# 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 iauExampl. 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 |
| ATCIQN | quick CIRS –> ICRS, multiple deflections |
| ATIO13 | CIRS –> observed |
| ATIOQ | quick CIRS –> observed |
| ATOC13 | observed –> astrometric ICRS |
| ATOI13 | observed –> CIRS |
| ATOIQ | 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 |

| | |
|---|---|
| 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

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      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 ( RBPN, 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, RBPN, 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 ( RBPN, 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, RM] )
      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_TTTCG  ( TT1, TT2, TCG1, TCG2, J )
   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 )


CALLS: C VERSION

       iauAb     ( pnat, v, s, bm1, ppr );
       iauAe2hd  ( az, el, phi, &ha, &dec );
       iauApcg   ( date1, date2, eb, eh, &astrom );
       iauApcg13 ( date1, date2, &astrom );
       iauApci   ( date1, date2, eb, eh, x, y, s, &astrom );
       iauApci13 ( date1, date2, &astrom, &eo );
       iauApco   ( date1, date2, eb, eh, x, y, s,
                   theta, elong, phi, hm, xp, yp, sp,
                   refa, refb, &astrom );
   i = iauApco13 ( utc1, utc2, dut1, elong, phi, hm, xp, yp,
                   phpa, tc, rh, wl, &astrom, &eo );
       iauApcs   ( date1, date2, pv, eb, eh, &astrom );
       iauApcs13 ( date1, date2, pv, &astrom );
       iauAper   ( theta, &astrom );
       iauAper13 ( ut11, ut12, &astrom );
       iauApio   ( sp, theta, elong, phi, hm, xp, yp, refa, refb,
                   &astrom );
   i = iauApio13 ( utc1, utc2, dut1, elong, phi, hm, xp, yp,
                   phpa, tc, rh, wl, &astrom );
       iauAtci13 ( rc, dc, pr, pd, px, rv, date1, 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 = iauAtco13 ( 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, date1, date2, &rc, &dc, &eo );
       iauAticq  ( ri, di, &astrom, &rc, &dc );
       iauAticqn ( ri, di, astrom, n, b, &rc, &dc );
   i = iauAtio13 ( 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 = iauAtoc13 ( type, ob1, ob2, utc1, utc2, dut1,
                   elong, phi, hm, xp, yp, phpa, tc, rh, wl,
                   &rc, &dc );
   i = iauAtoi13 ( type, ob1, ob2, utc1, utc2, dut1, elong, phi, hm,
                   xp, yp, phpa, tc, rh, wl, &ri, &di  );
       iauAtoiq  ( type, ob1, ob2, &astrom, &ri, &di );
       iauBi00   ( &dpsibi, &depsbi, &dra );
       iauBp00   ( date1, date2, rb, rp, rbp );
       iauBp06   ( date1, date2, rb, rp, rbp );
       iauBpn2xy ( rbpn, &x, &y );
       iauC2i00a ( date1, date2, rc2i );
       iauC2i00b ( date1, date2, rc2i );
       iauC2i06a ( date1, date2, rc2i );
       iauC2ibpn ( date1, date2, rbpn, rc2i );
       iauC2ixy  ( date1, 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, dpsi, 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, d1, d2, &iy, &im, &id, ihmsf );
i = iauDat    ( iy, im, id, fd, &deltat );
d = iauDtdb   ( date1, date2, ut, elong, u, v );
i = iauDtf2d  ( scale, iy, im, id, ihr, imn, sec, &d1, &d2 );
    iauEceq06 ( date1, date2, dl, db, &dr, &dd );
    iauEcm06  ( date1, date2, rm );
d = iauEe00   ( date1, date2, epsa, dpsi );
d = iauEe00a  ( date1, date2 );
d = iauEe00b  ( date1, date2 );
d = iauEe06   ( date1, date2 );
d = iauEect00 ( date1, date2 );
i = iauEform  ( n, &a, &f );
d = iauEo06   ( date1, 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 ( date1, date2, dr, dd, &dl, &db );
d = iauEqeq94 ( date1, 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, date1, 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, date1, 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, iymdf );
    iauLd     ( bm, p, q, e, em, dlim, p1 );
    iauLdn    ( n, b, ob, sc, sn );
    iauLdsun  ( p, e, em, p1 );
    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 ( date1, date2, rmatn );
    iauNum00b ( date1, date2, rmatn );
    iauNum06a ( date1, date2, rmatn );
    iauNumat  ( epsa, dpsi, deps, rmatn );
    iauNut00a ( date1, date2, &dpsi, &deps );
    iauNut00b ( date1, date2, &dpsi, &deps );
    iauNut06a ( date1, date2, &dpsi, &deps );
    iauNut80  ( date1, date2, &dpsi, &deps );
    iauNutm80 ( date1, date2, rmatn );
d = iauObl06  ( date1, date2 );
d = iauObl80  ( date1, date2 );
    iauPb06   ( date1, date2, &bzeta, &bz, &btheta );
    iauPfw06  ( date1, date2, &gamb, &phib, &psib, &epsa );
i = iauPlan94 ( date1, date2, np, pv );
    iauPmat00 ( date1, date2, rbp );
    iauPmat06 ( date1, date2, rbp );
    iauPmat76 ( date1, date2, rmatp );
    iauPmpx   ( rc, dc, pr, pd, px, rv, pmt, pob, pco );
i = iauPmsafe ( ra1, dec1, pmr1, pmd1, px1, rv1,
                ep1a, ep1b, ep2a, ep2b,
                &ra2, &dec2, &pmr2, &pmd2, &px2, &rv2);
    iauPn00   ( date1, date2, dpsi, deps,
                &epsa, rb, rp, rbp, rn, rbpn );
    iauPn00a  ( date1, date2,
                &dpsi, &deps, &epsa, rb, rp, rbp, rn, rbpn );
    iauPn00b  ( date1, date2,
                &dpsi, &deps, &epsa, rb, rp, rbp, rn, rbpn );
    iauPn06   ( date1, date2, dpsi, deps,
                &epsa, rb, rp, rbp, rn, rbpn );
    iauPn06a  ( date1, date2,
                &dpsi, &deps, &epsa, rb, rp, rbp, rn, rbpn );
    iauPnm00a ( date1, date2, rbpn );
    iauPnm00b ( date1, date2, rbpn );
    iauPnm06a ( date1, date2, rnpb );
    iauPnm80  ( date1, date2, rmatpn );
    iauP06e   ( date1, date2,
                &eps0, &psia, &oma, &bpa, &bqa, &pia, &bpia,
                &epsa, &chia, &za, &zetaa, &thetaa, &pa,
                &gam, &phi, &psi );
    iauPom00  ( xp, yp, sp, rpom );
    iauPr00   ( date1, date2, &dpsipr, &depspr );
    iauPrec76 ( date01, date02, date11, date12, &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    ( date1, date2, x, y );
d = iauS00a   ( date1, date2 );
d = iauS00b   ( date1, date2 );
d = iauS06    ( date1, date2, x, y );
d = iauS06a   ( date1, date2 );
d = iauSp00   ( date1, date2 );
i = iauStarpm ( ra1, dec1, pmr1, pmd1, px1, rv1,
                ep1a, ep1b, 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 = 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, &tai1, &tai2 );
i = iauTttcg  ( tt1, tt2, &tcg1, &tcg2 );
i = iauTttdb  ( tt1, tt2, dtr, &tdb1, &tdb2 );
i = iauTtut1  ( tt1, tt2, dt, &ut11, &ut12 );
i = iauUt1tai ( ut11, ut12, &tai1, &tai2 );
i = iauUt1tt  ( ut11, ut12, dt, &tt1, &tt2 );
i = iauUt1utc ( ut11, ut12, dut, &utc1, &utc2 );
i = iauUtctai ( utc1, utc2, dta, &tai1, &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 );
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