Planetary nebulae and the chemical evolution of the galactic bulge

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05/17/2011

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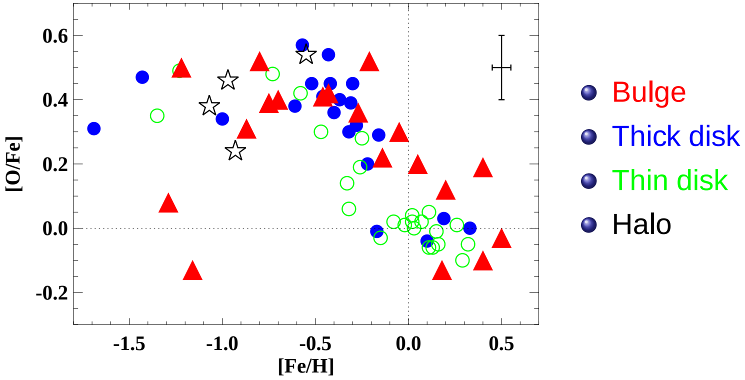
Acknowledgment: FAPESP CAPES CNPq Ciemat

Content

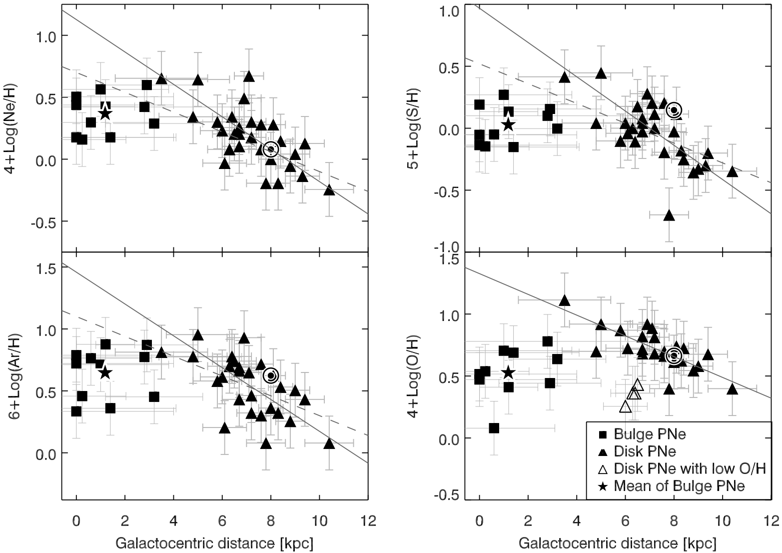
Abundances in the inner Milky Way

Red Giant Stars (Meléndez et al. 2008)



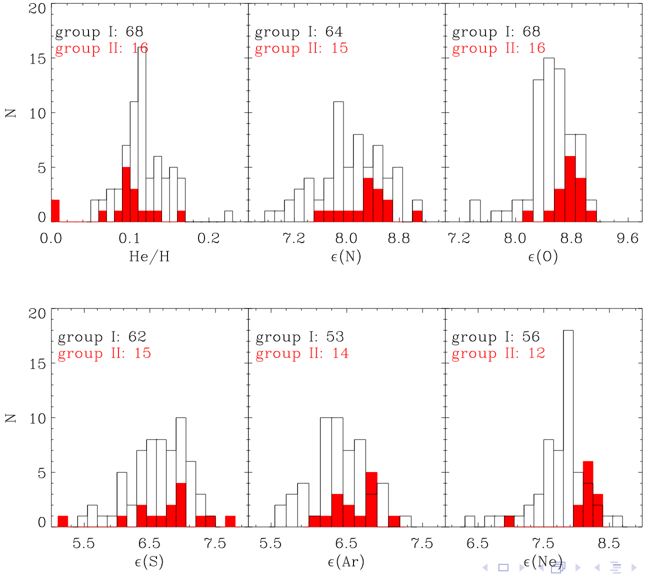
Abundances in the inner Milky Way

Planetary Nebulae (Gutenkunst et al. 2008)



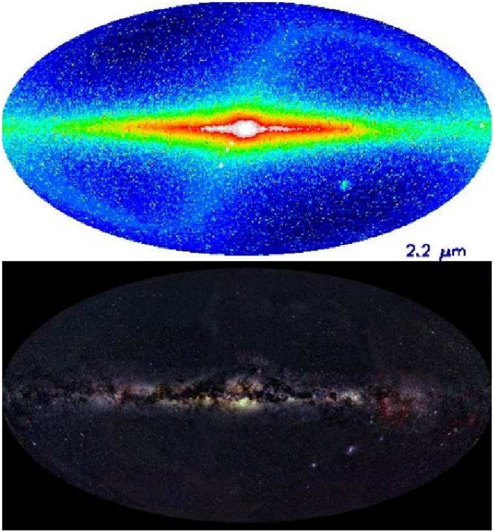
Abundances in the inner Milky way

Planetary Nebulae (Cavichia et al. 2011)



$R_L = 2.2$ kpc

The bulge/bar



COBE/DIRBE Near IR (Dwek et al. 1995) and Optical map (Copyright Axel Mallenhoff 2001).

The bulge/bar

Influences that a bar would has in the abundances distribution:

- Increases the gas flow towards the galactic center.
- Feed the star formation in the galactic center.
- Decreases the density of gas in the bulge-disk connection.
- Lower abundances in the bulge-disk connection.

Objectives

- To study of the distribution of chemical abundances in the inner Milky Way
- To obtain new chemical abundances of PNe in the inner Galaxy
- To provide observational constraints for the chemical evolution models
- Development of a chemical evolution model including radial gas flows

Observations

- Goodman Spectrograph (300 l/mm, 0.8” slit)
- 10 PNe from Jacoby & van de Steene 2005, A&A, 419, 563
- 2 PNe from Parker et al. 2006, MNRAS, 373, 79
- 4 nights (June 2009, 2010) in Remote Mode

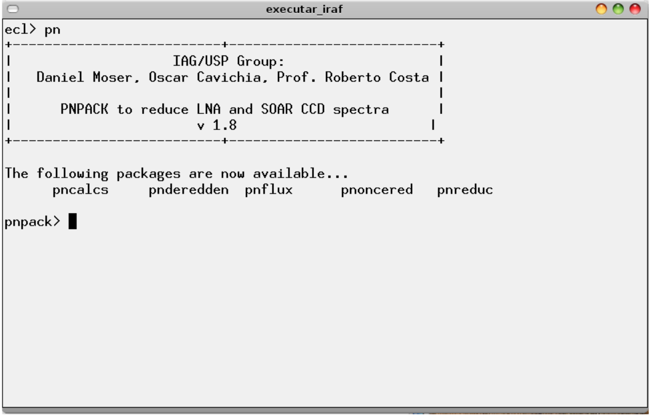
Data reduction

IRAF
Image Reduction and Analysis Facility

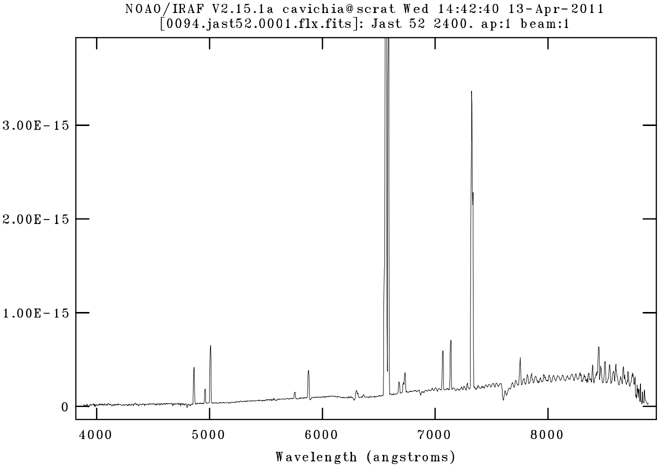
- Correction of bias and flat-field
- Spectrum extraction
- Calibration in wavelength
- Calibration in flux

Data reduction

Program PNPACK for data reduction and analysis



Data analysis



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Physical parameters

Electronic density

$$\frac{I_{31}}{I_{21}} = \frac{g_3 A_{31} \nu_{31}}{g_2 A_{21} \nu_{21}} \left[\frac{1 + (A_{21}/n_e \gamma_{21})}{1 + (A_{31}/n_e \gamma_{31})} \right] e^{-E_{32}/kT}$$

Electronic temperature

$$\frac{I_{495.9} + I_{500.7}}{I_{436.3}} = \frac{7.73 \times e^{3.29 \times 10^4/T}}{1 + 4.45 \times 10^{-4} n_e / T^{1/2}}$$

$$\frac{I_{654.8} + I_{658.3}}{I_{575.5}} = \frac{6.91 \times e^{2.50 \times 10^4/T}}{1 + 2.5 \times 10^{-3} n_e / T^{1/2}}$$

Determination of the abundances

Ionic abundances

- $\dfrac{n(X^i)}{n(H^+)} = f(n_e, T_e, \text{atomic data}) \times \dfrac{I(\lambda)}{I(H\beta)}$
- IRAF nebular software (Shaw & Dufour 1995)

Elemental abundances

- Ionization correction factors (ICF)
- Kingsburgh & Barlow 1994

Data analysis

Statistical Method for abundance determination

Alloin et al. (1979)

$$\epsilon(O) = 8.73 - 0.32 \times O3N2$$

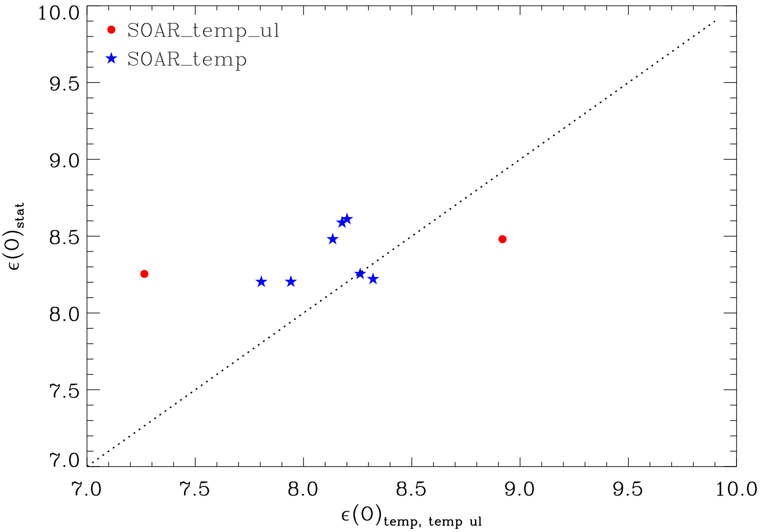
$$\epsilon(X) = log(X/H) + 12$$

$$O3N2 = log\left(\frac{[OIII]\lambda 5007/H\beta}{[NII]\lambda 6583/H\alpha}\right)$$

$$-1.0 < O3N2 < 1.9$$

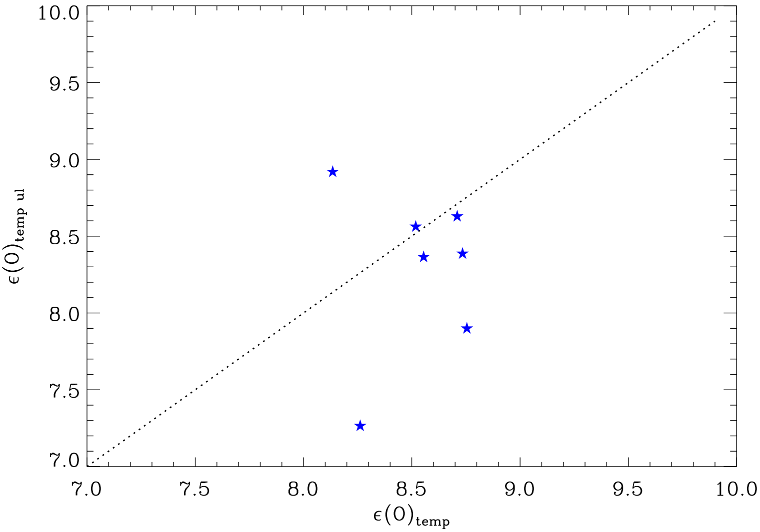
Data analysis

Statistical vs. temperature methods



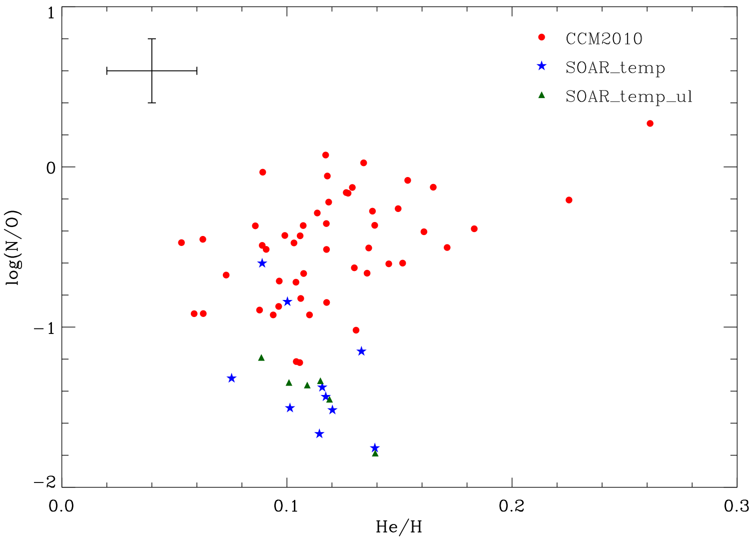
Data analysis

Temperature upper limit vs. temperature methods



Data analysis

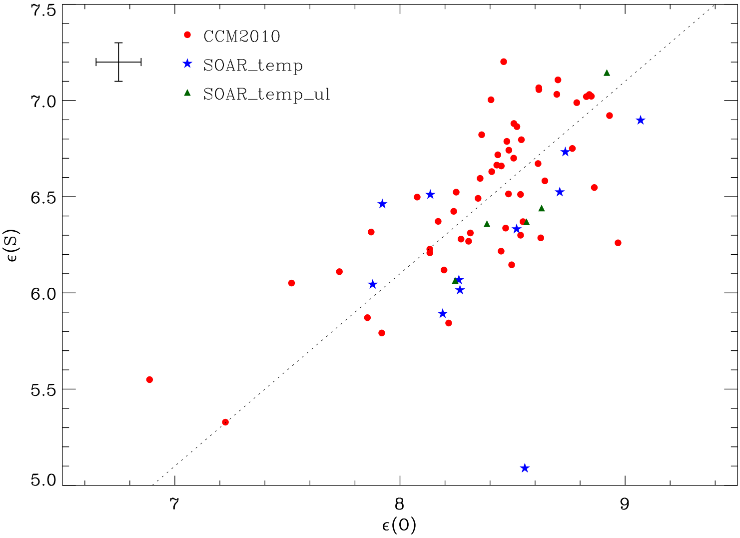
log(N/O) vs. He/H



CCM2010 = Cavichia et al. 2010

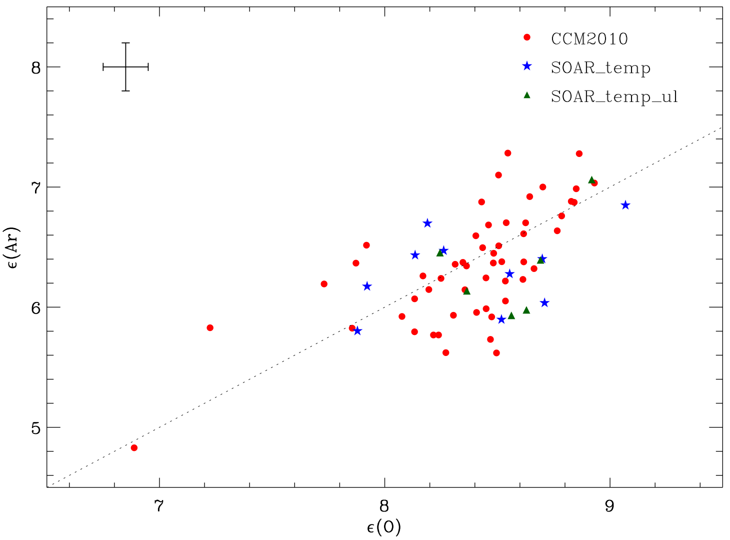
Data analysis

Sulfur vs. Oxygen



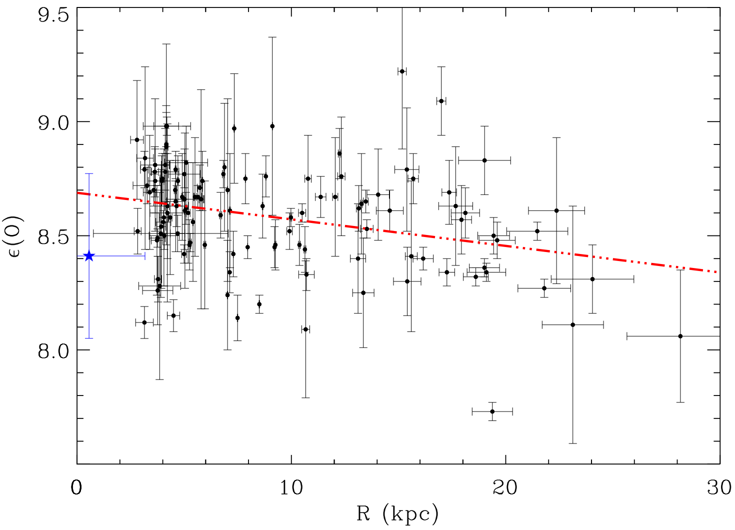
Data analysis

Argon vs. Oxygen



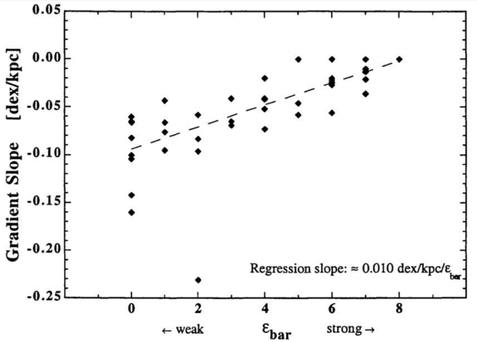
Data analysis

Oxygen radial abundance gradient



Disk data from Stanghellini et al. 2010

Gradients in barred galaxies



Martin & Roy (1994)

$\epsilon_{bar} = 10(1 - b/a)$

$d(O/H)/dR \simeq -0.140(b/a) + 0.033$

MWG: $b/a \sim 0.6$ (Merrifield 2003)

$d(O/H)/dR \simeq -0.051 dex/kpc$

Observations: $d(O/H)/dR \simeq -0.04$ to -0.07 (HII, PN, B stars)

The chemical evolution model

Description of the model

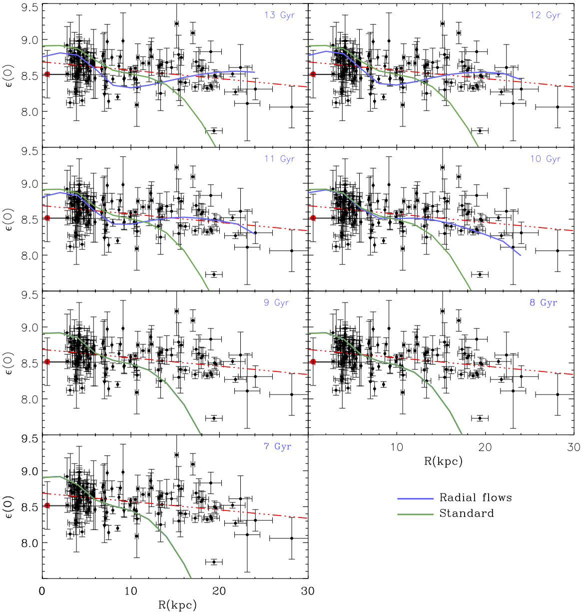
- Generalization of that developed by Ferrini et al. (1992) for the solar neighborhood
- Applied to the whole MWG by Ferrini et al. (1994)
- Other spiral galaxies by Mollá et al. (1996,1999)
- For the MW bulge by Mollá et al. (2000)

The chemical evolution model

Equations of the model

$$\begin{aligned}\frac{d}{dt}G_i(r_k,t) = \; & -X_i(r_k,t)\Psi(r_k,t) + \\ & + \int_{M_l}^{M_u} \Psi(r_k,t-\tau_M)R_i(M)\Phi(M)dM + \\ & + \left[\frac{d}{dt}G_i(r_k,t)\right]_{inf} + \\ & + \left[\frac{d}{dt}G_i(r_k,t)\right]_{rf}\end{aligned}$$

Model results



Conclusions

- SOAR spectra improved our knowledge about chemical abundances os PNe located near the galactic center
- First results show that they are originated from low mass stars
- The radial α-elements abundances indicate that they do not follow the trend of the disk
- A galactic chemical evolution model is used in order to simulate the effects of a bar on the chemical abundance gradient of the Galaxy
- The first results show that radial flows induced by the bar can flatten the gradient in a time scale of 4-5 Gyr.

Thanks SOAR people for the support!