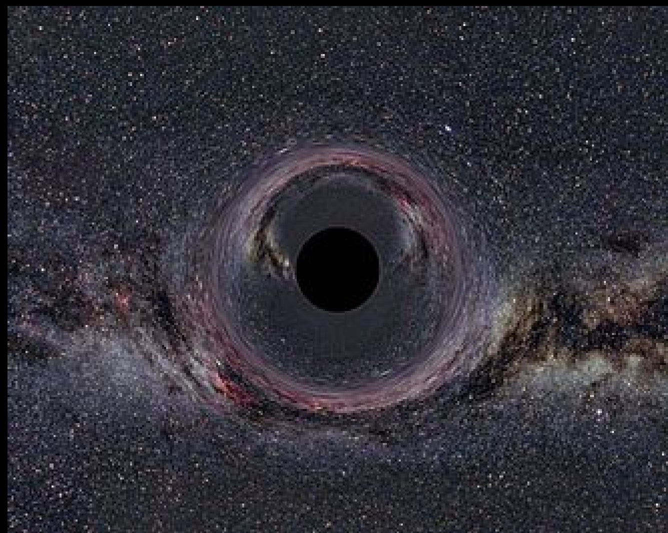
Dynamical evolution of supermassive single and binary in galactic nuclei



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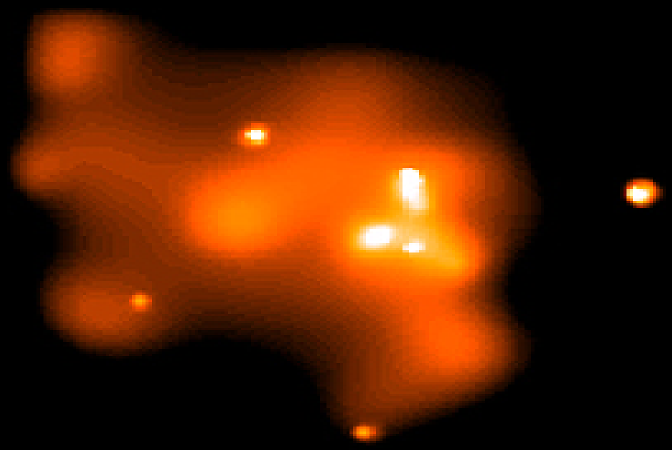
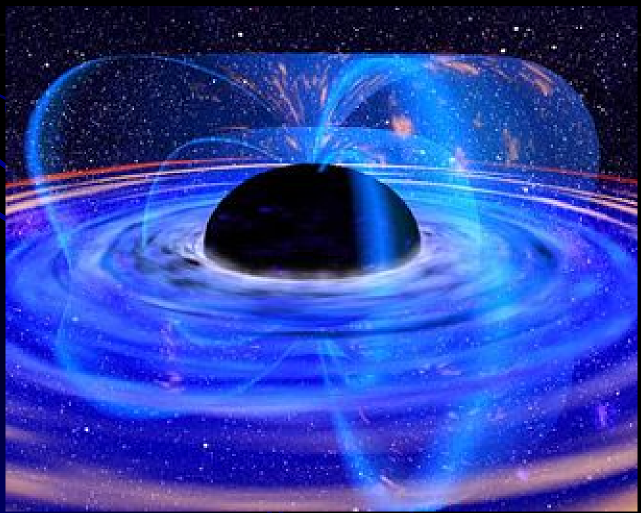
Overview

1. Introduction (statistics of supermassive black holes in galactic nuclei).
2. Models of galactic central regions.
3. Globular clusters as perturbers of black holes.
4. Results and conclusions.

Introduction





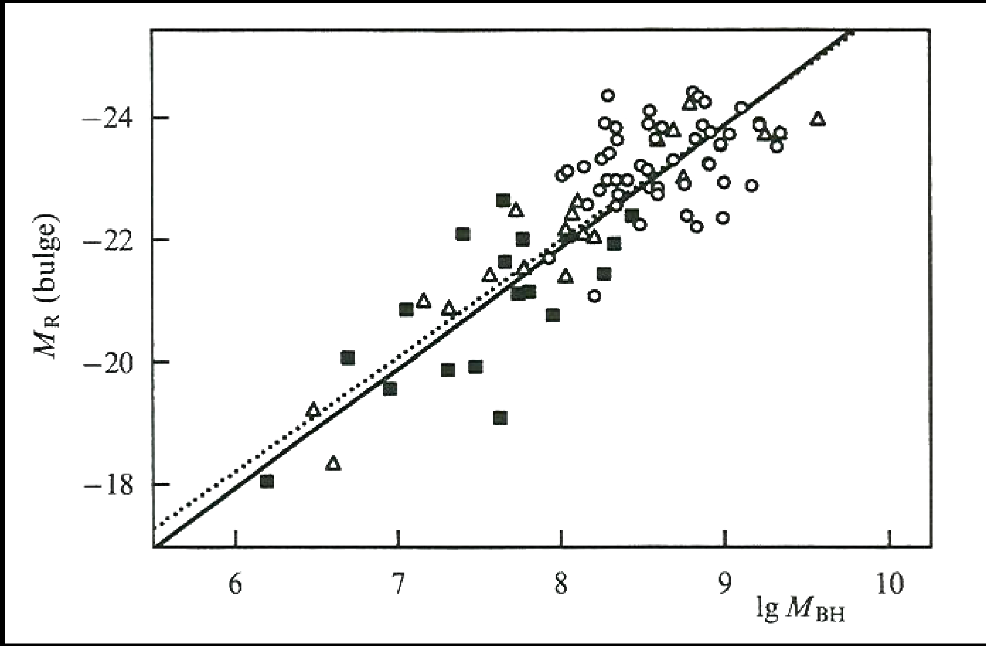
Statistics of supermassive compact objects in galactic nuclei (Cherepashchuk, 2007): More than 300 such objects are known.

Statistics of CMO

Mass range of Compact Massive Objects (CMO) in galactic nuclei is from 10^6 till 10^{10} solar masses.

There is a correlation between bulge absolute magnitude and CMO mass (open circles correspond to quasars, squares – to Seyfert I galaxies, triangles – to normal galaxies):

$$M_{BH} \cong 0.001\ M_{bulge}$$



Factors that influence to dynamics of central CMO in the galaxies

1) Bulge potential.
2) Encounters with massive objects of galactic field (globular clusters, GMC, black holes of intermediate masses etc.).
3) Bar potential and other possible global modes.
4) Dynamical friction on stars and gas.
5) Accretion of nearby medium on CMO.

Purpose of our studies

Investigation of CMO migration due to joint action of two factors:

1) Potential of galactic bulge.

2) Encounters with globular clusters.

The first factor stabilizes the CMO in the central potential well, while the second one leads to the CMO oscillations around the galactic center.

Model of galactic core

We assume the bulge of the galaxy as the Plummer's sphere with the potential:

$$\Phi(r) = \frac{GM_{bulge}}{(r^2+b^2)^{1/2}}$$

Parameters of bulge and CMO:

$M_{bulge} = (10^9 M_\odot - 10^{12} M_\odot)$

$M_{bh} = 0.001 M_{bulge}$

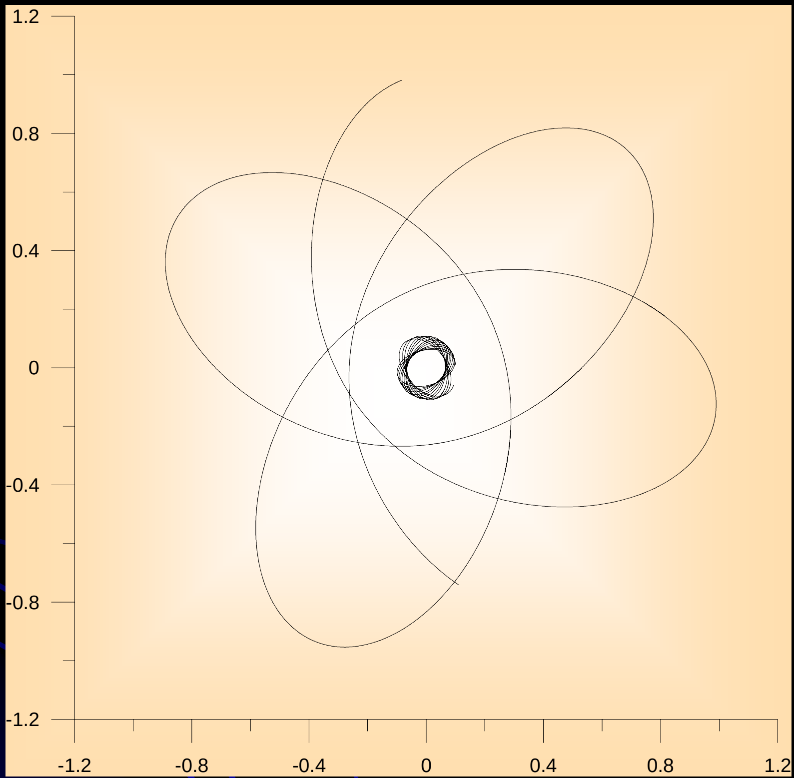
$b = (0.2 - 2.0)$ kpc

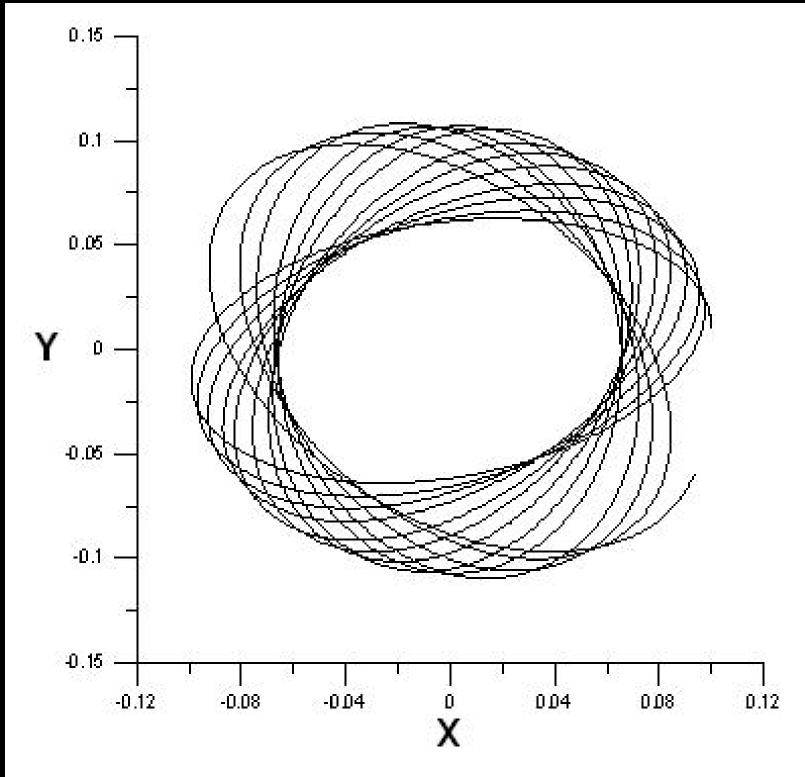
Calculations of the CMO motion

We take into account the interaction between CMO and globular cluster and effect of the bulge on CMO and cluster.

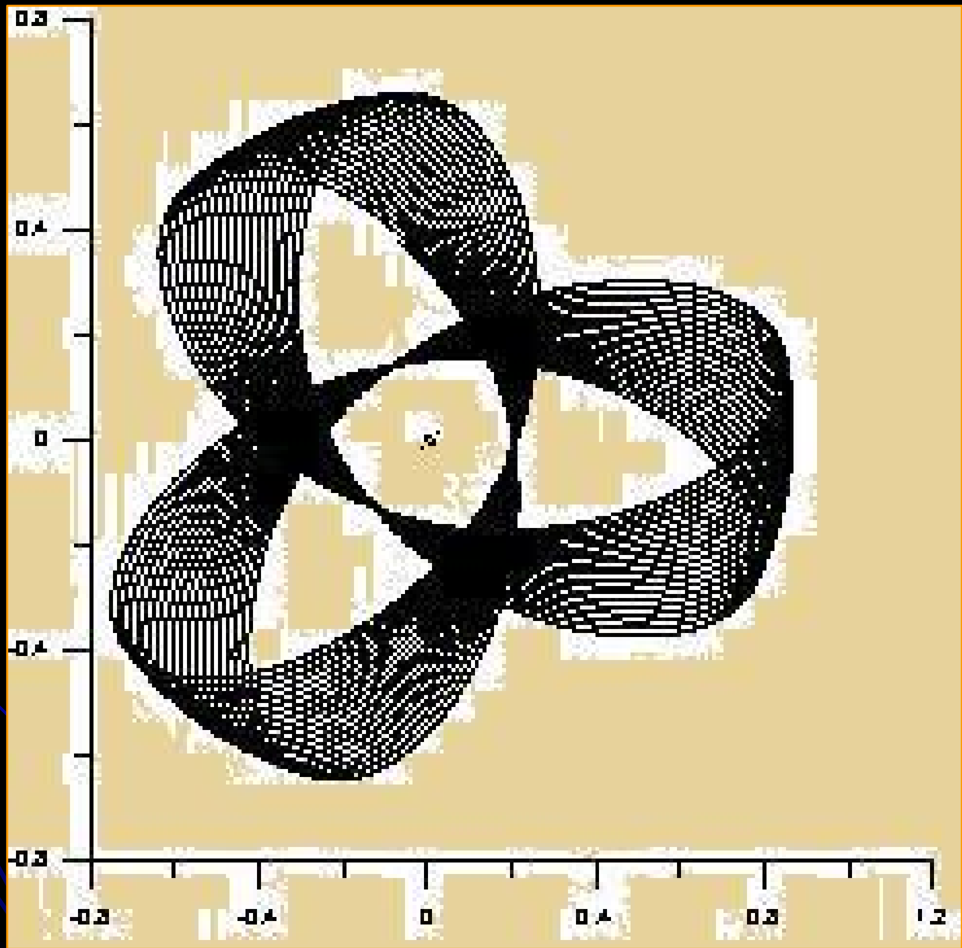
We neglect the reverse actions of CMO and cluster on the bulge motion.

Examples of CMO and cluster orbits in projection on the galactic plane





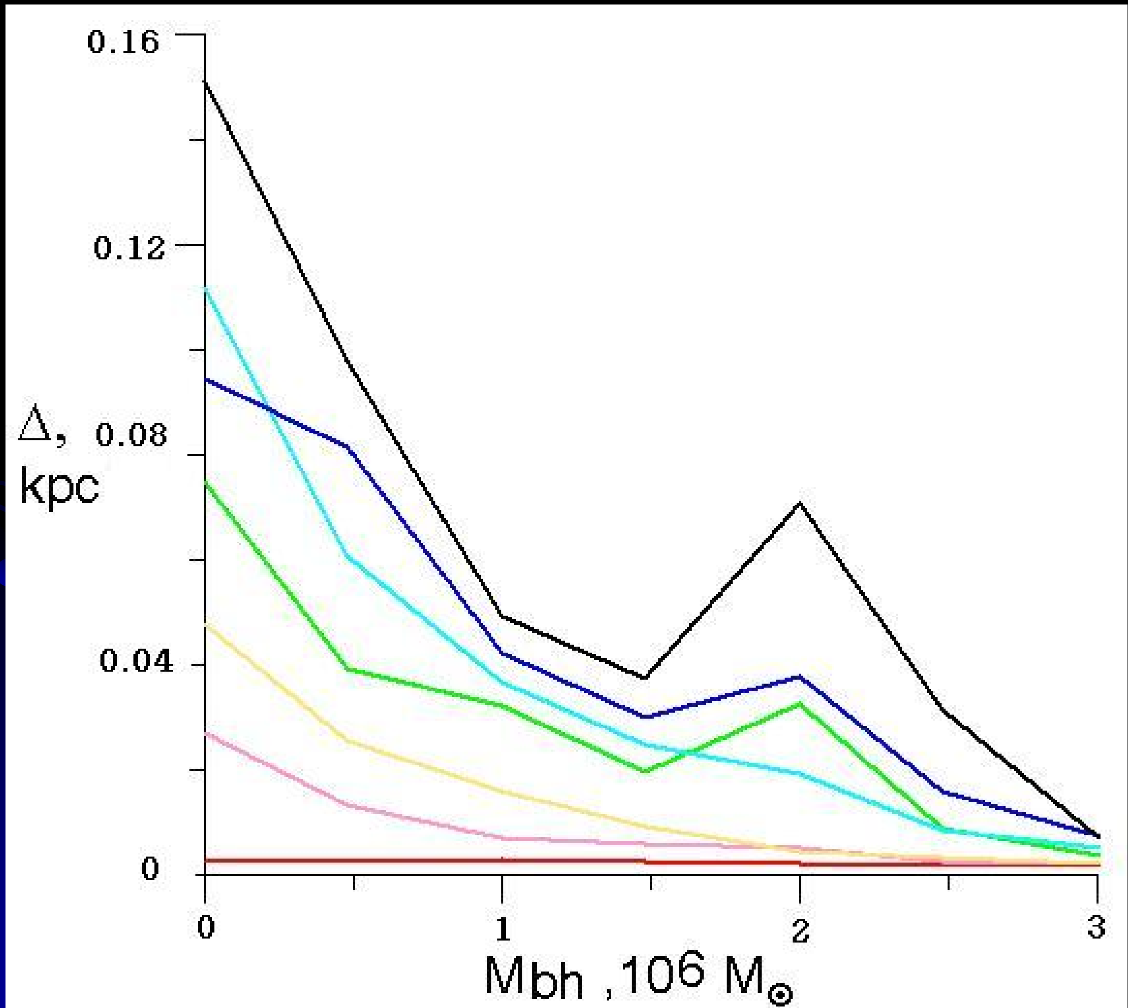
Tube-like orbit of globular cluster



The oscillation amplitude of CMO versus bulge size and its mass

$(M_{BH} = 0.001\ M_{bulge})$.

Initial velocity and mass of the cluster are V_0= 200 km/s, $M_{cl} = 10^6 M_\odot$.



b =

2.0 kpc

1.7 kpc

1.4 kpc

1.1 kpc

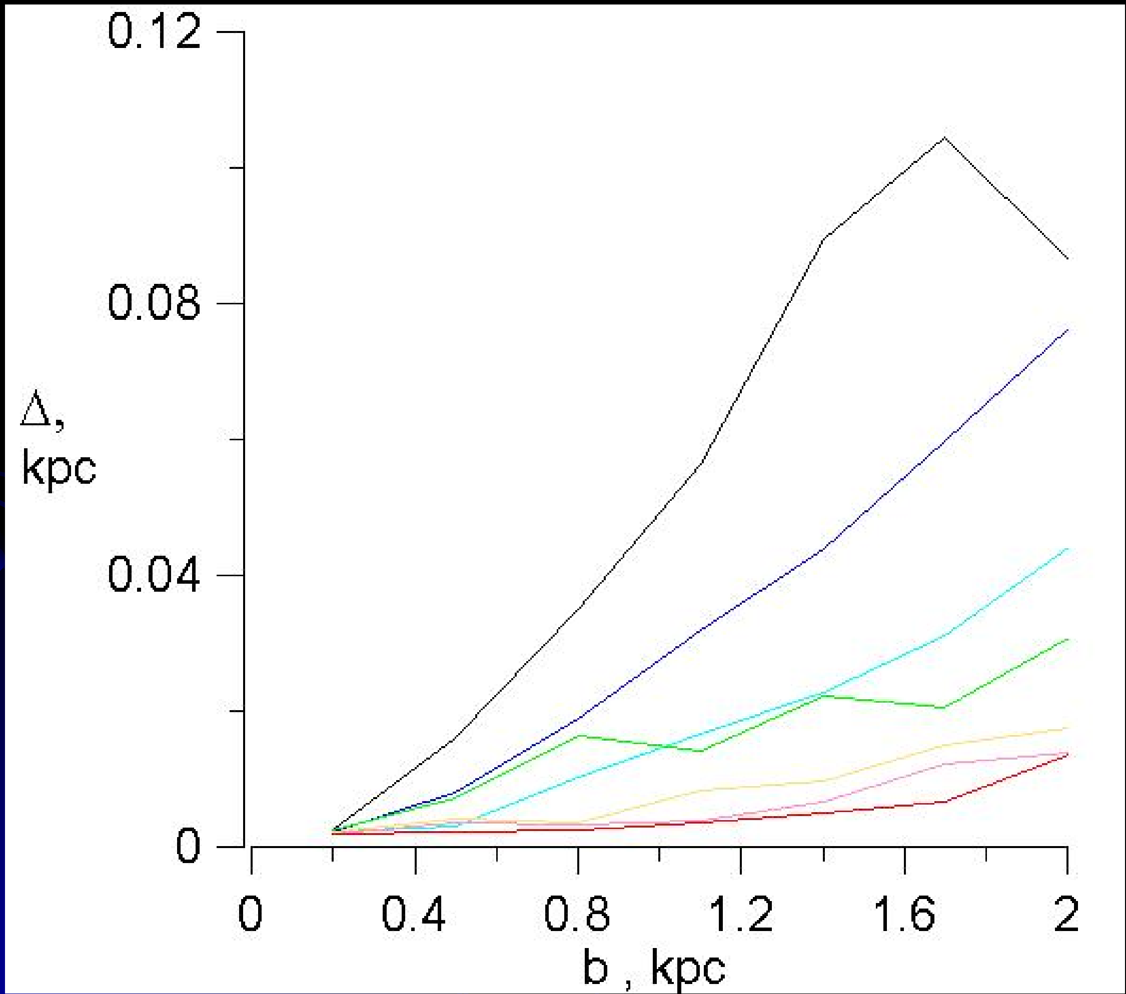
0.8 kpc

0.5 kpc

0.2 kpc

The oscillation amplitude of CMO versus bulge size and its mass

Initial velocity and mass of the cluster are V_0= 300 km/s, $M_{cl} = 10^6 M_\odot$.



M_{bulge} =

10^9 M⊙

$3 \cdot 10^9$ M⊙

10^{10} M⊙

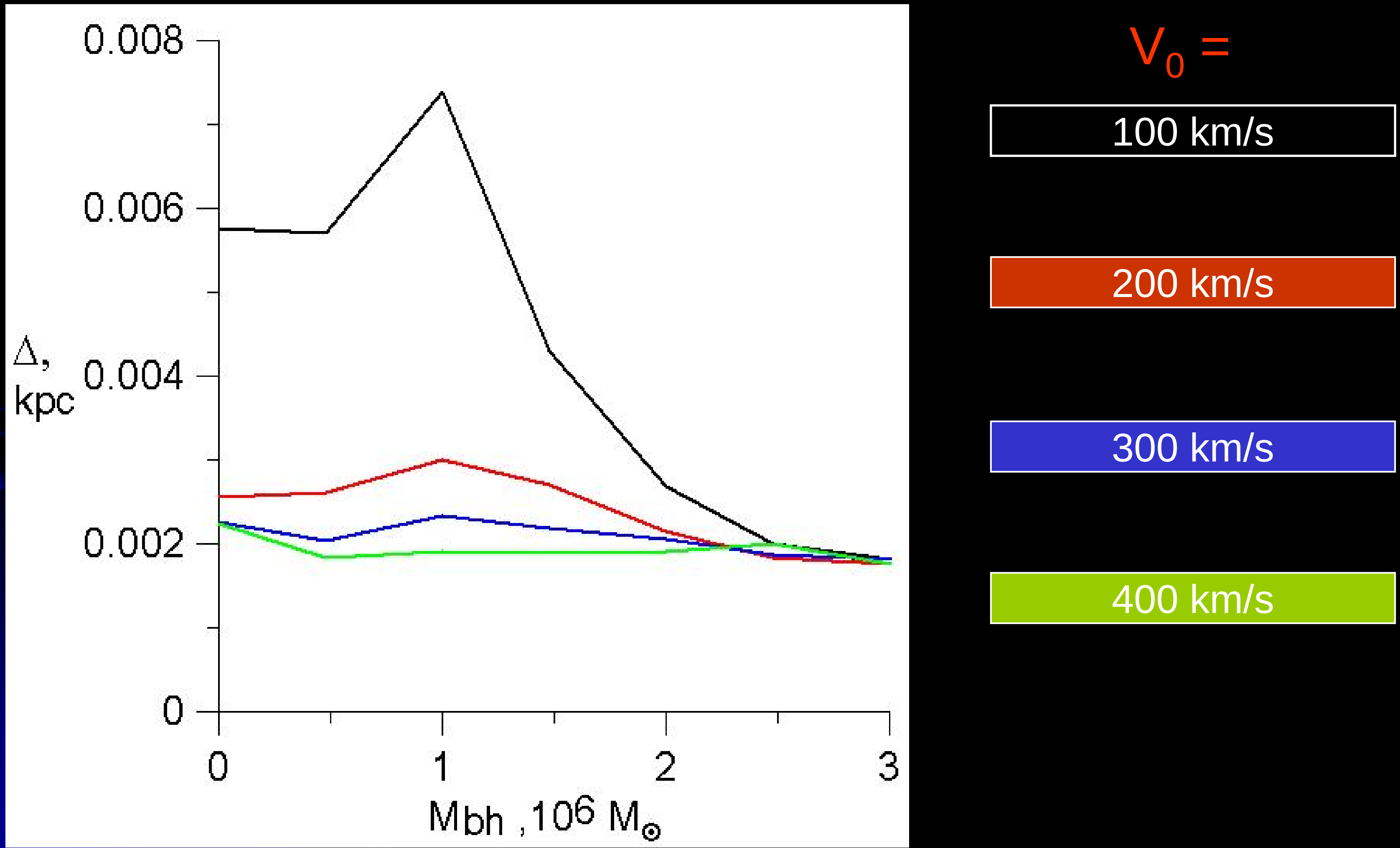
$3 \cdot 10^{10}$ M⊙

10^{11} M⊙

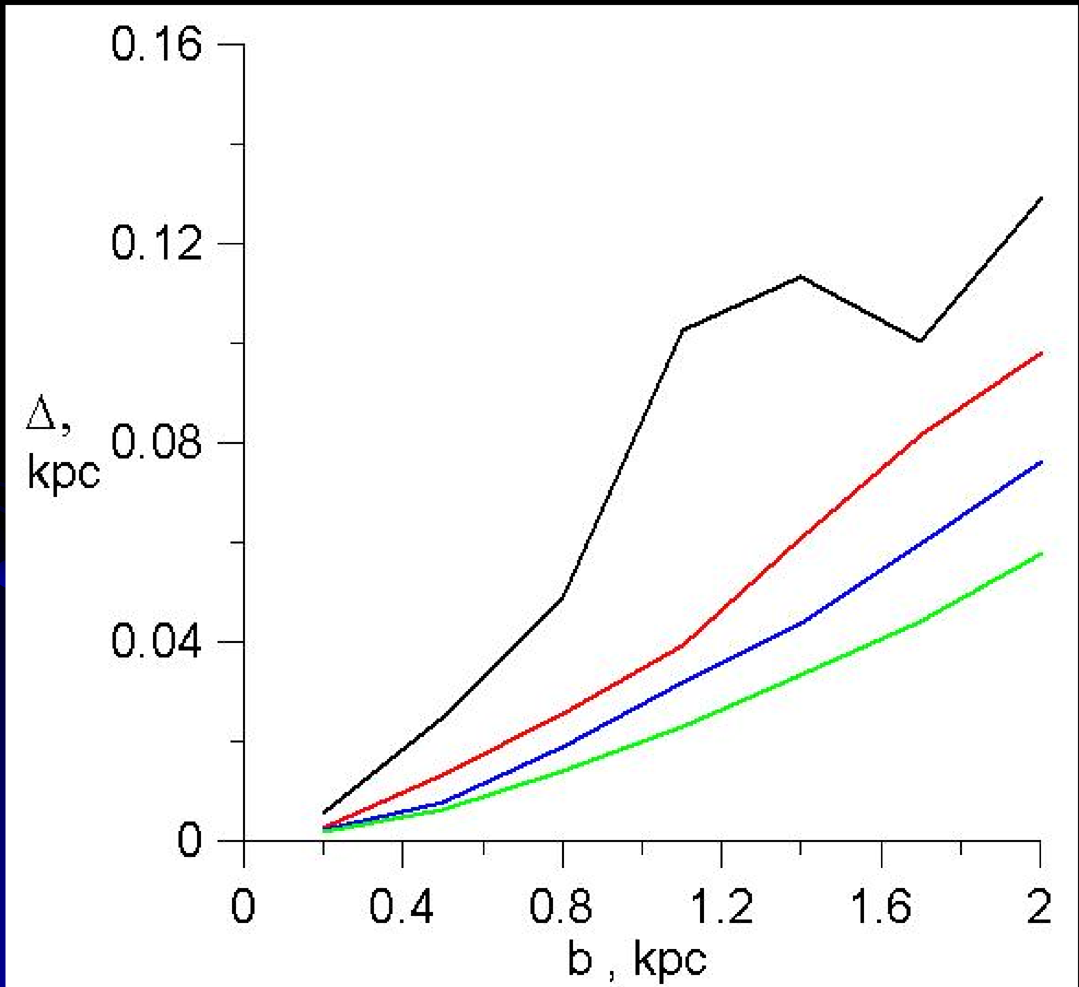
$3 \cdot 10^{11}$ M⊙

10^{12} M⊙

The oscillation amplitude of CMO versus bulge mass for different initial cluster velocity and fixed bulge size (b= 0.2 kpc). The cluster mass is $M_{cl} = 10^6 M_\odot$.



The oscillation amplitude of CMO versus bulge size for different initial cluster velocity and fixed bulge mass ($M_{bulge} = 3 \cdot 10^9 M_\odot$). The cluster mass is $M_{cl} = 10^6 M_\odot$.



V_0 =

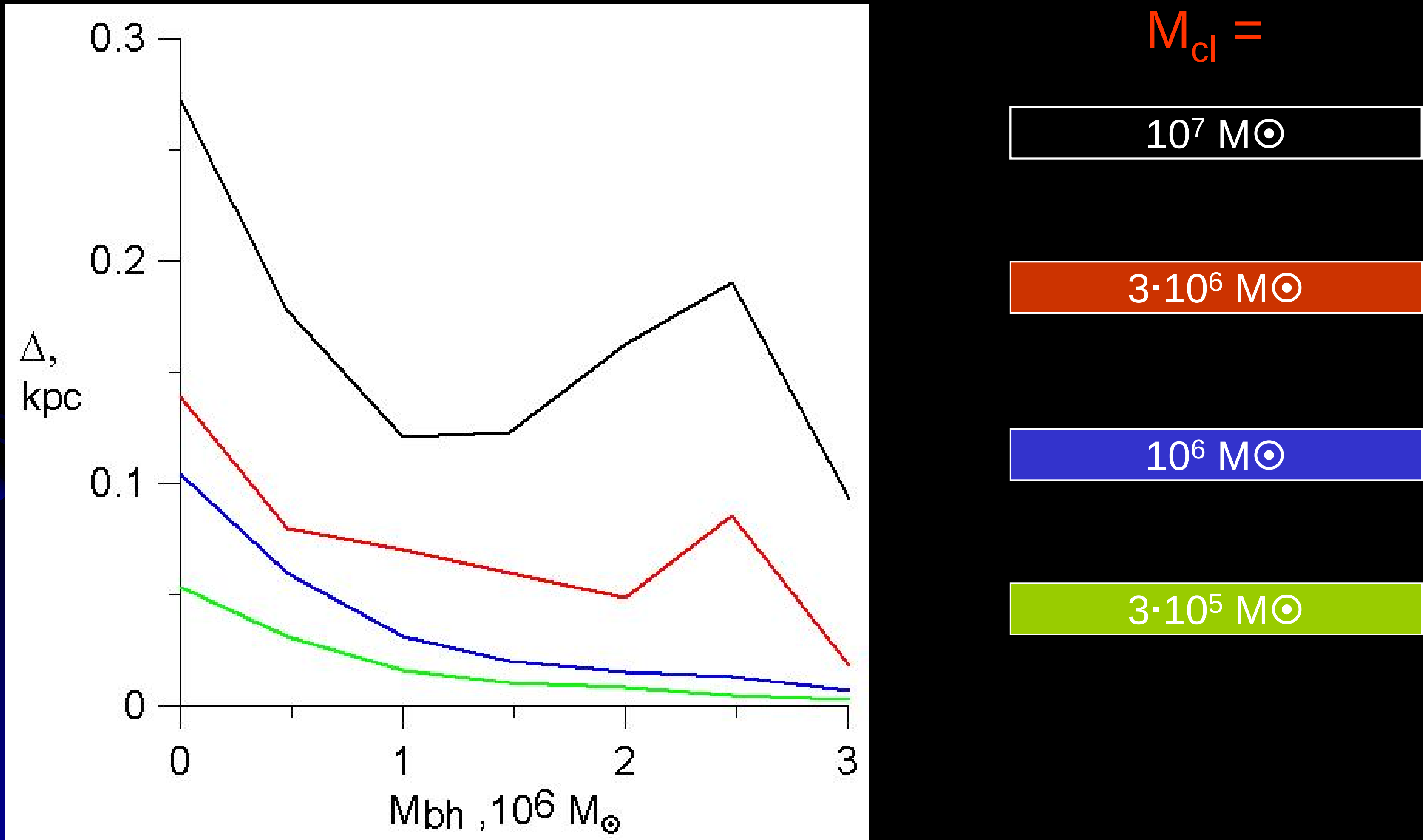
100 km/s

200 km/s

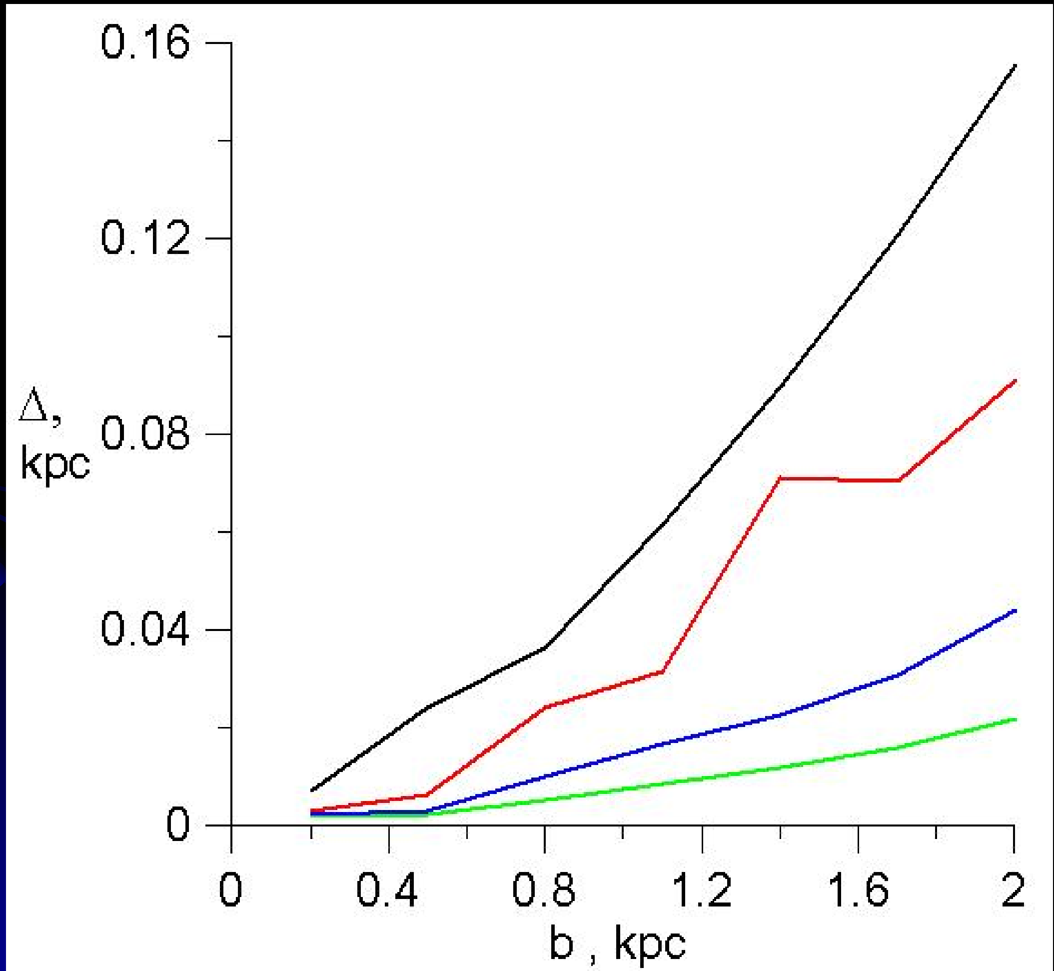
300 km/s

400 km/s

The oscillation amplitude of CMO versus bulge mass for different initial cluster mass and fixed bulge size (b= 1.7 kpc).
The initial cluster velocity is V_0 = 300 km/s.



The oscillation amplitude of CMO versus bulge size for different initial cluster mass and fixed bulge mass ($M_{bulge} = 10^{10}\ M_{\odot}$). The initial cluster velocity is $V_0 = 300$ km/s.



M_{cl} =

$10^7\ M_{\odot}$

$3 \cdot 10^6\ M_{\odot}$

$10^6\ M_{\odot}$

$3 \cdot 10^5\ M_{\odot}$

The oscillation amplitude of CMO versus bulge mass and size.

$M_{cl} = 3 \cdot 10^6\ M_\odot$, $V_0 = 300$ km/s.

Amplitude decrease

increase

Δ, pc		M_{bulge}, $M_\odot$			
		10^9	*10^{10}*	*10^{11}*	*10^{12}*
b, pc	*200*	1.967 ±0.004	1.801 ±0.014	1.807 ±0.022	1.742 ±0.002
	800	17.317 ±3.512	5.251 ±1.151	2.119 ±1.7	1.828 ±0.019
	1400	42.569 ±10.305	11.844 ±1.834	4.099 ±0.861	2.296 ±0.246
	2000	70.565 ±15.447	21.972 ±4.649	9.736 ±2.825	4.581 ±1.994

Conclusions

1. We have shown that the drift amplitude of central CMO in nuclei of spiral galaxies can reach a few hundreds parsecs due to encounters with globular clusters.
2. In average, the drift amplitude increases when the bulge size grows (at its fixed mass) and decreases when the bulge mass grows (at its fixed size).
3. In average, the drift amplitude increases when the cluster mass grows and its velocity diminishes