

DIVISION A / FUNCTIONAL WORKING GROUP STANDARDS OF FUNDAMENTAL ASTRONOMY (SOFA)

CHAIR	Catherine Y. Hohenkerk
MEMBERS	John Bangert,
	Steven Bell,
	Nicole Capitaine,
	William Folkner,
	Mickaël Gastineau,
	Jinling Li,
	Brian Luzum,
	Zinovy Malkin,
	Jeffrey Percival,
	Wendy Puatua,
	Scott Ransom,
	Patrick Wallace

TRIENNIAL REPORT 2015-2018

1. Introduction

Standards Of Fundamental Astronomy (SOFA) was designated a Functional Working Group of Division A, following the restructuring at the 2015 IAU General Assembly (GA). SOFA continues its task of establishing and maintaining an accessible and authoritative set of algorithms and procedures that implement standard models used in fundamental astronomy.

This service for the astronomical community and others is facilitated by the SOFA website at www.iausofa.org, which provides access to the Fortran and ANSI C software libraries. However, the content is reliant on the expertise of the international Board members. This report highlights the need for SOFA to continue.

2. Developments during the past triennium

Since the GA in 2015, there have been three major and two minor releases. The major releases were in 2016 May 3 (release 12), 2017 April 20 (release 13), with the latest release 14, in 2018 January 31.

The scope of the software has been expanded considerably from the original 27 astronomy routines of the first release in 2001. There are now 185 astronomy routines, with 19 routines added during this triennium. Of these, 59 are canonical and directly support IAU resolutions. The new routines include providing a long-term (± 200 millennia) precession model and transformations between ecliptic and equatorial coordinates (release 12). A new category in the latest release (14) deals with transformations in the tangent plane (or gnomonic) projection. We have also added simple routines to convert between hour angle, declination and horizon coordinates (elevation (altitude), azimuth) and to calculate the parallactic angle. The value and nomenclature for the astronomical

unit (au) was updated to the standards of the IAU 2012 resolution in major release 13. This required some effort, involving changes to many routines and cookbooks to ensure correctness and consistency throughout. There were also three minor releases, mostly making improvements within the code and documentation. However, the release in 2016 July was required to introduce the leap second for the end of December 2016.

As a result of a user request and after much discussion and some trial software (provided by Mickaël Gastineau), the Board ultimately decided to provide special and unique licensing conditions for the single leap-second routine. Thus users may modify this one routine without removing the IAU designation from the name. In practice this means that users may access their own procedure (perhaps using external files) to obtain the required information, rather than having to re-link their software every time there is a SOFA release when a leap second is introduced. This change was implemented in the latest release (14).

To promote SOFA, posters have been displayed at the IAU GA 2015 and the Science of Time symposium (2016 July). The latter also resulted in the chapter *IAU Standards of Fundamental Astronomy: Time and Date* (Hohenkerk 2016) in the symposium's proceedings. Also in 2016 I gave an invited review talk about "SOFA & IAU Standards" over the last 22 years at the workshop "Understanding the Earth core and nutation", held at the Royal Observatory, Belgium. At this workshop and the 2017 Journées des Systèmes de Référence et de la Rotation Terrestre meeting (Alicante) we joined with Fundamental Standards Commission (A3), and the Working Groups for Numerical Standards in Fundamental Astronomy (NSFA) and Cartographic Coordinates and Rotational Elements (CCRE) in submitting a joint poster. Following the Alicante meeting I met with a few people from their university and gave a talk about SOFA highlighting SOFA's Earth attitude tools.

There are three recognized implementations of SOFA provided by others. There is the Java version by Dr Paul Harrison of Jodrell Bank Centre, University of Manchester. Essential Routines for Fundamental Astronomy (ERFA), produced by the AstroPy group, is a library which copies the ANSI C version, but it is not IAU-badged and thus may be changed by anyone. Lastly there is the World Wide Astronomy version, by Attila Abrudá, which is a set of C# algorithms and procedures.

The website statistics indicate that release 13 (2017 April to 2018 January) was downloaded 3111 times, with 34% being for the Fortran library. During 2017, there were on average 4339 unique visitors per month. Thus, there has been a steady increase over the last ten years from a monthly average of 769 in 2008 to 1922 per month for 2015 and 2283 per month in 2016. We also now have 821 registered users. It is unclear how to quantify the use of SOFA. Registered users are not necessarily individual users, and visitors to the website do not necessarily use SOFA. However, we do ask users to acknowledge their use of SOFA. It is worth noting that the website not only provides a means to download the libraries, but individually any of the three Cookbooks (Fortran or ANSI C), the documentation and any individual routine may be viewed and copied/downloaded.

After the last GA (2015), in an effort to introduce new experience and skills onto the Board, we welcomed two new members, Wendy Puatua (USA) and Mickaël Gastineau (France). Looking forward, the SOFA Board will also need a new Chair.

3. Closing remarks

In summary the SOFA libraries continue to provide the astronomical community with a set of well-tested independent standard routines that support IAU resolutions. This gives users the tools for easily implementing and learning about fundamental astronomy

algorithms and procedures, such as Earth attitude, for use in research, in applications, and importantly in testing their particular implementation. This IAU service should continue.

I acknowledge and thank all the Board members and their host institutions for their work. In particular Patrick Wallace, who provides the coding, and the webmaster, Steven Bell. In particular the Board thank the United Kingdom Hydrographic Office for hosting the SOFA website.

Catherine Y. Hohenkerk
Chair of SOFA Board

References

Hohenkerk, C.Y., 2016, *IAU Standards of Fundamental Astronomy: Time and Date* in The Science of Time 2016, Astrophysics and Space Time Proceedings Vol. 50, p. 159, P. Gabor, E.F. Arias, L. Combrinck, C.Y. Hohenkerk, P.K. Seidelmann (eds.) Springer, DOI 10.1007/978-3-319-59909-0