MAVKA: Investigation of stellar brightness extrema approximation stability for various methods

Dmytro Tvardovskyi[1,2,3] **Ivan L. Andronov[2]**
Kateryna D. Andrych[1,2] **Lidiia L. Chinarova[1,2]**

[1] Odessa National I.I. Mechnikov University, Odessa, Ukraine
[2] Odessa National Maritime University, Odessa, Ukraine
[3] Université de Mocton, Moncton, New Brunswick, Canada

Contact us

dmytro.tvardovskyi@gmail.com
tt_ari@ukr.net
katyaandrich@gmail.com
llchinarova@gmail.com

Abstract

We discussed the methods for extended analysis of signals with irregularly spaced times with an application to variable stars of different types: eclipsing, cataclysmic, symbiotic, short- and long- periodic pulsating variables. Major complementary software with application of algorithms:
• "Multi-Column Viewer" (MCV, 2004AstSR...5..264A);
• "Multi-Analysis of Variables by Kateryna Andrych" (2019OEJV..197...65A)
MAVKA (11 methods, 21 approximations, 2 of them are to be tested).

Presented methods are effective for studies of eclipsing variables, transits of exoplanets and pulsating variables with negligible asymmetry. The comparison of the accuracy estimates for these methods was made for artificial data, as well as for real stars. The methods were tested and applied to photometric observations from space and ground-based surveys, as well as "one-target" monitoring.

Deviations between computed and generated minima

		JD								
		P	Y	W	L	N	M	S	R	A
normal	noise	-2.7	-2.9	-2.3	-1.5	-2.4	-2.7	-2.3	-1.8	-2.4
	points	-3.2	-2.9	-2.8	-2.7	-2.9	-2.9	-2.9	-2.8	-2.3
	asymmetry	-1.1	-0.8	-1.0	-0.6	-1.2	-1.2	-1.3	2.1	x
	completeness	-1.3	x	-2.0	-1.4	x	x	-1.7	-0.4	0.6
sharp	noise	-2.4	-2.7	-1.7	-0.6	-3.2	-3.4	-2.1	-1.1	-2.9
	points	-2.3	-2.7	-2.0	-1.3	-3.3	-3.1	x	-2.0	-2.9
	asymmetry	0.4	-1.0	-1.2	-1.0	-2.0	-2.1	-2.1	3.8	3.8
	completeness	-1.3	-1.3	0.3	0.4	0.4	0.4	0.3	-1.0	-1.5
flat	noise	-2.5	-2.7	-2.9	-2.1	-2.4	-2.4	-2.5	-0.7	-2.4
	points	-2.7	-2.8	-2.8	-2.8	-2.7	-2.6	-2.8	-2.7	-2.5
	asymmetry	-0.9	-1.0	-1.4	-1.3	-0.7	-0.7	-1.2	2.1	2.1
	completeness	-1.2	-1.2	-2.4	-2.1	-2.1	-2.1	-2.1	2.1	2.1

Formula:

$$\Delta = \frac{1}{N}\sum_{k=1}^{N} \log_{10}|\delta_k|$$

		magnitude								
		P	Y	W	L	N	M	S	R	A
normal	noise	-1.5	-2.0	-1.4	-1.2	-1.7	-1.9	-1.5	-1.2	-1.8
	points	-1.7	-2.2	-1.6	-2.0	-2.1	-2.0	-1.9	-2.0	-1.9
	asymmetry	-1.2	-0.6	-0.7	-0.7	-0.9	-0.9	-0.9	2.3	x
	completeness	-1.0	x	-1.7	-1.3	x	x	-1.6	-0.6	-1.5
sharp	noise	-0.8	-1.1	-1.1	-0.9	-2.3	-2.5	-1.3	-0.2	-2.1
	points	-0.7	-1.1	-1.2	-1.4	-2.0	-1.9	x	-0.7	-1.6
	asymmetry	-0.6	-0.4	-0.8	-0.6	-1.2	-1.1	-1.1	3.8	3.8
	completeness	-0.2	-0.2	-1.0	-0.5	-0.5	-0.5	-1.0	-0.7	-1.3
flat	noise	-1.7	-1.5	-1.7	-1.7	-1.4	-1.3	-1.2	0.2	-1.2
	points	-1.2	-1.2	-2.0	-1.9	-1.3	-1.3	-1.2	-1.2	-1.3
	asymmetry	-0.8	-0.4	-0.8	-1.2	-0.5	-0.4	-0.6	2.0	2.0
	completeness	-0.9	-0.9	-2.1	-2.4	-2.4	-2.4	-2.4	2.0	2.0

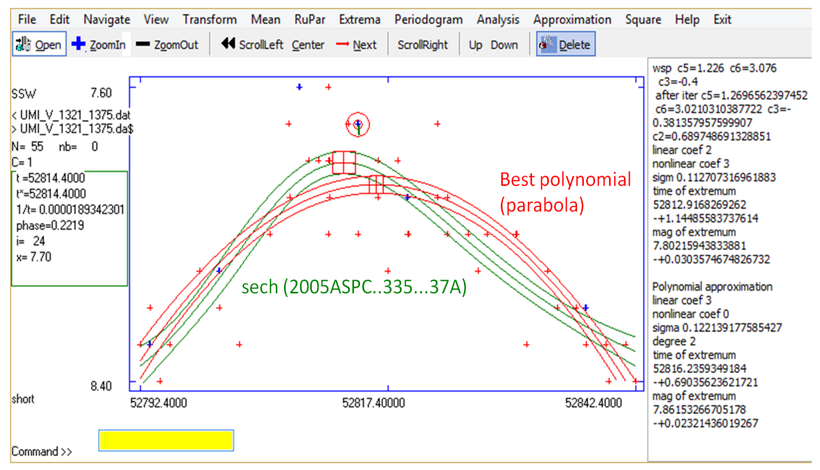
best
OK
worst

Methods rank

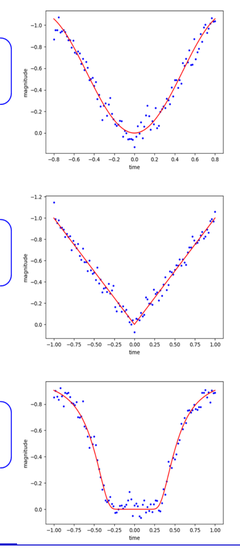
- best: NAV, Z.Mikulášek (modified), WSP, WSAP
- OK: Symmetric polynomial, Polynomial, WSL
- worst: Asymptotic parabola, Parabolic spline

	JD	mag	Σ
P	-1.8	-1.0	-1.4
Y	-2.0	-1.1	-1.5
W	-1.9	-1.3	-1.6
L	-1.4	-1.3	-1.4
N	-2.1	-1.5	-1.8
M	-2.1	-1.5	-1.8
S	-1.9	-1.3	-1.6
R	-0.2	0.3	0.0
A	-0.7	-0.5	-0.6

MAVKA: noisy real vs. generated data



normal
sharp
flat



Methods present in MAVKA

11 methods of approximation are present:

1. Polynomial (P)
2. Symmetric polynomial (Y)
3. *WSP* (W)
4. *WSL* (L)
5. NAV (N)
6. Z.Mikulášek (modified) (M)
7. *WSAP* (S)
8. Parabolic spline (R)
9. Asymptotic parabola (A)
10. **BSK** (B)
11. Sech (E)

Already tested

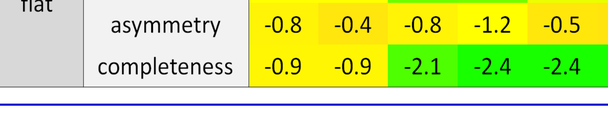
NEW

Legend
Universal method
For symmetric extrema
For asymmetric extrema
For transits of exoplanets

Algorithm of testing

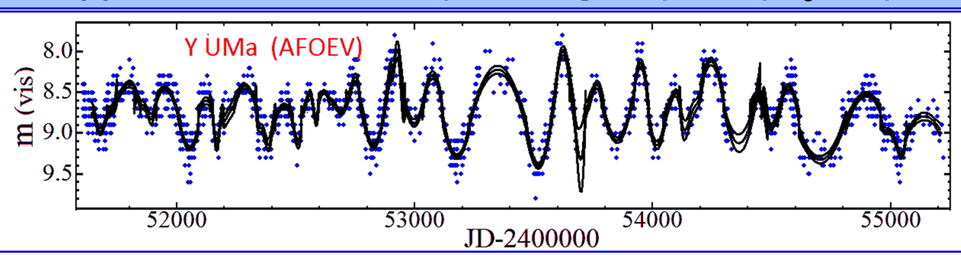
Generated data → Stability studying → Quality check → Processing real data → Choosing best methods

Application & references



Σ ≈ several hundred minima + now several dozens of stars

Application to the real (semi-regular) star ($m_c \pm 1\sigma$):



Systematic deviations presence

Legend

1	undervalued
2	correct
3	overvalued
x	not applicable

minimum type		magnitude									JD								
		P	Y	W	L	N	M	S	R	A	P	Y	W	L	N	M	S	R	A
normal	noise	1	1	2	2	1	1	2	2	2	1	1	1	1	2	3	1	2	3
	points	1	1	2	3	3	3	2	1	3	1	2	1	1	3	3	1	1	3
	asymmetry	1	1	1	2	1	1	1	3	x	1	2	1	1	2	2	1	3	x
	completeness	1	x	2	2	x	x	2	2	3	1	2	1	1	x	x	1	1	2
sharp	noise	1	1	2	3	2	2	3	2	3	1	1	1	1	1	1	1	2	1
	points	1	1	1	3	2	2	x	2	2	1	1	1	1	1	1	x	1	1
	asymmetry	1	1	1	2	2	2	2	3	3	1	1	1	1	1	1	1	3	3
	completeness	1	1	3	3	3	3	3	1	3	1	2	1	1	1	1	1	1	1
flat	noise	2	3	2	2	1	1	2	3	3	2	1	1	3	3	2	2	3	3
	points	3	3	2	1	1	1	2	1	3	3	1	1	3	3	3	3	3	3
	asymmetry	2	2	1	1	1	1	1	2	2	2	2	1	2	1	1	2	2	2
	completeness	2	2	1	1	1	1	1	3	3	2	2	1	3	3	3	3	3	3