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Spin axis of (2953) Vysheslavia and its implications

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Abstract

Photometric observations made during the years 2000–2005 are used to determine the pole orientation of (2953) Vysheslavia, a $\simeq$15-km size member of the Koronis family. We find admissible solutions for ecliptic latitude and longitude of the rotation pole P_3: $\beta_p = -64° \pm 10°$ and $\lambda_p = 11° \pm 8°$ or P_4: $\beta_p = -68° \pm 8°$ and $\lambda_p = 192° \pm 8°$. These imply obliquity values $\gamma = 154° \pm 14°$ and $\gamma = 157° \pm 11°$, respectively. The sidereal rotation period is $P_{sid} = 0.2622722 \pm 0.0000018$ day. This result is interesting for two reasons: (i) the obliquity value between 90° and 180° is consistent with a prediction done by Vokrouhlický et al. [Vokrouhlický, D., Brož, M., Farinella, P., Knežević, Z., 2001. Icarus 150, 78–93] that Vysheslavia might have been transported to its unstable orbit by the Yarkovsky effect, and (ii) with the obliquity close to 180°, Vysheslavia seems to belong to one of the two distinct groups in the Koronis family found recently by Slivan [Slivan, S.M., 2002. Nature 419, 49–51], further supporting the case of dichotomy in the spin axis distribution in this family. We also argue against the possibility that Vysheslavia reached its current orbit by a recent collisional breakup.

Keywords: Asteroids; Rotation, Yarkovsky effect

1. Introduction

Vysheslavia, a moderately large ($D \simeq 15$ km) member of the Koronis family, received considerable attention after Milani and Farinella (1995) discovered its very short dynamical lifetime. According to these authors, Vysheslavia will fall in the 5/2 mean-motion resonance with Jupiter in about 10–20 Myr (see also Vokrouhlický et al., 2001). As a result some mechanism must have placed Vysheslavia on its peculiar orbit a comparable time before the present, orders of magnitude shorter than the age of the Koronis family estimated from cratering on Ida and dynamical considerations (2–3 Gyr; e.g., Chapman, 2002; Bottke et al., 2001; Vokrouhlický et al., 2003).

Milani and Farinella (1995) suggested that Vysheslavia may be a by-product of a recent secondary collision (disruptive or non-disruptive), though they pointed out that it was unlikely to occur (less than 5% in their estimate). Recent collisional models (e.g., Bottke et al., 2005a, 2005b) render this probability even smaller because the estimated collisional lifetime of a plausible parent body ∼20–30 km in size is longer than previously believed. Vokrouhlický et al. (2001) proposed a more robust scenario, namely they assumed that Vysheslavia was driven inward by the Yarkovsky effect from a dynamically stable area exterior to the 5/2 resonance (see also Brož and Vokrouhlický, 2001). Assuming a low surface conductivity value ($\leqslant$0.01 W/m/K, say), a specific orientation of the spin axis is needed, namely the obliquity must be larger than 90° to allow inward drift of

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the asteroid. Values closer to 180° are more favorable, since the relevant dynamical time scale of the Yarkovsky transport is shorter, and thus the whole hypothesis more robust.

Here we report photometric observations of Vysheslavia that allowed us to determine its pole orientation, and thus its obliquity. Our results confirm the Yarkovsky-driven scenario outlined above and, additionally, they maintain the surprising dichotomy in the obliquity distribution of large Koronis members (Slivan, 2002; Slivan et al., 2003).

2. Observations

We observed Vysheslavia on 35 nights during five apparitions: January 2000, March–April 2001, September 2002, September–December 2003 and January–February 2005. The longest time span between the first and the last observation within one apparition—81 days in 2003—allows us to unambiguously link the sidereal rotation phase of all the other observations, prerequisite for a successful solution. The aspect data of the observations and other information are summarized in Table 1.

The January 2000 Vysheslavia observation was performed at Saint Veran Observatory (France) using a 0.62-m telescope equipped with a HiSys22 CCD camera (KAF400 chip) and a non-standard R filter. As a result, no transformation to the standard photometric system was possible. The data were processed with the software APHOT developed at Ondřejov Observatory. The aperture photometry was used as described by Pravec et al. (1996).

During the next four apparitions the asteroid was observed at Pic du Midi Observatory (France) using a 1.05-m reflector equipped with the Thomson 7863 CCD camera and R filter. A standard reduction was performed with the ASTROL software developed at the Institut de Mécanique Céleste in Paris. The aperture photometry was obtained with the CCLRS STARLINK package (see also Michałowski et al., 2000). Due to occasional non-photometric weather conditions, the data obtained were not transformed to the standard system and only relative instrumental magnitudes were used.

In March 2001, Vysheslavia was also observed by Bill Holliday at the River Oaks Observatory, New Braunfels (Texas) using a 0.4-m Newtonian telescope equipped with an SBIG ST8E CCD camera. The standard dark subtraction, flat fielding and differential photometry were performed using the Mira software (http://www.axres.com).

In 2003 and 2005 lightcurve observations were made at the Whitin Observatory at Wellesley College (Massachusetts), using the 0.61-m Sawyer telescope with a Photometrics camera housing a Tektronics (SITe) back-illuminated CCD detector. The data were calibrated to the standard system, yielding V and R magnitudes in 2003 and R magnitudes in 2005. Image processing and synthetic aperture photometry were performed using the IRAF software applications from NOAO. The calibrated data from 2003 are sufficient to derive the color index $V–R = 0.49 \pm 0.01$, and also Lumme–Bowell solar phase coefficients at that aspect: $H = 11.92 \pm 0.04$ and $G = 0.19 \pm 0.02$.

At the Kharkiv Observatory, where observations were also performed in 2003 and 2005, we used the 0.7-m reflector equipped with a CCD camera (ST-6UV in 2003 and IMG1024S in 2005) and standard V and R filters. Frames were reduced with the synthetic aperture package ASTPHOT developed at DLR (e.g., Mottola et al., 1995).

Three additional lightcurves were kindly provided by Richard Ditteon, who observed Vysheslavia in mid November 2003 from Oakley Observatory, Terre Haute (Indiana). A 0.36-m telescope was equipped with an AP7 CCD camera and a standard V filter. Relative photometry was obtained and analyzed using the Canopus program.

The observations are presented as composite lightcurves (Fig. 1) consistent with a synodic period of 6.295 ± 0.001 h. For presentation purposes the magnitude offset of each lightcurve was obtained by minimizing the dispersion of data points relative to their neighbors. The variations in the lightcurve amplitudes are due mainly to changes in the Sun–asteroid–observer phase angle; the mean amplitudes range from about 0.09 mag at the smallest phase angles to 0.15–0.17 mag at the largest phase angles. We estimate the error of the lightcurve amplitudes to be $\simeq$0.02 mag, while the error of the lightcurve maximum/minimum epochs is $\simeq$10 min. A preliminary look at the data, notably the small amplitude variations remaining after accounting for phase angle changes across the (0°, 17°) interval, suggest a non-ecliptic pole for Vysheslavia.

3. Shape and spin model of (2953) Vysheslavia

To strengthen the robustness of our conclusions we used two independent and different solution methods described below. Because we confirm the pole aspect close to 90°, further observations will help reduce the uncertainty in the pole solution but probably will not improve much the shape solution. Already, the 2005 apparition appears to closely repeat the 2000 configuration with only a moderate shift in the ecliptic longitude. Further data will improve the longitude coverage, but will likely not change the solution in a significant way.

3.1. Method #1

First, the orientation of the spin vector, sidereal period, and triaxial ellipsoid model of Vysheslavia have been determined using the method described by Michałowski (1993). This approach combines epoch, amplitude-aspect, and magnitude-aspect methods by building a set of non-linear equations whose solutions are found by least squares fitting the model to the times of lightcurve maxima, the lightcurve amplitudes, and (if available) the calibrated magnitudes. The amplitude-aspect equations represent basically the weighted amplitude-aspect (WAA) method (see also Drummond et al., 1988) that models the asteroid as a triaxial ellipsoid of uniform surface reflectivity. To a good approximation the brightness variations are given directly by the changing cross-section of the asteroid as it rotates about the shortest body axis; lightcurve amplitudes observed at different viewing aspects are used to

Table 1
Aspect data of the (2953) Vysheslavia observations

Date (UT)	r (AU)	Δ (AU)	ϕ (°)	λ (°)	β (°)	α (°)	δ (°)	Filter	Observation site
2000									
Jan 16.1	2.882	1.903	2.2	119.37	−0.79	123.42	18.66	R	Saint Veran
Jan 17.1	2.882	1.901	1.8	119.58	−0.80	123.20	18.70	R	Saint Veran
2001									
Mar 16.4	2.786	2.002	14.9	207.00	−0.75	219.14	−16.40	V	River Oaks
Mar 20.3	2.786	1.963	13.8	207.82	−0.74	218.90	−16.33	V	River Oaks
Mar 21.3	2.785	1.954	13.5	208.06	−0.74	218.82	−16.31	V	River Oaks
Apr 26.1	2.778	1.772	0.4	215.74	−0.62	212.97	−14.32	R	Pic du Midi
Apr 27.0	2.778	1.772	0.6	215.92	−0.62	212.79	−14.25	R	Pic du Midi
Apr 28.0	2.778	1.772	1.0	216.13	−0.62	212.58	−14.17	R	Pic du Midi
2002									
Sep 02.0	2.795	1.853	9.1	322.50	1.01	315.44	−15.33	R	Pic du Midi
Sep 03.0	2.795	1.859	9.4	322.71	1.01	315.29	−15.37	R	Pic du Midi
2003[a]									
Sep 24.3	2.884	2.233	17.3	41.93	0.53	56.86	20.65	V	Whitin
Sep 25.3	2.884	2.222	17.1	42.12	0.52	56.86	20.65	V	Whitin
Sep 30.2	2.885	2.167	16.0	43.12	0.51	56.80	20.63	V	Whitin
Oct 01.2	2.885	2.156	15.8	43.32	0.50	56.76	20.62	V	Whitin
Oct 04.3	2.886	2.126	15.1	43.92	0.49	56.62	20.59	V	Whitin
Oct 20.3	2.888	1.990	10.3	47.10	0.44	54.93	20.20	V	Whitin
Oct 29.0	2.889	1.939	7.0	48.88	0.41	53.42	19.82	V	Kharkiv
Nov 01.2	2.890	1.926	5.8	49.48	0.40	52.78	19.65	V	Whitin
Nov 05.1	2.890	1.913	4.2	50.29	0.38	51.96	19.45	R	Ondřejov
Nov 06.1	2.890	1.911	2.8	50.49	0.38	51.75	19.40	R	Ondřejov
Nov 15.2	2.891	1.902	0.2	52.26	0.35	49.71	18.83	V	Whitin
Nov 15.3	2.891	1.902	0.2	52.26	0.35	49.69	18.82	V	Oakley
Nov 16.3	2.891	1.902	0.4	52.45	0.35	49.47	18.78	V	Oakley
Nov 18.3	2.892	1.904	1.2	52.85	0.34	49.02	18.65	V	Oakley
Dec 01.7	2.893	1.949	6.8	55.56	0.29	46.21	17.83	R	Kharkiv
Dec 02.7	2.893	1.953	7.2	55.76	0.29	46.03	17.77	R	Kharkiv
Dec 13.1	2.894	2.022	10.8	57.80	0.25	44.39	17.24	R	Whitin
Dec 14.0	2.894	2.030	11.1	58.00	0.25	44.27	17.20	R	Whitin
2005									
Jan 05.1	2.866	2.077	13.8	134.93	−0.96	150.41	10.67	R	Pic du Midi
Jan 06.2	2.866	2.067	13.5	135.13	−0.96	150.32	10.69	R	Pic du Midi
Feb 06.2	2.859	1.877	2.2	141.40	−1.01	145.36	12.22	R	Whitin
Feb 07.0	2.859	1.875	1.8	141.61	−1.01	145.19	12.28	R	Pic du Midi
Feb 07.1	2.859	1.875	1.7	141.61	−1.01	145.17	12.28	R	Whitin
Feb 07.9	2.859	1.874	1.3	141.81	−1.01	144.99	12.33	R	Kharkiv
Feb 10.1	2.858	1.872	0.6	142.21	−1.01	144.52	12.50	R	Pic du Midi

Date is the mean epoch of the observation, r and Δ are the heliocentric and geocentric distances, ϕ is the phase angle, (λ, β) are the ecliptic longitude and latitude in the J2000.0 reference frame, and (α, δ) are the J2000.0 right ascension and declination. The observations can be found on our Web site http://sirrah.troja.mff.cuni.cz/yarko-site/2953_photometry.

[a] The 2003 observations provide the longest run within one apparition and enable unambiguous linking of sidereal rotation phase throughout the whole period 2000–2005.

deduce the spin axis orientation. The magnitude-aspect equations are based on a similar approach, except that they model lightcurves' overall brightnesses instead of their amplitudes. To resolve the sense of rotation about the axis we complemented the amplitude and magnitude information with equations representing the epoch method, namely tracking in time a chosen "prominent feature" on the rotation curve, assuming that it corresponds to a pattern at a fixed longitude on the asteroid.

This combined amplitude–magnitude–epoch analysis leads to a set of non-linear equations for the pole longitude λ_p and latitude β_p, the sidereal rotation period P_{sid}, and ratios a/b and b/c of the best-fit ellipsoid axes; Michałowski (1993) discusses the appropriate iterative method of their solution. At convergence, we obtained the following best-fit solutions (there is an obvious near-180° ambiguity in determination of the ecliptic longitude of the pole):

$$P_{sid} = (0.2622732 \pm 0.0000008) \text{ days},$$
$$P_3: \quad \lambda_p = 15° \pm 3°, \quad \beta_p = -60° \pm 8°,$$
$$P_4: \quad \lambda_p = 190° \pm 3°, \quad \beta_p = -65° \pm 8°,$$
$$a/b = 1.15 \pm 0.01, \quad b/c = 1.0 \pm 0.1,$$

implying indeed a retrograde sense of rotation and a pole far from the ecliptic. The mirror solutions, P_1 and P_2, with prograde rotation are rejected having χ^2 value 3 times larger than

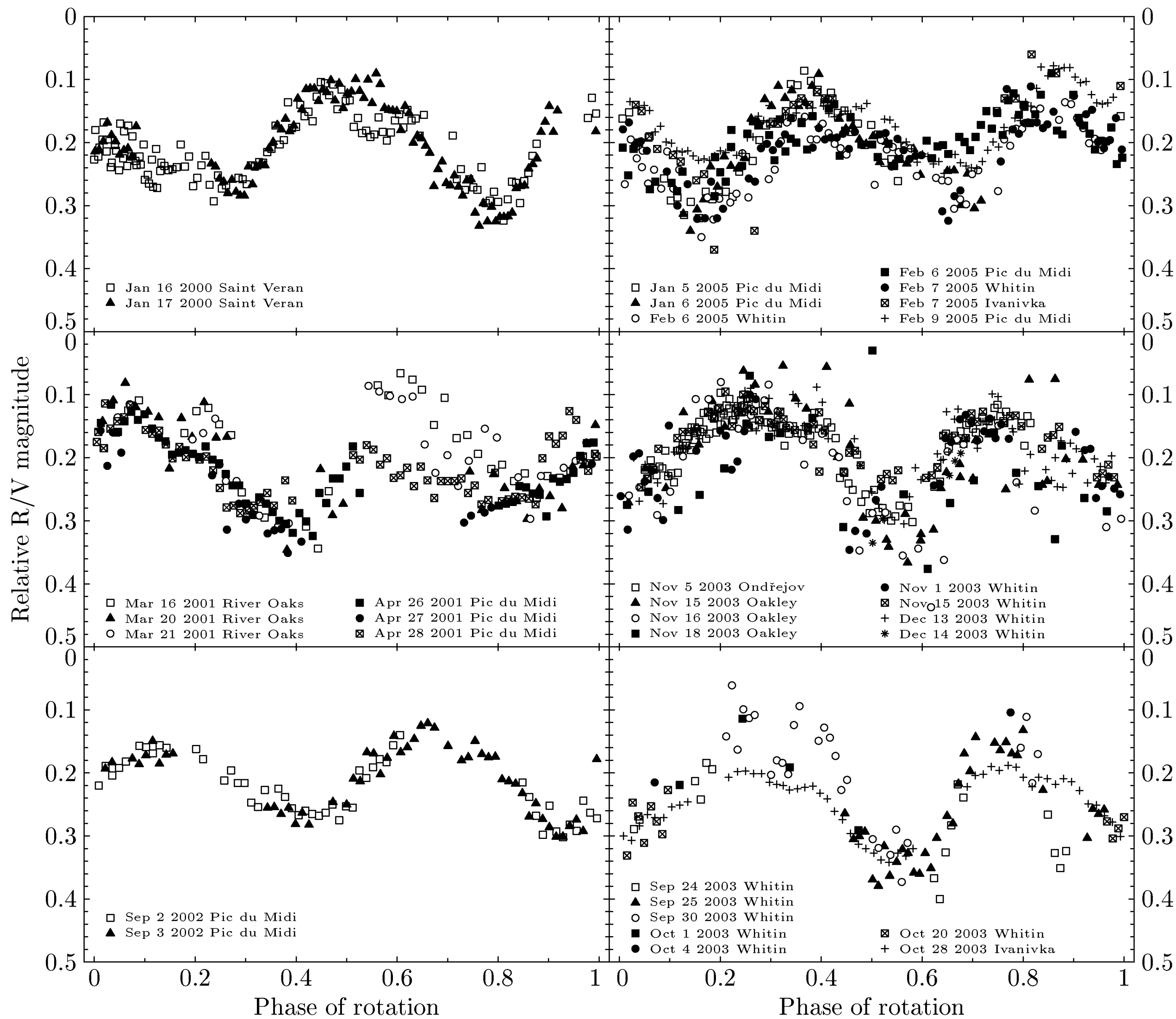

Fig. 1. Composite rotation lightcurves of (2953) Vysheslavia in five consecutive apparitions: January 2000, March–April 2001, September 2002, September–December 2003 and January–February 2005. The abscissa is the rotational phase with a common zero point corrected for light-time and related to the first observation in the panel and a synodic period 6.295 h. On the ordinate, relative instrumental magnitudes, either in the R or V bands, adjusted so that dispersion with respect to the neighbors is minimized. Variations in the lightcurves are mainly due to changing Sun–asteroid–observer geometry (see the phase angle in Table 1). Data are on our Web site http://sirrah.troja.mff.cuni.cz/yarko-site/2953_photometry.

P_3 and P_4 and statistically poor. This configuration is unfavorable to solve for the ratio b/c, and its value above is only formal (see Eqs. (3) and (5) in Michałowski, 1993).

3.2. Method #2

An independent analysis of the same data was done using the method described by Slivan et al. (2003). Brightness and epoch information related to low-order shape were extracted from the lightcurves by least-squares fitting Fourier series, and then analyzed with the sidereal photometric astrometry (SPA), weighted amplitude-aspect (WAA), and simultaneous amplitude–magnitude (SAM) methods based on those of Drummond et al. (1988).

Using only the timing information, SPA constrains the pair of pole solutions to be quite far from the ecliptic plane, with retrograde rotation and ecliptic longitude near 0° or 180°. A second pair of solutions with prograde rotation and ecliptic longitude near 90° or 270° is rejected, because the fit to the epochs is poor and unlikely multiple exchanges of the primary and secondary extrema are required over the range of aspects observed. The χ^2 acquires a value 2.3 times larger than that of the favored retrograde poles.

It is more difficult to use the lightcurve amplitude and brightness methods to reliably determine the spin axis of Vysheslavia, because the observed aspect-dependent changes in the available data are so small that they are comparable to the measurement uncertainties. In fact, for the adopted poles, neither the largest- nor the smallest-amplitude aspects have yet been observed. The WAA analysis of the amplitudes alone does not give satisfactory results; it finds spin axes consistent with only the rejected SPA solutions. The SAM analysis uses both amplitudes and overall brightness, and it does find axis solutions consistent with the favored SPA solutions, but the standard-calibrated data it needs have been recorded during only two of the five apparitions observed so far.

The adopted poles for method #2 were found at the intersections of the SPA "E-method arcs" and the SAM "AM Solution Curves" as described by Magnusson (1986). These poles were used with SPA to calculate the sidereal period. The same poles were also used with SAM to calculate axial ratios, but the limited aspect coverage of calibrated lightcurves leads to very large formal uncertainties and no useful constraints on the shape. We thus obtained (the shape parameters are not reported):

$$P_{\mathrm{sid}} = (0.2622713 \pm 0.0000002) \text{ days},$$
$$P_3: \quad \lambda_{\mathrm{p}} = 8^\circ \pm 6^\circ, \quad \beta_{\mathrm{p}} = -68^\circ \pm 4^\circ,$$
$$P_4: \quad \lambda_{\mathrm{p}} = 194^\circ \pm 7^\circ, \quad \beta_{\mathrm{p}} = -71^\circ \pm 4^\circ.$$

3.3. *Adopted solution*

The previous results indicate formal statistical errors of the solved parameters. They are close to each other,[1] but the fact they are not identical signals a presence of non-random errors in the data and/or not complete adequacy of the used solution methods and their assumptions (such as the triaxial shape of the asteroid). We also note that the numerical algorithms to solve for the best-fit parameters are different in methods #1 and #2, and this may also contribute to the observed difference in the two solutions.

A conservative, though perhaps too pessimistic, approach to merge the previous results into a single, adopted solution is to use an average of the best-fit values for the corresponding parameters and "realistic" errors that embrace formal uncertainty intervals of both solutions. With that approach we obtain:

$$P_{\mathrm{sid}} = 0.2622722 \pm 0.0000018 \text{ (days)},$$
$$P_3: \quad \lambda_{\mathrm{p}} = 11^\circ \pm 10^\circ, \quad \beta_{\mathrm{p}} = -64^\circ \pm 10^\circ,$$
$$P_4: \quad \lambda_{\mathrm{p}} = 192^\circ \pm 8^\circ, \quad \beta_{\mathrm{p}} = -68^\circ \pm 8^\circ.$$

Using the orbital inclination of 1.1° and longitude of the ascending node 251.3° for Vysheslavia, we thus obtain obliquity values $\gamma = 154^\circ \pm 14^\circ$ (P_3) and $\gamma = 157^\circ \pm 11^\circ$ (P_4), respectively.

The spin vector determination methods we used also suggest a low-order shape for Vysheslavia, but this shape information is very approximate owing to the simplifying assumptions of the models and the limited data available. Given sufficient data a more sophisticated analysis such as the convex inversion approach of Kaasalainen et al. (2001) should give better shape information, however, the science implications discussed in the following section do not depend on details of the shape model used, so such analysis is outside the scope of our present work. Slivan et al. (2003), and more recently Michałowski et al. (2004), demonstrated that the amplitude–magnitude–epoch and convex inversion methods give generally good agreement between derived pole locations, even if there are not enough data to derive a detailed model shape.

[1] The sky plane uncertainty ellipses of the pole solution overlap but the sidereal rotation period uncertainty intervals are disjunct.

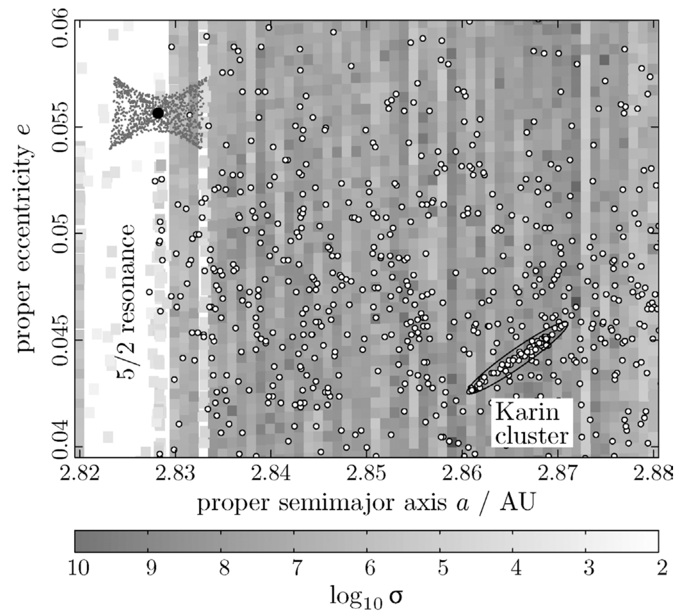

Fig. 2. Koronis family members (open circles) projected on the plane of synthetic proper semimajor axis and proper eccentricity (Knežević et al., 2002); the Karin cluster is indicated in the lower right corner. Assuming an isotropic velocity field, ejecta from a hypothetical secondary collisional disruption near Vysheslavia (full circle) would fall in the region indicated by grey dots. Only one of the observed Koronis asteroids falls in this zone, notably in its stable part exterior to the 5/2 mean-motion resonance with Jupiter. Orbital stability is indicated by grey shading indicating a parameter $\sigma = 1 - n^{(2)}/n^{(1)}$, where $n^{(1)}$ and $n^{(2)}$ are proper mean motions of test particles calculated in the two consecutive time intervals, each spanning 1.2 Myr (see Robutel and Laskar, 2001; dark zones of small σ value imply stability, white areas of high σ value, such as the 5/2 mean-motion resonance with Jupiter, are unstable). The family members were identified using the hierarchical clustering method with the standard metric and the velocity cutoff 60 m/s (e.g., Zappalà et al., 1995; Bottke et al., 2001).

4. Discussion

Our solution for the Vysheslavia pole has two interesting implications. First, it fits a prediction by Vokrouhlický et al. (2001) that the Yarkovsky effect drove Vysheslavia onto its unstable orbit. This result also agrees with a general model of dynamical evolution of asteroid families in which they continually spread due to the Yarkovsky effect. Their sharp termination at prominent mean-motion resonances (such as the 5/2 case with Jupiter; e.g., Bottke et al., 2001, 2002 and Fig. 2), fresh populations of asteroids inside weaker resonances (such as the 7/3 case with Jupiter; e.g., Tsiganis et al., 2003; Vokrouhlický et al., 2005a) and other anomalous features in distribution of asteroids in the proper element space (such as an adherence to high-order secular resonances; e.g., Vokrouhlický et al., 2005a, 2005b) strongly argue in favor of this view. Vysheslavia thus makes sense as the largest member of an asteroid population "on the brink," continually resupplied by new objects (for other asteroids in the Koronis zone see Knežević et al., 1997; Brož and Vokrouhlický, 2001). In the Koronis family, another argument for the ongoing spread in the semimajor axes is the existence of the Prometheus clan, whose asteroids have a significantly higher eccentricity value beyond the $g + 2g_5 - 3g_6$ secular resonance (Bottke et al., 2001).

An alternative possibility, discussed by Milani and Farinella (1995), is that Vysheslavia has a collisional origin, either as a result of a recent disruptive secondary break-up in the Koronis family or that a non-disruptive impact on Vysheslavia shifted its semimajor axis into the dynamically unstable region. A possible result of this collision could be a non-principal-axis rotation of Vysheslavia, provided it occurred so recently that internal dissipation would not damp the wobble energy. For a $\simeq$15 km size asteroid and 6.29-h rotation period the characteristic damping time scale is 0.5–5 Myr, depending on the physical parameters of the body (e.g., Vokrouhlický and Čapek, 2002; Paolicchi et al., 2002). The higher value, if correct, is a non-negligible fraction of the dynamical lifetime of Vysheslavia's orbit. Our observations, however, do not support the non-principal-axis rotation. Rather, they are consistent with a stable rotation mode about the short axis with a single rotation period over all five apparitions. This obviously does not rule out the recent collisional origin of Vysheslavia, but it makes it less likely.

We also note that the collisional lifetime of a hypothetical 20–30 km size parent body for Vysheslavia is likely $\gtrsim$5–10 Gyr (Bottke et al., 2005a, 2005b), making the probability of the recent secondary break-up in the Koronis family, with Vysheslavia being the largest fragment, less then 1% (note that there might be less then ten objects of that size in the family close enough to the 5/2 resonance).

Additionally, we examined spectra of 22 Koronis members, including Vysheslavia, available at the SMASSII Web site http://smass.mit.edu. The reflectance spectrum of Vysheslavia is quite typical for the Koronis family (S-type; e.g., Chapman et al., 1989; Bus and Binzel, 2002) and does not exhibit any anomalous feature that would be possibly related to its hypothetical younger age.

Another approach to this problem is to consider the recent break-up of the Karin cluster (Nesvorný et al., 2002) as a "benchmark" and deduce what fraction of observable ejecta from a hypothetical secondary disruption event would survive dynamical evolution until the present. Assuming the same velocity distribution as observed in the Karin cluster but centered on the position of Vysheslavia, we predict that from initially 20–40 fragments larger than $\simeq$3 km (depending on steepness of the size distribution), some 8–16 should survive 15 Myr. This is based on analyzing the dynamical stability of the fragments' orbits (Fig. 2). We find only one object in this close vicinity to Vysheslavia today. Taken together with the low probability of a secondary break-up described above, the absence of accompanying ejecta in the Vysheslavia neighborhood make the recent collisional disruption scenario exceedingly unlikely.

Secondly, Slivan (2002) and Slivan et al. (2003) analyzed spin vectors of the largest members in the Koronis family. They found a markedly non-random distribution with two statistically significant clusters having obliquity near 50° (prograde rotators) and between 150° to 180° (retrograde rotators). Though Vysheslavia is little smaller than the asteroids observed by Slivan et al. (with sizes of 20–40 km), it still seems to marginally fit the bimodal distribution of the pole directions in the family, namely it matches the observed characteristics of the retrograde rotators. Vokrouhlický et al. (2003) argue that the known spin vectors of Koronis members underwent a remarkable dynamical evolution driven by YORP effect, a rotational variant of the Yarkovsky effect. They also predict, that at small sizes the bimodal pattern should disappear, because of increasing strength of the YORP effect. It appears that Vysheslavia may be just in a transition interval of sizes. Photometric observations of further 10–20 km sized Koronis family members, with the goal to determine their spin vectors, is thus an important project for the future.

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