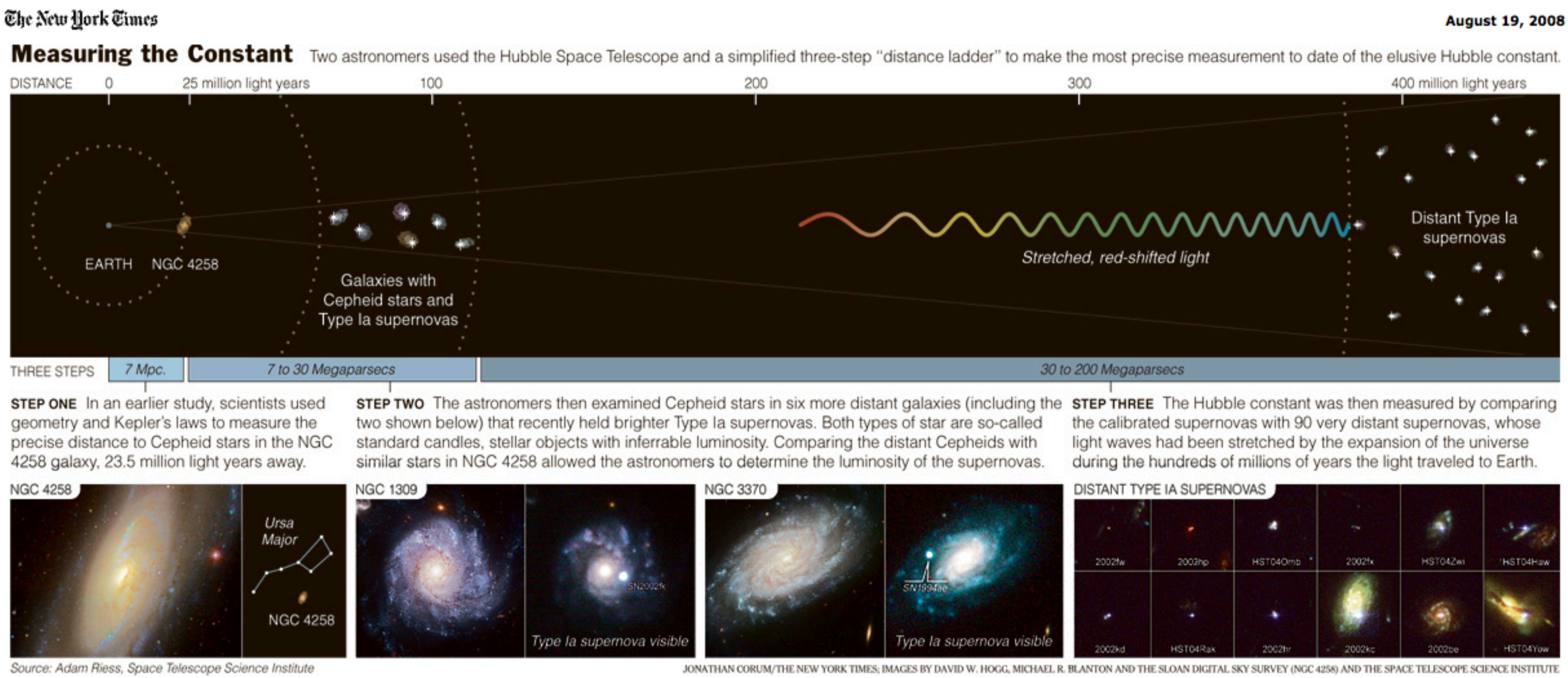
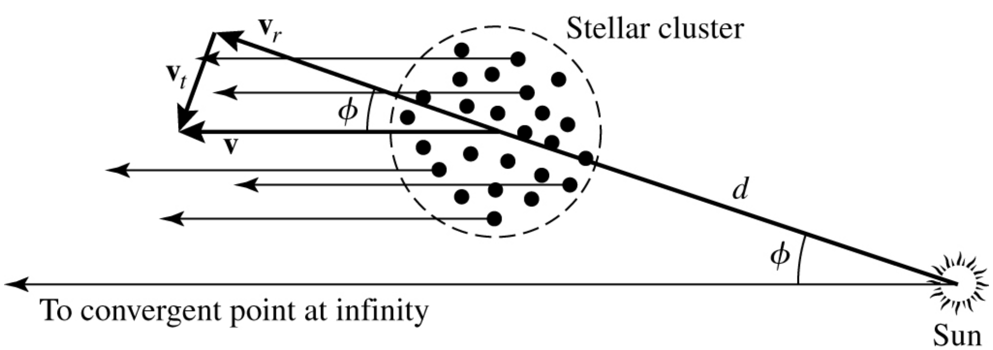
Measuring Distances



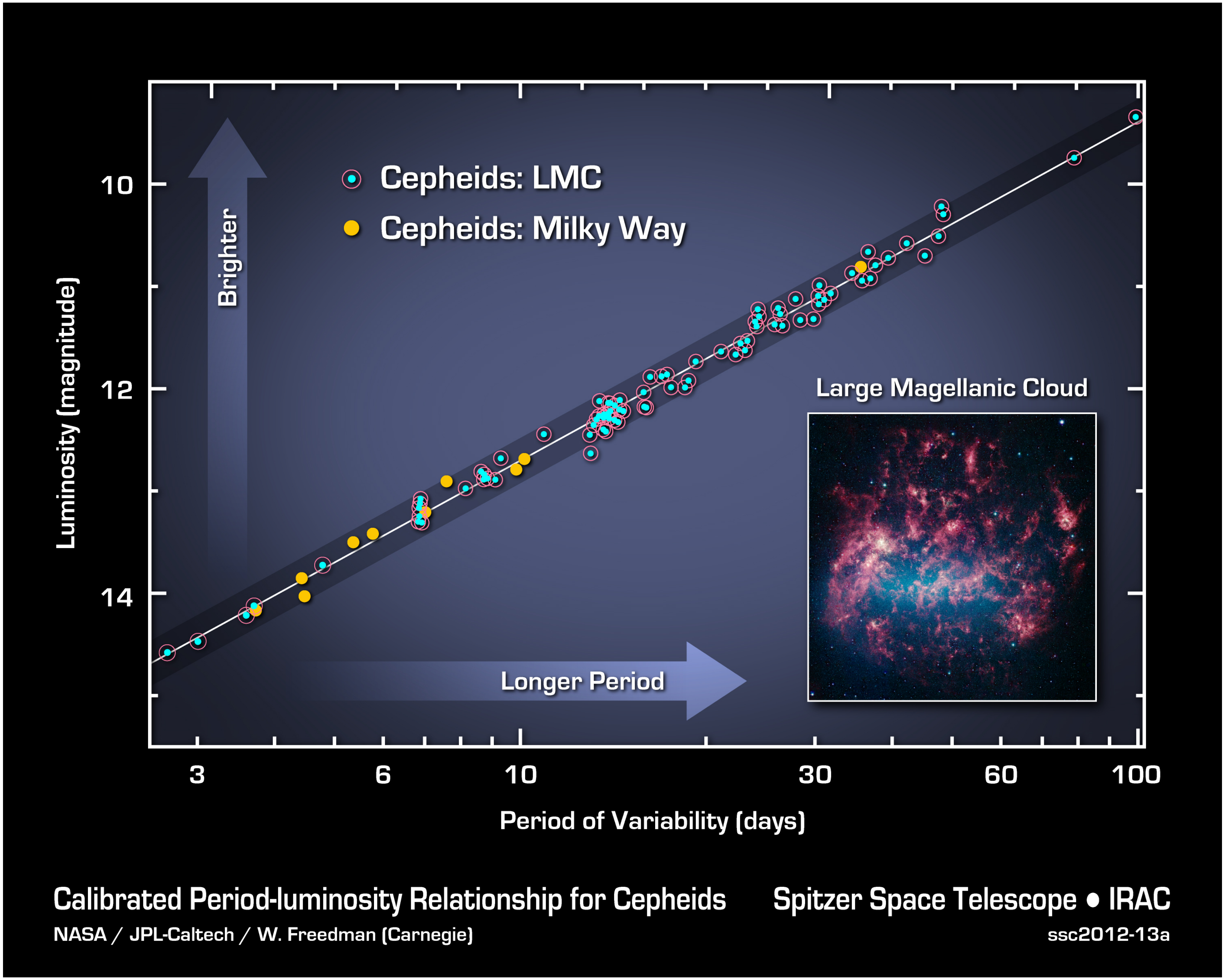
Close Window

Measuring Distances

- Apparent point of convergence: ϕ
- redshift: absolute average velocity $v_{||}$ along line of sight
- $v_{||} \tan\phi$: absolute average transverse velocity
- compare with observed average angular velocity: distance d

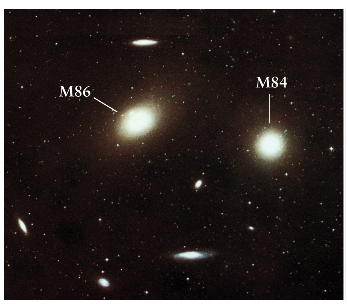


Measuring Distances

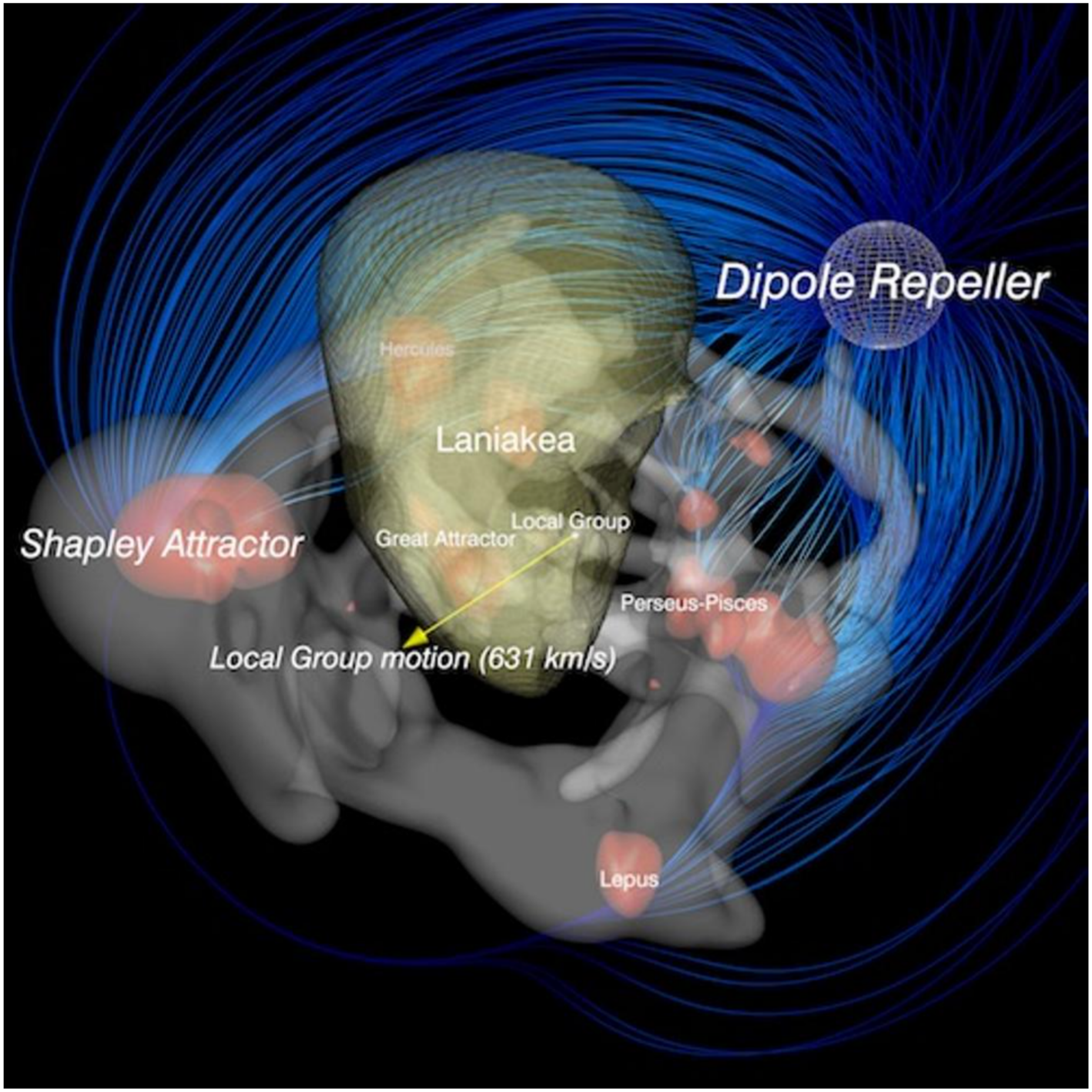


Distribution of Galaxies

- NOT random throughout space
  - tend to form groups
    - Satellite (dwarf) galaxies around Milky Way (LMC…)
    - local group contains Andromeda, more satellites
  - which form clusters (100-10^4 galaxies, 1 Mpc)

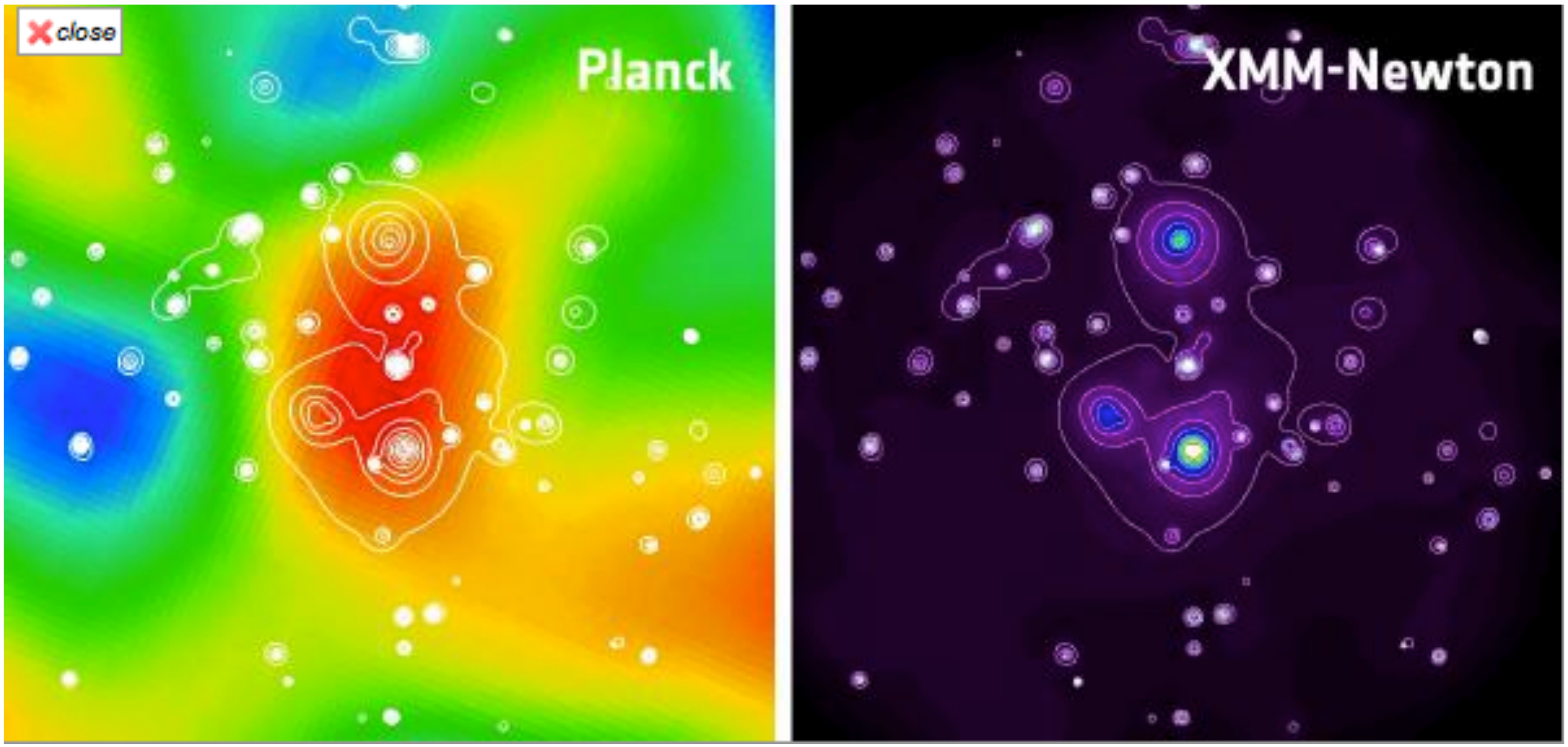


    - local group belongs to Virgo cluster
    - Coma cluster about 100 Mpc away (z = 0.023)
      - has 250 times more mass than luminosity! (about 10% is gas visible in x-rays)
  - which form superclusters (100 Mpc)
  - or walls, strings, etc. surrounding voids
    - bubbly appearance of the Universe



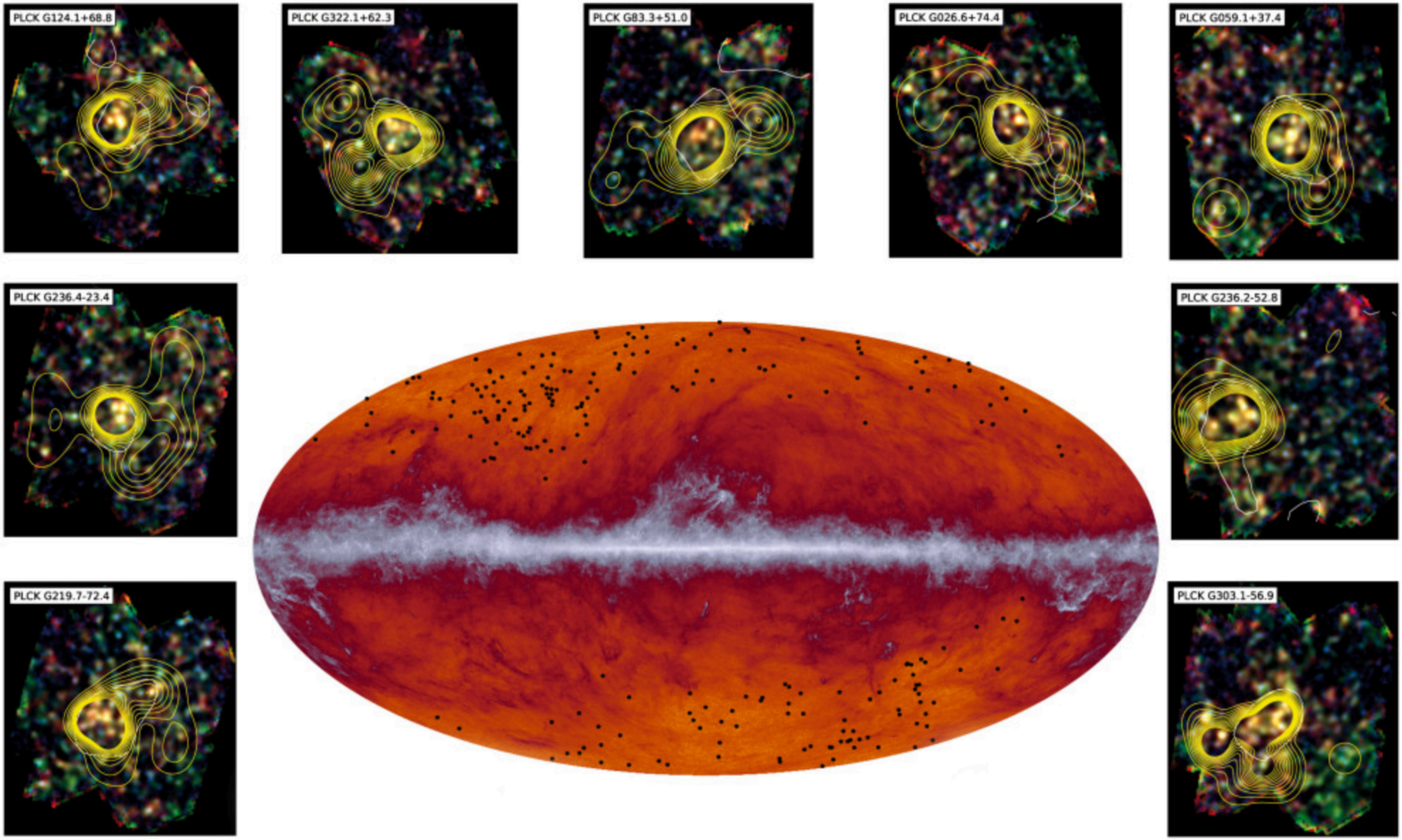
Map of the distribution and motions of galaxies on a scale of 1.5 billion light years. The Milky Way is located at the start of the yellow arrow near the center of the figure and is moving at 1.4 million miles per hour in the direction of the arrow. This motion is caused in roughly equal parts by attraction from overdense regions called the Great and Shapley attractors, and by the lack of attraction (which acts as a repulsion) from the underdensity of matter in the newly discovered Dipole Repeller. Flow lines in blue start in the Dipole Repeller and trace the deepening gravitational well into the Shapley Attractor. The grey surfaces represent the filamentary structure in the distribution of galaxies, with the red surfaces showing knots of high density. Galaxies move along flow lines from repellers to attractors, but they only move a short way in the age of the universe. Our home Laniakea Supercluster is shown in yellow, and lies in a gravitational basin of attraction centered on the region called the Great Attractor, 200 million light years from us. Laniakea is only a part of the much larger structure now described in this work.
(Credit: Yehuda Hoffman, Daniel Pomarede, R. Brent Tully, Helene Courtois.)

Superclusters



This image shows the newly discovered supercluster of galaxies detected by Planck (with the Sunyaev-Zel'dovich Effect) and XMM-Newton (in X-ray emission).

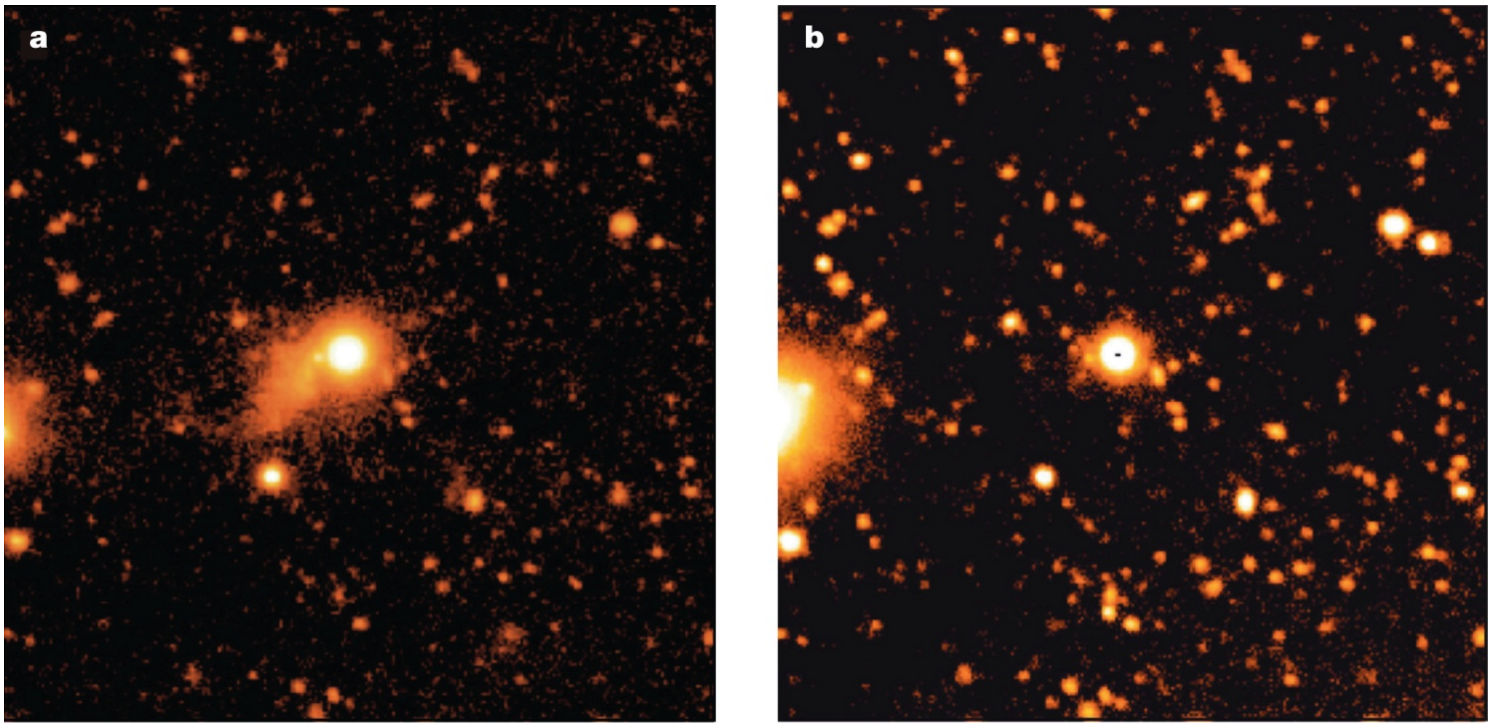
Young Galaxy Clusters



ESA/PLANCK COLLABORATION

A cosmic web filament revealed in Lyman-α emission around a luminous high-redshift quasar

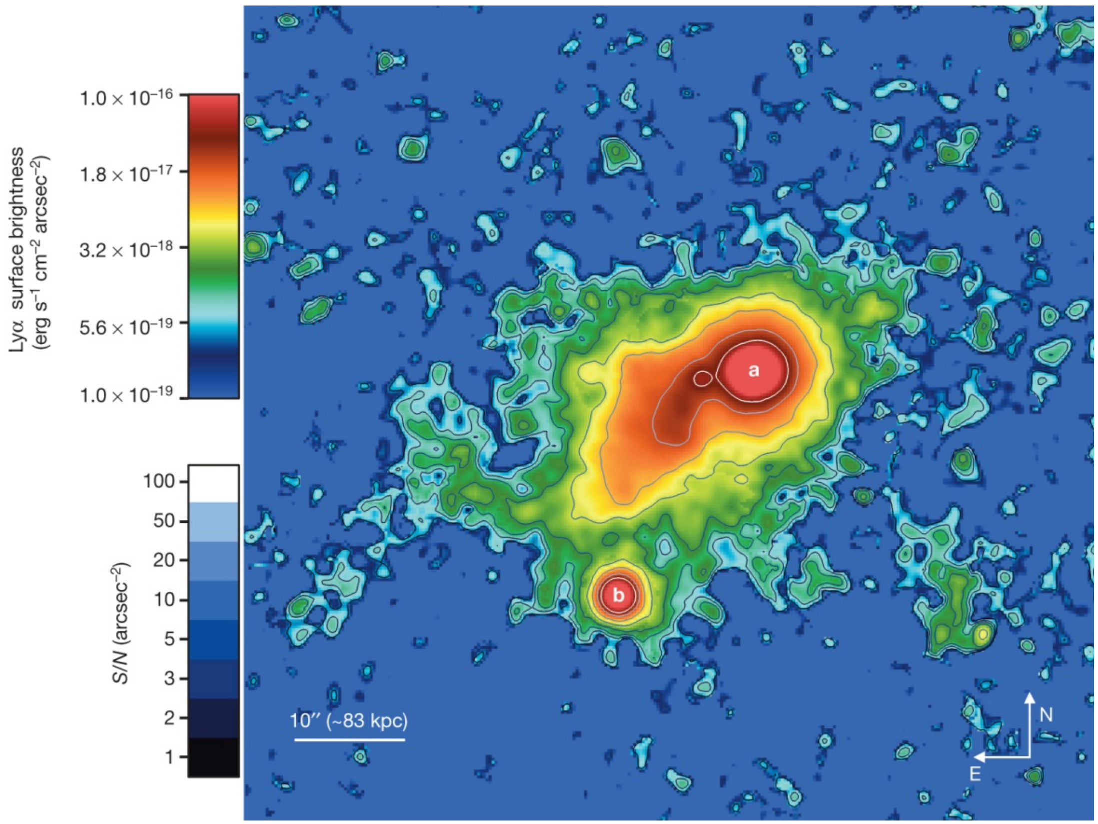
Processed and combined images of the field surrounding the quasar UM 287.

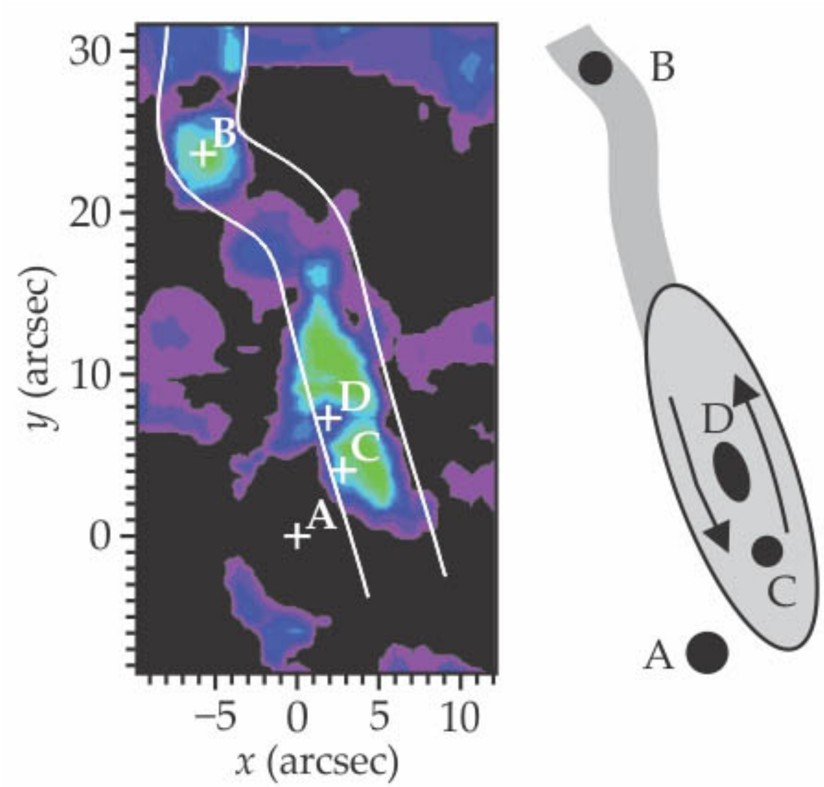


S Cantalupo *et al. Nature* **000**, 1-4 (2014) doi:10.1038/nature12898

nature

Lyman-α image of the UM 287 nebula.





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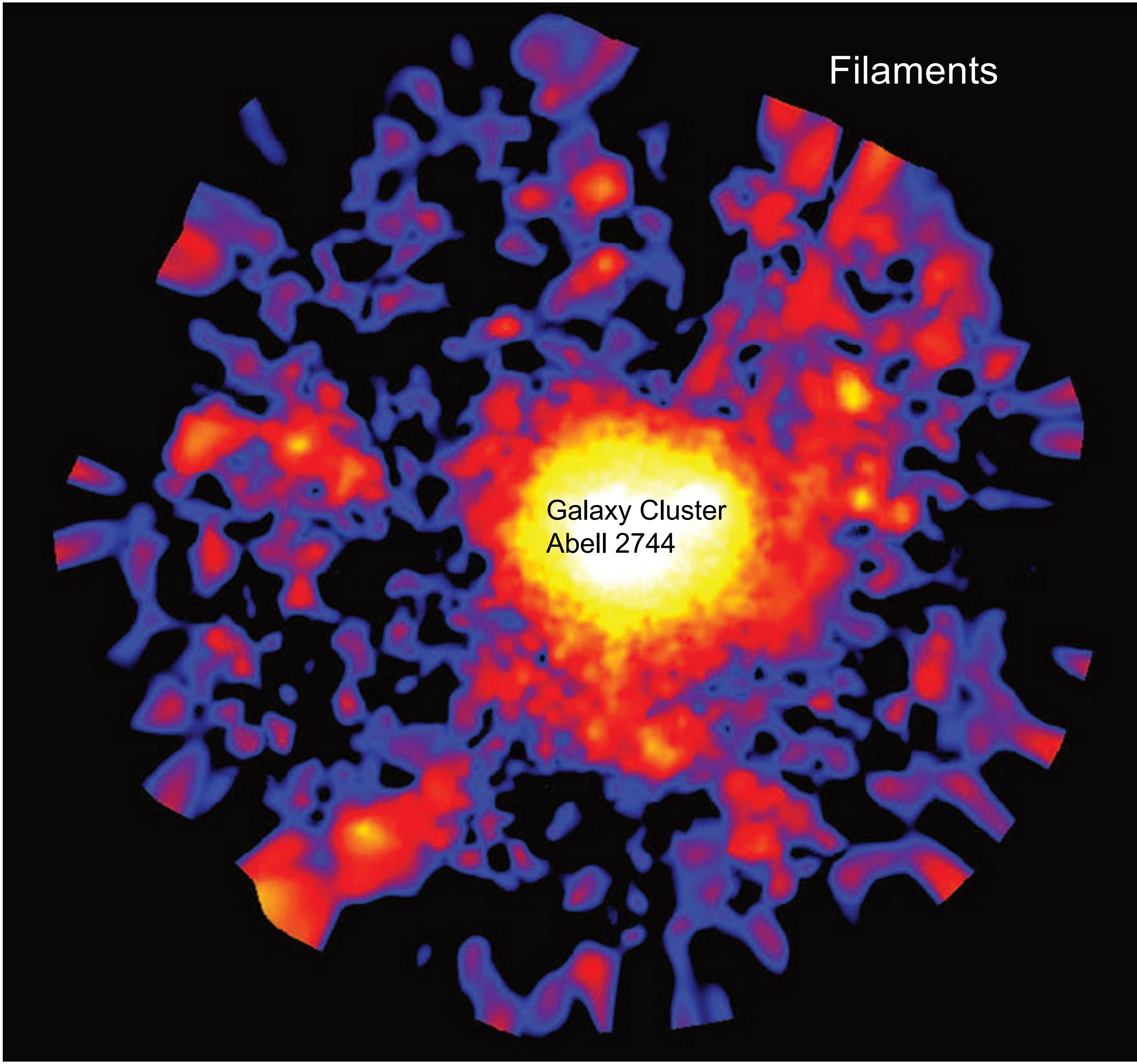
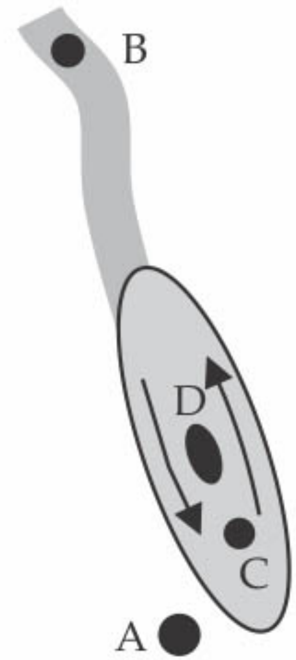
doi:10.1038/nature12898

Quasar = A
Cosmic string = B-C
CD = rotating galaxy

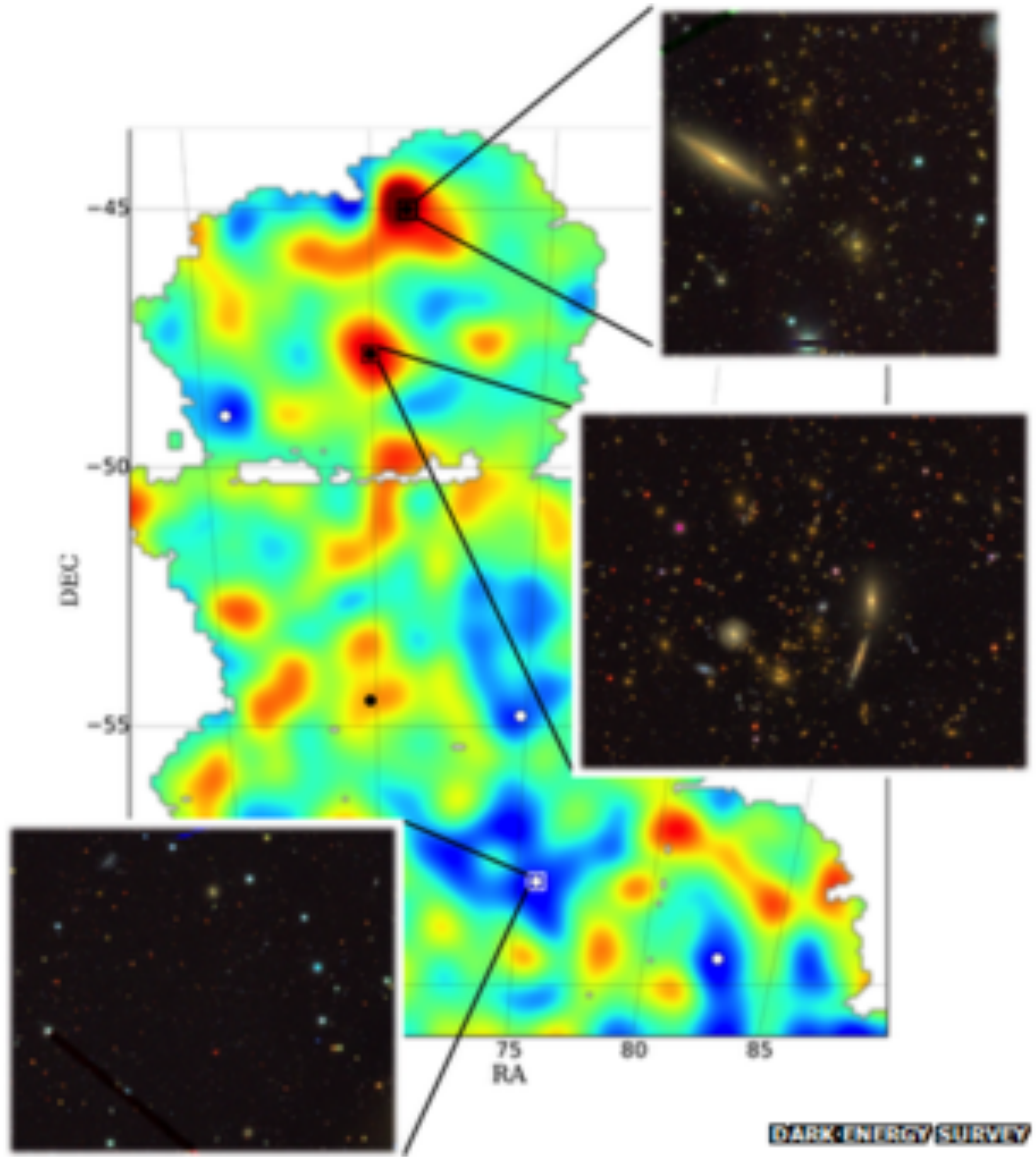




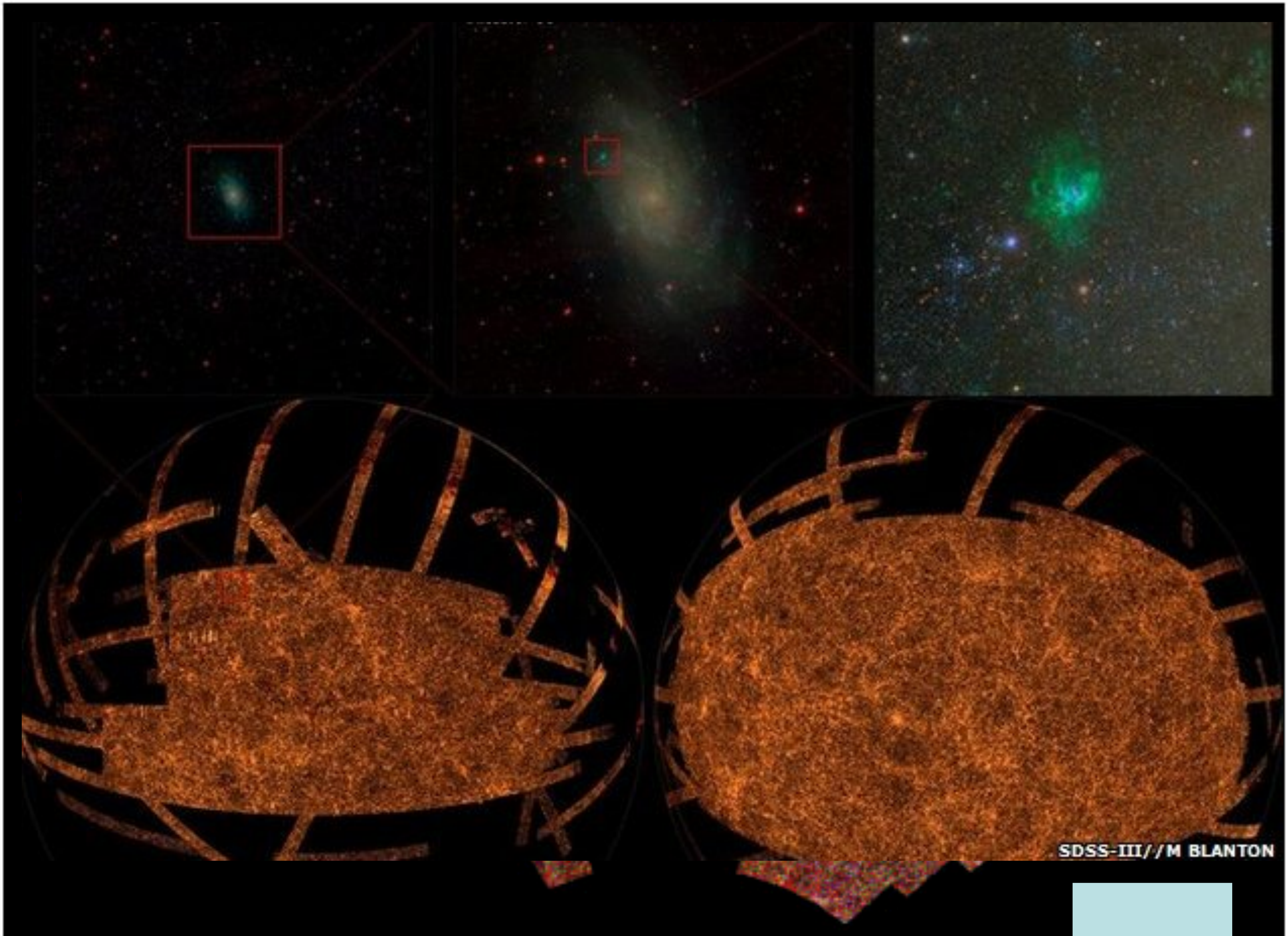
= B-C
galaxy

Dark Matter vs. Galaxies

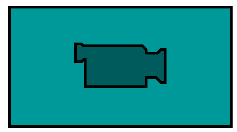
- Map of sky 0.4º across
- Dark matter density indicated by color
- Gravitational lensing to detect matter density



DES collaboration:
The survey involves more than 300 scientists from six countries and uses images taken by one of the best digital cameras in the world: a 570-megapixel gadget mounted on the Victor Blanco telescope at the Cerro Tololo Inter-American Observatory, high in the Chilean Andes.


SDSS-III//M BLANTON

We can simulate how a nearly smooth distribution of dark matter turns into our lumpy, grainy Universe with its hierarchy of structures - from galaxies to superclusters, great walls and voids



We can “see” some of the dark matter through gravitational lensing

We also have dark energy in addition to dark matter, accelerating the expansion of the universe

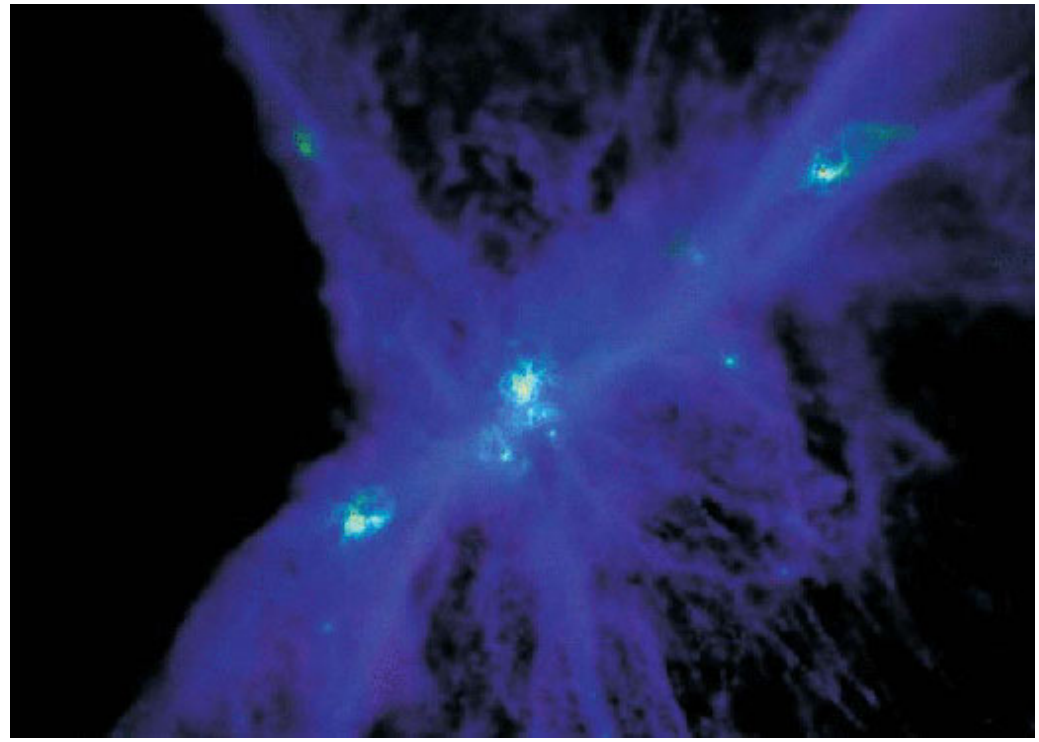
Matter Distribution Summarized

By the time the universe was three minutes old, all the baryonic building blocks of normal matter had formed. As the young universe aged, a minority of those primordial baryons—a few percent—joined clumps of the far more abundant dark matter to condense and form the first galaxies.

Those galaxies grew by merging with each other. They grouped together in clusters. New generations of stars sprang from the gas left by their predecessors' explosive demise. Throughout those processes, which are still going on, the overall distribution of baryons more or less persisted: Most baryons remain outside galaxy clusters.

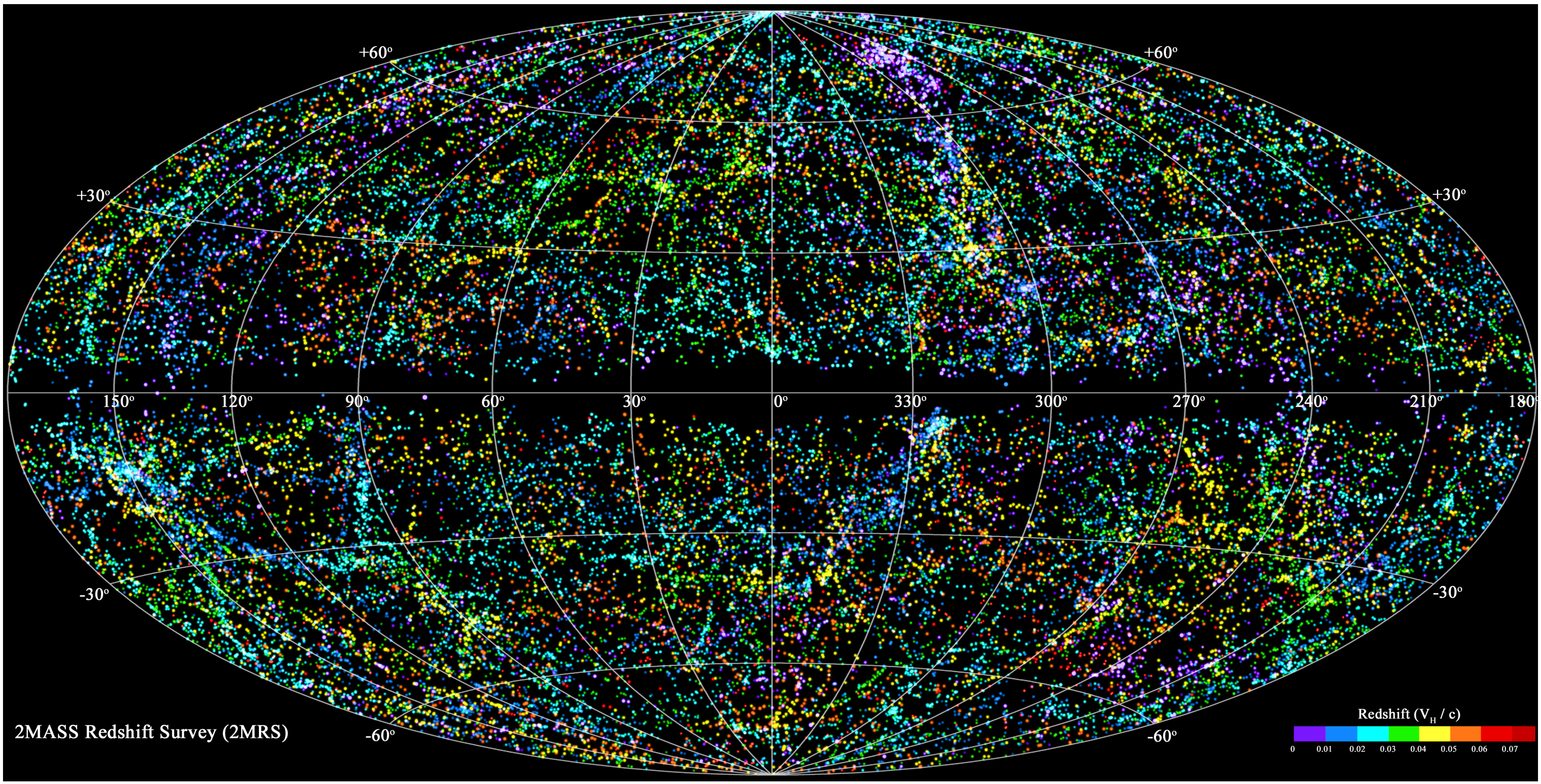
Astronomers have confidence in their predictions of how much baryonic matter formed in the Big Bang. And their observations of luminous matter indicate how much baryonic matter lies in stars, galaxies, and galaxy clusters. What's been harder to determine is the baryonic content of the intergalactic medium.

In principle, accounting observationally for all the IGM baryons is straightforward. Both the density fluctuations that led to the first galaxies and the mergers that formed their successors have squeezed dark and baryonic matter into a foamy network of widely spaced nodes, the galaxy clusters, connected by wispy filaments, the IGM.



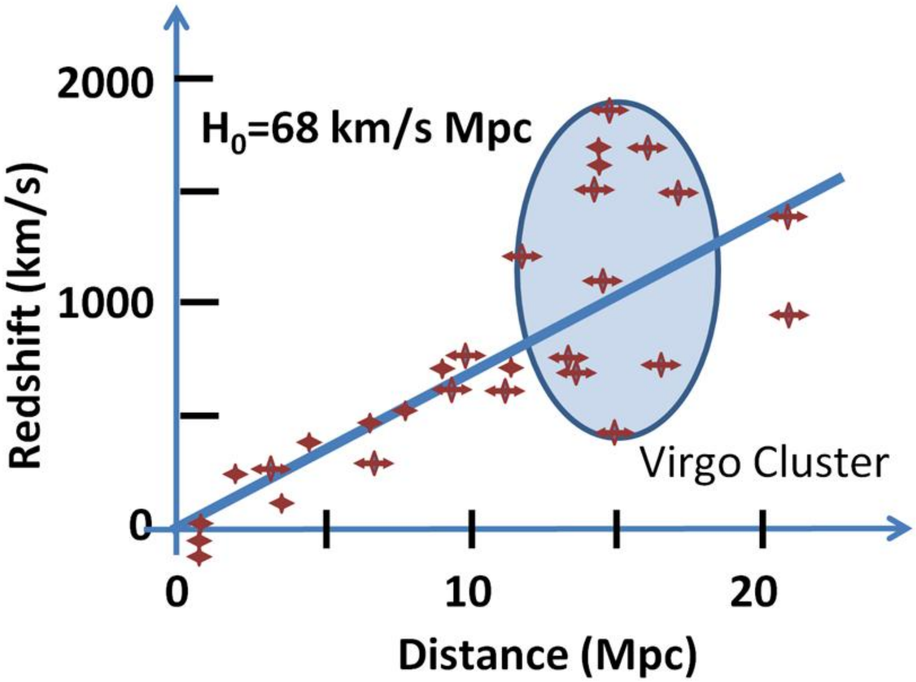
Computer simulations like this one show that galaxies and clusters of galaxies form at the nodes of a foamy, filamentary web. The area of sky in the image is about 100 000 light-years across. Stars appear in yellow. The colors from violet through blue and green to white correspond to gas of increasing density. CREDIT: Sergey Mashchenko, McMaster University and SHARCNET

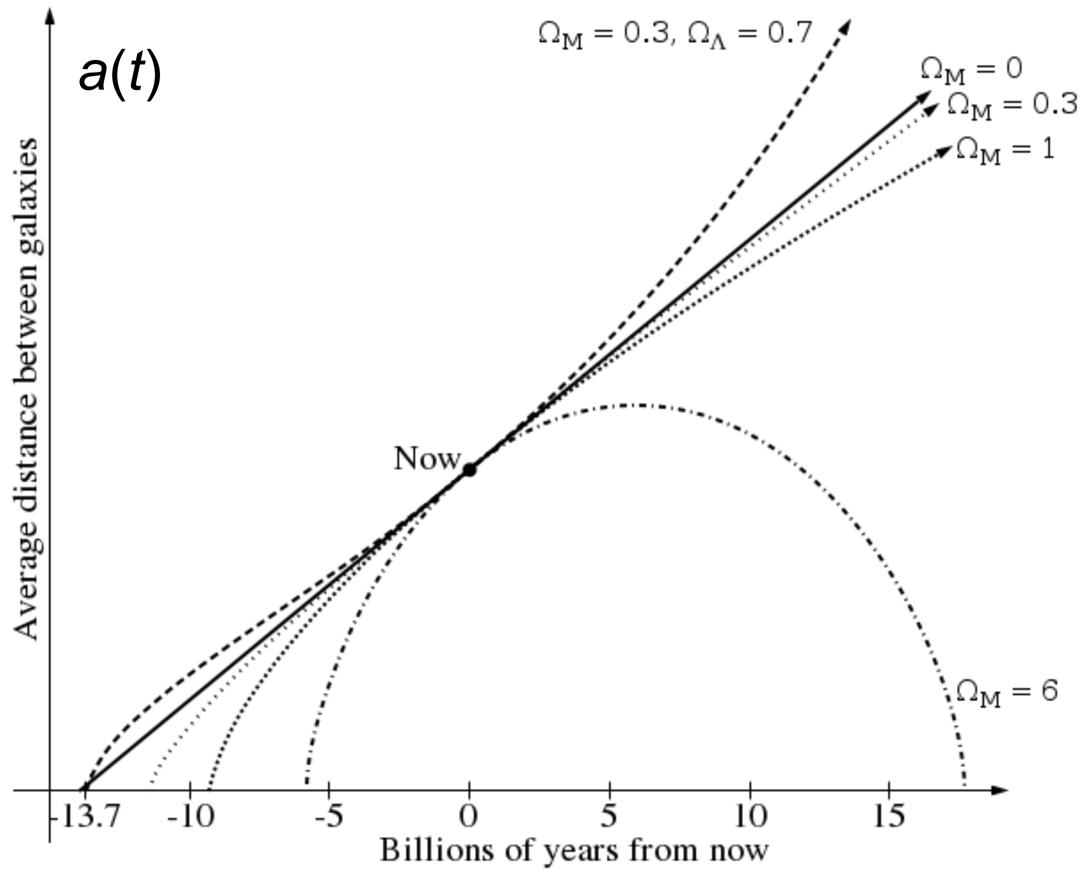
Redshift!



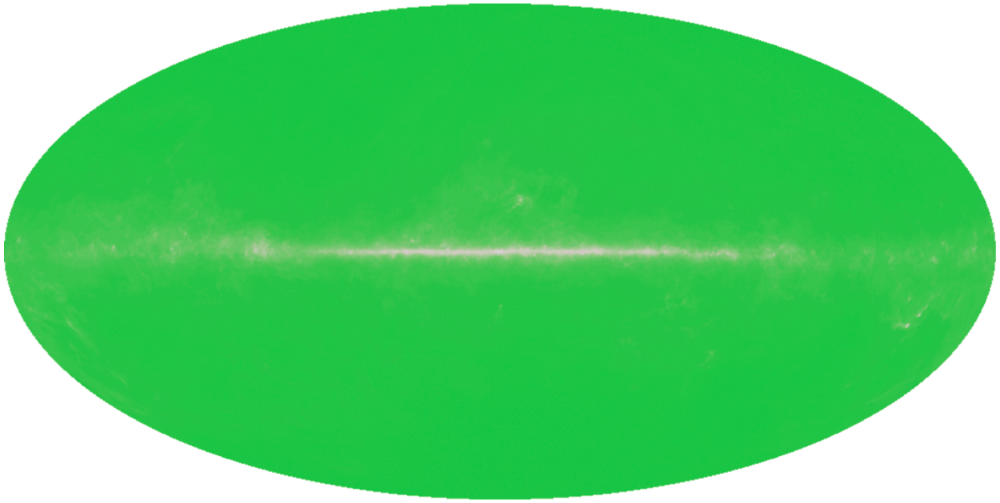
+60°
+60°
+30°
+30°
150°
120°
90°
60°
30°
0°
330°
300°
270°
240°
210°
180°
-30°
-30°
-60°
-60°
2MASS Redshift Survey (2MRS)
Redshift (V_H / c)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07

Redshift!

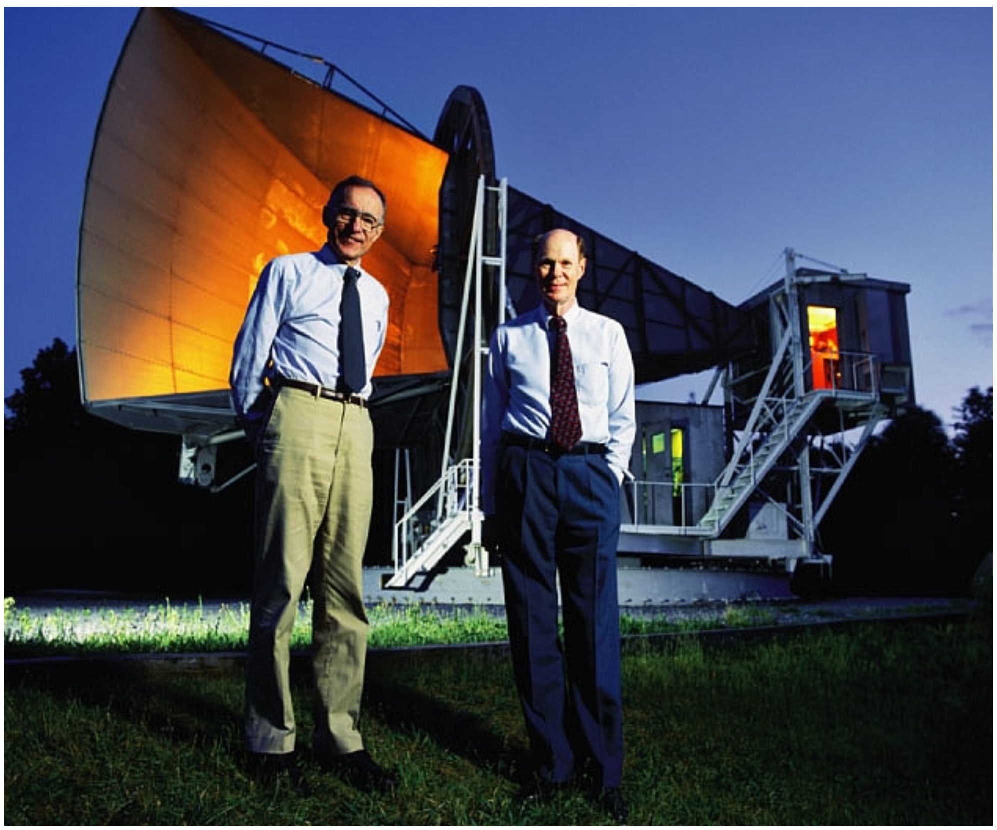


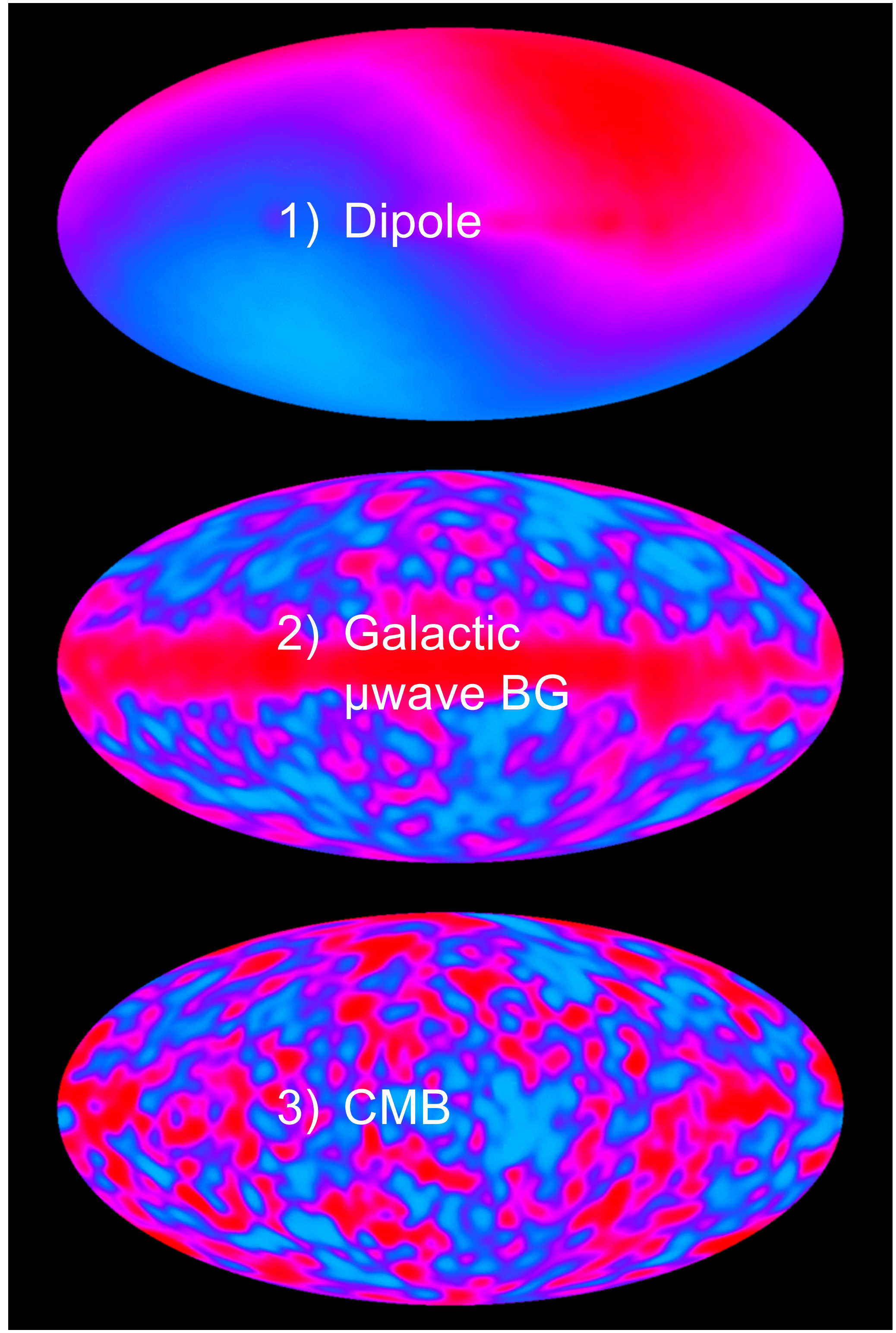


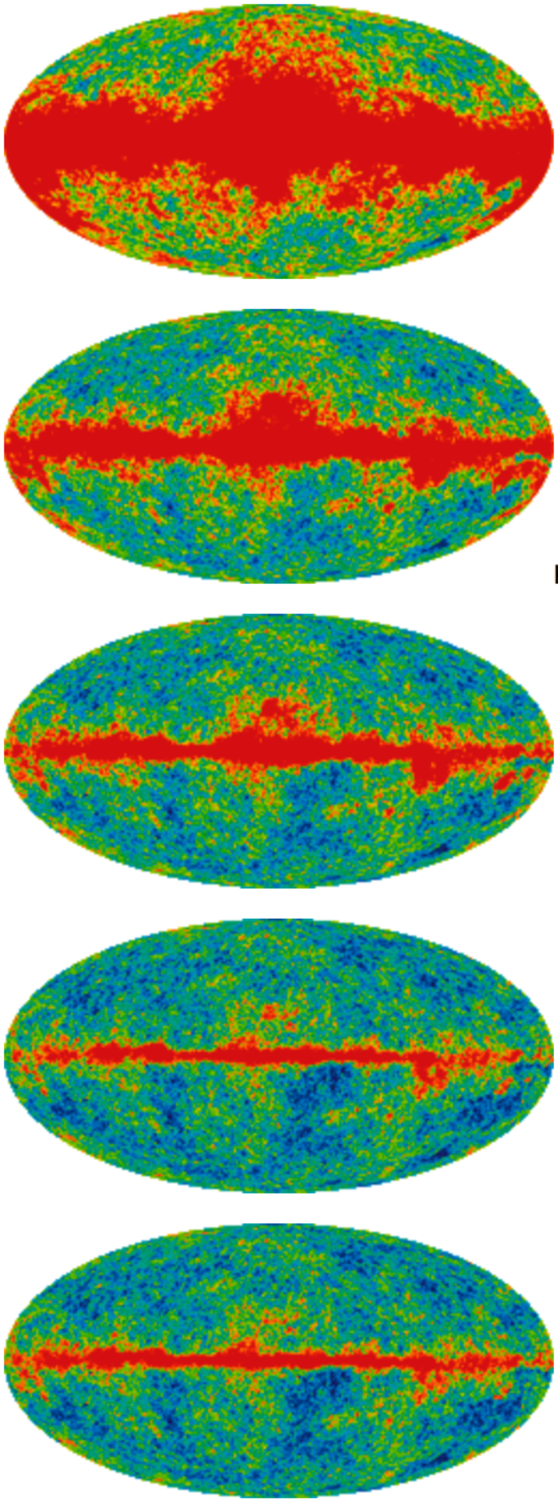
$$z = \frac{a(t_{obs})}{a(t_{emit})} - 1 \approx \frac{v}{c} \text{ for nearby galaxies}$$



Penzias and Wilson
(simulated)







K band

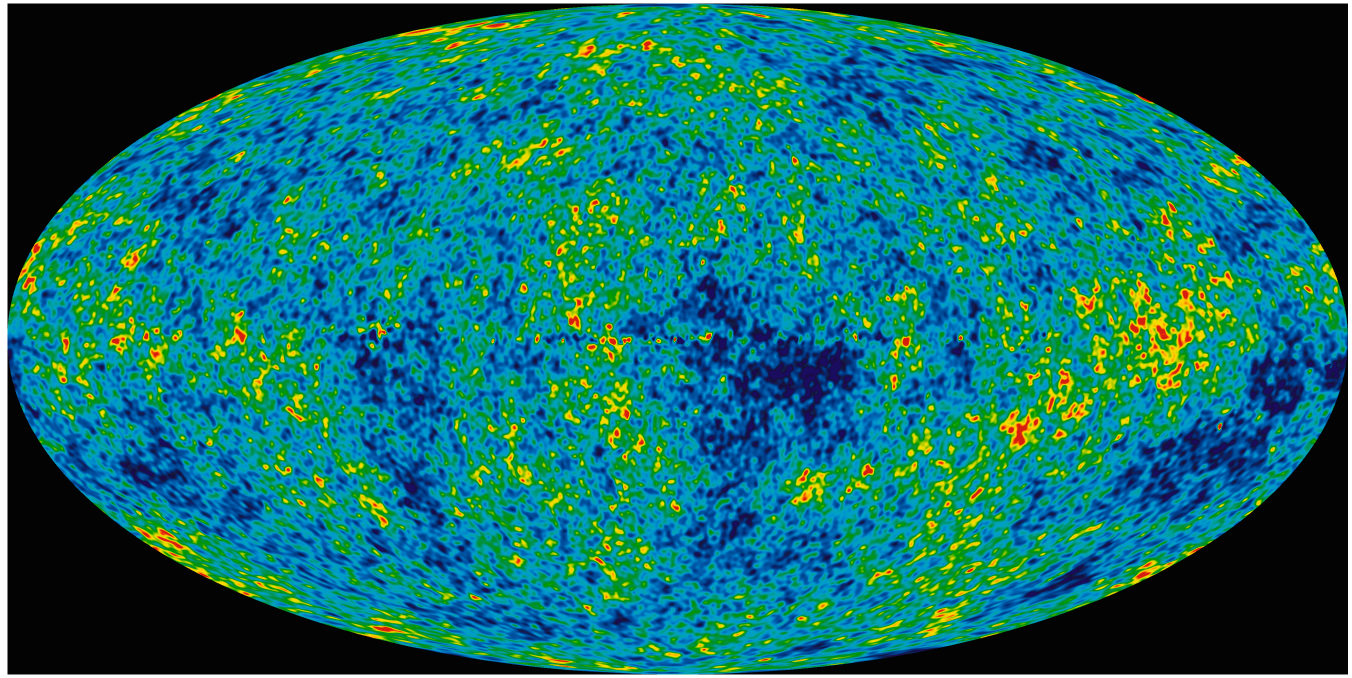
Ka band

Q band

V band

W band

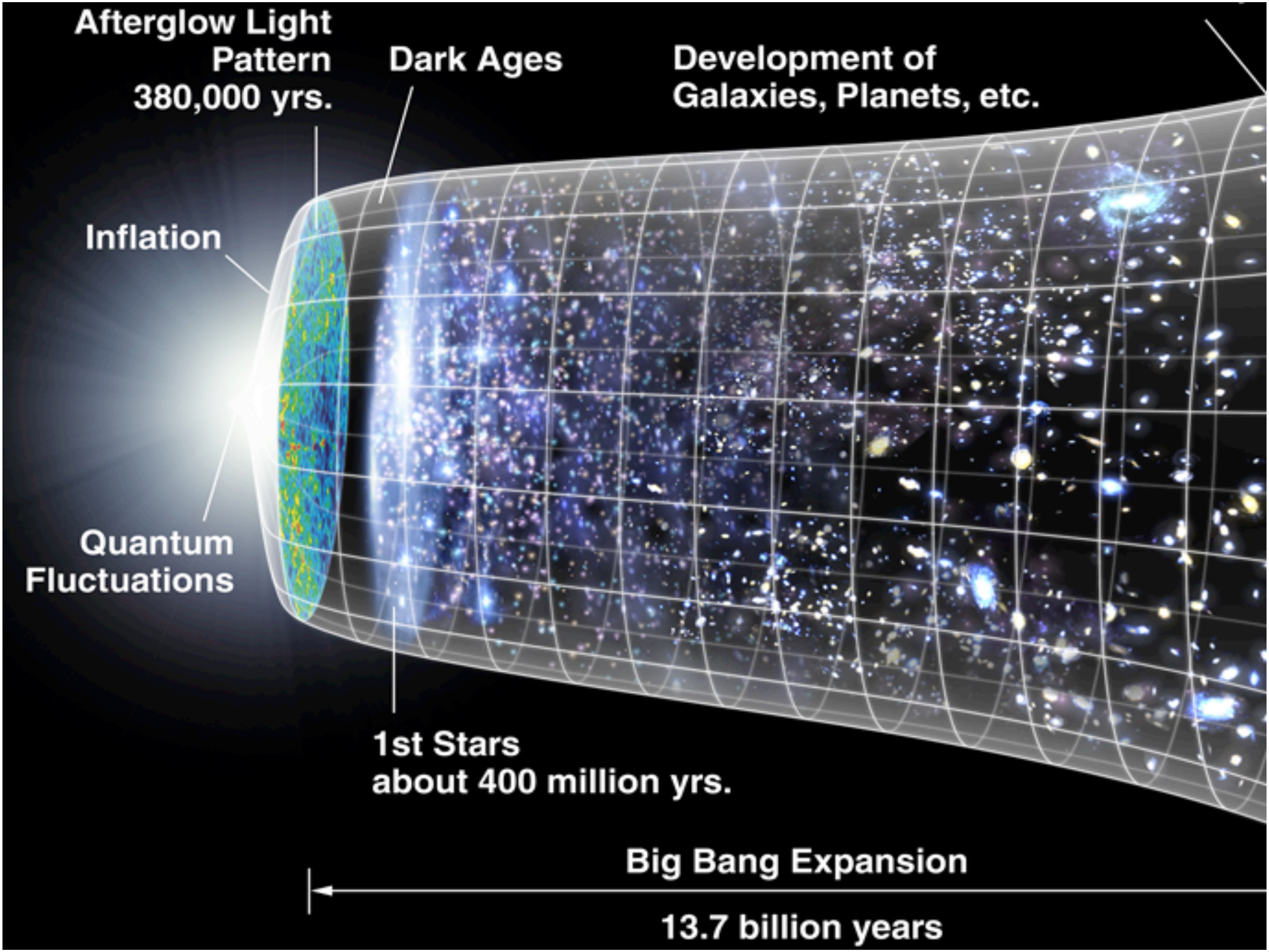
WMAP



- Emitted @ 0.0004 Byr (0.003% of present age)
- “Re”combination of e^- and p,d,α
- Blackbody radiation at roughly 3000K
- z = 1100 => now 2.7 K (temperature of universe)
- Defines a preferred rest frame!
- Anisotropy 10^{-3} due to proper motion
- Anisotropy 10^{-5} intrinsically.
- Why so little?
- Why any at all?

Large Scale Structure of Universe

- The Universe is expanding…
  - Hubble Constant H_0 = 70 km/s/Mpc = 1/14Gyr
- …initially it was filled with a smooth distribution of dark matter
  - and a smaller amount of nucleons + electrons
  - very small initial density fluctuations…
- …which began to clump to create the seeds of filaments, superclusters, walls, … , galaxies (central black holes?)


Afterglow Light Pattern 380,000 yrs.
Dark Ages
Development of Galaxies, Planets, etc.
Inflation
Quantum Fluctuations
1st Stars about 400 million yrs.
Big Bang Expansion
13.7 billion years

Afterglow Light