4.9. Globular Cluster M15: New Variable Stars

A. P. Zheleznyak

The search for variable stars in crowded stellar fields is important but at the same time difficult problem, especially for extreme dense objects like centers of globular clusters. It will suffice to mention that in the central part of globular cluster M15 up to the middle of nineteen of XX century only one variable star was known. A new approach to the problem of detection of variable objects in dense stellar fields was developed recently by Alard and Lupton in the area of galactic microlensing searches. The proposed method of optimal image subtraction (OIS) is used for processing of temporal sequences of CCD images of the same stellar field. The main problem in implementing of an image subtraction approach – coregistration of the reference and current images – is elegantly solved with OIS algorithm and allows one to obtain a difference close to the optimal, i.e. the method is limited only by photon noise.

The goal of our work was to implement the OIS method for investigation of globular cluster central parts. The globular cluster M15=NGC7078 was chosen as the target; it is known as the most dense and massive Galaxy cluster with the highest central star crowding. According to estimation with HST, the number of stars brighter that 19^m in the central part of M15 is 15-20 per square arcsecond. Totally, around 150 variable stars was

known in the region of M15; overwhelming majority of the new variables in the densest central (r < 20″) region of M15 have been discovered in the last decade with HST [AJ 106, 154] and 4.2 meter William Hershel telescope, equipped with adaptive optic system.

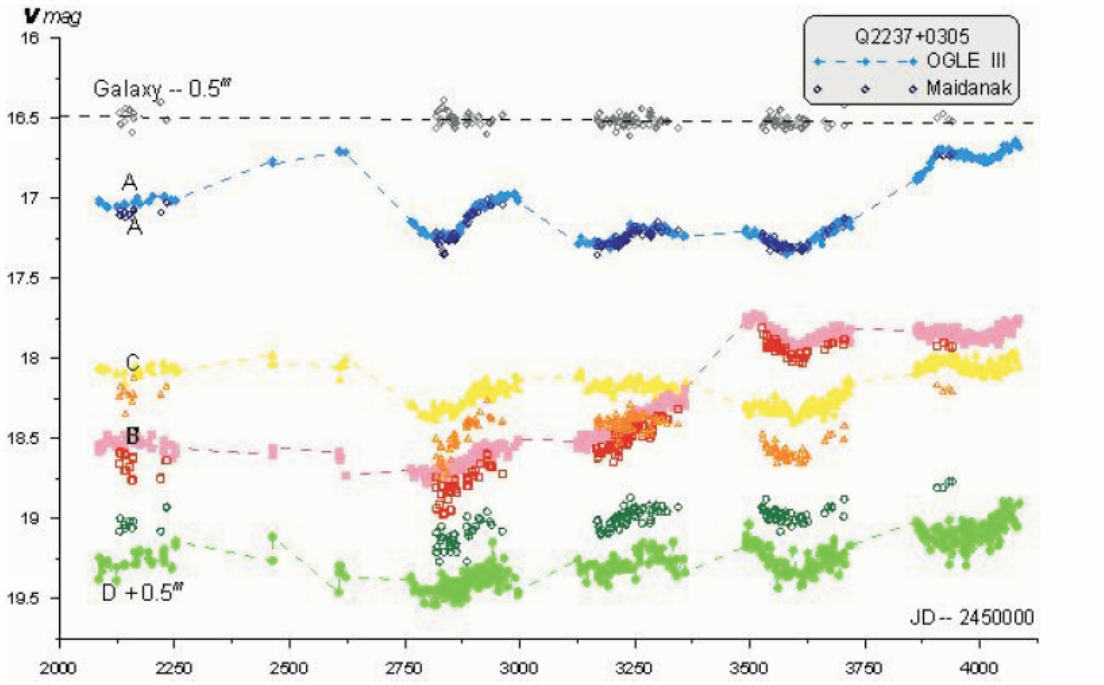

Figure 36. Comparison of our photometric data for the quasar Q2237+0305 (2001-2006, filter V) and data obtained in the frame of the programe OGLE III (see Fig. 34)

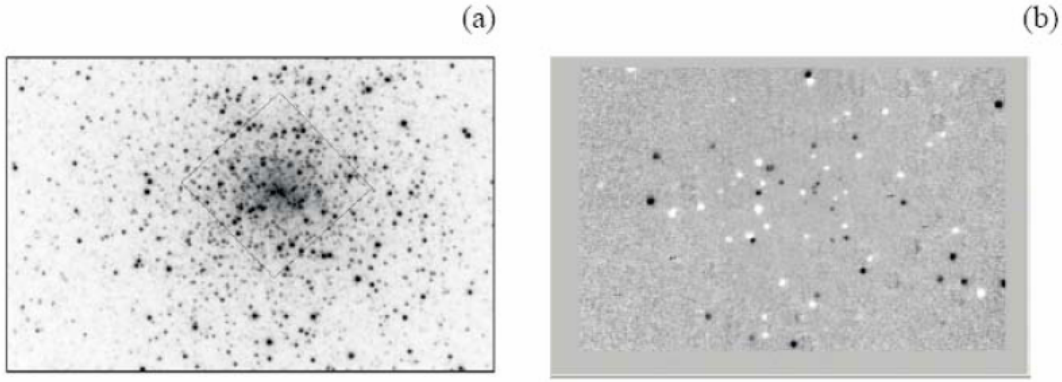

Figure 37. (a) One of CCD images of the globular cluster M15=NGC7078, obtained with 1.5 m telescope at Maidanak observatory on July 31, 2001 in R band. North is on the top; the seeing (FWHM) =0.60″. The intensity was logarithmically scaled to show inner and outer parts of the cluster simultaneously. The square shows the size and orientation of field of view of HST WFPC1 CCD chip. (b) The residual image, in the same scale and orientation as the image (a), obtained after processing of sequence of M15 CCD images with the algorithm of optimal image subtraction. Stars with variable in time intensity are clearly revealed as brighter or darker spots on relatively uniform grey background. Besides variable objects, some CCD defects (of evidently non-pointlike nature) became apparent in the residual image after subtraction

Our observation were carried out with the 1.5 m AZT-22 telescope at Maidanak observatory (Uzbekistan) during two consecutive nights (July 31 and August 1, 2001). The

detector (ST-7 CCD camera) was used in the short–focus mode of AZT- 22, giving the pixel size 0.15″ and field of view 115″×77″. The obtained observational data contain 248 CCD frames of M15 with exposure time 60 sec in R band. The seeing condition (FWHM), estimated from isolated star images in each frame, was practically subarcsecond for the whole volume of data; an appreciable fraction of images has a seeing FWHM < 0.6″. At the first stage all the data passed the standard procedures of astronomical CCD image processing. After implementation of the code, based on the OIS algorithm, 83 variable objects were found in the field of view, 55 of which were identified with the known cluster variables, and 28 are the candidates for the new variable stars. The typical CCD image of M15 from our dataset and the result of processing of the sequence of frames with the OIS method are given, respectively, in Fig. 37 a,b. Most of the newly discovered variables were classified as the RR Lyrae type; two of them most likely are of SX Phe type. Due to relatively high coordinate accuracy of obtained results, during the identification work it was possible to refine the coordinates of already known variables, as well as to correct some errors in the M15 variable stars catalogue. Considerable part of the newly discovered variables (18) are located in the most dense part near the center of M15; here we were able to rediscover all the variable stars, previously found with HST [AJ 106, 154] and almost all of the stars, found with 4.2 m WH telescope. The comparison between HST and our variable coordinates is given in Fig. 38; for convenience, the coordinates of variable stars in ST-7 coordinate system were transformed to the pixel coordinate system of HST WFPC1 chip.