PLANETARY NEBULAE AS A CHEMICAL EVOLUTION TOOL: ABUNDANCE GRADIENTS

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1. Introduction

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Astronomy & Astrophysics

An estimate of the time variation of the O/H radial gradient from planetary nebulae

W. J. Maciel, R. D. D. Costa, and M. M. M. Uchida

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An estimate of the time variation of the abundance gradient from planetary nebulae⋆

II. Comparison with open clusters, cepheids and young objects

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Motivation

Abundance gradients – and their time variation – provide critical observational constraints for the chemical evolution models of the Galaxy.

Planetary nebulae are particularly interesting objects to study the gradients and their variations: they are bright, the abundances are relatively well determined, the existence of several distance scales compensates for the lack of accurate individual distances and, especially, their progenitor stars span a considerable age bracket.

Abundance gradients

- Planetary nebulae: O/H, S/H
  IAG/USP group

- Open clusters: [Fe/H]
  Friel et al. (2002), Chen et al. (2003)

- Cepheid variables [Fe/H]
  Andrievsky et al. (2002–2004)

- Young objects: HII regions, OB stars
  Deharveng et al. (2000), Pilyugin et al. (2003)
  Daflon & Cunha (2004)

The key point in the estimate the time variation of the gradients appears to be the determination of the ages of the objects considered.

The best determined ages are those of the very young objects, such as HII regions, OB stars and cepheid variables.

However, the most interesting objects are the planetary nebulae and open clusters, which show a larger age bracket.

We have taken into account different age groups, and estimated the gradients for each of these groups.

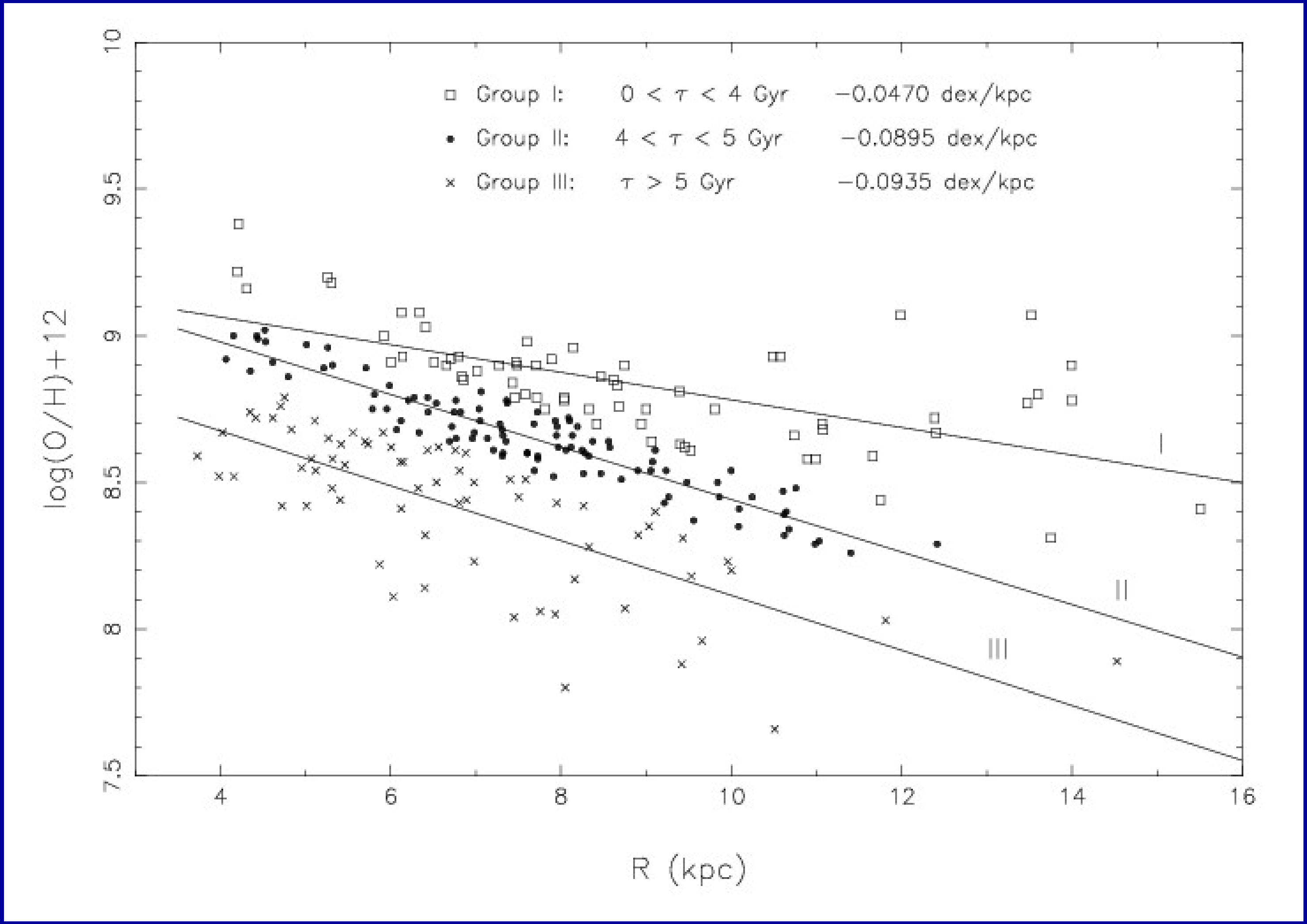
ABUNDANCE GRADIENTS FROM PN

$$\log\,(\mathrm{X/H}) + 12 = a + bR$$

Group	Age (Gyr)	a	b (dex/kpc)	r	n	d[Fe/H]/dR
O/H gradients						
I	0 − 4	9.252 ± 0.064	−0.047 ± 0.007	−0.64	66	−0.056 ± 0.008
II	4 − 5	9.337 ± 0.027	−0.089 ± 0.003	−0.94	99	−0.107 ± 0.004
III	5 − 8	9.049 ± 0.072	−0.094 ± 0.010	−0.75	69	−0.113 ± 0.012
S/H gradients						
I	0 − 4	7.648 ± 0.132	−0.080 ± 0.014	−0.66	44	−0.096 ± 0.017
II	4 − 8	7.730 ± 0.091	−0.113 ± 0.011	−0.76	72	−0.136 ± 0.013

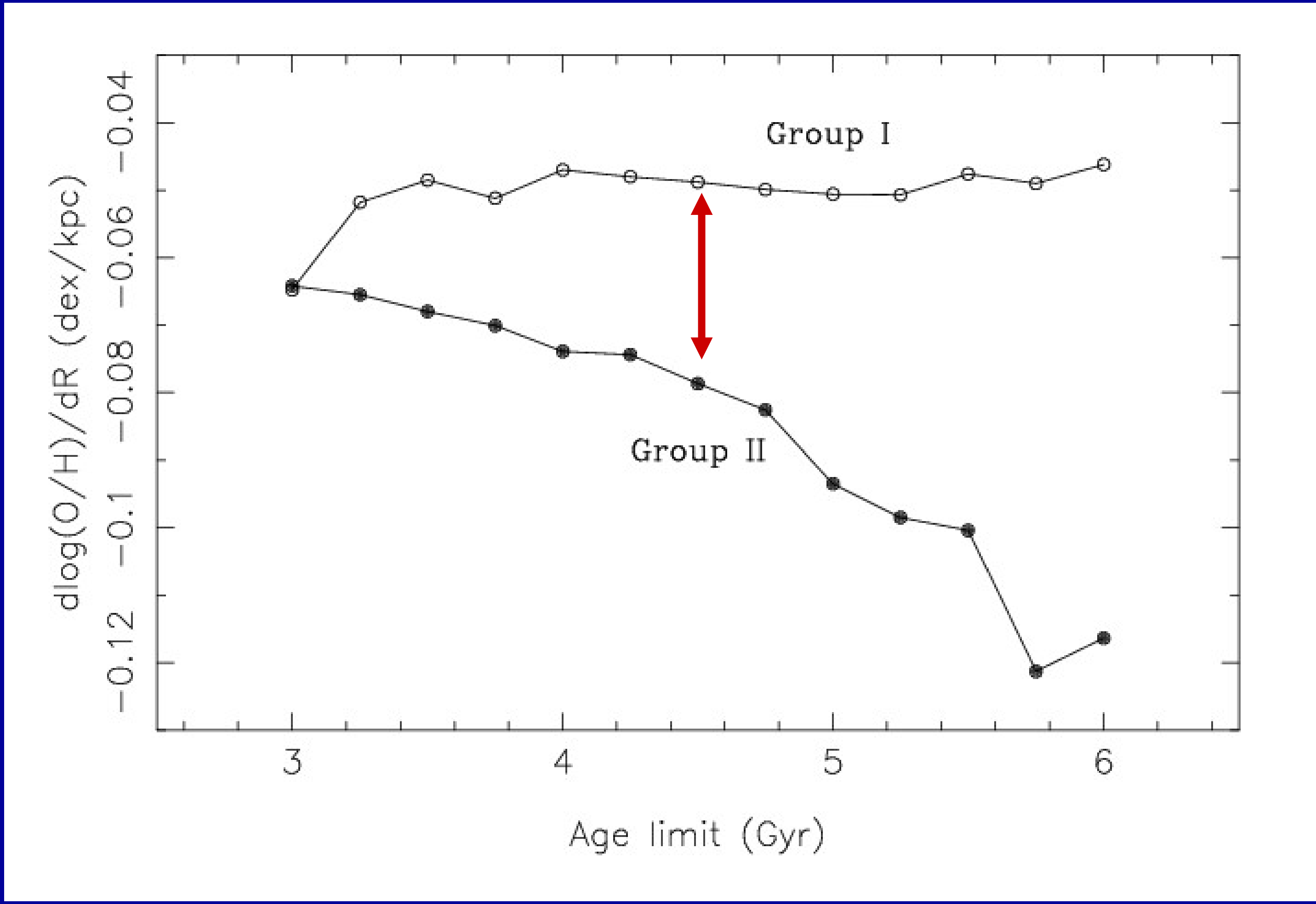
Maciel, Lago & Costa (2005)

O/H GRADIENTS FROM PN: 3 AGE GROUPS



Maciel, Costa & Uchida (2003)

O/H GRADIENTS FROM PN: 2 AGE GROUPS



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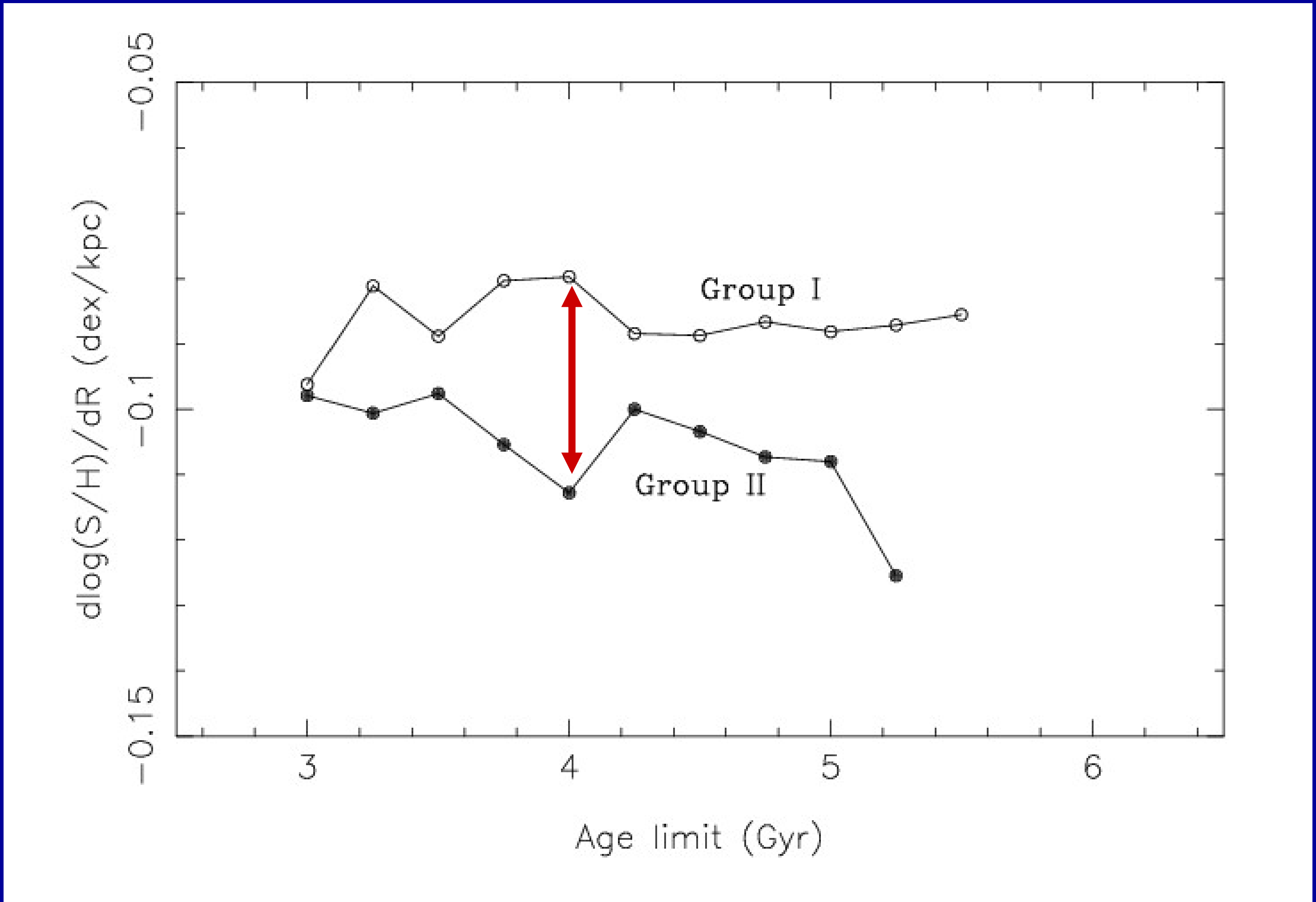
S/H GRADIENTS FROM PN: 2 AGE GROUPS



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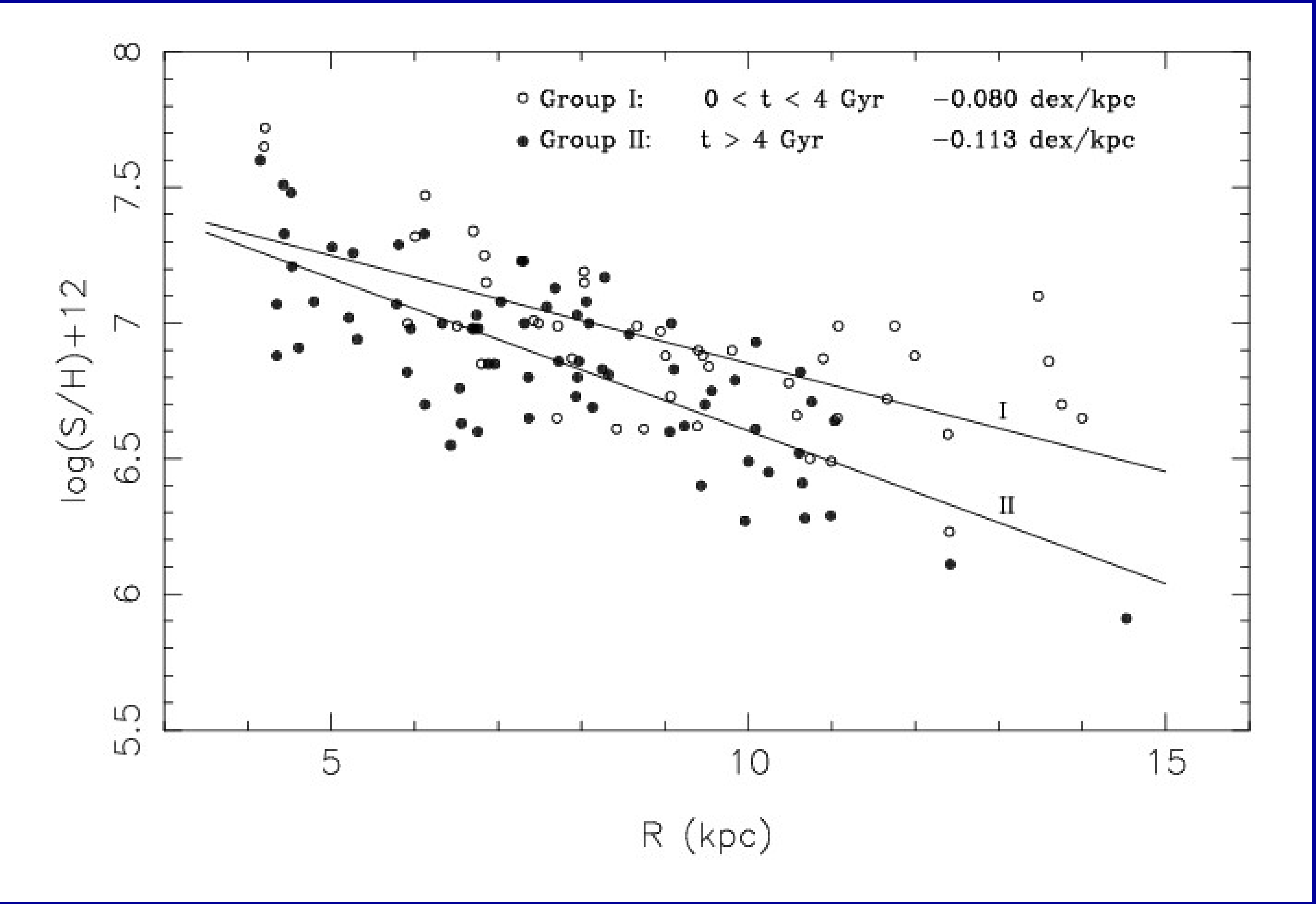
S/H GRADIENTS FROM PN: 2 AGE GROUPS



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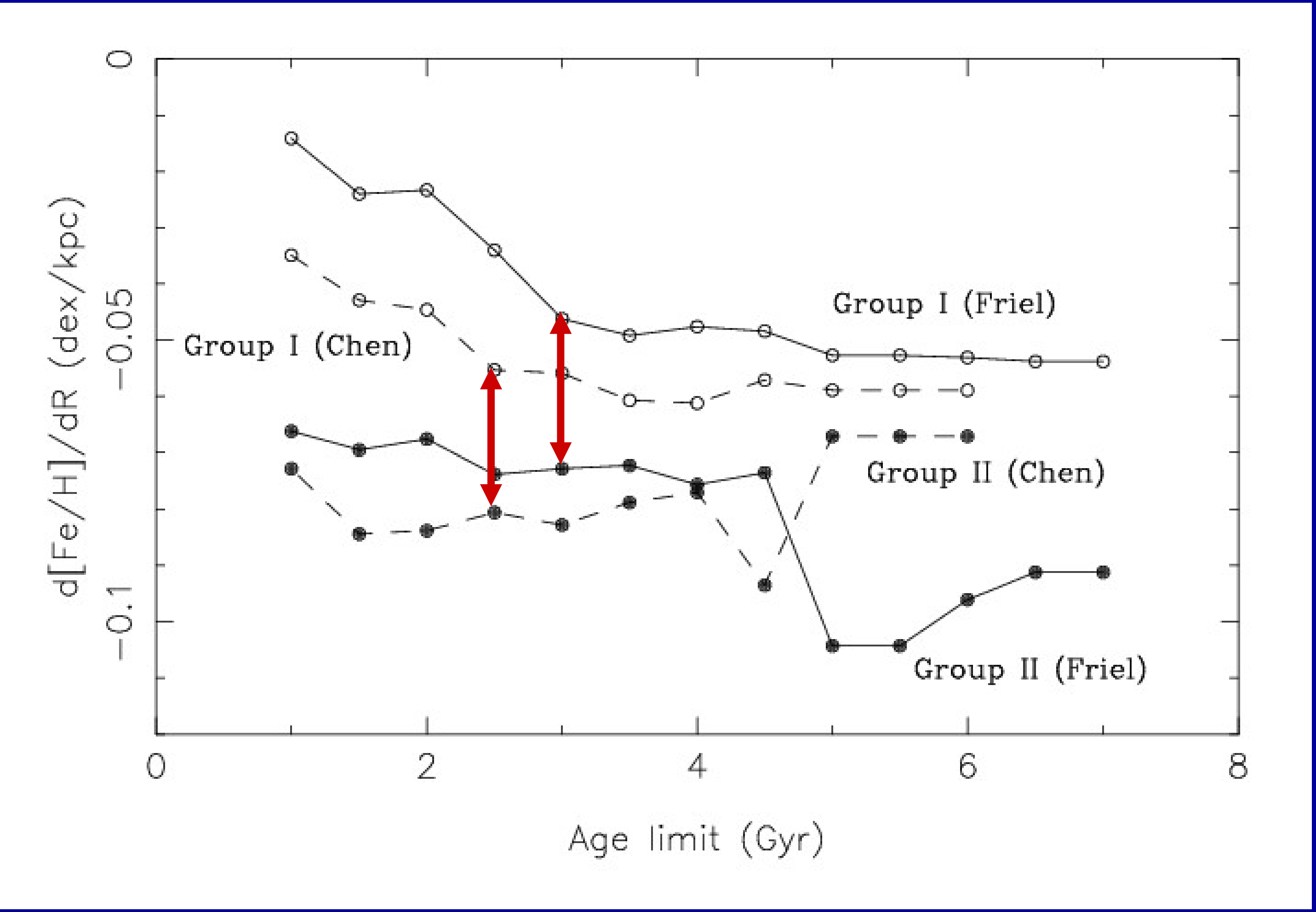
[Fe/H] GRADIENTS FROM OPEN CLUSTERS: 2 AGE GROUPS



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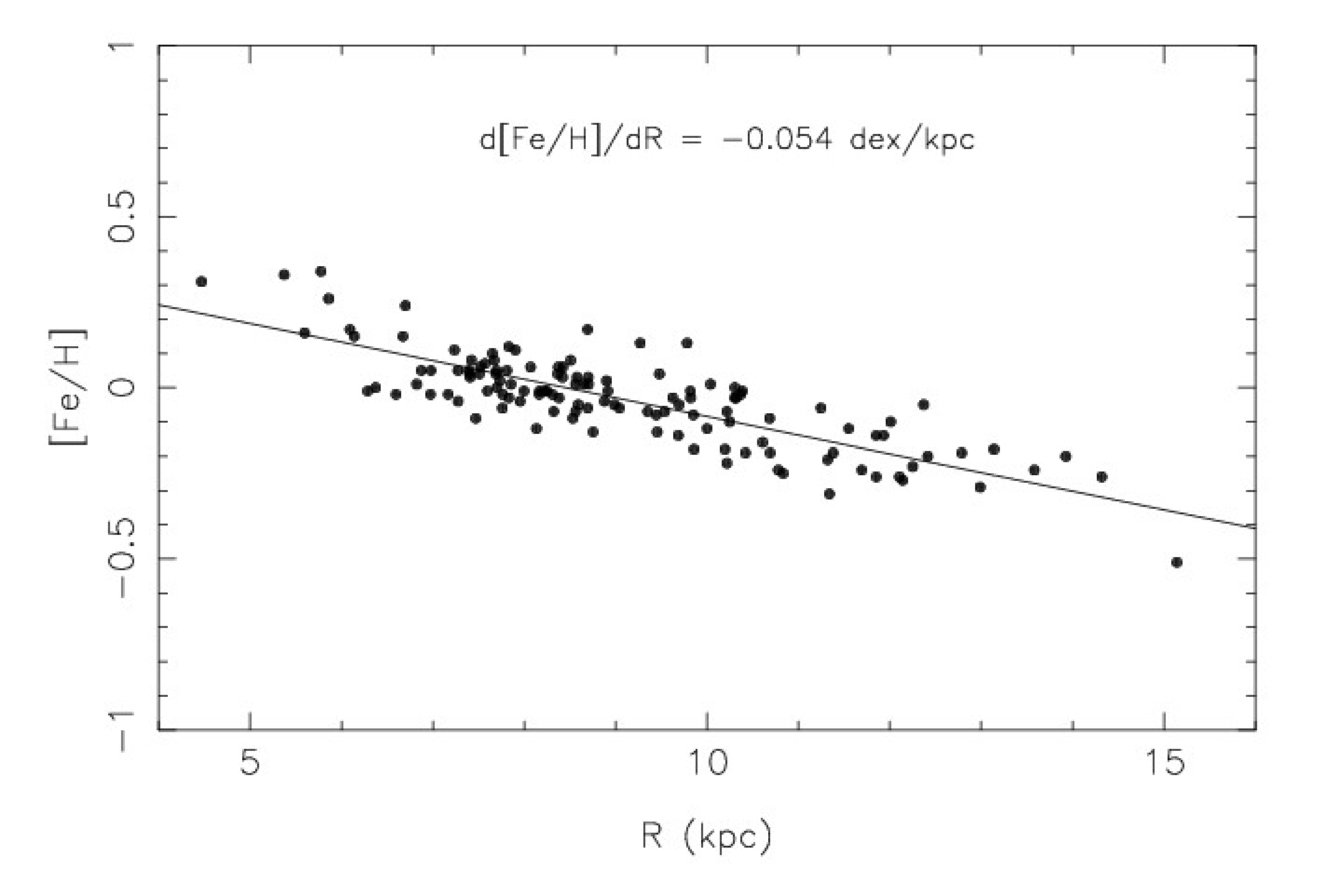
[Fe/H] GRADIENTS FROM CEPHEIDS



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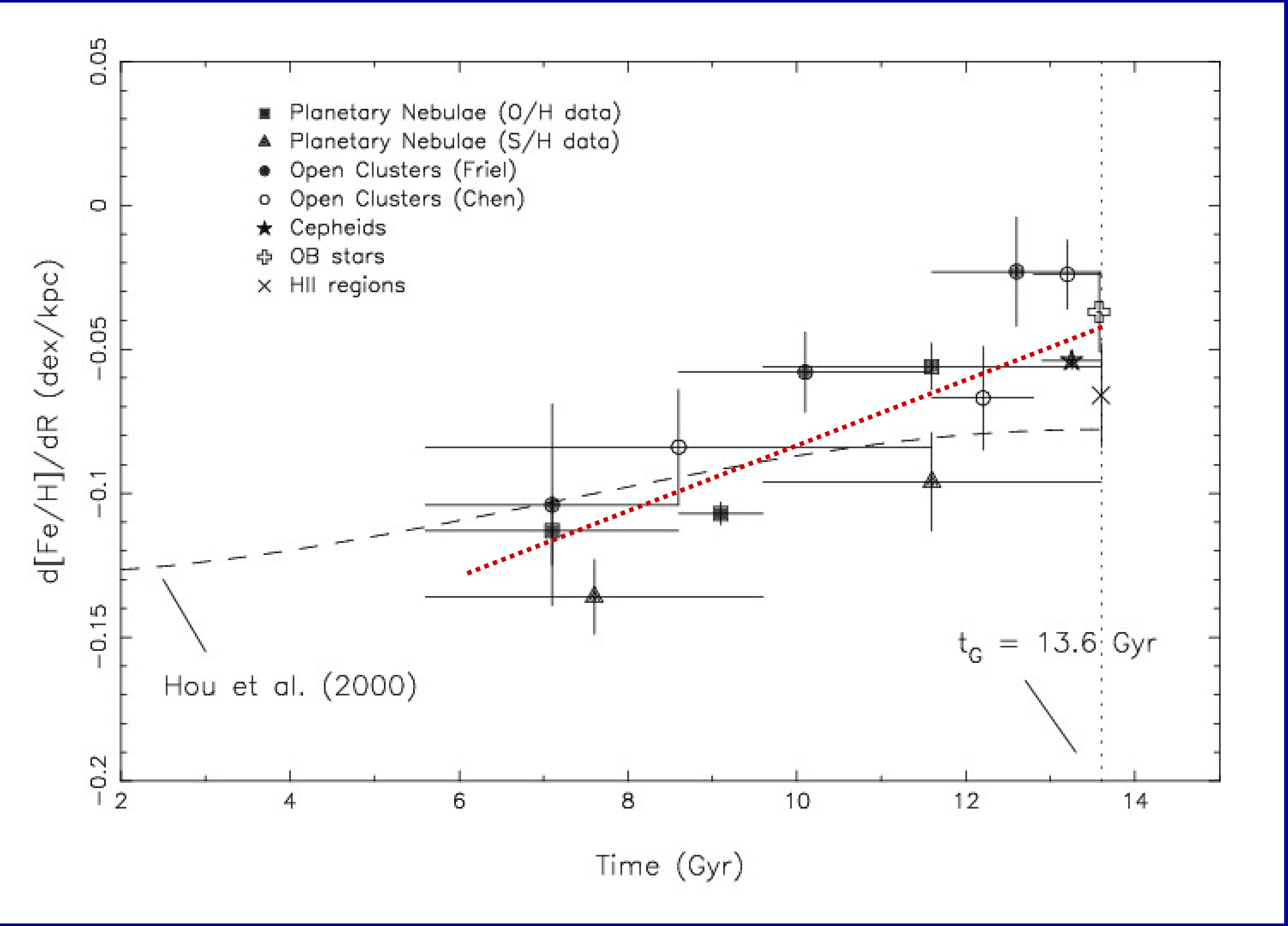
TIME VARIATION OF THE GRADIENTS



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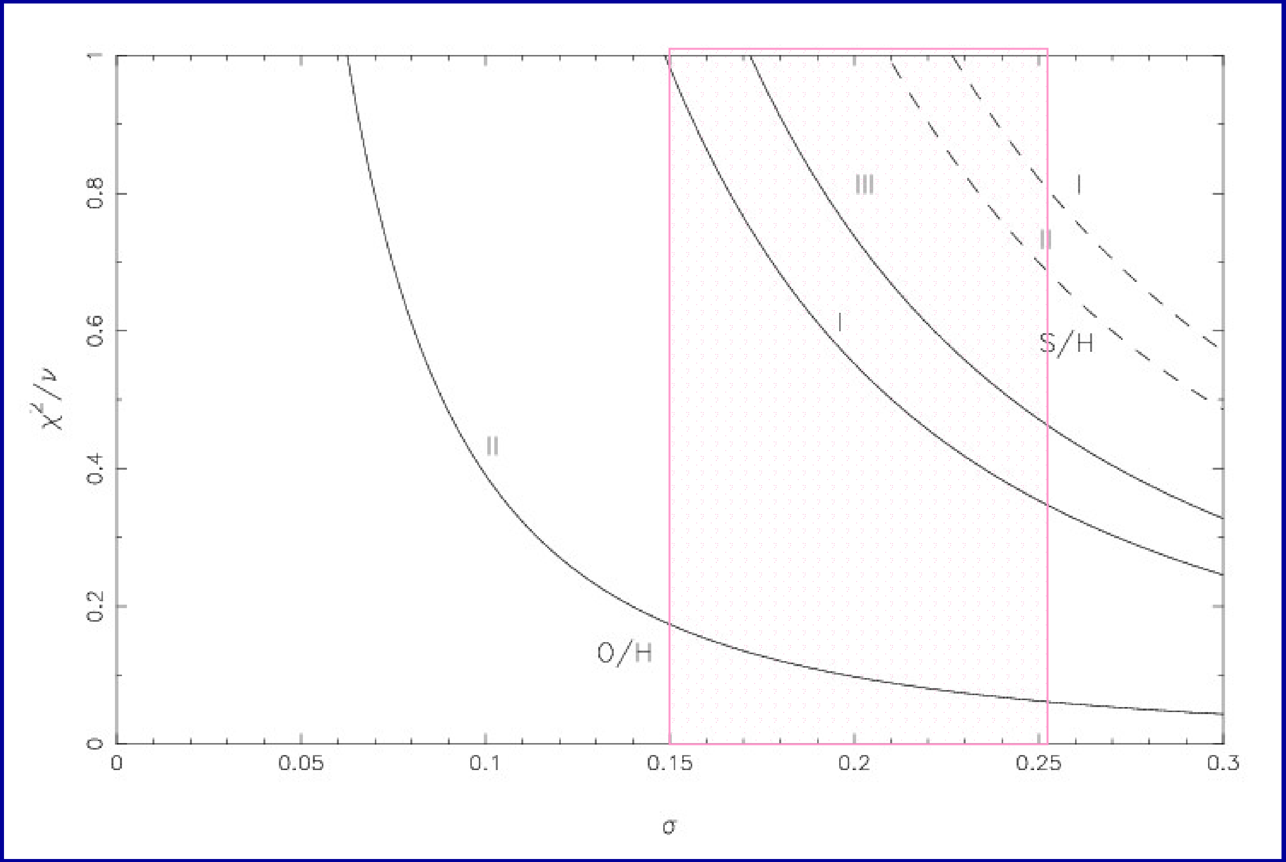
Discussion of the uncertainties

- Abundance uncertainties
- Distance uncertainties
- Age uncertainties
- Statistical fits

PROBABILITY THAT THE DATA SAMPLE REPRESENTS A UNCORRELATED POPULATION

	Group	$\vert r \vert$	n	$P(r,n)$
O/H – PN	I	0.64	66	<0.001
	II	0.94	99	<0.001
	III	0.75	69	<0.001
S/H – PN	I	0.66	44	<0.001
	II	0.76	72	<0.001
OC – Friel	I	0.33	15	0.230
	II	0.77	14	0.001
	III	0.73	10	0.017
OC – Chen	I	0.22	80	0.051
	II	0.69	18	0.002
	III	0.71	20	<0.001
Cepheids		0.82	127	<0.001

CHI–SQUARE TEST: LINEAR CORRELATION



CHI–SQUARE TEST: LINEAR CORRELATION X AVERAGE DISTRIBUTION

	Group	χ^2_ν average	$P(\chi^2,\nu)$ average	χ^2_ν linear	$P(\chi^2,\nu)$ linear
O/H – PN	I	1.69	0.06	0.98–0.55	0.52–1.00
	II	1.15	0.33	0.17–0.10	1.00–1.00
	III	1.26	0.23	1.31–0.74	0.05–1.00
S/H – PN	I	2.09	0.01	1.28–0.82	0.10–0.79
	II	0.98	0.49	1.09–0.70	0.28–0.97
OC – Friel	I	0.17	0.96	0.20–0.13	1.00–1.00
	II	0.67	0.68	0.29–0.18	0.99–1.00
	III	1.28	0.27	0.50–0.32	0.85–0.96
OC – Chen	I	3.82	0.00	0.56–0.36	1.00–1.00
	II	0.33	0.97	0.60–0.38	0.89–0.99
	III	0.84	0.62	1.26–0.80	0.21–0.70
Cepheids		1.96	0.04	0.60–0.27	1.00–1.00

Conclusions

Taking into account all objects, the results suggest that the gradients have been flattening out in the last 8 Gyr approximately by an amount of the order of 0.005 to 0.010 dex kpc^{-1} Gyr^{-1}.

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THE END