Entfernte Partikel haben einen starken und schnellen Einfluss auf das Molekülverhalten

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liquid water, 37°C, periodic boundaries
Lyapunov instability in liquid water at 37°C

randomization of motion

initial perturbation
consequences

- determinisitic chaos, Lyapunov time
- prediction every 0.23 ps further into the future requires one more decimal digit in start coordinates and calculations
- thus: cannot be predicted over intermediate times
- this is statement only about prediction, not about reality itself

thought experiment

- distant interacting molecule
- nearby observed molecule
- interaction
question:

- How long does it take until the interaction leads to an observable bifurcation?
- bifurcation = shift by molecular diameter

interaction of distant particle 1 for $\Delta t_{\text{interaction}}$

\[ F = G \frac{m_1 m_2}{r_{1,2}^2} \]

\[ F = m_2 a \]

\[ a = \frac{\partial^2 s}{\partial t^2} \]

$\Delta t_{\text{interaction}} \Rightarrow \Delta s_0$

\[ \Delta s = \Delta s_0 10^{\Delta t_{\text{scale}}} \]

$\Delta t_{\text{reaction}} = t_{\text{scale}} \left( \log_{10} \frac{2\Delta s}{Gm_1} + 2 \log_{10} r_{1,2} - 2 \log_{10} \Delta t_{\text{interaction}} \right)$
influence between two water molecules

interaction spheres at proceeding time

water molecule with van-der-Waals forces
water molecule with delta gravitation
water molecule with gravitation

reaction time in ps

distance in m

moon
sun
Andromeda galaxy
observable universe

interaction spheres

distant interacting particle

nearby observed molecule

x
y
z

observed molecule

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Liège université
cone of interaction

- particle at end of observable universe
- at $t = 0$: big bang

33 ps later: bifurcation

picture

- all particles send information
- travels with speed of light
- any particle experiences at every moment the sum of all interactions with all particles
- interactions superimpose linearly
- reacts to this interaction
- if any faraway particle would have been in a slightly different place, after at most 33 ps the observed particle would react differently at any multi-furcation
consequences

- all particles influence each other within 0 to 33 ps on universal scale (possibly much faster)
- but: speed of light
- this is about interaction in reality, not only about prediction
- randomizing effect
- even in a fully deterministic world view
- characterizes reality properly or model deficient
- state at big bang not only initial condition but all particles since then exert a current randomizing influence
- molecules behave random (strictly unpredictable) after few ps at most
- applies to all deterministically chaotic systems

Ernst Mach

There is no cause nor effect in nature; nature has but an individual existence; nature simply is.

A Critical and Historical Account of its Development.
Translated by Thomas J. McCormack.
The Open Court Publishing Co., Chicago, 1919.
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