CONCLUDING REMARKS

J.P. Swings
Institut d'Astrophysique, Université de Liège, Belgium

What have we been talking about during the last three days? According to Boyarchuk and Plavec, it is a small class of celestial sources: old disk population objects, just like planetary nebulae. Their number in catalogs has increased from 21 (Boyarchuk's compilation) to about 100 (Allen's catalog(s)), and possibly newer catalogs could contain up to 10^3 members: this is still debatable, however, due to uncertainties on distance estimates. But, in any case, we have been considering a wide, and wild, series of targets, and if we wish to give the oath of ignorance Nussbaumer mentioned, we can get as big a number we wish: so let's leave this meeting with the impression that we tackled a vital astrophysical problem.

How can we define "Symbiotic Stars"? We are getting into deep water right away, but maybe we can try to agree on a few characteristics:

- presence of high excitation emission lines;
- presence of low temperature absorption features (even if they are not really seen!);
- presence of very inhomogeneous regions (gas and/or dust; optically thin and/or optically thick);
- conspicuous variations in the spectrum and in the light curve (stressed by several of you, Boyarchuk, Ciatti, Viotti, etc.; see types I and II of Paczynski and Rudak, mentioned again by Fiederova and by Boyarchuk e.g.), sometimes quiescent phases, smooth variations (with or without periodicity, depending on the wavelength region we are observing at), erratic variations, flickerings, i.e. just about any variability between very rapid changes (5 min or so) to periods of several hundred days, and up to 35 years. Of course, objects such as spectroscopic binaries with true eclipses ought to be easier to tackle on the theoretical side, and in that respect an object like AR Pav, as mentioned by Slovak, is a good candidate for more study;

M. Friedjung and R. Viotti (eds.), The Nature of Symbiotic Stars, 297–302.

- from IR data (see Allen's report, and references therein), there are at least two classes of symbiotics: S-type (75%; cool star colors in the 1-4 μ region), and D-type (20-25%; dust at T $\lesssim$ 800-1000°K), and perhaps a third class, D', containing hotter stars (G-type e.g.) with much cooler dust. In addition, the IR variability leads Whitelock to define two classes, those objects with large amplitude (Mira-type), and those with small amplitude (normal late-type giants).

One thing is at least certain: we have added a lot to our knowledge, and/or to our confusion, by going to wavelength regions outside the visible: I shall try below to point out a few essential characteristics thus deduced for symbiotic stars.

a) The near infrared may give us the spectral type of the cool component, and is therefore very useful for classification purposes, as noted by Andrillat. It may also distinguish between objects of two types: those with poor and those with rich nebular spectra.

b) The infrared data and classes (S, D,D') correlate with dust temperature and variability, and give us very interesting knowledge of the presence of Mira variables (with periods such as 176, 387, 431, 580 days quoted by Whitelock).

c) The radio, where only about 10% of the objects are yet detected, probes different regions, and the power law index gives us some clue as to whether the object has an expanding shell, a wind or comes from a nova; I personally find fascinating the results obtained by V.L.A. techniques, e.g. the asymmetric structure + halo of V1016 Cyg and HM Sge that were reported by Kwok.

d) The ultraviolet data can be used at least in two ways:

(i) the first one is to know the continuum of the hot component, and in combination to visible and IR data, to deconvolve the energy curves and get the composition of the binary structure, such as B0 + M2 giant, as shown by Slovak and others; there may still remain a problem as to whether one deduces the true temperature of the star, or that of a disk: one has also to be sure not to try to extrapolate things too far from a very small wavelength region (Viotti, Keyes, Cassatella...).

(ii) the second is to use the lines in order to perform a diagnosis of densities, temperatures, extinction, abundances, and also, very interestingly, of the dimensions of some emitting regions: if the parameters are well known, models may be then derived. These lines analysis have been shown here by Nussbaumer and Kafatos e.g. One has to remain very careful, however, in applying the curves giving e.g. N_e or T_e from intensity ratios, and make sure that one is not trying to achieve an unreasonable accuracy, but essentially obtain ranges of values; or that one is really using the right lines for the right zones and for deducing the appropriate astrophysical parameters in the sort of nebula surrounding the objects we have been talking about. The International Ultraviolet Explorer has obviously made a major breakthrough in our observations (if not knowledge) of symbiotics, and almost all the objects we considered at length in the sessions on individual stars have been repeatedly observed with that satellite. It is clear, however, that IUE does not solve all the problems, and, as pointed out by Plavec, that data in the 900-1200 A are badly needed in order to convincingly get to know the nature of the hot component.

e) the X-ray (i.e. from the Einstein satellite) is of course the new domain, and we heard from Oliversen on the result of Anderson et al. on AG Dra (and their conclusion on the presence of a white dwarf or a very small compact object), and on the survey by Allen. The latter found only three objects with X-ray fluxes, and these turn out to be three objects that suffered slow-nova outburst(s): HM Sge, V1016 Cyg, RR Tel listed here in order of decreasing flux, also in order of increasing coolness, also in a normal sequence if one simply looks at the epoch of the (last) outburst (if an e-folding time really exists). It is also very interesting to note that the X-ray emission may come from the interacting winds' region in the models developed by Kwok.

f) So far I said nothing concerning visible data, although we heard an interesting review by Ciatti (insisting on the fact that symbiotics are variable, telling us about typical evolution of these stars, warning us about the use of radial velocity curves to deduce without any doubt that the objects are binaries, saying that the "flickering" I mentioned earlier is not necessary characteristic of symbiotics, mentioning that the λ 6830 feature still remains unidentified,...). This fac
This was followed by Oliversen's report on H_α observations of a series of stars to which we (i.e. Mrs. Andrillat and I) have added that protoplanetaries, B[e] s, variables and symbiotics had been observed in the same region in order to "test" the interacting winds theory for the formation of planetary nebulae.

If we now try to define symbiotic stars on the basis of Boyarchuk's talk and the discussion that followed, I guess we can take two approaches and say:

1 - A symbiotic star is a composite object, that suffers cyclic variations, and that looks like a planetary nebula in the UV and like a late-type giant in the IR (Houziaux);

or try to be a bit more specific, and say:

https://doi.org/10.1017/S0252921100097864 Published online by Cambridge University Press

2 – A symbiotic star in its quiescent phase comprises:
- the G-band, or absorption bands of TiO, H_2O, CO,..., and
- emission lines of HeII, or [NeIII] , or [OIII] , or of higher excitation, and varies on fairly large time scales.

It seems likely that the majority os symbiotic stars are binaries, although the situation is not crystal clear in all cases, as shown by Friedjung's talk and by this morning discussion. A wise word of caution was given by Plavec in the sense that one should not use criteria that are either too large or too narrow, so as not to get completly stuck.

Next, if I come to all the individual stars we discussed yesterday, according to an alphabetical order, so as not to put any bias on false groupings of objects, you will hopefully agree that it is impossible for me to summarize all the data that were thrown at us, although they were necessary to learn about. The objects actually included what several consider as the "prototype" of symbiotics, i.e. Z And, "fashionable" symbiotics (CI Cyg, AG Peg, RR Tel, HBV 475, and its counterpart in the LMC, HD 269227 (WN + M5) to become fashionable?), symbiotics with no forbidden lines in the visible (imagine the faces of Merrill, Struve, Thackeray, etc.!), but fortunately detected in the UV, such as AG Dra, what some of us include in the category of protoplanetary nebulae, like V1016 Cyg and HM Sge, weird beasts like RX Pup, marginal symbiotics such as CH Cyg, less fashionable symbiotics although quite interesting like YY Her, SY Mus, and even a "symbiotic or no symbiotic", in any case a nova, V4049 Sgr, and an object going from an F star to an M star (with [OIII] 5007 emission) to an F star again, PU Vul. I am pretty sure that each of you has his or her pet star, and even if recommendations were made as what star to observe in priority, nobody would agree (except maybe in the case of HBV 475 where an outburst is announced in 1982). I must personally say that I was impressed by the observations (essentially in the UV, but also in the visible) of several objects during eclipse(s), and to learn that e.g. permitted lines could be formed in a wind or in a shock, semi-forbidden lines in a low density envelope surrounding the system and the continuum in an accretion disk, keeping in mind that two very different things were to be considered: the eclipse, and the excitation mechanism(s). Also the fact that when a Mira exists in the systems, it keeps on displaying essentially the same IR light curve, whatever the outbursts in the visible and/or the modification(s) of the visible spectrum may be, is really quite impressive. The UV line profiles, within a same object, such as e.g. AG Peg or RX Pup, or from one to the other, as in the cases of "similar" objects like V1016 Cyg and HM Sge are truly something to try to understand, as well as the changes in the line ratios or the frequent case of CIV where the two components of the doublet at 1550 A have almost exactly the opposite ratio compared to what they "should" have.

The next step is of course to attempt to build models of the symbiotics, although "Nature has not been able of producing simple symbiotics, but only unnecessarily complicated objects" (Plavec dixit). He gave us a very enthousiastic report about how to form natural symbiotics, what he calls "Planetary Nebula" symbiotics, by combining a late giant and a subdwarf. He told us that we needed sources of late-type, of nebular material, and of excitation and ionization. The same ingredients were also considered by Fiederova.
We also heard from Fiederova and from Rudak how the initial conditions in the binary system can be very important to create different types of symbiotics. Rudak showed us for instance that whether or not there existed a formation of a common envelope during the rapid mass transfer phase, one would obtain some types of cataclysmic variables or, maybe, what Plavec called a "cataclysmic symbiotic". The problem of CNO abundances was also stressed and shown to have important consequences on the amount of energy released, i.e. whether the object is a type II symbiotic, a slow nova or a fast nova. I will give you a bit later a recipe about to form your own "pet symbiotic", not to be quoted in astrophysical literature. In any case, Kafatos gave strong arguments in favour of the presence of a hot subdwarf in the system, on the basis of temperatures, radii, gravity, etc. obtained via IUE data, whereas accretion disks don't seem to be the most plausible explanation, although one of them seems to have been observed in AR Pav. In any case, one has to be careful about the temperatures involved, especially since the X-rays that would be expected are not observed.

To end up with a "summary", Recipe 1 tells you how to build up your typical symbiotic star.

In conclusion(1), I do think that more observations are needed: for instance very few polarimetric measurements have been made and many additional ones would probably be of great help in refining some models; more monitoring of interesting targets ought to be performed, in both hemispheres. I thus suggest that we reconvene in, say, 2 or 3 years to discuss all the new data we will have obtained in all spectral regions, as well as to hear, and probably criticize, the new esoteric, and/or exotic, theories that will certainly be imagined in the meanwhile. The cordial welcome we received here, the wheather, ... were so pleasant that I can think of no better meeting place to suggest than the Observatoire de Haute Provence. Thank you.

(1) not delivered at the meeting because, as in cithara concerts in India, the audience applauded afetr Recipe 1, indicating that it had heard enough...!

Recipe 1

HOW TO MAKE YOUR "TYPICAL" SYMBIOTIC STAR

Start with: a hot source
and/or
a cool source
some gas (with abundances within a factor 10 of cosmic abundances)
some dust

Add (according to personal taste)
some: black-body radiation(s); free-free emission; two photon emission; bound-free emission; thermal emission or re-radiation; collisions; chromospheric or coronal activity; line fluorescence;.....
a little wind(s) and/or shock(s)

Mix well; let expansion take place, and, if necessary, the Zanstra temperature become $\gtrsim$ 100 000°K.

Presentation: make sure to distribute the right species onto an accretion disk, and don't worry about hot spots, inhomogeneities, Roche lobe overflows, variations,....

Monitor: line intensities with powerful rheostat

RESULT: Don't call it "SYMBIOTIC"

that's "ignorance"

but: observe it as often as possible
in X-ray, UV, visible, IR, radio...

https://doi.org/10.1017/S0252921100097864 Published online by Cambridge University Press