
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 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.

PROGRAMMING LANGUAGES

The SOFA routines are available in two programming languages at present: Fortran 77 and ANSI C.

Except for a single obsolete Fortran routine, which has no C equivalent, there is a one-to-one relationship between the two language versions. The naming convention is such that a SOFA routine referred to generically as "EXAMPL" exists as a Fortran subprogram `iau_EXAMPL` and a C function `iauExempl`. The calls for the two versions are very similar, with the same arguments in the same order. In a few cases, the C equivalent of a Fortran SUBROUTINE subprogram uses a return value rather than an argument.

GENERAL PRINCIPLES

The principal function of the SOFA Astronomy Library is to provide definitive 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", 3rd Edition, Sean E. Urban & P. Kenneth Seidelmann (eds.), University Science Books, 2013. Recent developments are documented in the scientific 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`. Those concerned with transformations between different time scales are described in `sofa_ts_f.pdf` (Fortran) and `sofa_ts_c.pdf` (C). Those concerned with astrometric transformations are described in `sofa_ast_f.pdf` (Fortran) and `sofa_ast_c` (C).

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

Astrometry

AB	apply stellar aberration
APCG	prepare for ICRS <-> GCRS, geocentric, special
APCG13	prepare for ICRS <-> GCRS, geocentric
APCI	prepare for ICRS <-> CIRS, terrestrial, special
APCI13	prepare for ICRS <-> CIRS, terrestrial
APCO	prepare for ICRS <-> observed, terrestrial, special
APCO13	prepare for ICRS <-> observed, terrestrial
APCS	prepare for ICRS <-> CIRS, space, special
APCS13	prepare for ICRS <-> CIRS, space
APER	insert ERA into context
APER13	update context for Earth rotation
APIO	prepare for CIRS <-> observed, terrestrial, special
APIO13	prepare for CIRS <-> observed, terrestrial
ATCI13	catalog -> CIRS
ATCIQ	quick ICRS -> CIRS
ATCIQN	quick ICRS -> CIRS, multiple deflections
ATCIQZ	quick astrometric ICRS -> CIRS
ATCO13	ICRS -> observed
ATIC13	CIRS -> ICRS
ATICQ	quick CIRS -> ICRS
ATICQN	quick CIRS -> ICRS, multiple deflections
ATIO13	CIRS -> observed
ATIOQ	quick CIRS -> observed
ATOC13	observed -> astrometric ICRS
ATOI13	observed -> CIRS
ATIOQ	quick observed -> CIRS
LD	light deflection by a single solar-system body
LDN	light deflection by multiple solar-system bodies
LDSUN	light deflection by the Sun
PMPX	apply proper motion and parallax
PMSAFE	apply proper motion, with zero-parallax precautions
PVTOB	observatory position and velocity
PVSTAR	space motion pv-vector to star catalog data
REFCO	refraction constants
STARPM	apply proper motion
STARPV	star catalog data to space motion pv-vector

Time scales

D2DTF	format 2-part JD for output
DAT	Delta(AT) (=TAI-UTC) for a given UTC date
DTDB	TDB-TT
DTF2D	encode time and date fields into 2-part JD
TAITT	TAI to TT
TAIUT1	TAI to UT1
TAIUTC	TAI to UTC
TCBTDB	TCB to TDB
TCGTT	TCG to TT
TDBTCB	TDB to TCB
TDBTT	TDB to TT
TTTAI	TT to TAI
TTTCG	TT to TCG
TTTDB	TT to TDB
TTUT1	TT to UT1
UT1TAI	UT1 to TAI
UT1TT	UT1 to TT
UT1UTC	UT1 to UTC
UTCTAI	UTC to TAI
UTCUT1	UTC to UT1

Earth rotation angle and sidereal time

EE00	equation of the equinoxes, IAU 2000
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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, IAU 2000
 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
 LTP long-term precession matrix
 LTPB long-term precession matrix, including ICRS frame bias
 LTPECL long-term precession of the ecliptic
 LTPEQU long-term precession of the equator
 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 catalog conversions

FK425 convert B1950.0 FK4 star catalog data to J2000.0 FK5
 FK45Z convert a B1950.0 FK4 star position to J2000.0 FK5, assuming zero
 proper motion in the FK5 system
 FK524 convert J2000.0 FK5 star catalog data to B1950.0 FK4
 FK52H transform FK5 star data into the Hipparcos system
 FK54Z convert a J2000.0 FK5 star position to B1950.0 FK4, assuming zero
 proper motion in FK5 system and zero parallax
 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

Ecliptic coordinates

ECEQ06 ecliptic to ICRS, IAU 2006
 ECM06 rotation matrix, ICRS to ecliptic, IAU 2006
 EQEC06 ICRS to ecliptic, IAU 2006
 LTECEQ ecliptic to ICRS, long term
 LTECM rotation matrix, ICRS to ecliptic, long-term
 LTEQEC ICRS to ecliptic, long term

Galactic coordinates

G2ICRS transform IAU 1958 galactic coordinates to ICRS
 ICRS2G transform ICRS coordinates to IAU 1958 Galactic

Geodetic/geocentric

EFORM a,f for a nominated Earth reference ellipsoid
 GC2GD geocentric to geodetic for a nominated ellipsoid
 GC2GDE geocentric to geodetic given ellipsoid a,f
 GD2GC geodetic to geocentric for a nominated ellipsoid
 GD2GCE geodetic to geocentric given ellipsoid a,f

Gnomonic projection

TPORS solve for tangent point, spherical
 TPORV solve for tangent point, vector
 TPSTS deproject tangent plane to celestial, spherical
 TPSTV deproject tangent plane to celestial, vector

TPXES project celestial to tangent plane, spherical
TPXEV project celestial to tangent plane, vector

Horizon/equatorial

AE2HD (azimuth, altitude) to (hour angle, declination)
HD2AE (hour angle, declination) to (azimuth, altitude)
HD2PA parallactic angle

Obsolete

C2TCEO former name of C2TCIO

CALLS: FORTRAN VERSION

CALL iau_AB (PNAT, V, S, BM1, PPR)
CALL iau_AE2HD (AZ, EL, PHI, HA, DEC)
CALL iau_APCG (DATE1, DATE2, EB, EH, ASTROM)
CALL iau_APCG13 (DATE1, DATE2, ASTROM)
CALL iau_APCI (DATE1, DATE2, EB, EH, X, Y, S, ASTROM)
CALL iau_APCI13 (DATE1, DATE2, ASTROM, EO)
CALL iau_APCO (DATE1, DATE2, EB, EH, X, Y, S,
: THETA, ELONG, PHI, HM, XP, YP, SP,
: REFA, REFB, ASTROM)
CALL iau_APCO13 (UTC1, UTC2, DUT1, ELONG, PHI, HM, XP, YP,
: PHPA, TC, RH, WL, ASTROM, EO, J)
CALL iau_APCS (DATE1, DATE2, PV, EB, EH, ASTROM)
CALL iau_APCS13 (DATE1, DATE2, PV, ASTROM)
CALL iau_APER (THETA, ASTROM)
CALL iau_APER13 (UT11, UT12, ASTROM)
CALL iau_APIO (SP, THETA, ELONG, PHI, HM, XP, YP,
: REFA, REFB, ASTROM)
CALL iau_APIO13 (UTC1, UTC2, DUT1, ELONG, PHI, HM, XP, YP,
: PHPA, TC, RH, WL, ASTROM, J)
CALL iau_ATCI13 (RC, DC, PR, PD, PX, RV, DATE1, DATE2, RI, DI, EO)
CALL iau_ATCIQ (RC, DC, PR, PD, PX, RV, ASTROM, RI, DI)
CALL iau_ATCIQN (RC, DC, PR, PD, PX, RV, ASTROM, N, B, RI, DI)
CALL iau_ATCIQZ (RC, DC, ASTROM, RI, DI)
CALL iau_ATCO13 (RC, DC, PR, PD, PX, RV, UTC1, UTC2, DUT1, ELONG,
: PHI, HM, XP, YP, PHPA, TC, RH, WL,
: AOB, ZOB, HOB, DOB, ROB, EO, J)
CALL iau_ATIC13 (RI, DI, DATE1, DATE2, RC, DC, EO)
CALL iau_ATICQ (RI, DI, ASTROM, RC, DC)
CALL iau_ATCIQN (RI, DI, ASTROM, N, B, RC, DC)
CALL iau_ATIO13 (RI, DI, UTC1, UTC2, DUT1, ELONG, PHI, HM, XP, YP,
: PHPA, TC, RH, WL, AOB, ZOB, HOB, DOB, ROB, J)
CALL iau_ATIOQ (RI, DI, ASTROM, AOB, ZOB, HOB, DOB, ROB)
CALL iau_ATOC13 (TYPE, OB1, OB2, UTC1, UTC2, DUT1,
: ELONG, PHI, HM, XP, YP, PHPA, TC, RH, WL,
: RC, DC, J)
CALL iau_ATOI13 (TYPE, OB1, OB2, UTC1, UTC2, DUT1,
: ELONG, PHI, HM, XP, YP, PHPA, TC, RH, WL,
: RI, DI, J)
CALL iau_ATOIQ (TYPE, OB1, OB2, ASTROM, RI, DI)
CALL iau_BI00 (DPSIBI, DEPSBI, DRA)
CALL iau_BP00 (DATE1, DATE2, RB, RP, RBP)
CALL iau_BP06 (DATE1, DATE2, RB, RP, RBP)
CALL iau_BPN2XY (RBP, X, Y)
CALL iau_C2I00A (DATE1, DATE2, RC2I)
CALL iau_C2I00B (DATE1, DATE2, RC2I)
CALL iau_C2I06A (DATE1, DATE2, RC2I)
CALL iau_C2IBPN (DATE1, DATE2, RBP, RC2I)
CALL iau_C2IXY (DATE1, DATE2, X, Y, RC2I)
CALL iau_C2IXYS (X, Y, S, RC2I)
CALL iau_C2T00A (TTA, TTB, UTA, UTB, XP, YP, RC2T)
CALL iau_C2T00B (TTA, TTB, UTA, UTB, XP, YP, RC2T)
CALL iau_C2T06A (TTA, TTB, UTA, UTB, XP, YP, RC2T)
CALL iau_C2TCEO (RC2I, ERA, RPOM, RC2T)
CALL iau_C2TCIO (RC2I, ERA, RPOM, RC2T)
CALL iau_C2TEQX (RBP, GST, RPOM, RC2T)
CALL iau_C2TPE (TTA, TTB, UTA, UTB, DPSI, DEPS, XP, YP, RC2T)
CALL iau_C2TXY (TTA, TTB, UTA, UTB, X, Y, XP, YP, RC2T)

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CALL iau_CAL2JD ( IY, IM, ID, DJM0, DJM, J )
CALL iau_D2DTF ( SCALE, NDP, D1, D2, IY, IM, ID, IHMSF, J )
CALL iau_DAT ( IY, IM, ID, FD, DELTAT, J )
D = iau_DTDB ( DATE1, DATE2, UT, ELONG, U, V )
CALL iau_DTF2D ( SCALE, IY, IM, ID, IHR, IMN, SEC, D1, D2, J )
CALL iau_ECEQ06 ( DATE1, DATE2, DL, DB, DR, DD )
CALL iau_ECM06 ( DATE1, DATE2, RM );
D = iau_EE00 ( DATE1, DATE2, EPSA, DPSI )
D = iau_EE00A ( DATE1, DATE2 )
D = iau_EE00B ( DATE1, DATE2 )
D = iau_EE06A ( DATE1, DATE2 )
D = iau_EECT00 ( DATE1, DATE2 )
CALL iau_EFORM ( N, A, F, J )
D = iau_EO06A ( DATE1, DATE2 )
D = iau_EORS ( RNPB, S )
D = iau_EPB ( DJ1, DJ2 )
CALL iau_EPB2JD ( EPB, DJM0, DJM )
D = iau_EPJ ( DJ1, DJ2 )
CALL iau_EPJ2JD ( EPJ, DJM0, DJM )
CALL iau_EPV00 ( DJ1, DJ2, PVH, PVB, J )
CALL iau_EQEC06 ( DATE1, DATE2, DR, DD, DL, DB )
D = iau_EQEQ94 ( DATE1, DATE2 )
D = iau_ERA00 ( DJ1, DJ2 )
D = iau_FAD03 ( T )
D = iau_FAE03 ( T )
D = iau_FAF03 ( T )
D = iau_FAJU03 ( T )
D = iau_FAL03 ( T )
D = iau_FALP03 ( T )
D = iau_FAMA03 ( T )
D = iau_FAME03 ( T )
D = iau_FANE03 ( T )
D = iau_FAOM03 ( T )
D = iau_FAPA03 ( T )
D = iau_FASA03 ( T )
D = iau_FAUR03 ( T )
D = iau_FAVE03 ( T )
CALL iau_FK425 ( R1950, D1950, DR1950, DD1950, P1950, V1950,
: R2000, D2000, DR2000, DD2000, P2000, V2000 )
CALL iau_FK45Z ( R1950, D1950, BEPOCH, R2000, D2000 )
CALL iau_FK524 ( R2000, D2000, DR2000, DD2000, P2000, V2000,
: R1950, D1950, DR1950, DD1950, P1950, V1950 )
CALL iau_FK52H ( R5, D5, DR5, DD5, PX5, RV5,
: RH, DH, DRH, DDH, PXH, RVH )
CALL iau_FK54Z ( R2000, D2000, BEPOCH, R1950, D1950, DR1950,
: DD1950 )
CALL iau_FK5HIP ( R5H, S5H )
CALL iau_FK5HZ ( R5, D5, DATE1, DATE2, RH, DH )
CALL iau_FW2M ( GAMB, PHIB, PSI, EPS, R )
CALL iau_FW2XY ( GAMB, PHIB, PSI, EPS, X, Y )
CALL iau_G2ICRS ( DL, DB, DR, DD )
CALL iau_GC2GD ( N, XYZ, ELONG, PHI, HEIGHT, J )
CALL iau_GC2GDE ( A, F, XYZ, ELONG, PHI, HEIGHT, J )
CALL iau_GD2GC ( N, ELONG, PHI, HEIGHT, XYZ, J )
CALL iau_GD2GCE ( A, F, ELONG, PHI, HEIGHT, XYZ, J )
D = iau_GMST00 ( UTA, UTB, TTA, TTB )
D = iau_GMST06 ( UTA, UTB, TTA, TTB )
D = iau_GMST82 ( UTA, UTB )
D = iau_GST00A ( UTA, UTB, TTA, TTB )
D = iau_GST00B ( UTA, UTB )
D = iau_GST06 ( UTA, UTB, TTA, TTB, RNPB )
D = iau_GST06A ( UTA, UTB, TTA, TTB )
D = iau_GST94 ( UTA, UTB )
CALL iau_H2FK5 ( RH, DH, DRH, DDH, PXH, RVH,
: R5, D5, DR5, DD5, PX5, RV5 )
CALL iau_HD2AE ( HA, DEC, PHI, AZ, EL )
D = iau_HD2PA ( HA, DEC, PHI )
CALL iau_HFK5Z ( RH, DH, DATE1, DATE2, R5, D5, DR5, DD5 )
CALL iau_ICRS2G ( DR, DD, DL, DB )
CALL iau_JD2CAL ( DJ1, DJ2, IY, IM, ID, FD, J )
CALL iau_JDCALF ( NDP, DJ1, DJ2, IYMDF, J )
CALL iau_LD ( BM, P, Q, E, EM, DLIM, P1 )
CALL iau_LDN ( N, B, OB, SC, SN )

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CALL iau_LDSUN ( P, E, EM, P1 )
CALL iau_LTECEQ ( EPJ, DL, DB, DR, DD )
CALL iau_LTECM ( EPJ, RMJ )
CALL iau_LTEQEC ( EPJ, DR, DD, DL, DB )
CALL iau_LTP ( EPJ, RP )
CALL iau_LTPB ( EPJ, RPB )
CALL iau_LTPECL ( EPJ, VEC )
CALL iau_LTPEQU ( EPJ, VEQ )
CALL iau_NUM00A ( DATE1, DATE2, RMATN )
CALL iau_NUM00B ( DATE1, DATE2, RMATN )
CALL iau_NUM06A ( DATE1, DATE2, RMATN )
CALL iau_NUMAT ( EPSA, DPSI, DEPS, RMATN )
CALL iau_NUT00A ( DATE1, DATE2, DPSI, DEPS )
CALL iau_NUT00B ( DATE1, DATE2, DPSI, DEPS )
CALL iau_NUT06A ( DATE1, DATE2, DPSI, DEPS )
CALL iau_NUT80 ( DATE1, DATE2, DPSI, DEPS )
CALL iau_NUTM80 ( DATE1, DATE2, RMATN )
D = iau_OBL06 ( DATE1, DATE2 )
D = iau_OBL80 ( DATE1, DATE2 )
CALL iau_PB06 ( DATE1, DATE2, BZETA, BZ, BTHETA )
CALL iau_PFW06 ( DATE1, DATE2, GAMB, PHIB, PSIB, EPSA )
CALL iau_PLAN94 ( DATE1, DATE2, NP, PV, J )
CALL iau_PMAT00 ( DATE1, DATE2, RBP )
CALL iau_PMAT06 ( DATE1, DATE2, RBP )
CALL iau_PMAT76 ( DATE1, DATE2, RMATP )
CALL iau_PMPX ( RC, DC, PR, PD, PX, RV, PMT, POB, PCO )
CALL iau_PMSAFE ( RA1, DEC1, PMR1, PMD1, PX1, RV1,
:               EP1A, EP1B, EP2A, EP2B,
:               RA2, DEC2, PMR2, PMD2, PX2, RV2, J )
CALL iau_PN00 ( DATE1, DATE2, DPSI, DEPS,
:             EPSA, RB, RP, RBP, RN, RBPN )
CALL iau_PN00A ( DATE1, DATE2,
:             DPSI, DEPS, EPSA, RB, RP, RBP, RN, RBPN )
CALL iau_PN00B ( DATE1, DATE2,
:             DPSI, DEPS, EPSA, RB, RP, RBP, RN, RBPN )
CALL iau_PN06 ( DATE1, DATE2, DPSI, DEPS,
:             EPSA, RB, RP, RBP, RN, RBPN )
CALL iau_PN06A ( DATE1, DATE2,
:             DPSI, DEPS, RB, RP, RBP, RN, RBPN )
CALL iau_PNM00A ( DATE1, DATE2, RBPN )
CALL iau_PNM00B ( DATE1, DATE2, RBPN )
CALL iau_PNM06A ( DATE1, DATE2, RNPB )
CALL iau_PNM80 ( DATE1, DATE2, RMATPN )
CALL iau_P06E ( DATE1, DATE2,
:             EPS0, PSIA, OMA, BPA, BQA, PIA, BPIA,
:             EPSA, CHIA, ZA, ZETAA, THETAA, PA, GAM, PHI, PSI )
CALL iau_POM00 ( XP, YP, SP, RPOM )
CALL iau_PR00 ( DATE1, DATE2, DPSIPR, DEPSPR )
CALL iau_PREC76 ( DATE01, DATE02, DATE11, DATE12, ZETA, Z, THETA )
CALL iau_PVSTAR ( PV, RA, DEC, PMR, PMD, PX, RV, J )
CALL iau_PVTOB ( ELONG, PHI, HM, XP, YP, SP, THETA, PV )
CALL iau_REFCO ( PHPA, TC, RH, WL, REFA, REFB )
D = iau_S00 ( DATE1, DATE2, X, Y )
D = iau_S00A ( DATE1, DATE2 )
D = iau_S00B ( DATE1, DATE2 )
D = iau_S06 ( DATE1, DATE2, X, Y )
D = iau_S06A ( DATE1, DATE2 )
D = iau_SP00 ( DATE1, DATE2 )
CALL iau_STARPM ( RA1, DEC1, PMR1, PMD1, PX1, RV1,
:             EP1A, EP1B, EP2A, EP2B,
:             RA2, DEC2, PMR2, PMD2, PX2, RV2, J )
CALL iau_STARPV ( RA, DEC, PMR, PMD, PX, RV, PV, J )
CALL iau_TAITT ( TAI1, TAI2, TT1, TT2, J )
CALL iau_TAIUT1 ( TAI1, TAI2, DTA, UT11, UT12, J )
CALL iau_TAIUTC ( TAI1, TAI2, UTC1, UTC2, J )
CALL iau_TCBTDB ( TCB1, TCB2, TDB1, TDB2, J )
CALL iau_TCGTT ( TCG1, TCG2, TT1, TT2, J )
CALL iau_TDBTCB ( TDB1, TDB2, TCB1, TCB2, J )
CALL iau_TDBTT ( TDB1, TDB2, DTR, TT1, TT2, J )
CALL iau_TPORS ( XI, ETA, A, B, A01, B01, A02, B02, N )
CALL iau_TPORV ( XI, ETA, V, V01, V02, N )
CALL iau_TPSTS ( XI, ETA, A0, B0, A, B )
CALL iau_TPSTV ( XI, ETA, V0, V )

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CALL iau_TPXES ( A, B, A0, B0, XI, ETA, J )
CALL iau_TPXEV ( V, V0, XI, ETA, J )
CALL iau_TTTAI ( TT1, TT2, TAI1, TAI2, J )
CALL iau_TTTTCG ( TT1, TT2, TCG1, TCG2, J )
CALL iau_TTTTDB ( TT1, TT2, DTR, TDB1, TDB2, J )
CALL iau_TTUT1 ( TT1, TT2, DT, UT11, UT12, J )
CALL iau_UT1TAI ( UT11, UT12, TAI1, TAI2, J )
CALL iau_UT1TT ( UT11, UT12, DT, TT1, TT2, J )
CALL iau_UT1UTC ( UT11, UT12, DUT, UTC1, UTC2, J )
CALL iau_UTCTAI ( UTC1, UTC2, DTA, TAI1, TAI2, J )
CALL iau_UTCUT1 ( UTC1, UTC2, DUT, UT11, UT12, J )
CALL iau_XY06 ( DATE1, DATE2, X, Y )
CALL iau_XYS00A ( DATE1, DATE2, X, Y, S )
CALL iau_XYS00B ( DATE1, DATE2, X, Y, S )
CALL iau_XYS06A ( DATE1, DATE2, X, Y, S )

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CALLS: C VERSION

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iauAb ( pnat, v, s, bml, ppr );
iauAe2hd ( az, el, phi, &ha, &dec );
iauApcg ( datel, date2, eb, eh, &astrom );
iauApcg13 ( datel, date2, &astrom );
iauApci ( datel, date2, eb, eh, x, y, s, &astrom );
iauApci13 ( datel, date2, &astrom, &eo );
iauApco ( datel, date2, eb, eh, x, y, s,
theta, elong, phi, hm, xp, yp, sp,
refa, refb, &astrom );
i = iauApcol3 ( utc1, utc2, dut1, elong, phi, hm, xp, yp,
phpa, tc, rh, wl, &astrom, &eo );
iauApcs ( datel, date2, pv, eb, eh, &astrom );
iauApcs13 ( datel, date2, pv, &astrom );
iauAper ( theta, &astrom );
iauAper13 ( utl1, utl2, &astrom );
iauApio ( sp, theta, elong, phi, hm, xp, yp, refa, refb,
&astrom );
i = iauApiol3 ( utc1, utc2, dut1, elong, phi, hm, xp, yp,
phpa, tc, rh, wl, &astrom );
iauAtcil3 ( rc, dc, pr, pd, px, rv, datel, date2,
&ri, &di, &eo );
iauAtciq ( rc, dc, pr, pd, px, rv, &astrom, &ri, &di );
iauAtciqn ( rc, dc, pr, pd, px, rv, astrom, n, b, &ri, &di );
iauAtciqz ( rc, dc, &astrom, &ri, &di );
i = iauAtcol3 ( rc, dc, pr, pd, px, rv, utc1, utc2, dut1,
elong phi, hm, xp, yp, phpa, tc, rh, wl,
aob, zob, hob, dob, rob, eo );
iauAtic13 ( ri, di, datel, date2, &rc, &dc, &eo );
iauAticq ( ri, di, &astrom, &rc, &dc );
iauAtciqn ( ri, di, astrom, n, b, &rc, &dc );
i = iauAtiol3 ( ri, di, utc1, utc2, dut1, elong, phi, hm, xp, yp,
phpa, tc, rh, wl, aob, zob, hob, dob, rob );
iauAtioq ( ri, di, &astrom, &aob, &zob, &hob, &dob, &rob );
i = iauAtocl3 ( type, obl, ob2, utc1, utc2, dut1,
elong, phi, hm, xp, yp, phpa, tc, rh, wl,
&rc, &dc );
i = iauAtoil3 ( type, obl, ob2, utc1, utc2, dut1, elong, phi, hm,
xp, yp, phpa, tc, rh, wl, &ri, &di );
iauAtoiq ( type, obl, ob2, &astrom, &ri, &di );
iauBi00 ( &dpsibi, &depsbi, &dra );
iauBp00 ( datel, date2, rb, rp, rbp );
iauBp06 ( datel, date2, rb, rp, rbp );
iauBpn2xy ( rbpn, &x, &y );
iauC2i00a ( datel, date2, rc2i );
iauC2i00b ( datel, date2, rc2i );
iauC2i06a ( datel, date2, rc2i );
iauC2ibpn ( datel, date2, rbpn, rc2i );
iauC2ixy ( datel, date2, x, y, rc2i );
iauC2ixys ( x, y, s, rc2i );
iauC2t00a ( tta, ttb, uta, utb, xp, yp, rc2t );
iauC2t00b ( tta, ttb, uta, utb, xp, yp, rc2t );
iauC2t06a ( tta, ttb, uta, utb, xp, yp, rc2t );
iauC2tcio ( rc2i, era, rpom, rc2t );
iauC2teqx ( rbpn, gst, rpom, rc2t );

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        iauC2tpe ( tta, ttb, uta, utb, dpsl, deps, xp, yp, rc2t );
        iauC2txy ( tta, ttb, uta, utb, x, y, xp, yp, rc2t );
i = iauCal2jd ( iy, im, id, &djm0, &djm );
i = iauD2dtf ( scale, ndp, dl, d2, &iy, &im, &id, ihmsf );
i = iauDat ( iy, im, id, fd, &deltat );
d = iauDtdb ( datel, date2, ut, elong, u, v );
i = iauDtf2d ( scale, iy, im, id, ihr, sec, &dl, &d2 );
        iauEceq06 ( datel, date2, dl, db, &dr, &dd );
        iauEcm06 ( datel, date2, rm );
d = iauEe00 ( datel, date2, epsa, dpsl );
d = iauEe00a ( datel, date2 );
d = iauEe00b ( datel, date2 );
d = iauEe06 ( datel, date2 );
d = iauEect00 ( datel, date2 );
i = iauEform ( n, &a, &f );
d = iauEo06 ( datel, date2 );
d = iauEors ( rnpb, s );
d = iauEpb ( dj1, dj2 );
        iauEpb2jd ( epb, &djm0, &djm );
d = iauEpj ( dj1, dj2 );
        iauEpj2jd ( epj, &djm0, &djm );
i = iauEpv00 ( dj1, dj2, pvh, pvb );
        iauEqec06 ( datel, date2, dr, dd, &dl, &db );
d = iauEqeq94 ( datel, date2 );
d = iauEra00 ( dj1, dj2 );
d = iauFad03 ( t );
d = iauFae03 ( t );
d = iauFaf03 ( t );
d = iauFaju03 ( t );
d = iauFal03 ( t );
d = iauFalp03 ( t );
d = iauFama03 ( t );
d = iauFame03 ( t );
d = iauFane03 ( t );
d = iauFaom03 ( t );
d = iauFapa03 ( t );
d = iauFasa03 ( t );
d = iauFaur03 ( t );
d = iauFave03 ( t );
        iauFk425 ( r1950, d1950, dr1950, dd1950, p1950, v1950,
                &r2000, &d2000, &dr2000, &dd2000, &p2000, &v2000 );
        iauFk45z ( r1950, d1950, bepoch, &r2000, &d2000 );

        iauFk524 ( r2000, d2000, dr2000, dd2000, p2000, v2000,
                &r1950, &d1950, &dr1950, &dd1950, &p1950, &v1950 );
        iauFk52h ( r5, d5, dr5, dd5, px5, rv5,
                &rh, &dh, &drh, &ddh, &pxh, &rvh );
        iauFk54z ( r2000, d2000, bepoch, &r1950, &d1950, &dr1950,
                &dd1950 );
        iauFk5hip ( r5h, s5h );
        iauFk5hz ( r5, d5, datel, date2, &rh, &dh );
        iauFw2m ( gamb, phib, psi, eps, r );
        iauFw2xy ( gamb, phib, psi, eps, &x, &y );
        iauG2icrs ( dl, db, &dr, &dd );
i = iauGc2gd ( n, xyz, &elong, &phi, &height );
i = iauGc2gde ( a, f, xyz, &elong, &phi, &height );
i = iauGd2gc ( n, elong, phi, height, xyz );
i = iauGd2gce ( a, f, elong, phi, height, xyz );
d = iauGmst00 ( uta, utb, tta, ttb );
d = iauGmst06 ( uta, utb, tta, ttb );
d = iauGmst82 ( uta, utb );
d = iauGst00a ( uta, utb, tta, ttb );
d = iauGst00b ( uta, utb );
d = iauGst06 ( uta, utb, tta, ttb, rnpb );
d = iauGst06a ( uta, utb, tta, ttb );
d = iauGst94 ( uta, utb );
        iauH2fk5 ( rh, dh, drh, ddh, pxh, rvh,
                &r5, &d5, &dr5, &dd5, &px5, &rv5 );
        iauHd2ae ( ha, dec, phi, &az, &el );
d = iauHd2pa ( ha, dec, phi );
        iauHfk5z ( rh, dh, datel, date2,
                &r5, &d5, &dr5, &dd5 );
        iauIcrs2g ( dr, dd, &dl, &db );

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i = iauJd2cal ( dj1, dj2, &iy, &im, &id, &fd );
i = iauJdcalf ( ndp, dj1, dj2, iy MDF );
iauLd ( bm, p, q, e, em, dlim, pl );
iauLdn ( n, b, ob, sc, sn );
iauLdsun ( p, e, em, pl );
iauLteceq ( epj, dl, db, &dr, &dd );
iauLtecm ( epj, rm );
iauLteqec ( epj, dr, dd, &dl, &db );
iauLtp ( epj, rp );
iauLtpb ( epj, rpb );
iauLtpecl ( epj, vec );
iauLtpequ ( epj, veq );
iauNum00a ( datel, date2, rmatn );
iauNum00b ( datel, date2, rmatn );
iauNum06a ( datel, date2, rmatn );
iauNumat ( epsa, dpsl, deps, rmatn );
iauNut00a ( datel, date2, &dpsi, &deps );
iauNut00b ( datel, date2, &dpsi, &deps );
iauNut06a ( datel, date2, &dpsi, &deps );
iauNut80 ( datel, date2, &dpsi, &deps );
iauNutm80 ( datel, date2, rmatn );
d = iauObl06 ( datel, date2 );
d = iauObl80 ( datel, date2 );
iauPb06 ( datel, date2, &bzeta, &bz, &btheta );
iauPfw06 ( datel, date2, &gamb, &phib, &psib, &epsa );
i = iauPlan94 ( datel, date2, np, pv );
iauPmat00 ( datel, date2, rbp );
iauPmat06 ( datel, date2, rbp );
iauPmat76 ( datel, date2, rmatp );
iauPmpx ( rc, dc, pr, pd, px, rv, pmt, pob, pco );
i = iauPmsafe ( ral, decl, pmr1, pmd1, px1, rv1,
               epla, eplb, ep2a, ep2b,
               &ra2, &dec2, &pmr2, &pmd2, &px2, &rv2 );
iauPn00 ( datel, date2, dpsl, deps,
          &epsa, rb, rp, rbp, rn, rbpn );
iauPn00a ( datel, date2,
           &dpsi, &deps, &epsa, rb, rp, rbp, rn, rbpn );
iauPn00b ( datel, date2,
           &dpsi, &deps, &epsa, rb, rp, rbp, rn, rbpn );
iauPn06 ( datel, date2, dpsl, deps,
          &epsa, rb, rp, rbp, rn, rbpn );
iauPn06a ( datel, date2,
           &dpsi, &deps, &epsa, rb, rp, rbp, rn, rbpn );
iauPnm00a ( datel, date2, rbpn );
iauPnm00b ( datel, date2, rbpn );
iauPnm06a ( datel, date2, rnpb );
iauPnm80 ( datel, date2, rmatpn );
iauP06e ( datel, date2,
          &eps0, &psia, &oma, &bpa, &bqa, &pia, &bpia,
          &epsa, &chia, &za, &zetaa, &thetaa, &pa,
          &gam, &phi, &psi );
iauPom00 ( xp, yp, sp, rpom );
iauPr00 ( datel, date2, &dpslpr, &depspr );
iauPrec76 ( date01, date02, datel1, datel2, &zeta, &z, &theta );
i = iauPvstar ( pv, &ra, &dec, &pmr, &pmd, &px, &rv );
iauPvtob ( elong, phi, hm, xp, yp, sp, theta, pv );
iauRefco ( phpa, tc, rh, wl, refa, refb );
d = iauS00 ( datel, date2, x, y );
d = iauS00a ( datel, date2 );
d = iauS00b ( datel, date2 );
d = iauS06 ( datel, date2, x, y );
d = iauS06a ( datel, date2 );
d = iauSp00 ( datel, date2 );
i = iauStarpm ( ral, decl, pmr1, pmd1, px1, rv1,
               epla, eplb, ep2a, ep2b,
               &ra2, &dec2, &pmr2, &pmd2, &px2, &rv2 );
i = iauStarpv ( ra, dec, pmr, pmd, px, rv, pv );
i = iauTaitt ( tai1, tai2, &tt1, &tt2 );
i = iauTaiut1 ( tai1, tai2, dta, &utl1, &utl2 );
i = iauTaiutc ( tai1, tai2, &utcl, &utcl );
i = iauTcbtdb ( tcb1, tcb2, &tdb1, &tdb2 );
i = iauTcgtt ( tcg1, tcg2, &tt1, &tt2 );
i = iauTdbtcb ( tdb1, tdb2, &tcb1, &tcb2 );

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i = iauTdbtt ( tdb1, tdb2, dtr, &tt1, &tt2 );
i = iauTpors ( xi, eta, a, b, &a01, &b01, &a02, &b02 );
i = iauTporv ( xi, eta, v, v01, v02 );
    iauTpsts ( xi, eta, a0, b0, &a, &b );
    iauTpstv ( xi, eta, v0, v );
i = iauTpxes ( a, b, a0, b0, &xi, &eta );
i = iauTpxev ( v, v0, &xi, &eta );
i = iauTttai ( tt1, tt2, &tail, &tai2 );
i = iauTttcg ( tt1, tt2, &tcg1, &tcg2 );
i = iauTttdb ( tt1, tt2, dtr, &tdb1, &tdb2 );
i = iauTtutl ( tt1, tt2, dt, &ut11, &ut12 );
i = iauUtltai ( ut11, ut12, &tail, &tai2 );
i = iauUtltt ( ut11, ut12, dt, &tt1, &tt2 );
i = iauUtlutc ( ut11, ut12, dut, &utc1, &utc2 );
i = iauUtctai ( utc1, utc2, dta, &tail, &tai2 );
i = iauUtcutl ( utc1, utc2, dut, &ut11, &ut12 );
    iauXy06 ( datel, date2, &x, &y );
    iauXys00a ( datel, date2, &x, &y, &s );
    iauXys00b ( datel, date2, &x, &y, &s );
    iauXys06a ( datel, date2, &x, &y, &s );
```