DSLR Photometry

Part 1

ASSA Photometry Nov 2016

Because of the complexity of the subject, these two sessions on DSLR Photometry will not equip you to be a fully fledged DSLR photometrists.

It is hoped however that your interest will be stimulated to the extent that, with the help of some literature and software, you will investigate further to enable you to make scientifically useful observations.

Are you ready? (Prerequisites)

Know how (or are willing to learn how) to operate your camera. In particular, be able to set the image format to RAW (CR2, NEF, etc.), shut off additional image-processing options, turn off auto focus, manually adjust focus, and mount your camera onto a tripod, piggy back on top, or at the prime focus, of a telescope.

Have a good working knowledge of computers and be able to install software on your machine and manipulate image and data files.

Highly recommended, but not required to have had some experience making visual variable star estimates.

What is photometry?

Photometry

Photo - **light**

metry - **measure**

Before the invention of electronic sensors and photographic equipment, astronomers had only their own eyes for estimating the brightness of stars.

Although this technique is ancient, it is still widely practiced and remains useful for observing certain types of variable stars, especially those which are relatively bright and which have large variations in brightness.

With visual estimates, there is no need for expensive, complex equipment, making it a highly economical method of variable star observing. However, visual estimates are prone to error due to the colour sensitivity of the human eye, age of the observer, experience in making visual measurements, and possible bias.

As a result, it is often difficult to detect subtle brightness variations visually, and different observers will often disagree as to the exact brightness of a variable star by as much as several tenths of a magnitude. The AAVSO Manual for Visual Observing of Variable Stars details the process of making visual observations of variable stars.

As amateur astronomers may find that measurement of variable stars adds a new dimension to your hobby. It is a real treat to see your own measurements build up the "light curve" of a star's changing brightness!

Most of us with a passing interest in astronomy have read an astronomy magazine every so often and seen the stunning photos that grace their pages.

Most of these pictures are taken with cameras attached to guided telescopes and heavily processed to make them look as good as they do.

***That is the realm of astrophotography*.**

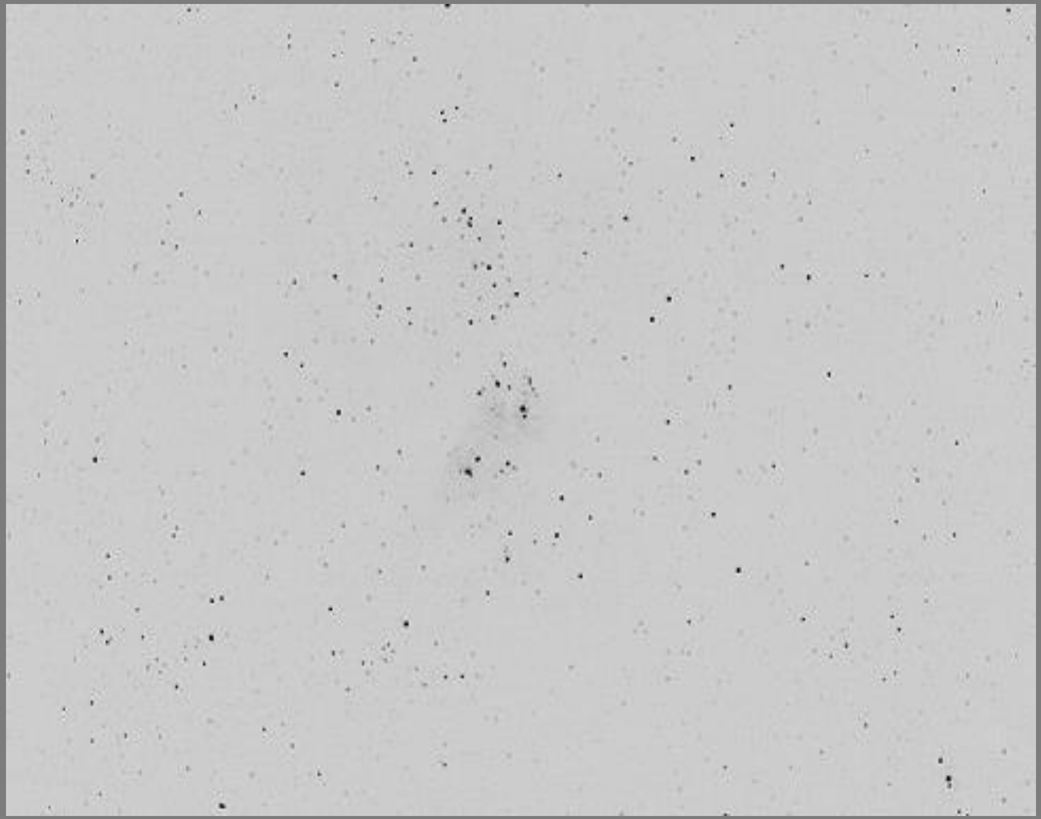
This course will take us in a different direction.

Here we're going to take a look at how you can record scientifically valuable photographs to measure the brightness of variable stars — stars whose brightness change over time.

***The goal of this course is to guide you through the process of using the same DSLR camera that you use for general photography to contribute scientific quality data to the astronomical community*.**

What you should, and should not, expect to see in DSLR photometry

This



Wider field of view image of same region, 20 sec exposure with 80 mm f6 refractor and Canon 600D DSLR, green channel image. (Mark Blackford)

Not this!

Spectacular image of eta Carinae nebula central region

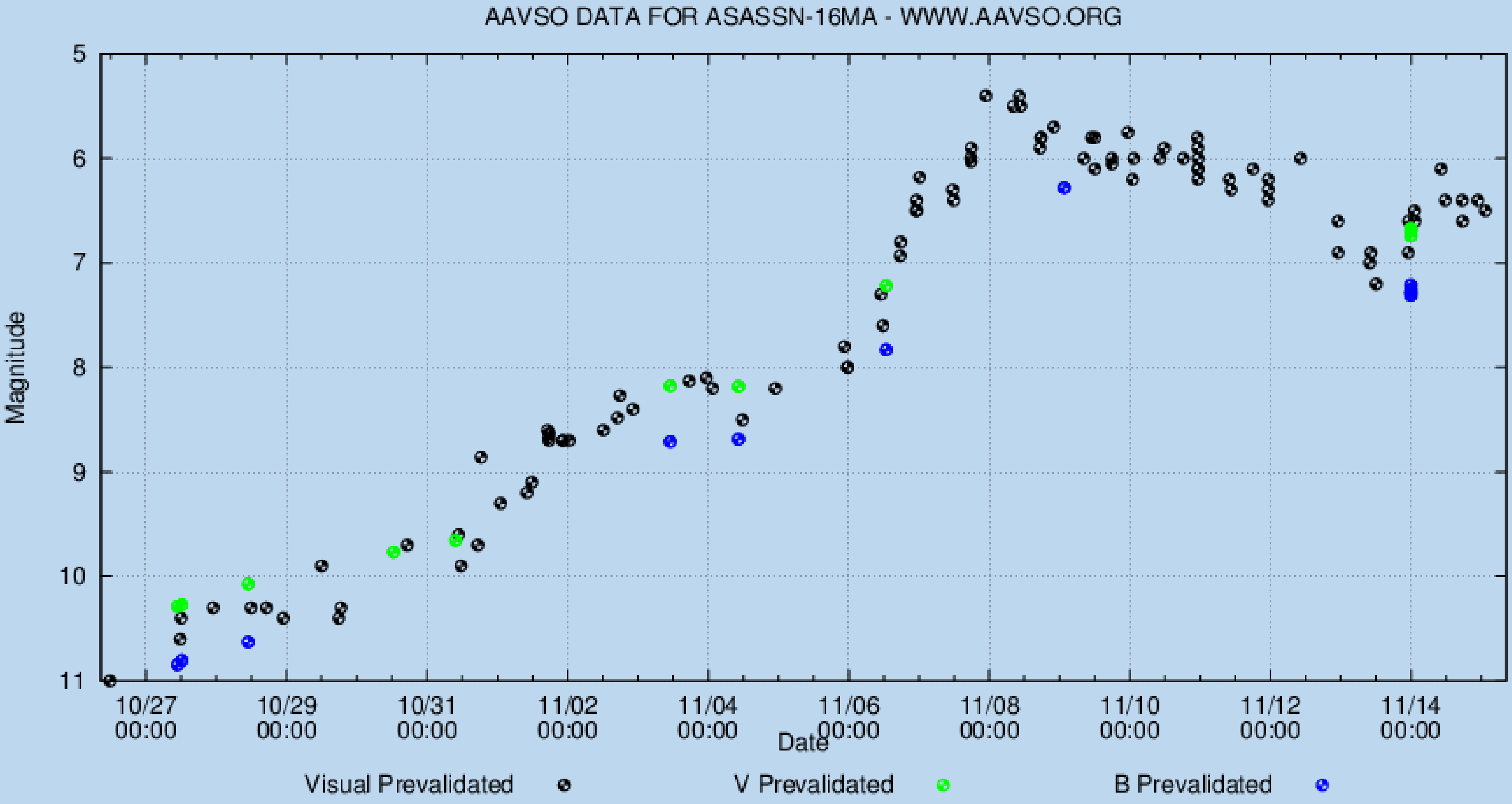
So photometry is the science of measuring how bright a particular object in the sky is. At first blush, this might not seem like a particularly thrilling subject, but it is actually a dynamic field in which amateurs can play a key role.

Although there are many types of objects for which photometry is important, this presentation concentrates on variable stars because stellar photometry is one of the easiest fields to learn and in which to contribute valuable measurements.

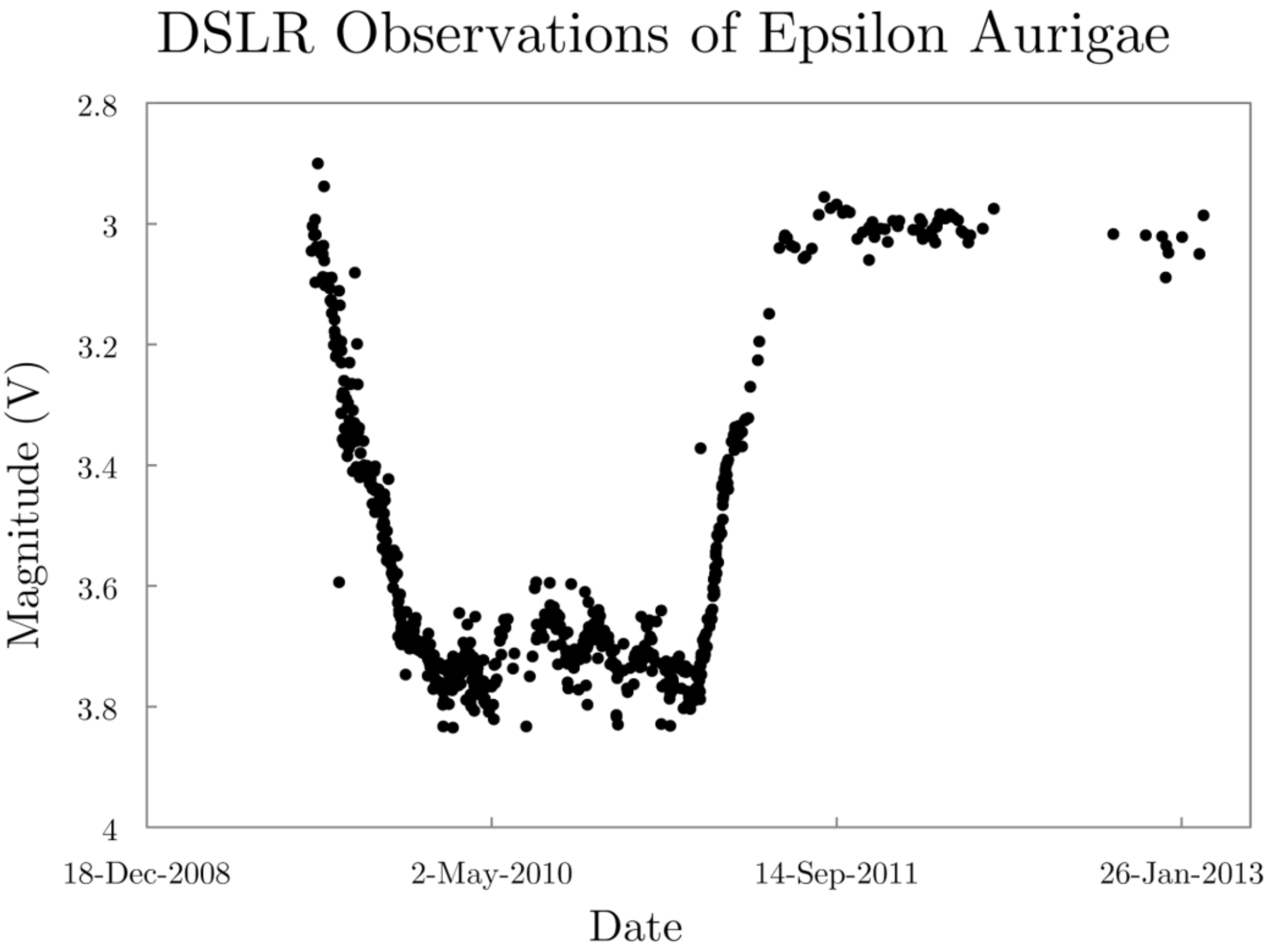
What are variable stars and why do we observe them?

Stars can change in brightness due to the physical processes happening inside, on, or near the star. By carefully observing this variability, it is possible to learn a great deal of information about the star and, more generally, astrophysical phenomena.

. In a very real sense, therefore, variable stars are like physics laboratories. The same fundamental physical processes that operate here on Earth – gravity, fluid mechanics, light and heat, chemistry, nuclear physics, and so on – operate exactly the same way all over the universe. By watching how stars change over time, we can learn why they change.



AAVSO DATA FOR ASASSN-16MA - WWW.AAVSO.ORG
Magnitude
5
6
7
8
9
10
11
10/27 00:00
10/29 00:00
10/31 00:00
11/02 00:00
11/04 00:00
11/06 00:00
11/08 00:00
11/10 00:00
11/12 00:00
11/14 00:00
Date
Visual Prevalidated
V Prevalidated
B Prevalidated



DSLR observations of epsilon Aurigae during its 2009-2011 eclipse. Each data point on this plot was contributed by an amateur astronomer.

Epsilon Aurigae (period 27 years)

Ok, so what is a DSLR camera?

DSLR stands for:

D*igital* **S***ingle* **L***ens* **R***eflex camera*

DIGITAL

CMOS – electronic detector

Complementary Metal Oxide Semiconductor

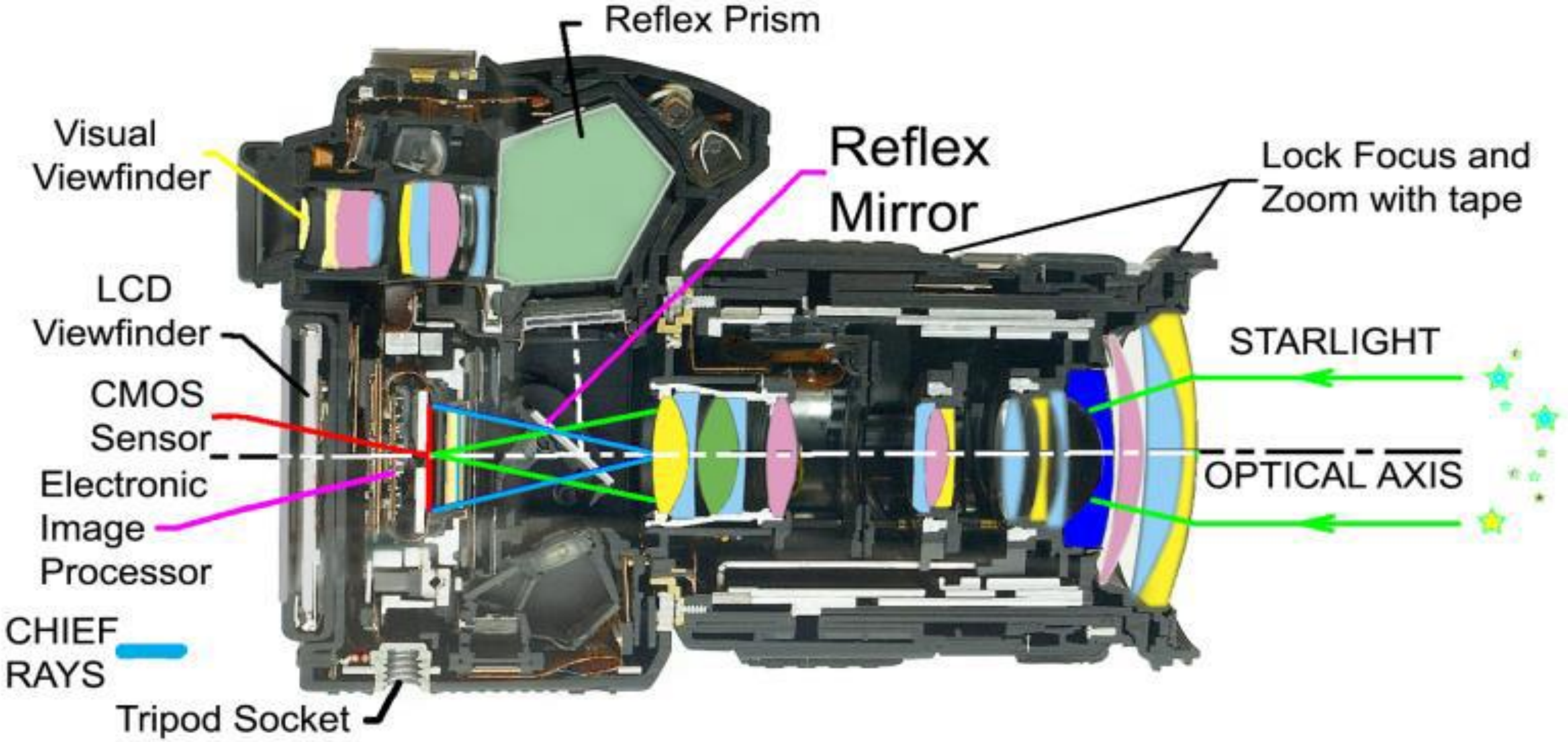
Single Lens

The light we see when we look through the viewfinder on our DSLR camera and the light that hits the image sensor when we make an exposure comes through a single lens. This might seem obvious until you consider that not all cameras work this way.

Reflex

Reflex gives us a clue as to how using the same lens to see through and also make the exposures is possible – **reflection**.

As you can see in the above image, there is a mirror placed at a 45 degree angle directly in the path of the light through the lens. This reflects the light upwards where it enters another reflective assembly above the mirror which corrects the image (remember, it's been reflected!) and then directs it out of the viewfinder and into your eye.



DIGITAL SINGLE LENS REFLEX CAMERA

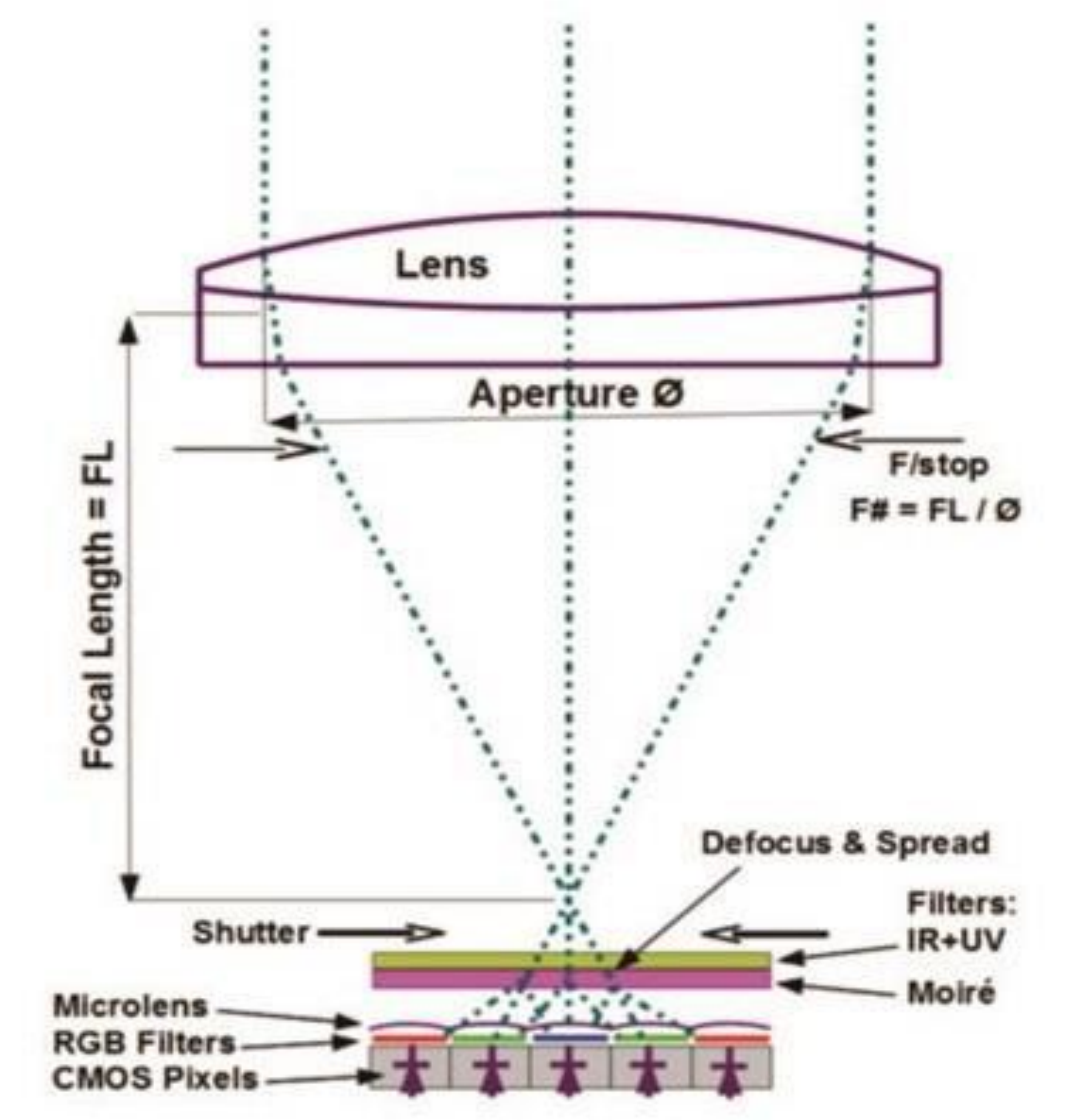

400mm F/5.6 Fluorite
F.L. must be fixed
for photometry
50mm f/1.4
50mm f/1.8
100mm f/2.0
18 - 55mm f/5 Zoom
DSLR LENSES

Fig. 2.6

Many DSLR cameras come equipped with standard kit zoom lenses like the 18-55mm f5 lens in Figure 2.6. These types of lenses are relatively slow (i.e. large f-numbers) and of poor optical quality when used at the widest aperture setting. They may perform adequately when stopped down, but generally it is recommended that they not be used for photometry.

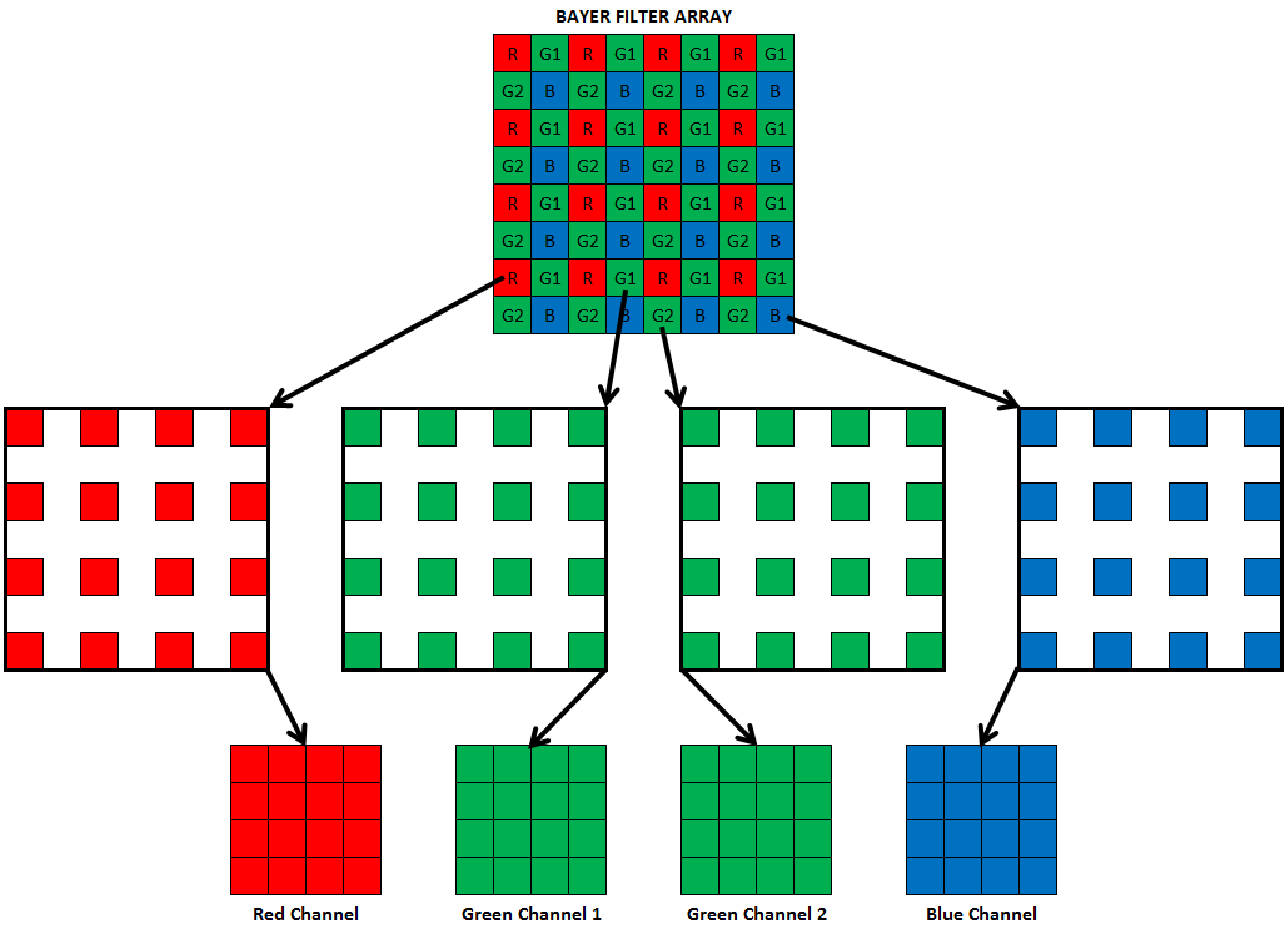
High quality (and therefore relatively expensive) zoom lenses are suitable for DSLR photometry if care is taken to avoid zoom and focus creep which may occur when pointing high in the sky.

Fixed focal length lenses are recommended for DSLR photometry as they generally have higher quality optics and faster f-number than similarly priced zoom lenses of comparable focal length.


Lens
Aperture Ø
Focal Length = FL
F/stop
F# = FL / Ø
Defocus & Spread
Filters:
IR+UV
Shutter
Moiré
Microlens
RGB Filters
CMOS Pixels

What is a Bayer Matrix?

A Bayer matrix is a grid of RGB filters on top of the pixels in the camera's sensor chip.



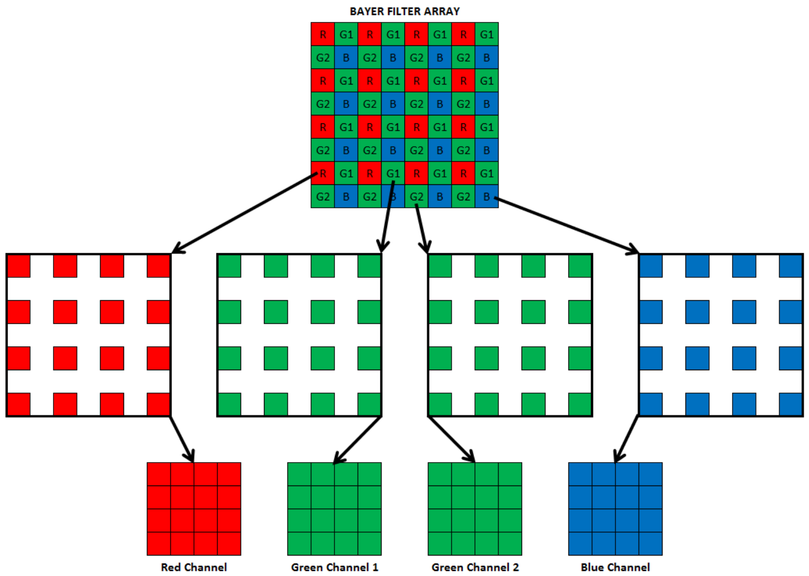
BAYER FILTER ARRAY
R G1 R G1 R G1 R G1
G2 B G2 B G2 B G2 B
Red Channel
Green Channel 1
Green Channel 2
Blue Channel

In photometry the brightness is measured at different wavelengths using ***standard*** filters.


Baader R-CCD Filter 2"(optically
Baader G-CCD Filter 2"(optically
Baader B-CCD Filter 2"(optically

R G B

Then some bright spark came up with the idea of doing photometry with a DSLR camera!


BAYER FILTER ARRAY
Red Channel
Green Channel 1
Green Channel 2
Blue Channel

=


Baader R-CCD Filter 2"
Baader G-CCD Filter 2"
Baader B-CCD Filter 2"
R
G
B

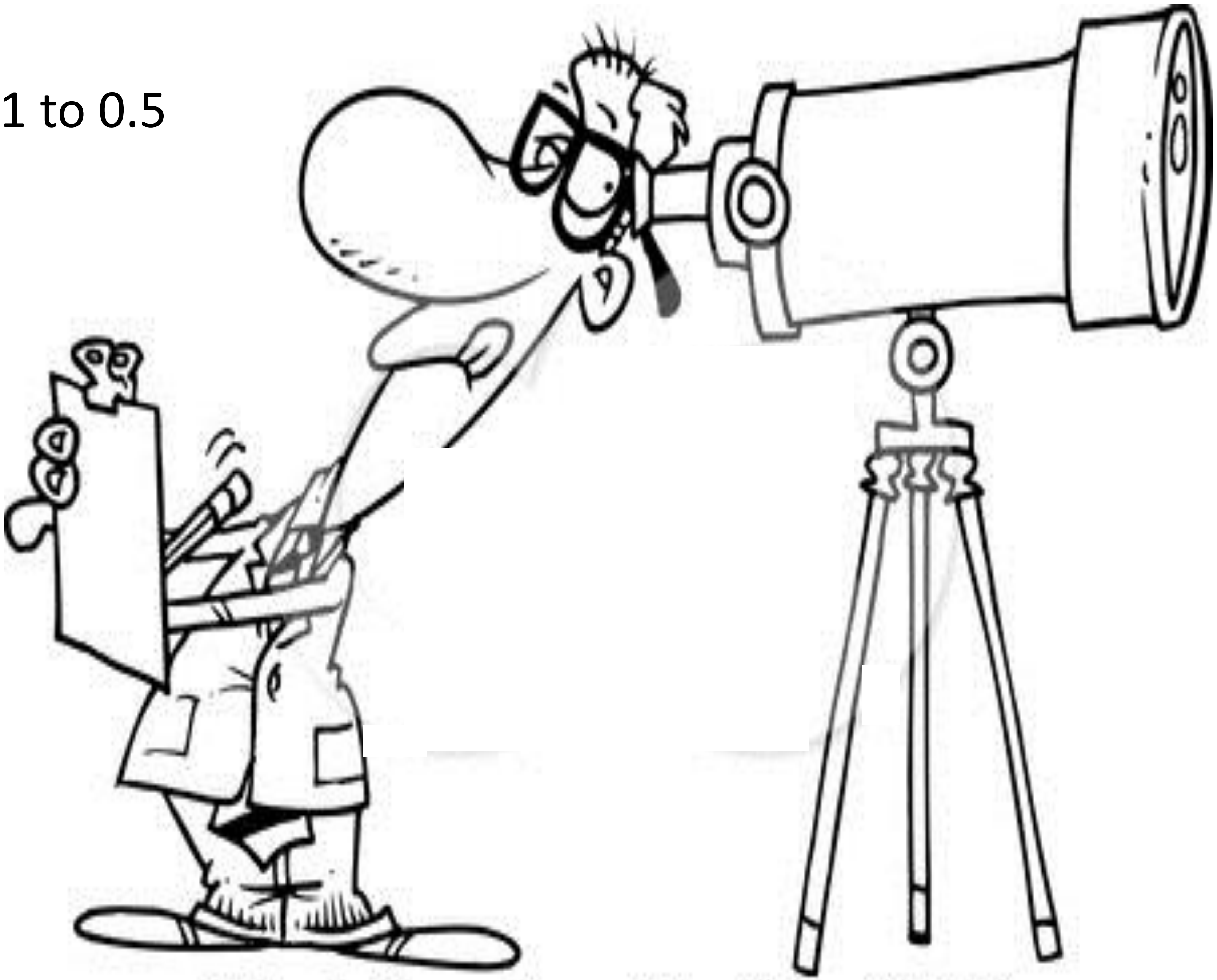
?

Is there any point in doing DSLR photometry rather than visual observing or CCD photometry?

Visual vs DSLR vs CCD observing

Visual

Accuracy 0.1 to 0.5 magnitude



DSLR
Accuracy 0.02 to
0.05 magnitude

CCD
Accuracy 0.01 magnitude or better

CCD camera for astronomy

Three features required in a DSLR camera for it to be suitable for photometry.

- Must be able to record RAW format images
- Manual (or computer) control of exposure times.
- The camera lens must be able to be focused manually or using a computer package

Advantages of DSLR cameras

Just like CCD cameras, there is an array of pixels to measure multiple stars in the field of view.

By using a normal camera lens or small telephoto lenses (50mm-300mm), bright stars can be measured that are too bright for a CCD camera with a telescope.

The scatter from visual observers is usually about 0.2 -0.5 mag, but in DSLR measurements the scatter is usually about an order of magnitude better (0.02-0.05 mag).

Other advantages of DSLR cameras compared with monochrome CCD cameras for photometry.

1. No filters are required.

2. No external power source required.

3. Records three colour channels.

4. Cost.

Also

Tracking is not necessary for short exposures.

The equipment required for bright stars and short exposures can be very portable.

In general, DSLR cameras are cheaper than CCDs and can also be used for non-astronomical purposes.

AND

Camera lenses have a wider field of view compared to a CCD camera and a telescope.

It is fairly easy to find a few stars around magnitude 4 to use as comparison stars with a 50mm lens (about 20 degrees).

It is not as easy to do so with a CCD camera.

Disadvantages of DSLR camera

CCD cameras are more sensitive than DSLR cameras. This lets them capture fainter stars.

High quality CCD cameras are cooled to reduce thermal electronic noise.

DSLR cameras generate more noise than CCD cameras, which increases uncertainty of measurements and makes it harder to measure faint objects.

DSLR camera features to avoid for photometry

JPEG images should never be used in astronomical photometry.

Some cameras have a de-noising or image enhancement function that modifies the underlying data, possibly corrupting the photometric data in the process.

Functions that measure the illumination of a scene, and autofocus, are nearly useless for stellar photometry.

Modern DSLR cameras have 14 bit analogue-to-digital converters (ADC) which nominally should give a maximum ADU value of (2e14 – 1) = 16383.

Some older cameras have a 12 bit ADC with nominal maximum ADU value of (2e12 – 1) = 4095.

Mounting the camera

Tripods and mounts

The camera needs to be attached to some kind of mount in order to obtain images of good quality; a hand-held camera will not provide enough stability to take data-quality images.

There are a number of ways to mount a camera, with a fixed tripod being the simplest and least expensive.

It is also possible to mount a camera equipped with a lens on an equatorial mount – a mount that follows the movement of the sky – or to attach (or "piggy-back") a camera onto a telescope that's on an equatorial mount. Doing so has the benefit of letting your camera point at exactly the same location in space as it moves across the sky during the night.

Finally, you can also attach a digital camera to a telescope focuser, in essence turning the telescope itself into a lens for the camera..

Use what you have!

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Which of these you use is a matter of personal preference and resources. While you can obtain good quality data with any of these mounts, your choice of mount will define what objects you can observe, and how you observe them

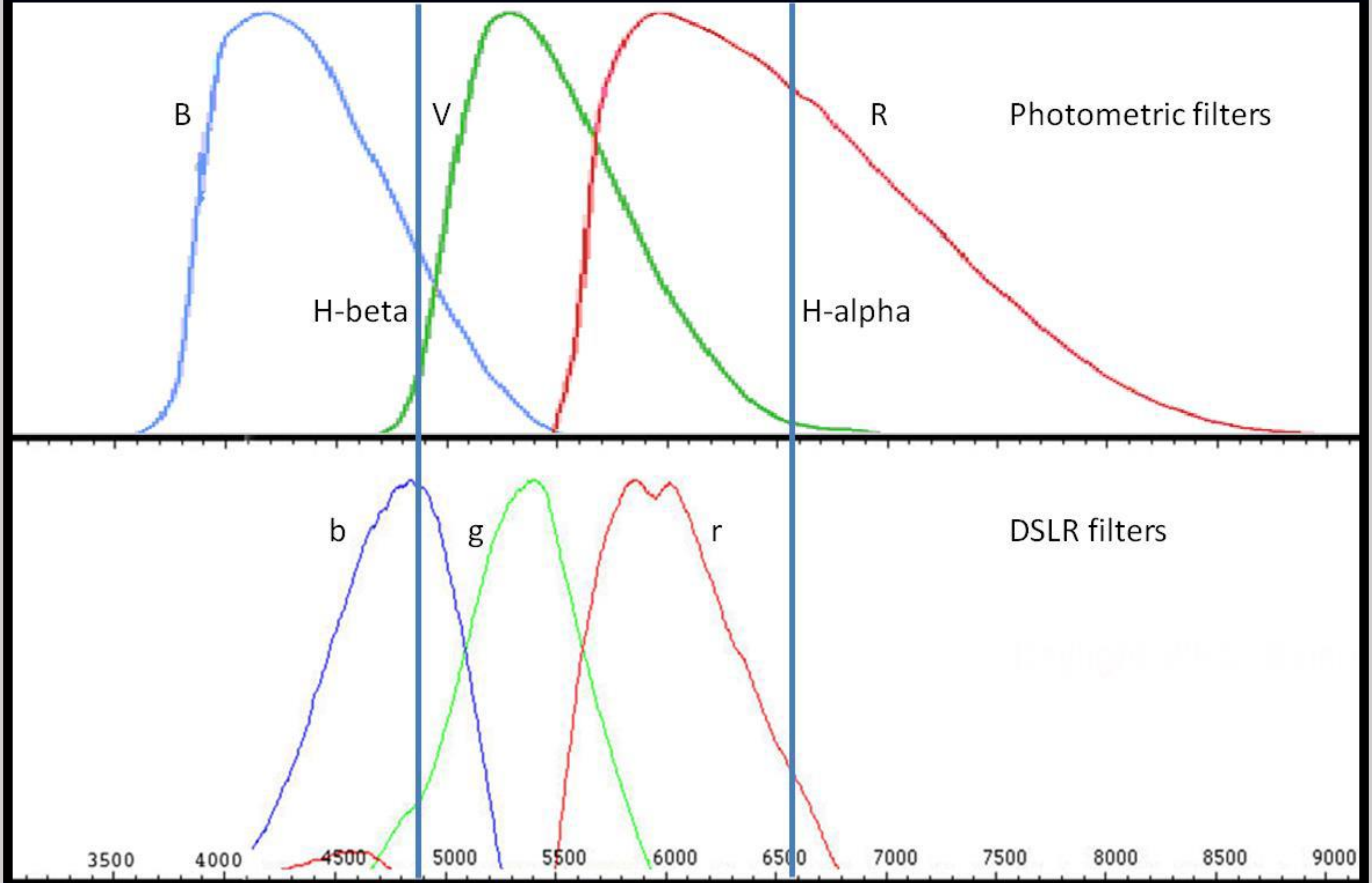
Filters and response curves

There are dozens of astronomical photometric filters covering the ultra violet, visible and infrared regions of the electromagnetic spectrum.
Each designed to extract specific astrophysical information

The ones most relevant to us are the *Johnson B and V* and the *Cousins R* filters which are the most widely used ones in the part of the spectrum DSLR detectors are sensitive to.

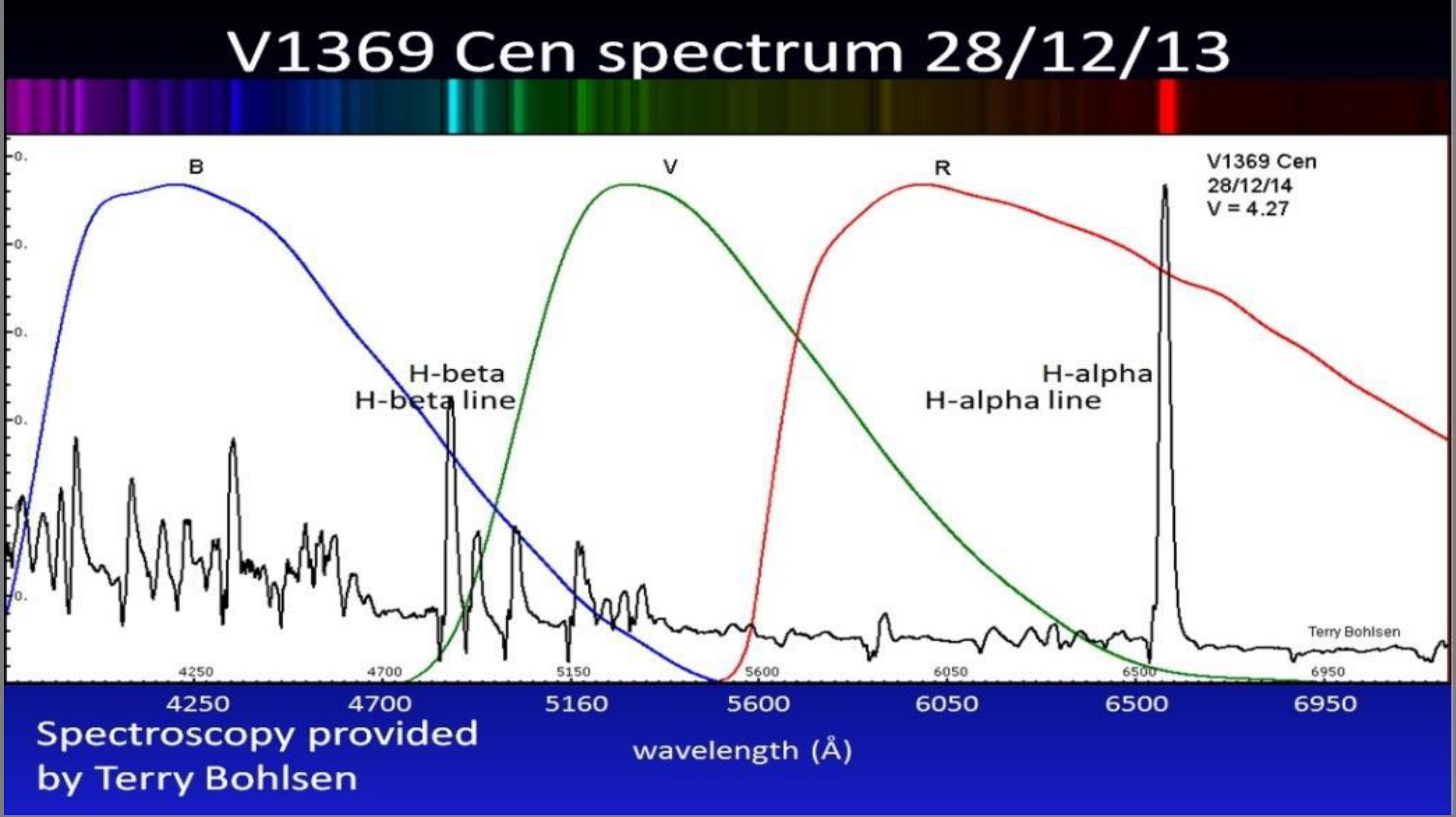
The spectral response of the DSLR camera’s b, g and r channels is not the same as the standard photometric B,V and R filters

Spectral Response Curves



The values from the b, v and r channels thus need to "transformed" to approximate the standard B, V and R filters.

Stars with significant spectral emission or absorption lines are unsuitable for DSLR photometry if transformed magnitudes are required, but these pathological stars can be observed by DSLR if you report non-transformed magnitudes.



At this point in the nova's evolution transformed DSLR R magnitudes were systematically lower by about 0.4 magnitudes than measurements made with CCD cameras through Cousins R filters. This was due to the intense H-alpha line.
On the other hand, transformed DSLR B and V magnitudes were systematically too bright by about 0.2 and 0.1 magnitudes, respectively, due mostly to the H-beta line

Finding and framing the field

● Learn to use star charts to find fields visually and/or with binoculars.
● Practice on easy-to-find and frame fields.
● Locate the nearest bright star to your target area. Use it for rough alignment.
● Looking through a camera that is pointing high in the sky is difficult for many people. Consider purchasing a right-angle finder for the camera.
● Purchase a red dot finder that attaches to your camera's flash hot shoe.

Take one test exposure and examine it on your camera. Use your camera's zoom-in feature to identify asterisms which may help you with further alignment.

The FOV needs to be large enough to include a good set of comparison stars in addition to the target star.

A short focal length lens has a wide FOV, thus it is well-suited for measuring bright variables (bright comparison stars are generally farther apart than faint ones).

FOV (degrees) = 57 x sensor size (mm) / focal length (mm)

Table 2.1. Example of focal length needed to cover a given FOV for typical sensor sizes. Blue cells: very expensive lenses, better to use a telescope connected to the camera body. (Roger Pieri)

All dimensions in mm	APS-C 14.9 x 22.3	4/3 System 13 x 17.3	1” System 8.8 x 13.2	1 / 1.7” 5.7 x 7.6	1 / 2.3” 4.6 x 6.1	Full Frame 24 x 36
FOV width deg.	**W/H=1.5 Foc.Length**	**W/H=1.33 Foc.Length**	**W/H=1.5 Foc.Length**	**W/H=1.33 Foc.Length**	**W/H=1.33 Foc.Length**	**W/H=1.5 Foc.Length**
64	18	14	11	6	5	29
48	25	19	15	9	7	40
32	39	30	23	13	11	63
24	52	41	31	188	14	85
16	79	62	47	27	22	128
8	159	124	94	54	44	257
4	319	248	189	---	---	515
2	639	496	378	---	---	1031

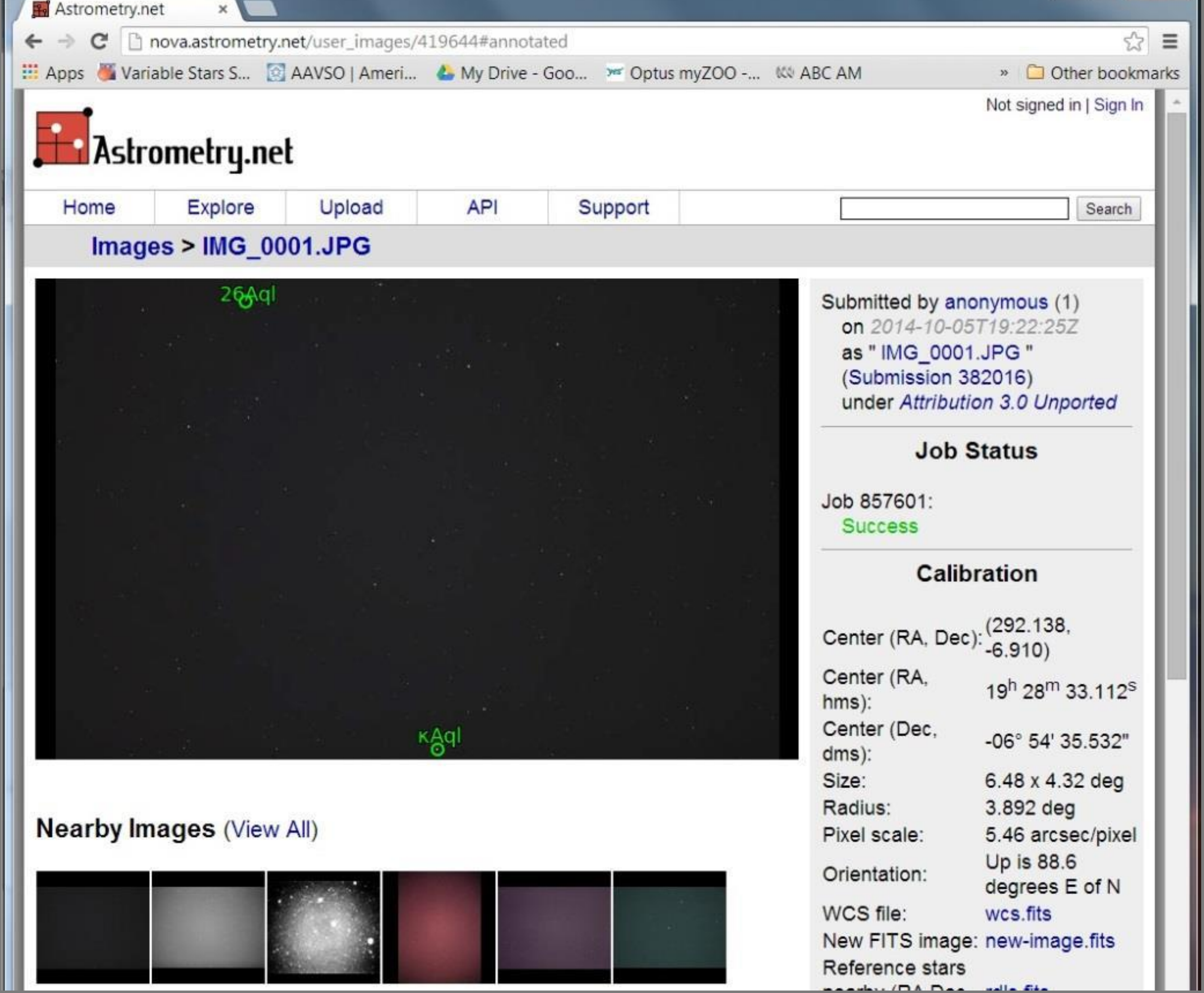
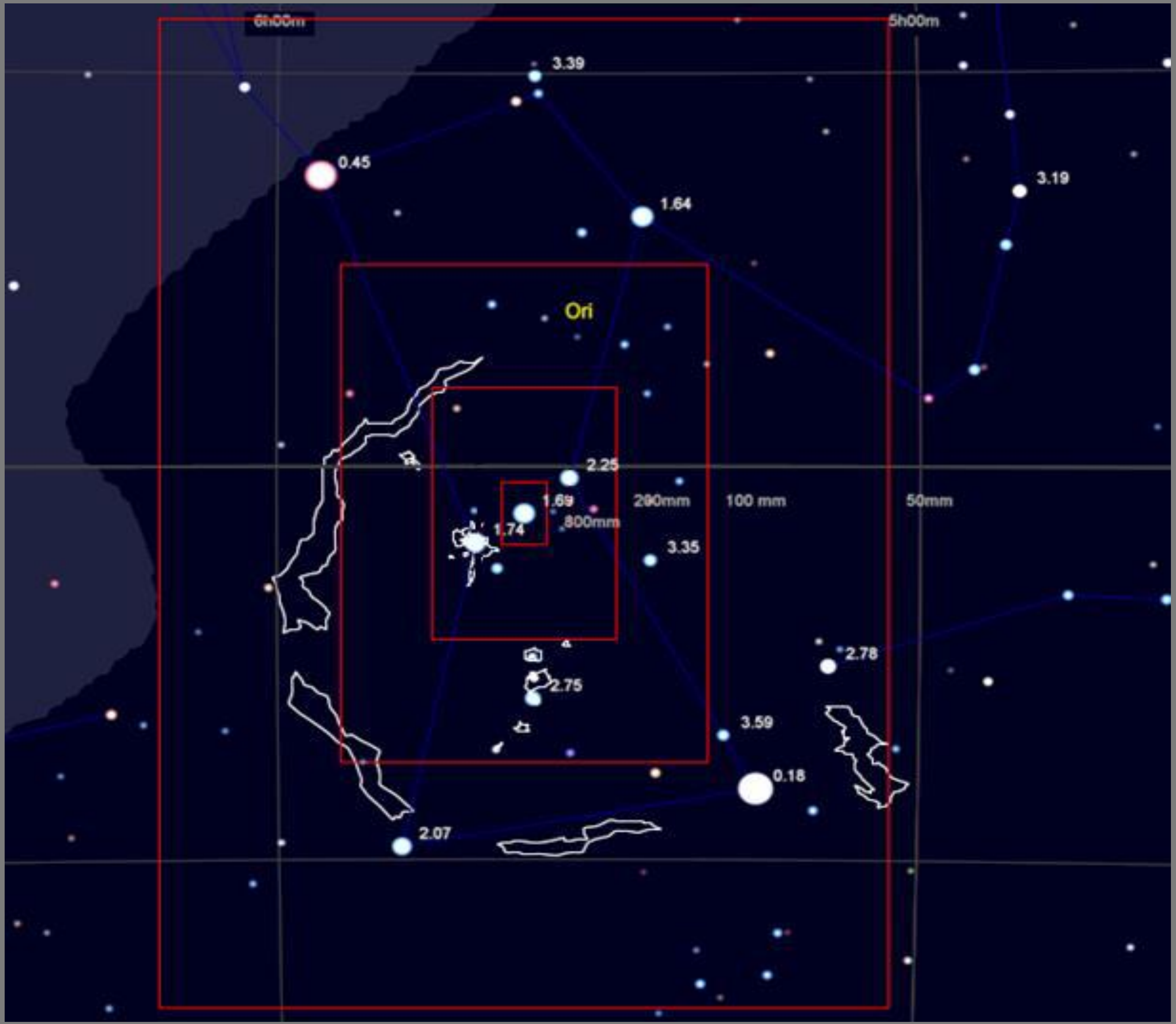

Astrometry.net
nova.astrometry.net/user_images/419644#annotated
Apps
Variable Stars S...
AAVSO | Ameri...
My Drive - Goo...
Optus myZOO -...
ABC AM
Other bookmarks
Not signed in | Sign In
Astrometry.net
Home
Explore
Upload
API
Support
Search
Images > IMG_0001.JPG
26Aql
κAql
Submitted by anonymous (1)
on 2014-10-05T19:22:25Z
as " IMG_0001.JPG "
(Submission 382016)
under Attribution 3.0 Unported
Job Status
Job 857601:
Success
Calibration
Center (RA, Dec): (292.138, -6.910)
Center (RA, hms): 19h 28m 33.112s
Center (Dec, dms): -06° 54' 35.532"
Size: 6.48 x 4.32 deg
Radius: 3.892 deg
Pixel scale: 5.46 arcsec/pixel
Orientation: Up is 88.6 degrees E of N
WCS file: wcs.fits
New FITS image: new-image.fits
Reference stars
Nearby Images (View All)

Figure shows the familiar constellation Orion and illustrates how the area of sky captured by a DSLR depends on the focal length of the lens used.



Identifying the star field

aavso - Google Search | AAVSO -- Variable Star P

https://www.aavso.org/apps/vsp/

Variable Star Plotter

- VSP Help Guide
- Request a Sequence
- Report chart errors

PLOT A QUICK CHART

WHAT IS THE NAME, DESIGNATION OR AUID OF THE OBJECT?

S CAR

Required if no coordinates are provided below

RIGHT ASCENSION

Allowed Formats: HH:MM:SS, HH MM SS, DDD.XXXX. Required if no name is given above

DECLINATION

Allowed Formats: ±DD:MM:SS, ±DD MM SS, ±DD.XXXX. Required if no name is given above

CHOOSE A PREDEFINED CHART SCALE

Select one...

A is larger, slower; G is smaller, faster

CHOOSE A CHART ORIENTATION

◉ Visual ○ Reversed ○ CCD

PLOT A FINDER CHART OR A TABLE OF FIELD PHOTOMETRY? *

○ Chart ◉ Photometry

CHART ID

A Chart ID will allow you to reproduce prior charts. Overrides all other fields in this form.

Plot Chart | Clear Form

ADVANCED OPTIONS

FIELD OF VIEW

420

In Arcminutes. Must be between 0' and 1200'

MAGNITUDE LIMIT

8.0

Stars fainter than this magnitude will not be displayed

RESOLUTION

150

Resolution in dpi to render the chart (default 150)

WHAT WILL THE TITLE FOR THIS CHART BE?

Desktop ENG 00:11 15 Nov 2016

S Car

Magn: 4.5 - 9.9 V
Period: 149.49
Type: M
Spec: K5e-M6e

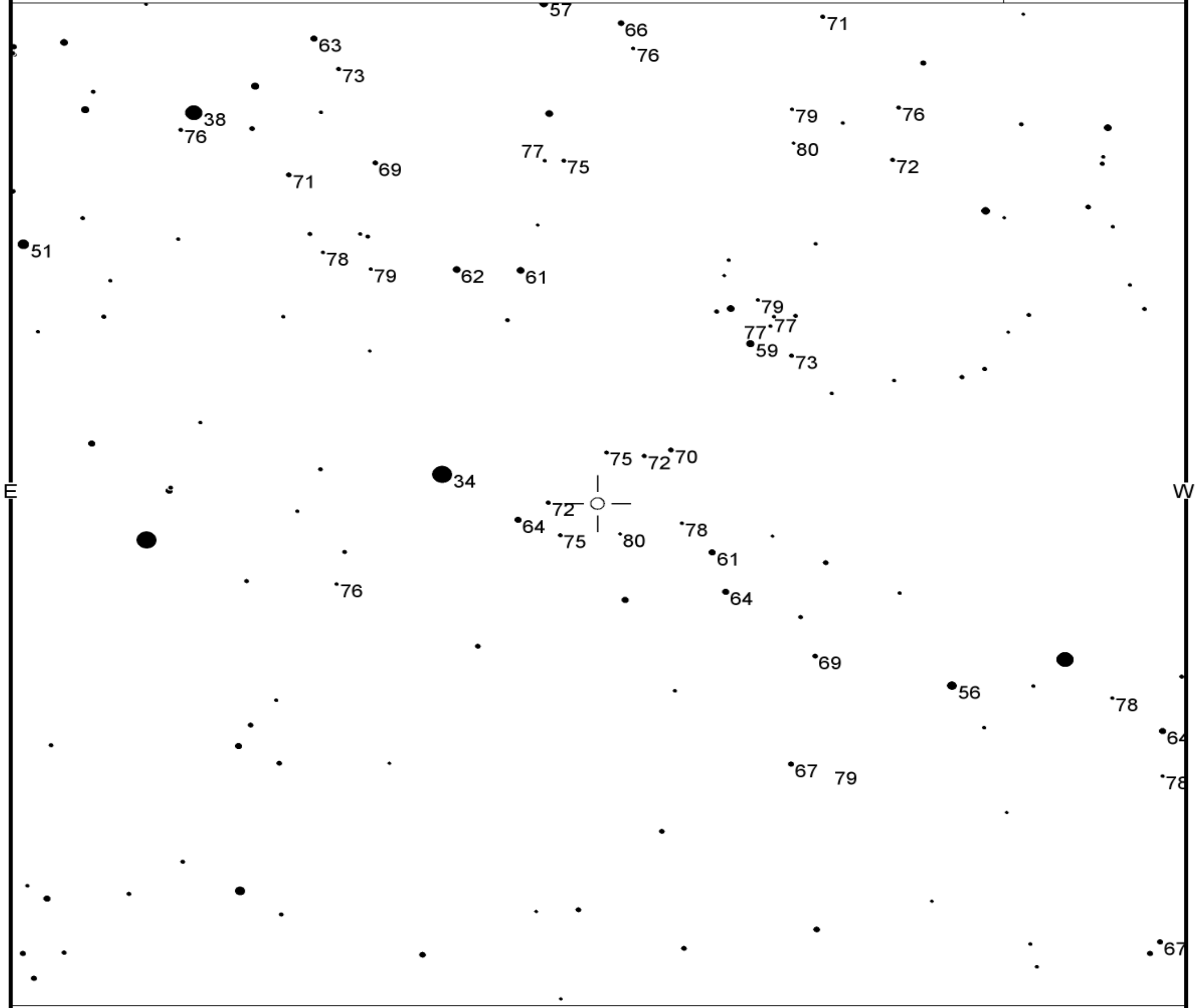
S CAR

(2000) 10:09:21.89 -61:32:56.4

AAVSO Chart

X15939BCA

N



FOV = 7.0°

Please use the photometry table for CCD observations.

https://www.aavso.org/vsp/

S

Equatorial coord. TAN
Apparent
2014-09-18
23h00m00s (EST)
Mag:10.2/20.0,2.0'
FOV:+07°30'00"
NGC 6322
C2
C3
C6
iot Ara
Chk
Variable
NGC 6352
C4
B 263
17h30m
σ
NGC 6388
θ
C1
C5
V0728 Sco
-48°00'
-47°00'
-46°00'
-45°00'
-44°00'
-43°00'
-42°00'

Software requirements for DSLR photometry

Minimum requirements for DSLR photometry software

- Support for the RAW format of your camera
- Integrated image calibration (bias, dark and flat frame correction)
- Extraction of individual colour channels
- Photometric analysis

Software

Some examples:

IRIS: free software. Not the most user friendly interface.

AIP4WIN: cost about $100. Includes a good book on image processing.

MaximDL: cost ranges from $200-$700. Higher-end software.

Table 3.1. Software Comparison Chart.

Features	IRIS[4]	Muniwin[5]	AIP4WIN[6]	MaxIm DL Pro[7]
Photometric Analysis	√	√	√	√
Use RAW Images	√	√[1]	√	√
Apply Bias, Dark & Flat Frames	√	√	√	√
Color Separation	√	√	√	√
Batch Processing	√	√	√	√
Alignment & Stacking	√		√	√
Camera Acquisition Display	√			√
Focus & Camera Control	√			√
Convert to FITS	√	√	√	√
Scripting	√	√		√
Telescope & Mount Control	√			√
Plate Solving	√		√	√
Report Generation			√	√

Before we start taking images of star fields the camera needs to be calibrated

A series of calibration images must be taken in addition to your science images. These bias, dark, and flat images characterize constant offsets, unequal illumination caused by your optics, and hot pixels (or other non-linearity) in your camera's detector.

Bias frames

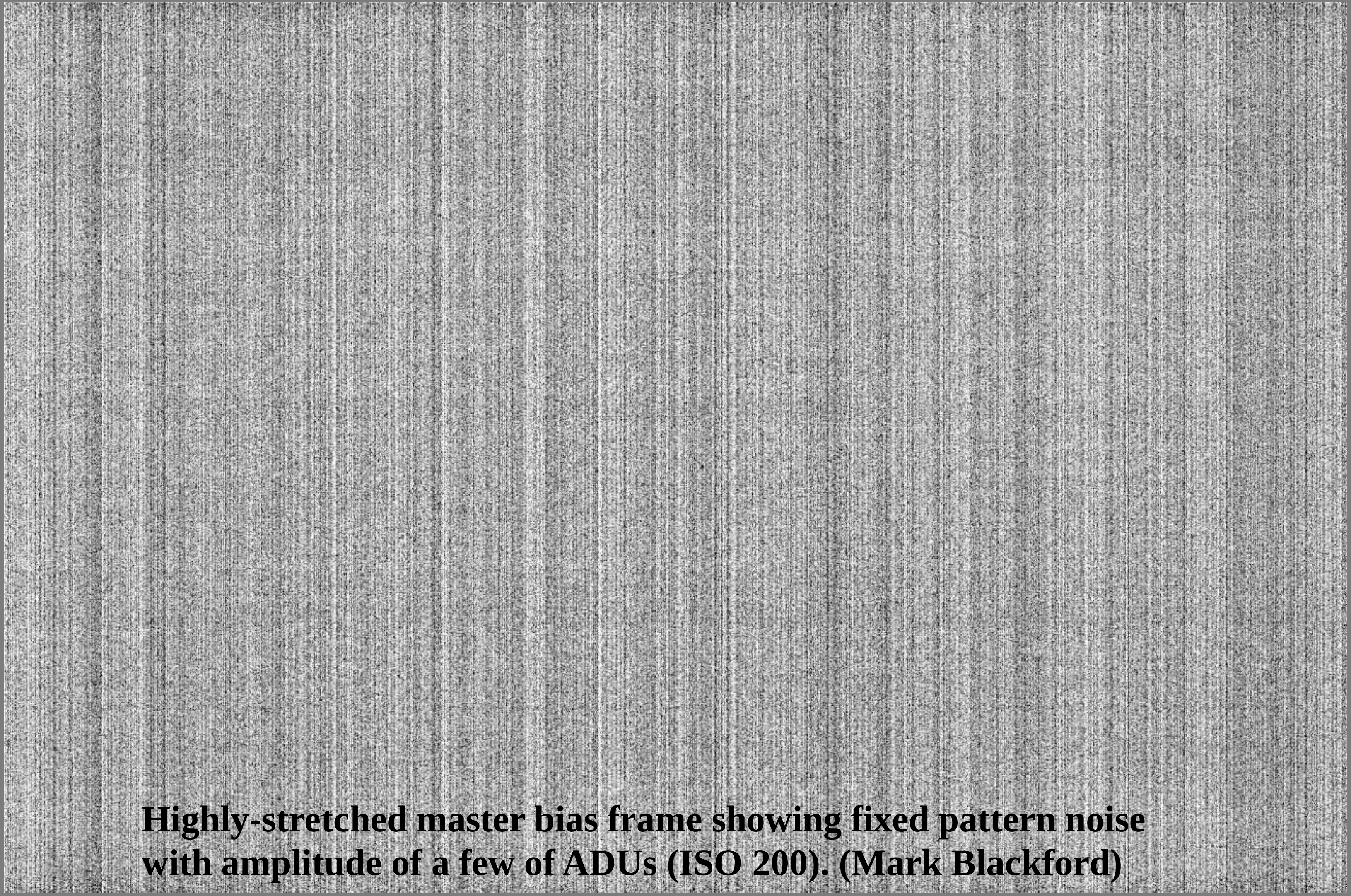
The master is made by stacking a number of shots taken in absolute dark, of very short exposure.

The ISO value used for the science images
Bias frames can be collected at any time because sensor temperature and focus setting are not important.

A separate master bias frame should be made for each ISO setting used for science images.

Block view finder, lens cap on, room darkened) and the shortest exposure time your camera allows (e.g. 1/4000th sec).

Bias frames



Highly-stretched master bias frame showing fixed pattern noise with amplitude of a few of ADUs (ISO 200). (Mark Blackford)

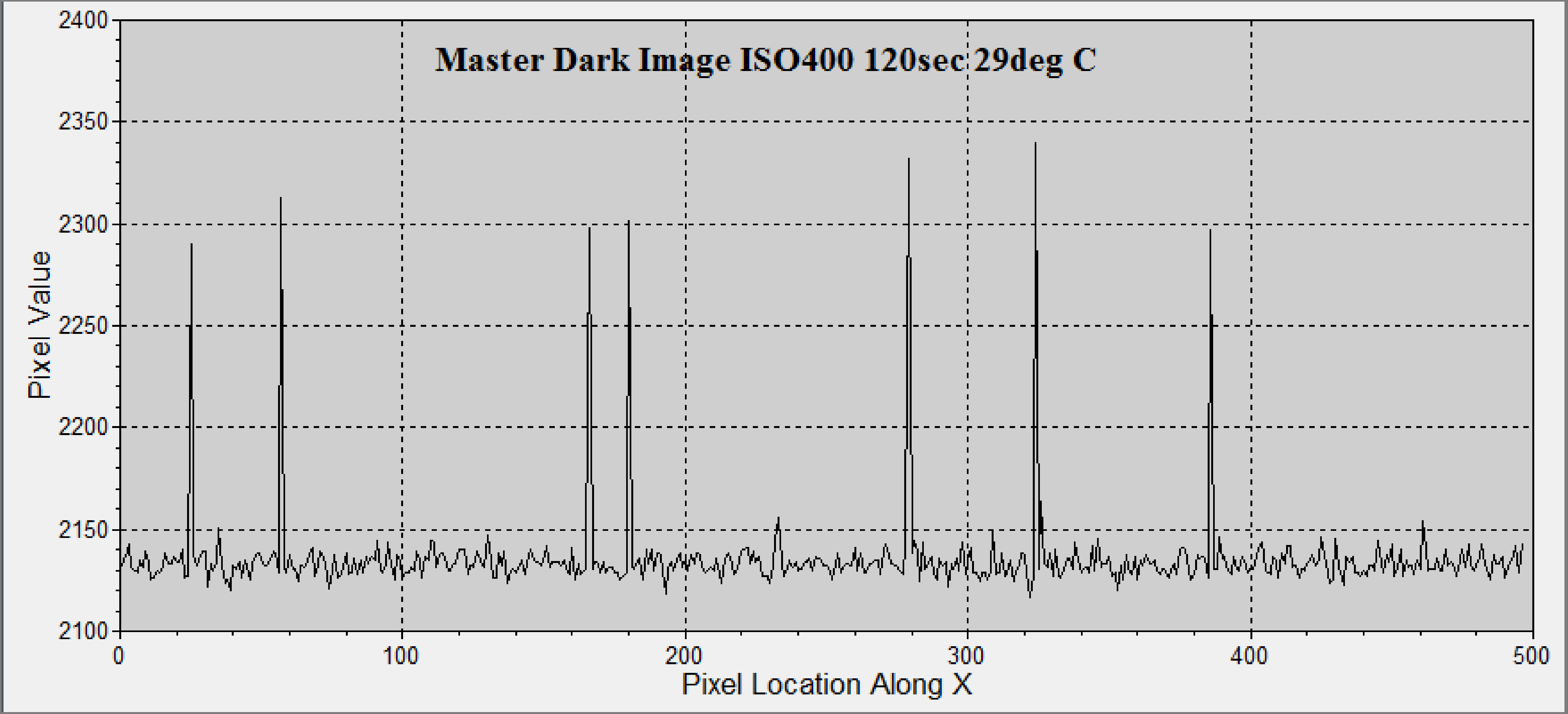
Bias and systematic offsets are present in all science and calibration images. They are removed by subtraction of a master bias frame

Dark frames

Any possible leak of light into the camera must be eliminated (viewfinder covered and lens cap on)

ISO set to the same value as the science image.

Exposure set to the same time as the science image
.
The ambient conditions should be the same as for the science images.



Line profile showing ADU values along an approximately 500-pixel section of a long exposure image. The fluctuations around ~2140 counts (ADU) are due to random noise. The prominent spikes are hot pixels. (Mark Blackford)

Although dark impulses are a truly annoying anomaly in astrophotography, they have less of an impact in photometry where the light is (intentionally) dispersed over a few hundred pixels. Background subtraction and stacking/averaging also reduces the impact of dark impulses.

Flat frames

Focus and aperture should be set to the same as the science image.

The ISO setting should be the same as the science image

Flat frames

Flat field frames are images of an evenly illuminated source which reveal asymmetries or artifacts in your camera's optical setup.
Unlike dark correction, flat field correction is mandatory for all images intended for photometry.
Flat field images must be recorded with the camera and telescope/lens in the same configuration (focus, f-stop, ISO, etc.) used for the science images. Exposure times should be adjusted to avoid saturation.

Flat frames

"Finding or making such an evenly illuminated source is surprisingly difficult and has led to many, shall we say, interesting discussions at AAVSO conferences. Thus we cannot (and dare not) advocate one particular technique. Before presenting a few popular options, we offer a few general words of advice."

Mark Blackford

A highly-stretched image of an evenly illuminated light box. (Mark Blackford)

In the image we can see several of the aforementioned artifacts. The circular splotches are caused by dust on the optics, the reduced intensity in the corners is due to vignetting, and the vertical and horizontal lines are due to pixel sensitivity variations and electronic noise. Although not obvious to the eye, these artifacts are also present in science images and should be removed before photometry is undertaken

Science frames

The ISO setting not more than 400.

The image should be defocused to give spread over several pixels.

Exposure time set low enough so that saturation of the images of stars of interest does not occur.

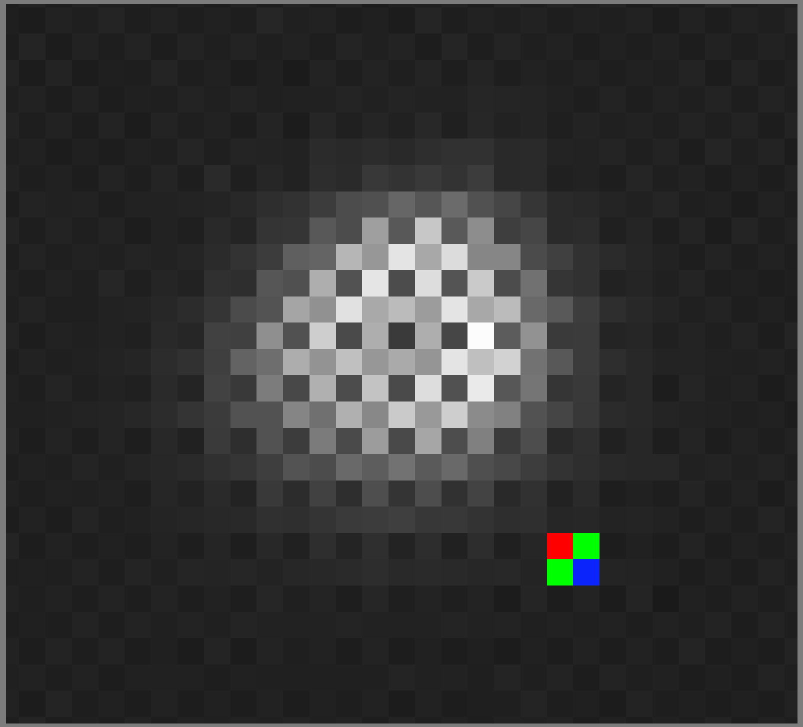
Exposure times should be limited so that stars are not trailed beyond the limits that the software can measure.

ISO settings higher than 400 not generally recommended for photometry.

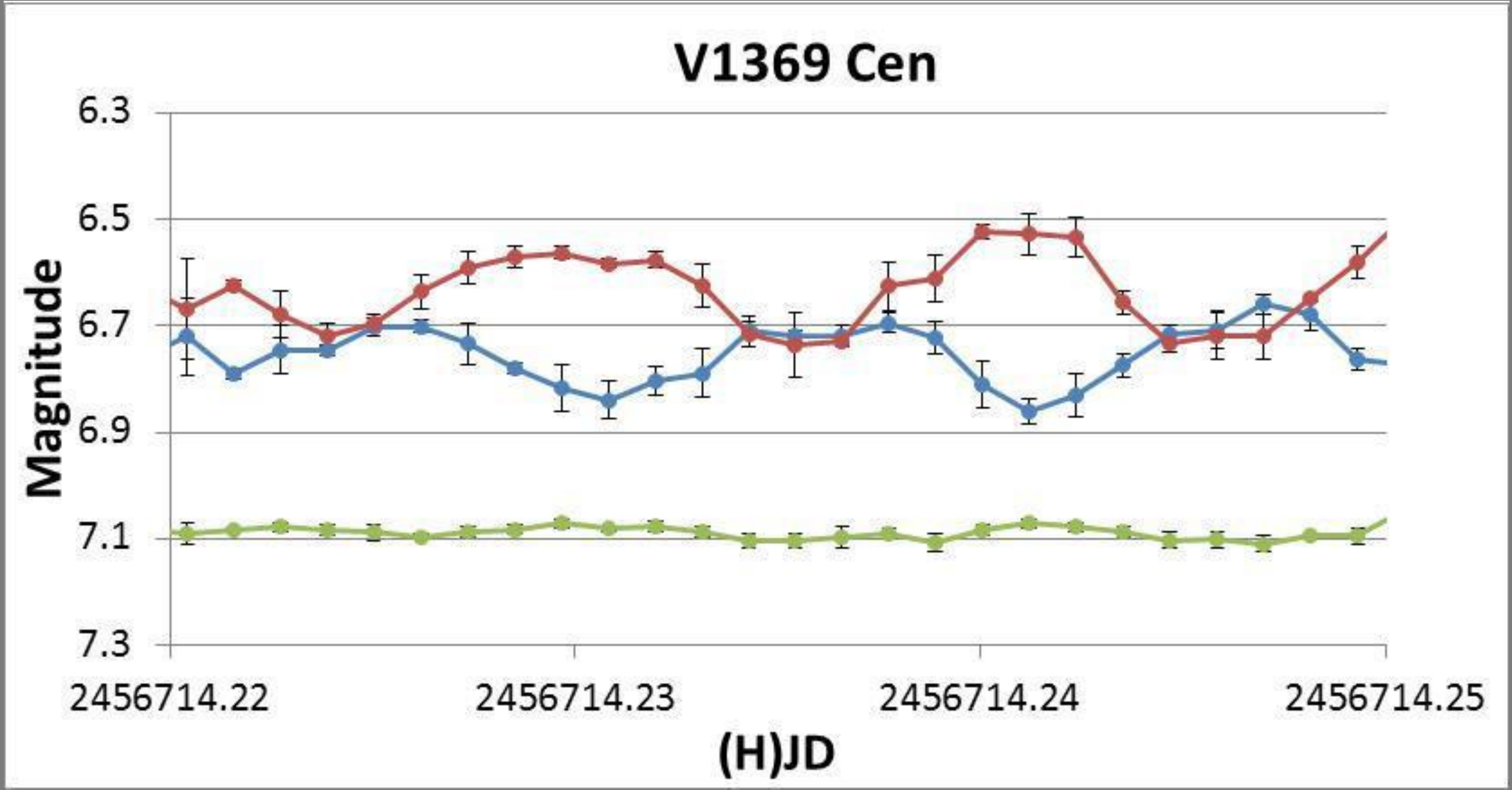
The recommended setting at ISO 400 is a compromise between optimum sensitivity and dynamic range. At ISO 400 and above, the output will record every electron collected by the photodiode.

At much lower ISO settings sensitivity is lost and at much higher ISO settings the dynamic range is reduced and scintillation can become problematic.

Checking Defocus



The star image should extend over many pixels
and not be overly elongated due to trailing



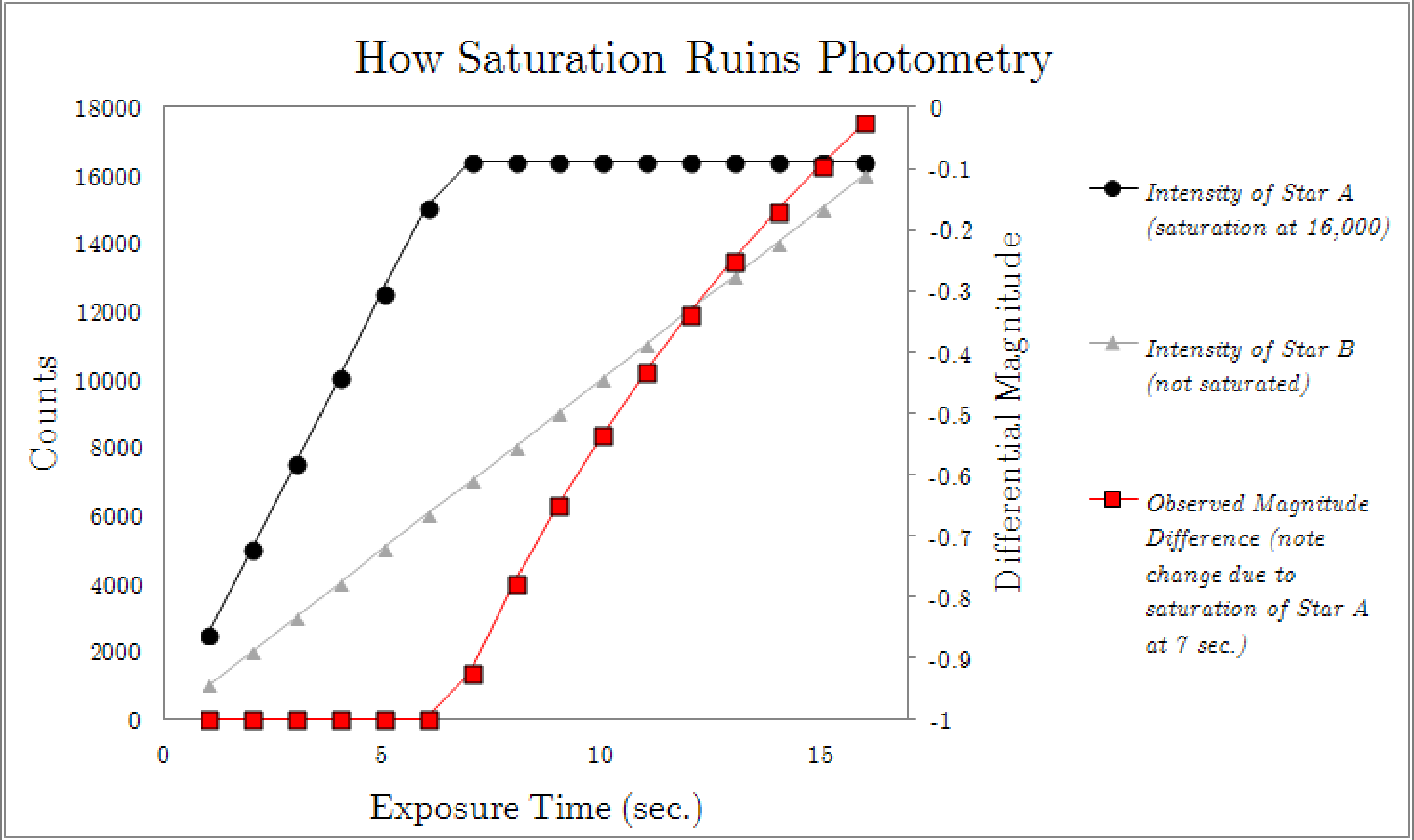
Nova Cen 2013 (V1369 Cen) light curves in B (blue line), V (green line) and R (red line) from images recorded with insufficient defocus. The oscillations are an artefact of the Bayer filter array, periodic error in the mount and drift due to imperfect polar alignment. (Mark Blackford)

Table 2.3. Suggested exposure times for fixed tripod (non-tracking) mount. (Roger Pieri)

Optics type	FL mm	F-stop	Aperture Size mm²	Max* Exposure	Limiting Mag	Sat. Mag	Sat. Mag	FOV** deg
Zoom 18-55mm f3.5-5.6	55	5.6	76	20 s	8	5.1	3.7	15.3 x 22.8
Zoom 70-300mm f4-5.6	70	4	240	16 s	9	6.2	4.8	12 x 18
Tele 200mm f4	200	4	1963	5.5 s	10	7.3	5.9	4.24 x 6.36
Zoom 70-300mm f4-5.6	300	5.6	2254	3.7 s	10	7.1	5.7	2.8 x 4.2
Refractor 400mm f5	400	5	5026	2.7 s	10.5	7.6	6.2	2.1 x 3.2

Table 2.4. Exposure examples for a tracking mount. (Roger Pieri)

Optics type	FL mm	F-stop	Aperture Size mm²	Max* Exposure	Limiting Mag	Sat. Mag ISO 400	Sat. Mag ISO 100	FOV** deg
Tele 200mm f4	200	4	1963	60 s	13	9.9	8.5	4.24 x 6.36
Zoom 70-300mm f4-5.6	300	5.6	2254	60 s	13	10	8.6	2.8 x 4.2
Refractor 400mm f5	400	5	5026	60 s	14	10.9	9.5	2.1 x 3.2
Newton 800 mm f4	800	4	31416	60 s	16	12.9	11.5	1 x 1.6


How Saturation Ruins Photometry
Counts
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
5
10
15
Exposure Time (sec.)
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
Differential Magnitude
Intensity of Star A (saturation at 16,000)
Intensity of Star B (not saturated)
Observed Magnitude Difference (note change due to saturation of Star A at 7 sec.)

The End part 1

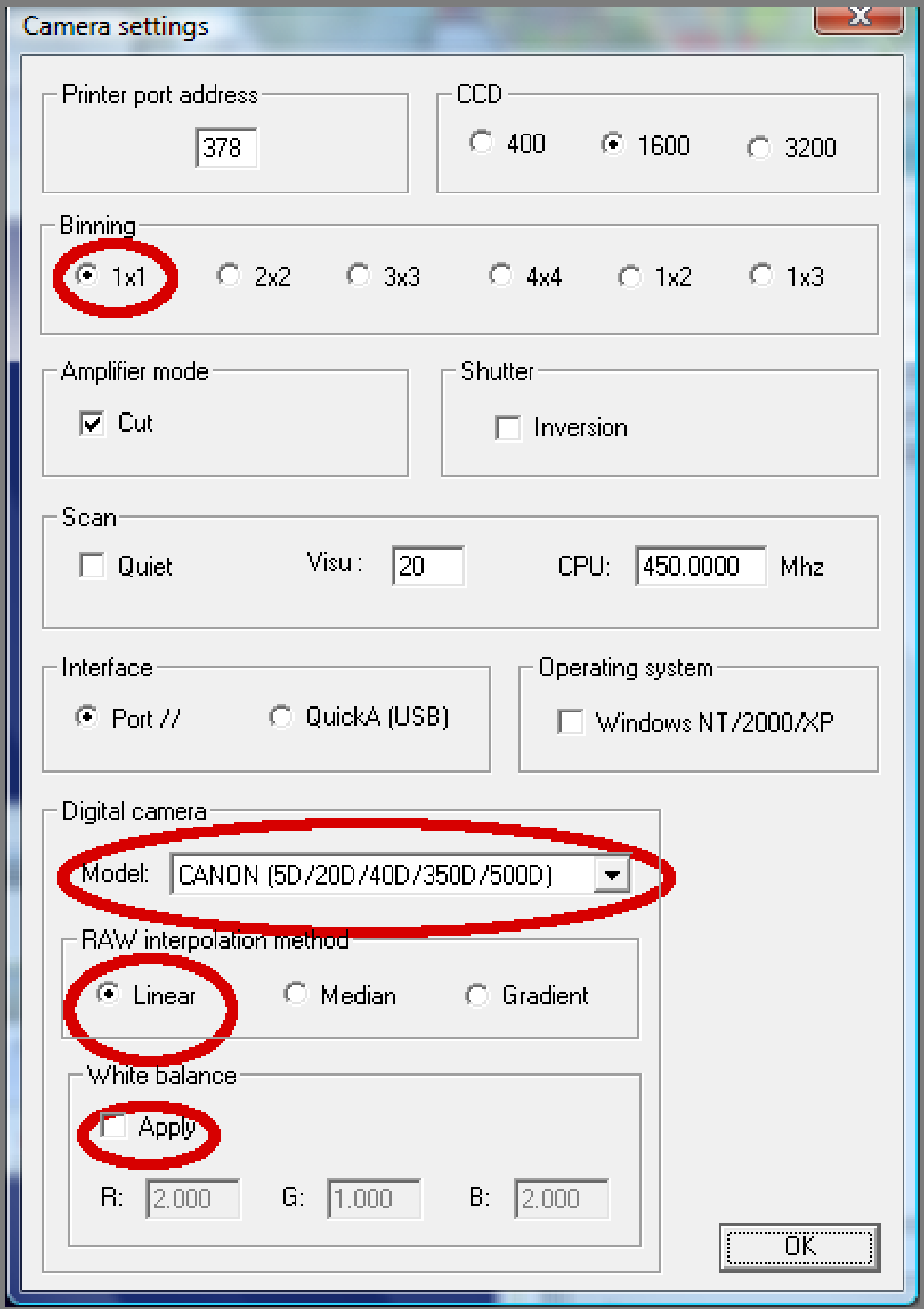
DSLR Photometry

Part 2

ASSA Photometry Nov 2016

1. *Initialize IRIS*
2. *Check raw images*
3. *Load and convert images*
4. *Create master calibration frames*
5. *Perform Bias and Dark subtraction, then Flat division*
6. *Align and stack*
7. *Extract red, green and blue channel images*
8. *Perform Aperture photometry*
9. *Option - Analyse each image instead stacking the images.*

Camera settings



Almost all DSLR variable-star projects use "differential photometry", in which the brightness of the target variable star is compared to the brightness of a nearby star of known constant brightness – a "comparison star".

The easiest way to avoid issues with saturation is to simply keep the maximum intensity for the target, check and comparison stars below 75% of the maximum value for your camera

.

If you have an older 12-bit camera, the maximum intensity is 2e12 or 4096 counts, so you would need to keep the intensity below about 3100 counts to be safe.

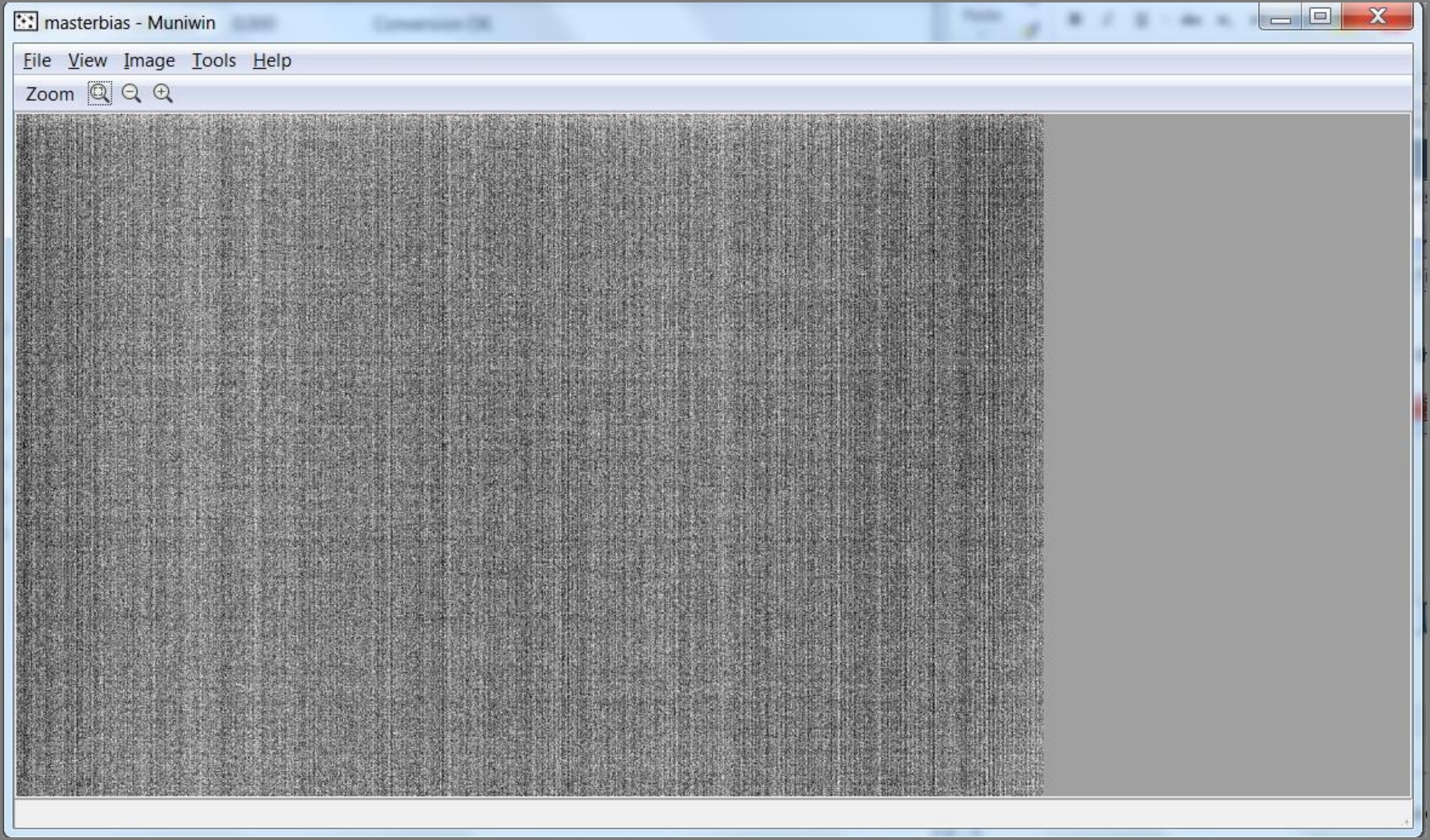
For a 14-bit camera, 12300 counts would be the cutoff. These numbers are very conservative but allow for changes in observing conditions, such as seeing or transparency, that might push a star into saturation.

The easiest way to avoid issues with saturation is to simply keep the maximum intensity for the target, check and comparison stars below 75% of the maximum value for your camera

. If you have an older 12-bit camera, the maximum intensity is 2e12 or 4096 counts, so you would need to keep the intensity below about 3100 counts to be safe.

For a 14-bit camera, 12300 counts would be the cut-off.

Master bias frame



Selecting the measurement and annulus radii

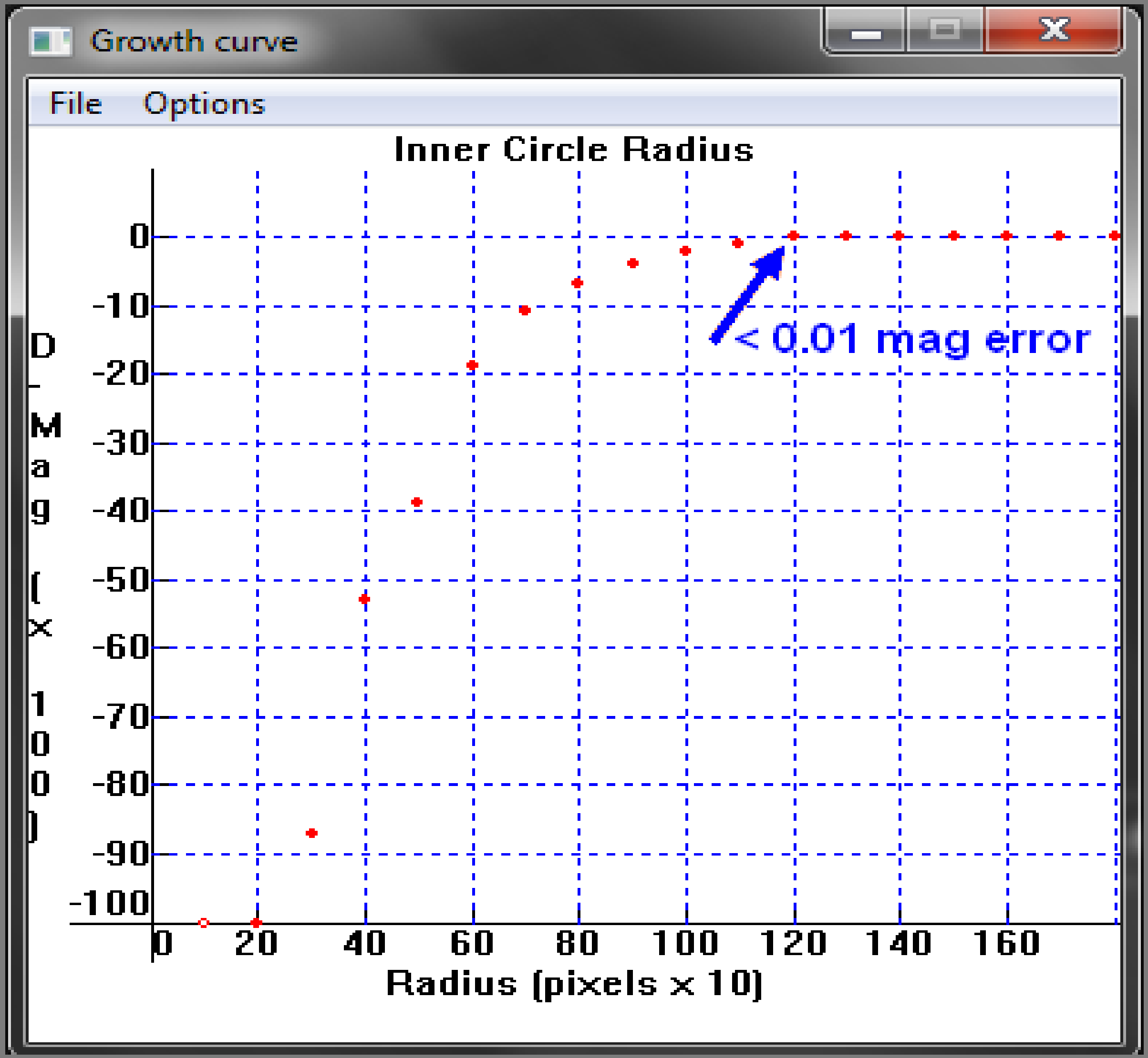
Based on the growth cuve select as follows:

Measurement aperture radius (pixels): **9**

Sky annulus inner ring radius (pixels): **13**

Sky annulus outer ring radius (pixels): **18**

Determine Photometry Aperture Size



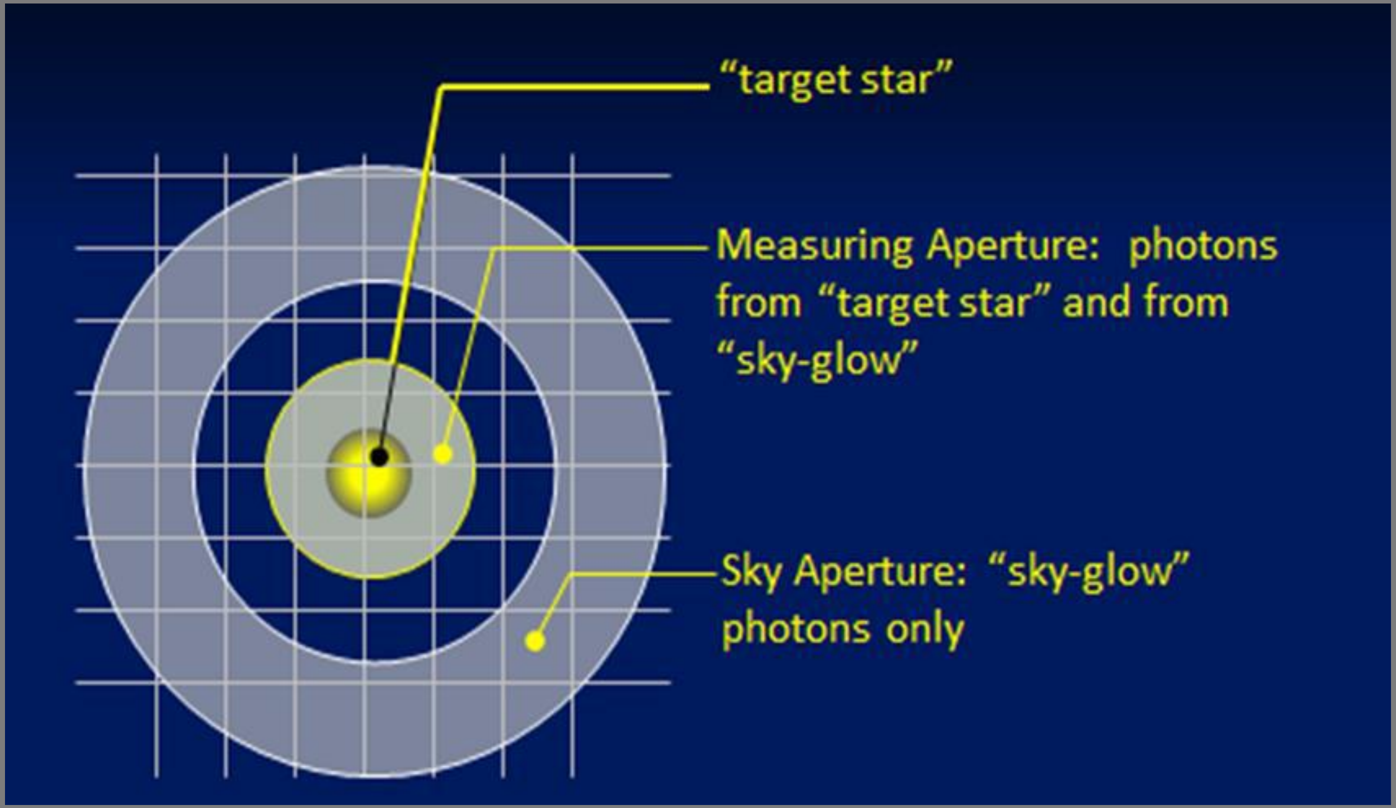
The AAVSO DSLR Observing Manual - Supplemental Information

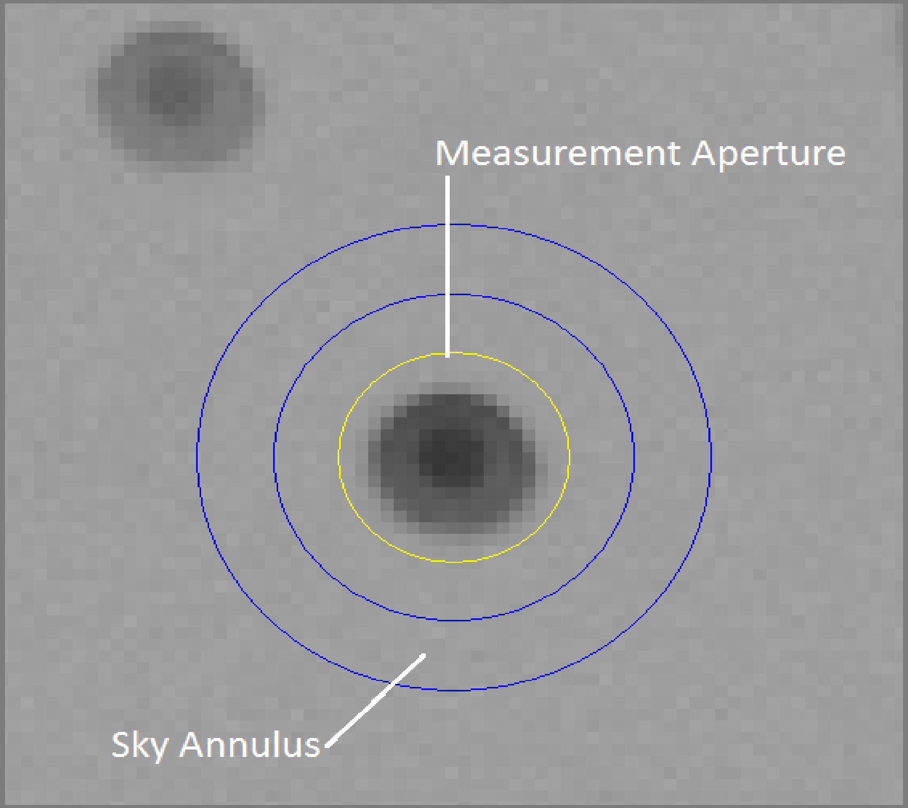
Photometry Software Calibration and Photometry Tutorials AAVSO Version 1.0

49 Bay State Road
Cambridge, MA 02138
email: aavso@aavso.org

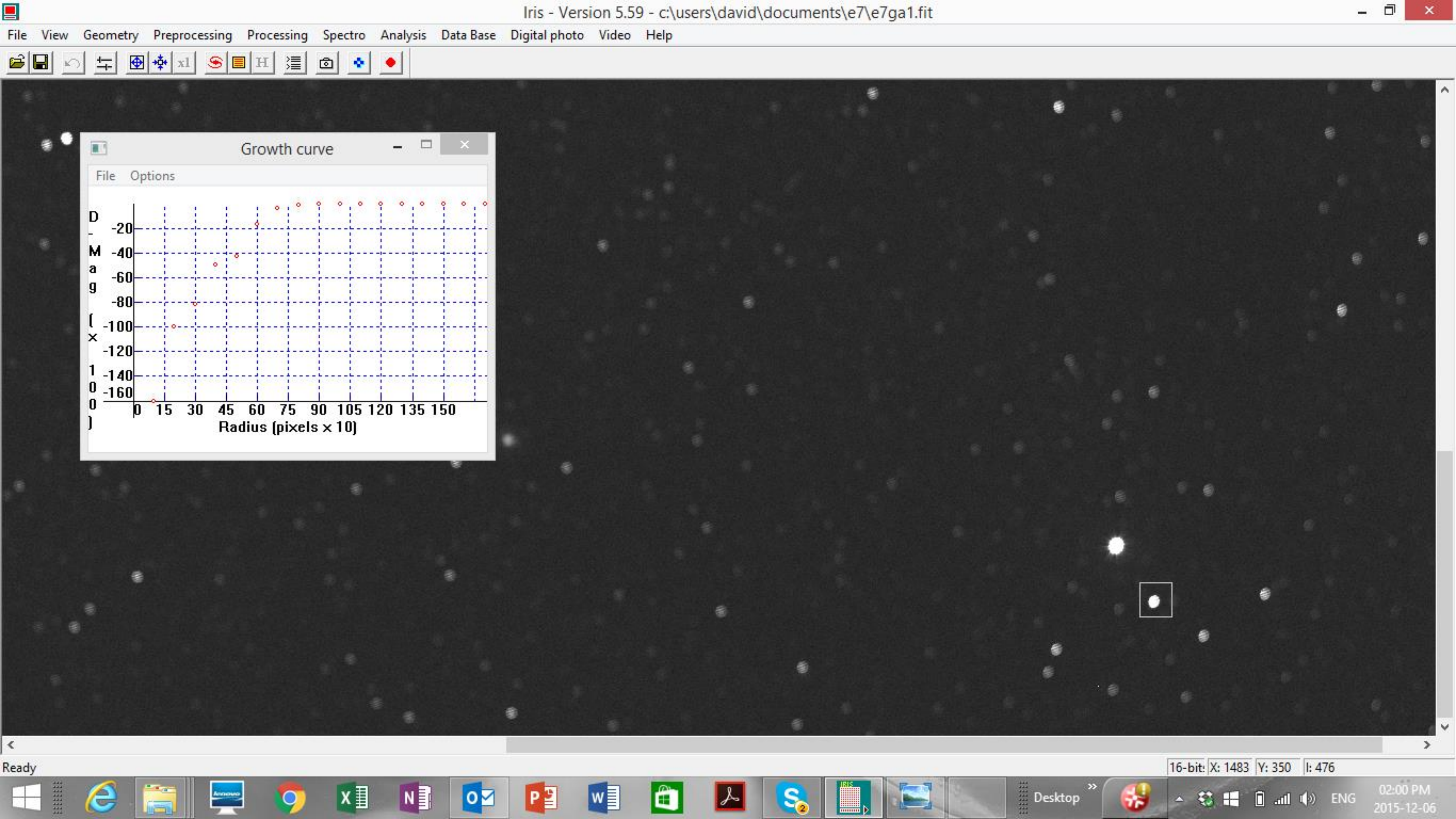
ISBN 978-1-939538-07-9

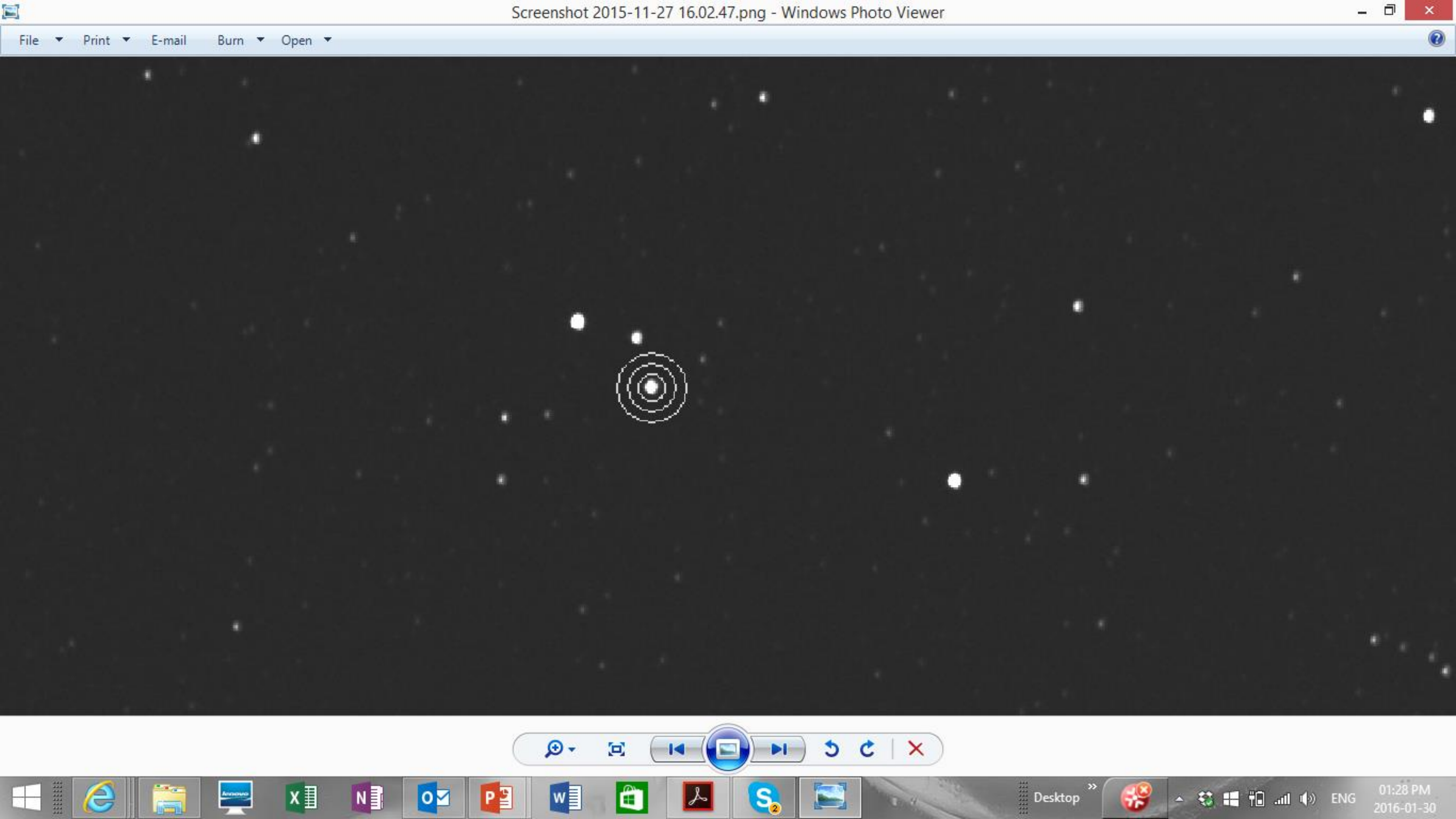
Aperture photometry

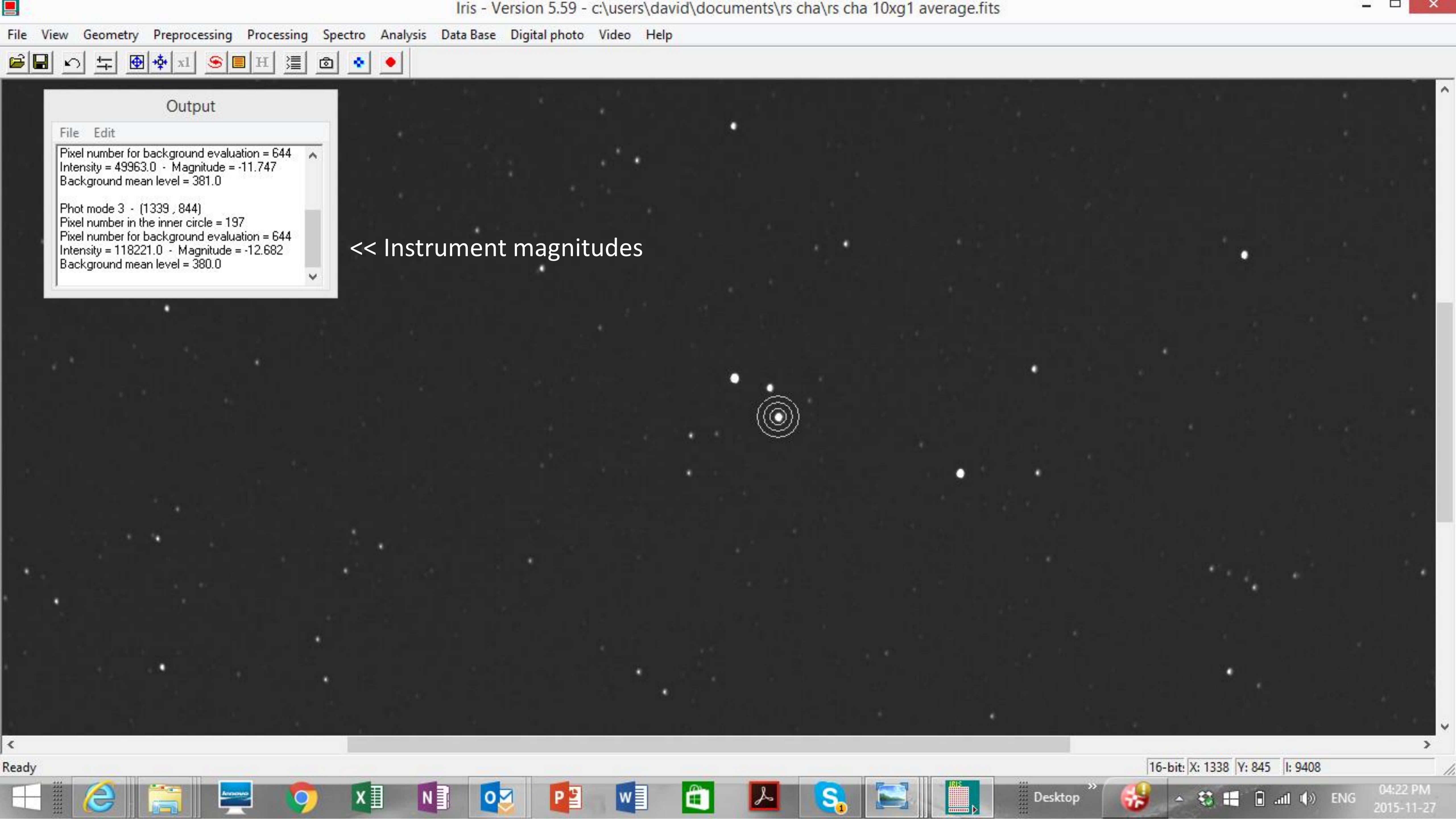




Equatorial coord. TAN
Apparent
2014-09-18
23h00m00s (EST)
Mag:10.2/20.0,2.0'
FOV:+07°30'00"
NGC 6322
C2
C3
C6
iot Ara
Chk
NGC 6352
Variable
C4
B 263
17h30m
σ
NGC 6388
θ
C1
C5
V0728 Sco
-48°00'
-47°00'
-46°00'
-45°00'
-44°00'
-43°00'
-42°00'


Iris - Version 5.59 - c:\users\david\documents\e7\e7ga1.fit
File View Geometry Preprocessing Processing Spectro Analysis Data Base Digital photo Video Help
Growth curve
File Options
D - Mag (x 100)
-20
-40
-60
-80
-100
-120
-140
-160
0 15 30 45 60 75 90 105 120 135 150
Radius (pixels x 10)
Ready
16-bit: X: 1483 Y: 350 I: 476
Desktop
ENG
02:00 PM
2015-12-06


Screenshot 2015-11-27 16.02.47.png - Windows Photo Viewer
File
Print
E-mail
Burn
Open
Desktop
ENG
01:28 PM
2016-01-30


Iris - Version 5.59 - c:\users\david\documents\rs cha\rs cha 10xg1 average.fits
File View Geometry Preprocessing Processing Spectro Analysis Data Base Digital photo Video Help
Output
File Edit
Pixel number for background evaluation = 644
Intensity = 49963.0 - Magnitude = -11.747
Background mean level = 381.0
Phot mode 3 - (1339 , 844)
Pixel number in the inner circle = 197
Pixel number for background evaluation = 644
Intensity = 118221.0 - Magnitude = -12.682
Background mean level = 380.0
<< Instrument magnitudes
Ready
16-bit: X: 1338 Y: 845 I: 9408
Desktop
ENG
04:22 PM
2015-11-27

Instrument Magnitudes

Object # 1
Object # 2
Object # 3
Object # 4
Object # 5

Time	Target	Check	#1	#2	#3
2456908.8710600	-10.543	-12.110	-12.950	-11.369	-11.700
2456908.8715741	-10.544	-12.104	-12.984	-11.372	-11.693
2456908.8720833	-10.537	-12.102	-12.954	-11.360	-11.704
2456908.8725926	-10.504	-12.097	-12.961	-11.369	-11.700
2456908.8731134	-10.570	-12.118	-12.967	-11.364	-11.696
2456908.8736227	-10.540	-12.102	-12.977	-11.354	-11.690
2456908.8741319	-10.567	-12.101	-12.973	-11.332	-11.702
2456908.8746412	-10.501	-12.114	-12.965	-11.371	-11.693
2456908.8751505	-10.510	-12.091	-12.965	-11.366	-11.693
2456908.8756713	-10.538	-12.093	-12.975	-11.361	-11.695

Object # 6
Object # 7
Object # 8

	#4	#5	#6
2456908.8710600	-11.441	-10.703	-12.178
2456908.8715741	-11.438	-10.727	-12.199
2456908.8720833	-11.468	-10.639	-12.218
2456908.8725926	-11.468	-10.696	-12.205
2456908.8731134	-11.447	-10.703	-12.198
2456908.8736227	-11.451	-10.721	-12.204
2456908.8741319	-11.432	-10.693	-12.200
2456908.8746412	-11.441	-10.735	-12.197
2456908.8751505	-11.449	-10.690	-12.183
2456908.8756713	-11.451	-10.691	-12.215

AAVSO Variable Star Plotter
Photometry for S CAR

AUID	RA	Dec	Label	V	B-V	Comments
000-BBR-306	10:17:04.98 [154.27075195°]	-61:19:56.3 [-61.33230591°]	**34**	3.400 (0.100)[22]	1.540 (0.173)	
000-BBR-115	10:03:34.12 [150.89216614°]	-61:53:02.5 [-61.88402939°]	**61**	6.140 (0.100)[22]	-0.040 (0.173)	BINO_COMP
000-BKS-909	10:02:49.41 [150.70587158°]	-62:09:24.0 [-62.1566658°]	**64**	6.404 (0.030)[20]	1.703 (0.045)	BINO_COMP, slightly variable (6.38-6.43), only for visual use
000-BBR-233	10:13:21.18 [153.33825684°]	-61:39:31.8 [-61.65883255°]	**64**	6.410 (0.100)[22]	-0.110 (0.173)	
000-BKS-915	10:05:44.28 [151.43449402°]	-61:10:20.3 [-61.17230606°]	**70**	7.045 (0.015)[20]	1.440 (0.021)	BINO_COMP
000-BJJ-642	10:07:03.08 [151.76283264°]	-61:12:52.4 [-61.21455383°]	**72**	7.163 (0.032)[1]	0.074 (0.057)	BINO_COMP
000-BBR-226	10:11:49.85 [152.95770264°]	-61:32:31.0 [-61.5419426°]	**72**	7.173 (0.032)[1]	-0.096 (0.057)	
000-BKS-916	10:08:55.27 [152.23028564°]	-61:11:32.9 [-61.19247055°]	**75**	7.494 (0.020)[20]	1.080 (0.032)	BINO_COMP
000-BJJ-643	10:11:14.67 [152.81112671°]	-61:46:06.1 [-61.76836014°]	**75**	7.460 (—)[20]	1.070 (—)	HD 88624,NSV 4778 #VSP_VOLUME_01.TXT NOMAD ID:0282-0189836 8.519T 7.464T 6.810B 0.11
000-BKS-917	10:05:08.23 [151.2842865°]	-61:40:54.4 [-61.68177795°]	**78**	7.765 (0.016)[12]	1.626 (0.030)	BINO_COMP
000-BBR-201	10:08:13.93 [152.05804443°]	-61:45:38.8 [-61.76077652°]	**80**	7.977 (0.032)[1]	1.028 (0.059)	BINO_COMP

AAVSO

American Association of Variable Star Observers

Home / VSP / Table

Variable Star Plotter

- Plot Another Chart
- Star Chart for this Table

Field photometry **for S CAR** from the AAVSO Variable Star Database

Data includes all comparison stars within 3.5° of RA: **10:09:21.89 [152.34121°]** & Dec: **-61:32:56.4 [-61.549°]**

Report this sequence as **X15939BCB** in the chart field of your observation report.

AUID	RA	Dec	Label	V	B-V	Comments
000-BBR-306	10:17:04.98 [154.27075195°]	-61:19:56.3 [-61.33230591°]	**34**	3.400 (0.100)[22]	1.540 (0.173)	
000-BBR-462	10:27:52.73 [156.9697113°]	-58:44:21.9 [-58.73941422°]	**38**	3.820 (0.100)[22]	0.310 (0.173)	
000-BBQ-615	09:39:21.00 [144.8374939°]	-61:19:41.0 [-61.32805634°]	**45**	4.520 (0.100)[22]	-0.070 (0.173)	BINO_COMP
000-BBR-573	10:38:44.99 [159.68745422°]	-59:10:58.8 [-59.18299866°]	**47**	4.660 (0.100)[22]	1.480 (0.173)	
000-BBR-	10:36:20.52	-59:33:51.8	**51**	5.075	1.174	BINO_COMP

Comparison star details

B5 | -26.533

Observation Information		Star Calibration Data	Target	Check	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5	Comp 6
Observer	Dave Blane	Star ID	HD 157487	HD 157316	HD 159707	HD 156236	HD 156623	HD 157795	HD 159384	HD 156398
Time Zone correction	0	RA (deg)	261.420	261.180	264.535	259.675	260.211	261.886	264.173	259.853
Observatory	Coordinates (deg)	DEC (deg)	-44.779	-45.008	-42.880	-46.799	-45.421	-43.543	-44.879	-44.223
Latitude	-26.5330	V Cat		6.656	6.091	7.213	7.252	7.254	7.383	6.644
Longitude	28.0050	(B – V) Cat	1.248	0.382	-0.069	0.624	0.088	0.430	1.432	0.232
		(V – R) Cat	0.625	0.223	-0.017	0.415	0.029	0.254	0.764	0.134

Instrumental Magnitudes	Image		Blue Channel Instrumental Magnitudes								Green Channel Instrumental Magnitudes							
	No.	JD	Target	Check	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5	Comp 6	Target	Check	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5	C
	1																	
	2																	
	3																	
	4																	
	5																	
	6																	
	7																	
	8																	
	9																	
	10																	
	11																	
	12																	
	13																	
	14																	
	15																	
	16																	
	17																	
	18																	
	19																	
	20																	

ASSA

Atmospheric extinction.

With a few precautions CCD photometrists imaging through a medium to long focal length telescope can safely ignore the effects of atmospheric extinction.

This is not always true for DSLR photometrists using a standard or telephoto lens where the relatively wide field of view can lead to significant differences in airmass across the image.

Calculation spreadsheet from AAVSO

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	
42	0 = None					Quality Check									
43	1 = Transformation (Tx)						Target	Check	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5	Comp 6	
44	2=Tx & Extinction (Ex)					Comp Star	HD 157487	HD 157316	HD 159707	HD 156236	HD 156623	HD 157795	HD 159384	HD 156398	
45	1					Fit Value	7.647	6.652	6.072	7.218	7.258	7.272	7.374	6.643	
46	Photometry Filter					Residual		0.004	0.019	-0.005	-0.006	-0.018	0.009	0.001	
47	1 = B					ABS(Residual)		0.004	0.019	0.005	0.006	0.018	0.009	0.001	
48	2 = V						comparison stars fit error (max)		0.019						
49	3 = R						check star mag error		0.004						
50	2						Air mass plausibility check		OK						
51															Helpe
52	Average Image Data	Target Star		Check Star			HD 157487	HD 157316	HD 159707	HD 156236	HD 156623	HD 157795	HD 159384	HD 156398	
53		Air Mass	Transformed V Mag	Air Mass	Transformed V Mag	JD	Target	Check	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5	Comp 6	JD
54	average	1.030	7.647	1.032	6.652	2456908.87336	-11.199	-12.319	-12.964	-11.718	-11.756	-11.693	-11.445	-12.350	24569
55	Stdev			V Cat - V Mag	0.004	stdev	0.007	0.007	0.008	0.006	0.009	0.007	0.010	0.011	
56						instr. b-v	0.663	0.216	-0.003	0.356	0.059	0.244	0.745	0.150	
57															
58	Individual Image Data	Target Star		Check Star						Instrumental Magnitudes					Helpe
59		average	7.647	average	6.652										
60		Stdev	0.007	Stdev	0.007										
61				V Cat - V Mag	0.004										
62	Image						HD 157487	HD 157316	HD 159707	HD 156236	HD 156623	HD 157795	HD 159384	HD 156398	
63	No.	Air Mass	Transformed V Mag	Air Mass	Transformed V Mag	JD	Target	Check	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5	Comp 6	JD
64	1	1.029	7.641	1.030	6.655	2456908.87106	-11.205	-12.317	-12.954	-11.724	-11.768	-11.690	-11.441	-12.349	24569
65	2	1.029	7.652	1.030	6.652	2456908.87157	-11.194	-12.319	-12.977	-11.713	-11.771	-11.700	-11.431	-12.362	24569
66	3	1.029	7.644	1.031	6.654	2456908.87208	-11.202	-12.317	-12.957	-11.707	-11.757	-11.688	-11.438	-12.365	24569
67	4	1.030	7.646	1.031	6.651	2456908.87259	-11.200	-12.320	-12.956	-11.728	-11.752	-11.698	-11.454	-12.344	24569
68	5	1.030	7.648	1.031	6.642	2456908.87311	-11.198	-12.329	-12.955	-11.712	-11.756	-11.685	-11.435	-12.348	24569
69	6	1.031	7.644	1.032	6.649	2456908.87362	-11.202	-12.322	-12.969	-11.720	-11.760	-11.702	-11.445	-12.346	24569
70	7	1.031	7.662	1.032	6.646	2456908.87413	-11.184	-12.325	-12.972	-11.721	-11.759	-11.686	-11.450	-12.351	24569
71	8	1.031	7.655	1.033	6.647	2456908.87464	-11.191	-12.325	-12.967	-11.722	-11.751	-11.681	-11.463	-12.343	24569
72	9	1.032	7.639	1.033	6.665	2456908.87515	-11.207	-12.307	-12.965	-11.714	-11.745	-11.700	-11.441	-12.331	24569
73	10	1.032	7.640	1.033	6.660	2456908.87567	-11.206	-12.311	-12.974	-11.717	-11.743	-11.698	-11.451	-12.362	24569
74	11														

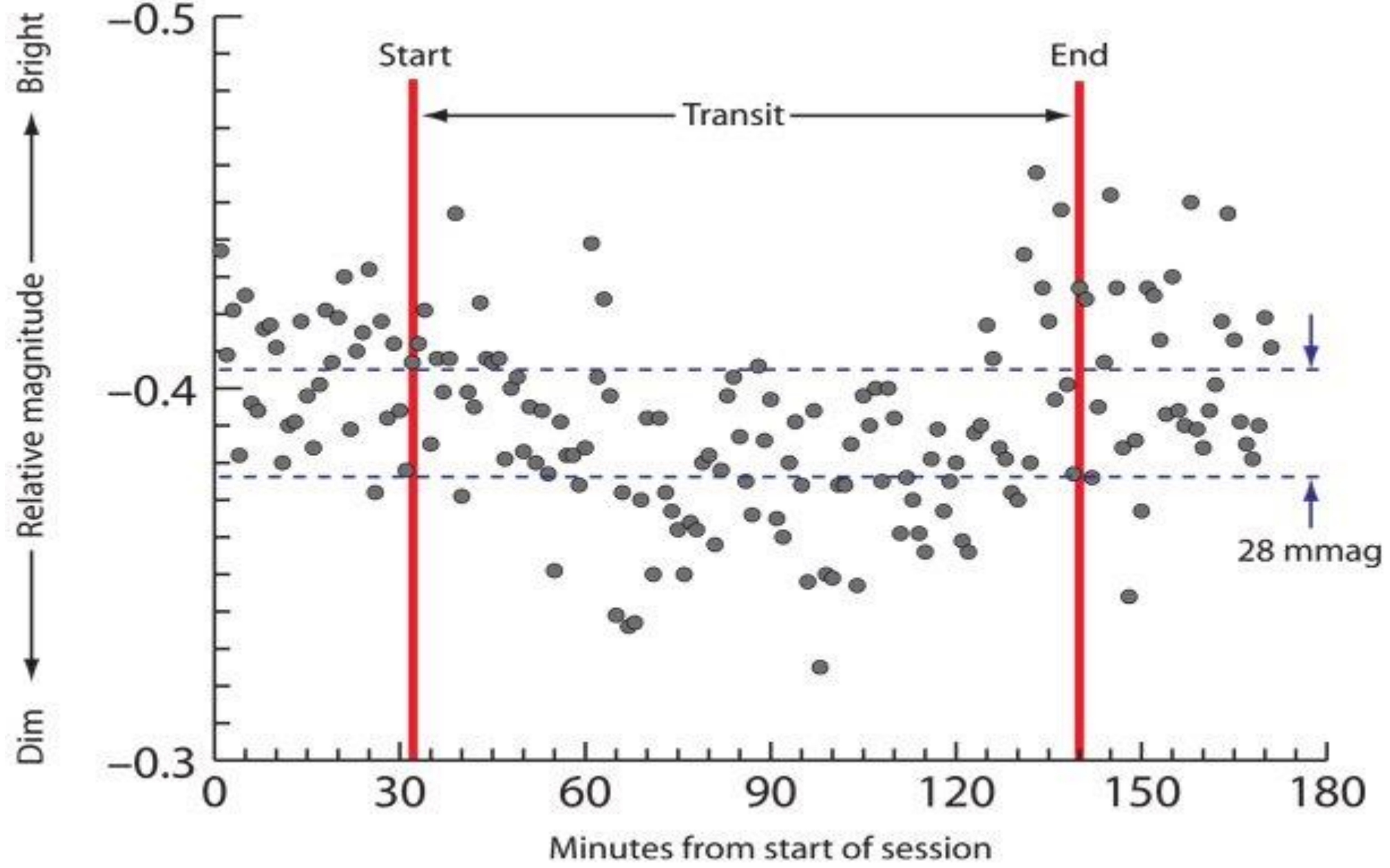
Data | Calculations | Conversions | U Aql | E7 Region

How accurately should the time be recorded?

TYPE OF STAR	OBSERVING FREQUENCY	REPORT JD TO
Cepheids	Every clear night	4 decimal places
Cataclysmic var.	Every clear night	4 decimal places
Mira variables	Once per week	1 decimal place
Semiregular	Once per week	1 decimal place
RV Tauri stars	Once per week	1 decimal place
Symbiotic stars*	Once per week	1 decimal place
R CrB* stars	During maximum once per week	1 decimal place
R CrB stars	During fadings every clear night	4 decimal places
Irregular variables	Once per week	1 decimal place
Suspected variables	Every clear night	4 decimal places
Flare stars	Continuously for 10 to 15 minutes for rare outbursts.	4 decimal places
Eclipsing binaries	Every 10 minutes during eclipse	4 decimal places
RR Lyrae stars	Every 10 minutes	4 decimal places

Note: Symbiotic stars and R CrB stars may experience possible small-magnitude, short-period variability. If you are interested in looking for this, then observations should be made every clear night and reported to 4 decimal places.

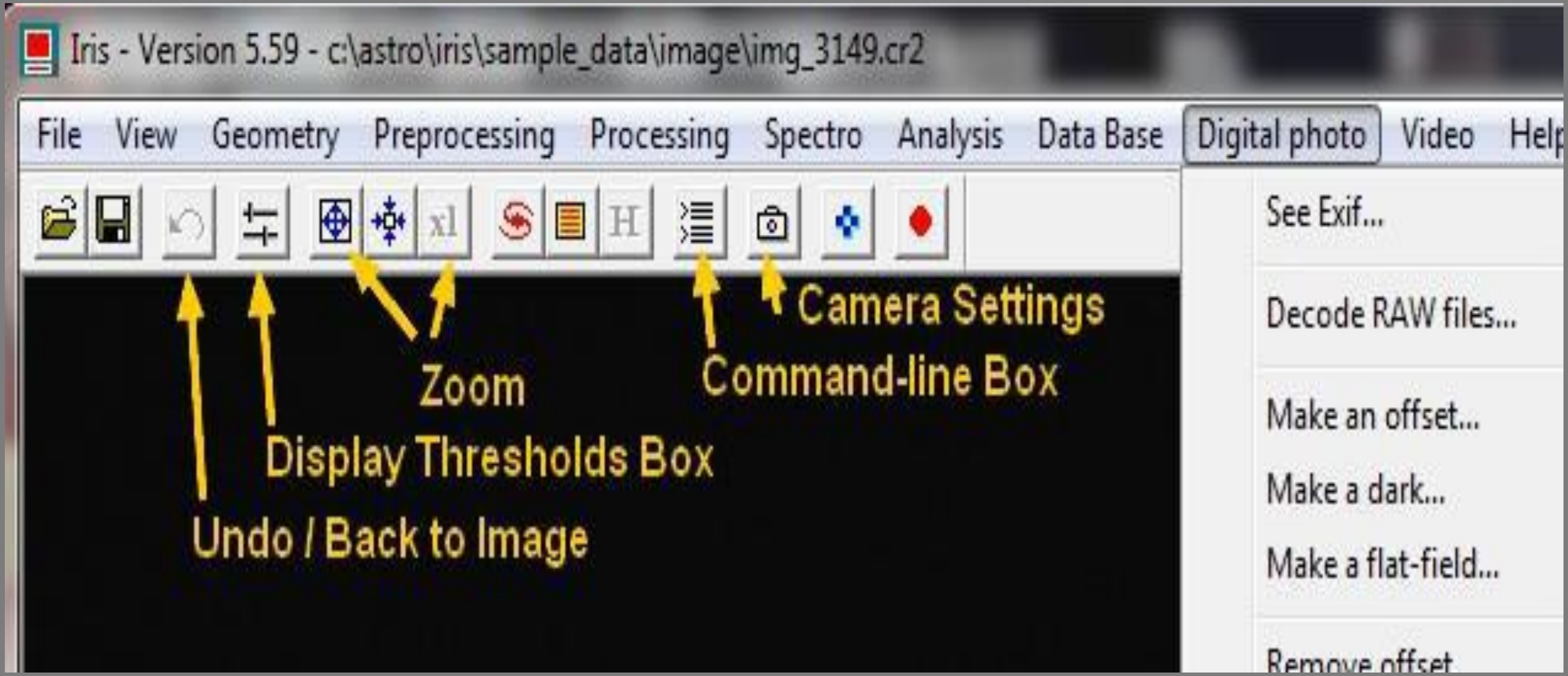
Equipment required to detect an exoplanet!



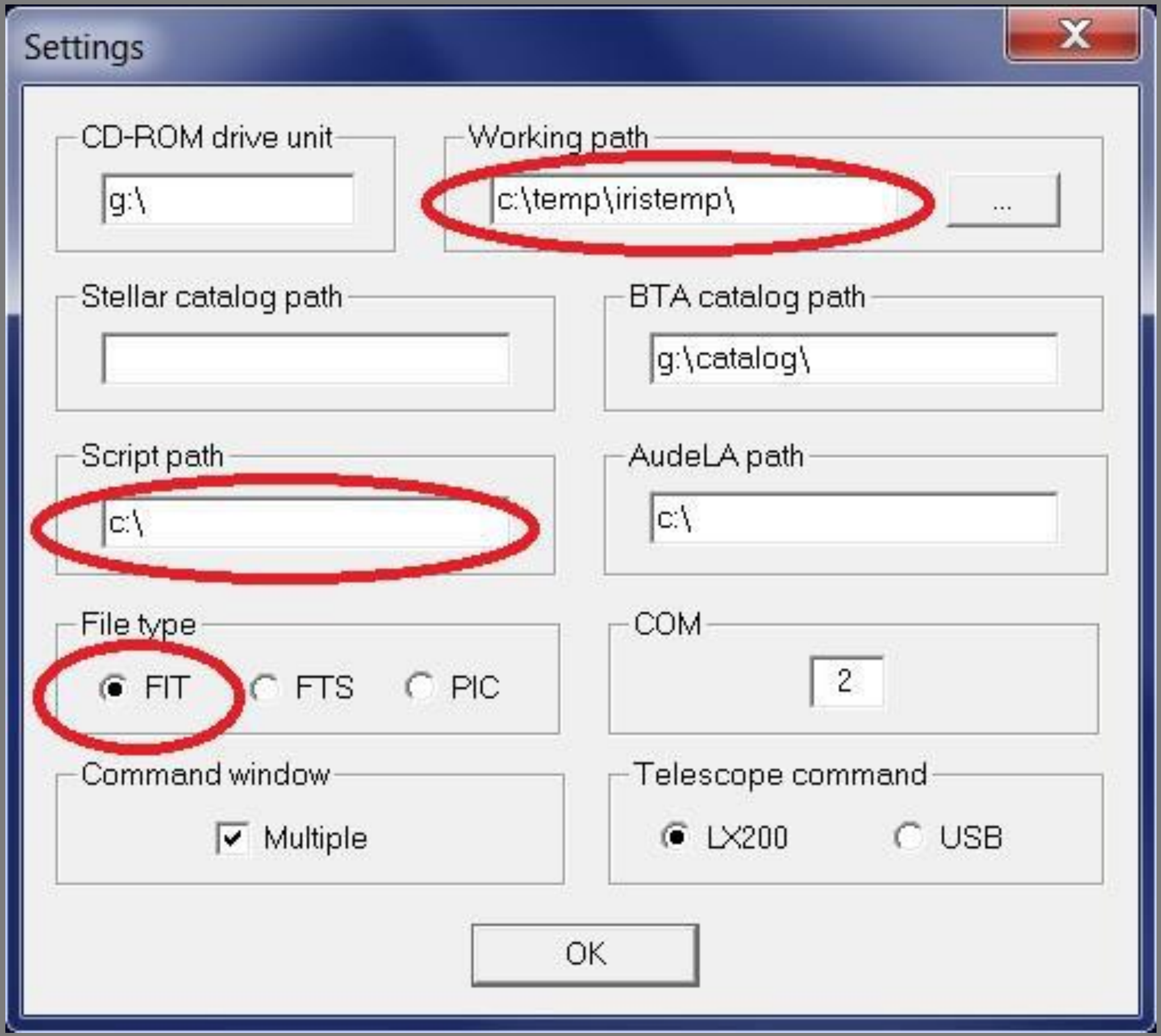
Bright
Relative magnitude
Dim
−0.5
−0.4
−0.3
Start
End
Transit
28 mmag
0
30
60
90
120
150
180
Minutes from start of session

<u>*HD 189733*</u>

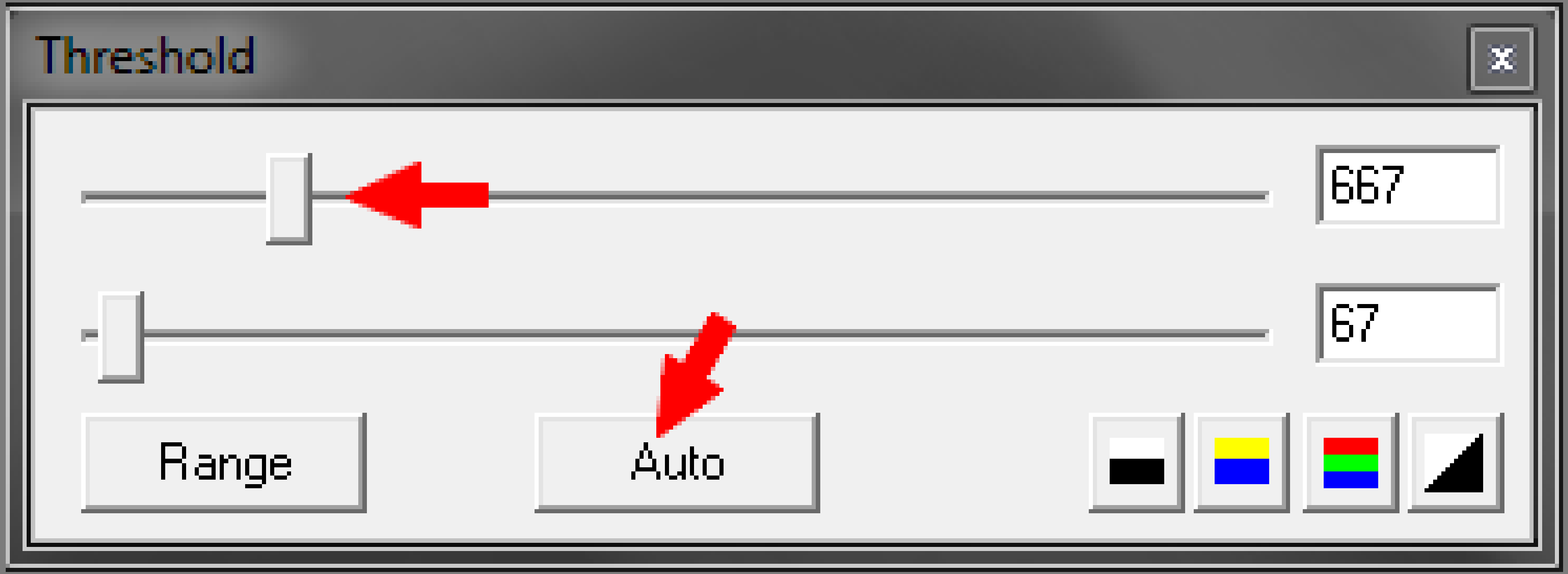
AAVSO DSLR Photometry Course


Iris - Version 5.59 - c:\astro\iris\sample_data\image\img_3149.cr2
File
View
Geometry
Preprocessing
Processing
Spectro
Analysis
Data Base
Digital photo
Video
See Exif...
Decode RAW files...
Make an offset...
Make a dark...
Make a flat-field...
Camera Settings
Command-line Box
Zoom
Display Thresholds Box
Undo / Back to Image

Choose your working path (where you have COPIES of your raw image files).

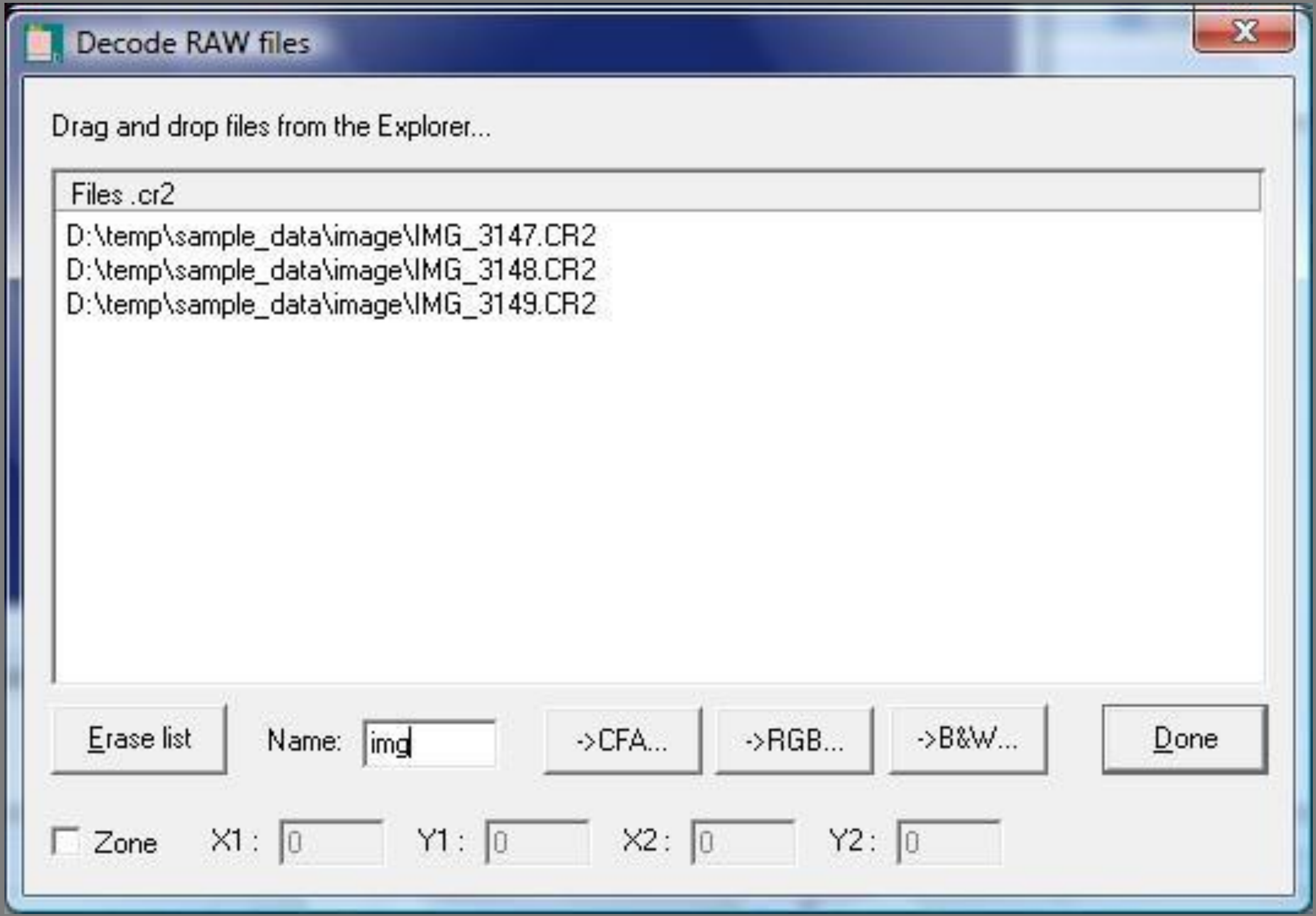


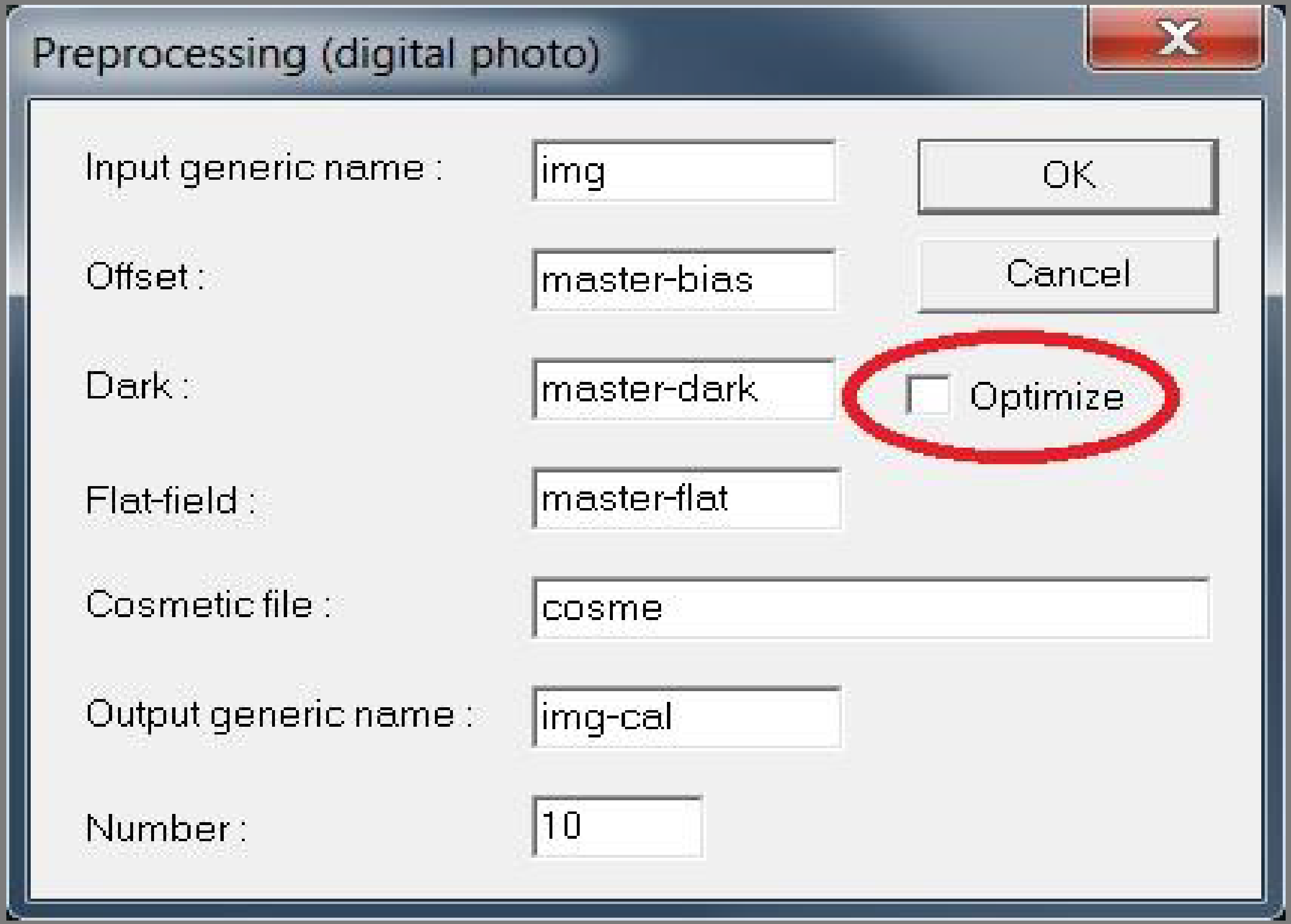
Threshold settings

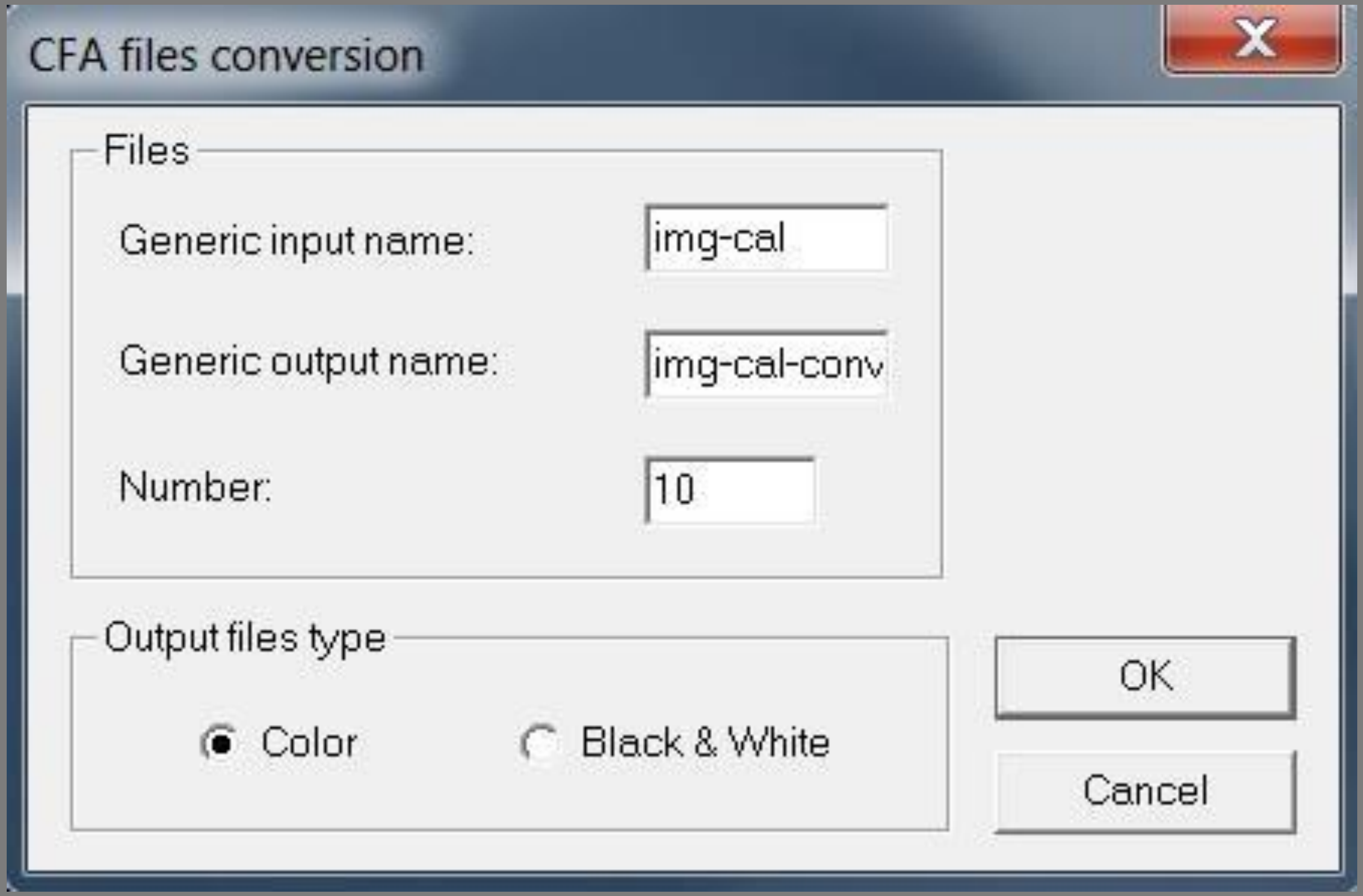



Make an offset
Generic name :
bias
Number :
3
OK
Cancel
Command
>save master-bias
>save master-flat
>save master-dark
>

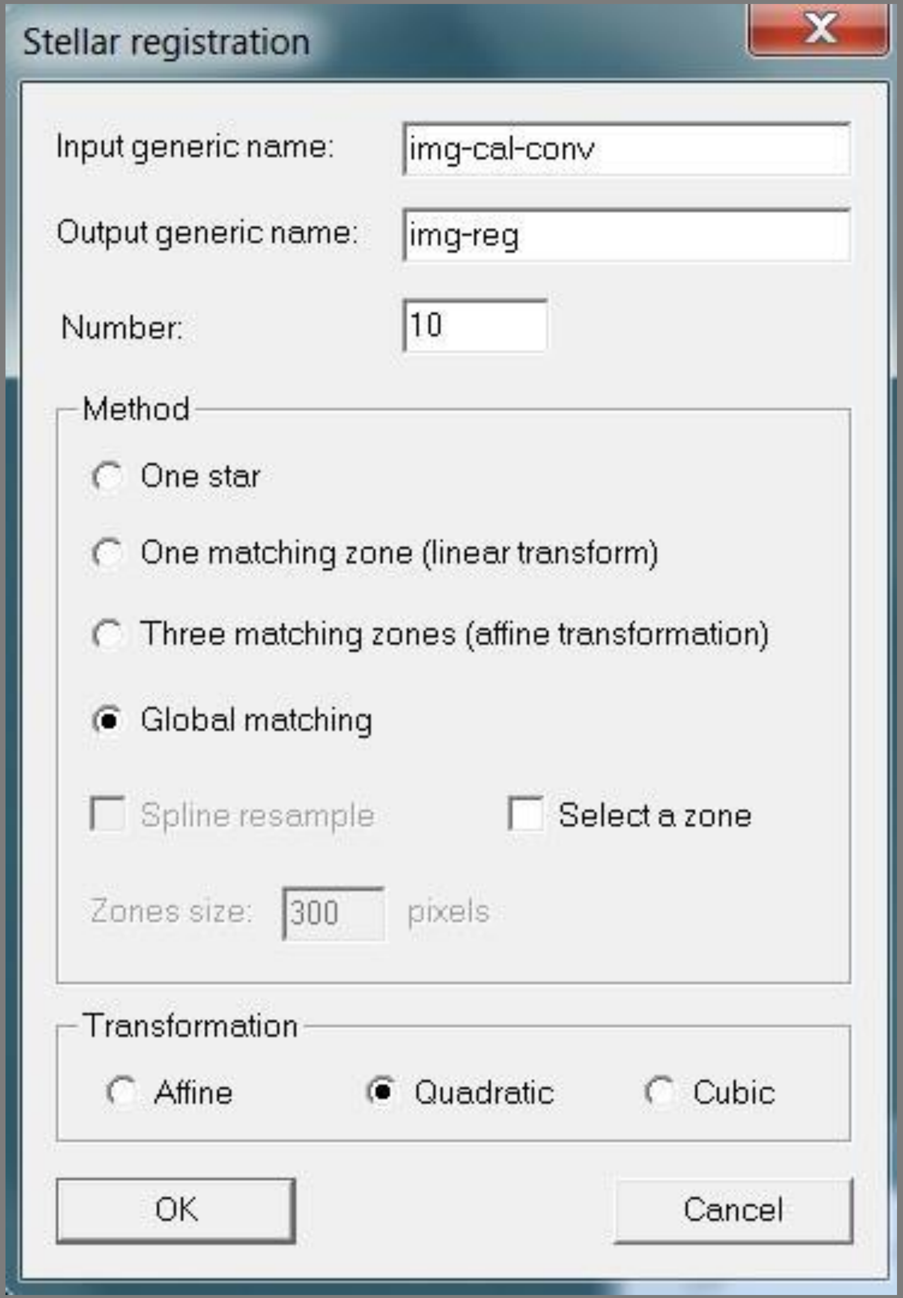
Converting a Sequence of Raw Image Files



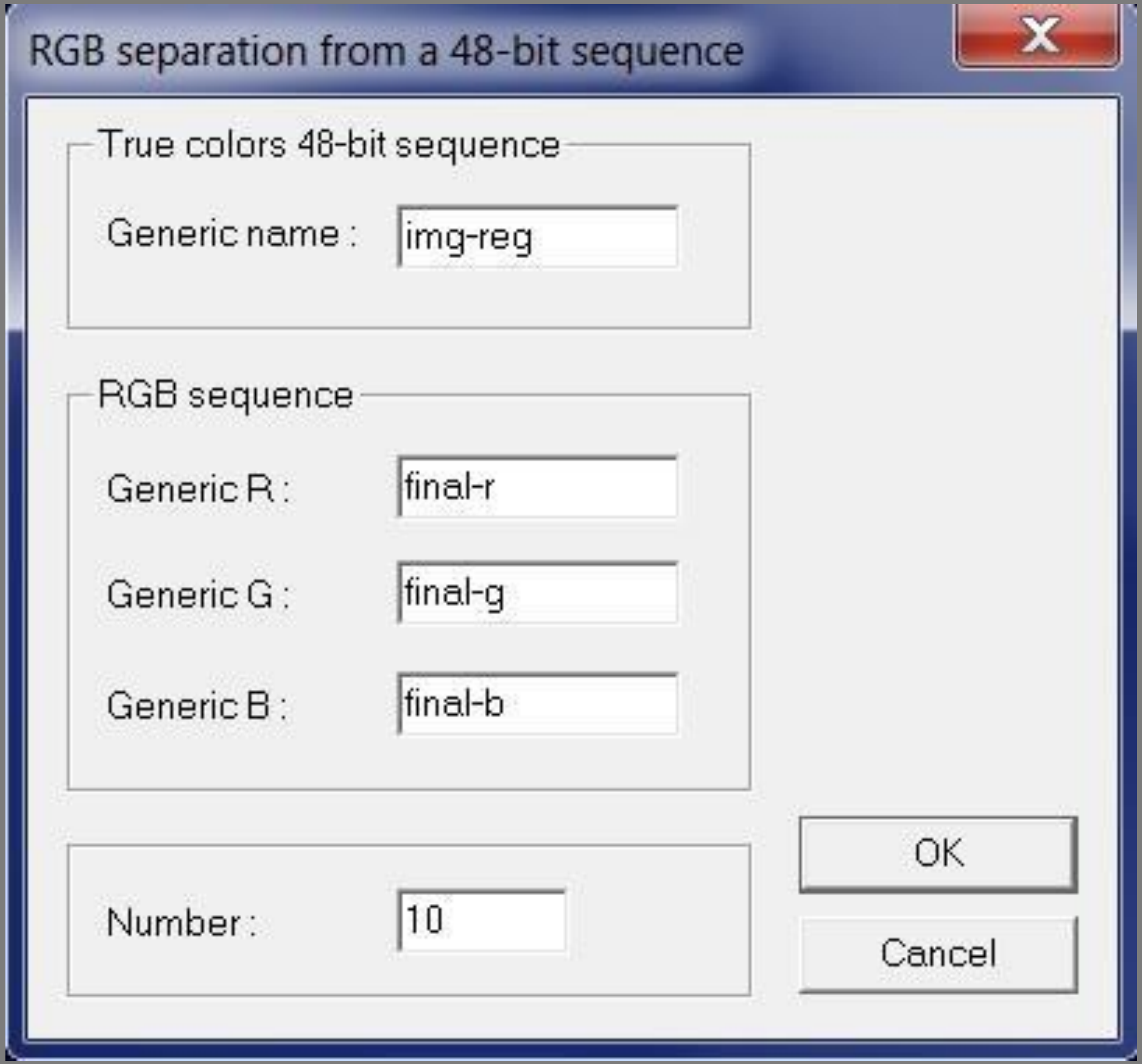

Preprocessing (digital photo)
Input generic name :
img
OK
Offset :
master-bias
Cancel
Dark :
master-dark
Optimize
Flat-field :
master-flat
Cosmetic file :
cosme
Output generic name :
img-cal
Number :
10


CFA files conversion
Files
Generic input name:
img-cal
Generic output name:
img-cal-conv
Number:
10
Output files type
Color
Black & White
OK
Cancel

This step identifies the same stars in each image and determines what translations and/or rotations are required to align them.



Sequence RGB separation



https://www.aavso.org/webobs/individual

Enter Observations Individu...

- Submit an Observation
- Upload a File
- Search for Observations

DSLR Observation

Observer Code: BLD

Your official AAVSO Observer Initials.

Star Identifier:* Variable

The name, desig, or AUID of the star you observed. More help...

Date/Time of Observation:* 2456908.87336

Exact time of observation in JD or yyyy/mm/dd/hh/mm/ss format. More help...

☐ Check this box if your date is in HJD. More help...

Magnitude:* 7.647

Magnitude of the variable star. A decimal point is required. More help...

☐ Check this box if your magnitude is a *fainter-than*.

☑ Check this box if your magnitude is *transformed*.

Mag Error: 0.007

Magnitude Error. More help...

Filter:* Johnson V

Chart ID:* E7 region

Label on chart used to make observation. More help...

Comment codes: ☐ B ☐ U ☐ W ☐ L ☐ D ☐ Y ☐ K ☐ S ☐ Z ☐ I ☐ V

Optional field. Check as many that apply. More help...

Comp Label:*	Comp Mag:*	Check Label:*	Check Mag:*
ensemble			

Comparison and Check Star Labels and Mags. More help...

Popular Web Tools

- **WebObs** - Search the AID or Submit data
- **VSP** - Variable Star Plotter
- **LCG** - Light Curve Generator
- **VSX** - Variable Star Index

Desktop ENG 06:20 PM 2015-12-07

IN CONCLUSION

Amateurs using nothing more than everyday photographic equipment and some specialized software can participate in observing programmmes of bright variable stars.

DSLR photometry opens up for visual observers the many bright stars that vary by less than 0.5 magnitude.

With some extra care, DSLR cameras have the precision to detect small magnitude changes due to events such as exoplanet transits.

Just one of many ways for amateurs to fill in the gaps where professional astronomers do not have the resources.

The material for this training session was largely based on :

The AAVSO DSLR Observing Manual

The AAVSO DSLR Observing Manual - Supplemental Information Photometry Software Calibration and Photometry Tutorials.

The calculation software spreadsheet and other spread sheets were produced by Mark Blackford of the AAVSO

The AAVSO DSLR Observing Manual

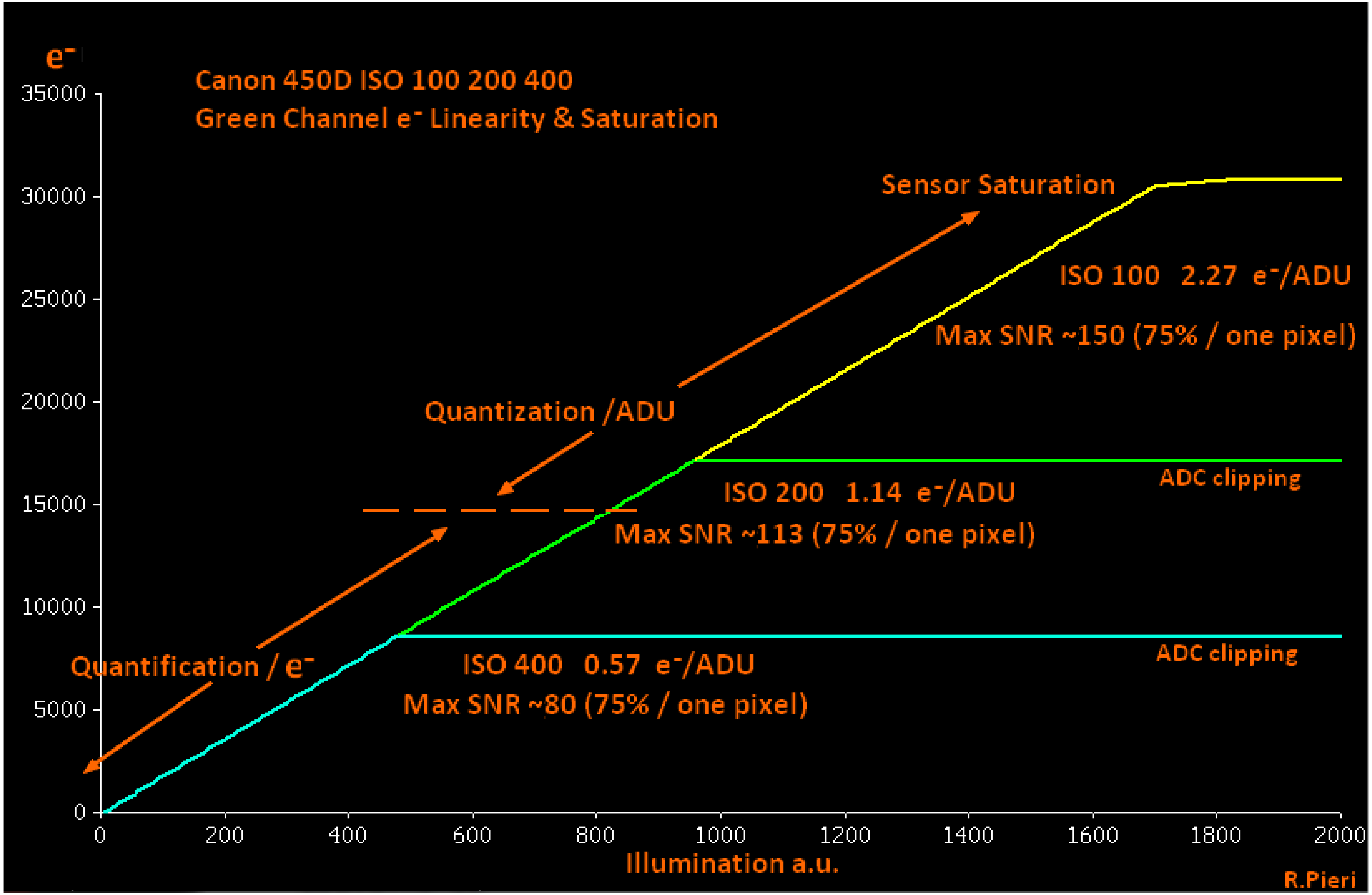
AAVSO
49 Bay State Road
Cambridge, MA 02138
email: aavso@aavso.org

Version 1.4

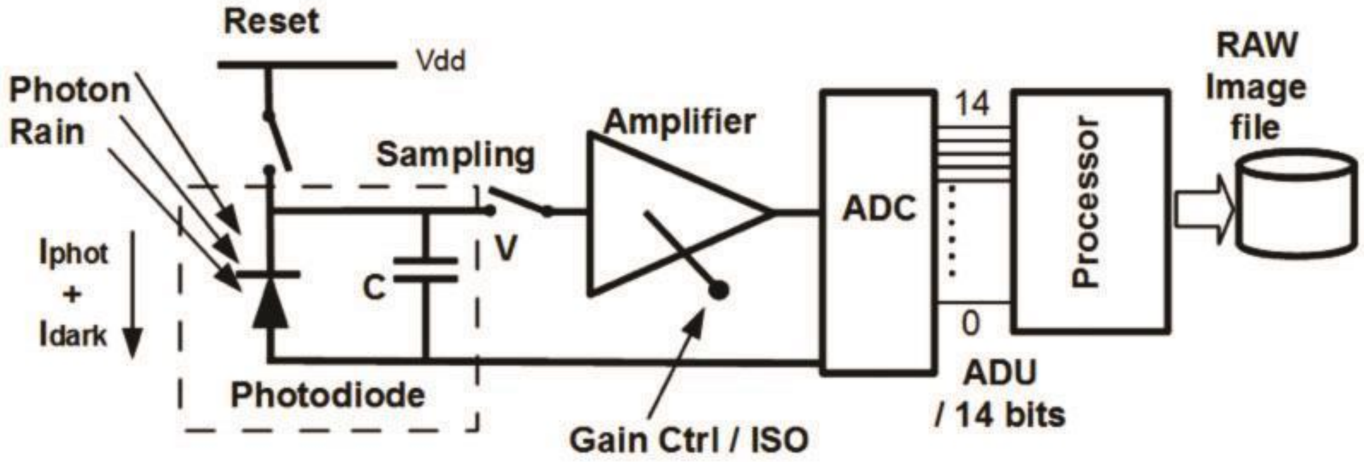
ISBN 978-1-939538-07-9

www.aavso.org/dslr-observing-manual

END Part 2

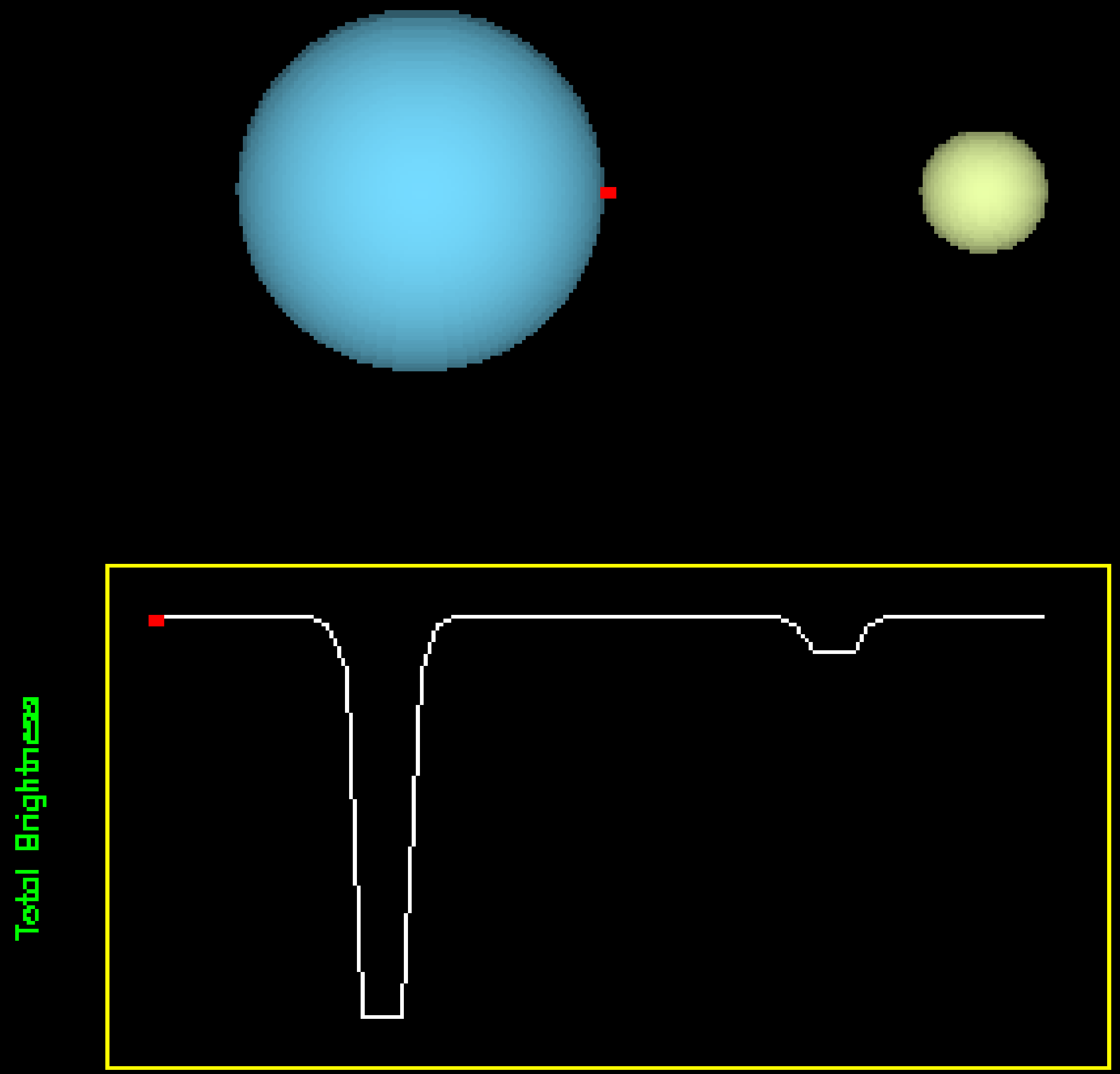


e⁻
Canon 450D ISO 100 200 400
Green Channel e⁻ Linearity & Saturation
Sensor Saturation
ISO 100 2.27 e⁻/ADU
Max SNR ~150 (75% / one pixel)
Quantization /ADU
ADC clipping
ISO 200 1.14 e⁻/ADU
Max SNR ~113 (75% / one pixel)
ADC clipping
Quantification / e⁻
ISO 400 0.57 e⁻/ADU
Max SNR ~80 (75% / one pixel)
35000
30000
25000
20000
15000
10000
5000
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Illumination a.u.
R.Pieri

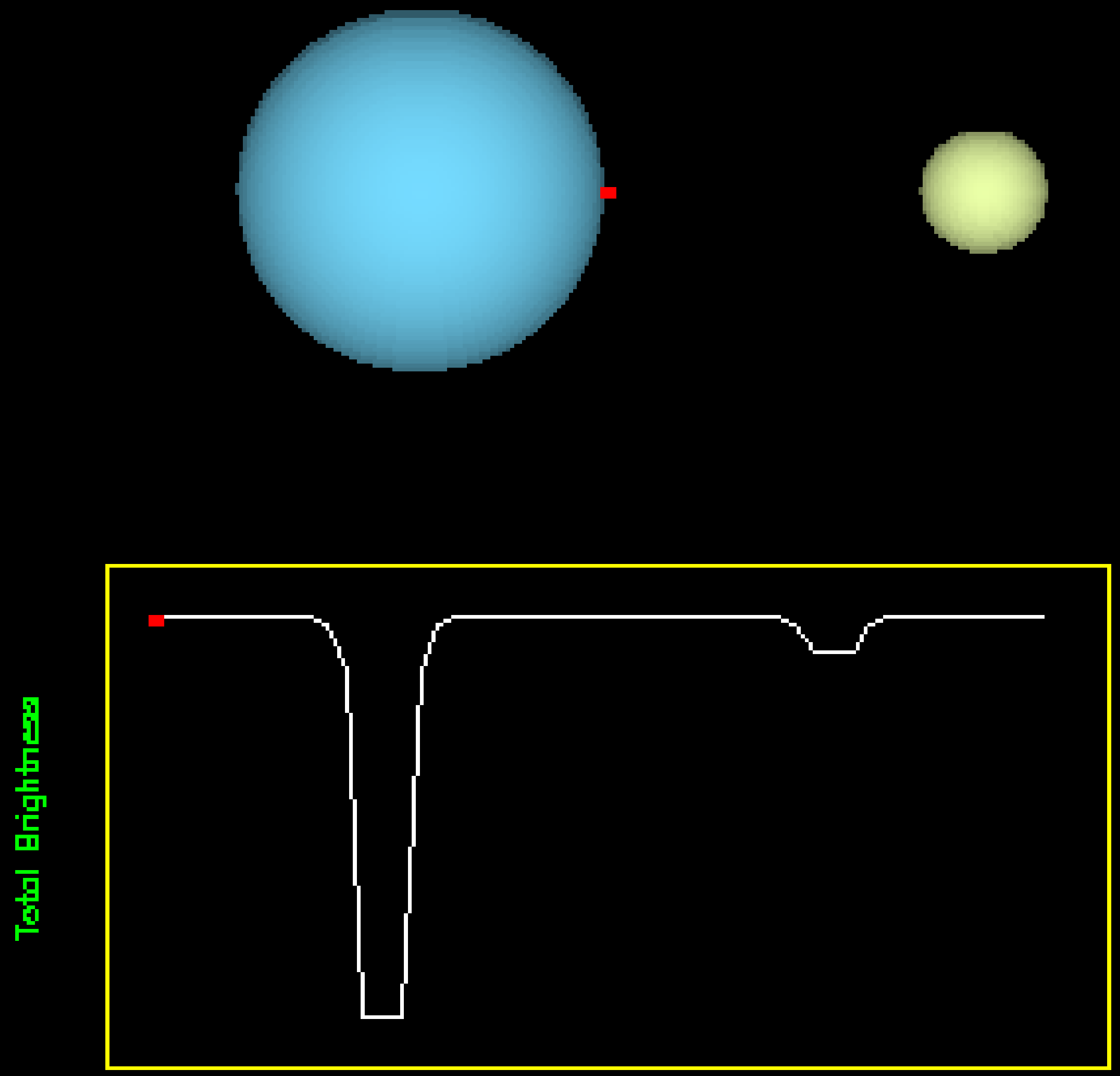


Schematic representation of the components of a CMOS detector


THE
IMAGING
SOURCE


Total Brightness

Photometry, in astronomy, is the measurement of the brightness of stars and other celestial objects such as nebulae, galaxies, planets and asteroids



Timing of eclipsing binaries

American Association of Variable Star Observers

Proudly recognizes and certifies that

David Blane (BLD)

has successfully completed the
Carolyn Hurless Online Institute for Continuing Education
course requirements for

DSLR Photometry

Awarded this 9th day of December, 2015

Stella Kafka, Director

To properly account for these effects, you must take a series of calibration frames and perform a number of mathematical operations on your science frames including subtraction of bias and dark frames to remove the fixed-component noise and division of the resulting image by a flat frame to remove the effects of vignetting and pixel-to-pixel sensitivity variations as well as dust shadows.

Master flat frame