
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.

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", 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

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
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

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

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

Obsolete

C2TCEO former name of C2TCIO

CALLS: FORTRAN VERSION

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 (RBPB, 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, RBPB, 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 (RBPB, 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)
 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)
 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)
 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_FK52H (R5, D5, DR5, DD5, PX5, RV5,
 : RH, DH, DRH, DDH, PXH, RVH)
 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_GC2GD (N, XYZ, ELONG, PHI, HEIGHT, J)

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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_HFK5Z ( RH, DH, DATE1, DATE2, R5, D5, DR5, DD5 )
CALL iau_JD2CAL ( DJ1, DJ2, IY, IM, ID, FD, J )
CALL iau_JDCALF ( NDP, DJ1, DJ2, IYMDF, J )
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_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 ( EP01, EP02, EP11, EP12, ZETA, Z, THETA )
CALL iau_PVSTAR ( PV, RA, DEC, PMR, PMD, PX, RV, J )
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_TAI TT ( 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_TDBTDB ( TDB1, TDB2, TCB1, TCB2, J )
CALL iau_TDBTT ( TDB1, TDB2, DTR, TT1, TT2, J )
CALL iau_TTTAI ( TT1, TT2, TAI1, TAI2, J )
CALL iau_TTTTCG ( TT1, TT2, TCG1, TCG2, J )

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CALL iau_TTTDB ( 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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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 );
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, imm, sec, &d1, &d2 );
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, pvh );
d = iauEpeq94 ( 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 );
iauFk52h ( r5, d5, dr5, dd5, px5, rv5,
&rh, &dh, &drh, &ddh, &pxh, &rvh );
iauFk5hip ( r5h, s5h );
iauFk5hz ( r5, d5, datel, date2, &rh, &dh );
iauFw2m ( gamb, phib, psi, eps, r );
iauFw2xy ( gamb, phib, psi, eps, &x, &y );

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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 );
    iauHfk5z ( rh, dh, datel, date2,
              &r5, &d5, &dr5, &dd5 );
i = iauJd2cal ( dj1, dj2, &iy, &im, &id, &fd );
i = iauJdcalf ( ndp, dj1, dj2, iymdf );
    iauNum00a ( datel, date2, rmatn );
    iauNum00b ( datel, date2, rmatn );
    iauNum06a ( datel, date2, rmatn );
    iauNumat ( epsa, dpsi, 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 );
    iauPn00 ( datel, date2, dpsi, 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, dpsi, 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, &dpsipr, &depspr );
    iauPrec76 ( ep01, ep02, ep11, ep12, &zeta, &z, &theta );
i = iauPvstar ( pv, &ra, &dec, &pmr, &pmd, &px, &rv );
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, &ut11, &ut12 );
i = iauTaiutc ( tai1, tai2, &utc1, &utc2 );
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 = iauTttai ( tt1, tt2, &tail, &tai2 );
i = iauTttcg ( tt1, tt2, &tcg1, &tcg2 );
i = iauTttdb ( tt1, tt2, dtr, &tdb1, &tdb2 );
i = iauTttut1 ( 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 = iauUtcut1 ( utc1, utc2, dut, &ut11, &ut12 );
    iauXy06 ( date1, date2, &x, &y );
    iauXys00a ( date1, date2, &x, &y, &s );
    iauXys00b ( date1, date2, &x, &y, &s );
    iauXys06a ( date1, date2, &x, &y, &s );
```