

Dernières Nouvelles de l'Univers



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Observatoire de Paris



CONTENT OF THE UNIVERSE

ATOMS, the building blocks of stars and planets:
represent only the **4.6%**

DARK MATTER comprises **23.4 %** of the universe.
This matter, different from atoms, does not emit or absorb
light. It has only been detected indirectly by its gravity.

72% of the Universe, is composed of **DARK ENERGY**
that acts as a sort of an anti-gravity.
This energy, distinct from dark matter, is responsible for
the present-day acceleration of the universal expansion,
compatible with cosmological constant

CONTENTS

(I) The Standard Model of the Universe Includes Inflation

(II) THE NATURE OF DARK MATTER IN GALAXIES

from Theory and Observations: **Warm (keV scale) DM**

(III) NEW: THE ESSENTIAL ROLE OF QUANTUM PHYSICS IN WDM GALAXIES:

Semiclassical framework: Analytical Results and Numerical (including analytical) Results

Observed Galaxy cores and structures from Fermionic WDM and more results.

(IV) NEW: The generic Galaxy types and properties from a same physical framework: From quantum (compact, dwarfs) to classical (dilute, large) galaxies. Equation of state

HIGHLIGHTS

(I) The Effective (Ginsburg-Landau) Theory of Inflation

PREDICTIONS vs Observations:

The Primordial Cosmic Banana: non-zero amount of primordial gravitons. And Forecasts for CMB exps.

NEW: BICEP2 !!!

(II) : TURNING POINT IN THE DARK MATTER

PROBLEM: DARK MATTER IN GALAXIES from

Theory and Observations: Warm (keV scale) dark matter

Physical Clarification and Simplification

**GALAXY FORMATION AND EVOLUTION IN
AGREEMENT WITH OBSERVATIONS**

naturally re-insert in COSMOLOGY (LWDM)

Analytical Results and Numerical

NEW RESULTS

FERMIONIC QUANTUM WDM and GRAVITATION DETERMINE THE OBSERVED PHYSICAL GALAXY PROPERTIES

-> Dark matter (DM) is the main component of galaxies.

Quantum mechanics is a cornerstone of physics from microscopic to macroscopic systems as quantum liquids He^3 , white dwarf stars and neutron stars.

-> Recent study : Destri, de Vega, Sanchez, (New Astronomy 22, 39, 2013) suggest that quantum mechanics is also responsible of galaxy structures at the kpc scales and below: near the galaxy center, below 10 - 100 pc, the DM quantum effects are important for warm DM (WDM), that is for DM particles with masses in the keV scale.

-> A new approach to galaxy structure with results in remarkable agreement with observations:

(i) Dwarf galaxies turn to be quantum macroscopic objects for WDM supported against gravity by the WDM fermion pressure

(ii) Theoretical analytic framework based on Thomas-Fermi approach determine galaxy structure from the most compact dwarf galaxies to the largest dilute galaxies (spirals, ellipticals).

The obtained galaxy mass, halo radius, phase-space density, velocity dispersion, are fully consistent with observations.

(iii) Interestingly enough, a minimal galaxy mass and minimal velocity dispersion are found for DM dominated objects, which in turn imply an universal minimal mass $m_{\min} = 1.9 \text{ keV}$ for the WDM particle.

- OBSERVED GALAXY CORES vs CDM CUSPS and WDM CORES-

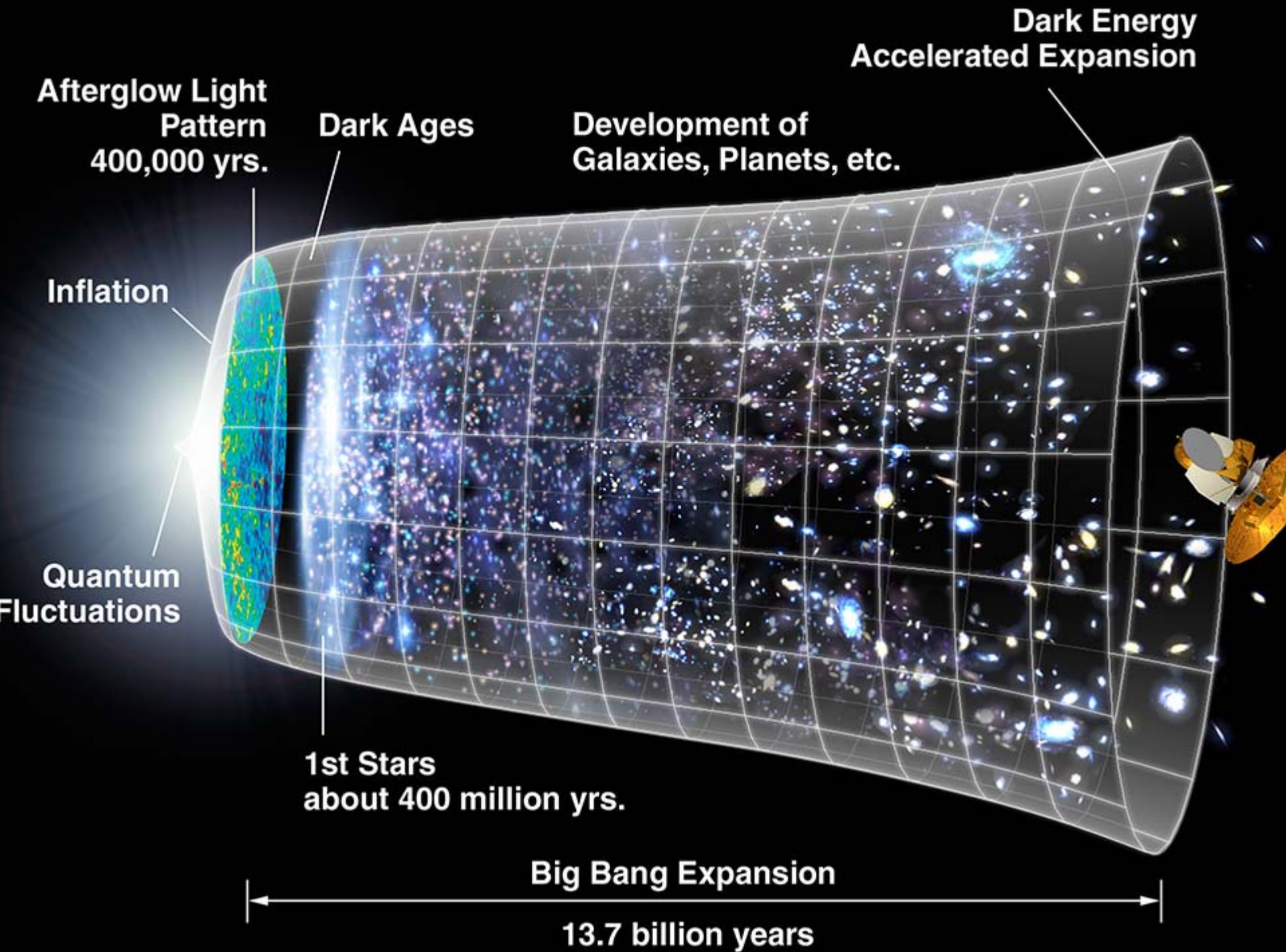
- Astronomical observations show that the **DM galaxy density profiles are cored**, that is, profiles which are flat at the center.

On the contrary, **N-body CDM simulations exhibit cusped density profiles**, with a typical $1/r$ cusped behaviour near the galaxy center $r = 0$.

Classical N-body WDM simulations exhibit cores but with sizes much smaller than the observed cores.

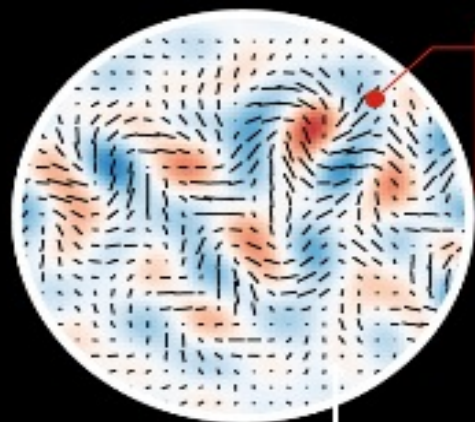
We have recently developed a new approach to this problem thanks to **Quantum Mechanics**.

- **Fermions** always provide a non vanishing **pressure of quantum nature** due to the combined action of the Pauli exclusion principle and Heisenberg uncertainty principle.
- **Quantum effects for WDM fermions rule out the presence of galaxy cusps for WDM and enlarge the classical core sizes because their repulsive and non-local nature extend well beyond the small pc scales.**



An echo of the Big Bang

US scientists have detected gravitational waves, the first direct evidence of a super-rapid expansion of the universe known as cosmic inflation



The gravitational waves rippling through the universe after inflation gave a "twisting" pattern in the polarisation of the CMB*



Observed by the BICEP2 telescope stationed at the South Pole

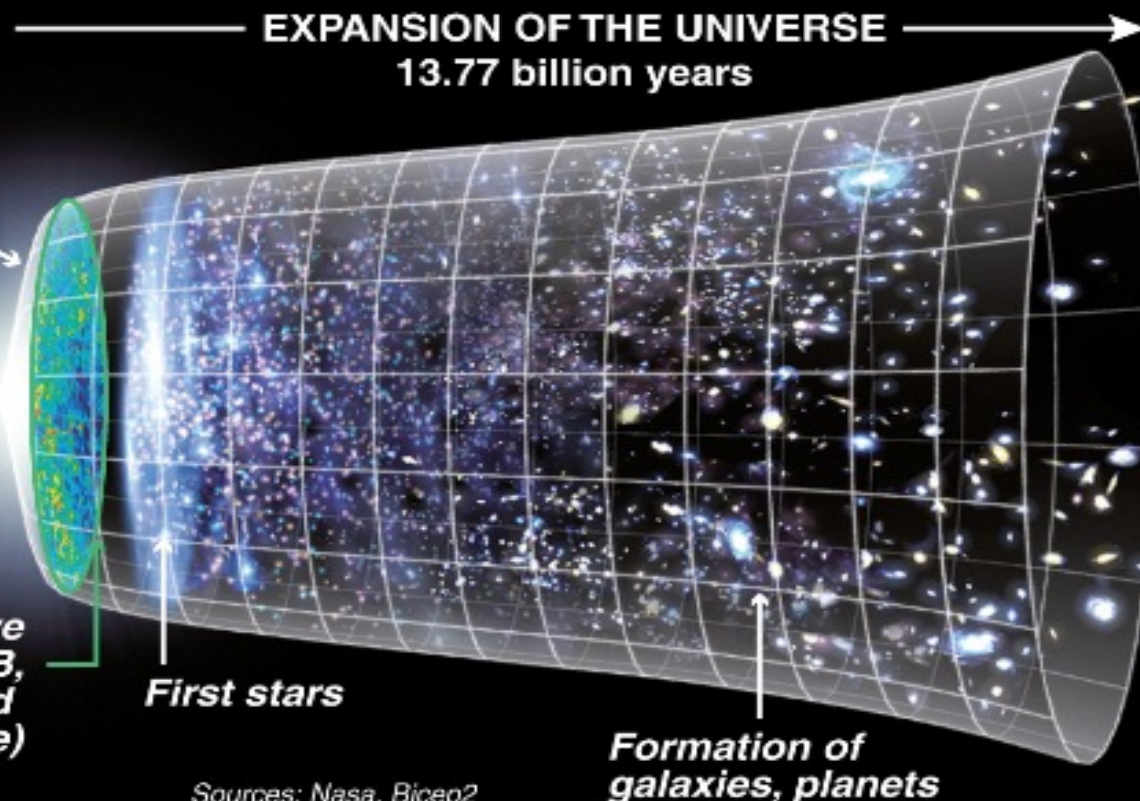
- ✗ Predicted by Albert Einstein's theory in 1915
- ✗ Cosmic inflation first proposed by US scientist Alan Guth in 1980

Cosmic inflation

A burst of exponential growth in less than the blink of an eye

BIG BANG

*Cosmic Microwave Background, or CMB, (light that spread across space)
380,000 years



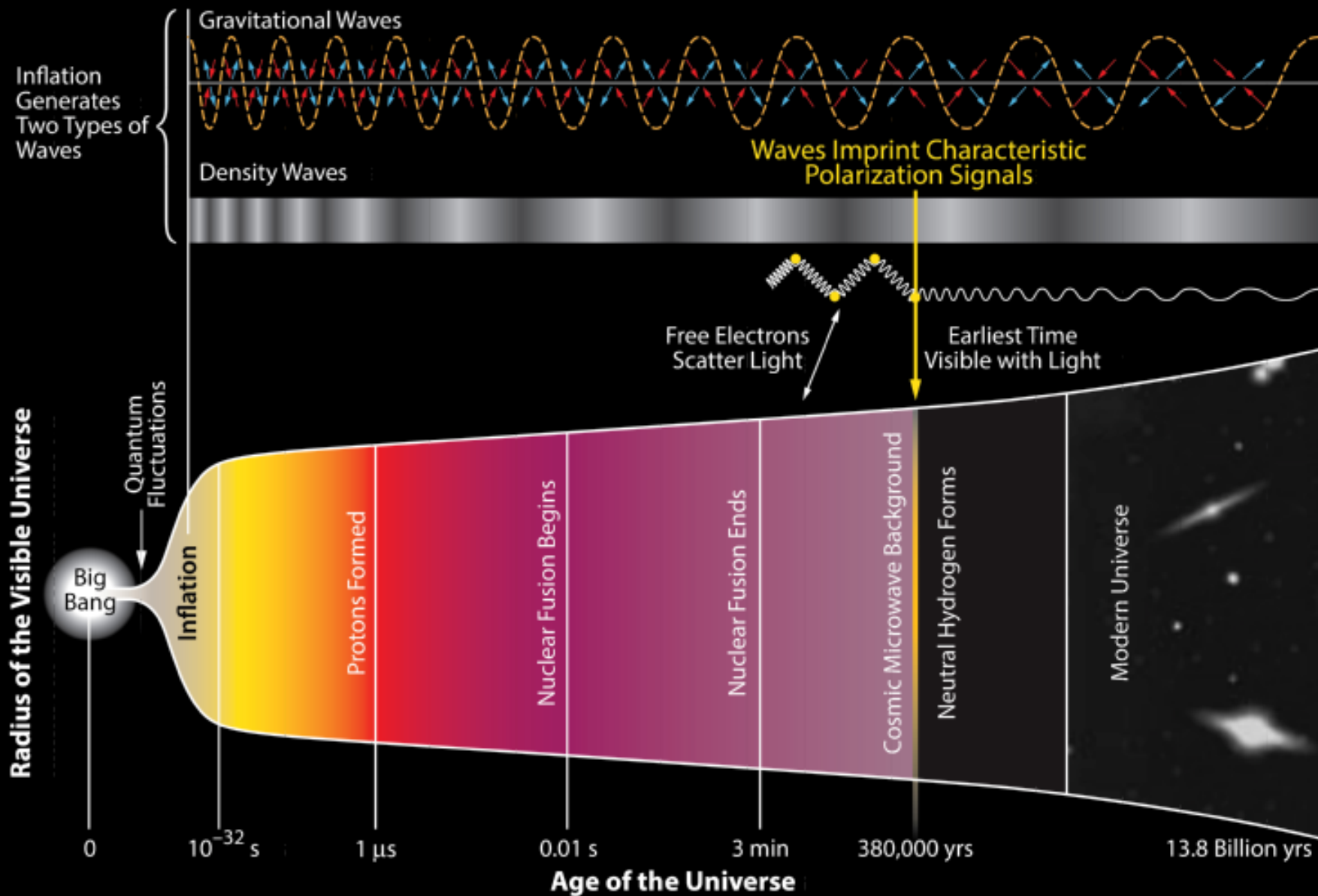
First stars

Formation of galaxies, planets

Sources: Nasa, Bicep2

AFP

History of the Universe



BIG BANG

INFLATION

END OF INFLATION

10^{-40}

10^{-30}

Time since big bang (seconds)

10^{-20}

10^{-10}

1

10^{10}

CMB
380,000 years
after big bang

TODAY
13.82 billion years (10^{17} seconds)

UNIVERSE OPAQUE

Light is effectively trapped because it scatters from electrons and protons

GRAVITATIONAL WAVES PROPAGATE

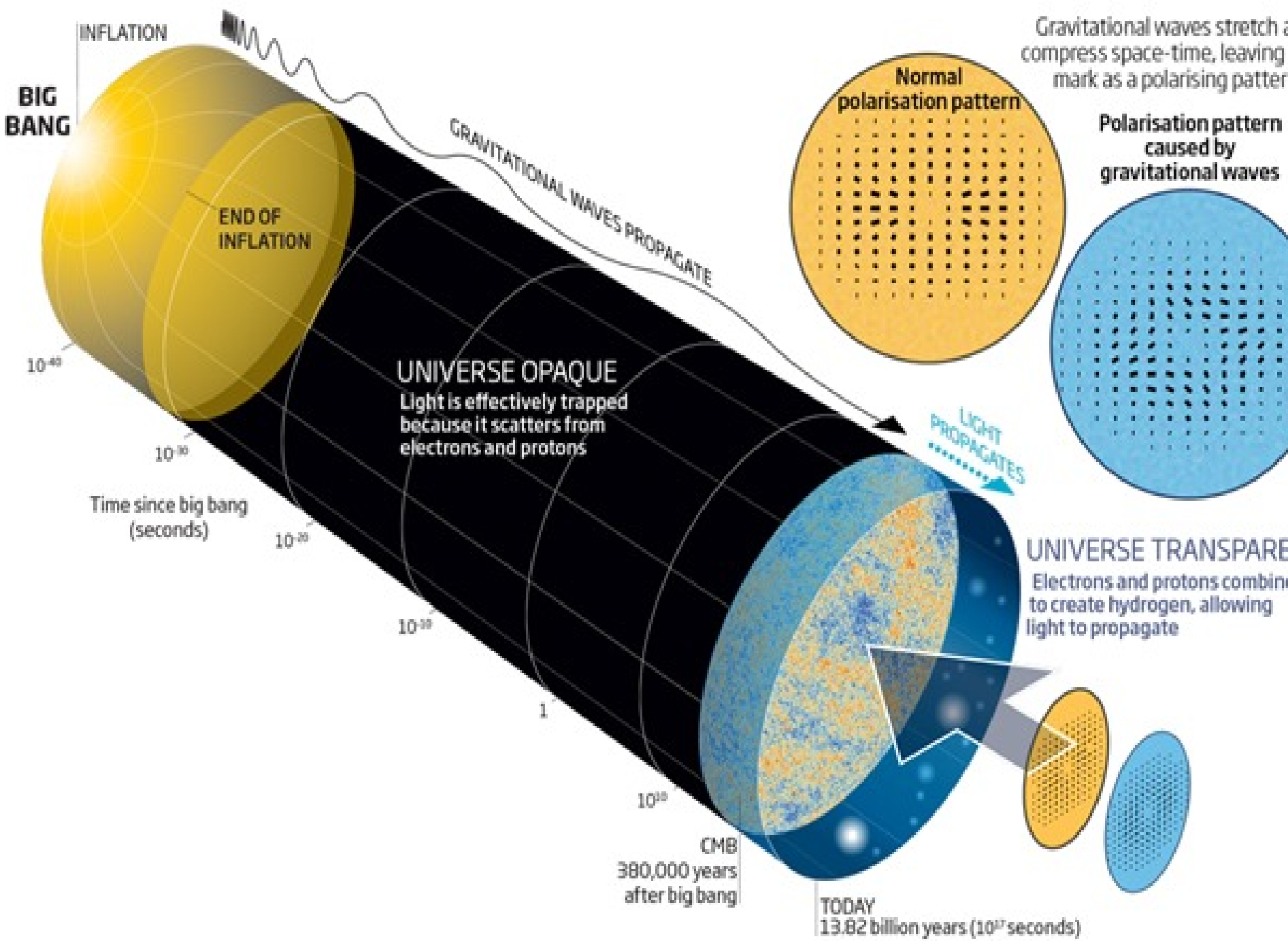
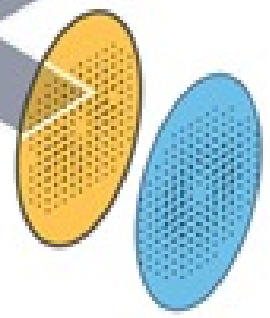
Normal polarisation pattern

Polarisation pattern caused by gravitational waves

LIGHT PROPAGATES

UNIVERSE TRANSPARENT

Electrons and protons combine to create hydrogen, allowing light to propagate



Quantum Fluctuations During Inflation and after

The Universe is homogeneous and isotropic after inflation thanks to the fast and **gigantic** expansion stretching lengths by a factor $e^{62} \simeq 10^{27}$. By the end of inflation: $T \sim 10^{14}$ GeV.

Quantum fluctuations around the classical inflaton and FRW geometry were of course **present**.

These inflationary quantum fluctuations are the **seeds** of the structure formation and of the CMB anisotropies today: galaxies, clusters, stars, planets, ...

That is, our present universe **was built** out of inflationary quantum fluctuations. CMB anisotropies spectrum:

$$3 \times 10^{-32} \text{cm} < \lambda_{\text{begin inflation}} < 3 \times 10^{-28} \text{cm}$$

$$M_{\text{Planck}} \gtrsim 10^{18} \text{ GeV} > \lambda_{\text{begin inflation}}^{-1} > 10^{14} \text{ GeV.}$$

total redshift since inflation begins till today = 10^{56} :

$$0.1 \text{ Mpc} < \lambda_{\text{today}} < 1 \text{ Gpc}, \quad 1 \text{ pc} = 3 \times 10^{18} \text{ cm} = 200000 \text{ AU}$$

**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 Energy Scale of Inflation

Grand Unification Idea (GUT)

- Renormalization group running of electromagnetic, weak and strong couplings shows that they **all meet** at $E_{GUT} \simeq 2 \times 10^{16}$ GeV
- Neutrino masses are explained by the **see-saw** mechanism: $m_\nu \sim \frac{M_{\text{Fermi}}^2}{M_R}$ with $M_R \sim 10^{16}$ GeV.
- Inflation energy scale: $M \simeq 10^{16}$ GeV.

Conclusion: the GUT energy scale appears in at least **three** independent ways.

Moreover, moduli potentials: $V_{\text{moduli}} = M_{\text{SUSY}}^4 v \left(\frac{\phi}{M_{\text{Pl}}} \right)$
resemble inflation potentials provided $M_{\text{SUSY}} \sim 10^{16}$ GeV.
First observation of SUSY in nature??

CONCEPTUAL UNIFICATION

- **Cosmological evolution** goes from a quantum gravity phase to a semi-classical phase (inflation) and then to the classical (standard Friedman-Robertson-Walker) phases
- **Black Hole Evaporation** (BH hole decay rate), heavy particles and extended quantum decay rates; black hole evaporation ends as quantum extended decay into pure (non mixed) non thermal radiation.
- The Hawking temperature, elementary particle and Hagedorn (string) temperatures **are the same concept in different gravity regimes (classical, semiclassical, quantum)** and turn out to be the precise classical-quantum duals of each other.

From WMAP9 to Planck

Understanding the direction in which data are pointing:

- **PREDICTIONS for Planck**

- **Standard Model of the Universe**

- **Standard Single field Inflation**

- **NO RUNNING of the Primordial Spectral Index**

- **NO Primordial NON GAUSSIANTY**

- **N_{eff} neutrinos : --> Besides meV active neutrinos:**

- **1 or 2 sterile neutrinos**

- **Would opens the sterile neutrino Family:**

- **keV sterile neutrino –WDM-**

• Large Hadron Collider

- The first LHC results at 7-8 TeV, with the discovery of a candidate Higgs boson and **the non observation of new particles or exotic phenomena**, have made a big step towards completing **the experimental confirmation of the Standard Model of particle physics.**
- It is thus a good moment **to recall our scientific predictions made several years ago on this matter because they are of full actuality.**

Large Hadron Collider - LHC-

The results are completely in line with
the Standard Model.

No evidence of SUSY at LHC

“Supersymmetry may not be dead but these latest results have certainly put it into hospital.”

(Prof Chris Parkes, spokesperson for the UK Participation in the LHCb experiment)

→ Does Not support wimps -CDM-

(In agreement with all dedicated wimp experiments at work from more than 20 years which have not found any

wimp's signal) “So far researchers who are racing to find evidence of so called "new physics", ie non-standard models, have run into a series of dead ends”.

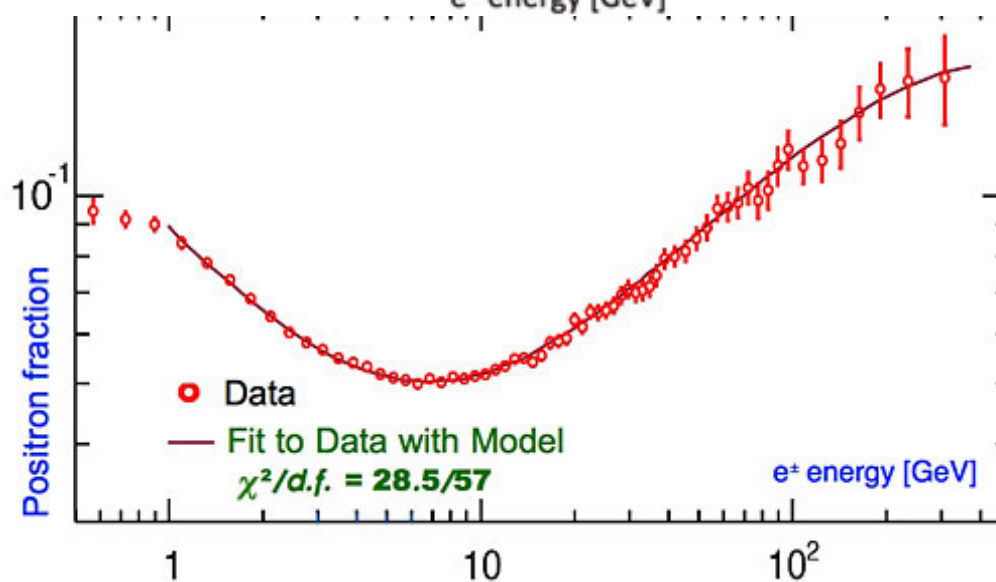
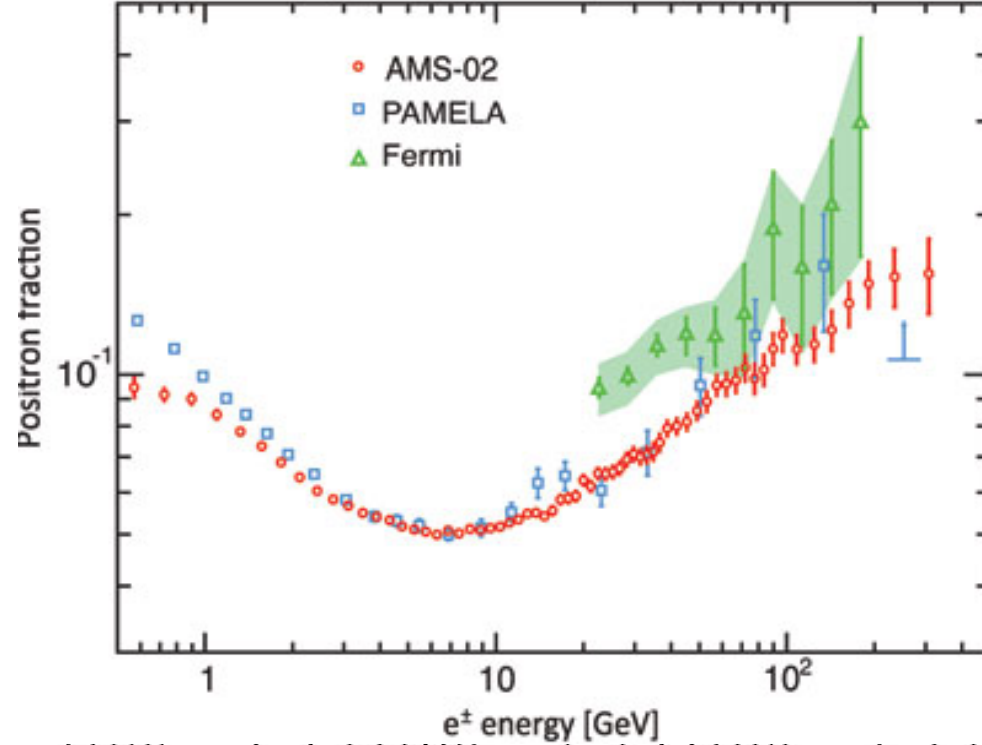
ANTIMATTER IN SPACE - AMS on board ISS Alpha Magnet Spectrometer



NASA



NASA



Positron excess in cosmic rays are not related to DM physics but to astrophysical sources and astrophysical mechanisms and can be explained by them

LHC
AMS
PLANCK

Three beautiful and big experiments of performant instruments, technology, industry, achievements and successful operation which do not find the main scientific objective emphasized by them (for which they were designed)

- **Why No Experimental Detection of the DM particle has been reached so far ?**

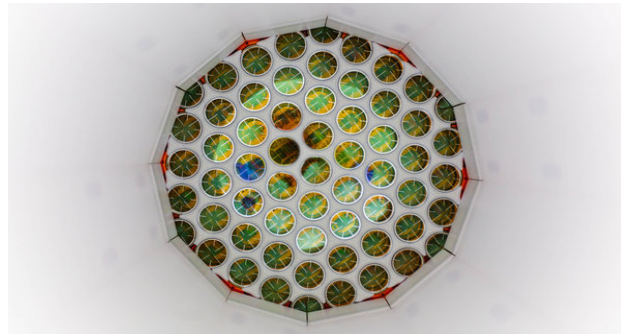
- **Because:**

- All experimental searches for DM particles are dedicated to CDM: wimps of $m > 1 \text{ GeV}$,
- While the DM particle mass is in the keV scale .
- Moreover, past, present and future reports of signals of such CDM experiments **cannot be due to DM** because of the same reason.
- **The inconclusive signals in such experiments should be originated by phenomena of other kinds.**
- In addition, such signals contradict each other supporting the idea that they are **unrelated to any DM detection.**

LUX Large Underground Xenon Detector

30 October 2013

**Dark Matter Experiment Has Detected Nothing,
Researchers Say Proudly**



- **They found no sign of WIMPS signals.**
beyond the expected background noise.
- The experiment did so at far better sensitivities than any such experiment before it.

Sterile Neutrinos ν

Rhenium and Tritium **beta decay** (MARE, KATRIN).

Theoretical analysis: H J de V, O. Moreno, E. Moya de Guerra, M. Ramón Medrano, N. Sánchez, Nucl. Phys. B866, 177 (2013).

[Other possibility to detect a sterile ν_s : a precise measure of nucleus recoil in tritium beta decay.]

Conclusion: the empty slot of right-handed neutrinos in the Standard Model of particle physics can be filled by **keV-scale sterile neutrinos** describing the DM.

An appealing **mass** neutrino hierarchy appears:

- Active neutrino: \sim mili eV
- Light sterile neutrino: \sim eV
- Dark Matter: \sim keV
- Unstable sterile neutrino: \sim MeV....

LHC
AMS
PLANCK

Three beautiful and big experiments of performant instruments, technology, industry, achievements and successful operation which do not find the main scientific objective emphasized by them (for which they were designed)

Recent News on Cosmological Observables

Before 2013: Hubble constant $H_0 = 73.8 \pm 2.4 \frac{\text{km}}{\text{s}} \frac{1}{\text{Mpc}}$ from direct observations of Cepheids by HST, $\Omega_m = 0.27 \pm 0.03$. A G Riess et al. ApJ 730, 119 (2011).

Planck 2013: $H_0 = 67.3 \pm 1.2 \frac{\text{km}}{\text{s}} \frac{1}{\text{Mpc}}$. $\Omega_m = 0.32 \pm 0.02$.

Planck **assumed** here only three massless neutrinos and **no sterile neutrinos** ν_s .

There is today **strong evidence** for ν_s with $m_s \sim \text{eV}$ from short baseline experiments (reactors, MiniBoone, LSND).

Adding **one** ν_s yields:

$H_0 = 70 \pm 1.2 \frac{\text{km}}{\text{s}} \frac{1}{\text{Mpc}}$. $\Omega_m = 0.30 \pm 0.01$ for $m_s = 0.4 \text{ eV}$.

These values for H_0 and Ω_m **are compatible** with the direct astronomical measurements.

M. Wyman et al. PRL. 112, 051302 (2014), J. Hamann & J. Hasekamp, JCAP,10,044H (2013) R. Battye & A. Moss, PRL. 112, 051302 (2014) G. G. Simonelli et al. MNRAS 434, 1211 (2013)

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 $dn_s/d\ln k$	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 :

$$n_s = 0.9608 , \quad r$$

PREDICTIONS

$$r > 0.021$$

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

BICEP2 result 2014: r about 0.20-0.16

THE PRIMORDIAL GRAVITONS

LOWER BOUND on r (2008)

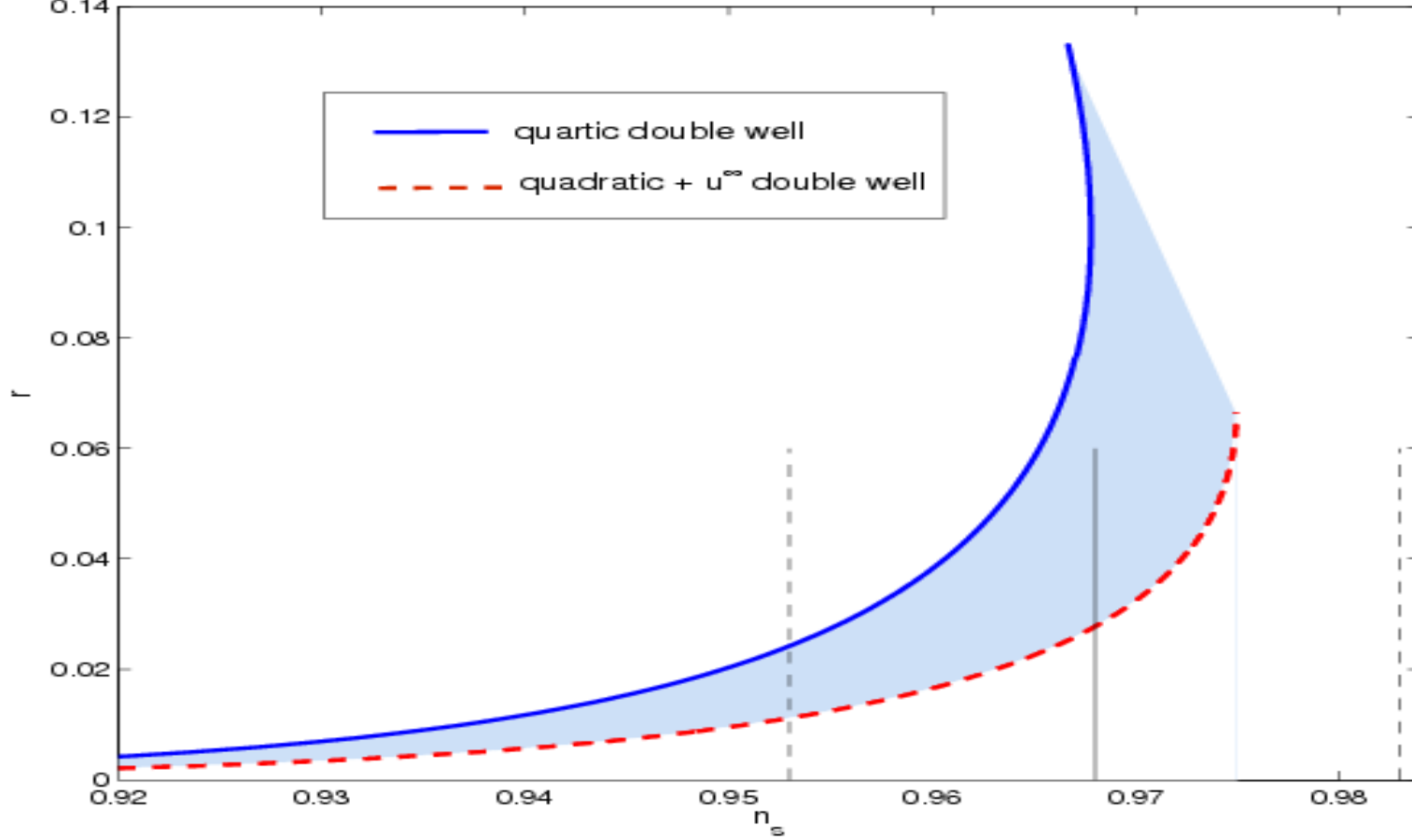
Our theory input (Effective Theory Inflation) in the MCMC data analysis of WMAP5+LSS+SN data).

C. Destri, H J de Vega, N G Sanchez, Phys Rev D77, 043509 (2008) shows:

Besides the upper bound for r (tensor to scalar ratio) $r < 0.22$, we find a clear peak in the r distribution and we obtain a lower bound

$$\begin{aligned} r &> 0.023 \text{ at } 95\% \text{ CL} \text{ and} \\ r &> 0.046 \text{ at } 68\% \text{ CL.} \end{aligned}$$

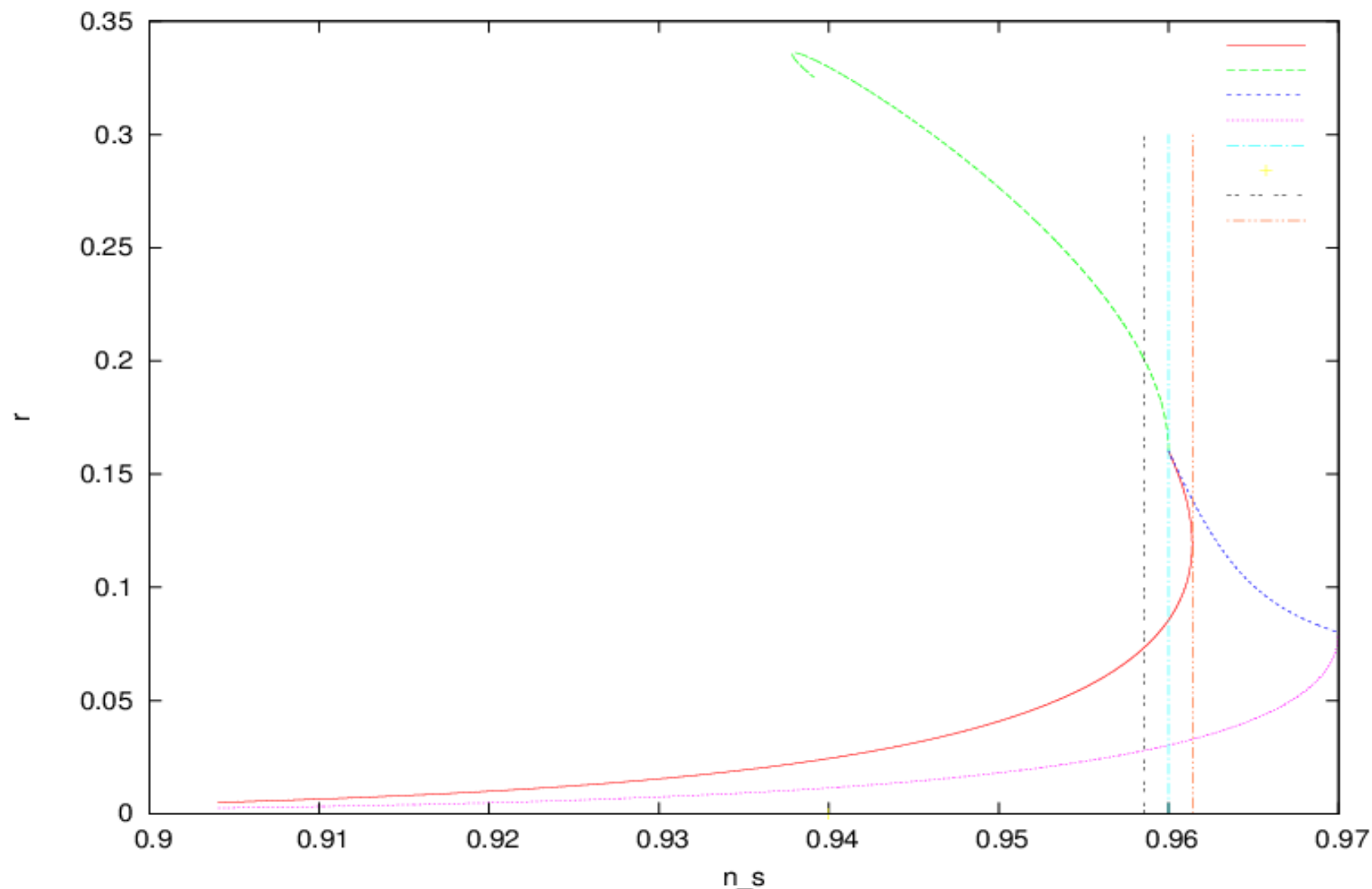
For the other cosmological parameters, both analysis agree.



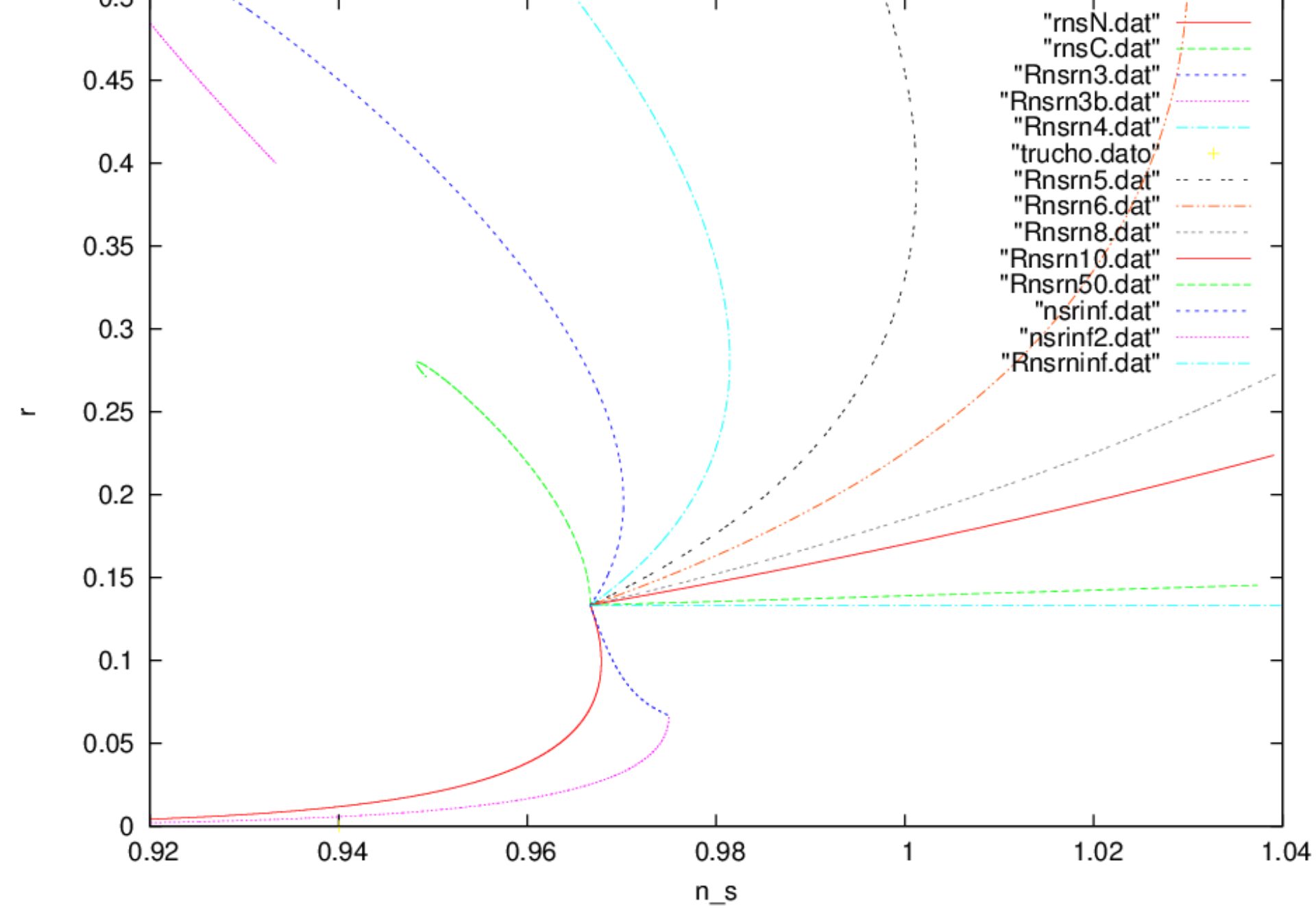
THE PRIMORDIAL COSMIC BANANA

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)

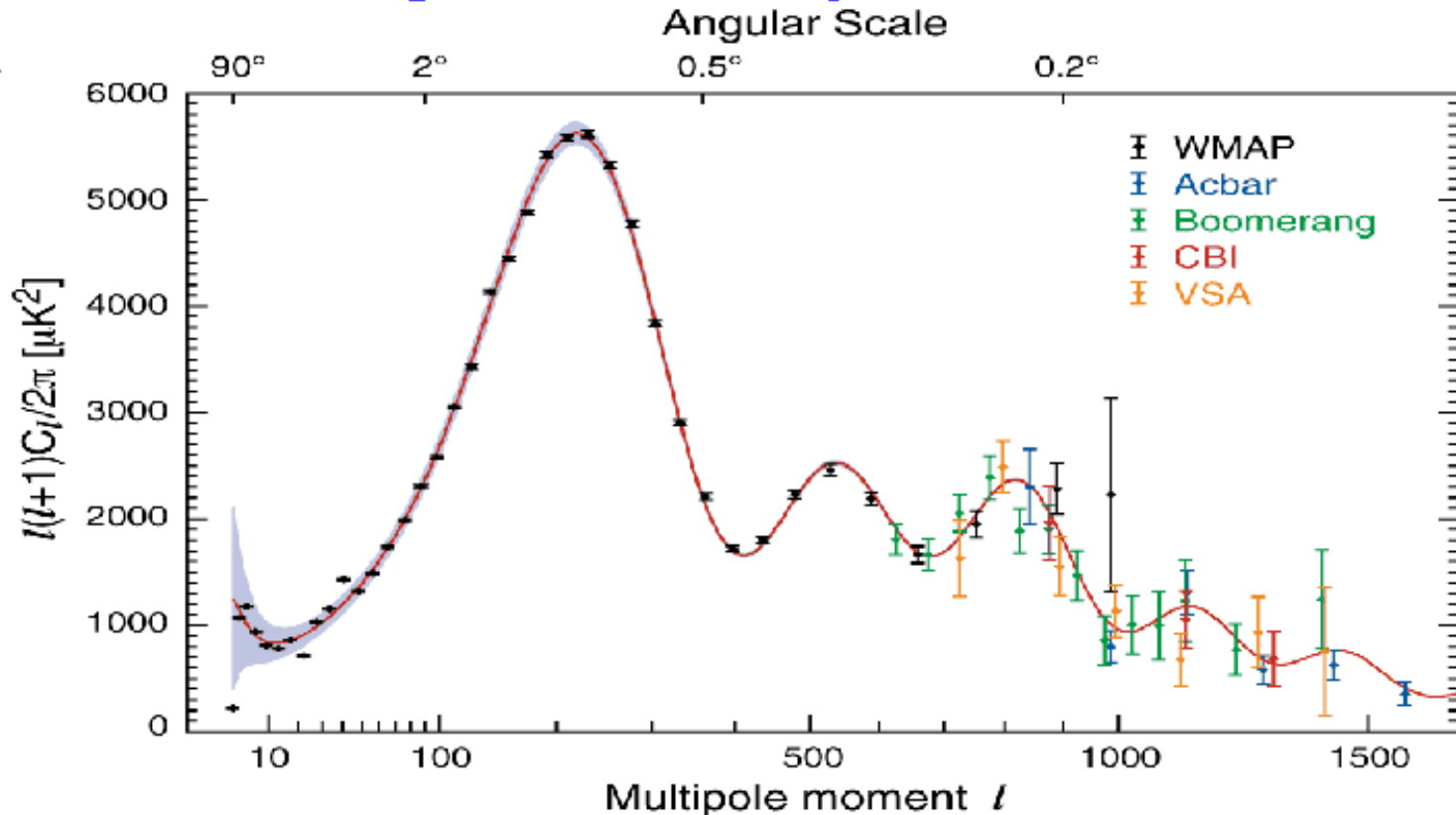
Single and Double Well Inflaton Potentials



The **cosmic banana** for double well potentials ($N=50$).
 $n_s = 0.96 \pm 0.014$ Planck + BAO + sterile (Melchiorri et al.)



WMAP 5 years data set plus other CMB data

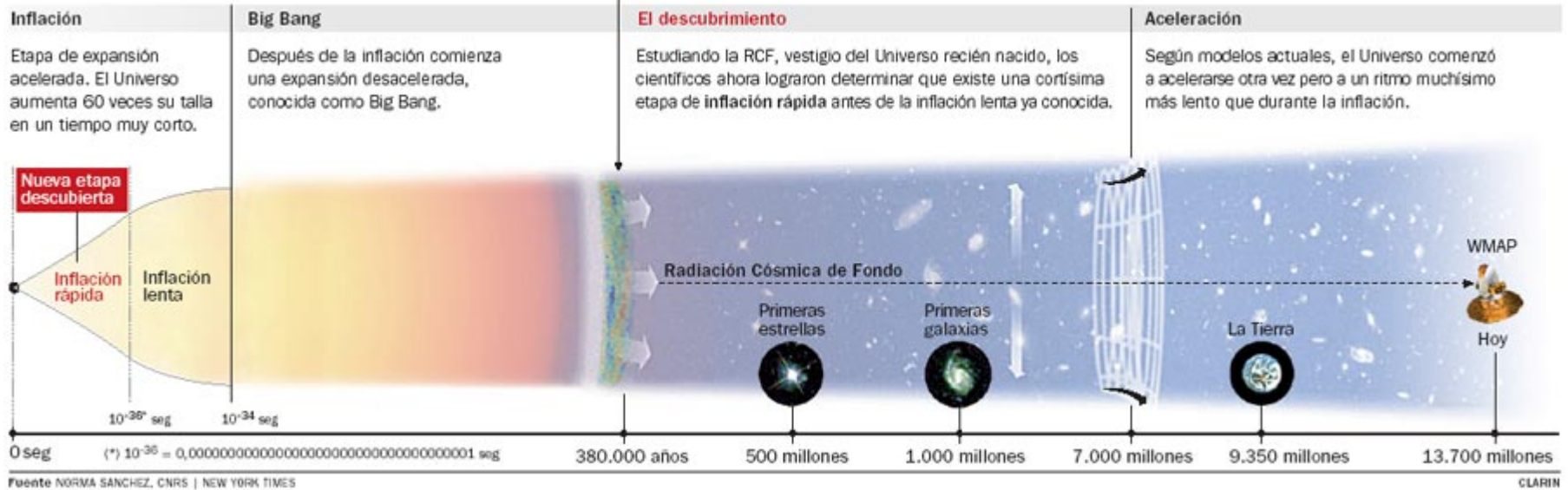


These Acoustic Oscillations are excited by the primordial inflationary power: $P(k) = \Delta k^{n_s-1}$, $n_s =$ spectral index.

An explanation for the **the quadrupole suppression**: the fast-roll stage of inflation. DB, HJdV, NGS, PRD74, 123006 and 123007 (2006).

Fast roll Inflation produces the Observed Quadrupole CMB Suppression

Cómo evolucionó el Universo



Fuente NORMA SANCHEZ, CNRS | NEW YORK TIMES

CLARIN

**D. Boyanovsky, H. J de Vega and N. G. Sanchez,
 " CMB quadrupole suppression II : The early fast roll stage "
 Phys. Rev. D74 , 123006 (2006)**

COSMIC HISTORY AND CMB QUADRUPOLE SUPPRESSION

DAWN
OF
TIME
?

Planck time: $t \sim 10^{-44}$ sec

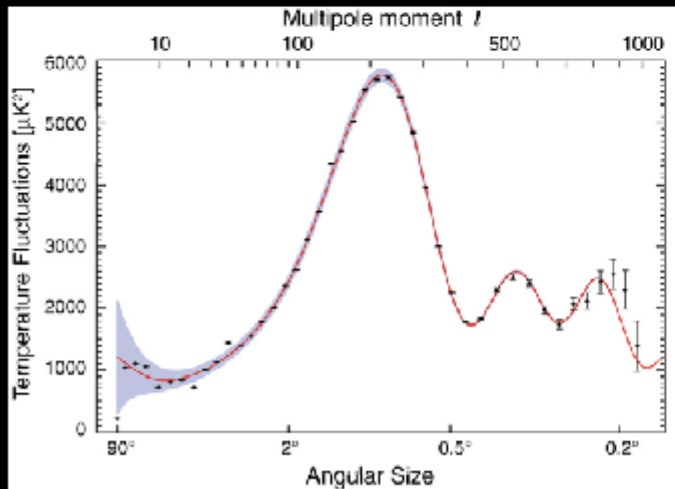
$t \sim 10^{-39}$ sec



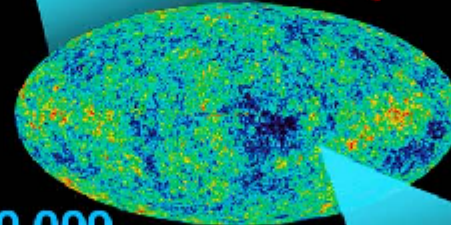
inflation

Fast roll inflation produces
the CMB quadrupole
suppression

Fast roll inflation
 10^{-39} sec \sim t \sim 10^{-38} sec
Slow roll inflation
 10^{-38} sec \sim t \sim 10^{-36} sec



380,000
years



13.7
billion
years



Dark Matter Particles

DM particles decouple due to the universe expansion, their distribution function **freezes out** at decoupling.

The characteristic length scale is the **free streaming scale** (or Jeans' scale). For DM particles decoupling UR:

$$r_{Jeans} = 57.2 \text{ kpc} \frac{\text{keV}}{m} \left(\frac{100}{g_d} \right)^{\frac{1}{3}}, \text{ solving the linear Boltz-V eqs.}$$

g_d = number of UR degrees of freedom at decoupling.

DM particles can **freely** propagate over distances of the order of the free streaming scale.

Therefore, structures at scales smaller or of the order of r_{Jeans} are **erased**.

The size of the DM galaxy cores is in the ~ 50 kpc scale $\Rightarrow m$ should be in the keV scale (WDM particles).

For neutrinos $m \sim \text{eV}$ HDM particles

$r_{Jeans} \sim 60 \text{ Mpc} \Rightarrow$ **NO GALAXIES FORMED.**

Dark Matter: from primordial fluctuations to Galaxies

❖ **Cold (CDM)**: small velocity dispersion: small structures form first, **bottom-up** hierarchical growth formation, *too heavy (GeV)*

❖ **Hot (HDM)** : large velocity dispersion: big structures form first, **top-down**, fragmentation, ruled out, *too light (eV)*

Warm (WDM): “in between”, *right mass scale, (keV)*

Λ WDM Concordance Model:

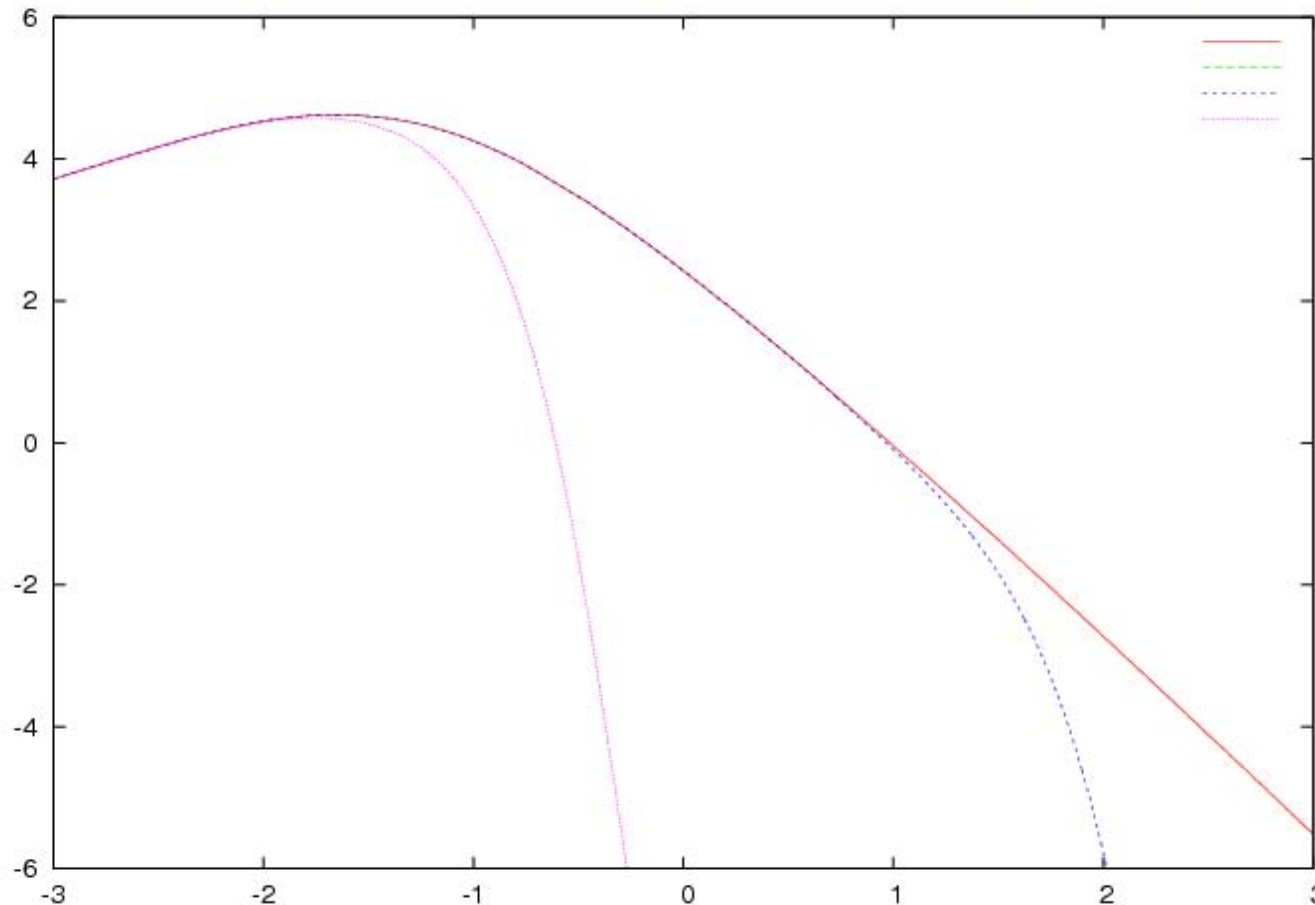
CMB + LSS + SSS Observations

DM is WARM and COLLISIONLESS

CDM Problems:

- “clumpy halo problem”, large number of satellite galaxies
- “satellite problem”, overabundance of small structures
- $\rho(r) \sim 1/r$ (cusp)
- And other problems.....

Linear primordial power today $P(k)$ vs. k Mpc h

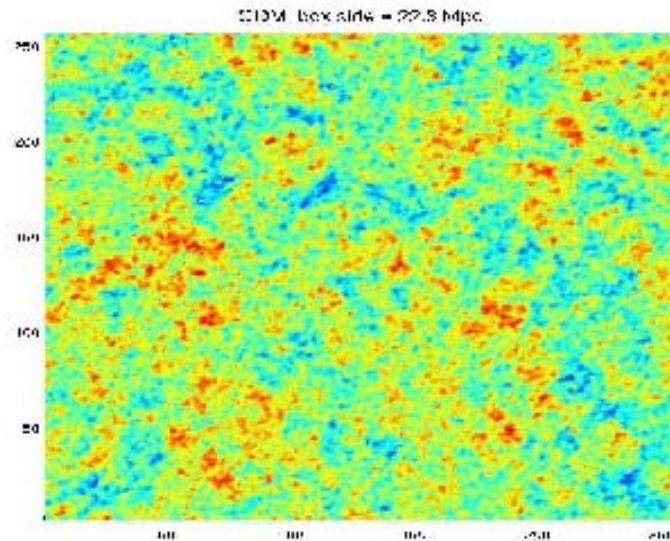


$\log_{10} P(k)$ vs. $\log_{10}[k \text{ Mpc } h]$ for **WIMPS**, **1 keV** DM particles and **10 eV** DM particles. $P(k) = P_0 k^{n_s} T^2(k)$.

$P(k)$ cutted for **1 keV** DM particles on scales $\lesssim 100$ kpc.

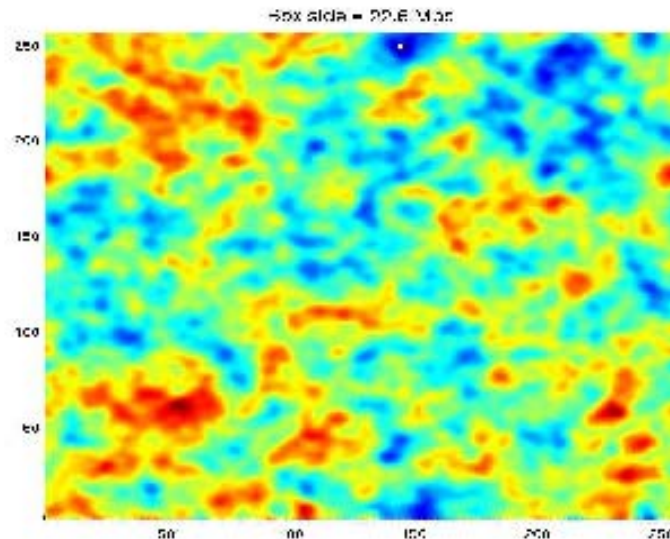
Transfer function in the MD era from Gilbert integral eq

WDM vs. CDM linear fluctuations today



Box side = 22.6 Mpc. [C. Destri, private communication].

WDM:



WARM DARK MATTER REPRODUCE

→ OBSERVED GALAXY DENSITIES
AND VELOCITY DISPERSIONS

→ SOLVES the OVERABUNDANCE (“satellite”) PROBLEM

-> OBSERVED SURFACE DENSITY VALUES OF DARK MATTER DOMINATED GALAXIES

→ OBSERVED GALAXY
CORED DENSITY PROFILES : QUANTUM
MECHANICS

Dwarf galaxies as quantum objects

de Broglie wavelength of DM particles $\lambda_{dB} = \frac{\hbar}{m \sigma}$

d = mean distance between particles,

σ = DM mean velocity

$$d = \left(\frac{m}{\rho} \right)^{\frac{1}{3}}, \quad Q = \rho / \sigma^3, \quad Q = \text{phase space density.}$$

ratio: $\mathcal{R} = \frac{\lambda_{dB}}{d} = \hbar \left(\frac{Q}{m^4} \right)^{\frac{1}{3}}$

Observed values: $2 \times 10^{-3} < \mathcal{R} \left(\frac{m}{\text{keV}} \right)^{\frac{1}{3}} < 1.4$

The **larger** \mathcal{R} is for ultracompact dwarfs.

The **smaller** \mathcal{R} is for big spirals.

\mathcal{R} near unity (or above) means a **QUANTUM OBJECT**.

Observations alone show that compact dwarf galaxies are **quantum objects** (for WDM).

The quantum radius r_q for different kinds of DM

DM type	DM particle mass	r_q	
CDM	1 – 100 GeV	$1 - 10^4$ meters	in practice zero
WDM	1 – 10 keV	0.1 – 1 pc	compatible with observed cores
HDM	1 – 10 eV	kpc - Mpc	too big !

RESULTS

All the obtained density profiles are cored.

The Core Sizes are in agreement with the observations

from the compact galaxies where $r_h \sim 20$ pc till the spiral and elliptical galaxies where $r_h \sim 0.2 - 60$ kpc.

The larger and positive is the chemical potential $\nu(0)$, the smaller is the core.

**The minimal one arises in the degenerate case $\nu(0) \rightarrow +\infty$
(compact dwarf galaxies).**

And

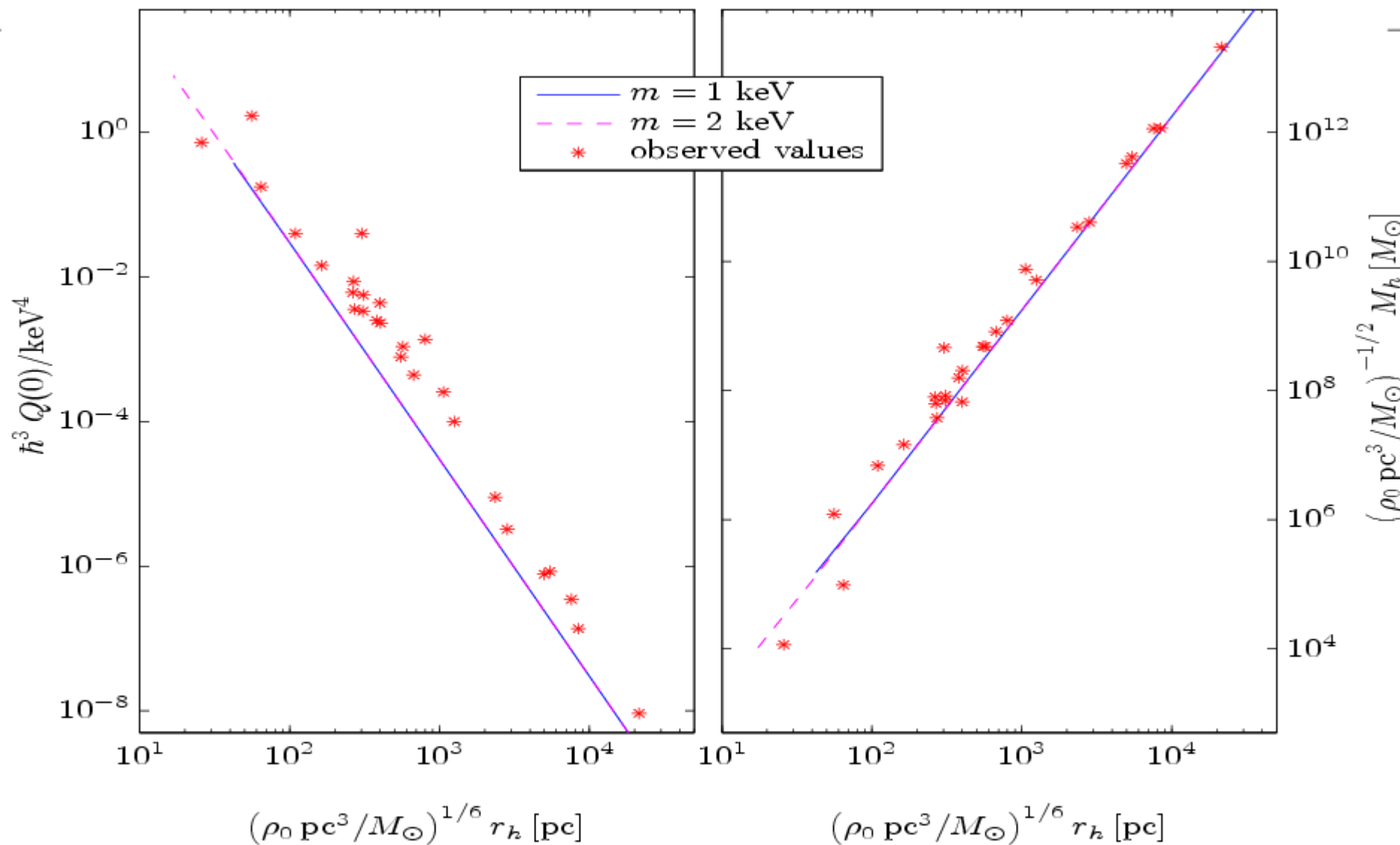
The Phase-space Density

The Galaxy halo Masses.

**Agreement is found in all the range of galaxies
for a DM particle mass m around 2 keV.**

Error bars of the observational data are not shown but they are at least about 10-20 %.

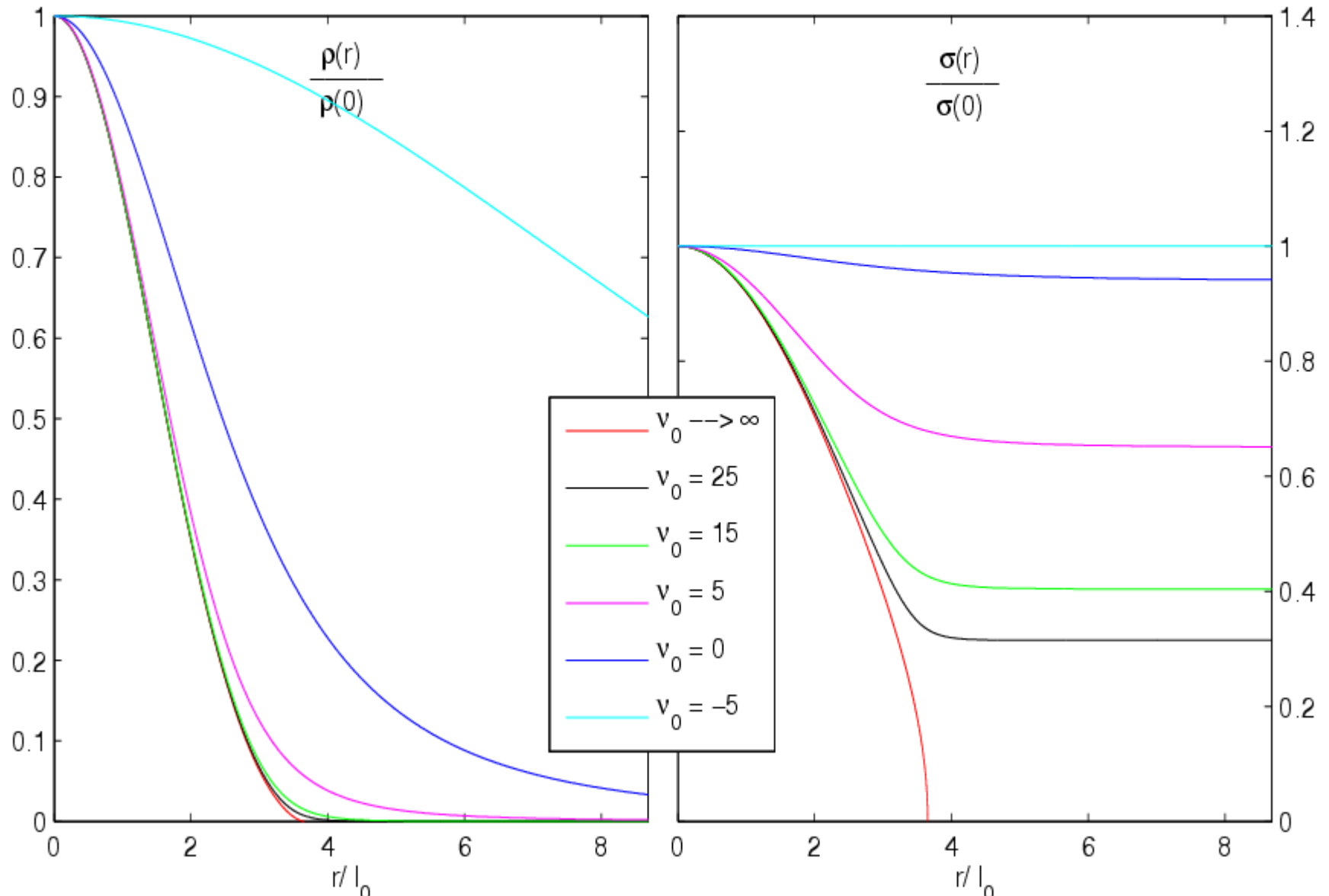
Q vs. halo radius. Galaxy observations vs. Thomas-Fermi



observed $Q = \rho/\sigma^3$ from stars are **upper bounds** for DM Q

Density and velocity profiles from Thomas-Fermi

Cored density profile and velocity profile obtained from Thomas-Fermi.



THE MINIMAL GALAXY MASS

A minimal galaxy mass and minimal velocity dispersion are found.

This in turn implies a **minimal mass $m_{\min} = 1.91$ keV** for the WDM particle.

This **minimal WDM mass** is a **universal** value, independent of the WDM particle physics model because only relies on the **degenerate quantum fermion state**, which is universal whatever is the non-degenerate regime.

These results and the observed halo radius and mass of the compact galaxies also **provide further indication that the WDM particle mass m is approximately around 2 keV.**

More precise data will make this estimation more precise.

Minimal galaxy mass from degenerate WDM

The halo radius, the velocity dispersion and the galaxy mass take their **minimum** values for degenerate WDM:

$$r_{h \min} = 24.51 \dots \text{ pc} \left(\frac{m}{\text{keV}} \right)^{\frac{4}{3}} \left[\rho(0) \frac{\text{pc}^3}{M_{\odot}} \right]^{\frac{1}{6}}$$

$$M_{\min} = 2.939 \dots 10^5 M_{\odot} \left(\frac{\text{keV}}{m} \right)^4 \sqrt{\rho(0) \frac{\text{pc}^3}{M_{\odot}}}$$

$$\sigma_{\min}(0) = 2.751 \dots \frac{\text{km}}{\text{s}} \left(\frac{\text{keV}}{m} \right)^{\frac{4}{3}} \left[\rho(0) \frac{\text{pc}^3}{M_{\odot}} \right]^{\frac{1}{3}} .$$

These **minimum** values **correspond** to the observations of compact dwarf galaxies.

Lightest known compact dwarf galaxy is Willman I:

$$M_{\text{Willman I}} = 2.9 \cdot 10^4 M_{\odot}$$

Imposing $M_{\text{Willman I}} > M_{\min}$ yields the **lower bound** for the WDM particle mass: $m > 1.91 \text{ keV}$.

WARM DARK MATTER REPRODUCE

→ OBSERVED GALAXY DENSITIES
AND VELOCITY DISPERSIONS

→ OBSERVED GALAXY
CORED DENSITY PROFILES

-> OBSERVED SURFACE DENSITY VALUES OF
DARK MATTER DOMINATED GALAXIES

→ SOLVES the OVERABUNDANCE (“satellite)
PROBLEM and the CUSPS vs CORES Problem

• **WDM OVERALL CONCLUSION**

- **To conclude, we find it is highly remarkable that in the context of warm dark matter, the quantum description provided by this semiclassical framework, (quantum WDM and classical gravitation), is able to reproduce such broad variety of galaxies.**
- **The resulting galaxy, halo radius, galaxy masses and velocity dispersion are fully consistent with observations for all different types of galaxies. Fermionic WDM treated quantum mechanically, as it must be, is able to reproduce the observed galactic cores and their sizes. In addition, WDM simulations produce the right DM structures in agreement with observations for scales $>$ kpc.**

IN PROGRESS

**H. J. de Vega, N. G. Sanchez:
BLACK HOLES FORMED
by WDM and BARYONS**

(GALACTIC SUPERMASSIVE, STELLAR)

**Galaxy Structure from Classical Cosmological
Boltzmann-Vlasov equations:
Generalized Larson equations**

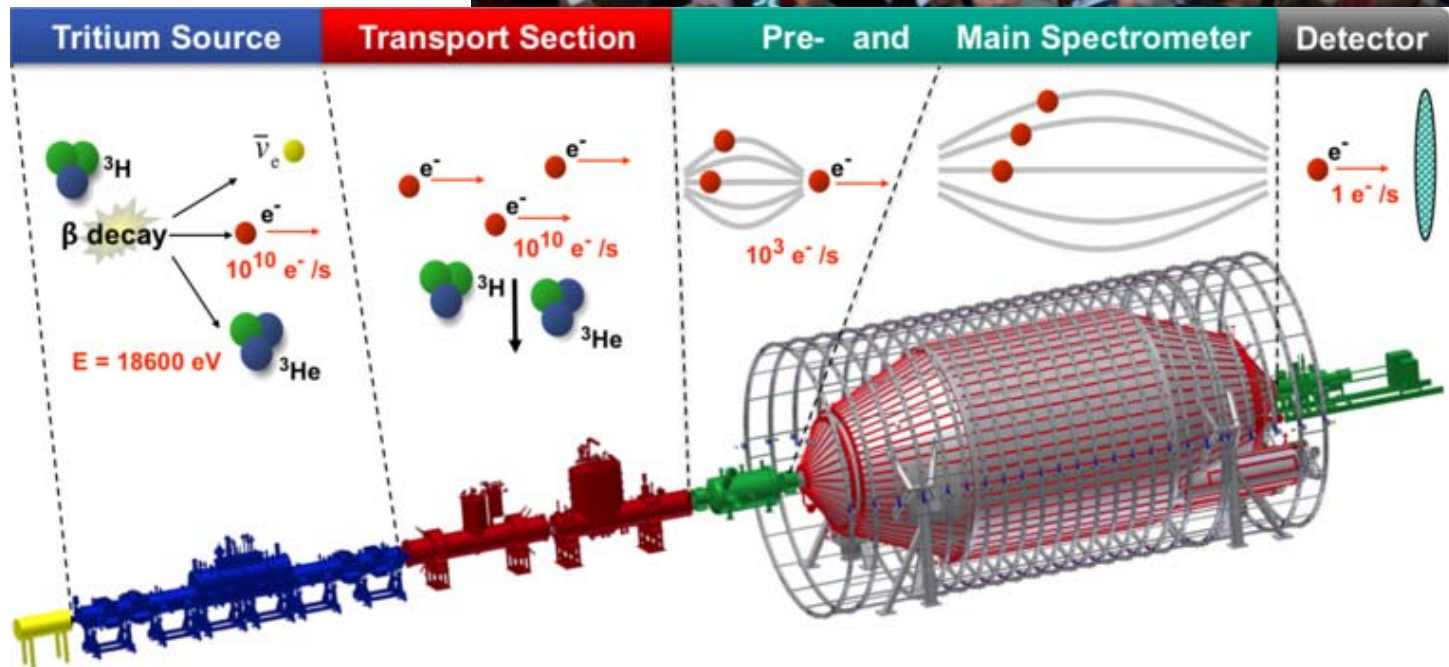
And other results.....

keV Sterile Neutrino Warm Dark Matter

Sterile neutrinos can decay into an active-like neutrino and a monochromatic X-ray photon with an energy half the mass of the sterile neutrino. **Observing the X-ray photon provides a way to observe sterile neutrinos in DM halos.**

WDM keV sterile neutrinos can be copiously produced in the supernovae cores. SN stringently constrain the neutrino mixing angle squared to be 10^{-9} for $m > 100$ keV (in order to avoid excessive energy lost) but for smaller masses the SN bound is not so direct. **Within the models worked out till now, mixing angles are essentially unconstrained by SN in the keV mass range.**

Sterile neutrinos are produced **out of thermal equilibrium** and their production can be non-resonant (in the absence of lepton asymmetries) **or resonantly enhanced** (if lepton asymmetries are present).



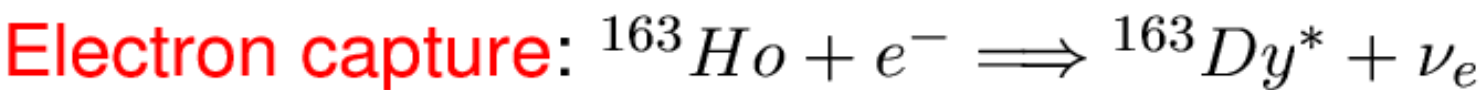
How to detect sterile neutrinos?

Sterile neutrinos **can be detected** in beta decay and in electron capture (EC) when a ν_s with mass in the keV scale is produced **instead** of an active ν_e .

Beta decay: the electron spectrum is slightly modified at energies around the mass (\sim keV) of the ν_s .



The electron energy spectrum is observed.



The nonradiative de-excitation of the Dy^* is observed and different for ν_s in the keV range than for active ν_e .

Experiments that may detect **sterile neutrinos**:

MARE (Milano), KATRIN (Karlsruhe), PTOLEMY (Princeton), ECHo (Heidelberg).

They search the mass of the ordinary neutrino.

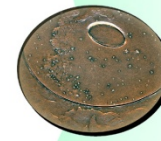
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22 MAY 2014: Spring Open Session of scientific culture / Session ouverte de printemps de culture scientifique interdisciplinaire : "L'homme et l'univers" (Bâtiment Perrault, Observatoire de Paris)

4-7 JUNE 2014: Chalonge Meudon workshop: "From large to small scale structures in agreement with observations: CMB, WDM, galaxies, black holes, neutrinos and sterile neutrinos" (Château de Meudon - CIAS, Meudon)

22-25 JULY 2014: The 18th Paris cosmology colloquium Chalonge 2014: "Latest news from the universe: A WDM, CMB, dark matter, A dark energy, neutrinos and sterile neutrinos" (Bâtiment Perrault, Observatoire de Paris)

25 JULY 2014: Summer Open Session of scientific culture / Session ouverte d'été de culture scientifique : A surprise session

AUTOMNE 2014: Cycle Les grandes questions posées aujourd'hui à la science : "Où va la science ?" (Cité Internationale Universitaire de Paris)

17-18 OCTOBER 2014: Chalonge Turin session: "Latest news from the universe: dark matter, galaxies and particle physics" (Palazzo de l'Università & Accademia delle Scienze, Piemonte region, Turin, Italy)

27-28 NOVEMBER 2014: Concluding session & Avant-première 2015

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