

## Operative Manual of FAQ3 software Ver.2.50

FAQ3 is a program for CCD exposure calculation takes with photometric BVRcIc filters by Johnson-Cousin-Bessel system. The U band output is not currently available and, I hope, coming soon.

Just enter the characteristics of the your equipment that you use, CCD, filters, characteristics of the observative site and obviously magnitude of the stars, to calculate the best exposure time for any single image and total. This for each photometric band, relatively to the magnitude of the faintest star, (lower limit) and brightest star magnitude (upper limit) in your star field.

This software is developed for an aid in differential photometry where the comparison star are essentially in the same field of variable star. The resulting values are indicative.

The algorithms and data used in the program come from the following sources:

U. Munari: FAQ n°3 ANS collaboration group communications.

U Munari M. Fiorucci and D. Moro: Asiago Database on Photometric Systems (ADPS)  
<http://ulisse.pd.astro.it/Astro/ADPS/>.

W Romanishin: An Introduction to Astronomical Photometry Using CCDs University of Oklahoma  
[wjr@nhn.ou.edu](mailto:wjr@nhn.ou.edu).

P. Camaiti: Guida ai CCD per l'astronomia Ed. Castello.

For the algorithms of saturation time's calculating see the Appendix of this manual.

### **Program files:**

FAQ3 software consists of the following files:

FAQ3.EXE	executable file
SETTING.TXT	setting file
EXPHOT.INI	path file
MANUAL.PDF	this file

If you want is possible to save your stellar field's magnitude values in a file with .FAQ extension. One different file for each stellar field.

### **Installation:**

The program no requires a real installation, just unpack it in a directory of your choice and run the file FAQ3.EXE.

## Use:

In the upper half of window's program are to be entered the instrumental and sky inputs data, obviously you can save this values; while the bottom side is for input of stellar field (left side) and display the results (right side). It 'also possible to save a file with stellar field and/or data of output. Finally you can visualize a graph of the system of Johnson-Cousin-Bessel which is your master reference in the data calculation.

The following images for a better explanation:

## Overall view:

**FAQ3: UBVRcIc Photometric CCD exposure calculation** Ver. 2.50

**Telescope and mount**

Telescope

Aperture: 30 cm.

Focal: 300 cm.

Focal ratio: 10.0

**Max exposure time**

U: 240 Sec.

B: 240 Sec.

V: 240 Sec.

Rc: 240 Sec.

Ic: 240 Sec.

**Exposure data inputs**

Star field magnitudes

	Brighter	Fainter
U	12.0	15.0
B	09.9	15.0
V	08.6	15.0
Rc	12.0	15.0
Ic	12.0	15.0

Clear

Star field data handling

Save values

Load values

**Exposure outputs**

Total exposure:	Single exposure	Exp. Numbers:	Estimated S/N:	Estimated S/N:	Saturation
Seconds	Minutes	time: (Sec.)	brighter star	fainter star	time: (Sec.)
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—

Write to file

Compute

Exit

**Diagram of JCB Photometric System**

**Save instrumental values**

**Sky parameters**

Airmass: 1

FWHM (pixel): 03.30

Extinction coeff:

K	U	B	V	Rc	Ic
0.405	0.265	0.138	0.084	0.053	

Sky magnitudes:

U	B	V	Rc	Ic
20.00	19.7	19.0	18.2	18.1

**Save outputs**

Clear stellar field magnitudes

Save stellar field magnitudes

Load stellar field magnitudes

Show Johnson-Cousin-Bessel curve response

Save instrumental parameters

Exit program

Make the outputs computation

## Telescope and mount:

Telescope focal ratio appears automatically

Telescope and mount

Telescope

Aperture  cm

Focal  cm.

Focal ratio: 10.0

Max exposure time

**U**  Sec.

**B**  Sec.

**V**  Sec.

**Rc**  Sec.

**Ic**  Sec.

Telescope aperture in cm

Telescope focal length in cm

Max exposure time allowed by mount.

annotation  
although the max exposure time permitted by mount is obviously the same in each band I preferred, for increase the modularity, split this value for each photometric band

## CCD and Filters features:

CCD And Filters Features

Gain  e-/ADU **U**

CCD Readout noise  e- **B**

CCD Dark current  e-/pix sec **V**

BIAS  ADU **Rc**

Saturation level  ADU **Ic**

Pix size X  micron

Pix size Y  micron

Binning

Q Eff.	Filter's tsm.
<input type="text" value="37.00"/> %	<input type="text" value="40.00"/> %
<input type="text" value="40.00"/> %	<input type="text" value="50.00"/> %
<input type="text" value="45.50"/> %	<input type="text" value="55.00"/> %
<input type="text" value="50.00"/> %	<input type="text" value="70.00"/> %
<input type="text" value="55.00"/> %	<input type="text" value="80.00"/> %

Filters transmittance: mean values for each photometric band

CCD quantum mean efficiency in each photometric band

CCD Gain

CCD Readout noise

CCD Dark current

CCD Bias: deduced by Bias frame, median value of several Bias frame is better.

CCD saturation level

CCD horizontal pixel size

CCD vertical pixel size

CCD binning mode

## Sky parameters:

The 'Sky parameters' dialog box contains the following fields and annotations:

- Airmass value:** A dropdown menu set to '1'.
- Full With Half Maximum value:** A text input field containing '03.30'.
- Extinction coeff.:** A column of five text input fields for different photometric bands:
  - K<sub>U</sub>: 0.405
  - K<sub>B</sub>: 0.265
  - K<sub>V</sub>: 0.138
  - K<sub>Rc</sub>: 0.084
  - K<sub>Ic</sub>: 0.053
- Sky magnitudes:** A column of five text input fields for different photometric bands:
  - U: 20.00
  - B: 19.7\_
  - V: 19.0\_
  - Rc: 18.2\_
  - Ic: 18.1\_
- Mean sky magnitude in each photometric band:** This annotation points to the 'Sky magnitudes' column.
- Mean extinction coefficients for each photometric band:** This annotation points to the 'Extinction coeff.' column.

## Exposure data inputs:

The 'Exposure data inputs' dialog box contains the following fields and annotations:

- Star field magnitudes:** A table with two columns: 'Brighter' and 'Fainter'.
 

	Brighter	Fainter
U	12_	15_
B	09.9	15_
V	08.6	15_
Rc	12_	15_
Ic	12_	15_
- Sky magnitudes of brighter star in each photometric band:** This annotation points to the 'Brighter' column of the 'Star field magnitudes' table.
- Sky magnitudes of fainter star in each photometric band:** This annotation points to the 'Fainter' column of the 'Star field magnitudes' table.
- Annotation:** of course it is said that the brightest or fainter star is always the same in each band. This annotation is present in both the left and right yellow boxes.
- Clear stellar field magnitudes:** A button labeled 'Clear'.
- Star field data handling:** A section containing:
  - Save stellar field magnitudes:** A button labeled 'Save values' next to a folder icon.
  - Load stellar field magnitudes:** A button labeled 'Load values'.

**Exposure outputs:**

The screenshot shows the 'Exposure outputs' window with the following components and callouts:

- Table Headers:**
  - Total exposure:** (first column) and seconds (second column) for each photometric band
  - Single exposure time: (Sec.)** (Time of single exposures in sec. for each photometric band)
  - Exp. Numbers: (Rounded)** (Number of single exposures for each photometric band)
  - Estimated S/N: brighter star** (Estimated S/N Ratio for brighter star in the final stacked image)
  - Estimated S/N: fainter star** (Estimated S/N Ratio for fainter star in the final stacked image)
  - Saturation time: (Sec.)** (Estimated time of saturation)
- Table Data:** The table contains 6 rows of data, each represented by a horizontal line of a different color (purple, blue, green, red, brown, black).
- Buttons:**
  - Write to file:** Callout: 'Choose the path for output .txt file'
  - Compute:** Callout: 'Make the compute of exposure output values'
  - Exit:** Callout: 'Program Quit'

## Appendix:

The Calculus of time saturation is originated from a personal approach to the problem, I confide and hope this approach be formally corrected.

I have proceeded in this mode:

In first time I inferred a formal equation for found the ADU value. This equation is:

$$1) \quad ADU = BIAS + \frac{RON}{G} + \frac{DCURR * t}{G} + \frac{SKY * t}{G} + \frac{STAR * t}{G}$$

Reducing it become :

$$2) \quad ADU = BIAS + \frac{RON}{G} + (DCURR + SKY + STAR) * \frac{t}{G}$$

Where :

**ADU** = Analogic to Digit Unit total of a star image

**BIAS** = Noise from CCD's electronic in ADU

**RON** = Readout noise in electrons\*sec<sup>-1</sup>

**G** = Gain in electrons

**DCURR** = Dark current in electrons\*pixel\* sec<sup>-1</sup>

**SKY** = electrons flux originates by skylight photons \* sec<sup>-1</sup>

**STAR** = electrons flux originates by star light photons \* sec<sup>-1</sup>

**t** = time of exposure

**SKY** and **STAR** electrons are calculated from their incidents photons in this mode:

$$3) \quad e_n^- = \frac{(Phot_n) * (Phot_e)}{3.65}$$

Where:

$e_n^-$  = electrons number create from photons

**Phot<sub>n</sub>** = number of incident photons from the star or sky

**Phot<sub>e</sub>** = energy of each inciden photons from the star or sky expressed in eV

3,65 is the eV value for the Silicon efficiency conversion Photon to electron. In other word the eV energy of photons's pack divided 3.65 result the electrons number was originated in the CCD pixel.

At this point if we use the saturation value of ADU (that we know well) and solve the equation 1 respect exposure time we obtained:

$$4) \quad t_s = \frac{(ADU_s - BIAS - \frac{RON}{G}) * G}{DCURR + SKY_p + STAR_{mip}}$$

Where :

$t_s$  = saturation time exposure

$ADU_s$  = ADU saturation value of each pixel that depending from Analogic to Digit Converter (ADC) of our CCD camera. i.e. a sensor with a 16 bit ADC have a ADU saturation of 65536 counts

$BIAS$  = Noise from CCD's electronic in ADU

$RON$  = Readout noise in electrons\*sec<sup>-1</sup>

$G$  = Gain in electrons

$DCURR$  = Dark current in electrons\*pixel\* sec<sup>-1</sup>

$SKY_p$  = electrons flux originates by skylight photons \* sec<sup>-1</sup> from a single pixel

$STAR_{mip}$  = electrons flux originates by star light photons \* sec<sup>-1</sup> from a more illuminated pixel

In fact sky photons are approx uniformed in the sky, and I can divide the total incident flux of sky photons for pixel area for result the number of sky photons for each pixel, but star photons are distributed in gaussian mode dependently from FWHM, therefore I can't assumed a simply mean value. The best way is the calculation of brighter pixel among all. This is possible precisely through the gaussian equation:

$$5) \quad f(x) = \frac{1}{\sigma * \sqrt{2 * \pi}} * e^{-\frac{(x-x_0)^2}{2*\delta^2}}$$

and the followed relation between  $\sigma$  and  $FWHM$ :

$$6) \quad FWHM \sim 2.335 * \delta$$

and then  $\sigma$  is:

$$7) \quad \delta \sim \frac{FWHM}{2.335}$$

In equation 5  $\sigma$  is the dispersion of the curve,  $x$  is the value of independent variable and  $x_0$  is the value of  $x$  at curve's peak. But we searched exactly the  $f(x)$  value at peak, therefore the equation 5 simply become:

$$8) \quad f(x) = \frac{1}{\sigma * \sqrt{2 * \pi}}$$

$f(x)$  is a value between 0 and 1.

At this point it's sufficient, in equation 8 to substitute  $\sigma$  with equation 7 and subsequently multiplied for **STAR** value for obtaining finally the value of more illuminated pixel.

$$9) \quad STAR_{mip} = STAR * \frac{1}{\frac{FWHM}{2.335} * \sqrt{2 * \pi}}$$

That's all folks!..

### **Thanks:**

A very special thanks for: Prof. U. Munari for his competence and patience and S. Tomaselli for his valuable suggestions and ideas.

Writed in August 2013 Alfonsine (RA) Italy

Mauro Graziani  
magraziani@racine.ra.it