Absolute Energy Distributions for Selected Quiescent Symbiotic Stars

M. H. Slovak and A. D. Code
Washburn Observatory
University of Wisconsin, Madison, Wisconsin, USA

ABSTRACT. Absolute continuum energy distributions for 1200 A to 100μ have been derived for eight quiescent symbiotics. These data are a combination of contemporaneous satellite and ground-based observations, including low resolution **IUE** and optical spectrophotometry, broadband **JKLM** infrared photometry and **IRAS** Point Source Catalogue fluxes. The resulting multifrequency energy distributions represent a merged, uniformly calibrated set of observations and provide a unique opportunity for comparison with quiescent theoretical models.

1. Multifrequency Observations of Symbiotics

The now nearly universal interpretation of the symbiotic stars as interacting binary systems reinforces the importance of obtaining multifrequency observations in order to successfully deconvolve the overall energy distributions. At this juncture, various surveys of the symbiotics have obtained contemporaneous sets of data spanning the X-ray through the radio wavelength domains. We have merged the available data for eight S-type symbiotics in quiescence to provide uniformly calibrated continuum energy distributions. These data permit a detailed comparison with theoretical predictions for the nature of the hot primary , the cool secondary and the circumbinary gas. When combined with recent orbital solutions from radial velocity studies, unique interpretations for the masses of the components, the nature of the mass exchange process and the evolutionary status will be possible.

2. Quiescent Continuum Energy Distributions

2.1. Low resolution **IUE** spectrophotometry

A significant number of the S-type symbiotics brighter than V = 14^{th} mag have now been observed at low resolution with the IUE satellite. We have produced an atlas of merged SWP and LWR low resolution data for selected S-type systems in quiescence. Representative data for BF Cygni are seen in Figure 1, where the observed fluxes are displayed. These data reveal the large diversity of continua and emission-line spectra which characterize the symbiotics in the ultraviolet. Estimates of E(B-V) have been derived using the interstellar 2175 A depression and additional determinations of (n_e, T_e) can be derived from suitable line ratios, as discussed by Nussbaumer (1982) and Nussbaumer and Storey (1981).

2.2. Cassegrain optical spectrophotometry

Contemporaneous with **IUE** observations, efforts have been made to obtain comparable ground-based optical spectrophotometry. Calibrated optical data have been published by Slovak (1982), Blair, Stencel, Feibelman, and

J. Mikolajewska et al. (eds.), The Symbiotic Phenomenon, 43–45.

Michalitsianos (1983) and Ipatov and Yudin (1986). We have combined high signal-to-noise Digicon spectrophotometry with low resolution **IUE** data for selected quiescent S-type symbiotics, adjusting the data to a common flux scale. Such data are shown for Z Andromedae in Figure 1. These data provide a critical constraint on model predictions in that both the primary and secondary contribute nearly equally in this regime.

2.3. Broadband JKLM infrared photometry

Broadband **JKLM** near-infrared photometry for many symbiotics has been provided by Allen and Glass (1974), Feast, Robertson and Catchpole (1977) and recently by Whitelock (1987) and her coworkers. For the S-type systems in quiescence, little variability is seen ($\Delta m_J \sim 0.2$ mag) and these data may be reasonably combined with other quiescent observations. The addition of low resolution IR spectra (e.g. Kenyon and Gallagher 1983) and the continued monitoring (Whitelock 1987) have continued to improve the ground-based IR results. Typical **KLM** results for AG Dra are seen in Figure 1.

2.4. IRAS Point Source Catalogue fluxes

The **IRAS** satellite detected a number of the symbiotic stars in the far infrared (Kenyon, Fernandez-Castro, and Stencel 1986; Slovak, Cassinelli, Anderson, and Lambert 1987; Whitelock 1987). Various of the S-type symbiotics have far IR distributions consistent with normal M giants (Kenyon *et al.* 1986). However, detailed modeling of AG Dra (Slovak *et al.* 1987) in quiescence reveals that the free-free emission from the circumbinary nebula may begin to contribute and even dominate the energy distribution longwards of 25μ. Unfortunately, many of the fluxes for the S-type symbiotics detected in the Point Source Catalogue (PSC) are upper limits, especially at 60μ and 100μ. The **IRAS** PSC color-corrected fluxes for AG Dra are seen in Figure 1, combined with other quiescent observations.

3. The Necessity of Simultaneous versus Contemporaneous Multifrequency Data

The essential requirement for *simultaneous* (at the *same* time) as opposed to *contemporaneous* (during the *same period*) data must be emphasized, even for studies of quiescent systems. While the uncertainty in integrating disparate data sets is minimized by carefully selecting quiescent systems, intrinsic variability of sensitive UV-optical line ratios and even continua argue that secure conclusions can only come from coordinated observing campaigns. Such efforts are even more essential to follow and understand the detailed behavior of the symbiotics during their activity phases.

4. References

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https://doi.org/10.1017/S0252921100103124 Published online by Cambridge University Press

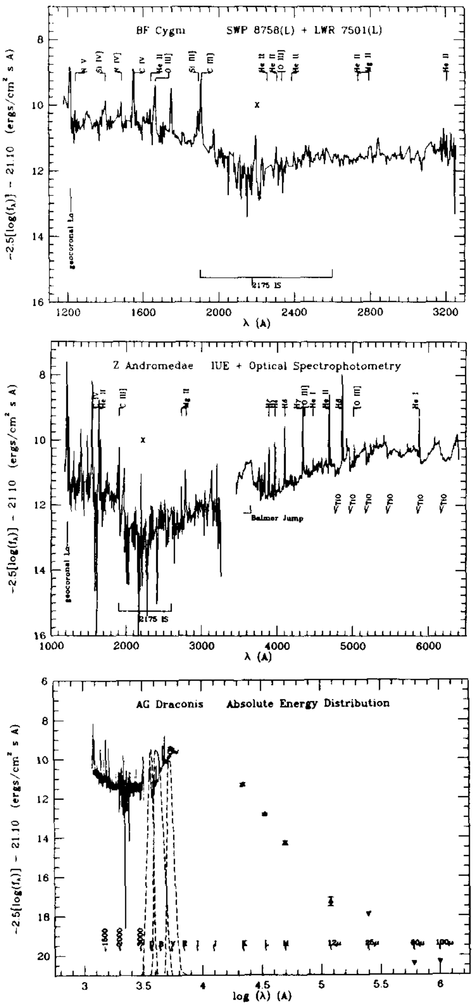

Figure 1. Representative multifrequency observations of three quiescent S-type symbiotics BF Cygni, Z Andromedae and AG Draconis. (Upper panel) Combined low resolution SWP and LWR **IUE** spectrophotometry for BF Cyg is displayed on a magnitude versus linear wavelength scale. Strong permitted and forbidden emission lines are identified and a pronounced 2175 interstellar reddening feature is evident, corresponding to E(B-V) $\approx$ 0.40. (Middle panel) Low resolution **IUE** and optical Cassegrain Digicon spectrophotometry are shown for Z And, displayed as for BF Cyg. A gap of 300 A exists between the satellite and ground-based data near 3300 A. The observed fluxes are moderately reddened [E(B-V) $\approx$ 0.45] and a strong Balmer Jump appears in emission. The optical data are dominated by hydrogen and helium emission lines, as well as a number of TiO molecular bandheads. (Lower panel) Merged IUE, optical, ground-based infrared and **IRAS** fluxes are seen for AG Dra displayed on a magnitude versus a logarithmic wavelength scale. The **IRAS** 25μ, 60μ, and 100μ fluxes are only upper limits. The dashed curves represent the Johnson **UBV** filter bandpasses and clearly reveal the limited portion of the energy distribution about which classical photometry provides information.

https://doi.org/10.1017/S0252921100103124 Published online by Cambridge University Press