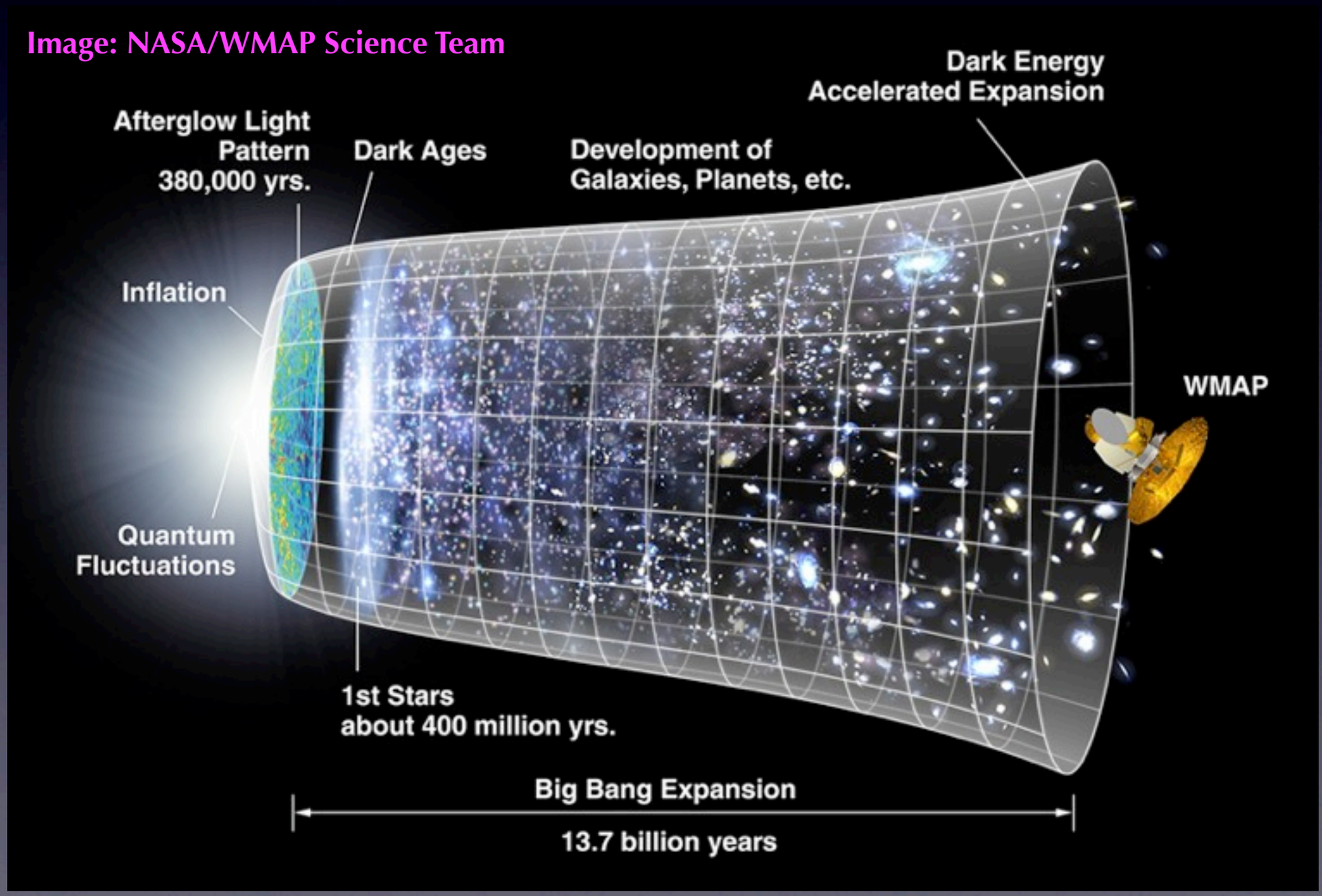
Inflation 2010

University of Sussex

Andrew Liddle

January 2010



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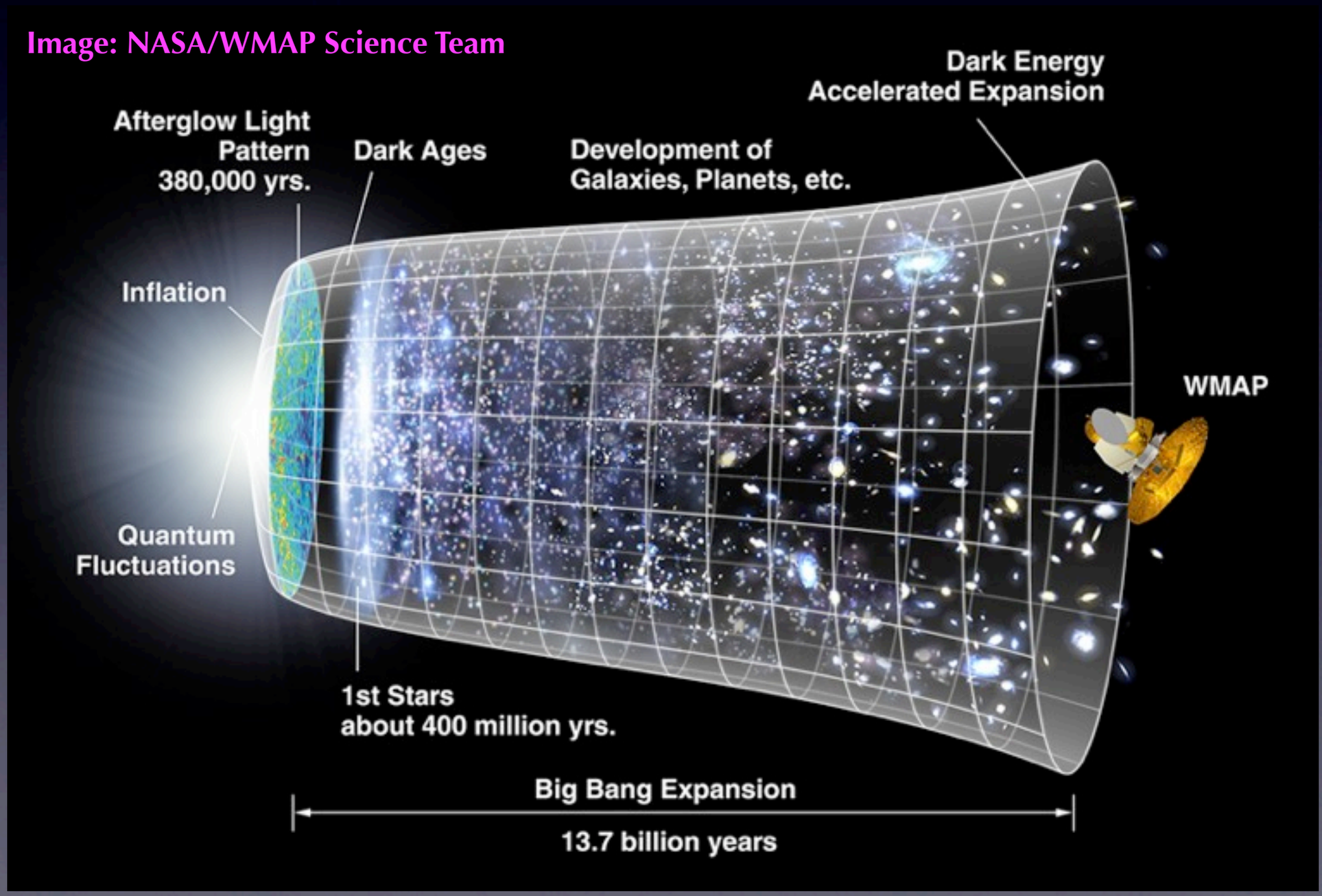
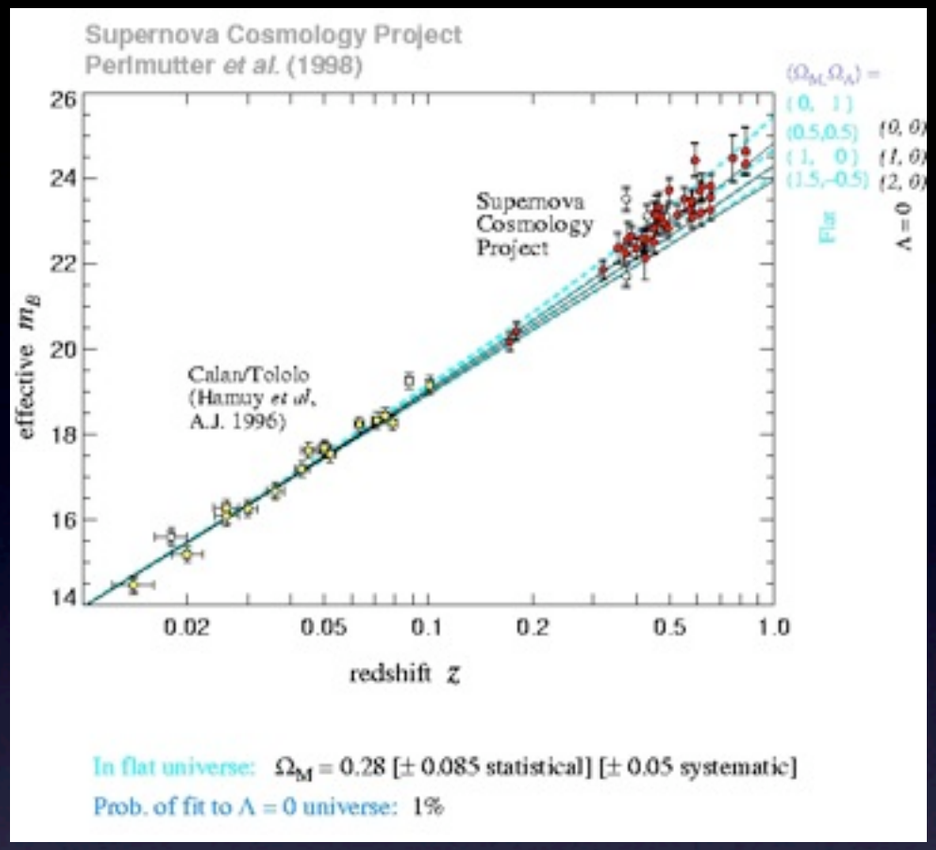


Lecture plan

- Lecture 1: Cosmology overview

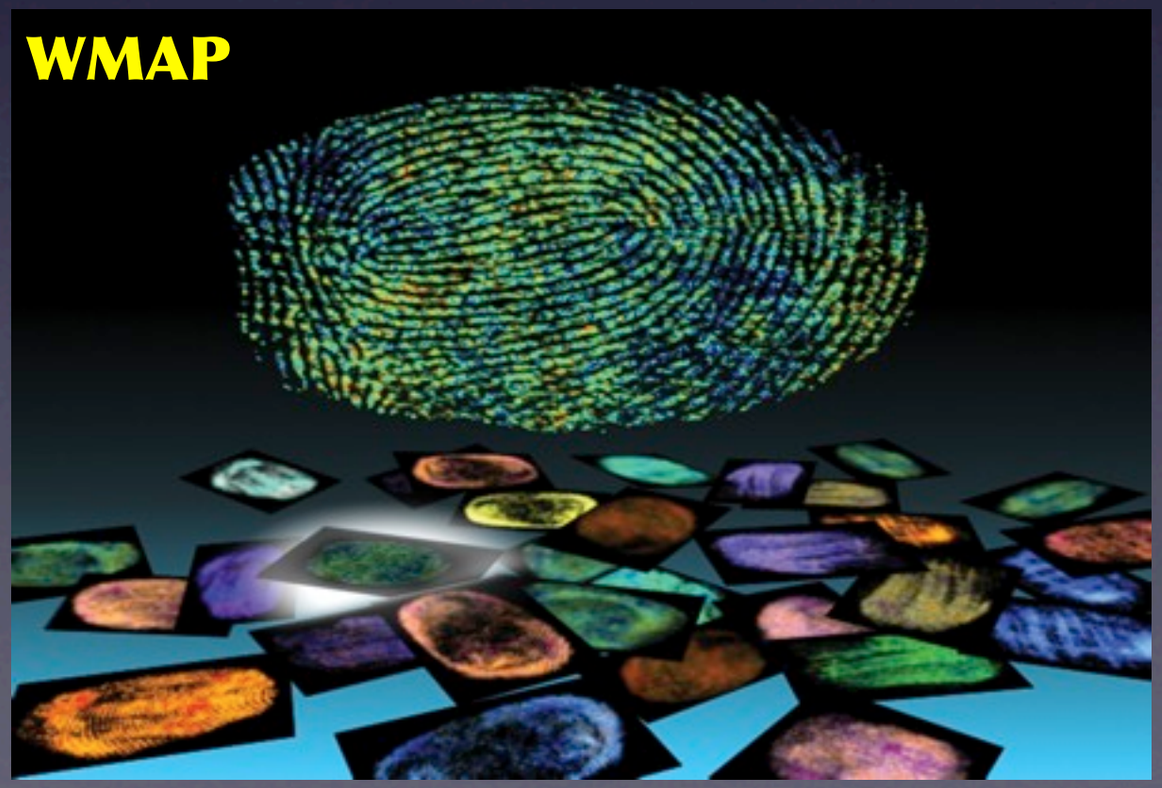
  Basics of inflationary cosmology
- Lecture 2: Observational status of inflation
- Lecture 3: The inflation-building toolkit.

Cosmological overview



COBE

WMAP



Millennium simulation

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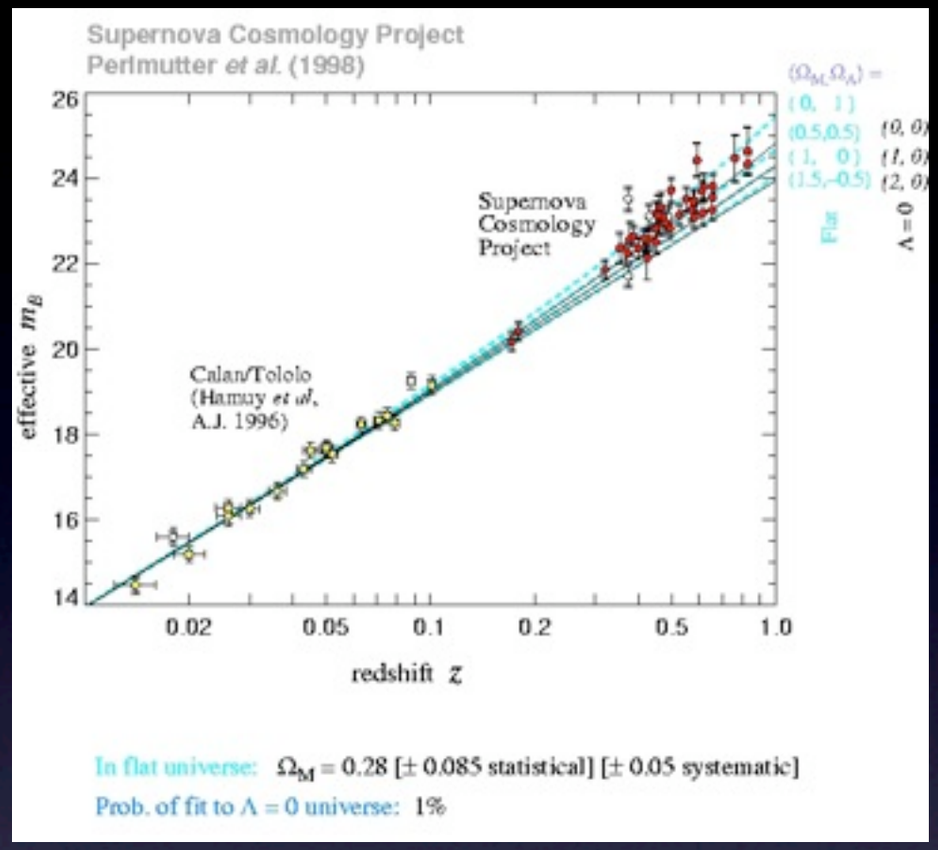

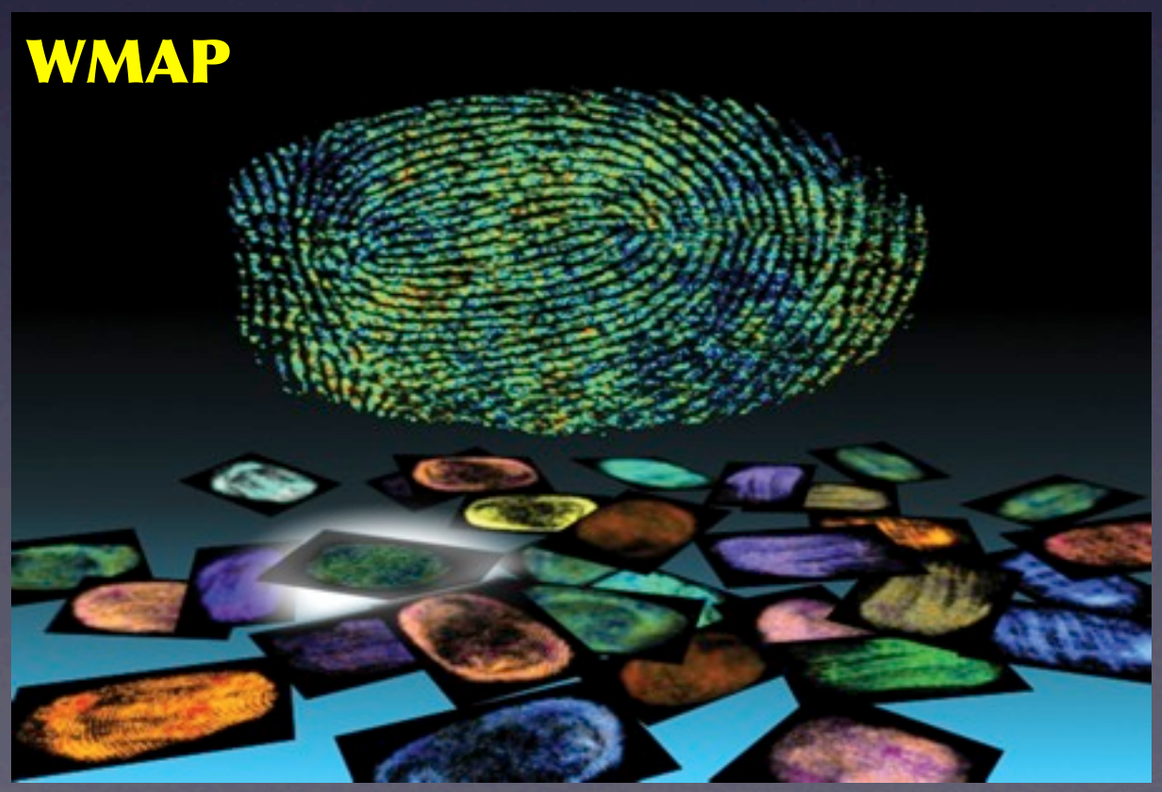

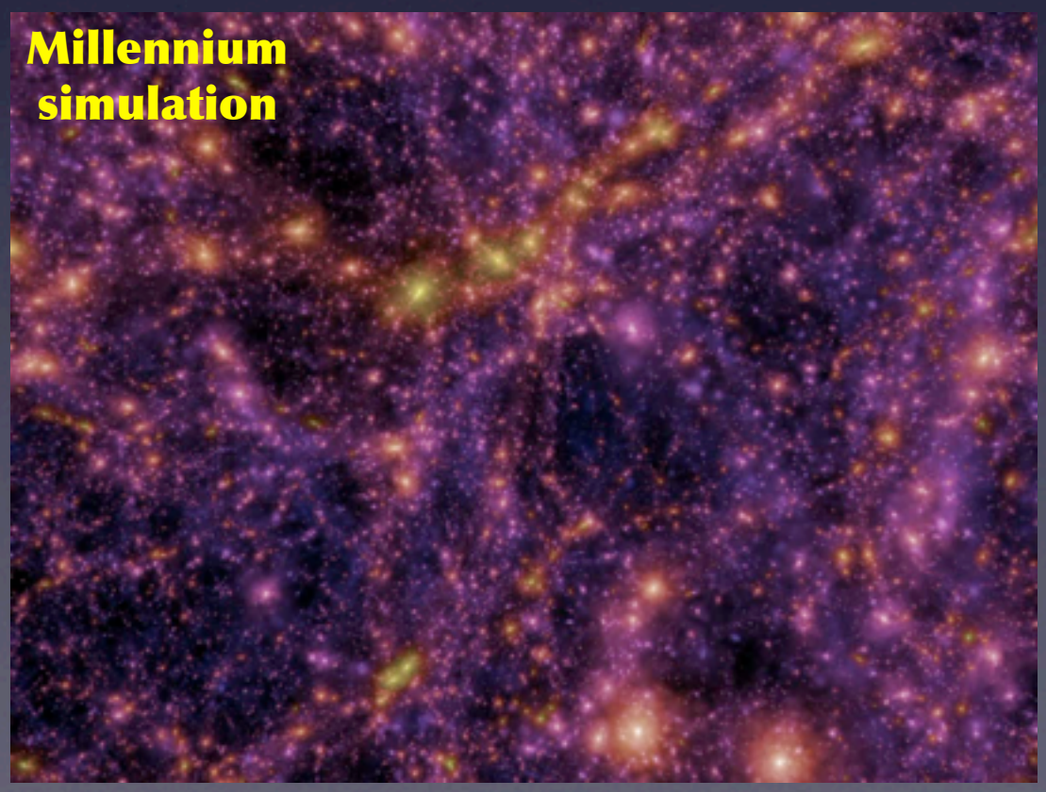

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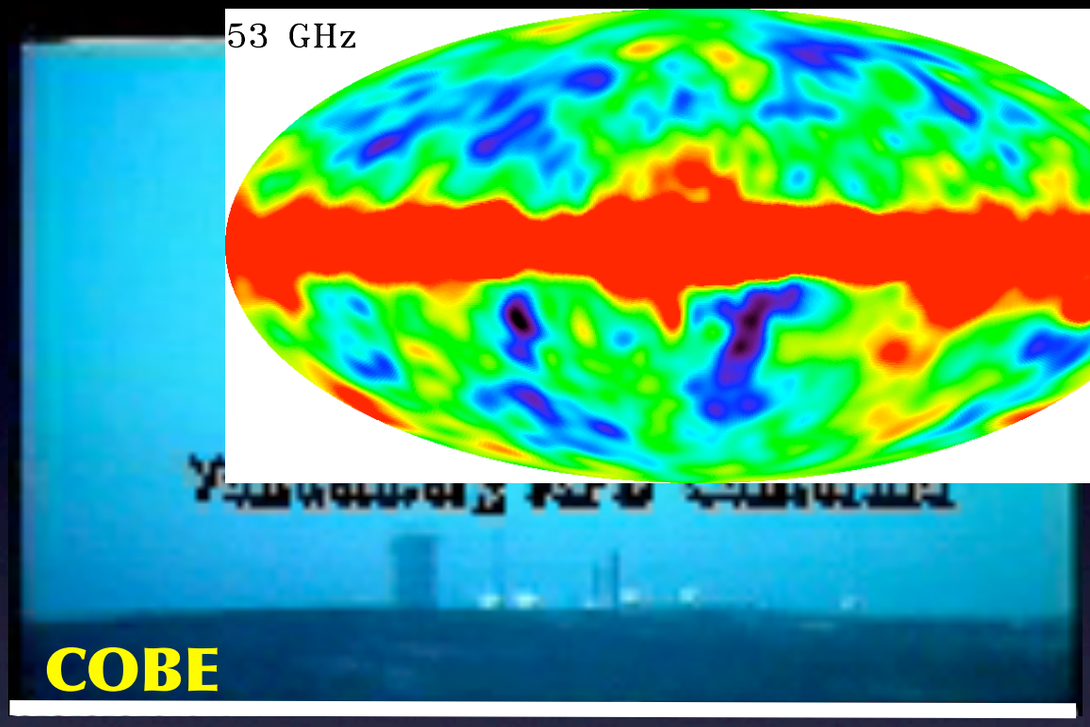

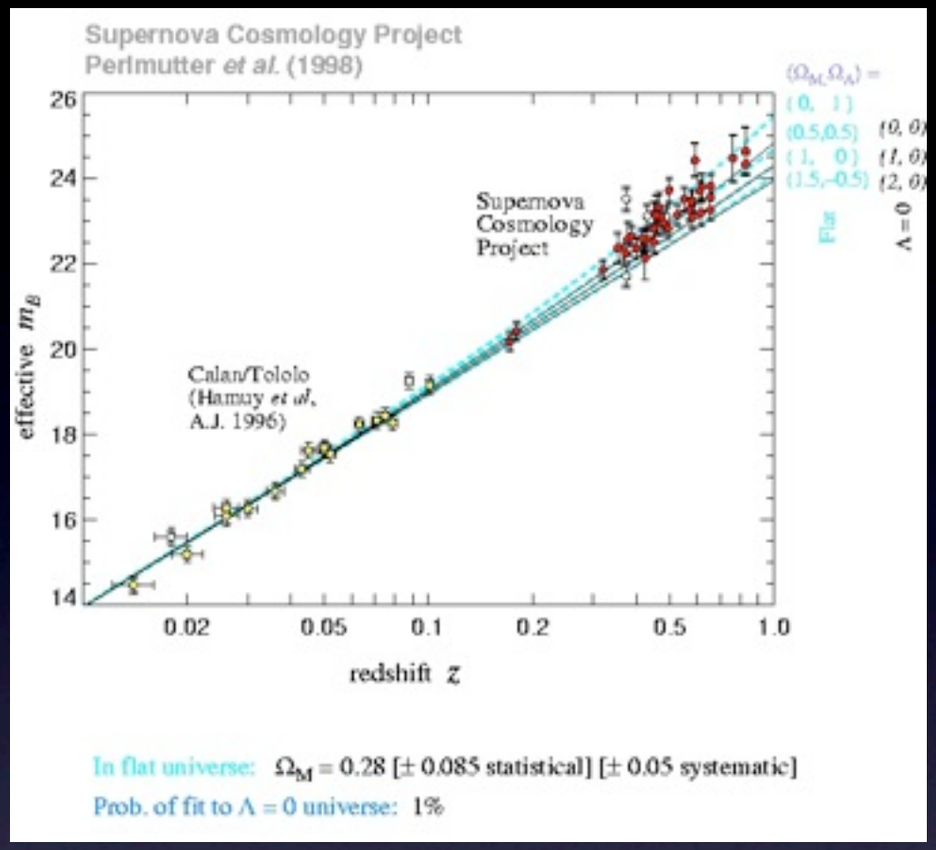

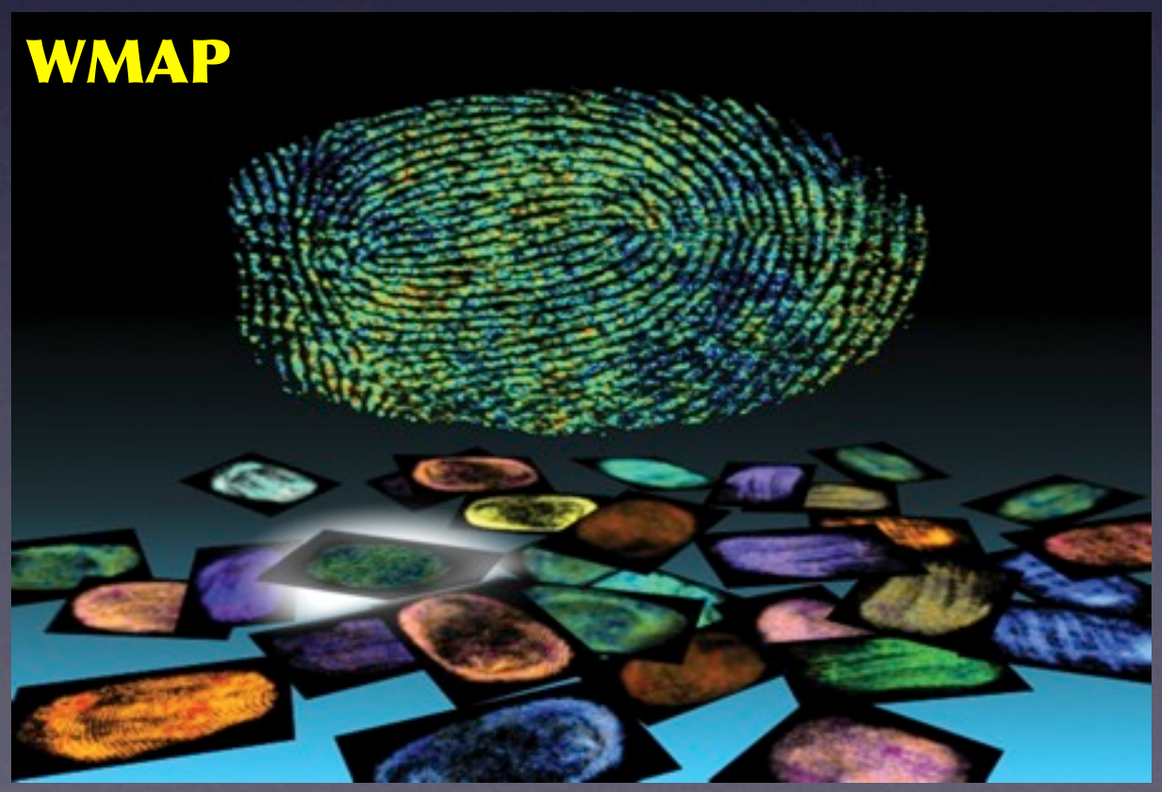

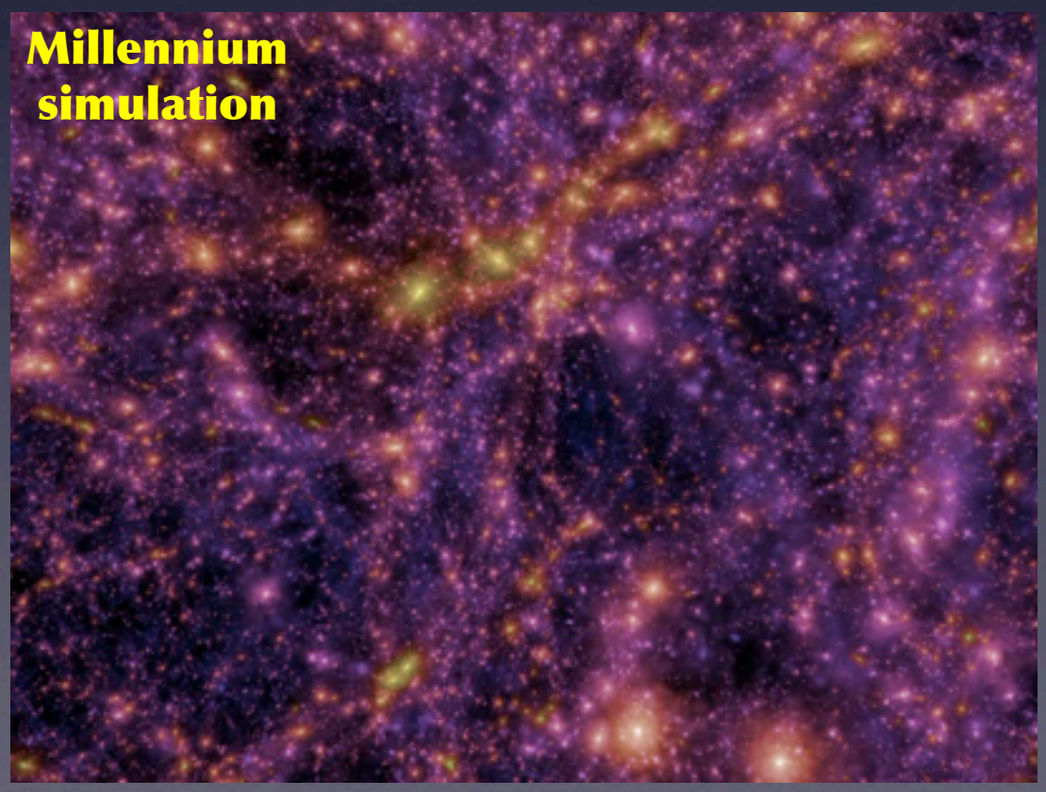

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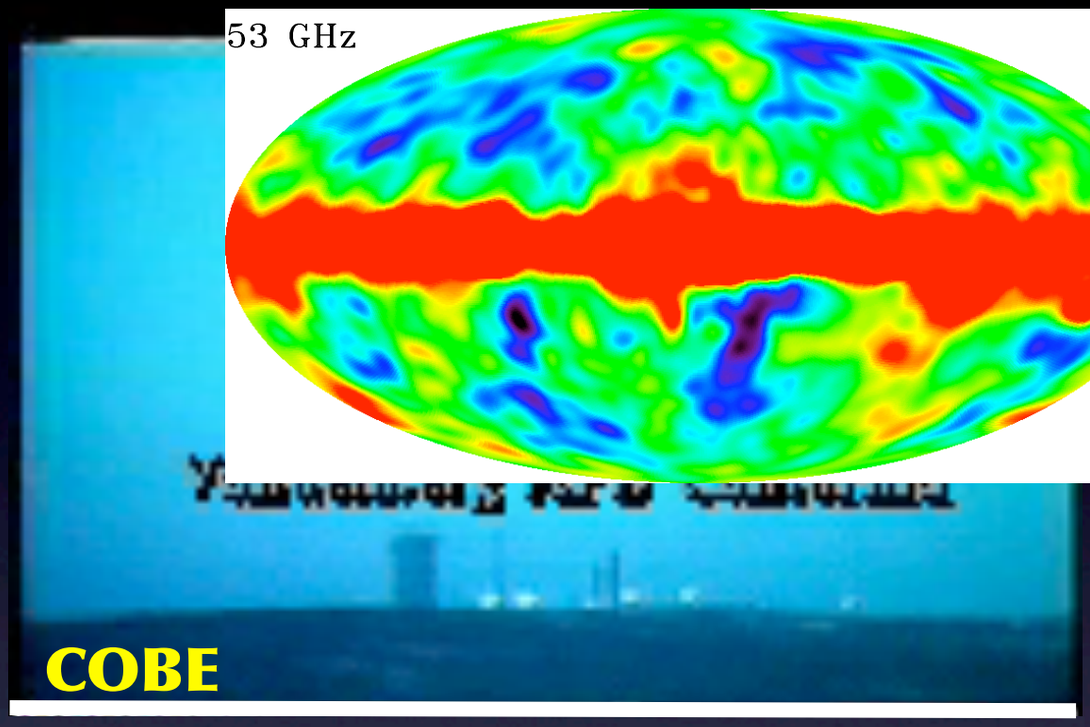

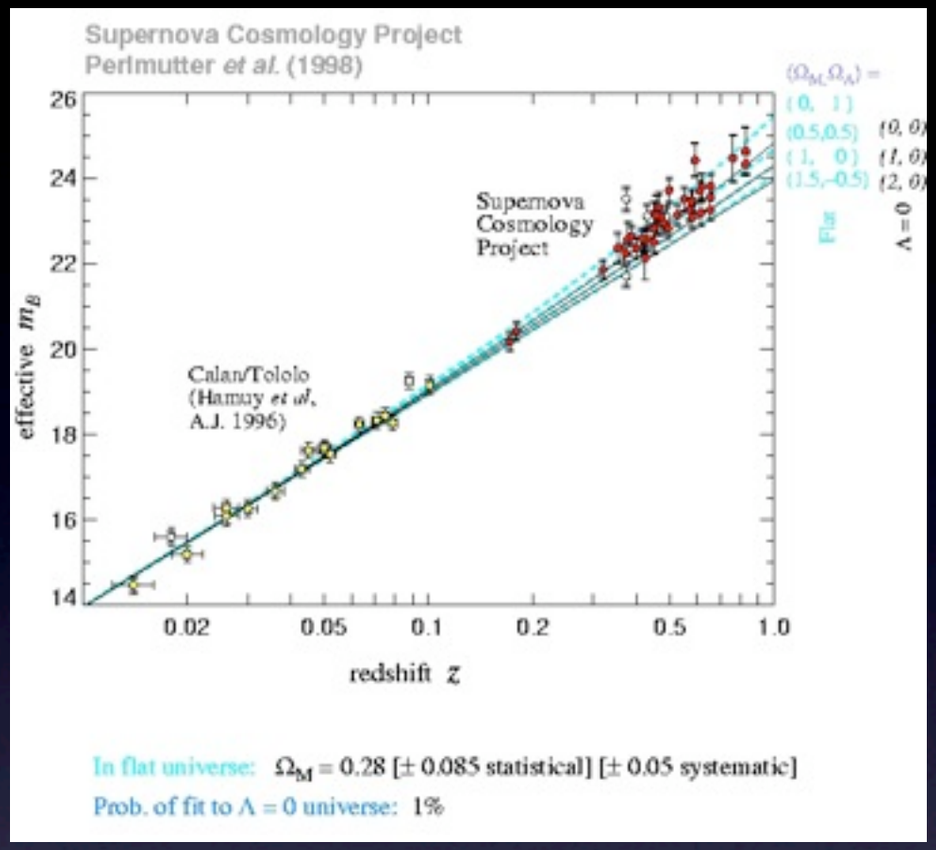

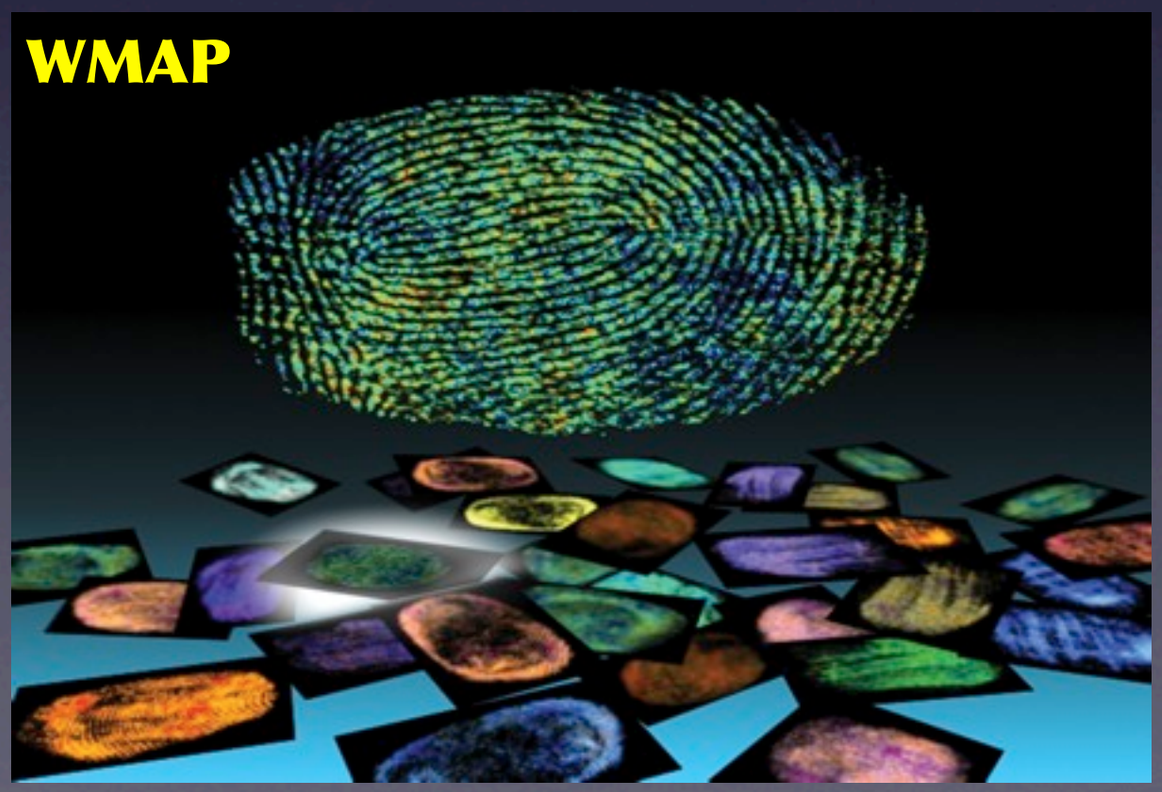

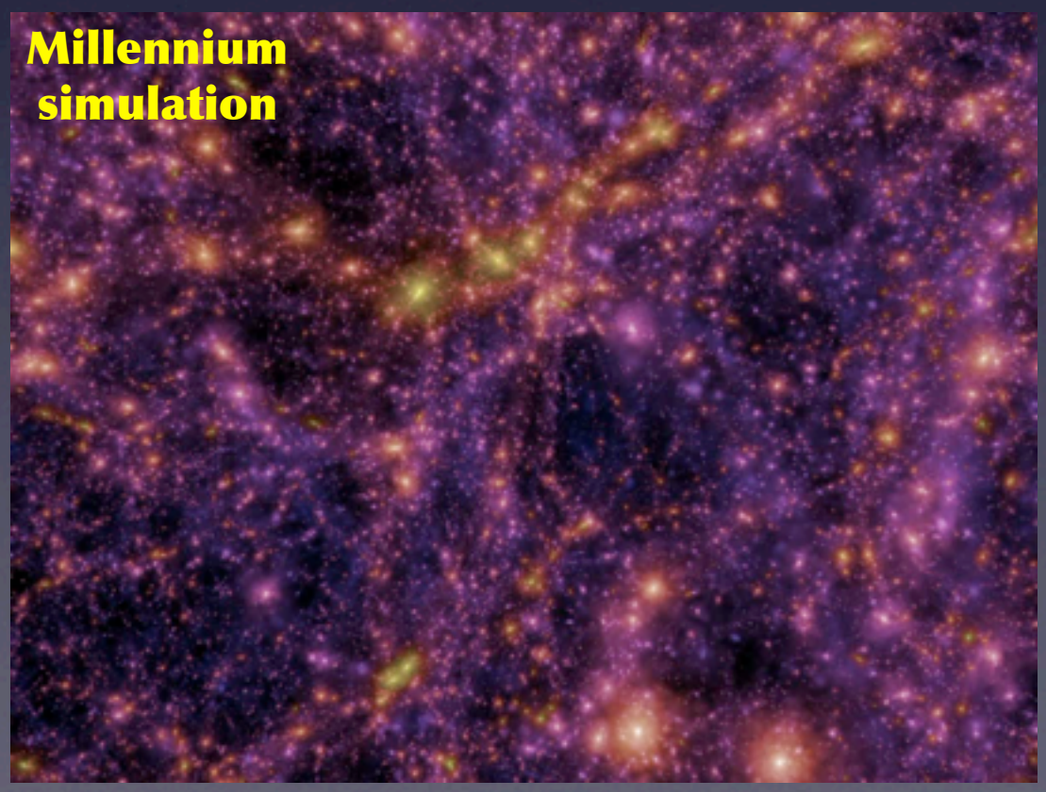

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- Inflationary cosmology

  The leading candidate theory for explaining where those initial irregularities came from: quantum fluctuations during rapid expansion of the young Universe.

What cosmological parameters?

The standard assumption is that the present Universe contains five types of material.

- Baryons (ie protons, neutrons and electrons)
- Radiation (photons)
- Neutrinos
- Dark matter
- Dark energy (eg cosmological constant)

The sum of their densities, plus the expansion rate, determines the spatial curvature, which nowadays is usually assumed to vanish.

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Plus the theoretical technology necessary to develop observational predictions based on the model assumptions.

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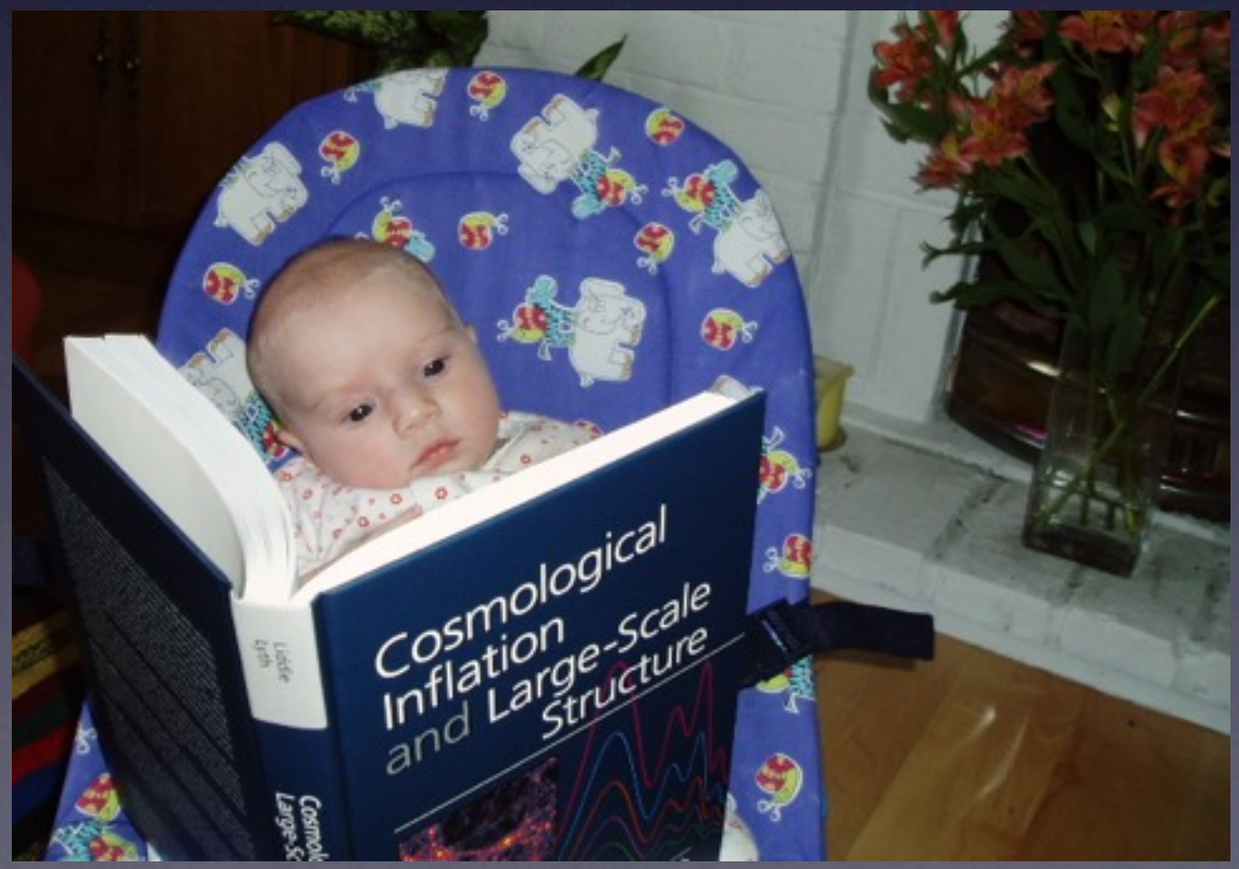
- Can fundamental properties of the Universe be predicted by theory at all?

Lecture 1

The basics of inflationary cosmology



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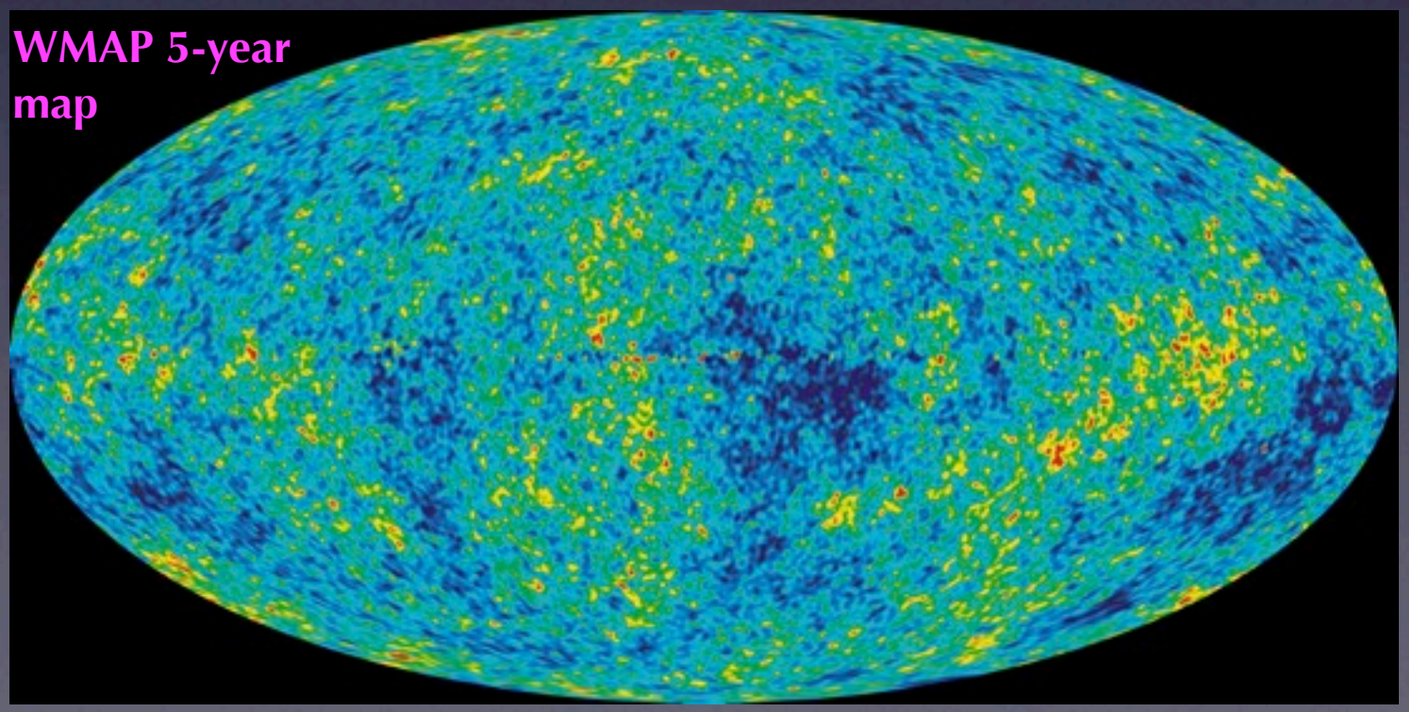

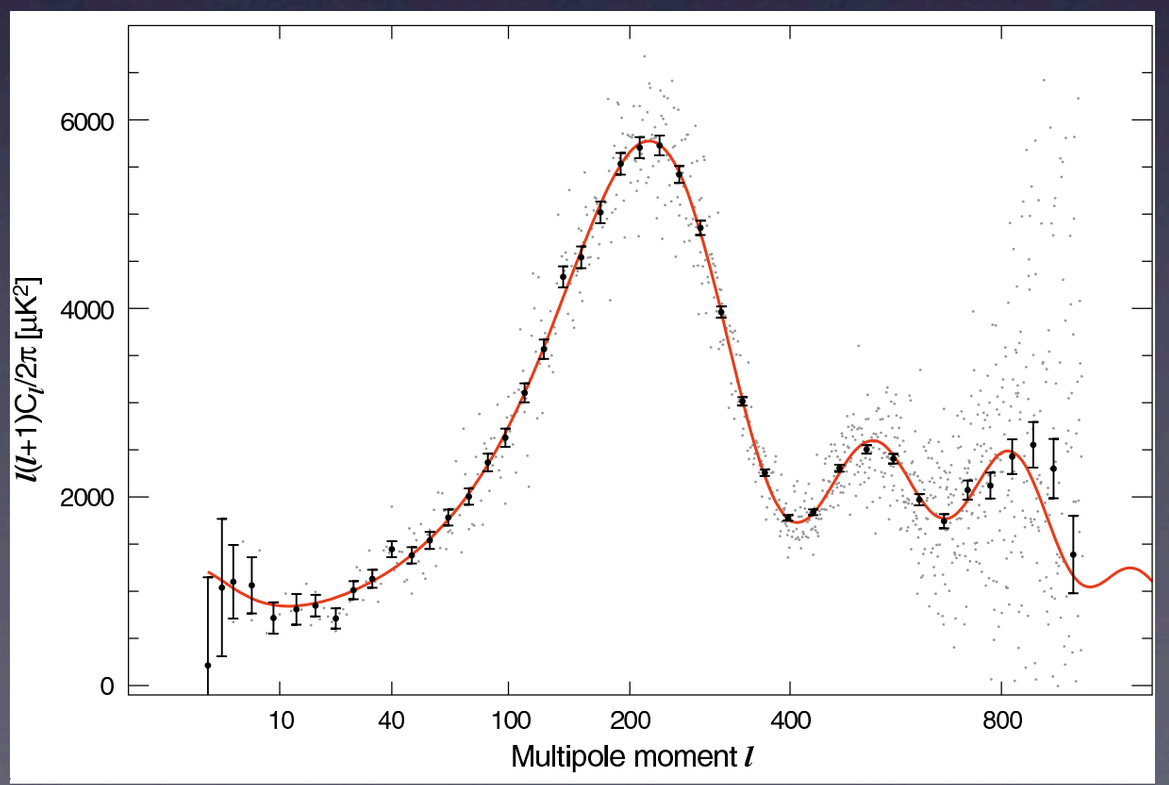

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and so acceleration requires $p < -\rho c^2/3$

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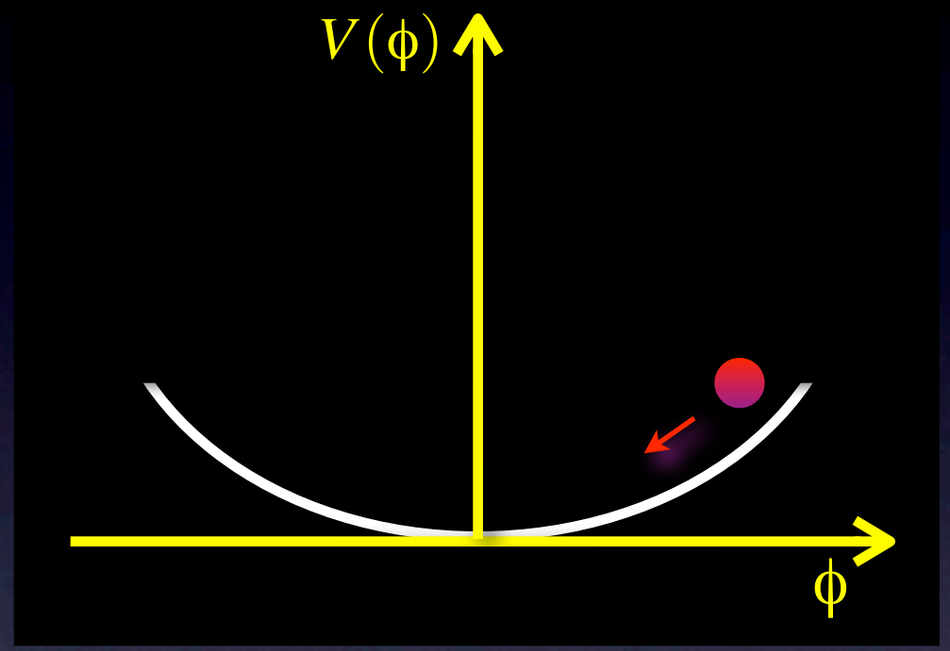

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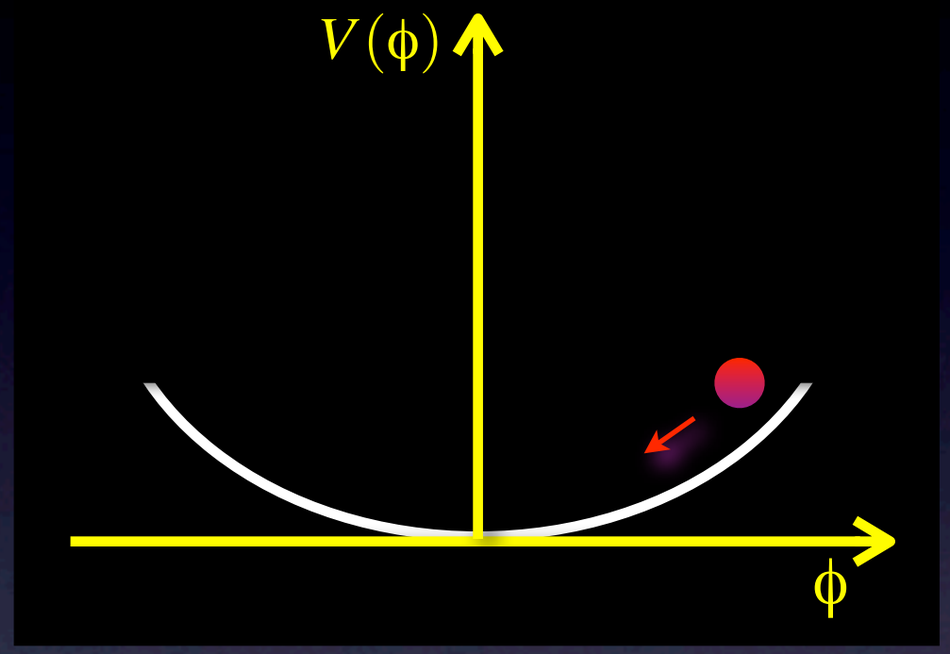

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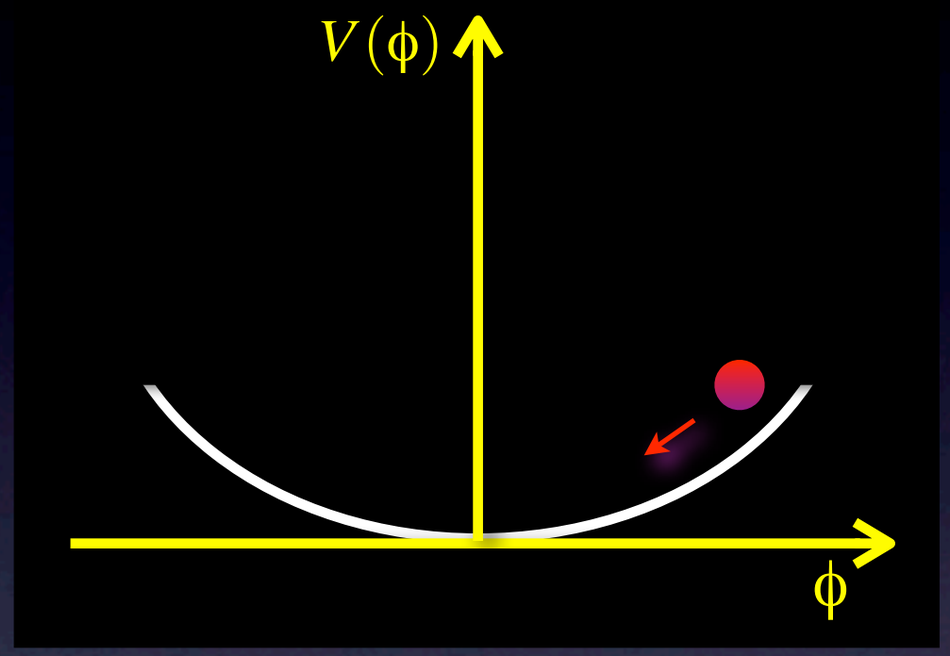

The simplest way for this to take place is for the Universe to become dominated by the potential energy of a scalar field. In fundamental physics, such a field describes spin-zero particles (eg the Higgs).

For now I will assume there is just a single field, though many models have more.

$$\rho = V(\phi) + \frac{1}{2}\dot{\phi}^2$$

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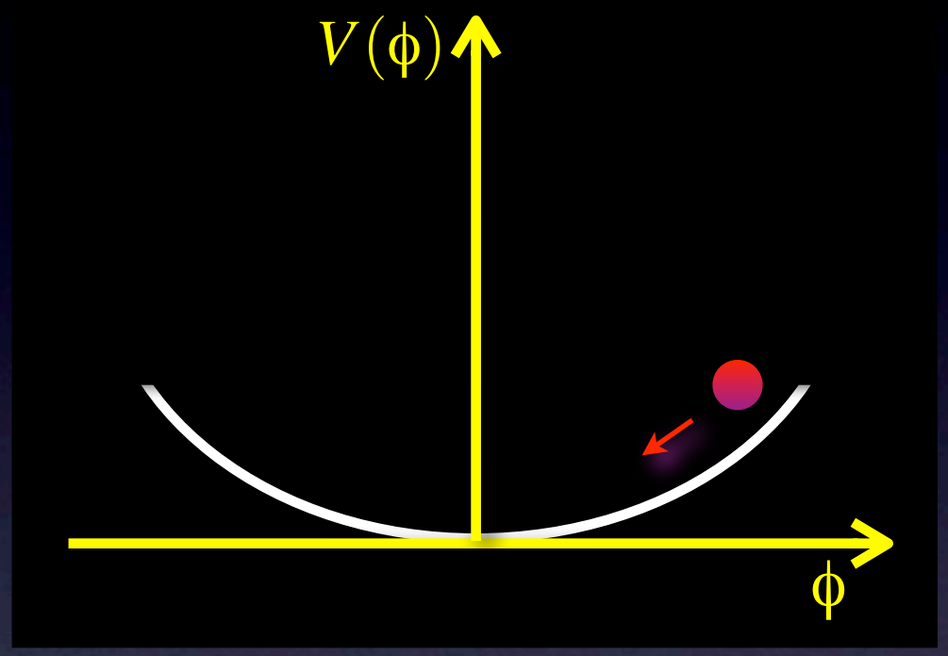
The scalar field potential

In the simplest scenarios, the potential energy is the only quantity which needs to be specified, and it describes the properties of the scalar field.



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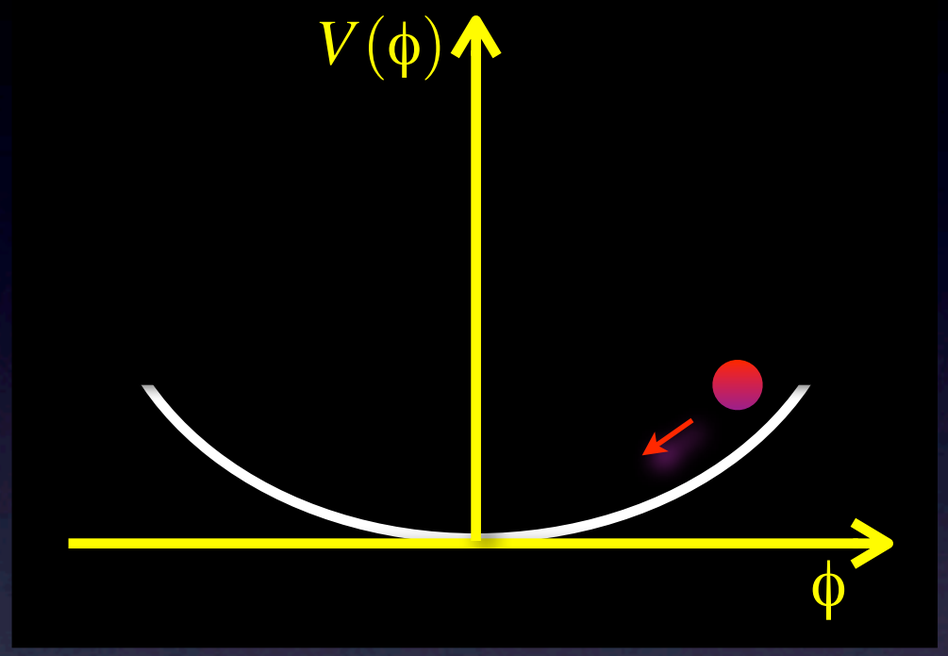

Unfortunately no fundamental scalar field has ever been observed, though particle theories predicts large numbers of them. In cosmology, we aim to constrain the potential using observations.

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Inflation and perturbations

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- Scalar field fluctuations
  - Lead to scalar metric perturbations
  - Cause gravitational collapse to form structures
- Gravitational wave perturbations
  - Not associated with gravitational collapse but may influence the CMB.

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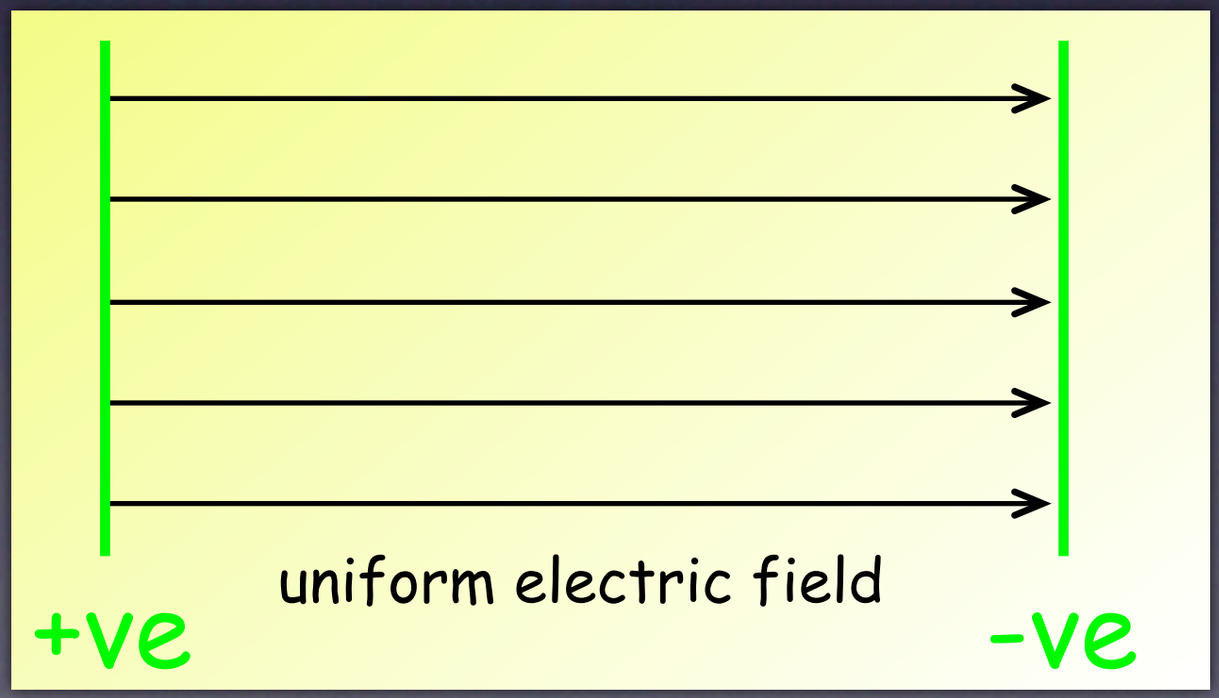

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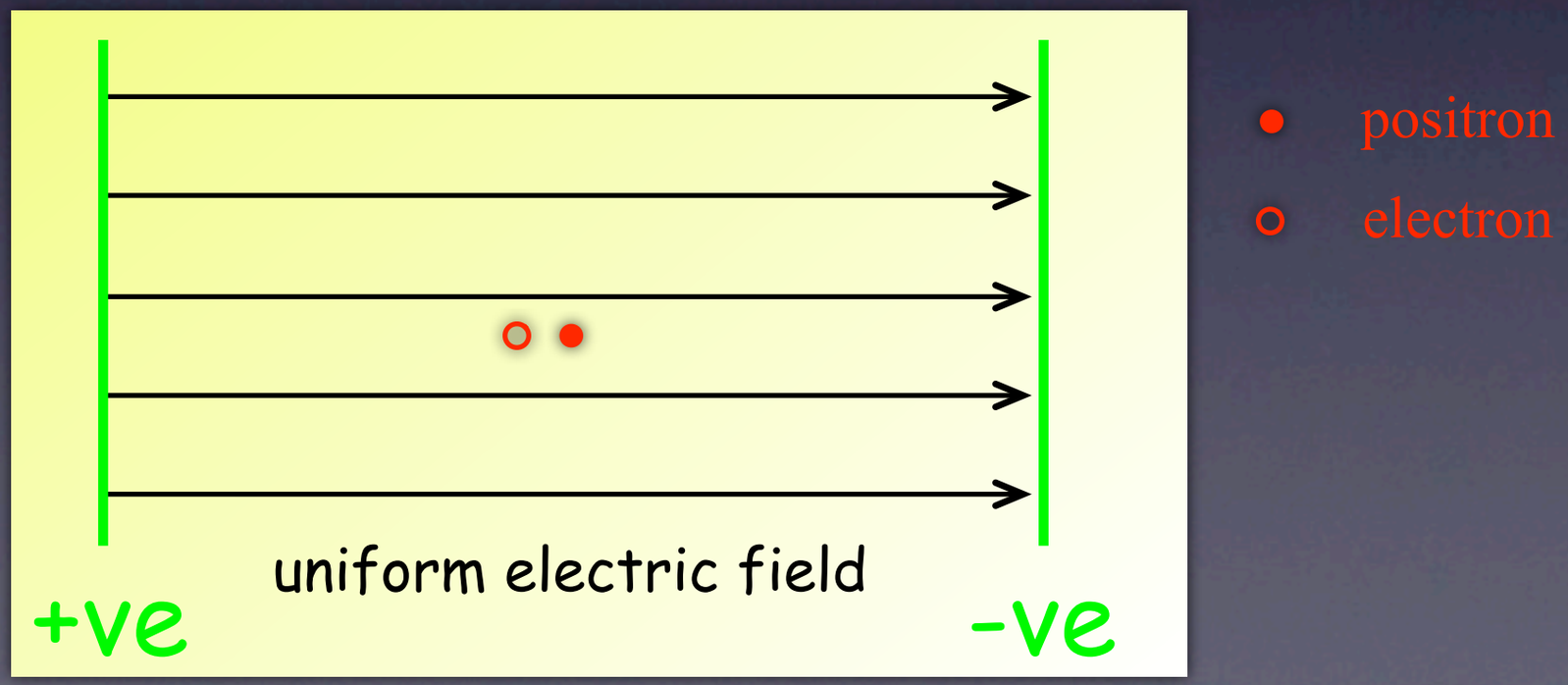

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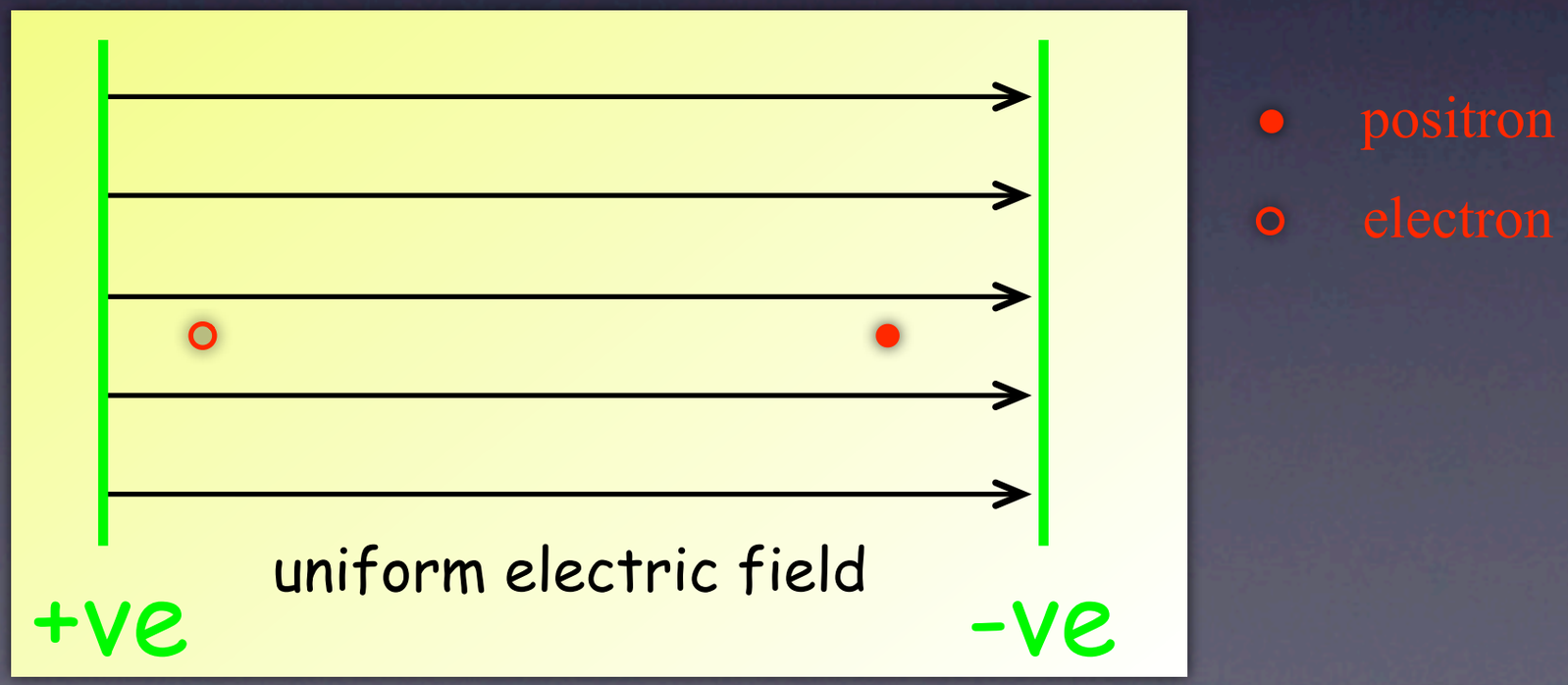

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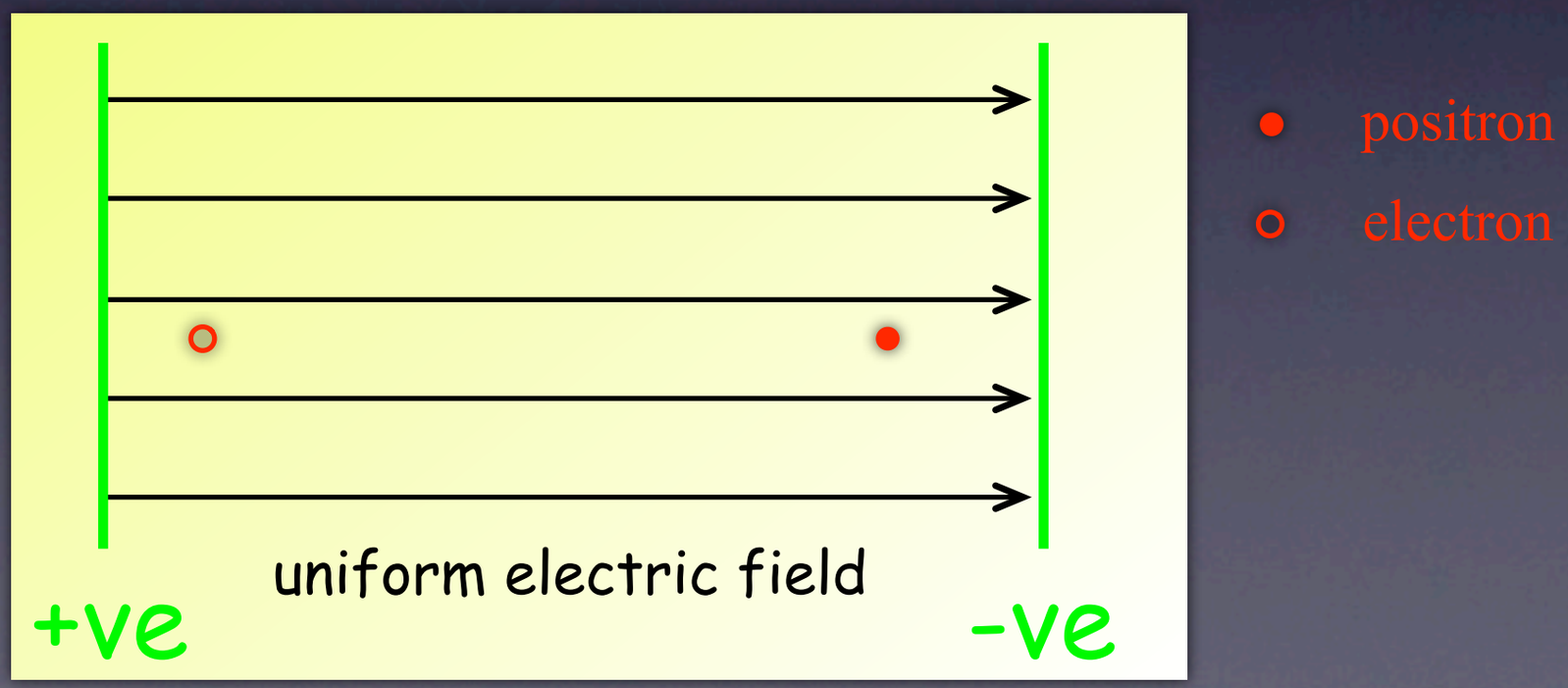
The pair production breaks the initial homogeneity.



Single-field inflation predictions (Liddle & Lyth 1992)

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Gravitational waves $$r = 16\varepsilon \qquad n_G = -2\varepsilon = -\frac{r}{8}$$

Other inflationary perturbations

It is a very reasonable working hypothesis that the single-field paradigm holds, and much work goes into constraining inflationary models of this type. But there is a broader phenomenology:

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- Generating perturbations after inflation: post-process perturbations acquired in a different field.

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- Generating perturbations after inflation: post-process perturbations acquired in a different field.

  - Curvaton mechanism: auxiliary field develops a significant density then decays. Large non-gaussianity possible if sub-dominant at decay.

Other inflationary perturbations

- Multi-field models.

  Perturbations in additional fields can give rise to isocurvature perturbations, depending on how inflationary degrees of freedom map to post-inflationary ones. Non-gaussianity also possible but requires tuning.

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- Generating perturbations after inflation: post-process perturbations acquired in a different field.

  - Curvaton mechanism: auxiliary field develops a significant density then decays. Large non-gaussianity possible if sub-dominant at decay.

  - Inhomogeneous reheating: Auxiliary field modulates the decay of the inflaton into conventional material.