REVIEW OF STUDIES ON CAPTURE OF COMETS BY NEPTUNE AND ITS ROLE IN THE DYNAMIC EVOLUTION OF COMETARY ORBITS

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ABSTRACT. A historical review of investigations on encounters of minor bodies with outer planets is presented. The dominating role of Jupiter in the capture of comets and in determining their secular evolution is emphasized. Participation in the above process of Saturn, Uranus and, especially, Neptune is investigated. In the present paper are considered five fictitious comets, penetrating into the depths of Neptune's sphere of action, where they undergo large orbital transformations and capture by Neptune. Two near-circular orbits are transformed into elliptical ones, their perihelia being moved inside the planetary system; one hyperbolic orbit is transformed into a transplutonian one, another into a typical short-period orbit of the Neptune's family with a perihelion accessible to terrestrial observers. One fictitious comet is captured by Neptune as a stable satellite.

1. REVIEW OF INVESTIGATIONS ON ENCOUNTERS OF MINOR BODIES WITH OUTER PLANETS (1967-1984)

Modern investigations on the secular evolution of cometary orbits are mainly concerned with large transformations of orbits within Jovian sphere of action and with the dominant role of Jupiter in cometary cosmogony.

Since 1967 the problem has attracted many researchers in the field in USSR and abroad and has been extensively and thoroughly developed. The following papers by Kazimirchak-Polonskaya (1967a,b; 1971, 1972, 1976, 1978a, 1982a,b), Kazimirchack-Polonskaya and Shaporev (1976), Belyaev (1967, 1973a,b), Belyaev and Khanina (1972), Belyaev and Shaporev (1974), Belyaev and Merzlyakova (1976) deal with large orbital transformations in Jupiter's sphere of activity as well as with capture and secular orbital

A. Carusi and G. B. Valsecchi (eds.), Dynamics of Comets: Their Origin and Evolution, 243–258.

evolution (400 yr) of several dozens of the real short-period comets (Lexell, Brooks 2, Wolf, Kearns-Kwee, Schwassmann-Wachmann 3, Oterma, Gehrels 3 etc. being included). On the basis of the data obtained Kazimirchack-Polonskaya (1967, 1972, 1978a) has formulated basic regularities in the multi-staged capture process of comets as well as those occurring in large transformations and during dynamic evolution of cometary orbits on a cosmogonic time scale.

Shtejns studied diffusion of long-period comets taking into account large stellar perturbations of their orbits (1961a,b; 1962) and the dynamic evolution of these (1964). Chebotarev (1972) gave a review of previous investigations on the problems under consideration.

Marsden in his pioneer work (1967) when studying motions of 100 periodic comets over the time span 1725-1965 comes to a conclusion that there exist various types of resonances in the motions of comets and Jupiter, as well as gaps in the Jovian family of comets.

Everhart (1972, 1973, 1976, 1982) on the basis of his large-scale studies of fictitious comets reached very interesting conclusions, especially in paper (1976) concerning the origin of various types of comets.

Kresák (1972, 1974) has initiated a new series of numerous studies dealing with investigations of encounters of fictitious minor bodies with Jupiter. Subsequently this attracted attention of Italian astronomers Carusi, Pozzi, Perozzi and Valsecchi and has been extensively elaborated by Kresák and the above mentioned authors (Carusi and Pozzi, 1978a,b; Carusi, Pozzi, Valsecchi, 1979; Carusi and Valsecchi, 1980; Carusi, Kresák and Valsecchi, 1981; Carusi and Valsecchi, 1981; Carusi, Kresák and Valsecchi, 1982; Carusi and Valsecchi, 1982a). In the first two papers Carusi and Pozzi presented their method for studying the close encounters with Jupiter and applied it for study of 3,000 fictitious minor bodies. In the rest of the above cited papers attention is given primarily to the temporary satellite captures as well as the encounters with Jupiter of those objects whose orbits are nearly tangent to that of the planet. Along with fictitious objects the authors have studied encounters with Jupiter and transformations of orbits also of real comets. Thus Carusi and Valsecchi (1982b) studied the dynamic evolution of 22 short-period comets having low velocity encounters with Jupiter.

Even earlier Rickman (1974) investigated the capture of fictitious comets; Buckley (1977) and Rickman (1979) studied motions and encounters with Jupiter of six new comets discovered during 1974-1977.

Rickman and Karm (1982), and Karm and Rickman (1982), performed an analysis of approaches to Jupiter of all short-period comets prior to their discovery. Vaghi and Rickman (1982) studied orbital evolution of 9 comets which had moved for some time in resonance orbits close to commensurability 2:1.

In this connection the author would also like to draw attention to an interesting investigation by Fernández (1980).

Such are in brief the principal works on close cometary encounters with Jupiter, large transformations and dynamic evolution of orbits both of real and fictitious objects.

None the less to get a more complete picture of the dynamic evolution of cometary orbits it was necessary to reveal, if only in general outline, the dynamics of the Saturn, Uranus and Neptune's spheres of action and to clarify the influence of these planets on the evolution of cometary orbits on a cosmogonic time scale.

The first studies in this field were carried out by the author (Kazimirchak-Polonskaya, 1972). However, insufficiency of material on the motions and observations of the real comets, belonging to the most distant planetary families, forced the author to turn first to fictitious objects. Then, considering their dynamical evolution over very long time intervals, we linked these fictitious objects with the real short-period comets of the Jupiter's family.

Using our method and complex of programs for electronic computers (1972, 1982a), we studied the secular orbital evolution both of fictitious and real comets, belonging to the Saturn and Uranus' families (Kazimirchak-Polonskaya, 1972, 1974, 1976, 1978b) as well as the large orbital transformations in the spheres of activity of these planets. During these investigations the author succeeded to reveal a capture of fictitious comet N-3 (1972) and N-4 (1974, 1976) into the Neptune's satellite orbit, the post-encounter orbit of N-4 being located between those of the two natural satellites of Neptune, namely Triton and Nereid.

Of a great interest (in the author's view) are penetrations of fictitious comets into the depths of the Neptune's sphere of action (1976, 1978b). In her paper (1978b) the author revealed the role of Neptune in the dynamic evolution of cometary orbits on a cosmogonic time scale and treated the problem of cometary origin as well.

The problem of cometary capture by Saturn, Uranus and Neptune has also attracted attention of some astronomers abroad. Thus, Everhart (1976) in his interesting generalizing conclusions notes that some of the short-period comets could have been formed inside the orbit of Neptune. He maintains also that orbits of long-period comets of small inclination and perihelia near Jupiter's orbit could have evolved into orbits typical of short-period comets. One phase of their evolution is represented by near-circular orbits located just outside the Jupiter's orbit. The results of our studies have shown that this Everhart's conclusion remains valid if we extend it over unobservable long-period comets of small inclination and perihelia close to the Saturn's, Uranus' and especially Neptune's orbit.

Exceptionally valuable contributions of a very large cosmogonic scale into the above discussed problems of cometary encounters with the four outer planets have been made in papers: Carusi and Valsecchi (1982c), Carusi, Perozzi and Valsecchi (1983). The first paper dealt with 1,000 fictitious minor bodies and 4,000 of their approaches to outer planets which resulted in 46 TSCs (Temporary Satellite Capture) by Jupiter, 16 by Saturn, 4 by Uranus and 4 by Neptune. In a more recent paper (1983) the authors have investigated the effects of low velocity encounters between fictitious minor bodies and the four outer planets as well as their consequences. Using definition of the TSC, given by Rickman and Malmort (1982), the authors on the one hand have established the capture zones for each outer planet and on the other hand determined, as a consequence, numerous TSCs which the authors divided into two types respectively. The other consequences of encounters (according to the authors) are: the exchange of perihelion with aphelion of the minor body orbit and a change of the minor body semi-major axis from one greater than that of the planet to the smaller one, or vice-versa. These changes due to large perturbations amounted to 117 in Jupiter, 57 in Saturn, 11 in Uranus and 17 in Neptune's families. Influence of all these processes on the dynamic evolution of the minor body orbits on a secular scale is discussed.

An outstanding completion of all these efforts is a unique Catalogue by Carusi, Kresák, Perozzi and Valsecchi (1984) containing data of the secular evolution of 126 comets with a period less than 200 years embracing the time span of 821 yr (1585-2406).

2. CAPTURE OF COMETS BY NEPTUNE AND ITS ROLE IN THE DYNAMIC EVOLUTION OF COMETARY ORBITS

From the author's point of view (1972, 1976, 1978b) of a particular interest are penetrations of comets into the depths of the Neptune's sphere of activity. Owing to the extent of this sphere, the slow motion of comets and the great heliocentric distance, such comets can dwell in the Neptune's sphere of activity for about 10-15-20... yr. Below are given several of the most interesting closest encounters of fictitious comets with Neptune and large transformations of their orbits.

The author (1972, 1976, 1978b) has treated two types of comets: 1) those entering Neptune's sphere of action on near-circular orbits, which can arise owing to diffusion of the long-period comets, and 2) those penetrating this sphere on interstellar hyperbolic orbits.

1. Thus, comet N-2 (1972, Fig. 15) is entering the Neptune sphere of action along a near-circular orbit (e=0.029) with a revolution period of 169 yr and perihelion near the orbit of Neptune. The comet penetrates deeply this sphere to a minimum distance ΔN_{min}=0.00093 AU and leaves it after a large transformation on an elliptic orbit (e=0.170) with revolution period 132 yr, the perihelion near Uranus orbit and the aphelion

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located in close vicinity to the Neptune's orbit; the apsidal line makes a forward turn of 161°.

Even more large orbital transformation, that of comet N-5, is represented in Fig. 14 (1976) and in Fig. 2 (1978b, in this paper comet N-5 received the designation "Neptunian 2"). We reproduce also here this characteristic transformation of the orbit (see Fig. 1). Comet N-5 is

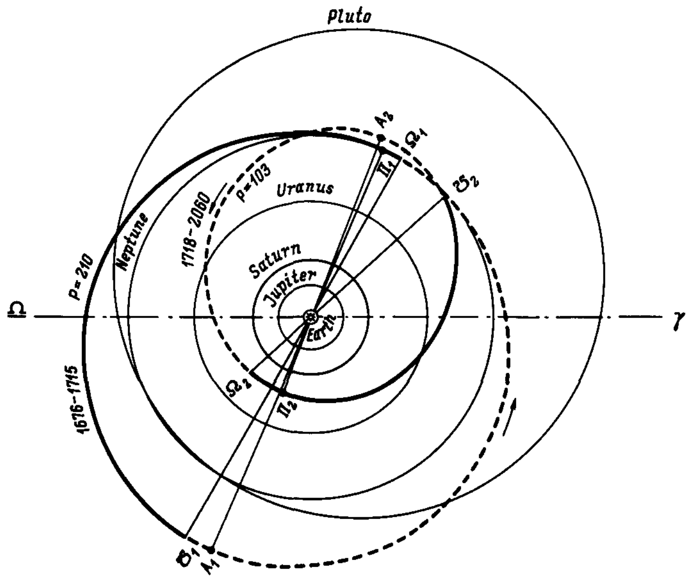

Figure 1. Capture of the N-5 comet by Neptune and transformation of its orbit within Neptune's sphere of action. The part of cometary orbit located under the ecliptic is always designated by a dotted line.

moving at the periphery of the planetary system on an orbit having eccentricity e=0.157, its perihelion on the Neptune's orbit, its aphelion far beyond this orbit, the inclination being 8.7° and the revolution period 210 yr. The comet penetrates Neptune's sphere of action even more deeply than comet N-2, to ΔN_{min}=0.00042 AU, and having done several revolutions around the planet leaves it on an orbit which is even more elliptic than before (e=0.434) with inclination 22.1°, revolution period 103 yr, perihelion between the orbits of Uranus and Saturn and aphelion near the orbit of Neptune. The whole process of the evolution and catastrophic transformation of the comet N-5 orbit as well as those of each orbital element are shown over the time interval 1676-2058 in Table 2 of paper (1978b).

These two large transformations of the orbits of comets N-2 and N-5 in the depths of the Neptunian sphere of action have the following features in common: the ellipticity of an orbit is increased, its revolution period is reduced, the new aphelion is located in the vicinity of an earlier perihelion near the orbit of Neptune, whereas the perihelion of the transformed orbit has moved inwards to the planetary system in a heliocentric direction, but both comets remain invisible from the Earth on this stage of their orbital evolution. This process may be considered as the first stage of cometary capture by Neptune.

The further dynamic evolution of the cometary orbit of N-5 (and similarly that of comet N-2) may proceed quite differently. For instance, after a long time (several millennia) the comet N-5 may repeatedly undergo the closest approaches with Neptune and the planet can either transfer it back to an orbit close to the original one (see for realization of such possibility Fig. 13 of the paper of 1972) or remove it beyond the planetary and even the Solar system limits (we have integrated several variants like the cited), or, finally, Neptune can increase the ellipticity of the comet orbit and move its perihelion still farther inside the planetary system, retaining its aphelion in the vicinity of Neptune's orbit. However, another variant of the orbital evolution of the comet is also quite feasible: over a very long time interval, under the influence of the continuously acting planetary perturbations, the cometary perihelion can approach to Uranus' orbit, and the comet may at some time penetrate deeply into the planet's sphere of action. An alternative situation may arise: the cometary perihelion may approach Saturn's orbit and then at a known period of time a close encounter between comet and Saturn will occur.

Then a new stage of the capture of comet N-5 by Saturn will come into effect, the comet leaving its sphere of action in a transformed orbit, whose aphelion will be close to the previous perihelion; the comet will belong to Saturn's family and its perihelion will advance to Jupiter's orbit and will be located either on the inner or outer side of it. At this stage of evolution, the final step of the capture of the comet by Jupiter into its family will occur; the cometary aphelion will be located near the orbit of Jupiter and the perihelion will appear in the region of visibility and thus the comet will be discovered by a terrestrial observer.

Such is a rough scheme of the dynamical evolution of cometary orbits in the form of multi-stage capture of the first type of comet.

At this stage we have closely advanced to the real short-period comets. Namely in this way a number of newly discovered comets were captured from the Saturnian to Jovian families: P/Oterma in 1937-1938, P/Gehrels 3 in 1970 etc. Likewise the whole series of comets (P/Schwassmann-Wachmann 3 in 1882, P/Brooks 2 in 1886, P/West-Kohoutek-Ikemura in 1972 etc.) were captured into Jupiter family from the boundary of the two planetary families Saturn-Uranus.

2. Kazimirchak-Polonskaya (1976, 1978b) outlined the two types of

the cometary capture by Neptune from hyperbolic orbits, whose perihelia (influenced by stellar perturbations or due to other reasons) have penetrated into the periphery of the planetary system and are located between the orbits of Neptune and Uranus. A catastrophic transformation of the orbit of comet N-6 in the Neptune sphere of action is depicted in paper (1976) and Fig. 15. In paper (1978b) this comet was designated "Neptunian 1"; its dynamic evolution over the time span 1710-2060 is represented there in Fig. 1 and Tab. 1. The comet N-6 (see Fig. 2) enters

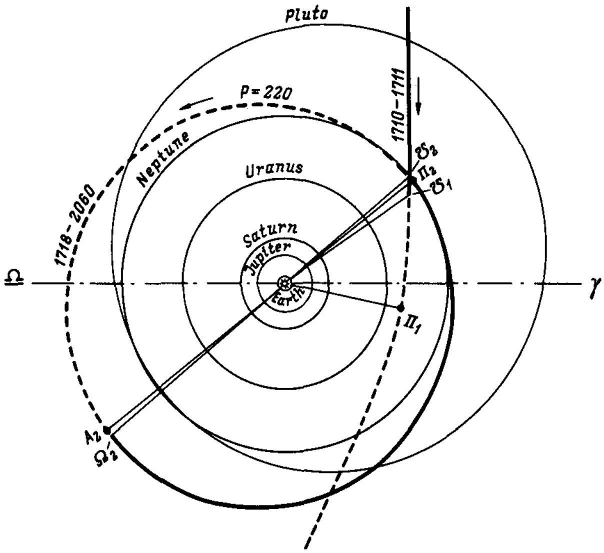

Figure 2. Capture by Neptune of the interstellar comet N-6 and its transformation into an unobservable periodic comet.

the Neptune sphere of action on a hyperbolic orbit with retrograde motion (indicated by an arrow in Fig. 2) and with orbital inclination 135° prior to perihelion passage Π_1. Its penetration into the depths of the Neptune sphere of action attaining ΔN_{min}=0.00046 AU, produces as usual a motion of the comet along a temporary satellite orbit. After a catastrophic transformation of the N-6 orbit in the course of the first stage of capture by Neptune, the comet leaves its sphere of action on a near-circular orbit (e=0.181) with a direct motion (i=16.0°), the period of revolution reaching nearly 220 yr, the aphelion being in the transplutonian area and the perihelion in close vicinity to Neptune's orbit (q=29.8 AU); this betokens a future (though a very remote one) inevitable penetration of the comet into Neptune's sphere of action and new large orbital transformations.

Comparing the orbit of comet N-6 after it had left this sphere with

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that of comet N-5 before it entered the sphere, one can see that these are of the same type. Therefore, further stages of the N-6 orbit as well as the new stages of its capture by Neptune and the other outer planets take a similar course as outlined above for the comet N-5.

Comet N-7 represents an exceptionally interesting object (see Fig. 3). Capture of the comets N-7 and the large transformation of its orbit in the Neptune sphere of action are depicted in Fig. 16 (1976) and in Fig. 3 in paper (1978b) where the comet was designated as "Neptunian 3". It penetrates the Neptune's sphere of action, after perihelion passage on

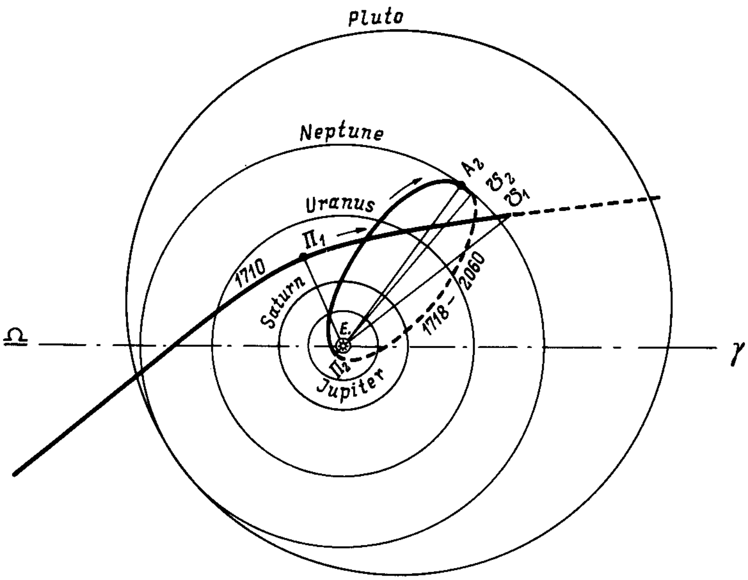

Figure 3. Capture by Neptune of the N-7 comet from a hyperbolic orbit and its transformation into a short-period retrograde comet of Neptune's family.

a hyperbolic orbit with retrograde motion (i=159°), and attainsΔN_{min} = 0.00035 AU. It implies that the comet dashes through perineptunian at a distance of about one Neptune's diameter from its surface. This case resembles the closest approach of P/Brooks 2 to Jupiter in 1886. In the depths of the Neptune's sphere of action within the powerful gravity field of the planet, a one-stage capture of the comet N-7 by Neptune and catastrophic transformation of its orbit are accomplished: the interstellar comet leaves the Neptune's sphere of action as a typical short-period comet of Neptune's family. Its orbit represents a stable (that is until a new close encounter with Neptune, Jupiter or some other outer planet), strongly elongated ellipse with a retrograde motion (i=136.5°), the period of revolution being about 62 yr, aphelion near the orbit of

Neptune and perihelion distance 1.2 AU, and consequently perihelion is situated in close vicinity to Earth's orbit. At this stage of evolution the comet becomes accessible to terrestrial observers.

The orbital elements of the comet N-7 on leaving the Neptune sphere of action are very much like those of real comets of Neptune's family (see Table 1).

TABLE 1. Comparative characteristics of orbits of N-7 and other short-period comets of Neptune's family. q and Q = perihelion and aphelion distances. e,q,P,i: Marsden (1982); a,Q: calculated by Kazimirchak-Polonskaya

Comet	a (AU)	e	q (AU)	Q (AU)	P (yr)	i (°)
N-7 (1985)	15.7	0.92	1.23	30.2	62.3	136
P/Pons-Gambart (1827 II)	14.9	0.95	0.81	29.0	57.5	136
P/Westphal (1852 IV)	15.5	0.92	1.25	29.8	61.2	41
P/Dubiago (1921 I)	15.7	0.93	1.11	30.3	62.3	22

The dynamic evolution of the comet over the period 1710-2056 is presented in Table 4 of the paper (1978b).

On the basis of the given figures and tables one can draw the following conclusions (Kazimirchak-Polonskaya, 1978b, pp. 411-413).

1. Neptune, due to its greatest heliocentric distance and its vast sphere of action participates actively in the capture of comets and like Jupiter is a powerful transformer of cometary orbits, substantially determining their dynamic evolution on a cosmogonic scale.

2. Capture of comets from the periphery of the planetary or Solar system (or even from the interstellar space), and their introducing into a region of visibility, represents a very complicated multi-stage process taking place over centuries, millennia and even millions of years in which all the outer planets participate (particularly Jupiter and Neptune), owing to the powerful dynamic transformations which occur deep within their spheres of action.

3. It is important, however, to point out the essential differences in the dynamics of the sphere of action of Jupiter and those of the other outer planets. Jupiter with its powerful mass is exerting a strong perturbing action on the cometary orbit long before it enters its sphere of action and for a long time after leaving it. Neptune having a significantly lesser mass is devoid of such a strong transforming influence

even within its sphere of action until the comet reaches ΔN < 0.1 AU. But when a comet is sweeping past at a short distance from the Neptune's surface, its gravity influence produces large or even catastrophic transformations of the cometary orbit.

Analogous observations (although with some modifications) apply also to dynamic transformations and the evolution of cometary orbits when comets penetrate into the depths of the Saturn's and Uranus' spheres of action.

4. On the basis of all her investigations the author established that beyond the Neptune's orbit and between the orbits of Neptune and Uranus as well as between those of Uranus and Saturn, Saturn and Jupiter there exist vast belts (or reservoirs) containing perihelia of the numerous unobservable comets.

Majority of these comets in the multi-stage capture by Neptune-Jupiter are gradually moving to the Sun and in vicinity of their perihelia they get into the region of visibility and owing to this situation the comets are discovered as new short-period comets. Existence of these belts is substantiated by studies of Whipple (1972) and Carusi, Perozzi and Valsecchi (1983).

3. CAPTURE OF A COMET ON THE NEPTUNE'S SATELLITE ORBIT

Finally we present in Fig. 4 the unusual orbit of comet N-4 captured by

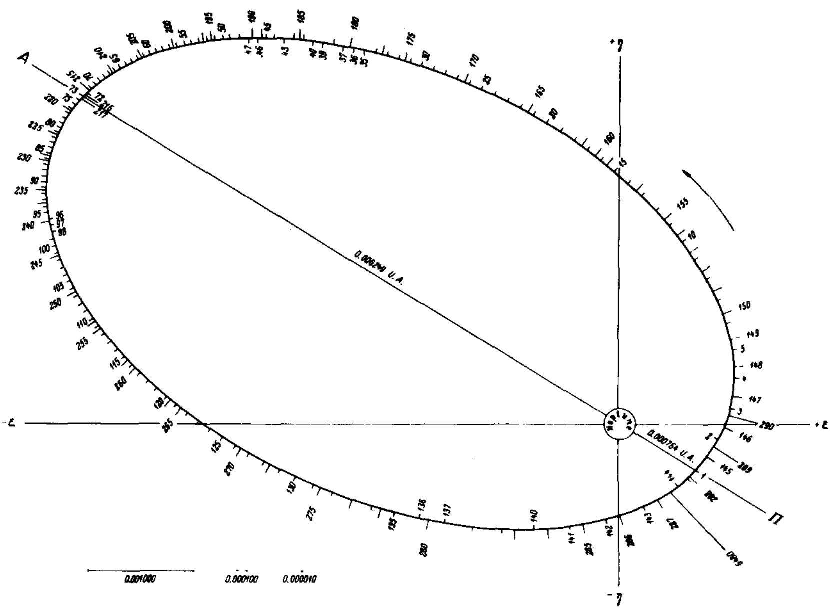

Figure 4. Comet-Satellite N-4 captured by Neptune.

Neptune as a stable satellite having an orbit intermediate between those of Neptune satellites, Triton and Nereid (see Table 2). The detailed catastrophic transformation of this extraordinary comet in the depths of Neptune's sphere of action is examined in the author's paper (1974) and presented also in (1976, Fig. 17, Tab. 2).

TABLE 2. Characteristics of orbits of Neptune's satellites: Triton, Nereid and N-4

Satellite	Mean distance from Neptune (10^3 km)	Δ_{min} (10^3 km)	Δ_{max} (10^3 km)	Sidereal period (d:hr:min:sec)	e^1	i^2
Triton	354	354	354	5:21:02:39	0.00	132.79°
N-4	524	91	957	11:05:31:12	0.73	60.87°
Nereid	5570	1337	9803	359:09:36	0.76	4.97°

1: eccentricity of mean orbit
2: inclination relative to ecliptic

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CONCERNING THE PAPERS BY R. DVORAK AND C. MARCHAL ON THE CAPTURE OF A COMET ON THE NEPTUNE'S SATELLITE ORBIT

The results of the investigations by Kazimirchak-Polonskaya (1974) were disputed by R. Dvorak (1976, Astron. Astrophys., 49, 293-298) and R. Dvorak and C. Marchal (1978, Astron. Astrophys., 69, 373-374).

Before passing to comments on these two papers it should be emphasized that the capture of a comet in the Neptune's sphere of action on the satellite orbit is an exceptionally rare occurrence. The author (1974) intended to determine such initial system of elements of a fictitious comet at the epoch of its entry into the Neptune's sphere of action which would allow realization of such an exclusive case. The system of N-4 elements at the epoch T_o=1726, March 28.0 UT satisfies the required condition (Table 1). Numerous experiments carried out by the author have shown that even the slightest changes although of a single element of the system prevent the capture of a comet on the satellite orbit of Neptune. Computations were performed with consideration of perturbations by eight planets (Venus-Pluto) using a specially devised method and complex of programs with increased precision (18 significant digits) constructed by the author as well as her stock of coordinates of major planets for 400 yr. The method and complex of programs are briefly given in (1972) and a more detailed presentation may be found in (1982). All results on N-4 orbital transformations in Neptune's sphere of action and those pertaining to its transition on the satellite orbit are presented in Tables I-IV and Fig. 1 (1974) but unfortunately due to purely technical reasons with the restricted number of significant digits. In 1974 the Institute of Theoretical Astronomy has moved to a new place of residence and at that time a fraction of the computer archives of the published papers was destroyed and among those - computations pertaining to the paper (1974). Therefore the author is not in a position to re-establish the initial system of elements in the original form. R. Dvorak (1976) made up his mind to verify my results, proceeding from the calculated by him heliocentric elements of N-4 for the epoch t_o=1738 Sept. 25.14 UT, i.e. for the moment of the comet transition into a stable satellite orbit around Neptune. In his studies of motion of the comet and when calculating coordinates of the major planets, Dvorak employed the n-body program by Shubart and Stumpff with precision to 13 significant digits introducing, according to his judgement required additions and changes conformably to the problem under consideration. Besides Dvorak utilized also the other unpublished materials. Having performed a very labour-consuming and initiative work Dvorak improved the initial system of elements for t_o, computed on its basis the neptunocentric coordinates of the comet $\bar{\xi}$, $\bar{\eta}$, $\bar{\zeta}$ for duration of 11 days, compared these with those of Kazimirchak-Polonskaya ξ, η, ζ (Table 3) and noted that the compared coordinates were in good agreement. Proceeding from the elements obtained for the epoch t_o, he integrated the equations of the comet motion back to the epoch t_1=1738 July 2.6 UT and compared his results with those of the author (Table 4). He found large discrepancies between the results.

From our point of view these discrepancies are due to the following causes: 1. Discrepancies between the results in the sixth decimal point (AU) (Table 3) for the period of 11 days: $\xi-\bar{\xi}$=+45, $\eta-\bar{\eta}$=+56, $\zeta-\bar{\zeta}$=-42 are too big, which is a direct consequence of the disagreement between the initial systems of elements of N-4 for the epoch t_o of Dvorak and the author. 2. Computations of both researchers were performed proceeding from differing initial conditions, using different methods and programs of various precision as well as coordinates of major planets obtained in different ways. No wonder that such verification of the author's results in a very complicated and difficult problem was unsuccessful which was admitted by Dvorak himself (1976, p. 297).

However, distrusting "the surprising" results of the author and seeking to find errors in her calculations, R. Dvorak in cooperation with C. Marchal undertook a new investigation (1978) of a more general theoretical nature. As its basis they assumed a priori statement that a duration of a capture of a fictitious comet on the planetary satellite orbit and a duration of an escape of the natural satellite of this planet from its stable orbit are equal. It is obvious both from the title of the paper: "Duration of escape or capture of a satellite", and from its content.

Correctness of such fundamental, non-evident statement should first have been proved. The authors have not done that and could not have done that since this statement is at variance with real facts for the two above mentioned processes: the process of capture of a fictitious comet and that of an escape of the natural satellite of the planet, are substantially different.

In fact, all prominent researchers of large transformations of cometary orbits in Jupiter's sphere of action (N. Belyaev, A. Carusi, A. Dubiago, E. Everhart, L. Kresák, M. Kamienski, B. Marsden, H. Rickman, G. Valsecchi and others) well know that these grand transformations due to Jupiter's attraction are swiftly realized and have duration of several years (rarely decades) and more often several months. This regularity was proved by numerous examples in exceptionally interesting studies by A. Carusi, E. Perozzi, G.B. Valsecchi (1983) as well as by a grand scale Catalogue (A. Carusi, L. Kresák, E. Perozzi, G.B. Valsecchi, 1984). When modelling transformations of cometary orbits the analogous velocity occurs in Neptune's sphere, specifically in transformation of N-4 orbit.

On the contrary, it is known that an escape of a natural satellite of the major planet from its stable orbit (if it is at all possible) is an exceptionally slow process and it is realized during many millennia and even millions of years.

Such misconception of the substance of a capture process of the comet as well as an erroneous formulation of the problem based on the wrong a priori statement have inevitably led R. Dvorak and C. Marchal to a fantastically unlikely conclusion that Kazimirchak-Polonskaya (1974) made an appalling error, having determined a duration of the capture of N-4 "of about 100 days instead of 135 centuries" (1978, p. 374).

By the way Dvorak and Marchal have made another mistake: the capture of comet N-4, i.e. a grand transformation of its orbit in the Neptune's aphere of action and transition of the comet on the satellite orbit of the planet had been realized not over a period of 100 days as stated by these authors, but over a period of about 12 years (from 1726 to 1738), as shown in the paper by Kazimirchak-Polonskaya (1974, Tables I-III).

It should be noted, in conclusion, that a high accuracy of the method and complex of programs by the present author have been repeatedly verified when studying the motion and comparing the calculations with observations of a series of short-period comets. Thus, for instance, in the paper by Kazimirchak-Polonskaya (1982) was presented a numerical theory of P/Wolf (1884 III) motion over 100 years (1884-1984) taking into account perturbations caused by 9 planets (Mercury-Pluto), nongravitational effects in all elements, as well as influence of minor planets and the Galilean satellites of Jupiter, Ganymede and Callisto, during a deep penetration of the comet into Jupiter's sphere of activity in 1922. This numerical theory made it possible a good representation of 1500 observations of the comet over 100 yr period. Using the elements and ephemeris of the author, the observer G.B. Gibson of the Mount Palomar Observatory was able to rediscover the comet as an object of 20^m with following differences: 1983 Aug. 123479, $\Delta\alpha \cos\delta = +0.2''$, $\Delta\delta = -0.0''$ (Kazimirchak-Polonskaya, 1983, Kometn. Tsirc., Kiev, **316**, 1-2) long before its passage through perihelion in 1983.