Representations of Celestial Coordinates in FI

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Initial (1979) FITS Coordinate Specificatio

Keywords

`CTYPE`n Coordinate type (8 characters)
`CRPIX`n Reference pixel location
`CRVAL`n Coordinate value at reference pixel
`CDELT`n Coordinate increment at reference pixel
`CROTA`n Coordinate "rotation"

Problems with this

- Types inadequate for celestial coordinates, velociti
- Physical meaning of reference pixel undefined
- Rotation undefined, inadequate for general use
- No provision for skew in images

AIPS 1983 enhancements

- Types defined for some celestial coordinates, veloc
- Reference pixel defined as tangent point
- Rotation limited to celestial coordinates
- Still no skew or offset rotations
- Limited view of projective geometries

Proposed FITS Coordinate Specification

New Keywords for All Coordinate Types

`CUNIT`n coordinate units string

- the units used in `CRVAL`n and `CDELT`n
- simple SI units (and degrees) preferred
- allowed units and format of string to be discussed

`PC`$nnnmmm$ Matrix

- Replaces `CROTA`n keywords
- Allows skew, offset and general rotations
- Allows dissimilar coordinates to be rotated togeth
- Relative coordinates given by linear transform :

$$\begin{pmatrix} x \\ y \\ z \\ \vdots \end{pmatrix} = \begin{pmatrix} \texttt{CDELT1} & 0 & 0 & \dots \\ 0 & \texttt{CDELT2} & 0 & \dots \\ 0 & 0 & \texttt{CDELT3} & \dots \\ \vdots & \vdots & \vdots & \ddots \end{pmatrix} \begin{pmatrix} \texttt{PC001001} & \texttt{PC001002} & \texttt{PC001003} \\ \texttt{PC002001} & \texttt{PC002002} & \texttt{PC002003} \\ \texttt{PC003001} & \texttt{PC003002} & \texttt{PC003003} \\ \vdots & \vdots & \vdots \end{pmatrix}$$

Proposed FITS Coordinate Specification

New Keywords for All Coordinate Types

Secondary description(s) of coordinate axis n

- `C`m`VAL`n coordinate value at reference pixel
- `C`m`PIX`n reference pixel array location
- `C`m`ELT`n coordinate increment at reference pixel
- `C`m`YPE`n axis type (8 characters)
- `C`m`NIT`n units of `C`m`VAL`n and `C`m`ELT`n (character valued as `CUNIT`m)

$$m = 2, 3, 4, 5, 6, 7, 8, \text{ or } 9$$

Astrometry-related keywords added

- `EQUINOX` replaces `EPOCH` for the epoch of the mean equator and equinox in years
- `MJD-OBS` modified Julian date of observation in da
- `RADECSYS` frame of reference of equatorial coordin as `FK4`, `FK4-NO-E`, `FK5`, `GAPPT`

Proposed FITS Coordinate Specification

Keywords for Celestial Coordinates

`CTYPE`n format defined

- First 4 characters give type of "standard coordinate sys
  equatorial — `RA--` and `DEC-`
  galactic — `GLON` and `GLAT`
  ecliptic — `ELON` and `ELAT`
- Second 4 characters give type of projection as `-`ccc
  where ccc defined by convention, such as
  `SIN`, `TAN`, `ARC`, `AIT`

`CRPIX`n meaning defined by projection

- Each projection has "native coordinate system "
- Reference pixel is native north pole $(0, 90°)$ for
  azimuthal and conical projections
- Reference pixel is native origin $(0, 0)$ for
  cylindrical and conventional projections

Proposed FITS Coordinate Specification

Celestial Coordinates Continued

CDELTn clarified

- Increment in physical units per pixel of physical ax
- Applied after pixel rotation and skew
- This linear physical "coordinate" then converted by non-linear formulæ to true physical coordinates

CRVALn clarified

- Value at the reference pixel in the standard coordin specified in CTYPEn

LONGPOLE keyword added for generality

- Native longitude of north pole of standard system
- Default value is 180°

PROJPj keywords added to define some projectio

Proposed FITS Coordinate Specification

Conventions and Matters of "Good Form"

1. The center of each pixel is its location.
2. Default viewing convention:
   - First pixel at lower left corner,
   - First axis displayed along horizontal,
   - Second axis displayed along vertical.
3. Diagonal elements of `PC`*iiijjj* should predominate.
   - Do not hide transpositions in the `PC` matrix.
4. Forbid rotation into axes which have only integral valu
5. `NCP` projection (of WSRT) changed to offset `SIN` proje
6. When possible, `CROTA`n should be written along with `P`
7. For longitude axis i and latitude axis j, the conversion

$$\begin{pmatrix} \texttt{PC}iiiiii & \texttt{PC}iiijjj \\ \texttt{PC}jjjiii & \texttt{PC}jjjjjj \end{pmatrix} = \begin{pmatrix} \cos(\texttt{CROTA}j) & -\sin(\texttt{CROTA}j) \\ \sin(\texttt{CROTA}j) & \cos(\texttt{CROTA}j) \end{pmatrix}$$