The Origin and Evolution of *Solar System Dynamics*

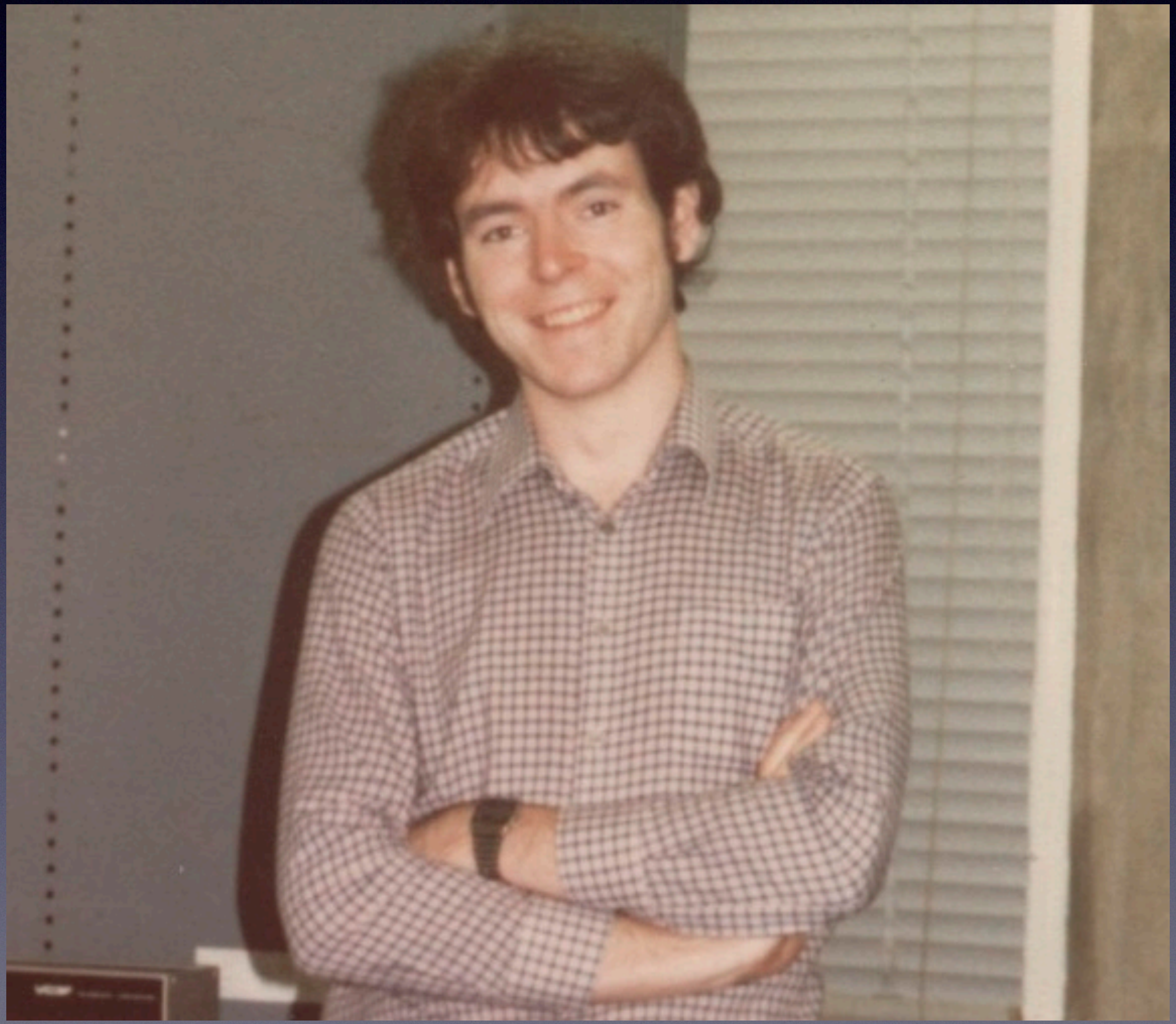
Carl Murray

Astronomy Unit
Queen Mary University of London

Stan Dermott Special Session, DDA, University of Chicago, June 24, 2026

Origin

Carl Murray at Queen Mary



Credit: Carl Murray

c.1978

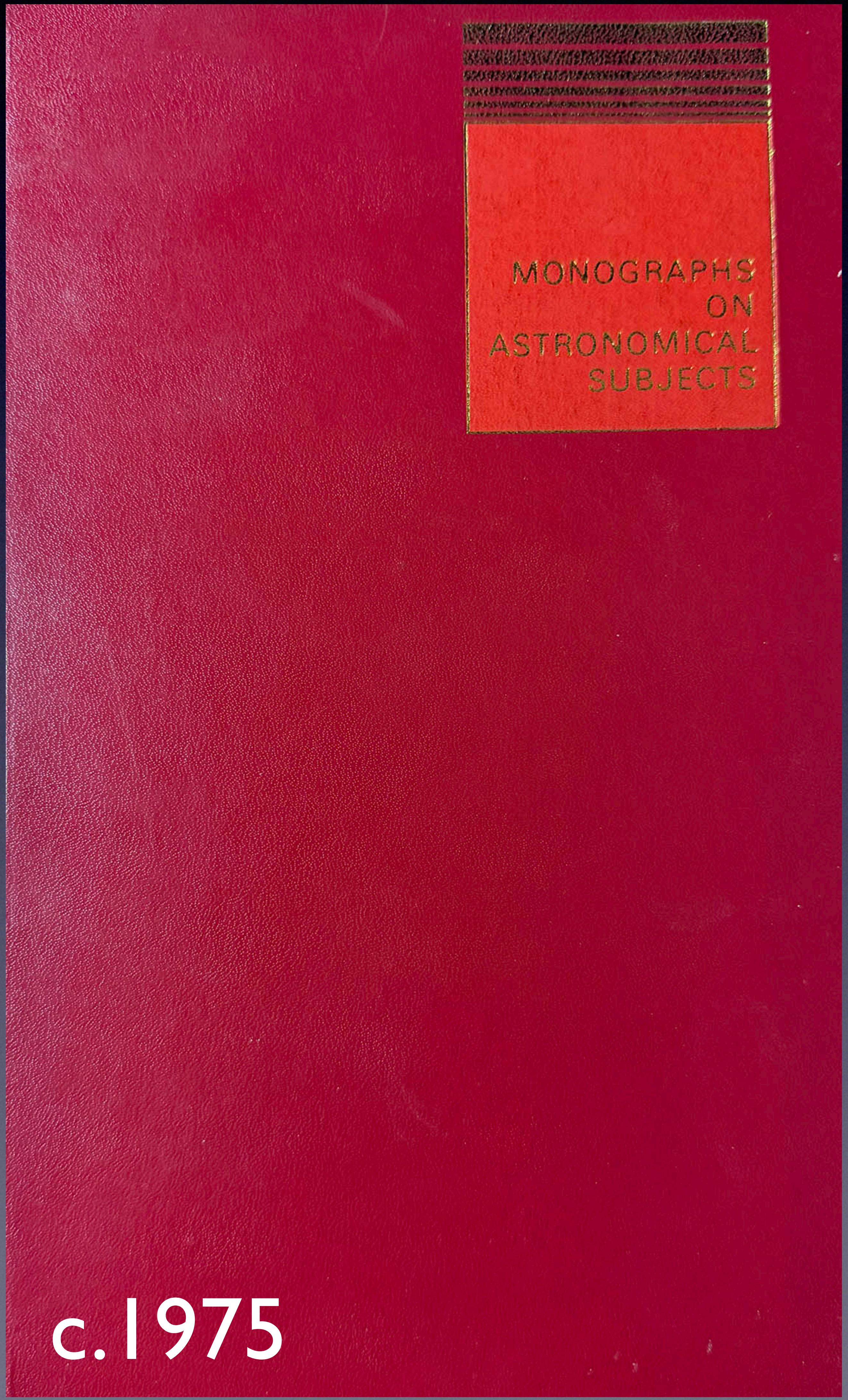
Stan Dermott at Cornell

Credit: Carl Murray

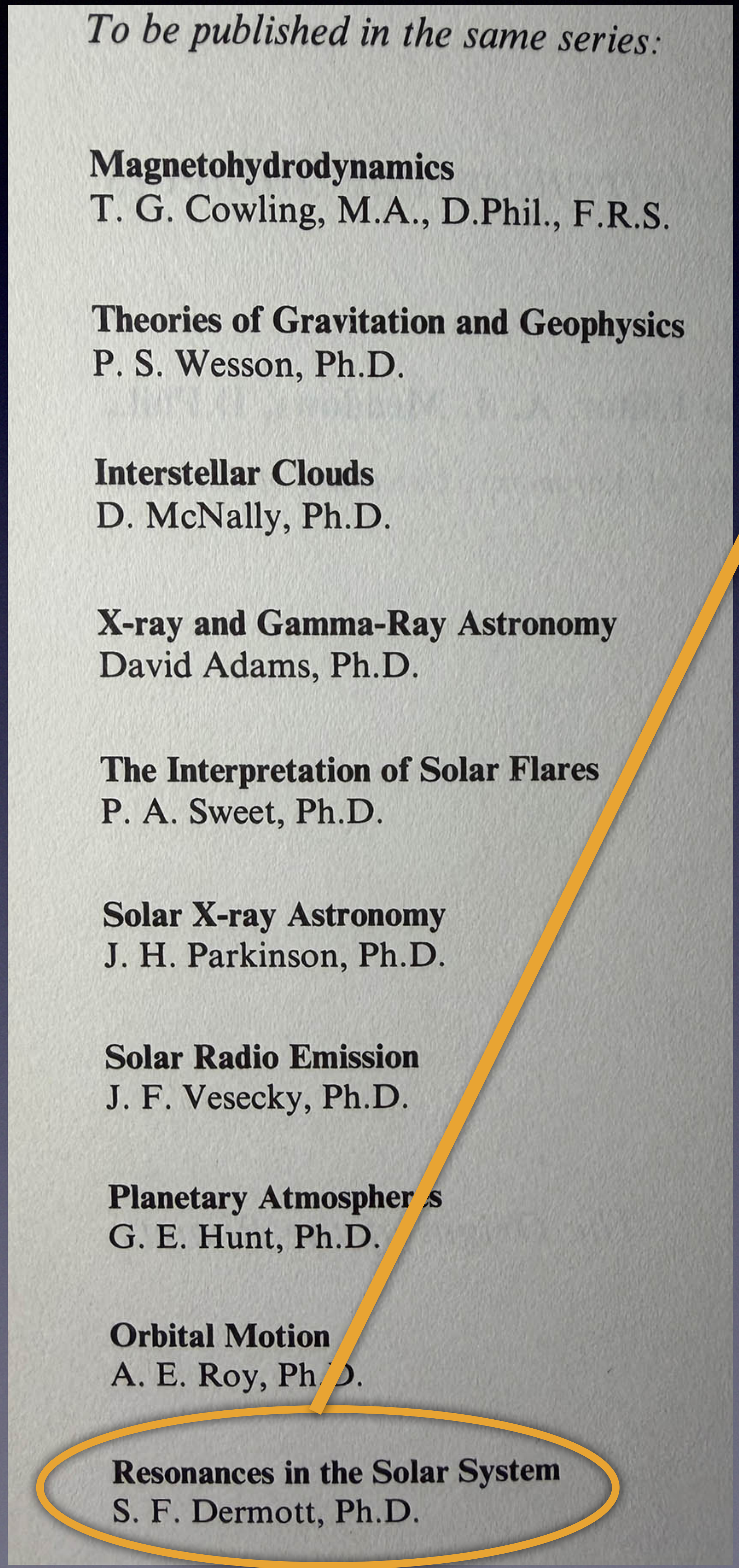
c.1982

Origin

Monographs published by Adams Hilger (IoP)



c.1975



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P. S. Wesson, Ph.D.

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D. McNally, Ph.D.

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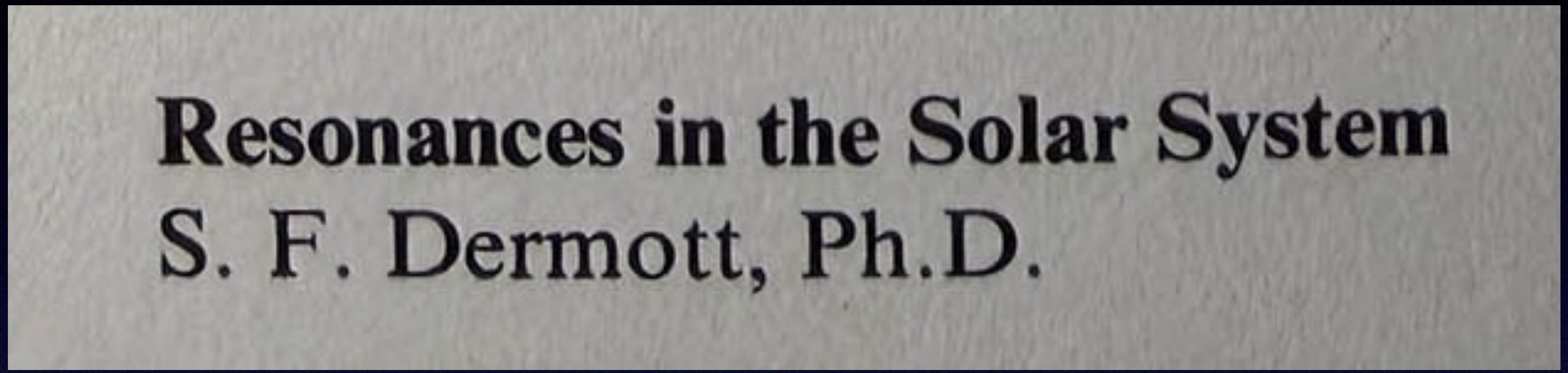


Resonances in the Solar System
S. F. Dermott, Ph.D.

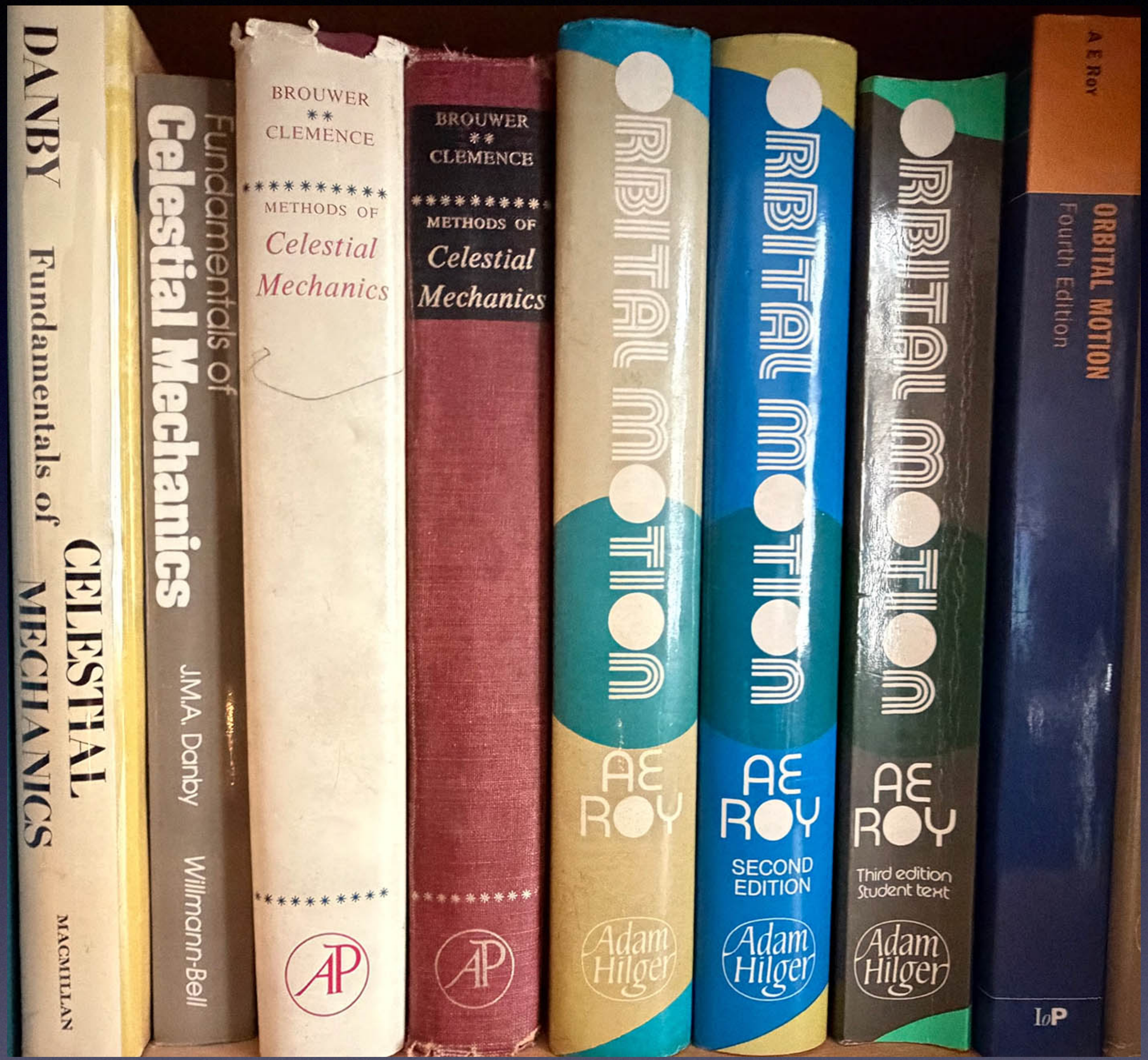
"Dear Stan, … I wondered how much progress you have made on your monograph?"

"Dear Stan, … do you have any idea how much longer it will take to finish your monograph?"

"Dear Stan, … I am retiring soon. Is there any chance that you can finish your monograph?"

(paraphrasing)

Origin



Our definition of solar system dynamics:

> "The application of the techniques of celestial mechanics to solve real problems in planetary science"

Guiding Principles

- “Write about what you know”
- “Don’t write the text-book until you have given the lecture course”
- Write a book that we would have like to have read when we were starting out as researchers
- Write to convey understanding
- Write a book that is as self-contained as possible

Evolution

- Work started in 1982 before Carl left Cornell
- Annual visits to Ithaca (then Gainesville) and London
- Exchange of material by mail, FAX and email
- Working drafts of the book used at QM and UF
- Submitted to CUP in 1997

Structure

- 2.5 Elliptic expansions
- 2.6 The guiding centre approximation
- 2.7 Barycentric orbits
- 2.10 Hamiltonian formulation
- 3.9 Tadpole and horseshoe orbits
- 3.12 Janus and Epimetheus
- 3.13 Hill's equations
- 7.2 Secular perturbations for two planets
- 7.3 Jupiter and Saturn
- 7.6 Gauss's averaging method
- 7.7 Generalised free and forced elements

Structure

- 8.9 The 2:1 resonance
- 8.12 Resonant encounters
- 8.20 Pulsar planets
- 9.3 Regular and chaotic orbits
- 9.4 Algebraic mappings
- 10.3 Resonances in rings
- 10.7 The F ring of Saturn
- 10.10 The Earth's dust ring
- Appendix B – Expansion of the Disturbing Function

Impediments

NATURE VOL. 312 6 DECEMBER 1984 — ARTICLES — 505

Origin of the Solar System dust bands discovered by IRAS

S. F. Dermott, P. D. Nicholson, J.

Center for Radiophysics and Space Research, Cornell Unive

Measurements of longitudinal variations in the brightness and the la
Infrared Astronomical Satellite determine the orbital elements of the
between cometary and asteroidal models of the origin of these band

Nature **312**, 505 (1984)

Proper Elements

ARTICLES

Masses of the satellites of Uranus

S. F. Dermott & P. D. Nicl

Center for Radiophysics and Space Research, Space Sciences Building, Cornel

The dynamical theory used to obtain the masses of the uranian satellites
fundamental error. The masses can be derived from the precession rates, bu
allow for the fact that the eccentricities, inclinations and precession rates c
secular perturbations.

Nature **319**, 115 (1986)

Secular Perturbations

LETTERS TO NATURE

Tidal effects of disconnected hydrocarbon seas on Titan

Stanley F. Dermott* & Carl Sagan†

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† Laboratory for Planetary Studies, Cornell University, Ithaca, New York 14853, USA

THERMODYNAMIC and photochemical arguments[1–4] suggest that Titan, the largest satellite of Saturn, has a deep ocean of liquid hydrocarbons. At visible wavelengths, Titan's surface is obscured by a thick stratospheric haze, but radar observations[5–7] have revealed large regions of high surface reflectivity that are inconsistent with a global hydrocarbon ocean. Titan's surface has also been imaged at infrared wavelengths[8–10], and the highest-resolution data (obtained by the Hubble Space Telescope) show clear variations in surface albedo and/or topography[10]. The natural interpretation of these observations is that Titan, like the Earth, has continents and oceans. But Titan's high orbital eccentricity poses a problem for this interpretation, as the effects of oceanic tidal friction would have circularized Titan's orbit for most configurations of oceans and continents[1,11]. Here we argue that a more realistic topography, in which liquid hydrocarbons are confined to a number of disconnected seas or crater lakes, may satisfy both the dynamical and observational constraints.

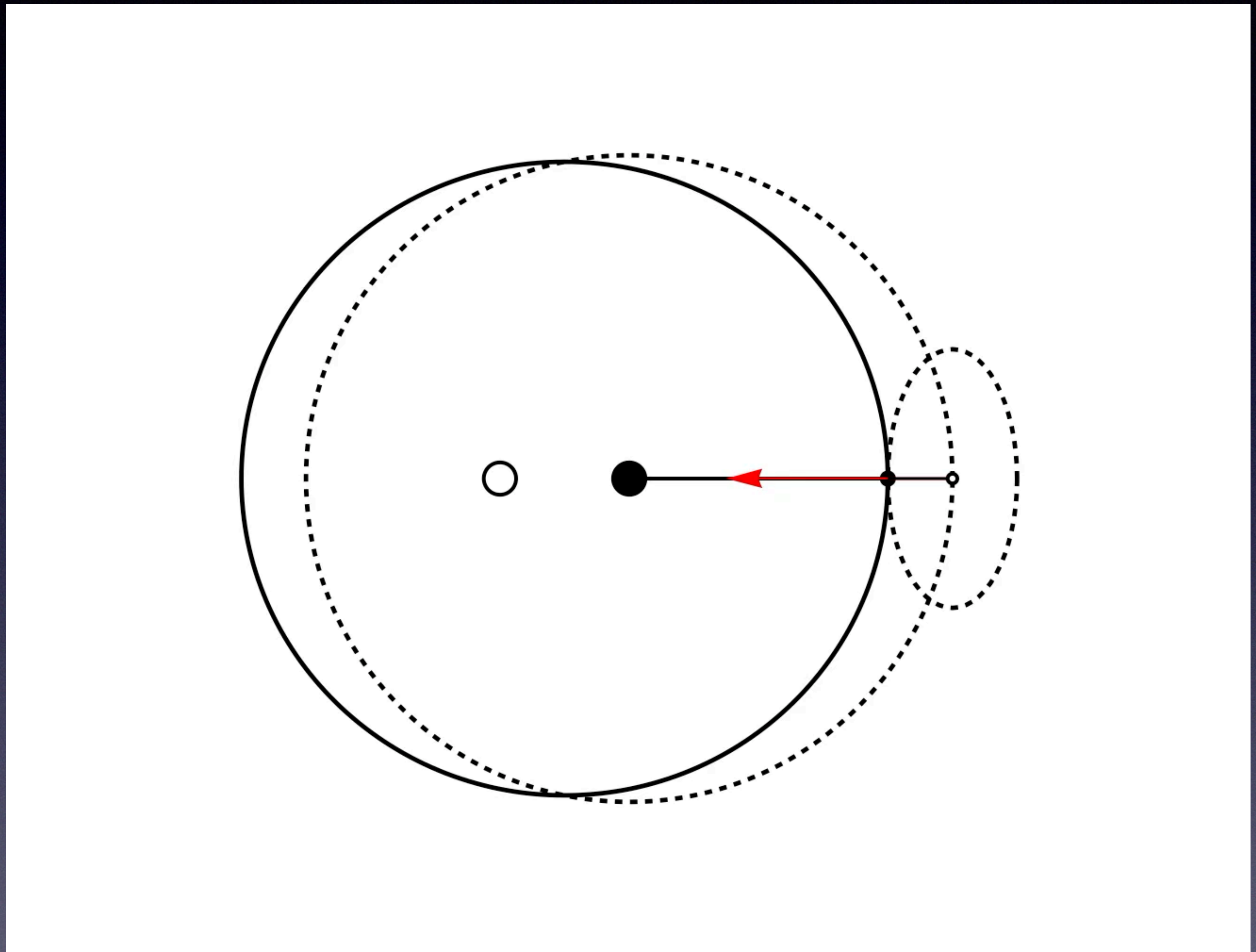
Recent observations[8–10] of the surface of Titan through windows in the infrared spectrum seem to confirm that the satellite is in synchronous rotation. In such a case, because the orbital eccentricity of Titan is high, Saturn raises two important tides on the satellite: a radial tide due to the variation of Titan's distance from Saturn and a librational tide due to the fact that Titan rotates at a uniform rate whereas its orbital motion is keplerian and non-uniform. Frictional damping of these tidal oscillations results in the circularization of Titan's eccentric orbit on a timescale determined by the energy dissipation rate or, equivalently, by Titan's tidal dissipation function, Q_T, which varies inversely with the dissipation rate. Assuming that tidal damping has operated over the age of the Solar System, the observation that Titan's eccentricity is still as high as 0.029 implies that Q_T is high (>200) and that the energy dissipation rate is low[1].

The Earth, which is the only body in the Solar System known to have an extensive ocean, has a tidal dissipation coefficient, Q_E, about 20 times smaller[12] than the lower limit on Q_T. This arises because land barriers modify the tidal flow and high rates of tidal dissipation occur in shallow seas and continental shelves (particularly the near-resonant shelves[13]) where the tidal currents are an order of magnitude greater than in the deep ocean[12–14]. The existence of both near-global oceans and extensive land barriers on Earth accounts for the low value of Q_E and led us to argue[1] that Titan's ocean must either be deep and global, with no significant protruding land, or else insignificant. The recent radar and infrared observations of Titan's surface

Nature **374**, 238 (1995)

“Dermott’s Law”

Guiding Centre Approximation (Fig. 2.10)



- Stan discovered this empirically while a postdoc at Newcastle University (mid-1970s)
- Independently discovered by Danby (1988) in 2nd edition of his book (problem on p.136)

2. Show that if the square of the eccentricity of the Moon’s orbit is neglected, then the Moon will always turn the same face toward the *empty* focus.

“A satellite in synchronous rotation keeps the same face pointed towards the empty focus of its orbit.”

Exercise Questions

Good News:
Typeset solutions for all problem questions exist!

Bad News:
They are in Norwegian!

The work was done in 2000 by Øystein Olsen, graduate student of Kaare Aksnes

Dermed så ser vi at den minste avstanden mellom Mars og Jorden varierer med en faktor på

$$\frac{0.67AU}{0.38AU} \approx 1.75$$

Ved å definere nære opposisjoner som opposisjoner der opposisjonen skjer når Mars er i nærheten av perihelion, så kan vi finne tidsrommet mellom to nære opposisjoner. Mars sin omløpstid er omtrent 687 dager. Hvis vi har en nær opposisjon ved et gitt tidspunkt, så vil Mars ved neste opposisjon ha passert perihelion for 780-687=93 dager siden. Etter 7 eller 8 opposisjoner så er det 651 eller 744 dager siden Mars passerte perihelion, d.v.s. at Mars er omtrent ved perihelion igjen. Dermed vil det i snitt være ca $7.5 \cdot 780 \approx 5850$ dager mellom hver nære opposisjon. Dette er ca. 16 år.

På neste side følger et plott av avstanden mellom Jorden og Mars fra JD 2446545.0 til JD 2452545.0. Enheten på aksen er dager før/etter JD 2451545.0. Programmet som regnet ut dette og viser datoen for minste og største opposisjon, er skrevet i Mathematica og kan finnes på

Credit: Øystein Olsen

Miscellaneous

Russian Translation

Ivan Shevchenko, 2009

Celebrity Endorsement

"… an amazing text-book – a bible for anyone entering the world of dynamical studies of Solar System bodies."

Brian May, 2008

Future

- Material is being added to the SSD website at solarsystemdynamics.info
- At their last meeting in January 2024 Stan and Carl discussed plans for possible second edition
- Tentative plans to include von Zeipel-Kozai-Lidov mechanism, PPN, + …(?) in second edition plus new chapter on drag forces and completely revised rings chapter
- No plans to include dynamics specific to exoplanetary systems

Thanks to the Error Finders:

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Paul Wiegert
Cong Yu
Shay Zucker

Credit: Carl Murray

Stanley F. Dermott (1942–2025)

Co-author of
Solar System Dynamics