

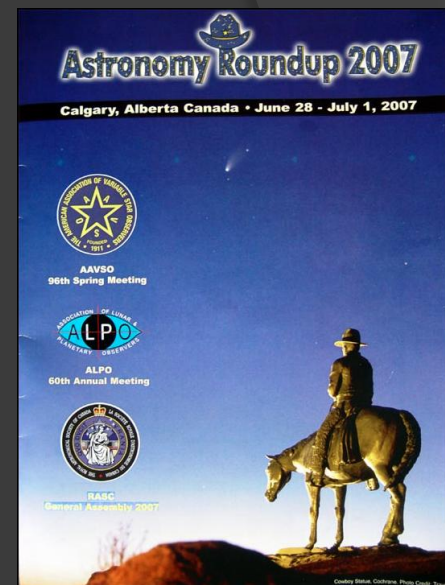
LESVEPHOTOMETRY

AN AUTOMATIC PHOTOMETRY SOLUTION
BASED ON A COMPARISON STAR DATABASE

LesvePhotometry

First ideas

- ◎ RASC – AAVSO Calgary 2007
 - presentation of preliminary version of VPHOT ancestor
 - → I started a first version based on Microsoft ACCESS database
- ◎ SAS – CBA - AAVSO Big Bear 2009
 - big impulse from Josch Hamsch and Tom Krajci



Automatic Photometry

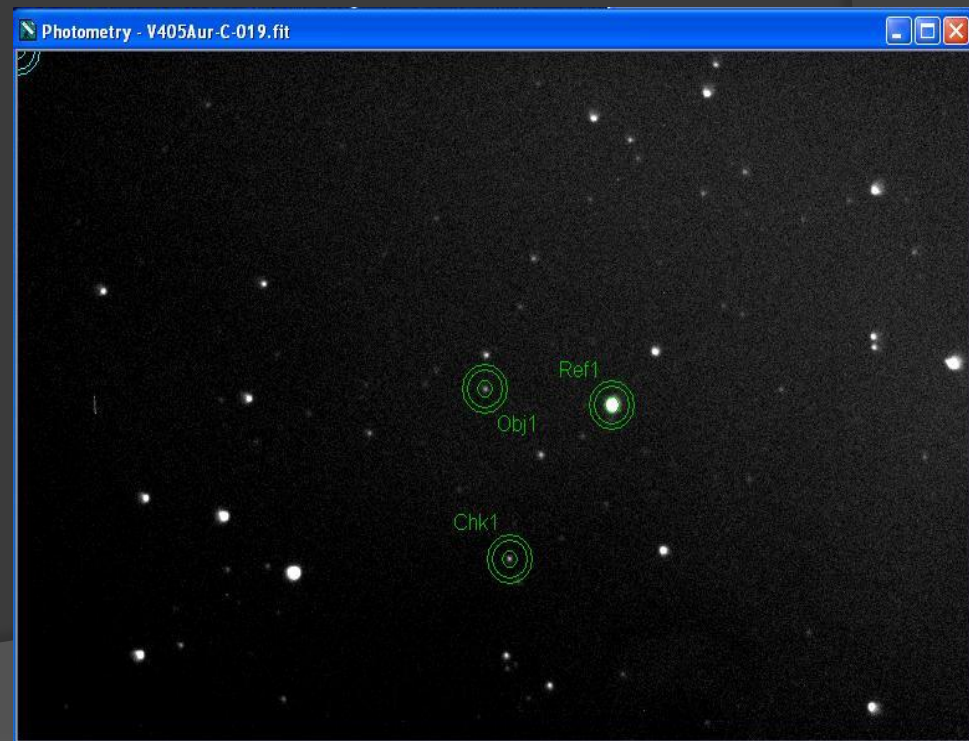
Why?

- ◎ Better reliability
 - less prone to mistakes
 - comparison stars are in a database
- ◎ Faster
- ◎ Easy
 - avoid tedious tasks
 - no need to look for a star chart at each session
 - stars are identified by the program and comparison star magnitudes are extracted from a database

With classical programs (e.g. MaximDL)

- ⦿ For each observation you need
 - sky chart (AAVSO)
 - comparison star magnitudes

- ⦿ Manually
 - identify stars
 - position aperture
 - provide comparison magnitudes



LesvePhotometry inputs

- ⦿ Sky images
 - FITS header contains all needed information
- ⦿ Comparison star database
 - easily populated from AAVSO VSP
- ⦿ Star catalogs
 - GSC
 - USNOA2, USNOB1
 - USNO UCAC2, UCAC3, UCAC4

LesvePhotometry process

- ⦿ Calibration : bias, darks, flats
 - have to be performed before calling LesvePhotometry with your favorite software
- ⦿ Detection of stars in sky image
 - using PinPoint (dc3.com \$149)
- ⦿ Astrometry
 - PinPoint – table of stars (RA, DE)
- ⦿ Differential aperture photometry
 - for variable and comparison stars
 - magnitudes, snr, airmass,...
- ⦿ Automatic generation of reports
 - AAVSO, CBA, xls
- ⦿ Interactive tool to determine maxima or minima of the light-curve

FITS header

```
SIMPLE      = T
BITPIX     = 16 /8 unsigned int, 16 & 32 int, -32 & -64 real
NAXIS      = 2 /number of axes
NAXIS1     = 1679 /fastest changing axis
NAXIS2     = 1268 /next to fastest changing axis
BSCALE     = 1.0000000000000000 /physical = BZERO + BSCALE*array_value
BZERO      = 32768.000000000000 /physical = BZERO + BSCALE*array_value
DATE-OBS   = '2019-07-08T22:29:57' / [ISO 8601] UTC date/time of exposure start
EXPTIME    = 4.800000000000E+002 / [sec] Duration of exposure
EXPOSURE   = 4.800000000000E+002 / [sec] Duration of exposure
SET-TEMP   = -35.0000000000000000 /CCD temperature setpoint in C
CCD-TEMP   = -35.0625000000000000 /CCD temperature at start of exposure in C
XPIXSZ     = 10.8000000000000001 /Pixel Width in microns (after binning)
YPIXSZ     = 10.8000000000000001 /Pixel Height in microns (after binning)
XBINNING   = 2 / Binning level along the X-axis
YBINNING   = 2 / Binning level along the Y-axis
XORGSUBF   = 0 /Subframe X position in binned pixels
YORGSUBF   = 0 /Subframe Y position in binned pixels
READOUTM   = 'Normal' / Readout mode of image
FILTER     = 'C' / Filter name
IMAGETYP   = 'Light Frame' / Type of image
FOCALLEN   = 1661.0000000000000000 /Focal length of telescope in mm
APTDIA     = 304.0000000000000000 /Aperture diameter of telescope in mm
APTAREA    = 72583.358688354492 /Aperture area of telescope in mm^2
EGAIN      = 0.370000000476837158 /Electronic gain in e-/ADU
SBSTDVER   = 'SBFITSEXT Version 1.0' /Version of SBFITSEXT standard in effect
SWCREATE   = 'MaxIm DL Version 6.20 190919 2XFUC' /Name of software
SWSERIAL   = '2XFUC-JMYVR-N3VST-WC6UY-EHJWR-NC' /Software serial number
OBJCTRA    = '16 10 02.59' / [hms J2000] Target right ascension
OBJCTDEC   = '-01 06 42.0' / [dms +N J2000] Target declination
OBJCTALT   = '33 08 00' / Nominal altitude of center of image
OBJCTAZ    = '214 15 41' / Nominal azimuth of center of image
SITELAT    = '50 23 00' / Latitude of the imaging location
SITELONG   = '04 48 00' / Longitude of the imaging location
```

missing keywords
in Header

may be defined
in a configuration file

Database : Variables stars

- SQLite.Net database engine is embedded in LesvePhotometry

VariableTableIndex *

AAVSOVarName *

AAVSODesignation

Chart

GSC

RA (hours sexa or dec.) *

DE (degrees sexa or dec.) *

* Mandatory

Comment

Variable Selector

- V0354VirOld
- V0360Aqr
- V0365Her
- V0378Peg
- V0386Ser**
- V0394Her
- V0405Aur
- V0421Her
- V0434Her
- V0442Her
- V0443_Her
- V0455And
- V0465Lyr
- V0559Hya
- V0603Aql
- V0729Cyg
- V1084Her

		Usage **	Colors	V	B - V
CMP1	<input type="text" value="000-BMY-597"/>	<input type="text"/>	<input type="text" value="4"/>	<input type="text" value="12.52"/>	<input type="text" value="1.084"/>
CMP2	<input type="text" value="000-BMY-598"/>	<input type="text"/>	<input type="text" value="4"/>	<input type="text" value="12.874"/>	<input type="text" value="0.803"/>
CMP3	<input type="text" value="000-BBX-116"/>	<input type="text" value="R"/>	<input type="text" value="2"/>	<input type="text" value="15.712"/>	<input type="text" value="0.677"/>
CMP4	<input type="text" value="000-BCT-114"/>	<input type="text" value="CK"/>	<input type="text" value="2"/>	<input type="text" value="16.302"/>	<input type="text" value="0.753"/>
CMP5	<input type="text" value="000-BCT-117"/>	<input type="text" value="C"/>	<input type="text" value="2"/>	<input type="text" value="17.227"/>	<input type="text" value="0.694"/>
CMP6	<input type="text" value="000-BBX-109"/>	<input type="text"/>	<input type="text" value="2"/>	<input type="text" value="17.757"/>	<input type="text" value="0.65"/>
CMP7	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
CMP8	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
CMP9	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
CMP10	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

Save it in database

Delete it in database

New (Clear boxes)

Export this star Group

** Usage
 R for Reference star (one or more for Ensemble Photometry)
 CK for Check star (only one!)
 C for other comparison star (none or more)
 Leave it blank if this Comparison star will not be used

Get UCAC4 info from clipboard

Database : Comparison stars

VariableTableIndex * V0386Ser

AAVSOVarName * V0386 Ser

AAVSODesignation 000-BBX-111

Chart X24486BBU

GSC

RA (hours sexa or dec.) * 16:10:37.63

DE (degrees sexa or dec.) * -01:02:23.2

* Mandatory

	Usage **	Colors
CMP1 000-BMY-597		4
CMP2 000-BMY-598		4
CMP3 000-BBX-116	R	2
CMP4 000-BCT-114	CK	2
CMP5 000-BCT-117	C	2
CMP6 000-BBX-109		2
CMP7		
CMP8		
CMP9		
CMP10		

Comparison star - C:\Users\Pierre\Documents\DPP Lesve\VS_DatabaseV04.db3

AUID * 000-BBX-116

Label 157

RA * 16:10:42.33

DE * -01:00:39.1

* Mandatory

U (B-V) 0.677

B 16.389

V 15.712

R

I

SU

SG V0386Ser

SR

SI

SZ

Save it in Database

Delete it in databas

New (Clear boxes)

ComparisonStar Selector

- 000-BBC-035
- 000-BBC-036
- 000-BBC-050
- 000-BBC-090
- 000-BBC-093
- 000-BBC-095
- 000-BBC-100
- 000-BBC-102
- 000-BBC-103
- 000-BBD-456
- 000-BBD-483
- 000-BBG-333
- 000-BBG-351
- 000-BBK-212
- 000-BBK-215
- 000-BBK-216
- 000-BBK-583
- 000-BBK-587

First used in

Comment

Used with Variables :

Calculate UVBRI from Sloan magnitudes

Calculate Sloan magnitudes from UVBRI

Calculate R I and SZ, from APASS data (B,V,SG,SR,SI)

Data from Database

** Usage
 R for Reference star (one or more for Ensemble Photometr
 CK for Check star (only one!)
 C for other comparison star (none or more)
 Leave it blank if this Comparison star will not be used

Get UCAC4 info from clipboard

Populate database with embedded AAVSO VSP tool

File Help

Online results | General Settings | Photometry param | Transform param | PinPoint param | Default settings | Config Save/Load | AAVSO VSP tool

Usage	AUID	Label	B-V	U	B	V	R	I
▼	000-BBX-118	144	0.702		15.144	14.442		
R ▼	000-BCT-116	146	0.837		15.423	14.586		
▼	000-BCT-119	150	0.751		15.775	15.024		
▼	000-BCT-113	155	0.771		16.285	15.514		
▼	000-BBX-116	157	0.677		16.389	15.712		
▼	000-BCT-111	160	0.697		16.648	15.951		
CK ▼	000-BCT-114	163	0.753		17.055	16.302		
▼	000-BBX-112	168	0.699		17.52	16.821		
C ▼	000-BCT-117	172	0.694		17.921	17.227		
▼	000-BCT-115	177	0.724		18.424	17.7		
C ▼	000-BBX-109	178	0.650		18.407	17.757		

LesvePhotometry database VariableTableIndex

V0386Ser

AAVSO variable name

V0386 Ser

Field of View (in arc minutes) 20

Max mag 18 StdField

ChartID

Download VSP sequence

Import VSP sequence in database

Variable name V0386 Ser

AUID 000-BBX-111

Ra 16:10:33.63

Dec -01:02:23.2

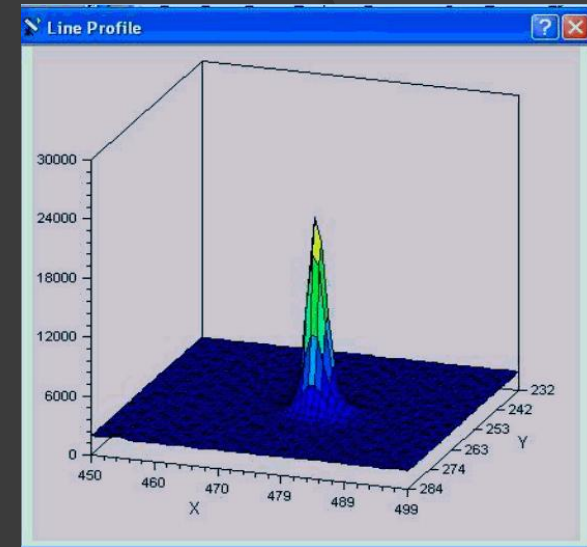
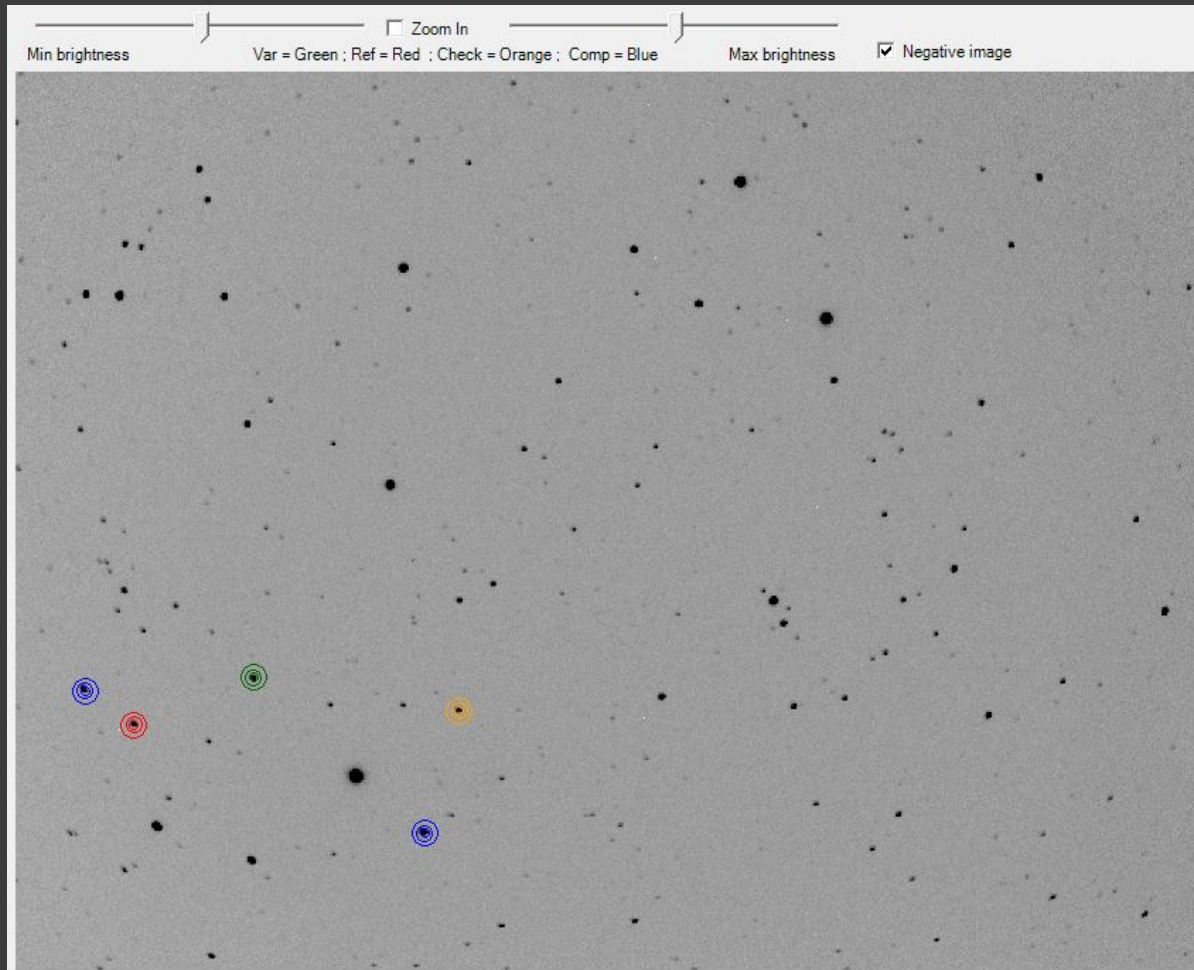
Chart X24542AFZ

Usage: R for reference (one or more for ensemble),
CK for check star (only one),
C for other comparison stars, leave blank for not used stars.
Select a maximum number of 10 stars.

First step – Astrometry

- ⦿ Solve the images with PinPoint of dc3.com (\$149)
 - detection of stars
 - matching the detected stars with stars of one catalog
 - GSC, USNOA2, USNOB1, UCAC2-3-4
- ⦿ List of detected stars
 - RA, DEC Image position x,y in pixels
- ⦿ Pixel coordinates are used to position the aperture circles for Variable and Comparison stars

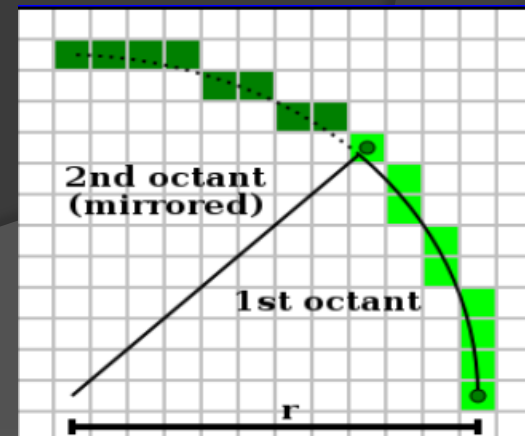
Aperture measurement



- Aperture : pixel value = star + background + pedestal
- Annulus : pixel value = background + pedestal
- Flux : Sum (Aperture – Annulus)

Aperture measurement

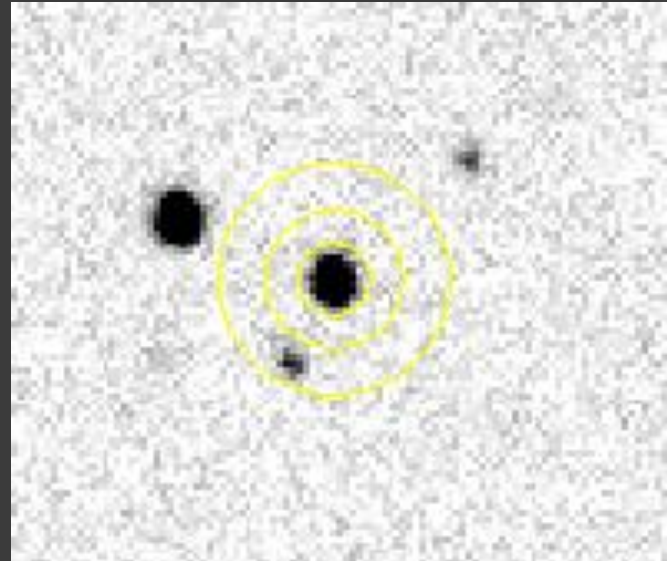
- Sum the ADU of pixels inside the circle
- To speed up the process integers are used for circle center and radius
- Pixel distance to circle center
 - calculated with Bresenham's algorithm
 - most of the calculations are additions / subtractions of integers
- Pixels straddling the circle are divided in 10 by 10 pixels and algorithm is repeated remaining straddling sub-pixels are counted for $\frac{1}{2}$
- Error on circle surface less than 0.2% for a circle radius of 5 pixels



Close stars??

- ◎ Stars in annulus affect
 - background value
 - SNR
- ◎ Astrometry provides a list of stars
- ◎ If a “spurious” star is in the annulus

the program doesn't use
this part of the annulus



Differential photometry

- ⊙ F_{obj} = Variable star flux
- ⊙ F_{ref} = Comparison star flux
- ⊙ M_{ref} = Comparison star magnitude
 - from the database

- ⊙ $m_{\text{obj}} = M_{\text{ref}} - 2.5 \log (F_{\text{obj}} / F_{\text{ref}})$

- ⊙ More than one star may be used for the reference
 - ensemble photometry
 - fluxes of reference stars are added (master star) or
 - mean value of magnitudes obtained for each reference stars

Error estimation

- ⦿ Poisson noise
- ⦿ Background noise

$$S/N = \frac{N_{ADU} \times G}{\sqrt{(N_{ADU} \times G) + n_{pix} \times ((N_{ADU,sky} \times G) + N_{dark} + (N_{r.n.})^2)}}$$

- ⦿ Errors on Variable and reference stars are added in quadrature

1st and 2nd extinctions

⊙ $V_0 = V - k' X - k'' X (B-V)$

V measured magnitude

V_0 exoatmosphere magnitude

X airmass > 1

k' 1st extinction coefficient

k'' 2nd extinction coefficient

(B - V) star color-index

extinction corrections become important when you observe :

- in B band

- at low altitude

(e.g. X = 3 for 20 deg above horizon)

-with a large distances between comparison stars ($X_2 - X_1$)

e.g. with large FOV as in DSLR

Extinction Coeffs	
1st order	2nd order
<input type="text"/>	<input type="text"/>
k'_B <input type="text" value="0.4"/>	k''_B <input type="text" value="-0.035"/>
k'_V <input type="text" value="0.2"/>	k''_V <input type="text"/>
k'_R <input type="text" value="0.1"/>	k''_R <input type="text"/>
k'_I <input type="text" value="0.08"/>	k''_I <input type="text"/>

Variable Color index (B-V)

Apply 1st and 2nd extinctions

Transformation to Standard system

- Transformation coefficients (Filter Band and Color Index) derived with LesvePhotometry from image measurement of a Standard field (e.g. M67)
- Applied after differential photometry

up to 5 colors bands may be used

The screenshot shows the 'Transformation Coeffs' window in the LesvePhotometry software. It is divided into three main sections: 'Color Bands for Transformations', 'Transformation Coeffs', and 'Extinction Coeffs'.

Color Bands for Transformations: This section contains five input fields for color bands, with 'B', 'V', 'R', and 'I' selected. Below these fields is a list of available bands: 'U B V R I SU SG SR SI SZ'. A note states: 'Enter here up to 5 Color Bands from the list: It's recommended to enter filters in this order from top to bottom. Otherwise you will have unconventional color like (V-B) instead (B-V)'. A 'Validate Color Bands' button is at the bottom.

Transformation Coeffs: This section is split into two columns: 'Filter Band Coefficients' and 'Color Index Coefficients'. Each column has five input fields and a corresponding numerical value.

Filter Band Coefficients	Color Index Coefficients
Tb_bv: 0.3155	Tbv: 1.6136
Tb_br: 0.1599	Tbr: 1.3572
Tb_bi: 0.2066	Tbi: 1.2395
Tv_vr: -0.1232	Tvr: 1.0418
Tv_vi: -0.0670	Tvi: 1.0016
Tr_ri: -0.1947	Tri: 0.9591

A 'Validate manual entries' button is located at the bottom of this section.

Extinction Coeffs: This section has two columns: '1st order' and '2nd order'. Each column has five input fields and a numerical value.

1st order	2nd order
k'_B: [empty]	k''_B: -0.035
k'_V: 0.5	k''_V: [empty]
k'_R: [empty]	k''_R: [empty]
k'_I: 0.33	k''_I: [empty]

Below the tables is a 'Variable Color index (B-V)' input field and a checkbox labeled 'Apply 1st and 2nd extinctions'.

Reports

- AAVSO report
ready to be uploaded to AAVSO database
- CBA report (text report)
table with JD, magnitudes, airmass, a.s.o
- Excel report
with a graph of the light curve
- Graphical interface to estimate
the extrema (JD, Mag) based on
Reinsch spline algorithm



Software installation

- ◎ LesvePhotometry
 - available as freeware www.dppobservatory.net
 - User guide and FAQ pages for documentation
 - Discussion group (46 members)
<http://groups.yahoo.com/neo/groups/lesvephotometry/info>
- ◎ OS XP, Win7, Win8, Win10
- ◎ Office 2007 or later
- ◎ PinPoint from dc3.com (\$149)
- ◎ Sky catalogs (used for astrometry)
 - GSC
 - USNOA2, USNOB1
 - USNO UCAC2, UCAC3, UCAC4

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Ken Menzies
Josch Hamsch
Richard Sabo
Tom Krajci
and others

for their

- improvement suggestions
- spent time for testing beta versions

LesvePhotometry
an amateur astronomer collaboration