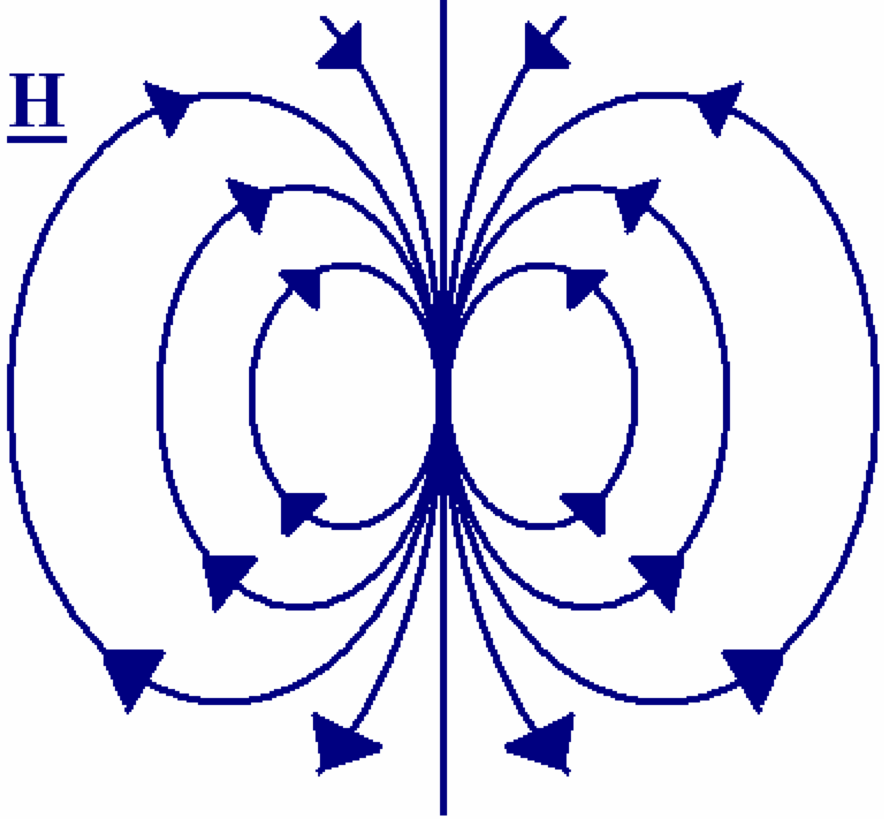
Measurement of the Lense-Thirring effect using the LAGEOS satellites

Ignazio Ciufolini
Università di LECCE
and
Erricos Pavlis
University of Maryland,
presented by
Alberto Franceschi
LNF-INFN

SPACEPART06 Beijing 21-4-2006

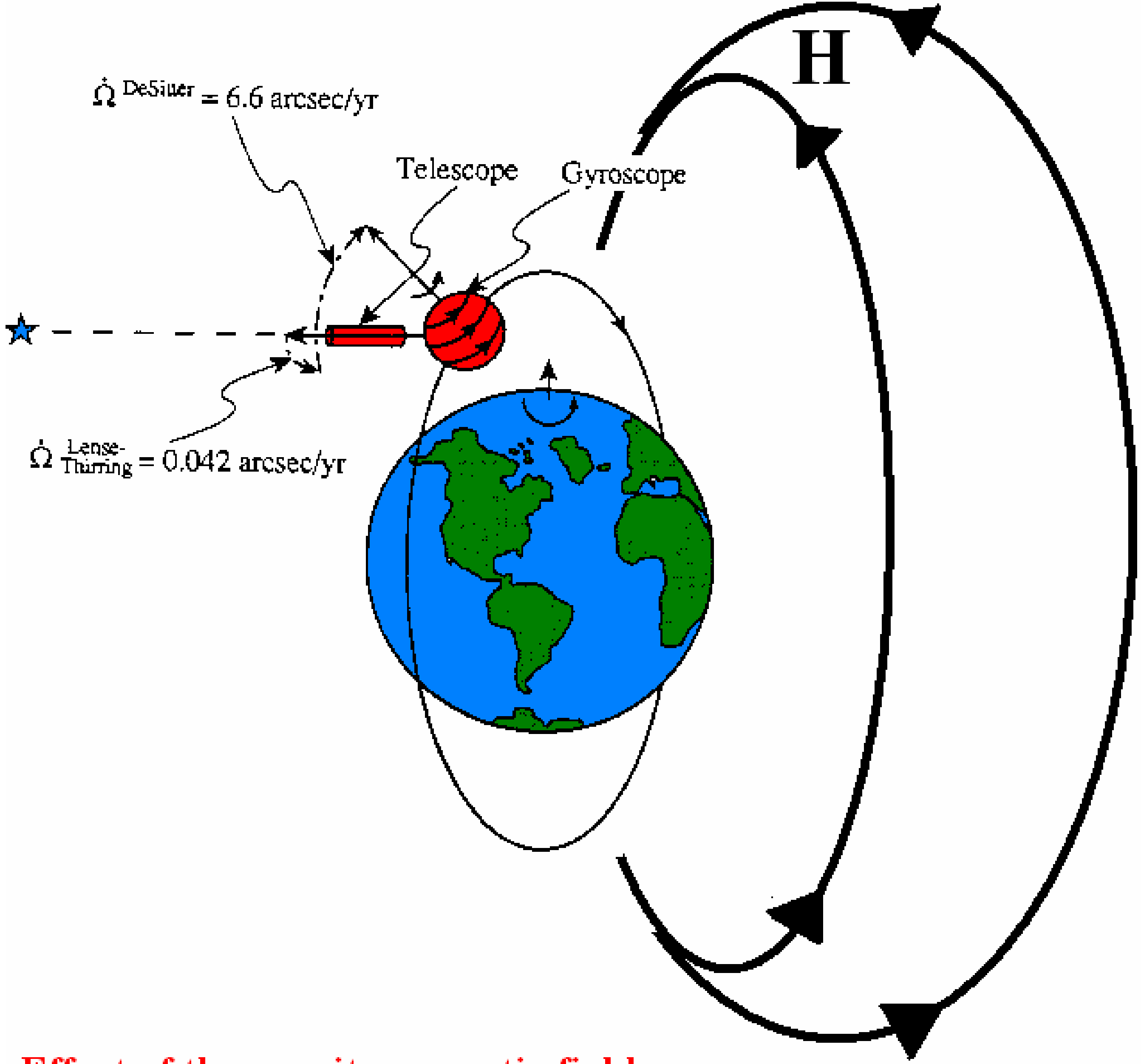
I apologize with the audience and the organizers of SPACEPART06 but my Lufthansa flight LH 3861, from Rome, had a serious technical problem and so the carrier had to come back to the terminal (but I am still alive!).
I thank very much Eng. Alberto Franceschi for presenting this simplified version of my talk. The details of this talk will be submitted to the proceedings of SPACEPART06.

Ignazio Ciufolini (19-4-2006)

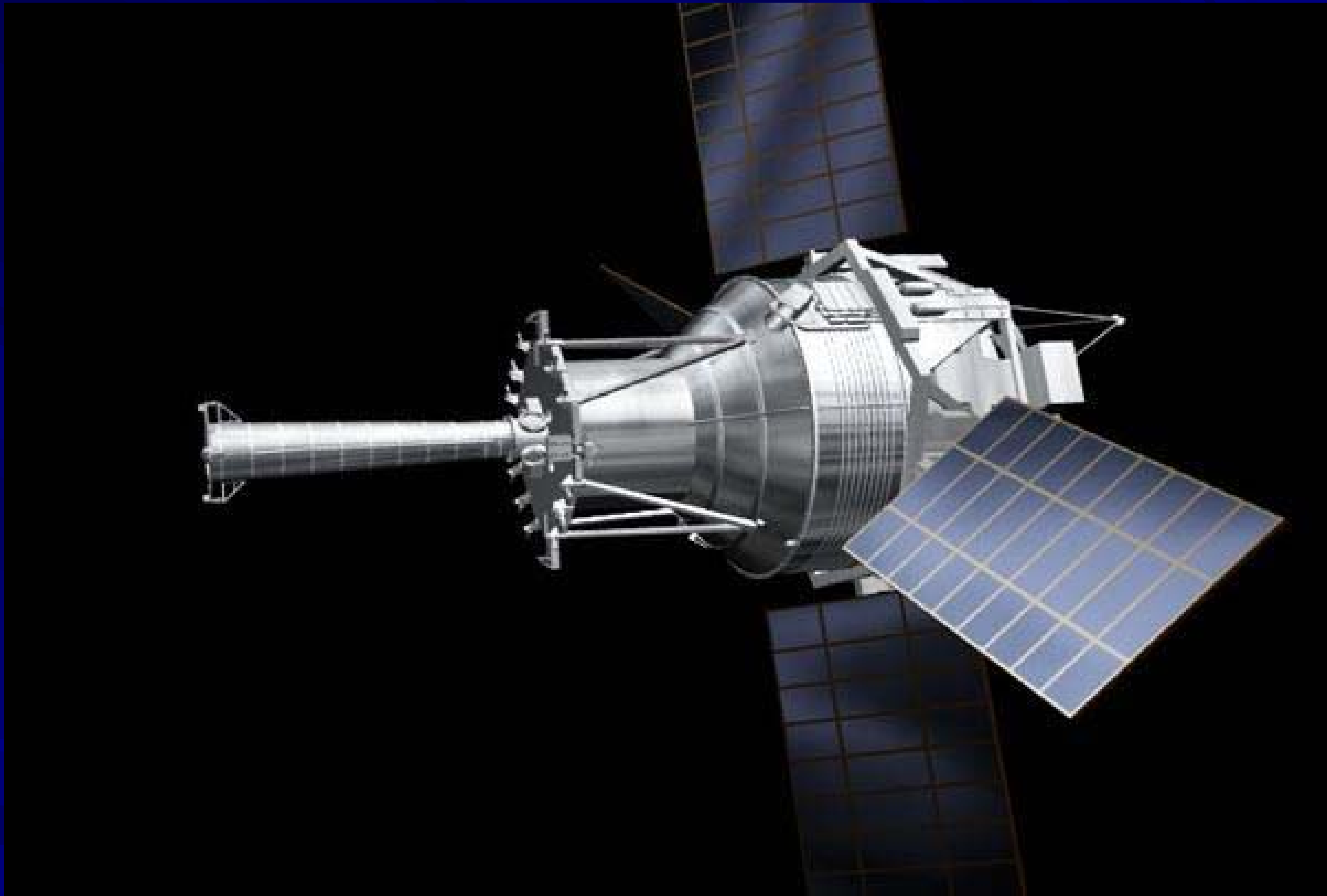


GRAVITOMAGNETIC FIELD
generated by the EARTH angular momentum

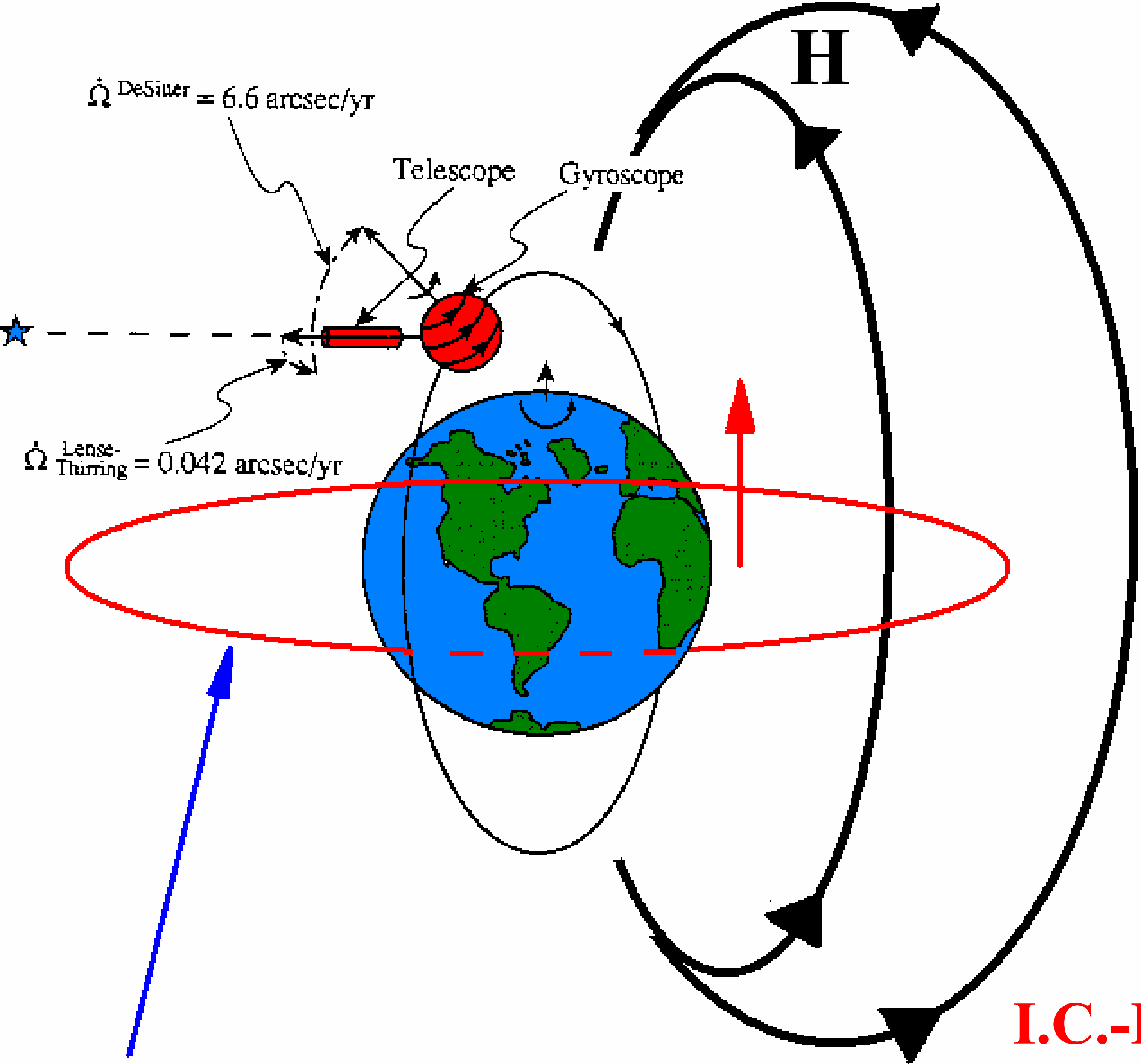
See: I.C. and J.A. Wheeler,
Gravitation and Inertia, 1995



Effect of the gravitomagnetic field on a test-gyroscope: it changes the orientation of the gyroscope with respect to distant stars (dragging of inertial frames)



Will be measured by: **GRAVITY PROBE B**

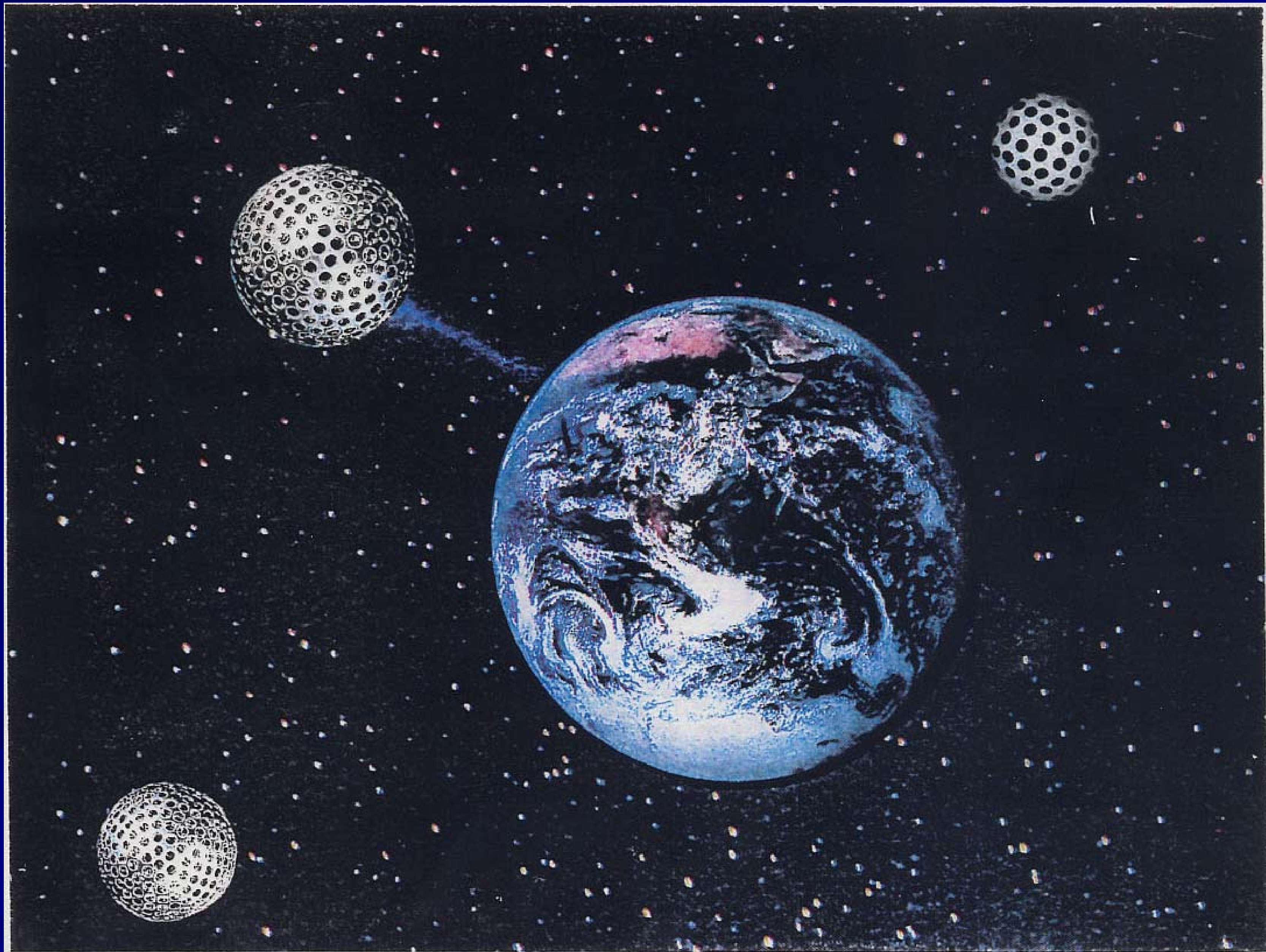


Effect of the gravitomagnetic field on a test-particle (small satellite): it changes the orientation of the orbital plane of the test-particle, i.e., it drags the line of the nodes of a satellite (Lense-Thirring effect-dragging of inertial frames).

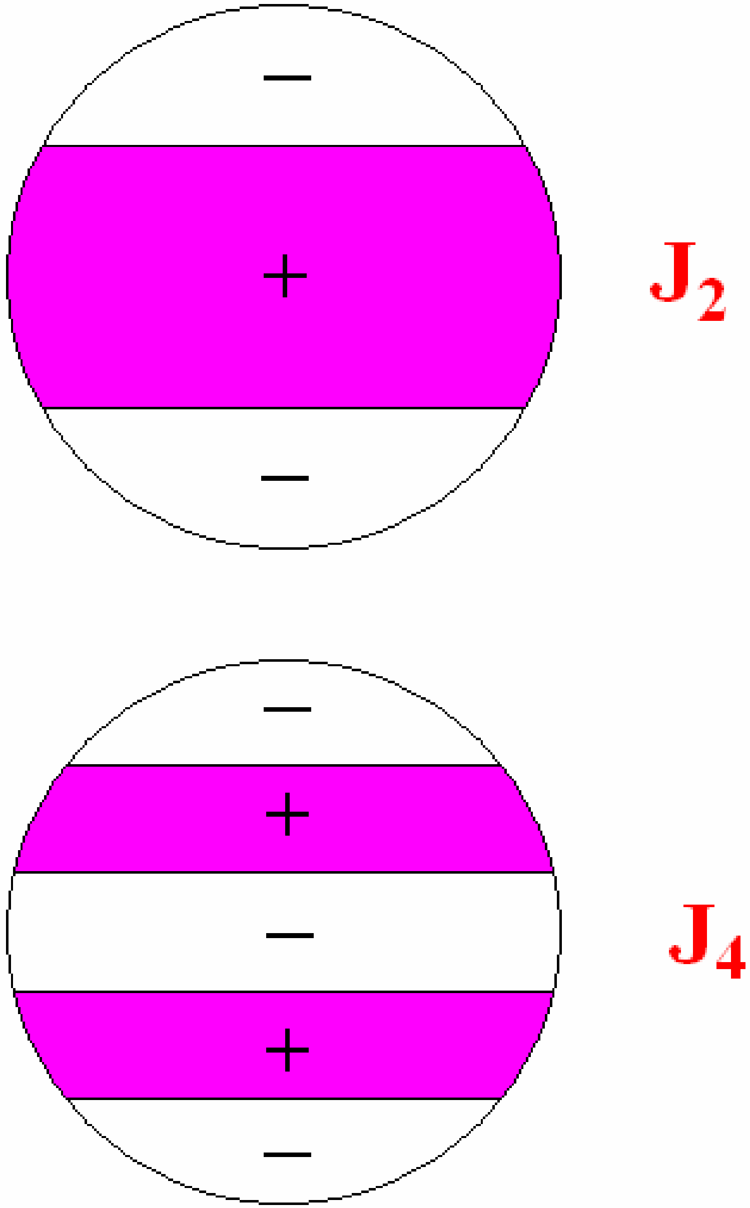
I.C.-Phys.Rev.Lett., 1986: Use the NODES of two LAGEOS satellites to measure the Lense-Thirring effect.

The technique to accurately measure the very tiny Lense-Thirring effect on the orbit of a satellite is:

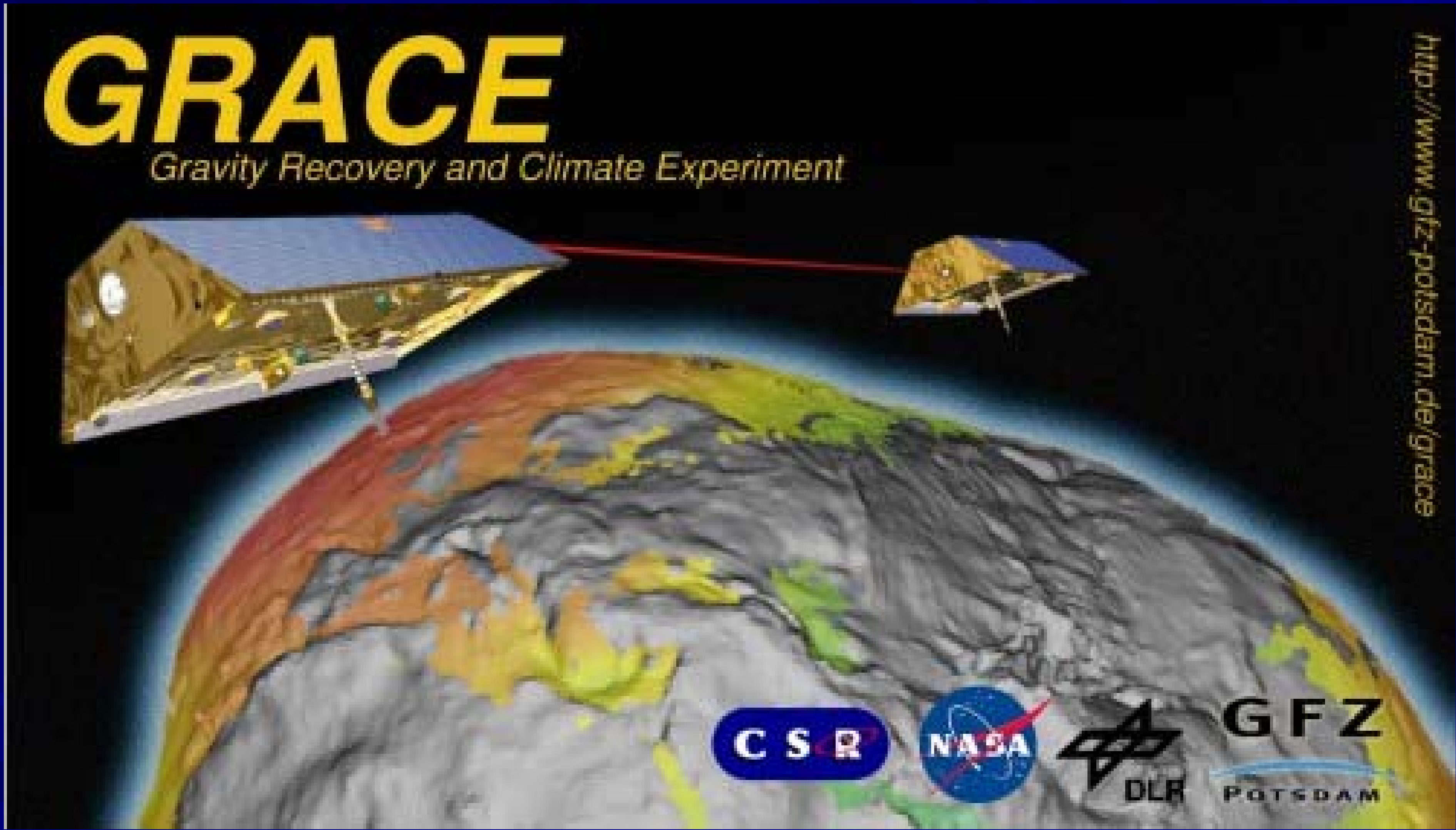
Satellite Laser Ranging



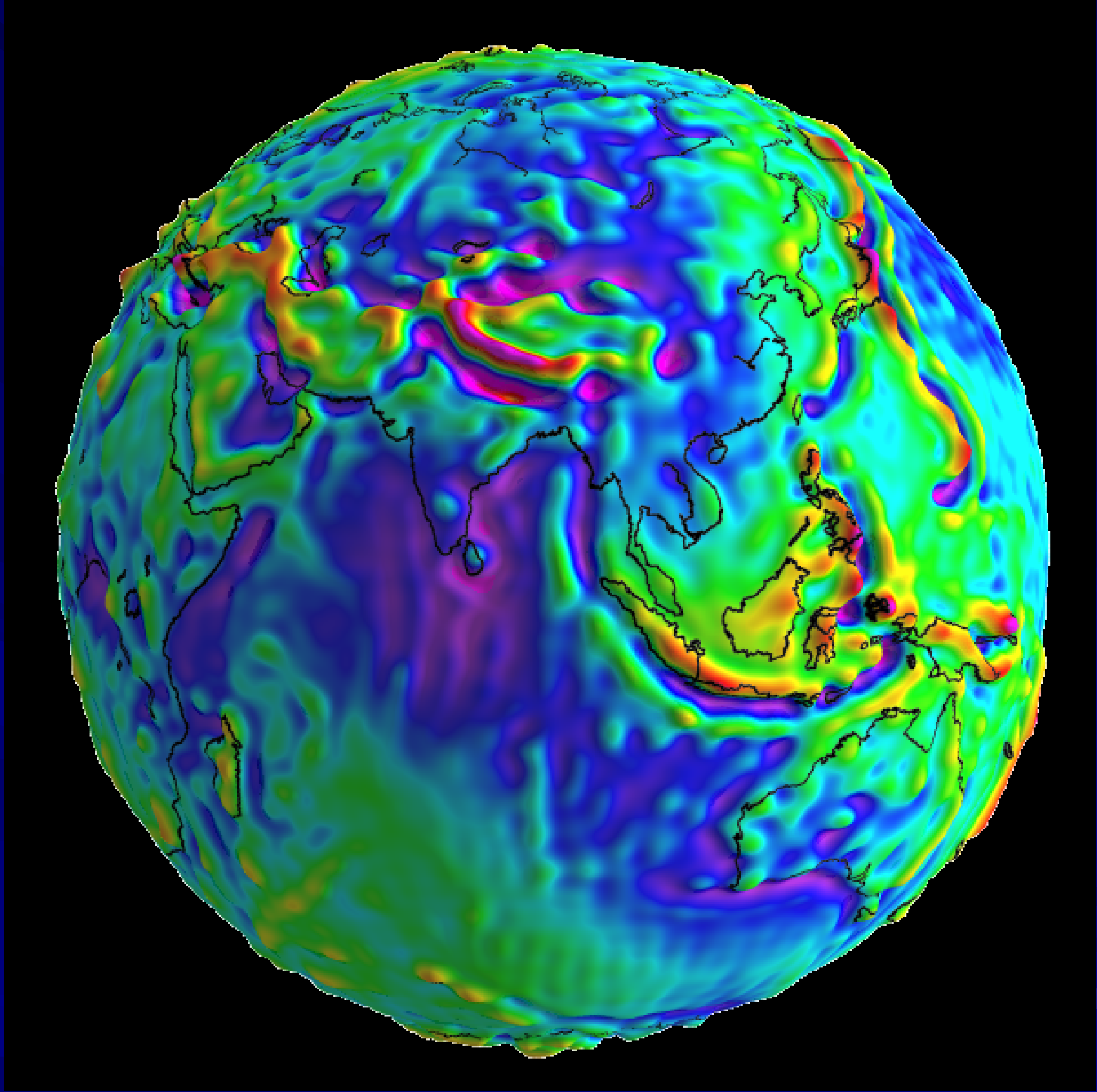
EVEN ZONAL HARMONICS



In order to improve the accurate measurements of the Earth gravity field, the GRACE mission was launched in 2002



It shows the →
very small
variations of
the Earth
gravity field
from that of
a perfect
ellipsoid

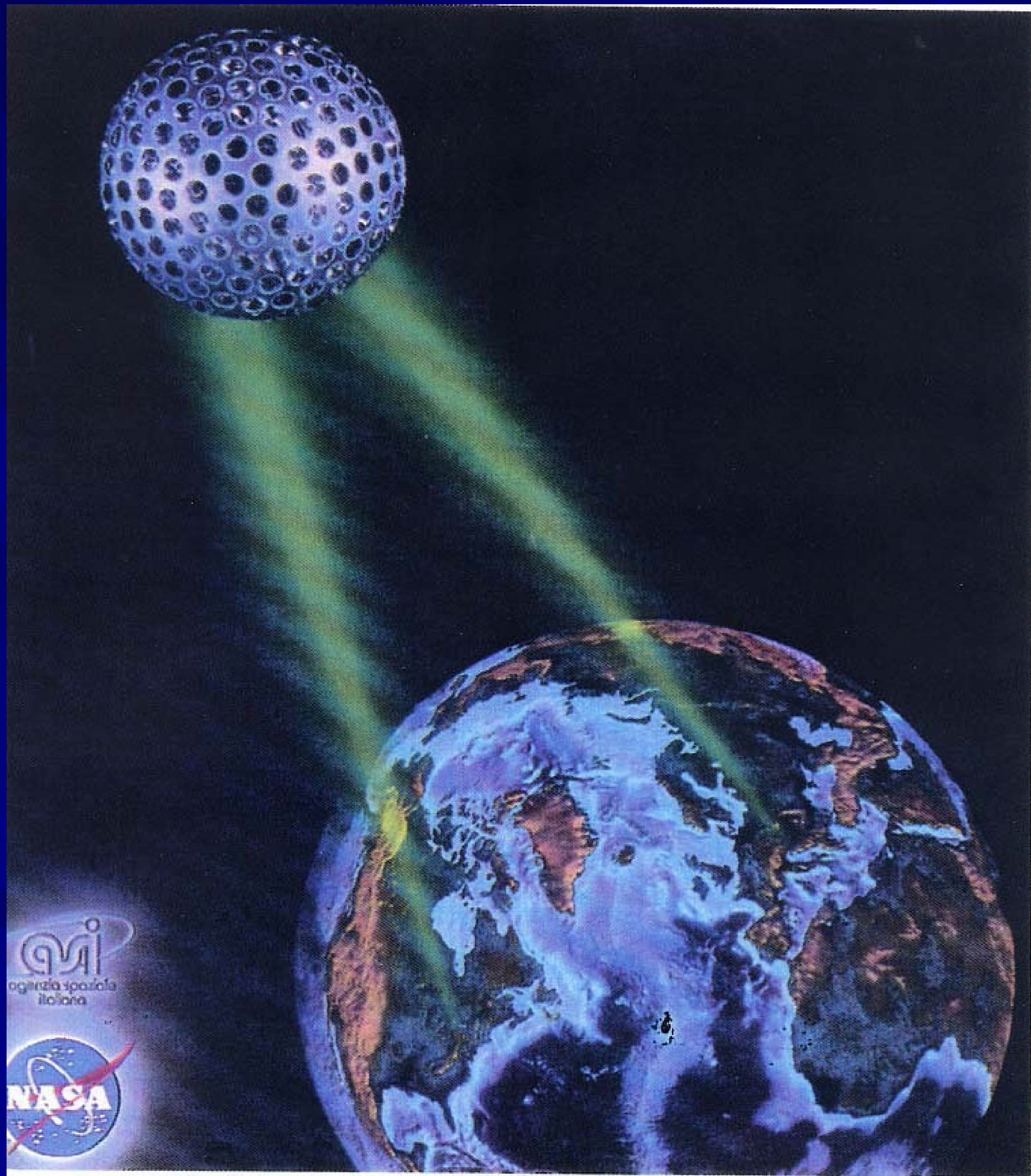


EIGEN-GRACE-S (GFZ)

This is a picture of the gravity field model EIGEN-GRACE-S produced by GFZ (Potsdam-Germany) using the data of the GRACE satellites only.

LAGEOS II

Launched →
in 1992 by ASI
Italian Space
Agency and
NASA



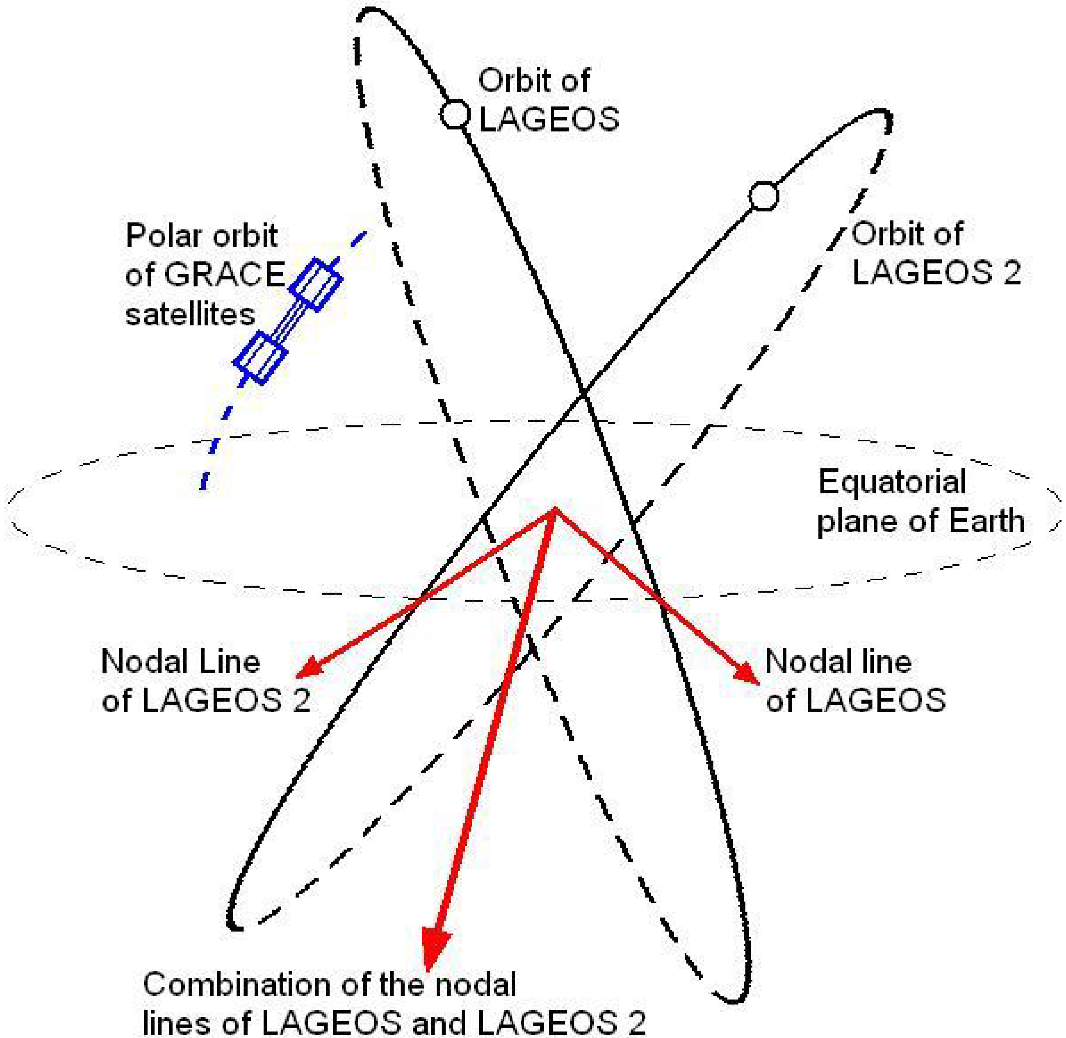
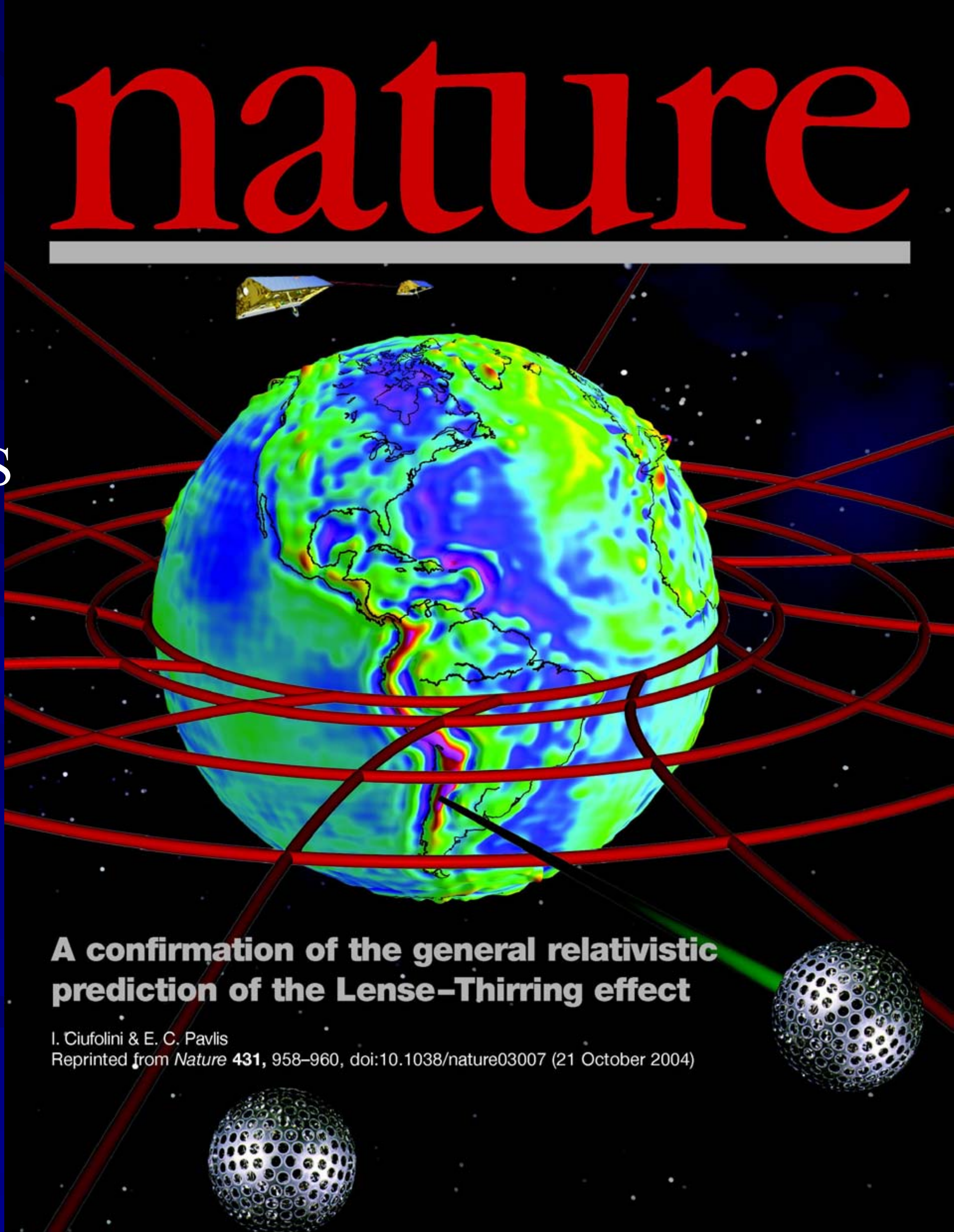


Figure 1

IDEA: USE OF THE NODES OF LAGEOS AND LAGEOS 2 TO ELIMINATE THE J2 EFFECT

I.C., Nuovo Cimento A 109, 1709, 1996, see also: I.C., Int. Journ. Mod. Phys. A 4, 3083, 1989, I.C., J.A. Wheeler, Gravitation and Inertia, 1995 and I.C., Proceedings of I SIGRAV School on GRG, Frascati, 2002.

Result published →
in Nature in 2004
using the very
accurate Earth
gravity field model
EIGEN-GRACE-02S
(produced in 2004
by GFZ of Potsdam,
Germany) and
the data of the
LAGEOS and
LAGEOS II
satellites



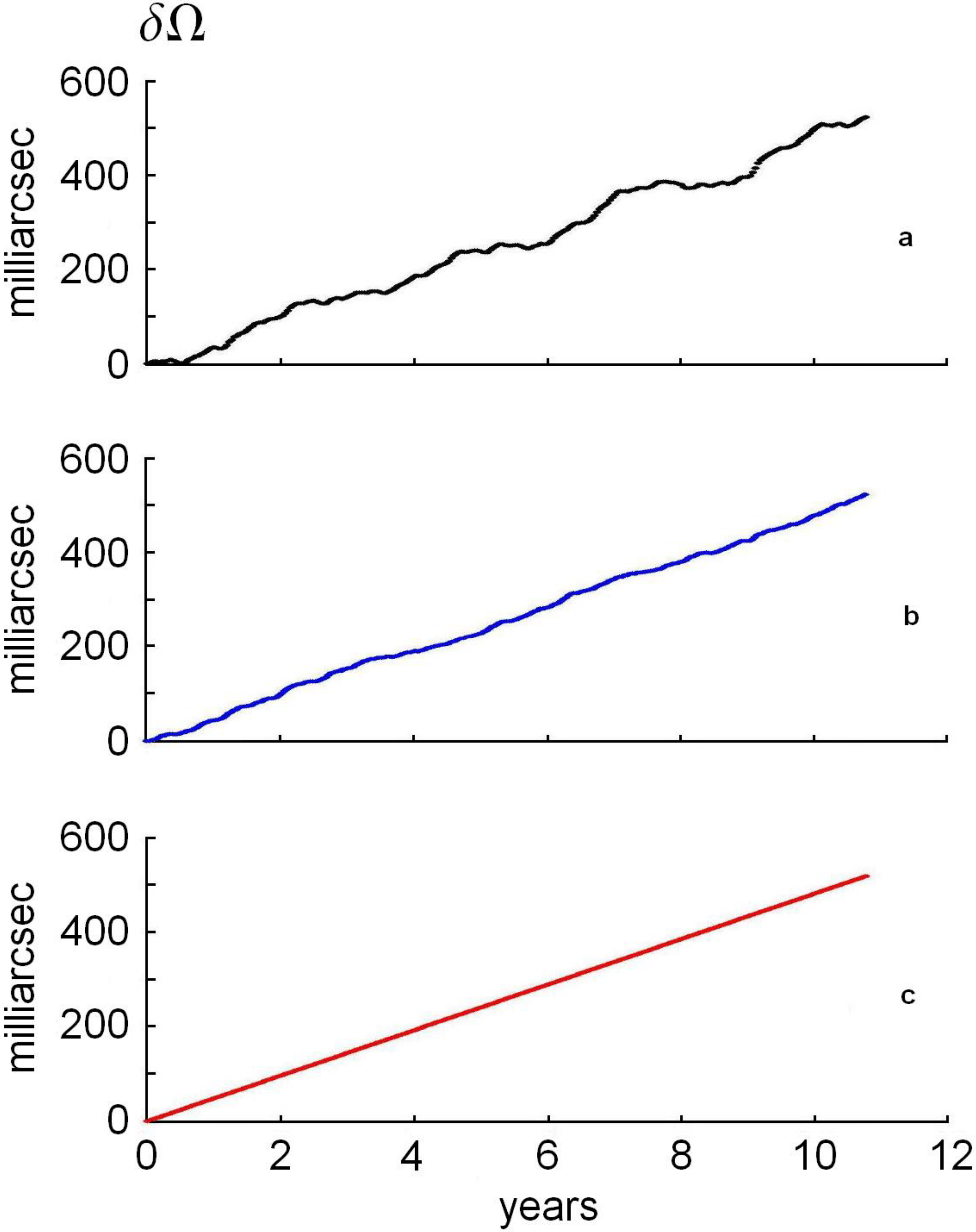


Figure 2

Observed value of Lense-Thirring effect using a combination of the LAGEOS nodes. Fit of linear trend only

Observed value of Lense-Thirring effect = 99% of the general relativistic prediction. Fit of linear trend plus 6 known frequencies

General relativistic Prediction = 48.2 mas/yr

I.C. & E.Pavlis, Letters to NATURE, 431, 958, 2004.

Error budget

- Static gravitational field (using the EIGEN-GRACE02S uncertainties):

  3 % to 4 % (the EIGEN-GRACE02S uncertainties include systematic errors)

  Time dependent gravitational field error:

  @ 2 %
- Non-Gravitational perturbations:

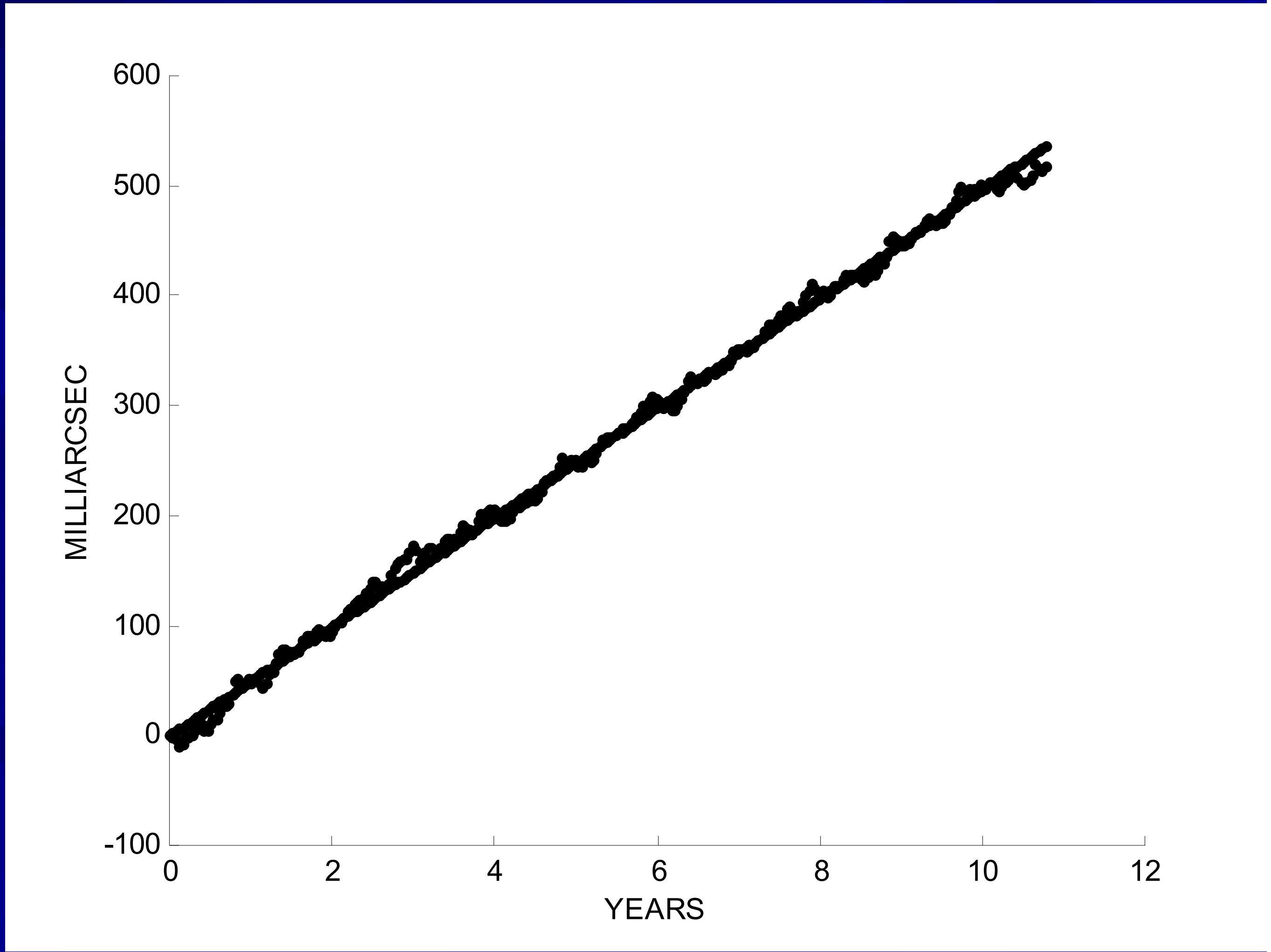
  2 % to 3%
- Other errors: about 2 %

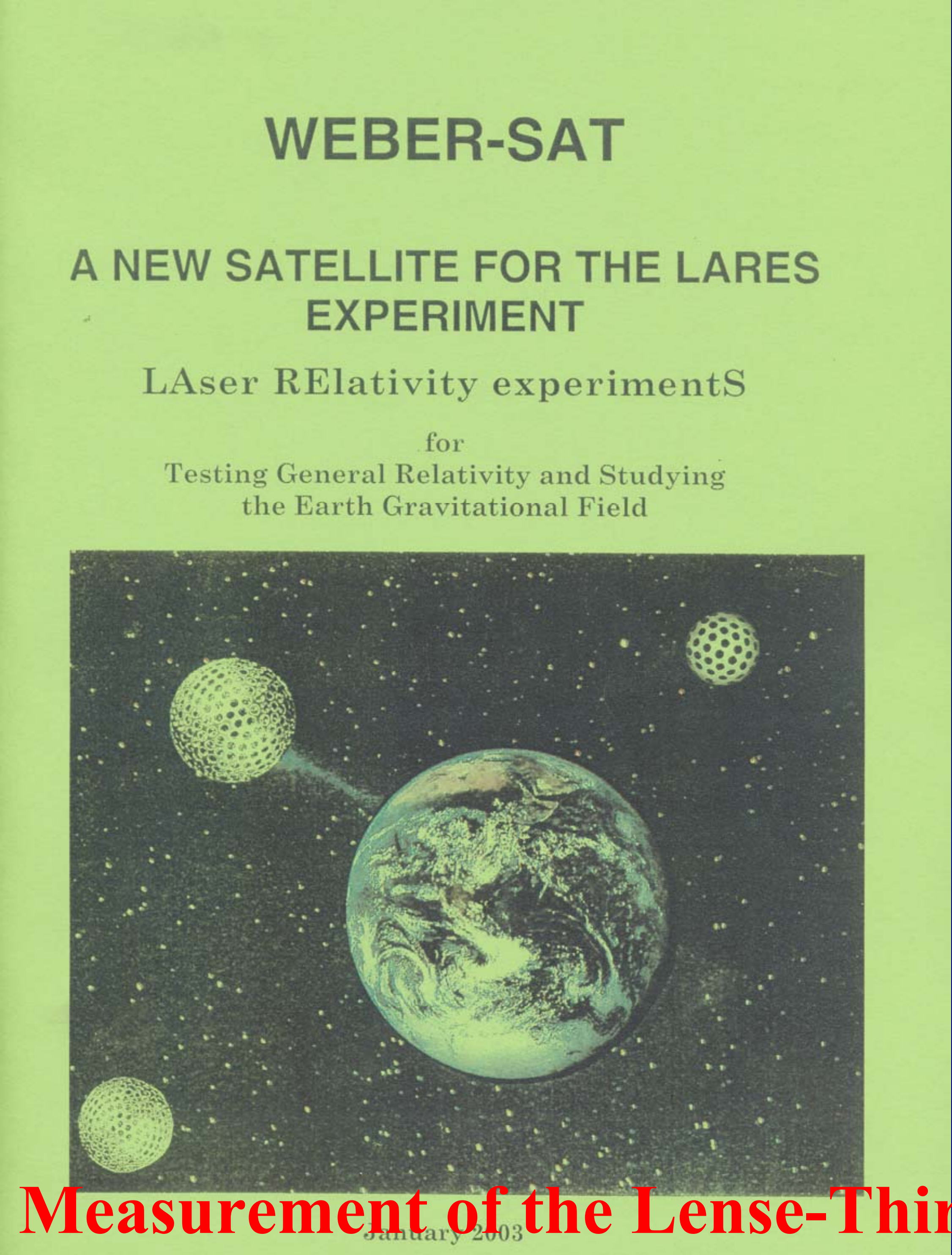
TOTAL: less than 10 % error (Root Sum Square)

A very detailed error analysis and error budget published in: I.C., E. Pavlis and R. Peron, New Astronomy 11, 527-550, 2006.

Present and future work includes the analysis of the LAGEOS and LAGEOS II data using more accurate perturbation models, more accurate gravity field models and different software; for example using the model JEM03, produced in 2005 by JPL-Caltech using a longer GRACE data set, we obtained the preliminary result and fit:

the Lense-Thirring effect measured with JEM03 is ~ 100 % of the general relativity prediction, confirming our 2004 result using EIGEN-GRACE02S →




WEBER-SAT

A NEW SATELLITE FOR THE LARES EXPERIMENT

LAser RElativity experimentS

for

Testing General Relativity and Studying the Earth Gravitational Field

January 2003

MAIN COLLABORATION

University of Lecce

I.C.

University of Roma
“La Sapienza”

A. Paolozzi, F. Graziani, A. Agneni

INFN of Italy

S. Dell’Agnello, A. Franceschi,
G. Delle Monache

University of Maryland

E. Pavlis

NASA-Goddard

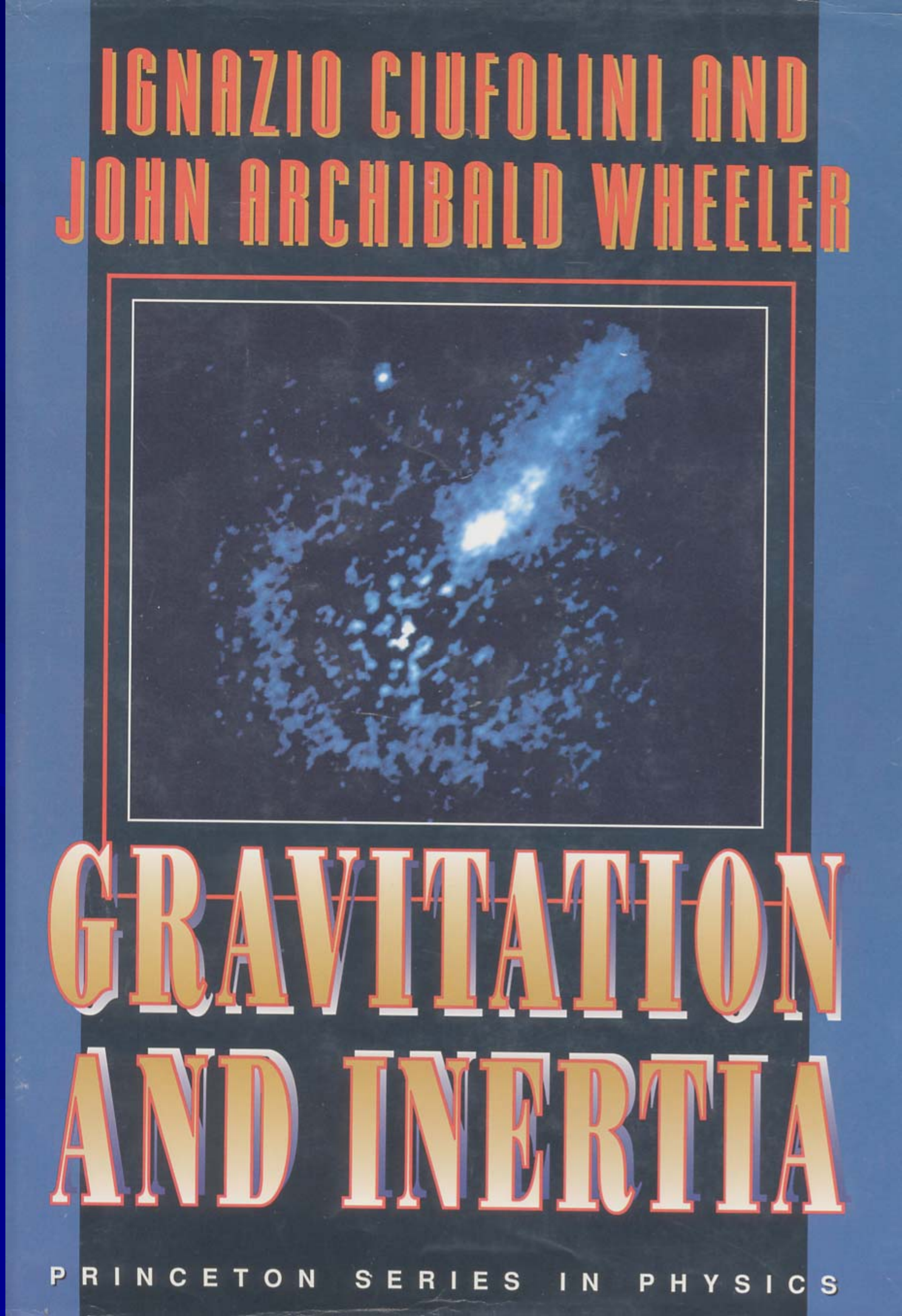
D. Rubincam

University of Texas at
Austin

R. Matzner

Measurement of the Lense-Thirring effect with accuracy of the order of 1 % and other gravitational tests

Theory in →



Latest measurements in →

I.C. & E.Pavlis, Letters to NATURE, 21 October, 2004 and I.C., E. Pavlis and R. Peron, New Astronomy, 2006.

Previous proposals in →

I.C., PRL 1986, I.C. NC A 1996 and I.C. IJMP A 1989.

GOALS OF LARES

Tests of Einstein's General Relativity and Gravitational Theories

- **Measurement of the Lense-Thirring effect and of the gravitomagnetic field with 1%, or less, accuracy.**

- **Test of the very-weak field limit of general relativity (inverse square law), test of the equivalence principle and of new long range forces: improvement by about three orders of magnitude with respect to existing limits. KENNETH NORDTVEDT**

- **Measurement of the parameter α_1 with 10^{-6} accuracy: improvement by about two orders of magnitude. This parameter measures the existence of preferred frames in the universe (if 0 no preferred frames). KENNETH NORDTVEDT**

- **Measurement of the Post-Newtonian parameters β and γ with 10^{-3} accuracy, or better, in the field of Earth (measurement of the general relativistic pericenter precession with 10^{-3} accuracy). These parameters measure the amount of spacetime curvature produced by a mass and the non-linearity of the gravitational interaction**

POSSIBLE PERSPECTIVES

- **In addition, it was recently pointed out by Ciufolini (Ciufolini et al. 2004) the possibility of testing with WEBER-SAT some recently proposed theories, based on a BRANE-WORLD model, which can explain the DARK ENERGY problem and the observations of accelerating supernovae (Dvali 2004).**

- **However, this possibility will imply the need of a much higher altitude orbit for the LASER satellite and therefore a MUCH more expensive mission.**