Observational aspects of Herbig Ae/Be stars and of candidate young A/B stars

de Winter, D.

Citation for published version (APA):

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: https://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.
CHAPTER B5 *

The new Be-type star HD 147196 in the ρ Oph dark cloud region

Co-authors: P.S. Thé1, M.R. Pérez2,3, and M.E. van den Ancker1

1 Astronomical Institute "Anton Pannekoek", University of Amsterdam, Kruislaan 403, 1098 SJ Amsterdam, The Netherlands
2 IUE Observatory - Code 684.9, NASA Goddard Space Flight Center, Greenbelt, MD 20771, U.S.A.
3 Guest Observer, the International Ultraviolet Explorer

Abstract. -- The newly discovered Hα-emission line star, HD 147196, by Irvine (1990) was observed spectroscopically and photometrically at the ESO. Furthermore, high and low resolution IUE spectra were obtained at the NASA, Goddard Space Flight Center. From the examination of the data of this star, which is located in the direction of the ρ Oph dark cloud, we report: (1) The finding of Irvine (1990) that this relatively bright star show its Hα-line in emission has been confirmed, (2) Previous Hα-surveys of the ρ Oph star-forming region (Haro 1949, Hidajat 1961) did not detect HD 147196 as an Hα-emission star, meaning that it must recently be very active, and has perhaps transformed itself from a B-type star at shell phase to a Be-phase, (3) The Mg ii h + k resonance lines are in absorption and they appear to be interstellar in nature, which means that either the abundance of Mg in the extended atmosphere of the star is low or that the shell is not extended enough to produce emission lines of Mg ii, (4) Photometric observations of this B8 V type star do not show: (a) any variations during at least the times (years) covered by our monitoring (V = 7.004), (b) excess of near-IR radiation in its spectral energy distribution (SED), up to the M-passband at 4.8 μm; this is a well known fact for late type Be stars.

1. Introduction

Recently Irvine (1990) reported the finding of a new bright Hα-emission line star, HD 147196 (R.A. = 16°18'18.91, Dec. = -23°35'23.71, 1950), located in the direction of the ρ Oph dark cloud complex. He tentatively considers it a member of the upper Scorpius OB association. This discovery has captured our attention because (1) HD 147196 has the strongest Hα-emission line compared to the other stars of Irvine's sample, (2) previous Hα surveys in the ρ Oph dark cloud (Haro 1949; Hidajat 1961) did not detect HD 147196 as an emission line star, (3) in the general catalogues of early type emission line stars of Merrill and Burwell (1933, 1943, 1949, 1950) and of Wackerling (1970) HD 147196 was not reported to have Balmer emission lines, (4) the star seems to be associated with the ρ Oph dark cloud, known as an active star-forming region, which suggest that HD 147196 is probably a pre-main sequence (PMS) object. It seems that by some phenomenon the star's immediate atmospheric surroundings recently attained a condition in which Balmer emission lines are formed. In the present paper we report the results of our observational study of this new Hα-emission line object.

2. The observations

In Table 1 we list UBVRI and near-IR photometric data of the star HD 147196 made at the ESO in June/July, 1991, and in March, 1992, with the ESO 50 cm and 1 m telescopes. The 50 cm telescope was equipped with a single channel photometer and an RCA 31034 (Quantacon) photomultiplier as detector, whereas to the 1 m telescope the Nitrogen-cooled near-IR photometer with an InSb detector was attached. Table 2 lists ANS, Walraven, Strömgren, Johnson/Cousins and near-IR photometric observations of HD 147196 taken from various sources and from Table 1.

HD 147196 has been observed by IUE in two different occasions. On April 9, 1990, it was observed in the Short Wavelength (SWP: range 1175 - 1950 Å) and in the Long Wavelength (LWP: range 1950 - 3250 Å) cameras. An additional high-dispersion LWP image was secured on September 7, 1990. All these data were acquired through the large aperture (oval: 10" x 20"). The standard IUESIPS processing system was used for the extraction and flux calibrations of the IUE images. A journal of the observations is provided in Table 3. We have also included in this table the V magnitude derived from the FES (Fine Error Sensor, IUE optical dissector scanner used for acquisition and guidance) measurements at the time of the acquisition of the

* Based partly on observations made at the European Southern Observatory, La Silla, Chile and with IUE at NASA Goddard Space Flight Center, Greenbelt, USA.
Table 2. Photometric data of HD 147196.

<table>
<thead>
<tr>
<th>Band</th>
<th>15W</th>
<th>18</th>
<th>22</th>
<th>25</th>
<th>33</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_\lambda$</td>
<td>6.422</td>
<td>6.642</td>
<td>7.460</td>
<td>7.172</td>
<td>7.100</td>
</tr>
<tr>
<td></td>
<td>±0.005</td>
<td>±0.007</td>
<td>±0.005</td>
<td>±0.005</td>
<td>±0.005</td>
</tr>
</tbody>
</table>

TD1 photometric data

<table>
<thead>
<tr>
<th>Band</th>
<th>2740</th>
<th>2365</th>
<th>1965</th>
<th>1565</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_\lambda$</td>
<td>7.20</td>
<td>7.19</td>
<td>6.81</td>
<td>6.27</td>
</tr>
<tr>
<td></td>
<td>±0.02</td>
<td>±0.05</td>
<td>±0.10</td>
<td>±0.05</td>
</tr>
</tbody>
</table>

Walraven photometric data (De Geus et al. 1989)

<table>
<thead>
<tr>
<th>Band</th>
<th>W</th>
<th>U</th>
<th>L</th>
<th>B</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>log$I_\lambda$</td>
<td>-0.5705</td>
<td>-0.4707</td>
<td>-0.2596</td>
<td>-0.1356</td>
<td>-0.0659</td>
</tr>
<tr>
<td></td>
<td>±0.0022</td>
<td>±0.0020</td>
<td>±0.0019</td>
<td>±0.0018</td>
<td>±0.0016</td>
</tr>
</tbody>
</table>

Strömgren photometric data (Lodén et al. 1980)

<table>
<thead>
<tr>
<th>Band</th>
<th>u</th>
<th>v</th>
<th>b</th>
<th>y</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_\lambda$</td>
<td>8.360</td>
<td>7.389</td>
<td>7.193</td>
<td>7.048</td>
</tr>
<tr>
<td></td>
<td>±0.024</td>
<td>±0.018</td>
<td>±0.013</td>
<td>±0.011</td>
</tr>
</tbody>
</table>

Johnson and Cousins photometric data derived from Table 1

<table>
<thead>
<tr>
<th>Band</th>
<th>U</th>
<th>B</th>
<th>V</th>
<th>R</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_\lambda$</td>
<td>7.026</td>
<td>7.188</td>
<td>7.021</td>
<td>6.906</td>
<td>6.763</td>
</tr>
<tr>
<td></td>
<td>±0.007</td>
<td>±0.005</td>
<td>±0.016</td>
<td>±0.009</td>
<td>±0.013</td>
</tr>
</tbody>
</table>

Near-IR photometric data derived from Table 1

<table>
<thead>
<tr>
<th>Band</th>
<th>J</th>
<th>H</th>
<th>K</th>
<th>L</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_\lambda$</td>
<td>6.60</td>
<td>6.59</td>
<td>6.49</td>
<td>6.32</td>
<td>6.3</td>
</tr>
<tr>
<td></td>
<td>±0.05</td>
<td>±0.05</td>
<td>±0.03</td>
<td>±0.06</td>
<td>±0.6</td>
</tr>
</tbody>
</table>

images which are nearly identical and in good agreement with the visual $V$ magnitudes given in Table 2.

Visual spectra of HD 147196 were obtained with the Boller and Chivens Cassegrain spectrograph attached to the ESO 1.52 m telescope. A spectrum of the H\$ region (4503 - 5120 Å; dispersion 0.6 Å/pixel; exposure time 5 min), obtained on June 24, 1991, is shown in Fig. 1. Fig. 2 shows the spectrum of the H\$ region (6242 - 6767 Å; dispersion 0.5 Å/pixel; exposure time 20 min) obtained on June 21, 1991. Both spectra were flux calibrated, using spectra of three standard stars taken each night. The wavelength has been calibrated utilising He-Ar reference spectra. For these purposes the MIDAS image processing system was employed running under SUN/OS at ESO headquarters. For optimal extraction of spectral data from the CCD images the optimal extraction algorithm of Horne (1986) was applied.

3. The IUE spectrum

The merged SWP and LWP spectra in Fig. 3 present a clear indication of large extinction by showing a well-developed 2200 Å bump. By using the colour excess, $E(B - V) = 0.29$, obtained...
CHAPTER B5: The new Be-type star HD 147196 in the ρ Oph dark cloud region

from visual magnitudes we were able to deredden the spectra as is shown in Fig. 4. We note that the LWP image is slightly saturated around 2800 Å. The important features of the spectra in Fig. 4 are: the strong Lyα (1215 Å) absorption typical of late B stars, the deep Si ii absorption at 1265 Å, the blend of Si iii and Si ii at 1300 Å, the C ii at 1336 Å, which happens to be of maximum strength for B8 stars, and the almost unnoticed blend of 1394 and 1403 Å of Si iv. It should be mentioned here that there is no contribution of O i at 1302 Å, frequently detectable in symbiotic and interacting binaries, at the blend near 1300 Å. We have drawn this conclusion from the fact that a companion line (O i at 1641 Å) is clearly not present in the UV spectrum. There is a weak emission superimposed on the deep Lyα absorption which appears to be geocoronal. The C iv absorption is not present indicating that this star is a late B star. Comparing the spectrum of Fig. 4 with that of B stars from the IUE Low-Dispersion Spectra Reference Atlas, Part 1 by Heck et al. (1984), we find that HD 147196 is almost identical to the reddened B8 V stars HD 23324, HD 183914 and HD 201908. The photospheric Lyα absorption for these four stars appears to be nearly equal, indicating the similitude of the photospheres and rotational velocities of these stars. According to Heck et al. (1984), the feature at 1400 Å, which is a blend of the Si iv lines at 1394 and 1403 Å, is at maximum in B1 stars but disappears around B8. The absence of this feature in the spectrum of HD 147196 confirms its late spectral type within the B class. The relative depths of the absorption lines at 1216 Å (Si ii), 1304 Å (Si iii + Si ii) and 1334 Å (C ii) in HD 147196, when compared with the other B8 V stars, are virtually the same revealing a similar spectral type. Furthermore, fitting the UV continuum to different Kurucz models and varying the abundances, we obtained the best fit throughout the region 1200-3000 Å for the model which is adopted. Therefore, we conclude that the UV spectral type of HD 147196 appears normal in these wavelengths and agrees with its optical spectral type derived by many observers. Although the unreddened fluxes of HD 147196 and the three comparison stars around 1200 to 1400 Å, where most of the lines occur, are nearly identical, we found one exception: the extra absorption in HD 147196 at 1277 - 1281 Å, which according to Wu et al. (1992) is due to C; it is a line often present in T Tauri and late type stars. Note that all the three comparison stars, HD 23324, HD 183914 and HD 201908 have large \( v \sin i \) (\( \sim 250 \text{ km s}^{-1} \)).

The high-dispersion LWP image (Fig. 5) presents the Mg ii doublet in absorption, characteristic of interstellar Mg ii and typically in the spectrum of main sequence B stars. We point out that the Mg ii interstellar lines are deep, indicating that despite of being a somewhat nearby star (\( \sim 180 \text{ pc} \); see Section 5), it appears projected towards a medium density cloud. The Mg ii lines at 2797.7 and 2797.9 Å (UV multiplet 3) characteristics of high density or shell spectrum are not present, indicating only a moderate environment in terms of cloud density in the line of sight (Fig. 5).

4. The visual spectrum

Several descriptions of blue spectra of HD 147196, containing H\( \beta \) and H\( \gamma \) absorption lines, can be found in the literature, e.g. Garrison (1967) and Buscombe (1969). Besides the very broad hydrogen lines, no peculiar properties were noted. This is confirmed by our blue low resolution spectrum (not shown), in which the hydrogen absorption lines up to H13 do not show any peculiarities.

As mentioned before, Irvine (1990) found for the first time a strong (EW \( \sim 15 \) Å) single peak Hα-emission line in his spectrum. Our red spectrum given in Fig. 2 confirms Irvine's discovery and shows, furthermore, that this line is double-peaked. It is also clear that this Hα-emission is located at the centre of the broad photospheric component. The central absorption of the Hα-emission profile lies at \( \lambda = 6562.4 \) Å, while the left and right emission peaks are located at \( \lambda = 6561.1 \) and \( \lambda = 6565.1 \) Å, respectively. This 4.0 Å peak separation is certainly too small to have been detected by Irvine's low resolution spectral survey (2.6 Å per diode). Therefore, it will remain unknown whether the appearance of the central absorption, superimposed on the broad Hα emission, is recent.

In the blue spectrum (Fig. 1) besides the central reversal of the H\( \beta \) line, the blended absorption lines of He i 48 + 49 around \( \lambda \sim 4921 \) Å and the absorption line of He i 14 at \( \lambda = 5015.7 \) Å are visible. In the red spectrum Fig. 2 the absorption line of N ii 46 at \( \lambda = 6340.7 \) Å and the blended absorption lines of N i and N ii at \( \lambda \sim 6482 \) Å are identified. Furthermore, the diffuse absorption band at 6275.5 Å is well visible.
5. The spectral energy distribution

The spectral type of HD 147196 has been classified by many observers to be B8 V, which we will also adopt. The following astrophysical quantities (Schmidt-Kaler 1982; Allen 1985) can then be derived: $M_V = -0^{m}23.0^{m}24$, $E(B - V) = 0^{m}29^{m}02$, $T_{eff} = 12,000 \pm 1,000$ K and $log g$ (cm s$^{-2}$) = 4.1, if we assume the spectral classification was made with an accuracy of one subclass. The calculated distance of HD 147196 is then about 180 ± 40 pc.

![Fig. 6. The observed and extinction-free spectral energy distribution.](image)

The extinction-free spectral energy distribution (SED) of HD 147196 was analysed by comparing it to the Kurucz (1979) theoretical SED-model corresponding to $T_{eff}$ of 12,000 K. For this purpose we used the method described by Steenman and Thé (1989), however, we chose the new extinction table in Steenman and Thé (1991). In this analysis the ratio of total to selective extinction $R_V = A_v / E(B - V)$ was found to be 3.1 - 3.2. (This agrees quite well with the value of $R_V = 3.3 \pm 0.3$ found by Whittet, 1974, using the colour difference method for stars in the Upper Scorpius association, which are not embedded in any nebulosity). The abundance of the elements was taken to be solar. Fig. 6 shows the observed and the extinction free SED for HD 147196. The latter agrees reasonably well with the adopted theoretical model of Kurucz (1991) from about $\lambda = 3000$ Å to 4.6 μm. Obviously no marked infrared excess is visible. In the ultraviolet there is excess radiation probably caused by bound-free emission, or a slight overcorrection of the extinction.

![Fig. 7. Comparison of UV fluxes from the Kurucz (1991) model and from the IUE data.](image)

The interstellar nature of the UV Mg II lines is confirmed by observations of Mg II of several stars in this region, such as $\alpha$ Oph and 70 Oph, analyzed by Genova et al. (1990). They found a value of $log N$(Mg II) cm$^{-2}$ of about 13.0 for the direction towards these stars. Furthermore, it must be mentioned here that even though HD 147196 is identified to be of spectral type B8V, the photospheric absorption lines of the Mg II resonance doublet are not present. This phenomena is not exceptional for young stars, as explained by Graham (1992). Photospheric absorption lines are not seen when the disks surrounding the stars are optically thick. A correlation of this effect with the orientation of the disks in the line of sight must also not be excluded. An example of this kind of object is R CrA (Graham, 1992). However, one must notice that in the case of HD 147196 the Hα and Hβ photospheric components are clearly visible. Thus at wavelengths around Mg II (2800 Å) the shell must be optically thick. This is perhaps the explanation that no IR-excess and Mg II-emission are seen. The disk surrounding HD 147196 is too small to account for these effects; it can just produce Hα and only a weak Hβ-emission.

As mentioned above, HD 147196 does not have any significant IR-excess. Perhaps only a slight beginning of excess radiation by free-free emission at 4.8 μm is visible. This property is typical for a late Be-type star (Coté and Waters 1987).

6. Discussion and conclusions

One of the primary questions to be answered is whether the surveys of Hα objects made in the past by Haro (1949) and Hidajat (1961) had missed, by some observational effect(s), to detect the Hα-emission line of HD 147196. The red objective-prism plates Haro had used for the survey, obtained with the Tonantzintla Schmidt telescope, have exposure times from 30 min to 2 hours. Since the spectra were usually not widened we believe that if HD 147196 had an Hα emission line at that time this line would not have been detected because its image will be overexposed. The 4 red plates used by Hidajat, obtained with the Lembang Schmidt telescope, were exposed for 30 min and 1 hour (both unwidened) and for 12 min and 75 sec (both widened). The two latter plates were ment especially for the inspection of the relatively bright objects, like HD 147196. Since this star lies in Hidajat's survey region of 25 square degree, and since the Hα emission-line is quite strong, this emission-line would certainly have been detected, if it was present at the time of observation. We therefore suspect that HD 147196 in recent years has transformed from a B-type star at shell phase to a Be-phase. Such transitions are well-known in classical Be stars; like Pleione (HD 23862, Doazan et al. 1988), which had undergone a similar transition in a timescale of tenths of years, or 59 Cyg (HD 200120, Doazan et al. 1985), in even a shorter time. Recently Walter (1992) reported another similar object, HD 17520, however of earlier spectral type (O9 V), which is in a new Be-phase. It is pointed out by Walter that in early type stars the Be-phase is unstable and the cycle of variation is short.
According to these authors usually late Be-type stars show excess radiation from free-free emission well above the SED only at about 10 μm.

It is of interest to report that examination of all available references from 1961 to 1980 of the Johnson V magnitude of HD 147196 shows that it varies only slightly from V = 7.9 at 7.7. Considering their accuracies, our recently observed V magnitude and that of the IUE FES agree well with this range in magnitude variation. Our conclusion is that with an average V magnitude of 7.04 HD 147196 varies only about a few hundreds of a magnitude which often is about the same as the accuracy of the data obtained.

Under the assumptions that the V magnitude is 7.02 and the Kurucz model with \( T_{eff} = 12,000 \text{ K}, \log g = 4.0 \) and solar abundance, describes the correct SED of this star, we have scaled the Kurucz (1991) model and verified the dereddened UV fluxes from the IUE data. This is indicated in Fig. 7. The V 7.02 mag yields a \( F_V = 6.095 \times 10^{-12} \text{ erg cm}^{-2} \text{ sec}^{-1} \text{ Å}^{-1} \), a flux value which determines the absolute flux scale. We have plotted the dereddened fluxes with \( E(B - V) = 0.29 \) and the Kurucz model with a thick line in Fig. 7. The stellar atmosphere model produces a reasonable well fit to the data, within the errors involved, confirming that \( E(B - V) = 0.29 \) is probably an accurate parameter.

The paper by Brand and Wouterloot (1988) gives some parameters derived from the Walraven photometry and discusses the membership of this star in the Upper-Scorpius subgroup. Their \( T_{eff} \) of 11,940 K is almost identical to the one we have used in the study of the SED of HD 147196 (12,000 ± 1,000 K), similarly their \( \log g = 3.95 \) as opposed to 4.1, and their spectral type is B7.5 IV with a 1/2 spectral class and 1/2 luminosity class uncertainty. For HD 147196 Brand and Wouterloot (1988) found a distance modulus of 6.53, corresponding to a distance of 202 pc, in agreement with our distance estimate of 180 pc within the observational errors. Furthermore, from 54 certain and probable member stars toward the Upper-Scorpius region they have derived an average distance modulus of 5.9 ± 0.09, corresponding to a distance of 153 ± 6 pc, and mentioned that, because of their calibration, this value is underestimated. It is important to point out that other researchers have found slightly larger distances, which in any instance may well prove the membership of HD 147196 with the star-forming region in the Upper-Scorpius complex. Consequently, we support the assumption of Irvine that the star belongs to the Scorpius OB association.

Finally, we want to comment on the possible pre-main-sequence nature of HD 147196, such as mentioned in the introduction. Even though its location in an active star-forming region (the \( \rho \) Oph dark clouds) suggests that this star is very young, the observational facts do not indicate that it is a pre-main sequence (PMS) object. Firstly, the presence of the interstellar Mg II absorption lines indicates that it is not a PMS star, as it was found by Pérez, Imhoff and Thé (1992) that PMS objects should have unique type III P Cygni profiles of the Mg II h and k emission lines, which are generally accompanied by similar profiles of the Ha emission line. Secondly, the lack of near- and far-IR excesses due to dust re-emission, and of brightness variations, are indications that HD 147196 is not a PMS object. Although, in this respect it must be noted that PMS stars of spectral type B8 and earlier usually have small variations in brightness only (Bibo and Thé 1991).

From the above discussions, it is not excluded that HD 147196 is a young main sequence object which has just arrived to the ZAMS. In this context its transition from a B-type to a Be-type star is a new and very interesting phenomenon. Therefore, HD 147196 deserves further attention.

References


