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Ultraviolet Observations of Low-Excitation Herbig-Haro Objects

Final Technical Report

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The Herbig-Haro (HH) objects rank among the faintest objects (v ~ 17) observed with the I.U.E. Our expectation that the low-excitation shock-excited HHs should be dominated by H° two-photon (2q) UV emission was borne out in our first observations of HH 43 and 47 obtained in 1982. The UV continuous energy distributions in the SWP spectra of these objects were found to peak near 1500Å as predicted by the 2q hypothesis. In addition, emission lines in the Lyman band of H_2, excited by Lyman alpha fluorescence, were detected in HH 43. It is not clear if the molecular gas is coextensive with the atomic gas responsible for the optical emission, or if the molecular gas is immediately adjacent to the region of optical emission. The two-photon energy distribution and H_2 fluorescent emission were discussed in Schwartz (1983).

In October, 1983, an additional SWP spectrum of HH 47 was obtained, and a first LWR spectrum of the object was also obtained. The H_2 fluorescent lines which were only marginally present in the 1982 SWP spectrum could not be confirmed in the 1983 spectrum. However, the continuous energy distribution as measured in the LWR spectrum mated nicely with that of the SWP spectrum, confirming the nature of the 2q emission over a broad range of wavelengths. Figure 1 displays data points (including optical continuum levels) for HH 47 and the theoretical 2q curve. The points in the λλ 1200-2000Å range are means of 100Å bins in the combined 1982 and 1983 spectra. Although the signal to noise level is still somewhat poor even after nearly 15 hours of SWP observing, the 2q trend is evident. Also of significance is the fact that HH 47 suffers little if any interstellar extinction, allowing a direct comparison with the theoretical 2q curve.

In the case of HH 43, significant extinction occurs, and we used this fact to obtain the interstellar extinction curve for this object. Basically, a comparison of the observed continuum flux with the theoretical 2q (plus free-bound) flux permitted reconstruction of the extinction curve[1] (Schwartz, Dopita, and Cohen 1985). It was found that the extinction curve was nearly neutral in the UV (similar to that of Θ Ori), with $E(B-V) \approx 0.2$ and $R > 5$.

Our theoretical modelling of HH spectra has continued with use of the MAPPINGS shock wave code. In addition to modelling the level of 2q emission in low-excitation ($V < 60$ km sec^{-1}) shocks, we are also obtaining estimates for the UV emission lines of C I], C II] and Mg II observed in HH 43 and HH 47. Best fits are obtained if we follow in detail the behavior of the postshock ion and electron temperatures. The electron temperature is depressed relative to the ion temperature owing to the efficient cooling of electrons via collisional excitation of hydrogen and subsequent 2q, Lyman and Balmer cooling. Results of this work, are being reported in the I.A.U. Symposium No. 115 on Star-Forming Regions to be held in Tokyo, Japan, November, 1985.

[1] Work carried out with support of NASA grant NAG 5-461.

References

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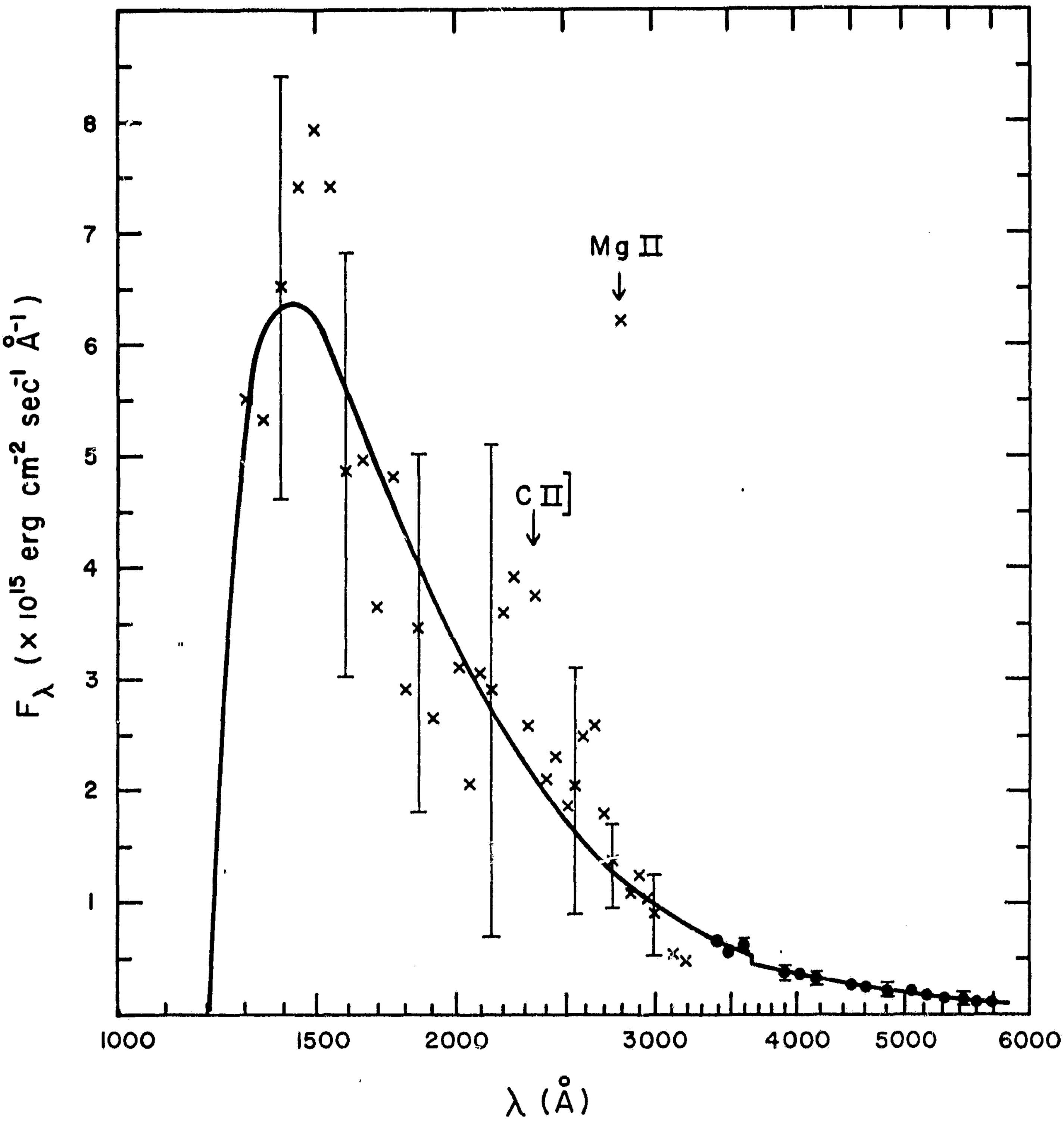

Figure 1. Continuum energy distribution of HH 47 in the ultraviolet (crosses) and the optical (dots). The solid curve is the theoretical energy distribution for hydrogen two-photon plus free-bound emission for a low-velocity shock.