

Variables in Clusters and Beyond

A.S.Hojaev

on behalf of India & Uzbekistan team

The Summary

- The main cornerstones of the current joint granted project between ARIES and UBAI
- other initiatives
- other partners

A Brief History

- 2004 ☯ at the invitation of the former director of ARIES, Prof. Ram Sagar I visited Nainital and had a fruitful discussion on possible joint research and collaboration in observational study
.....
- 2019 ☯ DST Govt.of India and MID (Innov.Develop.) of Uzbekistan
**Call for Proposals under Indo-Uzbek
Joint Research Programme**
... ~ 170 proposals → ~ 140 (after tech. exp.) → 21 awarded (mainly technol./applied)
- 2021 ☯ start of the joint project
‘Search for Variable Stars in Star Clusters’

Participating Sides

- Institutes : Aryabhata Research Institute of observational Sciences (ARIES) , DST of India
Ulugh Beg Astronomical Institute (UBAI), Uzbekistan Academy of Sciences
- PIs* : Ramakant Singh Yadav (India) & Alisher S. Hojaev (Uzbekistan)
- Indian participants : Ramakant Singh Yadav, Jeewan Chand Pandey, Nikita Agrawal et al.
- Uzbek personnel : Alisher S. Hojaev, Shuhrat A. Ehgamberdiev, Otabek Burkhonov, Rivkat Karimov,
Renat Gaysin, Dmitry Semakov, Azizbek Matekov, D.Mirzaqulov, B.Hafizov,
A.Shaymanov, T.Boyqobilov, R. Murtazin

* Project Initiators *awa* Principal Investigators

Instrumentation & Sites

- ▶ ARIES has 2 observatories :

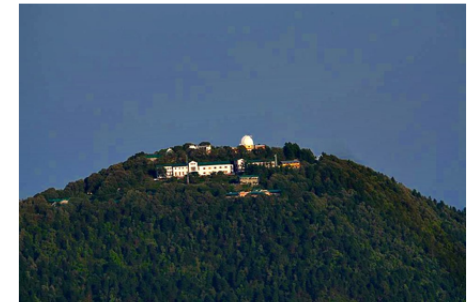
Nainital Manora Peak Campus 1,951 m amsl

Devasthal ("Abode of God") Peak Campus ~2450 m amsl

3.6-m Devasthal Optical Telescope (DOT); **1.3-m** diameter Devasthal Fast Optical Telescope (DFOT); 104-cm Sampurnanand Telescope by Carl Zeiss at Nainital; 80/50-cm Baker-Nunn Schmidt telescope (BNST); 4 m International Liquid Mirror Telescope (ILMT)

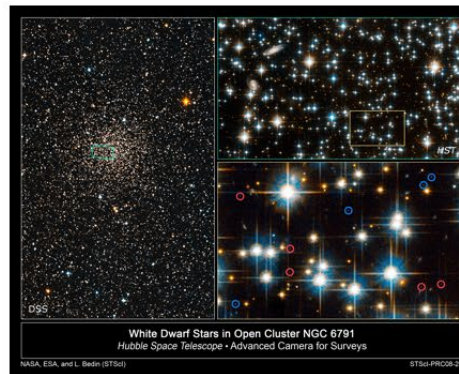
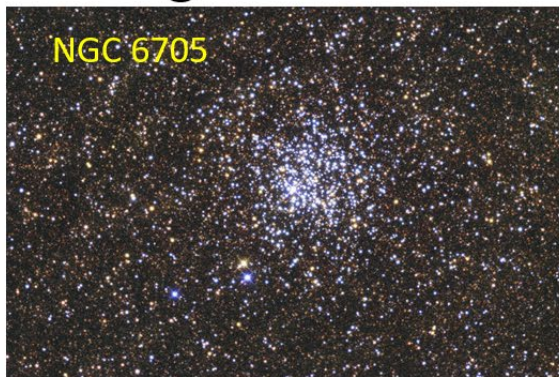
- ▶ UBAI has MAO 2593 m amsl :

1.5-m AZT (LOMO) ; 1-m Zeiss Telescope (temp. out-of-use); two 60-cm Zeiss Telescopes



Search for Variable Stars

- NGC 6705 and NGC 6791 pilot monitoring
- Young cluster IC1396 aka BRC 5 =SFO 5 and BRC 7=SFO 7 monitoring started



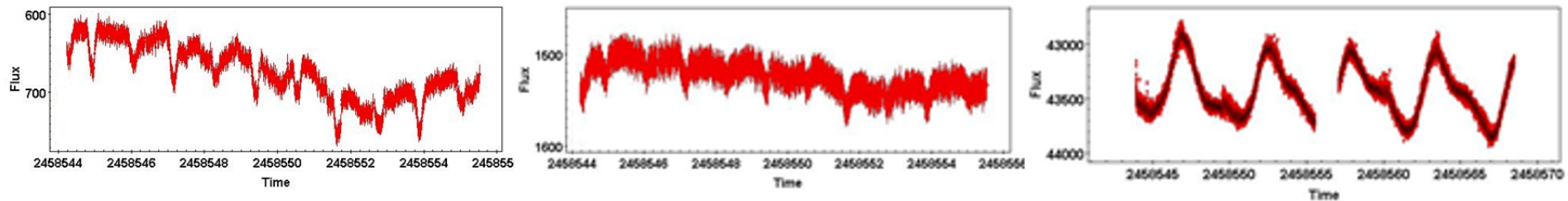
preliminary kick-off analysis : at least 13 new variable stars and precise measurements for 7 known variables in NGC 6791 - further analysis required

Search for Variable Stars in DBs

Transiting Exoplanet Survey Satellite (TESS), Kepler, etc.

open star cluster Gulliver 35:

According to the results of analysis of these data, 3 stars were found showing variability

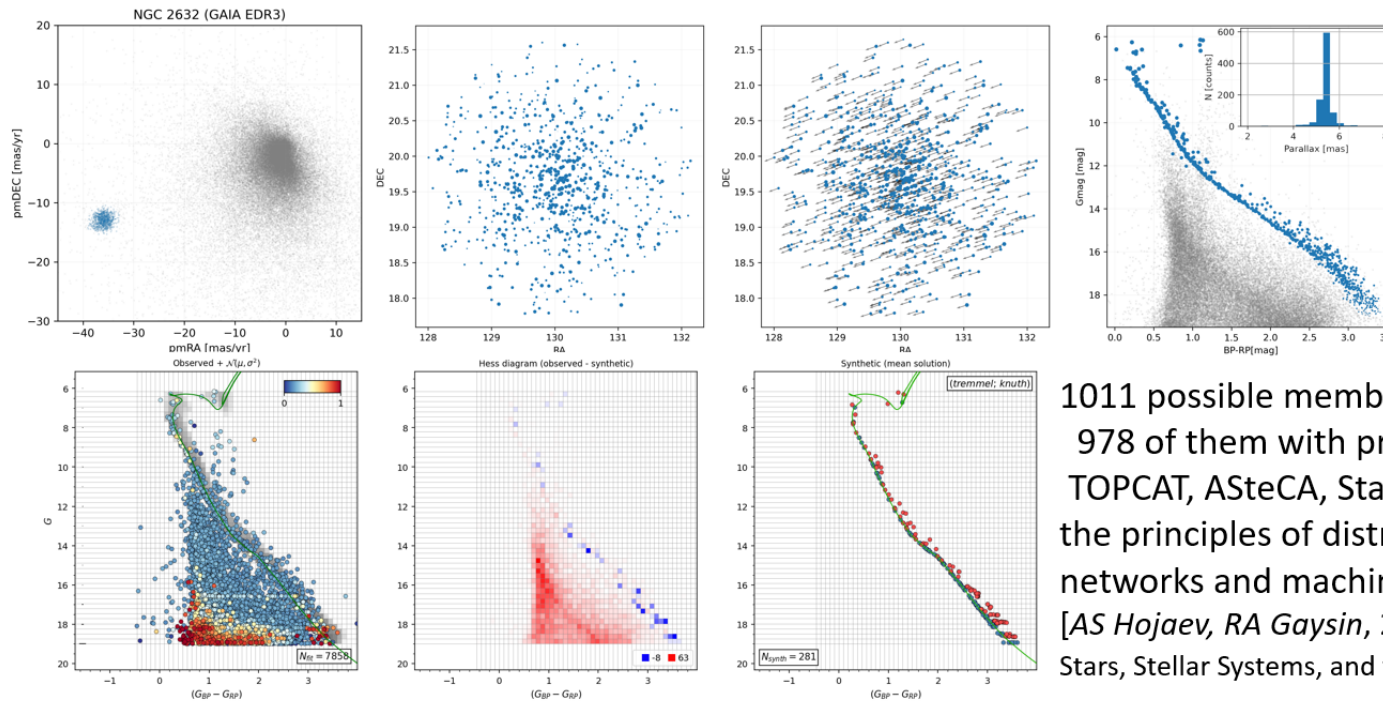


open star cluster NGC 6871:

From the TESS database, a sample of time series was carried out for 1340 stars from the region of the cluster location. According to the results of a preliminary analysis of the light curves, 4 variable stars were found, 3 of which are probably of the pulsating type, and one is an eclipsing variable star

DB Analysis

- Gaia EDR3 for star clusters deep analysis : kinematics, distance, age *awa* other astrophysical properties, 3-D modelling of the systems perspective



Synthetic cluster parameters
[PARSEC v1.2S + No]

IMF : Kroupa 2002
 $R_V = 9.38$
 $z = 0.02924 \pm 0.00049$
 $\log(\text{age}) = 8.803 \pm 0.044$
 $E_{(B-V)} = 0.039 \pm 0.020$
 $(m - M)_0 = 6.214 \pm 0.018$
 $M(M_\odot) = 399 \pm 65$
 $b_{frac} = 0.48 \pm 0.11$

1011 possible members of the cluster were discovered.
 978 of them with probability $0.8 \div 0.99$
 TOPCAT, ASteCA, StarGO software were applied, involving
 the principles of distributed computing in neural
 networks and machine learning.
 [AS Hojaev, RA Gaysin, 2021, 20.5th Cambridge Workshop on Cool
 Stars, Stellar Systems, and the Sun, pp.5, DOI:10.5281/zenodo.4729772]

Meticulous study of new and known variable stars

- MCV
- the recurrent [nova](#) RS Oph outburst follow-up
- binary stars, etc.

The dense observational series with a cadence of at least 4-4.5 hours have been obtained . Both classical MCVs and probable MCVs discovered from space surveys were observed (V533 Her, V1189 Her, RX J0153.3 + 7446, RX J0953-1458, 1RXSJ1743-0429, Swift J2241 + 5644, Swift J2237.2 + 6324, SDSSJ204827 .91 + 005008.9).

Preliminary analysis showed the high quality of their light curves. Upon completion of obtaining the necessary series of observations, the fine details of the phase curves will be highlighted, the beats will be determined, based on a thorough periodogram analysis and an accurate phenomenological 3-D model of each cataclysmic will be built.

Flares

Multi-messenger Study of Red Dwarf Flares

Objective: Polarimetric, spectroscopic, and photometric monitoring of LP245-10, an M7V in the solar neighborhood

Date: 2021 Nov 11~17

Sites by longitude :

Lulin (polarimetry): Chen, WP (陳文屏); Hsu, CY (許溱謙);

Tsai, A (蔡安理) ; Sharma, T

Weihai/Shandong: Hu, SM (胡紹明)

Xinlong/Beijing: Wu, H (吳宏) ;Zheng, J (鄭捷) ; Zhou, AY (周愛英) ; Wei, JY (魏建彥) ; Wang, J (王競) ; Bai, JY (白建迎)

Yunnan: Qian, SB (錢聲幫) ; Zhu, LY (朱俐穎)

Nanshan/Xinjiang: Liu, JZ (劉進忠)

ARIES/India (polarimetry): Panwar, N

Maidanak/Uzbekistan: Hojaev, A



Radio proposals

- We proposed the study of star clusters in radio, mm and sub-mm ranges, especially the young still forming ones. NGC 2264, NGC 6823, NGC 6705 etc. are among that targets . Details and analysis are in the paper :

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Scientific Problems and Possibilities of Studying Extended Molecular Clouds with RT-70

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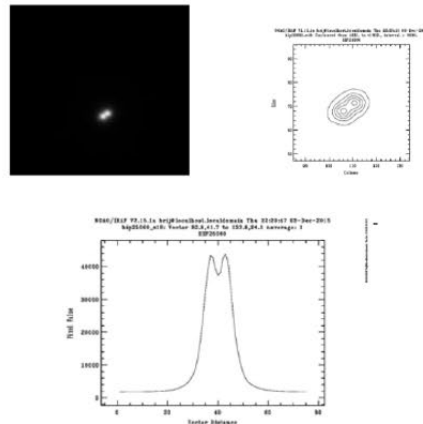
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Technology Issues

- ARIES has a solid experience in software creation for data analysis
- *awa* creation and use of modern facilities and instrumentation
- 3.6-m DOT AO-telescope is the largest in the region (installed in 2016)



One of the results from the DOT.
Figure 9: HIP 25060 - Peak to peak separation is 6 px (.34 arcsec). A broad band visible filter was used. The elongation seen in image/contour is due to atmospheric differential refraction. The exposure time is 1s.



Technology Exchange Issues

- Preparing the joint Indian-Uzbek project, it was emphasized the immediate participation of UBAI researchers in observations from 3.6-m DOT.
- The participation will be based on the successfulness of the proposals which will be submitted for the observations from DOT.
- This is literally crucial in preparing for the creation and further effective use of modern 4m UZT telescope which is planning to install at Maidanak observatory in Uzbekistan according the initiative of the COMSTECH/OIC supported by President of Republic of Uzbekistan at 1-st Summit of COMSTECH/OIC (10.09.2017, Astana).

6.2 Astronomy : There are no reasonably sized, functional astronomical telescopes in Member States, whereas this is one area where Muslim scientists made seminal contributions in the past. A ground-based 4m telescope using adaptive mirrors and laser 'guide stars' can now provide the same or better resolution as the Hubble space telescope. Turkey has started construction of an observatory in Eastern Anatolia, with commissioning expected in 2019.

➤ **Recommendations and Targets**

- i. Establish at least three 4 metre telescopes in the OIC region.
- ii. Start work on the Pakistani 4 m telescope, as announced in June 2016.
- iii. Set up one 4m telescope in Morocco, and one in Samarkand in honour of Ulugh Beg.

Instead of Conclusion

**Much remains to be learned...:
Per Aspera ad Astra !**

Appendix

- The **3.6m Devasthal Optical Telescope (DOT)** is currently the largest reflecting telescope in Asia.^[1] The telescope intends to fill a large longitudinal gap in the 4m class of telescopes in the Asia region. The telescope features an optical spectrograph, a CCD imager and a near-infrared spectrograph. The telescope is also the first of its kind in India that features an **adaptive optics**^[2] system, featuring a wavefront sensor and pneumatic actuators which compensates for small distortions in the shape of the 4.3 tonne mirror due to gravity or atmospheric aberrations.
- 3.6m DOT is a clear-aperture Ritchey–Chrétien telescope built by Aryabhata Research Institute of Observational Sciences (ARIES) and is located at the Devasthal Observatory site near Nainital, Uttarakhand, India. ARIES operates another 1.3m telescope at the same location. The telescope was activated remotely on 31 March 2016 by **Indian Prime Minister Narendra Modi** and **Belgian Prime Minister Charles Michel** from Brussels. The telescope optics has been built in collaboration with the Belgian firm Advanced Mechanical and Optical System (AMOS).
- https://en.wikipedia.org/wiki/List_of_largest_optical_reflecting_telescopes