Sinhronija u biologiji, matematici i umetnosti

Nenad Švrakić

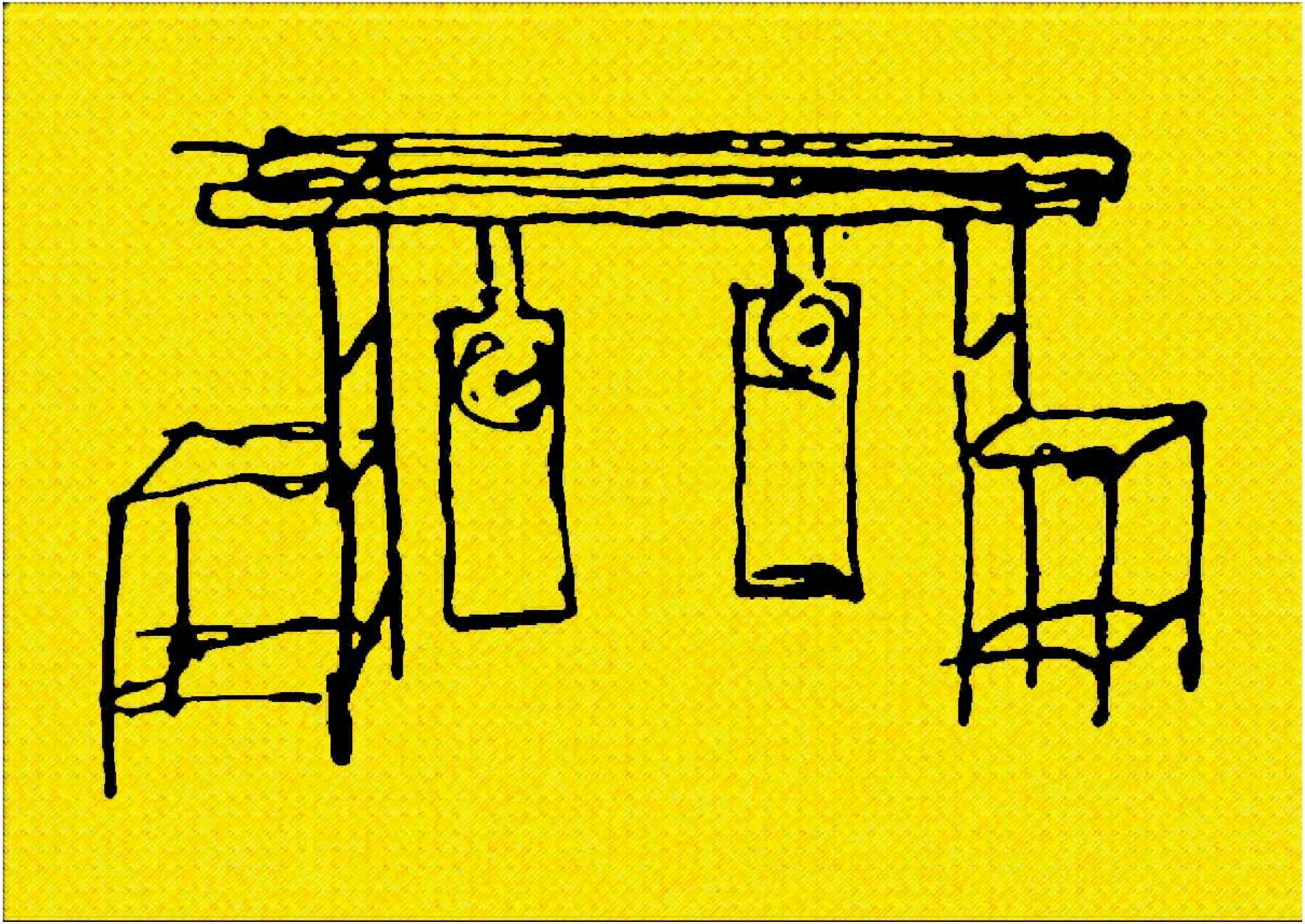
1. У почетку створи Бог небо и земљу.
2. А земља беше <u>без обличја</u> и пуста, и беше тама над безданом; и дух Божји дизаше се над водом

O	I	Φ
Nothing	Unity / God	Nothing split by Unity is Phi, the constant of creation

Christian Huygens

1685

Izumeo sat sa klatnom. Pokušaj da se preciznije izmeri geografska daužina



1: An original drawing describing the Huygens' experiment [Pikovsky et al., 2001; Huygens, 16

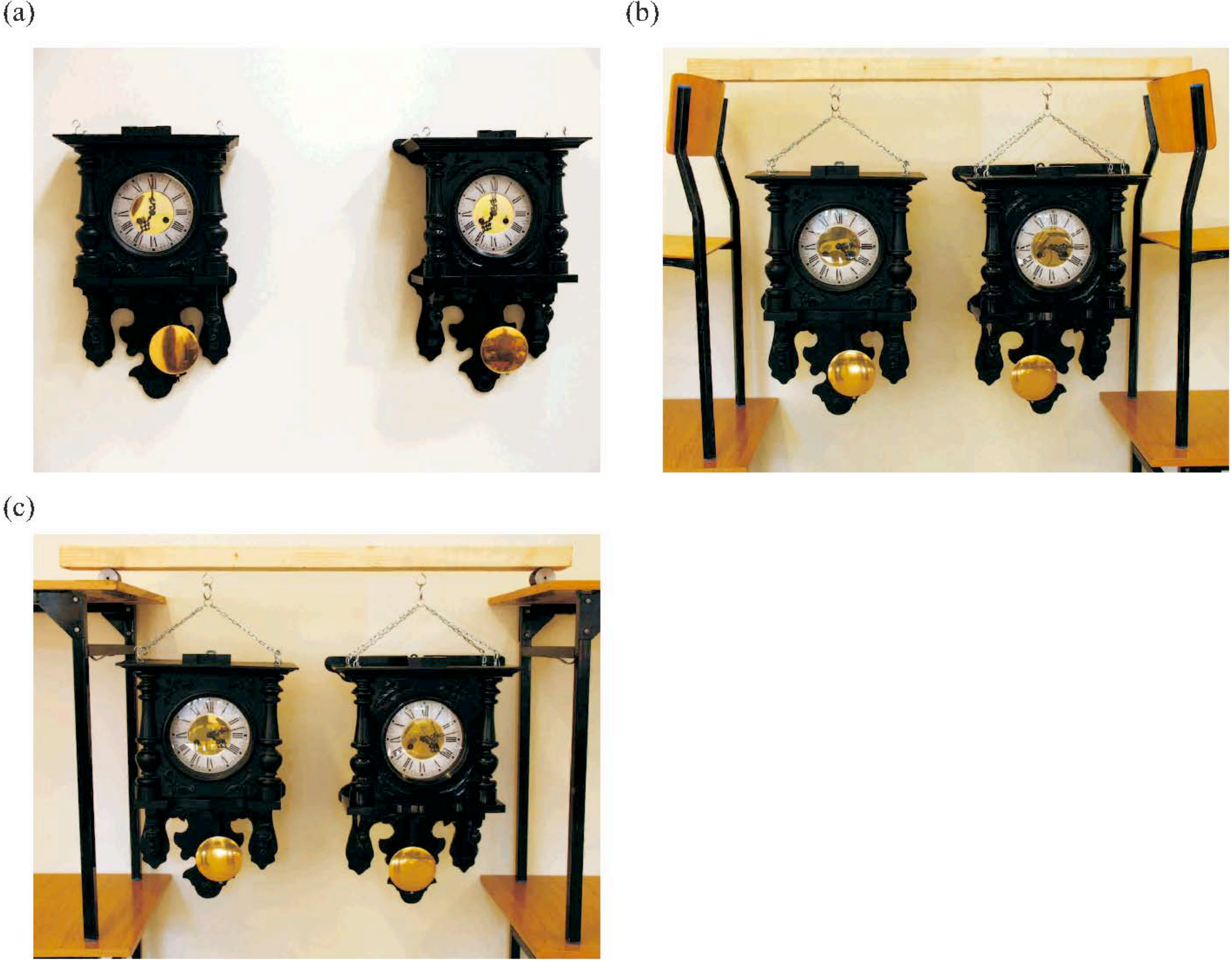


Fig. 2 Experiment with two pendulum clocks: (a) clocks hung on the wall, (b) clocks hung from the beam

SCIENTIFIC REPORTS

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The sympathy of two pendulum clocks: beyond Huygens' observations

Received: 18 November 2015
Accepted: 08 March 2016
Published: 29 March 2016

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This paper introduces a modern version of the classical Huygens' experiment on synchronization of pendulum clocks. The version presented here consists of two monumental pendulum clocks—ad hoc designed and fabricated—which are coupled through a wooden structure. It is demonstrated that the coupled clocks exhibit 'sympathetic' motion, i.e. the pendula of the clocks oscillate in consonance and in the same direction. Interestingly, when the clocks are synchronized, the common oscillation frequency decreases, i.e. the clocks become slow and inaccurate. In order to rigorously explain these findings, a mathematical model for the coupled clocks is obtained by using well-established physical and mechanical laws and likewise, a theoretical analysis is conducted. Ultimately, the sympathy of two monumental pendulum clocks, interacting via a flexible coupling structure, is experimentally, numerically, and analytically demonstrated.

In an era when science relied heavily on observation, experimentation, and reflection, the Dutch scientist Christiaan Huygens made a serendipitous discovery: two of his recently invented pendulum clocks—which were hanging from a common wooden beam placed at the top of two chairs—were showing an 'odd sympathy'. Namely, the pendula of the clocks were oscillating in perfect consonance but in opposite directions, i.e. the clocks were *synchronized* in anti-phase. He reported this odd phenomenon first to R. F. de Sluse, on February 22, 1665 and two days later to his father and to a member of the Royal Society of London[1,2].

Although at that time Huygens did not have the proper mathematical tools for explaining his observations—differential calculus had not been invented yet—he managed to find the mechanism responsible for the sympathy in his clocks: (the small vibrations of) the wooden bar on which the clocks were hanging.

For some reason, the sympathetic motion of pendulum clocks discovered by Huygens, hereinafter called *Huygens' synchronization*, did not attract the attention of the scientific community at that time. In fact, a 'hot topic' in those days was the problem of finding the longitude coordinate at sea. However, in 1739, the English clockmaker John Ellicot reported an odd phenomenon: two pendulum clocks placed sideways were interacting in such a way that the oscillations of one pendulum clock were quenched[3,4]. Latter, in 1873, the English astronomer William Ellis, noticed a sympathetic behaviour on two clocks that were placed on a common wooden stand: during several consecutive days, the pendula of the clocks were oscillating in harmony such that one pendulum was swinging to the left while the other pendulum was swinging to the right. Interestingly, Ellis attempted a 'network' experiment using 9 pendulum clocks. In this case, however, the previously observed harmony disappeared[5]. Unfortunately, neither Ellicot nor Ellis made a reference to the work of Huygens.

At the beginning of the 20th century, D.J. Korteweg made the first theoretical attempt to explain Huygens' observations. Specifically, Korteweg derived a linear model, neglecting damping and driving forces in the pendula. With his model, Korteweg envisioned that 'other kinds of sympathy' may be possible[6]. Besides this, the sympathy of coupled clocks was still considered as a fairly difficult problem among scientists and clockmakers at that time[7]. In fact, a Nature paper of 1911, reported: "it is apparently beyond human ingenuity to produce two clocks which will go together for one week"[8]. In fact, the same paper refers to an experiment, due to Mr. R. L. Jones of Chester, in which the pendula of a group of clocks were forced to beat 'in sympathy' by means of a regulator.

In the last years, Huygens' synchronization has become a relevant topic among scientists and researchers. By designing novel experimental platforms[9–13] and/or by conducting theoretical analyzes[14–24], further understanding

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Synchronization of Two Nonidentical Clocks: What Huygens was Able to Observe?

K. Czolczynski, P. Perlikowski, A. Stefanski, T. Kapitaniak · Computer Science, Physics · 2013

The sympathy of two pendulum clocks: beyond Huygens' observations

J. Peña Ramirez, Luis Alberto Olvera, H. Nijmeijer, J. Álvarez · Physics, Medicine · 2016

Huygens' clocks revisited

A. Willms, P. Kitanov, W. Langford · Biology, Medicine · 2017

Synchronization of clocks

M. Kapitaniak, K. Czolczynski, P. Perlikowski, A. Stefanski, T. Kapitaniak · Physics · 2012

Why two clocks synchronize: energy balance of the synchronized clocks.

K. Czołczyński, P. Perlikowski, A. Stefanski, T. Kapitaniak · Medicine, Physics · 2011

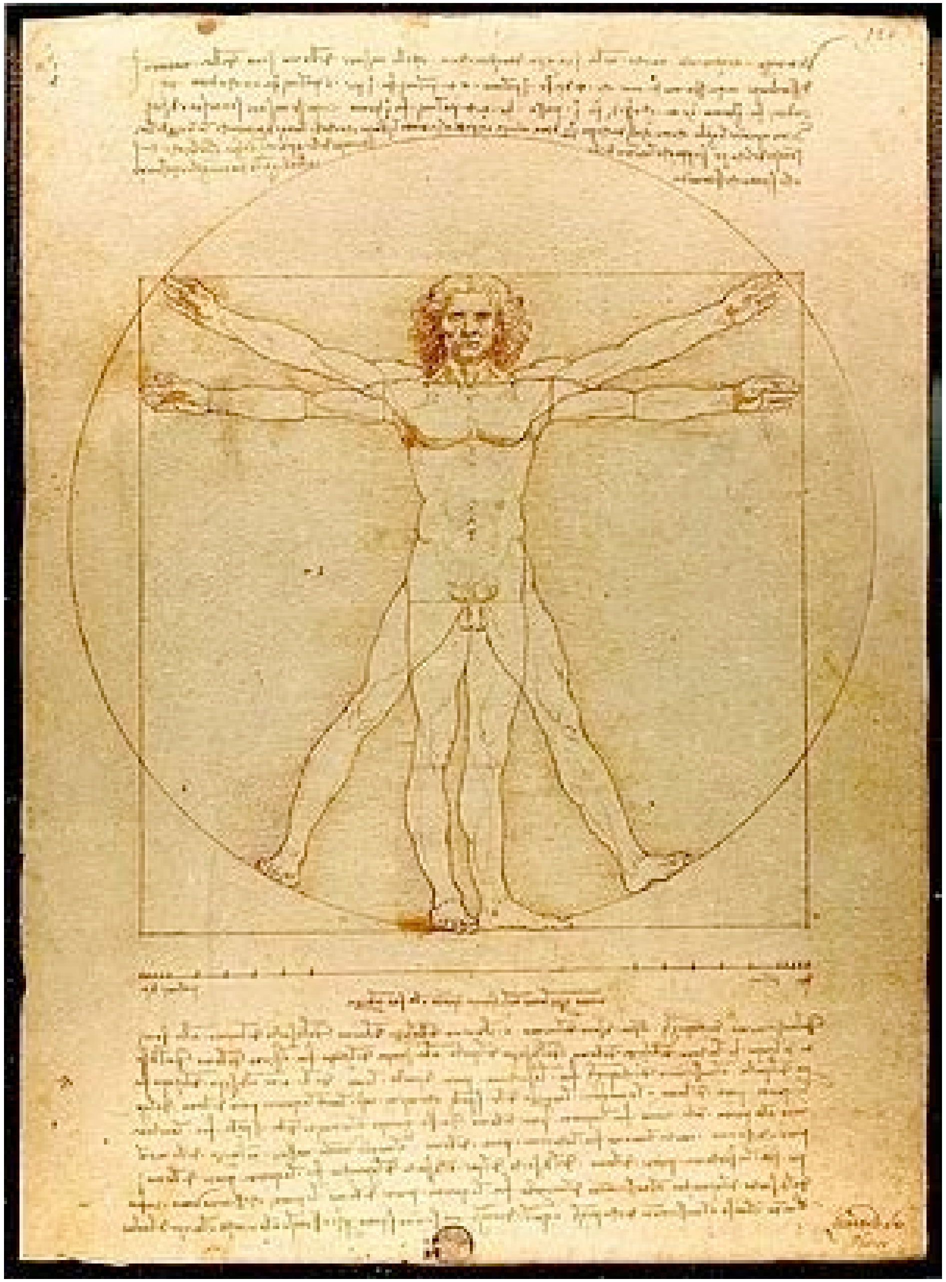
Synchronization of Huygens' clocks and the Poincaré method

V. Jovanovic, S. Koshkin · Physics, Mathematics · 2012

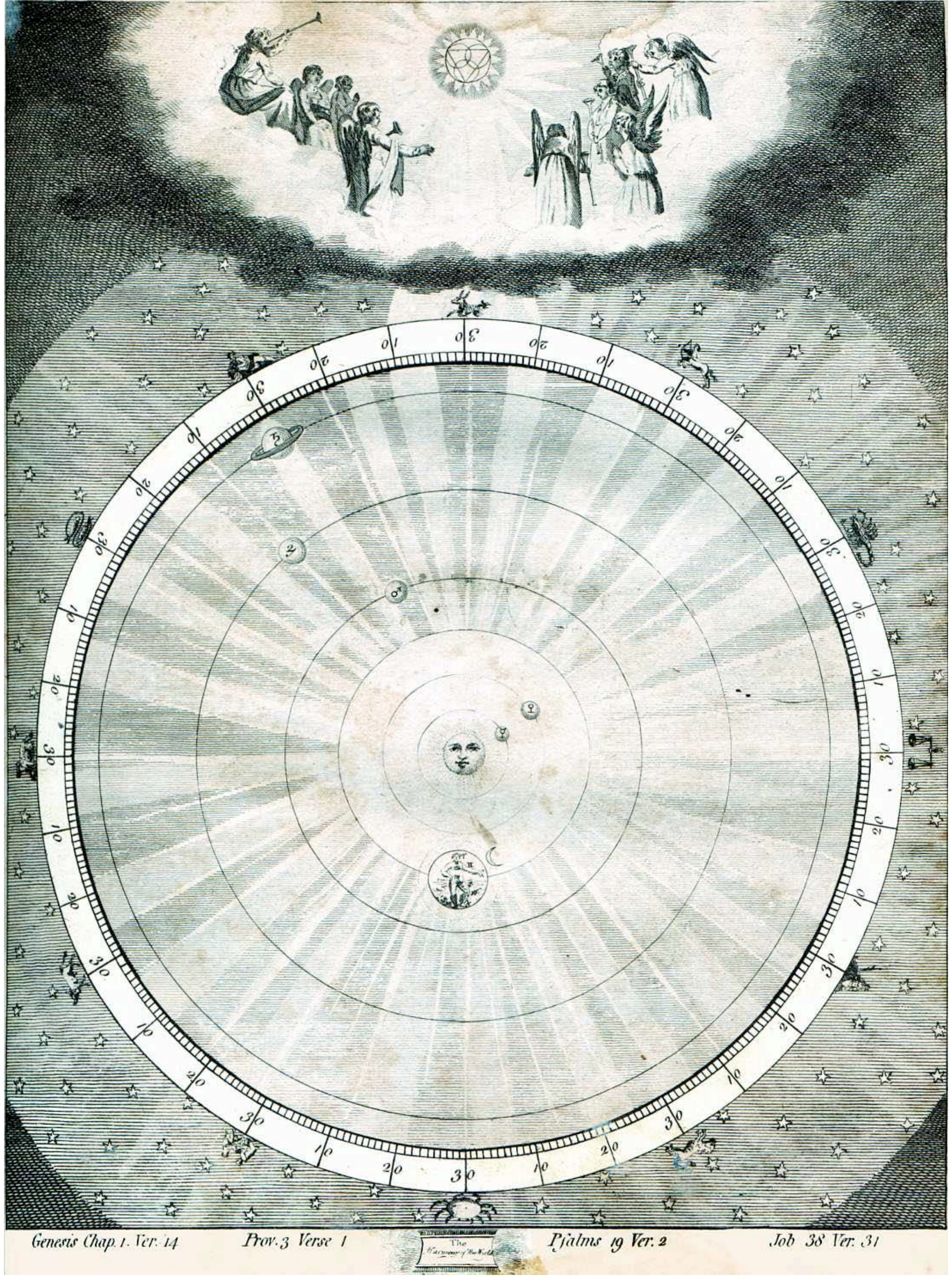
Statičke sinhronije (sklad)

Ljudska građevine
Čovekovo telo
Kosmos


FIFTY ONE EAST



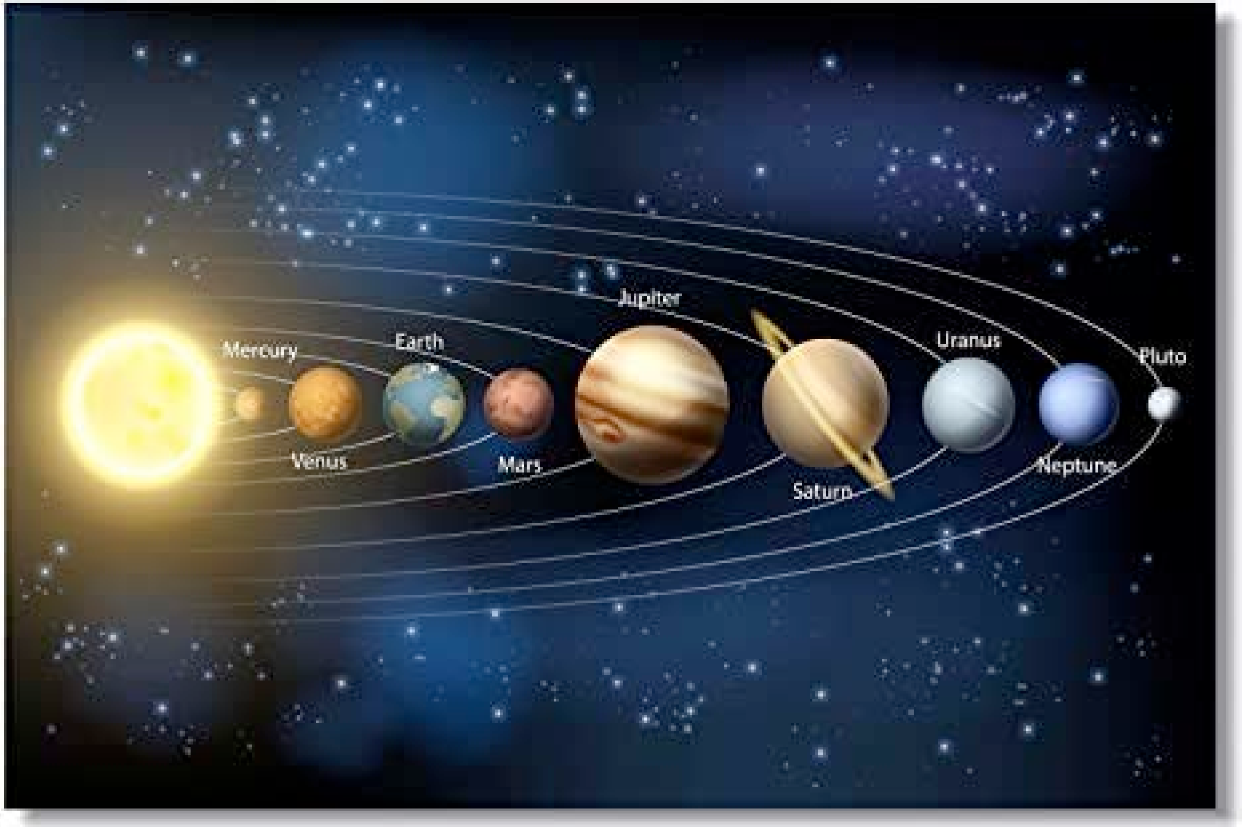
Leonardo Da Vinci 1490



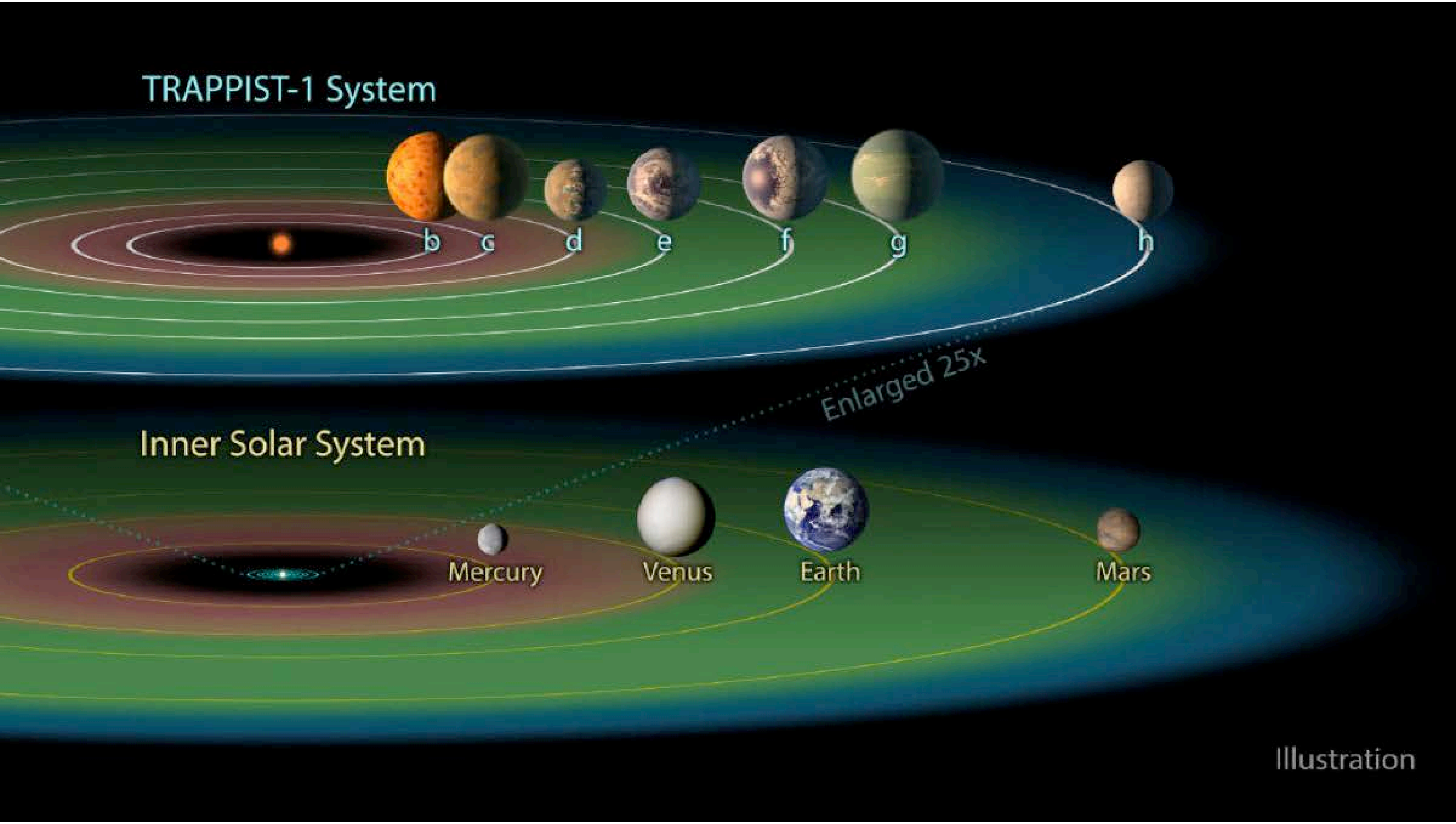
Musica universalis

Muzika sfera

Musica universalis



Januara 2017., NASA je objavila otkriće planetarnog sistema TRAPPIST 1, u sazvežđu Vodolije, na rastojanju od oko 39 svetlosnih godina od nas.



https://www.youtube.com/watch?v=WS5UxLHbUKc&feature=youtu.be

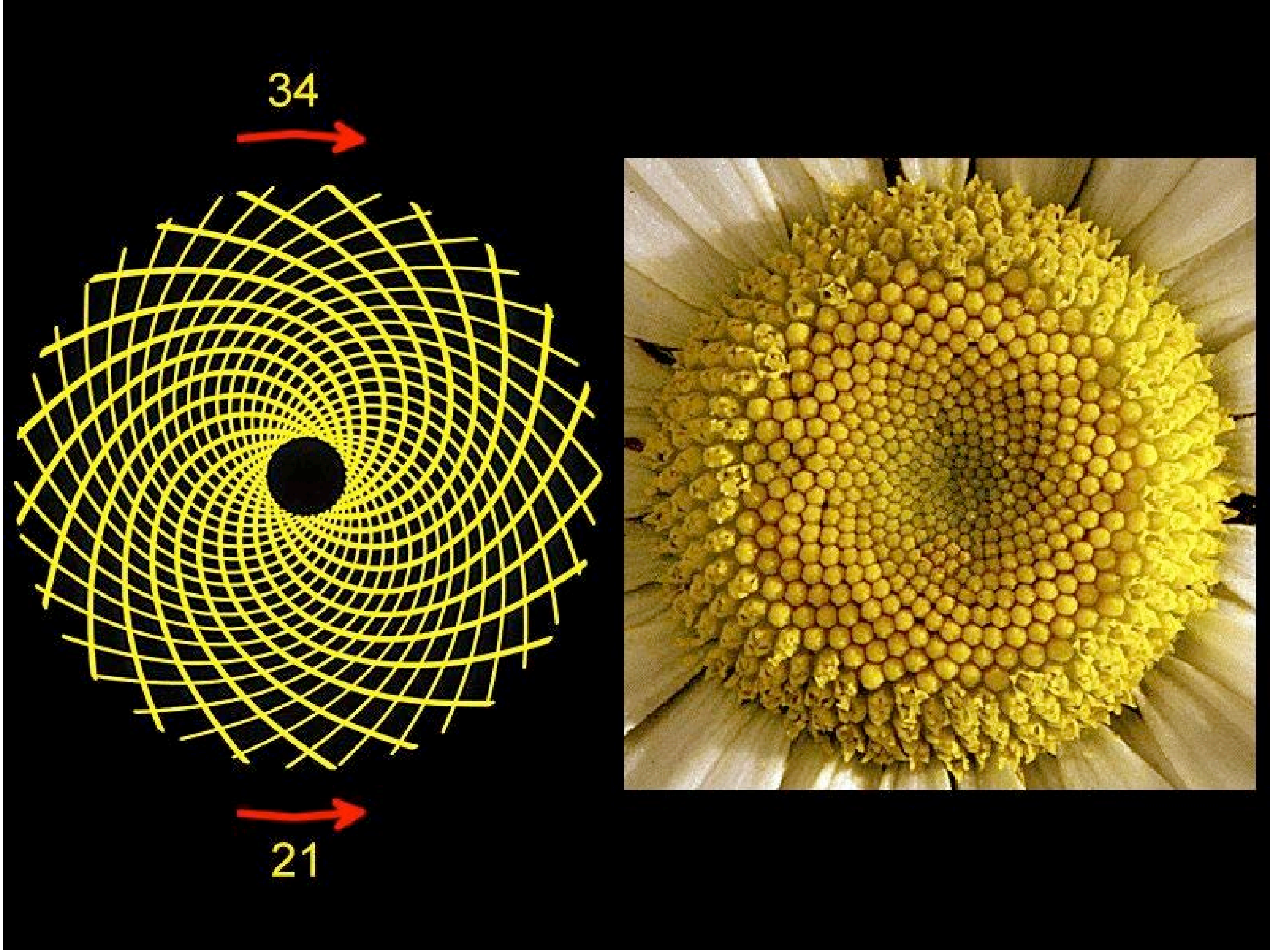
Muzika sfera

https://www.youtube.com/watch?v=WS5UxLHbUKc&feature=youtu.be

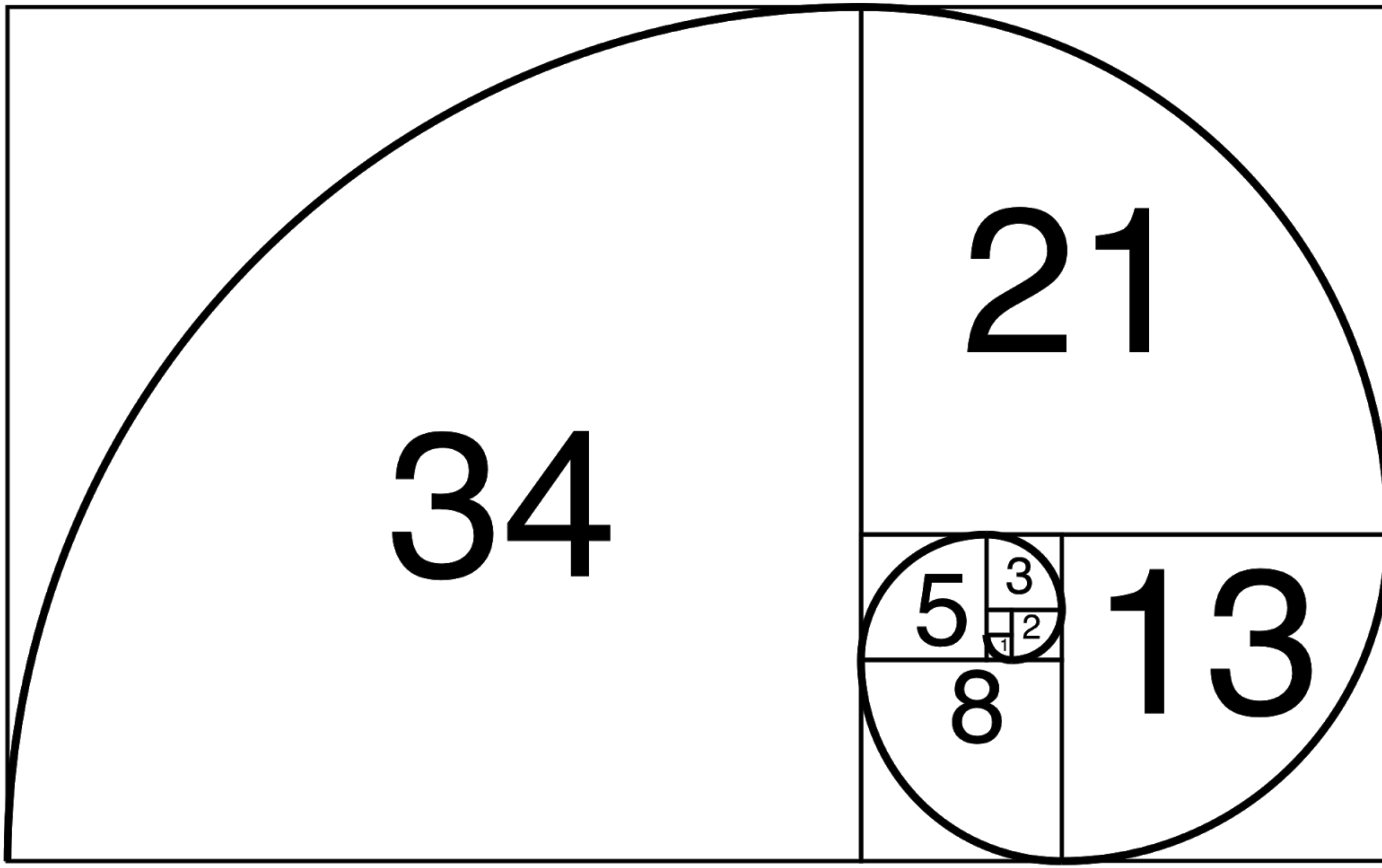
Sklad u prirodnim tvorevinama

Fibonačijev niz

1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610, 987, 1597, …



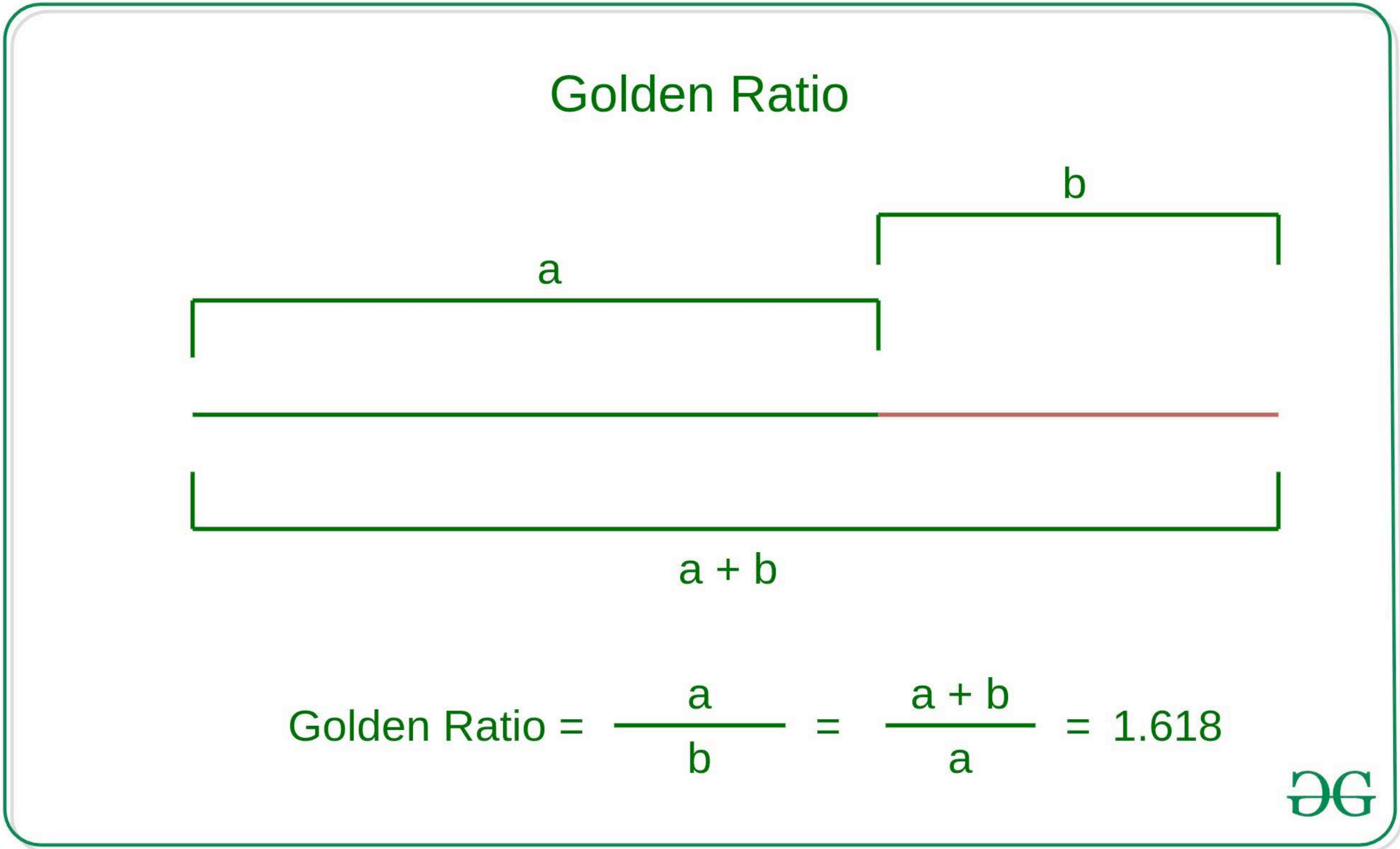
Zlatni presek

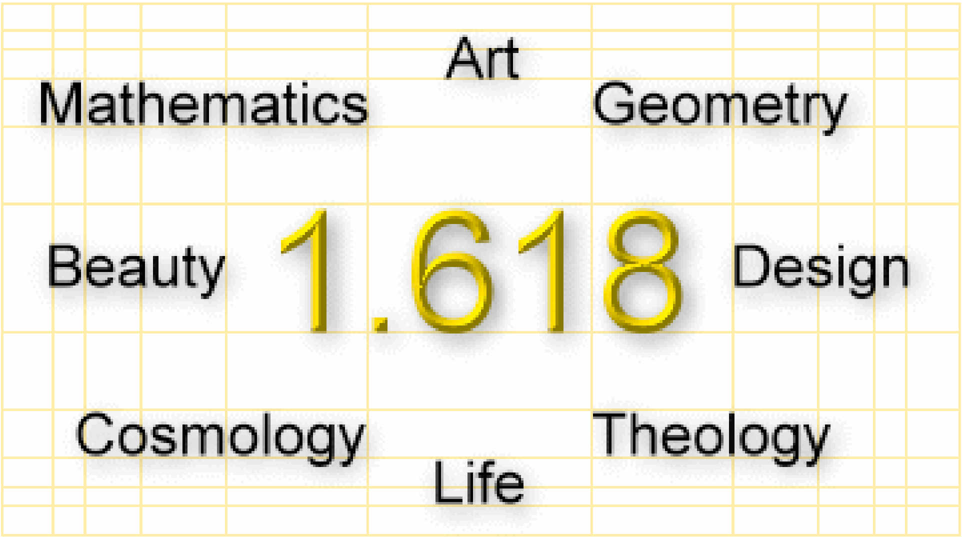

34
21
13
8
5
3
2
1

The ratios of adjacent terms of the fibonacci sequence are also interesting.

1 / 1 = 1	1 / 1 = 1
1 / 2 = .5	2 / 1 = 2
2 / 3 = .666667	3 / 2 = 1.5
3 / 5 = .6	5 / 3 = 1.666667
5 / 8 = .625	8 / 5 = 1.6
8 / 13 = .615385	13 / 8 = 1.625
13 / 21 = .619047	21 / 13 = 1.615385
21 / 34 = .617647	34 / 21 = 1.619047
34 / 55 = .618182	55 / 34 = 1.617647
55 / 89 = .617977	89 / 55 = 1.618182
89 / 144 = .618056	144 / 89 = 1.617977
144 / 233 = .618025	233 / 144 = 1.618056
233 / 377 = .618037	377 / 233 = 1.618025
377 / 610 = .618033	610 / 377 = 1.618037
	...

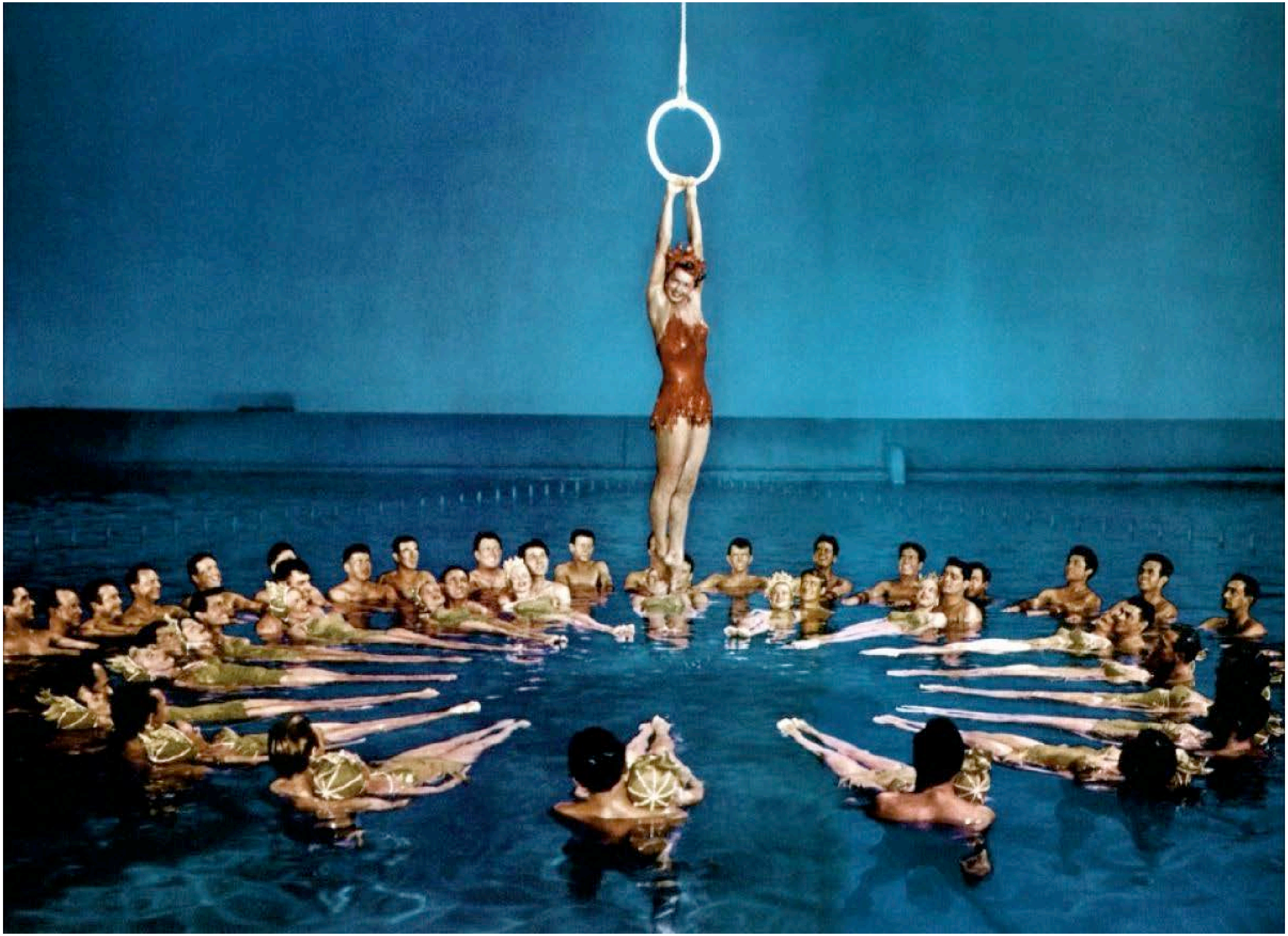
Tri-vizija celine




Art
Mathematics
Geometry
Beauty
1.618
Design
Cosmology
Theology
Life

Dinamičke sinhronije (koordinacija)

Ester Vilijams



https://www.youtube.com/watch?v=ZGvtnE1Wy6U

https://www.youtube.com/watch?v=V4f_1_r80RY

Starling - Čvorak

Sardele

13-godišnji cilkusi cikada
17-godišnji ciklusi cikada
60 godišnje cvetanje bambusa
120 godišnje cvetanje bambusa

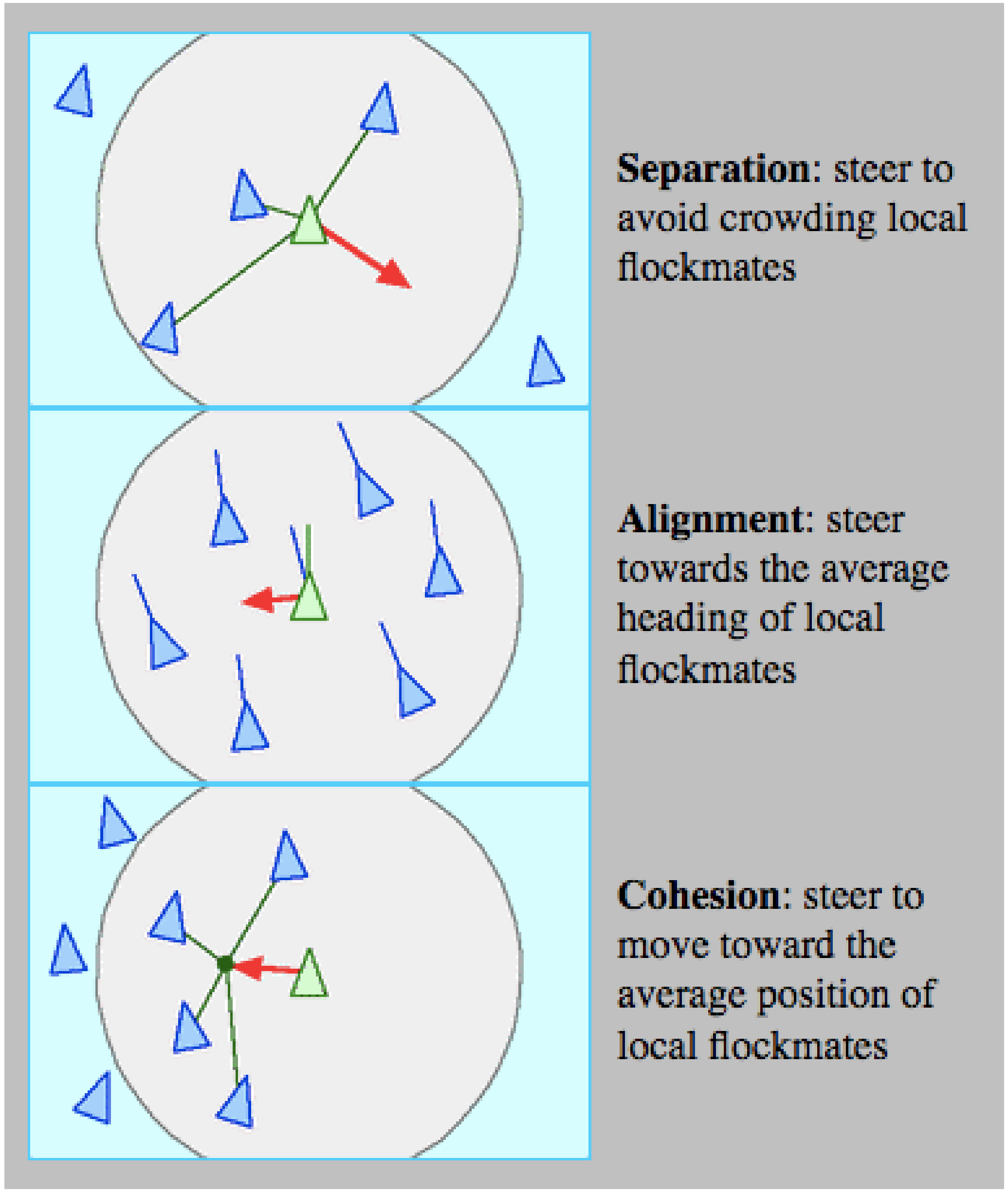
Cvrčak u Dalmaciji?

Cvrči kad je temperatura veća od 25C

Sinhronija cvrčanja

https://www.youtube.com/watch?v=cyIBbofXHzg

Matematički model dinamičke koordinacije



Moždani talasi – neuralne oscilacije

Hans Berger 1924

2.1. 1 Brain Waves

Frequency band	Frequency	Brain states
Beta (β)	12–**35 Hz**	Anxiety dominant, active, external attention, relaxed
Alpha (α)	8–**12 Hz**	Very relaxed, passive attention
Theta (θ)	4–8 Hz	Deeply relaxed, inward focused
Delta (δ)	0.5–4 Hz	Sleep
Theta (θ)	4–8 Hz	Deeply relaxed, inward focused
Delta (δ)	0.5–4 Hz	Sleep

VOLUME 93, NUMBER 17 PHYSICAL REVIEW LETTERS week ending 22 OCTOBER 2004

Chimera States for Coupled Oscillators

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(Received 19 July 2004; published 22 October 2004)

Arrays of identical oscillators can display a remarkable spatiotemporal pattern in which phase-locked oscillators coexist with drifting ones. Discovered two years ago, such “chimera states” are believed to be impossible for locally or globally coupled systems; they are peculiar to the intermediate case of nonlocal coupling. Here we present an exact solution for this state, for a ring of phase oscillators coupled by a cosine kernel. We show that the stable chimera state bifurcates from a spatially modulated drift state, and dies in a saddle-node bifurcation with an unstable chimera state.

DOI: 10.1103/PhysRevLett.93.174102 PACS numbers: 05.45.Xt, 89.75.Kd

"Wonderfully lucid and thoroughly entertaining."
—BRIAN GREENE, author of *The Elegant Universe*

SYNC

HOW ORDER EMERGES FROM CHAOS IN THE UNIVERSE, NATURE, AND DAILY LIFE

STEVEN STROGATZ