for observations with the VLA and the integration time was maximized at 6 hours for each wavelength region.

As it turned out, however, there was no trace of a radio emission from the bar and the spiral arms, but the nuclear region again proved to be rather interesting. The highest resolution was reached at 6 cm, and Fig. 4 shows our 6 cm radio map superposed on the optical Hα picture of the nuclear region. As can be seen, the radio structure is resolved into a number of components, some of which are still unresolved at arcsecond resolution. These discreet sources have intensities of 1–8 mJy. The total flux from the nuclear region is 190 and 450 mJy at 6 and 20 cm respectively. This gives an average spectral index of –0.72 which indicates non-thermal radiation and is a normal value for Seyfert galaxies. Observations with the Einstein satellite by T. Maccacaro, G.C. Perola and M. Elvis show that the soft X-ray luminosity is $1.6 \cdot 10^{41}$ erg s^{-1} (0.2–3.5 keV).

The intriguing question is now of course the nature of the radio sources and the optical hot spots, their interrelation and the origin of their energy output. As can be seen from Fig. 4, there is no clearcut correspondence between radio sources and optical hot spots, and the Seyfert nucleus itself is no strong source of radio radiation. Could activity in a Seyfert nuclear engine generate these compact sources far apart? But, at least as far as the Hα and [N II] emission is concerned, there seems to be no clear evidence for violent outflow or drastically noncircular motion. Or could the radio sources be supernova remnants? The radio luminosity of each of the compact sources is of the order of 100 times Cas A and their energy content can be modeled as if coming from 100 supernova remnants that would have to be confined to a volume of less than 50 × 200 pc. Steady-state calculations then show that about one supernova per year should occur in the nuclear region. So far, one supernova has been reported in 1957 to appear in one of the spiral arms. In the nuclear region a supernova would be more difficult to detect. As an alternative, one could imagine each compact source to be a radio supernova of the type detected in M 100, that reached a radio luminosity at 6 cm of 180 times Cas A. Their life time, however, is only of the order of years and would cause a noticeable change of the radio emission over a short time. Our repeated 6 cm VLA observations in September 1982, although with lower resolution, give no evidence for such a variation.

To support the supernova rate mentioned each of the radio sources would have to be associated with about 10^5 O and B stars. This number of hot stars may not be inconsistent with the Hβ flux from the hot spots that may be places for recent bursts of star formation. However, the luminosity function could not be a standard one, as the mass in low luminosity stars required would spoil the regular velocity field of the nuclear disk. Also the lack of clear association between concentrations of supernova remnants and hot stars needs an explanation.

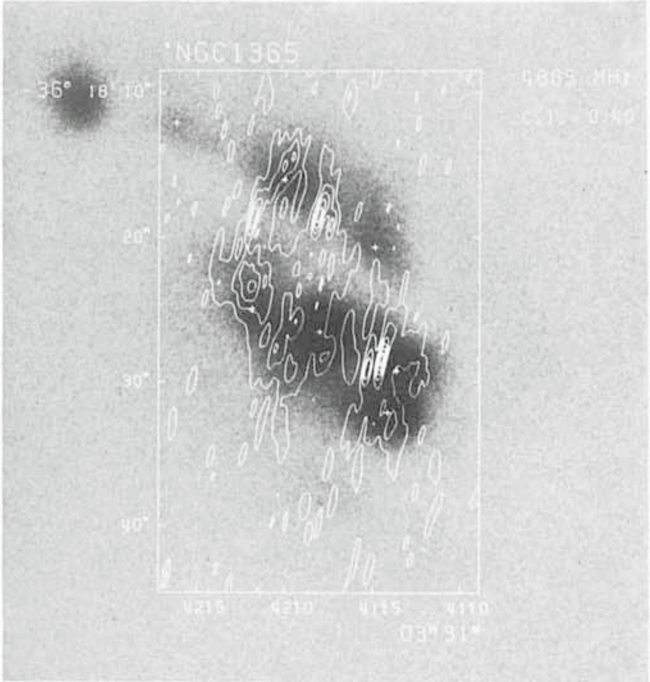

Fig. 4: *The VLA 6 cm map superposed on the Hα picture of Fig. 2.*

In the midst of this puzzling situation a very important observation has appeared to add to the confusion, but not improbably to ultimately give the clue to what is going on. M.M. Phillips, A.J. Turtle, M.G. Edmunds and B.E.J. Pagel show in a recent preprint that extended regions of high-excitation gas around the nucleus reveal a velocity field considerably more complicated than the rotating disk inferred above from the Hα and [N II] lines. As a matter of fact, the [O III] line at λ 5007 Å over this region is split up into several components with different velocities and velocity gradients. For some positions of their slit the [O III] line is actually inclined in opposite sense to that of the hydrogen lines. It seems that our IPCS observations show a peculiar behaviour also for the Ne III λ 3869 line. This may imply outflow of high-excitation matter from the nucleus in directions out of the plane of the disk. It could very possibly indicate a connection between the activity in the nucleus and the radio sources and hot spots in its surrounding.

Active Chromosphere in the Carbon Star TW Horologium

P. Bouchet, ESO, and M. Querci and F. Querci, Observatoire du Pic du Midi-Toulouse

Introduction

Herzberg (1948) was the first to suggest the existence of a corona-like nebulosity surrounding cool stars from strong Fe II emission lines he observed in the spectral region λλ 3150–3300 in the two supergiants α Herculis (M5 II) and α Scorpii (M1 Ib). Fifteen years later, Bidelman and Pyper (1963) suggested that these Fe II emission lines would be present in practically all giants of sufficiently late type. Then, Boesgaard and Boesgaard (1976) showed that this emission is nearly universal in M-type stars and thus appears to be a natural occurrence in stars with low temperature. At present, these emission lines are recognized as an undisputed chromospheric indicator. Chromospheres have been detected in late-type (F-M) stars, in particular for M giants through their bright UV emission lines (the Fe II lines besides the Mg II h and k lines), and most notably Linsky (1980) has pointed out that a wider spectral range of stars than was thought previously may possess chromospheres.

Bidelman and Pyper (1963) reported for the first time ultraviolet Fe II emissions in the variable carbon star TX Psc, and suspected that the structure of the outer layers of C-type stars is not greatly dissimilar from that of M giants. However, in contrast with the detailed data available on the emission-line spectra of M-type stars, relatively little is known concerning the chromospheric emission lines in variables of the carbon class. In fact, as it was generally thought that high grain density in the atmospheres of the coolest low-gravity stars would prevent any manifestation of chromospheric emission lines, very few efforts have been made to determine the presence of these lines. However, recent observations are to be reported: in spite of the first, unsuccessful, attempts to record ultraviolet emission lines in the spectra of four cool carbon stars with the IUE satellite by Querci et al. (1982), positive results were obtained for other N-type stars by Johnson and O'Brien (1982) and by Querci and Querci (in preparation).

The observational confirmation of the presence of chromospheric emission lines in cool low-gravity stars is important to ascertain how the emission is related to the properties of the star, and to show what conditions favour the formation of the emission features. It is thus an important test of the validity of recent theoretical stellar-chromosphere models and their related heating mechanisms. Moreover, the study of a chromospheric activity in these stars may shed considerable light on the structure and dynamics of their outer layers about which very little is known. Estimates of the inner radius of the shell are not reliable, and consequently the mass loss rates are highly uncertain. The gas extension is not determined, and the possible asymmetries in the circumstellar lines which, for example, could result from the ejection of irregular masses, are only just beginning to be recognized, mainly due to recent progress in echelle-resolution spectroscopy, as well as the possible polarization due to the envelopes themselves which are a mixture of gas and dust. Finally, and most important, it is difficult to understand the relation between the mass loss phenomenon and the stellar evolution. All the nonthermal mechanisms of mass loss are in themselves controversial.

Photometric and spectroscopic observations of a representative sample of C-type stars have been made mainly by one of us (P.B.) in the near-infrared, the visible and the near-ultraviolet. This sample was selected to cover a range of spectral types R and N, the latter including all types of variations (M, Lb, SRa, SRb) independently of the known existence or absence of a circumstellar shell. The observations were spread over several years in order to cover the phase of these stars over many periods of variability (from 150 to 500 days). In the sample of 12 stars, one, TW Hor (spectral type C7, 2 – NO), in fact a lot more observed than the others, showed (Fe II) chromospheric activity with peculiar and surprising behaviour.

The Chromosphere of TW Hor

1. Spectroscopic Observations

Among the most important chromospheric spectroscopic indicators that can be detected in carbon stars, are the Ca II H (λ3968) and K (λ3934), the Mg II h (λ2803) and k (λ2796) lines and the Fe II lines around λ3270. A search for Ca II and Fe II lines was made through observations with the coudé spectrograph of the ESO 1.5 m telescope between 1979 and 1981. Conditions were the same for all spectrograms: 12 Åmm^{-1} dispersion, IIa-O emulsion, 1″ entrance slit and equal number

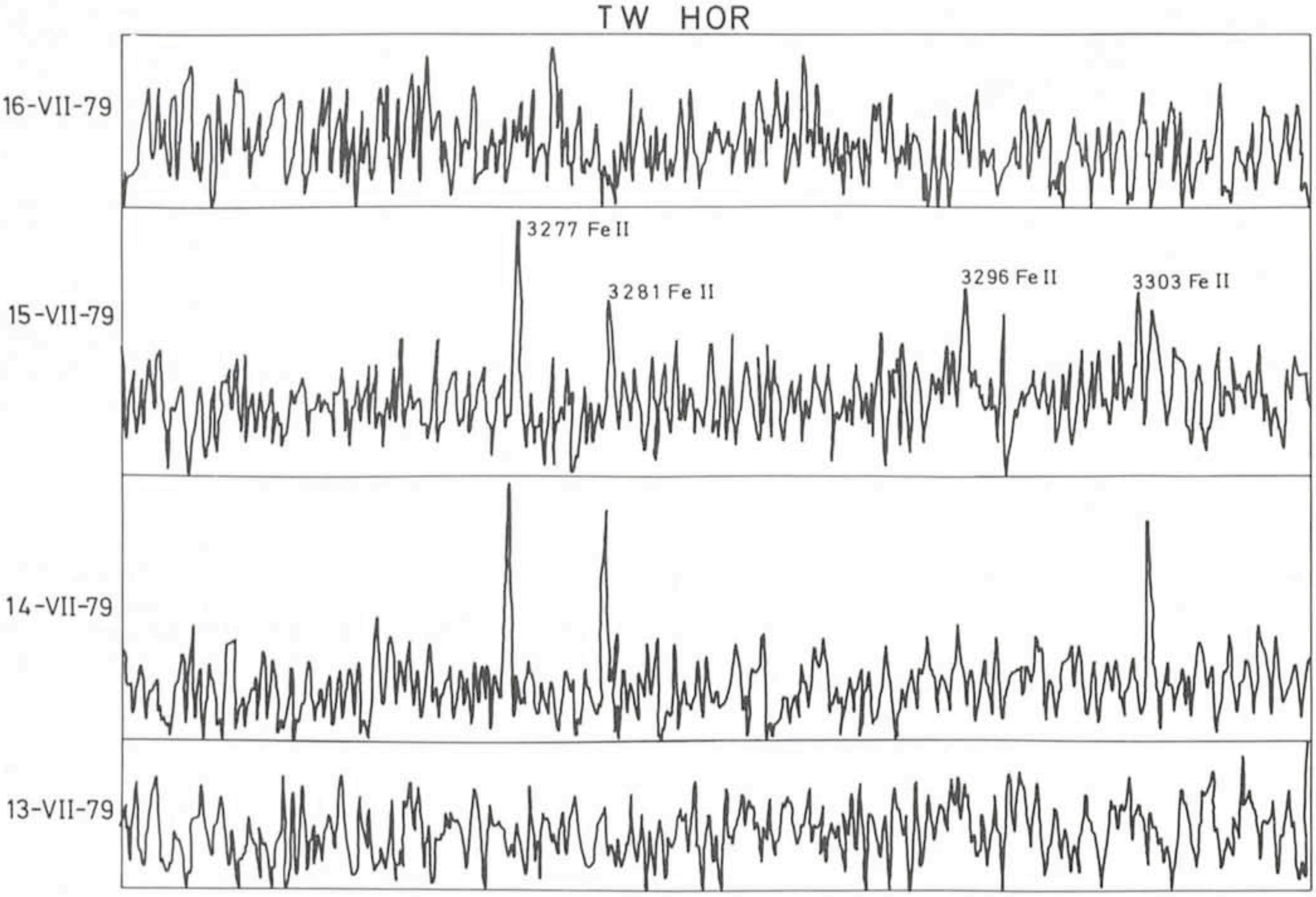

Fig. 1: *Intensity tracings of plates obtained during four consecutive days in July 1979. No continuum is observed. Plates have been recorded at the CDCA (Nice Observatory) and processed at the Pic du Midi Observatory. (IIa-O emulsion, 12 Å mm^{-1}.)*

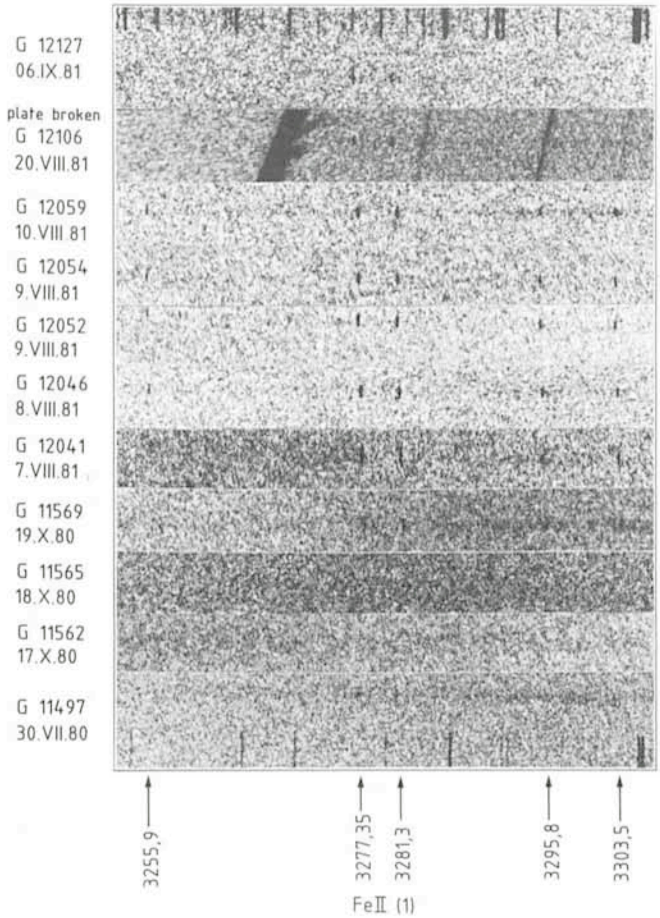

Fig. 2: *A sample of spectrograms from July 1980 to October 1981. The two plates taken on August 9, 1981, (G 12052 and G 12054) are separated by 4 hours. Note that on plate G 12127 only the two strongest lines (λλ 3277, 3281) can be seen. Plate G 11497 has been exposed twice as long as the other ones. This photographic assembling was done by Mr. R. Donarski at La Silla. (IIa-O emulsion; 12 Å mm^{-1}).*

of counts from an exposure meter with a blue spectral response. In the spectral range λλ3200–3500 the stars studied are so faint that in order to save exposure time, all spectra were taken without widening. However, due to faint continua, chromospheric lines, when present, stand out quite clearly. Figures 1 und 2 illustrate some results obtained for TW Hor. They show that the Fe II emission lines around λ3270 vary in strength in an irregular manner and sometimes even disappear completely in time scales of one day.

Wide absorption profiles of Ca II lines have also been observed under the same conditions. Re-emission such as the one seen in K-type giants and in some R-type stars was not detected in TW Hor. Note that, even if such emission could be observed with better resolution and signal/noise, it would still be very weak.

Further to the observations made at La Silla, IUE spectra of TW Hor obtained in the LWR range, with low resolution and large aperture by Querci and Querci (in preparation) show a variable emission of the h and k Mg II lines, the C II] lines at 2325 Å, the Al II U2 and V II U7 lines, besides the UV Fe II lines.

2. Interpretation

The behaviour of the spectral lines, indicators of chromospheres as quoted above, has to be studied simultaneously in order to give an insight into the various possible excitation mechanisms. In the case of TW Hor, a challenging point is that the Ca II H and K lines remain in absorption even when the UV Fe II and Mg II lines appear strongly in emission. It does not seem acceptable that the emission lines are excited in a shock front spreading accross the photosphere, as generally accepted for Mira-type stars (for example, Hill and Willson, 1979): it would not explain why Ca II is never seen in emission, nor would it explain the irregular variations of the Fe II lines. Other possibilities can be considered, among which the following are the most outstanding:

A – There is a chromosphere which implies a permanent excitation of the Fe II lines. However, inhomogeneities of the cloud-like chromosphere layers may occasionally prevent detection of these lines. Short-term variability could be due to time evolution of active regions, or flares (Linsky, 1980).

B – As it is established that cool giants have strong convective subphotospheric zones, the chromospheric heating may be due to short-periodic acoustic waves generated by the convective motions in the lower photosphere and dispersing as shock waves (Schmitz and Ulmschneider, 1980). In the wake of this train of waves, a reversal of temperature would provoke the excitation of Fe II and Mg II. In low-gravity stars, the acoustic waves are heavily damped when crossing the photospheric radiative zone and this prevents the growth of the shock discontinuity. The point where the temperature increase takes place due to shock dissipation (otherwise the temperature minimum), is far from the location of the shock formation. Because of the differences of abundances and ionization potential of Ca and Mg or Fe, the Ca II should be located in lower layers of the chromosphere than Mg II and Fe II. By comparison with the solar case, it should correspond to chromospheric layers between 5000° K and 8000° K. The absence of Ca II emission could then be explained if we suppose that Ca II is located in the region where the shock is not yet fully developed and where the energy is not sufficient to produce an emission. The irregular behaviour exhibited by the Fe II lines, for which we obtained strong observational evidence, may possibly be explained by a turbulent convection that gives rise to trains of acoustic waves of variable wavelengths.

C – The turbulent convective agitation may give rise to giant convective cells (Schwartzschild's hypothesis) which reach the surface of the stars and provide enough energy to sporadically extract relatively cool matter from the photosphere. Due to low gravity some of this material could escape and destroy the lower chromosphere. This mechanism would be similar to the one studied by Kafatos et al. (1979) and would give a time scale for M supergiants from 10 days up to 6 years between each photospheric eruption.

D – Another mechanism proposed by analogy with the Sun could be the following one: the variable Fe II emission lines should be caused by a discrete magnetic structure in the chromosphere whenever the field lines—which originate in the magnetic tubes existing in the photosphere—converge (for example, Tinbergen and Zwaan, 1981). However, it is not known whether the C-type stars have sufficiently strong magnetic fields. These stars have convective zones, but due to their small rotational velocities ($V \times \sin i \leq 10$ kms^{-1}) the classical dynamo principle must be excluded and the present hypothesis should only rely on a local dynamo mechanism similar for example to the one studied by Robinson and Durney (1982) for main-sequence stars.

The Circumstellar Shell

Fig. 3 shows the observed spectral energy distribution of TW Hor near maximum luminosity, together with predicted emer-

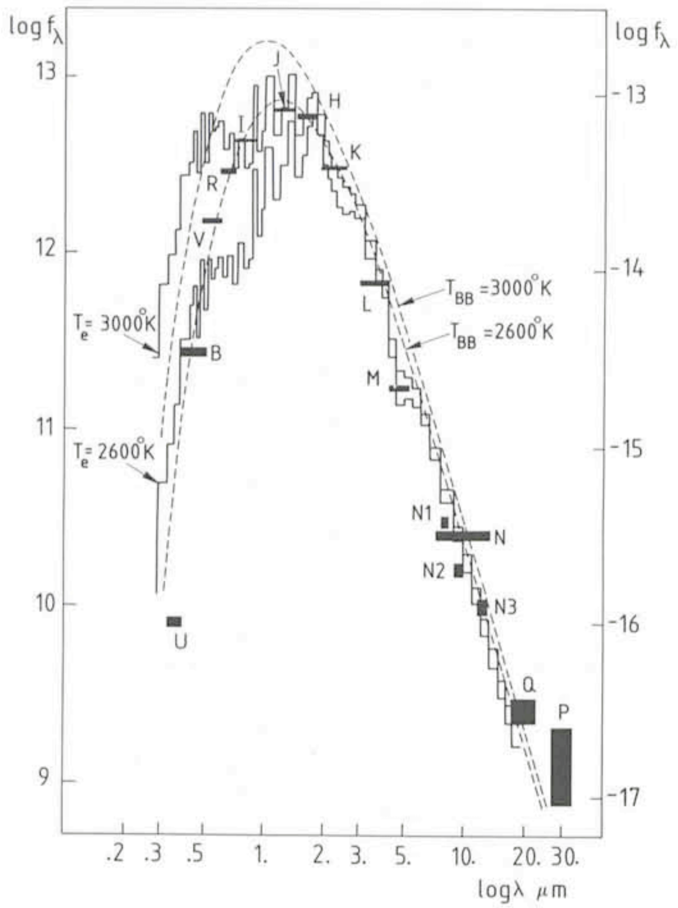

Fig. 3: *Broad and narrow pass-band photometry of the star TW HOR, near maximum luminosity (∅ = 0.89). UBVRI photometry was carried out at the ESO 50 cm telescope with its standard photometer and Quantacon photomultiplier on September 14, 1981. JHKLM photometry was performed with the ESO standard InSb photometer attached to the 1 m telescope, during the same night. 10 μm to 30 μm photometry was performed on the following night with the standard ESO-bolometer attached to the 1 m telescope. Note that filters N, N1, N2 and N3 do not have BaF_2 blocking filters to suppress leaks longward of 20 μm.*

The step-shaped solid lines are the predicted emergent line-blanketed fluxes from model atmospheres with Te=3000° K and Te=2600° K. The continuous lines are the black-body curves for the same temperatures: T_{BB}=3000° K and T_{BB}=2600° K. The right ordinate scale gives the logarithm of the observed fluxes in W/cm²/μm. The left ordinate scale gives the logarithm of the predicted fluxes in erg/cm²/sec per $\Delta\lambda$=1 cm.

gent fluxes of blanketed model atmospheres (Querci and Querci, 1976) with the effective temperatures Te=3000° K and Te=2600° K. The other parameters of the model atmospheres are a gravity g=1 cm/sec², a turbulent velocity V=5 km/sec and a chemical composition appropriate to the photosphere of carbon stars, named DE12 in the quoted reference. The molecular line blanketing taken into account in the models comes from the CO, CN and C_2 molecules, and the continuous opacity sources are the free-free, bound-free and scattering ones specific to cool stars.

From the V, R, I, J, H, K, L and M bands it can be seen that the effective temperature of the star is such as 2600°K < Te < 3000°K. Concerning the J, H, K, L bands, Tsuji (1981) reports that N-type irregulars — i. e. SRb type of variability applicable to TW Hor — are observed free from dust thermal emission. Also, this author demonstrates that the L flux is a good quasi-continuum, the HCN and C_2H_2 absorptions being situated at the edge of the L-band at 3 μm. In the absence of detailed spectrophotometric observations on the near-IR region of TW Hor, we consider that this star follows these general outlines.

As for the M-band, the absorption is due to CO (photospheric and circumstellar) and possibly to C_3 at 5.2 μm.

Now, let's examine the spectral range of the U and B bands where for the carbon stars the theoretical fluxes are above the black body and the observed ones are fairly below. These apparent discrepancies may be partly due to a neglect of atomic and SiC_2 and C_3 molecular blanketing in our theoretical opacities, such that the predicted fluxes are too high. This is confirmed by the detection of the infrared crystalline SiC (see below) which is a solid condensate of gaseous SiC_2 and implies the presence of this last molecule in the UV region of TW Hor. Moreover, as quoted by Bergeat et al. (1976a), absorption by small SiC and graphite grains could, at $\lambda < 0.5$ μm, increase the discrepancy between observed and predicted fluxes, because the opacity of grains has not been included in the atmosphere models. TW Hor is among the carbon stars having a high near-UV luminosity with its colour indices B – V = 2.5 and V – B = 3.3, so observed V and B values are nearer the predicted fluxes than those of many other carbon stars.

In the far-infrared part of the curves, the excesses visible in the N, Q and P bands clearly prove the presence of a circumstellar shell in TW Hor. The small excess at 11.2 μm in the N-band with respect to N1, N2 and N3 is due to the SiC emission band. Note that spectrophotometric observations of TW Hor (Bouchet, 1983) show an intense emission by SiC, while the large N-band with its effective wavelength at 8.8 μm cannot justify it fully. The emission in the Q-band at 22.5 μm reminds the one first seen by Goebel et al. (1980) in the carbon star Y CVn. On the other hand, though our theoretical energy distribution curves stop around 20 μm, an emission is evident in the P-band and would be due to an unidentified circumstellar emission previously pointed out by Hagen et al. (1975) in some cool stars. We have to emphasize that possible free-free emission from chromospheric H and H^- would contribute to the observed infrared excess, besides the circumstellar shell.

That a circumstellar shell is present around TW Hor seems obvious from the above considerations. Further arguments may be added, such as the colour difference [11 μm] – [3.5 μm] = –0.65, well known photometric shell indicator. Nevertheless, this goes against the classification by Bergeat et al. (1978) who stipulate that TW Hor is a star without shell. In fact, these authors give this star an effective temperature Te = 2530° K. However, from Fig. 3 it appears that TW Hor has a temperature certainly superior to 2600° K and rather close to 3000° K (an accurate value is being computed through a run of model atmospheres). So, if we adopt, say, Te = 2800° K and if we take into account the photometric data that we got: (R+I)–(J+K)=4.7, these values locate TW Hor among the non-Mira stars with shell in the Fig. 1 of Bergeat et al. (1976b). Moreover, our adopted temperature together with our value (R+I)–2J=3.3 would not be out of range in the (R+I)–2J index versus Te figure of these authors, which illustrates the effective temperature scale that they proposed.

Conclusions

The important result reported in this paper is that, for the first time, chromospheric variable activity has been detected in a cool low-gravity star of the carbon class. Though the mechanisms able to heat the chromosphere are not yet well understood, this would shed some light on the problems concerning chromospheres. For instance, the validity of the Wilson-Bappu relations for Ca II and Mg II (Linsky, 1980) should be carefully considered in this particular case. Let us recall that these relations are simple correlations between Ca II or Mg II emission core widths and stellar absolute visual magnitude. High-resolution UV observations with IUE are planned for TW Hor which appears relatively bright in the ultraviolet range. High resolution on Ca II H and K lines are undertaken at various phases with the La Silla Coudé Echelle Spectrometer (CES) to decide about re-emission in the line cores.

In short, we show that the outer layers of TW Hor consist in a photosphere (Te ~ 2800° K), a warm chromosphere (5000°K < T < 8000° K) and a circumstellar shell. This situation is not greatly dissimilar with what has already been seen in M giants of late type, but with different temperatures. It can be reasonably thought that this may be extended to other carbon stars. Its relative high UV luminosity enabled us to detect in TW Hor what may exist in UV-fainter stars as well. A conspicuous feature is the strong ultraviolet absorption underlined by the theoretical flux curves of carbon stars, contrary to the M stars (Tsuji, 1976): this is the best proof of the presence of dust grains absorbing in the UV spectral range of C stars.

Acknowledgements

It is a pleasure to thank Mr. D. Hofstadt and the technical staff of La Silla who are always very helpful. Special thanks go to Messrs. M. Bahamondes, L. Ramirez and H. Vega for night-assistance and initiatives when taking coudé spectra. The assistance of Mr. R. Vega for the infrared observations was also very valuable, as was the help of Mrs. B. Pech (Pic-du-Midi Observatory) in the improvement of the spectra reduction programmes.

One of us (P.B.) is grateful to Drs. A. Ardeberg, A.C. Danks and H. Pedersen for beneficial suggestions when preparing the draft of this paper and to Drs. P.S. The, J. Koornneef and D. Gillet for helpful discussions.

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136 Austria – Observed at ESO

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As an Austrian, I am happy to inform the ESO *Messenger* readers about photoelectric observations of the asteroid 136 Austria carried out successfully at ESO in February 1981 and just being published in *Astronomy and Astrophysics.*

This asteroid—discovered in 1874 by J. Palisa at Pola—is just a small object of only 41 km diameter with classification MEU-type which means that no type assignment was made: but it is definitely a bright asteroid with high reflectivity and does not belong to the darker C-type group.

My observations were carried out using the 0.6 m Bochum telescope during ESO time in February 1981. The nice result is shown in Fig. 1, where the four observing nights are overlapped, based on the resulting spinning period of $P = 11^h.5 \pm 0^h.1$ ($= 0^d.479 \pm 0.004$). Due to the compatibility of $2P = 23^h$, near a full day (and due to the short summer nights), it was not possible to get the complete rotation cycle. But the period should be established pretty well—the light-curve amplitude is at least $0^m.40$, and the mean V-magnitude of 136 Austria was about V= 13.30; the light-curve shows double-wave characteristic with nearly identical primary and secondary maxima; the secondary minimum was never observed.

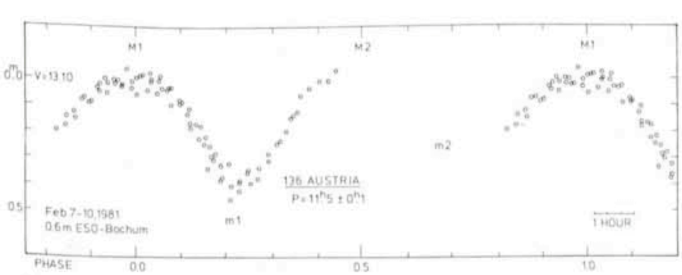

Fig. 1: *Overlap of photoelectric observations for the asteroid 136 Austria, obtained in four nights, Feb. 7–10, 1981 with the 0.6 m Bochum telescope at La Silla. The rotation period of 136 Austria is $P = 11^h.5$, all measurements were reduced to Feb. 10, 1981.*

The reader interested a little bit more in the general aspect of photoelectric observations of asteroids is advised to refer to earlier articles published in the ESO *Messenger* by H.J. Schober in No. 24 (1981) or by H.J. Schober and J. Surdej in No. 29 (1982).

I think I was especially lucky to have finally observed this asteroid at ESO—also in honour of my own country—and I would like to express my gratitude to Prof. L. Woltjer on behalf of ESO, for having allotted so much telescope time to me, though Austria is not a member state of ESO. I should also make my acknowledgements to the "Austrian Research Fund", projects 3136/4852, which helped to cover my travel expenses for those observations!

Applications for Observing Time at La Silla

Period 32 (October 1, 1983 – April 1, 1984)

Please do not forget that your proposals should reach the Section Visiting Astronomers **before April 15, 1983.**