lcplot

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Abstract

lcplot produces plots of the net source and background time series for a single time series FITS file or for several time series FITS files produced by **elcbuild** for EPIC and **omlcbuild** for the OM. Furthermore it performs Chi Square and Kolmogorov-Smirnov tests on the light curve to determine whether the source is variable.

1 Instruments/Modes

Instrument	Mode
EPIC MOS	IMAGING, TIMING
EPIC PN	IMAGING, TIMING
OM	FAST

2 Use

pipeline processing	yes
interactive analysis	yes

3 Description

lcplot produces plots of time series measured either by EPIC or by the OM. These plots show both net and background count rates. **lcplot** can be used to display a single time series directly or the multiple time series, produced by **elcbuild** for EPIC and by **omlcbuild** for the OM, and supplied as FITS files. Alternatively the task **omthlcplot** can be used to produce rate plots of the OM tracking star's intensities.

The input FITS files must contain net count rates, background count rates and the associated errors. The time series must follow a regular binning scheme (i.e. equispaced time bins) [1]. The bin width is given by the keyword `TIMEDEL`.

Each light curve (net and background) of the input file is plotted on a separate page. For instance, in a PPS use, EPIC time series are given in three energy bands, so the plots will be composed of three light curve pages. On the other hand, an OM FITS file which contains only one light curve, will give a single page plot.

The task performs 1) the Chi Square and 2) the Kolmogorov-Smirnov tests on the total counts. **lcplot** tests the null hypothesis (the source is not variable) using 1). A Chi Square fit is carried out on the count distribution and the constant distribution whose value is equal to the observed mean (both statistics and the probability are computed) using 2). A Kolmogorov-Smirnov test is carried out on the cumulative probability functions of the observed count distribution and the theoretical Gaussian distribution whose mean and variance are both equal to the observed mean count.

Results are written on a single page after the light curve(s).

Plots give time after `TSTART` (keyword in the FITS file) on the X-axis against count rates on the Y-axis. Please note, bins with a low exposure and therefore large errors are not plotted.

lcplot allows the user to input the device type (e.g. Xwindow, Postscript, ...) for output. The y-scale of the background counts can be forced to be the same as the source counts by setting the parameter 'bkgdyscale' to 'yes'. Otherwise the y-axis is scaled to the most appropriate value for the background counts.

As described in [1], light curves should be rebinned if necessary in order to limit the number of plotted data points to 500.

3.1 Examples

To create a postscript plot, called plot.ps, with both net and background count rates and the results of the Chi Square and Kolmogorov-Smirnov tests, from the FITS file 'lightcurve.ds', where the counts are binned up by a factor 10, a command such as,

```
lcplot set="lightcurve.ds" plotdevice="/VPS" plotfile="plot.ps" binsize=10
```

can be used.

4 Parameters

This section documents the parameters recognized by this task (if any).

Parameter	Mand	Type	Default	Constraints
set	yes	dataset	No default	

Name of the FITS file containing the time series. Case sensitive.

plotdevice	no	String	"/PS"	Constraint : valid device type

Not case sensitive.

plotfile	no	String	"plot.ps"	less than 1024 char.

Name of the output file containing the plot. Case sensitive.

binsize	no	Integer	5	Constraint : positive value
bkgdyscale	no	boolean	no	yes/no

To scale the y-axis of the plot of the background counts to be the same as the y-axis of the plot of the source counts

5 Errors

This section documents warnings and errors generated by this task (if any). Note that warnings and errors can also be generated in the SAS infrastructure libraries, in which case they would not be documented here. Refer to the index of all errors and warnings available in the HTML version of the SAS documentation.

Incorrect RATE extension *(error)*
Incorrect `RATE` extensions (see Developer's notes for more details)

Keyword TIMEDEL missing *(error)*
The keyword `TIMEDEL` is missing

Existing output file cannot be overwritten *(error)*
The output file exists, and cannot be overwritten because the SAS_CLOBBER variable is set to 0

Unavailable default device type and/or output file *(error)*
Unavailable default device type and/or output file

Invalid input file *(error)*
Invalid input column dimensions (the four columns `RATE`, `ERROR`, `BACKV`, `BACKE` contained in the FITS file must be arrays of dimension Nlightcurve × Nbins)

Unavailable device type and/or output file *(warning)*

corrective action: The device type and output file are set to the defaults.

Number of data points to plot is higher than 500 *(warning)*

corrective action: Increase binsize value until the number of points to plot is lower than 500 [1]

Too small number of bins *(warning)*
Number of valid bins is lower than 2. Cannot perform tests
corrective action: No variability tests are delivered

Mandatory keywords are missing from the input file *(warning)*
Some mandatory header keywords are missing or inconsistent
corrective action: A warning is raised and the task tries to proceed

6 Input Files

1. EPIC or OM FITS Time Series [1] (generated by **omlcbuild** or **elcbuild**).

7 Output Files

1. EPIC or OM Postscript Source Time Series [1] (Deliverable PPS product)

8 Algorithm

```
Subroutine lcplot

  Recover parameters (File names, Device type, Binning factor, Ouput file)

  Read source time series FITS file :
     Get dataset and table.
     Check important keyword consistency (notably TSTART and TIMEDEL).
     Call a warning or error if necessary.

  Recover all light curves included in table (in PPS use, 3 for EPIC, 1 for OM) :
     Net source rates and errors & background rates and errors are recorded in arrays
     of dimension Nlightcurve * Nbins.

  Open plot : create view surface in specified device format (check its validity).

  For each light curve :

     Delete gaps in data (when the IEEE NaN constant is found).

     Increase binsize if necessary to limit the number of points to 500.

     Rebin rate and error columns by binsize

     Create a labelled plot page separated into two panels in which time is graduated
     on X-axis (see Comments), and count rates on Y-axis (in counts/sec).

     Draw net source and background time series on different panels.

     Reconstruct net source counts and total counts rebinned :

     Perform variability tests on rebinned net source counts :
        Calculate mean count rate and variance.
        Test the null hypothesis (the source is not variable) by :
           - Processing a Chi Square fit between the count distribution and a
           constant distribution whose value is equal to the observed mean (statistic
           and probability are computed).
           - Processing a Kolmogorov-Smirnov test between the cumulative probability
           functions of the observed count distribution and a theorical Gaussian
           distribution whose mean and variance are both equal to the observed mean
           count.
  End for

  Write variability test results on a single plot page.

  Release memory.
```

```
    Close plot.

  End subroutine  lcplot
```

9 Comments

- **lcplot** only produces plots of light curves measured by EPIC or OM. We note that no RGS Source Time Series FITS file is specified in [1].
- Error rates are rebinned following a quadratic scheme (Central limit theorem).
- Time intervals all have the same length, the first one is [TSTART , TSTART + Binsize*TIMEDEL] where `TIMEDEL` is the bin width read from the file [1].
- We note in [1] that the keyword `TIMEDEL` is specified in MJD. We have assumed it to be given in seconds.
- Time on the X-axis is given as T-TSTART in seconds.
- The mean, variance, Chi Square, etc are provided with six significant digits.
- A Chi Square statistic close to the bin number and a small Kolmogorov-Smirnov statistic with probabilities higher than 0.01 indicate that the source is not variable.
- The output devices are those of the PGPLOT library. The device list is governed by the drivers available to PGPLOT.

10 Future developments

- A parameter Time_Unit could be added to the parameter file. It would allow a choice of different time axis units (e.g. Hours after `TSTART`).
- The results of the statistical analysis could be saved as keywords in the header of the light curves source FITS file. Example, for the first energy band, one could add :

```
AVRGE_1 =       ..............  / Avg, count/s in light-curve
FREXP_1 =       .............   / Avg. Frac exposure in light-curve
VAROB_1 =       .............   / observed variance
VAREX_1 =       .............   / expected variance
THRDM_1 =       .............   / third moment
MININ_1 =       .............   / Minimun Intensity
MAXIN_1 =       .............   / Maximun Intensity
EXVAR_1 =       .............   / excess of variance
CHI2_1  =       .............   / Chi squared
CHI2PR_1=       .............   / Chi squared probability
KS_1    =       .............   / K-S test value
KSPR_1  =       .............   / K-S probability
RMS_1   =       .............   / RMS variability
AVRGE_E1=       .............   / Error Avg count/s
VAROB_E1=       .............   / Error observed variance
VAREX_E1=       .............   / Error expected variance
CHI2_E1 =       .............   / Error Chi2
RMS_E1  =       .............   / Error RMS variability
```

10.1 CAL usage

- None

References

[1] SSC. XMM Survey Science Centre to Science Operations ICD for SSC Products. Technical Report XMM-SOC-ICD-0006-SSC Issue 2.1, SSC, Mar 2000.