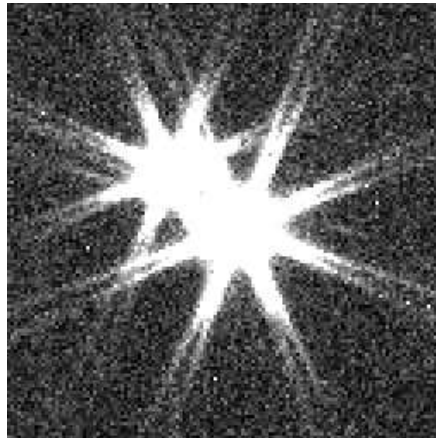


# CTIOPI Photometry Reduction User Guide



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## Revision History

1. 04/20/03 by Wei-Chun Jao — Remarks section added.
2. 08/05/03 by Wei-Chun Jao — New evalfit.pl script released to match CTIOPI/SMARTS photometry catalogue.
3. 08/07/03 by John Subasavage — Cosmic ray section added, grammar corrections.
4. 08/28/03 by Wei-Chun Jao — New standard.pl script released.
5. 04/17/08 by Jen Winters — Fixairmass and setairmass tasks added, grammar corrections.
6. 05/09/12 by Jen Winters — Clarification, reorganizing, grammar corrections.
7. 04/26/13 by John Lurie — Revised aperture sizes for aperture correction.  
Also,  $\text{RMS} < 0.02$  for fitparams (Section 3.7).

## 1. Before Starting

Before starting to reduce photometry, you might need to know a little background on photometry (ie, extinction, airmass, transformation equation, et. al.). **Astronomical Photometry** written by Henden, A. and Kaitchuck, R. is a good introductory book for those who want to get a first look at photometry. Users should also be familiar with IRAF. A couple of user guides can be found on IRAF's website – <http://iraf.noao.edu/docs/photom.html>, specifically

1. **A User's Guide to Stellar CCD Photometry with IRAF**
2. **A User's Guide to CCD Reductions with IRAF**

This manual will skip these introductory parts and start with the processed data. Please read the **Parallax Reduction Guide** to learn how to process the raw data for CTIO or see **Astrometry: Slurping Data from CTIO** on the RECONS Data Reduction page.

Have all the finder charts, observing log (if available) and airmass table (a bird's eye view of all the objects observed in that night) ready.

## 2. Organize Your Processed Data

Load packages **daophot**, **photcal**, **redpi** before you begin anything<sup>1</sup>. After processing the raw data, you will need to fix the airmass immediately. The new TCS does not

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<sup>1</sup>Patterson, R. J. *et al* (1998) shows that no significant difference was found between IRAF/APPHOT and IRAF/DAOPHOT, although **APPHOT** is claimed for aperture photometry

communicate effectively with the telescope, and thus, the airmass is not accurate. This package will correct the airmass. Run **files \*.o.fits >> listfile** in IRAF. You will also need to create a file called “coords” that contains the coordinates for each object. You can get these from the most recent photometry observing list posted on the protected page. The format for this file is as follows (note that you need the colons and only one space between the RA and DEC):

11:56:06.1 –48:39:46.0

Make sure that “listfile” and “coords” have the same number of lines or else it will crash. Then, run **fixairmass**

Next, you will need to fix the headers. Load the **astutil** task. See Fig 1. Edit **setairmass** parameters for the correct observatory site. Run this task to calculate the airmass at the middle of the exposure. A new header keyword, **utmiddle**, will be added in the header. If any of the following headers are missing, *date-obs*, *RA*, *ST*, *epoch* or *airmass*, this **setairmass** won’t work. You will need to add those header-keywords back to the header by using the **hedit** task.

Sort this data into two directories, **standard** and **science**.

Run **files \*.o.fits >> listfile** in IRAF in both the standard and science directories. Then, run **displayexam** task to examine the the images and note if any stars are saturated. This step is important for data reduction, as photometry of saturated stars cannot be determined. Furthermore, IRAF won’t generate the annoying “INDEF” in the data file. In the meantime, you can determine the average seeing (FWHM) for this night’s data. This average FWHM will be entered in the **phot** task. Because the science star images are sandwiched between the standard star frames, you can simply apply the FWHM of the standard stars to the science stars. If the observing log is available, you may select those good frames and the average seeing based on those recorded in log book. For example, if

a field was observed in V, R and I, choose the best one in the I-band in order to reduce potential output problems from IRAF. Otherwise, the same V and R images will need to be used twice to make two sets of VRI. If a field is observed in V, V, R, R, I and I, two sets of VRI can be chosen so that you will have two sets of photometry results calculated from IRAF. One additional step is to determine which stars will need an aperture correction. This is a good time to make a note of whether each frame can use the standard 7'' radius aperture and if not, what the maximum aperture is without contamination. Standards rarely need an aperture correction; however, science stars are often in crowded fields and require a correction.

### 3. Standard Stars

The basic steps for reducing uncrowded standard star fields are

1. Determine the FWHM and remove cosmic rays.
2. Determine the aperture size you wish to use. This aperture size will be applied to all the standard stars from all the nights for all the filters. Edit the **datapars**, **centerpars**, **fitskypars** and **photpars** task parameters in the **phot** task.
3. Use the **redpi/apercorr** task to tag the standard stars so that the instrumental magnitudes can be calculated.
4. Organize the standard star configuration file and collect your standard stars' VRI instrumental magnitudes.
5. Apply transformation equations to get the apparent magnitudes for the standard stars.

### 3.1. Remove Cosmic Rays

It is always better to remove a cosmic ray rather than apply an aperture correction to avoid it. This is done with the IRAF command **cosmicrays** in package **imred.crutil**. Using the default parameter values first is fine to see if it does the job. Often, this command will have to be run a few times to remove the cosmic ray of concern. You should always name the output image “test.o.fits”. That way, if something goes wrong, you don’t have to go back and reprocess the raw frame, etc. When the cosmic ray has been removed to your satisfaction, you can rename the test image to the star image. If you choose to review parameters interactively, you can delete specific points by placing the cursor over the point and pressing *d*. Repeat this process until the cosmic ray is completely removed or until its peak flux is no more than 1% of that of the science star. See the help page by typing *help cosmicrays* for information on parameter tweaking. A bad pixel map, which is located in the top level of CTIOPI photometry “default” directory, is needed to remove any bad columns, which we don’t usually do.

### 3.2. Determine the Aperture Size

The aperture size is key to aperture photometry reductions. You need to select a “suitable” aperture size to cover the brightness profile. Most of the standard stars we choose at CTIO are Landolt (1992) standard stars which are now included in the 2003 Astronomical Almanac. The aperture size he uses is 7" in radius (14" in diameter). Therefore, the aperture size we choose should not be less than 7" in radius. However, it highly depends on the FWHM of your images. Usually, if an image has a FWHM < 4 pixels in radius, the aperture size will be 12 to 15 pixels in radius according to IRAF manuals.

The main IRAF task to finish this aperture photometry is **phot**. This task has been

included in **redpi/apercorr option 3** task. **phot** is a task with other tasks – **datapars**, **centerpars**, **fitskypars** and **photpars** – nestled inside.

### 3.3. Modify Parameters in PHOT Task

When you load the **redpi/apercorr** task, there will be 4 options. Select option 4 for standard stars because standard stars are usually in uncrowded fields where no aperture correction necessary, unless some bonehead has positioned a star too close to the bad column. After choosing option 4, you will need to modify the following parameters in each task by scrolling down (using the up and down arrow keys) to each and typing *:e*.

#### 3.3.1. *photpars*

This task specifies the size of the aperture. It is 7'' in radius in Fig 1. If *mkapert* is set to “yes”, it will indicate the aperture size on the radial plot while you tag the stars. This is helpful to see whether any contamination will fall within the aperture.

#### 3.3.2. *datapar*

Fig 2 shows the parameter examples for this task. The key parameter is *fwhm<sub>psf</sub>* because it will be different from night to night. Average the FWHM for all the standard star images. If we specify the scale of the CTIO 0.9m data (i.e. the plate scale) to be 0.401'', then multiplying the FWHM by the scale will give us the FWHM in arcseconds. Other parameters are a one-time setup.

### 3.3.3. *centerpar*

This task will determine the centering algorithm while we tag the stars. Therefore, the *algorithm* will be “centroid” as shown in Fig 2. The other parameter needing modification from image to image is *cbox*. Usually it is two times of the *fwtmpsf*. The unit here is still in arcseconds.

### 3.3.4. *fitskypars*

The background noise will affect the quality of aperture photometry. You will need to select the size of the sky and sky annulus to calculate the background noise. Currently, we choose a radius of 20” with a 3” annulus width as shown in Fig 2. If *mksky* is set to “yes”, it will indicate the sky annulus on the radial plot.

After you modify all these parameters, the **apercorr** task will automatically display every image within the **listfile** so you can move the cursor onto the image to tag the stars you need using the spacebar. A radial plot will be shown and will mark the aperture and sky annulus size. A new file **\*.mag.1** will be generated after you click *q* to quit the tagging sequence. Please make sure that the tagging order of the images is the same in each filter.

## 3.4. Make Observation Files

The instrumental magnitude for each standard star has been calculated and listed within each **\*.mag.1** file. Before assembling them into a master file, you need to use the **mkimsets** task to sort these images. See Fig 3. The output file should be named “standard.imsets”, which stands for “standard fields image sets”. The first column indicates the ID of each standard field, the second, third and fourth column are V, R, and I filters,



respectively. You can see that the standard field 1 was observed one time in the V and R filters, but two times in the I filter (1004 and 1005) in Fig 3. Standard field 2 was observed two times in each.

### 3.5. Make Master List of Instrumental Magnitudes

The next step will be to extract all the instrumental magnitudes in **\*.mag.1** into a master file. The task to be used is **mknobsfile**, as shown in Fig 3. The output file “standard.obs” is the master list. If there are three stars in standard field 1, this “standard.obs” file will label these stars in sequential order, 1, 2 and 3. After it finishes, please open this output file to check the filter orders, because this task sometimes will have problems. If an aperture correction was applied, be sure to include that filename (usually **aperture.corr**) under the **apercors** parameter.

### 3.6. Make Configuration File and Standard *VRI* Magnitude Table

An example configuration file is shown in Fig 4 that defines the transformation equation for the photometry. More detail on this equation is in section 5. All of the “.cfg” files for standard and science stars are found in the directory named “default” in the top directory on the photometry disk. The standard star magnitude table needs to be created, and an example is shown in Fig 3. All standard stars you use need to be included in “landvri.dat” file. **The stars’ IDs in “landvri.dat” should be identical with those in “standard.obs”.**

### 3.7. Final Steps for Standard Stars

The last task to use in this standard star data processing is **fitparams**, shown in Fig 5. Basically, the task will apply the method of least-squares to the transformation equation to calculate apparent magnitudes for the standard stars and also to determine the transformation equation coefficients (**standard.coeff**) so that we can apply those coefficients to our science stars. We force the RMS to be less than 0.02, so pay attention to that.

This task will plot a residual and also tell you if the solution converges or not. If it does not converge in one filter, you may need to delete a couple of high residual stars and then fit again (shown in Fig 7). Please read the help manual of **fitparam** task for more details. You may quit this task after these three fittings converge. If the solution converges the first time, there will be three main blocks in the **standard.coeff** file. If not, some extra blocks with “diverge” will be noted in this file. The last three blocks in this file indicate the final coefficient results for this transformation.

In order to generate a master photometry list for CTIOPI, a perl script has to be run: **perl ~/bin/standard.pl**. The input files are “standard.imsets” and “standard.obs”. Please modify the “standard.imsets” file. First, remove the first two blank lines. Second, make one line for each object. A file “standard.catalog” as shown in Figure 6 is generated after running this script. **THIS SCRIPT WILL NOT CALCULATE THE EXTINCTION CURVE. IT GENERATES THE CATALOGUE ONLY.**

**FURTHERMORE, PLEASE MANUALLY ADD THOSE USELESS IMAGES (ex: bad images, saturated images) BACK TO THIS CATALOGUE FILE.**

Now you have finished processing the standard stars and have gotten the transformation

coefficients. Next, continue to work on the science stars.

#### 4. Science Stars

Science star fields are usually more crowded than the standard star fields. However, our CTIO images are far less crowded than those in globular clusters. The necessity of aperture correction strongly depends on the fields. Determining aperture size is more of an art than a science. The larger the aperture, the larger the error from the sky subtraction and the more cosmic included. Therefore, a correct “aperture size” is the one which is large enough to include most of the flux from a star. Theoretically, a star’s flux will not increase after a critical aperture size. An aperture correction is a magnitude correction from a small size to a larger critical aperture size. Basically, if there are no objects within the  $7''$  radius, the regular aperture photometry without aperture correction should work. If not, an aperture correction is necessary. The goal is that if you can apply a  $7''$  or larger radius aperture to an object, do not apply a smaller aperture size to it. No correction is better than correction.

The basic steps of the processing procedure for science stars are listed below:

1. **imexam** every science image to ensure that none are saturated and determine to which images to apply an aperture correction. Note any cosmic rays for removal, if necessary.
2. Edit all parameters in **phot**.
3. If an image needs an aperture correction, tag 3 or 4 field stars which are reasonably isolated.
4. Calculate the amount of correction based on these isolated stars.
5. Tag your science stars with selected aperture size.

6. Generate the science star configuration file and collect your science stars' VRI instrumental magnitudes.
7. Based on the transformation equation coefficients from standard stars, calculate apparent magnitudes.

#### 4.1. Examine Science Images

Understanding the quality of your science images is important because you need to apply the right method to process your precious data. Run the **redpi/displayexam** to examine all the science images. Meanwhile, determine the necessity of aperture correction for science stars and make a note of which images have cosmic rays within a 7" radius of the science star.

#### 4.2. Making an Aperture Correction

Sometimes no aperture correction is needed on any science star in a night of photometry. If that is the case, shout “Hooray” and skip to the section **Get Instrumental Magnitudes for Science Stars**. However, we are not usually that lucky, so if you *do* need to make an aperture correction, continue on to the next section.

##### *4.2.1. Tag Isolated Stars in a Crowded Field*

Load **redpi/apercorr** task and choose option 1. It will allow you to edit the parameters of the **phot** task. Section 3.3 has explained these parameters. The most important task is **photpars**. You need to choose a large variety of aperture sizes: 2", 2.5", 3", 3.5", 4", 4.5", 5", 5.5", 6", 6.5", and 7" in radius. Then you tag 3 or more “isolated”

stars with reasonable counts in the same field. These stars *do not* need to be tagged in the same order or even be the same stars in each filter, but you must tag the same *number* of stars in each filter. The new generated file is called **\*.aper.1**.

#### 4.2.2. Apply Aperture Correction

Option 2 in **redpi/apercorr** will do this work. The actual task behind the curtain is **mkapfile** shown in Fig5. A curve of growth, which is a plot of magnitude within a given aperture versus aperture size, will be shown for each image with **\*.aper.1**.

index	1	2	3	4	5	6	7	8	9	10	11
radius size	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7

The parameter **naperts** is the total number of apertures you want to extract. In the example above, there are fourteen different sizes. **smallap** indicates the small aperture *index* you would like to apply on the science stars. **largeap** indicates the large aperture size *index* which you would like to correct to. In the example shown in Fig 5, the **smallap** ID should be 7 (5" radius) and the **largeap** ID should be 11 (7" radius). The output file for this **mkapfile** is called **aperture.corr**.

This file is a simple text file containing the image name in column 1, the aperture correction computed from **smallap** to **largeap** in column 2, and the estimated error in the aperture correction in column 3. If multiple aperture sizes were used on one night, create a 4th column and enter the aperture radius in arcseconds for each image. A **#** needs to precede this column so that it does not affect the calculation to come later. For example:

```
20030101.09.101.o -0.01218093 8.684811E-4 #5"  
20030101.09.112.o -0.08370557 0.004138806 #1"
```

### 4.3. Get Instrumental Magnitudes for Science Stars

This step is similiar to the standard star tagging procedure. The task you need to load is **redpi/apercorr** option 3. This option will let you edit **phot** parameters. The only important parameter you need to notice is **apertures**. The correct aperture size is the same as the **smallap** (in units of arcseconds) which you used in the aperture correction. If no aperture correction was needed, this is just the (7" radius) that you used when you tagged the standard stars. Again, when tagging science stars, **the tagging order should be the same for all filters**, i.e., those cases where photometry for both components of a widely separated binary system is possible. The output file is called **\*.mag.1**.

### 4.4. make science star observation files and master list files

The **mkimsets** task is used for science stars just as for standard stars. The output file is “science.imsets”. After this file is generated, please make sure the top two blank lines are removed. Use **mknoobsfile** to generate a master list of instrumental magnitudes. Make the necessary changes for this task: **apercors**=“**aperture.corr**” if an aperture correction was done, **imsets**=“**science.imsets**”, and **observation**=“**science.obs**”. If no aperture correction was done, then the **apercors** line in the **mknoobsfile** task should be blank.

### 4.5. Calculate Apparent Magnitude

There are two ways to calculate the apparent magnitude. One is with **evalfit**, an IRAF standard task, and the other is with **evalfit.pl** which is a perl script. The latter produces an output consistent with the CTIOPI photometry catalogue and is preferred.

#### 4.5.1. *evalfit* task

Before using this task, you need to copy the “standard.coeff” file from the standard star directory. No modification to this file is necessary. The other two files you need to use in this task are “science.cfg” which is the same as “standard.cfg”, and “science.obs”. Therefore, science and standard stars will have the same transformation equation. An example parameter for **evalfit** is shown in Fig 5.

The output file is called “evalfit.out”. The S/N magnitude error is also printed in this file. More discussion about error can be found in section 5.

#### 4.5.2. *perl* script

This perl scrip is called **evalfit.pl**. Have a copy of it under your bin directory, because the date/format perl module is called, logon **penston**. Type **perl ~/bin/evalfit.pl** to excute it. This perl script is only applied for a second-order transformation equation as shown in section 5. The “standard.coeff” and “science.obs” files are also necessary for this script. However, you need to modify this file by leaving the last block of converged VRI results in this file. No divergent result can exist in this file.

The default name for the file created by **mkimsets** needs to be “science.imsets” for this script. Also in the case where a series of frames were taken of a double star, you need to insert an extra line for the second star which has the same frame name as the first star. For example,

```
LHS300AB : 20030101.09.101.o 20030101.09.102.o 20030101.09.103.o
```

should be modified to look as follows:

```
LHS300A : 20030101.09.101.o 20030101.09.102.o 20030101.09.103.o
```

```
LHS300B : 20030101.09.101.o 20030101.09.102.o 20030101.09.103.o
```

The output file “science.ans” is shown in Fig 6. This file includes the standard star error as well as other important parameters such as airmass. More discussion about magnitude error can be found in section 5. This file needs to be manually edited to include the diameter of the aperture size used. For example, if you used the standard 7” radius, you will enter 14” for that image.

As discussed in the standard star section, **PLEASE MANAULLY ADD THOSE USELESS IMAGES (ex: bad images, saturated images) BACK TO THIS CATALOGUE FILE.**

## 5. Transformation Equations

The transformation equations for aparent magnitude  $V(RI)_c$  are as follows,

$$V = m_V + a_1 + a_2X + a_3(m_V - m_I) + a_4(m_V - m_I)X \quad (1)$$

$$R = m_R + b_1 + b_2X + b_3(m_R - m_I) + b_4(m_R - m_I)X \quad (2)$$

$$I = m_I + c_1 + c_2X + c_3(m_R - m_I) + c_4(m_R - m_I)X \quad (3)$$

where, V,R and I are the aparent magnitudes for standard stars,  $m_{VRI}$  is the instrutmental magnitude from IRAF,  $a_1$  to  $a_4$  are the transformation coefficients (same for  $b_i$  and  $c_i$ ), and X is the airmass.

The method of least-squares is performed by the **fitparam** task to calculate the transformation coefficients based on the standard star observations. This task calculates not only the transformation coefficients but also the so-called “external error” or “standard star error”. This standard deviation error can be found in the **fitparam** output “logfile”.

Another magnitude error is the “internal error” or “night-to-night error”, which is the error from the repeated observation of the same object. The smallest error is called the



“photon error” which indicates the signal-to-noise ratio received by the detector. This error is printed in the output file of the **evalfit IRAF** task. Because of the large signal-to-noise ratio, this error is usually very small.

## 6. Remarks About Sky Subtraction

When subtracting the sky background, you must choose an inner radius for the sky annulus and a width for the annulus. The example given here uses the **noao.digiphot.daophot.phot** task applied to the standard star field SA98. The seeing on that night (14 NOV 2001) was  $1.4''$ , or 3.5 pixels. The parameter file for the task **fitskypars** is shown in Fig 2 (the numbers entered for the parameters “annulus” and “dannulus” are in arcseconds). Mean sky counts for two example inner radii for the sky annulus ( $10''$  and  $20''$ ) are shown in Table 1. In both cases the width is  $3''$ .

star	$10''$ (radius)	$20''$ (radius)	note
SA98–650	58.33632	57.91608	
SA98–670	63.51149	58.55741	
SA98–676	60.38068	58.39950	mix with SA98–675
SA98–675	61.22947	58.12084	mix with SA98–676

Two things can be seen in these results: (1) the  $20''$  inner annulus radius has lower counts (and lower standard deviations, not shown) than the  $10''$  radius — the smaller radius may include counts from the wings of the star, indicating that a larger sky annulus radius is preferred, and (2) even when a nearby star is within the sky annulus width, e.g. SA–676 and SA98–675, the mean sky counts are not affected.

```
-----
-setairmass-
-----
    images = "@listfile"      Input images
  (observatory = "CTIO")      Observatory for images
    (intype = "beginning")    Input keyword time stamp
    (outtype = "effective")   Output airmass time stamp\n
      (date = "date-obs")     Observation date keyword
  (exposure = "exptime")     Exposure time keyword (seconds)
  (airmass = "airmass")      Airmass keyword (output)
  (utmiddle = "utmiddle")    Mid-observation UT keyword (output)\n
    (show = yes)             Print the airmasses and mid-UT?
    (update = yes)          Update the image header?
  (override = yes)          Override previous assignments?
    (mode = "ql")

-----
-task=phot-
-----
    image = ""               Input image(s)
    coords = ""              Input coordinate list(s) (default: image.coo.?)
    output = ""              " Output photometry file(s) (default: image
    skyfile = ""            Input sky value file(s)
  (plotfile = "")           Output plot metacode file
  (datapars = "")          Data dependent parameters
  (centerpars = "")        Centering parameters
  (fitskypars = "")        Sky fitting parameters
  (photpars = "")          Photometry parameters
  (interactive = yes)       Interactive mode ?
  (radplots = yes)         Plot the radial profiles?
    (verify = )_.verify)   Verify critical phot parameters ?
    (update = )_.update)   Update critical phot parameters ?
    (verbose = )_.verbose) Print phot messages ?
  (graphics = )_.graphics) Graphics device
  (display = )_.display)   Display device
  (icommands = "")         Image cursor: [x y wcs] key [cmd]
  (gcommands = "")         Graphics cursor: [x y wcs] key [cmd]
    (mode = "ql")

-----
-photpars-
-----
  (weighting = "constant")  Photometric weighting scheme
  (apertures = "7")         List of aperture radii in scale units
    (zmag = 25.)           Zero point of magnitude scale
  (mkapert = yes)          Draw apertures on the display
    (mode = "ql")
```

Fig. 1.— parameter examples for **setairmass**, **phot** and **photpars**.

```
-----  
-datapars-  
-----  
      (scale = 0.401)      Image scale in units per pixel  
      (fwhmpsf = 1.3)     FWHM of the PSF in scale units  
      (emission = yes)    Features are positive ?  
      (sigma = 5.)        Standard deviation of background in counts  
      (datamin = -4.)     Minimum good data value  
      (datamax = 65535.)  Maximum good data value  
      (noise = "poisson") Noise model  
      (ccdread = "gtron21") CCD readout noise image header keyword  
      (gain = "gtgain21")  CCD gain image header keyword  
      (readnoise = 4.7)   CCD readout noise in electrons  
      (epadu = 3.1)       Gain in electrons per count  
      (exposure = "exptime") Exposure time image header keyword  
      (airmass = "airmass") Airmass image header keyword  
      (filter = "filter2") Filter image header keyword  
      (obstime = "utmiddle") Time of observation image header keyword  
      (itime = 20.)       Exposure time  
      (xairmass = 1.2660490274429) Airmass  
      (ifilter = "diar")  Filter  
      (otime = "4:50:29.7") Time of observation  
      (mode = "ql")  
  
-----  
-centerpars-  
-----  
      (calgorithm = "centroid") Centering algorithm  
      (cbox = 2.6)         Centering box width in scale units  
      (cthreshold = 0.)    Centering threshold in sigma above background  
      (minsnratio = 1.)    Minimum signal-to-noise ratio for centering alg  
      (cmaxiter = 10)      Maximum iterations for centering algorithm  
      (maxshift = 4.)      Maximum center shift in scale units  
      (clean = no)         Symmetry clean before centering  
      (rclean = 1.)        Cleaning radius in scale units  
      (rclip = 2.)         Clipping radius in scale units  
      (kclean = 3.)        K-sigma rejection criterion in skysigma  
      (mkcenter = no)      Mark the computed center  
      (mode = "ql")  
  
-----  
-fitskypars-  
-----  
      (salgorithm = "mode") Sky fitting algorithm  
      (annulus = 20.)      Inner radius of sky annulus in scale units  
      (dannulus = 3.)     Width of sky annulus in scale units  
      (skyvalue = 0.)      User sky value  
      (smaxiter = 10)     Maximum number of sky fitting iterations  
      (sloclip = 0.)      Lower clipping factor in percent  
      (shiclip = 0.)      Upper clipping factor in percent  
      (snreject = 50)     Maximum number of sky fitting rejection iterati  
      (sloreject = 3.)    Lower K-sigma rejection limit in sky sigma  
      (shireject = 3.)    Upper K-sigma rejection limit in sky sigma  
      (khist = 3.)        Half width of histogram in sky sigma  
      (binsize = 0.10000000149012) Binsize of histogram in sky sigma  
      (smooth = no)       Boxcar smooth the histogram  
      (rgrow = 0.)        Region growing radius in scale units  
      (mksky = yes)       Mark sky annuli on the display  
      (mode = "ql")
```

Fig. 2.— parameter examples for **datapars**, **centerpars** and **fitskypars**.

```

-----
-mkimsets-
-----

    imlist = "*.o.mag.1"      The input image list
    idfilters = "v,r,i"      The list of filter ids
    imsets = "standard.imsets" The output image set file
    (imobsparams = "")      The output image observing parameters file
      (input = "photfiles")  The source of the input image list
      (filter = )           The filter keyword
      (fields = "")         Additional image list fields
      (sort = "")          The image list field to be sorted on
      (edit = yes)         Edit the input image list before grouping
      (rename = yes)       Prompt the user for image set names
      (review = yes)       Review the image set file with the editor
      (list = "")
      (mode = "ql")

-----
standard.imsets example:
-----

field1 : dec02s.1001.o dec02s.1003.o dec02s.1004.o
field1 : dec02s.1001.o dec02s.1003.o dec02s.1005.o
field2 : dec02s.1009.o dec02s.1011.o dec02s.1010.o
field2 : dec02s.1012.o dec02s.1013.o dec02s.1014.o

-----
-mknobsfile-
-----

photfiles = "*.o.mag.1"      The input list of APPHOT/DAOPHOT databases
    idfilters = "v,r,i"      The list of filter ids
    imsets = "standard.imsets" The input image set file
    observations = "standard.obs" The output observations file
    (obsparams = "")        The input observing parameters file
    (obscolumns = " ")      The format of obsparams
    (minmagerr = 0.001)     The minimum error magnitude
    (shifts = "")          The input x and y coordinate shifts file
    (apercors = "")        The input aperture corrections file
    (aperture = 1)         The aperture number of the extracted magnitude
    (tolerance = 5.)       The tolerance in pixels for position matching
    (allfilters = no)      Output only objects matched in all filters
    (verify = yes)        Verify interactive user input ?
    (verbose = yes)       Print status, warning and error messages ?
    (mode = "ql")

-----
standard.obs example:
-----

field1-1      v      5:59:25.5  1.512  607.395  749.645  16.147  0.001
*             r      6:01:47.8  1.526  607.467  748.719  14.937  0.001
*             i      6:03:35.7  1.537  609.185  748.972  14.170  0.001
field1-2      v      5:59:25.5  1.512  543.660  558.728  17.673  0.003
*             r      6:01:47.8  1.526  543.682  557.738  17.036  0.003
*             i      6:03:35.7  1.537  545.469  558.193  17.288  0.005
field1-3      v      5:59:25.5  1.512  967.006  226.776  16.597  0.001
*             r      6:01:47.8  1.526  967.282  225.602  16.247  0.002
*             i      6:03:35.7  1.537  968.751  226.254  16.706  0.003

-----
example file of landvri.dat
-----

field1-1      10:54:05.0 -00:50:15.0      8.754      8.240      7.756
field1-2      10:53:52.0 -00:50:40.0      9.246      8.698      8.201
field1-3      10:48:13.0 -11:20:12.0     15.600     13.400     11.180
field2-1      04:02:40.9 -44:45:09.0     13.097     12.658     12.274
field2-2      04:02:31.8 -44:47:08.0     14.090     13.778     13.452
field2-3      04:02:44.0 -44:47:00.0     15.751     15.239     14.793

```

Fig. 3.— parameters for **mkimsets**, and the output file format.

```
# Declare the standards catalog variables
catalog
v      4          # the V magnitude
r      5          # the R magnitude
i      6          # the I magnitude

# Declare the observations file variables
observations
Tv      3          # time of observation in filter V
Xv      4          # airmass in filter V
xv      5          # x coordinate in filter V
yv      6          # y coordinate in filter V
mv      7          # instrumental magnitude in filter V
error(mv) 8        # magnitude error in filter V

Tr      10         # time of observation in filter R
Xr      11         # airmass in filter R
xr      12         # x coordinate in filter R
yr      13         # y coordinate in filter R
mr      14         # instrumental magnitude in filter R
error(mr) 15      # magnitude error in filter R

Ti      17         # time of observation in filter I
Xi      18         # airmass in filter I
xi      19         # x coordinate in filter I
yi      20         # y coordinate in filter I
mi      21         # instrumental magnitude in filter I
error(mi) 22      # magnitude error in filter I

# Sample transformation section for the Landolt UBVRI system
transformation

set rv = v-mv
set rr = r-mr
set ri = i-mi
set vr = mv-mr
set vi = mv-mi
set dri = mr-mi

fit v1=0.0, v2=0.0, v3=0.0, v4=0.0
VFIT: v = mv + v1 +v2*Xv + v3*(mv-mi) + v4*(mv-mi)*Xv

fit r1=0.0, r2=0.0, r3=0.0,r4=0.0
RFIT: r = mr + r1 +r2*Xr + r3*(mr-mi) + r4*(mr-mi)*Xr

fit i1=0.03, i2=0.02, i3=0.04, i4=0.03
IFIT: i = mi + i1 +i2*Xi + i3*(mr-mi) + i4*(mr-mi)*Xi
```

Fig. 4.— standard star configuration example.

```

-----
-fitparam-
-----
observations = "standard.obs"      List of observations files
  catalogs = "landvri.dat"        List of standard catalog files
  config = "standard.cfg"         Configuration file
  parameters = "standard.coeff"   Output parameters file
  (weighting = "photometric")     Weighting type (uniform,photometric,equations)
  (addscatter = yes)              Add a scatter term to the weights ?
  (tolerance = 1.0000000000000E-7) Fit convergence tolerance
  (maxiter = 30)                  Maximum number of fit iterations
  (nreject = 3)                   Number of rejection iterations
  (low_reject = 3.)               Low sigma rejection factor
  (high_reject = 3.)              High sigma rejection factor
  (grow = 0.)                     Rejection growing radius
  (interactive = yes)             Solve fit interactively ?
  (logfile = "logfile")           Output log file
(log_unmatche = yes)              Log any unmatched stars ?
  (log_fit = yes)                 Log the fit parameters and statistics ?
  (log_results = yes)             Log the results ?
  (catdir = " ")                 The standard star catalog directory
  (graphics = "stdgraph")        Output graphics device
  (cursor = " ")                 Graphics cursor input
  (mode = "ql")

-----
-mkapfile-
-----
  photfiles = "*.aper.1"          The input list of APPHOT/DAOPHOT databases
  naperts = 14                   The number of apertures to extract
  apercors = "aperture.corr"      The output aperture corrections file
  (smallap = 5)                   The first aperture for the correction
  (largeap = 9)                   The last aperture for the correction
  (magfile = " ")                 The optional output best magnitudes file
  (logfile = " ")                 The optional output log file
  (plotfile = " ")               The optional output plot file
  (obsparams = " ")              The observing parameters file
  (obscolumns = "2 3 4 5")       The observing parameters file format
  (append = no)                   Open log and plot files in append mode
  (maglim = 0.1)                  The maximum permitted magnitude error
  (nparams = 5)                   Number of cog model parameters to fit
  (swings = 1.2)                  The power law slope of the stellar wings
  (pwings = 0.1)                  The fraction of the total power in the stellar
  (pgauss = 0.5)                  The fraction of the core power in the gaussian
  (rgescale = 0.9)                The exponential / gaussian radial scales
  (xwings = 0.)                   The extinction coefficient
  (interactive = yes)             Do the fit interactively ?
  (verify = no)                   Verify interactive user input ?
  (gcommands = " ")              The graphics cursor
  (graphics = "stdgraph")        The graphics device
  (mode = "ql")

-----
-evalfit-
-----
observations = "science.obs"      List of observations files
  config = "science.cfg"          Configuration file
  parameters = "standard.coeff"   Fitted parameters file
  calib = "evalfit.out"           Output calibrated standard indices file
  (catalogs = " ")                List of standard catalog files
  (errors = "obserrors")          Error computation type (undefined,obserrors,equ
  (objects = "program")           Objects to be fit (all,program,standards)
  (print = " ")                   Optional list of variables to print
  (format = " ")                  Optional output format string
  (append = no)                   Append output to an existing file ?
  (catdir = )_catdir              The standard star catalog directory
  (mode = "al")

```

Fig. 5.— parameter examples for fitparam, mkapfile and evalfit.

Fig. 6.— example output file from evalfft.pl and standard.pl (bottom) script

Name	FILTER	FITS	AM	APER	MAG	SNerr	S*err	DATEreduce	WHO
LHS2621	v	20030329.09.096.o	1.587	---	16.187	0.006	0.013	2003-08-11	Subasavage
LHS2621	r	20030329.09.097.o	1.584	---	15.783	0.006	0.018	2003-08-11	Subasavage
LHS2621	i	20030329.09.098.o	1.581	---	15.445	0.010	0.017	2003-08-11	Subasavage
LHS2734A	v	20030329.09.104.o	1.094	---	16.126	0.006	0.013	2003-08-11	Subasavage
LHS2734A	r	20030329.09.103.o	1.103	---	15.322	0.004	0.018	2003-08-11	Subasavage
LHS2734A	i	20030329.09.102.o	1.112	---	14.593	0.004	0.017	2003-08-11	Subasavage
LHS2734B	v	20030329.09.104.o	1.094	---	18.827	0.057	0.013	2003-08-11	Subasavage
LHS2734B	r	20030329.09.103.o	1.103	---	17.893	0.031	0.018	2003-08-11	Subasavage
LHS2734B	i	20030329.09.102.o	1.112	---	16.743	0.025	0.017	2003-08-11	Subasavage
SCR1138-7721	v	20030329.09.131.o	1.538	---	14.767	0.004	0.013	2003-08-11	Subasavage
SCR1138-7721	r	20030329.09.132.o	1.542	---	13.201	0.001	0.018	2003-08-11	Subasavage
SCR1138-7721	i	20030329.09.133.o	1.547	---	11.250	0.001	0.017	2003-08-11	Subasavage
SCR1322-7254	v	20030329.09.144.o	1.387	---	15.322	0.003	0.013	2003-08-11	Subasavage
SCR1322-7254	r	20030329.09.145.o	1.390	---	14.122	0.002	0.018	2003-08-11	Subasavage
SCR1322-7254	i	20030329.09.146.o	1.392	---	12.594	0.002	0.017	2003-08-11	Subasavage
SCR1328-7253	v	20030329.09.149.o	1.399	---	16.895	0.006	0.013	2003-08-11	Subasavage
SCR1328-7253	r	20030329.09.148.o	1.396	---	15.645	0.004	0.018	2003-08-11	Subasavage
SCR1328-7253	i	20030329.09.147.o	1.393	---	13.994	0.003	0.017	2003-08-11	Subasavage
SCR1726-8433	v	20030329.09.150.o	1.757	---	14.254	0.002	0.013	2003-08-11	Subasavage
SCR1726-8433	r	20030329.09.151.o	1.755	---	13.004	0.001	0.018	2003-08-11	Subasavage
SCR1726-8433	i	20030329.09.152.o	1.753	---	11.415	0.001	0.017	2003-08-11	Subasavage
SCR1735-7020	v	20030329.09.170.o	1.333	---	99.999	0.005	0.013	2003-08-11	Subasavage
SCR1735-7020	r	20030329.09.169.o	1.337	---	99.999	0.004	0.018	2003-08-11	Subasavage
SCR1735-7020	i	20INDEF	0.000	---	99.999	0.000	0.017	2003-08-11	Subasavage
SCR2012-5956	v	20030329.09.191.o	1.287	---	16.063	0.011	0.013	2003-08-11	Subasavage
SCR2012-5956	r	20030329.09.192.o	1.280	---	15.484	0.008	0.018	2003-08-11	Subasavage
SCR2012-5956	i	20030329.09.193.o	1.275	---	15.035	0.012	0.017	2003-08-11	Subasavage
SCR2012-5956	f	20030329.09.194.o	xxxxx	xxx	xxxxxxx	xxxxxx	xxxxxx	2003-08-11	Subasavage << bad image
-----									
E2_M	v	20030127.09.071.o	1.050					2003-08-28	jao
E2_M	r	20030127.09.072.o	1.055					2003-08-28	jao
E2_M	i	20030127.09.073.o	1.061					2003-08-28	jao
E2_O	v	20030127.09.071.o	1.050					2003-08-28	jao
E2_O	r	20030127.09.072.o	1.055					2003-08-28	jao
E2_O	i	20030127.09.073.o	1.061					2003-08-28	jao
E2_S	v	20030127.09.071.o	1.050					2003-08-28	jao
E2_S	r	20030127.09.072.o	1.055					2003-08-28	jao
E2_S	i	20030127.09.073.o	1.061					2003-08-28	jao
E2_I	v	20030127.09.071.o	1.050					2003-08-28	jao
E2_I	r	20030127.09.072.o	1.055					2003-08-28	jao
E2_I	i	20030127.09.073.o	1.061					2003-08-28	jao
E2_T	v	20030127.09.071.o	1.050					2003-08-28	jao
E2_T	r	20030127.09.072.o	1.055					2003-08-28	jao
E2_T	i	20030127.09.073.o	1.061					2003-08-28	jao
E2_T	f	20030127.09.074.o	xxxxxx					2003-08-28	jao << bad image
98_675	v	20030127.09.124.o	1.412					2003-08-28	jao
98_675	r	20030127.09.123.o	1.402					2003-08-28	jao
98_675	i	20030127.09.122.o	1.388					2003-08-28	jao
98_676	v	20030127.09.124.o	1.412					2003-08-28	jao
98_676	r	20030127.09.123.o	1.402					2003-08-28	jao
98_676	i	20030127.09.122.o	1.388					2003-08-28	jao
98_682	v	20030127.09.124.o	1.412					2003-08-28	jao
98_682	r	20030127.09.123.o	1.402					2003-08-28	jao
98_682	i	20030127.09.122.o	1.388					2003-08-28	jao
98_685	v	20030127.09.124.o	1.412					2003-08-28	jao
98_685	r	20030127.09.123.o	1.402					2003-08-28	jao
98_685	f	20030127.09.122.o	1.388					2003-08-28	jao

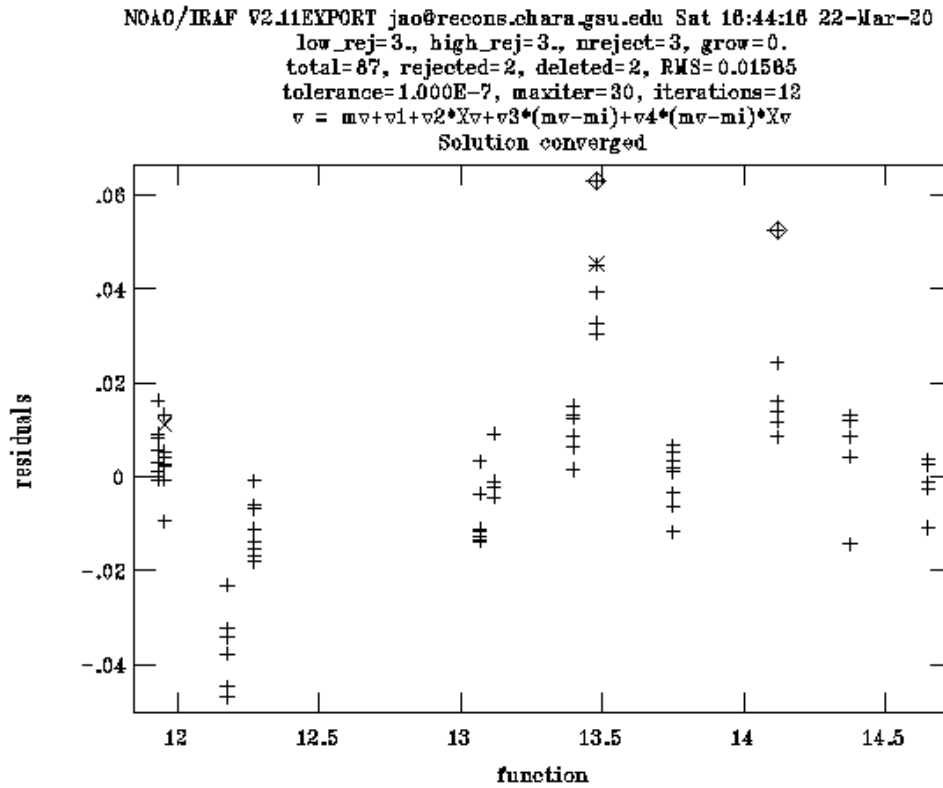


Fig. 7.— **fitparam** fitting plot example, and it shows that this solution is converged. Two diamonds indicate this task deleted data automatically and two crosses indicate they were deleted by users.