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ORBIT IMPROVEMENT OF THE SATELLITES OF THE OUTER PLANETS

NASA Grant NGR 09-015-213

Final Report

For the period 1 November 1973 to 30 April 1981

Principal Investigators
Dr. Kaare Aksnes
Dr. Fred Franklin

November 1981

Prepared for
National Aeronautics and Space Administration
Washington, D. C. 20546

Smithsonian Institution
Astrophysical Observatory
Cambridge, Massachusetts 02138

The Smithsonian Astrophysical Observatory and the Harvard College Observatory are members of the Center for Astrophysics

The NASA Technical Officer for this grant is Dr. William E. Brunk, Code SL, Planetary Programs, NASA Headquarters, Washington, D. C. 20546.

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Final Report

1. Description of Research

We shall here only highlight the scientific results obtained, most of which are detailed in the publications listed in Section 3 and in the 11 progress reports issued earlier under this grant.

1.1 Astrometric Observations

Of the total 127 plates taken at Harvard's Agassiz Station of Jupiter's and Saturn's satellites in the interval 1972-74, around 100 plates have been reduced. The satellite positions have not been published but they are available on computer cards in the form of (O-C) residuals referred to Sampson's and Struve's satellite theories (see Progress Reports Nos. 1-4).

1.2 Orbital Computations

The initial orbit calculations and several later orbit improvements for Jupiter XIII (Leda), discovered in 1974, were performed under this grant. This work culminated in an extended ephemeris for Leda to the year 2000.

Orbit calculations were also performed for several other suspected satellites, in support of satellite searches conducted by C. Kowal with the 122 cm Schmidt reflector at Palomar Mountain.

We also undertook a critical analysis of the observations that W. H. Pickering, A. Dollfus, J. W. Fountain, and S. M. Larson

had presented in evidence of a 10-th and 11-th satellite of Saturn. Because of severe orbital ambiguities, we predicted the possible existence of several small satellites just outside Saturn's rings and recommended a temporary satellite nomenclature that has since found many applications in new satellites of several of the outer planets.

1.3 Revision of De Sitter's Theory

During a 6-month visit to Tokyo Astronomical Observatory in 1976, Aksnes reviewed de Sitter's incomplete theory for the motion of the Galilean satellites and published a detailed outline for a revised and

complete theory.

1.4 Mutual Satellite Events

We were actively involved in computing predictions, observing and analyzing the observations of mutual satellite events in 1973, 1979 and 1980. The 1973 observing campaign and our subsequent analysis produced nearly 100 relative positions of the Galilean satellites with a mean accuracy of about 100 km (0.03 arc sec). We used these observations to substantially improve on Sampson's theory for these satellites.

For the three outermost of these satellites new radii were defined, in very good agreement with the radii that resulted from direct photographs obtained by the Voyager spacecraft in 1979. That year a less favorable series of mutual events occurred, some of which were observed, adding valuable new information by increasing the baseline from 1 to 6 years.

A less extensive but highly successful observing program was conducted for the mutual events of Saturn's satellites in 1979/80. At the time of writing, we have nearly completed analyzing a total of about 20 photometric observations. By revising some of the elements in Struve's theory for Saturn satellites, we have shown that the mutual events technique allows at least as high accuracy for these satellites as for Jupiter's, despite the twice as large distances and generally much smaller sizes of Saturn's satellites.

We have also undertaken several studies that are somewhat indirectly linked with the orbits of planetary satellites because they investigate the orbits of planets, their rotation rates and gravitational fields. Some published results, credited to this contract, are:

(1) establishment of a long-term upper limit to Jupiter's orbital eccentricity;

(2) deviation of an accurate modern value of the ellipticity of Uranus from ballon borne (Project Stratosphere) images and consequent evaluation of planet's rotation rate;

(3) identification of features in Saturn's rings as produced by heretofore undetected tesseral (i.e. non-axis symmetric) harmonics of Saturn's gravitational field.

2. Publications

Following is a list of the most important publications issued under this grant.

Aksnes, K., and Franklin, F. A., Mutual phenomena of the Galilean satellites in 1973, I. Total and near-total occultations of Europa by Io. Astron. Journ. 80, 56-63, 1975.

Kowal, C. T., Aksnes, K., Marsden, B. G., and Roemer, E., The thirteenth satellite of Jupiter. Astron. Journ. 80, 460-464, 1975.

Aksnes, K., and Franklin, F. A., DeSitter's theory "melts" Europa's polar cap. Nature 258, 503-505, 1975.

Aksnes, K. and Franklin, F. A., Mutual phenomena of the Galilean satellites in 1973, III. Final results from 91 light curves. Astron. Journ. 81, 464-481, 1976.

Van Biesbroeck, G., Vesely, C. D., Aksnes, K. A., and Marsden, B. G., Observations of comets, minor planets, Pluto and satellites. Astron. Journ. 81, 122-124, 1976.

Aksnes, K., and Marsden, B. G., The orbit of a probable fourteenth satellite of Jupiter. Bull. Amer. Astron. Soc. 8, 433, 1976.

Aksnes, K., Properties of satellite orbits: Ephemerides, dynamical constants, and satellite phenomena. In "Planetary Satellites", ed. by J. A. Burns, Univ. of Arizona Press, pp. 27-42, 1977.

Aksnes, K., Quantitative analysis of the Dermott-Gold theory for Uranus' rings. Nature 269, 783, 1977.

Aksnes, K., New formulation of de Sitter's theory of motion for Jupiter I-IV. I. Equations of motions and the disturbing functions. In "Dynamics of Planets and Satellites and Theories of Their Motion", ed. by V. G. Szebehely, D. Reidel Pub. Co., pp 189-206, 1978.

Aksnes, K., and Franklin, F. A., Mutual phenomena of Jupiter's five inner satellites in 1979. Icarus 34, 188-193, 1978.

Aksnes, K., and Franklin, F. A., Mutual phenomena of Saturn's satellites in 1979-80. Icarus 34, 194-207, 1978.

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Aksnes, K. and Franklin, F., The evidence for faint satellites of Saturn reexamined. Icarus 36, 107-118, 1978.

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Aksnes, K. and Franklin, F. A., Preliminary analysis of mutual satellite events in 1979/80. Presented by K. Aksnes at 12th DDA/AAS meeting in Tuscaloosa, Alabama, 24 March 1981. To appear in Bull. Amer. Astron. Soc., 1981.

Franklin, F. A., Implications from the motions of outer belt asteroids. Icarus 40, 329, 1979.

Franklin, F. A., Lecar, M., Lim, D. and Papaloizou, J., Tidal torques and infrequency colliding particle disks and the truncation of the asteroid belt. Icarus 42, 271, 1980.

Franklin, F. A., Avis C. C., Colombo, G. and Shapiro, I. I., The geometric oblateness of Uranus. Astrophys. Journ. 236, 1031, 1980.

Franklin, F. A., Colombo, G. and Cook, A. F., A link between the rotation of Saturn and its' ring structure. Nature, in press, 1981.

3. Acknowledgements

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We would also like to thank the many people at the Center for Astrophysics who have been involved with this grant on a scientific or administrative level.