

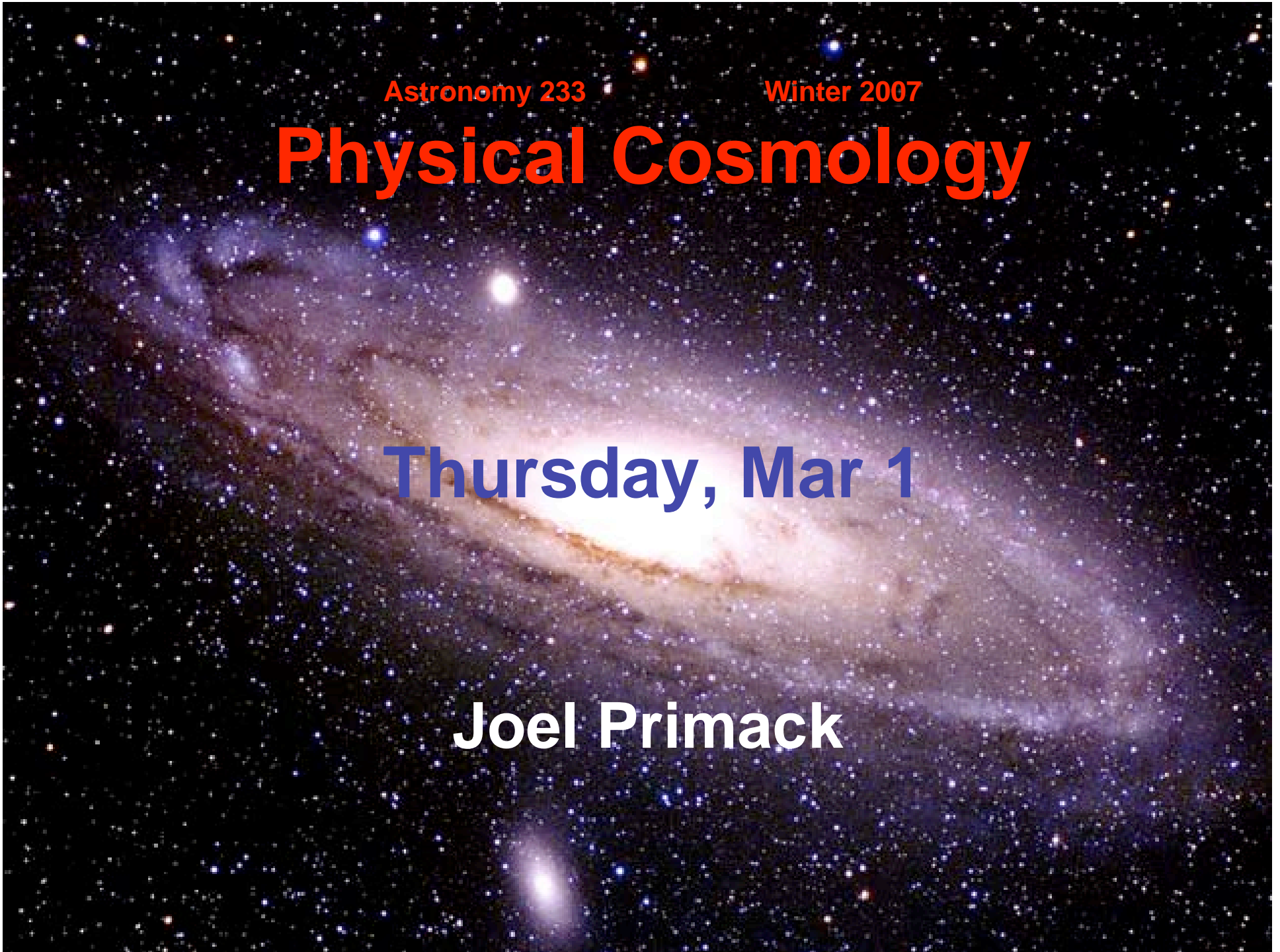
Astronomy 233

Winter 2007

# Physical Cosmology

Thursday, Mar 1

Joel Primack



# EVOLUTION OF THE UNIVERSE

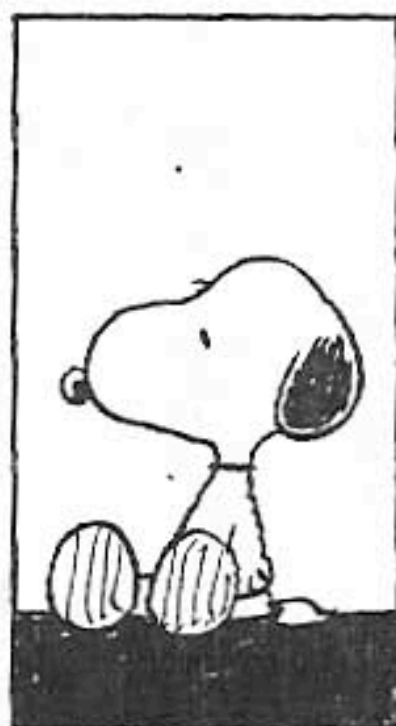
Joel R. Primack, UCSC

Cosmology is going through a scientific revolution that is creating humanity's **first picture of the history of the universe as a whole that might actually be true.**

In this new scientific picture, **we are cosmically central, and we live at a pivotal time.**

PEANUTS

Charles Schulz

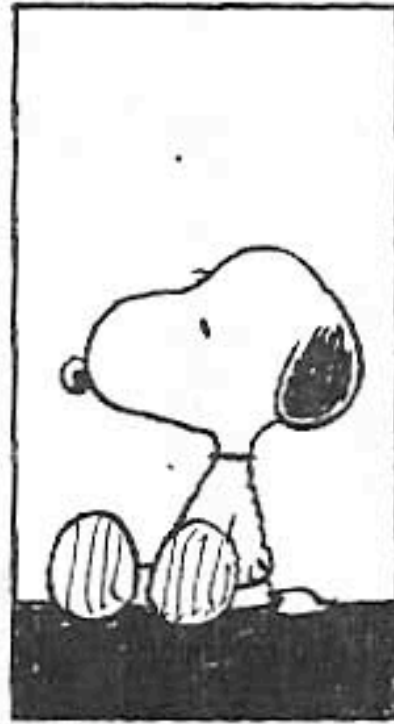


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PEANUTS

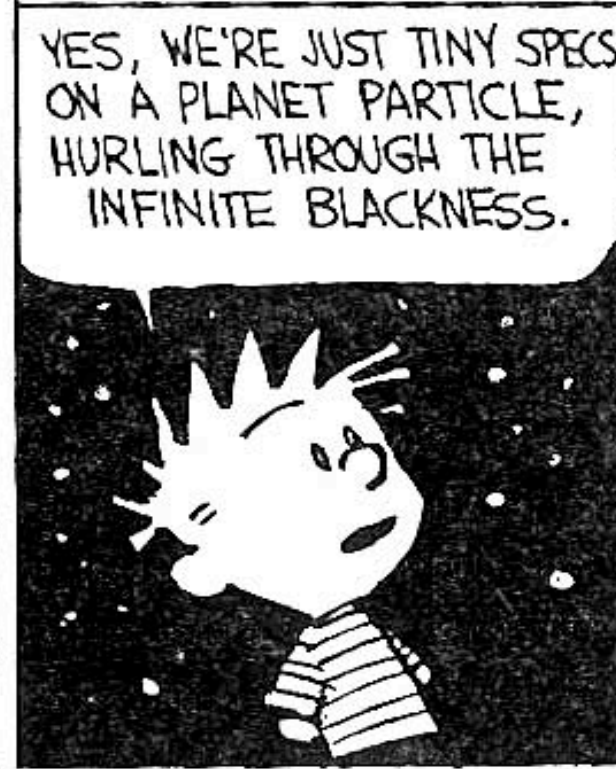
Charles Schulz



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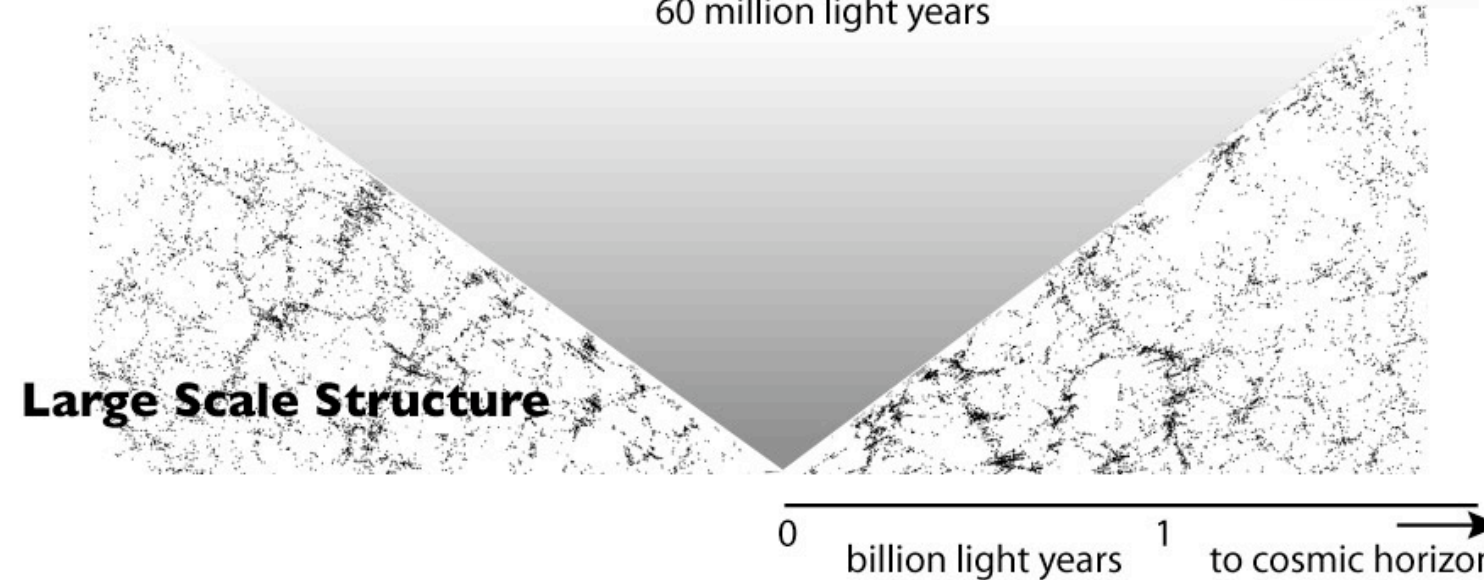
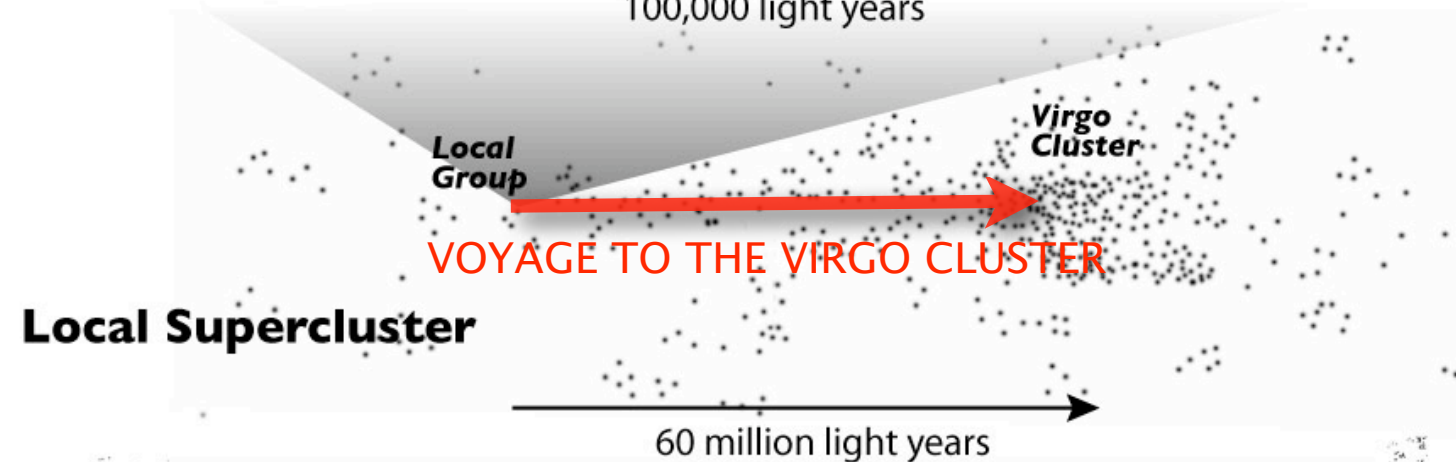
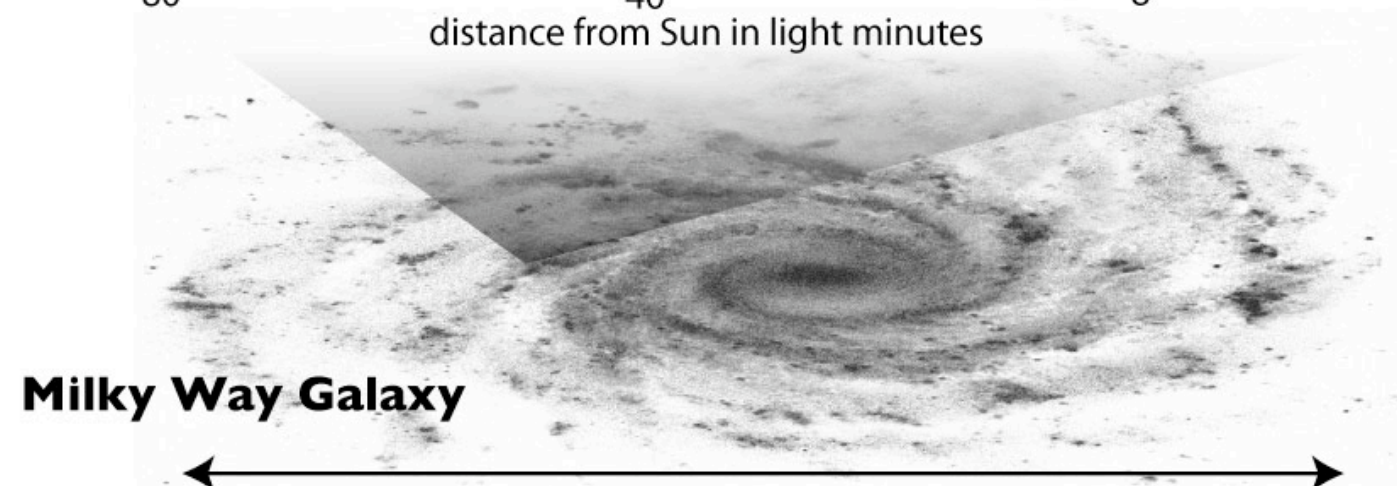
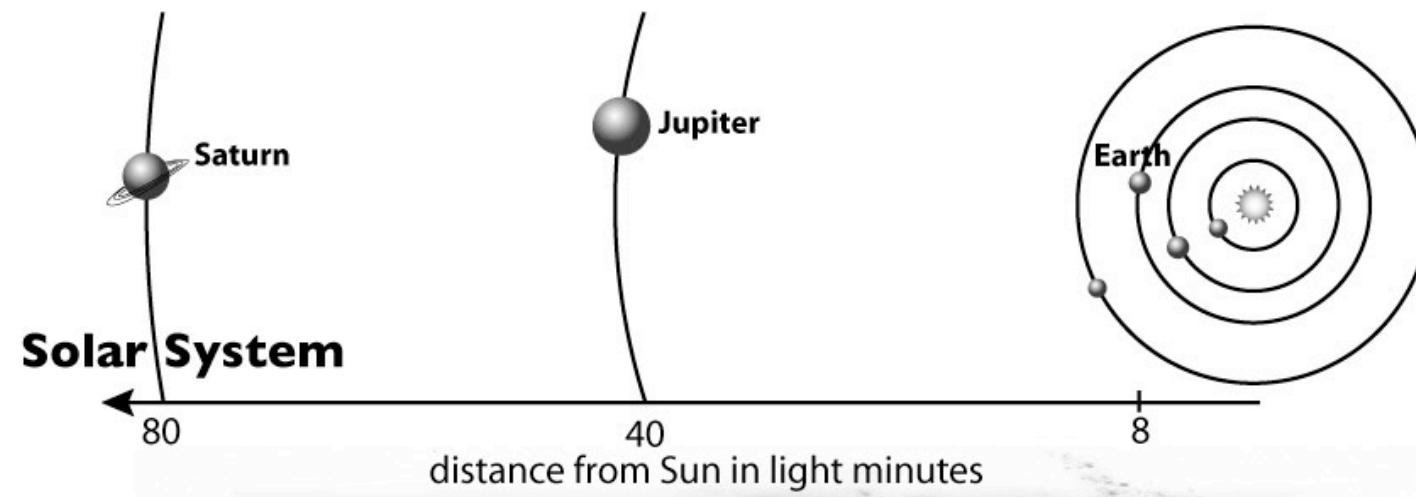


CALVIN AND HOBBS





# Our Cosmic Address



# The Modern Scientific Cosmos

each dot is a big galaxy

Sloan Digital Sky Survey

# VOYAGE TO THE VIRGO CLUSTER



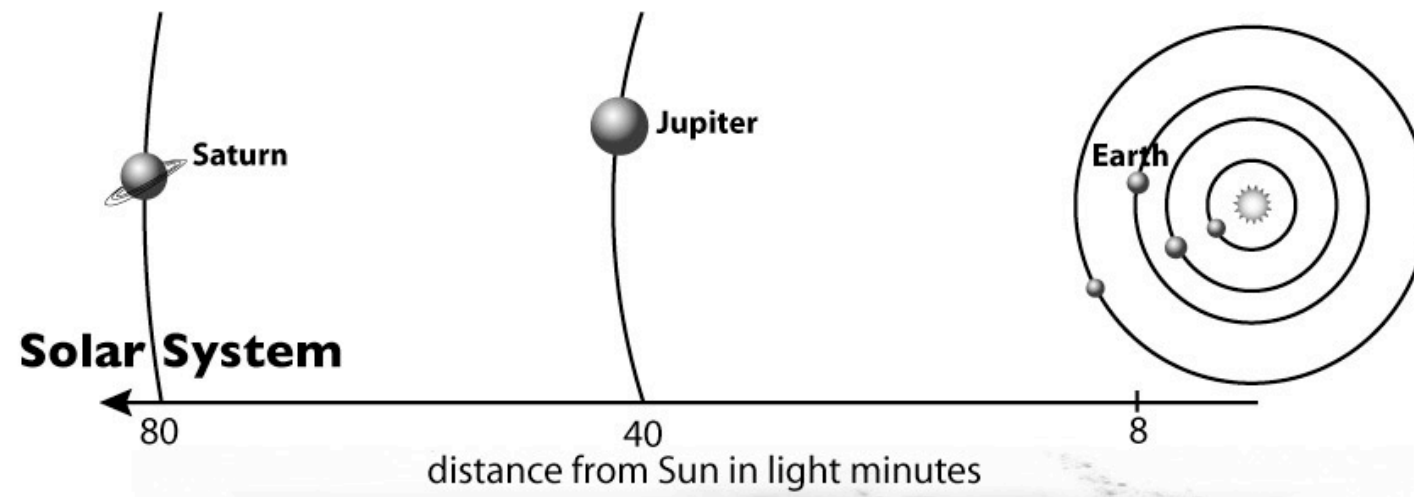
Orion



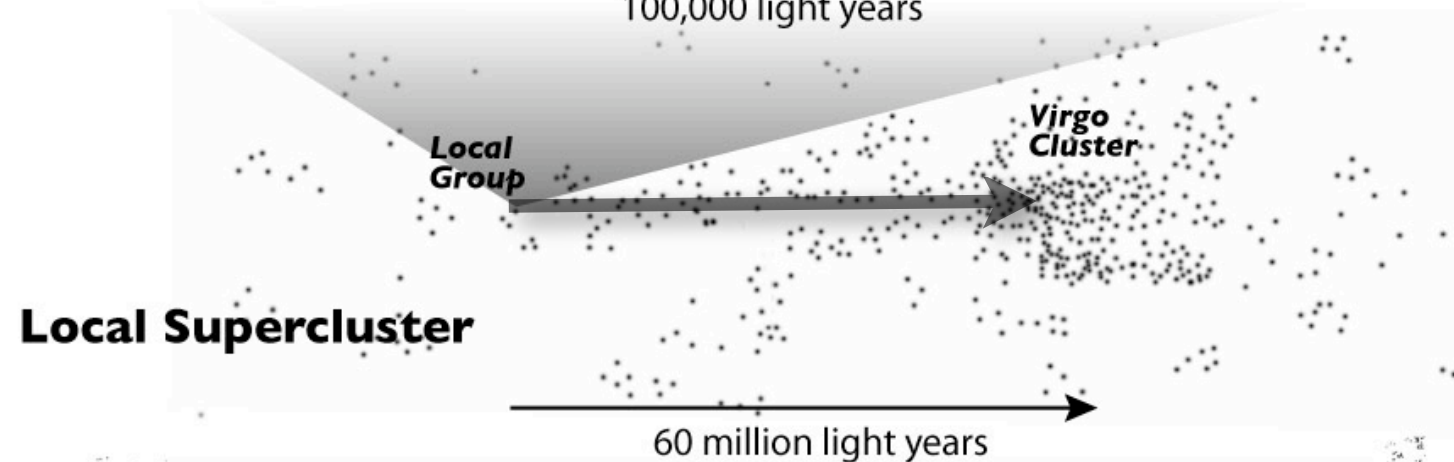
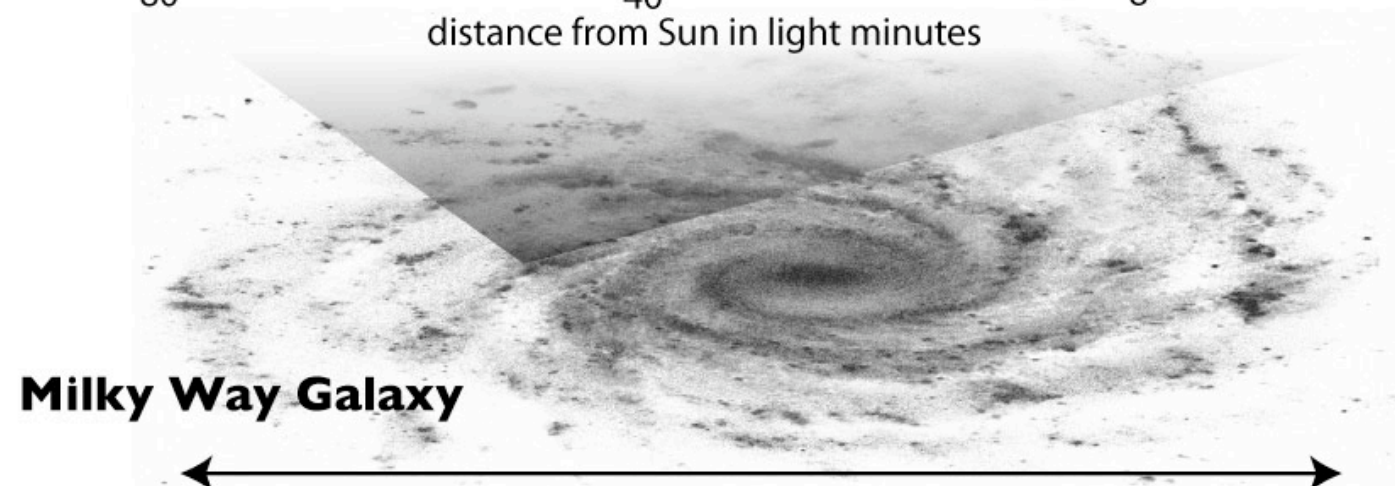
# VOYAGE TO THE VIRGO CLUSTER

A deep space photograph of the Virgo Cluster of galaxies. The image shows a vast field of galaxies in various colors and orientations, set against a dark background. The galaxies are densely packed, with some appearing as bright, elongated structures and others as smaller, more distant points of light. The overall scene is a rich and diverse collection of celestial bodies.

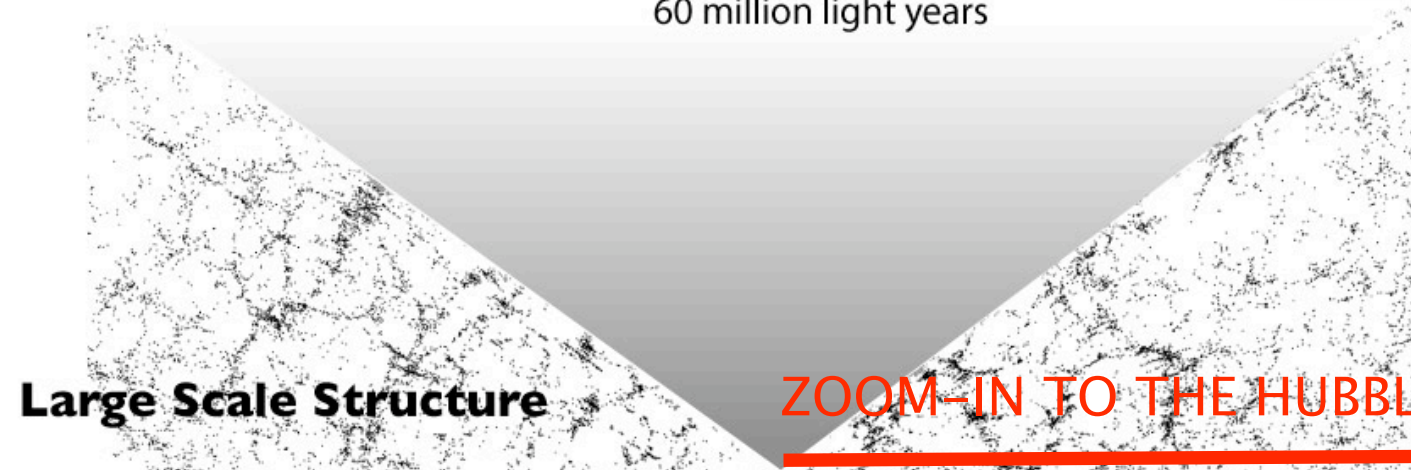
# The Modern Scientific Cosmos



Our Cosmic Address



each dot is a big galaxy



Sloan Digital Sky Survey

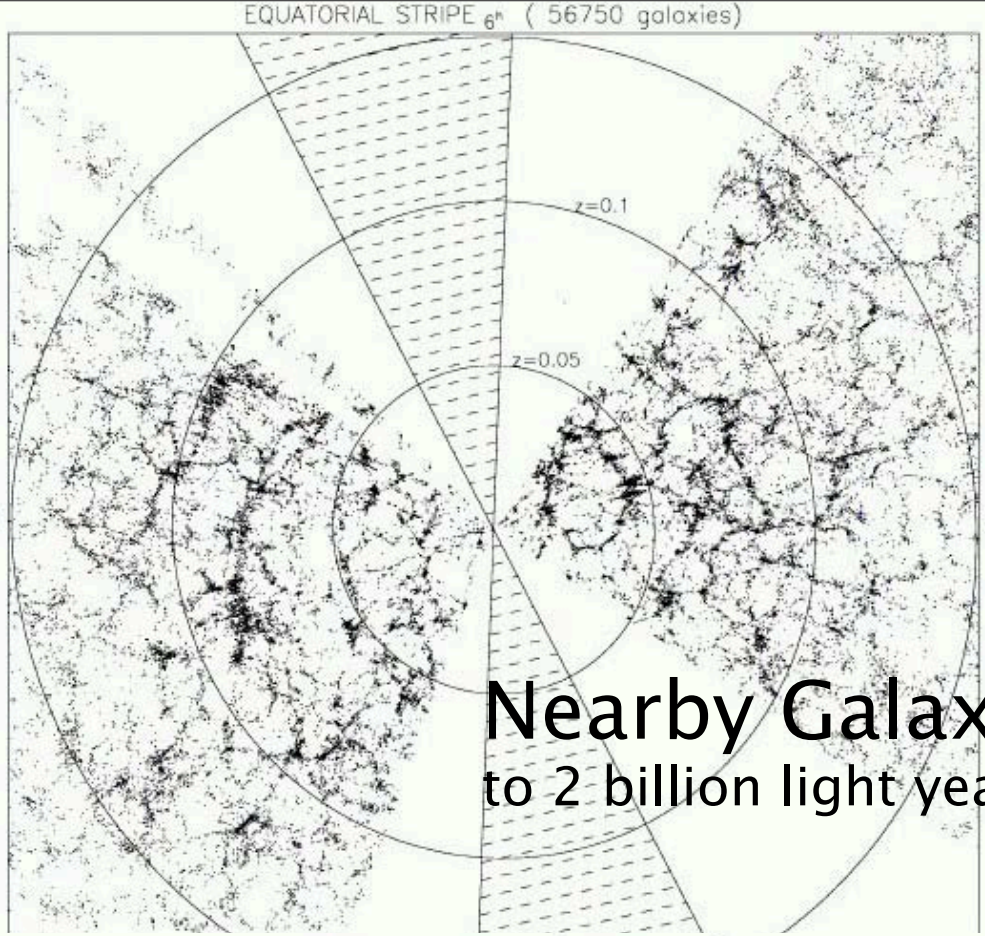
ZOOM-IN TO THE HUBBLE ULTRA DEEP FIELD



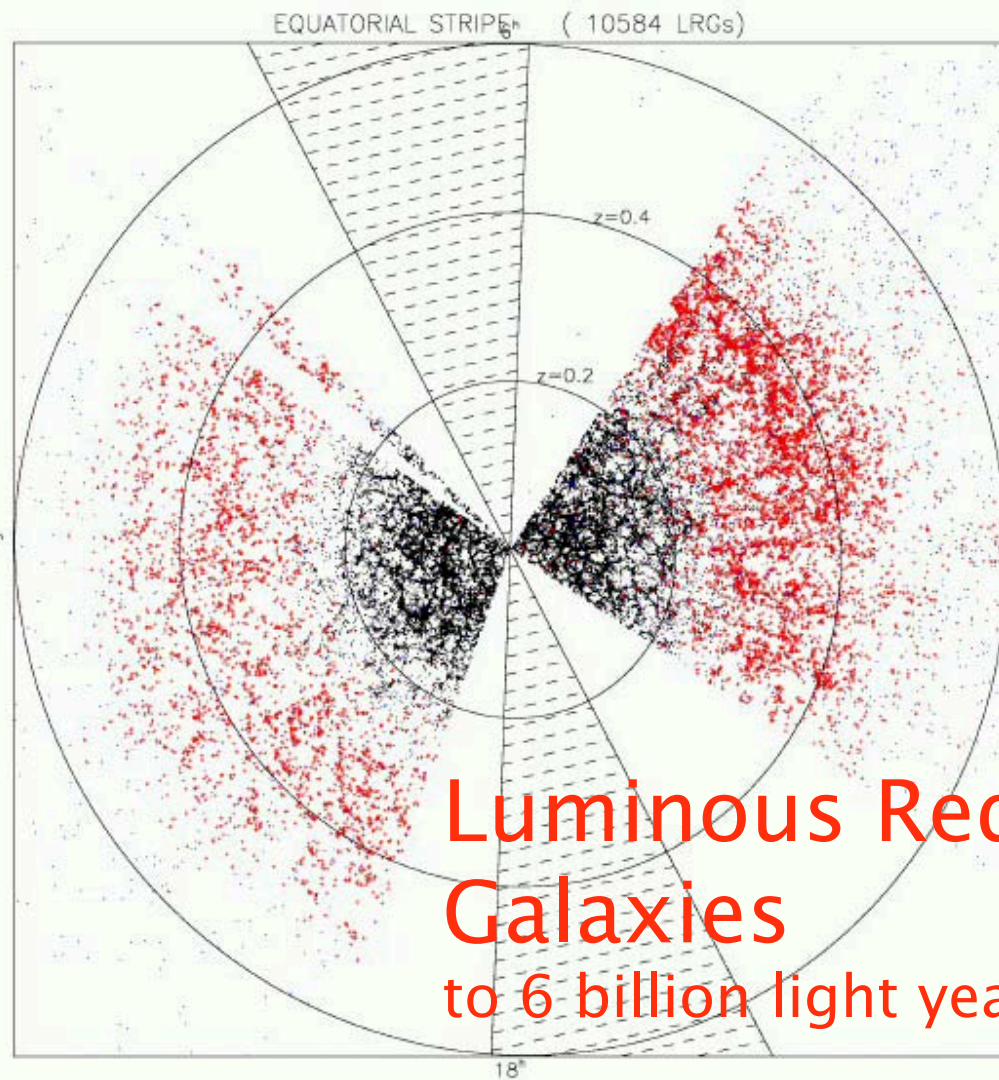


ZOOM-IN TO THE HUBBLE ULTRA DEEP FIELD

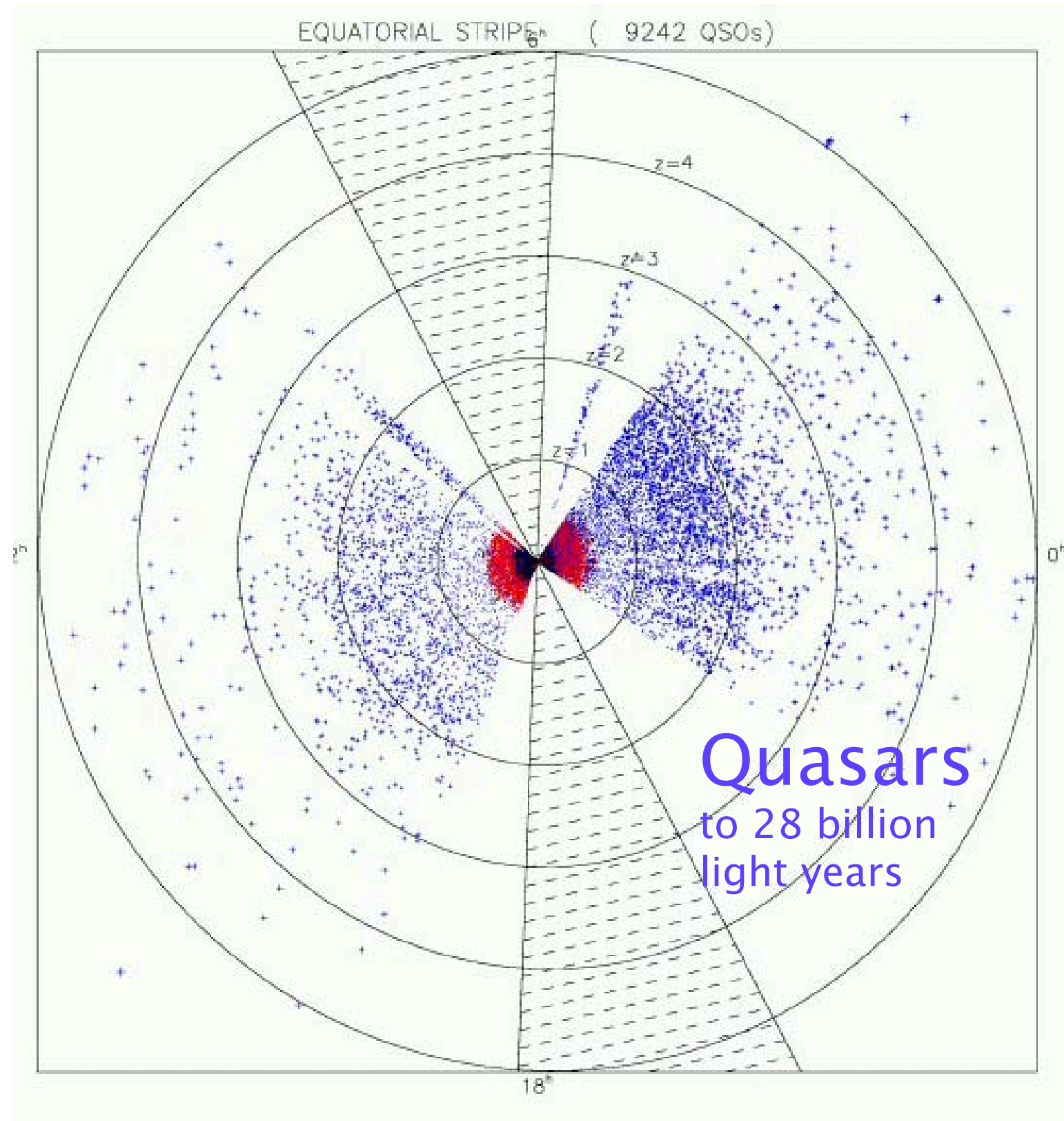
# Sloan Digital Sky Survey



**Nearby Galaxies**  
to 2 billion light years



**Luminous Red Galaxies**  
to 6 billion light years



**Quasars**  
to 28 billion light years



# GALAXIES MAPPED BY THE SLOAN SURVEY

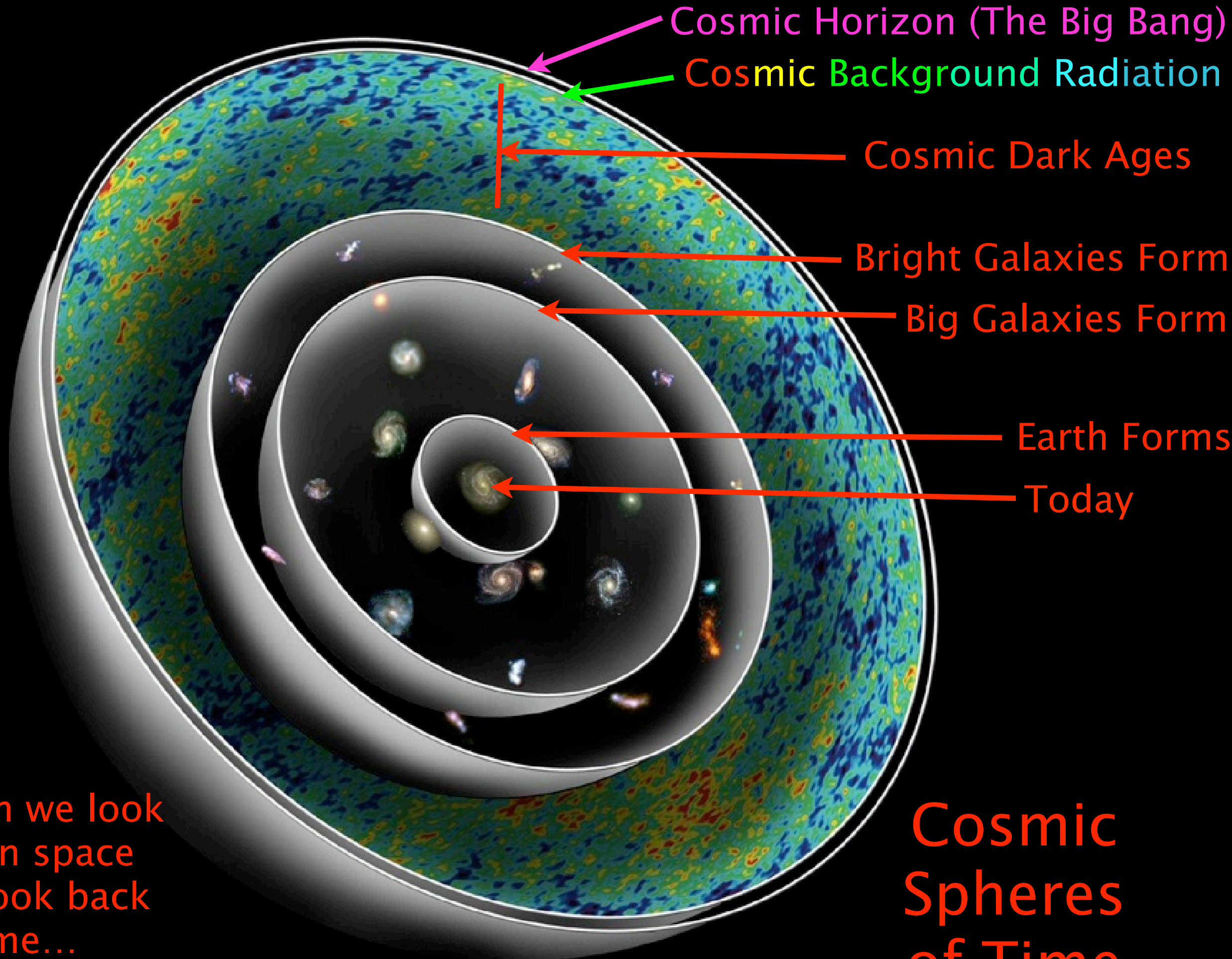
Data Release 4:

565,715 Galaxies & 76,403

Quasars

# GALAXIES MAPPED BY THE SLOAN SURVEY





Cosmic Horizon (The Big Bang)

Cosmic Background Radiation

Cosmic Dark Ages

Bright Galaxies Form

Big Galaxies Form

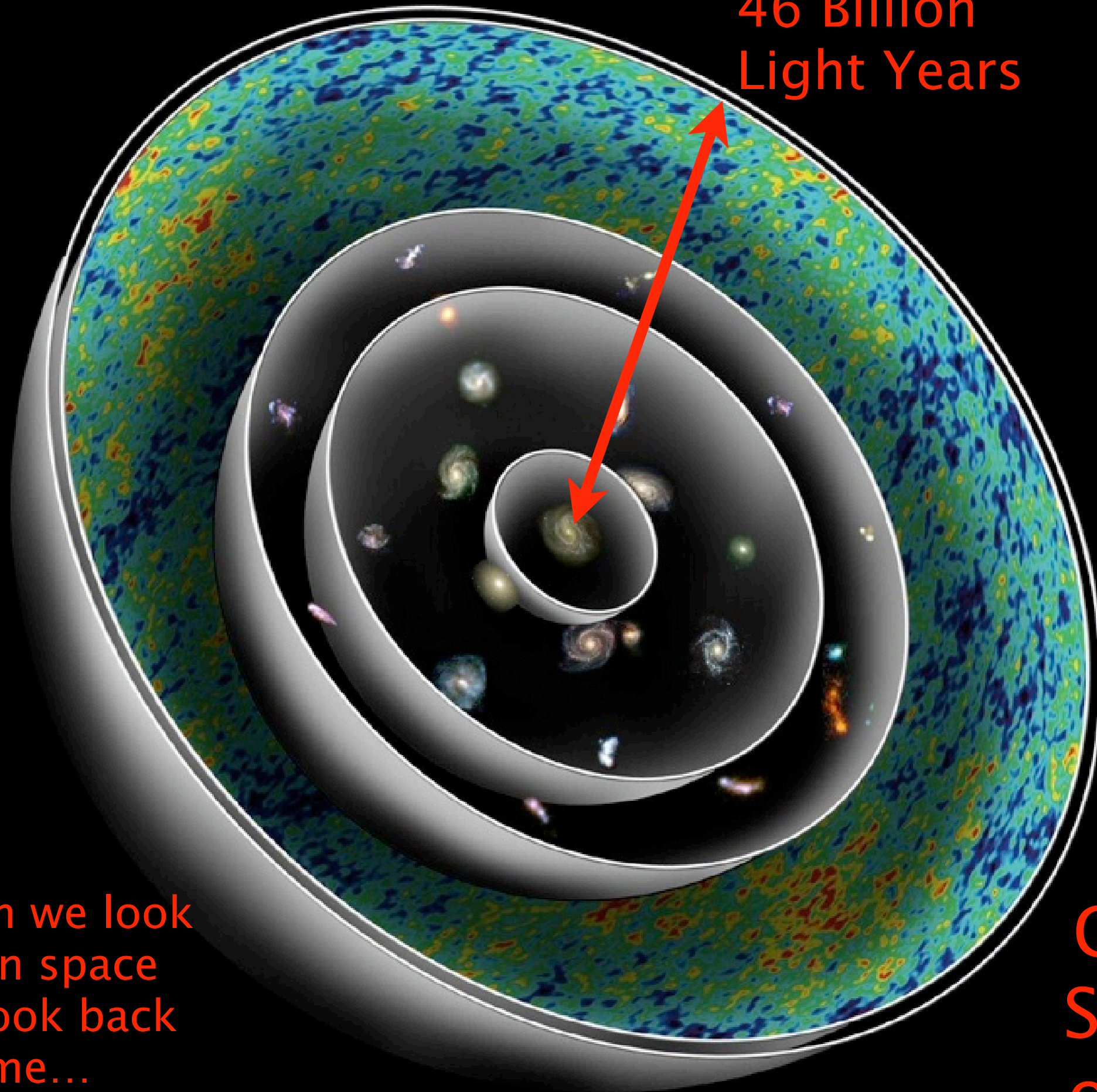
Earth Forms

Today

When we look out in space we look back in time...

Cosmic Spheres of Time

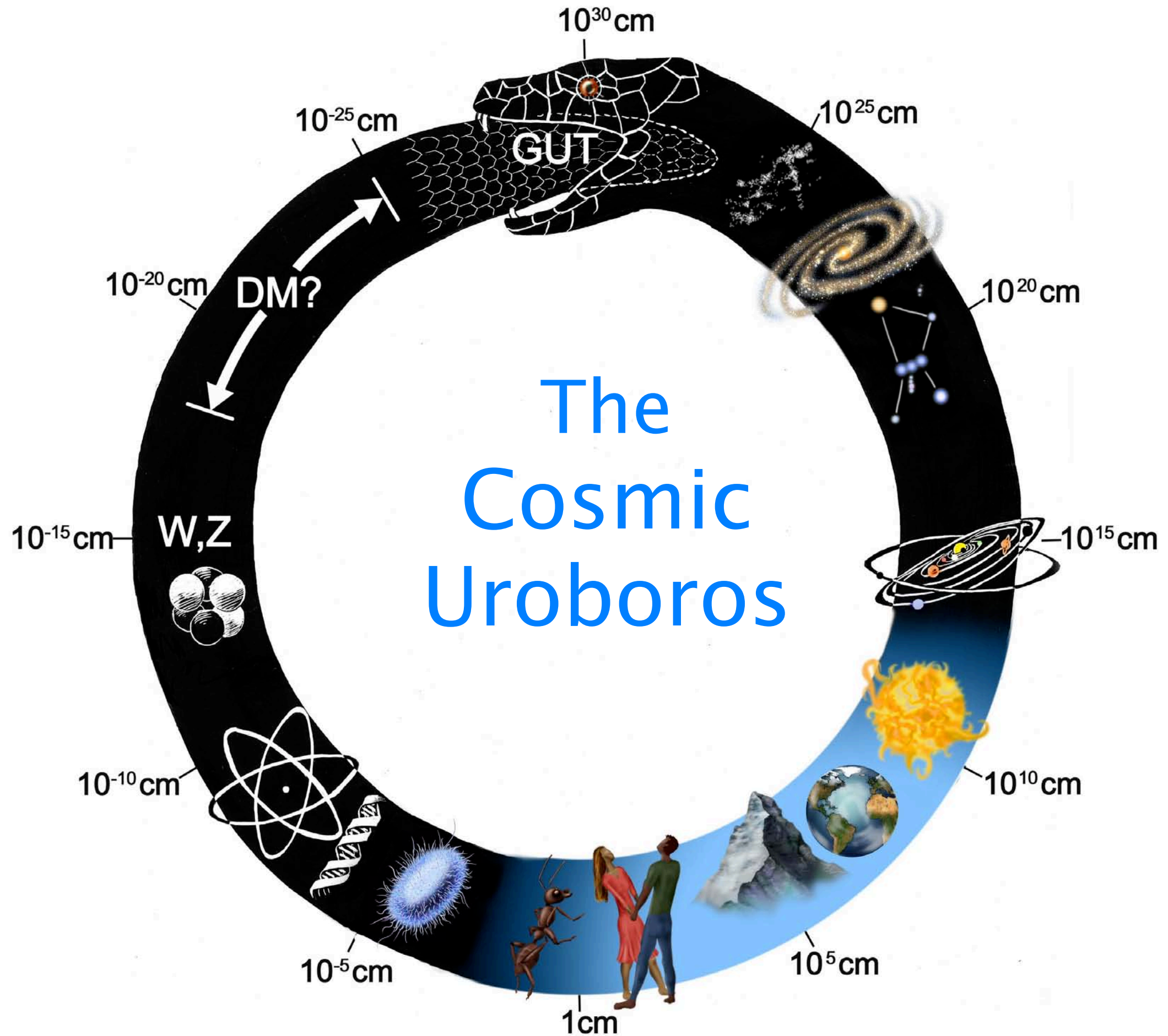
46 Billion  
Light Years



When we look  
out in space  
we look back  
in time...

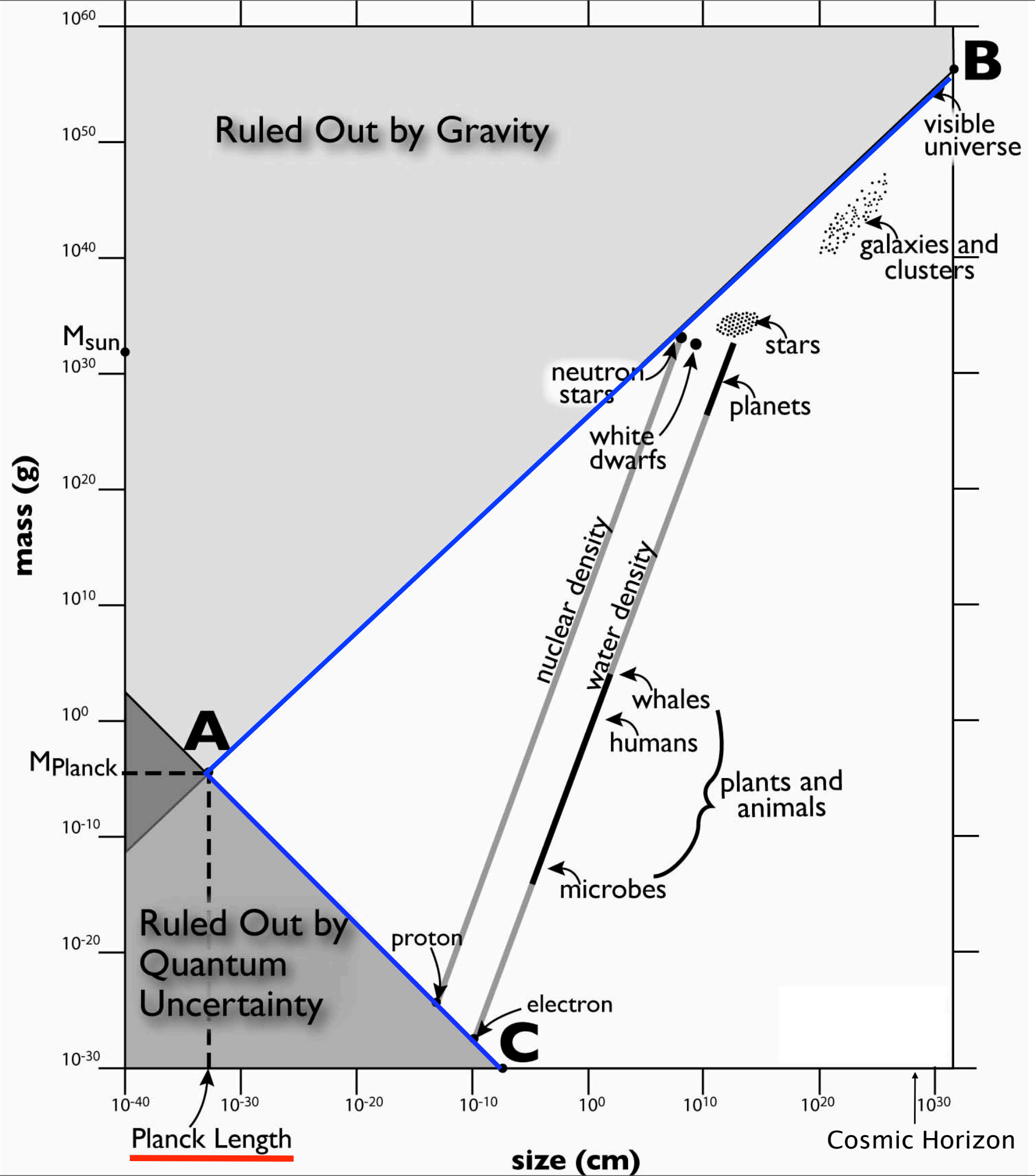
Cosmic  
Spheres  
of Time





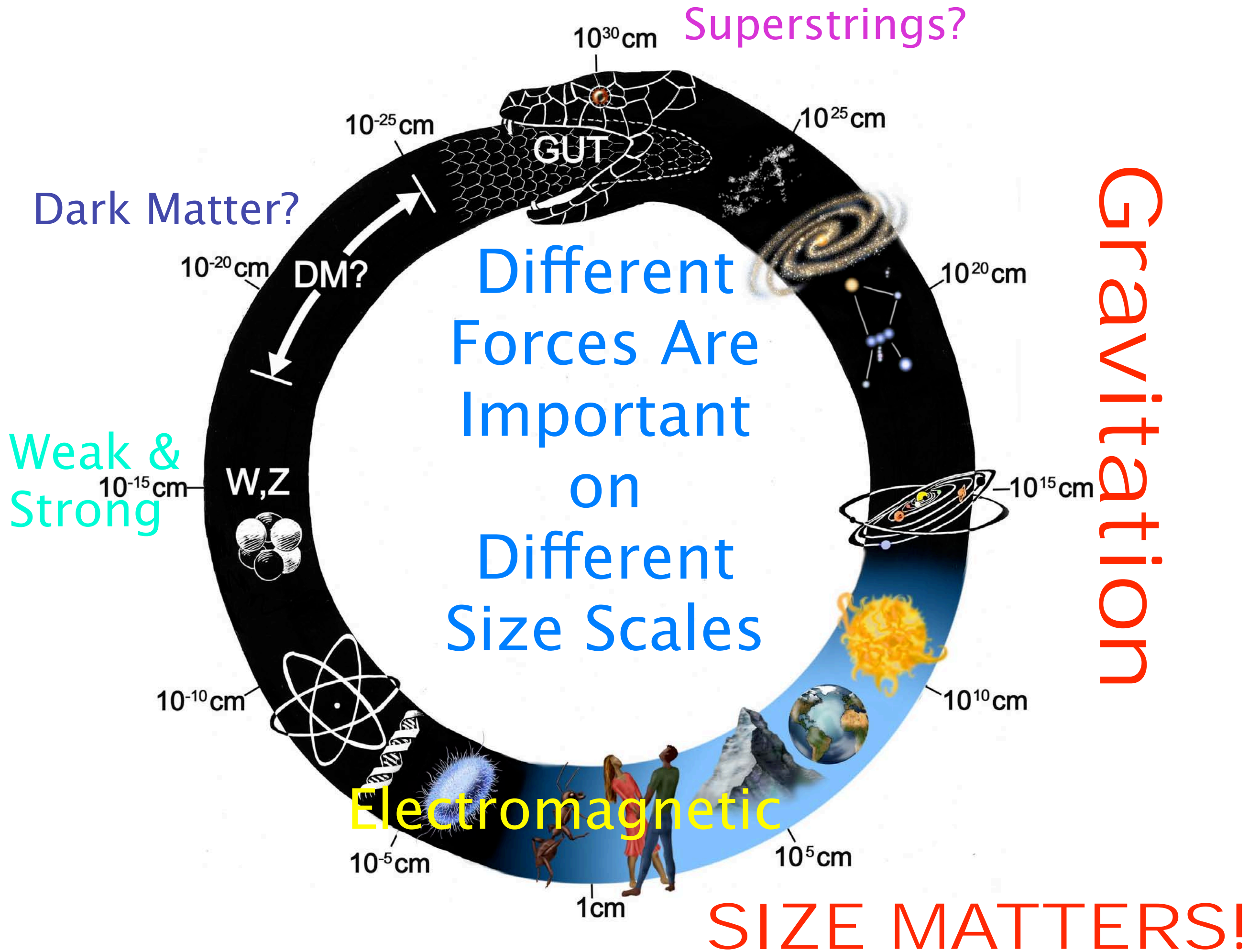
# The Wedge of Material Reality

General Relativity and Quantum Uncertainty  
↓  
a smallest size, the Planck length





Superstrings?



# SIZE MATTERS!

No animal could be 3 times its normal height and stay the same shape, simply scaled up.

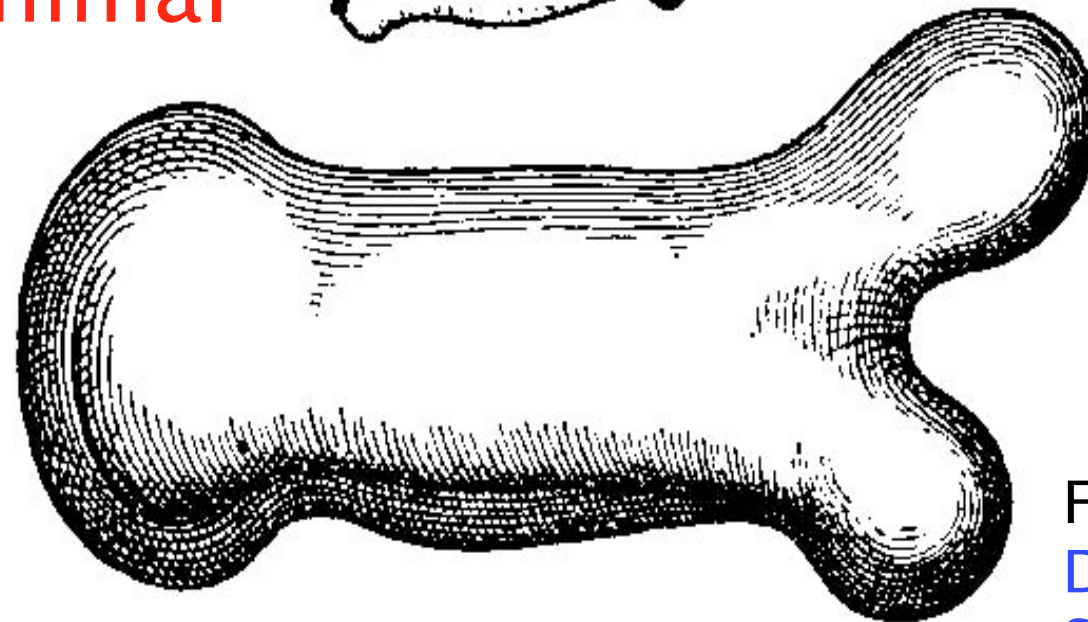
If height increases 3 times,  
strength of bones increases  $3 \times 3 = 9$  times.  
But weight increases  $3 \times 3 \times 3 = 27$  times.  
Its weight would crush its bones!

That is why an elephant does not look like a large gazelle.

Bone of small animal



Bone of  
animal 3  
times longer



From Galileo's last book,  
[Discourses On Two New Sciences](#) (1638).

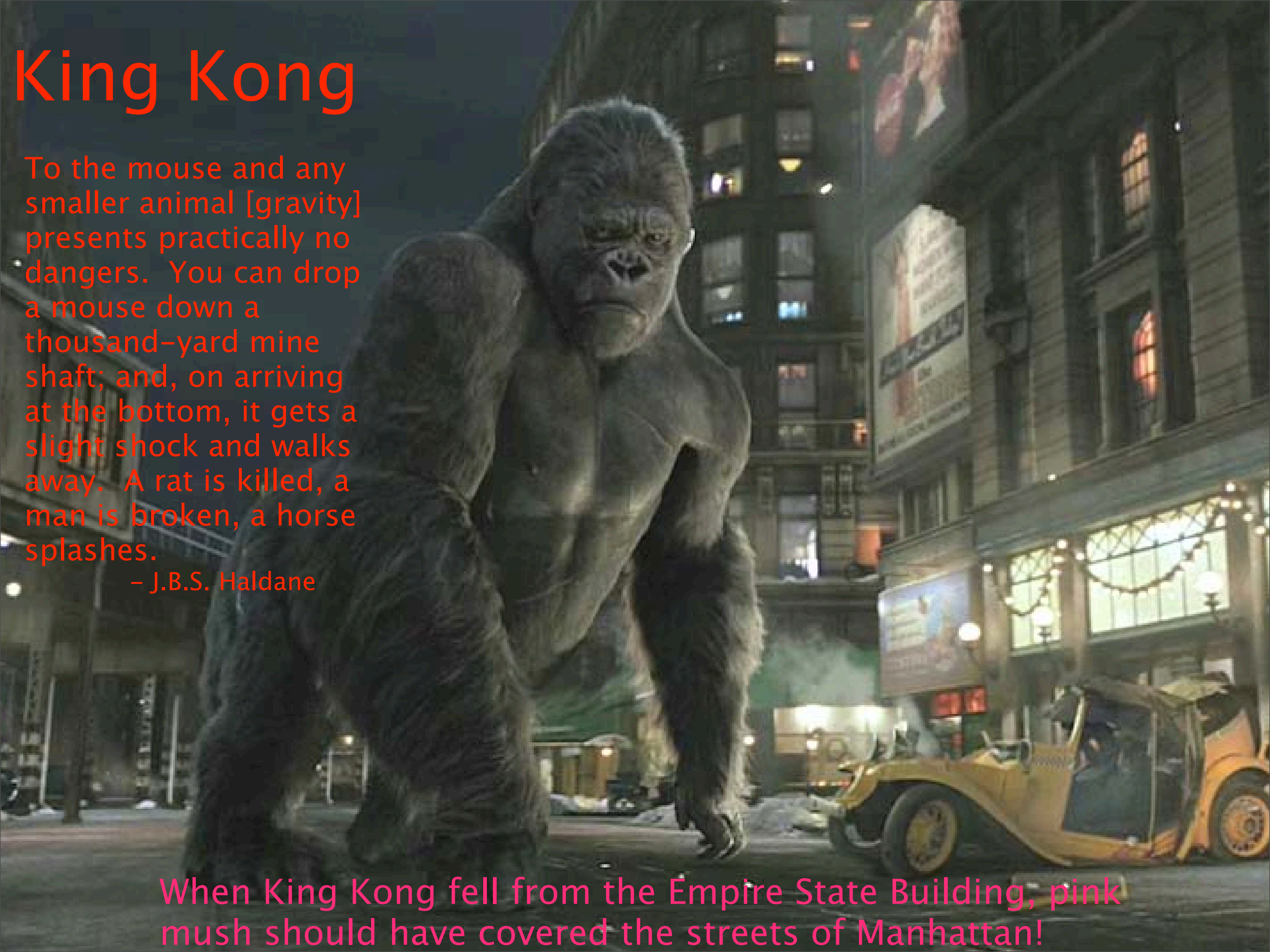


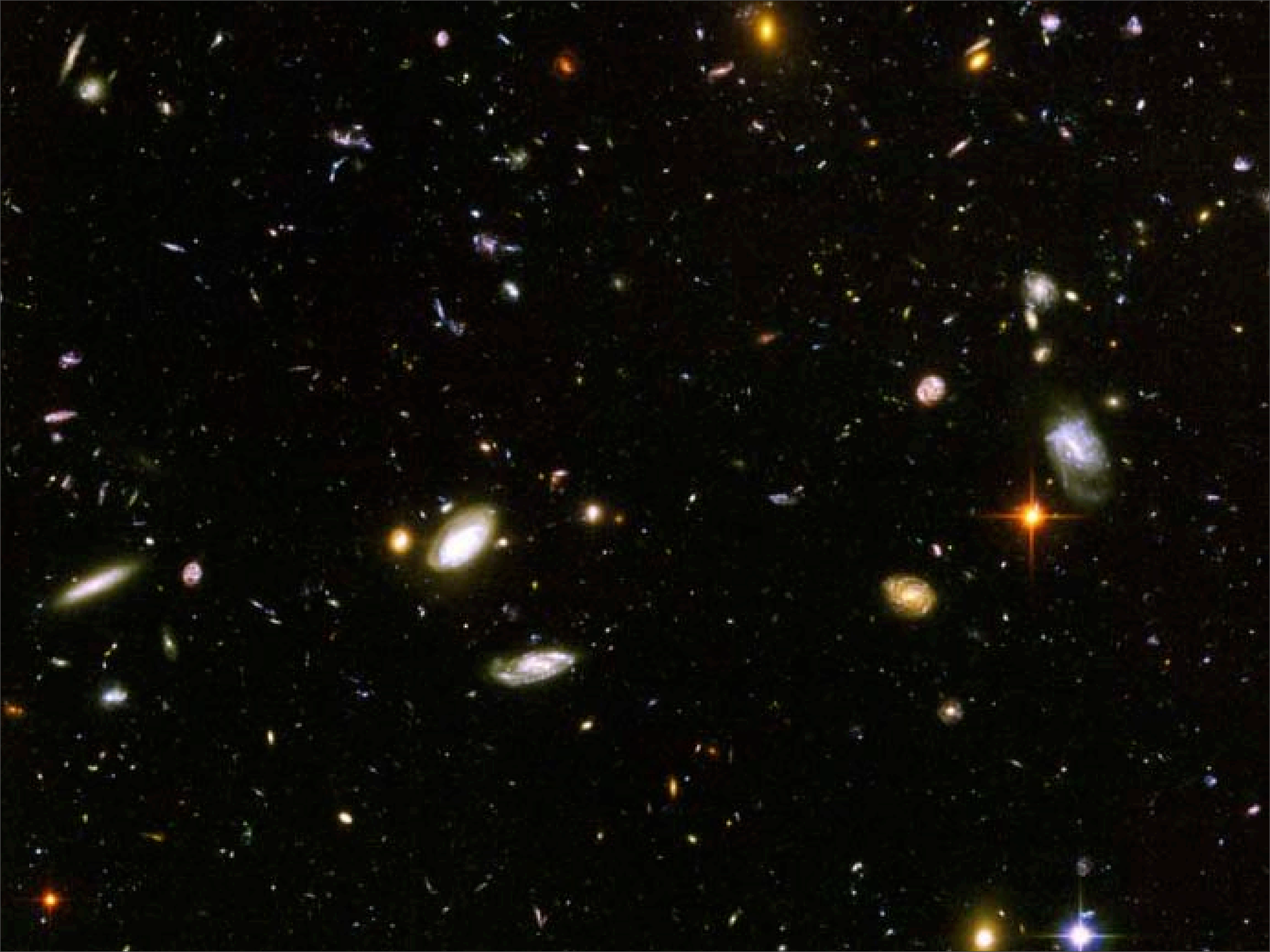
# King Kong

To the mouse and any smaller animal [gravity] presents practically no dangers. You can drop a mouse down a thousand-yard mine shaft; and, on arriving at the bottom, it gets a slight shock and walks away. A rat is killed, a man is broken, a horse splashes.

– J.B.S. Haldane

When King Kong fell from the Empire State Building, pink mush should have covered the streets of Manhattan!







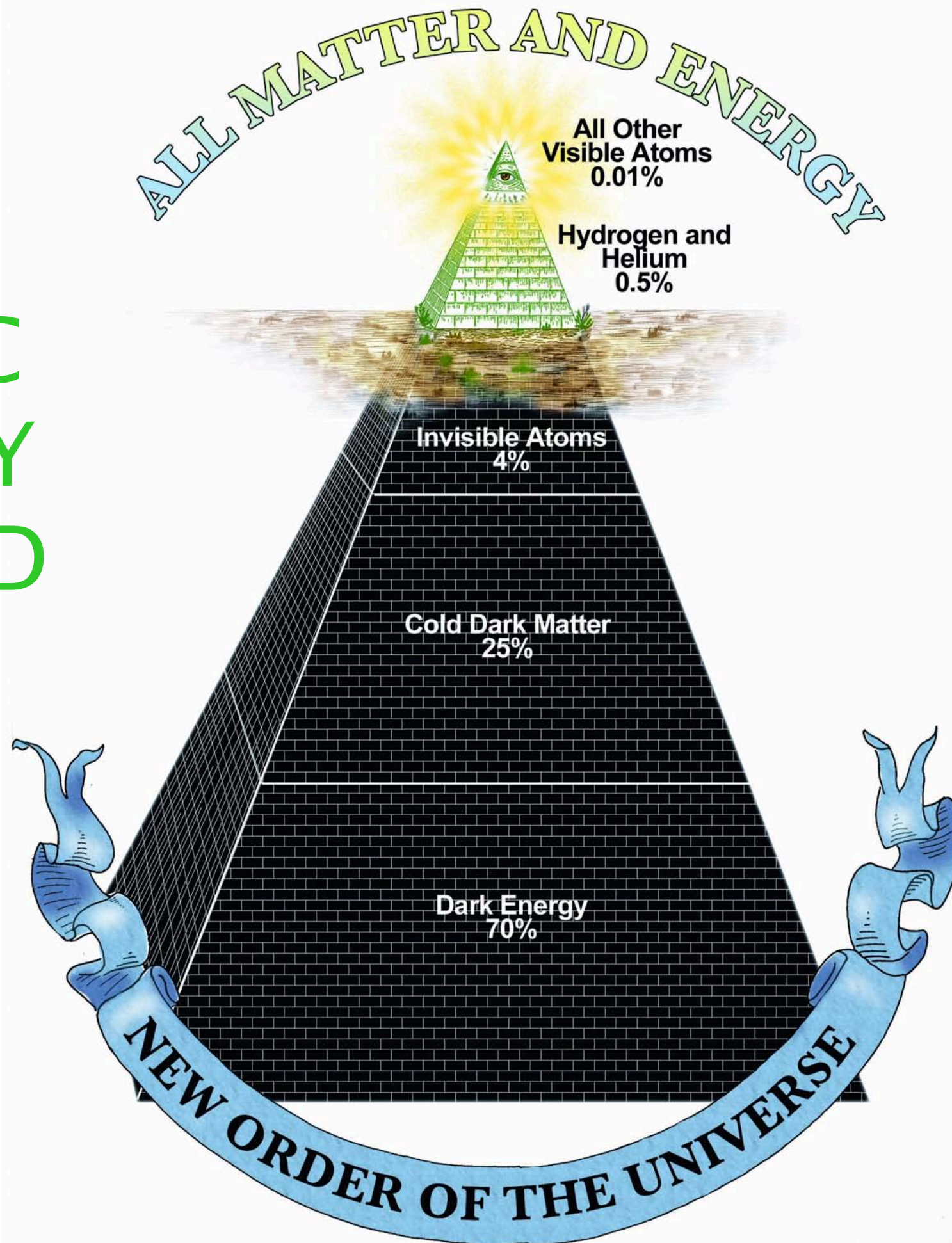


stardust

stars

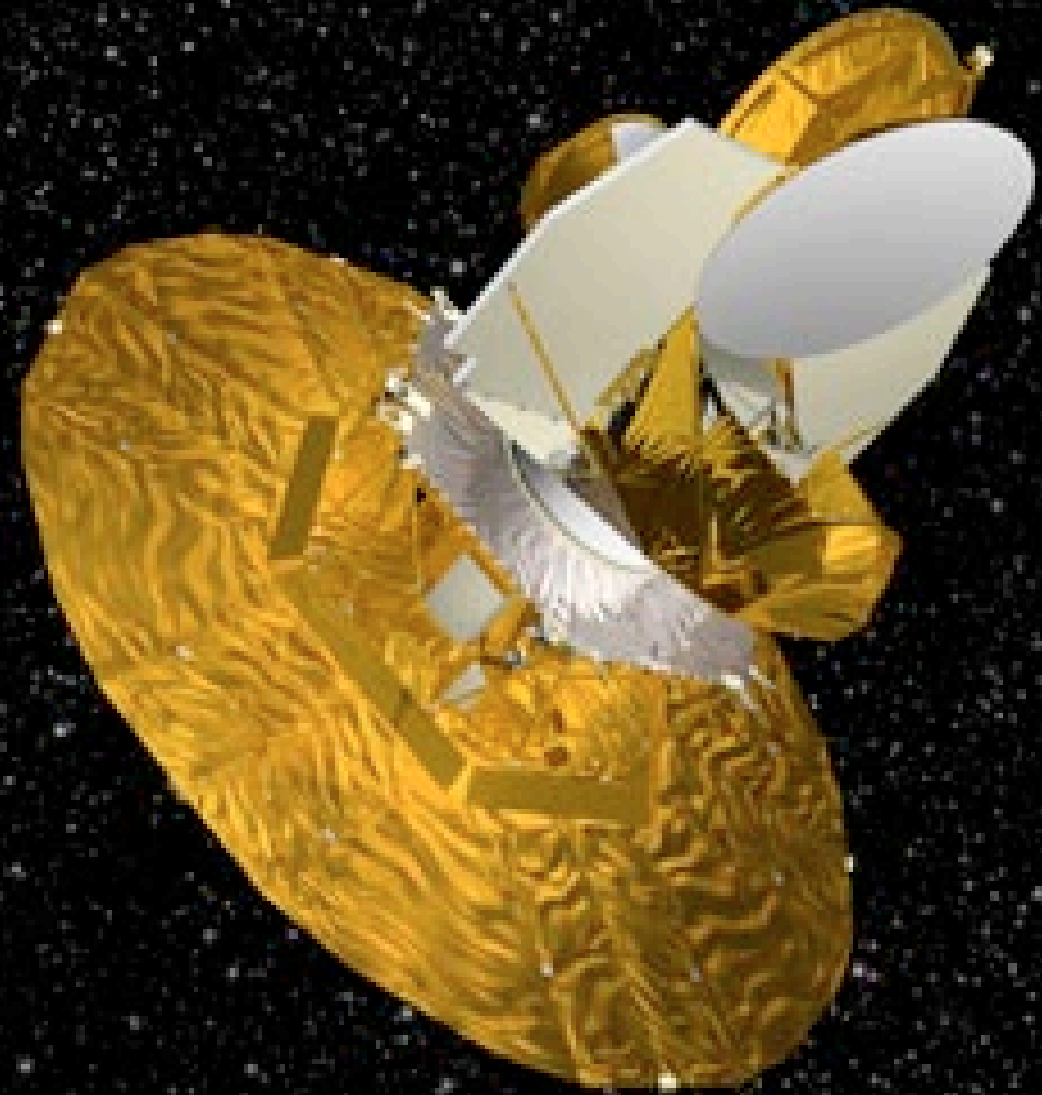


# COSMIC DENSITY PYRAMID



# NASA's WMAP satellite

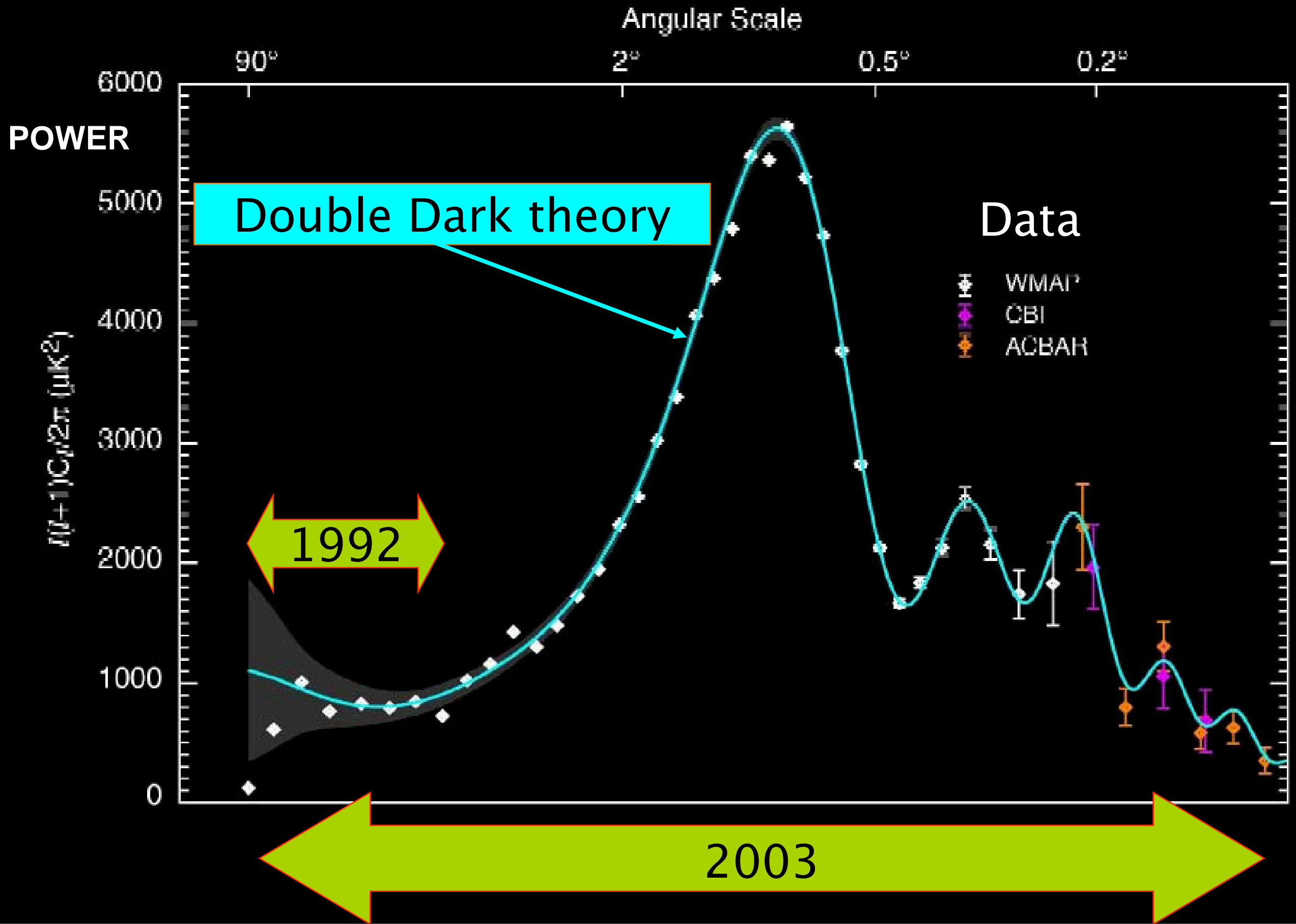
*Wilkinson Microwave Anisotropy Probe*



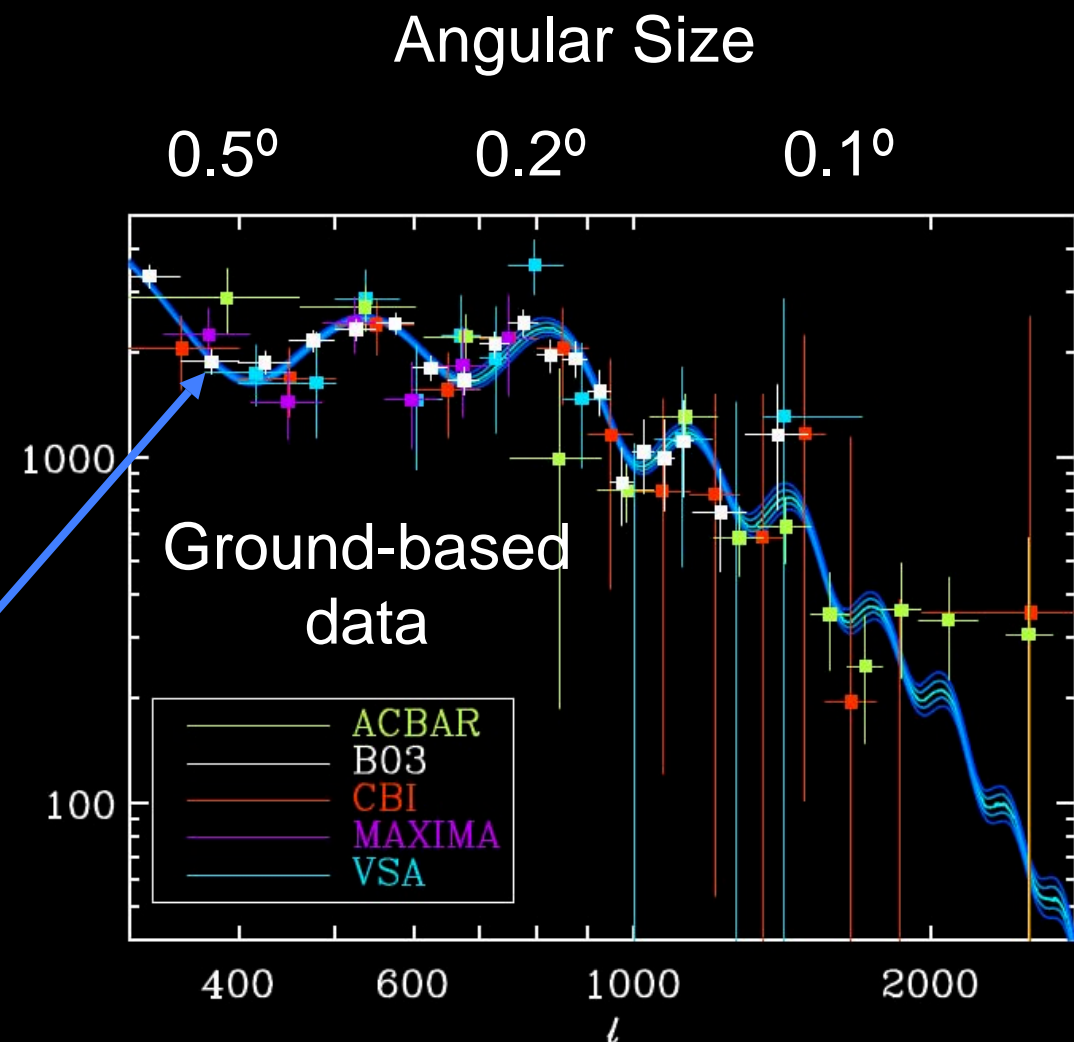
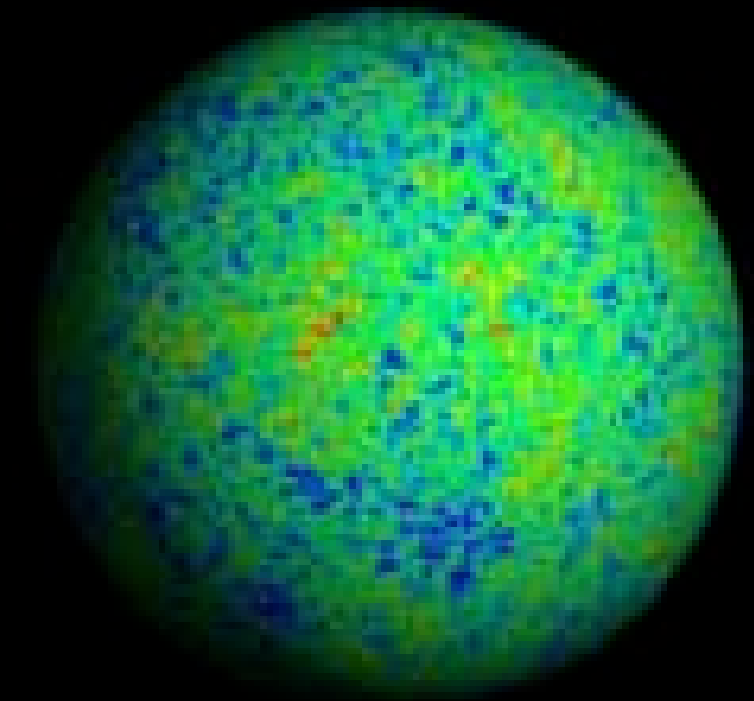
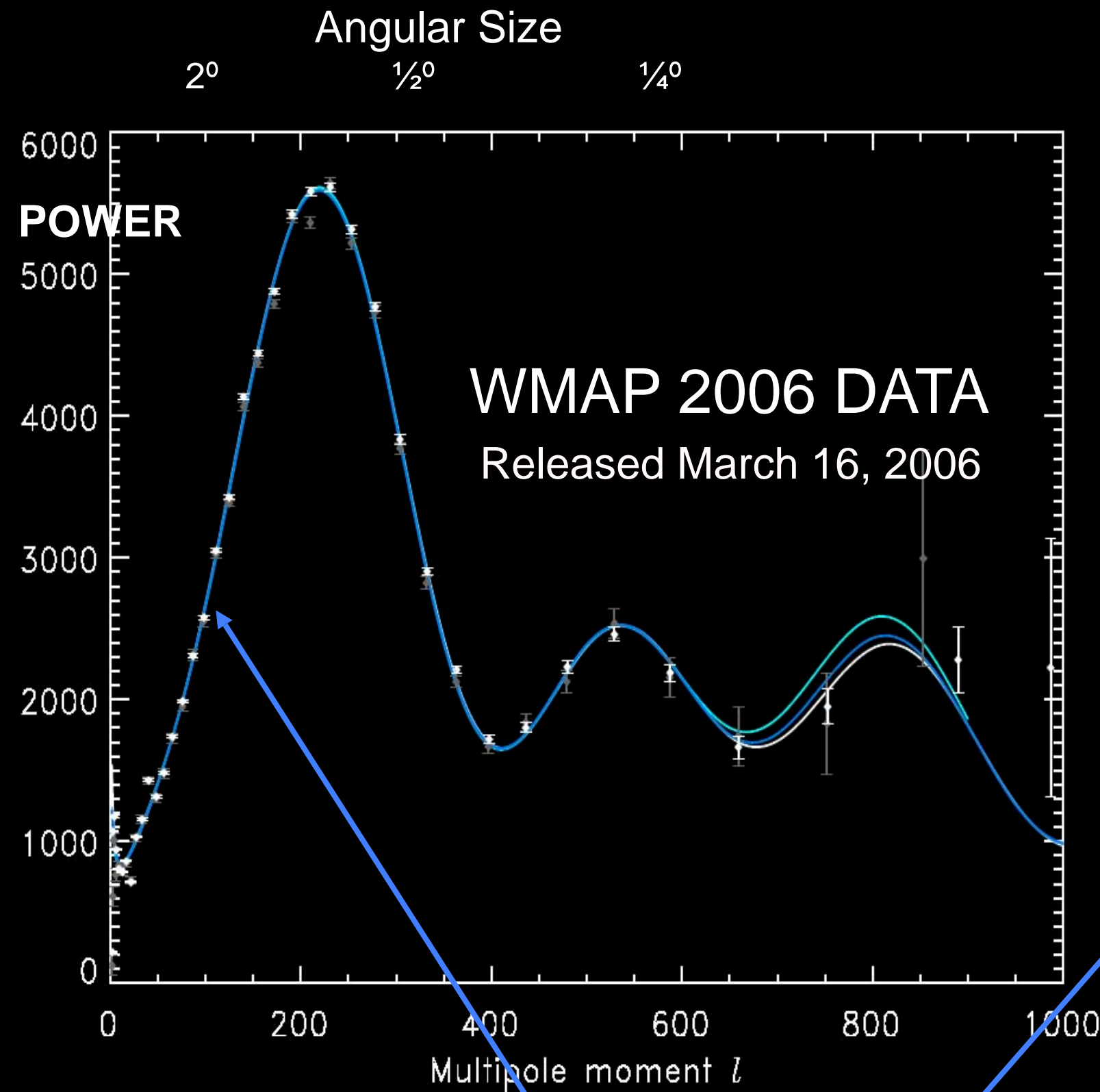
1<sup>st</sup> results reported: March 2003; 2<sup>nd</sup> March 2006



# Big Bang Data Agrees with Double Dark Theory!



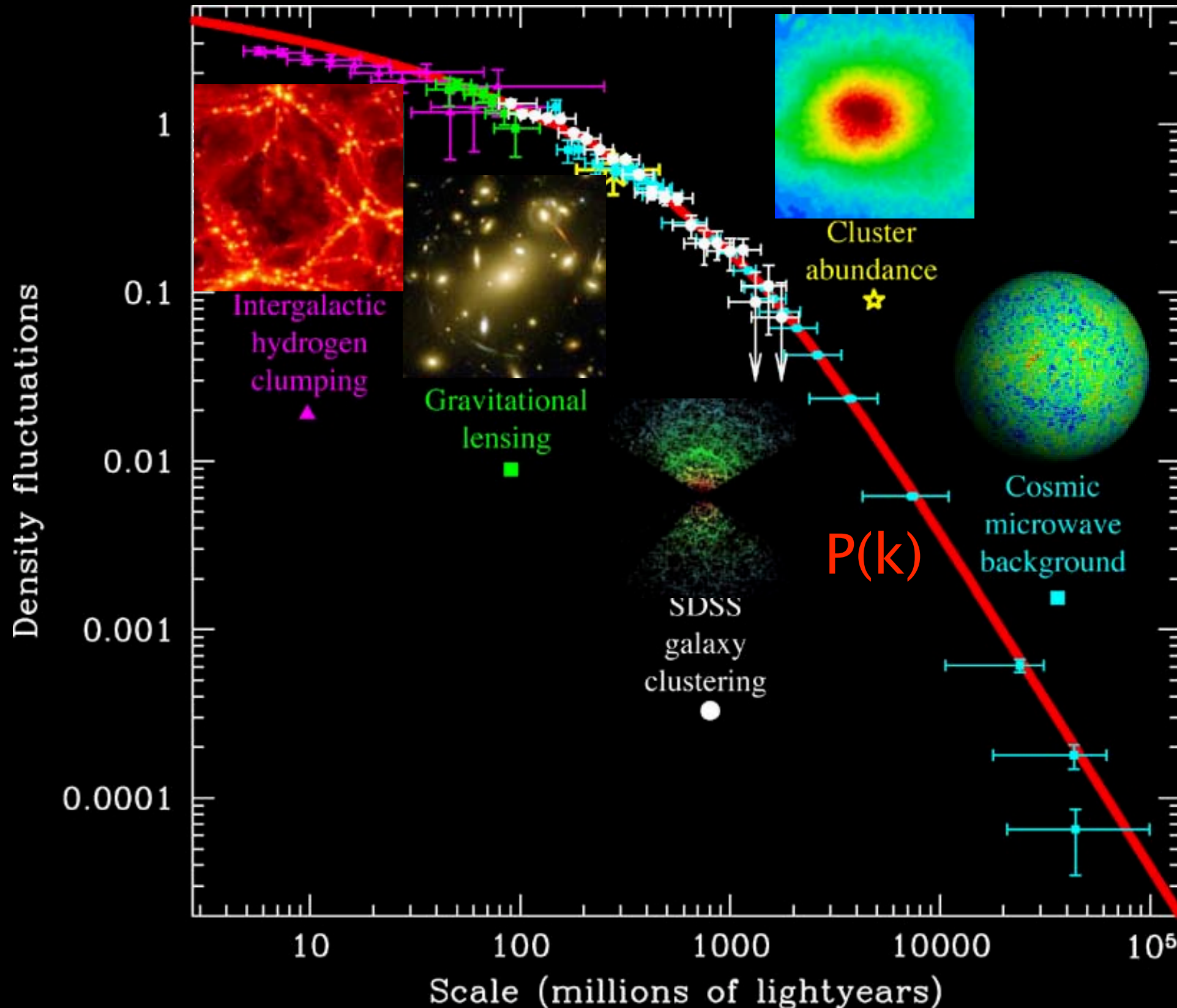
# Latest Big Bang Data Strengthens the Agreement!



**Double Dark theory**

# Distribution of Matter

Also Agrees with Double Dark Theory!





1998 **BREAKTHROUGH OF THE YEAR** 2003

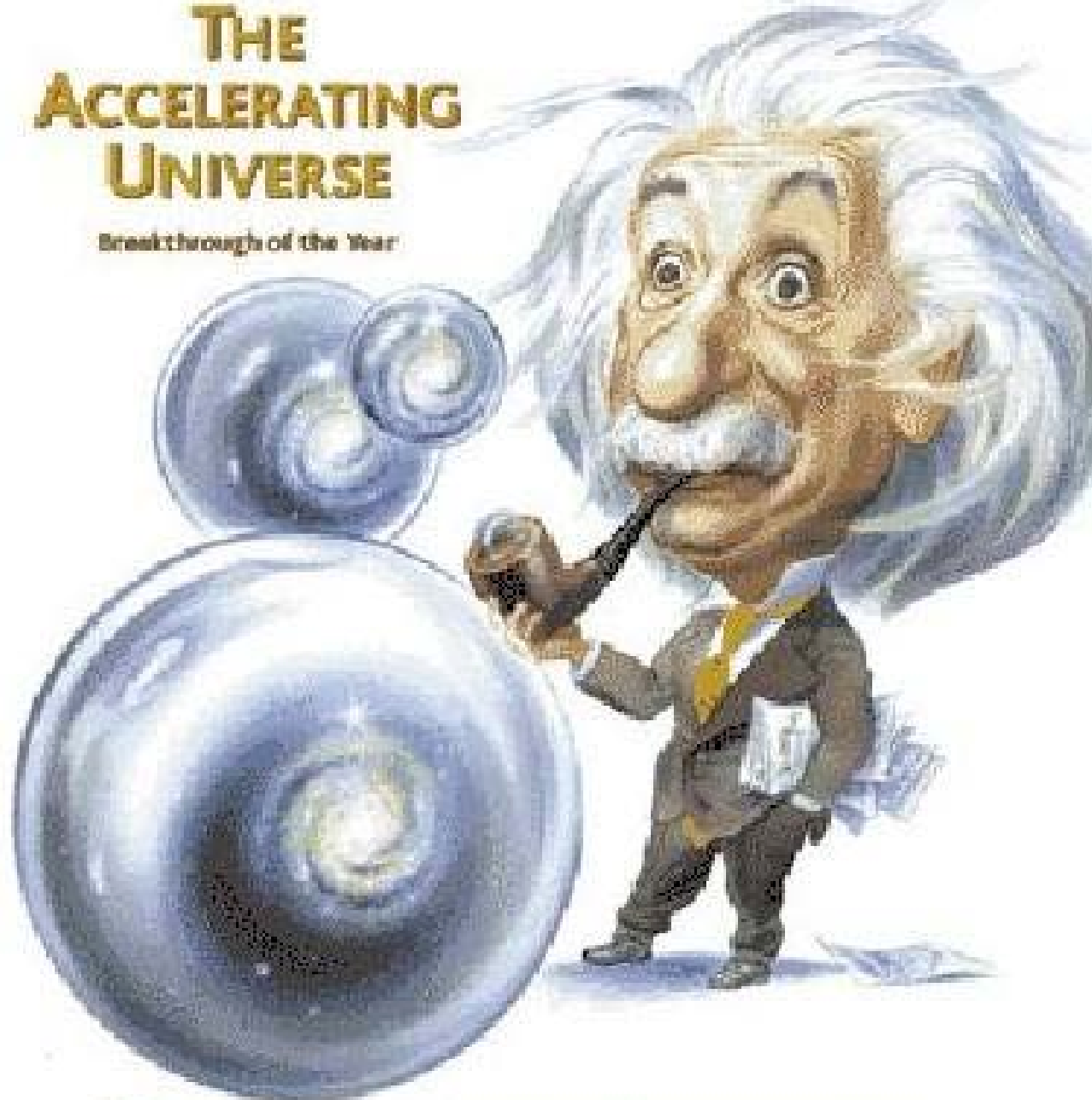
# Science

18 December 1998

Vol. 282 No. 5397  
Pages 2141-2336 \$7

## THE ACCELERATING UNIVERSE

Breakthrough of the Year

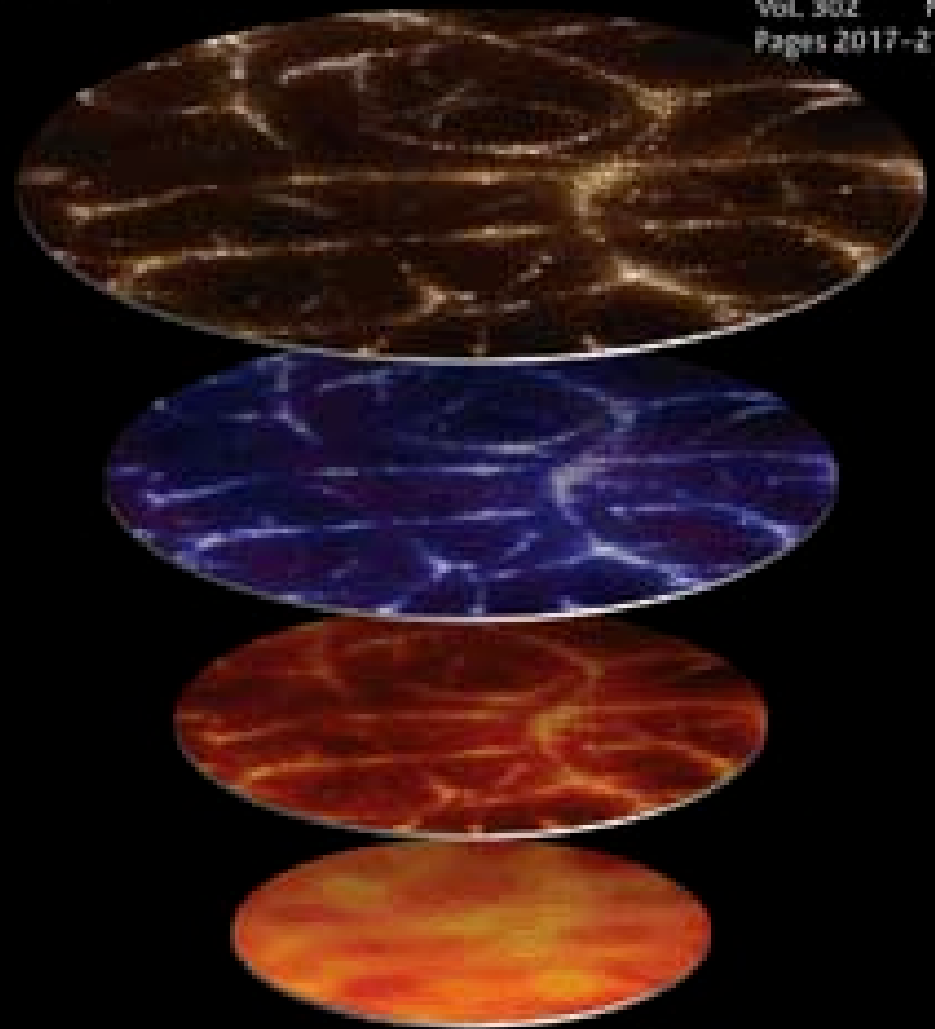


AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

# Science

19 December 2003

Vol. 302 No. 5653  
Pages 2017-2172 \$10



Breakthrough of the Year

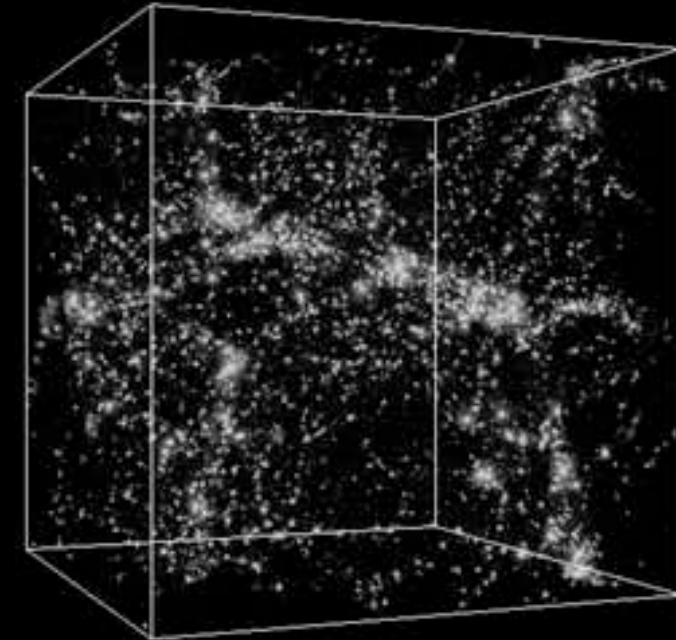
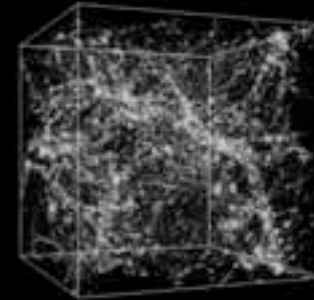
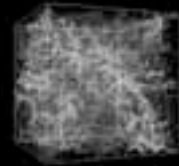
## Cosmic Convergence

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

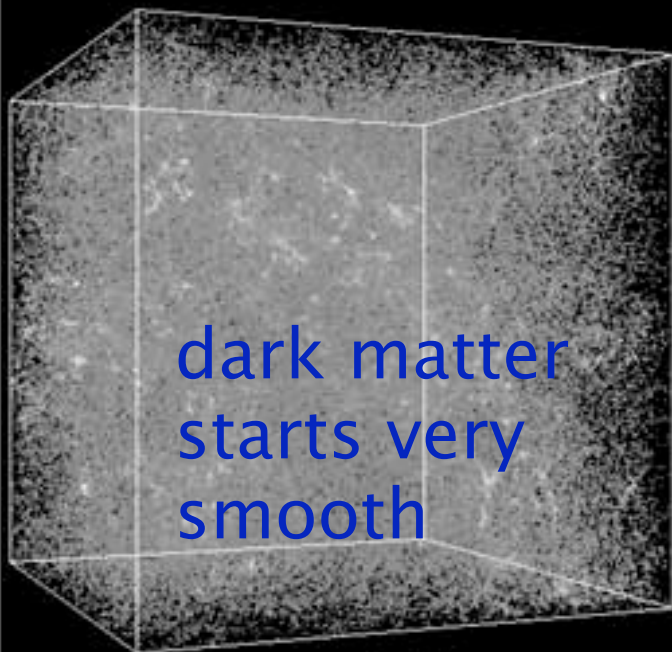


"QUARKS. NEUTRINOS. MESONS. ALL THOSE DAMN PARTICLES  
YOU CAN'T SEE. THAT'S WHAT DROVE ME TO DRINK.  
BUT NOW I CAN SEE THEM!"

# dark matter simulation – expanding with the universe



# same simulation – not showing expansion



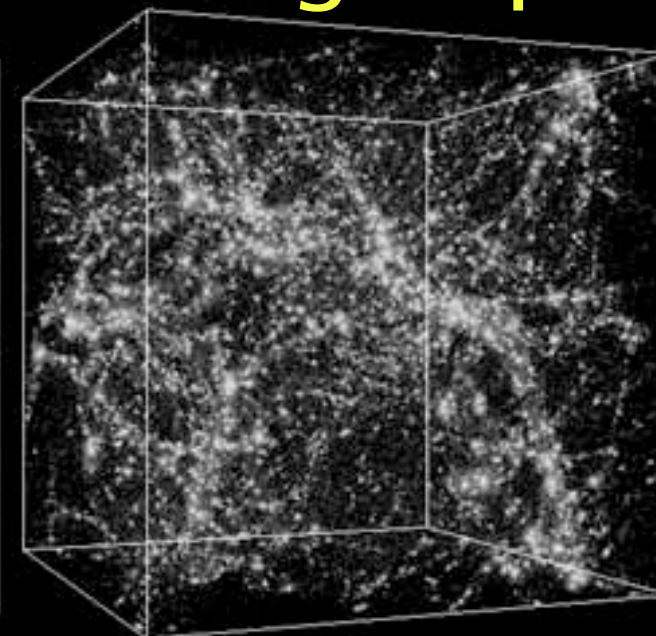
dark matter starts very smooth

0.5

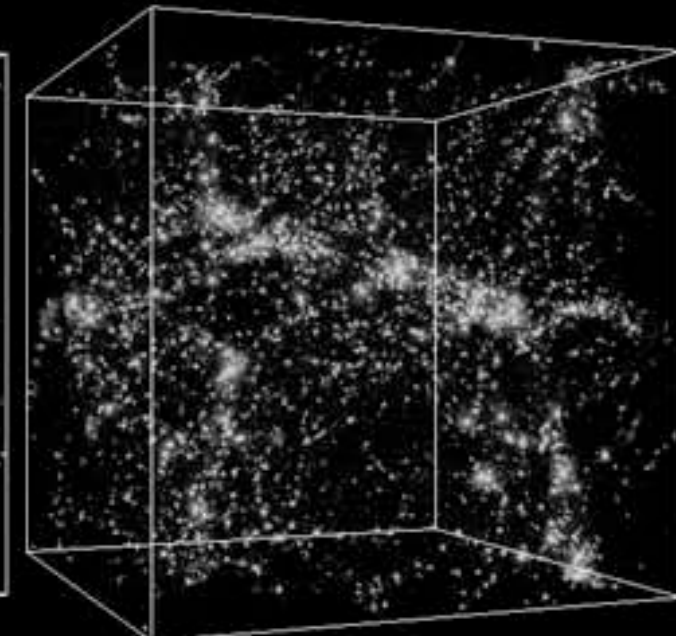


... but is attracted to the wrinkles in space

2.1



5.7



13.5

Billions of years after the Big Bang



# Double Dark Simulation

Rotation is to show 3-D shapes

Yellow marks dense regions  
where galaxies are forming

Dark  
Matter  
Simulation

Columbia  
Super-  
Computer

NASA  
Ames  
Laboratory

CLOCK



Billion  
years ago **13.3960**





Columbia  
Super-  
Computer

# FORMATION OF THE DARK MATTER HALO OF A BIG GALAXY LIKE THE MILKY WAY

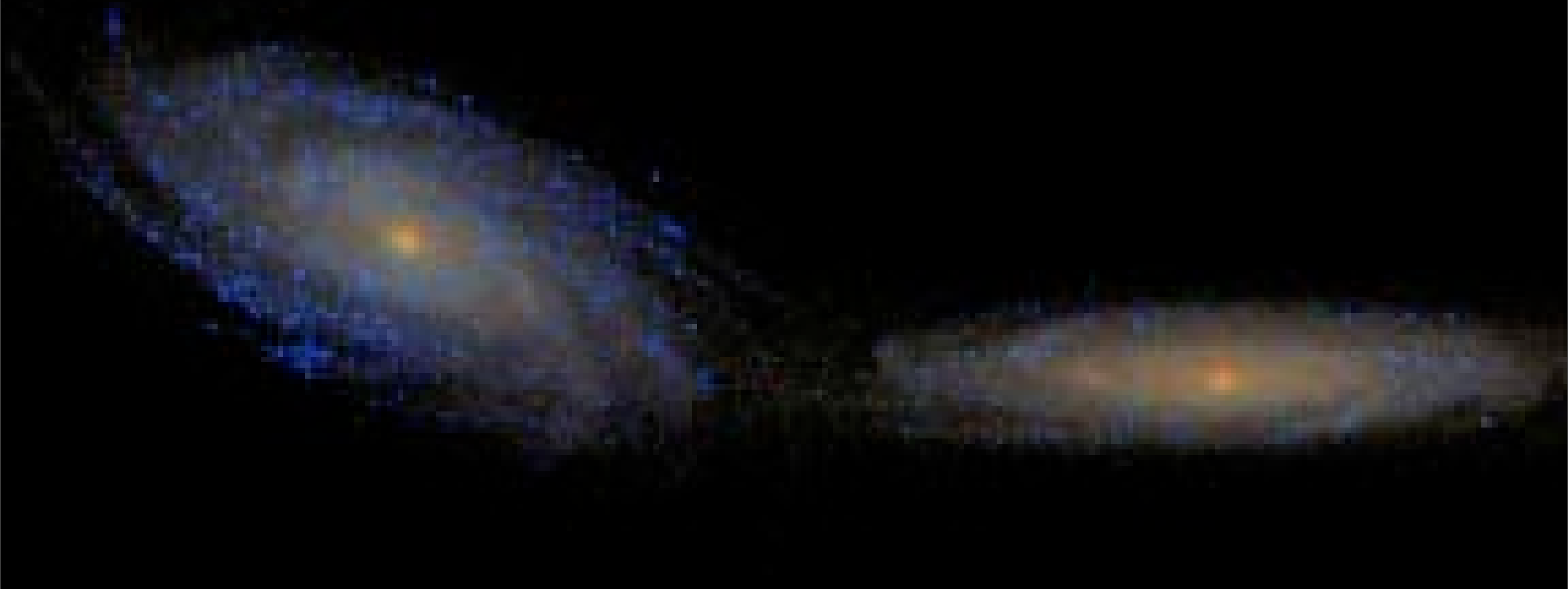
Zoom-In  
of  
Dark  
Matter  
Simulation:

Columbia  
Super-  
Computer

NASA  
Ames  
Laboratory

# Galaxy Merger Simulation

run on the Columbia Supercomputer



This image and the following video show a merger between two Sbc galaxies, each simulated with 1.7 million particles. The images are realistic color composites of u, r, and z-band images. Galaxy mergers like this one trigger gigantic “starbursts” in which millions of stars form. But dust absorbs about 90% of the light, and reradiates the energy in the far infrared. We calculate this “radiative transfer” using  $\sim 10^6$  light rays per image.



# Galaxy Merger Simulation

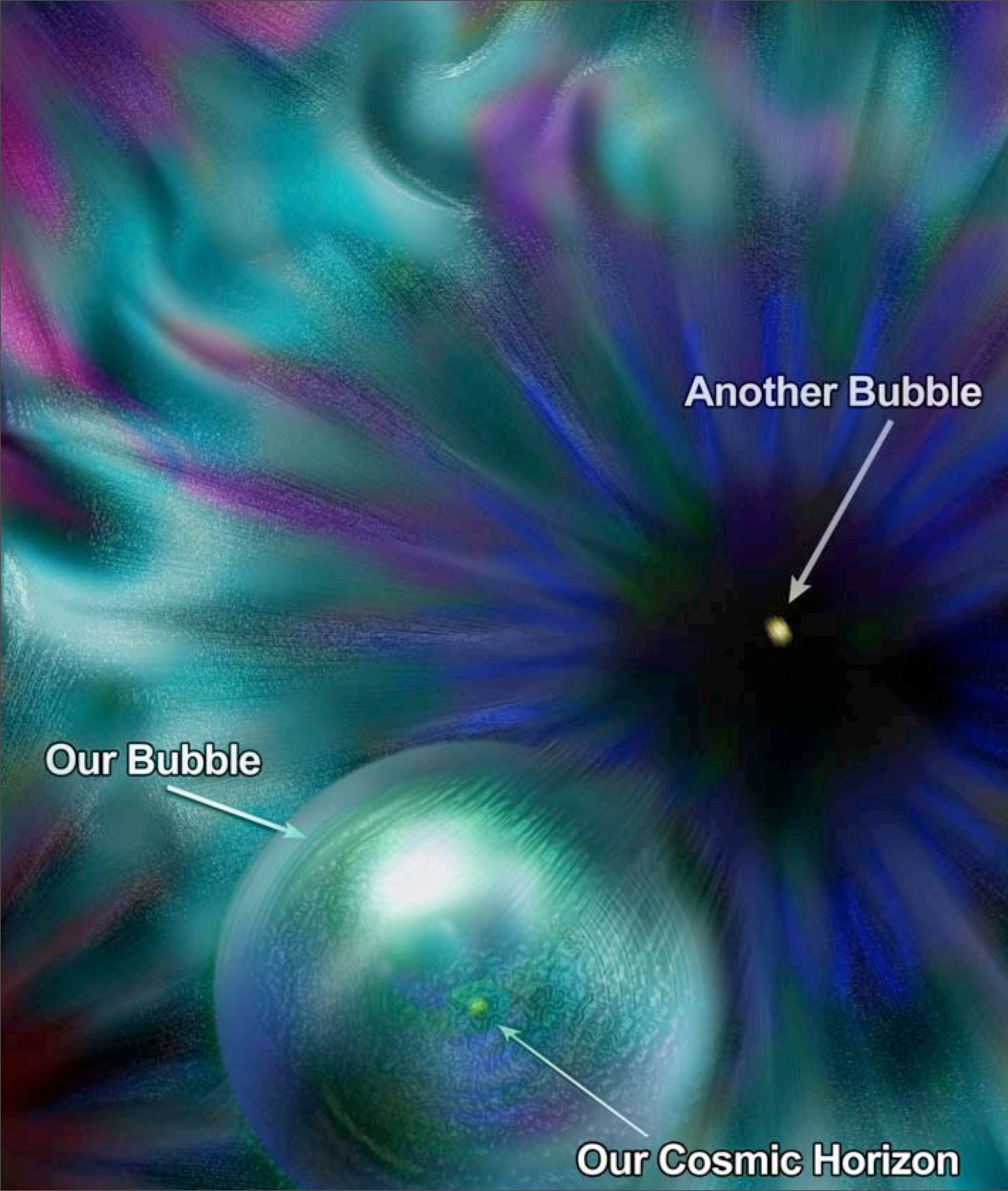
run on the Columbia Supercomputer

What happened before  
the Big Bang?

No one knows!  
But there is a favorite  
theory...

ETERNAL INFLATION

# OUR COSMIC BUBBLE IN ETERNAL INFLATION





# THE COSMIC LAS VEGAS

Coins constantly flip. Heads, and the coin is twice the size and there are two of them. Tails, and a coin is half the size.

Consider a coin that has a run of tails. It becomes so small it can pass through the grating on the floor.



At the instant it passes through the floor, it exits eternity.

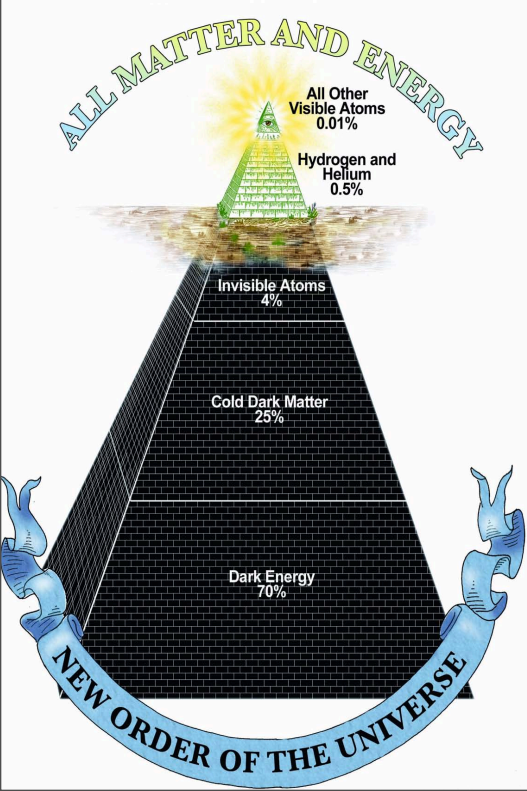
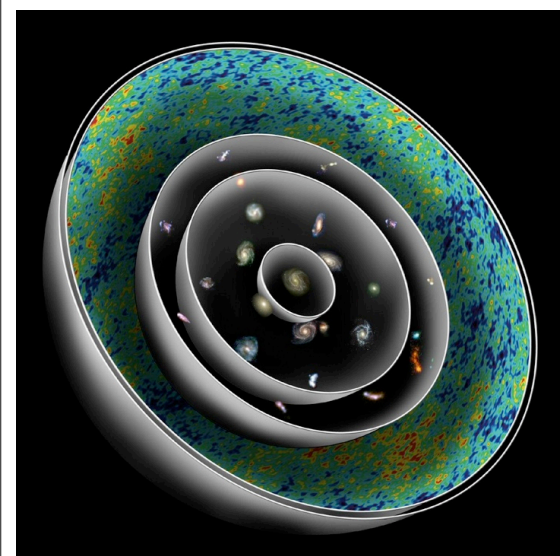


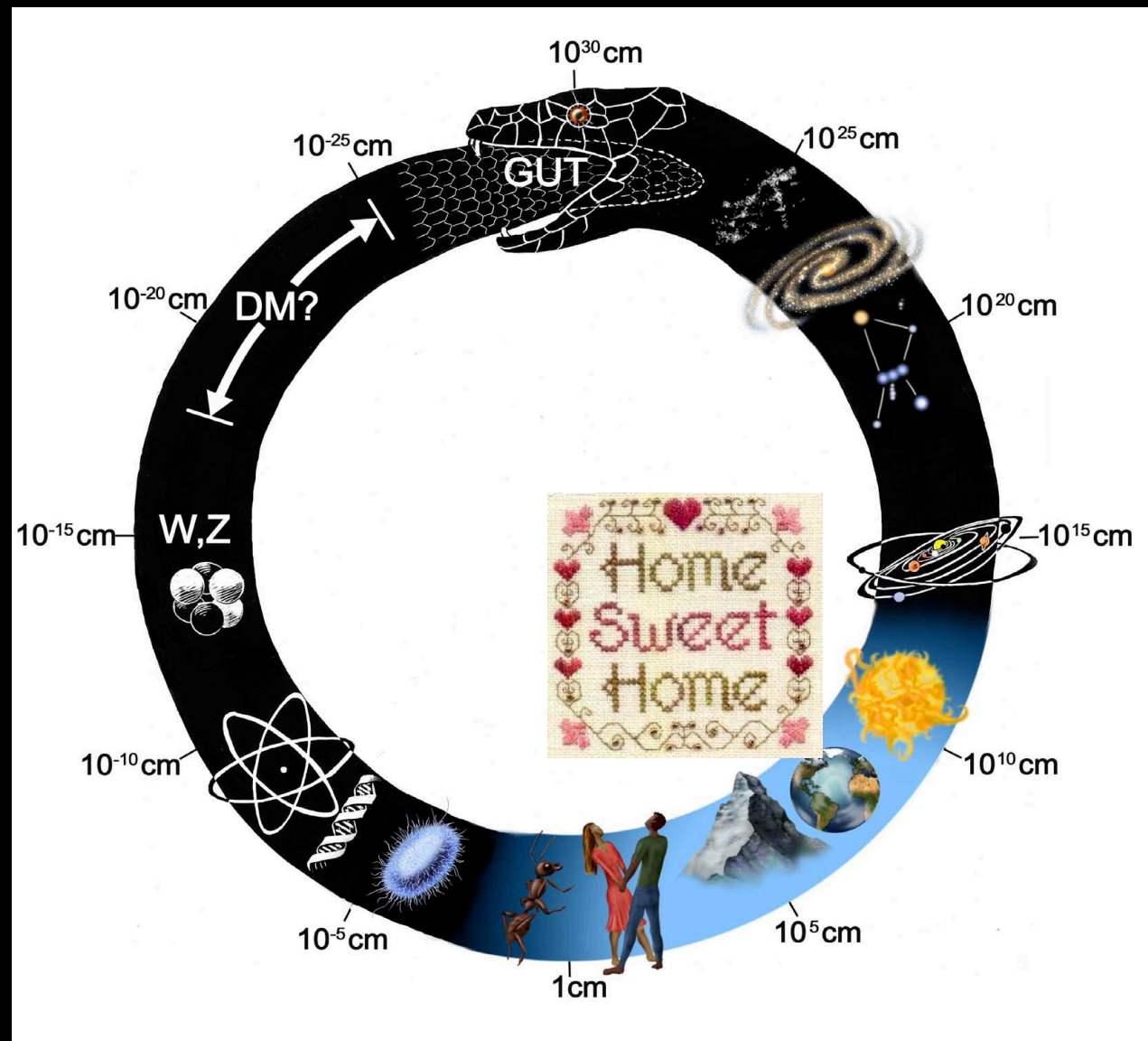
Time begins with a Big Bang, and it becomes a universe and starts evolving.

Human beings are central to the Universe not in a simple geographic sense but in at least six different ways all of which follow directly from astronomy and physics.

1) We live at the center of our Cosmic Spheres of Time. The finite speed of light makes this inevitable.

2) We are made of the rarest stuff in the universe: stardust.





3) We live at the middle of all possible sizes – in Midgard, where the possibility of tremendous variety and complexity coming in small packages keeps life interesting. Life of our complexity could bloom nowhere else on the Cosmic Uroboros.





4) We live in a universe that may be a rare bubble of spacetime in the infinite, seething cauldron of the eternal superuniverse. Outside our unique and isolated bubble, which we call the Big Bang, there is neither space nor time as we know it. But here inside there is time for evolution and history, and there is space across which connections can form and structures can develop.

5) We live at the midpoint of time, which is also the peak moment in the entire evolution of the universe for astronomical observation. The most distant galaxies – which we have just acquired the ability to see – are beginning to disappear over the cosmic horizon now that the expansion of the universe has begun to accelerate.

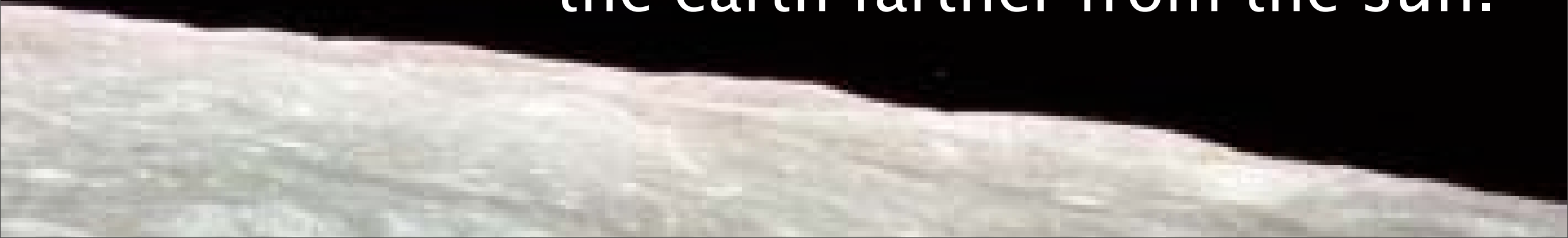


6) We live at the midpoint in the life of our planet. It formed, along with the sun and the other planets,

about four and a half billion years ago. It has about six billion years to go before it is roasted when our sun swells into a red giant star.

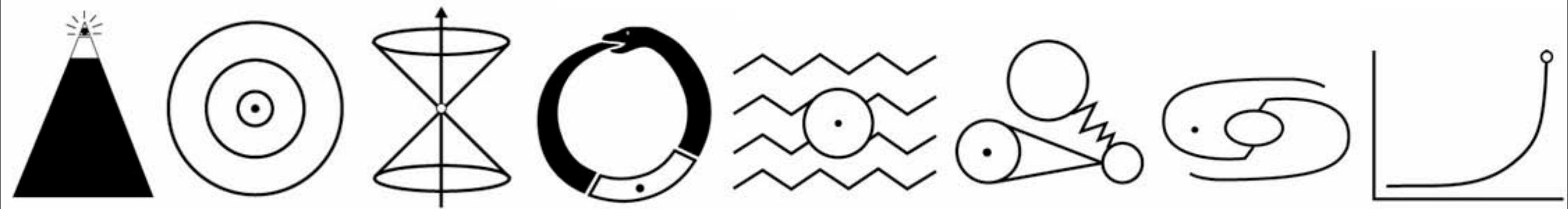
Complex life evolved about half a billion years ago, and has about half a billion years to go until the warming sun overheats the earth.

Or billions of years if our descendants move the earth farther from the sun.





# A new scientific cosmology is emerging today.



In each of the icons above, the point represents our central or special place in the cosmos.

How will a new picture of the universe at the turn of the 21st century affect global culture? Can the new cosmos provide new metaphors and inspire us to approach global problems in new ways?

DISCOVERING OUR  
EXTRAORDINARY PLACE  
IN THE COSMOS

THE VIEW  
*from the*  
CENTER  
*of the*  
UNIVERSE

JOEL R. PRIMACK *and* NANCY ELLEN ABRAMS

extras and enhancements at  
[http://  
ViewfromtheCenter.com](http://ViewfromtheCenter.com)



Penguin Group

**Riverhead Books**



# Videos:

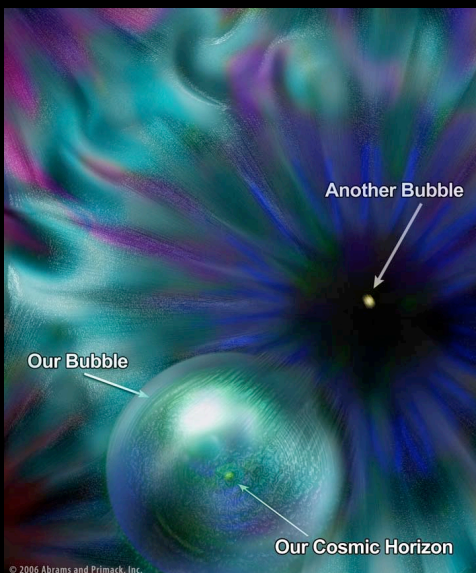
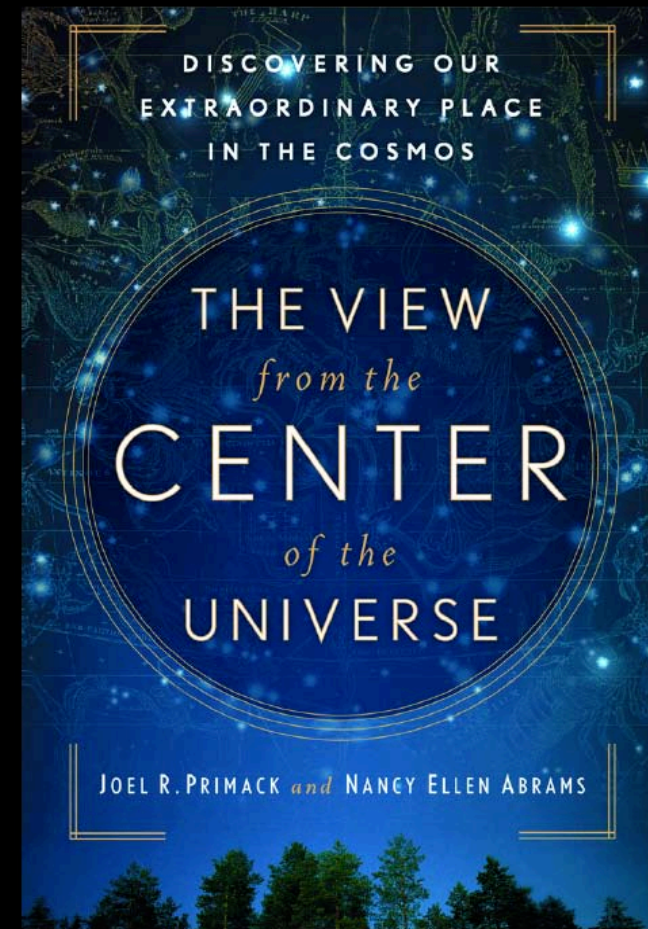
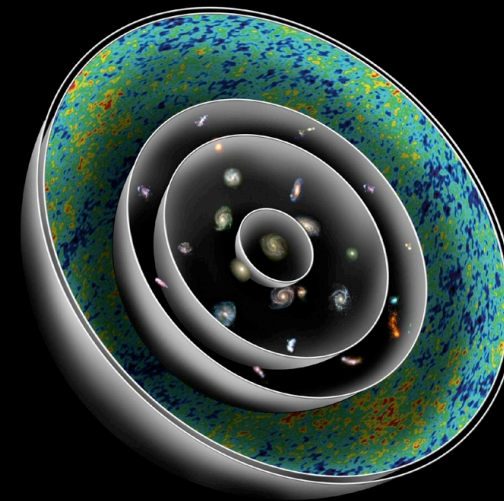
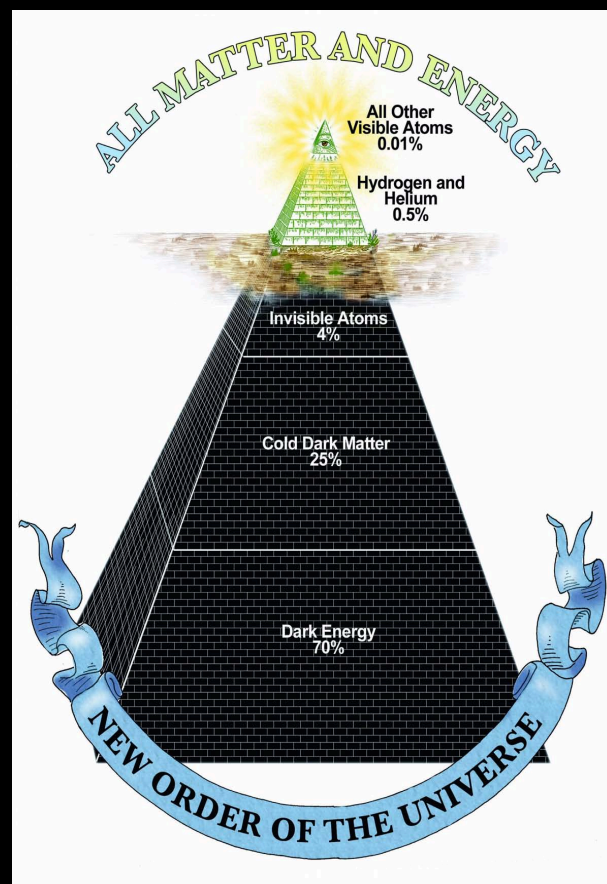
Voyage to Virgo Cluster – [www.ifa.hawaii.edu/~tully](http://www.ifa.hawaii.edu/~tully)  
 Hubble UDF zoom-in – Summers – [Hubblesite.org](http://Hubblesite.org)  
 SDSS map galaxies – [astro.uchicago.edu/cosmus](http://astro.uchicago.edu/cosmus)  
 LCDM simulation – Allgood & Henze, NASA Ames  
 – [people.nas.nasa.gov/chenze/Brandon](http://people.nas.nasa.gov/chenze/Brandon)  
 Galaxy Merger Simulation – Novak & Jonsson

# Credits

# Music:

Nancy Abrams  
 R. Carlos Nakai  
 Nancy Abrams  
 R. Stoltzman/  
 C. Debussy  
 Nancy Abrams

## Symbolic Images of the Cosmos: Cosmic Density Pyramid      Spheres of Time



### Our Bubble

LINKS and IMAGES  
 are at our website  
<http://>

**ViewfromtheCenter.com**