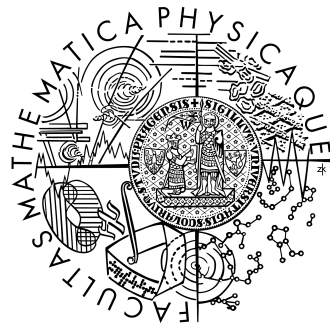


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Abstract of the PhD Thesis

Multi-frequency research of symbiotic binaries

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Introduction

Symbiotic variables are strongly interacting binary systems consisting of a cool evolved star and a hot component (Fig. 1) in which the physical mechanisms related to the transfer and accretion of matter usually cause some observable activity (e.g., Allen 1984; Kenyon & Webbink 1984; Kenyon 1986; Mikołajewska 2007). Both the light curves and the spectra of these variable stars are complex. The investigation of these objects requires long-term monitoring as all symbiotic systems are open detached (or semi-detached) binaries with orbital periods of hundreds to thousands of days (e.g., Mürset & Schmid 1999; Belczyński et al. 2000; Gromadzki et al. 2013). Their active stages can last for years. Moreover, several other processes can also contribute to the complexity of the light curves, such as eclipses, ellipsoidal and reflection effects, the intrinsic variation of both components, or flickering. All of these manifest on the various timescales from minutes to years. Thanks to their properties, symbiotic stars can serve as unique astrophysical laboratories for studying accretion processes, winds, jets, or thermonuclear outbursts. Moreover, they are important for evolutionary models as they may be one of the type Ia supernova progenitors.

Since the beginning of this century, a systematic search for symbiotics has begun, not only in the Milky Way but also in the Local Group of galaxies, and has already led to the discovery of many new objects. Until 2019, the last published catalog (Belczyński et al. 2000) contained 188 confirmed symbiotic systems, including 17 objects beyond the Galaxy. However, over the past two decades, the number of confirmed systems has more than doubled, and many dozens of new candidates have emerged. The specialized surveys searching for symbiotic stars focused not only on the galactic symbiotic stars (e.g., Corradi et al. 2008, 2010; Miszalski et al. 2013; Miszalski & Mikołajewska 2014; Rodríguez-Flores et al. 2014), but also identified new extragalactic symbiotic variables or at least promising candidates (e.g., Gonçalves et al. 2008, 2012, 2015; Kniazev et al. 2009; Mikołajewska et al. 2014, 2017; Magrini et al. 2017; Roth et al. 2018; Ilkiewicz et al. 2018; Saeedi & Sasaki 2020, 2022).

Recently, a new census of symbiotic stars in the 2MASS, *WISE* and *Gaia* surveys was published by Akras et al. (2019). The authors presented the list of 323 known and 87 candidate symbiotic stars. However, they did not collect all available data on individual objects, as they focused mainly on the temperatures and IR types of

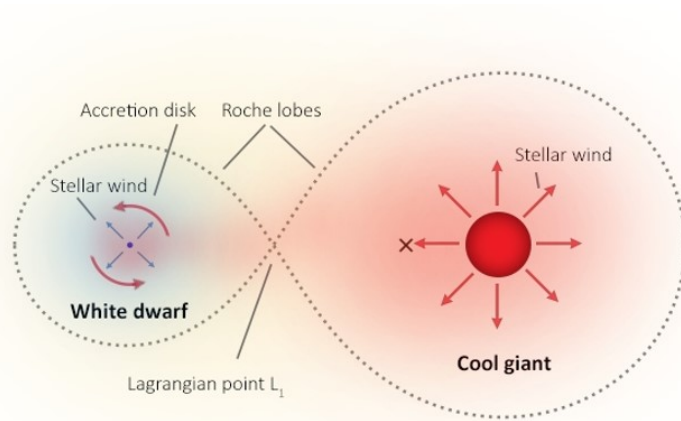


Figure 1: Simplified model of the symbiotic system consisting of a white dwarf as an accretor and the cool giant as a donor of matter.

symbiotic binaries. They also discussed in detail the presence of the Raman-scattered O VI lines in their spectra. This leaves the demand for a new full-scale catalog of symbiotic stars open.

Aims of the thesis

The present PhD thesis has three main goals. The first is to collect and summarize published information on all known symbiotic systems and candidates and process them into a comprehensive database that will replace outdated catalogs from the beginning of this century. This will allow systematic and statistical research of the symbiotic population. For this reason, the second task is to analyze the orbital, stellar and observational characteristics of known symbiotic stars in order to understand their position among other variable stars, recognize common patterns leading to the symbiotic phenomenon, and uncover the relations between the parameters of the components and their activity. Finally, on the basis of the catalog, poorly studied symbiotic systems and especially the candidates (primarily in our Galaxy and Magellanic Clouds) will be selected. These objects will be subjected to comprehensive research using archival and new multi-frequency photometric and spectroscopic data in order to confirm or reject their symbiotic nature and characterize their components. In this way, the number of confirmed symbiotic binaries will increase and a clean sample of these variable stars will be available for subsequent research.

New Online Database of Symbiotic Variables

The rising number of symbiotic stars in recent years has increased the demand for a new catalog of symbiotic binaries allowing studies of the symbiotic population in detail. The last catalog was published more than 20 years ago (Belczyński et al. 2000). We have therefore decided to prepare a new, comprehensive, modern catalog - the New Online Database of Symbiotic Variables (Merc et al. 2019). The database should serve not only as a catalog of data for all known symbiotic systems with consistent references, but we prepared also a web portal for easy access to this information (<http://astronomy.science.upjs.sk/symbiotics/>). In contrast with all the previous catalogs which became outdated virtually already at the time when their paper versions were published, our database is available online. This allows the addition of new objects as soon as they are discovered and adding or updating the data when new information becomes available. In this way, the up-to-date lists of symbiotic variables and information about particular objects can be available to the community at any time.

The aim of the work was to collect all the objects which were classified as symbiotic stars or symbiotic candidates in the published literature or in the various databases. The New Online Database of Symbiotic Variables contains both types of symbiotic variables: shell-burning (white dwarf accretor) and accreting-only (white dwarf or neutron star accretor). Interacting binaries with main-sequence accretors or whose donors are not cool evolved stars are not considered symbiotic binaries for the purpose of this work.

The database is divided into two main parts according to the location of symbiotic variables. The first part consists of 825 galactic objects, of which 290 are confirmed symbiotic stars, 393 objects are classified in one of the candidate groups and 142 objects were previously classified as symbiotic stars or symbiotic candidates, but are reclassified as something else. The second part of the database contains 179 objects (70 confirmed symbiotics, 103 candidates, and 6 misclassified objects) located in 16 galaxies (LMC, SMC, Draco Dwarf, IC 10, M31, M33, M81, M87, NGC 55, NGC 185, NGC 205, NGC 300, NGC 2403, NGC 6822, Sculptor Dwarf, Willman 1), see Tab. 1.

Table 1: Numbers of confirmed symbiotic stars, symbiotic candidates, and misclassified objects in the current version of the New Online Database of Symbiotic Variables (as of June 30, 2022). Please refer to the online version of the database (<http://astronomy.science.upjs.sk/symbiotics/>) for the up-to-date numbers.

Galaxy	Confirmed	Likely	Possible	Suspected	Misclassified
Milky Way	290	45	89	259	142
Draco Dwarf	1	0	3	0	0
IC 10	1	0	0	0	0
LMC	10	0	5	22	3
M31	31	5	2	8	1
M33	12	0	0	0	1
M81	0	0	1	0	0
M87	0	0	0	9	0
NGC 55	0	0	0	3	0
NGC 185	1	0	0	0	0
NGC 205	1	0	2	0	0
NGC 300	0	1	0	8	0
NGC 2403	0	0	0	0	1
NGC 6822	1	0	11	0	0
Sculptor Dwarf	0	0	0	9	0
SMC	12	1	7	5	1
Willman 1	0	0	0	1	0
Total	360	52	120	324	148

There are two possibilities for working with the data contained in the database. Users can either download the whole database or particular tables (see the following section) to a computer, and work with the data offline, or can explore the data online, through the web portal. Moreover, on the web portal, users can choose either to work with the tabular data (see the example in Fig. 2) or can access the object pages of the particular symbiotic binary.

The Database is published online which allows us to update the information when they become available and include the new objects as soon as they are discovered. At the same time, the Database constitutes the most comprehensive collection of orbital, stellar, and observational parameters of all known symbiotic binaries.

Several symbiotic systems are now relatively well characterized, including the parameters of both stellar components. Based on the data collected for the New Online Database of Symbiotic Variables and analyzed in this thesis, we can summarize the typical parameters of known symbiotic binaries. One should still keep in mind that the symbiotic group is quite heterogeneous and some objects differ significantly from any 'prototype'.

A typical S-type symbiotic binary ($\sim 77\%$ of all symbiotic stars) would have an orbital period of 300 – 800 days, orbit close to circular, and would consist of:

- a normal giant or bright giant of a spectral type M3 – M6, semi-regularly pulsating with a period of 50 – 200 days, with a mass in the interval of $1 - 2.5 M_{\odot}$, slightly sub-solar metallicity, losing its mass at rate $\sim 10^{-7} M_{\odot} \text{ yr}^{-1}$,
- a hot white dwarf with $T_{\text{eff}} > 10^5 \text{ K}$, luminosity $L \approx 10^2 - 10^4 L_{\odot}$, a mass in the range $0.4 - 0.8 M_{\odot}$ on whose surface the shell-burning of hydrogen-rich matter accreted from the giant is present, or an accreting-only white dwarf with a similar temperature and mass but much lower luminosity $L \approx 10^1 - 10^2 L_{\odot}$,
- a circumbinary nebula formed from the matter lost by winds of the components, especially that of the giant with a size of few au, a temperature of 10^4 K , and an electron density $n_e \sim 10^8 - 10^{12} \text{ cm}^{-3}$.

There are some specific groups of S-type symbiotic systems not fitting into the picture above. In yellow symbiotic stars, a metal-poor K-type giant is found instead of the M giant. In symbiotic recurrent novae, there is a more massive white dwarf present (with a mass of $1.1 - 1.3 M_{\odot}$). Moreover, a few symbiotic stars with accreting-only neutron stars have been detected. These do not manifest a typical symbiotic optical spectrum (i.e., do not have prominent emission lines in their spectra).

A typical D-type symbiotic binary has a much longer orbital period (tens of years) and its components are:

- a very evolved Mira giant of spectral type M7 – M8 with a pulsation period of 250 – 600 days surrounded by an optically thick dust envelope, the mass transfer rate of the cool component is at $10^{-5} M_{\odot} \text{ yr}^{-1}$,
- a low mass white dwarf as in S-type systems, accreting the matter from the wind of the giant,
- a more extended (10 – 100 au) and less dense ($n_e \sim 10^6 - 10^7 \text{ cm}^{-3}$) nebula.

There are also a few dusty systems whose cool component is a warmer G-type giant, these are denoted as D'-type systems and constitute about 3% of known symbiotic stars. In this thesis, we have also analyzed the symbiotic objects, which were claimed to be of a new infrared type (S+IR). Our results suggested that this class is not real and that all the objects can be easily classified in the former S/D/D' scheme.

Symbiotic systems also represent a significant population of X-ray sources. As a part of this thesis, we have evaluated the X-ray observations of the objects, which

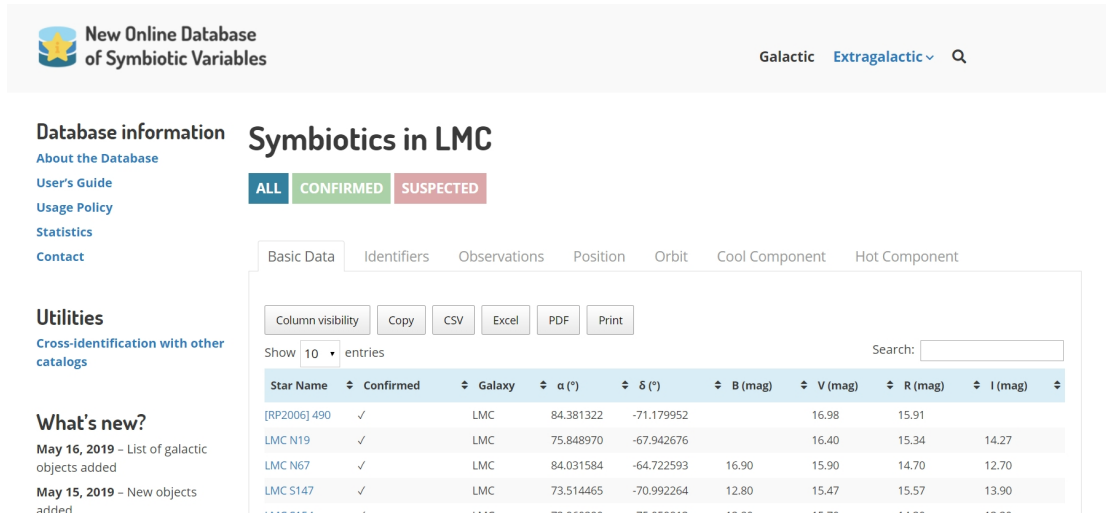


Figure 2: Example of tabular data in the Database.

have not been analyzed in the literature before. We report on the detection or non-detection of 271 objects from the New Online Database of Symbiotic Variables, more than doubling the sample of the objects for which this information is available (from the number of 234). The first X-ray classification is provided for 8 confirmed symbiotic binaries.

In the Database, we have collected the information on the outburst activity of symbiotic stars: 79 of the confirmed symbiotic systems are firmly established as outbursting sources, while another 9 systems might have been also observed in outbursts. Based on the data in the New Online Database of Symbiotic Variables and the literature information on individual objects, we have also suggested the model which provides possible relations between accreting-only and shell-burning symbiotic stars and all types of outbursts observed in these binaries (classical, Z And-type; 'slow' symbiotic nova; symbiotic recurrent nova), and also quiet symbiotic stars.

Our analysis confirmed many previous suggestions based on the significantly smaller samples. We have provided strong evidence that some of the stellar and orbital parameters (or their combination) are preferred for the symbiotic phenomenon to occur. This leaves several open questions, e.g., there is a clear peak in the distribution of the orbital periods of S-type symbiotic stars around 500 – 700 days, while the population synthesis models predict that most of the symbiotic stars should have orbital periods longer than 1 000 days with a maximum around 1 500 days. This discrepancy suggests that the mass transfer mechanisms in play are not fully understood and well incorporated in the models. It is still not completely clear in what fraction of symbiotic stars the mass is transferred by the Roche-lobe overflow and by the wind.

Spectroscopic and photometric analysis of symbiotic candidates

The demand for a larger sample and a better understanding of these objects is a driving force of surveys looking for them in our Galaxy and in the galaxies of the Local Group. Ongoing projects searching for symbiotic stars have resulted in the number of known symbiotic systems growing rapidly. The present version of the New Online Database of Symbiotic Variables contains 1 004 objects. Many of the known symbiotic stars are only poorly studied. Moreover, there are several objects proposed to be symbiotic stars based only on their photometric appearance or behavior. Some of them are not symbiotic in reality which is sometimes not reflected in the commonly used databases such as SIMBAD. For this reason, we have decided to analyze available data on selected symbiotic candidates from our Database and supplement them with new observations, in order to confirm or reject their symbiotic nature.

To provide a 'clean' sample of symbiotic stars which can be used for subsequent research and to increase the number of confirmed systems, we have initiated the observational campaign in order to collect sufficient material for the characterization of these objects. We have supplemented new, primarily spectroscopic data, with the available long-term light curves of the objects, multi-frequency photometric data from ground- and space-based surveys, astrometric measurements from *Gaia* satellite, and information from the literature. In Figure 3, examples of light curves, SEDs and spectra of selected candidates are shown. In this way, we subjected a substantial sample of 47 symbiotic candidates to a thorough analysis.

In the first part, we have focused on 11 candidates on the classical symbiotic stars. We have classified one object as a shell-burning symbiotic star (V2204 Oph). Two other objects, Hen 4-204 and V1988 Sgr are definitely not shell-burning symbiotic stars. However, V1988 Sgr still can be an accreting-only symbiotic star and Hen 4-204 seems to be very similar to the known symbiotic star BD Cam with an S-type cool component. Subsequent long-term photometric and spectroscopic observations in various spectral regions would be needed to fully confirm or reject their symbiotic status. In addition, we have reclassified another eight symbiotic candidates as either nearby single main-sequence stars (V379 Peg, 2MASS J07363415+6538548 in the field

of NGC 2403), single giants (IRAS 19050+0001), or binaries (V1017 Cyg, the MS-MS pair; PN K1-6, the system of MS star and white dwarf; EC 19249-7343, possible M dwarf-white dwarf binary or detached M dwarf-M dwarf system; V562 Lyr, the appearance of M3 giant with a long-lasting eclipse detected in past). V503 Her is a K-type giant star showing prominent pulsations and might be a part of an eclipsing binary with a long-orbital period. These results were partly published in Merc et al. (2020a, 2021c) and Dubovský et al. (2021).

In the second part, we analyzed available archival and new data on 9 candidates on 'slow' symbiotic novae. Three objects are confirmed to be 'slow' symbiotic novae: ASAS J174600-2321.3 (S-type; eclipsing), V618 Sgr (S-type; eclipsing), and V5590 Sgr (D-type). In addition, we claim that V618 Sgr is the first galactic recurrent 'slow' symbiotic nova as it has been observed at least in three outbursts already. TYC 1371-69-1 has the appearance of a single red giant, and we classify it as a pre-symbiotic binary. It was observed in an outburst in past, therefore it can be also classified as a transient symbiotic star. If the outburst was of a nova kind, then it is a post-symbiotic nova system in which the red giant is not capable of fueling the shell-burning on the surface of the white dwarf. M31N 2017-05b is not a symbiotic nova, but a classical symbiotic star. It is the first extragalactic symbiotic star discovered by the *Gaia* satellite. 2MASS J01093484-0800329 is probably not a symbiotic nova, but a cataclysmic variable or a central star of a planetary nebula. 2MASS J06422218-0226285 is reclassified as an outbursting young stellar object. HH Sge is most probably a single K-type star. The nature of V627 Cas is still not conclusive, but the observations suggest that it might be a binary system. The shell-burning symbiotic star classification is not supported by the data, but the accreting-only system cannot be ruled out. It can also be a post-AGB star.

Finally, we have analyzed all 27 symbiotic candidates located in the Large Magellanic Cloud and listed in the New Online Database of Symbiotic Variables. We classified four objects as bona-fide symbiotic stars (2MASS J05311676-6901041, HV 13055, [RP2006] 227, [RP2006] 295) and another four ([RP2006] 803, [BE74] 583, [RP2006] 883, 2MASS J05450015-6918192) are possibly symbiotic objects too, but more data are needed for definite classification. The rest of the candidates is classified either as planetary nebulae, other types of emission-line stars, superposition of the giant star and an emission nebula, and one target is a foreground source, most probably a cataclysmic variable.

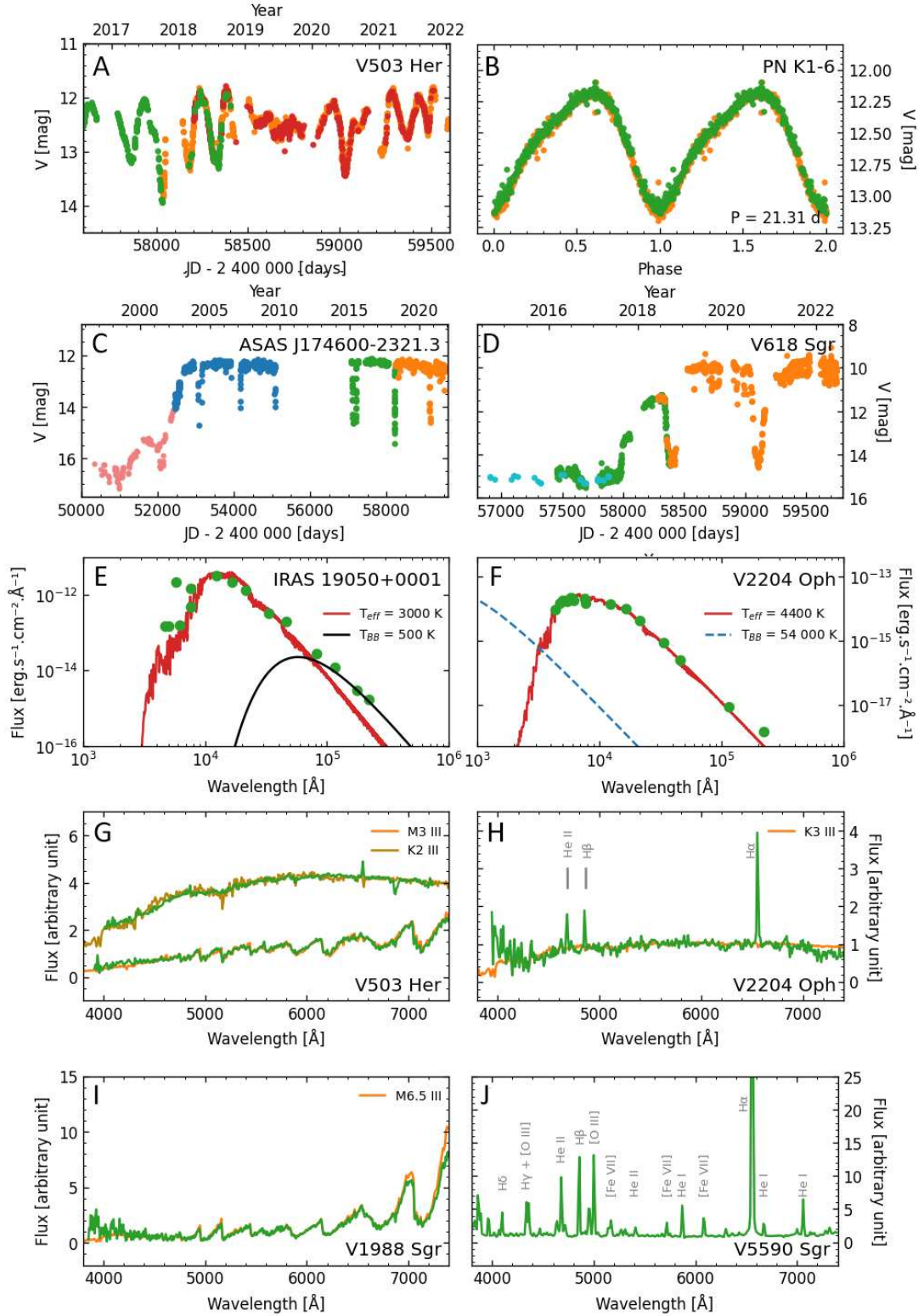


Figure 3: Example of the analyzed data for symbiotic candidates. Panels A – D show light curves of selected classical (V503 Her and PN K1-6) and symbiotic nova candidates (ASAS J174600-2321.3 and V618 Sgr). Panels E and F show multi-frequency SEDs of two symbiotic candidates (IRAS 19050+0001 and V2204 Oph). In panels G – J, the spectra of the selected studied candidates (V503 Her, V2204 Oph, V1988 Sgr, V5590 Sgr) are shown, together with the best fitting spectra from the library and the identification of most prominent emission lines.

Characterization of newly discovered symbiotic stars

We have used the tools developed for the characterization of the symbiotic candidates selected from the New Online Database of Symbiotic Variables also to study the objects that were neither known as symbiotic binaries nor suspected of a symbiotic nature in the literature. These objects were either identified based on the recent brightenings (by the ground- and space-based surveys) or noticed serendipitously in the scope of projects not focusing on symbiotic binaries. In many cases presented here, we followed up on the prolific collaboration with amateur observers.

We report on the discovery and characterization of Gaia18aen, an object detected in brightening by the *Gaia* satellite and confirmed in this study to be the first symbiotic star discovered by this European mission. We also present the analysis of the photometric and spectroscopic data of the newly discovered southern eclipsing symbiotic star, Hen 3-860, detected in outburst by the ASAS-SN survey. Finally, we report on the discovery of the southern symbiotic binary DeGaPe 35 which was discovered during the amateur observational campaign of the planetary nebula candidates.

Other results of the ongoing project focused on the characterization of new symbiotic binaries are not presented here, but we refer the reader to the published works: discovery of the new symbiotic star, TCP J18224935-2408280, in outburst (Merc et al. 2021a); detection of the first recorded outbursts of SS73 141 (Merc et al. 2021b) and WRAY 15-1167 (Merc et al. 2022c); low-resolution observations of the recently discovered accreting-only symbiotic star THA 15-31 (Merc et al. 2022a).

Gaia18aen: First symbiotic star discovered by Gaia

Gaia18aen (= AT 2018id, WRAY 15-136; $\alpha_{2000} = 08:02:52.06$, $\delta_{2000} = -30:18:37.19$) was previously classified as an emission-line star by Wray (1966). Its outburst was detected by the *Gaia* satellite and announced by the *Gaia* Science Alert (GSA; Wyrzykowski & Hodgkin 2012; Hodgkin et al. 2013, 2021) on January 17, 2018 (Delgado et al. 2018), when the star had the brightness $G = 11.33$ mag. In the alert, the transient was described as a bright emission-line star in the Galactic plane which

brightened by 1 magnitude. Previous measurements of the *Gaia* satellite over the period from October 31, 2014 to November 3, 2017 show that the average magnitude of the star was 12.31 ± 0.10 mag with no significant changes. According to the *Gaia* data, the star started to increase its brightness at the turn of November and December 2017. The observation obtained on December 3, 2017 revealed the star with 12.07 mag, and the object continued to brighten in the following weeks. Kruszynska et al. (2018) suggested a 'nova?' classification for the object based on the spectrum obtained by VLT/X-Shooter as a part of the program focused on the spectroscopic classification of candidates for microlensing events.

We collected two spectroscopic observations of Gaia18aen and all available photometric data from the databases of several surveys and from the literature to supplement the light curve in the *G* filter obtained by *Gaia*. Our main findings are as follows: Gaia18aen is a classical symbiotic star, fulfilling the traditional criteria for symbiotic stars. Raman scattered O VI lines are observed in its spectra outside the outbursts. The system is located at the distance ~ 6 kpc, 0.2 kpc from the central disk surface. The cool component of this symbiotic binary is an M giant with $T_{\text{eff}} \sim 3500$ K of a slightly super-solar metallicity, $[\text{Fe}/\text{H}] = +0.25$ dex, with a radius of $\sim 230 R_{\odot}$. Its luminosity, $L \sim 7400 L_{\odot}$, makes this star one of the brightest symbiotic giants. The NIR spectrum and IR photometry from 2MASS and *WISE* are consistent with a non-dusty S-type symbiotic star. The system experienced an outburst of about 3.3 mag in 2018, followed by re-brightening detected approximately after 100, 240, and 350 d. At least the first outburst was accompanied by the increase of the hot component luminosity ($L_{\text{h}} \sim 28000 L_{\odot}$ at the optical maximum) and the decrease in temperature (A or F-type photosphere), in comparison with temperatures ~ 68 kK and ~ 135 kK, and luminosities of ~ 26600 and $5500 L_{\odot}$, corresponding to the observations obtained 20 and 81 d after the optical maximum, respectively. The outburst was accompanied by the changes in emission spectral lines typical for classical symbiotic stars. In the outburst, higher fluxes of lower ionization lines of H I and He I have been observed, together with the decrease of intensity of high ionization lines of He II, [O III], [Fe VII], and O VI. The quiescent light curves of the object are characterized by a periodicity of approximately 487 d, which we tentatively attributed to the orbital modulation. The scatter in the light curves might be caused by stellar pulsations of the red giant with a period of 50 - 200 d, which are typical for cool components in S-type symbiotic systems. These findings make Gaia18aen the first symbiotic star discovered by the *Gaia* satellite. This discovery proves the fact, that besides the astrometric mission of

the *Gaia*, its repeated and high-precision observations can serve also as an photometric transient survey. The results presented here have been published in Merc et al. (2020b).

Hen 3-860: New southern eclipsing symbiotic star observed in outburst

The star Hen 3-860 (= WRAY 15-10622; $\alpha_{2000} = 13:06:12.93$, $\delta_{2000} = -53:22:52.50$) was previously classified as an H α emitter by Wray (1966) and Henize (1976). The object was included in the International Variable Star Index database (VSX; Watson et al. 2006) as a symbiotic candidate in November 2018 by an amateur astronomer Gabriel Murawski. This classification was based on the peculiar light curve of Hen 3-860 from the ASAS-SN survey (Shappee et al. 2014; Kochanek et al. 2017), showing recent brightening (starting at the end of 2016) resembling a symbiotic outburst.

We have included the object in our observational campaign focused on never spectroscopically observed and/or very poorly studied symbiotic candidates selected from the New Online Database of Symbiotic Variables and obtained two low- and two high-resolution of Hen 3-860. The spectroscopic observations were supplemented by available photometry obtained from the ground-based all-sky surveys and from the archive of digitized glass photographic plates of the Harvard College Observatory. Additional measurements in B , V , R_c , and I_c filters were obtained at the Danish 1.54-meter telescope at La Silla, Chile.

Our analysis confirmed that Hen 3-860 is a classical symbiotic star of the S-type. The cool component is an M2-3 giant with $T_{\text{eff}} \sim 3\,550$ K, $\log g \sim 1.0$, radius $60 - 75 R_{\odot}$ and luminosity of $540 - 760 L_{\odot}$. The second component is a shell-burning white dwarf possessing a high temperature of $1 - 2 \times 10^5$ K and luminosity of $\approx 10^3 L_{\odot}$. The recent light curve of Hen 3-860 confirmed that the object is a representative of a group of eclipsing symbiotic binaries. The presence of eclipses allowed to obtain the orbital period of the system of 602 days. The symbiotic system experienced at least 4 outbursts in the last 120 years (1928, 1941, 2006, 2016 – 2019). Hen 3-860 is now in the transition period from the active stage to the quiescence. Based on its similarity to AX Per, a well-known eclipsing symbiotic binary, we can assume that after a few orbital cycles, the narrow eclipses in the light curve of Hen 3-860 will gradually change into wave-like variability typically observable in quiescent symbiotic stars. Therefore

it is worth monitoring the system in order to document in detail the recovery of the system from the recent outburst during the transition into quiescence. The results presented here have been published in Merc et al. (2022b).

DeGaPe 35: Amateur discovery of a new southern symbiotic star

DeGaPe 35 (= 2MASS J15211785-5900339; $\alpha_{2000} = 15:21:17.86$, $\delta_{2000} = -59:00:33.90$) was identified as a possible emission-line object in the scope of an amateur survey searching for planetary nebulae. This survey is operated as a supplementary program at the amateur-built, remotely-operated Atacama Photographic Observatory located in San Pedro de Atacama, Chile. The main goal of the observatory is the astrophotography of the southern deep-sky objects. However, the field of view of four square degrees makes the obtained data excellent to search for conspicuous objects (especially planetary nebulae candidates) in the vicinity of the photographed targets. DeGaPe 35 was discovered in the field of the well-known Wolf-Rayet star WR 68 during the observations in 2017. A follow-up in June 2021 contradicted the planetary nebula nature of the source, and the object was reclassified as an emission-line star.

Our analysis of two low-resolution spectroscopic observations, supplemented by the photometry from *Gaia* DR3 and multi-frequency SED of DeGaPe 35. This object was previously classified as an emission-line star in the scope of an amateur survey searching for new planetary nebula candidates. Our results confirm that this source is a symbiotic star whose optical spectrum shows prominent emission lines, including highly ionized [Fe VII] and O VI lines. The cool component of this symbiotic binary is an M4-5 giant with $T_{\text{eff}} \sim 3\,380 - 3\,470$ K and luminosity $\sim 3 \times 10^3 L_{\odot}$ (for the adopted distance of 3 kpc). The inferred parameters of the hot component (temperature of $1 - 2 \times 10^5$ K and luminosity of $\sim 10^{2-3} L_{\odot}$) confirmed that it is a shell-burning white dwarf. The infrared data of DeGaPe 35 allowed us to classify it as an S-type symbiotic star. The photometric observations of the *Gaia* satellite, published recently in *Gaia* DR3 suggested the variability with the period of about 700 – 800 days, which we tentatively attributed to the orbital motion of the binary.

Conclusions

In this thesis, we present a theoretical background that summarizes all the relevant knowledge on symbiotic binaries necessary for the study of the parameters of these binaries, and for understanding their variability on various timescales in different parts of the electromagnetic spectrum is presented. This includes a short historical overview, a detailed discussion on both stellar components and a nebula, the definition of symbiotic binaries, their quiescent and outburst variability and provides also information on the evolution of these objects. The text is supplemented by the original figures illustrating various phenomena typical for symbiotic stars.

We introduced the New Online Database of Symbiotic Variables, the most up-to-date catalog of symbiotic binaries. Its structure and content are described in detail. This is followed by a discussion on the size of the galactic and extragalactic symbiotic population. Extensive analysis of the orbital periods, eccentricities of the orbits, and detection of the eclipses is presented, together with the in-depth investigation of the parameters of the cool and hot symbiotic components (their spectral types, effective temperatures, luminosities, metallicities, masses, pulsations, etc.). Part of the discussion is devoted to the activity of these systems, and a model of a possible relation between various types of the symbiotic phenomenon is suggested. Finally, data on symbiotic stars presented very recently in the *Gaia* Data Release 3 are analyzed.

A part of the thesis is devoted to a comprehensive analysis of the symbiotic candidates (classical, symbiotic nova and the Large Magellanic Cloud candidates) selected from our Database. All-together, 47 individual objects are analyzed in detail in this part of the thesis. Finally, we present the results obtained using the tools developed for the study of symbiotic candidates applied to three newly discovered objects: Gaia18aen, Hen 3-860, and DeGaPe 35.

Taken together, the New Online Database of Symbiotic Variables presented in this thesis provides a tool for the whole community useful for studies of the symbiotic population. The catalog represents the most comprehensive collection of the orbital, stellar, and other observational parameters of the symbiotic stars ever published. The presented analysis of the symbiotic candidates and newly-discovered objects helped to increase the number of known symbiotic binaries and provide a 'clean' sample for subsequent studies.

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1. **Merc, J.**, Gális, R., Wolf, M., et al. (2022). Hen 3-860: new southern eclipsing symbiotic star observed in the outburst, *Monthly Notices of the Royal Astronomical Society* (IF 5.287), 510, 1404.
2. **Merc, J.**, Gális, R., Wolf, M., et al. (2021). Spectroscopic and photometric analysis of symbiotic candidates - I. Ten candidates on classical symbiotic stars, *Monthly Notices of the Royal Astronomical Society* (IF 5.287), 506, 4151.
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7. **Merc, J.**, Gális, R., Kára, J., Wolf, M., & Vrašťák, M. (2020), The nature of the symbiotic candidate 2MASS J07363415+6538548 in the field of NGC 2403, *Monthly Notices of the Royal Astronomical Society* (IF 5.287), 499, 2116.
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