

Scales of the Universe

a distinguished speaker series

Sep 28 John R. Spencer (Southwest Research Institute)

"Taking the Measure of the Solar System"

Oct 05 Carl Heiles (Berkeley)

"Our Local Microcosmos"

Oct 19 Mario Mateo (Michigan)

"Galaxies: Where Space Becomes Time"

Nov 02 Niel Brandt (Penn State)

"A Rich and Evolving Tapestry of Cosmic Structure"

Nov 16 Michael S. Turner (Chicago) *Mohler Prize Lecture*

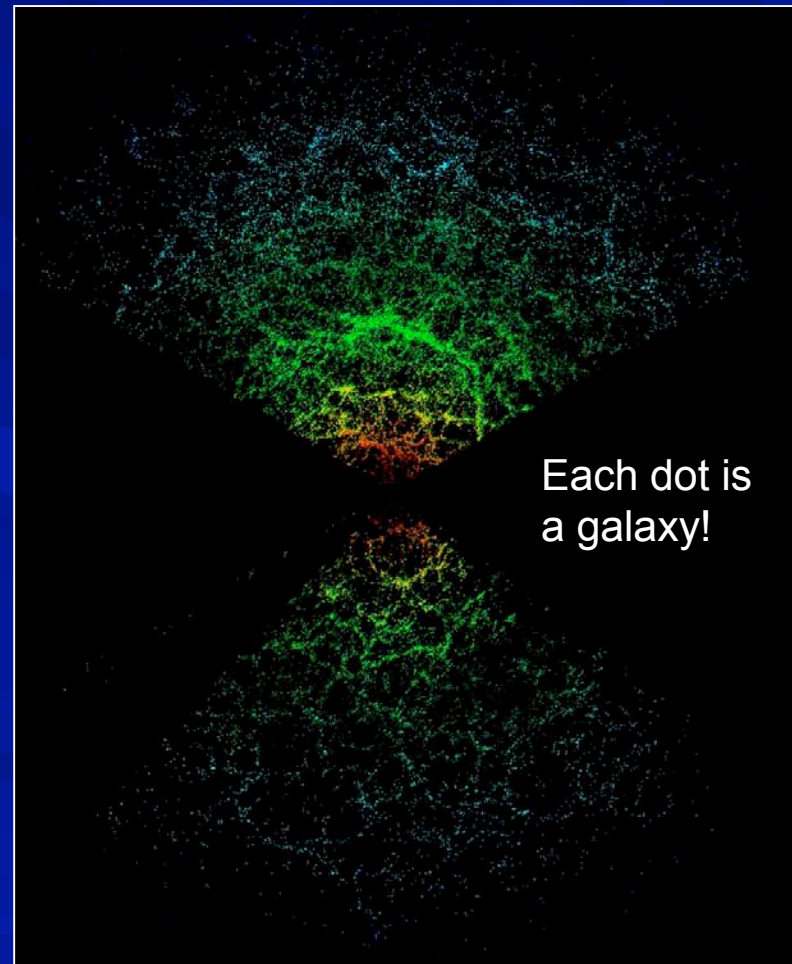
"Quarks to the Cosmos: Connecting the Smallest and Largest Scales"

7:30 PM, 1800 Dow Chemistry Building
Telescope observing / planetarium show following



From Galaxies to the Universe: A Rich and Evolving Tapestry of Cosmic Structure

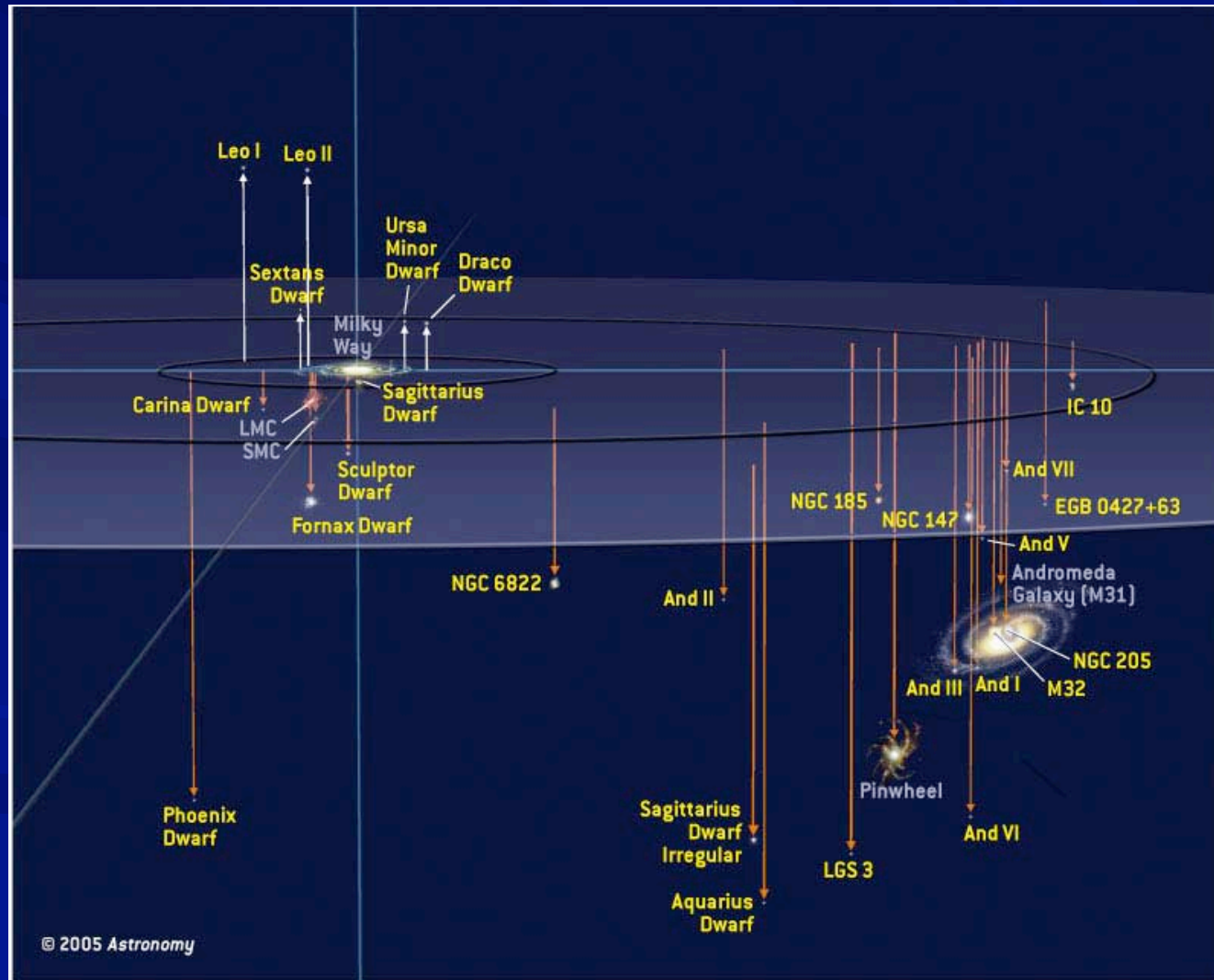
Niel Brandt (Penn State University)



Each dot is
a galaxy!

The Richness of Cosmic Structure

Our Local Group of Galaxies



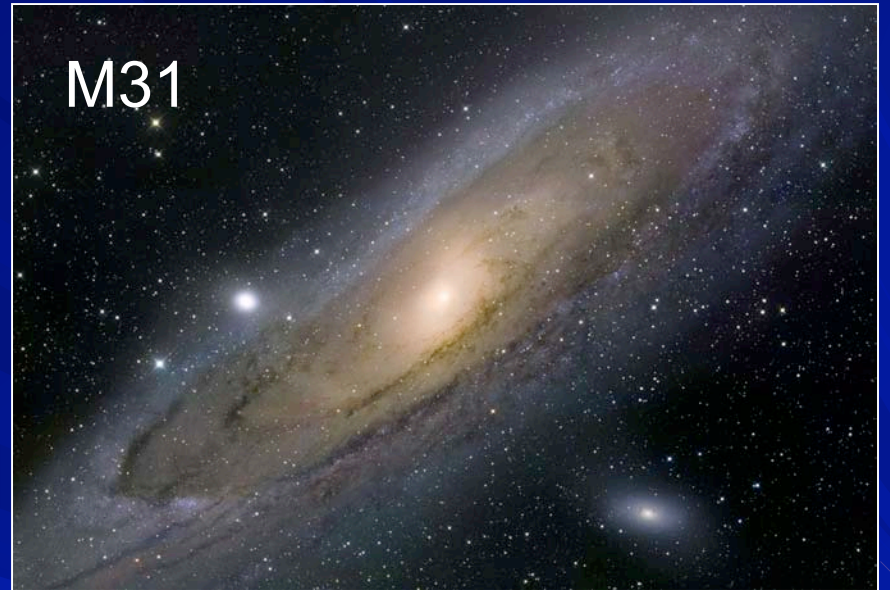
Major Galaxies of the Local Group

DIRBE 1.25, 2.2, 3.5 μm Composite



Milky Way Galaxy

M31



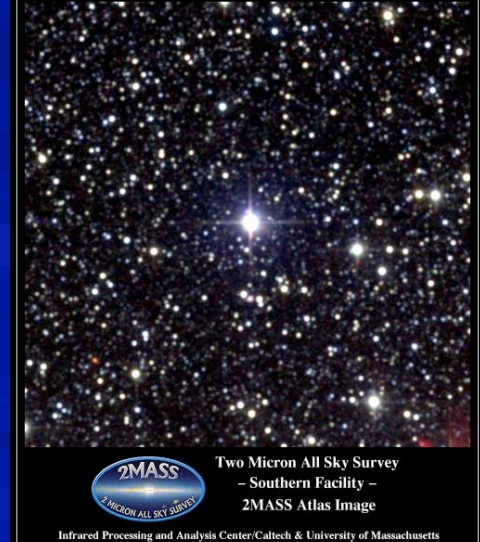
M33



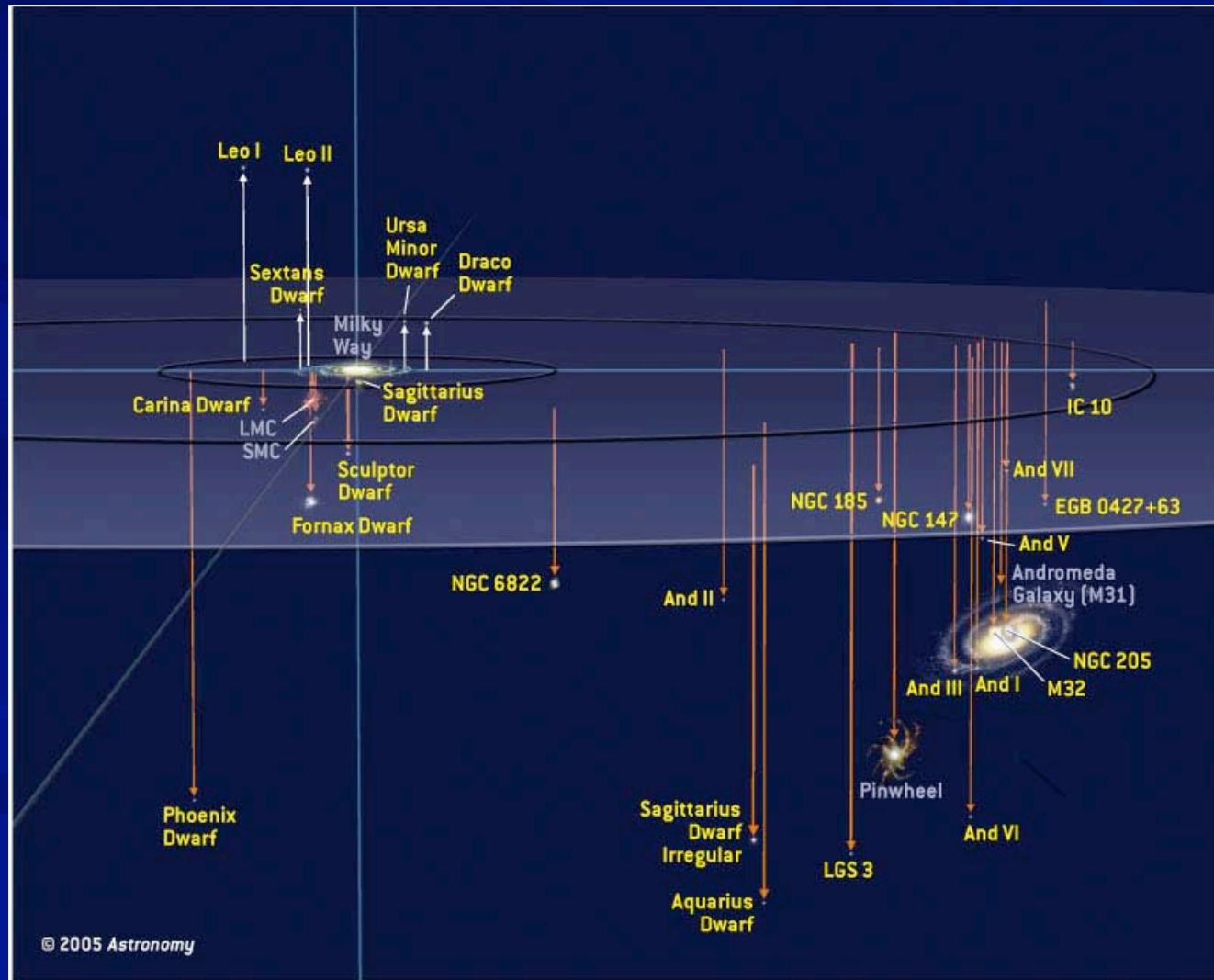
Relative Separations of Stars vs. Galaxies



The nearest star, Proxima Centauri



Our Local Group of Galaxies

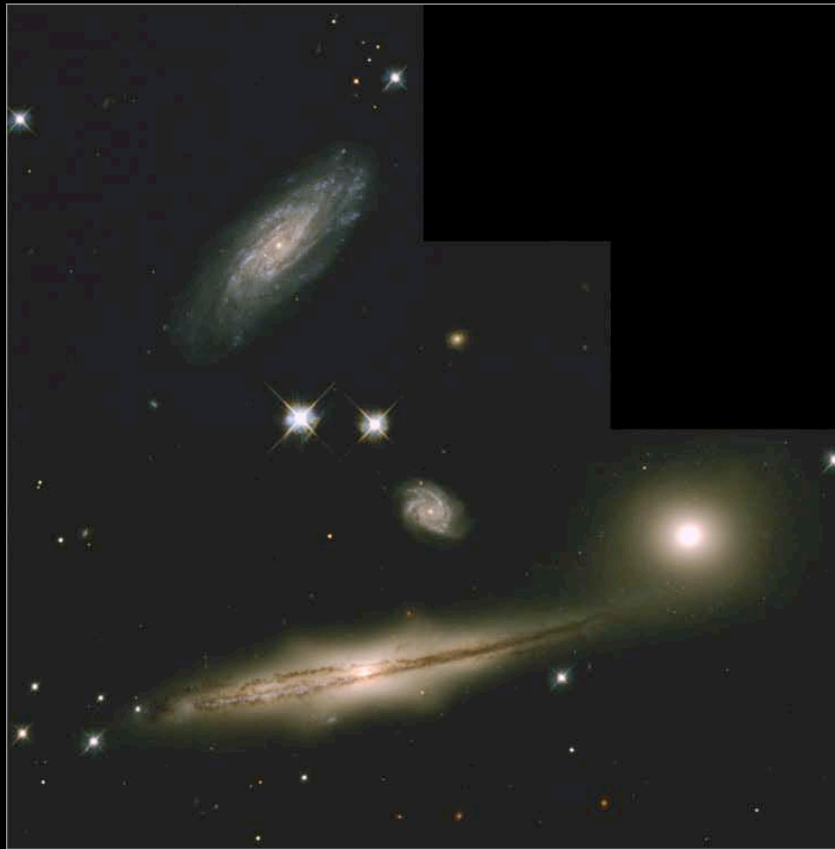


Stephan's Quintet: Collisions in a Galaxy Group



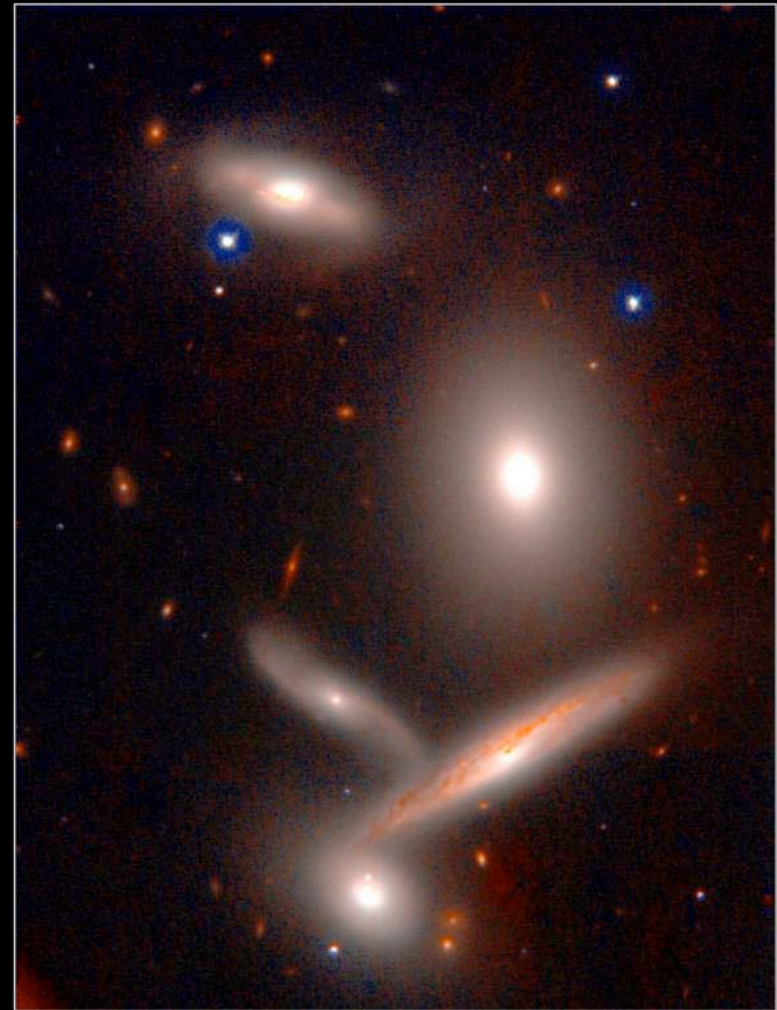
Hickson Compact Groups

Hickson Compact Group 87



Hubble
Heritage

PRC99-31 • Space Telescope Science Institute • Hubble Heritage Team (AURA/STScI/NASA)



Hickson Compact Group 40

Subaru Telescope, National Astronomical Observatory of Japan

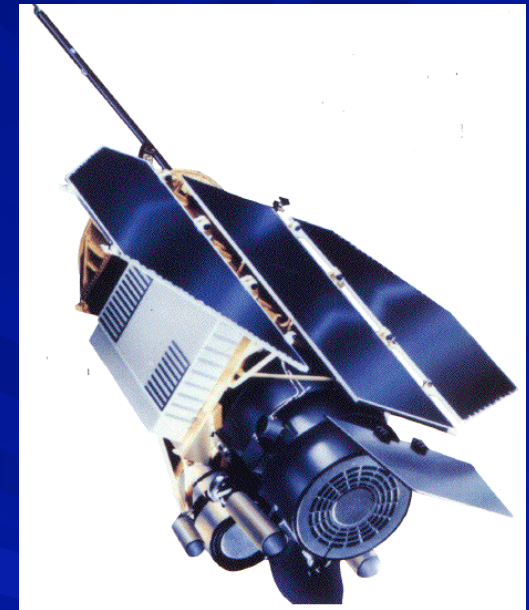
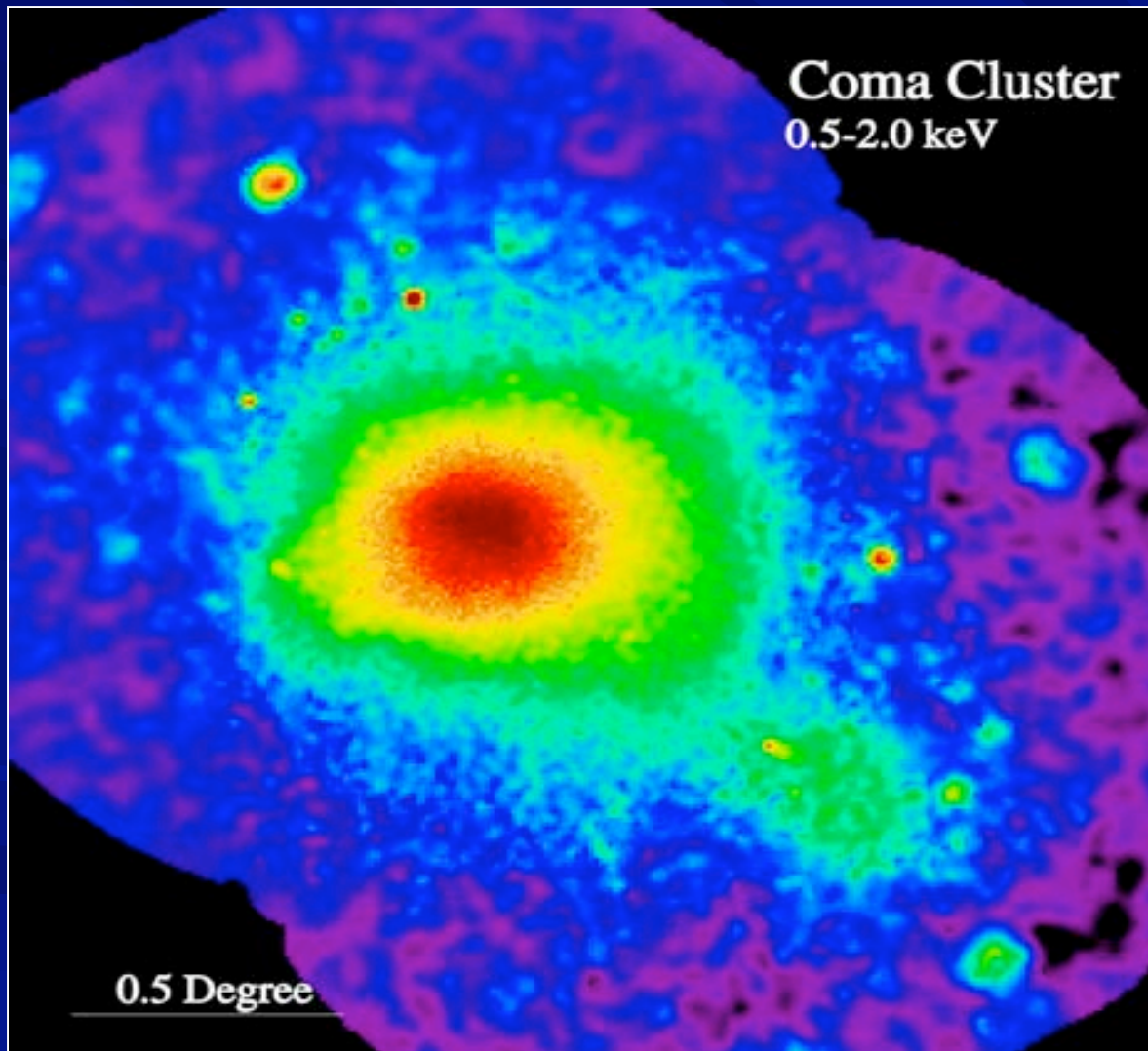
CISCO (J & K')

January 28, 1999

The Coma Cluster of Galaxies - Optical



The Coma Cluster of Galaxies - X-ray



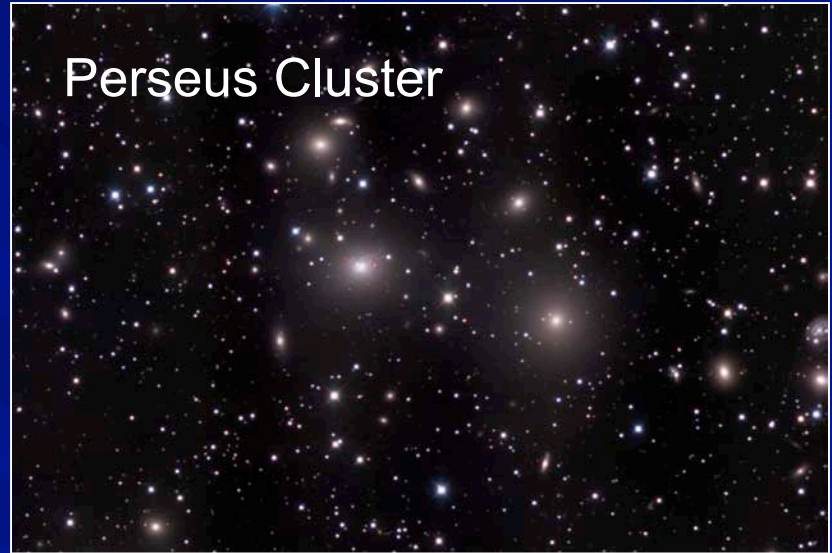
ROSAT

Examples of Galaxy Clusters

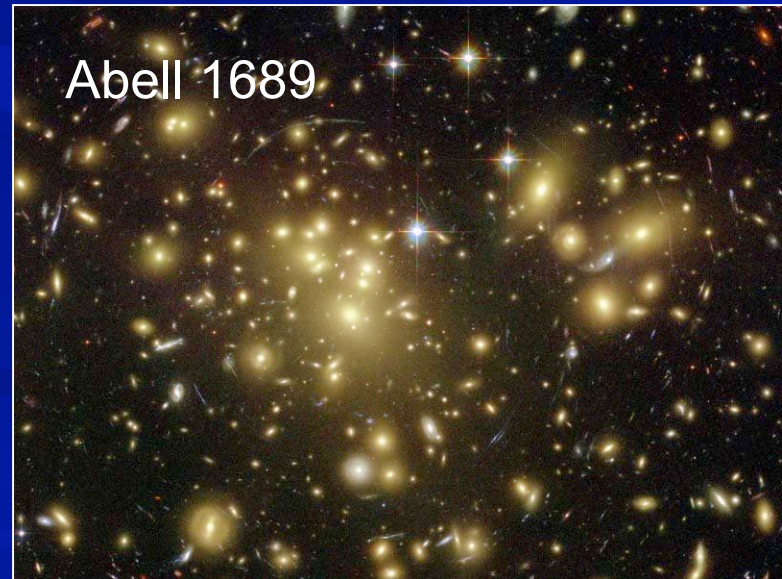
Hercules Cluster



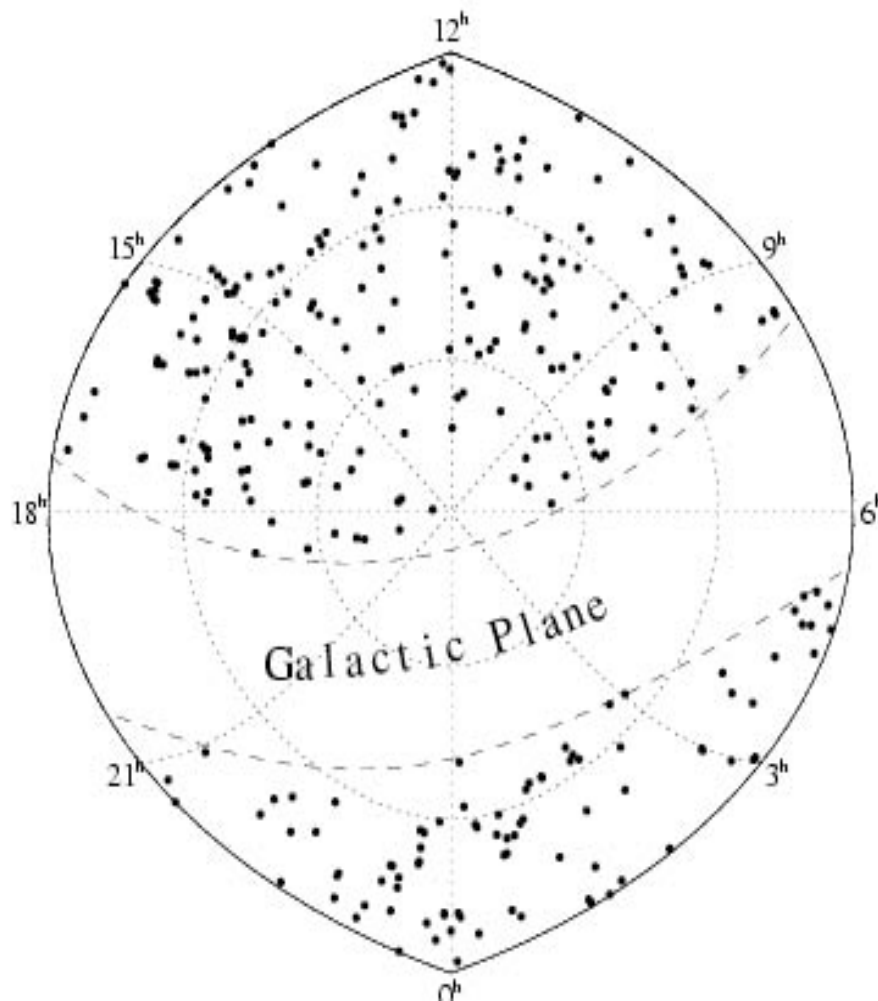
Perseus Cluster



Abell 1689



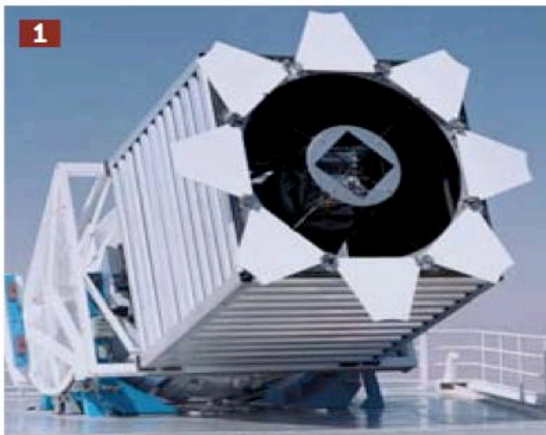
310 of the Brightest Clusters Selected by Their X-ray Emission



Now ~ 20,000+
clusters known.

For example, 13,823
from large optical
cluster survey led by
Univ. of Michigan
astronomers.

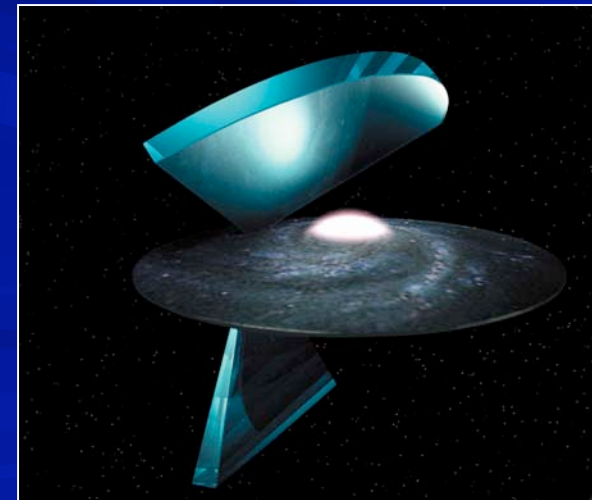
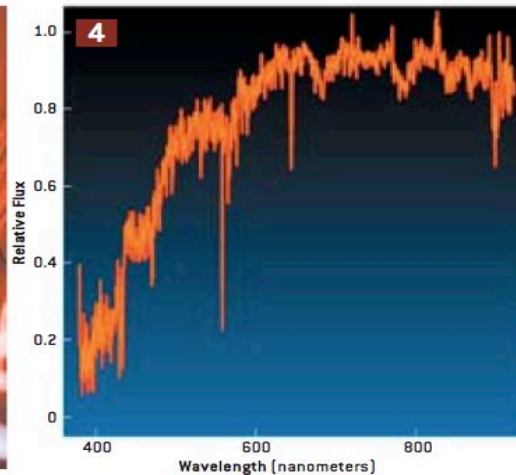
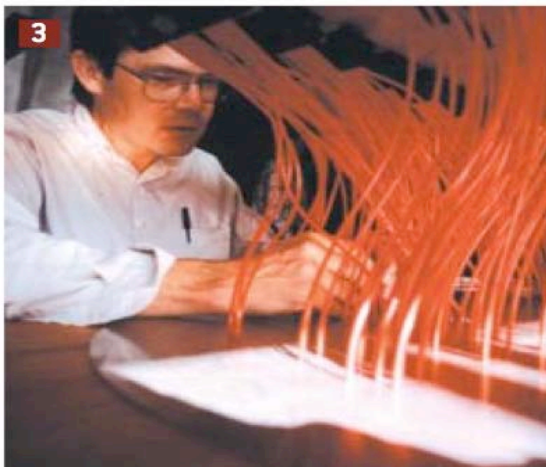
Sloan Digital Sky Survey: Example of Galaxy Survey Methods



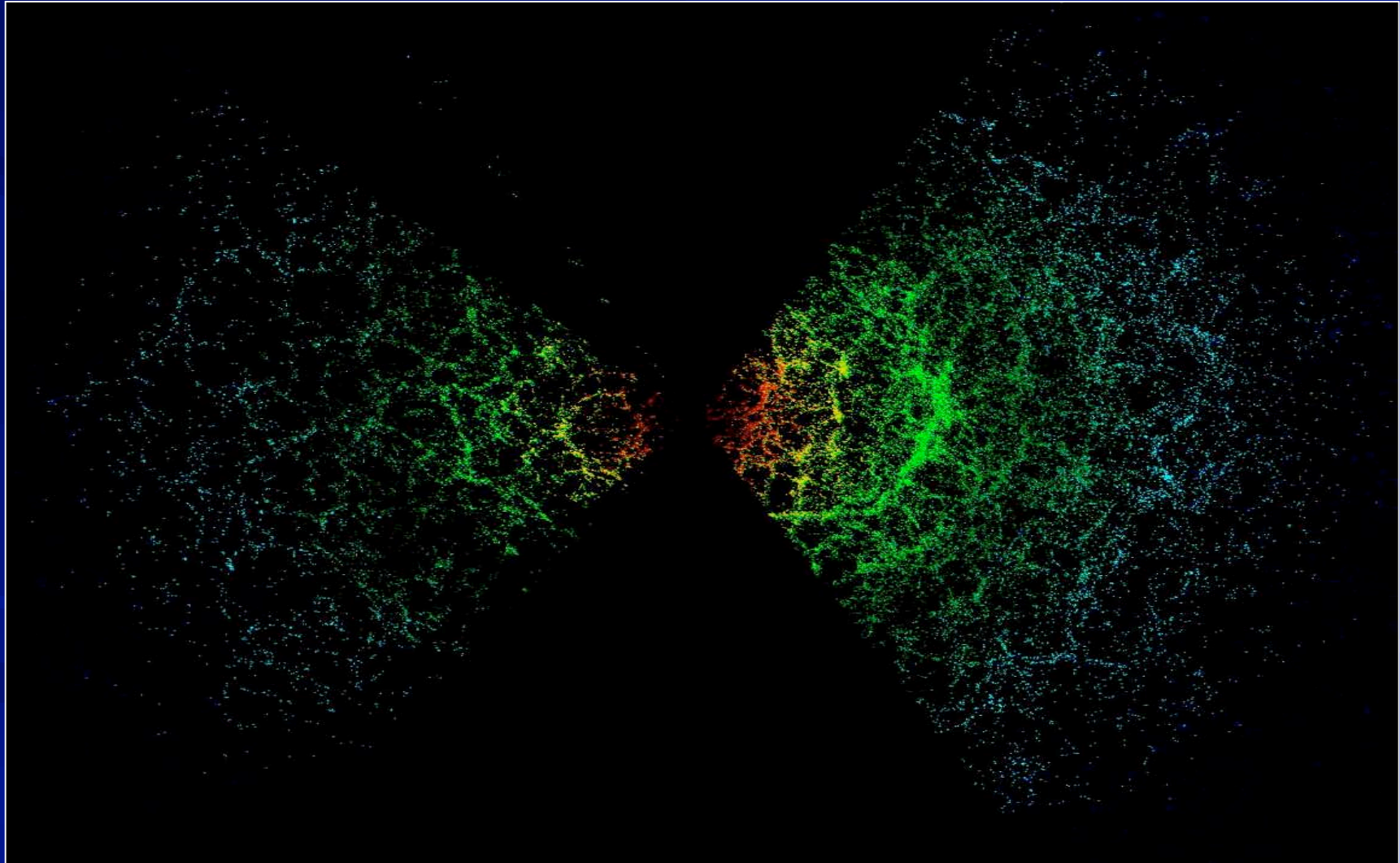
1 THE TELESCOPE operates in camera mode on clear nights, taking pictures through five color filters at the rate of 20 square degrees an hour—netting millions of celestial bodies per night.



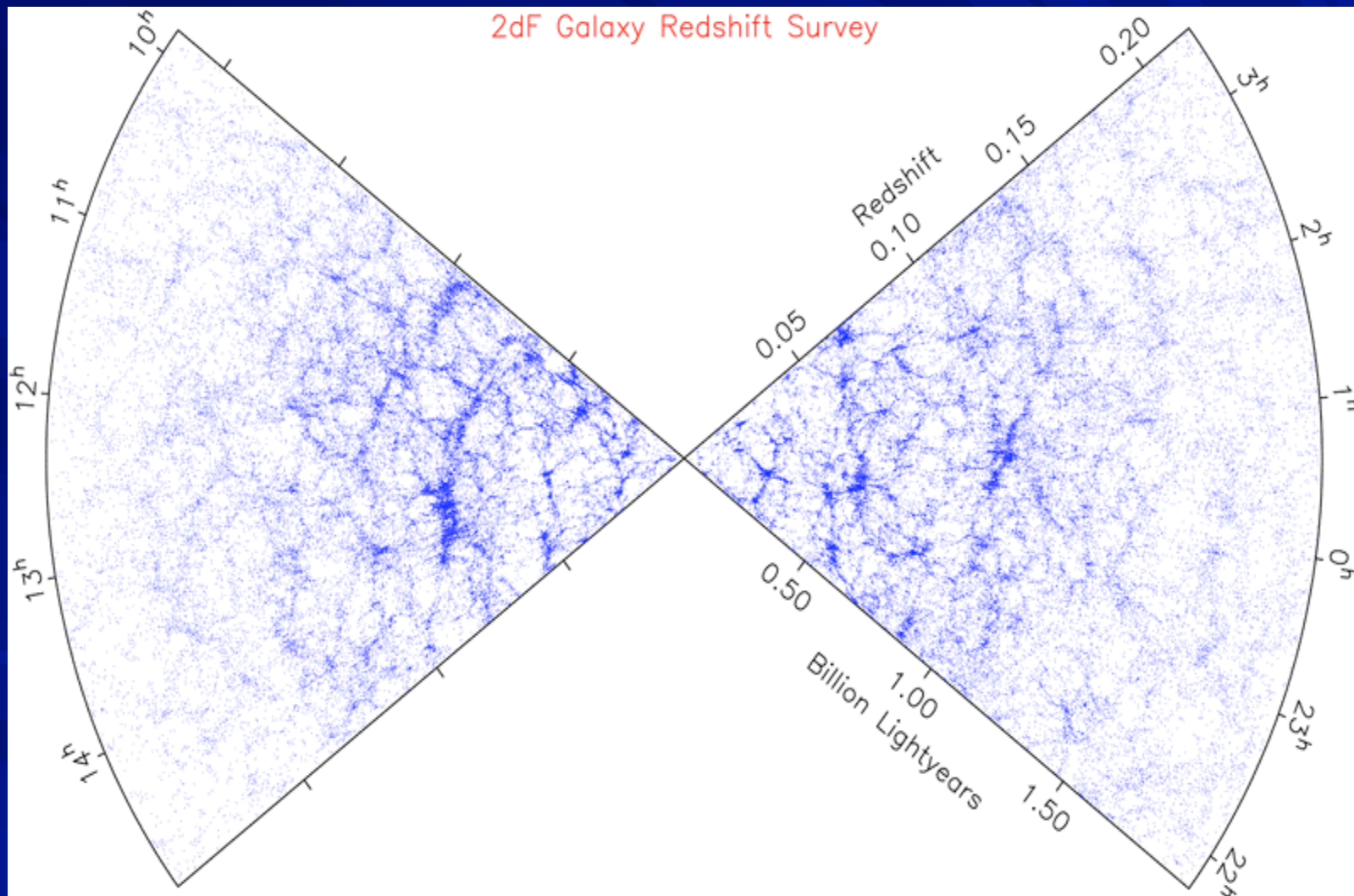
2 GALAXIES and other objects are identified by software and selected for follow-up spectroscopy. The object shown here is the spiral galaxy UGC 03214 in the constellation Orion.



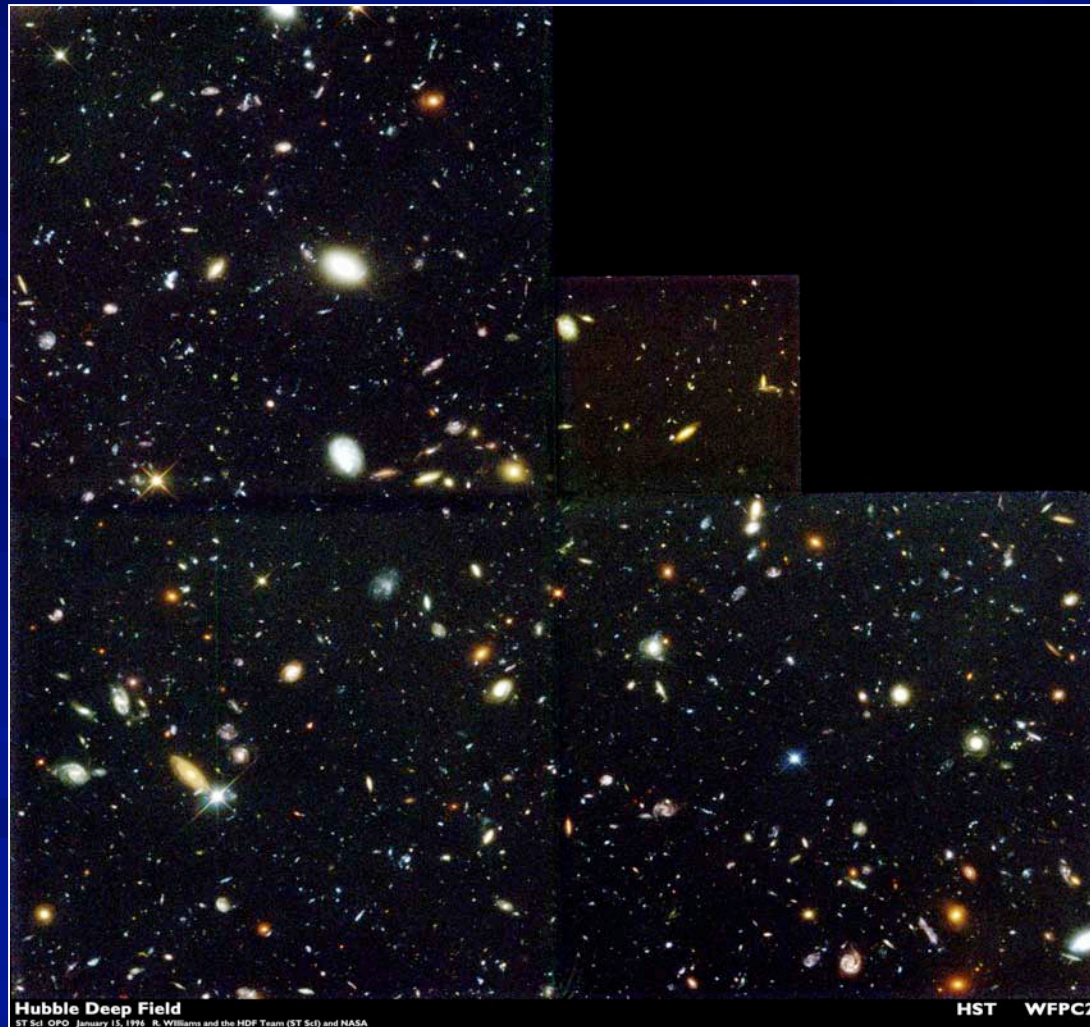
Distribution of Galaxies in the Universe from the Sloan Digital Sky Survey



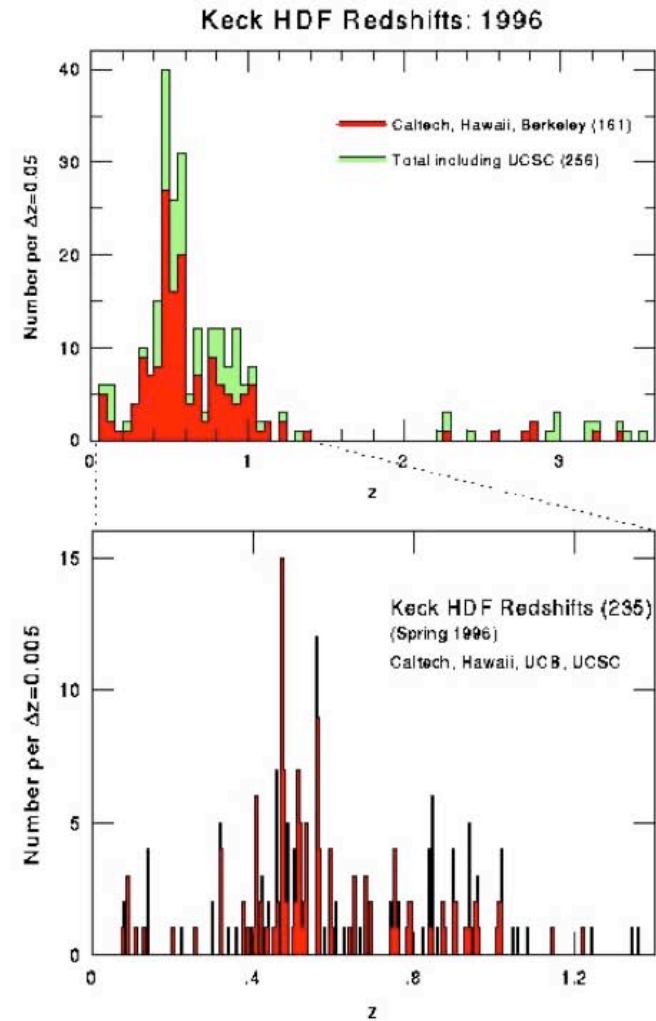
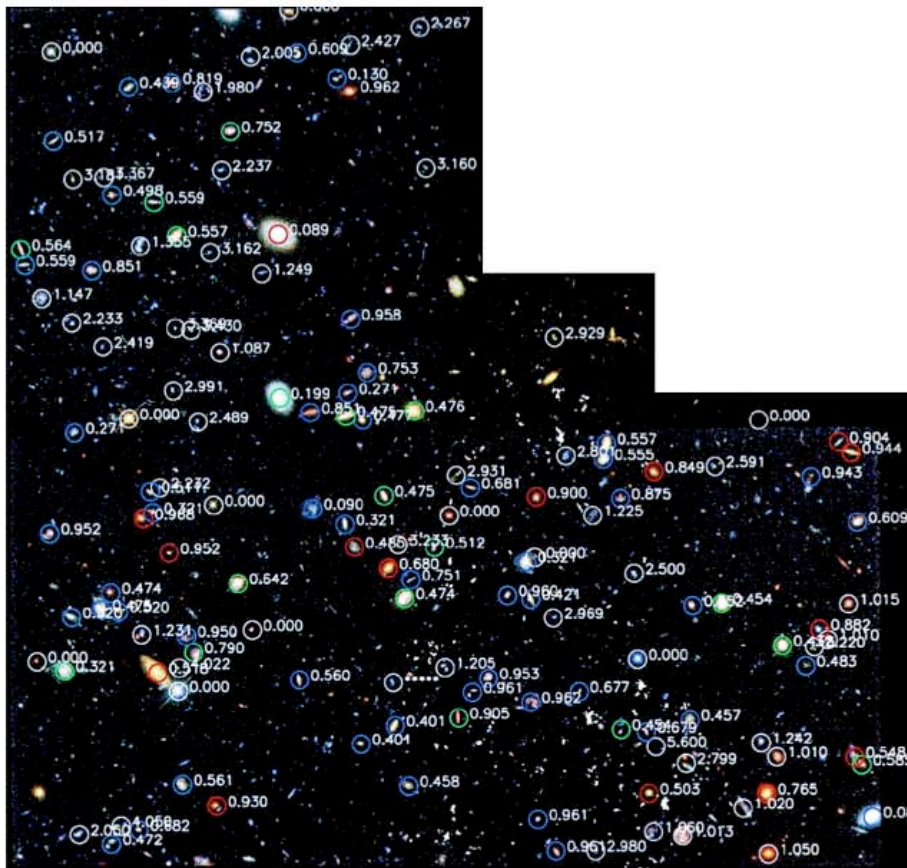
Distribution of Galaxies in the Universe from the 2dF Galaxy Survey



The Distant Universe - Hubble Deep Field-North

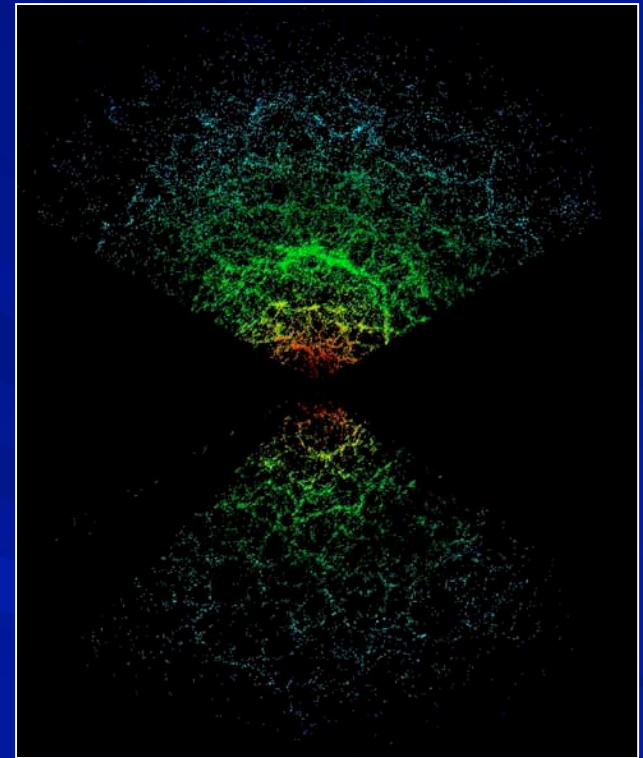


Structures in the Distant Universe - Hubble Deep Field-North

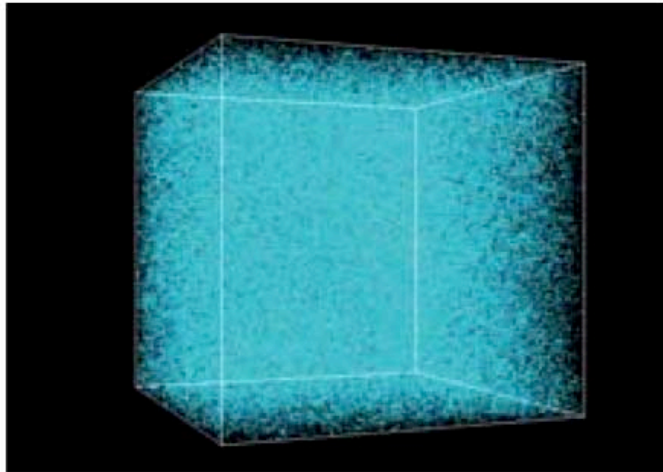


The Evolution of Cosmic Structure

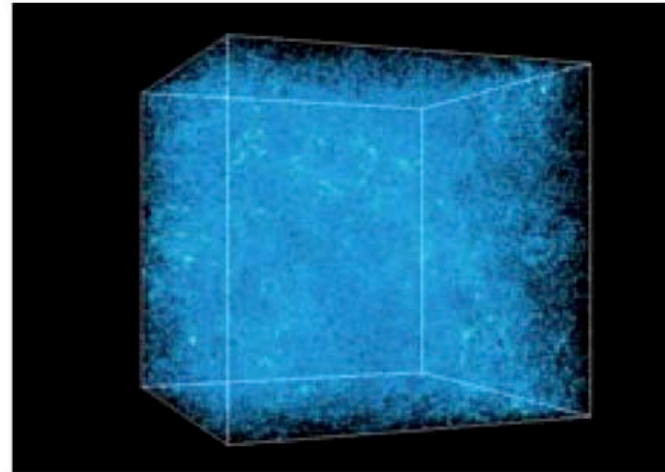
Can Gravity Do the Job?



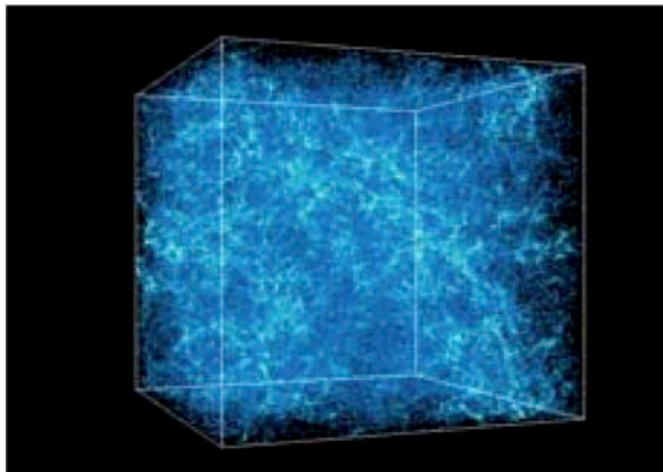
Simulations of Structure Formation



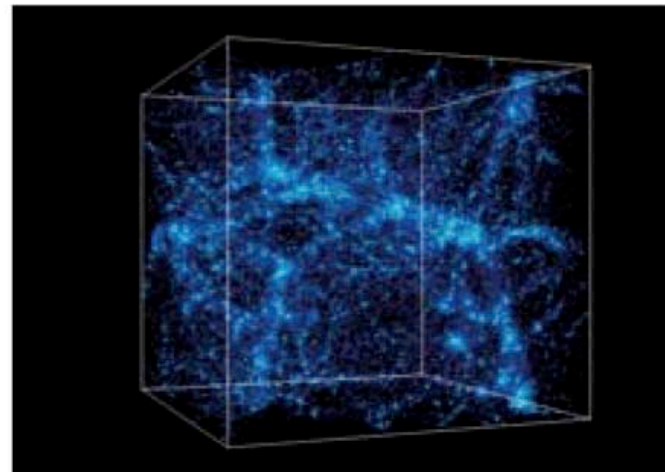
120 MILLION YEARS: Early on, matter was spread out in a nearly uniform sea with subtle undulations.



490 MILLION YEARS: Dense regions gained material at the expense of less dense ones. The first galaxies formed.



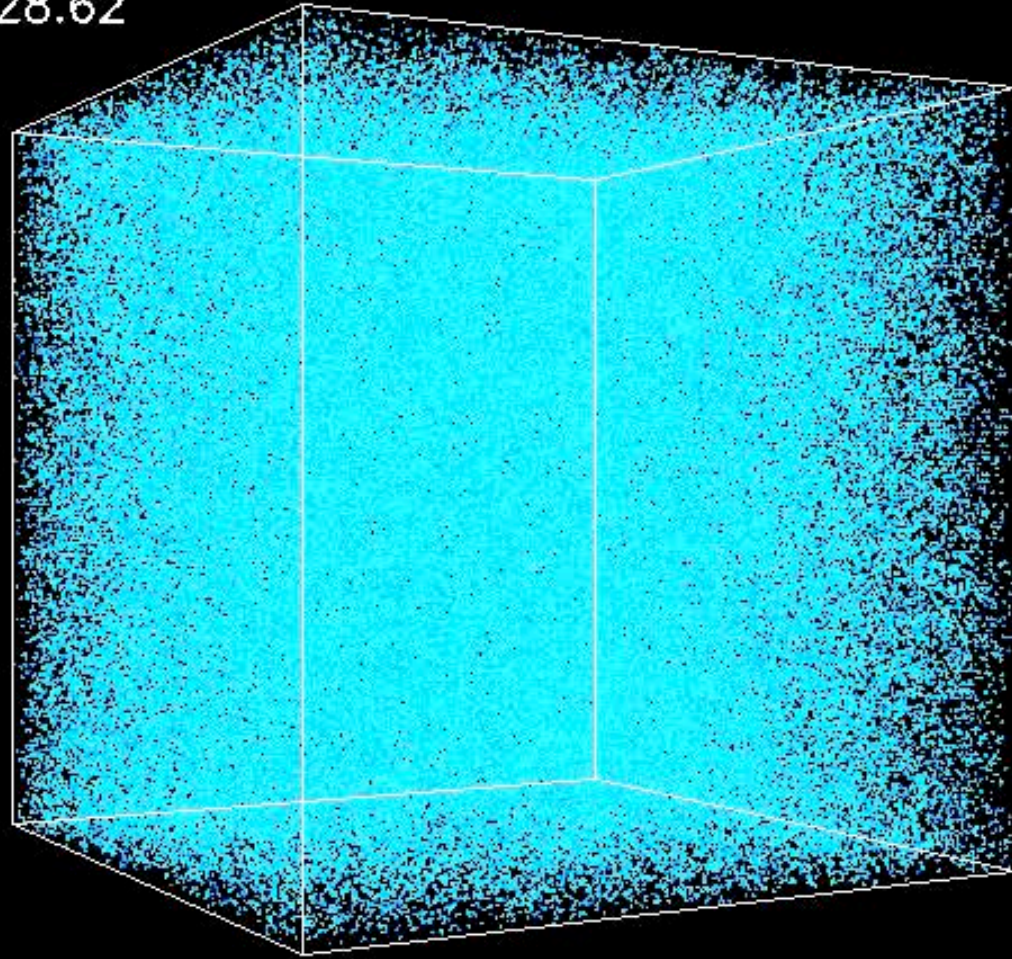
1.2 BILLION YEARS: Over time, gravity pulled matter into vast filaments and emptied the intervening voids.



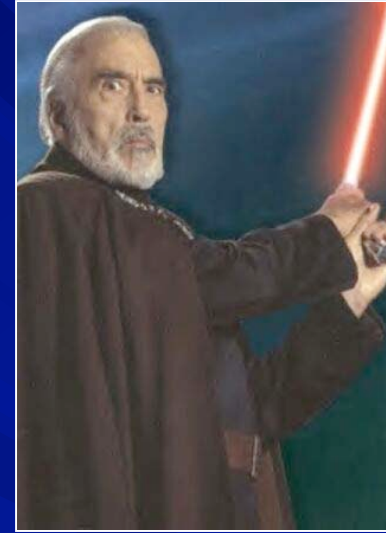
13.7 BILLION YEARS (TODAY): The growth of large structures has ceased because cosmic acceleration counteracts clumping.

Simulations of Structure Formation

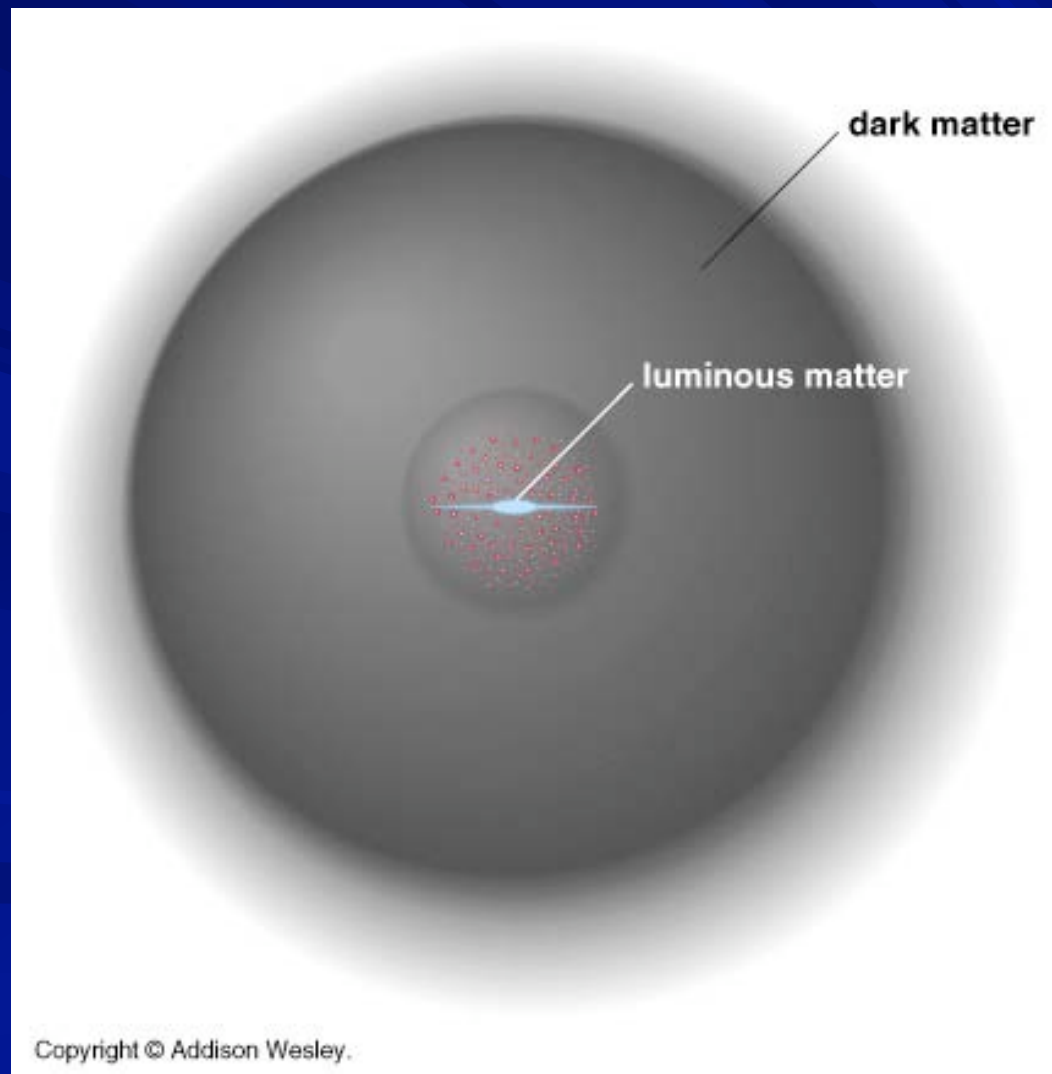
$Z=28.62$



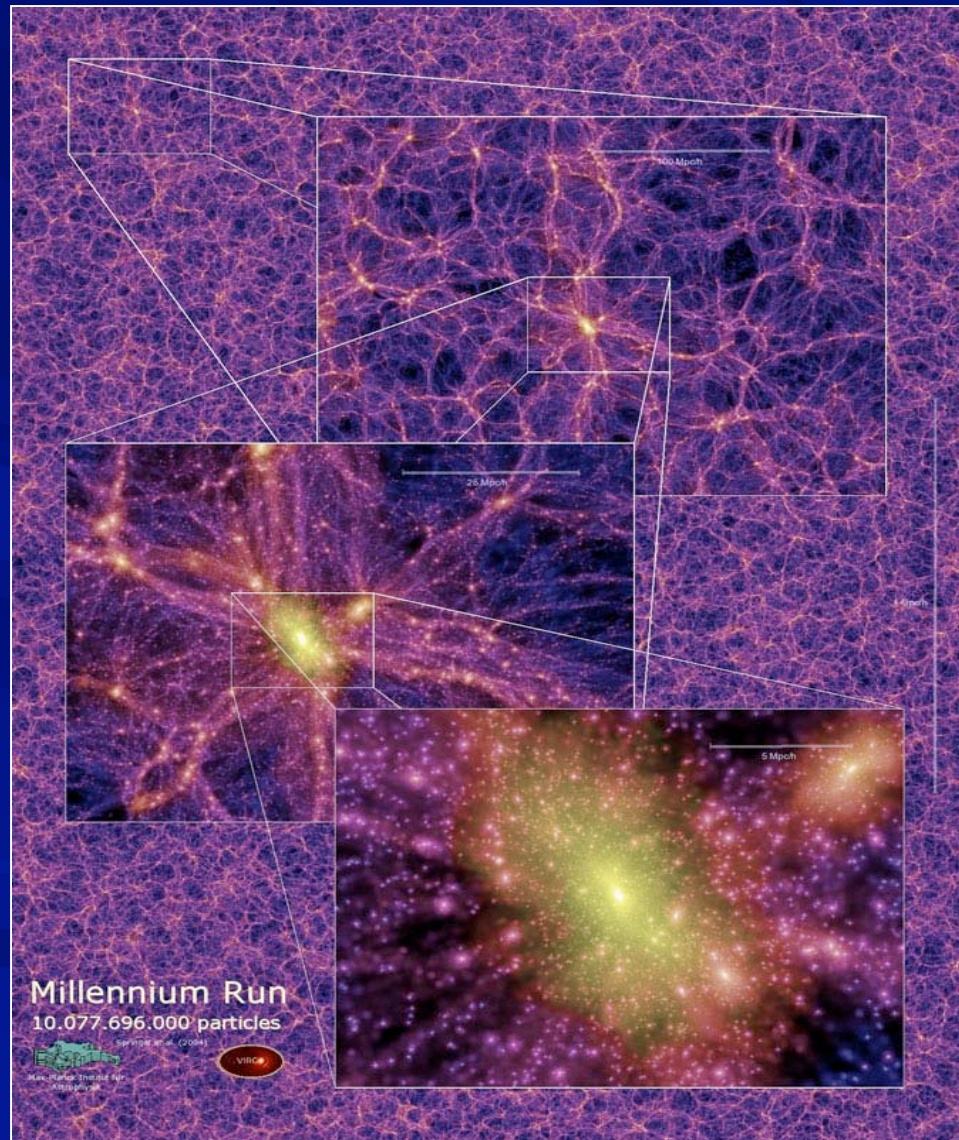
The Dark Side of the Universe



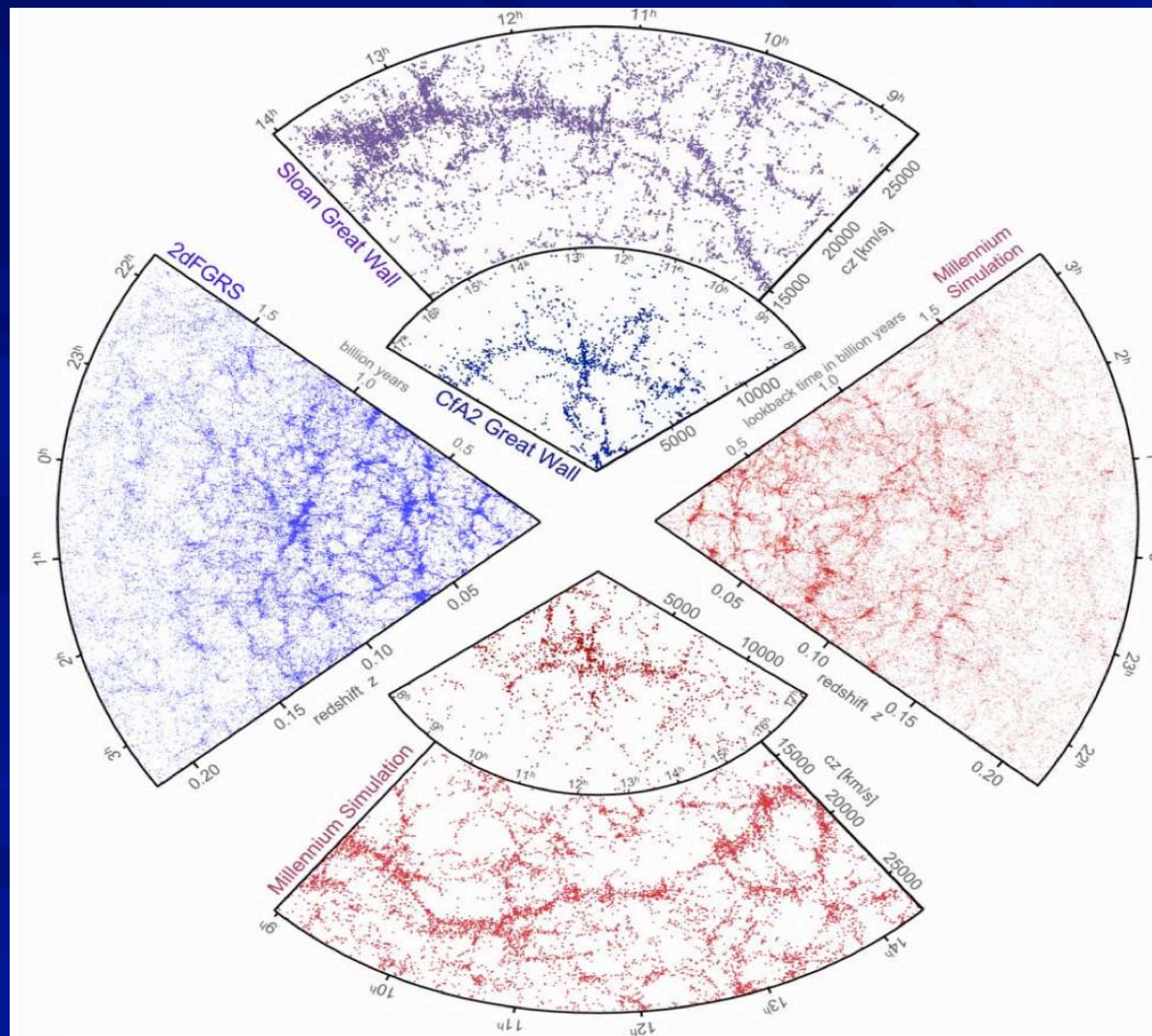
The Real Nature of a Galaxy



A Very Large Simulation of Structure Formation



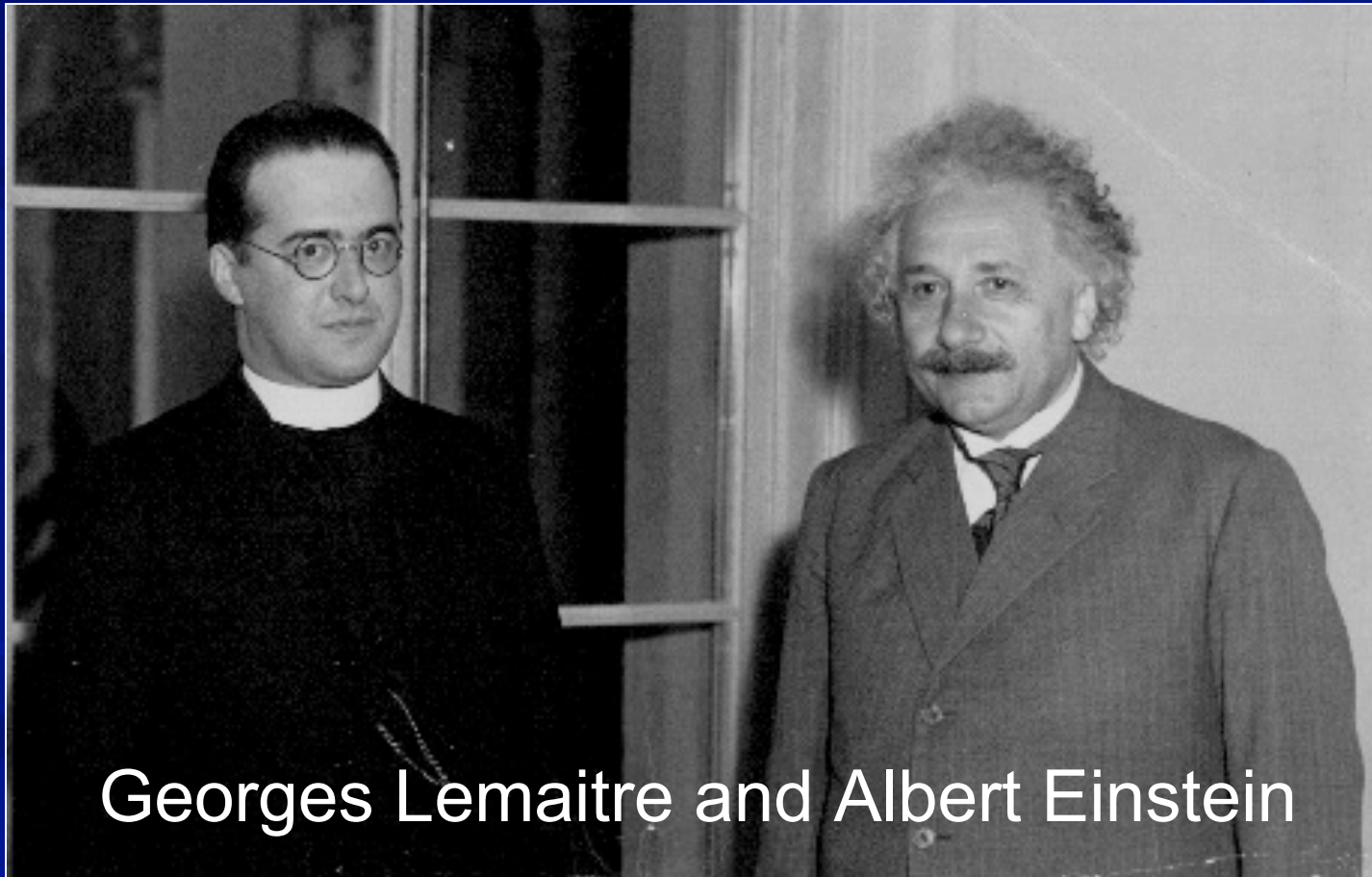
Simulations vs. Measurements



An End to Cosmic Structure

The Cosmological Principle

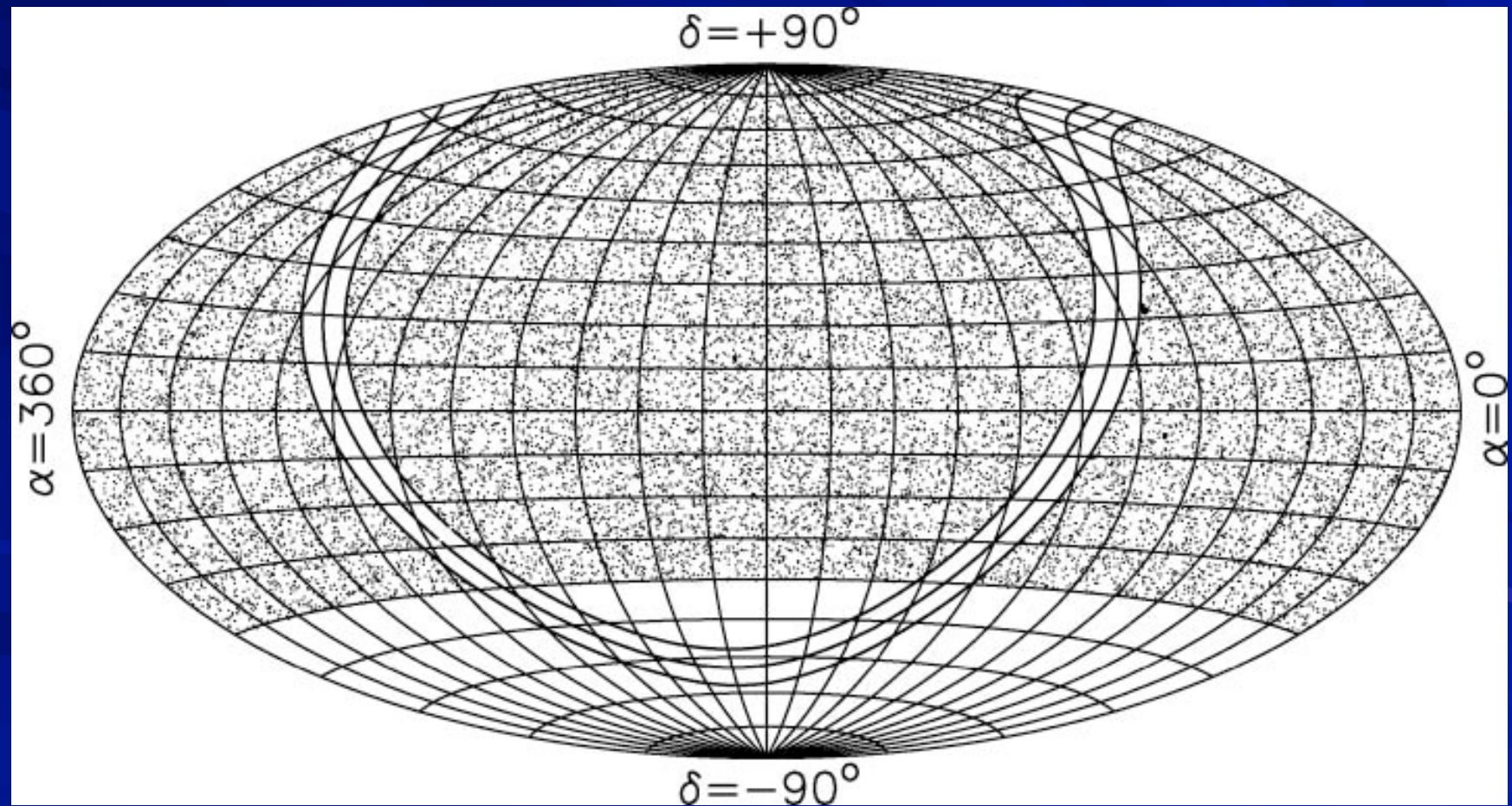
On large spatial scales, the Universe is homogeneous.



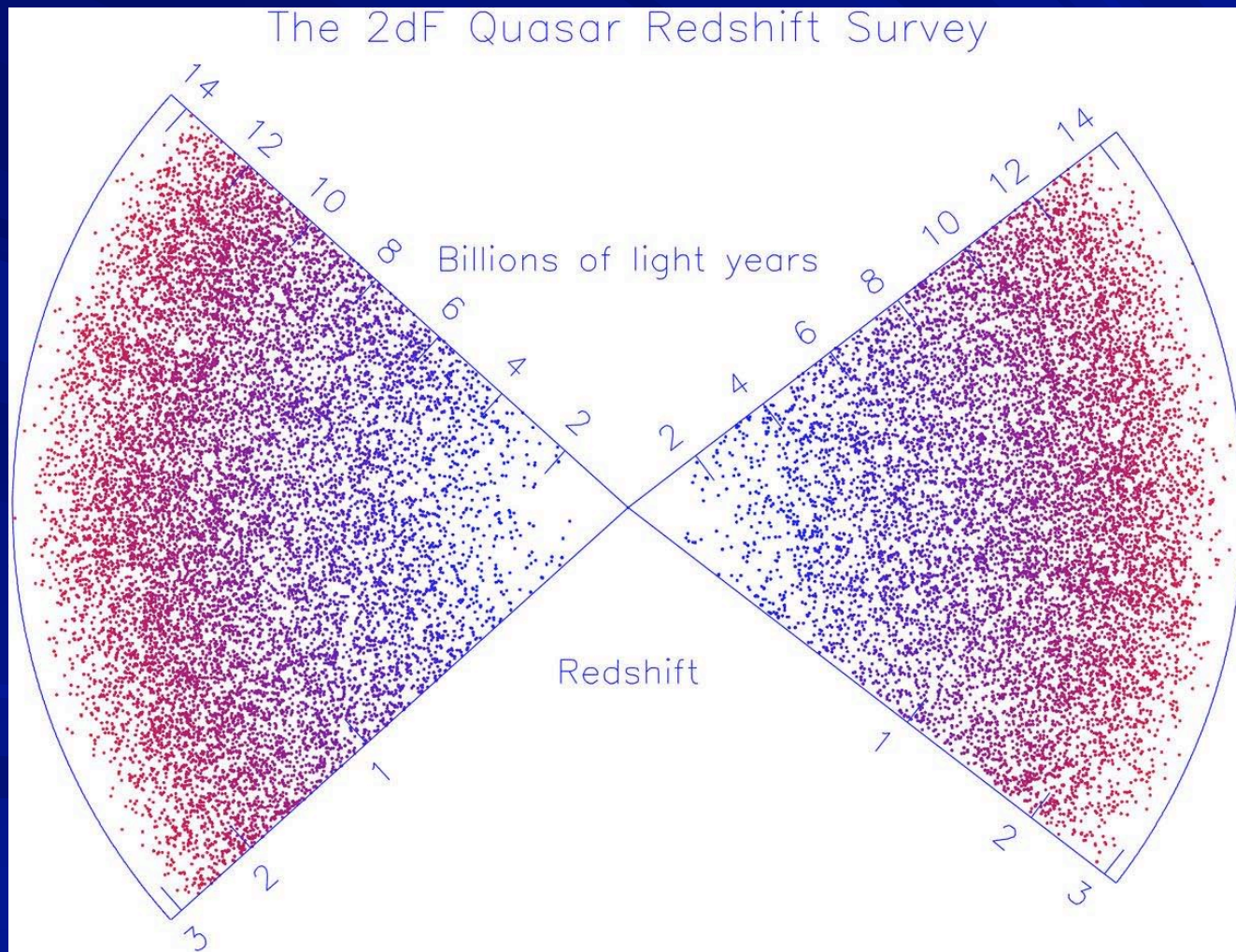
Georges Lemaître and Albert Einstein

Uniformity on the Very Largest Scales - Radio Galaxies

Sky Distribution of Radio Sources from the VLA Sky Survey



Uniformity on the Very Largest Scales - Quasars



Summary

Key Points to Take Away

Universe is rich with cosmic structure.

Great advances being made measuring this structure.

Gravity can make the structure, allowing for dark matter and dark energy.

Viewed on the largest possible scales, the Universe is quite uniform.

A Major Outstanding Question: What is the Ultimate Origin of this Structure?

This is a *very* fundamental question, requiring understanding of the first instants of our Universe.

People don't have a complete answer, but have good ideas and making rapid progress.

See the next talk in this series, by Mike Turner!