

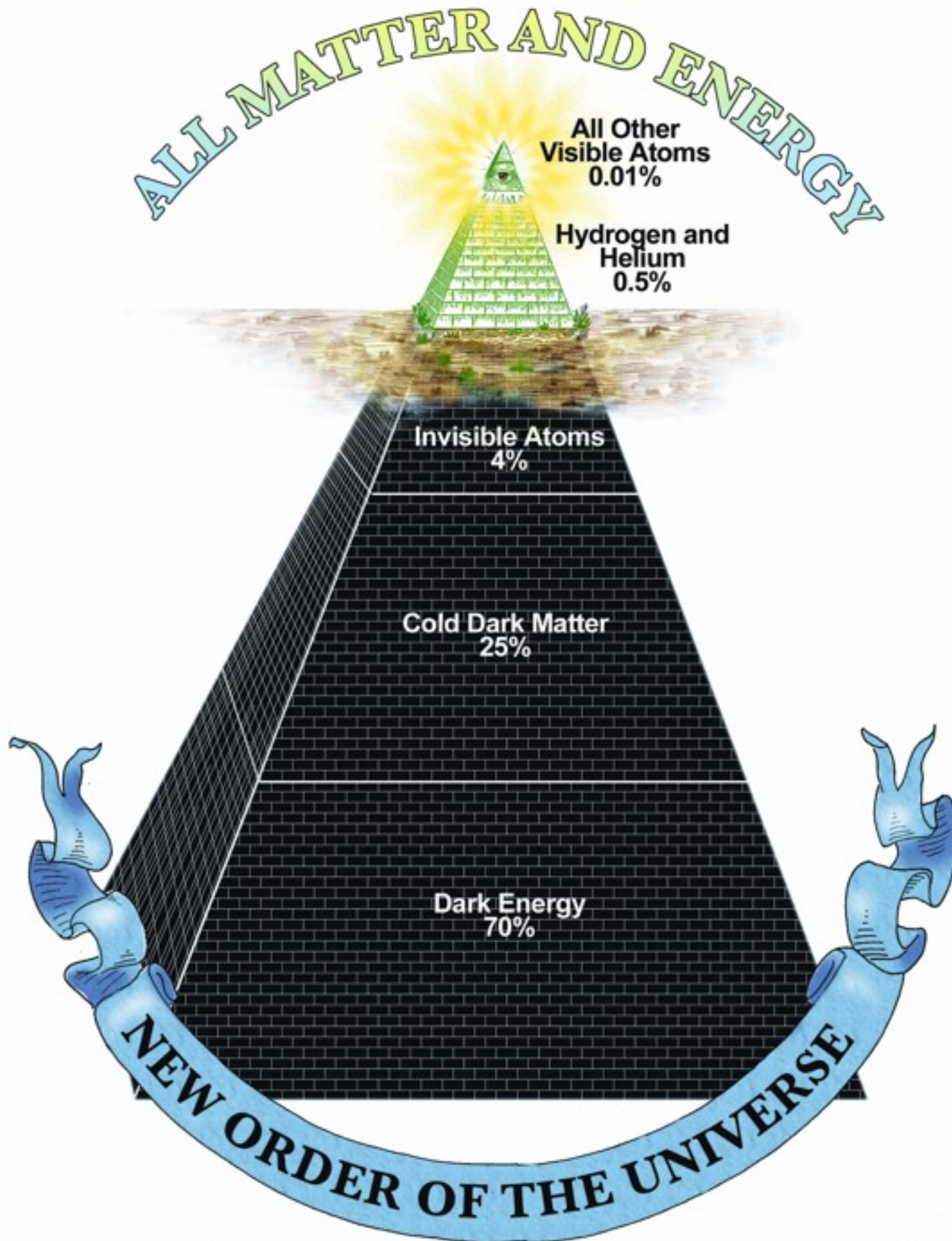
# Cosmology & Culture

## Lecture 4

Wednesday April 22, 2009

The Composition of the Universe,  
& The Cosmic Spheres of Time



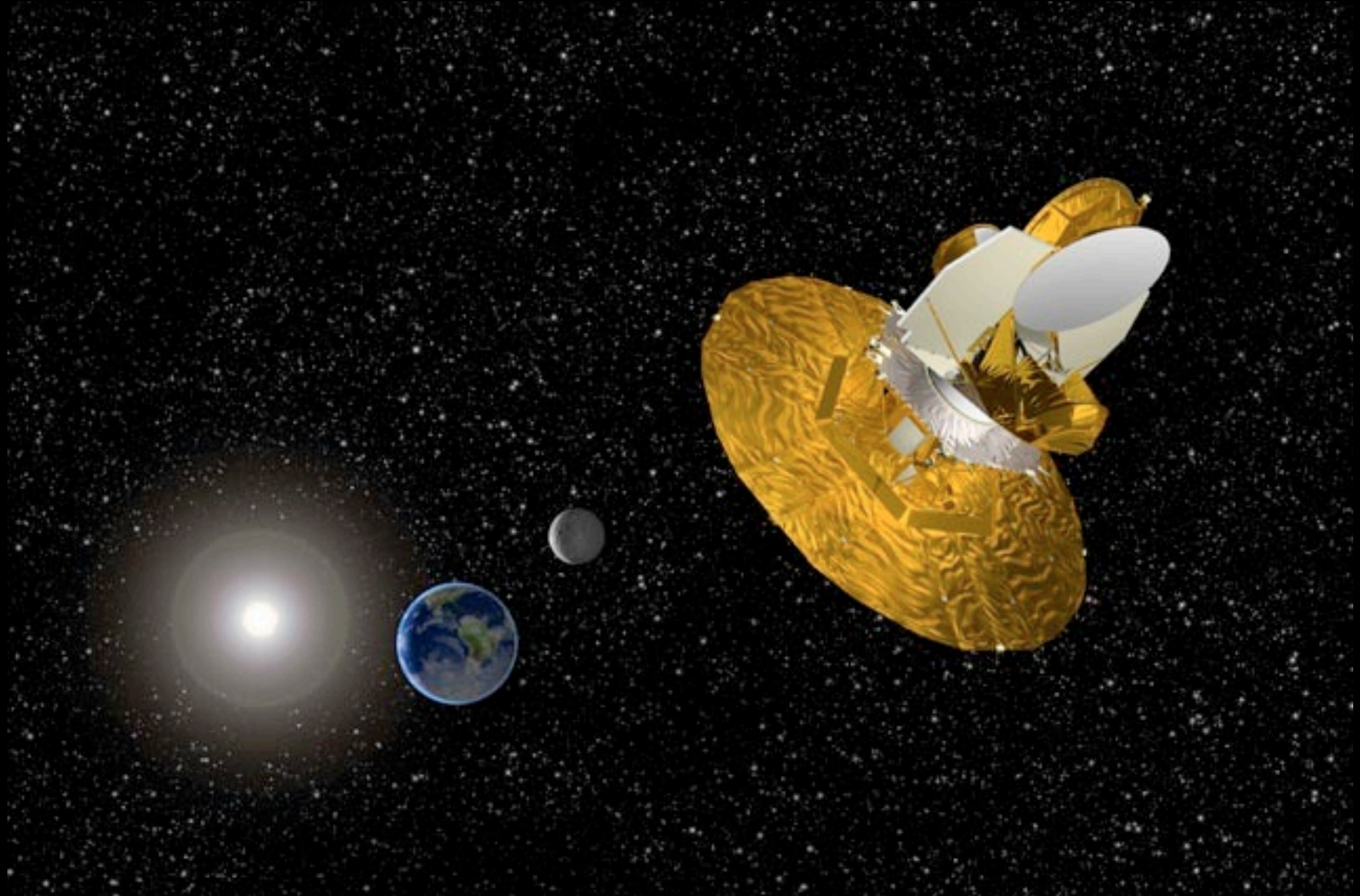


**Why do scientists take seriously the Double Dark cosmology, which says that more than 99% of the cosmic density is invisible, and more than 95% is mysterious Dark Matter and Dark Energy?**



# NASA's WMAP satellite

*Wilkinson Microwave Anisotropy Probe*

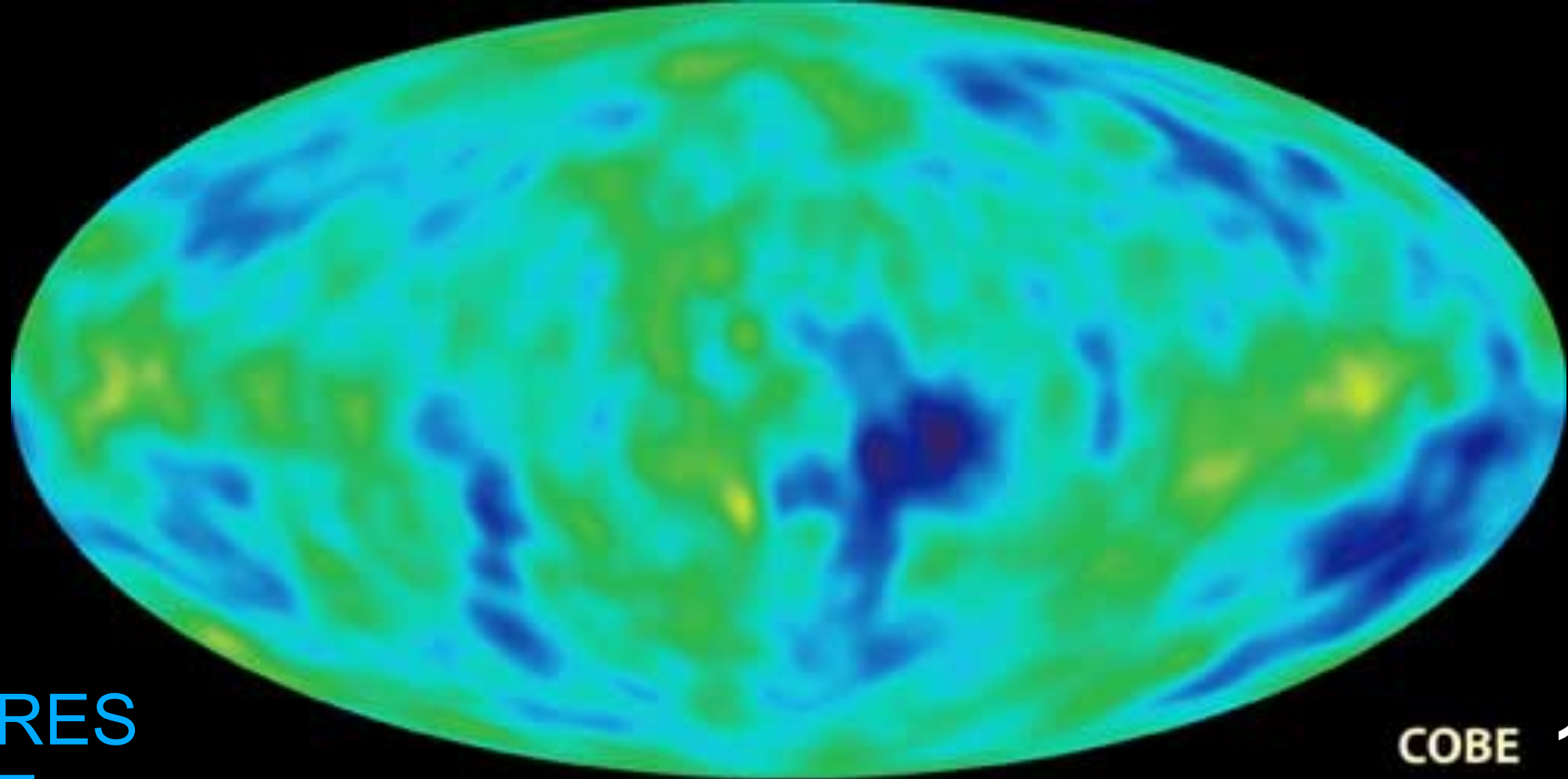


*1<sup>st</sup> results reported: March 2003*

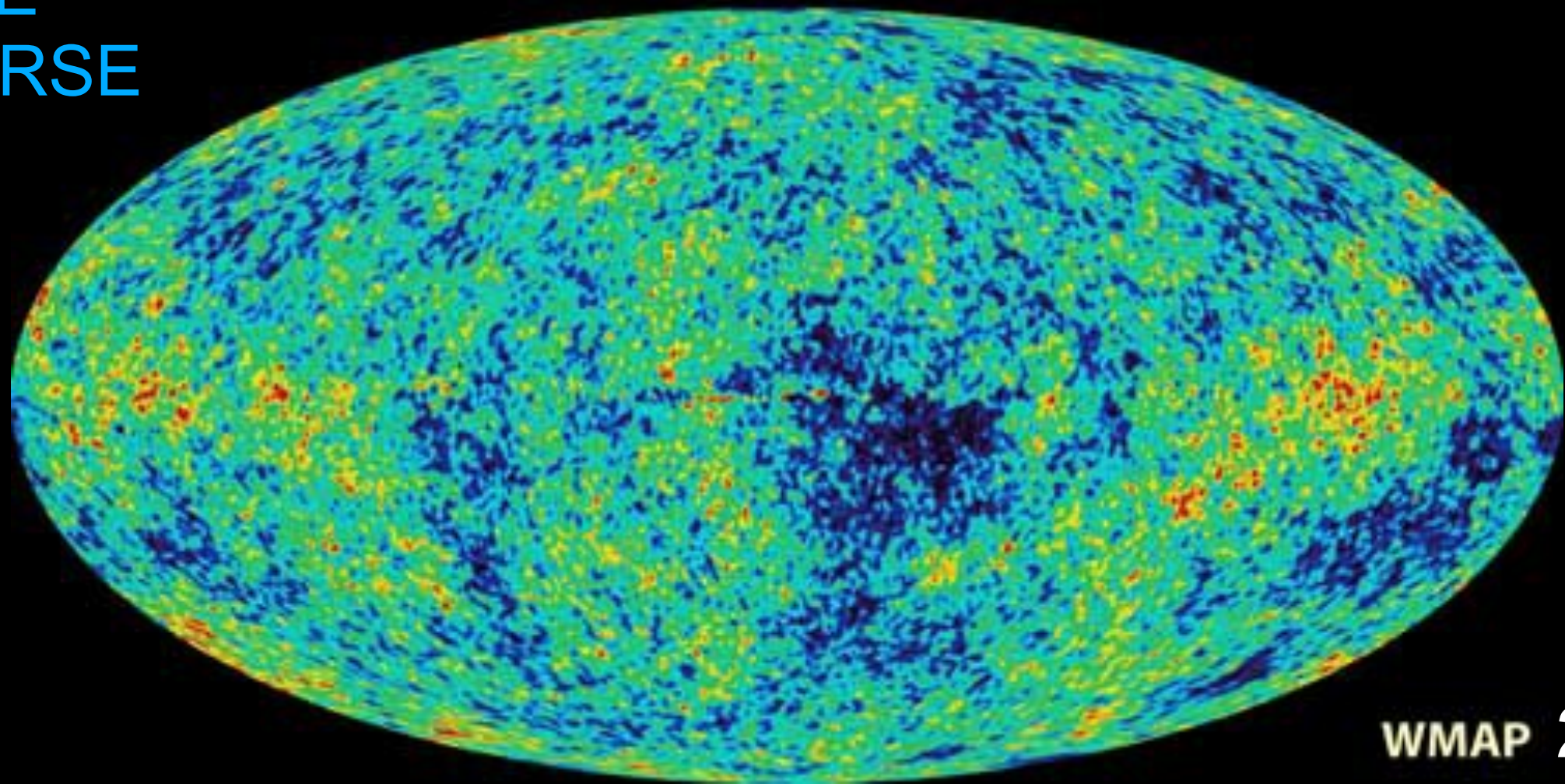




BABY  
PICTURES  
OF THE  
UNIVERSE



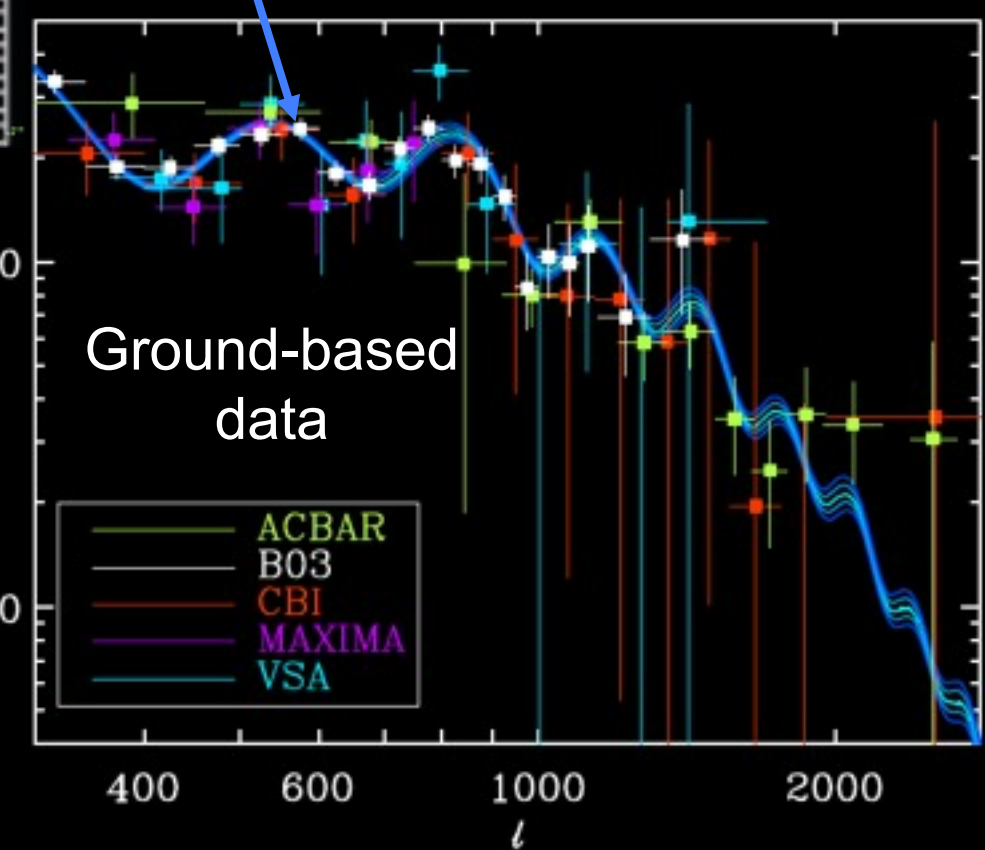
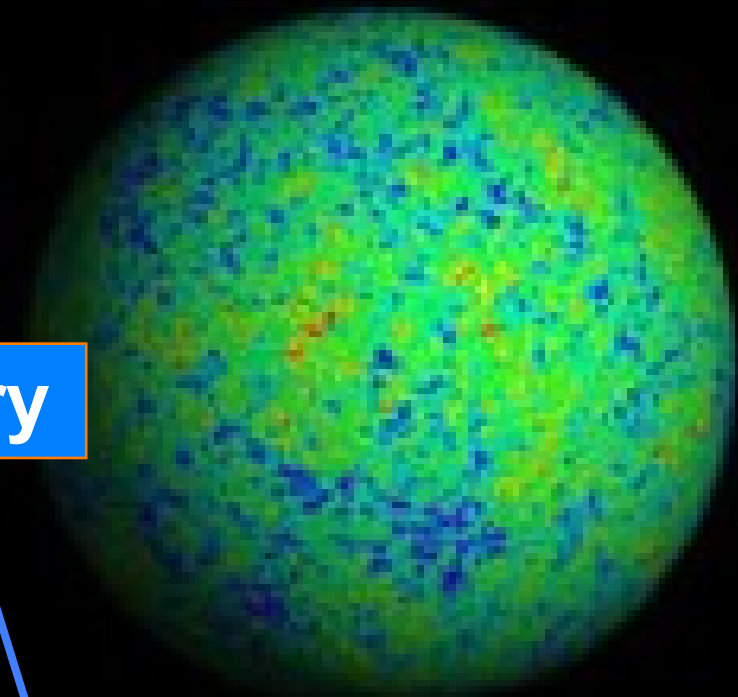
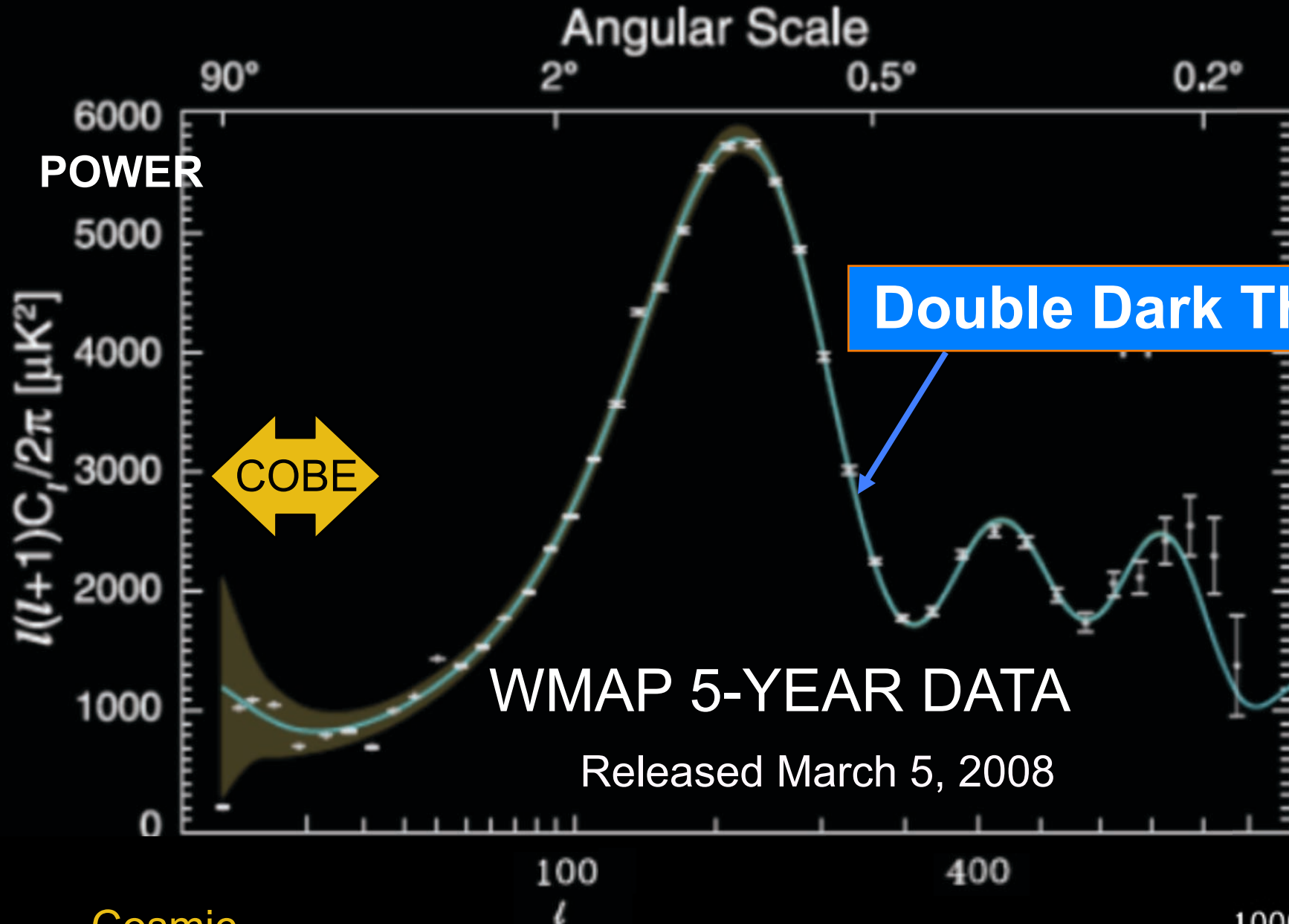
COBE 1992



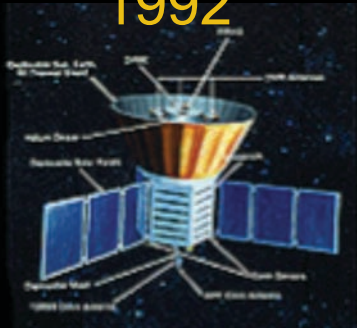
WMAP 2003



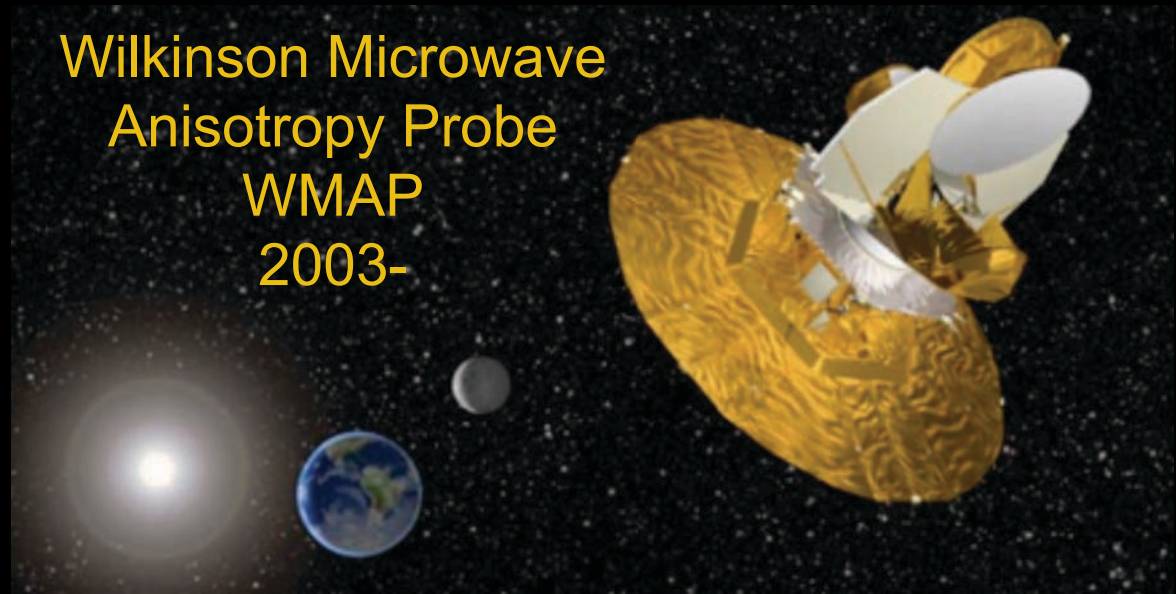
# Big Bang Data Agrees with Double Dark Theory!



Cosmic Background Explorer  
COBE  
1992

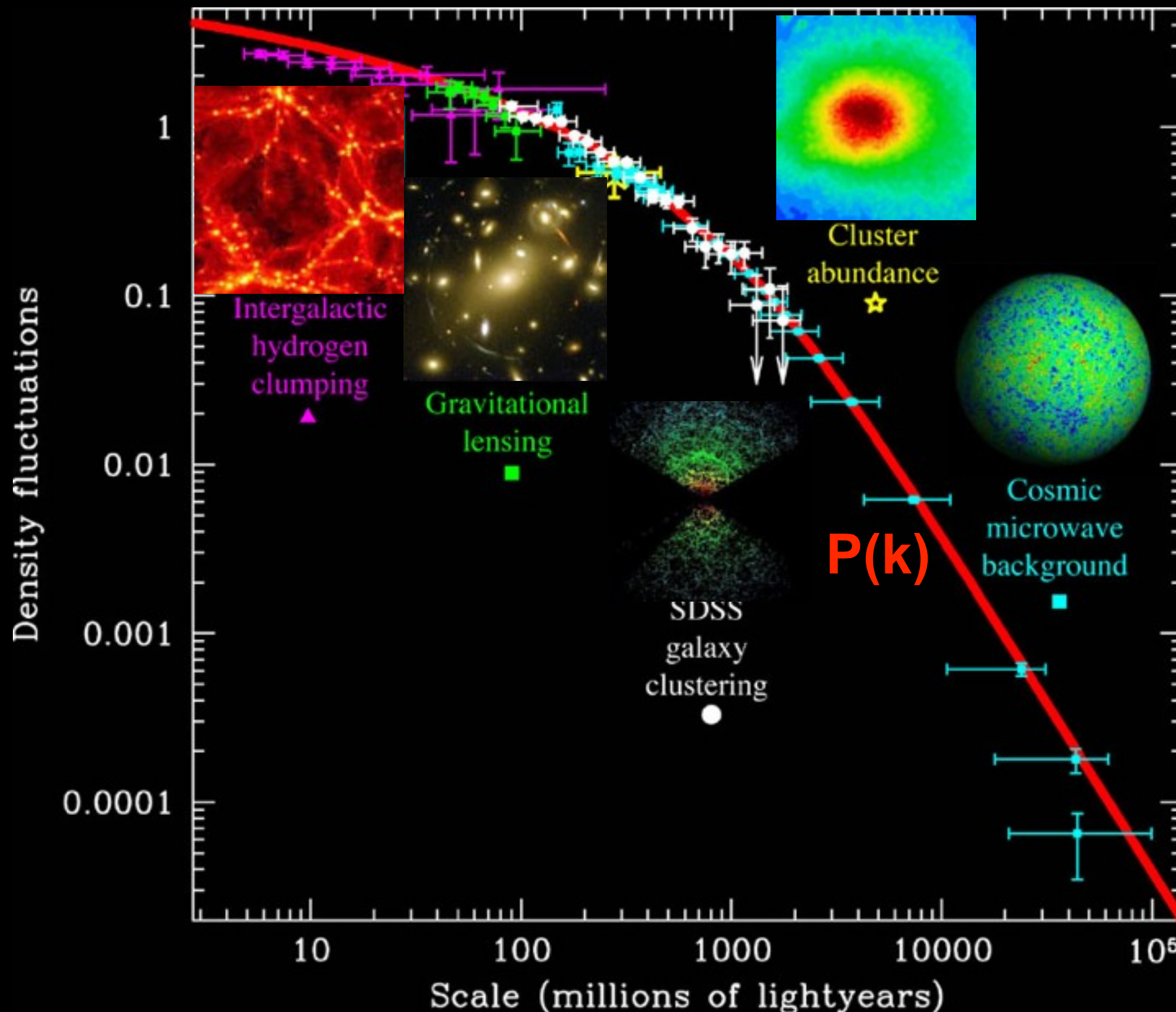


Wilkinson Microwave Anisotropy Probe  
WMAP  
2003-



# Distribution of Matter

Also Agrees with Double Dark Theory!





1998 **BREAKTHROUGH OF THE YEAR** 2003

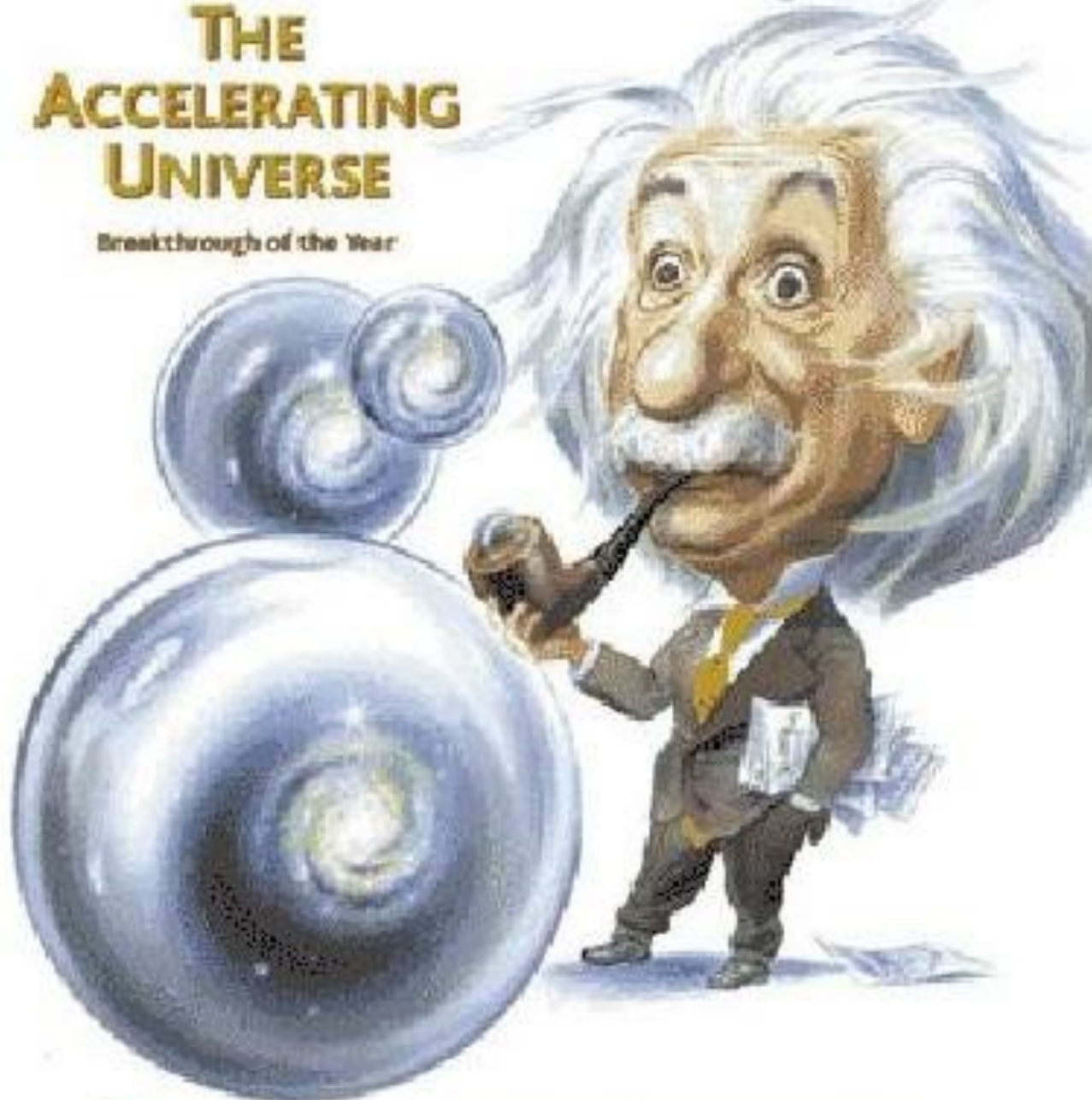
# Science

18 December 1998

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

## THE ACCELERATING UNIVERSE

Breakthrough of the Year

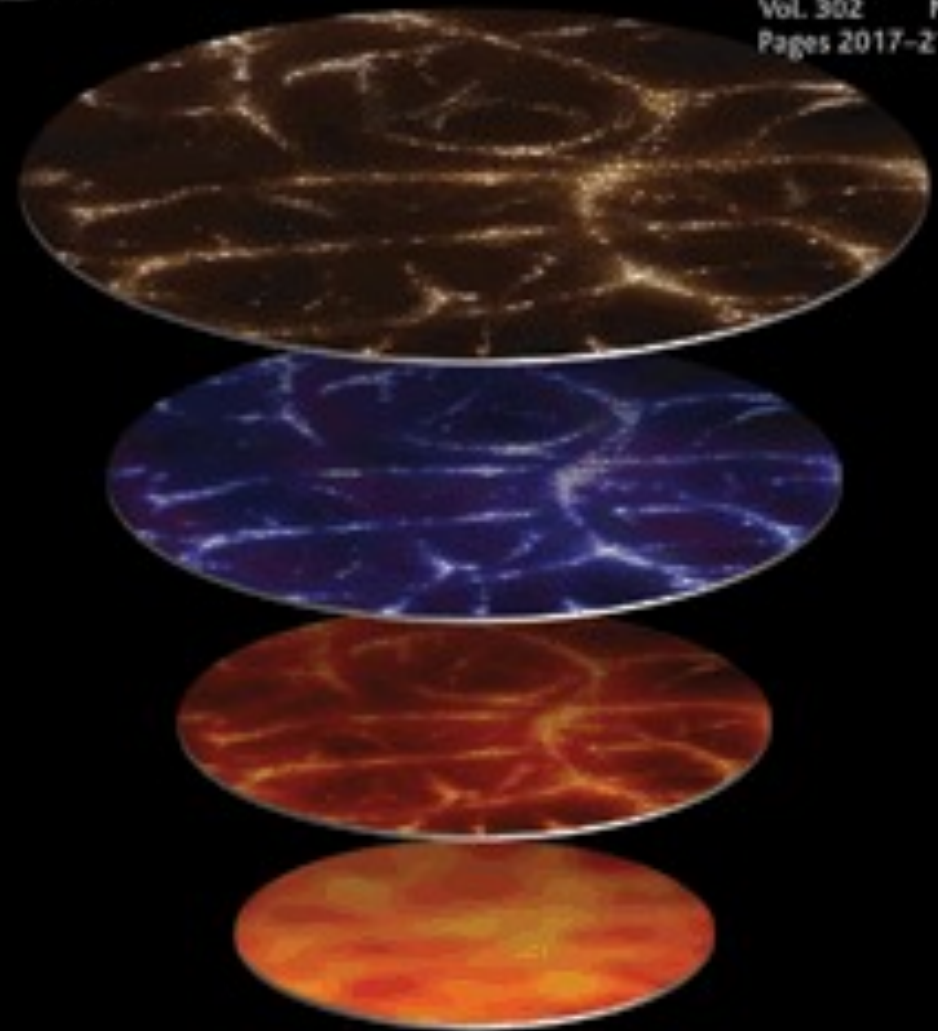


AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

# 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

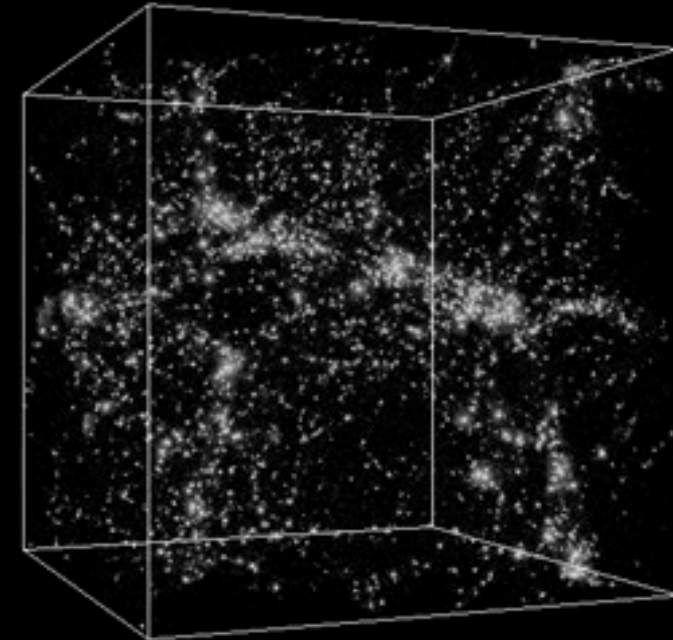
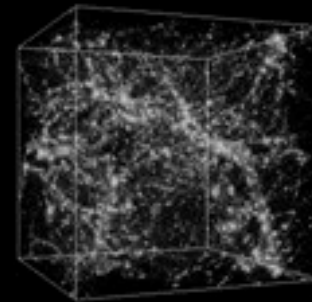
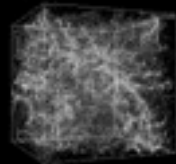




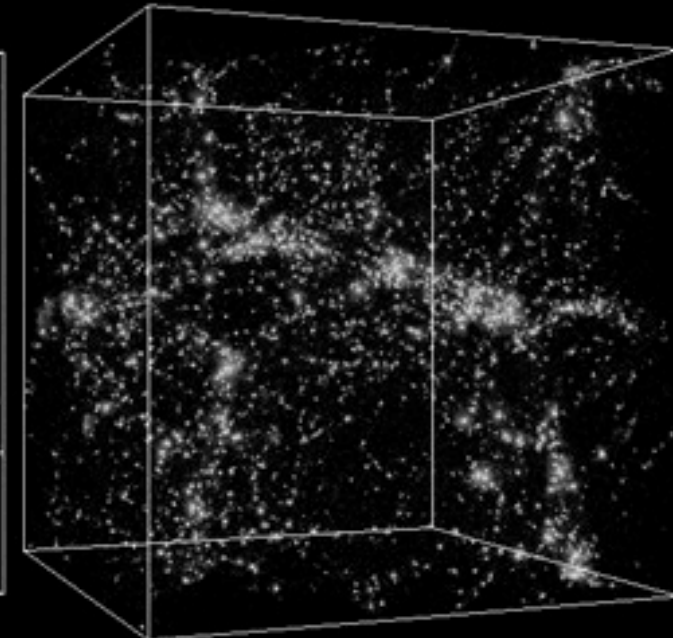
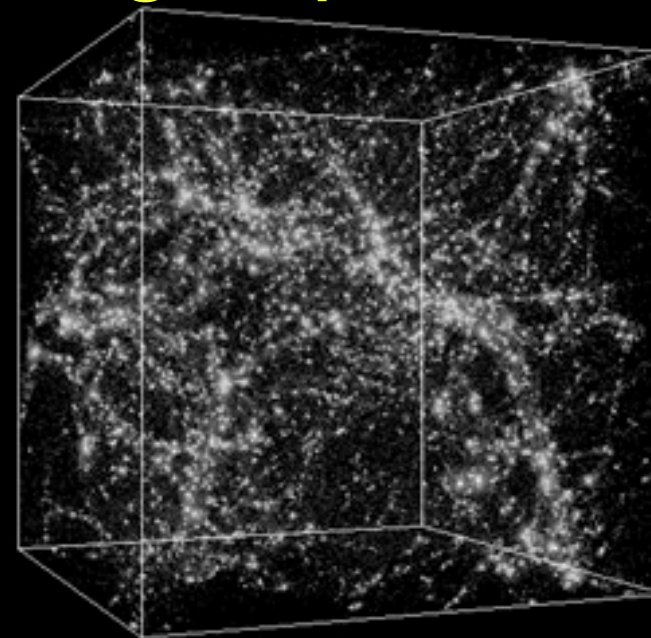
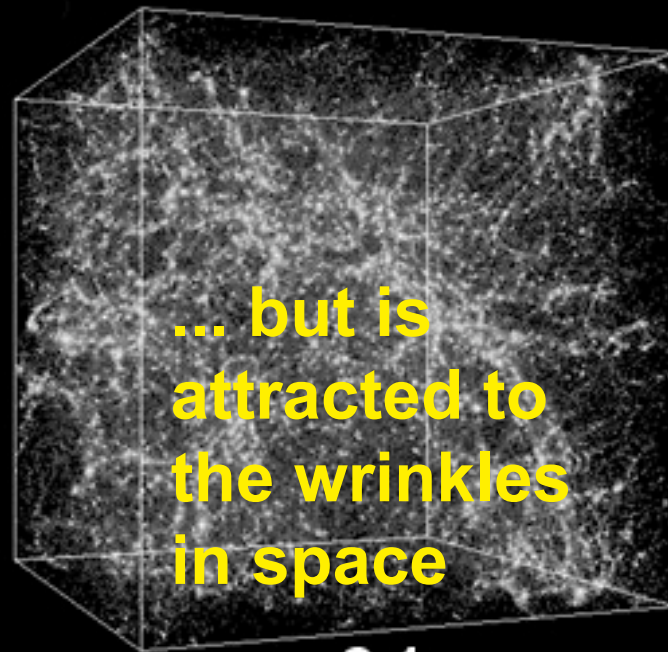
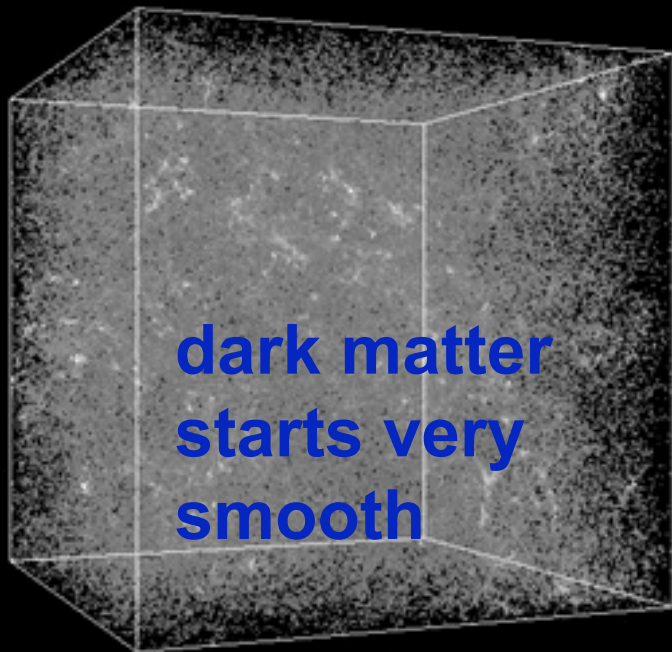
"QUARKS. NEUTRINOS. MESONS. ALL THOSE DAMN PARTICLES YOU CAN'T SEE. THAT'S WHAT DROVE ME TO DRINK. BUT NOW I CAN SEE THEM!"



# dark matter simulation - expanding with the universe



# same simulation - not showing expansion



dark matter starts very smooth

... but is attracted to the wrinkles in space

0.5

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

**CLOCK**



**Billion  
years ago 13.3960**

Dark  
Matter  
Simulation:

Columbia  
Super-  
Computer

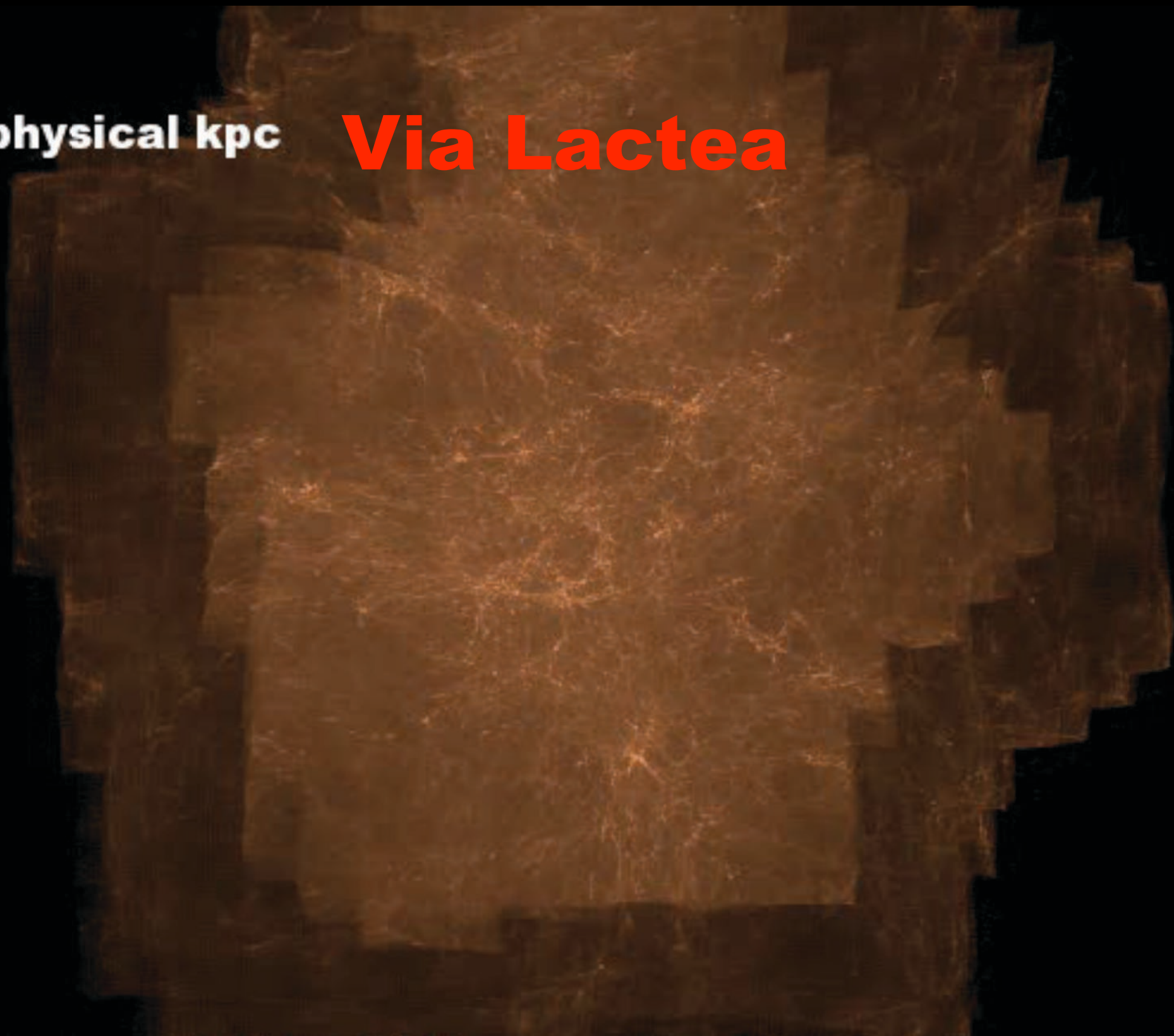
NASA  
Ames  
Laboratory



**z=11.9**

**800 x 600 physical kpc**

**Via Lactea**



**Diemand, Kuhlen, Madau 2006**

**Music: Bach Suite #2 for Flute**





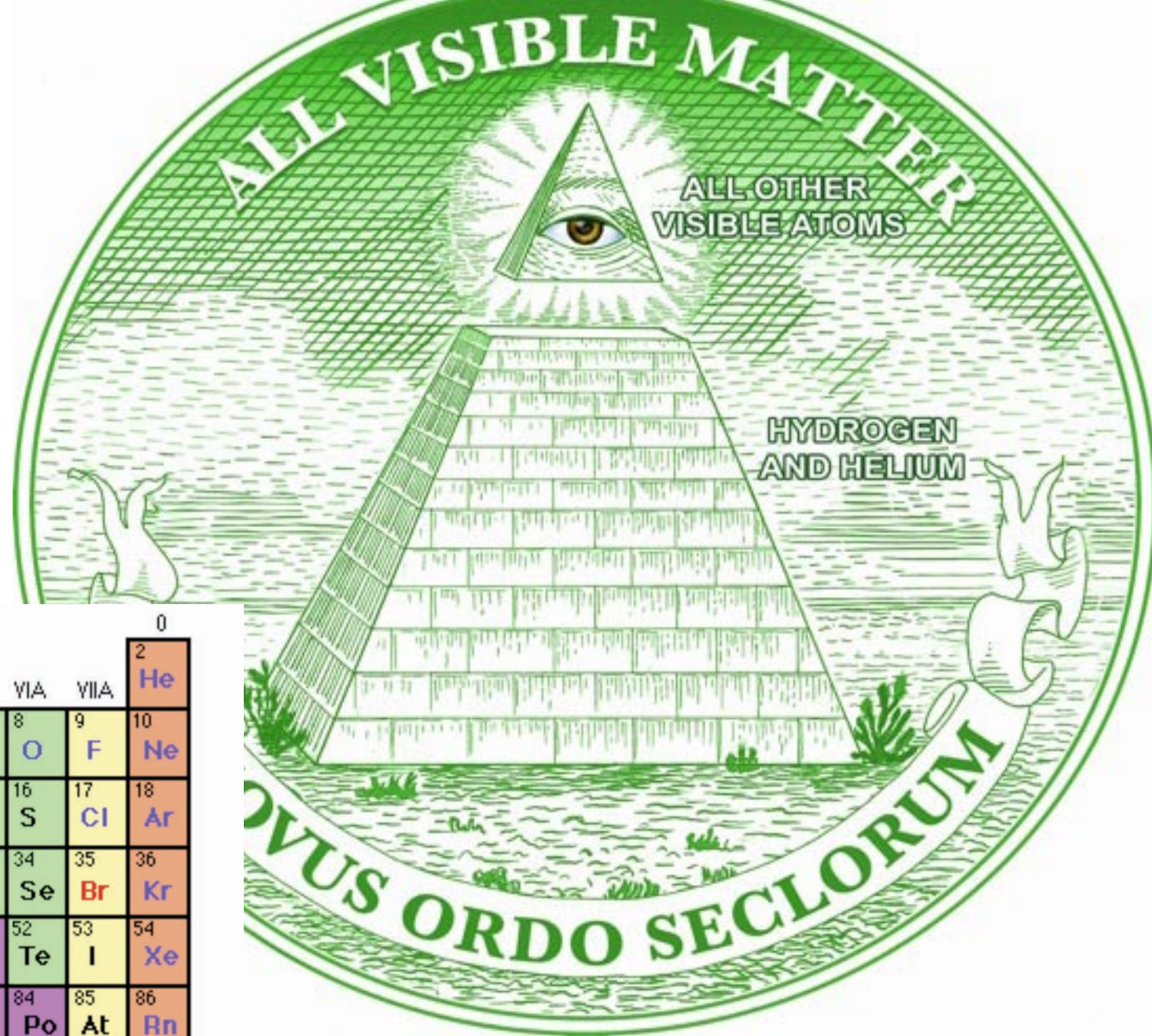
ALL VISIBLE MATTER

ALL OTHER  
VISIBLE ATOMS

HYDROGEN  
AND HELIUM

NOVUS ORDO SECLORUM





## Periodic Table of Elements

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar										
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 *La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 +Ac	104 Rf	105 Ha	106	107	108	109	110								

* Lanthanide Series	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
+ Actinide Series	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Legend - click to find out more...

H - gas

Li - solid

Br - liquid

Tc - synthetic

Non-Metals

Transition Metals

Rare Earth Metals

Halogens

Alkali Metals

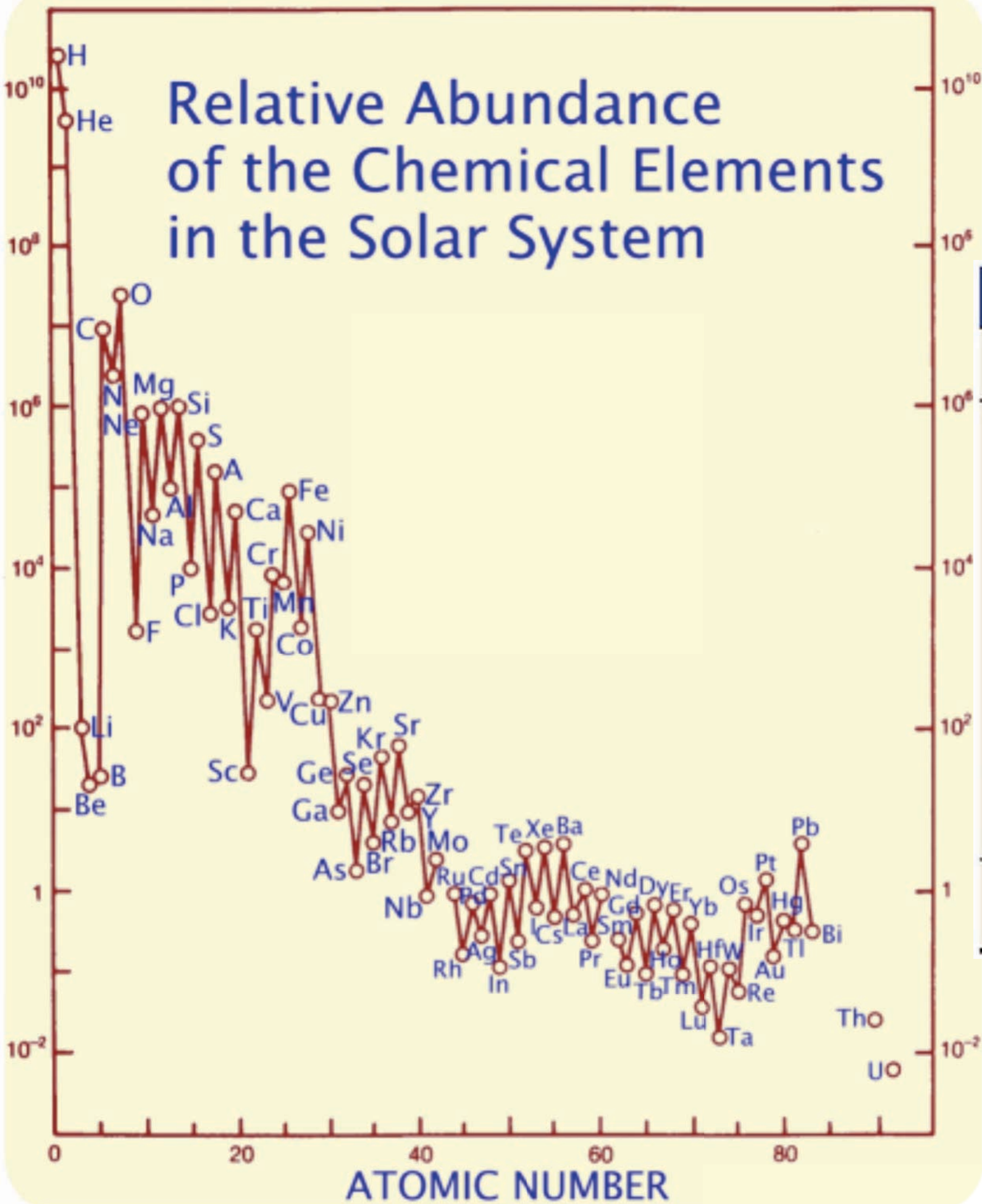
Alkali Earth Metals

Other Metals

Inert Elements



# Relative Abundance of the Chemical Elements in the Solar System



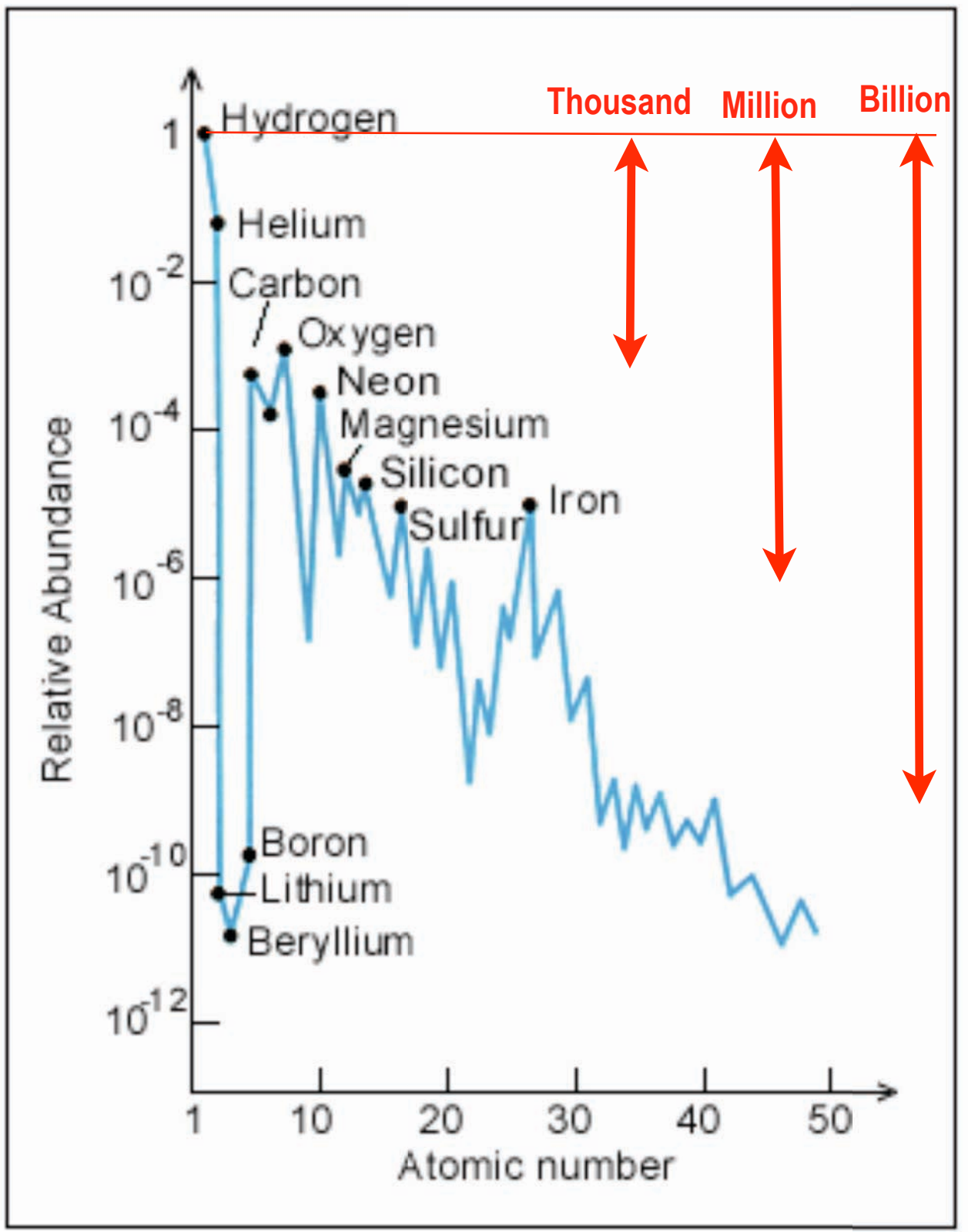
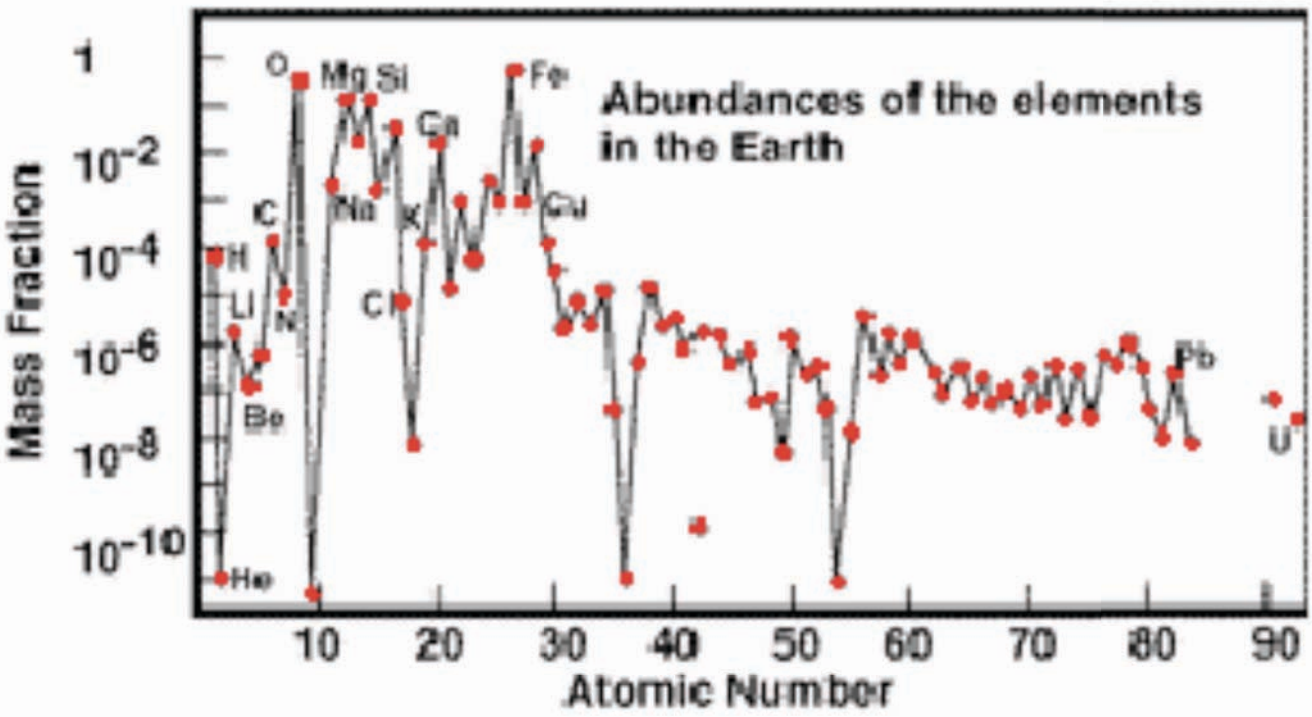
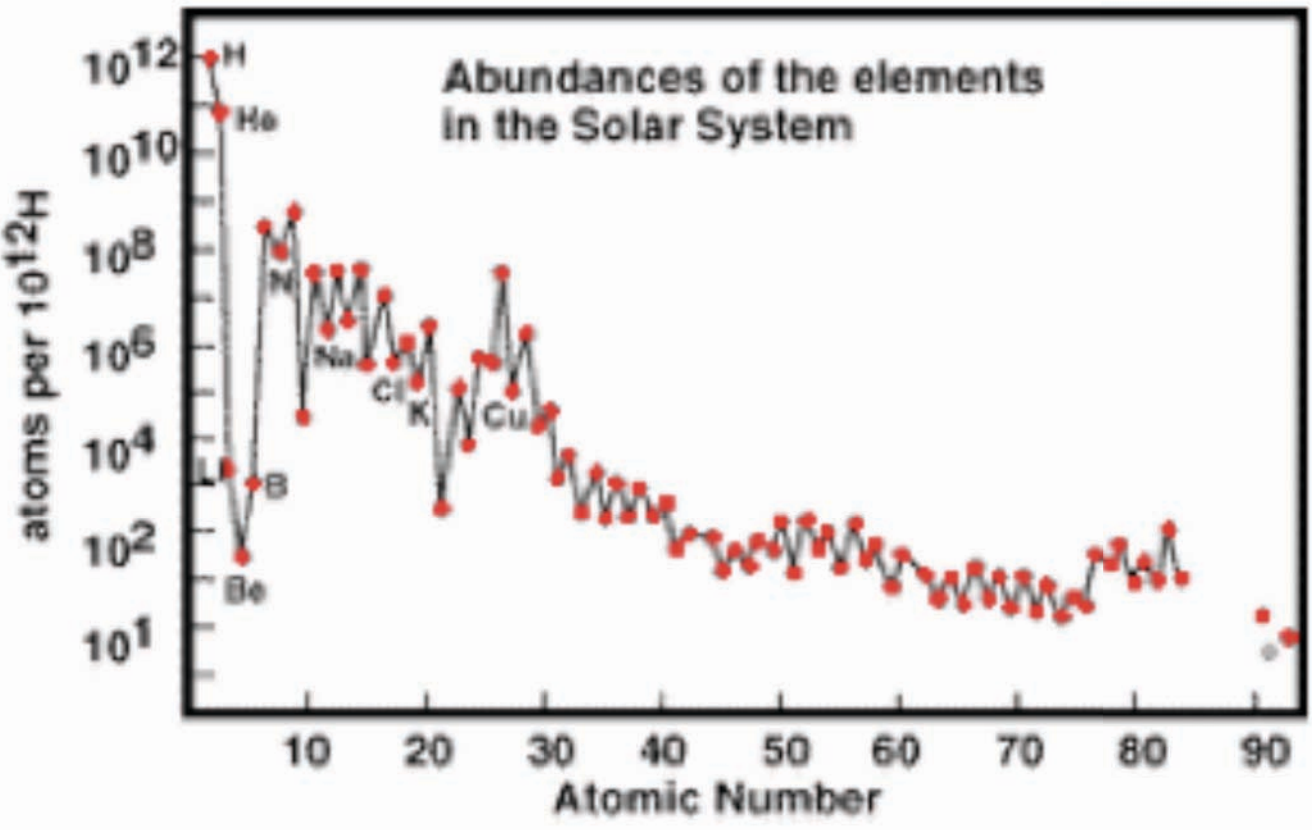
**TABLE 21.1 Cosmic Abundances of the Elements**

Elemental Group of Particles	Percent Abundance by Number*
Hydrogen (1 nuclear particle)	90
Helium (4 nuclear particles)	9
Lithium group (7–11 nuclear particles)	0.000001
Carbon group (12–20 nuclear particles)	0.2
Silicon group (23–48 nuclear particles)	0.01
Iron group (50–62 nuclear particles)	0.01
Middle-weight group (63–100 nuclear particles)	0.00000001
Heaviest-weight group (over 100 nuclear particles)	0.000000001

\*The total does not equal 100 percent, because of uncertainties in the abundance of beryllium. All isotopes of all elements are included.



# Solar System Relative Abundances





## ***Top 10 Elements in the Human Body***

<b>Element</b>	<b>by # atoms</b>
<b>10. Magnesium (Mg)</b>	<b>0.03%</b>
<b>9. Chlorine (Cl)</b>	<b>0.04%</b>
<b>8. Sodium (Na)</b>	<b>0.06%</b>
<b>7. Sulfur (S)</b>	<b>0.06%</b>
<b>6. Phosphorous (P)</b>	<b>0.20%</b>
<b>5. Calcium (Ca)</b>	<b>0.24%</b>
<b>4. Nitrogen (N)</b>	<b>1.48%</b>
<b>3. Carbon (C)</b>	<b>9.99%</b>
<b>2. Oxygen (O)</b>	<b>26.33%</b>
<b>1. Hydrogen (H)</b>	<b>61.56%</b>



# Top 10 Elements in the Human Body

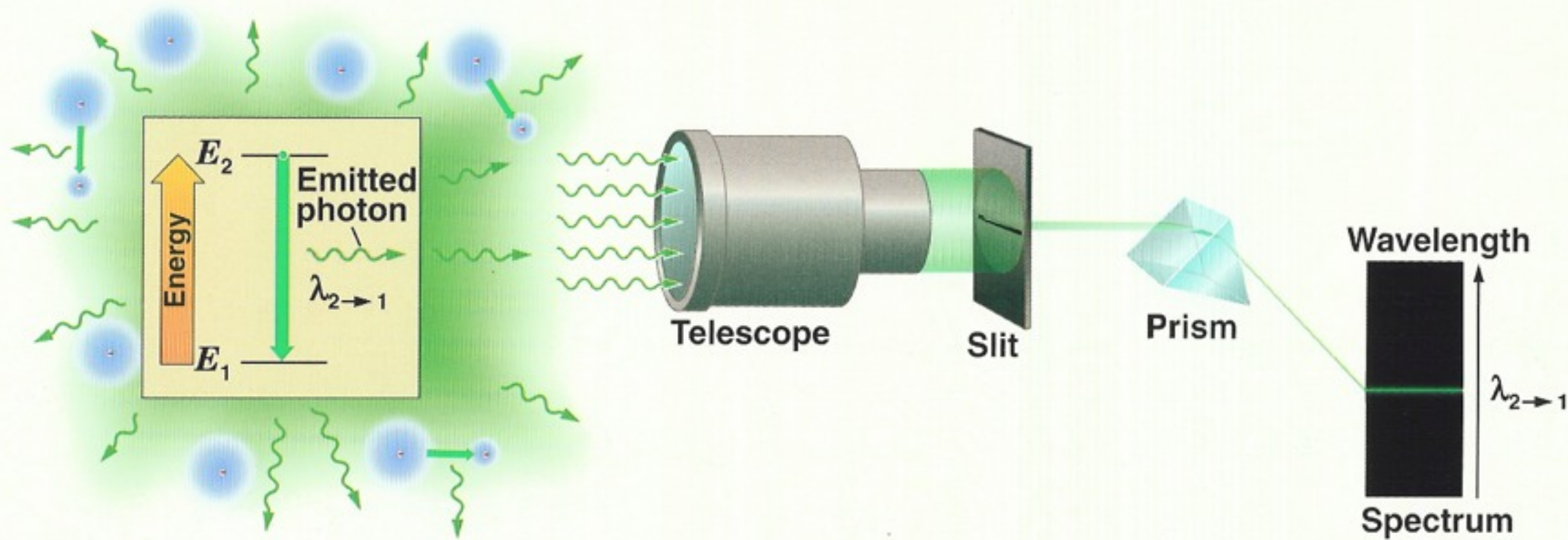
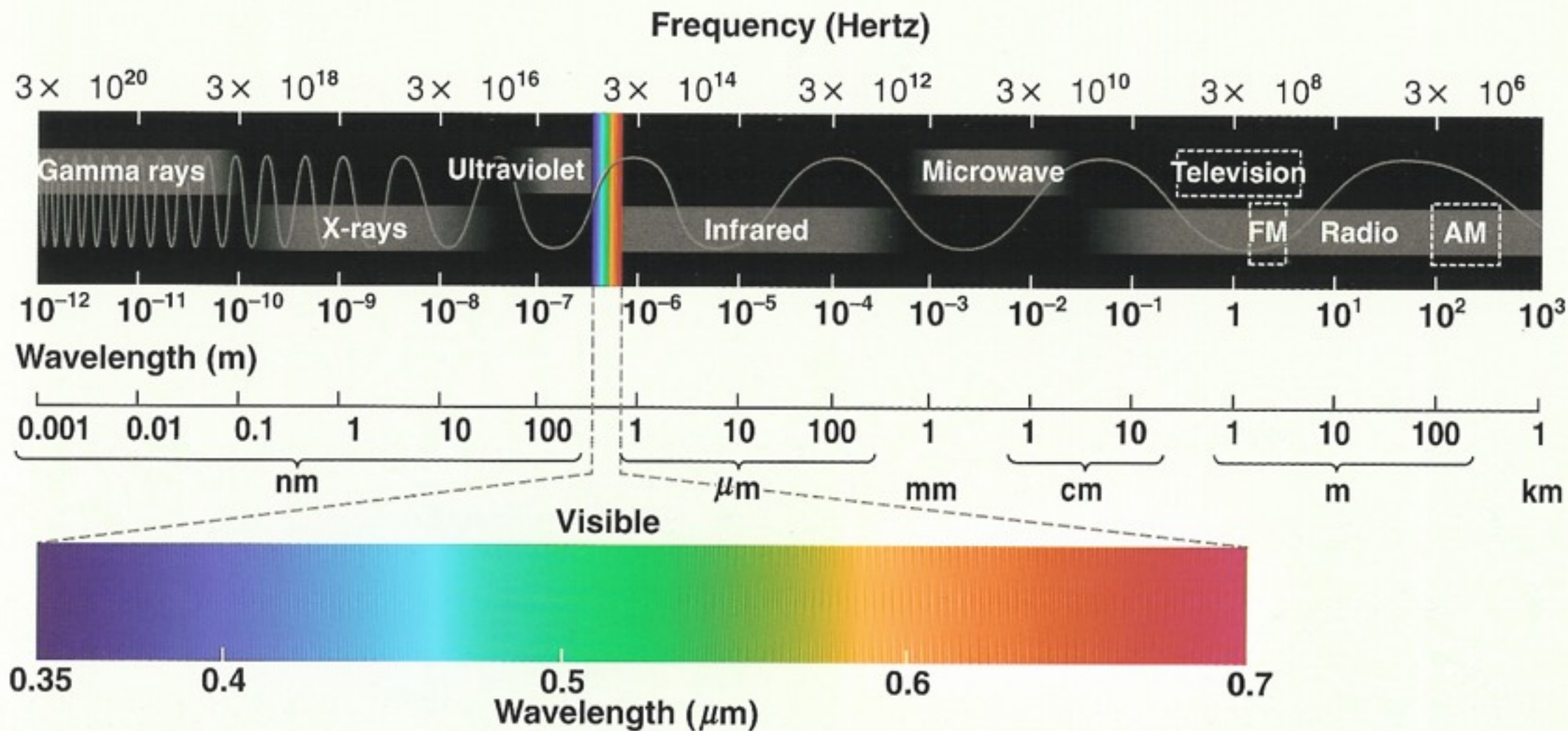
Element	by mass
10. Magnesium (Mg)	0.05%
9. Sodium (Na)	0.15%
8. Sulfur (S)	0.25%
7. Potassium (K)	0.35%
6. Phosphorous (P)	1.0%
5. Calcium (Ca)	1.5%
4. Nitrogen (N)	3%
3. Hydrogen (H)	10%
2. Carbon (C)	18%
1. Oxygen (O)	65%

To make an apple pie from scratch,  
you must first invent the universe.

Carl Sagan

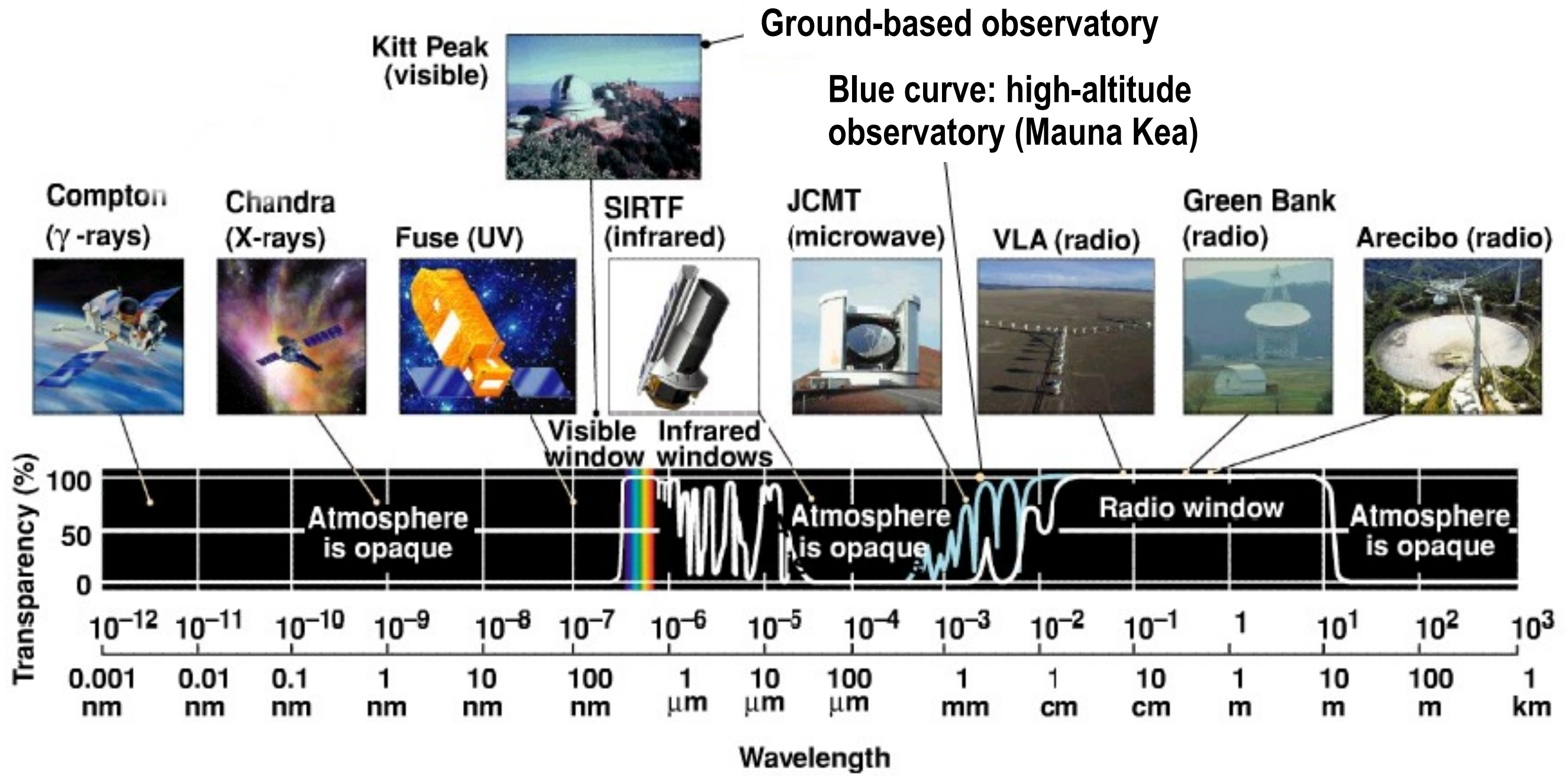








# The Atmosphere is Transparent to Light and Radio





# *Spectral Analysis*

---

Each element has a unique spectral signature:

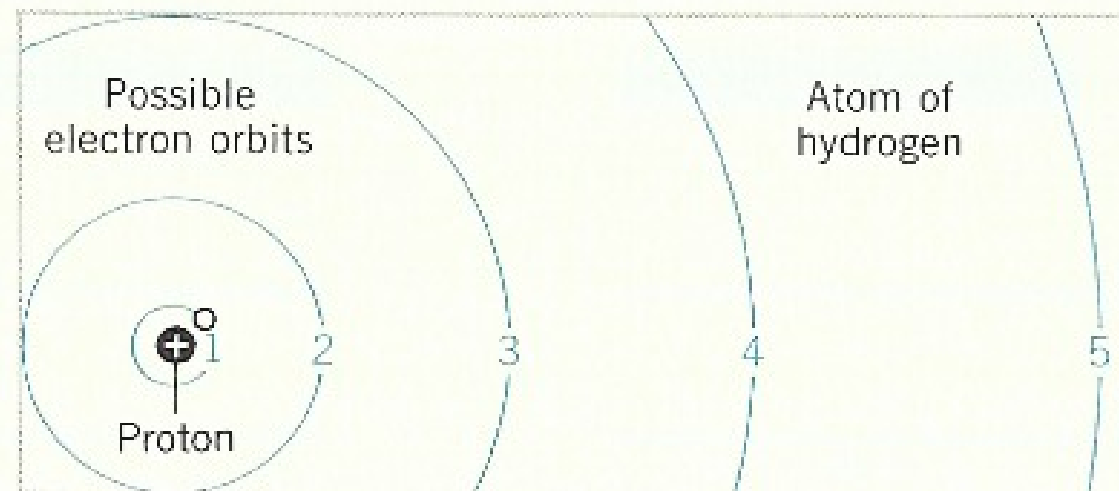
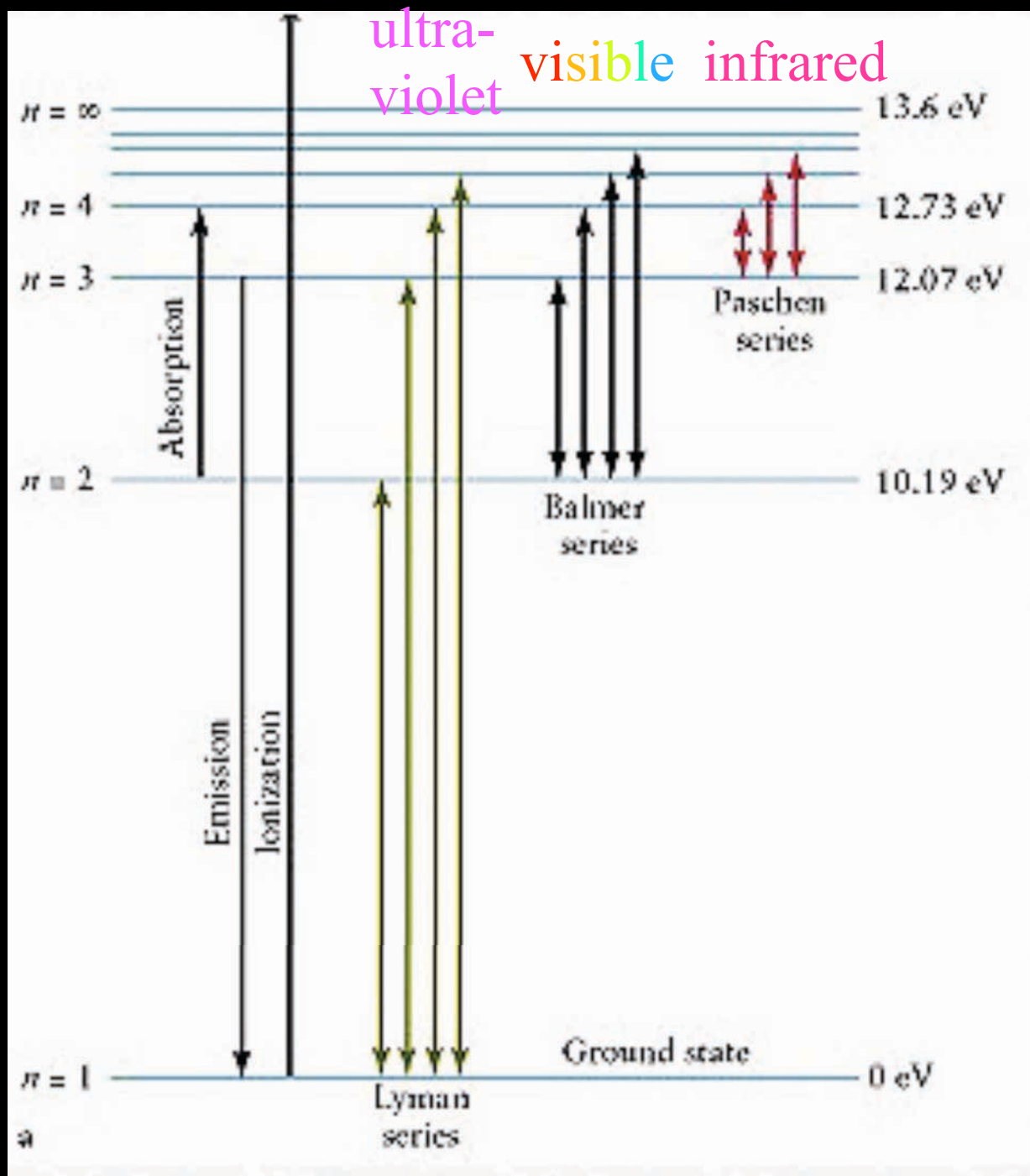
- Determined by arrangement of electrons.
- Lines of emission or absorption arise from re-arrangement of electrons into different energy levels.



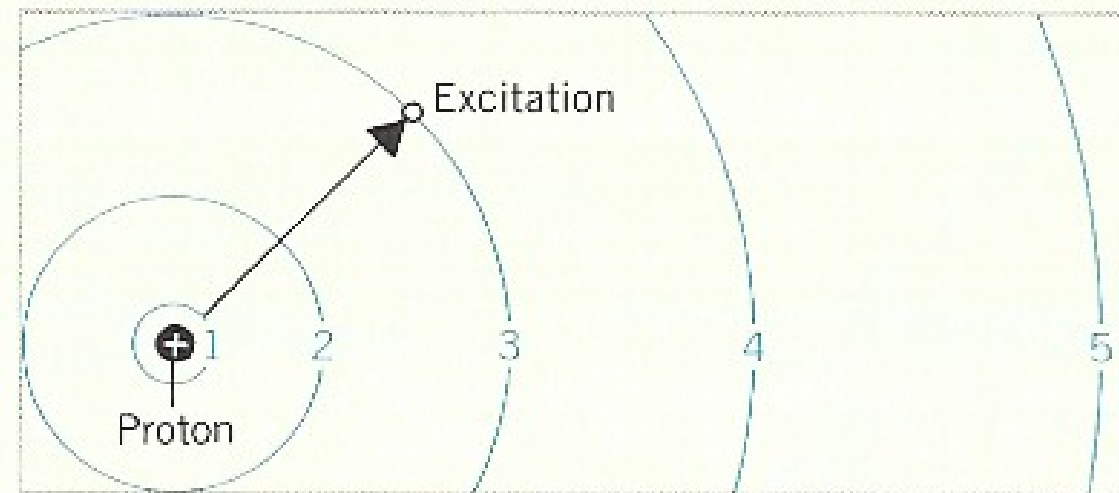
Hydrogen



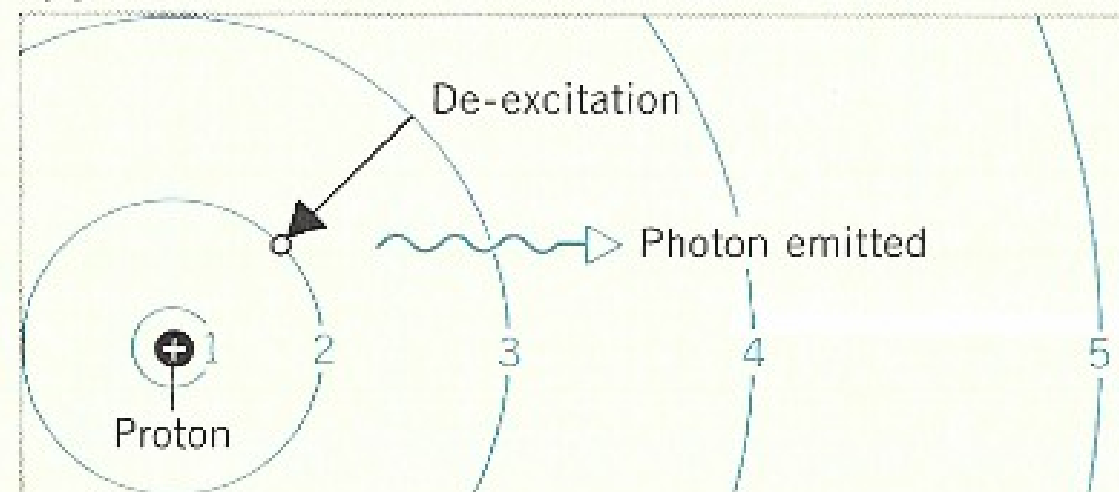
# Hydrogen Atom Spectrum



(a)



(b)



Orbit drop 3 to 2



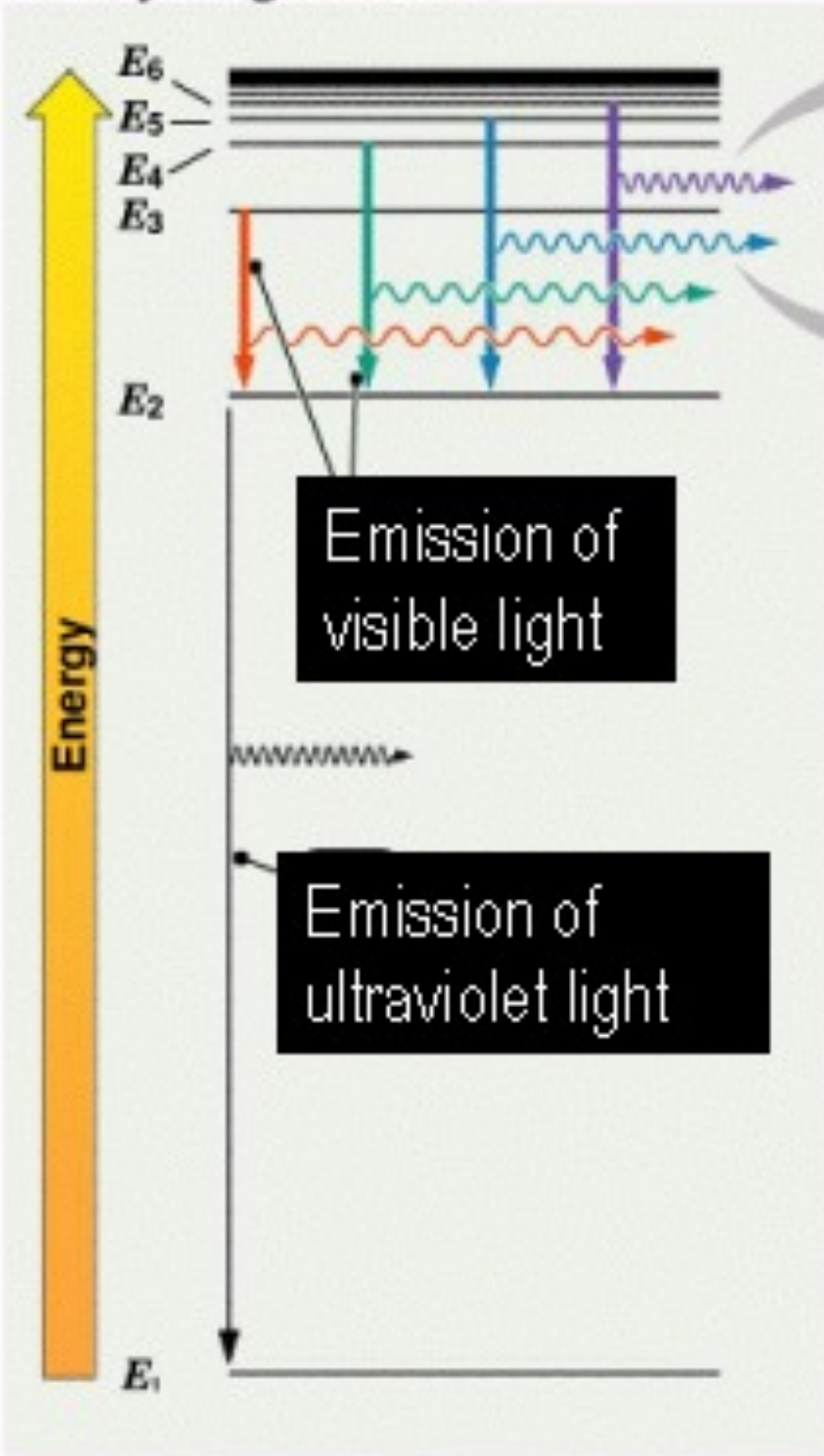
4000 5000 6000 7000

Wavelength (Å)

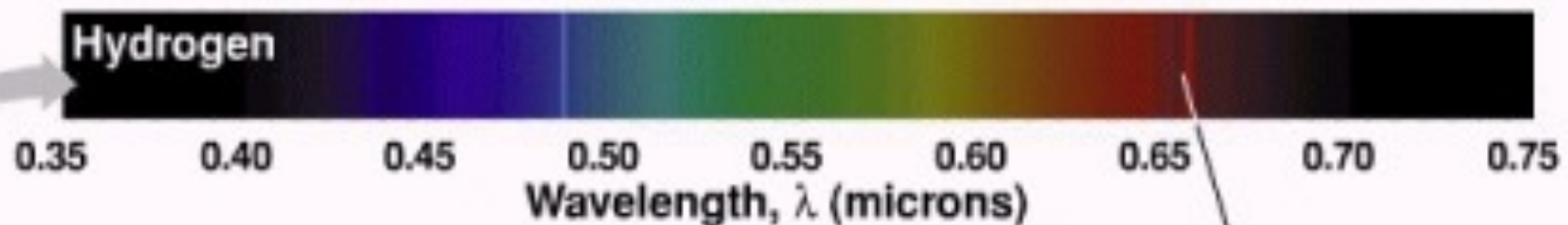
(c)



(a) Energy states of the hydrogen atom



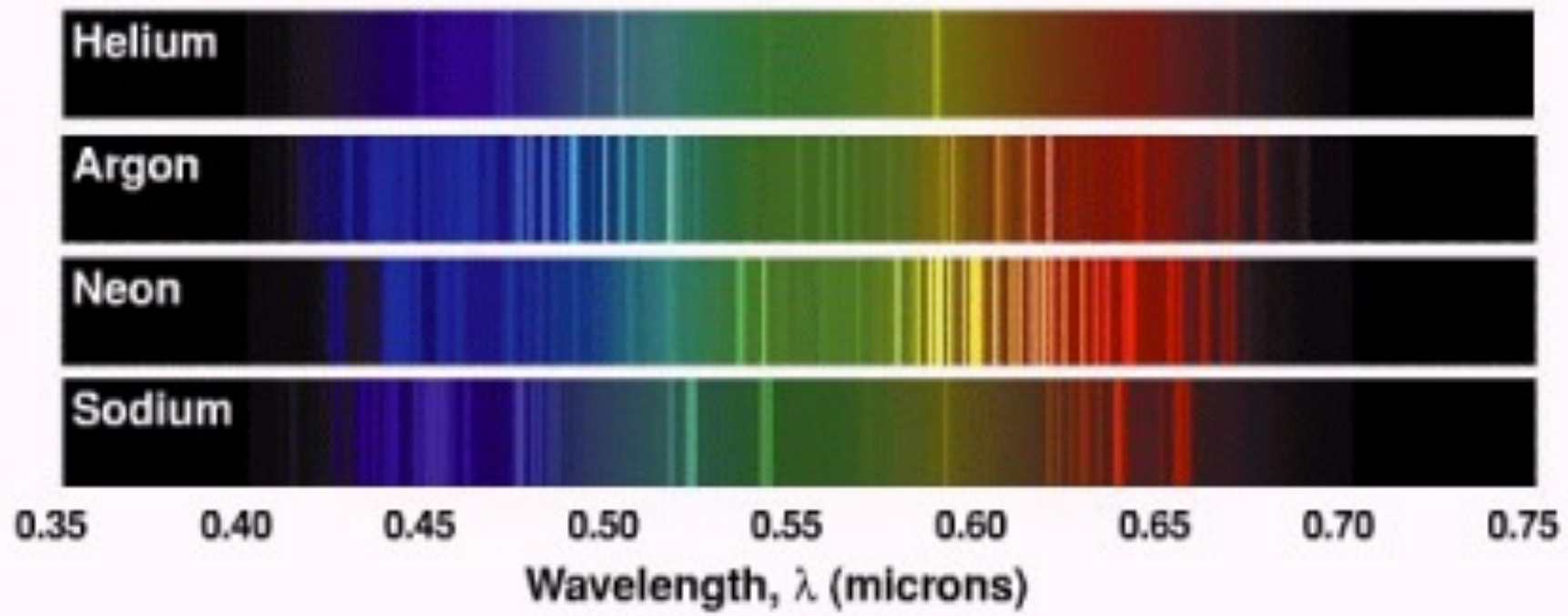
(b) Visible emission spectrum from hydrogen



(c) Hydrogen emission spectrum (intensity vs. wavelength plot)



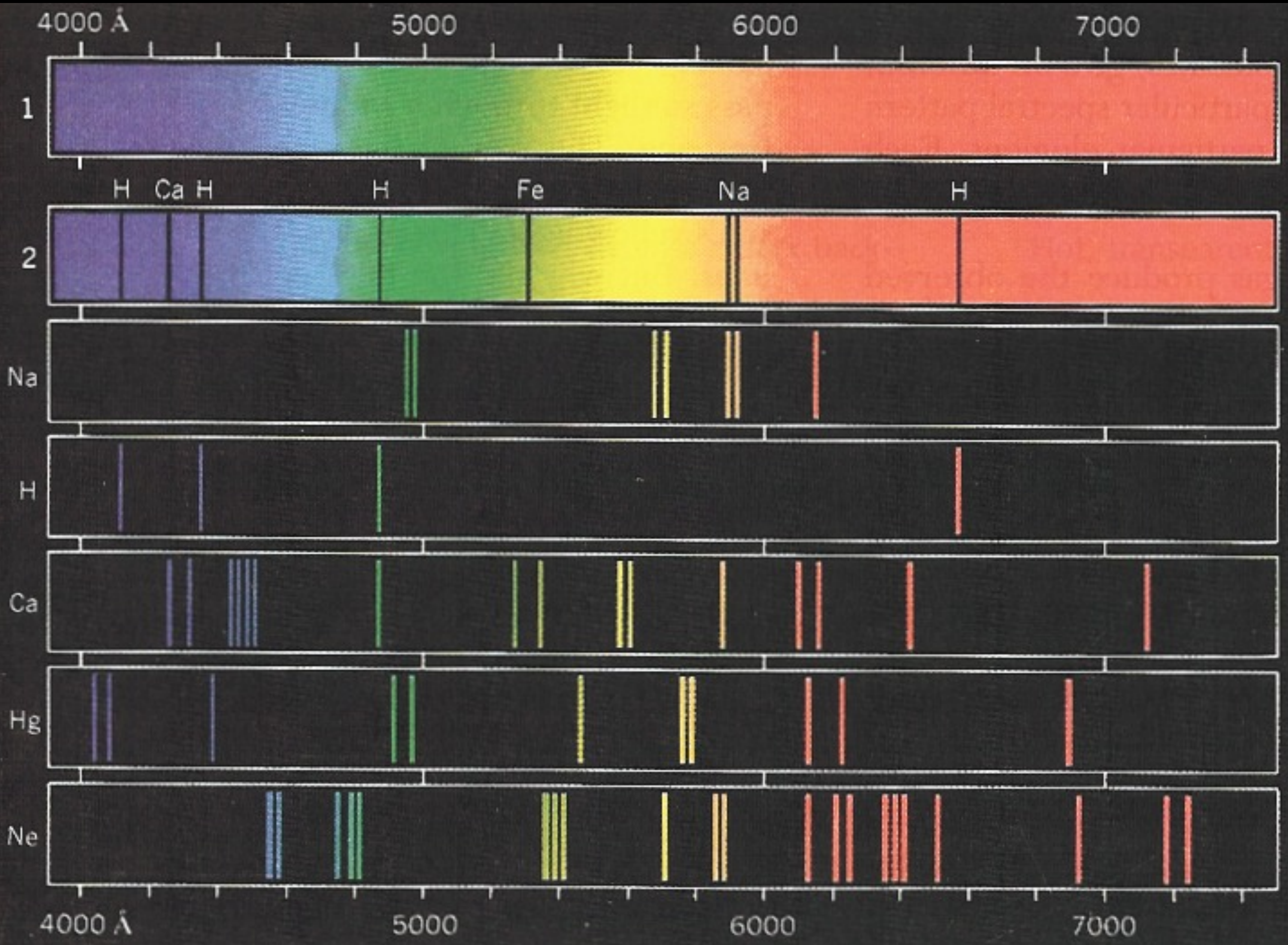
(d) Emission spectra for helium, argon, neon and sodium



Each element has a characteristic spectrum



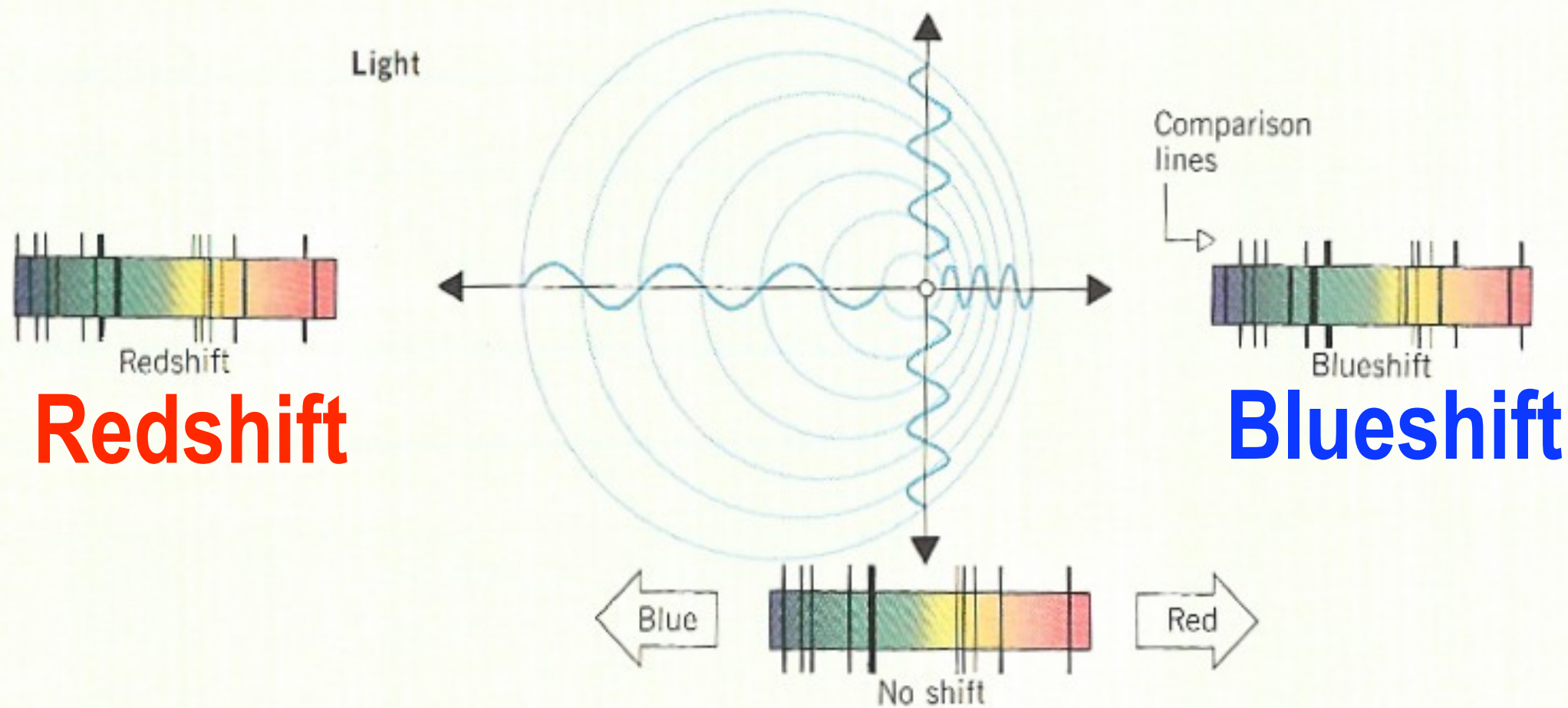
# Spectra of Sodium, Hydrogen, Calcium, Mercury, and Neon





# Motion Away from Us: Redshift

The Doppler shift for light waves. In the direction of the motion, the waves appear compressed, so a blueshift is seen in the positions of the spectral lines of the source. If the source is moving away, the waves appear to be stretched out, and a redshift is seen. At right angles to the motion, no shift is seen in the spectral lines.



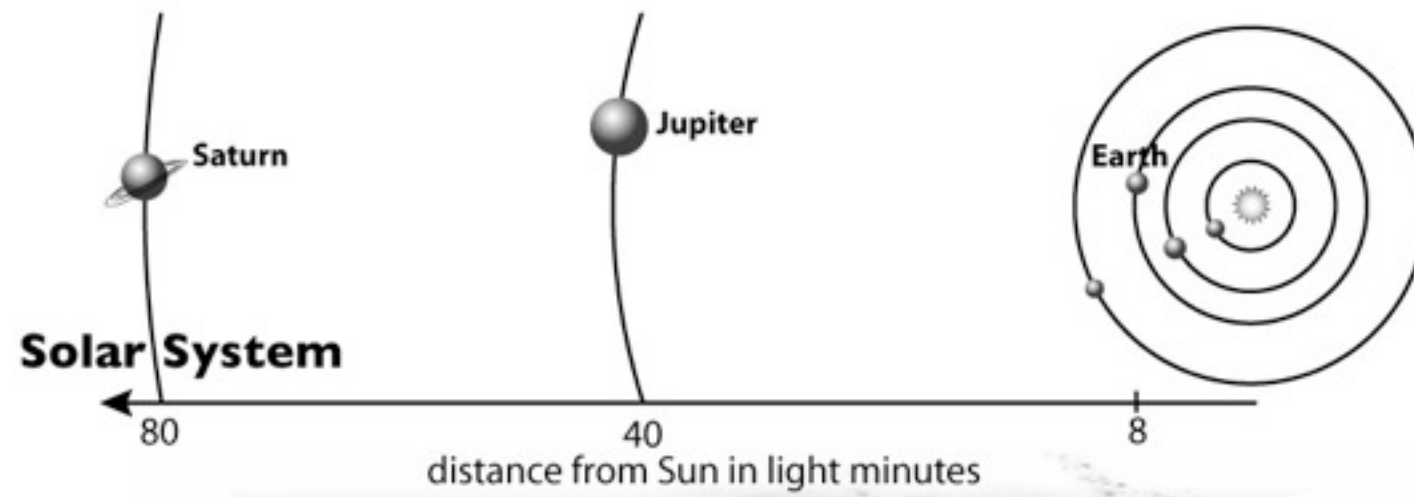


# How redshift shows that the universe is expanding

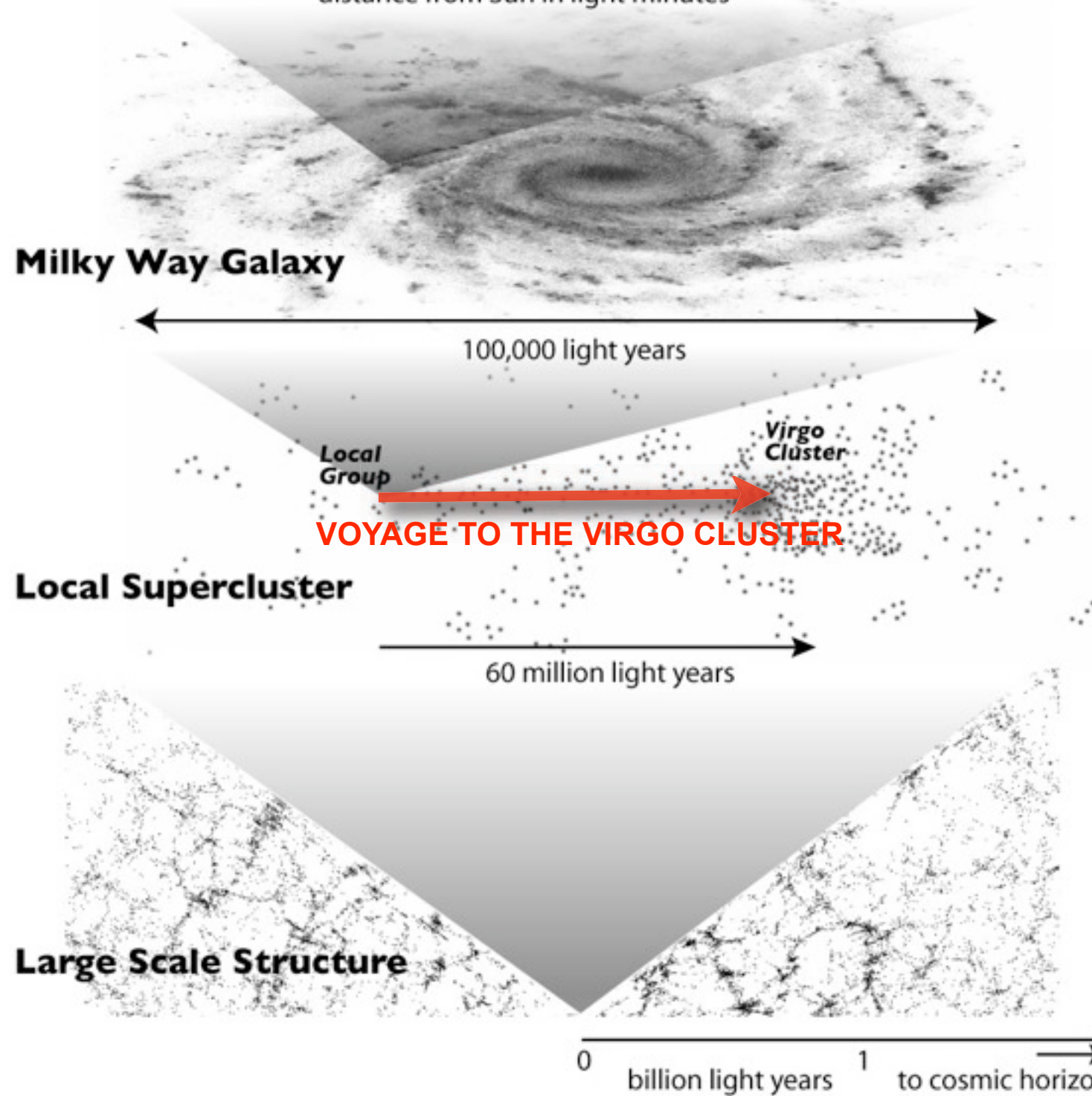
- The laws of physics are the same throughout the universe
- Hot atoms emit characteristic patterns of colors
- The whole pattern is shifted toward red (longer wavelengths) if atoms are moving away from us
- Galaxy redshifts increase with the distance of distant galaxies, showing that the universe is expanding.



# The Modern Scientific Cosmos



**Our Cosmic Address**



each dot is a big galaxy

Sloan Digital Sky Survey



# VOYAGE TO THE VIRGO CLUSTER



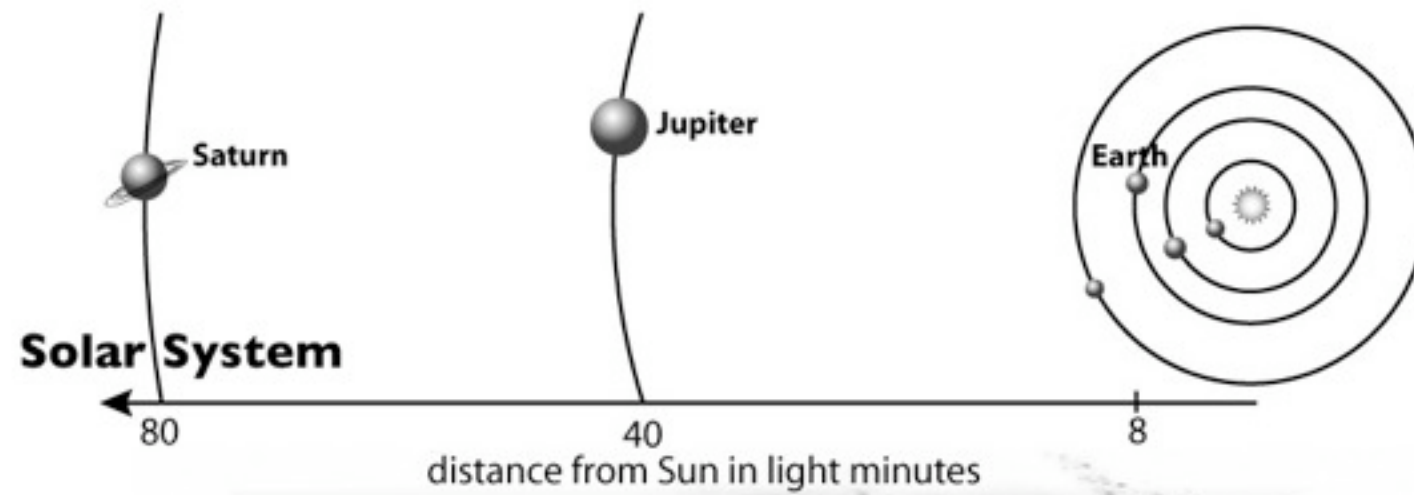


# VOYAGE TO THE VIRGO CLUSTER

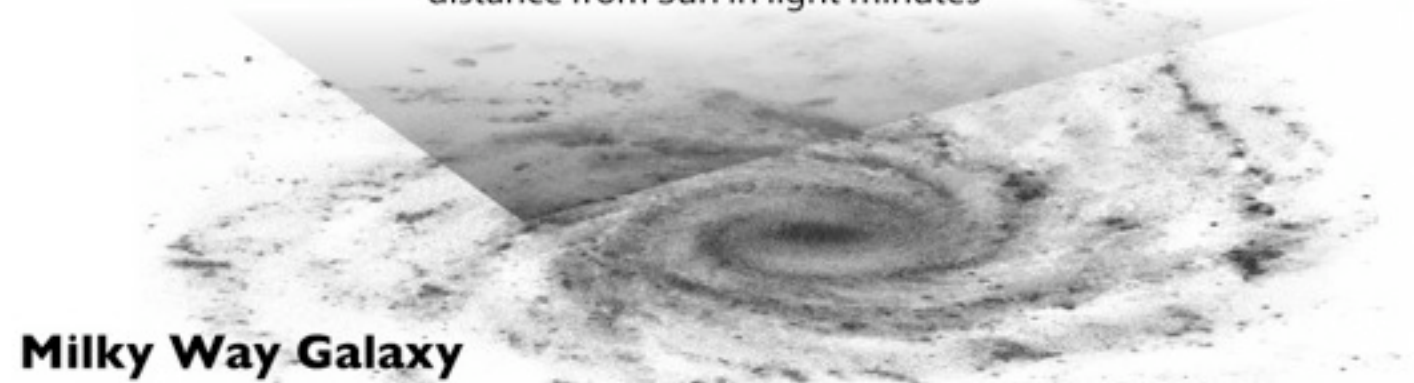
A deep space photograph of the Virgo Cluster of galaxies. The image shows a vast field of galaxies in various colors and orientations, set against a dark background. The galaxies are densely packed, with some appearing as bright, elongated structures and others as smaller, more distant points of light.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



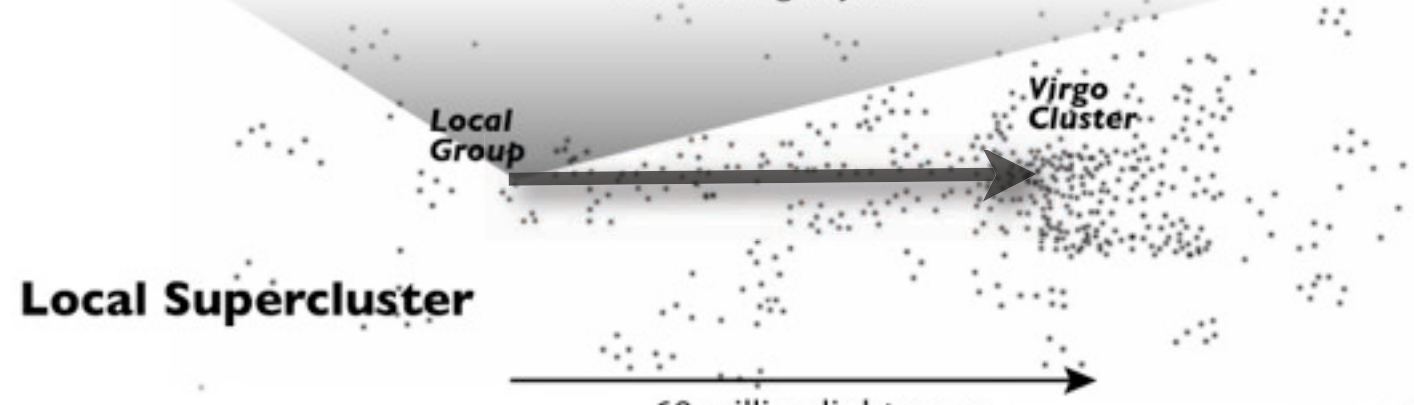
# The Modern Scientific Cosmos



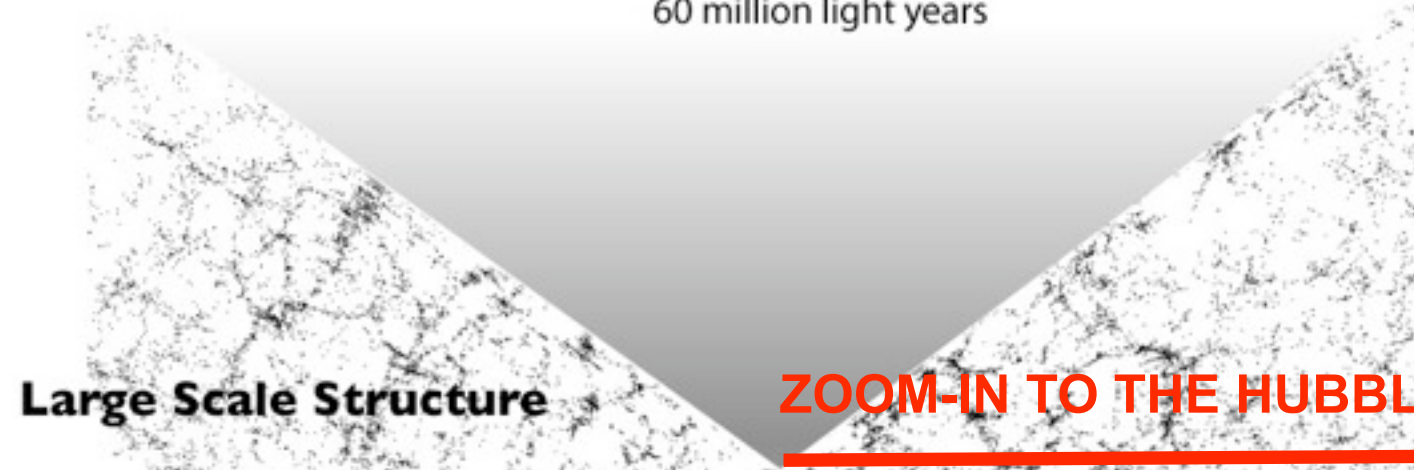
**Our Cosmic Address**



100,000 light years



each dot is a big galaxy



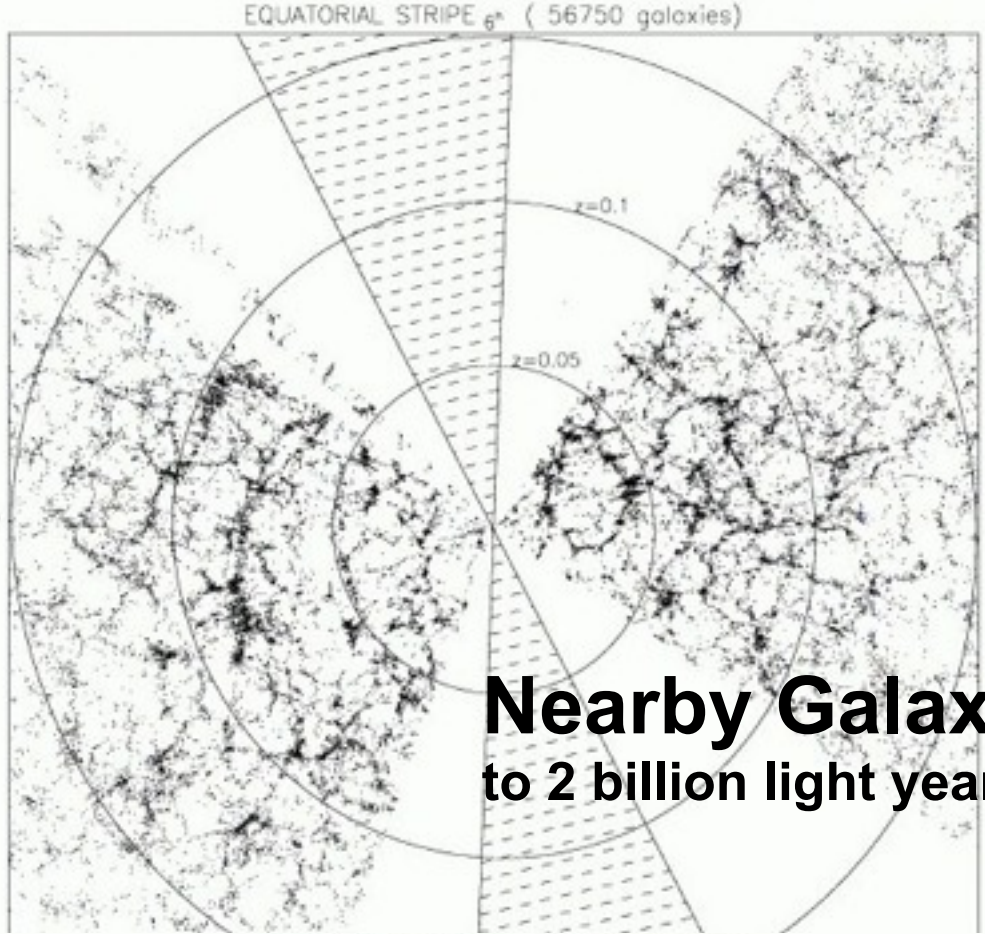
Sloan Digital Sky Survey

**ZOOM-IN TO THE HUBBLE ULTRA DEEP FIELD**

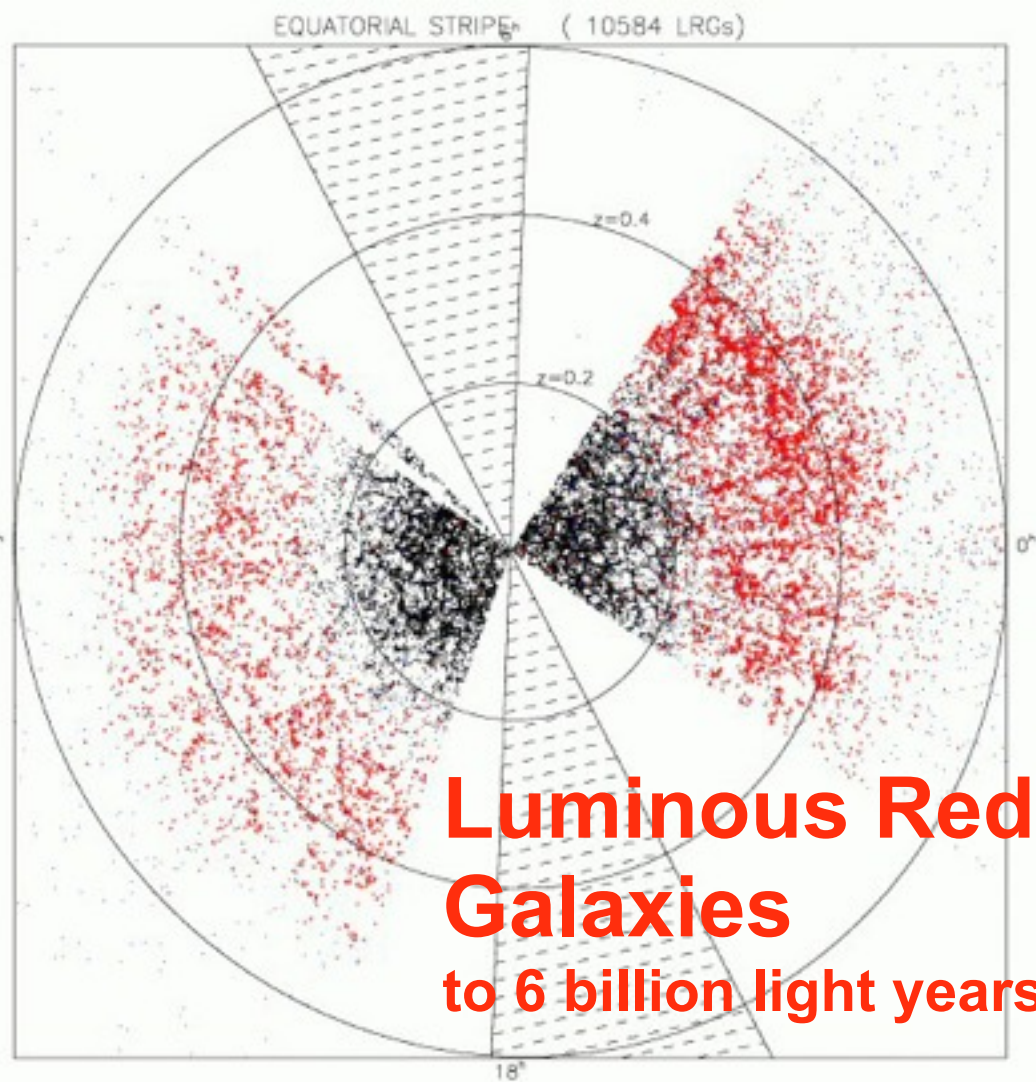




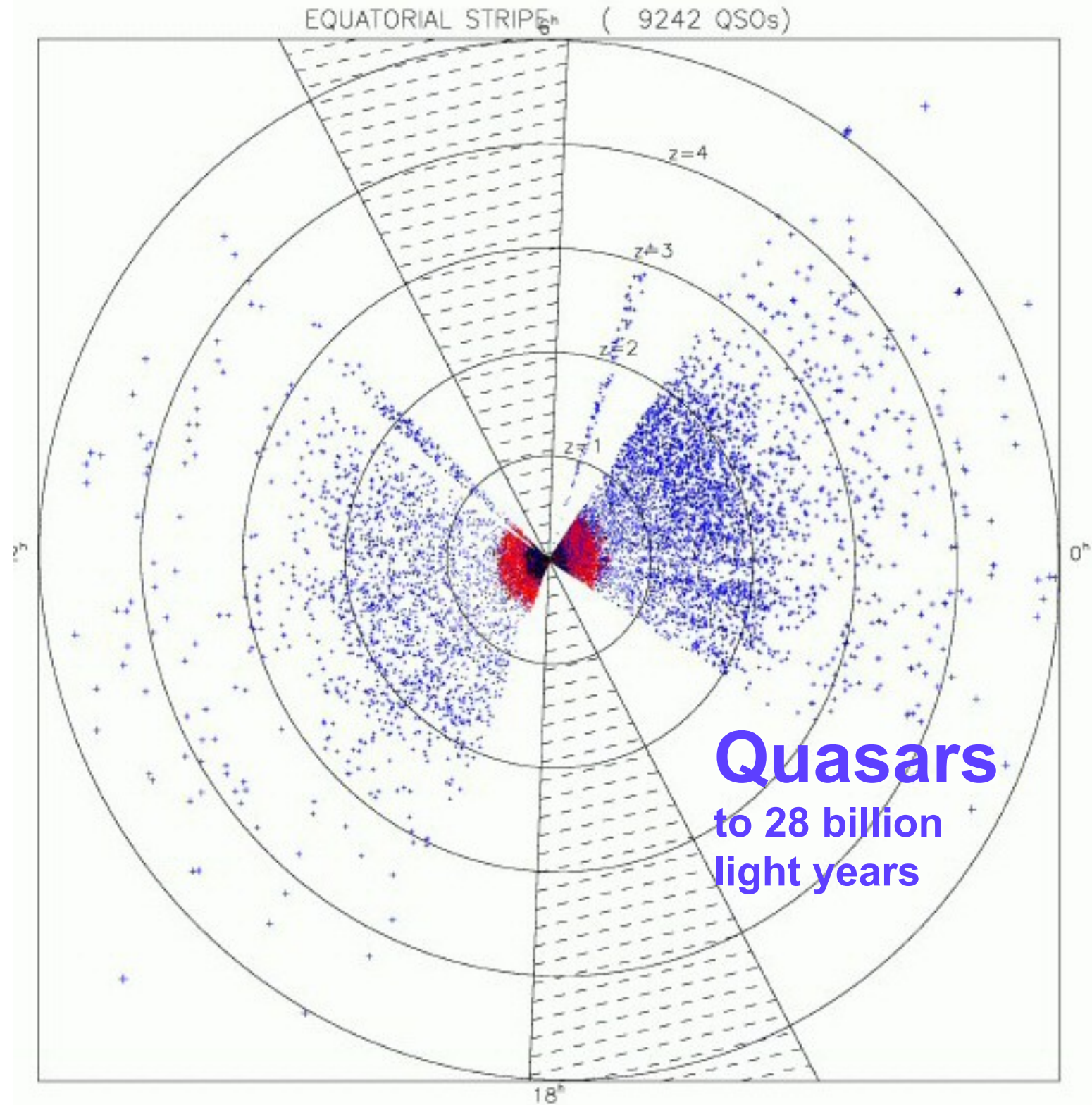
# Sloan Digital Sky Survey



**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:

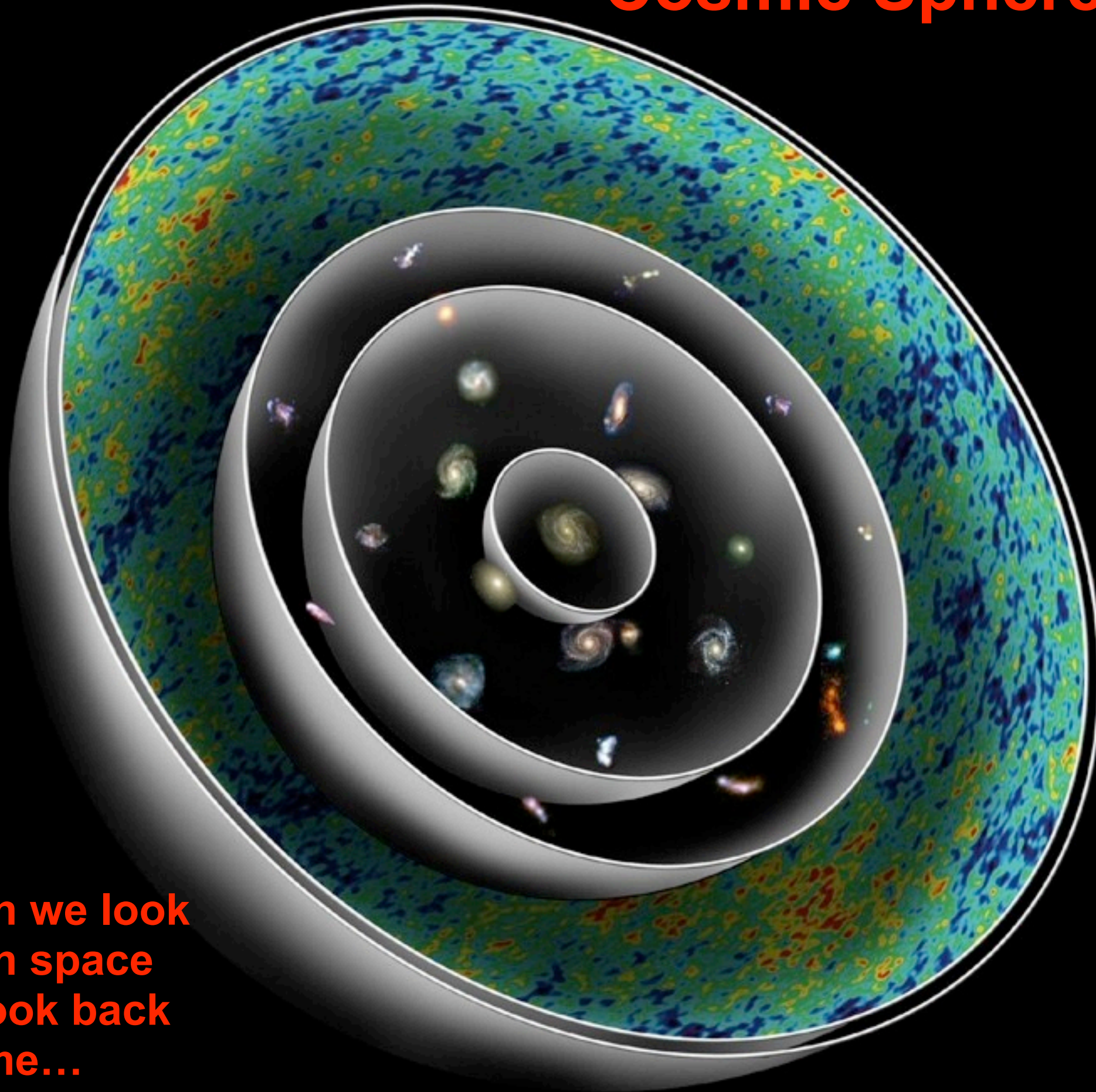
565,715 Galaxies & 76,403 Quasars



# GALAXIES MAPPED BY THE SLOAN SURVEY

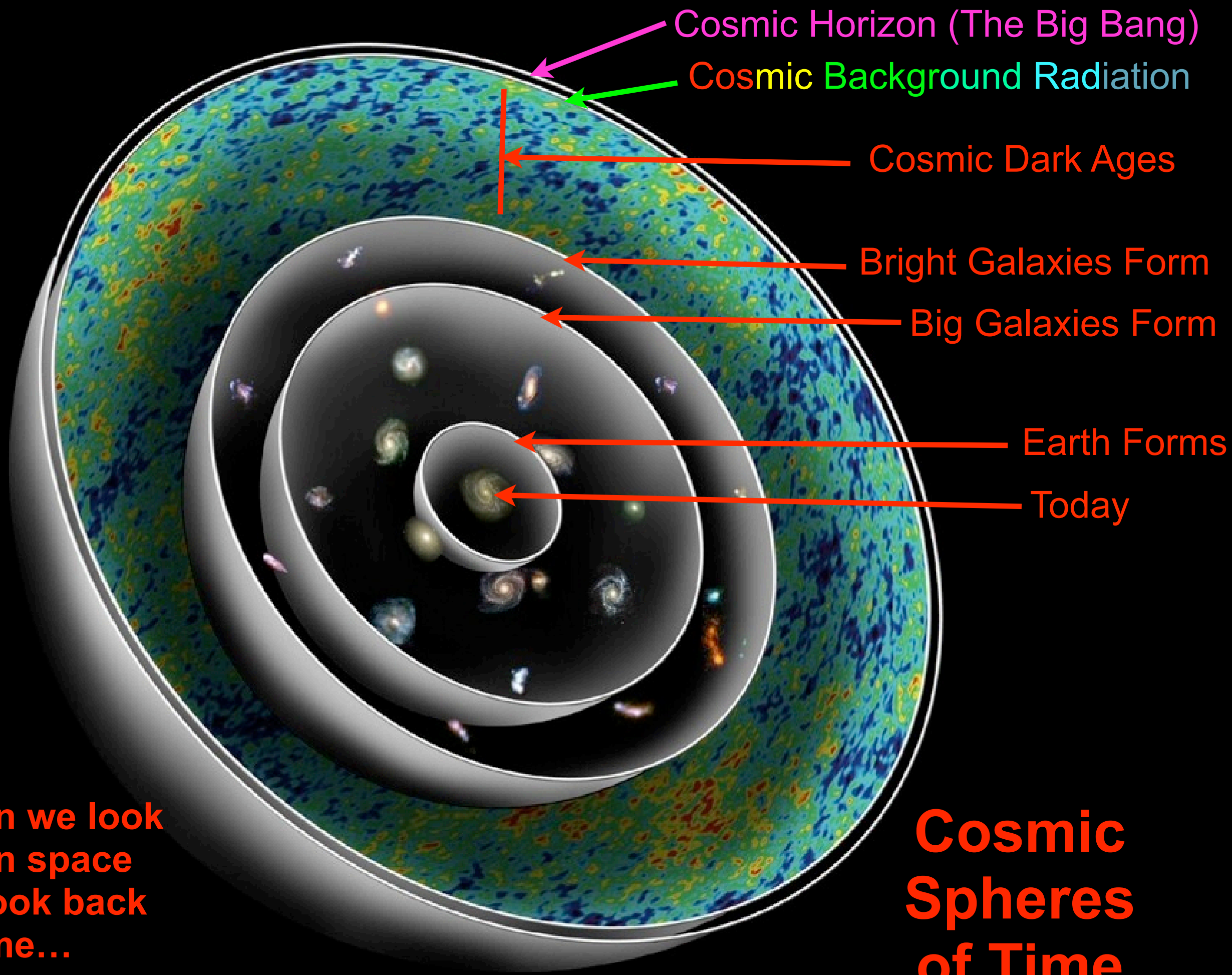


# Cosmic Spheres of Time



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





Cosmic Horizon (The Big Bang)

Cosmic Background Radiation

Cosmic Dark Ages

Bright Galaxies Form

Big Galaxies Form

Earth Forms

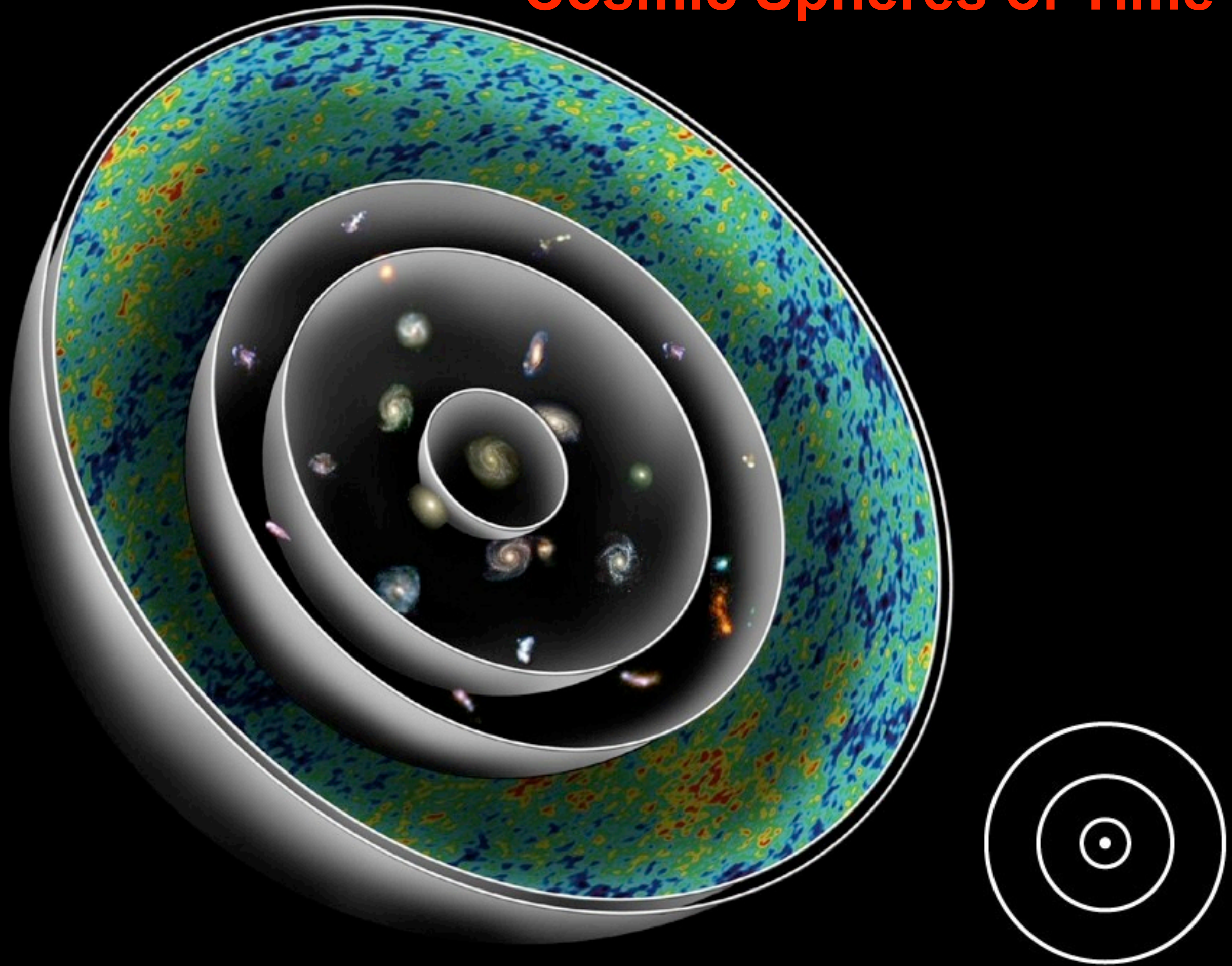
Today

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

Cosmic Spheres of Time



# Cosmic Spheres of Time





# Credits

## 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)

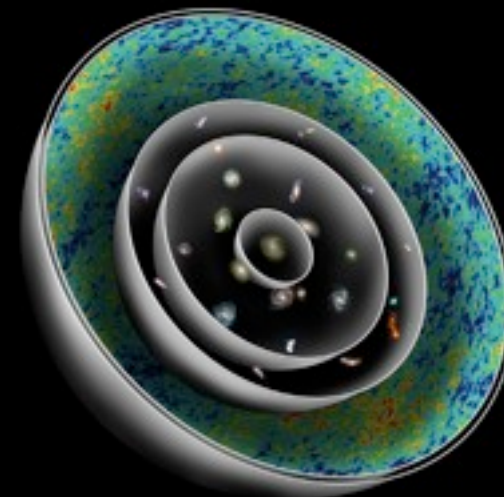
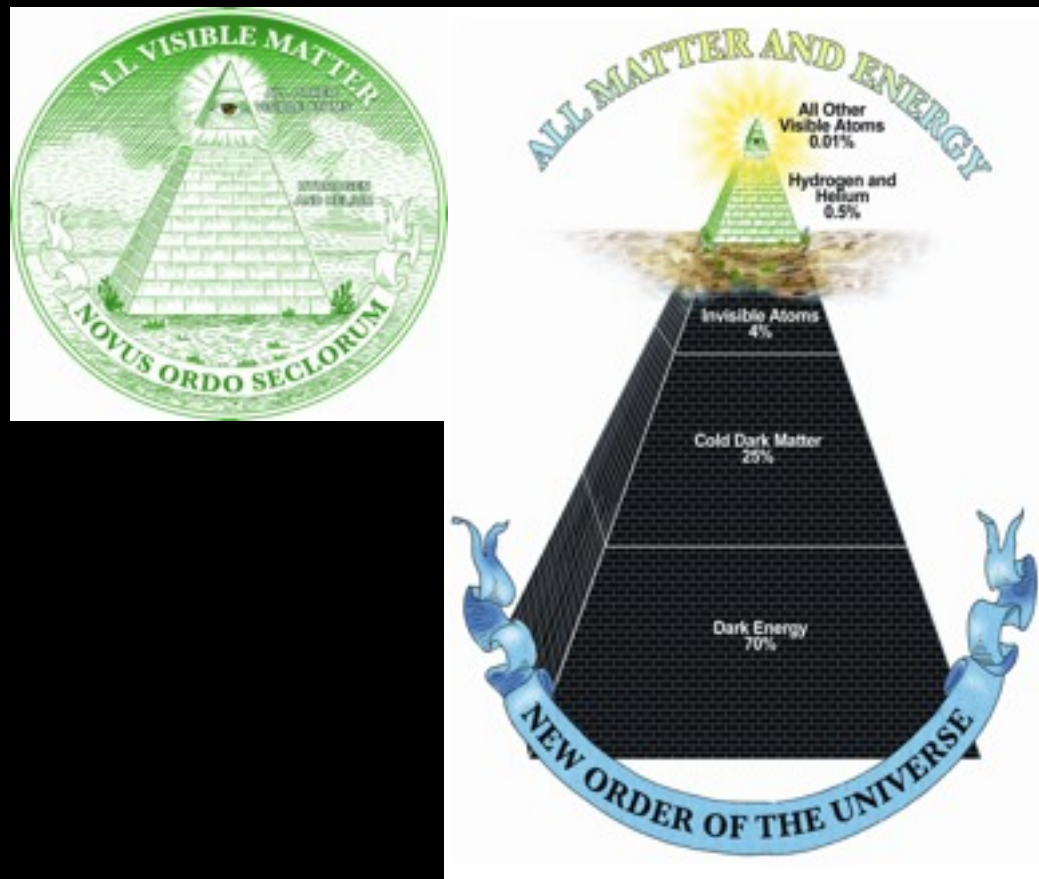
## Music:

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

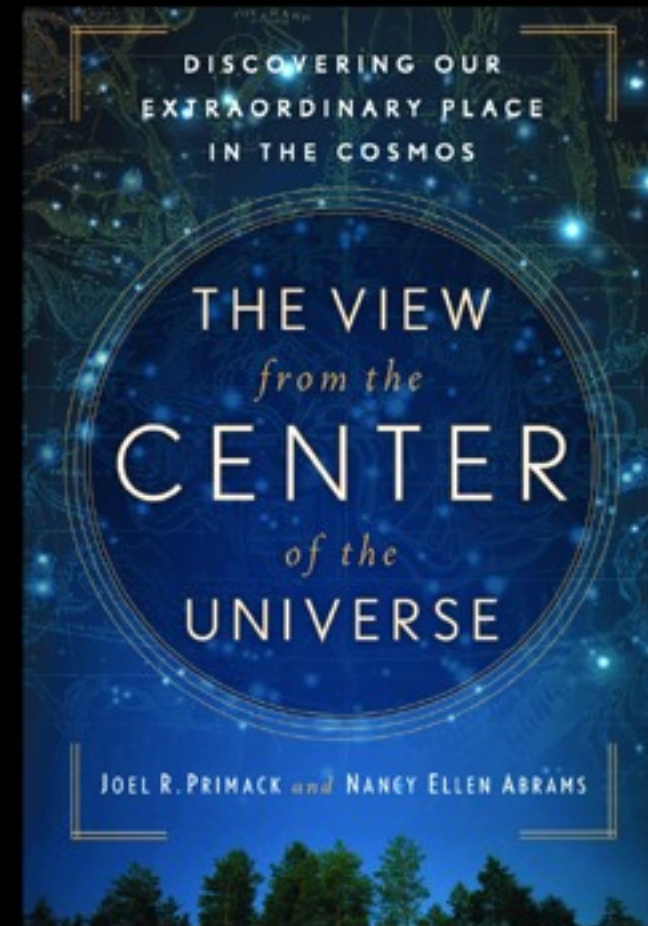
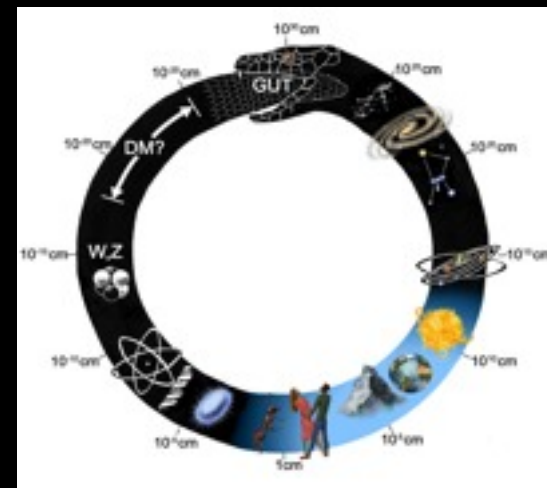
# Symbolic Images of the Cosmos:

### Cosmic Density Pyramid

### Spheres of Time



### Cosmic Uroboros



<http://ViewfromtheCenter.com>