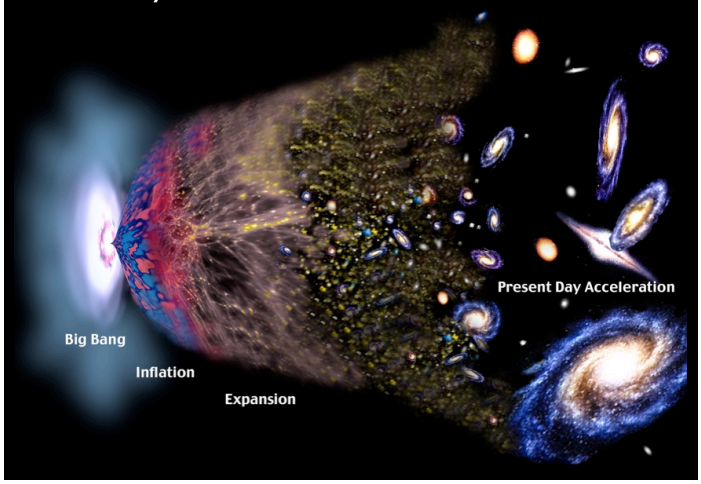
What is Dark Energy?

Chris Blake (Swinburne)

- What are the big questions today in cosmology?
- How can large galaxy surveys help us to address these questions?
- The WiggleZ survey : measuring cosmic sound waves

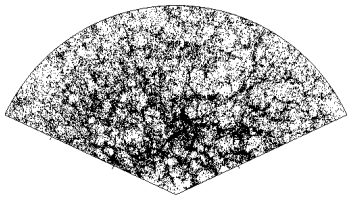
The history of the Universe!



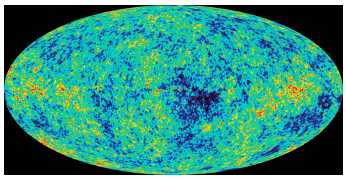
The main probes of cosmology

Supernovae

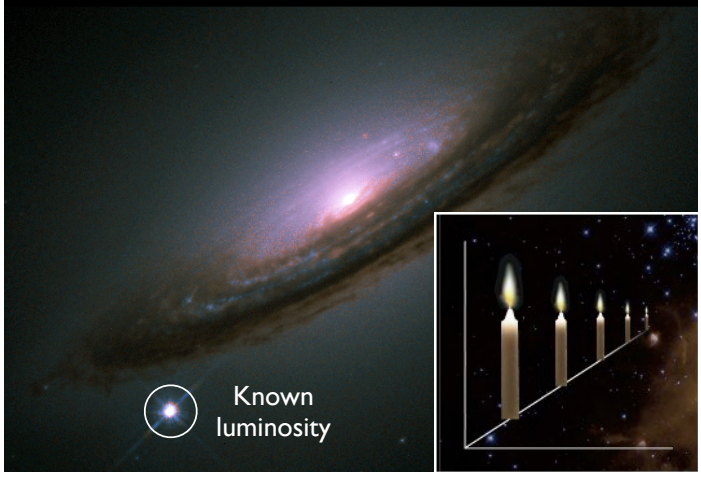
Large-scale structure



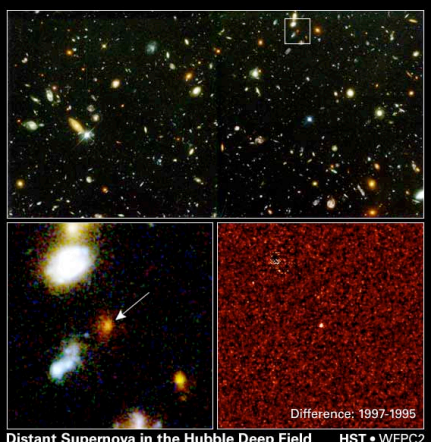
Cosmic Microwave Background



Supernovae - standard candles

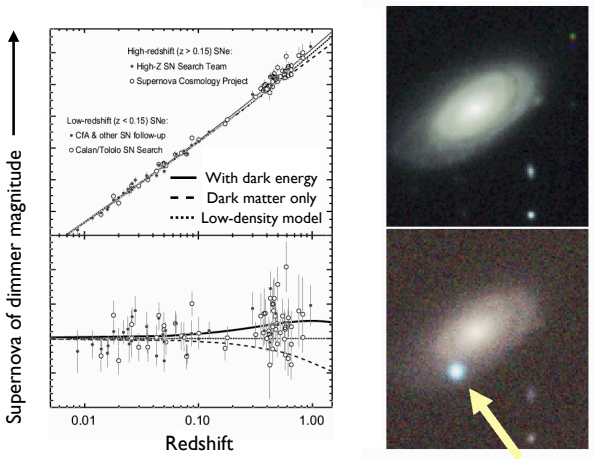


Supernovae - standard candles

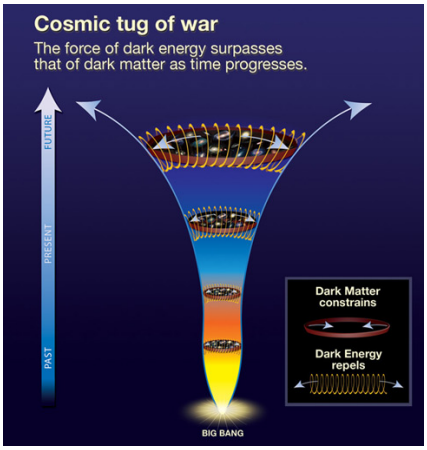


Distant Supernova in the Hubble Deep Field HST • WFPC2
NASA and A. Riess (STScI) • STScI-PRC01-09

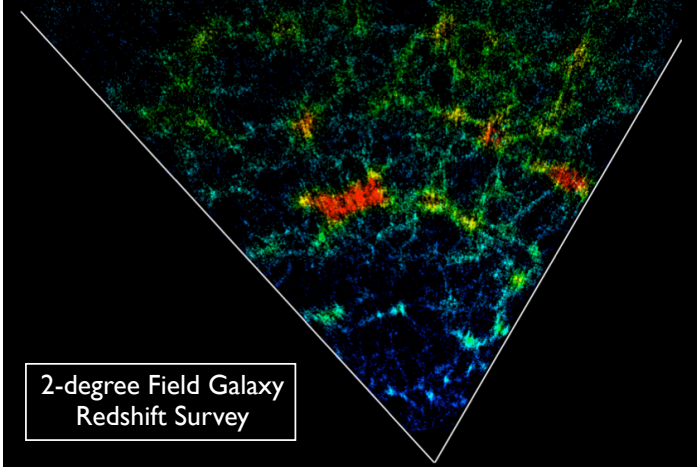
Supernovae - standard candles



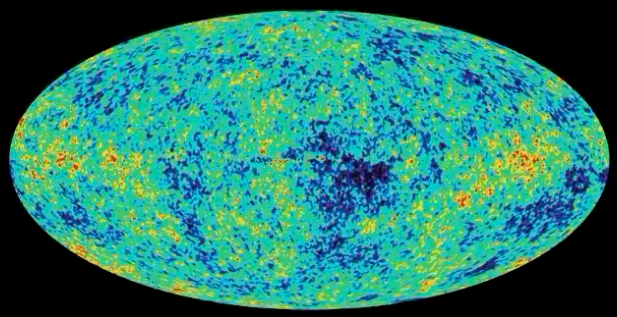
The accelerating expansion



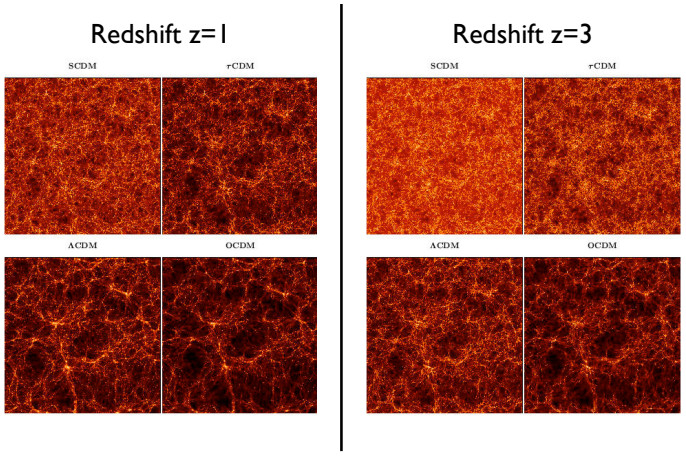
Large-scale structure of the Universe



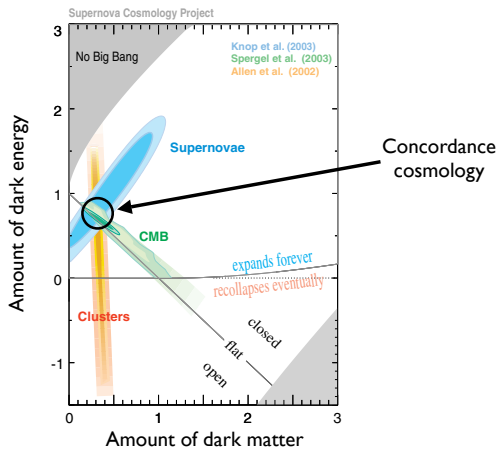
Fluctuations in the Cosmic Microwave Background



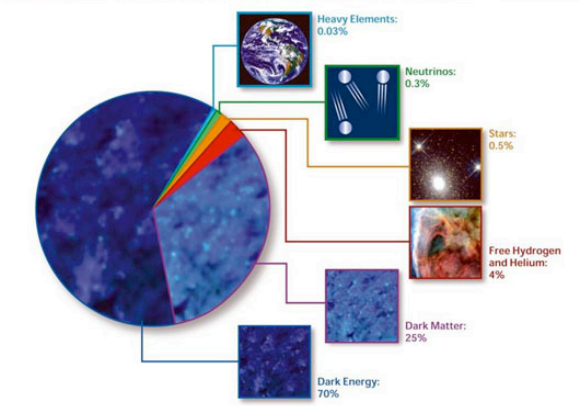
Theoretical simulations



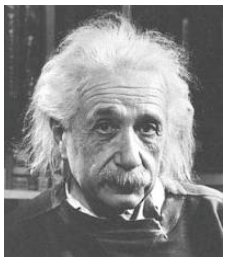
What is the composition of the Universe?

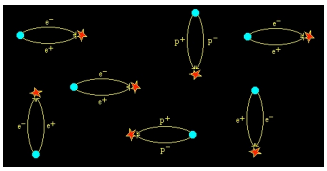


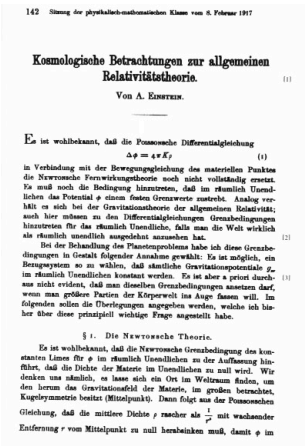
What is the composition of the Universe?



Einstein's cosmological constant







142 Sitzung der physikalisch-mathematischen Klasse vom 8. Februar 1917

Kosmologische Betrachtungen zur allgemeinen Relativitätstheorie.

Von A. Einstein.

Es ist wohlbekannt, daß die Poissonsche Differentialgleichung

$$\Delta\varphi = 4\pi K\varrho \qquad (1)$$

in Verbindung mit der Bewegungsgleichung des materiellen Punktes die Newtonsche Fernwirkungstheorie noch nicht vollständig ersetzt. Es muß noch die Bedingung hinzutreten, daß im räumlich Unendlichen das Potential φ einem festen Grenzwerte zustrebt. Analog verhält es sich bei der Gravitationstheorie der allgemeinen Relativität; auch hier müssen zu den Differentialgleichungen Grenzbedingungen hinzutreten für das räumlich Unendliche, falls man die Welt wirklich als räumlich unendlich ausgedehnt anzusehen hat.

Bei der Behandlung des Planetenproblems habe ich diese Grenzbedingungen in Gestalt folgender Annahme gewählt: Es ist möglich, ein Bezugssystem so zu wählen, daß sämtliche Gravitationspotentiale $g_{\mu\nu}$ im räumlich Unendlichen konstant werden. Es ist aber a priori durchaus nicht evident, daß man dieselben Grenzbedingungen ansetzen darf, wenn man größere Partien der Körperwelt ins Auge fassen will. Im folgenden sollen die Überlegungen angegeben werden, welche ich bisher über diese prinzipiell wichtige Frage angestellt habe.

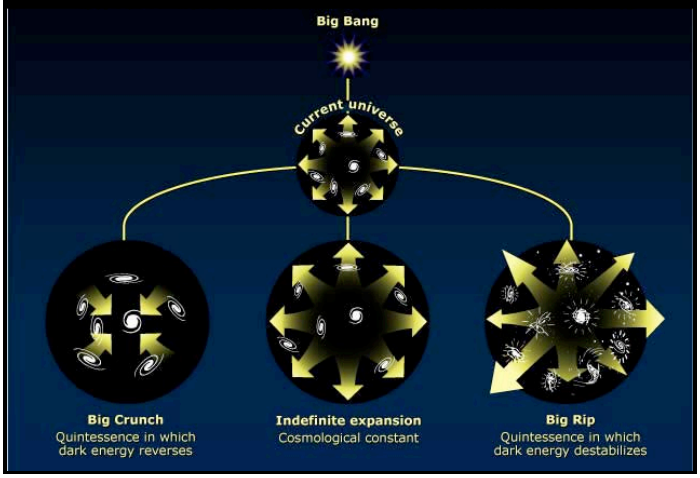
§ 1. Die Newtonsche Theorie.

Es ist wohlbekannt, daß die Newtonsche Grenzbedingung des konstanten Limes für φ im räumlich Unendlichen zu der Auffassung hinführt, daß die Dichte der Materie im Unendlichen zu null wird. Wir denken uns nämlich, es lasse sich ein Ort im Weltraum finden, um den herum das Gravitationsfeld der Materie, im großen betrachtet, Kugelsymmetrie besitzt (Mittelpunkt). Dann folgt aus der Poissonschen Gleichung, daß die mittlere Dichte ϱ rascher als $\frac{1}{r^2}$ mit wachsender Entfernung r vom Mittelpunkt zu null herabsinken muß, damit φ im

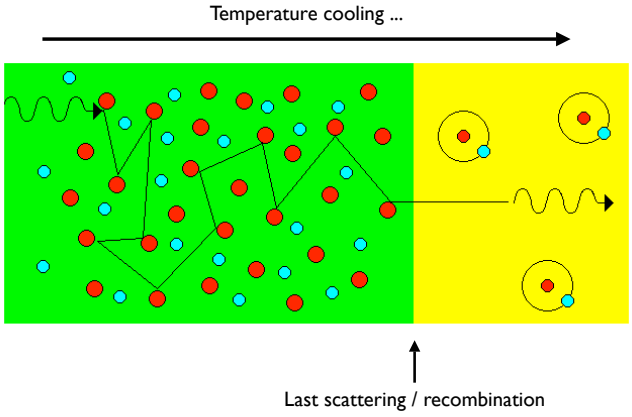
The problem of dark energy

- Cosmological constant is profoundly inconsistent with quantum mechanics
- We must either change the laws of gravity or explain a "substance" that comprises the bulk of the universe
- Alternative models (quintessence) predict properties of dark energy should evolve with redshift
- Current observations cannot discriminate between these models

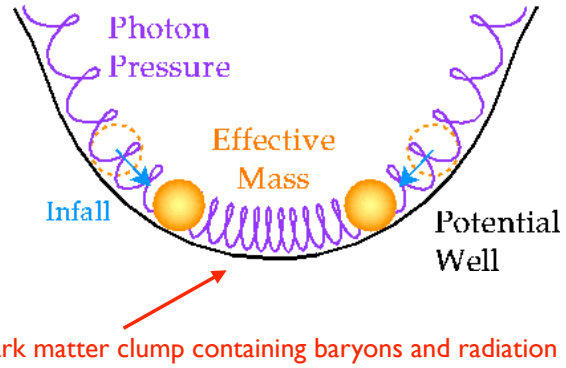
Fate of the Universe



Cosmic sound waves

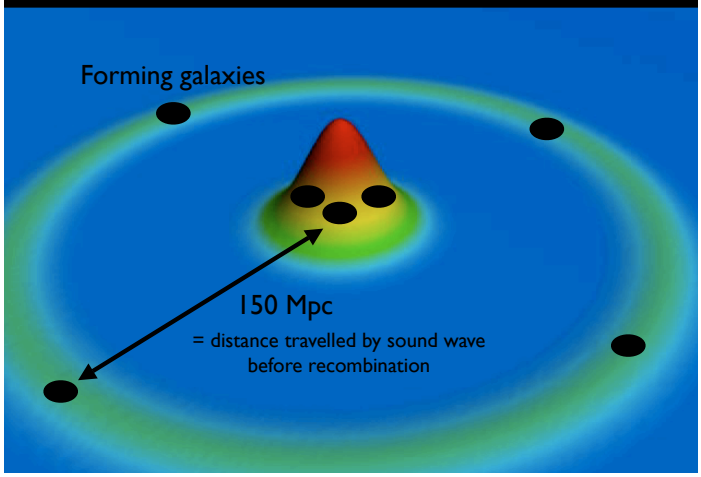


Cosmic sound waves



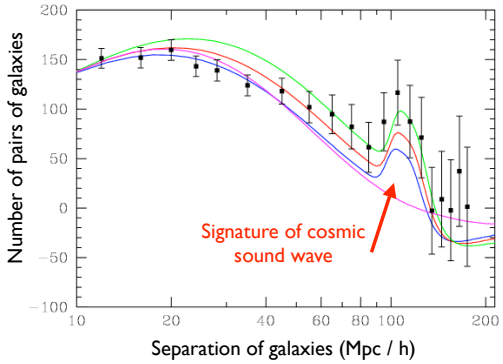
Dark matter clump containing baryons and radiation

Cosmic sound waves



Cosmic sound waves

Result from the Sloan Digital Sky Survey of local galaxies:

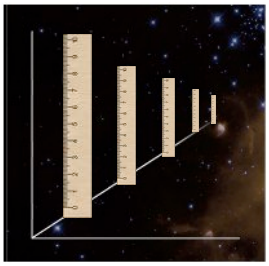


Cosmic sound waves

Standard candle

Supernova

Standard ruler



Cosmic sound wave

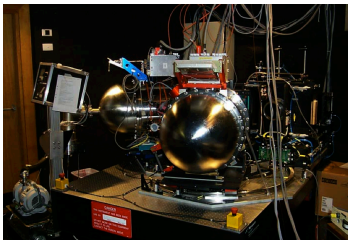
$$\left(\frac{\dot{R}}{R}\right)^2 - \frac{8}{3}\pi G\rho - \frac{1}{3}\Lambda = -\frac{kc^2}{R^2}$$

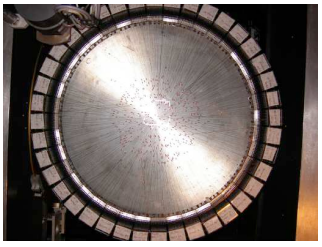
The WiggleZ survey

The WiggleZ survey

Survey mission : obtain redshifts of 200,000 high-redshift galaxies (0.5 < z < 1.0) over 1000 sq degs

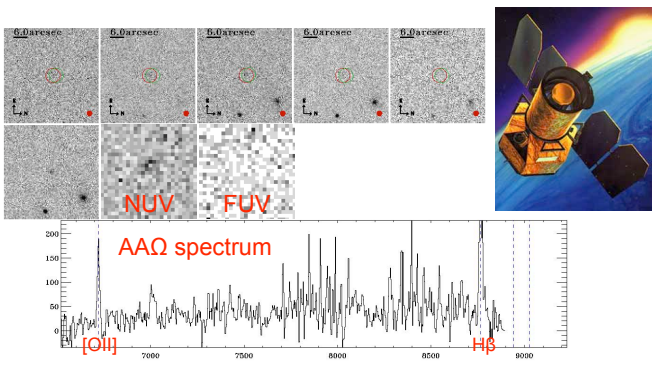
Science goal : first detection of cosmic sound waves at high redshift and a robust test of dark energy



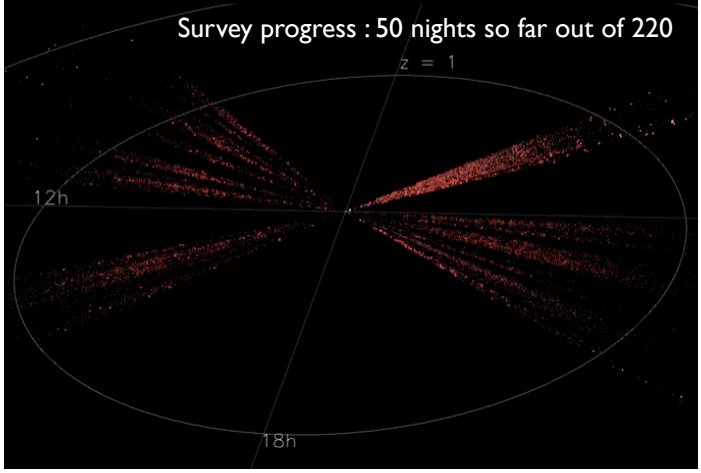


The WiggleZ survey

Example target : high-redshift star-forming galaxies

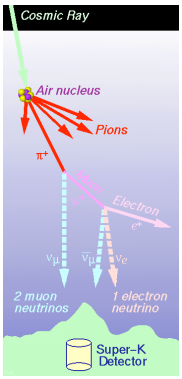


The WiggleZ survey



The WiggleZ survey

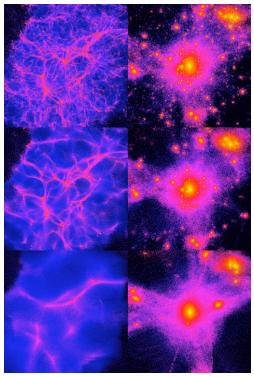
- What is the mass of the neutrino ?



Cold

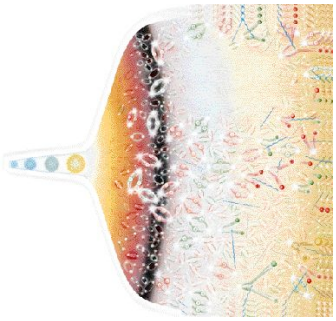
Warm

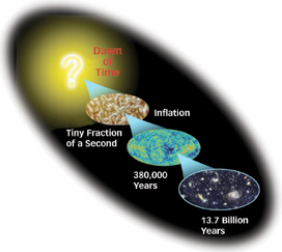
Hot



The WiggleZ survey

- Measuring the physics of inflation





To sum up ...

- Dark energy is a fundamental problem
- Galaxy surveys can measure dark energy by mapping the imprint of cosmic sound waves
- WiggleZ survey will provide first high redshift application of this technique

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