# THE ABUNDANCES OF OXYGEN, SULPHUR, NEON, AND ARGON IN PLANETARY NEBULAE: NUCLEOSYNTHEISS AND CHEMICAL EVOLUTION

W. J. Maciel, R. D. D. Costa, O. Cavichia

IAG/USP – São Paulo, Brazil

- INTRODUCTION

- PART A: O, S, Ne, AND Ar IN PN AS NUCLEOSYNTHESIS CONSTRAINTS

- PART B: OXYGEN AS A METALLICITY PROXY: THE O X Fe RELATION IN THE GALAXY

# • INTRODUCTION

Planetary nebulae (PN) allow the determination of accurate abundances of elements that <u>are not</u> produced by the progenitor stars (O, S, Ne, Ar).

➔ Chemical evolution of the host galaxies

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

➔ Intermediate mass star nucleosynthesis

Some of these elements <u>are difficult</u> to study in stars.

➔ Comparison with stellar data

Measurements of the oxygen abundances and [Fe/H] metallicities in stars can be used to estimate the O x Fe relation in the Galaxy.

➔ Comparison of [Fe/H] and O/H radial abundance gradients

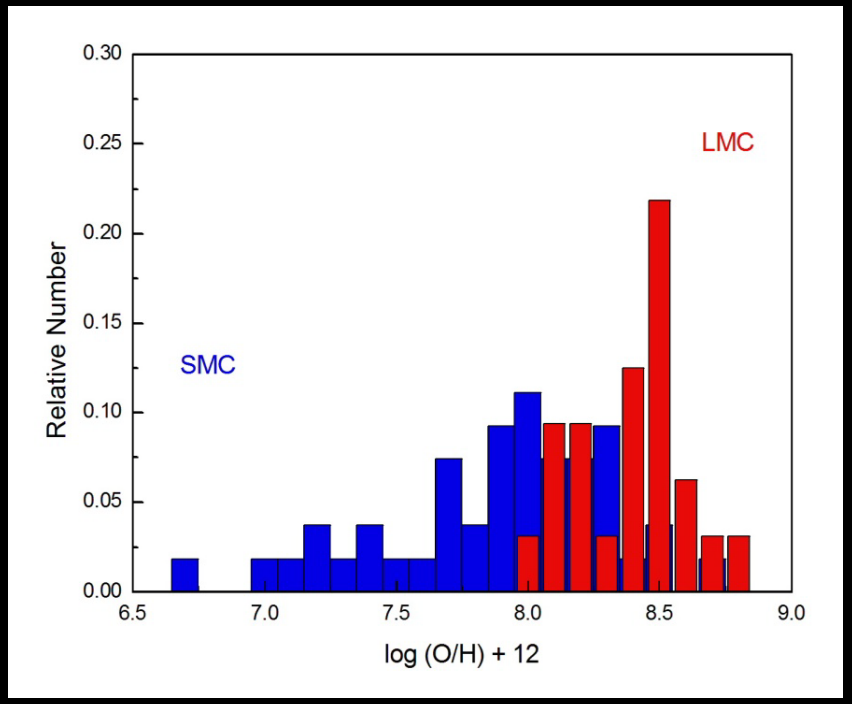
# • PART A: O, S, Ne, AND Ar IN PN AS NUCLEOSYNTHESIS CONSTRAINTS

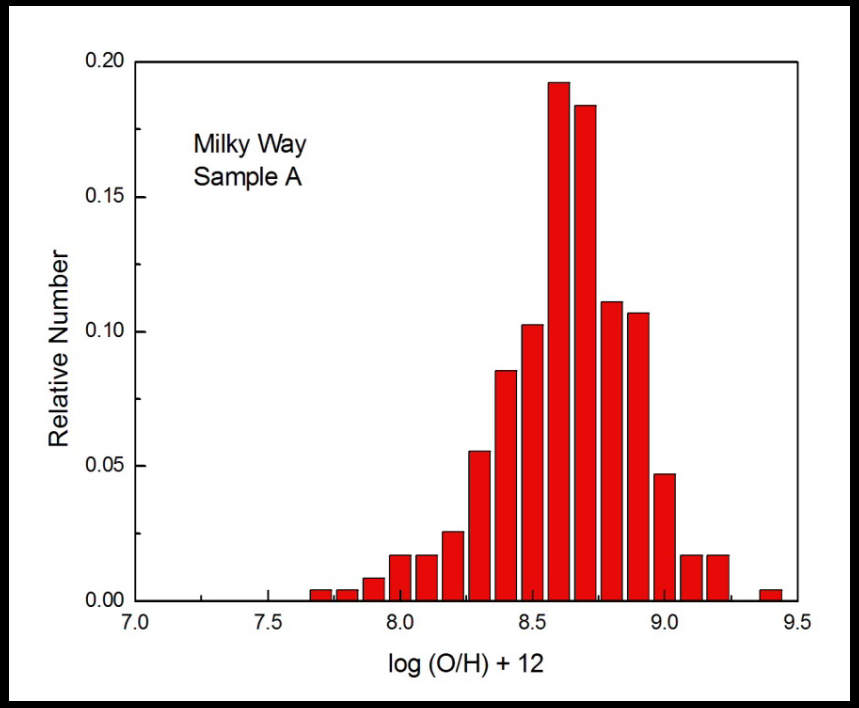
THE SAMPLE

| System | Number of objects | Reference |
|---|---|---|
| MW disk - Sample A | 234 | IAG |
| MW disk - Sample B | 372 | IAG + Literature |
| MW bulge | 184 | IAG |
| LMC | 282 | IAG, SRM, LD |
| SMC | 144 | IAG, SRM, LD |
| MW | 54 | Cavichia |
| MW disk | 61 | CGSB |
| MW bulge | 168 | CGSB |
| LMC | 110 | CGSB |
| HII regions | 20 | Kennicutt |
| HII regions | 10 | Bresolin |
| HII regions | 5 | Tsamis |
| HII regions | 34 | Afflerbach |
| HII regions | 53 | Guseva |
| BCG | 54 | Izotov |

CGSB – Chiappini et al. (2009); SRM – Stasińska et al. (1998); LD – Leisy & Dennefeld (2006)

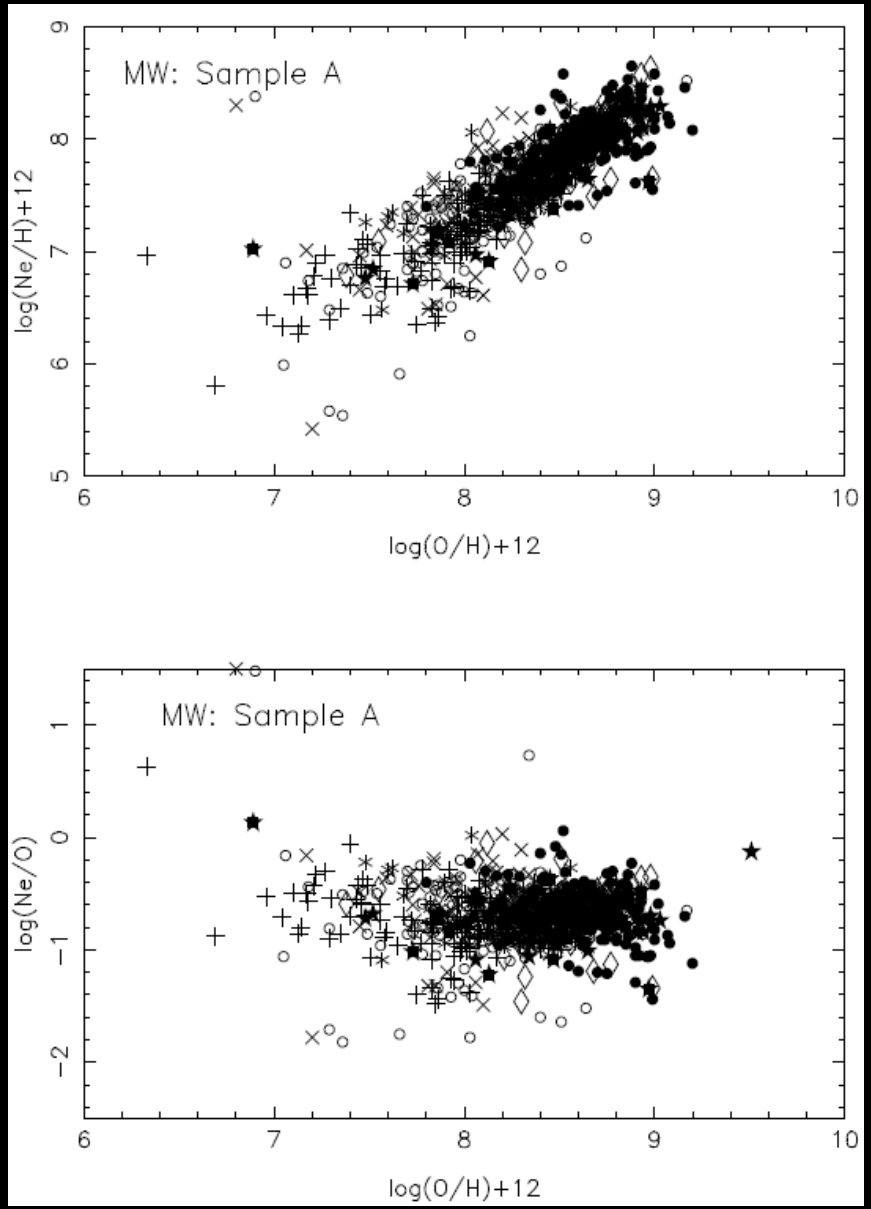
# RESULTS



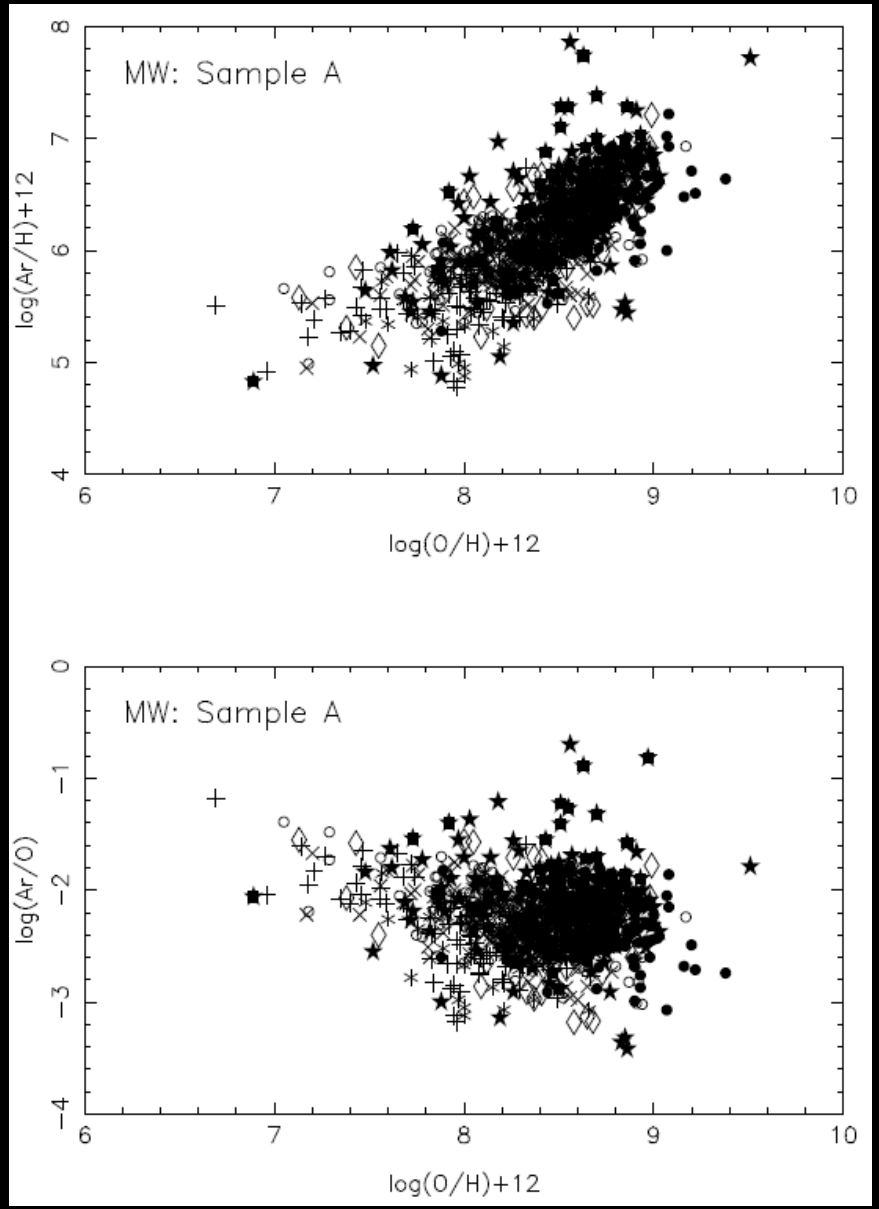




Metallicity differences: SMC, LMC and the Milky Way

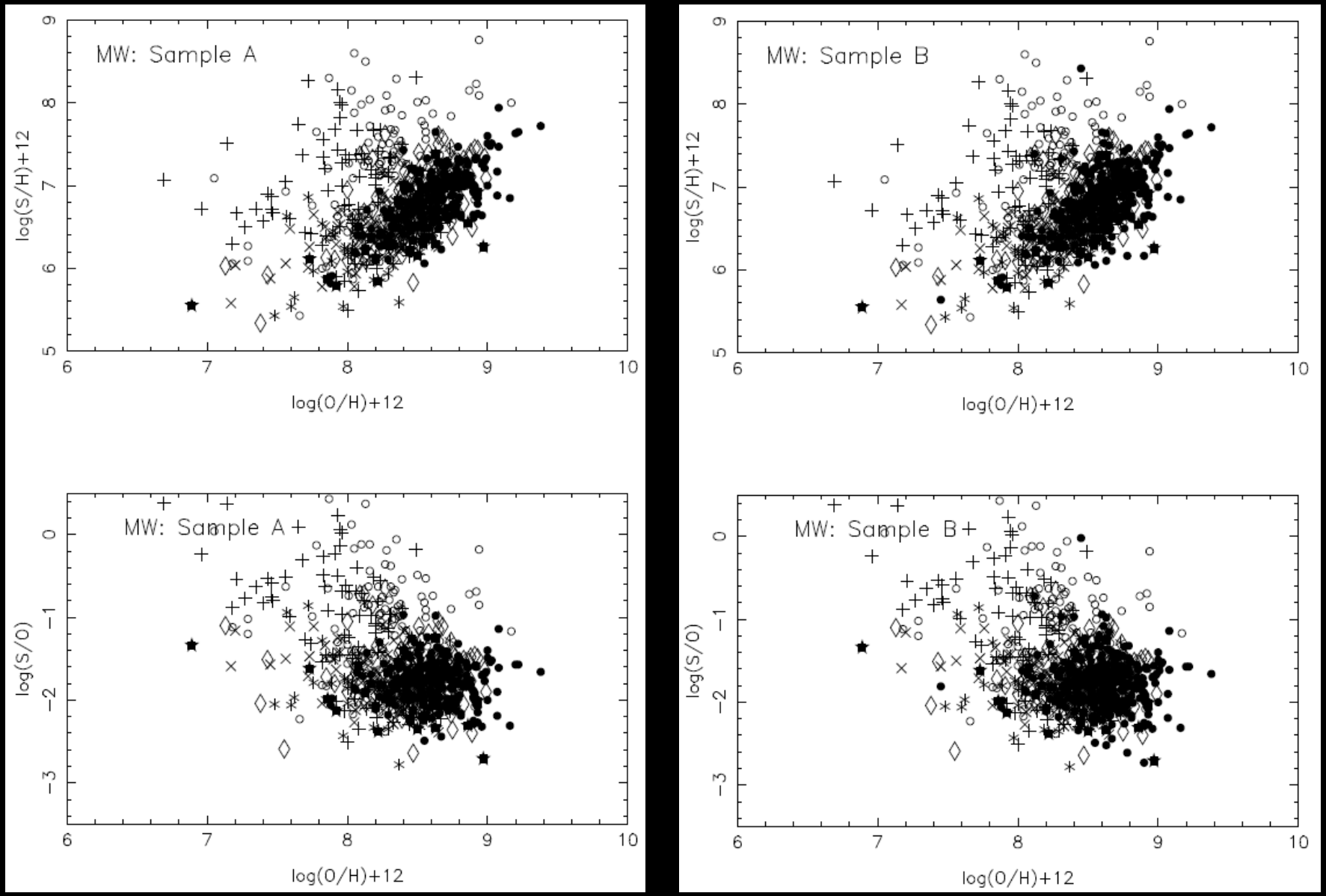
# Neon


MW: Sample A
log(Ne/H)+12
log(O/H)+12
MW: Sample A
log(Ne/O)
log(O/H)+12

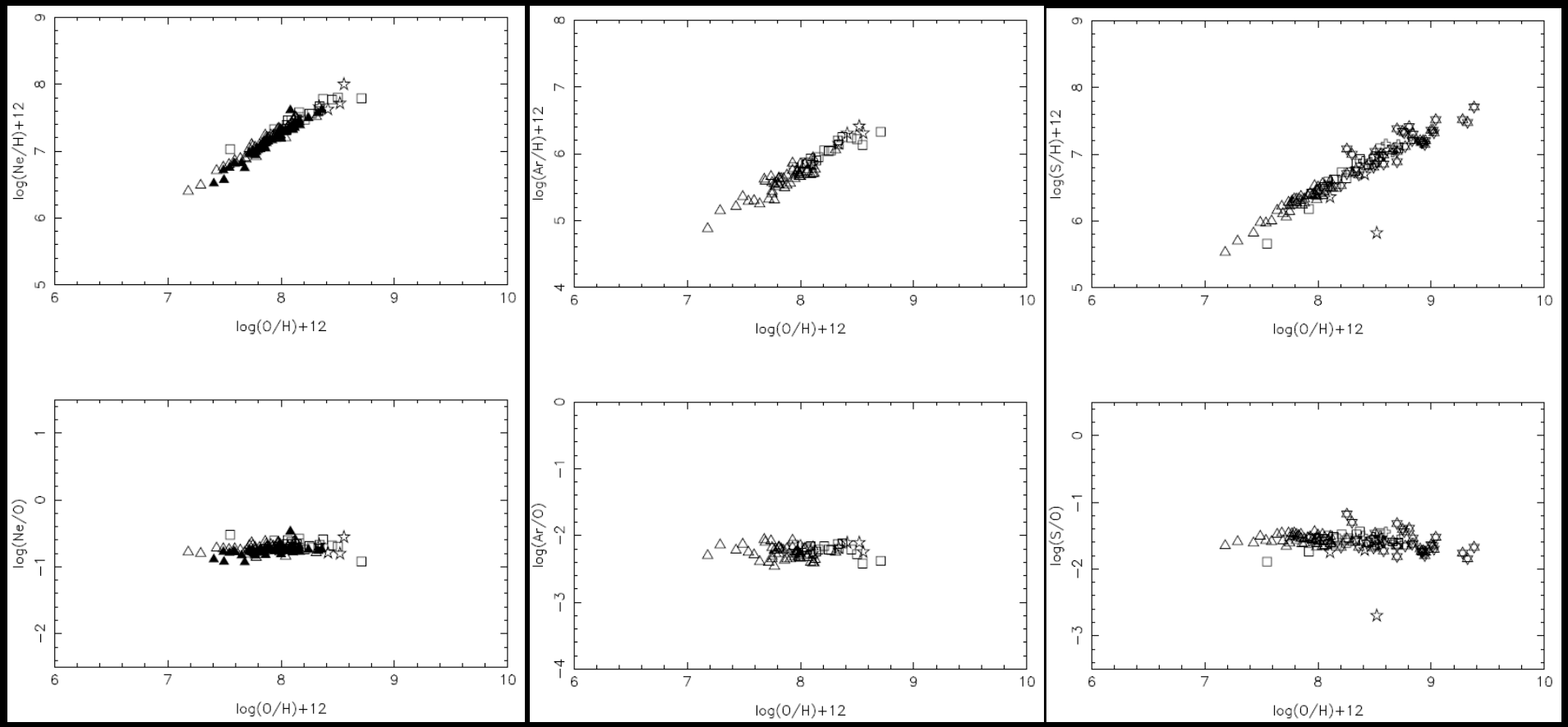
# Argon


MW: Sample A
log(Ar/H)+12
log(O/H)+12
MW: Sample A
log(Ar/O)
log(O/H)+12

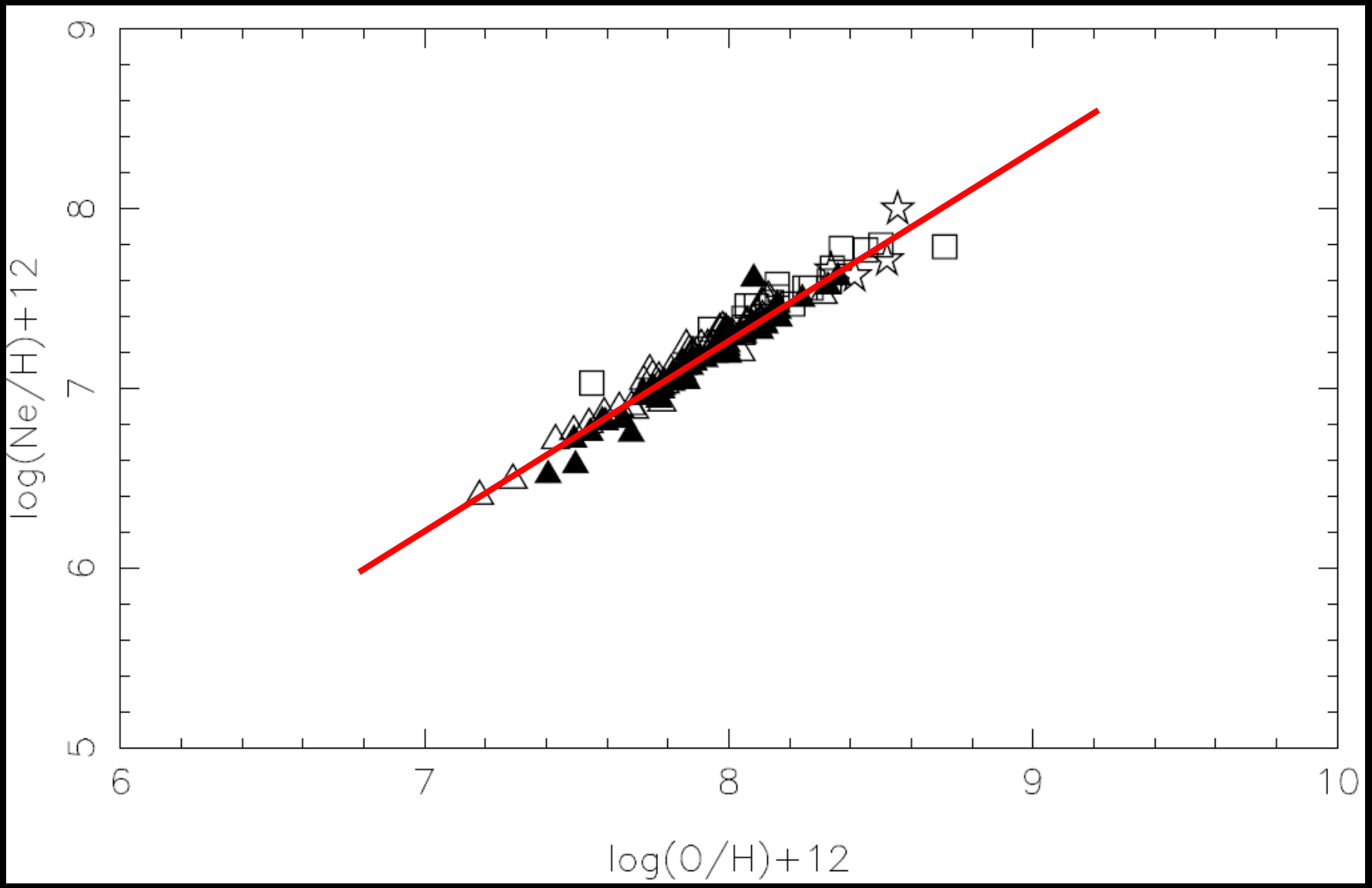
# Sulphur


MW: Sample A
MW: Sample B
MW: Sample A
MW: Sample B
log(S/H)+12
log(O/H)+12
log(S/O)
log(O/H)+12

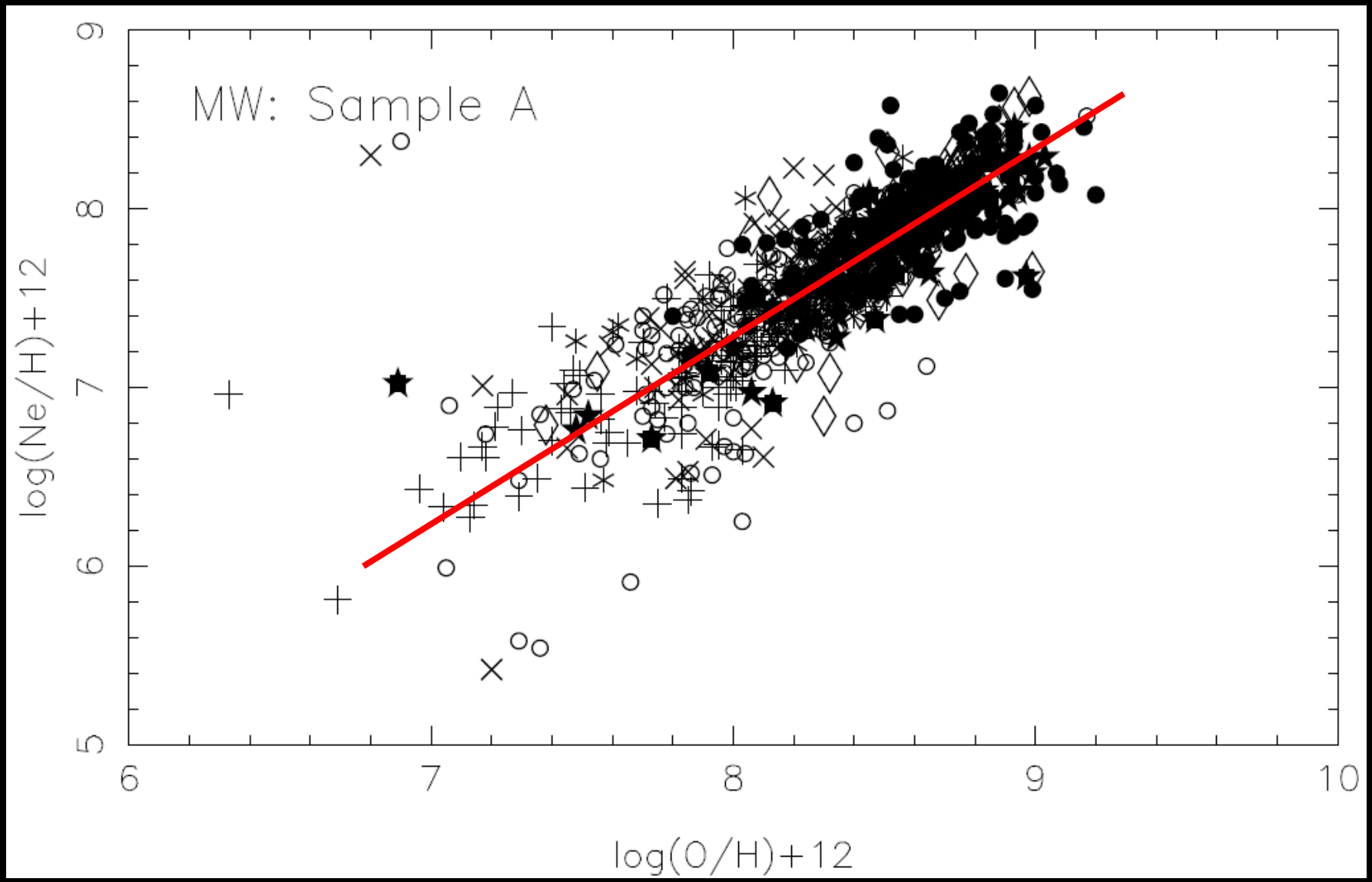
Neon Argon Sulphur

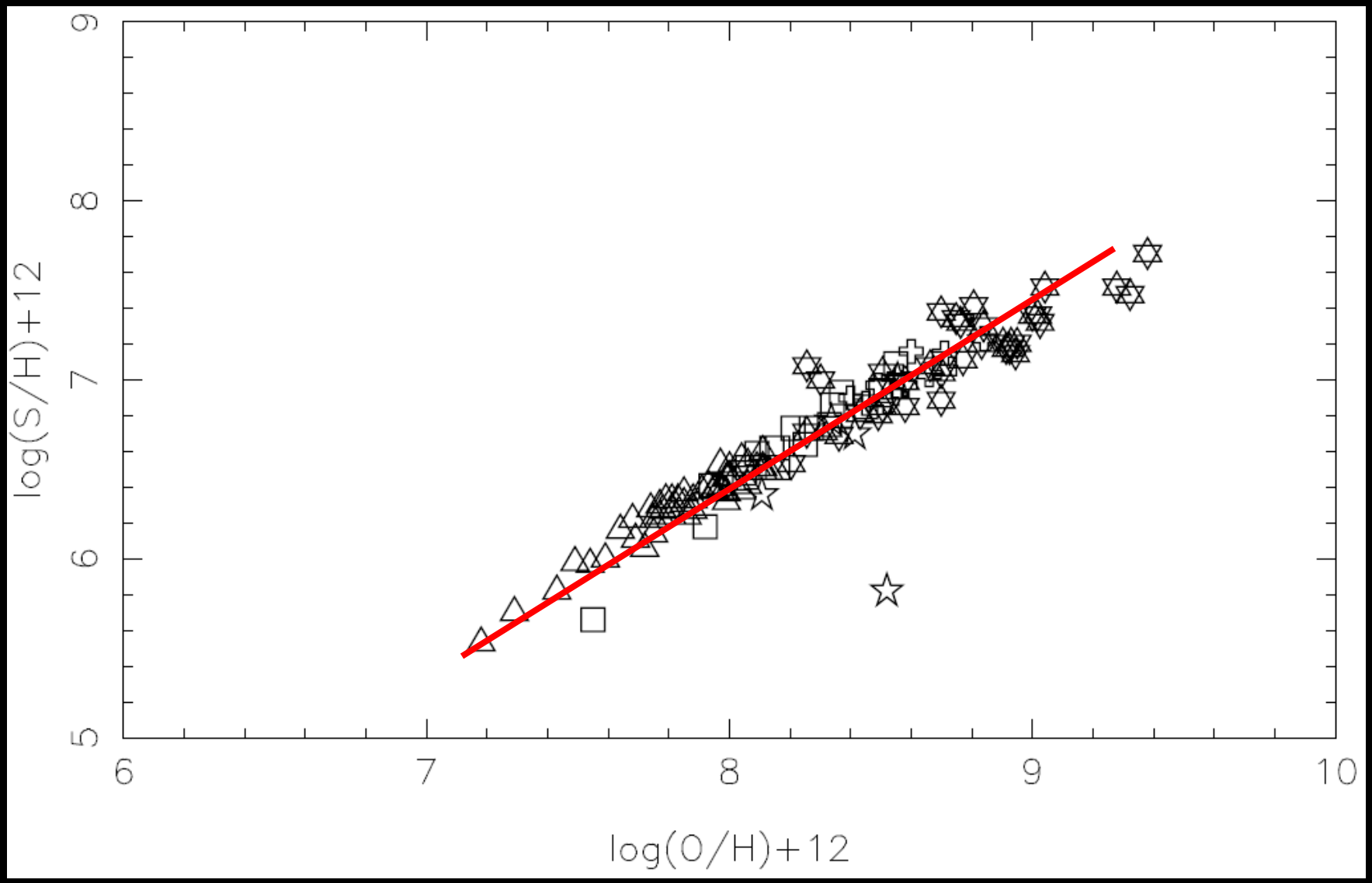



HII regions, Blue Compact Galaxies

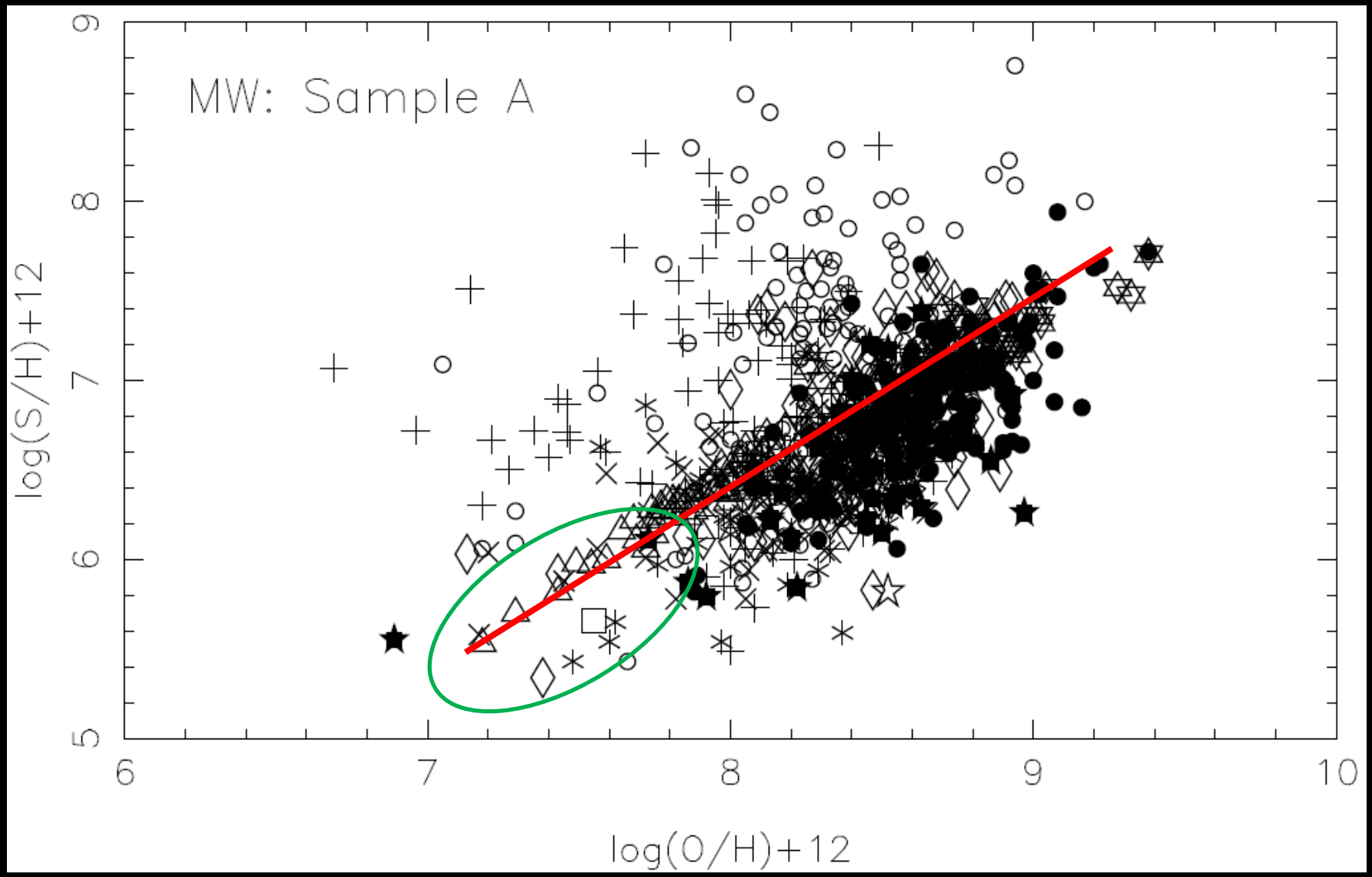


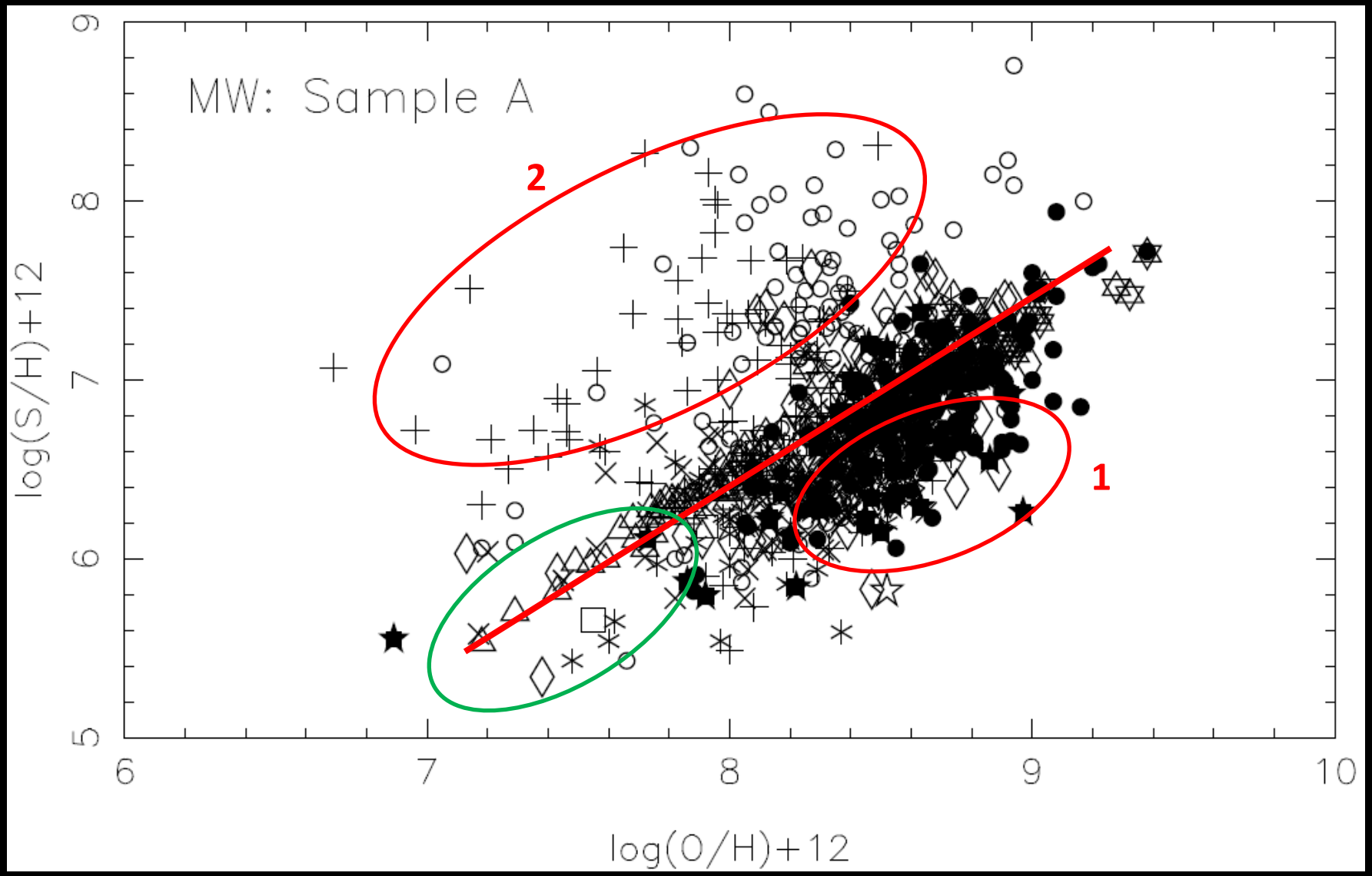

# HII regions, Blue Compact Galaxies


MW: Sample A
log(Ne/H)+12
log(O/H)+12
5
6
7
8
9
6
7
8
9
10



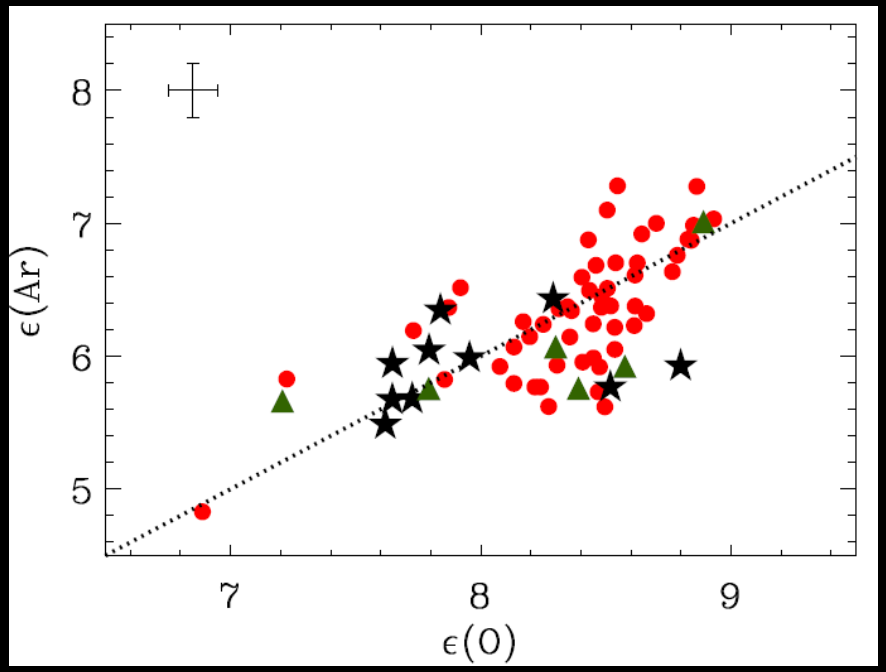

# HII regions, Blue Compact Galaxies

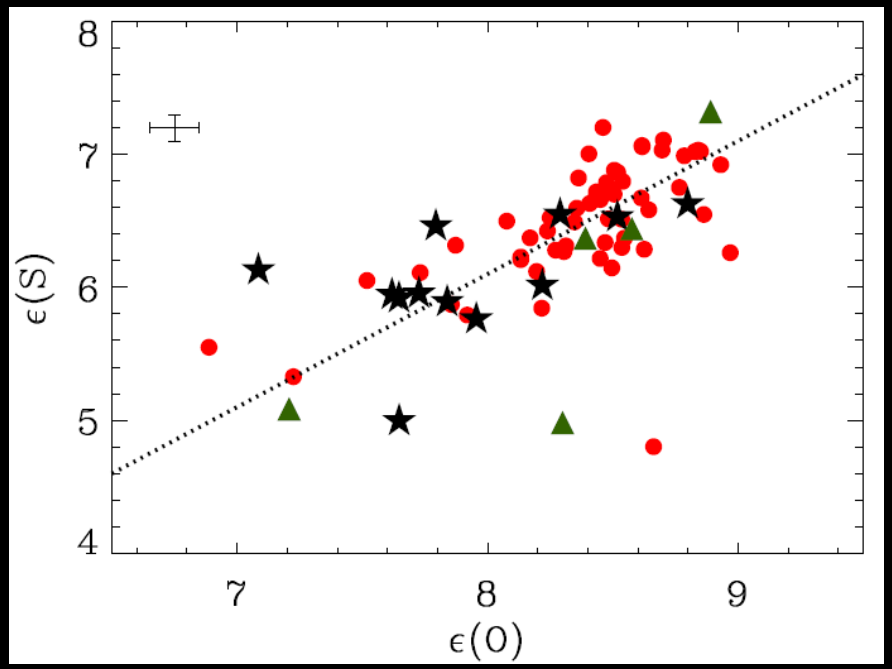

MW: Sample A
log(S/H)+12
log(O/H)+12
5
6
7
8
9
6
7
8
9
10




(1) sulphur anomaly (2) SMC/LMC overestimated (3) higher dispersion

Cavichia
PhD Thesis (2012)



# CONCLUSIONS – PART A

➔ PN abundances of O, Ne, Ar show good correlations, indicating that Ne and Ar vary in lockstep with O. Abundances relative to oxygen are essentially constant.

➔ Sulphur is still a problem:
(1) PN abundances in the MW are lower than expected.
(2) PN abundances in the SMC/LMC are probably overestimated.
(3) Average dispersion is higher than for Ne and Ar.

➔ Taking into account the abundances of elements that are produced by the progenitor stars (N, He), agreement with theoretical models is fair, but abundance determinations should be improved and expanded.

- PART B: OXYGEN AS A METALLICITY PROXY: THE O X Fe RELATION IN THE GALAXY

$$[X/Y] = \log (X/Y) - \log(X/Y)_{\odot}$$

$$[Fe/H] = \varepsilon + \delta\, [O/H]$$

$$[Fe/H] = \gamma + \delta\, [\log (O/H) + 12]$$

$$\gamma = \varepsilon - \delta\, [\log (O/H) + 12]_{\odot}$$

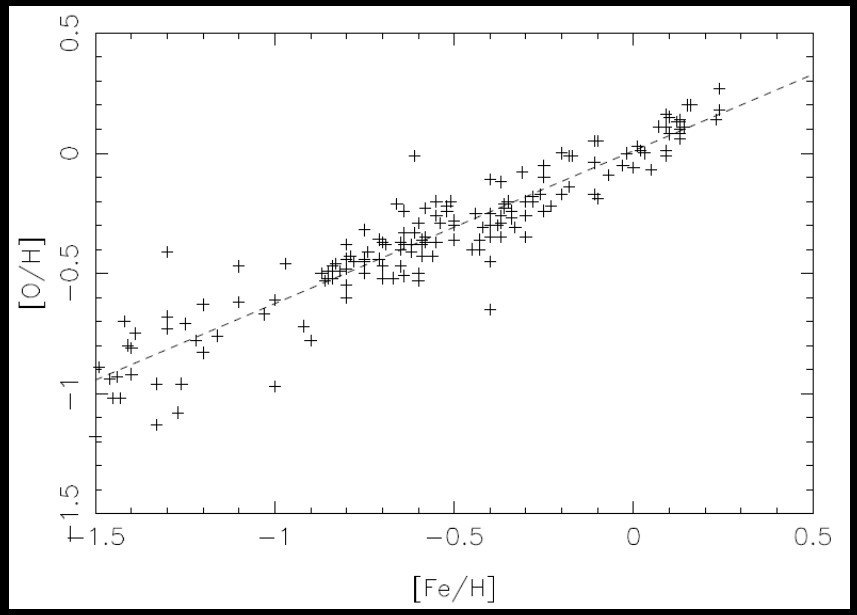
The parameter $\delta$ is the most interesting one, as it directly relates the Fe and oxygen abundances

# THE SAMPLE

THE “OLD” SAMPLE: Maciel (2002)
212 STARS IN THE GALACTIC THIN DISK, THICK DISK, AND HALO

THE “NEW” SAMPLE: 837 stars with accurate [Fe/H] and [O/H] abundances
Bensby et al. (2004)
Soubiran and Girard (2005)
Ramirez et al. (2007)

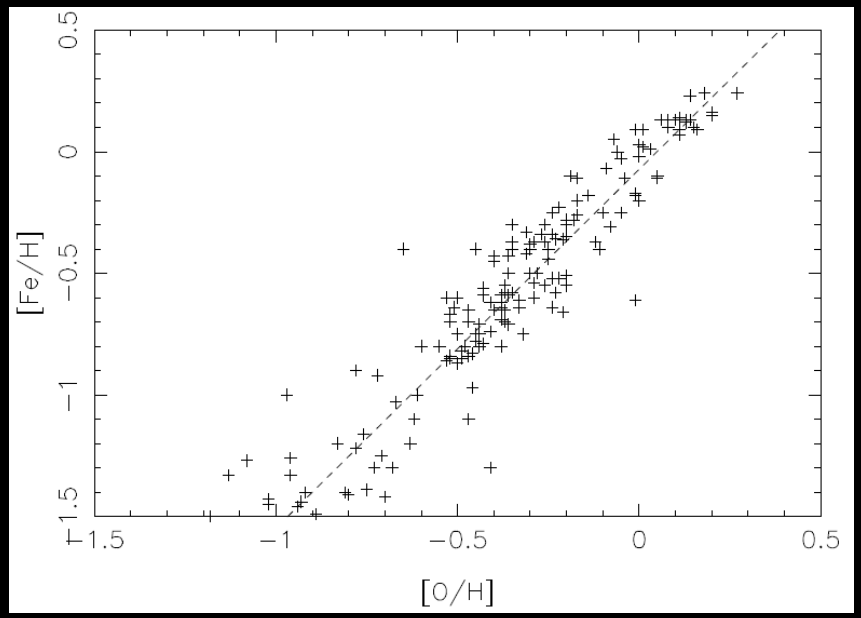
# RESULTS

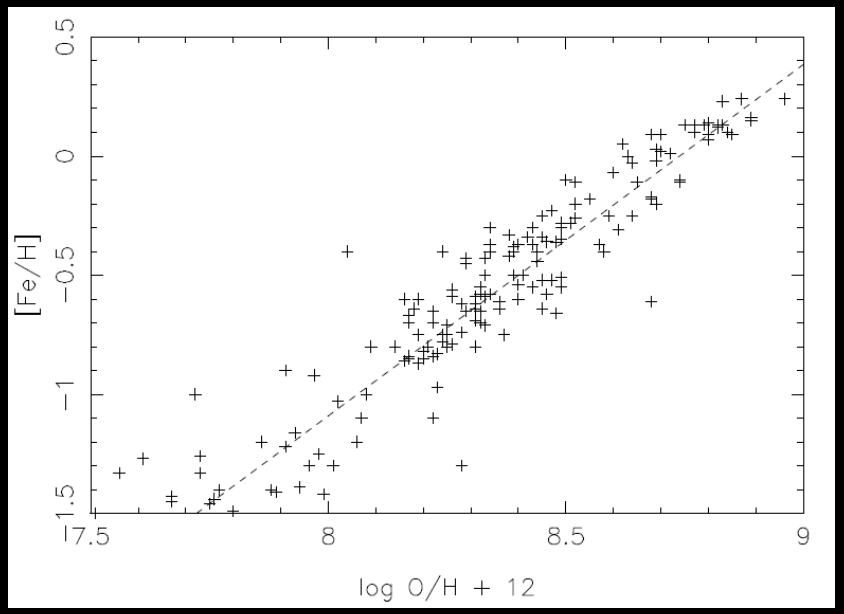


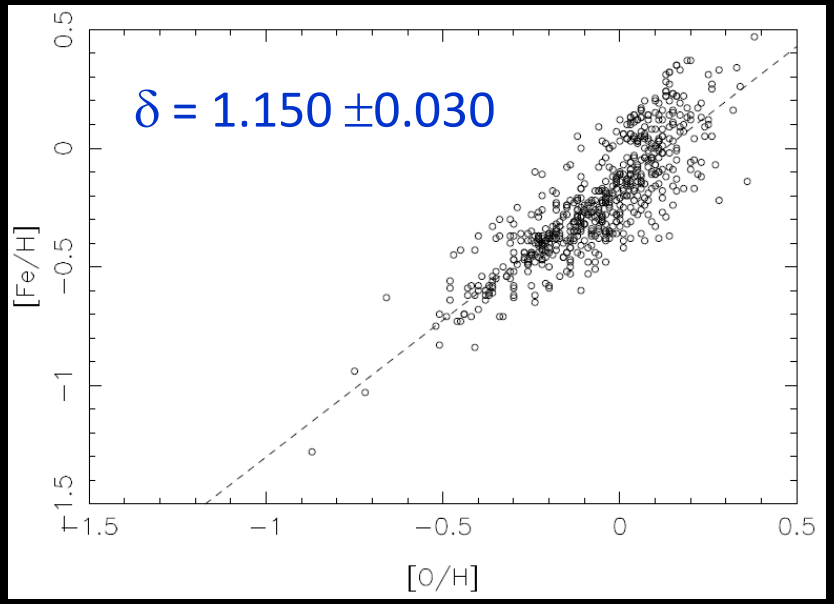

"OLD" SAMPLE

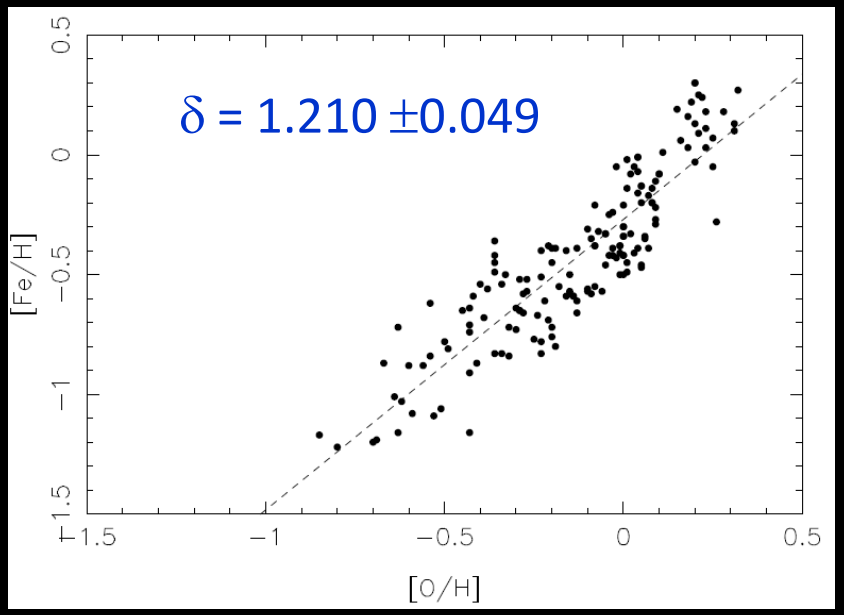
$\delta$= 1.470 $\pm$0.026

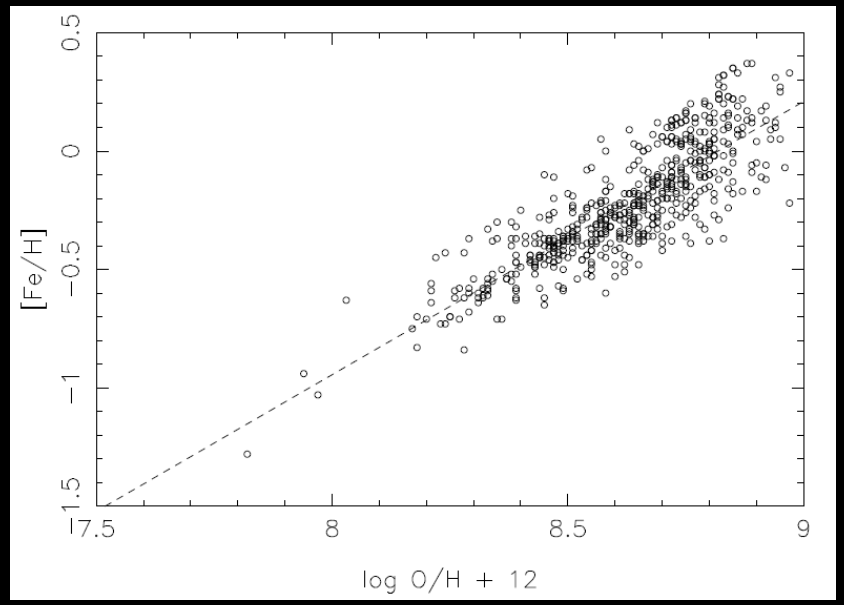
R = 0.97

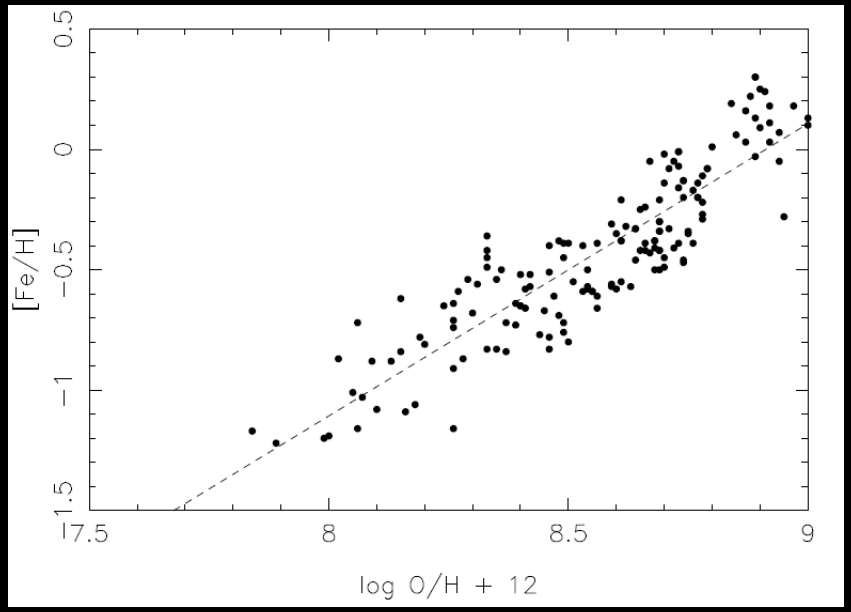




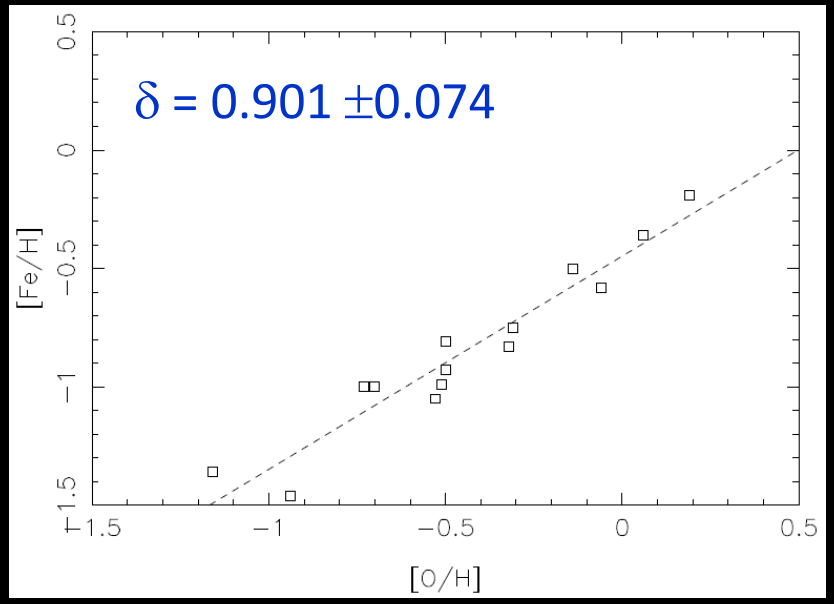



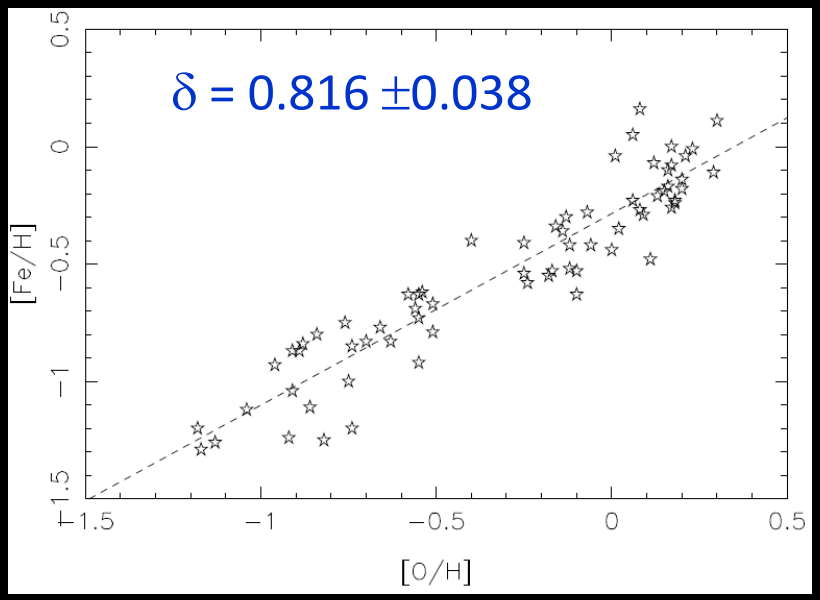



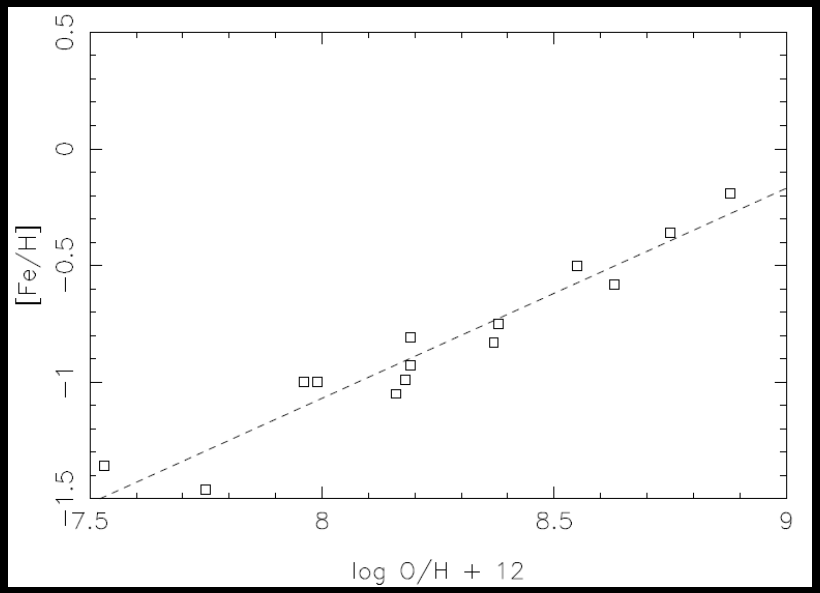



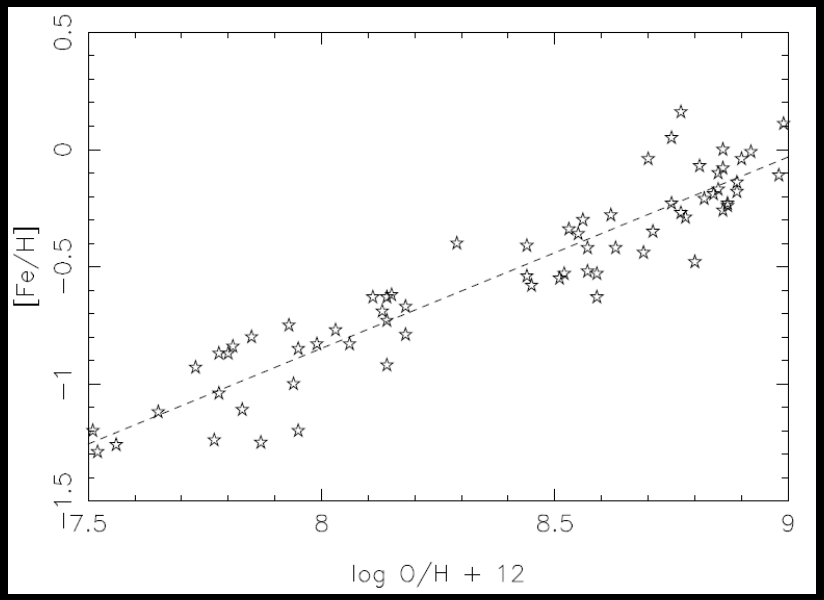

THIN DISK

THICK DISK



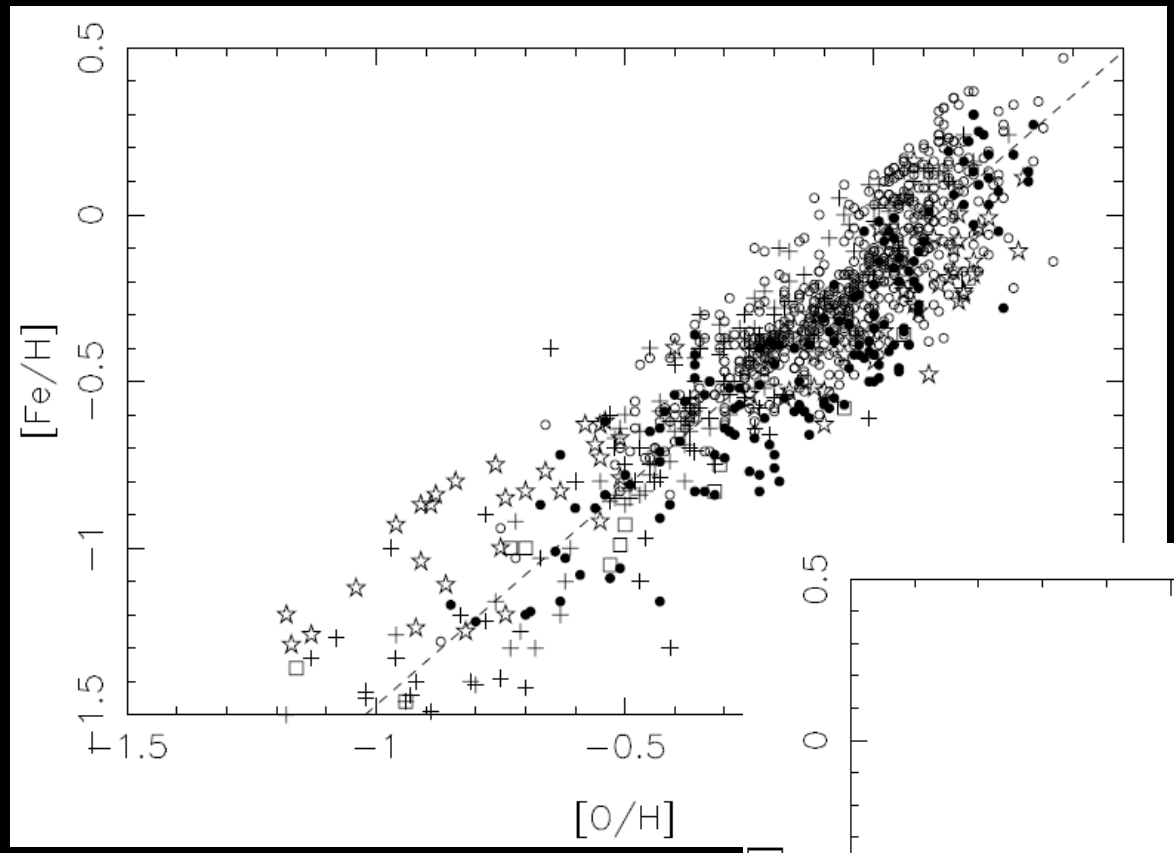




HALO

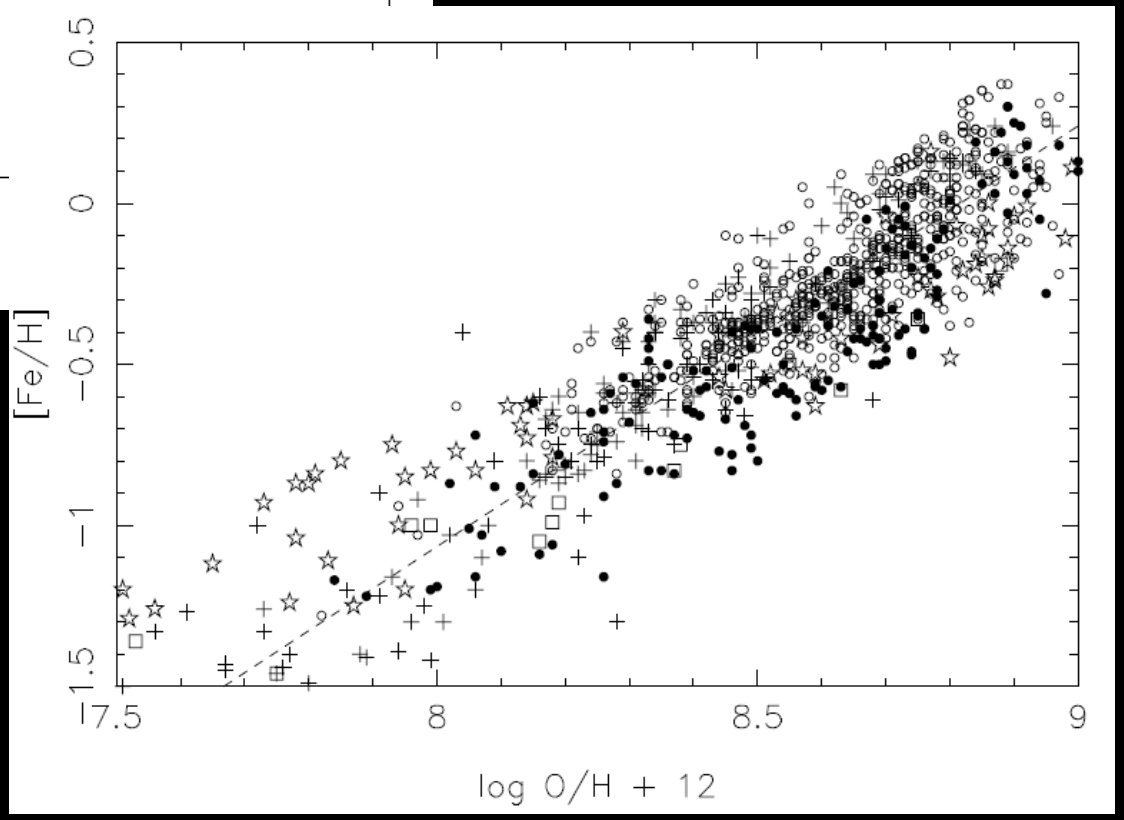
UNCLASSIFIED




ALL DATA

$\delta = 1.310 \pm 0.014$

$r = 0.94$




Tenerife - 2012

| | n | ε | δ | γ | r |
|---|---|---|---|---|---|
| older sample | 212 | -0.072 ± 0.020 | 1.470 ± 0.026 | -12.90 ± 0.21 | 0.97 |
| thin disk | 594 | -0.148 ± 0.006 | 1.150 ± 0.030 | -10.20 ± 0.26 | 0.84 |
| thick disk | 161 | -0.270 ± 0.014 | 1.210 ± 0.049 | -10.80 ± 0.42 | 0.89 |
| halo | 14 | -0.448 ± 0.042 | 0.901 ± 0.074 | -8.27 ± 0.62 | 0.96 |
| unclassified | 68 | -0.285 ± 0.020 | 0.816 ± 0.038 | -7.38 ± 0.32 | 0.94 |
| all data | 1049 | -0.164 ± 0.006 | 1.310 ± 0.014 | -11.50 ± 0.12 | 0.94 |

# CONCLUSIONS – PART B

➔ There is a well defined correlation between the iron and oxygen abundances in the Galaxy, which is valid for the galactic disk and probably for the halo.

➔ The average slope of the iron – oxygen relation is $\delta = 1.310 \pm 0.014$.

➔ Assuming linear radial gradients in the galactic disk, this parameter gives the ratio between the [Fe/H] gradient as measured in cepheids and open clusters and the O/H gradient as measured in planetary nebulae and HII regions.

Tegueste
San Cristóbal de La Laguna
Santa Cruz de Tenerife
El Sauzal
TF-5
El Rosario
Puerto de la Cruz
Santa Ursula
San Juan de la Rambla
La Orotava
TF-1
Buenavista del Norte
Garachico
Icod de Los Vinos
La Guancha
Los Silos
El Tanque
Los Realejos
Candelaria
Arafo
Guimar
Santiago del Teide
Tenerife
TF-82
Parque Nacional del Teide
Fasnia
Guia de Isora
TF-82
Arico
TF-1
Vilaflor
Granadilla de Abona
Adeje
Arona
San Miguel

THE END