Subaru Data Reduction Winter School 2016
December 7-9, 2016
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Supplemental material

MCSRED an IRAF-based data reduction package by Dr. Ichi Tanaka (Subaru Telescope)

(English) http://www.naoj.org/staff/ichi/MCSRED/mcsred_e.html
(Japanese) http://www.naoj.org/staff/ichi/MCSRED/mcsred.html

You can find a textbook for MOIRCS imaging data reduction.
(English)
http://subarutelescope.org/Observing/Instruments/MOIRCS/mcsred_1e.pdf
(Japanese)
http://subarutelescope.org/Observing/DataReduction/mtk/spring12/references/text_moircs_v4.01.pdf

NOTE

␣ = space

PREPARATION

Make your working directory (as you like) and move to the directory. This is an example.

```
$ mkdir␣~/moircs
$ cd␣~/moircs
```

Then, download the latest version of the package from the above URL or run the following command.

```
$ wget␣http://www.naoj.org/staff/ichi/MCSRED/mcsred20141205.tar.gz
```

Extract the package.

```
$ tar␣xvzf␣mcsred20141205.tar.gz
```

You should find the directory 'MCSRED'.

Preparation for IRAF according to the textbook. See sections of 3.1.2 and 3.1.4.

```
$ mkiraf
$ emacs␣login.cl
$ emacs␣~/.bashrc
$ source␣~/.bashrc
```

If you complete the setup, make sure that MCSRED has been successfully loaded.

```
$ cl
ecl> mcsred
        ================================================
         MCSRED: MOIRCS Imaging Data Reduction Package
```

```
                    Release Version 2014-12-05
          !! Read README in the package directory first !!
          ================================================
   awk          cleanall     gmkgtrimages  kage          mcsgeocorr    moscorcalc    psfestimate   sccalc
   basename     cutpr        gsextcat      listprep      mcsimstat     mosgcsbimg    qmsepskysb    tiltskycor
   checkwdither dmosimg      imcheck       mcs_mksflat   mkcorrawdata  noddata       quadcor       tsubanomaly
   chkgmpdata   eachflat     imreflection  mcsall        mkdistmask    plsatellite   randaperr
   clean2nd     findms       invmask       mcsdisplay    mkdome        prmask        sbselfsky
mcsred>
mcsred> logout
```

Download the data used in this school. Note that the size of 'data.tar.gz' is 522MB.
The data are available in the URL only during this school.

```
$ wget_http://optik2.mtk.nao.ac.jp/~hayashi/tmp/data.tar.gz
$ tar_xvzf_data.tar.gz
```

You can also download the data via SMOKA. SMOKA is a science archive where public data of Subaru Telescope are distributed. [URL] http://smoka.nao.ac.jp/index.jsp

The data.tar.gz has 90 FITS files.

- **Abell2390 (galaxy cluster at z=0.231)**

Bandpass	Frame ID	Exposure time (per frame)	Observation date
Ks	MCSA00038477 – MCSA00038494	150 sec	2006/09/01
J	MCSA00039001 – MCSA00039018	150 sec	2006/09/02
H	MCSA00039021 – MCSA00039038	120 sec	2006/09/02

- **FS103 (standard star)**

Bandpass	Frame ID	Exposure	Date	Note
Ks	MCSA00039115 – MCSA00039126	2 sec	2006/09/01	chip1: 21,23,25 chip2: 16,18,20
J	MCSA00039129 – MCSA00039140	2 sec	2006/09/02	chip1: 29,31,33 chip2: 36,38,40
H	MCSA00039145 – MCSA00039156	2 sec	2006/09/02	chip1: 46,48,50 chip2: 51,53,55

These FITS data of standard star are partial-readout images with 512x512 pixels.
Note: The number shows which chip the standard star is taken in. '21' means MCSA00039121.

(Table and finding charts of standard stars)

http://www.ing.iac.es/astronomy/instruments/ingrid/IRstandards.html
http://www.gemini.edu/sciops/instruments/nir/photstandards/UKIRT-fs-charts.html

Make sure that DS9 and SExtractor are available. If OK, the preparation is completed.

DATA REDUCTION

The data you just downloaded are reduced according to the textbook. Note that the data you use in this school are different from those shown in the textbook. Thus, you read the textbook carefully and then you have to input proper data to run the commands.

Current working directory: /home/hayashi/moircs/
Data directory: /home/hayashi/moircs/data/
Change them to your directory accordingly.

Check the fits images.

```
$ ls␣data/
```

Check the header of fits images.

```
$ cl
ecl> mcsred
mcsred> hselect␣data/*.fits␣FRAMEID,OBJECT,FILTER01,EXPTIME,DATE-OBS␣yes
MCSA00038477    A2390           KS      150.000 2006-09-01
MCSA00038478    A2390           KS      150.000 2006-09-01
MCSA00038479    A2390           KS      150.000 2006-09-01
.....
MCSA00039156    "FS103 Standard"        H       2.000   2006-09-02
```

Make lists of input files. (see section 3.2.3 in the textbook)

```
mcsred> listprep␣/home/hayashi/moircs/data/␣a2390ks␣38477␣38494
```

You can find **a2390ks_[12].lst** in current directory.
Start **ds9** for viewing images.

```
mcsred> !ds9␣&
```

Check the images. (see sections 3.2.4 and 3.2.5 in the textbook) This is an example.

```
mcsred> imcheck␣a2390ks_1.lst
```

MCSRED has a task of '**mcsall**' which processes data from the dual detector arrays separately and performs whole the reduction process at a time. There are 8 steps in whole the processes. However, we run the task '**mcsall**' to take each step one by one in this school to understand the individual processes. It is important to check the resultant images after finishing each process. '**mcsall**' is an assembly of several tasks for each reduction process. You can know the specific tasks by reading 'dir_mcsred/mcsall.cl'.

These are parameters of '**mcsall**'. You should understand all of the parameters well.

inlist =	The list of raw images (listprep output)
resimg =	The name of the final resulting image
(jump = 1)	Jump to the i-th procss
(bye = 8)	Stop after the i-th procss

```
(disp = yes)              Display the process?
(config = "dir_mcsred$DATABASE/ana_nov14.cfg")  The name of mcsred config file
(dosf = yes)              Step1: make selfflat or not?
(sflat = "")              Step1: the name of self-flat frame.
(extflat = "")            Step1: if dosf=no, supply the name of flatframe.
(dodk = no)               Step1: subtract the dark frame ?
(dark = "")               Step1: the name of the user-supplied Dark Frame
(rail = no)               Step1: do the rail remain on chip 1?
(sthresh = 1.25)          Step1: threshold for object mask.
(msksize = 4.0)           Step1: object expansion size (pix).
(mskcr = yes)             Step1: cosmic-ray cleaning during making mask?
(eachflat = no)           Step2: make individual flats for each frame
                                 (yes          recommended if the number of frame is less than 20)?
(skipsky = no)            Step3: skip median-sky subtraction process?
(nself = 3)               Step3: 2 x nself frames are used for making sky
(nmin = 5)                Step3: minimum number of frames for sky (<2*nsf)
(skipqms = no)            Step4: skip qmsepsky process (cautious!)?
(moresky = no)            Step4: more constant sky subtraction after qmsepsky?
(crrej = yes)             Step5: Cosmic-ray cleaning during mcsgeocorr?
(minfw = 2.8)             Step7: Minimum FWHM for matching catalog
(maxfw = 10.0)            Step7: Maximun FWHM for matching catalog
(satur = 18000.0)         Step7: Saturation counts
(thres = 4.0)             Step7: SExtractor: detect_thresh
(conn = 12)               Step7: SExtractor: connected pixel
(fstop = yes)             Step8: Pause the process after xyxymatch and before final combine?
(combine = "average")     Step8: type of final combine?
(reject = "sigclip")      Step8: type of rejection
(weight = "sigma")        Step8: weight -sigma or exptime?
(lsigma = 3.0)            Step8: lower sigma clipping factor
(hsigma = 3.0)            Step8: upper sigma clipping factor
(nmat = 40.0)             Step8: nmatch parameter in xyxymatch
```

The following is an example of the reduction of Ks-band data. See also section 3.2.7 of the textbook.

- **Abell2390 (galaxy cluster at z=0.231)**

[STEP 1] object mask and sky flat image

```
mcsred> mcsall␣a2390ks_1.lst␣a2390ks_1.fits␣jump=1␣bye=1\
        ␣config="dir_mcsred$DATABASE/ana_aug06.cfg"\
        ␣dosf+␣sflat=SFlat_ks_1.fits
mcsred> mcsall␣a2390ks_2.lst␣a2390ks_2.fits␣jump=1␣bye=1\
        ␣config="dir_mcsred$DATABASE/ana_aug06.cfg"\
```

```
        _dosf+_sflat=SFlat_ks_2.fits
```

[STEP 2] flat fielding

```
mcsred> mcsall_a2390ks_1.lst_a2390ks_1.fits_jump=2_bye=2\
        _config="dir_mcsred$DATABASE/ana_aug06.cfg"\
        _eachflat+
mcsred> mcsall_a2390ks_2.lst_a2390ks_2.fits_jump=2_bye=2\
        _config="dir_mcsred$DATABASE/ana_aug06.cfg"\
        _eachflat+
```

[STEP 3] subtract the median sky from each frame

```
mcsred> mcsall_a2390ks_1.lst_a2390ks_1.fits_jump=3_bye=3\
        _config="dir_mcsred$DATABASE/ana_aug06.cfg"
mcsred> mcsall_a2390ks_2.lst_a2390ks_2.fits_jump=3_bye=3\
        _config="dir_mcsred$DATABASE/ana_aug06.cfg"
```

[STEP 4] subtract the residual sky level by fitting

```
mcsred> mcsall_a2390ks_1.lst_a2390ks_1.fits_jump=4_bye=4\
        _config="dir_mcsred$DATABASE/ana_aug06.cfg"
mcsred> mcsall_a2390ks_2.lst_a2390ks_2.fits_jump=4_bye=4\
        _config="dir_mcsred$DATABASE/ana_aug06.cfg"
```

[STEP 5] fix each quadrant boundary

```
mcsred> mcsall_a2390ks_1.lst_a2390ks_1.fits_jump=5_bye=5\
        _config="dir_mcsred$DATABASE/ana_aug06.cfg"
mcsred> mcsall_a2390ks_2.lst_a2390ks_2.fits_jump=5_bye=5\
        _config="dir_mcsred$DATABASE/ana_aug06.cfg"
```

[STEP 6] correct distortion

```
mcsred> mcsall_a2390ks_1.lst_a2390ks_1.fits_jump=6_bye=6\
        _config="dir_mcsred$DATABASE/ana_aug06.cfg"
mcsred> mcsall_a2390ks_2.lst_a2390ks_2.fits_jump=6_bye=6\
        _config="dir_mcsred$DATABASE/ana_aug06.cfg"
```

[STEP 7] object detection

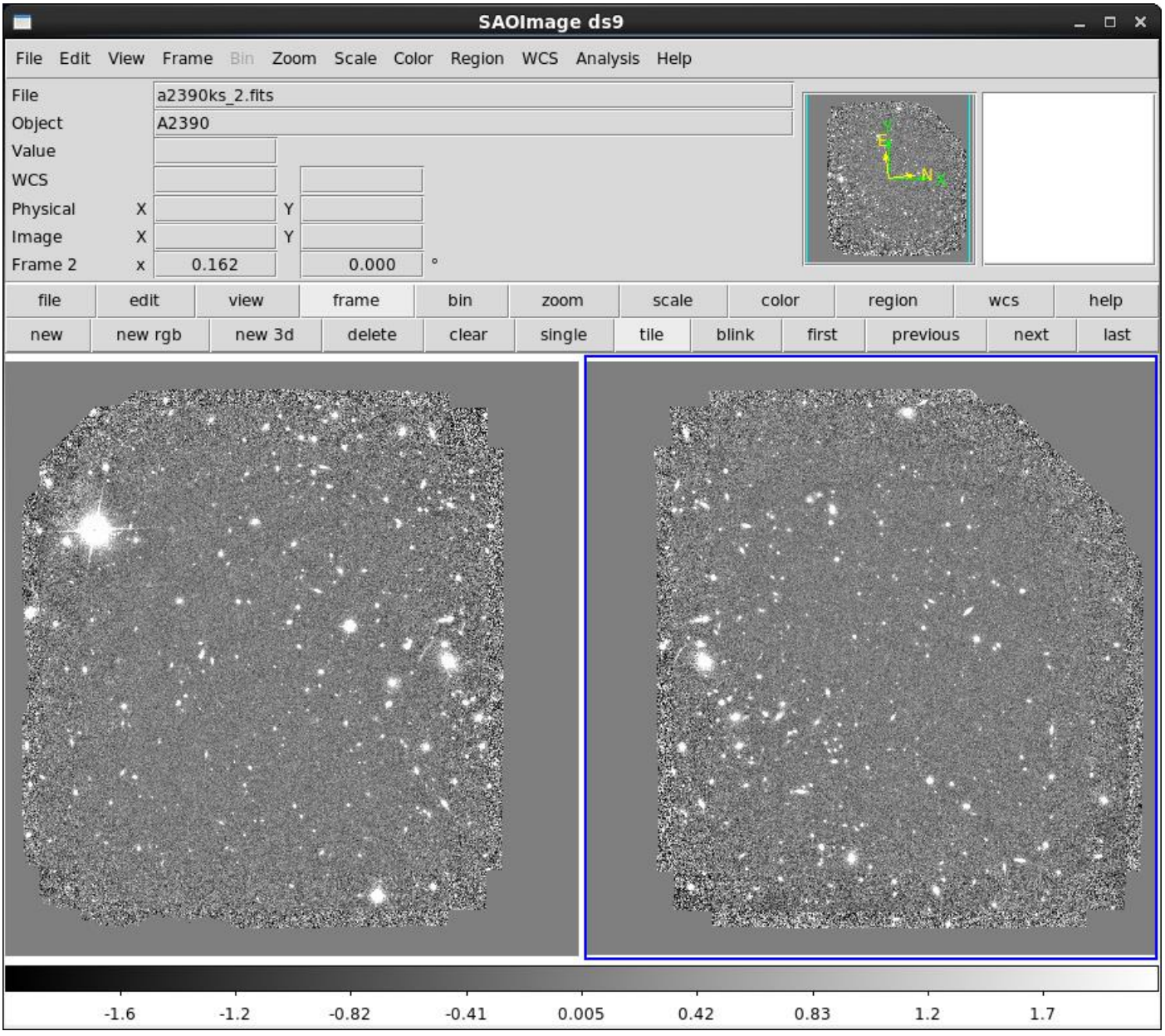
```
mcsred> mcsall_a2390ks_1.lst_a2390ks_1.fits_jump=7_bye=7\
        _config="dir_mcsred$DATABASE/ana_aug06.cfg"\
        _thres=3.5
mcsred> mcsall_a2390ks_2.lst_a2390ks_2.fits_jump=7_bye=7\
        _config="dir_mcsred$DATABASE/ana_aug06.cfg"\
        _thres=3.5
```

[STEP 8] combine

```
mcsred> mcsall␣a2390ks_1.lst␣a2390ks_1.fits␣jump=8␣bye=8\
        ␣config="dir_mcsred$DATABASE/ana_aug06.cfg"\
        ␣fstop+
mcsred> mcsall␣a2390ks_2.lst␣a2390ks_2.fits␣jump=8␣bye=8\
        ␣config="dir_mcsred$DATABASE/ana_aug06.cfg"\
        ␣fstop+
```

When you run this task, you are asked like that, "Proceed to final combine? (yes/no)". Before you answer "yes", you should check the result of catalog matching. If there are enough number of objects matched, "Matched obj=xxx", for all of the input images, catalog matching succeeded. So, go ahead. If not, you have to go back to step 7, adjust the parameters for object detection, and then resume from step 7.

Now, you have two reduced Ks-band images, namely chip1 and chip2 separately.



Next step is to mosaic the reduced images from chip1 and chip2. Mosaic process can be done with another task of **dmosimg**. See section 3.3 of the textbook.

[STEP 9] mosaic (section 3.3.1)

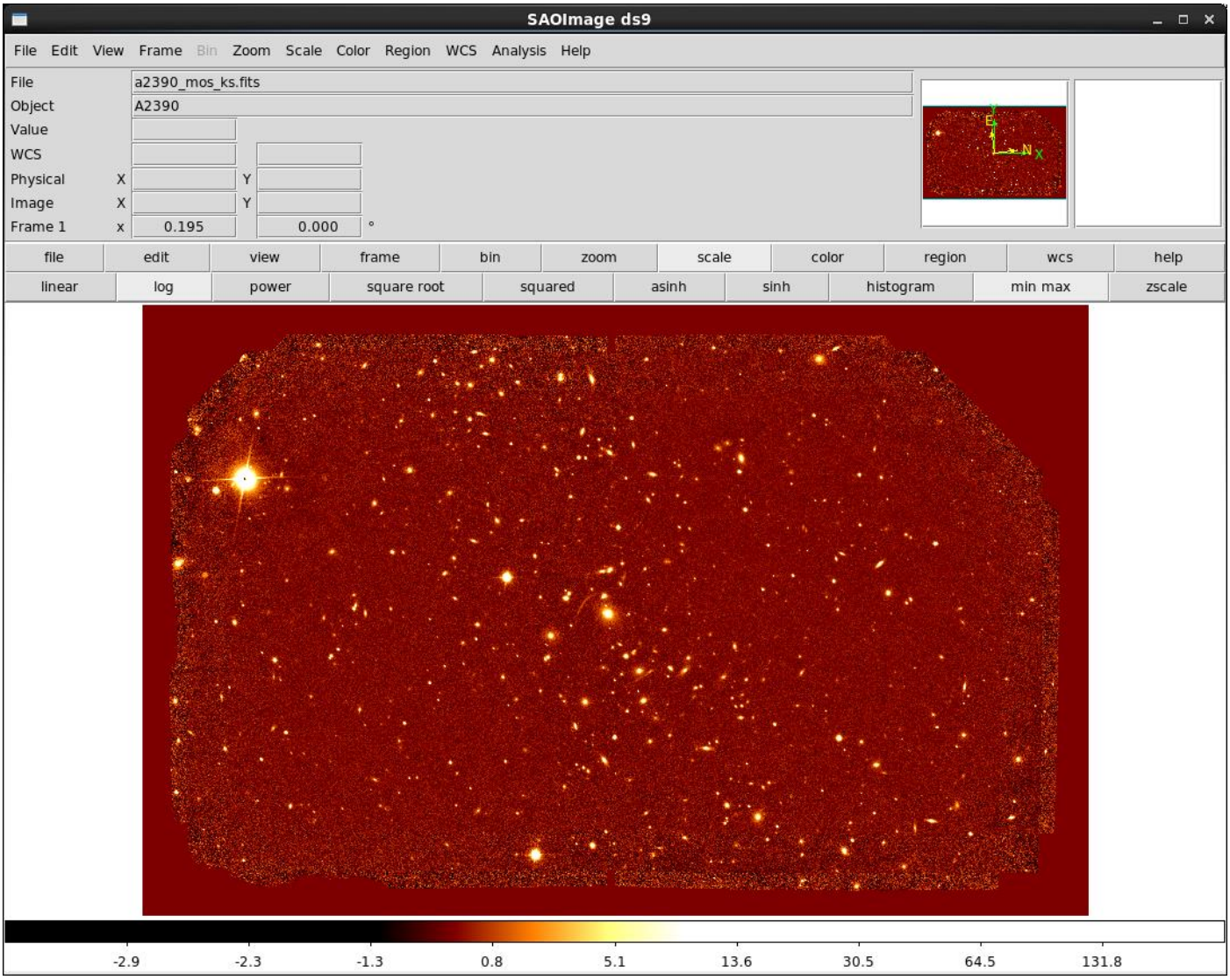
```
mcsred> !ls -1 gcSB*3847[789].fits > gcall_ks.lst
mcsred> !ls -1 gcSB*3848?.fits >> gcall_ks.lst
mcsred> !ls -1 gcSB*3849[01234].fits >> gcall_ks.lst
mcsred> dmosimg␣gcall_ks.lst␣kstmos␣sc=0.768572847\
        ␣config="dir_mcsred$DATABASE/ana_aug06.cfg"
```

[STEP 10] object detection for mosaicked images (section 3.3.2)

```
mcsred> gsextcat␣@mos_gcall_ks.lst\
        ␣detmin=20␣thresh=10␣minfw=4␣maxfw=7\
        ␣satur=18000␣cx0=100␣cy0=100␣cwx=3369␣cwy=1848
```

[STEP 11] combine all frames (section 3.3.3)

```
mcsred> gmkgtrimages␣mos_gcall_ks.lst␣a2390_mos_ks.fits\
        ␣gtrlst=GTR_mos_gcall_ks.lst␣reject=sigclip␣fstop+
```



The reduction of Ks-band imaging data is completed.

- **FS103 (standard star)**

The following is an example of the reduction of Ks-band data of the standard star. See section 3.5 of the textbook, in particular, section 3.5.3. This is because the images for the standard star are partial-readout data. If the images are whole-readout data with 2048x2048 pixels, you can use '**mcsall**' to reduce the data for standard stars as well.

```
mcsred> listprep␣/home/hayashi/moircs/data/␣fs103ks␣39115␣39126
mcsred>
mcsred> prmask␣fs103ks_1.lst
mcsred> prmask␣fs103ks_2.lst
mcsred>
mcsred> !gawk␣'{printf("fl%s\n",$1)}'␣bisfs103ks_1.lst␣>␣flbsfs103ks_1.lst
mcsred> !gawk␣'{printf("fl%s\n",$1)}'␣bisfs103ks_2.lst␣>␣flbsfs103ks_2.lst
mcsred>
mcsred> imarith␣@bisfs103ks_1.lst␣/␣SFlat_ks_1.fits␣@flbsfs103ks_1.lst
mcsred> imarith␣@bisfs103ks_2.lst␣/␣SFlat_ks_2.fits␣@flbsfs103ks_2.lst
mcsred>
mcsred> sbselfsky␣flbsfs103ks_1.lst␣nsf=3␣nmin=5
mcsred> sbselfsky␣flbsfs103ks_2.lst␣nsf=3␣nmin=5
mcsred>
mcsred> cutpr␣sbflMCSA00039116.fits␣prsbflMCSA00039116.fits
mcsred> cutpr␣sbflMCSA00039118.fits␣prsbflMCSA00039118.fits
mcsred> cutpr␣sbflMCSA00039120.fits␣prsbflMCSA00039120.fits
mcsred> cutpr␣sbflMCSA00039121.fits␣prsbflMCSA00039121.fits
mcsred> cutpr␣sbflMCSA00039123.fits␣prsbflMCSA00039123.fits
mcsred> cutpr␣sbflMCSA00039125.fits␣prsbflMCSA00039125.fits
mcsred>
mcsred> tsubanomaly␣prsbflMCSA00039116.fits
mcsred> tsubanomaly␣prsbflMCSA00039118.fits
mcsred> tsubanomaly␣prsbflMCSA00039120.fits
mcsred> tsubanomaly␣prsbflMCSA00039121.fits
mcsred> tsubanomaly␣prsbflMCSA00039123.fits
mcsred> tsubanomaly␣prsbflMCSA00039125.fits
mcsred>
mcsred> ls␣SBprsbflMCSA*fits
```

If you have the reduced images in J, H, and Ks, you can make pseudo-color image where Red=Ks, Green=H, and Blue=J. You have to match geometry of the three images. The values of the shift can be roughly estimated with **imexam**. More precisely, it is better to use IRAF tasks of **geomap** and **geotran**. Anyway, this is an example.

```
mcsred> imshift␣a2390_mos_ks.fits␣a2390_mos_ks_match.fits␣45.77␣16.53
mcsred> imshift␣a2390_mos_h.fits␣a2390_mos_h_match.fits␣-0.09␣2.77
mcsred> imshift␣a2390_mos_j.fits␣a2390_mos_j_match.fits␣-0.70␣-0.11
```

Color image of Abell 2390 galaxy cluster at z=0.231