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SOFA Astronomy Library  
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## PREFACE

The routines described here comprise the SOFA astronomy library. Their general appearance and coding style conforms to conventions agreed by the SOFA Review Board, and their functions, names and algorithms have been ratified by the Board. Procedures for soliciting and agreeing additions to the library are still evolving.

At present the routines are all written in Fortran 77, complying with the ANSI standard (X3.9-1978) except in two respects:

- (1) All routine names are prefixed with the string "iau\_". If necessary, the string can be removed globally; the result is correctly functioning code.
- (2) All routines include an IMPLICIT NONE statement. This can be removed without affecting the behaviour of the code.

If the "iau\_" string and/or the IMPLICIT NONE statements are removed globally, the resulting code is fully ANSI-compliant and is functionally unaffected.

## GENERAL PRINCIPLES

The principal function of the SOFA Astronomy Library is to define algorithms. A secondary function is to provide software suitable for convenient direct use by writers of astronomical applications.

The astronomy routines call on the SOFA vector/matrix library routines, which are separately listed.

The routines are designed to exploit the full floating-point accuracy of the machines on which they run, and not to rely on compiler optimizations. Within these constraints, the intention is that the code corresponds to the published formulation (if any).

Dates are always Julian Dates (except in calendar conversion routines) and are expressed as two double precision numbers which sum to the required value.

A distinction is made between routines that implement IAU-approved models and those that use those models to create other results. The former are referred to as "canonical models" in the preamble comments; the latter are described as "support routines".

Using the library requires knowledge of positional astronomy and time-scales. These topics are covered in "Explanatory Supplement to the Astronomical Almanac", P. Kenneth Seidelmann (ed.), University Science Books, 1992. Recent developments are documented in the journals, and references to the relevant papers are given in the SOFA code as required. The IERS Conventions are also an essential reference. The routines concerned with Earth attitude (precession-nutation etc.) are described in the SOFA document sofa\_pn.pdf.

## ROUTINES

## Calendars

CAL2JD	Gregorian calendar to Julian Day number
EPB	Julian Date to Besselian Epoch
EPB2JD	Besselian Epoch to Julian Date
EPJ	Julian Date to Julian Epoch
EPJ2JD	Julian Epoch to Julian Date
JD2CAL	Julian Date to Gregorian year, month, day, fraction

JDCALF Julian Date to Gregorian date for formatted output

#### Time scales

DAT Delta(AT) (=TAI-UTC) for a given UTC date  
DTDB TDB-TT

#### Earth rotation angle and sidereal time

EE00 equation of the equinoxes, IAU 2000  
EE00A equation of the equinoxes, IAU 2000A  
EE00B equation of the equinoxes, IAU 2000B  
EE06A equation of the equinoxes, IAU 2006/2000A  
EECT00 equation of the equinoxes complementary terms  
EQEQ94 equation of the equinoxes, IAU 1994  
ERA00 Earth rotation angle, IAU 2000  
GMST00 Greenwich mean sidereal time, IAU 2000  
GMST06 Greenwich mean sidereal time, IAU 2006  
GMST82 Greenwich mean sidereal time, IAU 1982  
GST00A Greenwich Apparent Sidereal Time, IAU 2000A  
GST00B Greenwich Apparent Sidereal Time, IAU 2000B  
GST06 Greenwich apparent ST, IAU 2006, given NPB matrix  
GST06A Greenwich apparent sidereal time, IAU 2006/2000A  
GST94 Greenwich Apparent Sidereal Time, IAU 1994

#### Ephemerides (limited precision)

EPV00 Earth position and velocity  
PLAN94 major-planet position and velocity

#### Precession, nutation, polar motion

BI00 frame bias components, IAU 2000  
BP00 frame bias and precession matrices, IAU 2000  
BP06 frame bias and precession matrices, IAU 2006  
BPN2XY extract CIP X,Y coordinates from NPB matrix  
C2I00A celestial-to-intermediate matrix, IAU 2000A  
C2I00B celestial-to-intermediate matrix, IAU 2000B  
C2I06A celestial-to-intermediate matrix, IAU 2006/2000A  
C2IBPN celestial-to-intermediate matrix, given NPB matrix, IAU 2000  
C2IXY celestial-to-intermediate matrix, given X,Y, IAU 2000  
C2IXYS celestial-to-intermediate matrix, given X,Y and s  
C2T00A celestial-to-terrestrial matrix, IAU 2000A  
C2T00B celestial-to-terrestrial matrix, IAU 2000B  
C2T06A celestial-to-terrestrial matrix, IAU 2006/2000A  
C2TCIO form CIO-based celestial-to-terrestrial matrix  
C2TEQX form equinox-based celestial-to-terrestrial matrix  
C2TPE celestial-to-terrestrial matrix given nutation, IAU 2000  
C2TXY celestial-to-terrestrial matrix given CIP, IAU 2000  
EO06A equation of the origins, IAU 2006/2000A  
EORS equation of the origins, given NPB matrix and s  
FW2M Fukushima-Williams angles to r-matrix  
FW2XY Fukushima-Williams angles to X,Y  
NUM00A nutation matrix, IAU 2000A  
NUM00B nutation matrix, IAU 2000B  
NUM06A nutation matrix, IAU 2006/2000A  
NUMAT form nutation matrix  
NUT00A nutation, IAU 2000A  
NUT00B nutation, IAU 2000B  
NUT06A nutation, IAU 2006/2000A  
NUT80 nutation, IAU 1980  
NUTM80 nutation matrix, IAU 1980  
OBL06 mean obliquity, IAU 2006  
OBL80 mean obliquity, IAU 1980  
PB06 zeta,z,theta precession angles, IAU 2006, including bias  
PFW06 bias-precession Fukushima-Williams angles, IAU 2006  
PMAT00 precession matrix (including frame bias), IAU 2000  
PMAT06 PB matrix, IAU 2006  
PMAT76 precession matrix, IAU 1976  
PN00 bias/precession/nutation results, IAU 2000  
PN00A bias/precession/nutation, IAU 2000A  
PN00B bias/precession/nutation, IAU 2000B  
PN06 bias/precession/nutation results, IAU 2006

PN06A bias/precession/nutation results, IAU 2006/2000A  
 PNM00A classical NPB matrix, IAU 2000A  
 PNM00B classical NPB matrix, IAU 2000B  
 PNM06A classical NPB matrix, IAU 2006/2000A  
 PNM80 precession/nutation matrix, IAU 1976/1980  
 P06E precession angles, IAU 2006, equinox based  
 POM00 polar motion matrix  
 PR00 IAU 2000 precession adjustments  
 PREC76 accumulated precession angles, IAU 1976  
 S00 the CIO locator s, given X,Y, IAU 2000A  
 S00A the CIO locator s, IAU 2000A  
 S00B the CIO locator s, IAU 2000B  
 S06 the CIO locator s, given X,Y, IAU 2006  
 S06A the CIO locator s, IAU 2006/2000A  
 SP00 the TIO locator s', IERS 2003  
 XY06 CIP, IAU 2006/2000A, from series  
 XYS00A CIP and s, IAU 2000A  
 XYS00B CIP and s, IAU 2000B  
 XYS06A CIP and s, IAU 2006/2000A

#### Fundamental arguments for nutation etc.

FAD03 mean elongation of the Moon from the Sun  
 FAE03 mean longitude of Earth  
 FAF03 mean argument of the latitude of the Moon  
 FAJU03 mean longitude of Jupiter  
 FAL03 mean anomaly of the Moon  
 FALP03 mean anomaly of the Sun  
 FAMA03 mean longitude of Mars  
 FAME03 mean longitude of Mercury  
 FANE03 mean longitude of Neptune  
 FAOM03 mean longitude of the Moon's ascending node  
 FAPA03 general accumulated precession in longitude  
 FASA03 mean longitude of Saturn  
 FAUR03 mean longitude of Uranus  
 FAVE03 mean longitude of Venus

#### Star space motion

PVSTAR space motion pv-vector to star catalog data  
 STARPV star catalog data to space motion pv-vector

#### Star catalog conversions

FK52H transform FK5 star data into the Hipparcos system  
 FK5HIP FK5 to Hipparcos rotation and spin  
 FK5HZ FK5 to Hipparcos assuming zero Hipparcos proper motion  
 H2FK5 transform Hipparcos star data into the FK5 system  
 HFK5Z Hipparcos to FK5 assuming zero Hipparcos proper motion  
 STARPM proper motion between two epochs

#### Obsolete

C2TCEO former name of C2TCIO

#### CALLS

SUBROUTINE iau\_BI00 ( DPSIBI, DEPSBI, DRA )  
 SUBROUTINE iau\_BP00 ( DATE1, DATE2, RB, RP, RBP )  
 SUBROUTINE iau\_BP06 ( DATE1, DATE2, RB, RP, RBP )  
 SUBROUTINE iau\_BPN2XY ( RBP, X, Y )  
 SUBROUTINE iau\_C2I00A ( DATE1, DATE2, RC2I )  
 SUBROUTINE iau\_C2I00B ( DATE1, DATE2, RC2I )  
 SUBROUTINE iau\_C2I06A ( DATE1, DATE2, RC2I )  
 SUBROUTINE iau\_C2IBPN ( DATE1, DATE2, RBP, RC2I )  
 SUBROUTINE iau\_C2IXY ( DATE1, DATE2, X, Y, RC2I )  
 SUBROUTINE iau\_C2IXYS ( X, Y, S, RC2I )  
 SUBROUTINE iau\_C2T00A ( TTA, TTB, UTA, UTB, XP, YP, RC2T )  
 SUBROUTINE iau\_C2T00B ( TTA, TTB, UTA, UTB, XP, YP, RC2T )  
 SUBROUTINE iau\_C2T06A ( TTA, TTB, UTA, UTB, XP, YP, RC2T )  
 SUBROUTINE iau\_C2TCEO ( RC2I, ERA, RPOM, RC2T )  
 SUBROUTINE iau\_C2TCIO ( RC2I, ERA, RPOM, RC2T )

SUBROUTINE        iau\_C2TEQX ( RBPN, GST, RPOM, RC2T )  
SUBROUTINE        iau\_C2TPE ( TTA, TTB, UTA, UTB, DPSI, DEPS,  
                    XP, YP, RC2T )  
SUBROUTINE        iau\_C2TXY ( TTA, TTB, UTA, UTB, X, Y, XP, YP,  
                              RC2T )  
SUBROUTINE        iau\_CAL2JD ( IY, IM, ID, DJM0, DJM, J )  
SUBROUTINE        iau\_DAT ( IY, IM, ID, FD, DELTAT, J )  
DOUBLE PRECISION FUNCTION  
                    iau\_DTDB ( DATE1, DATE2, UT, ELONG, U, V )  
DOUBLE PRECISION FUNCTION  
                    iau\_EE00 ( DATE1, DATE2, EPSA, DPSI )  
DOUBLE PRECISION FUNCTION  
                    iau\_EE00A ( DATE1, DATE2 )  
DOUBLE PRECISION FUNCTION  
                    iau\_EE00B ( DATE1, DATE2 )  
DOUBLE PRECISION FUNCTION  
                    iau\_EE06A ( DATE1, DATE2 )  
DOUBLE PRECISION FUNCTION  
                    iau\_EECT00 ( DATE1, DATE2 )  
DOUBLE PRECISION FUNCTION  
                    iau\_EO06A ( DATE1, DATE2 )  
DOUBLE PRECISION FUNCTION  
                    iau\_EORS ( RNPB, S )  
DOUBLE PRECISION FUNCTION  
                    iau\_EPB ( DJ1, DJ2 )  
SUBROUTINE        iau\_EPB2JD ( EPB, DJM0, DJM )  
DOUBLE PRECISION FUNCTION  
                    iau\_EPJ ( DJ1, DJ2 )  
SUBROUTINE        iau\_EPJ2JD ( EPJ, DJM0, DJM )  
SUBROUTINE        iau\_EPV00 ( DJ1, DJ2, PVH, PVB, J )  
DOUBLE PRECISION FUNCTION  
                    iau\_EQEQ94 ( DATE1, DATE2 )  
DOUBLE PRECISION FUNCTION  
                    iau\_ERA00 ( DJ1, DJ2 )  
DOUBLE PRECISION FUNCTION  
                    iau\_FAD03 ( T )  
DOUBLE PRECISION FUNCTION  
                    iau\_FAE03 ( T )  
DOUBLE PRECISION FUNCTION  
                    iau\_FAF03 ( T )  
DOUBLE PRECISION FUNCTION  
                    iau\_FAJU03 ( T )  
DOUBLE PRECISION FUNCTION  
                    iau\_FAL03 ( T )  
DOUBLE PRECISION FUNCTION  
                    iau\_FALP03 ( T )  
DOUBLE PRECISION FUNCTION  
                    iau\_FAMA03 ( T )  
DOUBLE PRECISION FUNCTION  
                    iau\_FAME03 ( T )  
DOUBLE PRECISION FUNCTION  
                    iau\_FANE03 ( T )  
DOUBLE PRECISION FUNCTION  
                    iau\_FAOM03 ( T )  
DOUBLE PRECISION FUNCTION  
                    iau\_FAPA03 ( T )  
DOUBLE PRECISION FUNCTION  
                    iau\_FASA03 ( T )  
DOUBLE PRECISION FUNCTION  
                    iau\_FAUR03 ( T )  
DOUBLE PRECISION FUNCTION  
                    iau\_FAVE03 ( T )  
SUBROUTINE        iau\_FK52H ( R5, D5, DR5, DD5, PX5, RV5,  
                              RH, DH, DRH, DDH, PXH, RVH )  
SUBROUTINE        iau\_FK5HIP ( R5H, S5H )  
SUBROUTINE        iau\_FK5HZ ( R5, D5, DATE1, DATE2, RH, DH )  
SUBROUTINE        iau\_FW2M ( GAMB, PHIB, PSI, EPS, R )  
SUBROUTINE        iau\_FW2XY ( GAMB, PHIB, PSI, EPS, X, Y )  
DOUBLE PRECISION FUNCTION  
                    iau\_GMST00 ( UTA, UTB, TTA, TTB )  
DOUBLE PRECISION FUNCTION  
                    iau\_GMST06 ( UTA, UTB, TTA, TTB )  
DOUBLE PRECISION FUNCTION

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        iau_GMST82 ( UTA, UTB )
DOUBLE PRECISION FUNCTION
        iau_GST00A ( UTA, UTB, TTA, TTB )
DOUBLE PRECISION FUNCTION
        iau_GST00B ( UTA, UTB )
DOUBLE PRECISION FUNCTION
        iau_GST06 ( UTA, UTB, TTA, TTB, RNPB )
DOUBLE PRECISION FUNCTION
        iau_GST06A ( UTA, UTB, TTA, TTB )
DOUBLE PRECISION FUNCTION
        iau_GST94 ( UTA, UTB )
SUBROUTINE
        iau_H2FK5 ( RH, DH, DRH, DDH, PXH, RVH,
                  R5, D5, DR5, DD5, PX5, RV5 )
SUBROUTINE
        iau_HFK5Z ( RH, DH, DATE1, DATE2,
                  R5, D5, DR5, DD5 )
SUBROUTINE
        iau_JD2CAL ( DJ1, DJ2, IY, IM, ID, FD, J )
SUBROUTINE
        iau_JDCALF ( NDP, DJ1, DJ2, IY MDF, J )
SUBROUTINE
        iau_NUM00A ( DATE1, DATE2, RMATN )
SUBROUTINE
        iau_NUM00B ( DATE1, DATE2, RMATN )
SUBROUTINE
        iau_NUM06A ( DATE1, DATE2, RMATN )
SUBROUTINE
        iau_NUMAT ( EPSA, DPSI, DEPS, RMATN )
SUBROUTINE
        iau_NUT00A ( DATE1, DATE2, DPSI, DEPS )
SUBROUTINE
        iau_NUT00B ( DATE1, DATE2, DPSI, DEPS )
SUBROUTINE
        iau_NUT06A ( DATE1, DATE2, DPSI, DEPS )
SUBROUTINE
        iau_NUT80 ( DATE1, DATE2, DPSI, DEPS )
SUBROUTINE
        iau_NUTM80 ( DATE1, DATE2, RMATN )
DOUBLE PRECISION FUNCTION
        iau_OBL06 ( DATE1, DATE2 )
DOUBLE PRECISION FUNCTION
        iau_OBL80 ( DATE1, DATE2 )
SUBROUTINE
        iau_PB06 ( DATE1, DATE2, BZETA, BZ, BTHETA )
SUBROUTINE
        iau_PFW06 ( DATE1, DATE2, GAMB, PHIB, PSIB, EPSA )
SUBROUTINE
        iau_PLAN94 ( DATE1, DATE2, NP, PV, J )
SUBROUTINE
        iau_PMAT00 ( DATE1, DATE2, RBP )
SUBROUTINE
        iau_PMAT06 ( DATE1, DATE2, RBP )
SUBROUTINE
        iau_PMAT76 ( DJ1, DJ2, RMATP )
SUBROUTINE
        iau_PN00 ( DATE1, DATE2, DPSI, DEPS,
                  EPSA, RB, RP, RBP, RN, RBPN )
SUBROUTINE
        iau_PN00A ( DATE1, DATE2, DPSI, DEPS, EPSA,
                  RB, RP, RBP, RN, RBPN )
SUBROUTINE
        iau_PN00B ( DATE1, DATE2, DPSI, DEPS, EPSA,
                  RB, RP, RBP, RN, RBPN )
SUBROUTINE
        iau_PN06 ( DATE1, DATE2, DPSI, DEPS,
                  EPSA, RB, RP, RBP, RN, RBPN )
SUBROUTINE
        iau_PN06A ( DATE1, DATE2,
                  RB, RP, RBP, RN, RBPN )
SUBROUTINE
        iau_PNM00A ( DATE1, DATE2, RBPN )
SUBROUTINE
        iau_PNM00B ( DATE1, DATE2, RBPN )
SUBROUTINE
        iau_PNM06A ( DATE1, DATE2, RNPB )
SUBROUTINE
        iau_PNM80 ( DATE1, DATE2, RMATPN )
SUBROUTINE
        iau_P06E ( DATE1, DATE2,
                  EPS0, PSIA, OMA, BPA, BQA, PIA, BPIA,
                  EPSA, CHIA, ZA, ZETAA, THETAA, PA,
                  GAM, PHI, PSI )
SUBROUTINE
        iau_POM00 ( XP, YP, SP, RPOM )
SUBROUTINE
        iau_PRO0 ( DATE1, DATE2, DPSIPR, DEPSPR )
SUBROUTINE
        iau_PREC76 ( EP01, EP02, EP11, EP12,
                  ZETA, Z, THETA )
SUBROUTINE
        iau_PVSTAR ( PV, RA, DEC, PMR, PMD, PX, RV, J )
DOUBLE PRECISION FUNCTION
        iau_S00 ( DATE1, DATE2, X, Y )
DOUBLE PRECISION FUNCTION
        iau_S00A ( DATE1, DATE2 )
DOUBLE PRECISION FUNCTION
        iau_S00B ( DATE1, DATE2 )
DOUBLE PRECISION FUNCTION
        iau_S06 ( DATE1, DATE2, X, Y )
DOUBLE PRECISION FUNCTION
        iau_S06A ( DATE1, DATE2 )
DOUBLE PRECISION FUNCTION
        iau_SP00 ( DATE1, DATE2 )
SUBROUTINE
        iau_STARPM ( RA1, DEC1, PMR1, PMD1, PX1, RV1,
                  EP1A, EP1B, EP2A, EP2B,

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          RA2, DEC2, PMR2, PMD2, PX2, RV2, J )
SUBROUTINE iau_STARPV ( RA, DEC, PMR, PMD, PX, RV, PV, J )
SUBROUTINE iau_XYS06 ( DATE1, DATE2, X, Y )
SUBROUTINE iau_XYS00A ( DATE1, DATE2, X, Y, S )
SUBROUTINE iau_XYS00B ( DATE1, DATE2, X, Y, S )
SUBROUTINE iau_XYS06A ( DATE1, DATE2, X, Y, S )
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