GENERAL DISCUSSION – FIFTH SESSION

Münch: All of us who have attempted to construct high-temperature model atmospheres are aware of the difficulties introduced by the large values of the radiation pressure and its gradient. The problem is not purely computational but it may actually happen that the outer layers are not in hydrostatic equilibrium and continuous mass loss is taking place. On the observational side, I may remark that in the bluest stars known (those at the extreme blue sequence of the globular clusters), although possessing extremely blue B-V colors, the line spectrum is definitely cooler, and I suggest that there is a false photosphere which is optically thick in the Balmer lines but not in the Paschen continuum.

Underhill: When an O-type model atmosphere is constructed ($T_{\rm eff} \simeq 35000°$) including the opacity due to the resonance lines between 912 and 1500 Å, the radiation-pressure gradient term becomes very large in the outer atmosphere. A hydrostatic equilibrium atmosphere could only be obtained by empirically reducing the radiation-pressure gradient to an acceptably small value in the outer part of the atmosphere.

No difficulty with standard-model atmosphere methods is encountered if the line blanketing is left out of consideration. Models without line blanketing in the far UV, however, are not very real from a physical viewpoint. Considerable doubt exists about their value in interpreting the spectra of stars of type B I and earlier.

Aller: The profiles of the hydrogen and helium lines seem to be similar to those in main-sequence stars (see e.g. the paper by Wilson and Aller (1954), *Astrophys. J.*, **119**, 243). The lines are evidently broadened by Stark effects rather than by rotation. While shells are certainly present in some instances, e.g. the nuclei with Of stars and NGC 6543 which may resemble P Cygni, I believe that we are seeing the 'normal' photospheres of the stars in many instances, whatever constitutes the normal photosphere of an O star.

Seaton: I would like to emphasize again that, if one trusts the results of model atmosphere calculations, then one should use the calculated fluxes (instead of black-body fluxes) in deducing temperatures by Zanstra-type methods.

Capriotti: I would like to report on some recent work done by William Kovach and me. We have used the Böhm and Deinzer models in order to estimate the effective temperatures of the central stars. We have used the same method that Harman and Seaton employed. One has

$$\frac{I(\lambda 4686)}{I_{\rm pg}(\text{star})} \sim \int_{\nu_0}^{\infty} \frac{F_\nu(T_{\rm eff})}{h\nu}\, \mathrm{d}\nu \Big/ \int_0^{\infty} F_\nu(T_{\rm eff})\, S_{\rm pg}\, \mathrm{d}\nu\,. \tag{1}$$

Osterbrock and O'Dell (eds.), Planetary Nebulae, 355–358. © *I.A.U.*

$I(\lambda 4686)$ is the observed intensity in the $\lambda 4686$ line of He^+ and I_{pg} (star) is the observed intensity in the continuum of the central star in the photographic region of the spectrum. ν_0 is the frequency that corresponds to the ionization potential of He^+, $F_\nu(T_{eff})$ is the emergent flux of a Böhm and Deinzer model star with effective temperature T_{eff}, and S_{pg} is a filter function. We can re-write Equation (1) as

$$\frac{I\,(4686)}{I_{pg}(\text{star})} \sim \left[\int\limits_{\nu_0}^{\infty} \frac{B_\nu(T_{eff})}{h\nu}\,d\nu \Big/ \int\limits_{0}^{\infty} B_\nu(T_{eff})\,S_{pg}\,d\nu\right] \times \left[\int\limits_{\nu_0}^{\infty} \frac{F_\nu(T_{eff})}{h\nu}\,d\nu \Big/ \int\limits_{\nu_0}^{\infty} \frac{B_\nu(T_{eff})}{h\nu}\,d\nu\right]. \tag{2}$$

$B_\nu(T_{eff})$ is the Planck function. We have left $F_\nu(T_{eff})$ in integrand in the denominator of Equation (1) because in the frequency region where the product $F_\nu(T_{eff})\,S_{pg}$ is large, the Böhm and Deinzer model for a given value of T_{eff} is just like a black-body model. The Böhm and Deinzer models show flux deficits at frequencies greater than ν_0.

Therefore

$$\int\limits_{\nu_0}^{\infty} \frac{F_\nu(T_{eff})}{h\nu}\,d\nu \Big/ \int\limits_{\nu_0}^{\infty} \frac{B_\nu(T_{eff})}{h\nu}\,d\nu < 1\,. \tag{3}$$

Since the product on the right-hand side of Equation (2) is equal to some observationally determined quantity, then the quantity $[\int_{\nu_0}^{\infty} \{B_\nu(T_{eff})/h\nu\}\,d\nu / \int_{\nu_0}^{\infty} B_\nu(T_{eff})\,S_{pg}\,d\nu]$ has to be as big or bigger when one uses a Böhm and Deinzer model than it is when one uses a black-body spectral distribution. Consequently, the effective temperature that one obtains using a Böhm and Deinzer model is as big or bigger than the effective temperature obtained through the use of a black-body model. We obtained temperature differences as large as 24000 °K. The highest temperature considered by Böhm and Deinzer was 150000 °K. Therefore, for temperatures larger than that we had to extrapolate.

At any rate, as said before, it is a bit premature to conclude that the central stars of planetary nebulae have flux excesses at frequencies greater than ν_0 on the grounds that then the predicted $\lambda 4686/H\beta$ intensity ratios would agree with the observed intensity ratios. One would first have to construct a model nebula with a central star having a temperature that is consistent with the type of model star used. A more detailed report on this study has now been published: Capriotti, E. R., Kovach, W. S. (1968), *Astrophys. J.*, **151**, 991 (*Ed.*)

Osterbrock: Are the abundances indicated by line spectra of planetary nuclear stars consistent with the assumption that their atmospheres have the same composition as nebulae?

Aller: I know of no observational data inconsistent with this assumption. The spectra of the nuclei of planetaries do not appear to be inconsistent with the suggestion that they have a chemical composition similar to that of the surrounding nebula. I think that we must regard their compositions as normal.

Kohoutek: One comment on the distance of NGC 1514. I derived the mean distance from the following individual values applying our photographic and photoelectric data:

Author	*Method* pg parsec	pe parsec
Shklovsky (1956)	416	359
O'Dell (1962)	720	621
Abell (1966)	522	488
Kohoutek (1962)	488	383
Perek (1963)	442	397

Mean distance 484 ± (m.e.) parsec

In this case the accuracy of the mean value is less than 10%.

Underhill: The object NGC 1514 seems to be at a distance of 480 parsec where the radial velocity of the A0 III star and nebula is about +70 km/sec. This velocity is much larger than that expected for an A-type star close to the Sun; thus, one finds reason to conclude that the system may indeed belong to an old fast-moving population.

Perek: The radial velocity of NGC 1514 is not normal for an A-type star but it is not normal for a planetary nebula at that galactic longitude either. It is rather an outside value.

Evans: I would urge further observations of the radial velocity of this central star to determine the orbital elements. In the ordinary way the mass function of a single-lined binary is not very interesting but in this case a good estimate of the minimum mass of the hypothetical blue star could be made. The mean radial velocity is very high for a population-I star of this type.

There is a considerable resemblance to the A star in NGC 3132 where the star and nebular velocities did not come out quite the same but the possibility of velocity variation did not occur to us. It will be worthwhile referring to this. Incidentally, it seems probable that there is no considerable relative proper motion of the A star because Sir John Herschel – a very accurate draftsman – made a drawing in the period 1834–38 which closely resembles the modern picture.

Westerlund: Number 36 in Henize's Catalogue of Southern Planetary Nebulae has a star of A type centered in it. The velocity difference between this star and nebula appears similar to that of the star in NGC 3132 and the nebula itself.

Münch: When we observe faint blue stars at high galactic latitude we find mostly spectra which look like late B type, indistinguishable at low dispersion, from 'normal' main-sequence stars of the same type. I do not see why we have to insist on making the central star of NGC 1514 a normal main-sequence A0 type. More likely it is a star of population II such as those found in globular clusters immediately outside the RR Lyrae gap.

Shao: The existence of a planetary nebula in a binary system is very interesting and important in studying the evolution of the physical properties of the planetary component. Therefore, I should like to call attention to another object, VV 68. It was first discovered by Vorontsov-Velyaminov in 1960 and listed as a probable planetary. The star is $V_m = 8{\cdot}5$ and the spectral type is as late as B 9. The surface brightness of the nebulosity is very faint (about 15th mag/arc-minute^2). If this star is the real nucleus of the planetary, it would make it the brightest central star of all planetary nuclei. Therefore, we need both photometric and spectroscopic studies of this object.

Abell: There was a preliminary finding list of planetary nebulae discovered on the Palomar Sky Survey in *Publ. astr. Soc. Pacific*, **67** (1955), 258. Later a more complete list of new planetaries, and a discussion of them, appeared in *Astrophys. J.*, **144**, (1966), 259. The latter list not only includes the objects in the former list, but also additional ones, and the catalogue numbers are different. To avoid confusion I urge investigators to refer to their numbers in the *Astrophys. J.*, not the earlier *Publ. astr. Soc. Pacific* note.