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Ph.D. Thesis Summary

Determination of the physical parameters of stars, star clusters and minor planets by spectrophotometric methods

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1. Scientific background

- Although globular clusters play an important role in testing stellar evolutionary models, one can still find suprisingly bright and neglected clusters, especially in the southern hemisphere. NGC 362 is such an object, having been target of relatively few studies and so far lacking any comprehensive search for variable stars, particularly in the central regions of the cluster. Apart from the pioneering work of Sawyer, which contained data for fourteen variable stars, recent works mainly aimed at obtaining deep Color-Magnitude Diagrams. In the catalog of globular cluster variables there are only 16 stars, of which many are far from the cluster center and have ambiguous properties.

  Models for globular clusters suggest that all the member stars were formed from the same gas cloud at approximately the same time. Hence physical parameters of member stars are representative of the cluster itself. Recently, many empirical relations have been calibrated for RR Lyrae stars, which can be used to determine metallicities, absolute magnitudes, reddenings and other physical parameters from the light curve shapes of these variables. In my PhD thesis I present an analysis of RR Lyrae stars in NGC 362 and briefly discuss properties of variable stars of other types.

- Globular clusters are among the oldest objects in our Galaxy and their stars provide unique information on Galactic evolution through cosmic times. These clusters are sensitive indicators of the Galactic gravitational potential because the velocity distribution of their stars is affected by the ambient field of the Milky Way. They are believed to have undergone substantial dynamical evolution, which is affected by processes responsible for the „evaporation" of stars: tidal interaction with the Galaxy and two-body relaxation. When moving around the Galactic center, a cluster experiences strong gravitational interactions which can result in tidal shocks and lead to the formation of tidal tails.

  AAOmega, a multi-object spectrograph on the 3.9 meter Anglo-Australian Telescope provides an excellent opportunity to measure up to 350-360 radial velocities with a single exposure. Due to its large field of view (2 degrees) it can observe stars which are located far from the cluster in the plane of the sky. With a velocimetric accuracy of about 1-2 km s^{-1}, one can easily identify escaped stars which have the same or very similar radial velocities as the host cluster.

  In the 4th section of my thesis I present an analysis of radial velocities of cluster member stars in terms of systemic rotation for five southern globular clusters. A detailed investigation of their possible tidal tails has been reported by Kiss et al. (2007).

- High-amplitude δ Scuti stars are either Pop. I stars close to the main sequence or evolved Pop. II stars (these are also known as SX Phe variables) with very characteristic light variations caused by radial pulsations. Owing to their short periods and high amplitudes, these stars are very good targets for small and moderate-sized telescopes, so that interesting astrophysical phenomena can be easily studied even with modest instrumentation.

In a recent comprehensive catalogue of δ Scuti type pulsating stars there are many objects belonging to binary or multiple stellar systems. Of those, only a fraction of stars are components of eclipsing binaries. These stars are desired compound for asteroseismology in order to identify pulsation modes through determination of fundamental physical parameters. Another interesting possibility is the study of tidal effects on oscillation.

The 5th section of my thesis contains the analysis of two variable stars: GW UMa is a high-amplitude δ Scuti star, and SZ Her is an Algol-type eclipsing binary, respectively.

- More than 200 years after the discovery of the first main-belt asteroid, 1 Ceres, highly automatized and sensitive surveys yielded an unimaginable number of newly discovered minor planets. The process is still accelerating, and the observations arrived to the realm of the faintest, thus the smallest objects. On the other hand, the huge number of objects causes a strong limitation in determining and understanding their physical properties. The overwhelming majority of these newly found objects goes without further notice and a large body of solar system objects is accumulating without known observable properties (e.g. rotation, shape). That is why a new field has emerged, to which even well-equipped amateur astronomers or small college observatories can make significant contribution: follow-up photometric observations of moderately faint and small asteroids.

  In Section 6 of my thesis I present the study of the light curves of 23 minor planets.

2. Research methods

During my work I used the equipments of several observatories. Globular cluster photometric data were obtained with the use of the 1m ANU telescope at Siding Spring Observatory, Australia. Data points of variable stars and minor planets were acquired with the 0.4m Cassegrain-telescope of the Szeged Observatory and with the 60/90/180 cm Schmidt-telescope of the Konkoly Observatory.

For 5 RR Lyrae stars in NGC 362 I measured radial velocities from optical spectra taken with the 2.3m ANU telescope and the Double Beam Spectrograph in Siding Spring.

With AAOmega, a multi-object spectrograph on the 3.9 meter Anglo-Australian Telescope we took spectra for more than 10,500 stars. The spectra were reduced with the standard 2dF data processing pipeline.

Photometric data were processed with standard IRAF routines. Globular cluster images were analysed both with PSF photometry and image subtraction photometry. For standard photometric calibrations we observed selected equatorial Landolt-fields, then the transformation coefficients were determined with the IRAF task $photcal$. RR Lyrae radial velocities were measured with cross-correlation. Light curves from PSF-fitting and image subtraction were analysed for finding periods. For this, I applied a combination of Fourier analysis, phase dispersion minimization and string-length minimization.

During my work I heavily relied on self-developed *C* and shell-script codes.

3. Results

1. NGC 362: Using PSF and image subtraction photometry I have found 45 RR Lyr variables in the field of the cluster, of which 28 are new discoveries. I have converted flux curves into magnitudes for all RR Lyrae stars with a self-developed simple method, which allowed me to use empirical light curve shape vs. physical parameter calibrations. With these, I have determined metallicities, absolute magnitudes, reddenings and other physical parameters for 16 RR Lyraes.

   I have found a rather high-percentage of modulated RR Lyr light curves, i.e. the Blazhko effect, both for RRab and RRc-type stars. NGC 362 could be an excellent target for studying the Blazhko effect in a chemically homogeneous environment.

   From isochrone fitting I have also determined the main parameters of the cluster. Both the RR Lyraes and the color-magnitude diagram result in a consistent set of physical parameters, which are in good agreement with the values found in the literature. The newly determined parameters are the following: [Fe/H] equals -1.34, the distance of the cluster is 8.5 kpc, and the age is $11 \cdot 10^9$ years.

   I have also discovered variable stars of other types, including Cepheids and long-period variables in the Small Magellanic Cloud, eclipsing binaries and δ Sct-type pulsating stars in the galactic field (Székely et al., 2005; Székely et al., 2006a; Székely et al., 2006b; Székely et al., 2007).

2. For 10,500 stars in and around five southern globular clusters using the recently commissioned multiobject-spectrograph AAOmega on the 3.9m AAT we have obtained medium-resolution near-infrared spectra. The targets were 47 Tuc, M12, M30, M55 and NGC 288. We have measured radial velocities to ± 1 km s^{-1} with the cross correlation method and estimated metallicity, effective temperature, surface gravity and rotational velocity for each star by fitting synthetic model spectra. My analysis of the velocity maps and velocity dispersion of member stars revealed systemic rotation in four of the target clusters (Kiss et al., 2007a; Székely et al, 2007b).

3. I have presented the first observations of GW UMa since its discovery by the Hipparcos satellite. Based on the R_{21} Fourier amplitude parameter GW UMa is right on the border between RR Lyrae and HADS stars. The stability of the light curve shape excludes the possibility of a relatively high-amplitude secondary period, thus I have excluded the possibility of first- or second-overtone RR Lyrae pulsation. Eight new times of maximum were determined. Judged from the O$-$C diagram it is possible that the star exhibited a slight period change in the last decade (Derekas et al., 2002; Derekas et al., 2003a; Derekas et al., 2005).

4. Using VRI filtered CCD photometry dataset obtained during 9 nights four new epochs of primary minimum were calculated for Algol-type SZ Herculis. The

Fourier analysis of the lightcurves revealed there is no pulsating component in the system of SZ Her. Deduced from O−C diagram SZ Her may have a third component (Székely, 2003).

5. I have presented CCD R-filtered and unfiltered photometric data for 23 small and intermediate-sized main-belt asteroids. 8 of them were not investigated previously. 17 minor planets exhibited detectable light variations. With composite light curves, I have derived synodical periods for seven objects. In case of three minor planets I have estimated the rotational period. For the rest only lower limits of rotational parameters can be concluded. In two cases (894 Erda, 3682 Welther), I have found rapid brightness changes superimposed on the much slower rotationally induced variations, which might be attributed to possible binarity (Székely, 2002; Székely et al., 2005).

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