Classical Fractons: Hamiltonian attractors, non-equilibrium steady states and an arrow of time

arXiv:2501.12445 with A. Babbar, Y. Sadki and S.L. Sondhi

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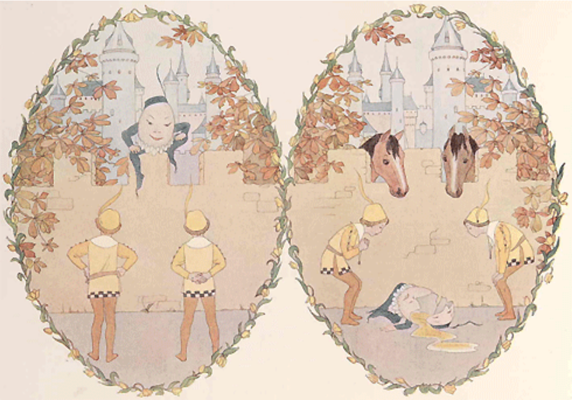
This talk will be about:

- A toy resolution of the ‘Arrow of time’ paradox
- Model: classical dipole conserving ‘fractons’

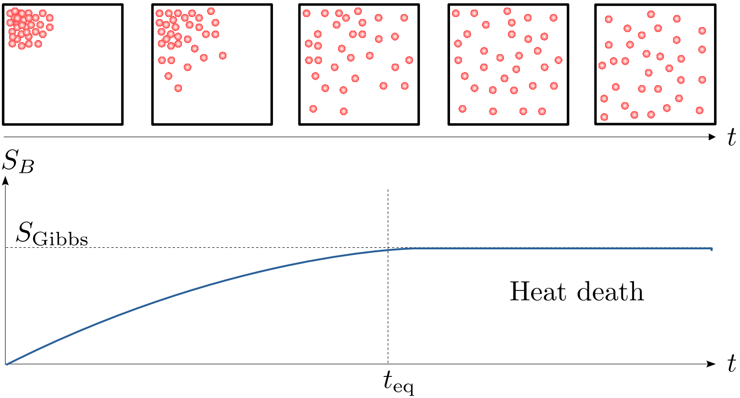
Plan of action:

1. Arrow of time paradox
2. Fracton resolution
3. Hot take

Arrow of time

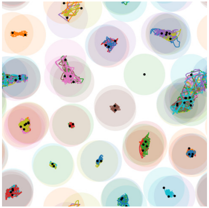


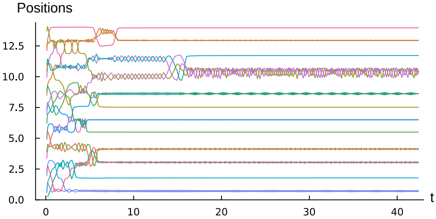
- Macroscopic evolution towards increase in Boltzmann entropy
- II Law of Thermo: entropy increase $\leftrightarrow$ arrow of time



- Equilibrium: entropy saturates at Gibbs value
- Non-equilibrium microstates highly atypical
- Time perception needs (a) special initial conditions “past hypothesis”, (b) far away from equlibrium “heat death”
- What happens when the system does not equilbriate

Classical Fractons as a toy non-equilibrium system

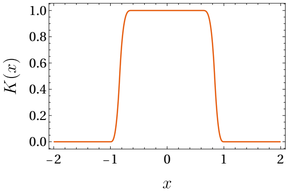




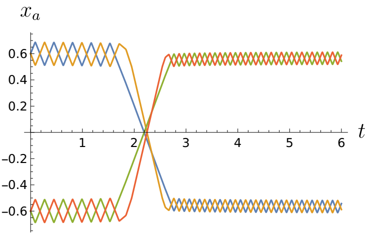
- Classical non-relativistic dipole conserving point particles
- Non-equilibrium ergodicity breaking steady states
- Attractors in position-velocity space, evades Hohenberg-Mermin-Wagner-Coleman theorem
- **'Natural' arrow of time**

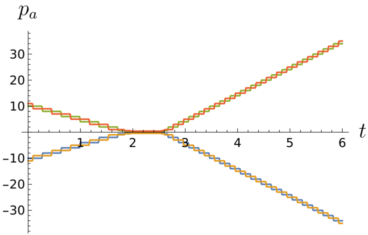
Low complexity 'Janus point' in trajectories

$$H = \sum_{a<b} \frac{|p_a - p_b|^2}{2} K(x_a - x_b)$$

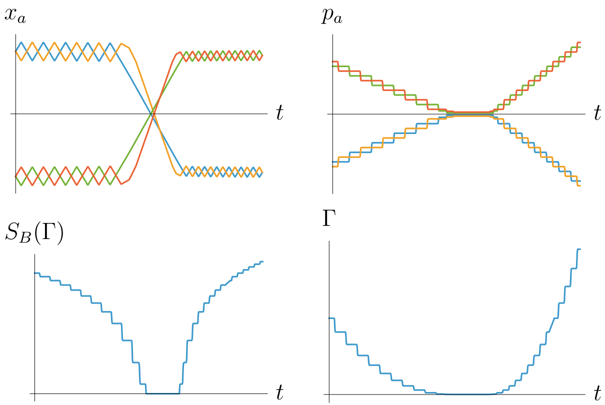


Translation: $\vec{x}_a \mapsto \vec{x}_a + \vec{\chi}$, Dipole conservation: $\vec{p}_a \mapsto \vec{p}_a + \vec{\phi}$





Boltzmann entropy reveals a bi-directional arrow of time



- $S_B(\Gamma)$: volume of microstates producing observable Γ
- Macro observable, Γ: measure of clustering $\frac{1}{2}\sum_{j<k}(p_j - p_k)^2$, $S_B \propto \log \Gamma$

Spontaneous Inflation and the Origin of the Arrow of Time

Sean M. Carroll, Jennifer Chen

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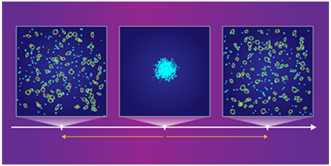
Identification of a Gravitational Arrow of Time

Julian Barbour[1], Tim Koslowski[2], and Flavio Mercati[3,*]

Is the hypothesis about a low entropy initial state of the Universe necessary for explaining the arrow of time?

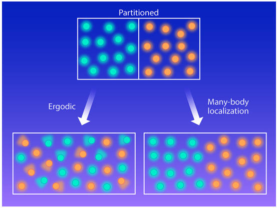
Sheldon Goldstein[1,*], Roderich Tumulka[2,†], and Nino Zanghì[3,‡]



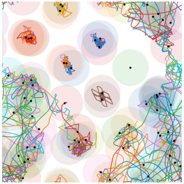
- Unbounded entropy growth necessary for 'natural' arrows of time
- Enforced previously through infinite spatial volume
- Fractons: unbounded *momentum* growth even in *finite spatial volume*

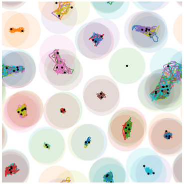
Non equilibrium dynamics as a resolution to arrow of time?

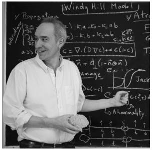
- Janus point and arrow of time in other non-equilibrium systems?

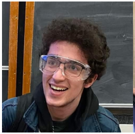


- Is our universe a non-equilibrium system? **Fractons as a toy model?**






Classical nonrelativistic fractons

Abhishodh Prakash, Alain Goriely, and S. L. Sondhi
Phys. Rev. B **109**, 054313 – Published 27 February 2024

Machian fractons, Hamiltonian attractors, and nonequilibrium steady states

Abhishodh Prakash, Ylias Sadki, and S. L. Sondhi
Phys. Rev. B **110**, 024305 – Published 3 July 2024

arXiv:2501.12445 [pdf, other]

Classical Fractons: Local chaos, global broken ergodicity and an arrow of time
Aryaman Babbar, Ylias Sadki, Abhishodh Prakash, S. L. Sondhi

arXiv:2502.02650 [pdf, other]

Phase space fractons
Ylias Sadki, Abhishodh Prakash, S. L. Sondhi, Daniel P. Arovas

arXiv:2408.10321 [pdf, other]

Universal Freezing Transitions of Dipole-Conserving Chains
Jonathan Classen-Howes, Riccardo Senese, Abhishodh Prakash