A NEW DARK MATTER DENSITY PROFILE FOR MILKY WAY WHICH DEPENDS ON GRAVITATIONAL FIELD

Author Manuel Abarca Hernandez **email** mabarcaher1@gmail.com

1. ABSTRACT

The main target this paper is to check a theory about dark matter nature, which was published by the author in previous papers. It was postulated it that dark matter density is a function which depend on E, gravitational field. Also were proposed several experimental test to check that theory.

In this work has been calculated a new function for DM density for Milky Way. Reader could think, why disturb me with a new DM density profile, called Bernoulli profile in this paper, whose values have relative differences with NFW dark matter density profile below 15%?

The reason is clear. This DM profile has been got starting from hypothesis that DM is generated by the own gravitational field. Therefore if DM Bernoulli profile fits perfectly to NFW DM density profile then it is possible conclude that observational data supports author´s hypothesis about DM nature.

To find reasons that author has to do so daring statement, reader can consult [1] Abarca,M.2014. *Dark matter model by quantum vacuum.* [2] Abarca,M.2015. *Dark matter density function depending on gravitational field as Universal law.* [3] Abarca,M.2015. *A new dark matter density profile for NGC 3198 galaxy to demonstrate that dark matter is generated by gravitational field.* [4] Abarca, M.2016.*A New Dark Matter Density Profile for M33 Galaxy to Demonstrate that Dark Matter is Generated by Gravitational Field*. [5] Abarca, M.2016.*A New Dark Matter Density Profile for M31 Galaxy to Demonstrate that Dark Matter is Generated by Gravitational Field* and finally [7] Abarca, M.2016 *A new Dark Matter Density Profile for Milky Way.*

Briefly will be explained method followed to develop this paper. Firstly are presented rotation curve and table with data about rotational velocity depending on radius inside Milky Way galaxy. These data come from [8] Huang,Y.2016.

In fourth chapter, it has been calculated and tabulated gravitational field through Virial theorem, which is a direct calculus having velocity data depending on radius. In this paper, dominion of gravitational E extends from 26 kpc to 100 kpc.

In fith epigraphs it has been tabulated data of NFW DM density profile published by [8] Huang, Y.2016. for Milky Way.

In sixth epigraph has been fitted data of NFW DM density profile as power of gravitational field, E, with a correlation coefficient bigger than 0,999. Particularly formula found is $\varphi_{DM}(r) = A \cdot E^B$ .Where A= 5,1085837 $\cdot 10^{-7}$ and B= 1,568156686 being regression coefficient r= 0,9886366654 into I.S. of units.

In seventh epigraph it has been compared DM density as power of E and NFW profiles. Tables and plots show clearly that relative differences between both profiles are below 16% inside main part of dominion.

In eighth epigraph it is considered derivative of gravitational field in halo region (26 to 100 kpc) where density of baryonic matter is negligible regarding DM density. As consequence $M'(r) = 4\pi r^2 \varphi_{DM}(r)$ and considering that $\varphi_{DM}(r) = A \cdot E^B(r)$ then $M'(r) = 4\pi r^2 \cdot A \cdot E^B$. If M´(r) is replaced on derivative of E (r) then it is got a Bernoulli differential equation whose solution allows to get a new DM density profile through formula $\varphi_{DM}(r) = A \cdot E^B(r)$.

In ninth epigraph Bernoulli and NFW DM density profiles have been compared. Its relative differences are below 18% for radius lower than 70 kpc.

This is a superb result, especially if it is considered that NFW profile come from calculus got through experimental data with important errors.

In tenth epigraph are introduced a study of ancient and recent measures of local dark matter also it is calculated local dark matter through power of E formula. Finally it is concluded that the new one value of local dark matter is similar to local dark matter values published currently.

2. INTRODUCTION

As reader knows Milky Way radius is approximately 20 kpc.
and according [6] Sofue, Y. 2015. Baryonic mass of Milky Way is $M_{BARYONIC} = 1{,}37 \cdot 10^{11} M_{SUN}$

As radius is 20 kpc is supposed that for radius bigger than 26 kpc baryonic matter density is negligible versus DM density. This is the reason why radius dominion in this work is from 26 kpc to 100 kpc. In chapter eight it will be got a simple Bernoulli differential equation for gravitational field. However to get a so simple differential equation it is needed that $M'(r) = 4\pi r^2 \varphi_{DM}(r)$ .In other words, it is needed that density of baryonic matter would be negligible versus D.M. density.

In paper [1] Abarca,M.2014, it was postulated that DM density depends on gravitational field. Further papers has studied DM density as power of gravitational field in several galaxies: M31, M33, NGC3198 and others galaxies. Correlation coefficient of both magnitudes has been always higher than 0,99.

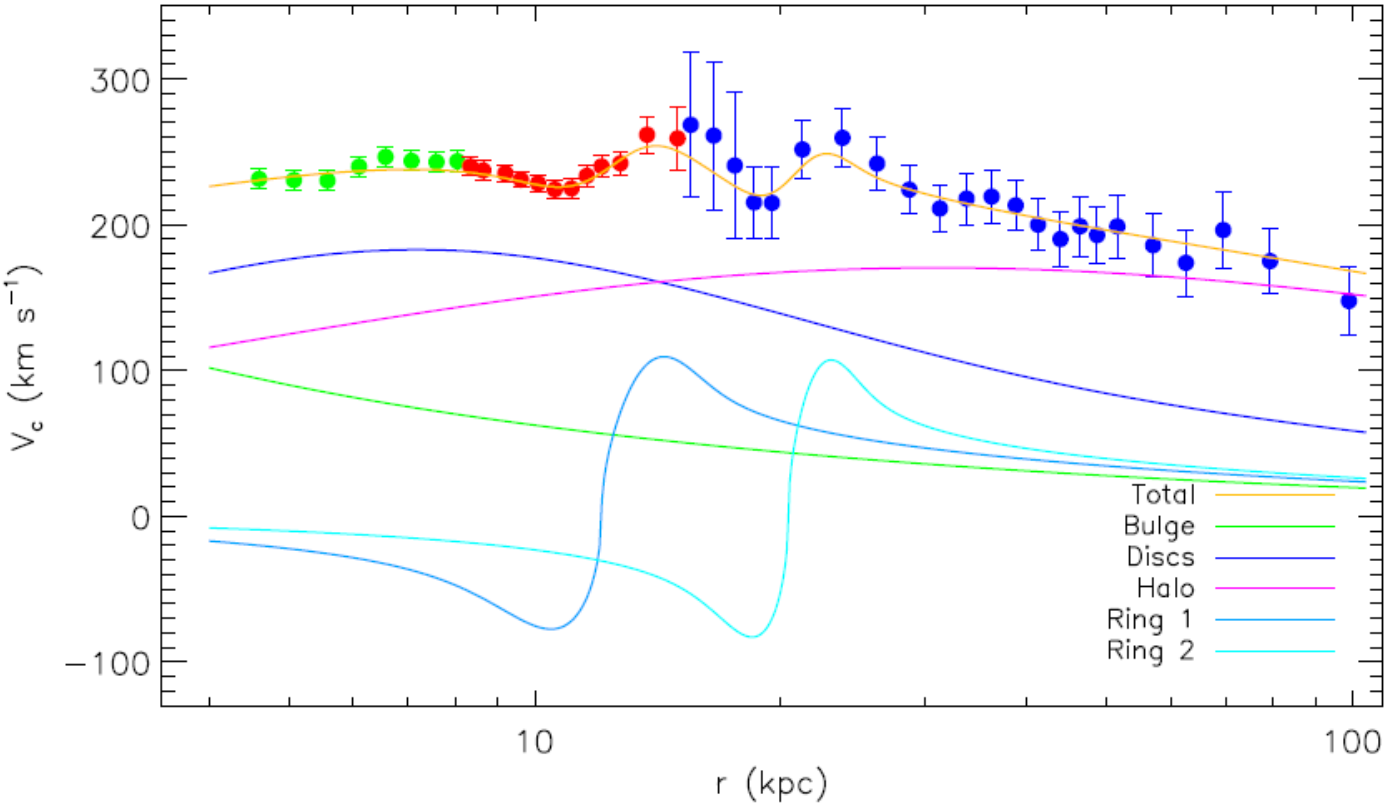
In paper [2] Abarca,M.2015 it was justified properly that DM density is a function as power of E. $\varphi_{DM}(r) = A \cdot E^B$
Where A and B may be got by statistical regression and its values depend on each galaxy, although galaxies with similar mass have similar coefficients A & B.

Having formula $\varphi_{DM}(r) = A \cdot E^B$ it is right to get a Bernoulli equation for galactic E, whose solution allows to get a DM density profile called in this paper Bernoulli profile.

The main target this paper is to get Bernoulli profile for Milky Way and compare its values with NFW profile got by Huang, Y.2016. Results have been successful because relative differences are under 15 % inside main part of dominion. A detailed comparison is shown in chapter 10. A relative error around 15% or 20 % is not important because error in measures of rotation velocities are similar.

In graph bellow published by Huang, Y. 2016. reader can check that average error in rotation curve is 20 % from 20 kpc to 100 kpc.

3. OBSERVATIONAL DATA FROM HUANG Y. 2016 PAPER.

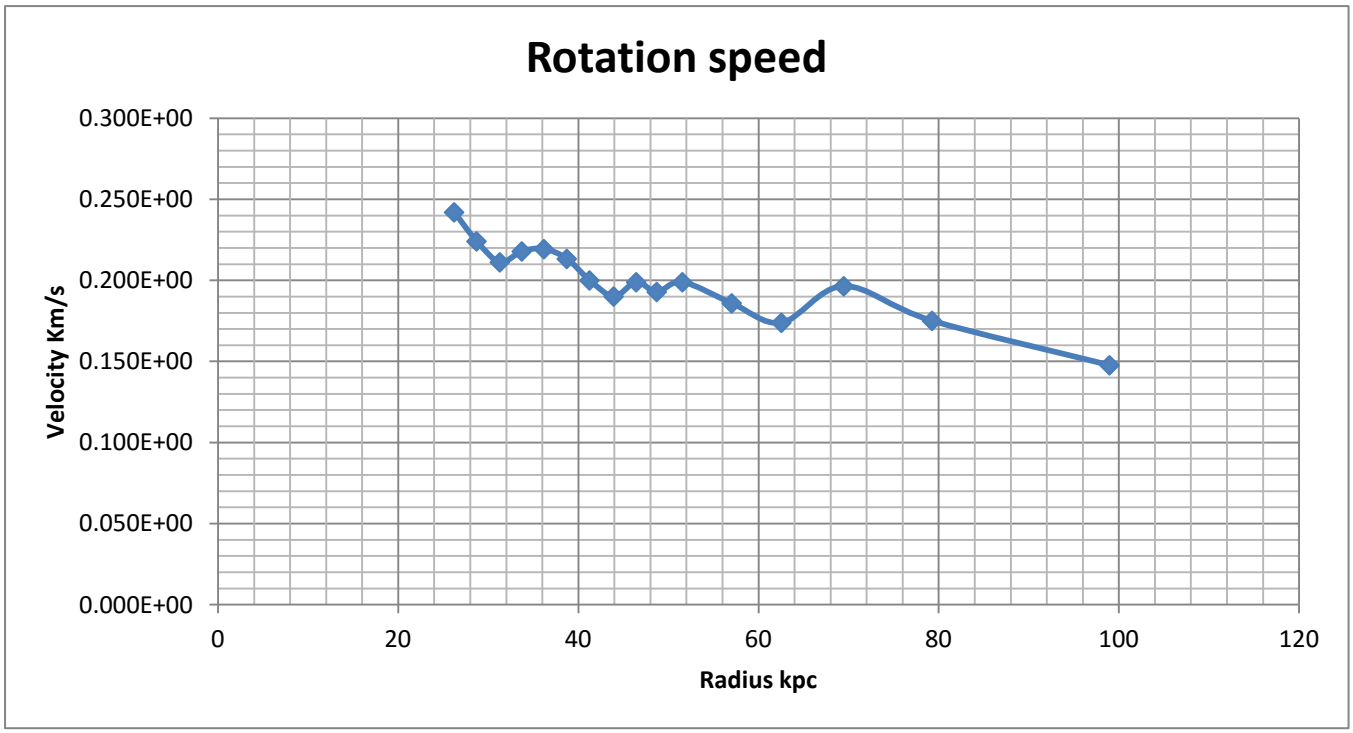


r (kpc)	V_c (km s^{-1})	σ_{V_c} (km s^{-1})	tracer	r (kpc)	V_c (km s^{-1})	σ_{V_c} (km s^{-1})	tracer
4.60	231.24	7.00	H I	17.56	240.66	49.91	HKG
5.08	230.46	7.00	H I	18.54	215.31	24.80	HKG
5.58	230.01	7.00	H I	19.50	214.99	24.42	HKG
6.10	239.61	7.00	H I	21.25	251.68	19.50	HKG
6.57	246.27	7.00	H I	23.78	259.65	19.62	HKG
7.07	243.49	7.00	H I	26.22	242.02	18.66	HKG
7.58	242.71	7.00	H I	28.71	224.11	16.97	HKG
8.04	243.23	7.00	H I	31.29	211.20	16.43	HKG
8.34	239.89	5.92	MRCG	33.73	217.93	17.66	HKG
8.65	237.26	6.29	MRCG	36.19	219.33	18.44	HKG
9.20	235.30	5.60	MRCG	38.73	213.31	17.29	HKG
9.62	230.99	5.49	MRCG	41.25	200.05	17.72	HKG
10.09	228.41	5.62	MRCG	43.93	190.15	18.65	HKG
10.58	224.26	5.87	MRCG	46.43	198.95	20.70	HKG
11.09	224.94	7.02	MRCG	48.71	192.91	19.24	HKG
11.58	233.57	7.65	MRCG	51.56	198.90	21.74	HKG
12.07	240.02	6.17	MRCG	57.03	185.88	21.56	HKG
12.73	242.21	8.64	MRCG	62.55	173.89	22.87	HKG
13.72	261.78	14.89	MRCG	69.47	196.36	25.89	HKG
14.95	259.26	30.84	MRCG	79.27	175.05	22.71	HKG
15.52	268.57	49.67	HKG	98.97	147.72	23.55	HKG
16.55	261.17	50.91	HKG	–	–	–	–

Graphic and table data come from [1] Huang,Y. 2016.

As Milky Way radius is 20 kpc it is sure that baryonic density is negligible versus DM density for radius bigger than 26 kpc. This hypothesis will be used in this work to introduce a new DM density profile called Bernoulli profile because it is got through a Berrnoulli differential equation for gravitational field.

Below is plotted data speed.



4. GRAVITATIONAL FIELD E THROUGH VIRIAL THEOREM

In this work dominion of radius extend from 26 kpc to 100 kpc. despite the fact that rotation curve has accuracy measures for radius lower than 26 kpc because for further calculus is is needed that baryonic density would be neglible versus DM density in the whole radius dominion.

As it is known total gravitational field may be calculated through Virial theorem, formula $E = v^2/R$ whose I.S. unit is m/s^2. Hereafter, gravitational field got through this formula will be called Virial E. In fourth column is shown results of Virial E. Reader can check these data taking into account that $1\ Kpc = 3{,}0857 \cdot 10^{19}\ m$.
Data of velocity have been got from Huang paper [1].

Radius kpc	Rot. Speed	Radius	Virial E
kpc	km/s	m	m/s^2
26,22	2,420E+02	8,09E+20	7,2384E-11
28,71	2,241E+02	8,86E+20	5,6689E-11
31,29	2,112E+02	9,66E+20	4,6199E-11
33,73	2,179E+02	1,04E+21	4,5619E-11
36,19	2,193E+02	1,12E+21	4,3066E-11
38,73	2,133E+02	1,20E+21	3,8070E-11
41,25	2,000E+02	1,27E+21	3,1426E-11
43,93	1,901E+02	1,36E+21	2,6659E-11
46,43	1,989E+02	1,43E+21	2,7613E-11
48,71	1,929E+02	1,50E+21	2,4757E-11
51,56	1,989E+02	1,59E+21	2,4866E-11
57,03	1,86E+02	1,76E+21	1,9638E-11
62,55	1,74E+02	1,93E+21	1,5668E-11
69,47	1,96E+02	2,14E+21	1,7994E-11
79,27	1,75E+02	2,45E+21	1,2535E-11
98,97	1,48E+02	3,05E+21	7,1434E-12

5. NFW DARK MATTER DENSITY PROFILE

According [1] Huang,Y., 2016. Parameters of NFW profile for Milky Way are

Dark matter density function profile NFW
Rs = $14,4 \pm 1,3$ Kpc
Do = $8,19 \cdot 10^{-22}$ kg/m^3
Do = $(12,1 \pm 2) \cdot 10^{-3}$ Msolar/pc^3 = 12,1 mMsolar/pc^3

Knowing that mMsolar/pc^3 = $6,768 \cdot 10^{-23}$ Kg /m^3
Unit of Do has been changed into mMsolar/pc^3 which is a very common unit for galactic densities.

$$D_{NFW}(R) = \frac{D_0}{x \cdot (1+x)^2}$$ Where x= radius/ Rs Rs is called scale length and Do is scale density.

Below are tabulated NFW DM density depending on radius. This data will be used in next chapter to get a power regression of DM density as power of gravitational field E.

Radius kpc	NFW DM	NFW DM
kpc	mMsun/pc^3	kg/m^3
26,22	0,83514199	5,6539E-23
28,71	0,67714801	4,5843E-23
31,29	0,55312714	3,7447E-23
33,73	0,46240741	3,1305E-23
36,19	0,3900811	2,6408E-23
38,73	0,33048041	2,2374E-23
41,25	0,2828255	1,9147E-23
43,93	0,24172841	1,6365E-23
46,43	0,21029964	1,4237E-23
48,71	0,18623374	1,2608E-23
51,56	0,16106406	1,0904E-23
57,03	0,12416757	8,4061E-24
62,55	0,09755023	6,6042E-24
69,47	0,07393707	5,0055E-24
79,27	0,0519473	3,5168E-24
98,97	0,02840357	1,9229E-24

6. NFW D.M. DENSITY AS POWER OF VIRIAL FIELD E

Below are tabulated values of gravitational field E and NFW DM density, because DM density will be fitted with a power function of E. Units are International System.
Reason why the author has decided to fit this function is explained in [2] Abarca,M.2015. & [1] Abarca,M.2014. Briefly, the author defends hypothesis that DM is generated by the own gravitational field. Therefore it is right to look for a function of DM density depending on E.

Data for Virial E comes from chapter 4.Data of NFW DM density comes from chapter 5.

Radius kpc	Virial E	NFW DM
kpc	m/s^2	kg/m^3
26,22	7,2384E-11	5,6539E-23
28,71	5,6689E-11	4,5843E-23
31,29	4,6199E-11	3,7447E-23
33,73	4,5619E-11	3,1305E-23
36,19	4,3066E-11	2,6408E-23
38,73	3,8070E-11	2,2374E-23
41,25	3,1426E-11	1,9147E-23
43,93	2,6659E-11	1,6365E-23
46,43	2,7613E-11	1,4237E-23
48,71	2,4757E-11	1,2608E-23
51,56	2,4866E-11	1,0904E-23
57,03	1,9638E-11	8,4061E-24
62,55	1,5668E-11	6,6042E-24
69,47	1,7994E-11	5,0055E-24
79,27	1,2535E-11	3,5168E-24
98,97	7,1434E-12	1,9229E-24

Doing power regression of DM density versus gravitational field according formula Density $_{DARK\ MATTER} = A \cdot E^B$ through International System of units, it is right to get A= 5,1085837 $\cdot 10^{-7}$ and B= 1,568156686 being coefficient regression r= 0,9886366654 . Therefore there is a very high correlation between DM density and gravitational field.

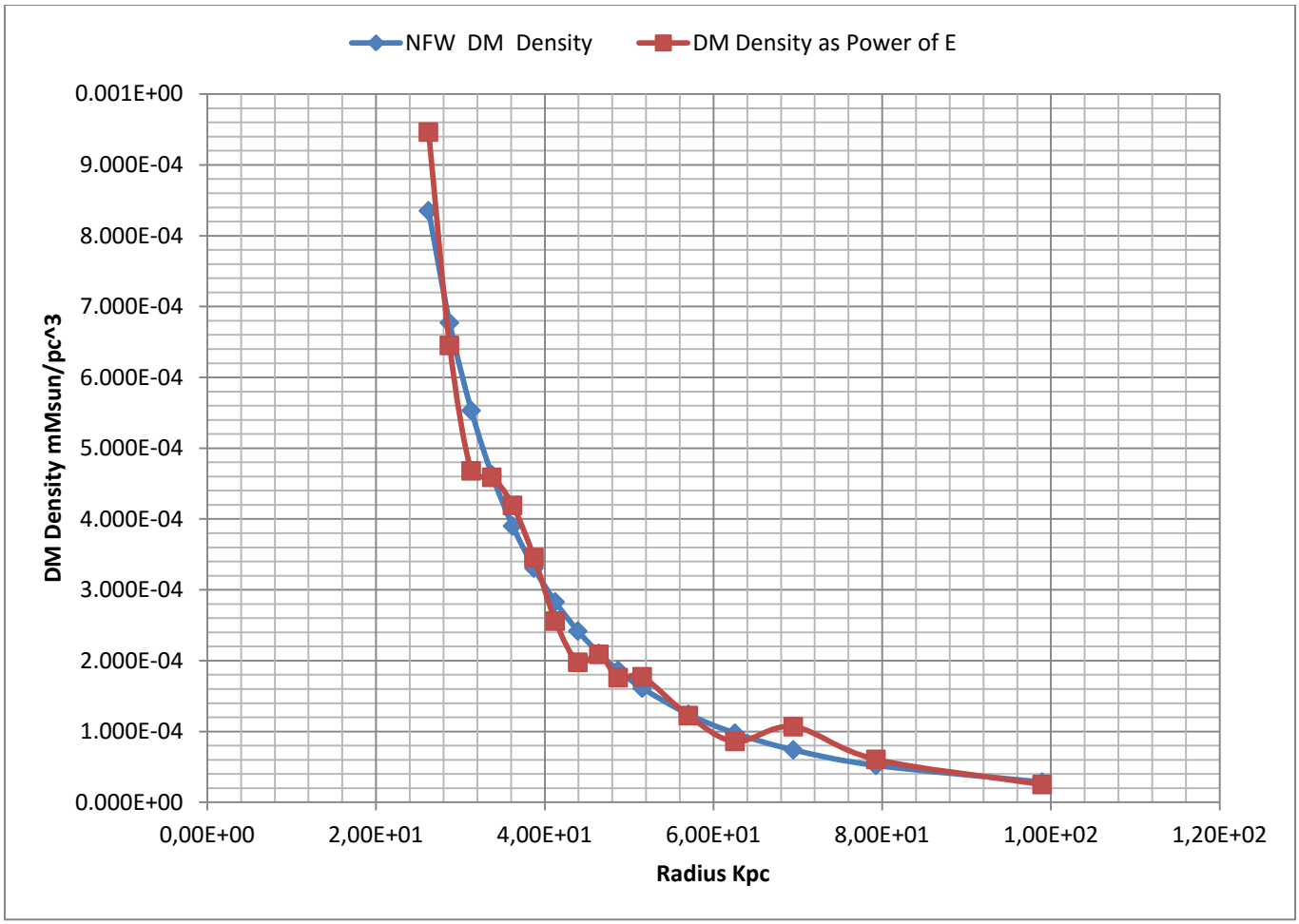
NFW Dark Matter Density as power of Virial E for Milky Way inside dominion 26 kpc < radius < 99kpc
$D_{DM\ Pw\ VE} = A \cdot E^B$
Where A= 5,1085837 $\cdot 10^{-7}$ and B= 1,568156686 being regression coefficient r= 0,9886366654

Hereafter dark matter density as power of Virial E will be shortened as $D_{DM\ VE} = A \cdot E^B$

7. COMPARISON BETWEEN DM DENSITY AS POWER OF E AND NFW PROFILE

In this paragraph will be compared NFW DM density introduced in chapter 5 and DM density as power of E got in chapter 6.As reader can see relative differences are below 16% everywhere except for 69,5 kpc whose relative difference is 44%.

Virial E	Radius	DM Density NFW	DM Density Power of E	Relt. difference NFW-power of E
m/s^2	Kpc	mMsun/pc^3	mMsun/pc^3	%
7,2384E-11	2,62E+01	8,351E-01	9,463E-01	1,3E+01
5,6689E-11	2,87E+01	6,771E-01	6,450E-01	-4,7E+00
4,6199E-11	3,13E+01	5,531E-01	4,680E-01	-1,5E+01
4,5619E-11	3,37E+01	4,624E-01	4,588E-01	-7,8E-01
4,3066E-11	3,62E+01	3,901E-01	4,192E-01	7,5E+00
3,8070E-11	3,87E+01	3,305E-01	3,455E-01	4,5E+00
3,1426E-11	4,13E+01	2,828E-01	2,557E-01	-9,6E+00
2,6659E-11	4,39E+01	2,417E-01	1,976E-01	-1,8E+01
2,7613E-11	4,64E+01	2,103E-01	2,088E-01	-7,1E-01
2,4757E-11	4,87E+01	1,862E-01	1,759E-01	-5,5E+00
2,4866E-11	5,16E+01	1,611E-01	1,772E-01	1,0E+01
1,9638E-11	5,70E+01	1,242E-01	1,224E-01	-1,5E+00
1,5668E-11	6,26E+01	9,755E-02	8,586E-02	-1,2E+01
1,7994E-11	6,95E+01	7,394E-02	1,067E-01	4,4E+01
1,2535E-11	7,93E+01	5,195E-02	6,051E-02	1,6E+01
7,1434E-12	9,90E+01	2,840E-02	2,505E-02	-1,2E+01


NFW DM Density
DM Density as Power of E
0.001E+00
9.000E-04
8.000E-04
7.000E-04
6.000E-04
5.000E-04
4.000E-04
3.000E-04
2.000E-04
1.000E-04
0.000E+00
DM Density mMsun/pc^3
0,00E+00
2,00E+01
4,00E+01
6,00E+01
8,00E+01
1,00E+02
1,20E+02
Radius Kpc

8. BERNOULLI DIFFERENTIAL EQUATION FOR GRAVITATIONAL FIELD IN MILKY WAY HALO

It will be considered the region 26 Kpc < Radius < 100 Kpc where density of baryonic matter is negligible versus baryonic density. So for radius bigger than 26 Kpc, it will be considered that derivative of M(r) depend on dark matter density only.

As it is known in this formula $E = G\frac{M(r)}{r^2}$, M(r) represents mass enclosed by a sphere with radius r. If it is considered radius > 26 Kpc then the derivative of M(r) depend on dark matter density only and therefore $M'(r) = 4\pi r^2 \varphi_{DM}(r)$ As $\varphi_{DM}(r) = A{\cdot}E^B(r)$ Where A= 5,1085837·10^{-7} and B= 1,568156686 then $M'(r) = 4\pi r^2 \cdot A{\cdot}E^B$

Now it will differentiated E(r) when r > 26 Kpc

If $E = G\frac{M(r)}{r^2}$ is differentiated it is got $E'(r) = G\frac{M'(r)\cdot r^2 - 2rM(r)}{r^4}$

If $M'(r) = 4\pi r^2 \varphi_{DM}(r)$ is replaced above it is got $E'(r) = 4\pi G\varphi_{DM}(r) - 2G\frac{M(r)}{r3}$ As $\varphi_{DM}(r) = A{\cdot}E^B(r)$ it is right to get $E'(r) = 4\pi{\cdot}G{\cdot}A{\cdot}E^B(r) - 2\frac{E(r)}{r}$ which is a Bernoulli differential equation.

$E'(r) = K{\cdot}E^B(r) - 2\frac{E(r)}{r}$ being $K = 4\pi{\cdot}G{\cdot}A$ then K = 4,28383285924E-16

I.S. as A= 5,1085837·10^{-7}

Calling ***y*** to E, the differential equation is written this way $y` = K{\cdot}y^B - \frac{2{\cdot}y}{r}$

Bernoulli family equations $y` = K{\cdot}y^B - \frac{2{\cdot}y}{r}$ may be converted into a differential linear equation with this variable change $u = y^{1-B}$.

General solution is $E(r) = \left(Cr^{2B-2} + \frac{Kr(1-B)}{3-2B}\right)^{\frac{1}{1-B}}$ $with\ B \neq 1\ and\ B \neq 3/2$ where C is the parameter of initial condition of gravitational field at a specific radius.

Calling $\alpha = 2B-2$ $\beta = \frac{1}{1-B}$ and $D = \left(\frac{K(1-B)}{3-2B}\right)$ formula may be written as

$E(r) = \left(Cr^{\alpha} + Dr\right)^{\beta}$ Where specifically values for these parameters are the following ones:

$\alpha = 2B-2$ = 1,1363133720

$$\beta = \frac{1}{1-B} = -1{,}7600778529$$

$$D = \left(\frac{K(1-B)}{3-2B} \right) = 1{,}78550955418\text{E-}15$$

Initial condition for parameter C calculus

Suppose R_0 *and* E_0 are specific initial conditions for radius and gravitational field then $C = \frac{E_0^{\,1/\beta} - D \cdot R_0}{R_0^{\,\alpha}}$

In order to check calculus it will be calculated parameter C for different initial condition.

Radius	radius	Velocity	E virial	param. C
kpc	m	Km/s	m/s^2	
26,22	8,09E+20	2,42E+02	7,23843E-11	-1,51428E-18
28,71	8,86E+20	2,24E+02	5,66887E-11	-1,44659E-18
31,29	9,66E+20	2,11E+02	4,61986E-11	-1,39806E-18
33,73	1,04E+21	2,18E+02	4,56189E-11	-1,45296E-18
36,19	1,12E+21	2,19E+02	4,30660E-11	-1,47512E-18
38,73	1,20E+21	2,13E+02	3,80698E-11	-1,45946E-18
41,25	1,27E+21	2,00E+02	3,14255E-11	-1,40355E-18
43,93	1,36E+21	1,90E+02	2,66593E-11	-1,36185E-18
46,43	1,43E+21	1,99E+02	2,76132E-11	-1,42281E-18
48,71	1,50E+21	1,93E+02	2,47567E-11	-1,40071E-18
51,56	1,59E+21	1,99E+02	2,48658E-11	-1,44233E-18
57,03	1,76E+21	1,86E+02	1,96593E-11	-1,39457E-18
62,55	1,93E+21	1,74E+02	1,56862E-11	-1,34559E-18
69,47	2,14E+21	1,96E+02	1,79210E-11	-1,47217E-18
79,27	2,45E+21	1,75E+02	1,25203E-11	-1,39212E-18
98,97	3,05E+21	1,48E+02	7,17243E-12	-1,27589E-18

As it was expected parameter C is very similar for different initial condition.

Numerically may be checked that data below minimize relative difference between NFW DM density and DM density got through Bernoulli solution therefore these values will be considered as initial condition.

Initial condition values Ro & Eo	
Ro =	46 Kpc
Eo =	$2{,}76 \cdot 10^{-11}$ m/s^2
C =	$-1.42 \cdot 10^{-18}$ units I.S.

Finally it is possible to write formula for DM density profile got through Bernoulli method.

Bernoulli Solution for Gravitational field inside halo 30 kpc < Radius < 200 kpc
$E_{BER}(r) = \left(Cr^{\alpha} + Dr\right)^{\beta}$ C = $-1.42 \cdot 10^{-18}$ D= $1{,}78550955418 \cdot 10^{-15}$ α = 1,1363133720 β = -1,7600778529

9. BERNOULLI PROFILE OF DARK MATTER DENSITY FOR MILKY WAY

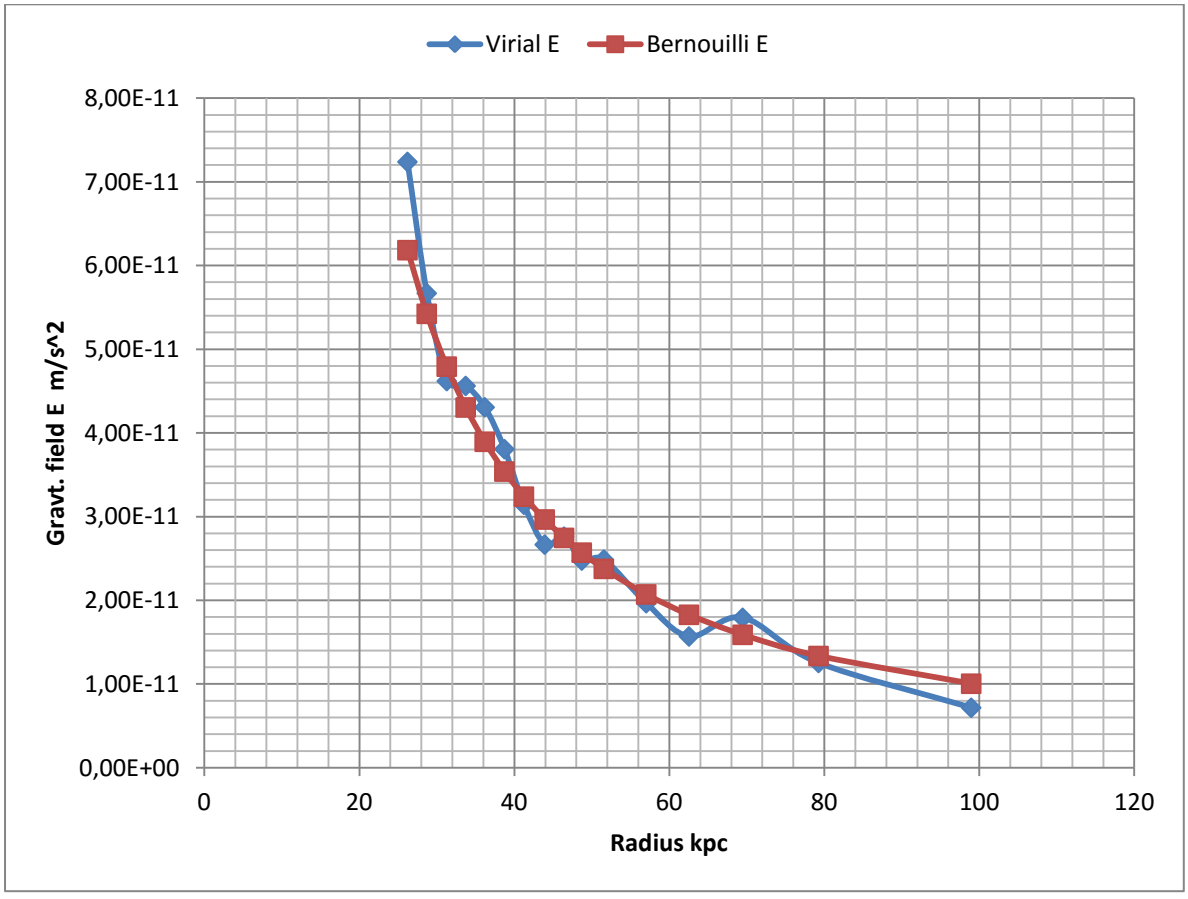
Thanks Bernoulli solution for gravitational field is right to get DM density through power of E formula.

DM Density Bernoulli profile for Milky Way inside halo 26 kpc < radius < 100 kpc
$E_{BER}(r) = \left(Cr^{\alpha} + Dr\right)^{\beta}$ C = $-1.42 \cdot 10^{-18}$ D= $1{,}78550955418 \cdot 10^{-15}$ α = 1,1363133720 β = -1,7600778529
Density $_{\text{D.M. BERNOULLI}}$ (r) = $D_{DM\,B}$(r) = $A \cdot E^{B}$ Unit Kg/m^3 Where A= $5{,}1085837 \cdot 10^{-7}$ and B= 1,568156686 Units I.S.

10. COMPARISON BETWEEN BERNOULLI AND NFW PROFILES

10.1 COMPARISON BETWEEN VIRIAL GRAVT. FIELD AND BERNOULLI SOLUTION FOR E

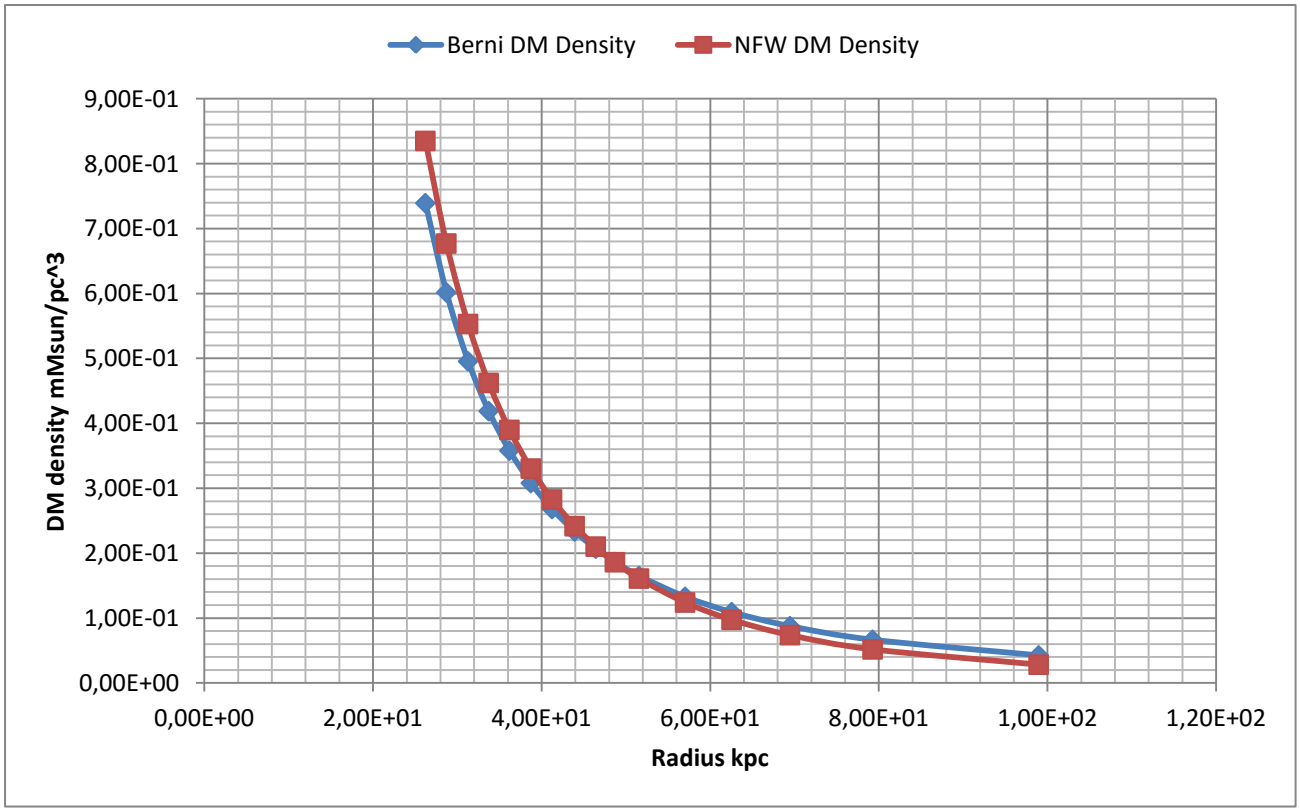
radius	Virial E	Bernouilli E	Relt. Diff.
kpc	m/s^2	m/s^2	%
26,22	7,24E-11	6,18E-11	1,71E+01
28,71	5,67E-11	5,42E-11	4,52E+00
31,29	4,62E-11	4,79E-11	-3,60E+00
33,73	4,56E-11	4,30E-11	5,97E+00
36,19	4,31E-11	3,89E-11	1,06E+01
38,73	3,81E-11	3,54E-11	7,57E+00
41,25	3,14E-11	3,24E-11	-2,97E+00
43,93	2,67E-11	2,97E-11	-1,01E+01
46,43	2,76E-11	2,75E-11	5,45E-01
48,71	2,48E-11	2,57E-11	-3,67E+00
51,56	2,49E-11	2,38E-11	4,63E+00
57,03	1,97E-11	2,07E-11	-5,07E+00
62,55	1,57E-11	1,83E-11	-1,42E+01
69,47	1,79E-11	1,59E-11	1,28E+01
79,27	1,25E-11	1,34E-11	-6,23E+00
98,97	7,17E-12	1,00E-11	-2,86E+01



Bernoulli solution for gravitational field fits almost perfectly to Virial gravitational data got through observational values of spin speed of rotational curve of Milky Way.

10.2 COMPARISON BETWEEN NFW DM PROFILE AND BERNOULLI DM PROFILE

Radius	Berni DM	NFW DM	Rel diff.
kpc	mMsun/pc^3	mMsun/pc^3	%
2,62E+01	7,39E-01	8,35E-01	1,14754E+01
2,87E+01	6,02E-01	6,77E-01	1,11269E+01
3,13E+01	4,96E-01	5,53E-01	1,03849E+01
3,37E+01	4,19E-01	4,62E-01	9,40574E+00
3,62E+01	3,58E-01	3,90E-01	8,20061E+00
3,87E+01	3,08E-01	3,30E-01	6,76869E+00
4,13E+01	2,68E-01	2,83E-01	5,19148E+00
4,39E+01	2,34E-01	2,42E-01	3,37001E+00
4,64E+01	2,07E-01	2,10E-01	1,55606E+00
4,87E+01	1,87E-01	1,86E-01	1,82688E-01
5,16E+01	1,65E-01	1,61E-01	2,45621E+00
5,70E+01	1,33E-01	1,24E-01	7,08832E+00
6,26E+01	1,09E-01	9,76E-02	1,20667E+01
6,95E+01	8,77E-02	7,39E-02	1,86719E+01
7,93E+01	6,68E-02	5,19E-02	2,86221E+01
9,90E+01	4,27E-02	2,84E-02	5,04483E+01



Reader can check that maximum relative difference is lower than 18% and is lower than 15 % inside main part of dominion. This result is superb because error of velocity measures in rotation curve published by Sofue are bigger than 15 %. See chapter 3. In addition error of scale density parameter Do = $18{,}2 \pm 7{,}4$ m Msolar/pc^3 , belonging to NFW profile, is 40 %. See chapter 6.

11. LOCAL DARK MATTER DENSITY

11.1 CURRENT DATA FOR LOCAL DM DENSITY

In his remarkable paper the author - [9] J. I. Read.2014- presents a review of ancient and recent measures of local DM density which is summarized in table below.

Label	Reference	Description	Sampling	$\rho_{\rm dm}$ [$M_\odot$ pc^{-3}]	$\rho_{\rm dm}$ [GeV cm^{-3}]
a) Local measures ($\rho_{\rm dm}$)					
Kapteyn	Kapteyn (1922)	–	–	0.0076	0.285
Jeans	Jeans (1922)	–	–	0.051	1.935
Oort	Oort (1932)	–	–	0.0006 ± 0.0184	0.0225 ± 0.69
Hill	Hill (1960)	–	–	-0.0054	-0.202
Oort	Oort (1960)	–	–	0.0586 ± 0.015	2.2 ± 0.56
Bahcall	Bahcall (1984a)	–	–	0.033 ± 0.025	1.24 ± 0.94
Bienayme†	Bienayme et al. (1987)	–	–	0.006 ± 0.005	0.22 ± 0.187
KG†	Kuijken & Gilmore (1991)	–	–	0.0072 ± 0.0027	0.27 ± 0.102
Bahcall	Bahcall et al. (1992)	–	–	0.033 ± 0.025	1.24 ± 0.94
Creze	Creze et al. (1998)	–	–	-0.015 ± 0.015	-0.58 ± 0.56
HF†	Holmberg & Flynn (2000b)	–	–	0.011 ± 0.01	0.4 ± 0.375
HF†	Holmberg & Flynn (2004)	–	–	0.0086 ± 0.0027	0.324 ± 0.1
Bienayme	Bienaymé et al. (2006)	–	–	0.0059 ± 0.005	0.51 ± 0.56
		Latest measurements			
MB12	Moni Bidin et al. (2012)	CSF	412	0.00062 ± 0.001 [0 ± 0.001]	0.023 ± 0.042 [0 ± 0.042]
BT12	Bovy & Tremaine (2012)	CSF	412	0.008 ± 0.003	0.3 ± 0.11
G12	Garbari et al. (2012)	VC	2×10^3	$0.022^{+0.015}_{-0.013}$	$0.85^{+0.57}_{-0.5}$
G12*	Garbari et al. (2012)	VC + Σ_b	2×10^3	$0.0087^{+0.007}_{-0.002}$	$0.33^{+0.26}_{-0.075}$
S12	Smith et al. (2012)	CSF	10^4	0.005 [no error] [0.015]	0.19 [0.57]
Z13	Zhang et al. (2013)	CSF	10^4	0.0065 ± 0.0023	0.25 ± 0.09
BR13	Bovy & Rix (2013)	CSF + MAP	10^4	0.006 ± 0.0018 [0.008 ± 0.0025]	0.22 ± 0.07 [0.3 ± 0.094]
b) Global measures assuming spherical symmetry ($\rho_{\rm dm,ext}$)					
S10	Salucci et al. (2010)	NP	–	0.011 ± 0.004	0.43 ± 0.15
CU10	Catena & Ullio (2010)	NFW; SP	–	0.0103 ± 0.00072	0.385 ± 0.027
WB10	Weber & de Boer (2010)	NFW/ISO; WP	–	0.005 - 0.01	0.2 - 0.4
I11	Iocco et al. (2011)	gNFW; WP; ML	–	0.005 - 0.015	0.2 - 0.56
M11	McMillan (2011)	NFW; SP	–	0.011 ± 0.0011	0.4 ± 0.04

Although I recommend to read the paper, briefly I comment that measures of group a) are made through local methods which involve measures of stars few hundred parsecs away. Local measures use the vertical kinematics of stars near the Sun called `tracers'.

Group of measures b) involve global measures which extrapolate $\varphi_{DM-EXTR}$ from the rotation curve of Galaxy.

11.2 LOCAL DENSITY THROUGH POWER OF E FORMULA

In chapter 6 has been got this formula for DM density.

NFW Dark Matter Density as power of Virial E for Milky Way inside dominion 26 kpc < radius < 99kpc
$D_{DM\ Pw\ VE} = A \cdot E^B$
Where A= 5,1085837 $\cdot 10^{-7}$ and B= 1,568156686 being regression coefficient r= 0,9886366654

Although this formula has been got through radius data bigger than 26 kpc, basis of theory state that it is true inside region where baryonic density is not cero. Particularly it is true for Sun region.

Currently it is accepted that Vsun = 240 km/s and its galactocentric distance is 8.3 kpc. So according formula $E_{SUN} = V^2/\text{Radius} = 2.24382 \cdot 10^{-10}$ m/s^2.
Reader can check this result taking into account that 1 kpc = 3.0857 $\cdot 10^{19}$ m
Therefore Local DM density according power of E formula is $D_{DM\ SUN} = 3.778262 \cdot 10^{-22}$ kg/m^3

As 1 m M_Θ/pc^3 = 6,768$\cdot 10^{-23}$ Kg/m^3 $D_{DM\ SUN} = 3.778262 \cdot 10^{-22}$ kg/m^3 = 5.5821 mMsun/ pc^3

As 1 m M_Θ/pc^3 = 10^{-3} M_Θ/pc^3 = 0,038 GeV/cm^3

$D_{DM\ SUN} = 3.778262 \cdot 10^{-22}$ kg/m^3 = 5.5821 mMsun/ pc^3 = 0.21212 GeV/cm^3

Although this value is a bit lower than $D_{DM\ SUN}$ = 0.32 GeV/cm^3 stated by [8] Huang,Y.2016, reader can check that it is similar other values published recently. In other words, local DM density got in this paper belong to interval of values currently calculated by local DM density.

12. CONCLUSION

It seem clear that inner logic of development this paper suggests strongly that DM origin is gravitational field.

This is the inner logic: NFW DM density profile, which has been got by meticulous measures of Milky Way rotation curve, is fitted with a function as power of E with a correlation coefficient bigger than 0.999. Particularly formula found in chapter 7 was $D_{DM} = A \cdot E^B$ where A = 7.310686 $\cdot 10^{-7}$ & B= 1,59883364 into I.S. of units.

Thanks this function it has been possible to state a Bernoulli differential equation for gravitational field E, inside galactic halo where density of baryonic is negligible in comparison with DM density.

Solution of Bernoulli for gravitational field is used to get a new DM profile called Bernoulli DM profile, which has been compared with NFW DM density getting relative differences under 18 % inside main part of dominion despite the fact that rotation curve measures have errors around 20 % in the whole dominion considered from 26 kpc to 100 kpc.

In my opinion these results suggest strongly that DM density is generated according a Universal law as power of E $D_{DM} = A \cdot E^B$ where A and B are parameters which depend on each galaxy, more exactly, values of coefficients A and B depend on mass of galaxies.

This paper is the sixth work to study DM density as power function of gravitational field E for different galaxies.

All of them, except M33 galaxy, are big spiral galaxies.

Below is gathered coefficient A & B from several galaxies, first column shows galaxy and paper where are published their results.

$Density_{DM\ AS\ POWER\ OF\ VIRIAL\ E} = A \cdot E^B$ I.S. of units		
Paper & Galaxy	A	B
[7] Abarca, M.2016. & Milky Way	$7.310686 \cdot 10^{-7}$	1,59883364
This paper & Milky Way	$5,1085837 \cdot 10^{-7}$	1,568156686
[5] Abarca, M.2016. & M31	0,0012004275	1.878838501
[2] Abarca,M.2015 M31-Milky Way and other big galaxies	$2,526 \cdot 10^{-5}$	1,74
[3] Abarca,M.2015 & NGC 3198	$4,04598703 \cdot 10^{-5}$	1,70654481
[4] Abarca, M.2016. & M33	29,02219371	2,242193511

All galaxies named above are big galaxies except M33, well known as Triangle Galaxy. As M33 is an intermediate galaxy whose velocity in flat rotation curve is 120 km/s its parameters A & B are a great deal bigger than parameters belonging to big galaxies. As a result DM density in M33 is several times bigger than DM density in big galaxies at a specific value of E.

In paper [2] Abarca,M.2015 is suggested reason why DM density is bigger for intermediate and dwarf galaxies at a specific value of gravitational field E, according DM model by quantum vacuum.

At first sight reader could think that different galaxies with different parameters A & B may have very different values of DM density at a specific value of gravitational field E. However results show that DM density at a specific value of E inside big galaxies are very similar independently of galaxies despite the fact A & B are different.

A further paper will try to study its relative differences. In this paper only will be pointed that bigger parameters A & B may produce the same result that lower parameters A &B at a specific value of E if it is considered function $Density_{DM} = A \cdot E^B$

In table below are organized parameters A& B in decreasing order.

Paper & Galaxy	A	B
[5] Abarca, M.2016. & M31	0,0012004275	1.878838501
[3] Abarca,M.2015 & NGC 3198	$4,04598703 \cdot 10^{-5}$	1,70654481
[7] Abarca, M.2016. & Milky Way	$7.310686 \cdot 10^{-7}$	1,59883364
This paper & Milky Way	$5,1085837 \cdot 10^{-7}$	1,568156686

In this table has been excluded [2] Abarca,M.2015 because parameter A& B were got as average of several galaxies.

In conclusion, for big galaxies, results suggest that DM density is similar at a specific value of E in different galaxies on condition that their mass are similar.

13. BIBLIOGRAPHYC REFERENCES

[1] Abarca,M.2014,viXra:1410.0200

Dark matter model by quantum vacuum

[2] Abarca,M.2015,viXra:1510.0324
Dark matter density function depending on gravitational field as Universal law

[3] Abarca,M.2015. viXra.org/abs/1512.0309
A new dark matter density profile for NGC 3198 galaxy to demonstrate that dark matter is generated by gravitational field.

[4] Abarca, M.2016.viXra. 1601.0014
A New Dark Matter Density Profile for M33 Galaxy to Demonstrate that Dark Matter is Generated by Gravitational Field

[5] Abarca, M.2016.viXra. 1601.0242v1

A New Dark Matter Density Profile for M31 Galaxy to Demonstrate that Dark Matter is Generated by Gravitational Field.

[6] Sofue, Y.2015. arXiv:1504.05368v1
Dark halos of M31 and the Milky Way.
[7] Abarca, M.2016. viXra.1602.0047
A new Dark matter density profile for Milky Way to demonstrate that dark matter is generated by gravitational field.
[8] Huang,Y.2016. et al. arXiv:1604.01216v1
The Milky Way's rotation curve out to 100 kpc and its constraint on the Galactic mass distribution.

[9] J. I. Read.2014. arXiv:1404.1938v2
The Local Dark Matter Density