Extra-Galactic Astronomy - I
Cosmology

IUCAA / NCRA Graduate School 2016-17

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http://www.ncra.tifr.res.in:8081/~tirth/Teaching/Cosmology/index.html

Distances in the Universe

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A.U. → *Light year* / *Parsec (pc)* → *kiloparsec (kpc)* → *Megaparsec (Mpc)*

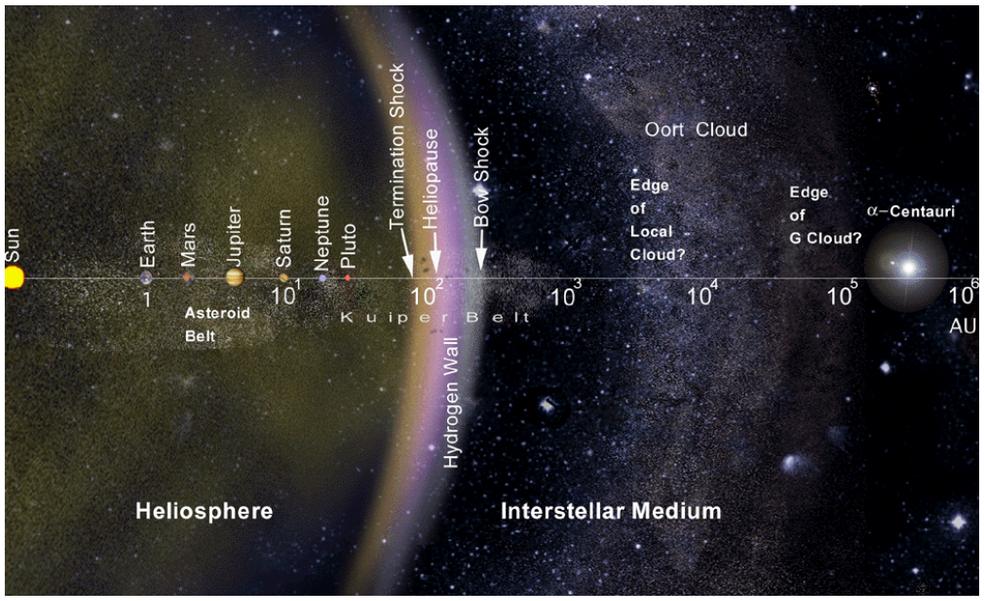
1 AU = 1.5×10^8 km

1 ly $\approx 10^{13}$ km

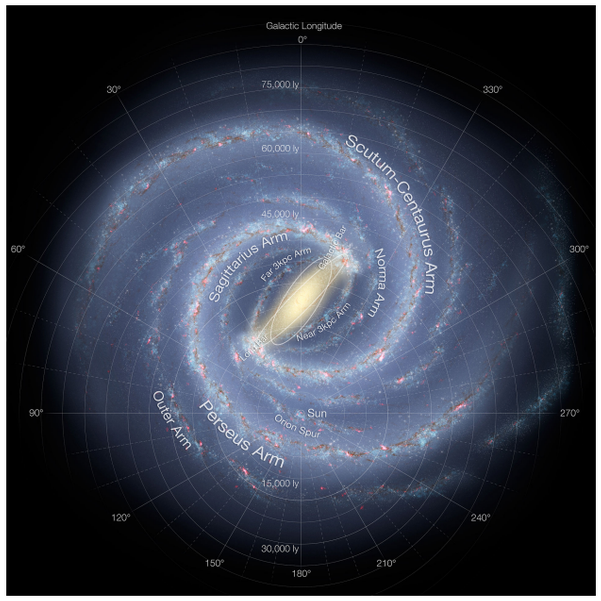
1 pc $\approx$ 3.25 ly

1 kpc = 10^3 pc

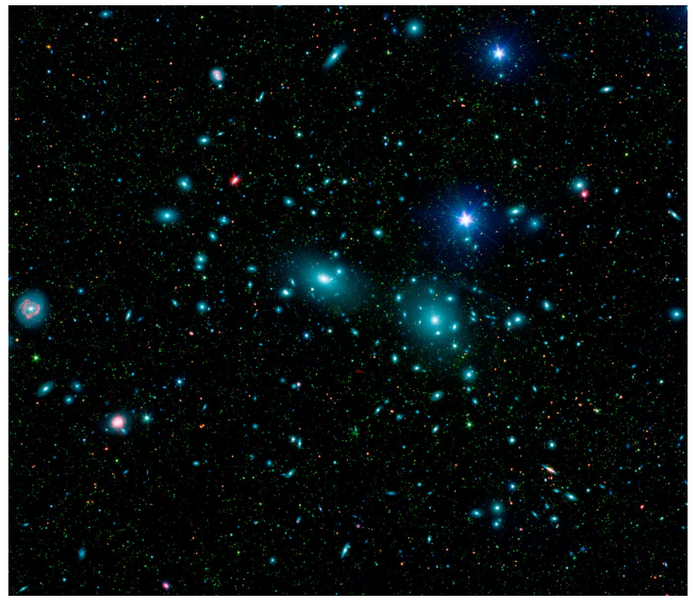
1 Mpc = 10^3 kpc



5 pc



50 kpc

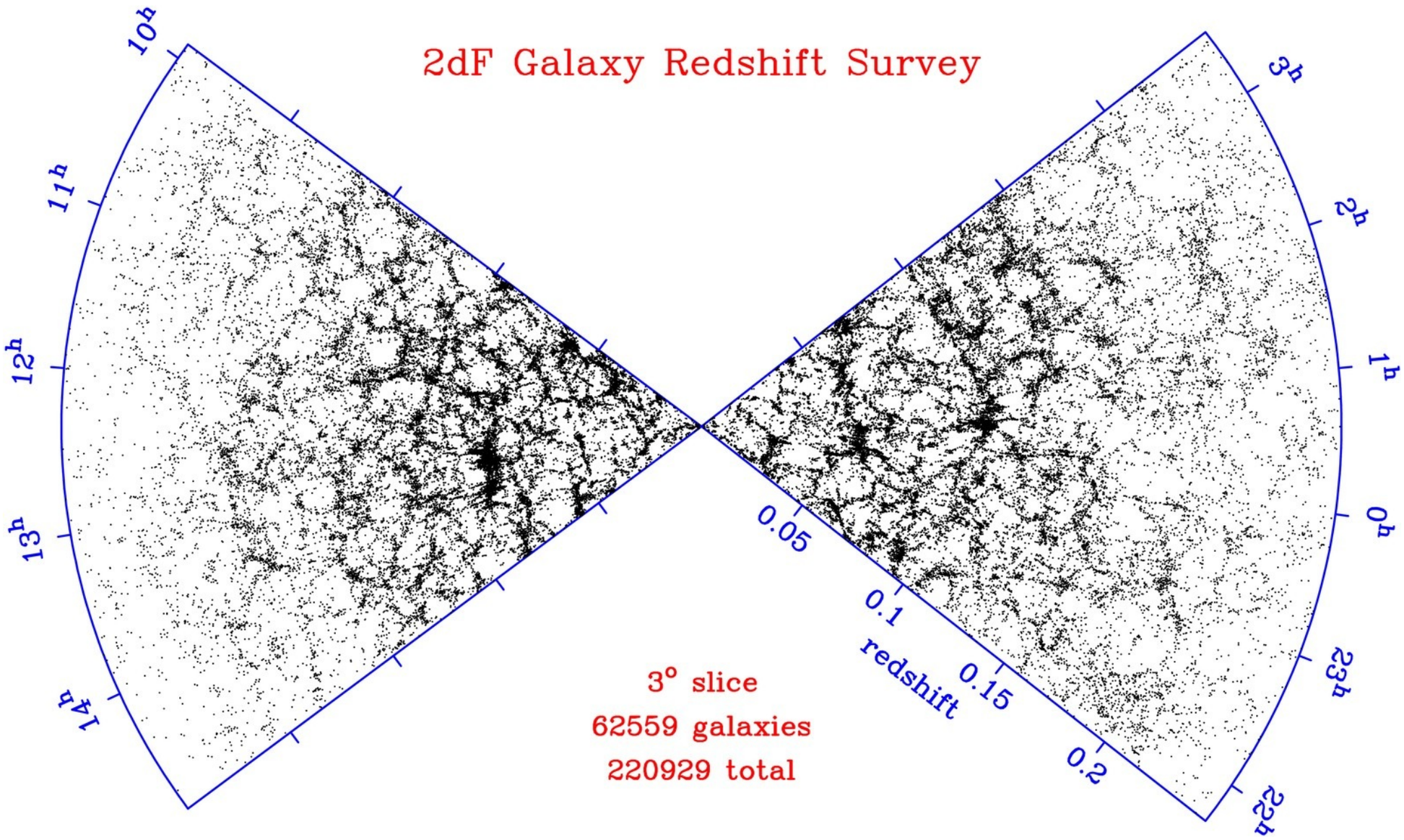


10 Mpc

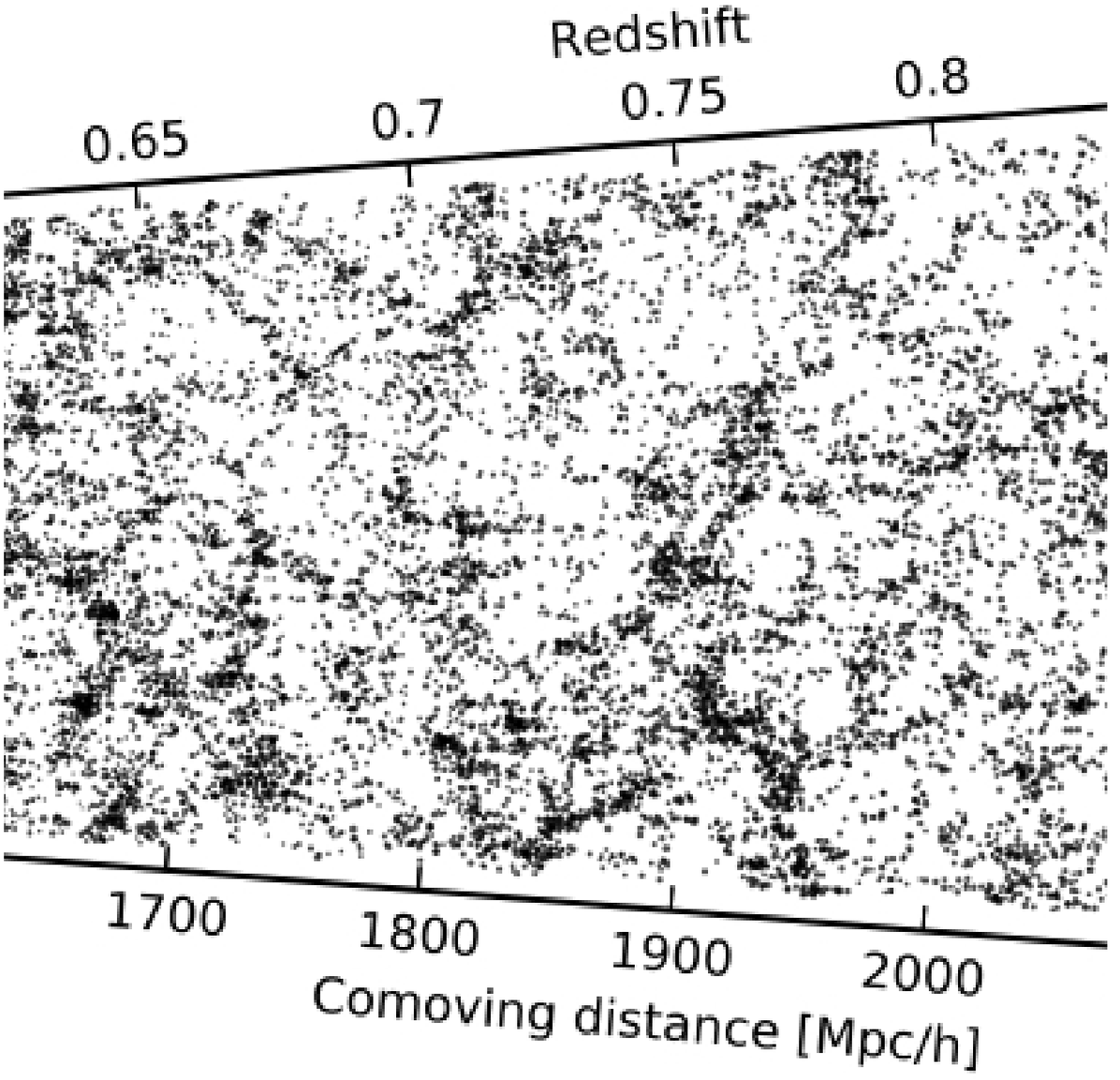
(Images: Wikimedia Commons / NASA)

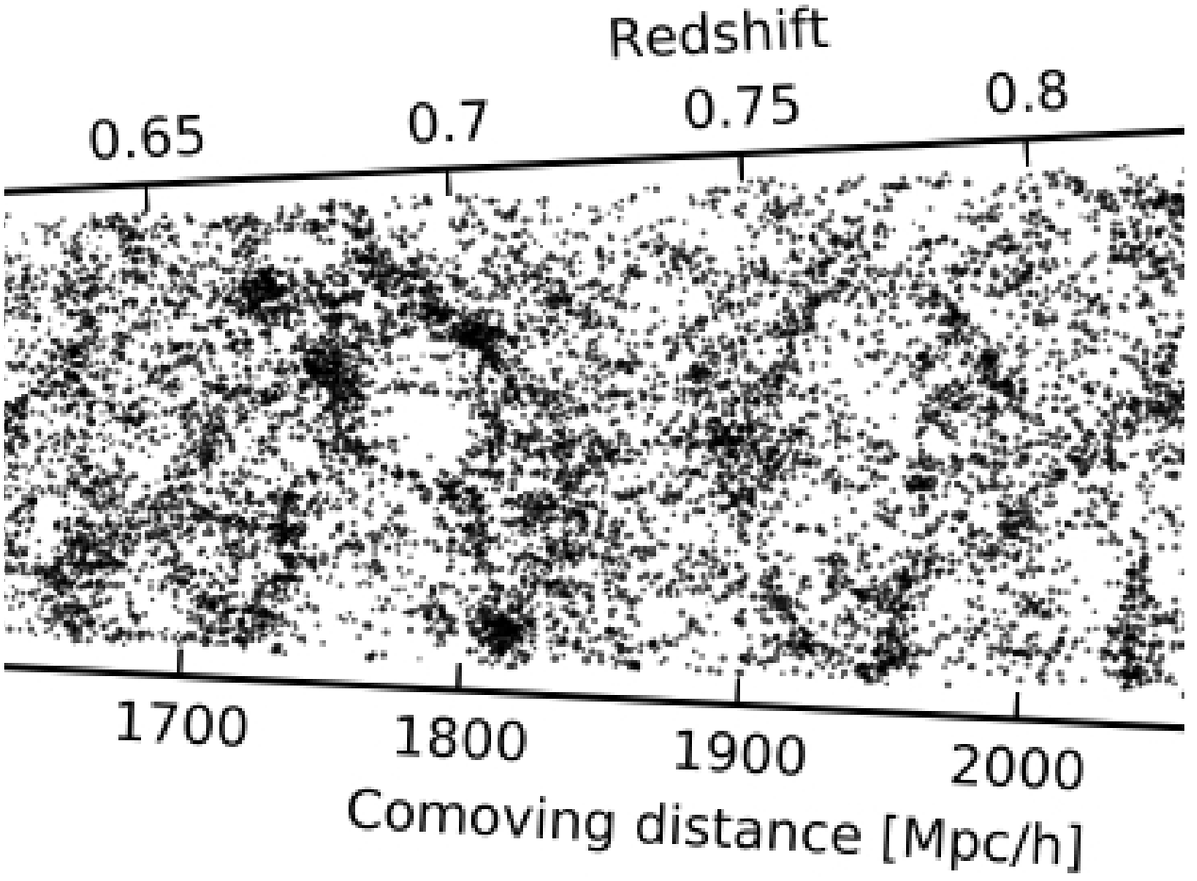
The low redshift Universe

(Image: Colless+01)



The Cosmic Web





(Image: Guzzo+13)

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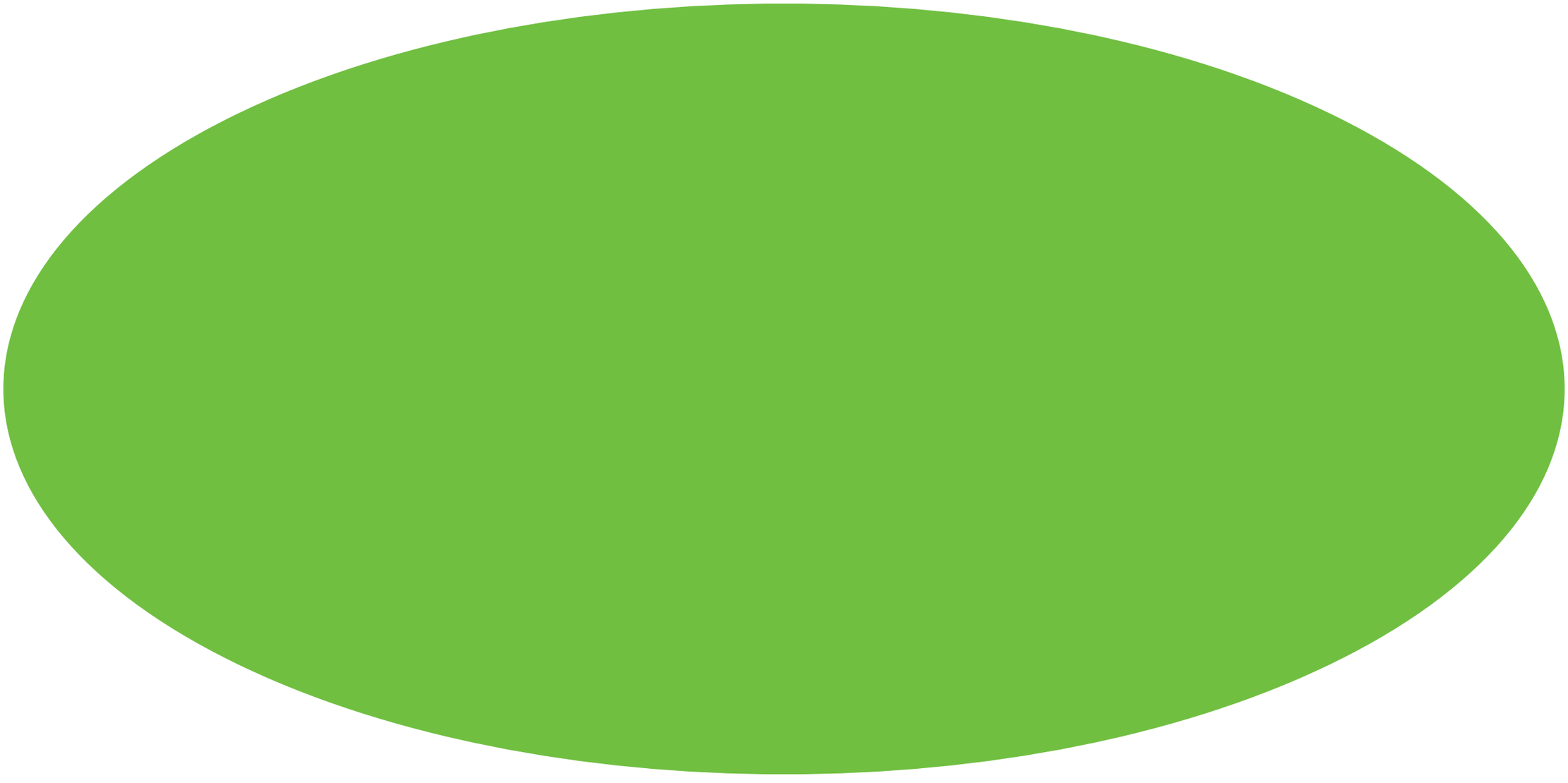
Cosmic Microwave Background

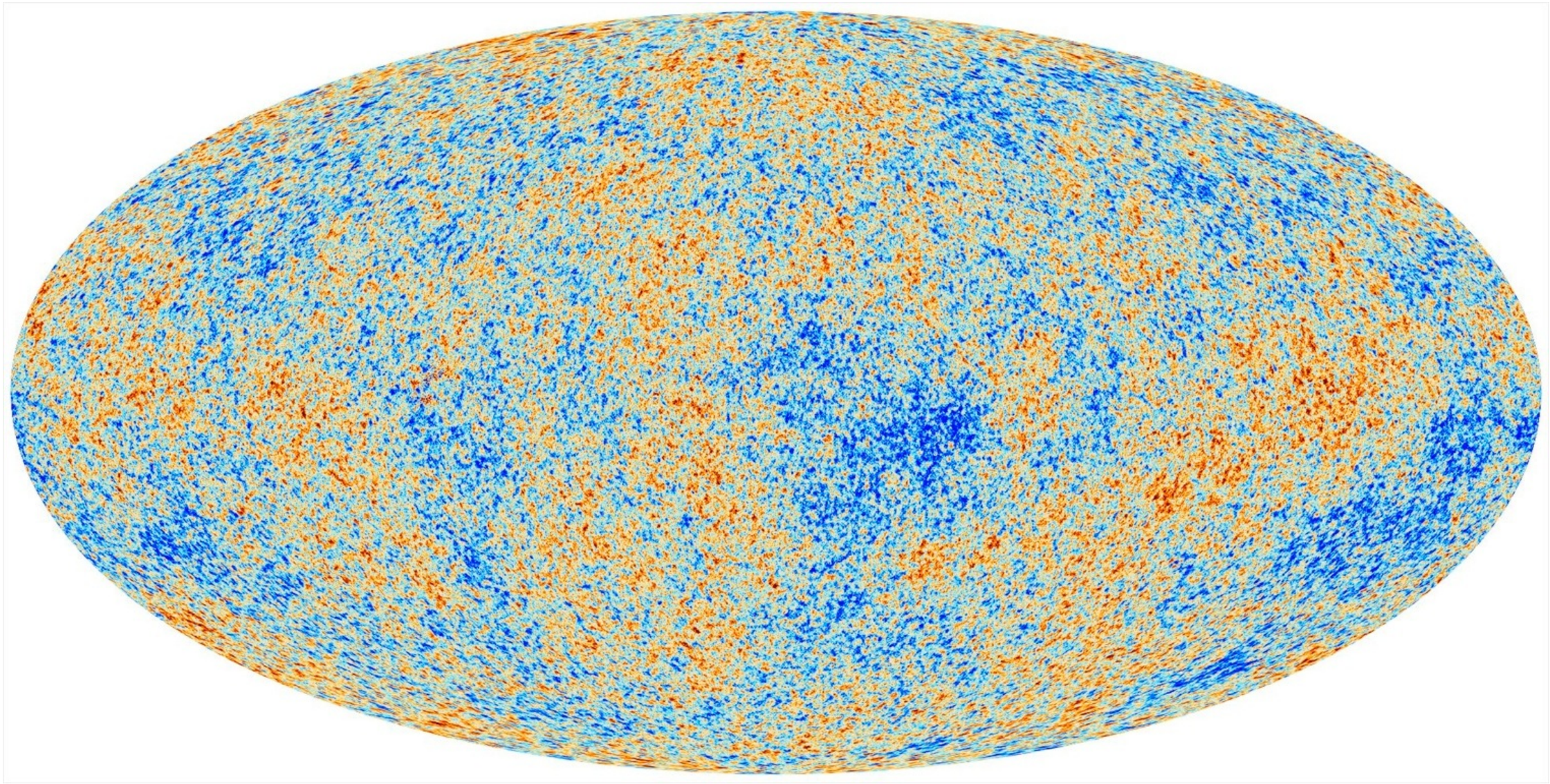
Uniform-temperature radiation bath…



T = 2.725 K

Cosmic Microwave Background

… with tiny anisotropies



$\Delta T / T \approx 10^{-5}$

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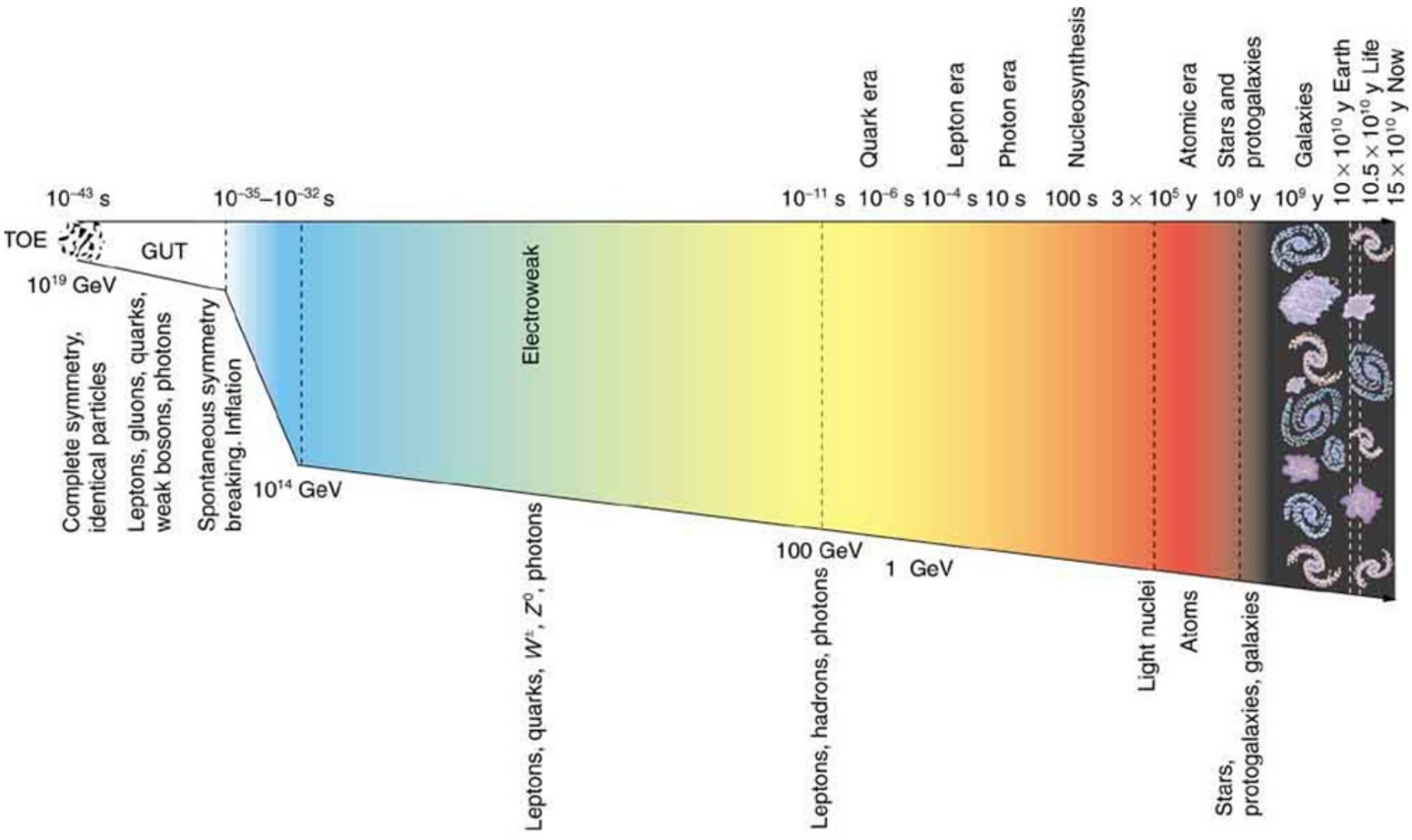
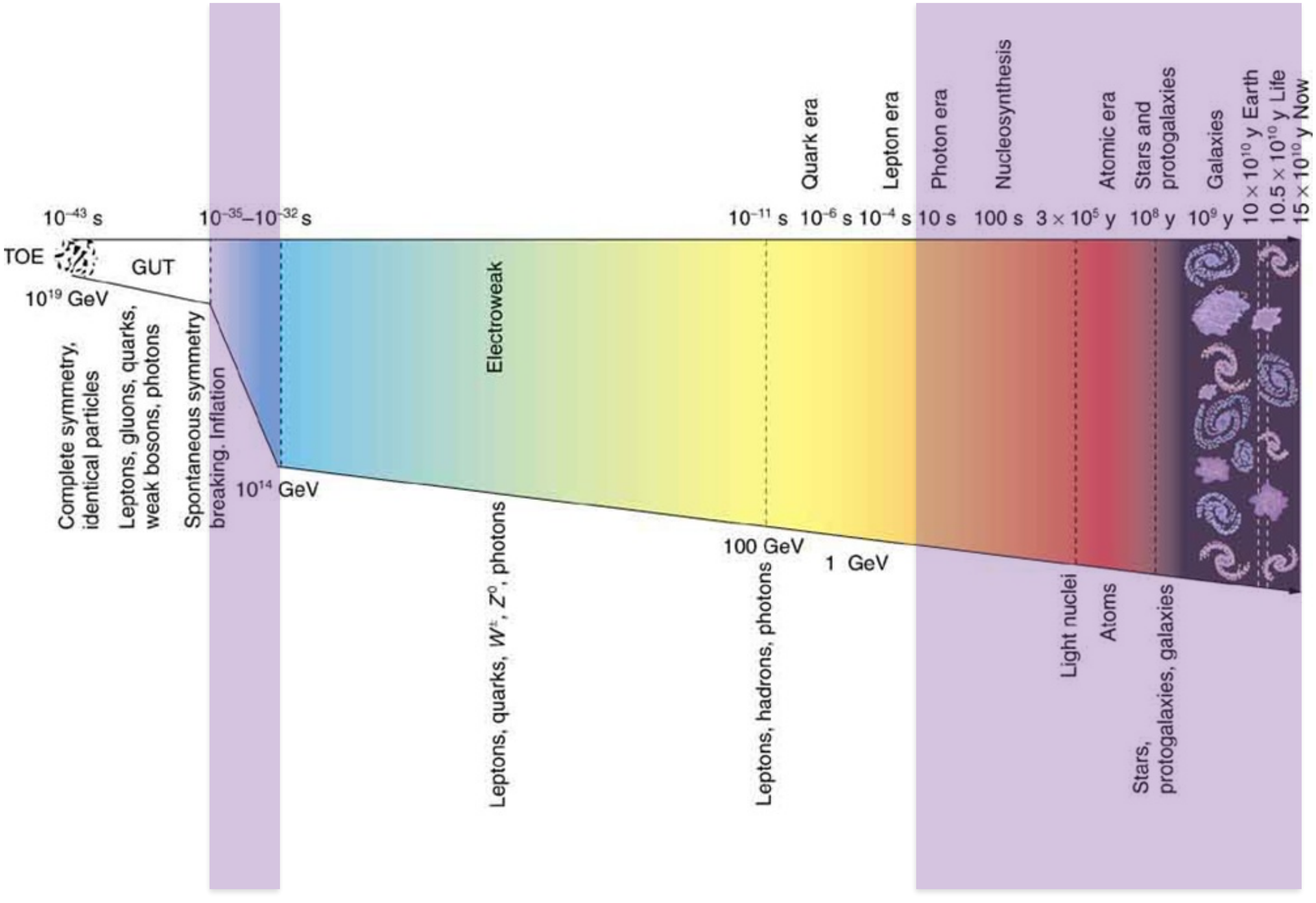
How did this come to be?...

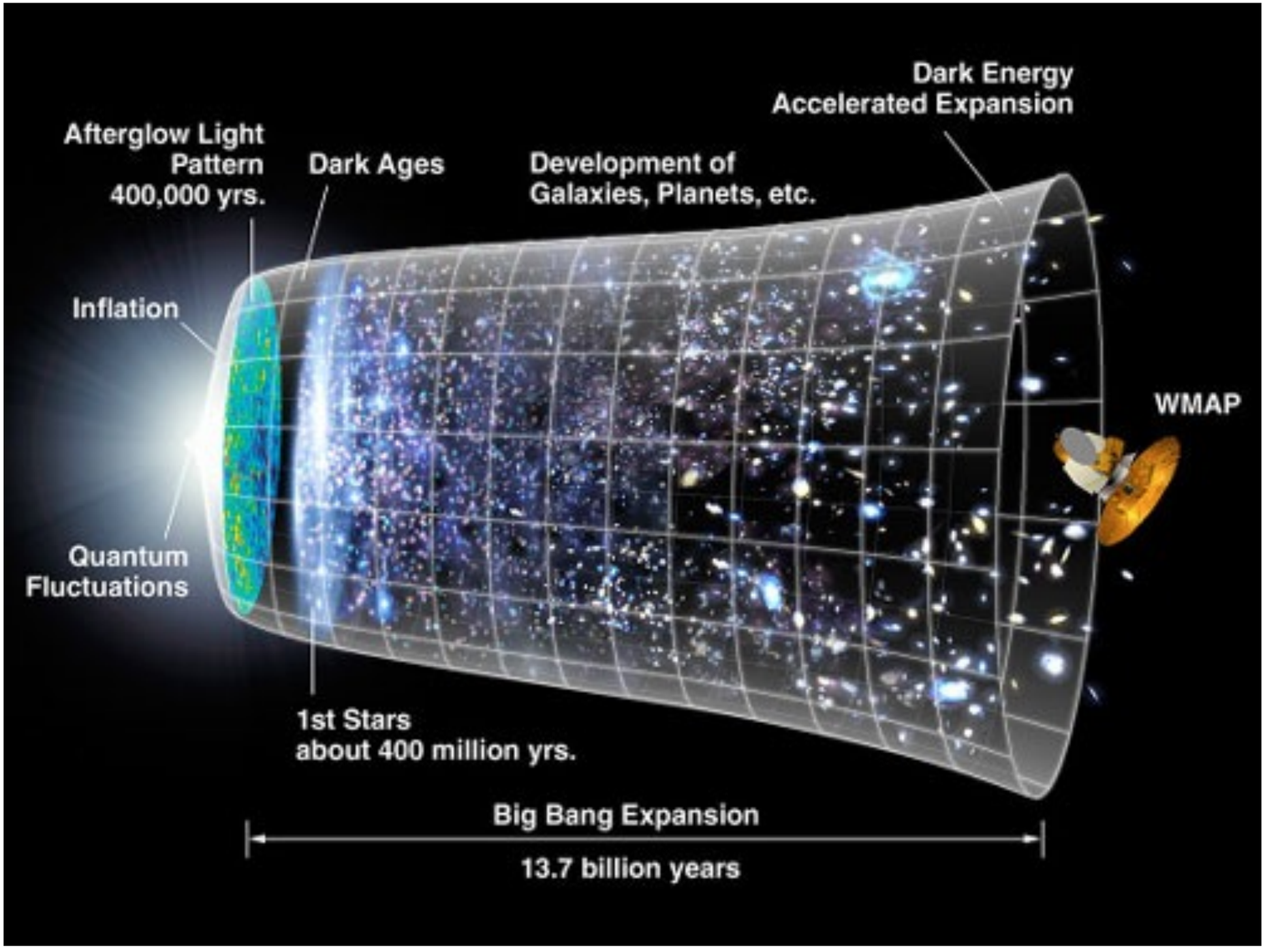
Hot Big-Bang Cosmology



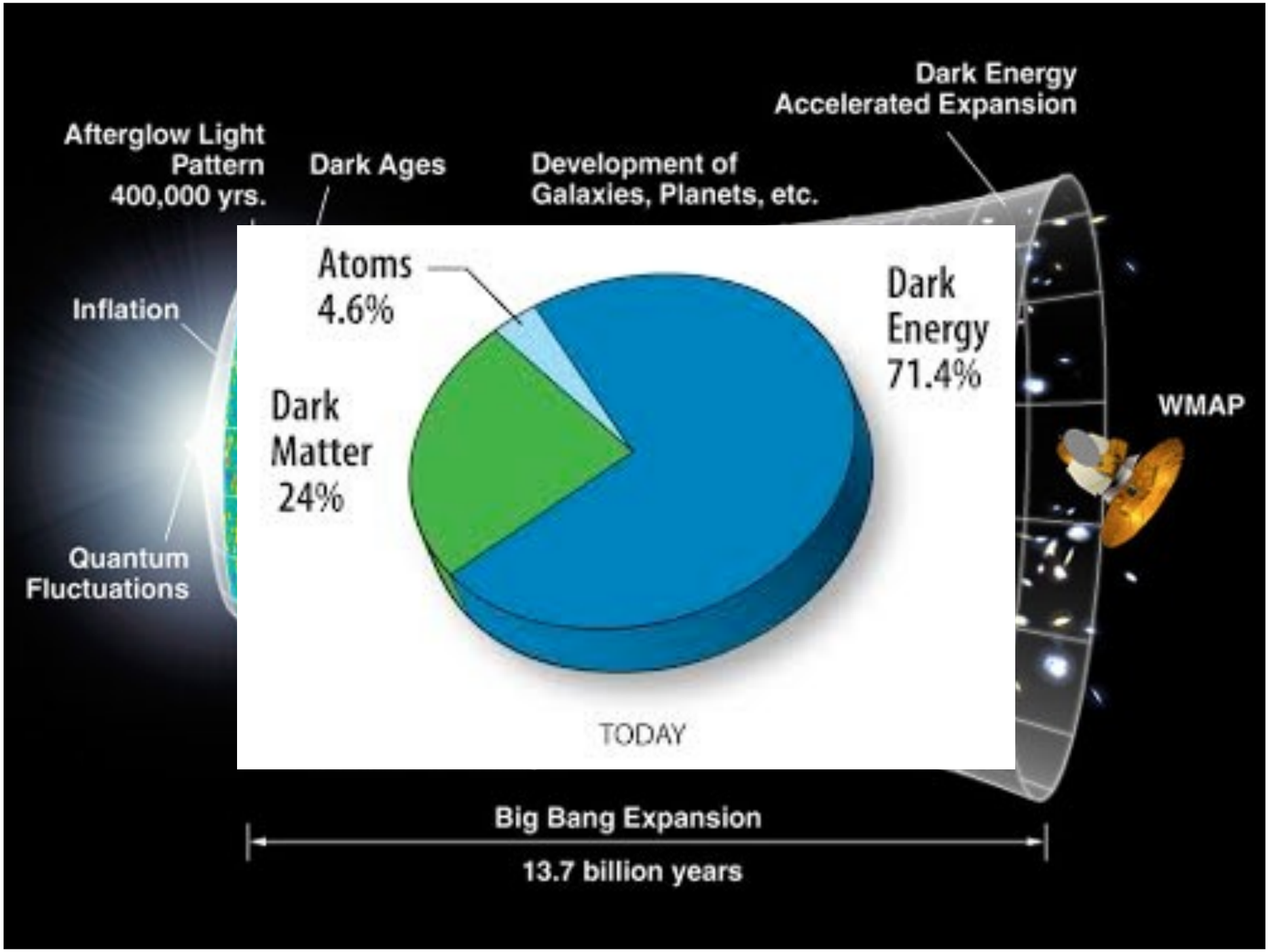
Hot Big-Bang Cosmology



Hot Big-Bang Cosmology



Concordance Cosmology



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This Course:

- *Part I - Smooth Universe*
  Physics & Mathematics of Relativistic Cosmology
  Fundamentals of the Standard Model of Cosmology

- *Part II - Inhomogeneous Universe*
  Structure formation in the Standard Model using
  linear perturbation theory & simplified nonlinear models

(Approximately historically ordered)

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Part I - Smooth Universe

- The expanding Universe (Hubble's Law)
- Relativistic cosmology: FLRW metric
- FLRW kinematics (light propagation, distances, cosmography)
- FLRW dynamics (Friedmann equations & solutions, standard model components + observational evidence)
- Thermal history of the Universe (evolution in equilibrium, decoupling of species, dark matter, Big-Bang nucleosynthesis, recombination)
- Inflation
- Alternatives to the standard model

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Part II - Inhomogeneous Universe

- Relativistic linear perturbation theory (scale-dependent dynamics, perturbations in radiation & dark matter, transfer function)
- Non-relativistic fluid formulation (linear & quasi-linear evolution of dark matter, linear evolution of baryons)
- Non-linear growth: Zel'dovich approx; Spherical Collapse
- Statistical treatment of linear inhomogeneities (Gaussian random fields, power spectrum)
- Statistics of non-linear objects (redshift space distortions, halo mass function, galaxy clustering, galaxy formation)

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Projects

Constructed to provide introduction to basic analytical, numerical & statistical tools used in observational cosmology.

- Supernova data analysis
- Light element abundances from BBN
- Relativistic linear perturbation theory
- Spherical collapse in LCDM model
- Power spectra of dark matter and halo number density fields
- Halo abundance matching and galaxy clustering
- Photo-ionisation rate from Lyman-alpha mean flux
- Estimating sound horizon from galaxy clustering