

# TCP'S USER MANUAL

## REAL TIME PHOTOMETRY (RTP)



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## 1. INTRODUCTION

CCD images normally require a lot of calibration work to be rendered useful for high precision photometry. It is therefore not unusual to spend considerable time processing the data before accurate photometric magnitudes are obtained. Time-series photometry requires additional steps to produce differential photometry that can be subjected to Fourier analysis to reveal faint periodic modulations. A requirement for the TCP (Trømso CCD Photometer) was that light-curves of the targets could be produced in real time, so that the observer can investigate the results as they arrive.

The real time photometry (RTP) is performed by using the window definition files '*photwins.dat*' and '*photwccd.dat*' to convert the CCD pixel data written by the acquisition program to aperture images for pre-processing. The flat-field images are converted to a window list format by extracting the proper areas using the information in the file '*photwins.dat*'. During processing, each observation frame will be divided by the appropriate flat-field window. A bias level value is computed from the last window in the raw CCD image if there is information about such a window in the file '*photwccd.dat*'. Each CCD window is flat-fielded and bias level subtracted before the aperture sums are computed.

### 1.1. How does RTP work

RTP uses circular apertures with an arbitrary centre and radius within the aperture windows when computing the total flux inside the windows. It is important to remember that the first few columns read from the CCD is useless. In particular, the pixel read in a line is always zero, the next pixel has a somewhat high level, and then the amplifier gives progressively more stable output as more pixels are read in sequence. The default setup avoids the first four columns, using an aperture mask with a radius of 30 pixels, centred at pixel [34 , 30]. The aperture can be set from the command line with the `-r <radius>` `-x <xcenter>` `-y <ycenter>` options.

RTP can also use an automatic centring algorithm. This computes a simple geometric centre of gravity within the aperture, and re-centres the aperture iteratively. The centring algorithm is specified on the command line when RTP is started. The option `-O` will compute initial offsets for each stars, and the `-M` option will invoke the *Moving Aperture Photometry* (MAP) mode, computing a new aperture centre for each frame. For both option, the `-i <num>` parameter can be given to specify the number of iterations desired.

Sky subtracted photometry values are computed either by using the value from the last ('*sky channel*') aperture or by using a sky annulus around each aperture. This last option is accomplished by invoking RTP with the `-s <rad>` parameter. The quantity `<rad>` gives the number of pixels along each edge to be used. The first four rows in the image are avoided.



Differential photometry is computed for the target (channel #1) and each reference stars. If more than two reference stars are available, differential photometry is computed between them so that any periodic variability in the reference stars can be easily checked. If possible, a differential photometry value is also given for the target relative to the sum of all the reference stars, which is useful in fields where all reference stars are significantly fainter than the target.

These data are continuously appended to three separate photometry files ('*phot.raw*', '*phot.dat*' and '*phot.dif*') as soon as each new integration has been received and stored by the acquisition programs (*Qtcp* or *tcpcom*). While waiting for new data to arrive, RTP calls *gnuplot* to show plots of the photometry files so that the observer can analyse the light curves. In addition, RTP can show the Fourier transforms of the photometry files as the observations are being made. This gives opportunity to the observer to inspect the data in real time, being e.g. really useful for programs trying to detect new variable stars.

## 2. WORKING WITH RTP

- a) To process data with RTP is necessary to previously **set up a working directory**. Making a directory at any desired path and creating a symbolic link in this directory to the actual directory containing the data do this.

When real time photometry is being done a directory to keep the processed data must be created so that existing files are not overwritten! A link must be made to the data directory where *Qtcp15* (or *tcpcom*) stores the incoming CCD frames. For instance, if *Qtcp15* is saving images at */home/observer/1805072030/data* the following actions must be done:

```
> cd /home/observer/1805072030 /  
> mkdir RedB (if you want to reduce B images)  
> cd RedB  
> ln -s ../data/1/ data
```

**NOTE: Be sure that you have copied the files *phot\** to the *data* directory**

- b) If **flat-field processing** of the data is required then another symbolic link named *flats* to the data directory containing the correct flat field images should be made. You have previously stored the flats with the "separator" program. It can be the same as the previous data directory. As an example, for filter B flats:

```
> ln -s ../flat/1/ flats
```

**Note: the first time it appears written "flat" and then "flats"**

RTP will then sum all fits files in the *flats* directory having names matching the default string '*flat\*.fits*'. To specify another query string for the flat-fields



RTP must be started with the **-f** <flatstr> option. The flat-fields that match the query will be averaged, normalised and saved as *Flat.fits* in the working directory. This file will be used next time RTP is run, unless a specific filename or query string is given.

- c) RTP can be **started and stopped** at any point during or after the observation run. When it is started it will get the flat-field and prepare the output data files, *'phot.raw'* and *'phot.dat'*, before searching for input CCD fits files in the data directory. It will immediately process all the files it finds, and then go into a delayed loop where it will process files as they arrive.

RTP can also be used for **simple processing of the data** after the original session is over. Then it can sometimes be useful to have a delay between the processing of the images, to monitor the progress. This can be done by calling RTP with the **-d** <delay> option, where the delay time is given in seconds and can be a floating-point number.

- d) To **start RTP** just write:

```
> rtp -parameter1 [argument] -parameter2 [argument] ...
```

The RTP front-page will appear (see Figure 1). This page lists the most used options for RTP, and has been designed so that the keystrokes used to set the parameters are the same as those used for the processing flags on the command line. So, this page works both as a reminder and a way to check the input parameters before the processing is started. One new command line option has been added: **'G'** will inhibit the display of the start-up screen, and cause RTP to commence processing immediately. **'G'** is also the command in the front-page menu to give the system the "Go!" signal. The basic keystrokes you have to check always are **r** and **s**, which control the radius and the sky annulus region for each aperture, respectively.



```
observer@tccd:~/Data_Jose/AMCVn_March04_JAC80/AMCVn_21_3/Red - Terminal - K
RTP - real time processing, Version 1.30 (Roy H. Østensen 1999-2002)
a - Data filename format      : data/w%05d.fits
n - Number of first data file  : 0
r - Radius of fitting aperture : 15
s - Sky annulus region (pixels) : 10
t - Sky field number to use    : 1
z - Number of sky data fields  : 1
f - Name of flat field images  :
o - Object name                :
M - Moving aperture photometry (MAP) : ON
i - Number of iterations for MAP : 1
O - Offsets of individual apertures : ON
T - Times from FITS headers    : OFF
R - Differential photometry mode : ratio
G - Go RTP!
Q - Quit!

Startup Menu - Change setup or hit G to start processing: █
```

Figure 1. RTP program front-page.

**Example:**

```
> rtp -r 15 -s 10
```

This example selects a radius of 15 pixels for the aperture photometry and performs the sky subtraction with the sky annulus option using a ring of 10 pixels. This also can be done by typing only *RTP* and then, on the RTP front-page, using the 'r' and 's' keystrokes. Then, after hitting 'G' the following screen appears:

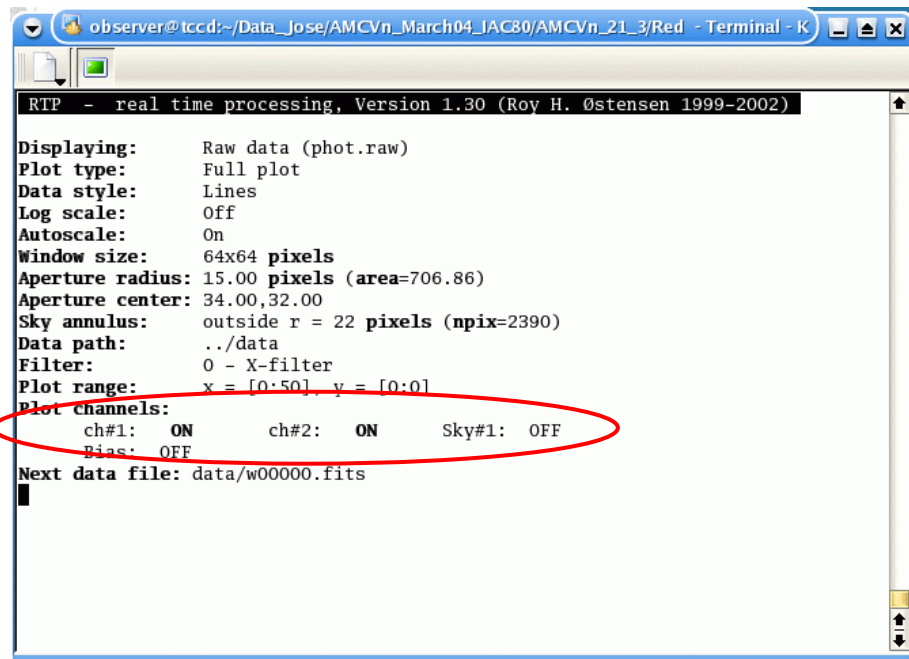


Figure 2. RTP program (information panel) running. The number keys (indicated in red) will toggle on and off which channels to display.

### e) Changing the display.

When RTP runs it displays through gnuplot the propagating light curve (see Figure 3). The '**d**' key switches from raw data (Figure 3) and processed data (data with sky subtraction, and differential photometry –see Figure 4–), whilst the '**F**' key displays the Fourier transform of the light-curves (see Figure 5). To go back to the light curves is necessary to press '**d**' again. The centroid file (generated as before and written to '*phot.cen*') can be plotted in real time, aiding the observer in keeping track of the accuracy of the telescope guiding. The '*phot.cen*' file is plotted in the same way as the photometry files upon pressing the '**C**' key. To switch on/off plot channels, just press the corresponding channel number.

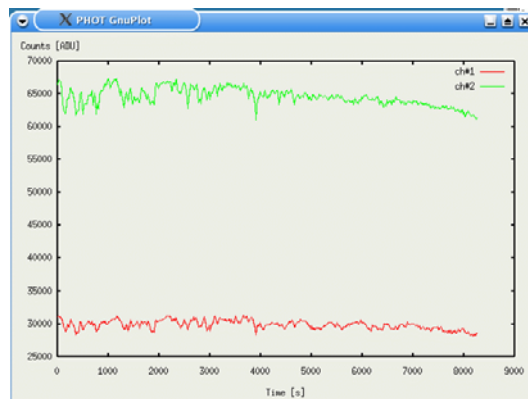


Figure 3. RTP displaying light curves (raw data) in real time.

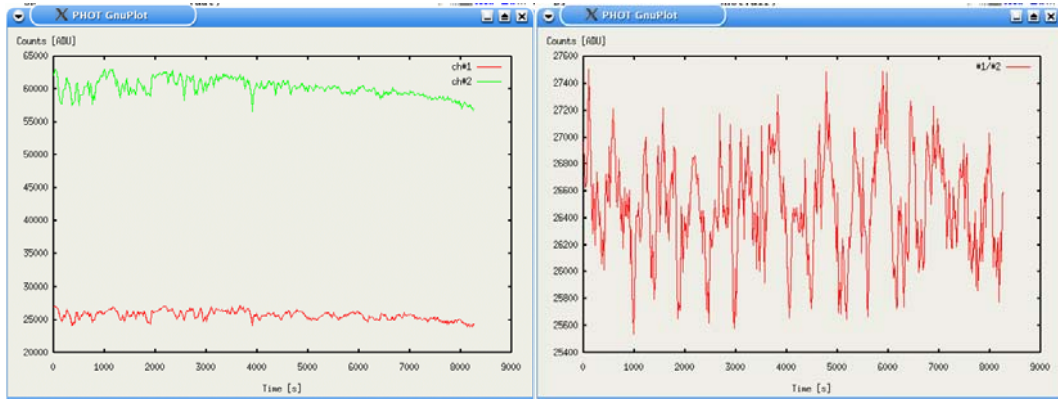


Figure 4. RTP displaying processed data (sky subtracted and differential photometry).

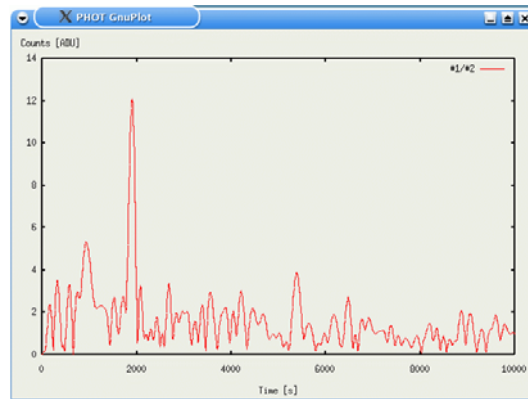


Figure 5. RTP displaying the Fourier Transform.

#### f) Producing plots.

It is possible to save the currently displayed plot as a postscript file with the 'P' key. The filename will be 'rtplot.ps'.





## APPENDIX: LIST OF COMMANDS

To display the list of keystroke commands while running RTP the '?' key must be used. The following display will appear.

```
observer@tccd:~/Data_Jose/AMCVn_March04_IAC30/AMCVn_21_3/Red - Terminal - K
Keystroke commands:
d = Plot Raw, Sky or Processed data      p = Plot full or ranged plot
0-9 = Plot channel # toggle              _ = Plot channel #1/#ALL toggle
s = Plot sky channel toggle              F = Calculate and plot FT
C = Plot aperture centroids              a = Toggle autoscale on/off
f = Plot next filter in sequence          ;/: = Increase or Decrease fold range
% = Fold lightcurve every [seconds]      L = Make LaTeX plot (rtplot.tex)
P = Make PostScript plot (rtplot.ps)
+/- = Bigger or smaller aperture
[] = Move aperture left() or right()    {} = Move aperture down() or up()
S = Plot style toggle (lines/points)    l = Logarithmic scale plot toggle
R = Reprocess all data                   M = Make new Mask (mask.fits)
O = Set object name (for saveplots)     W = Test image (testview.fits)
q = Quit                                 ? = This help page

Press a key to continue: █
```

Figure 6. RTP keystroke commands.

### Command line options.

- d delay  
Include a delay (in seconds) between each processed frame. Default is no delay.
- f flat-files  
Filename base for flat-fields. Default is 'flat\*.fits'.
- l log-file  
Filename for log-file. Default is 'rtp.log'.
- m nsigma  
Median filter sky annulus values, rejecting values that lie more than *nsigma* times the standard deviation away from the mean value.
- r aperture radius
- x aperture x position
- y aperture y position
- s sky annulus  
Use sky annulus to correct for sky level. Annulus is all pixels outside the given radius.





- F  
Compute the Fourier transform of the light-curves. Produce the file *'phot.sft'*.
- O  
Activates the offsets for the stars.
- M  
Activates the Moving Average Photometry (MAP) option.
- i number of iterations  
Set the number of iterations used to compute offsets and MAP.
- C  
Compute the centroid values.
- S  
Display apertures in Saoimage.
- R  
Reprocess all data.
- W  
Use weighted sums when computing aperture values.