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DIAGRAMMATIC REPRESENTATIONS OF THE FUNDAMENTAL ASTRONOMY

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Abstract

Two diagrams are given. The first one shows the relations between concepts, observation and calculation objects, phenomena and products in the field of positional astronomy. The second one shows the relations between the astronomical constants, concepts and quantities. The first diagram represents the procedures for establishing the fundamental reference system, on which scales are graduated by the procedures represented by the second diagram.

1. Introduction

Positional astronomy, the oldest field of natural science, is the most fundamental branch of astronomy and its results have been applied not only to the fields within astronomy but also to the other fields of science, such as geodesy and time determination problem. However, when we reflect on the construction of positional astronomy, we may find various internal intricacies of its contents as well as its complicated links with neighbouring fields of science in and outside of astronomy. This tendency is being accelerated by rapid developments of theories and observational techniques in stellar astronomy, time determination science, geodesy and geophysics, and will become more serious in future.

Therefore, in order that we understand the structure of positional astronomy clearly and construct the research project deleibarately, it seems worthwhile to represent the system of this fundamental field of astronomy by diagrammes or bird's-eye views.

2. System of positional astronomy

1) Principle of diagram composition

Positional astronomy may generally be defined as the field of science to investigate positions and motions of heavenly bodies. In order to investigate the characters of positions and motions we must at first set a coordinate system of space and time. Hence, the essential functions of positional astronomy are:

(1) to establish a coordinate system of space and time, and

(2) to investigate positions and motions of heavenly bodies on the basis of this system.

Here, we shall restrict our discussion within the range in which the Newtonian

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mechanics holds; the effect of the relativity theory is treated as a correction to the Newtonian mechanics. Then, space-time coordinate system is an inertial system. The functions (1) and (2) above are not independent to each other. The system of (1) is chosen from (2) through the Newtonian mechanics, or, in other words, in such a way that the Newtonian mechanics holds. See the papers by Clemence (1966) and Wayman (1966). The most fundamental processes for establishing the inertial system, which are also the progresses of the historical development of positional astronomy, are the derivation of the equator by fixing the pole of the earth's rotation axis, and then the setting the First Point of Aries as the cardinal point on the celestial sphere from the motions of the sun and planets.

For representing the celestial coordinates practically, fixed stars in the back ground sky are employed. For this purpose, a special group of stars, called the Fundamental Stars, is selected from thier high accuracy in position and motion. These processes are interpreted plainly in the Newcomb's Compendium (1906) and a good example is given by Yasuda (1967).

Above process is based on the assumption that the system of the fixed stars composes the inertial system, but the development in stellar astronomy has revealed the systematic motions of fixed stars and the galactic rotation, yielding the contact between positional astronomy and stellar astronomy. Results of posititional astronomy give basic data for stellar astronomy, while the informations from stellar astronomy feed back to positional astronomy to clarify the character of the adopted space-time coordinate system; e. g. various works in deriving the corrections to the Newcomb's precessional constants and equinox belong to the latter category and the Aoki's work (1967) may be remarked as the former category. Further, we should note the programme to establish the fundamental coordinate system with reference to the extragalactic nebulæ.

It is unnecessary to emphasize the mutual relation between positional astronomy and the establishment of time syftems, such as UT, ET and AT and their keepings.

Positional astronomy also contributes substantially to researches in geodesy and geophysics. Knowledges on these sciences feed back to positional astronomy in researching the motions of the pole with respect to the earth as well as to the celestial sphere. Further, in accordance with increase of the observation precision of positional astronomy, geodesy and geophysics provide the values of corrections due to the displacement of observation station of positional astronomy through horizontal and vertical motions of the earth's crust and deflection of the plumb line.

The purpose of making the present diagram is the elucidations of (1) the logical process between the concepts in positional astronomy and its neighbouring sciences, observation objects, and the products, such as ephemeris, star catalogues and time service, (ii) the deriving processes through theory and observation and (iii) the correction effect to the observation and theoretical construction.

2) Explanation of the diagram

The individual explanations of the respective elements and their connections in the diagram are the explanation of positional astronomy itself. The difficulty of such systematic explanation is the reason why the present diagram has been planned to be composed. The meaning of the diagram may be self-evident.

In the diagram, the legend of the symbols are as follows:

concept, notion or idea,
reference object for observation or calculation,
phenomenon,
product.

It is frequently difficult to distiguish the first three categories above from each other, aud such distinction may become sometimes meaningless. The meanings of the lines connecting the elements are:

i) substantially identical but not identical in practice,

ii) logical induction,

iii) deduction

——— by calculation

– – – – – from observation

deduction of precessional constants,

—·—·—·— from positions of fixed stars,

—··—··—·· from positions of extragalactic nebulæ,

—···—···— from motions of the planets,

deduction to evaluate the corrections to the orbital elements of the sun, moon and planets and to the coordinate system of the fundamental stars,

iv) ..... correction.

The main structure of the diagram is:

i) Central and upper left part...Process to establish the fundamental coordinate system,

ii) Upper right part...Stellar astronomy,

iii) Lower left part...Time,

iv) Lower right part...Geodesy and geophysics.

The most fundamental object is the [Pole], while theoretical base is (Newtonian mechanics). [Equatorial coordinates] and (Fundamental coordinate system) should be substantially identical but are not identical in practice due to the precession and the polar motion. In connection with these motions various works are made in the fields of stellar astronomy and geodesy. [Ephemeris] stands for the all products of the works on celestial mechanics deduced from the Newton's law and calculated by e. g. the tables of Newcomb, Brown and Hill.

3) Remarks

The observation precision in positional astronomy has now so progressed that the effect of the relativity theory is required to be taken into account in many cases.

Though in the present diagram the relativistic effects are treated as corrections, the rigid establishment of the space-time system in the frame of the Newtonian mechanics itself will make the character of the relativity effect clearly.

Correction for the refraction of light is merely a technical problem and is not included in the diagram.

Our diagram shows merely the present status of the structure of positional astronomy. With new discovery by observation and development of theory, new elements and connecting lines should appear in the diagram.

3. System of the astronomical constants

1) Composition of the diagram

In the present section it is intended to clarify the system of basic geometrical and physical dimensions or quantities, viz. astronomical constants, for describing the graduation of coordinate axes, and positions and motions of heavenly bodies, which form the foundation of producing the ephemerides.

The system of astronomical constants must be self-consistent, i. e. their numerical values should satisfy the mutual relations theoretically and also be compatible with observations (e. g. de Sitter, 1938, and A. E. Suppl. 1961). By the system we shall mean not only the assembly of values of the constants but also relationship. We aim at investigating the consistency by representing diagrammatically the interrelations within the system.

The diagram is constructed on the basis of the IAU System 1964. The symbols used are:


Defining constants,


Primary constants, planetary masses, and orbital elements of the sun, moon and planets,


Auxiliary constants,


Derived constants,


Other concepts and quantities,

Procedure for deriving a constant,

Procedure to evaluate a constant by theory,

Procedure to evalute a constant from observation,

Correction to be applied.


Newcomb's system,

Adoption from the Newcomb's system.

Arrows on the lines denote the direction of procedure for conventional derivation. In principle backward procedures exist. As for the processes to determine the precessional constants from observations, refer the diagram of positional astronomy.

2) Remarks

Most of the current values of the constants have been obtained on the basis of projected positions of heavenly bodies on the celestial sphere. It is expected that

in accordance with the development of space-probe techniques and electronics **GE**, **GS**, **GM** and **GP** (**P**=mass of a planet) and distances will be more accurately determined, while the relativistic effect on time-scale will be clarified by the experiment on space-probe. In such case the system of constants might be improved, as the above quantities would be of greater weight. The direction of our research project on the system of constants for such revision may be suggested by the diagram by tracing the effects of changes in these fundamental quantities to the others.

References

Aoki, S. 1967; Pub. Astr. Soc. Japan, **19**, 585.
Clemence, G. M. 1966: Quart. J. Roy. Astr. Soc. **7**, 10.
de Sitter, W. 1938: B. A. N. 8, 213 (edited and completed by D. Brouwer).
Explanatory Supplement to A. E., 1961, p. 168.
Newcomb, S. 1906: A Compendium of Spherical Astronomy.
Wayman, P. A. 1966: Quart, J. Roy. Astr. Soc. **7**. 138.
Yasuda, H. 1967: Ann. Tokyo Astr. Obs. (II), **10**, 113.

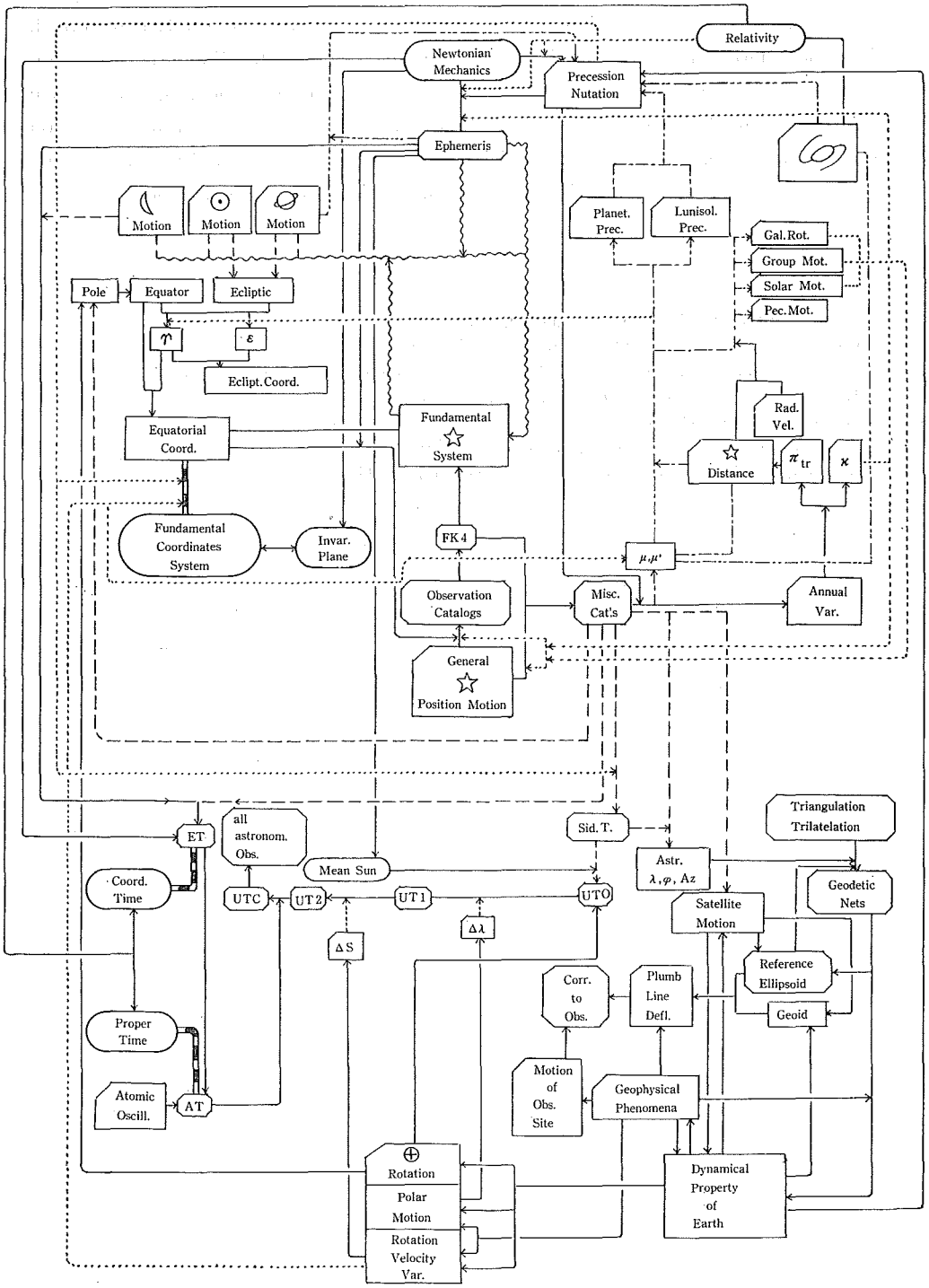

Fig. 1 System of Positional Astronomy

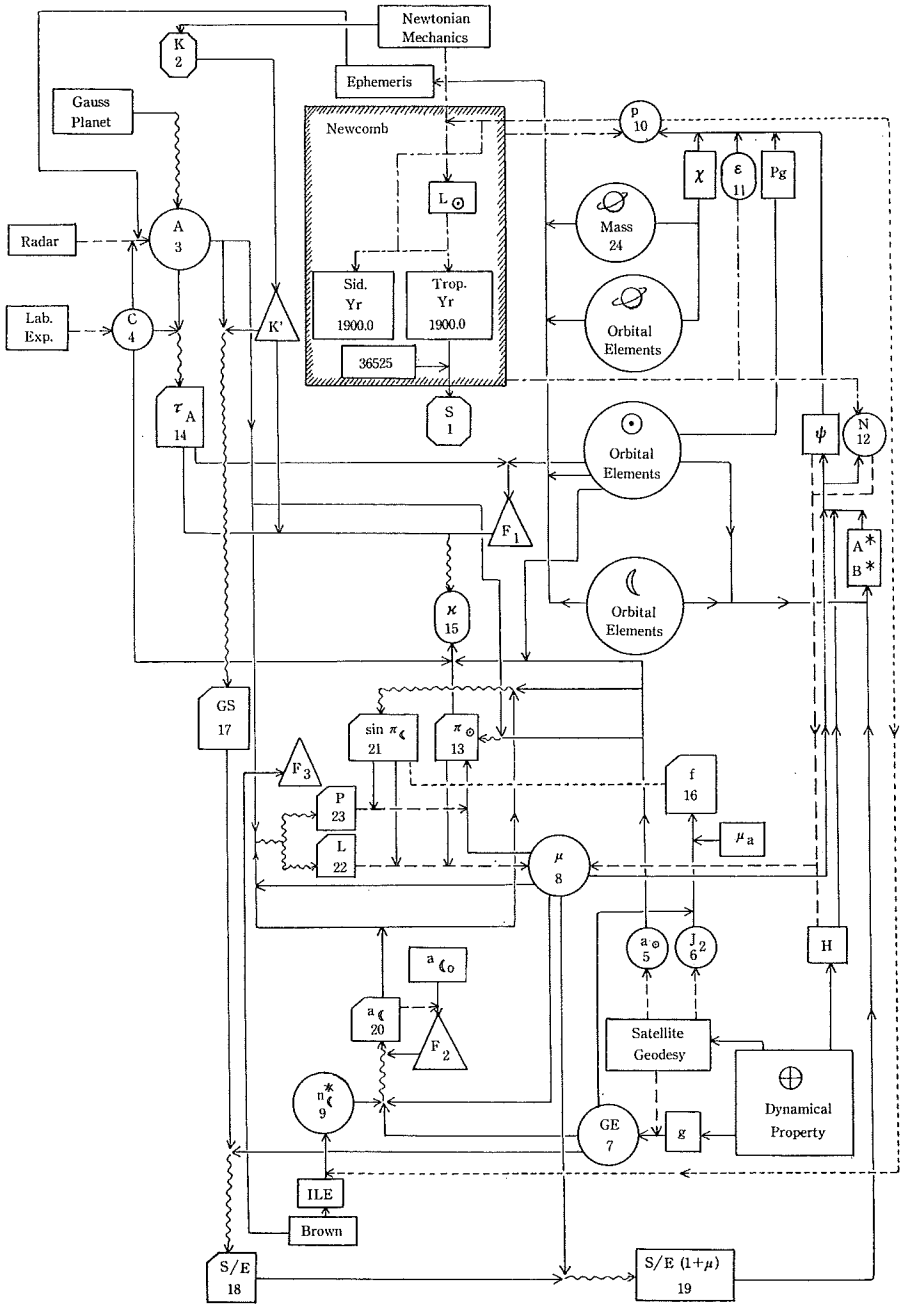

Fig. 2 System of Astronomical Constants