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Ensemble of planetary nebulae of Milky Way

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The modern observations of the planetary nebulae (PNe) are used to create a new catalogue of He, C, N, O and other element abundances for Galactic and extragalactic PNe. This catalogue is planned to be used for studies of galactic chemical evolution. The inclusion of UV data for PNe from IUE lets us to define more precisely the element abundances. We have used the modern observations of PNe to determine the parameters of nebulae and element abundance in them. The abundances of He, C, N and O in Galactic PNe are compared with those calculated in the model by Marigo [1]. A class of nebulae with low element abundances is picked out. The properties of PNe in the class are considered.

Keywords: Planetary nebulae; Milky Way; Element abundances

1 Introduction

Chemical abundances of planetary nebulae (PNe) can be used to test low and intermediate mass stars evolution theories and chemical evolution models of the Galaxy (e.g. [1–3]). Kholtygin [4–6] proposed the *stochastic model* of PNe. He used the classical idea of Peimbert [7] to take into account both large and small-scale fluctuations of electron temperature T_e and electron density n_e inside the nebula for modelling the spectra of PNe. Moreover the effect of different exactness of the weak and strong lines in spectra of PNe is also taken into consideration in the *stochastic model*.

This model allows us to determine the good quality element abundances for the Galactic PNe [8]. These new abundances are stored by us in a catalogue of planetary nebulae parameters described in the next sections. In Section 3 we compare the abundances obtained by us with predictions of synthetic modes of stellar evolution. In the last section we pick up the group of PNe with low element abundances and try to establish their state of evolution.

2 Catalogue of PNe's parameters

We used a stochastic model of PNe [6] and new observational data to find the precise element abundances and other nebulae parameters for large sample of Galactic and

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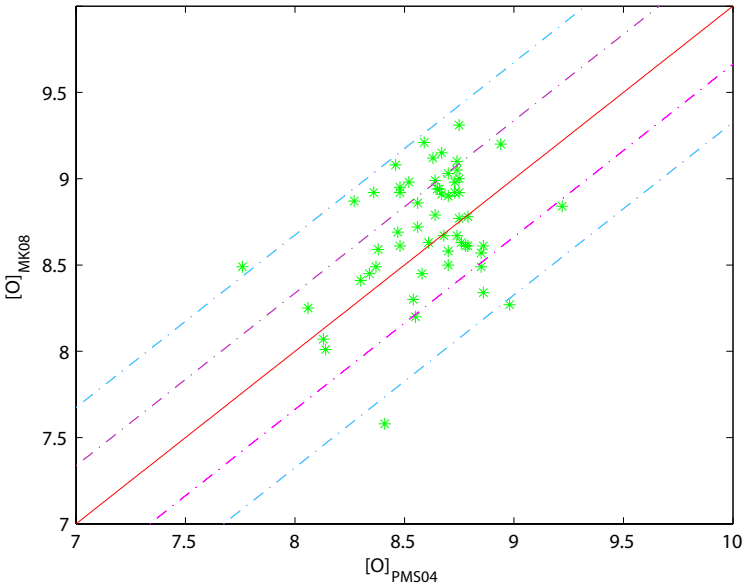


Figure 1 A comparison of oxygen abundances obtained in [10] (horizontal axe) with our data (vertical axe). Straight line corresponds to the case of equal abundances, the first dotted line shows the 1σ level, the second corresponds to the 2σ level, where σ is the standard deviation for distribution of errors in element abundance in our sample.

Magellanic Clouds' PNe. These data are used for updating the electronic version of our catalogue of Galactic and Magellanic Clouds' planetary nebulae parameters [9]. In this catalogue the readers can be also found the references on the sources of the line intensities in spectra of nebulae.

We compare our new He, C, N and O abundances with data of other authors. Figure 1 illustrates the comparison of our data with those from Perinotto et al. [10]. We see a good agreement of our O abundances with Perinotto's one. For C and N the differences between two set of abundances can be larger. We explain this fact by taking into account the temperature and density fluctuations for PNe in our model.

3 The comparison of relative C, N and O abundances in PNe ensemble with predicted in synthetic models

The synthetic star evolution models are used to avoid the huge calculations of full star evolution models and to describe simplified asymptotic giant branch star evolution or its observed parameters. Marigo et al. [11] (see also [12]) proposed the synthetic evolution model of low and intermediate stars from AGB-stage till white dwarf phase.

We compared the relative abundances of C, N and O in PNe ensemble with predicted in synthetic model [1]. Some results of this comparison are presented in Fig. 2. We can see the decreasing of C/O ratio in galactic PNe for model [1] with increasing the initial solar metallicity from $Z = 0.004$ to $Z = 0.019$. This decreasing agrees with our relative abundances for galactic PNe.

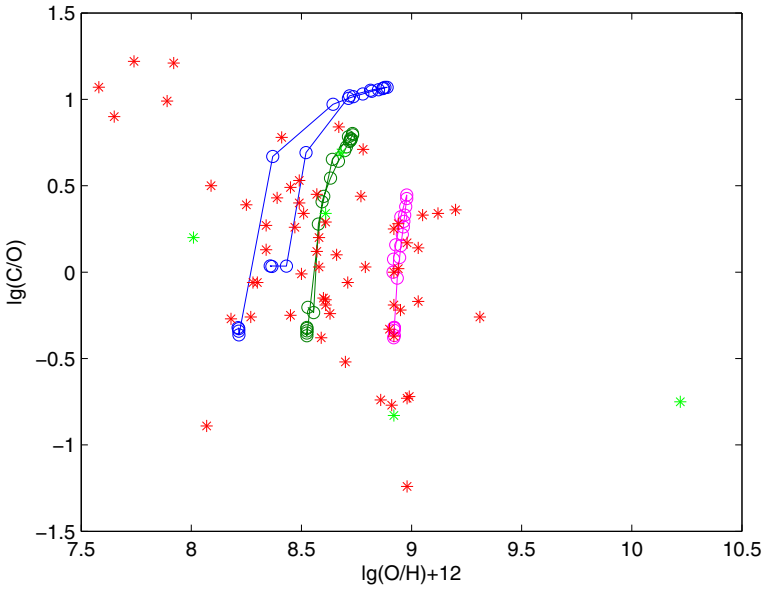


Figure 2 Abundance ratios for galactic PNe. Calculated data (stars) – C and O abundances derived in this work. Predicted abundances by Marigo [1] are shown as a function of the initial mass of different metallicity progenitor star: $Z = 0.004$ (left-hand side line (with two branches), middle line – for $Z = 0.009$, right-hand side line – for $Z = 0.019$.

There also can be seen a small group of PNe considered in the last section with extremely low oxygen abundances in a left upper corner of the figure. The central stars of these PNe are possibly the low mass white dwarfs and their precursors are probably formed in the early stages of Galaxy evolution.

4 Extremely low abundance PNe

There exist an important group of stars in our Galaxy with extremely low initial element abundances. These stars are considered to be born at the early stages of the Galaxy evolution, and their investigation can strongly facilitate the understanding of dark ages of the Galaxy evolution.

Abundances of He, C and O are strongly changed during the stellar evolution, so to establish if the progenitor of the PN is the star with low initial element abundances we have to use those elements the abundances of which were weakly changed during the progenitor star evolution. In consequence of that we consider the O, Ne, S, Cl and Ar abundances only.

We adopt the next criteria of selection for extremely low abundant progenitors of PNe:

$$[X]_\odot < -1.0 \text{ for one element from above mentioned list}$$

or

$$[X]_\odot < -0.5 \text{ for at least two elements}\,.$$

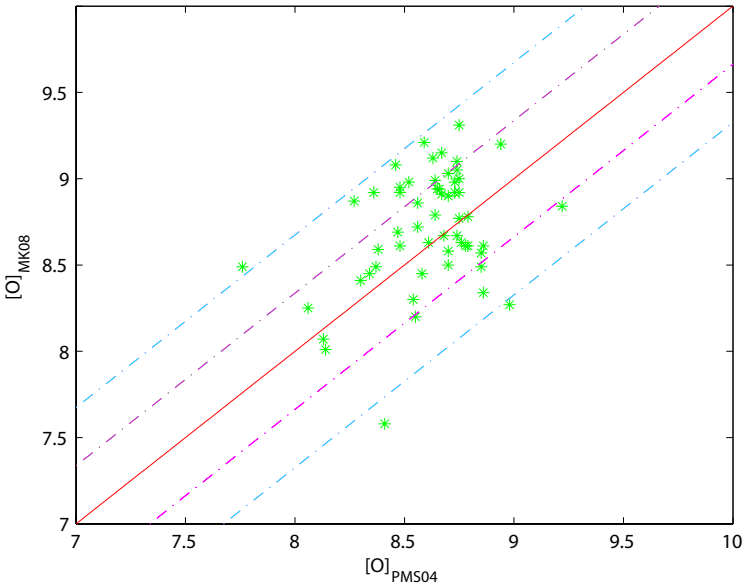


Figure 3 Distribution function of [He/H] for PNe with low O, Ne, S, Cl Ar abundances.

Here the value of $[X]_\odot$ is the *mettallicity*, which are determined by next relation:

$$[\mathrm{X}]_\odot = [\mathrm{X/H}] - [\mathrm{X/H}]_\odot \,.$$

A list of objects obtained on applying these criteria is given in Table 1. In columns 1–6 the names of PNe, their Peimbert's types [13], galactic coordinates and masses of central stars, which are taken from catalogue [9] are given.

The metallicities of He, O, Ne, S, Cl and Ar for selected nebulae are given in columns 6–13. We see from Table 1 that nebulae with low element abundances are the objects of Peimbert's II, III and IV types. It means that they belong to thick disk or Halo of the Galaxy. The can also be the objects if thin disk with large distances from the galactic plane. It says us that the progenitors of these nebulae are stars with large ages and small masses of their progenitors.

Most of the PNe which are presented in Table 1 have high He abundances. The distribution of ratios [He/H] for these nebulae is presented in Fig. 3. From this figure we can conclude that the ratio [He/H] for PNe with low element abundances is about of 1.5 times of the solar value of this ratio.

Figure 4 shows the positions on the HR diagram of the nebulae from list in Table 1. The evolution tracks for the progenitor stars for PNe with different masses of stars are taken from [14]. We plot the tracks for initial stellar metallicity $Z = 0.008$.

We see the concentration of the central stars of the considered PNe in the region of the relatively low masses of the progenitor stars $M_{cs} < 3\,M_\odot$.

Table 1 Planetary nebulae with extremely low element abundances.

PN	Type	PNG	R_z	M_{cs}	$[He]_\odot$	$[O]_\odot$	$[Ne]_\odot$	$[S]_\odot$	$[Cl]_\odot$	$[Ar]_\odot$
DdDm1	IV	061.9+41.3	-	-	0.11	-0.59	-0.57	-0.86		-0.31
H1-54	V/IV	002.1-04.2	0.28	0.580	0.04	0.09		-0.57	-0.55	-0.25
H4-1	IV	049.3+88.1	-	-	0.15	-0.25	-1.24	-1.8		-1.46
Hb12	IIb	111.8-02.8	13.03	-	0.1	-1.01	-0.24	0.29	-1.14	
Hu2-1	IIb	051.4+09.6	6.04	0.613	0.18	-0.17	-0.27	-1.21		-0.3
IC3568	IV/IIb	123.6+34.5	9.59	0.576	0.08	-0.32	-0.19	-0.86	-0.77	-0.3
IC5117	IIb	089.8-05.1	9.60	0.677	0.4	-1.08	-0.03	-0.65		-0.05
J320	III	190.3-17.7	10.73	0.609	0.24	0.21	-0.14	-1.283	-0.65	-0.347
K1-7	IIb	197.2-14.2	10.95	0.690	0.13	-0.63		-0.78		0.11
K3-66	IIa	167.4-09.1	-	-	0.16	-0.41	-0.5	-0.975		-0.27
M1-9	IIb	212.0+04.3	14.19	-	-0.04	-0.43	-1.38	-1.03		-0.18
M1-14	IIb	234.9-01.4	11.42	0.587	0.08	-0.57		-1.09		0.095
NGC0040	IIb	120.0+09.8	8.48	0.562	-0.06	-0.05	-0.015	-0.71	-0.59	-0.3
NGC2440	IIa	234.8+02.4	8.33	0.802	0.17	0.28	0.133	-0.55	-0.74	0.235
NGC3242	IIb	261.0+32.0	7.92	0.607	0.09	-0.39	0.285	-0.53	-0.57	0.45
NGC5307	IIb/(III/IV)	312.3+10.5	6.45	0.599	0.15	0.32	0.08	-0.82	-0.67	-0.28
NGC6369	IIa	002.4+05.8	6.01	0.605	0.23	0.42	0.19	-0.64		-1.13
NGC6790	IIb	037.8-06.3	5.51	-	0.15	-0.36	-0.07	-0.893	-0.73	-0.38
NGC6826	IIb	083.5+12.7	7.67	0.586	0.15	-0.21	-0.16	-0.95	-0.61	-0.385
NGC6879	IIb	057.2-08.9	6.77	0.614	0.17	0.06	0.6	-0.725	-0.76	-0.135
NGC6891	IIb	054.1-12.1	6.54	0.584	0.15	-0.15	0.08	-0.88	-0.67	0.03

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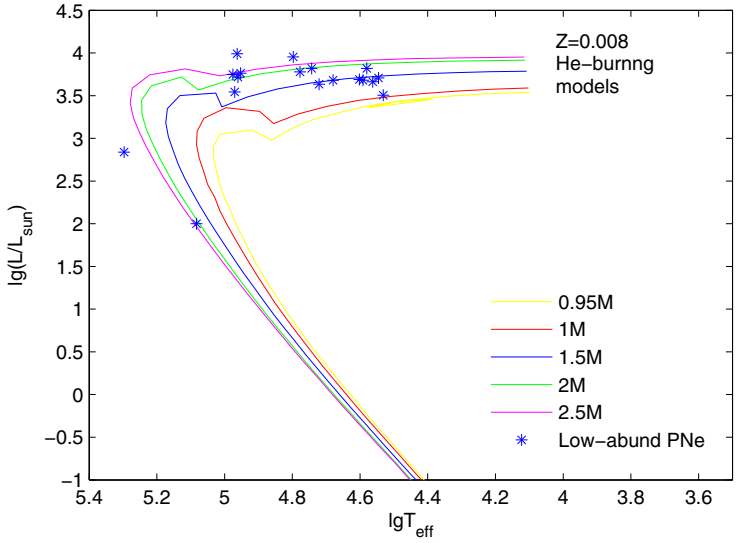


Figure 4 PNe' central stars from Table 1 on a Herzshprung–Russel diagram. He-burning PNN evolutionary model [14] with initial metallicity $Z = 0.008$. Tracks correspond to initial masses of PNN equal to 0.95, 1.0, 1.5, 2.0, and 2.5 in solar masses (bottom-up).

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