Planetary Nebulae as tracers of SMC formation

T.P. Idiart, R.D.D.Costa & W.J. Maciel
IAG/USP – São Paulo Brasil
E-mail: thais@astro.iag.usp.br

A comprehensible trace of formation and chemical enrichment of a given stellar system involves the built of several chemical diagrams describing the evolution of elemental abundances with time. In particular, derived age *versus* abundance diagrams are fundamental to impose constrains and to decrease the number of possible solutions given by chemical evolution models.

In this work we obtain chemical diagrams for the Small Magellanic Cloud (SMC) using planetary nebulae (PNe) data. To do this, high quality PNe data is needed, mainly to derive the properties of PNe progenitors to estimate the formation age of each object. Our first goal was to collect the largest number of measured spectral fluxes for each SMC PNe, in order to derive accurate physical parameters and abundances. Here are presented new spectral data for a sample of SMC PNe obtained between 1999 and 2002. These data are used together with all data available in the literature to improve the accuracy of the fluxes for each PN spectral line.

Finally we present the resulting oxygen versus age diagram, and discuss their implications for SMC formation.

1. THE DATA

❑ Planetary nebulae sample observed between 1999 and 2002

Object	Date	Site	E(B-V)
SMP01	99 Aug 19 02 Set 25	ESO ESO	0.11 0.14
SMP02	99 Aug 19	ESO	0.11
SMP03	99 Aug 19	ESO	0.04
SMP04	99 Aug 20 02 Oct 12	ESO ESO	0.00 0.00
SMP05	99 Jul 18	LNA	0.42
SMP06	99 Jul 18 02 Set 25 02 Oct 13	LNA ESO ESO	0.23 0.28 0.38
SMP07	99 Aug 15	ESO	0.09
SMP08	99 Aug 20 02 Set 27	ESO ESO	0.02 0.34
SMP09	99 Jul 20 99 Dec 28	ESO ESO	0.60 0.58
SMP10	99 Jul 20 02 Set 28	LNA ESO	0.57 0.04
SMP11	99 Jul 20 02 Oct 08	ESO ESO	0.37 0.39
SMP12	99 Aug 16	ESO	0.00
SMP13	99 Dec 26 02 Set 28	ESO ESO	0.03 0.40
SMP14	99 Dec 27	ESO	0.03
SMP15	99 Aug 16 02 Oct 10	ESO ESO	0.16 0.00
SMP16	99 Dec 29	ESO	0.02
SMP17	99 Aug 17	ESO	0.40
SMP18	99 Aug 17 02 Oct 11	ESO ESO	0.17 0.23
SMP19	99 Aug 18	ESO	0.28
SMP20	02 Oct 11	ESO	0.00
SMP21	99 Dec 28	ESO	0.16
SMP22	99 Aug 17	ESO	0.24
SMP23	99 Aug 20	ESO	0.00
SMP24	02 Oct 10	ESO	0.02
SMP25	99 Dec 28	ESO	0.00
SMP27	02 Set 27	ESO	0.00
SMP28	02 Oct 10	ESO	0.00
MG 2	02 Oct 10	ESO	1.95
MG 3	02 Oct 11	ESO	0.10
MG 5	02 Oct 12	ESO	0.00
MG 13	02 Set 27	ESO	0.24
N9	99 Aug 15	ESO	0.15

❑ Measured spectral line fluxes

Hβ λ4861	Hα λ6563

CIII] λλ1907+09	⇨ (IUE data)			
[OII] λλ3727+29	[NeIII] λ3869	[NeIII] λ3968	[OIII] λ4363	He I λ4471
He II λ4686	[OIII] λ4959	[OIII] λ5007	He II λ5412	[NII] λ5754
He I λ5876	[SIII] λ6312	[NII] λ6548	[NII] λ6584	He I λ6678
[SII] λ6717	[SII] λ6731	[ArV] λ7005	[ArIII] λ7135	[OII] λλ7320+30

Additional data from:

Webster (1976)
Osmer (1976)
Dufour & Killen (1977)
Aller et al. (1981)
Monk, Barlow & Clegg (1988)
Boroson & Liebert (1989)
Meatheringham & Dopita (1991a)(1991b)
Vassiliadis et al. (1992)
Meyssonnier (1995)
Leisy & Dennefeld (1996)
Costa et al. (2000)

2. DETERMINATION OF AGE-ABUNDANCE RELATIONS

Age derivation for PNe
1) Effective temperature (T_{eff}) → **of each PN central star**
2) Luminosity ($L/L_{\odot}$) → **of each PN central star**
3) The bulk of heavy elements present in each PN (Z)

⇓

Progenitor mass derived from theoretical isochrones = AGE DETERMINATION

Parameters for T_{eff} derivation :
He II (λ4686)/Hβ ratios
Kaler & Jacoby 1989 ApJ, 345, 871
or
[O III] (λ5007)/ Hβ ratios
Kaler & Jacoby 1991 ApJ, 382, 134

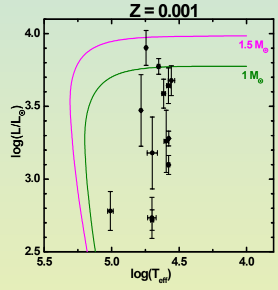
$L/L_{\odot}$ derivation :
Observed V magnitudes estimated using
Kaler & Jacoby 1989 ApJ, 345, 871
Parameters for V estimate :
1) Hβ absolute flux data from
Wood et al. 1987 ApJ 320, 178
Meatheringham et al. 1988 ApJ 329, 166
2) Previously derived T_{eff}
3) Extintion data from
the same references in section 1

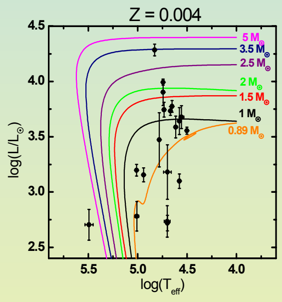
Parameters for V to $L/L_{\odot}$ transformation:
1)Bolometric corrections from
Maciel (private comunication)
2) SMC distance = 57.5 kpc from
Feast and Walker 1987 A.R.A&A 25, 345

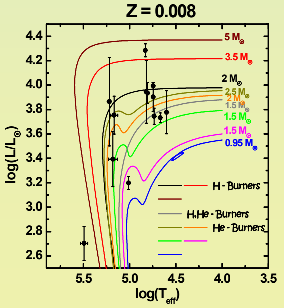
Elemental Abundances for Z estimate:
Oxigen, Nitrogen, Sulphur
Carbon, Neon, Argon

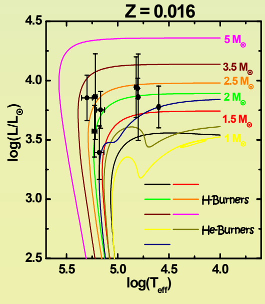
3 . RESULTS FOR INITIAL MASSES OF PNe PROGENITOR

❑ Theoretical tracks from Vassiladis & Wood 1993 ApJ 413, 641



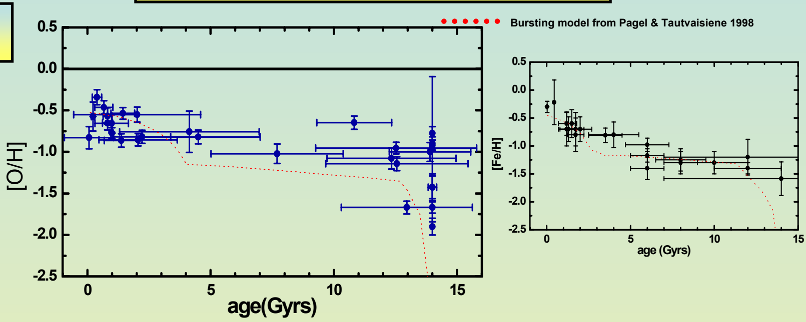






4 . THE ABUNDANCE × AGE DIAGRAMS

THE OXYGEN ABUNDANCE EVOLUTION



The oxygen-age diagram for SMC PNe shows a behavior compatible with bursting models (Pagel & Tautvaisiene MNRAS 1998, 299,535) where the star formation rate seems to rise at an age of 2 to 4 Gyrs. The iron-age diagram build from globular cluster data presents an apparently similar trend. It can be noticed that the model does not fit the [O/H] data for older age objects. Another solutions from Pagel & Tautvaisiene's models must be considered in this case, to ajust the [O/H] and [Fe/H] data.

For the age interval from 6 to12 Gyrs, the mean [O/Fe] ratio is 0.2 dex, indicating a larger influence of type II supernovae in the enrichment of SMC interstelar medium (IM) at these epochs. The burst of star formation at younger ages (≤ 5Gyrs) seems to be coincident with the beginning of type Ia supernovae influence in IM enrichment.

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