 STELLAR LIFETIMES AND ABUNDANCE GRADIENTS: HINTS FROM CENTRAL STARS OF PLANETARY NEBULAE

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1. Abundance gradients
2. PN abundances
3. CSPN lifetimes
4. Results

WORK IN PROGRESS
PRELIMINARY RESULTS
1. Abundance gradients

Abundance gradients are the variation of the chemical abundances with the galactocentric distance or with the height above the galactic plane. They basically reflect the changes of the star formation rate in the Galaxy.

Several chemical elements can be studied in objects such as HII regions, planetary nebulae, hot stars, AGB stars, supernova remnants, etc.
Abundance gradients provide some of the main constraints of chemical evolution models. The goal is to determine the average magnitude of the gradients, their space variations along the galactic disk and their time variations since the formation of the Galaxy.
Average gradients

Henry & Worthey (1999)
Average gradients

- Spitoni e Matteucci (2011)
- Luck, Andrievsky et al. (2011)

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Space variations

Cescutti et al. (2007)

Sestitio et al. (2006)

Gutenkunst et al. (2008)
PLANETARY NEBULAE
Costa, Uchida & Maciel (2004)

CEPHEIDS
Andrievsky et al. (2004)
Time variation

Some recent theoretical models predict a time flattening of the observed radial abundance gradients, while other models predict the opposite behaviour. This can be analyzed on the basis of abundances of planetary nebulae and open clusters, and in both cases the results depend on the ages of the objects considered.
2. PN abundances

Why study planetary nebulae?
Planetary nebulae have strong emission lines of H, He, O, N, Ne, S, Ar, etc. The analysis of these lines give abundances accurate to about 0.2 dex or better.
Planetary nebulae are ejected by stars having between 0.8 and 8 $M_\odot$ on the main sequence: this means they may be representative of different ages and populations.
Planetary nebulae (PN) allow the determination of accurate abundances of elements that are not produced by the progenitor stars (O, S, Ne, Ar, ...).  

- Chemical evolution of the host galaxies

Accurate abundances of elements that are produced by the progenitor stars are also measured in PN (He, N, C).  

- Intermediate mass star nucleosynthesis

Some of these elements are difficult to study in stars.  

- Comparison with stellar data
PN abundances of O, Ne, Ar, and S generally show good correlations, indicating that Ne and Ar vary in lockstep with O.
Oxygen as a metallicity proxy

\[ [\text{Fe/H}] = \gamma + \delta [\log (\text{O/H}) + 12] \]

Measurements of the oxygen abundances and [Fe/H] metallicities in disk stars can be used to estimate the O vs Fe relation in the Galaxy. This allows the comparison of [Fe/H] and O/H radial abundance gradients.
3. CSPN lifetimes

<table>
<thead>
<tr>
<th>progenitor mass</th>
<th>central star mass</th>
<th>progenitor’s birth</th>
<th>PN type$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4 – 8 $M_\odot$</td>
<td>$&gt; 0.64 M_\odot$</td>
<td>1 Gyr ago</td>
<td>Type I</td>
</tr>
<tr>
<td>1.2 – 2.4 $M_\odot$</td>
<td>0.58 – 0.64 $M_\odot$</td>
<td>3 Gyr ago</td>
<td>Type II</td>
</tr>
<tr>
<td>1.0 – 1.2 $M_\odot$</td>
<td>$\sim 0.56 M_\odot$</td>
<td>6 Gyr ago</td>
<td>Type III</td>
</tr>
<tr>
<td>0.8 – 1.0 $M_\odot$</td>
<td>$\sim 0.555 M_\odot$</td>
<td>10 Gyr ago</td>
<td>Type IV</td>
</tr>
</tbody>
</table>

$^a$ PN types according to Peimbert (1978, 1990)

Stasińska (2000)
Age distribution of the central stars of galactic disk planetary nebulae

W. J. Maciel, R. D. D. Costa, and T. E. P. Idiart

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KINEMATIC AGES OF THE CENTRAL STARS OF PLANETARY NEBULAE

W. J. Maciel, T. S. Rodrigues, and R. D. D. Costa
METHODS BASED ON PN ABUNDANCES

Method 1: The age-metallicity-radius relation
Method 2: The galactic age-metallicity relation
Method 3: N/O masses of CSPN

METHODS BASED ON KINEMATIC DATA

Method 4: The galactic rotation velocity
Method 5: The U, V, W velocity components
METHOD 1
THE AGE-METALLICITY-RADIUS RELATION

O/H abundances of PN are converted to [Fe/H] metallicities according to the results by Maciel, Costa & Uchida (2003). The age-metallicity-radius relation by Edvardsson et al. (1993) is used to obtain the stellar ages.
METHOD 5
THE U, V, W COMPONENTS

The $U$, $V$, $W$, and total $T$ velocity components are calculated from the CSPN data (distances, velocities and proper motions). Using the velocity dispersion – age relation $\sigma(t)$ from the Geneva-Copenhagen survey, the age distribution of the CSPN can be obtained.
4. Results

We have used the method proposed by Maciel, Lago & Costa (2005):

This method consists in separating the PN sample into two groups according to their ages, and estimating the O/H and Ne/H average abundances and the magnitude of the radial gradients as functions of the age limit.
Method 1
Example
Age limit: 4.0 Gyr

Sample of well studied PN

Young
-0.07± 0.01 dex/kpc

Old
-0.07± 0.01 dex/kpc
Method 1
Example
Age limit: 4.5 Gyr

Young
-0.07 ± 0.01 dex/kpc

Old
-0.08 ± 0.01 dex/kpc
Method 5

From the CSN sample by Maciel et al. (2011) (403 objects) we estimated the kinematic ages using the W and Total Velocities for a total of 241 objects.

To avoid the problem of the space variation of the gradients, we have considered only the nebulae in the range of galactocentric distances given by $3 < R \, (\text{kpc}) < 12$. 
Similar results for Ne/H
Example:
O/H abundances
Age Limit: 2.5 Gyr

-0.02 dex/kpc

-0.03 dex/kpc
Comparison: Independent Sample

Application of the kinematic method to the PN sample by Henry et al. (2010)

- Young
  \[ -0.05 \pm 0.02 \text{ dex/kpc} \]

- Old
  \[ -0.03 \pm 0.01 \text{ dex/kpc} \]
The younger group has slightly higher O/H abundances, as expected, although the differences are small.

The gradients of O/H and Ne/H for both groups are similar within the uncertainties. The average O/H gradient is in the range -0.03 to -0.07 dex/kpc.

This reinforces the conclusion that the average gradient has remained approximately constant in the last 3-5 Gyr. Radial migration and mixing may affect this conclusion.
Gibson et al. (2012)
THANK YOU
MUCHAS GRACIAS