# A NEW DARK MATTER DENSITY PROFILE FOR M33 GALAXY TO DEMONSTRATE THAT DARK MATTER IS GENERATED BY 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 and supported, with several experimental evidences, that dark matter density is a function which depend on E, gravitational field. That paper studied six big galaxies whose velocity in flat area of rotation curve is bigger than 200 km/s.

Current paper studies a similar law for M33, which is an intermediate satellite galaxy of M31, it is 850 kpc away from Earth and its velocity in flat area of rotation curve is approximately 120 km/s.

In this work has been calculated a new function for DM density for M33. Reader could think, why disturb me with a new DM density profile, called Bernoulli profile in this paper, whose values have relative differences with Burket ones below 2%?

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 Burket DM 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.*

Briefly will be explained method followed to develop this paper. Firstly are presented rotation curve and table with data about DM density inside halo of M33 galaxy. These data come from [4] E. Corbelli, 2014.

In fourth epigraph, considering rotation curve of M33 from Corbelli data, it is right to calculate gravitational field E, through Virial theorem. So in this epigraph has been tabulate gravitational field inside a wide region of halo, from 8 kpc to 22 Kpc.

In fifth epigraphs has been tabulated and plotted data of Burket DM density profile published by [4] E. Corbelli, 2014. for M33.

In sixth epigraph has been fitted data of Burket 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= 29,02219371 and B= 2,242193511 into I.S. of units.

In seventh epigraph it has been compared DM density as power of E and Burket profiles. Tables and plots show clearly that relative differences between both profiles are mainly below 5%.

In eight epigraph it is considered derivative of gravitational field in halo region 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 nineth epigraph Bernoulli and Burket DM density profiles have been compared. Its relative differences are below 2% for radius bigger than 10 kpc, which is a superb result.

Last chapter makes a comparison between DM densities as power of E for M33 and NGC 3198 galaxies. The goal is to show a general law for galaxies: the more massive galaxy is the less DM density at a specific value of E.

## 2. INTRODUCTION

M33 galaxy is a satellite galaxy of M31. Also is known as Triangle galaxy and is the third massive galaxy of Local Group. M33 is approximately 880 kpc away and its distance to M31 is 220 kpc aprox. In addition stellar galactic radius is 8 kpc approximately. Therefore it has been considered that baryonic density is negligible versus DM density for radius bigger than 8 kpc, although at the end of work will be found evidences to consider baryonic density negligible for radius bigger than 10 kpc not for 8 kpc.

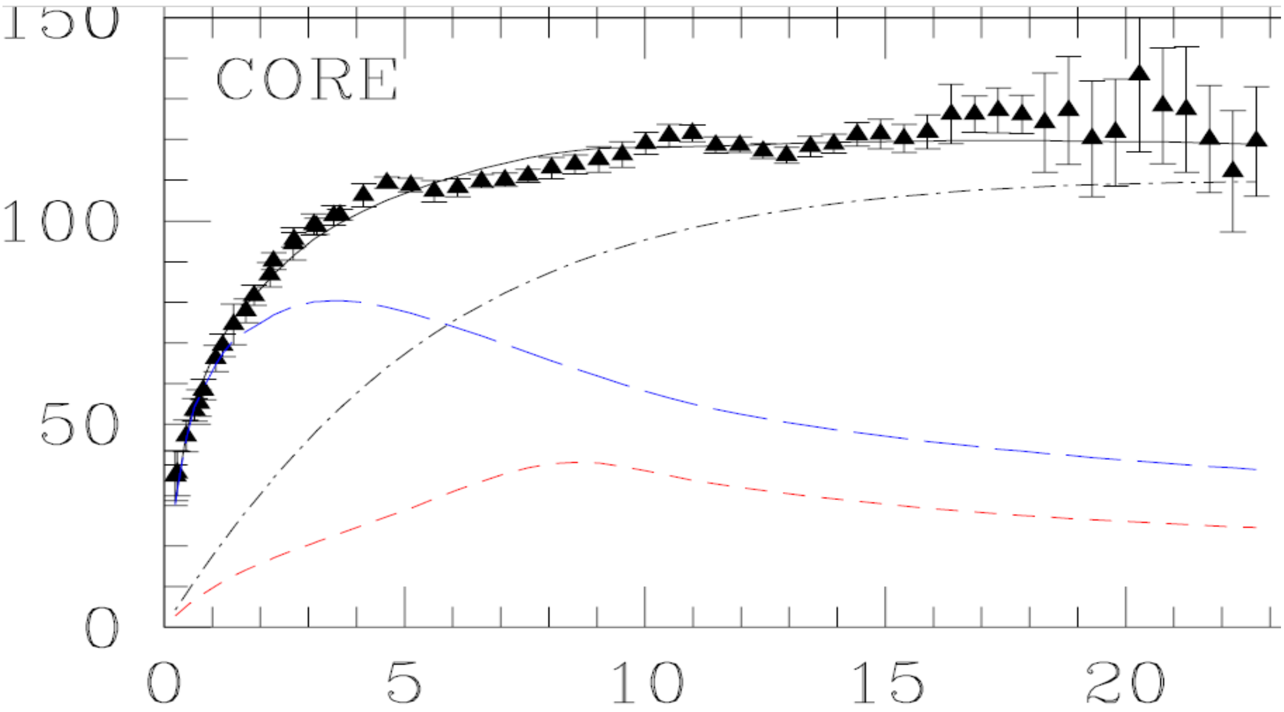
Some data mass of M33 are quoted from the meticulous work [4] E. Corbelli, 2014. Stellar mass of M 33 galaxy is $M_* = (4{,}8 \pm 0{,}6) \cdot 10^9 \, M_\Theta$. When is added gas to stellar mass this gives a baryonic fraction of order of 0.02 and halo mass are found to be $M_{halo} = (4{,}3 \pm 1) \cdot 10^{11} \, M_\Theta$.

The main target this paper is to get a new DM density profile got through a Bernoulli differential equation. Hereafter this new profile will be called Bernoulli profile. It is required as starting point to get DM density as power of gravitational field $\varphi_{DM}(r) = A \cdot E^B$ . Therefore it is needed data about DM density and data about gravitational field

E at specific radius. Data of E may be calculated from rotation curve through Virial theorem. Data about DM density has been calculated by Corbelli through NFW and Burket profiles. I have chosen Burket profile for this paper.

In my previous paper **[3]** Abarca,M.2015, I have got Bernoulli DM density for NGC 3198. As initial data I used **[5]** E.V. Karukes, 2015. In this paper, Karukes published galactic rotation curve and a table of DM density depending on radius. Thanks these data I was be able to calculate parameters of $\varphi_{DM}(r) = A \cdot E^B$ where A= 4,04598703 $\cdot 10^{-5}$ and B= 1,70654481 into I.S. of units. However $\varphi_{DM}(r) = A \cdot E^B$ for M33 have different coefficients. Specifically are A= 29,02219371 and B= 2,242193511 into I. S. of units. Reason why these coefficients are different will be explained at the end of paper, in chapter 10, although briefly I will say that remarkable difference of values of A and B is due to difference of masses between both galaxies.

## 3. OBSERVATIONAL DATA FROM CORBELLI. 2014 PAPER




Graphic come from [4] E Corbelli, 2014. Fig. 15

The rotation curve of M33, data are filled triangles and the best fitting model is the solid line. Dark matter halo with a constant density core is known as Burket profile. The dark halo contribution to rotation curve is shown with a dashed and pointed line. The small and large dashed lines show respectively the gas and stellar disk as contribution to the rotation curves.

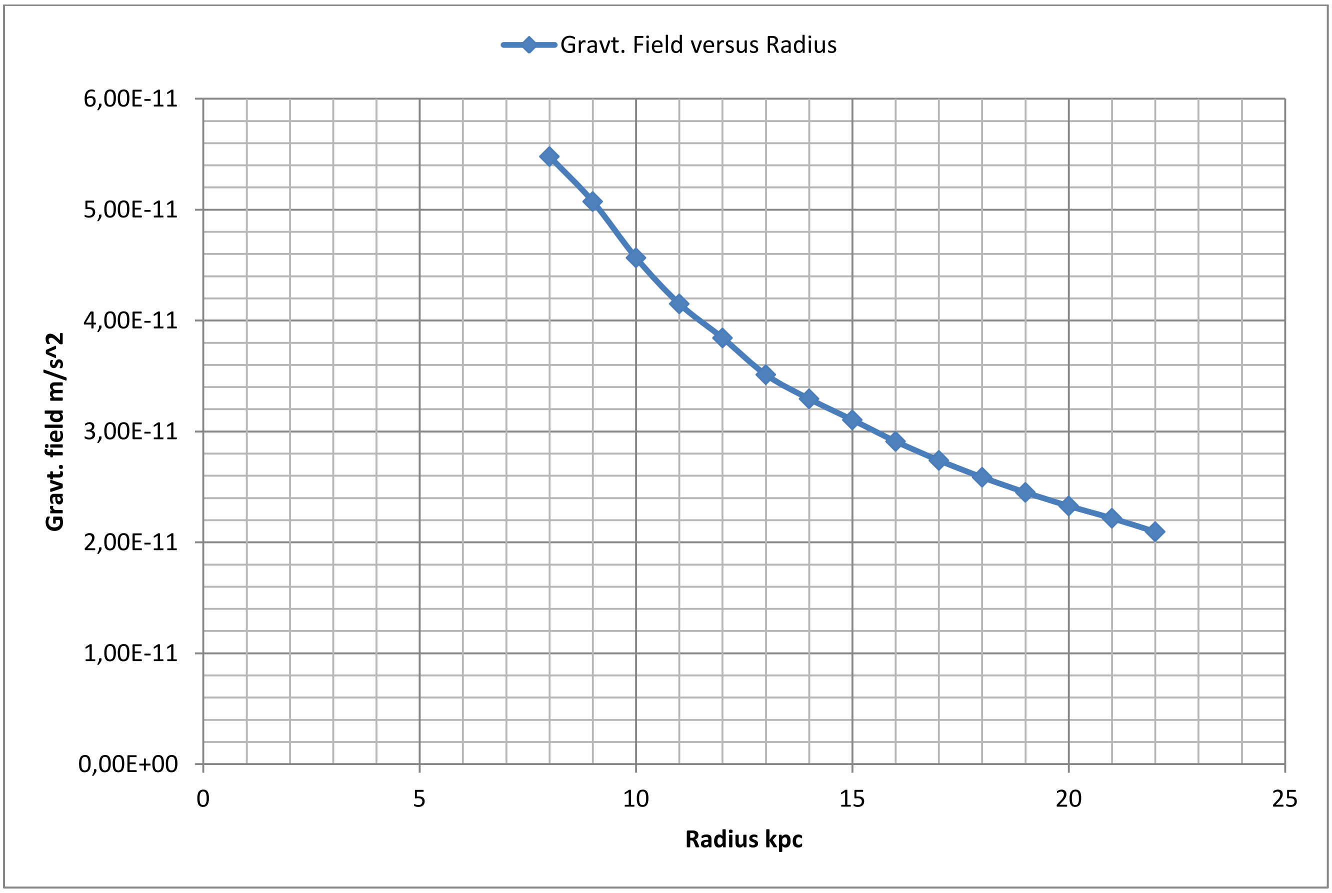
According [4] E Corbelli, 2014. parameters of Burket profile are Rs = 7,5 Kpc and Do = 0,018 Msun/pc^3.

## 4. GRAVITATIONAL FIELD E THROUGH VIRIAL THEOREM

In this work dominion of radius extend from 8 kpc to 22 kpc, despite the fact that rotation curve has accuracy measures for radius lower than 8 kpc. 8 kpc is an approximate measure of galactic radius. Therefore it is supposed that for radius bigger than 8 kpc density of baryonic matter is negligible versus DM density. This hypothesis will be used to get a differential equation for gravitational field in this paper. This is the reason why it is studied only rotation curve for radius bigger than 8 kpc.

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, 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 has been got from solid line, which fits series of triangles in above figure.

| Radius | Radius | Velocity | Virial E |
|---|---|---|---|
| m | kpc | km/s | m/s^2 |
| 2,47E+20 | 8 | 116,3 | 5,47918E-11 |
| 2,78E+20 | 9 | 118,7 | 5,07347E-11 |
| 3,09E+20 | 10 | 118,7 | 4,56612E-11 |
| 3,39E+20 | 11 | 118,7 | 4,15102E-11 |
| 3,70E+20 | 12 | 119,3 | 3,84367E-11 |
| 4,01E+20 | 13 | 118,7 | 3,51240E-11 |
| 4,32E+20 | 14 | 119,3 | 3,29457E-11 |
| 4,63E+20 | 15 | 119,88 | 3,10491E-11 |
| 4,94E+20 | 16 | 119,88 | 2,91085E-11 |
| 5,25E+20 | 17 | 119,88 | 2,73962E-11 |
| 5,55E+20 | 18 | 119,88 | 2,58742E-11 |
| 5,86E+20 | 19 | 119,88 | 2,45124E-11 |
| 6,17E+20 | 20 | 119,88 | 2,32868E-11 |
| 6,48E+20 | 21 | 119,88 | 2,21779E-11 |
| 6,79E+20 | 22 | 119,3 | 2,09655E-11 |



## 5. BURKET DARK MATTER DENSITY PROFILE

According [4] E. Corbelli. 2014 these are Burket profile parameters for M33.

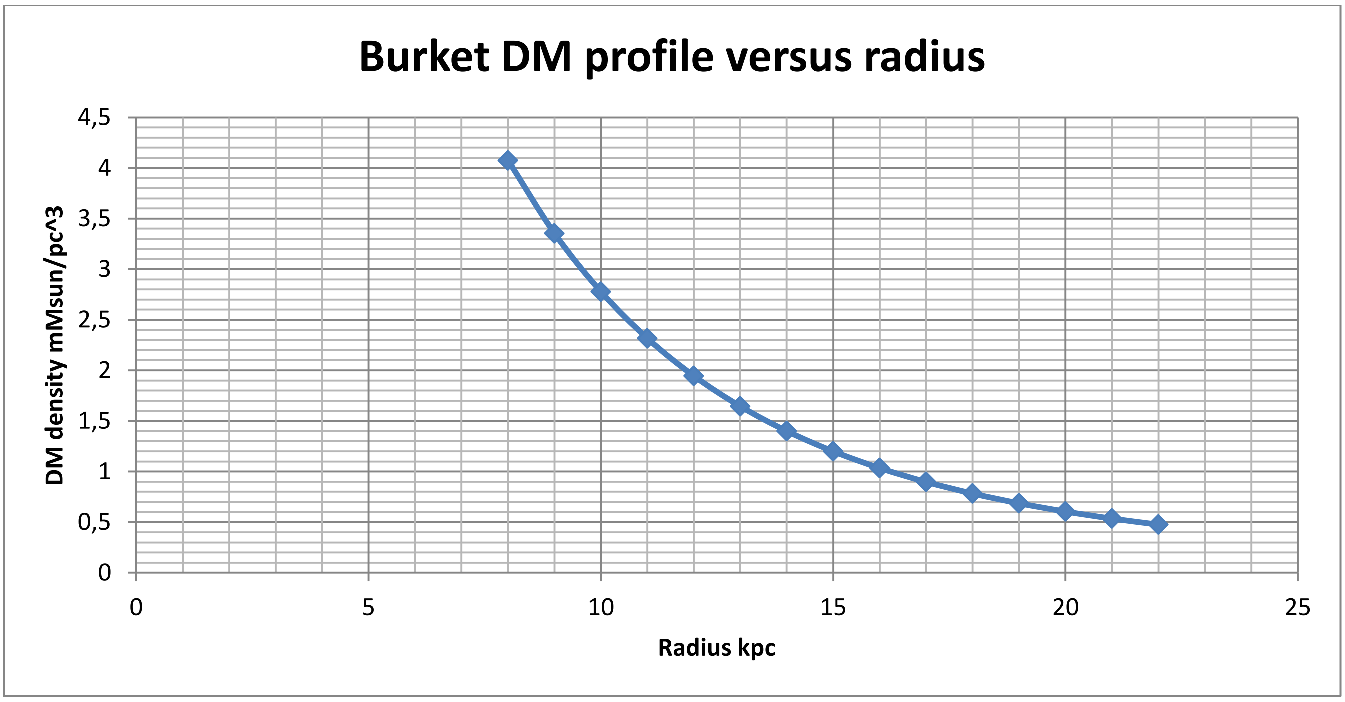
| Dark matter density Burket profile |
|---|
| Rs = 7,5 Kpc |
| Do = 18 mMsolar/pc$^3$ |

Unit of Do is 0,001 Msun/pc^3 = mMsun/pc$^3$ which is a very common unit for galactic densities.

Rs is called length scale and Do is density scale.

$$D_{BURKET}(R) = \frac{D_0}{(1+x)\cdot(1+x^2)}$$ Where x= radius/ Rs

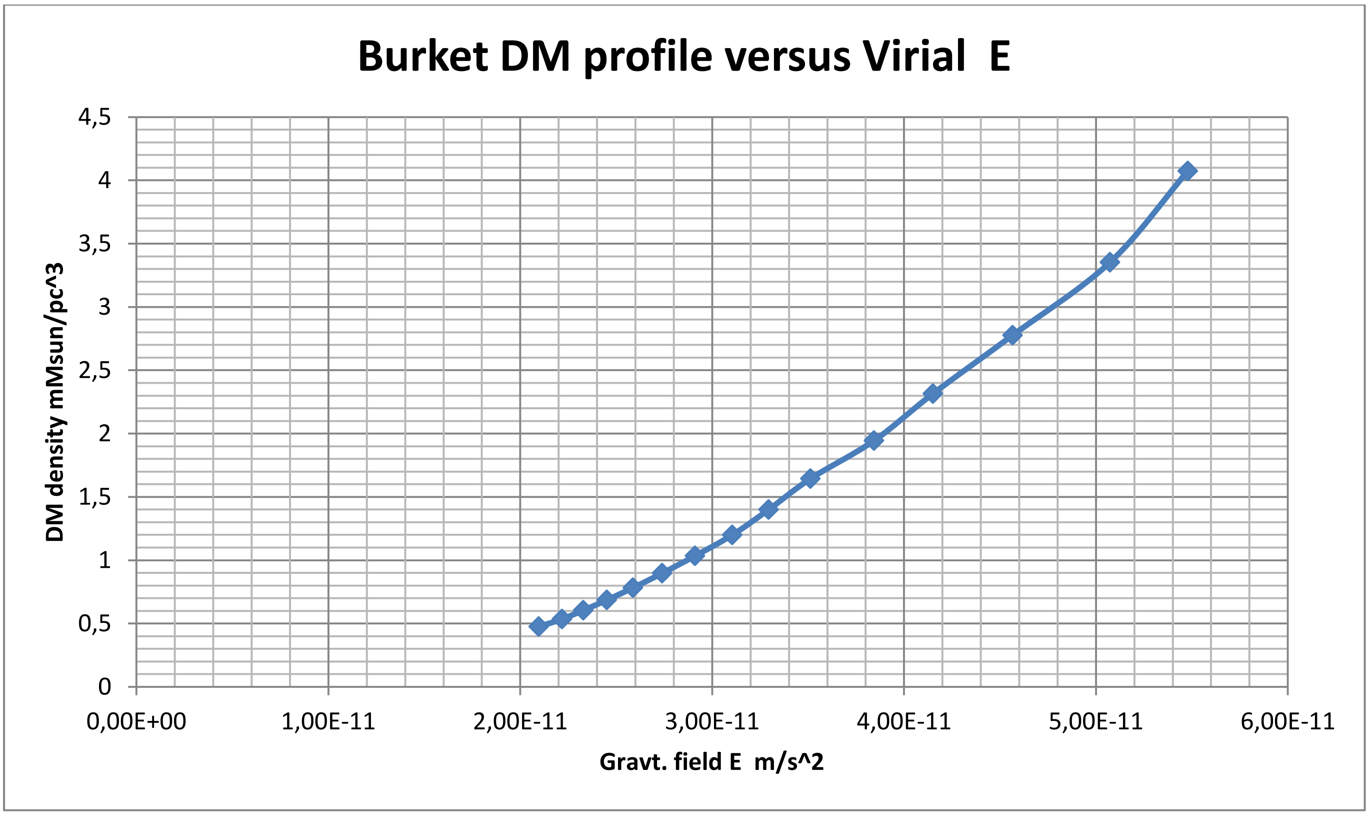
| Radius | Burket DM profile |
|---|---|
| Kpc | mMsun/pc^3 |
| 8 | 4,07417343 |
| 9 | 3,35320417 |
| 10 | 2,77714286 |
| 11 | 2,31578546 |
| 12 | 1,94468453 |
| 13 | 1,64451423 |
| 14 | 1,400189 |
| 15 | 1,2 |
| 16 | 1,03487045 |
| 17 | 0,89775229 |
| 18 | 0,7831535 |
| 19 | 0,68677436 |
| 20 | 0,60523039 |
| 21 | 0,53584187 |
| 22 | 0,47647433 |



## 6. BURKET D.M. DENSITY AS POWER OF VIRIAL FIELD E

Below are tabulated values of gravitational field E and Burket 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. In paper [2] is defended DM density depend on E according a Universal law for big galaxies, as M33 is an intermediate galaxy there is a similar law with different coefficients.

| Radius | Virial E | Burket DM | Burket DM |
|---|---|---|---|
| kpc | m/^2 | mMsun/pc^3 | Kg/m^3 |
| 8 | 5,48E-11 | 4,07417343 | 2,7582E-22 |
| 9 | 5,07E-11 | 3,35320417 | 2,2701E-22 |
| 10 | 4,57E-11 | 2,77714286 | 1,8801E-22 |
| 11 | 4,15E-11 | 2,31578546 | 1,5678E-22 |
| 12 | 3,84E-11 | 1,94468453 | 1,3166E-22 |
| 13 | 3,51E-11 | 1,64451423 | 1,1133E-22 |
| 14 | 3,29E-11 | 1,400189 | 9,4793E-23 |
| 15 | 3,10E-11 | 1,2 | 8,1240E-23 |
| 16 | 2,91E-11 | 1,03487045 | 7,0061E-23 |
| 17 | 2,74E-11 | 0,89775229 | 6,0778E-23 |
| 18 | 2,59E-11 | 0,7831535 | 5,3019E-23 |
| 19 | 2,45E-11 | 0,68677436 | 4,6495E-23 |
| 20 | 2,33E-11 | 0,60523039 | 4,0974E-23 |
| 21 | 2,22E-11 | 0,53584187 | 3,6276E-23 |
| 22 | 2,10E-11 | 0,47647433 | 3,2257E-23 |

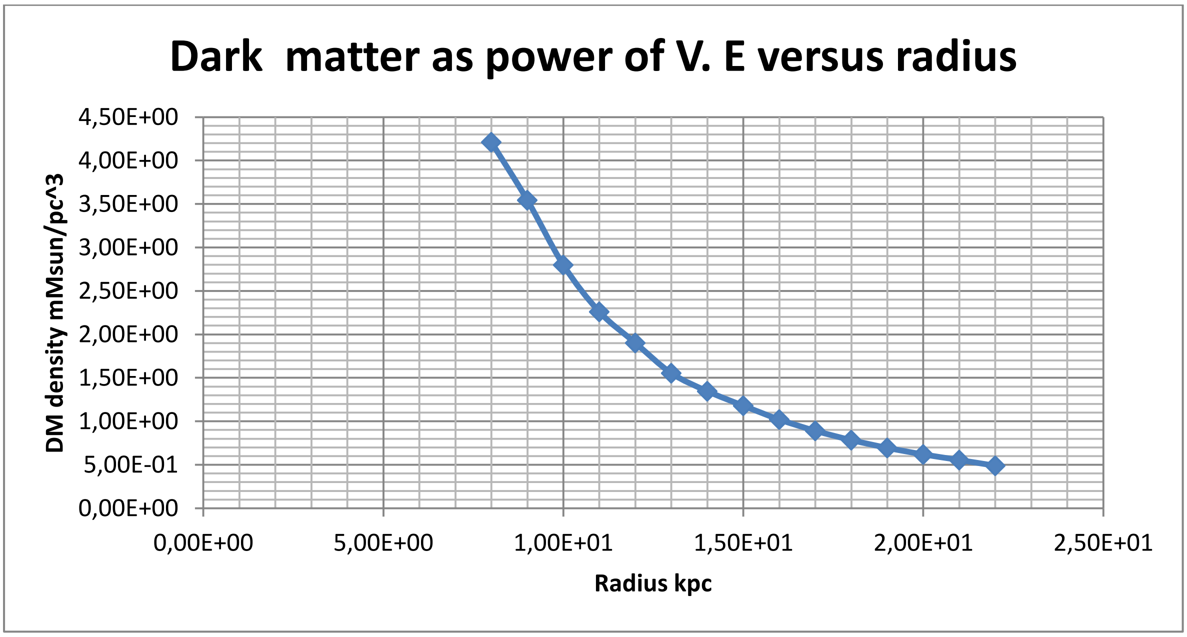


Doing power regression of DM density versus gravitational field according formula Density $_{\text{DARK MATTER}} = A\cdot E^B$ through International System of units, it is right to get A = 29,02219371 and B= 2,242193511 being correlation coefficient r = 0,9990083703. There is a very high correlation between DM density and gravitational field.

| Burket Dark Matter Density as power of Virial E for M33 inside dominion 8 kpc < radius < 22 kpc |
|---|
| $D_{\text{DM Pw VE}} = A\cdot E^B$ |
| A = 29,02219371 B= 2,242193511 and correlation coefficient r = 0,9990083703. |

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

| Radius | Virial E | DM pow VE | DM pow VE |
|---|---|---|---|
| kpc | m/s^2 | Kg/m^3 | mMsun/pc^3 |
| 8,00E+00 | 5,48E-11 | 2,85E-22 | 4,21E+00 |
| 9,00E+00 | 5,07E-11 | 2,40E-22 | 3,54E+00 |
| 1,00E+01 | 4,57E-11 | 1,89E-22 | 2,80E+00 |
| 1,10E+01 | 4,15E-11 | 1,53E-22 | 2,26E+00 |
| 1,20E+01 | 3,84E-11 | 1,29E-22 | 1,90E+00 |
| 1,30E+01 | 3,51E-11 | 1,05E-22 | 1,55E+00 |
| 1,40E+01 | 3,29E-11 | 9,11E-23 | 1,35E+00 |
| 1,50E+01 | 3,11E-11 | 7,98E-23 | 1,18E+00 |
| 1,60E+01 | 2,91E-11 | 6,91E-23 | 1,02E+00 |
| 1,70E+01 | 2,74E-11 | 6,03E-23 | 8,91E-01 |
| 1,80E+01 | 2,59E-11 | 5,30E-23 | 7,84E-01 |
| 1,90E+01 | 2,45E-11 | 4,70E-23 | 6,94E-01 |
| 2,00E+01 | 2,33E-11 | 4,19E-23 | 6,19E-01 |
| 2,10E+01 | 2,22E-11 | 3,75E-23 | 5,55E-01 |
| 2,20E+01 | 2,10E-11 | 3,31E-23 | 4,89E-01 |



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

According [4] E. Corbelli. 2014 these are Burket profile parameters for M33.

| Dark matter density Burket profile |
|---|
| Rs = 7,5 Kpc |
| Do = 18 mMsolar/pc$^3$ |

Unit of Do is 0,001 Msun/pc^3 = mMsun/pc$^3$ which is a very common unit for galactic densities.

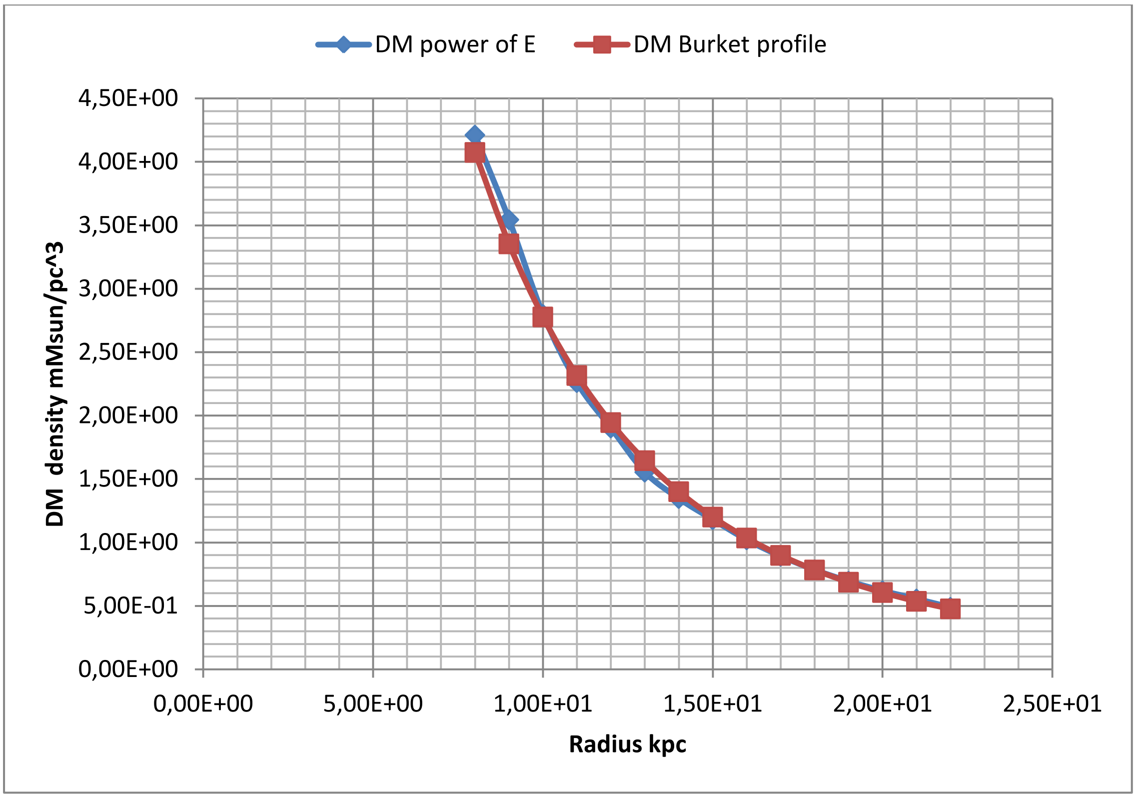
$$D_{BURKET}(R) = \frac{D_0}{(1+x)\cdot(1+x^2)}$$ Where x= radius/ Rs Rs is called length scale and Do is density scale.

According results in previous epigraph DM density as power of virial E is the following formula.

| Burket Dark Matter Density as power of Virial E for M33 inside dominion 8 kpc < radius < 22 kpc |
|---|
| $D_{DM\ Pw\ VE} = A\cdot E^B$ |
| A = 29,02219371 B= 2,242193511 and correlation coefficient r = 0,9990083703. |

Below are compared Burket DM density with DM density as power of E. Except five values differences are below 3%, and all of them are below 6%.

| Radius | Burket DM | DM as power of E | Relt. Diff. |
|---|---|---|---|
| kpc | Kg/m^3 | Kg/m^3 | % |
| 8 | 2,7582E-22 | 2,85066E-22 | 3,3516E+00 |
| 9 | 2,2701E-22 | 2,39901E-22 | 5,6778E+00 |
| 10 | 1,8801E-22 | 1,89424E-22 | 7,5077E-01 |
| 11 | 1,5678E-22 | 1,52977E-22 | 2,4252E+00 |
| 12 | 1,3166E-22 | 1,28740E-22 | 2,2139E+00 |
| 13 | 1,1133E-22 | 1,05185E-22 | 5,5230E+00 |
| 14 | 9,4793E-23 | 9,11187E-23 | 3,8759E+00 |
| 15 | 8,1240E-23 | 7,97755E-23 | 1,8027E+00 |
| 16 | 7,0061E-23 | 6,90278E-23 | 1,4744E+00 |
| 17 | 6,0778E-23 | 6,02545E-23 | 8,6112E-01 |
| 18 | 5,3019E-23 | 5,30066E-23 | 2,4323E-02 |
| 19 | 4,6495E-23 | 4,69549E-23 | 9,8992E-01 |
| 20 | 4,0974E-23 | 4,18536E-23 | 2,1465E+00 |
| 21 | 3,6276E-23 | 3,75165E-23 | 3,4182E+00 |
| 22 | 3,2257E-23 | 3,30733E-23 | 2,5295E+00 |




## 8. BERNOULLI DIFFERENTIAL EQUATION FOR GRAVITATIONAL FIELD IN M33 HALO

It will be considered the region 8 Kpc < Radius < 22 Kpc where density of baryonic matter is negligible versus baryonic density. So for radius bigger than 8 Kpc, it will be considered that derivative of M(r) depend on dark matter density only. Results at the end of chapter might suggest that this hypothesis it is not very good for 8 kpc although it would be good for radius bigger than 10 kpc.

As it is known in this formula $E = G\dfrac{M(r)}{r^2}$ , M(r) represents mass enclosed by a sphere with radius r. If it is considered radius > 8 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= 29,02219371 B= 2,242193511 then $M'(r) = 4\pi r^2 \cdot A{\cdot}E^B$
Now it will differentiated E(r) when r > 8 Kpc

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

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

$E'(r) = K{\cdot}E^B(r) - 2\dfrac{E(r)}{r}$ being $K = 4\pi{\cdot}G{\cdot}A$ then K= 2,43367309·10$^{-8}$ I.S. as A= 29,022119371

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

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:

$\alpha = 2B - 2$ = 2.484387022

$\beta = \frac{1}{1-B}$ = - 0.80502755

$D = \left( \frac{K(1-B)}{3-2B} \right)$ = $2.03659 \cdot 10^{-8}$

**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 $R_O$ | Virial $E_O$ | C |
|---|---|---|
| Kpc | m/s^2 | I.S. |
| 22 | 2,10E-11 | 8,052965E-40 |
| 20 | 2,33E-11 | 7,986818E-40 |
| 18 | 2,59E-11 | 8,278137E-40 |
| 16 | 2,91E-11 | 8,483274E-40 |
| 14 | 3,29E-11 | 9,178529E-40 |
| 12 | 3,84E-11 | 8,921487E-40 |
| 10 | 4,57E-11 | 8,886540E-40 |
| 8 | 5,48E-11 | 1,197559E-39 |

As it was expected parameter C is very similar for different initial condition, although its value for R = 8 kpc is clearly different the other ones. This fact shows clearly that hypothesis about Density of baryonic matter is negligible versus DM density is not good for radius = 8 kpc.

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

| Initial condition values Ro & Eo | |
|---|---|
| Ro = | 17 Kpc |
| Eo = | 2,74E-11 m/s$^2$ |
| C = | $8{,}40\cdot 10^{-40}$ 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 8 kpc < Radius < 22 kpc |
|---|
| $E_{BER}(r) = \left(Cr^{\alpha} + Dr\right)^{\beta}$ C = $8.40 \cdot 10^{-40}$ D= $2.03659 \cdot 10^{-8}$ $\alpha$ = 2.484387022 $\beta$ = -0.80502755 |

**8.1 BERNOULLI PROFILE OF DARK MATTER DENSITY FOR M33 GALAXY**

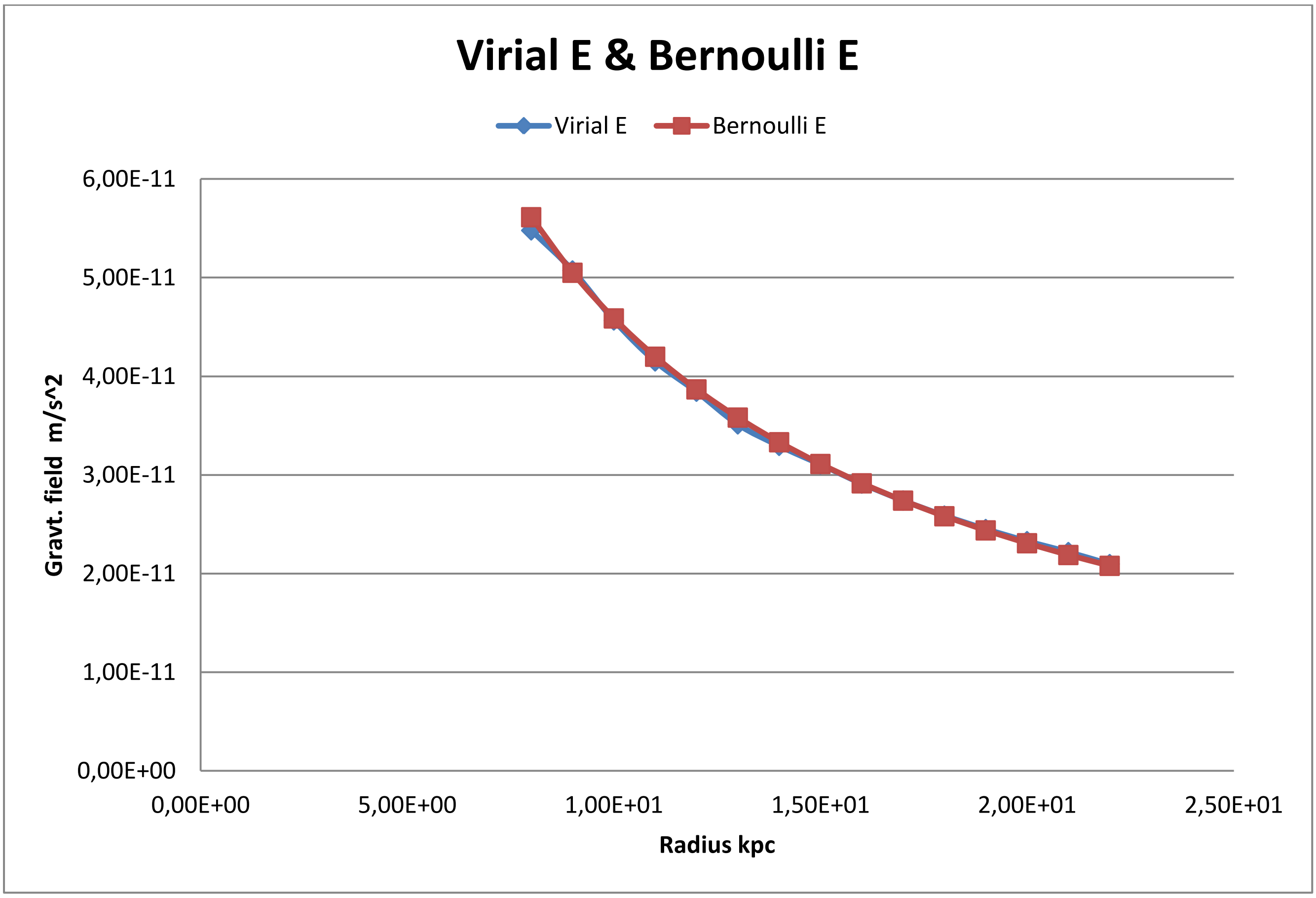
Thanks Bernoulli solution for gravitational field is right to get DM density through power of E formula.

| DM Density Bernoulli profile for M33 inside halo 8 kpc < radius < 22 kpc |
|---|
| $E_{BER}(r) = \left(Cr^{\alpha} + Dr\right)^{\beta}$ C = $8{,}40 \cdot 10^{-40}$ D= $2{,}03659 \cdot 10^{-8}$ $\alpha$ = 2,484387022 $\beta$ = -0,80502755 |
| Density $_{\text{D.M. BERNOULLI}}$ ( r ) = $D_{DM\,B}$( r ) = $A\cdot E^{B}$ Where A= 29.02219371 & B= 2.242193511 unit Kg/ m$^3$ |

## 9. COMPARISON BETWEEN BERNOULLI AND BURKETT PROFILES

### 9.1 COMPARISON BETWEEN VIRIAL GRAVT. FIELD AND BERNOULLI SOLUTION FOR E

| Radius | Virial E | Bernoulli E | Rel. diff. |
|---|---|---|---|
| kpc | m/s^2 | m/s^2 | % |
| 8,00E+00 | 5,48E-11 | 5,61E-11 | 2,38E+00 |
| 9,00E+00 | 5,07E-11 | 5,05E-11 | 4,68E-01 |
| 1,00E+01 | 4,57E-11 | 4,59E-11 | 4,52E-01 |
| 1,10E+01 | 4,15E-11 | 4,20E-11 | 1,13E+00 |
| 1,20E+01 | 3,84E-11 | 3,87E-11 | 6,15E-01 |
| 1,30E+01 | 3,51E-11 | 3,58E-11 | 1,93E+00 |
| 1,40E+01 | 3,29E-11 | 3,33E-11 | 1,11E+00 |
| 1,50E+01 | 3,11E-11 | 3,11E-11 | 1,68E-01 |
| 1,60E+01 | 2,91E-11 | 2,92E-11 | 1,14E-01 |
| 1,70E+01 | 2,74E-11 | 2,74E-11 | 3,34E-02 |
| 1,80E+01 | 2,59E-11 | 2,58E-11 | 2,65E-01 |
| 1,90E+01 | 2,45E-11 | 2,44E-11 | 5,72E-01 |
| 2,00E+01 | 2,33E-11 | 2,31E-11 | 9,46E-01 |
| 2,10E+01 | 2,22E-11 | 2,19E-11 | 1,38E+00 |
| 2,20E+01 | 2,10E-11 | 2,08E-11 | 8,54E-01 |
| | | Tot sum % -> | 1,24E+01 |
| | | | |



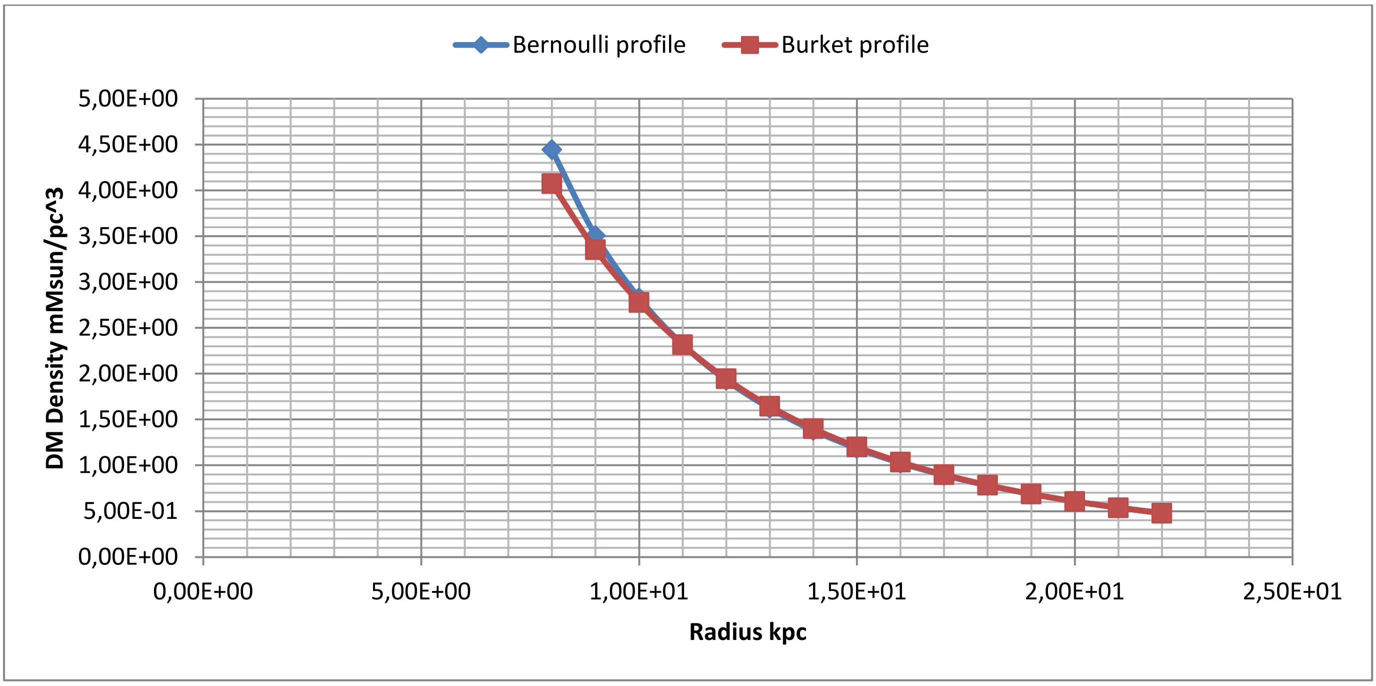
Bernoulli solution for gravitational field fits almost perfectly to Virial gravitational data got through observational values of spin speed of rotational curve of M33 galaxy.

### 9.2 COMPARISON BETWEEN BURKET DM PROFILE AND BERNOULLI DM PROFILE

| Radius | Bernoulli DM profile | Burket DM profile | Relt. Diff. |
|---|---|---|---|
| kpc | mMsun/pc^3 | mMsun/pc^3 | % |
| 8,00E+00 | 4,44E+00 | 4,07E+00 | 9,09E+00 |
| 9,00E+00 | 3,51E+00 | 3,35E+00 | 4,58E+00 |
| 1,00E+01 | 2,83E+00 | 2,78E+00 | 1,78E+00 |
| 1,10E+01 | 2,32E+00 | 2,32E+00 | 9,62E-02 |
| 1,20E+01 | 1,93E+00 | 1,94E+00 | 8,51E-01 |
| 1,30E+01 | 1,62E+00 | 1,64E+00 | 1,31E+00 |
| 1,40E+01 | 1,38E+00 | 1,40E+00 | 1,44E+00 |
| 1,50E+01 | 1,18E+00 | 1,20E+00 | 1,36E+00 |
| 1,60E+01 | 1,02E+00 | 1,03E+00 | 1,15E+00 |
| 1,70E+01 | 8,90E-01 | 8,98E-01 | 8,61E-01 |
| 1,80E+01 | 7,79E-01 | 7,83E-01 | 5,42E-01 |
| 1,90E+01 | 6,85E-01 | 6,87E-01 | 2,19E-01 |
| 2,00E+01 | 6,06E-01 | 6,05E-01 | 8,78E-02 |
| 2,10E+01 | 5,38E-01 | 5,36E-01 | 3,62E-01 |
| 2,20E+01 | 4,79E-01 | 4,76E-01 | 5,94E-01 |

Reader can check that relative differences are lower than 2% for radius bigger than 10 kpc., which is a superb result¡.

For radius 8 kpc and 9 kpc relative differences are a bit bigger because density of baryonic matter is not so negligible as happens for bigger radius.



**10. COMPARISON BETWEEN D.M. DENSITY DEPENDING ON  E  IN M33 AND NGC 3198 GALAXIES**

Below is reproduced  rotation curve of NGC 3198  published by [5] E.V. Karukes, 2015.

Taking that information from Karukes paper and with the same method followed in this paper by M33 I have got Bernoulli DM profile for NGC 3198 and results were published in **[3**] Abarca,M.2015.

Rotation velocity is approximately 150 Km/s inside flat area, this velocity is bigger than velocity in M33. Reason why dark matter density is lower in NGC 3198 than DM density in M33 is that NGC 3198 is a galaxy more massive than M33. In paper [**2**] Abarca,M.2015  are exposed what is the reason, in my view,  to explain why  the more massive galaxies the less  DM density.

*A&A proofs:* manuscript no. N3198A_A2col

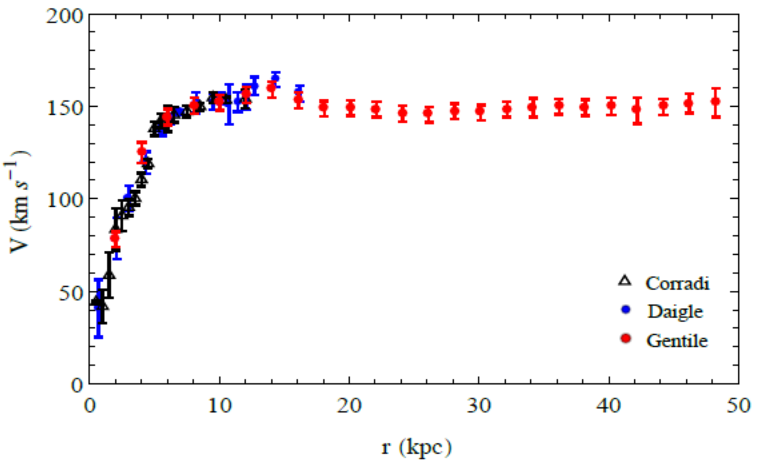



**Fig. 1.** Comparison between Hα and HI RCs black open triangles with error bars from Corradi et al. (1991), blue circles with error bars are from Daigle et al. (2006), and red circles with error bars are from Gentile et al. (2013).

**10.1 DARK MATTER DENSITY DEPENDING ON GRAVITATIONAL FIELD IN NGC 3198**

As galactic radius is approximately 15 kpc data of DM was studied for radius bigger than 20 kpc in order to assure that density of baryonic matter is negligible. Below are  results  published  in **[3**] Abarca,M.2015 about  DM density depending on E.

| NGC 3198   Galaxy | | | |
|---|---|---|---|
| Radius kpc | Virial E m/s^2 | DM  Den. data kg/m^3 | DM  Den. data mMsunes/pc^3 |
| 20,1 | 3,58E-11 | 5,8E-23 | 8,57E-01 |
| 22,1 | 3,23E-11 | 4,80E-23 | 7,09E-01 |
| 24,1 | 2,87E-11 | 4,20E-23 | 6,21E-01 |
| 26,1 | 2,63E-11 | 3,60E-23 | 5,32E-01 |
| 28,1 | 2,50E-11 | 3,30E-23 | 4,88E-01 |
| 30,2 | 2,30E-11 | 3,00E-23 | 4,43E-01 |
| 32,2 | 2,22E-11 | 2,70E-23 | 3,99E-01 |
| 34,2 | 2,11E-11 | 2,50E-23 | 3,69E-01 |
| 36,2 | 2,01E-11 | 2,30E-23 | 3,40E-01 |
| 38,2 | 1,89E-11 | 2,10E-23 | 3,10E-01 |
| 40,2 | 1,81E-11 | 2,00E-23 | 2,96E-01 |

| | | | |
|---|---|---|---|
| 42,1 | 1,73E-11 | 1,80E-23 | 2,66E-01 |
| 44,2 | 1,65E-11 | 1,60E-23 | 2,36E-01 |
| 46,2 | 1,61E-11 | 1,30E-23 | 1,92E-01 |

Doing power regression of measures into international system, formula for DM Density as Power of E is:

$D_{DM\ PwE} = A \cdot E^B$ Where A= 4,04598703 $\cdot 10^{-5}$ B= 1,70654481 being correlation coefficient r = 0,9899977.

### 10.2 DARK MATTER DENSITY DEPENDING ON GRAVITATIONAL FIELD IN M33

| M33 Galaxy | | | |
|---|---|---|---|
| Radius | Virial E | Burket DM | Burket DM |
| kpc | m/^2 | mMsun/pc^3 | Kg/m^3 |
| 8 | 5,48E-11 | 4,07417343 | 2,7582E-22 |
| 9 | 5,07E-11 | 3,35320417 | 2,2701E-22 |
| 10 | 4,57E-11 | 2,77714286 | 1,8801E-22 |
| 11 | 4,15E-11 | 2,31578546 | 1,5678E-22 |
| 12 | 3,84E-11 | 1,94468453 | 1,3166E-22 |
| 13 | 3,51E-11 | 1,64451423 | 1,1133E-22 |
| 14 | 3,29E-11 | 1,400189 | 9,4793E-23 |
| 15 | 3,10E-11 | 1,2 | 8,1240E-23 |
| 16 | 2,91E-11 | 1,03487045 | 7,0061E-23 |
| 17 | 2,74E-11 | 0,89775229 | 6,0778E-23 |
| 18 | 2,59E-11 | 0,7831535 | 5,3019E-23 |
| 19 | 2,45E-11 | 0,68677436 | 4,6495E-23 |
| 20 | 2,33E-11 | 0,60523039 | 4,0974E-23 |
| 21 | 2,22E-11 | 0,53584187 | 3,6276E-23 |
| 22 | 2,10E-11 | 0,47647433 | 3,2257E-23 |

In chapter 6 was calculated coefficient of formula into I.S.

$Density_{DARK\ MATTER} = A \cdot E^B$ , being A = 29,02219371 B= 2,242193511 and r = 0,9990083703

**10.3 COMPARISON OF BOTH GALAXIES**

In tables below has been selected common values of gravitational field for both galaxies.

| NGC 3198 Galaxy | |
|---|---|
| Virial E | DM Den. data |
| m/s^2 | mMsun/pc^3 |
| 3,58E-11 | 8,57E-01 |
| 3,23E-11 | 7,09E-01 |
| 2,87E-11 | 6,21E-01 |
| 2,63E-11 | 5,32E-01 |
| 2,50E-11 | 4,88E-01 |
| 2,30E-11 | 4,43E-01 |
| 2,22E-11 | 3,99E-01 |
| 2,11E-11 | 3,69E-01 |

| M33 Galaxy | |
|---|---|
| Virial E | Burket DM |
| m/^2 | mMsun/pc^3 |
| 3,51E-11 | 1,64451423 |
| 3,29E-11 | 1,400189 |
| 3,10E-11 | 1,2 |
| 2,91E-11 | 1,03487045 |
| 2,74E-11 | 0,89775229 |
| 2,59E-11 | 0,7831535 |
| 2,45E-11 | 0,68677436 |
| 2,33E-11 | 0,60523039 |
| 2,22E-11 | 0,53584187 |
| 2,10E-11 | 0,47647433 |

When are compared values of density which belong the same value of E, it is clearly shown that DM density is bigger in M33 regarding NGC 3198. Because M33 is less massive than NGC 3198.

In paper [**2**] Abarca,M.2015 were studied a set of sis big galaxies, whose velocity of rotation curve inside flat area is bigger than 200 km/s. It was checked that DM density at a specific value of E is lower inside these galaxies than DM density inside NGC 3198, because these galaxies are more massive than NGC 3198. Therefore it has been found that the more massive the galaxy the less DM density is at a specific value of E. Results also suggest that two galaxies with similar mass have similar DM density at a specific value of E.

## 11. CONCLUSION

It seem clear that inner logic of development this paper allow to state that this paper has demonstrated that DM origin is gravitational field.

This is the inner logic: Burket DM density profile, which has been got by meticulous measures of M33 rotation curve, is fitted with a function as power of E with a correlation coefficient bigger than 0.999. 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 Burket DM density getting relative differences under 2 % inside main part of dominion, exactly for radius bigger than 10 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. In other words, if two galaxies have similar mass their coefficients A and B are similar whereas a more massive galaxy has a lower DM density at a specific radius.

## 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**] E.Corbelli. 2014. arXiv:1409.2665v2
*Dynamical signatures of a* $\Lambda$ *CDM-halo and the distribution of the baryons in M33.*

**[5]** E.V. Karukes, 2015. A&A. N3198A.
*The dark matter distribution in the spiral NGC 3198 out to 0.22 Rvir*