Column Limits Convention: FITS Keywords for Describing the Minimum and Maximum Values in Columns of FITS Tables

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A. KEYWORD DEFINITIONS

This convention defines 4 optional keywords to describe the minimum and maximum values in columns of a FITS ASCII or binary table:

TDMINn Keyword: The value field shall contain a number giving the minimum physical value contained in column **n** of the table. This keyword is analogous to the `DATAMIN` keyword that is defined in the FITS standard for use with FITS images.

TDMAXn Keyword: The value field shall contain a number giving the maximum physical value contained in column **n** of the table. This keyword is analogous to the `DATAMAX` keyword that is defined in the FITS standard for use with FITS images.

TLMINn Keyword: The value field shall contain a number giving the minimum legally defined physical value that might be contained in column **n** of the table.

TLMAXn Keyword: The value field shall contain a number giving the maximum legally defined physical value that might be contained in column **n** of the table.

The following conventions should be followed in the use of these keywords:

- The 'physical value' is defined as the value after applying the `TSCALn` and `TZEROn` linear scaling keywords, if present.
- These keywords are not applicable to columns containing ASCII strings or logical data.
- These keywords should have the same data type as the physical values in the associated column (either an integer or a floating point number).
- These keywords apply to all the elements of a vector column.
- Any undefined elements (or any other IEEE special values in the case of floating point columns in binary tables) should be excluded when determining the value of these keywords.
- The `TLMINn` and `TLMAXn` keywords define the allowed legal range of the column values; there is no requirement that the column actually contain any or all of the allowed values.
- It is permissible to have values in the column that are less than `TLMINn` or greater than `TLMAXn`; the interpretation of any such out-of-range column elements is not defined by this convention.
- If `TDMINn` is greater than `TDMAXn`, or `TLMINn` is greater than `TLMAXn`, then this should be taken to mean that the pair of keywords are undefined.

B. EXAMPLES

These keywords are commonly used in *event list* tables in which each row of the table describes an event, such as the measured arrival time, position, and/or energy of a detected photon. For example, if a particular CCD photon counting detector is 512 by 384 pixels in size, then the location of each photon in the 'chip' coordinate system would have an X coordinate ranging from 1 to 512 and a Y coordinate ranging from 1 to 384. Other coordinate frames could also be defined, such as a 'detector' coordinate system which might be defined so that the origin is centered on the chip. The FITS header keywords appropriate for this case are shown below:

```
XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                   16 / width of table in bytes
NAXIS2  =                34803 / number of rows/events
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    4 / number of columns in each row
EXTNAME = 'EVENTS  '           / name of this binary table extension
TTYPE1  = 'CHIPX   '           / Chip coordinatess
TFORM1  = '1I      '           / format of column 1
TTYPE2  = 'CHIPY   '           / Chip coordinates
TFORM2  = '1I      '           / format of column 2
TTYPE3  = 'DETX   '            / Detector coordinates
TFORM3  = '1I      '           / format of column 3
TTYPE4  = 'DETY   '            / Detector coordinates
TFORM4  = '1I      '           / format of column 4
TLMIN1  =                    1 / minimum legal value in column 1
TLMAX1  =                  512 / maximum legal value in column 1
TLMIN2  =                    1 / minimum legal value in column 2
TLMAX2  =                  384 / maximum legal value in column 2
TLMIN3  =                 -256 / minimum legal value in column 3
TLMAX3  =                  255 / maximum legal value in column 3
TLMIN4  =                 -192 / minimum legal value in column 4
TLMAX4  =                  191 / maximum legal value in column 4
TDMIN1  =                   17 / minimum actual value in column 1
TDMAX1  =                  510 / maximum actual value in column 1
TDMIN2  =                    6 / minimum actual value in column 2
TDMAX2  =                  378 / maximum actual value in column 2
```

The CHIPX and CHIPY columns in this example give the photon location in the chip reference frame, and the DETX and DETY columns give the location in the detector reference frame. The `TLMINn` and `TLMAXn` keywords give the allowed range of values in each column. The `TDMINn` and `TDMAXn` keywords are given for the first 2 columns in this example, to illustrate that the actual range of values in the column need not cover the entire allowed range.

The `TLMINn` and `TLMAXn` keywords are often used to define the default binning range when creating a histogram of the values in the column(s). To create a 2D image from the CHIPX and CHIPY columns, the `TLMINn` and `TLMAXn` keywords for those columns indicate that the histogram bins should cover the coordinate range from 1 to 512 in the X direction, and from 1 to 384 in the Y direction to create an image of the entire chip. To make a similar image from the DETX and DETY columns,

the bins would need to cover the coordinate range from -256 to +255 in X, and -192 to +191 in the Y direction (i. e., the first pixel in the lower left corner of the binned image would record the number of events that have DETX = -256 and DETY = -192). It is important to note that the values in the columns are allowed to exceed the range given by `TLMINn` and `TLMAXn`. For example, any anomalous photon events might be assigned a chip coordinate of (-1, -1), therefore the histogramming algorithm should be prepared to deal with such outliers.

In practice, the `TDMINn` and `TDMAXn` keywords have been rarely used in publicly archived data sets. In contrast, the `TLMINn` and `TLMAXn` keywords are widely used, especially in the event list data files that have been produced by ROSAT, Chandra, XMM-Newton, INTEGRAL, and other X-ray and gamma-ray astrophysics missions since about 1994.