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A Spectroscopic and Photometric Study of MWC 342 and Its B[e] Phenomenon over the Last 40 Years

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Abstract: MWC 342 (V1972 Cyg) was discovered nearly 90 years ago as an early-type emission-line star. It was among the first hot stars whose strong infrared excess was detected in the early 1970s. Several mostly short-term photometric and spectroscopic studies resulted in contradictory conclusions about the nature and evolutionary status of MWC 342. It has been classified as a pre-main-sequence Herbig Be star, an evolved suspected binary system, and a long-period variable star. Suggestions on the nature of the secondary component to this B0/B1 primary included a cool M-type giant and an X-ray source. We collected medium- and high-resolution optical spectra of MWC 342 taken in 1994–2024 as well as optical photometric data taken in 1986–2024. Analysis of these data shows strong variations in the object's brightness and spectral line properties at various time scales, but no strictly periodic phenomena have been found. Inparticular, such a long-term dataset allowed us to reveal the optical brightness variations over a nearly 20-year-long quasi-period, as well as their anti-correlation with the Hα emission-line strength. Also, we did not confirm the presence of He II emission lines and absorption lines of the star's atmosphere that were suspected in previously published studies.

Keywords: spectroscopy; photometry; emission-line stars; circumstellar matter

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1. Introduction

MWC 342 is an example of a variable star whose nature has been the subject of scientific debate for decades. Initially identified in 1933 through hydrogen emission lines, it attracted

attention due to its complex spectral profile, including both permitted and forbidden Fe II lines [1,2]. Subsequent observations revealed a significant infrared excess [3]. The coexistence of permitted and forbidden lines in its spectrum led to its early classification as a peculiar Be star and its later inclusion in the B[e] class characterized by dense circumstellar gaseous and dusty environments and diverse physical processes [4].

In 1978, MWC 342 was classified as a B3 III star surrounded by an optically thin gas-and-dust shell [5], suggesting a developed circumstellar envelope capable of producing complex spectral line profiles. However, later studies uncovered additional components that made the interpretation of its properties even more unclear. In 1982, analysis of its spectral energy distribution (SED) in the optical range via spectrophotometry resulted in the suggestion of a cool (M0–type) secondary companion, raising the possibility of a binary system [6].

Efforts to clarify MWC 342's evolutionary status through multicolor photometry led to its tentative classification as a pre-main-sequence Herbig Ae/Be star [7] (the object's ID is misspelled in this paper title: MWC 324 instead of MWC 342). However, the absence of a nearby star-forming region and a visible nebulosity made this interpretation less probable. Analysis of the observed properties of MWC 342 and comparison with those of other objects with the B[e] phenomenon from their original list compiled by Allen and Swings [4] led Lamers et al. [8] to conclude that its evolutionary status could not be determined from the existing data and to suggest putting it in a group of unclassified objects with the B[e] phenomenon.

From 1999 onward, high-resolution spectroscopic and photometric data rejected the hypothesis of MWC 342 as a young star [9]. Instead, it was suggested as a binary system with mass transfer, typical of FS CMa objects—intermediate-mass binary systems at various evolutionary stages [10]. More recently, data from the Gaia mission identified the star as a long-period variable candidate [11]. As demonstrated by its research history, the nature and evolutionary status of MWC 342 remain unresolved.

In this study, we present the results of our preliminary analysis of decades-long spectroscopic and photometric observations of MWC 342. Our aim is to analyze variations in its spectrum and brightness, attempt to uncover the physical mechanisms underlying its complex behavior, and refine its evolutionary status. These findings may provide insights into common processes in objects with the B[e] phenomenon.

2. Observations

We collected all optical photometric and spectroscopic data available in the literature and added our own data taken over the last two decades. The previously published spectroscopic data were either relatively low-resolution and/or covered selected spectral regions, typically around emission lines. In particular, the Hα line equivalent widths which we use in our study were taken from 9 spectra obtained in 1986–1995 [9], 3 spectra obtained in 1987–1990 [12], and 102 spectra obtained in 2004–2010 [13]. For the past 20 years, we took 66 mostly higher-resolution spectra with various instruments which are listed in Table 1.

The published photometric data collected in one place for the first time are shown in Table 2. Additionally, we took photometric data in the Johnson–Cousins BVR bands using a 1 m telescope in the Tien-Shan Astronomical Observatory (TShAO) [14] of the Fesenkov Astrophysical Institute (Kazakhstan) in 2002–2024, the 60 cm telescope of the Maidanak Observatory (Uzbekistan) in 1999–2008 [15], and the 1.25 m telescope of the Crimean Astrophysical Observatory in 2008.

Table 1. Spectroscopic observations.

Observatory	Dates	Telescope/Spectrograph/Location	R	Range (Å)	# sp.	Ref
Mauna Kea	2004–2022	3.6 m, CFHT, ESPaDoNs, Hawaii	65,000	3800–10,500	10	[16]
OAN SPM	2005–2019	2 m, REOSC, Baja California, Mexico	18,000	3700–7300	14	[17]
McD	2005–2012	2.7 m, Texas, USA	60,000	3700–10,500	2	[18]
Pic du Midi	2007	2 m, NARVAL, France	65,000	3700–10,500	1	[19]
Indian Astron. Obs.	2018–2019	2 m, HCT, Hanle, India	25,000	4200–10,500	4	[20]
ORLM	2010–2021	1.2 m, HERMES, La Palma, Spain	85,000	3800–9,000	30	[21]
Apache Point	2021–2023	3.5 m, ARCES, New Mexico, USA	31,500	3600–10,500	2	[22]
TCO	2023	0.81 m, Eshel, North Carolina, USA	12,000	3800–7800	2	[23]

Notes: R—solving power, # sp.—total number of spectra taken, Ref.—references to descriptions of the spectrographs. Observatory IDs: SPM—Observatorio Astronómico Nacional San Pedro Martir; CFHT—Canada–France–Hawaii Telescope; McD—McDonald Observatory; NARVAL—Bernard Lyot Telescope; ORLM—Observatorio del Roque de Los Muchachos; APO—Apache Point Observatory; TCO—Three College Observatory; HCT—Himalayan Chandra Telescope.

Table 2. Photometric observations.

Observatory	Dates	Telescope/Location	Filters	#	Ref
Majdanak	1984–1999	0.6 m, Uzbekistan	$UBVR$	774	[15]
Assy-Turgen	1986–1994	1.0 m, Kazakhstan	$UBVRI$	46	[7,9]
TShAO	1995–1999	1.0 m, Kazakhstan	$UBVR$	16	[9]
INTEGRAL	2002–2008	OMM *, space	V	28	[24]
Abastumani	1989–1993	1.25 m, Georgia	$uvby$	48	[25]
APAS DR10	2011	multiple telescopes	$BVgriz$	2	[26]
ASAS-SN	2015–2024	multiple telescopes	V, g	1178	[27,28]

Notes: Information in columns 1–3 is the same as in the corresponding columns of Table 1, column 4 shows the filters used, column 5 shows the number of photometric data points obtained, and column 6 shows references to the publications of these data. *—OMM is the Optical Monitoring Mission onboard the INTEGRAL space mission.

3. Results and Discussion

The optical spectrum of MWC 342 contains many emission lines, among which double-peaked lines of the Balmer series with a much stronger red peak are most pronounced. These features were first described by Swings and Struve [2], and later Miroshnichenko and Corporon [9] confirmed their profiles. Based on 102 spectra obtained at the Ondrejov Observatory (Czech Republic) in 2004–2010, variations in the peak shapes, line intensity, and equivalent width (EW) were revealed, especially noticeable in the blue-shifted peak of the Hα line [13]. These data showed a possible ∼1500-day cycle in the Hα line violet-to-red peak intensity (V/R) variations. However, only two V/R maxima were observed due to the limited period of the monitoring.

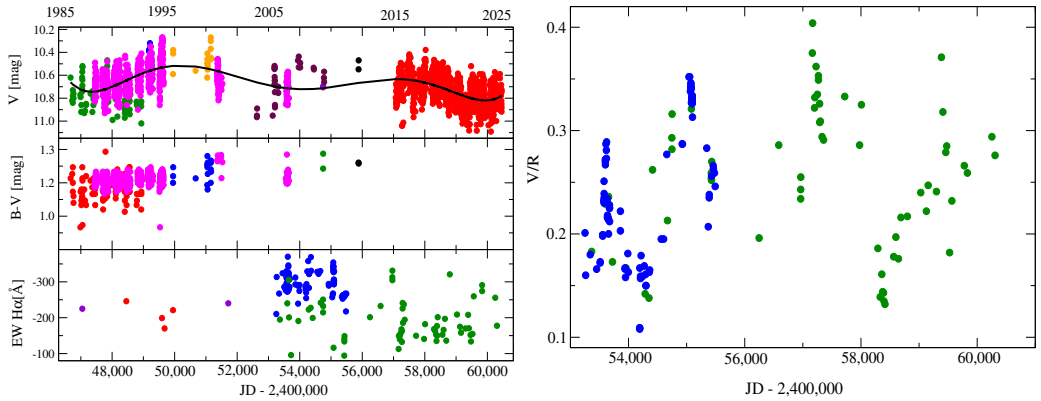
The He I and O I lines demonstrate complex dynamics associated with the circumstellar medium, including asymmetric emission wings. These features are typical for objects with the B[e] phenomenon and hot supergiants, where the interaction of the stellar wind and disk plays a key role. There are a few absorption lines present in the spectrum (mostly interstellar ones) that indicate a strong veiling of the photospheric spectrum. The latter is also reflected in the discrepancy between the interstellar and total extinction noticed in [9].

3.1. Variability

The optical brightness variability of MWC 342 has been discussed several times based on monitoring from the 1980s to the 1990s, e.g., [7,9,13,25]. It was found that the object exhibits quasi-periodic behavior with characteristic times from a few weeks to a few months. However, no cycle exhibited long-term stability. More recent data from ASAS SN revealed longer cycles of 632.75 days based on a sample of V-band observations during ∼1400 days with an amplitude of 0.37 mag (The results for ASASSN–V J202303.63+392949.8 are shown at https://asas-sn.osu.edu/variables/1131d03b-0b32-53d7-bebb-daedd95aaeaa (accessed

on 14 May 2025). However, the whole collection of the ASAS SN data taken so far does not support this conclusion.

Analysis of our collection of photometric data (see Table 2 for the time coverage and statistics) revealed even a longer cycle of ∼20 years (see the upper left panel of Figure 1). Although the time frame between 2003 and 2015 has a scarce coverage, two local brightness maxima around 1995 and 2017 as well as three minima near 1987, 2007, and 2024 are noticeable. There is also a hint of a gradual fading (minima ∼11 mag near 1987 and ∼11.2 mag near 2024, maxima ∼10.2 mag near 1999 and ∼10.4 mag near 2017), but this may be due to irregular monitoring before 1999. At the same time, the $(B - V)$ color-index changed very slightly and showed a modest increase between 1986 and 2015 along with a smaller variation amplitude compared to that in the V-band.



(**a**) Light curve (**b**) V/R variations in the Hα line profile.

Figure 1. (**a**) Light curve of MWC 342 in the V-band (top panel), $B - V$ color-index (middle panel), and the equivalent width of the Hα line (bottom panel). The symbols represent data taken at different sites: Maidanak Observatory (magenta); TShAO (orange); Assy-Turgen Observatory (green); Abastumani Observatory (blue); CrAO (violet); INTEGRAL (maroon); APAS DR10 (black); and ASAS SN (red). The g-band data from ASAS SN are shifted by 0.48 mag to match the V-band data. The black solid line in the top panel traces the average V-band brightness. The Hα EW data symbols are taken from the following sources: red [9], blue [13], violet [12], and green—our measurements (see Table 1). (**b**) V/R temporal variations from [13] (blue symbols) and our data (green symbols).

It is harder to describe the emission-line strength variability, as the observations were sparse before ∼2005. There has been no significant drop in the Hα line strength for the last 20 years. The visible difference between our data (green points in the bottom left panel of Figure 1) and the measurements from [13] can be explained by the continuum normalization of the spectra, which were noisier in the latter set. Comparison of our Hα EW measurements with the photometric behavior in the ASAS SN data suggests that the brightness decrease between 2017 and 2024 is accompanied by a Hα fading, which may be partially due to a fainter continuum. At the same time, the fadings might have been due to an enhanced mass-loss (or transfer) that would make the emission lines stronger.

The Hα V/R ratio (see right panel of Figure 1) in our data shows similar variations to those found in [13], but it does not follow the 1560-day cycle suspected by these authors. We detected two increases in the V/R ratio near JD 2,457,200 and JD 2,459,500 separated by a longer time (∼2300 days). Comparing this behavior with the V-band light curve indicates that such increases occur when the object is fainter than average. If true, this effect may be due to decreases in the mass-loss rate from the underlying star, as the blue-shifted P Cyg–type absorption component typical of stellar winds becomes weaker, thus leading to larger V/R ratios.

The color-index $B - V$, whose temporal behavior is shown in the middle panel of Figure 1, shows small variations between 1.1 and 1.3 mag. A slight increase is noticed

toward the end of active monitoring around 2010–2015. Using the ASAS SN V- and g-band data taken contemporaneously before this survey completely shifted to taking g-band data only, we found that the average $g - V$ color-index was 0.48 ± 0.04 mag. Translation of this value into $B - V$ using an equation from [29] gives $B - V = 1.07 \pm 0.04$ mag. However, if a strong Hα line which contributes to the V–band brightness is taken into account, the $B - V$ color-index does not seem to exhibit any significant changes compared to the earlier data taken in the Johnson photometric system.

3.2. Extinction, Distance, and Luminosity

Due to uncertainties in the extinction and distance to MWC 342, its luminosity is not as well-known. Bergner et al. [7] estimated the distance to be ∼1 kpc based on the interstellar extinction law found from UBV data for stars projectionally close to the object. Miroshnichenko and Corporon [9] used EWs of the strongest diffuse interstellar bands (DIBs) and estimated the interstellar part of the reddening to be $\mathrm{E}^{\mathrm{IS}}(B - V) = 0.7 \pm 0.2$ mag. These authors also estimated the circumstellar reddening, due to gasesous and dusty components, to be $\mathrm{E}^{\mathrm{ff}}(B - V) \sim 0.3$ mag and $\mathrm{E}^{\mathrm{dust}}(B - V) \sim 0.5$ mag, respectively. Assuming that the ratio of the total to selective visual interstellar extinction is typical for field stars ($\mathrm{A}_V/\mathrm{E}(B - V)$ = 3.1), they derived $\mathrm{A}_V = 3.7 \pm 0.6$ mag and, using an average visual brightness of $V = 10.5$ mag, found a luminosity of $\log \mathrm{L}/\mathrm{L}_\odot = 4.2 \pm 0.4$.

This calculation does not take into account the contribution of the circumstellar continuum due to free–free and free–bound transitions. This continuum is obviously present, because the emission-line spectrum is strong and some of the absorption lines are filled with emissions (e.g., H I, He I, Si II). Removing the circumstellar continuum would make the star's luminosity lower.

Another uncertainty in the luminosity calculation presents the determination of the visual brightness of the star's photosphere. Miroshnichenko and Corporon [9] used the averaged V-band brightness measured from the photometric data available at the end of the 20th century ($V = 10.5$ mag). The 21st century photometry slightly expanded this range, but the average brightness remained unchanged. At the same time, using the average is not strictly correct, because the emission lines and thus the circumstellar continuum are present even at the lowest brightness level.

Monnier et al. [30] took interferometric observations of MWC 342 at a wavelength of 10.7 μm with the 10 m Keck telescope and detected an asymmetric structure (a dusty disk), which was barely resolved along the major axis (Full Width at Half Maximum, FWHM, 39 ± 11 milliarcseconds) and unresolved along the minor axis (FWHM 37 ± 37 milliarcseconds). This result is consistent with a nearly edge-on view of the circumstellar disk, which may also be responsible for double-peaked profiles with a much weaker blue-shifted peak (see right panels of Figures 1 and 2) and deep central absorption components of high members of the Balmer series, see Figure 3 in [9]. Monnier et al. [30] also used a mid-IR size versus luminosity diagram for young stars to estimate the objects' luminosity. Although these authors did not quote the distance to MWC 342, their luminosity estimate turned out to be just a little over 10^4 $\mathrm{L}_\odot$.

According to Gaia DR3 [31], the distance to MWC 342 is $D = 1.68 \pm 0.33$ kpc, which is ∼70% larger than the estimate from [9]. Combining our high-resolution CFHT spectra to increase the signal-to-noise ratio in continuum to ≥250 allowed us to improve the accuracy of the interstellar extinction estimate based on the DIB strengths compared to that obtained in [9]. Using the DIBs at 5780, 5797, and 6614 Å whose EWs were 0.35 Å, 0.14 Å, and 0.17 Å, respectively, and the calibrations from [32,33], we determined an interstellar reddening of $\mathrm{E}(B - V) = 0.8 \pm 0.1$ mag. This estimate virtually coincides with that taken from the extinction map by [34] for the Gaia DR3 distance in the direction of MWC 342.

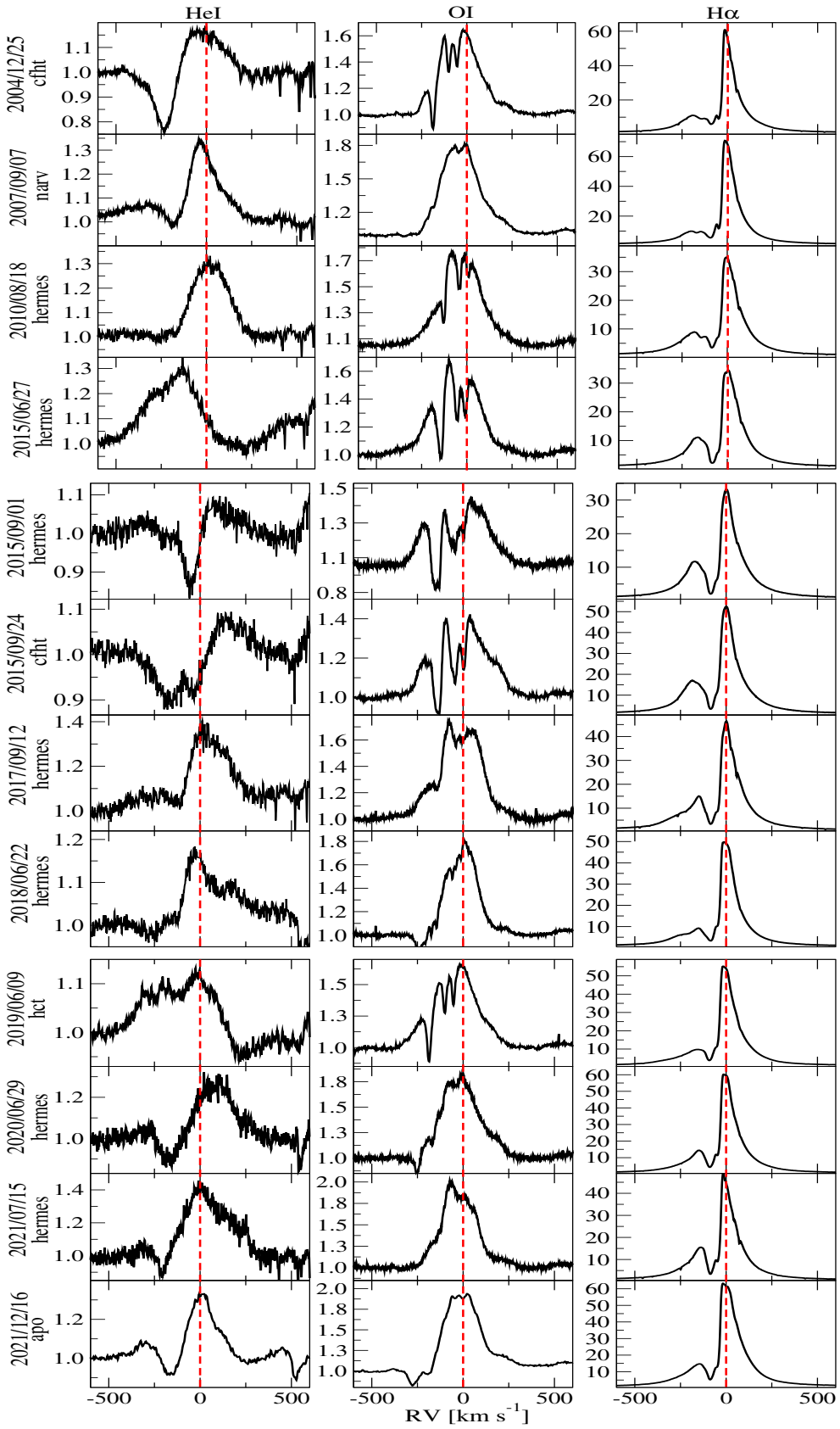


Figure 2. From left to right: Profiles of the He I (5875 Å), O I (7771/7774/7775 Å), and Hα (6563 Å) lines. The vertical red dotted lines show the stationary positions of the spectral lines; however, for the oxygen line, the average wavelength of the three lines is given. The horizontal axis shows heliocentric RVs on km s^{-1}, and the vertical axis shows the line intensity in units of the local continuum.

In order to produce a new object's luminosity estimate, one needs to take into account the circumstellar free–free and bound–free continuum and the fact that even at the lowest optical brightness of $V \sim 11.2$ mag the emission-line spectrum is still strong. However, the circumstellar continuum contribution should not be very large, as we still see some absorption lines that most likely form in the star's atmosphere (see Section 3.3). These considerations suggest a rough estimate for the circumstellar contribution to the visual brightness of ∼0.5 mag.

Therefore, with the new consistent data on the distance and interstellar reddening of MWC 342, the photospheric brightness of ∼11.5–12.0 mag, and a total extinction of $A_V \sim 3.7$ mag [9], we derive an absolute visual magnitude of $M_V \sim -3.1$ mag and (with a bolometric correction of $BC_V \sim -1.9$ mag for T_{eff} = 20,000 K) a luminosity of $\log L/L_\odot \sim 3.9$. The uncertainty of the luminosity that contains the distance, circumstellar contribution, T_{eff}, and total extinction is rather large. However, it still coincides with the abovementioned estimates within the uncertainty.

A lower limit for the luminosity ($\log L/L_\odot \sim 3.5$) is set by the zero-age main sequence for early B-type stars. It is unlikely that the underlying star is underluminous for its surface temperature. Also, if the star is single, then its fundamental parameters indicate an initial mass of 6–10 $M_\odot$ unless the adopted circumstellar contribution (both absorption and emission) to the observed brightness is significantly off. It is unusual for a single intermediate-mass star to be surrounded by such a large amount of circumstellar matter if it is not at the pre-main-sequence stage of evolution. However, the absence of a nearby star-forming region mentioned above (see Section 1) and a fast decrease in the IR flux longward of $\lambda \sim 10$ μm [10], which is one of the distinguishing features of FS CMa objects, rule out the early age of the object.

3.3. Spectral Features

Our higher-resolution and higher signal-to-noise spectra compared to those previously published allowed us to refine the description of several observed features in order to obtain a better understanding of the underlying energy source in this system. In particular, Andrillat and Jaschek [35] suspected the presence of absorption lines of O II at 4649 and 5208 Å and C II at 5242 Å in their low-resolution spectrum ($R \sim 5000$) taken in 1997. We see a hint of an absorption line near 4649 Å in our spectra with a S/N ≥ 100, but it is very weak and may be an artifact of the continuum drawing between Fe II emission lines in this region. Moreover, no other lines of O II (Mult. 8) are present. No obvious absorptions were detected near 5208 and 5242 Å.

Miroshnichenko and Corporon [9] discussed the possibility of the presence of He II emission lines at 4541, 4686, and 5411 Å. Figure 4 in their paper shows an emission line at 5412 Å. Neither of our high S/N spectra show any sign of an emission or an absorption line at 4686 Å, while the emission features present near 4541 and 5412 Å can be confidently identified with the Fe II (Mult. 38) 4541.52 Å and [Fe II] (Mult. 17) 5412.64 Å lines, respectively (see Figure 3).

The He II 4541.59 Å line is located very close to the Fe II (Mult. 38) 4541.52 Å line and, in principle, can be considered an identification of the line shown in the left panel of Figure 3. However, the other Fe II (Mult. 38) lines are obviously present in this spectral part and have similar profiles that makes it more appropriate to identify this line with that of Fe II (Mult. 38). At the same time, the He II 5411.52 Å line is shifted by 60 km s^{-1} from the position of the [Fe II] (Mult. 17F) 5412.64 Å line, which has a similar profile and RV with that of the other [Fe II] line shown in the right panel of Figure 3. Moreover, both mentioned He II lines belong to the same Multiplet 2 and should not have such different profiles as

those seen in the panels of Figure 3. As a consequence of the absence of He II lines, the Teff of the underlying star being higher than $\sim 28,000$ K can be ruled out, see ref. [36].

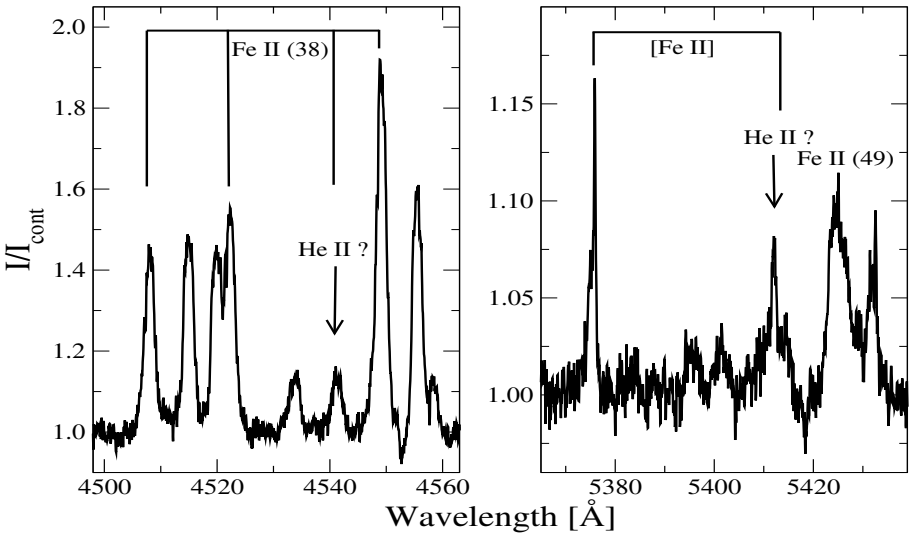


Figure 3. Parts of the ARCES spectra of MWC 342 around possible locations of the He II 4541.59 Å (**left** panel) and 5411.52 Å (**right** panel). All the lines in the left panel are Fe II lines of Multiplets 37 and 38. The two narrow emission lines in the right panel are the 5376.47 Å [Fe II] (Mult. 19F) and the 5412.64 Å [Fe II] (Mult. 17F) lines.

The underlying star's spectral type was estimated to be B3 III [5], B0/B1 [9], or B0 [35] from spectroscopy and B8 from optical spectrophotometry, from an SED fitting [6]. The strong emission-line spectrum, which is always present, clearly suggests a hot excitation source. Our spectra show that several He I lines, such as those at 4471 and 4713 Å, are seen in pure absorption most of the time, while those at 5876, 6678, and 7065 Å exhibit either P Cyg-type or purely emission profiles (see the left panel of Figure 2). Along with the presence of strong emission lines of O I (7772–7775 Å, see central panel of Figure 2), Si II (5979, 6347, and 6371 Å), and the hydrogen lines of the Paschen series, see Figure 1 in [35], this behavior is consistent with an underlying early B-type star.

The emission line profile variations are very strong in both shape and position. This is especially noticeable for the He I 5875 Å line (left panel of Figure 2) and the near-IR oxygen triplet (central panel of Figure 2). Although no regular component has been clearly found in the variations, they seem to be indicative of fast active changes of the circumstellar gas distribution near the star.

4. Conclusions

We collected and preliminarily analyzed optical spectroscopic and photometric variations of the emission-line star MWC 342 which does not have a well-understood evolutionary status. The variations in the profiles and positions of spectral lines of MWC 342 were not found to exhibit strictly periodic behavior (Figure 2). Similarly, the photometric data analysis reveals the absence of long-term periodic variability. Instead, quasi-periodic changes are observed, most likely linked to fluctuations in the optical depth of the circumstellar envelope. In addition to the various possible periods found in the literature (from a few weeks to a few months), we found a nearly 20-year-long quasi-period in the optical brightness of the object. We also found signs of an anti-correlation between the optical brightness and the EW of the Hα line that suggests that the latter is partly due to the variations in the underlying continuum.

Using higher-resolution and higher S/N spectra than those published previously, we did not confirm the presence of He II emission lines in the spectrum of MWC 342 that

were suspected in [9]. Also, we used a Gaia DR3 distance and a new estimate of the interstellar reddening based on the extinction map from [34] and a new evaluation of the circumstellar contribution to the object's brightness to derive a new estimate of the object's luminosity ($\log L/L_{\odot} \sim 3.9$). It turned out to coincide with the previously published ones, $\log L/L_{\odot} \sim 4.2$ [9,30]. However, the luminosity uncertainty is still rather large (of the order of 0.4 dex) and requires a careful modeling of this complicated system.

The findings underscore the importance of continued multi-wavelength observations of MWC 342, particularly in the IR region, to gain deeper insights into the processes occurring in its circumstellar environment. Special attention should be devoted to tracking temporal variability to refine the understanding of the envelope's dynamic structure. Since the photometric variations are large at a variety of time scales, it would be important to organize a contemporaneous photometric (especially multicolor) and high-resolution spectroscopic campaign in order to more closely study variations in the brightness and spectral features. The most helpful would be weekly monitoring for a few years. Currently, the ASAS SN survey frequently provides one-band brightness data, but the addition of spectroscopic coverage is crucial for further understanding of the object's nature.

Thus, MWC 342 remains a fascinating and intricate object, offering valuable opportunities to study the interaction between a star and its circumstellar environment as well as the evolutionary pathways of stars exhibiting the B[e] phenomenon. It is one of the most active objects with the B[e] phenomenon from the FS CMa group. Other very active group objects are the group prototype, FS CMa (HD 45677), and HD 50138, both of which we are actively investigating and will be presenting long-term studies on in the nearest future. A review of recent results on the FS CMa group objects can be found in [37].

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Abbreviations

The following abbreviations are used in this manuscript: RV—radial velocity, R—spectral resolving power, SED—spectral energy distribution.

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