

Numerically solving the early universe

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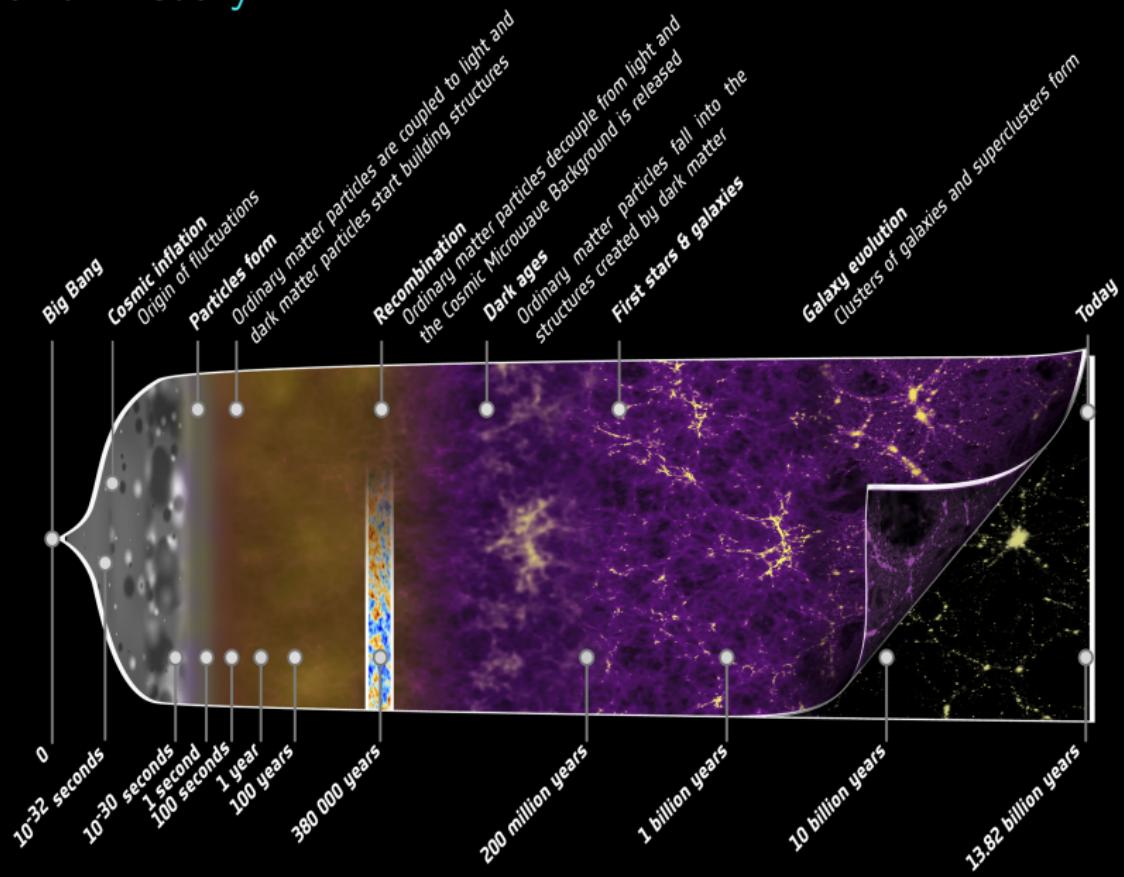
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- ▶ Theories of gravity
- ▶ Particle physics, beyond the Standard Model
- ▶ Large-scale structure formation (galaxies, clusters)

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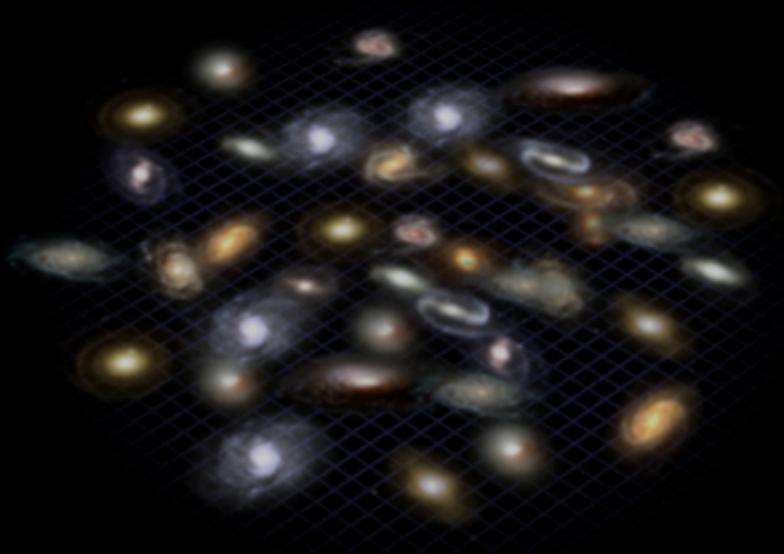
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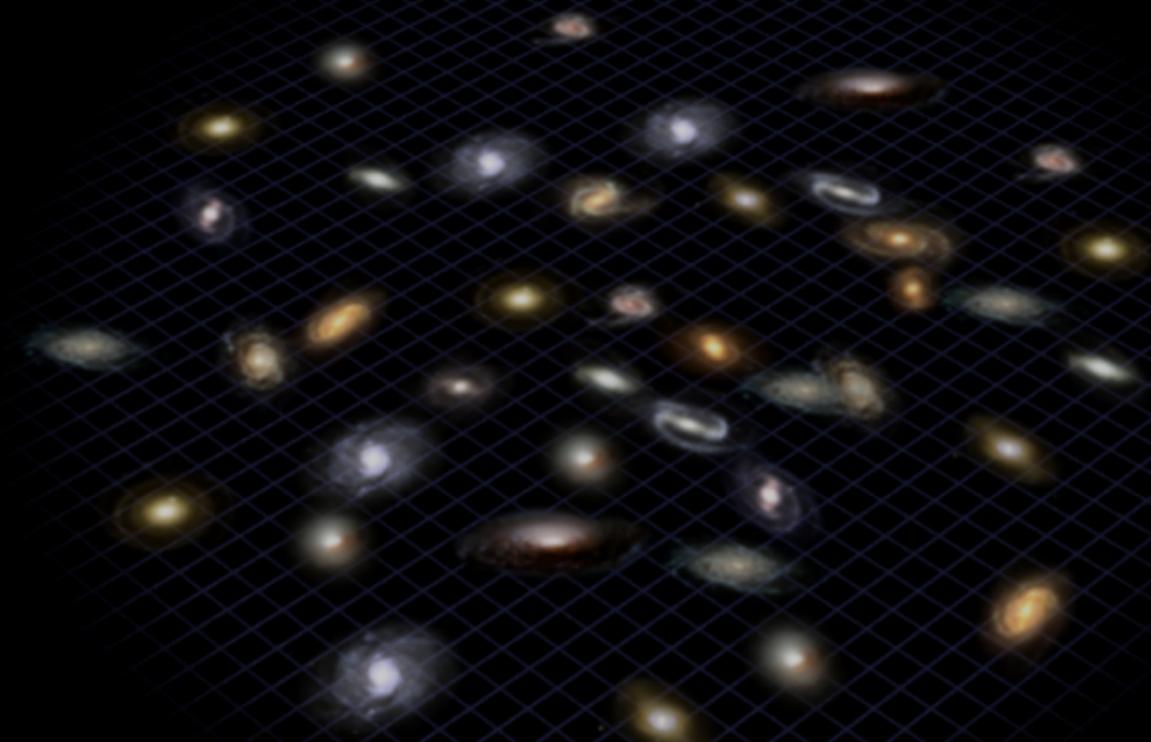
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- ▶ Particle accelerators can reach the energy scale of the era, ~ 1 TeV¹ → fundamental laws experimentally tested
- ▶ Before then (at higher energies), the physics is more speculative

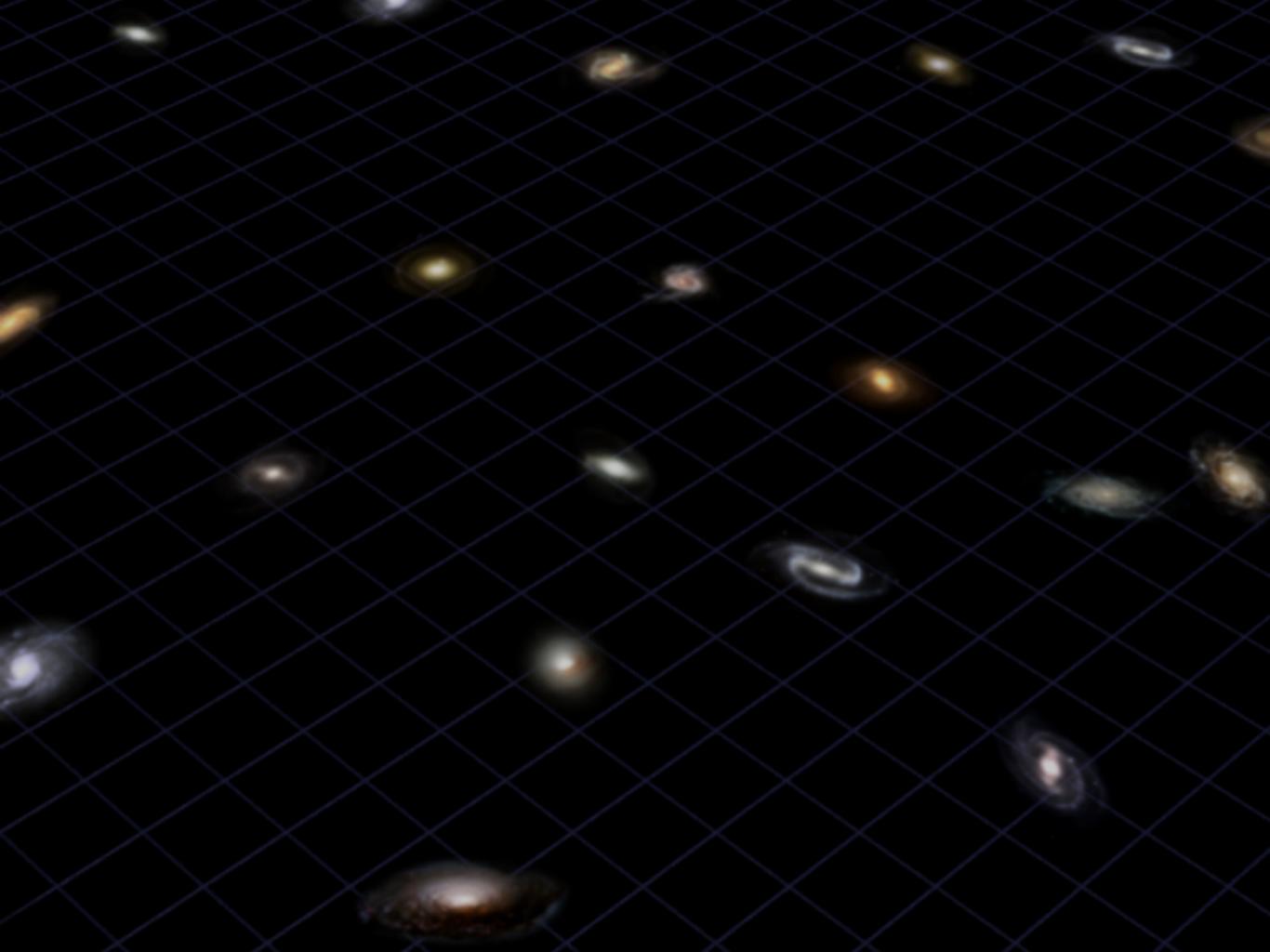
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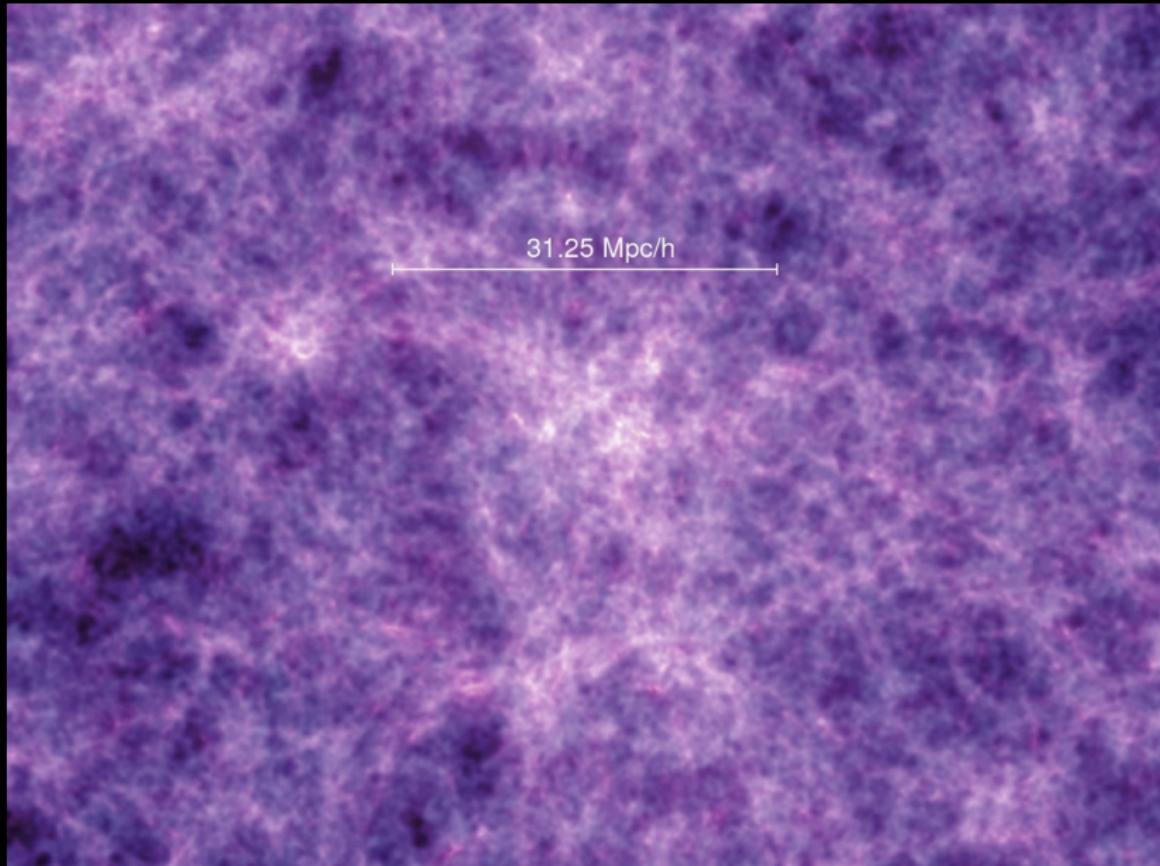
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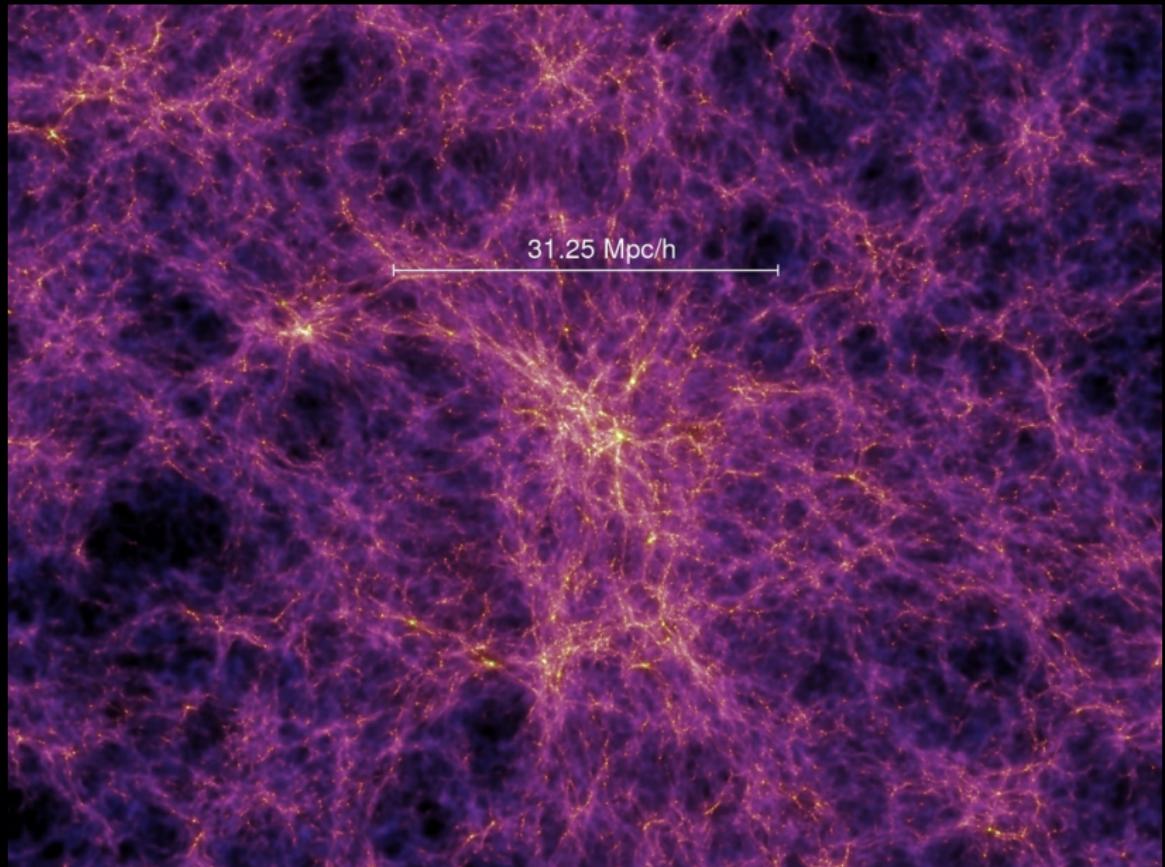
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- ▶ Matter self-gravitates, clusters and areas devoid of matter form

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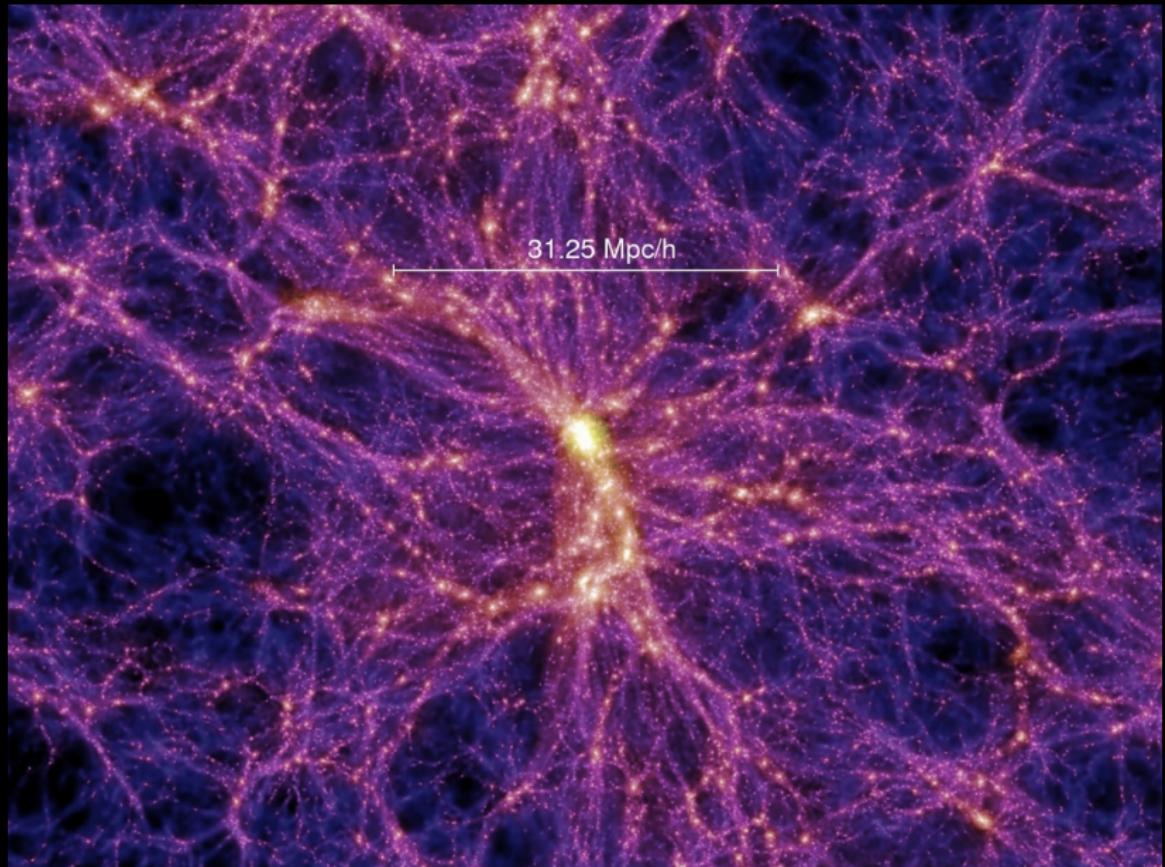
Gravitational collapse



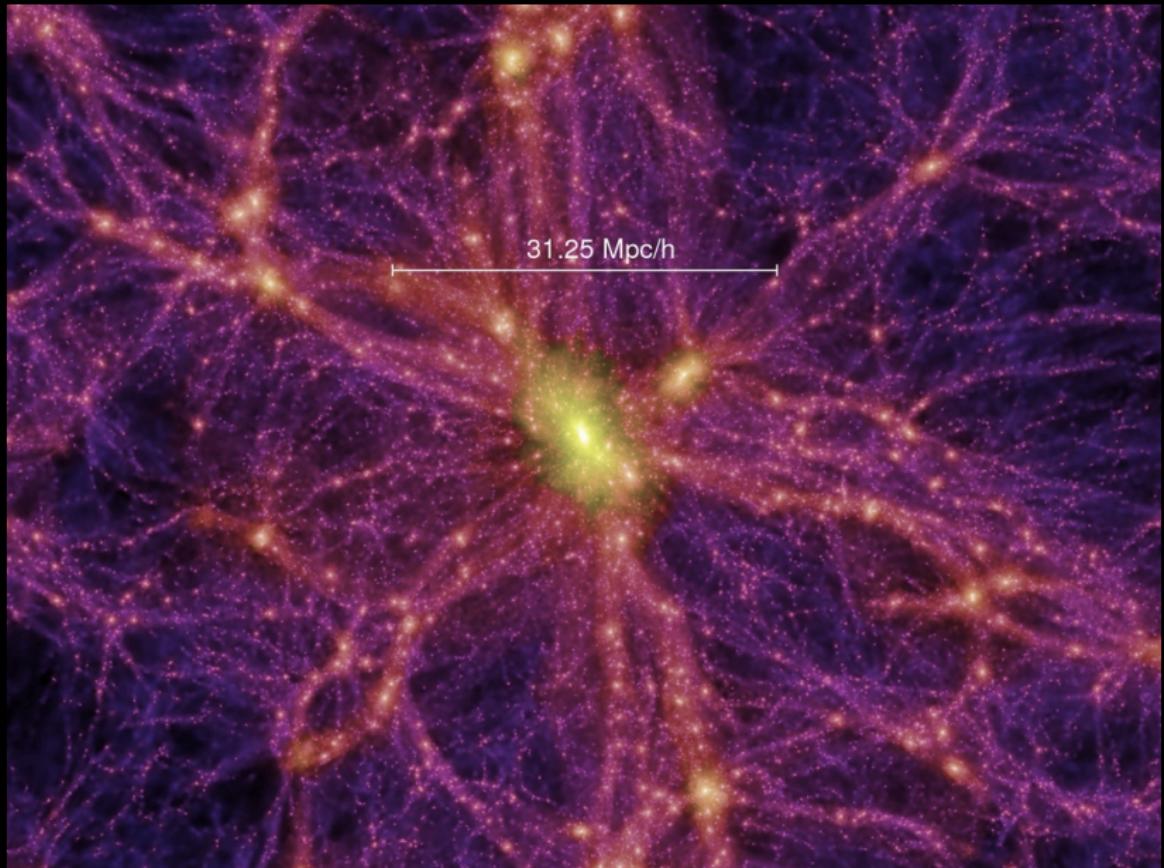
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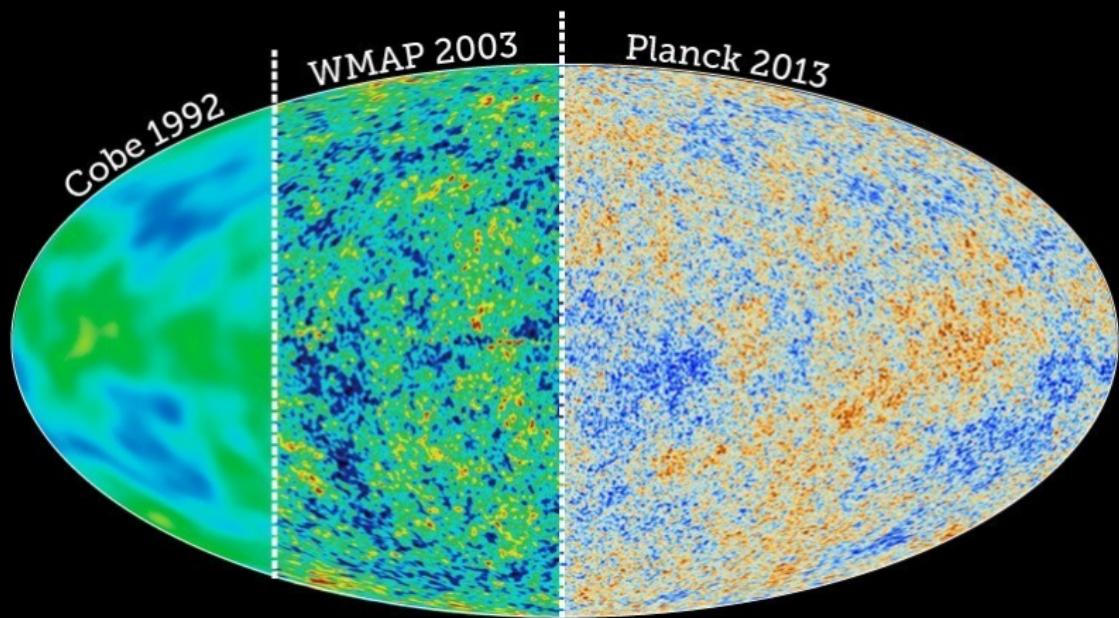
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- ▶ How did it decay into ordinary matter?
- ▶ How was it distributed?

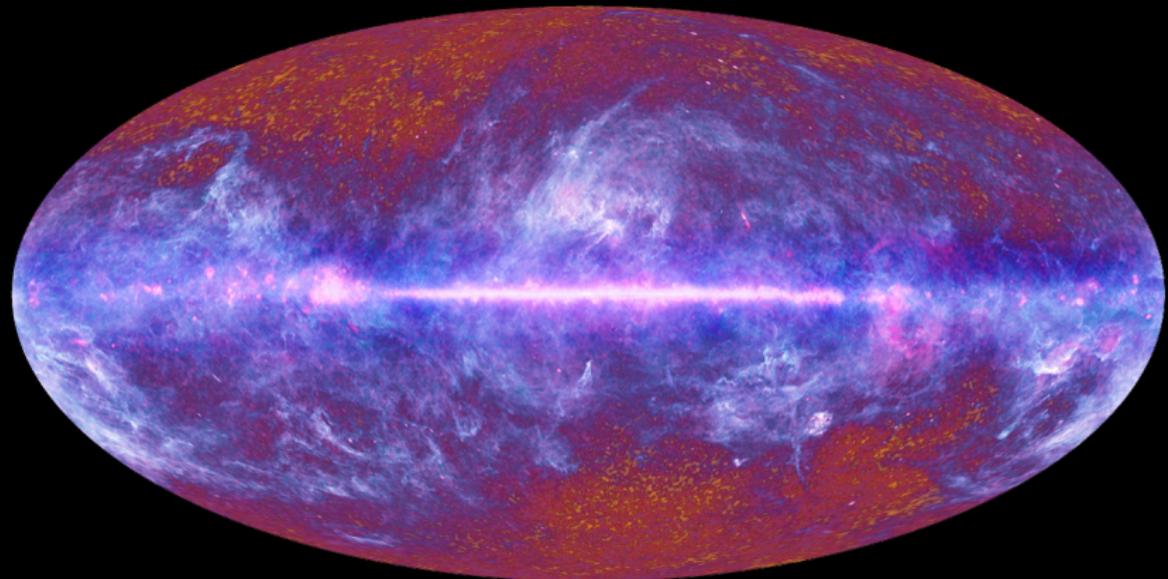
How do we begin to answer these questions?

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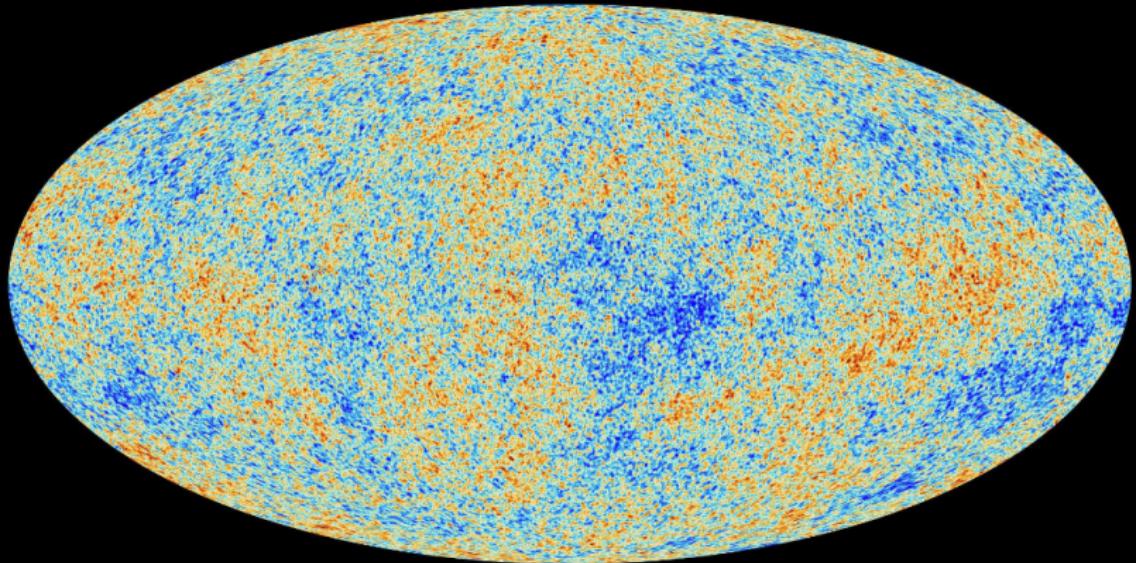
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- ▶ → CMB shows state of the universe long before the first stars formed!

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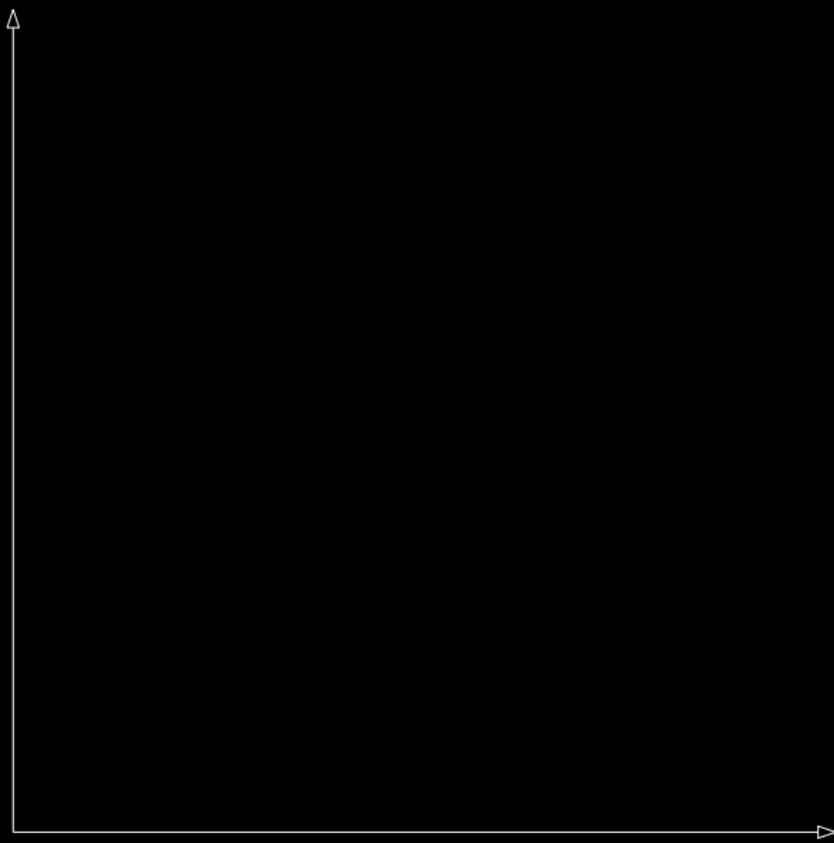
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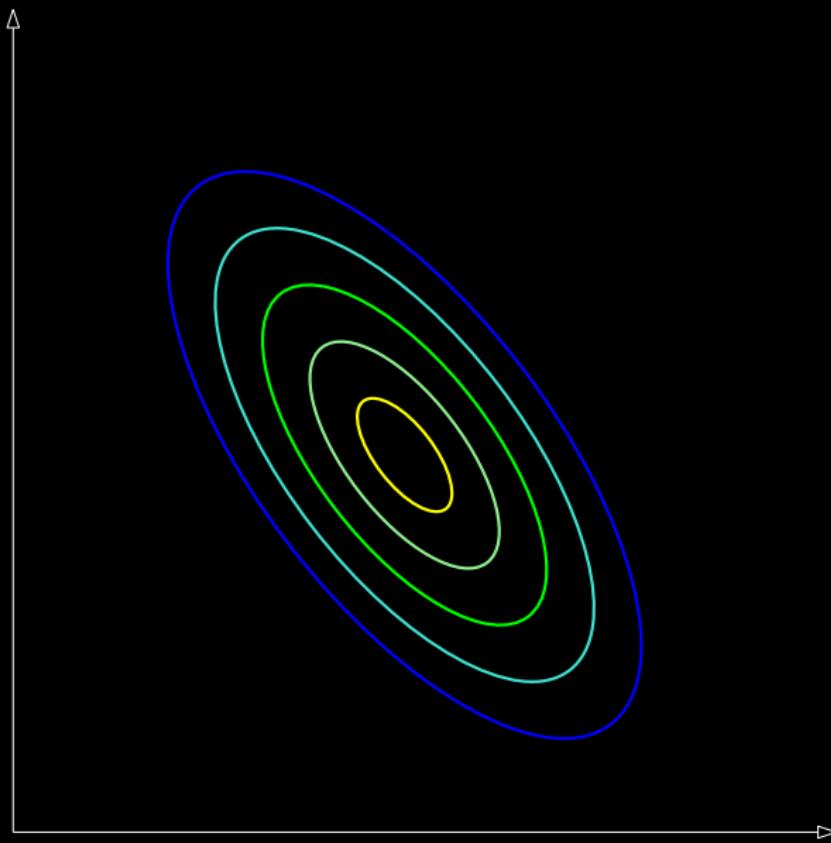
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5. Repeat! (Until best-fit parameters are found)

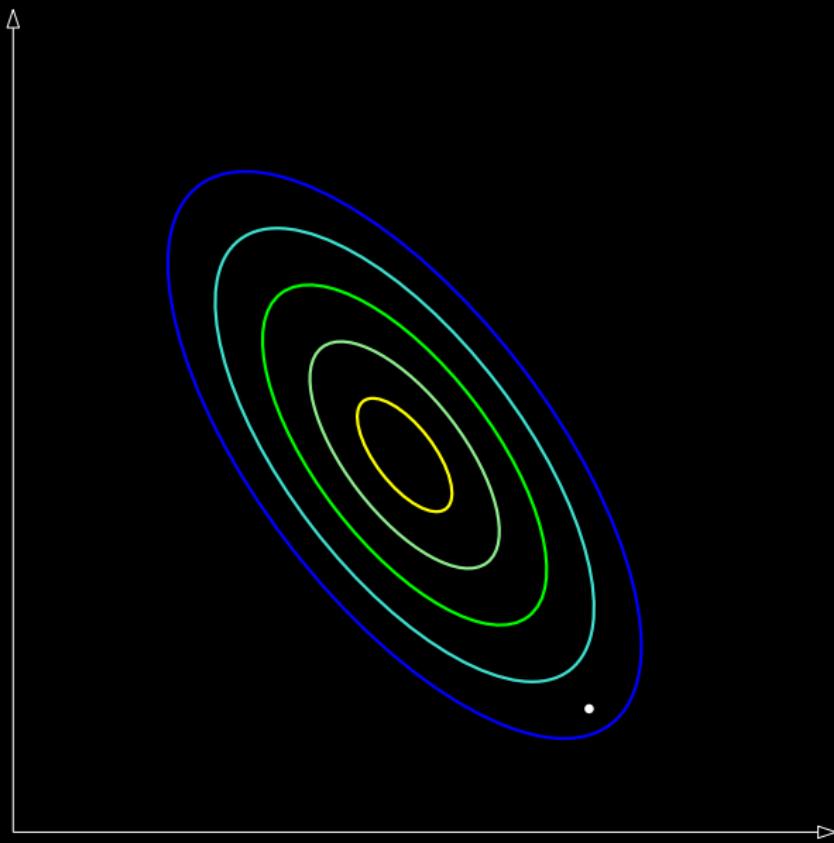
Parameter estimation in cosmology



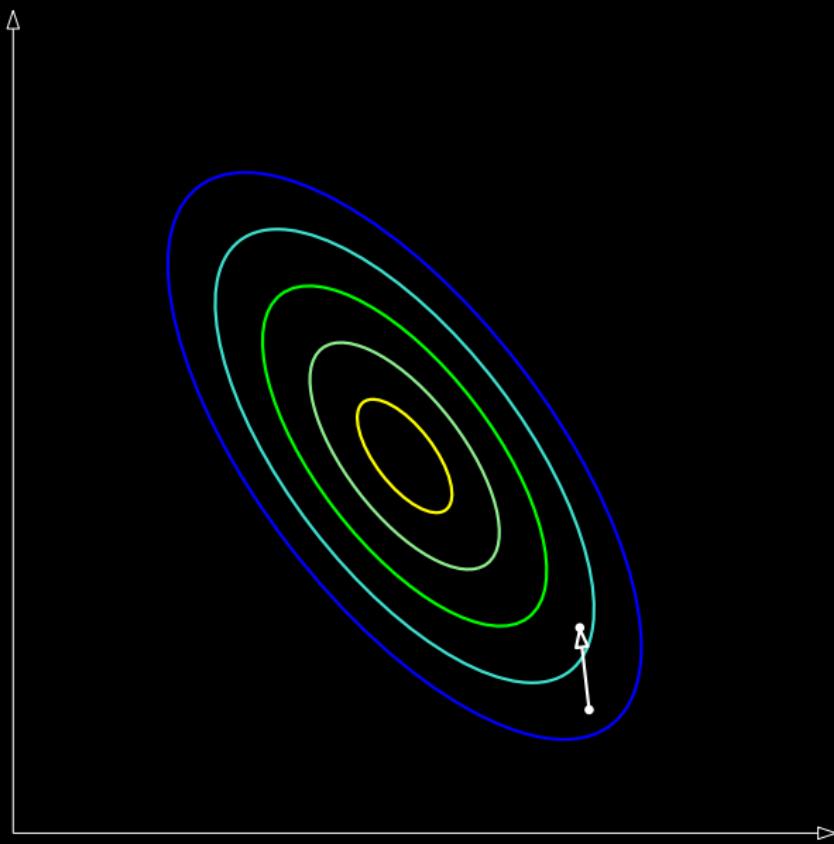
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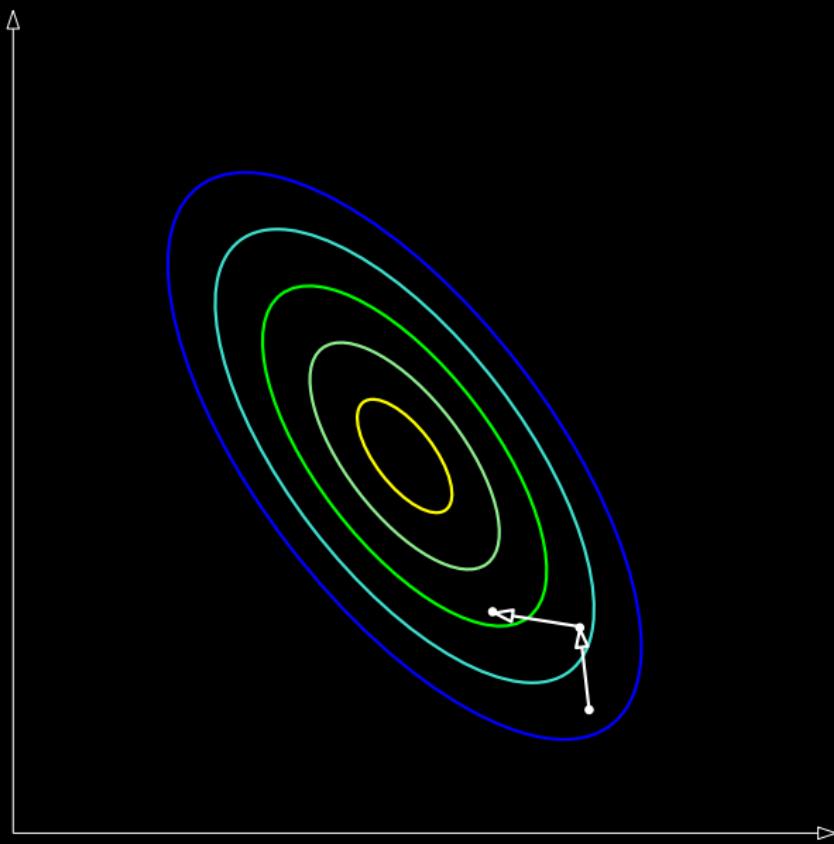
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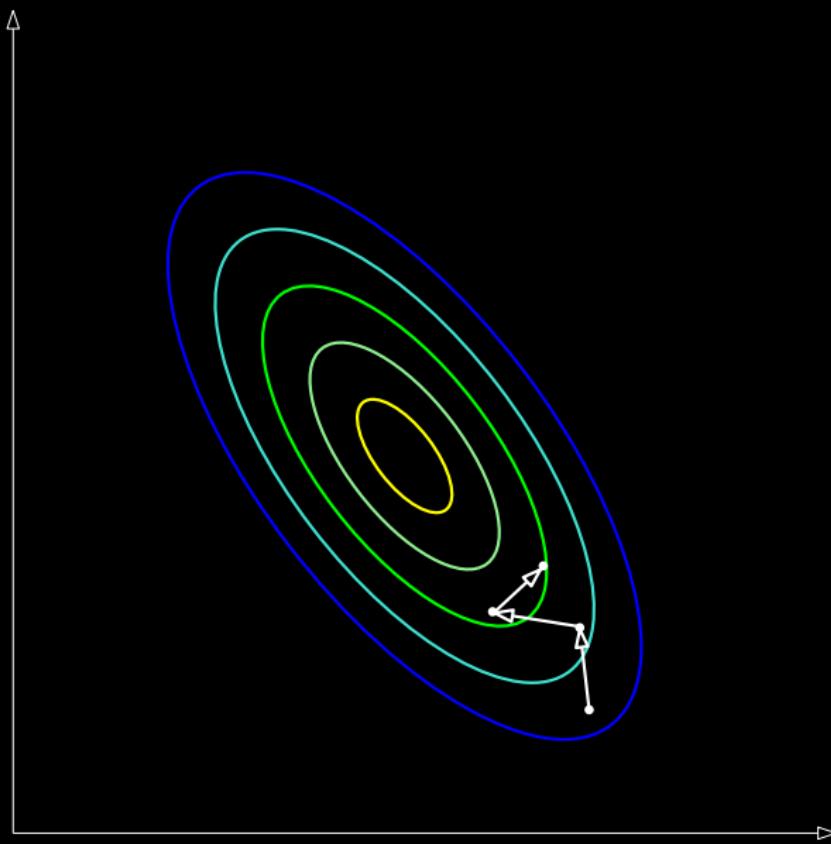
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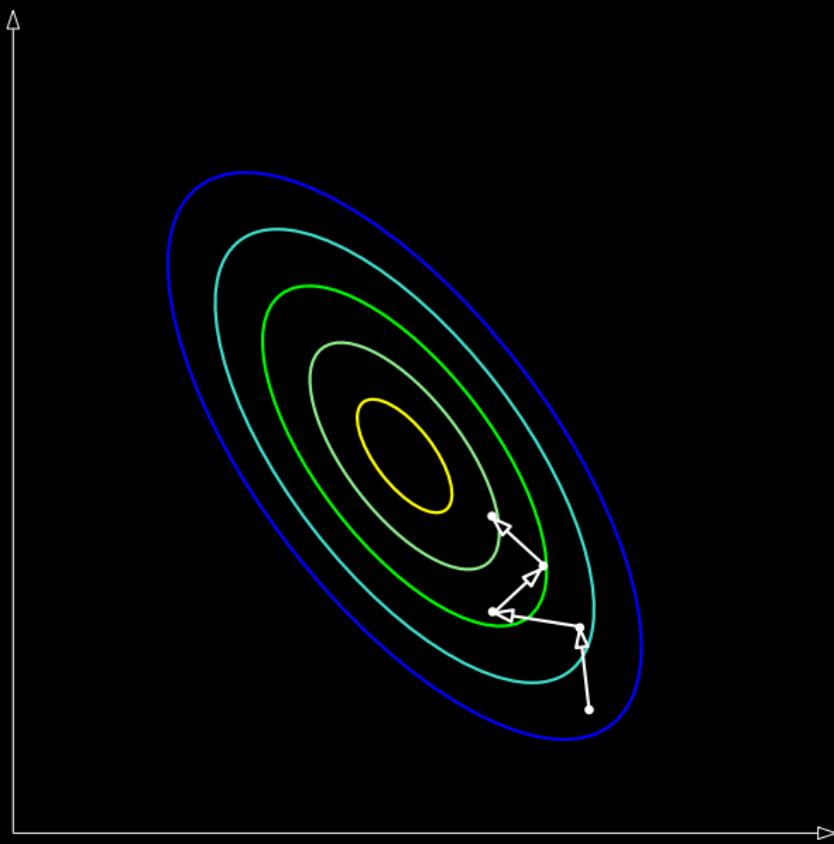
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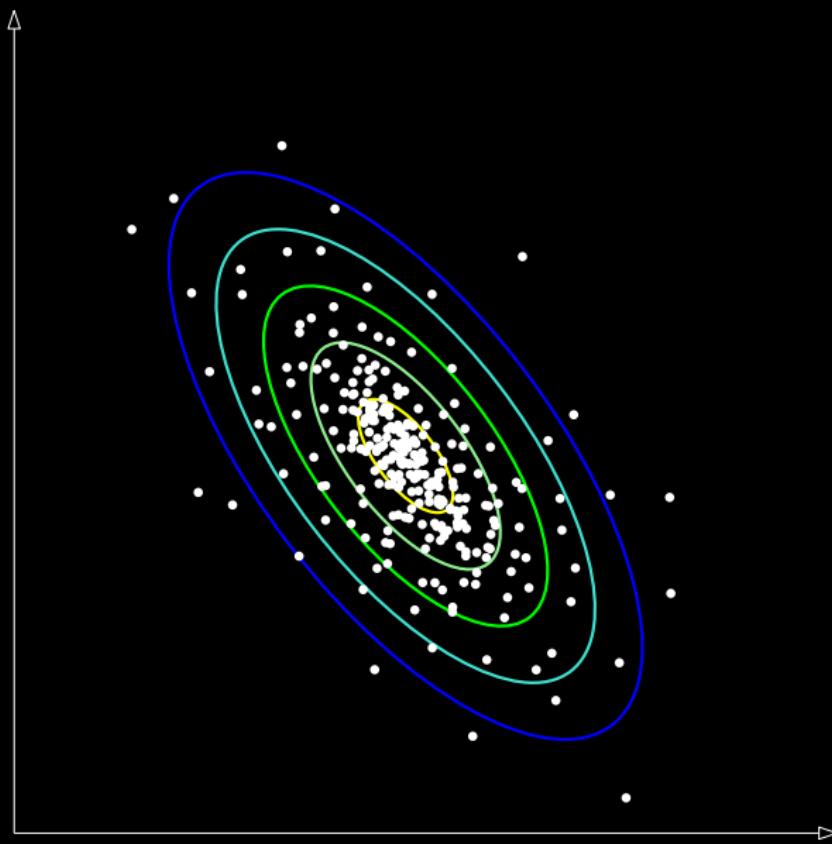
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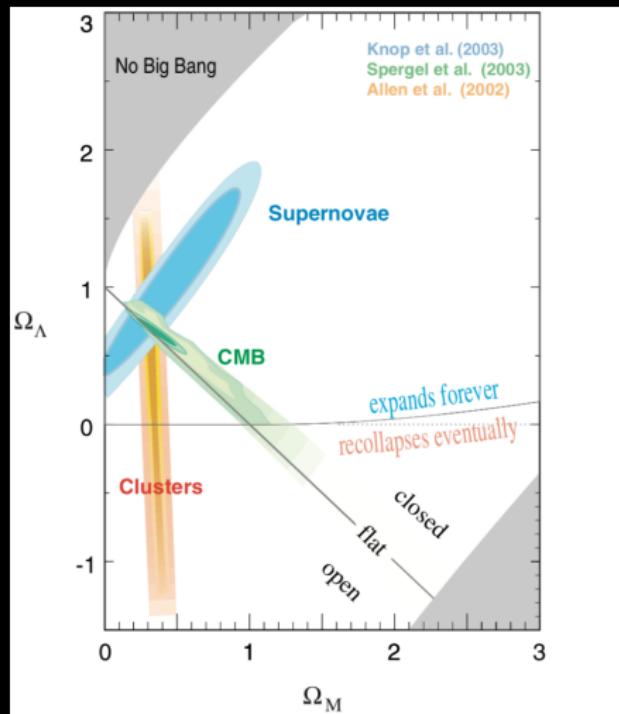
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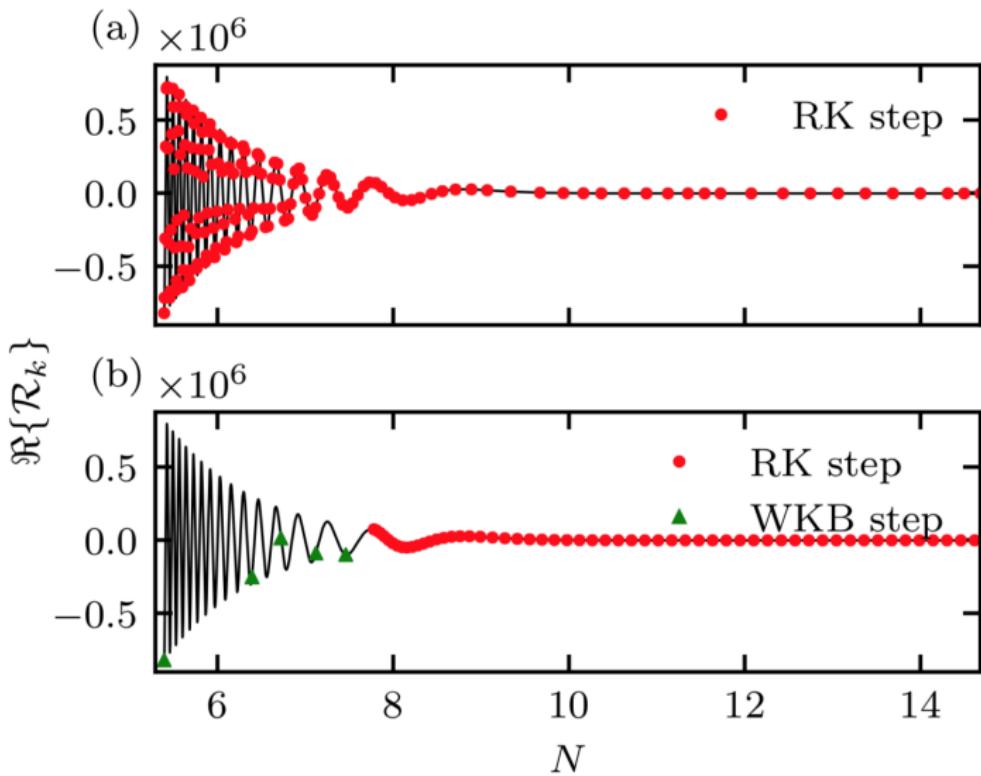
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- ▶ Describes initial fluctuations' growth in time



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- ▶ Applications beyond cosmology

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- ▶ CMB (cosmic microwave background) is rich source of information
- ▶ Modelling of the universe is computationally challenging, especially the first fractions of a second
- ▶ oscode is an open-source numerical solver that can speed the early stages up by at least 1000x

Thank you

