Radial Orbit Instability In Triaxial Systems

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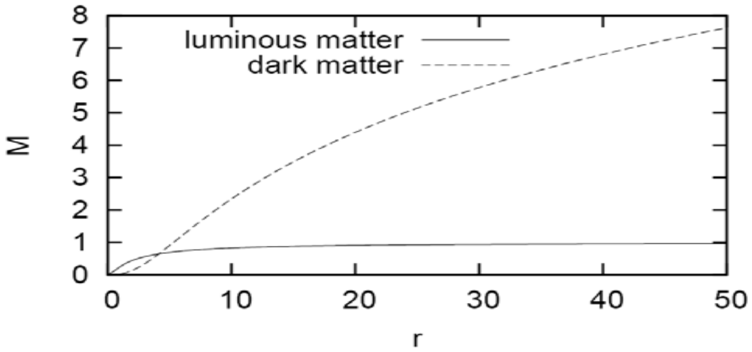
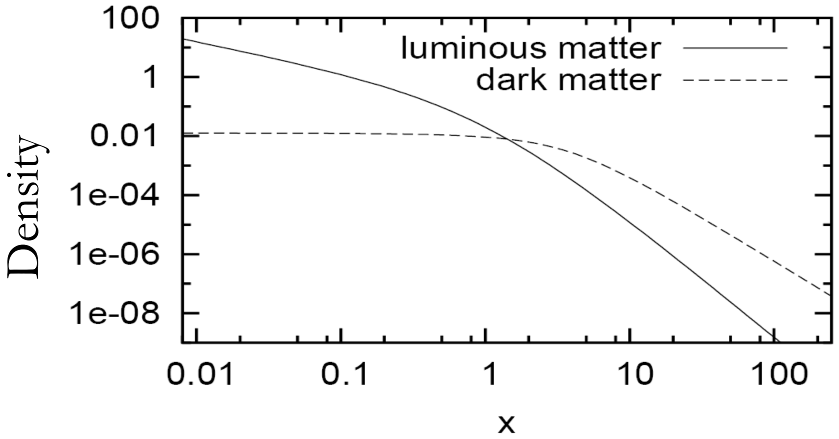
Mass models





R. Capuzzo Dolcetta et al. constructed models of cuspy triaxial galaxies with dark matter halos using the method of orbital superposition (Schwarzschild 1979)

$$\rho_l(m) = \frac{M}{2\pi a_l b_l c_l} \frac{1}{m(1+m)^3}$$

$$\rho_{dm}(m') = \frac{\rho_{dm,0}}{(1+m')\,(1+m'^2)}$$

MODEL	a_l	b_l	c_l	T_l	a_d	b_d	c_d	T_d
$MOD1(MOD1-bis)$	1	0.86	0.7	0.5	1	0.86	0.7	0.5
$MOD2$	1	0.86	0.7	0.5	1	0.66	0.5	0.75
$MOD3$	1	0.86	0.7	0.5	1	0.93	0.7	0.25

Monte Carlo realizations of the N-body models

Once that a self-consistent solution is found, the initial conditions for a N-body system are obtained by placing, uniformly over the all integration time, a number of particles on the ***kth*** orbit proportional to ***C_k*.**

$$N_{dm} = \sum_{k=1}^{n_{dorb}} C_{k;dm}/m_{dm} \sim \quad 150{,}000$$

$$N_{lm} = \sum_{k=1}^{n_{lorb}} C_{k;lm}/m_{lm} \sim \quad 20{,}000$$

Orbital families

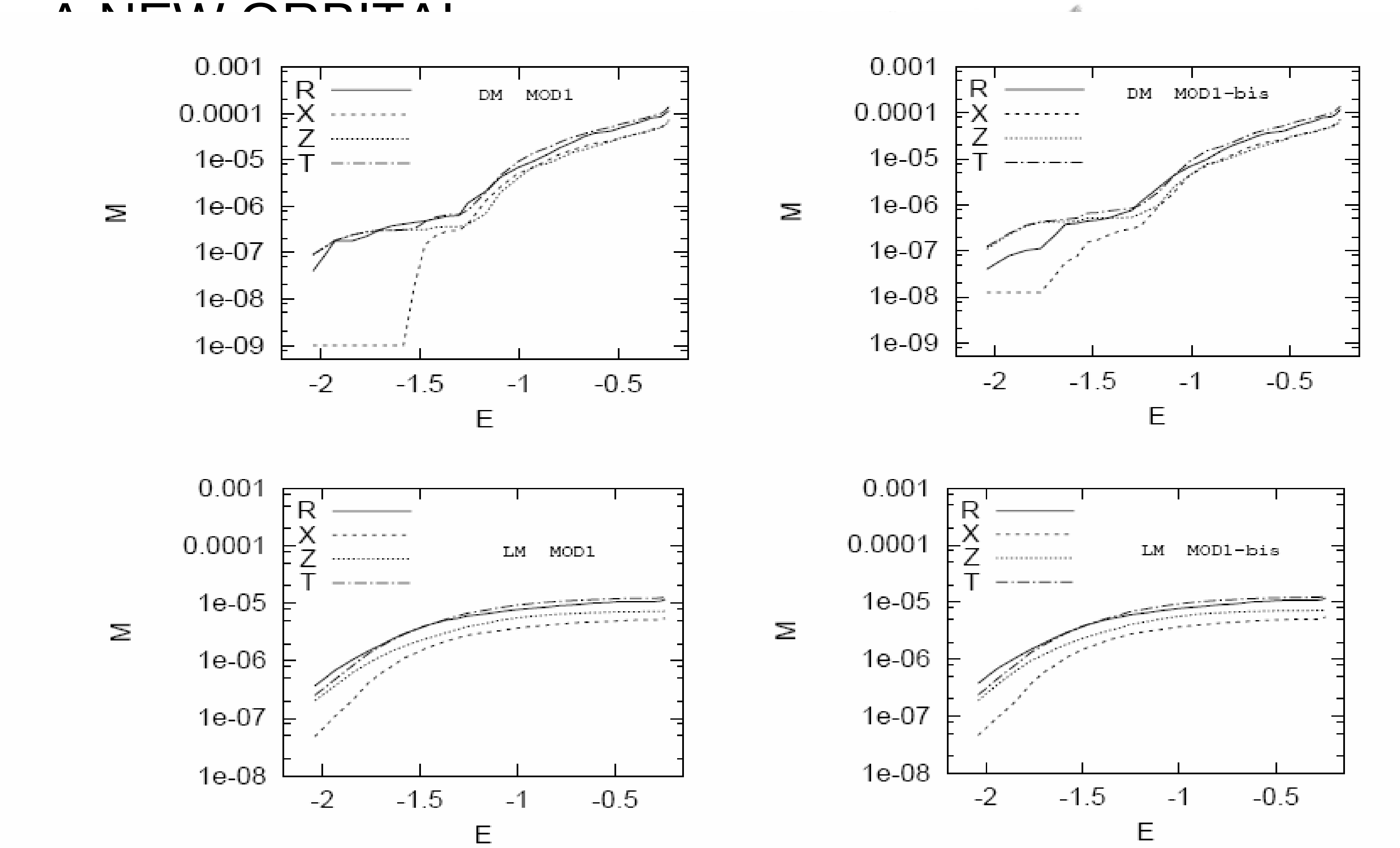
MOD1 MOD1_bis

A NEW ORBITAL

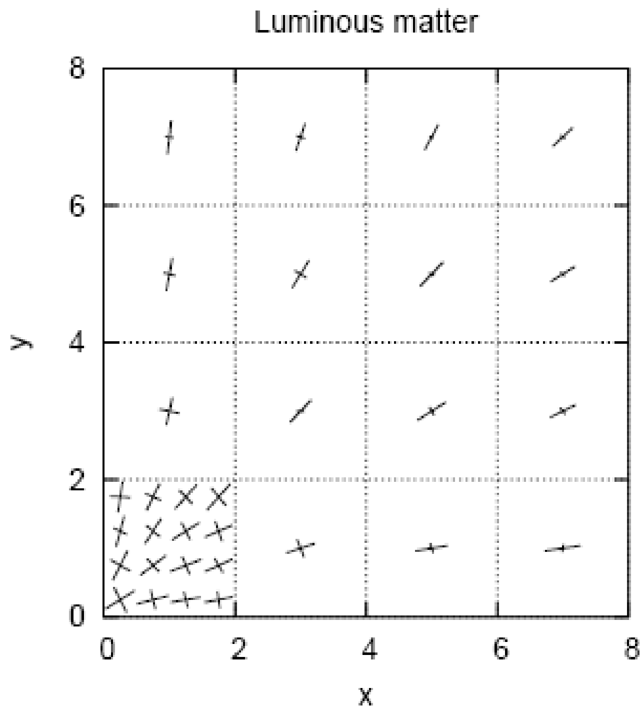
to
ir
cla
the
frc

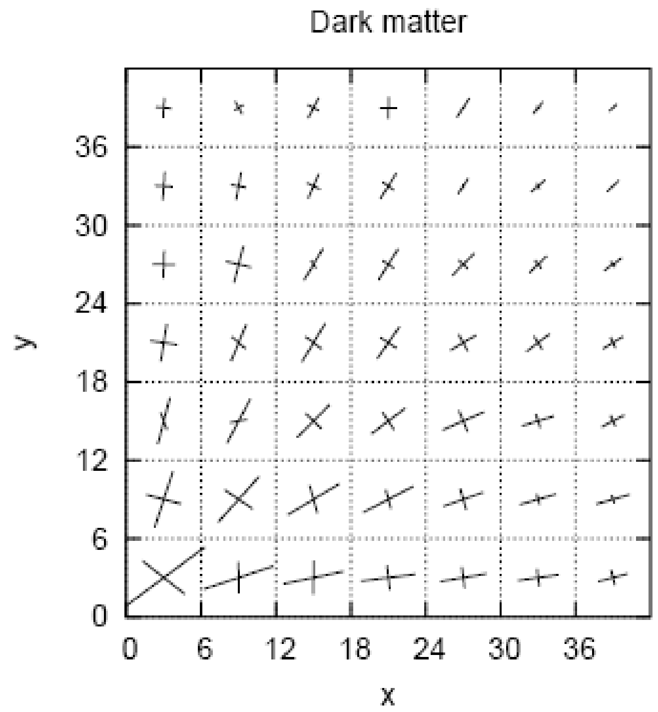
Dark Matter

Luminous matter



Velocity dispersion tensor





$T_r = < v_r^2/2 >$ $\quad$ $T_t = < v_t^2/2 >$

Anisotropy parameters ⟶ $[2T_r/T_t]_{lm} \approx 1.4$ $\quad$ $[2T_r/T_t]_{dm} \approx 2$

N-body initial conditions

"The persistence of sense of motion around the x-axis permits tube orbits to cause stream motions of the character of a rotation" (Schwarzschild 1979).

We prepared two different initial conditions for each model:

1) Obtaining the maximum rotation rate
2) Minimizing the angular momentum

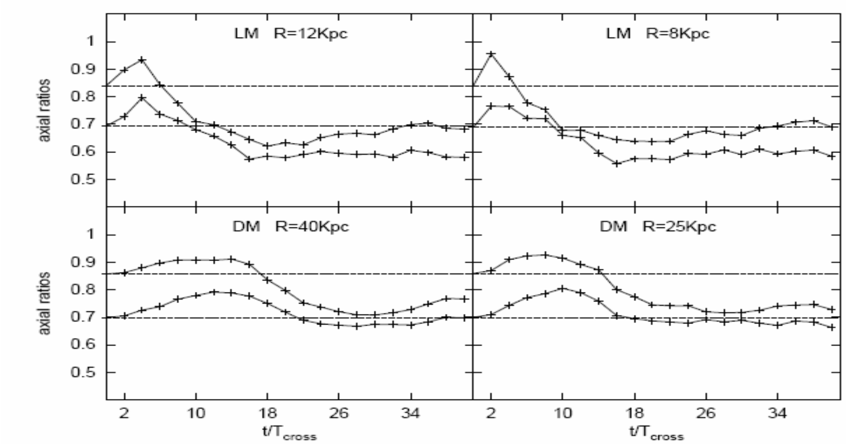
$System$	$Solution$	L	N_{lm}	N_{dm}
HL	$MOD1$	23.71448	19684	144886
HL_{bis}	$MOD1-bis$	23.57945	19709	146485
LL	$MOD1$	0.401937	19684	144886
LL_{bis}	$MOD1-bis$	0.337428	19709	146485

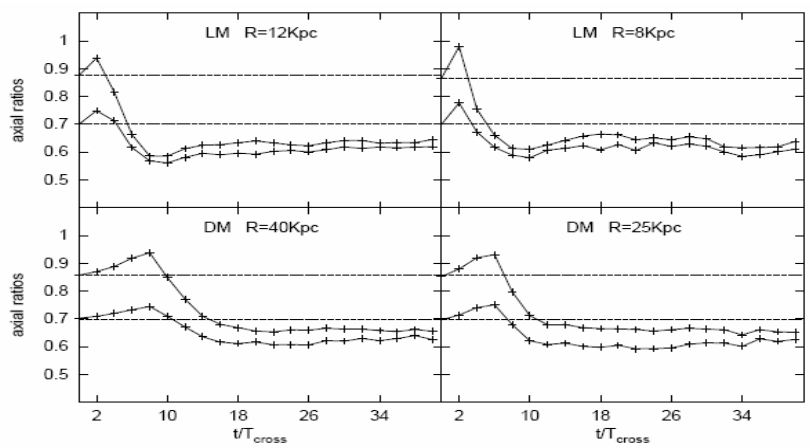
Instability of the systems

High L

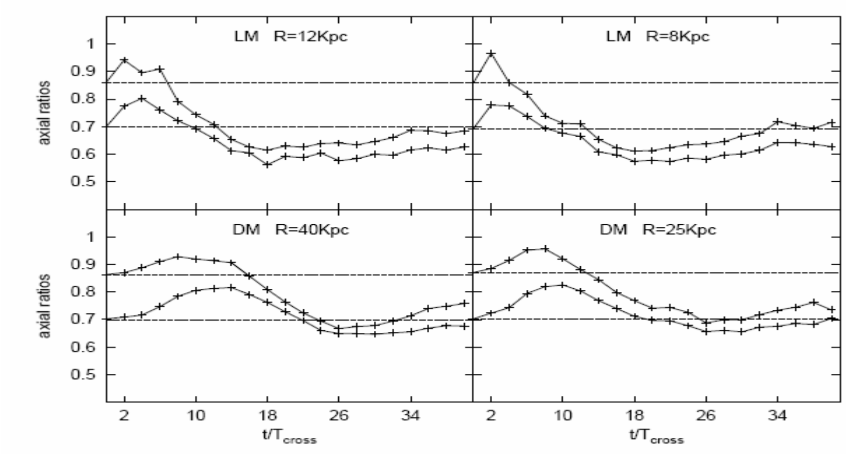
Low L

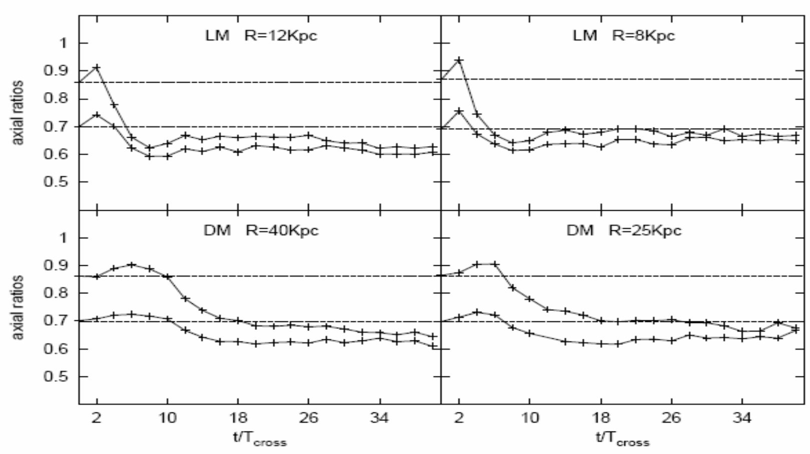
MOD1





MOD1_BIS

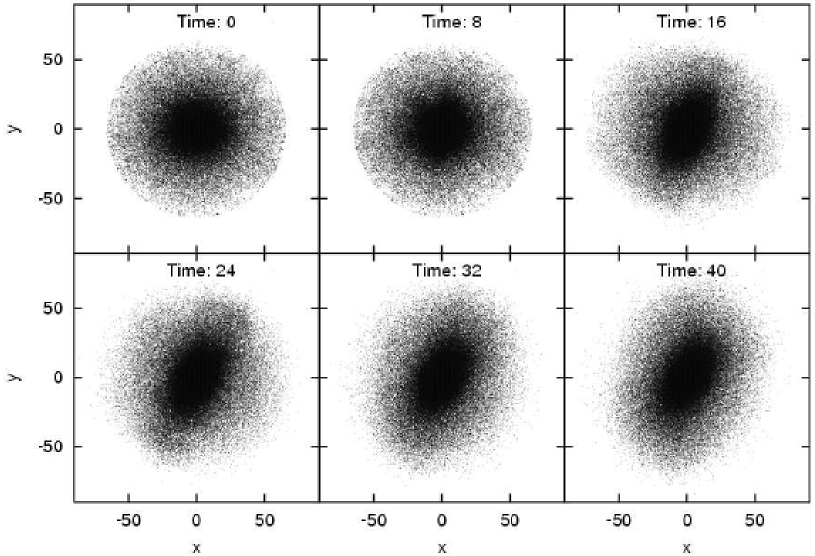




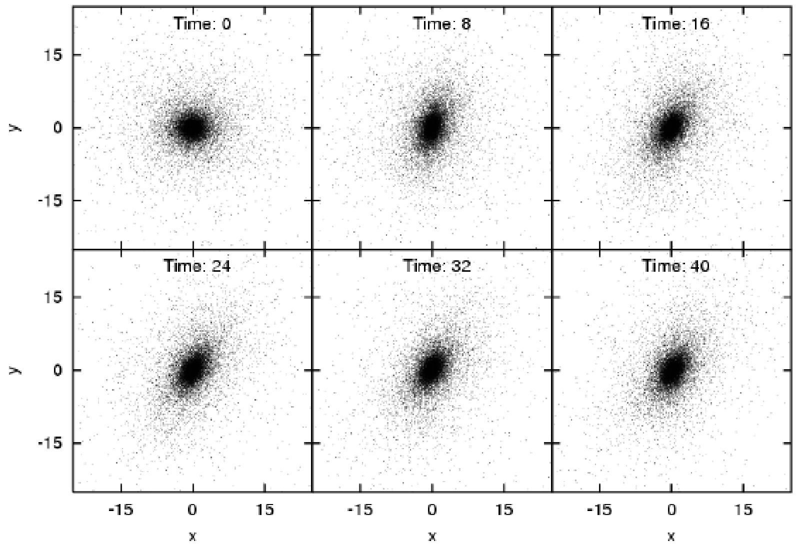
Simulation Results

LL_{BIS}

Dark Matter



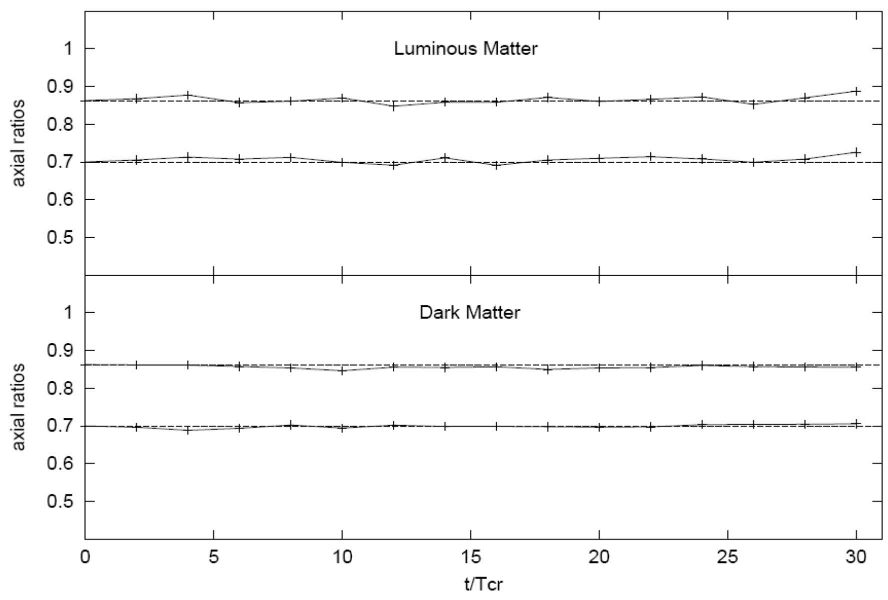
Luminous matter



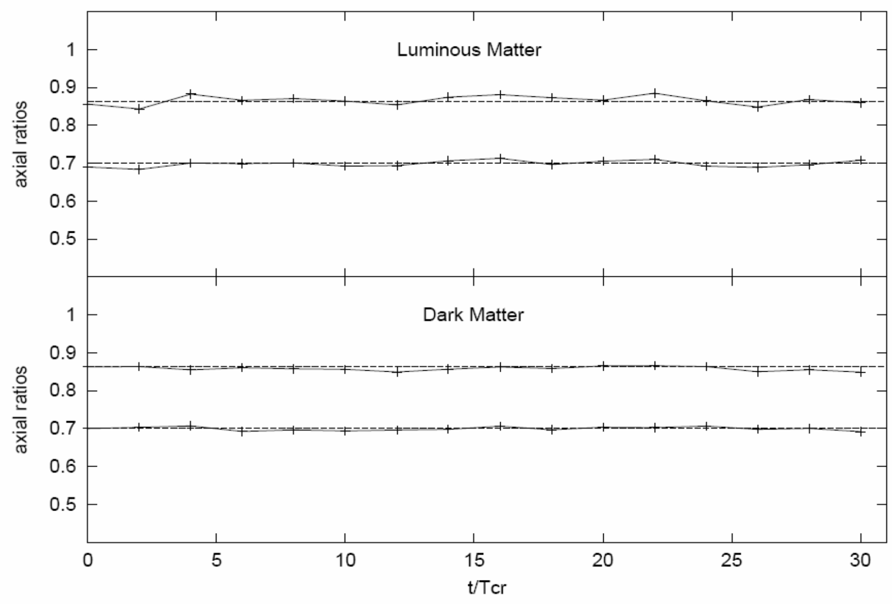
Dynamical instability or chaotic evolution?

To check that the instability seen with the N-body simulations is a manifestation of a collective instability and not of a chaotic evolution, we integrated the motion of every particle of the N-body system in the fixed analytic potential of the galaxy.

MOD1



MOD1_bis



On The Radial Orbit Instability

If a galaxy contains initially many "radial orbits", a small deviation of the angular distribution of these orbits from spherically symmetric creates a collective collaboration of the orbits, based on their mutual torques, that results in a large departure of the system from the spherical symmetry.

- 1973 Antonov sugests that a spherical model constructed from purely radial orbits would be unstable to clumping of particles around any radius vector
- The instability is similar to one first described by Lynden-Bell(1979) in the context of radially hot disks
- 1985 The "radial orbit instability" is numerically investigated by Merritt and Aguilar in the case of spherical systems

"Radial Orbit Instability"?

- Are new solutions with lower number of *semi*-radial orbits possible?
- Are these solutions stable?

"penalty" function

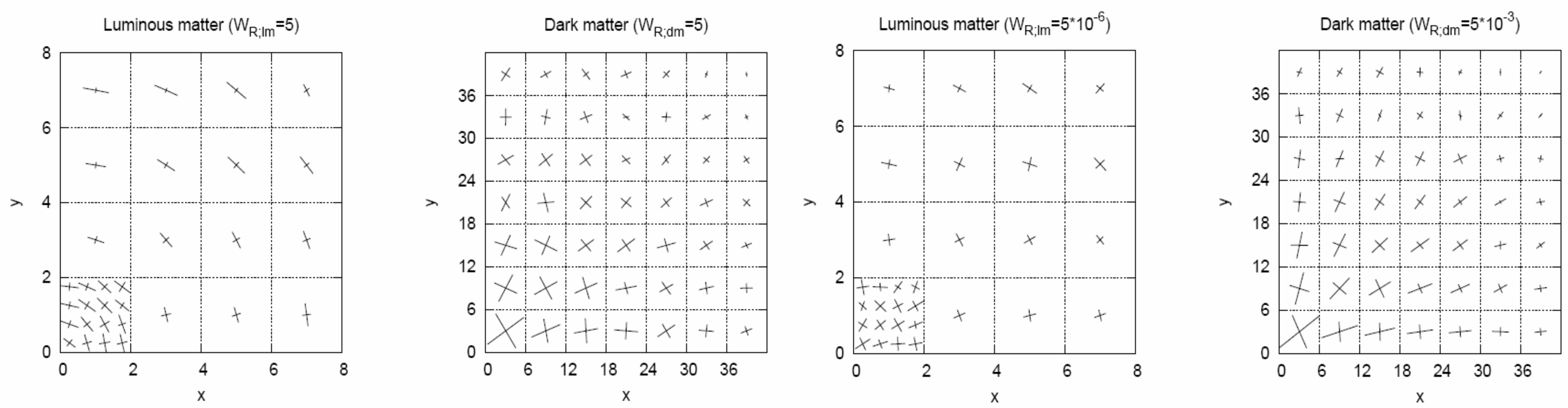
$$\chi^2_{lum} = \frac{1}{N_{cells}} \sum_{j=1}^{N_{cells}} (M_{j;lm} - \sum_{k=1}^{n_{orb}} C_{k;lm} B_{k,j;lm})^2 + \sum_{k=1}^{n_{orb}} (C_{k;lm} W_{k;lm})$$

$$\chi^2_{dm} = \frac{1}{N_{cells}} \sum_{j=1}^{N_{cells}} (M_{j;dm} - \sum_{k=1}^{n_{orb}} C_{k;dm} B_{k,j;dm})^2 + \sum_{k=1}^{n_{orb}} (C_{k;dm} W_{k;dm})$$

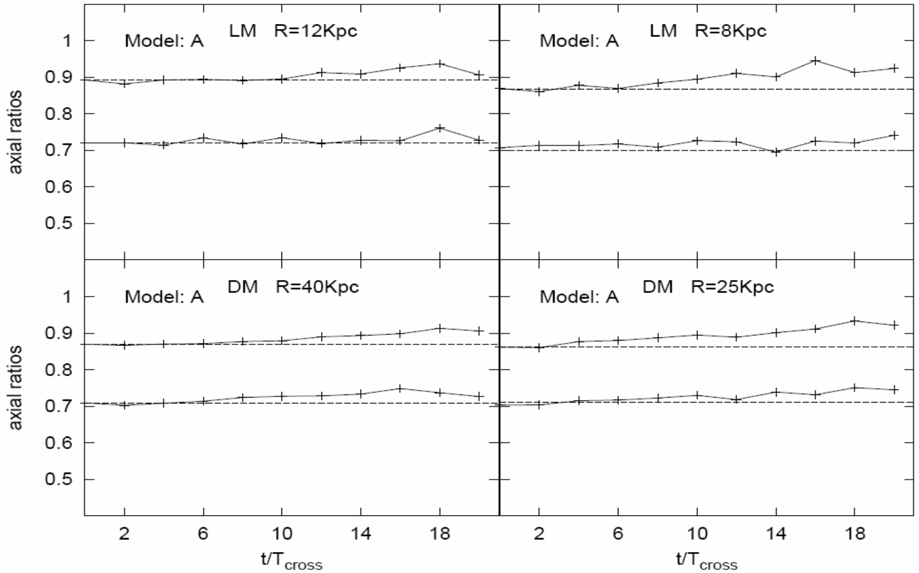
$$W_k \begin{cases} = 0 & \text{for tube orbits} \\ > 0 & \textit{semi}\text{-radial orbits} \end{cases}$$

NEW MODELS :

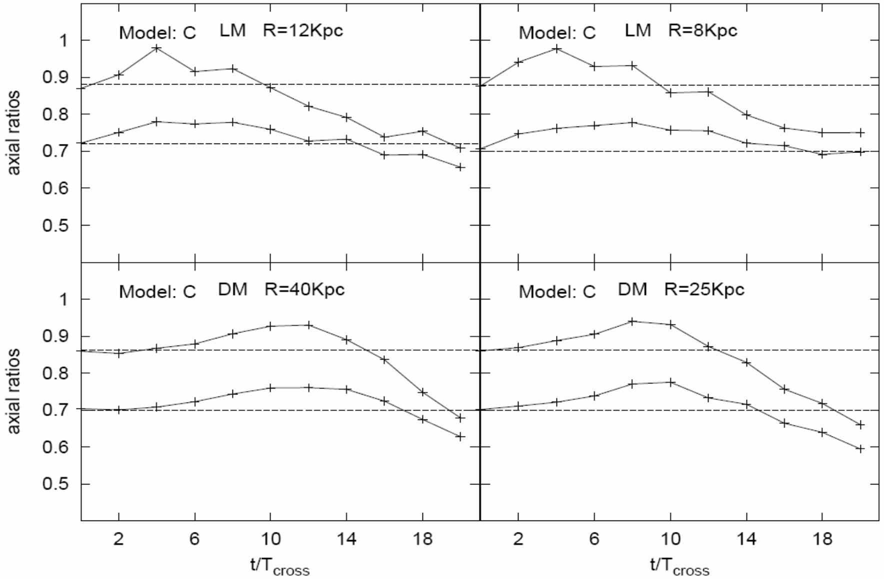
MODEL	$W_{R;lm}$	$W_{R;dm}$	$[2T_r/T_t]_{lm}$	$[2T_r/T_t]_{dm}$
A	50	50	0.512	1.175
B	5	5	0.784	1.335
C	5×10^{-6}	5×10^{-3}	1.220	1.754
D	5×10^{-6}	50	1.230	1.174



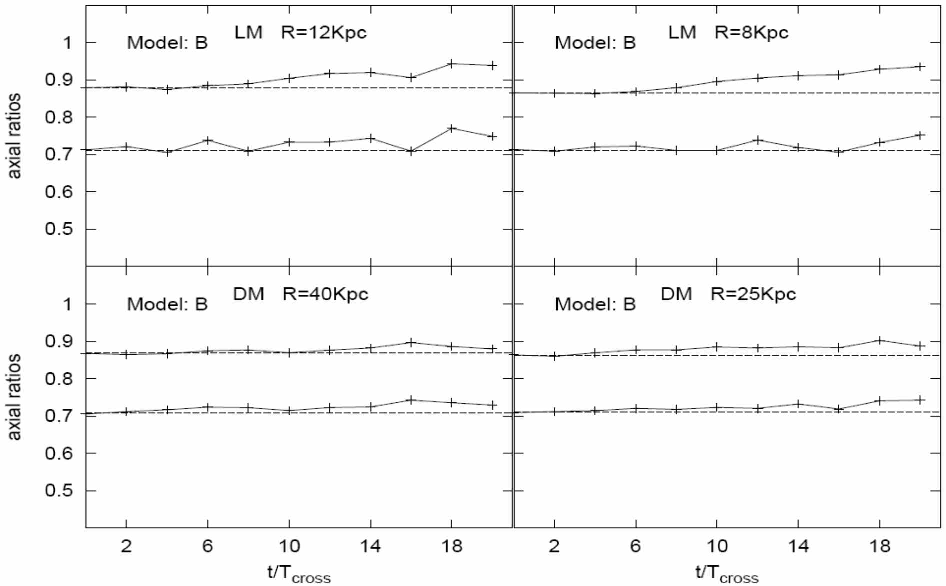
RESULTS



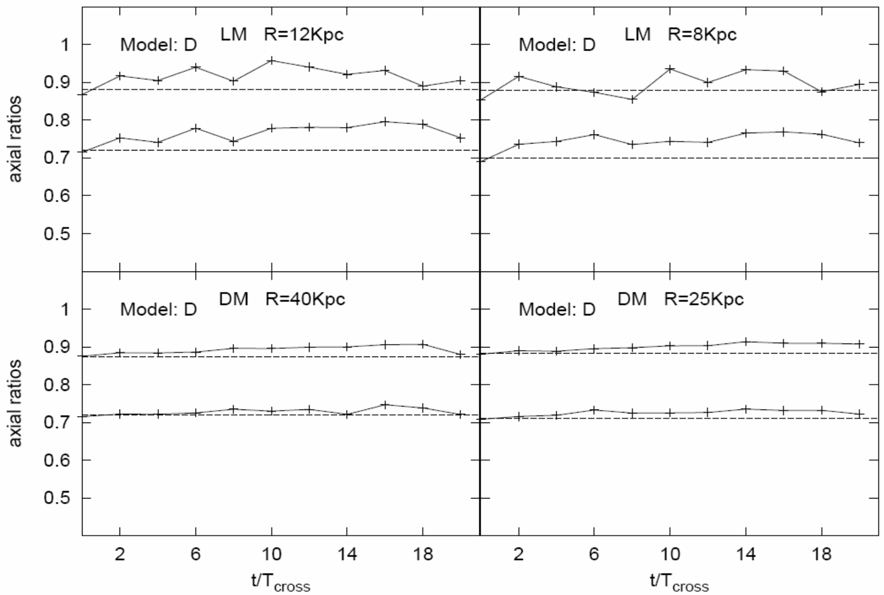
Model: A LM R=12Kpc
Model: A LM R=8Kpc
Model: A DM R=40Kpc
Model: A DM R=25Kpc
axial ratios
t/T_{cross}



Model: C LM R=12Kpc
Model: C LM R=8Kpc
Model: C DM R=40Kpc
Model: C DM R=25Kpc
axial ratios
t/T_{cross}



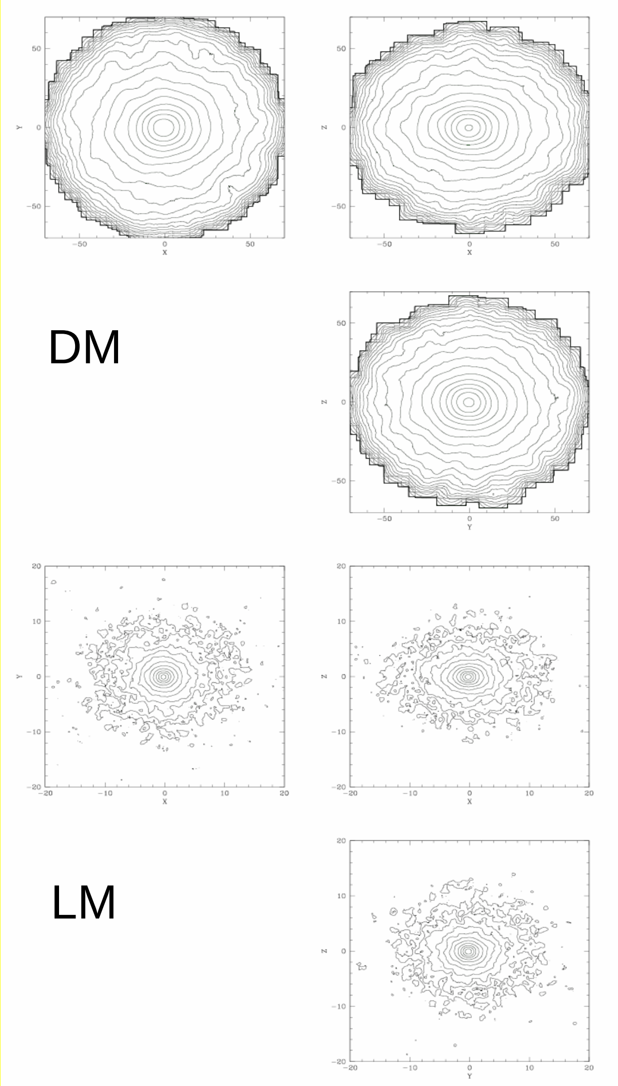
Model: B LM R=12Kpc
Model: B LM R=8Kpc
Model: B DM R=40Kpc
Model: B DM R=25Kpc
axial ratios
t/T_{cross}



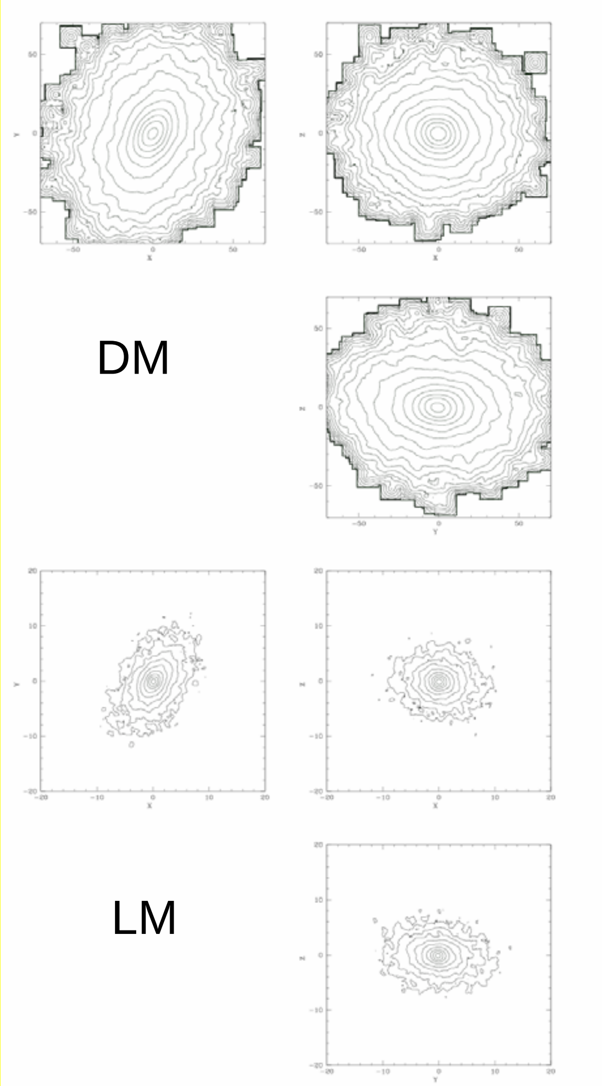
Model: D LM R=12Kpc
Model: D LM R=8Kpc
Model: D DM R=40Kpc
Model: D DM R=25Kpc
axial ratios
t/T_{cross}

Isodensity Contours

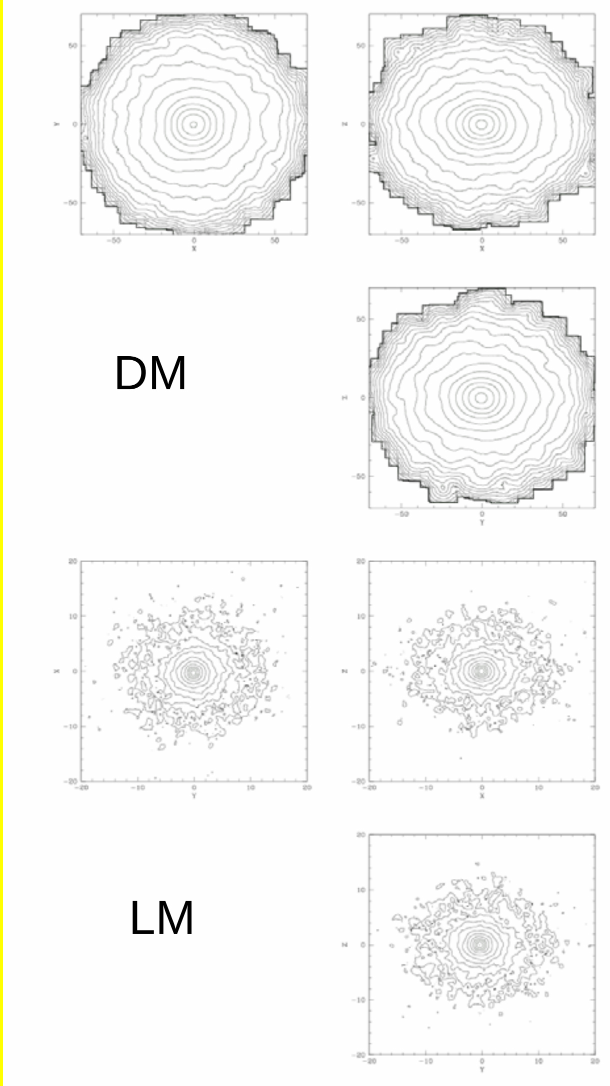
INITIAL



LL_{BIS}; 20TCROSS



D; 20TCROSS

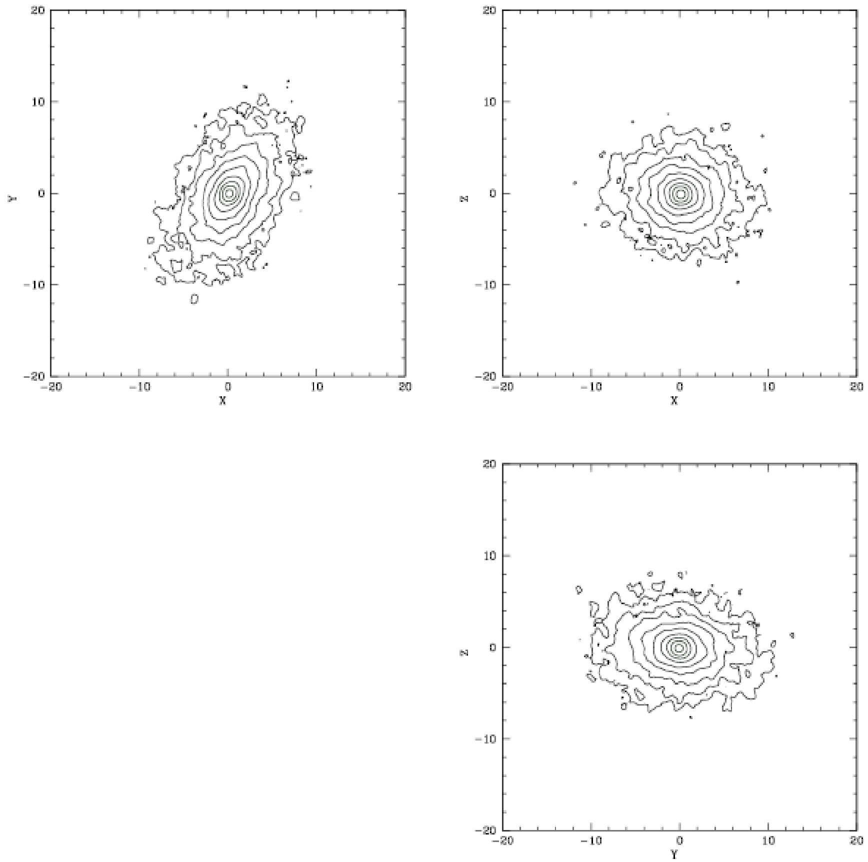


Conclusions

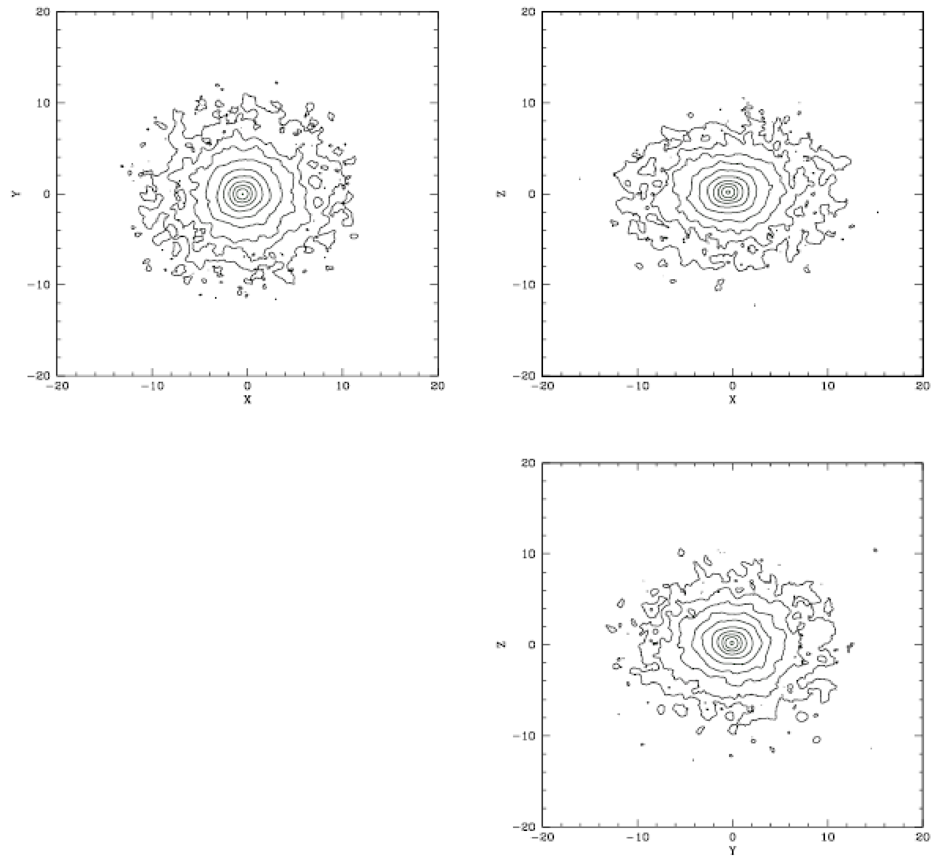
- Our results show for the first time the occurrence of Radial Orbit Instability in triaxial stellar systems. These models are characterized by values of the kinetic anisotropy paramters $[2T_r/T_t]_{DM}$~2 and $[2T_r/T_t]_{LM}$~1.4 ;
- The instability time scale is ~18 T_{cross} causing a final prolate shape with a shortest/longest axis ratio ~ 0.6-0.7;
- Our numerical experiments suggest that the instability is due to the high concentration of radially biased orbits in the dark halo. Stability is guaranteed by $[2T_r/T_t]_{DM}$ below 1.4 .

FINAL CONFIGURATIONS

UNSTABLE



STABLE

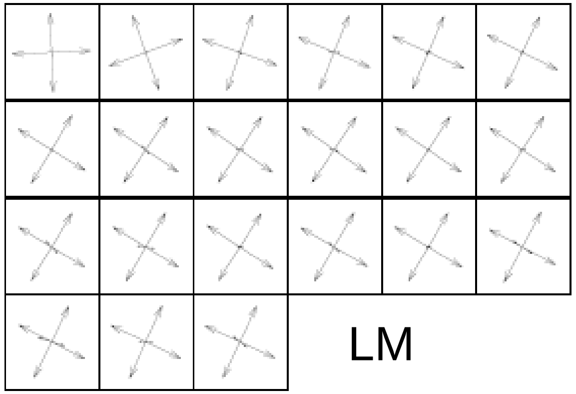


ROTATION

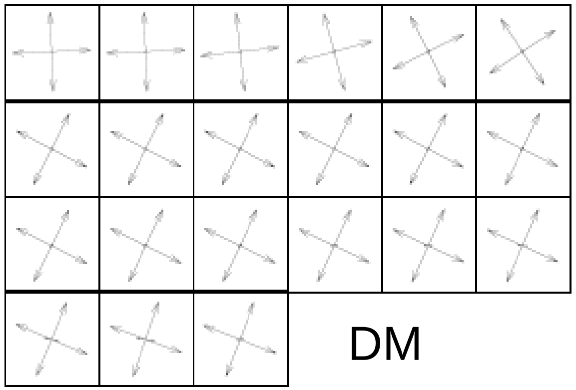
The inertia tensor was computed separately for both components and then diagonalized.
Then, the eigenvectors of the inertia tensor were plotted at different times.

The evolution is strongly influenced by stream internal motion in the case of high angular momentum

Low L

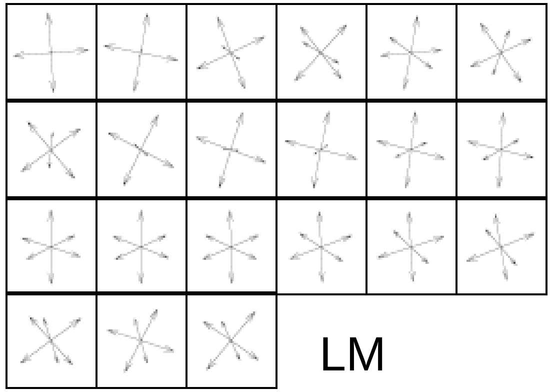


LM

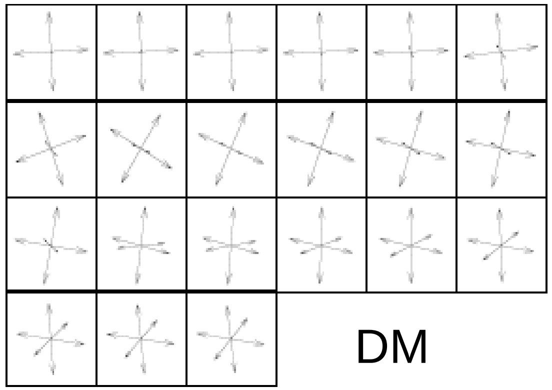


DM

High L



LM



DM