*A Giant Step: from Milli- to Micro-arcsecond Astrometry*
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# Astrometry course at University of Tokyo

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**Abstract.** The astrometry course at Department of Astronomy, University of Tokyo, is reviewed as an example of educational efforts for top-class students, the possible candidates of professional astronomers, in Japan. The method of teaching is unique in the sense that it gives lectures by using *incomplete* text books both as MS Powerpoint slides posted at a web site, http://chiron.mtk.nao.ac.jp/ toshio/education.html, and as printed materials in the form of self-study notebooks. Also there are self-study notebooks on the related issues; the courses of relativistic astrometry, of rotational motions, of numerical astronomy, and of orbital motions, the last of which is under development.

**Keywords.** astrometry, education

## 1. Introduction

We report by this short article our efforts to teach the very basics of astronomy, astrometry, to students in astronomy course. In Japan, a very limited number of universities with Department of Astronomy offer a complete program of teaching astronomy. One rare exception is the University of Tokyo (UoT).

This university is one of the universities with the emphasis on graduate-course education. As a result, the number of graduate students are many more than that of undergraduates. In the case of Department of Astronomy, which is a branch of Faculty of Science, we welcome around two dozen new graduate students and 10 undergraduates each school year. This means that more than a half of UoT graduate students are not educated in the manner the UoT undergraduate students are.

To mitigate this situation, we select three basic courses to teach both the undergraduate students and graduate students without dedicated astronomy course in their curricula. The astrometry is one of the three. The other two are the optical observational astronomy and the galaxy dynamics. This is an exception in the days of lacking astrometry courses worldwide.

At any event, the astrometry or the positional astronomy in its old name has been taught at UoT by famous scholars such as Profs Yoshihide Kozai in 70's, Gen-Ichiro Hori in 80's, and Masanori Miyamoto in 90's. Since 1998, the author has taken on this important task until now.

## 2. Contents of course

The current style of course is to teach basic concepts of astrometry in one semester. Actually the course is scheduled for the first semester, which is April to July in Japanese academic year, of the fourth year undergraduate students and freshman graduate students. The form of teaching is ordinary. Namely, we give 90 minute lecture in 15 consecutive weeks. Since it is rare to have all 15 classes as scheduled, we design the course to consist of one introduction and 11 topics. The selected topics are; (1) Observation, (2) Time, (3) Space, (4) Coordinate System, (5) Motion of Celestial Bodies, (6) Rotation,

(7) Earth Rotation, (8) Keplerian Motion, (9) Signal Propagation, (10) Least-Squares Method, and (11) General Relativity Effects.

Each topic, which is aimed to be taught in 90 min class, is composed from around a dozen items. For example, the topic of "Signal Propagation" is divided into the following subtopics; (a) One-Way Propagation, (b) Passive Observables, (c) Equation of Light Time, (d) Light Direction, (e) Aberration, (f) Parallax, (g) Doppler Shift, (h) Propagation Delay, (i) Refraction, (j) Multi-Way Propagation, (k) Round-Trip Propagation, (l) Interferometric Observation Equation, and (m) Arrival-Time Observation Equation. Finally, each subtopic consists of a few MS Powerpoint slides. This number would be the maximum if considering the time for each subtopic is several minutes at most. The detailed content is available at the author's home page shown below.

## 3. Self-study note

None of the previous lecturers of astrometry at UoT adopted standard text books on astrometry. Rather they gave lectures based on their own original manuscripts. Unfortunately none of them are published or available in any form. To change this situation, in 2002, the author started to publish the materials in an easy way, i.e. posting them in downloadable files in the PDF format, MS Powerpoint file, or plain ASCII text, at the author's web site;

`http://chiron.mtk.nao.ac.jp/~toshio/education.html`

For the educational purposes, especially to encourage students to think by themselves, we intended to provide not every detail of the topic but only selected key descriptions. Besides the astrometry course, we created similar materials on the related fields such as the general relativistic astrometry, the rotation dynamics, and the numerical astronomy in the chronological order of preparation. Also we prepared an introductory course of astronomy, the contents of which is basic and general but with an emphasis on astrometry.

Currently available are the following materials; (i) Theoretical Astrometry, in English, self-study notes, 214 pages, 3.9MB, `Astrometry(Note-BW).pdf`, (ii) Rotational Dynamics, in English, self-study notes, (Vol.1) 183 pages, 0.6 MB, `rotation/Rotation1_e.pdf`, (Vol.2) 178 pages, 0.7 MB, `rotation/Rotation2_e.pdf`, (iii) General Relativistic Astrometry, in Japanese, full text, 75 pages, 0.5MB, `astrometry.pdf`, (iv) Numerical Astronomy, in Japanese, MS Powerpoint slides, 519 slides, 6.4MB, `numerical2006.ppt`, and (v) Introduction to Astronomy, in Japanese, for college students/general public, MS Powerpoint slides, (Vol.1) 111 slides, 8.7 MB, `showa2005-1.ppt`, (Vol.2) 210 slides, 13.4 MB, `showa2005-2.ppt`. The first two are available both in English and in Japanese. Meanwhile the remaining three are in Japanese only. Under development is the preparation of self-study notes on orbital dynamics, which will complement that of rotational dynamics. Also, the English translation of Numerical Astronomy is planned in the near future.

Based on about 10 years experience of teaching the astrometry class by using these downloadable materials, we have come to the conclusion that the Powerpoint slides is not sufficient for educational purposes. Then, we initiated freely providing printed materials, or the so-called self-study notebooks. Each page of the notebook consists of one Powerpoint slide in the top half and blank space in the bottom half. The space is for students to take notes or make exercises. Each blank space is covered by lightly-colored graphs of a 4mm×4mm bin size. This is for students to draw diagrams, lists, equations, and/or comparison tables.

A limited number of copies of printed materials are available from the author.

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