Danish telescope – Czech participation

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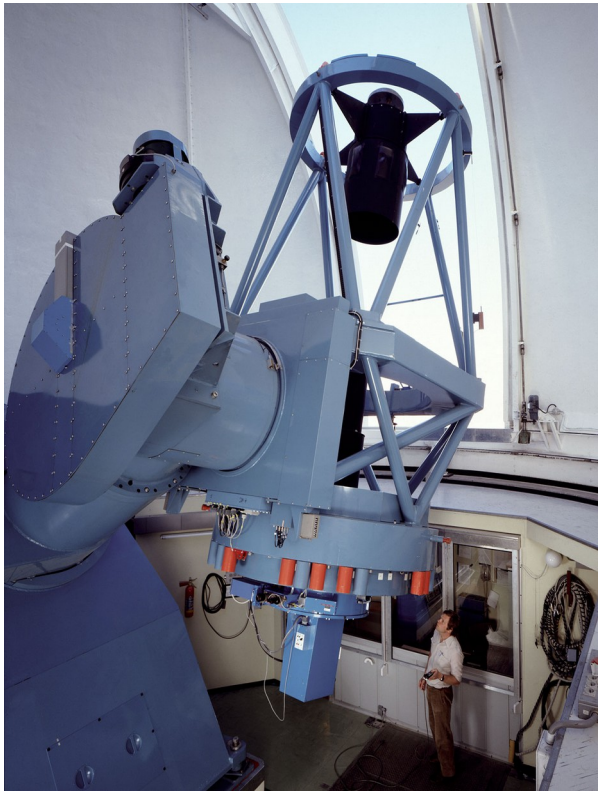
Technical specification

- Danish national telescope
- Operated since 1979
- Located on ESO La Silla observatory
- Complete robotization since 2012
- Remote control and observing
  - Off-axis mount
  - Diameter of mirror - 1.54 m
  - Pointing restriction due to the limited space inside dome



Current state

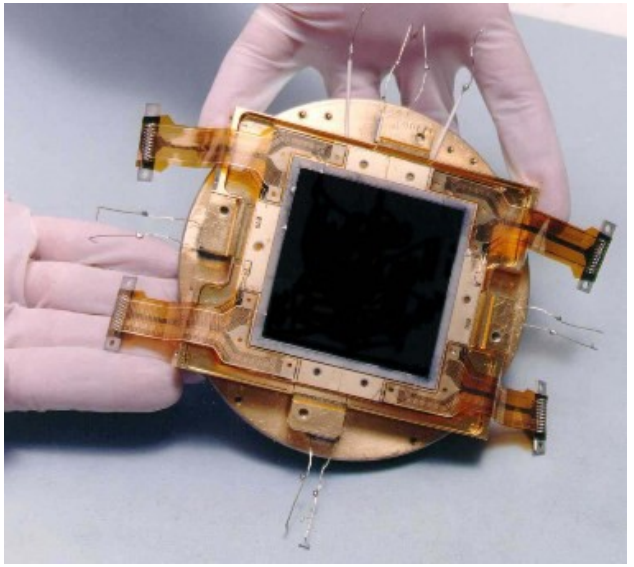
- CCD controller (Danish Copenhagen)
- CCD chip E2V – CCD44-82
- 2048 by 4096 pixels, used 2kx2x
- Pixel size 13.5 μm
- Resolution 0.395"/pixel
- Field of View 13.48 x 13.48 arcmin

CCD Chip improvement

Close future:

CCD231-42-0-F61 (Danish)

- 2048x2046 pixels
- Pixel size 13.5 μm
- Lower noise



λ [nm]	QE [%]	QE [%]
350	46.8	55.2
400	89.6	99.0
450	91.0	99.0
500	88.1	96.9
550	87.9	99.0
600	90.0	99.0
650	91.8	99.0
700	92.8	99.0
750	92.6	99.0
800	88.7	99.0
850	77.8	99.0
900	57.2	63.2

Available filters

Filtr	CWL [nm]	FWHM [nm]	PWL [nm]	T[%]
U	355.596	53.3725	363.5	66.0853
B	421.168	99.1674	419	69.0825
V	544.269	115.543	524.5	89.8388
R	641.367	158.477	597	86.1088
I	795.076	148.752	800	91.4829
u	348.343	348.343	32.8539	339
v	410.816	19.007	409.5	60.0922
b	468.3	16.0105	465.5	75.5174
y	548.26	18.2505	544.5	82.7296
Hb	486.256	7.54895	486	83.6236
Hb	477.382	7.34235	477	81.0857
Ha	665.444	6.16058	666	53.3313

Time schedule

Good news:

- Totally 50 % of Danish observing time for Czech side
- 25% OT for interplanetary matter group
- 25% OT for three different stellar groups

- Totally for Czech astronomers – 180 observing days
- For interplanetary group 90 observing days
- For stellar groups also 90 observing days together

- Data storage located in Ondrejov contains all photometric observations made by Czech and Danish astronomers

Bad news:

- 30 observing days for one group
- Random distribution from October to April

Data processing

- Automatical data reduction based on MuniPack
- One whole observing night ~ 2 hours of CPU
- VO compatible output
- VO database under construction

Scientific projects:

- mostly short and middle time variability
  LMC , SMC and GSEP region

- Eclipsing binnaries
  Double Periodic Variables
- LMC and SMC Be stars monitoring
  Gaia allerts follow-up

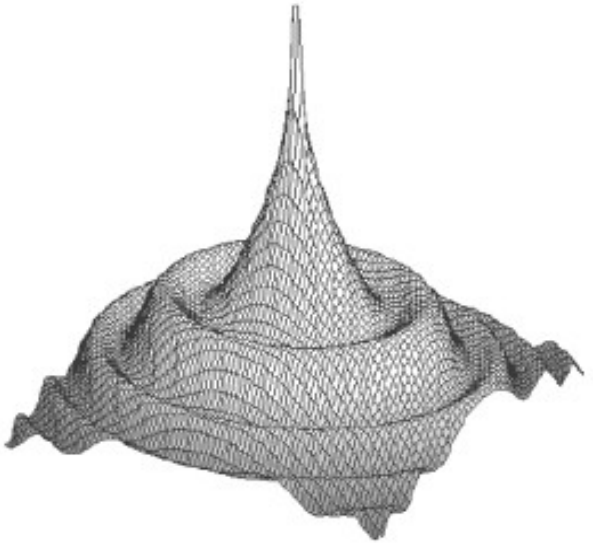
- Target of opportunity cooperation between stellar groups

Photometry reduction - MuniPack

Munipack

A general astronomical image processing software

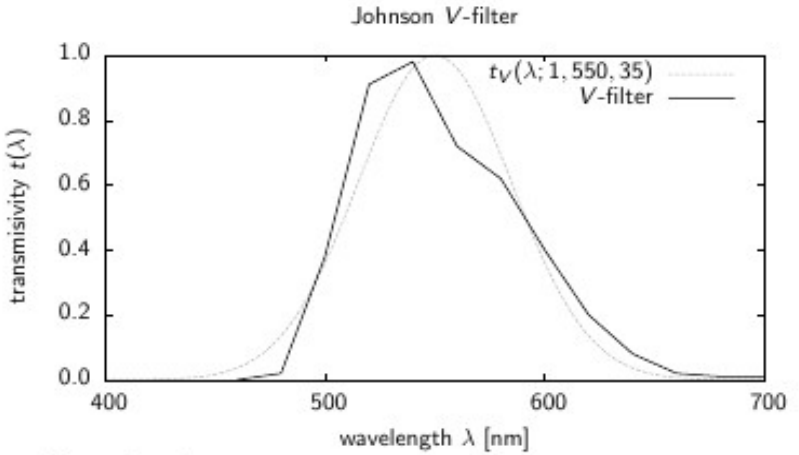
- photometry corrections (bias, flat-field)
- astrometry (including matching)
- full photometry calibration (photon-based, colour system transformations, atmospheric corrections)
- robust statistical estimators
- Virtual observatory access
- basic FITS utilities
- command-line and GUI interface
- Open source (Fortran and C++), GPL



Photometry reduction - MuniPack

Calibration By Photons

- CCD is photon counting detector
- Flux in filter by Gauss-Hermite quadrature



Flux F and photon flux Φ relations

$$F = \int_0^\infty f_\lambda(\lambda)\, t(\lambda)\, \mathrm{d}\lambda = \int_0^\infty \Phi_\lambda(\lambda) \frac{hc}{\lambda}\, t(\lambda)\, \mathrm{d}\lambda.$$

Approximation of deconvolution

$$N_V = AT\, \Phi_V \approx \sqrt{2\pi}\, AT\, f_V \delta_V\, \frac{\lambda_V}{hc} \approx ATF_V\, \frac{\lambda_V}{hc} \cdot 10^{-0.4\, m_V}.$$

Photometry reduction - MuniPack

Robust Statistics

The effective attenuation

$$C = tN$$

Normalisation

$$N(0,1) \sim \frac{C - tN}{\sqrt{C + \sigma^2 + \ldots}}, N \gg 1$$

Parameter is solved by the equation

$$L = \prod_{i=1}^{N} \frac{1}{s\sqrt{\sigma_{n_i}^2 + t^2\sigma_{c_i}^2}} f\left(\frac{c_i - tn_i}{s\sqrt{\sigma_{n_i}^2 + t^2\sigma_{c_i}^2}}\right).$$

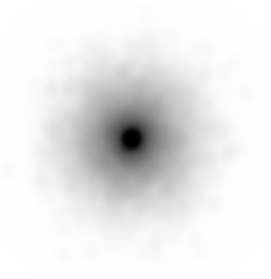
where $f(x) = \exp(-\varrho(x))$ is a robust function:

$$\varrho(x) = \begin{cases} -ax - a^2/2, & x < -a \\ x^2/2, & -a < x < a \\ ax - a^2/2, & x > a \end{cases}$$

Photometry reduction - MuniPack

Spread Bessel Profile

Bessel



Spaded Bessel

Convolution profile

$$I(r) = \frac{1}{\sqrt{2\pi}s} \int_{-\infty}^{\infty} e^{-(r-x)^2/2s^2} \cdot \left[\frac{2J_1(x)}{x}\right]^2 dx.$$

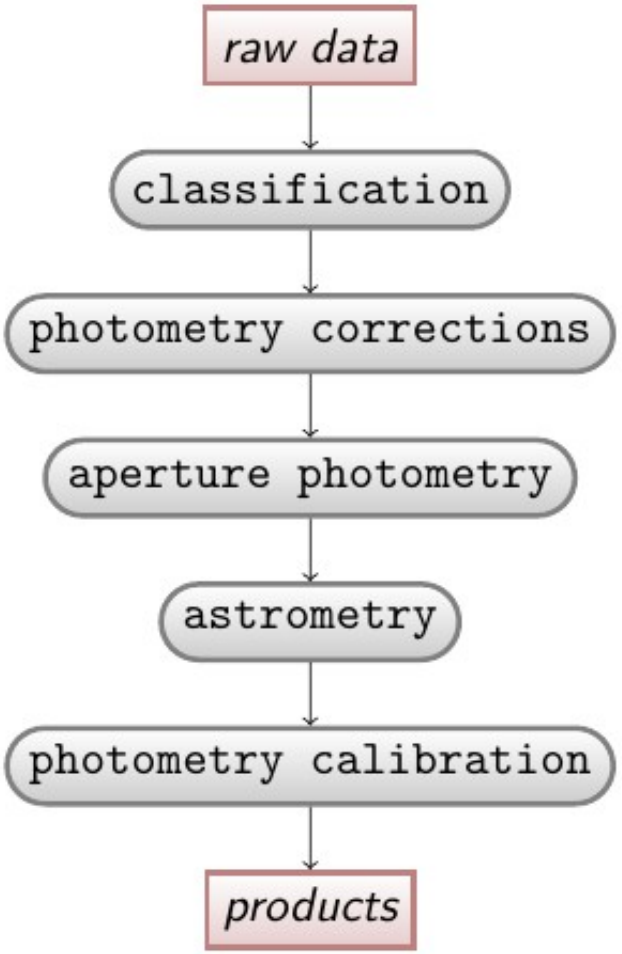
Approximation

$$I(r) = -\frac{8}{\sqrt{\pi}} \sum_{j=1}^{n} H_j \frac{4J_1(r - \sqrt{2}sa_j)^2}{(r - \sqrt{2}sa_j)^2}.$$

Photometry pipeline

Astro-mill

Reduction pipe-line on base of Munipack



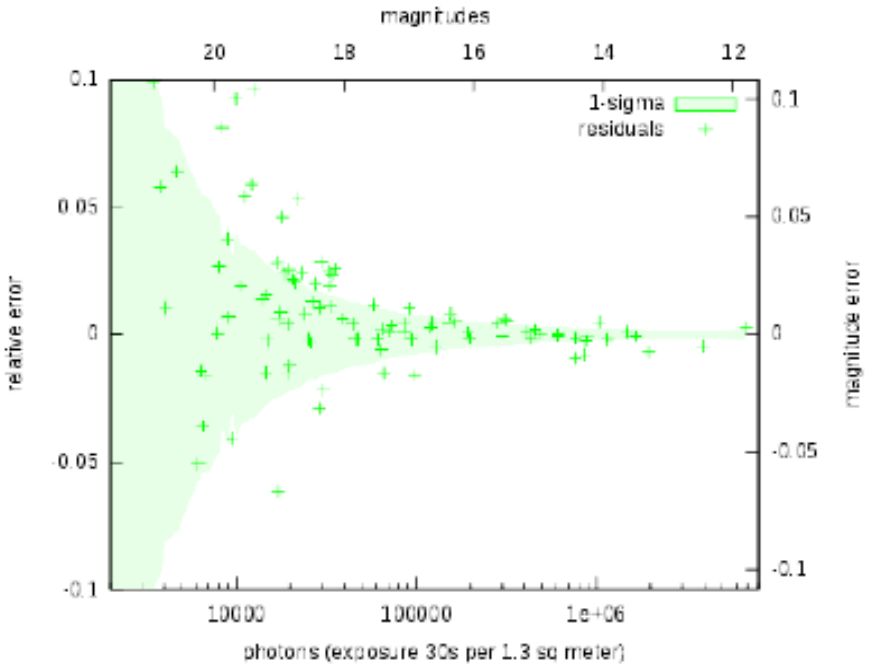
- Fully automatics reduction
- Mean bias and flat-fields
- Astrometry on base UCAC4
- Photometry with OSPS Photometry Catalogue
- (July 2015): 702 nights, 146261 RAW frames

OSPS catalogue

OSPS Photometry Catalogue

Ondřejov Southerland Photometry Survey

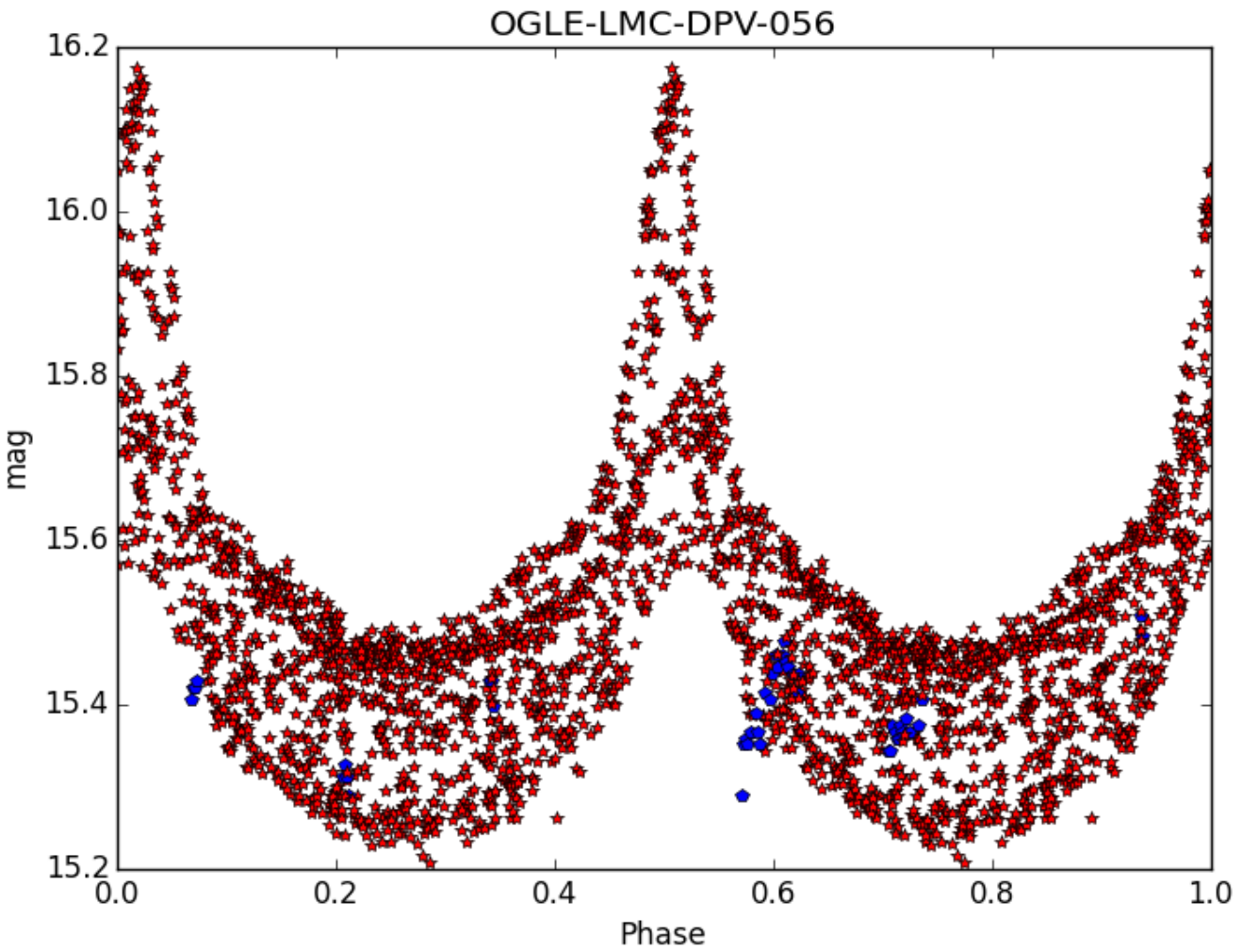
- about 3600 stars (Landolt fields, SMC, LMC)
- magnitude range 12 - 17 in Johnson UBVRI filters
- alone stars above 10 FWHM
- more than 3 different nights
- verification required



Double periodic variable observation

- LMC DPV (Poleski+,2010)
- OGLE-LMC-DPV – 056

  Mean magnitude(I): 15.37
- Period(1): 176.146d
  Observed during 2014/2015



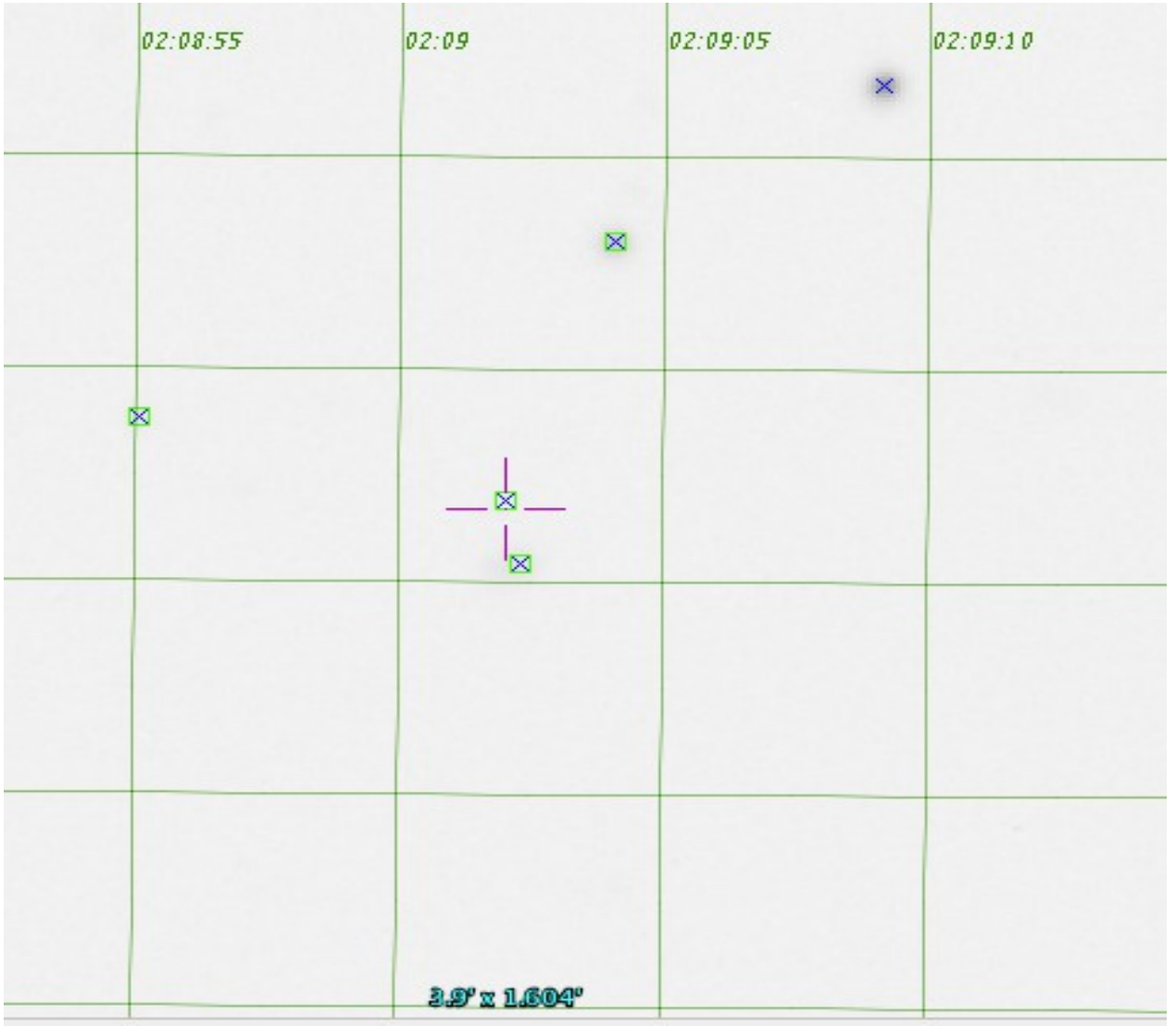
OGLE Transients

L. Wyrzykowski (2014)

OGLE15mg

Ra = 2:09:02.37
Dec =-73:24:41.8

m_V ~ 20.94 mag



Thank for your attention

Reference:

MuniPack
http://munipack.physics.muni.cz/

OGLE IV transients
http://ogle.astrouw.edu.pl/ogle4/transients/transients-lite.html