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www.crabnebula.it/rc/menu_EAN.htm

REFERENCE GUIDE OF ACQUISITION SOFTWARE ©TRel

PROCEDURE FOR IMAGING TRANSITS OF EXTRASOLAR PLANETS

EXTRASOLARI LIVE!
FEBRUARY 13th, 2010 - WATCHING THE TRANSIT OF PLANET XO-3b FROM THE WHOLE EUROPE

ALL AMATEURS ARE WARMLY INVITED TO SHOOT THE TRANSIT WITH PROPER TELESCOPES!

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Promotori del progetto
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WHAT PROCEDURE TO FOLLOW TO OBSERVE AN EXTRASOLAR PLANET TRANSIT?

Rodolfo Calanca

The "step by step" following description is already partially included in the Appendix B. Since some participants to the Worlds of the Sky Project expressly requested that all operations to execute while shooting a transit were precisely “step by step” listed, we reproduce this description (with some adjustment) also at the tutorial beginning.

WE RECOMMEND TO TEST THE PROCEDURE USED TO DETERMINE THE CORRECT EXPOSURE TIME DURING A PREVIOUS OBSERVATION NIGHT

DURING A NIGHT PRECEDING THE TRANSIT, WE DETERMINE THE CORRECT EXPOSURE TIME

A. We get the thermic stabilization of instrumentation and operating room.

B. Point the telescope on the target star, put in action the autoguider, having the essential role to reduce enormously the photometric error caused by a blurred star image.

C. When centered the target star, we settle the exposure time for example at 60 seconds: we never use a lower integration time, for no reason and whatever telescope or CCD we are operating with. We can surely say this is the minimum integration time because with a 60” exposure we obtain – for any amateur telescope – a reasonably low value for the atmospheric scintillation. The atmospheric scintillation is the greater cause of photometric error and his value can be calculated using mathematical formula shown on Appendix A, holding in due consideration telescope diameter and air mass influence. Remember that any shooting exposure time from 60 seconds to 4 – 5 minutes is fully acceptable!

D. VERY IMPORTANT: THE STAR WITH THE TRANSITING PLANET (target star) MUST HAVE NO SATURATED PIXEL! One of the essential conditions to get the due photometric parameters necessary to clearly “observe” the transit is that the brighter pixel ADU level of the target star should be about 25000-30000 (for a 16 bit CCD camera). In order to obtain this value we can also insert a filter (R or V), to reduce brightness and reaching in such a way at least the minimum integration time. When using no filter, it is also possible to get the same result by putting the target star out of focus (FWHM value 2x or 3x). FOR A 20-30cm DIAMETER TELESCOPE AN EXPOSURE TIME BETWEEN 90 AND 180 SECONDS IS EXCELLENT! Rememher you have to set the exposure time in order to obtain a brighter pixel ADU level for the target star of about 25000-30000! You can verify this value with usual availed software (IRIS, MAXIM, ASTROART).
PROCEDURE DURING THE TRANSIT NIGHT:

1. Before shooting, get the thermic stabilization of instrumentation. Open the dome or the sliding roof some hours before the transit beginning. Put the CCD in action, waiting for the required time, so it can reach his thermodynamic balance after cooling. REFERRING TO PHOTOMETRIC PURPOSES, REMEMBER THAT CCD SHOOTING MUST BEGIN 30 MINUTES BEFORE TRANSIT BEGINNING AND TERMINATE 30 MINUTES AFTER THE END OF THE EVENT. We need to acclimatize instrumentations A LOT of time before the transit beginning also because software TRel requires getting bias, dark, and flat fields before really shooting the transit.

2. Expose for bias (at least 20), then for dark (between 20 and 40) and then for flat fields (some dozens). FLAT FIELD quality enormously influences photometric measurements precision. TAKE A LOT OF FLAT FeldS, AT LEAST 20 (BUT MUCH MORE IS ALWAYS BETTER). The median master flat get from many images, is characterized with a little “Poisson noise” that will be greater - on the contrary – when obtained from few integrations (for further information see Appendix A). We also can contribute to reduce “Poisson noise” by shooting many dark and bias. Now, if we decided to shoot the transit with a 2 minutes exposure time, it will take about one hour to get 20 relative dark frames. It will be the same also for the flat fields: 50 x 5 seconds flat fields - as we suppose – can require also more than one hour, with regard to the used CCD. SO IT IS INDISPENSABLE TO TAKE INTO CONSIDERATION A TWO HOURS (MAYBE MORE) PRELIMINARY JOB.

3. One hour before the transit beginning we move the telescope to the target star. Put in action the autoguider: never deactivate the autoguider during the event because of it essential role to reduce enormously the photometric error caused by a blurred star image.

4. A USEFUL BUT NON INDISPENSABLE CONTROL: When transit shooting is over, we get some test integrations with the same exposure time, verifying by Astroart or Maxim the S/N value of the “transit” star and of the reference stars we used for processing data. If we want to reach a precision measurement of 2/1000 magnitude, S/N ratio must have at least
value 500 (due to a characteristic of the Maxim and Astroart, when measuring S/N using this software we have to redouble the shown value. This fact means we have to reach: $S/N > 1000$). When S/N ratio doesn’t reach this value (1000 or more) we cannot expect an high photometric precision.

WE CAN NOW MAKE USE OF THE SOFTWARE TRel!!!!

(English translation by Alberto Villa – Centro Astronomico Libbiano – Peccioli, Pisa)
How to use ©TRel

English translation by Manlio Bellesi[4]

©TRel is a software designed to detect transits. Developed in DELPHI environment, it makes use of the ACTIVEX I/O made available by the well-known MAXIM DL/CCD software. A 30–days trial version of MAXIM can be downloaded at the address:


IMPORTANT NOTICE: in order to receive the license key (necessary to start the programme) a valid e-mail address must be entered.

The software automates the acquisition of CCD images, as well as the magnitude readings for the transit and the reference star.

As the CCD device acquires the images, ©TRel performs calibration, makes the requested alignments and gets photometric data (automatically plotted on graph for public display).

IMPORTANT: Image calibration files (bias and dark frames, flat fields) must be available in advance and stored in a folder (hereafter called CALIB).

Usage of MAXIM for image calibration

IMPORTANT: if flats’ exposure is about one seconds, the same value for dark frames is recommended. During the calibration process MAXIM will apply bias and dark frames to flats also.

Calibration files are to be set once and for all; MAXIM stores defaults in memory and will apply them to images as the acquisition proceeds.

To set calibration files, click on the Process command from the MAXIM menu; then select the Set Calibration command (see figure 1)

The Set Calibration display (see figure 2) allows to set the images calibration files. First, tick the desired options: looking at figure 2, all options have been selected. The options Dark Subtract Flats may be usually omitted, in case the flats aren’t too long.

A click on the window with arrow (displayed in figure 2) gives access to the selection menu for calibration type (see figure 3). In the following, only the instructions for loading bias files are given: the same procedure, however, can be used for other calibration files.

Select Bias and click (figure 3), then click the button Add Group (figure 4); the selected file type will appear in the upper window (see green arrows in figure 4). Now click Add to enter the filenames. A second window will open (see figure 5). Now choose the folder containing the desired files, select them and click on the Open command. Select MEDIAN on Combine Type. (figure 4)

Repeat the same procedure for darks and flats (for flats’ darks also, if that be the case). In our example, the output on screen is shown in figure 6; make sure that the ticks displayed match the ones on your own screen. Then select OK.

[4] Amateur Astronomers Association “Crab Nebula” of Tolentino (MC), Italy
Figure 1 – Display of MAXIM showing the Set Calibration menu

Figure 2 – Display of the Set Calibration command
Figure 3 – How to select the file type for calibration (I)

Figure 4 – How to select the file type for calibration (II)
Figure 5 – How to select the file type for calibration (III)

Figure 6 – How to select the file type for calibration (IV)
Usage of acquisition software ©TRel

The software © TRel is distributed in a zip file, called Setup.zip. To install, double click on Setup.zip and on Setup.msi, then follow instructions of the installation menu.

When the program starts a MAXIM session is opened. Then, the CCD camera must be connected: next, wait until the sensor reaches the working temperature (figure 7).

![Figure 7 – Display of ©TRel with MAXIM DL when starting the procedure](image)

The programme configuration data can be accessed by checking:

- The folder into which images are saved and stored
- The plot labels
- (optional) The language file used to translate program messages. The default language is ENGLISH.

![Figure 8: Parameters of ©TRel](image)

We advise at this stage to check that fits used for calibration are correctly reported in MAXIM, by opening the Set Calibration window from the Process command (something like figures 6).
Having accomplished the above task, go back to ©TRel to set exposure length, delay between exposures and their number.

WARNING: in setting the delay, the time the system takes for downloading, calibrating and reading the image data must be taken into account. For instance, suppose we wish to get our images with a delay of 2 minutes (120 seconds), our time exposure is, say, 60 seconds, and the system needs 5 seconds for image downloading plus 3 seconds for its calibration. Then we must set a delay of $120 - (60 + 5 + 3) = 52$ seconds. An accuracy of at least one second is needed, so make sure that the computer clock meets such a requirement.

How to perform the task of getting a Reference Image

When clicking on the Reference Image command the system sends a starting command to MAXIM, which starts image acquisition and calibration (with the previously chosen defaults). As soon as image is ready, the programme requests selection – by mouse click – of a reference star; several clicks are allowed, in order to get as near the very centre of the star as possible. Figure 9 shows the reference star (pointed to by the arrow), chosen by the research team operating at the Osservatorio Comunale in Peccioli (Pisa, Italy) (hereafter, Peccioli team). This star was used in imaging the transit of the extrasolar planet XO–2b in the night between 22 and 23, December, 2007. After selection, click OK in the programme window (figure 10).

Figure 9 – Stellar field including XO–2b; the arrow points to the reference star.
Figure 10: Selecting the reference star in the reference image

Figure 11: Selecting XO–2b in the reference image
The programme now requests to identify the star chosen for measures; it will suffice to repeat the procedure already described for the reference star (in figure 11 planet XO–2b is indicated by the arrow). To confirm selection, press **OK**.

Click with mouse’s right button on reference image to set annuli’s diameters for aperture photometry (see figure 12). Select **Set Aperture Radius** so that it easily contains the star’s image (the reference image by the Peccioli team used a value of 8; however, this varies depending on the instrumental apparatus). Then, select **Set Gap Width** and **Set Annulus Thickness** to set the annulus used for determination of sky background. Because of the proximity with the reference star, the annulus cannot be too wide, lest it collects light from the nearby star; values 1 and 6 were chosen for Peccioli team’s reference image (figure 13).

©TRel is now ready to image the transit. Acquired images can be downloaded and aligned, then used to draw the light curve (see figure 14 for partial light curve).
Figure 13 – Defining annuli’s radii for aperture photometry

Figure 14 – Building a light curve with ©TRel
Some important notices:

1. Use of an external auto-drive device is recommended. Such an arrangement simplifies image sensor’s work, at the same time allowing to deal easier with any case of malfunctioning (due either to the driving or imaging system).

2. In case of interruption, there’s always the chance to restart the system without any loss of data, proceeding as follows:
   a. Reset acquisition parameters (exposure, time intervals, number of exposures left).
   b. Acquire the reference image again (by selecting the reference star and the star to be measured)
   c. Reload previously acquired data (via the **Load Data** command)
   d. Restart the procedure using the **Restart** command

   If everything works properly, you should be able to build a light curve for the transit. Figure 15 shows a simulated light curve for the transit of TrES–2 (September 1, 2007), taken from Monte d’Aria Observatory. Actually, in this case ©**TRel** didn’t directly acquire images - previously stored frames were used instead.

![Figure 15 – Light curve obtained at the end of transit. This was a simulated curve, built using transit data of TReS–2, on September 1st, 2007, taken at Monte d’Aria Observatory.](image)
APPENDIX A

CCD imaging of the transit of an extrasolar planet

Angelo Angeletti

Introduction

The search for extrasolar planets by the transit method is well within the possibilities of many amateurs. It requires a lot of patience, a 15–20 cm telescope (the evergreen Newtonian, for instance), a CCD camera equipped with an accurate motorized drive (auto–drive is highly recommended).

A planet passing before its parent star produces a small drop in brightness, lasting up to several hours.

![Figure 16 - A typical light curve of a transit](image)

The planet plays the same role as Venus when it passes before our Sun. In the latter case, however, Venus can be easily seen against the solar disc whereas, in the former case, all one can see is a point (the star) whose brightness is only very slightly dimmed when the extrasolar planet transits. The drop in the brightness is proportional to planet’s surface; typical values are 1% for a gaseous giant (like Jupiter or Saturn) and about 0.01% for a Earth–sized planet. More precisely, we can say that

\[
\frac{\Delta L}{L_*} \approx \left( \frac{R_p}{R_*} \right)^2,
\]

where \(\Delta L\) is the drop in the star’s brightness – whose default value is \(L_*\) – and \(R_p, R_*\) are the planet’s and the star’s radius, respectively.

A severe limitation of the transit method is the very low probability to have the planet’s orbit correctly aligned to the line connecting Earth and the parent star (a necessary requirement, in order to be able to see the planet crossing the star’s disc). Such a probability \(p\) is:

\[
p = \frac{R_p}{a}
\]

where \(a\) is the semi–major axis of planet’s orbit. For a planet placed at a distance of 1 AU (Astronomical Unit = 149,600,000 km) from its parent star, \(p \approx 0.005\) (or 0.5%). Should an alien – only a few parsecs away – make use of our transit method on the Sun, he/she/it wouldn’t be able to spot a single planet!

In order to correctly outline the imaging and processing techniques used during a transit (whose photometric precision must be very high), we now give a (very) sketchy description of the various types of “noise” that can seriously affect our data. Only by minimizing all noise sources a
sufficiently accurate photometric precision can be attained: a fair result is 0.002 magnitudes (corresponding to 10% of the total measurements). The most important noises are:

1) The **Poisson noise** ($\sigma_p$)
2) The noise by **atmospheric scintillation** ($\sigma_S$)
3) The **standard stochastic error** ($\sigma_ST$)

1) The Poisson Noise effect on magnitude measurements is of the order of

$$\sigma_p = \frac{1}{\sqrt{N}},$$

where $N$ is the total number of photoelectrons counted within the measure area. For our accuracy to be of the order of 0.002 magnitudes, we must count $N = \frac{1}{\sigma_p^2} = 250000$ photoelectrons; the overall number of photoelectrons arriving from the star is given by $N = G \cdot I$, where $G$ is CCD’s gain and $I$ is the star’s intensity, expressed in ADU. When using a ST7 CCD, $G = 2.57$ and we obtain $I \approx 97000$).

2) Influence of atmospheric scintillation on data is too often underestimated by non-professional observers. This noise source, however, must be taken into account whenever any results of any scientific importance are to be obtained, the more so as far as extrasolar transits are concerned. The error on magnitudes due to atmospheric scintillation can be estimated using an approximate formula by Radu Corlan:

$$\sigma_S = 0.09 \frac{A^{1.75}}{D^{0.66} \sqrt{2t}}$$

The above formula (also used by AAVSO) is accurate enough for our purposes. $A$ is the air mass[^1], $D$ the telescope aperture in centimetres, $t$ the exposure time in seconds. Tables 1 and 2 display values of $\sigma_S$ for some diameters and exposure times varying between 10 and 60 seconds (however, experience taught us never to drop below the 60 seconds threshold).

<table>
<thead>
<tr>
<th>t (seconds)</th>
<th>20 cm</th>
<th>25 cm</th>
<th>30 cm</th>
<th>40 cm</th>
<th>50 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.0028</td>
<td>0.0024</td>
<td>0.0021</td>
<td>0.0018</td>
<td>0.0015</td>
</tr>
<tr>
<td>20</td>
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<td>0.0017</td>
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<td>0.0012</td>
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<td>0.0009</td>
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<td>0.0012</td>
<td>0.0011</td>
<td>0.0009</td>
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<td>0.0010</td>
<td>0.0008</td>
<td>0.0007</td>
</tr>
<tr>
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<td>0.0011</td>
<td>0.0010</td>
<td>0.0009</td>
<td>0.0007</td>
<td>0.0006</td>
</tr>
</tbody>
</table>

[^1]: An estimate of the air mass can be made by using the formula $A = \frac{1}{\sin h}$; $h$ is the star’s height over the horizon.
For a star near the zenith \((A = 1)\), the scintillation effect is about, or below, the 0.002–magnitudes value mentioned above, provided the integrating time exceeds 20 seconds. However, as we move farther away from the zenith things get much worse. When the star is only 25° over the horizon \((A \approx 2)\), only 40 cm–telescopes (or larger) and integrating times of more than 60 seconds allow not to exceed the 0.002–magnitudes threshold. Since a transit can last several hours – usually with ample variations in the star’s height – the atmospheric scintillation noise greatly influences the data (see figure 1.2).

3) To further improve precision, the standard stochastic error also must be taken into account. We give the following formula (see for details the article by Rodolfo Calanca – sorry, in Italian – published on COELUM ASTRONOMIA magazine, n. 105, pp. 60–65):

\[
\sigma_{ST} = \frac{1.09}{(S/N)}, \quad \text{where} \ S/N \ \text{stands for “Signal-to-Noise”}
\]

Currently available software for photometric analysis (Maxim DL, Astroart) gives a \((S/N)\) value about twice the value worked out by using the above formula.

All these things considered, the overall noise can be estimated by putting:

\[
\sigma = \sqrt{\sigma_p^2 + \sigma_s^2 + \sigma_{ST}^2}.
\]

According to knowledge gained through summer 2007 observations, atmospheric scintillation is the most influential noise source. Keeping formula [1] in mind, one can conclude that exposure time is the only parameter through which data precision can be improved – but choosing too a large value can result in stepping outside CCD’s linearity range. Experience taught us to keep the maximum ADU value for the imaged star (and – if possible – for the reference star as well, whose magnitude should then be similar) to about 25000 for a 16 bit CCD. All the proceedings/communications (sorry, in Italian) of observations performed at Monte d’Aria Observatory in the course of summer 2007 can be found at the internet address www.crabnebula.it/transiti.htm.

The obtained frames must not be added nor averaged. Although examples of such kind do exist in scientific literature, we advise against it, especially when using non-professional instruments. A great number of dark and bias frames, as well as flat fields, must be prepared before and after imaging a transit (in our last work we made use of 30 bias frames, 30 dark frames and 60 flat fields). They are to be averaged and compared to images, for calibration; the procedure can be automated by currently available software.

Flat fields should be carefully prepared. At Monte d’Aria Observatory we use a plexiglass translucent white sheet, pinned to the dome and illuminated with two 15-watt energy-saving lamps (reference temperature: 6000 K), symmetrically placed at each side. When time integration of the flat fields increases to several seconds we apply dark and bias frames to flat fields also.

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**Table 2**

\(\sigma_5\) from atmospheric scintillation, versus telescope diameter and exposure time, in the case \(A = 2\) (star’s height between 25° and 45° over the horizon)

<table>
<thead>
<tr>
<th>(t) (seconds)</th>
<th>20 cm</th>
<th>25 cm</th>
<th>30 cm</th>
<th>40 cm</th>
<th>50 cm</th>
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</thead>
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<td>0.0045</td>
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<td>0.0036</td>
<td>0.0032</td>
<td>0.0026</td>
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</tr>
<tr>
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<td>0.0032</td>
<td>0.0028</td>
<td>0.0023</td>
<td>0.0020</td>
</tr>
<tr>
<td>60</td>
<td>0.0034</td>
<td>0.0029</td>
<td>0.0026</td>
<td>0.0021</td>
<td>0.0018</td>
</tr>
</tbody>
</table>

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Figure 17 - Summary of uncertainties on measurements performed during the transit of planet WASP-1 (14 September 2007) at Monte d’Aria Observatory. Discontinuity at 1.30 UT is due to the change exposure length to maintain low the atmospheric scintillation.

Figure 18 - The team of Monte d’Aria Observatory (Italy) at work. From left: Angelo Angeletti, Francesco Barabucci, Fabiano Barabucci, Gianclaudio Ciampechini.
Minimum requirements of the instrumentation for digital imaging and data processing

Minimum requirements of the instrumentation

The magnitude of the stars displaying transiting planets usually ranges between 8 and 12. Therefore, it’s not necessary to use huge telescopes to detect and study the light curve of a transit with high precision results; nonetheless, first-rate optics, mechanics and electronics are required. Here are some (hopefully useful) suggestions for the choice and use of a suitable equipment:

- Telescopes with diameters larger than 15 cm (reflectors, refractors or Schmidt-Cassegrain) can be profitably used. Focal length should not be increased too much, in order to easily find, within the sensor field, the reference stars needed for differential photometry. When necessary, add a high-quality, low-vignetting focal reducer.
- The optimum focal length should range between 1 and 2 metres. For instance, a SBIG ST-8 CCD (a 9.2 mm x 13.8 mm sensor), used with a 1-metre focal length, produces a field size 31 ’ x 47’, reduced to 15’ x 24’ when focal length increases to 2 metres. With this type of CCD, and using a 1-metre focal length, we can always find one or more reference stars within the chosen field.
- The telescope must have an equatorial mounting and be permanently mounted.
- Alignment of the polar axis must be as careful as possible, in order to avoid even the slightest field rotation (such an event can easily occur when the telescope follows a star for several hours).
- The telescope should be equipped with a first-rate motorized drive. Stellar discs can never be blurred, else precision of photometric measurements will rapidly deteriorate.
- An auto-drive device is highly recommended. Without it, exposure times must be reduced, because in this case the driving precision relies only on the telescope drive (remember, however, that a minimum exposure time of 60 seconds is required).
- A CCD camera with good photometric performance should have a very low readout noise (i.e. the uncertainty associated to the reading of a matrix photo-element).

A short summary of digital imaging and data processing

Here are some remarks on the process of acquiring digital frames.

- Always wait for the instrumentation to thermally stabilize before starting a working session.
- Set the MINIMUM integration time via the atmospheric scintillation formula (see paragraph 1). Make sure to insert the correct data for telescope aperture and air mass in the field. Exposure times can always be increased, provided you have a good telescope drive - better still, an auto-drive device. However, always bear in mind the remarks in the following.
- NO SATURATED PIXELS WHATSOEVER ARE ALLOWED IN YOUR IMAGES. To attain a high photometric precision, the ADU level of the brightest pixel in the frame must be kept, more or less, at 25000 ADU (for a 16 bit-CCD camera) or 1800 ADU (for a 12-bit CCD camera).
or digital camera). In case the exposure time obtained from the atmospheric scintillation formula is too long – which in turn would saturate the star’s image – there are two ways to keep it below the saturation threshold: 1) by interposing a filter (R, V, I or neutral) to attenuate the incoming light flux and reach, at least, the minimum integration time; 2) by defocusing the star’s image twice or thrice the FWHM (Frequency Width at Half Maximum). In any case, however, **never drop below the minimum time resulting from the scintillation formula**.

- Once exposure time has been determined, perform some test imaging on the chosen stellar field, checking (using Astroart or MaxIm) the $S/N$ (signal-to-noise) ratio for the parent star as well as for the reference ones. For the uncertainty of measurements to stay below 0.002 magnitudes, the $S/N$ ratio should be at least 500. Unfortunately, determination of this parameter via Astroart or MAXIM is not extremely accurate; to get a more significant value, we should put $S/N > 1000$. A more exact formula is reported in Rodolfo Calanca’s article cited above (COELUM Magazine, n. 65, p. 64). If the $S/N$ ratio is less than the required minimum value, we should expect to attain a lower photometric precision.

- Frames are to be taken about every two minutes. Imaging must start – at least – half an hour before transit begins and must end not earlier than half an hour after the transit is over.

- Quality of flat fields decisively influences photometric accuracy. Making a lot of flats (up to several tens) and averaging has the effect to reduce Poisson noise. For the same reason, a great number of dark and bias frames is needed.

**Reduction of the frames to produce a light curve**

Once a complete series of frames for the transit is made available, data processing must yield a light curve. This task can be accomplished via differential photometry. To this aim, **Angelo Angeletti** and **Fabiano Barabucci** wrote a procedure, making use of MaxIm DL software. A tutorial is now available in English and Italian (soon in French, too).
APPENDIX C

OUR PROPOSAL: WATCHING THE TRANSIT OF PLANET XO-3b FROM THE WHOLE EUROPE – 13th February 2010

EXTRASOLAR PLANET TRANSIT OBSERVATION ON THE WEB
The live broadcasting from the web site www.crabnebula.it will start at 19:00 UT – 13th February 2010
FROM: BRERA ASTRONOMICAL OBSERVATORY

ALL AMATEURS ARE WARMLY INVITED TO SHOOT THE TRANSIT WITH PROPER TELESCOPES!

We are organizing an observational event for Italy (hoping, however, to see it arranged in other European countries as well): on 13 February 2010, we will watch the transit of the extrasolar planet XO-3b. The event will be observed by telescopes, and commented for participants, from 19:00 to 23:30 U.T. (Universal Time).

The observation of the exoplanet XO-3b transit on next Feb 13 has a scientific as well as cultural relevance. Collecting several simultaneous light curves opens indeed the possibility to globally analyze them in order to get a final, high-accuracy transit light curve. This could unveil peculiar features like for example asymmetries of the transit profile, possibly related to evaporation phenomena like those observed in the first discovered transiting exoplanet, HD209458b.

It is important to remark that because of their time-dependence, these phenomena are best studied with this kind of observations, rather than co adding light curves referring to different transits and therefore acquired over a large period.

The National Institute for Astrophysics – Astronomical Observatories of Brera and Palermo Italy - plans to collect light curve data acquired on next Feb 13 by as many observers as possible, and to perform a accurate analysis of them.

It represents therefore a unique opportunity to provide a scientific acknowledgement for any amateur astronomer who will like to contribute to this data acquisition. The Observatories of Brera and Palermo will appreciate the collaboration of observers, across Europe, who will observe the XO-3b transit on next Feb 13 and will make their data available.

Astronomers of INAF - Brera Astronomical Observatory: Paolo D'Avanzo, Jirong Mao and Christina Thoene (see movie: www.youtube.com/watch?v=wsbW5TRo9g0)
**XO-3b and XO-2b Data**

**XO-3b** is an exoplanet with about 11.79 times the mass of Jupiter and an orbit around its parent star in about 3.2 days. The radius of this object is 1.217 times that of Jupiter. Its large size is believed to be caused by the intense heating of its parent star at very small orbit and because of the huge mass the object probably radiates enough of its internal heat making it glow red hot.

**XO-2b** was discovered in 2007 by an international research group - including the Italians F. Mallia and G. Masi. We now know XO-2b to be slightly smaller than Jupiter: it completes an orbit in 2 days plus 15 hours, being 5.5 million kilometres away from its star. The system is 500 light-years away from the Earth; the star has about the same mass as our Sun, though it’s orange in colour.

### Table 3
**XO-3b and XO–2b transits: January – February 2010**
(location: long. 13° E; lat. 43° N)

<table>
<thead>
<tr>
<th>planet</th>
<th>Start transit</th>
<th>End transit</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Date</td>
<td>time (UT)</td>
<td>h/Az</td>
</tr>
<tr>
<td>XO-3b</td>
<td>09.01.10</td>
<td>16:48</td>
<td>66°/NE</td>
</tr>
<tr>
<td>XO-2b</td>
<td>15.01.10</td>
<td>20:23</td>
<td>59°/NE</td>
</tr>
<tr>
<td><strong>XO-3b</strong></td>
<td><strong>13.02.10</strong></td>
<td><strong>19:22</strong></td>
<td><strong>71°/NW</strong></td>
</tr>
<tr>
<td>XO-2b</td>
<td>18.02.10</td>
<td>20:32</td>
<td>81°/NE</td>
</tr>
</tbody>
</table>

### Table 4
**EXTRASOLAR PLANET XO-3b**

**Table 4**
**Planet data**

<table>
<thead>
<tr>
<th>Name</th>
<th>XO–3b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discovered in</td>
<td>2007</td>
</tr>
<tr>
<td>Mass</td>
<td>11.79 (± 0.59) $M_J$</td>
</tr>
<tr>
<td>Semi major axis</td>
<td>0.0454 (± 0.00082) AU</td>
</tr>
<tr>
<td>Orbital period</td>
<td>3.1915 (±0.00023) days</td>
</tr>
<tr>
<td>Radius</td>
<td>1.217 (± 0.073) $R_J$</td>
</tr>
<tr>
<td>Inclination</td>
<td>84.2°</td>
</tr>
</tbody>
</table>

### Table 5
**Star data**

<table>
<thead>
<tr>
<th>Name</th>
<th>XO–3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance</td>
<td>260 pc</td>
</tr>
<tr>
<td>Spectral Type</td>
<td>F5V</td>
</tr>
<tr>
<td>Apparent Magnitude V</td>
<td>9.8</td>
</tr>
<tr>
<td>Mass</td>
<td>1.2 $M_{sun}$</td>
</tr>
<tr>
<td>Age</td>
<td>2.8 Gyr</td>
</tr>
<tr>
<td>Effective Temperature</td>
<td>6429 (± 100) K</td>
</tr>
<tr>
<td>Radius</td>
<td>1.377 $R_{sun}$</td>
</tr>
<tr>
<td>Metallicity [Fe/H]</td>
<td>0.177 (± 0.08)</td>
</tr>
<tr>
<td>Right Asc. Coord.</td>
<td>04 21 53</td>
</tr>
<tr>
<td>Decl. Coord</td>
<td>+57 49 02</td>
</tr>
</tbody>
</table>
**EXTRASOLAR PLANET XO-2b**

### Table 6

**Planet data**

<table>
<thead>
<tr>
<th>Name</th>
<th>XO-2b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discovered in</td>
<td>2007</td>
</tr>
<tr>
<td>( M \cdot \sin i )</td>
<td>0.57 (± 0.06) ( M_J )</td>
</tr>
<tr>
<td>Semi major axis</td>
<td>0.0369 (± 0.002) AU</td>
</tr>
<tr>
<td>Orbital period</td>
<td>2.615838 (± 8 \cdot 10^{-6}) days</td>
</tr>
<tr>
<td>Radius</td>
<td>0.973 (± 0.03) ( R_J )</td>
</tr>
<tr>
<td>( T_{\text{transit}} )</td>
<td>2454147.74902 (± 0.0002) JD</td>
</tr>
<tr>
<td>Inclination</td>
<td>&gt; 88.58°</td>
</tr>
</tbody>
</table>

### Table 7

**Star data**

<table>
<thead>
<tr>
<th>Name</th>
<th>XO-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance</td>
<td>149 (± 4) pc</td>
</tr>
<tr>
<td>Spectral Type</td>
<td>K0V</td>
</tr>
<tr>
<td>Apparent Magnitude V</td>
<td>11.18</td>
</tr>
<tr>
<td>Mass</td>
<td>0.98 (± 0.02) ( M_{\text{sun}} )</td>
</tr>
<tr>
<td>Age</td>
<td>2 Gyr</td>
</tr>
<tr>
<td>Effective Temperature</td>
<td>5340 (± 32) K</td>
</tr>
<tr>
<td>Radius</td>
<td>0.964 (± 0.02) ( R_{\text{sun}} )</td>
</tr>
<tr>
<td>Metallicity ([\text{Fe/H}])</td>
<td>0.45 (± 0.02)</td>
</tr>
<tr>
<td>Right Asc. Coord.</td>
<td>07 48 07</td>
</tr>
<tr>
<td>Decl. Coord</td>
<td>+50 13 33</td>
</tr>
</tbody>
</table>
XO-2b STAR CHART
FOV: 30’ x 30’

XO – 2b (red)

Star Magnitude
R = 10.80; B = 12.20; V = 11.20

AR (J2000): 07h 48m 07s
Decl: +50° 13’ 33”

Reference Star
1 → R = 11.10; B = 12.30
LINKS OF "WORLDS OF THE SKY" PROJECT
- INAF - Brera Astronomical Observatory: www.mi.astro.it/
- INAF - Palermo Astronomical Observatory: www.astropa.unipa.it/
- Info technical informations in english: http://exoplanet.eu/
- http://fsalvaggio.blogspot.com/
- AAVSO extrasolar observing: www.aavso.org/observing/programs/ccd/transitsearch.shtml
- Bruce Gary tutorial: http://brucegary.net/tutorial_exoplanet/
- Italian webzine L’ASTROFILO: www.astropublishing.com/