FIFTY YEARS OF SYMBIOTIC STARS

Jorge Sahade
Instituto de Astronomía y Física del Espacio,
Buenos Aires, Argentina
Member of the Carrera del Investigador Científico,
CONICET, Argentina

Fifty years ago, Merrill and Humason wrote a note that was published the following year in the Publications of the Astronomical Society of the Pacific (Merrill and Humason, 1932), where they called attention to the existence of a group of stars –a very small group, then, with only AX Persei, RW Hydrae and CI Cygni, and "possibly" T Coronae Borealis and R Aquarii as members– characterized by the fact that their spectra display titanium oxide absorption bands together with emissions of He II 4686, [O III] 4363 and other nebular lines. The stars in the group were later called "symbiotic stars" by Merrill, on the ocassion of a paper on BF Cygni that he presented before the American Astronomical Society in 1941 (cf. Merrill, 1958), and their spectra were described, also by Merrill, as "combination spectra".

IAU Colloquium No. 70 comes, therefore, at the right time to celebrate such a significant anniversary in the investigation of symbiotic stars. These have been dealt with in a number of colloquia and symposia, but always as a chapter of a more general subject, and this meeting is the first one ever devoted exclusively to discuss them. Consequently, it provides an unvaluable opportunity to assess our present knowledge in the field and its implications and to plan lines for future research. We already have available a large amount of information over a wide wavelength range and, in addition, the space astronomical observations have opened up new possibilities of understanding phenomena connected with the structure of extended envelopes in stars. So, an exchange of ideas and discussions on the problematics of symbiotic stars at this time should prove to be most useful and to have far-reaching effects in our understanding of the symbiotic stars.

Z Andromedae has been always considered to be the prototype of the group because it was the first member whose spectrum was studied in detail. Such a study was undertaken by H.H. Plaskett (1928) at the Dominion Astrophysical Observatory, Victoria, Canada, and published in 1928. Plaskett identified the high excitation lines and concluded that the spectrum originates in an extended atmosphere where the pressure is lower than that of the solar chromosphere. A few years later, Mer-

M. Friedjung and R. Viotti (eds.), The Nature of Symbiotic Stars, 1–9.

https://doi.org/10.1017/S0252921100097360 Published online by Cambridge University Press

rill detected, on Plaskett's prints, the molecular (TiO) absorption bands.

The remark by Merrill and Humason led Merrill to start a series of investigations (Merrill, 1932, 1933, 1934, 1941, 1943, 1944, 1947, 1948, 1950a, 1950b) aimed at gathering information on the spectral and radial velocity behavior of a number of symbiotic stars. Merrill's pioneering work on the field, which was done at the Mount Wilson Observatory over a period of several years, has provided much of our knowledge on the spectral changes that symbiotic stars undergo in parallel with changes in their brightness, and has yielded the picture of the broad correlation between light and spectrum that has been stated as follows,

when the star is faint, a giant M spectrum is prominent;

when the star brightens, an early type shell spectrum develops and the continuum dominates the photographic region and covers the M-type spectrum;

when the star declines in brightness, the shell spectrum weakens and emission lines of progressively increasing excitation and forbidden lines develop.

In connection with the light variability of symbiotic stars we should recall that the photometric work done at Harvard suggested that the symbiotic objects are semiregular, long period variables with periods of the order of one to two years. The names of Mrs. Fleming, the Gaposchkins and Mrs. Mayall, among others, are associated with Harvard important published photometric results.

The coming into being of the McDonald Observatory in 1939 with a quartz prism spectrograph attached to the 208-cm reflecting telescope, that permitted the extension of our knowledge of the spectrum farther into the violet than hitherto possible, gave rise to a series of papers by Swings and Struve that were produced in the early 40's and were devoted to the study of peculiar stars. In these investigations we find a large and valuable contribution to the field of symbiotic stars.

It is interesting to quote from the 1940-41 Annual Report of the Yerkes Observatory the following paragraph that states the reasons underlying Swings and Struve's series of papers on peculiar stars (Swings and Struve, 1935, 1940, 1941a, 1941b, 1942a, 1942b, 1943a, 1943b, 1945; Struve, 1940). In that report, Struve (1942) wrote that "one of the pressing problems of astrophysics is to explain the origin and support of extensive gaseous envelopes surrounding otherwise normal stars. This problem is related to that of supporting the solar chromosphere, and its solution is required before we can be certain that we fully understand the structure and the physical properties of the outer layers of a star".

On the other hand, to Merrill (1958) "these bizarre objects present challenging problems. In addition to their intrinsic interest as peculiar individuals, there is another reason for studying them. The apparently anomalous phenomena which are so conspicuous and so easily open to study in these stars may perhaps be exaggerated or pathological examples of features, which, scarcely noticed, occur in a minor degree in many other stars. Symbiotic stars may thus be strategic objects in which to study phenomena actually of fairly common occurrence. For example, it is possible that studies of symbiotic stars may eventually extend our comprehension of phenomena in normal dwarf stars of type G, e.g., the sun with its mysterious corona".

So, Merrill, as well as Swings and Struve, were attracted by the symbiotic objects not only because these stars were so peculiar in their spectrum, but largely because it was hoped that their study would throw light upon the problems of extended atmospheres in stars. And there is no need to stress again how greatly the three scientists have contributed to our knowledge of the symbiotic stars in the photographic region.

Now a crucial question comes up, namely, which are the criteria that would permit us to decide whether or not an object is a symbiotic star. Originally, Merrill's designation was supposed to single out a group of objects characterized, as we have already said, by the combination, in their spectra, of features of a low temperature object with features that require high excitation conditions. This characterization was certainly not enough because it led to non-homogeneous lists of objects when attempts to produce catalogues of symbiotic stars were made.

In a review paper, Boyarchuk (1969) suggested that an additional criterium be added, namely, that the brightness of the object be variable with an amplitude up to 3 magnitudes and with a period of several years; furthermore, he pointed out that the late-type component should actually be an M giant. Boyarchuk's criterium would leave out recurrent novae such as RS Ophiuchi and slow novae like RR Telescopii, which are generally considered to belong to the group.

The degree of excitation in the extended envelope reaches, in some of the objects, a level that is reminiscent of that of the solar corona. For instance, [Fe XIV] and [A XI] have been observed in RS Oph and in T CrB, while [K XI], [Ca XIII] and [Ni XV] were found in RS Oph. In other objects, however, the excitation reaches much lower levels and one detects lines of [Fe III], [O III] and [Ne III] for instance.

More recently, Allen (1979) has suggested that the criteria for membership be stated as follows: 1) The object must appear stellar; 2a) Emission from ions of greater than 55 eV ionization potential (i.e. He II emission) must at some time have been present; evidence for stellar spectral type G or later must also exist; 2b) In the absence of convincing evidence of a late-type star, the ionization potential represented must at some time have exceeded 100 eV (e.g. [Fe VII] emission).

https://doi.org/10.1017/S0252921100097360 Published online by Cambridge University Press

We need to analyze and discuss thoroughly the criteria that define the symbiotic stars. Then, we will be able to decide whether or not stars like WY Velorum or 17 Leporis or AX Monocerotis, which until rather recently were considered as symbiotic objects, or, as a matter of fact, any other star, actually do belong to the group.

The first catalogue of symbiotic stars, or stars with combination spectra, was a short list included as Table II in Merrill and Burwell's (1933) Catalogue of Be and Ae Stars. Further cataloguing attempts were later due to Bidelman (1954), Payne-Gaposchkin (1957), Boyarchuk (1969), Wackerling (1970) and Allen (1979); the latter list containing 115 entries, 3 of them, Magellanic Cloud objects.

Among the catalogued objects we find recurrent novae like T CrB and RS Oph, definitely binary systems like those in Table 1, taken from Sahade and Wood's (1978) book on interacting binaries, and slow novae like RR Tel, V1016 Cygni, RT Serpentis and HM Sagittae.

Table 1
Symbiotic Stars that are Binary Systems

Star	Period (days)	Spectrum	f(m)
17 Leporis	260	M1 III + B9	0.24
AX Monocerotis	232	gK + B3nn	3.0
T Coronae Borealis	230	M3 III + sd Be	
AR Pavonis	605	M3 III + sd	
AG Pegasi	820	M3 III + ...	0.014

As far back as in 1934, Hogg (1934) suggested that in symbiotic objects we are dealing with binary systems that combine "normal, possibly somewhat variable M giant, and a variable, very high temperature dwarf of the visual magnitude of about +2, which excites a nebular envelope... fainter than normal planetaries". This interpretation is the most generally accepted one and places the group within the evolutionary framework of close pairs (Plavec, 1973; Paczyński and Rudak, 1980). At any rate, since all novae are close binary systems (cf. Sahade and Wood, 1978), it would seem that, to the objects in Table 1, we should add the slow novae and the recurrent novae that are symbiotic objects.

The observations of AR Pavonis that were worked out by Thackeray and Hutchings (1974) suggested that the M star fills its Roche lobe and that there is a stream of matter flowing towards the hot member of the pair. This picture is in line with what we know about mass outflow in interacting binaries but is at variance with Hutchings, Cowley and Redman's (1975) model for AG Pegasi. The picture for AR Pav also agrees with the one advanced by Kuiper (1940, 1941) when he proposed his theoretical interpretation of β Lyrae and pointed out that T CrB, Z And, AX Per, CI Cyg, WY Geminorum probably are cases of instability at the La-

https://doi.org/10.1017/S0252921100097360 Published online by Cambridge University Press

grangian point L_1 of binaries that combine "a giant extending up to L_1, and a dwarf".

If the close binary interpretation of symbiotic stars would hold, then these would represent a certain stage in the evolution of a particular group of double stars and such a stage would be characterized by the particular combination of objects that we have already mentioned. The interaction of these components would give rise to outbursts and to the spectral changes that are observed. Boyarchuk (1966, 1967) tried to assign some figures to the model by attempting to reproduce the spectrum of Z And at different times and concluded that the three sources that contribute to the continuous spectrum are an M giant, a hot companion with a temperature of the order of 10^5 K and a nebula characterized by an excitation temperature of some 17000° and an electron density of $n_e \gtrsim 10^6$ cm^{-3}. Boyarchuk also showed that the hot component is responsible for the very large variation in brightness of Z And, and that the companions to the M giants in symbiotic stars should be located below the main sequence in the HR diagram.

IUE observations of symbiotic stars (cf. Sahade and Brandi, 1981) have been partly planned so as to ascertain whether the ultraviolet spectra would confirm or disprove the notion that all symbiotic stars are binaries. So far, the results seem to confirm that we are dealing with binary systems.

One of the symbiotic slow nova objects that have been more thoroughly followed in their behavior as a nova, is RR Tel. Thackeray has published several papers (Thackeray, 1950, 1953, 1955, 1959, 1977; Thackeray and Webster, 1974) and also reproductions of spectra that depict the changes since its outburst in 1946. At the Córdoba Observatory, Landi Dessy and myself have also collected a large amount of material of RR Tel that starts at about the same time as Thackeray's observations. We have, then, available the most valuable set of spectrograms that describe the evolution of a slow nova spectrum that results from the interaction of the two components of the binary system.

Another problem that has been considered since an early date refers to the kind of objects that result from the evolution of the symbiotic stars. Several astronomers have, at one time or the other, suggested that symbiotic stars develop into planetary nebulae. The rationale for the idea lies in the fact that the observations suggest, as we have already mentioned, that there is a sort of a nebula associated with the object or objects (cf. Aller, 1954; Boyarchuk, 1969) and because there are cases which seem to be intermediate between a symbiotic star and a planetary nebula. As we pointed out (Sahade, 1976), to investigate the possibility of the symbiotic stars turning into planetary nebulae "imply to investigate the nature of the central stars of the latter objects". And this field, about ten years old, is not easy because we are then dealing with faint objects; at any rate, information is being slowly gathered and, eventually, we may be able to step on more solid ground regarding this subject.

A few papers have proposed, on different basis, that the symbiotic stars can be sorted out in two different groups. Thus,

Ilovaisky and Wallerstein (1968) suggest two groups depending on whether the excitation of the emission spectrum arises in shock dissipation or in the radiation field;

Webster and Allen (1975) [see also Allen, 1979] find objects with infrared excess that suggests the presence of hot circumstellar dust clouds, and objects without dust emission; moreover,

Sahade and Brandi (1981) have proposed two groups based on the characteristics of the far ultraviolet spectrum: those that display strong emissions of highly ionized species would be in one group, and those that show only very few or no emissions would be in a second group.

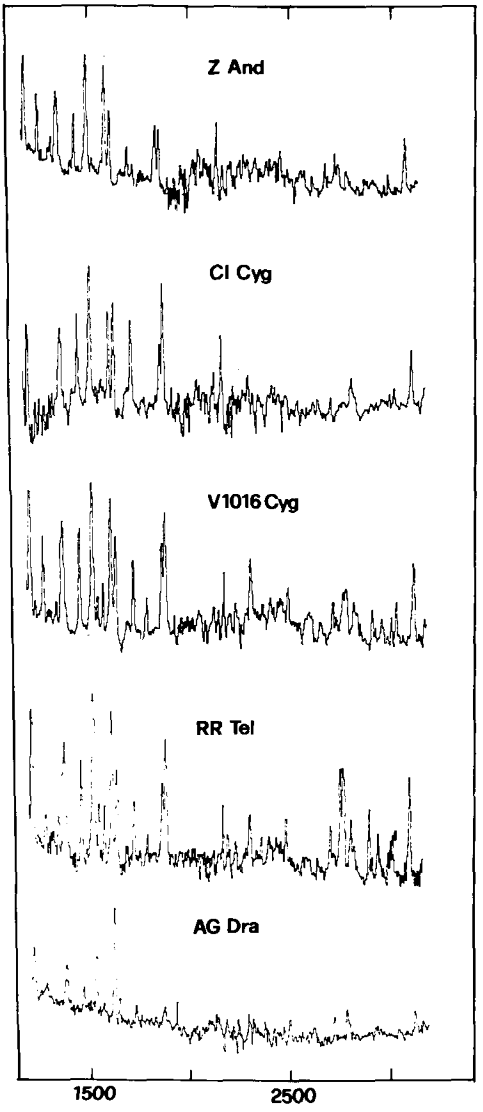
Finally, Paczyński and Rudak (1980) have discussed, on the assumption that all of them are binaries, two types of symbiotic stars, in the framework of binary star evolution: type I would correspond to the cases where "the luminosity is produced in a stably burning hydrogen shell", and type II would correspond to the cases where "hydrogen burning proceeds through shell flashes".

The thing is that there is no one-to-one correlation between the groups of the different proposals or suggestions. So, perhaps the apparent observational groupings result from phase effects or perhaps there is no physical connection whatsoever between the criteria used for the classifications. This is another point that may become clarified with further observations at different phases in the spectral evolution of the objects.

I should like to finish this introduction by pointing out the change in the attitude of the astronomers towards the symbiotic stars which is most illustrative of how trends change in Astronomy. When the existence of the group was brought out, its members were considered very bizarre objects, difficult to handle and to understand properly. The contributions by Merrill, Swings and Struve were very important to open up the field and build up information and were complemented by those of other scientists like Mao Lin and Marie Bloch, who observed at Haute Provence, and many others, particularly A.D. Thackeray, in South Africa, and A.A. Boyarchuk, in the Soviet Union.

Research on the symbiotic stars acquired new impetus when it was thought that they could be understood in terms of close binary evolution. But still when the first proposals for the IUE were evaluated, the only proposal for observing the symbiotic stars that was submitted deserved a second category qualification. However, before the first IUE observing runs were over, the proposals containing symbiotic objects

https://doi.org/10.1017/S0252921100097360 Published online by Cambridge University Press



The low resolution ultraviolet spectra of selected symbiotic stars obtained with the International Ultraviolet Explorer (IUE).
Log of dereddened fluxes are given according to E(B-V) = 0.35 (Z And), 0.40 (CI Cyg), 0.28 (V1016 Cyg), 0.10 (RR Tel), and 0.06 (AG Dra).
The spectrum of CI Cyg was obtained in August 1980 just after eclipse.
AG Dra was observed in June 1979 during a minimum phase.
(Courtesy of Angelo Cassatella).

began pouring in and now the number of images that have been secured is amazingly large.

So, it would seem that we are now entering a new era in the investigation of symbiotic stars and IAU Colloquium No. 70 will undoubtedly be instrumental in suggesting the pathways to follow for the writing of the new chapter, fifty years after our group of objects was brought to the limelight.

REFERENCES

Allen, D.A. 1979, Changing Trends in Variable Star Research, eds. F.M. Bateson, J. Smak and I.H. Urch (Hamilton, New Zealand: U. of Waikoto), p.
Aller, L.H. 1954, Pub. Dominion Astrophys. Obs. Victoria 9, 321.
Bidelman, W.P. 1954, Astrophys. J. Suppl. 1, 175.
Boyarchuk, A.A. 1966, Astr. Zu. 43, 976.
Boyarchuk, A.A. 1967, Astr. Zu. 44, 12.
Boyarchuk, A.A. 1969, Non-Periodic Phenomena in Variable Stars, ed. L. Detre (Budapest: Academic Press), p. 395.
Hogg, F.S. 1934, Pub. American Astron. Soc. 8, 14.
Hutchings, J.B., Cowley, A.P. and Redman, R.O. 1975, Astrophys. J. 201, 404.
Ilovaisky, S.A. and Wallerstein, G. 1968, Pub. Astron. Soc. Pacific 80, 155.
Kuiper, G.P. 1940, Pub. American Astron. Soc. 10, 57.
Kuiper, G.P. 1941, Astrophys. J. 93, 133.
Merrill, P.W. 1932, Astrophys. J. 75, 413.
Merrill, P.W. 1933, Astrophys. J. 77, 44.
Merrill, P.W. 1934, Astrophys. J. 81, 312.
Merrill, P.W. 1941, Pub. Astron. Soc. Pacific 53, 121.
Merrill, P.W. 1943, Astrophys. J. 98, 336.
Merrill, P.W. 1944, Astrophys. J. 99, 15.
Merrill, P.W. 1947, Astrophys. J. 105, 120.
Merrill, P.W. 1948, Astrophys. J. 107, 317.
Merrill, P.W. 1950a, Astrophys. J. 111, 484.
Merrill, P.W. 1950b, Astrophys. J. 112, 514.
Merrill, P.W. 1958, Étoiles à raies d'émission (Cointe-Sclessin: Institut d'Astrophysique), p. 436.
Merrill, P.W. and Burwell, C.G. 1933, Astrophys. J. 78, 87.
Merrill, P.W. and Humason, M.L. 1932, Pub. Astron. Soc. Pacific 44, 56.
Paczyński, B. and Rudak, B. 1980, Astron. Astrophys. 82, 349.
Payne-Gaposchkin, C. 1957, Galactic Novae, eds. J.H. Oort, M.G. Minnaert and H.C. van de Hulst (Amsterdam: North-Holland Pub. Co.).
Plaskett, H.H. 1928, Dominion Astrophys. Obs. Victoria 4, 119.
Plavec, M. 1973, Extended Atmospheres and Circumstellar Matter in Spectroscopic Binary Systems, ed. A.H. Batten (Dordrecht: Reidel), p. 216.
Sahade, J. 1976, Mém. Soc. R. Sci. Liège, 6e série, 9, 303.

https://doi.org/10.1017/S0252921100097360 Published online by Cambridge University Press

Sahade, J. and Brandi, E. 1981, The Universe at Ultraviolet Wavelengths, ed. R.D. Chapman (NASA CP-2171), p. 451.
Sahade, J. and Wood, F.B. 1978, Interacting Binary Stars (Pergamon Press), p. 114.
Struve, O. 1940, Proc. Nat. Ac. Sci. 26, 458.
Struve, O. 1942, Pub. American Astron. Soc. 10, 201.
Swings, P. and Struve, O. 1935, Astrophys. J. 71, 312.
Swings, P. and Struve, O. 1940, Astrophys. J. 91, 546.
Swings, P. and Struve, O. 1941a, Astrophys. J. 93, 356.
Swings, P. and Struve, O. 1941b, Astrophys. J. 94, 291.
Swings, P. and Struve, O. 1942a, Astrophys. J. 95, 152.
Swings, P. and Struve, O. 1942b, Astrophys. J. 96, 257.
Swings, P. and Struve, O. 1943a, Astrophys. J. 97, 194.
Swings, P. and Struve, O. 1943b, Astrophys. J. 98, 91.
Swings, P. and Struve, O. 1945, Astrophys. J. 101, 224.
Thackeray, A.D. 1950, Mon. Not. R. Astron. Soc. 110, 45.
Thackeray, A.D. 1953, Mon. Not. R. Astron. Soc. 113, 211.
Thackeray, A.D. 1955, Mon. Not. R. Astron. Soc. 115, 236.
Thackeray, A.D. 1959, Observatory 79, 11.
Thackeray, A.D. 1977, Mem. R. Astron. Soc. 83, 1.
Thackeray, A.D. and Hutchings, J.B. 1974, Mon. Not. R. Astron. Soc. 167, 319.
Thackeray, A.D. and Webster, B.L. 1974, Mon. Not. R. Astron. Soc. 168, 101.
Wackerling, L.R. 1970, Mem. R. Astron. Soc. 73, 153.
Webster, B.L. and Allen, D.A. 1975, Mon. Not. R. Astron. Soc. 171, 171.