WARM DARK MATTER COSMOLOGY

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Basement- ground Zero

Dark matter is the dominant component of Galaxies and is an essential ingredient to understand Galaxy properties and Galaxy formation

Dark matter and Galaxy Formation must be treated in an cosmological context

The nature (the type) of Dark Matter and the cosmological model need to be explicitated when discussing galaxies and galaxy formation

All the building of galaxy formation depends on

the nature of Dark Matter

UPDATE and CLARIFICATIONS

ΛCDM agrees with CMB + LSS **BUT**
ΛCDM **DOES NOT agree with SSS (GALAXIES)**

ΛWDM agrees with CMB + LSS + SSS (GALAXIES)
The Standard Model of the Universe is LWDM =
{GR, Newtonian Gravity, Field Theory, QFT}

Sentences like « CMB confirms the ΛCDM model é »
Must be completed by adding: « in the large scalesò »
and must be updated with the sentence:
CMB confirms the ΛWDM model in large scales

NEW: Gravity and Quantum Mechanics in Galaxies. Newton, Fermi and Dirac meet together in Galaxies because of keV WDM

WDM solves naturally the problems of CDM and CDM + baryons , provides the same large scale and CMB results than ş CDM and agrees with the observations at the galactic and small scales.

Warm Dark Matter Cosmology (ΛWDM) is a more complete, correct and general theory than Cold Dark Matter (ΛCDM) because it contains CDM as a limiting case (for high particle masses), reproduces ΛCDM at large scales and solves the known problems of CDM at small and intermediate scales.

So far, not a single valid objection arose against WDM.

ΛWDM Cosmology

(I) The Standard Model of the Universe Includes Inflation

(II) 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. Generalized Eddington approach to galaxies

(V) The case for the keV sterile neutrino

THE PRIMORDIAL GRAVITONS

LOWER BOUND on r (2008)

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

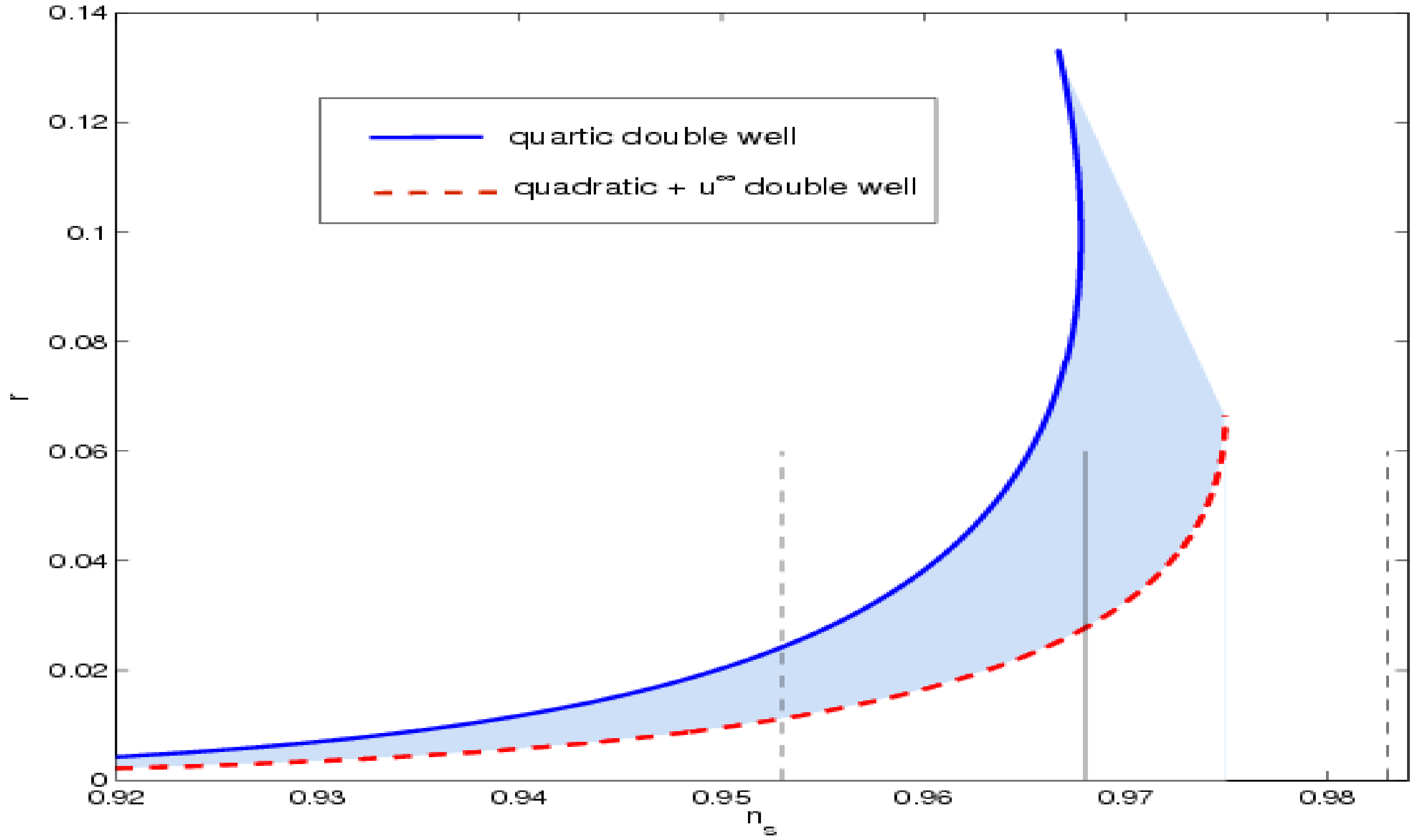
C. Destri, H J de Vega, N G Sanchez, Phys Rev D77, 043509 (2008) shows:

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

$$r > 0.023 \text{ at } 95\% \text{ CL and}$$

$$r > 0.046 \text{ at } 68\% \text{ CL.}$$

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)

From WMAP9 to Planck

Understanding the direction in which data are pointing:

ÅPREDICTIONS for Planck

ÅStandard Model of the Universe

ÅStandard Single field Inflation

ÅNO RUNNING of the Primordial Spectral Index

ÅNO 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 :

$$n_s = 0.9608 \,, \quad r$$

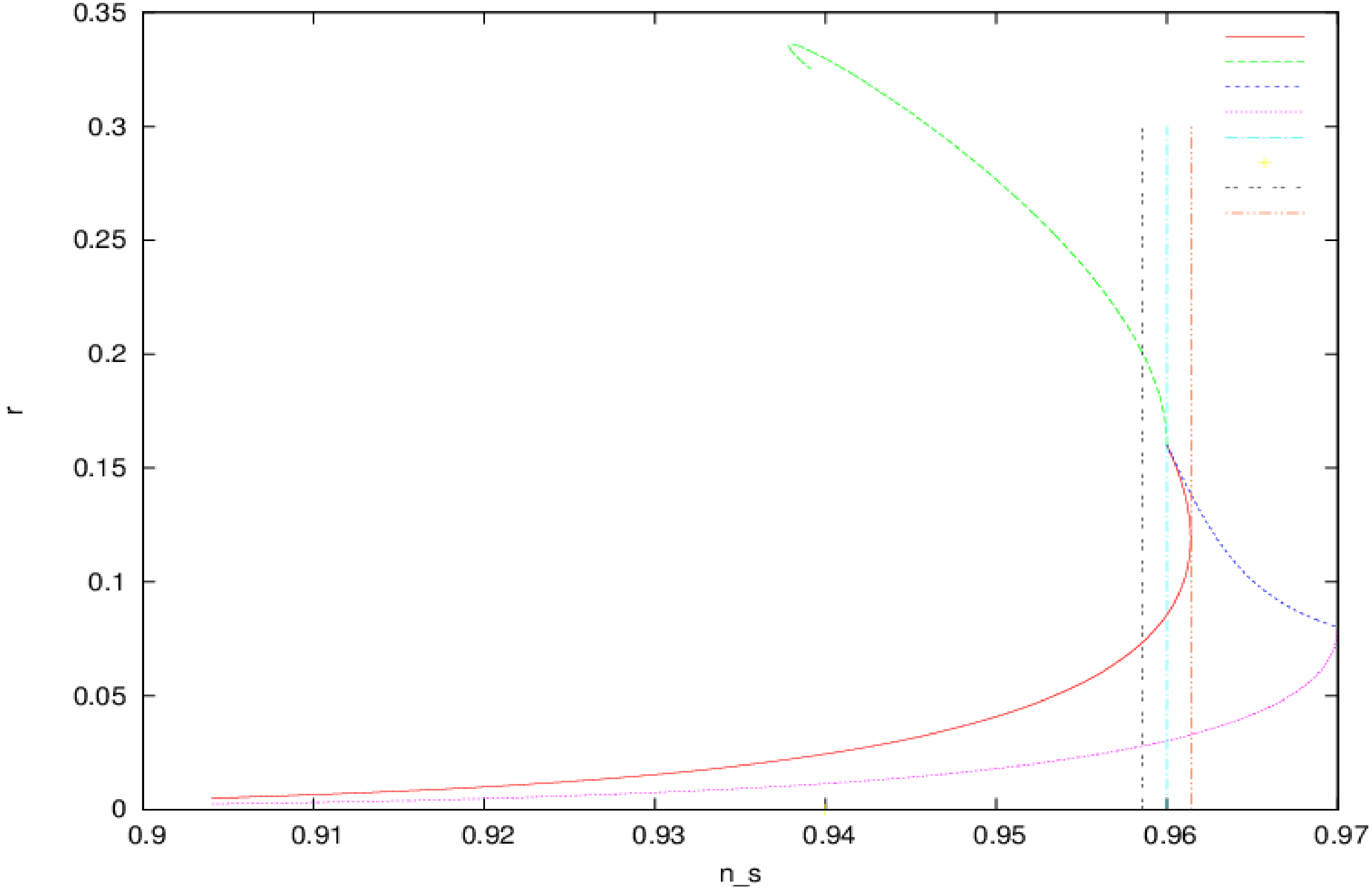
PREDICTIONS

$r > 0.021$

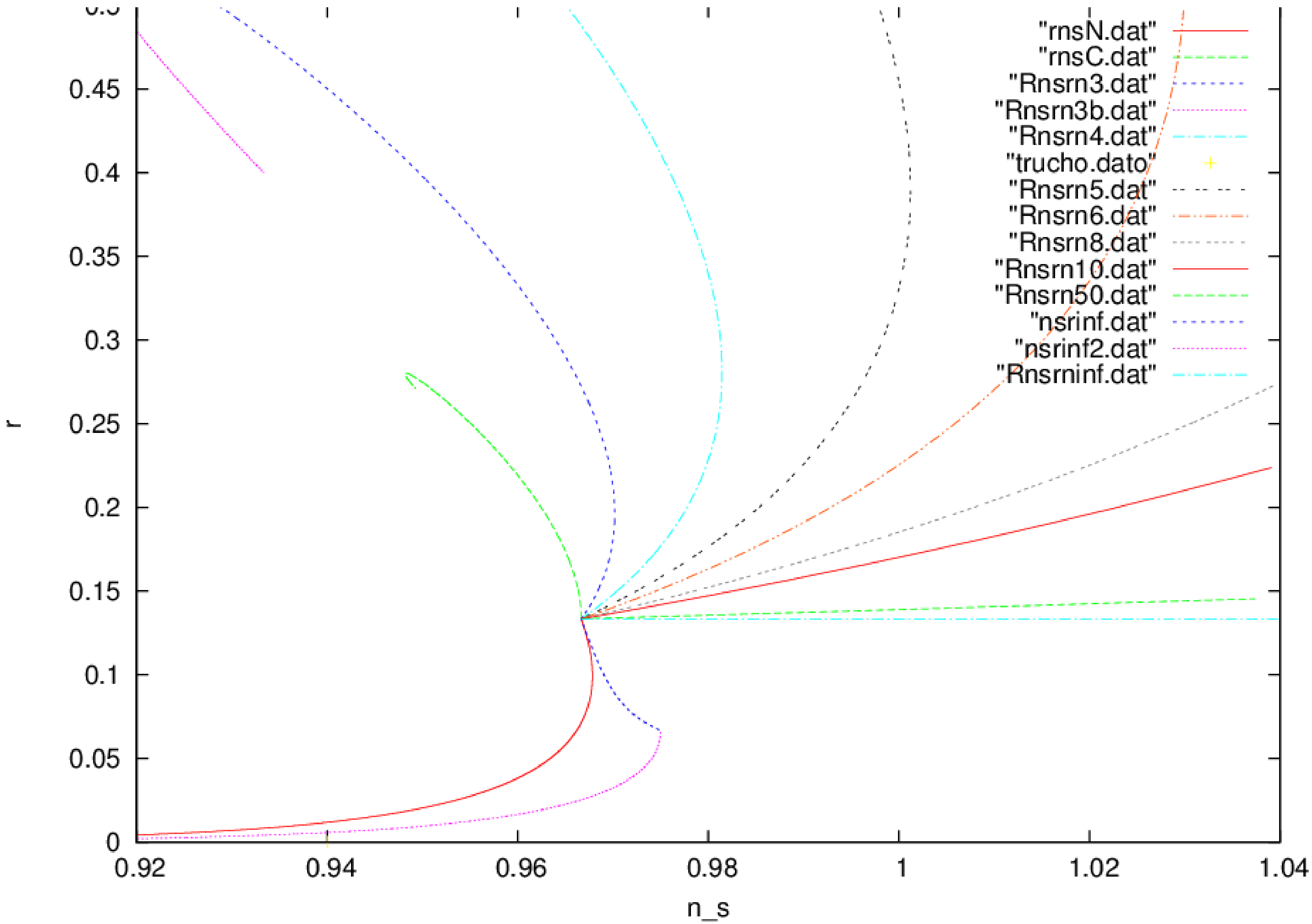
DdS: Destri, de Vega, Sanchez & from WMAP data (PRD 2008)

PlanckBICEP2Keck 2015: $r < 0.09$

Single and Double Well Inflaton Potentials



The cosmic banana for double well potentials (N=50).



"rnsN.dat"
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0.94
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0.98
1
1.02
1.04

2016 DARK MATTER UPDATE

Å THERE IS NO CUSP/CORE problem:

Å Observed Galaxy profiles are cored.

Å WDM Galaxy density profiles are cored

Å THERE IS NO satellite problem

Å WDM abundance of structures agrees with observations

Å In addition, these are not fundamental problems.

NO DM WIMPS, NO DM annhilation,

NO DM axions. NO DM bosons

Jeans length for Bose-Einstein condensates (BEC):

$$\lambda_J \sim 4 \ (10^{-22} \, eV \ / m)^{1/2} \quad kpc$$

$$\lambda_J \sim 1.2 \times 10^{17} \ (10^{-22} \, eV / m)^{1/2} \ km$$

Hence, in BEC dark matter in order to reproduce the observed galactic structures, one should have $m \sim 10^{-22}$ eV

CONSTRAINTS: ρ_{DM} and phase space density

$$\rho_{DM} = 0.9259 \ 10^{-23} \ keV^4$$

$$Q_{today} \leq Q , \qquad Q_{today} \equiv Q/Z$$

$$5 \times 10^{-6} < (Q_{today} / keV^4)^{2/3} < 1.4,$$

$$\frac{Q_{BEC}}{keV^4} = 0.461 \ 10^{-68} \frac{m^3}{(10^{-22} \, eV)^3} \left(\frac{M}{10^7 \, M_\odot}\right)$$

BEC objects would correspond to compact halos, ie typically $M \sim 10^7 \, M_\odot$, **thus $Q \sim 10^{-68}$** for the typical $m \sim 10^{-22}$ eV

Q_{BEC} more than sixty orders of magnitude smaller than the observed values

Although $m \sim 10^{-22}$ eV provides reasonable BEC free-streaming lengths, the corresponding BEC phase-space density turns to be ridiculously small.

The BEC particle masses compatible with the DM $<\rho>$ and Q constraints are:

m > 3 keV (for TE) and **m > 0.03 eV (out of TE),**

yielding exceedingly small Jeans lengths:

λ_J (keV) = 3.8×10^4 km for **TE .**

λ_J (10 eV) = 6.9×10^6 km out TE .

Unrealistically small by eleven to thirteen orders of magnitude to form observed galaxy structures.

DM structures of all sizes above these minuscule Jeans lengths will be formed.

Even worse than CDM: λ_J CDM $\sim 3 \times 10^{12}$ km.

For m $\sim 10^{-22}$ eV appropriate for λ_J BEC galaxies,

the **gd** values are : **$g_d \sim 2 \times 10^{11}$ TE ,**

$g_d \sim 2 \times 10^{14}$ out of TE .

These gigantic values of g_d are totally impossible for decoupling in the radiation dominated era.

They are absolutely unrealistic for whatever particle physical model one considers.

Hence, there is no way to realize the tiny BEC DM mass m $\sim 10^{-22}$eV.

These results strongly disfavour BEC DM

de Vega Sanchez ï Theory Approach
to Galaxy Structure

FERMIONIC QUANTUM WDM and GRAVITATION DETERMINE THE OBSERVED PHYSICAL GALAXY STRUCTURE

-> Dark matter (DM): main component of galaxies.
Quantum mechanics: cornerstone of physics from microscopic to macroscopic systems: quantum liquids He3, white dwarf stars, neutron stars. NOT Exotic Physics.

-> Quantum mechanics also responsible of galaxy structures at the kpc scales and below: near the galaxy center, below 10 - 100 pc, the DM quantum effects important for warm DM (WDM), that is for DM particles with masses in the keV scale.
DdVS (New Astronomy 2013)
dVS PRD 2013, dVSS MNRAS 2014, dVS IJMPA 2016

->Approach to galaxy structure with results in remarkable

(i) Dwarf galaxies are 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 keV for the WDM particle.

- OBSERVED GALAXY CORES vs CDM CUSPS and WDM CORES-

- Well established sets of 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 Physics N-body WDM simulations exhibit cores but with sizes much smaller than the observed cores.

We have recently developped 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.**
- **Smoothing the density profile at the central regions has an effect on the whole galaxy halo.**

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.

WDM THEORY OF GALAXIES
REPRODUCES THE OBSERVED GALAXY STRUCTURES

Gravity and Quantum Mechanics meet together in Galaxies

de Vega, Salucci, Sanchez MNRS 2014 reproduced the main observed properties of galaxies of all types, masses and sizes, as the rotation curves, density profiles, phase space density, and scaling relations between the galaxy masses, sizes and velocities, with a physical theory to galaxy structure which captures the essential ingredients of galaxies: **dark matter and gravity.**

Newton, Fermi and Dirac, meet together in Galaxies through Warm Dark Matter

This new framework **requires dark matter particles to be fermionic** with mass in the scale of thousands electron Volts (**keV "warm dark matter")** and described by their quantum mechanical properties, as their quantum pressure resulting from the combination of the Pauli exclusion principle and the Heisenberg uncertainty principle. Compact dwarf galaxies are thus near the Fermi gas degenerate regime, while large dilute galaxies are in the classical gas Boltzmann regime.

This approach corresponds to the Schrödinger equation in the large number of particles regime **and is for galaxies the analogue of the Thomas-Fermi approach for atoms, with gravitation instead of the electric potential**.

Universal rotation curves and Universal density profiles: The same for all galaxies

The theoretically obtained galaxy rotation curves and density profiles reproduce extremely well the observational curves from ten different and independent sets of data for galaxy masses from 5×10^{9} solar masses untill 5×10^{11} solar masses.

Remarkably enough, the normalized theoretical circular velocities and density profiles are universal (URC): they are the same for all galaxies of different types, sizes and masses, and they agree extremely well with the observational curves described by cored profiles (flat smooth profiles at the center) and their sizes.
Interestingly enough, small deviations from the exact scaling relations show up for compact dwarf galaxies as a manifestation of the quantum macroscopic effects present in these galaxies.

Robust Results

Results of this work are independent of any particular warm dark matter particle physics model, they only follow from the self-gravitation of the warm dark matter particles and their fermionic nature. These important results show the ability of this approach to describe the galaxy structures. They also show that baryonic corrections are not very important to warm dark matter, consistent with the fact that dark matter is in average at least six times more abundant than baryons. The fraction of dark matter over the total mass of galaxies goes from the 95% for large dilute galaxies till 99.99% for dwarf compact galaxies. The baryon fraction in large galaxies can only reach values up to 5 %.

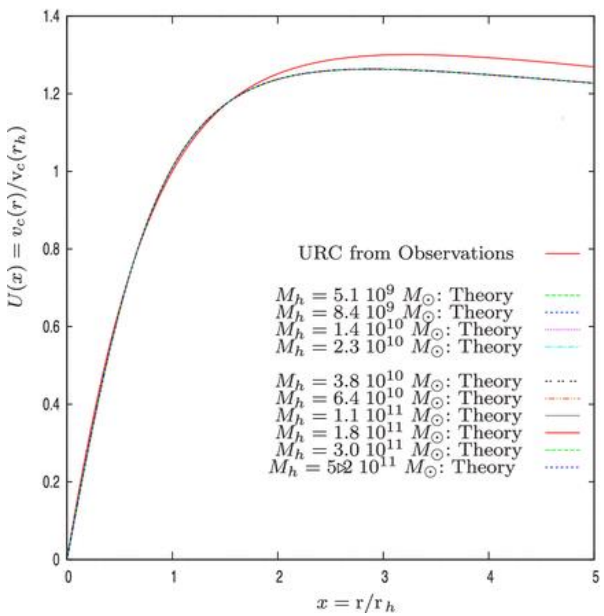
Reference:

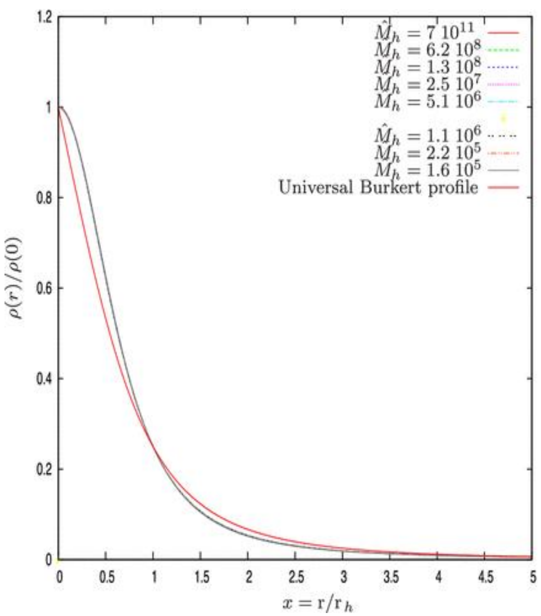
H.J. de Vega; P. Salucci; N. G.Sanchez MNRAS 442 (2): 2717-2727 (2014)

Newton, Fermi and Dirac, meet together in Galaxies through keV Warm Dark Matter

Rotation curves (left panel): The theoretical curves for 10 different galaxy masses all fall one into each other providing an Universal Rotation Curve (URC) which remarkably coincides with the observed universal curve (displayed in red) . Small deviations show up only at distances outside twice the *radius.*

The right panel shows the density profiles for the 10 galaxy masses: All fall into the same and universal density profile which reproduces the observed universal density profile and its size (in red). Interestingly enough, small deviations show up for compact dwarf galaxies as a manifestation of the quantum macroscopic effects predicted in these galaxies, and which can be further tested by next observations. (Examples of other macroscopic objects in nature are dwarf stars, neutron stars and the liquid Helium 3).





The equation of state of galaxies

We have derived the equation of state of galaxies, that is the relation between pressure and density, and provided its analytic expression : $P(r) = V^2(r)\ \rho(r)$

Two regimes for galaxies emerge :

(i) Large dilute galaxies for $M_h > 2{,}3\ 10^6$ Msun and effective températures $T_0 > 0{,}017$ K described by the classical Boltzmann gaz selfgravitational with local ideal gaz equation of state at each point (r-dependent).

(ii) Compact dwarf galaxies for $1{,}6\ 10^6\ M_{sun} > M_h > M_{h,\,min} = 30000\ (2keV / m)^{16/5}\ M_{sun}$, $T_0 < 0{,}011_h$ K described by the fermion WDM quantum regime with an equation of state more steep near (but not at) the degenerate state. In particular, the denerated limit T_0 = or extreme quantum limit yields the more compact and smallest galaxy. Moreover, in the dilute regime: the halo radius r_h , the v^2 and the temperature T_0 show scaling laws in terms of M_h. The amplitudes of these analytic scaling laws have been computed too.

→ **The normalized density and velocity profiles are <u>universal</u> fonctions <u>of</u> r / r_h. Thus, the scaling laws and the universality appearing in the dilute classical regime of large galaxies are linked to the <u>ideal gaz behaviour of WDM</u> in this regime.**

→**These results and the theoretical rotation curves remarquably reproduce for r <r_h the galaxy observations.**

→**In the compact regime of small galaxies the equation of state depends on the mass of each galaxy, the density and velocity profiles are not anymore universal , this reflects the <u>quantum physics of the WDM fermions in the compact regime</u> (which generically are <u>near but not at exactly</u> the degenerate limit-state)**

The Distribution Function of Dark Matter

→ We developped inverse methods allowing to determine the distribution function f(E) from the real density profiles obtained from observations or from numerical simulations:

→ Thus, we have found the distribution function f (E) of galaxy DM halos and the corresponding equation of state from the DM observed density profiles .

→ That is to say, we have solved for galaxies the analogue of the integral Eddington equation of the gaz of stars in globular clusters . The observed density profiles are a realistic starting point, thus the f(E) obtained from them are realistic fonctions .

NEW RESULTS

(i) CORED density profiles $\rho(r) \to \rho(0)$ ï Kr^2 produce distribution functions which are finite and positives at the center , while cusped density profiles with "cusps" growing as 1/r or more, always produce distribution functions which are divergent at the center.

(ii) The observed CORED density profiles produce distribution functions which are very near the THERMAL Boltzmann distributions for $r < 3r_h$. (r_h being the halo radius).

(iii) The analytic expresions for the dispersion velocity and the pressure are derived, they verify the ideal gaz equation of state for the DM with a local temperature $T(r) = mv^2(r) / 3$.

T (r) is slowly variable and turns out to be constant in the same region where the distribution function is thermal.

(iv) The DM halos can be consistently considered as being in Local Thermal Equilibrium with a temperature

$T(r) = T_0$ constant for $r < 3\, r_h$,

and $T(r) = m\, v^2 (r) / 3$

for $3\, r_h < r < R_{virial}$,

which slowly decreases with r.

That is to say, for $r < R_{virial}$,

the DM halo is a Self-Gravitant

Thermal Gaz without collisions.

(v) In the external halo region T(r) follows nicely the decreasing of the squared circular velocity

The DM in the halos of galaxies is thermalized

- Å **All these results show robustly that <u>the DM self-gravitating gaz</u> can <u>thermalize</u> in despite of being collissionless:**
- Å **This is due to the <u>gravitational interaction</u> between the DM particles and to the fact that this is an <u>ergodic</u> system.**
- Å **The collisionless self-gravitating gas is an isolated system which is <u>not integrable</u>.**
- Å **Namely, the particle trajectories explore <u>ergodically</u> the constant energy manifold in phase-space, covering it uniformly according to precisely the <u>microcanonical measure</u> and yielding to a thermal situation**

ÅPhysically, these phenomena are clearly understood :

ÅIn the inner halo region the density is higher than beyond the halo radius.

The gravitational interaction in the inner region is strong enough and thermalizes the self-gravitating gas of DM particles

while beyond the halo radius the particles are too dilute to thermalize, namely, although they are virialized, they had not enough time to accomplish thermalization.

The DM in the galaxy halos is thermalized II

Å Virialization always starts before than thermalization.

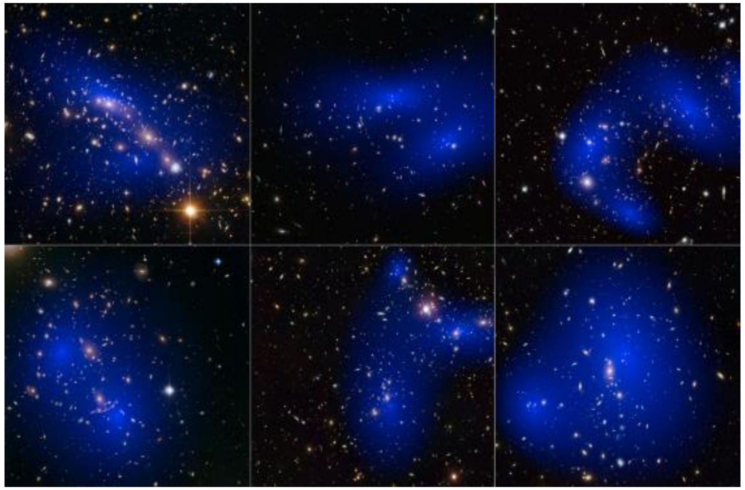
Å In the process of thermalization there is an energy transfer flow of potential energy into kinetic energy.

Å Clearly, in the outside halo region we find that the kinetic energy is lower than in the inside the region thermalization is already achieved.

Å And All these results are consistent with the result found : The local temperature T(r) in the outside halo region is lower than the temperature inside the halo region where thermalisation is achieved.

Self-interacting dark matter becames disfavored

Dark matter even darker than once thought



Hubble & Chandra show that dark matter interacts with itself even less than previously thought, and narrow down the options for what dark matter might be.

Good News for WDM

(« Options to CDM »: WDM and self-interacting DM)

The non-gravitational interactions of dark matter in colliding galaxy clusters

David Harvey, Richard Massey, Thomas Kitching, Andy Taylor, Eric Tittley

Science, 2015

Collisions between galaxy clusters provide a test of the non-gravitational forces acting on dark matter.

Previously: Dark matterôs lack of deceleration in the ôbullet cluster collisionô constrained its Self-interaction DM cross-section /m < 1.25 cm^2/g (68% CL)

Using the Chandra and Hubble Space Telescopes 72 collisions have now been observed. Combining these measurements statistically, imply :

1. The existence of dark mass at 7.6 sigma significance.

2. Self-interaction DM cross-section /m < 0.47 cm^2/g (95% CL) **→ strongly disfavoring the proposed self-interacting DM models**

30 systems, mostly between redshift $0.2 < z < 0.6$
plus two at $z > 0.8$,
containing 72 pieces of structure in total

The EXISTENCE of DARK MATTER is Reaffirmed:

Observations that do not presuppose the existence of dark matter show that clusters of galaxies with 10^{14} M_{sun}

contain only 3.2% of their mass in the form of stars.

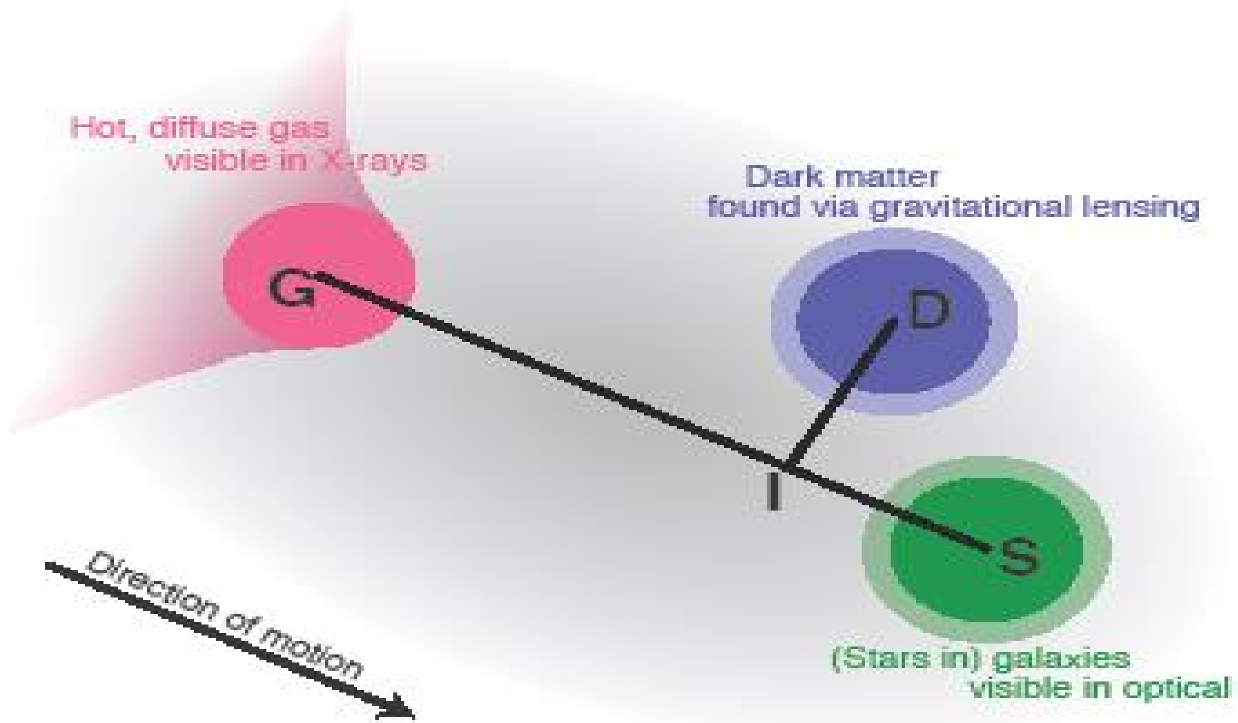
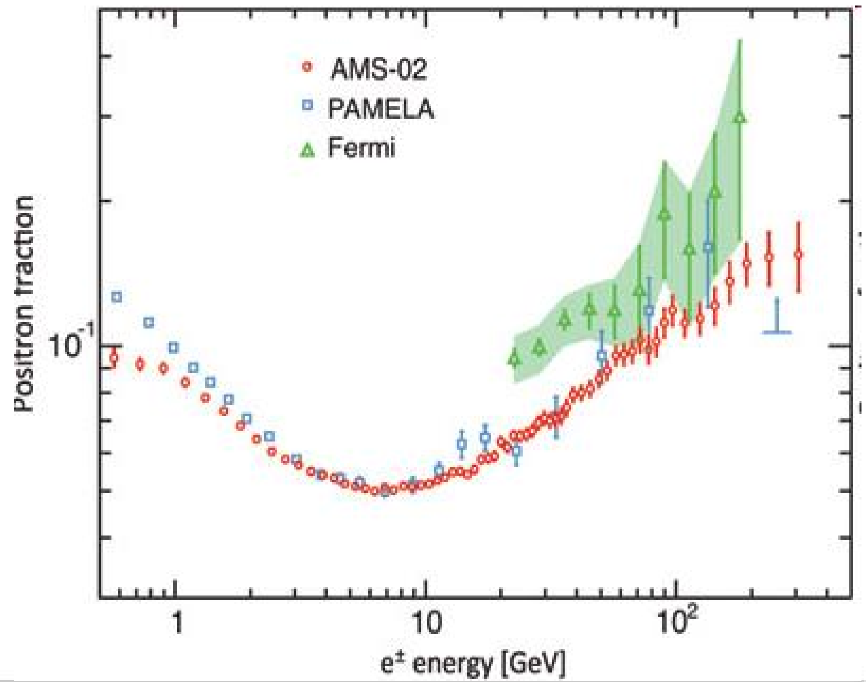
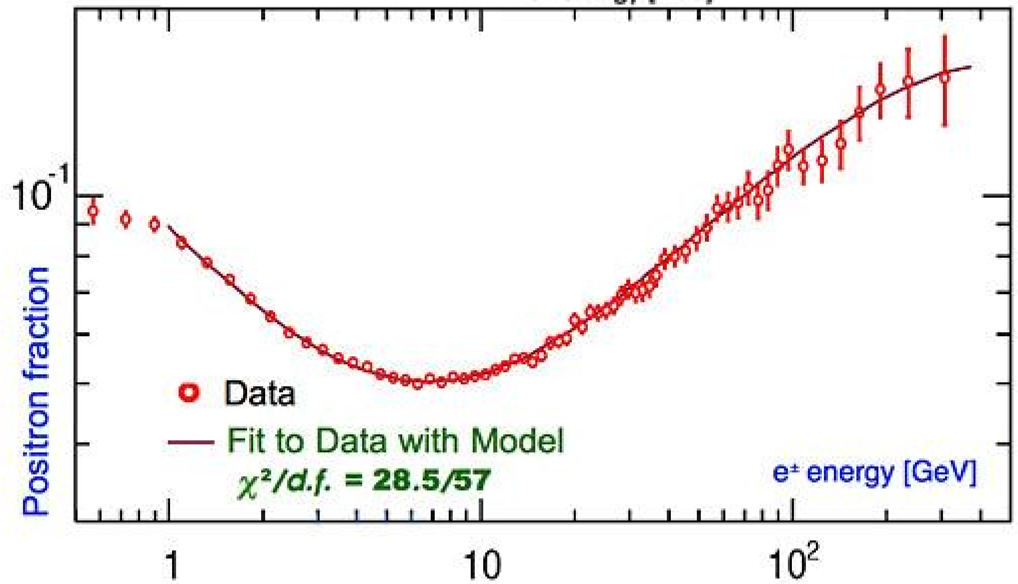


Figure 1: Cartoon showing the three components in each piece of substructure, and their relative offsets, illustrated by black lines. The three components remain within a common gravitational potential, but their centroids become offset due to the different forces acting on them, plus measurement noise. We assume the direction of motion to be defined by the vector from the diffuse, mainly hydrogen gas (which is stripped by ram pressure) to the galaxies (for which interaction is a rare event). We then measure the lag from the galaxies to the gas $\delta_{\rm SG}$, and to the dark matter in a parallel $\delta_{\rm SI}$ and perpendicular $\delta_{\rm DI}$ direction.





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

DARK MATTER FIRMELY EXISTS WITH
A VERY CLEAR MODEL INDEPENDENT STATUS
FROM LSS and SSS OBSERVATIONS:

NO CDM : DARK MATTER IS NOT COLD (nor GeV DM , nor TeV DM…)
NO WIMPs DM NO ANNIHILATING DM
NO SELF-INTARACTING DM (which is variation of CDM)

NO BOSONIC DM. NO BOSE EINSTEIN CONDENSATE DM
(NO QUANTUM BOSONIC WAVE FUNCTION DM)
NO AXION DM: DARK MATTER IS NOT BOSONIC.

DM IS WARM: keV scale mass: O(keV) means between 2 and 9 keV
DM is FERMIONIC. DM is a Fermion with mass in the keV scale
Therefore, the QUANTUM aspects of DM must be taken into account
MANY PARTICLE PHYSICS CANDIDATES: ex keV Sterile Neutrino
GRAVITATION IS NEWTONIAN IN GALAXIES and GR in the LSS UNIVERSE. NO MOND.
EXTENSION OF GRAVITY at the PLANCK SCALE but NOT at LARGE SCALES.

What next for the LHC?

APRIL 2015: **The Large Hadron Collider (LHC) has been**
Et cela recommanceé .restarted after a two-year shutdown.

Searching Beyond the Standard Model of Particle Physics

PREDICTIONS :

NO Dark Matter at LHC

NO SUSY at LHC

NO Extra-dimensions at LHC

NO Black Holes at LHC

Recall

Our Predictions for CMB: primordial gravitons r, inflation,

Our Predictions for Planck

Our Predictions for Auger, AMS, Pamela, Fermi

Our Predictions for LHC

Our Predictions for DM

Å ***Science is built up with facts,***

Å ***as a house is with stones.***

Å ***But a collection of facts is no more a science***

Å ***than a heap of stones is a house.***

-- Henri Poincaré

Å ***La science est construit avec des faits,***

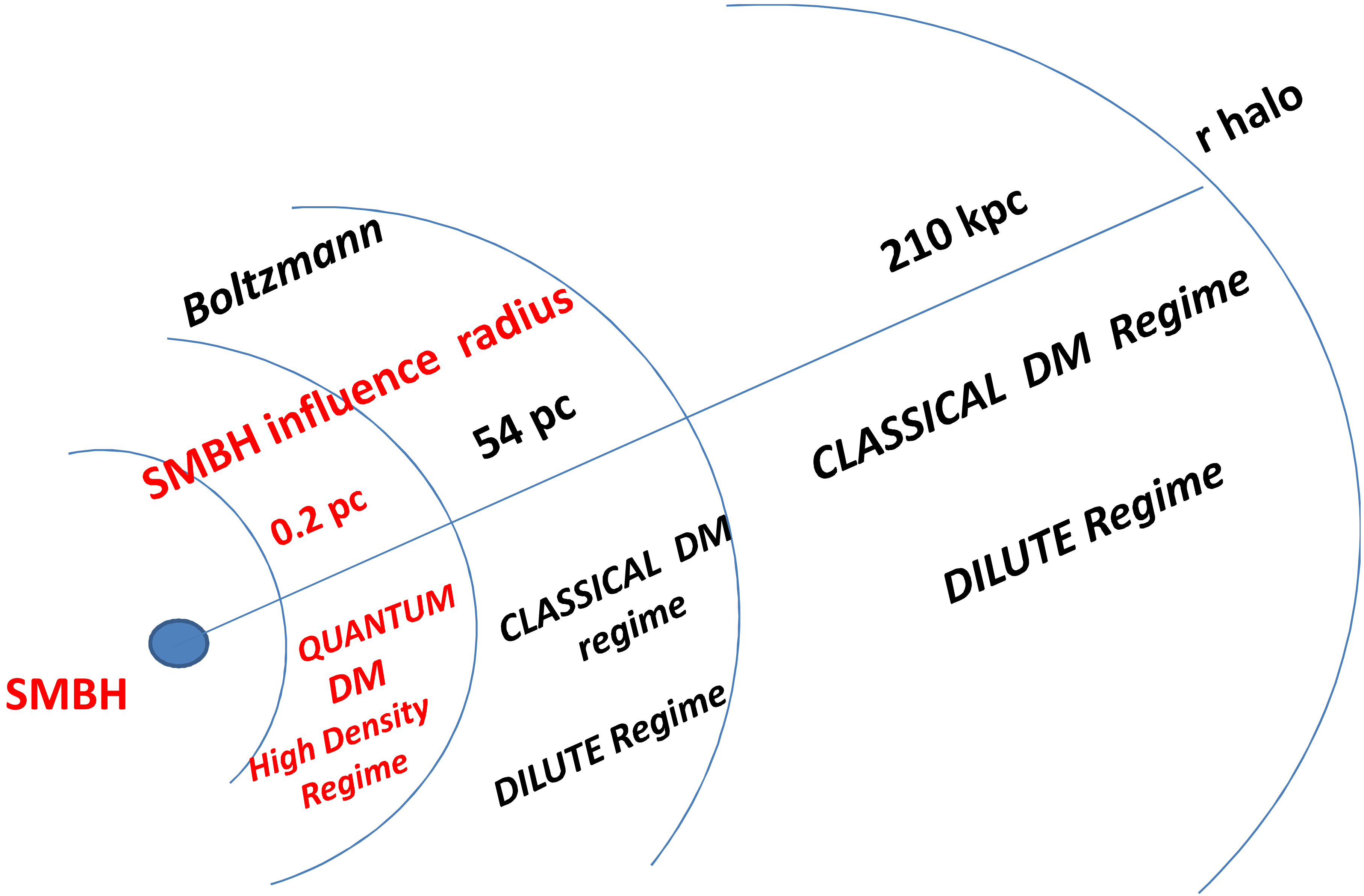
Å ***ainsi comme une maison est construite***

Å ***avec des pierres.***

Å ***Mais une collection de faits nôest pas une science, ainsi comme un tas de pierres nôest pas une maison.***

END

THANK YOU FOR YOUR ATTENTION



WDM Thomas-Fermi Galaxy Theory with SMBH

de Vega & Sanchez, 2015

WARM DARK MATTER REPRODUCE

→OBSERVED GALAXY DENSITIES AND VELOCITY DISPERSIONS

→SOLVES the OVERABUNDANCE (ñsatellite) PROBLEM

->OBSERVED SURFACE DENSITY VALUES OF DARK MATTER DOMINATED GALAXIES

→OBSERVED GALAXY CORED DENSITY PROFILES : QUANTUM MECHANICS

Å WDM OVERALL CONCLUSION

Å **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.**

Å **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.**

WDM + BARYONS

Baryons have not been included in this study. This is fully justified because on one hand dwarf compact galaxies are composed today 99.99 % of DM, and on the other hand **the baryon fraction in large galaxies can reach values up to 1 - 3 %.**

Since Fermionic WDM by itself produces galaxy main properties and structures in agreement with observations for all types of galaxies, masses and sizes, the effect of including baryons is expected to be a small correction to these pure WDM galaxy structural results, **consistent with the fact that dark matter is in average six times more abundant than baryons.**

ÅLarge Hadron Collider

- ÅThe first LHC results at 7-8 TeV, with the discovery of the 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.

- ÅIt 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

ñSupersymmetry 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 wimpôs signal) **ñSo far researchers who are racing to find evidence of so called "new physics", ie non-standard models, have run into a series of dead endsò.**

ANTIMATTER IN SPACE - AMS on board ISS Alpha Magnet Spectrometer

NASA

Planck and Dark Matter, Dec2014,2015

DM annihilation est absente: OK. Sur cet aspect, les données ne laissent pas d'ambigüité possible: Souvenez-vous:

Depuis plusieurs années nous avons toujours prédit, dit, et redit qu'il nóy a pas de DM annihilation importante et que le positron excès (Pamela, FERMI, AMS-02, etc.) n'est pas du a DM annihilation mais aux sources/ phénomènes astrophysiques: c'est dans nos slides., voir Programme 2014 chalonge par exemple http://chalonge.obspm.fr/Programme2014.html**Et ceci est de plus, un autre résultat négatif pour les modèles DM des Wimps, comme nous l'avons toujours dit.**

ÅWhy No Experimental Detection of the DM particle has been reached so far ?

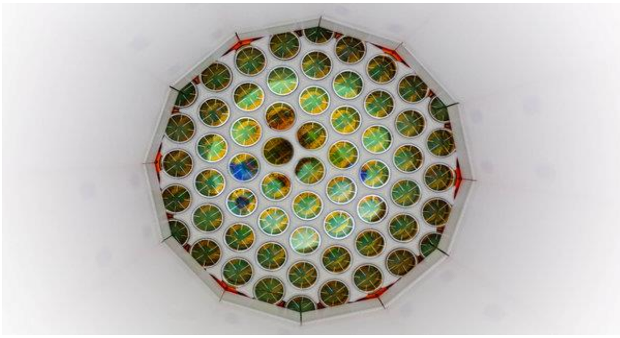
Because:

- Å All experimental searches for DM particles are dedicated to CDM: wimps of m > 1 GeV,
- Å While the DM particle mass is in the keV scale .
- Å Moreover, past, present and future reports of signals of such CDM experiments cannot be due to DM because of the same reason.
- Å The inconclusive signals in such experiments should be originated by phenomena of other kinds.
- Å 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



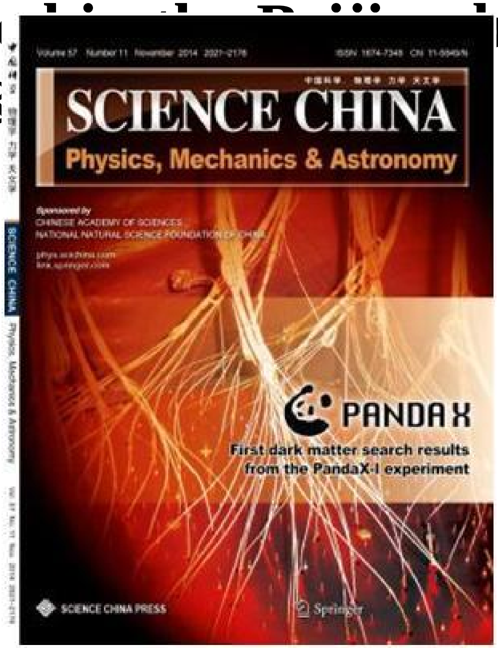
- **They found no sign of WIMPS signals.** beyond the expected background noise.
- The experiment did so at far better sensitivities than any such experiment before it.

ÅFirst dark matter search results from Chinese underground lab hosting

ÅPandaX-I experiment

Å30 SEPTEMBER 2014

Scientists across China and the United States collaborating on the PandaX search for dark matter from an underground lab in southwestern China report results from the first stage of the experiment in a new study publish[...]based journal *Science China Physics, Mechanics &*



ÅNEGATIVE RESULTS

Åfor Wimps

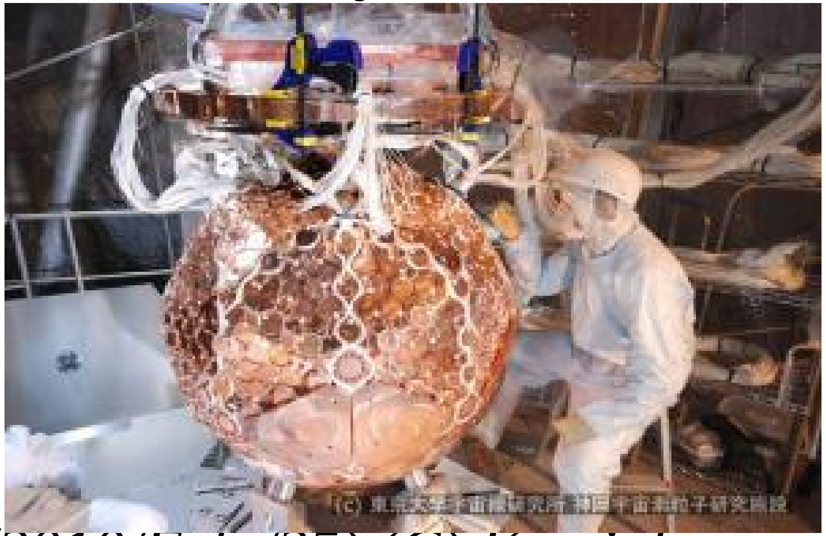
ÅChina Science Press

Å XMASS Recent News: October 6, 2014

A Warm Dark Matter Search Using XMASS

(Originally published by the University of Tokyo) **The XMASS collaboration, led by Yoichiro Suzuki at the Kavli IPMU, has reported its latest results on the search for warm dark matter. Their results rule out the possibility that super-weakly interacting massive bosonic particles (bosonic super-WIMPs) This result was published in the September 19th issue of the Physical Review Letters as an Editorsô Suggestion.**

NEGATIVE RESULTS for WIMPS



Å *Construction of XMASS Ⅰ detector (2010/Feb./25) (C) Kamioka Observatory, ICRR (Institute for Cosmic Ray Research), University of T...*

What next for the LHC?

APRIL 2015: **The Large Hadron Collider (LHC) has been restarted after a two-year shutdown. Et cela recommanceé .Searching Beyond the Standard Model of Particle Physics**

PREDICTIONS:

NO Dark Matter at LHC

NO SUSY at LHC

NO Extra-dimensions at LHC

NO Black Holes at LHC

Sterile neutrinos and CMB fluctuations

CMB data give the effective number of neutrinos, $N_{\rm eff}$.
$N_{\rm eff}$ is related in a subtle way to the number of active neutrinos (3) plus the number of sterile neutrinos.
Planck result: $N_{\rm eff} = 3.5 \pm 0.5$ (95%;P+WP+highL+H_0+BAO)
Entropy conservation determines the contributions to $N_{\rm eff}$.
WDM sterile neutrino contribution at recombination
$\Delta N^{WDM} = \left(\frac{T_d}{T_{rc}}\right)^4 = \left[\frac{g_{rc}}{g(T_d)}\right]^{4/3}$. At recombination $g_{rc} = 29/4$.
WDM decouples early at T_d beyond the Fermi scale
The number of UR degrees of freedom at decoupling $g(T_d)$ includes all SM particles and probably beyond.
$g_{SM} = 427/4 \quad , \quad g_{MSSM} = 915/4,$
$\Delta N^{WDM}_{SM} = 0.02771\ldots \quad , \quad \Delta N^{WDM}_{MSSM} = 0.01003\ldots$
Too small to be measurable at present !
Conclusion: Planck results say nothing about WDM.
Besides, Planck results are **compatible** with one or two eV sterile neutrinos (see e. g. G. Steigman, 1303.0049).

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 $m_s \sim$ 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 $m_s = 0.4$ 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. Haserkamp, JCAP,10,044H (2013) R. Battye & A. Moss,

Planck and the cosmological parameters

La valeur Neff est très importante et corrélée aux autres paramètres cosmologiques.

Planck a refait l'analyse des données 2014/2015 avec les mêmes priors (a priori) que en 2013 : ils ont donc très peu des corrections aux paramètres cosmologiques par rapport a Planck 2013 et donc ils ont un Neff compatible avec 3 neutrinos et les mêmes problèmes 2013 pour H_0 , pour la proportion de dark énergie et pour the dark matter proportion, pour sigma_8, etc. , car ils sont tous corrèles

Trop haute oméga DM (of about 26-27 %) , une trop basse oméga lambda (68%) et une trop basse H_0 pour n'arriver qu'a Neff compatible avec 3 neutrinos.... et donc ils ont les mêmes quôavant.

Planck and Neutrinos

Å **At early times:** CMB sensitive to radiation The radiation density other than photons is described by the **parameter Neff:** rad = C(Neff) photons.

Å **At late times:** CMB sensitive to neutrino masses

Å **The Priors in the Planck analyse:**

Å **Standard value for Neff= 3.046, 3 active neutrinos**

□ **Σ mν = 0.06 eV (1 massive, the other massless)**

Å **This is the source of the conflict with the values of H0 , lensing and clusters (sigma8)**

Planck and Neutrinos. 2

- **Une analyse plus fine que celle fait par Planck sur les données Planck 2013 a été faite par plusieurs groups différents et donne Neff compatible avec 4 neutrinos = les 3 actifs connus + 1 stérile et les paramètres cosmologiques sans tensions avec les autres observations .**
- **Donc, les données Planck 2014 pourront être a nouveau ré-analyses par d'autres teams et Neff et les valeurs des paramètres cosmologiques corrigés.**

Planck and Neutrinos.3

- Å →En fait le **CMB** est sensible à la valeur de sigma8 très tôt dans l'Univers, **à redshift =1100** (moment où l'Univers devient transparent **380 000 après le Big Bang**), **alors que les amas qui se forment tard, mesurent la valeur de sigma8 à z~1 (il y a 8 milliards d'années).**
- Å →La relation entre ces deux valeurs dépend de la croissance des structures. **Or celle-ci est ralentie par les neutrinos**, d'autant plus qu'ils sont massifs. Dans le modèle standard de la cosmologie, la somme des masses des neutrinos est aujourd'hui fixée à une valeur minimale de 0.06 eV (correspondant à la mesure de la somme des masses d'oscillation déterminée par les expériences de neutrinos et en considérant que la masse du **neutrino** le plus léger est nul).
- Å →**Le désaccord** sur sigma8 **entre le CMB et amas peut être résolu** si on permet que la somme des masses des neutrinos soit comprise entre **0.2 et 0.3 eV.** Cependant, cette valeur haute doit être confrontée aux contraintes posées par les BAO et l'analyse des forêts Lymann-

Sterile Neutrinos ν

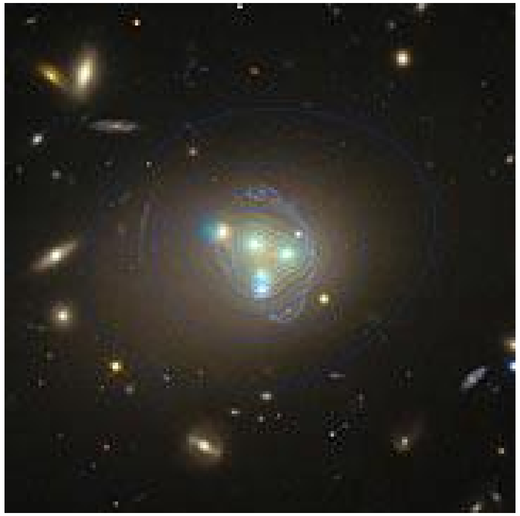
Rhenium and Tritium beta decay (MARE, KATRIN).
Theoretical analysis: H J de V, O. Moreno, E. Moya de Guerra, M. Ramón Medrano, N. Sánchez,
Nucl. Phys. B866, 177 (2013).

[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....



Le suivi d'une collision galactique au moyen du Très Grand Télescope de l'ESO et du Télescope Spatial Hubble du consortium NASA/ESA a permis de collecter des informations sur la matière noire.

En combinant les données duVLT de l'ESO au Chili aux images acquises par le télescope spatial Hubble, la collision simultanée de quatre galaxies au sein de l'amas Abell 3827 a été étudiée.

Elle a notamment été en mesure de localiser la matière contenue au sein de ce système et de comparer la distribution de matière noire aux positions occupées par les galaxies lumineuses.

A SUIVREé .