TWO NEW D.M. DENSITY PROFILES FOR MILKY WAY HALO GOT FROM ROTATION CURVE

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

1. ABSTRACT 2
2. INTRODUCTION....3
3. OBSERVATIONAL DATA FROM SOFUE. 2015 PAPER FOR MILKY WAY 4
3.1 POWER REGRESSION TO ROTATION CURVE....5
4. DIRECT FORMULA FOR DM DENSITY ON MILKY WAY HALO GOT FROM ROTATION CURVE 6
4.1 THEORETICAL DEVELOPPMENT FOR GALACTIC HALOS....6
4.2 DIRECT DM DENSITY FOR MILKY WAY HALO....6
5. DARK MATTER DENSITY AS POWER OF GRAVITATIONAL FIELD....7
5.1 GRAVITATIONAL FIELD E THROUGH VIRIAL THEOREM 7
5.2 DARK MATTER DENSITY AS POWER OF GRAVITATIONAL FIELD....7
6. RATIO BARYONIC MASS VERSUS DM MASS DEPENDING ON RADIUS FOR MILKY WAY 8
7. COMPARISON BETWEEN DIRECT DM DENSITY AND NFW DARK MATTER DENSITY....9
8. MASSES IN MILKY WAY....10
8.1 DYNAMICAL MASS UP TO 44 KPC....10
8.2 DYNAMICAL DM THROUGH DYNAMICAL MASSES 10
8.3 DM HALO MASSES THROUGH NFW PROFILE....11
8.4 DYNAMICAL DM VERSUS NFW DM....12
8.5 DYNAMICAL CORONA HALO COMPARED TO NFW CORONA HALO MASSES 13
9. D.M. DENSITY AS POWER OF E IN MILKY WAY VERSUS D.M. DENSITY AS POWER OF E IN M31 ..14
10. HALO RADIUS OF MILKY WAY & M31 ACCORDING D.M. AS POWER OF E THEORY 16
10.1 MASSES IN MILKY WAY & M31 AT EXTENDED HALOS 17
11. CONCLUSION....17
12. BIBLIOGRAPHYC REFERENCES....18

1. ABSTRACT

In this work has been calculated two new DM density profiles inside halo region of Milky Way, MW hereafter, and it has been demonstrated that both ones are mathematically equivalents.

The first is called *direct DM density* because it is got directly from velocity as power regression of radius in halo rotation curve. In other words velocity of rotation curve depend on radius as a power function. In fact this function got by power regression has a correlation coefficient of 0,85.

The second one, *DM density as power of E*, E is gravitational field, has been introduced by author in previous papers, [8] Abarca,M.2016, where it has been used to study DM in several galaxies. It is called as power of E because DM density depend on E as a power function.

Hypothesis which is the basis of theory is that DM is generated locally by the own gravitational field according a power law. DM density = A· E^B where A& B are coefficients and E is gravitational intensity of field.

To find reasons that author has to do so daring statement, reader can consult [1] Abarca,M.2014. *Dark matter model by quantum vacuum*. [8] Abarca,M.2016. *Dark matter density on big galaxies depend on gravitational field as Universal law* and other papers quoted in bibliography.

Briefly will be explained method followed to develop this paper. Firstly are presented rotation curve and table with data points inside MW halo. These data come from [5] Sofue,Y.2015. In addition it is got a power regression for rotation curve points in halo region whose function is $v = a \cdot r^b$ getting a correlation coefficient bigger than 0,85.

In fourth chapter it is developed a mathematical method to get a new DM density depending on radius called direct DM density because it is got directly from power regression function got in chapter three.

In fifth chapter it has been demonstrated that a power regression function for rotation curve is mathematically equivalent that DM density depend on gravitational field, as a power function i.e. DM density = A· E^B where A& B are cleared up depending on a & b (parameters of power regression of rotation curve).

In sixth chapter it has been got that for radius bigger than 44 kpc ratio baryonic density versus DM density is under 2% so it is reasonable to consider negligible baryonic density in order to develop theory introduced in this work.

The seventh is a short chapter where is compared direct DM density got with NFW density profile fitted by Sofue in his paper. [5] Sofue, Y.2015. Relative differences between both density profiles are under 25% inside main part of halo dominion. In addition it is explained why NFW profile is bigger than direct DM throughout dominion.

Eighth chapter, called *Masses in Milky Way*, is dedicated to calculate masses through dynamical method and NFW profile. In addition both methods are compared at different radius. Results show that relative differences of masses are under 20% inside main part of radius dominion.

In ninth chapter is compared DM density as power E in MW with DM density as power E in M31, which was published in [11] Abarca,M.2016. Results show that at a specific E, both DM densities are very similar. Relative differences are under 15 % inside main part of dominion. This fact support strongly author hypothesis about DM as power of E as Universal law.

In tenth chapter, it is introduced a new definition for halo radius. According theory DM generated by gravitational field, it is right to definite halo as region where gravitational field dominate over gravitational field of galactic neighbour. So it is calculated that halo radius for MW is 292 kpc and halo radius for M31 is 478 kpc. Also are calculated total masses which belong these new radius and it is calculated new ratio baryonic mass vs total mass. Such ratio is 18% for MW and 8 % for M31.

2. INTRODUCTION

As reader knows Milky Way is the twin galaxy of M31 in Local Group of galaxies. Its disk radius is approximately 20 kpc and according [5] Sofue, Y. 2015 its baryonic mass is $M_{BARYONIC} = 1{,}37 \cdot 10^{11} M_{SUN}$
In previous paper [6] Abarca, M.2016, author has studied DM inside MW halo through DM as power of E. However in such paper DM density used it was NFW profile provided by [5] Sofue, Y. 2015, whereas in this paper DM density profile has been got directly from a power regression function at rotation curve in halo region.

This new DM profile has been called direct DM density because this profile is fitted directly from data measures inside halo region. In this work radius dominion begin at 44 kpc because at this distance baryonic density is negligible as it will be shown in chapter six. Therefore the only one kind of matter in halo region it is supposed to be non baryonic dark matter.

It is known that there is baryonic dark matter such us giant planets, cold gas clouds, brown dwarfs but this kind of DM is more probable to be placed inside galactic disk. Reader can consult: [12] Nieuwenhuizen,T.M. 2010. [13] Nieuwenhuizen,T.M. 2012. [14] Nieuwenhuizen,T.M. 2010 [15] Wyrzykowski,L.2010. [16] M.R.S. Hawkins 2015.In fact there are an important amount of researchers in this way because baryonic DM and non baryonic DM are open problems still.

However DM theory introduced in [1] Abarca, M.2014. *Dark matter model by quantum vacuum* and developed in others papers quoted in bibliography refers a kind of weird matter which is generated by the own gravitational field. $\varphi_{DM}(r) = A \cdot E^B$ Therefore it is needed to consider a radius dominion where baryonic matter would be negligible.

In fact according [5] Sofue, Y. 2015 data, in chapter six will be got that for radius bigger than 44 kpc baryonic matter density is under 2,3 % regarding DM density. This is the reason why radius dominion in this work is from 44 kpc up to 190 kpc.

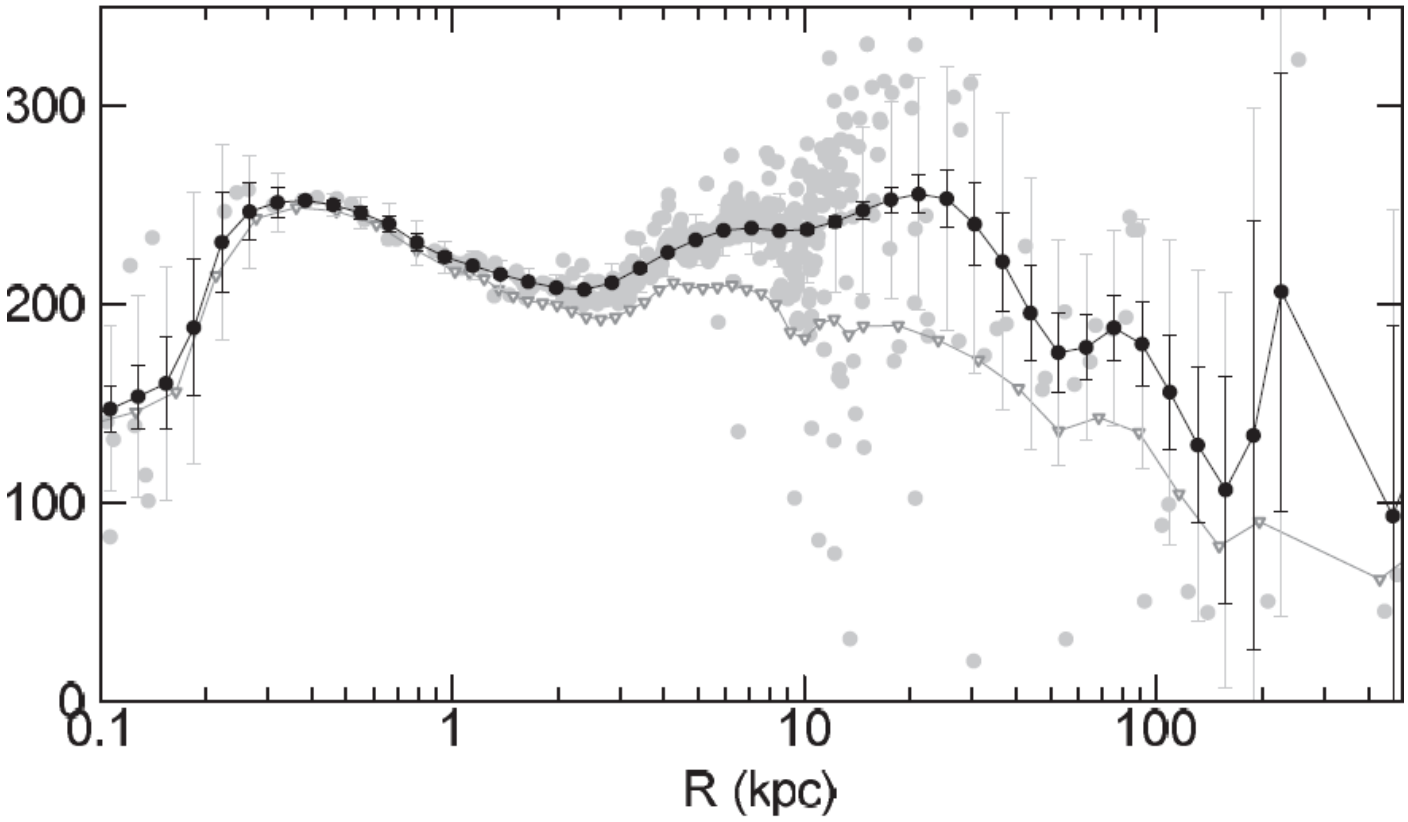
In paper [1] Abarca,M.2014, it was postulated that DM density depends on gravitational field. Further papers [2] Abarca,M.2015 and others have studied DM density as power of gravitational field in several galaxies: M31, NGC3198 and others galaxies. Results got support such hypothesis. $\varphi_{DM}(r) = A \cdot E^B$

Summarising, in this paper it is got a new DM density called direct which is calculated directly from a power regression function in halo of rotation curve of MW

As it is supposed that for radius bigger than 44 kpc baryonic matter is negligible then direct DM profile is a precise function to know non baryonic DM density. In adittion as it is supposed hypothesis $\varphi_{DM}(r) = A \cdot E^B$ it is found that a power regression for rotation curve in halo is equivalent a law $\varphi_{DM}(r) = A \cdot E^B$, in halo as well, whose coefficients A& B depend on a &b.

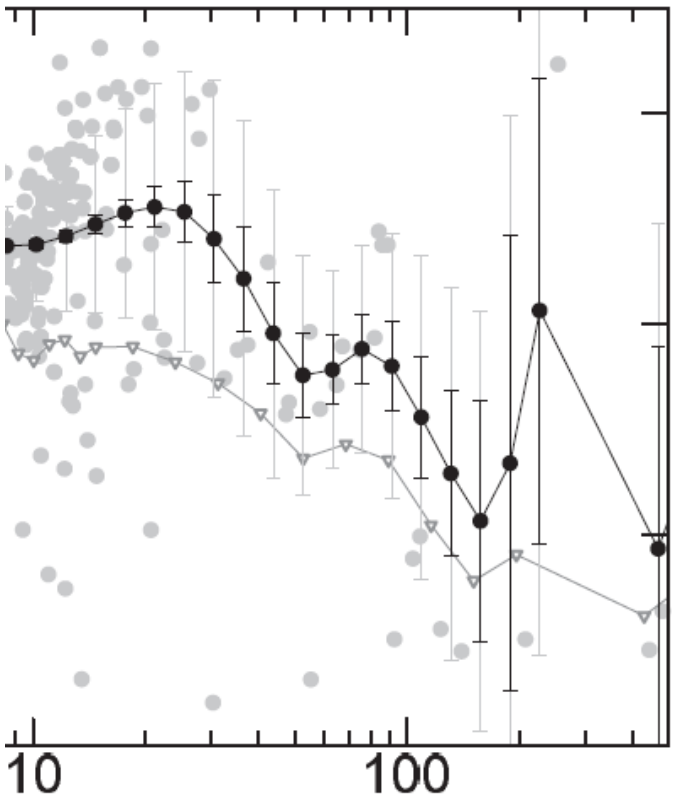
As consequence of DM as power E it is right to definite halo radius as region where own gravitational field dominates over gravitational field of neighbour galaxy and therefore it is needed to recalculate total mass associated this new halo.

3. OBSERVATIONAL DATA FROM SOFUE. 2015 PAPER FOR MILKY WAY



Graphic come from [5] Sofue,Y. 2015.

radius	vel
kpc	km/s
43,92	1,951E+02
50,72	1,754E+02
63,85	1,768E+02
75,9	1,878E+02
91,1	1,790E+02
110,3	1,549E+02
133,7	1,293E+02
158,9	1,059E+02
192,5	1,336E+02



Data are black points.

In chapter six will be shown reason why dominion data begin at 44 kpc in this work, despite the fact that it is supposed radius of galactic disk is 20 kpc.

3.1 POWER REGRESSION TO ROTATION CURVE

It is seen that experimental measures of rotation curve has a very good fitted curve by power regression.

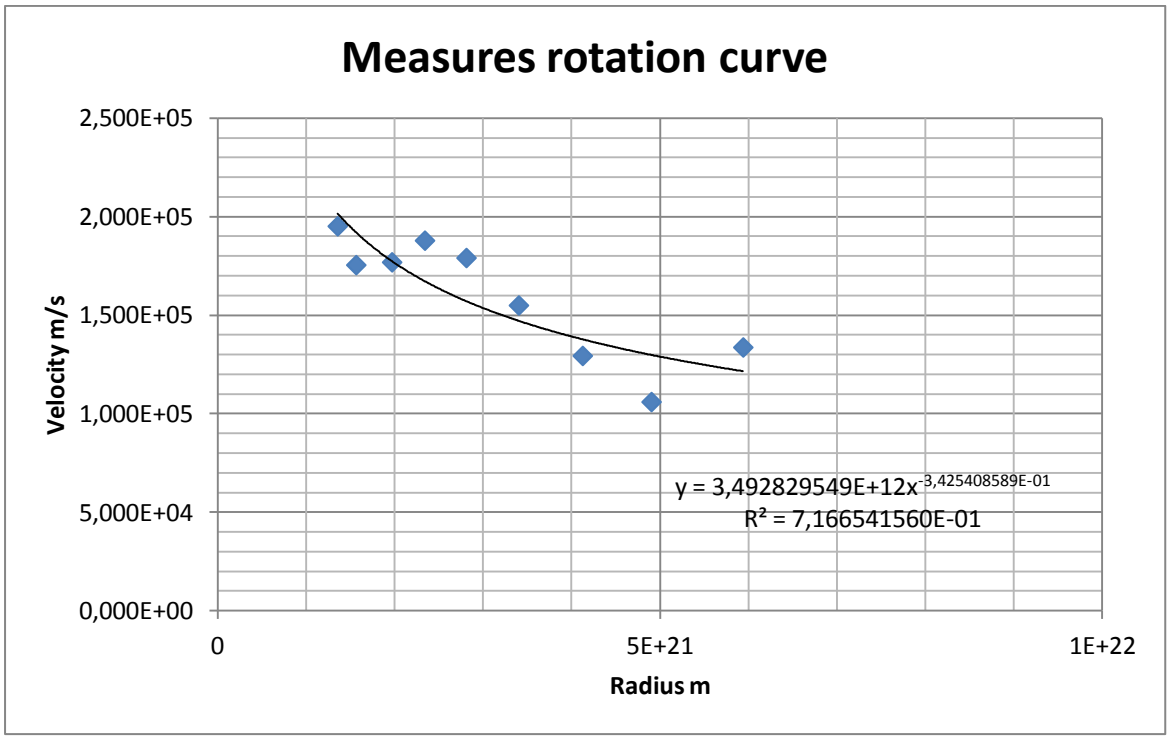
In particular coefficients of $v = a \cdot r^b$ are in table below. Units are into I.S.

Power regression for Milky Way rot. curve	
V=a*r^b	
a	3,492829549E+12
b	-3,425408589E-01
Correlation coeff.	0,85

Data fitted are in grey columns below.
In third column is shown results of fitted velocity and fourth column shows relative difference between measures and fitted results.
Correlation coefficient is 0.85 which is a good correlation.

radius	vel	vel fitted	rel diff.	radius
m	m/s	m/s	%	kpc
1,35524E+21	1,951E+05	2,01650E+05	-3,36	43,92
1,56507E+21	1,754E+05	1,91948E+05	-9,43	50,72
1,97022E+21	1,768E+05	1,77393E+05	-0,34	63,85
2,34205E+21	1,878E+05	1,67193E+05	10,97	75,90
2,81107E+21	1,790E+05	1,57059E+05	12,26	91,10
3,40353E+21	1,549E+05	1,47100E+05	5,04	110,30
4,12558E+21	1,293E+05	1,37718E+05	-6,51	133,70
4,90318E+21	1,059E+05	1,29808E+05	-22,58	158,90
5,93997E+21	1,336E+05	1,21553E+05	9,02	192,50

Below is shown a graphic with measures data and power regression function.



A coefficient of 0,85 is a good correlation. Therefore this value support hypothesis that rotation curve of Milky Way follows a law $v = a \cdot r^b$ where a & b are written above.

4. DIRECT FORMULA FOR DM DENSITY ON MILKY WAY HALO GOT FROM ROTATION CURVE

4.1 THEORETICAL DEVELOPPMENT FOR GALACTIC HALOS

Outside disk region, rotation curve it is fitted by power regression with a high correlation coefficient according formula $v = a \cdot r^b$. As $M(<r) = \frac{v^2 \cdot R}{G}$ represents total mass enclosed by a sphere with radius r, by substitution of velocity results $M = \frac{v^2 \cdot R}{G} = \frac{a^2 \cdot r^{2b+1}}{G}$

If it is considered outside region of disk where baryonic matter is negligible regarding dark matter it is possible to calculate DM density by a simple derivative. In next chapter will be shown that for r > 44 kpc baryonic matter is negligible.

As density of D.M. is $D_{DM} = \frac{dm}{dV}$ where $dm = \frac{a^2 \cdot (2b+1) \cdot r^{2b} dr}{G}$ and $dV = 4\pi r^2 dr$ so $D_{DM} = \frac{a^2 \cdot (2b+1)}{4\pi G} \cdot r^{2b-2}$

Writing $L = \frac{a^2 \cdot (2b+1)}{4\pi G} \cdot$ results $D_{DM}(r) = L \cdot r^{2b-2}$. In case b = -1/2 DM density is cero which is Keplerian rotation.

4.2 DIRECT DM DENSITY FOR MILKY WAY HALO

Parameters a & b from power regression of Milky Way rotation curve allow calculate easily direct DM density.

Direct DM density for Milky Way halo 40 < r < 300 kpc
$D_{DM}(r) = L \cdot r^{2b-2}$ kg/m^3
L = 4,58164747068706 $\cdot 10^{33}$
2b -2 = -2,6850817178

Beside is such function and table.

Below is shown results of DM density inside its dominion. Calculus are into I.S.

Radius	Radius	Direct DM
kpc	m	kg/m^3
44,00	1,35771E+21	8,27388768E-24
50,00	1,54285E+21	5,87003998E-24
70,00	2,15999E+21	2,37834768E-24
90,00	2,77713E+21	1,21119348E-24
110,00	3,39427E+21	7,06656209E-25
130,00	4,01141E+21	4,51235967E-25
150,00	4,62855E+21	3,07278024E-25
170,00	5,24569E+21	2,19571888E-25
190,00	5,86283E+21	1,62882611E-25
210,00	6,47997E+21	1,24498977E-25

5. DARK MATTER DENSITY AS POWER OF GRAVITATIONAL FIELD

As independent variable for this function is E, gravitational field, previously will be studied formula for E in the following paragraph.

5.1 GRAVITATIONAL FIELD E THROUGH VIRIAL THEOREM

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 is well known. Hereafter, virial gravitational field, E, got through this formula will be called E.

By substitution of $v = a \cdot r^b$ in formula $E = \frac{v^2}{r}$ it is right to get $E = \frac{a^2 \cdot r^{2b}}{r} = a^2 \cdot r^{2b-1}$ briefly $E = a^2 \cdot r^{2b-1}$

Radius	Radius	E virial
m	kpc	m/s^2
1,35771E+21	44,00	2,991225E-11
1,54285E+21	50,00	2,411559E-11
2,15999E+21	70,00	1,367918E-11
2,77713E+21	90,00	8,956593E-12
3,39427E+21	110,00	6,386864E-12
4,01141E+21	130,00	4,819854E-12
4,62855E+21	150,00	3,787124E-12
5,24569E+21	170,00	3,066991E-12
5,86283E+21	190,00	2,542817E-12
6,47997E+21	210,00	2,148186E-12

5.2 DARK MATTER DENSITY AS POWER OF GRAVITATIONAL FIELD

According hypothesis dark matter by quantum vacuum $D_{DM} = A \cdot E^B$. Where A & B are parameters to be calculated. This hypothesis has been widely studied by author in previous papers. [1] Abarca,M. [2] Abarca,M.

[8] Abarca,M. [9] Abarca,M. [10] Abarca,M.

As it is known direct DM density $D_{DM} = \frac{a^2 \cdot (2b+1)}{4\pi G} \cdot r^{2b-2}$ depend on a & b parameters which come from power regression formula for velocity. In previous paragraph has been shown formula for gravitational field $E = \frac{a^2 \cdot r^{2b}}{r} = a^2 \cdot r^{2b-1}$ which depend on a & b as well. Through a simple mathematical treatment it is possible to get A & B to find function of DM density depending on E i.e. $D_{DM} = A \cdot E^B$

Specifically formulas are $A = \frac{a^{\frac{2}{2b-1}} \cdot (2b+1)}{4\pi G}$ & $B = \frac{2b-2}{2b-1}$.

Milky Way	$D_{DM} = A \cdot E^B$
A	$4{,}8679319197425 \cdot 10^{-7}$
B	1,5934430297574

According parameters a & b got in previous chapter, A& B parameters are:

Below is tabulated DM density as power of E and direct DM density, both are identical as it was expected.

		$E = a^2 \cdot r^{2b-1}$	$D_{DM}(r) = L \cdot r^{2b-2}$	$D_{DM} = A \cdot E^B$
Radius	Radius	E virial	Direct DM	DM pwE
kpc	m	m/s^2	kg/m^3	kg/m^3
44,00	1,35771E+21	2,99122522E-11	8,273888E-24	8,273888E-24
50,00	1,54285E+21	2,41155893E-11	5,870040E-24	5,870040E-24
70,00	2,15999E+21	1,36791842E-11	2,378348E-24	2,378348E-24
90,00	2,77713E+21	8,95659316E-12	1,211193E-24	1,211193E-24
110,00	3,39427E+21	6,38686417E-12	7,066562E-25	7,066562E-25
130,00	4,01141E+21	4,81985393E-12	4,512360E-25	4,512360E-25
150,00	4,62855E+21	3,78712444E-12	3,072780E-25	3,072780E-25
170,00	5,24569E+21	3,06699080E-12	2,195719E-25	2,195719E-25
190,00	5,86283E+21	2,54281720E-12	1,628826E-25	1,628826E-25
210,00	6,47997E+21	2,14818606E-12	1,244990E-25	1,244990E-25

As conclusion, in this chapter has been demonstrated that a power law for velocity

$v = a \cdot r^b$ *is mathematically equivalent a power law for DM density depending on E.* $D_{DM} = A \cdot E^B$

6. RATIO BARYONIC MASS VERSUS DM MASS DEPENDING ON RADIUS FOR MILKY WAY

In this paragraph will be estimated radius which is needed to consider negligible baryonic density regarding DM density in M31 galaxy.

[5] According Sofue, Y. data for M31 disk are

Milky Way	Baryonic Mass at disk	a_d	Σ_0
	$M_d = 2\pi \cdot \Sigma_0 \cdot a^2{}_d$		
	M_d = 1,12·10^{11} Msun	5,73 kpc	1,134683098 kg/m^2

Where $\Sigma(r) = \Sigma_0 \exp(-r/a_d)$ represents superficial density at disk. Total mass disk is given by integration of superficial density from cero to infinite. $M_d = \int_0^\infty 2\pi \cdot r\Sigma(r) \cdot dr = 2\pi \cdot \Sigma_0 \cdot a^2{}_d$

In order to compare baryonic density and DM density it is considered differential baryonic mass and differential DM masses depending on radius.

$dM_{DISK} = 2\pi r\Sigma(r)dr$ where $\Sigma(r) = \Sigma_0 \exp(-r/a_d)$ and

$dM_{DM} = 4\pi r^2 D_{DM}(r)dr$ where $D_{DM}(r) = \frac{a^2 \cdot (2b+1)}{4\pi G} \cdot r^{2b-2}$

It is defined ratio function as quotient of both differential quantities $Ratio = \frac{dM_{DISK}}{dM_{DM}} = \frac{\Sigma(r)}{2 \cdot r \cdot D_{DM}(r)}$

Radius Kpc	Radius	Ratio	$\Sigma(r)$	Direct DM
kpc	m		kg/m^2	kg/m^3
30	9,25710E+20	1,410112E-01	6,0406196E-03	2,3137854E-23
32	9,87424E+20	1,108914E-01	4,2608405E-03	1,9456453E-23
34	1,04914E+21	8,663196E-02	3,0054470E-03	1,6533634E-23
36	1,11085E+21	6,728553E-02	2,1199366E-03	1,4181265E-23
38	1,17257E+21	5,198799E-02	1,4953287E-03	1,2264965E-23
40	1,23428E+21	3,998107E-02	1,0547522E-03	1,0686915E-23
42	1,29599E+21	3,061779E-02	7,4398512E-04	9,3746997E-24
44	1,35771E+21	2,335781E-02	5,2478093E-04	8,2738877E-24
46	1,41942E+21	1,775729E-02	3,7016200E-04	7,3430029E-24
48	1,48114E+21	1,345663E-02	2,6109925E-04	6,5500444E-24
50	1,54285E+21	1,016775E-02	1,8417023E-04	5,8700400E-24
52	1,60456E+21	7,661980E-03	1,2990720E-04	5,2832985E-24

For a radius 44 kpc ratio baryonic matter versus DM is only 2,3 % therefore is a good approximation to consider negligible baryonic mass density regarding DM density when radius is bigger than 44 kpc.

This is the reason why in this work dominion for radius begin at 44 kpc

7. COMPARISON BETWEEN DIRECT DM DENSITY AND NFW DARK MATTER DENSITY

According [5] Sofue,Y., 2015. Parameters of NFW profile for Milky Way are

Dark matter density function profile NFW
Rs = $10,7 \pm 2.9$ Kpc
Do = $1,2318 \cdot 10^{-21}$ kg/m^3

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

Below are tabulated NFW DM density and direct DM density depending on radius both. Third column shows relative differences, which oscillate between 28% and 15% throughout dominion.

DM power E	DM NFW	Rel diff.	Radius
kg/m^3	kg/m^3	%	kpc
8,27389E-24	1,14621E-23	27,8152565	44,00
5,87004E-24	8,19114E-24	28,3366819	50,00
2,37835E-24	3,31014E-24	28,1496449	70,00
1,21119E-24	1,65345E-24	26,7473331	90,00
7,06656E-25	9,41639E-25	24,9546354	110,00
4,51236E-25	5,86354E-25	23,0437807	130,00
3,07278E-25	3,89555E-25	21,1207122	150,00
2,19572E-25	2,71848E-25	19,2299356	170,00
1,62883E-25	1,97171E-25	17,3902065	190,00
1,24499E-25	1,47526E-25	15,608596	210,00

It is remarkable the fact that NFW profile is bigger than direct DM profile through the whole dominion.

This is an important fact and in next paragraph will be exposed some ideas which in author opinion might explain the fact that direct DM profile gives values of density a bit lower than values calculated by NFW profile.

As it was pointed at introduction, it is known that there is baryonic dark matter

such us giant planets, cold gas clouds, brown dwarfs but this kind of DM is more probable to be placed inside galactic disk and bulge.

Reader can consult these papers about this open problem: [12] Nieuwenhuizen,T.M. 2010. [13] Nieuwenhuizen,T.M. 2012. [14] Nieuwenhuizen,T.M. 2010 [15] Wyrzykowski,L.2010. [16] M.R.S. Hawkins 2015

As it is known, NFW profile is fitted over bulge, disk and galactic halo and taking in consideration that there is an unknown amount of baryonic DM in bulge and galactic disk it is right to conclude that NFW profile is fitted through a set of DM data whose values include baryonic DM and non baryonic DM, especially in bulge and disk. Therefore it is right to get a function fitted, NFW, which produce high values of DM throughout its dominion, bulge, disk and halo.

However direct DM profile, as it is got through a power regression function fitted with data velocity in halo region, it is fitted only with non baryonic DM.

.

8. MASSES IN MILKY WAY

8.1 DYNAMICAL MASS UP TO 44 KPC

It has been chosen 44 kpc, because at this radius baryonic density is negligible regarding DM density in Milky Way

According power regression law for velocity $v = a \cdot r^b$ rotation velocity is v = 2,01524·10^5 m/s at 44 kpc.

And $M_{DYNAMICAL}(< 44kpc) = \frac{v^2 \cdot R}{G}$ = 4,15·10^{11} Msun i.e. M $_{TOTAL}$ (< 44 kpc) = 4,15·10^{11} Msun

In other words dynamical mass is equivalent to total mass.

According Sofue data Milky Way Baryonic matter = $1,37 \pm 0,42 \cdot 10^{11}$ Msun

M31 masses up to 44 kpc		
$M_{DYNAMICAL}$ = Total mass	Baryonic mass Bulge + disk	Dynamical Dark matter mass
4,15·10^{11} Msun	1,37·10^{11} Msun	2,78·10^{11} Msun

so dynamical DM (<44 kpc) = 2,78·10^{11} Msun.

It is called dynamical DM because it is got subtracting Baryonic to total dynamical mass.

8.2 DYNAMICAL DM THROUGH DYNAMICAL MASSES

Power regression for M31 rot. curve	
$V=a \cdot r^b$	
a	3,492829549E+12
b	-3,425408589E-01
Correlation coeff.	0,85

As it was shown in chapter four, rotation curve is fitted with a high correlation by this function $v = a \cdot r^b$ whose parameter are in table below.

Also it is known that $M(<r) = \frac{v^2 \cdot R}{G}$ represents total mass enclosed by a sphere with radius r, by substitution of velocity results $M(<r) = \frac{v^2 \cdot R}{G} = \frac{a^2 \cdot r^{2b+1}}{G}$.

So it is possible to calculate DM enclosed by a sphere with R radius by subtraction of baryonic matter, that according Sofue, for Milky Way Baryonic matter $= 1{,}37 \pm 0{,}42 \cdot 10^{11}$ Msun where Msun = $1{,}99 \cdot 10^{30}$ kg

In table below, second column show total or dynamical mass inside a sphere with radius R and the third column show DM calculated subtracting baryonic mass to total mass. $M_{BARYONIC} = 1{,}37 \cdot 10^{11}$ Msun. So DM calculated by this method is called dynamical DM.

Velocity	Dynamical Mass M(<R)	Dynamical DM(<R)	Radius
m/s	Msun		kpc
2,015244503E+05	4,152E+11	2,782E+11	44,00
1,928904792E+05	4,323E+11	2,953E+11	50,00
1,718921205E+05	4,806E+11	3,436E+11	70,00
1,577137393E+05	5,202E+11	3,832E+11	90,00
1,472370247E+05	5,541E+11	4,171E+11	110,00
1,390482300E+05	5,841E+11	4,471E+11	130,00
1,323967327E+05	6,110E+11	4,740E+11	150,00
1,268403837E+05	6,355E+11	4,985E+11	170,00
1,220987508E+05	6,582E+11	5,212E+11	190,00
1,179838177E+05	6,793E+11	5,423E+11	210,00
1,143639521E+05	6,990E+11	5,620E+11	230,00
1,111437399E+05	7,176E+11	5,806E+11	250,00
1,082520188E+05	7,352E+11	5,982E+11	270,00
1,056344344E+05	7,519E+11	6,149E+11	290,00

8.3 DM HALO MASSES THROUGH NFW PROFILE

Formula of NFW profile is $D_{NFW}(R) = \frac{D_0}{x \cdot (1+x)^2}$ where x= R / Rs

Dark matter density profile NFW for Milky Way Data come from [5] Sofue, Y.2015.
Rs = 10,7 Kpc
Do = $1.2318 \cdot 10^{-21}$ kg/m^3

According NFW DM density profile, total DM enclosed by a sphere with R radius is

$$M(<R) = 4\pi R^3{}_S \cdot D_o \cdot \left[\ln(1+x) - \frac{x}{1+x} \right]$$

Calling $f(x)=\left[\ln(1+x)-\frac{x}{1+x}\right]=\ln(1+r/Rs)-\frac{r}{r+Rs}$ and $Z_{NFW}=4\pi R^3{}_S\cdot D_0$ then

$$DM_{NFW}(<r)=Z_{NFW}\cdot f(x)$$

According data for Milky Way $Z_{NFW}=2{,}8\cdot10^{11}$ Msun.

Radius	NFW DM(<R)
kpc	Msun
44,00	2,316E+11
50,00	2,554E+11
70,00	3,229E+11
90,00	3,775E+11
110,00	4,233E+11
130,00	4,627E+11
150,00	4,972E+11
170,00	5,280E+11
190,00	5,558E+11
210,00	5,810E+11
230,00	6,042E+11
250,00	6,256E+11
270,00	6,454E+11
290,00	6,640E+11

Beside is tabulated total NFW DM inside a sphere with R radius.

By addition of DM(< 44 kpc) plus Baryonic mass it is supposed to have total mass. Total Mass(< 44 kpc) = $2{,}31\cdot10^{11}$ + $1{,}37\cdot10^{11}$ = $3{,}69\cdot10^{11}$ Msun.

At epigraph 10.1 was got that dynamical mass(< 44 kpc) = $4{,}15\cdot10^{11}$ Msun.

Therefore there is a difference not negligible which may be acceptable because according Sofue, for Milky Way Baryonic matter = $1{,}37\pm0{,}42\cdot10^{11}$ Msun .i.e. experimental error for baryonic matter is similar to mass difference.

8.4 DYNAMICAL DM VERSUS NFW DM

Joining results got in previous epigraphs it is possible to compare DM got by these methods.

Radius	Dynamical DM(<R)	NFW DM(<R)	Rel diff.
kpc	Msun	Msun	%
44,00	2,782E+11	2,316E+11	16,75
50,00	2,953E+11	2,554E+11	13,52
70,00	3,436E+11	3,229E+11	6,04
90,00	3,832E+11	3,775E+11	1,49
110,00	4,171E+11	4,233E+11	-1,48
130,00	4,471E+11	4,627E+11	-3,50
150,00	4,740E+11	4,972E+11	-4,91
170,00	4,985E+11	5,280E+11	-5,91
190,00	5,212E+11	5,558E+11	-6,63
210,00	5,423E+11	5,810E+11	-7,14
230,00	5,620E+11	6,042E+11	-7,50
250,00	5,806E+11	6,256E+11	-7,74
270,00	5,982E+11	6,454E+11	-7,89
290,00	6,149E+11	6,640E+11	-7,98

It is remarkable that at 44 kpc dynamical DM is 16 % bigger than NFW, progressively difference decrease at 110 kpc NFW DM become bigger than dynamical DM and at 290 kpc NFW DM is 8 % bigger than dynamical DM.

8.5 DYNAMICAL CORONA HALO COMPARED TO NFW CORONA HALO MASSES

As for radius bigger than 44 kpc it is supposed that baryonic matter is negligible. This radius is a good reference to calculated DM enclosed in spherical corona from 44 kpc up to R kpc.

As $DM_{NFW}(<r) = Z_{NFW} \cdot f(x)$ represents total DM under radius R, it is right to get NFW DM corona halo mass with this simple formula: DM Corona (44 kpc to R_2) = $Z_{NFW} \cdot (f_2 - f_1)$. Where $f_2 = f(R_2)$ and $f_1 = f$ (44 kpc).

Similarly dynamical DM Corona (44 kpc to R) = dyn. M(<R) – dyn M(<44 kpc)

In table below in the fourth column is tabulated dynamical DM corona by substraction of dynamical mass at R radius minus dynamical at 44 kpc.

In the fifth column is tabulated NFW corona DM by subtraction of NFW DM mass at R radius minus same kind of mass at 44 kpc.

In sixth column is shown relative difference between both methods to calculate DM corona at different radius.

Differences oscillate between 28 % and 22 % .

Dynamical mass (total) M(<R)	NFW DM(<R)	Radius	Dynamical corona DM(44<R)	NFW Corona DM(44<R)	Rel. Diff. Coronas Dynam. Vs NFW
Msun	Msun	kpc	Msun	Msun	%
4,152E+11	2,316E+11	44,00	0,000E+00	0,000E+00	
4,323E+11	2,554E+11	50,00	1,706E+10	2,373E+10	28,12
4,806E+11	3,229E+11	70,00	6,538E+10	9,124E+10	28,34
5,202E+11	3,775E+11	90,00	1,050E+11	1,459E+11	28,04
5,541E+11	4,233E+11	110,00	1,389E+11	1,917E+11	27,53
5,841E+11	4,627E+11	130,00	1,688E+11	2,311E+11	26,93
6,110E+11	4,972E+11	150,00	1,957E+11	2,656E+11	26,31
6,355E+11	5,280E+11	170,00	2,203E+11	2,964E+11	25,67
6,582E+11	5,558E+11	190,00	2,430E+11	3,241E+11	25,04
6,793E+11	5,810E+11	210,00	2,640E+11	3,494E+11	24,43
6,990E+11	6,042E+11	230,00	2,838E+11	3,725E+11	23,83
7,176E+11	6,256E+11	250,00	3,024E+11	3,939E+11	23,24
7,352E+11	6,454E+11	270,00	3,200E+11	4,138E+11	22,67
7,519E+11	6,640E+11	290,00	3,367E+11	4,324E+11	22,12

It is remarkable that NFW corona values (turquoise column) are bigger than Dynamical corona values (grey column). Reason to explain this fact is the same that was exposed in chapter seven regarding NFW DM density and direct DM density.

9. D.M. DENSITY AS POWER OF E IN MILKY WAY VERSUS D.M. DENSITY AS POWER OF E IN M31

In chapter 5 were developed theory of DM density as power of E. DM density = $A \cdot E^B$. In this chapter was demonstrated that mathematically it is equivalent a law of $v = a \cdot r^b$ for rotation curve to a law for DM density as power of E. Where formula coefficients are: $A = \frac{a^{\frac{2}{2b-1}} \cdot (2b+1)}{4\pi G}$ & $B = \frac{2b-2}{2b-1}$.

In addition was shown formula for gravitational field through virial theorem. $E = a^2 \cdot r^{2b-1}$

Coefficients of Milky Way are below.

Power regression for Milky Way rot. curve	
V=a*r^b	
a	3,492829549E+12
b	-3,425408589E-01
Correlation coeff.	0,85

Milky Way	$D_{DM} = A \cdot E^B$
A	4,8679319197425 ·10^{-7}
B	1,5934430297574

In paper [11] Abarca,M.2016. Two New Dark Matter Density Profiles for M31 Halo Got from Rotation Curve were published coefficients a &b for power regression velocity depending on radius. Also were published coefficients A&B for DM density as power of E. Below are couple of data.

Power regression for M31 rot. curve	
V=a*r^b	
a	4,15011040E+10
b	-2,47554520E-01
Correlation coeff.	0,952254

M31 galaxy	$D_{DM} = A \cdot E^B$
A	3,766521943774E ·10^{-6}
B	1,668847537702

Now is going to tabulate Virial E according Milky Way data.
First and second columns refers radius regarding Milky Way. At that radius is calculated gravitational field E, which is used to calculate DM density for Milky Way and M31 in order to compare both results at the same E.
Third column shown such E. Fourth and fifth column show DM density as power of E for Milky Way and M31 and sixth column shows relative difference between both DM densities.

Surprisingly relative difference for field E belonging to 90 kpc or bigger radius, fall below 12 %. See grey row.

Radius for Milky Way	Radius for Milky Way	MW Virial E	DM power E Milky Way	DM power E M31	Rel. Diff. MW vs M31
m	kpc	m/s^2	kg/m^3	Kg/m^3	%
1,35771E+21	44	2,99123E-11	8,27389E-24	1,02976E-23	19,652
1,54285E+21	50	2,41156E-11	5,87004E-24	7,18811E-24	18,337
2,15999E+21	70	1,36792E-11	2,37835E-24	2,79050E-24	14,770
2,77713E+21	90	8,95659E-12	1,21119E-24	1,37642E-24	12,004
3,39427E+21	110	6,38686E-12	7,06656E-25	7,82839E-25	9,732
4,01141E+21	130	4,81985E-12	4,51236E-25	4,89384E-25	7,795
4,62855E+21	150	3,78712E-12	3,07278E-25	3,27251E-25	6,103

5,24569E+21	170	3,06699E-12	2,19572E-25	2,30154E-25	4,598
5,86283E+21	190	2,54282E-12	1,62883E-25	1,68337E-25	3,240
6,47997E+21	210	2,14819E-12	1,24499E-25	1,27042E-25	2,002
7,09711E+21	230	1,84288E-12	9,75174E-26	9,83657E-26	0,862
7,71425E+21	250	1,60131E-12	7,79560E-26	7,78054E-26	-0,194
8,33139E+21	270	1,40655E-12	6,34021E-26	6,26639E-26	-1,178
8,94853E+21	290	1,24698E-12	5,23329E-26	5,12560E-26	-2,101
9,2571E+21	300	1,17774E-12	4,77795E-26	4,65952E-26	-2,542

Relative differences of DM density for MW vs DM density for M31 oscillate from a maximum 19,6 % at the biggest field E and decreases up to -2,5% at the lowest field E.

In table below has been calculated Virial E through M31 parameters a &b. Gravitational field belong to radius for M31 tabulated in first and second columns.

Surprisingly relative differences of DM density in M31 and Milky Way are mainly below 20 % and for field E belonging to 150 kpc or bigger radius, relative differences fall below 10 %.

Radius for M31	Radius for M31	M31 Virial E	DM power E Milky Way	DM power E M31	Rel. Diff. MW vs M31
m	kpc	m/s^2	kg/m^3		%
1,23428E+21	40	5,03682E-11	1,89809E-23	2,45702E-23	22,748
1,54285E+21	50	3,60799E-11	1,11543E-23	1,40802E-23	20,780
2,15999E+21	70	2,18166E-11	5,00392E-24	6,08139E-24	17,718
2,77713E+21	90	1,49832E-11	2,74971E-24	3,24844E-24	15,353
3,39427E+21	110	1,10996E-11	1,70476E-24	1,96891E-24	13,416
4,01141E+21	130	8,64639E-12	1,14504E-24	1,29779E-24	11,770
4,62855E+21	150	6,98098E-12	8,14257E-25	9,08110E-25	10,335
5,24569E+21	170	5,78957E-12	6,04312E-25	6,64523E-25	9,061
5,86283E+21	190	4,90259E-12	4,63641E-25	5,03483E-25	7,913
6,47997E+21	210	4,22123E-12	3,65284E-25	3,92223E-25	6,868
7,09711E+21	230	3,68443E-12	2,94107E-25	3,12575E-25	5,908
7,71425E+21	250	3,25258E-12	2,41121E-25	2,53864E-25	5,020
8,33139E+21	270	2,89906E-12	2,00728E-25	2,09510E-25	4,192
8,94853E+21	290	2,60529E-12	1,69306E-25	1,75296E-25	3,417
9,2571E+21	300	2,47653E-12	1,56169E-25	1,61078E-25	3,047

Relative differences of DM density for MW vs DM density for M31 oscillate from a maximum 22,7 % at the biggest field E and decreases up to 3 %.

DM density as power of E regarding both galaxies are astonishing similar despite the fact that both galaxies have very different rotation curves coefficients a & b, their baryonic masses are clearly different and their galactic disks have different laws for superficial density masses.

In addition it is well known that experimental errors are not negligible despite the fact measures are made by prestigious research teams equipped with high technology tools.

Despite these facts, relative differences fall below 12% at E belonging radius bigger 90 kpc in Milky Way and fall below 10 % at E belonging radius bigger 150 kpc in M31.See rows in grey in tables above.

In my opinion this result suggest strongly that DM is generated by gravitational field as power of E according a Universal law. [8] Abarca,M.2016. *D.M. density on big galaxies depend on gravitational field as Universal law.*

10. HALO RADIUS OF MILKY WAY & M31 ACCORDING D.M. AS POWER OF E THEORY

According theory D.M. as power of E it is right to deduce that halo radius of each galaxy extend up to both galaxies have the same gravitational field.

Power regression for Milky Way rot. curve	
V=a*r^b	
a	3,492829549E+12
b	-3,425408589E-01
Correlation coeff.	0,85

Power regression for M31 rot. curve	
V=a*r^b	
a	4,15011040E+10
b	-2,47554520E-01
Correlation coeff.	0,952254

In chapter five was got this formula $E = a^2 \cdot r^{2b-1}$ for Virial E so it is right calculus of E when it is known coefficients of power regression of rotation curve in halo.

In table below is calculated E for MW and M31 at different radius to find radius which give the same value for E in both galaxies. It is supposed that distance between MW & M31 is 770 kpc.

For example at 292 kpc radius of MW belong a 478 kpc of radius for M31. At these radius gravitational field generated by both galaxies is almost identical as reader can see at grey row in table below.

So according this theory it is right to considerate 292 kpc halo radius of Milky Way and 478 kpc halo radius of M31.

It is important to see DM density at these distances for both galaxies DM density $_{\text{MILKY WAY}} = 5{,}1376 \cdot 10^{-26}$ and

DM density $_{\text{M31}} = 5{,}038 \cdot 10^{-26}$. Both values differs only 1,9 %. Astonishing¡ See row in grey in table below.

Radius MW	Radius M31	Radius MW	Radius M31	MW E virial	M31 E virial	M31 -Direct DM	MW-direc DM
kpc	kpc	m	m	m/s^2	m/s^2	kg/m^3	
200	570	6,171E+21	1,7588E+22	2,33226E-12	9,48587E-13	3,24724E-26	1,41926E-25
210	560	6,48E+21	1,7280E+22	2,14819E-12	9,74024E-13	3,39386E-26	1,24499E-25
220	550	6,789E+21	1,6971E+22	1,98622E-12	1,00062E-12	3,54993E-26	1,09880E-25
230	540	7,097E+21	1,6663E+22	1,84288E-12	1,02845E-12	3,71623E-26	9,75174E-26
240	530	7,406E+21	1,6354E+22	1,71534E-12	1,05760E-12	3,89366E-26	8,69867E-26
250	520	7,714E+21	1,6046E+22	1,60131E-12	1,08815E-12	4,08318E-26	7,79560E-26
260	510	8,023E+21	1,5737E+22	1,49890E-12	1,12021E-12	4,28588E-26	7,01639E-26
270	500	8,331E+21	1,5429E+22	1,40655E-12	1,15387E-12	4,50297E-26	6,34021E-26
280	490	8,64E+21	1,5120E+22	1,32294E-12	1,18925E-12	4,73577E-26	5,75036E-26
290	480	8,949E+21	1,4811E+22	1,24698E-12	1,22649E-12	4,98579E-26	5,23329E-26
300	470	9,257E+21	1,4503E+22	1,17774E-12	1,26571E-12	5,25470E-26	4,77795E-26
291	479	8,979E+21	1,4781E+22	1,23977E-12	1,23032E-12	5,01180E-26	5,18514E-26
292	478	9,01E+21	1,4750E+22	1,23262E-12	1,23417E-12	5,03800E-26	5,13760E-26
293	477	9,041E+21	1,4719E+22	1,22554E-12	1,23804E-12	5,06440E-26	5,09065E-26

10.1 MASSES IN MILKY WAY & M31 AT EXTENDED HALOS

According conclusion previous epigraph it is right to consider MW halo radius equal to 292 kpc and M31 halo radius equal to 478 kpc.

As dynamical mass is $M(<r)=\frac{v^2\cdot R}{G}$ it is right to calculate dynamical masses for MW & M31 from power regression velocity at halo radius distances.

Dynamical Mass Milky Way (< 292 kpc) = $7{,}54\cdot 10^{11}$ Msun

Dynamical Mass M31 (< 478 kpc) = $2{,}02\cdot 10^{12}$ Msun

According [5] Sofue,Y. 2015. Baryonic Mass MW = $1{,}37\cdot 10^{11}$ Msun and Baryonic Mass M31 = $1{,}61\cdot 10^{11}$ Msun

So Ratio Baryonic mass vs Total mass for MW = 18,2 % and Ratio Baryonic mass vs Total mass of M31 = 8 %

11. CONCLUSION

This work is focused in halo region of Milky Way where baryonic density is negligible regarding DM non baryonic. Reason is that the main hypothesis all my papers is that DM non baryonic is generated locally by gravitational field. Therefore it is needed to study radius dominion where it is possible to study gravitational field propagation without interference of baryonic mass density or at least where this density is negligible.

In order to defend properly conclusion this paper is important to emphasise a result got in chapter 3 which is that correlation coefficient of power regression at rotation curve in halo region is 0,85.

This acceptable value of correlation between radius and velocity, support that velocity of Milky Way rotation curve follows a power law regarding radius $v=a\cdot r^b$ whose coefficient a & b were got in chapter 3.

In chapter four was mathematically demonstrated that a power law $v=a\cdot r^b$ in halo region is equivalent a DM density called direct DM in this paper whose formula is $D_{DM}=\frac{a^2\cdot(2b+1)}{4\pi G}\cdot r^{2b-2}$.

In chapter five was demonstrated mathematically that *a power law for velocity* $v=a\cdot r^b$ *at rotation curve is mathematically equivalent a power law for DM density depending on E.* $D_{DM}=A\cdot E^B$

Being $E=\frac{a^2\cdot r^{2b}}{r}=a^2\cdot r^{2b-1}$ *and being* $A=\frac{a^{\frac{2}{2b-1}}\cdot(2b+1)}{4\pi G}$ & $B=\frac{2b-2}{2b-1}$.

Therefore joining chapters 3,4 and 5 it is concluded that a correlation coefficient as 0,85 at power regression law for rotation curve $v=a\cdot r^b$ in halo region support that DM density inside halo region is a power of gravitational field $D_{DM}=A\cdot E^B$ whose parameters A & B are written above.

In chapter seven was compared direct DM profile got in this paper with NFW fitted by [5] Sofue, Y.2015.It was pointed that relative differences fluctuate between 15 % and 28% throughout dominion in halo region and it was explained reason why direct DM profile is more precise than NFW profile to describe non baryonic DM density and why direct DM density gives lower values than NFW DM density.

Similarly in chapter eight was compared corona masses got through both methods. Their relative difference fluctuate between 28 % and 22 % inside radius dominion being NFW profile bigger than direct DM throughout dominion. As it was pointed and explained in chapter seven, this fact is an important evidence that suggest strongly about existence of baryonic DM inside bulge and disk and existence a weird non baryonic DM in halo region which is generated by gravitational field according hypothesis proposed in this and other works.

In chapter nine was compared DM density as power of E in Milky Way with DM density as power of E in M31 halo by this formula $D_{DM} = A{\cdot}E^{B}$.

To do this comparison was tabulated E at different radius and through this set of values of E were got DM density in MW halo with MW parameters and DM density in M31 halo with M31 parameters. Results for both sets of values are astonishingly similar throughout halo dominion since relative differences oscillate between 22 % and 3%. The less value has E the less relative difference have both values.

This results support strongly author hypothesis exposed in previous papers. [8] Abarca,M.2016. *Dark matter density on big galaxies depend on gravitational field as Universal law.* This hypothesis estate that this law $D_{DM} = A{\cdot}E^{B}$ is Universal, that is DM density is similar in different galaxies at a specific E, on condition that galaxies would be similar giant galaxies

In my opinion these facts suggest strongly nature of non baryonic DM. which is very important because shows a way to develop a new quantum gravitation theory.

Finally in tenth chapter was introduced a new definition of halo radius. This new definition was justified as a consequence of theory of DM generated by gravitational field. It has been calculated total mass at these new halo radius for MW and M31and it has been estimated ratio baryonic mass versus total mass that for MW is 18 % and for M31 is 8 %.

12. 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] Sofue, Y.2015. arXiv:1504.05368v1
Dark halos of M31 and the Milky Way.

[6] 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.

[7] Abarca, M.2016. viXra:1606.0007
A new Dark matter density profile for Milky Way which depend on gravitational field.

[8] Abarca,M.2016. viXra:1606.0279v1

Dark matter density on big galaxies depend on gravitational field as Universal law.

[9] Abarca,M.2016.vixra:1607.0427

A New Dark Matter Density Profile as Power of Gravitational Field for Coma Cluster.

[10] Abarca,M.2016.vixra:1601.0242

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

[11] Abarca,M.2016.vixra:1609.0035

Two New Dark Matter Density Profiles for M31 Halo Got from Rotation Curve

[12] Nieuwenhuizen,T.M. 2010 .arXiv:1011.2530v1

Do micro brown dwarf detections explain the galactic dark matter?

[13] Nieuwenhuizen,T.M. 2012. arXiv:1210.0489v2

Do the Herschel cold clouds in the Galactic halo embody its dark matter?

[14] Nieuwenhuizen,T.M. 2010 arXiv:1003.0453v1

Gravitational hydrodynamics versus observations of voids, jeans clusters and MACHO dark matter.

[15] Wyrzykowski,L.2010 .arXiv:1012.1154v2

The OGLE View of Microlensing towards the Magellanic Clouds. III. Ruling out sub-solar MACHOs with the OGLE-III LMC data.

[16] Hawkins M.R.S. 2015. arXiv: 1503.01935v1

A new look at microlensing limits on dark matter in the Galactic halo.