# The Visual and Infrared Spectrum 1968—71 of MH$\alpha$ 328-116 = V 1016 CYG — Note III —

F. CIATTI, A. MAMMANO, L. ROSINO (Asiago)

## *I. Introduction*

The peculiar object MH$\alpha$ 328-116 was included in the spectroscopic programme of Asiago since 1965. Its spectral evolution during 1965—66 and 1966—67 has been described in two previous communications (hereafter referred to as Paper I and Paper II) by MAMMANO and ROSINO (1966, 1968).

The present paper is concerned with the spectroscopic observations made at Asiago after 1967, mostly with the Carnegie image intensifiers S20 (blue-red) and S1 (infrared). Direct photographs of the variable were also taken, from time to time, with the purpose of correlating the spectroscopic observations to a homogeneous light curve. The B and V magnitudes of the comparison stars were derived by transfer from stars of a field close to the variable, whose B magnitudes and spectra were given by NASSAU and McRAE (1949) The magnitudes of V 1016 Cyg, obtained by visual estimates on the photographs, are reported in Table I. They are not of high precision ($\pm$ 0$^m$1) and there may be some shift in the zero point of the B and V systems. However, the light curve represented in Fig. 1, with the pre-discovery magnitudes given by HOFFLEIT (1966), shows well the photometric evolution of the star. After the relatively rapid increase in brightness which took place in 1964, the variable reached 11.8 pg, rising slowly to 10.8—10.7 at the beginning of 1968. Since then the star has maintained a nearly constant brightness. The B-V color index has shown very little changes: at first it was slightly positive, then nearly zero or slightly negative. It may be observed, in this connection, that the major contribution to the brightness is given by the strong emission lines rather than by the relatively faint continuum, so that a conventional photometry in the UBV system has little meaning, the magnitude representing chiefly the integrated flux of the emission lines in the spectral range covered by the detector, and their variations. This easily explains how the color indices determined by different observers are not always in good agreement.

Finally, it may be interesting to note that the light curve of V 1016 Cyg strongly resembles that of RR Telescopii, before the gradual fading of the nova after 1948.

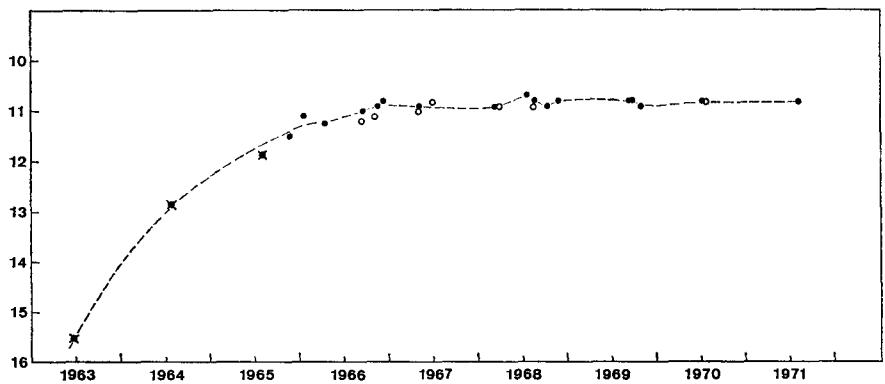


Fig. 1: Light curve of V 1016 Cygni. Dots and open circles indicate B and V magnitudes. Crosses are observations by D. HOFFLEIT.



https://doi.org/10.1017/S0252921100032711 Published online by Cambridge University Press

Table I: B and V magnitudes of V 1016 Cygni.

| Date | B | V | Date | B | V |
|---|---|---|---|---|---|
| Jul 26, 1965 | 11.9 | 11.6 | March 28, 1968 | 10.9 | 10.9 |
| Aug 6, „ | 11.9 | — | Jul 22, „ | 10.7 | — |
| „ 27, „ | — | 11.6 | Aug 19, „ | — | 10.9 |
| Sep 4, „ | 11.9 | — | „ 24, „ | 10.8 | — |
| Nov 24, „ | 11.5 | — | Sep 24, „ | 10.9 | — |
| Nov 27, „ | — | 11.2 | Oct 17, „ | 10.9 | — |
| Jan 20, 1966 | 11.1 | — | Nov 22, „ | 10.8 | — |
| Apr 17, „ | 11.25 | — | Sep 7, 1969 | 10.8 | — |
| Sep 22, „ | 11.0 | 11.2 | „ 13, „ | 10.8 | 11.3: |
| Oct 20, „ | 10.9 | — | Oct 29, „ | 10.9 | — |
| Nov 8, „ | 10.8 | — | Jul 4, 1970 | 10.8 | 10.8 |
| May 4, 1967 | 10.9 | 11.0 | Aug 13, 1971 | 10.8 | — |
| Jul 1, „ | — | 10.8 | | | |

*II. Evolution of the Blue-Red Spectrum*

The spectrum 1965—66 of V 1016 Cyg was characterized by the presence of forbidden nebular lines of OI, OII, OIII, NeIII, NII, SII, AIII besides H, HeI, HeII ($\lambda$ 4686), CII, CIII, NIII, OII. Many permitted and forbidden lines of FeII were also present (see Paper I, Table II). On 1966—67, while the star was still increasing in brightness, a steady evolution towards higher stages of excitation was observed, with the emergence of emission lines of highly ionized atoms (NeIV, AIV, AV, FeV, FeVI) and the strengthening of HeI, HeII and the nebular lines. Some unidentified lines were later found to belong to forbidden FeIV (BLOCH and SWINGS, 1969). At the same time the FeII permitted lines faded out and disappeared, while the FeII forbidden lines maintained their strength (Paper II, Table II).

The spectroscopic material secured with the 122 cm telescope from 1968 up to now is listed in Table II. The successive columns give: number of the spectrum; date; spectrograph; exposure time; detector. Additional data are given in the Notes.

Table II: Spectroscopic material 1968-71

| Spectrum No. | Date | Camera | Exp. | Detector | Notes |
|---|---|---|---|---|---|
| 8407 | 1968 Mar 23 | A-VI | 30m | S20 (IIa-0) | 1 |
| 8604-5-6 | Jun 22 | A-VI | 84,30,10 | S20 (IIa-0) | |
| 1247 | Jul 23 | C-800 | 90 | 103a-F | 2 |
| 8767-68 | Oct 17 | A-VI | 120,30 | S20 (103a-0) | |
| 9158 | 1969 Jan 31 | A-VII | 62 | S1 (103a-0) | 3 |
| 9330-31 | May 20 | A-VI | 120,10 | S20 (103a-0) | |
| 9393 | Jul 3 | A-VII | 100 | S1 (103a-0) | |
| 1295 | Jul 16 | C-400 | 30 | S20 (IIa-0) | 4 |
| 1305-06 | Aug 19 | C-400 | 65,2 | S20 (103a-0) | |
| 9565 | Oct 6 | A-VI | 140 | S20 (103a-0) | |
| A61 | 1970 May 22 | A-IX | 260 | S1 (103a-0) | 5 |
| A94-95 | Jul 1 | A-VI | 150,18 | S20 (103a-0) | |
| A107 | Jul 19 | A-V | 120 | 103a-F | 6 |
| A140 | Aug 19 | A-III | 300 | 103a-0 | 7 |
| A214 | Oct 13 | A-III | 300 | 103a-F | |
| A247 | Oct 26 | A-VII | 210 | S1 (103a-0) | |
| A294 | Nov 22 | A-VI | 120 | S20 (103a-0) | |
| A553 | 1971 Mar 7 | A-VI | 120 | S20 (103a-0) | |
| A570-71 | Mar 29 | A-VI | 15,5 | S20 (IIa-0) | |
| A573 | Apr 5 | A-VII | 200 | S1 (103a-0) | |
| A663 | Jul 25 | A-VI | 86 | S20 (103a-0) | |
| A680 | Aug 3 | A-VII | 240 | S1 (103a-0) | |

*Notes to Table II:*

1. One-prism Cassegrain spectrograph, Camera VI, dispersion 60 A/mm at Hγ, with Carnegie image-tube S-20.
2. Grating nebular spectrograph, Newtonian focus. Dispersion 200-100 A/mm.
3. One-prism Cassegrain spectrograph, Camera VII, with Carnegie image-tube S-1 for the infrared (6500—11 000 A). Dispersion 500 A/mm at 9000 A.
4. Grating nebular spectrograph with S-20. Dispersion 150-75 A/mm.
5. Cassegrain infrared spectrograph camera IX, dispersion 470 A/mm at 9000 A. With Carnegie image-tube S1.
6. One-prism Cassegrain spectrograph: dispersion 180 A/mm at Hγ.
7. Two-prisms Cassegrain spectrograph; dispersion 40 A/mm at Hγ.

The analysis of the blue-red spectra still indicates that the excitation has been slowly increasing. A comparison with the spectra taken in 1966—67 gives the following results:

*H*: No significant changes in the Balmer lines. A continuum appears on the ultraviolet spectrum well beyond the series limit.

*HeI*: A slight weakening of the emission lines, compared to hydrogen lines, has been noticed. The strongest emissions are λ 7065, λ 5876, λ 6678, λ 4471. The element is represented by the same lines as in 1967. In addition, HeI λλ 3634, 3554 have been recorded in the ultraviolet.

*HeII*: λ 4686, which was prominent in 1967, has been still increasing in strength. On 1971 it appears as strong as Hγ. Other emission lines stronger than in 1967 are: λλ 4199, 4542, 5411. New lines are weakly recorded at λλ 6233, 6406.

*CII, CIII, CIV*: No significant variations. The CII line λ 3946 is no more visible on 1971 spectra.

*NII, NIII*: The forbidden [NII] lines λλ 5755, 6548, 6583 have maintained the intensity reached on 1967. [NII] 5755 is still prominent.

The permitted NIII lines have faded considerably: λλ 4004, 4330, 4379, 4511 disappeared or are barely recorded. λλ 4640, 4634 appear sharper than in 1967, being still fairly strong.

*OI, OII, OIII*: Most of the permitted lines have disappeared. OIII 3444, 3428, 3340, 3312, the first fairly strong, are recorded in the ultraviolet spectra.

[OI] is still represented by the pair λλ 6300, 6363 and by the auroral line λ 5577, with about the same strength as in 1967.

[OII] is represented in the ultraviolet by the pair 3726-29, very weak.

The [OIII] lines λλ 5007, 4959. 4363 are outstanding. As in 1967, 5007 is the strongest emission line in the blue-red spectrum, following Hα.

*[NeIII]*: λλ 3869, 3968 maintained their strength, being comparable in intensity with Hβ. [NeIII] λ 3342 is recorded in the ultraviolet.

*[Ne IV]*: λ 4714 and 4724 (mult. 1F) showed a conspicuous strengthening, from 1967 to 1971.

*[NeV]*: λλ 3345, 3425 have been increasing since 1967.

*Mg I*: The line λ 4571 previously attributed to MgI is still present. Considering the high stage of ionization reached by this object, the identification should be considered very doubtful.

*SiII*: λλ 3856-3862 have not been recorded. The element, however, is represented by the lines 5041-5056 (mult. 5) which were not observed on 1967 spectra.

*[SII], [SIII]*: [SII] is still represented by the lines 4068-4076, slightly weakened. The 2F pair 6716-30 is also faintly recorded. Its presence gives further support to the identification of the [OII] nebular pair 3726-29, the physical conditions for the appearance of [SII] 6716-30 and [OII] 3726-29 being closely similar.

[SIII] appears with the lines $\lambda$ 3721 and $\lambda$ 3797, blended with $H_{14}$ and $H_{10}$, and with $\lambda$ 6310 (2F). Its intensity has shown a steady increase since 1967.

*[AIII], [AIV], [AV]*: No apparent variations for the forbidden lines 5191 of [AIII] and 4740 of [AIV], while [AV] 6435 and $\lambda$ 7006 (mult. 1F) have been steadily increasing in intensity since 1967.

*[CaV], [CaVI], [CaVII]*: The forbidden lines of CaV have been strengthening since 1967, becoming prominent in 1971, as shown in Table III. The [CaVI] 2F lines 5587, 5460, 5631 have made their appearance. The presence of [CaVII] 5615, weakly recorded, is doubtful.

Table III: Forbidden CaV-CaVII lines, 1967—1971

| Ion | Mut. | $\lambda$ | 1967 | 1971 | Notes |
|---|---|---|---|---|---|
| [CaV] | 1F | 5309.1 | 1 | 4—5 | |
| | | 6086.9 | 0 | 8 | 1 |
| [CaVI] | 1F | 3646.3 | — | 0—1 | Doubtful |
| | | 3702.7 | — | 0—1 | Doubtful |
| | 2F | 5460.0 | — | 0—1 | |
| | | 5587.2 | — | 1 | |
| | | 5631.0 | — | 2 | 2 |
| [CaVII] | 1F | 5615.8 | — | 0 | 3 |

*Notes to Table III:*

The intensities are visually estimated in the same scale as in Paper II.

1. Blended with [FeVII]
2. Blended with [FeVI].
3. Barely visible. Its presence, however, seems to be certain.

*[FeII-FeVII]*: One of the chief characteristics of the evolution of V 1016 Cyg has been the gradual increase of its degree of excitation. From 1965 to 1967 the permitted FeII lines, which at the beginning (Paper I) were very numerous, faded out and disappeared (Paper II). The further evolution from 1968 to 1971 has shown the progressive weakening and disappearance of most of the forbidden [FeII] lines. The weakening of the low I.P. lines was accompanied by a moderate strengthening of FeIII, FeIV and FeV forbidden lines and by the very strong increase in the intensity of [FeVI] lines, some of which became conspicuous. At the end of 1968 [FeVII] made its first appearance. On the last spectra (1971) the lines $\lambda\lambda$ 5721, 6085 (mult. 1F); 5159, 5277 (mult. 2F) were represented, while the presence of $\lambda$ 3759 (mult. 3F) is suspected.

The following Table IV represents the evolution of the Fe spectrum in MH$\alpha$ 328-116 from 1967 to 1971. As noticed in the footnotes to Table III, the intensities are visually estimated with the same criterion as in Paper II.



https://doi.org/10.1017/S0252921100032711 Published online by Cambridge University Press

Table IV: Forbidden FeII-FeVII lines on the spectra 1967—1971 of MHα 328-116

| Ion | Mult. | λ | Int. 1967 | Int. 1971 | Notes |
|---|---|---|---|---|---|
| [FeII] | 3F | 4889.7 | 1 | — | 1 |
| | | 5036.6 | 1 | — | |
| | | 5086.5 | 1 | 0? | 2 |
| | 4F | 4889.6 | 0 | — | |
| | 5F | 4604.5 | 1—2 | — | |
| | 6F | 4414.5 / 4416.2 | 4—5 | 2—3 | |
| | | 4432.5 | 0 | — | |
| | | 4457.6 | 2—3 | 0 | |
| | | 4488.8 | 1—2 | — | |
| | | 4492.6 | 0—1 | 0? | 2 |
| | | 4533.0 | 0—1 | — | |
| | 7F | 4287.4 | 5 | 2 | |
| | | 4452.1 | 2 | 0 | |
| | 17F | 5495.8 | 0—1 | — | |
| | | 5527.3 | 2—3 | 1 | |
| | 18F | 5433.2 | 0—1 | — | |
| | 19F | 5072.4 | 0—1 | — | |
| | | 5111.6 | 1 | 0? | 2 |
| | | 5158.8 | 3 | ? | 3 |
| | | 5220.1 | 1 | 0 | |
| | | 5261.6 | 2 | 1—2 | |
| | | 5333.7 | 2 | — | |
| | | 5376.5 | 2 | 1 | |
| | 20F | 5814.6 | 2—3 | 0—1 | |
| | | 5874.5 | 0 | — | |
| | | 4903.3 | 3—4 | — | |
| | | 5043.5 | 2 | — | |
| | 21F | 4177.7 | 1—2 | — | |
| | | 4231.6 | 1—2 | — | |
| | | 4244.0 | 5—6 | 1—2 | |
| | | 4276.8 | 5 | 2 | |
| | | 4305.9 | 2 | 0? | |
| | | 4319.6 | 3 | 0 | |
| | | 4352.8 | 2—3 | 0 | |
| | | 4372.4 | 1—2 | 0? | |
| | 39F | 5588.2 | 0 | — | |
| | | 5543.4 | 0 | — | |
| [FeIII] | 1F | 5060.3 | 2 | 1—2 | |
| | | 5270.9 | 3—4 | 4 | |
| | 3F | 4607.0 | 1 | 1 | |
| | | 4658.1 | 4—5 | 4—5 | |
| | | 4701.5 | 2—3 | 3—4 | |
| | | 4754.7 | 1—2 | 1—2 | |
| | | 4769.4 | 1 | — | |
| | | 4777.7 | 0—1 | 1 | |
| | 4F | 4046.4 | — | 1 | |
| [FeIV] | | 4152.4 | 2—3 | 1 | |
| | | 4206.5 | 3 | 1—2 | |
| | | 4903.5 | 3—4 | 3—4 | |



https://doi.org/10.1017/S0252921100032711 Published online by Cambridge University Press

| Ion | Mult. | λ | Int. 1967 | Int. 1971 | Notes |
|---|---|---|---|---|---|
| | | 5032.5 | 0 | 0 | |
| | | 5210.9 | 0 | 0—1 | |
| | | 6791.9 | 1 | 1—2 | |
| [FeV] | 1F | 3895.7 | 1 | 1—2 | blended |
| | | 4071.5 | 1? | 1? | blended |
| | | 4180.9 | 4—5 | 4—5 | |
| | 3F | 3735.2 | 1—2 | 1—2 | |
| | | 3782.9 | 0—1 | 1 | |
| | | 3820.2 | 1 | 1—2 | |
| | | 3891.8 | 6—7 | 10? | 4 |
| | 4F | 3445—63 | — | 4—5 | 5 |
| [FeVI] | 1F | 5236.6 | 2 | 4—5 | |
| | | 5279.2 | — | 1—2 | |
| | | 5335.5 | 2 | 3 | |
| | | 5423.9<br>5426.6 | — | 1—2 | |
| | | 5630.9 | — | 2 | 6 |
| | | 5677.0 | 0—1 | 4 | |
| | 2F | 4967—72 | 1 | 3—4 | |
| | | 5145.8 | 2 | 5 | |
| | | 5176.4 | 3—4 | 8—10 | |
| | | 5370.5 | — | 1 | |
| | 3F | 3815.1 | — | 0? | 7 |
| [FeVII] | 1F | 5721.1 | — | 4 | |
| | | 6085.5 | 0 | 8 | 8 |
| | 2F | 4699.0 | 2—3 | 3—4 | 9 |
| | | 4893 | — | 0—1 | |
| | | 4942.3 | — | 1 | |
| | | 5159.0 | — | 2 | |
| | | 5277.7 | — | 0—1 | |
| | 3F | 3759.9 | 3 | 3—4 | 10 |

*Notes to Table IV:*

1. A dash indicates that the line is no more visible in 1971.
2. The presence of the line is doubtful.
3. Blended with 5159 [FeVII], which mostly contributes to the intensity.
4. Partly blended with $H_\varepsilon$. The estimated intensity is doubtful.
5. In Paper II this line was attributed to OIII. The identification is uncertain.
6. Blended with [CaVI] 5631, which partly contributes to the estimated intensity.
7. Doubtful identification.
8. [CaV] 6082.9 is also a contributor of the blend.
9. In 1967 (see Paper II) the main contributor was probably [FeIII] 4701.5, which may still be present, blended with the [FeVII] line.
10. The line was attributed, in 1967, to OIII. The emergence of [FeVII] is proved by the increased strength of the blend.

In conclusion, the blue-red spectra obtained during the last four years show that the gradual increase in the stage of ionization, which was pointed out in our Paper II, is still going on, although the brightness of the star is now almost constant. This fact is well exemplified by the fading of FeII permitted and forbidden lines and by the great strengthening of high ionization potential lines, like FeVI (I.P. 79ev) and CaV (I.P. 67ev), together with the emergence of lines of still higher potential, as FeVII (I.P. 103 ev), CaVI (I.P. 84 ev) CaVII



https://doi.org/10.1017/S0252921100032711 Published online by Cambridge University Press

(I.P. 109 ev). With the dispersions employed, the lines appear generally sharp, without structure, being different, from this point of view, from the lines of novae, which have very complex profiles, and similar to those of planetary nebulae.

Spectra of this object, of 1967 and 1971, together with the spectrum of the planetary nebula NGC 7027 for comparison, are reproduced in Fig. 2.

### *III. The Infrared Spectrum*

In the previous papers some indications have been given on the near infrared spectrum of $MH_\alpha$ 328-116. On 1969, through the courtesy of the Carnegie Institution, we had the possibility of using an S1 image-tube, refrigerated with dry-ice, having spectral sensitivity from $H_\alpha$ to about 11 000 A. It is a pleasure to thank here Dr. K. FORD of the Carnegie Institution of Washington, and Dr. BERTOLA and Dr. STAGNI who took care of the mounting of the intensifier and made the laboratory and sky tests.

The infrared spectra secured from 1969 to 1971 with the S1 intensifier are listed in Table II. Table V presents a list of the lines observed in these spectra. The successive columns give: identification; laboratory wave-length; mean relative intensity $(I_l - I_c)/I_c$ corrected for the spectral sensitivity (determined by CIATTI and MAMMANO); visually estimated intensities (ROSINO, Spectrum A 680, 1971) on an arbitrary scale ($\lambda$ 7065 = 20; trace = 0; notes. Remarks and comments are reported in the foot-notes.

Reproductions of infrared spectra and microphotometer tracings are given in Figs. 3 and 4.

Table V and the notes indicate that also in the infrared, as well as in the blue-red spectra, the chief characteristic of the evolution of $MH_\alpha$ 328-116 has been the gradual increase of ionization. The spectrum of this exceptional object, even more than in the past years, matches closely with that of a high excitation planetary nebula.

An interesting feature, which is not present in planetary or diffuse nebulae, has been noticed in some of the best infrared spectra of this object: the presence of a wide absorption band at 10460 A which may be tentatively attributed to VO; it is well known that VO bands have been observed in advanced M type stars. In this connection, it may be worthy to recall *that, several years before the outburst, $MH_\alpha$ 328-116 was found to be variable by NASSAU and CAMERON (1954) who examined late M-type stars with strong VO bands on objective prism plates, in the near infrared. Many of these stars, as well as $MH_\alpha$ 328-116, showed a variable brightness.*

If the presence of a late type spectrum in the infrared should be confirmed by further observations, this would contribute to classify $MH_\alpha$ 328-116 as an exceptional symbiotic star, rather than a slow nova or a planetary nebula in its first stages of formation.

References:

BLOCH, M., SWINGS, J. P., **1969**, Ap. Letters **3**, 141.
HOFFLEIT, D., and al., **1966**, Ap. J. **144**, 1139.
MAMMANO, A., ROSINO, L., **1966**, Mem. SAIt. **37**, 3 = Asiago Contr. No. 185.
MAMMANO, A., ROSINO, L., **1968**, Mem. SAIt. **39**, 471 = Asiago Contr. No. 209.
NASSAU, J., CAMERON, D., **1954**, Ap. J. **119**, 175.
NASSAU, J., McRAE, D. **1949**, Ap. J. **110**, 478.

### *Discussion to the paper of CIATTI, MAMMANO and ROSINO*

BAKOS: On two plates the continuum has maximum at two different wavelengths, at $\lambda$ 10 000 and $\lambda$ 8 000 A. Is this a real effect?

CIATTI: It is difficult to deduce the distribution of the continuum in this region, because of low sensitivity of the S-1 intensifier.

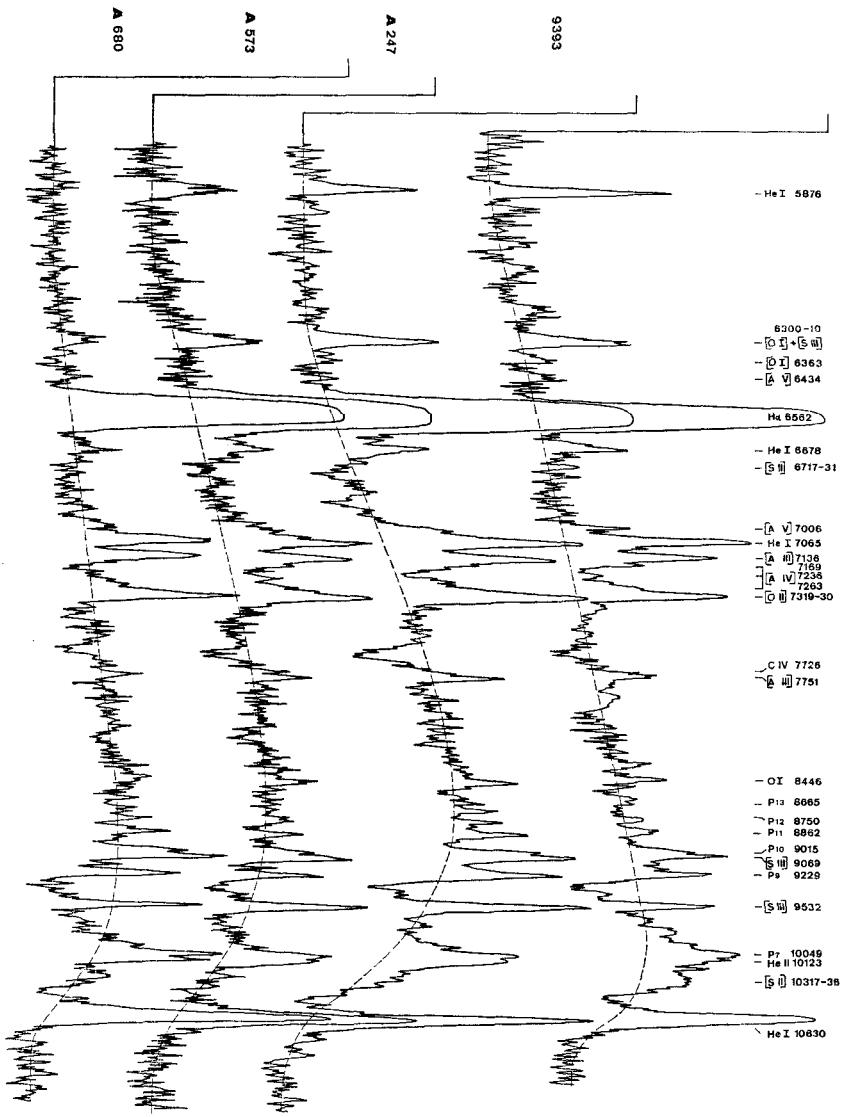


Fig. 4: Microphotometer tracings of infrared spectra of V 1016 Cygni (1969—1971). Ordinates are transparencies.



https://doi.org/10.1017/S0252921100032711 Published online by Cambridge University Press

Table V: The infra-red spectrum of $MH_\alpha$ 328-116 = V 1016 Cygni

| Ion | $\lambda$ | Mult. | $\frac{I_l - I_c}{I_c}$ | $I_{1971}$ | Notes |
|---|---|---|---|---|---|
| $H_\alpha$ | 6563 | 1 | (180) | — | Overexposed |
| HeI | 6678 | 46 | 9 | 3—4 | Slowly fading |
| HeII | 6683 | 7 | — | — | 1 |
| [SII] | 6717—31 | 2F | — | 1—2 | |
| [AV] | 7006 | 1F | 5 | 2 | 2 |
| HeI | 7065 | 10 | 20 | 20 | |
| [AIII] | 7136 | 1F | 14 | 15 | 3 |
| [AIV] | 7169 | 2F | — | 2—3 | |
| [AIV] | 7236 | 2F | — | 1 | |
| [AIV] | 7263 | 2F | — | 1 | |
| HeI | 7281 | 45 | — | 1 | |
| [OII] | 7319—30 | 2F | 16 | 25 | 4 |
| HeII? | 7592 | 6 | — | 0 | Barely visible; doubtful |
| CIV? | 7726 | — | — | 1 | 5 |
| [AIII] | 7751 | 1F | 3 | 5 | |
| [Cl IV] | 8046 | 1F | — | 0 | Uncertain identification |
| HeII | 8237 | 6 | — | 0—1 | Uncertain identification |
| — | 8350 | — | — | 1 | 6 |
| OI | 8446 | 4 | 2—1 | 1 | 7 |
| HI ($P_{14}$) | 8598 | 9 | — | 0—1 | |
| HI ($P_{13}$) | 8665 | 9 | — | 1 | |
| HI ($P_{12}$) | 8750 | 9 | 1 | 1—2 | |
| HI ($P_{11}$) | 8862 | 9 | 2 | 2—3 | |
| HI ($P_{10}$) | 9015 | 9 | 3 | 3 | |
| [SIII] | 9069 | 1F | 5 | 10 | 8 |
| — | 9160 ? | — | — | 0 | Not identified |
| HI ($P_9$) | 9229 | 8 | 4 | 5—6 | |
| [SIII] | 9532 | 1F | (22) | 12 | 9 |
| HI ($P_8$) | 9546 | 8 | | | |
| — | 9705 ? | — | — | 0 | Not identified |
| HI ($P_7$) | 10049 | 8 | 5 | 10 | |
| HeII | 10123 | 2 | 6 | 10—12 | 10 |
| [SII] | 10317—36 | 3F | 2 | — | 11 |
| HeI | 10830 | 1 | (140) | — | 12 |

*Notes to Table V:*

1. Blended with HeI 6678. In some spectra, however, the complex structure of the blend can be perceived.
2. This line has become much stronger than in 1967.
3. The line strength has been steadily increasing since 1967. On 1971 the line is prominent in the near infrared.
4. This pair of forbidden lines, well known in nebular spectra, has been steadily increasing from 1969 to 1971.
5. The identification is doubtful. In Paper II the line was identified with [SiI] $\lambda$ 7726 which also occurs in planetary nebulae.
6. Possible contributors may be HeI 8362 or CIII 8322-8359.

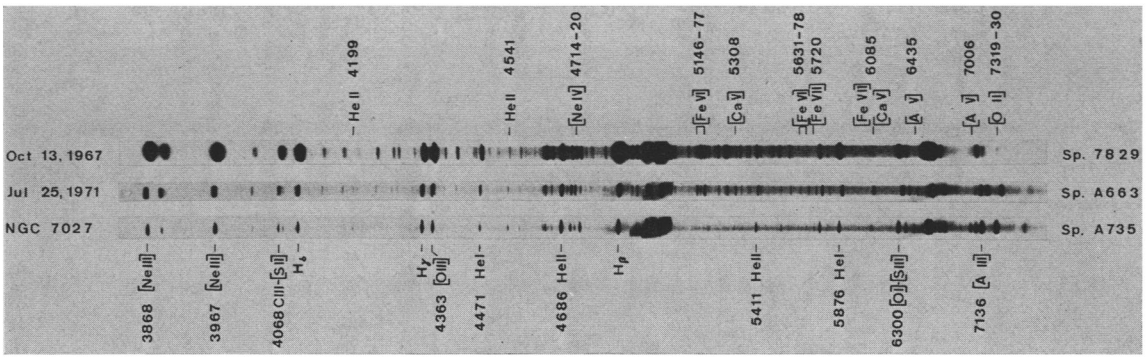


Fig. 2: Blue-red spectrum of V 1016 Cygni in 1967 and 1971, compared with the spectrum of NGC 7027.

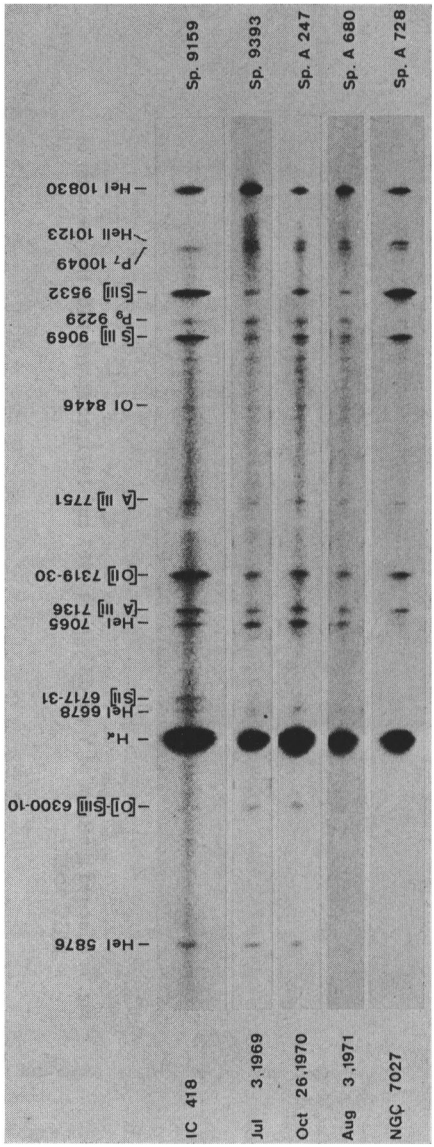


Fig. 3: Infrared spectra of V 1016 Cygni, compared with spectra of Planetary Nebulae (IC 418, NGC 7027) in different stages of excitation.

https://doi.org/10.1017/S0252921100032711 Published online by Cambridge University Press

7. This line, which on 1965 (Paper I) was outstanding in the infrared (est. int. 30) has been steadily fading. Already weak on 1967, further declined and in the last 1971 spectra is barely visible. The weakening of this line, excited by a resonance effect due to $Ly\beta$ indicates that, with the increasing degree of ionization, most of the OI atoms have been ionized.

8. The strength of this line has been increasing from 1969 to 1971. The same strengthening has been noticed in the [SIII] line $\lambda$ 9532, in the 2F line 6310 and in the 3F lines 3721—3796.

9. The shortest wave-length line of the blend ([SIII]) appears to be the main contributor. The two infrared [SIII] lines 9069 and 9532 are outstanding in the spectra of planetary nebulae, like NGC 7027.

10. Very strong on planetary nebulae of high excitation.

11. A slight fading has been noticed from 1969 to 1971.

12. It is the strongest line in the extreme infrared spectrum.

# V 1016 Cygni, Spectral Observations 1968—1971

M. PIM FITZGERALD (Waterloo, Ontario)

*Abstract*

**Identification of approximately 230 emission lines between 3120 Å and 5045 Å have been** made on twelve plates taken between 1968 and 1971. The line intensities and ratios fail to give a consistent detailed picture of the nebula, but indicate that on average the electron **pressure and density have changed little. The Balmer decrement has become less steep since** 1968, indicating higher optical depth. However, the permitted iron lines have completely gone, indicating lower density. Excitation is increasing in some parts of the nebula, as indicated by **the increased strength of the [Fe V] lines, and the recent appearance of strong lines of [Ne V].** The continuum remains weak, though it is easily seen on plates taken on April 8, 1969, and on those taken in June 1971. The radial velocity of the object fluctuates between −50 and **−70 km/sec, and the line widths remain about 120 km/sec. The wing to the violet of the** emission lines is still present. The continued brightness of this object, and the relative lack of change in the spectrum over several years, indicate even more strongly that V 1016 Cygni **is likely to be a planetary nebula in the stages of formation.**

## *I. Introduction*

The peculiar emission object V 1016 Cygni, discovered by McCUSKEY (1965), has continued to be of interest to several people (BOYARCHUK, 1967; FITZGERALD et al., 1966, 1969, 1970), MAMMANO and ROSINO (1966, 1968); and O'DELL (1967, 1968). It is not the purpose of this paper to present a massive list of figures on the more than 230 emission lines now identified on plates taken at the Warner and Swasey Observatory (130 Å/mm, and objective prism) and the David Dunlap Observatory (12 Å/mm and 40 Å/mm), but rather to touch on a few of the more interesting results found for this object. A more detailed paper will be prepared at the end of this observing season.



https://doi.org/10.1017/S0252921100032711 Published online by Cambridge University Press