# STIS Near-IR Fringing. III. A Tutorial on the Use of the IRAF Tasks

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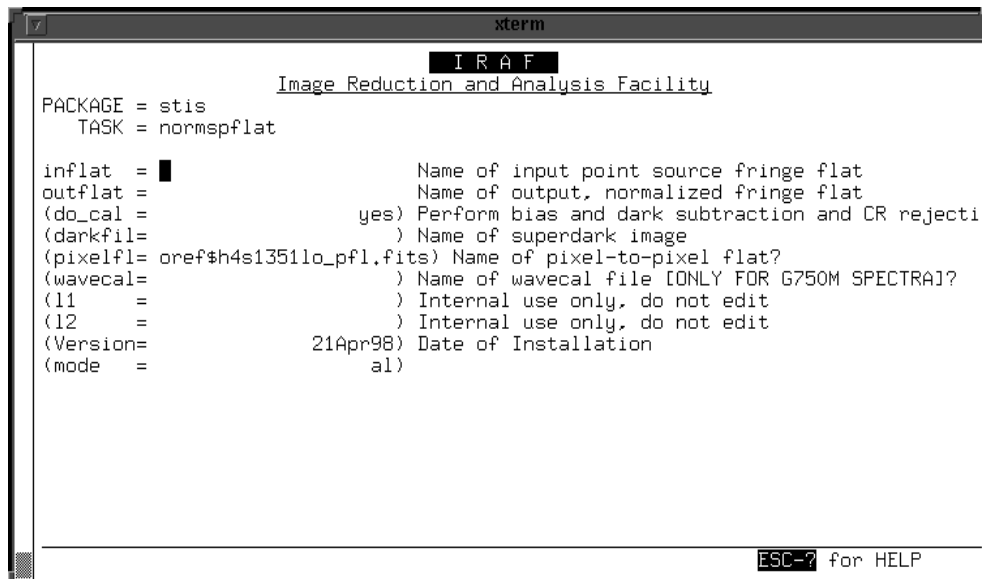**ABSTRACT**

*We guide the user through the process of "defringing" STIS G750L and G750M spectra with central wavelength > 7000 Å, as accomplished by four IRAF tasks available in the* **stsdas.hst_calib.stis** *package. We discuss all relevant task parameters and their meaning. Finally, flow charts of the calibration steps performed in the different tasks are presented in an Appendix.*

## 1. Introduction

STIS CCD spectra at wavelengths longward of about 7000 Å (i.e., spectra taken with gratings G750L and G750M) show a phenomenon called "fringing". This effect is caused by interference of multiple reflections between the two surfaces of the CCD in case the wavelength of the incident light is a small integer multiple of the distance between the two surfaces of the CCD (see Goudfrooij et al. 1998 for a more detailed discussion of fringing). In the case of STIS observations, the best correction for fringing (hereafter "defringing") is accomplished by the use of "contemporaneous fringe flats". This process has been described in detail in two earlier STIS Instrument Science Reports (hereafter ISRs): ISR 97-16 (Walsh et al. 1997) deals with defringing spectra of extended objects, and ISR 98-19 (Goudfrooij et al. 1998) deals with defringing spectra of point sources. We have created a four-step procedure to defringe STIS spectra. It is accomplished by the use of four IRAF tasks in the stsdas.hst_calib.stis package: **normspflat**, **prepspec**, **mkfringeflat**, and **defringe**. While the actual running of these tasks is not difficult, choosing the parameters so as to accomplish the best fringe correction can be non-trivial and should be done with care and thought. This document serves the following purposes: (1) a tutorial to guide the user through the "defringing" process (described in the following sections), and (2) three appendices containing (A) a step-by-step guide on how to retrieve STIS Reference files, (B) Figures illustrating the effect of the defringing process, and (C) the flow charts of the calibration steps performed in the different IRAF tasks.

## 2. Task NORMSPFLAT: Normalizing the STIS CCD fringe flat field.

The first step in the defringing process is to normalize the "contemporaneous" fringe flat field, which was taken in conjunction with the science data. Make sure that the fringe flat field was taken according to the prescriptions in ISR 97-15 (Baum et al. 1997). Apart from the fringe flat field, you need to retrieve the best dark reference file for your data from the archive. This could be a weekly darkfile for the same date range as your data, or a daily dark that you create yourself with the IRAF task **daydark** (also available in the sts-das.hst_calib.stis package). You can then run the IRAF task **normspflat**, of which the input parameters are shown below (in the usual IRAF eparam notation):

```
                                         xterm
                                     I R A F
                          Image Reduction and Analysis Facility
          PACKAGE = stis
             TASK = normspflat

          inflat  = █                     Name of input point source fringe flat
          outflat =                       Name of output, normalized fringe flat
          (do_cal =                  yes) Perform bias and dark subtraction and CR rejecti
          (darkfil=                     ) Name of superdark image
          (pixelfl= oref$h4s1351lo_pfl.fits) Name of pixel-to-pixel flat?
          (wavecal=                     ) Name of wavecal file [ONLY FOR G750M SPECTRA]?
          (l1     =                     ) Internal use only, do not edit
          (l2     =                     ) Internal use only, do not edit
          (Version=              21Apr98) Date of Installation
          (mode   =                  al)

                                                              ESC-? for HELP
```
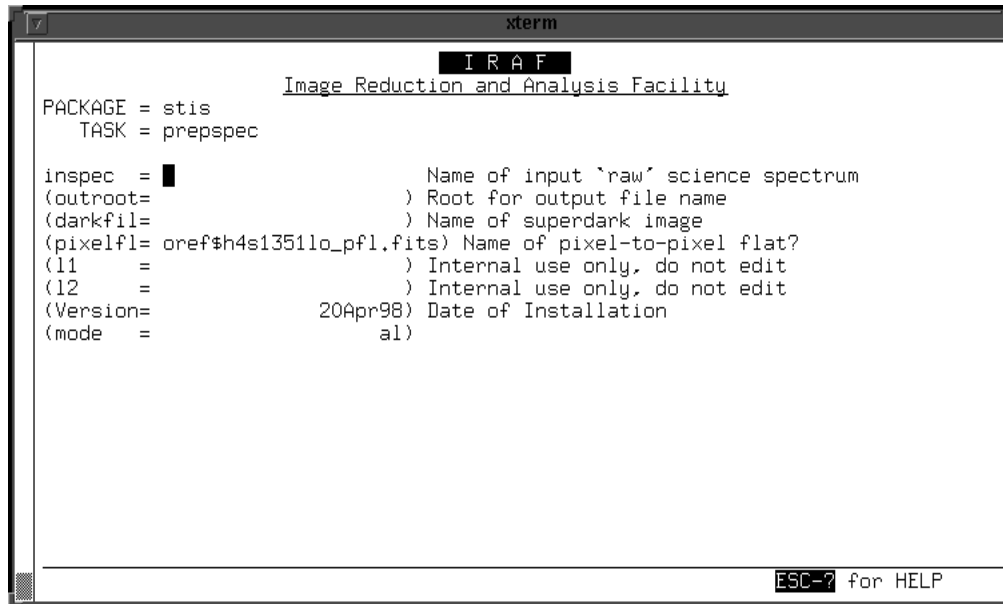
The inflat parameter will be the contemporaneous flat field taken along with the data. The outflat will be your output file (to be used in the next stages of the defringing process). You should put the appropriate dark reference file as the darkfile parameter. If you plan to use a `_raw.fits` file for the input you will need to set do_cal = yes (which is the default). The task also allows normalization of flat fields that are already cosmic-ray-rejected (i.e., `_crj.fits` files); set do_cal = no in that case. The parameter pixelflat designates the flat field image to be used to correct for the pixel-to-pixel variations as well as the effect of dust 'motes' on the CCD window prior to any fringe correction[1]. A good choice for pixelflat is a 50CCD (clear) imaging flat field (i.e., a flat field that does not contain any fringes), which one has to retrieve from the Archive. We explain in Appendix A how to retrieve the latest STIS Reference flat field image from the Archive. pixelflat is currently defaulted to `oref$h4s1351lo_pfl.fits`. If you are using G750M spectra, do not forget to place the appropriate wavecal file in the wavecal parameter. The task works by normalizing the flat field on a line-by-line basis using a cubic spline fit. It will work on contemporaneous flat field images, or, alternatively, a flat field from the Archive.

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1.  Note that when one uses an already cosmic-ray-rejected flat field as inflat, the task handles it as having been corrected for pixel-to-pixel variations and the effect of dust motes (and issues a warning).

## 3. Task PREPSPEC: Preparing the Science Spectra for Defringing

   Like the contemporaneous flat field, the science spectra must be prepared before they can be defringed. The task called **prepspec** will calibrate it with the correct dark and pixel-to-pixel flat field so that it can be defringed later:

```
                                    xterm
                          I R A F
                 Image Reduction and Analysis Facility
    PACKAGE = stis
       TASK = prepspec

    inspec  = █                    Name of input `raw´ science spectrum
    (outroot=                    ) Root for output file name
    (darkfil=                    ) Name of superdark image
    (pixelfl= oref$h4s1351lo_pfl.fits) Name of pixel-to-pixel flat?
    (l1     =                    ) Internal use only, do not edit
    (l2     =                    ) Internal use only, do not edit
    (Version=            20Apr98) Date of Installation
    (mode   =                al)

                                                  ESC-? for HELP
```

   The input spectrum inspec must be your raw science data that you eventually wish to defringe. The outroot parameter may be the same root name as the input file (which is the default) or a different one. The proper extensions will be appended to the output files, as specified in ISR 98-10 (Hodge et al. 1998). The darkfile parameter is exactly the same as in **normspflat**, i.e., it should be a weekly dark from the archive or a daily dark you created yourself. The pixelflat parameter is also exactly the same as in **normspflat**. Again, this is a pixel-to-pixel flatfield from the database which contains no fringes. The output of this task will be used in the next stages of the defringing process.

## 4. Task MKFRINGEFLAT: Matching Fringes in the Fringe Flat Field to those in the Science Spectra

   Once you have normalized your fringe flat field with **normspflat**, you need to shift and scale the fringes in it to match the fringes in your science data so that they can be removed (see Goudfrooij et al. 1998 for details). This is accomplished through the **mkfringeflat** task. The output files from **normspflat** and **prepspec** constitute the input files for **mkfringeflat**. While the parameters for **mkfringeflat** seem obvious and straightforward, be aware that it can be tricky to optimize some of them for "non-standard" data (e.g., emission-line objects, data taken with a slit containing a fiducial bar, or both). In order to arrive at the best fringe correction, the input parameters must be chosen

with care, and it might take several attempts in some cases. The parameter file of **mkfringeflat** appears as follows:

```
                                        xterm
                                       I R A F
                          Image Reduction and Analysis Facility
        PACKAGE = stis
           TASK = mkfringeflat

        inspec  = █                       Name of input science spectrum
        inflat  =                         Name of input normalized fringe flat
        outflat =                         Name of output [final] fringe flat
        (do_shif=               yes) Shift flat to match fringes in spectrum?
        (beg_shi=              -0.5) Starting shift for shift determination
        (end_shi=               0.5) End shift for shift determination
        (shift_s=               0.1) Step through range of shifts
        (do_scal=               yes) Scale fringe amplitude to match science spectrum
        (beg_sca=               0.9) Lower limit of range of scaling factors
        (end_sca=               1.1) Upper limit of range of scaling factors
        (scale_s=              0.02) Step through range of scaling factors
        (extrloc=             INDEF) Central line (row) to be extracted from 2-D spec
        (extrsiz=             INDEF) Number of lines to be extracted from 2-D spectru
        (opti_sp=             INDEF) Spectral range (first:last) to normalize spectru
        (rmsregi=           570:900) Spectral range (first:last) to measure RMS's?
        (l1     =                  ) Internal use only
        (Version=           25Aug98) Date of Installation
        (mode   =               al)
                                                           ESC-? for HELP
```

The parameter inspec must be the science data that is the processed output from **prepspec** (for G750L spectra this will be a `_crj.fits` file, for G750M spectra it will be either a `_x2d.fits` or a `_sx2.fits` file). The inflat parameter must be the output from **normspflat**. Parameter outflat will be your output file to be used in the next (and last) stage of defringing. The "tricky" part of the **mkfringeflat** task is choosing the shifts, scales, location of the rows to be extracted, and range of pixels to use in normalizing the continuum and in measuring RMSs. To pick the best choice for these parameters you should display your data (i.e., the inspec parameter) using your favorite plotting task (e.g., splot, or implot). The default parameters for **mkfringeflat** were chosen to accommodate the most common fringed spectra *of point sources in the center of the slit*. If your data is "sufficiently non-standard" in this context (for instance, a target off the center of the slit, or an extended object, or data taken with an occulting bar), the defaults will most likely *not* suit your needs. For your first attempt we advise you to leave the shift and scale parameters (do_shift, beg_shift, end_shift, shift_step, do_scale, beg_scale, end_scale, scale_step) as the defaults, but make sure that you choose an rmsregion (spectral range in which to measure RMSs) that has no spectral lines in it, but still hosts as many fringes as possible. The units of this parameter are pixels (in the format first:last pixel). Should you choose an rmsregion that has strong spectral lines in it, the task may well attempt to align the spectral lines with (one or more of) the fringes, so that the output will not make sense. The opti_spreg parameter is the spectral region (in the same format as that of rmsregion) used to fit the continuum of the science data. The fit is a cubic spline and will ignore pixels 5 sigma or more from the local average, which makes it fairly insen-

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sitive to spectral lines in the spectrum. However, it is still advised to choose a region that does not contain strong spectral features. Setting this parameter to INDEF (which is the default) will select the full spectral region. The extrloc parameter should be the central row of the science target in your spectral image. The program will optimize the fringe correction around this point. If you do not provide a location (the INDEF default) the program will determine the center of the brightest object it can find in the central 20% of the image and use that location as the center for extraction. The extraction size (in pixels) is set by parameter extrsize. If this parameter is chosen as INDEF (the default), the program will choose the extraction size that is the default for the slit used in the fringe flat field. These default extraction sizes are: 11 pixels for a long slit, 9 for the 0.3x0.09 slit, and 7 for the 0.2x0.06 slit. The first time you try running **mkfringeflat** you may find that either the scale or the shift (or both) are on the edge of the designated range. Should this occur, a warning message will appear on the screen indicating this and suggesting that you try running the task again with a different range. Change the range(s) accordingly using the parameters beg_shift, end_shift, and/or shift_step for the shift range, and beg_scale, end_scale, and/or scale_step for the scale range.

If you do not have a contemporaneous flat field taken in conjunction with your data, you will have to retrieve an appropriate flat field from the Archive (see Appendix A). In this case, the necessary shift to be performed to the flat field may be very large (up to several pixels) due to the intrinsic inrepeatability of the STIS Mode Select Mechanism. Use a large shift range in that case, e.g., beg_shift = -3.0, end_shift = 3.0 (pixels).

As a guide line to users of **mkfringeflat**, the following list shows a number of examples of different possible science spectrum/fringe flat field combinations and how to use **mkfringeflat** in those cases.

1. **A spectrum of a point source in the center of a 52x0.2 slit, along with a contemporaneous fringe flat field. The latter should normally have been taken with the 0.3x0.09 slit (Baum et al. 1997; Goudfrooij et al. 1998).**

   This is the default case for **mkfringeflat**. The default parameters should all work correctly, but do check on the input file (which has a _crj extension for G750L spectra, and a _sx2 extension for G750M spectra) if there are any obvious spectral lines in the spectral region covered by rmsregion. If so, change rmsregion accordingly (this check should be done in ANY case, but we explicitly mention it only in this case).

2. **The same as item #1, but a contemporaneous fringe flat field is missing.**

   In that case, retrieve a fringe flat field from the archive (or a few, just to be sure) with the same central wavelength, taken through the 0.3x0.09 slit. Run this flat field through **normspflat**. In running **mkfringeflat**, use a large shift range, e.g., beg_shift = -3.0, end_shift = 3.0, shift_step = 0.5. With such a large shift_step, you may want to run mkfringeflat another time, with a smaller shift_step. If either the "best" shift or the "best" scale factor are found at the edge of the ranges chosen, run **mkfringeflat** again with the range(s) chosen appropriately.

3.  **A spectrum of the inner 0.15 arcsec of an extended source through the 52x0.1 slit, along with a contemporaneous fringe flat field (which should be taken through the same slit).**

    In this case, be sure to (a) specify extrloc and extrsize to reflect the part of the slit for which you want to optimize the fringe correction. Use a rather large scale range to start off with, e.g., beg_scale = 0.7, end_scale = 1.5, scale_step = 0.1, perhaps followed by another run with a smaller scale range and -step to optimize the result.

4.  **A spectrum of a point source taken through the 52x0.2F1 barred slit (e.g., to study the nature of any circumstellar material), along with a contemporaneous fringe flat field.**

    The 0.3x0.09 slit was the originally recommended one to be used for the contemporaneous fringe flat field in this case. However, the spatial extent of this slit is too small to yield good results outside the fiducial bar (ISRs 97-15 and 98-19 have been revised in the mean time, recommending long-slit fringe flat fields for use with 52x0.2F1 spectra instead). In case one only got a contemporaneous fringe flat taken with the 0.3x0.09 slit along with the science spectra, one therefore has to retrieve a fringe flat that is taken with the 52x0.2F1 slit from the archive. After retrieval, be sure to carefully choose the use large shift ranges and steps during the **mkfringeflat** step, as well as large scale ranges and steps (see items #2 and #3 above).

## 5. Task DEFRINGE: Defringing your Data

Finally, the actual defringing of your data is performed using the task **defringe**. This task takes the raw science spectrum, and divides it by the fringe flat field which you created with **mkfringeflat** (i.e., its outflat parameter), thus removing the fringes.

```
                                 xterm
                               I R A F
                   Image Reduction and Analysis Facility
  PACKAGE = stis
     TASK = defringe

  inspec  = ▉                      Name of input science spectrum
  inflat  =                        Name of input [final] fringe flat
  outspec =                        Name of output science spectrum
  (do_cal =                   no)  Perform calstis processing before defringing?
  (darkfil=                    )   Name of superdark image
  (pixelfl= oref$h4s1351lo_pfl.fits) Name of pixel-to-pixel flat?
  (do_defr=                  yes)  Correct spectrum for fringing?
  (l1      =                    )  Internal use only, do not edit
  (l2      =                    )  Internal use only, do not edit
  (Version=            17Apr98)    Date of Installation
  (mode    =               al)

                                            ESC-? for HELP
```

The output from **mkfringeflat** should be placed in the inflat parameter, and the science data you wish to defringe in the inspec parameter. You may input the raw science

spectrum and set do_cal = yes (in which case one should be sure to choose the appropriate darkfile again), or input a previously calibrated _crj.fits file (e.g., the output of **prepspec**; this may be the most common situation) and set do_cal = no. Again, pixelflat should remain as the default, as in the case of **normspflat** and **prepspec**.

## 6. What to do with the Output Spectra from DEFRINGE

### 6.1. G750L Spectra

In case of G750L spectra, the final output spectrum from defringe (outspec) is the equivalent of a _crj.fits file. This means that wavelength calibration, 2-D rectification, and/or spectral 1-D extraction still have to be performed. The IRAF tasks x1d (one-dimensional extraction of spectra) and x2d (two-dimensional rectification of spectra), both available within the stsdas.hst_calib.stis package, allow one to accomplish this.

### 6.2. G750M Spectra

In case of G750M spectra, defringe produces the equivalent of a _x2d.fits or a _sx2.fits file, i.e., a two-dimensional rectified spectrum. One-dimensional extractions should be done using this file as input. Note that the x1d task is *not* appropriate for this purpose, since the spectrum has already been rectified within the defringing procedure (this is necessary prior to defringing G750M spectra because of the large tilts of G750M spectral traces with respect to the CCD rows, see Goudfrooij et al. 1998). Instead, extractions can be performed with e.g., tasks within the noao.imred.specred package within IRAF. In case spectrophotometry is required, make sure flux corrections are made to extracted spectra according to STIS ISR 98-01 (Bohlin 1998)

### References

1. Baum, S. A., Ferguson, H. C., Walsh, J. R., Goudfrooij, P., Downes, R., Lanning, H., 1997, "GO Added Near-IR Fringe Flats", STIS Instrument Science Report 97-15 (Rev. A)

2. Bohlin, R. C., 1998, "Diffuse Source Absolute Sensitivity and Point Source Relative Sensitivity as a Function of Extraction Slit Height for STIS First-Order Modes", STIS Instrument Science Report 98-01

3. Goudfrooij, P., Bohlin, R. C., Walsh, J. R., Baum, S. A., 1998, "STIS Near-IR Fringing: Basics and Use of Contemporaneous Flats for Spectroscopy of Point Sources", STIS Instrument Science Report 98-19 (Rev. A)

4. Hodge, P., et al., 1998, "Calstis0 - Pipeline Calibration of STIS Data - A Detailed View", STIS Instrument Science Report 98-10

5. Walsh, J. R., Baum, S. A., Malumuth, E. M., Goudfrooij, P., 1997, "STIS Near-IR Fringing: Basics and Use of Contemporaneous Flats for Extended Sources", STIS Instrument Science Report 97-16

## Appendix A: How to Retrieve the Latest Reference Clear Imaging (50CCD) STIS Flat Field Image from the Archive

1. Enter Starview or Xstarview.

2. Click on the "HST Instrument Searches" button.

3. Click on the "Calibration" button for STIS.

4. Enter the following search constraints:

   Detector = "CCD"
   Optical Element = "MIRVIS"
   Aperture = "50CCD"
   Reference File Type = "PFL"

(note that one can use any combination in this window to search for STIS Reference Files of any kind. The combination mentioned above provides the appropriate constraints to search for the Clear (50CCD) imaging flat field images).

5. Click on "Begin Search".

6. When next window pops up, click on "Scan Forward".

7. When ready, click on "View Result as Table".

8. When next window pops up, mark the file with the latest "Public" date and click on "Retrieve Datasets".

9. If you are happy with the data to be retrieved shown in the next window, click on "Submit Request".

10. When the next window pops up, select "Uncalibrated" in the "Science Files Requested" subwindow.

11. Enter your Archive Username and Password, choose your favorite Retrieval Medium and start the retrieving process.

12. Have a coffee or two while eagerly waiting for the STIS Reference File to arrive. Be aware, however, that STScI does not take any responsibility for coffee-induced illnesses of any kind.

# Appendix B: Examples of the Effect of the Fringe Correction Procedure

**Figure 1:** Example of cosmic-ray-rejected G750L spectrum of an extended source (Jupiter's moon Io in this case) BEFORE defringing. The ordinate units are ADU.
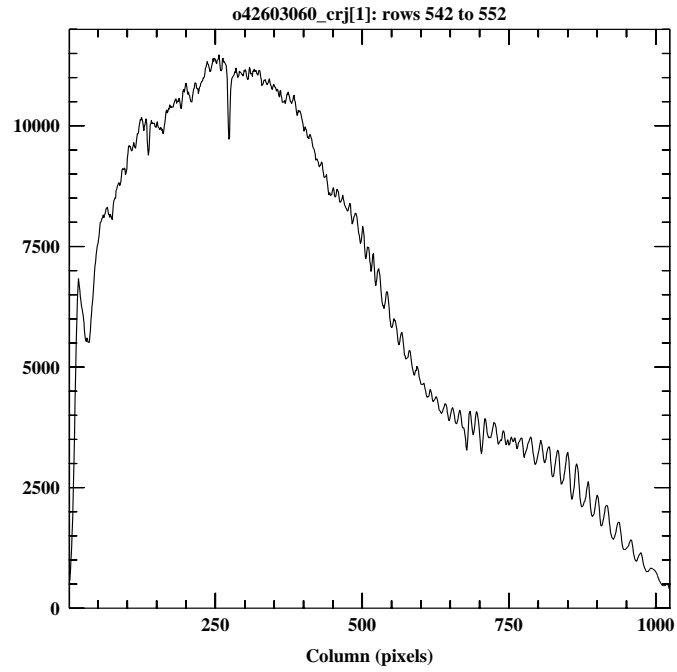


o42603060_crj[1]: rows 542 to 552

Column (pixels)

**Figure 2:** The same G750L spectrum AFTER the defringing process:



IO_by_finff[1]: rows 542 to 552

Column (pixels)
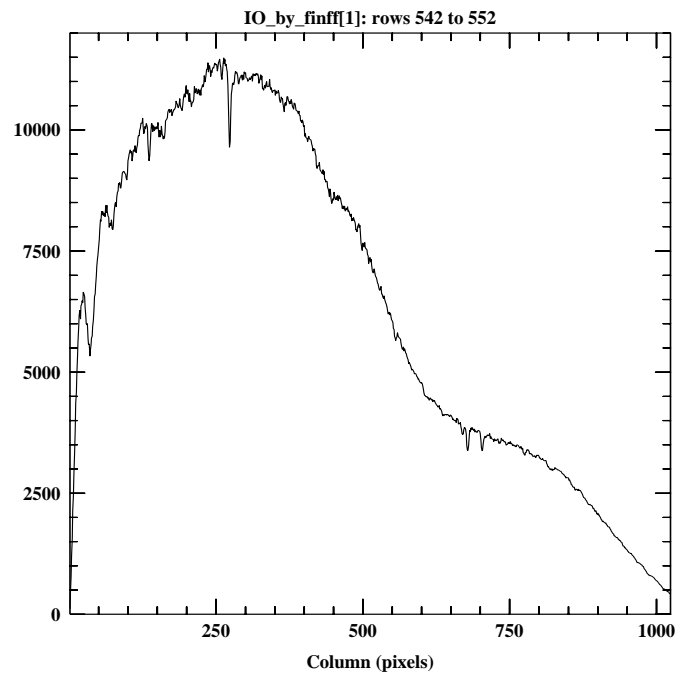
**Figure 3:** An example of a cosmic-ray-rejected G750M spectrum (central wavelength is 8561 Å) of a point source BEFORE defringing:
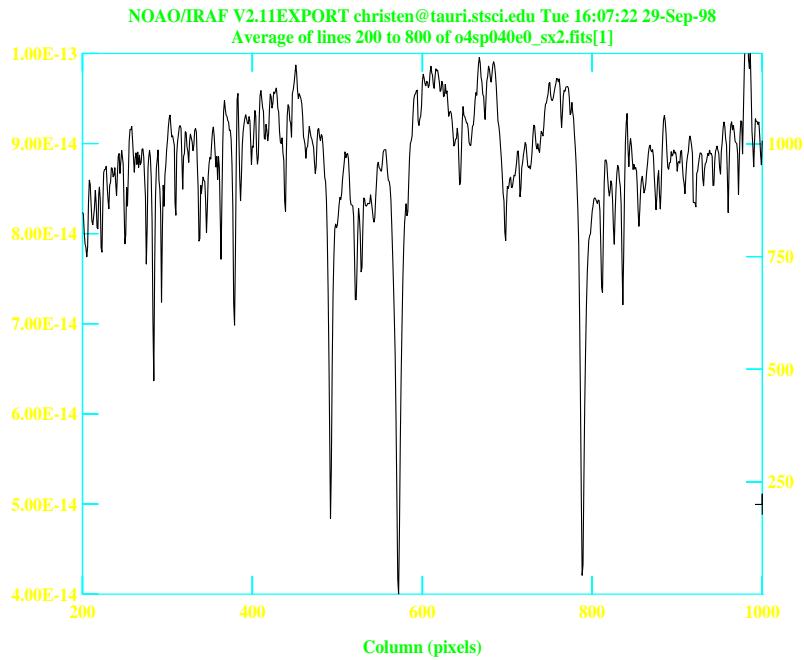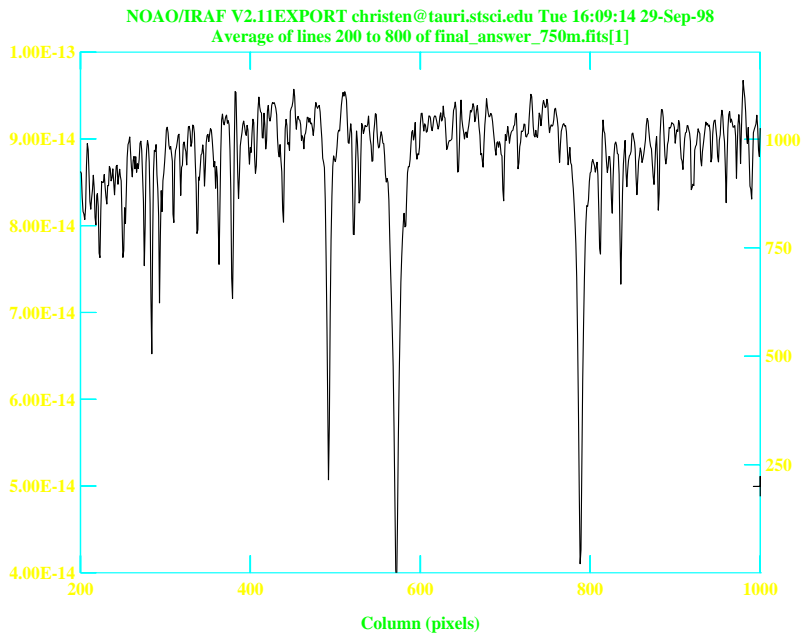


**Figure 4:** The same G750M spectrum AFTER defringing:

# Appendix C: Flow Charts of the Processes within the IRAF tasks.

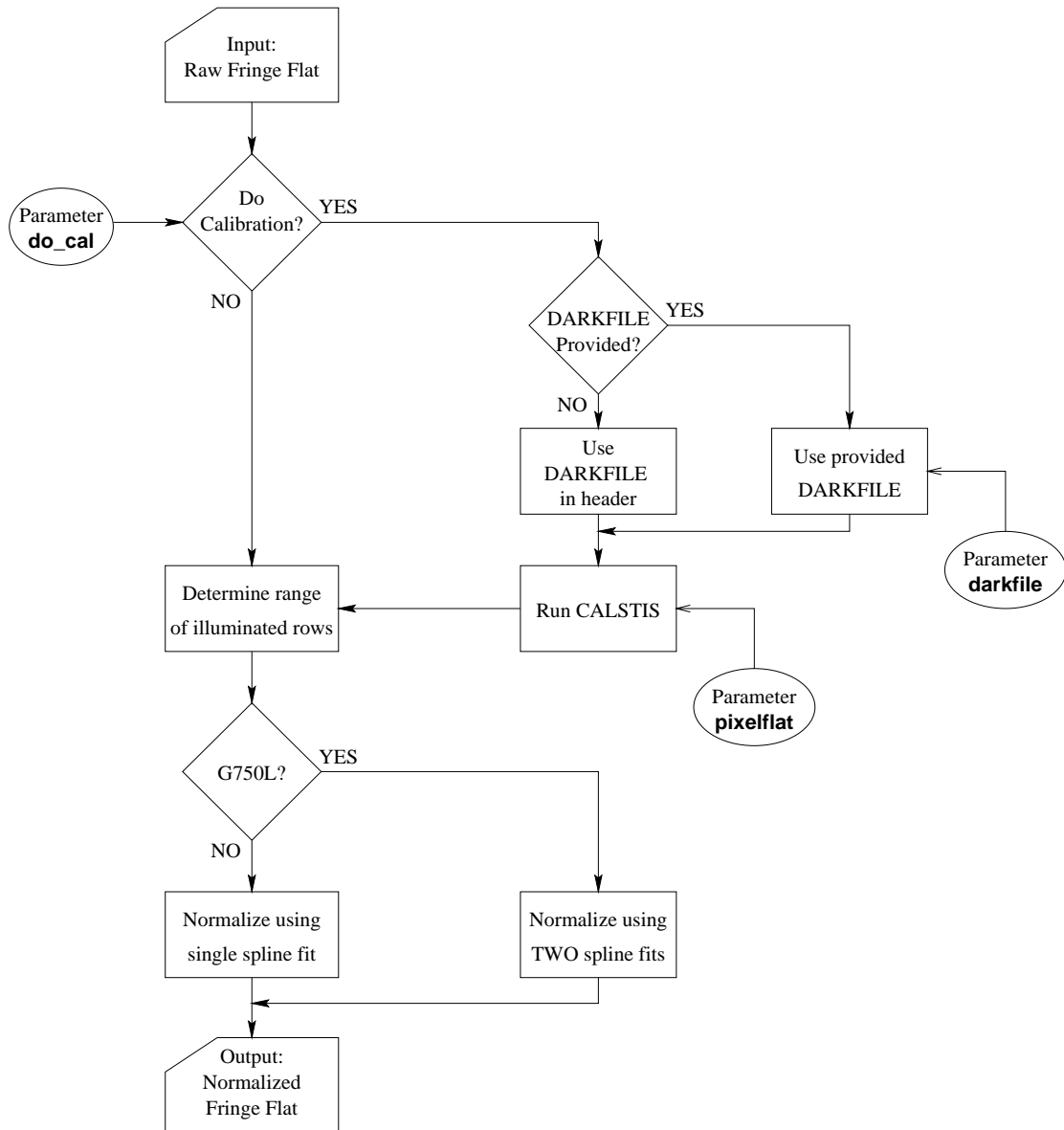**Figure 5:** Flow chart of the processes within the **normspflat** task.

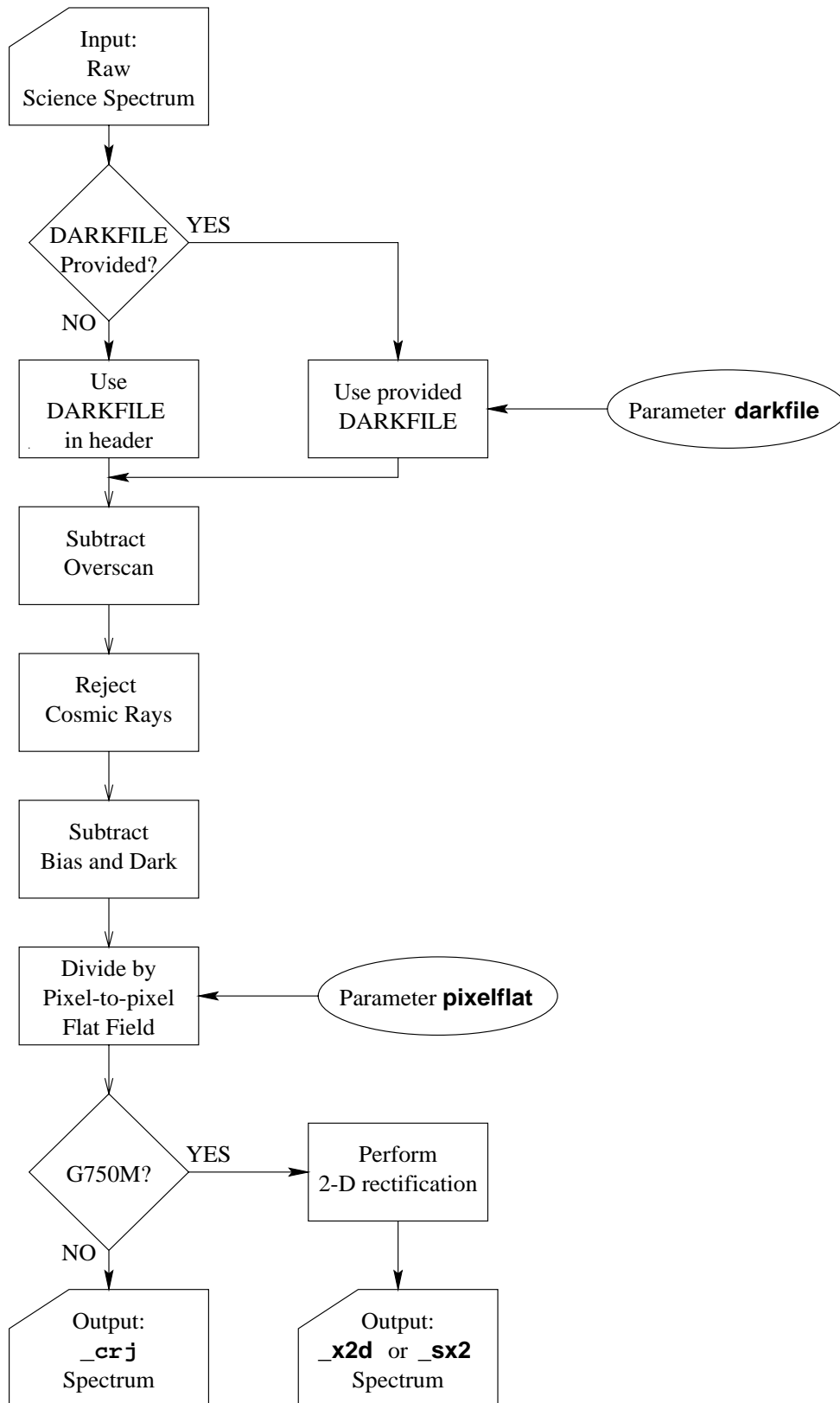**Figure 6:** Flow chart of the processes within the **prepspec** task.

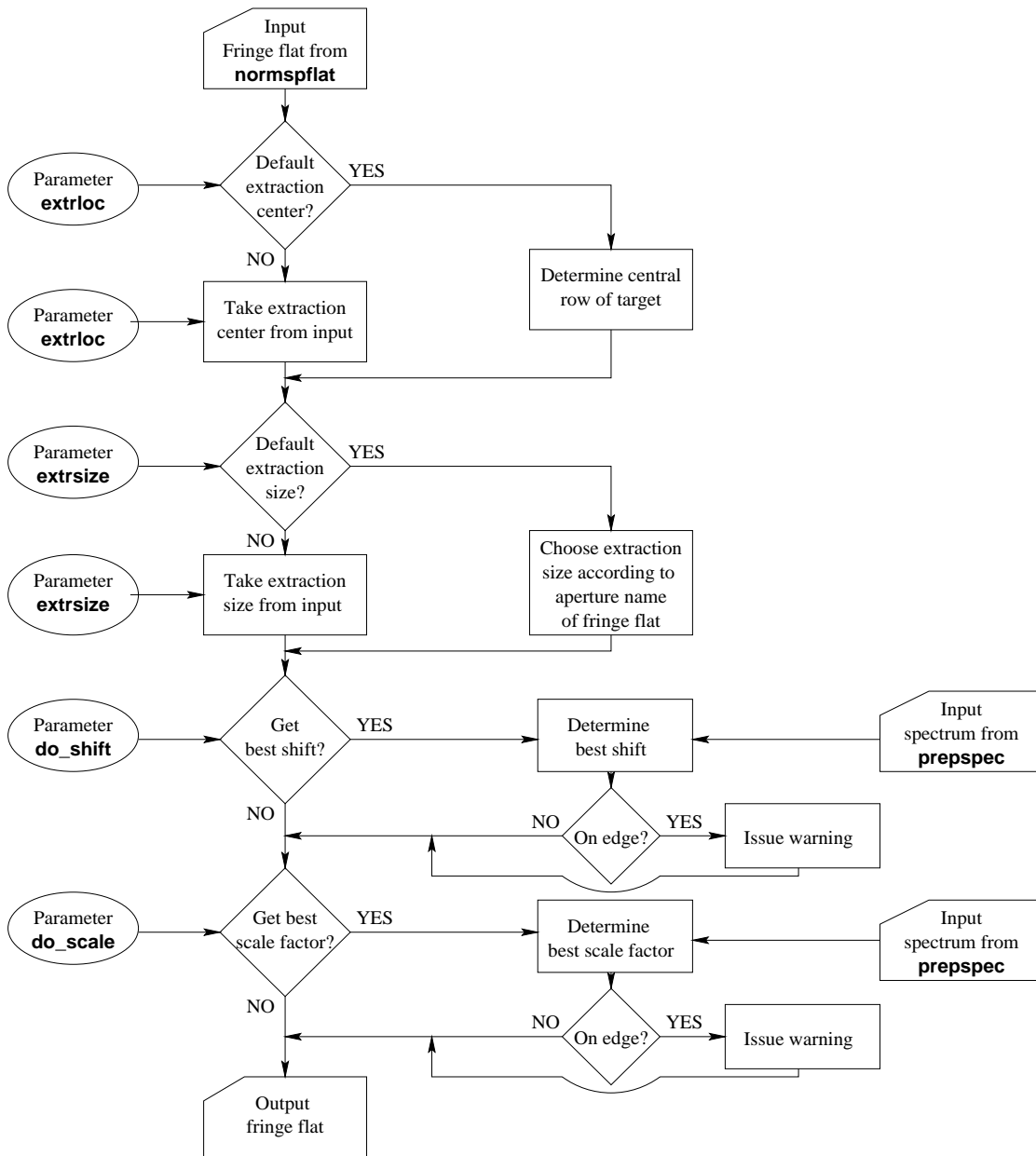**Figure 7:** Flow chart of the processes within the **mkfringeflat** task.

**Figure 8:** Flow chart of the processes within the **defringe** task.

Input:
Science Spectrum
(raw or
from **prepspec**)

Parameter
**do_cal**

Do
calibration?

YES

NO

DARKFILE
Provided?

YES

NO

Use
DARKFILE
in header

Use provided
DARKFILE

Parameter
**darkfile**

FLATCORR
complete?

Skip all steps
before & including
FLATCORR

Run **calstis**

Parameter
**pixelflat**

Parameter
**do_defringe**

Defringe?

YES

NO

Divide spectrum
by Fringe Flat

Input Fringe
Flat from (e.g.)
**mkfringeflat**

STOP

Output:
defringed
Science Spectrum