



from **COMPLEXITY**  
to **SIMPLICITY**  
to **COMPLEXITY**  
to **SIMPLICITY**:  
the Universe at Large

the **BOUND**ed flow of information  
the **BOUND**less thought of man

“To me every hour of the light and dark is a miracle. Every cubic inch of space is a miracle.”

– Walt Whitman

**IN EVERY** teaspoon of air  $\sim 5$  cubic cm  
**Ordinary Matter**  $\sim 1$  amu /nm<sup>3</sup> 4.8% O<sub>2</sub> N ; H,He

## THE DARK

### Dark Matter

$\sim 26.0 \pm 1\%$  compressed in MilkyWay  $\sim 0.1$  amu /cm<sup>3</sup> ;  
for LHC@CERN-type relics  $\sim 1$  every 10 cm

### Dark Energy

$\sim$ vacuum potential  $\sim 69.2 \pm 1.0\%$

## THE LIGHT

### cosmic radiation

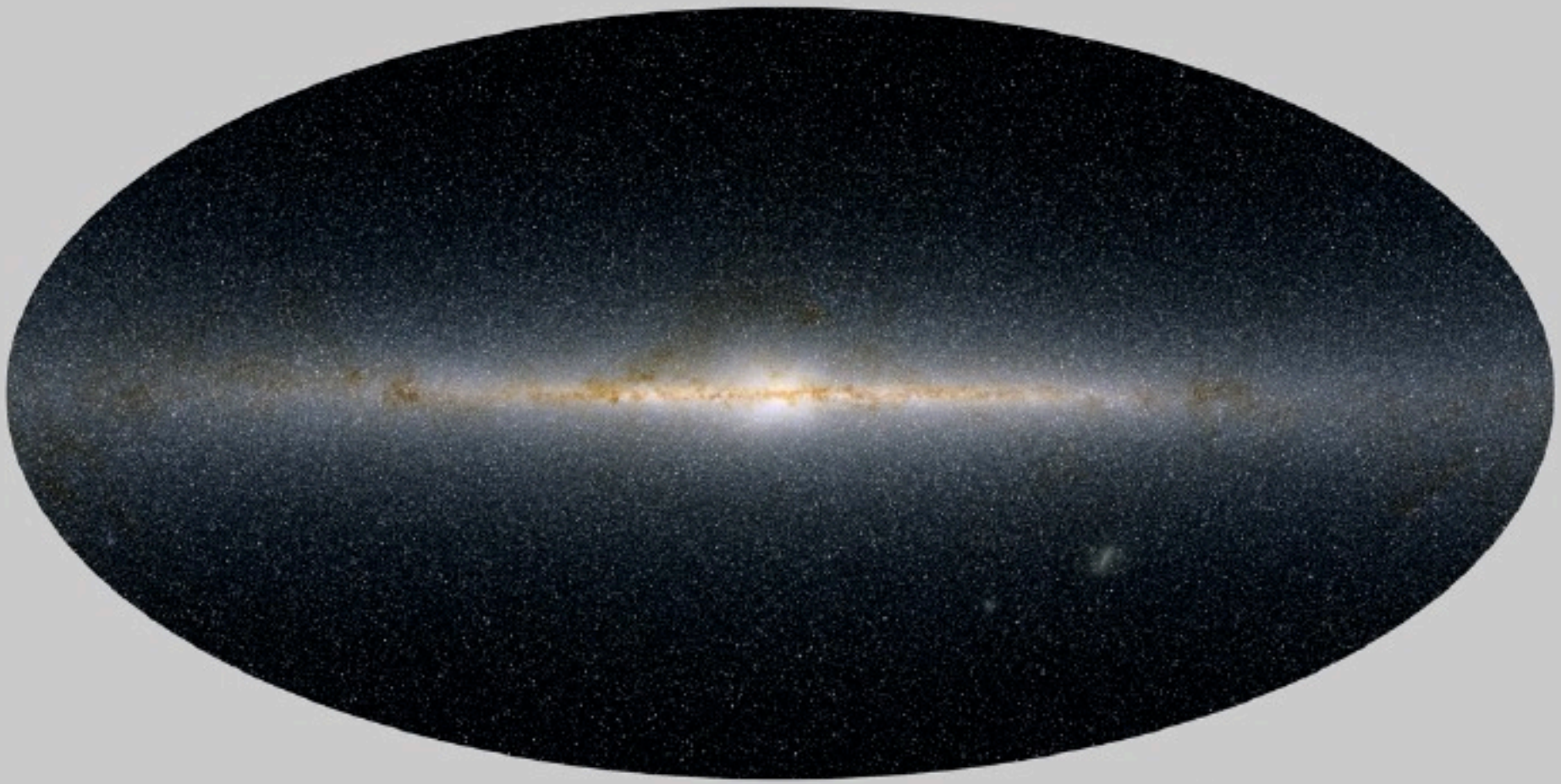
the 1st light of the universe 412 /cm<sup>3</sup> 0.005%  
cosmic neutrinos  $\sim$ cosmic photons  $> 0.47\%$   
cosmic gravity waves  $\ll$  cosmic photons

## THE VACUUM

Higgs@CERN vacuum origin of mass  
vacuum fluctuations origin of all the cosmic structure we see

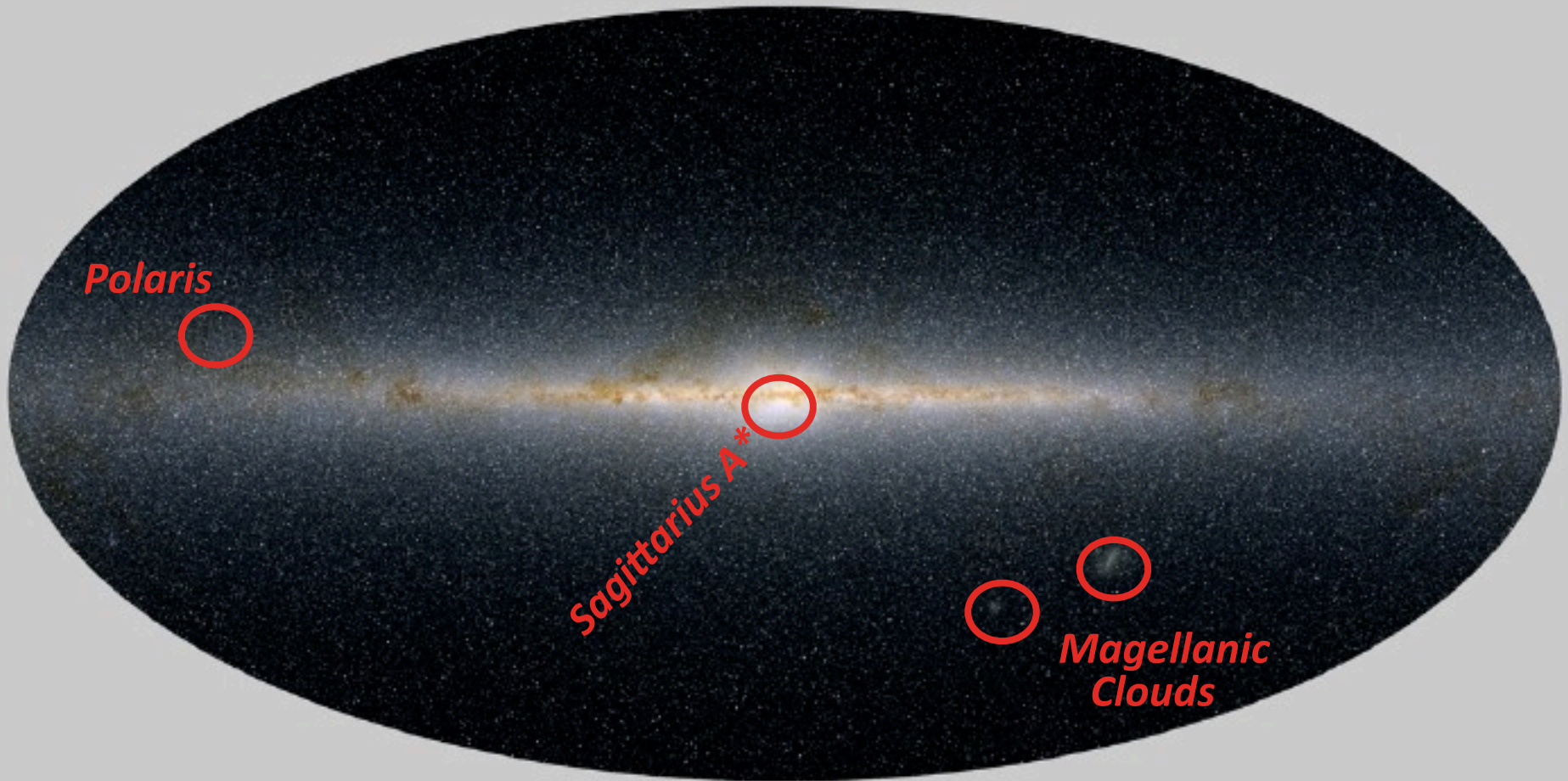


Monday, 22 July, 13

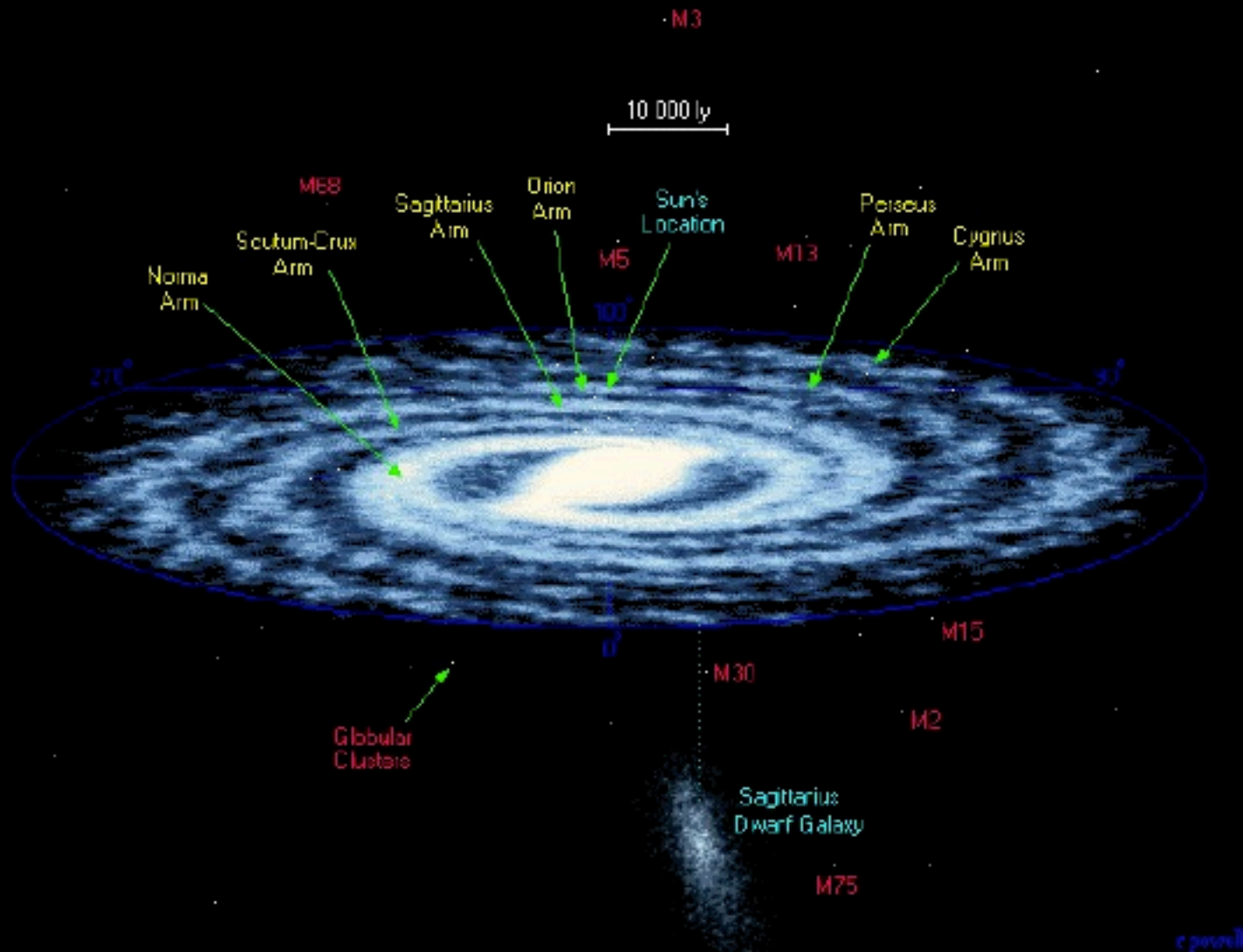


Two Micron All Sky Survey Image: Massach. Infrared Processing and Analysis Center/Catalina B. University of Massachusetts

# Milky Way in infra-red: half a billion stars, a disk galaxy

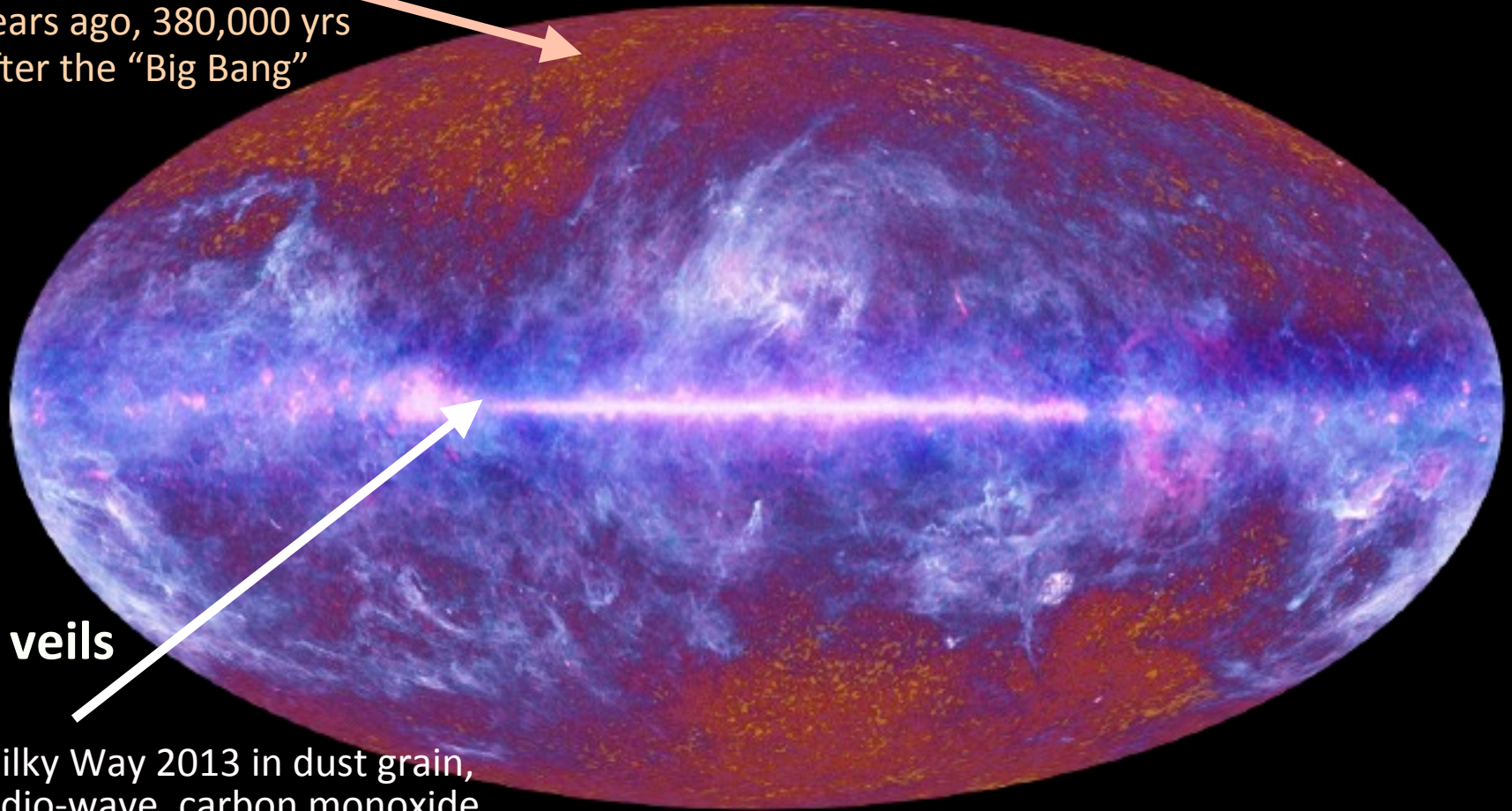


# Milky Way: a disk galaxy with a large dark matter halo



# COMPLEXITY of here & now

the primordial light,  
released 13.8 billion  
years ago, 380,000 yrs  
after the "Big Bang"

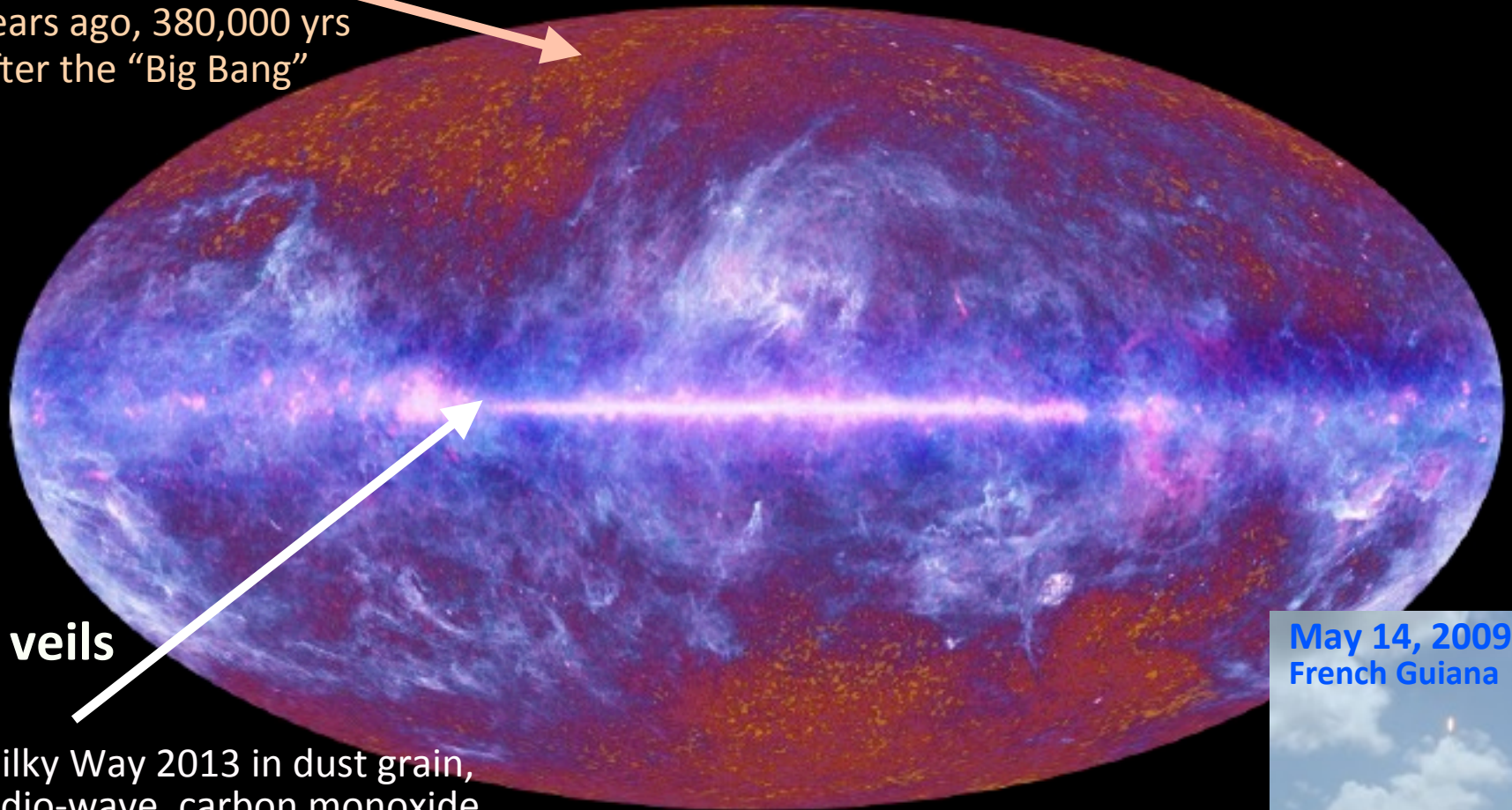


**7 veils**

Milky Way 2013 in dust grain,  
radio-wave, carbon monoxide  
emissions; plus stellar, X-ray,  
gamma ray, cosmic ray  
emissions ...

# COMPLEXITY of here & now

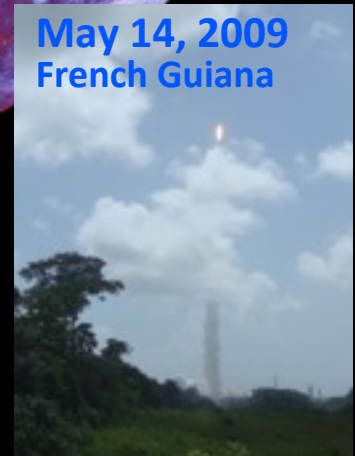
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May 14, 2009  
French Guiana



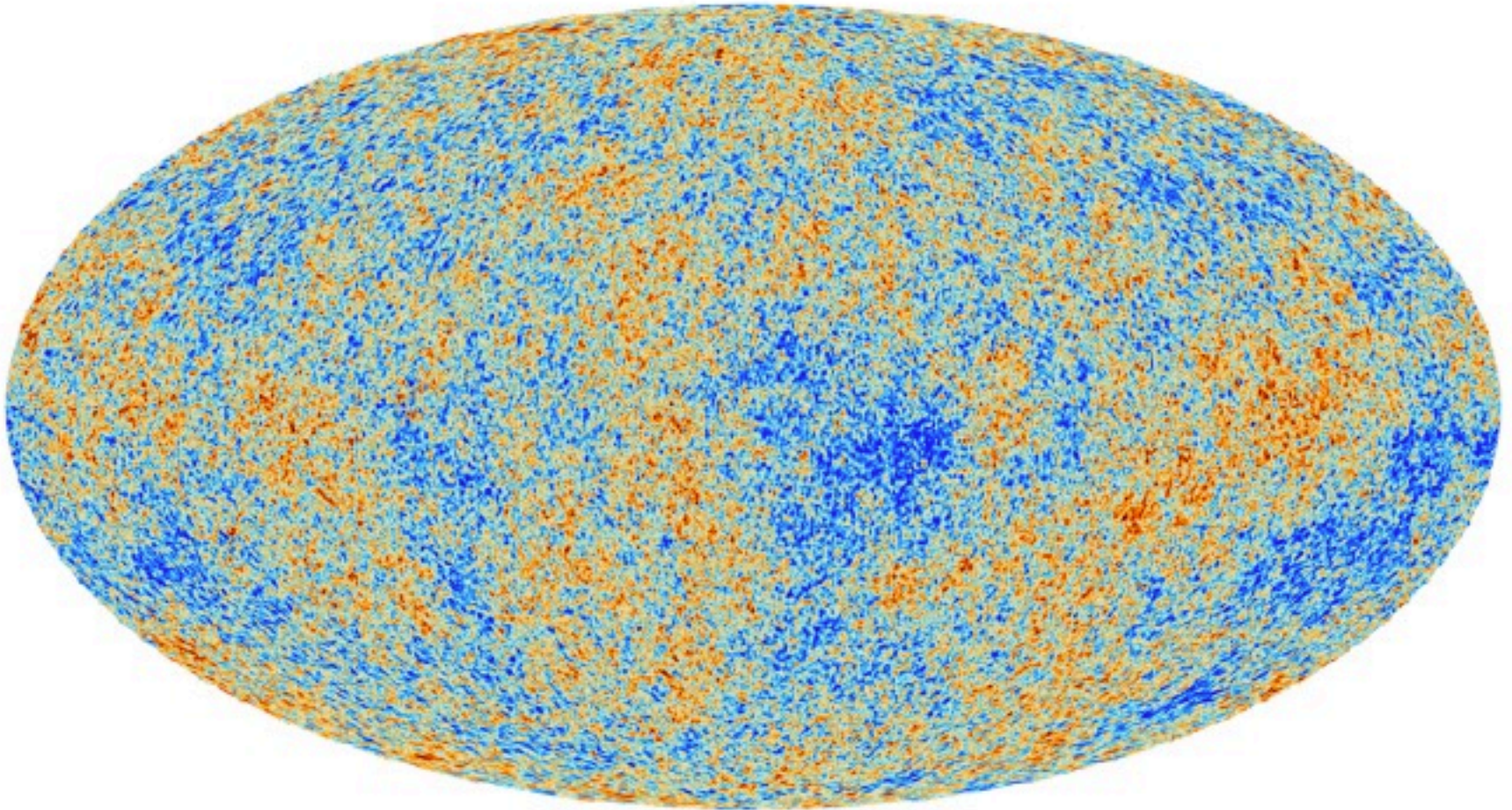
The Planck one-year all-sky survey



(c) ESA, MPE and LFI consortia, July 2010



Planck's primordial light unveiled, March 21, 2013  
reveals the **SIMPLICITY** of primordial cosmic structure  
**in 7+ numbers**



**Temperature changes  
in micro-degrees**

# Google “Planck Satellite 2013 results”: yields ~ 1 million links

THE GLOBE AND MAIL

SPACE

New glimpses of ancient light fuel cosmic debate

Government of Canada / Gouvernement du Canada

Canada

Canadian Space Agency

Home > Audiences > Media > News releases > 2013

> Canadian astronomers reveal surprising new portrait of the Early Universe

Canadian astronomers reveal surprising new portrait of the Early Universe

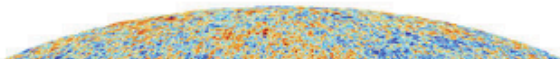
The New York Times

Space & Cosmos

WORLD U.S. N.Y. / REGION BUSINESS TECHNOLOGY SCIENCE HEALTH SPORTS OPINION

ENVIRONMENT SPACE & COSMOS

Universe as an Infant: Fatter Than Expected and Kind of Lumpy



L'enfance de l'Univers dévoilée

LE MONDE | 21.03.2013 à 11h27 • Mis à jour le 21.03.2013 à 13h44



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Plancking at U of T: space

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RESEARCH

CIFAR  
cosmologists  
contribute to  
new portrait  
of the Early  
Universe



CITA-ICAT

NEWS ARCHIVE

PLANCK

Light



# a scale of the Universe

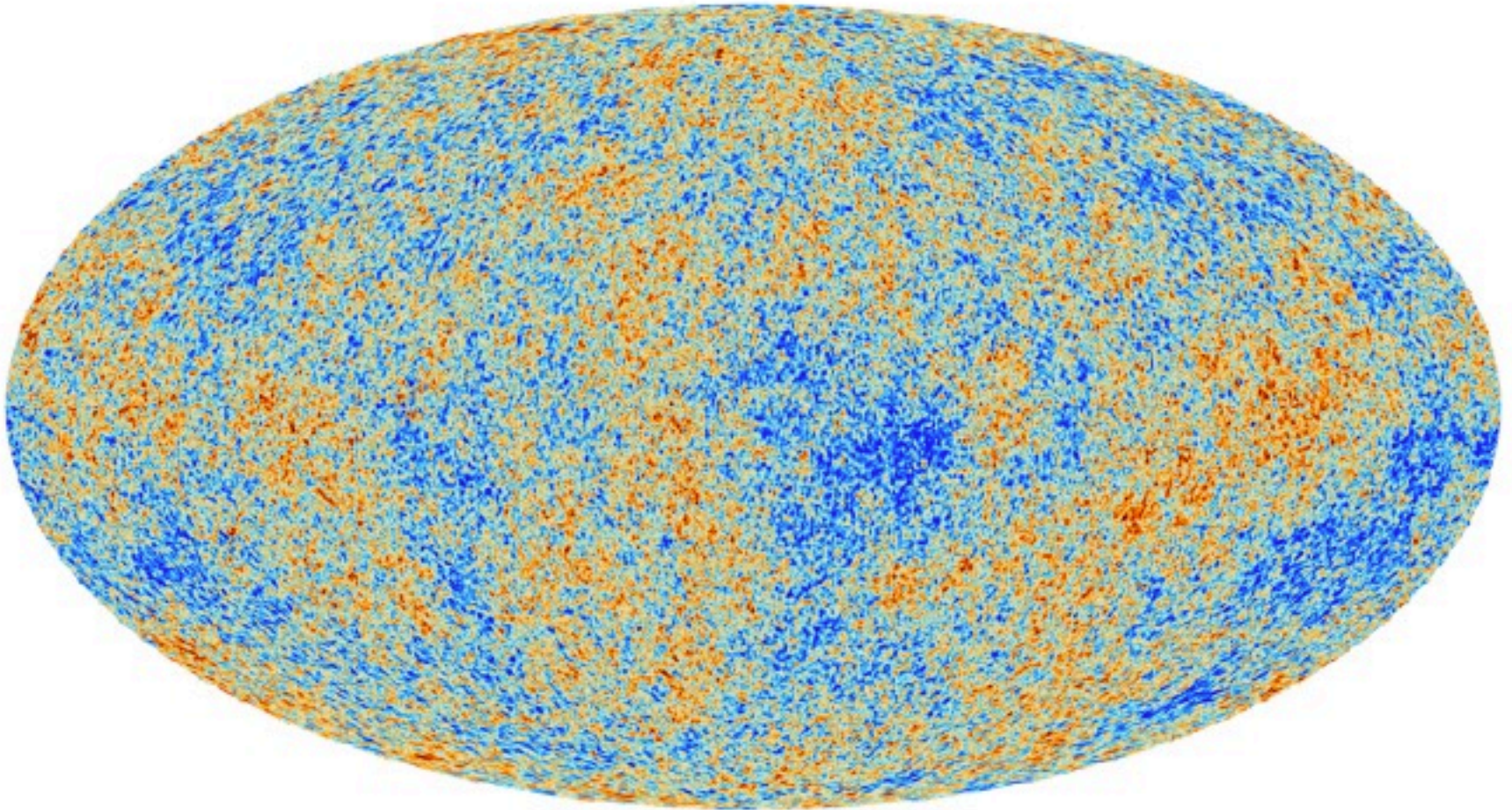
**now = 1** when we **observe** the **1st light**

**then = 1/1100** when the **1st light**  
was **released from matter**,  
billion X denser

**galaxies forming ~ 1/4**

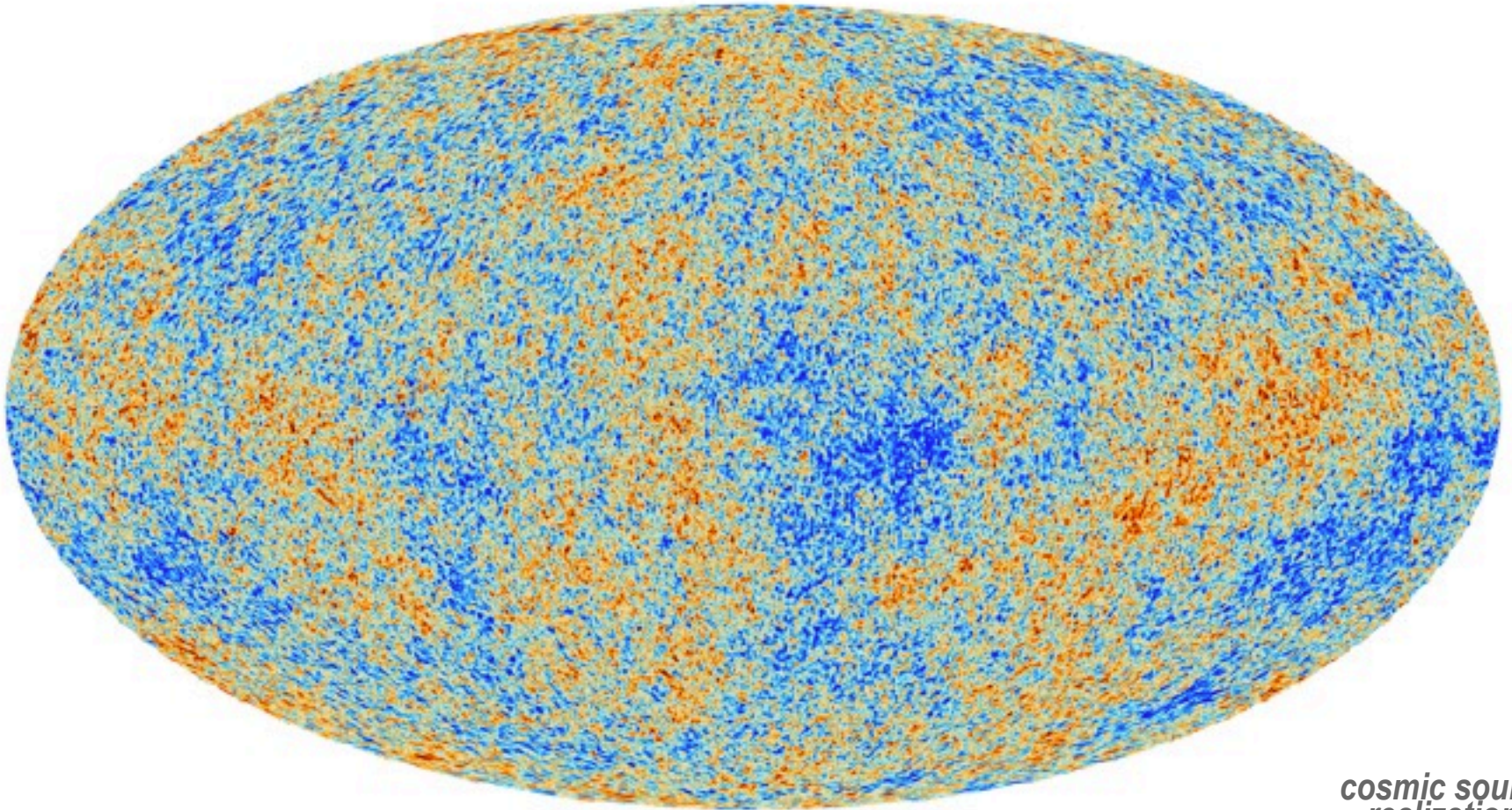
there were **no galaxies** when  $a < 1/20$

reveals **primordial sound waves**  
=> the inharmonious '*music of the spheres*'  
**in 7<sup>+</sup> numbers**



**Temperature changes  
in micro-degrees**

reveals **primordial sound waves**  
=> the inharmonious '*music of the spheres*'  
**in 7<sup>+</sup> numbers**



*cosmic sound  
realization*

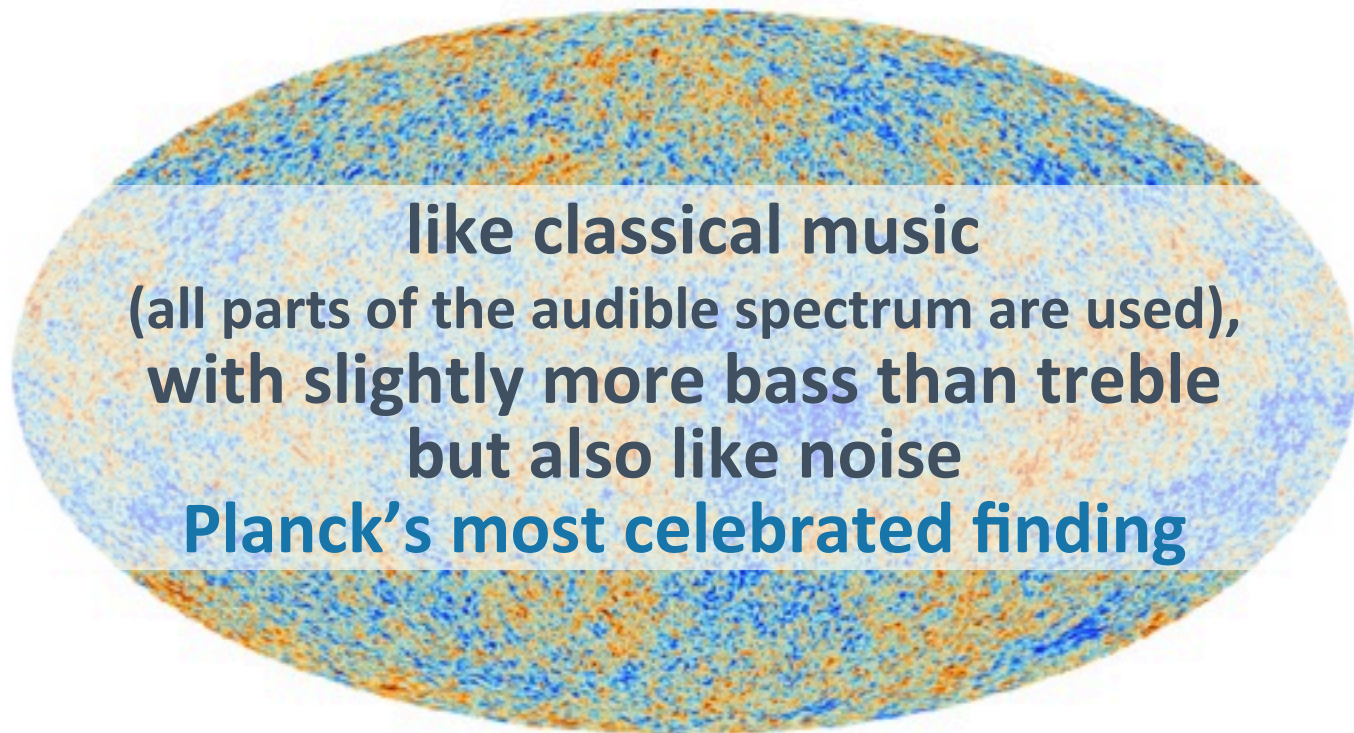
**Temperature changes  
in micro-degrees**

reveals **primordial sound waves**

=> the inharmonious '*music of the spheres*' **in 7<sup>+</sup> numbers**

=> learn **matter & energy content & structure** at  $a \sim e^{-7}$  380000 yr

=> infer structure **far far earlier**  $a \sim e^{-127} \sim 1/10^{55}$  **in 2 numbers**



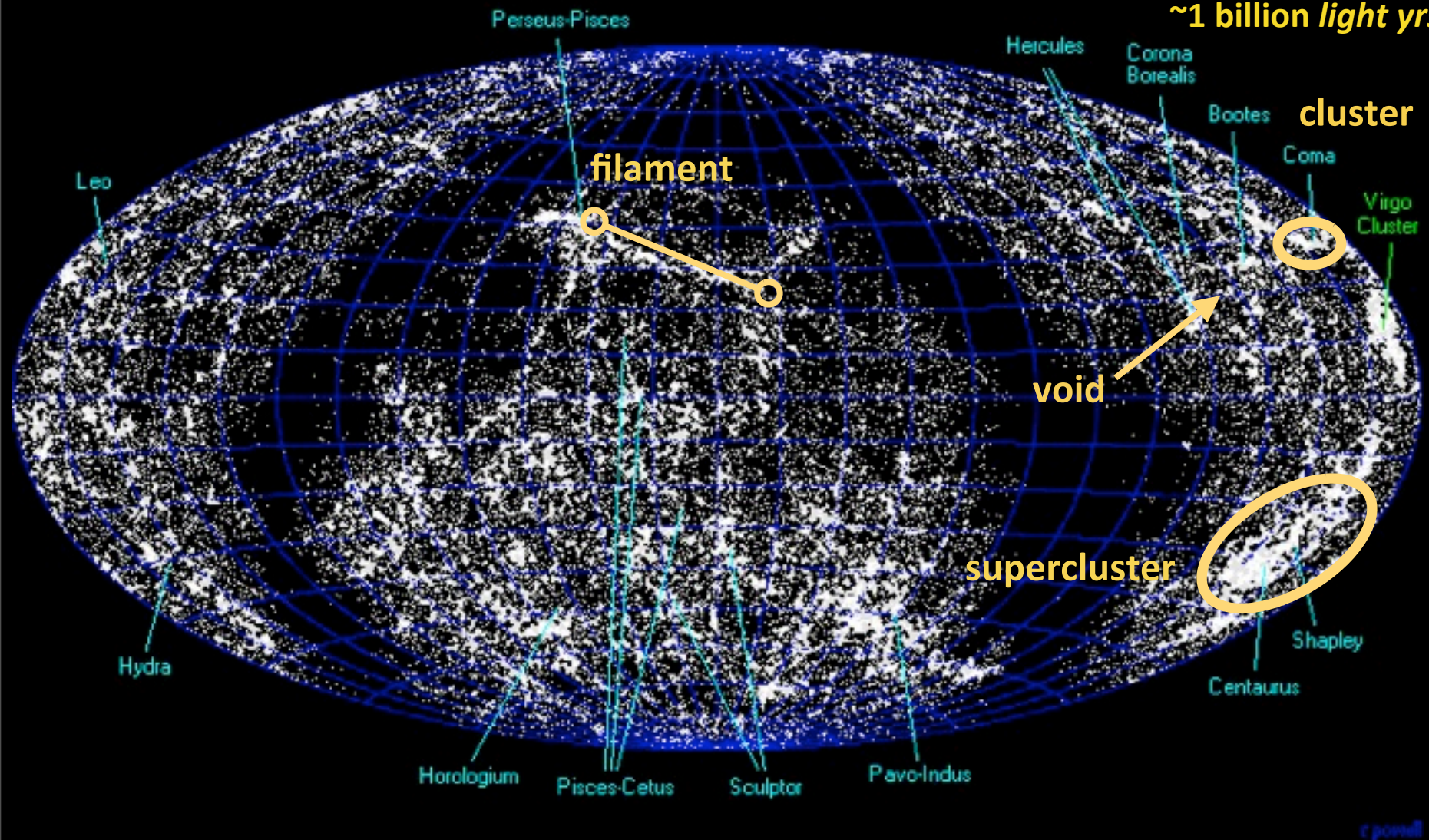
like classical music  
(all parts of the audible spectrum are used),  
with slightly more bass than treble  
but also like noise  
**Planck's most celebrated finding**

**Temperature changes  
in micro-degrees**

# Cosmic Web of 60,000 nearby galaxies: exhibits “local” COMPLEXITY

$$a \sim e^{-0.1} = 1/1.1$$

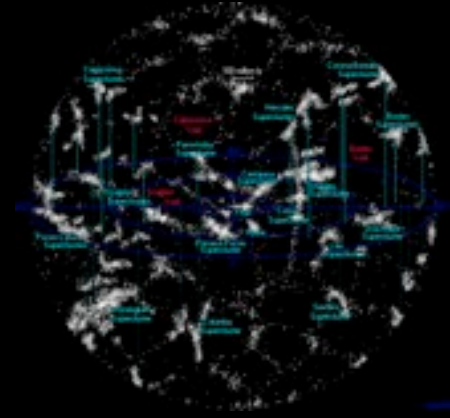
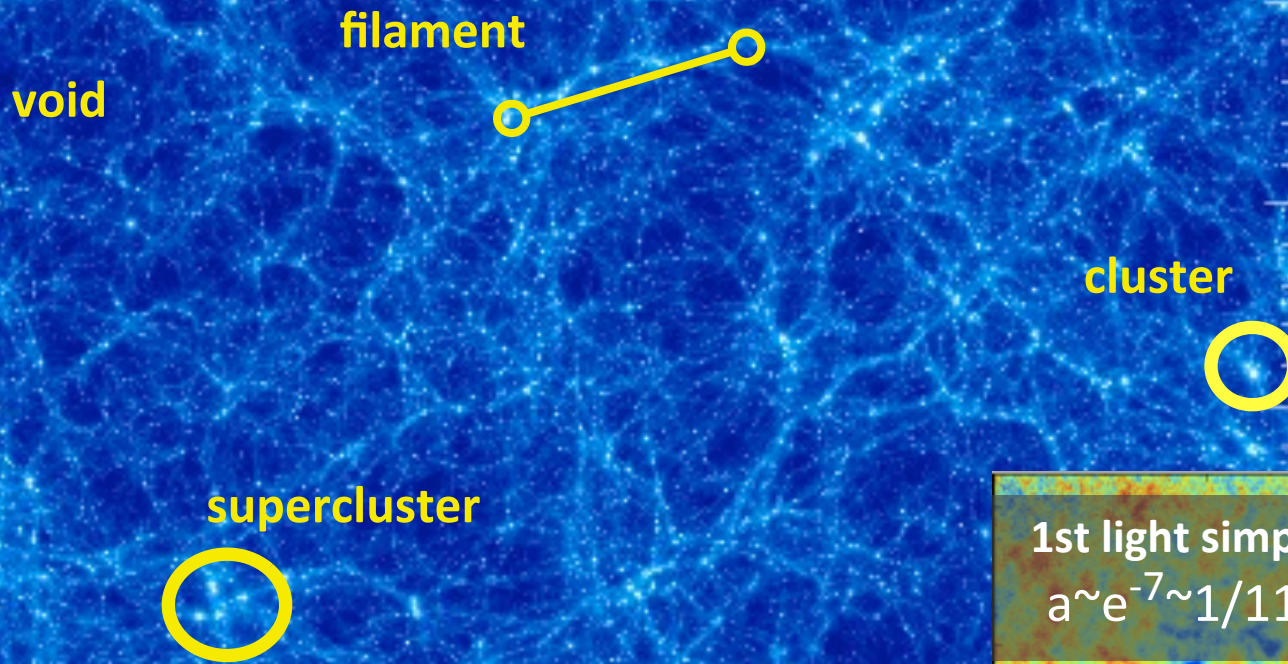
*~1 billion light yrs*



# Simulation of the 7<sup>+</sup> numbers

begets the **Cosmic Web** of clusters now  $a \sim 1$  & galaxies then  $a \sim 1/4$

**SIMPLICITY to COMPLEXITY under Gravity**



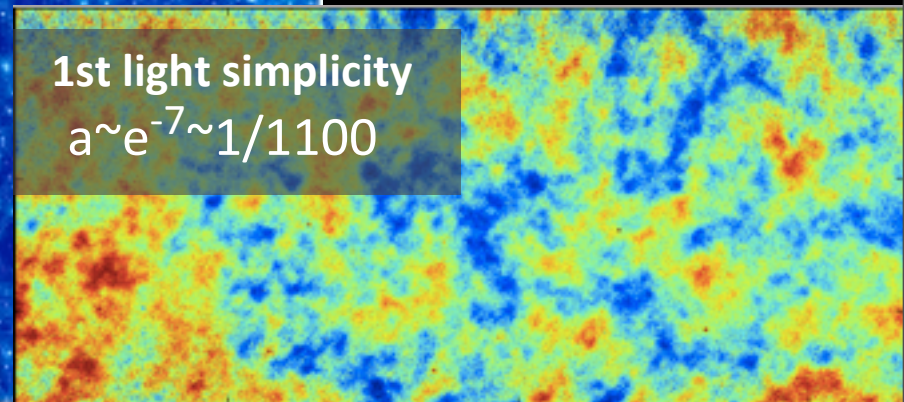
$\sim$  billion light years

state of the art simulation  
 $a \sim 1$  to  $1/1.1$

ordinary matter  
dark matter  
dark energy

1st light simplicity

$a \sim e^{-7} \sim 1/1100$





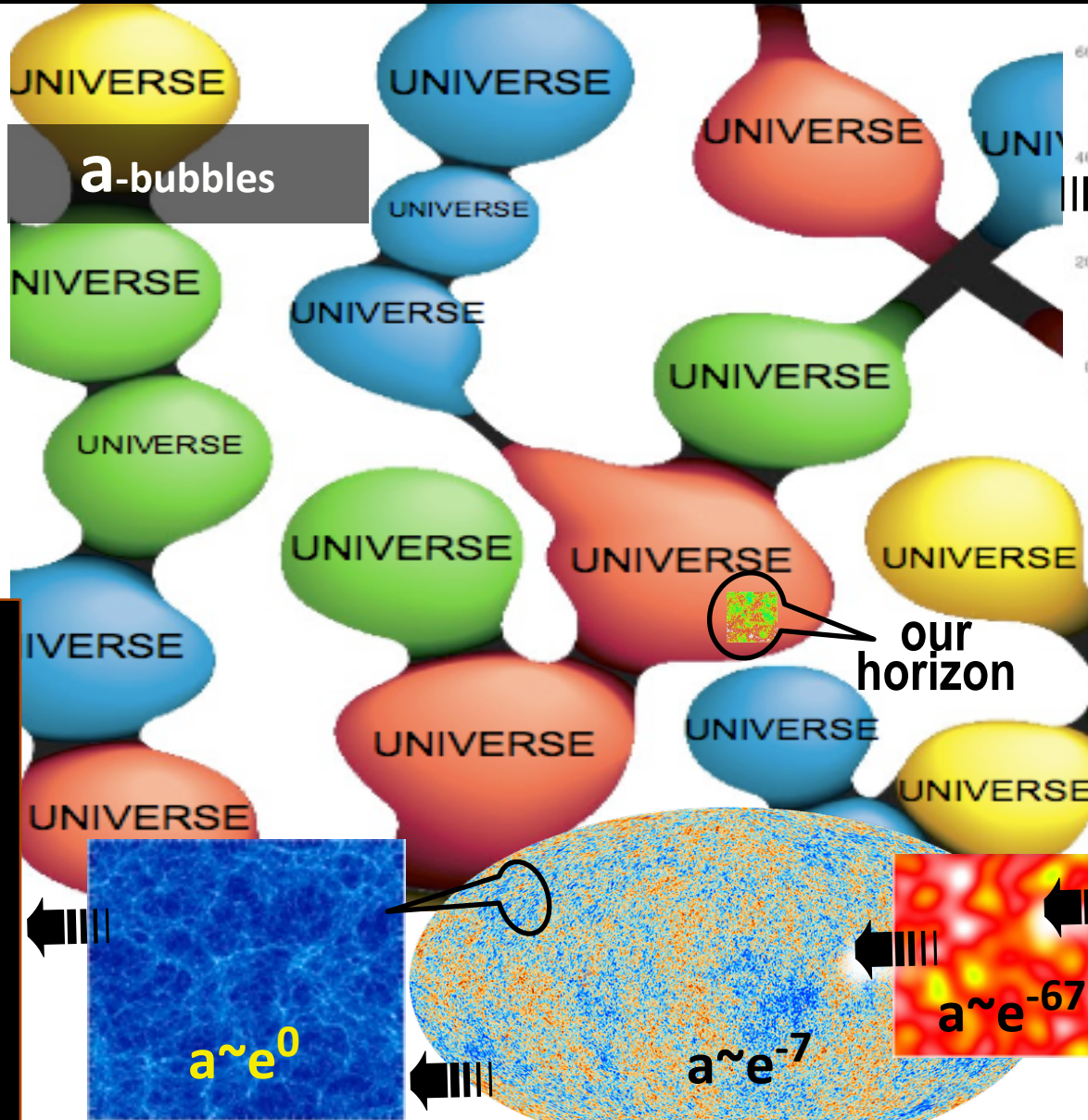
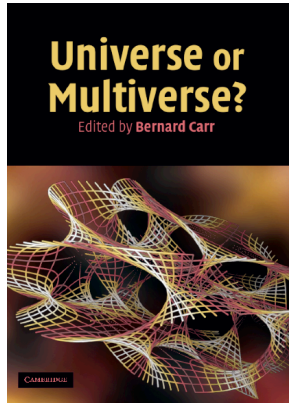
A dark field of galaxies, likely from the Sloan Digital Sky Survey. The image shows a vast field of galaxies in various colors (yellow, orange, red, blue, white) and shapes (spiral, elliptical, irregular). A bright star with a prominent diffraction pattern is visible in the center. The text is overlaid on the image.

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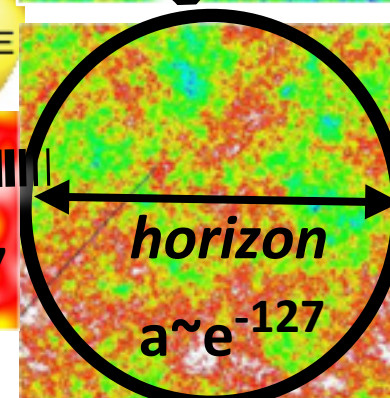
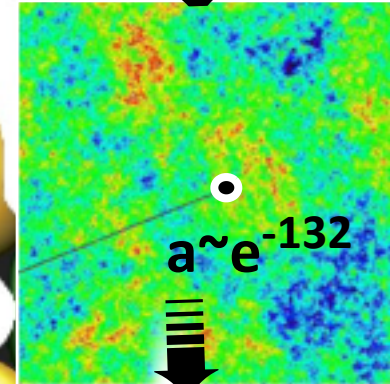
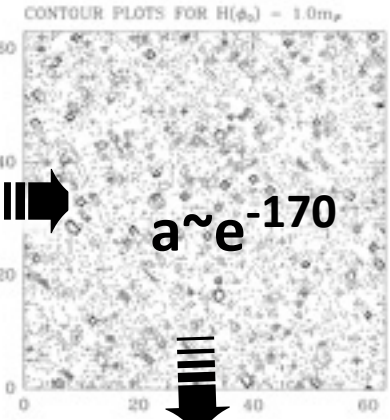
beyond our Horizon

# ultra-Ultra Large Scale Structure of the Universe

Horizons: the ultimate-speed constraint on light & information



$a$ -bubbles



END

a future DE-Void



$a \sim e^{+++}$

$a \sim e^0$

$a \sim e^{-7}$

$a \sim e^{-67}$

our horizon

horizon

$a \sim e^{-127}$

# Let there be.....

Early **Dark Energy** from  $e^{-170?}$  to  $e^{-67}$

**2 numbers** quantum **noise**  $e^{-127}$  to  $e^{-67}$

Heat: matter & **radiation**  $a \sim e^{-67}$

**Dark Matter**, light nuclei  $a \sim e^{-21}$  to  $e^{-35}$

Cosmic **Light**: 1st light released, 1st atoms  $a \sim e^{-7}$

1st stars  $a \sim e^{-3}$ , 1st heavy nuclei (O, C, Fe,..)

Galaxies  $> e^{-2.2}$

**Earth**  $a \sim e^{-0.34}$

1st human writing  $a \sim e^{-0.0000004}$

Late **Dark Energy** to  $e^{+++}$

# Let there be.....

Early **Dark Energy** from  $e^{-170?}$  to  $e^{-67}$

semi **ETERNAL** Universe  
most of it never Banged

**2 numbers** quantum **noise**  $e^{-127}$  to  $e^{-67}$

Heat: matter & **radiation**  $a \sim e^{-67}$

Our little **Big Bang**

**Dark Matter**, light nuclei  $a \sim e^{-21}$  to  $e^{-35}$

Cosmic **Light**: 1st light released, 1st atoms  $a \sim e^{-7}$

1st stars  $a \sim e^{-3}$ , 1st heavy nuclei (O, C, Fe,..)

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Late **Dark Energy** to  $e^{+++}$

Will our bit of the Universe re-Bang?  
**NO...** maybe



**We shall not cease from exploration  
And the end of all our exploring  
Will be to arrive where we started  
And know the place for the first time**

– T. S. Eliot