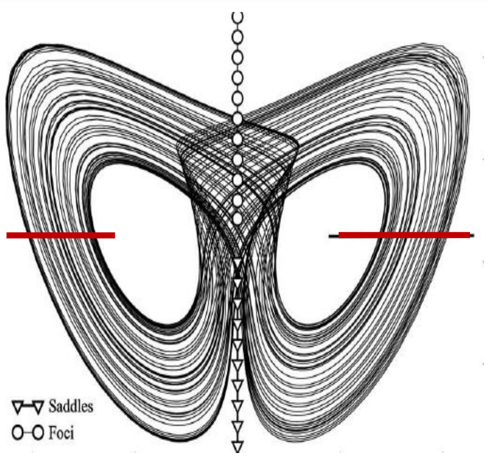
Strange Attractors, Chaotic Behavior, and Information Flow *

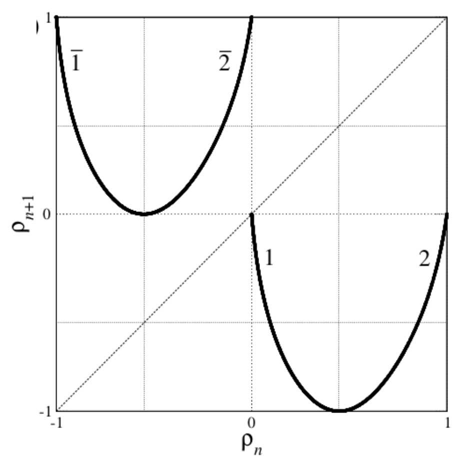
Robert Shaw

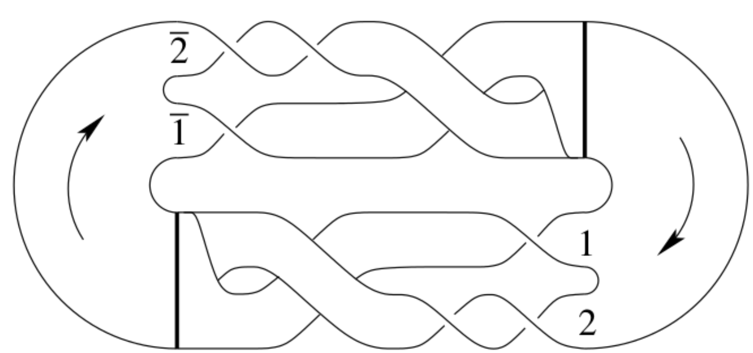
Physics Department, University of California, Santa Cruz, California 95064, USA

Z. Naturforsch. 36 a, 80—112 (1981); received October 15, 1980

Burke and Shaw attractor







Double scroll attractor

1977

Rössler, O. E. [1977] "Continuous chaos," *Synergetics*, ed. Haken, H., *Proc. Int. Workshop on Synergetics at Schloss Elmau* (Bavaria, May 2–7, 1977) (Springer-Verlag), pp. 184–197.

A simple autogenerator with stochastic behavior

A. S. Pikovskii and M. I. Rabinovich

Gor'kii Radiophysics Scientific Research Institute

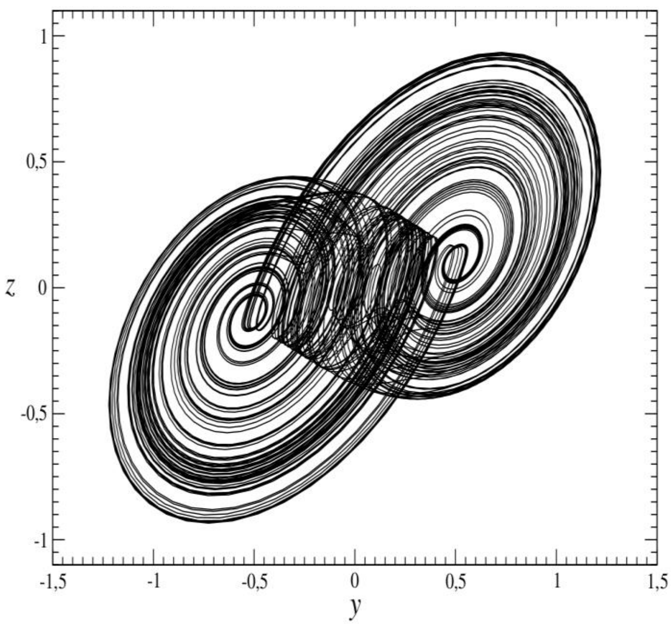
(Presented by Academician A. V. Gaponov-Grekhov, November 12, 1977)
(Submitted March 31, 1977)
Dokl. Akad. Nauk SSSR **239**, 301–304 (March 1978)

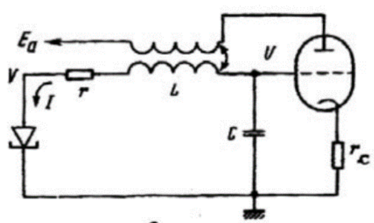
PACS numbers: 02.50.Ey

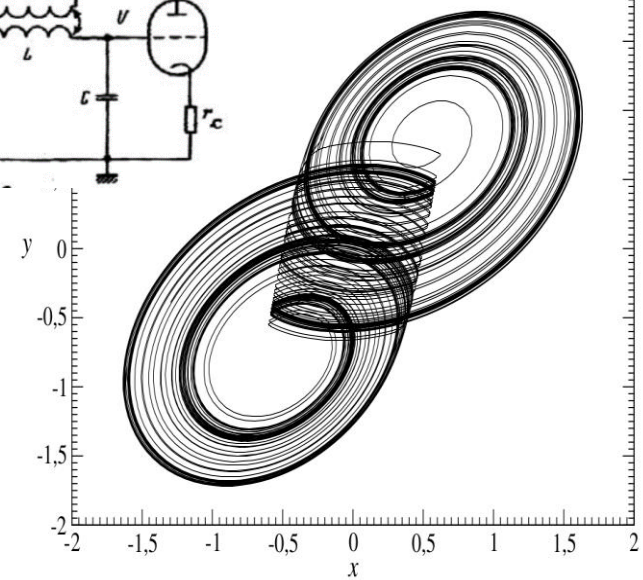
1978

$$\begin{cases} \dot{x} = -ax - y(1 - x^2) \\ \dot{y} = \mu(y + 0.3x - 2z) \\ \dot{z} = \mu(x + 2y - 0.5z) \end{cases}$$

$$\begin{cases} \dot{x} = y - \delta z \\ \dot{y} = -x + 2\gamma y + \alpha z + \beta \\ \dot{z} = \dfrac{x - z + z^3}{\mu} \end{cases}$$







Lorenzian chaos without any symmetry

$$
\begin{cases}
\dot{x} = ax + by - cxy - \dfrac{(dz+e)x}{x+K_1} \\
\dot{y} = f + gz - hy - \dfrac{jxy}{y+K_2} \\
\dot{z} = k + lxz - mz
\end{cases}
$$

Lecture Notes in Biomathematics 21, 51 (1978

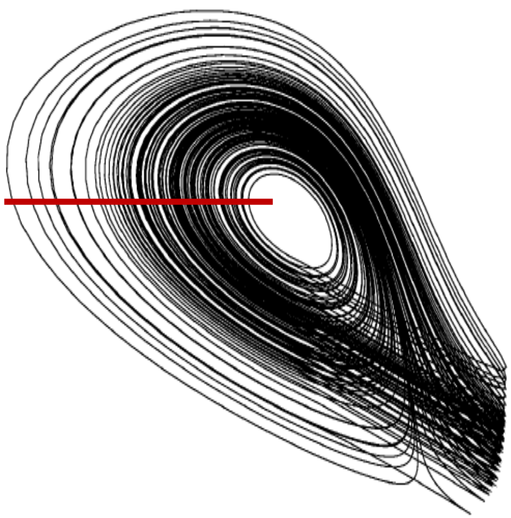
1978

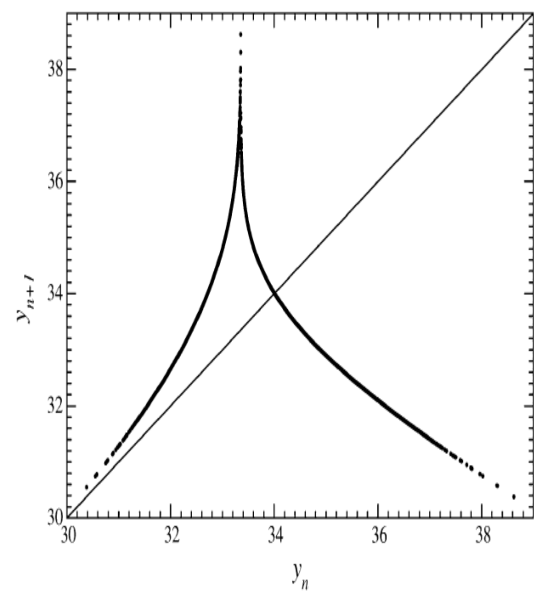
STRANGE ATTRACTORS IN 3-VARIABLE REACTION SYSTEMS

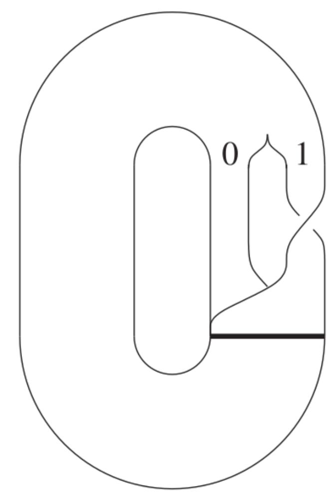
Otto E. Rössler
Institute for Physical and Theoretical Chemistry
University of Tübingen and
Institute for Theoretical Physics
University of Stuttgart

and

Peter J. Ortoleva
Department of Chemistry
Indiana University, Bloomington, Indiana







Hyperchaos

1979

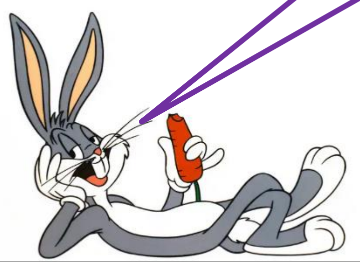
Volume 71A, number 2,3 PHYSICS LETTERS

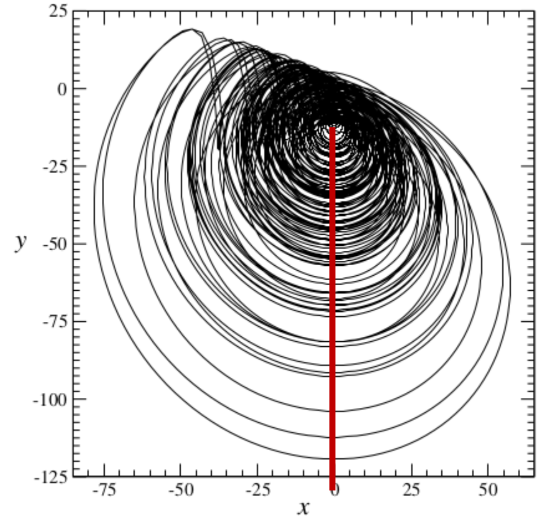
AN EQUATION FOR HYPERCHAOS

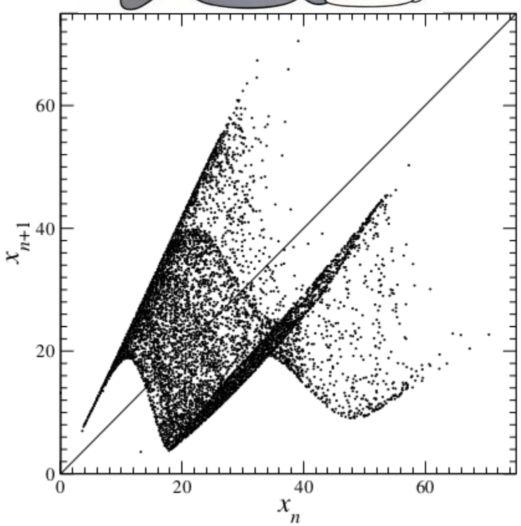
O.E. ROSSLER
Institute for Physical and Theoretical Chemistry,
and Institute for Theoretical Physics, University of

Hey, we are waiting for templex…

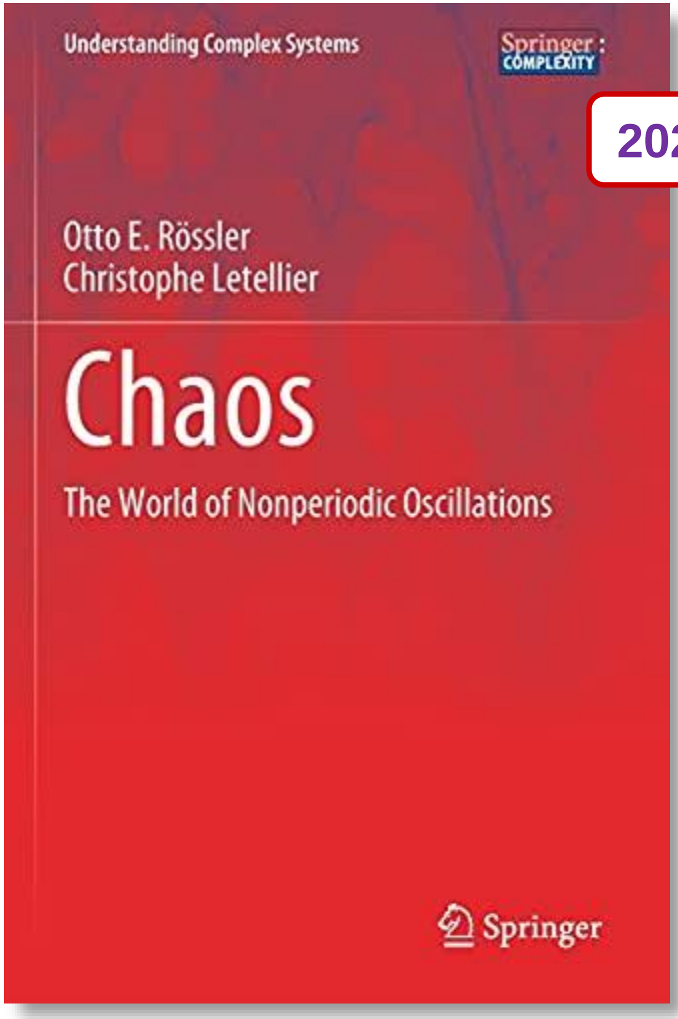
$$\begin{cases} \dot{x} = y - z \\ \dot{y} = x + 0.25y + w \\ \dot{z} = 3 + xz \\ \dot{w} = -0.5z + 0.05w \end{cases}$$







2010



2020

July 13, 2023

The End

conducted by
Christophe Letellier

Rouen Normandie University
2023