

# IAU STANDARDS – ITS FUTURE

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**Abstract.** The ongoing movement of standardization in Fundamental Astronomy was reviewed. Its history was briefly presented with an emphasis on the problems which triggered its creation. The achievements of the first term of the IAU WG on Astronomical Standards were given. The major goals of a second term were presented with the author's view to resolve them.

## 1. Past

### 1.1. —1989

The present movement of the standardization in Fundamental Astronomy was initiated in 1989 when the Sub-Group on Astronomical Constants of the IAU WG on Reference Systems (WGRS/SGAC) was formed to give a report on the possible update of the IAU (1976) system of astronomical constants. Refer to Fukushima (1991) and other related papers which appeared in the proceedings of IAU Colloquium 127. At that time, more than a decade after the adoption of the current IAU system of constants, various questions had come up with the system itself and the philosophy implicitly embedded in it. The apparent problems could be listed as:

1. There had been some confusion on the determination of constants mainly based on the difference in the interpretations of their definitions within the general relativistic framework. See Fukushima et al. (1986).
2. Some planetary masses were obsolete, especially that of Pluto and, as well, those of some outer planets. See Fukushima (1991). Note that the IAU (1976) system adopted the masses before the Voyager observations.

3. The discrepancy of the adopted precession constant was already clear. See Fukushima (1991). This discovery was greatly owe to the precision Earth rotation observations such as conducted by the IERS.

Also, in the author's personal sense, there had been some opinions about our mechanism to authorize the system of constants and other general rules under the name of the IAU. Some unspoken ones might be:

1. We were so slow in keeping up with the cutting-edge information both observational and theoretical.
2. We were so drastic in introducing the changes in creating reference works such as the compilation of nautical almanacs and star catalogs.
3. Sometimes, we recommended systems which are inconsistent themselves or incompatible with those authorized by other organizations.

### 1.2. 1989-1991

During the discussions within the SGAC, we noticed that the problem was not limited within the list of constants to be updated. Imagine to replace the precession constant. A mere revision of this constant never means the way to calculate the precession is updated. We need not only the revised constant of general precession, such as given in the IAU (1976) system, but also a formula to compute the precession matrix as a function of time as provided by Lieske et al. (1977). Then, we reached a conclusion that the scope of revision should be enlarged to cover the actual computational procedure. This matched with the increasing requirements of established routines for basic computations in Fundamental Astronomy. Also, we can not deny that the success of the MERIT standards and the following IERS Standards had spurred us to this direction. Meanwhile, the issues on the general relativistic considerations were the major items of the other two Sub-Groups: Reference Frame and Time. Therefore, the SGAC did not provide a recommended list of constants that time and asked the IAU to extend its activity to study the possibilities to create and maintain the IAU version of the IERS Standards, which we call roughly the *IAU Standards*.

### 1.3. 1991-1994

The Buenos Aires General Assembly in 1991 permitted us to reform the SGAC into a multi-commissions supported working group: the WG on Astronomical Standards (WGAS). The activity of the WGAS in this period was fully reported in the proceedings of the Joint Discussion 14 of the last IAU General Assembly (IAU 1995a). Also, some of its conclusions were adopted as the IAU (1994) Resolutions B11, C6, and C7 (IAU 1995b). Please refer to them for the details. In summary, the WG conducted four

sub-groups: Numerical Standards, Standard Procedures, Electronical Distribution, and Issues on Time. The major conclusions are:

1. To establish the two-tier mechanism for constants: those maintained in a long term for reference works and those frequently revised for up-to-date researches:
2. To make efforts to create the IAU-authorized standard procedures named the SOFA (=Standards Of Fundamental Astronomy).
3. To continue the WGAS to do these tasks.

As a first step of the first item, we recommended the usage of the IAU (1976) System for reference works and provided the IAU (1994) File of Current Best Estimates of Astronomical Quantities for research use, which is published in the proceedings of JD 14 mentioned above. Here, we reproduce it in a compact form.

Also, the consideration on general relativistic definitions of astronomical units and constants was given as its homework for next three years. We should mention that a new fundamental constant  $L_C$  has been introduced: the scale factor or the conversion factor among the newly introduced multiple timescales based on the general relativistic considerations. See details in Seidelmann and Fukushima (1992) and Fukushima (1995).

## 2. Present

### 2.1. CONSTRUCTION AND POLICY

At the Hague General Assembly in 1994, a new layer was introduced into the IAU structure: Divisions. Since all the Commissions supporting the WGAS (Commissions 4, 8, 19, 24, and 31) belong to the Division 1, the WG has become one of WGs under the Division 1, automatically. Based on the consultation with Presidents/Vice-Presidents of these Commissions, the Division 1 President has nominated the author as the Chair of the WGAS for its second term, namely for 1994-1997.

To comply with the given missions, we have reorganized the WGAS into three sub-functions: the Maintenance Committee (of Numerical Standards) headed by Dr. D.D. McCarthy, the Reviewing Board (of SOFA) chaired by Mr. Patrick T. Wallace and the Sub-Committee on General Relativistic Issues (on Units and Astronomical Constants) lead by Prof. Victor A. Brumberg. Together with more than 30 Members, who substantially do the jobs, we will continue to invite opinions from the wide communities of Fundamental Astronomy, Earth rotation studies, space geodesy and related sciences, through an electronically published newsletter named IAU/WGAS/Circulars. The activity of the WG will be mainly kept by E-mail exchanges among Members and informal and open discussions held on the Circulars, as we did in the last term.

TABLE I – IAU (1994) File of Current Best Estimates of Astronomical Quantities

Name	Value	Units	Ref
<b>Defining Constants</b>			
$k$	0.01720209895	$[au^3/day^2]^{1/2}$	
$c$	299792458.	$m/s$	
<b>Primary Constants</b>			
$L_C$	$1.4808268452(1) \times 10^{-8}$		[10]
$\tau_A$	499.00478642(7)	$SI : s$	[3]
	499.00478384(7)	$TDB : s$	
$p$	5028.83(4)	$"/cy$	[13]
	5028.83(3)		[14]
$\epsilon$	84381.412(5)	$''$	[3]
$M_{Sun}/M_1$	6023600.(250.)		[1]
$M_{Sun}/M_2$	408523.71(6)		[2]
$M_{Sun}/M_B$	328900.56(2)		[3]
$M_{Sun}/M_4$	3098708.(9.)		[4]
$M_{Sun}/M_5$	1047.3486(8)		[5]
$M_{Sun}/M_6$	3497.898(18)		[6]
$M_{Sun}/M_7$	22902.98(3)		[7]
$M_{Sun}/M_8$	19412.24(4)		[8]
$M_{Sun}/M_9$	$1.35(7) \times 10^8$		[9]
$M_{Moon}/M_{Earth}$	0.012300034(3)		[3]
$G$	$6.67259(30) \times 10^{-8}$	$m^3/(gs^2)$	[15,16]
$GM_{Earth}$	$398600.4415(8) \times 10^9$	$SI : m^3/s^2$	[12]
	$398600.4356(8) \times 10^9$	$TDB : m^3/s^2$	
$a_E$	6378136.55(1)	$m$	[15,16]
$W_0$	62636857.5(1.0)	$m^2/s^2$	[17]
	62636856.26(1.0)		
$J_2$	$1082.6269(6) \times 10^{-6}$		[15,16]
$1/f$	1/298.257(1)		[15,16]
$\omega$	$7292115. \times 10^{-11}$	$rad/s$	[15,16]
<b>Derived Constants</b>			
$L_B$	$1.550519747(3) \times 10^{-8}$		[10]
$c\tau_A$	149597871475.(30.)	$SI : m$	[3]
	149597870700.(30.)	$TDB : m$	
$M_{Earth}/M_{Moon}$	81.30059(1)		[3]
$GM_{Sun}$	$1.32712440042 \times 10^{20}$	$m^3/s^2$	[3]
$M_{Sun}/M_{Earth}$	332946.05(2)		[3]

Table I (cont.) - References

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## 2.2. TOOLS

At the time of writing this summary, we are glad to report that some tools have been prepared already. Among them, we should refer the completion of new JPL DE403 planetary ephemeris which is fully compatible with the IAU (1994) Best Estimates *and* the IERS reference frame. Refer the report by Dr. Standish in the same proceedings. Another work was done by the Bureau des Longitudes: new formulas on the precession calculation. It is remarkable that they contain partial derivatives with fundamental constants such as the planetary masses so that they can keep up with the future

change of the constants. Apart from astronomical works, the recent spread of Internet and World Wide Web (WWW) has drastically changed the way to retrieve massive and up-to-date information. For example, thanks to Prof. R.B. Langley of Univ. of New Brunswick, Canada, all the WG's electronic newsletters, the IAU/WGAS/Circulars, are accessible via WWW, under the Canadian Space Forum archive whose URL is

<http://www.unb.ca/Geodesy/CANSPACE.html>

See IAU/WGAS/Circular No.97 for the details. This and the development of inexpensive and capable computers will reduce the time and labor which will be required to create, maintain and distribute the IAU Standards. As for the non-networked distribution, two will remain as major ways: the 3.5" Floppy disks for small data such as the list of constants and softwares and CD-ROMs for large data such as the ephemerides and/or star catalogs. Fortunately, the recent technological development makes it easy to press CD-ROMs much less expensively.

### 3. Future

Since the future trend is difficult to predict and the activity of the WGAS in the second term has just begun, here I would like to present very personal views of mine. By the time of this publication, the situation will be different. Please keep in touch with us through subscribing our electronic Newsletter, the IAU/WGAS/Circular.

#### 3.1. MEANING OF STANDARDS

So far, the IAU System of Constants have seemed to be more compulsory than it was intended. In proceeding the new two-tier mechanism on astronomical system of constants, we would like to confirm that the major purpose of these systems is to serve a reference. Also, this can be said with the procedures. In this sense, the word *Standards* is more suitable. No one has to follow these standards. They are there to be used as a scale. Everyone can express his/her parameters, model or method by noting the (small?) differences from the standards, which finally makes it easier to compare with others.

#### 3.2. PRECESSION

Now that the planetary masses were effectively revised in the IAU (1994) Best Estimates and realized by the JPL DE403 planetary/lunar ephemeris and that the schedule of the present and the near future space explorations within the solar system makes us feel that these Best Estimates will be not so drastically changed in the possible near future, the most important

and urgent item remained can be the precession constant. Unfortunately the situation is not so clear-cut, since this issue is tightly connected with the problem of the current IAU nutation theory, especially its long-periodic terms. This issue is being discussed by the WG lead by Dr. Dehant. Anyway, it is clear that the present adopted value needs a correction of around  $3.0''/\text{cy}$ . I feel that the amount of revision is not so controversial. Rather the timing of introduction could be. If a consensus on the next generation nutation theory will be formed within a few years, I personally think that to recommend the introduction of a new precession constant from J2000.0 would be most convenient.

### 3.3. OPEN POLICY ON SOFA CREATION/MAINTENANCE

Another issue is how to construct the SOFA actually. For this purpose, I have much expectation on the anonymous public. Though it might sound too revolutionary, we are seriously considering to invite the ideas and contribution both on the submission of software and on their reviewing procedure 1) from the astronomers in other fields via announcing our activities through ADASS and other conferences on the general astronomical/astrophysical data archiving and software and 2) from the really general public through already established computer-based electronic forums such as the `sci.astro.research` USENET newsgroup. I hope that this will bring us great merits: to save huge labors and time of the SOFA center, to advertise the IAU's activity and to introduce the new and fresh energy into our fields.

### 3.4. COLLABORATION WITH THE IERS AND IAG

Apart from the collaboration with the other IAU WGs such as those for Non-Rigid Earth Nutation Theory and Reference Frame, which is our obligation, we should seek the way to have substantial cooperation with two outside organizations: IERS and IAG. The IERS has its famous Standards Committee, which has continuously published the IERS Standards (McCarthy 1989, 1992, 1996). Also, the IAG has its own dedicated Special Committee, SC on Fundamental Constants, under the Section V. To enhance these collaborations, we have done a few things. First, we have adopted the two-tier system on maintaining the system of constants, which was originally introduced in geodesy. Thus, the two closely-related fields, astronomy and geodesy, have had a similar mechanism to refer standard values of constants. Also, we are very glad to welcome Dr. McCarthy as the Head of Maintenance Committee of our WG. This will be a great step toward the fusion of similar activities, which are now conducted in separately in the IAU, IERS and IAG.

### 3.5. KYOTO, 1997

The next General Assembly will be held in Kyoto, Japan, during the last two weeks of August, 1997. We are anticipating to hold a Joint Discussion similar to the JD 14 we had in the Hague. Though it would be much earlier, we are also seeking a possibility to propose a satellite IAU Symposium together with other WGs in the same field; say together with the Non-Rigid Earth Nutation Theory WG chaired by Dr. Veronique Dehant and the WG on Reference Frame headed by Dr. Leslie V. Morrison.

## 4. Conclusion

We presented a quick summary of the activities of WGAS and its predecessor, WGRS/SGAC since 1988. Also the view on its future movement is given. However, please understand that this view is just one of the possible choices, and the actual policy of the WG will be and should be decided through a diverse discussion among the astronomical and other related communities. Not the Members themselves but YOU, who are reading this note, determine the future of this movement! To catch up with the current trend and to reflect your opinions to the activity, please start free subscription of the WGAS's electric newsletter, IAU/WGAS/Circular. To do this, you only have to send a request to the author

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Let's join to discuss the most essential and stimulating issues in Fundamental Astronomy: the *IAU Standards*.

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