Nobelio fizikos 2021 metų premija. Laureatai ir jų tyrimai

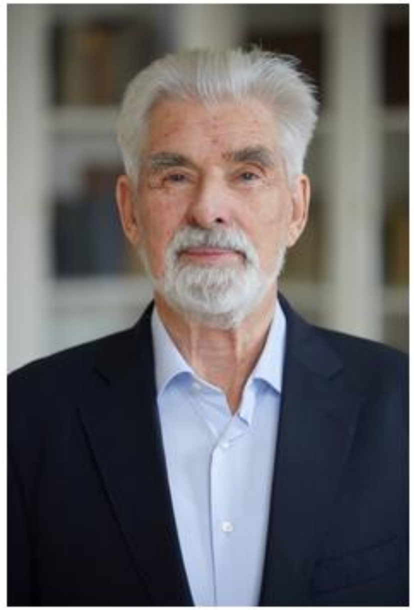
Bronius Kaulakys

Vilniaus universitetas
Teorinės fizikos ir astronomijos institutas

The Nobel Prize in Physics 2021

Syukuro Manabe

Prize share: 1/4



Klaus Hasselmann

Prize share: 1/4

Giorgio Parisi

Prize share: 1/2

Gimė 1931 m. Mokėsi Tokijo universitete, Japonija. Dirbo Prinstono universitete, JAV

Gimė 1931 m. Mokėsi ir dirbo Hamburgo universitete ir Makso Planko institute, Vokietija

Gimė 1948 m. Mokėsi ir dirba Romos Sapienza universitete, Italija.
La Sapienza -didžiausias Europoje įkurtas 1303 m. universitetas

2021 m. Nobelio fizikos premija už „novatoriškus indėlius didinant mūsų supratimą apie sudėtingas (kompleksines) fizikines sistemas"

The Nobel Prize in Physics 2021 was awarded "for groundbreaking contributions to our understanding of complex systems"

Pusė premijos už "Žemės klimato fizinį modeliavimą, kintamumo kvantifikaciją ir patikimą pasaulinio atšilimo prognozavimą"

with one half jointly to Syukuro Manabe and Klaus Hasselmann "for the physical modelling of Earth's climate, quantifying variability and reliably predicting global warming"

Kita premijos pusė už "netvarkos ir fluktuacijų tarpusavio sąryšio fizinėse sistemose, pradedant atomų, baigiant planetų lygmeniu, atradimą"

and the other half to Giorgio Parisi "for the discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales."

Prof. S. Manabe, gimęs 1931 m. Šingu, Japonijoje, dirba Prinstono universitete – meteorologas ir klimatologas – **vienas pirmųjų pastebėjęs, kad anglies dvideginis prisideda prie atmosferos kaitimo ir visuotinio atšilimo**.
Anglies dvideginio koncentracija atmosferoje didina Žemės paviršiaus ir troposferos (iki 10 km virš Žemės) temperatūrą (***Šiltnamio efektas***), bet mažina stratosferos (tarp 10 ir 50 km virš Žemės) temperatūrą. Tai buvo ir yra toliau intensyviai plėtojama.

Meteorologo ir okeanografo **K. Hasselmanno** tyrimai daugiausia susiję su orų prognozėmis ir klimato kaita. **Prof. K. Hasselmannas**, gimęs 1931 m. Hamburge, Veimaro respublikoje, dirba Makso Planko institute Hamburge. Labiausiai žinomas kaip jo vardu pavadinto modelio, ***Hasselmann model***, autorius. Šis modelis **susieja ilgos atminties vandenynų raidą su sparčia, sunkiai numatoma orų ir klimato kaita**.

Prof. G. Parisi, gimęs 1948 m. Romoje, – labai garsus, plataus mąsto daug padaręs **fizikas teoretikas**. Dirba Romos „La Sapienza“ universitete.

Jo tyrimų sritys apima **nuo kvantinės chromodinamikos, medžiagų sandarų formavimosi, iki viesulų ir paukščių būrių susidarymo**.

Jis atliko **fundamentalius teorinius darbus statistinės fizikos, kuri plėtojama jau daug dešimtmečių, srityje**.

Žinomos ir plačiai naudojamos **fundamentalios lygtys, kurių pavadinimuose yra prof. G. Parisi pavardė**.

Oficialus Nobelio fizikos komiteto premijos skyrimo pagrindimas

Scientific Background on the Nobel Prize in Physics 2021
“FOR GROUNDBREAKING CONTRIBUTIONS TO OUR UNDERSTANDING OF COMPLEX PHYSICAL SYSTEMS”
The Nobel Committee for Physics

Pradedamas nuo
Įvado

“This year's Nobel Prize in Physics focuses upon **the complexity of physical systems, from the largest scales experienced by humans, such as Earth's climate, down to the microscopic structure and dynamics of mysterious and yet commonplace materials, such as glass**.”

Toliau nuo nestabilumo, netiesiškumo, daugia-masteliškumo, kompleksiškumo ir stochastiškumo

A. Instability and nonlinearity underlie multiscale complexity and stochasticity

Nuo laminaraus ir turbulentinio judėjimo (**1953** m. monografija), tvarkos ir netvarkos…
B. B. Mandelbrot straipsnio ir t. t.
link klasikinio **Edward Lorenz 1963** m. Deterministic nonperiodic flow. J. Atmos. Sci. **20**, 130 ir kitų darbų.

Lorenco lygtys

$$\frac{dX}{dt} = \sigma(Y - X),$$
$$\frac{dY}{dt} = X(Ra - Z) - Y \qquad \text{and}$$
$$\frac{dZ}{dt} = XY - \beta Z,$$

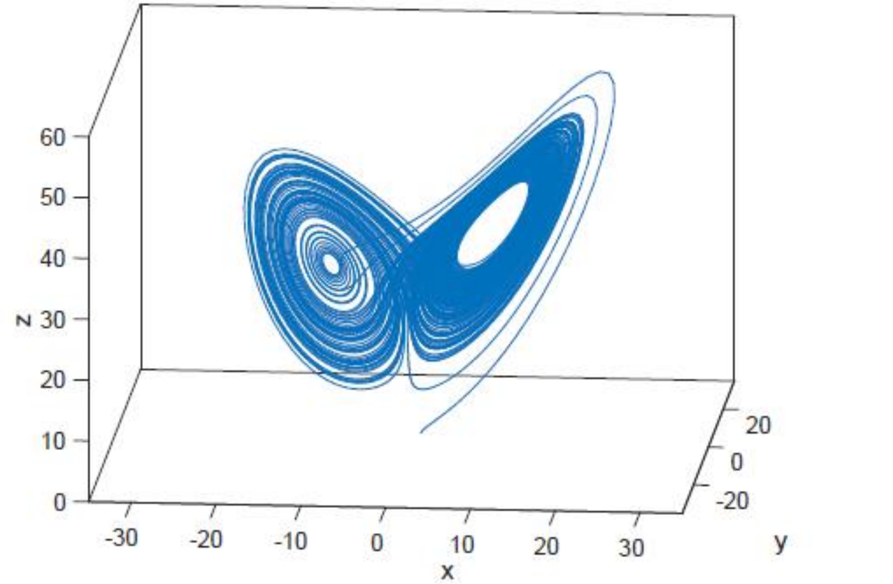


FIG. 1. Plot in (X, Y, Z) phase space of numerical simulation of a circuit version of Lorenz system at $(\sigma, \beta, Ra) = (10, 8/3, 33.5)$, from Weady *et al.* (2018).

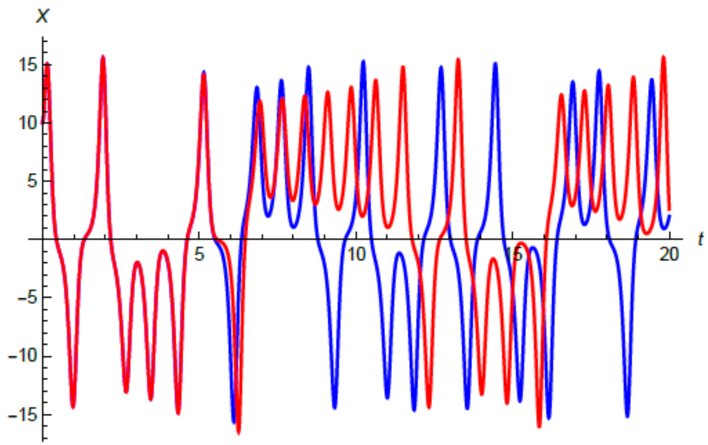


FIG. 2. Plot of $X(t)$ of the Lorenz system with $(\sigma, \beta, Ra) = (10, 8/3, 24.9)$ in which the initial data for all three variables are 10 (blue) or 10.01 (red). The divergence of the two solutions with slightly different initial conditions begins at $t = 5.5$; this is sensitive dependence on initial conditions, often whimsically referred to as the "Butterfly Effect".

Prof. Kęstučio Pyrago dažnai rodomi paveikslai pasakojant apie deterministinį (dinaminį) chaosą

Jo straipsnis, nors nėra tiesiogiai siejamas su Lorenz sistema, bet str. K. Pyragas, *Continuous Control of Chaos by Self-Controlling Feedback*, Phys. Lett. A **170**, 421-427 (1992). **Cituotas apie 3000 kartų.**

Kituose strainsniuose nagrinėjama ir Lorenz sistema:

V. Pyragas, K. Pyragas, *Delayed feedback control of the Lorenz system* …Phys. Rev. E **73**, 036215 (**2006**).

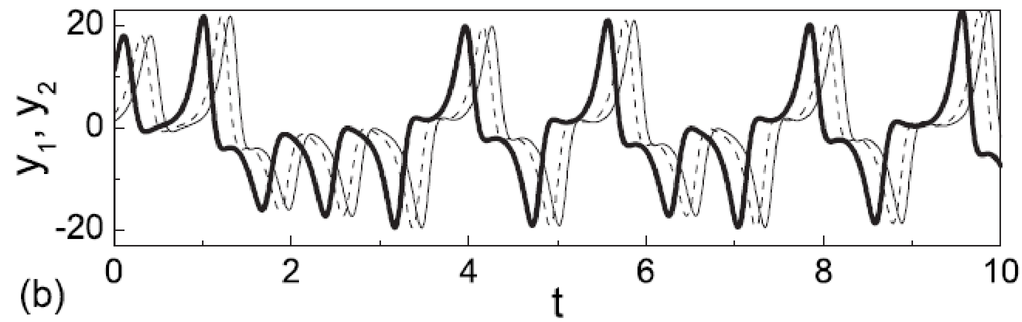
V. Pyragas, K. Pyragas, *Analytical treatment of the delayed feedback controlled Lorenz system close to a subcritical Hopf bifurcation*, **Lith. J. Phys.** **48**, 5 (**2008**).

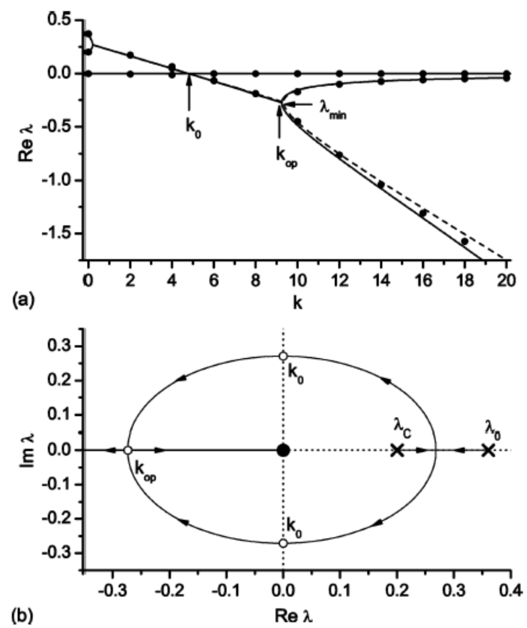
K. Pyragas, T. Pyragienë, Phys. Rev. E **78**, 046217–4 (**2008**).

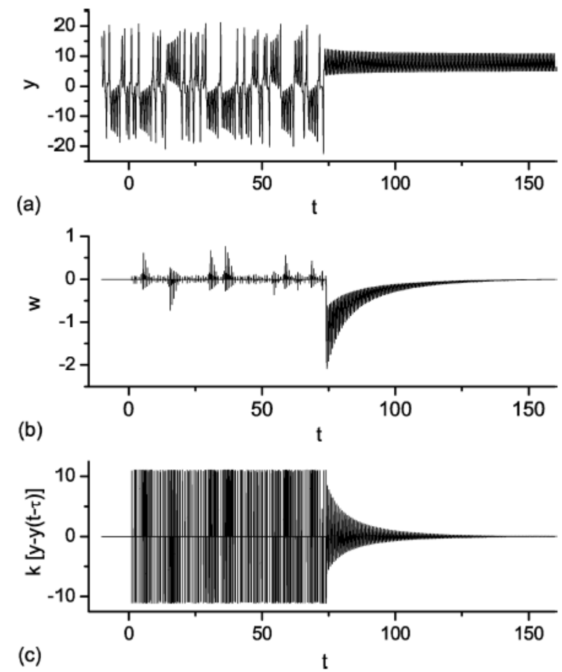
$$\dot{x} = \sigma(y - x)\,,$$

$$\dot{y} = rx - y - xz\,,$$

$$\dot{z} = xy - bz\,,$$







Kitas skyrelis

B. Stochasticity and Disorder Imply Predictability

Kalbama apie signalo ir triukšmo santykį **klasikiniame Brauno judėjime pusiausvyros atveju**, kai yra tolygusis pasiskirstymas (equipartition).

Ir kai yra **nukrypimas nuo pusiausvyros**.

Tada **situacija yra dramatiškai kitokia**:

Cituojamas **Giorgio Parisi** straipsnis

year of physics **concept**

Brownian motion

Giorgio Parisi

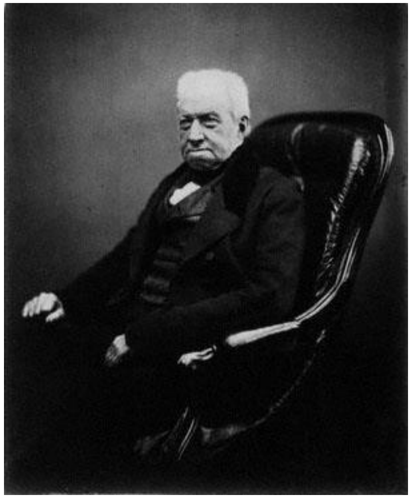
"I did not believe that it was possible to study the Brownian motion with such a precision."
From a letter from Albert Einstein to Jean Perrin (1909).

Mintis "But the situation is different for systems that are only slightly out of equilibrium. … this situation typically applies to disordered systems, such as **spin glasses** and **structural glasses**."

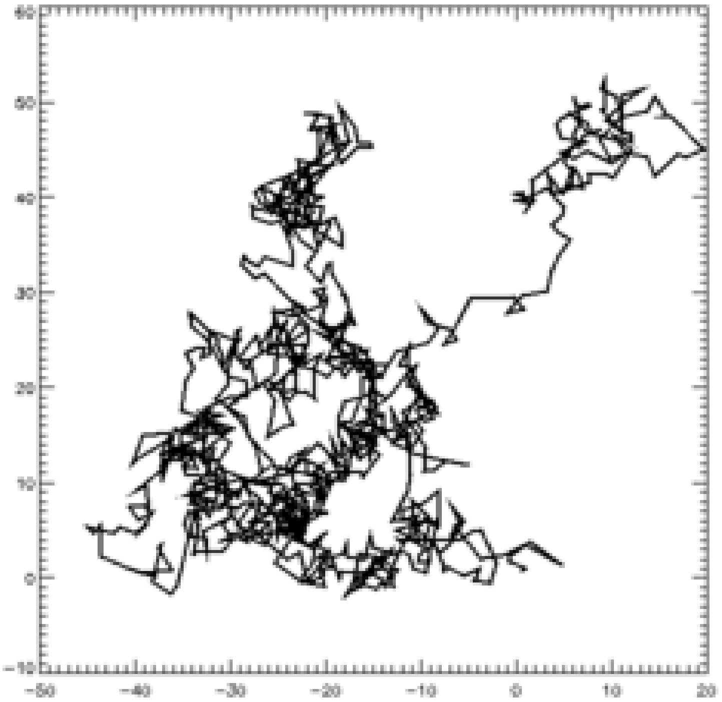
Iškyla mikroskopinės trumpų trukmių ir makroskopinės ilgų trukmių laikų skalės

Brown'o judesys (1)

1. Robert Brown (1827) "…Microscopical Observation of Active Molecules…"



Brown'o judesys erdvėje



Brown'o judesys (2)

2. Louis Bachelier (1900)

"Théorie de la spéculation"

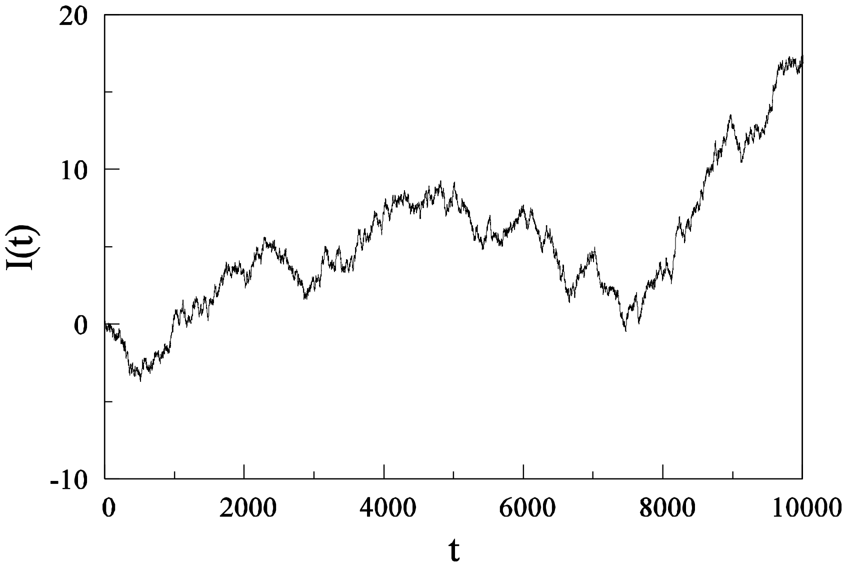
Brown'o judesio teorija

'Pioneering Econophysics'

Louis Bachelier
(1870-1946)

Signalo intensyvumo

Brown'o judesys



Brown’o judesys (3)

3. Albert Einstein (1905)

"*Über die von der molekularkinetischen Theorie der Wärme geforderte Bewegung von in ruhenden Flüssigkeiten suspendierten Teilchen*“

("*On the Motion—Required by the Molecular Kinetic Theory of Heat—of Small Particles Suspended in a Stationary Liquid* “)

Brown’o judesio teorija

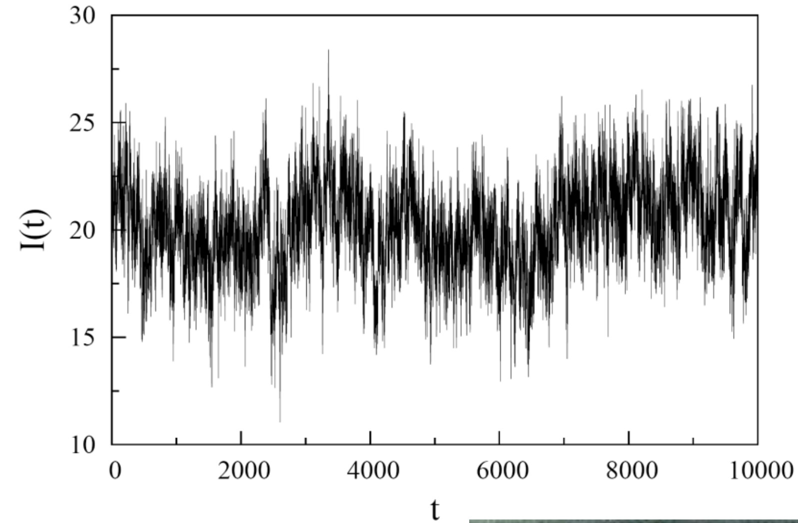
Numatė (patvirtino) molekulinę medžiagos sandarą

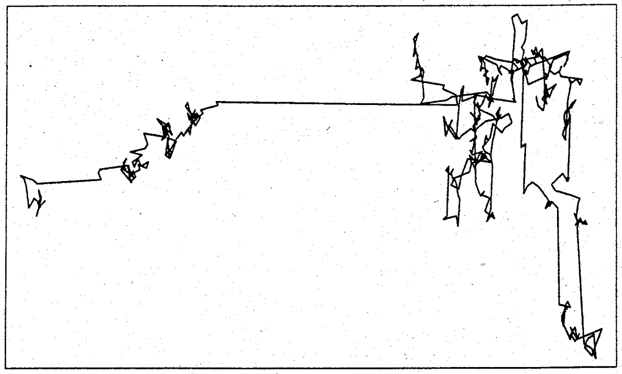
Brown’o judesys erdvėje

Brown'o judesys (4) Matematinė teorija

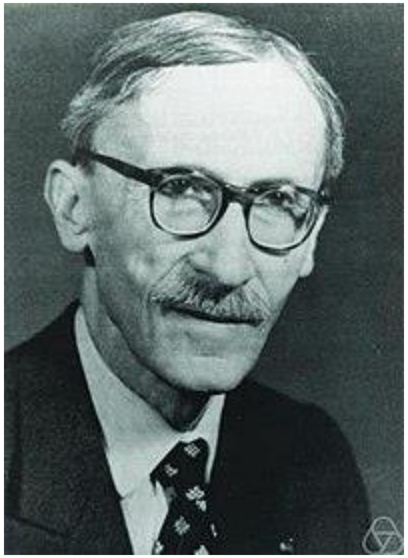
Norbert Wiener (1923)
"continuous-time Gaussian stochastic process with independent increments"

(1909 – 1946)





Paul Levy (1925, 1937-54)
"continuous-time stochastic process that has stationary independent increments"
Lévy flights etc.



(1886 – 1971)

Signalo intensyvumo
ir/arba
erdvėje Brown'o judesys

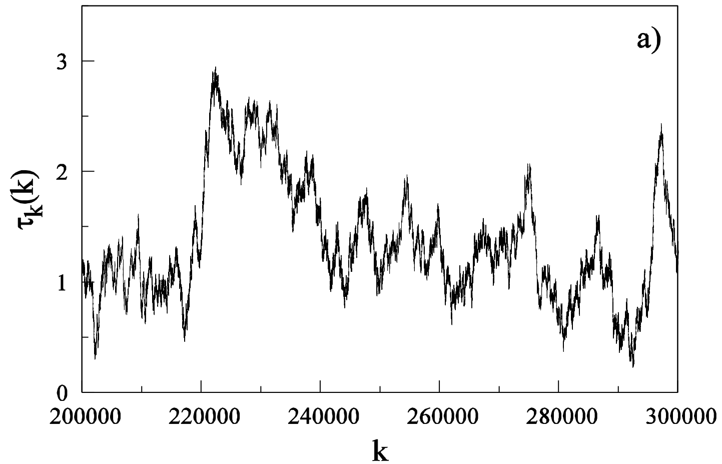
Brown'o judesys (5, mūsų)

B.Kaulakys, T.Meškauskas, V.Gontis, J.Ruseckas, M.Alaburda (1997-2016)

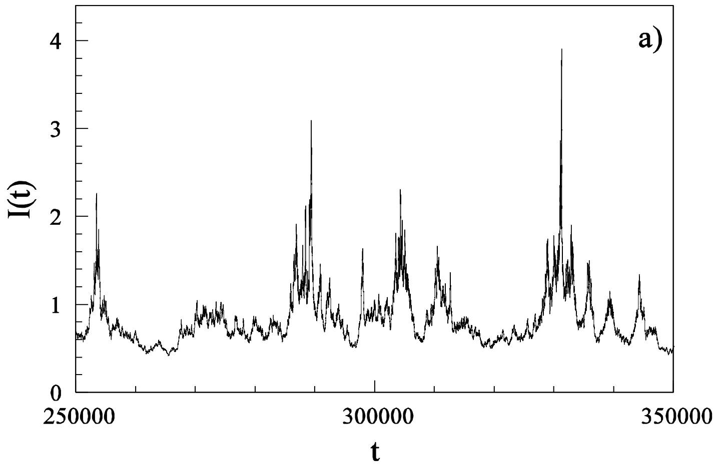
Brown'o ir Brown'o tipo judesys

laiko ašyje **(vidutinės trukmės tarp įvykių, impulsų, objektų)**

kaip galimas 1/*f* fliuktuacijų šaltinis



Trukmės tarp įvykių kitimas



Signalas

Brown'o judesys (6, mūsų)

Nechaotinis Brauno pobūdžio judėjimas

Dalelių ansamblio atsitiktinis trikdymas gali sinchronizuoti dalelių judėjimą ir sukelti fazinio virsmo analogą – chaotinio judėjimo virsmą nechaotiniu atsitiktiniu judėjimu.

Šie tyrimai sukėlė VU matematikų prof. F.Ivanausko, prof. V.Mackevičiaus ir kt. susidomėjimą

- ✓ **B. Kaulakys, G. Vektaris, Phys. Rev. E 52, 2091 (1995).**
- ✓ **B. Kaulakys, Nonlinear Analysis: Model. Contr. 2, p.43-58 (1998).**
- ✓ **B. Kaulakys, F. Ivanauskas, T. Meškauskas, Intern. J. Bifurc. Chaos 9, 533 (1999).**
- ✓ **A. Ambrazevičius, F. Ivanauskas, V. Mackevičius, Nonlin. Analysis 93, 122 (2013).**




Consider a system of particles of mass m moving with friction according to Newton's equations

$$\frac{d\mathbf{r}}{dt} = \mathbf{v}\,, \quad \frac{d\mathbf{v}}{dt} = -\frac{1}{m}\frac{dV(\mathbf{r},\,t)}{d\mathbf{r}} - \gamma\mathbf{v} \qquad (1)$$

in the time dependent potential $V(\mathbf{r},\,t)$, e.g. in the potential $V(x,\,t) = x^4 - x^2 - ax\sin\omega t$, and with the friction coefficient γ. $\mathbf{v}_k^{\mathrm{ran}}$: $\mathbf{v}^{\mathrm{new}} = \alpha\mathbf{v}^{\mathrm{old}} + \mathbf{v}_k^{\mathrm{ran}}$

Lyapunov exponents or KS entropy of the system

$$\sigma_k = \left\langle \frac{1}{\tau_k}\ln|\mu_k| \right\rangle = \lim_{N\to\infty}\frac{1}{N}\sum_{k=1}^{N}\frac{1}{\tau_k}\ln|\mu_k(\mathbf{r}_k,\,\mathbf{v}_k,\,\tau_k)| \qquad (6)$$

A criterion for transition to chaotic behavior is

$$\sigma_{\max} = 0\,. \qquad (7)$$

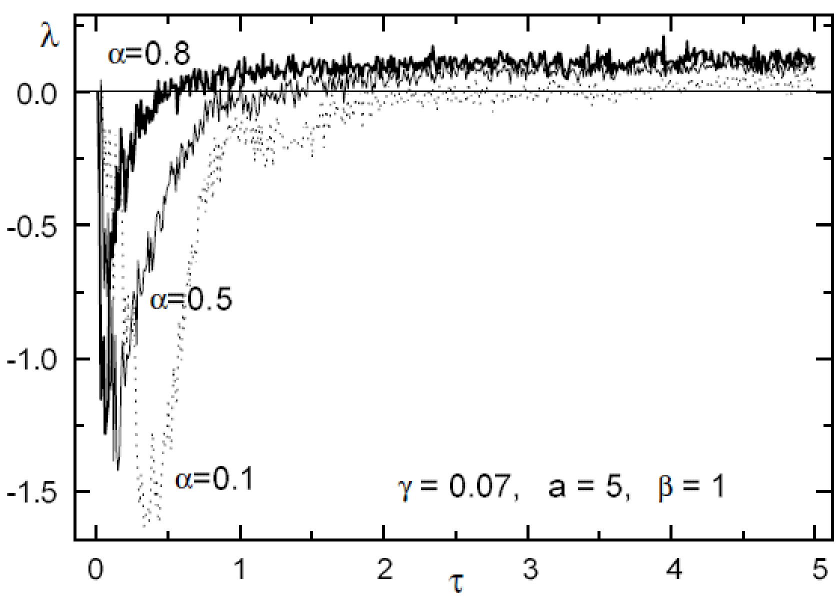


Fig. 7. Lyapunov exponent λ versus the time τ between the resets of the velocity $v^{\mathrm{new}}(k\tau) = \alpha v^{\mathrm{old}}(k\tau) + \beta v_k^{\mathrm{ran}}$, $k = 1, 2, \ldots$ for different values of the parameter α for motion in the driven Duffing potential with friction according to Eq. (8).

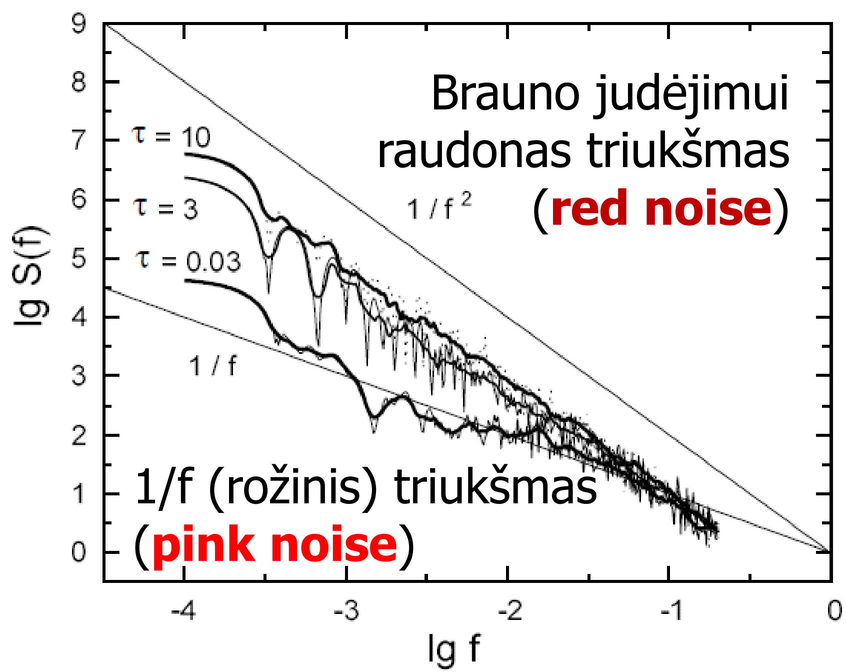


Fig. 8. The power spectral density of the current of the ensemble of particles moving according to Eq. (9) with $F = 1$, $\gamma = 0.1$ and perturbed by the common for all particles noise

Matematikai išanalizavo griežtai, su lemomis ir teoremomis

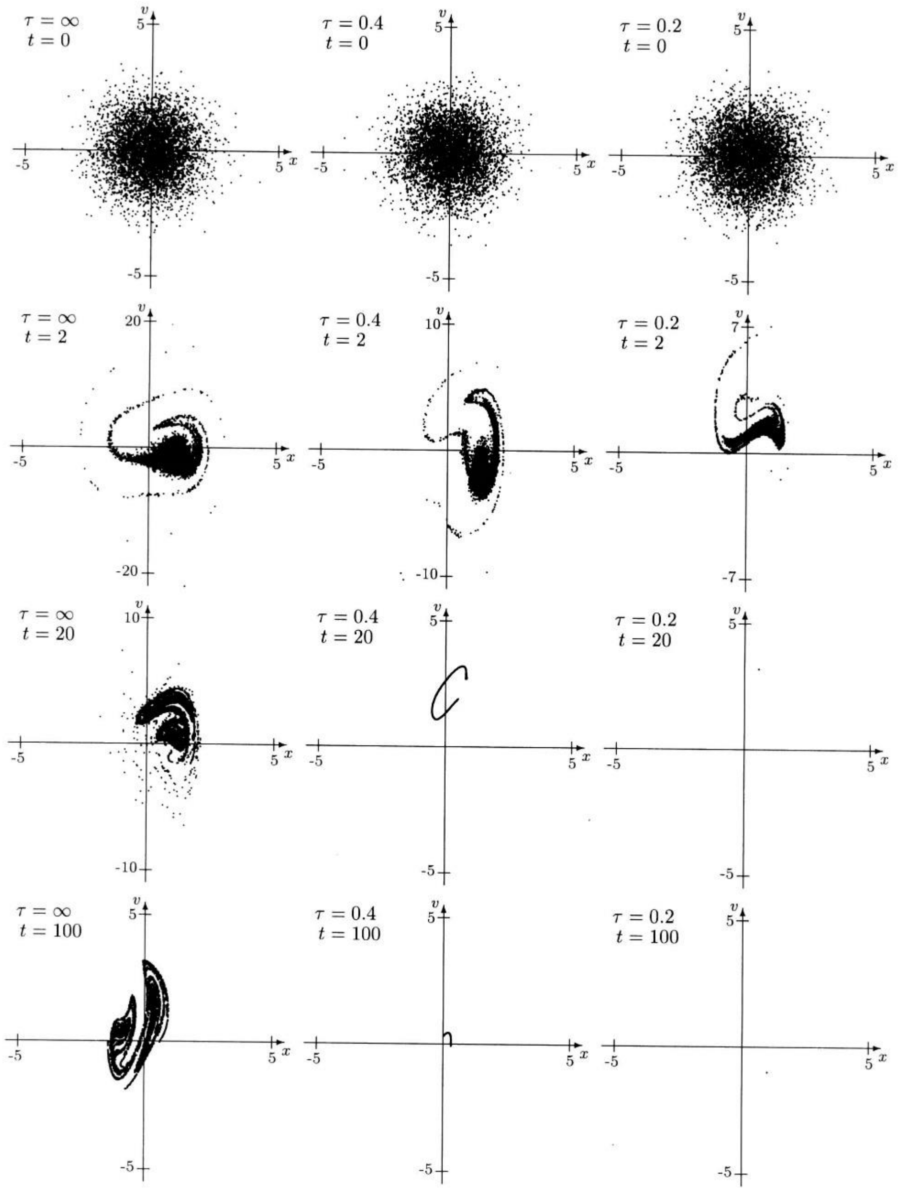


Fig. 6. As in the Fig. 1 but for motion according to Eq. (8) in the nonautonomous Duffing potential with $\gamma = 0.07$, $a = 5$, $\alpha = 0.8$ and $\beta = 1$. A transition from the actual chaotic (at $\tau = \infty$) to the nonchaotic dynamics with the decrease of the time interval τ between the resets of the velocity is observable.

A. Ambrazevičius et al. / Nonlinear Analysis 93 (2013) 122–131

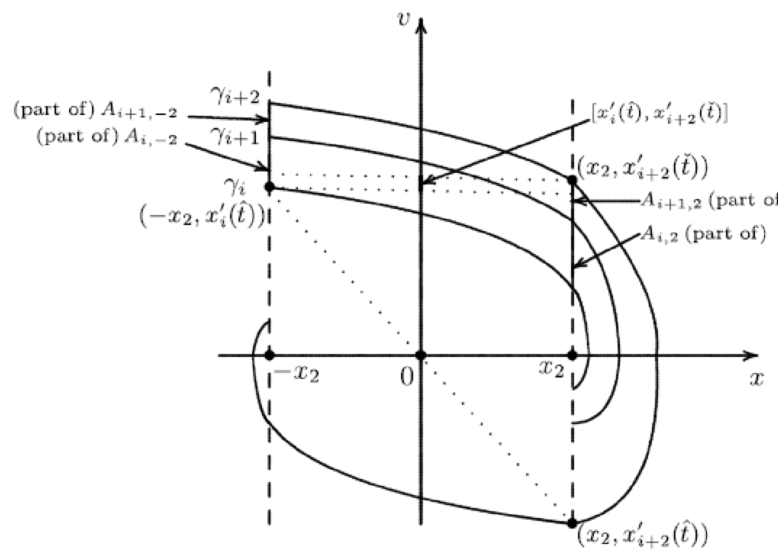


Fig. 2. Illustration to the proof of Lemma 1 ($m = 2$).

II. CLIMATE PHYSICS: BACKGROUND AND HISTORY

Since **Fourier's** studies of the **Earth's energy budget**….
"**Two hundred years ago, French physicist Joseph Fourier** (**1768- 1830**) studied the energy balance between the sun's radiation towards the ground and the radiation from the ground."

"The heating effect of the absorption of solar radiation by CO_2 and other gases was measured by **Eunice Foote** (**JAV, 1819- 1888**), **pirmoji mokslininkė, padariusi išvadą, kad kai kurios dujos įšyla veikiamos saulės spindulių, o didėjantis anglies dvideginio lygis pakeis atmosferos temperatūrą ir gali turėti įtakos klimatui – reiškinys dabar labai aktualus** but in **1861 John Tyndall** published a then technological tour-de-force of systematic absorption and emission of infrared radiation by a wide variety of gases, including water vapor and CO_2",

J. Tyndall, On the absorption and radiation of heat by gases and vapours, and on the physical connexion of radiation, absorption, and conduction. Philosophical Magazine Series 4 **22**,169-194; 273-285 (**1861**).

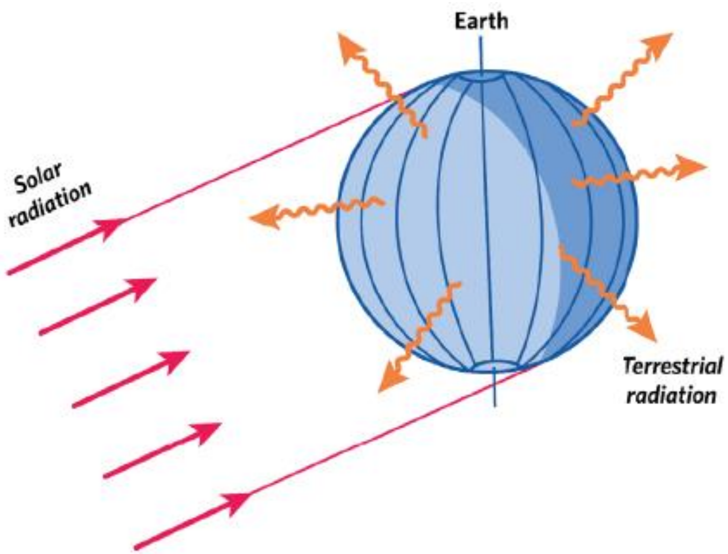
………………………

In the 1950s, Japanese atmospheric physicist **Syukuro Manabe** was one of the young and talented researchers in Tokyo who left Japan … and continued their careers in the US. The aim of Manabes's research, like that of Arrhenius around seventy years earlier, **was to understand how increased levels of carbon dioxide can cause increased temperatures.**

Syukuro Manabe, Nobel Lecture: Physical modeling of Earth's climate, Rev. Mod. Phys. **95**, 010501 (2023).

"Today, I would like to discuss the role of greenhouse gas in climate change, using relatively simple climate models that we constructed prior to 1990. I begin with the explanation of the so-called **greenhouse effect** of the atmosphere."

"Radiative transfer from Earth's surface and in the atmosphere obeys Kirkhoff's law."



Outgoing Longwave Radiation = $\sigma \cdot (T_E)^4$

T_E = 255K ~ -18.7C

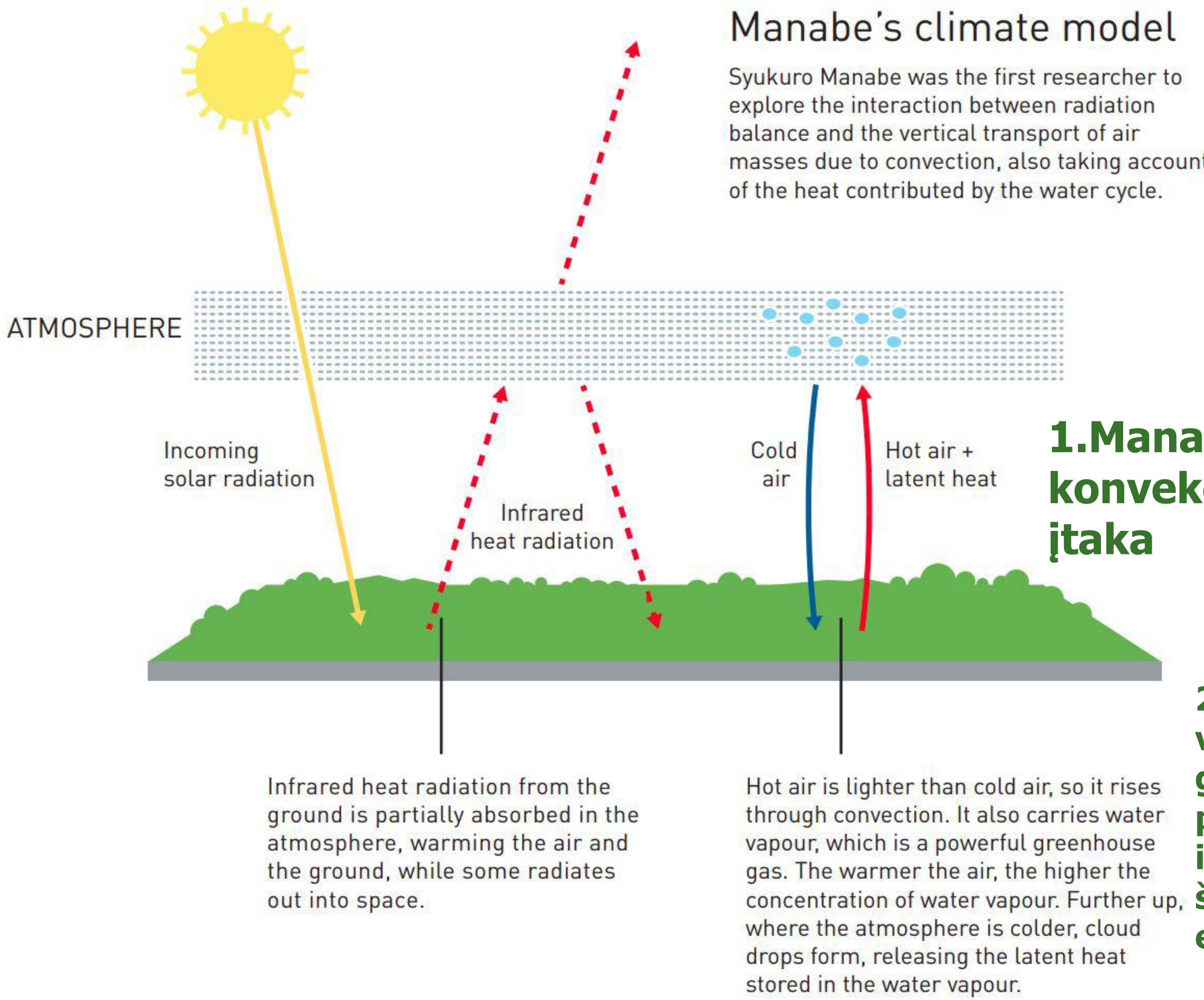
T_S = 270K ~ +14.7C

$T_E - T_S$ = +33.4C

FIG. 4. The temperature thus obtained is −18.7 °C, which is colder than +14.7 °C, which is the global mean temperature of Earth's surface. This implies that Earth's surface is warmer than it would be in the absence of the atmosphere by as much as 33 °C. In other words, the atmosphere has a so-called greenhouse effect that increases the temperature of Earth's surface by as much as 33 °C. It is the satellite observation of outgoing longwave radiation that has provided the most convincing evidence for the existence of the greenhouse effect of the atmosphere.

Be atmosferos Žemės temperatūra būtų -18,7 C, o yra +14,7 C.

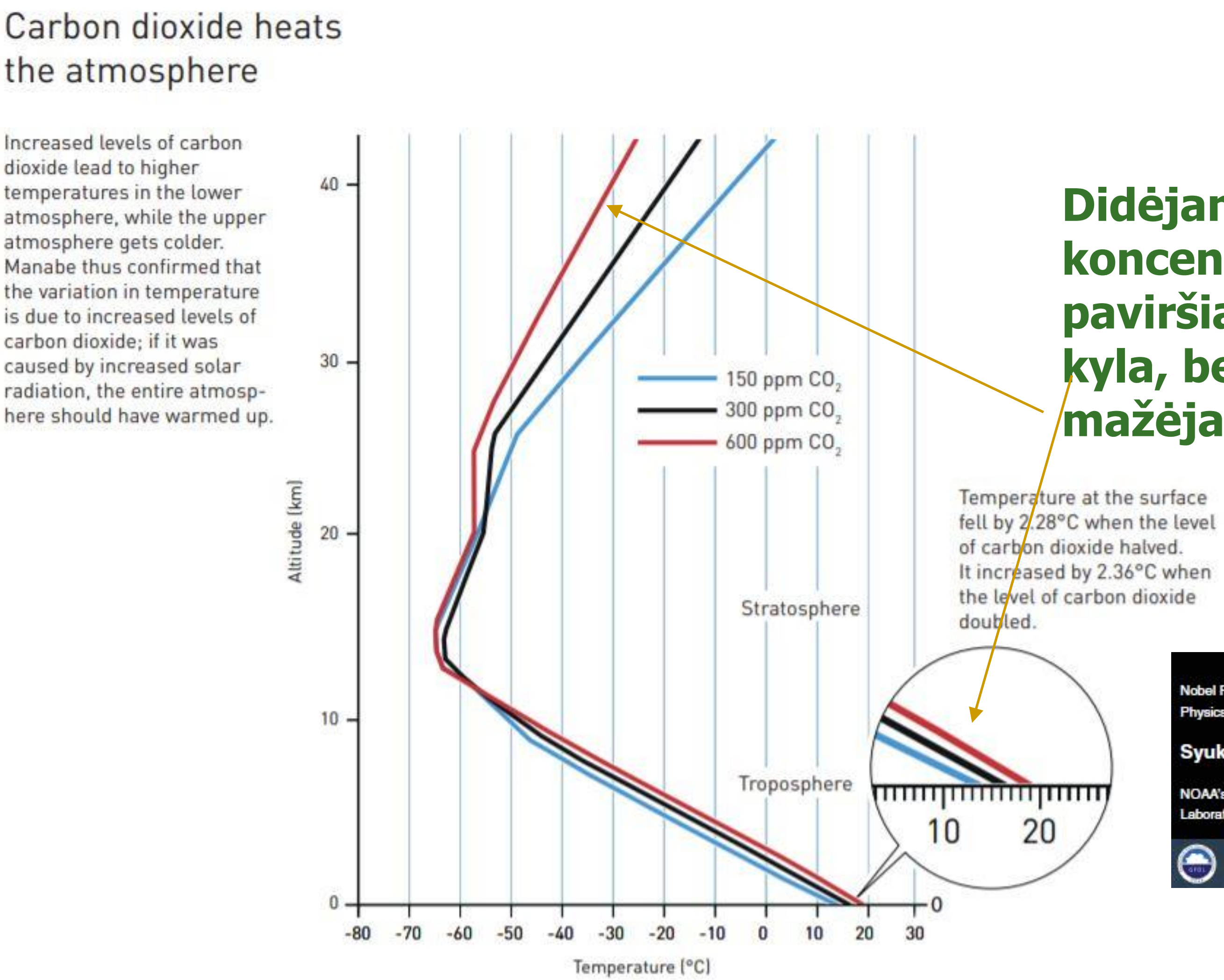
Skirtumas 33 laipsniai !



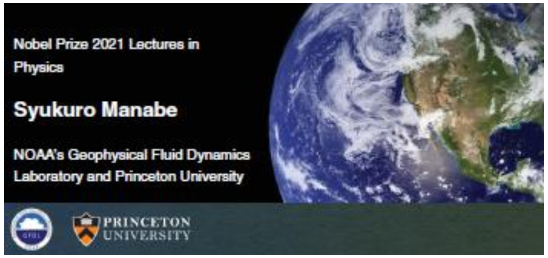
1.Manabe – konvekcijos įtaka

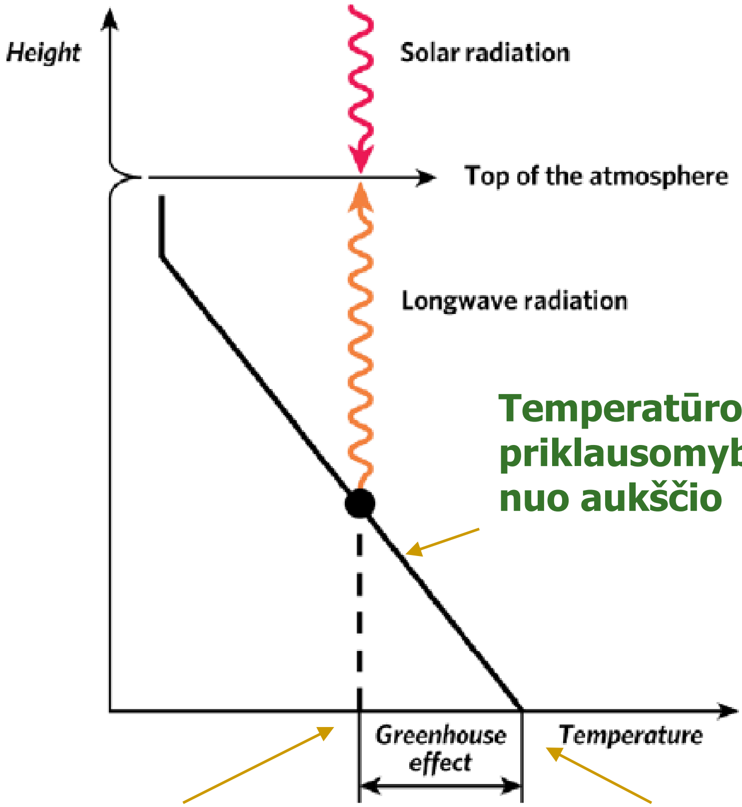
2. Manabe – vandens garavimo padidėjimas ir garų įtaka šiltnamio efektui

3. S. Manabe vienas pirmųjų pastebėjo, kad **anglies dvideginis** prisideda prie atmosferos kaitimo ir visuotinio atšilimo. Anglies dvideginio koncentracija atmosferoje didina Žemės paviršiaus ir troposferos (iki 10 km virš Žemės) temperatūrą (***Šiltnamio efektas***), bet mažina stratosferos (tarp 10 ir 50 km virš Žemės) temperatūrą…



Didėjant CO2 koncentracijai – Žemės paviršiaus temperatūra kyla, bet stratosferos – mažėja.

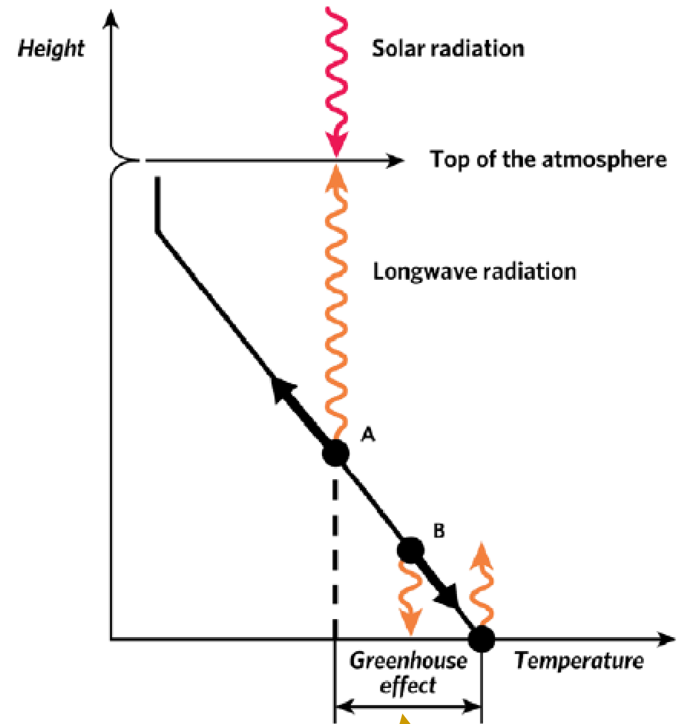




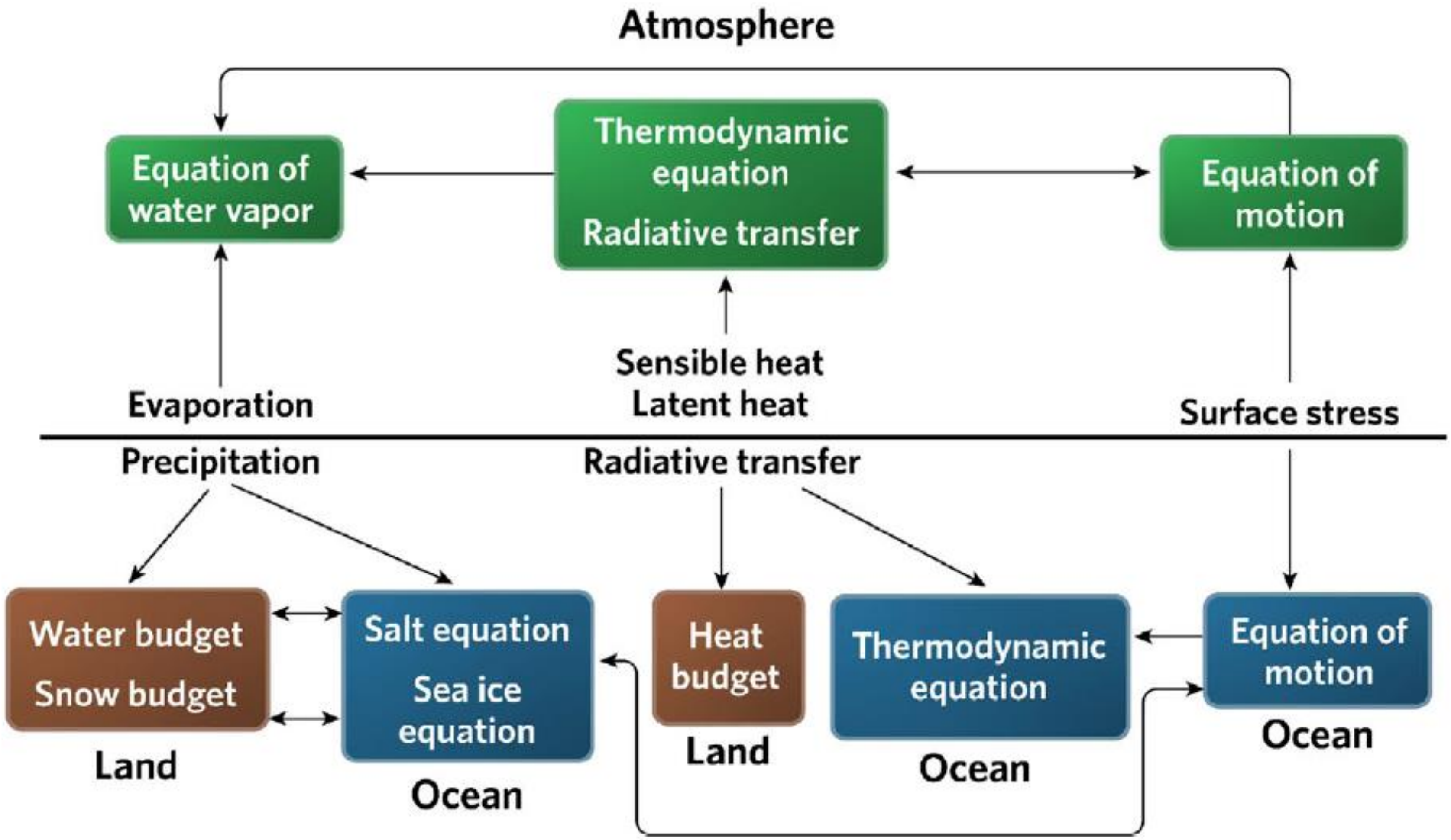
Temperatūros priklausomybė nuo aukščio

Būtų -18,7 C be dujų šiltnamio efekto

Yra +14,7 C

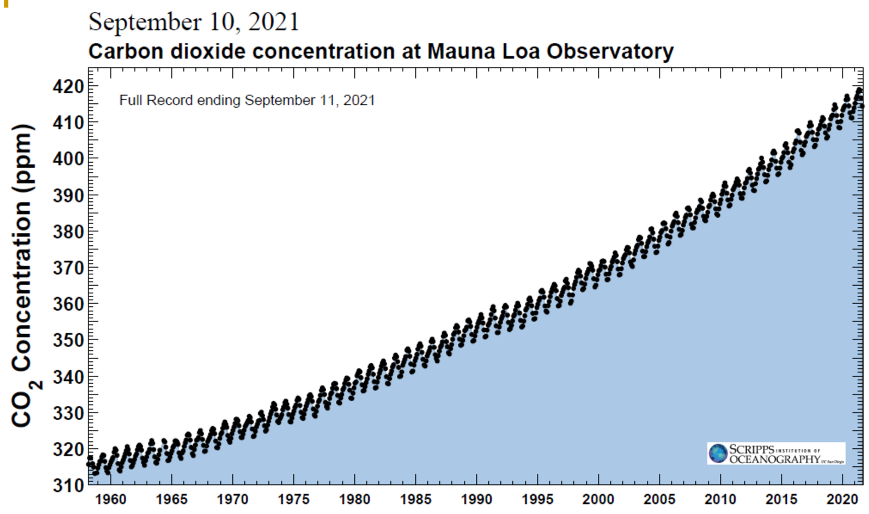


Kai mažiau skaidri atmosfera šiltnamio efektas stiprėja

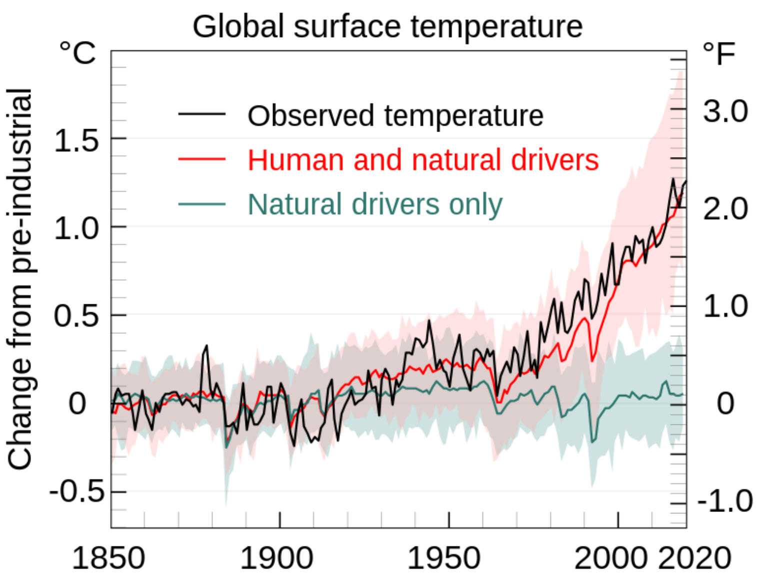


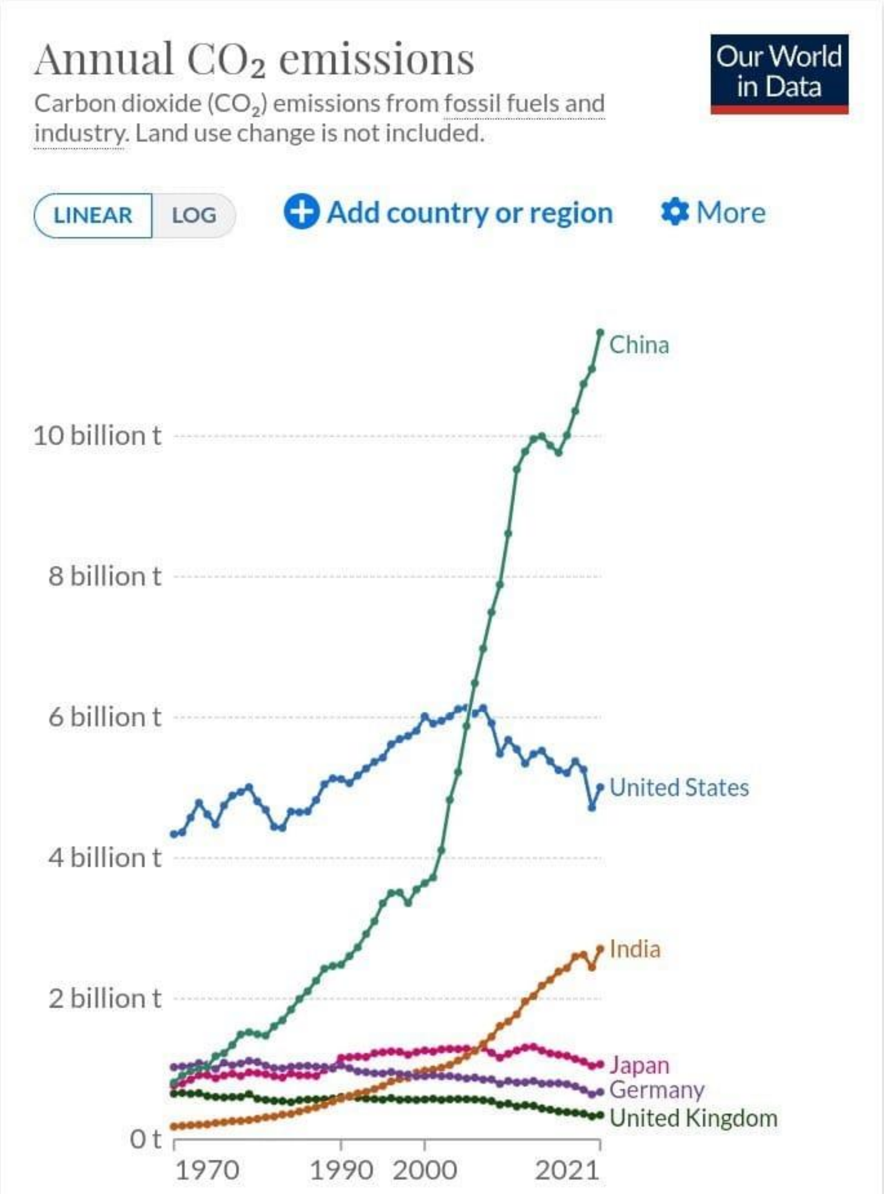
Pilnesnis šilumos srautų balansas pagal Syukuro Manabe, 1959 and Kirk Bryan 1961, "*Climate Calculations with a Combined Ocean-Atmosphere model*" (1969).

Anglies dvideginio koncentracija tikrai didėja…



Temperatūra tikrai kyla





Oras yra chaotinis / Weather is chaotic

About ten years **after Manabe**, **Klaus Hasselmann** succeeded **in linking together weather and climate** by finding a way to outsmart the **rapid and chaotic weather changes that were so troublesome for calculations**.

Climate Calculations with a Combined Ocean-Atmosphere model

"The **Lorenz system** acts as a rich toy model of **low-dimensional chaos**."

"**Poincare (Anri Puankarė**, 1854-1912, prancūzų matematikas, fizikas, filosofas. Laikomas **paskutiniu matematiku – universalu**, suvokusiu visas matematikos šakas**)** is generally credited with launching the field by **discovering that the long-term behavior of the three-body problem was infinitely more complex than had been anticipated**."

"He recognized that the solar system could be viewed dynamically as a perturbation of the integralable **Kepler (Hamiltonian)** problem."

Mažų dimensijų sistemų chaosą nagrinėjome ir mes jau labai seniai ir gavome "Keplerio atvaizdą"

Tirti netiesinių klasikinių ir kvantinių sistemų chaotinės dinamikos ypatumai, pvz., atomų chaotinė (difuzinio tipo) jonizacija vienspalviame, daugiaspalviame bei impulsiniame elektromagnetiniuose laukuose.

Gauti rekurentiniai sąryšiai („Keplerio atvaizdas")

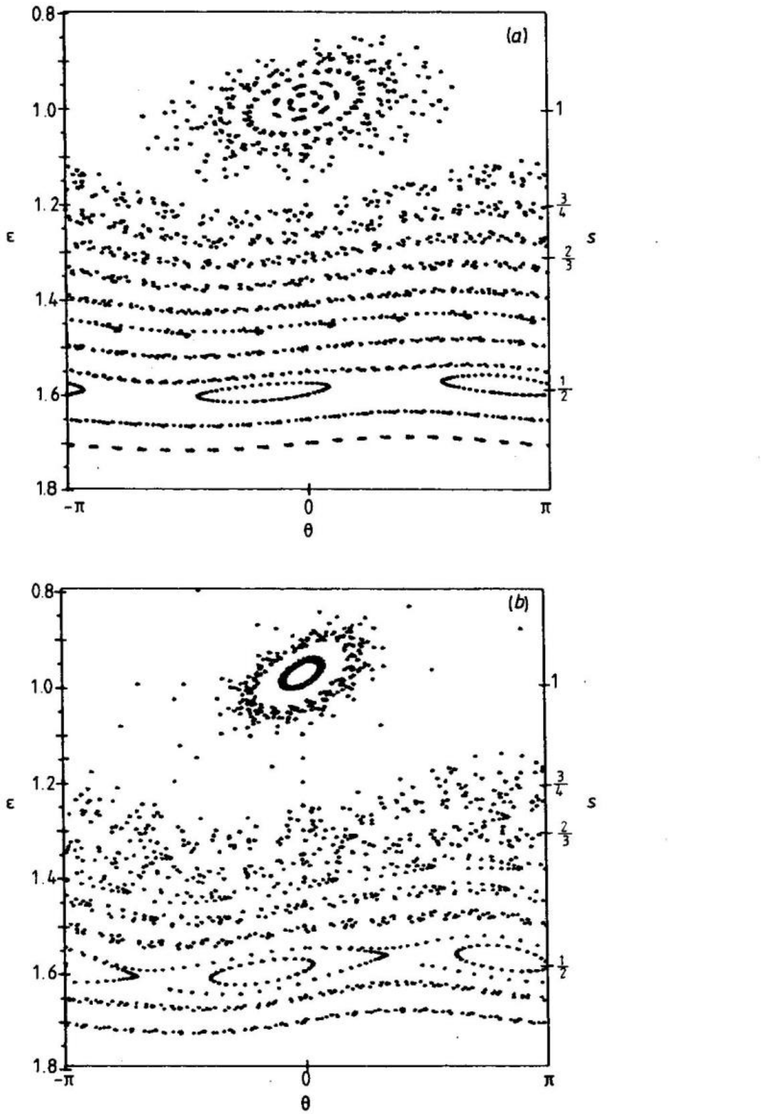


Figure 2. Trajectories for the map (14) with equations (18) and (19) on the pl
(θ, ε). (*a*) $\pi\varepsilon_0^2\Phi_0 = 0.06$; (*b*) $\pi\varepsilon_0^2\Phi_0 = 0.12$. The initial conditions are $\theta_0 = 0$, ε_0
$(i = 0, 1, 2, \ldots)$.

- ✓ V. Gontis, B. Kaulakys, J. Phys. B: At. Mol. Phys. 20, 5051 (1987).
- ✓ B. Kaulakys, D. Grauzhinis, G. Vilutis, Europhys. Lett. 43, 123 (1998).
- ✓ B. Kaulakys, G. Vilutis, **Kepler map**, Physica Scripta 59, p. 251-256 (1999).
- ✓ M. Alaburda, V. Gontis, B. Kaulakys, Lith. J. Phys. 40, 242 (2000).

Klause Hasselmano darbai

with a **long memory** (the ocean) He is best known for developing the ***Hasselmann model*** of **climate variability** … system integrates stochastic forcing, thereby **transforming a white-noise signal** into a **red (Brownian) noise** …**swell waves**).

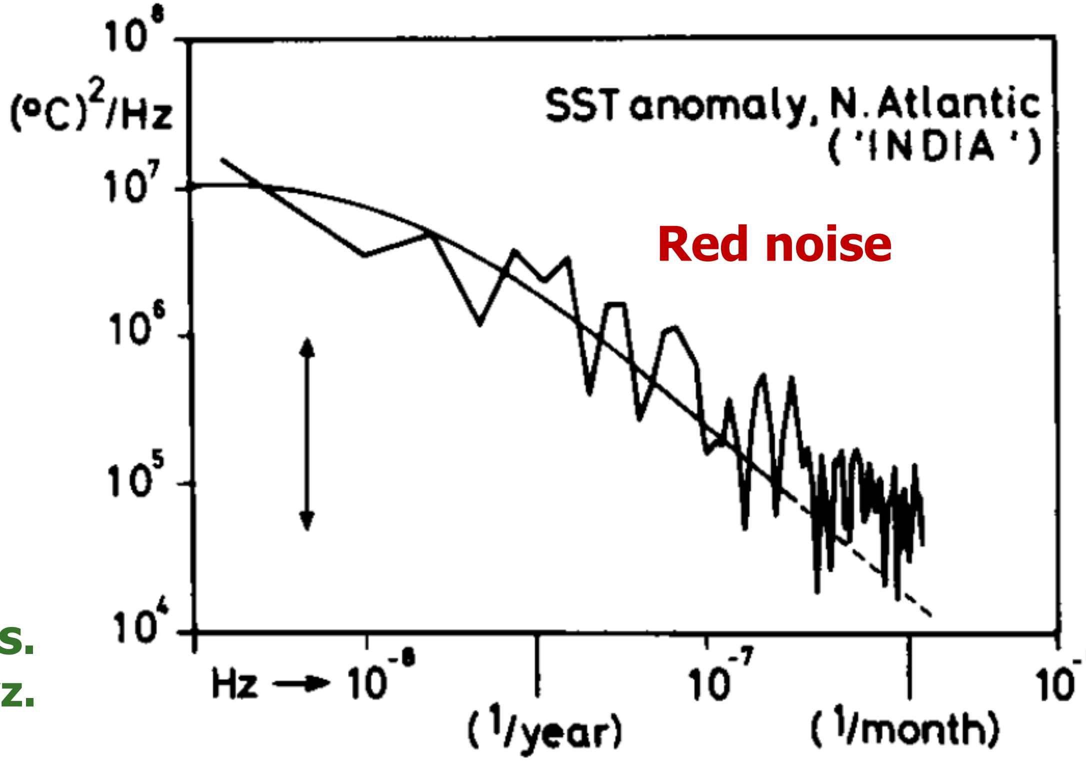
"Analysis of observations of the spectral properties of pressure fields … motivated Mitchell to posit an autonomous **Langevin equation** description of the ocean climate.

…. **Klaus Hasselmann** was creatively using **fundamental physics concepts** to quantify the surface ocean wave **spectra** [**1, 2**], … the nature of **fluctuations** … and **Lorenz's chaotic weather …** he derived a generalizable **stochastic description** of ocean climate in which the "noise" is associated with the "weather"… [**3, 4**].

… provided both the motivation and the observational structure for climate scientists to address **variability**.

1. **K. Hasselmann**, **Feynman diagrams** and interaction rules of wave-wave scattering processes. Rev. Geophys. **4**, 1 (**1966**).
2. **K. Hasselmann**, **Non-linear interactions** treated by the methods of **theoretical physics** (with application to the generation of waves by wind). Proc. R. Soc. A **299**, 77 (**1967**).
3. **K. Hasselmann**, **Stochastic climate models**, part I. Theory, Tellus **28**, 473 (**1976**).
4. C. Frankignoul, **K. Hasselmann**, **Stochastic climate models**, Part II. Application to sea-surface temperature anomalies and thermocline variability. Tellus 29, 289305 (**1977**).
5. **K. Hasselmann**, 1997. Multi-Pattern Fingerprint Method for Detection and Attribution of Climate Change. Clim. Dyn. **13**, 601 (**1997**).

The first application of the **Hasselmann stochastic model** [**3**] for climate variability to climate data [**4**]. **The spectrum** of the Sea Surface Temperature (SST) in the period 1949-1964 in the North Atlantic.



Stebimos ir 1/f fluktuacijos. Cituojami ir mūsų darbai, pvz. Straipsniuose:

"1/*f* model for long-time memory of the **ocean surface temperature**, Phys.Rev E (2004);

… "vertical high-resolution distributed-temperature-sensing system".. HYDROLOGY AND EARTH SYSTEM SCIENCES (2011)

"**Tropical convective variability as 1/*f* noise**", JOURNAL OF CLIMATE (2001)

"Thermal convection…" PHYSICAL REVIEW FLUIDS (2020)

Orai, klimatas, **milžinišką įtaką jiems turintys vandenynai** yra **labai sudėtinga sistema**, ją modeliuojant atliekami sudėtingi skaičiavimai. Prognozuojant klimato šilimą dirba didžiulės tarptautinės mokslininkų grupės, o

Manabe ir Hasselmannas tokiems tyrimams padėjo pamatus. Nobelio premija šiems mokslininkams skirta dar ir todėl, kad **globalinio atšilimo problema yra labai aktuali.**

Keletas solidžiausių straipsnių:

Y. Pomeau, The long and winding road.. **Nature Phys.** **12**, 198 (2016).

K. Hamilton, At the dawn of global climate modeling: the strange case of the Leith atmosphere model, Hist. Geo Space Sci. **11**, 93 (**2020**).

M. Ghil, V. Lucarini, The Physics of Climate Variability and Climate Change. **Rev. Mod. Phys**. **92**, 035002 (**2020**).

M.E. Mann, B.A. Steinman and S.K. Miller, Absence of internal multidecadal and interdecadal oscillations in climate model simulations. **Nat Commun** **11**, 1 (**2020**).

Spalio 24 d. minima klimato kaitos diena. **Šylant klimatui, kyla pavojus gyvybės Žemėje išlikimui. Klimato kaitą sukelia išmetamosios dujos, kietosios dalelės, kurias į atmosferą išskiria automobiliai, pramonė. Siekiant mažinti klimato kaitą, gyventojai turėtų atsakingai vartoti, keliauti. Pasaulyje plinta įvairios prieš klimato kaitą kovojančios iniciatyvos, pavyzdžiui, skrydžio gėdos judėjimas**.

Yra ir reikšmingų darbų su **lietuviškomis pavardėmis**. Pvz.,

Darius Ceburnis

Natl Univ Ireland Galway, Sch Phys, Univ Rd, Galway, Ireland

Per 140 str., cituotas per 7000 kartų

Keletas darbų:

O'Dowd, C., Facchini, M., Cavalli, F. .. **Darius Ceburnis** (Airija), et al*.* Biogenically driven organic contribution to marine aerosol. **Nature** **431**, 676 **(2004**).

… Darius Ceburnis, et al*.* ...aerosol particle formation … **Nature** **537**, 532 **(2016**).

…Darius Ceburnis, et al*.* ….cloud droplet… **Nature** **546**, 637 **(2017**).

Ch. Lin, **D. Ceburnis** et al, Air quality—climate forcing double whammy from domestic firelighters, **npj** Climate Atmosph. Sc. **6**, 101 (**2023**)

Vėlesni mūsų grupės artimos tematikos darbai

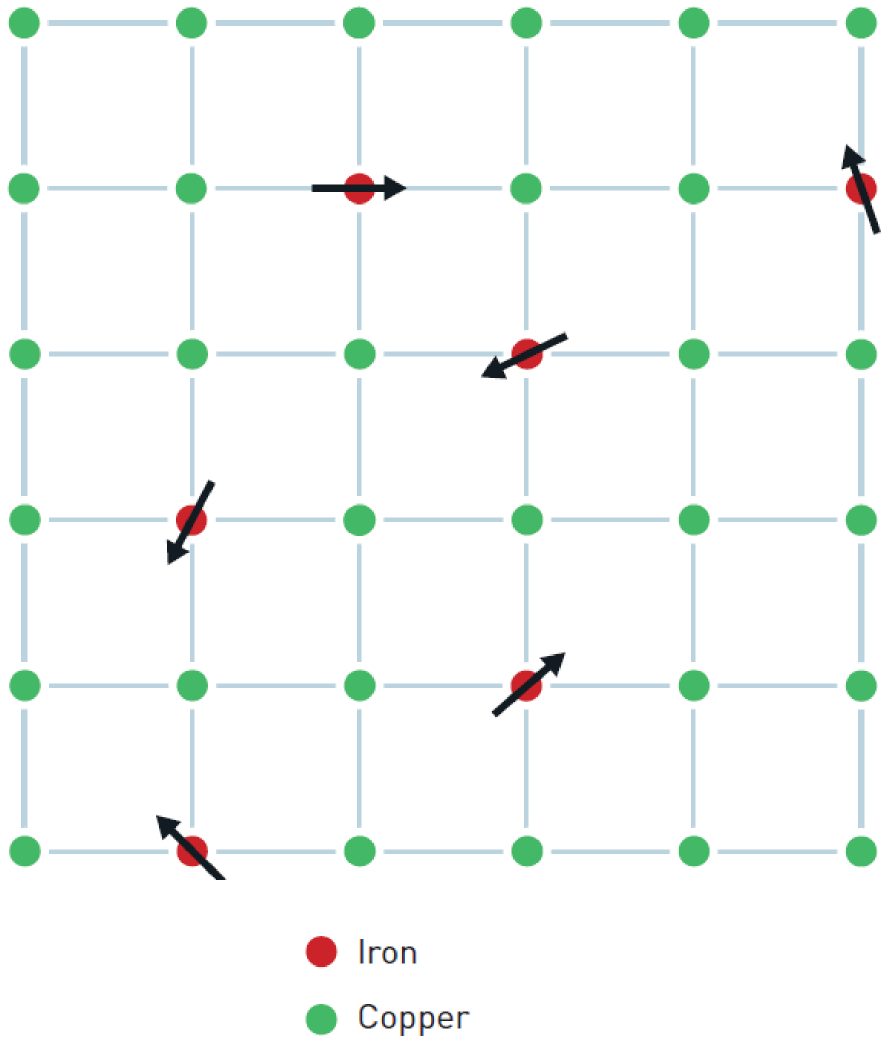
- ✓ J. Ruseckas, R. Kazakevičius and B. Kaulakys, 1/f noise from point process and **time-subordinated Langevin equations**. J. Stat. Mech. **2016**, P054022 (2016).
- ✓ J. Ruseckas, R. Kazakevičius and B. Kaulakys, **Coupled nonlinear stochastic differential equations** generating arbitrary distributed observable with 1/f noise, J. Stat. Mech. **2016**, P043209 (2016).
- ✓ R. Kazakevičius, A. Kononovicius, B. Kaulakys, V. Gontis. Understanding the nature of **the long-range memory phenomenon in socio-economic systems**. Entropy **23**: 1125 (2021).
- ✓ A. Kononovicius, B. Kaulakys. **1/f noise from the sequence of nonoverlapping rectangular pulses**. Physical Review E **107**: 034117 (2023).
- ✓ R. Kazakevičius, A. Kononovicius, **Anomalous diffusion** and **long-range memory** in the **scaled voter model**, Phys. Rev. E **107**, 024106 (2023
- ✓ A. Kononovicius, B. Kaulakys. **1/f noise in electrical conductors** arising from the heterogeneous detrapping process of individual charge carriers. (to be published)




Giorgio Parisi tyrimai sunkiai aprėpiami

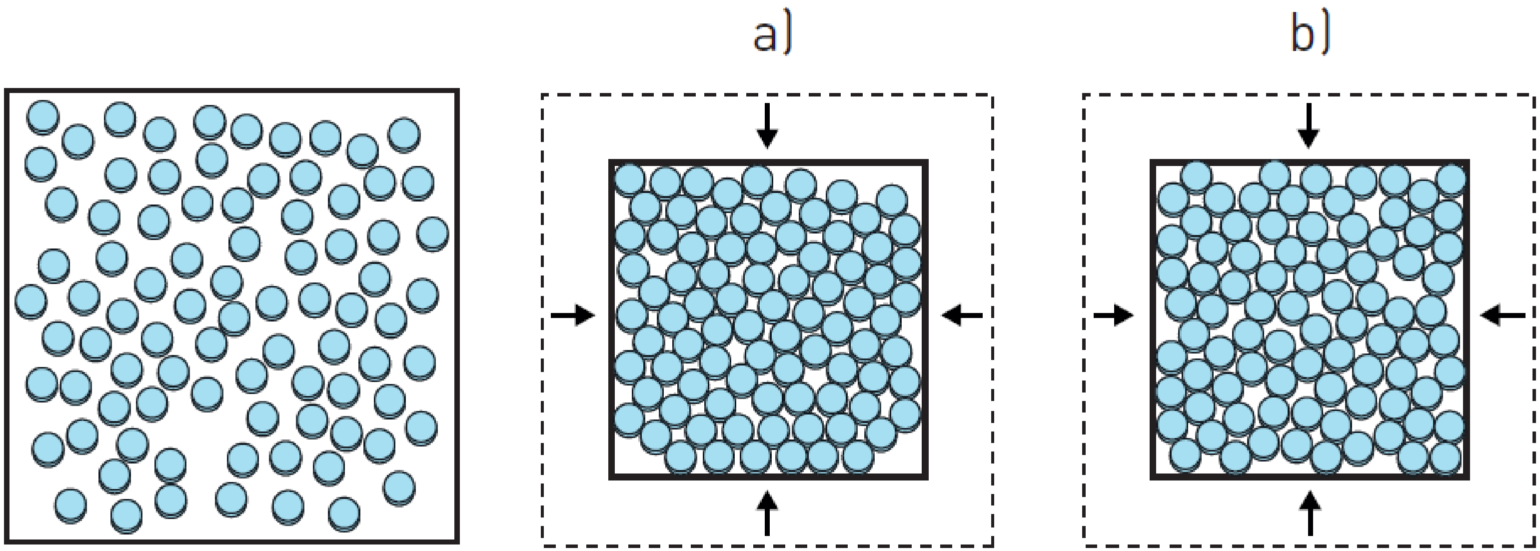
Around 1980, **Giorgio Parisi discovered hidden patterns** in disordered complex materials.
His discoveries are **among the most important contributions to the theory of complex systems.**
They make it possible to understand and describe many different and apparently entirely **random complex materials and phenomena**,
not only in **physics**
but **also in other, very different areas**,
such as **mathematics**, **biology**, **neuroscience** and **machine learning**….

Sukininiai stiklai



A **spin glass** is a metal alloy where iron atoms, for example, are randomly mixed into a grid of copper atoms.
Each iron atom behaves like a small magnet, or spin, which is affected by the other magnets around it.
However, in a spin glass they are frustrated and have difficulty choosing which direction to point.

Using his studies of spin glass, **Parisi developed a theory of disordered and random phenomena that covers many other complex systems.**



Mathematics for complex disordered systems

Every time many identical discs are squeezed together, **a new irregular pattern is formed despite them being squeezed in exactly the same way**.
What governs the result?

Giorgio Parisi discovered a hidden structure in such complex disordered systems, which these discs represent, and found a way of describing them mathematically.

Giorgio Parisi solved the problem of replica symmetry breaking
by realizing that, in contrast to ferromagnets which have only two \pure states" (up/down) in the ordered phase, **there must be an infinite number within the ordered phase of the spin glass.**

Not only did this provide the solution, but it had a stunning array of **extensions to a wide range of spin-glass and other systems**

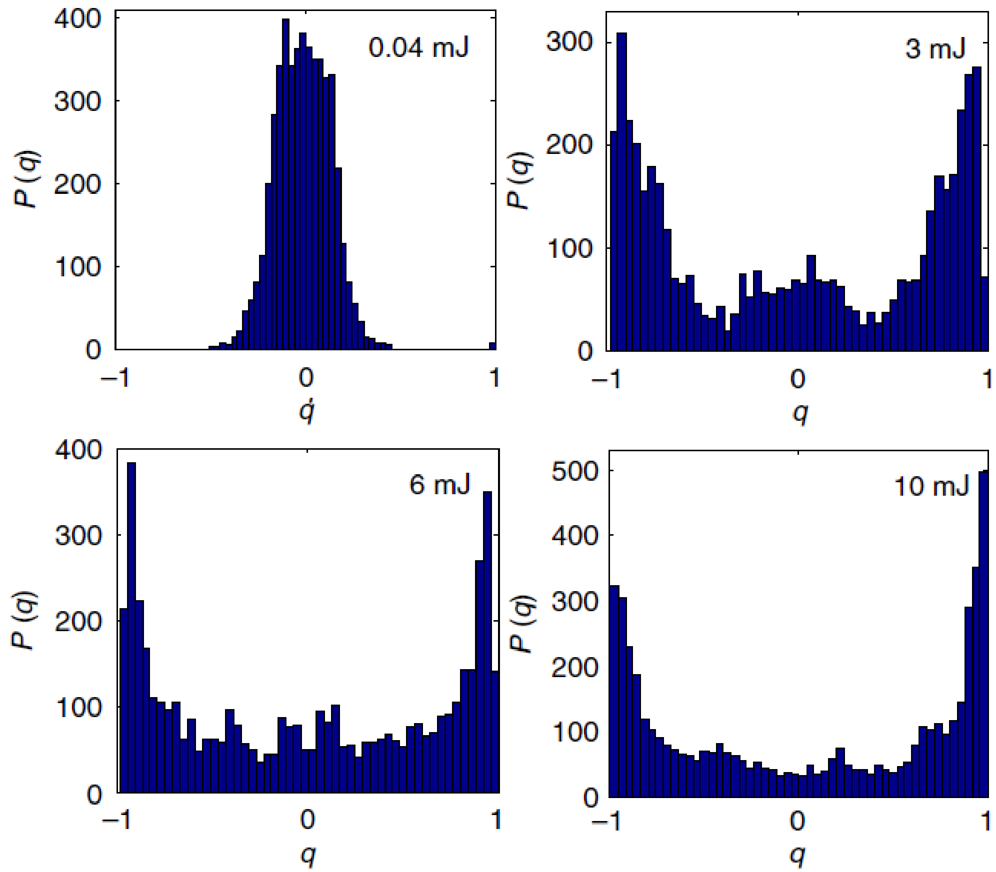
G. Parisi, **Innite number of order parameters for spin-glasses** Phys. Rev. Lett. 43, 1754 (**1979**).

G. Parisi, **Statistical Field Theory** (Addison-Wesley, Redwood City, CA,1988, pp. 352)

The broad reach of broken replica symmetry concepts and methods has exploded since Parisi's original work. In particular,
Parisi and his collaborators have shown that in John Hopeld's **neural network model**, and its many offspring, the multiple memories stored in the network correspond to the **multiple equilibria of the spin glass**.
Moreover, their methods allowed them to address the **classical optimization problem of the traveling salesman who stops at many local minima but of course the global minimum/minima are the targets of interest.**

Random laser

The theoretical interest in random lasers in connection with replica **symmetry breaking**…
In random lasers it is possible to observe directly **the occupancy of different harmonic modes** and therefore one can measure directly the function P(q).



The distribution P(q) of the overlap q for **different pump energies**.
The pump energy plays the role of the inverse temperature.
As the pump energy increases the distribution of first order replica **symmetry breaking appears.**

R. Benzi, G. Paladin, **G. Parisi**, A. Vulpiani, On the **multifractal nature of fully developed turbulence and chaotic systems**, J. Phys. A **17** 3521 (**1984**).

M. Mezard, **G. Parisi**, R. Zecchina, Analytic and Algorithmic Solution of Random Satisability Problems. **Science** **297**, 812 (2002).

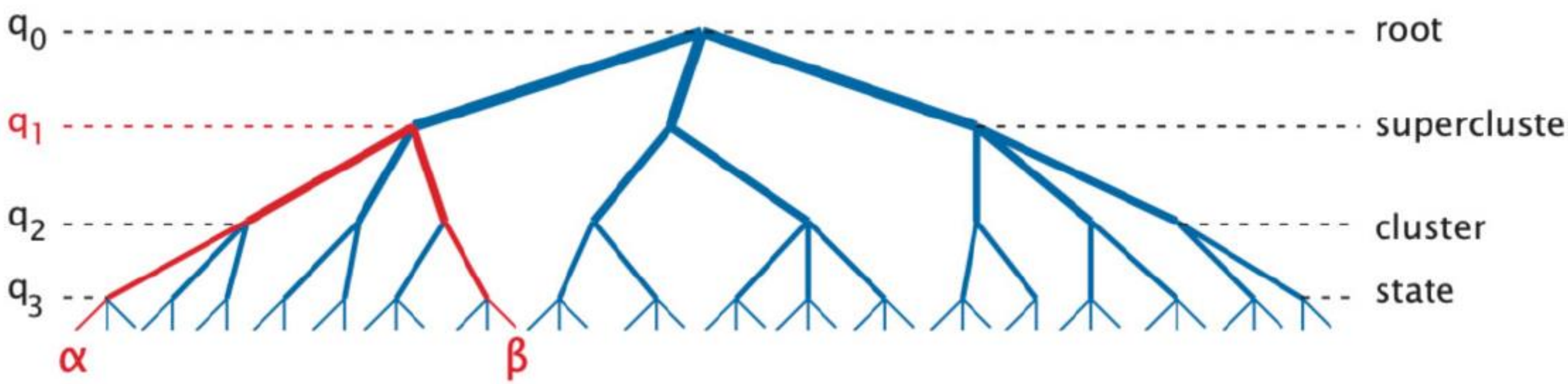
G. Parisi and F. Zamponi, Mean-eld theory of hard sphere glasses and jamming. **Rev. Mod. Phys**. **82**, 789 (2010).

G. Parisi, **Physics, complexity and biology**. Advan. Compl. Syst. **10**, 223 (2007).

J-P Bouchaud, M. Mézard, and **G. Parisi**. Scaling and **intermittency** in **burgers** turbulence. Phys. Rev. E, 52(4):3656, 1995.

P. Rissone, E.I. Corwin,. **G. Parisi**, Long-Range Anomalous Decay of the **Correlation** in Jammed Packings. **Phys. Rev. Lett**. 127, 038001 (**2021**).

G. Parisi, **Nobel Lecture: Multiple equilibria**, **Rev. Mod. Phys**. **95**, 030501 (2023).



Italijos mokslininkai ragina žiniasklaidą geriau paaiškinti klimato kaitą

Laišką, atsiųstą iš Italijos Klimato žiniasklaidos centro, pasirašė ir **2021 m. Nobelio fizikos premijos laureatas Giorgio Parisi iš Romos Sapienzos universiteto**.

„Karščio bangos, potvyniai, užsitęsusios sausros ir gaisrai yra tik keletas požymių, rodančių, kad klimato kaitos poveikis mūsų teritorijoms stiprėja“, – sakoma 96 mokslininkų pasirašytame laiške

„Tačiau **Italijos žiniasklaida vis dar per dažnai kalba apie „blogą orą“, o ne apie klimato kaitą**.

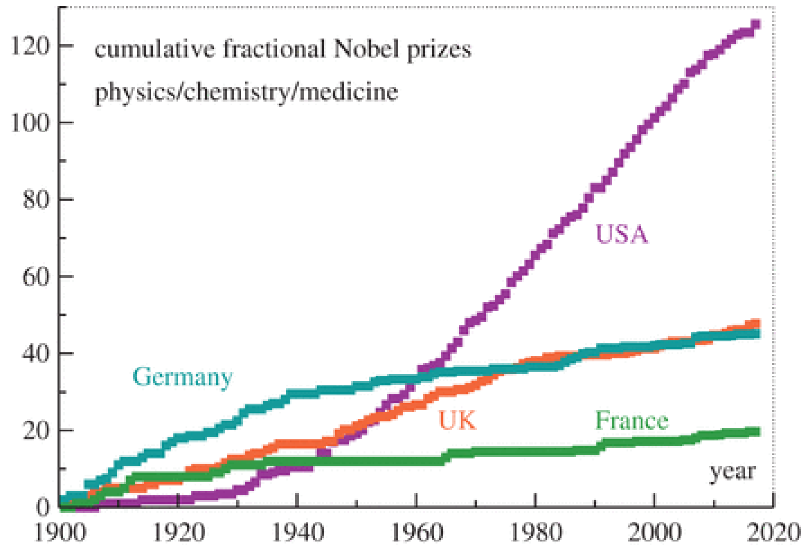
Kalbėdama apie tai, ji dažnai nutyli priežastis ir sprendimus“,

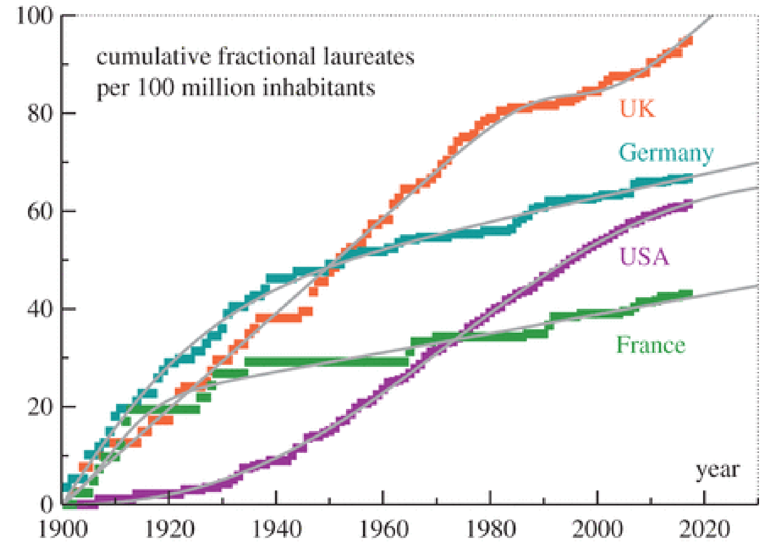
….**karščio bangos tapo labiau tikėtinos dėl klimato kaitos**.
…pasaulio temperatūra kyla, prognozuojama, kad karščio bangos taps dažnesnės ir intensyvesnės, o jų poveikis bus didesnis.

…**dėl pasikeitusių kritulių kylanti temperatūra ir padidėjęs sausumas sukuria idealias sąlygas krūmynų ar miškų gaisrams.**

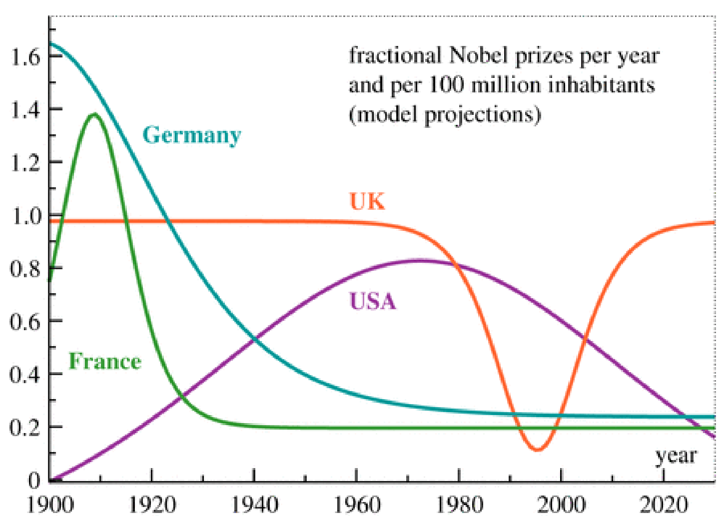
VU klimatologas Justinas Kilpys: … “įžengėme į teritoriją, kurios nebuvo per pastaruosius milijoną metų”…

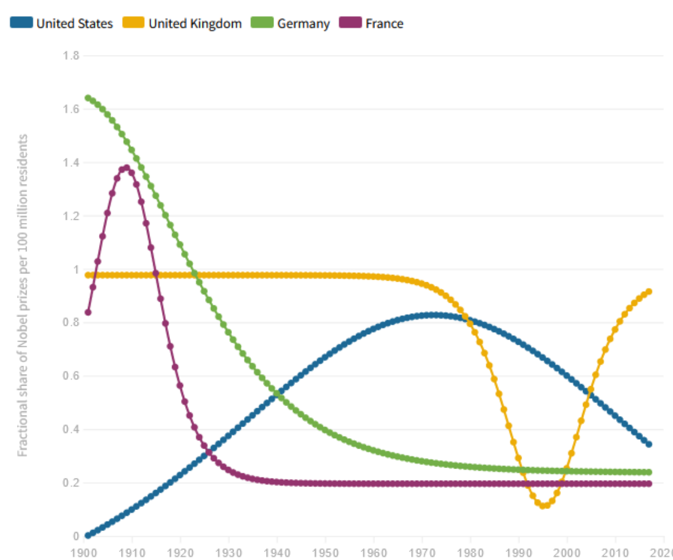
Šiek tiek Nobelio premijų statistikos





Bando aprašyti formulėmis





Ačiū už dėmesį !