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REPORTS ON ASTRONOMY

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TRANSACTIONS
OF THE
INTERNATIONAL ASTRONOMICAL UNION
VOLUME XVII A - PART 1

REPORTS ON ASTRONOMY

Edited by
G. CONTOPOULOS
General Secretary of the Union



D. REIDEL PUBLISHING COMPANY
DORDRECHT-HOLLAND / BOSTON U.S.A.



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INTRODUCTION

The reports on Astronomy, 1976, have been arranged into three Volumes of moderate size and as much as possible homogeneous contents. The Commission Reports have been divided as follows:

VOL. XVIA-1

See the Contents for this volume, p. VII.

VOL. XVIA-2

Commissions

8	Positional Astronomy
10	Solar Activity
12	Radiation and Structure of the Solar Atmosphere
24	Photographic Astrometry
25	Stellar Photometry and Polarimetry
26	Double Stars
27	Variable Stars
29	Stellar Spectra
30	Radial Velocities
35	Stellar Constitution
36	Theory of Stellar Atmospheres
42	Close Binary Stars
45	Spectral Classifications and Multi-band Colour Indices

VOL. XVIA-3

Commissions

28	Galaxies
33	Structure and Dynamics of the Galactic System
34	Interstellar Matter and Planetary Nebulae
37	Star Clusters and Associations
47	Cosmology
40	Radio Astronomy
44	Astronomical Observations from outside the Terrestrial Atmosphere
48	High Energy Astrophysics

It is hoped that the present system will allow a wider circulation of the separate Volumes to Members of the IAU and other scientists interested in particular topics of astronomical research.

Still it was necessary to adopt the utmost conciseness in the Reports. Otherwise, in view of the considerable increase of the astronomical activity (including the work of physicists, chemists and other non professional astronomers) each of the three volumes could well be more than double its present size.

In view of this restriction the various Presidents of Commissions reacted in different ways. Some have reviewed the recent research in the area of their Commissions, giving only a few general references, others have provided extensive references but little description of the published work. However, in most Commissions' Reports I found a wealth of useful and exciting information that would be valuable for research workers in any field of Astronomy.

I want to thank all Presidents of Commissions and their Colleagues who took part in preparing the various Commissions' Reports.

G. CONTOPOULOS
General Secretary

Athens
January 31, 1976

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4. EPHEMERIDES (EPHÉMÉRIDES)

PRESIDENT: R. L. Duncombe.

VICE-PRESIDENT: V. K. Abalakin.

ORGANIZING COMMITTEE: J. Kovalevsky, T. Lederle, B. Morando, J. D. Mulholland, A. M. Sinzi, G. A. Wilkins.

1. INTRODUCTION

The reports of the directors of the national ephemeris offices appended here review the programs for the production and publication of the navigational almanacs (marine and air), the almanacs for surveyors, as well as the ephemerides and special tables prepared for the use of astronomers and space scientists. Related programs conducted by other organizations and individuals are reviewed at the end of the Appendix. As a consequence of the research carried on by the national ephemeris offices these reports are of interest also to the commissions on positional astronomy and celestial mechanics. The comments following will review the principal work of Commission 4 since the XVth General Assembly and some items to be presented at the XVIth General Assembly.

Before proceeding it is fitting to pay tribute to the memory of Prof. Gerald M. Clemence who passed away 22 November 1974 at the age of sixty-six. During his long association with the International Astronomical Union, he served as member and Chairman of the U.S. National Committee, and as President of Commissions 4 and 7. Among subjects in our field, he made important contributions to our knowledge of the motions of the principal planets and the system of astronomical constants.

2. COMMISSION 4 WORKING GROUPS

As a result of discussions at IAU Colloquium No. 9, (Heidelberg 1970) and in agreement with the recommendations of Commission 4, the XIVth General Assembly established working groups to study the subjects — precessional constants, units and time scales, and planetary ephemerides. The Chairmen of these working groups are W. Fricke, G. Wilkins, and R. Duncombe. In 1975 P. K. Seidelmann became Chairman of the Planetary Ephemerides Working Group. Following preliminary exchanges of ideas among members of the working groups and various consultants, a symposium on Precessional Constants, Units and Time Scales, and Planetary Ephemerides was held during the XVth General Assembly at Sydney. The ideas presented there were further refined at a meeting in October 1974 held at the U.S. Naval Observatory, Washington, D.C. Comprising approximately twenty-five invited participants, this meeting formulated preliminary reports which were then circulated widely to interested astronomers. The comments and suggestions received were carefully considered in a final revision of the working group reports during a meeting of the three Chairmen at the Royal Greenwich Observatory, Hailsham, England, in October 1975. The final recommendations of the working groups will be made available to all IAU Members prior to the XVIth General Assembly and will be discussed at a Joint Meeting of Commissions 4, 8 and 31.

3. INTERNATIONAL INFORMATION BUREAU ON ASTRONOMICAL EPHEMERIDES

The following information has been provided by the Director, B. Morando:

"The International Information Bureau on Astronomical Ephemerides established by IAU in 1970 and located at Bureau des Longitudes in Paris has completed the following business since the last General Assembly in 1973.

Information cards nos. 73 to 77 have been published in December 1973; cards nos. 78 to 93 in April 1974; cards nos. 94 to 102 in August 1974; cards nos. 103 to 111 in March 1975. Other cards are being printed (September 1975).

The Scientific Advisory Council met at Sydney in 1973, and in Washington in 1974."

4. FUNDAMENTAL EPHEMERIDES

Following discussions by representatives of H. M. Nautical Almanac Office, the Astronomisches Rechen-Institut, the Bureau des Longitudes and the American Nautical Almanac Office held in Washington in October 1974, plans were drawn up for a revision of form and content of the Astronomical Ephemeris and the American Ephemeris (both henceforth referred to as the A.E.). Involved also in these plans are new methods for the distribution of advanced data and a possible re-distribution of the basic computations for the AE among the cooperating national ephemeris offices. These plans to further improve the efficiency of production and distribution of fundamental ephemerides will be discussed at meetings of Commission 4 at Grenoble.

R. L. DUNCOMBE
President of the Commission

APPENDIX: REPORTS OF THE DIRECTORS OF THE NATIONAL EPHEMERIDES

*H.M. Nautical Almanac Office, Royal Greenwich Observatory,
Herstmonceux, England*

Unified publications. The Nautical Almanac Offices of the U.S. Naval Observatory and of the Royal Greenwich Observatory have continued to produce jointly without substantial change of content or arrangement the three unified publications: *The Astronomical Ephemeris*, *The American Ephemeris*, which is primarily intended for use by astronomers; *The Nautical Almanac*, for astronavigation at sea; and *The Air Almanac*, for astronavigation in the air. These almanacs are printed separately in the two countries from identical reproducible material; this material can be made available by Her Majesty's Stationery Office, at a small charge, to the official almanac-producing agency in any country that desires to publish similar ephemerides in this form. Proof editions of the first part of the *Astronomical Ephemeris* for 1977-79 have been distributed on a limited basis.

As from the editions for the year 1977 the *Air Almanac* will be published in two, instead of three, volumes for each year. There will be no change in the main tabulations, but some minor changes in the arrangement of the auxiliary data are being made.

Good progress has been made in the planning of a revision of content and arrangement of the volumes for the astronomical ephemerides for the year 1981 and onwards. The revised volume will contain a wider range of data and it is hoped that it will be more convenient in use. Further details of the proposals for the contents and for new publication arrangements will be available for discussion at the meetings of the Commission at Grenoble. It is intended that the volumes of *Astronomical Phenomena* and *Planetary Coordinates* shall also be prepared jointly and published well in advance so that the special distribution of advanced proofs will not be necessary.

It is understood that as from the year 1981 the volume *Connaissance des Temps* will change its character and contain special ephemerides that are complementary to those in *The Astronomical Ephemeris*, thus extending still further the sharing of the work and costs of the publication of astronomical ephemerides for international use. The volume *Apparent Places of Fundamental Stars*, prepared by the Astronomisches Rechen-Institut in Heidelberg and *Ephemerides*

of *Minor Planets* prepared by the Institute of Theoretical Astronomy in Leningrad, have for many years been published in one country only for general use.

Other publications. Apart from the unified almanacs referred to above, the Office has continued to publish *The Star Almanac for Land Surveyors*, and to distribute special tabulations of local astronomical data to observatories throughout the world.

The publication of an amended edition of the *Explanatory Supplement to the Astronomical Ephemeris* has unfortunately been very much delayed by industrial disputes and other difficulties, but took place in 1975 November. The new edition includes a reprint of the *Supplement to AE 1968* concerning the introduction of the IAU system of astronomical constants and draws attention to changes in the ephemerides and procedures that have been made since 1960.

Occultation programme. The regular distribution of the predictions of occultations of stars by the Moon has been continued in collaboration with the Nautical Almanac Office of U.S. Naval Observatory. Special predictions have been issued for lunar occultations of radio, X-ray and γ -ray sources as and when required. The Office has received and processed about 7 000 timings of occultations each year during the period. Magnetic tapes containing about 60 000 observations made in the period 1943–1971, and the approximate coordinates of the stations, are now available; it is hoped that the data will also be published in printed form. The timings of grazing occultations have also been processed systematically and the results are being prepared for publication.

Published observations of occultations for the period 1860–1942 are being collected in a joint project with U.S. Naval Observatory for use in a comprehensive analysis for the determination of the variations of the rotation of the Earth and the secular changes in the elements of the Moon's orbit.

The search for, and detailed prediction of, occultations of stars by major and minor planets and by satellites has been continued. Special ephemerides of minor planets whose diameters are believed to exceed 100 km have been provided by the Institute of Theoretical Astronomy, Leningrad, and the Minor Planets Center, Cincinnati.

Motions of Mercury and of the Moon. A new analysis of some 2400 individual observations of 33 transits of Mercury made during the period 1677 to 1973 has been completed (L. V. Morrison and C. G. Ward, *Monthly Notices Roy. Astron. Soc.* **173**, 183, 1975). The differences (ΔT) between the ephemeris and universal timescales and corrections to the values of Mercury's orbital elements in Newcomb's theory have been determined. The long-term behaviour of the values of ΔT agree best with those deduced from lunar occultations when a value of $-13'' \pm 1'' T^2$ is adopted for the tidal term in the lunar mean longitude. This is in good agreement with the currently-adopted value of $-11'' \cdot 22 T^2$. The non-Newtonian component of the motion of Mercury's perihelion is found to be $+41'' \cdot 9 \pm 0'' \cdot 5 T$: Einstein's general theory of relativity predicts a value of $+43'' \cdot 0 T$.

G. A. WILKINS

Astronomisches Rechen-Institut, Heidelberg, Germany

The computation and publication of *Apparent Places of Fundamental Stars* (APFS, in annual volumes) has been continued. In addition, the apparent places of FK4 Sup stars have been computed and distributed in listed form to users on request. Preparations are being made to make the APFS and the apparent places of FK4 Sup stars available on magnetic tape from 1980 besides the published volumes of APFS.

In accordance with a resolution adopted by the IAU in 1973 work has been carried out on the improvement of FK4 and its extension, in particular, to a fainter magnitude limit. Numerous catalogues of observations which have become available after the completion of FK4 have been examined and key-punched for use in the determination of individual and systematic corrections to FK4. Other catalogues containing relevant observations for the extension of FK4 to a fainter magnitude limit have also been examined and key-punched. The documentation of data on punched cards has been under the supervision of Lederle; the U.S. Naval Observatory,

and the Centre de Données Stellaires at Strasbourg have contributed efficiently to this task. Dr Billaud, Grasse (France), has kindly taken over the task of exploiting all available Astrolabe observations for FK5. Fricke and Lederle have contributed to the preparation of a revision of the IAU System of Astronomical Constants.

W. FRICKE, T. LEDERLE

Hydrographic Department, Tokyo, Japan

The *Japanese Ephemeris*, the *Nautical Almanac*, the *Abridged Nautical Almanac*, and the *Polaris Almanac for Azimuth Surveying* have continued to be published for the years 1974, 1975 and 1976 without substantial changes, respectively. The first part of the Japanese Ephemeris has been reproduced from the advanced data of the Astronomical Ephemeris provided by the H.M. Nautical Almanac Office. The *Altitude and Azimuth Almanac for Antarctic Observations* and the *Abstract from the Japanese Ephemeris* have been compiled annually at the request of the National Defense Agency.

Reconstructions of the fundamental ephemerides given in the AE are in progress using newly installed computer.

Prediction of occultations of the planets and four principal minor planets by the moon has continued to be made. Maps of all of these events are to be given in the Japanese Ephemeris in the volume after 1977. Detailed data have been sent to individual astronomers at their request.

Occultation observations are made as routine and the number of data acquisition has increased over 800 data including 300 photo-electric ones, annually. For reduction analysis of occultation data, a composite catalogue of 25 233 stars in the FK4 system was compiled from the FK4, FK4 Sup. NZC, AGK3 and SAO catalogues. Provisional results of reduction analysis have been published annually in the *Data Report of Hydrographic Observations, Series of Astronomy and Geodesy* (Mori *et al.* 1973, 1974, 1975). The value of ΔT for use in prediction of eclipses and compilations of the almanacs and the national calendar, (the latter is published by the Tokyo Astronomical Observatory) has been settled by arrangement with the TAO from the above results of occultation data, taking the tendency of TAI-UT into account.

Contact time observation was made cinematographically at the solar eclipse in 1973, 30 June, in Mauritania, taking the flash spectra at its total phase, similarly to that made for the 1970 eclipse in Mexico. Reduction analysis (Mori and Ganeko, in press) of the data for both eclipses has yielded the following (O-C)'s for the relative position of the Moon to the Sun:

$$\begin{array}{lcl} & & [(m.e.)] \\ (L_{\ell} - L_{\odot}) & = & - 0''.17 \pm 0''.03, \text{ for the 1970 eclipse,} \\ (B_{\ell} - B_{\odot}) & = & + 0.21 \quad 0.06, \\ (L_{\ell} - L_{\odot}) & = & + 0.40 \pm 0.02, \text{ for the 1973 eclipse,} \\ (B_{\ell} - B_{\odot}) & = & + 0.42 \quad 0.10, \end{array}$$

employing the Sun's ephemeris in the 1964 IAU system, the Moon's ephemeris in $j = 2$ and $ET - TAI = 32^s.0$.

A. M. SINZI

Bureau des Longitudes, Paris, France

Le Bureau des Longitudes a continué à publier la *Connaissance des Temps* et les *Ephémérides Nautiques* et à contrôler la publication par la Société SONOVISION des *Ephémérides Aéronautiques*. Le Bureau des Longitudes donne par ailleurs, sous forme de listages ou de cartes, les coordonnées des satellites galiléens de Jupiter à un instant quelconque.

La réforme de la *Connaissance des Temps* pour les années qui suivront 1980 est à l'étude, compte tenu du coût élevé de la publication actuelle et du fait qu'elle ne correspond plus tout à

fait aux besoins des utilisateurs. Il est à souhaiter que l'avenir des éphémérides astronomiques soit le fait d'une collaboration internationale étroite.

B. MORANDO

Instituto y Observatorio de Marina, San Fernando (Cadiz), Spain

The Ephemeris Office continued the publications *Almanaque Nautico* and *Efemerides Astronomicas* as usual.

From 1972 on, the *Almanaque Aeronautico* is a copy of the British *Air Almanac*.

Computations for *Almanaque Nautico* were performed from 1974 by a H.P. 2100S computer.

M. RODRIGUEZ

*Nautical Almanac Unit, Regional Meteorological Centre,
India Meteorological Department, Calcutta, India*

During the period under review, three issues of the *Indian Ephemeris and Nautical Almanac* for the years 1974, 1975 and 1976 were published.

Calculations of geocentric longitude and latitude of planets, longitude and latitude of certain important stars, moonrise-moonset times for the Central meridian and also for certain stations in India, apparent position of Pluto from its astrometric position, elements of occultations of bright stars and planets by the Moon with special reference to their visibility in India, and ending moments of *tithis*, *nakshatras* and *yogas* etc. have been done on IMB-360/44 computer commencing from the issue for 1976 of the *Indian Ephemeris and Nautical Almanac*.

In addition the following two other publications have been issued annually for meeting public demand of certain additional astronomical information:

(i) Tables of Sunrise, Sunset and Moonrise, Moonset.

(ii) *Rashtriya Panchang* in English and eleven other Indian languages giving details of astronomical data required for the Indian Calendar.

A. BANDYOPADHYAY

*Nautical Almanac Office, U.S. Naval Observatory
Washington, D.C., U.S.A.*

The American Ephemeris and Nautical Almanac, *The Nautical Almanac*, *The Air Almanac*, and *The Astronomical Phenomena* have continued to be published in accordance with the international agreements on these publications. Beginning with 1977 editions, *The Air Almanac* will be published semiannually, instead of the present three times per year. Development of automatic typesetting techniques has continued (Janiczek, P. M. and Kaplan, G. H., *U.S. Naval Obs. Circ. No. 149*, 1974).

The advance predictions of solar eclipses 1981–1990 have been published (*U.S. Naval Obs. Circ. No. 142*). Circumstances of solar eclipses with argument in UT have also been prepared (*U.S. Naval Obs. Circ. No. 144*, 153). A special circular of Lunar Limb Profiles for Solar eclipses has been published (*U.S. Naval Obs. Circ. No. 141*).

A special ephemeris of Mars based on the theory by G. M. Clemence and constants determined by R. Laubscher has been prepared for the years 1960–1980 (*U.S. Naval Obs. Circ. No. 151*). Normalized observations of Mercury 1901–1937 were published (*U.S. Naval Obs. Circ. No. 145*). Additional astronomical information has been prepared and published in U.S. Naval Observatory Circulars to meet public demand; Sunlight, Moonlight and Twilight for Antarctica 1975–1977 (No. 147) and Physical Ephemeris of Mars (No. 148). A new catalog of astronomical data in machine readable form has been published (*U.S. Naval Obs. Circ. No. 146*, 1974).

I. Lunar Research

T. C. Van Flandern is reducing and analyzing occultation observations and the new derived values for the secular acceleration of the Moon may indicate a secular decrease in the gravitational constant (*Monthly Notices Roy. Astron. Soc.* 170, 33, 1975) and (*Annals N.Y. Acad. Sci.*, 1975).

In cooperation with H.M. Nautical Almanac Office, ET-UT is being redetermined for the period 1627-1955 from lunar occultation observations.

T. C. Van Flandern, and K. F. Pulkkinen have transformed the analytical lunar theory into analytical expressions for the Moon's osculating elements by means of a computerized algebraic manipulator.

T. C. Van Flandern, G. H. Kaplan and K. F. Pulkkinen are investigating high precision integration techniques suitable for a numerical integration of the Moon extending over several centuries.

II. Planetary Research

P. K. Seidelmann is working with L. Carpenter of Goddard Space Flight Center to prepare programs and to calculate general theories for the inner planets using Musen's method.

R. L. Duncombe, P. K. Seidelmann, P. M. Janiczek and W. J. Klepczynski have continued the analysis of observational determinations of the masses of the principal planets (*Ann. Rev. Astron. Astrophys.* 11, 135, 1973), (*Fundam. Cosm. Phys.* 1, 119, 1974), (*IAU Highlights of Astron.* Vol. 3, p. 170, Reidel 1973). A discussion of celestial reference systems derivable from solar system dynamics appears in *Proc. IAU Coll.* 26, Toruń 1975).

A. D. Fiala, and D. Pascu are analyzing photographic observations of the Nov. 1973 transit of Mercury to obtain an accurate time of least separation of centers.

L. E. Doggett is applying Chebyshev polynomials to the problem of planetary theories to determine polynomial representations of the planetary motions to different accuracies.

III. Satellite Research

Using filtering techniques in order to obtain proper relative exposure of the primary, satellites and field stars, D. Pascu and A. D. Fiala have obtained photographic observations of the Martian satellites, Galilean satellites and seven brightest satellites of Saturn (*Astron. J.* 78, 794, 1973). The Martian satellite observations have been analyzed by Pascu for orbital corrections and the Galilean satellite observations have been analyzed by J. E. Arlot and S. Ferraz Mello for orbital corrections.

P. K. SEIDELMANN

*Ephemeris Department of the Institute for Theoretical Astronomy
of the U.S.S.R. Academy of Sciences*

During the period under review three volumes of the *Astronomičeskij Ežegodnik SSSR* (*The Astronomical Year-Book of the U.S.S.R.*) for the years 1976, 1977, 1978 have been published, the volume for 1979 being in press. The positions and proper motions of the stars are given as usual in the FK4 system in conformity with the decision of Commission 4 (Ephemerides) at the Eleventh IAU General Assembly (Berkeley 1961).

As recommended by Commission 4 at its meeting in Hamburg on 28th of August, 1964 (*IAU Trans.* 12B, 105, 1966) the new IAU System of Astronomical Constants 1964 was introduced into tabulations of the Day Numbers, solar and lunar eclipses data, ephemerides for astrophysical observations of the Sun, Moon, and planets, the table of factors C and S.

In accordance with the recommendations of, and specification by, Commission 4 adopted at the Thirteenth IAU General Assembly (Prague 1967) the Lunar ephemeris with the nomenclature index $j = 2$ is published.

The regular publication of the ephemerides of the Lunar crater Mösting A. has been continued in the volumes of the *Astronomical Year-Book of the U.S.S.R.* mentioned above.

Fundamental ephemerides of the Sun, Moon, and planets have been printed in full conformity with the First Part of the *Astronomical Ephemeris* circulated in advance by H.M. Nautical Almanac Office, Royal Greenwich Observatory.

The Appendices to the volumes of the *Astronomical Year-Book of the U.S.S.R.* for 1978 and 1979 have been published containing the ephemerides of the four ancient (Galilean) satellites of Jupiter for 1977 and 1978 as computed in, and received from, the Bureau des Longitudes, Paris, France.

The navigational almanacs have regularly been produced as before. The *Nautical Almanac* has been issued for the years 1975–1977, and the *Air Almanac* for 1974–1976.

As before, the photostates of predicted Lunar occultations data listings, both for stars (planets) and radio sources for 1975–1977, calculated in, and obtained from, H.M. Nautical Almanac Office, were distributed among the Soviet observatories.

A series of papers on various topics of Celestial Mechanics and computational procedures were published in the publications of this Institute and elsewhere.

V. K. ABALAKIN

Brief Reports and Notes

A. M. Sinzi and S. Aoki in a report from Japanese Institutes report the following:

“The Hydrographic Department (K. Inoue) and the Tokyo Astronomical Observatory (S. Aoki) are jointly reconstructing the EWE Lunar Tables based on a private communication from USNO (Duncombe). They are now just reproducing almost the same results with the data given in the *Astronomical Ephemeris* 1973 onwards.

Kinoshita (H.) *et al.* (*Ann. Tokyo Astron. Obs.* 14, 1, 1974) published a direct comparison of Newcomb's Tables of the Sun with the trigonometric series given by Newcomb. Besides the inconsistency in the action by Venus, they found some errors amounting $\pm 0''.04$ in action by Jupiter, etc. Kinoshita (*Smithsonian Special Report* No. 364, 1975) recalculated Newcomb's Precession Formulas with new astronomical constants. He also is preparing a new theory of the rigid Earth, using Andoyer's variables (to be submitted to *Celes. Mech.*). Among others he found that the secular term in the obliquity given by Woolard, ($-0''.056/\text{cent.}$) is in error.

A. Deprit reports a general algorithm has been proposed to find the best approximation of an astronomical ephemeris to an assigned accuracy in terms of Chebyshev polynomials. It has been applied to the corrections due to the nutation, to the inner planets and to the Galilean satellites of Jupiter. (*Compt. Rend. Acad. Sci. Paris*, 278, 1055, 1974) and (*Mechanics Res. Commun.* 1, 209, 1974).

The Jet Propulsion Laboratory, Pasadena, California, U.S.A., is continuing its efforts in the development of planetary, lunar and satellite ephemerides. The currently available JPL lunar and planetary ephemerides will shortly be replaced by a new set based on analyses of planetary meridian circle and radar data, lunar laser and optical observations; as well as radio tracking data from Mariner 9 and Pioneers 10 and 11. New FORTRAN computer programs are available for calculating the positions and partial derivatives of Jupiter's Galilean satellites.

J. D. Mulholland, reporting on lunar ephemeris development at the University of Texas at Austin, states that a combined analysis of lunar laser delays and photoelectric occultation observations has been undertaken as a means of tying the laser-based numerical lunar ephemeris to the FK4 system. Another possible result of the investigation will be a determination of the location in three dimensions of the center of the Watts datum relative to the mass center of the Moon.

R. L. DUNCOMBE
President of the Commission

7. CELESTIAL MECHANICS (MÉCANIQUE CÉLESTE)

PRESIDENT: P. J. Message.

VICE-PRESIDENT: V. Szebehely.

ORGANISING COMMITTEE: E. P. Aksenov, V. A. Brumberg, M. S. Davis, A. Deprit, G. N. Duboshin, G. E. O. Giacaglia, G. Hori, Y. Kozai, B. Morando, L. Schnal.

This report is written both to indicate the topics within the main field of Celestial Mechanics on which research has been carried out in the last three years, as well as to assist the enquirer who seeks the published work on a particular topic. To approach both of these objectives within the requirement of brevity, it has seemed best to collect together, according to topic, most (though inevitably, alas, not all) of the work in the Commission's field published in the period 1973 to 1975. I am very grateful to Dr V. K. Abalakin for a most helpful review of research in the U.S.S.R., and to all colleagues who sent me details of their work. Each paper is indicated, where possible, by a reference in the form (v.s.a.), where a mention of the paper (with a full reference to the original journal of publication) is numbered 'a', in section 's', of volume 'v' of *Astronomy and Astrophysics Abstracts*. Where no such mention has appeared at the time of writing, the reference given is to the journal of publication, followed by the volume number, the page reference, and the year of publication. The following abbreviations are used, as well as the standard ones:

AA =	Astron. Astrophys.	CM =	Celes. Mech.
AJ =	Astron. J.	CR =	Compt. Rend. Acad. Sci. Paris
AN =	Astron. Nachr.	MN =	Monthly Notices Roy. Astron. Soc.
AZ =	Astron. Zh. (Akad. Nauk SSSR)	TKAO =	Trudy Kazan Gorod Astron. Obs.
BITA =	Bjull. Inst. Teor. Astron.		

Beginning with general analytical theory in celestial mechanics, there has been much fruitful work on transformations of the Lie series and Von Zeipel types, their extensions, and equivalences between the various formulations, including that of J. S. Choi and B. Tapley (09.042.003), J. S. Griffith (09.042.038), Y. Thiry (*Comm. 92e Congrès de l'Assoc. pour l'Avancement des Sci.*, 1973), U. Kirchgraber (09.042.044 and 10.042.094), the latter with M. Vitins (CM 12, 139, 1975), L. M. Berkovitch and B. E. Gel'fat (09.042.048), R. Cid and M. Calvo (10.042.001), the latter with J. M. Correas (CM 12, 131, 1975), J. Henrard (10.042.081), the latter with J. Roels (12.042.077), M. Rapaport (11.042.016), K.R. Meyer (11.042.064), N. Watanabe (12.042.013), J. Moser (12.042.028), K. V. Kholoshevnikov (12.042.065), and J. Meffroy (CR 280 A, 21, 1975). Much of this work has also been concerned with the stability of particular solutions in Hamiltonian systems, as has that of J. Hadjidemetriou (10.042.095), N. Burgoyne and R. Cushman (11.042.008), R. McGehee (11.042.049), M.A. Vashkov'yak (12.042.069), F. I. Kiselov (12.042.080), and G. Merman (BITA 14, 37, 1975). Also on this topic, with especial reference to resonance with the variational frequencies, and periodic solutions associated with them, is the work of K. T. Alfrend and D. L. Richardson (09.042.040), D. S. Schmidt (11.042.013), the latter with D. Sweet (*J. Diff. Equations* 14, 597, 1973), and G. I. Shirmin (12.042.016). Further advances in the ideal resonance problem and its extensions have been made by B. Garfinkel (09.042.009, 10.042.021, CM 12, 208, 1975), the latter with C.A. Williams (11.042.014), and by A. H. Jupp (09.042.004, with errata in .901, 09.042.019, 10.042.022, 11.042.011, 12.042.039). The latter writer has applied his solution to the free rotation of a rigid body (11.042.012). L. Losco (10.042.010 and 12.042.041) has studied an integral invariant deriving from Poincaré and Cartan. G. Aymerich (09.062.035) studied integral invariants, and F. Nahon (10.021.014) particular solutions of Levi-Civita. C. Froeschlé

(10.042.030), and the latter with J.P. Scheidecker (12.151.017), and F. Rannou (11.042.021) have made numerical studies of mappings and dynamical systems, in the study of the phenomenon of 'wildness'. Further developments in the study of the regularisation of the Kepler problem, and applications to perturbation theory, are due to P. E. Kustaanheimo (11.052.028, 12.042.055, *Phys. Fennica* 8, 7, 1973, *Soc. Sci. Fennica Comm. Phys. Math.* 44, 1, 1974, *CR* 279 A, 675, 1974, and *AN* 296, 163, 1975), E. Stiefel (10.042.065), U. Kirchgraber (10.042.026), O. Volk (10.042.032), F. A. E. Pirani (11.042.085), V. R. Bond (12.042.058), and R. Broucke and H. Lass (*CM* 12, 317, 1975). Regularisation of the two-body problem with variable masses was studied by P. Guillaume (12.042.015), and J. P. Vinti (12.042.062) has given a solution of the two-body problem with 'G' varying inversely to a linear function of time. Integrable cases of the three-body problem with variable masses have been given by B. E. Gel'fat (12.042.083), and the perturbed Kepler problem with variable masses has been studied by T. B. Omarov (10.042.040) and F. Verhulst (*CM* 11, 95, 1975). J. P. Vinti (10.042.025) has given a quadrature solution for general relativistic motion, and the relation between time scales has been studied by V. S. Nuovio (12.006.060) and J. B. Thomas (*AJ* 80, 405, 1975). New forms of the Gaussian perturbation equations have been given by J. P. Vinti (09.042.020) to non-Keplerian reference orbits, by S. N. Yashkin (11.042.071), M. Silver (*CM* 11, 39, 1975), and R. Sridharan and M. L. Renard (*CM* 11, 179, 1975), and by G. H. Born, E. J. Christensen and L. K. Seversike (11.052.003), using a new form of universal variable. Trajectory deviations and optimal orbits have been studied by E. L. Liiola (11.042.060) and D. J. Jezewski (*CM* 12, 297, 1975).

Turning to work relating to the analytical development of perturbation theories, methods of expansion of co-ordinates and velocity components have been studied by E. Fichera (11.042.063), K. Ahmad (11.042.072), R. Broucke (12.042.075), the latter with P. Cefola (09.042.022), and, for hyperbolic motion, by A. Kahkorov (12.042.085). New work on the expansion of the disturbing function has been done by C. A. Altavista (09.042.025), E. I. Timoshkova (09.042.030), H. Kinoshita, G. Hori and H. Nakai (11.042.053), V. B. Titov (11.042.069), N. Abu-el Ata and J. Chapront (*AA* 38, 57, 1975), E. Z. Khotimskaya (*BITA* 14, 47, 1975), and, using ellipsoidal co-ordinates, E. J. Burstein (*CM* 11, 255, 1975). The calculation of high-order perturbations is the subject of studies by Yu. V. Plakhov (09.042.014, and .036, 11.042.044, and .075). Questions arising in the determination of orbits underly the work of E. E. Burniston and C. E. Siewert (09.042.010 and 12.042.004), K. V. Kholishevnikov (09.042.056), and C. Simo (12.042.073). Methods for computer handling of multiple Fourier series, including algebraic manipulation, have been developed by J. R. Cherninck (09.042.005), J. Chapront, M. Chapront, and J. L. Simon (11.042.020), S. G. Kapralov (11.042.076), R. J. Fateman (12.042.021), A. L. Kutuzov (12.042.086), L. A. Moskovkina (12.042.087), V. A. Brumberg and L. A. Isakovich (12.042.051, and *Algorithms of Celestial Mechanics, Inst. Teor. Astron., Leningrad*, No. 4, 75), and P. J. Shelus and W. H. Jefferys (*CM* 11, 75, 1975). Increased efficiency in the storage of ephemerides is achieved in a method employing Chebyshev polynomials, devised by A. Deprit, W. Poplarchek, and A. Deprit-Bartholomé (*CM* 11, 53, 1975). J. D. Mulholland (09.042.021) has studied the avoidance of badly-determined equations in differential correction.

Considering methods of numerical integration, of especial utility in celestial mechanics, D. G. Bettis (10.021.003), and E. Everhart (12.042.006) have studied developments of the Runge-Kutta type, while A. E. Roy, W. Black and P. E. Moran (09.042.006 and .011, 10.042.059 and .061) have developed a Taylor series method based on recurrence relations for the n -body problem, and O. Graf (11.042.036) has studied multi-revolution methods. V. F. Lager and A. T. Onishchenko (12.042.070) have given two multi-step analytical methods. Refinement of conventional methods has been undertaken by M. S. Yarov-Yarovoy (*Trudy Sternberg Astron. Inst.* 45, 179, 1974), J. Baumgarte (10.042.024), and the latter with E. Stiefel (11.042.034 and 12.042.007), N. Sigrist (*Z. Angew. Math. Phys.*, 1974), C. E. Velez (12.042.074), and K. Zare and V. Szebehely (*CM* 11, 469, 1975) have studied methods of stabilisation by means of transformation of the equations of motion.

Reviews of recent work on planetary and satellite motion have been made by G. A. Wilkins and A. T. Sinclair (11.091.028), by V. A. Brumberg and G. A. Krasinsky (*Usp. Fiz. Nauk* 114,

377, 1974), and by J. M. A. Danby (11.042.037). Quasi-periodic motions for the major planets of the solar system have been computed by V. A. Brumberg, L. S. Evolokunova and V. I. Skripnichenko (*CM* 11, 131, 1975 and *AZ* 52, 420, 1975), and the resonances between three or more mean motions, of zero order in the eccentricities and inclinations, identified. J. Meffroy and O. S. M. Kamel (12.042.014 and .054) have worked to second order in the eccentricities and inclinations, using Poincaré's variables and Von Zeipel's method, examining the critical terms arising from the near-commensurabilities of orbital period between Jupiter and Saturn, and between Uranus and Neptune. P. Bretagnon (11.042.001) has worked to fourth order in the eccentricities and inclinations. A new set of variables for the calculation of secular perturbations in the case of close commensurability has been given by N. I. Lobkova and M. S. Petrovskaya (12.042.037). C. J. Cohen, E. C. Hubbard and C. Oesterwinter (09.091.060 and 11.042.066), using results of their numerical integrations, have given the variations of the orbital elements of the major planets over a period of ten million years. J. Birn (09.091.017), using numerical integration experiments with fictitious planetary systems in which the planetary masses are augmented to increase the impact of the perturbations, finds zones both of stability and instability in the ratios of the major semi-axes. Note that, however, in the formal asymptotic series for the planetary elements, the expressions for the major semi-axes differ from constants only by periodic terms, to all orders in the perturbations, when periods up to those arising in the classical secular variation theory are taken into account (see P. J. Message, *Proc. Adv. Study Inst. on Long Term Prediction in Dynamics*, Cortina, 1975). V. A. Brumberg (12.042.036), J. Chapront (*CM* 11, 379, 1975), and T. V. Ivanova (*AZ* 52, 839, 1975) have developed iterative methods for the construction of general planetary theories. V. A. Brumberg and J. Chapront (10.042.058) have constructed a general theory to first order, identifying the resonant terms. J. L. Simon and J. Chapront (11.042.042) have derived second-order perturbations for Jupiter and Saturn, and carried out comparison with Leverrier. J. L. Simon and P. Bretagnon (*AA* 42, 259, 1975) have constructed first-order perturbations for the four great planets, using Poincaré variables. J. Meffroy (10.042.089) has used the Lie series method to develop the short-period terms to second order, using Henrard's variables, related to those of Poincaré. P. E. Nacozy and R. E. Diehl (11.101.001) have investigated the libration phenomena underlying the long-period perturbations of Pluto by Neptune, concluding that Pluto's apse regresses on average relative to Neptune's. A review of values for the masses of the planets and natural satellites has been made by R. L. Duncombe, W. J. Klepczynski and P. E. Seidelmann (*Fundam. Cosmic Phys.* 1, 119, 1973), and a set of mean elements is given by P. K. Seidelmann, L. E. Doggett, and M. R. de Luccia (11.042.022). Elements of Mars' orbit have been given by N. I. Glebova (*BITA* 3,612, 1975). Mass and position limits for a possible tenth major planet have been given by D. Rawlins and M. Hammerton (09.101.016).

Developments in analytical lunar theory have been made by A. Bec, J. Kovalevsky and C. Meyer (10.094.103), M. Chapront-Tourie (12.042.063), G. F. Osipov (09.094.116), and a suggestion for the use of the Saros has been made by A. E. Roy (09.094.042). Corrections to the constants of the orbit and limb charts have been derived from Washington observations from 1925 to 1968 by L. N. Kizyun (09.094.919). G. I. Eroshkin (12.094.005) has studied the effect of the Moon's figure on its motion, through the resonance between its rotational and orbital periods. L. I. Rumyantseva (12.094.001) has carried out numerical integration in lunar theory, improving the orbital data. The theory of the physical libration has been studied by K. S. Shakirov (11.094.007, and *Astron. Circ.* 853, 5, 1975) and an extended analytical theory is being developed by A. H. Cook. Our knowledge of the Moon's motion and physical libration are being very greatly increased by the impact of laser ranging data; we note the work of V. A. Abalakin, O. Calame, Yu. L. Kokurin, J. D. Mulholland, A. Orszay, and E. C. Silverberg (09.094.166), P. L. Bender, D. G. Currie, R. H. Dicke, D. H. Eckhardt, J. E. Faller, W. M. Kaula, J. D. Mulholland, H. H. Plotkin, S. K. Poultney, E. C. Silverberg, D. T. Wilkinson and C. O. Alley (10.094.074), W. M. Kaula and P. A. Baxa (10.094.085), J. G. Williams, M. A. Slade, D. H. Eckhardt and W. M. Kaula (10.094.107), J. D. Mulholland and P. J. Shelus (10.094.111), R. I. Abbott, P. J. Shelus, J. D. Mulholland, and E. C. Silverberg (10.094.101), the last three authors (*AJ* 80, 154, 1975), and V. K. Abalakin, N. N. Boyko, Yu. L. Kukurin and V. F. Lobanov (*AZ* 52, 387, 1975). The lunar acceleration, secular changes in the Earth's rotation, and