REPORT OF THE WORKING GROUP ON ORBITS AND EPHEMERIDES OF COMETS FOR THE TRIENNIUM 1967–70

INTRODUCTION

This report has been compiled from information received in response to an inquiry sent by E. Roemer as chairman of the Working Group to members of the Group (Candy, Kresák, Marsden, Makover, Sitarski) as well as to twelve others known to be working actively in dynamical study of comets whose work might not otherwise be adequately represented in the report. Responses were received from J. L. Brady (Livermore), Candy, Kresák, A. L. Friedlander (Astro Sciences Center, Illinois Institute of Technology Research Institute), Makover, Marsden, Milet, E. Rabe, Sekanina, Schubart, and Van Biesbroeck.

Highlights of the triennium include a reasonably satisfactory level of observational activity, although further application of large reflectors would be highly desirable; attainment of a new high level of predictional accuracy through the more rigorous application of dynamical theory permitted by the availability of large-scale computing machinery; significant progress in the investigation of nongravitational effects; and important studies of the dynamical evolution of comet orbits, including diffusion of comets from near-parabolic to short-period orbits and resonance effects within the Jupiter family.

Several specialized symposia and meetings during the triennium have been devoted to dynamical problems of comets. All-Union Conferences on Comets have been held annually in Kiev, and meetings particularly connected with space missions to comets have been held in the U.S.A. Most significant, however, is the IAU Symposium No. 45, 'The Motion, Evolution of Orbits, and Origin of Comets,' being held in Leningrad just preceding this General Assembly.

I. GENERAL

Most discoveries of new comets during the triennium bear witness to the enthusiasm of amateur astronomers, particularly the Japanese. Amateurs have also been of considerable help in confirming relatively bright new objects in instances wherein the discoverer has had difficulty in making adequate observations, or in which considerable time elapsed between date of a photographic observation and detection of a new object on the plates. Note is taken with satisfaction of the prize offered by the Astronomical Society of Japan, and of the newly established Comet Medal of the Astronomical Society of the Pacific.

Early recovery of returning periodic comets and prolonged observation of both periodic and near-parabolic comets are at least as desirable as ever. The outstanding achievement during this triennium of K. Tomita, who recovered no less than ten periodic comets during 1967, including four on the single night of October 5, deserves special mention. Z. M. Pereyra has given valuable help with observation of comets in southern declinations, including two recoveries and extended observation of a number of comets not followed elsewhere. The last observations of the recent sungrazer, 1970 *f*, White-Ortiz-Bolelli, are an excellent example of Pereyra's important contributions. Roemer has had consistent success with the 154-cm Catalina reflector, and particularly, since October 1969, with the 229-cm reflector of the Steward Observatory on Kitt Peak. In instances in which positional uncertainty has complicated the search for relatively faint objects, important work has been done by G. A. Tammann and C. T. Kowal, who have had the opportunity to apply the 122-cm Schmidt telescope of the Palomar Observatory to observation of comets.

Preliminary orbit computations seem to be in a satisfactory state at the present time, thanks in significant degree, to good computing facilities available to Marsden, who is in the pivotal position of director of the IAU Central Telegram Bureau at the Smithsonian Astrophysical Observatory. Note should be taken, however, of the calculations of orbits and ephemerides at the Institute for Theoretical Astronomy, Leningrad, on behalf of the several Soviet observatories engaged in observation of comets, and by several individuals, including Candy, S. W. Milbourn, and T. Seki, who have much more modest computing facilities at their command.

Calculations of definitive orbits by present standards typically include allowance for perturbations during the observed arc wherever significant, and a least-squares adjustment that takes account of all valid observations. Such work is carried on at the major centres, including the Institute for Theoretical Astronomy, Smithsonian Astrophysical Observatory, Institute of Astronomy of the Polish Academy of Sciences, Astronomisches Rechen-Institut, and the Minor Planet Center, Cincinnati. In some cases important aid is given through a centre to an individual working independently, as, e.g., between Marsden and Van Biesbroeck.

During the triennium, I. Hasegawa has published an interesting Catalogue of Periodic Comets, in which alternate sets of elements for each object are presented. Sekanina has circulated the first supplement to his Catalogue of Original and Future Comet Orbits.

II. ASTROMETRIC OBSERVATIONS

Astrometric observations of comets with astrographs or Schmidt-type cameras are carried on regularly at Abastumani, Burakan, Berne, Crimean Astrophysical Observatory, Flagstaff (Lowell Observatory), Kleť, Nice, Perth, Pulkovo, Skalnaté Pleso, Tartu, Uccle, Washington, and, among other amateurs, by R. L. Waterfield (Woolston), and T. Seki (Kochi). Several of the Soviet observatories receive assistance with reductions from the Institute for Theoretical Astronomy, Leningrad.

The principal contributors having access to long-focus instruments include Z. M. Pereyra (154-cm reflector, Bosque Alegre Station, Córdoba Observatory for the CNEGH), K. Tomita (91-cm reflector, Dodaira; 188-cm reflector, Okayama, about 20 nights per year), E. Roemer (154-cm reflector, Cataline Station, LPL, about 25 nights per year; 229-cm reflector, Steward Observatory, Kitt Peak, 10-20 nights per year?). H. L. Giclas reports that the 183-cm Perkins reflector at the Lowell Observatory has been equipped for photography of moving objects, and some success has been achieved. The need for observations with powerful instruments such as these is, if anything, greater than ever as computational standards have risen to permit critical comparison of various theoretical interpretations of nongravitational effects and orbital evolution. Several of these telescopes can reach objects of 19th and 20th magnitude, and the Steward reflector has played a critical role on several occasions in reaching objects of magnitude 21.

Note is taken with considerable satisfaction of the progress with redetermination of plate constants for the northern zones of the Astrographic Catalogue. New values, on the system FK4, are soon to be published in *Astronomy and Astrophysics Supplement* (cf. A. Günther and H. Kox, *Astron. Astrophys.* **4**, 156, 1970). Availability of the new constants will be a definite factor in increasing the accuracy and consistency of the positions from long-focus instruments.

III. ORBITS OF SHORT-PERIOD COMETS

By present standards of computation, predictions for returning periodic comets are based on starting orbits that represent in satisfactory manner all valid observations at the most recent previous apparition. Allowance for all significant perturbational effects of the major planets is made in arriving at the predicted orbit and ephemeris. In an increasing number of instances, several apparitions have been rigorously linked, resulting in determination of, and some form of empirical allowance for, nongravitational effects. Many recoveries now involve reobservation of the comet within less than one arcminute of the predicted place. At the principal centres, the procedures to carry out the necessary computations have been standardized to a considerable degree and are carried out with the aid of modern digital computers.

For details of specific results for individual objects, including references, it is very gratifying to be able to refer to the annual reports on comets prepared by Marsden and published in the *Quarterly Journal* of the RAS.

The principal new areas of activity (reported in greater detail in Section 5 of this report) include analyses of the nature of the nongravitational effects, resonances and librations arising from interactions with the principal planets and affecting orbital stability, as well as the persistent problem of the dynamical origin and orbital evolution of the short-period comets.

Another new interest attaches to short-period comets in connection with proposed direct exploration of comets by means of space missions. Orbital analyses of a considerable number of such comets have been carried out in connection with feasibility studies for missions. Practicable missions fall into two basic categories, (1) fly-through missions, and (2) rendezvous missions. In the first type the probe intercepts the comet fairly close to perihelion but passes through with a rather high relative velocity (of the order of 10 to 20 km sec^{-1}, typically), spending only a few hours in data-gathering in the near vicinity of the comet. Farther in the future are the rendezvous missions, in which the probe's trajectory is closely adjusted to that of the comet, intercept being achieved near aphelion and the probe traveling with the comet for prolonged periods of data-gathering during the comet's physical development on approach to the Sun. Extremely high standards of accuracy of positional prediction are required by either type of mission. (For a general discussion see A. L. Friedlander, J. C. Niehoff, J. I. Waters: 'An Interim Report on Comet Rendezvous Opportunities,' *Illinois Institute of Technology Technical Memorandum* No. T-21, November 1969.)

On the observational side, the orbits of several comets of one apparition have been closely investigated by Marsden with the finding that in some cases renewed searches at current apparitions can be sufficiently limited in area to give reasonable chance of reobservation of the comet. The recovery of P/du Toit-Neujmin-Delporte by Kowal as a result of this effort is particularly gratifying.

IV. ORBITS OF NEARLY PARABOLIC COMETS

Definitive orbits have been calculated for several near-parabolic comets of recent years by O. N. Barteneva, L. M. Belous, R. Branham, Jr., M. A. Mamedov, L. E. Nikonova, Z. Sekanina, G. Van Biesbroeck, and G. T. Yanovitskaya. More complete details are included in the annual reports published in the *Quarterly Journal* of the RAS, to which it is again very satisfying to be able to refer.

Original and future orbits for a number of objects have been calculated by Barteneva, Marsden in collaboration with Van Biesbroeck, Sekanina, and Yanovitskaya.

Brady reports that he has finished integrating the orbits of all the available near-parabolic comets that fit his criteria – some 143 objects. He mentions in particular that a critical value of the osculating eccentricity stands out prominently. Of those comets with osculating eccentricity above 1.00017, 75% pick up energy through the effects of planetary perturbations and escape; of those with e below this value, about 50% escape and 50% remain bound.

E. Everhart also has studied the changes of energy of near-parabolic comets in passing through the solar system, more particularly from a statistical point of view. His work is referred to in greater detail in Section V.

It is clear, however, that the proved presence of nongravitational effects in the motion of many short-period comets, and in the near-parabolic comets Arend-Roland (1957 III) and Burnham (1960 II), complicates the interpretation of original and future orbits computed by purely gravitational representations.

V. THEORETICAL INVESTIGATIONS

Nongravitational effects have been investigated by Marsden in a series of papers that establish their presence and empirical character. Deviations of the observed motion of 15 out of 18 long-observed comets from the corresponding rigid representation by gravitational theory have been definitely established. The principal force component seems in general to be radial; that along the orbit is roughly an order of magnitude smaller; and no component perpendicular to the orbit plane is required by observations. There is a correlation between the appearance of the comet and the magnitude of the nongravitational effects; the two comets of most nearly stellar appearance seem to move strictly gravitationally. Nongravitational effects generally seem to show a secular decrease in amount, which leads Marsden to speculations concerning the relationship between comets and

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minor planets. There are, however, significant dynamical differences between comets and minor planets, particularly with regard to resonance effects and the occurrence of close approaches to principal planets. An outstanding question relates to apparent changes in nongravitational effects associated with close approaches to Jupiter. There is some evidence that random and impulsive effects do occur from time to time, but P/Schwassmann-Wachmann 1, which might be expected to be the prime candidate to show such effects, in fact does *not* show them.

Sekanina also has done important work in the area of nongravitational effects, concentrating on physical models of how such effects may arise. Reference is made to the Bibliography for his extended series of papers. He concludes that both mass loss from a rotating nucleus and nuclear splits, either spontaneous or arising from collisions, contribute to observed orbital deviations. Sekanina also has considered nuclear splits of several comets in a more general context. An interesting finding by Sekanina has been the association of meteor streams, using Harvard radio meteor data, with certain Apollo asteroids. If this finding can be substantiated, weight would be added to the idea of evolution of these asteroids from comets, a suggestion put forward long ago by E. Öpik.

P. Stumpff is continuing his studies of differential perturbations of comet orbits, the motion of P/Brooks 2 since 1886 being under particular investigation. Resolution of nongravitational effects is complicated by the two close approaches to Jupiter during the interval included in the perturbation calculations.

D. E. Gonzales has shown that the solar wind-induced drag on comets is much less than the mechanical effect of mass loss.

The origin of the Kreutz group of sungrazers has been the subject of study by both Marsden and Sekanina. Marsden argues rather convincingly that the known members fall into two distinct groups that very likely arose from tidal disruption of a parent comet near perihelion only one or two revolutions ago. Observed disruptions of several of these comets near perihelion lend credence to the suggestion. Sekanina proposes that a parent comet may have been disrupted by collision with a 'cosmic projectile' far from perihelion, or, alternatively, that the group may have arisen through a glancing collision of two parent comets.

E. Everhart in a series of papers has attempted to allow for selection effects in discovery of long-period comets to reconstruct the intrinsic distribution of perihelia and magnitudes of the parent population. Then he has investigated the changes in total energy that arise in passage of members of such a population of comets through the solar system, first through small perturbations, then through single close encounters. The aim has been to investigate the mode of the presumed diffusion of long-period orbits to short-period ones.

G. Sitarski has studied the approaches of the 494 actually observed parabolic comets to the outer planets, finding that 50% of comets can approach outer planets closer than 1 UA. Orbital changes were calculated for 62 close approaches. Capture into an elliptic orbit by Jupiter seems to be possible even for orbits with e as large as 1.5.

E. M. Pittich also has investigated selection effects on discovery, with interesting findings related to the contribution of photographic discoveries. In a second paper he concludes that sudden brightness changes are a factor in some 8% of comet discoveries. Kresák notes that it is intended to extend the work of Pittich, which is broadly concerned with investigation of the changing population of the inner zone of comets, to the central problem of the equilibrium between perturbational capture of comets from outside, on one hand, and ejection and disintegration in the inner part of the solar system, on the other hand.

H. I. Kazimirchak-Polonskaya is continuing her investigations on evolution of orbits of some 45 short-period comets in the interval 1660–2060, with the aim of clarifying the role of outer planets in this evolution. N. A. Beljaev also has contributed substantially to this investigation.

Cometary motion in the outer solar system has been the subject of investigations by Chebotarev and, more recently, by Sekanina. Both have been interested in the sphere of action of the solar system and perturbations of comets of the Oort cloud by nearby stars.

Hamid, Marsden, and Whipple have investigated the influence of a hypothetical comet belt beyond Neptune, both in its possible influence on motions of periodic comets and on the motions of Uranus and Neptune. A not very restrictive upper limit to the mass of such a belt of one Earth-mass within 50 UA from the Sun has been found.

Hamid and Whipple have searched for evidence of P/Encke in ancient records, especially the Chinese. They have computed the gravitational position 2500 yr into the past as the basis for identification of possible observations, but uncertainties remain as a consequence of unknown nongravitational effects.

VI. COMPUTING TECHNIQUES

Various developments in computing techniques have been implicit in the programming necessary to carry out the orbit determinations, perturbation calculations, and adjustments of elements already referred to as a part of the rigorous application of gravitational theory to the motions of comets. Many of these are described incidentally in the principal papers indexed in Section 5 of the Bibliography.

Makover reports that V. F. Myachin and O. A. Sizova have worked out and programmed a method of simultaneous integration of equations of celestial mechanics, based on ideas by Teylor and Steffensen. In this method each comet coordinate is expanded into a series containing, instead of high-order differences of the function *f*, the derivatives to any order. The method is particularly suitable for integrations carried out with a variable step. Makover also reports the work of G. T. Yanovitskaya, who has derived a set of formulae for the method of variation of arbitrary constants for the case of nearly parabolic motion.

E. Roemer

BIBLIOGRAPHY

An effort has been made to include articles from the general literature which have come to attention through communications from authors, supplemented by a non-comprehensive search of the literature. With respect to determination of orbital elements of individual comets, the annual report on comets presently prepared by B. G. Marsden and published in the *Quarterly Journal* of the Royal Astronomical Society includes far more comprehensive references than the present report.

1. *General*

Everhart, E., Raghavan, N. 1970, Changes in Total Energy for 392 Long-Period Comets, 1800–1970, *Astr. J.* **75**, 258.

Hasegawa, I. 1968, Catalogue of Periodic Comets (1967), *Mem. Coll. Sci., Kyoto Univ., Ser. Phys., Astrophys., Geophys., Chem.* **32**, 37. (Alternate sets of orbital elements.)

Marsden, B.G. 1967, One Hundred Periodic Comets, *Science* **155**, 1207. (General discussion of current problems.)

Sekanina, Z. 1968, Supplementary Catalogue 1 of Original and Future Comet Orbits, *Astr. Inst. Charles Univ., Prague, Publ. Ser. II*, no. 56. Related publication by the same author: An Interference Effect in the Calculation of Original and Future Comet Orbits, *Bull. astr. Inst. Csl.* **18**, 369.

2. *Astrometric Observations*

Bejtrishvili, I. 1967, Observations of Comets Kopff (1963 *i*) and Everhart (1964 *h*) at Abastumani Observatory, *Bull. Inst. teor. Astr.* **11**, 286.

Bronnikova, N. 1967, Photographic Observations of the Comet Alcock (1963 *b*) at Pulkovo, *Bull. Inst. teor. Astr.* **11**, 288.

Haupt, H., Schroll, A. 1967, Photographische Positionsbestimmungen des Kometen Kilston (1966 *b*), *Ann. Univ. Sternw. Wien* **27**, 123.

Kurpińska, M., Michalec, A. 1968, Positions of Comet Kilston 1966 *b*, *Acta astr.* **18**, 321.

Milet, B., Soulié, G. 1967, Positions de petites planètes et de comètes, *J. Observateurs* **50**, 219.

Mintz, B. 1968, Observations of Bright Minor Planets and Comets, *Astr. J.* **73**, 49.

Morkowska, B. 1969, Observations of Comets Made at the Poznan University Observatory, *Acta astr.* **19**, 85.

Polyakova, T., Romashin, G. 1967, Observations of Comet Everhart (1964 *h*) at Burakan, *Bull. Inst. teor. Astr.* **11**, 287.

https://doi.org/10.1017/S0251107X00020095 Published online by Cambridge University Press

Velthuyse, F.H.M., Wisse, P.N.J. 1969, Photographic Positions of Minor Planets and of Comet Barbon (1966 *c*), *Bull. astr. Inst. Netherlds., Suppl.* **3**, 117.

3. *Orbits of Short-Period Comets*

Belyaev, N.A. 1967, The Orbital Evolution of Comets Neujmin 2 (1916 I), Comas Solá (1927 III), Schwassmann-Wachmann 2 (1929 I) over the 400 Years from 1660 to 2060, *Astr. Zu.* **44**, 461.
Brady, J.L., Carpenter, E. 1967, The Orbit of Halley's Comet, *Astr. J.* **72**, 365.
Brady, J.L. 1967, Note Regarding Nongravitational Forces on Halley's Comet, *Astr. J.* **72**, 1184.
Herget, P. 1968, Revised Orbit of Comet Schwassmann-Wachmann 1, *Astr. J.* **73**, 729.
Herget, P. 1968, Ephemerides of Comet Schwassmann-Wachmann 1 and the Outer Satellites of Jupiter, *Cincinnati Obs. Publ.*, no. 23.
Kamieński, M., Sitarski, G. 1967, Comet P/Wolf 1 in 1958–1968, *Acta astr.* **17**, 73.
Kazimirchak-Polonskaya, H.I. 1967, Quelques problèmes actuels de l'astronomie cométaire du point de vue de la mécanique céleste contemporaire, *Trudy Inst. teor. Astr.* **XII**, 3.
Kazimirchak-Polonskaya, H.I. 1967, Perfectionnement de la théorie de la comète Wolf 1 pendant la période 1918–1925 contenant son rapprochement de Jupiter en 1922, *Trudy Inst. teor. Astr.* **XII**, 24.
Kazimirchak-Polonskaya, H.I. 1967, Evolution de l'orbite de la comète Wolf 1 durant 400 ans, 1660–2060. Investigations préliminaires, *Trudy Inst. teor. Astr.* **XII**, 64.
Kazimirchak-Polonskaya, H.I. 1967, Sur la possibilité de l'origine commune des comètes Wolf 1 (1884 III) et Barnard (1892 V). Investigations préliminaires, *Trudy Inst. teor. Astr.* **XII**, 86.
Khanina, F.B. 1968, (Investigation of the Motion of Faye comet), *Problems of Cosmic Physics* (Kiev) **4**, 152.
Marsden, B.G., Aksnes, K. 1967, The Orbit of Periodic Comet Kearns-Kwee (1963 VIII), *Astr. J.* **72**, 952.
Rasmusen, H. 1967, The Definitive Orbit of Comet Olbers for the Periods 1815–1887–1956, *Copenhagen Obs. Publ.*, no. 194.
Schrutka-Rechtenstamm, G. 1968, Definitive Bahnbestimmung des ersten periodischen Tempelschen Kometen, *Ann. Univ. Sternw. Wien* **27**, 188.
Sitarski, G. 1967, The Orbit of the Periodic Comet Harrington 1953 VI, *Acta astr.* **17**, 321.
Sitarski, G. 1968, The Improved Orbit and the Ephemeris of the Periodic Comet Kopff (1906 IV) for its Reappearance in 1970/71, *Acta astr.* **18**, 155.
Sitarski, G. 1968, The Orbits and the Ephemerides of the Periodic Comets Tsuchinshan 1 (1965 I) and Tsuchinshan 2 (1965 II), *Acta astr.* **18**, 163.
Sitarski, G. 1968, The Orbit and the Ephemeris of the Periodic Comet Slaughter-Burnham (1958 VI) for 1969/70, *Acta astr.* **18**, 419.
Sitarski, G. 1968, An Attempt to Link the Appearances of Comet P/Perrine-Mrkos in 1955 and 1961/62. *Acta astr.* **18**, 423.
Sitarski, G. 1968, The Orbit and the Ephemeris of the Periodic Comet Kearns-Kwee (1963 VIII) for its Reappearance in 1972/73, *Acta astr.* **18**, 429.
Sitarski, G. 1969, Ephemeris of Comet Grigg-Skjellerup for its Reappearance in 1971/72, *Acta astr.* **19**, 175.

4. *Orbits of Nearly Parabolic Comets*

Barteneva, O.N. 1969, Definitive Orbit of the Comet Whipple-Fedtke-Tevsadse 1943 I, *Bull. Inst. teor. Astr.* **11**, 585.
Branham, R., Jr. 1968, Orbit of Comet 1961 V (Wilson-Hubbard), *Astr. J.* **73**, 97.
Mamedov, M.A. 1969, Definitive Orbit of the Comet 1957 III Arend-Roland, *Bull, Inst. teor. Astr.* **11**, 598.
Sekanina, Z. 1967, Future Orbits for Ten Comets of the General Catalogue of Original and Future Comet Orbits, *Bull. astr. Inst. Csl.* **18**, 1.
Sekanina, Z. 1967, Definitive Orbit of Comet Pereyra (1963 V), *Bull. astr. Inst. Csl.* **18**, 229.
Yanovitskaya, G. 1968, Definitive Orbit of the Comet 1959 IV Alcock, *Bull. Inst. teor. Astr.* **11**, 544.
Yanovitskaya, G. 1969, Original and Future Orbits of the Comet 1959 IV Alcock, *Bull. Inst. teor. Astr.* **11**, 705.

5. *Theoretical Investigations*

Aver'yanova, T.V., Stanyukovich, K.P. 1967, Application of General-Relativity Methods to the Study of Long-Period Comet Trajectories, *Astr. Zu.* **43**, 1301.

Chebotarev, G. 1966, Cometary Motion in the Outer Solar System, *Astr. Zu.* **43,** 435.
Everhart, E. 1967, Comet Discoveries and Observational Selection, *Astr. J.* **72,** 716.
Everhart, E. 1967, Intrinsic Distributions of Cometary Perihelia and Magnitudes, *Astr. J.* **72**, 1002.
Everhart, E. 1968, Change in Total Energy of Comets Passing Through the Solar System, *Astr. J.* **73,** 1039.
Everhart, E. 1969, Close Encounters of Comets and Planets, *Astr. J.* **74,** 735.
Hamid, S., Marsden, B.G., Whipple, F. 1968, Influence of a Comet Belt beyond Neptune on the Motions of Periodic Comets, *Astr. J.* **73,** 727.
Hamid, S.E. 1969, Influence of a Cometary Belt on Uranus and Neptune, *Smithsonian Astrophys. Obs., Special Report*, no. 299.
Kazimirchak-Polonskaya, H.I. 1967, Evolution of the Short-Period Comet Orbits from 1660 to 2060, and the Role of the Outer Planets, *Astr. Zu.* **44,** 439.
Kazimirchak-Polonskaya, H.I. 1968, Rôle des Planètes Extérieures dans l'Évolution des Orbites des Comètes, *L'Astronomie* **82,** pp. 217–27, 323–39, 432–8.
LePoole, R. S., Katgert, P. 1968, The Major-Axis Distribution of Long-Period Comets, *Observatory* **88,** 164.
Lyttleton, R.A. 1968, On the Distribution of Major-Axes of Long-Period Comets, *Mon. Not. R. astr. Soc.* **139,** 225.
Marsden, B.G. 1967, The Sungrazing Comet Group, *Astr. J.* **72,** 1170.
Marsden, B.G. 1968, Comets and Nongravitational Forces, *Astr. J.* **73,** 367.
Marsden, B.G. 1969, Comets and Nongravitational Forces. II, *Astr. J.* **74,** 720.
Marsden, B.G. 1970, Comets and Nongravitational Forces. III, *Astr. J.* **75,** 75.
Marsden, B.G. 1970, On the Relationship between Comets and Minor Planets, *Astr. J.* **75,** 206.
Pittich, E.M. 1969, The Selection Effects on the Discoveries of New Comets, *Bull. astr. Inst. Csl.* **20,** 85.
Pittich, E.M. 1969, Sudden Changes in the Brightness of Comets Before Their Discovery, *Bull. astr. Inst. Csl.* **20,** 251.
Sekanina, Z. 1967, On the Origin of the Kreutz Family of Sungrazing Comets, *Bull. astr. Inst. Csl.* **18,** 198. Also see: Problems of Origin and Evolution of the Kreutz Family of Sungrazing Comets, *Acta Univ. Carolinae, Math, Phys.*, No. 2, 33 = *Publ. astr. Inst. Charles Univ.*, no. 51.
Sekanina, Z. 1968, Splitting of the Primary Nucleus of Comet Ikeya-Seki, *Problems of Cosmic Physics* (Kiev) **3,** 66.
Sekanina, Z. 1967, Nongravitational Effects in Comet Motions and a Model of an Arbitrarily Rotating Comet Nucleus I. Hypothesis, *Bull. astr. Inst. Csl.* **18,** 15; II. Push-effect, *Bull. astr. Inst. Csl.* **18,** 19; III. Comet Halley, *Bull. astr. Inst. Csl.* **18,** 286; IV. Comet Splits, *Bull. astr. Inst. Csl.* **18,** 296; V. General Rotation of Comet Nuclei, *Bull. astr. Inst. Csl.* **18,** 347; VI. Short-Period Comets. Empirical Data, *Bull. astr. Inst. Csl.* **19,** 47; VII. Short-Period Comets. Analysis, *Bull. astr. Inst. Csl.* **19,** 54. See also Nongravitational Effects in Comet Motions and a Model of an Arbitrarily Rotating Comet Nucleus, *Problems of Cosmic Physics* (Kiev) **3,** 82, 1968.
Sekanina, Z. 1968, Non-Gravitational Forces and Comet Nuclei, *Sky and Telescope* **35,** 282.
Sekanina, Z. 1968, Dynamical Effects of Explosive Phenomena in Comet Halley and its Nuclear Rotation, *Problems of Cosmic Physics* (Kiev) **3,** 75.
Sekanina, Z. 1968, Disruption of Comet P/Biela and Explosive Mechanisms of Cometary Splits, *Bull. astr. Inst. Csl.* **19,** 63.
Sekanina, Z. 1968, Motion, Splitting and Photometry of Comet Wirtanen 1957 VI, *Bull. astr. Inst. Csl.* **19,** 153.
Sekanina, Z. 1968, Dynamics of Comet Alcock 1963 III and its Enhanced Activity, *Bull. astr. Inst. Csl.* **19,** 170.
Sekanina, Z. 1968, Anomalous Comet Burnham 1960 II, *Bull. astr. Inst. Csl.* **19,** 210.
Sekanina, Z. 1968, A Dynamic Investigation of Comet Arend-Roland 1957 III, *Bull. astr. Inst. Csl.* **19,** 343.
Sekanina, Z. 1968, Non-Gravitational Impulses on 20 Short-Period Comets, *Bull. astr. Inst. Csl.* **19,** 351.
Sekanina, Z. 1968, Existence of Meteor Showers Associated with Short-Period Comets Anomalous in Motion, in *Physics and Dynamics of Meteors*, L. Kresák and P. Millman (eds.), D. Reidel Publ. Co., Dordrecht (IAU Symposium No. 33).
Sekanina, Z. 1968, On the Perturbations of Comets by Nearby Stars I. Sphere of Action of the Solar System, *Bull. astr. Inst. Csl.* **19,** 223; II. Encounters of Comets with Fast-Moving Stars, *Bull. astr. Inst. Csl.*, **19,** 291.

Sekanina, Z. 1969, Total Gas Concentration in Atmospheres of the Short-Period Comets and Impulsive Forces Upon Their Nuclei, *Astr. J.* **74,** 944.
Sekanina, Z. 1969, Dynamical and Evolutionary Aspects of Gradual Deactivation and Disintegration of Short-Period Comets, *Astr. J.* **74,** 1223.
Sekanina, Z., Vanysek, V. 1967, Irregularities in the Motion of Comet Halley in 1910 and its Physical Behavior, *Icarus* **7,** 168.
Sitarski, G. 1968, Approaches of the Parabolic Comets to the Outer Planets, *Acta astr.* **18,** 171.
Vsehsvjatskij, S. K. 1968, On the question of existence of Oort's comet cloud, *Problems of Cosmic Physics* (Kiev) **3,** 98.

6. *Computing Techniques*

Benima, B., Cherniack, J.R., Marsden, B.G., Porter, J.G. 1969, The Gauss Method for Solving Kepler's Equation in Nearly Parabolic Orbits, *Publ. astr. Soc. Pacific* **81,** 121.
Illyinsky, I. 1968, The Comparison of Computations of the Comet Orbit by the Gauss' Method and the Method Offered by the Author, *Vestnik Kiev Univ., Ser. Astr.*, No. 10.
Mamedov, M.A. 1966, On the Computation of a Nearly Parabolic Orbit from Three Observations of a Comet, *Bull. Inst. teor. Astr.* **10,** 549.
Sitarski, G. 1968, On the Barycentric Method of Computing the Perturbations, *Acta astr.* **18,** 149.
Sitarski, G. 1968, Digital Computer Solution of the Equation of Position of a Comet on a Keplerian Orbit, *Acta astr.* **18,** 197.