Spiral Density Wave Parameters from data on young Open Star Clusters

Anisa Bajkova & Vadim Bobylev

Central (Pulkovo) Astronomical Observatory of RAS, St.-Petersburg, Russia

Goal of the work:

Spiral density wave (SDW) parameters determination from three-dimensional velocity field of young OSCs using kinematical equations including the SDW perturbations according to Lin and Shu theory

DATA

At present, more than 1700 OSCs are known in the solar neighborhood. Data on their proper motions, radial velocities, and positions are needed for our purposes. A catalog that includes 652 OSCs (Kharchenko 2001; Kharchenko et al. 2005a, 2005b; Piskunov et al. 2006) forms the basis for our work list. The advantage of this catalog is a homogeneity and a high accuracy of the determination of mean cluster proper motions achieved by using the ASCC-2.5 all sky catalog (Kharchenko 2001) compiled from Hipparcos (1997), Tycho-2 (Hog et al. 2000), and several other sources. The age estimates obtained by comparison with isochrones are available for the clusters of this catalog. The cluster distance estimates are based on the results by Loktin and Beshenov (2003), who reconciled the photometric estimates with the Hipparcos distance scale.We took other data from the compilation by Dias et al. (2002) and the WEBDA database (http://obswww.unige.ch/webda/). For such open clusters as ASCC 16, ASCC 18, and Tr 10, we used the mean radial velocities that we improved (Bobylev 2006) using the OSACA catalog (Bobylev et al. 2006a). As a result, we compiled a database on the proper motions, radial velocities, and distances of 394 OSCs (Bobylev et al, 2007). They are located within about 5 kpc of the Sun. Their ages do not exceed 1.5 Gyr.

METHOD

$$V_r = -U_0 \cos(b)\cos(l - l_0) - V_0 \cos(b)\sin(l - l_0) - W_0 \sin(b) -$$
$$- R_0 (R - R_0)\cos(b)\sin(l - l_0)\Omega'_0 - R_0 (R - R_0)^2 \cos(b)\sin(l - l_0)\Omega''_0 / 2 +$$
$$+ r\cos^2(b)K +$$
$$+ \cos(b)(V_\theta \sin(l - l_0 + \theta) - V_R \cos(l - l_0 + \theta)),$$

$$V_l = -U_0 \sin(b)\cos(l - l_0) - V_0 \cos(l - l_0) +$$
$$+ ((R - R_0)r\cos(b) - R_0 (R - R_0)\cos(l - l_0))\Omega'_0 + ((R - R_0)r\cos(b) - R_0 (R - R_0)^2 \cos(l - l_0))\Omega''_0 / 2 +$$
$$+ r\cos(b)\Omega_0 + (V_\theta \cos(l - l_0 + \theta) + V_R \sin(l - l_0 + \theta)),$$

$$V_b = U_0 \sin(b)\cos(l - l_0) + V_0 \sin(b)\sin(l - l_0) - W_0 \cos(b) +$$
$$+ R_0 (R - R_0)\sin(b)\sin(l - l_0)\Omega'_0 + R_0 (R - R_0)^2 \sin(b)\sin(l - l_0)\Omega''_0 / 2 -$$
$$- r\cos(b)\sin(b)K -$$
$$- \sin(b)(V_\theta \sin(l - l_0 + \theta) - V_R \cos(l - l_0 + \theta)).$$

According to (Lin,Yuan & Shu, 1969):

$$V_R = f_R \cos(\chi), \quad V_\theta = f_\theta \sin(\chi),$$

$$\chi = m[\cot(i)\ln(R/R_0) - \theta] + \chi_0 .$$

Adopting Ro=8kpc, m=2, we have p=12 unknown parameters

$$\Omega_0, \Omega_0^{'}, \Omega_0^{''}, U_0, V_0, W_0, l_0, K, f_R, f_\theta, i, \chi_0$$

which were found by solving the following nonlinear optimization problem:

Nonlinear optimization problem:

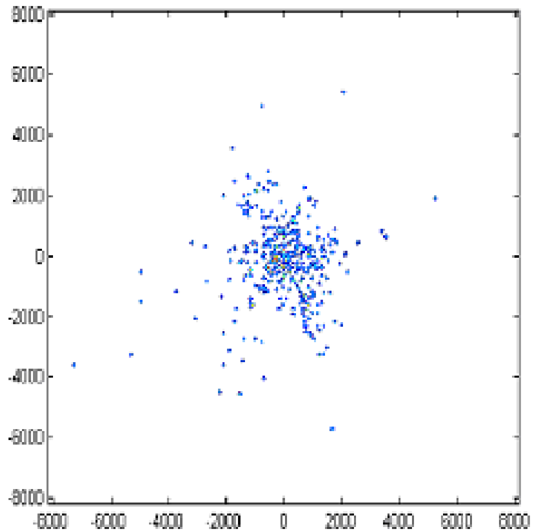
$$\min \delta^2 = \frac{1}{(3N-p)} \sum_{i=1}^{N} w_r^i (V_r^i - \hat{V}_r^i)^2 + w_l^i (V_l^i - \hat{V}_l^i)^2 + w_b^i (V_b^i - \hat{V}_b^i)^2,$$

where

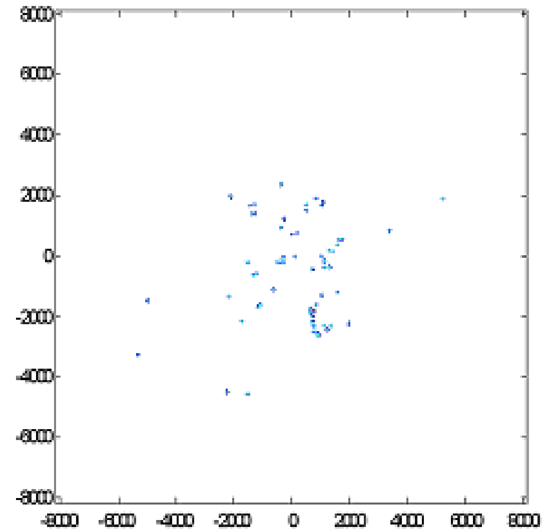
$$w_r = S_0 / \sqrt{(S_0^2 + \sigma_{v_r}^2}, \quad w_l = \beta^2 S_0 / \sqrt{(S_0^2 + \sigma_{v_l}^2}, \quad w_b = \gamma^2 S_0 / \sqrt{(S_0^2 + \sigma_{v_b}^2}, \quad S_0 = 8,$$

$$\beta = \sigma_{V_r} / \sigma_{V_l} = 1, \quad \gamma = \sigma_{V_r} / \sigma_{V_b} = 2,$$

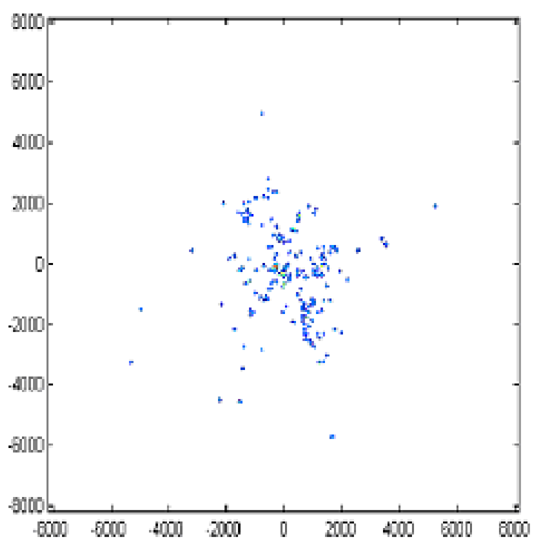
$$\sigma_{V_l, V_b} = \frac{4.74}{\pi} \sqrt{\mu_{l,b}^2 \left(\frac{\sigma_\pi}{\pi} \right)^2 + \mu_{l,b}^2}.$$



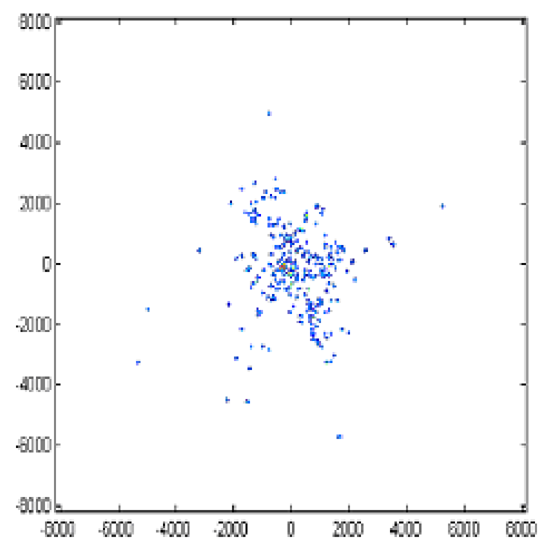
All OSCs



<10 Myr



<50 Myr

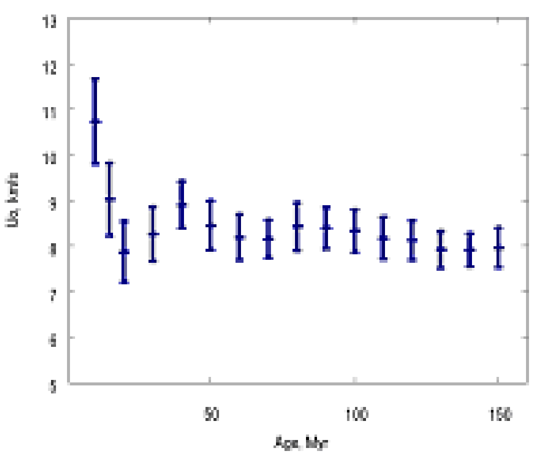


<150 Myr

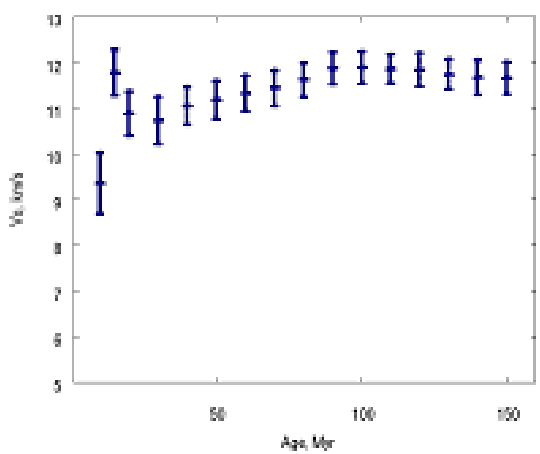
RESULTS

Solar peculiar velocities

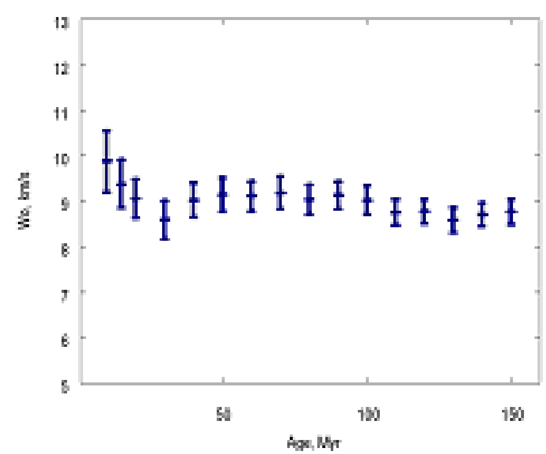
U0



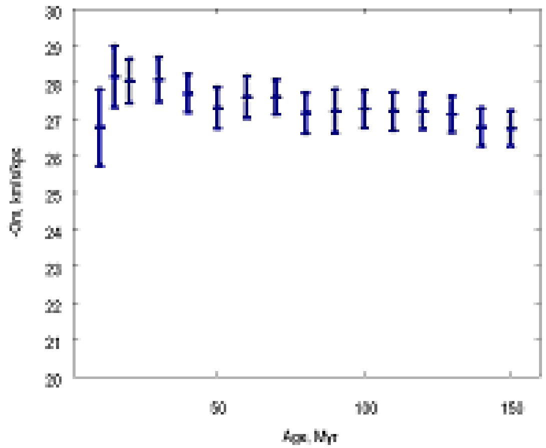
V0



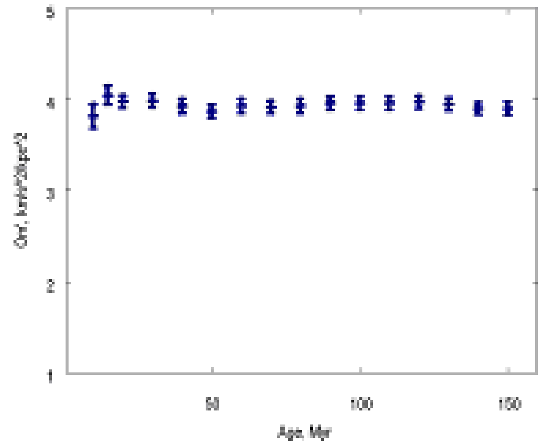
W0



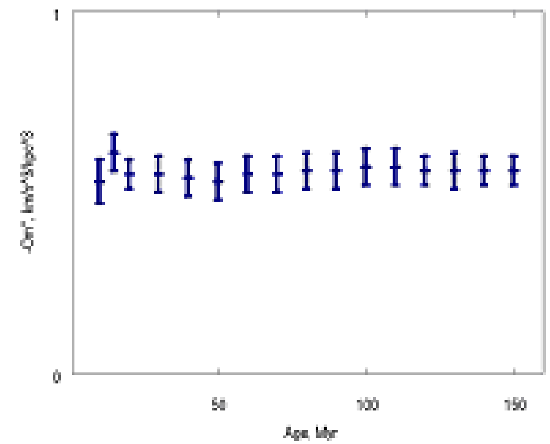
Ω_0



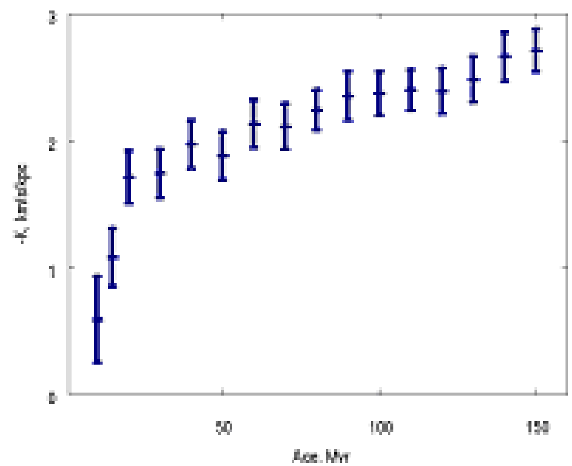
Ω_0'



Ω_0''

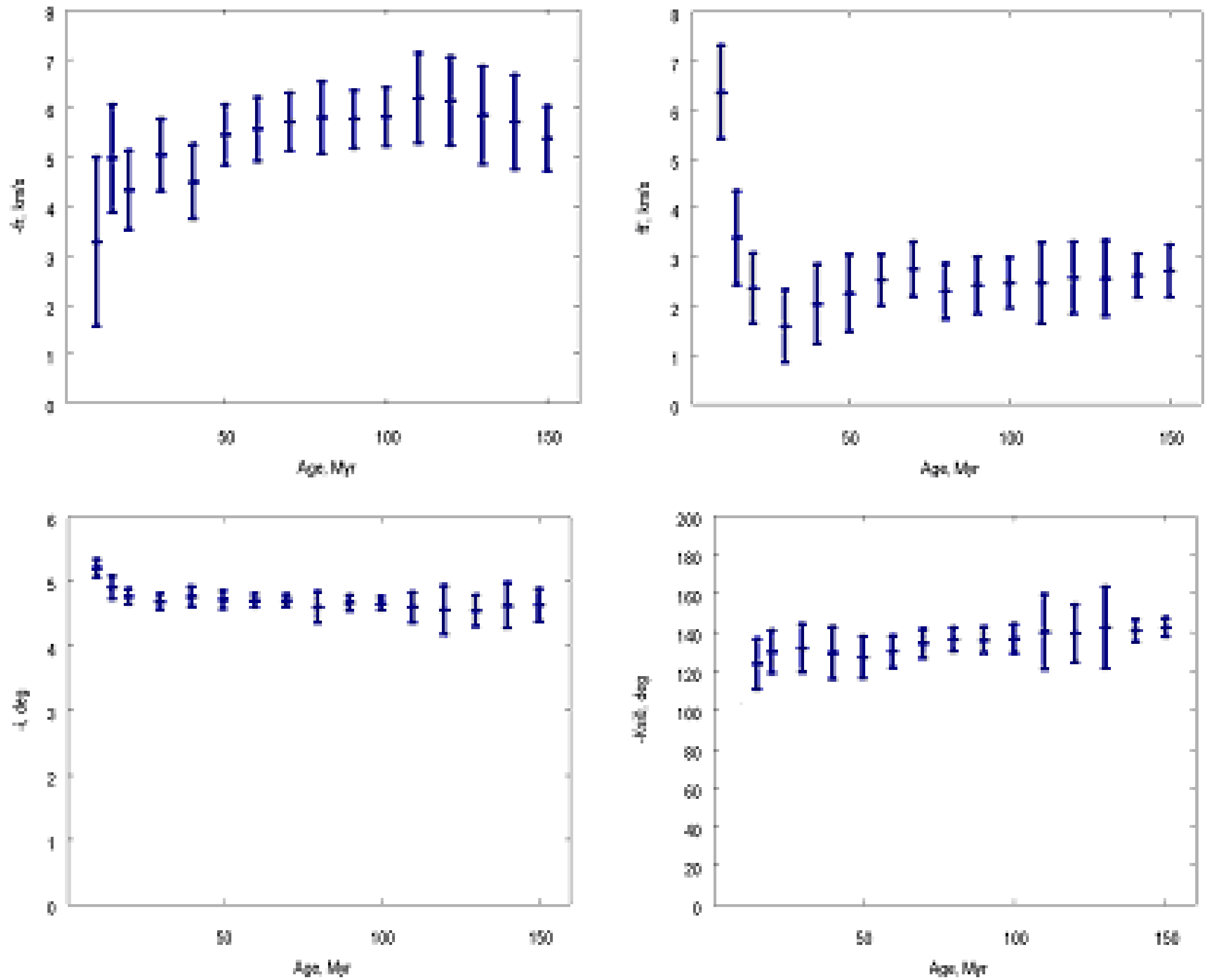


Galactic angular rotation parameters



K-term

f_R f_θ



i χ_0

Spiral density wave parameters

Average solution:

U_0=9.0±1.0 km/s

V_0=11.5±0.5 km/s

W_0=9.5±0.5 km/s

Ω_0=27.9±0.6 km/s/kpc

Ω_0'=4.0±0.1 km/s/kpc^2

Ω_0''=0.62±0.2 km/s/kpc^3

K=-1.1±0.2 km/s/kpc

f_R=-5.5±1.0 km/s

f_θ=3.0±1.0 km/s

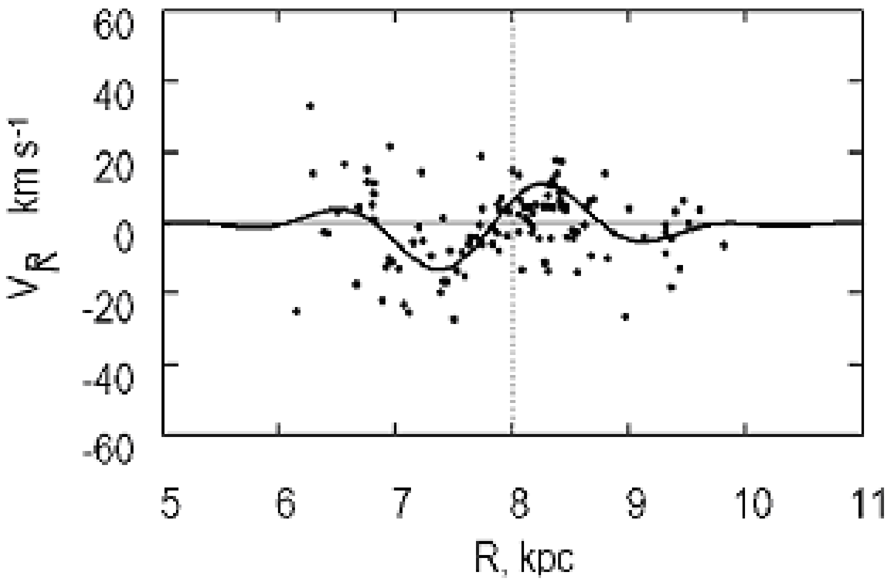
i=-5±0.5 deg.

χ_0=-120±20 deg.

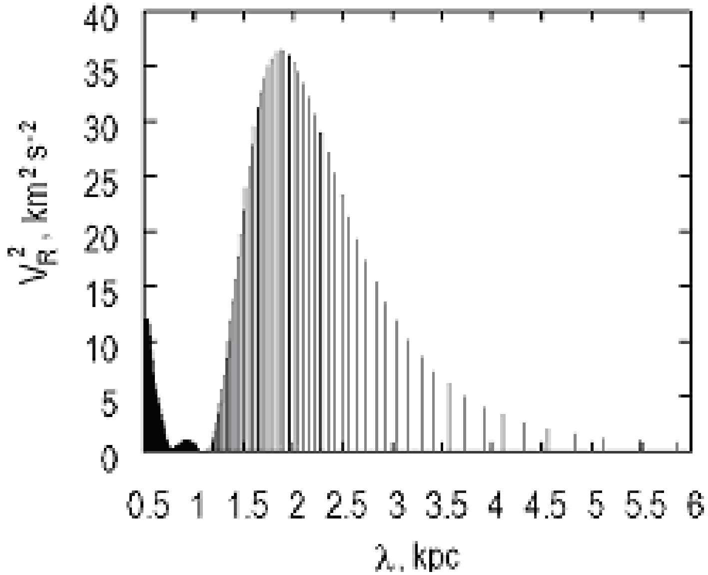
Fourier analysis of radial velocities V_R

117 OSCs were selected using the following restrictions:

(i)age<50 Myr;
(ii)r<2 kpc
(iii)modulus of residual velocities <50 km/s.



Radial velocities versus R (dotted line marks the Sun position)



Power spectrum of radial velocities

The spiral density wave parameters obtained from Fourier analysis of radial velocities are:

$f_R = 6$ km/s, $\chi_0 = -117^\circ$, $\lambda = 2$ kpc.

Conclusions

Parameters of spiral density wave obtained from young OSCs (R_0=8 kpc, m=2) are:

$$f_R = -5.5 \pm 0.5 \text{ km/s}, \; f_\theta = 3 \pm 0.5 \text{ km/s}, \; i = -5^\circ \pm 0.5^\circ, \; \chi_0 = -120^\circ \pm 20^\circ, \; \lambda = 2 \pm 0.1 \text{ kpc}.$$

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