Fingerprinting the Universe

Image courtesy
NASA

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- The superb quality of new observational data, from many sources.

What is a model?

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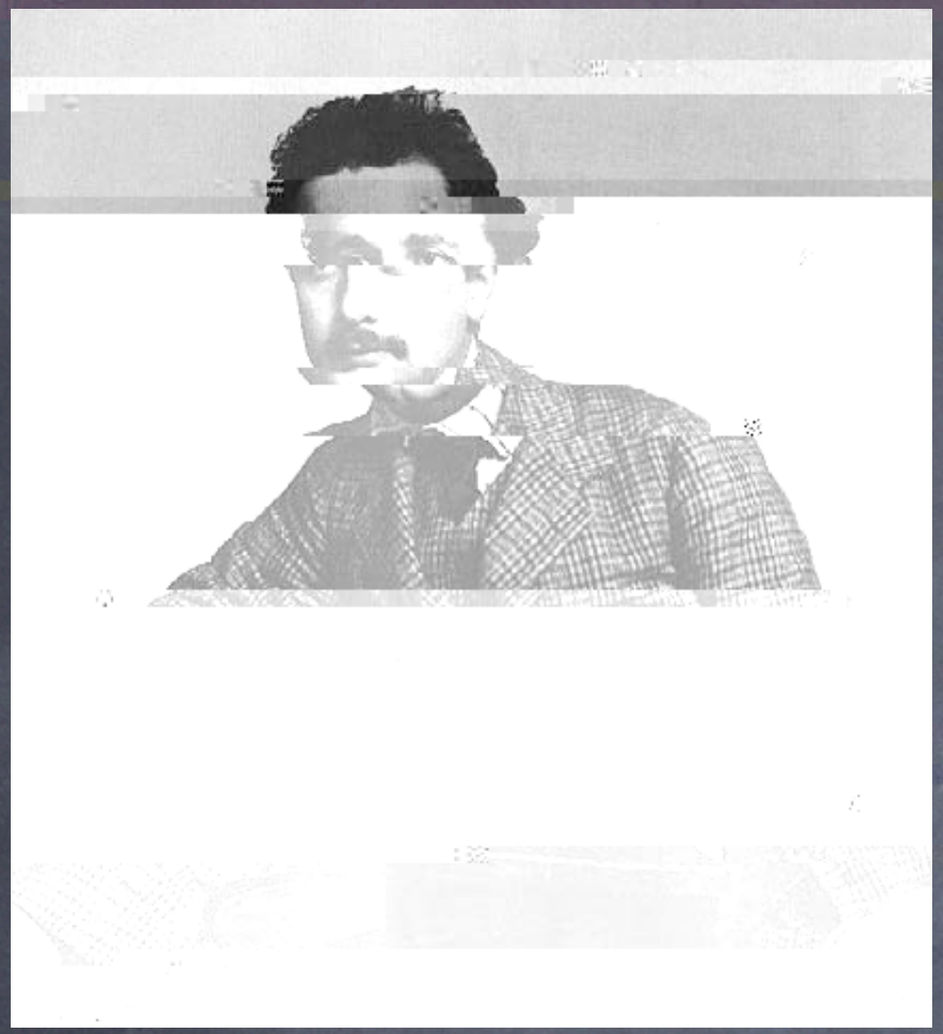
If a model is to be much good, it should be
(a) consistent with observations, and (b) predictive.



Albert Einstein

Declared `Person of the Century' by Time Magazine, 1999

- In 1915, Einstein published his general theory of relativity. It was a theory of gravity, attributing gravitational forces to a curvature of space-time.

- In 1922, Friedmann constructed the first expanding Universe models, still known today as the Friedmann models.
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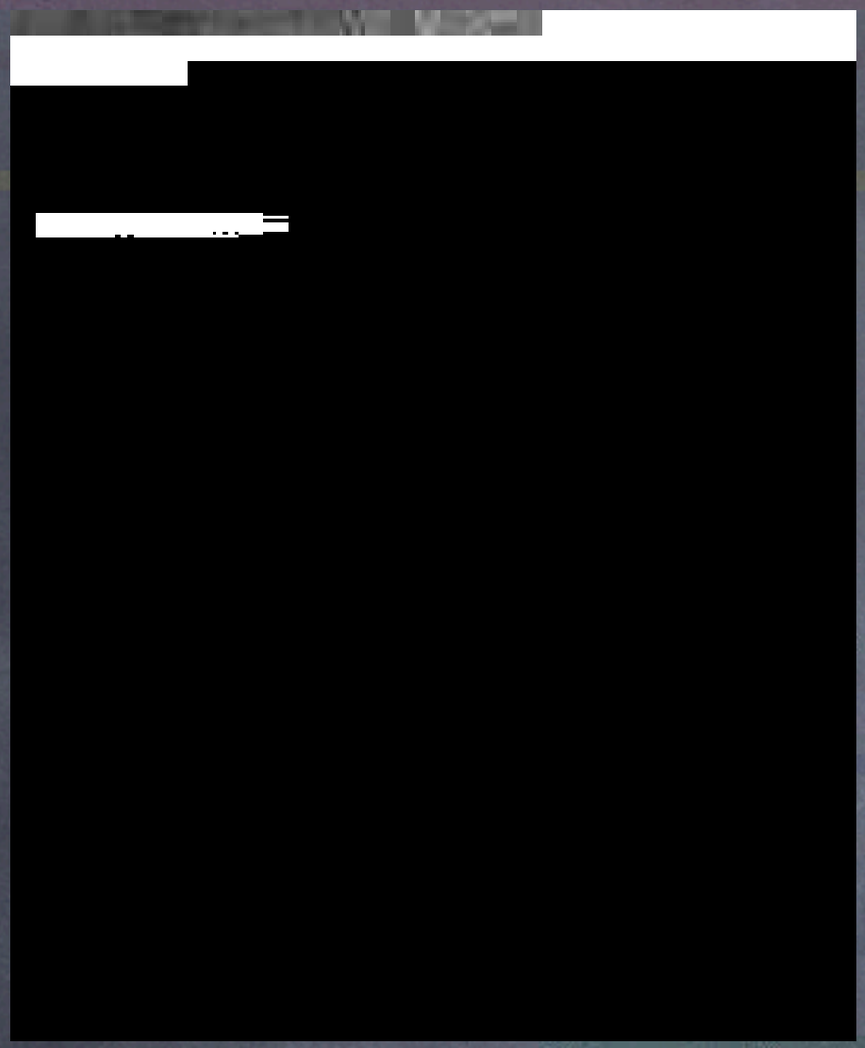
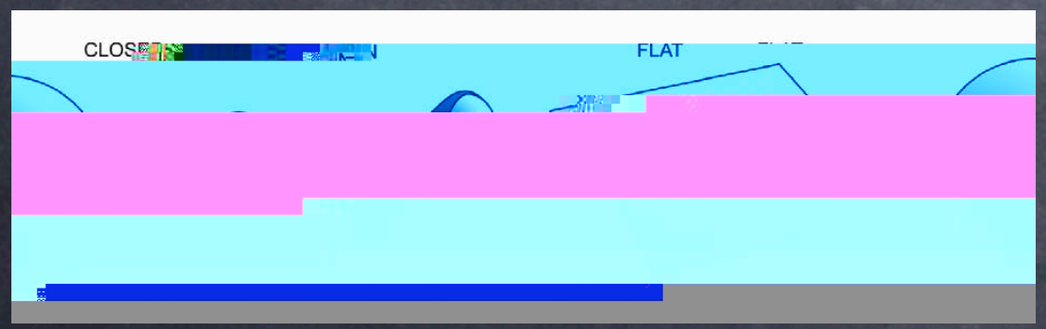
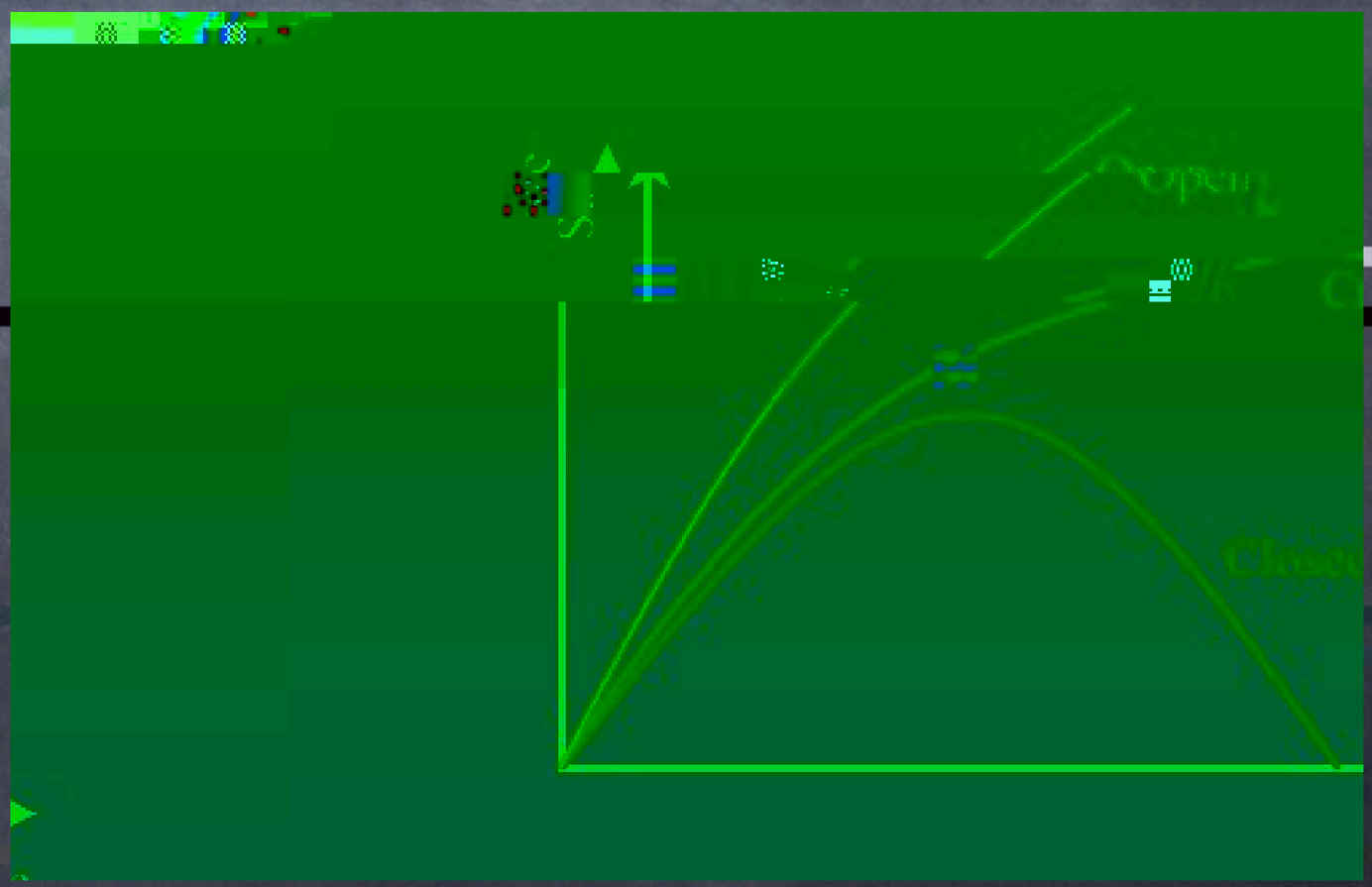


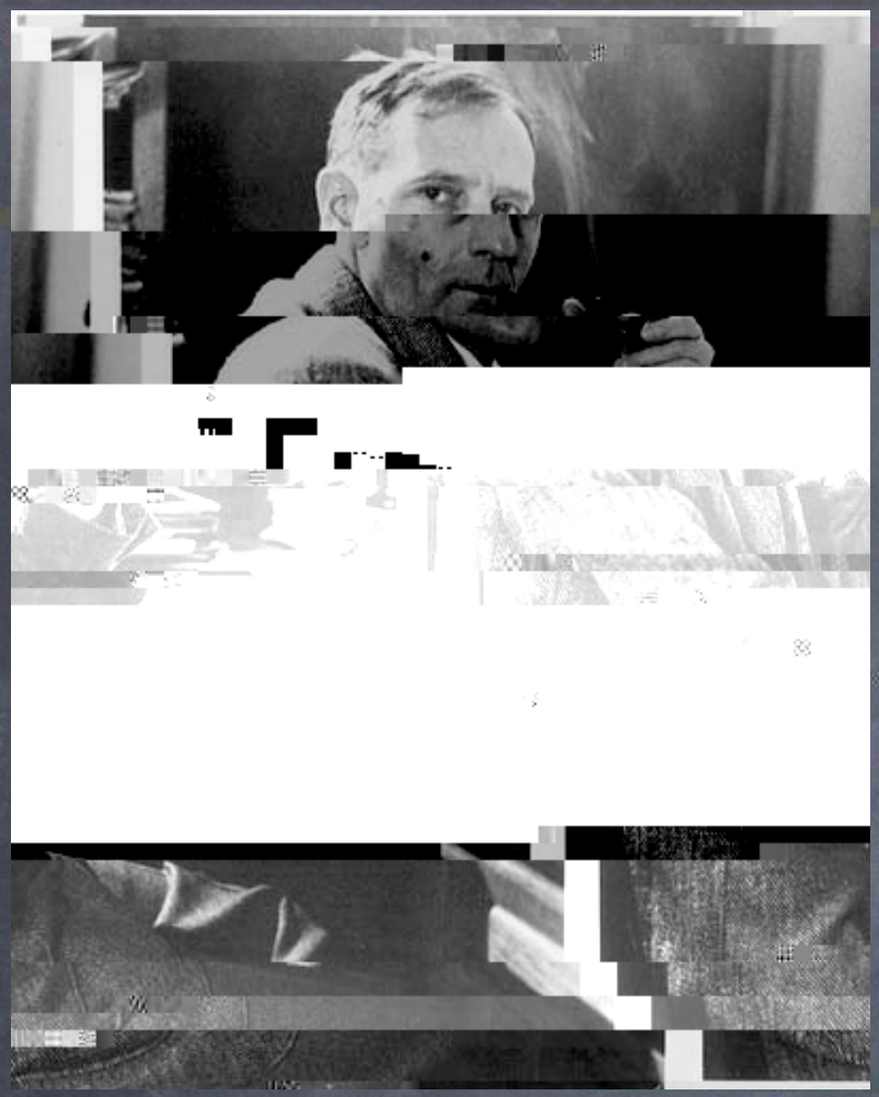
Alexander Friedmann

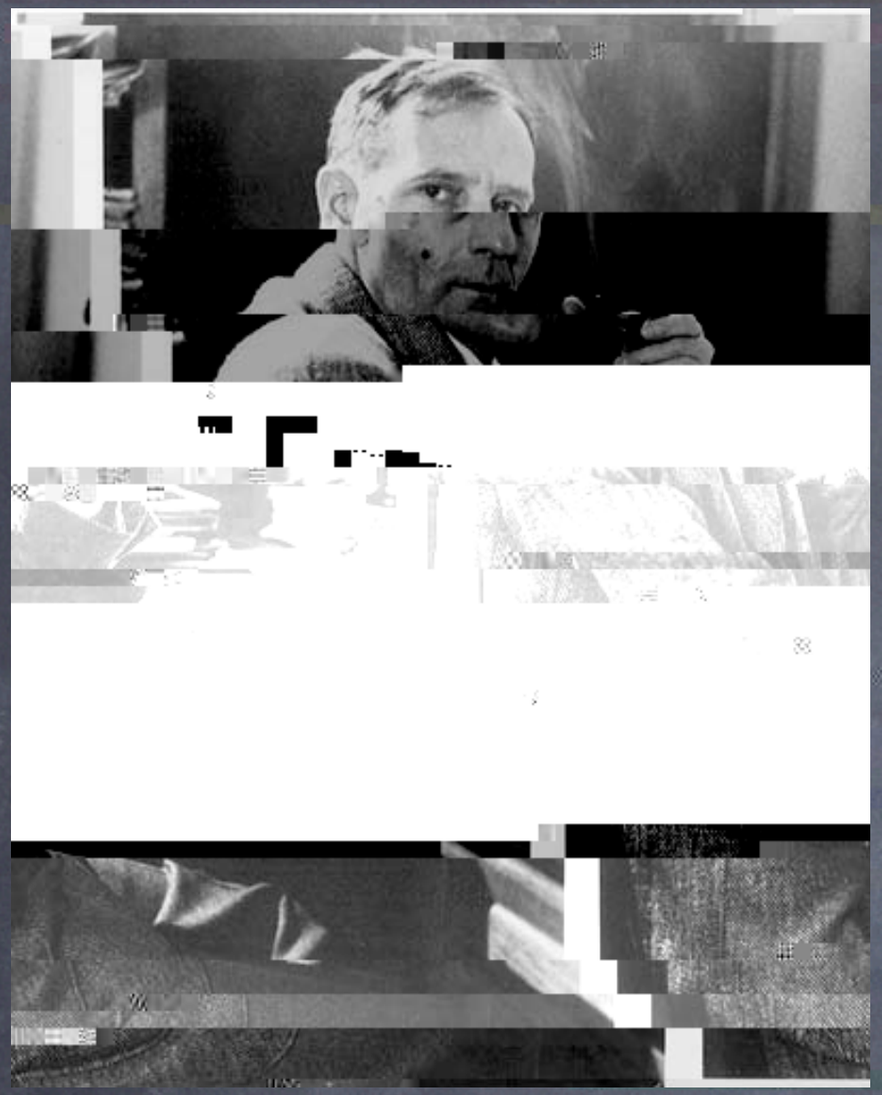
- In 1922, Friedmann constructed the first expanding Universe models, still known today as the Friedmann models.
- He realised that the geometry of the Universe could come in three types: flat, spherical (closed), or hyperbolic (open).





Edwin Hubble





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"... an Olympian, tall, strong, and beautiful, with the shoulders of the Hermes of Praxiteles ... there was a sense of power, channeled and directed in an adventure that had nothing to do with personal ambition and anxieties and lack of peace. There was hard concentrated effort and yet detachment. The power was controlled."

Grace Hubble, recollecting her first meeting with her future husband.

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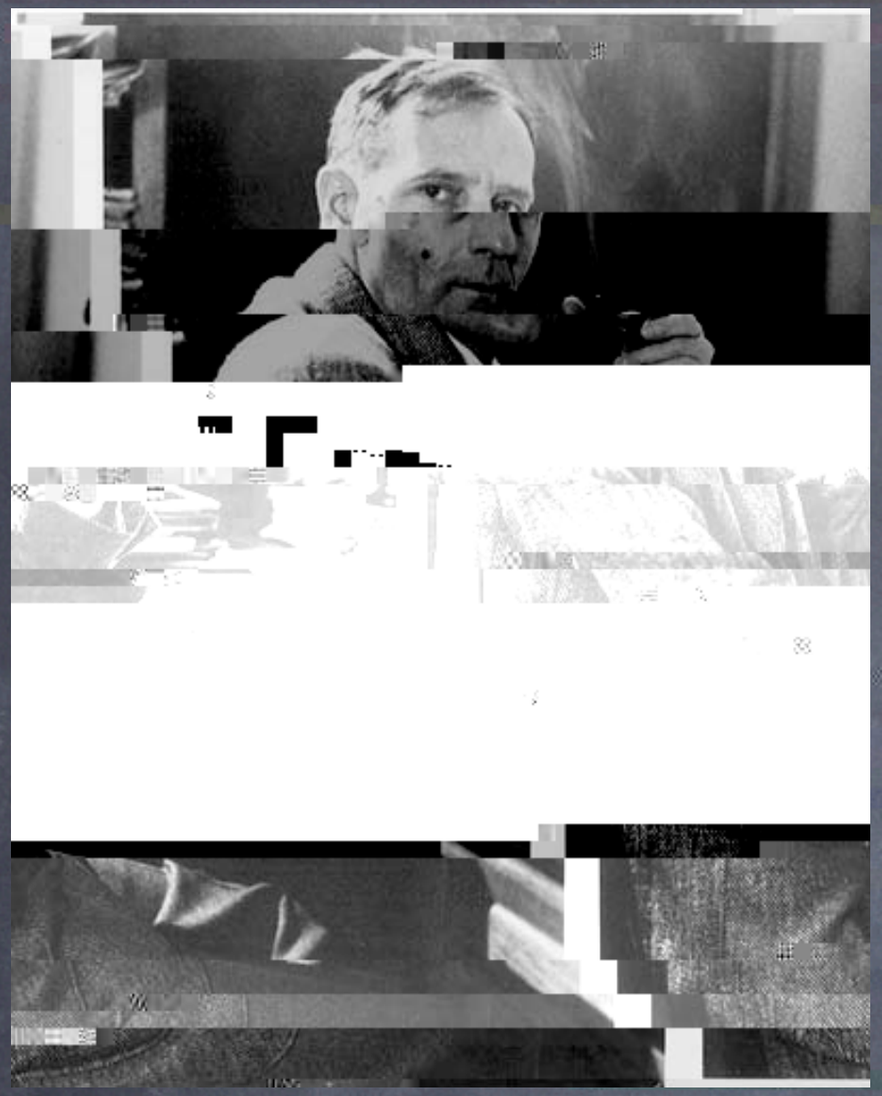

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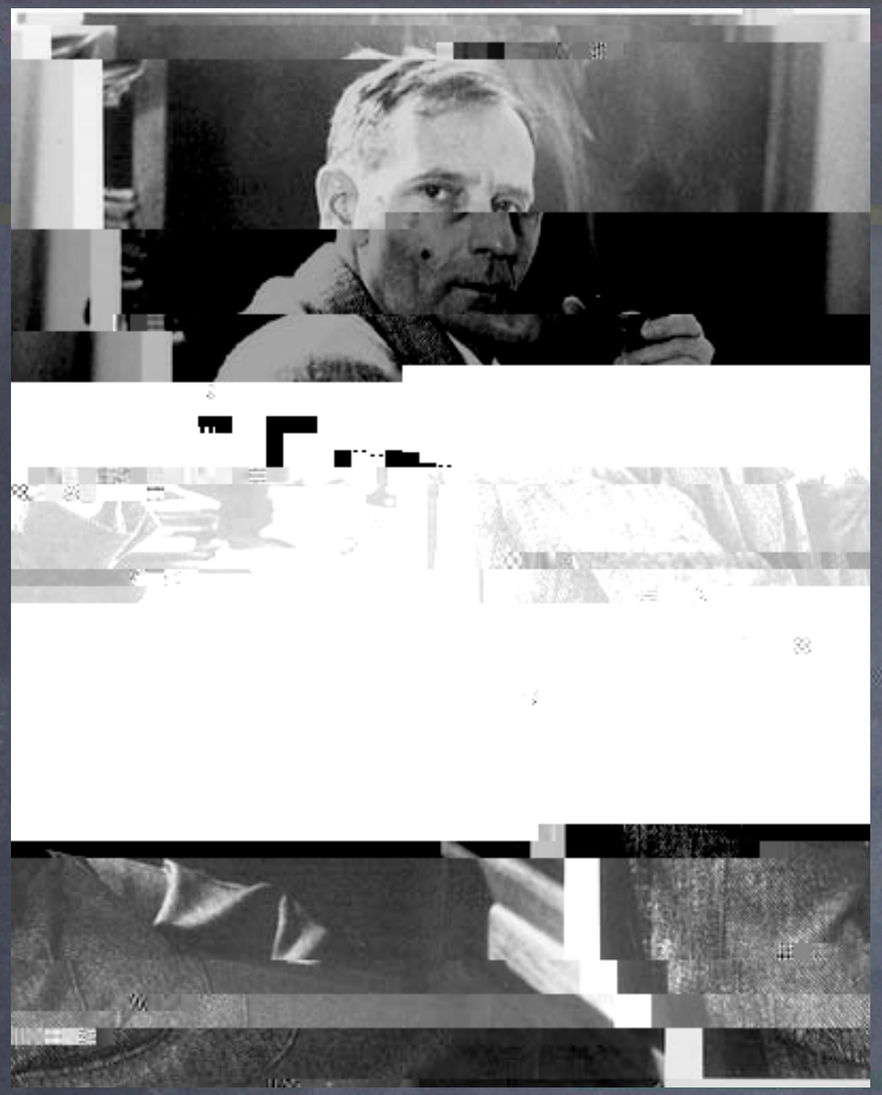

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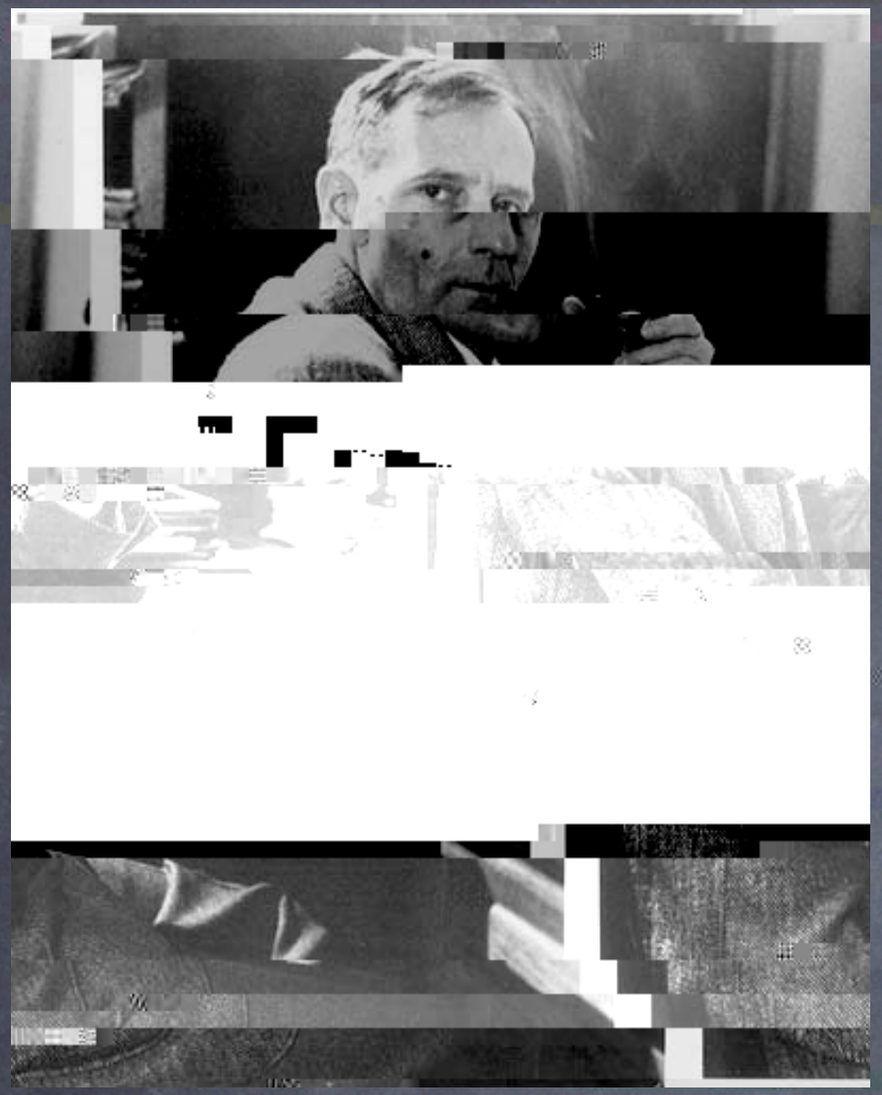

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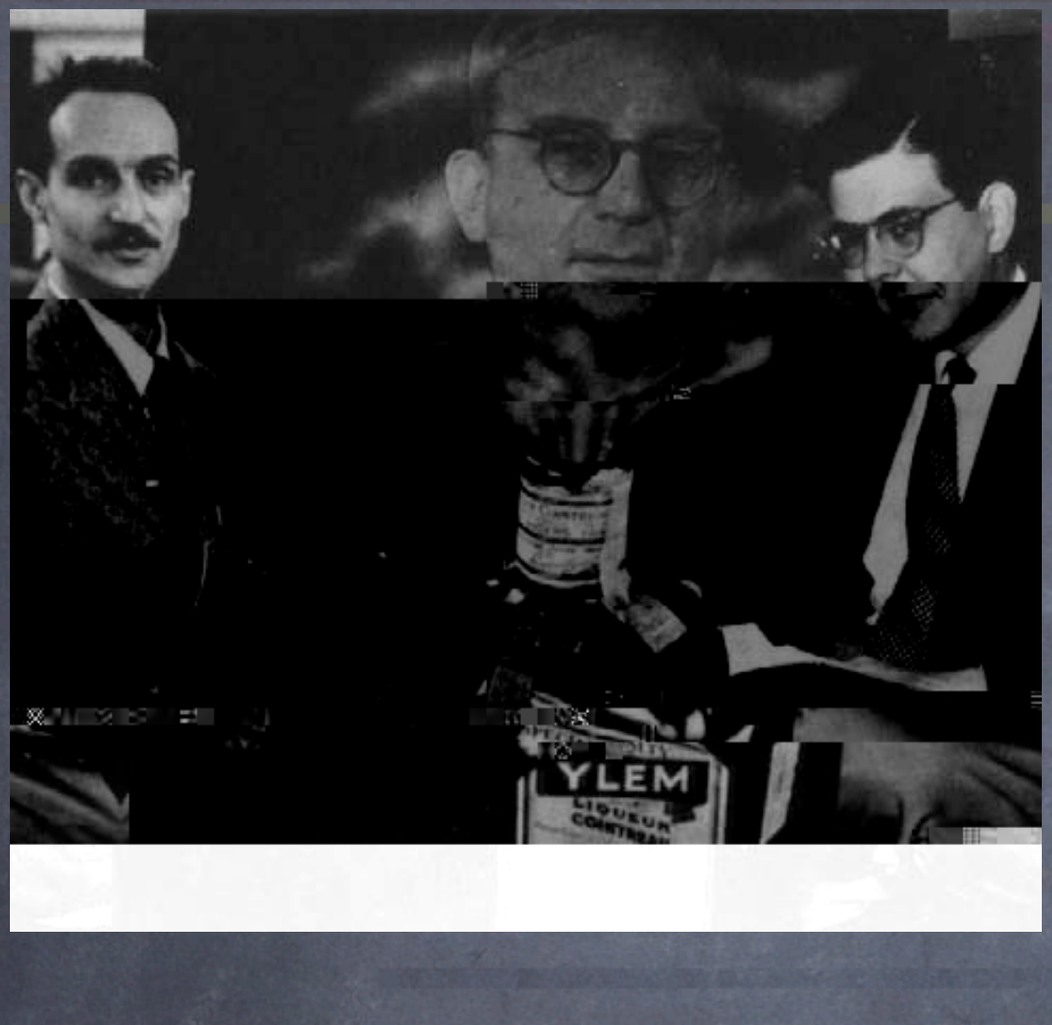
- In 1929, with Milton Humason, he measured the expansion rate of the Universe, by determining the distances and velocities of nearby galaxies.



George Gamow & co

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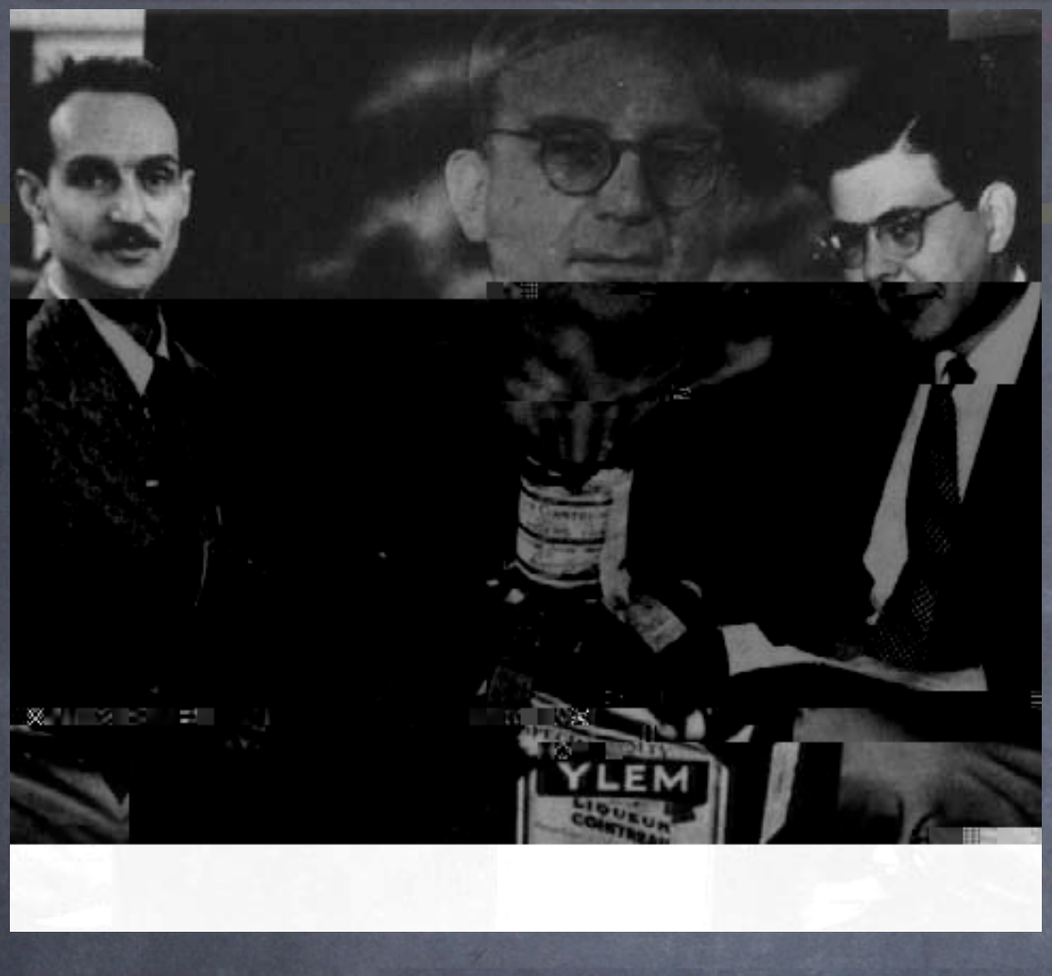

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- Gamow was especially interested in the formation of light elements by nuclear reactions, when the Universe was around one second old.

The cosmic microwave background

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In this epoch of cosmological studies, attention was mostly focussed on measuring two parameters, the Hubble constant and the total density of the Universe (combined, these determine the curvature).

The dark stuff, part I

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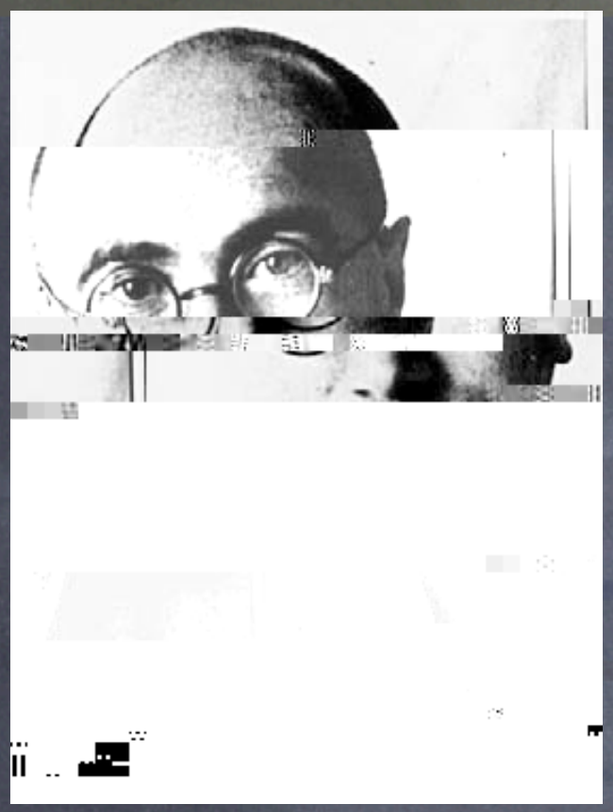
- As long ago as the mid 1930s, Fritz Zwicky discovered dark matter in a nearby cluster of galaxies, the Coma cluster.
- In the 1970s, detailed studies of galaxy dynamics, especially by Vera Rubin, left cosmologists in little doubt that there was more to the Universe than met the eye.

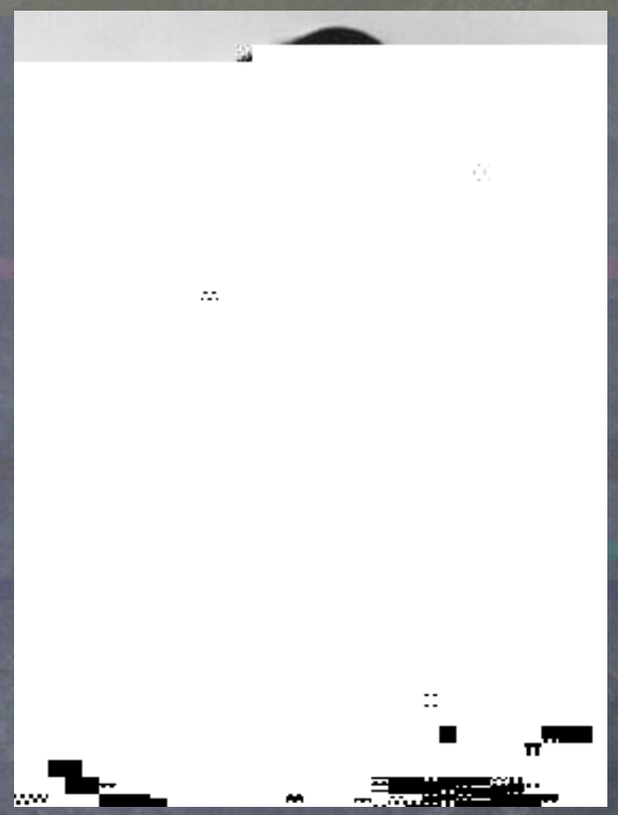
Suddenly, there were more than two cosmological parameters.

The formation of structures



Yakov Zel’dovich

James Peebles



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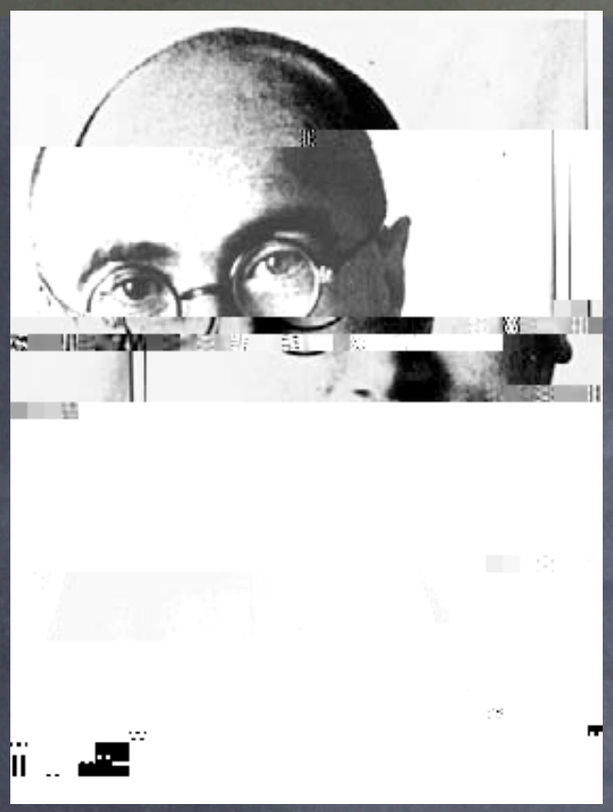

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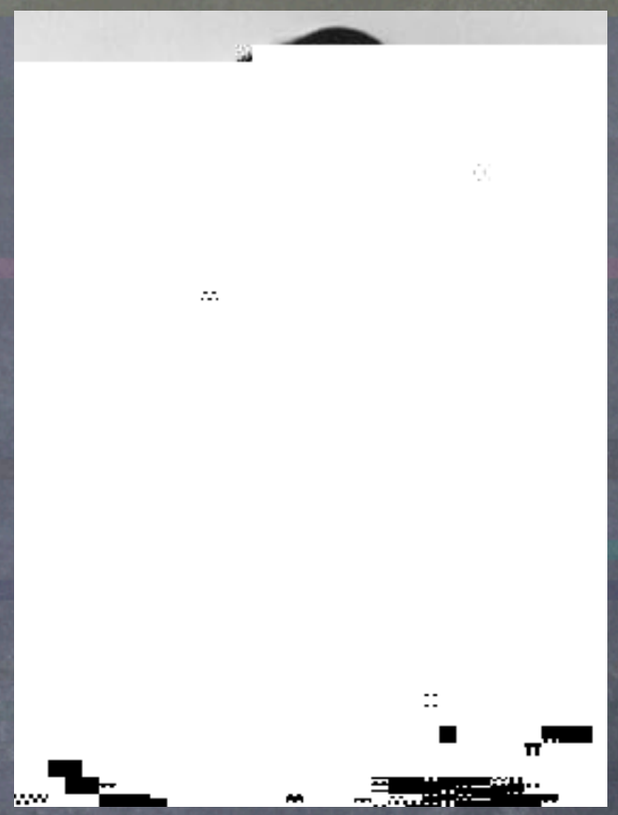

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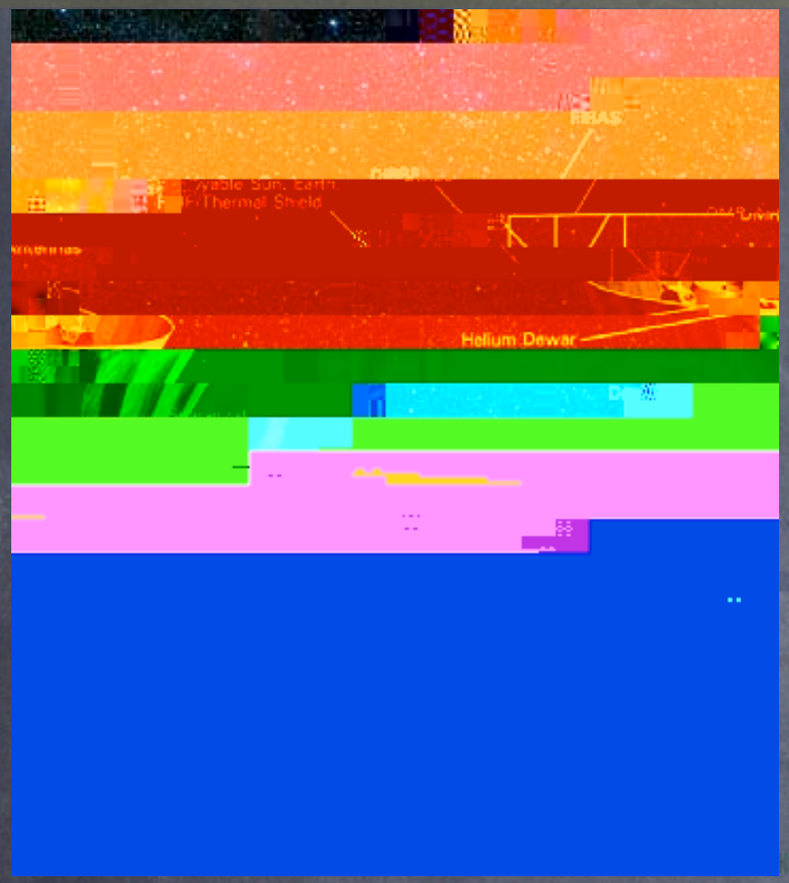
Simulation (n): The action or practice of simulating, with intent to deceive; false pretence, deceitful profession.

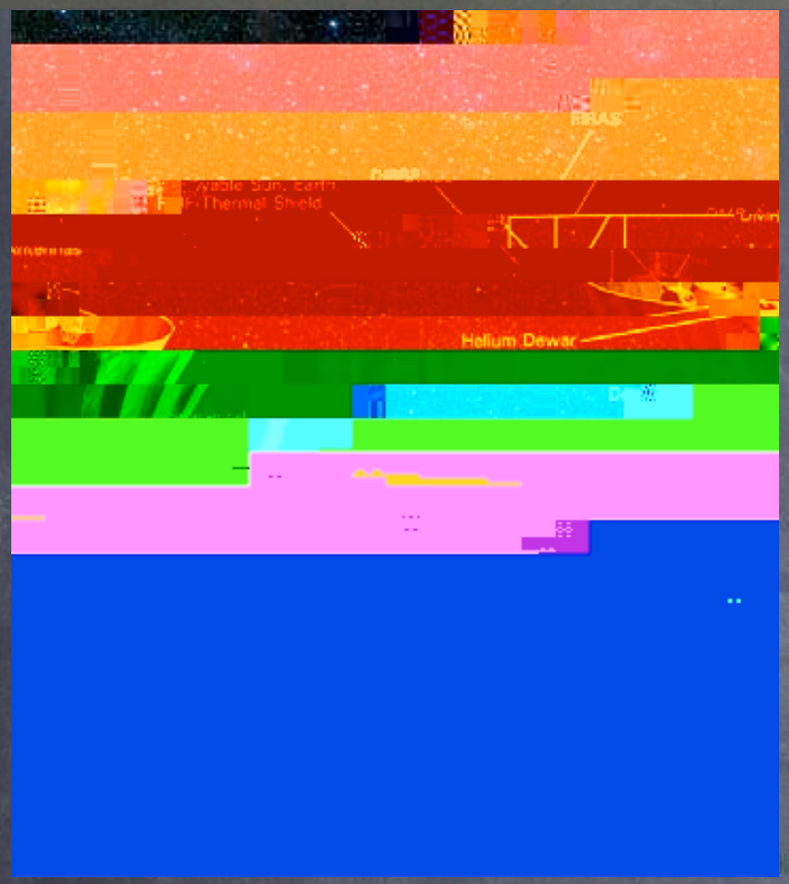
Oxford English Dictionary

The road to precision cosmology



The COBE satellite, launched 1989.

The road to precision cosmology



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Four-year COBE map of the cosmic microwave background sky.

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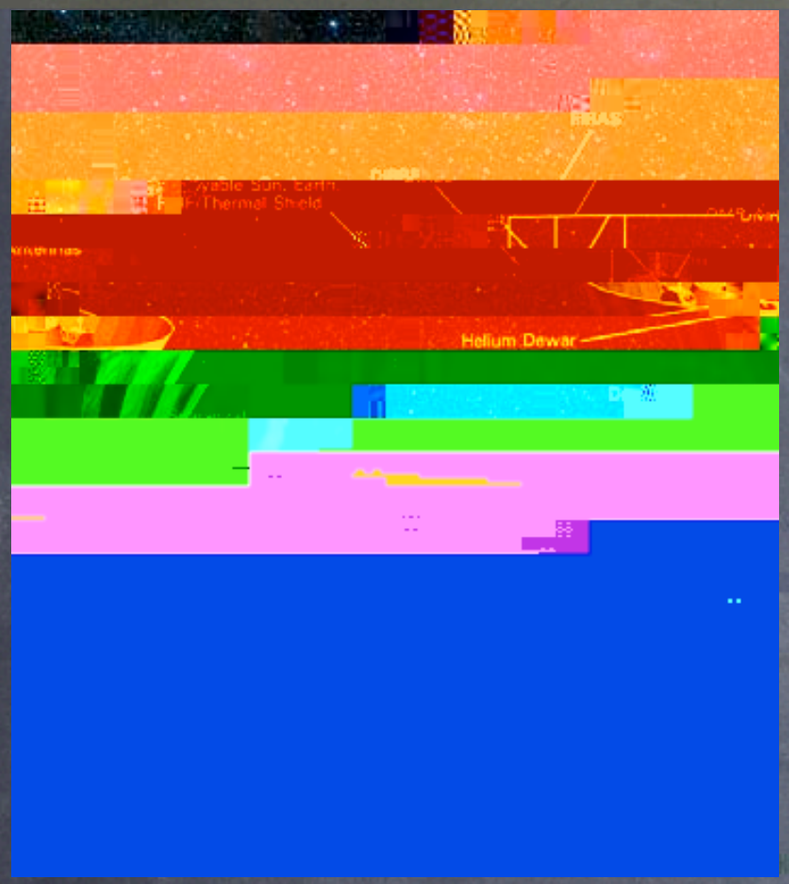

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Four-year COBE map of the cosmic microwave background sky.

- The COBE satellite made the first detection of irregularities in the cosmic microwave background in 1992.
- These are the irregularities that later evolve to form galaxies. They correspond to temperature variations of only about one part in a hundred thousand.

The road to precision cosmology

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The dark stuff, part II

The last ingredient of modern cosmological models fell into place in the late 1990s. Observations of distant supernovae indicated that the expansion of the Universe is accelerating. Several types of observation now support this conclusion.

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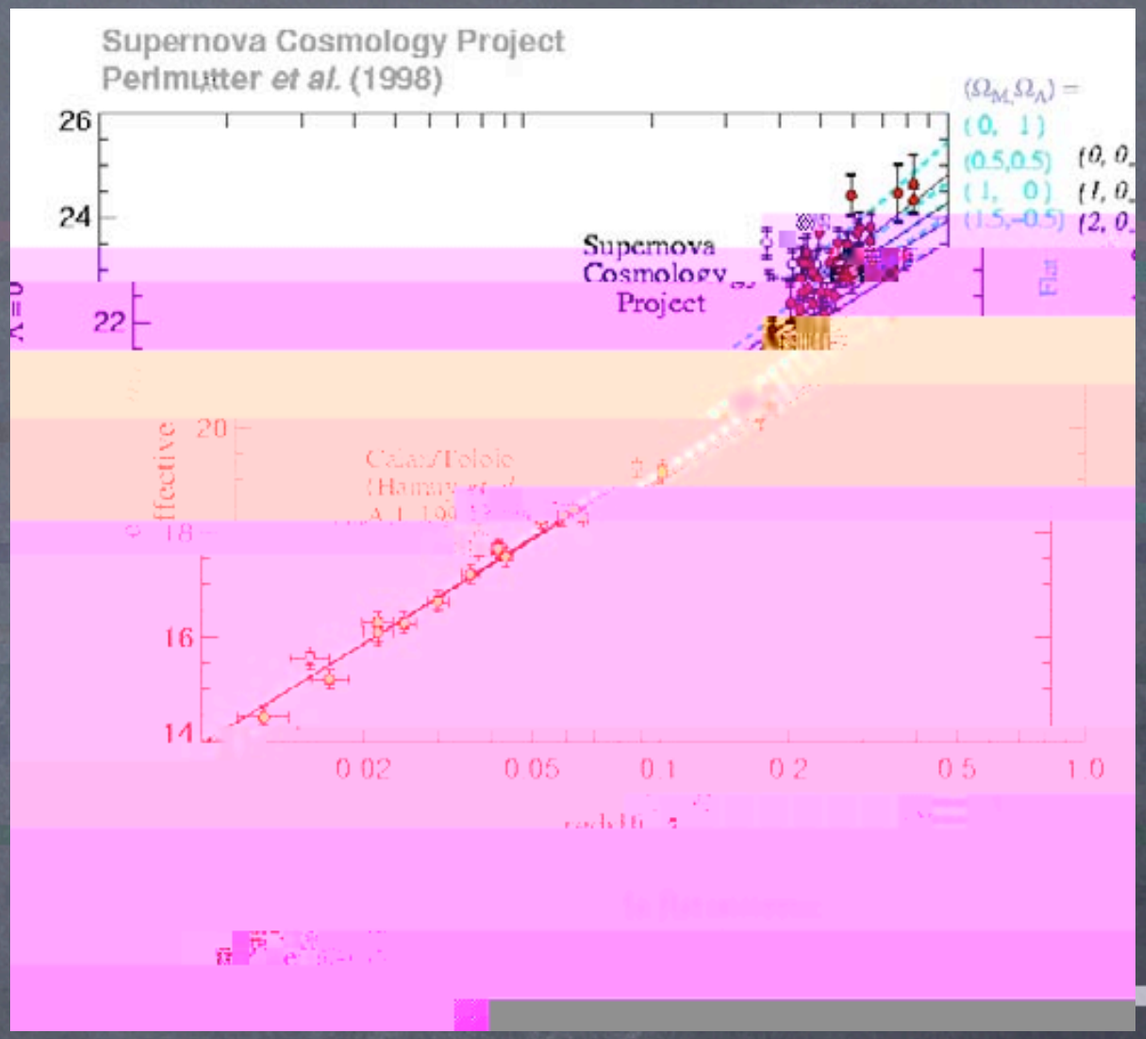

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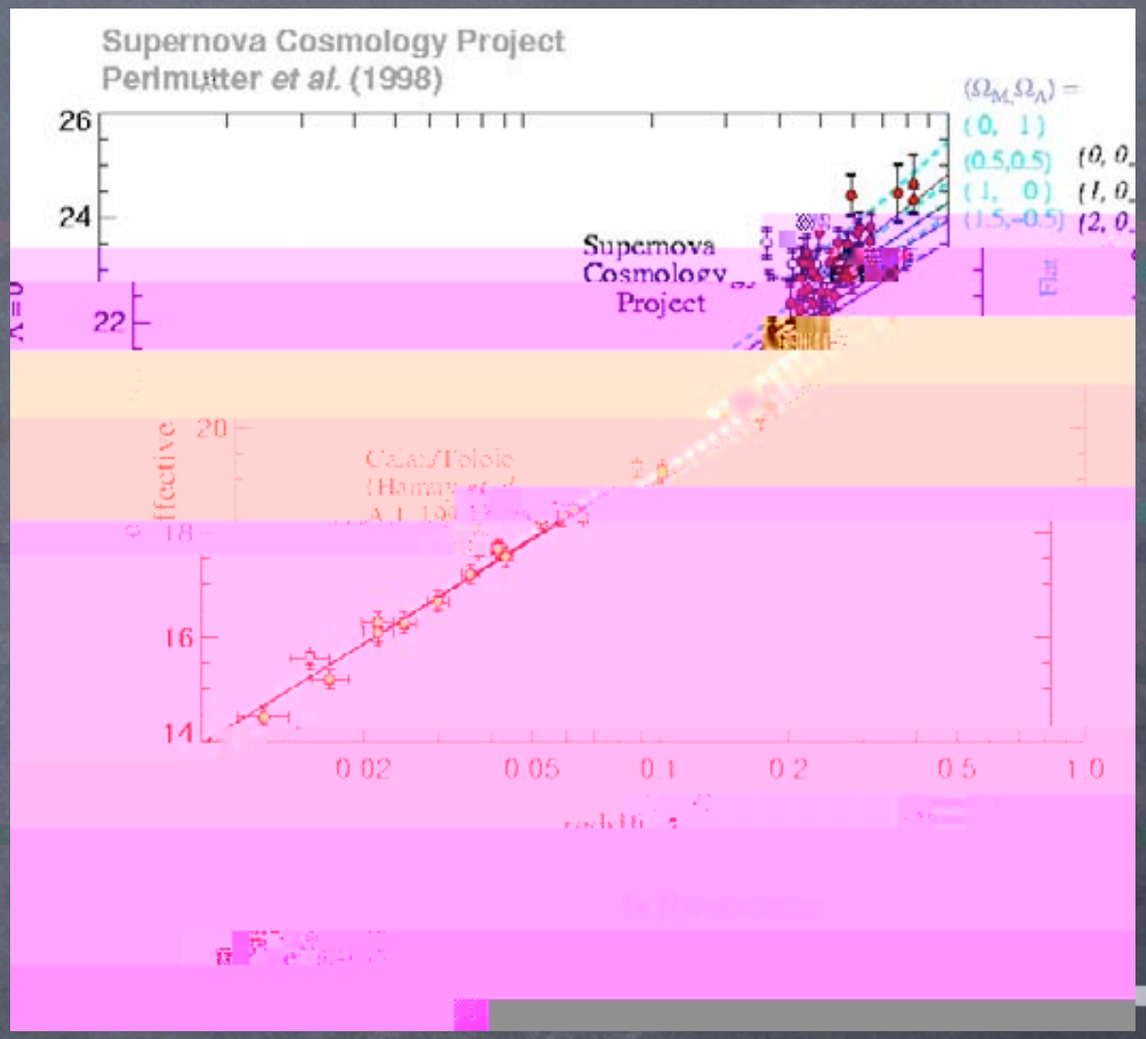

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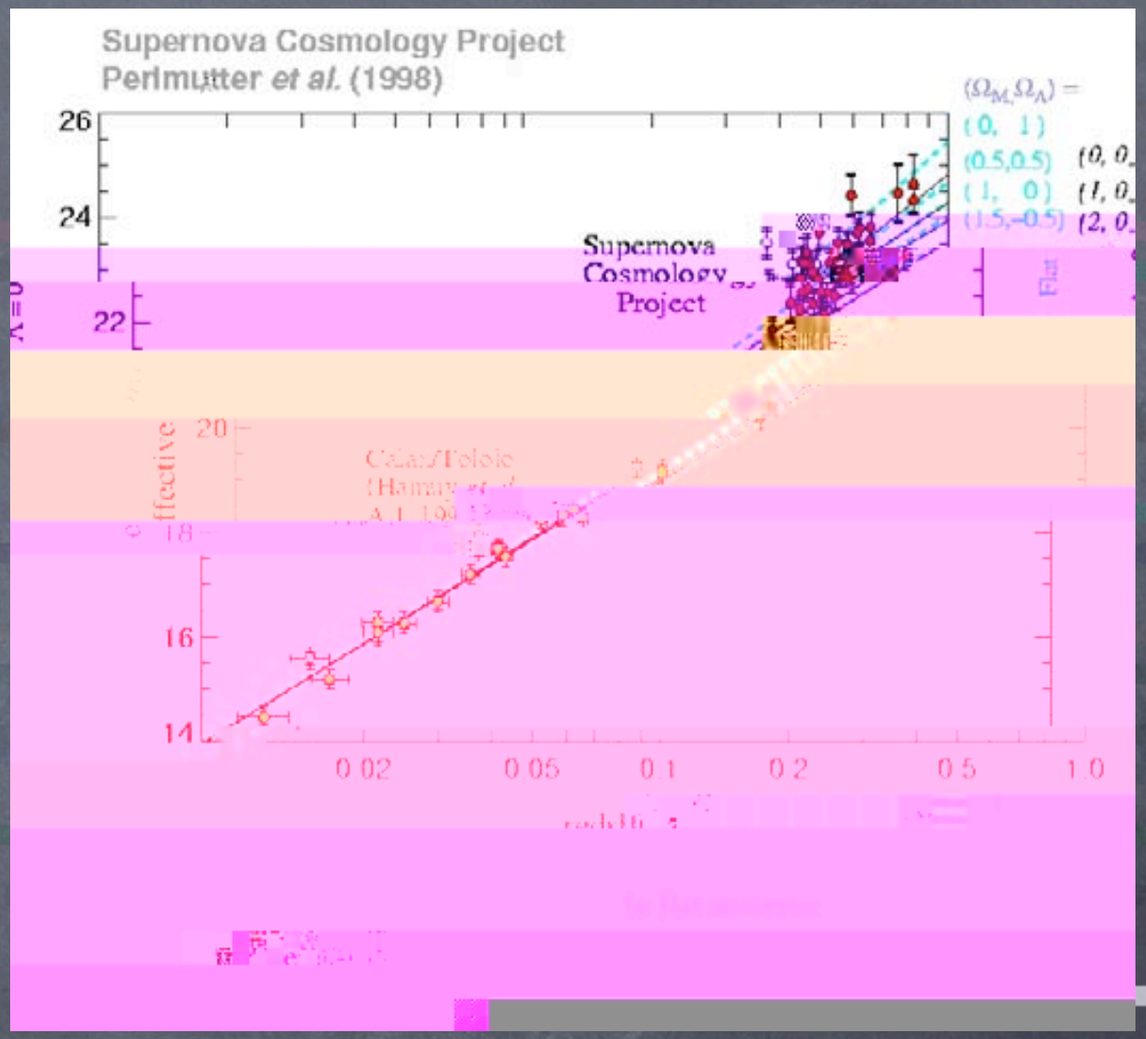

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- The simplest type of dark energy, known as a cosmological constant, was actually first considered by Albert Einstein!

Interlude

What does a theoretical cosmologist actually do?

A day in the life ...

What cosmology actually looks like ...

"Karma police, arrest this man
he talks in maths
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- New statistical approaches to cosmology.

  We aim to develop new methods to extract the best possible information from observational data.

- Large cosmological surveys

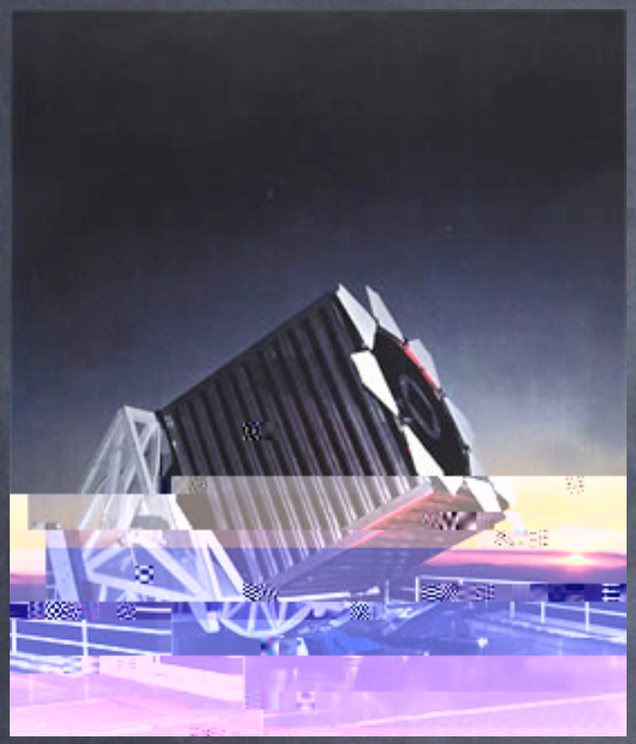
  We are involved in large ground- and space-based observational programmes.

The era of precision cosmology

Precision observations

Precision theory

The era of precision cosmology



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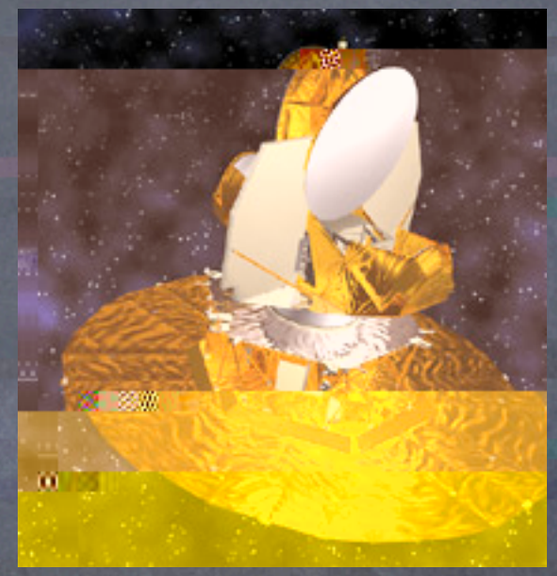

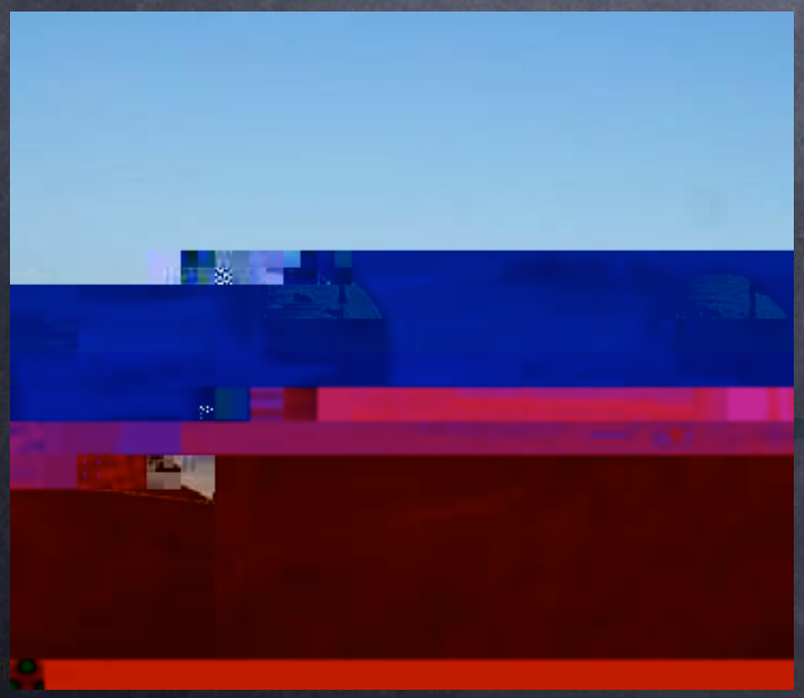

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- Inflationary cosmology

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

The cosmic fingerprint

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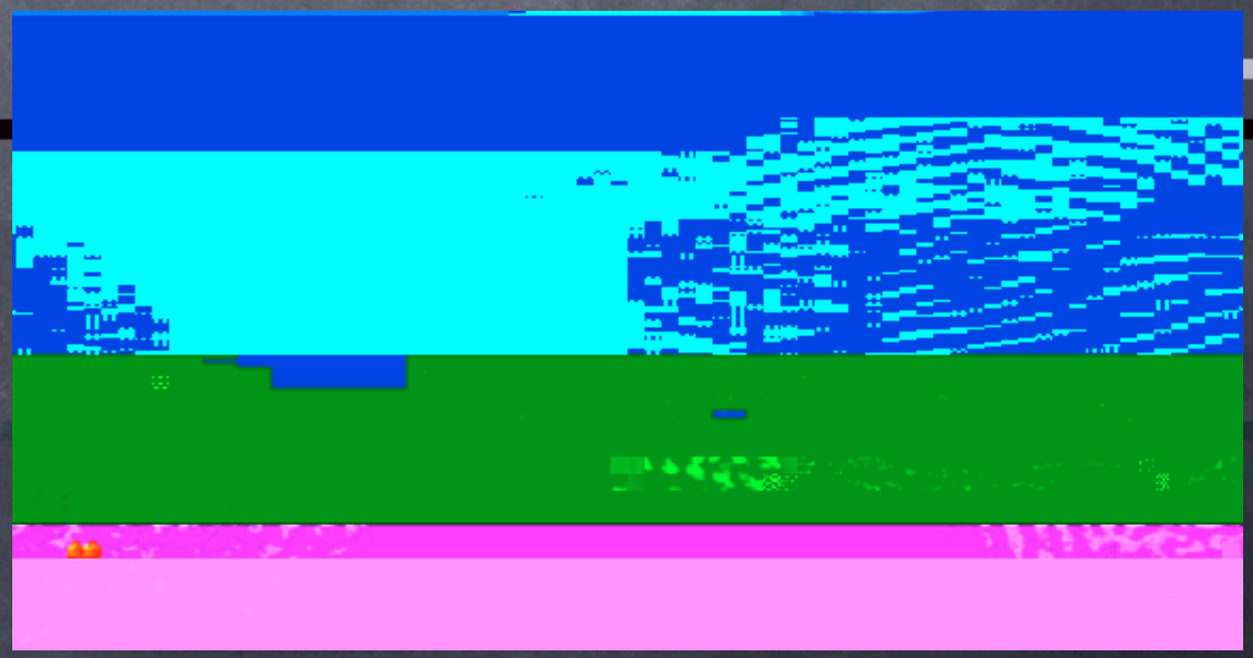
Each of these different possible Universes predicts a distinctive pattern in the structures seen in the



The Wilkinson Microwave Anisotropy Probe

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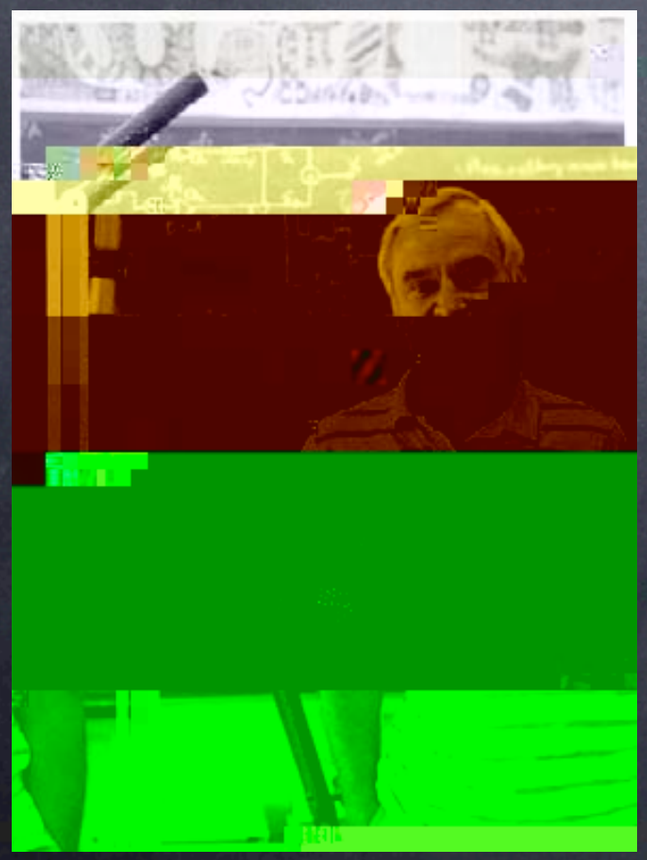
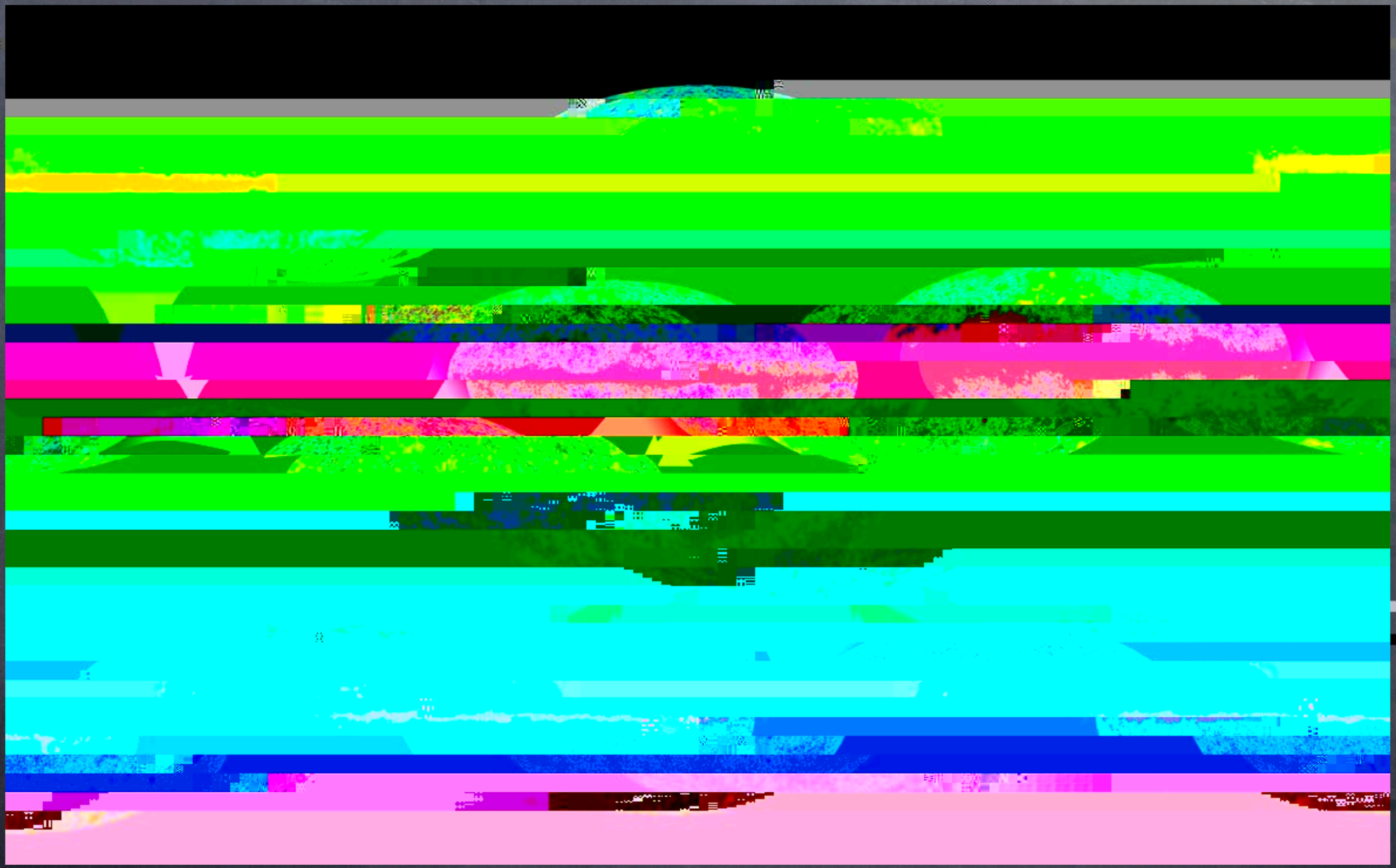
The WMAP satellite was the successor to COBE, aiming to make precision maps of the CMB, with higher sensitivity and angular resolution...



WMAP launch, June 2001

The cosmic microwave background as imaged by WMAP (three years of data, released March 2006).

To make the best map of the sky, combine several frequencies.



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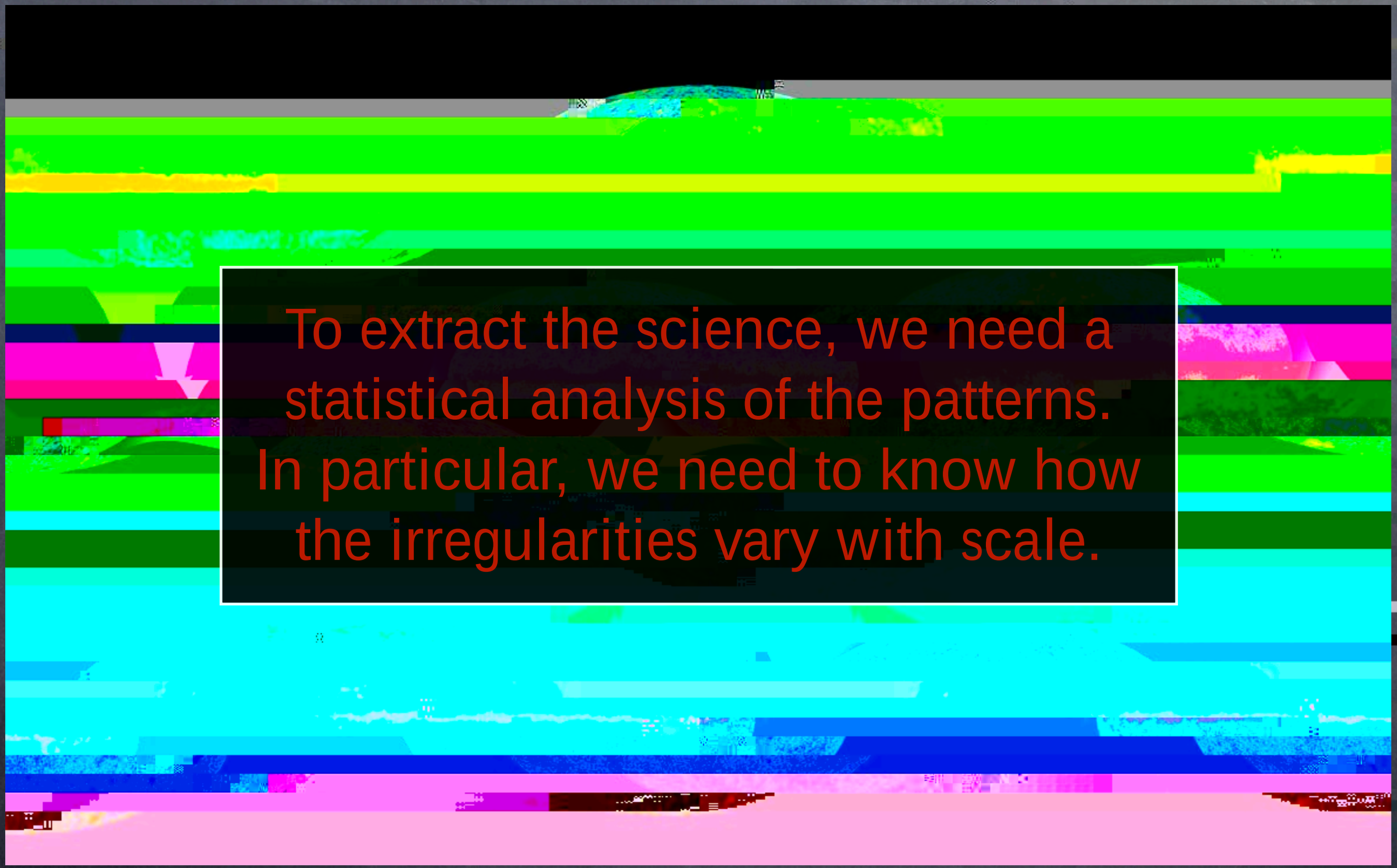
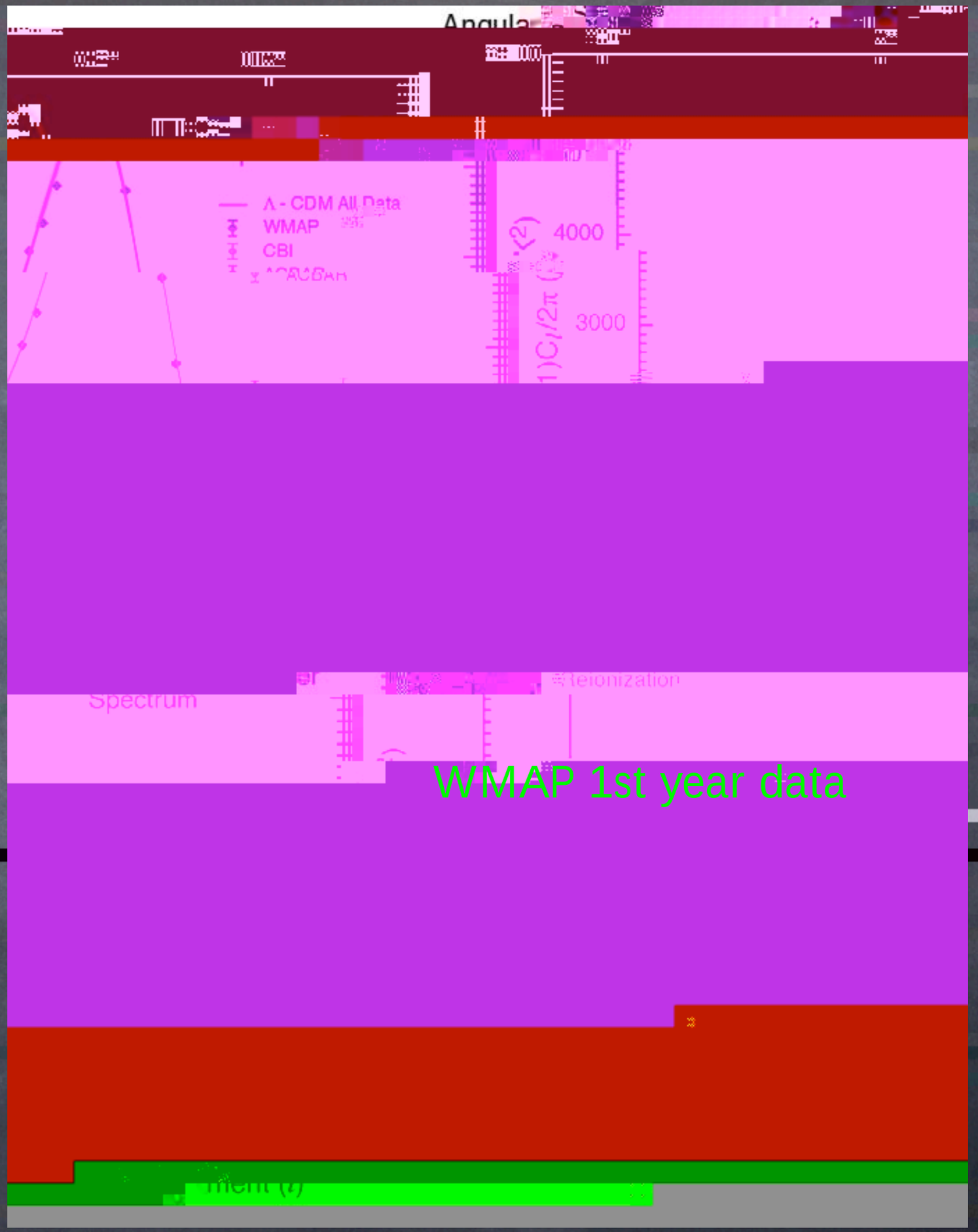


To extract the science, we need a statistical analysis of the patterns. In particular, we need to know how the irregularities vary with scale.

The Cosmic Microwave Background

WMAP has given an exquisite measurement of the CMB irregularities.



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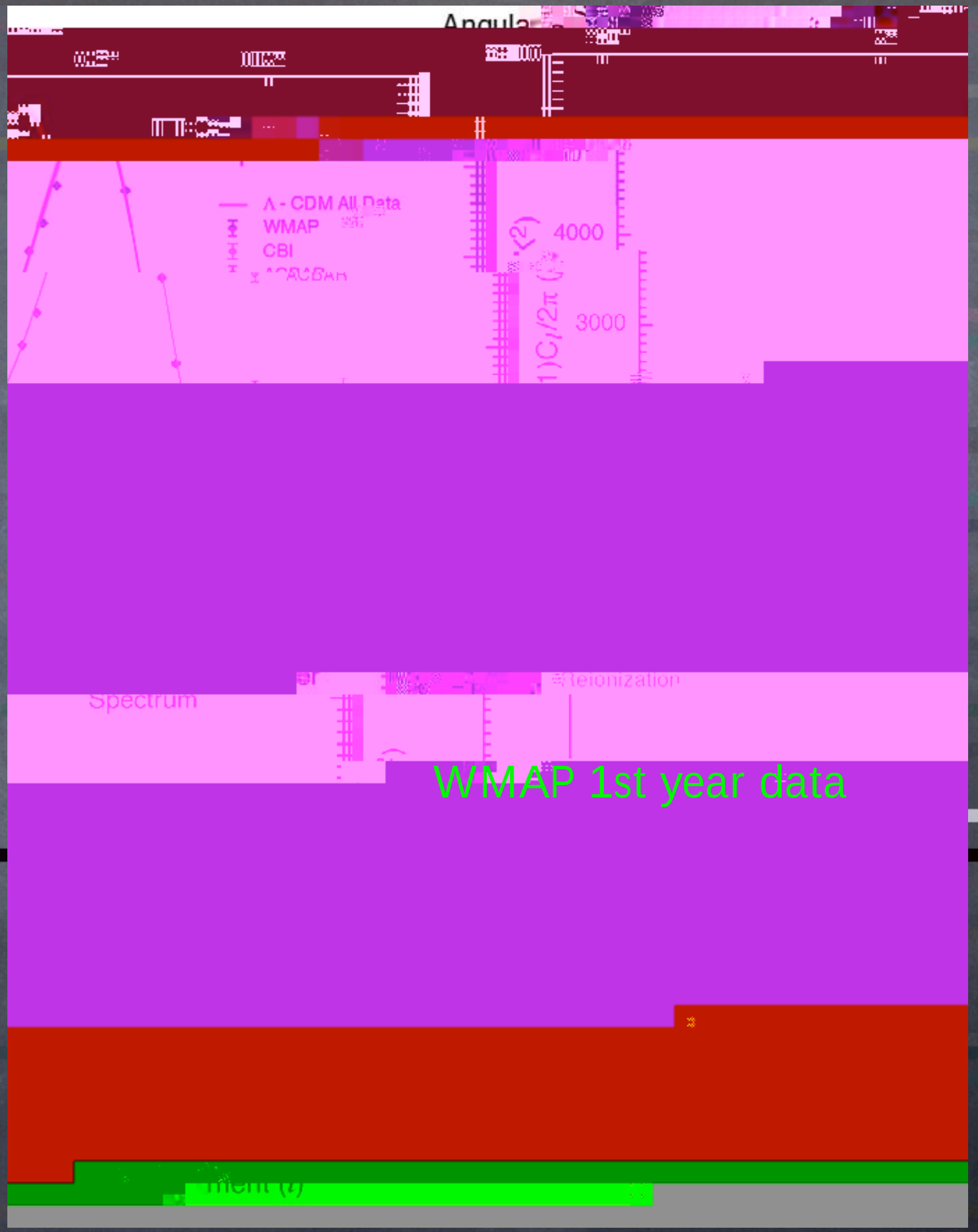

Old Universe

WMAP Science Team

To the future ...

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