Twin paradox and chaos

Particles’ trajectories in standing gravitational waves field

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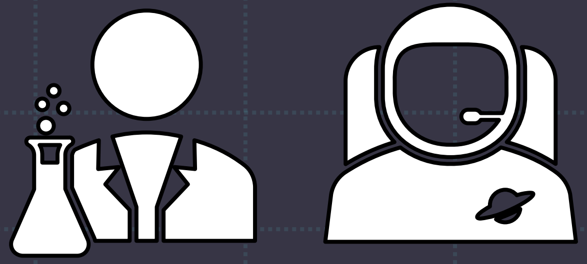
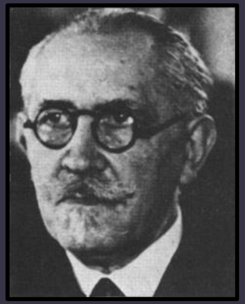
Outline

1. The twin paradox
2. (Standing) Gravitational waves
3. Chaos
4. Chaos vs standing gravitational waves
5. „Twin paradox” and Chaos
6. Summary

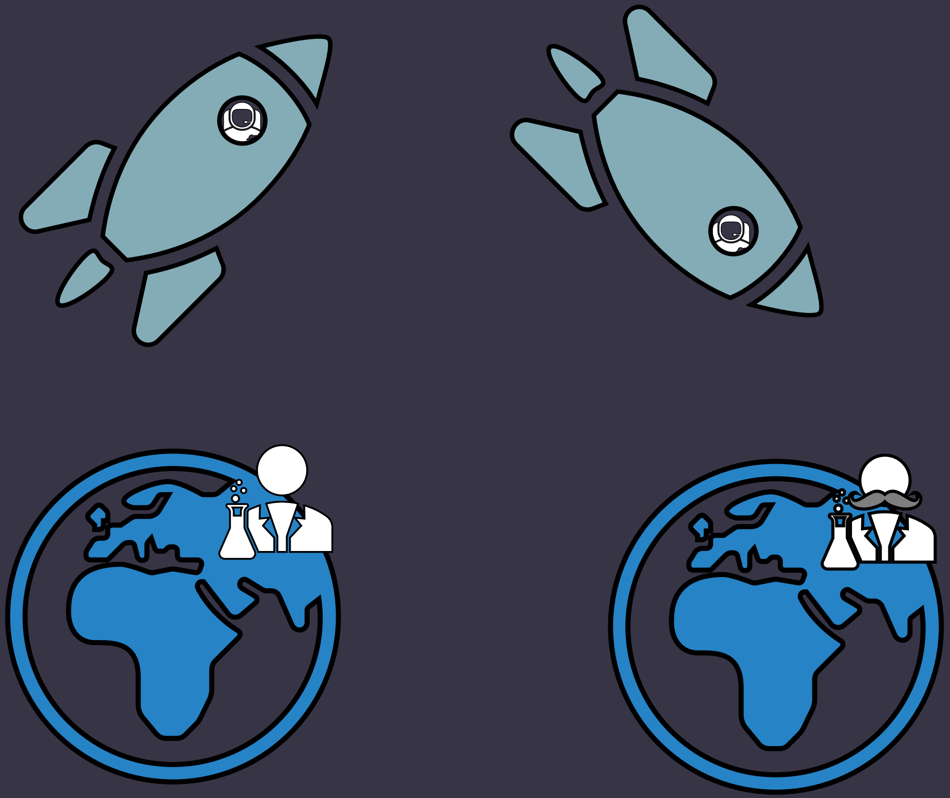
The twin paradox



First formulation

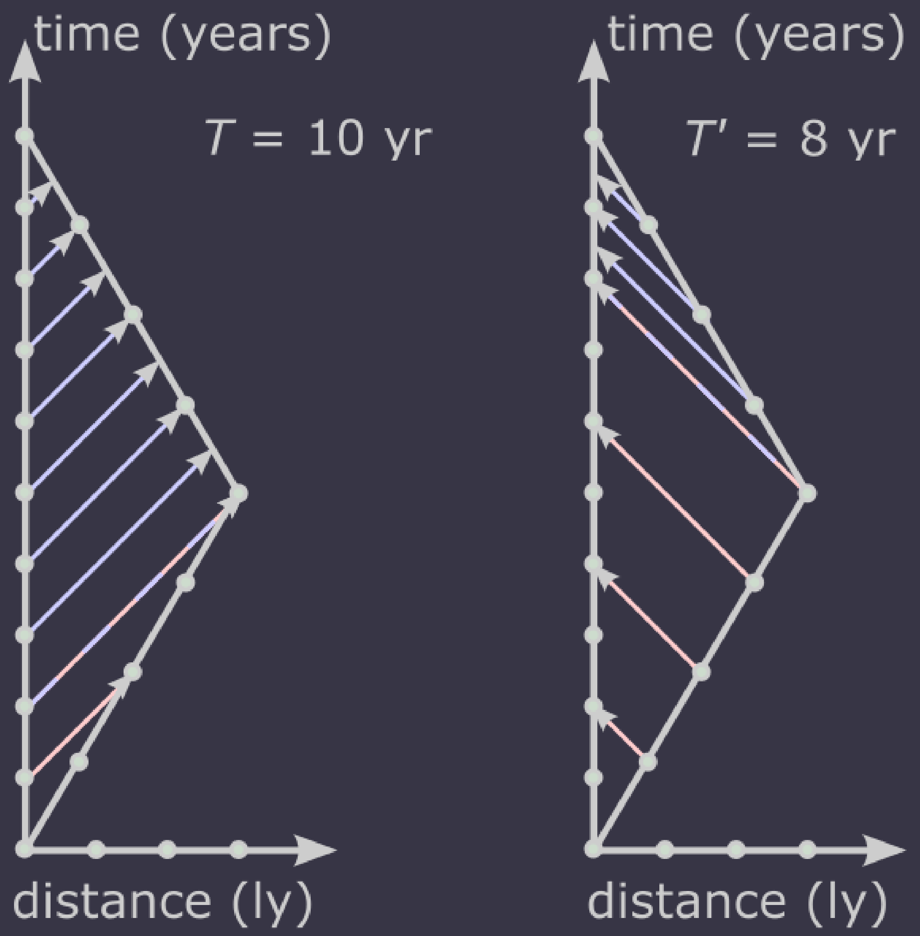


1. 1911 r. Paul Langevin
2. Thought experiment
3. Flat (no gravity) spacetime
4. First twin is setting off on a journey, while second is staying on the Earth



Why the „paradox"?

1. Misunderstanding of Einstein's theory of relativity
2. The twins are not equivalent
3. There is no paradox here
4. The „Traveller" is always younger (in flat spacetime)

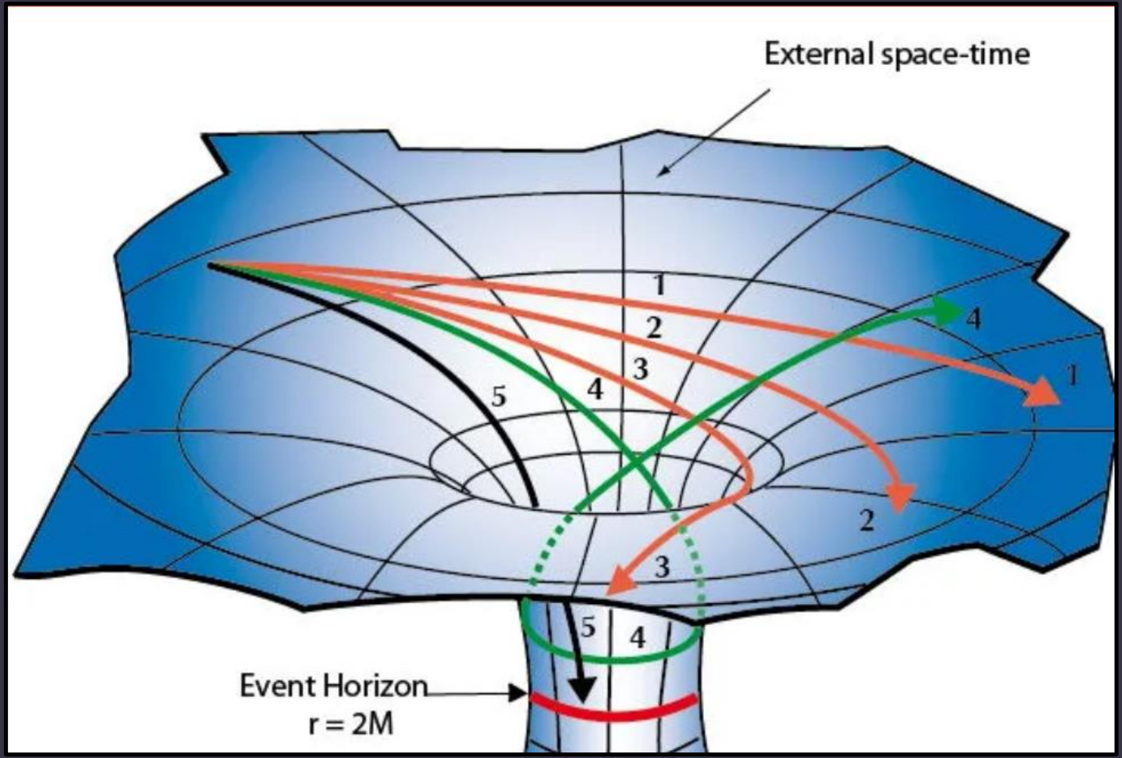


Credit: Prokaryotic Caspase Homolog

Schwarschild spacetime

1. More complicated
2. Sokołowski (2012)
3. Trajectory matters (neither velocity nor acceleration)
4. The twin on radial geodesics ($\phi = const$) always the oldest

Image credit: solarseven via Getty Images

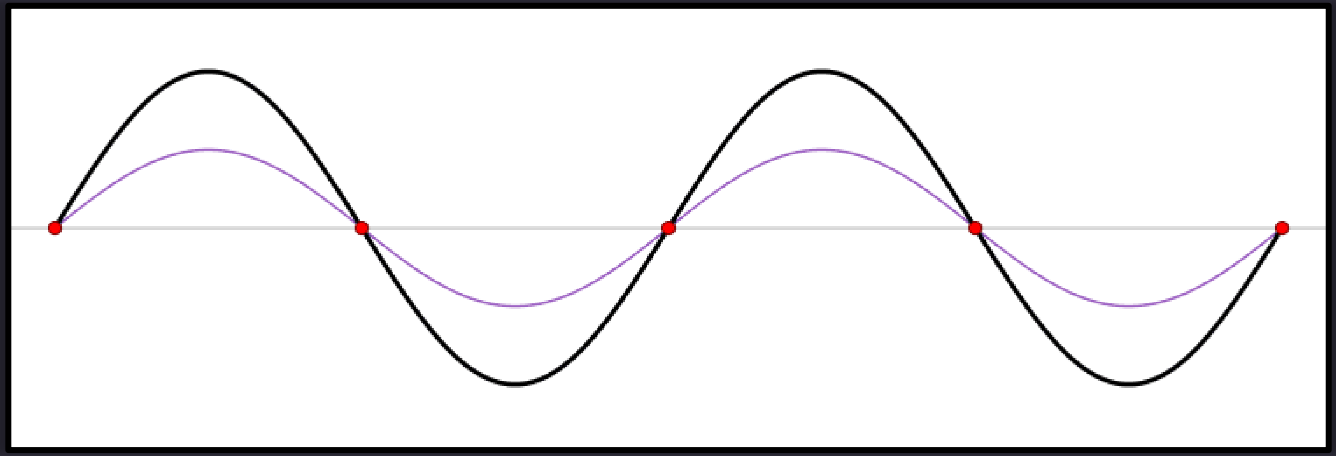


https://weinsteing.wordpress.com/2017/12/14/the-geodesics-of-the-schwarzschild-metric-3/

Standing gravitational waves

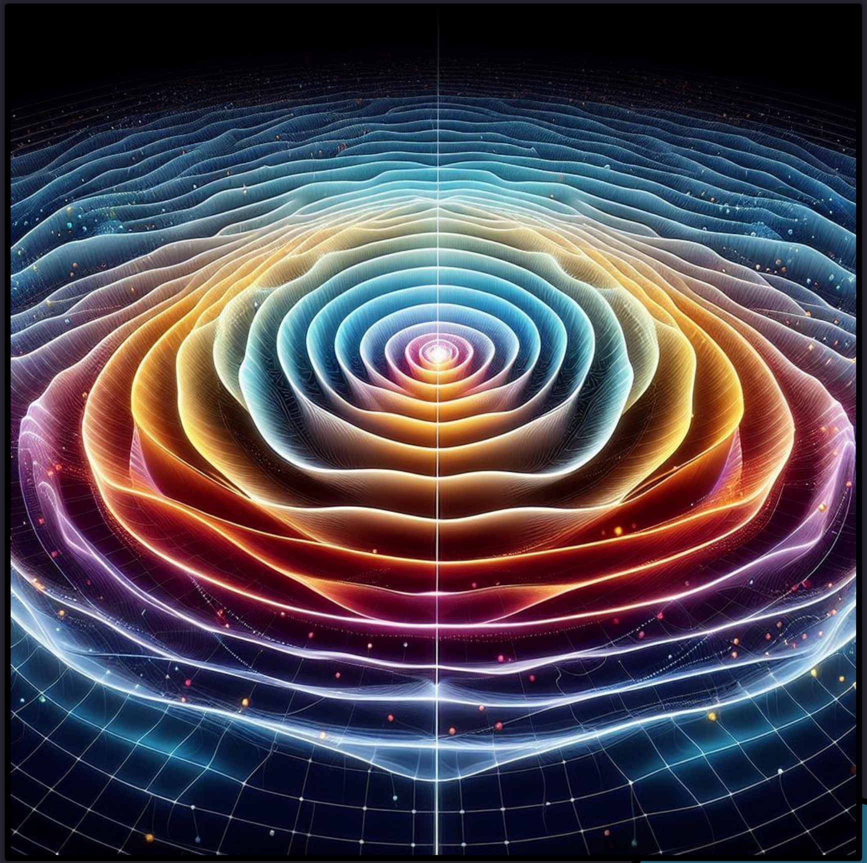
Standing mechanical waves

1. Not moving in space
2. Result of interference
3. Music (string) instruments

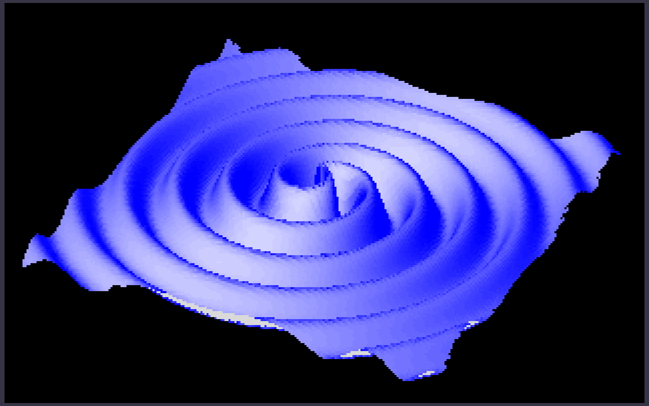


Standing Gravitational Waves (GW)

1. Similar to mechanical standing waves
2. Cylindrical symmetry
3. Vacuum solution of Eintein time-dependent equations

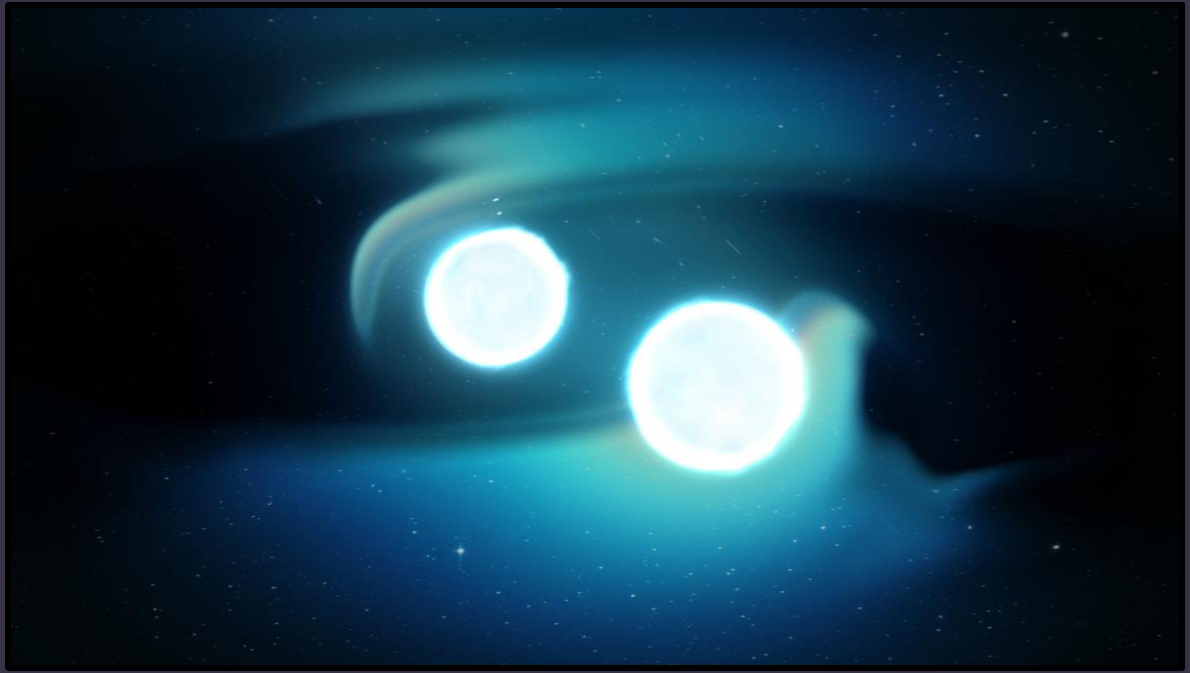


Gravitational wave sources



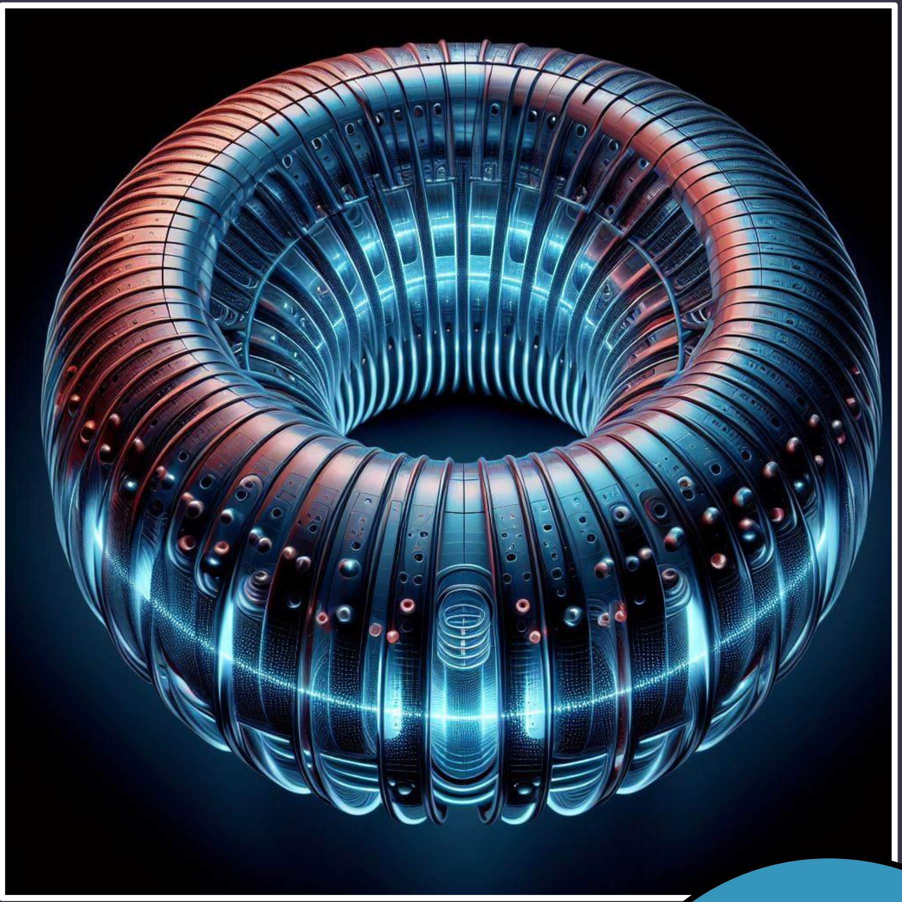
1. For example: Close binary systems of compact objects

2. What about standing gravitational wave sources?



Experiment

1. Production and detection
2. A source of GW: A Torus with excited altering EM field
3. Interference of produced GW → Standing waves
4. Cylindrical symmetry



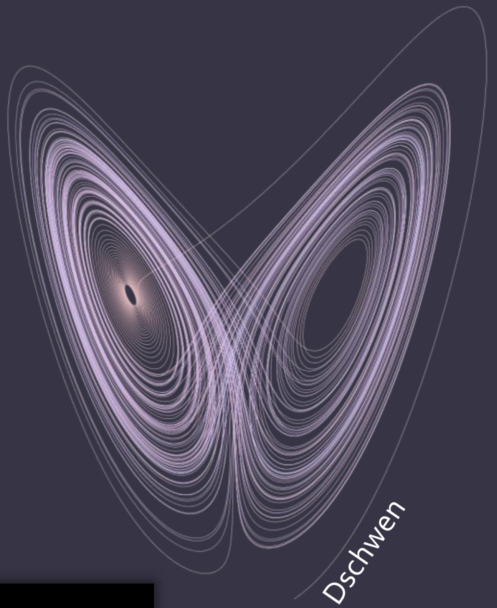
Chaos

What is chaos?

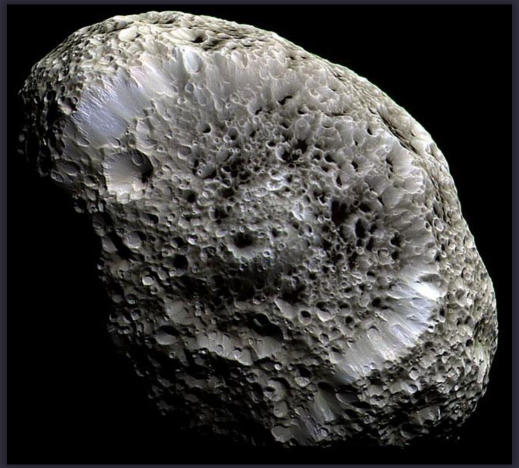
1. Sensitivity for initial conditions
2. Deterministic
3. Can „imitate” randomness after enough long time

Examples of chaotic systems

1. „Butterfly effect” and weather forecast

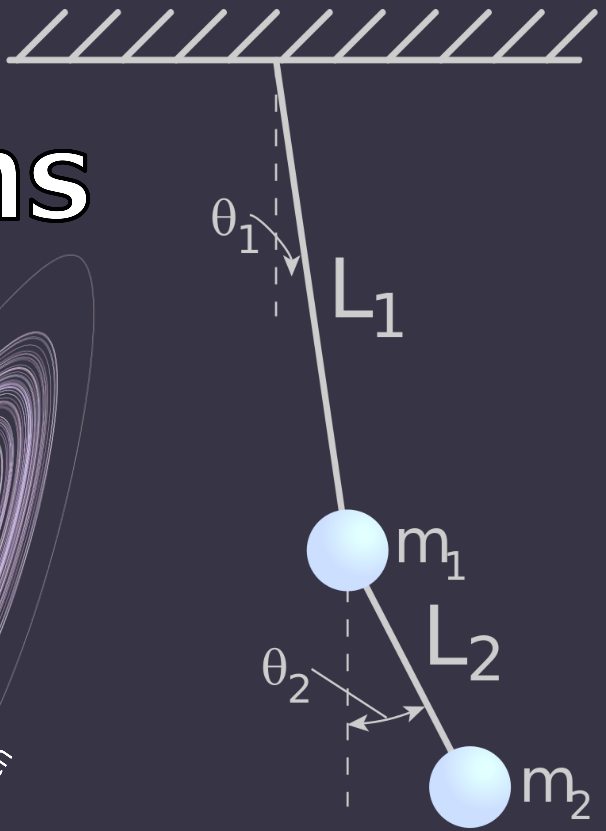


2. Hyperion (Saturn’s moon) trajectory



Credit: NASA/JPL/Space Science Institute

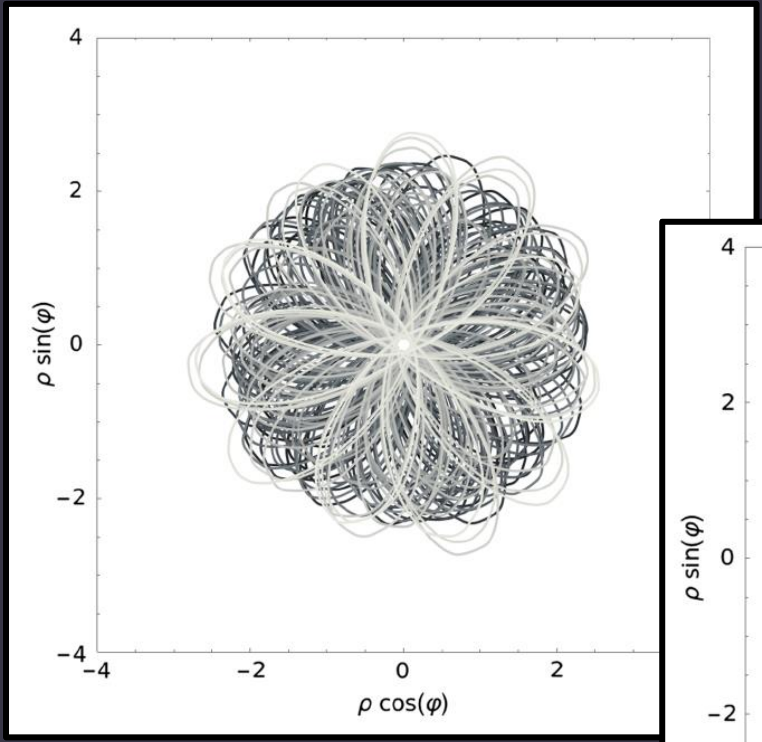
3. Double pendulum



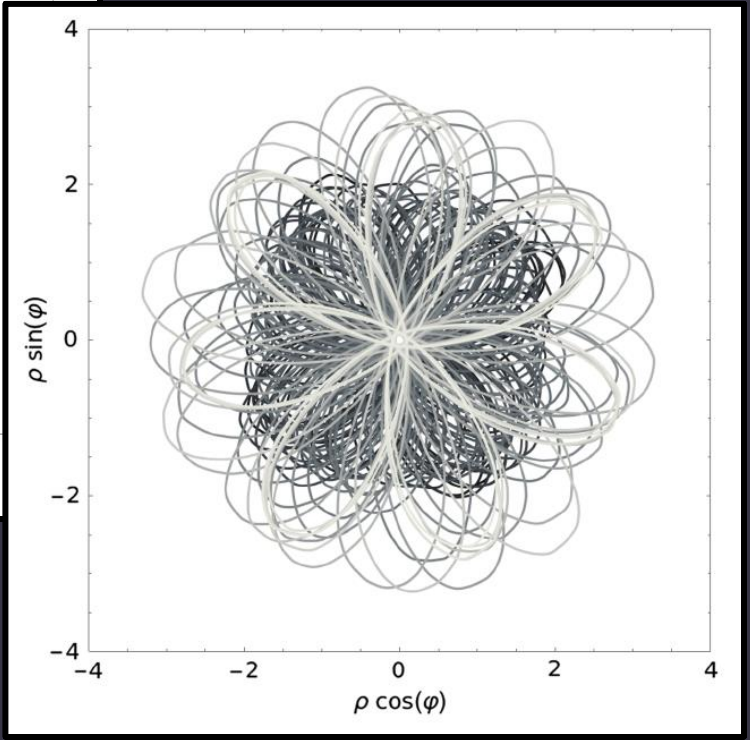
Chaos and standing gravitational waves

„Chaos and Einstein-Rosen GW"

- Szybka, Naqvi, Phys. Rev. D, 108, L081501 (2023)
- $z = const$
- Trajectories for freely falling particles

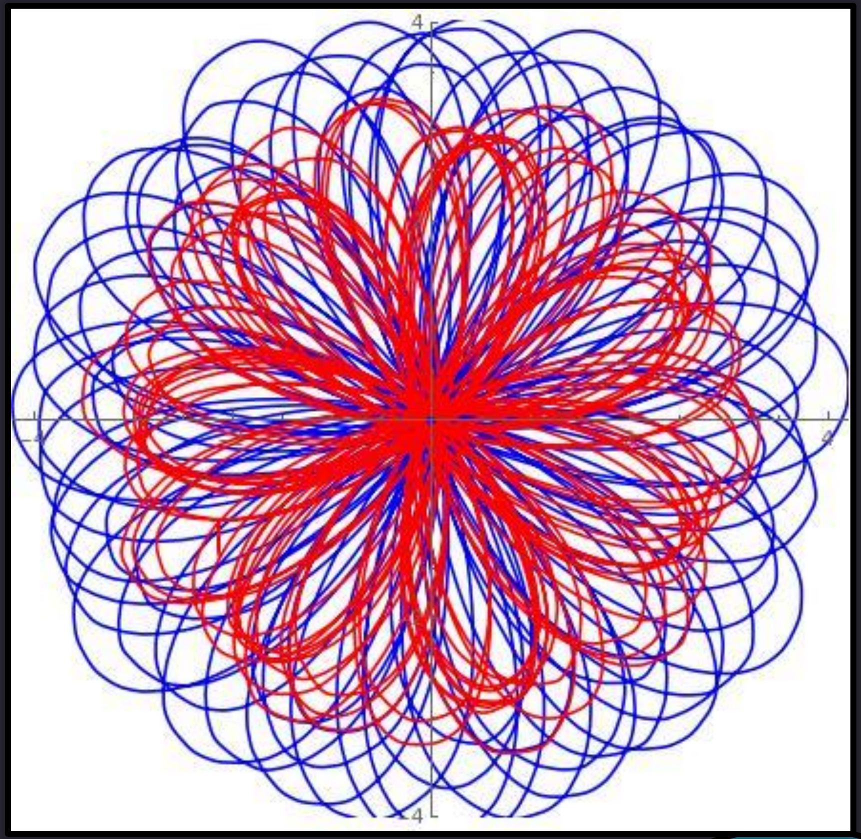


Change of $\dot{\rho}$ by 6×10^{-5}



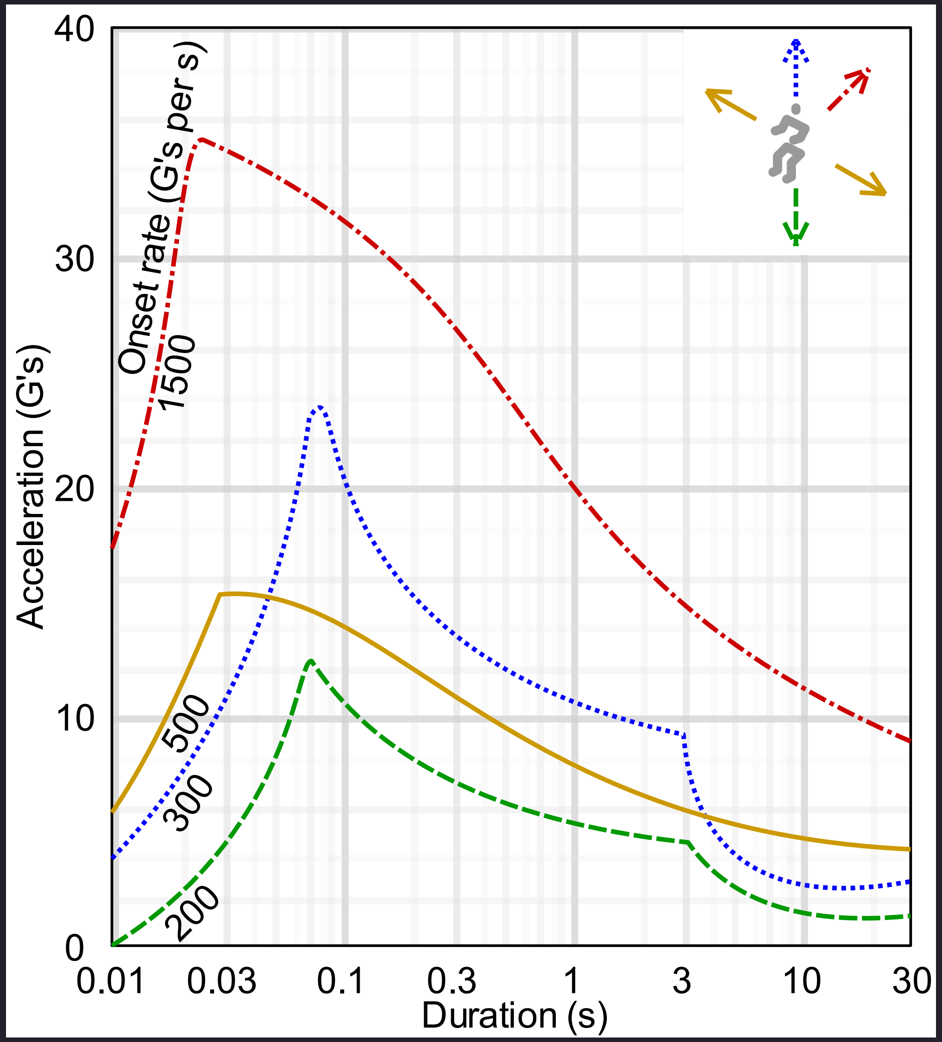
„Twin paradox" and chaos

1. Particles start moving from very similar position: $\rho_A = 3.21,\ \rho_B = 3.22$
2. Trajectories = geodesics
3. Particles need to reunite
4. Comparing proper times („age") of particles: particle B is 17% older



Particles → humans

1. Safe conditions for people
2. Diagram: Acceleration vs duration
3. Different colours - different directions



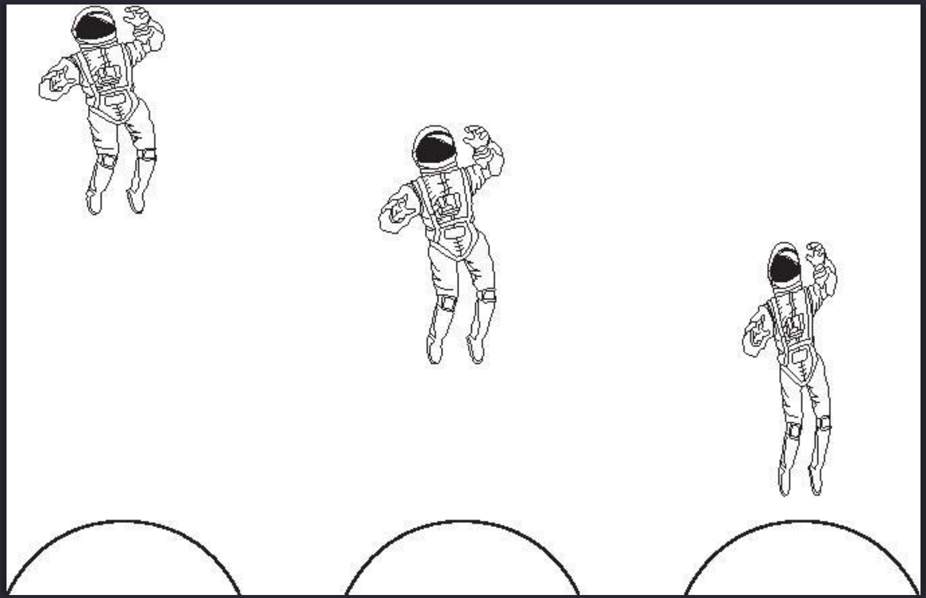
Tidal forces

1. No external forces, just effects from standing graviational waves

2. Nearby geodesics (trajectories) are becoming closer / more distant

↓

Tidal forces



Żr.: https://www.rmg.co.uk/stories/topics/what-happens-if-you-fall-black-hole

Summary

1. Spacetime with standing gravitational waves
2. Chaotic trajectories
3. „Twin paradox" – age difference for freely falling particles
4. Tidal forces safe (e.g.) for humans → scale of the system

Literature

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6. Halilsoy, Nuovo Cimento B 102, 563 (1988)
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