Norma G. SANCHEZ

Séance Daniel Chalonge Héctor de Vega

le 19 Juin 2018

au Collège d'Espagne CIUP, Paris 14e

Le dernier travail de Stephen HAWKING

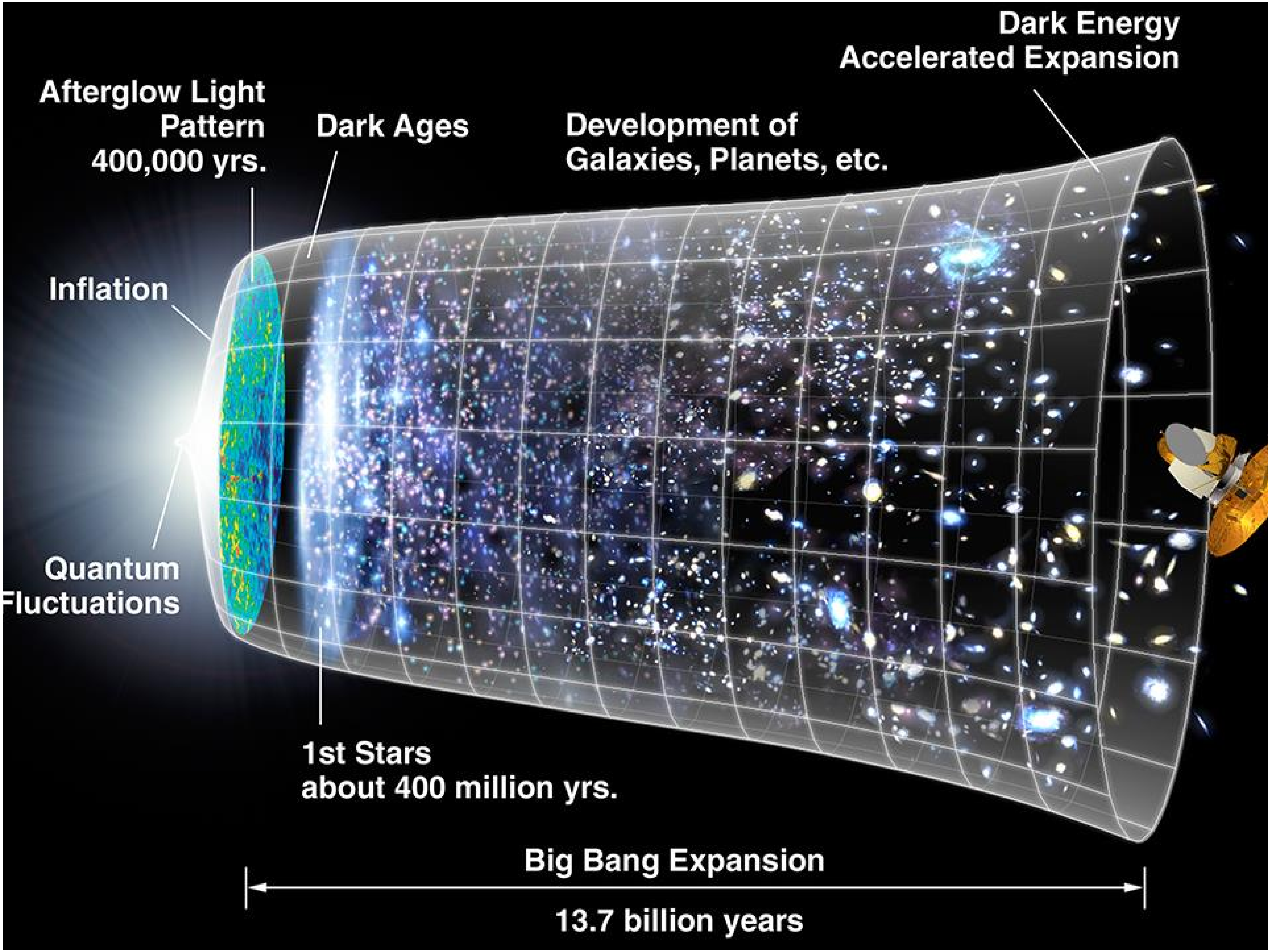
ou une mise en perspective scientifique à travers plusieurs mois de mai (de mai 1979 au mai 2018)

1. L'inflation . 2 L'inflation « éternelle »: l'évolution du concept et son contexte : 3. Les Multivers et leur contexte : 4: Fractalité, self-similarité, universalité, univers, multivers.

1. Inflation: Gravitation semiclassique, non speculative.

2. Inflation « éternelle »: spéculative. Non éternelle.

3. Multivers: « Naturel » dans Cosmologie Quantique actuelle et dévéloppements récents.


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

THE ENERGY SCALE OF INFLATION IS THE

THE SCALE OF GRAVITY IN ITS SEMICLASSICAL REGIME

(OR THE SEMICLASSICAL GRAVITY TEMPERATURE)

(EQUIVALENT TO THE HAWKING TEMPERATURE)

The CMB allows to observe it

(while is not possible to observe for Black Holes)

The Universe Today is Essentially Empty

Inter galactic distances $\sim$ Mpc. (pc = 3.0857×10^{13} kms.)

Galaxy sizes $\sim 0.0001 - 0.1$ Mpc. (pc = 3.262 light years.)

99.9 % of the universe volume is the intergalactic space with an average energy density of 5 proton masses per m^3 (cosmological constant).

Galaxy masses: $10^6 - 10^{12}\ M_\odot$ from dwarf compact galaxies to (diluted) big galaxies spirals.

Galaxy density:

$\sim 4000 - 40000$ proton masses per m^3 for big galaxies.

$\sim 4 \times 10^6$ proton masses per m^3 for small compact galaxies.

For comparison: air density at the atmospheric pressure and 0^o C $\sim 3.9 \times 10^{26}$ proton masses per m^3.

De Sitter Geometry and Scale Invariance

The De Sitter metric is scale invariant:

$$ds^2 = \frac{1}{(H\ \eta)^2}\left[(d\eta)^2 - (d\vec{x})^2\right] \ .$$

$\eta =$ conformal time.

But inflation only lasts for N efolds !

Corrections to scale invariance:

$|n_s - 1|$ as well as the ratio r are of order $\sim 1/N$,

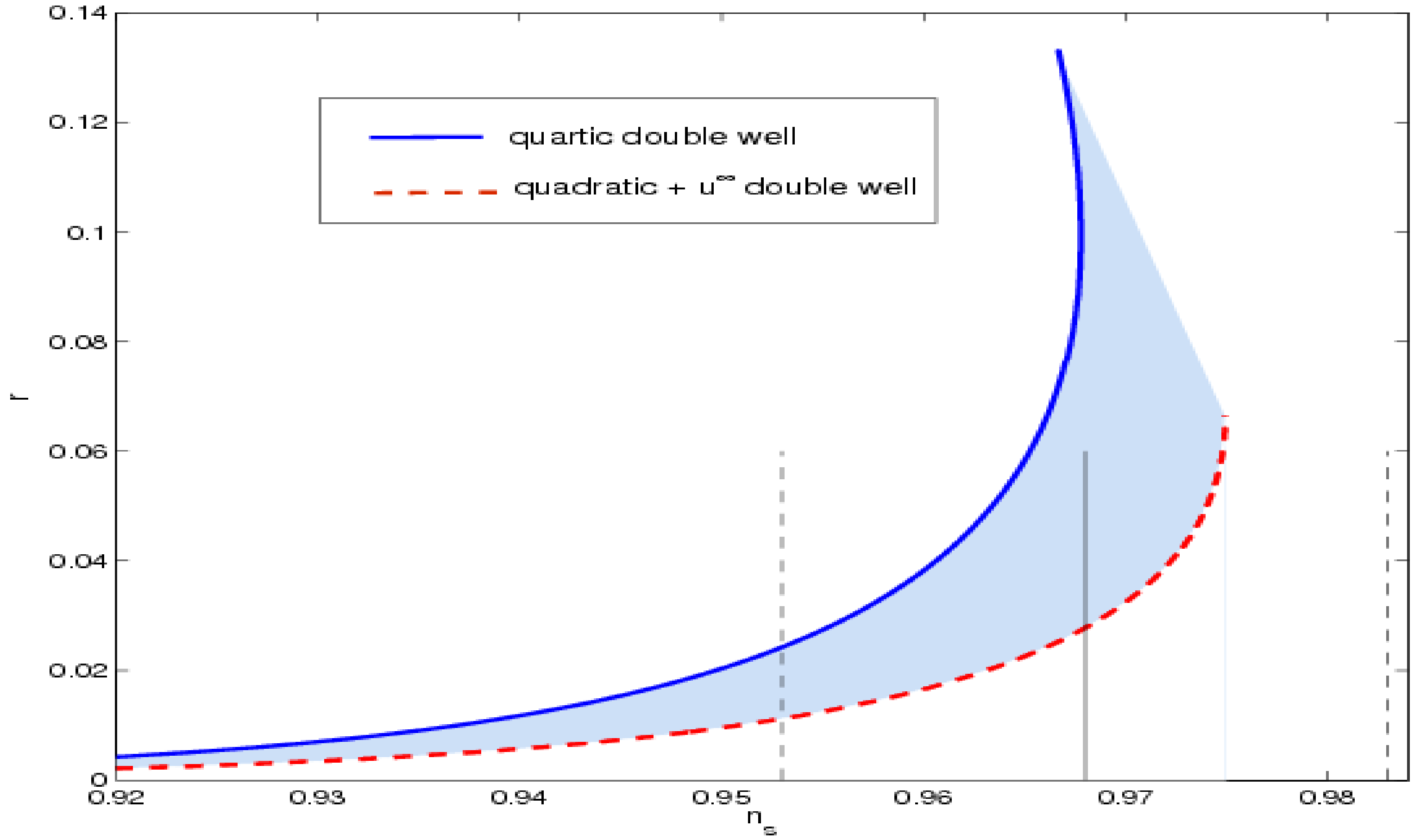
$n_s = 1$ and $r = 0$ correspond to a critical point.

It is a gaussian fixed point around which the inflation model hovers in the renormalization group (RG) sense with an almost scale invariant spectrum during the slow roll stage.

The quartic coupling:

$$\lambda = \frac{G_4}{N}\left(\frac{M}{M_{Pl}}\right)^4 \quad , \quad N = \log \frac{a(\text{inflation end})}{a(\text{horizon exit})}$$

runs like in four dimensional RG in flat euclidean space.



THE PRIMORDIAL COSMIC BANANA

The tensor to scalar ratio r (primordial gravitons) versus the scalar spectral index n_s. The amount of r is always non zero

H.J. de Vega, C. Destri, N.G. Sanchez, Annals Phys 326, 578(2011)

From WMAP9 to Planck

Understanding the direction in which data are pointing:

Å PREDICTIONS for Planck

Å Standard Model of the Universe

Å Standard Single field Inflation

Å NO RUNNING of the Primordial Spectral Index

Å NO Primordial NON GAUSSIANITY

Effective Theory of Inflation (ETI) confirmed by Planck

Quantity	ETI Prediction	Planck 2013
Spectral index $1 - n_s$	order $1/N = 0.02$	0.04
Running $dn_s/dlnk$	order $1/N^2 = 0.0004$	< 0.01
Non-Gaussianity f_{NL}	order $1/N = 0.02$	< 6
	ETI + WMAP+LSS	
tensor/scalar ratio r	r > 0.02	< 0.11 see BICEP
inflaton potential curvature $V''(0)$	$V''(0) < 0$	$V''(0) < 0$

ETI + WMAP+LSS means the MCMC analysis combining the ETI with WMAP and LSS data. Such analysis calls for an inflaton potential with negative curvature at horizon exit. The double well potential is favoured (new inflation).
D. Boyanovsky, C. Destri, H. J. de Vega, N. G. Sanchez, arXiv:0901.0549, IJMPA 24, 3669-3864 (2009).

Two key observable numbers :

associated to the primordial density and primordial gravitons :

PREDICTIONS

ns = 0.9608 , r ~ 0.04

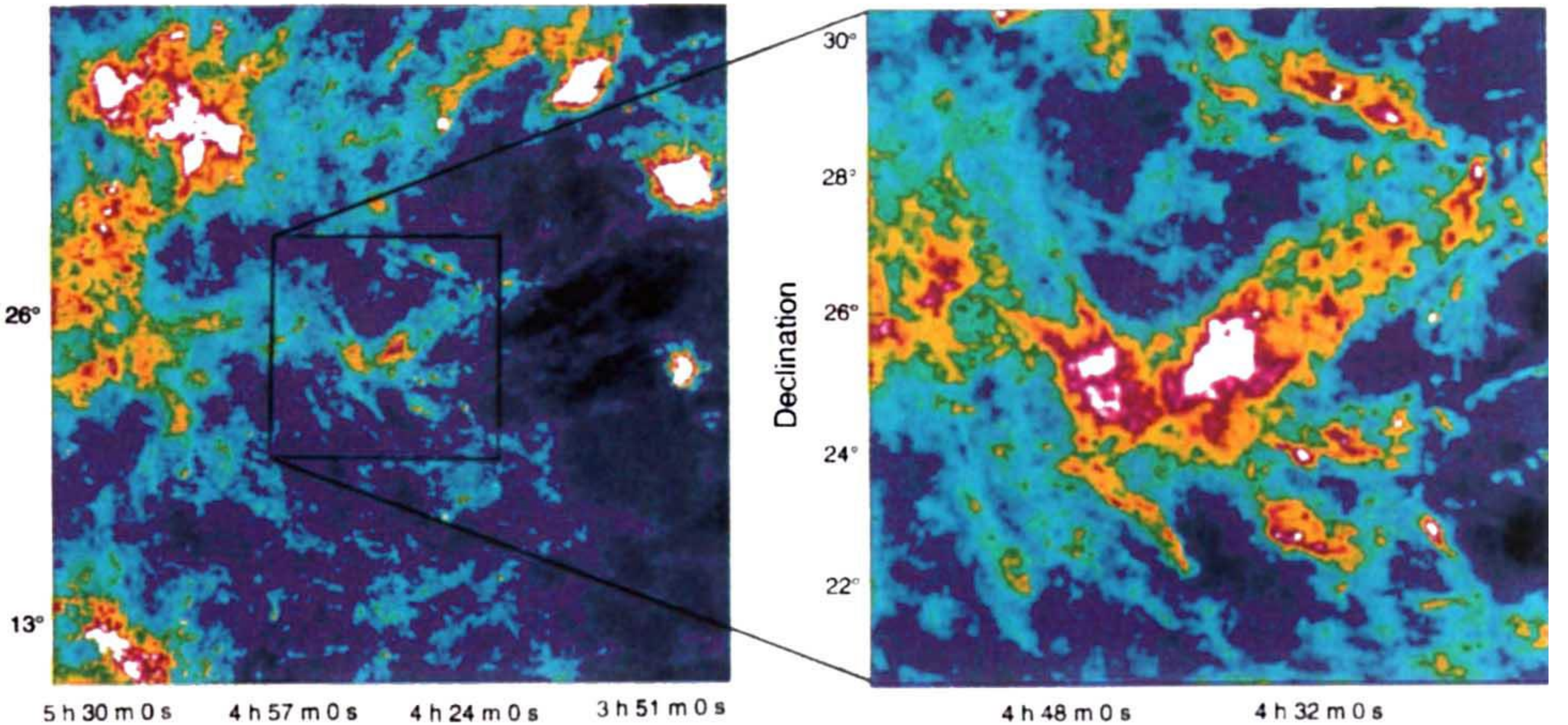
r > 0.021

DdS: Destri, de Vega, Sanchez & from WMAP data (PRD 2008)

PlanckBICEP2Keck 2015: r < 0.08

LETTERS TO NATURE

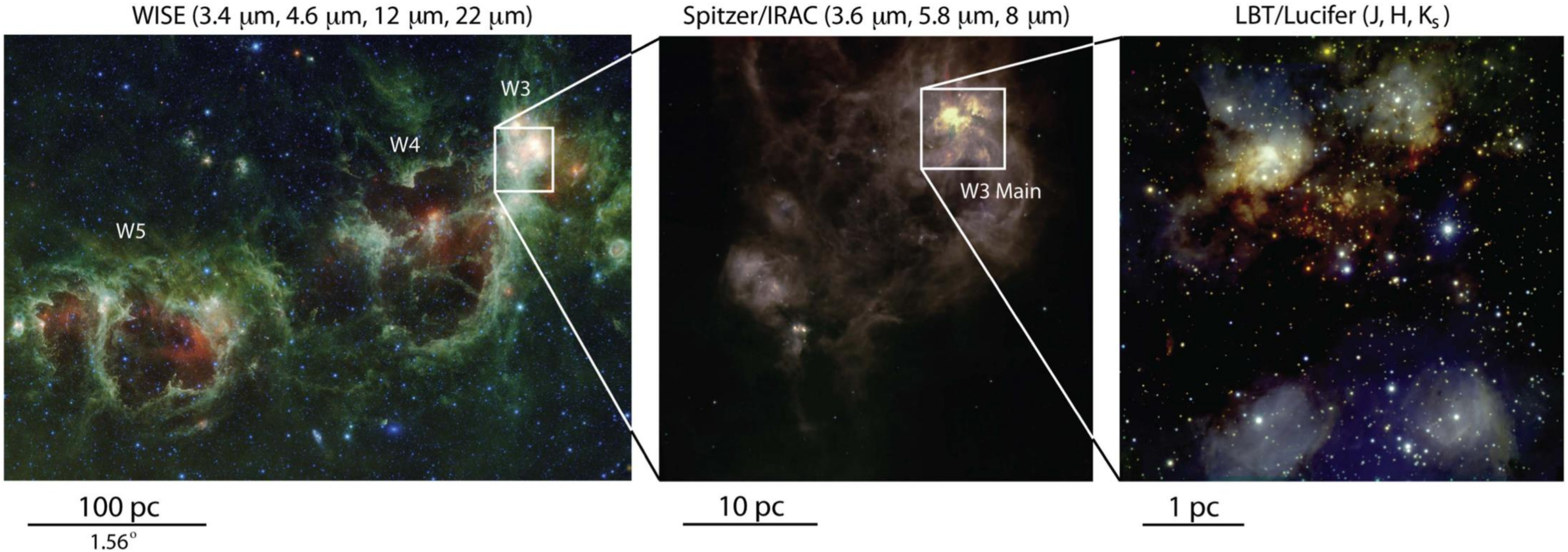
de Vega, Sanchez et al (1995)



This self-similar structure is confirmed by compilations of many different observations at widely different scales revealing the fractal structure of the ISM

HIERARCHICAL STRUCTURE OF ISM & STAR FORMATION

Publications of the Astronomical Society of the Pacific, July 2018, Gouliermis



Hierarchy in the general area of the Galactic W3/W4/W5 cloud complex.

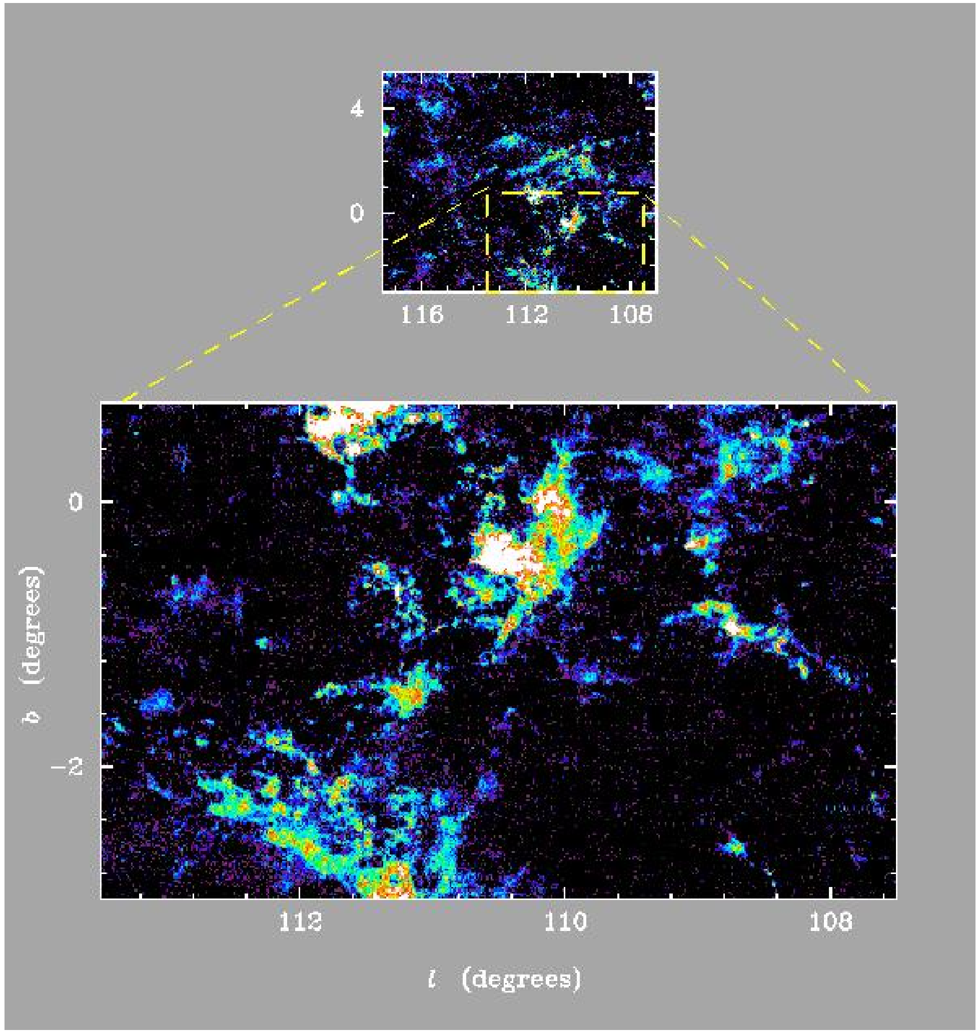
<u>Left:</u> the gaseous structures W4 and W5 (the heart and soul nebulae) in the NASA/WISE infrared image, covering <u>at 100 pc scale</u> the general region of the OB association Cas OB6.

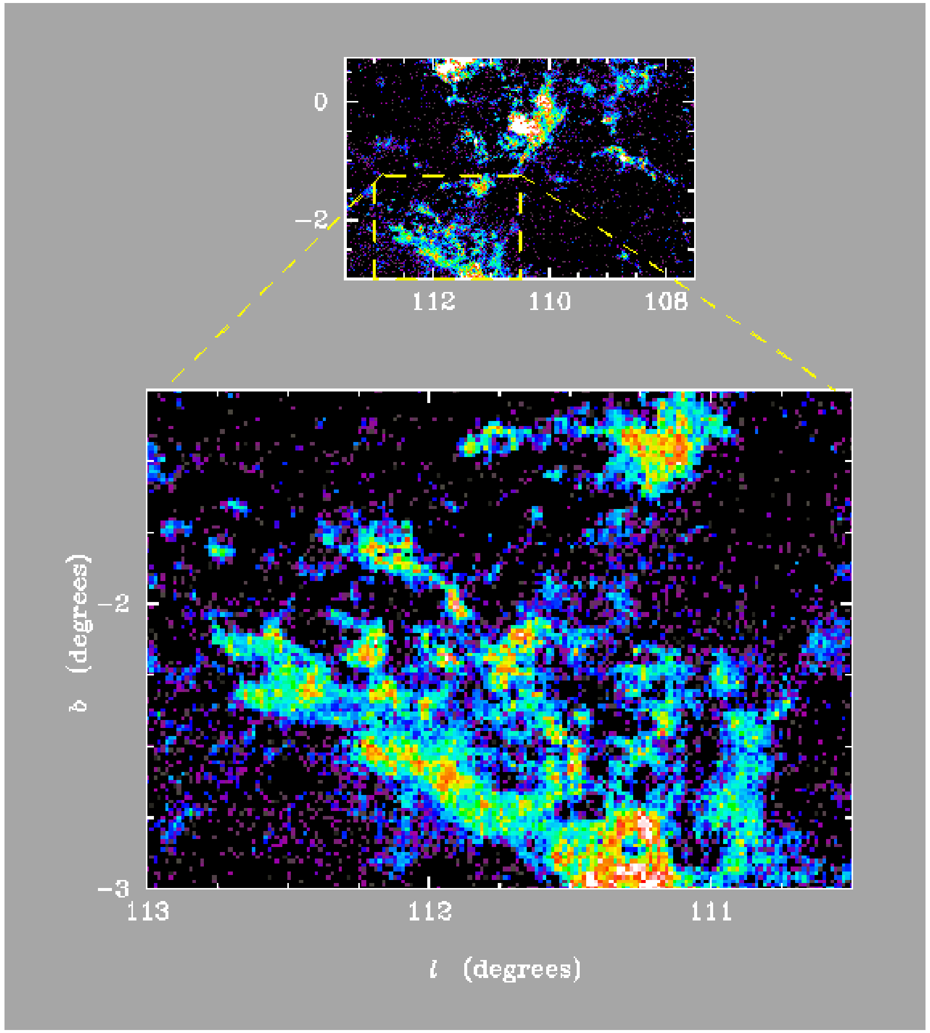
<u>Middle:</u> the giant star-forming region W3, which is part of the W4 complex, at <u>10 pc</u> scale in the NASA/Spitzer image. The star-burst of W3 Main, is the most active part of W3.

<u>Right:</u> the star-forming cluster of W3 Main is resolved in near-IR images from LBT/Luci <u>at 1 pc scale</u>.

WISE image: NASA/JPL-Caltech/WISE Team. Spitzer

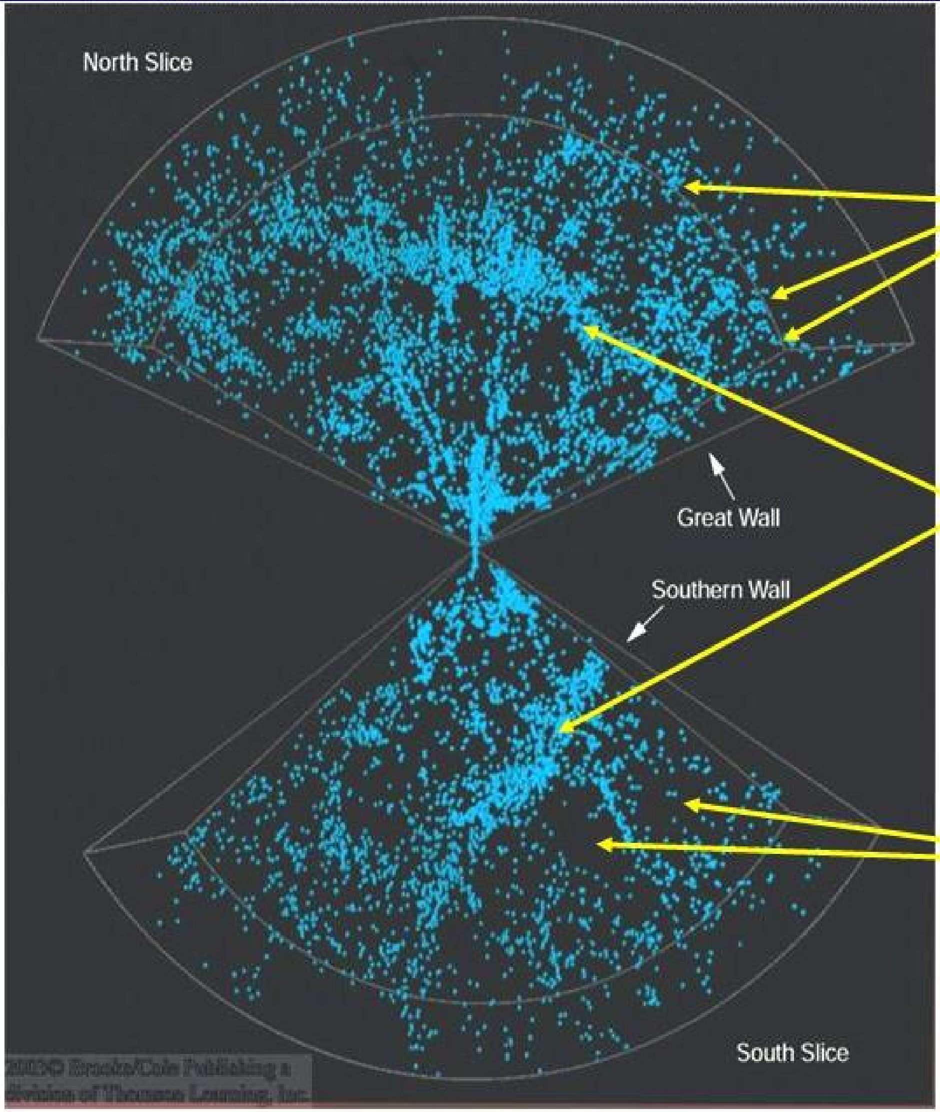
THE FRACTAL STRUCTURE OF THE ISM





FRACTAL STRUCTURE IN LSS

Large Scale Structure



Superclusters = clusters of clusters of galaxies

Superclusters appear aligned along walls and filaments.

Vast regions of space are completely empty:

“voids”

The Cosmic Web

Large Scale Structure:

Like Soap Bubbles

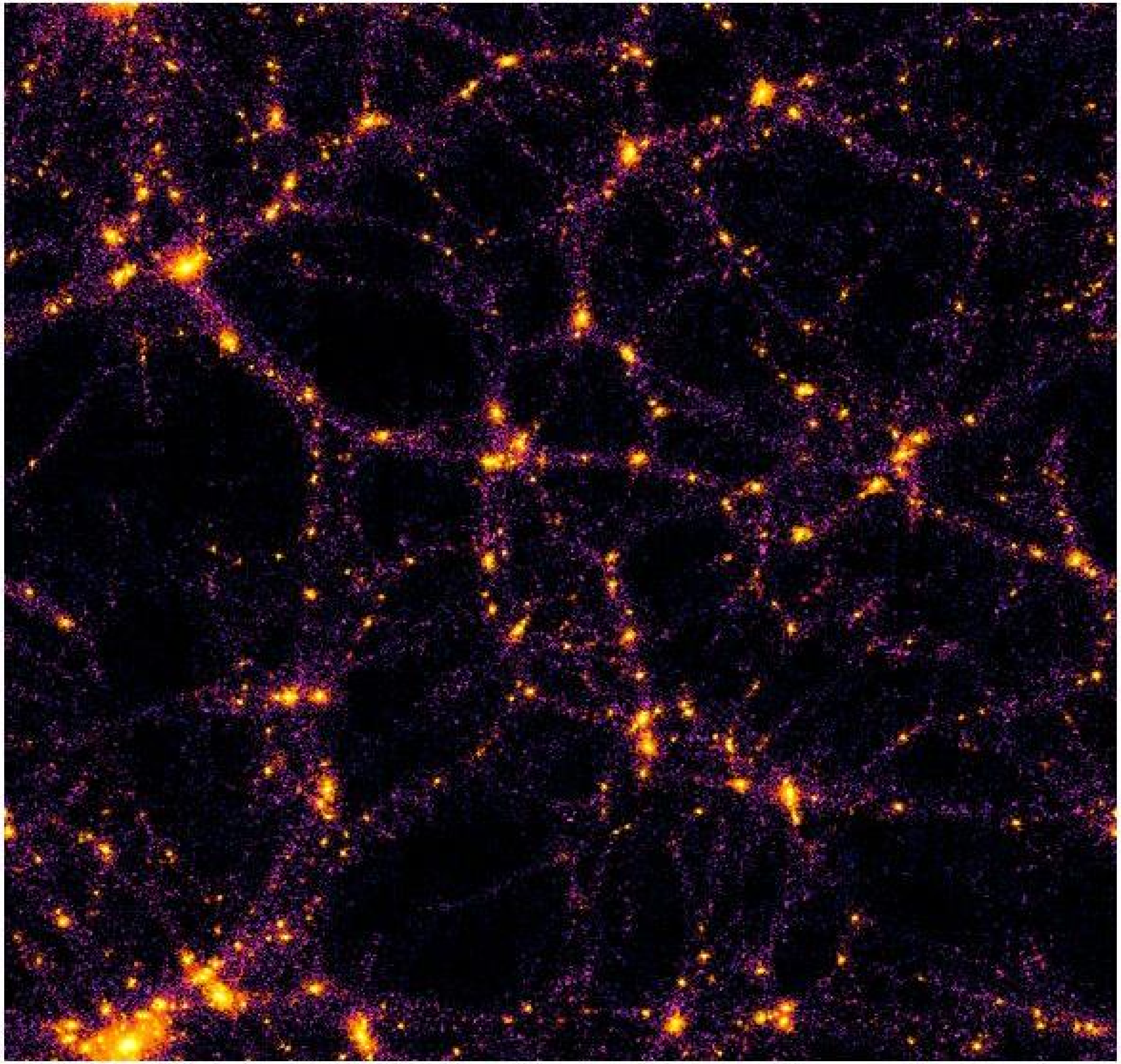
Empty **Voids**

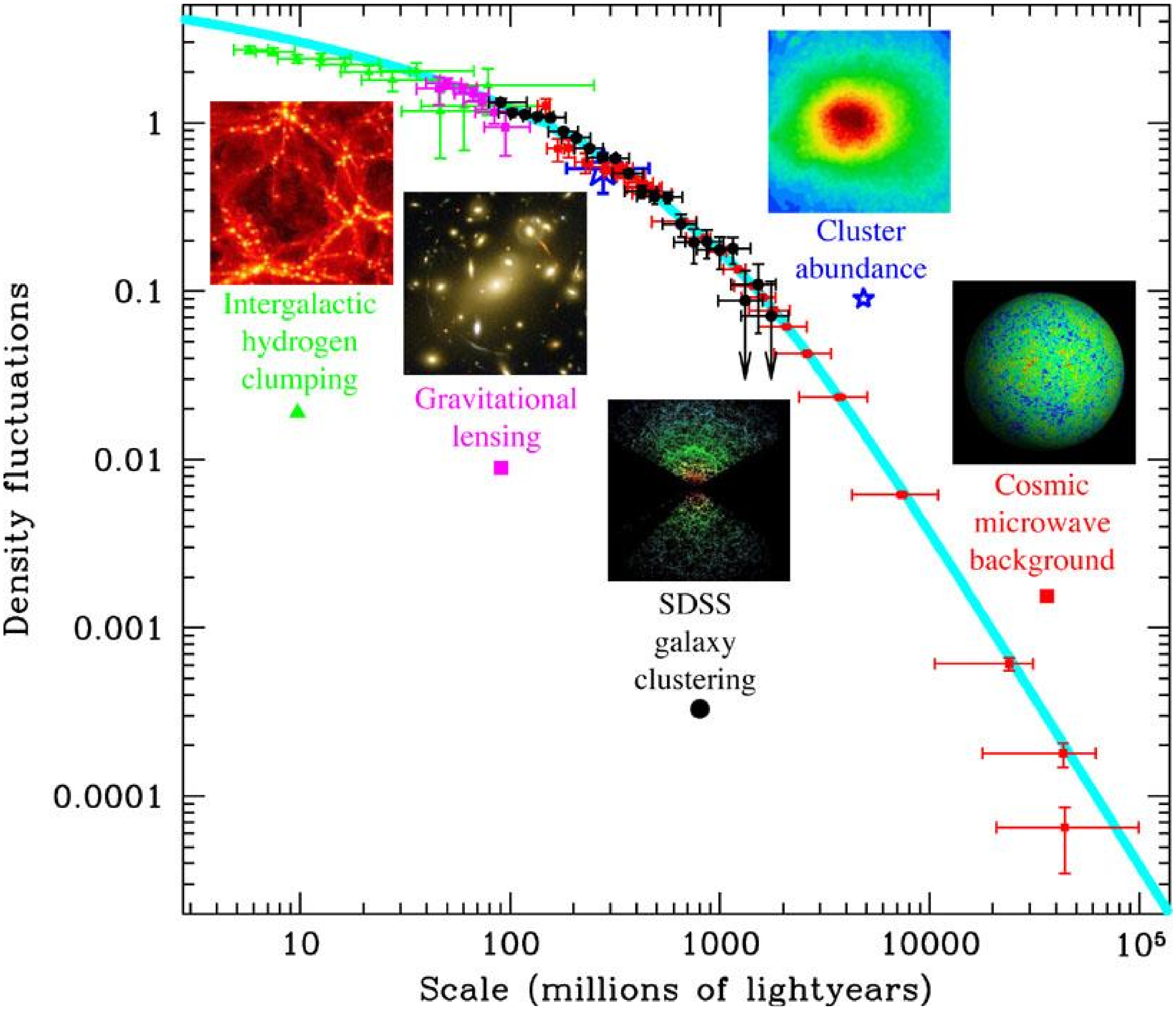
~50Mpc.

Galaxies are in
1. **Walls** between voids.

2. **Filaments** where walls intersect.

3. **Clusters** where filaments intersect.





Intergalactic hydrogen clumping
Gravitational lensing
SDSS galaxy clustering
Cluster abundance
Cosmic microwave background
Density fluctuations
Scale (millions of lightyears)
1
0.1
0.01
0.001
0.0001
10
100
1000
10000
10⁵

For a fractal medium, the mass depends on the size as

$$M(r) \propto r^{D}$$

D being the fractal (Haussdorf) dimension.

The conditional density behaves as

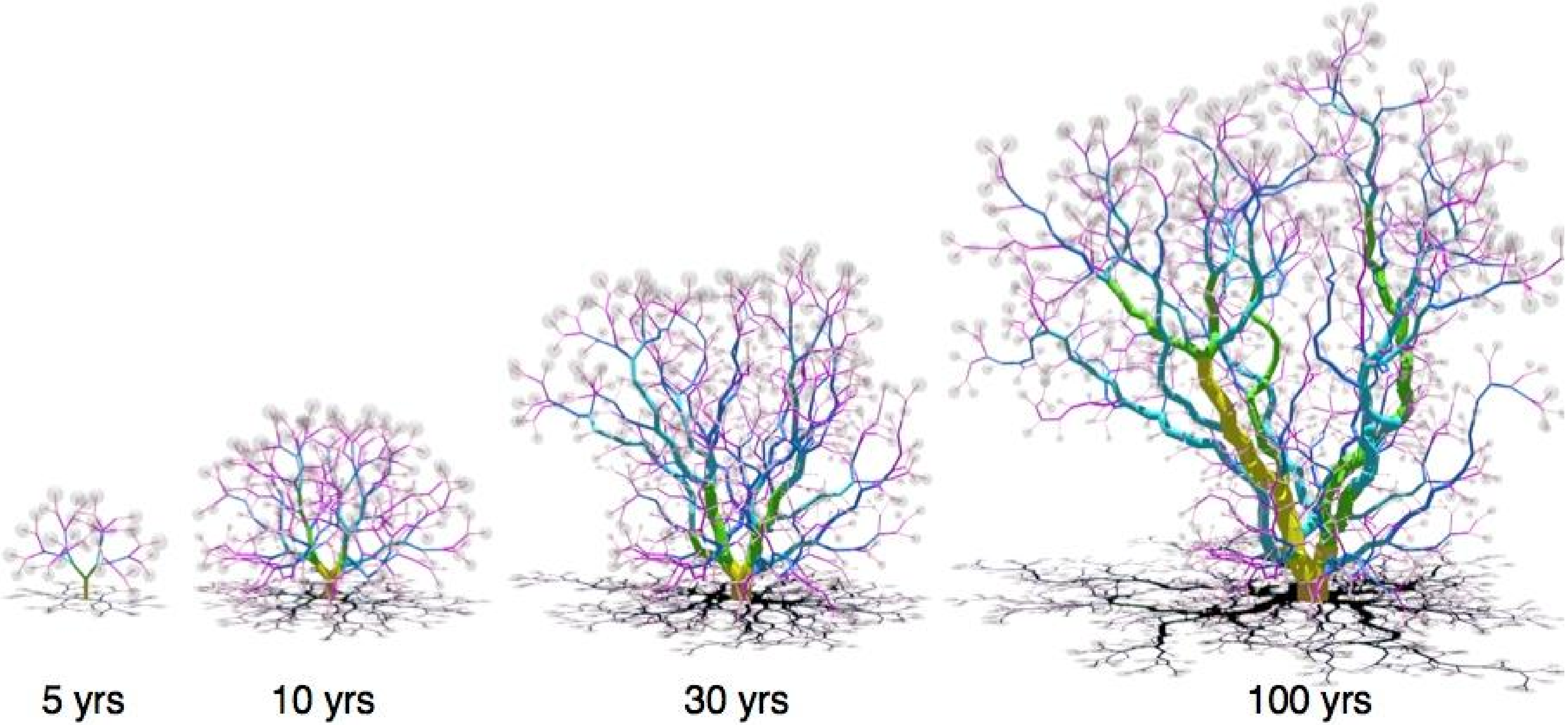
$$\Gamma(r) \propto r^{D-3}$$

This is exactly the statistical analysis used for the interstellar clouds, without adopting from the start any large-scale homogeneity assumption.

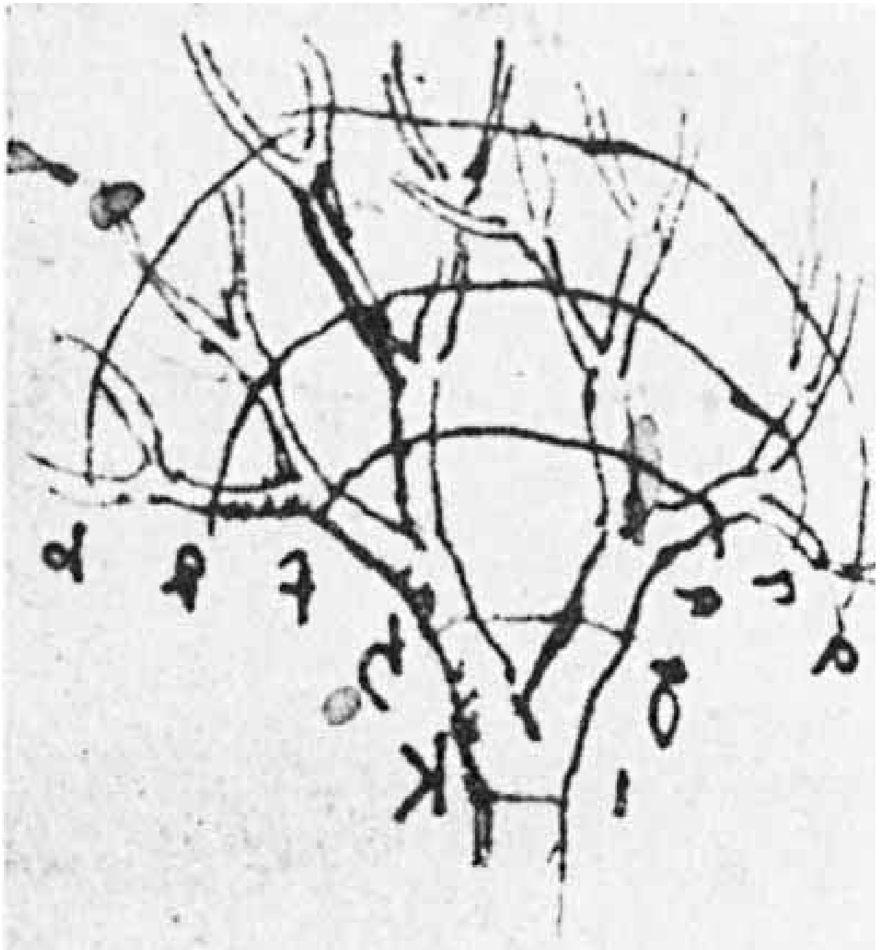
$$M = C\,R^{D}$$

C : constant , and D = 1.9 – 2.2

THE FRACTAL STRUCTURE OF TREES



THE LEONARDO DA VINCI FRACTAL TREE



Dessin extrait d'un des carnets de Léonard de Vinci illustrant sa découverte de la loi mathématique gouvernant les diamètres des branches d'un arbre.

Leonardo's Rule, Self-Similarity, and Wind-Induced Stresses in Trees

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(Received 12 May 2011; published 12 December 2011)

Examining botanical trees, Leonardo da Vinci noted that the total cross section of branches is conserved across branching nodes. In this Letter, it is proposed that this rule is a consequence of the tree skeleton having a self-similar structure and the branch diameters being adjusted to resist wind-induced loads.

DOI: 10.1103/PhysRevLett.107.258101 PACS numbers: 87.10.Pq, 89.75.Da, 89.75.Hc

Leonardo da Vinci observed in his notebooks that "all the branches of a tree at every stage of its height when put together are equal in thickness to the trunk" [1], which means that when a mother branch of diameter d splits into N daughter branches of diameters d_i, the following relation holds on average

$$d^\Delta = \sum_{i=1}^{N} d_i^\Delta, \qquad (1)$$

where the Leonardo exponent is $\Delta = 2$. Surprisingly, there have been few assessments of this rule, but the available data indicate that the Leonardo exponent is in the interval $1.8 < \Delta < 2.3$ for a large number of species [2–4]. In fact, Leonardo's rule is so natural to the eye that it is routinely used in computer-generated trees [5]. Yet, alternative analyses of the branching geometry have been proposed based on analogies with river networks, bronchial trees, and arterial trees [6].

Two different models have been proposed to explain Leonardo's rule: the *pipe model* [7], which assumes that trees are a collection of identical vascular vessels connecting the leaves to the roots, and the principle of *elastic similarity* [8,9], which postulates that the deflection of branches under their weight is proportional to their length. However, none of these explanations are convincing. The first because the portion of a branch cross section devoted to vascular transport (i.e., the sapwood) may be as low as 5% in mature trees and it seems thus dubious that the whole tree architecture is governed by hydraulic constraints. The second because the postulate behind elastic similarity is artificial, hard to relate to any adaptive advantage, and, furthermore, it seems unlikely that trees can respond to branch deflections.

In this Letter, an alternative explanation is offered: Leonardo's rule is a consequence of trees being designed to resist wind-induced stresses. Plants are known to respond to dynamic loading for a long time, a phenomenon called thigmomorphogenesis [10,11]. In that line of thinking, Metzger [12] proposed in the 19th century the constant-stress model. This model states that the trunk

remains constant along the trunk length. The constant-stress model has been shown to agree with observations [13], however, its implication on the whole branching architecture has not yet been addressed (except in the recent study of Lopez *et al.* [14]). The other important point is that constant stress might not be the best design since it implies that breakage is more likely to occur in the trunk or in large branches where the presence of defects is more probable.

To address this problem, two equivalent analytical models are first considered: one discrete, the fractal model, and one continuous, the beam model, inspired from McMahon and Kronauer [8], with the difference that wind loads are considered instead of the weight.

The fractal model [Fig. 1(a)] is constructed such that

$$\frac{l_k}{l_{k+1}} = N^{1/D}, \qquad \frac{d_k}{d_{k+1}} = N^{1/\Delta}, \qquad (2)$$

where l_k and d_k are the length and diameter of a branch at rank k (with $1 \le k \le K$), N is the number of daughter branches at each branching node, Δ is Leonardo exponent, and D is the fractal (Hausdorff) dimension of the tree skeleton [2]. Here, the tree skeleton is supposed to be self-similar such that D is uniform within the structure, but Δ can depend on k.

The fractal dimension D has never been measured directly on real trees. However, the fractal dimension of the foliage surface has been measured to lie in the interval $2.2 < D_{\mathrm{foli.}} < 2.8$ [15] and, except for very particular architectures, it can be shown that $D = D_{\mathrm{foli.}}$. As already

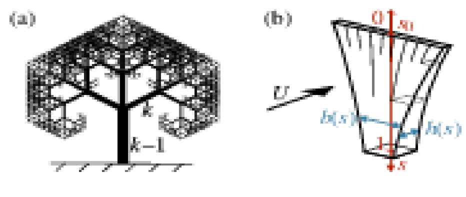

FIG. 1 (color online). Two analytical models: (a) The fractal

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A smooth exit from eternal inflation?

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Abstract: The usual theory of inflation breaks down in eternal inflation. We derive a dual description of eternal inflation in terms of a deformed Euclidean CFT located at the threshold of eternal inflation. The partition function gives the amplitude of different geometries of the threshold surface in the no-boundary state. Its local and global behavior in dual toy models shows that the amplitude is low for surfaces which are not nearly conformal to the round three-sphere and essentially zero for surfaces with negative curvature. Based on this we conjecture that the exit from eternal inflation does not produce an infinite fractal-like multiverse, but is finite and reasonably smooth.

Keywords: AdS-CFT Correspondence, Gauge-gravity correspondence, Models of Quantum Gravity, Spacetime Singularities

ArXiv ePrint: 1707.07702

JHEP04(2018)147

Les Multivers, le dernier héritage de Stephen Hawking…

[Les développements scientifiques incorporent des nouveaux concepts et langage, ou attribuent des nouveaux contenus à des mots existants . Ce qui est perçu à un moment donné comme "difficile" ou non habituel, devient par la suite "standard" et incorporé à la pensée "habituel" par l'usage de ces mots dans les communications courantes....]

Avec le dernier article de Hawking paru en mai 2018 je mets en perspective et fais une intégration scientifique de divers domaines de recherche dans lesquels j'ai activement travaillé avec les théories physiques classiques et quantiques, la théorie des cordes, l'inflation, la fractalité de (et dans) l' Univers et des multivers que j' incorpore dans une nouvelle approche dans mes travaux en cours….

Quantum Multiverses, arXiv:1801.08631

James B. Hartle (Univ California Santa Barbara, Jan 2018

A quantum theory of the universe consists of a theory of its quantum dynamics and a theory of its quantum state
The theory predicts quantum multiverses

Quantum multiverses are not a choice or an assumption but are consequences of the theory

Quantum multiverses are generic for simple theories

We argue that the quantum multiverses of the universe are scientific, real, testable, falsifiable, and similar to those in other areas of science even if they are not directly observable on arbitrarily large scales.

Are quantum multiverses scientific. Yes, in the author's opinion: As sketched above, in many areas of science one finds multiverses of the kind of an ensemble of possible situations only one of which is observed by us

If we find $\Omega \gtrsim 1$, will it **disprove** inflation?

No!

At the present moment we have several models explaining homogeneity of closed and open universes, and all these models are based on inflation.

If we find $\Omega = 1$, will it **prove** inflation?

I believe so, since 99% of all inflationary models predict $\Omega = 1 \pm 10^{-4}$, and no other theories make this prediction

What is the meaning of stationarity of the universe?

We know that our universe is about 10^{10} years old!

Do we?

A typical distance from the root to the apple is 10^{10} years. However, most apples grow infinitely high...