distinctive light curves and spectra in which the lines of hydrogen and helium are absent and only lines of the heavier atoms such as calcium and iron show. If the observed velocity of expansion is really of the order of 13000 km sec^{-1} as apparently derived by Oke, this also agrees qualitatively with that expected to be produced by the implosion of an iron white dwarf.

As to the original bodies producing the other four types of supernovae, no real progress seems to have been made yet, except that it appears fairly certain that supernovae of the Zwicky type III are not due to the collapse of any star but rather that of gas clouds of much greater mass.

Supernovae of the type I which have appeared in the Coma cluster (and other clusters of galaxies) show a remarkably small dispersion in apparent and therefore in absolute magnitudes. If this fact is confirmed by future observations, supernovae of the type I would therefore be the first and only cosmic objects available for the determination of large distances provided that we had a good value for their absolute brightness. Present indications for supernovae of the type I are that their photographic absolute magnitude at maximum is about $M_p = -18{\cdot}0$. The Lundmark-Hubble redshift constant consequently would be about 150 km sec^{-1} million parsecs. In any event it should be emphasized that those who are deriving much smaller values through the use of sizes of H II regions and luminosities of globular clusters and variable stars are deluding themselves, since the sizes and luminosities of all of these objects are not intrinsically fundamental and they are furthermore observationally unsuitable to gauge distances large enough for a reliable determination of the universal redshift constant.

Finally it should be mentioned that several new means have been developed to facilitate the search for supernovae. For instance, Wild at Zimmerwald now uses a twin Schmidt telescope which automatically will eliminate the difficulties caused by the interference of photographic defects. The large Tautenburg Schmidt telescope has now been equipped with a fullsize prismatic Schmidt plate which produces spectra of stars as faint as the apparent photographic magnitude 19·0. On the plates obtained supernovae may be recognized directly, eliminating thus the very laborious and time-consuming (by blinking or other means) comparison of two different epoch plates. J. Strong and F. Zwicky had three 45 cm × 45 cm transparent objective laminar gratings constructed for the same purpose. Finally Hynek at Correlitos and Colgate at Socorro have been constructing telescopes using television and photo-electronic scanning and computers. While Hynek's group has already discovered some supernovae, no news has been as yet received from Colgate's group at Socorro, N.M.

For the IAU meetings in Australia and Poland Professors Detre, Rosino and the Palomar group (Kowal, Oke, Sargent Zwicky) have some additional suggestions aiming at making the supernova search and analysis more effective than in the past.

F. ZWICKY
Chairman of the Working Group

APPENDIX III

REPORT ON THE SPECTRA OF VARIABLE STARS

G. H. Herbig

1. *General*

Götz and Wenzel (*MVS*, **5**, 105; **6**, 35) have continued their work on the spectra of variable stars classified on objective-prism plates. The very extensive lists of peculiar, carbon, and emission-line stars contained in the Southern Objective-Prism Survey by Stock and Wroblewski (*Pub. Dept. Astr., Univ. Chile*, **2**, No. 3) contain many objects that deserve detailed spectroscopic investigation. A list of 101 new northern M, C, and bright-line stars found at Haute Provence has been published by Barbier and Viale (*AA Suppl*, **2**, 201).

2. *Red variables: Miras, semiregulars, RV Tauris, and "infrared stars"*

The high level of new activity in this area is due to the discovery of infrared excesses and of

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microwave line emission in several kinds of red variables. The book by Fujita: *Interpretation of Spectra and Atmospheric Structure in Cool Stars* (University of Tokyo Press, 1970) is a good introduction and survey of the subject as it stood just prior to these new developments. It contains as well a summary of the work of Fujita's associates. That work in atmospheric structure has continued with an analysis of the near infrared spectra of the S stars R And and R Cyg by Tsuji (*PAS Japan*, **23**, 275), who thereby constructed an empirical atmospheric model and estimated the mass loss rate; and Maehara *ibid.*, **23**, 313, 503) has derived atmospheric parameters from an analysis of coudé plates of 8 Mira variables, discussed line weakening in *o* Cet, and constructed models for χ Cyg and *o* Cet on the basis of differential line displacements. The Indiana group is also active in this subject: Keller *et al.* (*AA*, **4**, 415) have derived a rotational temperature for TiO in R Hya, while their studies of carbon stars are referred to below. Vardya (*Ann. Rev. AAp.*, **8**, 87) has thoroughly reviewed the theoretical problems of atmospheres of late-type stars.

The spectra of long period variables in globular clusters, near the galactic center and in the solar neighborhood have been discussed by Feast (*QJRAS*, **13**, 191) from the point of view of population characteristics, and the red variables in metal-poor cluster ω Cen have been examined from the same point of view (Dickens, Feast, and Lloyd Evans, *MN*, **159**, 337). The general features of the spectra of small-range semiregular variables in the near infrared, with emphasis on molecular bands, have been studied by Gusev and Caramish (*VS*, **17**, 305). Odell *et al.* (*PASP*, **82**, 883) measured *o* Cet spectrophotometrically in the Hγ, Hδ lines and a TiO head through the 1969 maximum at a resolution of 16 Å. The spectra of Mira variables of all kinds near minimum light have been observed in the near infrared and illustrated by Wyckoff and Wehinger (*ApJ*, **162**, 203; **164**, 383; **172**, 117; *PASP*, **83**, 89; **84**, 424), who discussed some unidentified molecular bands that appear only in these very cool objects.

The advent of new detectors and techniques has made possible broad-band spectrophotometry of red variables to about 20 μ, and very high-resolution spectroscopy at intermediate infrared wavelengths. The general subject of infrared excesses in stars of all kinds is surveyed by Neugebauer, Becklin, and Hyland (*Ann. Rev. AAp.*, **9**, 67), and from a more theoretical point of view by Stein (*PASP*, **84**, 627). A fundamental paper by Low *et al.* (*ApJ*, **160**, 531) presented broad-band observations to 22 μ of a variety of largely late-type peculiar stars, some of which have since been scanned at increasingly higher resolution by Forbes *et al.* (*AJ*, **75**, 158: 1·35 to 4·10 μ at $\lambda/\Delta\lambda \approx 100$), by Johnson and Méndez (*AJ*, **75**, 785: 1·1 to 4 μ at $\lambda/\Delta\lambda \approx 500$), by Hyland *et al.* (*AA*, **16**, 204: 2·0 to 2·4 μ at $\lambda/\Delta\lambda \approx 350$ and 700), by Gillett *et al.* (*ApJ*, **160**, L173: 2·9 to 14 μ at $\lambda/\Delta\lambda = 50$–100), by Gammon *et al.* (*ApJ*, **175**, 687: 8 to 12 μ at $\lambda/\Delta\lambda \approx 250$), by Kovar *et al.* (*PASP*, **84**, 46: near 1·3 μ at $\lambda/\Delta\lambda \approx 2000$), and by Geballe *et al.* (*ApJ*, **177**, L27: near 4·7 μ at $\lambda/\Delta\lambda = 12000$); Chauville *et al.* (*AA Suppl.*, **2**, 181) have published a list of atomic lines identified in high-resolution spectra of 4 M stars. This wealth of new information has not as yet been fully exploited, although there has been some discussion of molecular abundances (notably H_2O, by Frogel: *ApJ*, **162**, L5, and of CO by Geballe *et al.*) and C isotope ratios.

In the radio region, the discovery of H_2O (1.95 cm) and OH (near 18 cm) line emission from a small number of late-type variables presented these objects in a wholly new light. The occurrence of H_2O emission has been discussed in papers by Schwartz and Barrett (*ApJ*, **159**, L123; *Bamberg Colloq.*, p. 44) and Sullivan (Thesis, Maryland, 1971), while the OH situation has been described as it developed in papers by W. J. Wilson and his associates (*ApJ*, **160**, 545; **177**, 523). It appeared from the data of Wilson and Barrett (*AA*, **17**, 385; see also Nguyen-Quang-Rieu *et al.*, *ibid.*, **14**, 154) that examination of a sample of late M-type variables was likely to yield about 1 OH emitter for about 20 stars examined, but a southern survey by Caswell *et al.* (*Ap. Lett*, **9**, 61) revealed only 1 in 94. Nor is the nature of the correlation of OH emission with other characteristics clear, except that H_2O emission does often occur in OH objects. The remarkable M supergiants VY CMa and VX Sgr (see below) are both OH/H_2O sources.

There has been considerable interest in specific atomic and molecular features of late-type variables. Keenan (*Vistas Astr.*, **13**, 223) has given an excellent survey of the occurrence of diatomic molecular bands in Mira variables. The initial identification of high overtone bands of SiO near

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2 μ in an S and a C-type variable (Fertel, *ApJ*, **159**, L7; **162**, L75) was challenged (Wing and Price, *ApJ*, **162**, L73) but subsequent observations at higher resolution near 4 μ by Cudaback *et al.* (*ApJ*, **166**, L49) established the presence of SiO in α Ori. However, the transition probabilities for SiO calculated by Hedelund and Lambert (*Ap.Lett.*, **11**, 71) do not seem to support the overtone identifications. Li I λ 6707 can become very strong especially in S stars; a thorough observational investigation has been made by Boesgaard (*ApJ*, **161**, 1003). An explanation in terms of Be^7 convected to the surface has been proposed by Cameron and Fowler (*ApJ*, **164**, 111). Boesgaard has also studied the Ti/Zr ratio in a variety of late-type stars (*ApJ*, **161**, 163). The Zr isotope ratios in the S star R Cyg have been determined by Peery and Beebe (*ApJ*, **160**, 619), and departures from terrestrial values interpreted in terms of s-process nucleosynthesis. Peery has also studied the occurrence of Tc I in M, S, and C stars (*ApJ*, **163**, L1; *PASP*, 162; **83**, 496), and Davis (*ApJ*, **167**, 327) has found some evidence for the occurrence of Pm I in two S stars. Nussbaumer and Swings (*ApJ*, **172**, 121) have studied the excitation mechanisms that control the intensities of Mn I, [Mn I], and [Fe II] lines in Mira variables. The theory of fluorescent Fe I in Miras has been investigated by Willson (*AA*, **17**, 354), and molecular fluorescence has been detected for the first time, in the case of SiH excited by Hδ in Mira variables, by Maehara (*PAS Japan*, **22**, 119).

Much attention has been given to the nebulous M supergiant VYCMa which not only shows intense OH and H_2O radio lines but also has TiO and ScO band emission in the optical region. Various spectroscopic aspects of this remarkable object, together in some cases with evolutionary speculations, have been presented by Feast (*Obs.*, **90**, 24), Hyland *et al.* (*ApJ*, **160**, 381), Herbig (Liège 1969, p. 13; *ApJ*, **162**, 557), Wallerstein (*ApJ*, **169**, 195), Humphreys (*PASP* **82** 1158), and by Gillett *et al.* (*ApJ*, **160**, L173). VX Sgr is a similar but clearly not identical case, whose variable spectrum has been described by Wallerstein (*A. Lett.*, **7**, 199) and by Humphreys and Lockwood (*ApJ*, **172**, L59). The OH radio emission in the two objects has been compared by Caswell, Robinson and their associates (*Ap. Lett.*, **7**, 75; **7**, 79; **8**, 171). Wing (*PASP*, **83**, 301) has pointed out that the M8 semi-regular R Dor is the nearest giant later than M6, and thus is a favorable object for detailed study.

Interest in the spectra of variable M supergiants less anomalous than VY CMa VX Sgr has been stimulated by the discovery of strong 11 μ excesses in type Ic variables and RV Tau stars by Gehrz *et al.* (*ApJ*, **161**, L213, L219), confirmed by Gillet *et al.* (*ApJ*, **164**, 83). The classification of such stars has been discussed by Humphreys and her colleagues (*ApJ*, **160**, 1149; **172**, 75) and by Schild (*ApJ*, **161**, 855), while Wallerstein (*ApJ*, **166**, 725) has examined, in the case of W Cep, the possibility of explaining the infrared excess by free-free emission in an extended envelope.

Carbon variables have received somewhat less attention than M and S stars, but there have been a number of significant investigations. Westerlund (*AA Suppl.*, **4**, 51) has published a catalogue of some 1124 C stars found on objective-prism plates of the Southern Milky Way. The classification of C stars has been reexamined by Richer (*ApJ*, 521) who gives a useful atlas of their near-infrared spectra at moderate dispersion, and by Mosidze (*Bull. Abastumani*, **40**, 29). Gordon (*PASP*, **83**, 667) discussed the so-called J subclass of C stars (objects having unusually strong C^{13} features), and found a correlation between C^{13} and the strength of Li I λ 6707. Warner and Dean (*PASP*, **82**, 904) also discussed the presence of Li I λ 6707 in both C and CS stars. Krempec (*Ap. Sp. Sci.*, **6**, 131) examined the correlations between population indices and spectroscopic characteristics of C stars. Coarse curve-of-growth analyses of 22 C-type stars were made by Utsumi (*PAS Japan*, **22**, 93), and a very detailed abundance analysis of the $C5_4$ variable UU Aur was performed by the Quercis (*AA*, **9**, 1), with particular emphasis on the C and N abundances and isotope ratios. Fäy (*ApJ*, **168**, 99) has synthesized the near-infrared spectra of several carbon stars by superposition of overlapping red CN rotational structure, as have Marenin and Greene (*ApJ*. **177**, 841) at somewhat shorter wavelengths. Thompson and Schnopper (*ApJ*, **160**, L97) have pointed out the presence of the 2–4 and 3–5 CN band heads at about 2.2 μ in several C variables.

Probably the remarkable nebulous carbon variable IRC + 10216 (= CW Leo) has received as much individual attention as any single C star. In the near infrared, the absorption spectrum is about C9 (on Richer's system) with no obvious abnormalities (Miller: *ApJ*, **161**, L95; Herbig and Zappala: *ibid.*, **162**, L15, and unpubl.) but in the microwave region, emission lines of CO, CN, CS and HCN have been reported (Solomon *et al.*: *ApJ*, **163**, L53; Wilson *et al.*: *ibid.*, **169**, L35; Morris *et al.*: *ibid.*, **170**, L109). A detection of the object at 3.5 mm probably is also due to emission lines in the bandpass (Woolf *et al.*, *ApJ*, **167**, L65). The profile of the variable + nebula on the sky has been determined in an occultation experiment by Toombs *et al.* (*ApJ*. **173**, L71).

The CS stars are cool, weakly-banded objects that probably have C/O = 1. Catchpole and Feast (*MN*, **154**, 197) have assigned 6 new members to the group, and discussed the spectroscopic characteristics. Keenan (*MN*, **153**, P1) has pointed out another bright, new member. The very usuful atlas of low-dispersion spectra of S stars by Stephenson and Ross (*AJ*, **75**, 321) shows examples. Catchpole and Feast (*Obs.*, **91**, 29) have also found a high-velocity Se variable that probably belongs to the halo population, a quite unexpected discovery.

In connection with circumstellar explanations of the infrared excesses in RV Tau variables, Preston (*ApJ*, **172**, L105) pointed out changes in the shell spectrum of U Mon. He also (*PASP*, **83**, 52) pointed out that VW Eri is a high-velocity, weak-lined semiregular variable similar to SX Her. QT CrA is apparently another high-velocity, weak-lined G star with variable Balmer emission (Feast, *IBVS* 424).

3. *Cepheids*

Van Paradijs (*AA*, **11**, 299) carried out a coarse curve of growth analysis of δ Cep from coudé spectrograms taken through the cycle. He derived the atmospheric parameters, and suggested from the line asymmetries he observed that a velocity gradient moved through the atmosphere in the pulsation cycle. Kobayashi and Takeuti (*Sendai Astr. Rep.*, 121) have performed a similar analysis. Schmidt (*ApJ*, **170**, 109) has investigated the Fe spectra of 4 Cepheids, using both conventional coarse analysis and static model atmospheres, and discussed the problems of gravity and density variations inferred from such analyses. He has also (*ApJ*, **162**, 871) examined the possibility of obtaining the temperature variation from the Hα profile. Estes and Wood (*AJ*, **75**, 999) measured the temperature variation of β Dor through its cycle by photometry of the G band, and concluded that it was a safer indicator than Hα. Analysis of the spectra of two Pop. II cepheids, W Vir (Barker *et al.*, *ApJ*, **165**, 67) and TW Cap (Anderson and Kraft, *ApJ*, **167**, 119) provided material for a discussion of shock-wave phenomena and metal deficiencies in those stars. It would be of interest to compare such observations with the predictions of the radiation-hydrodynamic model atmospheres of Hillendahl (*PASP*, **82**, 1231). The influence of shock waves on the continuum and lines of Pop. II variables has been studied theoretically by Golinko (*Astrofiz.*, **8**, 91).

Jacobsen (*ApJ*, **159** 569) has studied the radial velocity curve of U Sgr and from both the systemic velocity and that of the interstellar lines, confirmed the membership in M25. Wallerstein (*PASP*, **84**, 656) has observed the velocity of the 27-day Cepheid T Mon through the cycle, and attempted to interpret the complex vaiations of the Hα profile in terms of moving layers in the chromospher.

The spectra of two other possible Pop. II cepheids have been described at low dispersion: V553 Cen, which appears to be carbon-rich (Lloyd Evans *et al.*, *MN*, **159** 67) and SZ Mon, which has an unusually pronounced cycle alternation (Lloyd Evans, *Obs.*, **91**, 159).

4. *β CMa variables, dwarf cepheids, δ Scuti stars and magnetic variables*

Van Hoof (*Spectroscopic Astrophysics*, p. 343) has presented a review of the β CMa phenomenon as it stood about 1966, which contains considerable spectroscopic information. Much of this material is updated in papers by Watson (*ApJ*, **169**, 343; *ApJ Suppl.*, **24**, 167) on spectroscopic and spectrophotometric properties. He finds a normal He abundance, and locates an instability strip in the (T_{eff}, log g) plane. Lesh and Aizenman (*C.R. Paris*, **274B**, 911) have refined the MK classifications of the β CMa stars through a Q, β index. They consider that the existence of non-variables among the variables in the HR diagram is a consequence of its being populated by stars of different evolutionary age, with different structure.

More detailed studies of individual stars have also been made. Popov (*VS*, **17**, 142) has investigated the cyclic variation of line strengths in β CMa, β Cep, γ Peg. Laskarides *et al.* (*AJ*, **76**, 363) have

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followed radial velocities, profiles, and line strengths through the cycle of υ Eri at high dispersion. Lecontel *et al.* (*AA*, **8**, 29) have studied LU Gem (= HD 43818), a broad-lined β CMa variable discovered by Hill. They interpret rapid variations in line structure to mean that the line broadening is not due to rotation. Four new broad-lined β CMa variables have been found by Shobbrook and Lamb: λ and κ Sco (*MN*, **156**, 181) and ε Cen and δ Lup (*MN*, **157**, 5P), while o Vel has been recognized as a new sharp-lined member by Van Hoof (*AA*, **18**, 51). Percy and Madore (Bamberg, p. 197) have reviewed the problem of spectroscopic binaries among the β CMa stars.

Stock and Tapia (*AA*, **10**, 134 and 147) have measured the radial velocity of the dwarf cepheid SX Phe on nearly 500 spectrograms, and line strengths on about 75, and investigated the variation with phase. They suspect from this vast material combined with *UBV* photometry (*AA Suppl.*, **3**, 253) that the star is not a single pulsating object. Wood (Bamberg, p. 176) has reported narrow-band line photometry of the same star.

Dickens *et al.* (*MN*, **153**, 1) have performed a coarse analysis of the δ Sct star 20 CVn (= AO CVn) on spectrograms exposed through the entire cycle. The metal/H abundance was very near that of the Hyades, and no anomalies were found. Breger (*ApJ*, **162**, 597), in a reanalysis of earlier observations of δ Del by Bessel, and Reimers (*AA*, **3**, 94) found that the metals in that star were slightly underabundant with respect to the sun (although one might ask if the unresolved duplicity of δ Del might affect these analyses). Breger found that, on the other hand, the metals were somewhat overabundant in ϱ Pup and δ Sct. The lack of any clear pattern is puzzling. The radial velocity of 20 CVn has been observed by Penfold (*PASP*, **83**, 497). Breger has also determined new $v \sin i$ values from line widths in some 15 δ Sct stars or suspects (*ApJ Suppl.*, **19**, 79).

Among the magnetic variables, the spectrum of α^2 CVn and its variations has been studied by Cohen (*ApJ*, **159**, 473), with special attention to the continuum variation through the cycle. A rough abundance analysis was interpreted in terms of an oblique rotator model. An investigation and analysis of the velocity and magnetic field variations in the same star was carried out by Oetken *et al.* (*AN*, **292**, 1). The spectroscopic variations of 56 Ari have been studied by Bonsack and Wallace (*PASP*, **82**, 249), Bonsack (*PASP*, **84**, 260), and by Aslanov and Khokhlova (*AJUSSR*, **49**, 271), and interpreted by a model having He I and Si II, in effect, distributed non-uniformly over the surface. The magnetic field variations of several Ap variables have been examined and discussed by Preston and the Wolffs: β CrB (*ApJ*, **160**, 1049), HD 126515 (*ApJ*, **160**, 1059), HD 9996 (*ApJ*, **160**, 1071), and HD 111133 (*ApJ*, **176**, 433). Megessier and Garnier (*Ap. Lett.*, **11**, 113) have observed simultaneously the light and spectral changes of 108 Aqr, and measured the variation in metallic line profiles through the cycle. Khokhlova (*AJUSSR*, **48**, 939) has interpreted the variation of He I line strengths in HD 124224 (= CU Vir) through the cycle as due to the presence of two regions of differing helium concentration on the star's surface.

There has been a surprising lack of spectroscopic activity in the field of RR Lyr variables during the triennium; one does note the list of new ΔS values for 20 variables by Willis (*Obs.*, **91**, 14), and a determination of spectral type and ΔS for a similar number of stars by Alania (*IBVS* 702).

5. *R CrB, symbiotic (including VV Cep stars), and Nova-like variables*

The very comprehensive spectroscopic study by Alexander *et al.* (*MN*, **158**, 305) of the deep 1967–70 minimum of RY Sgr is both a major step forward and an excellent review of the history of the subject. They describe the rich emission-line spectrum in detail, and discuss the properties of the deep atmosphere that must produce it. They also studied the superimposed 39-day cycle in light and radial velocity, which seems now to be explicable in terms of the pulsations of a helium star of about 1–2 $M_\odot$ (Trimble, *MN*, **156**, 411). The luminosities of the R CrB variables are best established by their association with other objects of known distance. Rodgers (*Obs.*, **90**, 197) has reported that W Men in the Large Magellanic Cloud is spectroscopically an R CrB-like object, confirming earlier work by Feast, who has shown (*MN*, **158**, 11P) that 2 other candidates in the LMC also have strong C_2 bands, and thus may well be R CrB variables as the light curves suggest.

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Further observations of the infrared excess (3·5–11 μ) in R CrB by Forrest *et al.* (*ApJ*, **170**, L29) show that there is a very poor correlation with visual-region magnitude. Feast and Glass (*MN*, in press) have extended the infrared photometry (1·25 to 20 μ) to many more R CrB stars, and reported on the spectra as well. The very red star found by Sanduleak and Seggewiss in the very young cluster NGC 6231, and initially suspected to be an R CrB variable (Bessell *et al.*, *ApJ*, **162**, L11) has turned out to be a normal background F5 supergiant (Herbig, *ApJ*, **174**, L89).

P. Swings (*Spectroscopic Astrophysics*, p. 189) has reviewed in detail the spectroscopic properties of symbiotic and miscellaneous peculiar stars, as the situation stood about 1968. Boyarchuk (*Izv. Crim.*, **41–42**, 264) has determined the chemical composition of the envelopes of 6 symbiotic stars from spectrophotometry of their Balmer and forbidden emission lines; he finds that they do not differ significantly from that of the planetary NGC 7027. Nussbaumer and Swings, in a discussion of the spectrum of [Cr II], show that the ion is present in η Car and HD 45677. The spectra of two new probable symbiotic stars have been described by MacConnell (*IBVS* 734).

An extensive observational and theoretical program on symbiotic stars is underway at Frascati, in an effort to study the short- and long-period spectral changes, and to determine the continuum and emission-line variations in absolute units. Special attention is given to the theory and interpretation of Fe II emission by Ricciardi and by Viotti (*Mem, SAI*, **41**, 513), while the observational program is carried out at Campo Imperatore by Viotti in collaboration with Baratta and Cassatella (Roma). The utility of Fe II in studies of excitation and color temperatures, and reddening in several symbiotic stars (KQ Pup, AG Peg, AG Car, Z And, V1016 Cyg) has been demonstrated also by Caputo and associates (*Ap. Sp. Sci.*, **10**, 93; *PASP*, **83**, 62; *Ap. Lett.*, **5**, 275) and in the case of η Car, by Ade and Pagel (*Obs.*, **90**, 6).

The changes in the shell spectrum and Fe II emission lines of KQ Pup (= B 1985, HR 2902) over part of the 27-year orbital cycle of the M2 I + B pair have been described by Cowley (*PASP*, **83**, 213); the ultraviolet shell lines in 1971 have been discussed also by Jaschek and Brandi (*AA*, **16**, 115). Three new VV Cep-like binaries have been discovered by Barbier (*AA*, **14**, 396), and KM Cas is another prospective member (Wackerling, *IBVS*, 436). CH Cyg does not seem to be such a pair: it is an M6 III with a hot continuum superimposed that according to the comprehensive study of the 1967–70 activity by Faraggiana and Hack (*AA*, **15**, 55) does not originate in another star. Investigations of the 1967–69 spectrum by Nguyen-h-Doan (*AA*, **8**, 307) and by Jimsheleishvili (*Astrofiz.*, **7**, 63) provide further detail. The ultraviolet brightening of the carbon star HD 59643, described by Greene and Wing (*ApJ*, **163**, 309), could represent a similar event. The spectacular emission spectrum of V 1016 Cyg in 1965–69, following its brightening, has been described in detail by FitzGerald and Houk (*ApJ*, **159**, 963; Bamberg, p. 73; *IBVS*, 400), while the infrared in 1968–71 has been observed by Ciatti *et al.* (Bamberg, p. 64). The emission spectrum of the rather similar object V 1329 Cyg (= HBV 475) was described by Crampton *et al.* (*Ap. Lett.*, **6**, 5) at the time its brightening was first detected, but the extensive observations over 1969–71 by Mammano and Righini have as yet been described only in condensed form (Bamberg, p. 63). Dean and Van Citters (*PASP*, **82**, 924) have compared the spectrum with that of Z And in the 5700–7300 Å region, and Andrillat has also studied the near infrared (C. *R. Paris*, **270B**, 1066). Hutchings and Redman (*PASP*, **84**, 240) have measured both the emission lines and the M3 III spectrum in AG Peg, and confirmed that the 800-day velocity cycle is still detectable. The symbiotic variable V 2905 Sgr (= AS 299, MHα 208-92) was unusually bright in mid-1971 (Hoffleit, *IAUC* 2354). Spectroscopic observations were made by Ciatti (*IAUC* 2359) and by Herbig. The Lick spectrogram showed only small changes compared to a low-dispersion plate of 1961.

The spectral and light variations of the peculiar high-luminosity Aeq variable S Dor between 1948 and 1970 have been described by Alexander and Thackeray (*Obs.*, **91**, 25). The [Fe II]/Fe II ratio changes along with the light, and some form of extinction is involved although the star is apparently not a 40-year eclipsing binary, as once suspected. The somewhat similar spectra of the P Cyg-type stars AG and HR Car have been described by Bond and Landolt (*PASP*, **82**, 313), Caputo and Viotti (*AA*, **7**, 266), Humphreys (*PASP*, **82**, 1161), and Viotti (*PASP*, **83**, 1970).

6. *Novae and Be stars*

During the triennium, two spectacular and unexpected discoveries about novae were made. First, the detection at radio wavelengths of Nova (HR) Del 1967 and Nova (FH) Ser 1970 by Wade and Hjellming (*ApJ*, **162**, L1; **163**, L65), and of Nova (V 368) Sct 1970 by Herrero *et al.* (*ApJ*, **166**, L19). Second, the discovery of strong infrared ($> 2\ \mu$) excesses in novae, particularly Nova (FH) Ser 1970, by Geisel *et al.* (*ApJ*, **161**, L101). It seems fair to say that the significance of these results has not as yet been expoited, or even fully appreciated. Most of the spectroscopic work on novae published in 1970–72 has been of a more conventional nature.

Friedjung (*AA*, **14**, 440) has considered the ionization and excitation processes in a thick, continuously-ejected envelope in order to explain the 'principal' absorption spectra of typical novae. Antipova (*AJUSSR*, **48**, 288) has considered various mechanisms for Balmer absorption line production in the early spectrum of Nova (DQ) Her 1934, and how the structure of the ejected envelope may be inferred from these results. Hutchings (*MN*, **158**, 177; *Pub. DAO Victoria*, **13**, 397) has fitted observed emission-line profiles in several novae to a picture of non-spherically-symmetric ejection from one component of a close binary, always assuming that the envelope is transparent. Gorbatski (*AJUSSR*, 4942) has investigated the production of coronal lines by shock excitation of old circumstellar gas by newly-ejected material.

The structure and radial velocities of the displaced absorption components in *Nova* (V 533) *Her* 1963 have been studied by Friedjung (*AA*, **14**, 246) and by Tremko (*AA*, **8**, 381). Doroshenko *et al.* (*AJUSSR*, **47**, 1153) have determined the parameters of the ejected shell by spectrophotometry of the Balmer and forbidden lines on spectrograms taken about 3 years following maximum.

The spectrum of the slow *Nova* (*HR*) *Del 1967* has been the subject of many papers. The most extensive material published so far is that of Hutchings (*Pub. DAO Victoria*, **13**, 347) extending from discovery to the nebular stage mostly at disperions 10, 15, 40 Å/mm. Friedjung and Malakpur (*AA*, **18**, 310) studied the profiles of the narrow, shortward-displaced metallic lines present before maximum in an effort to determine the mode of line formation. Galeotti and Pasinetti (*Mem SAI*, **41**, 47) investigated the development of the spectrum through 1968 at 35 Å/mm, and Seitter (Bamberg, p. 268) used line profiles determined at 29 to 136 Å/mm in 1968–70 to estimate the structure and physical conditions within the envelope. Ivanova (*Soob. Biurakan*, **43**, 18) measured the change in energy distribution of the continuum in 1967–8. Andrillat and Houziaux have studied the evolution of the emission spectrum in the red and near infrared, with special attention to nebular and coronal lines, from 1968 through 1970 (*AA*, **6**, 36; **9**, 410; **13**, 100).

Nova (*FH*) *Ser 1970* is of considerable interest because of its infrared excess (see above). Hutchings *et al.* (*Pub. DAO Victoria*, **14**, 17) have described the spectral activity for the 2 months following discovery, as observed at 6.5 to 40 Å/mm; Grygar and Hutchings (*PASP*, **83**, 15) discussed the subsequent transition phase on 15 Å/mm spectrograms of the same series. Burkhead *et al.* (*PASP*, **83**, 558) observed the maximum and early decline at 130 Å/mm, as did Walborn (*PASP*, **83**, 813) at 84 Å/mm. Andersen *et al.* (*PASP*, **83**, 5) followed the nova from early decline to the nebular stage at 40, 60, and 320 Å/mm, and Borra (*PASP*, **83**, 447) described 320 Å/mm spectrograms of the nebular stage. Wagner *et al.* (*ApJ*, **165**, 431) reported spectrophotometry of the continuum near maximum, and Gehlich *et al.* (*IBVS* 428) described the early spectrum as observed at 70 Å/mm.

Apparently the only published spectroscopic observation of *Nova* (V 1330) *Cyg 1970* is the very brief description by Ciatti *et al.* (*IAUC* 2257). Short descriptions of the spectrum of *Nova* (V 1229) *Aql 1970* by Cowley (*IAUC* 2237), Stienon (*IAUC* 2239), Tsuji *et al.* (*IAUC* 2243), and Rosino (*IAUC* 2245) have appeared, as well as a reproduction and comment by Walborn (*PASP*, **83**, 813) and a report on spectrophotometry near maximum by Grenfell (*PASP*, **83**, 66). *Nova* (*IV*) *Cep 1971* has been studied spectrophotometrically by Bahng (*MN*, **158**, 151); the line spectrum was described by Weitenbeck and Bidelman (*IAUC* 2342), and investigated in some detail by Fehrenbach and Andrillat (*C.R. Paris*, **273B**, 572; **274B**, 1179; *l'Astr.*, **85**, 409). *Nova Men 1970b*, the second nova to appear in the Large Magellanic Cloud in that year, has been observed by Havlen *et al.* (*AA*, **16**,

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404) who find it spectroscopically and photometrically to be a typical fast nova. The spectrum of another LMC nova found by Graham in 1971 February has been observed by Thackeray (*IAUC* 2308). MacConnell (*IBVS* 437) has briefly described the discovery spectrogram of *Nova Men 1970a*, as have Arhipova and Dokuchaeva (*IBVS* 494) for *Nova* (V 3645) *Sgr 1970*. Two low-dispersion spectrograms of the 1967 outburst of *T Pyx* have been reproduced by Landolt (*PASP*, **82**, 86).

Among the Be stars, Hutchins *et al.* (Bamberg, p. 279) have used a TV technique to observe rapid changes in the structure of emission Hα in a number of stars, on a time scale of 1 minute or less. Bahng (*ApJ*, **167**, L75) has, at lower resolution, also found rapid changes in the equivalent widths of Balmer lines over intervals of about 10 minutes. Marlborough (*ApJ*, **163**, 525) has with some success compared observations of the Pleione shell episode of 1938–54 with the theory of the structure and evolution of the circumstellar envelope developed by Limber, although some discrepancies remain. Gobros (*AJUSSR*, **47**, 445) has described the secular changes in structure and intensity of both emission and absorption lines in EW Lac (= HD 217050) over the interval 1951–60, as observed at 35 Å/mm. J. Swings and Allen (*ApJ*, **167**, L41) have discussed the velocity and spectrum of the Be star HD 45677, which is abnormally bright in the infrared; they attribute this excess to circumstellar material. The star's variability has been established by J. and P. Swings (*AA*, **17**, 142).

7. *T Tauri stars and related objects; flare stars*

Herbig and Rao (*ApJ*, **174**, 401) have published a catalogue listing some 323 emission-line objects of the Orion population – i.e., T Tau stars, nebulous Ae and Be stars, etc. – that have been observed with slit spectrographs, and including extensive bibliographic references. Götz and Wenzel and their colleagues have continued their important series of detailed investigations of bright Orion-population stars in which they combine photometric data with spectroscopic information; the results on SV Cep (*MVS*, **5**, 75; **6**, 1, *AN*, **292**, 221) suggest variable extinction by circumstellar material Other stars studied are SU Aur (*MVS*, **5**, 53), T Tau (*ibid.*, **5**, 142), and RY Tau (*ibid.*, **5**, 117). Walker (*ApJ*, **175**, 89) has published an extensive account of his spectroscopic observations of bright-ultraviolet T Tau stars, mostly in the Orion Nebula. He discusses the excess and the longward-displaced H and Ca II absorption components sometimes observed in these spectra in terms of material infall. Observations of near-infrared emission lines in T Tau stars have been reported by Wallerstein (*PASP*, **83**, 77). Götz (*MVS*, **5**, 174) has studied the strength of Hα emission in T Tau stars by differential photometry. Zaitseva (*Astrofiz.*, **7**, 333) has determined spectrophotometrically the continuous energy distributions and emission line intensities in 2 T Tau stars and 4 Ae–Be variables, and Zaitseva and Kolotilov (*Astr Circ USSR*, 699) have followed the variations of the Hα emission profile in 3 of the latter stars. Kuhi (Liège 1969, p. 295) has discussed his photoelectric scanner data on energy distributions, with special attention to the ultraviolet excess and the contribution of emission lines. Strom *et al.* (*ApJ*, **165**, 479; **171**, 267; **173**, 353) have studied a number of Ae, Be stars that appear to be young, and interpreted the data (including 4-color and infrared photometry) in terms of extinction and emission by circumstellar shells.

Of the individual Orion-population objects that have received extensive individual attention, V 1057 Cyg (= Lk Hα 190) is perhaps the most bizarre. A number of authors have discussed the evolution of the spectrum: Welin (*AA*, **12**, 312), Herbig and Harlan (*IBVS* 543), Haro (*IBVS* 565, 714), Schwarz and Snow (*ApJ*, **177**, L85), and Gahm and Welin (*IBVS* 741). The photometry by Mendoza (*ApJ*, **169**, L117), Rieke *et al.* (*PASP*, **84**, 37), and Simon *et al.* (*AA*, **20**, 99) contains a great deal of additional information. The star was formerly a T Tau variable which brightened to V = 9 in late 1969. Since then the spectrum has gradually changed from a peculiar early Aeq type to a late A or early F. There are still clear dissimilarities between the two stars, but it is possible that V 1057 Cyg is undergoing the same phenomenon that struck FU Ori thirty years before.

RW Aur, a very active but relatively conventional T Tau star, has been studied in some detail spectroscopically by Gahm who investigated the rich emission-line spectrum (*ApJ*, **160**, 1117), by Chalonge *et al.* (*Astrofiz.*, **7**, 345) who studied both lines and continuum at somewhat lower resolution, and by Kharadse and Bartaya (*Vistas*, **13**, 257), who summarized their earlier spectrophotometric results. BD $-10°$ 4662 (= FK Sct) was at first believed to be a flare star, but Herbig (*ApJ*, in press) has shown that it is a close binary, both components of which appear to be post-T Tauri, pre-main sequence stars. The peculiar brightline spectrum of Lk Hα-101, the heavily-obscured illuminating star of NGC 1579, has been discussed by Herbig (*ApJ*, **169**, 537); it is rich in ions such as [O II], [Fe II], [Cr II], and contains a number of strong unidentified lines that occur also in η Car. Kazarian and Khachikian (*Astrofiz.*, **8**, 17) have made an extensive study of the spectrum of R Mon and NGC 2261, including measures of both continua and emission lines.

Gershberg has published a very useful book *Flares of Red Dwarf Stars* which is now available in English translation by D. J. Mullan (Armagh, 1971). Gershberg and Shakovskaya (Bamberg, p. 126) have reviewed the spectroscopic material on flare stars, with special attention to the interpretation of the emission lines. Gershberg has also (*Astrofiz.*, **6**, 191) studied the emission lines outside the flares, and interpreted them by comparison with the solar chromosphere. He has also set upper limits on projected rotational velocities of some flare stars from Hα widths (*Izv. Crim.*, **43**, 66) and has observed a slow decay in the Ca II emission of YZ CMi following a large flare (*ibid.*, **45**, in press). Kunkel (*ApJ*, **161**, 503) has also made a comprehensive study of the flare phenomenon, featuring time-resolved low-dispersion spectra; he interpreted the flare spectra as the result of hydrogen recombination with parameters similar to those of solar flares. M. Boyarchuk (*Izv. Crim.*, **46**, in press) has found that the Li abundance in the flare star AD Leo is less than that of the non-variable Barnard's Star.

Eggen and Sandage (*ApJ*, **148**, 911) have discussed the spectrum and light variations of the dMe eclipsing binary and flare star CM Dra (= LP 101-15), which seems to be a similar but somewhat later system than YY Gem, in which flaring has been detected by Moffet and Bopp (*ApJ*, **168**, L117).

8. *X-ray sources, hot subluminous variables, variable nuclei of planetary nebulae*

Changes in the status of optical identifications of stellar X-ray sources can be very rapid. The present summary of spectroscopic work on identifications or candidate stars is likely to become obsolete very soon. References are therefore only to the more recent work wherein earlier results will usually be cited. The "2U" numbers are to the *Uhuru Catalogue of X-ray Sources* (Giacconi *et al.*, 1972).

2U0352 + 30: the bright irregular Bnne variable X Per is the current candidate for the optical identification; the most recent spectroscopic discussion is by Brucato and Kristian (*ApJ*, **173**, L105).

2U0900 − 40: the variable-velocity B0·5 I*b* star HD 77581 has been suggested as the source by Brucato and Kristian (*loc. cit.*), and a single-line 7-day binary orbit has been determined by Hiltner *et al.* (*ApJ*, **175**, L19).

2U1119 − 60 = Cen X-3. There are two peculiar objects near the position: the eclipsing binary LR Cen, with shell characteristics and Hα emission (Bessell, *ApJ*, **175**, L133), and the B5e star Wray 795 (Brucato *et al.*, *ibid.*, **175**, L137). Neither, however, seems to be a convincing identification.

Cen X-4 is a variable X-ray source of somewhat uncertain position. The variable S 5003 Cen = = CoD − 32° 10517 was suggested as the identification by Eggen and Rodgers (*ApJ*, **158**, L111). The spectrum of this star was described more extensively by Feast (*Obs.*, **91**, 112); it shows emission lines of H and the ionized metals, together with a shell absorption spectrum.

2U1617 − 15 = Sco X-1 = V818 Sco. Mook *et al.* (*ApJ*, **163**, L69; **177**, L63) have observed variations in Hα and λ4686 emission strengths, and in the structure of the Balmer lines.

2U1639 − 62. Brucato and Lanning (*IAUC* 2406) have noted that the peculiar emission-line object Henize 177, apparently variable in line intensity, is near the X-ray position.

Sco X-2 is a source of somewhat uncertain position whose possible identification with HD 152667, a B0 Ia spectroscopic binary ($P = 7^d.8$), has been discussed by Walker; he has also analysed the system thoroughly (*MN*, **152**, 333; **159**, 253).

2U1705 + 34. The identification with HZ Her is discussed by Davidsen *et al.* (*ApJ*, **177**, L97) and others, but the peculiar optical spectrum of HZ Her is described also in a series of preliminary

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notes by Bopp *et al.* (*IAUC* 2424 and 2434), Crampton and Morbey (*ibid.*, 2428), and Koo (*ibid.*, 2441); the consensus seems to be that the absorption spectrum is that of a B or A star, apparently with He II λ4686 and perhaps other high-excitation emission lines of variable intensity.

2U1744 − 26 = GX3 + 1. Rodgers (*Nature*, **237**, 273) has examined the spectra of several candidates for an optical identification, but finds none to be persuasive.

2U1956 + 35 = Cyg X-1: the identification with HD 226868 = BD + 34° 3815 seems secure. The star is a B0 Ib single-line binary with a period of 5·6 days (Webster and Murdin: *Nature*, **235**, 37; Bolton, *ibid.*, **235**, 271). A secondary component has been detected viz emission He II λ4686 by Brucato and Kristian (*IAUC* 2421) and by Bolton (*IAUC* 2424).

2U2030 + 40 = Cyg X-3. Bolton considers the double-line A0 spectroscopic binary BD + 40° 4218 to be an unlikely candidate for the identification (*IAUC* 2424).

2U2142 + 38 = Cyg X-2. Bopp and van den Bout (*PASP*, **84**, 68) have found emission C III + + N III λ4650 of variable intensity.

The spectra of hot subluminous binaries in which one component is an eruptive U Gem variable have been discussed by Walker (Bamberg, p. 243). A careful spectrophotometric study of SS Cyg has been presented by Kharadse and Bartaya (*Vistas*, **13**, 257). The spectrum of the rapid eclipsing binary G61–29, featuring strong emission lines of He I, has been described by Burbidge and Strittmatter (*ApJ*, **170**, L39). Irvine (*PASP*, **84**, 671) has discussed the spectrum (G5eα) of the erratic variable EZ Peg, and suggests that it may be a U Gem star.

The spectrum of FG Sge, which has halted the steady brightening that has been underway since early in the century, is under intensive study by Maffei and by Kraft and Langer. The spectrum has become exceedingly complex and peculiar in recent years, and now features ions such as Zr II and other *s*-process elements in great strength. Herbig and Flannery have observed the doubling of the emission lines in the planetary nebula-like envelope around FG Sge, and find a well-determined expansion velocity near 35 km/sec, which is entirely normal for planetaries. Miller (*Bull. AAS*, **4**, II, 290) has suggested that the central star of the peculiar emission nebula Sharpless 71 may be an object like FG Sge.

APPENDIX IV

REPORT OF THE WORKING GROUP ON FLARE STARS

(a) *Participants*: The remarkable feature of the last three years is the increase in the number of observatories where the photoelectric technique is used for systematic monitoring of the solar neighbourhood red dwarf stars. These observations are carried out in the course of cooperative programmes on several well known flare stars as well as for a number of unstudied or little studied red dwarf stars.

The following investigators have continued the observations with photoelectric photometers: Godoli, Christaldi and Rodono at the Catania Observatory (91-cm reflector with B filter and 61-cm reflector used for simultaneous *UBV* observations); Osawa, Ichimura, Noguchi and Watanabe at the Okayama Station of the Tokyo Astronomical Observatory (91-cm reflector and either B or simultaneously *UBV*); Jarrett and Eksteen at the Boyden Observatory (40-cm reflector and B filter); Kunkel at the Cerro Tololo Observatory (16-inch or 36-inch reflectors, U-band); Oskanian at the Byurakan Observatory (50-cm reflector, B filter); Herr at the Mount Cuba Observatory, University of Delaware (61-cm reflector and either U or narrow-band ultra-violet filters); Chugainov and Shakhovskaya at the Crimean Observatory (64-cm meniscus telescope, B filter); Szeidl and his collaborators at the Konkoly Observatory (24-inch telescope, B filter).

Visual observing of flare stars by the Variable Star Section, Royal Astronomical Society of New Zealand has largely been discontinued because of its inherent drawbacks. Photoelectric minitoring is carried out at the Auckland Observatory and some results have appeared.

Mavridis and his collaborators have started a systematic series of photoelectric observations of selected flare stars using the 30-inch reflector of University of Thessaloniki installed at Stephanion