MOND In Galactic Scales

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under supervising

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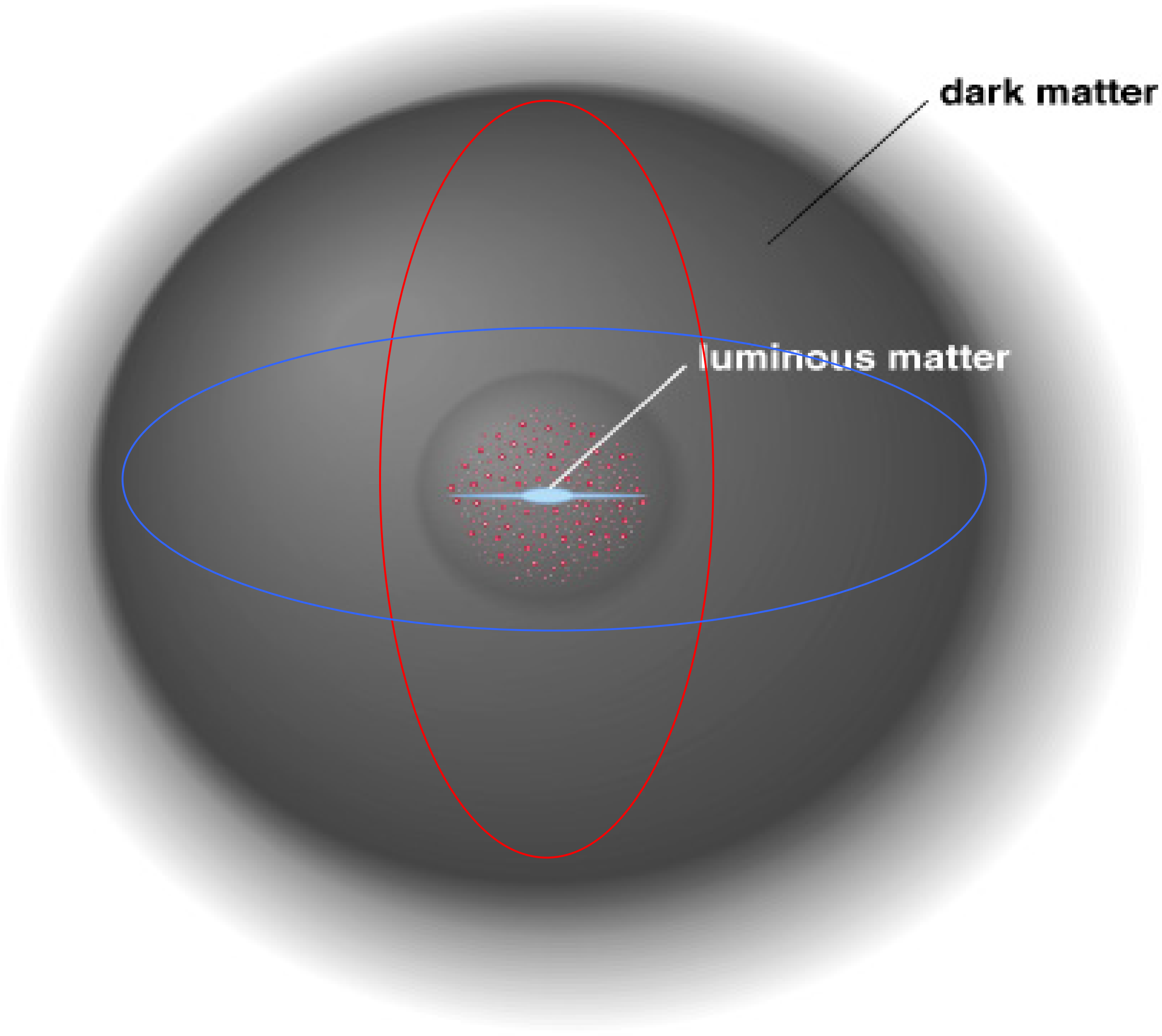
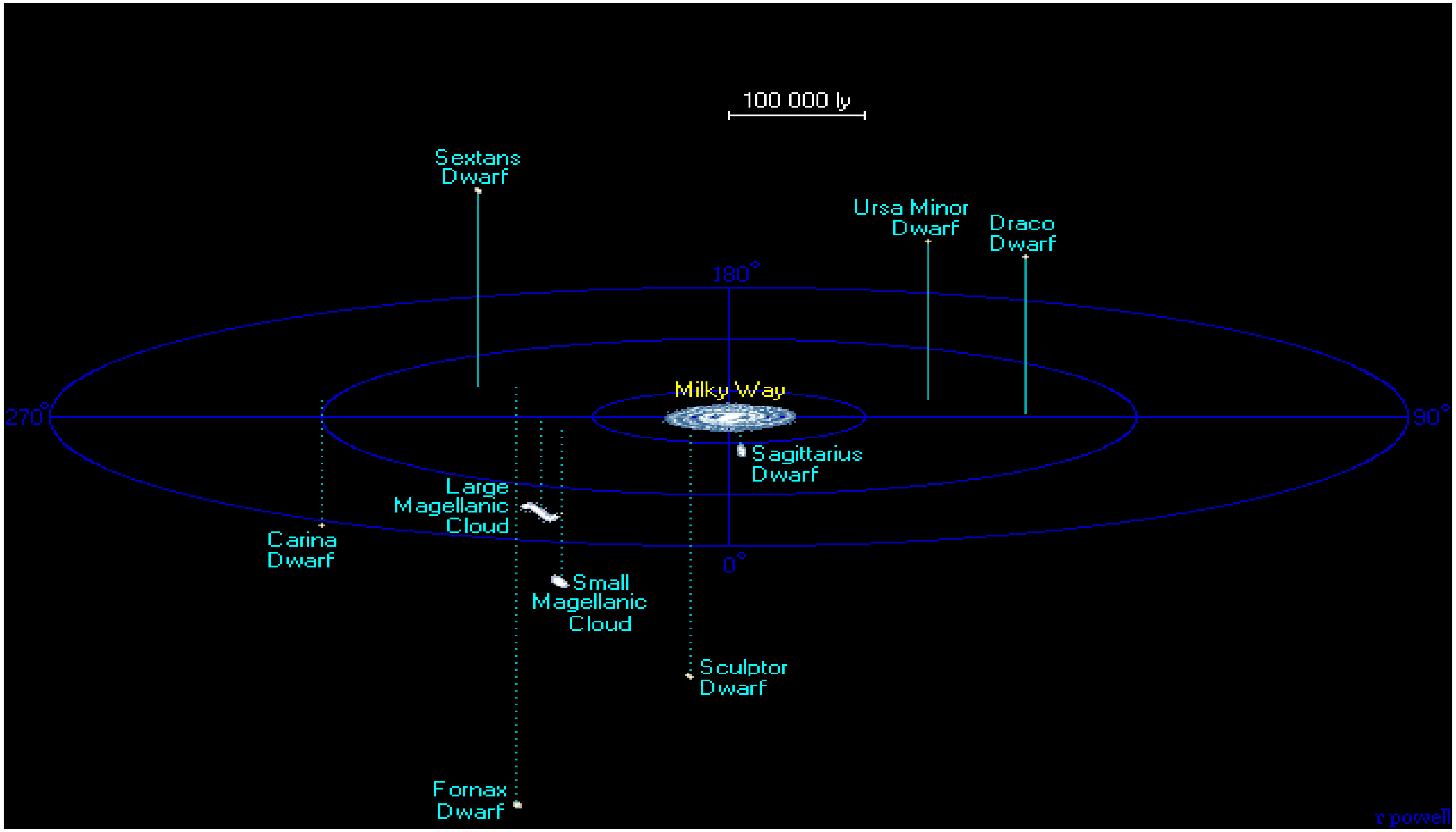
How is the shape of halo??

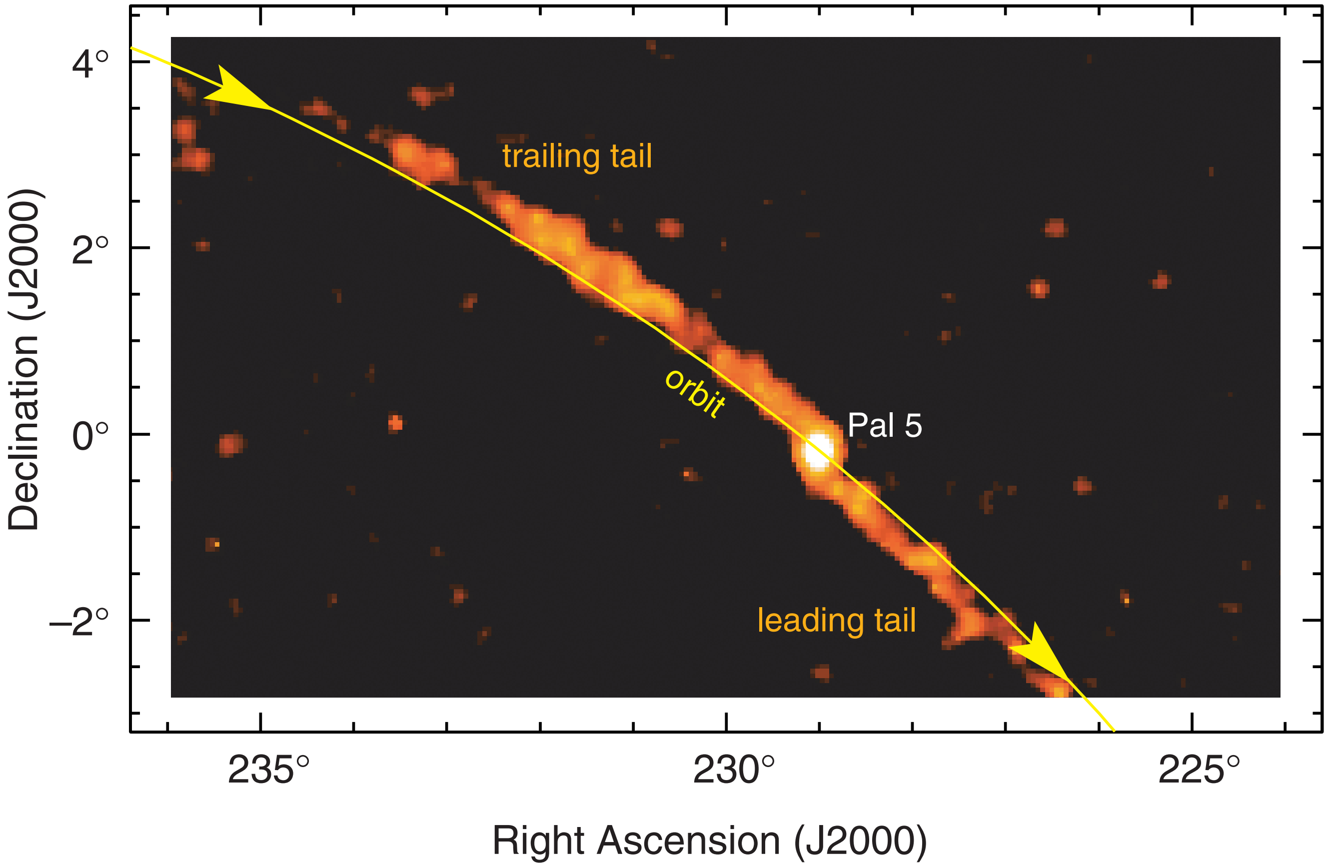
→ **Galactic models**



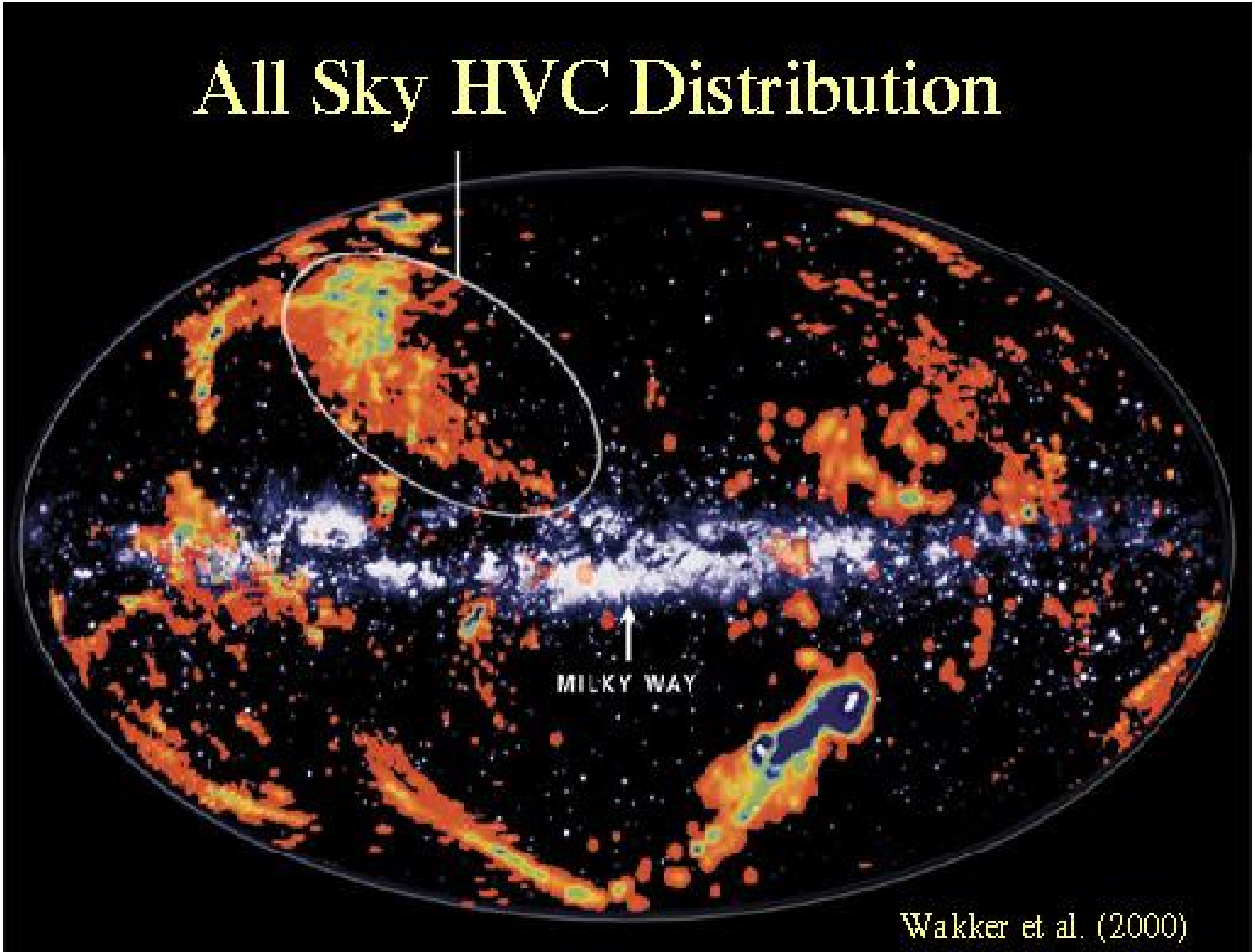
The MW's satellite provide information about the density of •
Galactic halo at large radii.



Discover tidal streams from globular clusters and dwarf galaxies in the Galactic halo (**Michael Odenkirchen, MPIA**)



High velocity clouds (HVCs) and Magellanic Stream(MS)

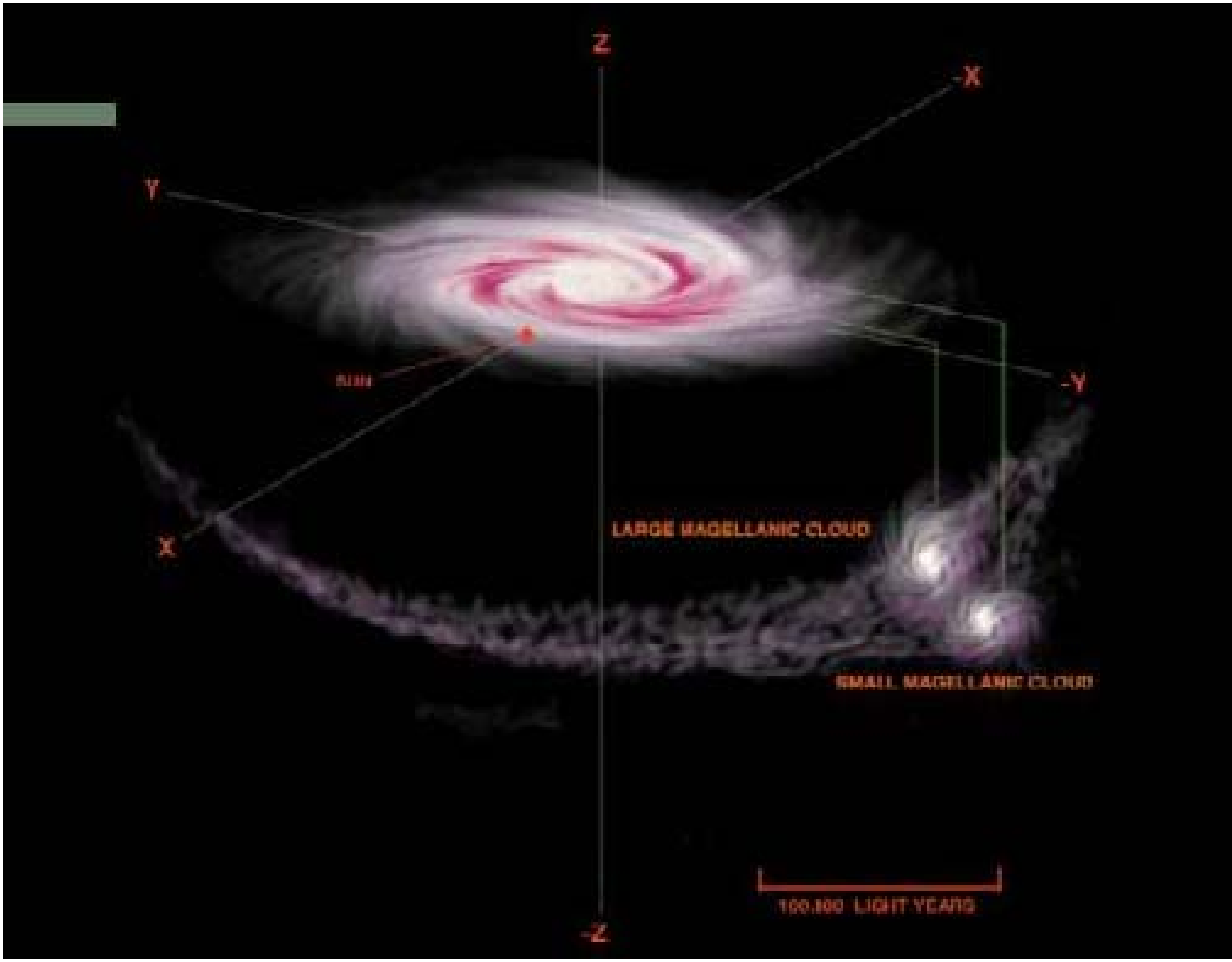


Magellanic systems

- A gaseous bridge connects the two galaxies (LMC, SMC) •

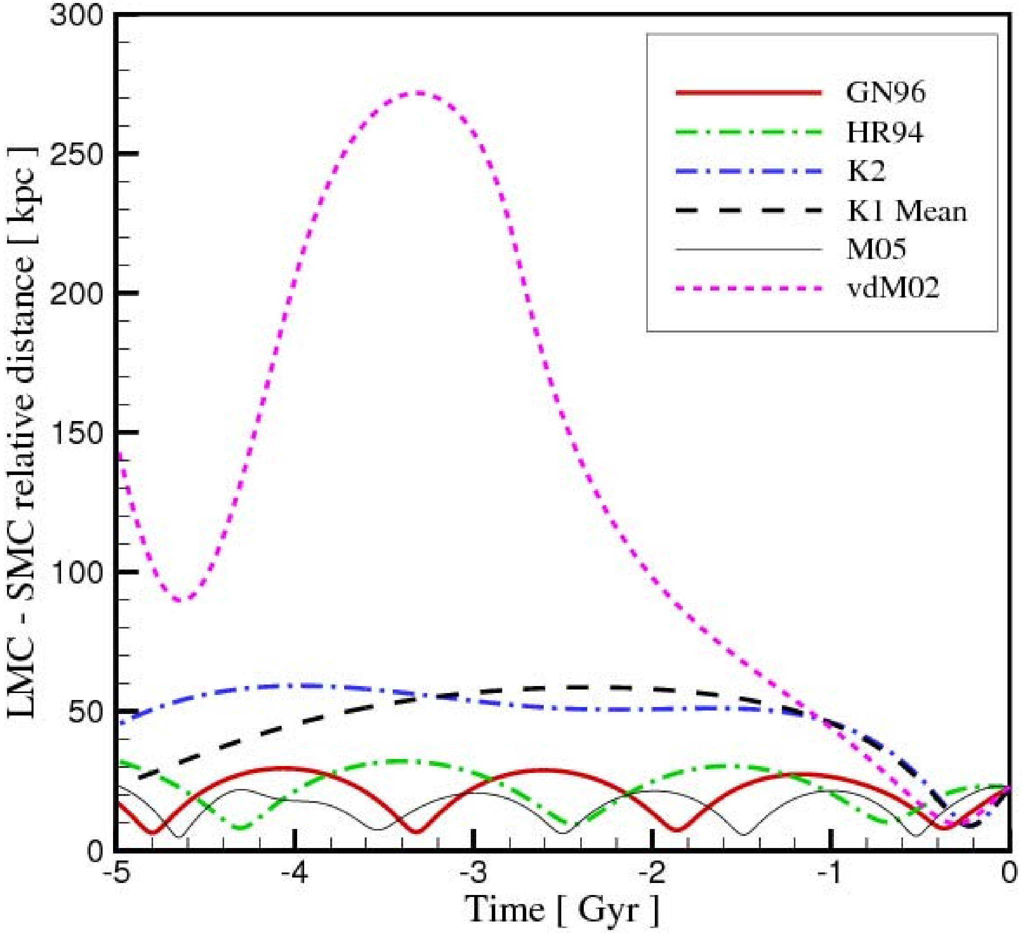
- The Magellanic Stream, is large gas stream extended from the • MCs into the bridge between the Magellanic Clouds, and goes towards south galactic pole.

The Magellanic Clouds orbit each other and made a close • approach to the Milky Way 200-800 million years ago

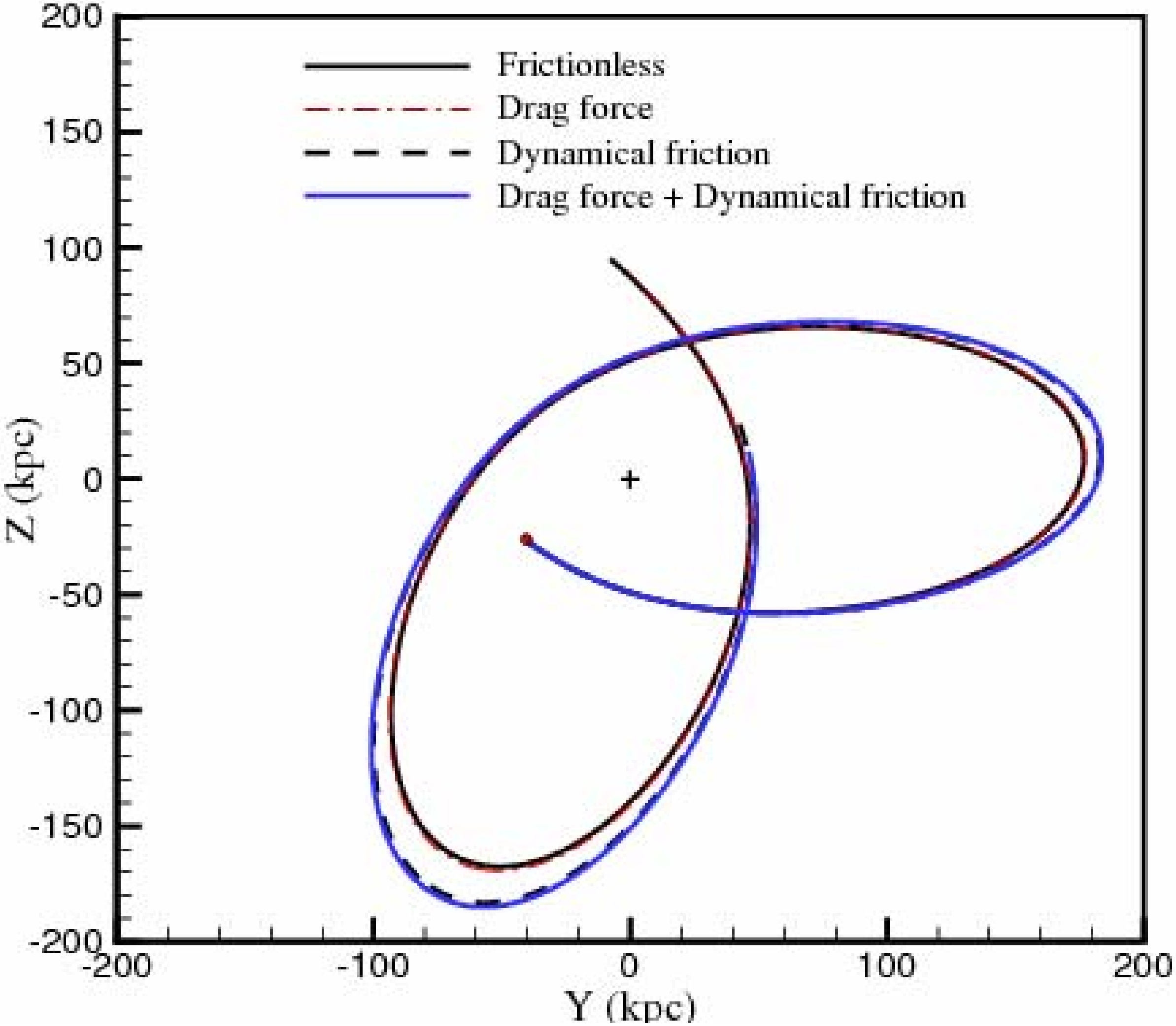


Z
-X
Y
SUN
-Y
X
LARGE MAGELLANIC CLOUD
SMALL MAGELLANIC CLOUD
100,000 LIGHT YEARS
-Z

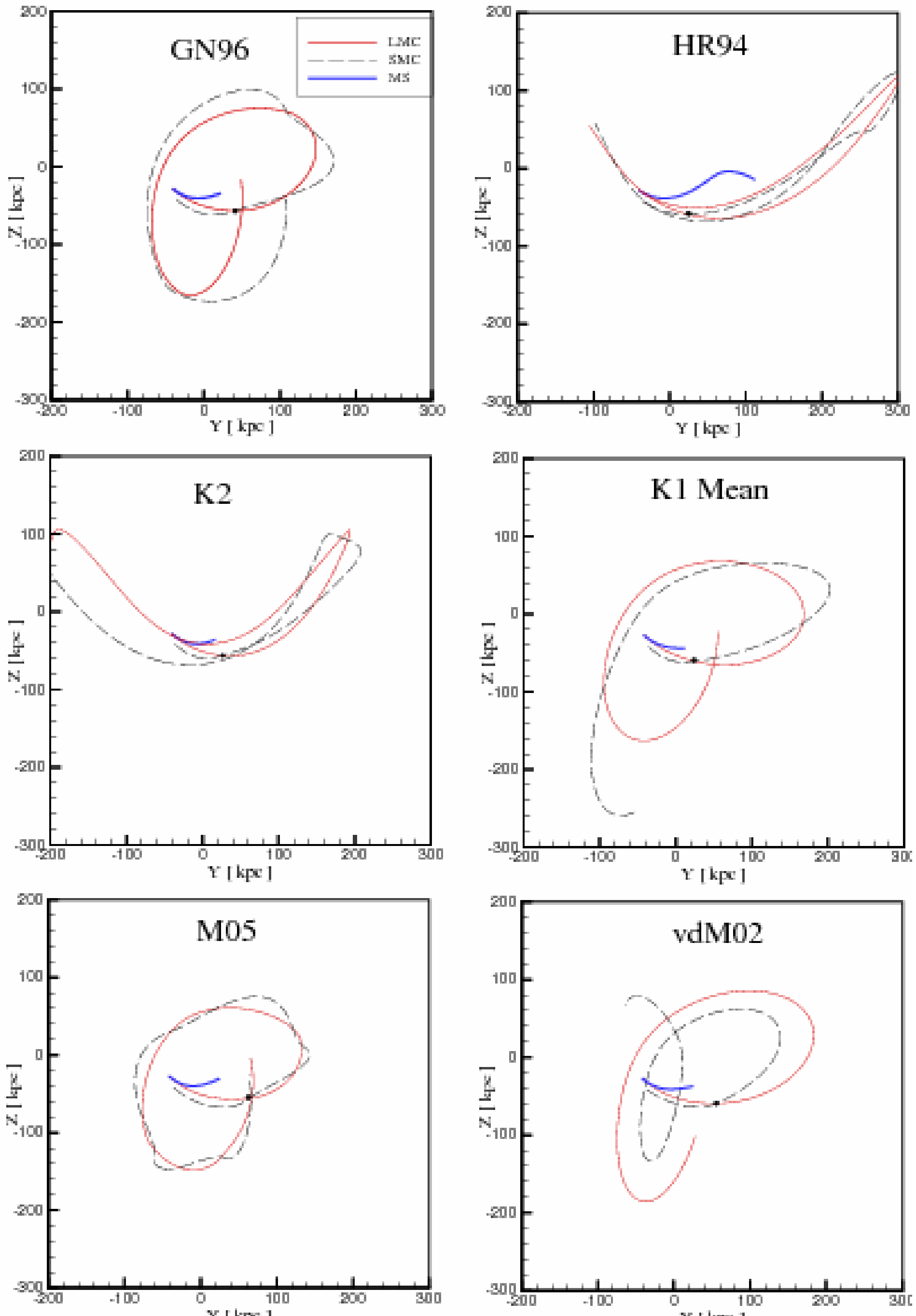
- Dynamics of Magellanic Clouds
  - initial condition????
- Dynamics of Magellanic Stream
- Various models for the origin and dynamics of MS
- Magellanic Stream: A Possible Tool for Studying Dark Halo Model (Submitted to A&A 2006)

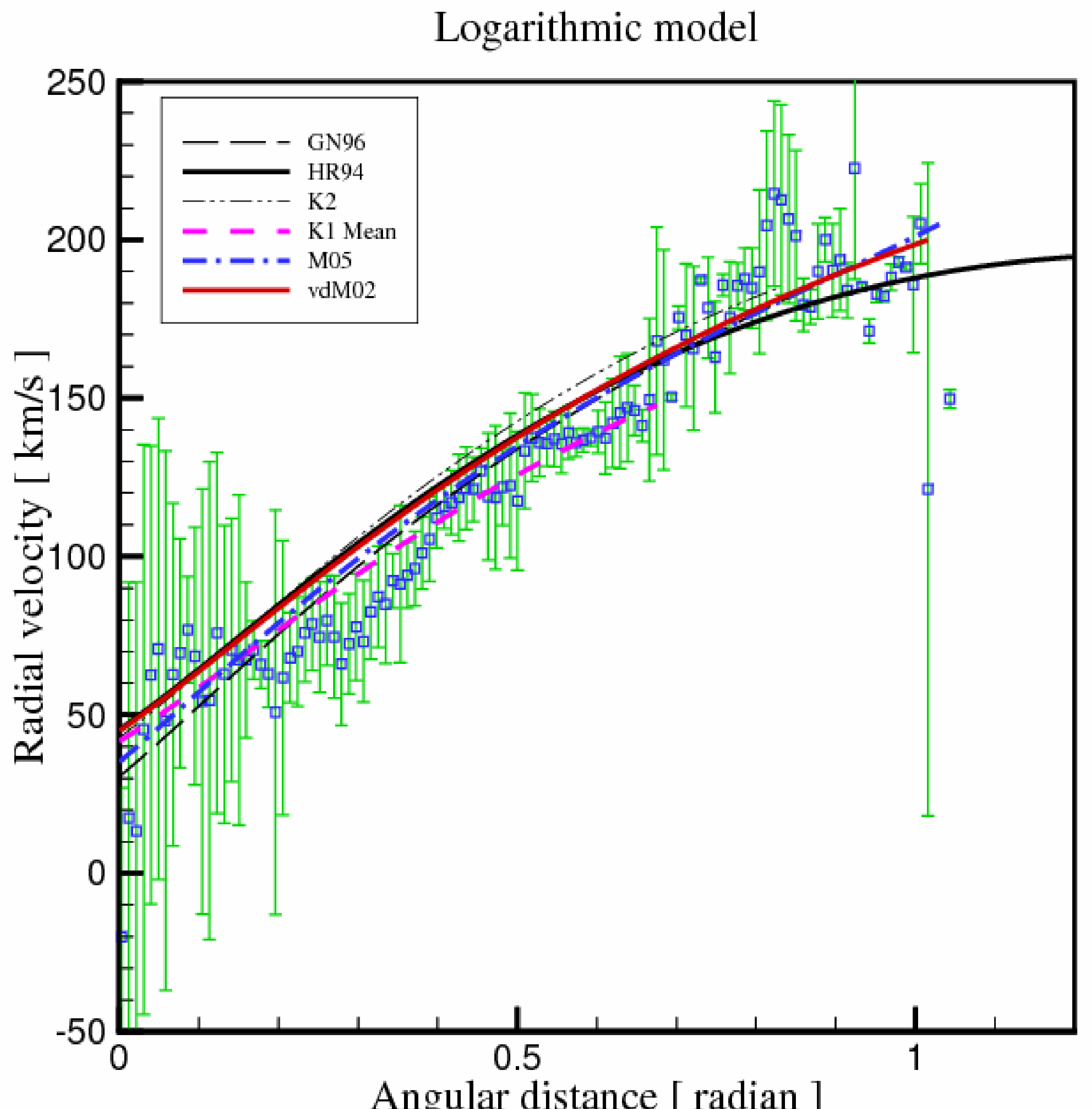


GN96
HR94
K2
K1 Mean
M05
vdM02
LMC - SMC relative distance [kpc]
Time [Gyr]
300
250
200
150
100
50
0
-5
-4
-3
-2
-1
0



Frictionless
Drag force
Dynamical friction
Drag force + Dynamical friction
200
150
100
50
0
-50
-100
-150
-200
Z (kpc)
-200
-100
0
100
200
Y (kpc)


GN96
LMC
SMC
MS
HR94
K2
K1 Mean
M05
vdM02
Z [kpc]
Y [kpc]
200
100
0
-100
-200
-300
-200
-100
0
100
200
300



Logarithmic model
GN96
HR94
K2
K1 Mean
M05
vdM02
250
200
150
100
50
0
-50
0
0.5
1
Radial velocity [km/s]
Angular distance [radian]

Problems with dark matter theory

-- Prediction of more substructure than what is seen •

(Moore et al. 1999 , Klypin et al 2000)

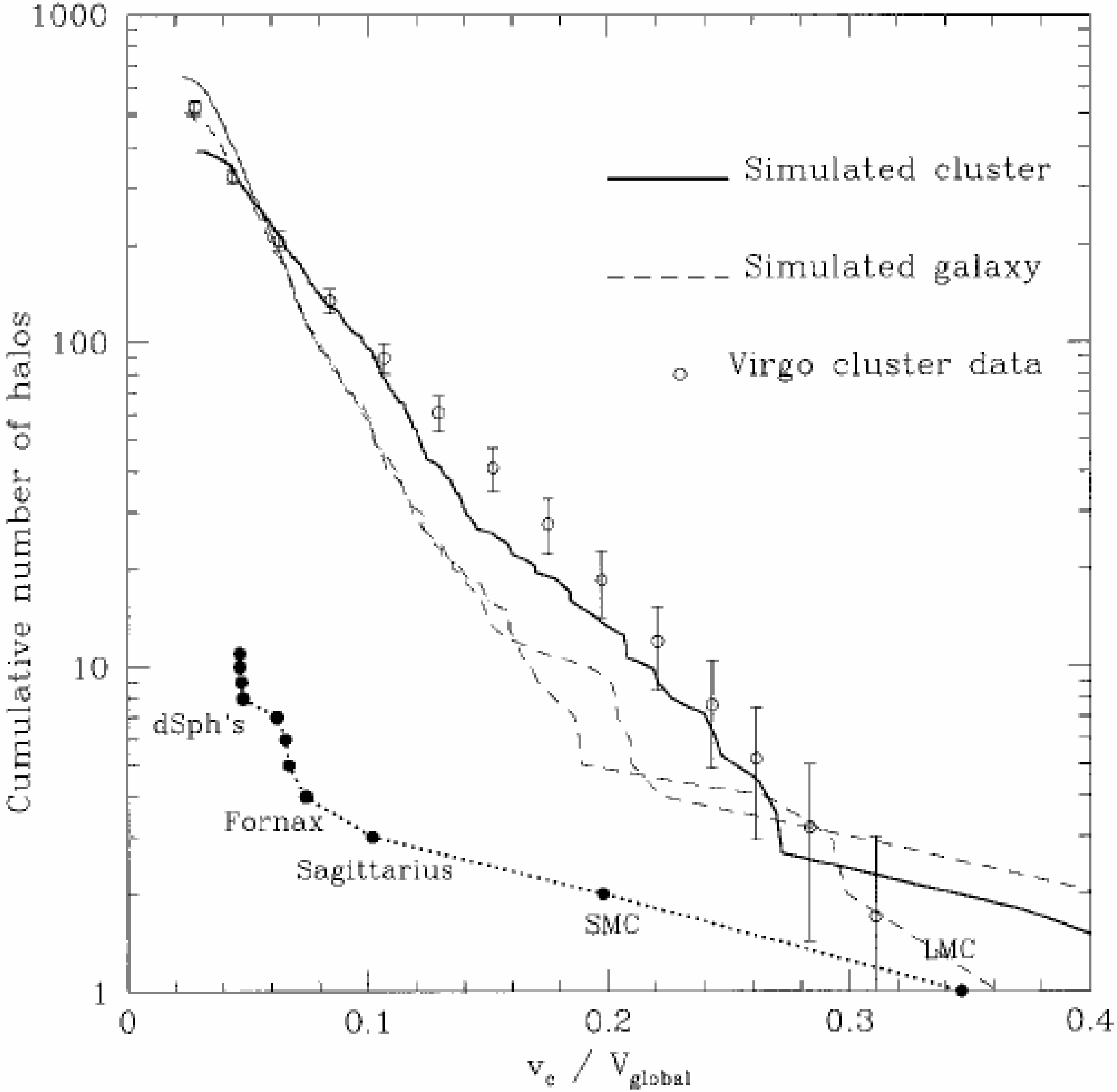
-- Prediction of overly dense cores in the center of • Galaxies and clusters (Moore et al. 1999 , Klypin et al 2000).

-- Fine tuning in dark matter halo shape parameters . In • other word More parameters acquired to fit RC.

-- Tully Fisher relation!! •

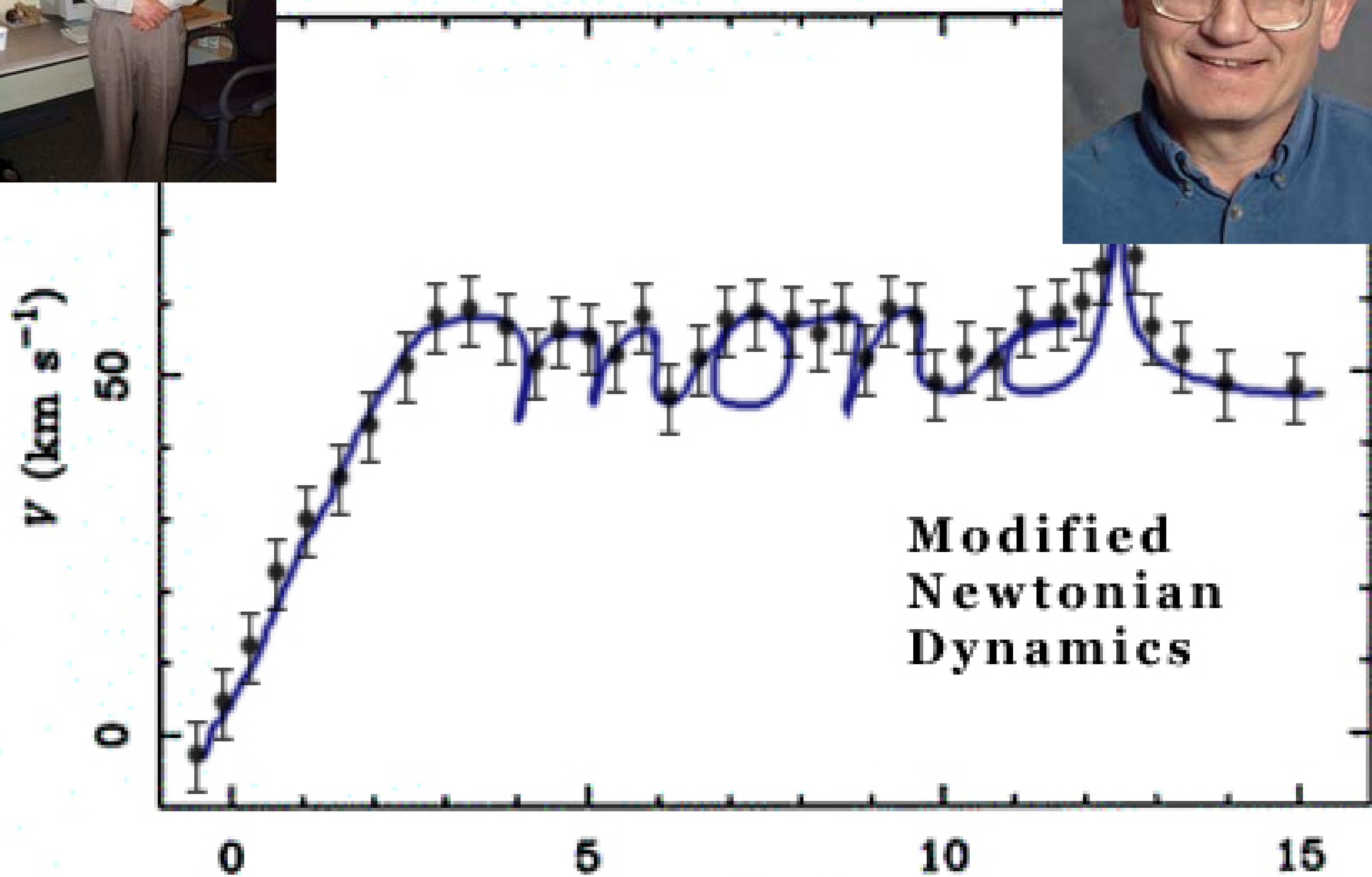
-- and . . . (Selwood and Kosowsky 2001)

•



Simulated cluster
Simulated galaxy
Virgo cluster data
dSph's
Fornax
Sagittarius
SMC
LMC
Cumulative number of halos
v_c / V_{global}
1000
100
10
1
0
0.1
0.2
0.3
0.4

Pamela Bingcang's MOND page



MONDian potential of disk

$$\underline{\nabla} \cdot [\mu(|\underline{\nabla}(\Phi)|/a_0)\underline{\nabla}\Phi] = 4\pi G\rho$$

$$\nabla \cdot \left[\frac{\|\nabla\Phi\|}{a_0}\nabla\Phi - \nabla\Phi_N\right] = 0$$

$$\frac{\|\nabla\Phi\|}{a_0}\nabla\Phi - \nabla\Phi_N = \nabla \times \mathbf{h}$$

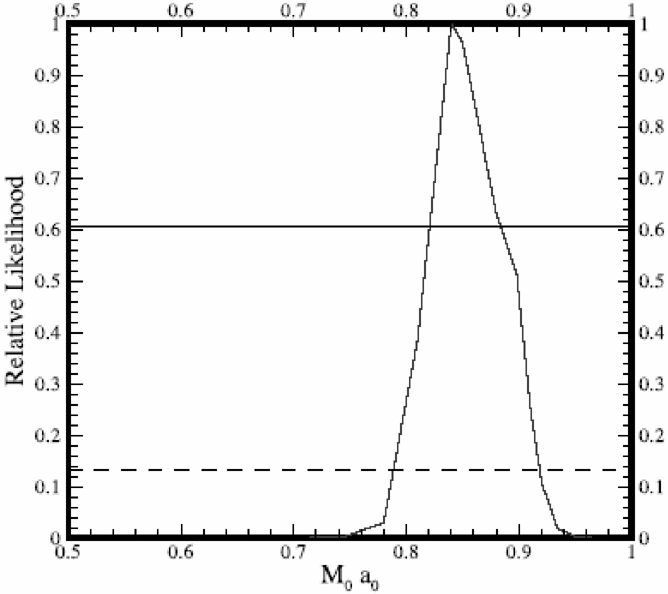
$$\mu(|\underline{g}|/a_0)\underline{g} = \underline{g_N}$$

$$\mu(x) \;=\; x(1 + x^2)^{-1/2}$$

$$\underline{g} = \underline{g_N}\,\frac{\left(1 + \sqrt{1 + 4a_0^2/|\underline{g_N}|^2}\right)^{1/2}}{\sqrt{2}}$$

$$\Phi_N(R,z) = \frac{-GM}{\sqrt{R^2 + (a + |z|)^2}}$$

$$\Phi \simeq \frac{(MGa_0)^{1/2}}{2}\ln(R^2 + (|z| + a)^2)$$



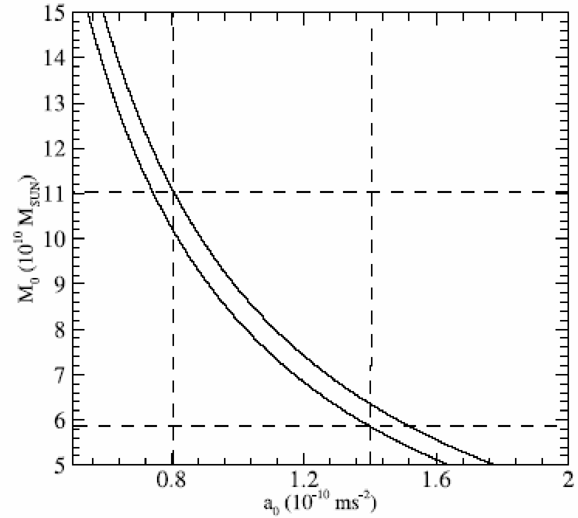
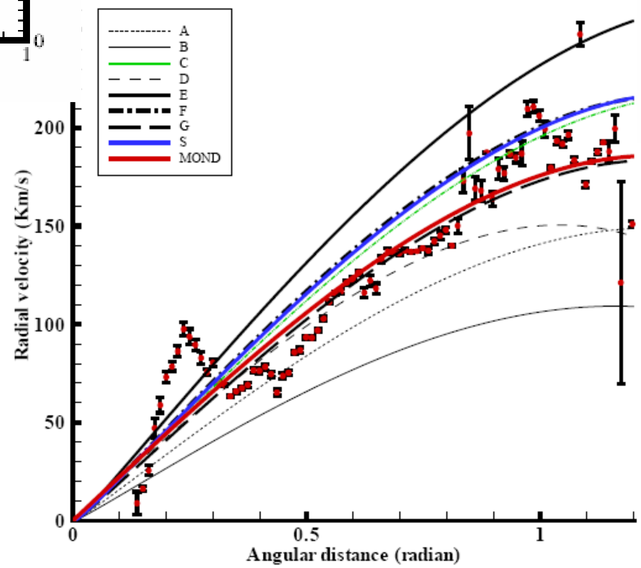


FIG. 4.—Constraints on $M_0 a_0 = 8.4^{+0.5}_{-0.2}$ from the maximum likelihood analysis, with 1 σ confidence interval (M_0 in terms of $10^{10}\ M_\odot$ and MONDian acceleration scale a_0 in terms of 10^{-10} m s^{-2}). Using the range $a_0 = 0.8$–1.4 implies $M_0 = 6$–11 for the mass of the Kuzmin disk.



The Magellanic Stream in Modified Newtonian Dynamics

Haghi , Rahvar & Hasani (2006 ApJ...652..354H)

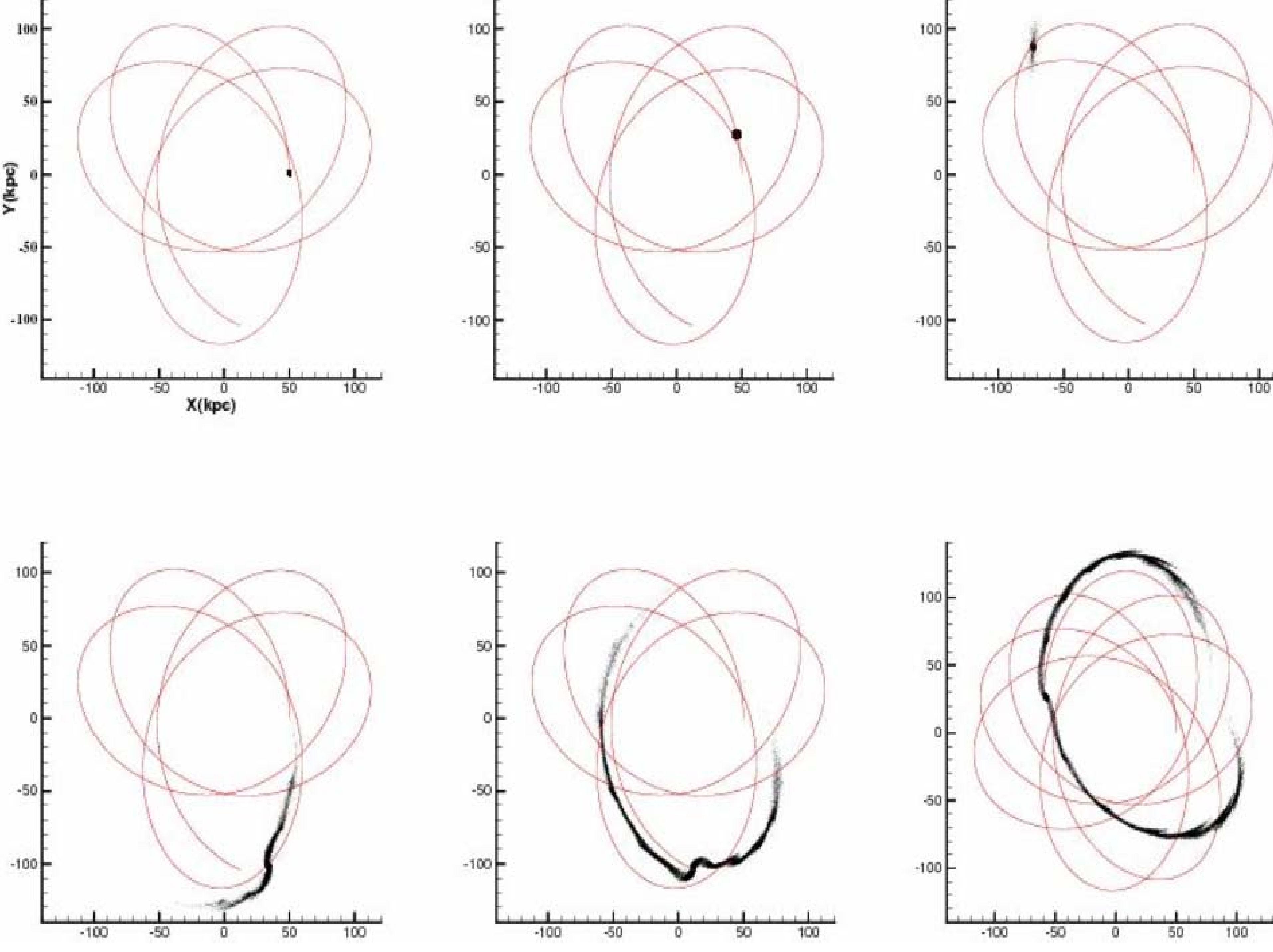
Globular Clusters

A Test of Newton's Law of Gravity in the Weak Acceleration Regime :

1- Globular Clusters as a Test for Gravity in the Weak Acceleration Regime

(R. Scarpa 2003, H.Baumgardt 2005, H.S.Zhao 2005)

2 -Testing MOND with Ultra-Compact Dwarf Galaxies (**R. Scarpa 2005**)


Y(kpc)
X(kpc)
100
50
0
-50
-100
-100
-50
0
50
100

Orbital family of Kuzmin disk in MONDian regime (Haghi, Jalali, Zhao, Rahvar) In preparation

In dMOND regime the equation of motion is:

$$\ddot{z} = -\sqrt{GMa_0}\left(\frac{z \pm a}{R^2 + (z \pm a)^2}\right)$$

$$\ddot{R} = -\sqrt{GMa_0}\left(\frac{R}{R^2 + (z \pm a)^2}\right)$$

In TeVeS model $g = g_N + g_s$, So that for Bekenstein μ-function we have:

$$\mu(s)\mathbf{g}_s = \mathbf{g}_N, \mu(s) = \frac{g^s}{a_0}$$

$$\mathbf{g} = \mathbf{g}_N + \mathbf{g}_N\sqrt{\frac{a_0}{g_N}}$$

$$\ddot{z} = -\left(\frac{\sqrt{GMa_0}}{R^2 + (z \pm a)^2} + \frac{GM}{[R^2 + (z \pm a)^2]^{3/2}}\right)(z \pm a)$$

$$\ddot{R} = -\left(\frac{\sqrt{GMa_0}}{R^2 + (z \pm a)^2} + \frac{GM}{[R^2 + (z \pm a)^2]^{3/2}}\right)R$$

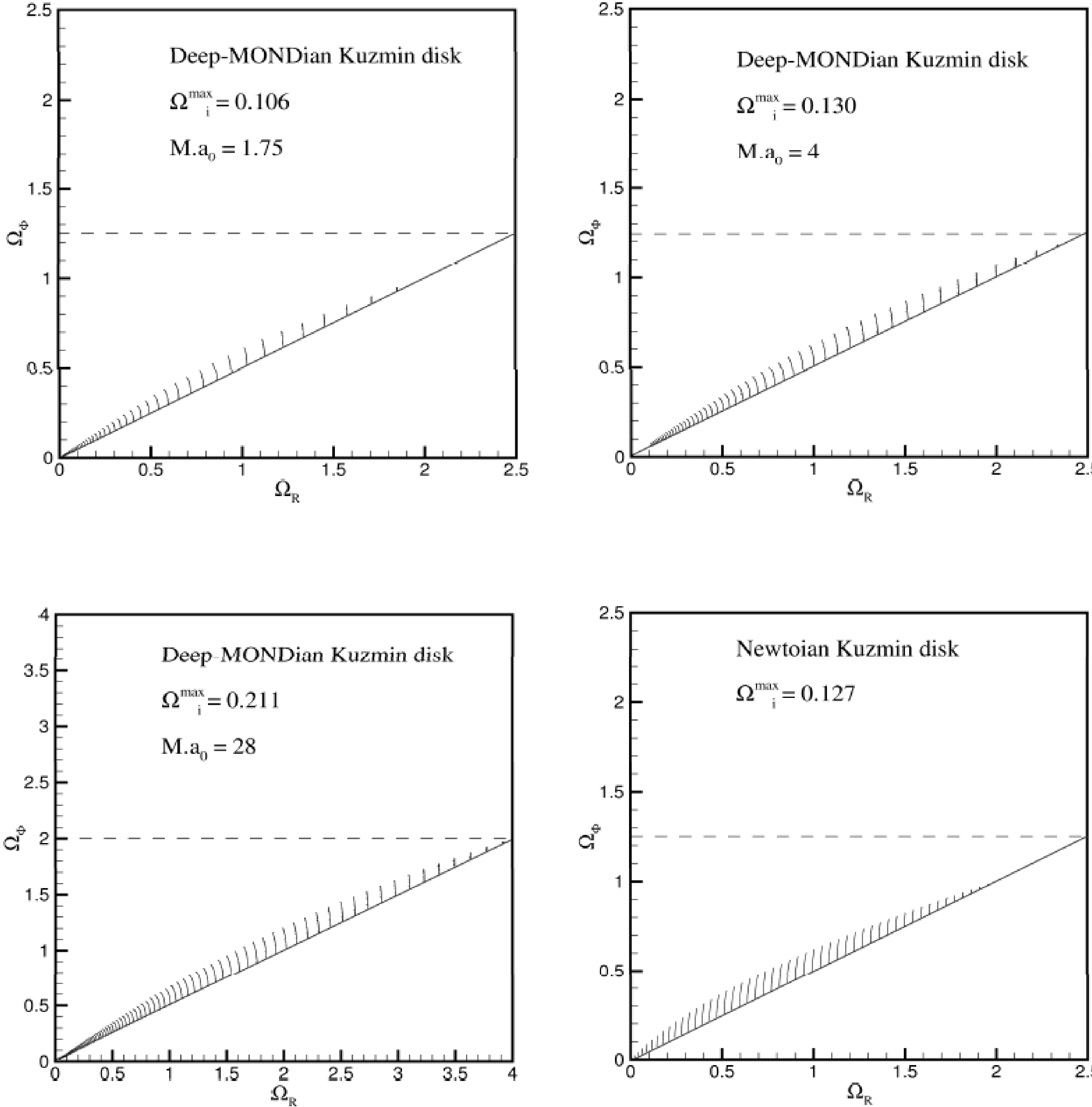
Orbital in Equatorial Plane

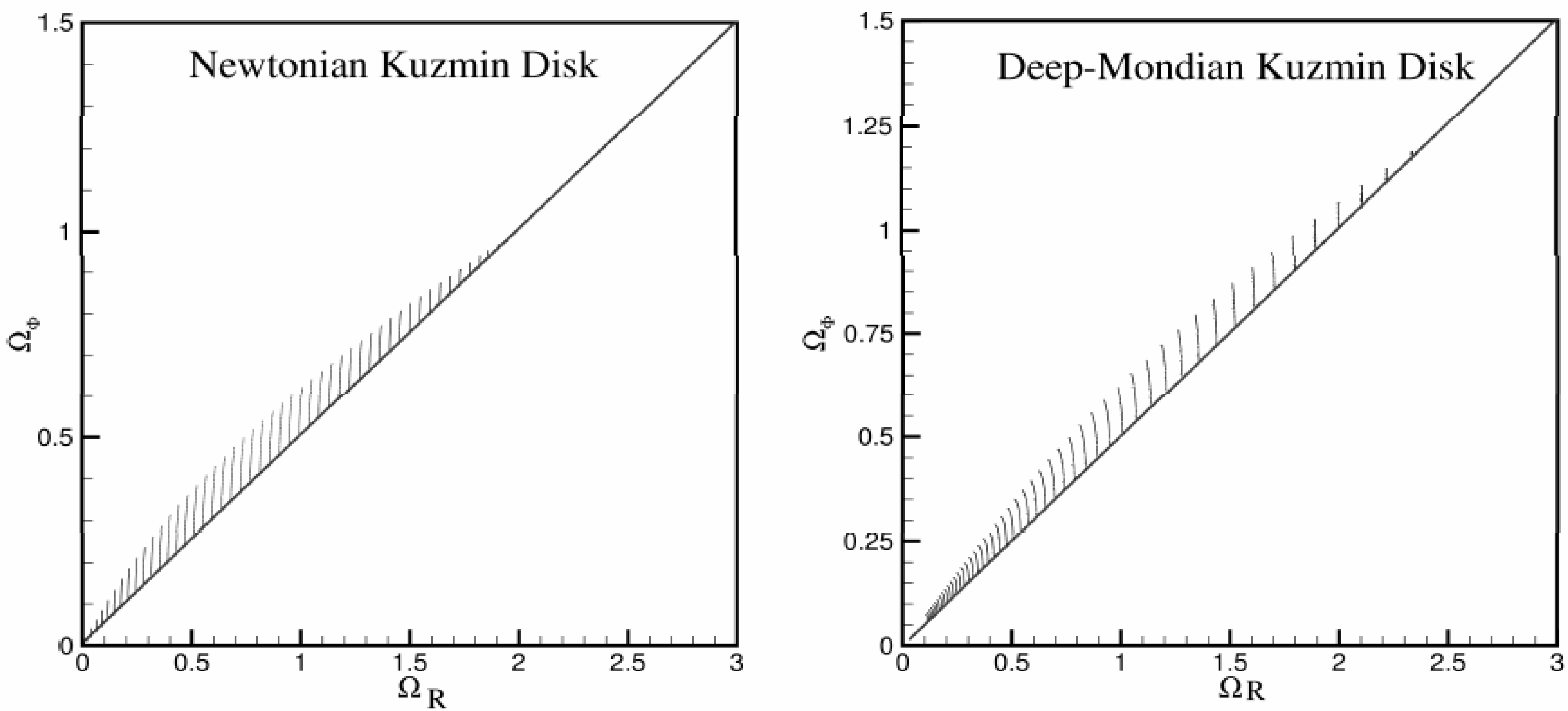
In Teves:

$$\ddot{R} = -(\frac{\sqrt{GMa_0}}{R^2 + a^2} + \frac{GM}{[R^2 + a^2]^{3/2}})R$$

In CDM:

$$\ddot{R}^N = (\frac{-V_0^2}{[R^2 + R_c^2]} + \frac{GM}{[R^2 + a^2]^{3/2}})R$$


Deep-MONDian Kuzmin disk
Ω^max_i = 0.106
M.a_0 = 1.75
Deep-MONDian Kuzmin disk
Ω^max_i = 0.130
M.a_0 = 4
Deep-MONDian Kuzmin disk
Ω^max_i = 0.211
M.a_0 = 28
Newtoian Kuzmin disk
Ω^max_i = 0.127
Ω_Φ
Ω_R
0
0.5
1
1.5
2
2.5
3
3.5
4


Newtonian Kuzmin Disk
Deep-Mondian Kuzmin Disk
Ω_ϕ
Ω_R
0
0.5
1
1.5
2
2.5
3
0.25
0.75
1.25

Galaxy merging in MOND

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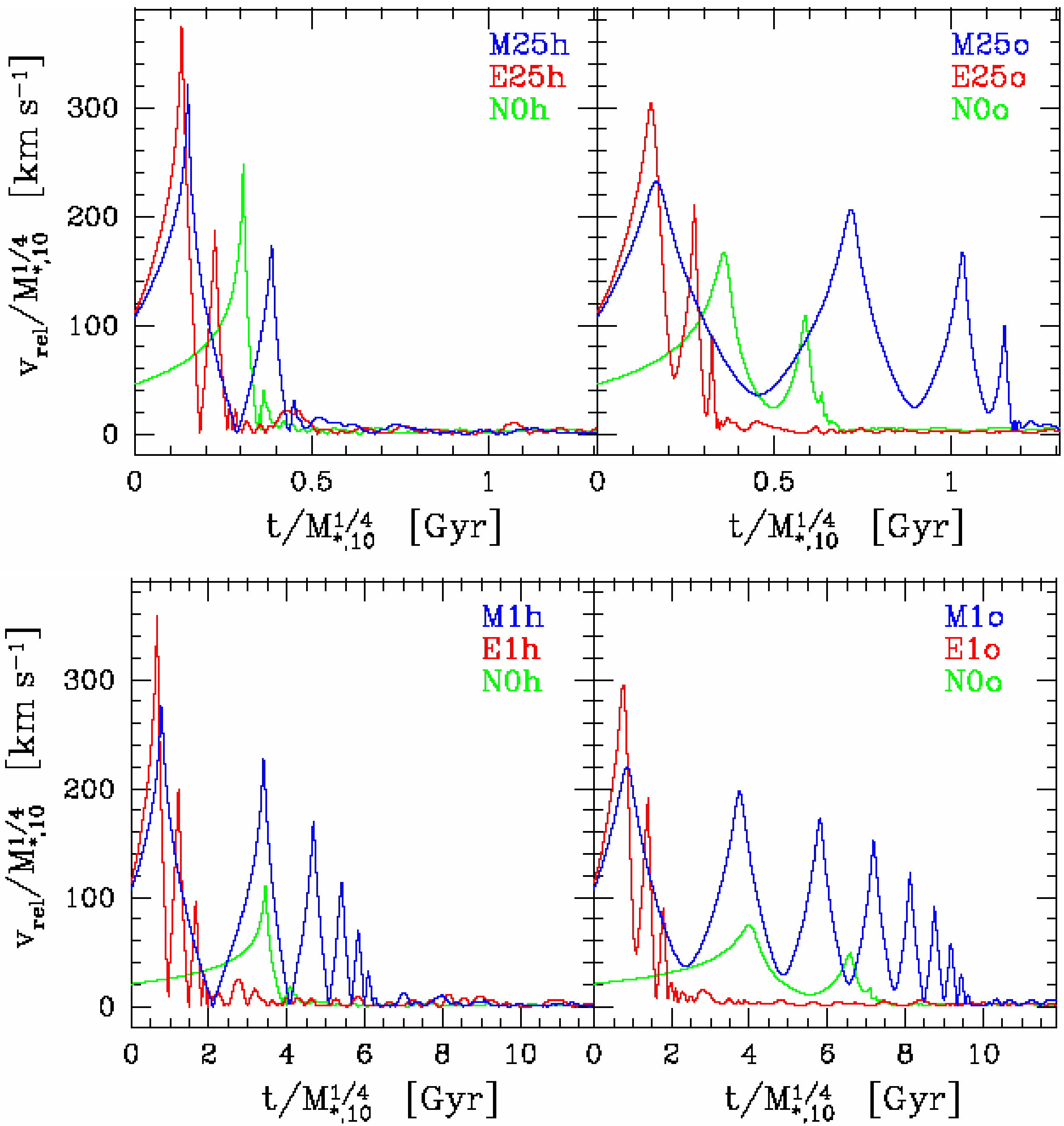
[1]*Astronomy Department, University of Bologna, via Ranzani 1, 40127 Bologna, Italy*
[2]*INAF-Bologna Astronomical Observatory, via Ranzani 1, 40127 Bologna, Italy*

$$v_0^2 = 4G(M_* + M_{\rm DM})\left(\frac{1}{d_0} - \frac{1}{d_{\rm rest}}\right),$$

while in the MOND cases

$$v_0^2 \simeq 0.8\sqrt{8GM_* a_0}\ln\frac{d_{\rm rest}}{d_0},$$



M25h
E25h
N0h
M25o
E25o
N0o
M1h
E1h
N0h
M1o
E1o
N0o
$v_{rel}/M_{*,10}^{1/4}$ [km s^{-1}]
$t/M_{*,10}^{1/4}$ [Gyr]