1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title:

Study of the empirical relation between the superhump excess and the mass ratio of cataclysmic variables and AM Canum Venaticorum-type stars based on the photometric and spectroscopic observations.

1.1. Project goals

The main goal of this project is to find new, proper calibrators for the empirical relation between the superhump excess and the mass ratio of cataclysmic variables (CVs) and AM Canum Venaticorum-type (AM CVn) stars based on the photometric and spectral analysis.
This project aims to:

- study the spectroscopic behaviour of CVs and AM CVn stars. We plan to dynamically constrain the mass ratio of even the most challenging systems where the donor star is undetected in absorption, prohibiting the use of traditional methods.
- study the photometric behaviour of CVs and AM CVn stars during outbursts and/or eclipses. This will allow to test and calibrate the superhump excess and the mass ratio relation.

1.2. Outline

Cataclysmic variables (CVs) and AM Canum Venaticorum-type (AM CVn) stars are close binaries containing a white dwarf as a primary component, and as a donor a main-sequence star (in CVs) or white dwarf (in AM CVn). The main goal of this project is to find new calibrators for the empirical relation between the superhump excess and the mass ratio based on the photometric and spectral analysis. For the project, we will use the data already collected by the project submitter, and by our world wide collaborators.

The components' stellar masses are among the fundamental properties of interest in the characterization of close binary systems because these properties constrain the evolution and formation mechanism. However, the orbital period is often the only measurable for most short period CVs due to faint donor stars. The superhump period, which is easy to measure, and hence superhump excess could potentially indicate the mass ratio of the systems via the empirical relation between the period excess and the mass ratio. While this relation is potentially beneficial for determining mass ratios, the large scatter in the calibrators, especially at the low mass ratio end, prohibits a direct conversion between easy to measure light curve variability and the much sought after mass ratio. To place a short period of CVs (e.g. pre- or post bouncers) and AM CVn systems firmly on the evolutionary track, a better calibration and validation of the period excess - mass ratio relation based on more direct and reliable methods of determination of the mass ratio are required.

In order to achieve this, in the photometric part of the project, we plan to use already obtained and processed data of over 20 CVs and AM CVn, collected by the project submitter, on a 1.3-meter telescope located in MDM Observatory, Arizona. PhD student will gather new photometric observations of superoutbursts and superhumps on the newly renovated 0.6-meter and 0.9-meter telescopes, owned by N.Copernicus University and located in Piwnice. The PhD student will also investigate all observations available in the public databases, e.g. AAVSO, and the data presented in the literature. The next step of this project is rigorous calculations of mass ratio and period excess based on superhumps and eclipses

detected in the light curves. For the spectroscopic analysis, we will use the observations from the biggest telescopes (e.g. VLT, NTT, Magellan and ING) already gathered by our collaborators. Therefore, we will dynamically constrain the mass ratio even in the most challenging CVs and AM CVn systems. As a result, by comparing values from the photometric and spectroscopic investigation, we will determine and validate new calibrators for the period excess - the mass ratio empirical relation.

1.3. Work plan

1. Reduction and analysis of spectroscopic data.
2. Reduction, photometry of light curves, analysis of photometric data in the literature.
3. Estimation of physical and orbital parameters of cataclysmic variables from photometric and spectroscopic data.
4. Determination and investigation of the values of the mass ratio from photometric and spectroscopic data.

1.4. Literature

- Bąkowska et al., 2021, A&A, 645
- Bąkowska et al., 2017, A&A, 603
- Kupfer, T. et al., 2018, MNRAS, 480
- Levitan, D. et al., 2014, MNRAS, 446
- Marsh, T.R. & Horne, K., 1988, MNRAS, 235

1.5. Required initial knowledge and skills of the PhD candidate

- Well-documented experience in observations on small and medium-size telescopes
- Good knowledge of the MaximDL software which is used in Piwnice Observatory to conduct observations
- Experience in photometric data analysis
- Basic experience in IRAF in data reduction and analysis

1.6. Expected development of the PhD candidate's knowledge and skills

- Data processing of photometric and spectroscopic data from miscellaneous instruments
- Broad knowledge of spectroscopy and photometry analysis of close binary stars
- Broad knowledge of cataclysmic variable stars and their properties