

Representations of Celestial Coordinates in FITS

Eric W. Greisen

National Radio Astronomy Observatory

Mark Calabretta

Australia Telescope National Facility

Initial FITS Coordinate Specification

Keywords

CTYPE n Coordinate type (8 characters)

CRPIX n Reference pixel location

CRVAL n Coordinate value at reference pixel

CDEL Tn Coordinate increment at reference pixel

CROTA n Coordinate “rotation”

Problems with this

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

AIPS enhancements

- Types defined for some celestial coordinates, velocities
- 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

Keywords for All Coordinate Types

$CD_{n_m} = CD_{nnnnmmmm}$ Matrix

- Replaces $CDEL T_n$ and $CROTA_n$ keywords
- Allows skew, offset and general rotations
- Allows dissimilar coordinates to be rotated together
- Relative coordinates given by linear transform :

$$\begin{pmatrix} x \\ y \\ z \\ \vdots \end{pmatrix} = \begin{pmatrix} CD1_1 & CD1_2 & CD1_3 & \dots \\ CD2_1 & CD2_2 & CD2_3 & \dots \\ CD3_1 & CD3_2 & CD3_3 & \dots \\ \vdots & \vdots & \vdots & \ddots \end{pmatrix} \begin{pmatrix} i - i_0 \\ j - j_0 \\ k - k_0 \\ \vdots \end{pmatrix}$$

Proposed FITS Coordinate Specification

Keywords for Celestial Coordinates

CTYPE n format defined

- First 4 characters give type of “standard coordinate system” as
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

CRVAL n clarified

- Value in standard coordinates at the reference pixel
- LONGPOLE keyword added for generality
Native longitude of north pole of standard system
Default value is 180°

PROJP j keywords added to define some projections

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 days
- RADECSYS frame of reference of equatorial coordinates
as FK4, FK4-NO-E, FK5, GAPPT

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 $CD_{i,j}$ should predominate.
 - Do not hide transpositions in the CD matrix.
4. Forbid rotation into axes which have only integral values.
5. NCP projection (of WSRT) changed to offset SIN projection.
6. When possible, $CDEL T n$ should be written along with $CD_{i,j}$.
7. For longitude axis i and latitude axis j , the conversion is

$$\begin{pmatrix} CD_{i,i} & CD_{i,j} \\ CD_{j,i} & CD_{j,j} \end{pmatrix} = \begin{pmatrix} CDEL T i \cos(CROTA j) & -CDEL T j \sin(CROTA j) \\ CDEL T i \sin(CROTA j) & CDEL T j \cos(CROTA j) \end{pmatrix}.$$