Astronomical and Astrophysical Transactions (*AApTr*), 2012, Vol. 27, Issue 3, pp. 441–444,
ISSN 1055-6796, Photocopying permitted by license only, ©Cambridge Scientific Publishers

Migration of compact massive objects in galactic nuclei

A.S. Kondratiev, V.V. Orlov*

Sobolev Astronomical Institute, St. Petersburg State University, 28 Universitetskii Pr., St. Petersburg, Stary Peterhof, 198504 Russia

Received 20 November, 2008

The migration of compact massive objects (CMO) in galactic nuclei through their encounters with massive objects (e.g. globular clusters or molecular clouds) is studied. We take into account gravitational interaction between CMO, clusters and galactic bulge. Mass of CMO is assumed to be equal to 0.001 of bulge's mass. The dependences of the CMO's drift amplitude on mass and size of bulge, velocity and mass of cluster have been found. The drift amplitude of the CMO increases when velocity of cluster and bulge's mass decrease. When we fix bulge's mass, drift amplitude grows while the bulge size increases. Drift amplitudes were obtained for several observed galaxies.

Keywords: Galactic nuclei; Central compact objects; Dynamics

1 Introduction

During the last years a few hundred compact massive objects (CMO) were discovered. Statistical studies of these objects have shown that there is a correlation between CMOs' masses and bulges' masses and luminosities (Cherepashchuk, 2007). These objects can oscillate around galactic center due to different effects (Kondratiev and Orlov 2008). One of mechanisms of such migration is interaction with globular clusters encountering with galactic center. Previously we considered the drift amplitude of CMO due to this effect for a few types of spiral galaxies. Now we would like to generalize this investigation for a wider range of galactic models. Also we use empirical relation between masses of CMO and bulge (Cherepashchuk, 2007):

$$M_{\rm bh} \approx 0.001 M_{\rm b}.$$

We investigate dependences of drift amplitude on bulge parameters (mass and size) and cluster parameters (mass and velocity).

*Email: vor@astro.spbu.ru

2 Galactic models and algorithm

The goal of our paper is to study the motion of a central compact massive object (CMO) in a galaxy under the effect of its encounters with other massive objects (e.g., globular clusters). Since this object moves near the galactic center, we take into account only the galactic bulge potential and disregard the effects of the disk and the halo. Let us consider a coordinate system with the origin at the bulge center. The bulge potential corresponds to the model by Plummer (1911):

$$\Phi\left(r\right) = \frac{GM_{\rm b}}{\left(r^2 + b^2\right)^{1/2}},$$

where G is the gravitational constant, b is the effective bulge radius, $M_{\rm b}$ is the bulge mass, and r is the distance to the bulge center. The bulge is assumed to be spherically symmetric. At the initial time, the CMO is located near the bulge center (at a distance of 1 pc in each of the X, Y, and Z coordinates). The initial CMO velocity is 0.001 km/s, the velocity vector is directed along the OY axis.

Let us consider the encounter of a CMO with mass $M_{\rm bh}$ and a globular cluster with mass $M_{\rm cl}$. Initially, the globular cluster is located at a point with coordinates (X_0, Y_0) and moves along the OX axis with a velocity V_0 toward the galactic center. We set initial velocities of cluster within range from 100 km/s to 400 km/s and its masses within range from $3\cdot10^5\,M_\odot$ to $10^7\,M_\odot$. The bulge mass changes from $10^9\,M_\odot$ to $10^{12}\,M_\odot$, bulge size changes from 0.2 kpc to 2.0 kpc. For each case set of initial conditions we trace evolution during 250 Myr.

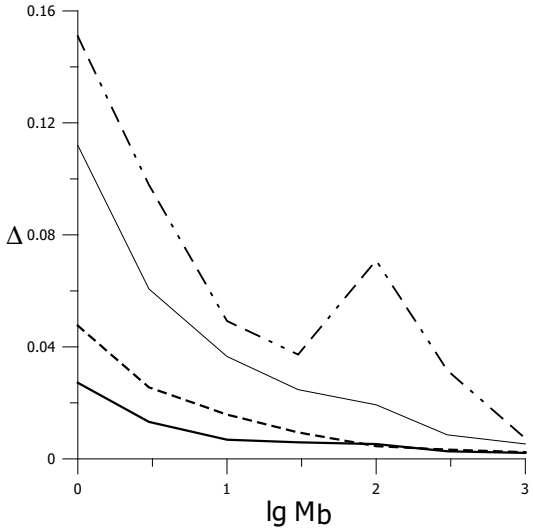


Figure 1 The drift amplitude versus bulge size and its mass. Initial velocity and mass of the cluster are $V_0 = 200$ km/s, $M_{\rm cl} = 10^6\,M_\odot$. $M_{\rm b}$ is measured in units of $10^9\ M_\odot$. Thick solid line corresponds to bulge size 0.5 kpc, dashed − to 0.8 kpc, thin solid − to 1.4 kpc, dashed-dot − to 2.0 kpc.

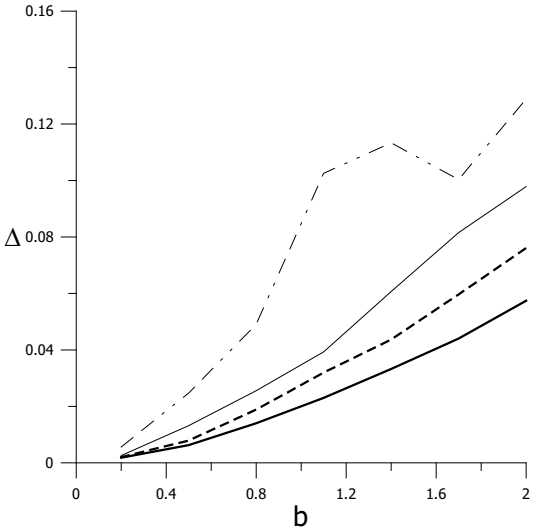


Figure 2 The drift amplitude versus bulge size for different cluster velocities. Thick solid line corresponds to cluster velocity 400 km/s, dashed − to 300 km/s, thin solid − to 200 km/s, dashed-dot − to 100 km/s. Cluster mass is $10^6\,M_\odot$.

Table 1 The drift amplitude versus bulge size and its mass for $V_0 = 300$ km/s, $M_{\rm cl} = 10^6\,M_\odot$.

Δ, pc		$M_{\rm b}$, $M_\odot$			
		10^9	10^{10}	10^{11}	10^{12}
b, kpc	0.2	2.3±0.3	2.3±0.4	2.1±0.2	1.89±0.04
	0.8	34.9±13.6	10.1±4.1	3.4±0.9	2.4±0.2
	1.4	89±39	22.5±7.2	9.6±3.4	5.2±1.2
	2.0	87±36	44±17	17±5	13±5

3 Results

In Fig. 1 we show dependences of drift amplitude Δ on bulge mass for different bulges' sizes b. We see that Δ decreases while $M_{\rm b}$ increases and b decreases. Maximum values reach about 100 pc when masses of CMO and clusters are comparable and bulge is the most extended.

In Fig. 2 we show dependences of Δ on initial velocity of cluster and size of bulge. We see that Δ increase while V_0 decrease.

In Fig. 3 we show dependence of Δ on cluster mass and size of bulge. It can be seen that Δ increases while $M_{\rm cl}$ grows.

In Table 1 we can see common quantitative results and tendencies. The main trend is that extension of bulge and decreasing of its mass makes Δ greater. We can see that changing of bulge size affects Δ stronger than changing of $M_{\rm b}$.

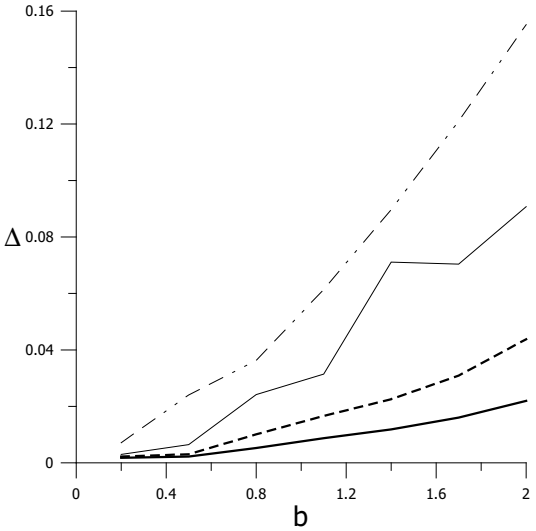


Figure 3 The drift amplitude versus bulge size for different cluster masses. Thick solid line corresponds to cluster mass $3 \cdot 10^5\, M_\odot$, dashed – to $10^6\, M_\odot$, thin solid – to $3 \cdot 10^6\, M_\odot$, dashed-dot – to $10^7\, M_\odot$. The initial cluster velocity is 300 km/s.

4 Conclusions

The mean drift amplitude depends strongly on galactic-bulge parameters: its mass and extent. Also it depends on mass and velocity of the cluster. In particular, the nucleus of our Galaxy is fairly massive and compact; therefore, the displacement of the central object is small, no larger than 10 pc.

Acknowledgements

This work was supported by the President Program for Support of Leading Scientific Schools (project NSh-1323.2008.2) and RFBR (grant 08-02-00361).

References

A.M. Cherepashchuk, Astronomy: Traditions, Present, Future (St. Peterburg. Gos. Univ., St. Petersburg, 2007), p. 198.
A.S. Kondratiev, V.V. Orlov, Letters to Astron. Zhurn. 34,593 (2008).
H.C. Plummer, Mon. Not. R. Astron. Soc. 71, 460 (1911).