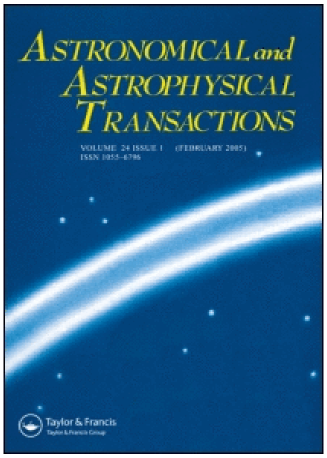

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DYNAMICAL ESTIMATES OF GAS–STAR COMPLEX TOTAL MASSES†

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Gas–star complexes introduced by Efremov and Sitnik (1988) are approximated by ellipsoids. The total mass and the mean density of some complexes are estimated from the data on young open cluster sizes and their tidal sizes in the Galaxy gravitational field. The total mass ranges from 0.19 to 120 million solar masses, and the mean density ranges from 0.35 to 3.8 solar masses per cubic parsec.

KEY WORDS Open clusters, tidal effects, gas–star complexes

As a result of recent investigations of open clusters (OCl), the mean matter density of the OCl are becoming clear to be less than it was considered earlier and to be close to the critical one in the external force field (Danilov and Seleznev, 1993). So, even a small change of the external force field can result in the OCl disruption during about one crossing time. Such systems are close to the stability limit in the external force field, and they can serve for the estimation of the characteristics of the external force fields acting on the clusters.

In accordance to Efremov (1989), star formation in galaxies (and the OCl formation) is concentrated in the gas–star complexes (GSC) developed from HI superclouds of the mass of $\sim 10^7 M_\odot$ and the size of ~ 1 kpc. The action of the GSC and the galactic force fields onto young OCl reduces the tidal size of such clusters as compared with their tidal size in the field of the Galaxy alone (Danilov, 1990, 1991, 1993; Danilov and Beshenov, 1992; Danilov and Seleznev, 1991). Since the OCl radius is limited by the OCl tidal radius in the external force field, the estimates of the OCl radii (Danilov and Seleznev, 1993) can be used for the determination of the total masses and matter densities in the GSC.

This work is devoted to the estimation of the sizes, masses and mean matter densities of GSC from the solar neighbourhood using data on young OCl sizes and their tidal sizes in the galactic gravitational field (taken in the Becker–Fenkart distance scale).

The GSC from Efremov and Sitnik (1988, hereafter ES) are fitted by ellipsoids in this work (see Table 1). A simple geometrical model of an inclined cylinder with

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Table 1. Geometrical GSC parameters (the Becker–Fenkart distance scale)

GSC	*Semiaxes, pc*				γ *degree*	Θ *degree*
	a	b	c	$c_0(\gamma = 0)$		
2-I	530	240	47	50	2.5 ± 0.9	106
Vulpecula	250	120	22	52	16.0 ± 5.7	85
3	670	190	57	64	6.4 ± 5.6	95
4	360	140	66	105	10.8 ± 4.6	142
5	380	350	74	109	6.7 ± 7.1	70
6-II	630	400	93	147	12.3 ± 1.1	100
7-II	540	175	164	176	8.2 ± 4.6	84
8	290	120	30	49	7.7 ± 5.5	97
9	270	120	12	76	$17. \pm 25.$	80
10	510	135	26	31	6.8 ± 1.6	96
11	100	90	13	46	19.4 ± 4.6	2

the generating line normal to the galactic plane is used to estimate the inclination and the minor semiaxis of a GSC. The projection of such a cylinder onto the sky plane was inscribed into a rectangle set by the extreme values of galactic coordinates for GSCs from ES. The inclination of the cylinder base to the galactic plane was determined by the young OCls-members of the GSC. The parameters of the ellipse in the cylinder base were determined by the view of the GSC in the projection onto the galactic plane (according to the data of ES).

The 1-st column contains the ordinal number of the GSC (by ES), the 2-nd and the 3-rd is the semiaxes of the ellipse in the GSC projection onto the galactic plane, the 4-th is the semithickness of the inclined cylinder, the 5-th is the semithickness of a straight cylinder satisfying the extreme values of the galactic coordinates from the ES data, the 6-th is the angle between the base of the cylinder and the galactic plane (the dispersion is due to the cluster distance errors of about 10%), the 7-th is the angle between the minor axis of the ellipse in the GSC projection onto the galactic plane and the direction from the Sun to the center of this projection.

In order to estimate the masses of the GSCs, they were presented as ellipsoids with the semiaxes a, b, c, (or a, b, c_0), and their symmetry plane was accepted to coincide with the galactic plane. Two possible cases were considered: a stationary spheroidal GSC model (1) with the density decreasing from the center according to the law accepted by Danilov (1990, 1991), and a nonstationary ellipsoidal GSC model (2) with a uniform density at the initial time (Danilov, 1993).

The formulas are obtained in this work, they allow to estimate the total GSC mass from the ratio of the OCl radius to its tidal radius in the galactic force field (Danilov and Seleznev, 1993). The condition of the OCl model stability with respect to disruption in the combined field of the stationary spheroidal GSC and the Galaxy was used to obtain these formulas (Danilov, 1991). An equation was used also that connected the initial and final radii of a virialized expanded OCl in the center of a nonstationary ellipsoidal GSC, the latter being uniform initially and losing mass from its central region, in the presence of the external galactic field (Danilov, 1993).

Table 2. GSC mass estimates

GSC	M, $10^7 M_\odot$	*c*, *pc*	*Model*	*OCl*
3	1.2–3.5	57	stationary	NGC 6910
	12.	57	nonstationary	NGC 6910
5	3.2–4.5	74	stationary	NGC 7128
6-II	3.5	93	stationary	NGC 457
10	0.31–0.56	26	stationary	NGC 2169
	1.5	26	nonstationary	NGC 2169
11	0.019–0.034	13	stationary	NGC 2323

The final OCl radius (at the moment of the complete GSC matter loss from the OCl vicinity) is assumed to be equal to the OCl tidal radius in the galactic field, and the initial OCl radius is assumed to be equal to observed cluster radius.

The mass estimates were obtained for five GSC (see Table 2). The GSC models (the 4-th column) were selected by the character of the dependence of the cluster size on distance to the center of the GSC that contains the cluster (Danilov and Seleznev, 1991). The OCl sizes decrease to the periphery of a stationary complex and increase to the periphery of a nonstationary one (Danilov 1991, 1993).

The 2-nd column contains an estimate of the GSC mass (the lower and upper values correspond to direct and retrograde cluster orbits inside the GSC), the 3-rd is the value of the minor semiaxis used, the 5-th is the name of the OCl, parameters of which were used for the GSC mass estimation.

If all young clusters observed in the GSC would have the radii equal to the tidal ones for the orbits and positions of OCl in the combined gravitational field of the GSC and the Galaxy, then all these clusters must lead to the same value of the total GSC mass. However, the young OCl sizes are as a rule less than or equal to the tidal ones in the external force field, then we obtain the upper estimates of the GSC total mass. The young OCl give lower and more accurate mass estimates if these clusters fill to a greater extent the volume under the tidal surface in the external force field.

The data on the sizes and the tidal sizes in the galactic gravitational field for several clusters were used for the estimation of mass for every GSC. Then the minimum estimates of the GSC total mass were selected. The mean matter density in the spheroidal stationary GSC model exceeds the critical one in the galactic gravitational field (for uniform spheroids): for GSC No. 5, 10, 11 in the case of both direct and retrograde orbits, and for GSC No. 6-II – only in the case of a retrograde orbit. The estimates of the mean GSC densities obtained in this work range from 0.35 to 3.8 $M_\odot \cdot \mathrm{pc}^{-3}$.

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DISCUSSION

Efremov: Did I understand correctly that a complex is stable in the tidal force of the galactic field according to your results?
Seleznev: All the complexes in Table 2 have mean densities greater than the critical one for a uniform spheroid in the galactic gravitational field. The non-stationarity of some complexes was determined by the character of the dependence of the cluster radii on distance to the complex center. The non-stationarity may be caused by astrophysical reasons but not by dynamical ones.
Khoruzhii: What can you say about the accuracy of your final results, i.e. the mass estimates? What is the main parameter whose effect on the accuracy is the strongest?
Seleznev: The accuracy of the mass estimates is about the order of magnitude, maybe somewhat better (a factor of $3 \div 5$), however we have not estimated the accuracy. The main parameter which influences the mass estimates is the small semi-axis c, because it strongly depends on the inclination angle determined with a low accuracy. But we plan to improve further our geometrical models of gas–star complexes.
Ossipkov: It is evident you cannot use statistical methods but you can use the theory of small samples for complex parameter estimates.
Seleznev: Yes. The values of parameters given here are preliminary.
Chernin: What are errors in the estimates of sizes, angles etc.?
Seleznev: We have not estimated the errors, but I think they are rather large. In the case of the inclination angle, the error may be of about 5°. However we shall improve our geometrical estimates.