THE IMPORTANCE OF ABSOLUTE PHOTOMETRY

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Résumé. — *On compare les valeurs de flux stellaires ultraviolets obtenus par trois groupes d'observateurs. Cette comparaison est étendue au domaine visible et ultraviolet proche. Dans tous les cas on porte attention aux intensités absolues : on note un excès d'ultraviolet dans ι Ori, un défaut d'ultraviolet dans tous les autres cas.*

Abstract. — *A comparison is made between the ultraviolet stellar fluxes measured by three sets of observers. The comparison is extended to visible and near ultraviolet measurements. Absolute intensities are compared in all cases and an enhanced ultraviolet emission is noted in ι Ori. The well known ultraviolet deficiency is found in other cases.*

Резюме. — Сравнены значения ультрафиолетовых звездных потоков полученных тремя группами наблюдателей. Это сравнение распространено на видимую область и на ближайшую внимание на абсолютные интенсивности ; отмечается избыток ультрафиолетового излучения в ι Ori, недостаток ультрафиолетового излучения во всех других случаях.

The results of three sets of measurements of the ultraviolet irradiance of stars had been reported [1-3] before this symposium. These measurements differ in an important respect from the general run of measurements made at more accessible wavelengths. The significant difference is that they are *absolute* measurements ; the stellar irradiance being determined in terms of a laboratory standard rather than in terms of the irradiance of some " standard star ". While it seems quite possible (and to the present author desirable) that such absolute photometry will become general at all wavelengths, this topic will not be pursued further here. Some of the approximately 150 stars for which data are available have been studied by more than one observer and a comparison between these observations and with absolute photometry at longer wavelengths can be made. Observers commonly compare their own observations with the predictions of theory, and it is surprising that one set of data has been so compared only in a relative fashion, the fact that the measurements are on an absolute scale being ignored. In a discussion of the interpretation of the ultraviolet emission of B stars Underhill [4] has also ignored the absolute nature of these measurements. This paper presents a comparison which takes account of this.

It is common practice to specify the measured intensity in terms of an energy flux, but the measured quantity (in all the experiments so far reported) is a photo-electric current and this can be more directly interpreted in terms of a photon flux. The spectrum bandwidth is usually expressed in terms of wavelength rather than frequency. In this paper the observed intensities, denoted by Φ_λ, will be expressed as the photon flux per second and per Angstrom bandwidth incident normally per square centimetre above the atmosphere of the earth.

The different observations for four stars are compared in figures 1-4. The data at visible and near ultraviolet wavelengths are from the absolute photometry of Willstrop [5] and Kharitonof [6]. In the case of ι Ori Bahner's [7] measurements in terms of α Lyr have been combined with Kharitonov's absolute measurements of α Lyr. The experimental results can be compared with the predictions of model atmosphere theory by normalizing the theoretical curve at some wavelength. A wavelength near 5400 Å has been chosen for this purpose. The physical significance of the normalisation process is discussed in an Appendix. The model atmosphere results used in this paper are based on the set of eight published by Underhill [4]. An interpolation on the basis of Balmer discontinuity has been made to give a comparison with the B7 star α Leo. Three of the experimental points represent only limiting values: β CMa and γ Ori saturated Chubb and Byram's [2] photometers ; α Leo was not observed by Alexander *et al* [3] though it passed through the field of view of their photometers and an upper limit is accordingly shown.

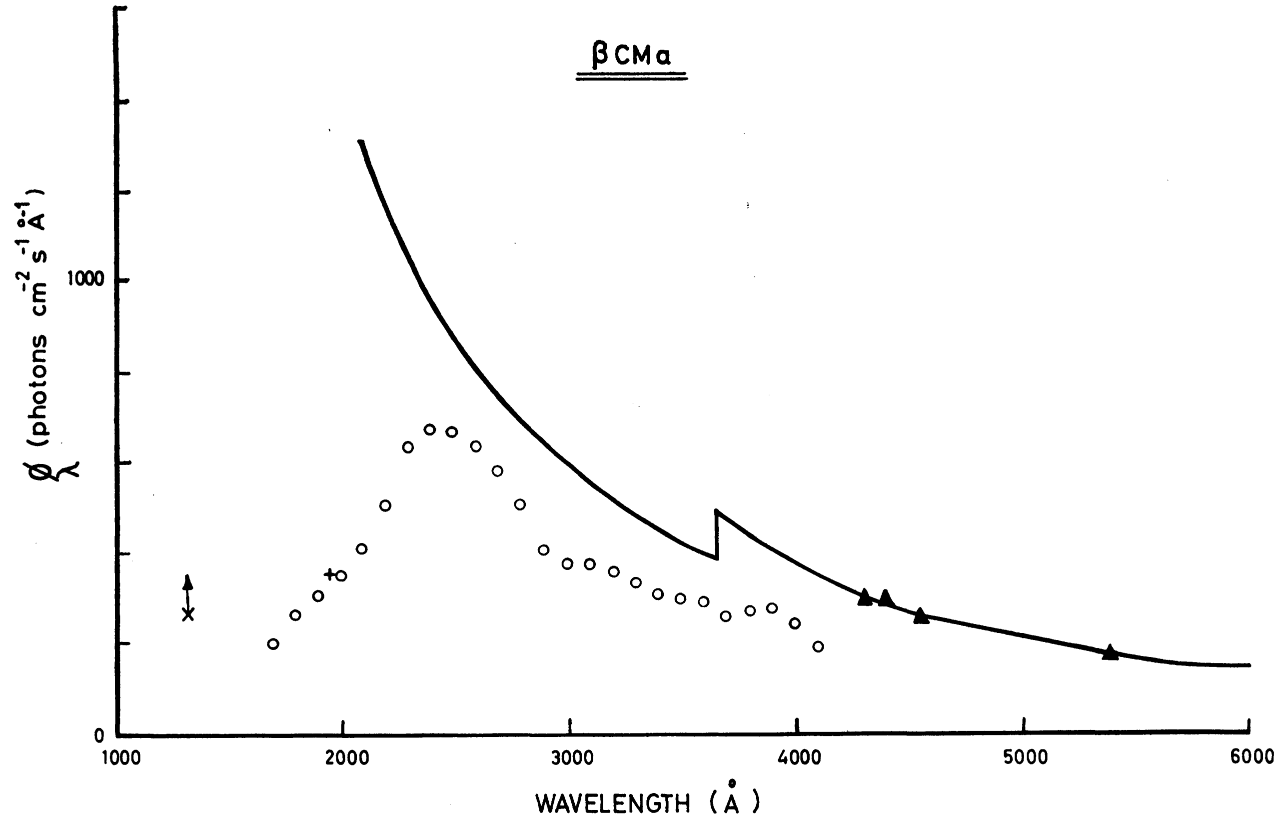

Fig. 1. — The spectrum of β Canis Majoris, B1II.

▲ Willstrop. ○ Stecher and Milligan. + Alexander *et al.* × Chubb and Byram. — Underhill, model 89.

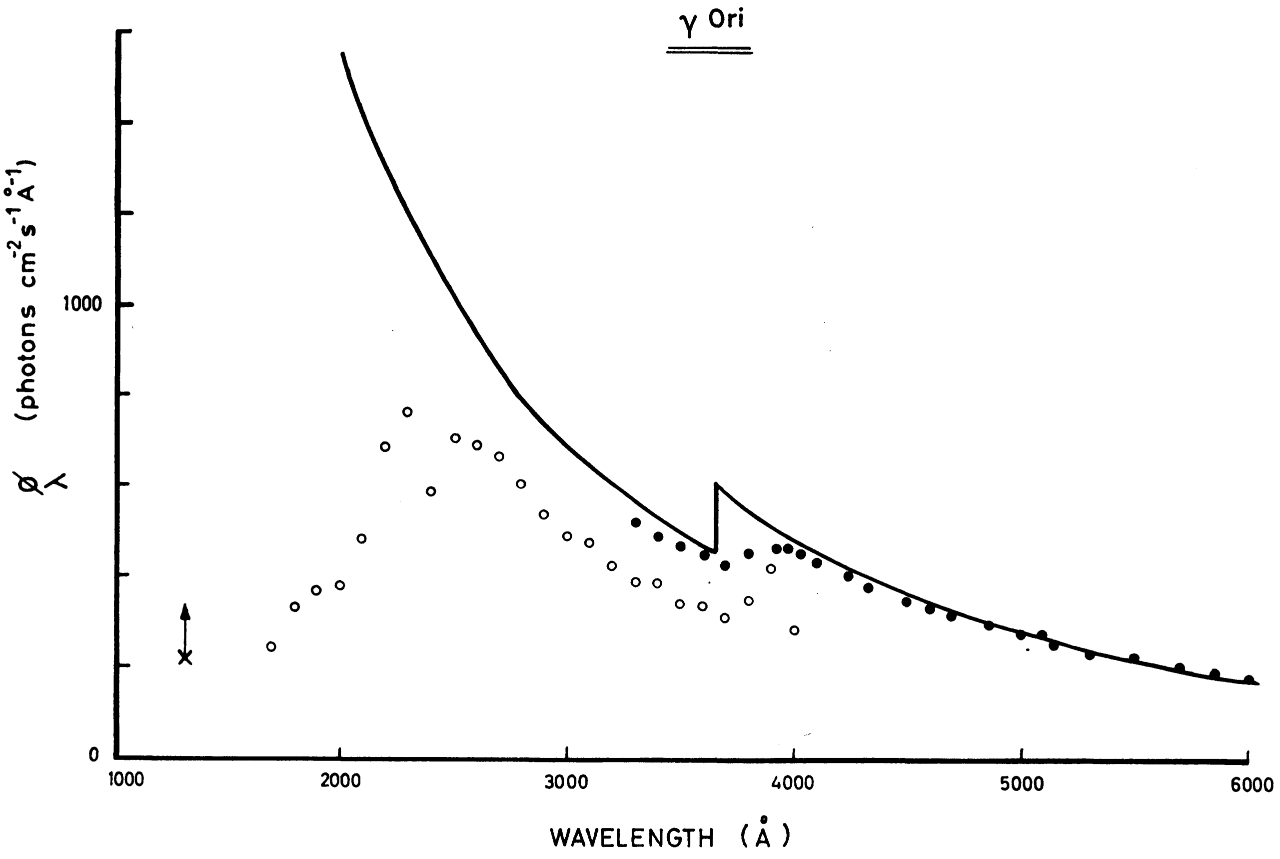

Fig. 2. — The spectrum of γ Orionis, B2 IV.

● Kharitonov. ○ Stecher and Milligan. × Chubb and Byram. — Underhill, model 63.

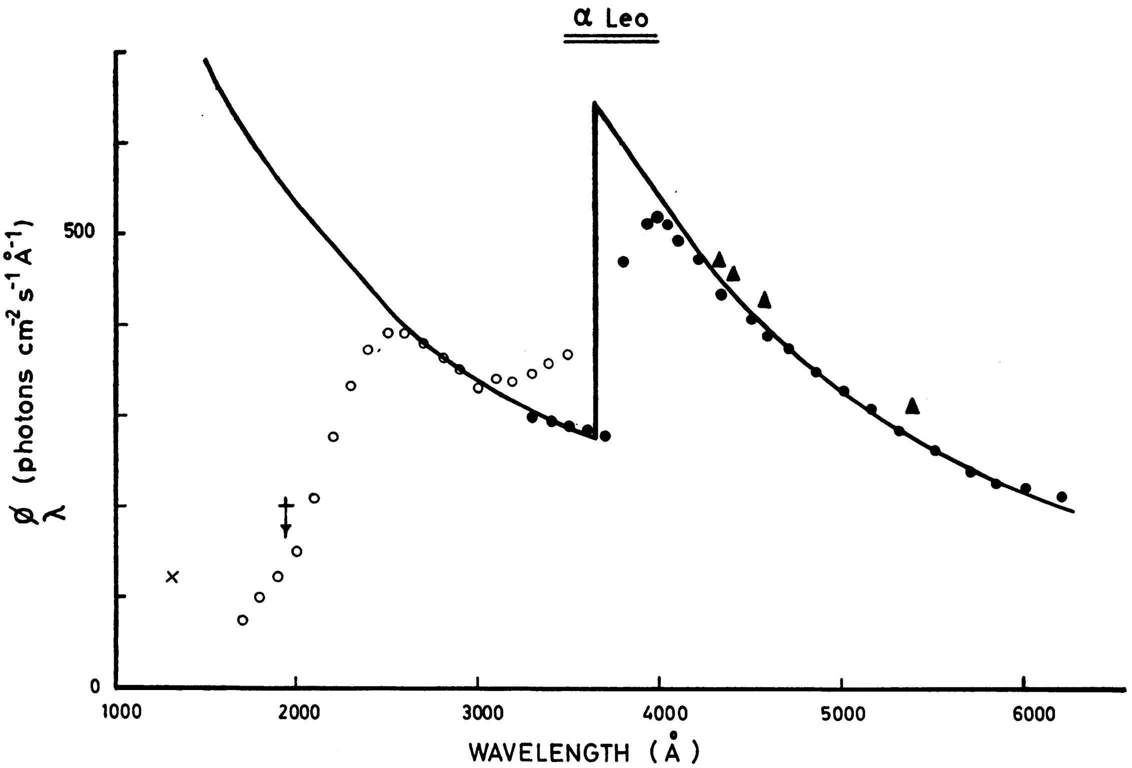

Fig. 3. — The spectrum of α Leonis, B7 V.

▲ **Willstrop.** ● **Kharitonov.** ○ **Stecher** and **Milligan.**

+ **Alexander** *et al.* × **Chubb** and **Byram.** — **Underhill,** interpolation between models 66 and 73

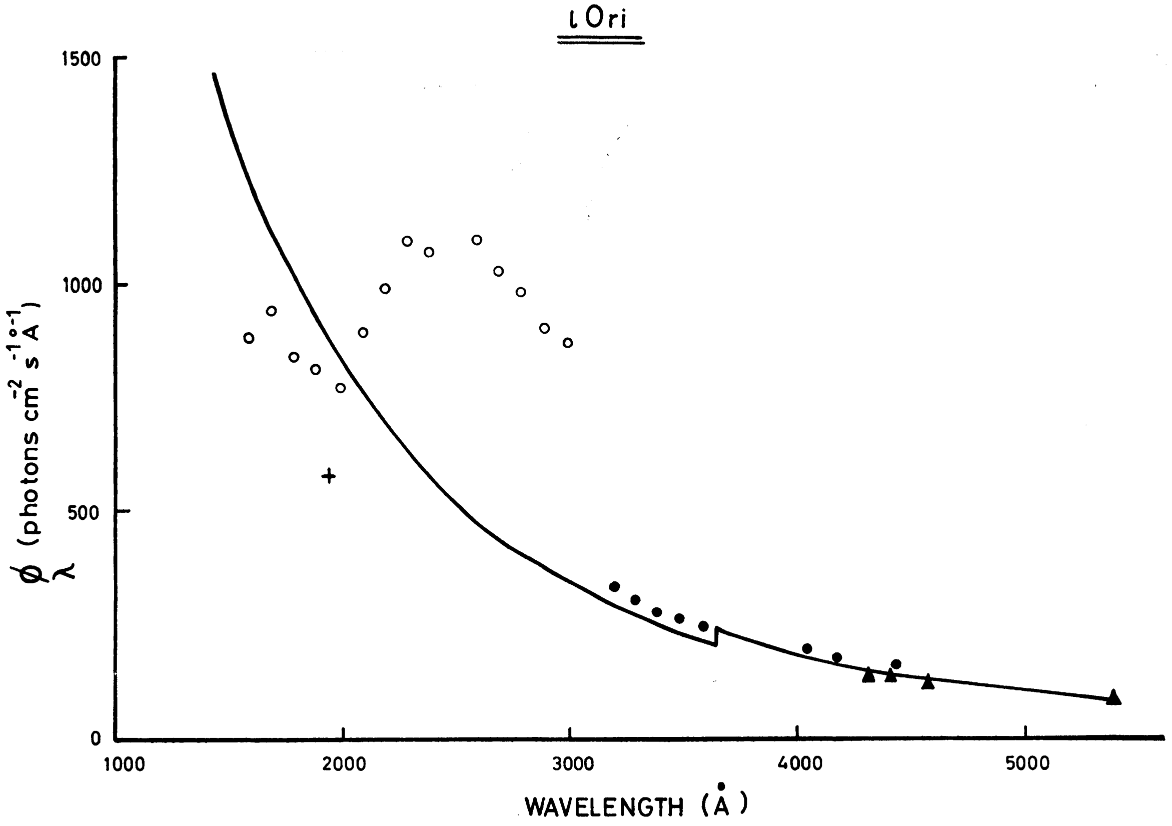

Fig. 4. — The spectrum of ι Orionis, 09 V.

▲ **Willstrop.** ● **Bahner.** ○ **Stecher** and **Milligan.** + **Alexander** *et al.* — **Underhill,** model 98.

In the cases of β CMa (Fig. 1), γ Ori (Fig. 2) and α Leo (Fig. 3) for $\lambda > 2500$ Å the agreement between theory and experiment is very reasonable. At shorter wavelengths the observed intensity is appreciably less than that predicted by the model atmosphere calculations. In general appearance Figures 1-3 are very similar to previous comparisons [1, 4] in which an *arbitrary* scaling has been made and which have been comparisons only of the shape of the spectrum and have taken no account of the fact that the measurements are on an absolute scale. The importance of taking note of the absolute values is shown in Figure 4 where the observations of ι Ori are compared with the UNDERHILL 09 V model atmosphere. Though the shape of the observed spectrum is similar to that of the other hot stars, the significant spectrum feature is not a decrease in intensity for $\lambda < 2400$ Å, but an enhancement for $\lambda > 2000$ Å. For $\lambda < 2000$ Å the agreement between observation and theory is quite as good as the agreement for $\lambda > 2400$ Å in Figures 1-3.

While the agreement between the different ultraviolet observations [1-3] is not so good as that between the visible observations [5, 6] it is quite encouraging. Similar agreement to that presented here is found for γ Vel and α Car, but in the case of the remaining star observed by STECHER and MILLIGAN [1], ε CMa, ALEXANDER *et al.* [3] find a flux some 3-4 times as great as would be expected on the basis of the spectrum response of their photometers and the spectrum observed by STECHER and MILLIGAN.

APPENDIX

Well established methods exist for the computation of the continuous spectra of hot stars. The quantity calculated is the flux of radiation emerging from the stellar atmosphere. The total energy radiated by the star is not calculated : this would require knowledge of the stellar radius and the calculations are in fact made for plane parallel atmospheres. The calculated intensity is normally expressed as an energy flux per unit frequency interval but for comparison with the experimental measurements it is convenient to express it as a photon flux Φ_λ photons/sec.Å.cm² of stellar surface.

In the absence of interstellar reddening the ratio $\varphi_\lambda/\Phi_\lambda$ is clearly equal to $(r/d)^2$ where r is the stellar radius and d the distance of the star from the earth. A direct comparison of theory and observation can be made (at any wavelength) provided only that the angular radius, $\alpha = r/d$, of the star is known. The angular radii of the stars discussed in this paper have not been measured directly. However values of φ_λ at visible wavelengths are known with some precision [5, 6] and the angular radii can be calculated from a comparison of these values and the Φ_λ predicted by the models. Values are given in Table I. The model atmosphere calculations can now be used to predict values of φ_λ in the ultraviolet and so give a proper basis for comparison with observation.

TABLE I

ANGULAR RADII OF CERTAIN HOT STARS

STAR	SPECTRUM CLASS	m_v	φ_{5390}	Φ_{5390}	α
ι Ori	09 III	2.79	84	166 × 10^{18}	0.00015″
β CMa	B1 II	1.99	176	103	0.00027″
ε CMa	B2 II	1.505	275	92	0.00036″
γ Ori	B2 IV	1.70	230	92	0.00033″
α Leo	B7 V	1.37	312	31	0.00065″
α Car	F0 Ia	— 0.70	2000	4.6	0.0044″

The magnitudes are from WILLSTROP [5] except that for γ Ori which is from ALLEN [8]. The Φ_{5390} are from UNDERHILL [4] except for the FO value which corresponds to the model with $\theta_{-} = 0.75$, $\log g = 1.80$ of the Series V of CANAVAGGIA and PECKER [9].

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