The importance of inner boxiness for understanding barred galaxies Dynamics

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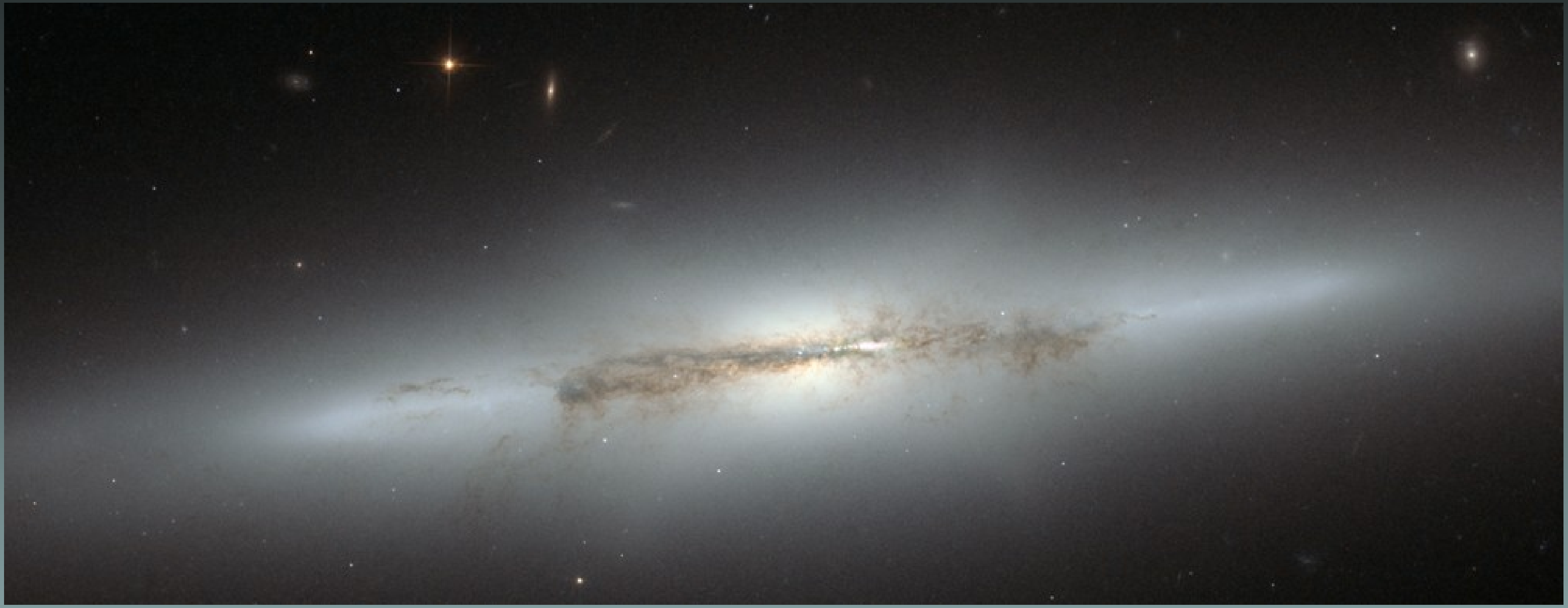
(results from recent work with M. Katsanikas and L. Tsigaridi)

Bars

- NGC 1300 (VLT, HAWK-I)

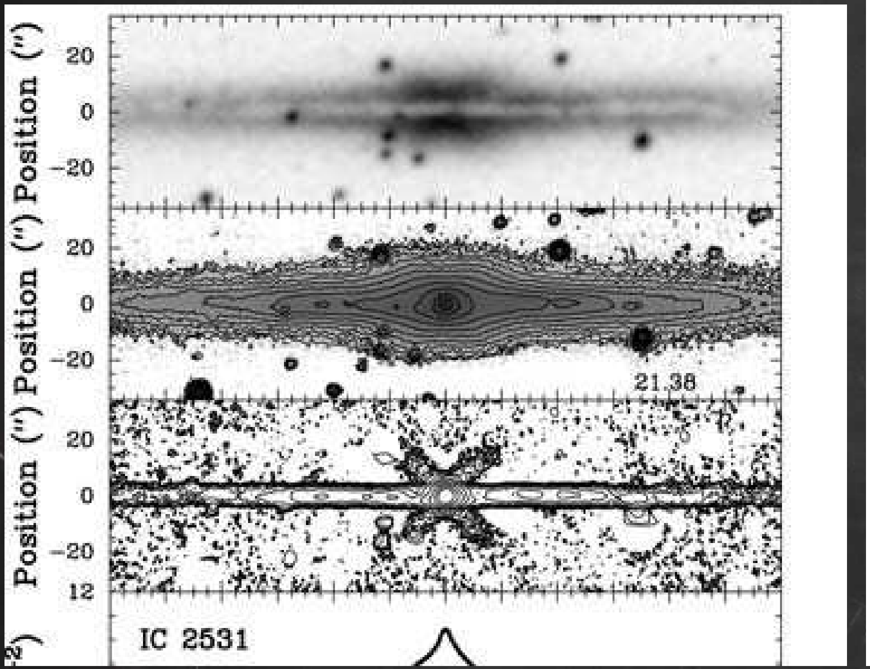
Bars edge-on: Boxy, Peanut-shaped bulges

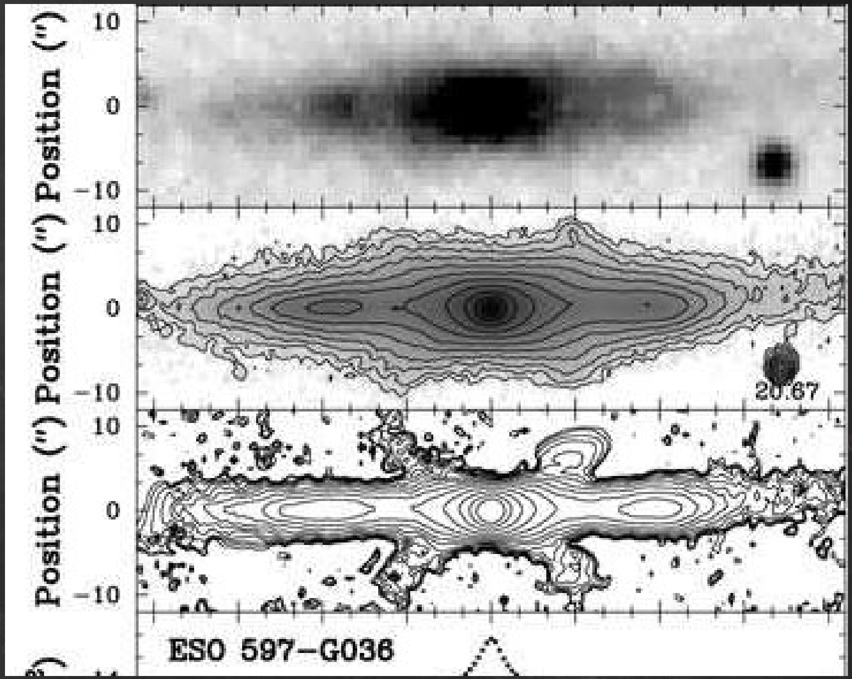
NGC 4710, $\alpha=12^h\ 49^m\ 38.9$, $\delta=+15°\ 9'\ 56''$



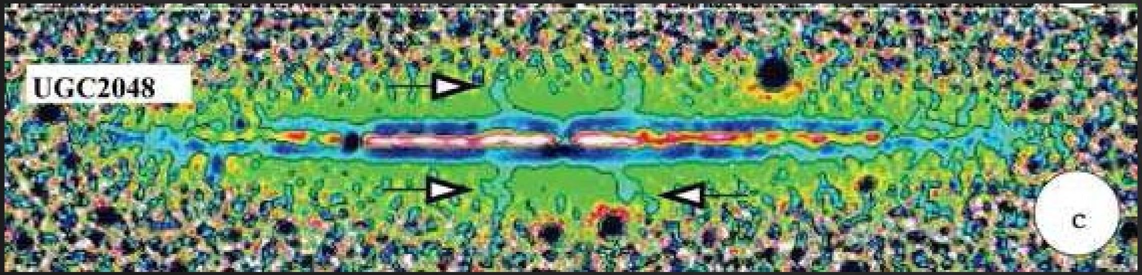
This natural-color photo was taken with the Hubble Space Telescope's Advanced Camera for Surveys on January 15, 2006

CX vs OX profiles



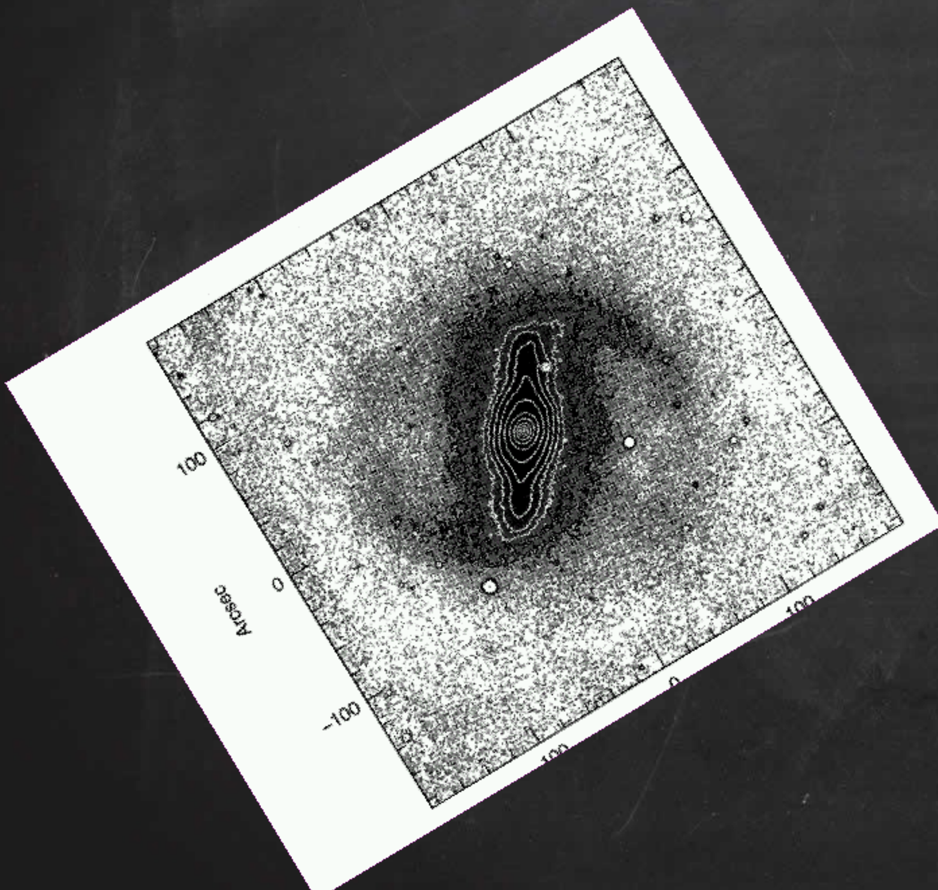


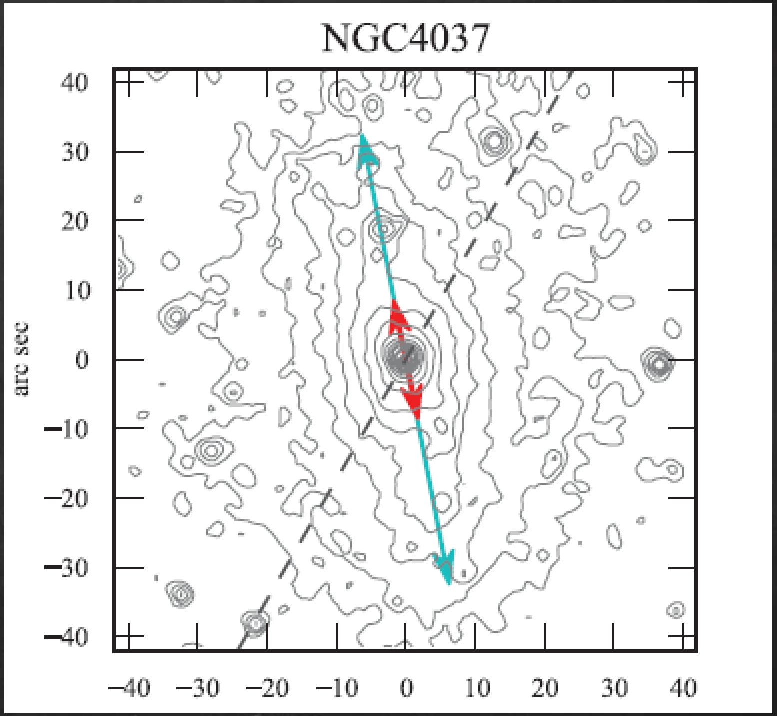
Bureau et al. 2006



Patsis & Xilouris 2006

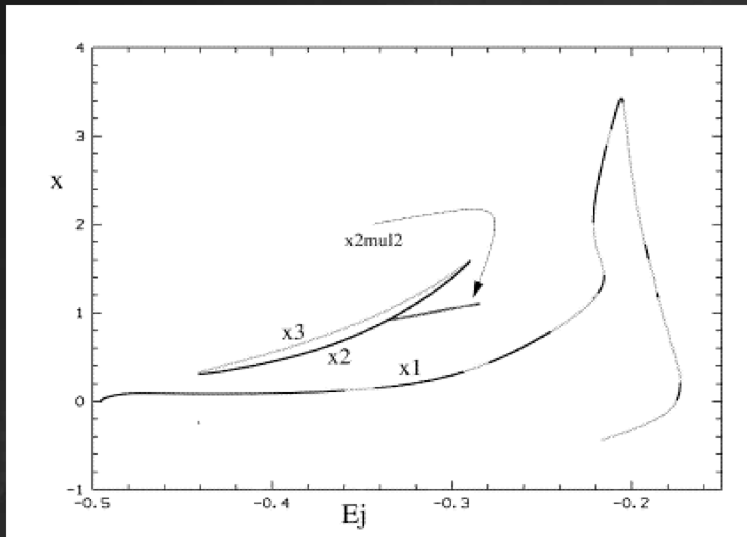
Outer and Inner boxiness of the bars in face-on views

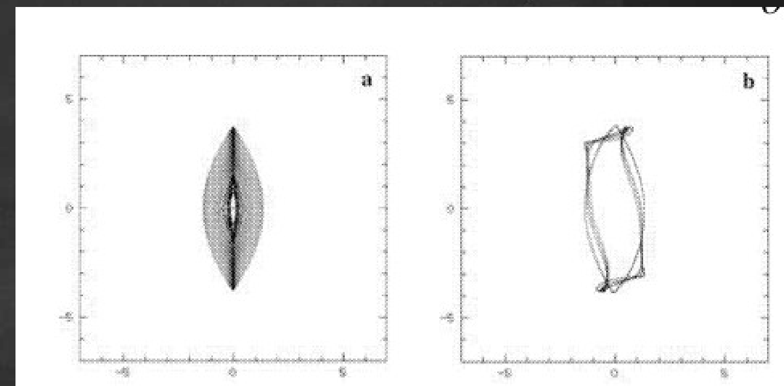




Erwin & Debattista 2013

Standard bar building blocks





Skokos, Patsis, Athanassaoula 2002, 2003

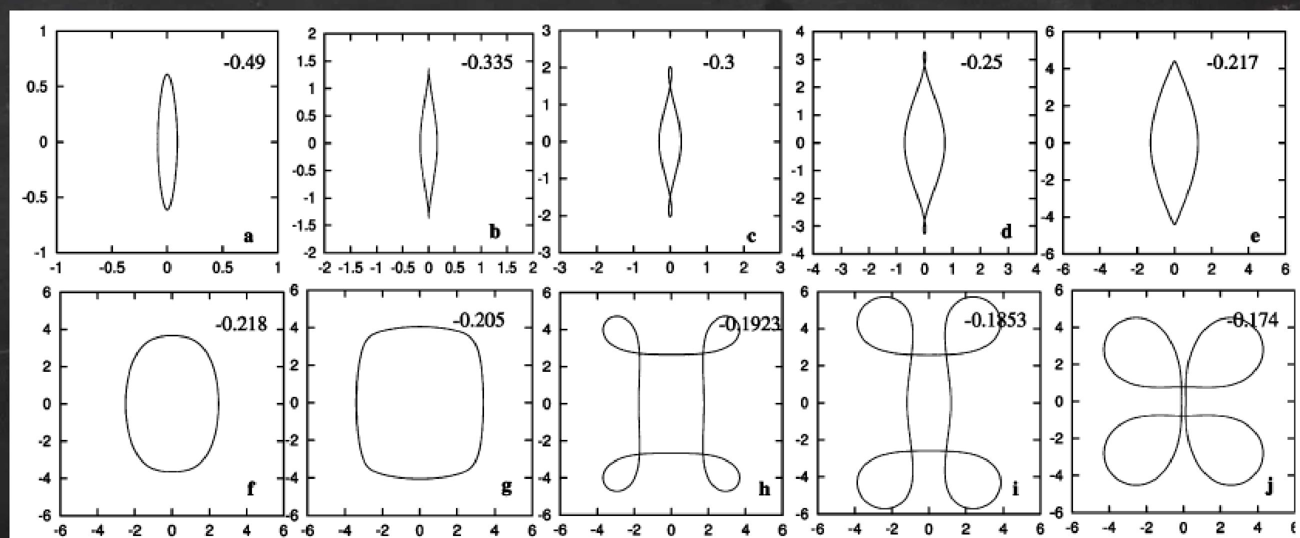
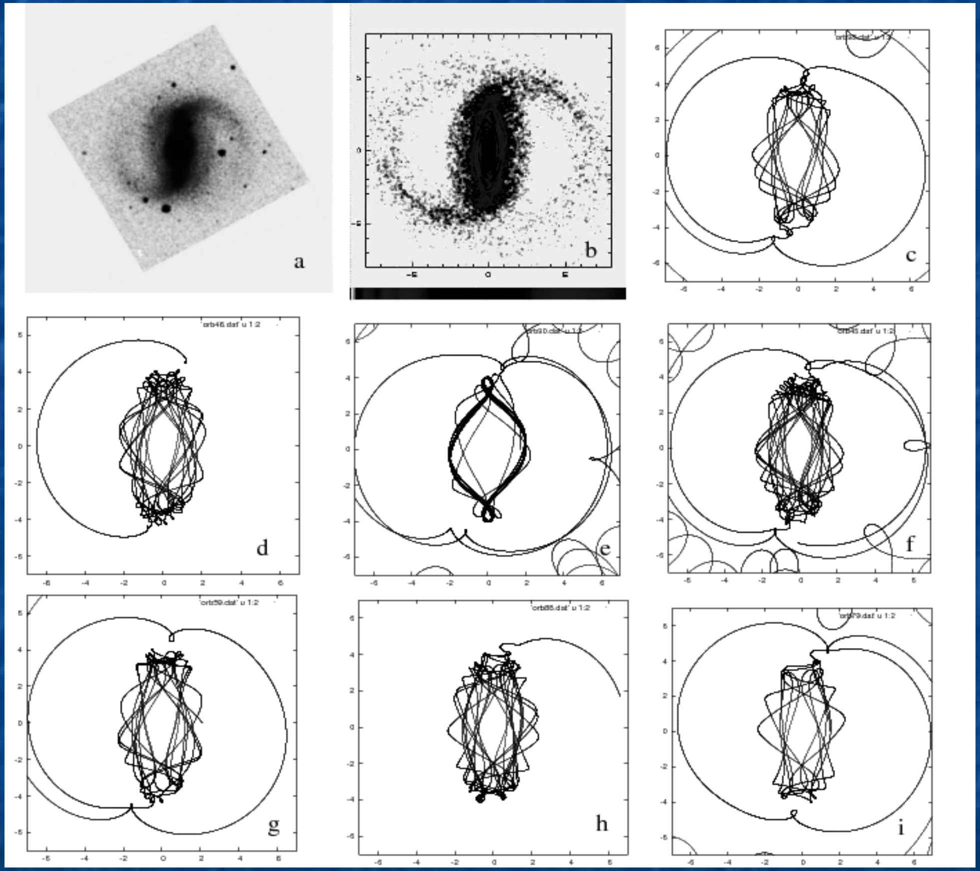


Figure 2. x1 stable orbits in model A1. The numbers at the upper right-hand corners of the panels indicate their E_j values.

4:1 resonance-type chaotic orbits.



Φ=Miyamoto disk + Plummmer sphere + 3D Ferrers bar

$$H = \frac{1}{2}(p_x^2 + p_y^2 + p_z^2) + \Phi(x, y, z) - \Omega_b(xp_y - yp_x),$$

with

$$\Phi(x, y, z)_{eff} = \Phi(x, y, z) - \Omega_b(xp_y - yp_x)$$

$$\dot{x} = p_x + \Omega_b y, \qquad \dot{y} = p_y - \Omega_b x, \qquad \dot{z} = p_z$$

$$\dot{p}_x = -\frac{\partial\Phi}{\partial x} + \Omega_b p_y, \quad \dot{p}_y = -\frac{\partial\Phi}{\partial y} - \Omega_b p_x, \quad \dot{p}_z = -\frac{\partial\Phi}{\partial z}$$

$$\Phi(x, y, z) = \Phi_D + \Phi_S + \Phi_B$$

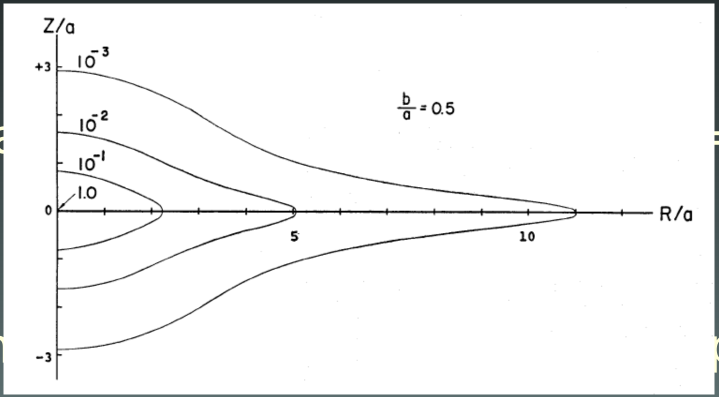
4D space of section, i.c. (x,p_x,z,p_z) in the plane $y=0$ with $p_y>0$

$$\Phi_D = -\frac{GM_D}{\sqrt{x^2 + y^2 + (A + \sqrt{B^2 + z^2})^2}},$$

- Miya =1

$$\Phi_S = -\frac{GM_S}{\sqrt{x^2 + y^2 + z^2 + \epsilon_s^2}},$$

- Plun pc

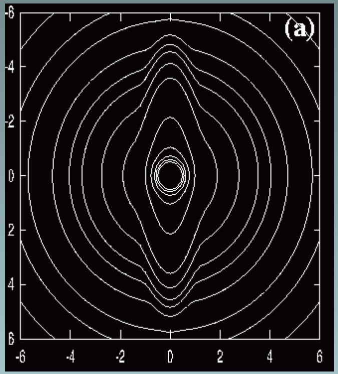


$$\rho = \begin{cases} \frac{105 M_B}{32\pi abc}(1 - m^2)^2 & \text{for} \quad m \leqq 1 \\ 0 & \text{for} \quad m > 1 \end{cases},$$

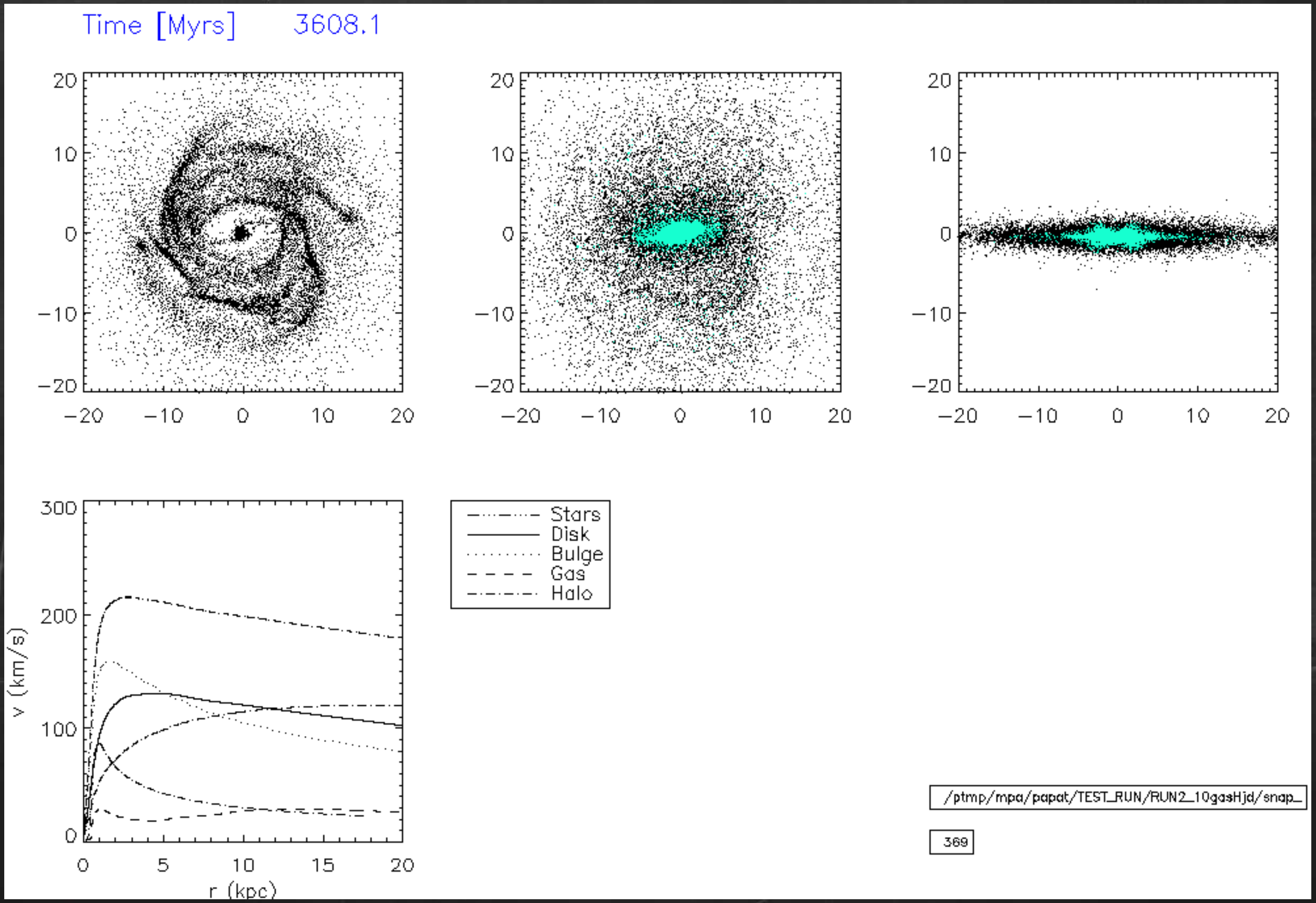
where

$$m^2 = \frac{y^2}{a^2} + \frac{x^2}{b^2} + \frac{z^2}{c^2}, \quad a > b > c,$$

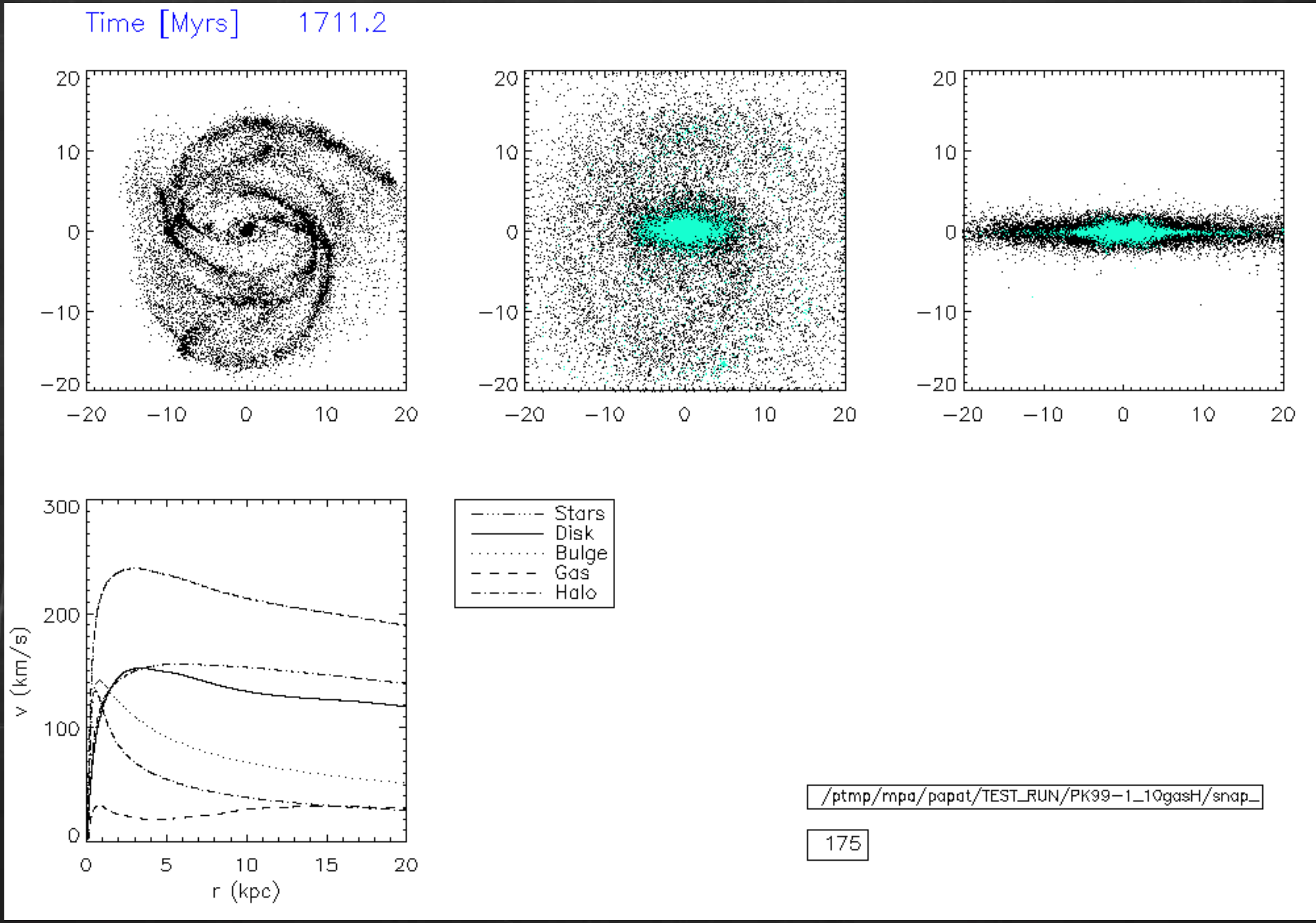
- Ferrers bar, a:b:c = 6:1.5:0.6



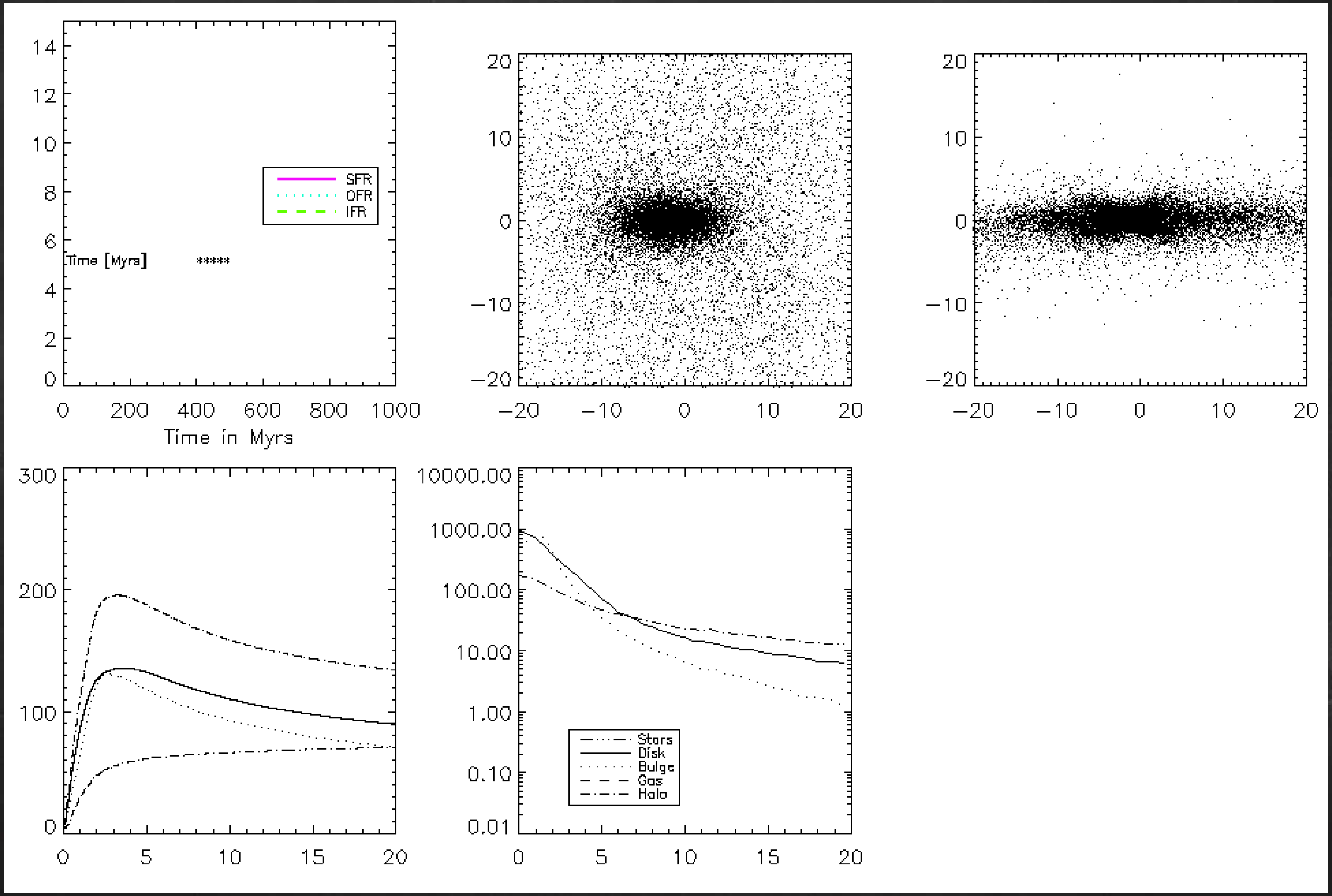
N-body peanuts I



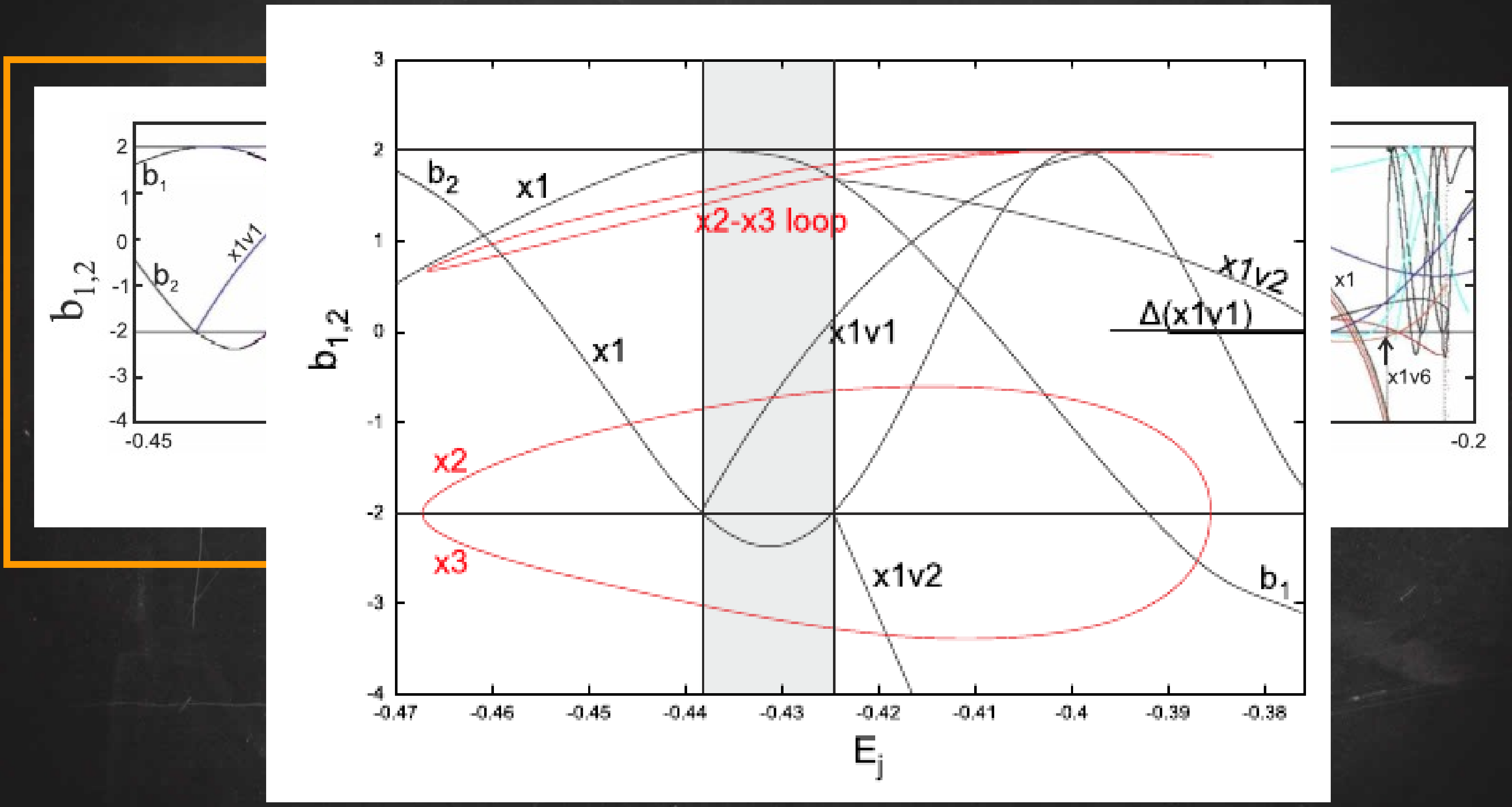
N-body peanuts II



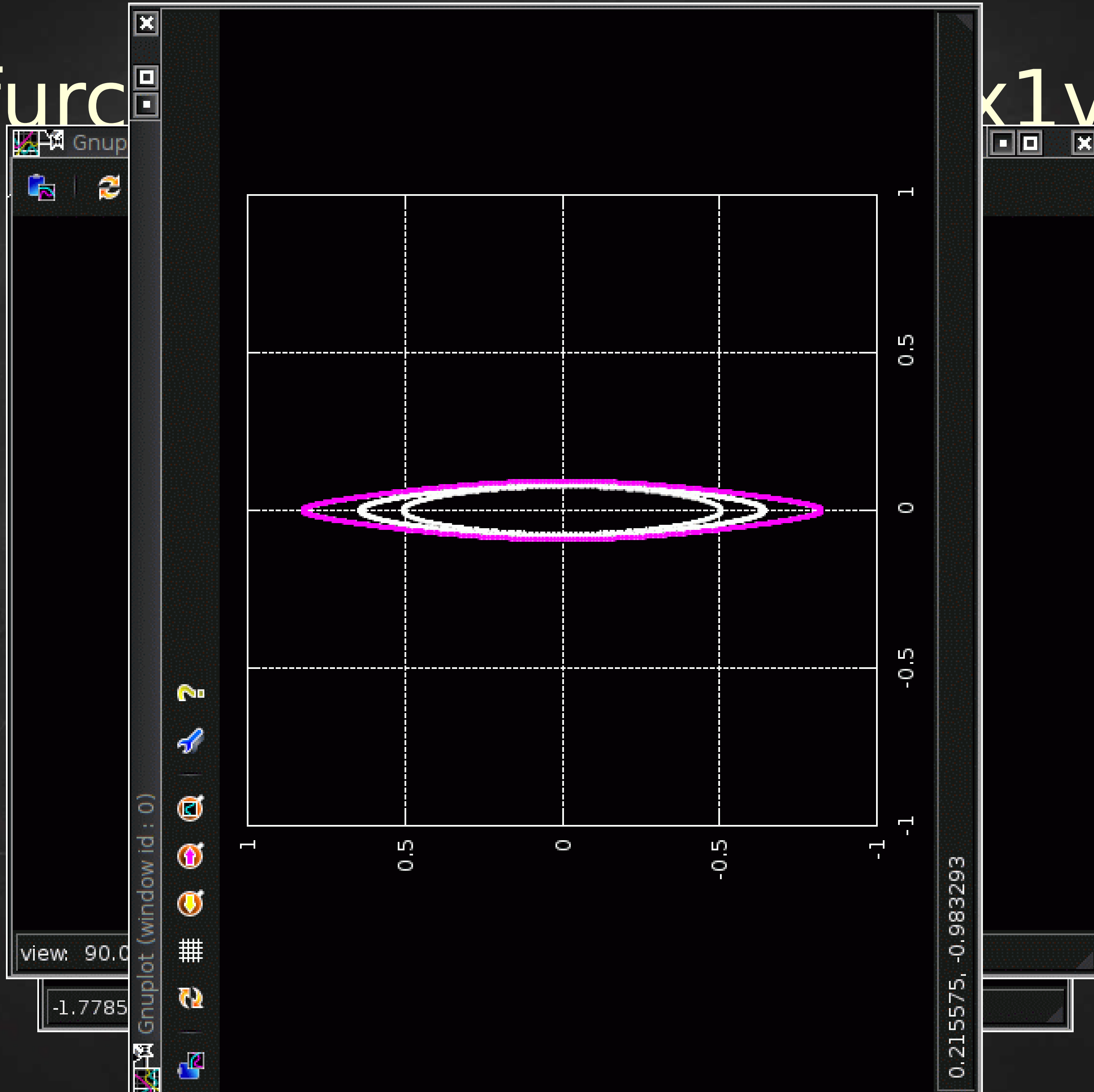
N-body peanuts III



Where does the b/p start?

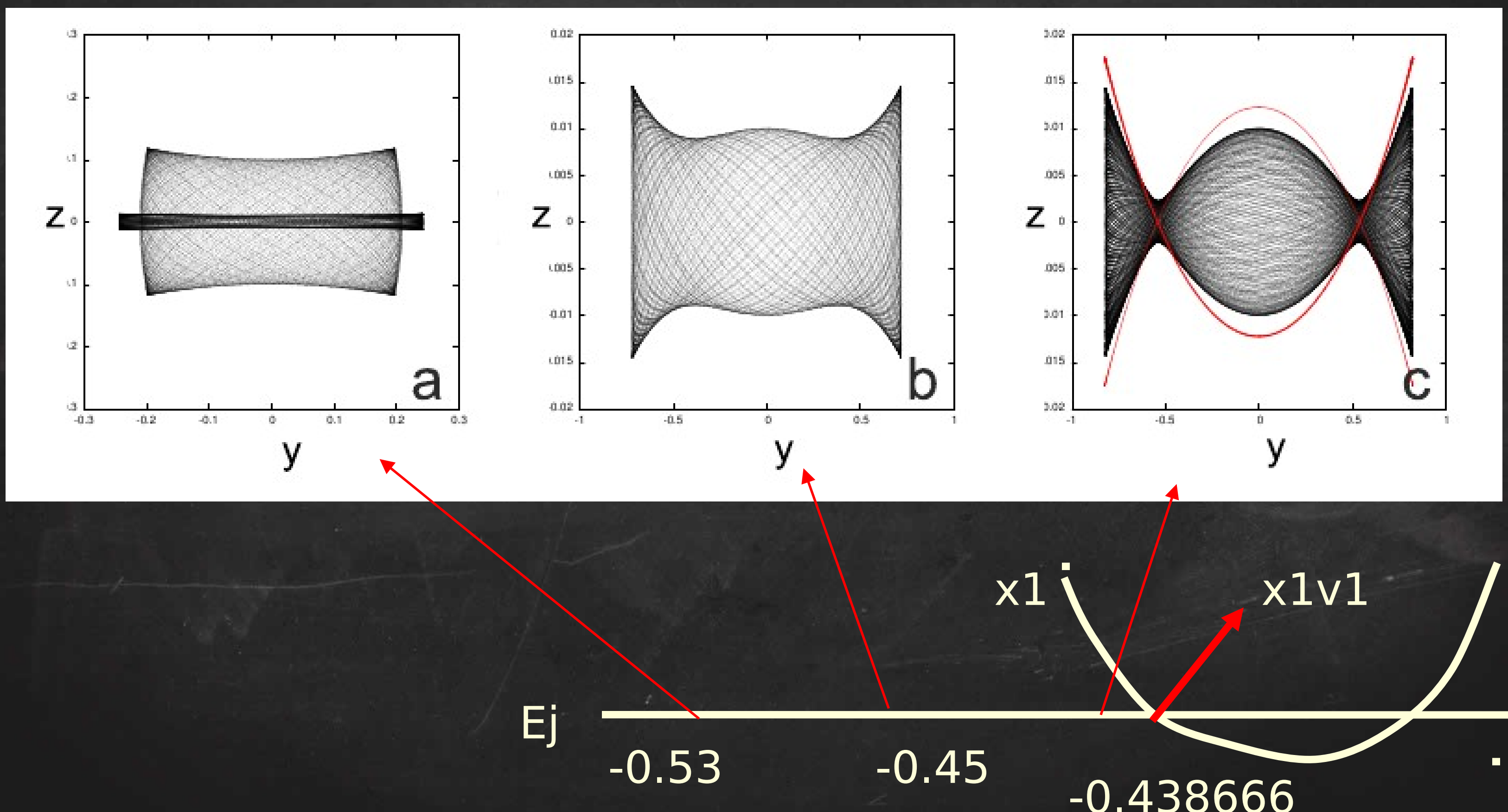


Bifurc… x1v1’


Gnup
view: 90.0
-1.7785
Gnuplot (window id : 0)
0.215575, -0.983293
1
0.5
0
-0.5
-1

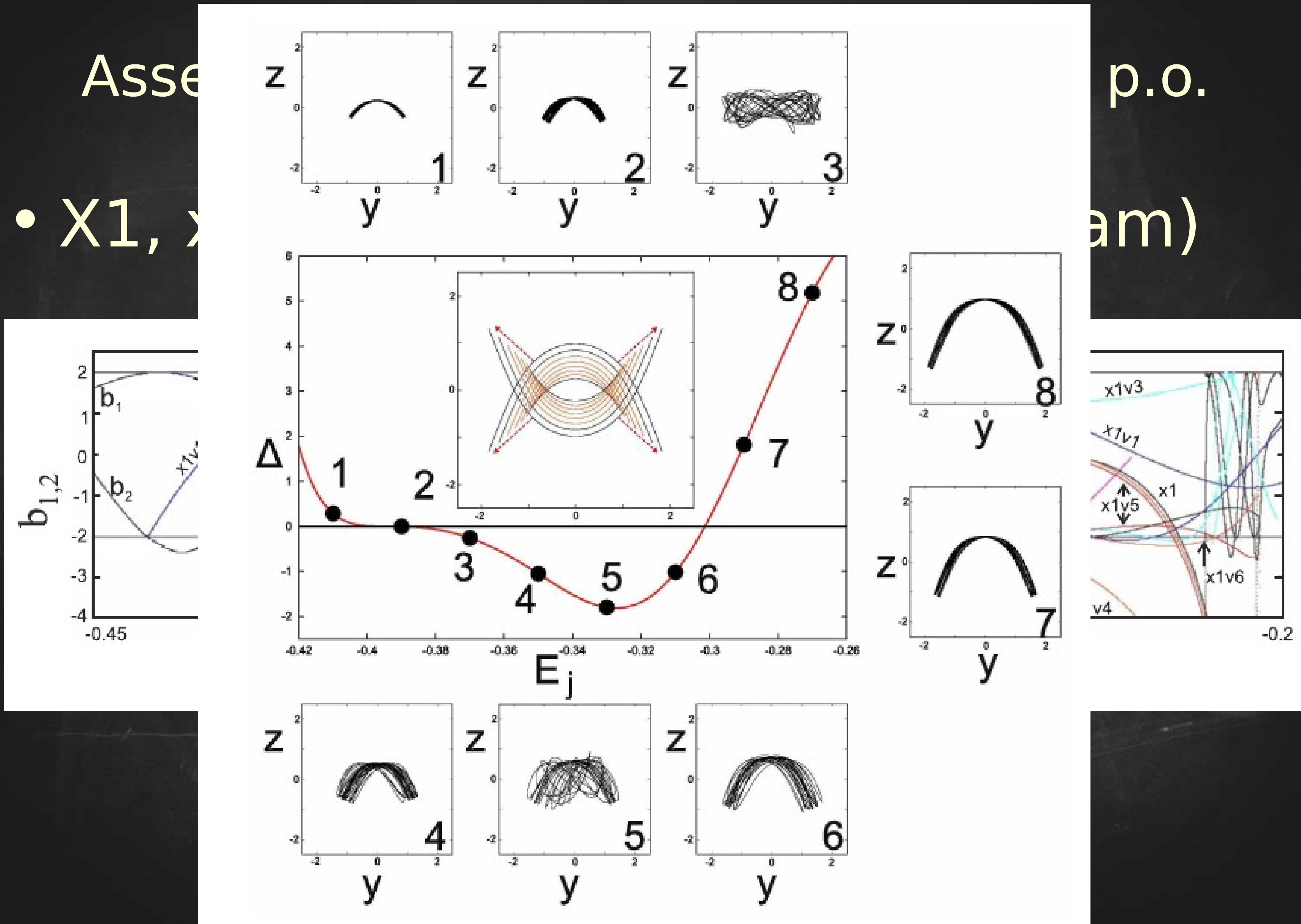
Early q-p x1 orbits

x1v1

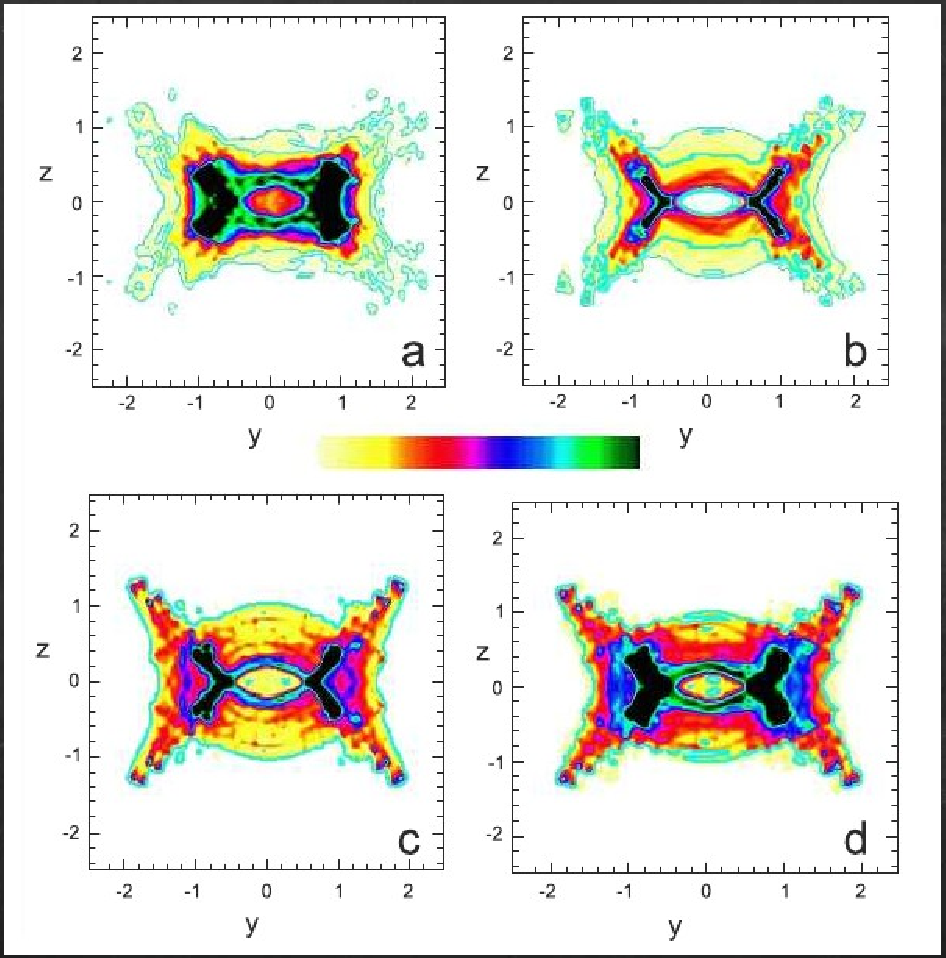


Asse… p.o.

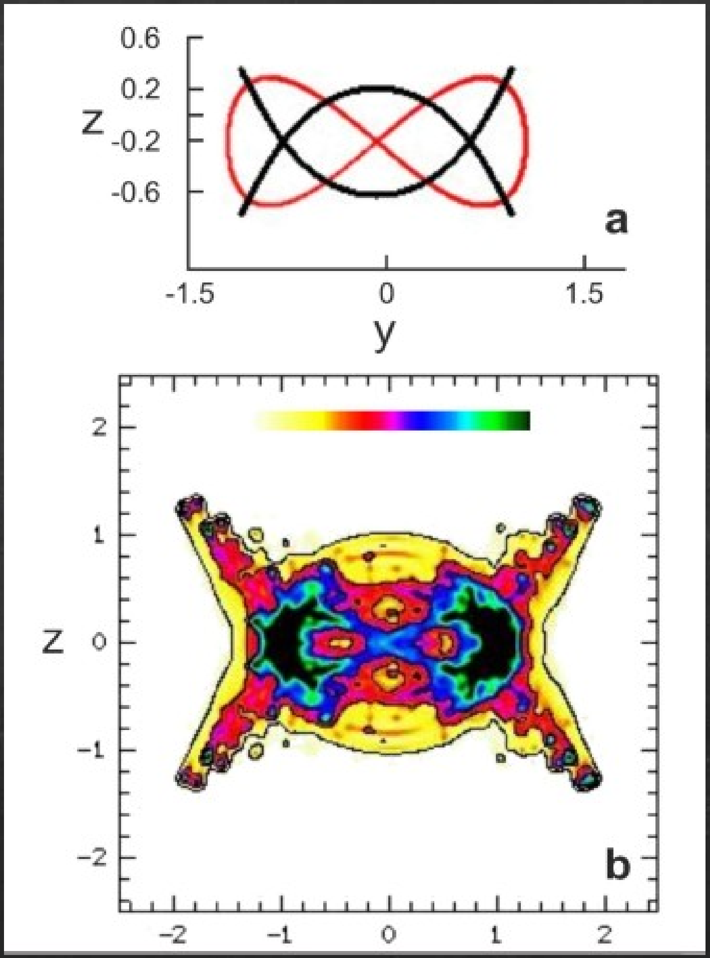
- X1, x… am)



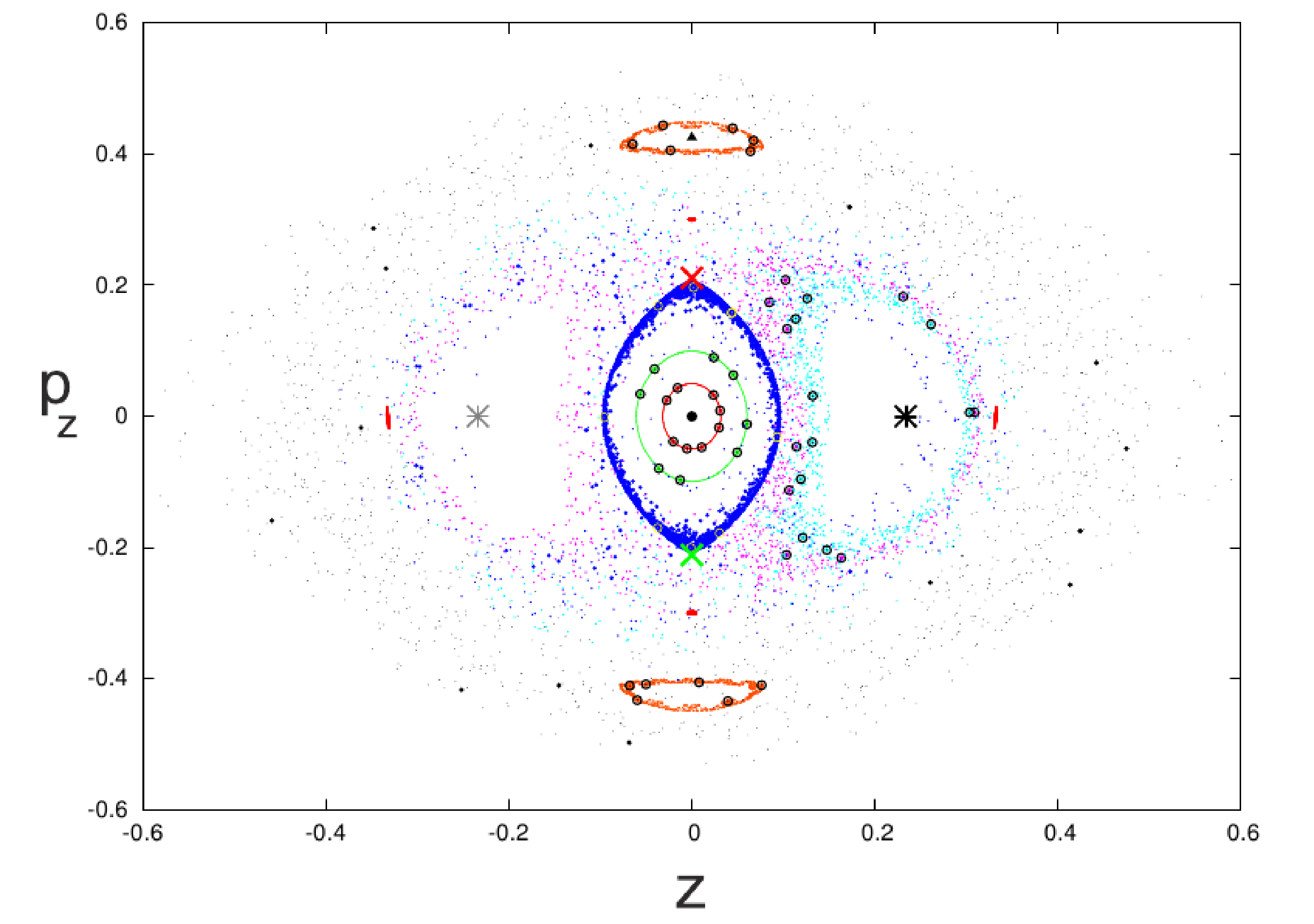
the "x1v1" scenario



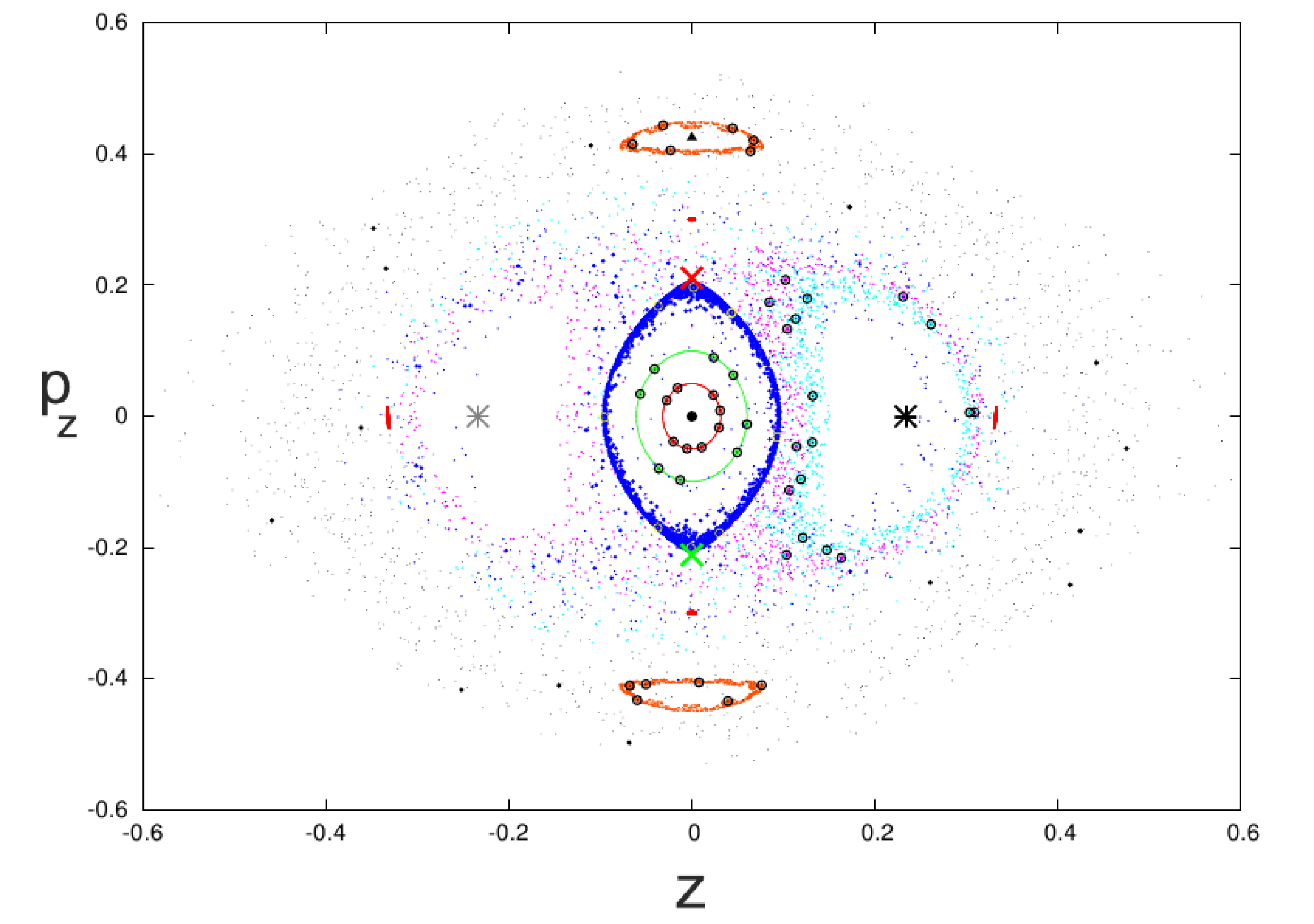
adding x1v2-like (CX-OX profiles)



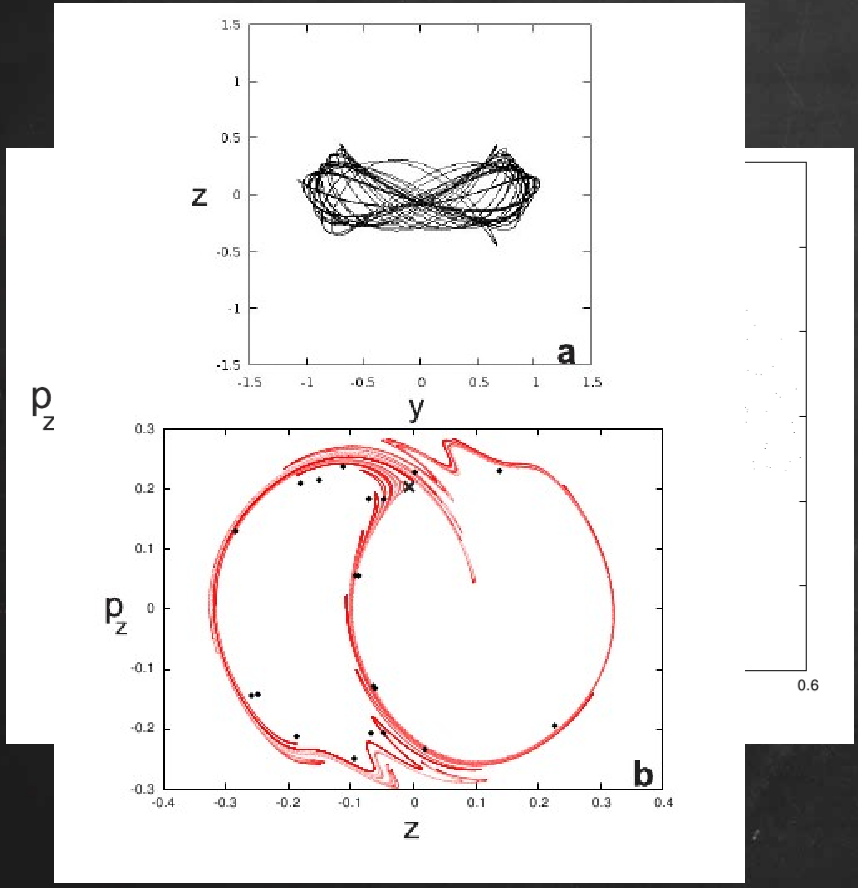
“CX”-profiles
Ej=-0.41 (x1,x1v1 S; x1v2 U)

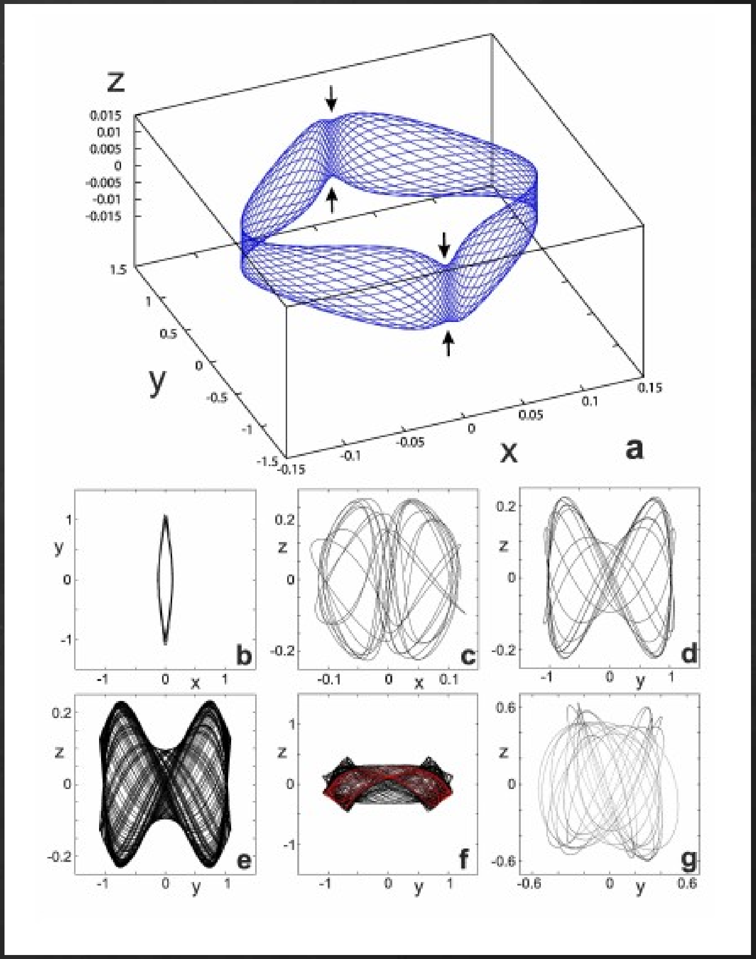


The x1v1 – x1v1’ attractor

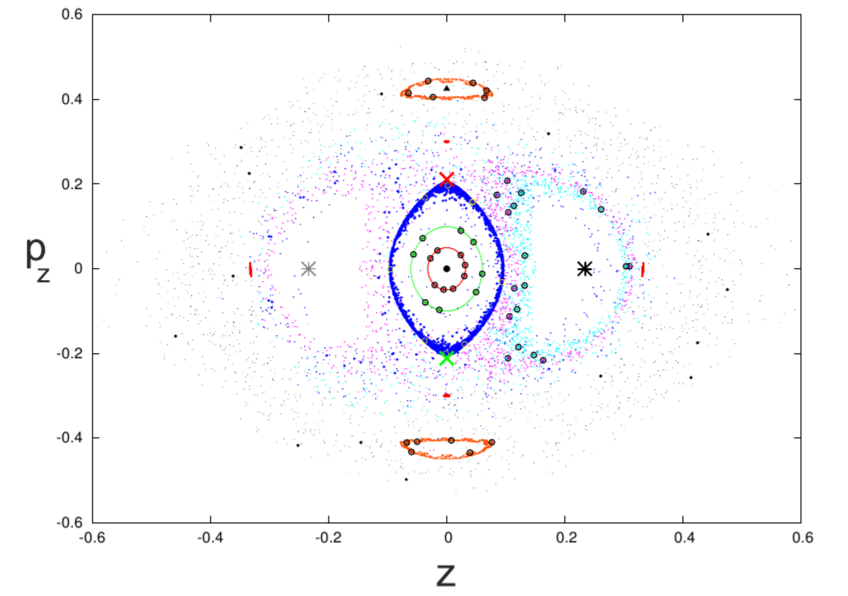


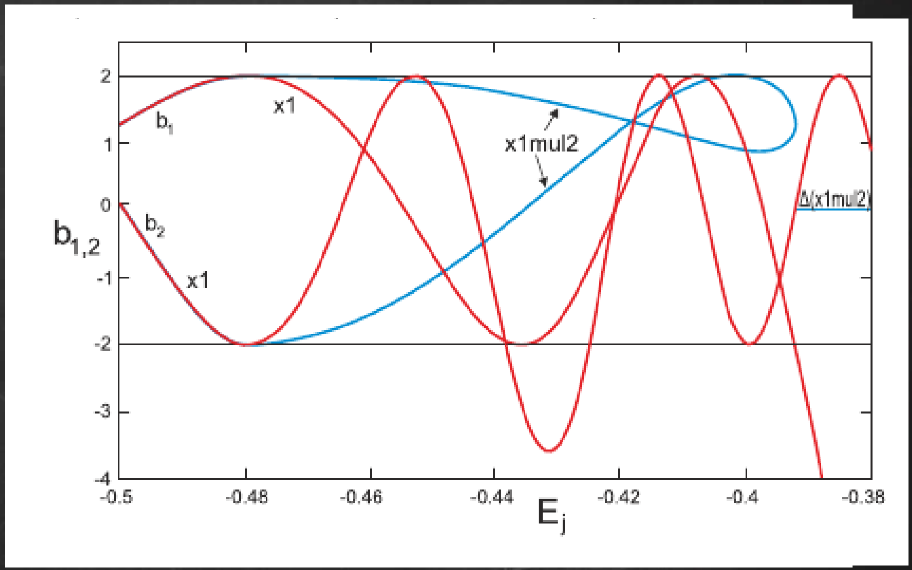
Ej=-0.41



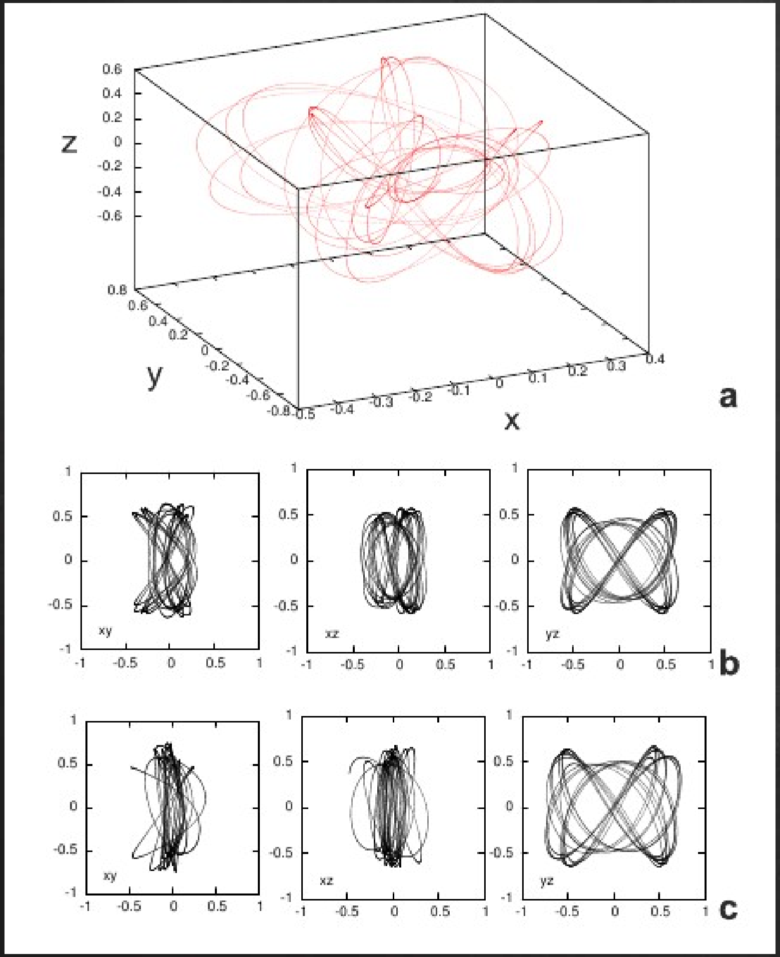


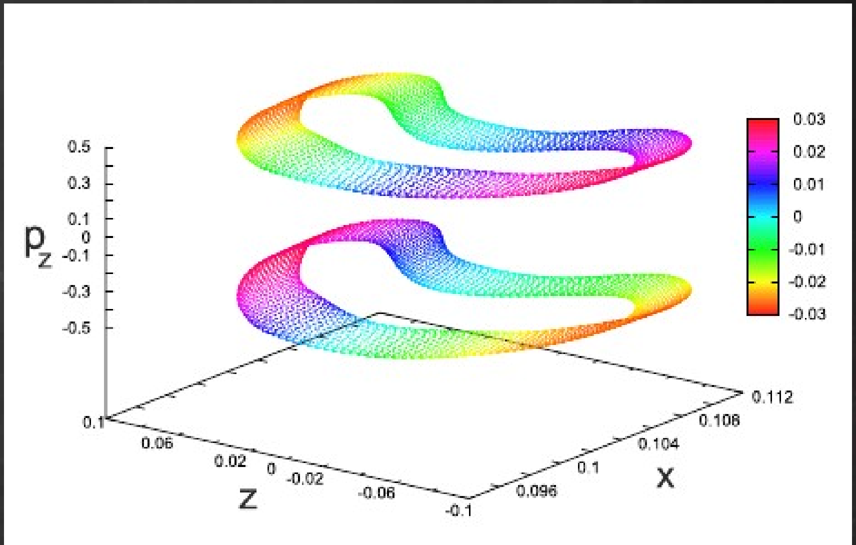
x1mul2

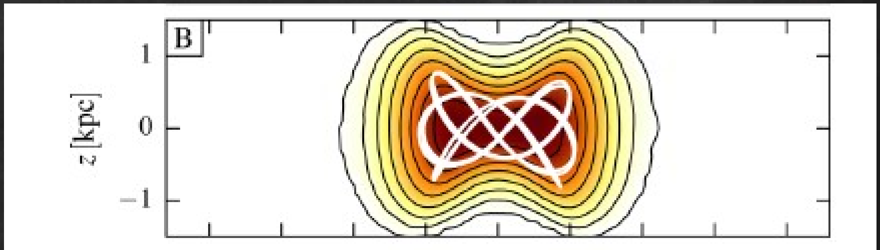




s & Δ x1mul2

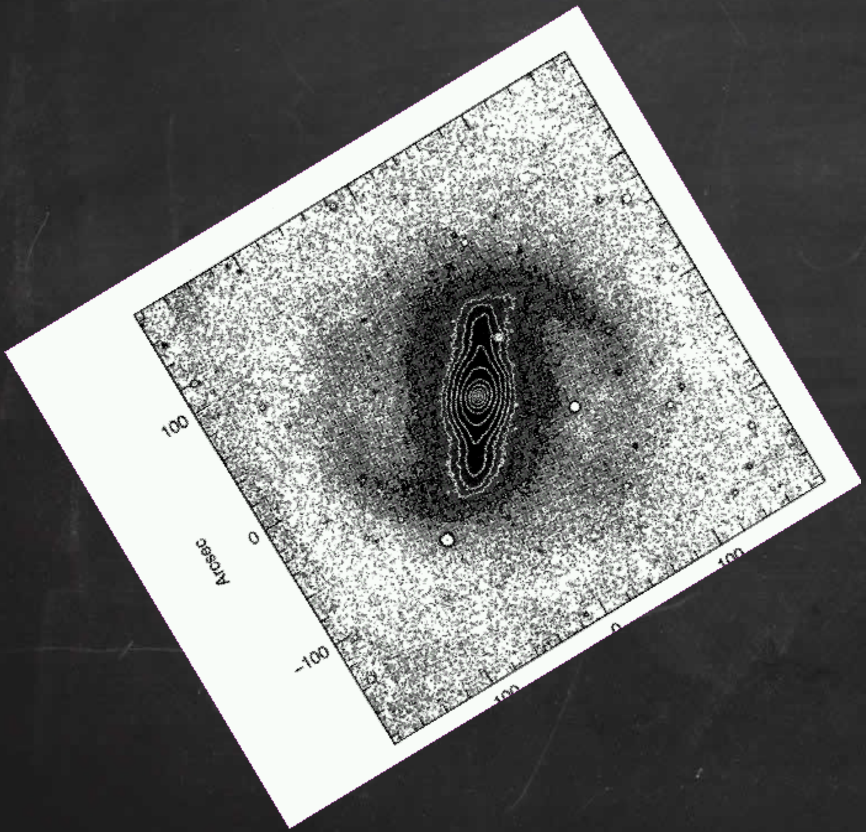


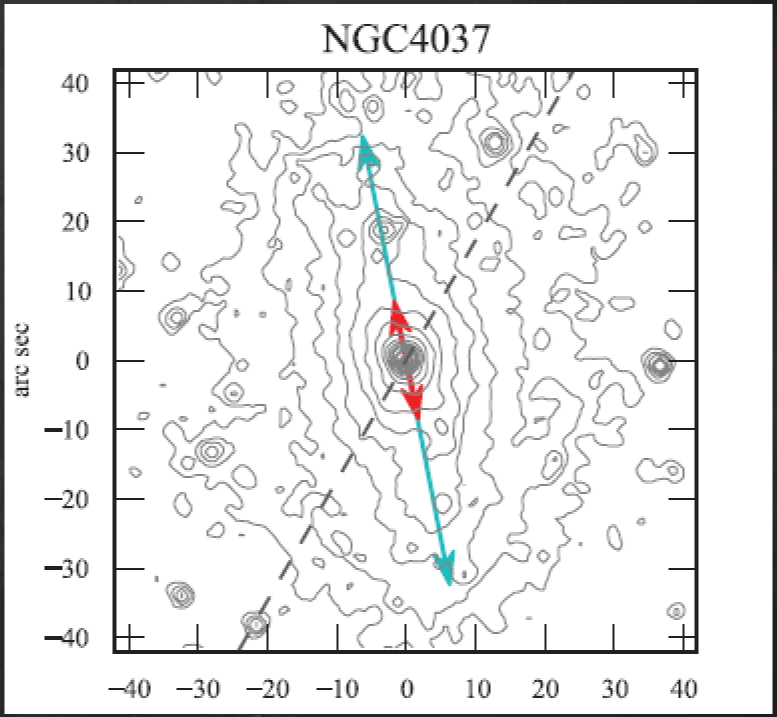




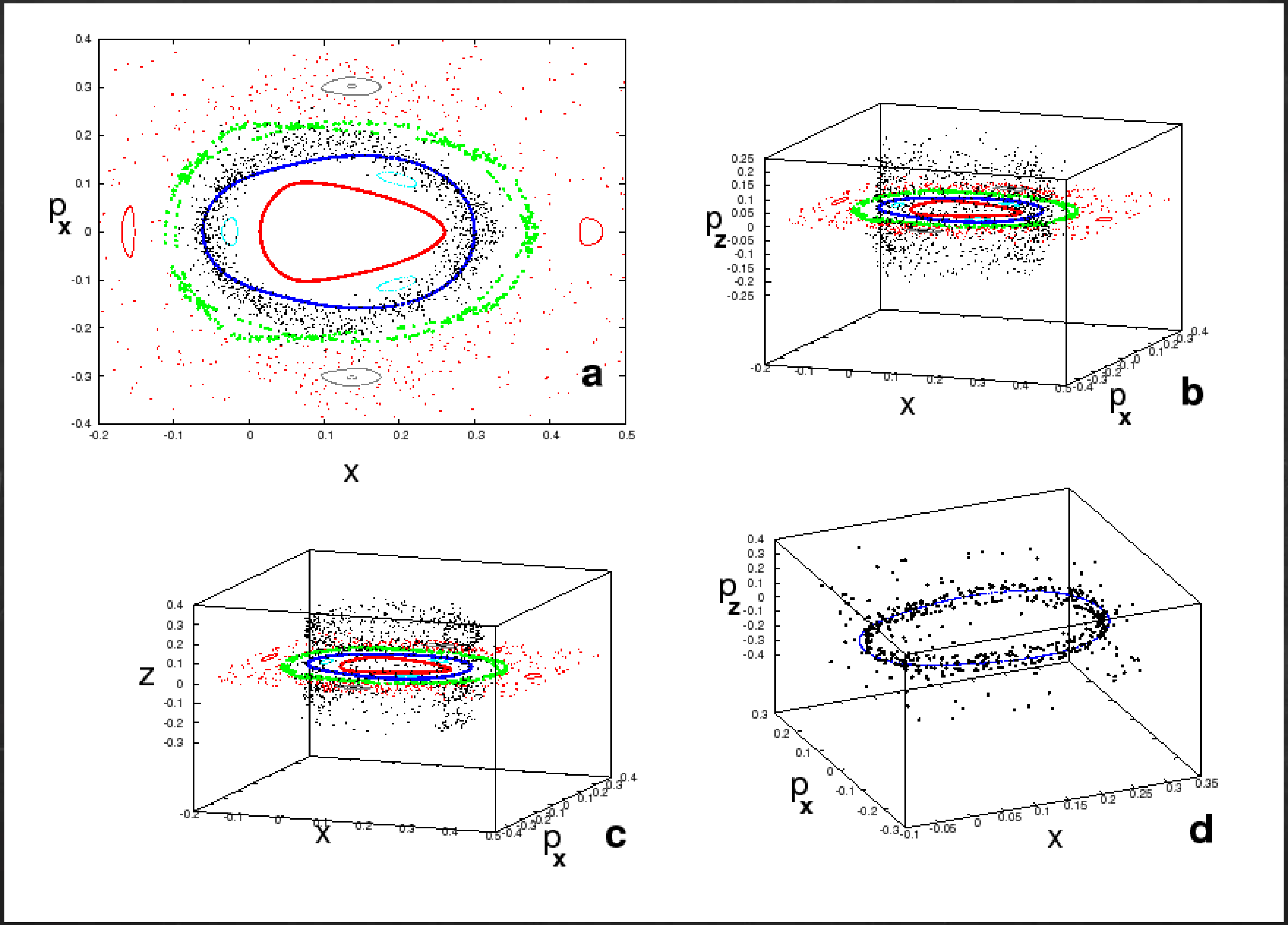
Portail, Wegg & Gerhard 2015

4. Inner boxiness of the bars

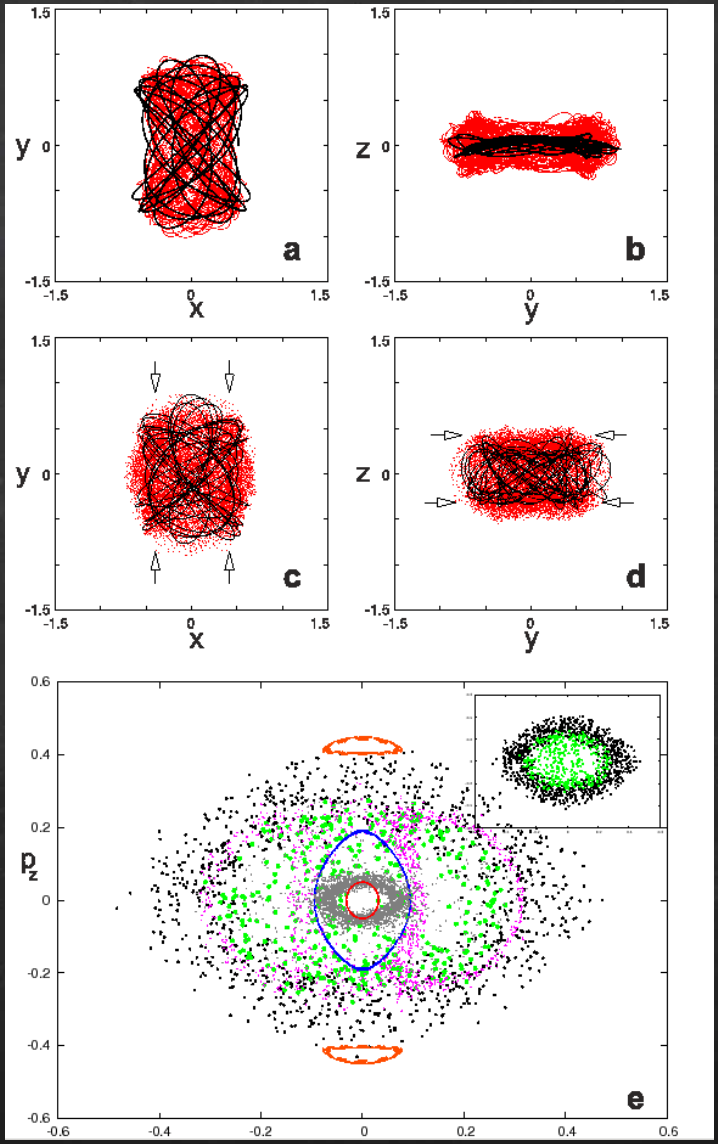




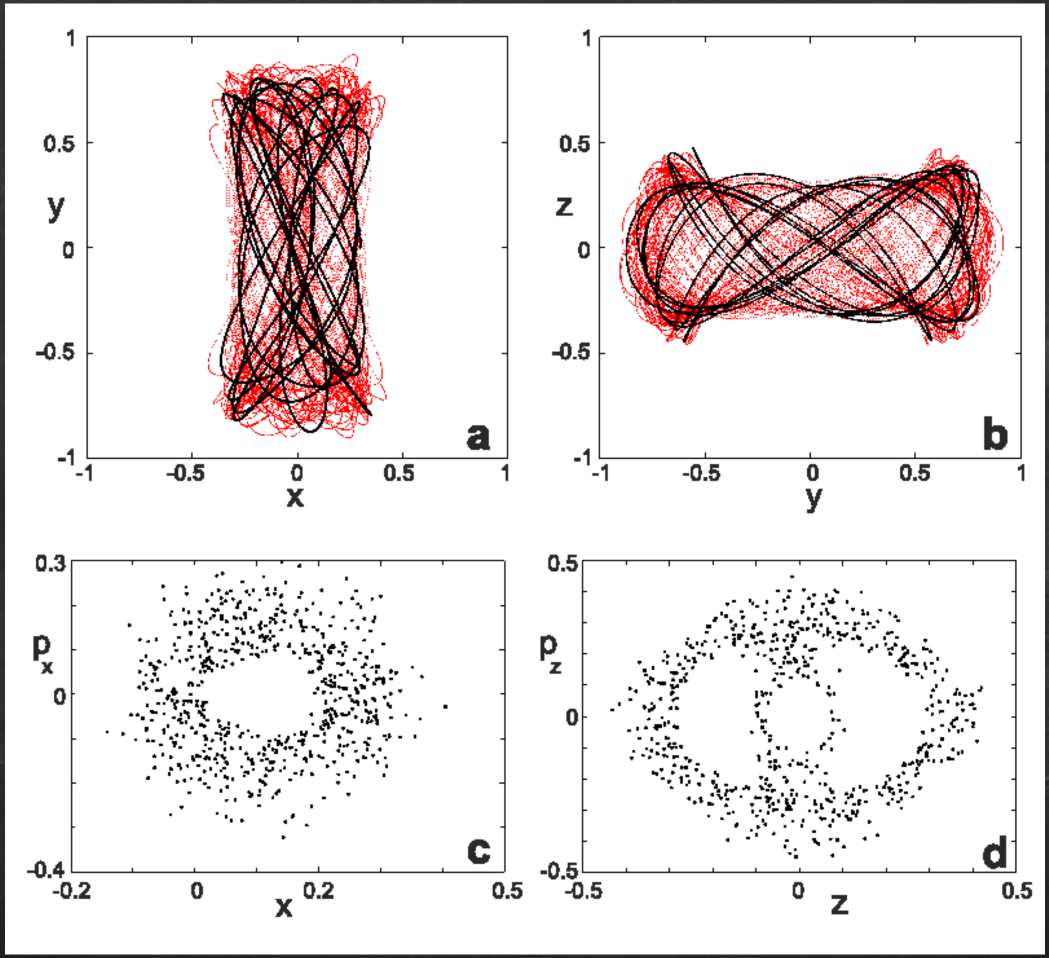
(x, p_x) + vertical perturbations



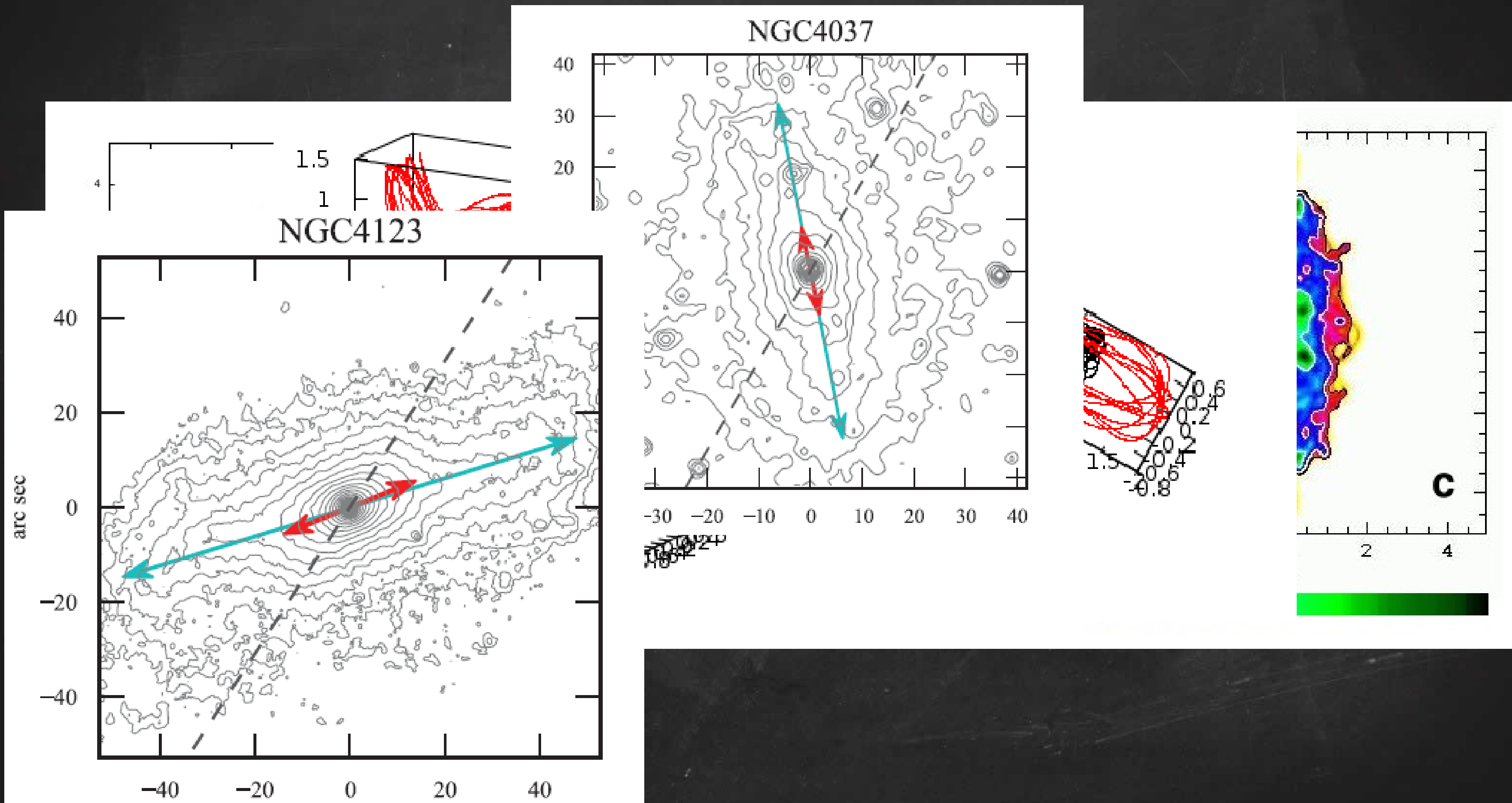
(x,p_x) in the chaotic sea



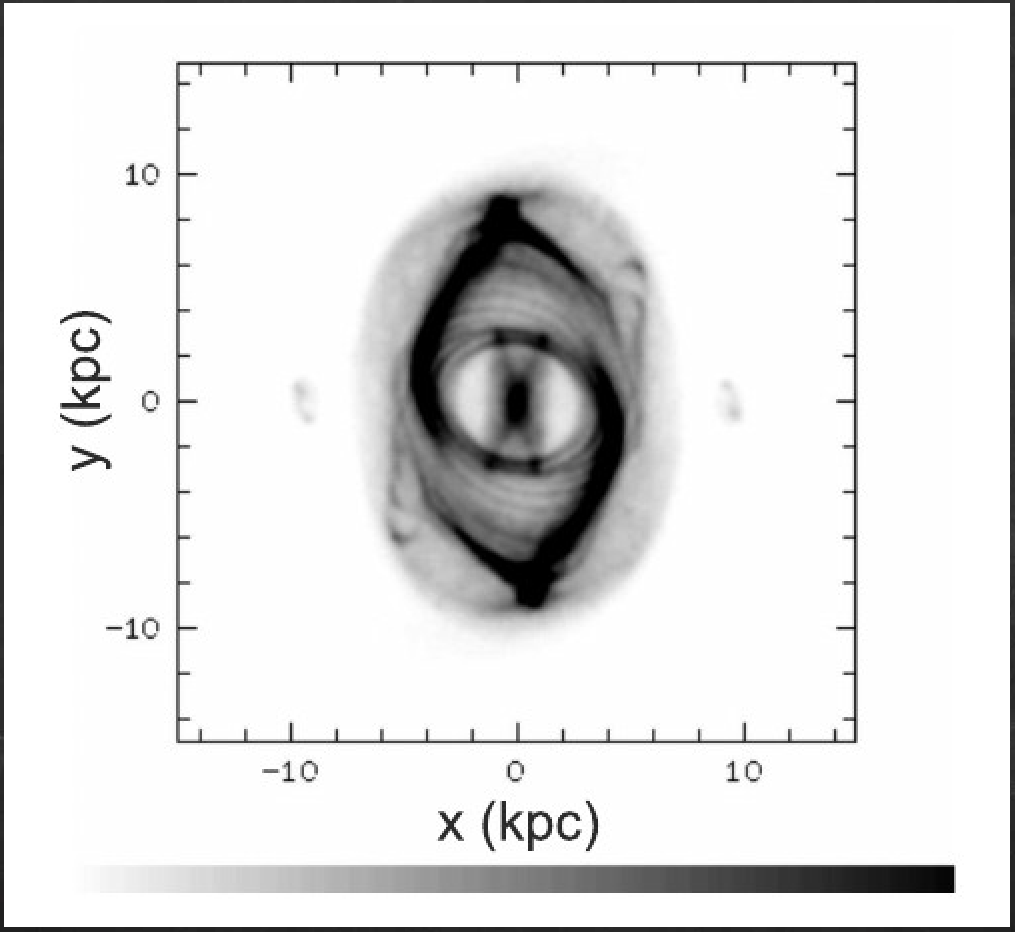
(x,p_x) in the stability island

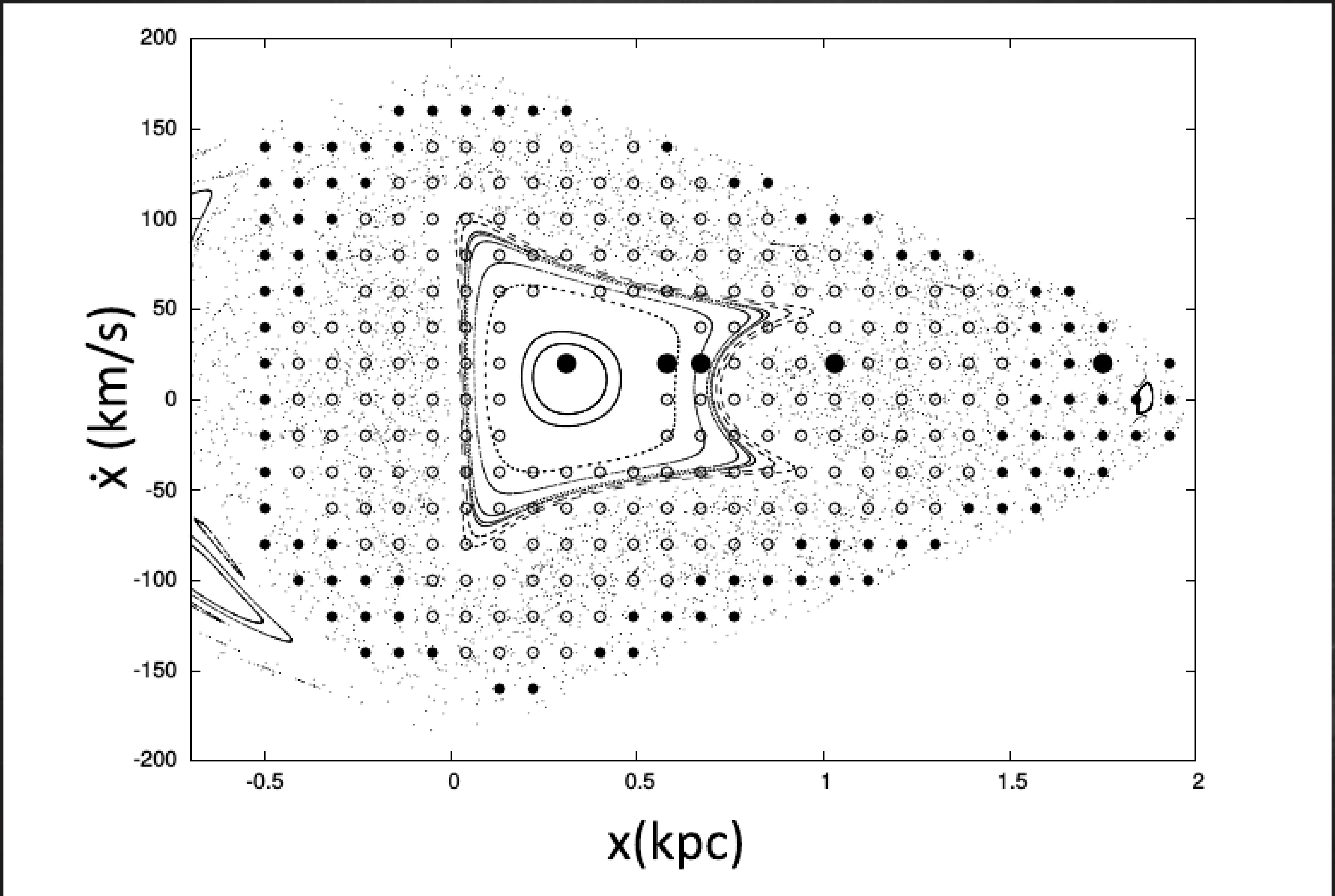


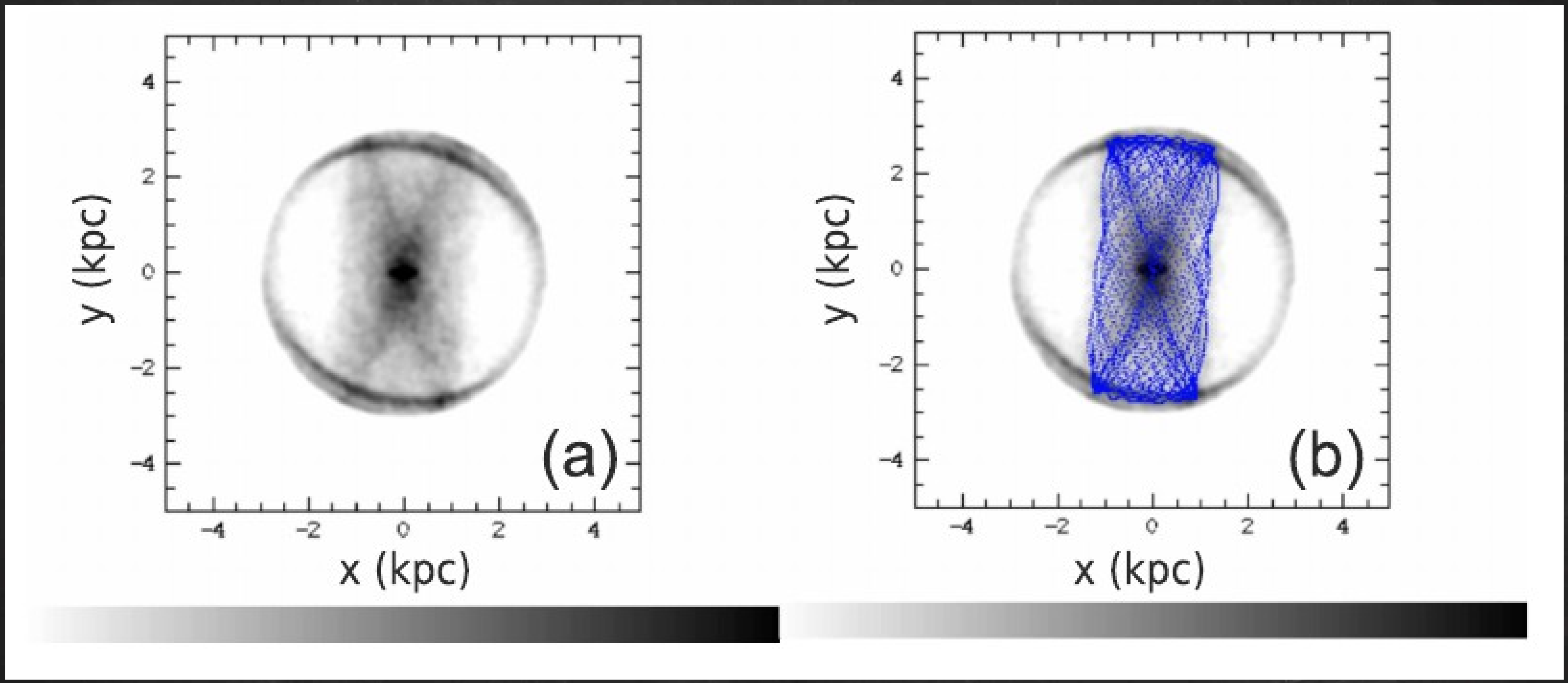
face-on profiles



sticky chaotic orbits behind boxy barred features?




200
150
100
50
0
-50
-100
-150
-200
ẋ (km/s)
-0.5
0
0.5
1
1.5
2
x(kpc)


y (kpc)
x (kpc)
(a)
(b)
4
2
0
−2
−4

Summary

- Inner boxiness observed in face-on bars can be supported by chaotic orbits sticky to x1.
- The presence of inner boxy isophotes in face-on views of bars is a strong indication for the participation of chaos in the building of the bar

Summary

- There is a direct relation between inner boxy face-on and inner boxy edge-on features.

Both are determined by the dominance of the x1v1 – x1v1' tori in 4D cross sections.

- The internal structure of a peanut depends on the amount of non-periodic orbits populated in the phase space of the v/r-ILR region.

Thank you for your attention