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COCO — Conversion of Celestial Coordinates

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User Guide

Contents

1 Introduction

The COCO program converts star coordinates from one system to another. Both the improved IAU system, post-1976, and the old pre-1976 system are supported. COCO can perform accurate transformations between the following coordinate systems:

- mean $[\alpha, \delta]$, old system, with E-terms (loosely FK4, usually B1950)
- mean $[\alpha, \delta]$, old system, no E-terms (some radio positions)
- mean $[\alpha, \delta]$, new system (loosely FK5, usually J2000)
- geocentric apparent $[\alpha, \delta]$, new system
- ecliptic coordinates $[\lambda, \beta]$, new system (mean of date)
- galactic coordinates $[l^{II}, b^{II}]$, IAU 1958 system

COCO's user-interface is spartan but efficient. The program offers control over report resolution, and there has a simple online help facility. All input is free-format, and defaults are provided where this is meaningful.

The input/output arrangements of COCO are flexible, to allow a variety of operating styles – interactive, input from a file, report to a file, batch, *etc.* Also, in addition to the report which is produced, the results of the conversions are also available in a raw form, to a fixed resolution and free from extraneous formatting; this file is intended to be read easily by other programs.

In order to comply with the IAU 1976 recommendations, all position data published from 1984 on should be given in the new system, using equinox J2000.0. However, positions are still frequently given in the old system, using equinox B1950.0. Discriminating astronomers and astrophysicists are best advised to give both B1950 and J2000 positions for sources mentioned in their publications; the conversion can be done using COCO.

2 Operating Instructions

To run COCO interactively, on either VAX/VMS platforms or the Sun SPARCstation and DECstation Unix-based platforms, simply type:

```
COCO
```

The program then accepts commands and outputs appropriate replies.

The primary commands are as follows:

```
Command                        Function

   I p    specify input coordinate system (p defined below)
   O p    specify output coordinate system (       "       )
 <coords> perform conversion  (or = to repeat last coordinates)
   E      exit
```

where the parameter p, specifying the coordinate system, is as follows:

```
4 [eq] [ep]     equatorial, FK4 (barycentric)
B [eq] [ep]     like FK4 but without E-terms (barycentric)
5 [eq] [ep]     equatorial, FK5 (barycentric)
A  ep           equatorial, geocentric apparent
E  ep           ecliptic (barycentric)
G [ep]          galactic (barycentric)

eq = equinox, e.g. 1950 (optional B or J prefix)
ep = epoch, e.g. 1984.53 or 1983 2 26.4
```

Coordinates type 4 and B default to equinox B1950. Coordinates type 5 default to equinox J2000. In all three of these coordinate systems the epoch defaults to the equinox. For coordinate type G the epoch defaults to B1950.

The following commands are also available:

```
Command                     Function

  F          specify RA mode: x = H for hours, D for degrees
  S          display current settings
  ?          show format of <coords>
  /<file>    switch to secondary input file <file>
  H          list the commands
  R x        select report resolution:  x = H, M or L
                                         (high,medium,low)
```

Input is free-format, with spaces separating the fields (comma is also acceptable as a field separator within coordinates). Both upper and lower case letters are acceptable. Blank lines can be input freely, and a comment can be appended to any line by preceding it with an asterisk.

The α format command, F, selects either hours or degrees as the units for α, affecting both the input formats which are accepted and the format of the outputs. The command “F D” selects degrees as the α unit, limits the input formats to a single number in degrees for both α and δ, and causes the output formats to be a single number in degrees for both α and δ. The command “F H” switches to the hours format, enabling a variety of sexagesimal input formats as well as plain hours and degrees, and causing the output formats to be h,m,s,d,$'$,$''$.

On startup, COCO is set to input FK4 B1950 and output FK5 J2000, with α in hours and medium report resolution.

In a typical COCO run, the first step would be to specify the input and output coordinate systems by means of the I and O commands, and then to enter the coordinates to be transformed. For example, suppose that we wish to convert a QSO position measured from a plate taken in mid-1976 and using reference stars from the B1950.0 SAO catalogue to coordinates in the new J2000.0 system. The following commands could be used:

```
I 4 1950 1976.5        * input system is FK4 B1950; epoch is 1976.5
O 5                    * output system is FK5 J2000
12 43 25.3 +32 15 29   * measured 1950 position; no proper motion
```

Some additional operating modes are described in a later section.

Notes:

1. The results output by COCO are believed to be of more than adequate accuracy for all practical purposes at present and are far more precise than any available star coordinates. Geocentric apparent place is the least accurate form, and is limited (in the worst case) to about 0.3 milliarcsec by the model for Earth velocity and position that is used. The more straightforward conversions are, as implementations of the accepted algorithms, several orders of magnitude better than this figure. It should be noted, however, that there is a lingering debate about the precise formulation of the conversion between FK4 data and the new FK5 system. COCO uses the algorithm published in the 1985 Astronomical Almanac. The differences are far too small to pose problems for non-specialists.

2. The three report resolutions provided are referred to simply as L (low), M (medium), and H (high). At resolutions "L" and "M", all the figures output are trustworthy. Resolution "H" is provided mainly to allow comparison with other predictions and to decrease rounding errors where differences are taken.

3. COCO is for use only with sources well outside the solar system. Where appropriate, stellar parallax and aberration are allowed for, but the corrections for gravitational deflection assume that the source is distant. In particular, COCO is not suitable for predicting apparent places for the Sun.

4. COCO is not intended for the conversion of catalogue data, and reports positions only; updated proper motions *etc.* are not reported. Full conversion of catalogue data is best done by writing *ad hoc* programs, using the subprograms in the SLALIB library (see SUN/67).

5. COCO accepts both commands and data from up to two sources, called the *primary* and *secondary* input files. To switch to a secondary input file called STARS.DAT, for example, would require the command /STARS.DAT. (The switch command itself is available only from the primary input file.) When an E command, or end of file, is detected during input from a secondary file, control reverts to the primary file. The same secondary input file may be processed several times in one COCO run, as in the example of producing the apparent places of a fixed list of stars for a series of dates – the secondary file could be the list of stars and the primary file a series of pairs of commands, each pair specifying a new epoch and then switching again to the secondary file to process all the stars anew.

6. All of COCO's coordinate systems except for geocentric apparent are barycentric, *i.e.* unaffected by parallax. Mean places which include displacements due to parallax can be handled by working via the intermediary of geocentric apparent place. For example, the following procedure takes a J2000 barycentric place and adds the (small) effect of parallax for a given date:

   (a) Set the report resolution to high.
   (b) Set the input system to J2000.
   (c) Set the output system to geocentric apparent place for the required date.
   (d) Enter the mean place with proper motions and parallax (and radial velocity if available).

(e) Note the apparent place.

(f) Set the input system to geocentric apparent, specifying the same date as in step (c).

(g) Set the output system to J2000.

(h) Type in the apparent place from step (e). The result will be close to the position entered in step (d), but with the effects of parallax added.

3 Input Formats

The input and output coordinate systems require, variously, *equinoxes* and *epochs*. The timescale is TDB, which for most uses of COCO can be regarded as the same as UTC.

Equinoxes are Besselian or Julian epochs. They can be preceded by a B or J as appropriate; in default, epochs before 1984.0 are assumed to be Besselian, while epochs 1984.0 and after are assumed to be Julian (the distinction is usually unimportant in this context). Valid examples are B1950.0, J2000, 1975.

Epochs may either be expressed as Besselian or Julian epochs, or as year,month,day in the Gregorian calendar. Valid examples are J1984.3296 and 1985 2 13.2439. Calendar dates have to have valid years and months, but a days value outside the conventional range is permissible (*e.g.* 1992 12 32)

In the mean $[\alpha, \delta]$ systems, the equinox defines the coordinate system while the epoch defines the date of observation. In the two cases where the reference frame is inertial – FK5 and galactic – the epoch is required merely to allow the proper motion to be calculated.

Each input coordinate system has its own data format, as follows.

3.1 The three sorts of Mean RA,Dec

For α in hours the following formats are accepted:

```
         RA      Dec          PM        Px     RV
        h m s   d ' "   [s/y  "/y      ["    [km/s]]]
  or    h m s   d '
  or    h m     d '
  or    h       d
```

The first two, four, five, or six numeric fields, representing α and δ, are mandatory. The seventh, eighth, ninth and tenth, representing proper motion, parallax and radial velocity, are optional, with the proviso that both proper motions are required if present at all. The $[\alpha, \delta]$ fields are permitted to exceed the conventional ranges; this is to remain consistent with many existing tabulations (for example α 24 00 01.063 would be accepted and correctly interpreted). The scope for data validation is correspondingly limited.

Note that the proper motions are per year rather than per century. Note also that east-west proper motion is normally seconds of time (of α) rather than arcseconds (on the sky). However, COCO will accept east-west proper motion expressed in arcseconds on the sky if the α proper motion is followed by the double-quote character fstring". Star data from catalogues which express proper motions in other ways (for example per century or in terms of position-angle) have to be transformed before they can be used by COCO.

In the case of FK4 coordinates (with or without E-terms), omitting proper motions is interpreted as meaning that the proper motions are assumed negligible in an inertial frame. If a star has zero proper motion in the FK4 system, then zeroes must be entered explicitly; such a star will have a real proper motion of up to 0.5 arcsec per century (just as distant sources, galaxies for example, have a fictitious proper motion in the FK4 system). In addition, because the FK4 system is rotating relative to an inertial frame, if the proper motions are omitted it is important to specify the epoch at which the position was correct.

In the case of FK5 coordinates, omission of proper motions simply implies zero proper motion (FK5 is presumed not to be rotating).

The parallax and radial velocity both default to zero. (Even when the parallax is not zero, the $[\alpha, \delta]$ is barycentric – see Section 2, Note 6.)

For α in degrees (selected by the command "F D"), the following format is accepted:

```
        RA      Dec
        d        d
```

Both numbers are required. There is provision for neither sexagesimal notation nor proper motion.

3.2 Geocentric Apparent

For α in hours the following formats are accepted:

```
        RA      Dec
       h m s   d ' "
 or    h m s   d '
 or    h m     d '
```

Four, five, or six numbers are required.

For α in degrees (selected by the command "F D"), the following format is accepted:

```
        RA      Dec
        d        d
```

Both numbers are required.

3.3 Ecliptic

```
       lambda  beta
         d       d
```

Both numbers are required.

3.4 Galactic

```
L2  B2
 d   d
```

Both numbers are required.

4 Further Operating Modes

The VMS DCL command procedure and Unix C-shell script which invoke COCO both have optional parameters which allow the sources and destinations of the main input and output streams to be defined:

```
COCO   [input]  [report]  [output]
```

In the case of interactive operation, both input and report are assigned to the terminal. The output file includes only the results, in a fixed format and without extraneous formatting; it is intended to be easy to read in other programs.

The combination of parameters presented causes COCO's input/output streams to be assigned one of several configurations which are intended to produce sensible results in a variety of modes of use, both interactive and batch. More direct control of COCO may be desirable on occasion.

Under VMS, it is permissible to invoke the COCO executable program by first assigning the logical names `FOR0nn` to the required files:

```
FOR011    output    raw output for redirection
FOR012    output    echo of input
FOR013    output    report (including error warnings)
FOR015    input     commands and data
FOR016    output    prompts
FOR017    output    error warnings
```

(In addition, I/O unit 14 is used internally to read secondary files.)

As an example, suppose that we wish to run COCO in batch on a VMS system, with the commands included in the batch command procedure itself, with no output file, and with the results to appear in the printed log. This could be accomplished by submitting the following command procedure:

```
$  ASSIGN/USER_MODE NL:         FOR011  ! raw output
$  ASSIGN/USER_MODE SYS_$OUTPUT FOR012  ! echo of input
$  ASSIGN/USER_MODE SYS_$OUTPUT FOR013  ! report
$  ASSIGN/USER_MODE SYS_$INPUT  FOR015  ! commands
$  ASSIGN/USER_MODE SYS_$OUTPUT FOR016  ! prompts
$  ASSIGN/USER_MODE NL:         FOR017  ! errors
$  RUN COCO_DIR:COCO
```

```
I 5       * input J2000 FK5
O 4       * output B1950 FK4

*  Source position
14 39 36.087 -60 50 07.14   -0.49486 +0.6960   0.752 -22.2

E
```

On the Unix platforms, the COCO executable may be invoked by means of the following shell command:

```
coco.x terml output echo report input prompts errors
```

The seven command-line parameters, all of which must be present, are, respectively, the string identifying the terminal (perhaps obtained by using the command `set terml = 'tty'`) and the six filenames.

5 Acknowledgments

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