Counterpart method for abundance determination in HII regions

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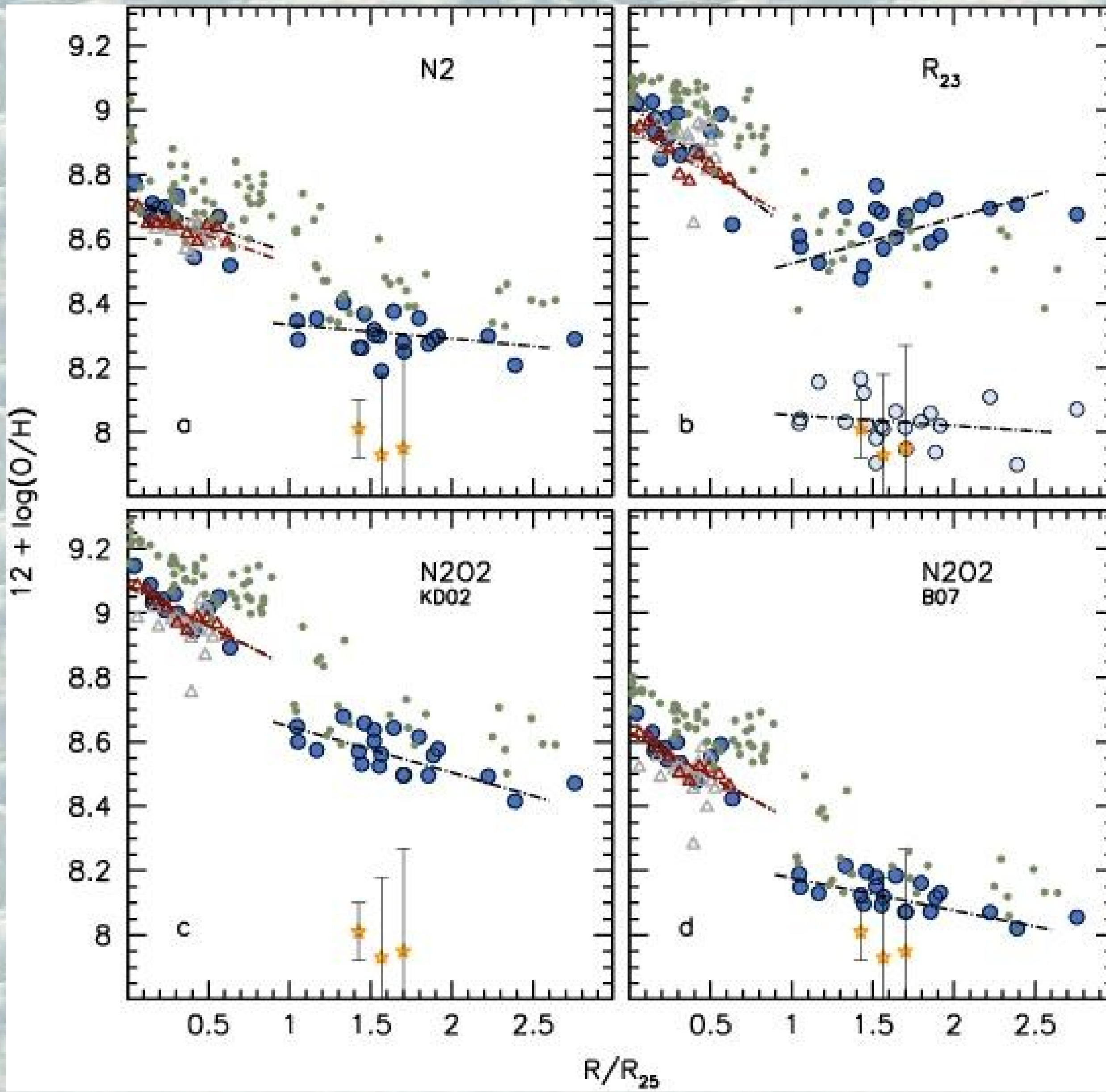
Mapping oxygen in the Universe, Puerto de la Cruz, Tenerife, 16 May 2012

Radial oxygen abundance gradient in the extended disk of the NGC 4625, determined using various strong line methods (Goddard et al. 2011, MNRAS, 412, 1246)



Our approach to the abundance determination in HII region is based on the standard suggestion:

Some combination of the strong line intensities can be used as an indicator of the metallicity in HII region.

Then, HII regions with similar intensities of the strong lines have similar electron temperatures and abundances

Realization:

A sample of the reference HII regions with measured electron temperatures and abundances is compiled. We choose among the reference HII regions that has minimum difference of strong line intensities compared to the investigated HII region, i.e. we search for the counterpart for the investigated HII region. Then the abundance in the investigated HII region can be adopted to be the same as that in its counterpart.

To obtain more reliable estimation of the abundance in the investigated HII region, we select a number of counterparts and then estimate the abundance in the investigated HII region through extra(inter)polation.

To find the counterpart for the HII region under study, we will compare not the four measured nebular lines

$$R_3, \; R_2, \; N_2, \; S_2$$

but instead four other values that are expressed in terms of these line intensities

$$P = R_3/(R_3+R_2), \quad \log R_3, \quad \log(N_2/R_2), \quad \log(S_2/R_2)$$

We specify the difference between the spectra of two HII regions as

$$\Delta Sp = \{¼ \; [(\Delta P)^2 + (\Delta \log R_3)^2 + (\Delta \log(N_2/R_2))^2 + (\Delta \log(S_2/R_2))^2] \}^{1/2}$$

The HII region with smallest value of the ΔSp will be considered as the counterpart for the investigated HII region.

The oxygen and nitrogen abundances in the studied HII region can be assumed to be the same as those in its counterpart

- The number of reference HII regions is limited. Hence, in some cases there may be significant differences between oxygen or/and nitrogen abundances of the studied HII region and its counterpart.

- The Te-based abundances for the reference HII region can involve some errors.

Therefore, the assumption that the oxygen abundance in the investigated HII region is equal to that in its counterpart can result in appreciable error in abundance of target HII region

To get more reliable abundance for the considered HII region, a number of reference HII regions should be selected and then the abundance in the target HII region is estimated through extra-/interpolation.

Using a number of the reference HII regions with metallicities near the metallicity of the selected counterpart HII region, one can obtain a linear expression for the oxygen abundance of the form

$$12 + \log(O/H) = a_0 + a_1 \log R_3 + a_2 P + a_3 \log(N_2/R_2) + a_4 \log(S_2/R_2)$$

and estimate the abundance in the investigated HII region from this relation

The coefficients a_j in equation depend of the adopted interval of metallicity around the metallicity of the counterpart Δ(O/H) which defines a subsample of reference HII regions used to derive these coefficients

Selection of reference HII regions.

Our list contains 714 spectra with measured auroral lines (in some cases 3 auroral lines), then the resulting number of electron temperatures measurements is 899

The uncertainty of the oxygen abundance can be quantified by the discrepancy between C-based and Te-based abundances

$D_{O/H} = (O/H)_C - (O/H)_{Te}$ and $D_{N/H} = (N/H)_C - (N/H)_{Te}$

We select reference HII regions where the discrepansies in the oxygen and nitrogen abundances are less than a fixed values of $D^*_{O/H}$ and $D^*_{N/H}$ Then, the selected sample of reference HII regions depends on three parameters

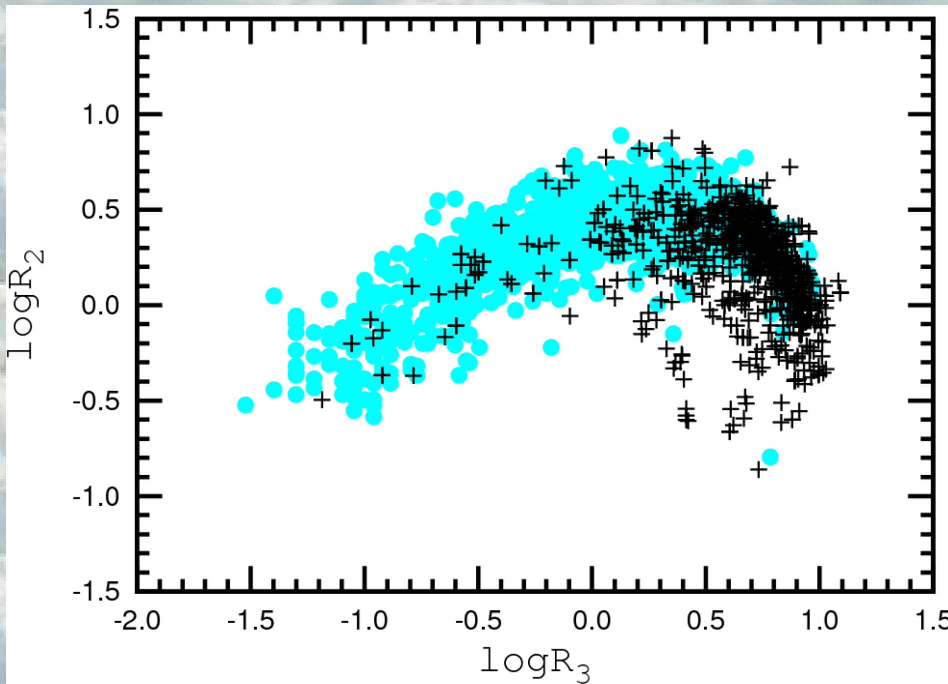
$D^*_{O/H}$, $D^*_{N/H}$ and $\Delta(O/H)$

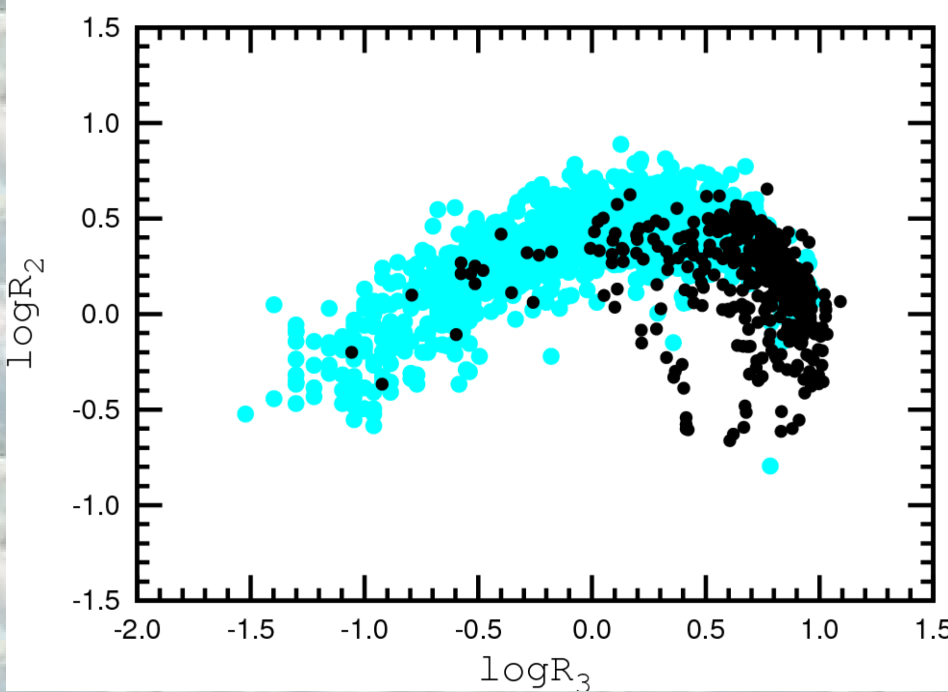
In the case $\Delta(O/H) = 2 D^*_{O/H}$ and $D^*_{N/H} = D^*_{O/H}$ each sample of reference HII regions can be specified by a single parameter, $D^*_{O/H}$

The sample Rsample12 with $D^*_{O/H} = 0.12$ dex has been selected from our compilation of HII regions

The sample Rsample10 with $D^*_{O/H} = 0.10$ dex has been selected from the sample Rsample12

The sample Rsample08 with $D^*_{O/H} = 0.08$ dex has been selected from the sample Rsample10



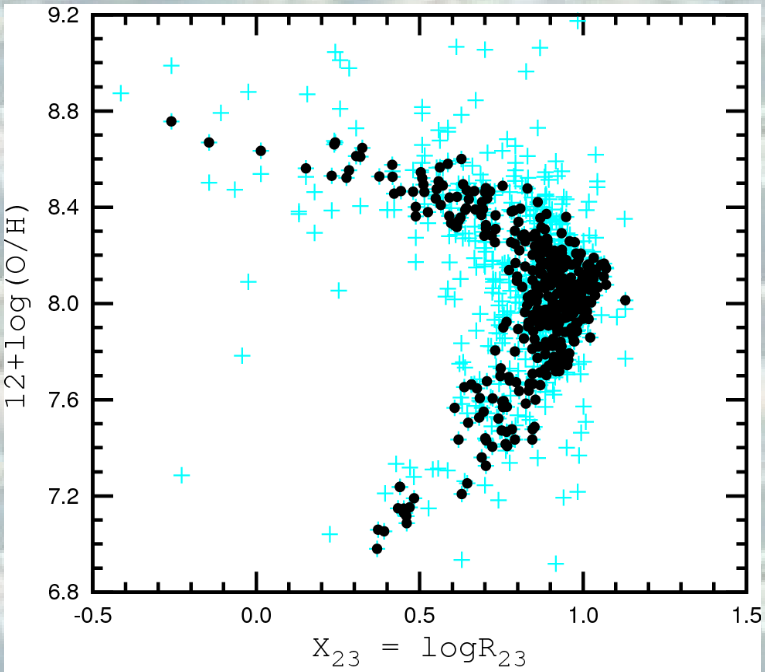


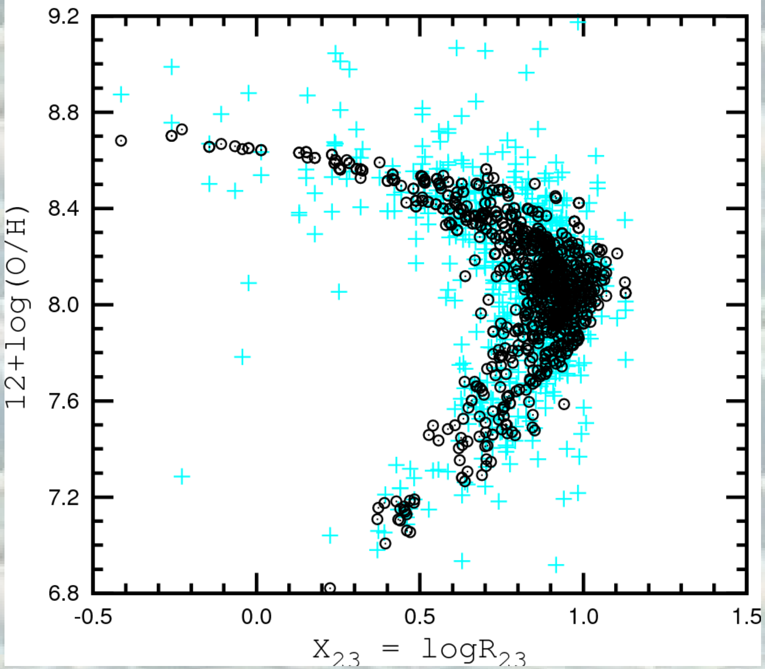
The $\log R_3$ - $\log R_2$ diagram

The blue circles are HII regions in nearby galaxies (they are shown in order to outline the area occupied by the HII regions in the diagram)

Top. Black plus signs.
The HII regions with the Te-based abundances from the presnt compilation.

Bottom. Black circles.
The selected reference HII region, the sample *Rsample10*





The $\log R_{23}$ - O/H diagram

The blue plus signs are HII regions from the present compilation for the case of Te-based abundances

Top. Black points.
The selected reference HII regions, the sample *Rsample10*
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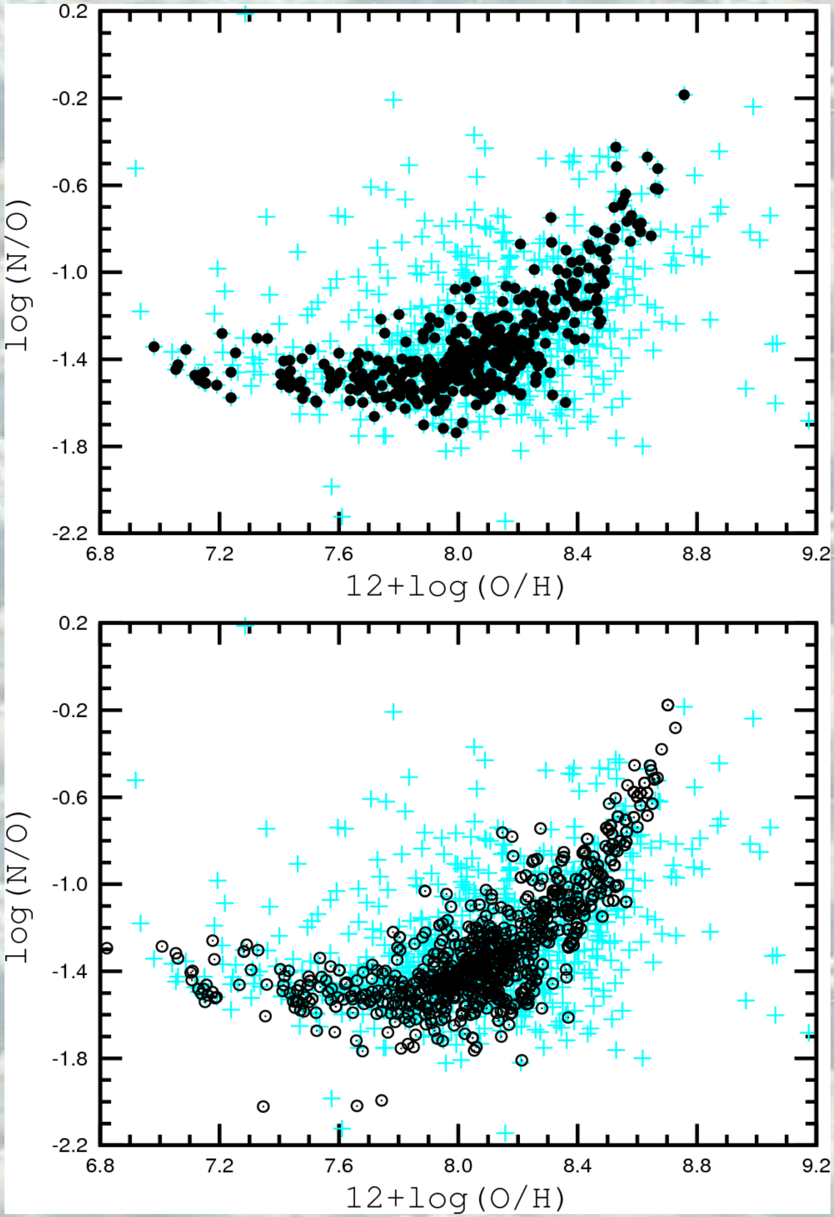
Bottom. Black circles.
HII regions from the present compilation for the case of C-based abundances



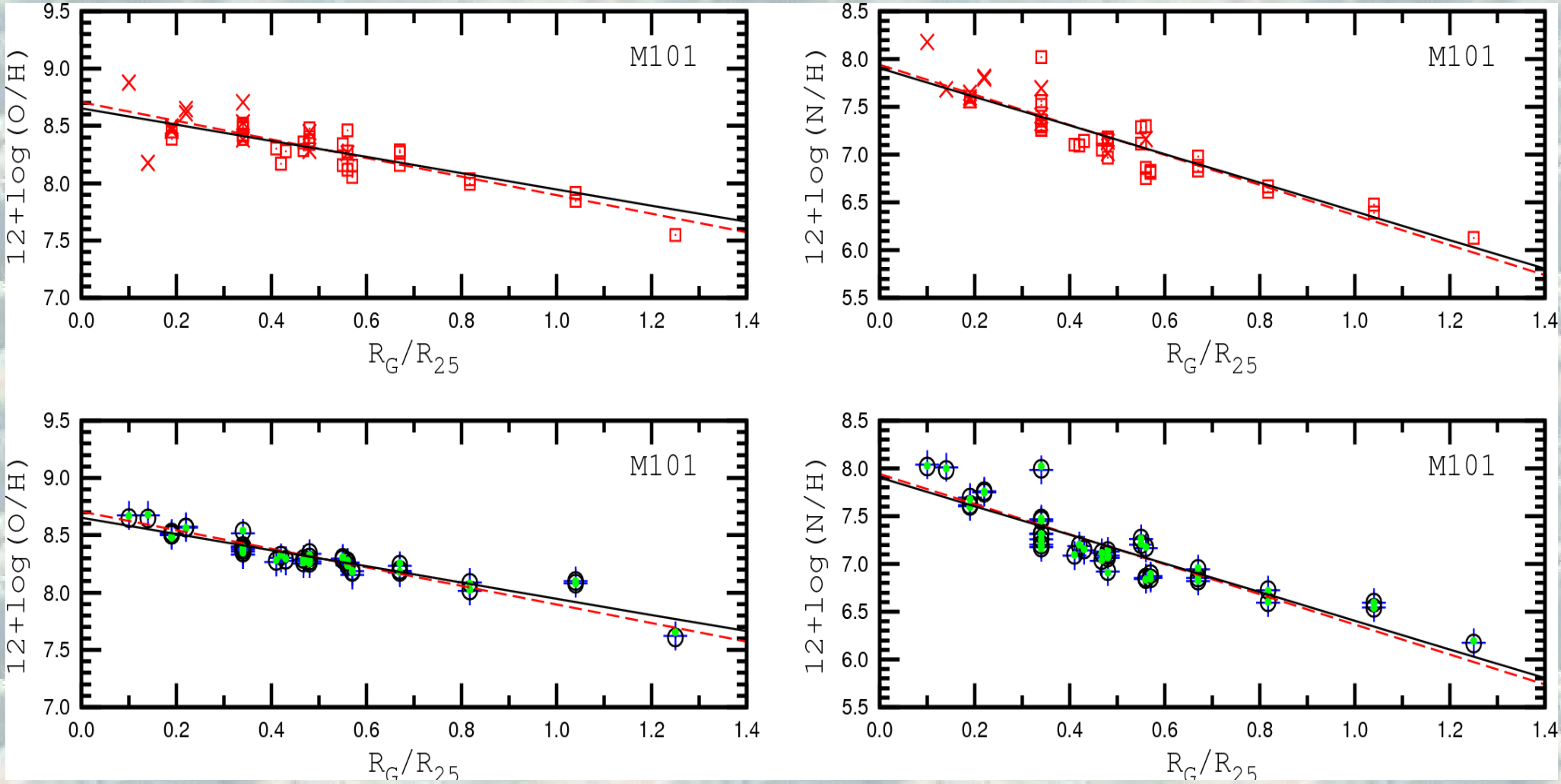
The O/H — N/O diagram

The blue plus signs are HII regions from the present compilation for the case of Te-based abundances

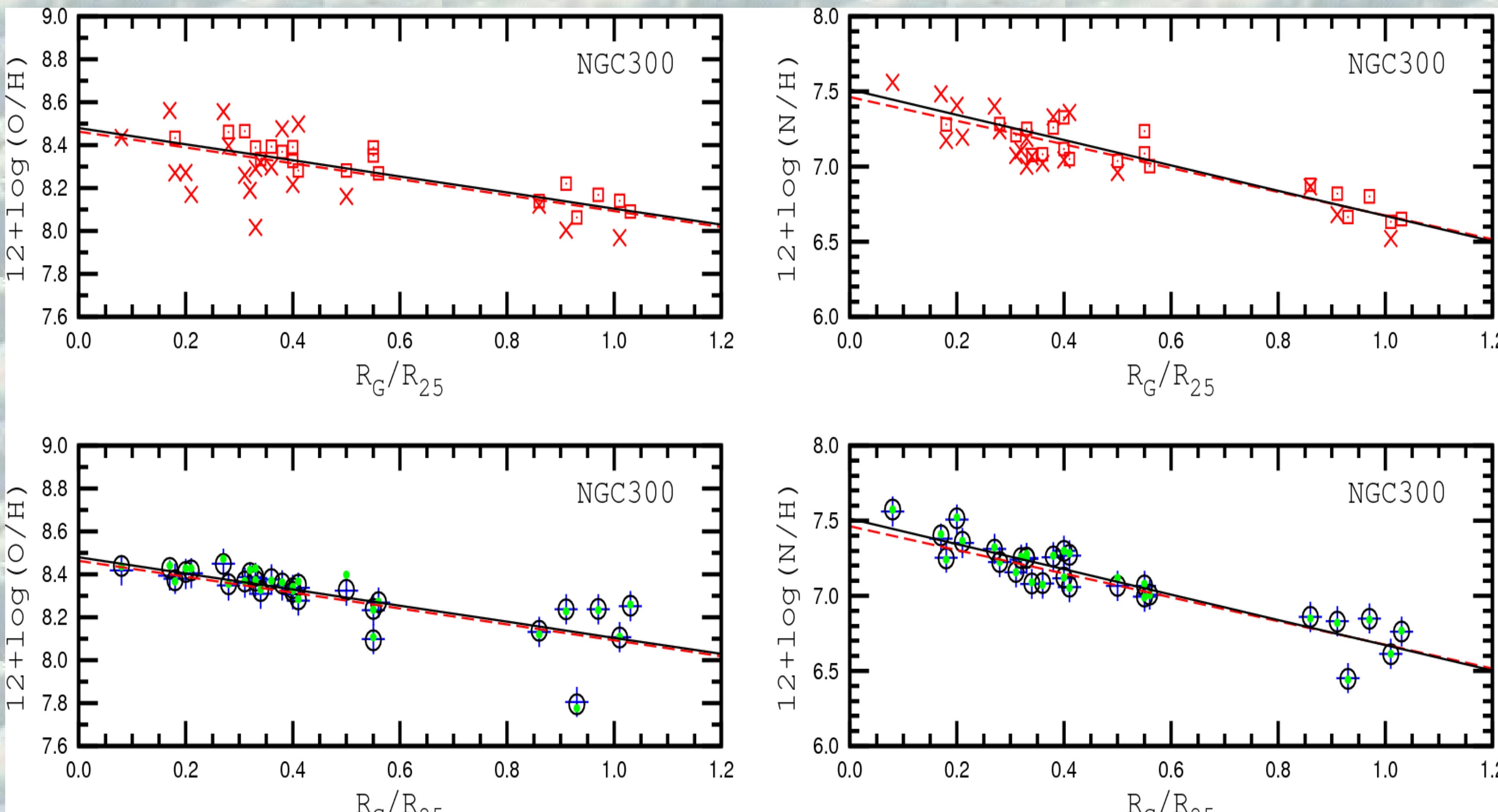
Top. Black points.
The selected reference HII regions, the sample *Rsample10*

Bottom. Black circles.
HII regions from the present compilation for the case of C-based abundances

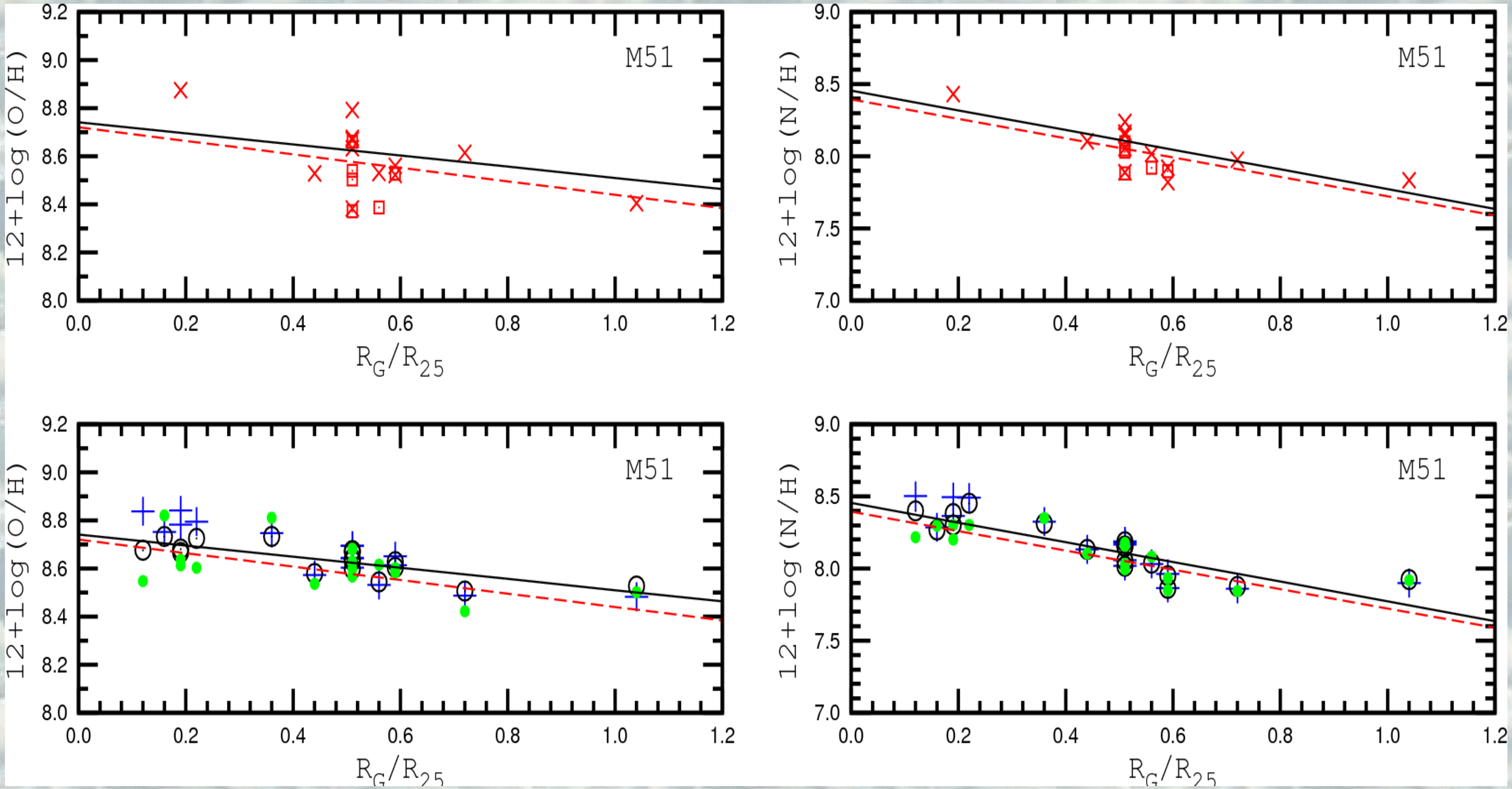
The radial distribution of the oxygen (left) and nitrogen (right) abundances in the disk of M101. Red symbols are Te-based abundances (squares with $t_{3,O}$ and crosses with $t_{2,N}$). The C-based abundances are shown by the green dots (with Rsample08), open circles (with Rsample10), and plus signs (with Rsample12).



The radial distribution of the oxygen (left) and nitrogen (right) abundances in the disk of NGC300. Red symbols are Te-based abundances (squares with $t_{3,O}$ and crosses with $t_{2,N}$). The C-based abundances are shown by the green dots (with Rsample08), open circles (with Rsample10), and plus signs (with Rsample12).



The radial distribution of the oxygen (left) and nitrogen (right) abundances in the disk of NGC300. Red symbols are Te-based abundances (squares with t_{3S} and crosses with t_{2N}). The C-based abundances are shown by the green dots (with Rsample08), open circles (with Rsample10), and plus signs (with Rsample12).



The measured fluxes are considered as the "true" fluxes and C-method based abundances as "true" abundances. Then a random relative error ε is introduced to every line flux

$$R_3^* = (1 + \varepsilon_{R3}) R_3^{true} \qquad R_2^* = (1 + \varepsilon_{R2}) R_2^{true}$$

$$N_2^* = (1 + \varepsilon_{N2}) N_2^{true} \qquad S_2^* = (1 + \varepsilon_{S2}) S_2^{true}$$

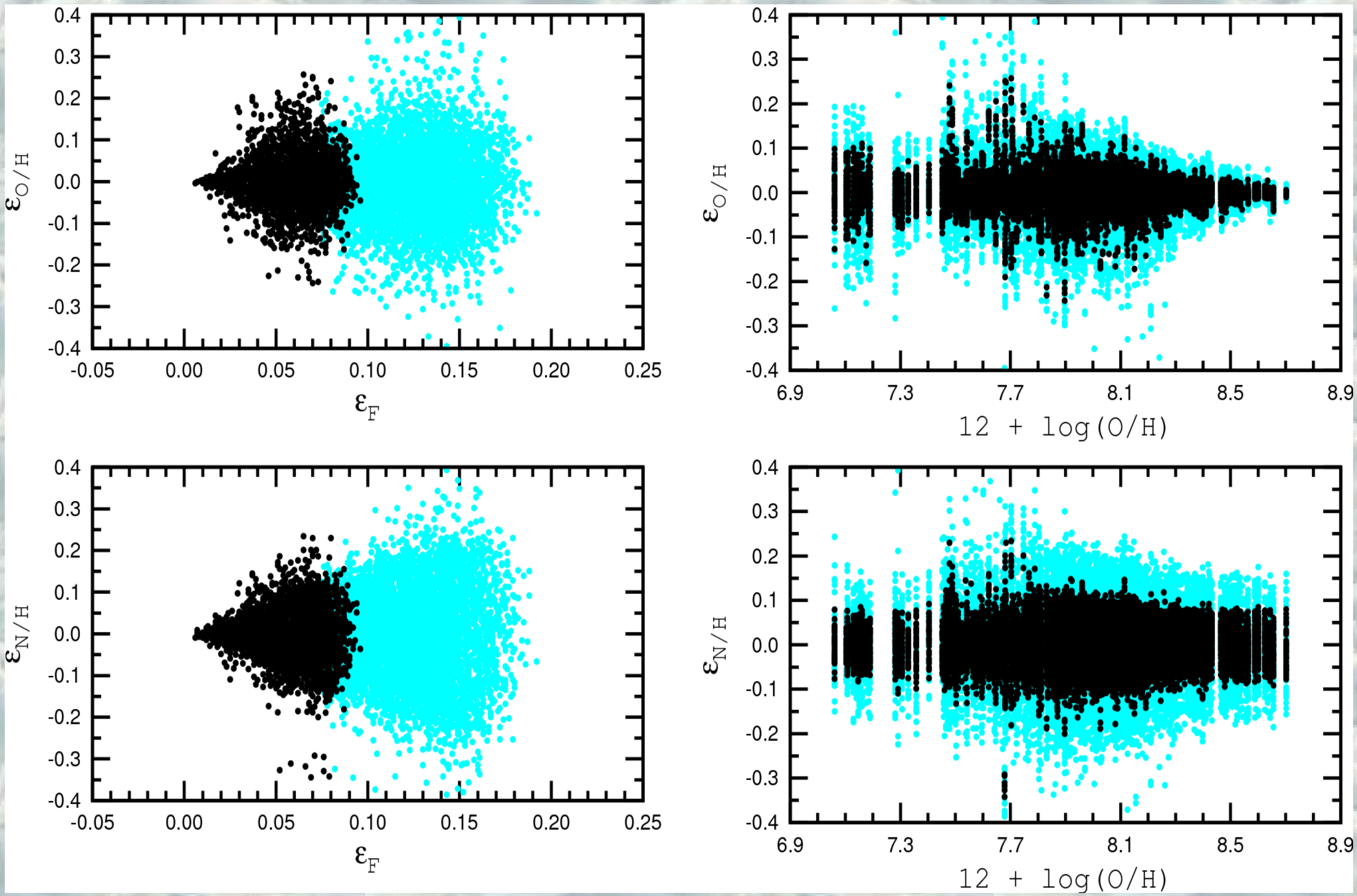
The mean error in the line flux measurement is defined as

$$\varepsilon_F = (¼ \ (\varepsilon_{R3} + \varepsilon_{R2} + \varepsilon_{N2} + \varepsilon_{S2}))^{1/2}$$

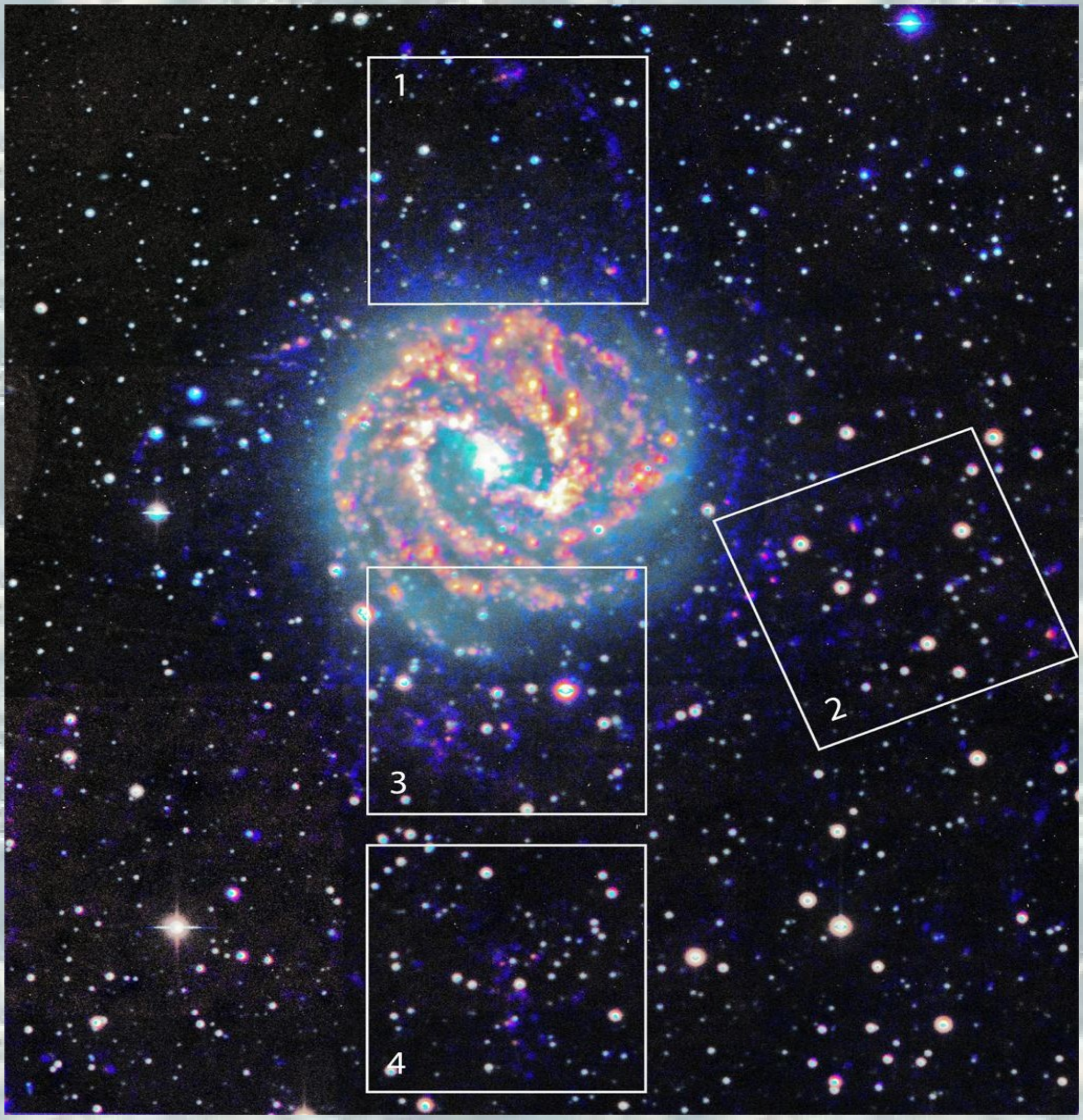
The value of the error in the oxygen abundance is defined as

$$\varepsilon_{O/H} = \log(O/H)_C^* - \log(O/H)_C^{true}$$

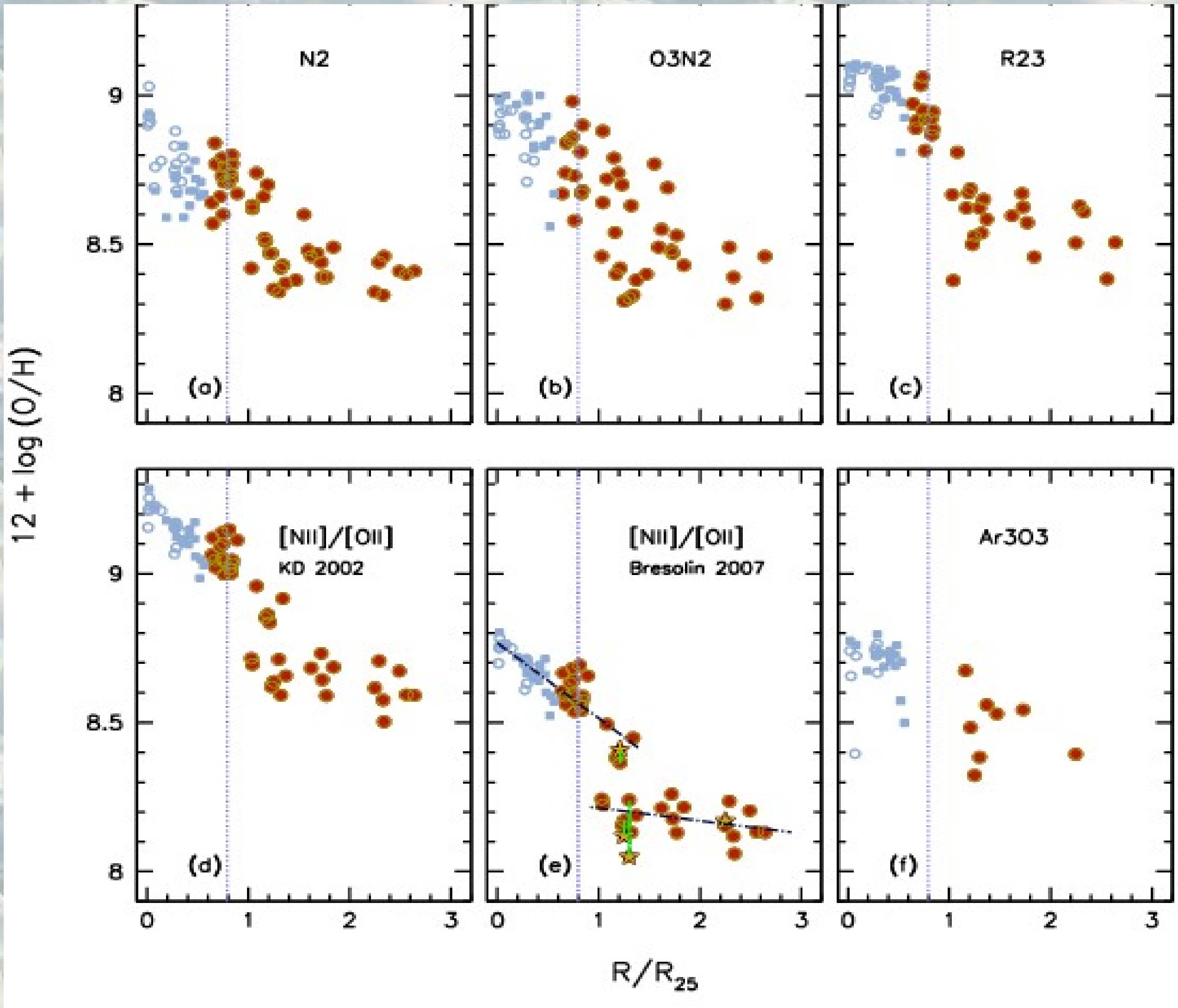
The error in the oxygen $\varepsilon_{O/H}$ (top) and nitrogen $\varepsilon_{N/H}$ (bottom) abundances as a function of the error in the line fluxes ε_F (left) and oxygen abundance (right). Black circles are Monte Carlo simulation with ε_F from -10 to 10%. Blue circles are that with ε_F from -20 to +20%.

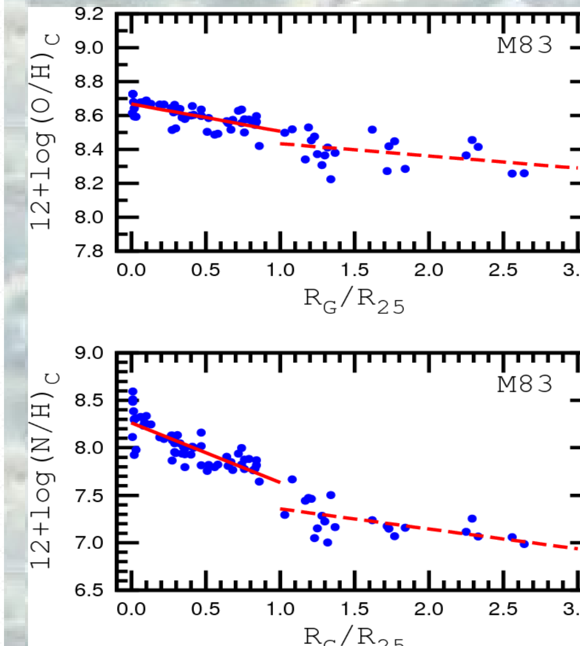


Extended disk of the spiral galaxy M83 (NGC5236). Distribution of the four fields in which spectroscopy of HII regions has been carried out by Bresolin et al., 2009, ApJ, 695, 580.

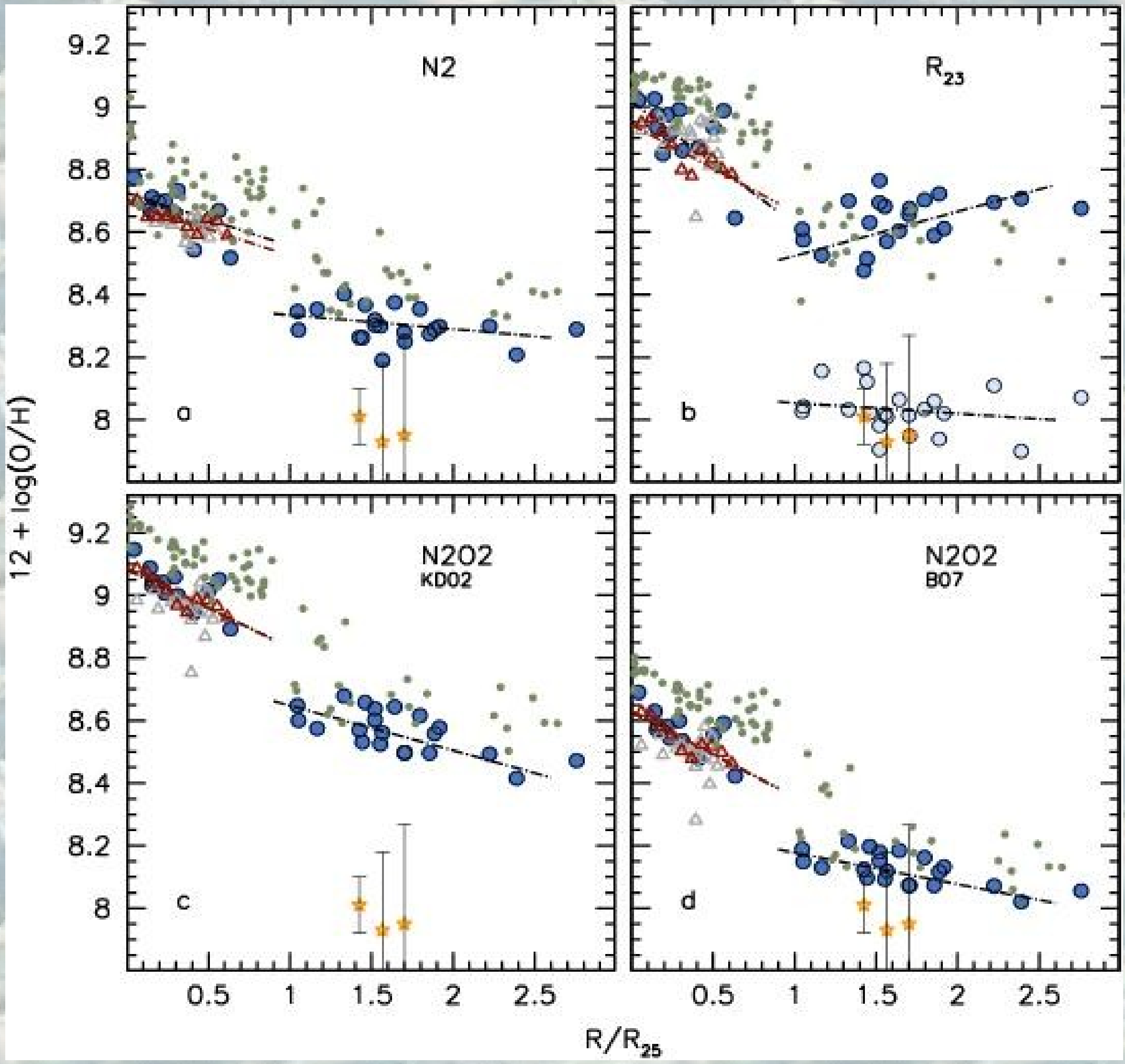


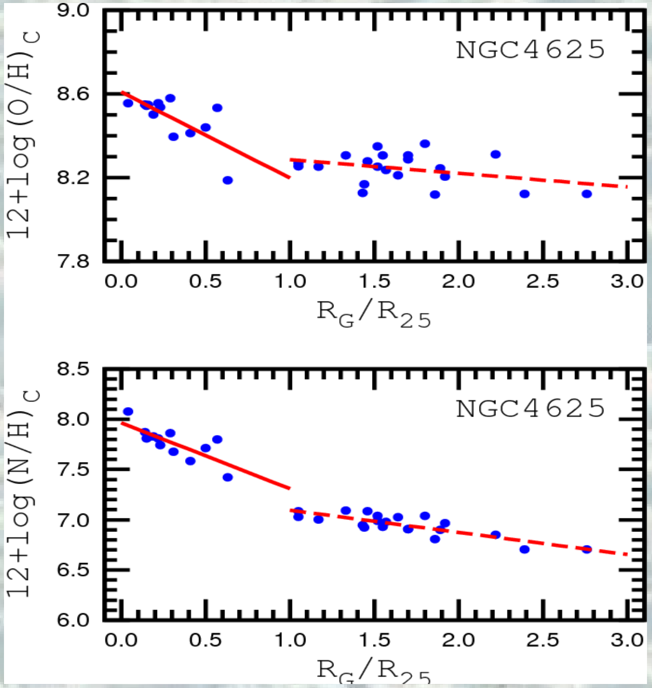
Radial abundance gradient in M83, where the oxygen abundance has been determined from different strong-line methods by Bresolin et al. (2009) R_{25} = 8.6 Kpc, d= 4.5Mpc



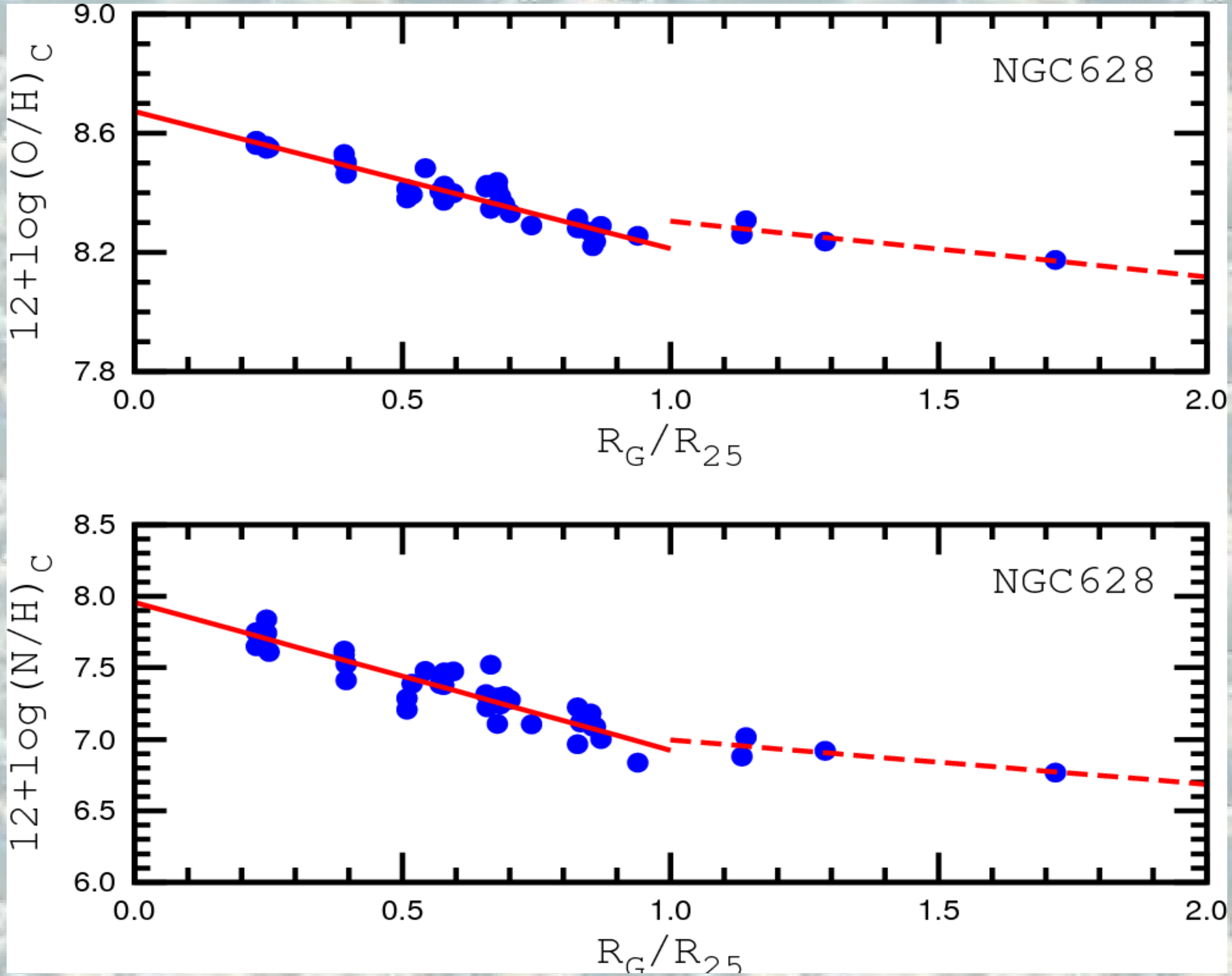


Radial oxygen abundance gradients in the extended disk of the NGC 4625 are determined using various strong line methods by Goddard et al. (2011). R_{25} = 3 Kpc





Radial oxygen and nitrogen abundances gradients in the extended disk of the NGC628 are determined using C method. R_{25} = 11,3 Kpc



Спасибо за внимание
Thank you for attention