PHOTOIONIZED NEBULAE IN THE LOCAL GROUP: NUCLEOSYNTHESIS AND CHEMICAL EVOLUTION

W. J. Maciel
University of São Paulo
Brazil

R. D. D. Costa

O. Cavichia

1. Introduction

2. The data

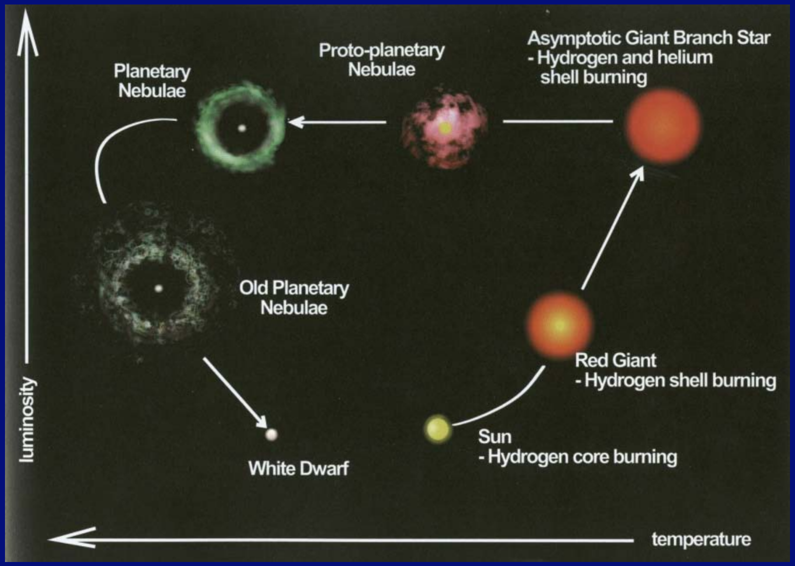
3. Elements not produced by the PN progenitor stars

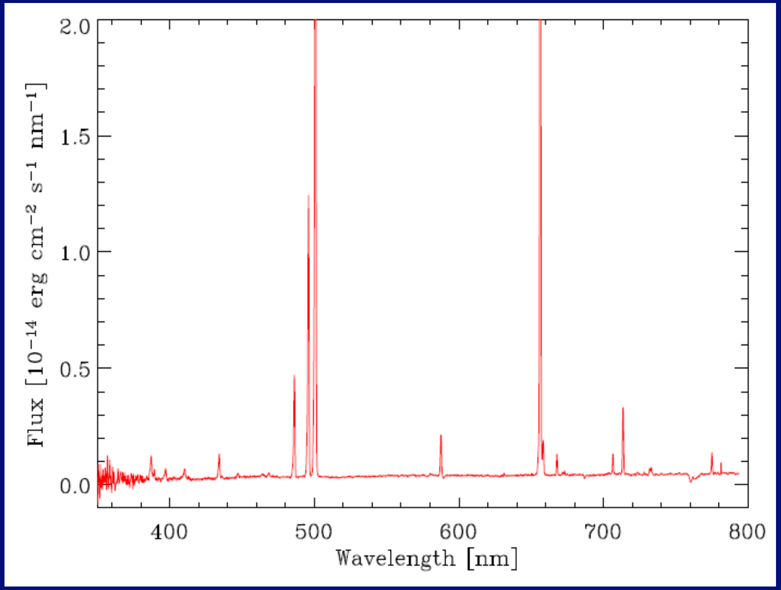
4. Elements produced by the PN progenitor stars

1. Introduction

Why study planetary nebulae?

Planetary nebulae have strong emission lines of H, He, O, N, Ne, S, Ar, etc., including forbidden lines and recombination lines. The analysis of these lines gives abundances accurate to about 0.2 dex or better.





Cavichia et al. (2010)

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

GOALS

☞ Comparison of PN and HII region data

☞ Comparison of data for different objects in the Local Group

2. The data

Comparison samples include HII regions and Blue Compact Galaxies (BCG)

SYSTEM	PN	HII/BCG
MW - SAMPLE 1	392	
MW - SAMPLE 2	168	212
LMC	406	2
SMC	151	1
M31	18	62
M32	14	
M33	109	79
M51		10
M101		24
NGC 185	4	
NGC 205	10	
NGC 300	26	37
NGC 3109	7	10
Sextans	6	17

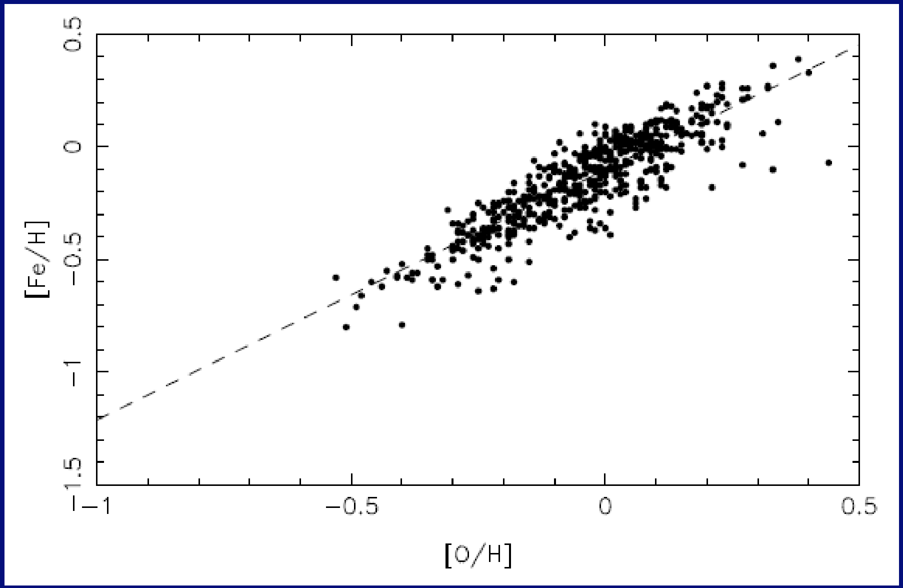
3. Elements not produced by the PN progenitor stars

The abundances of the elements O, Ne, S, Ar are not significantly affected by the evolution of the PN progenitor stars. The measured abundances therefore reflect the interstellar abundances at the time the progenitor stars were born.

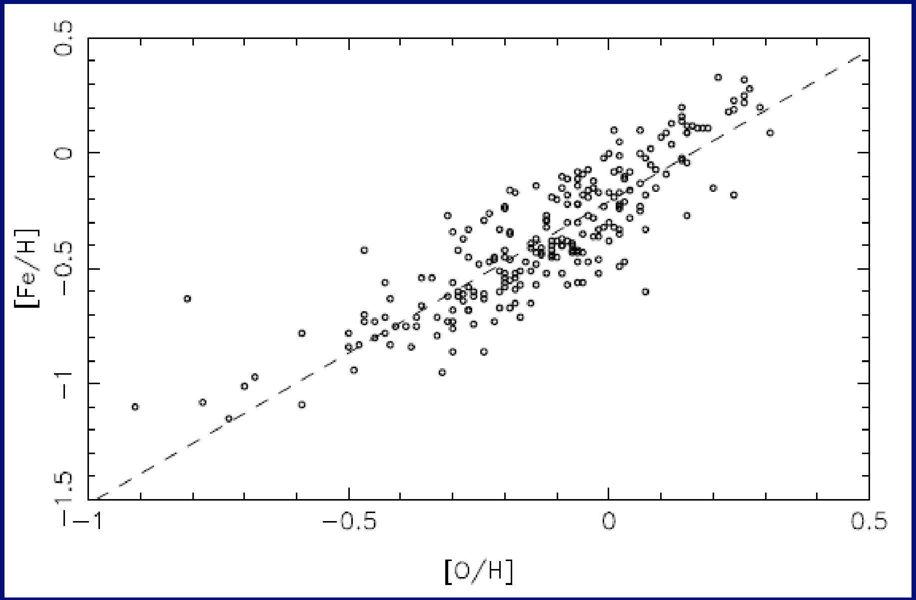
Oxygen can be used as a metallicity proxy, provided a relationship between O and Fe is determined.

Measurements of the oxygen abundances and [Fe/H] metallicities in stars can be used to estimate the O x Fe relation in the Galaxy. This is important, since in photoionized nebulae Fe is mostly locked up in grains

There is a well defined correlation between Fe and O abundances in the Galaxy, which is valid for the galactic disk and approximately for the halo.



Ramirez et al. (2013)



The average slope of the Fe – O relation is:

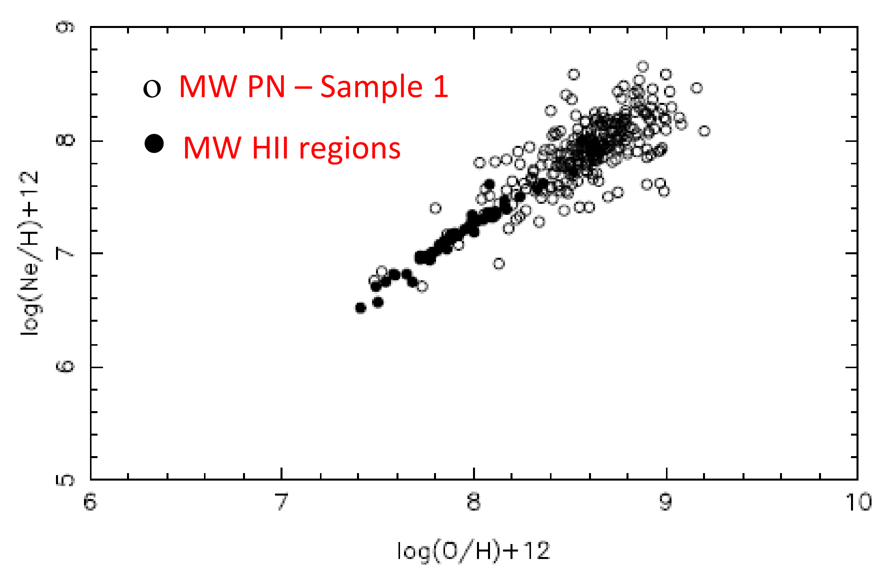
δ = 1.11 (thin disk)

δ = 1.31 (thick disk)

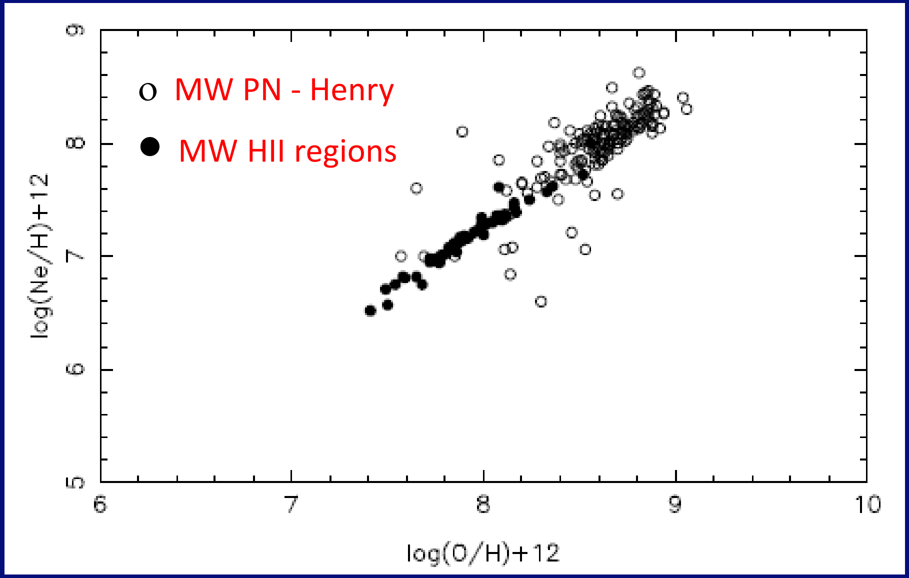
In the Galaxy, it is particularly important to distinguish distance-independent correlations from the correlations that depend on the distances, such as the abundance gradients that are observed in the disks of the Milky Way and other spirals.

We will consider the abundances of Neon, Argon, and Sulphur compared to the better determined Oxygen abundances.

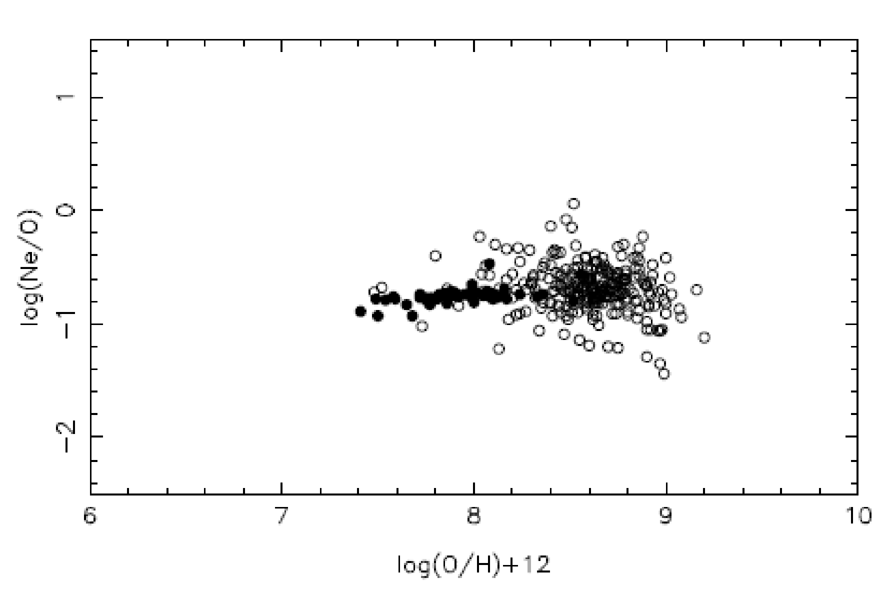
NEON



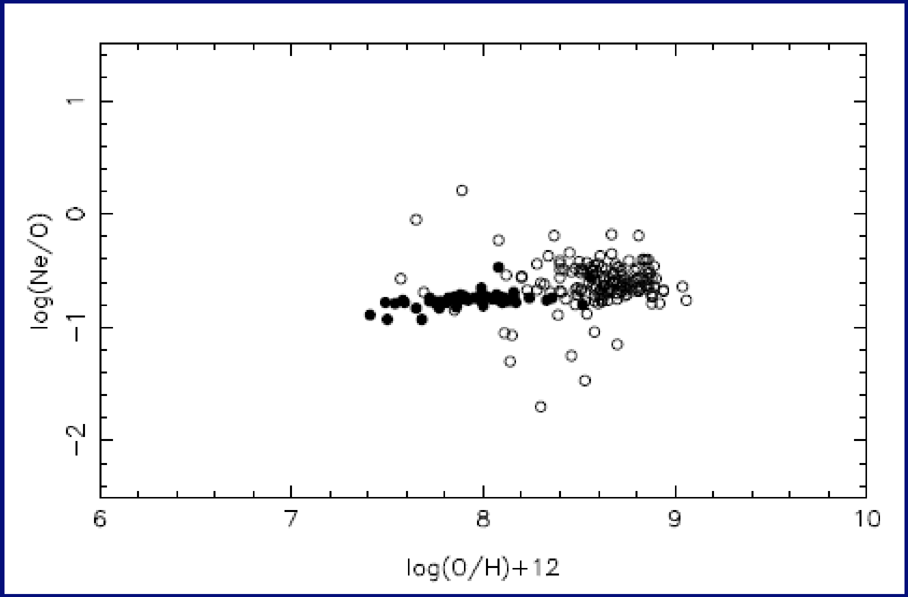
o MW PN – Sample 1
● MW HII regions
log(Ne/H)+12
log(O/H)+12



o MW PN - Henry
● MW HII regions
log(Ne/H)+12
log(O/H)+12

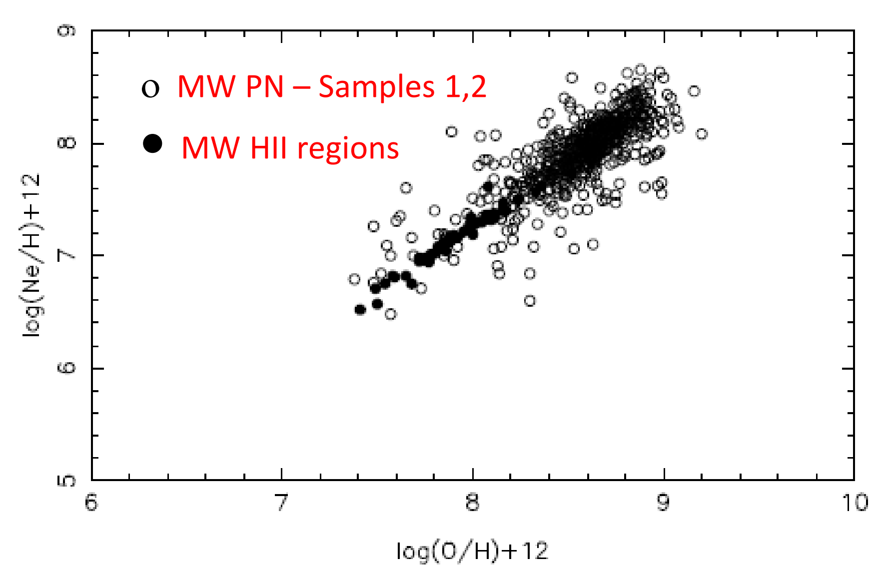


log(Ne/O)
log(O/H)+12

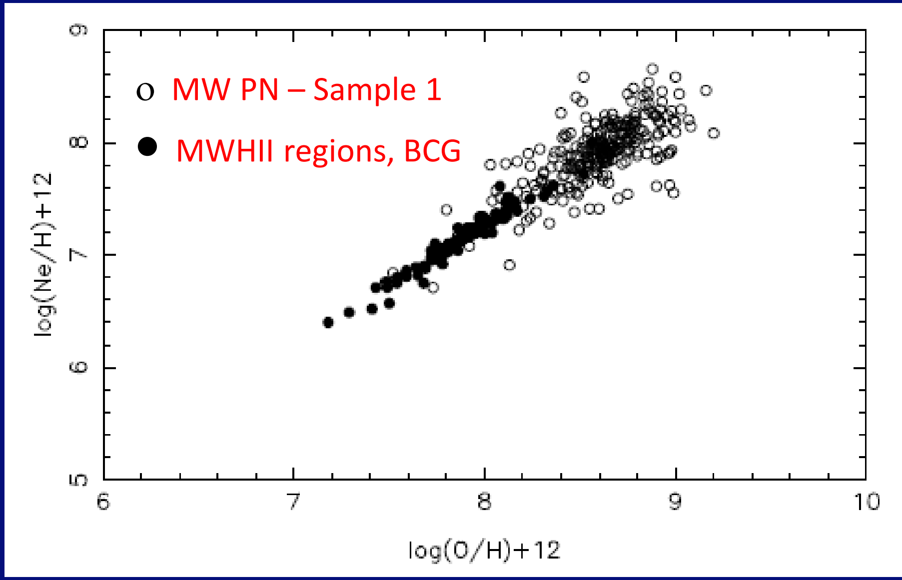


log(Ne/O)
log(O/H)+12

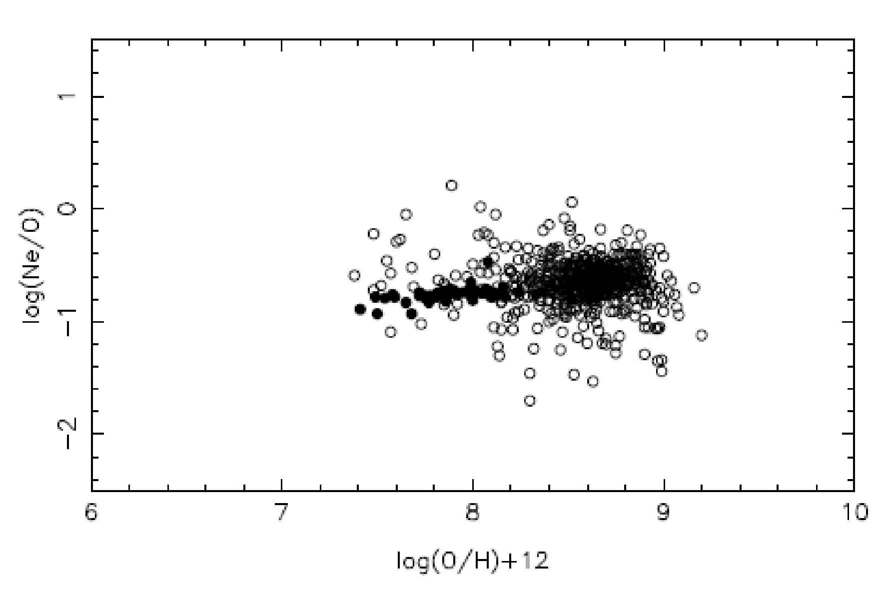
NEON



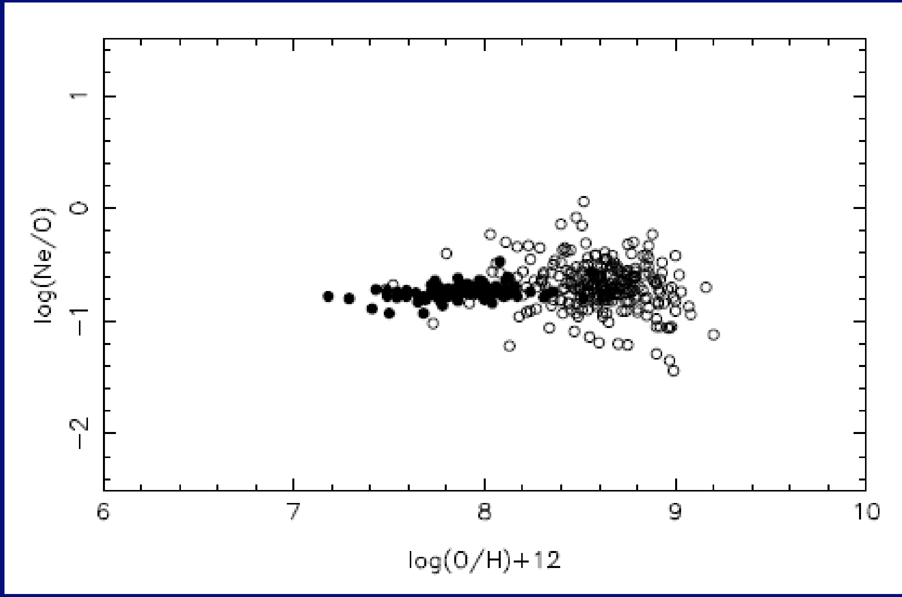
o MW PN – Samples 1,2
● MW HII regions
log(Ne/H)+12
log(O/H)+12



o MW PN – Sample 1
● MWHII regions, BCG
log(Ne/H)+12
log(O/H)+12

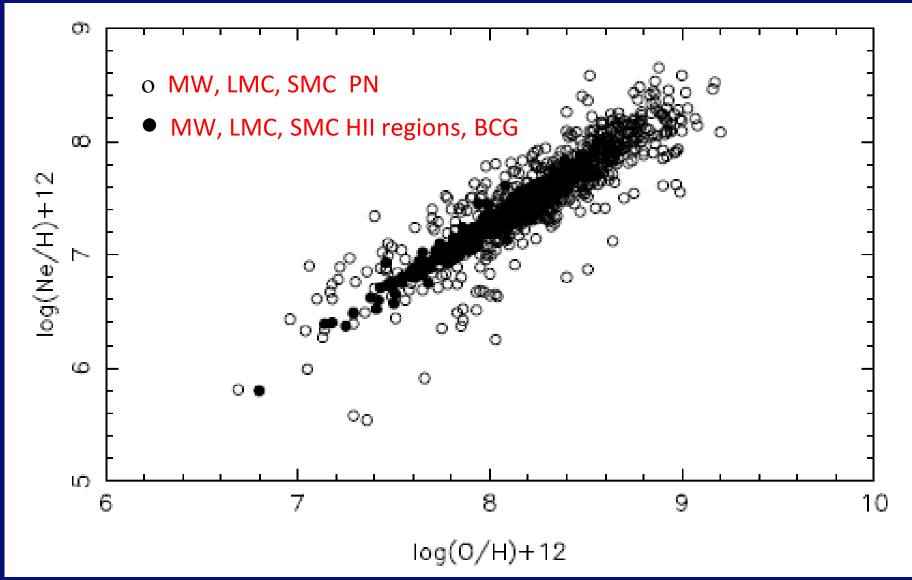


log(Ne/O)
log(O/H)+12

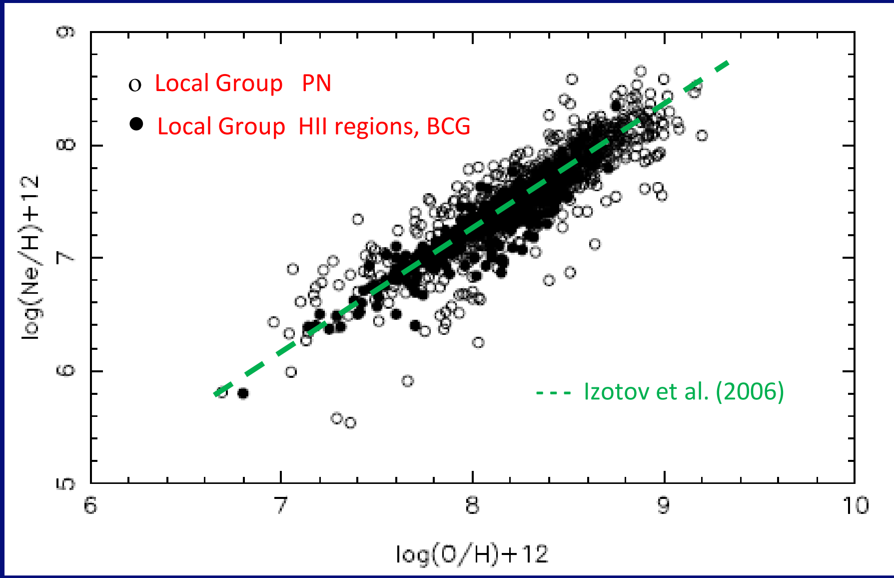


log(Ne/O)
log(O/H)+12

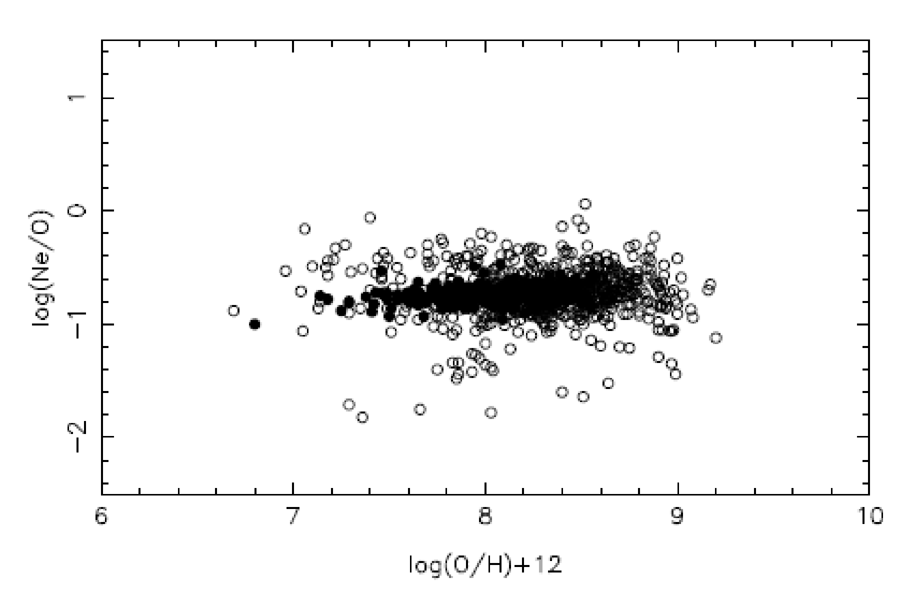
NEON



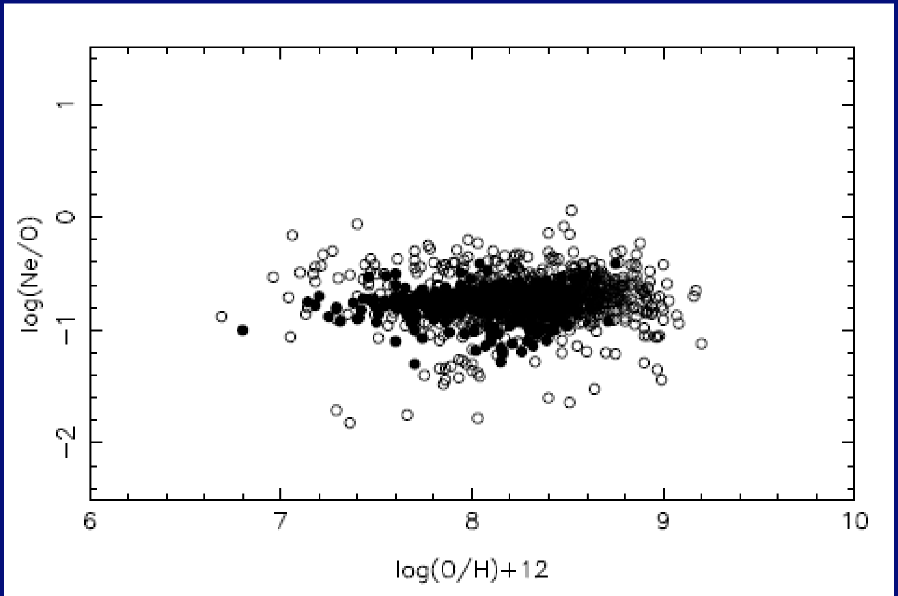
o MW, LMC, SMC PN
● MW, LMC, SMC HII regions, BCG
log(Ne/H)+12
log(O/H)+12



o Local Group PN
● Local Group HII regions, BCG
- - - Izotov et al. (2006)
log(Ne/H)+12
log(O/H)+12

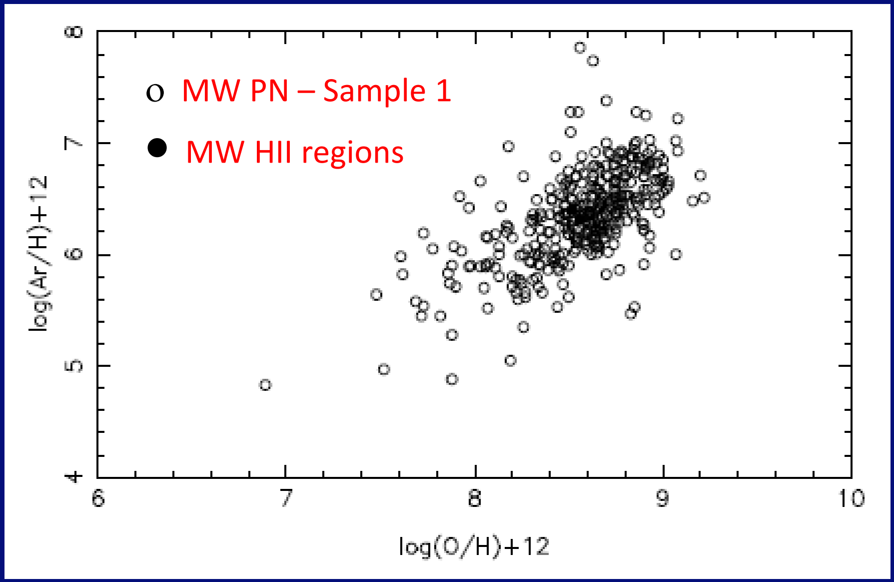


log(Ne/O)
log(O/H)+12

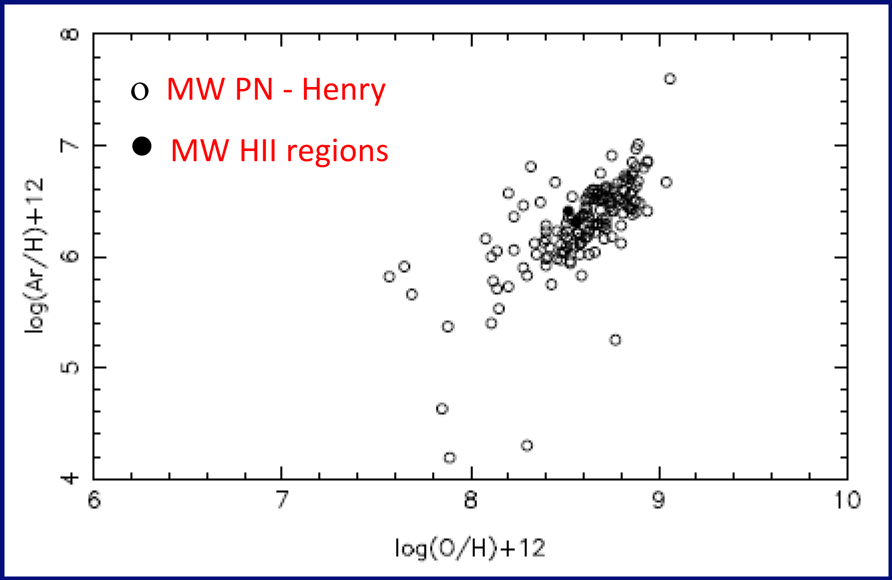


log(Ne/O)
log(O/H)+12

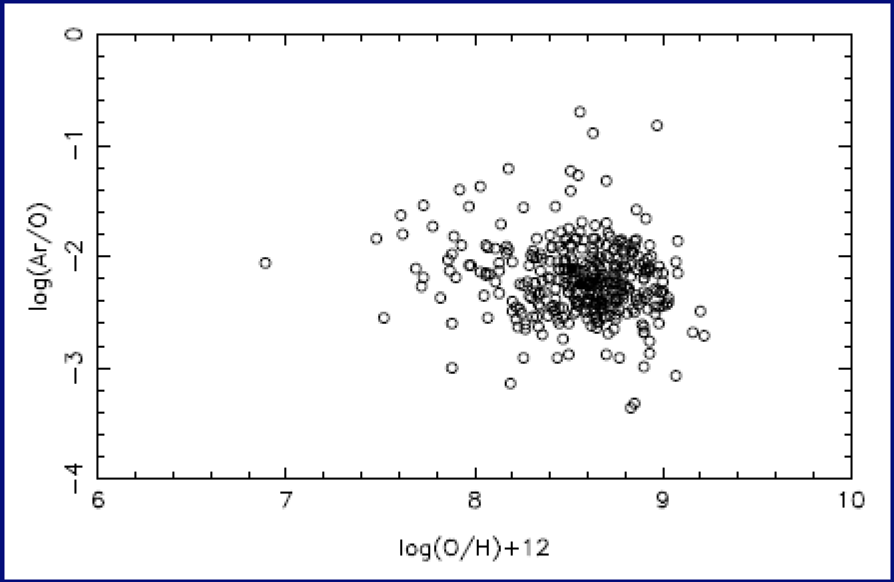
ARGON



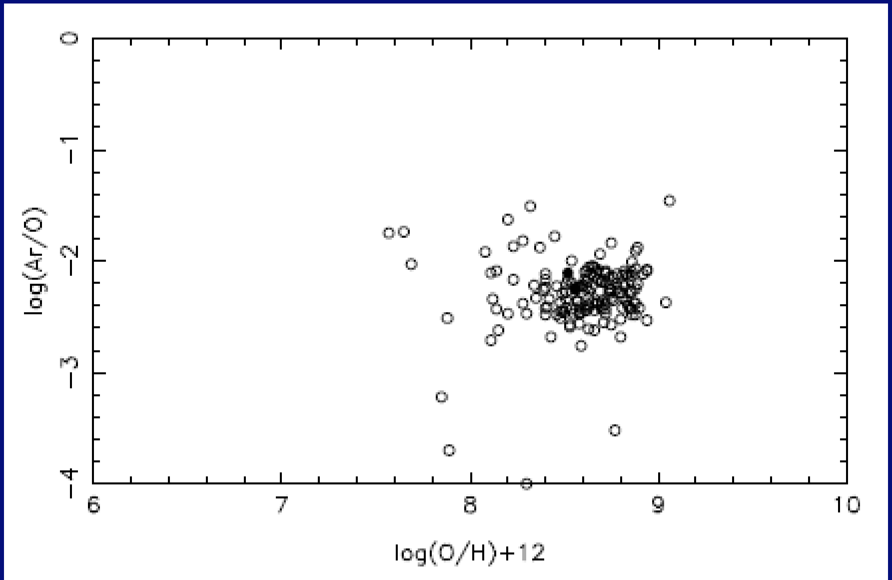
o MW PN – Sample 1
MW HII regions
log(Ar/H)+12
log(O/H)+12



o MW PN - Henry
MW HII regions
log(Ar/H)+12
log(O/H)+12

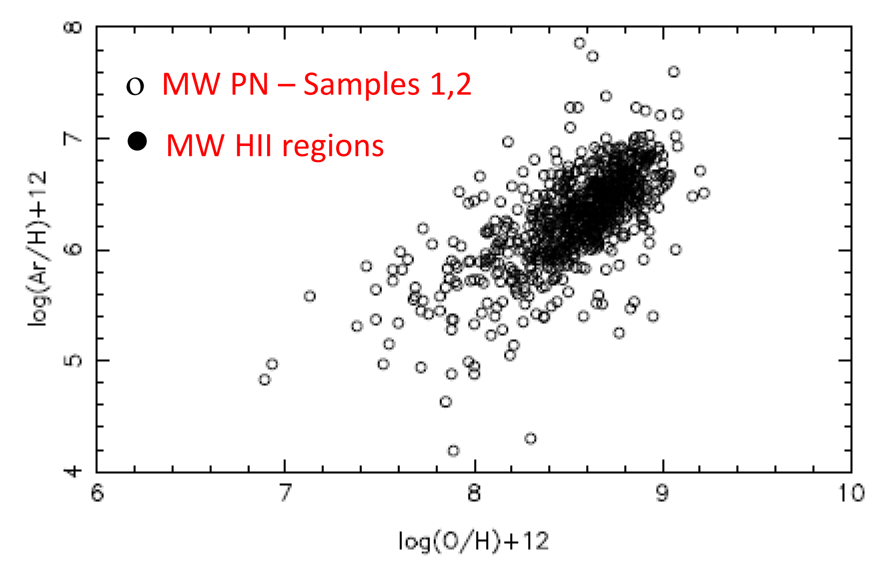


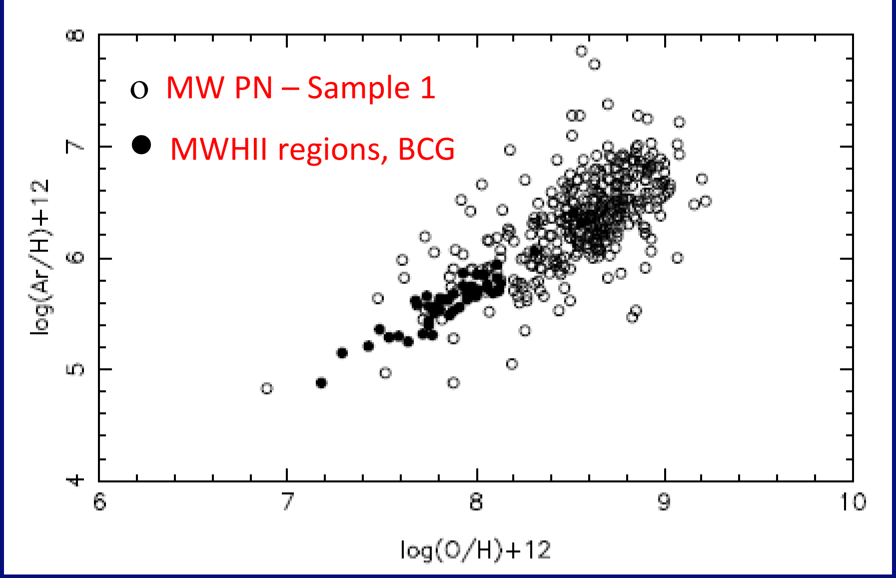
log(Ar/O)
log(O/H)+12

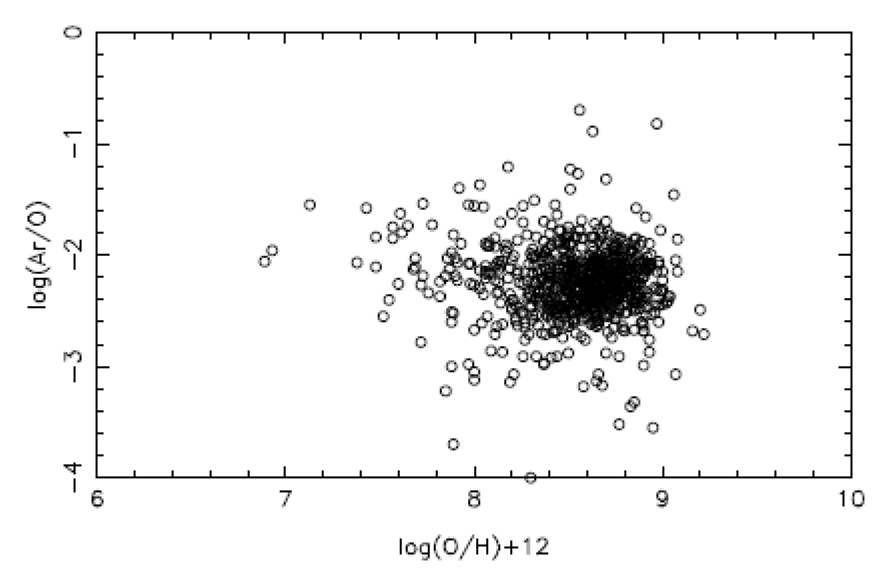


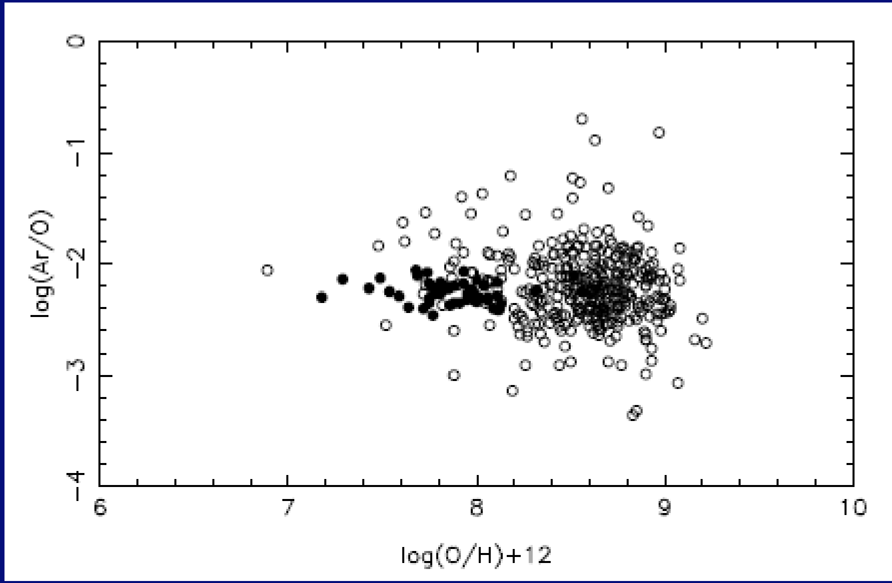
log(Ar/O)
log(O/H)+12

ARGON

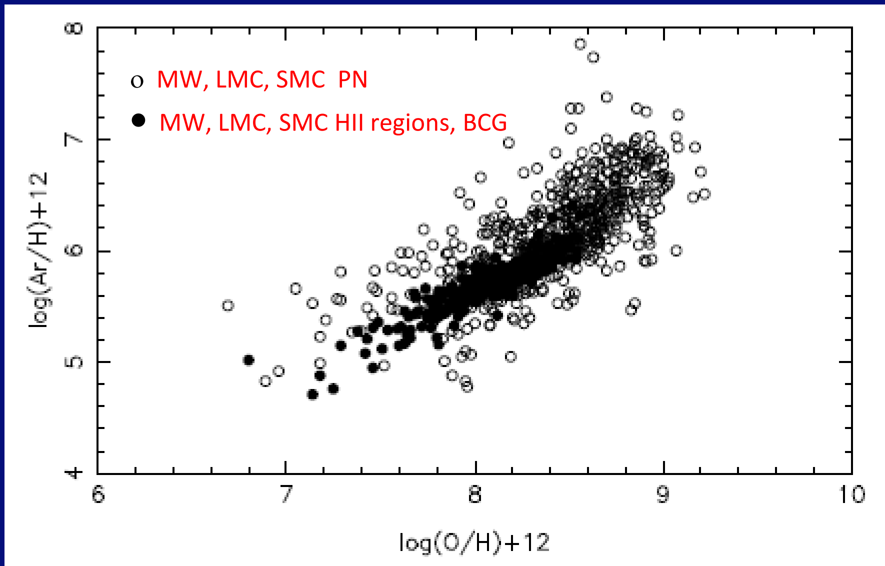

o MW PN – Samples 1,2
● MW HII regions
log(Ar/H)+12
log(O/H)+12


o MW PN – Sample 1
● MWHII regions, BCG
log(Ar/H)+12
log(O/H)+12

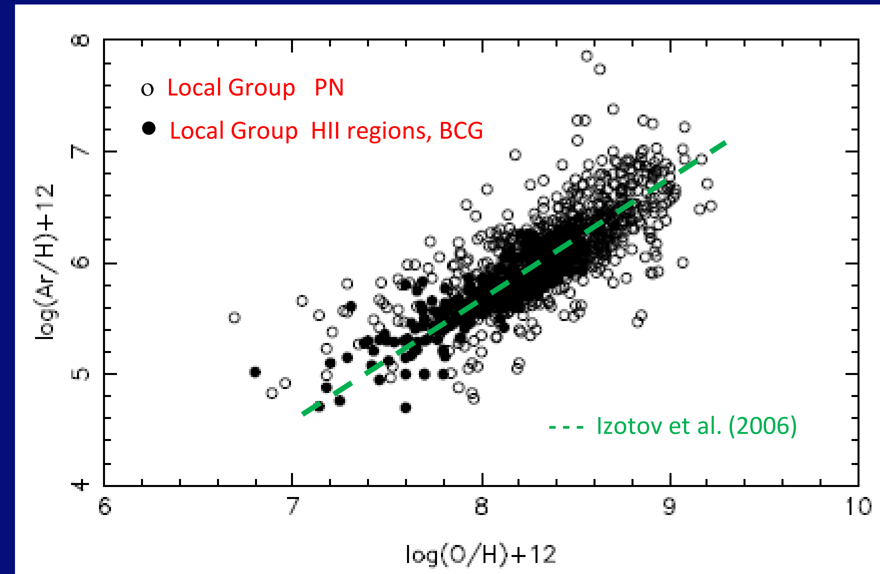

log(Ar/O)
log(O/H)+12


log(Ar/O)
log(O/H)+12

ARGON



o MW, LMC, SMC PN
● MW, LMC, SMC HII regions, BCG
log(Ar/H)+12
log(O/H)+12
4
5
6
7
8
6
7
8
9
10



o Local Group PN
● Local Group HII regions, BCG
- - - Izotov et al. (2006)
log(Ar/H)+12
log(O/H)+12
4
5
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7
8
6
7
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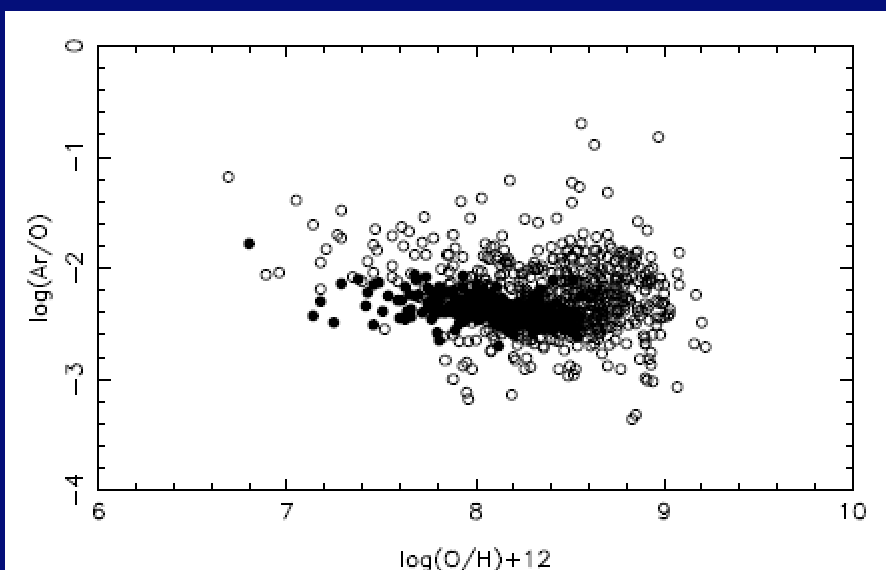
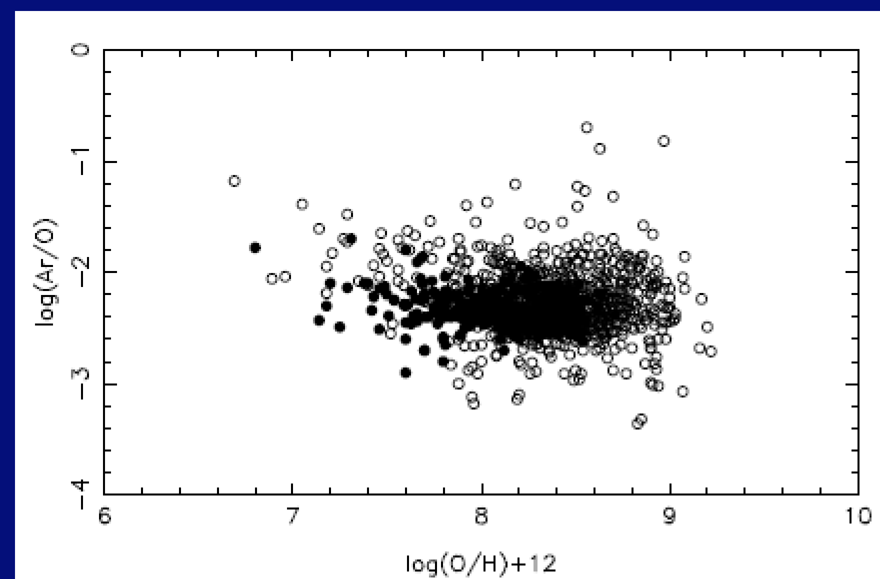
9
10

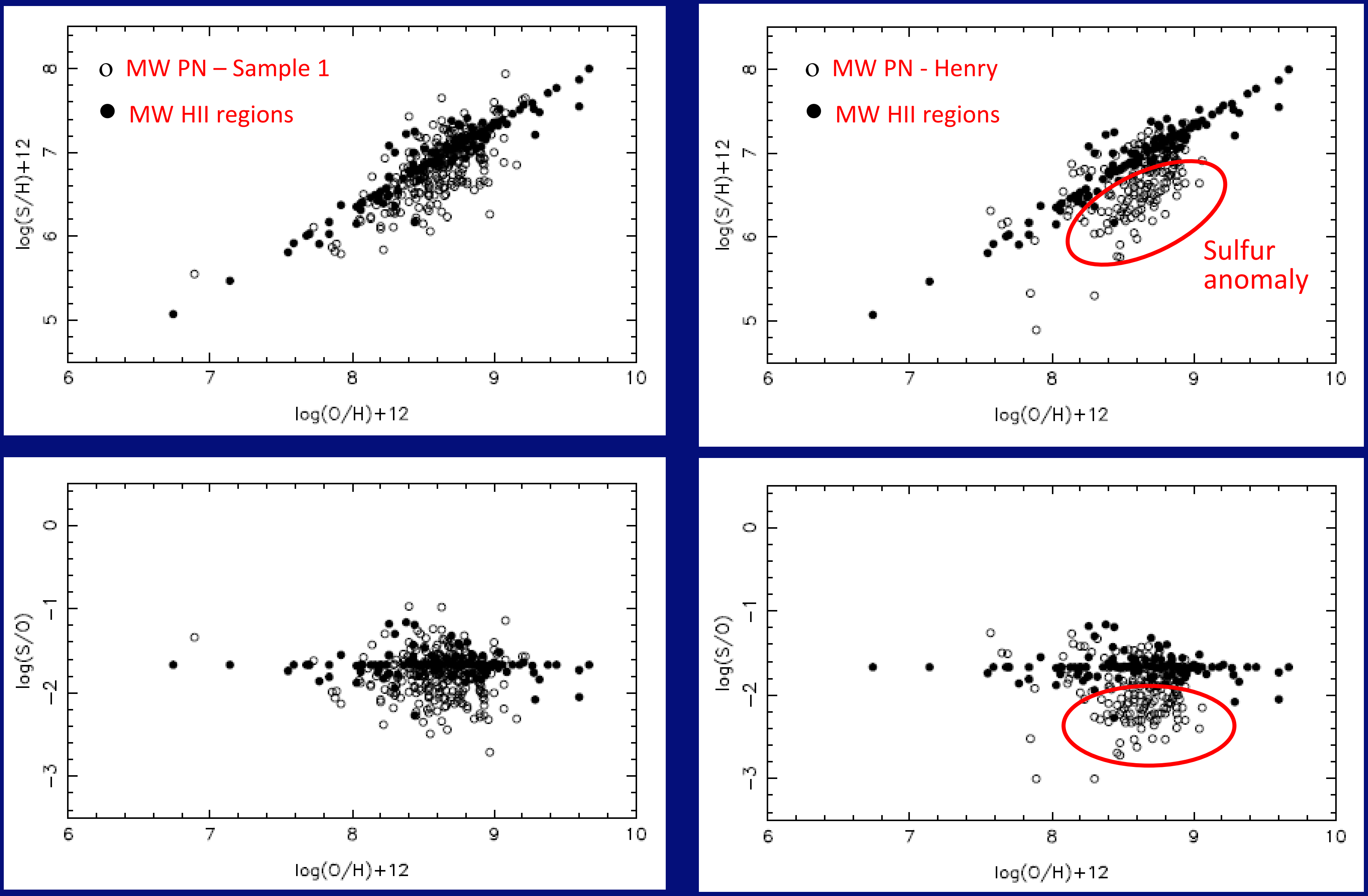


log(Ar/O)
log(O/H)+12
0
−1
−2
−3
−4
6
7
8
9
10



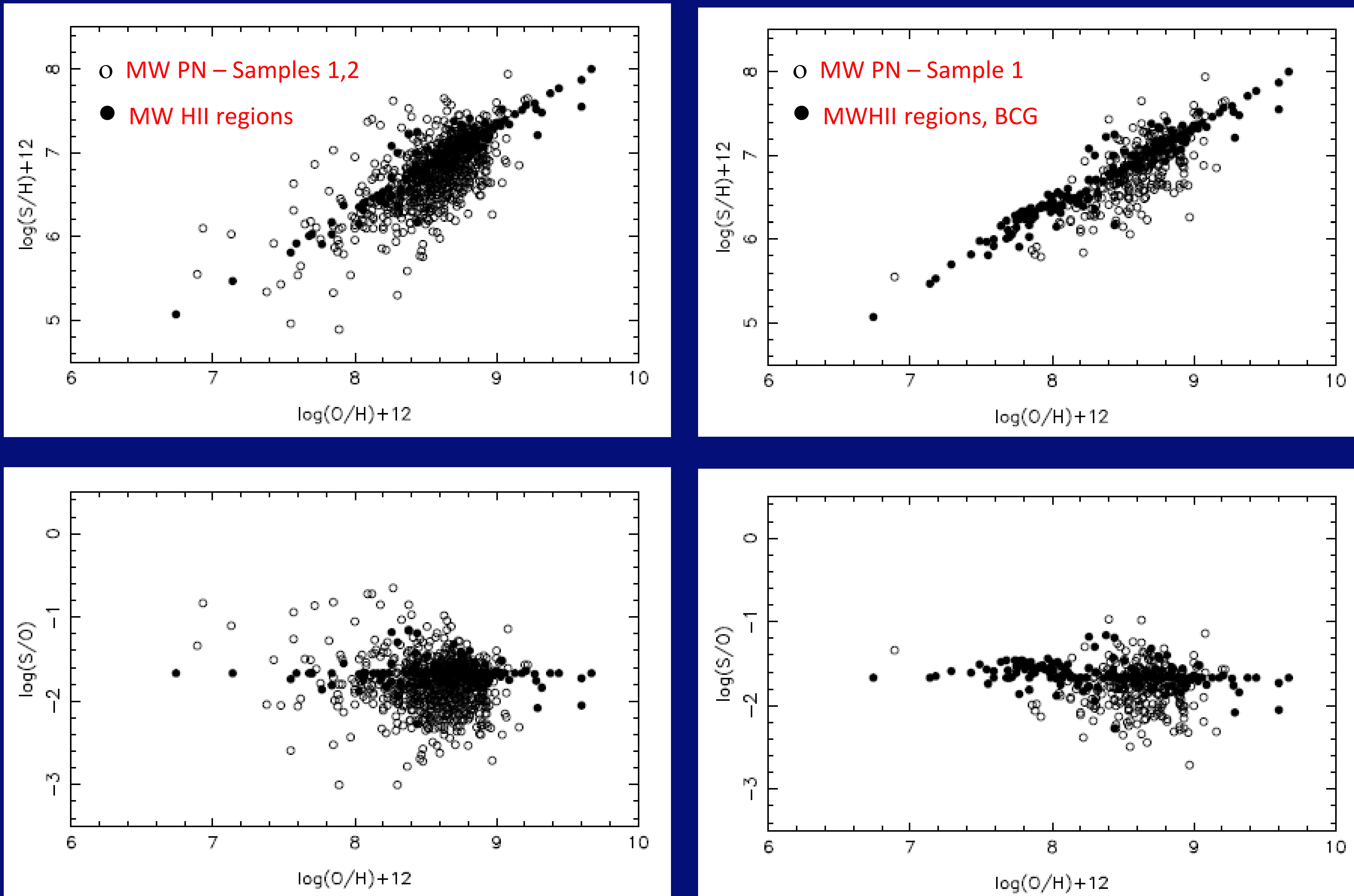
log(Ar/O)
log(O/H)+12
0
−1
−2
−3
−4
6
7
8
9
10

SULFUR



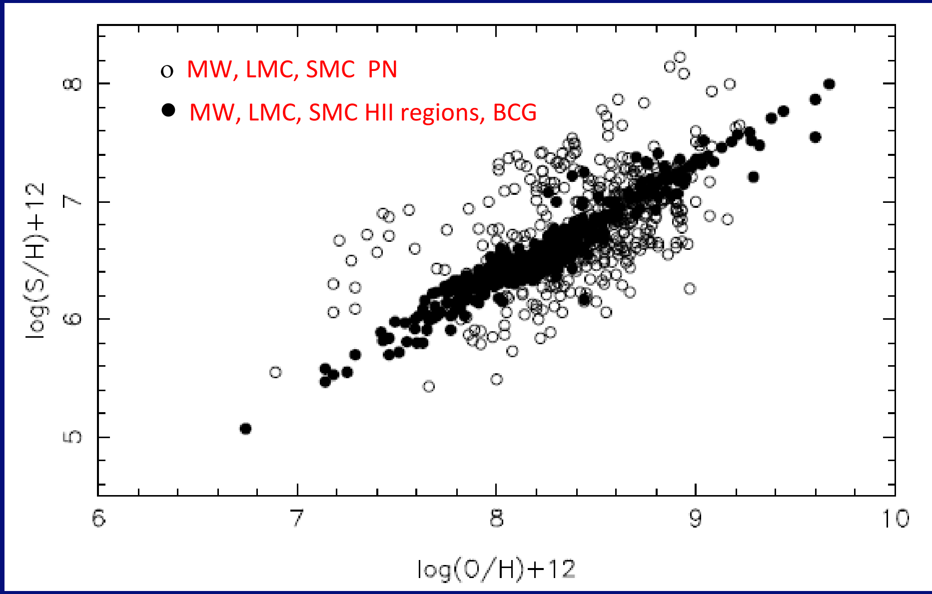
o MW PN – Sample 1
● MW HII regions
log(S/H)+12
log(O/H)+12
o MW PN - Henry
● MW HII regions
Sulfur anomaly
log(S/O)

SULFUR

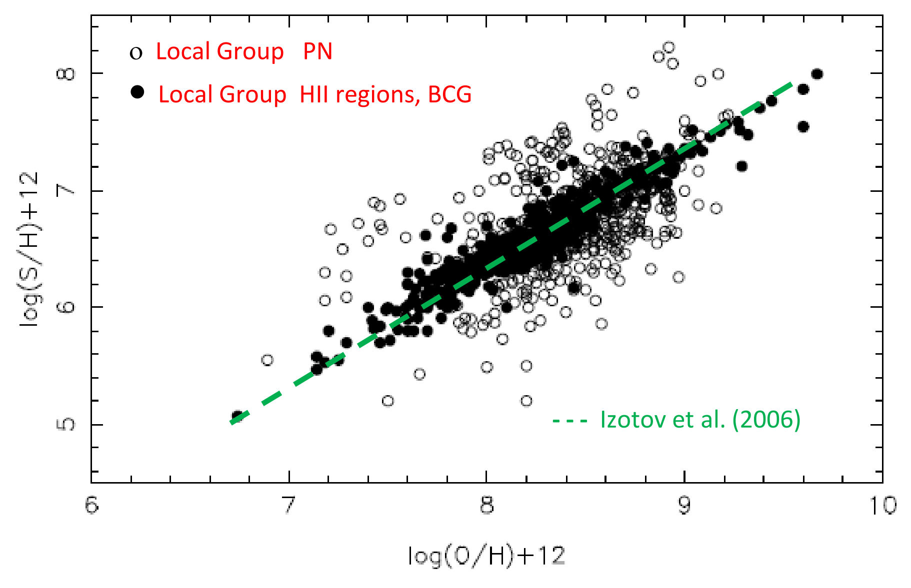


o MW PN – Samples 1,2
● MW HII regions
log(S/H)+12
log(O/H)+12
o MW PN – Sample 1
● MWHII regions, BCG
log(S/H)+12
log(O/H)+12
log(S/O)
log(O/H)+12
log(S/O)
log(O/H)+12

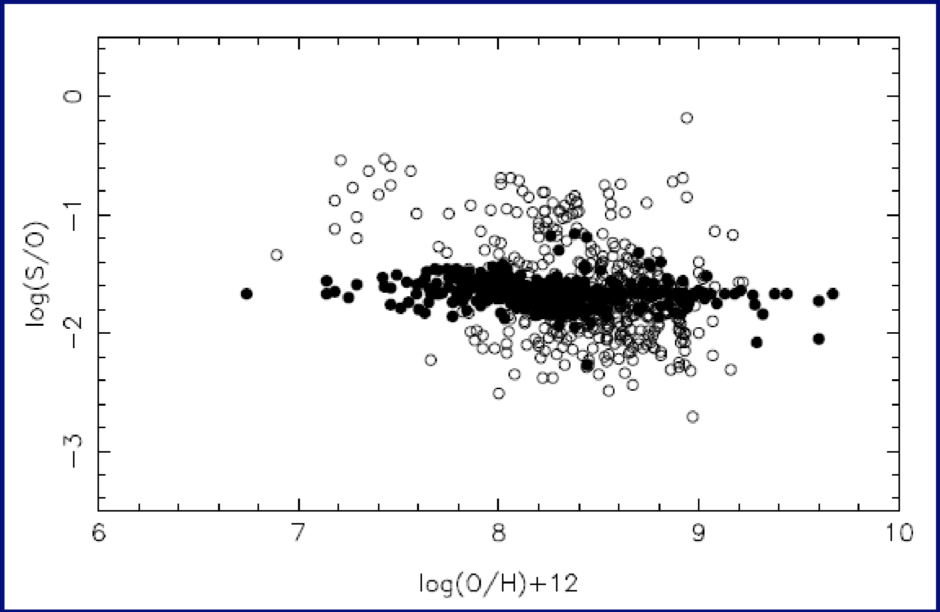
SULFUR



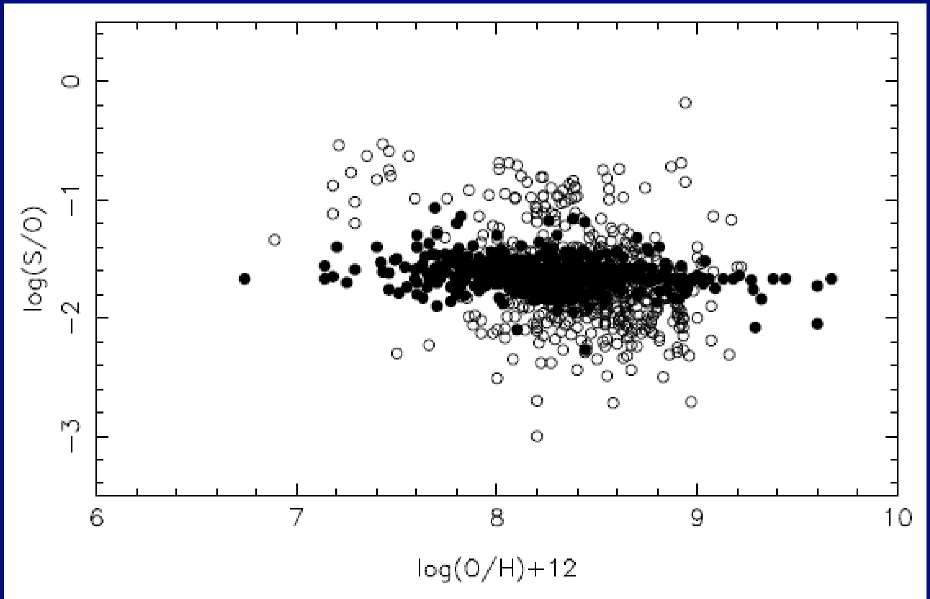
o MW, LMC, SMC PN
● MW, LMC, SMC HII regions, BCG
log(S/H)+12
log(O/H)+12



o Local Group PN
● Local Group HII regions, BCG
--- Izotov et al. (2006)
log(S/H)+12
log(O/H)+12



log(S/O)
log(O/H)+12

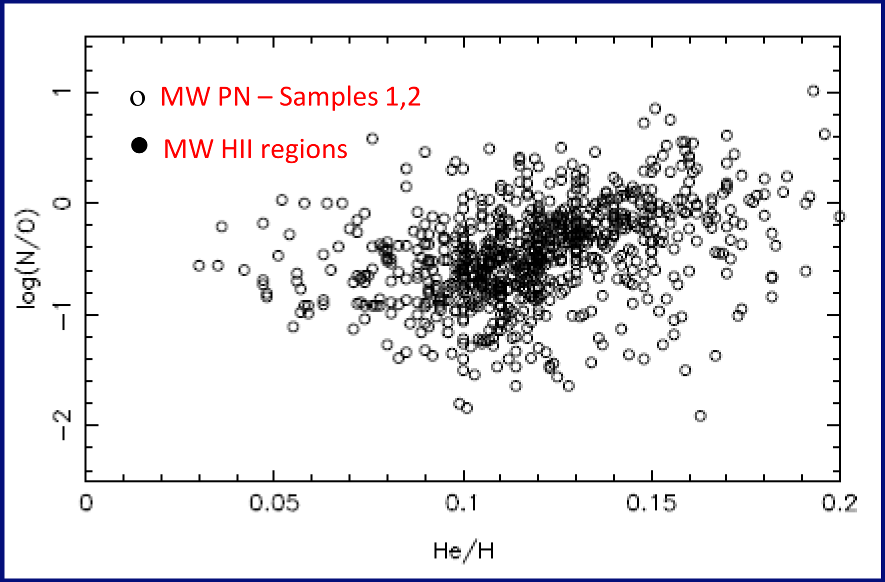


log(S/O)
log(O/H)+12

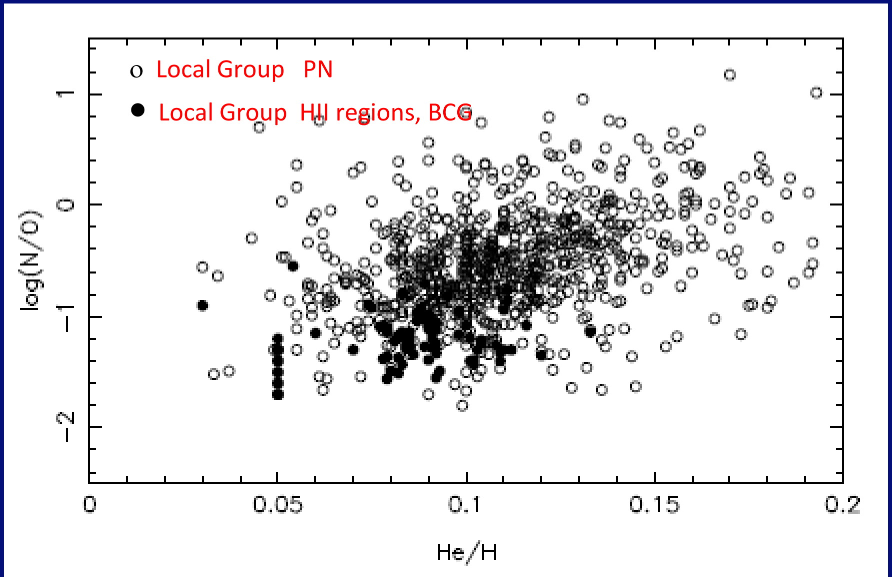
4. Elements produced by the PN progenitor stars

The abundances of He, N, and C are changed by the evolution of the progenitor star, particulary by the dredge-up processes that occur in the intermediate mass stars.

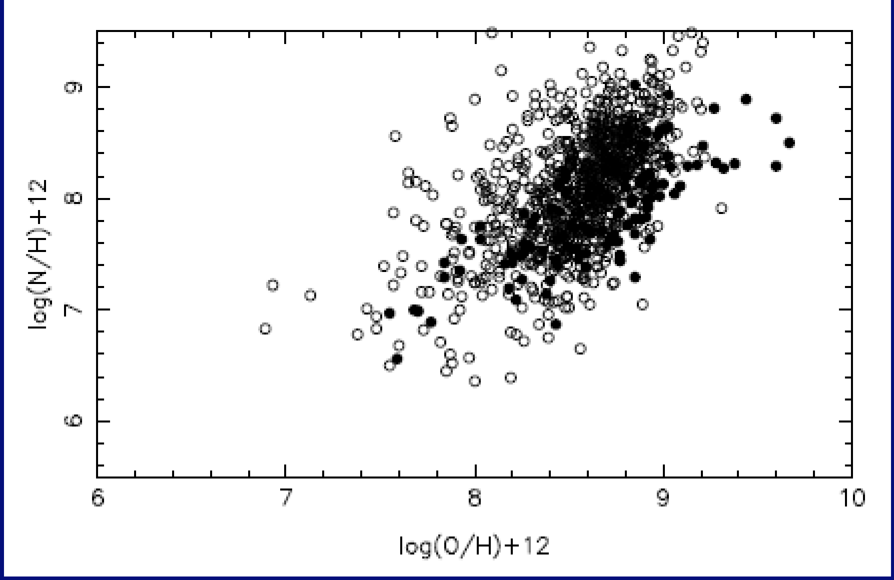
NITROGEN



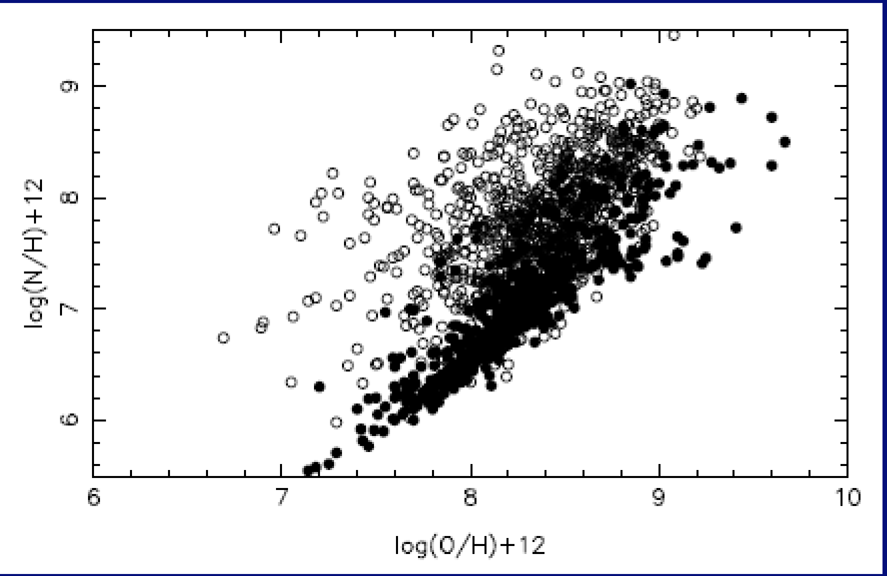
o MW PN – Samples 1,2
● MW HII regions
log(N/O)
He/H



o Local Group PN
● Local Group HII regions, BCG
log(N/O)
He/H



log(N/H)+12
log(O/H)+12

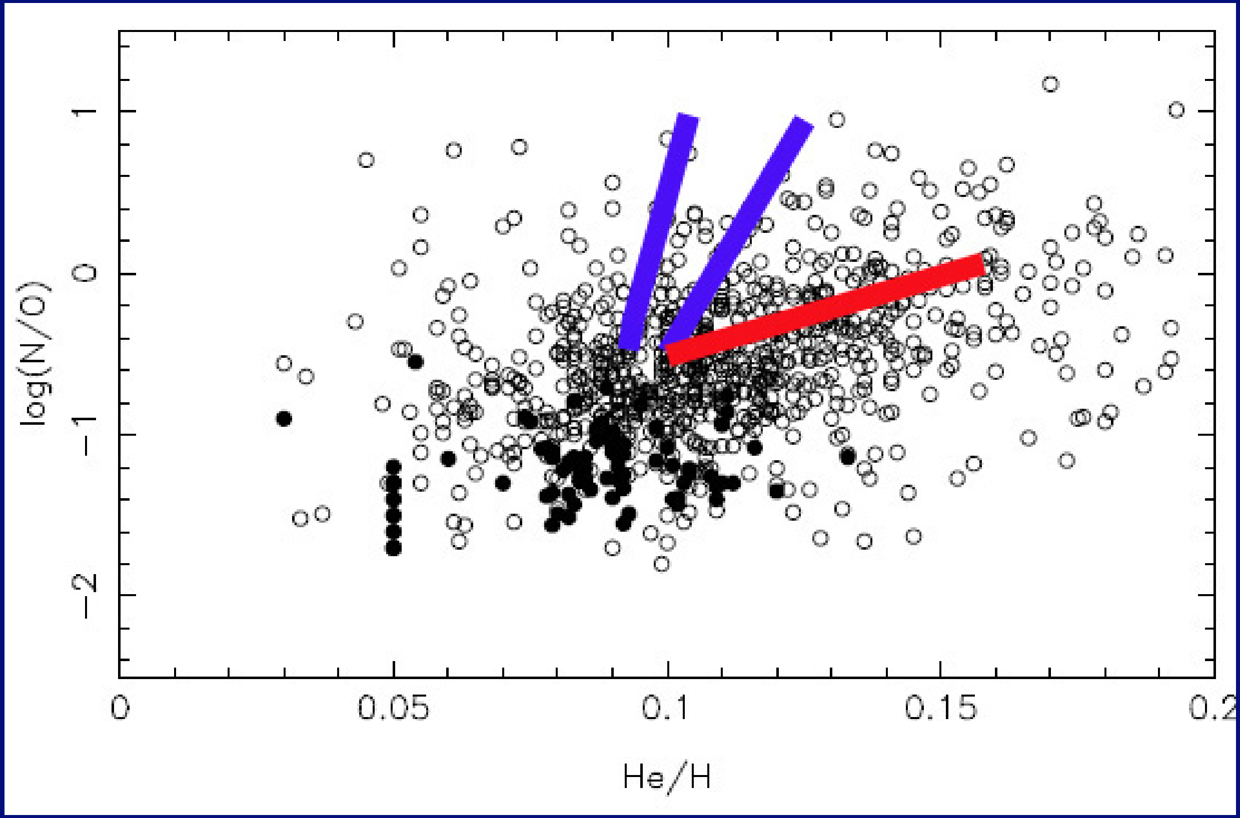


log(N/H)+12
log(O/H)+12

Comparison with theoretical models

Marigo (2003)
Z = 0.019

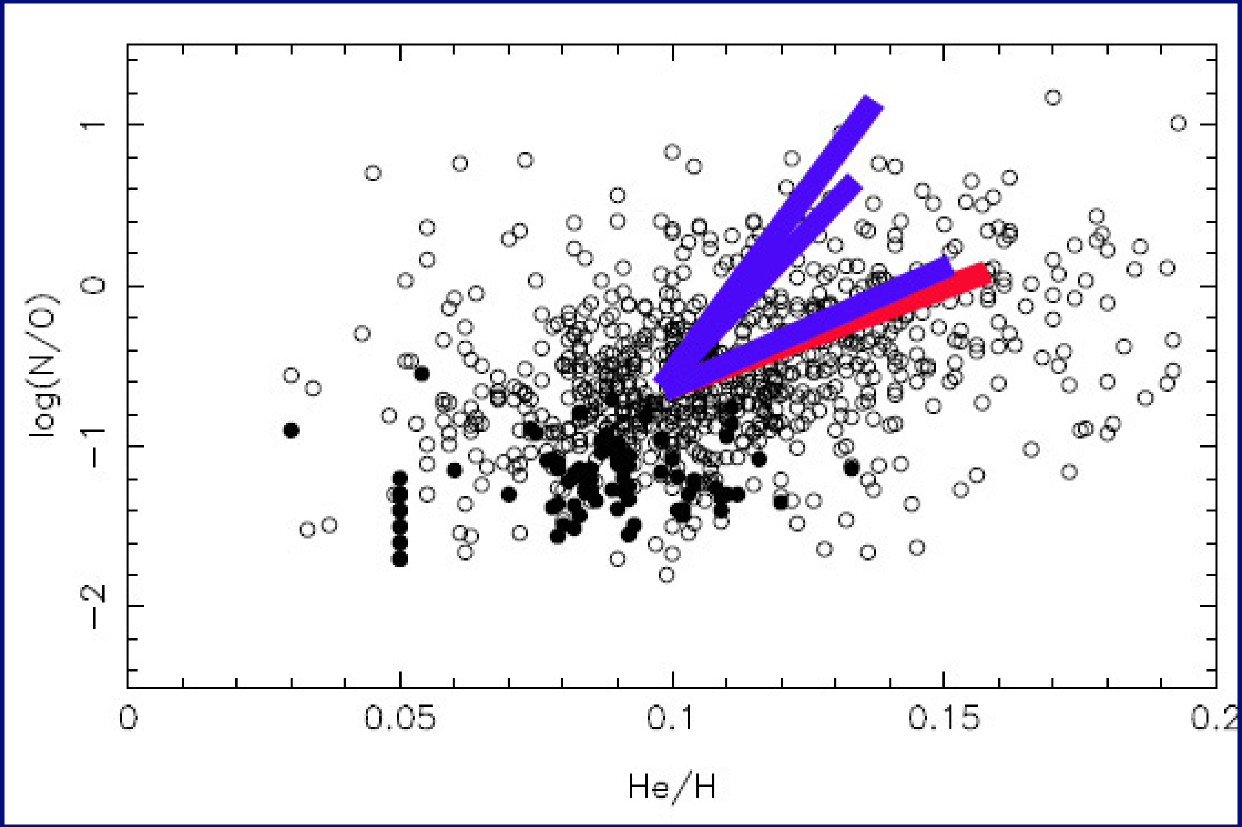
Karakas (2003)
Z = 0.004, 0.008



Comparison with theoretical models

Marigo (2003)
Z = 0.019

Karakas (2010)
Z = 0.02, 0.004, 0.008



These are synthetic evolutionary models for the thermally-pulsing AGB with initial masses of 1 to 6 solar masses, in which up to three dredge-up episodes occur, apart from hot-bottom processes (HBB) for the most massive objects.

According to these models, progenitors having 0.9 to 4 solar masses and solar composition can explain the “normal” abundances, He/H < 0.15, while for objects with higher enhancements (He/H > 0.15) masses of 4 to 5 solar masses are needed, plus an efficient HBB.

CONCLUSIONS

➔ PN abundances of O, Ne, S, and Ar show good correlations, indicating that Ne, S, and Ar vary in lockstep with O. Abundances relative to oxygen are essentially constant. Sulfur abundances in PN present the “sulfur anomaly” in some samples, probably due to incorrect ICFs.

➔ All correlations for HII, BCG, and ELG show smaller dispersions, as expected, but the same trends are observed in both types of photoionized nebulae.

➔ The dispersion observed in PN is probably real, and reflects the different ages of the progenitor stars.

➔ For the elements that are produced by the progenitor stars (N, He), some dispersion is observed even for HII regions, so that part of the nitrogen is probably secondary. For intermediate mass stars, agreement with theoretical models is fair, but abundance determinations should be improved and expanded.


Thank You
Köszönöm