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Review of doctoral dissertation of Muhammad Zain Mobeen

The dissertation presented by Muhammad Zain Mobeen consists of four parts: an extended introductory text, two peer-reviewed papers (published in Astronomy and Astrophysics), and a manuscript submitted for peer review. Muhammad Zain Mobeen is the first author of both papers and the manuscript. All parts are connected by the same topic: mid- and near-infrared (MIR and NIR) interferometric study of a luminous red nova (LRN) V838 Mon. It is widely accepted that V838 Mon eruption was a product of a merger of an 8 M_{Sun} B-type star and an 0.3 M_{Sun} young stellar object. In general, all LRNe are thought to be merger products with a single case (V1309 Sco) being monitored pre-outburst and showing a stellar binary system with rapidly deacreasing orbital period.

The first part of the dissertation is divided into five sections. The first presents basic concepts about interferometry and is followed by a description of currently used interferometers: VLTI and CHARA. The following section is devoted to the description of techniques used in the image reconstruction process. The fourth section presents basic information about the LRNe and is followed by a review of previous interferometric observations of V838 Mon. This part is an important introduction to the following papers and presents all the necessary concepts. The mathematical details are presented at the proper level. However, some portions of the text should be presented more rigorously, e.g., 1) eq. 1.12 on p. 8 lacks parentheses, 2) fig. 3.1 p. 22 – meaning of the color coding is not explained, 3) citation to Thiébaut and Giovannelli 2010 (p. 23) is not presented in the references, and 4) the last sentence on p. 39 incorrectly claims that astrometric measurements showed pre-outburst orbit contraction in V1309 Sco (these were photometric, not astrometric measurements). In my opinion, this is the weakest part of the dissertation.

The first paper presents the analysis of V838 Mon observations in the *L* band (2.8–4.2 μm) obtained using the MATISSE instrument at the VLTI. The author conducted image reconstruction with several simple geometric models. The analysis indicated that V838 Mon is surrounded by a disk-like structure with a position angle similar to ones obtained in the literature studies at other wavelenghts (the *N* band and sub-mm regime). The comparison with literature studies also reveals that the disk-like structure is stable over a timescale of at least a decade. The analysis of the *L*-band spectrum indicates that SiO and H_2O are observed, while SH and OH are not present in the V838 Mon environment. The excitation temperature is on the order of a few hundred K. The V838 Mon surroundings were not observed in the *L* band before, which makes this study an important step in better understanding of the post-merger environment. This paper shows that Muhammad Zain Mobeen has a critical approach to the obtained

data (see, e.g., rejection of low signal-to-noise ratio *N*-band data) and is able to analyze interferometric data using various assumed models. Similar comments apply to the second paper.

More in-depth analysis is presented in the second paper. The data used were obtained mainly with the MATISSE (*LMN* bands) and GRAVITY (*K* band) instruments (both at the VLTI) and MIRCX/MYSTIC (*HK* bands; at the CHARA). The available data allow higher-resolution (at the sub-milliarcsecond scale) reconstruction of the V838 Mon environment. The existence of a disk-like structure is confirmed and an additional bi-polar structure (or jets) in the vicinity of the central star is detected. The latter finding has already been commented on in the literature, leading to the conclusion that jets should be observed in all LRNe. It is also found that jets are asymmetric. The paper presents an analysis of a large number of datasets collected with various facilities, which both strengthen the conclusions and indicate the author's ability to draw astrophysical conclusions from various observations. There are multiple plots presented, however, some plots presented in the appendices are very hard to read because of small fonts and thin lines. The presented papers were published in 2021 and 2024 and have already been cited a few times by other authors.

The final part of the dissertation analyzes previously discussed interferometric observations and the *BVRI* polarimetry from the HIPPO instrument at the SAAO 1.9 m telescope. In order to gain a better astrophysical understanding (i.e., dust density distribution), the data are modelled using a well-established radiative transfer code. The analysis results in a three-component model: jets, an inclined torus (corresponding to the disc-like structure found before), and a relatively small elliptical structure surrounding the central star. Additional data and a different approach to the analysis of the whole dataset support findings from the two papers discussed above. The manuscript ends with a well-written discussion. An unavoidable shortcoming of the paper (noted by the authors) is the non-uniqueness of the model found. It would be valuable if this aspect could be discussed further.

The presented dissertation is well focused on a study of V838 Mon surrounings in NIR and MIR wavelentghts. The three manuscripts presented have multiple authors. The statements submitted by the co-authors clearly indicate that Muhammad Zain Mobeen conducted the main scientific part of the investigation. Importantly, the wavelength and resolution ranges make these studies unique ones. Various datasets are analyzed and a consistent picture emerges from them. I consider this dissertation to be the best evidence for the presence of jets in the V838 Mon environment. The number of known LRNe is small and they are evolving on areasonably short timescales, which indicates that follow-up studies (some already suggested in the dissertation) will be undertaken.

Summing up, I consider the doctoral dissertation of Muhammad Zain Mobeen to be a valuable contribution and to meet the criteria prescribed by the law. Therefore, I request that this dissertation be admitted to a public defense.

Podpisany elektronicznie przez
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