# PECULIARITIES OF THE NUCLEOSINTHESIS OF HEAVY ELEMENTS IN A DISK OF SPIRAL GALAXY

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ABSTRACT. The goal of paper to see that different models for spiral pattern of galactic disks lead to distinguishable radial distribution of heavy elements. Moreover it will be explained why the distributions, demonstrated different chemical elements show different pattern. This fact has extremely importance for understanding of the processes, which occur in a galactic disk and allows to narrow down the possible class of their models.

**Key words**: Galaxy:abundances; Galaxy:structure

## 1. Introduction

The work is devoted research of influence of galactic spiral arms on formation of radial distribution of heavy elements abundance. It is widely believed that the radial distribution of heavy elements in the galactic disk retains important information about its structure and evolution.

Earlier, it was assumed that the radial distribution of metallicity in the Galaxy could be described by a simple linear function.In the last decade pupleshed observations, which demonstrate different peculiarities on this distribution [1-12]. Moreover, in these article was demonstrated that the radial abundance distributions for different chemical elements show different pattern.

We have to bear in mind that sources of heavy elements are different objects,which space distribution also different. As believed, the main source of oxygen, supernovae Type II (SN II). These stars are known to be concentrated in the spiral arms [13]. Moreover, the progenitors of stars of this type have very short lifetimes, implying that SN II have not moved significantly from their birth places. On the other hand, the progenitors of the sources of most of the iron ($\sim 70\,\%$) – type Ia supernovae (SN Ia) – may be several billions years old [14]. Even if they were born inside an arm, they have had enough time to move far from their birth place. Thus conserns other elements, distinction in yilds proportion from supernovaes reach up to several times.

The enrichment of the any volume of interstellar gas take place only when its located near its sources, so spatial distribution of heavy elements in young objects must repeat spatial distribution of its sources.

First of all, we mention the bimodal radial abundance pattern,i. e. rather steep gradient in the inner part of the galactic disc for galactocentric distances $r < 7.5$ kpc and a plateau up to 11 kpc for oxygen.

Of course, researches of thin structure of radial distribution of heavy elements are still far from the end, and we are only in the beginning of the way. Probably, future observations will be more informative. However as show our calculations, peculiarities in the radial distribution of heavy elements may be formed under the influence of galactic spiral arms. Thus different models of spiral structure lead to distinguishable pictures of the radial abundance distributions.

## 2. Basic ideas and equations

For research of chemical evolution of a galaxy traditionally use the equations formulated by Tinsley [15] and specified by Lacey & Fall [16]. We also use their approach, but with two essential additions: 1) the influence of spiral arms will be considered and 2) the effect of diffusion of elements will be taken into account.

The corresponding equations:

$$\frac{\partial \mu_s}{\partial t} = (1-R)\psi, \quad (1)$$

$$\frac{\partial \mu_g}{\partial t} = -(1-R)\psi + f, \quad (2)$$

$$\mu_g \frac{\partial Z}{\partial t} = P_Z \psi + f(Z_f - Z) + \frac{1}{r}\frac{\partial}{\partial r}(r\mu_g D \frac{\partial Z}{\partial r}), \quad (3)$$

where $Z$ is the oxygen content, $\mu_s$ and $\mu_g$ are the surface densities for the stellar and gaseous disks correspondingly, $\psi$ is the star formation rate (SFR; we use the instantaneous recycling approximation), $f$ is the in fall rate of matter onto the galactic disk, $Z_f$ is its abundance (we adopt $Z_f = 0.17 Z_\odot$), $R$ is the stellar mass fraction returned into interstellar medium (ISM), $P_Z$ is the part of the stellar mass ejected into ISM as a newly synthesized element (oxygen in our case), $r$ is the galactocentric distance, $t$ is time. The last term in equation (3) describes the heavy element diffusion due to turbulent motions in ISM. Let us now discuss the influence of spiral arms on radial oxygen distribution. SN II, according to observations, accurately concentrate in spiral arms. SN Ia do not show such close communication with spiral arms, they can be present out of arms and even out of a disk [13]. Therefore, first of all, influence of spiral arms will affect oxygen distribution. Here sees two possible channels.

The first is caused by that rate nucleosinthesis of oxygen is connected with rate of birth SN II. Rate of birth SN II depends on star formation rate, which is defined, according to Roberts [17], intensity of the galactic shock wave arising in interstellar gas at its flowing in a spiral arms. Such idea of influence of spiral arms on nucleosinthesis has been done by Oort 1974 [18].

Here it is necessary to tell, that there are different opinions concerning that, whether or not galactic shock waves influence on star formation rate. There are researches with arguments both for and against this assumption. As a whole, for today it is definitely may to speak, that the most massive stars (SN II, stars of classes O,B) really concentrate to spiral arms. At the same time the equations of chemical evolution include SFR $\psi$ of stars all masses, including low masses. Thus, this problem still waits for the unambiguous decision.

Therefore we will pass to discussion of other effect which is connected by that enrichment of some volume of interstellar gas by oxygen will occur only when the volume appears close its sources, SN II, i. e. in spiral arms. Therefore rate of enrichment on the given radius is defined, it is obvious, frequency of occurrence of the considered volume of gas in arms.

The matter is that a spiral pattern as the density wave, rotates as a solid body, i. e. its angular velocity $\Omega(r)$ is constant. The galactic disk rotates differentially, its angular velocity $\Omega_P$ is function of radius. It is visible, that frequency of occurrence of an element of gas in arms is defined by a difference of rotation velocity of a disk matter and wave pattern velocity $\Omega(r) - \Omega_P$. Therefore quantity $P_Z$ which is interpreted as the part of the stellar mass ejected into interstellar medium on the given radius in the form of new synthesised oxygen not be a constant as in previous researches, but proportional to the above difference. So we can write

$$P_Z \sim |\Omega(r) - \Omega_P|, \qquad (4)$$

Area where both these velocities coincide $\Omega(r_C) = \Omega_P$, is called the corotation. Frequency of entering into spiral arms the volume of ISM is close to zero near corotation, so here there is a feature: oxygen injection into interstellar medium will be suppressed. Competing process is turbulent diffusion of elements. With influence corotation and diffusion we connect the mechanism of occurrence of features in radial distribution of oxygen in a galactic disk.

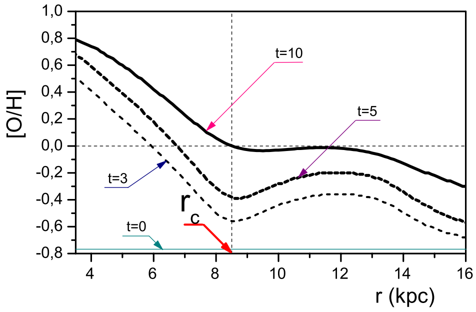


Figure 1: Evolution of the radial oxygen distribution in the model of a stationary long-lived spiral pattern with corotation resonance at solar position $r_C = r_\odot$. The Sun is at $r_\odot = 8.5$ kpc. Time is in Gyrs.

## 3. Results and discussion

In what follows, we will examine the oxygen radial abundance patterns, predicted by various models for the spiral pattern, because it is the most sensitive indicator of the influence of spiral arms on galactic enrichment by heavy elements.

Results of research show, that different models of density waves pattern differ from each other in the oxygen radial distribution and evolution.

In models with long-lived (or quasi-stationary) spiral structure, the location of corotation resonance is crucial for the final pattern oxygen abundance. Only for a case with corotation radius being situated in the intermediate region of the galactic disc (it is close to solar position) the structure of such distribution like bimodal.Example of calculation in the frame of this model are presented on Fig. 1.

As to models with corotation resonance on the very end of a galactic disk or close to its centre, they do not show any features on radial distribution of an abundance in the area accessible to observations, it monotonic. In the first case, the gradient close to those which is traditionally resulted in observant works. If the corotation radius is located near the centre of Galaxy the oxygen gradient is too steep, that is not supported by any observations.These results are presented on Fig. 2 and Fig. 3.

Very interesting result are obtained in the model in

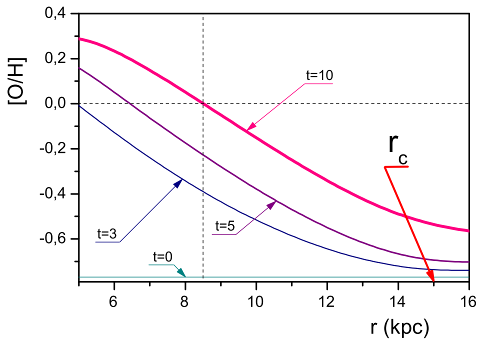


Figure 2: The same as in Fig.1 but for a model with corotation resonance at $r_C = 15$ kpc

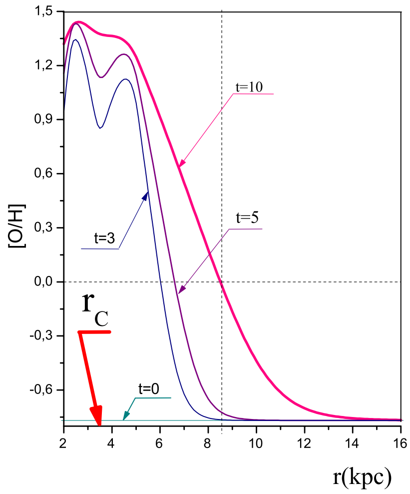


Figure 3: The same as in Fig.1 but for a model with corotation resonance at $r_C = 3.5$ kpc

which corotation radius drifts along r in time: abundance distribution depends on a direction and the region of the corotation resonance drift.

As to model in which corotation radius wanders over a large galactic radius (from outskirts to the inner part), abundance distribution linear (Fig. 4).

In the cases when the corotation resonance drifts from 9 to 7 kpc during the galactic disk life and in the opposite direction from 7 to 9 kpc we have similar pictures with a bimodal-like structure (Fig. 5).

The concept in which the spiral structure is a succession of transient (or short-lived) spiral waves, irrespective of time of existence of each private pattern, the resulting gradient appears too steep (Fig. 6).

Thus, our work strongly suggests that models of the chemical evolution of the Galactic disc must take into account the effect of the spiral pattern.

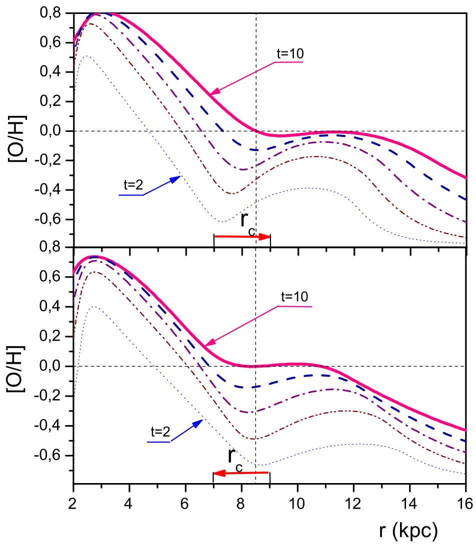


Figure 4: The same as in Fig. 1 but the pattern rotation velocity $\Omega_P$ changes so as the corotation resonance drifts between 15 kpc and 4 kpc

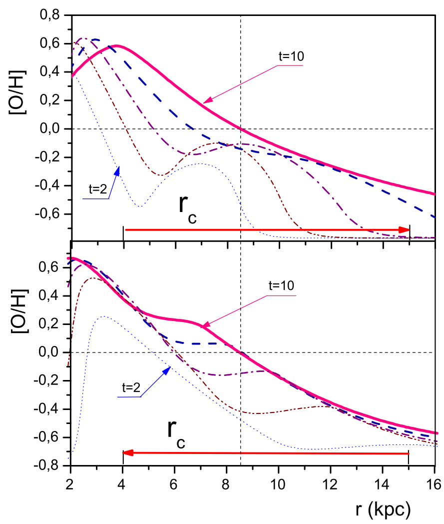


Figure 5: The same as in Fig. 1 but for the corotation resonance driftsbetween 7 kpc and 9 kpc

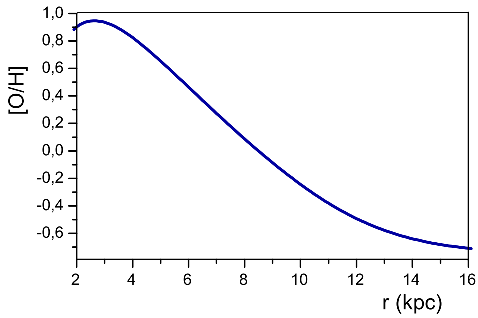


Figure 6: The final (at $t$ = 10 Gyr) radial oxygen distribution for a succession of transient spiral density waves)

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