SOFA Astronomy Library

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

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    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 ( RBPN, 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, RBPN, 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 )
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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, IYMDF, 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_PR00   ( 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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