Basic Lightcurves

CIAO 3.4 Science Threads

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Overview

Last Update: 1 Dec 2006 − updated for CIAO 3.4: CHIPS version

Synopsis:

The CIAO `lightcurve` tool is no longer actively maintained or enhanced. Users instead are encouraged to create lightcurves with the new functionality of `dmextract`, which more carefully and accurately applies good time interval (GTI) information.

Purpose:

To create lightcurves for use in a variety of analyses.

Related Links:

- Why topic: Timing Analysis with Lightcurves: caveats that one should be aware of when doing timing analysis on Chandra data.

Proceed to the HTML or hardcopy (PDF: A4 | letter) version of the thread.

Get Started

Sample ObsIDs used: 953 (ACIS−I, 47 Tuc); 461 (HRC−I, 3C 273)

File types needed: evt2; dtf1 (ObsID 461 only)

Tool: dmextract vs. lightcurve

Here we compare the syntax of the two tools; more information is available from the help files for `dmextract` and `lightcurve`.

This `lightcurve` command:

```
unix% lightcurve infile="acis_evt2.fits[ccd_id=3,sky=region(src.reg)]" \
      outfile="lightcurve.fits" binlength="259.28"
```

becomes the following for `dmextract`:

```
unix% dmextract \
      infile="acis_evt2.fits[ccd_id=3,sky=region(src.reg)][bin time=::259.28]" \
      outfile="lightcurve.fits" opt="ltc1"
```

ACIS Lightcurves

The most common lightcurve is made from a point source observed with the ACIS detector. This may be done to get an idea of the variability of the source or to help identify periods of high background.

To begin, we define the regions − two source and one background − which will be used to create the lightcurves. For instructions on how to create regions in ds9, see the Using CIAO Region Files thread. The regions used here are shown in Figure 1 📷:

```
unix% more src1.reg
# Region file format: CIAO version 1.0
circle(4008.5,4035.5,8)

unix% more src2.reg
# Region file format: CIAO version 1.0
circle(4032.5,4032.5,8)

unix% more bkg.reg
# Region file format: CIAO version 1.0
circle(3875.5,3972,54.5)
```

Determine which chips are being used

`dmextract` uses a `ccd_id` filter on the input file ensure that the proper GTIs are used. Use `dmstat` to determine the correct chip:

```
unix% dmstat "acisf00953N002_evt2.fits[sky=region(src1.reg)][cols ccd_id]"
ccd_id
    min:        3             @:        1
    max:        3             @:        1
   mean:        3
  sigma:        0
    sum:        6975
   good:        2325
   null:        0

unix% dmstat "acisf00953N002_evt2.fits[sky=region(src2.reg)][cols ccd_id]"
ccd_id
    min:        3             @:        1
    max:        3             @:        1
   mean:        3
  sigma:        0
    sum:        5622
   good:        1874
   null:        0

unix% dmstat "acisf00953N002_evt2.fits[sky=region(bkg.reg)][cols ccd_id]"
```

```
ccd_id
    min:        3             @:        1
    max:        3             @:        1
   mean:        3
  sigma:        0
    sum:        660
   good:        220
   null:        0
```

The regions with which we are working are all located on chip 3 (ACIS−I3); see Figure 6.1 of the POG for an illustration of the focal plane)

Create a background−subtracted lightcurve

First we extract a background−subtracted lightcurve for "src2":

```
unix% punlearn dmextract
unix% pset dmextract \
      infile="acisf00953N002_evt2.fits[ccd_id=3,sky=region(src2.reg)][bin time=::2000]"
unix% pset dmextract outfile="src2_sub_lc.fits"
unix% pset dmextract bkg="acisf00953N002_evt2.fits[ccd_id=3,sky=region(bkg.reg)]"
unix% pset dmextract opt="ltc1"
unix% dmextract
Input event file  (acisf00953N002_evt2.fits[ccd_id=3,sky=region(src2.reg)][bin time=::2000]):
Enter output file name (src2_sub_lc.fits):
```

You can check the parameter file that was used with plist dmextract.

The lightcurve may be plotted using *ChIPS*:

```
unix% chips

Welcome to ChIPS, version CIAO 3.4
Copyright (C) 1999−2003, Smithsonian Astrophysical Observatory

chips> curve "src2_sub_lc.fits[cols time,net_rate,err_rate]" yerr 3
chips> curve simpleline
chips> curve red
chips> exit
```

This lightcurve is shown in Figure 2. Notice that there is a significant drop in count rate near 6.961x10^{7} seconds. This information is used again in the next section.

Looking for variability

It is also valuable to compare the lightcurves of sources in the same field when looking for variation. Here we extract a lightcurve for each of the "src1" and "src2" regions (intentionally including the background counts):

```
unix% punlearn dmextract
unix% dmextract outfile="curve_1.fits" opt="ltc1" \
      infile="acisf00953N002_evt2.fits[ccd_id=3,sky=region(src1.reg)][bin time=::2000]"

unix% dmextract outfile="curve_2.fits" opt="ltc1" \
      infile="acisf00953N002_evt2.fits[ccd_id=3,sky=region(src2.reg)][bin time=::2000]"
```

and compare the results in *ChIPS*:

[redacted]

```
unix% chips

Welcome to ChIPS, version CIAO 3.4
Copyright (C) 1999−2003, Smithsonian Astrophysical Observatory

chips> split 2
chips> split gap 0.05
chips> d 1 curve "curve_1.fits[cols time,count_rate]"
chips> d 2 curve "curve_2.fits[cols time,count_rate]"
chips> d all curve simpleline
chips> d all curve red
chips> d 1 ylabel "curve\_1.fits"
chips> d 1 ylabel "curve\_1.fits"
chips> d 2 ylabel "curve\_2.fits"
chips> d all ylabel size 1.5
chips> exit
```

These commands produce Figure 3. Comparing this to the background−subtracted lightcurve created in the previous section proves two things:

1. This is not an intrumental effect, since it shows up in `curve_2.fits` but not `curve_1.fits`. An instrumental feature would appear in both sources, as they are close together, on the same chip, etc.
2. This is not a background feature, since it is present in both the subtracted (`src2_sub_lc.fits`) and unsubtracted (`curve_2.fits`) lightcurves.

It is highly likely, therefore, that the dip in count rate is an indication of a variable star. In the case of 47 Tuc, this is due to a binary system; see the Chandra Photo Album entry for 47 Tucanae for more information.

High background levels

The technique for identifying periods of high background from a lightcurve − and subsequently filtering them out − is explained in detail in the Filtering Lightcurves thread.

HRC Lightcurves

The proper method of creating an HRC lightcurve requires accounting for the Dead Time Factor (DTF). The DTF describes the detector's deviation from the standard detection efficiency. This time−dependent change is due to the physical effect of an event striking the micro−channel plate, as illustrated in the MCP Principles page. The DTF is evaluated roughly every 2 seconds and the data are stored in the "`dtf1.fits`" file. The DTF is correlated with the count rate, requiring careful attention for proper analysis.

As of CIAO 3.3, the DTF file can be input to the exp parameter of `dmextract`, which greatly simplifies the process of creating HRC lightcurves. The average DTF value within the time bin is used to correct the exposure time and count rate in the lightcurve.

The source region for this example has been saved in the file `hrc_src.reg`. Again, for instructions on how to create regions in ds9, see the Using CIAO Region Files thread.

```
unix% more hrc_src.reg
# Region file format: CIAO version 1.0
circle(16478,16292,19.5)
```

```
unix% punlearn dmextract
unix% pset dmextract infile="hrcf00461N003_evt2.fits[sky=region(hrc_src.reg)][bin time=64938947.367:
unix% pset dmextract outfile=hrc_lc.fits
unix% pset dmextract opt=ltc1
unix% pset dmextract exp=hrcf00461_001N003_dtf1.fits
unix% dmextract
Input event file  (hrcf00461N003_evt2.fits[sky=region(hrc_src.reg)][bin time=64938947.367:64959159.5
Enter output file name (hrc_lc.fits):
```

You can check the parameter file that was used with plist dmextract.

Plotting the lightcurve in *ChIPS*:

```
unix% chips

Welcome to ChIPS, version CIAO 3.4
Copyright (C) 1999−2003, Smithsonian Astrophysical Observatory

chips> curve "hrc_lc.fits[cols time,count_rate]"
chips> limits y 10.7 auto
chips> c 1 simpleline
chips> c 1 red
```

creates Figure 4 📷.

Refer to the Filtering Lightcurves thread for information on how to handle the low point at ~6.496E+07 seconds.

Caveats

There are a number of subtleties that it is important to be aware of when using lightcurves for timing analysis. These issues are described in the Timing Analysis with Lightcurves why topic; please read that document before continuing with the analysis.

```
Parameters for /home/username/cxcds_param/dmextract.par



#--------------------------------------------------------------------
#
# DMEXTRACT -- extract columns or counts from an event list
#
#--------------------------------------------------------------------
        infile = acisf00953N002_evt2.fits[ccd_id=3,sky=region(src2.reg)][bin time=::2000] Input even
       outfile = src2_sub_lc.fits Enter output file name
          (bkg = acisf00953N002_evt2.fits[ccd_id=3,sky=region(bkg.reg)]) Background
                                  region file or fixed background (counts/pixel/s) subtraction
        (error = gaussian)        Method for error determination(poisson|gaussian|<variance file>)
     (bkgerror = gaussian)        Method for background error determination(poisson|gaussian|<varian
      (bkgnorm = 1.0)             Background normalization
          (exp = )                Exposure map image file
       (bkgexp = )                Background exposure map image file
      (sys_err = 0)               Fixed systematic error value for SYS_ERR keyword
```

```
          (opt = ltc1)            Output file type: pha1
     (defaults = ${ASCDS_CALIB}/cxo.mdb -> /soft/ciao/data/cxo.mdb) Instrument defaults file
         (wmap = )                WMAP filter/binning (e.g. det=8 or default)
      (clobber = no)              OK to overwrite existing output file(s)?
      (verbose = 0)               Verbosity level
         (mode = ql)
```

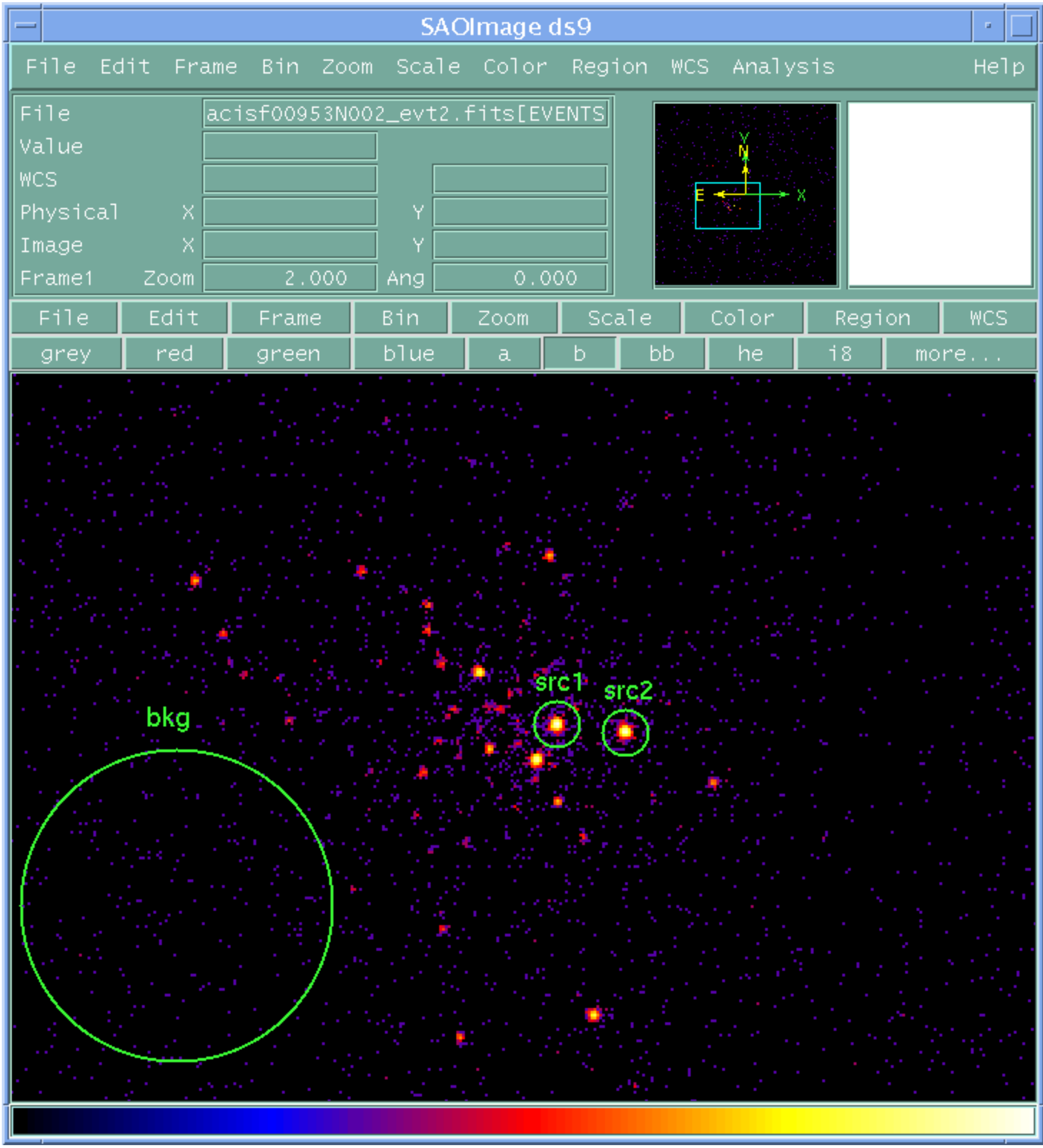
```
Parameters for /home/username/cxcds_param/dmextract.par



#--------------------------------------------------------------------
#
# DMEXTRACT -- extract columns or counts from an event list
#
#--------------------------------------------------------------------
        infile = hrcf00461N003_evt2.fits[sky=region(hrc_src.reg)][bin time=64938947.367:64959159.548:1000]
       outfile = hrc_lc.fits      Enter output file name
          (bkg = )                Background region file or fixed background (counts/pixel/s) subtraction
        (error = gaussian)        Method for error determination(poisson|gaussian|<variance file>)
     (bkgerror = gaussian)        Method for background error determination(poisson|gaussian|<variance file
      (bkgnorm = 1.0)             Background normalization
          (exp = hrcf00461_001N003_dtf1.fits) Exposure map image file
       (bkgexp = )                Background exposure map image file
      (sys_err = 0)               Fixed systematic error value for SYS_ERR keyword
          (opt = ltc1)            Output file type
     (defaults = ${ASCDS_CALIB}/cxo.mdb -> /soft/ciao/data/cxo.mdb) Instrument defaults file
         (wmap = )                WMAP filter/binning (e.g. det=8 or default)
      (clobber = no)              OK to overwrite existing output file(s)?
      (verbose = 0)               Verbosity level
         (mode = ql)
```

History

03 Jan 2005	reviewed for CIAO 3.2: no changes
21 Dec 2005	updated for CIAO 3.3: default value of `dmextract` `error` and `bkgerror` parameters is "gaussian"; `dmextract` can now accept a DTF file in the `exp` parameter, which simplifies the process of creating HRC Lightcurves
01 Dec 2006	updated for CIAO 3.4: CHIPS version

URL: http://cxc.harvard.edu/ciao/threads/lightcurve/ Last modified: 1 Dec 2006

Image 1: Image of 47 Tuc with extraction regions



File acisf00953N002_evt2.fits[EVENTS

Frame1 Zoom 2.000 Ang 0.000

SAOImage ds9
File Edit Frame Bin Zoom Scale Color Region WCS Analysis Help
Value
WCS
Physical X Y
Image X Y
N
Y
E
X
File Edit Frame Bin Zoom Scale Color Region WCS
grey red green blue a b bb he i8 more...
src1
src2
bkg

Image 2: Background−subtracted lightcurve

The background−subtracted lightcurve of "src2". Notice the significant drop in count rate near 6.961x10^{7} seconds.

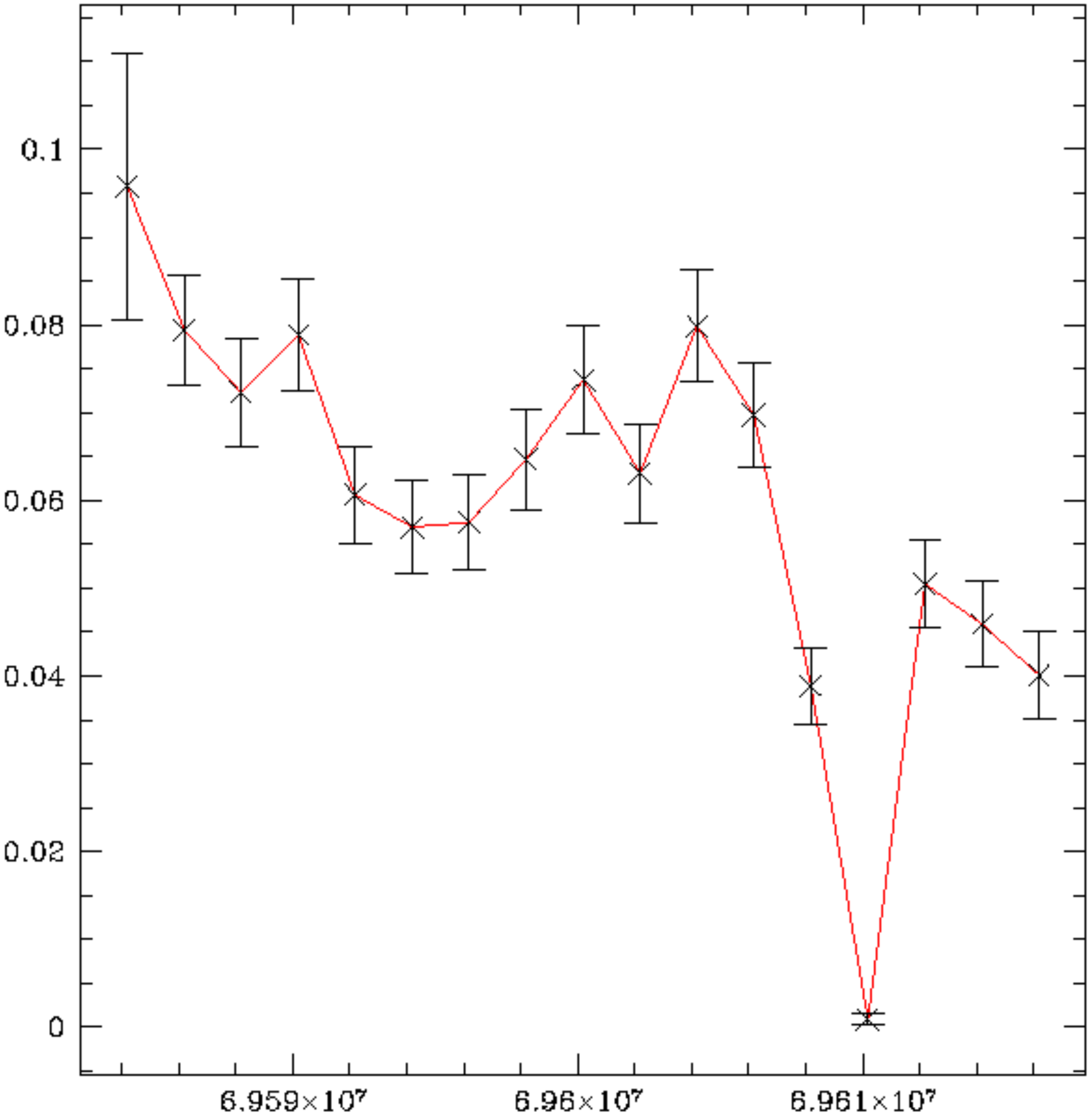


Image 3: Lightcurves for "src1" and "src2"

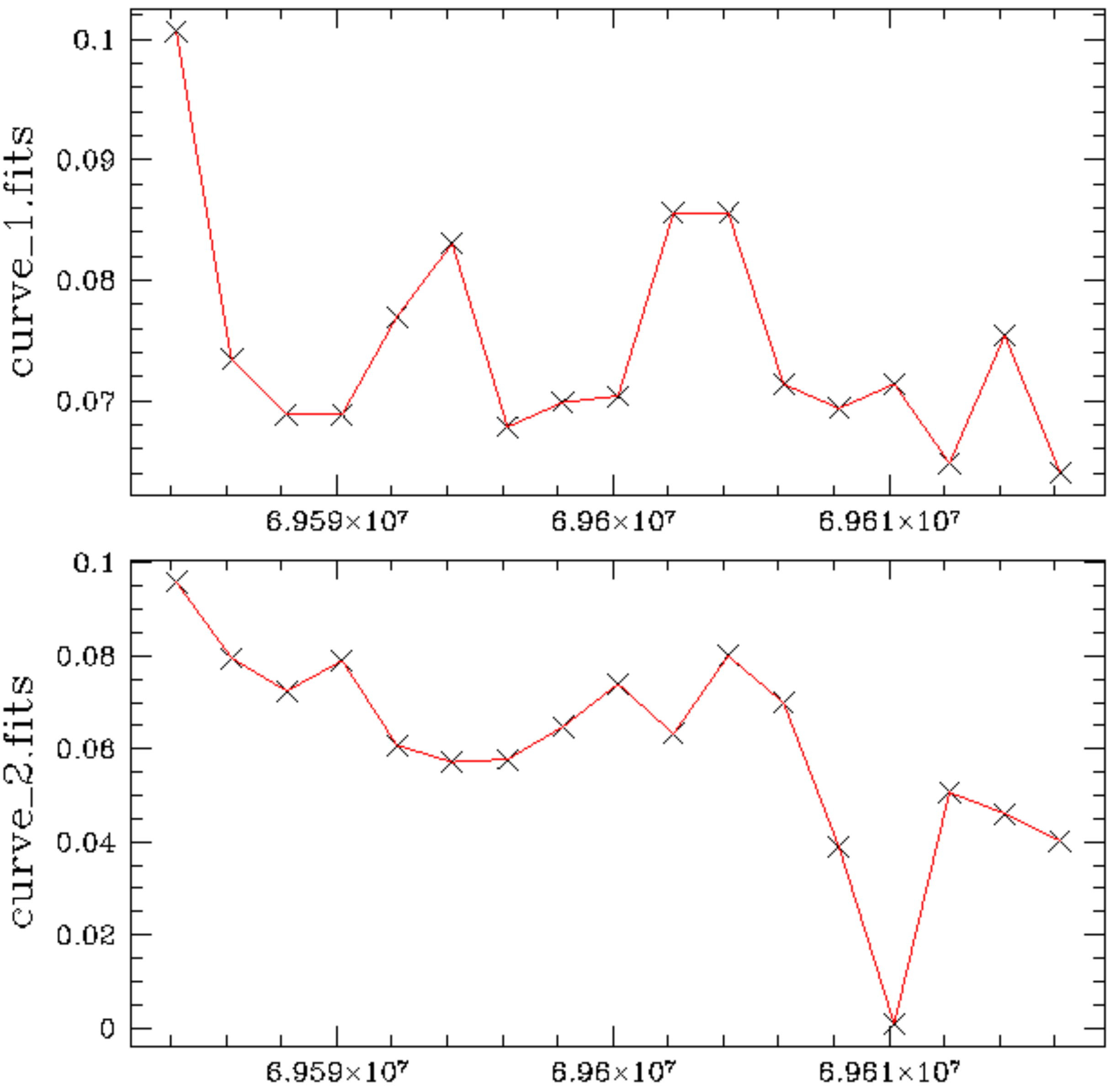
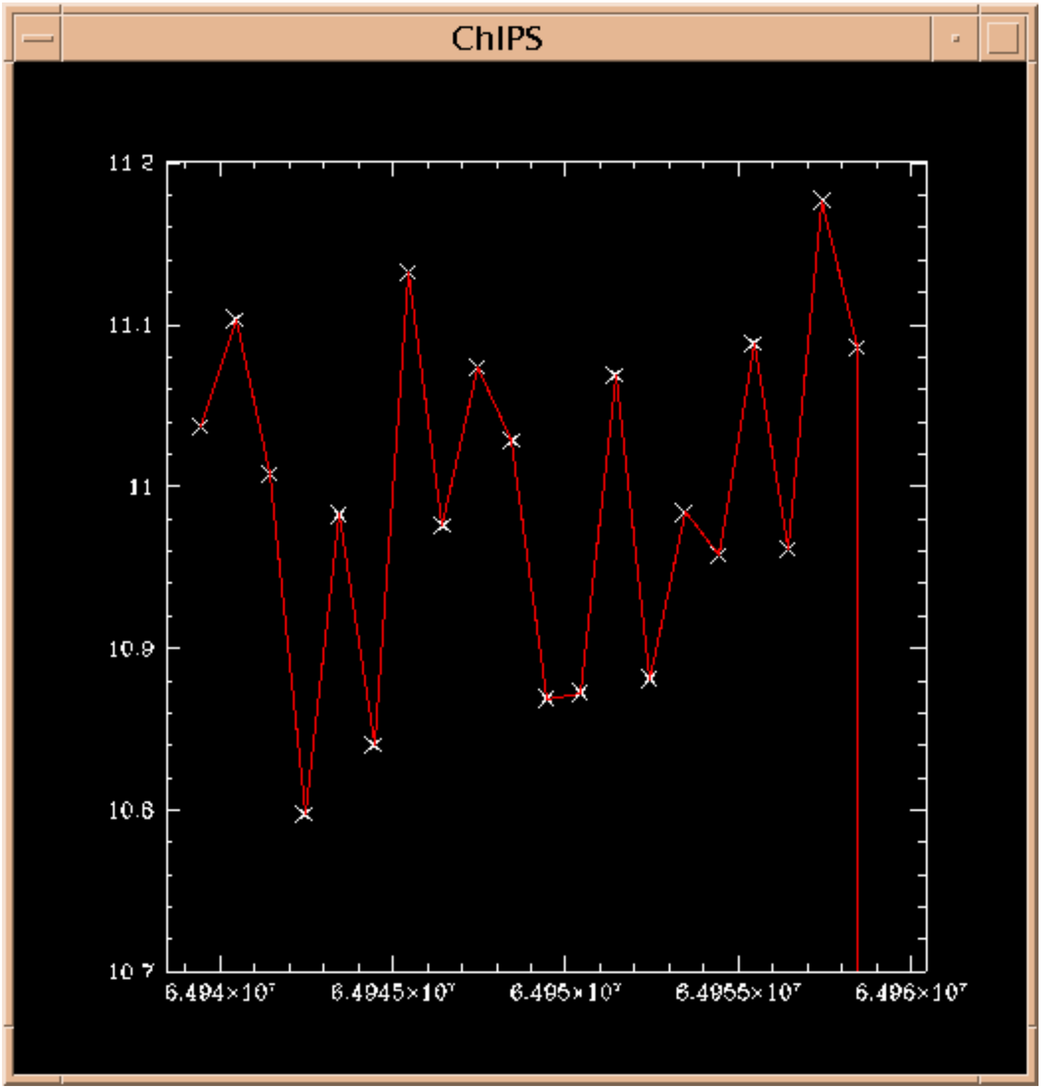


Image 4: HRC lightcurve with DTF correction


ChIPS
11.2
11.1
11
10.9
10.8
10.7
6.494×10⁷
6.4945×10⁷
6.495×10⁷
6.4955×10⁷
6.496×10⁷