NLTE Spectral Analysis of Central Stars of PN Interacting with the ISM

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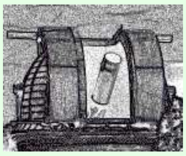

Abstract

The analysis of Planetary Nebulae (PNe) provides a tool to investigate the properties of their exciting central stars (CSPN) at the moment of the PN ejection as well as on the properties of the ambient interstellar medium (ISM). The spectral analysis of the CSPN is a prerequisite to calculate the ionizing flux which is a crucial input for reliable PN modeling.
In the framework of a systematic study of PNe interacting with the ISM (Kerber et al. 2000), we present preliminary results of ongoing NLTE spectral analyses of nine of their CS based on new optical medium-resolution spectra.

Introduction

Recent developments in observational and deprojection techniques, spectral analysis, and numerical methods facilitate to closely examine and model PNe and their CS. These stars are at their hottest stage of evolution close to the end of nuclear burning, and gravitational effects become dominant, i.e. they display directly the formation of white dwarfs.
An indicator for their evolution is the interaction of the associated PN with the ambient ISM: the highly evolved CS is no longer dominating the processes in the PN (Kerber & Rauch 2001); the nebula displays brightness asymmetries that reflect the degree of the interaction process. These complex objects are crucial tests for our models as well as evolutionary theory.
Spectral analysis of CSPN by means of NLTE model atmosphere techniques provides information about photospheric parameters. In comparison with evolutionary calculations, we can determine their evolutionary status, distances, masses, and luminosities. The model fluxes can then be used as realistic ionizing spectra in analyses of the PNe. These allow us to obtain detailed information on the ionisation structure of the nebulae, particularly in their complex interaction zones.

Observations

In July 1999, we performed medium-resolution spectroscopy of nine CS with the TWIN spectrograph attached to the 3.5m telescope at Calar Alto, Spain. The CS of A 21 had been observed in January 1999 with EFOSC 1 at the 3.6m telescope of ESO, La Silla.

name	PN	m_V	exposure time / sec
A 21	G205.1+14.2	16	3600 + 3600
A 52	G050.4+05.2	18	3600
A 75	G101.8+08.7	18	3600 + 3600
DeHt 5	G228.2−22.1	15	3600 + 2400
EGB 1	G124.0+10.4	17	3600 + 2700
NGC 6781	G041.8−02.9	17	1200 + 1200
NGC 6842	G065.9+00.5	16	1200 + 1200
RX J2117.1+3412	G080.3−10.4	13	1200
Sn 1	G013.3+32.7	15	1200
WeSb 5	G058.6−05.5	17	3600

NLTE Model Atmospheres

The evolution of our NLTE model atmosphere code is briefly summarized in the following:

- NLTE code PRO2 (Werner 1986, 1988, Werner & Dreizler 1999)
  - plane-parallel
  - hydrostatic equilibrium
  - radiative equilibrium
- → H – Ca (Rauch 1997)
  - more than 300 levels treated in NLTE
  - more than 1 000 individual lines
- → iron group (Dreizler & Werner 1993, Deetjen et al. 1999)
  - millions of lines from Kurucz's lists (1996) and Opacity Project (Seaton et al. 1994)
  - spherical (Nagel et al. 2001)
- → H – iron group (Rauch 2003)

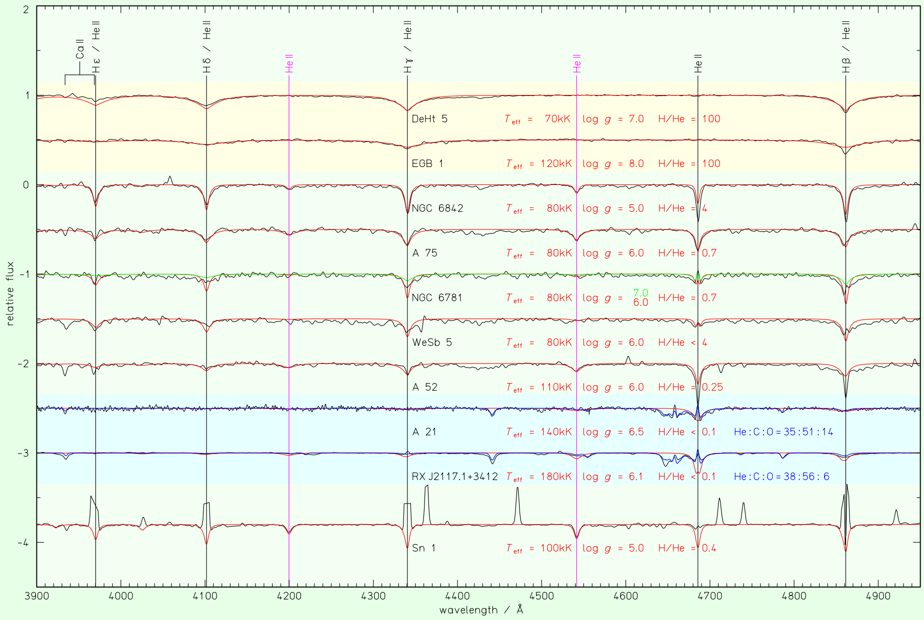

Figure 1: Comparison of synthetic spectra, calculated from our H+He model atmosphere grid (red lines), with the observations (black lines). Since the nebular emission is highly asymmetric across the projected face of these PN, the emission can not be subtracted perfectly. Especially in the case of Sn 1, there exists a small (about 8" diameter), compact inner nebula which makes the background subtraction almost impossible. However, the line wings can be used for log g determination, and He II 4199.8Å and He II 4541.6Å yield information about the H/He ratio. However, the determination of T_{eff} is uncertain in such a case. Note that the CSPN of A 21 and RX J2117.1+3412 are PG 1159-type CS (Rauch & Werner 1995) and show the typical PG 1159 absorption trough around He II 4686Å which is composed out of He II and C IV lines. For these two objects, we show synthetic spectra of He+C+O models (blue lines).

For the classification and preliminary analysis of hot compact stars, we have set up a new grid of H+He NLTE model atmospheres within T_{eff} = 50 – 190 kK (in 10 kK steps), log g = 5 – 9 (in 0.5 steps – presently available only in 1.0 steps) in cgs units, and H/He from pure H to pure He (in 0.1 steps by mass) which is currently being calculated. With this new grid, we aim to arrive at an error of about 20 kK in T_{eff}, 0.5 dex in log g, and 0.5 dex in H/He.

In Figure 1, we show the comparison between our preliminary synthetic spectra and our TWIN observations. The observed spectra have a resolution of 2.7Å and S/N ratios from 10 – 30. They have been smoothed with a Gaussian of 3Å (FWHM) for clarity. The synthetic spectra have been convolved with a Gaussian of 4Å. A subsequent fine tuning of the parameters will improve the fit.

The grid which we used for this analysis and some other grids of NLTE model atmosphere fluxes with different chemical composition will be available at **http://astro.uni-tuebingen.de/~rauch**.

Results

Within our sample of ten CS of PN, which show interaction with the ISM, our preliminary classification and spectral analysis yields two hydrogen-rich DA (pre-) white dwarfs (DeHt 5, EGB 1), two hydrogen-deficient PG 1159 stars (A 21 and RX J2117.1+3412 – both already known), and six CS with intermediate H/He ratios (from 0.25 to 4 by mass).

Fine tuning of the parameters in the next part of this analysis will enable us to determine e.g. their spectroscopic distance reliably.

However, the analysis is hampered by the relatively high seeing (1.6" - 2.5") during the observations. Further high S/N optical and UV observations with better spatial resolution would significantly reduce the error ranges.

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