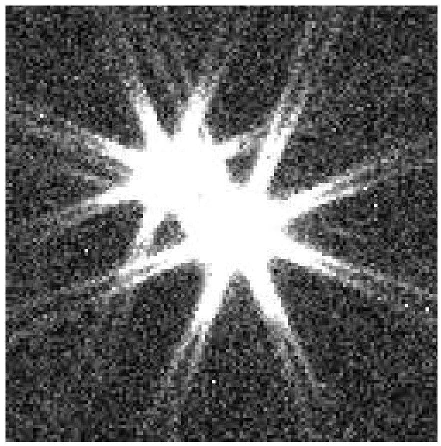
CTIOPI Photometry Reduction User Guide



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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 — Task fixairmass added, grammar corrections.

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. Besides, users should be familiar with IRAF. A couple of user guides can be found on IRAF's website – **http://iraf.noao.edu/docs/photom.html**, especially

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.

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

2. Oragnize Your Processed Data

Load package **daophot, photcal, redpi** before you begin anything[1]. After processing the raw data, you will need to fix the air mass immediately. The new TCS does not communicate effectively with the telescope, and thus, the airmass is not accurate. This

[1]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

package will correct the airmass. Load **astutil/fixairmass** task. You will need to create a file containing the coordinates for each object. 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

Next, you will need to fix the headers. Load the **setairmass** task. See Fig 1. Edit **setairmass** parameters for the correct observatory site. Run this task to calculate airmass at the middle 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 need to add those header-keywords back to the header by using **hedit** task.

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

Run **files *.o.fits** >> **listfile** in IRAF for both standard and science images. Then, run **displayexam** task to select the images without saturated stars. This step is important for data reduction, since photometry for saturated stars can't be determined. Furthermore, IRAF won't generate annoying "INDEF" in the data file. In the mean time, you can determine the average seeing (FWHM) for this night's data. This average FHWM will be entered in the **phot** task. If the oberving 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 is observed in V, R and I, choose the best one in I band in order to reduce some 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 star frames 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 the correction.

3. Standard Stars

The basic steps for reducing uncrowded standard star fields are

1. Determine the aperture size you wish to use. This aperture size will be applied for all the standard stars from all the nights for all the filters. Edit **datapars, centerpars, fitsskypars and photpars** task parameters in the **phot** task.

2. Use **redpi/apercorr** task to tag the standard stars so that instrumental magnitudes can be calculated.

3. Organize the standard star configuration file and collect your standard stars' VRI instrumental magnitudes.

4. Apply transformation equations to get apparent magnitudes for standard stars.

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 and $14''$ 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 inside which are **datapars, centerpars, fitsskypars and photpars**.

3.1. Modify Parameters in PHOT Task

When you load the **redpi/apercorr** task, there will be 4 options. You need to select option 4 for standard stars because standard stars are usually in uncrowded fields, and no aperture correction will be applied. After choosing option 4, you will need to modify the following parameters in each task by scrolling down to each and typing *:e*.

3.1.1. photpars

This task specifies the size of the aperture. It is 7″ in radius in Fig 1. If *mkapert* is set "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.

3.1.2. datapar

Fig 2 shows the parameter examples for this task. The key parameter is *fwhmpsf* because it will be different from night to night. This FWHM will be the average for all the images. If we specify the scale to be 0.401″ for CTIO 0.9m data (i.e. the plate scale), the unit of FWHM will be in arcseconds. Other parameters are a one-time setup.

3.1.3. centerpar

This task will determine the centering algorithm while we tag the stars. Therefore, the *calgorithm* 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 *fwhmpsf*. The unit here is still in arcseconds.

3.1.4. 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 the radius as 20″ with a 3″ annulus width as shown in Fig 2. If *mksky* is set "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. A radial plot will be shown and 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 on the images is consistent in each filter.

3.2. 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 is 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 is observed two times in each.

3.3. 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 named "standard.obs" is a 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.

3.4. Make Configuration File and Standard *VRI* Magnitude Table

An example configuration file is shown in Fig 4, and it 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"**.

3.5. 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 a least-square method on 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.

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 detail. 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 AND IT GENERATES THE CATALOGUE ONLY.**

FURTHERMORE, PLEASE MANAULLY 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 culsters. 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, determine the average FWHM and also determine to which images to apply an aperture correction. Remove cosmic rays 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, record the FWHM of each image and also determine the necessity of aperture correction for science stars. In addition, make a note of which images have cosmic rays within the 7″ radius of the science star.

4.2. Remove Cosmic Rays

It is always better to remove a cosmic ray rather than to apply an aperture correction to avoid it. This is done with the iraf command **cosmicrays** in package **imred.crutil.cosmicrays**. A bad pixel map, which is located in the top level of CTIOPI photometry "default" directory, is needed to remove any bad columns. Using 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. 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 its peak flux is no more than 1% of that of the science star. See the help page by typing *help cosmicrays* for infomation on parameter tweaking.

4.3. Tag Isolated Stars in a Crowded Field

Load **redpi/apercorr** task and choose option 1. It will bring you to edit the parameters of the **phot** task. Section 3.1 has explained these parameters. The most important task is **photpars**. You need to choose a large variety of aperture sizes, 3″, 3.5″, 4″, 4.5″, 5″, 5.5″, 6″, 6.5″, 7″, 7.5″, 8″, 8.5″ and 9″ in radius. Then you tag 3 or more "isolated" stars with reasonable counts in the same field. The new generated file is called ***.aper.1**.

4.4. 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	12	13	14
radius size	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5

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. The example shown in Fig 5 is that **smallap** ID is 5 (5″ radius) and **largeap** ID is 9 (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 preceed 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″

4.5. 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 **smallap** which you used in aperture correction. Again, when tagging science stars, **the tagging order should be the same for all filters**. The output file is called ***.mag.1**.

4.6. 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. **mknobsfile** is also used for generating a master list of instrumental magnitudes. Make necessary changes for this task. **imsets="science.imsets", observation="science.obs" and apercors="aperture.corr"**.

4.7. 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.

4.7.1. evalfit task

Before using this task you need to copy the "standard.coeff" file from the standard star directory. No modification for 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 definition of 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 section5.

4.7.2. 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 VRI converged fitting 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 is called "science.ans" 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,

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

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

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

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 least-square method is performed by the **fitparam** task to calculate those transformation coefficients based on the standard star observations. This task not only calculates the transformation coefficients but calcualtes 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". This error calculates 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")

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standard.imsets example:
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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:
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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**.

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	i	20030329.09.194.o	xxxxx	xxx	xxxxxx	xxxxx	xxxxx	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	i	20030127.09.074.o	xxxxx	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	i	20030127.09.122.o	1.388	2003-08-28	jao

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

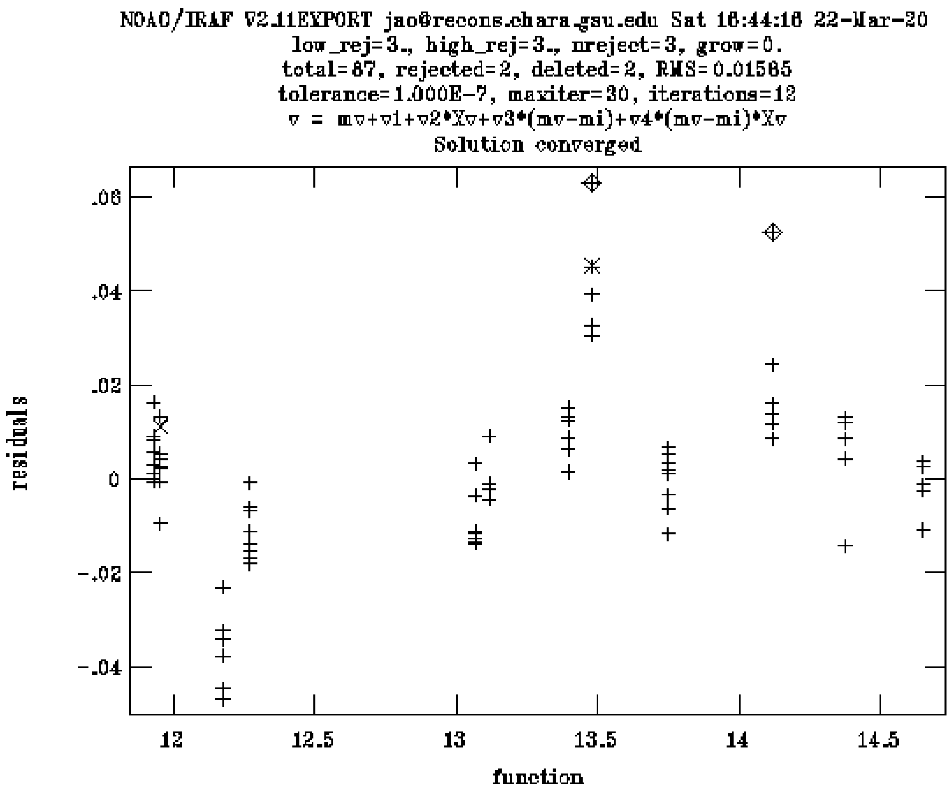

Fig. 7.— **fitparam** fitting plot example, and it shows that this solution is converged. Two diamonds indicate this task deleted data automatically and two crosses indicate they were deleted by users.