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"PLANETARY NEBULAE I. PHOTOELECTRIC PHOTOMETRY" BY PEIMBERT & TORRES-PEIMBERT (1971) REVISITED

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RESUMEN

Me parece de interés describir las condiciones que prevalecían en el campo cuando se realizó el trabajo por M. Peimbert y S. Torres-Peimbert, 1971, BOTT, 6, 36, 21. Para ello presento una discusión de las condiciones observacionales en esa época. Explico brevemente algunos de los progresos que han ocurrido en el campo de las nebulosas planetarias. Incluyo una reseña del impacto que esta contribución en particular aportó al conocimiento de las nebulosas planetarias.

ABSTRACT

I consider interesting to describe the conditions that prevailed at the time of the work by M. Peimbert and S. Torres-Peimbert 1971, BOTT, 6, 36, 21. For this purpose I present a discussion on the observational conditions at the time. I explain briefly some aspects of the progress that has taken place in the study of planetary nebulae. I include a description of the papers that followed this research and their contribution to our knowledge of planetary nebulae.

Key Words: planetary nebulae — techniques: photometric

1. INTRODUCTION

In these frantic times where publication of new results is more and more demanding, it is of interest to look back and reflect on the work carried out in the past. This meeting on the highlights of the Boletin de los Observatorios de Tonantzintla y Tacubaya has given me the opportunity to reflect on the research that was taking place 40 years ago and the conditions under which the observations of the planetary nebulae observations were carried out.

M. Peimbert and myself had recently returned to our country, Mexico, and wanted both to publish in the journals with the most visibility, and to push forward our own publication. Therefore we decided to publish our research on planetary nebulae in both journals. At the time we were not sure we had taken the optimum route for the dissemination of our work; in retrospect, I consider that indeed we followed the right path.

Here I present a discussion on the objects under study, the observational conditions at the time, a description of the work carried out by Peimbert & Torres-Peimbert (1971a, hereafter PNI) and the importance of it at the time. I further include a description of the present status of the field, and finally my personal view of the papers that followed this research and their contribution to our knowledge of planetary nebulae.

2. PURPOSE OF THE RESEARCH

The article under review presented photoelectric photometry of emission lines and continuum of 13 PNe observed at Lick Observatory during 1966–1969.

The purpose of the observations was to determine accurate line intensities of the emission lines to derive physical conditions and chemical abundances for the objects under consideration. The idea was to measure with the best precision available line intensities of the important lines to carry out the computations. As expected, for those PNe of high surface brigthness we were able to measure more emission lines and overall parameters (H I, He I, He II, [O I], [O II], [O III], [N I], [N II], [Ne II], [S II] and [S III] lines), while for the fainter objects, the number of measured lines was reduced. In all cases, excepting BD+30 3639, we were able to measure [O III] 4363.

The selected objects were among those northern nebulae of high surface brightness. All these PNe had already been observed spectroscopically, some of them with high spectral resolution, however the observations had been photographic, and although with calibrated plates, the intensity calibrations were of limited accuracy.

3. INSTRUMENTATION USED

Of these objects, 12 were observed with the 90 cm Crossley telescope. In this reminescence I feel I have

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to describe some of the features of this great instrument. It had been built in 1879 in Great Britain, being one of the first large reflectors ever built.This telescope was later moved to Mount Hamilton in California. The optical quality of the telescope was superb, although its operation was most cumbersome, where the observer had to stand on a mezzanine 25 feet above the dome floor to look through the telescope, and had to take extreme care to avoid falling while observing.

The observations carried out used the spectrograph mostly with a $8'' \times 80''$ slit, to derive accurate line intensities, and a limited number through a $30''$ diameter circular aperture. Only one of the PNe was observed with the 3 m Shane telescope with a $2.7'' \times 27''$ slit.

The observations were recorded with the "Wampler scanner", constructed and described by Wampler (1966, 1967). Optically the instrument is a 3-mirror device with a 3.75-in collimator beam and a 600-groove/mm grating. A 20-inch camera provided 15 Å/mm resolution in the second order blue, where scanning was accomplished by driving the grating with a stepping motor. The spectral ranges available were $\lambda\lambda$ 3500–5400 Å and $\lambda\lambda$4900–11000 Å. The scanner was used in a pre-programmed spectrophotometer mode. The selection of wavelengths to be observed was performed by mean of a set of pins inserted physically onto a programming board. At each wavelength an integration was carried out, at the end of the integration period the count number was recorded and the grating moved to the next wavelength for the following integration. An ITT FW-130 blue cell (S20 surface) with a modified 0.25 inch cathode was used for the blue region ($\lambda\lambda$ 3500–7400) and an RCA 7102 cell for the red region ($\lambda\lambda$ 5600–11000). The scanner yielded a dispersion of 32 Å/mm in the second order. A pulse counting device was used, and in general the observation was continued until the desired signal to noise ratio was achieved. We carried out longer integration times for the weaker lines, as well as for the continuum points, while for the case of the strong lines the integrations were considerably shorter.

4. WHAT WAS IT ALL ABOUT?

At the time, the known planetary nebulae (1036 objects) had been catalogued and identification maps provided by Perek & Kohoutek (1967); however there were not enough studies about their physical conditions and chemical composition of these objects.

The work under consideration was a set of extremely high precision observations of those lines significant for abundance determinations. That is, with the limitations imposed by the detector, only the bright lines of interest for abundance determinations and that yielded a high enough signal-to noise-ratio were measured. The continuum in the neighboring wavelengths was also measured to derive the emission line intensities. In addition, for the 9 relatively small PNe, the absolute flux in Hβ was determined.

The calibration was carried out with a newly acquired set of standard stellar fluxes (Hayes 1970) making use of the integrating photon pulse counter at a number of discrete wavelengths with previously unobtainable accuracy.

Reddening corrections for nine objects were determined comparing the observed Balmer decrement with the theoretical one for case B considering the normal extinction law. In addition, the reddening value was verified by comparing the Hβ flux with the radio frequency flux. The errors in the logarithmic reddening correction at Hβ, C(Hβ), were of about 0.1 to 0.2 dex. In the observed objects no deviations from the normal reddening law were found, which had not been the case in the infrared observations of early type stars. It should be noted that our reddening determinations were systematically lower than those values determined previously (Osterbrock 1964; Collins et al. 1961; O'Dell & Terzian 1970).

5. IMPORTANCE AT THE TIME

The physical properties of gaseous nebulae are normally inferred from spectral and photometric data by assuming the correctness of atomic theory. In general, these properties have been internally consistent within the errors of observations. In some cases however, rather large discrepancies have been observed which have led some authors to question the theoretical predictions.

The set of line intensity measurements in the paper under review led to very accurate physical conditions determinations. The setup of the scanner and the detector used were proven to be essentially linear.

It became clear very soon after its first astronomical applications that photoelectric photometry is significantly more accurate than photographic photometry. Previous to our observations, spectroscopy was carried out photographically, which suffered from extreme non-linearity and very imprecise intensity calibration. Very few photoelectric measurements of emission line objects had been carried out (e.g., O'Dell 1962, 1963), and they included a recording system where all the spectrum was scanned, which was not very efficient for the measurement of faint lines. In the photographic spectroscopic work that was available there were strong inconsistencies between the intensities of the high-n Balmer lines measured photographically with those predicted theorically under the assumption of case B. Several authors made unsuccessful attempts to explain the observed intensity ratios of the higher excitation Balmer lines as compared to the lower excitation ones (e.g., Pengelly 1963; Pengelly & Seaton 1964). The photoelectric observations of NGC 7027 and NGC 7662 by Miller (1971) led him to suggest that there were possible systematic errors in the published phtographic photometry of these objects, "since the lines measured photographically appeared to be about 1.5 times the photoelectric intensity, while the brighter lines of [O II] show better agreement". The issue was essentially confirmed by the theoretical Case B computations by Brocklehurst (1971) and new observations by Miller & Mathews (1972)

This single channel instrumentation was substituted in the seventies with what were called Intensified Image Dissector Scanners, IIDS, which were able to record simultaneously all the visual spectral range. In those instruments the detected events were accumulated in up to 2048 channels, half of which were normally used for simultaneous night-sky observations. These devices, although very sensitive and much more powerful, years later were proven to be non-linear (see Peimbert & Torres-Peimbert 1987), which affected the line determinations, and thus introduced systematic errors in the derived physical conditions and abundance ratios. The systematic errors which at the beginning of the use of the IIDS went unnoticed, later on were corrected in some of the papers. At the end of the eighties the IIDS detectors were substituted with CCD detectors.

6. SITUATION TODAY

The use of small telescopes for observing planetary nebulae is still very useful and important because it allows to determine the integrated flux in many significant emission lines. In particular the absolute flux in the Hβ line is one of the crucial observational parameters; an extensive compilation of integrated Hβ fluxes of PNe has been given by Acker et al. (1991). These fluxes are needed to constrain modern photoionization models of these objects. Unfortunately the accuracy of the absolute flux is often rather low, especially for extended PNe.

In the intervening years, the study of planetary nebulae, as is the case for other fields, has been fantastic! The improvements have been along many fronts. In the optical regime it has been recognized that CCD detectors are linear and have reached essentially the attainable limit of sensitivity. With passing time, these detectors originally of relatively small size, are now of larger size, with more pixels, and are frequently arranged in mosaic configurations. Echelle spectrographs are now available in many telescopes, thus making it possible to obtain medium to high resolution spectra in a few frames. At the same time, all the wavelength ranges have become observable, so that the information available about planetary nebulae has increased manyfold. The software and hardware accesible for data reduction have multiplied prodigiously and the number of observers around the world has increased more than tenfold.

There have been many detailed studies of individual PNe to determine their properites. Also there have been extensive surveys in our galaxy leading to an increased number of identified planetary nebulae in our galaxy (e.g., Acker, Peyaud, & Parker 2006) as well as in other galaxies, where a large number of PNe have been observed at distances well beyond the Local Group (e.g., Herrmann, et al. 2008). This progress has led to a larger number of objects having accurate intensity determinations, better understanding of the chemical composition and the role that planetary nebulae play in the evolution of the interstellar medium.

7. PAPERS THAT FOLLOWED THIS WORK

The set of line intensity measurements in the paper under review led to very accurate electron temperature and electron densities of the objects where the spatial electron density and temperature fluctuations are recognized as being present in the objects (Peimbert 1971, hereafter PNII). These two papers led in turn to a third contribution where more dependable abundance determinations of these objects were presented; in particular, where a more precise N(He)/N(H) value was derived. Furthermore, it was recognized that the N/O ratio in some PNe was considerably higher than in H II regions (Torres-Peimbert & Peimbert 1971, hereafter PNIV).

Finally, Peimbert & Torres-Peimbert (1971b, hereafter PNIII) studied the change in chemical abundances in the interstellar medium from the envelope of intermediate mass stars. This work was based on stellar evolution models of 1.0, 1.25 and 1.45 $M_\odot$ at the red giant phase by Torres-Peimbert (1971), where it was found that there is a modest change of the chemical composition of the surface abundance of normal stars that had not been studied before. PNIV were able to compare for the first time the results of stellar evolution to the observations of planetary nebulae reported by PNI. They found that the contribution of planetary nebulae to the N/O abundance gradient present across disks of spiral galaxies is considerably more important than that produced by supernovae. The work by Torres-Peimbert (1971) refers to what is now known as the "first dredge-up" that produces a substantial increase of N in the surface of stars of low and intermediate masss, (LIMS) – from 0.8 to 8 $M_{\odot}$ accompanied with a small decrease of C and a small increase of He. Later, Renzini & Voli (1981) computed the post main sequence stellar evolution of intermediate mass stars up to the ejection of the PN envelope taking into account the three dredge-up phases and found substantial enrichment of C, N and He. Recent chemical evolution models of the Galaxy find that low and intermdediate mass stars have produced about 65 to 80% of the N present in interstellar medium, while the remainder amount of this element has been produced by massive stars (Carigi et al. 2005). Furthermore, Carigi & Peimbert (2008, 2011) have found that 50% of the post Big Bang nucleosynthesis produced He and 50% of C is due to LIMS.

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