INTRODUCTION

PAST AND FUTURE OF RESEARCH METHODS IN PROBLEMS OF THE EARTH'S ROTATION

Presidential Address

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It is a great honor and a great privilege to have the duty of opening the discussions of such a distinguished Assembly of astronomers, geodesists and geophysicists.

It is also a great responsibility to be in charge of tracing the past and the future of the research methods in the Earth's rotation as there are many papers on the program of this Symposium dealing with this subject and I am not sure that some authors will not present quite different views from my own. But the reason for organizing a Symposium is indeed to give the opportunity of a confrontation of different opinions and to try to realize a general agreement upon the basic lines of the development of our scientific research.

We have come from different fields of research: astronomy, geodesy, geophysics. I will try to show in this lecture, as clearly as possible, how a synthesis of these disciplines can be found in investigations about the rotation of the Earth. I hope this lecture can serve as an introduction for many more detailed papers that will be presented during this week.

The rotation of the Earth with its theoretical as well as its experimental aspects is the basis of Fundamental Astronomy. It is a matter for surprise that this is the first time that an International Symposium has been organized to discuss this subject.

We must evidently infer that the problem is far from being solved and that some important anomalies are observed which need more correct explanations and more precise measurements.

However it is to be remembered that this famous problem of the Earth's rotation has been investigated by the most prominent scientists.

Laplace was convinced of its importance when he wrote in volume five of his *Celestial Mechanics*: "The whole of Astronomy is based upon the invariability of position of the axis of rotation of the Earth at the surface of the terrestrial spheroid".

During the last century Celestial Mechanics was the privileged branch of Astronomy with the works of Euler, Lagrange, Laplace, Poinsot, Tisserand...

As it is often the case there resulted a kind of breathlessness: all the fundamental work seemed to be done and it seemed that only some details had to be refined.

The first attempts of the founders of Geophysics, Kelvin and Darwin however let them foresee some difficulties as the Earth, an elastic and viscous body, has its figure

P. Melchior and S. Yumi (eds.), Rotation of the Earth, XI–XXIII.

and potential varying with time. These variations are produced by the forces acting upon the Earth and mainly by the external tidal forces due to the Moon and the Sun. At this epoch the instrumental technique did not allow direct measurements of these forces. Only their existence could be detected, and it was useless to develop theoretical computations with high precision.

This is why modern technological developments produce a revolution in Fundamental Astronomy:

(1) Angular measurements have been further improved with the introduction of astrolabes and PZT;

(2) Atomic time standards are currently available;

(3) Precise measurements of tidal forces are possible with recently developed gravimeters, horizontal pendulums and extensometers;

(4) Direct measurements of distances upon the Earth and in the Earth Moon system are possible owing to laser techniques;

(5) Doppler measurements of range rate of satellites provide very useful and precise material for orbit determinations;

(6) Very Long Base interferometry seems to give most promising accuracies;

(7) Electronic computers make it possible to build millions of models of the Earth's interior and to select those that agree with observations made on the Earth's surface.

To appreciate the exact significance of this experimental progress, we must clearly define the respective roles of Celestial Mechanics and Positional or Fundamental Astronomy.

We have to choose a system of reference fixed with respect to the Earth's crust. We cannot do anything else because Observatories are built on this crust.

The differential equations of the rotation of the Earth are referred to this system and their second members are the external forces due to the Sun and the Moon.

These equations contain derivatives with respect to the time and we suppose that we have a uniform time scale.

As the equations are of the second order, their integration in this uniform time scale gives for each perturbing term two integration constants: an amplitude and a phase depending from the initial conditions, that is the conditions existing at the adopted instant $t=0$.

The main objects of positional astronomy are:

(a) to fix the reference directions at instant $t=0$;

(b) to refer the epochs of astronomical measurements to the uniform time scale;

(c) to determine the integration constants by a discussion of all astronomical observations performed in the time interval considered.

These operations would not present major difficulties if the Earth was an absolutely rigid, undeformable body, what rheologists call a Euclid body.

Observations show that this is not the case as many typical deformations may be measured.

However, for a very long time, one could propose the following satisfactory solution of this problem:

(a) the principal axes of inertia of the Earth as reference axes, as the instantaneous axis of rotation is never more distant than 0".3 from the principal axis of inertia;

(b) the period of rotation of the Earth as a time scale;

(c) integration constants deduced with a precision of something like 10^{-3} of the amplitudes.

The well known external perturbations are those due to the attraction potential of the Moon and the Sun which produces several effects:

(1) precession and nutation of both axes of inertia and rotation in space, due to the tesseral part of this potential;

(2) nearly diurnal nutations of the axis of rotation with respect to the Earth itself, due also to the tesseral part of the potential and related to the movement in space by the Poinsot theory;

(3) periodic deviations of the direction of the vertical and variations of the intensity of gravity at each point within the Earth. This phenomenon is called Earth Tides and produces visco-elastic tesseral, sectorial and zonal deformations of the whole of the Earth body. There is an effect, due to the same cause, at the surface on the oceanic tides;

(4) a secular retardation of the Earth's speed of rotation resulting from dissipation of Energy due to internal friction of sectorial Earth tides and superficial friction between oceanic currents and the crust.

This short description of the rotation of the Earth is an ideal scheme and if the Earth was really following these rules it would not have been difficult to produce precise ephemerides and deduce at the same time essential indications about its elastic and viscous properties. This is just the point where astronomers and geophysicists have met the first difficulties not yet solved to day.

We said that the axis of rotation is distant about 0".3 from the principal axis of inertia. In such conditions the rotation of the Earth produces another tesseral tidal potential due to the centrifugal force. This tidal potential deforms slightly the Earth's body and we observe this elastic effect as a lengthening of the free Eulerian period. This is Chandler's discovery, at the end of last century. This tidal deformation also evidently produces internal friction and one should observe a damping in the amplitude of the Chandlerian motion and derive from it a relaxation time which may be interpreted with the help of some rheological model of the Earth.

The Chandlerian phenomenon is of very great importance in this respect because it is, until now, the only geophysical deformation phenomenon of intermediate period. We know indeed very short period effects in seismology (range of seconds) and Earth tides have short periods (range is one half day and one day).

We know also the effects of very long period phenomena such as isostatic effects (post-glacial uplift). But the precision of measurements is such that we can use a Hooke body in the first case and a Newton body in the second case. The Chandlerian phenomenon, with a period of some 430 days, should give us the unique opportunity of checking some more sophisticated rheological bodies.

The results, till now, were very disappointing as the analyses made by many different authors have provided very strange results: a Chandler period varying from 414 to

460 days and a relaxation time running from 10 to 100 yr. Moreover till now no satisfactory explanation has been given for the excitation mechanism maintaining the Chandler wobble.

One can object that the observations in the 70 past years were not precise enough to allow such conclusions and that we have to wait for the very promising new techniques to solve these difficulties. I do not agree with this point of view. The first reason is that even with these new techniques we have to wait for a minimum of six years homogeneous observations to separate the main components of the polar motion and that it will be very difficult to deduce a correct value of the relaxation time from such a short duration of observations.

The second reason is that we have at our disposal data of 70 years with 651 807 observations of star pairs (at the end of 1969), the longest existing series of nearly homogeneous astronomical observations and I am convinced that a better mathematical treatment can be applied now to these numerous measurements.

In any case, we have no right to abandon this enormous amount of work performed by all the astronomers who devoted themselves to these measurements unless we ourselves have made all possible efforts to reduce the observations correctly. Moreover we now have the advantage of using fast computers which our predecessors did not have. The big difficulty lies in the fact that these observations are not absolutely homogeneous. You know well that changes of star catalogues must be introduced to minimize the tremendous effects of incorrect values of screw pitches. In addition to this the number of stations was not constant, some instruments were renewed and observers changed very often, of course.

But the main principle of observation remained exactly the same, that is the Horrebow-Talcott method. To understand the situation correctly, we must explain the fundamental role of screw pitches in this question. The problem is a problem of calibration. In every experimental technique this question is fundamental.

What is the value in seconds of arc of a turn of the screw? What is the stability of this value within the whole telescope field, what is its stability with temperature, with time? What is the precision of these determinations?

To avoid the influence of an error of calibration of the screw pitch in the latitude variation of one station, the Central Bureau, when preparing the catalogue of stars to be used, arranges each group of stars in such a way that the sum of micrometer measurements should practically be zero inside each group. This can be realized for the mean epoch of observations of each program but not for the total duration because the precession effect shifts systematically all the stars of a group in one direction in the telescope field, except for the groups centered on 6h and 18h right ascension where precession is zero.

This is the reason why the Central Bureau had to change the star list every 12 years almost (1906, 1912, 1922–7, 1935, 1955, 1967). There was unfortunately one exception, the program 1935.0–1955.0 which was used for such a long time that many difficulties in the reduction arise for the last years. This long time interval was requested by Sir Harold Spencer Jones, as he wanted to use the observational data obtained by the latitude service in order to determine a new value of the main nutation constant. I think this was an error.

To improve knowledge on screw pitches, the latitude deviations are represented by equations of the form

$$\Delta\phi = \Delta\delta + \Delta R(M_E - M_W)$$

M_E, M_W being the micrometer readings.

It is clear that big errors in declinations vitiate the determination of ΔR.

Now, if ΔR is not correctly determined for each station a fictitious annual component in the polar motion follows from the yearly succession of the observed star groups. This can clearly be seen when comparing provisional polar coordinates as published in the past with the definitive ones and this vitiates all geophysical interpretations. This is the reason why I think that a general revision of ILS data must start with a substantial improvement of the declinations and proper motions in declination. Boss's *General Catalogue* used as basic data for the latitude service reductions contains declination errors very often reaching one second of arc and sometimes more.

The Royal Observatory of Belgium has undertaken a new determination of the declinations of all the stars used by the ILS, with the great Askania meridian circle of modern construction and observing a minimum of 12 positions for each star. As a second step, a catalogue of declinations and proper motions in declination was built in the FK4 system, using all the meridian positions measured since the Bradley epoch, that is some 11 500 positions.

This system has been used by Y. Wako who derived from it a very interesting interpretation of the Kimura *z* term variation with time. Some calculations were performed by Fichera too who obtained excellent agreement between this new catalogue and position corrections derived from the latitude observations themselves. We hope that, using this catalogue, the screw pitch values will be improved and the interpretation of Kimura *z* term clarified.

We have said that astronomical nutations are closely associated with tesseral earth tides. Indeed, each tesseral component in the development of the tidal potential gives rise to a torque producing a circular nutation of the axis of inertia in space. Tides having a period longer than a sidereal day yield a nutation in the clockwise sense while those having a period shorter than the sideral day a nutation in the counter-clockwise sense. The combination of two symmetrical circular nutations gives as resultant an elliptic nutation component.

Earth Tides are very important as they are the only phenomenon in Geophysics for which the exact calculation of the forces acting is possible as well as the comparison of the Earth's body response to these forces.

Much effort has been made since the International Geophysical year to promote new researches in this field and some important results have been obtained:

(1) new very sensitive instruments have been developed: recording gravimeters with a precision of 1 microgal, quartz horizontal pendulums provided with automatic

calibration devices related to a spectroscopic line and having a resolution of 0″0002 and more recently extensometers;

(2) new methods of numerical tidal analysis have been developed, using fast electronic computers.

The purposes in Earth tide investigation, directly related to the rotation of the Earth are:

(a) the determination of Love elastic parameters h, k, l;

(b) the resonance effect on tesseral diurnal waves produced by the earth's liquid core;

(c) the phase lag of the sectorial semi-diurnal waves, the parameter describing the internal friction and hence the viscosity of the Earth.

But here too, the solution of the problem is far from being obtained.

The main difficulty here arises from the fact that the oceanic tides produce a very important contribution to the deformation of the upper crust, called *the indirect effect*.

The *indirect effect* is a combination of:

the varying gravitational attraction of moving water masses;

the loading effect of these masses on the crust;

the change of potential of the Earth itself due to this deformation.

These indirect effects are very important for the semi-diurnal waves because this kind of tide in oceans generally has a large amplitude. Therefore we cannot hope to determine Love numbers from the M_2, S_2, N_2 waves until a correct model of the loading effects on the crust is available.

But I think that in some respects we shall have to solve the inverse problem and to try to determine crustal structure from the anomalies in the indirect effects. In Europe these anomalies are very important in the North-South component.

On the contrary, diurnal waves have very low amplitudes in the Oceans. We have now many Earth tide stations in Europe where we observe a very satisfactory homogeneity in the amplitude factors of diurnal waves. This indeed is of great importance in investigating the liquid core effects on the Earth's rotation, as these diurnal waves are associated with the nutations.

The possibility of a resonance effect was indicated first by Poincaré and by Sloutsky independently.

Later on, Sir Harold Jeffreys developed a theory of which some numerical results were given, just before the IGY, inducing the IGY Committee for Earth Tides to propose experimental investigations on this effect.

Jeffreys and Vicente developed a more extensive theory for two models and Molodensky another one for two other models.

It is evident that, to check these models, the exact calibration of the instruments is fundamental. We meet here the same need as with the screw pitches of zenith telescopes.

I cannot now enter into many details and give a full discussion of these measurements, but only present the result of European stations (Western Europe, Scandinavia, Eastern Europe) compared with theoretical models in Table I.

As the resonance effect due to the liquid core seems to be really experimentally

TABLE I

Theoretical models

Tidal factors

Waves	Doodson code	$\gamma = 1 + k - h$				$\delta = 1 + h - \frac{3}{2}k$			
		JV1	JV2	MO1	MO2	JV1	JV2	MO1	MO2
K_1	165.555	0,714	0,693	0,734	0,730	1,183	1,185	1,136	1,142
P_1	163.555	0,676	0,696	0,699	0,697	1,209	1,172	1,154	1,158
O_1	145.555	0,658	0,658	0,688	0,686	1,221	1,211	1,159	1,164
Semi-Diurnal	–	0,704	0,675	0,686	0,685	1,152	1,188	1,160	1,164

Experimental results
(16000 days of observations)

		$\gamma = 1 + k - h$	$\delta = 1 + h - \frac{3}{2}k$
K_1	165.555	$0{,}749 \pm 0{,}005$	$1{,}140 \pm 0{,}005$
P_1	163.555	$0{,}717 \pm 0{,}018$	$1{,}155 \pm 0{,}030$
O_1	145.555	$0{,}674 \pm 0{,}005$	$1{,}164 \pm 0{,}001$
		horizontal pendulums	gravimeters
$k = 0{,}316 \pm 0{,}010$		$h = 0{,}637 \pm 0{,}016$	$k/h = 0{,}495 \pm 0{,}020$

Nutations

			New proposed values		IAU values (rigid Earth)	
			$\Delta\theta$	$\sin\theta\,\Delta\psi$	$\Delta\theta$	$\sin\theta\,\Delta\psi$
Principal	55.565	165.545 165.565	9.2014	6.8408	9.2100	6.8584
Annual	56.554	ψ_1;164.556	0.0056	0.0579	0.0000	0.0502
Semi-Annual	57.555	P_1/ϕ_1	0.5724	−0.5230	0.5522	−0.5066
Fortnightly	75.555	O_1/OO_1	0.0906	−0.0828	0.0884	−0.0811

demonstrated, we must conclude that such an effect is also present in the amplitudes of the astronomical nutations and that some corrections of these amplitudes are needed.

At the IAU Heidelberg Colloquium on Astronomical constants, I presented corrections deduced from these Earth tide results as given in the last part of Table I. I did not recommend of course immediate changes in the nutation tables as it is not desirable to change the astronomical constants very often. But the question must be kept in mind for a next revision of these constants. The new calculation of ILS data will provide excellent material to check these values, mainly those ten star pairs centered on 6 hr and 18 hr right ascension which have been observed continuously since 1899.

The result obtained for the O_1 wave is practically the static value of the Love numbers. It gives $k = 0{,}316 \pm 0{,}010$; $h = 0{,}637 \pm 0{,}016$; $k/h = 0{,}495 \pm 0{,}020$.

It is known that the condition

$$k/h \leqslant 0{,}504$$

must hold.

This k value corresponds to a Chandler period

$$\tau = 460 \text{ days}$$

the value formerly obtained by Walker and Young by auto-correlation analysis...

We note here how much our ideas have changed since the IGY and the development of precise Earth tide observations: in 1957 the following values $\gamma = 0{,}72 \pm 0{,}02$ and $\delta = 1{,}18 \pm 0{,}02$ $k = 0{,}20 \pm 0{,}08$, were considered as the most probable ones.

Similar evolution of our conceptions can happen from the renewal of our methods of observation of the Earth's rotation. Evidently Earth tide results are needed in other parts of the world but it is not always easy to find sufficiently deep mines to instal instruments like horizontal pendulums. However a great enterprise is in a realisation with a set of high precision gravity meters by Prof. J. T. Kuo of the Lamont Observatory. It consists of transverse profiles across the United States as well as coastal profiles. To solve the problem of calibration, Prof. Kuo has brought three of his instruments to Europe and has installed them simultaneously in the gravity tidal station at Bruxelles Royal Observatory where he achieved some months of observations. Then he displaced his instruments along two transverse profiles in order to connect strongly the US net with the European net.

Several German gravimeters are now or will be in Bruxelles station. Thus this station will operate as a fundamental tidal station for comparison of calibration factors with time, just as Potsdam functioned in gravimetry.

The need of measurements of the tesseral tidal waves in different parts of the world is obvious and that is why Bonn University and the Royal Observatory of Bruxelles decided to organize, with the cooperation of the Norges Geografiske Oppmåling an expedition to Spitsbergen. It was called 'Astro-geo project Spitsbergen 1968–1970'. This place was chosen because tesseral waves have a maximum amplitude in both horizontal principal directions in polar regions only. We have so far obtained one year of measurements with eight instruments (six quartz horizontal pendulums and two gravity meters) in a mine the depth of which is 300 m and its latitude 78° north. The results are very promising and will be presented during the General Assembly of UGGI at Moscow in next August.

The gravity meter measures the vertical component of the tidal deformation. It gives directly the phase angle of the tidal bulge and, accordingly, the parameter essential to estimate the deceleration of the Earth's rotation. However, here again it is not yet possible to present a conclusion.

The reason is the same as before. The tidal waves concerned are the semi-diurnal ones and they are disturbed by the oceanic indirect effect. The result is that the phase of the M_2 wave shows a systematic regional distribution

Western Europe	advance	0°7
Eastern Europe, Mediterranean zone	lag	1°7
U.S.S.R., Asia, Japan	lag	3°5

Moreover the gravity meters used are more or less heavily damped instruments. Damping introduces an instrumental phase lag which is not always exactly known. But it is possible to determine it correctly.

If we admit that the phase lag of diurnal tides represents the effect of the Earth's viscosity we can overcome this difficulty. The phase lag of waves K_1 and O_1 is more uniform than the phase lag of semi-diurnal tides and is practically $-1°$. This gives for the tidal bulge a phase lag of 7° which should explain exactly the retardation of Earth's rotation given by paleontology. That means a lengthening of 2 seconds a day every 100.000 years. It corresponds to about 20% of the heat flow observed at present, assuming that all the heating flows across the Earth's crust.

Of course this must not be considered as a proof but simply shows that there is no contradiction between these different kinds of measurements.

All the phenomena we have described are due to external causes, essentially the tidal luni-solar potential and as we can calculate very accurately this tidal potential we were able to develop a more or less satisfactory theory.

It is far from being so clear when we consider the internal causes of perturbations in the rotation of the Earth. These causes should be responsible for the irregularities in the speed of the Earth's rotation and in changes in the curvature of the polar path. This opens a new and important field of research. Very often in the past one has thought about influences or correlations with earthquake phenomena. This idea receives now support from dislocation theory and some of our colleagues have found correlations with strong earthquakes while others contest this relation. The matter is of such importance that it deserves much attention.

In this respect it is essential to measure correctly the strains in the Earth's crust. Extensometers developed for Earth tides or free oscillations observations will be useful but there are not yet, active seismic areas excepted, many underground stations equipped with such instruments. Here again calibration problems are not always well resolved.

Of most importance, in my opinion, is the measurement of crustal deformations, tilts and strains, in non-seismic areas. Therefore we have developed an important underground geodynamical laboratory at Walferdange, near Luxembourg. It is now equipped with quartz tiltmeters, gravimeters and extensometers and Figure 1 shows the 26 meters quartz tube extensometer. We plan to develop also laser technique as has been done by Vali and others.

The future of the research methods is based upon several new techniques:

(1) Doppler and Laser Tracking of artificial satellites;

(2) Laser distance measurements to the reflectors placed on the Moon;

(3) Very long base interferometry.

The precise determination of satellite orbits will provide important information about the polar motion. For the first time it will be possible to determine, with respect to the Conventional International Origin, both the positions of the pole of inertia and the pole of rotation as well.

This can be easily understood if we look at Figure 2.

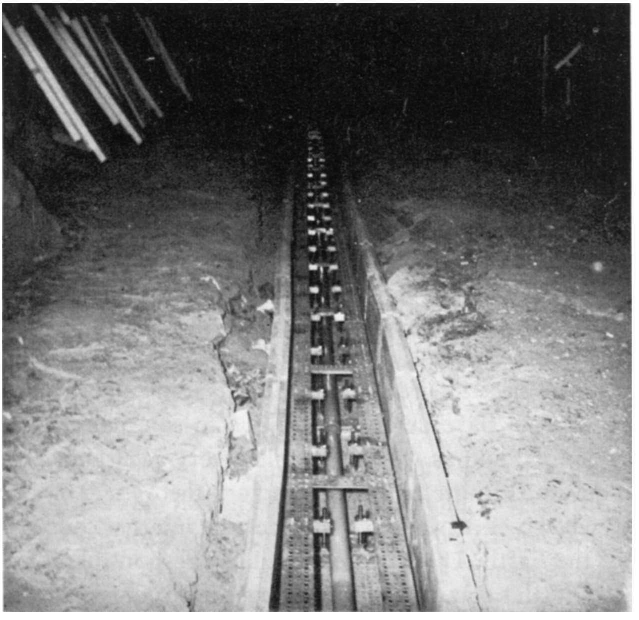

Fig. 1.

The reference frame adopted, by international decision, is a system of axes the Z axis of which passes through CIO. Then, as the axis of rotation moves with respect to CIO, the system is no longer an inertial system and a kinematic effect in the coordinates of a satellite are observable.

For example, the latitude argument of a satellite such as a Transit satellite having a polar orbit presents a variation

$$\Delta u = \psi \cos(\Omega - t_s - A)$$

ψ being the distance of the instantaneous pole of rotation to CIO, A the azimuth of this direction. If the orbit of the satellite has an inclination i, one has obviously

$$\Delta u' = \psi \cos(\Omega - t_s - A) \operatorname{coséc} i \, .$$

This is essentially the base of the method of determination of the pole coordinates used by Anderle and Beuglass from Doppler range rate measurements on four Transit satellites. They obtained the coordinates of the pole with a precision similar to that of the IPMS and BIH. The method is thus very promising for the future.

But there is evidently a dynamic effect which can be determined and may lead to the determination of the position of the pole of inertia. The Standard Earth is also referred to the CIO, and up to now no attention was paid to the coefficients C_{21} and S_{21} of the tesseral harmonics of order 2 because they were considered as negligible.

With very precise data, one can now determine these coefficients related directly to the products of inertia:

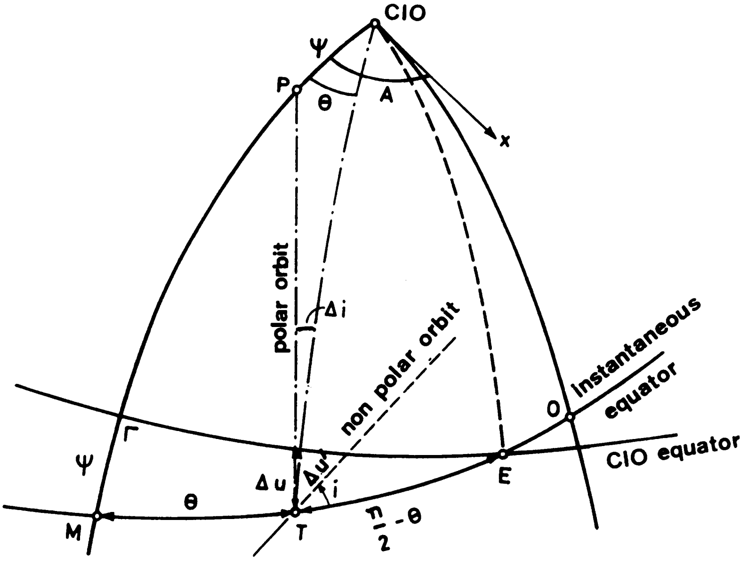

Fig. 2.

$$\theta = OM - OT = A - (\Omega - t_s) = A + t_s - \Omega$$

$$\Delta u = \psi \sin\left(\frac{\pi}{2} - \theta\right)$$

$$\Delta i = \psi \sin\theta$$

$$\Delta u' = \Delta u \operatorname{cosec} i$$

$$\Delta u = \psi \cos(\Omega - t_s - A)$$

$$\Delta i = -\psi \sin(\Omega - t_s - A)$$

$$\Delta u' = \psi \cos(\Omega - t_s - A) \operatorname{cosec} i$$

$$C_{21} = \frac{E}{Ma^2}, \qquad S_{21} = \frac{D}{Ma^2}.$$

If they are different from zero, it means evidently that the system of axes is not the system of principal axes of inertia and that the coordinates of the pole of inertia with respect to CIO are

$$\xi = -\frac{D}{C - A} = \frac{S_{21}}{C_{20} - 2C_{22}}$$

$$\eta = -\frac{E}{C - A} = \frac{C_{21}}{C_{20} - 2C_{22}}.$$

For the first time we have a method of determination of the position of the axis of inertia by astronomical observations. The simultaneous determination of both axes with respect to CIO offers a promising field of research for the dynamics of the Earth's rotation.

The two other new methods proposed in fact have not yet been applied and thus it is very difficult to have a clear idea of the results they will give. They involve a great number of unknowns and to separate their effects may be difficult.

Laser distance measurements of the Moon make it necessary to determine with the same material not only the rotation parameters of the Earth but also those of the Moon (free and forced librations) as well as the orbit parameters and tidal effects on the Moon and on the Earth.

The main problem undoubtedly is that new more powerful methods of fundamental astronomy which will be developed and used during the last part of our century will involve quite different types of systematic errors. As no experimental measurement is free from systematic errors, I have insisted so much in the first part of this lecture on the problems of calibrations.

Hence a comparison between the best classical methods now available and the new ones is to be performed with very great care. At the same time, this will help to discover the sources of the errors and allow of taking them into account. To make possible such a comparison of all kinds of measurements, it is clear that everyone will have to use the same reference system based upon the CIO definition.

To conclude this lecture, I wish to point out that no explanation of the anomalies in the Earth's rotation detected by whatever astronomical technique can be given without developing at the same time and with the same goal the geodetical and geophysical measurements.

So we have to consider simultaneously three fundamental aspects:

The astronomical aspect that is the polar motions, precession and nutations and the determination of the rotation speed.

The geodetical aspect that is the long period or secular crustal motions, the geopotential and its variations with time.

The geophysical aspect, that is the tidal phenomena, the strains in the Earth's crust, the crustal block motions, the drift of the pole and most probably other phenomena not yet discovered.

Geodynamics is the general field involving these three aspects. This is why at the Royal Observatory of Belgium we decided to call the Department in charge with these researches the Department of Fundamental Astronomy and Geodynamics.

I hope that, as a result of this Symposium, we shall recommend the development of theoretical as well as experimental investigations tending towards a synthesis of these different aspects.

There is now an International Geodynamics Project introduced by ICSU

Among the recommendations of the Inter-Union Commission on Geodynamics we find the following

the Geodynamic Commission notes that recent evidence regarding the structure and evolution of Satellite and planetary interiors and of their motions in space is being provided by use of radio and optical methods, as well as by space technology. Theories about the evolution of the earth should therefore be tested by these data and full interchange of information and discussion between scientists working in these fields is essential.

It is essential that Astronomers should take part in this program. My feeling is that it is one of the main tasks of this Symposium to express recommendations in this direction.

The study of the planet Earth is one of the most important research fields for mankind. Astronomers must not forget that it is the basis of Fundamental Astronomy.