CCD photometry of variable stellar sources

Data reduction workflow, assessment of accuracy, case studies

Taavi Tuvikene

Photometric studies of variable stars nowadays involve observations with CCD cameras, producing large amounts of CCD frames, which call for a highly automated data reduction approach. As data often originate from a variety of telescopes and instruments, the same reduction steps cannot always be applied to all data. Thus, what is needed is not a fully automated pipeline, but rather a workflow, an organised and consistent set of reduction procedures. A workflow for reducing heterogeneous CCD data was developed in the framework of this thesis.

In order to check for systematic errors arising from data reduction, we carried out comparative tests that involved independent reductions of the same CCD frames. We found systematic discrepancies between light curves obtained with different software packages and concluded that in order to achieve high accuracy, data should be reduced in a consistent way, preferably using a single software package.

Part II of the thesis is devoted to five case studies involving CCD photometry of variable stellar sources. We participated in observations of a stellar occultation by Pluto's moon Charon in 2005. Recording such an event required fast photometry together with accurate timing of CCD exposures. The occultation observations eventually led to the determination of Charon's radius and density. The same observing technique was also applied to the pulsating star CY Aquarii, producing a unique high-resolution light curve over nearly two periods. We obtained a large amount of photometric observations of CY Aquarii and presented a total of 155 new times of maximum, which were analysed using an O-C diagram.

We discovered the variability of the Delta Scuti star GSC 08613-02122. Our results revealed the presence of erratic amplitude and phase variations, which we showed not to be of instrumental nor procedural origin. A deep study of the close binary star GSC 04778 – 00152 was carried out, involving photometric and spectroscopic observations. The star was found to have a 1-magnitude fainter visual companion about 2 arcseconds away from the binary. We derived the parameters of the binary system from light-curve modelling.

Finally, we applied the workflow to a target for which it was initially designed – the open cluster NGC 3293, known to contain 11 Beta Cephei-type pulsators and numerous other variable stars. The cluster was photometrically monitored for a time span of ten years (1997-2007), resulting in a massive set of over 22000 CCD frames. Careful reduction and analysis led to the conclusion that truly constant stars among brighter cluster members are rather rare. Special focus was given to the long-term variability of the cluster stars.