Planetary Research Team

Associazione Astrofili ALTA VALDERA

Centro Astronomico di LIBBIANO

Operating Handbook

for shooting

EXRASOLAR PLANETS TRANSIT

Alberto VILLA(*)

Version 2 – 17th Dec. 2007
English

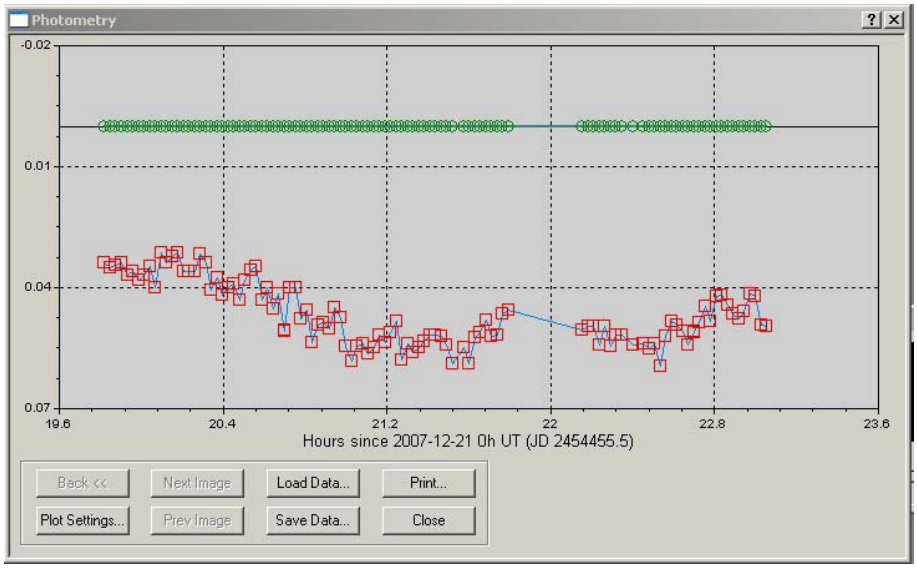
(*) President of Associazione Astrofili Alta Valdera (AAAV) - Peccioli (PI) / ITALY
Web: www.astrofilialtavaldera.com E-mail: vilalber@tin.it

PRELIMINARY REMARKS

The procedure described in this handbook refers to the Centro Astronomico di Libbiano (CAL) routine and instrumentation availed for shooting extrasolar planets transit. Obviously some conceptions must be interpreted and adapted to proper routine and instrumentations.

Referring to Planetary Research Team (PRT) projects, we think this handbook can contribute to easily use the software Maxim DL and the connected procedure TRel as described in the document named "Manuale di utilizzo del software di acquisizione TRel" (particularly the chapter: "Procedure per le riprese digitali del transito di un pianeta extrasolare") written for PRT by Angelo Angeletti, Fabiano Barabucci (Crab Nebula Association) and Rodolfo Calanca (Assistant Editor of the Italian magazine "Coelum Astronomia").

Respecting in full the procedure described in the following pages, on 21st December 2007 we were possible to "see" the XO-2b extra solar planet transit, using the CAL standard instrumentation: we obtained from data processing the following light curve (red colour for XO-2b, green colour for the reference star)



The 21st december 2007 working session at CAL is described in detail in the Paolo Bacci's (AAAV member) report, part of the already named document written for PRT by Mr. Angeletti, Barabucci and Calanca.

CENTRO ASTRONOMICO DI LIBBIANO (M.P.C. code B33)

The "Centro Astronomico di Libbiano" (CAL) is located in Tuscany (Italy) near Pisa, and it is property of Peccioli municipal district. The CAL is composed of the Astronomical Observatory "Galileo Galilei" and an educational centre, equipped with meeting room and planetarium. CAL activities are handled and organized by Associazione Astrofili Alta Valdera–Peccioli.**(web: www.astrofilialtavaldera.com – E-mail: vilalber@tin.it)**

AAAV executive is composed by Alberto Villa, Enzo Rossi, Emilio Rossi, Paolo Piludu, Francesco Biasci, Paolo Bacci and Domenico Antonacci: in the following images we can see some of them working at the CAL "Galileo Galilei" Observatory.

Fron left to tight:
Paolo Bacci, Alberto Villa, Emilio Rossi, Paolo Piludu ed Enzo Rossi at the Observatory computers.

Main instruments at Centro Astronomico di Libbiano

At Centro Astronomico di Libbiano we can find the following instrumetation:

- **main reflecting telescope Ritchey-Chretien 500mm , f/8;**
- **180mm f/9 apocromatic refractor placed in parallel with the main telescope;**
- **Main CCD Finger Lakes FLI IMG digital sensor Kodak KAF 1001E class 1, 1024 x 1024 pixels;**
- **autoguider CCD Starlight SXVF-H5;**
- **Coronado Solarmax 60 available with the apocromatic refractor;**
- **Planetarium Go-To Ex 3 / meeting room.**
- **Software: Maxim DL e The Sky**

SHOOTING AN EXTRASOLAR PLANET TRANSIT
OPERATING PROCEDURE

PRELIMINARY / FOCUSING

Open the dome doors at least one hour before the beginning of the transit, in order to acclimatize as more as possible instrumentations and operating room.
When done:

1) Switch on the telescope engine, pointing RC 500 on a bright reference star (40mm eyepiece). Center and synchronize the star (software THE SKY).

2) Place both CCD at the telescopes prime focus (autoguider at the refractor, FLI at the RC) focusing approximately as per previous measurements; both CCD must be orthogonally placed referring to A.R. / DECL.

3) Verify both CCD are not subject to any kind of mechanical flexion or bending stress. On the contrary, adjust as due: this fact is very import referring to Flat Field application.

4) Put in action CCD connections and RC ventilation)

5) Activate both CCD trough Maxim DL and set them, cooling the FLI one at the target temperature of -30° (cool CCD gradually, to avoid ice generation on the optical windows)

6) Focus precisely both CCD, operating manually on the refractor autoguider. FLI CCD on RC must be focused using the software ROBOFOCUS: while focusing verify when FWHM value (in INSPECT) appears as the best one. Take note of the FHWM value for next controls.

VERY IMPORTANT

AFTER FOUSING BY ROBOFOCUS CCD AND TELESCOPES MUST NOT BE MANUALLY HANDLED (this refers to final Flat Field application)

7) Create on PC the directories where all images will be saved (Destination Path). You can eventually organize in proper subdirectories at your best convenience.

8) Place the halogen lamp in the well-known Flat Field position.
Switch on the lamp.

9) Move the telescope to the well-known Flat Field position by manually using the FS2 push-button panel. DO NOT SWITCH OFF TELESCOPES ENGINE: in such a way software "The Sky" doesn't lose the telescope pointing coordinates.

10) Put the Flat Field screen in the well-known position, in front of the RC telescope.

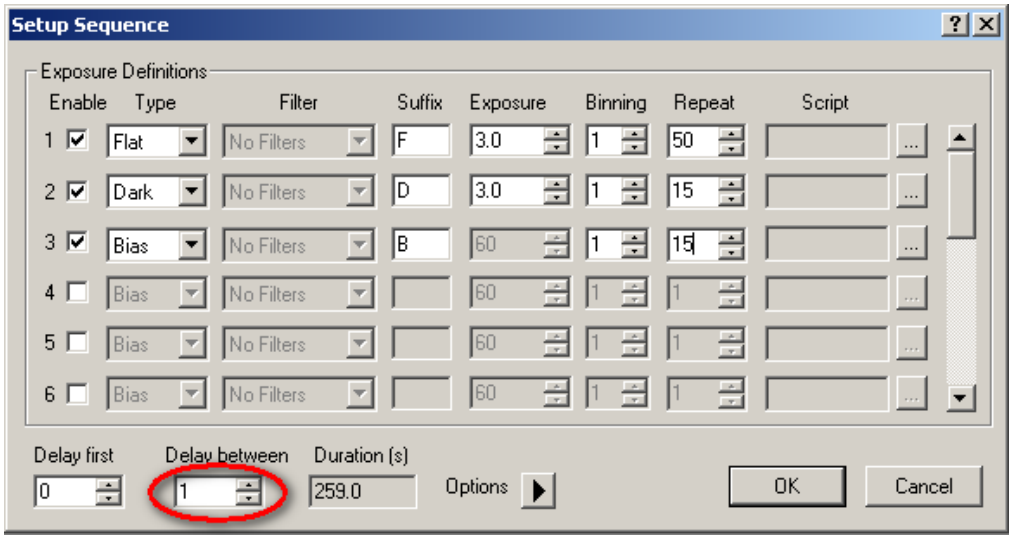
SHOOTING FLAT / DARK /BIAS

11) Verify FLI CCD temperature stabilization at -30° (Cooler)

12) Try to shot as follows: one 3" Light, one 3" Flat, one 3" dark and one Bias:

If shooting test is OK, we now set up the required shooting sequence.

13) In the mask "Maxim CCD", click on the "SEQUENCE" label.
Then: "Options" ⟶ "Setup sequence"



Create the sequence as shown above. Set up as follows:

- **no. 50 FLAT - 3" exposure (suffix F);**
- **no. 15 DARK - 3" exposure (suffix D);**
- **no. 9 BIAS - no exposure time (suffix B).**

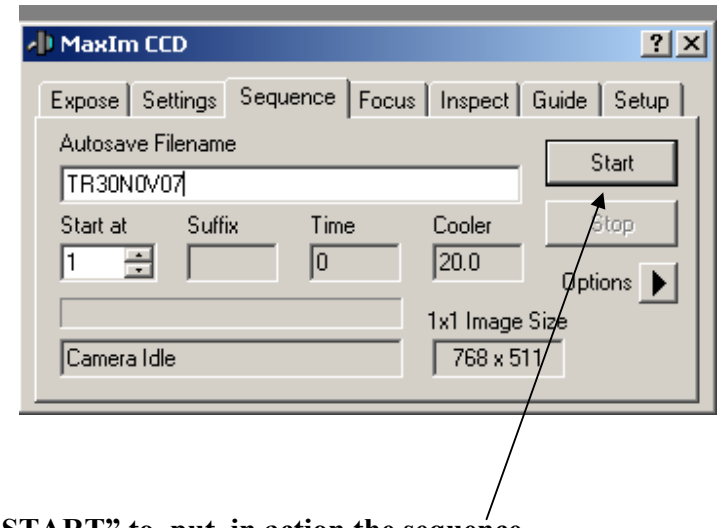
All exposures at binning 1x1 (in this case, total time 259"). Click on "OK"

14) Always in "SEQUENCE" label, click again on "Options", selecting "Set Destination Path"

Select the Destination Path Directory (see point 7). - Click on "OK"

15) Always from "SEQUENCE" label:

- **type the "AUTOSAVE NAME" (at your pleasure: it the portion of the name assigned by software in common to all integration file names);**
- **set the field "START AT" = 1**



16) Click on "START" to put in action the sequence.
The images acquisition will end automatically .
The relative files will be saved in the Destination Path Directory (see point 7).

17) Close all images.

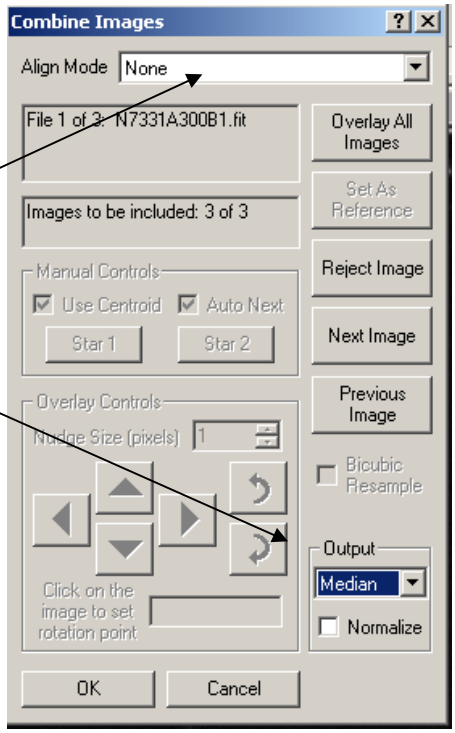
MASTER BIAS FLAT CREATION

18) Open all BIAS images (Suffix B)

19) Sum them setting "Align Mode" = None and output = "Median"

20) Save the outcoming image as "MASTERBIASFLAT.FIT"

21) Close now all visible images.



MASTER DARK FLAT CREATION

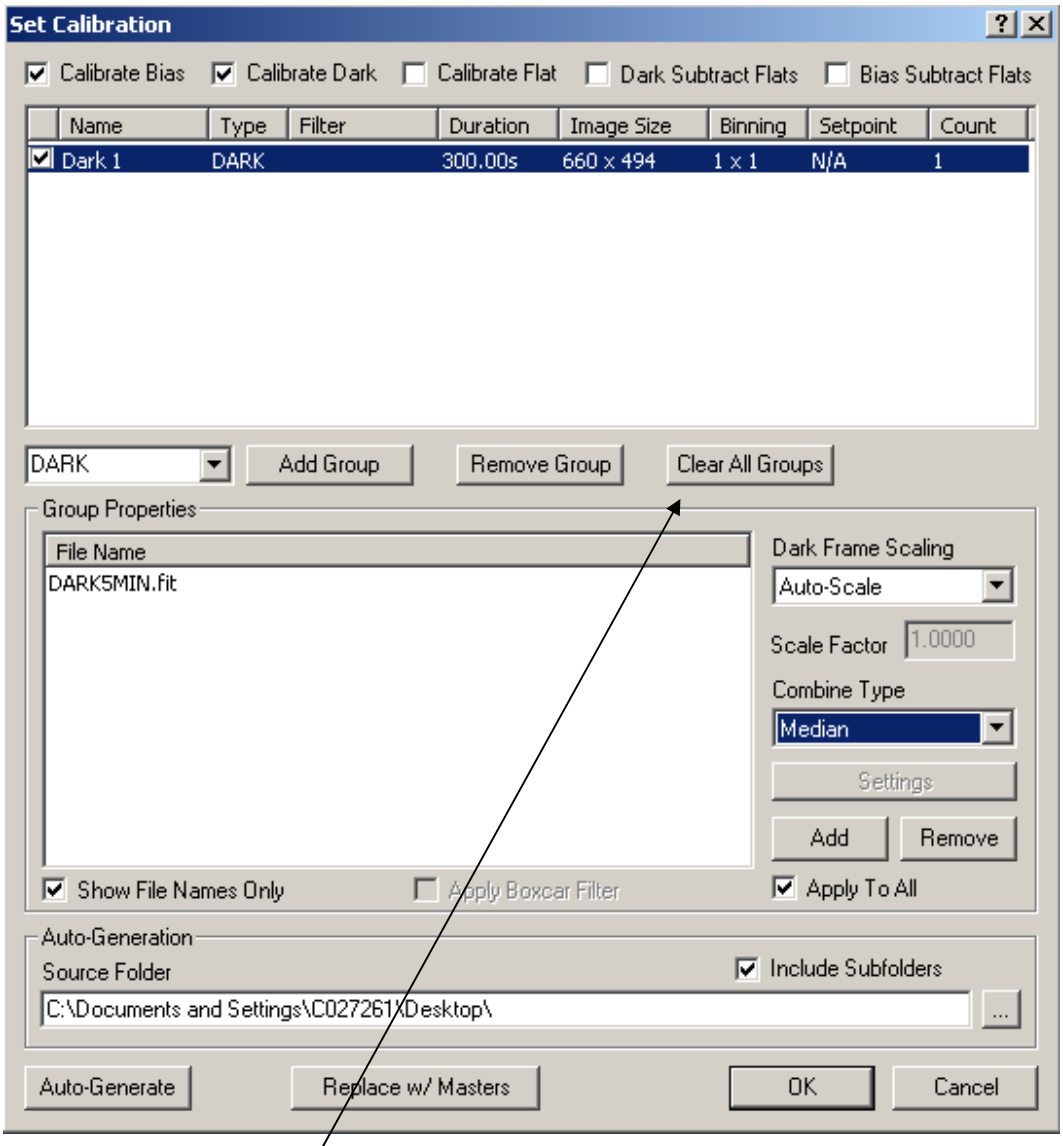
22) Open all DARK images (Suffix D) repeating the procedure from point 18 to point 21, saving the outcoming image as "MASTERDARKFLAT.FIT"

Close all images again

FLAT FIELD CALIBRATION

23) Open all Flat Field images (suffix F)

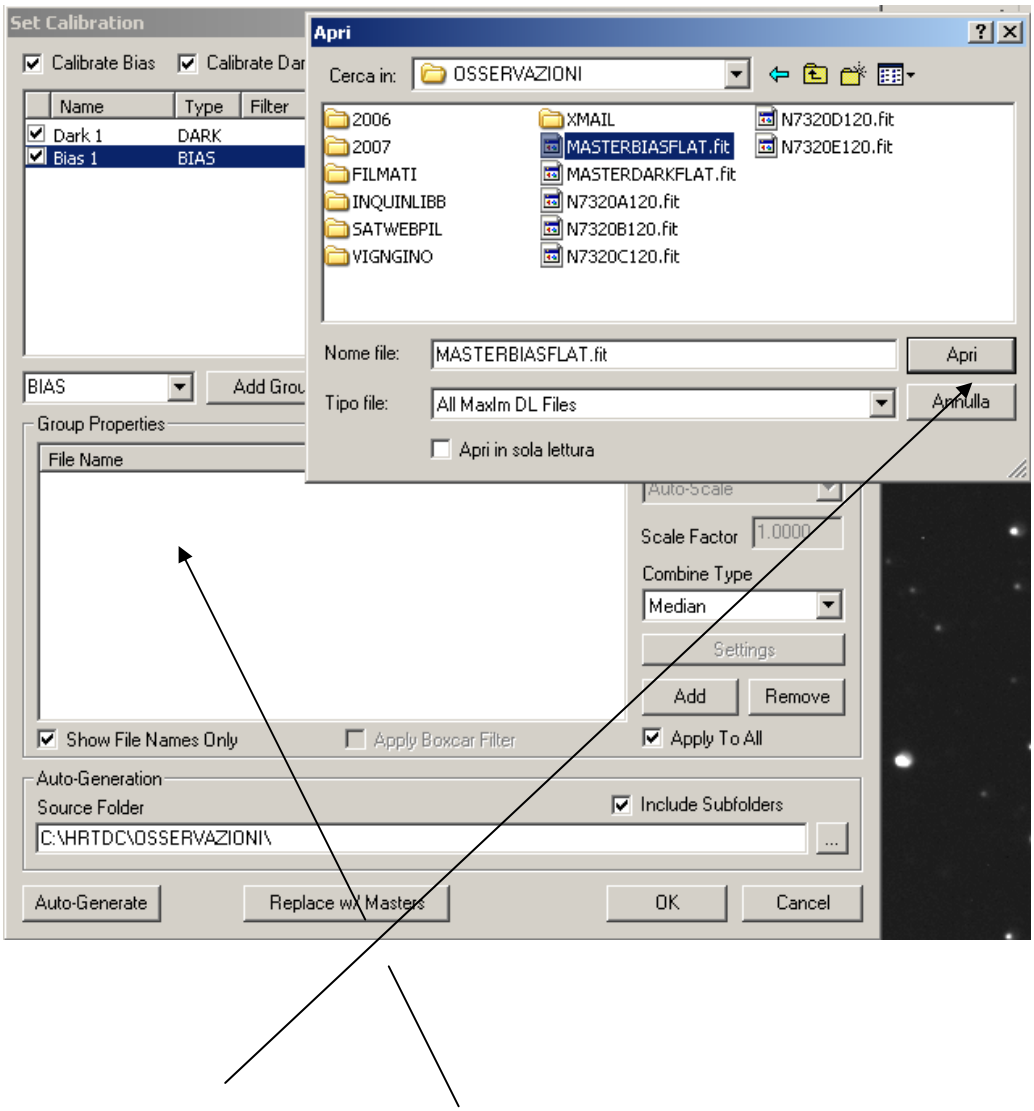
24) In the Maxim DL main mask, click on "Process", selecting "Set Calibration". We can now see the following screen.



Click on "<u>Clear All Groups</u>" to clean the mask: in such a way files and groups names eventually shown will disappear.

25) Create the necessary groups (Bias / Dark):
Select "BIAS" and click on "Add Group": group BIAS will appear in the mask.
Select "DARK" and click on "Add Group": group DARK will appear now.
The MASTERBIASFLAT.FIT e MASTERDARKFLAT.FIT flies must be now linked to the due / correct group.

26) Linking files to the due / correct groups.
Always staying in "Set Calibration", click on BIAS group: his line becomes blue coloured.
Click on "ADD" and open the Destination Path Directory (see point 7), where files MASTERBIASFLAT.FIT e MASTERDARKFLAT.FIT will now appear.
Since now Bias line is blue coloured, select MASTERBIASFLAT.FIT file.



Click on "APRI" (Open): the relative mask closes, while in the "File name" field the selected file will appear.

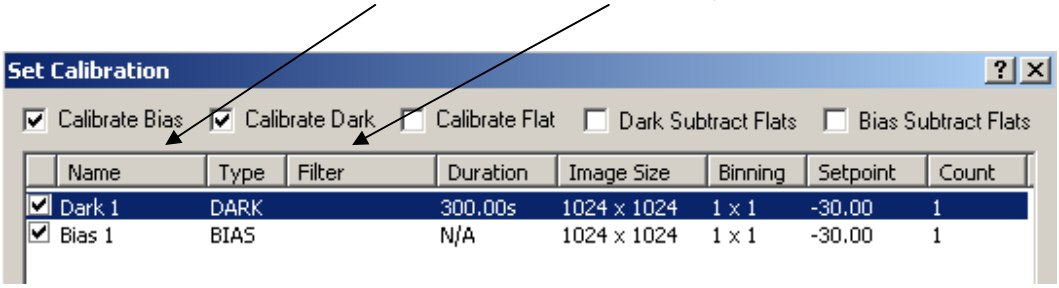
Repeat point 26, but blue colouring the Dark group and selecting the MASTERDARKFLAT.FIT file.

27) To control if we have well worked, verify that:

- **when BIAS line is blue coloured (click on it), file MASTERBIASFLAT.FIT must appear in the field "File Name";**
- **when DARK line is blue coloured (click on it), file MASTERDARKFLAT.FIT must appear in the field "File Name".**

28) Always in the Maxim DL mask "Set Calibration" now verify that:

- **Combine Type = MEDIAN;**
- **fields Calibrate Bias and Calibrate Dark are selected;**



Then click on "OK".

The "Set Calibration" mask disappears, while software Maxim DL has memorized the next operation to do.

29) Open all Flat Field images and click on "PROCESS" in the Maxim DL main mask; select "CALIBRATE ALL".

All Flat Field images will be automatically calibrated by subtracting BIAS e DARK.

30) Calibrated Flat Field sum.

The calibrated Flat Field now opened on the screen, must be summed following the procedure described from point 18 to point 21.

We save the outcoming image as MASTERFLAT.FIT

SHOOTING TRANSIT IMAGES WITH THE TELESCOPE

30) Since we didn't switch off telescope engine, by using software "The Sky" we can point again the telescope on the starting bright reference star (see point 1).

31) By shooting same fast images with FLI CCD, we move the bright reference star at the center of the framing (FS2 push-button panel).

32) Synchronize "The Sky" on the bright star just centered.

33) Always using software "The Sky", move the telescope to the extrasolar planet transit star (from now on, called "target star").

34) Check framing and eventually center the target star as shown at point no. 31.

35) Check focus, comparating actual FWHM value with the FWHM value obtained at point no. 6. Eventually adjust by using software Robofocus.
DO NOT MANUALLY HANDLE CCD OR TELESCOPES!

36) Synchronize PC watch to get exact shooting time in the FIT reports.

37) Prepare LIGHT sequence to shoot the event (see points from no. 13 to no. 17).

38) Put in action the CCD autoguider.

If the transit is going to begin, the following points no. 39 and 40 can be executed at the end of the event.

39) If the transit shots esposure time is known, we can take a 15 Dark Frames sequence with the same exposure time. (see points from no. 13 to no. 17).

Set "Autosave Filename" = DARKIMG (or similar at your best convenience).
Set "Suffix" = X (at your best convenience, to differentiate from previous file suffix). Always save files in the already created Destination Path directory.

40) Sum Dark Frame just obtained (see points from no. 18 to no. 21).
Save the outcoming image as MASTERDARKIMG.FIT

41) Verify again FLI CCD temperature stabilization at -30° (Cooler).

42) Shoot a test CCD integration with the same exposure time to be used during the transit. If test is OK, we are now ready to shoot the extrasolar planet transit.

43) SHOOTING OF THE EVENT:
AT THE DUE TIME PUT IN ACTION THE LIGHT SEQUENCE DESCRIBED AT POINT NO. 37.

44) Light transit images calibration.

At the end of light sequence, open all obtained target star images in order to calibrate them with DARK, FLAT e BIAS.

In Maxim DL main mask, , click on "Process" – "Set Calibration"

Clean the "Set calibration" mask (see point no. 24).

Create the following group (see point no. 25):

- **DARK**
- **FLAT**
- **BIAS**

45) Link the just created group to the pertaining files (see point no. 26)

- **Group BIAS – Link to MASTERBIASFLAT.FIT file**
- **Group FLAT – Link to MASTERFLAT.FIT file**
- **Group DARK – Link to MASTERDARKIMG.FIT file**

46) Eventually check as per point no. 27

47) Click on "OK" in the "Set Calibratiom" mask. The "Set Calibration" mask disappears, while software Maxim DL has memorized the next operation to do.

48) Open all Light transit images and click on "PROCESS" in the Maxim DL main mask, selecting "CALIBRATE ALL".

All Transit images will be automatically calibrated by subtracting MASTERBIABIAS and MASTERDARKIMG, and dividing by MASTERFLAT.

TRANSIT IMAGES ALIGNMENT

49) To align transit images (actually all opened in the screen), in the Maxim DL main mask click on "PROCESS" selecting "ALIGN".

Set ALIGN MODE = AUTO STAR MATCHING

Click on "OK" and the transit image will be automatically aligned.

PHOTOMETRY

50) TRANSIT LIGHT CURBE GENERATION

In the Maxim DL main mask click on "ANALIZE" - "PHOTOMETRY"

- **Mouse Click Targ As = NEW OBJECT for the transit target star;**
- **Mouse Click Targ As = NEW REFERCE STAR for the reference star.**

Click on "VIEW PLOT" to obtain the light curves graphic (see "Preliminary remarks").

Click on "SAVE DATA" to save in Excel file, for next data processing.

Alberto Villa

AAAV – Associazione Astrofili Alta Valdera
Centro Astronomico di Libbiano – MPC Code B33

www.astrofilialtavaldera.com

Observation date: **24th January 2008**

SHOOTING OF EXTRASOLAR PLANET XO-2b TRANSIT ON 24th JANUARY 2008 (R.A. 07h 48m 07s - Decl. 50° 13' 33")

This observation at "Centro Astronomico di Libbiano" has been organized with the following purposes:

- **to shoot the XO-2b extrasolar planet transit on 24.01.2008 (event beginning at 20:47 TU – ending at 23:33 TU);**
- **to test software TRel (by Fabiano Barabucci, got from PRT - Planetary Research Team) purposely planned to follow image after image (in real time) the brightness fluctuation of the star concerned with the transit during the event.**

Work beginning at 06.15 p.m. / 24th Jan 08 – Work end 02.00 a.m. 25th Jan 08 (local time).

Main instrumentation used

- **main reflecting telescope Ritchey-Chretien 500mm , f/8;**
- **180mm f/9 apocromatic refractor placed in parallel with the main telescope;**
- **Main CCD Finger Lakes FLI IMG digital sensor Kodak KAF 1001E class 1, 1024 x 1024 pixels – placed at the RC 500 primary focus of;**
- **autoguider CCD Starlight SXVF-H5 placed at the refractor primary focus;**
- **Software: Maxim DL, The Sky, Robofocus and TRel (by Fabiano Barabucci)**

MAKE REFERENCE TO THE FOLLOWING HANDBOOKS:

- □ ***Manuale di utilizzo del software di acquisizione TRel – Procedure per le riprese digitali del transito di un pianeta extrasolare*** **(by Angelo Angeletti, Fabiano Barabucci and Rodolfo Calanca);**
- □ ***Operating handbook for shooting extrasolar planet transit*** **(by Alberto Villa)**

PROCEDURE

We open the dome doors at 6.20 p.m. (more than 3 hours before event beginning) in order to acclimatize as more as possible instrumentations and operating room.

We follow the procedure shown in the "*Operating handbook for shooting extrasolar planet transit*", already successfully used to shoot the same event on 21st Dec. 2007.

We switch on the telescope engine, pointing RC 500 equipped with a 40mm eyepiece on Betelgeuse, centered and synchronized through software THE SKY.

We start software TRel (Maxim DL starts automatically)

When FLI CCD is gradually cooled at the temperature of -30,3°, we take the following integrations saved in the proper directories:

- □ **No. 50 Flat Fields (3" exposure);**
- □ **No. 15 Bias;**
- □ **No. 15 Dark Frames (3" exposure).**

Then images are processed getting Master Bias – Master Dark Flat e Masterflat.
In order to calibrate transit "light" images, we use a Master Dark already obtained with same parameters during a previous working session.
Before starting transit shooting, we prepare "Set calibration" mask in Maxim DL, since software TRel absolutely need it to calibrate in real time transit images as they are taken.

We frame the field of XO-2b (target) and focus through software Robofocus: best FHWM value = 3,08 at binning 1x1. We put in action the CCD autoguider (adjustments every 3").

Using TRel, we shoot a test integration (60" exposure time as required for the transit images) verifying the following values both for the target star and per the "twin" reference star (only 30" far).

	TARGET	REF. STAR
Max Pixel	46.335	46.701
S/N	2.495	2.566
Intensity	914.600	942.500

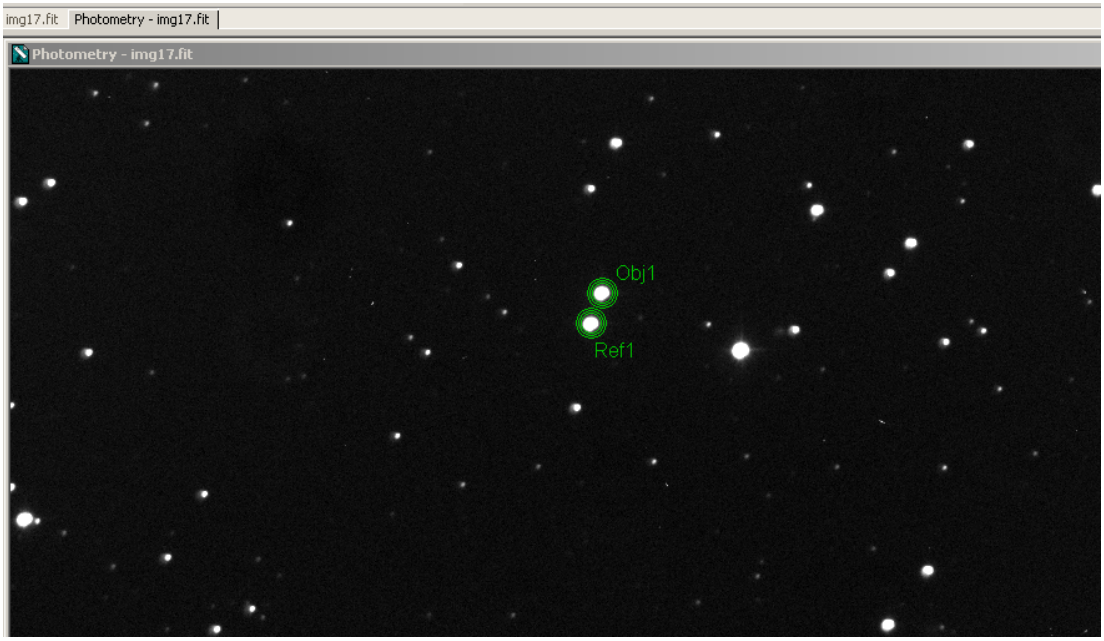


Fig. 1 – The CCD framing: XO-2b = Obj1 / Reference star = Ref1

We prepare the shooting transit sequence in software TRel as follows: no. 160 images (60" exposure each), and 30" pause between the end of an integration and the big inning of the next one, for a total time of about 4 hours.

After setting up configuration in TRel main mask, we take the reference image where we indicate the "twin" star as "reference star" and XO-2b as "target star" (to be measured). Photometric "rings" value established as follows: aperture radius = 8, gap width = 2, annulus thickness = 2 (see fig. 1).

Transit shooting sequence (handled by TRel) starts at 19:50:14 TU.

We worked very well by using TRel (Maxim e TRel light curves exactly alike) till to 22:02:43 TU. Then we had some problem: probably, since TRel does not align images before processing them to create the light curve (in Maxim DL we can do this using the function "Auto Star Matching) TRel measurements were influenced by material bending stress that happens when the telescope moves from East to South (local meridian), modifying instrumentations' weight balance (we can think – for example – to the refractor supports). We think so because autoguider tracking worked very well during all the transit, as confirmed looking to the light curve processed through Maxim DL.
In the following image, we can see the transit light curve screen obtained using TRel till to 22:02:43, when software was correctly performing.

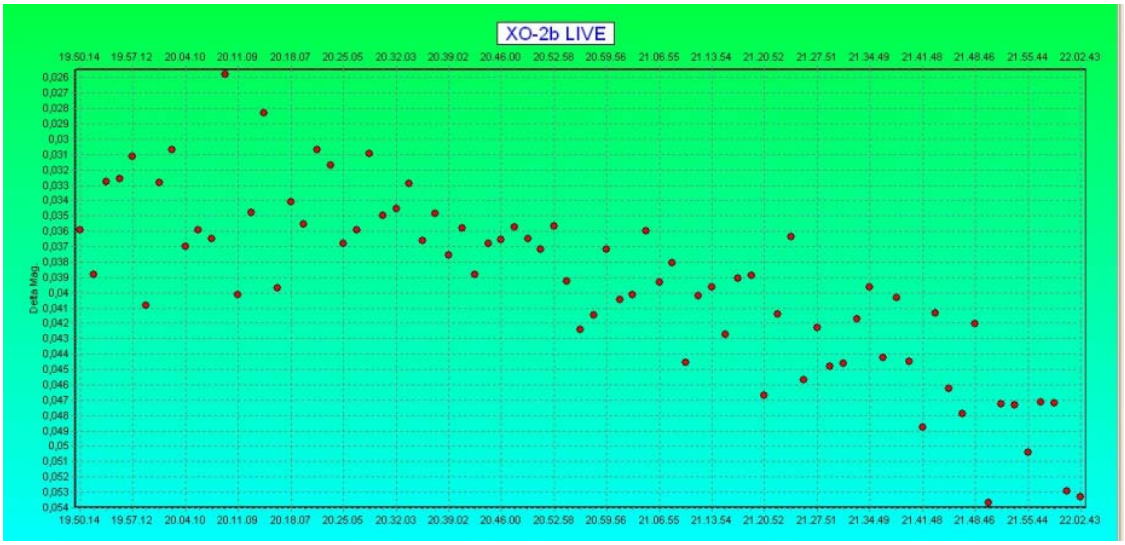


Fig. 2 - We can clearly observe the expected magnitude reduction during the event.

So we decided to stop shooting sequence. Taking again a reference image and replacing the relative photometric "ring" on reference and target stars, we started a new TRel sequence: by using the "Restart sequence" instruction, software began to work correctly again (if reference/target stars move also few pixels compared with photometric rings position, data measuring is incorrect and false).

The same setback happens at 23:00 TU. We aligned and processed the transit images (obtained through TRel) using Maxim DL, obtaining the following XO-2b light curve.

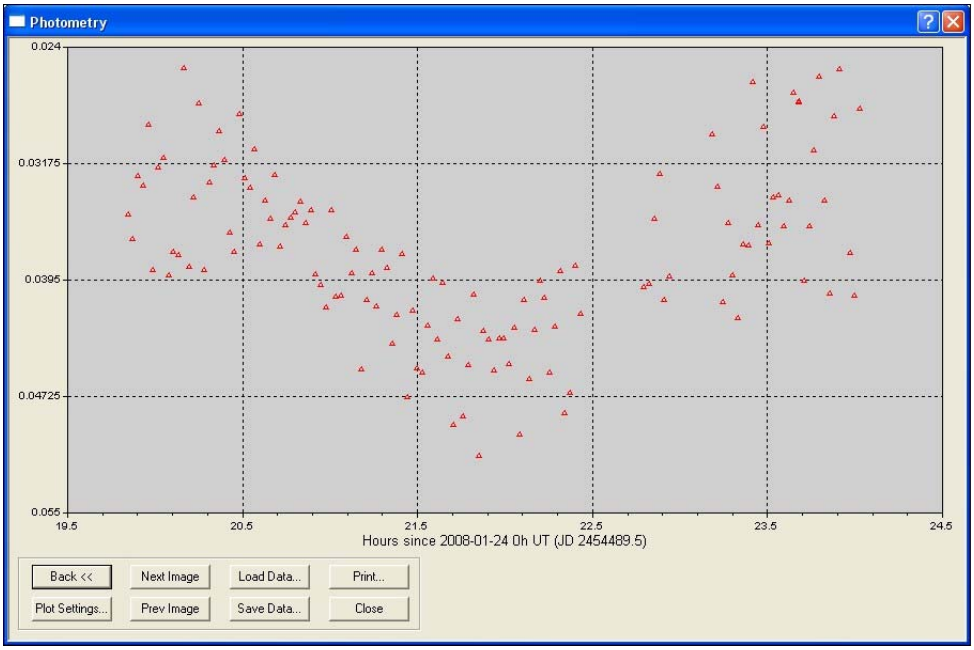


Fig. 3 – 24th Jan 2008. XO-2b transit light curve processed through Maxim DL

Clearly visible the magnitude reduction with complete correspondence about expected time. Nevertheless the light curve progress is different if compared with the same event happened on 21st Dec. 2007, when the lowest magnitude value arrived more quickly keeping constant (straight line) during the central part of the transit. In this case, on the contrary, the transit light curve looks like a "V": maybe we can suppose XO-2b transit path was more distant from the star diameter..

The processed light curve points out a 0,015 star magnitude reduction instead of the expected 0,020 (well measured during XO-2b transit happened on 21st Dec. 2007): totally confiding in the obtained value we could imagine a little portion of XO-2b planet was not entirely superimposed with the star disk.

Libbiano, 25th January 2008

Alberto Villa
(President of AAAV)