Kinetic Field Theory

Short winter-seminar talk by Laurin Söding

Montafon, 05.02.2023

Laurin Söding

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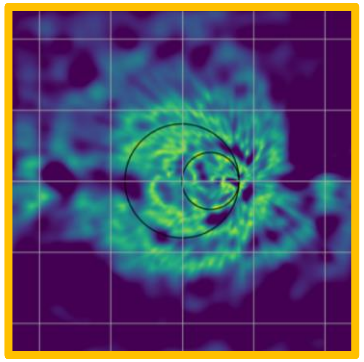
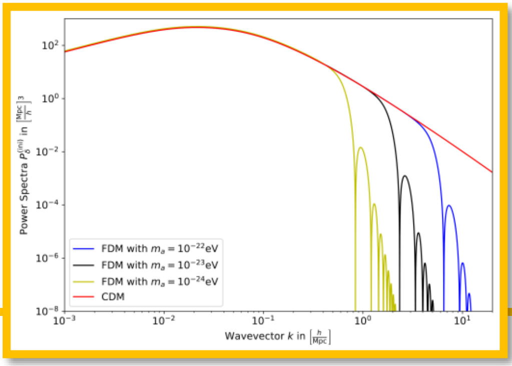
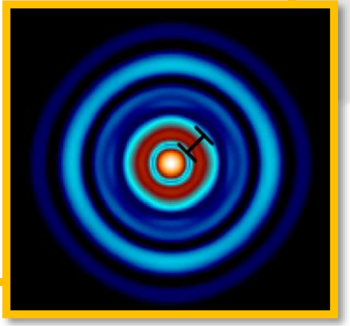
Research Interests:
- Galactic Gas Reconstruction
- Cosmic Rays
- Bayesian Inference



Formerly:
- Axion (Fuzzy) Dark Matter
- Kinetic Field Theory





Personal Interests:
- Sports (Jogging, Gym, …)
- Board Games
- Hiking

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Kinetic Field Theory as an analytic approach to cosmic structure formation

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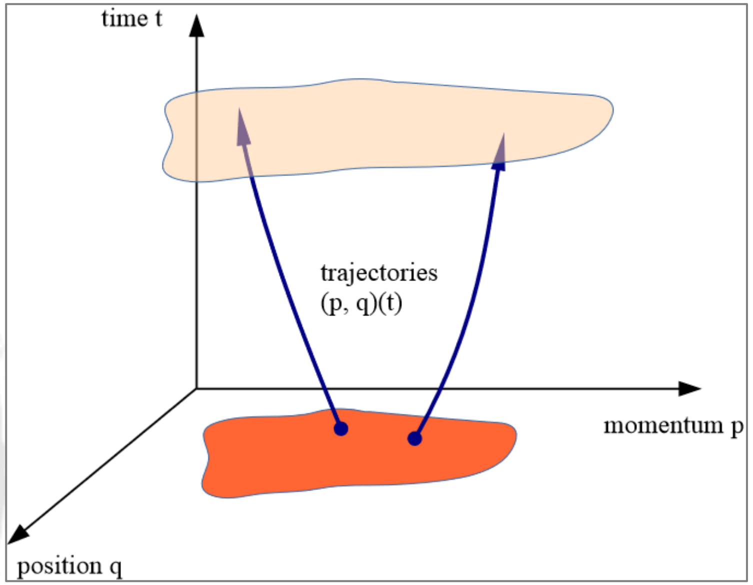
What is Kinetic Field Theory?

- What?
  - Statistical description of classical particle ensemble
  - In and out of equilibrium
  - Basis: Hamilton's equations:

$$\dot{x}(t) = -\begin{pmatrix} 0 & \mathbb{1}_3 \\ \mathbb{1}_3 & 0 \end{pmatrix} \nabla H(x(t), t) = E_0(x(t)) + E_I(x(t))$$

- How?
  - Generating functional $Z[J,K] = e^{\widehat{S_I}} \int \mathrm{d}\Gamma e^{i\langle J, x_0[K]\rangle}$



Bartelmann et al. 2019: Cosmic Structure Formation with Kinetic Field Theory

Interaction operator: $e^{\widehat{S_I}} = e^{\frac{\delta}{i\delta K}\cdot E_I\left(\frac{\delta}{i\delta J}\right)}$

Perturbation series: $e^{\widehat{S_I}} = 1 + \widehat{S_I} + \frac{\widehat{S_I}^2}{2} + \cdots$

Weighed integral over initial states
→Initial ensemble statistics
→Correlated particle positions and momenta

"free" particle trajectories:
Chosen as Zel'dovich trajectories
→Mimic linear growth (and possibly a little further)

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$$\rho(q,t) = \sum_{j=1}^{N} \delta_D\left(q - q_j(t)\right)$$

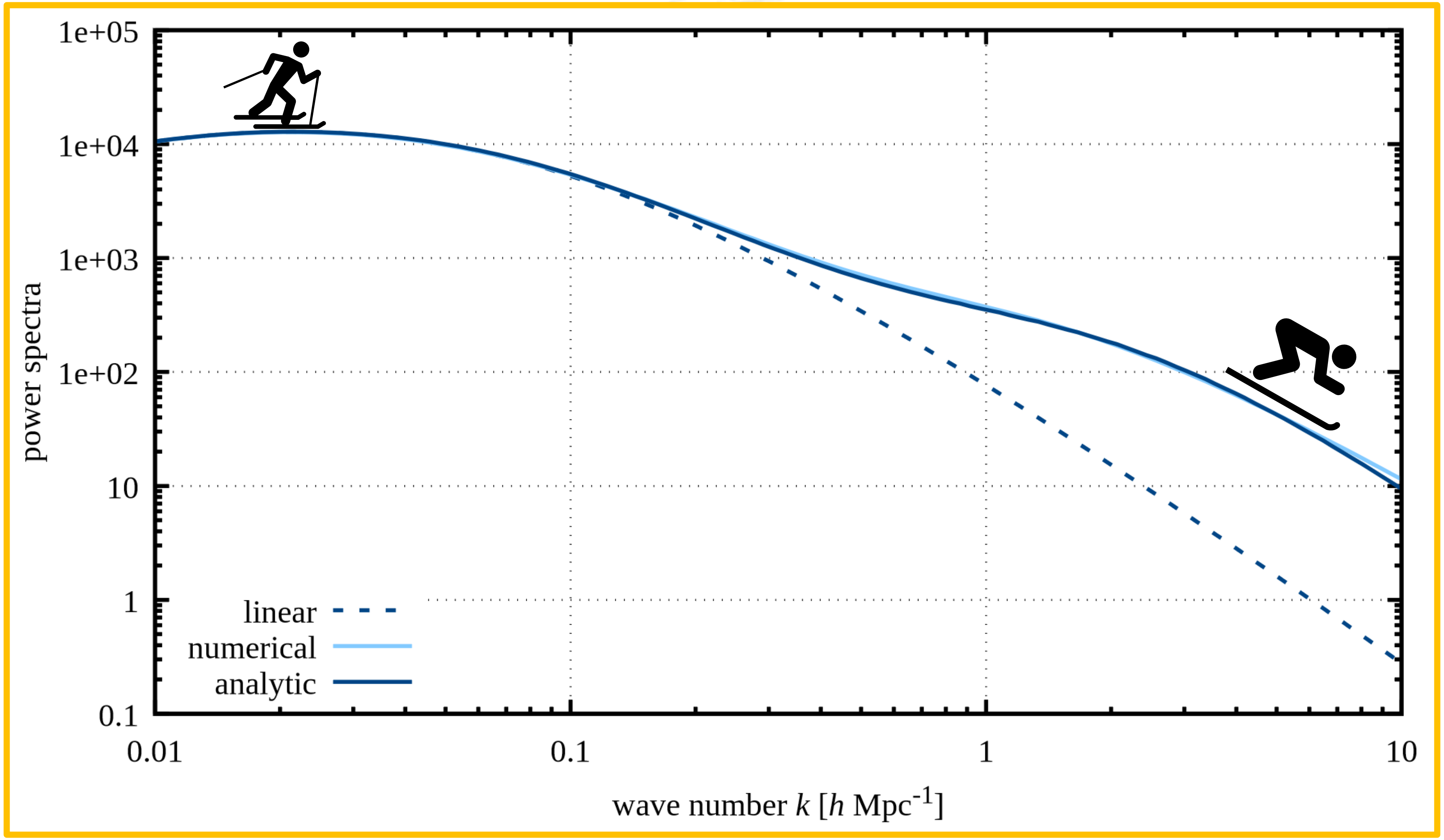
→

$$\hat{\rho}(k,t) = \sum_{j=1}^{N} \exp\left(-ik\cdot\left[-i\frac{\partial}{\partial J_{q_j}(t)}\right]\right) = \sum_{j=1}^{N} \hat{\rho}_j(k,t)$$

Density operator allows for computation of 2-pt. cumulant by successive application:

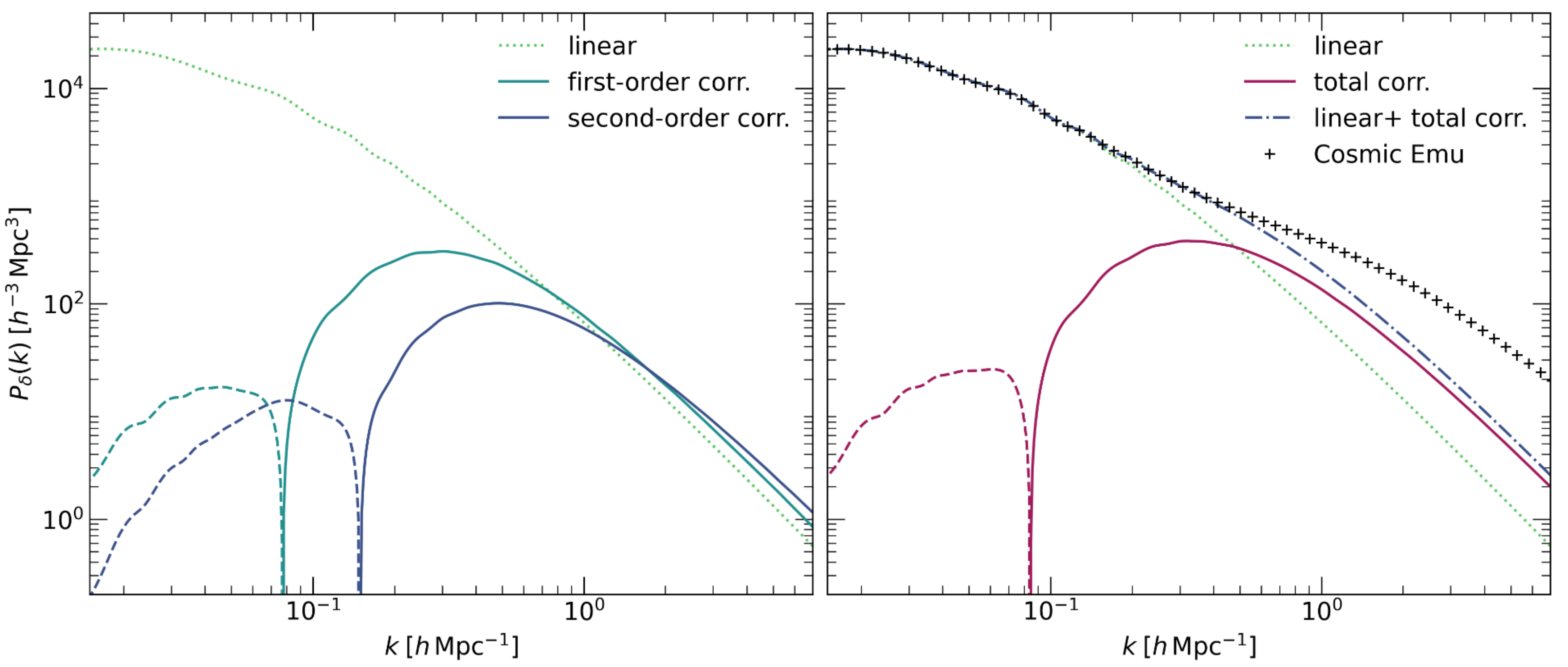
$$\langle\rho\rho\rangle = \hat{\rho}\hat{\rho}Z[J,K]\Big|_{J=K=0}$$

The Cosmic Power Spectrum 1: The Mean Field Approximation



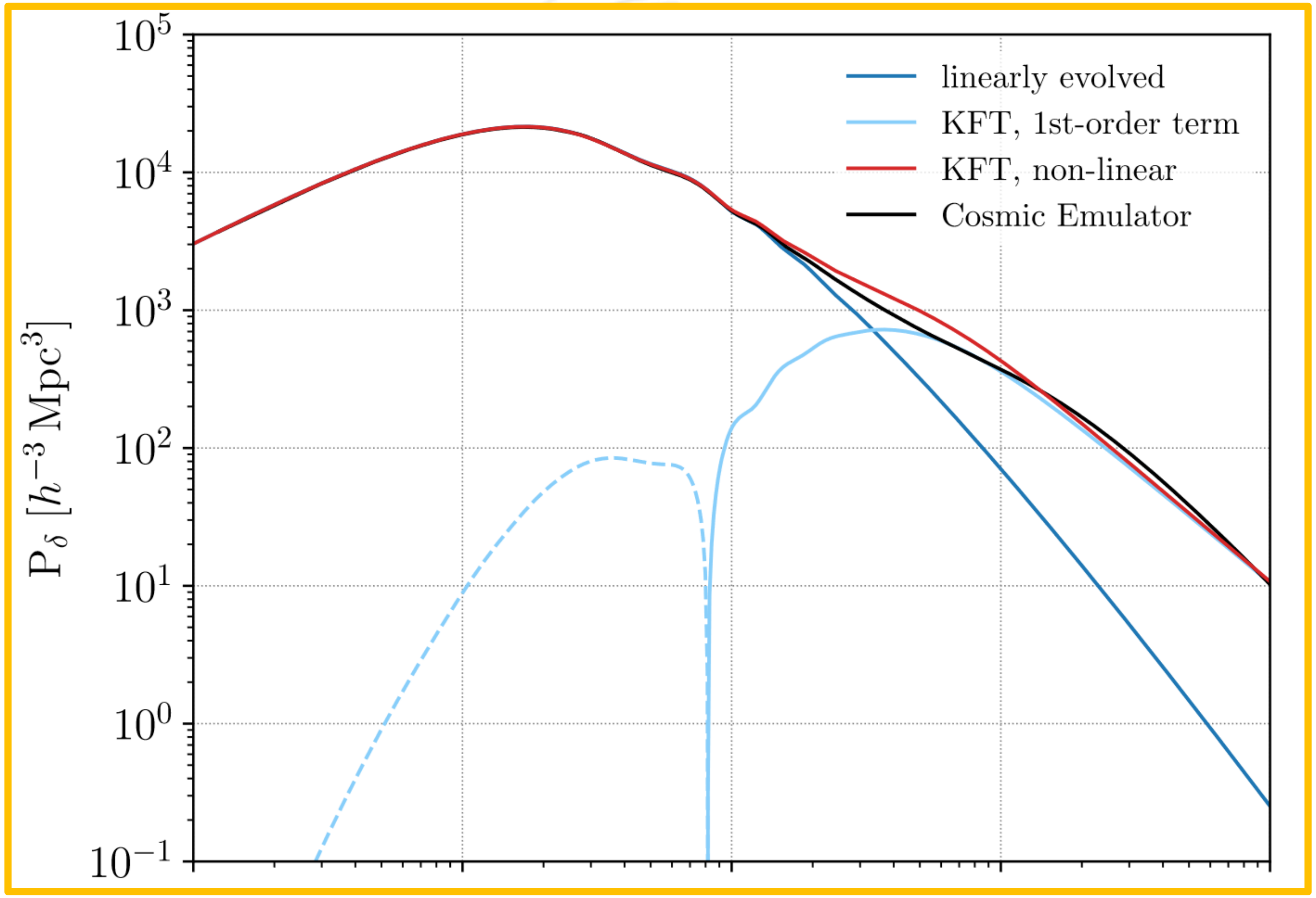
Konrad et al. 2022: Kinetic Field Theory for Cosmic Structure Formation

The Cosmic Power Spectrum 2: Perturbation Theory



Pixius et al. 2022: Kinetic Field Theory: Perturbation theory beyond first order

The Cosmic Power Spectrum 2: Perturbation Theory



Bartelmann et al. 2022: Cosmic Structure Formation with Kinetic Field Theory