

Example:A composite image of the M74 galaxy

In this example we demonstrate how the tasks in the **FITSH** package can be exploited to create a color composite astronomical image from individual scientific frames. In principle, a nice colorful image requires low noise, so either we need long exposure frames or multiple images should be combined in order to obtain this sufficiently low noise level. Since both the guiding errors of the telescope mounts and the presence of the atmospheric refraction impede us from longer exposure times, we focus on now methods based on multiple image combination. Additionally, this method also has the advantage that small but explicit dithering in the telescope position allows us to reject bad pixels or flat errors from the final image by taking a median average of the individual frames.

This actual example uses 3×10 individual images, in B, V and R filters from the galaxy M74. These images were taken on the night of 2010 November 15/16, between 18:48 and 20:00 UT using the 60/90/180 cm Schmidt telescope ^[1] located on the Piszkes-tető Mountain Station ^[2] of the Konkoly Observatory ^[3], Hungary. Each frames were exposed for 2 minutes. This example assumes that all of these 30 frames have already been calibrated using some standard calibration processing (see other examples related to Example:calibration here). The calibrated frames are supposed to be named as `Rm74-0001-B.fits`, `Rm74-0001-V.fits`, `Rm74-0001-R.fits`, and so on (the sequence number in the file names are between 0001 and 0010). The basic steps of the image processing are going to be the following:

- Registering all of the images to the same reference system.
- Scaling the images to the same background and flux level (a correction of possible variations in the sky transparency and scatter).
- Combine the individual registered and scaled `imm74-trim-0.png`ages into a single, high signal-to-noise ratio image, in all of the 3 channels.
- Scale the 3 combined images into a flux range to have a nice vision from the galaxy and the surrounding stars.
- Combine these images into a single color composite (RGB) image and convert it into some conventional image format.

If you intend to try this set of data reduction scripts in your system, the full archive of related data can be downloaded by downloading the individual files listed here: `m74-galaxy.list` ^[4]. This archive includes the 30 calibrated frames and the `base.list` file containing the "basenames" of these frames. This archive linked above is relatively large: the individual calibrated images have a size of 4096×4096 pixels, thus each image is approximately 64 megabytes (using 32-bit floating point representation), therefore the whole archive is around 2 gigabytes.

Registration

The step of image registration has the same three sub-steps like in the case of, for instance, photometry of (20000) Varuna. Namely, first, we detect some stars on the images; second, using these lists of stars we derive relative astrometric transformations and third, apply these transformations on the individual images. All of these steps can simultaneously handle the images taken with the three different filters. Thus, in all of these three substeps we follow the similar methods (like here). The list of file basenames (filenames without the extensions) are listed and should be set up before these procedures in the file `base.list`.

So, first stars are searched and listed to individual files, using the `fistar` task. If the images are de-focused and stars are somehow blurred, it is easier to detect stars on a shrunk image. The shrink factor `$SHF` can be set to any arbitrary positive integer. If it is larger than unity, then both the task `fitrans` is called in `--shrink` mode and the program `awk` is used to multiply the resulted X and Y centroid coordinates by this factor.

```
#!/bin/bash
```

```
FITS=./fits
```

```

ASTR=./astrom

SHF=2

cat base.list | \
while read base dummy ; do

    if test 1 -lt $SHF ; then
        fitrans $FITS/$base.fits --shrink $SHF
    else
        cat      $FITS/$base.fits
    fi | \
    fistar --input - \
           --flux-threshold 20000 --model elliptic \
           --format id,x,y,s,d,k,flux,mag \
           --output - | \
    awk -v s=$SHF \
        '{ print $1,$2*s,$3*s,$4,$5,$6,$7,$8;
        }' > $ASTR/$base.stars

    l=`cat $ASTR/$base.stars | wc -l`

    echo "$base: done [$l]." >> /dev/stderr

done

```

If we have the list of stars on each image, we use the task `grmatch` to obtain the relative astrometric transformations between the individual images and a previously selected reference image. Here, this reference image is Rm74-0005-R.

```

#!/bin/bash

ASTR=./astrom

ref=Rm74-0005-R

cat base.list | \
while read base dummy ; do

    grmatch --reference $ASTR/$ref.stars --col-ref 2,3 --col-ref-ordering -8 \
            --input $ASTR/$base.stars --col-inp 2,3 --col-inp-ordering -8 \
            --max-distance 1 \
            --order 3 --triangulation auto,unitarity=0.01,maxref=1000,maxinp=1000 \
            --weight reference,column=8,magnitude,power=2 \
            --comment --output-transformation $ASTR/$base.dtrans

    echo "$base: done." >> /dev/stderr

done

```

```
done
```

Once these relative transformations are known, we have to simply apply the task `fitrans` to shift the individual frames to the reference system.

```
#!/bin/bash

FITS=./fits
ASTR=./astrom
REG=./reg

cat base.list | \
while read base dummy ; do

    fiign  $FITS/$base.fits --output - | \
    fitrans --input-transformation $ASTR/$base.dtrans \
           -c --reverse --output $REG/$base.fits

    echo "$base: done." >> /dev/stderr

done
```

Flux level scaling

The flux level scaling is done in two distinct steps. First, aperture photometry is performed on a list of stars (that have been detected on the astrometric reference image, `Rm74-0005-R`). The results of this aperture photometry are stored in the directory `./phot`. These photometric results are used in the second step, where the background information is used to subtract the background of the image to a nearly zero level.

Since the FOV of these images is relatively large (1.167×1.167 degrees), the background removal is done in a linear (first) order. To fit a certain background level or a flux scale level, the task `lfit` is used to obtain the coefficients. In order to subtract the background, the task `fiarith` is used to evaluate the coefficients obtained by `lfit`.

```
#!/bin/bash

ASTR=./astrom
REG=./reg
PHOT=./phot

ref=Rm74-0005-R

cat base.list | \
while read base dummy ; do

    fiphot --input $REG/$base.fits \
          --input-list $ASTR/$ref.stars --col-xy 2,3 --col-id 1 \
          --aperture 8:15:25 --sky-fit mode --format IXY,FfBbs \
          --output - | \
    grep "G" > $PHOT/$base.phot

done
```

```
echo "$base: done." >> /dev/stderr
```

```
done
```

Since the galaxy itself is relatively small (less than 10') compared to the FOV of the Schmidt telescope (that is 70' × 70'), we focus on the center of the image, i.e. we include only the central 2048 × 2048 region of the images for fitting the background information. Moreover, after subtracting the background level, the images are also trimmed to this smaller size.

```
#!/bin/bash
```

```
PHOT=./phot
```

```
SCALED=./scaled
```

```
ref=Rm74-0005-R
```

```
cat base.list | \
```

```
while read base dummy ; do
```

```
    A=( $( grmatch -r $PHOT/$ref.phot -i $PHOT/$base.phot \
            --match-id --col-ref-id 1 --col-inp-id 1 \
            --output-matched - | \
```

```
        awk \
```

```
        '{ x=$2;y=$3;
```

```
          if ( 1024 <= x && x < 3072 && 1024 <= y && y < 3072 )
              print;
```

```
        }' | \
```

```
        lfit \
```

```
        -c x:2,y:3,bgr:6,bgi:14 -v a=0,b=0,c \
```

```
        -f "a*(x-2048)/2048+b*(y-2040)/2048+c" -y bgi ))
```

```
    fiarith ["reg/$base.fits"] (a-(( ${A[0]} ) *x + ( ${A[1]} ) *y + ( ${A[2]} ))) \
        --output - | \
```

```
    fitrans --offset 1024,1024 --size 2048,2048 -o $SCALED/$base.fits
```

```
echo "$base: done." >> /dev/stderr
```

```
done
```

Image combination

Once the individual images are registered and scaled, it is safe to do a median average on them. Since the basenames of the individual files ends with the appropriate filter name, we can use a simple shell wildcard pattern to select between the three bands. For the combination, we use the `ficombine` task.

Scaling to a visual dynamic range

In order to have a smooth and nicely visualized image, we do some initial processing on the combined images as well, before feeding them to the task `fiinfo`. This task will then convert and "visualize" data from FITS to PGM format. The initial processing do a moving median box averaging with a box size of 3×3 pixels (done by `fitrans`, see `--smooth median, hsize=1`) and the resulted images are shrunk by a factor of 2.

To display the images, here `fiinfo` uses a simple linear scaling with a histogram percentage limitations of 99.7%. It means that the lower and higher intensity limits are derived as the boundaries of the central 99.7% of the pixel intensity distributions.

Create the composite image

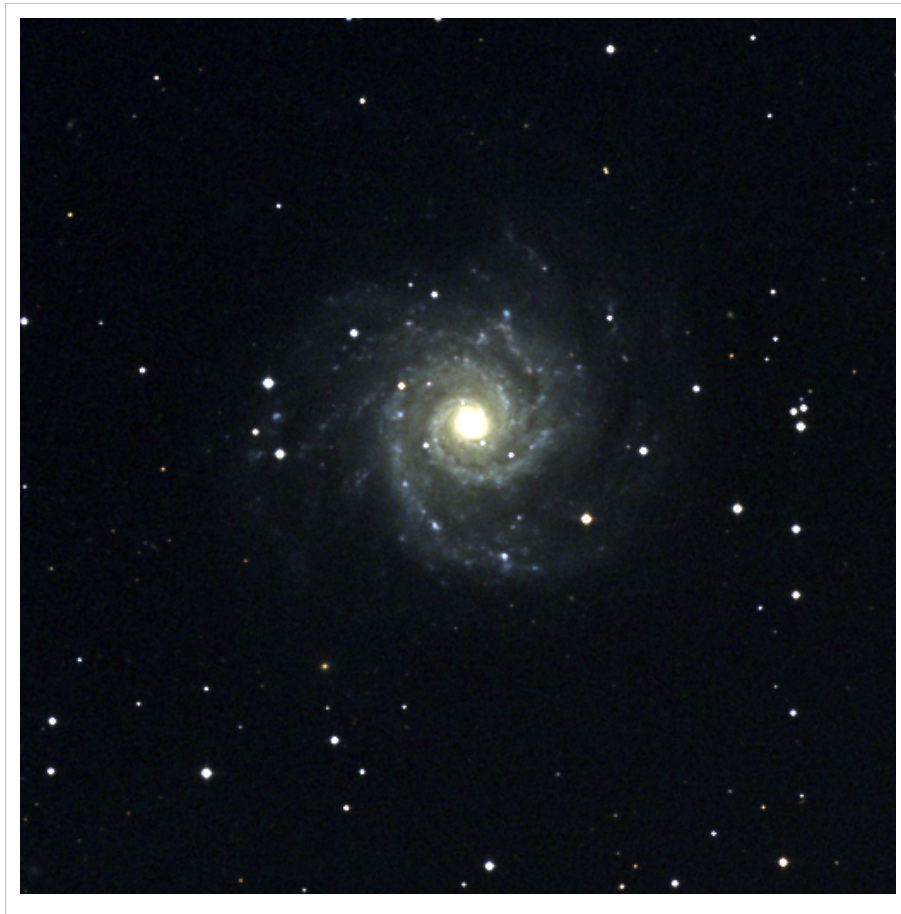
The utilities found in the NetPBM package can be used to create the composite RGB image from the individual PGM images as well as to do some post-processing (trimming and conversion) on the resulted color (PPM) image. And at last, the utility `pnmtopng` is used to get the final image in the conventional PNG format.

```
#!/bin/bash

base=m74

rgb3toppm $base-r.pgm $base-g.pgm $base-b.pgm > $base.ppm
cat $base.ppm | pnmcut 192 160 512 512 | pnmtopng > $base-trim.png
```

The output of this script, i.e. the color composite image of the M74 galaxy is then:



References

- [1] http://cedsh.konkoly.hu/wiki/Schmidt_telescope
- [2] http://cedsh.konkoly.hu/wiki/Piszk%C3%A9stet%C5%91_Mountain_Station
- [3] http://www.konkoly.hu/index_en.shtml
- [4] <http://fitsh.net/archive/list/m74-galaxy.list>