

SOFA—an IAU service fit for the future

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Abstract. Standards of Fundamental Astronomy (SOFA) is an International Astronomical Union (IAU) service that provides accessible and authoritative algorithms and procedures that implement standard models used in fundamental astronomy. This paper summaries the current status, noting the changes during 2009-2012, and discusses issues that may arise in the future.

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1. Introduction

Standards of Fundamental Astronomy (SOFA) is an activity of IAU Division I. It was instigated in 1994 by the Working Group on Astronomical Standards, chaired by Toshio Fukushima. To accomplish its task SOFA is made up of three parts: a board of experts, a collection of software, and a web site—the SOFA Centre—that makes the software accessible to everybody. SOFA is described in *Scholarpedia* (6(1):11404).

2. The SOFA Board

In order to be authoritative and maintain IAU standards, SOFA has a Board of experts that produces and validates the material. Upon his retirement in March 2010, Patrick Wallace stepped down as chair (with acknowledgements and thanks) and Catherine Hohenkerk was elected as his replacement. The Board were saddened by the death of Anne-Marie Gontier, who provided a strong link with the Observatoire de Paris. Board members belong to most of the Commissions of IAU Division I as well as C5, Division XII and the Working Groups on FITS and Astronomical Data. Brian Luzum represents the International Earth Rotation and Reference Systems Service. SOFA welcomed new board members Nicole Capitaine, William Folkner, George Hobbs and webmaster Steve Bell.

3. The SOFA Center

The SOFA Centre—the public face of SOFA—is at www.iausofa.org. In January 2010, the web site was updated and streamlined and a lot of work was required on compliance, particularly to minimize accessibility issues for all types of users. New features include user registration, “News” items and a search facility. The terms and conditions have been relaxed so that it is not mandatory for installers to acknowledge SOFA, thus facilitating inclusion of the SOFA libraries in the Debian operating system release. However, we remind our users that their acknowledgement matters.

Over the last three years we have issued three major releases; introducing (1) transformations between geodetic and geocentric coordinates, (2) transformations between time scales, and (3) an update for the leap second at the end of June 2012, and minor release 9a in July. At the time of the 9th release on 2012 March 1 (release numbers unified) there were 619 registered users. On average, the web site receives over 1200 unique visits each

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month. This average has risen from 789 in 2009 to 1244 now. There were 2836 downloads of a whole library for the 8th release (2010 December 31) and 1205 for the 9th release, split $\sim 40:60$ for Fortran and ANSI C. The total size of the web site, including the archive, is ~ 250 Mbytes.

4. The SOFA Software

The SOFA collection provides the building blocks that enable users to write their own applications using authoritative methods. The library of routines (Fortran and ANSI C) currently has 187 routines, of which 59 are *canonical* and support IAU resolutions. During the last triennium, 16 canonical routines were added to time scales, while five routines were added for geocentric/geodetic transformations. Routine DTDB has been degraded to “support” status. In total there were 23 additional routines.

Geodetic/Geocentric: In this category there are the routines GD2GC, GC2GD, GD2GCE and GC2GDE and the canonical routine EFORM that gives the parameters for the WGS 84, GRS 80 and WGS 72 ellipsoids.

Time Scales: SOFA recognizes seven time scales, namely TAI, UTC, UT1, TT, TCG, TDB and TCB. The strategy is to provide routines that link adjacent pairs of time scales (e.g. TAIUTC and UTCTAI). This is the simplest scheme, and gives the user the most flexibility. It also allows users to provide the supplementary quantities such as ΔT and UT1–UTC, which either cannot be predicted or for which there are model choices to make. The routines use SOFA’s two-argument Julian date convention, which enables rounding errors to be minimised. The routines DTF2D and D2DTF handle the conversion between civil date and time and Julian date (or, in the case of UTC, quasi-JD) and vice versa. In the case of UTC this deals with leap seconds, when it is correct to report 60... seconds. Importantly, the routines preserve precision by ensuring that the tiny differences are added to (or subtracted from) the smaller of the two date arguments.

Documentation & Tools: The manual contains the introductory comments of all the routines giving a complete specification. The “cookbooks” contain more descriptive material including examples. The latest is *SOFA Time Scale & Calendar Tools*, while the previous cookbook is *SOFA Tools for Earth Attitude*. SOFA provides the Unix `make` file to build the library as well as an improved validation program. This calls all the routines at least once and checks, to some specified precision, the calculated results against stored values, which have been produced independently using quadruple precision.

5. The Future

We are currently working on code for the effects of parallax, light-time, light-deflection and aberration, balancing the need for simple interfaces with accuracy requirements. Other coordinate transformations are being considered (e.g. equatorial/ecliptic/galactic).

Making SOFA available in other languages has been discussed. However, new code must be written to an agreed standard and the resulting output verified by the Board.

The position of SOFA within Division I will be reviewed during the 2012-2015 restructuring of the IAU. SOFA provides a service to all users requiring standard fundamental astronomical software. This activity is provided by a small and dedicated team.

Acknowledgements

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