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Long term follow-up coverage of Gaia photometric alert sources by Ondrejov robotic telescopes

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Abstract. The robotic telescopes at the Ondrejov Observatory are providing long-term optical multi-color coverage for selected 25 Gaia alert triggers located in the northern sky hemisphere. I will present and briefly discuss examples of selected results, mostly unpublished, obtained with these devices. In addition to that, I will present and discuss the potential of large historical photographic plate archives located around the globe as sources of both photometric as well as spectroscopic data. They allow us to perform the long-term study of photometric and spectroscopic evolution for astrophysical sources in general and for Gaia alert sources in particular. Some of these databases were digitized and on-line access is provided.

Key words: Gaia – robotic telescopes – multicolor photometry

1. Introduction

The robotic telescopes (RT) at the Ondrejov Observatory (recently 3 RTs: CTA-N/FRAM (recently at La Palma), D50, BART/SBT), apart from gamma–ray bursts (GRB) follow–up, provide valuable data for analyses of various types of high–energy (HE) sources (Nekola et al., 2009, 2010; Hudec, 2019; Štrobl et al., 2019). Up to 100 targets are in the list for continuous monitoring, mostly INTEGRAL HE sources, blazars, cataclysmic variables (CVs), and newly detected Gaia alert sources. An automated data pipeline was developed by M. Jelinek allowing these data to be evaluated in an efficient way. There are more than 2 million CCD frames in the database, with more than 2 billion star images. The telescopes support also various satellite observing campaigns and GRBs alert follow–up (Jelínek et al., 2022; Oganesyan et al., 2023).

2. Gaia photometric alert sources monitored

The following Gaia photometric alert targets (Wyrzykowski et al., 2012) are observed by the D50 robotic telescope on a daily basis, weather permitting as follows. Note that this list is regularly updated according to scientific demands.

id="1111" name="Gaia16aye - Ayers Rock"
id="1129" name="Gaia18arn (Arnica) - microlensing event"
id="1137" name="Gaia18cik - microlensing event"
id="1133" name="Gaia18cjk - microlensing event"
id="1138" name="Gaia18clv - microlensing event"
id="1136" name="Gaia18chq - microlensing event"
id="1145" name="Gaia18cmy - microlensing event"
id="1153" name="Gaia21bnh"
id="1156" name="ZTF18aarippg (binary SMBH merger)"
id="1157" name="Gaia22awa - microlensing event"

and the following Gaia alert targets are observed less frequently on a weekly basis, as follows.

id="1122" name="Gaia17cem - fading galaxy centre"
id="1123" name="Gaia16bnz - very bright CV"
id="1144" name="Gaia18cnz - probably Mira"
id="1147" name="Gaia17bpi"

3. Examples of monitoring data obtained

In this section, we give examples of monitoring (multicolor photometric data) for selected Gaia photometric alerts[1] gained, mostly by the Ondrejov D50 RT.

- Gaia16aye. 1.2 magnitude rise in red star near Galactic Plane. From BP/RP red spectrum. Microlensing trigger, confirmed and published. The lens system consists of two main sequence stars with Solar masses 0.57 0.05 and 0.36 0.03, at a distance of 780 pc (2,500 ly), and an orbital period of 2.88 years (Wyrzykowski et al., 2020).

- Gaia17cem. Gaia source on Seyfert 1 Galaxy 2MASX J17085915+2153082 dims by 1.2 mags over ∼4 months. Daily means are plotted (Fig. 2).

- Gaia16bnz. Classification: Gaia16bnz is a new CV with 2 epochs variable LAMOST spectra taken in 2015 October and December (Huo et al., 2020).

[1] https://gsaweb.ast.cam.ac.uk/alerts

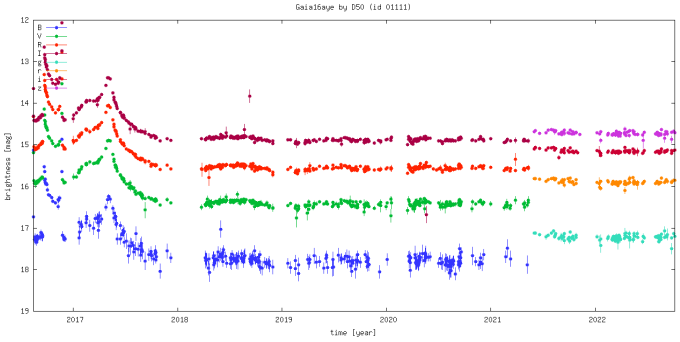

Figure 1. Gaia16aye, 1.2 mag rise in red star near Galactic Plane. BP and RP (Gaia blue and red photometers) indicate red spectrum of this source. Microlensing trigger, confirmed and published (Wyrzykowski et al., 2020). The lens system consists of two main sequence stars with Solar masses 0.57 +− 0.05 and 0.36 0.03, at a distance of 780 pc (2,500 ly), and an orbital period of 2.88 years (Wyrzykowski et al., 2020)

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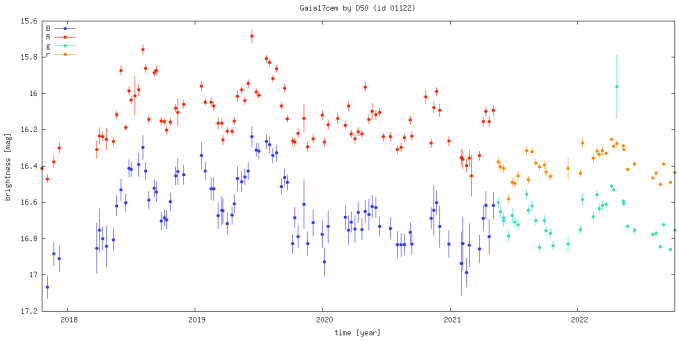

Figure 2. Gaia17cem, Gaia source on Seyfert 1 Galaxy 2MASX J17085915+2153082 dims by 1.2 mags over ∼ 4 months. Daily means are plotted.

– Gaia18cmy. 2 mag brightening of red Gaia source. BP/RP spectra are red. Late-type star showing emission in Halpha line, very likely T Tauri star. Originally misclassified as SN [2]

– Gaia17bpi. Classification: A new FU Ori Type variable according to spectrum Hankins et al. (2020).

[2]http://gsaweb.ast.cam.ac.uk/alerts/alert/Gaia18cmy/

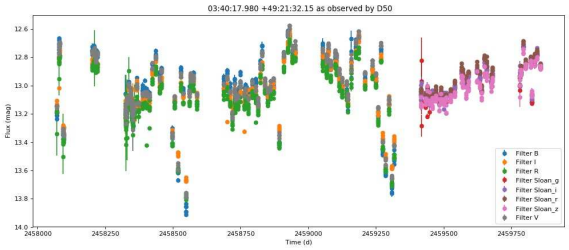

Figure 3. Gaia16bnz. All points, last 5 years Classification: Gaia16bnz is a new CV with 2 epochs variable LAMOST spectra taken in 2015 October and December (Huo et al., 2020)

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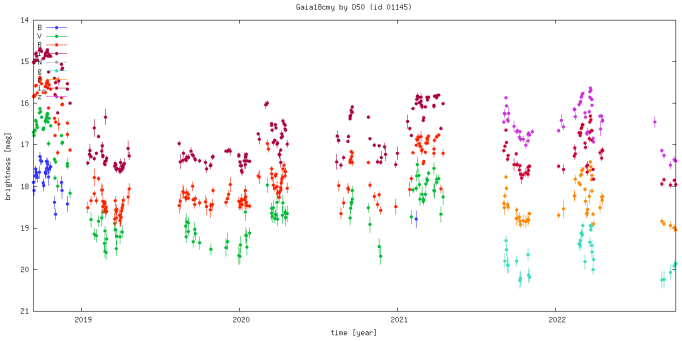

Figure 4. Gaia18cmy. 2 mag brightening of red Gaia source. BP/RP spectra red. Late–type star showing emission in Halpha line, very likely T Tauri star. Originally misclassified as a supernova (SN).

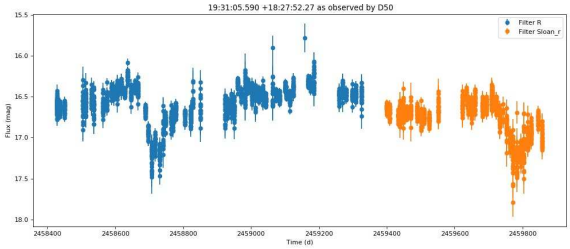

Figure 5. Gaia17bpi. All points during the last 5 years are plotted. Classification: A new FU Ori Type variable star according to spectrum (Hankins et al., 2020).

– Gaia21blj. ∼ 5.5 mag outburst in a known cataclysmic variable (CV) TT Boo. Blue spectra from Gaia BP/RP [3].

Figure 6. Gaia21blj, ∼5.5 mag outburst in known CV TT Boo. Blue spectra from Gaia BP/RP[3]

– Gaia21bnh. Known CV RX J1715.6+6856 in outburst[4].

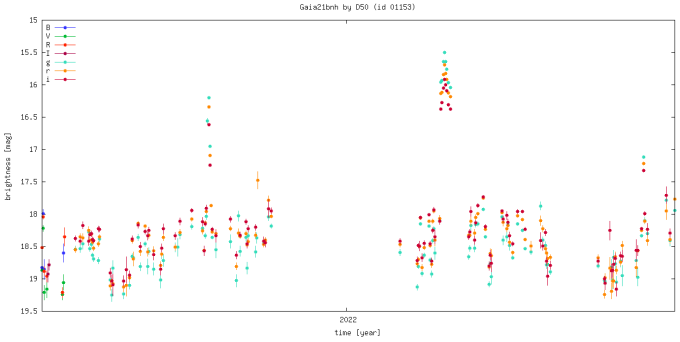

Figure 7. Gaia21bnh, known CV RX J1715.6+6856 in outburst. [4]

– Gaia21azb. ∼2.3 mag rise in Galactic plane source – candidate microlensing event. BP/RP spectrum is red. Unclassified. No spectra available. [5]

[3]http://gsaweb.ast.cam.ac.uk/alerts/alert/Gaia21blj/
[4]http://gsaweb.ast.cam.ac.uk/alerts/alert/Gaia21bnh/
[5]http://gsaweb.ast.cam.ac.uk/alerts/Gaia21azb/

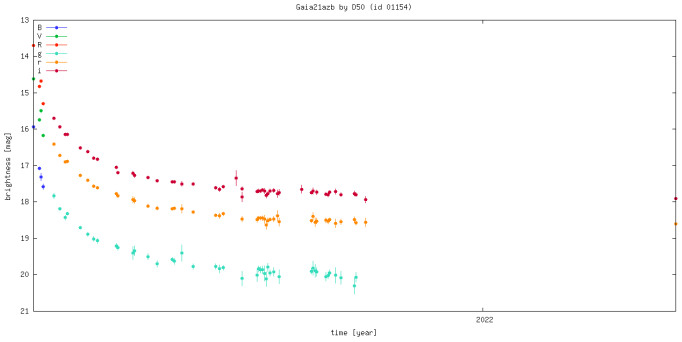

Figure 8. Gaia21azb, ∼2.3 magnitude rise in Galactic plane source – candidate microlensing event. BP/RP spectrum is red. Unclassified. No spectra available.[5].

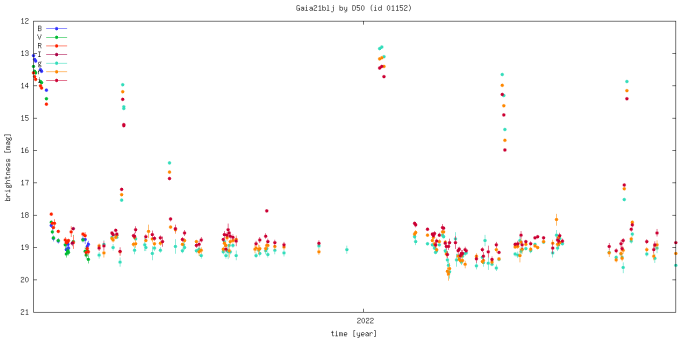

Figure 9. Gaia21blj, ∼5.5 mag outburst in known CV TT Boo. Blue spectra from Gaia BP/RP[3]

– Gaia18arn. Gaia source in the Galactic plane brightens by ∼0.25 mags. Classification strong Halpha emission reddened Be star. BP/RP spectrum is red.[6]

– Gaia18cjk. Long-term brightening of ∼1 mag in Gaia source in Galactic plane, candidate microlensing event.[7]

– Gaia18cmk. Gaia source near Galactic plane brightens by almost 1 mag, no spectra available, confirmed microlensing trigger (Mróz et al., 2020).

– Gaia18cmk. Our light curve is not complete, we observed the target soon after the maximum, the pulse had an amplitude of (0.660.02) mag and a

[6]http://gsaweb.ast.cam.ac.uk/alerts/alert/Gaia18arn/
[7]http://gsaweb.ast.cam.ac.uk/alerts/alert/Gaia18cjk/

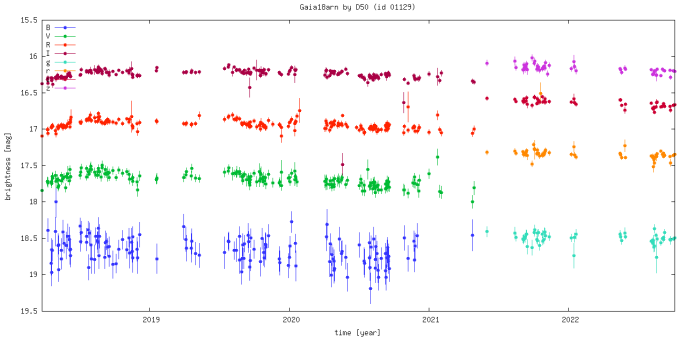

Figure 10. Gaia18arn. Gaia source in the Galactic plane brightens by 0.25 mags. Classification strong Halpha emission reddened Be star. BP/RP spectrum is red.[6]

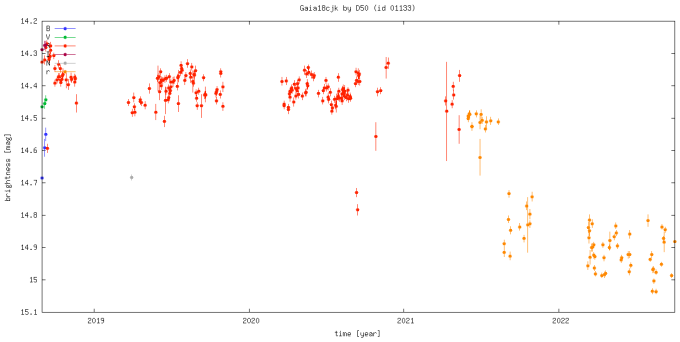

Figure 11. Gaia18cjk. Long-term brightening of ∼1 mag in Gaia source in Galactic plane, candidate microlensing event.[7]

duration FWHM = (45.11.3) days. The object was observed from February 10, 2019 until June 10, 2021, when we decided to stop the monitoring as there was no activity for two years.

– Gaia18clv. A faint Gaia source in the Galactic Plane slowly rises by almost 3 mags. Classification as a binary microlensing event is probably wrong due to the long–term light curve. [8]

– Gaia18cnz. Very red spectrum, also from Gaia RP/BP. M–type supergiant, very likely Mira variable.[9]

[8]http://gsaweb.ast.cam.ac.uk/alerts/alert/Gaia18clv/
[9]http://gsaweb.ast.cam.ac.uk/alerts/alert/Gaia18cnz/

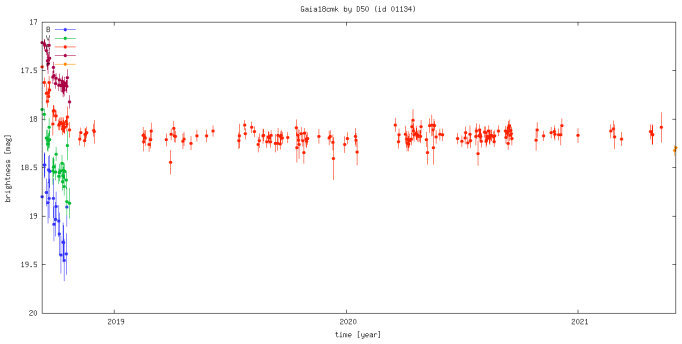

Figure 12. Gaia18cmk Gaia source near Galactic plane brightens by almost 1 mag, no spectra, confirmed microlensing trigger (Mróz et al., 2020).

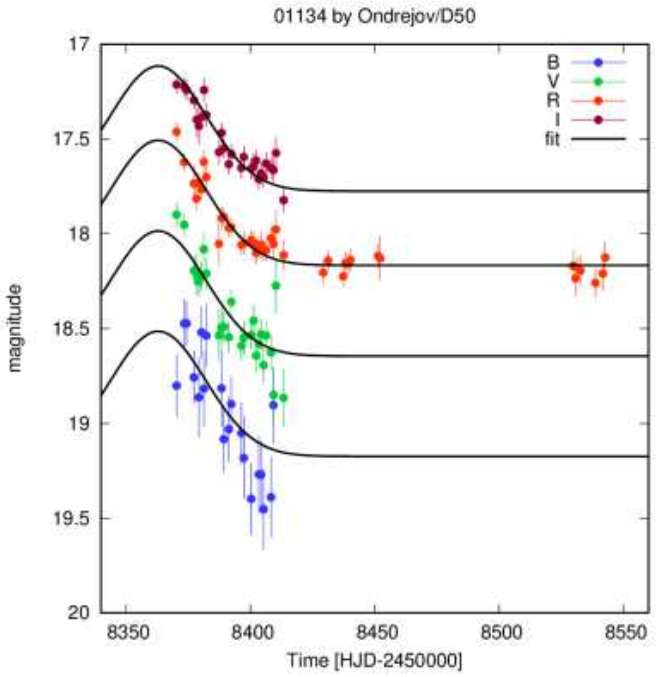

Figure 13. Gaia18cmk. Our light curve is not complete, we observed soon after the maximum, that pulse had an amplitude of (0.660.02) mag and duration FWHM = (45.11.3) days. Observed from February 10, 2019 until June 10, 2021, when we decided to stop the target after 2 years without activity.

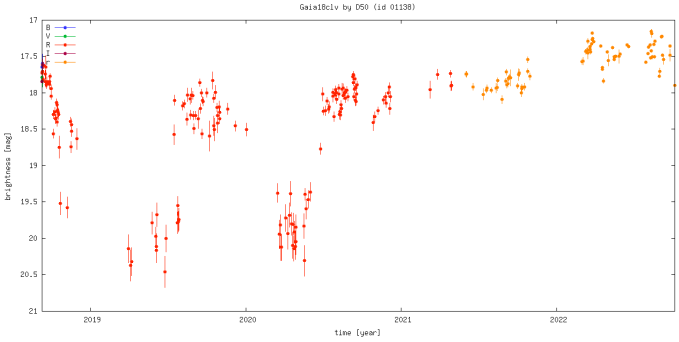

Figure 14. Gaia18clv, faint Gaia source in the Galactic Plane slowly rises by almost 3 mags. The binary microlensing event classification is probably wrong due to the long-term light curve.[8]

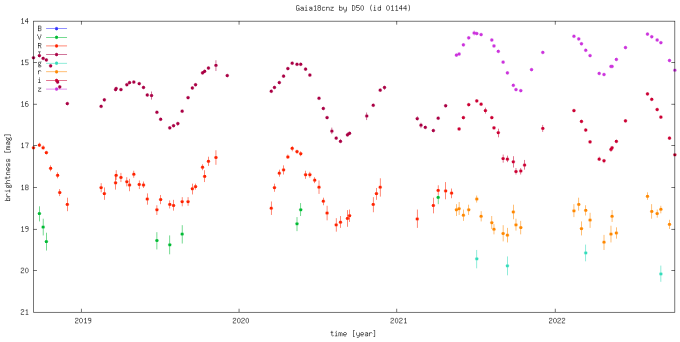

Figure 15. Gaia18cnz. Very red spectrum, also from Gaia RP/BP. M-type supergiant, very likely Mira variable.[9]

4. TT Bootis: an example of gaining new results on classified Gaia alert trigger

TT Bootis is a poorly investigated dwarf nova despite of its large–amplitude outbursts. The star is located at RA 224.43643 and DEC 40.72790 (914:57:44.74, 40:43:40.44) and in galactic coords. at 968.7414, 60.703850.

Multi-station photometry of TT Boo was reported during its June 2004 superoutburst however other outbursts are poorly investigated. The amplitude of the superoutburst in June 2004 was about 5.5 mag and its length was about 22 days. The star showed a small re-brightening starting around the 9th day of the superoutburst. During the entire bright state we observed clear superhumps with amplitudes from 0.07 mag to 0.26 mag and a mean period of Psh=0.0779589(47)

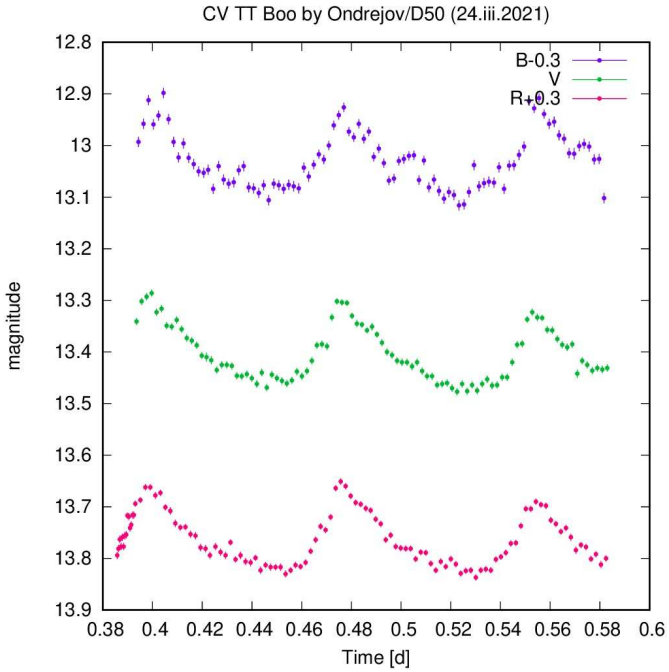

Figure 16. TT Boo, an example of searches for fast intra-night variations.

days (112.261+/-0.007 min). The period was found not constant but decreased at the beginning and the end of superoutburst and increased in the middle phase (Olech et al., 2004).

The brightening of TT Bootis was alerted as Gaia Scientific Alert Gaia21blj with the Alerting date 2021-03-21 14:23:02 (Julian date 2459295.10) and Alerting magnitude of 13.53 (Historic Gaia magnitude 17.19). The provided LDS (low dispersion spectra) data from Gaia BP and RP Photometers indicate the blue color of the source.

We have performed photometric sets lasting most of the night in order to study TT Boo variability during its 2021 outburst. Eventually, we acquired 6 nights of the outburst, obtaining almost 2000 photometric points in filters B, V and R.

Our observations have revealed five outbursts not described in the scientific literature in multi-color photometry. We plan to publish these data later in a more detailed scientific publication (Hudec et al., 2023, in preparation).

5. Adding historical epochs

We note that in addition to follow–up and monitoring by recent robotic telescopes, additional photometric data can be obtained from astronomical data archives namely large collections of astronomical photographic plates. These databases can add photometry for these sources typically for epochs between 1890 and 1980 including faint sources down to magnitude 20 (Hudec, 2019) (Hudec, 2018). This approach can extend the photometric coverage for selected Gaia alert sources for several decades or even more.

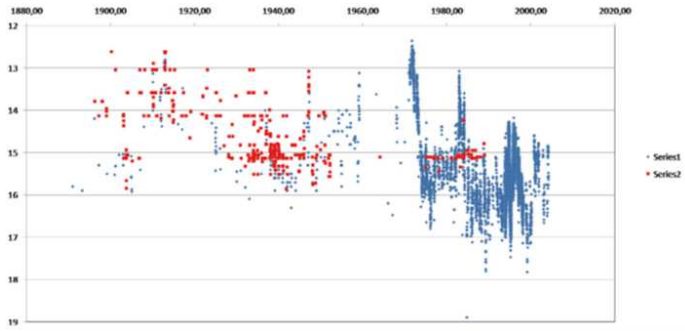

Figure 17. Example of very long–term (more than 100 years) light curve based on astronomical photographic plate archives: blazar OJ287 (supermassive binary black hole candidate).

6. Conclusions

The Ondrejov Observatory robotic telescopes provide valuable data for various aspects of high–energy astrophysics including GRBs alerts. Furthermore they can be efficiently used also for other tasks of modern astrophysics such as follow–up and dense and long–term multicolor monitoring of Gaia satellite photometric alert sources.

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