*Astronomical and Astrophysical Transactions* (*AApTr*), 2025, Vol. 35, Issue 3, pp. 261–268,
ISSN 1055-6796, Photocopying permitted by license only, ©Cambridge Scientific Publishers

# Preliminary results of the study of the open cluster Stock 1

M.T. Parmanova[1,2], O.A. Burkhonov[1,*], R.G. Karimov[1], R.A. Gaysin[1],
I.L. Satovsky[3], M.M. Muminov[4], A.M. Shaimanov[1]

[1] *Ulugh Beg Astronomical Institute, Uzbekistan Academy of Sciences, Astronomicheskaya 33, Tashkent 100052, Uzbekistan*
[2] *Tashkent Institute of Irrigation and Agricultural Mechanization Engineers National Research University, 100000, Tashkent, Uzbekistan*
[3] *State Corporation Roscosmos, Moscow, Russia*
[4] *Andijan State University, Andijan, Uzbekistan*

*Received 27 April, 2025; accepted 31 May, 2025*

This work presents intermediate results from the study of the open star cluster Stock 1. Observational data used to identify probable variable stars within the cluster were obtained at the Maidanak Astronomical Observatory of the Astronomical Institute of the Academy of Sciences of the Republic of Uzbekistan. The GAIA DR2 catalog was used to determine the astrometric characteristics of the cluster stars. We have identified 113 probable members of the Stock 1 cluster, four of which are variable stars. The average values of their proper motions and parallaxes have been determined: $\mu_\alpha \cos\delta = -6.055 \pm 0.253$ mas/yr, $\mu_\delta = -0.221 \pm 0.243$ mas/yr, $Plx = 2.433 \pm 0.149$ mas.

*Keywords*: Star cluster: individual (Stock 1); star: astrometry; photometry; variable; astrophysics – solar and stellar astrophysics; astrophysics – astrophysics of galaxies

## 1 Introduction

It is well known that stars form from clouds of interstellar gas and dust under the influence of gravitational instability. The regions where this formation occurs typically give rise to groups of stars – ranging from several dozen to several thousand – that share a common origin. As a result, these stars generally have the same age, chemical composition, and distance from the observer, with variations mainly attributed to differences in their masses. Although stars initially form in groups, over time some of them disperse and populate the surrounding space. Meanwhile, others remain gravitationally bound and evolve into star clusters (Krause et al., 2020; Lada & Lada, 2003; Krumholz et al., 2019). However, due to ongoing gravitational interactions,

*Email: boa@astrin.uz

these star clusters will eventually disintegrate (Tutukov et al., 2024). This dynamic evolution underscores the importance of studying open star clusters, as they serve as ideal objects for investigating the stellar population of our Galaxy.

Research into the stellar composition of open star clusters is one of the key tools for testing theories of stellar evolution. To do this effectively, it is essential to unambiguously determine which stars are members of a given cluster. Various methods have been developed for this purpose (Olivares et al., 2025), but astrometric selection remains the most reliable. In this context, the Gaia astrometric data catalogs (Gaia Collaboration et al., 2021) are invaluable, providing highly accurate astrometric measurements for a vast number of stars. These catalogs offer a five-dimensional parametric survey of the Galactic stellar population, reaching distances of up to 20 kpc from the Sun.

In parallel, the study of variable stars provides vital information about the physical characteristics of stars including: mass, radius, luminosity, temperature, and internal structure, as well as their kinematic properties. Various types of variable stars are found in open clusters (Maurya et al., 2023), and their cluster membership imposes certain constraints due to their formation conditions. Therefore, a comprehensive study of star clusters and the variable stars they contain is especially valuable from an astrophysical perspective (Lata et al., 2023). In our study, we observed and analyzed the open star cluster Stock 1 ($\mathrm{RA} = 19^h36^m35.0^s, \mathrm{DEC} = +25°09'47''$ ), which was originally believed to contain 26 members. This cluster, located in the northern hemisphere, was discovered by J. Stock in 1954 (Stock, 1954). Stock also conducted the first two-color photographic photometry of the cluster's stars in 1956 (Stock, 1956). A more systematic photographic study was later carried out by Spalding (1979), who used V and B filters, estimated a reddening value of $E(\mathrm{B}-\mathrm{V}) \approx 0.19$, and determined a distance modulus of 7.75. In 2002, Osborn et al. performed BVRI photometry of stars in the field of Stock 1. They determined a reddening of $E(\mathrm{B}-\mathrm{V}) = 0.16 \pm 0.04$, a distance modulus of $\mathrm{V}_0 - \mathrm{M}_\mathrm{V} = 7.5 \pm 0.1^m$, and estimated the cluster's age at $300 \pm 50$ Myr. However, Osborn and colleagues identified only 17 probable cluster members and did not address the presence of variable stars in the region.

Here, we present the interim results of our study based on astrometric data from the Gaia DR2 catalog and observational data collected at the Maidanak Astronomical Observatory.

## 2 Observations

All observational data on the Stock 1 open star cluster (OCl) presented in this work were obtained by the authors using the 0.5-m robotic telescope AMT-1 at the Maidanak Astronomical Observatory (MAO) of the Astronomical Institute of the Academy of Sciences of Uzbekistan. MAO is located at an altitude of 2,600 meters above sea level in the Kamashi district of the Kashkadarya region, Uzbekistan, and is known for its excellent astroclimatic conditions for astronomical observations (Ehgamberdiev, 2018; Tillayev et al., 2023). All observations were conducted remotely. The 50-cm automated telescope AMT-1 (AstroTel Maidanak Telescope 1) is equipped with an

Apogee Alta U16M CCD camera (4 K × 4 K), operated remotely. During the observations, the CCD camera was maintained at an operating temperature of −15°C. The telescope is mounted on a Mathis Instruments MI-750 equatorial fork mount and features an ASTROSIB RC500 optical tube with a Ritchie–Chrétien design and a focal length of 4000 mm. The physical pixel size of the Apogee Alta U16M is 9 microns. A binning mode of 2 × 2 was used, yielding an angular pixel scale of 0.907″ and a field of view of 30.9′ × 30.9′. Image acquisition was managed using MaxIm DL software.

Observations were carried out using B, V, and Rc filters of the JohnsonCousins photometric system (Astrodon), with exposure times of 300, 240, and 210 seconds, respectively. Data were collected over 7 nights, from July 20 to July 28, 2022 (JD_start = 2459782.2171643521 to JD_end = 2459789.2574189813). A total of 612 images were captured, out of which 581 high-quality images were selected for final analysis, excluding those with poor quality.

Calibration frames – including bias (zero-point offset), dark frames with exposure times matching those of the science frames, and flat-field images for each corresponding filter – were taken each night before and after observations during evening and morning twilight. These calibration images were used for the primary processing of the CCD data.

## 3 Data processing and photometry

The Image Reduction and Analysis Facility (IRAF) software package was used for the pre-processing of CCD images obtained during observations. All CCD image preprocessing steps were carried out using the CCDRED package within IRAF. To obtain a super bias, the zerocombine command was used. Super darks were created using the darkcombine command, taking into account the exposure time of the working images.

Before creating super flats, flat-field images were sorted by filters, and the flatcombine command was applied. The complete primary processing of the operational (OCl Stock 1) CCD images was performed using the ccdproc command from the IRAF software suite.

Photometric measurements of all stars captured in the CCD images were conducted using the VaST (Variability Search Toolkit) program (Sokolovsky & Lebedev, 2018), employing the aperture photometry method. A key advantage of the VaST program is its ability to immediately identify variable stars.

For suspected variable stars – regardless of whether they are members of OCl Stock 1 – control aperture photometric measurements were also performed using the APPHOT package within IRAF. The selection of reference stars for these measurements focused on their isolation, similarity in magnitude, and color index based on the 2MASS reference catalog.

## 4 Variable stars in the OCl Stock1 field

According to the results of photometric measurements and their analysis, more than 200 variable stars were identified. For each of these stars, key characteristics were

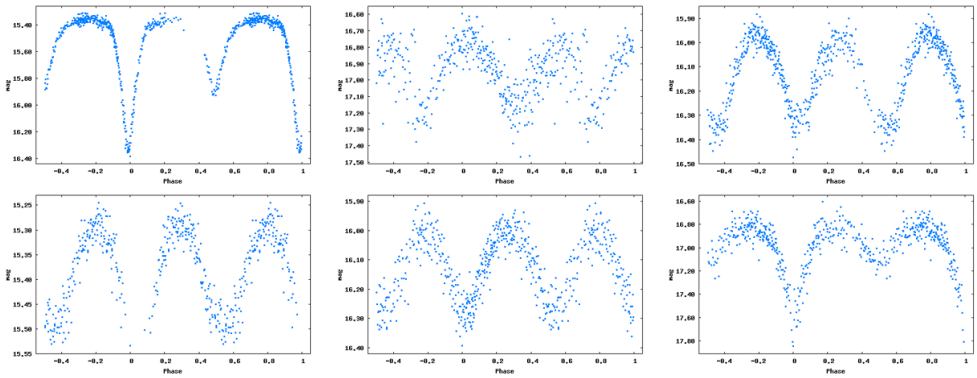


**Figure 1** Phased lightcurves of some variable stars located in the Stock 1 cluster region.

determined: the period of brightness variation, the amplitude of brightness change, the type of variability, and the light elements. Light curves were constructed for these stars to illustrate the dynamics of their luminosity. Figure 1 shows the phase light curves of some of the variable stars discovered in the cluster region.

A comparative analysis of the identified variable stars with known variable stars revealed 14 previously unknown variable stars located in the OCl Stock 1 field (Table 1). Of these, nine are eclipsing binaries, four are classified as Delta Scuti-type variables, one is likely a BY Draconis-type variable, and one is a variable star of indefinite type. Detailed information on the newly discovered variable stars in the OCl Stock 1 field is provided in the appendix of the journal Variable Stars (Parmanova et al., 2024).

## 5 Identifying probable members of the Stock1 OCl

Gaia DR2 catalog data were used to study the astrometric characteristics of the OCl Stock 1. For this purpose, the following data were used: sky position, parallaxes, and proper motions, with a magnitude limit of G = $21^{\mathrm{m}}$. The data errors from the catalog for proper motion values are 0.06 mas/yr (for G $\leq 15^m$ ), 0.02 mas/yr (for G $\sim 17^m$), and 1.2 mas/yr (for G $\sim 20^m$). To analyze the astrometric measurements of the studied star cluster, the TOPCAT program was employed, which enables working with large datasets and performing both mathematical and statistical calculations.

The selection method proposed by Bisht et al. (2019) was used to identify probable cluster members. Based on the data analysis results, a OCl proper motion vector-point diagram was constructed and analyzed, which led to the identification of 113 probable cluster members.

During the study of stars in the Stock 1 field, their average values of proper motions and parallax were determined: $\mu_c \cos\delta = -6.055\pm 0.253$ mas/yr, $\mu_\delta = -0.221\pm 0.243$ mas/yr, $Plx = 2.433\pm 0.149$ mas.

**Table 1** Newly identified variable stars in the Stock 1 field.

| No | GAIA ID | Coord (J2000) | Type | Max | Min | Period (days) |
|---|---|---|---|---|---|---|
| 1 | Gaia DR3 2021434299305459968 | 193515.765 +24 5941.15 | EB | 16.23 | 16.74 | 0.44 |
| 2 | Gaia DR3 2021446978049705216 | 193519.187 +25 1159.30 | EB | 16.12 | 16.46 | 0.54 |
| 3 | Gaia DR3 2021521538687523200 | 193553.651 +252617.20 | DSCTC | 14.58 | 14.61 | 0.072 |
| 4 | Gaia DR3 2021521160730408960 | 193607.670 +252710.78 | BY | 13.97 | 14.01 | 0.85 |
| 5 | Gaia DR3 2021428041491192960 | 193618.142 +245910.62 | EB | 16.94 | 17.55 | 0.471 |
| 6 | Gaia DR3 2021453575119944832 | 193623.346 +250711.71 | EA | 15.98 | 16.64 | 0.784 |
| 7 | Gaia DR3 2021468276749118208 | 193653.515 +251702.91 | DSCTC | 15.97 | 16.02 | 0.207 |
| 8 | Gaia DR3 2021452853565343104 | 193659.882 +250720.69 | DSCTC | 14.95 | 14.97 | 0.2484 |
| 9 | Gaia DR3 2021456495697916928 | 193703.364 +251614.45 | EA | 15.60 | 15.97 | 1.35 |
| 10 | Gaia DR3 2021462405573585920 | 193706.357 +251729.37 | EB | 16.07 | 16.22 | 11.55 |
| 11 | Gaia DR3 2021462336854101632 | 193709.453 +25 1640.96 | EB | 16.56 | 16.92 | 0.4272 |
| 12 | Gaia DR3 2021462543012544128 | 193712.750 +251821.41 | EB | 15.18 | 15.32 | 0.8360 |
| 13 | Gaia DR3 2021455048249451264 | 193718.958 +251201.45 | EA | 16.42 | 16.70 | 1.058 |
| 14 | Gaia DR3 2021450551462745344 | 193731.203 +250524.47 | | 15.77 | 15.94 | |

The constructed proper motion vector-point diagram and position distribution of stars in the OCl are presented in Figure 2. The histograms of the distribution of proper motions and parallaxes for the probable cluster members are shown in Figure 3. The color magnitude diagram is displayed in Figure 4.

## 6 Conclusion

After identifying probable cluster members, we performed a crosscorrelation analysis with the ZTF catalog (Chen et al., 2020) to identify variable stars that are probable members of Stock 1. As a result, three variable stars from the ZTF catalog and one from our list of new variable stars coincided with probable members of the Stock 1 (see Table 2). The number of probable members of the Stock 1 cluster that we identified was slightly smaller than the list of probable cluster members compiled by Dias et al. (2021). The average proper motions and parallaxes of the Stock 1 stars we obtained are in good agreement with the values determined by Dias et al. (2021): $\mu_\alpha \cos\delta = -$

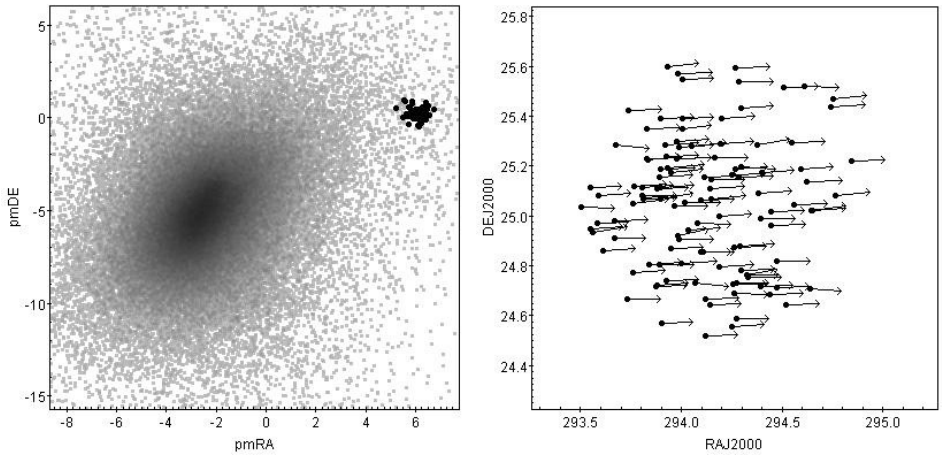



**Figure 2** Proper motion vector-point diagram and position distribution of stars in the Stock 1 cluster region. Selected probable members are marked in black, and field stars are marked in gray.

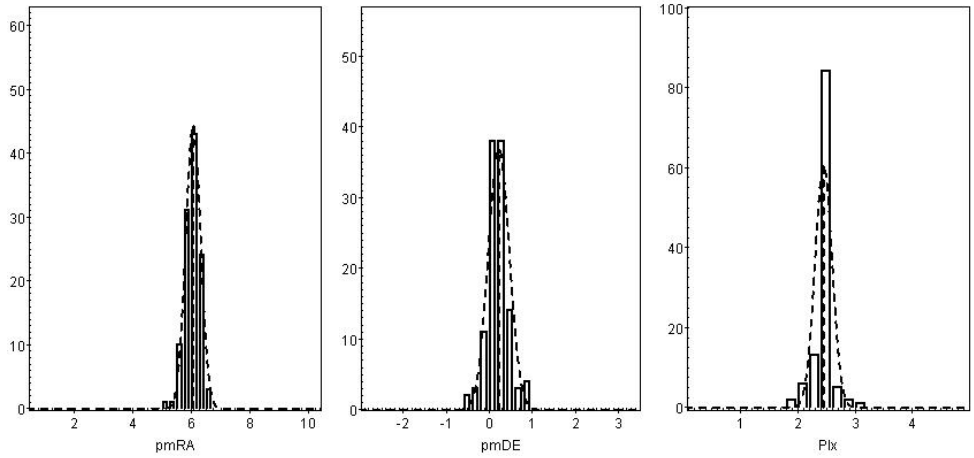



**Figure 3** Histograms showing the distribution of proper motions and parallaxes for the probable members of Stock 1.

$6.031 \pm 0.323$ mas/yr, $\mu_\delta = -0.299 \pm 0.425$ mas/yr, $Plx = 2.446 \pm 0.082$ mas. The differences in the obtained estimates can be attributed to the different methods used to select the probable cluster members.

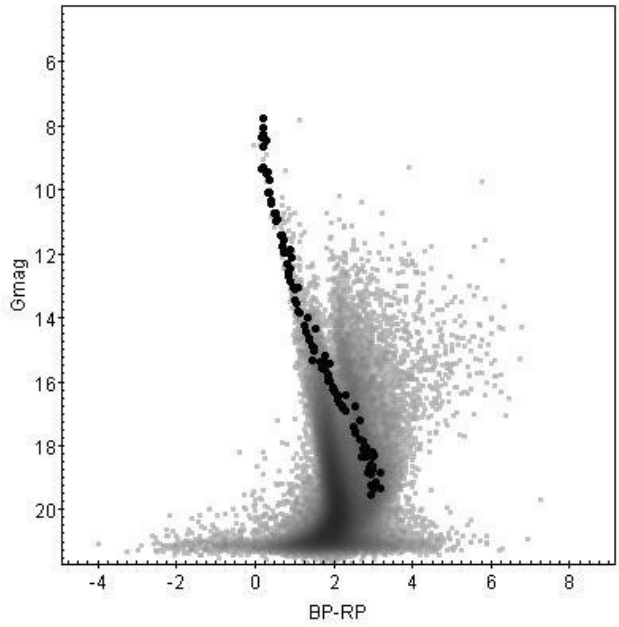



**Figure 4** Color–magnitude diagram of the stars in the direction of Stock 1. Field stars are marked in gray, and probable members of the cluster are marked in black.

**Table 2** Variable star members of the open cluster Stock 1.

| No | Coord (J2000) | Cross ident. | Mag. (r) | Var. type | Period (days) |
|---|---|---|---|---|---|
| 1 | 193502.21 +24 4628.25 | ZTF J193502.21+244628.3 | 16.22 | BY* | 0.753935 |
| 2 | 193556.05 +24 5514.54 | ZTF J193556.05+245514.6 | 15.462 | BY* | 0.786123 |
| 3 | 193711.20 +24 4702.56 | ZTF J193711.21+244702.6 | 16.514 | BY* | 0.710874 |
| 4 | 193731.20 +25 0524.47 | Gaia DR3 2021450551462745344 | 15.77 | ? | ? |

## References

Bisht D., Yadav R. K. S., et al. 2019. MNRAS, Vol. 482, Issue 2, p.1471-1484.

Chen X., Wang S., et al. 2020. ApJS., Vol. 249, Issue 1, id.18

Dias W. S., Monteiro H., et al. 2021. MNRAS, Vol. 504, Issue 1, pp. 356-371.

Ehgamberdiev Sh. 2018. Nature Astronomy, Vol. 2, 349–351.

Gaia Collaboration, Brown A. G. A., et al. 2021, A&A, Vol. 649, id. A1, 20 pp.

Martin G.H. Krause, et al. 2020, The Physics of Star Cluster Formation and Evolution. Space Sci. Rev. 216, 64.

Lada, C.J.; Lada, E.A. Embedded Clusters in Molecular Clouds. Annu. Rev. Astron. Astrophys. 2003, 41, 57–115.
Ishchenko M., Masliukh V., et al. 2025. A&A, Vol. 694, id. A33, 13 pp.
Krumholz M. R., McKee C.F., and Bland-Hawthorn J. 2019. ARA&A., vol. 57, p.227-303.
Lata S., Chen W. P., et al., 2023, MNRAS, Vol. 520, Issue 1, pp.1092-1110
Maurya J., Joshi Y. C., Panchal A., Gour A. S., 2023, AJ., Vol. 165, Issue 3, id.90, 17 pp.
Olivares J., Bouy H., et al. 2025. A&A, Vol. 693, id. A12, 20 pp.
Osborn W., Sano Y., Spalding R. 2002, PASP, Vol. 114, Issue 802, pp. 1382-1388.
Parmanova M., Gaysin R., et al. 2024. "Peremennye Zvezdy", Prilozhenie, vol. 24, N 2.
Sokolovsky K. V., Lebedev A. A. 2018. Vol. 22, p. 28-47.
Spalding, R. D. 1979, M.S. thesis, Central Michigan Univ.
Stock J. 1954. Astronomical Journal, Vol. 59, p. 332. 1954
Stock J. 1956. Astrophysical Journal, 1956, vol. 123, p.258.
Tillayev Y., Azimov A., Ehgamberdiev S., Ilyasov S. 2023. Atmosphere, 14, 199.
Tutukov A. V., Vereshchagin S. V., Chupina N. V. 2024. ARep., Vol. 68, Issue 10, pp. 978-994
Zhou J.-W., Kroupa P., Dib S. 2024, A&A, Volume 688, id. L19, 6 pp.