Morphological and Physical Study of Planetary Nebulae

C. T. Hua, Laboratoire d'Astronomie Spatiale de Marseille, and R. Louise, Faculté des Sciences d'Amiens and Observatoire de Marseille

Summary

The photographic and spectrophotometric observations in order to carry out the "Monochromatic Atlas of Planetary Nebulae" are described. These observations are made in both hemispheres by using classical plates as well as modern receivers (IDS, Multiphot and Photon-Counting System). Preliminary results are presented.

Introduction

For years, Planetary Nebulae (PN) were thought to be expanding shells the interior of which is more or less filled with gas. A glance on direct photographs of familiar planetaries such as the Ring Nebula (NGC 6720), Helix (NGC 7293), Dumb-Bell (NGC 6853) or the Eskimo Nebula (NGC 2392) must convince us how complex their structure is. Although an ever increasing number of theories have been proposed since the Strömgren pioneering work (1939 *Astrophysical Journal* **89,** 526) some structure of PN remains unexplained (Louise, 1982, *Astronomy and Astrophysics Suppl.* **47,** 575). From the morphological point of view, a geometrical model must be built for each nebula. However, most people working on PN think or/and hope that they may be derived from a few geometrical models (2 or 3). Their difference from each other must be interpreted in terms of the evolution of a common main structure. Any evolutionary model needs an accurate knowledge of the physical parameters (T_e, N_e, relative abundances, etc.) and must take into account the interaction between an active nucleus with its surrounding interstellar matter (Louise, 1982, *Astronomy and Astrophysics* **102,** 303). This is important not only for studying planetary nebulae but also for understanding the general stellar evolution.

Observing Programme

Some features of PN structure can be interpreted directly from observations, others not or not yet because they require further investigations. If we examined in detail the large bibliography published within the last three decades concerning observational data of PN we could merely make the following comments:

(a) Direct photographs, monochromatic or not, are generally poor, inhomogeneous and photometrically underexploited. In some cases they are not suitable at all.

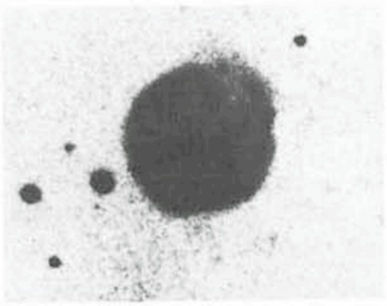
(b) Extensive spectrophotometric observations are generally performed for one or two points of a given nebula, rarely more. Only very few of the brightest PN have been accurately observed from point to point with a classical procedure. Today modern fast cameras such as IDS, CCD and photon-counting systems make available such observations for most PN, including the fainter ones.

(c) Since Minkowski's work (1964, *Publications of the Astronomical Society of the Pacific,* **76,** 197) faint nebulosities associated with PN are detected in some of them. However, no systematic search for such "secondary structures" (Louise, 1982, *Astronomy and Astrophysics* **102,** 303) is planned.

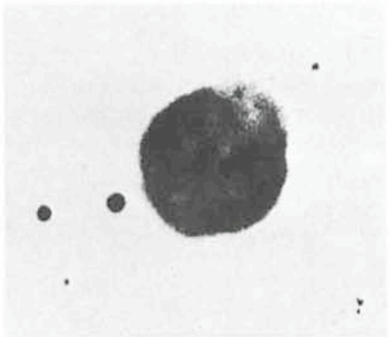
(d) High spectral resolution observations, with a spectral resolving power as high as 10^5, in order to obtain accurate line profile leading to the expanding shell velocity determination, are still exceptional.

Our observing programme is derived from previous remarks. Indeed, we are now planning the "Monochromatic Atlas of PN". Monochromatic photographs must be made by using narrow interference filters ($\Delta\lambda$ = 10 Å) centered on Hα, Hβ, [NII] λ 6584, [OI] λ 6300, [OII] λ 3727, [OIII] λ 5007 and [SII] λ 6717. In order to access to photometric measures, each plate must be accurately calibrated. For northern PN an observing programme is engaged since 1981 by using the F/6 Newtonian focus of the 1.2 m telescope at the Haute Provence Observatory (OHP). A sample of preliminary results is given in Fig. 1 (a, b, c) showing NGC 7048 respectively in Hα, [NII] and [OIII] lines. Fainter PN must be observed with modern receivers such as the photon-counting system. Fig. 2 shows A 76 in the Hα, Hβ and [NII] lines. As for southern PN, observations are foreseen at the 1.54 m Danish telescope coupled with the CCD camera at La Silla.

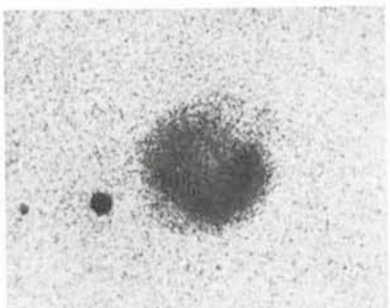
NGC 7048 (PK 88 - 1°1)



Hα - 50 Å
2^h05



[NII] λ 6584 - 10 Å
2^h30



[OIII] λ 5007 - 10 Å
2^h45

Fig. 1: *Monochromatic photographs of NGC 7048 obtained with the 1.2 m telescope of the Haute-Provence Observatory.*

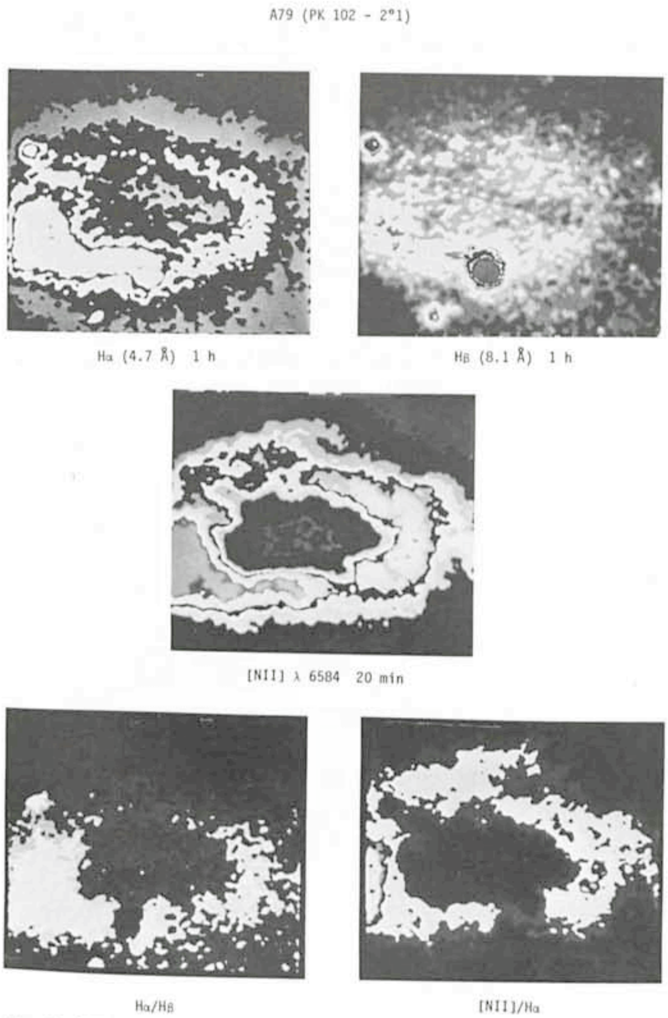


Fig. 2: *A79 observed with a photon-counting system.*

The Use of Monochromatic Plates

Monochromatic plates lead to the following data:

(1) Isophotic contour maps in an arbitrary scale are constructed for each observed line. The absolute scale may be obtained by using absolute spectrophotometric measures of one or more "connecting points" for a given nebula.

(2) Morphology and ionization structure of O°, O^{+}, O^{++} ions as well as N^{+} and S^{+} ions are directly seen in monochromatic plates.

(3) As pointed out by Louise (1974, *Astronomy and Astrophysics* **30,** 189) ring PN are either a result of the shell projection on the plane of sky or a toroidal main structure. Monochromatic observations combined with high spectral resolving power observations obviously lead to an accurate geometrical model (Louise et Maurice, 1982, *The Messenger,* **28,** 28). Such a model can tell us about the formation and evolution of some ring PN (Louise, 1981, *Astrophysics and Space Science* **79,** 229).

(4) Ratios of different emission lines derived from monochromatic plates are available for drawing contours of equal ratio-lines (Hua et Louise, 1982, *Publications of the Astronomical Society of the Pacific* **94,** 453). Usual important line ratios connected with physical properties of PN are as follows:

(a) Isothermal contours are derived from the I (4363)/I(5007) of the [OIII] lines (Louise, 1981, *Astronomy and Astrophysics,* **98,** 81).

(b) Internal dust distribution is revealed by Hβ/Hα ratio variation from point to point.

(c) Iso-density contours are given by I(6730)/I(6717) of the [SII] lines.

(d) Stratification structure of oxygen atoms is derived from combined ratios of [OI], [OII] and [OIII] lines.

Systematic Search for Faint Nebulosities

Long exposure plates using classical or/and modern cameras not only reveal faint nebulosities associated with PN but also detect new faint nebulae. In a next paper, Louise et Maurice will discuss about the detection of three faint nebulae located within 3 arcmin at the N-E side of NGC 1714 during their recent observing run at the 1.54 m Danish telescope coupled with the CCD camera.

Following our observations made at both OHP and ESO at La Silla, it seems likely that outer fainter halos around classical PN may be common. This result has implications on the total mass ejected from the PN progenitors, and possibly on the origin of the nebula (Terzian, 1982, *IAU Symposium* **103,** final review).

Spectrophotometric Observations

Obviously, monochromatic plates can lead only to relative photometric measures. In addition, classical plates are less accurate than modern electronic receivers. Nevertheless, Hua et Louise (*Publications of the Astronomical Society of the*

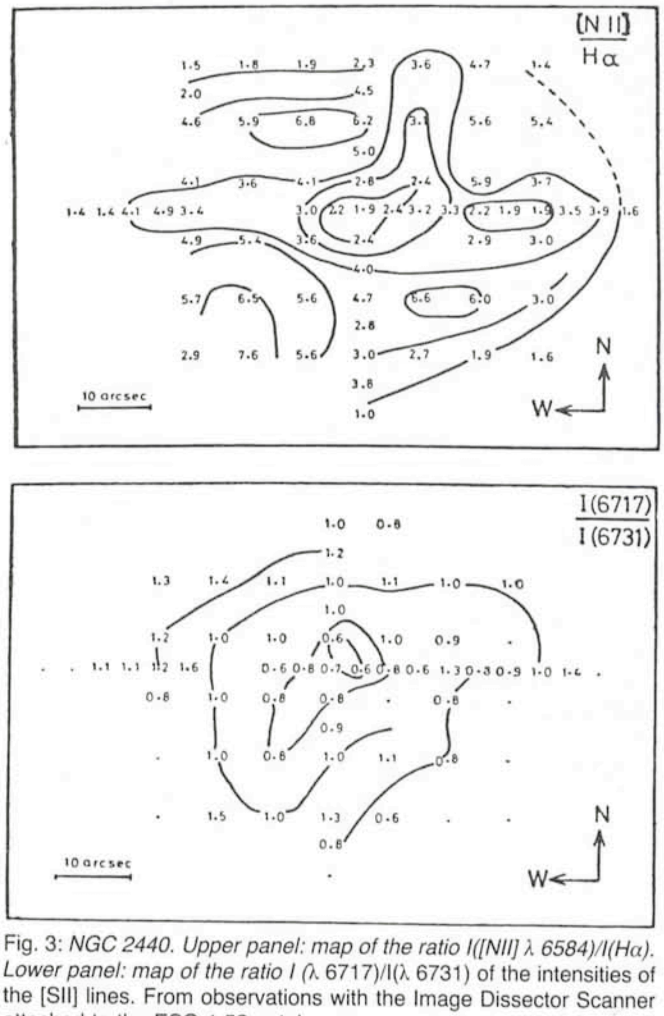


Fig. 3: *NGC 2440. Upper panel: map of the ratio I([NII] λ 6584)/I(Hα). Lower panel: map of the ratio I (λ 6717)/I(λ 6731) of the intensities of the [SII] lines.* From observations with the Image Dissector Scanner attached to the ESO 1.52 m telescope.

Pacific **94,** 453) pointed out the possibility of using combined classical plates and modern devices. The procedure they proposed has the simplicity of classical plates and the photometric accuracy of modern cameras. This procedure will be used throughout when making up the "Monochromatic Atlas of PN".

For southern PN the IDS system will be used extensively in order to obtain spectra from point to point over the whole image of the nebula. We give in Fig. 3 a preliminary result on a peculiar nitrogen-rich nebula NGC 2440. The observations were made with the 1.52 m ESO telescope using the B & C spectrograph with a 4″ × 4″ entrance slit and a spectral dispersion of 59 Å/mm. We have obtained more than 65 spectra covering the whole image of NGC 2440. Contours of I (6717)/I(6731) of the [SII] lines shown in Fig. 3 reflect the variation of the "skin density" within the nebula, because [SII] lines are originated only from low-excitation part of the filamentary structure of NGC 2440.

Conclusion

Monochromatic photographs in various emission lines and extensive spectrophotometric measures are complementary data which increase our knowledge about both morphological and physical structure of PN. Filamentary structure, globules, faint halos, etc. are the consequence of the evolution of these fascinating objects. There are so many physical and stellar processes occurring within the expanding shell! Routine but accurate observations foreseen for our Atlas will tell us more about expected and unexpected features of PN.

The Bright Star Catalogue Complete in Radial Velocities

J. Andersen and B. Nordström, Copenhagen University Observatory, Denmark

In many investigations, it is desirable to have certain observational data available for all stars of a given group, all over the sky, but – alas – reality is often far from this ideal. If you are an observing stellar astronomer, you have probably heard the reproach that "even in the Bright Star Catalogue, there are still xx stars without . . .", and it is true that even for the 9,000 brightest stars many basic data are still missing.

One kind of such data is (was) radial velocities. A few years ago there were still some 1,500 HR stars with no radial velocity determination at all – only 12 of them in northern declinations. At the same time, uvbyβ photometry had become available for all HR stars to spectral type G0, with Geneva photometry in progress for the rest. Radial velocities were needed in order to include kinematics in the astrophysical discussion of ages, metal abundances, etc.

So, we decided to do something about it, and we are happy to report that after our final observation on September 28, 1982, all stars in the Bright Star Catalogue should now have a radial velocity determination.

The ~ 800 HR stars later than F5 were observed with the CORAVEL scanner as part of the larger collaboration to use this instrument on the Danish 1.5 m telescope (Imbert and Prevot, 1981, *Messenger* No. **25,** 6). The accuracy of CORAVEL is so high (about ± 0.2 km/s for bright stars) that just two observations per star, separated by a few months, are enough to detect most of the binaries. The speed and ease of observing with CORAVEL on a computer-controlled TV-equipped telescope was an experience we were well qualified to enjoy from the earlier part of the programme: With CORAVEL we could sit quietly and observe up to 17 stars per hour, results fully reduced – and no plates to develop and measure afterwards.

What a change from our 65 exhausting nights on the ESO 1.5 m coudé spectrograph, where we took some 3,000 plates of our ~ 800 early-type programme and standard stars! Unfortunately, CORAVEL cannot observe the early-type and/or fast-rotating stars, so the B–F4 stars had to be observed in the classical way. Even at 20 Å/mm, exposures are only about 5 minutes, and if you subtract the few nights that were too cloudy even for this kind of work, we took an average of about 50 plates per night, with a maximum of 89. To avoid losing time between exposures, ESO consented to our proposal for an observing team of two night assistants and two astronomers, where everyone had their assigned jobs like setting the telescope, making the exposures, changing and making plates, and keeping the observing log.

This may sound like overstaffing, but if you take 3–5 minute exposures all night, everyone is really busy all the time, even too busy to eat a decent meal at midnight. Often we just had to grab some snacks as we went along – had you ever realized that it takes about five radial velocities to eat a fried egg? If you then count an additional four hours of darkroom work every afternoon, you may well guess that we were exhausted after our two-week runs. So, we are sure, were all our devoted night assistants who raced back and forth all night with great enthusiasm. We trust they will be rewarded with a long life in strong health from all this physical exercise, and thank them all again for their efforts.

But our work only began when the plates had been taken: Using an oscilloscope measuring engine constructed with the kind help of ESO and the Munich Observatory, the plates still had to be measured, a much larger job.

Our two first catalogues of new velocities have just been accepted by *Astronomy and Astrophysics* together with a paper describing our standard star observations, spectral line selection where we have included specifically the problems caused by stellar rotation, variability criteria, etc. Let us just note here that the standard error for one plate turns out to be in the range 1.3–2.5 km/s, depending on rotational line broadening. Our mean velocities (from 3–4 plates per star) are thus quite good.

Although observations were still in progress and not all checks and calibrations were final at the time, we were happy to be able to supply some 700 new, preliminary radial velocities for the 4th edition of the Bright Star Catalogue, which has just appeared. We expect the remaining final data to become available towards the end of this year.

During the coudé programme, we came across many new interesting stars: If a star has no radial velocity determination, it was possibly never observed at high dispersion before. E.g., among the 50 or so new double-lined binaries we found in all, some 6 were subsequently discovered to be eclipsing, and we have now observed complete light curves and spectrographic orbits for them. One of them is TZ For (HD 20301), which is the only known double-lined eclipsing system with two normal G giants. Its long period (P = 75.7 days) has led to a collaboration