



International Interdisciplinary PhD Workshop

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International Symposium on Automatic Control

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Keynote

Mathematical Modelling of Measurement Results

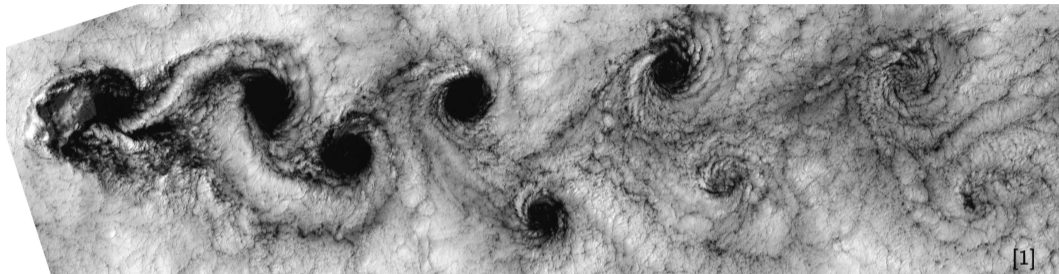
Michael Böhm

Hochschule Wismar

May 3, 2023



classifications of mathematical modeling



[1]

simple vs. **complex**

static vs. dynamic

linear vs. nonlinear

explicit vs. implicit

discrete vs. continuous

deterministic vs. stochastic

panta rhei (everything flows)

emergence: chaos, solitons, ...

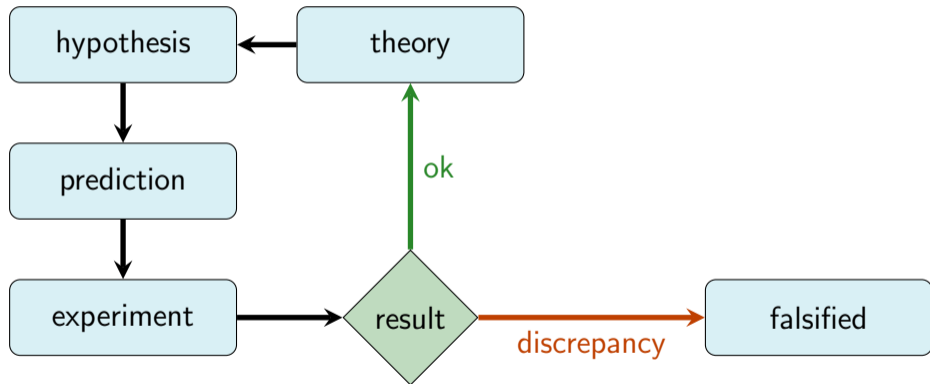
inverse problem: remote sensing, tomography

particle or wave

error analysis, quantum mechanics, thermodynamics

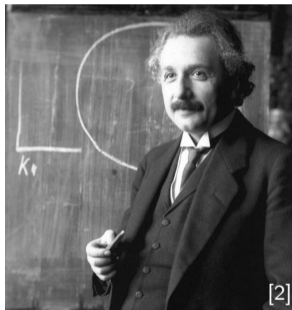


improved models: reduce contradictions



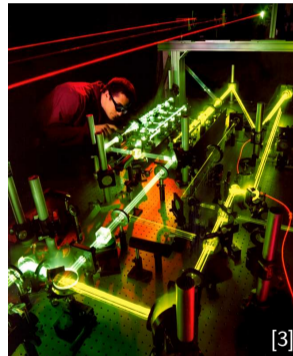


theory vs. experiment



“ No one trusts a theory
except the person who put it forward ”

“ Everyone trusts a measurement
except the person who performed it ”





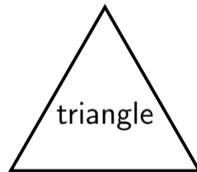
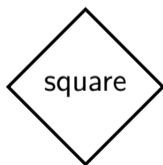
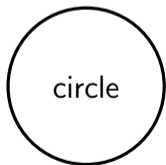
let us conduct an experiment

Please describe the tubes on the table!

color

blue, brown, black, red, ...

shape

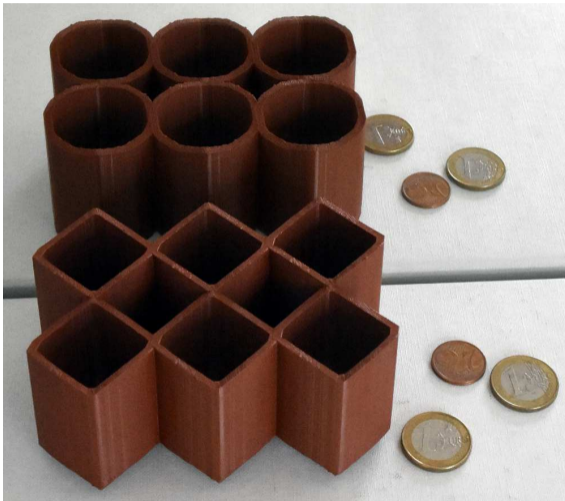


number

1, 2, 3, 4, 5, 6, 7, 8, 9, 10, ...



optical illusion

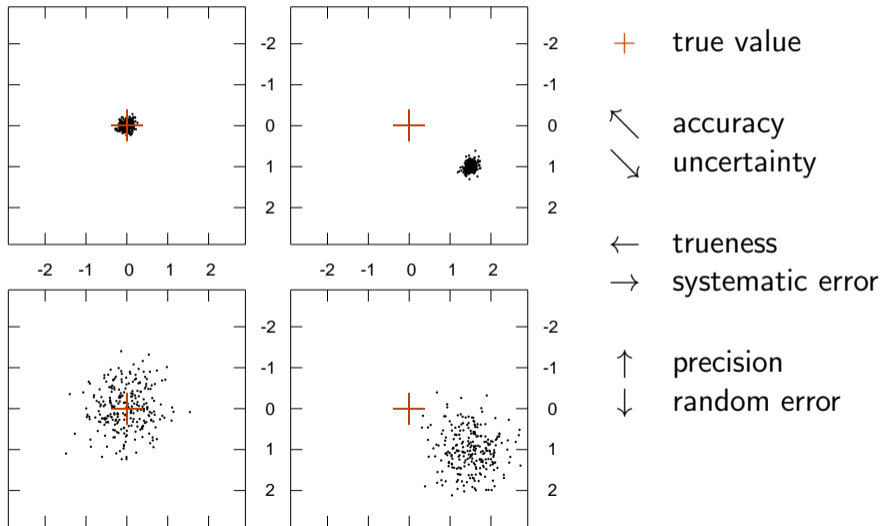


Kokichi Sugihara



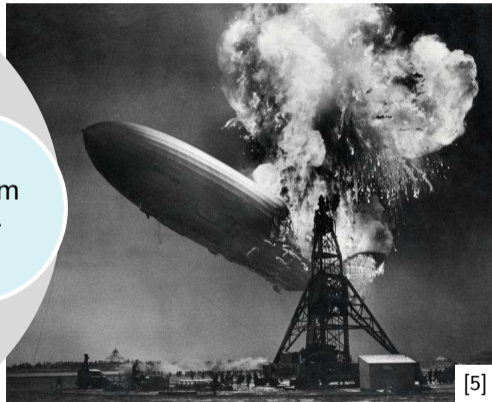
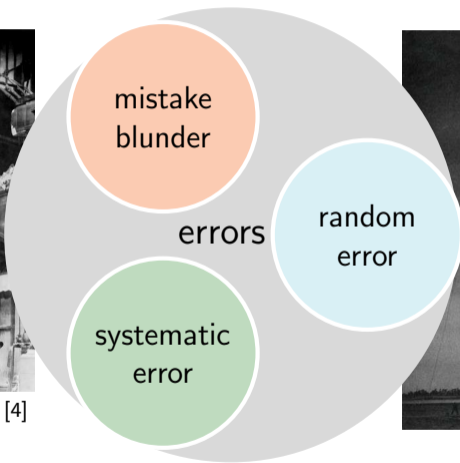
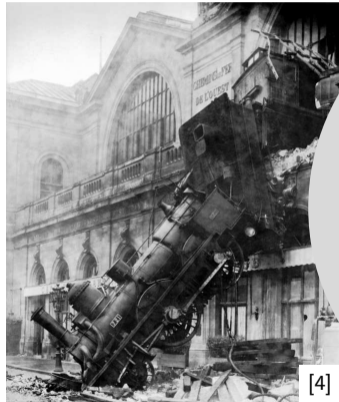


types of observational errors





variety of errors





variety of errors

random error noise; vibration; reaction time; ...

reduce cooling; damping; shielding; filter;

measure N times \rightarrow error scales with $\frac{1}{\sqrt{N}}$

systematic error clock drift; parallax error; graduation of the scale; ...

calibrate computationally eliminate;

multiple measurements with variation of the cause for errors; ...

mistake, blunder mixing up something; read the wrong data; transposed numbers; mistype; expectations; measuring instrument has defects; ...

avoid confirmatory measurement; redundancy; accurate protocol; back-of-the-envelope calculation; multiple measuring instruments; check digit; ...



p-hacking

problem false positive

occurrence if you do one experiment a day

1σ (68.2%) two or three times wrong per week

2σ (95.4%) every three weeks

3σ (99.7%) yearly

4σ (99.994%) 43 years

5σ (99.999 999 4%) 4776 years

idea inflate the number of hypotheses

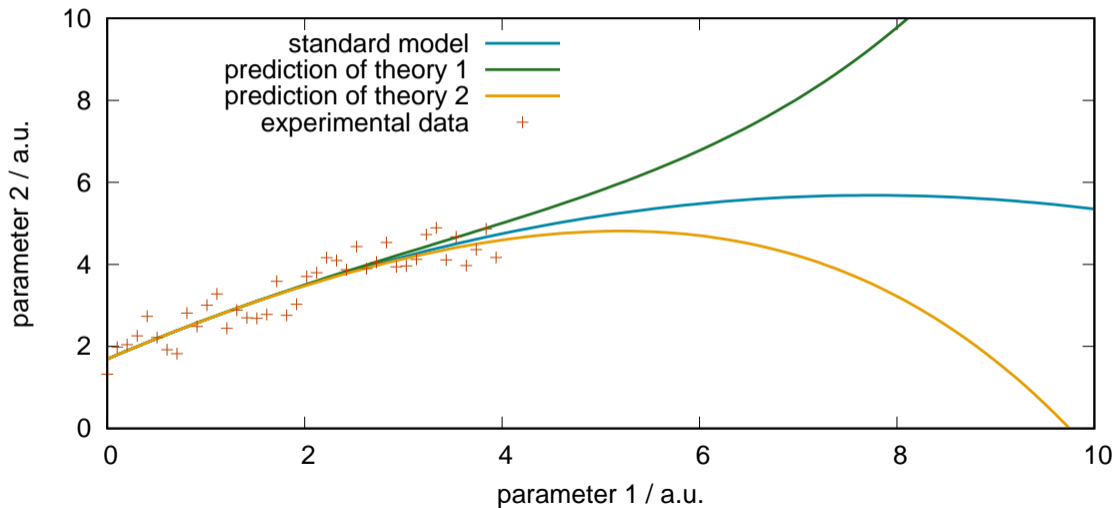
→ at least some will be statistically significant

example “chocolate . . . as a weight-loss accelerator”

[Bohannon et al., Global J. of Med. Research, XV (2) 1, (2015)]

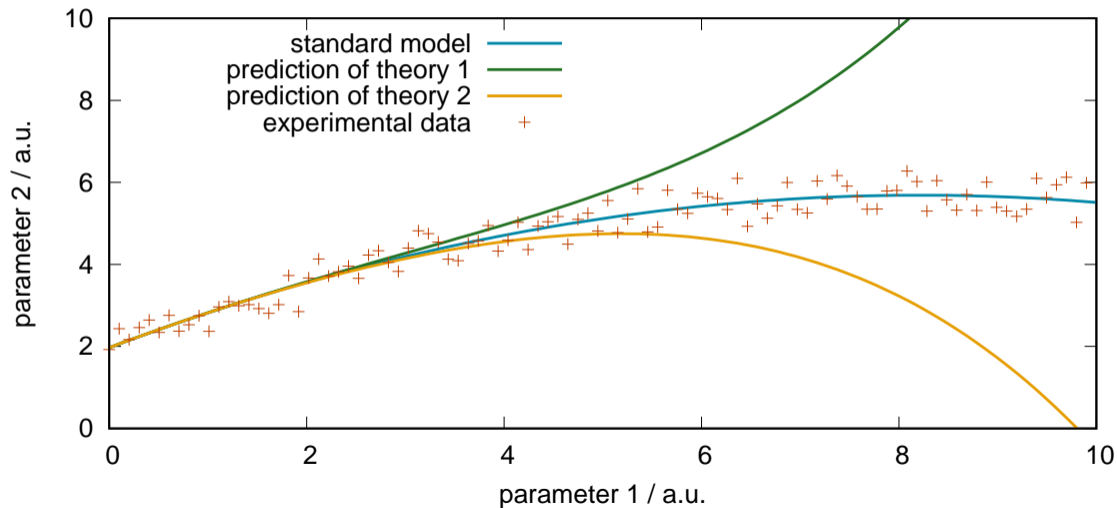


searching for improved models





searching for improved models





good science

“ A person can claim more in 5 minutes,
than a scientist can disprove in his whole life. ”

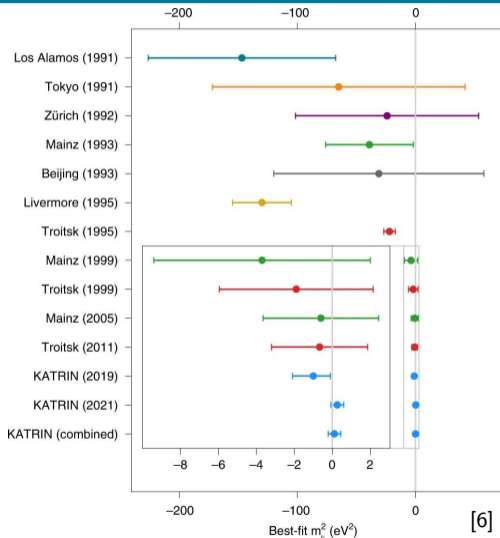
strategy search for the internal inconsistency in the theory or experimental data
and try to reduce contradictions

examples

speed of light is constant	→	theory of relativity
ultraviolet catastrophe	→	black-body radiation
uncertainty of measurement	→	quantum mechanics
missing energy in experiment	→	neutrino



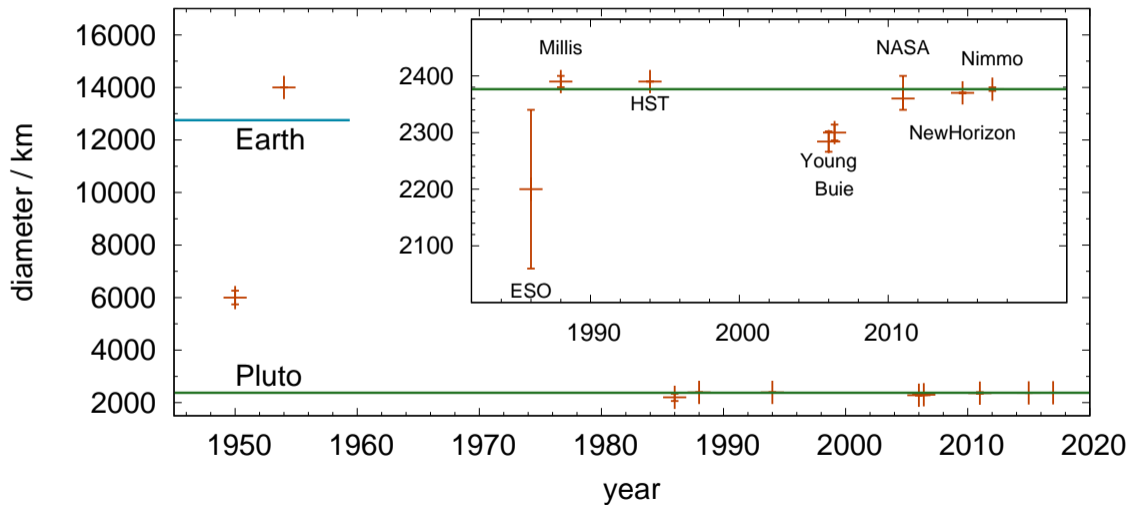
error bars: neutrino mass



[6] The KATRIN Collaboration. Nat. Phys. 18, 160–166, (2022)



error bars: Pluto





correlation vs. causality

example more light on a solar panel \rightarrow more output power

idea search for correlations and assume causality

problem correlation does not imply causation

example claim Most electronic devices run on smoke.

proof If you let the smoke out, then they do not work anymore.

technique SED (smoke emitting device); NED (noise emitting device)

reverse causation windmill rotate faster \leftrightarrow more wind \rightarrow windmill produce wind

spurious correlation more ice is soled \leftrightarrow more persons drown \rightarrow ice drowns persons



which model is needed?

project build a solid state laser ($\text{Cr}^{4+}:\text{YAG}$) with femtosecond pulses *

beam propagation laser shows stable continuous wave operation

non-linearity Kerr-lens, thermal lens, self-phase modulation

dispersion compensation with prisms and chirped mirrors

temporal and spacial propagation split-step Fourier methode

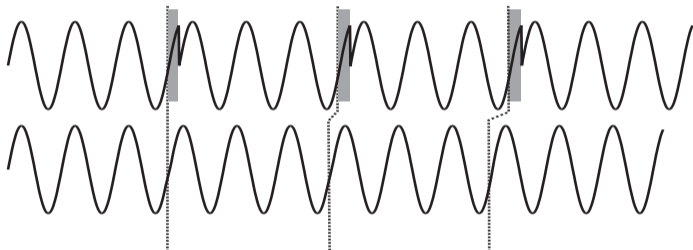
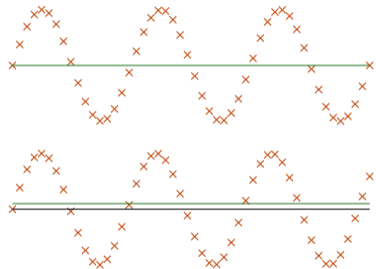
experiment measuring the solar spectrum (spurious correlation)

*M. Böhm, “... non-linear propagation of light pulses” dissertation, University of Rostock (2003)



adapting the Fourier transform to the measurement

problem: Fourier transform on finite measuring sample

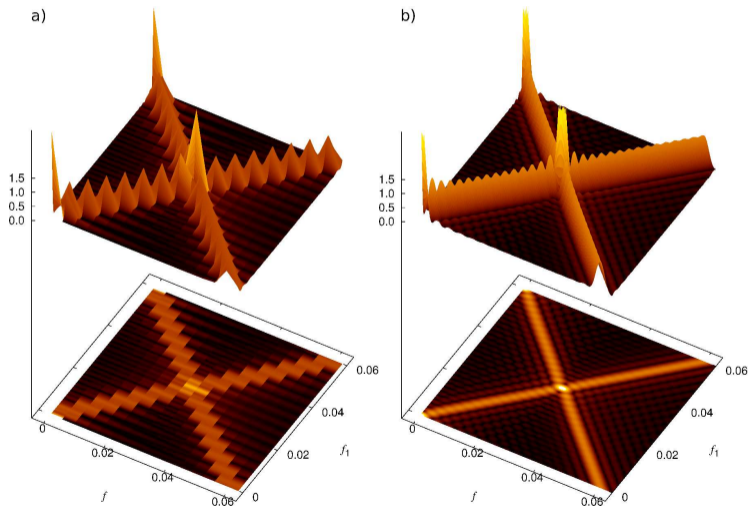


M. Böhm, et al., *Trim-to-coherence Fourier transform*, J. of Comput. Phys. **228**: 2906-2917 (2009)

→ „Phase shift Fourier transform“



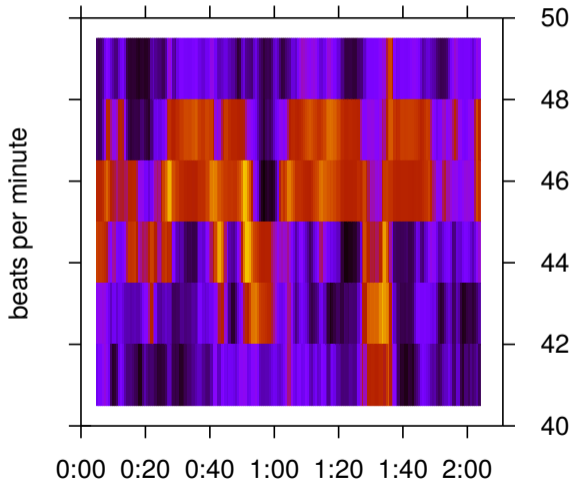
Fourier transform without and with trim-to-coherence



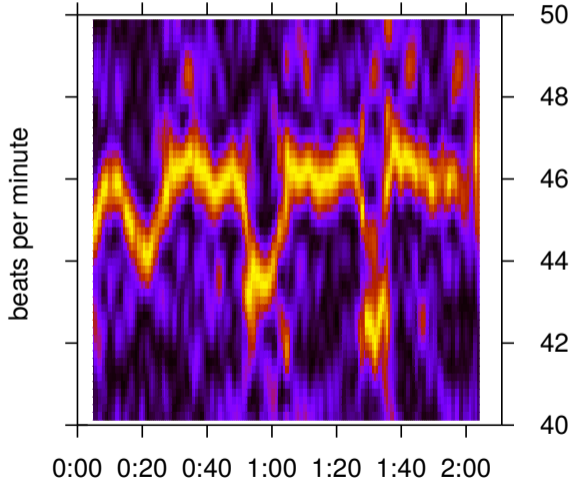


example: Elvis - Blue Suede Shoes

spektrogramm with Fourier transformation



phase shift Fourier transform





Chatbots: e.g. ChatGPT

I need a program,
which can prepare hundreds of slides for presenting data.

You need a program,
which can listen to boring presentations and can give a short summery.

problem ChatGPT has problems citing its sources



Review

P 18.5 Mi 10:30 Aula

Optimising plasma injection in field coils — •LEA BRAHMS¹, REGINALD BARCLAY², ZEFRAH COCHRANE², GEORDI LAFORGE² and MILES O BRIAN² — ¹Polytechnical Institute For Material Sciences, Novosibirsk, Russia — ²Daystrom Institute For Advanced Technological Studies, Honolulu, Hawaii (USA)

In modern field coil technology the problem of plasma injection takes a lot of attention. In recent years this problem was solved by canalising the plasma flow into Dyson-tubes, which caused considerable inefficiencies in the power management of the field reactor. New magnetic valve injectors that have been developed during the last four years guarantee a steady and reliable plasma flow in the coils. With this new optimised field geometry the closing-reopening cycle of the injectors could easily be varied between 25 and 50 ns. A maximum reliable cycle time of more than 53 ns could be achieved using arkenium duranite instead of conventional duranite in the injectors. Due to sequential firing of the plasma injectors, the warp field sheaths are pressed together corresponding to the plasma pulse frequency. These cumulative field sheath forces lead to a considerable mass reduction. In conclusion this new technology offers a variety of new possibilities to go where no man has ever gone before.

Verhandlungen DPG 2000







something is wrong: find the error

Asiana Airlines Flight 214



[7]

KTVU reports

Video [8]    



good errors, bad errors

mistakes are needed for learning

“ A man of genius makes no mistakes.
His errors are volitional and are the portals to discovery. ” †

avoid unnecessary studies ‡

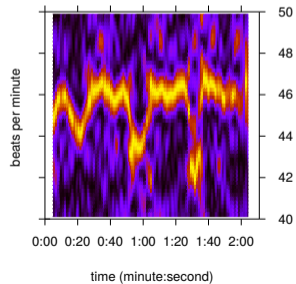
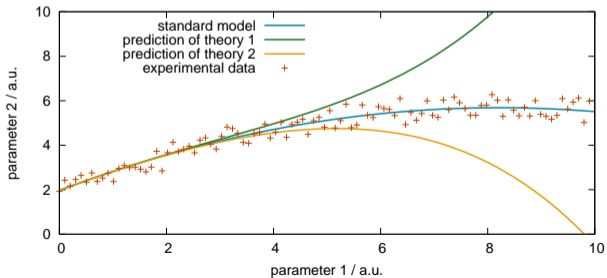
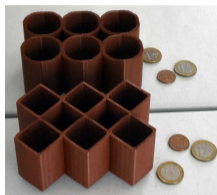
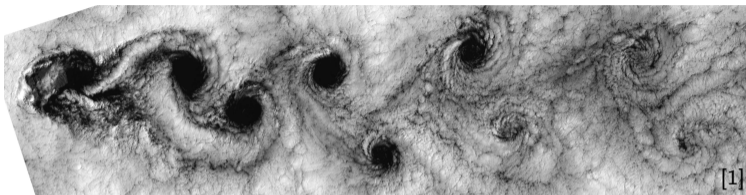
- prospective registration
- timely results reporting
- open access

†James Joyce, *Ulysses* (1922), Chapter 9: Scylla and Charybdis

‡Franzen et al. *Institutional dashboards on clinical trial transparency for University Medical Centers: A case study*. PLOS Medicine 20(3): e1004175 (2023). <https://doi.org/10.1371/journal.pmed.1004175>



Thank you for your attention





References

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- [5] Sam Shere, May 2012.
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- [6] The KATRIN Collaboration. Direct neutrino-mass measurement with sub-electronvolt sensitivity. *Nat. Phys.* 18, 160–166, February 2022.
<https://doi.org/10.1038/s41567-021-01463-1>.
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- [8] Jim Michaud (Youtube).
<https://www.youtube-nocookie.com/embed/CaOkTKfxu44>.