Communications of BAO, Vol. 73, Issue 2, 2026, pp. 281–291

Variable Stars in Clusters and Beyond

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Abstract

Variable stars provide direct probes of stellar structure, magnetic activity, accretion, binary interaction, and stellar evolution. Their interpretation becomes especially powerful when they are studied in open clusters and stellar associations, where common distance, age, and approximately common initial chemical composition provide an environmental framework. Field variables, in turn, extend the comparison to older populations and rare or transient systems that are not readily sampled in clusters. This review outlines the historical foundations of cluster-variable research at the Byurakan Astrophysical Observatory (BAO), summarizes the complementary roles of cluster and field studies, and discusses the opportunities created by wide-field time-domain surveys and space photometry. We focus on our observational programme and recent results from the Uzbek–Indian collaboration, including searches for variables in open clusters and monitoring of selected active systems beyond clusters. The review emphasizes results traceable to original publications and distinguishes refereed research papers from conference summaries and preliminary candidate lists.

Keywords: *stars: variables; open clusters and associations; flare stars; stellar activity; binaries: eclipsing; surveys; time-domain astronomy*

1. Introduction: a Byurakan legacy beginning in 1946

The history of variable-star research in the region is inseparable from the development of the Byurakan Astrophysical Observatory (BAO). Founded in 1946 on the initiative of Viktor A. Ambartsumian, BAO was organized around the investigation of astrophysical processes that reveal non-stationarity and evolution in the Universe. In 1947, Ambartsumian's work on stellar associations helped establish that star formation is occurring in the present-day Galaxy and that stars can be born in groups rather than only as isolated objects. This result gave stellar associations a central role in studies of young stellar populations and created a natural setting for investigating variable stars at different evolutionary stages (Ambartsumian, 1978, Ambartsumian & Mirzoyan, 1975, BAOweb, 2026, Hojaev, 1983, 1984a,b, 1987, Mirzoyan, 1995, Sedrakian et al., 2006).

The observatory's early scientific meetings reflected this emphasis. A conference on stellar associations was held at Byurakan in 1951, and the official opening in 1956 was marked by a meeting on non-stable stars. Over subsequent decades, the study of flare stars in clusters and associations became one of BAO's distinctive research directions. Photographic monitoring of systems of different ages made it possible to compare flare populations and investigate how activity changes as low-mass stars evolve. The IAU Symposium 137, *Flare Stars in Star Clusters, Associations, and the Solar Vicinity*, held at Byurakan in 1989, recognized this international contribution of the observatory staff (BAOweb, 2026, Mirzoyan et al., 1990). The title of the present review therefore connects two complementary traditions: the study of variable stars in physically related stellar systems and the investigation of variables beyond those systems.

The modern observational context is broader than it was in the photographic era. Ground-based time-series photometry now combines with astrometry, spectroscopy, and space-based light curves from missions and surveys such as Gaia, TESS, and Kepler. In our review of variable stars and star clusters, we summarized recent work on open clusters and associations alongside selected variable systems in the Galactic field, including results from Uzbek–Indian collaboration (Hojaev, 2024). Related work has discussed monitoring of open clusters and selected magnetic cataclysmic variables, illustrating why a cluster-only approach is not sufficient for a complete view of stellar variability (Hojaev, 2026b, Hojaev & Karimov, 2024).

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2. Why compare clusters, associations, and the field?

Open clusters provide useful approximate constraints: member stars are at broadly similar distances and share a common formation history, age, and initial composition to first order. Stellar associations are generally less gravitationally bound and more extended, and can preserve a view of recent star formation. The Galactic field contains stars spanning a much wider range of ages, compositions, and evolutionary histories. Membership must be assessed rather than assumed: projected proximity to a cluster does not establish physical association. Astrometric information, especially proper motions and parallaxes, should be combined with colour–magnitude diagrams, radial velocities where available, and probabilistic membership methods.

The comparison is scientifically productive in both directions. Cluster members help calibrate the age dependence of activity, rotation, pulsation, and binary evolution. Field variables extend the population baseline and provide access to rare systems, evolved objects, novae, supernovae, and accreting binaries that may be absent from any one cluster. The word "beyond" in this review thus refers not only to objects outside cluster boundaries, but also to a broader range of physical mechanisms and observational environments.

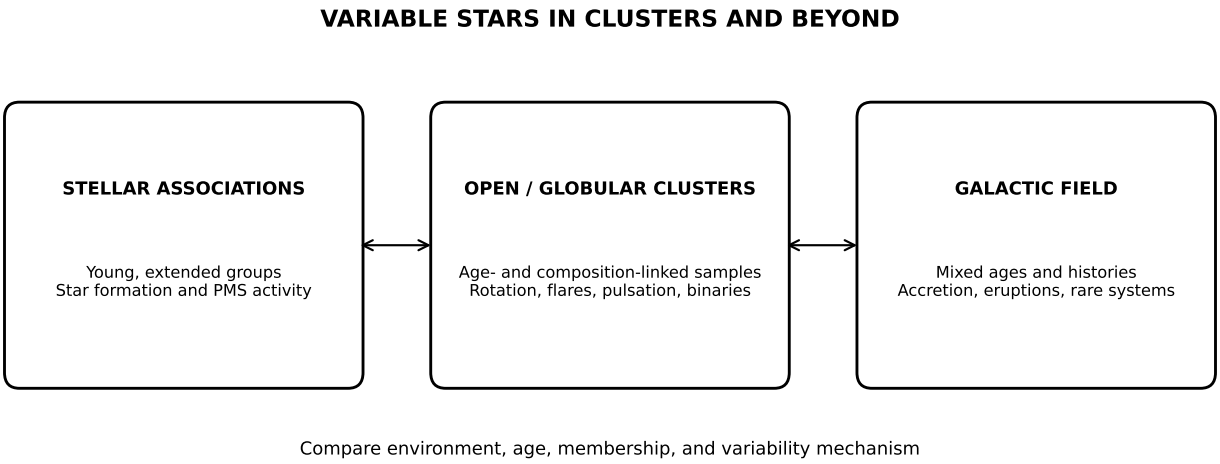


Figure 1: Conceptual map of the environments considered in this review. It is a schematic guide, not a physical scale diagram.

3. Classes of variable stars and their diagnostic value

The variability taxonomy is diverse, and observed classes may overlap. The categories below are organized by dominant physical mechanism rather than by a single mutually exclusive classification.

3.1. Flare stars and magnetic activity

Flare stars have played a central role in the history of cluster-variable studies at BAO. Comparing systems of different ages allows the changing incidence and amplitude of magnetic activity to be investigated. Such comparisons require consistent detection thresholds: a shallow survey can miss low-amplitude events, while sparse cadence can fail to resolve short flares. Field flare stars complement cluster samples but require independent constraints on age and population membership.

3.2. Pre-main-sequence variables

Young stellar objects can exhibit irregular brightness changes caused by accretion, spots, extinction by circumstellar structures, or combinations of these processes. Their association with star-forming regions is scientifically valuable, but crowding, nebulosity, and uncertain membership can complicate interpretation. Multi-band time series and spectroscopy are particularly important when distinguishing intrinsic changes from variable extinction.

Table 1: Representative variable-star classes and the information they can provide.

Class	Typical mechanism	Main diagnostic value
Flare stars / active dwarfs	Magnetic reconnection and rapid energy release	Magnetic activity, age dependence, rotation–activity relations
Pre-main-sequence variables	Accretion, spots, circumstellar material	Early stellar evolution, disk interaction, ongoing star formation
Pulsating variables	Radial or non-radial oscillations	Stellar structure, masses and radii, distance-scale calibration
Eclipsing binaries	Mutual occultation; sometimes tidal distortion	Fundamental stellar parameters, binary evolution, period changes
Rotational variables	Spots or surface inhomogeneities carried through rotation	Rotation periods, magnetic cycles, differential rotation
Cataclysmic variables	Accretion onto a white dwarf	Accretion physics, magnetic fields, outbursts and transient behaviour
Novae and supernovae	Thermonuclear eruption or stellar explosion	Explosive evolution, progenitor constraints, transient populations
Irregular / eruptive variables	Multiple or incompletely constrained processes	Discovery space; requires multi-band and spectroscopic follow-up

3.3. Pulsators, eclipsing binaries, and rotation

Pulsating stars provide probes of internal structure and, for selected classes, distance. Eclipsing binaries can yield precise masses and radii when photometric and spectroscopic constraints are combined. Rotational modulation can measure rotation periods, although spot evolution and harmonics can produce aliases. Cluster samples make age-dependent comparisons possible; field samples widen the range of evolutionary states and metallicities.

3.4. Accreting and eruptive systems beyond clusters

Magnetic cataclysmic variables, classical and recurrent novae, and supernovae are examples of systems for which field monitoring is essential. Their rarity and transient nature mean that targeted patrol observations can complement long-baseline surveys. Our recent programme includes monitoring of selected magnetic cataclysmic variables and observations of the recurrent nova RS Ophiuchi, alongside cluster work (Hojaev, 2026b). A co-authored multiwavelength study of 1RXS J174320.1−042953 and YY Sex is a concrete example of the field-system strand: both objects were confirmed as polars using optical light curves, spectroscopy, X-ray timing/spectra and (for YY Sex) circular polarimetry (Rawat et al., 2023). These targets are complementary case studies, not a statistically complete field sample.

4. From photographic plates to time-domain big data

The historical photographic surveys at Byurakan established the value of repeated observations over wide fields. Modern studies add calibrated CCD photometry, large public archives, and automated variability searches. Gaia contributes astrometry and broad-band photometry; TESS and Kepler provide high-cadence space photometry over selected fields; ground-based surveys add long time baselines and access to bright or geographically distributed targets. The strongest analyses combine these sources rather than treating any

single catalogue as definitive.

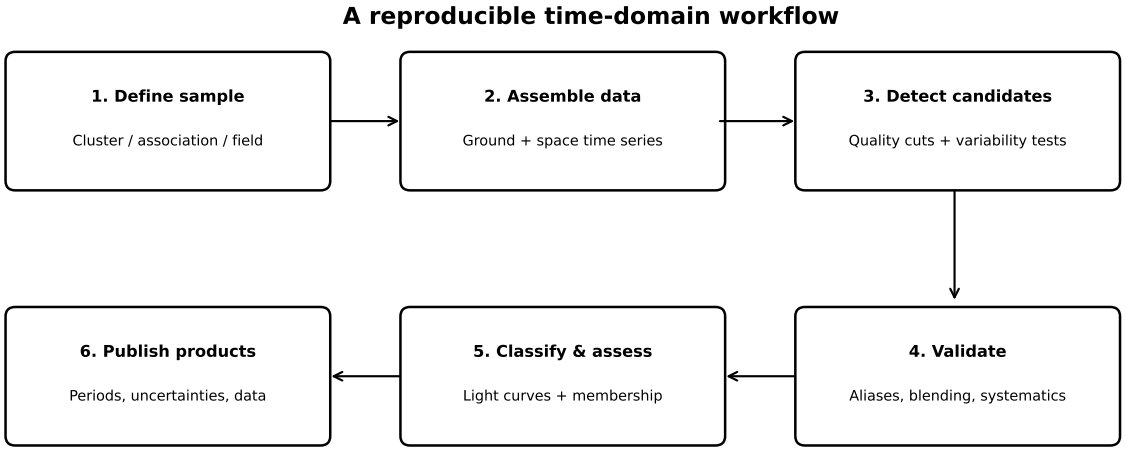


Figure 2: Suggested workflow for a reproducible cluster and field variability study.

A robust workflow typically includes: (1) defining the field and target population; (2) obtaining calibrated time series and metadata; (3) detecting candidate variability with more than one statistic; (4) checking aliases, systematics, blending, and data gaps; (5) classifying the light curve while preserving uncertainty; (6) assessing cluster membership; and (7) obtaining follow-up photometry or spectroscopy for high-value candidates. Reproducibility requires recording data releases, apertures, quality filters, cadence, period-search settings, and the criteria used to reject candidates.

5. Our cluster programme and individual systems beyond clusters

Our publications show a progression from ground-based patrol observations to the combined use of archival space photometry, Gaia astrometry, and coordinated Uzbek–Indian observing campaigns. The early cluster programme is documented in the Maidanak work on NGC 6823 and its associated nebula, and in a 2005 report describing multiwavelength work on NGC 6823 together with variability monitoring of seven compact open clusters (Hojaev, 2005, Hojaev et al., 2003). The 2005 paper is important as a programme-level predecessor: it describes the observing strategy and prospects, rather than a modern, homogeneous catalogue of classified variables. Later summaries describe time-series campaigns on 15 Galactic open clusters during 2021–2023, with an earlier set of seven clusters observed in 2003, and combine ground-based time series with TESS and Gaia data (Hojaev, 2024, 2026b, Lata et al., 2026). In our 2024 review, we reported 12,051 CCD frames from the 2021–2023 cluster/association campaign and 6,539 frames covering magnetic cataclysmic variables and their surrounding fields. Our review also lists preliminary variable counts from database searches: 136 in NGC 6871, 88 in NGC 6823, 65 in Gulliver 35, 26 in Berkeley 98, and 43 in the King 18 region; more than 430 candidates were reported in the NGC 6791 field as preliminary and still under characterization (Hojaev, 2024). These are heterogeneous discovery-stage counts from different searches, not a homogeneous, completeness-corrected census.

5.1. Uzbek–Indian cooperation, earlier projects and their publication record

Our Uzbek–Indian collaboration builds on the long-standing exchange of observing facilities, time-series data, and expertise in variable-star photometry. The early Maidanak programme established a practical basis for coordinated cluster studies, while later campaigns combine observations from Uzbekistan and India with public TESS light curves and Gaia astrometry. The historical and methodological context includes our report on the experience of Indo–Uzbek collaboration presented at the IAU XXXII General Assembly, as described by Hojaev (2026a); the Maidanak NGC 6823 work is documented by Hojaev et al. (2003), and the collaborative open-cluster programme is described by Hojaev (2005). Recent examples include

doi: https://doi.org/10.52526/25792776-26.73.2-281

Table 2: Variable-star counts reported in our 2024 review (Hojaev, 2024). These are source-specific discovery counts and should not be interpreted as completeness-corrected cluster populations.

Field / cluster region	Reported probable variables
NGC 6871	136
NGC 6823	88
Gulliver 35	65
Berkeley 98	26
King 18	43
NGC 6791	$>$ 430 (preliminary)

the NGC 6823 and NGC 7209 time-series studies by Lata et al. (2023) and Mwanzia et al. (2025), and the coordinated photometric, polarimetric, and X-ray investigation of J1743 and YY Sex by Rawat et al. (2023). The publication record also includes the extensive Hα survey of the Taurus dark clouds (Hojaev (1998)), the study of star-formation research prospects at the Suffa radio observatory (Hojaev & Zinchenko (2025)), and an earlier report article on the binary-star research programme at Maydanak (Zakirov et al. (1996)), the absolute-dimension analysis of V364 Lacertae with Maidanak collaborators (Torres et al. (1999)), and earlier short reports in the *Information Bulletin on Variable Stars*. These papers span young-star activity, eclipsing binaries, cluster variability, and accreting systems rather than a single homogeneous survey (Hojaev, 1983, 1984a,b, 1987, 1996, 1998, 2026a, Hojaev & Zinchenko, 2025, Torres et al., 1999).

5.2. NGC 6823: a young cluster with pre-main-sequence and main-sequence variability

Our most detailed co-authored cluster study in this set is Lata et al. (2023), which used time-series V- and I-band photometry and multiwavelength/astrometric membership evidence for NGC 6823 in the Sharpless 86 star-forming complex. We identified 88 variables, 14 of which had been previously recognized. Our membership analysis assigned 72 variables to the cluster; the paper reports 25 main-sequence variables and 48 pre-main-sequence variables among the member sample, with a small bookkeeping difference in these class totals relative to the member count that should be retained as published rather than silently reconciled. The member population implies an age of approximately 2 Myr. The pre-main-sequence sample includes classical T Tauri and Herbig Ae/Be objects as well as weak-lined T Tauri stars, while the main-sequence sample includes candidate β Cephei, δ Scuti, slowly pulsating B-type, and less securely classified variables. TESS light curves independently validate variability for 32 objects (Lata et al., 2023). Representative original light curves are reproduced in Fig. 3; the source paper also presents the phased curves in its Figs. 4–6 and the photometric/observing log in Table 1.

For the review's figure selection, the most directly relevant original visual is the sample of differential V- and I-band light curves in Fig. 3 of Lata et al. (2023), supplemented by the paper's TESS-light-curve examples. These plots demonstrate why a single cluster field can contain qualitatively different signals: irregular or asymmetric pre-main-sequence changes coexist with more periodic pulsation/rotation-like modulation. Our membership analysis is as important as the curves themselves: its 88 detected variables should not be described as 88 cluster members.

5.3. NGC 7209: candidate discovery, membership filtering, and a flare

In our 2025 study of NGC 7209 with Mwanzia et al., we analysed V-band CCD time-series photometry and Gaia DR3 information. Among 4,499 measured stars, 284 candidate variables were detected. HDBSCAN and Gaia DR3 astrometry identified 246 cluster members with membership probability above 60

It should be noted here that, for an expanded set of illustrations, one should select from the published paper those time-series panels that pertain to the variable stars under consideration within the cluster, as well as the flare event itself—an event recorded during the monitoring of this stellar cluster. In such cases, the figure caption should include the source identifier and the number of the original figure. It is important to point out that the flare detected in a star within this cluster serves as a connecting link between, on the one hand, traditional research conducted under the Byurakan Astrophysical Observatory (BAO) program—which focused on searching for and conducting in-depth studies of flare stars, both in clusters and in the general field—and, on the other, contemporary studies of stellar clusters carried out in the era of large-scale observational surveys. It should be particularly emphasized that the authors' estimate

of the flare energy accounts for the margin of error specified in the paper, and that, in the authors' view, the event itself should not be classified as a "superflare."

5.4. King 18: TESS candidates and the importance of membership

In our King 18 study, we examined TESS high-level science product time series retrieved through MAST (Hojaev & Karimov, 2024). We inspected 415 time series, initially identified 42 suspected variables, and selected ten objects whose light curves showed convincing brightness changes. We used the Lomb–Scargle periodogram and Lightkurve tools. Published candidate periods include 3.56809 d for Gaia source 371667757 and a concentration of values near 2.27 d for several other candidates; we explicitly describe the results as preliminary. Our Table 1 lists ten suspected variables, while the membership discussion gives only partial kinematic information for the first three entries, including membership probabilities of 0.4, 0.6, and 1.0. Thus the defensible result is a set of variables in the King 18 field, with membership established only for a subset—not ten confirmed cluster members (Hojaev & Karimov, 2024). The candidate light curves and periodograms are shown in the source paper Fig. 1, while its Table 1 lists the selected candidates; King 18 remains a preliminary case in this review.

The original light-curve and periodogram examples in Fig. 1 of our King 18 paper are the preferred illustration for this subsection. Our broader 2024 review separately lists 43 candidates in the King 18 region and shows phased light curves and periodograms in its Fig. 5; this larger count should not be conflated with the ten selected objects in the focused King 18 paper, which applies a different data product/selection stage. The discrepancy is best presented as a difference in sample definition and processing stage, not as a contradiction to be resolved by adding the counts. Their colour–magnitude diagram and spatial distribution should be used to discuss membership, not as independent proof of it. This is a useful methodological contrast with NGC 6823: the King 18 paper is a compact preliminary search based on space photometry, while NGC 6823 has a larger multi-band data set and a more extensive membership analysis.

5.5. Individual systems outside clusters: magnetic cataclysmic variables and eruptive stars

Our field-object programme includes targeted observations of selected magnetic cataclysmic variables (MCVs), recurrent nova RS Ophiuchi, and other active systems summarized in our 2024 review and 2026 IAU proceedings contribution (Hojaev, 2024, 2026b, Lata et al., 2026). The clearest fully refereed field example in our joint work is Rawat et al. (2023), which analysed 1RXS J174320.1−042953 (J1743) and YY Sex. In J1743, the optical data show distinct high and low states, while the orbital X-ray modulation persists only in the soft 0.3–2.0 keV band. Spectral modelling finds a partially covering absorber with column density around 7.5×10^{23} cm^{-2} covering approximately 56 per cent of the emission, and a soft blackbody component near 97 eV. For YY Sex, extensive TESS data refine the orbital period to 1.5746 ± 0.0011 h; we do not recover the previously claimed spin or beat periods; the polarimetric observations show circular polarization modulated at the orbital period. Strong Balmer and He II 4686-Å emission in both systems supports their classification as polars (Rawat et al., 2023). The J1743 multiwavelength light curves appear in Fig. 1 of the original paper, and the YY Sex orbital/TESS results are presented in its later figures and tables.

The original light curves in Rawat et al. (2023)—particularly the long-term state changes of J1743, the phase-folded optical modulation, and the TESS data for YY Sex—illustrate the different temporal scales that matter outside clusters: secular high/low states, orbital modulation, and multiwavelength changes in the accretion flow. They should be cited as source figures rather than redrawn from approximate values. This paper is a stronger case study than an isolated mention of a target because its classification rests on mutually supporting photometric, spectroscopic, polarimetric, and X-ray evidence.

Earlier individual-star work also connects this programme to young stellar objects and eclipsing systems. We have contributed to high-resolution observations of the peculiar T Tauri star V1331 Cyg and collaborative analysis of the active eclipsing binary WZ Cep (Djurasevic et al., 1998, Hojaev, 1999). These are distinct physical cases and should not be combined into a single homogeneous population: PMS flares probe early magnetic/accretion activity, V1331 Cyg probes a young star and its nebular environment, and WZ Cep is a close binary. Together they substantiate the "beyond" component of the title without implying that all such targets are members of clusters.

5.6. Publication inventory and light-curve traceability

Table 3 distinguishes the main cluster studies from individual-system papers and identifies the original light-curve material to consult. Counts and classifications are quoted as reported by the cited papers; they are not combined into a grand total because the samples, instruments, epochs, and selection thresholds differ.

Table 3: Selected studies from our cluster and field programme, based on published results (Hojaev, 2005, Hojaev & Karimov, 2024, Hojaev et al., 2003, Lata et al., 2023, Mwanzia et al., 2025, Rawat et al., 2023). Figure references identify published light-curve material; they are not new measurements.

Study	Environment / data	Published result	Light-curve material to consult
Hojaev (2005)	NGC 6823; seven compact clusters; ground-based patrol	Early programme report; multiwavelength NGC 6823 work and variability-monitoring strategy	Use for historical observing context; not a modern classified-variable catalogue
Hojaev (2024)	Review across clusters and field	Reports 15 clusters/associations observed in 2021–2023, 12,051 CCD frames, including 6,539 frames on MCV fields; gives cluster-specific counts	Review Fig. 5: King 18 phased light curves/periodograms; consult the original study for selected objects
Lata et al. (2023)	NGC 6823; V, I and TESS	88 variables; 72 reported members; 32 TESS validations; reported MS/PMS subtotals (25 + 48) exceed the stated member count of 72	Fig. 3 and TESS examples in the original paper
Hojaev & Karimov (2024)	King 18; TESS/MAST	415 time series screened; 42 suspected; ten selected; periods for candidates	Fig. 1 (light curves and periodograms)
Mwanzia et al. (2025)	NGC 7209; V-band and Gaia DR3	284 probable variable stars; 246 members by HDBSCAN/Gaia criterion; 17 member variables; one flare	Published member-variable time series and source ID 1329 flare plot
Rawat et al. (2023)	J1743 and YY Sex; optical, TESS, polarimetry, X-rays	Both systems confirmed as polars; YY Sex period 1.5746 ± 0.0011 h	Long-term/state and orbital light curves; YY Sex TESS modulation
Hojaev (1999); Djurašević et al. (1998)	V1331 Cyg; WZ Cep	Young-star/nebulosity structure and eclipsing-binary activity	Consult the original papers for the appropriate light curves or image-based evidence

It is essential to ensure that the final version of any article prepared for publication—which incorporates figures from the aforementioned works—includes only those illustrations for which reuse is permitted by the original source's license, or for which explicit permission has been obtained from the authors and the publisher. For every reproduced or adapted element (panel), the figure caption must cite the original source and the number of the original figure, and must also specify whether the element has been reproduced or adapted.

Table 4: Recommended information to report for cluster and field samples.

Item	Minimum information to include
Target definition	Cluster/association name, coordinates, angular coverage, adopted radius
Observations	Telescope, detector, dates, filters, exposure times, cadence, time baseline
Photometry	Calibration, aperture/PSF method, comparison stars, uncertainty estimation
Variability search	Statistics, period-search methods, thresholds, false-positive checks
Membership	Gaia data release, astrometric criteria, colour–magnitude consistency, probability or adopted flag
Classification	Evidence used, ambiguity, external catalogue matches, follow-up status
Data products	Tables of candidates, light curves, periods, amplitudes, quality flags, machine-readable files

5.7. Published figure and table traceability

Figure 3 reproduces selected original time-series panels from Lata et al. (2023), Mwanzia et al. (2025), and Rawat et al. (2023). Captions identify the original figure and source. It should be noted that the NGC 7209 article is distributed under CC BY 4.0; the King 18 paper is open access under CC BY 4.0; its original light-curve/periodogram and colour–magnitude panels are included below with source attribution (see Figure 4). Table 3 summarizes the studies and directs readers to their original tables and figures.

6. Limitations and common sources of bias

A variable-star catalogue is shaped by its observing window. Short-period systems are easier to detect in dense time series; long-period and irregular variables require longer baselines. Amplitude limits depend on magnitude, crowding, and photometric precision. Cluster fields can contain many unrelated foreground and background variables, while membership catalogues may be incomplete for faint, highly variable, or crowded sources. Periods may be aliased by the day–night cycle or spacecraft systematics. A classification inferred from a single light curve should be described as provisional when multiple mechanisms can produce similar morphology.

For these reasons, a strong review should separate confirmed results from possible or even probable variable star lists and preliminary classifications. Numerical totals should be quoted with a clear sample definition and source reference. Where two surveys disagree, the discrepancy may arise from different sensitivity, time coverage, or membership criteria rather than a contradiction in the underlying astrophysics.

A further limitation is that the meaning of a "variable-star sample" changes between observing programmes. A target list assembled from a cluster field is not equivalent to a membership-selected catalogue, and neither is identical to a set of objects with secure physical classifications. The NGC 6823, NGC 7209, and King 18 studies illustrate these successive levels: photometric variability is identified first, membership is assessed using astrometry and colour–magnitude information where available, and physical interpretation then depends on the quality and wavelength coverage of the follow-up data. These stages should be kept explicit when comparing reported counts across papers. In particular, a candidate may be astrophysically interesting even when its membership or variability type remains uncertain; the uncertainty should be recorded rather than removed from the narrative.

The same distinction applies to heterogeneous time-series archives. TESS provides long, relatively uniform space-based sequences for many targets, but sector boundaries, cadence choices, scattered-light events, and instrumental trends affect sensitivity to different periods and amplitudes. Ground-based observations can add filters and longer historical baselines, while often having gaps caused by weather, daylight, and seasonal visibility. These data sets are complementary rather than interchangeable. A robust synthesis therefore benefits from recording the observing window and data provenance alongside the derived period, amplitude, and classification. Reproducible detrending and period-search procedures, with inspection of aliases and instrumental artefacts, are especially important before a periodic signal is interpreted as rotation, pulsation, or orbital modulation.

Finally, a review should preserve the difference between what an original paper measured and what a later synthesis infers from it. Figures are useful evidence only when their source and original purpose are clear; a light curve demonstrates observed morphology, but does not alone prove cluster membership or establish a unique physical mechanism. In this manuscript, published results are therefore discussed with their original sample definitions and figure references, and preliminary classifications are identified as such. This approach makes the comparison more useful for follow-up planning without turning a review of prior work into a new, unverified catalogue.

7. Future prospects

The next phase of cluster and field variability research will be driven by the combination of long-baseline ground-based photometry, space-based precision light curves, astrometric membership, and multi-wavelength follow-up. In this regard, ground-based projects such as the LSST (Vera C. Rubin Observatory) — along with other ground-based, all-sky time-domain surveys — are particularly attractive and effective, offering a high cadence, a deep limiting magnitude, and high photometric precision. Priority areas include young variables in star-forming complexes, age-dependent magnetic activity, rotation and spot evolution, eclipsing binaries

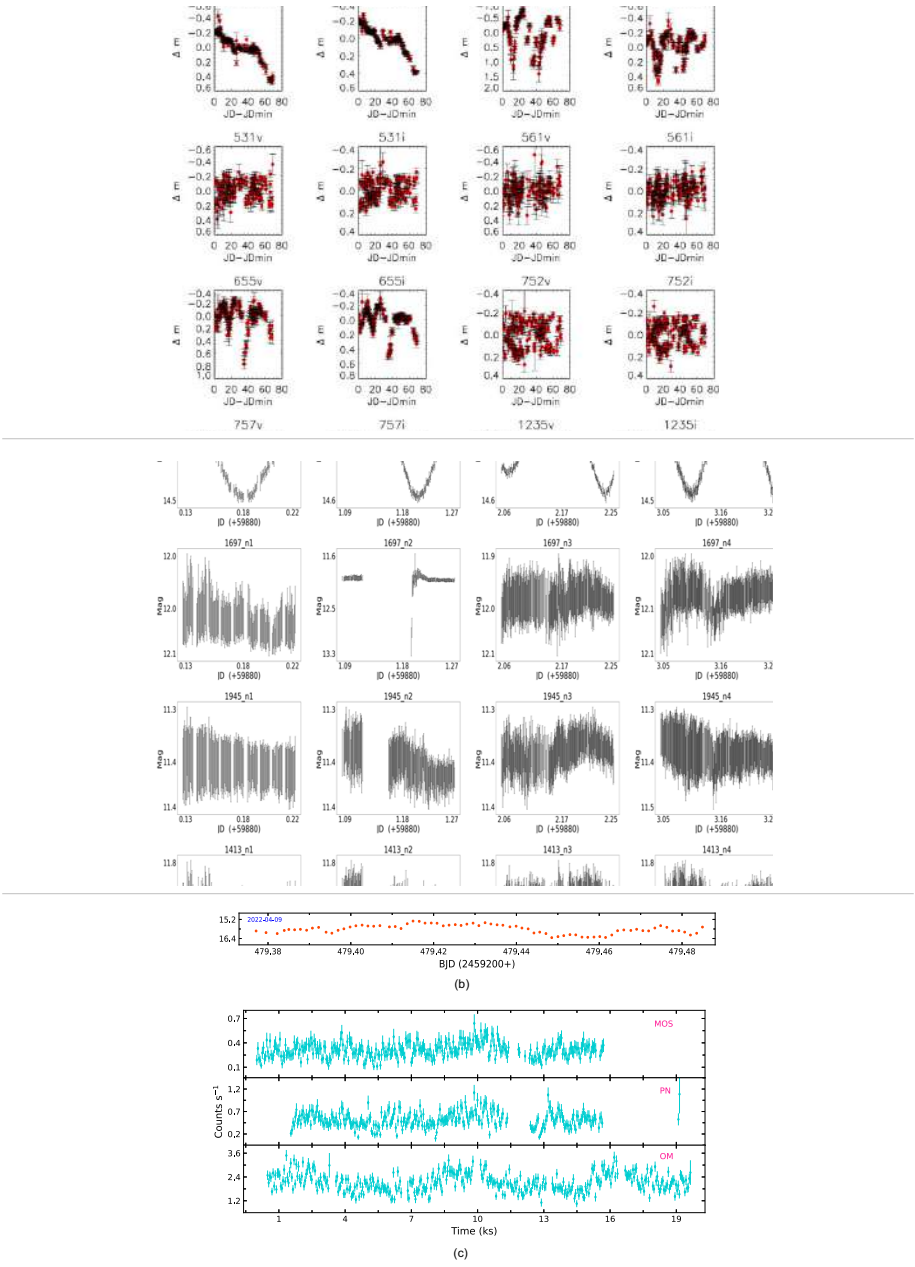
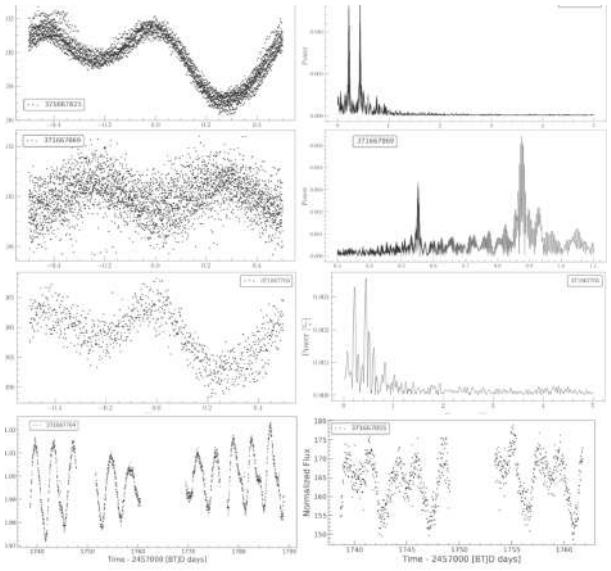
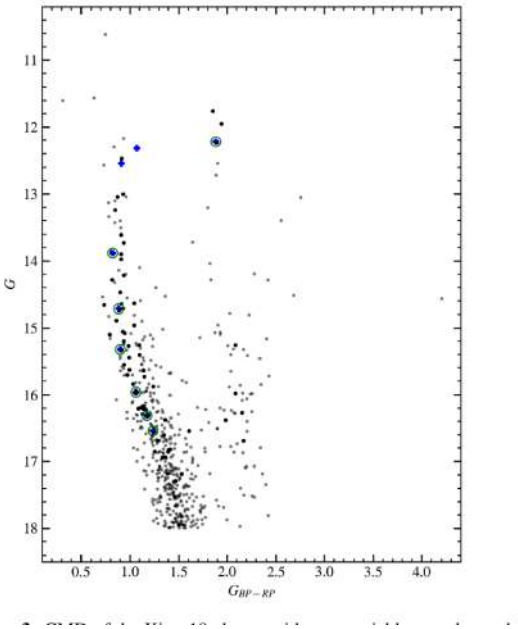


Figure 1. Optical, X-ray, and UV light curves of J1743. (a) The long-term ASAS-SN along with *R*-band observations. (b) Present *R*-band observations, where the date of each observation is mentioned over each light curve. J1743 experienced a low-accretion state in June 2021, which can be seen in the light curves of three epochs: June 10, 11, and 14. (c) EPIC light curves in the 0.3–10.0 keV energy range and OM light curve in the UVW1 filter, binned in 50-s intervals.

Figure 3: Selected published time-series evidence. Top: sample V/I light curves in NGC 6823 (Lata et al. 2023, original Fig. 3; reproduced panel) (Lata et al., 2023). Middle: selected sample variable-star light curves in NGC 7209 (Mwanzia et al. 2025, original Fig. 4; reproduced under CC BY 4.0) (Mwanzia et al., 2025). Bottom: optical, X-ray, and UV light curves of J1743 (Rawat et al. 2023, original Fig. 1) (Rawat et al., 2023). Axes, data points, and source annotations are retained from the original figures; no synthetic observations are shown.



(a) Sample TESS light curves and periodograms (original Fig. 1).



(b) Colour–magnitude diagram and candidate variables (original Fig. 3).

Figure 4: Published diagnostic figures for King 18, reproduced from Hojaev and Karimov (2024) under CC BY 4.0.

in well-characterized clusters, and targeted monitoring of rare accreting systems. Coordinated observations across longitudes can improve coverage of rapid events and reduce aliasing. Publicly archived light curves and reproducible analysis pipelines will make it easier to compare samples from different observatories.

For an observatory with BAO's legacy, a particularly meaningful direction is to connect the historical study of stellar associations and flare stars with modern survey-driven research. The scientific continuity is not simply technological: in both eras, the key question is how variability changes with environment, age, and evolutionary state.

8. Conclusions

The study of variable stars in clusters and beyond links stellar physics to the environments in which stars form and evolve. BAO's foundation in 1946, Ambartsumian's early work on stellar associations, and the observatory's long tradition of flare-star research provide a compelling historical framework. Modern surveys extend this programme through precise astrometry, high-cadence photometry, and large multi-epoch databases. Our cluster–field programme exemplifies the value of combining observations of open clusters with targeted monitoring of active systems outside them. The expanded examples show how the cluster and field strands complement one another: membership-filtered cluster samples constrain population context, while individual accreting systems expose rapid state changes and multiwavelength physics. The figure identifies published light-curve evidence for the cluster and field examples, with original figure numbers and source credits in the caption.

Acknowledgements

The authors thank the observing staff at the participating observatories for their support of the photometric monitoring programme. We acknowledge the TESS team for making the mission data publicly available and the Mikulski Archive for Space Telescopes (MAST) for providing access to the data. We also acknowledge the use of Lightkurve, NASA/IPAC Infrared Science Archive (including 2MASS data), Gaia, SIMBAD and the Centre de Données astronomiques de Strasbourg (CDS), and the NASA Astrophysics Data System (ADS). We are grateful to colleagues in the Uzbek–Indian collaboration for discussions and contributions to the cluster and variable-star studies.

References

Ambartsumian V. A., 1978, Astrophysics, 14, 209

Ambartsumian V. A., Mirzoyan L. V., 1975, in Variable Stars and Stellar Evolution. pp 3–14

BAOweb 2026, History of the Byurakan Astrophysical Observatory, https://www.bao.am/about/history.php

Djurasevic G., Zakirov M., Hojaev A., Arzumanyants G., 1998, Astronomy and Astrophysics Supplement Series, 131, 17

Hojaev A. S., 1983, Information Bulletin on Variable Stars, p. 1

Hojaev A. S., 1984a, Information Bulletin on Variable Stars, p. 1

Hojaev A. S., 1984b, Information Bulletin on Variable Stars, p. 1

Hojaev A. S., 1987, Astrofizika, 27, 207

Hojaev A. S., 1996, in Cool Stars, Stellar Systems, and the Sun. Astronomical Society of the Pacific, p. 429

Hojaev A. S., 1998, Publications of the Astronomical Society of Australia, 15, 152

Hojaev A. S., 1999, New Astronomy Reviews, 43, 431

Hojaev A. S., 2005, Journal of Astrophysics and Astronomy, 26, 293

Hojaev A. S., 2024, Astronomical Journal of Azerbaijan, 19, 31

Hojaev A. S., 2026a, in Proceedings of the International Astronomical Union. pp 43–44, doi:10.1017/S174392132400320X

Hojaev A. S., 2026b, in Proceedings of the International Astronomical Union. pp 100–104, doi:10.1017/S1743921324001650

Hojaev A. S., Karimov R. G., 2024, Bulletin de la Société Royale des Sciences de Liège, 93, 236

Hojaev A. S., Zinchenko I. I., 2025, Astrophysical Bulletin, 80, 140

Hojaev A. S., Chen W.-P., Lee H. T., 2003, Astronomical and Astrophysical Transactions, 22, 799

Lata S., et al., 2023, Monthly Notices of the Royal Astronomical Society, 520, 1092

Lata S., Mwanzia D. M., Okeng'o G., Mondal S., Buers J., Hojaev A. S., 2026, New Astronomy, 125, 102530

Mirzoyan L. V., 1995, in Flares and Flashes. pp 47–54

Mirzoyan L. V., Pettersen B. R., Tsvetkov M. K., (eds.) 1990, IAU Symposium 137: Flare Stars in Star Clusters, Associations, and the Solar Vicinity, Proceedings, Kluwer Academic Publishers, Dordrecht, The Netherlands, 410 p., https://www.bao.am/meetings/meetings/iaus137.php

Mwanzia D. M., et al., 2025, The Astrophysical Journal, 985, 26

Rawat N., Pandey J. C., Joshi A., Potter S. B., Hojaev A. S., De Becker M., Rao S. M., Yadava U., 2023, Monthly Notices of the Royal Astronomical Society, 521, 2729

Sedrakian D., Harutyunian H. A., Kalloghlian A. T., 2006, Astrophysics, 49, 281

Torres G., et al., 1999, The Astronomical Journal, 118, 1831

Zakirov M. M., Hojaev A. S., Arzumanyants G. G., 1996, Journal of the Korean Astronomical Society, Supplement 1, 29, 245