Central stars of PNe in the Magellanic Clouds

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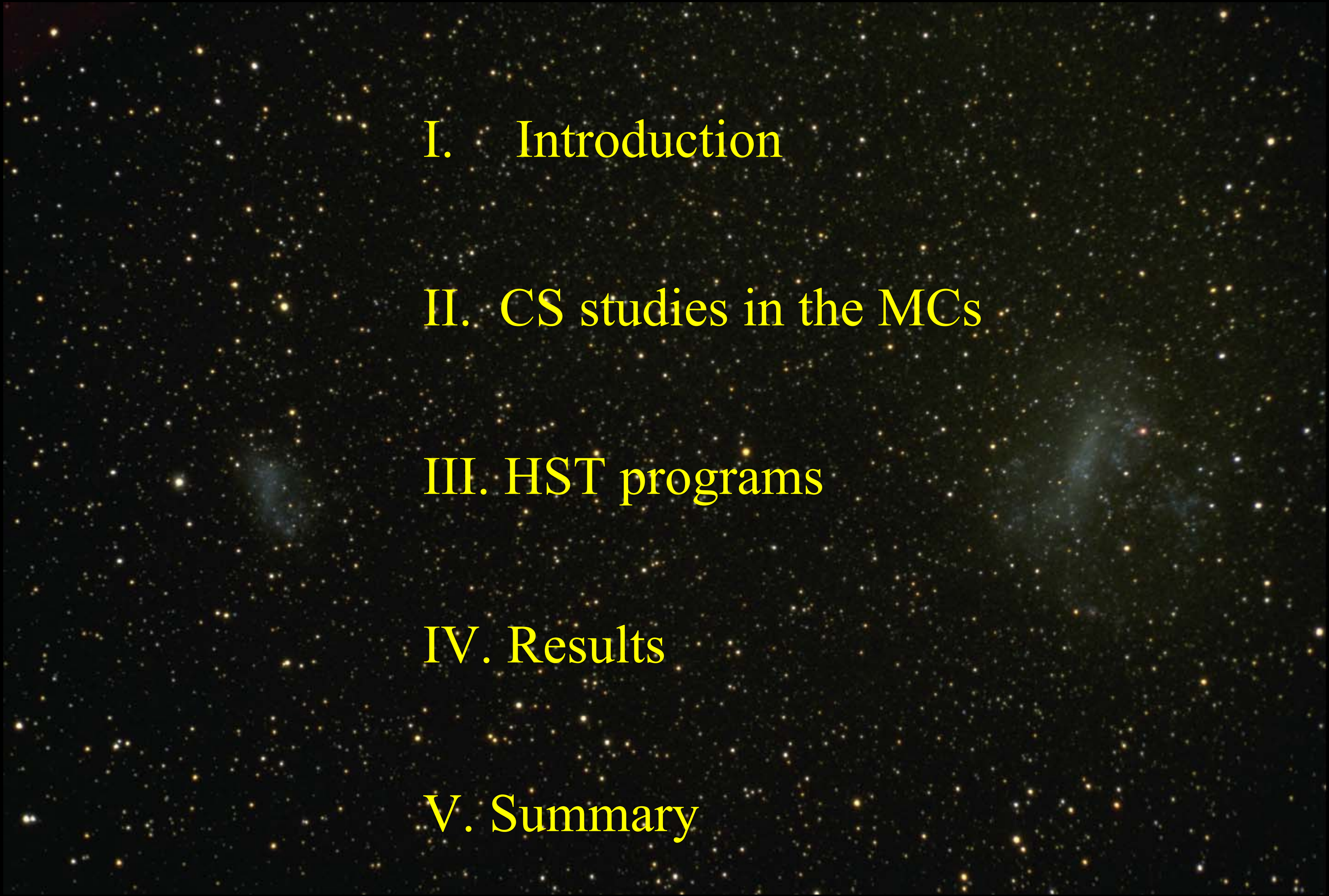

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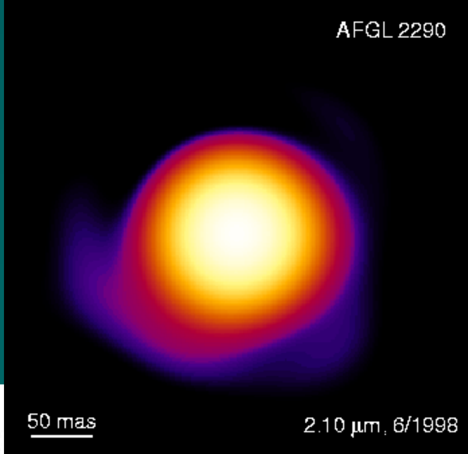
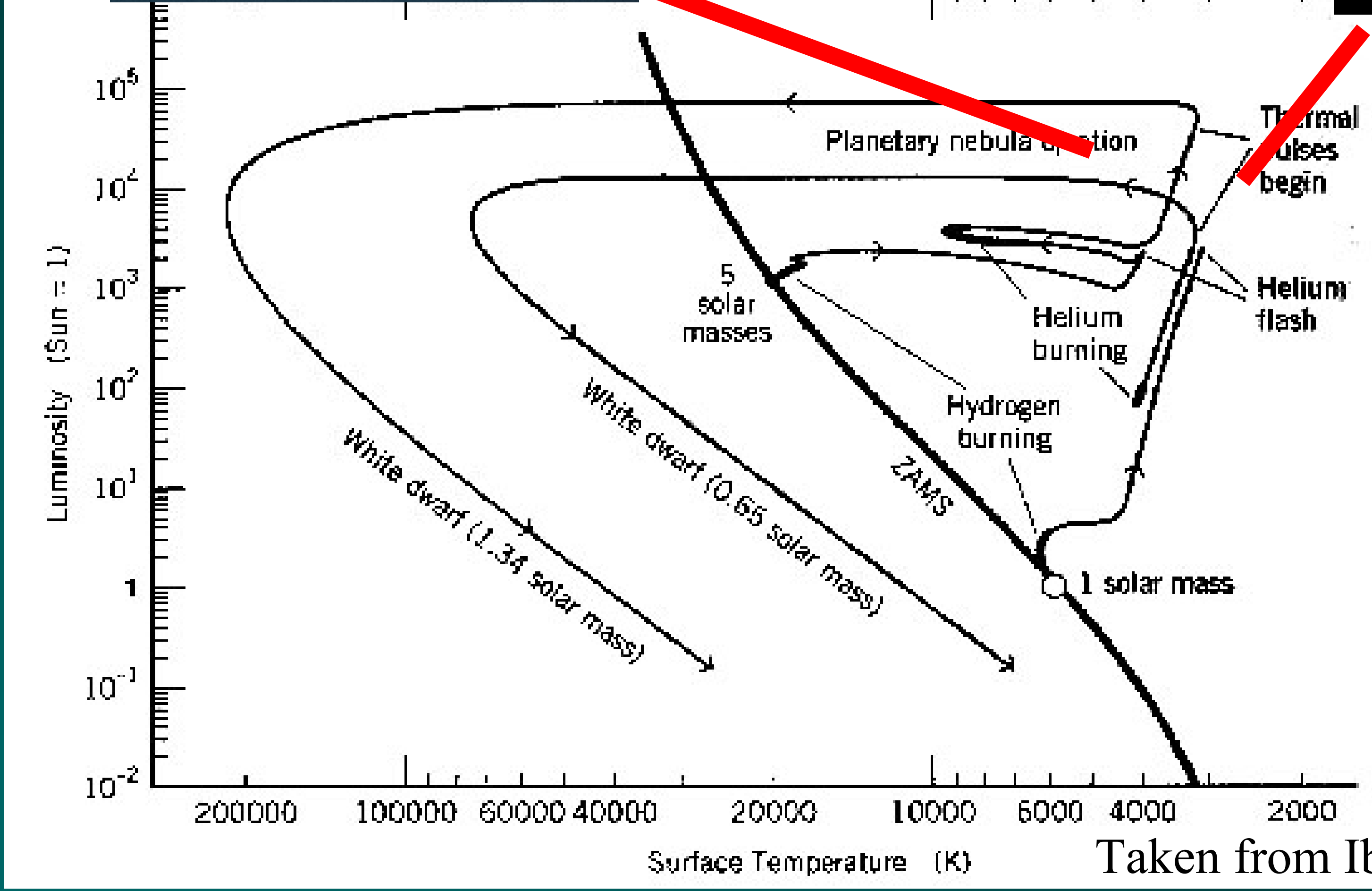


AGB star
Gauger etal.98



Taken from Iben

- The CS mass depends on the initial mass and on the mass-loss during the AGB phase (Vassiliadis & Wood 1993; Blocker 1995; Herwing 2000).
- Mass-loss during the AGB is poorly understood

Decrease in Metallicity

↓

Reduce in Mass-loss

a. Affects dust formation (Winters et al. 2000)

b. In the absence of dust the star has a smaller R for a given mass and Luminosity (Willson et al. 1996; Willson 2000).

White dwarfs are observed to posses a very narrow mass distribution that peaks at 0.57 M (Bergeron et al. 1992; Finley et al. 1997). CSs of PNe mass in the Galaxy peak around the same value.

Initial-to final mass relation is expected to change with the metallicity (Weidemann 1987). A lower metallicity implies:

- A higher fraction of MS stars will reach the Chandrasekhar mass limit → SNe Type II explosions
- Decrease upper mass limit for white dwarf production (Umeda et al. 1999; Girardi et al. 2000).
- CSs of PNe in the MCs:
  - Probe stellar evolution and mass-loss under different metallicity enviroments.
  - As immediate precursors of the WD population probe the initial- to final-mass relation.

LMC: 50.7 Kpc

- Flattened disk view with an inc. of ~34° (van der Marel & Cioni 2001)
- Metallicity ½ of the Solar Mix (Rusell & Bessell 89; Russel & Dopita 1990)

SMC: 58.29 Kpc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- Line of sight depth between 6 –12 Kpc (Crowl et al 2001)
- Metallicity 1/4 of the Solar Mix (Rusell & Bessell 89; Russel & Dopita 1990)

- Ground-based estudies CS parameters inferred from the nebular spectra:
  - Aller et al. (1987)
  - Dopita & Meatheringham (1990, 1991ab)
  - Jacoby & Kaler (1993)
  - Kaler & Jacoby (1990, 1991)
  - Metheringham & Dopita (1991ab);
  - Monk, Barlow & Clegg (1988)
  - Peña & Ruiz (1988)
  - Vassiliadis, Dopita & Morgan (1992)
- Four CS masses determined in the LMC from direct measurement of the stellar flux:
  - Dopita et al. (1993)
  - Bianchi, Vassiliadis & Dopita (1997)
  - Hamman et al. (2003)
- HST allow the first spatially resolved studies:
  - Dopita et al. (1993, 1996, 1997)
  - Vassiliadis et al. (1998)

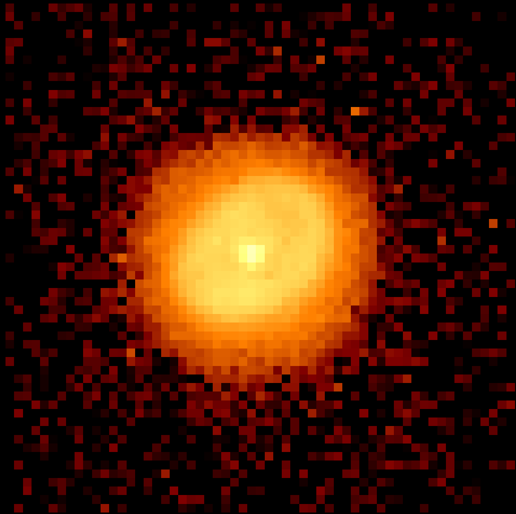
- The distribution of CSs of PNe in the HR diagram is rather uncertain for Galactic PNe. Lack of reliable distances.

- Because LMC PNe are seldom resolved from the ground, most of the mass determinations are highly model dependent; based on CS luminosities derived solely from nebular fluxes.

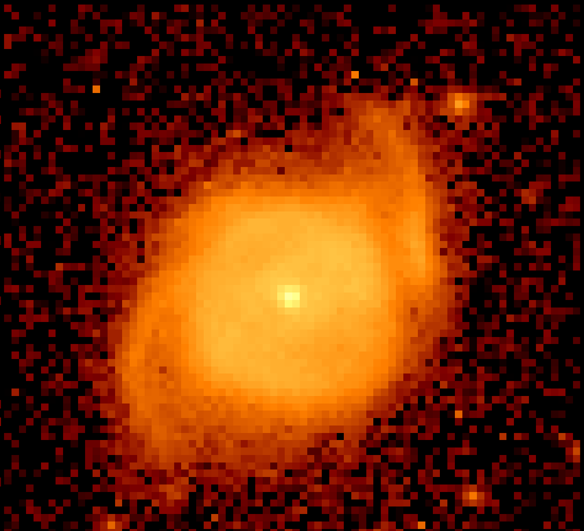
- Previous HST observations mainly through narrow band filters do not allow the CS mass determination.

- Our HST data:
  - – STIS broadband imaging (HST#8271; HST#8663)

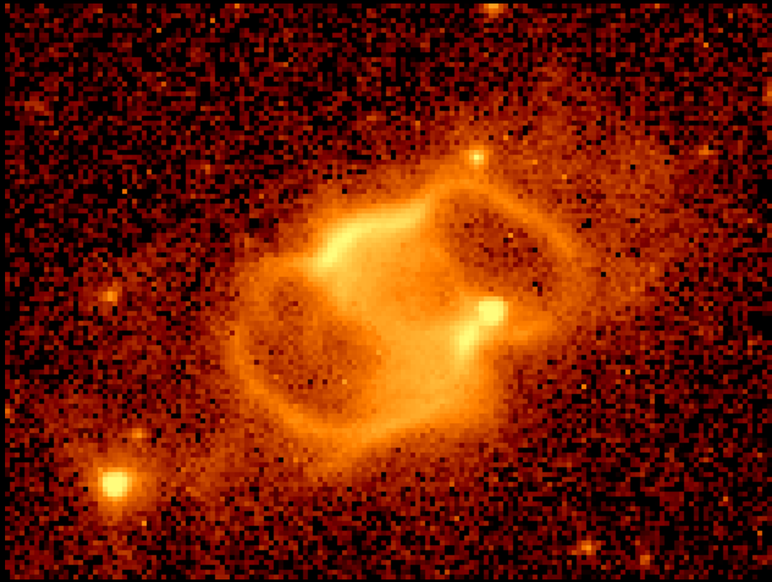
    (λc = 5850Å; Δλ=4410Å)
    - 29 LMC PNs (Shaw et al. 2001; Stanghellini et al. 2002a)
    - 27 SMC PNs (Stanghellini et al. 2003)
  - – WFPC2 (HST#8702) (Stromgren y filter λc =5454Å; Δλ487Å)
    - 13 LMC PNs (7 in comon with HST#8271+6 from HST# 6402 P.I. Dopita with only narrow band images)
- Ground-based data (Hβ, c, and HeII 4686Å fluxes):
    - Jacoby & Kaler (1993); Meatheringham et al. (1988); Meatheringham & Dopita (1991); Vassiliadis et al. (1992); Boronson & Liebert (1989); Monk et al. (1988); Leisy & Dennefeld (1996); Dopita & Meatheringham (1991ab); Shaw et al (2004); Palen et al. (2004).



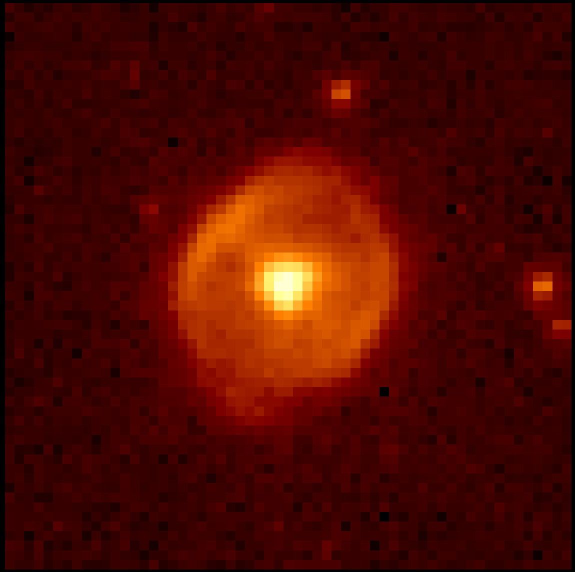
LMC SMP 4



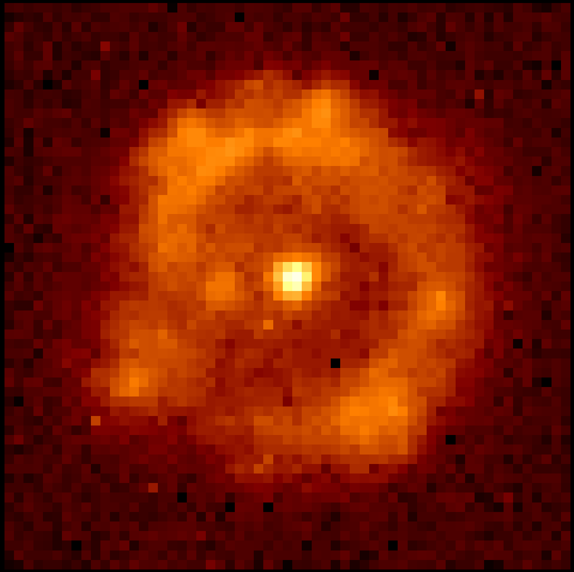
LMC SMP 10



LMC SMP 93



SMC MG 8

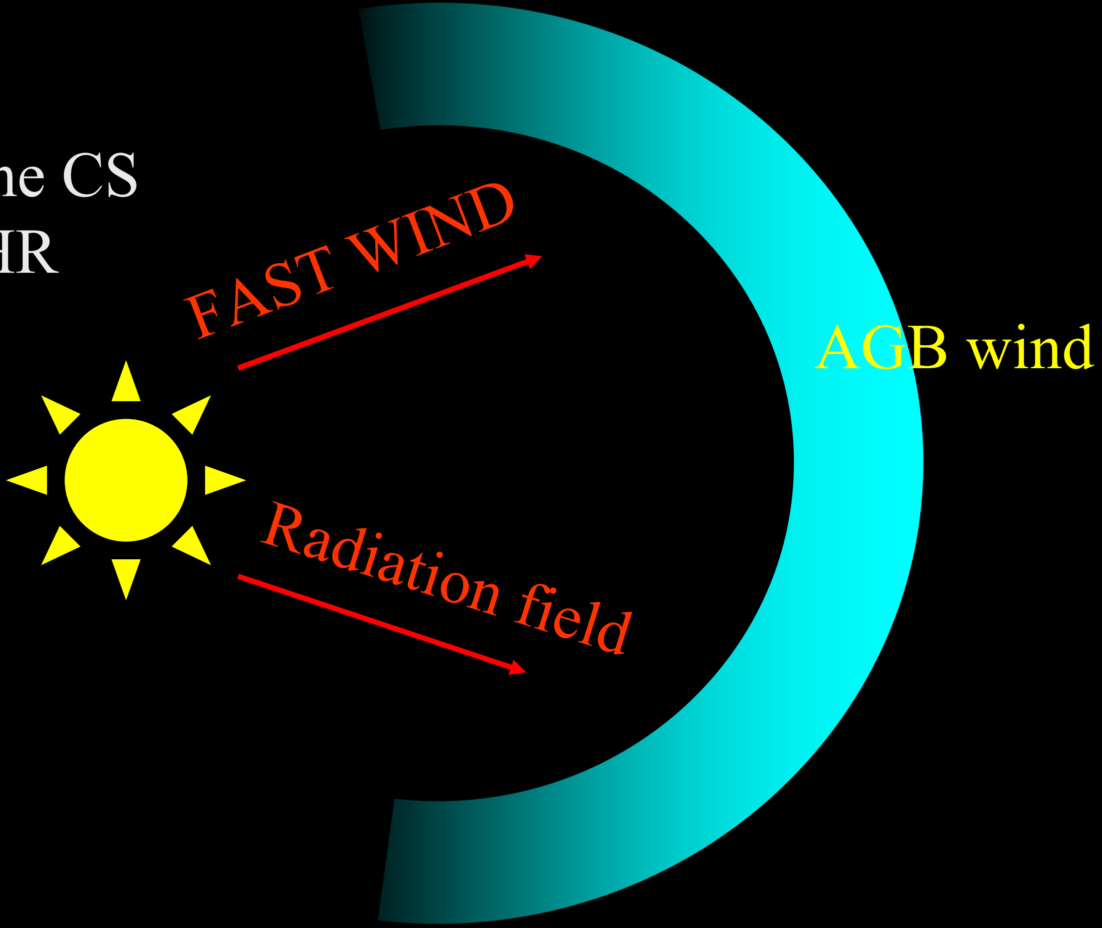


SMC MG 13

The method:

- The HST resolution allows us to apply aperture photometry techniques to determine the stellar flux.
- Extinction correction we used the nebular balmer decrement.
- We use Synphot to convert the STIS mag to standard V mag.
- The CS temperature through Zanstra method.
- Bolometric Corrections from Vacca et al. (1996)
- We estimated the error introduced in the derivation of the luminosity due to the distance variation caused by the depth of the galaxies.

Gas evolution
Determined by the CS
Position on the HR
diagram.



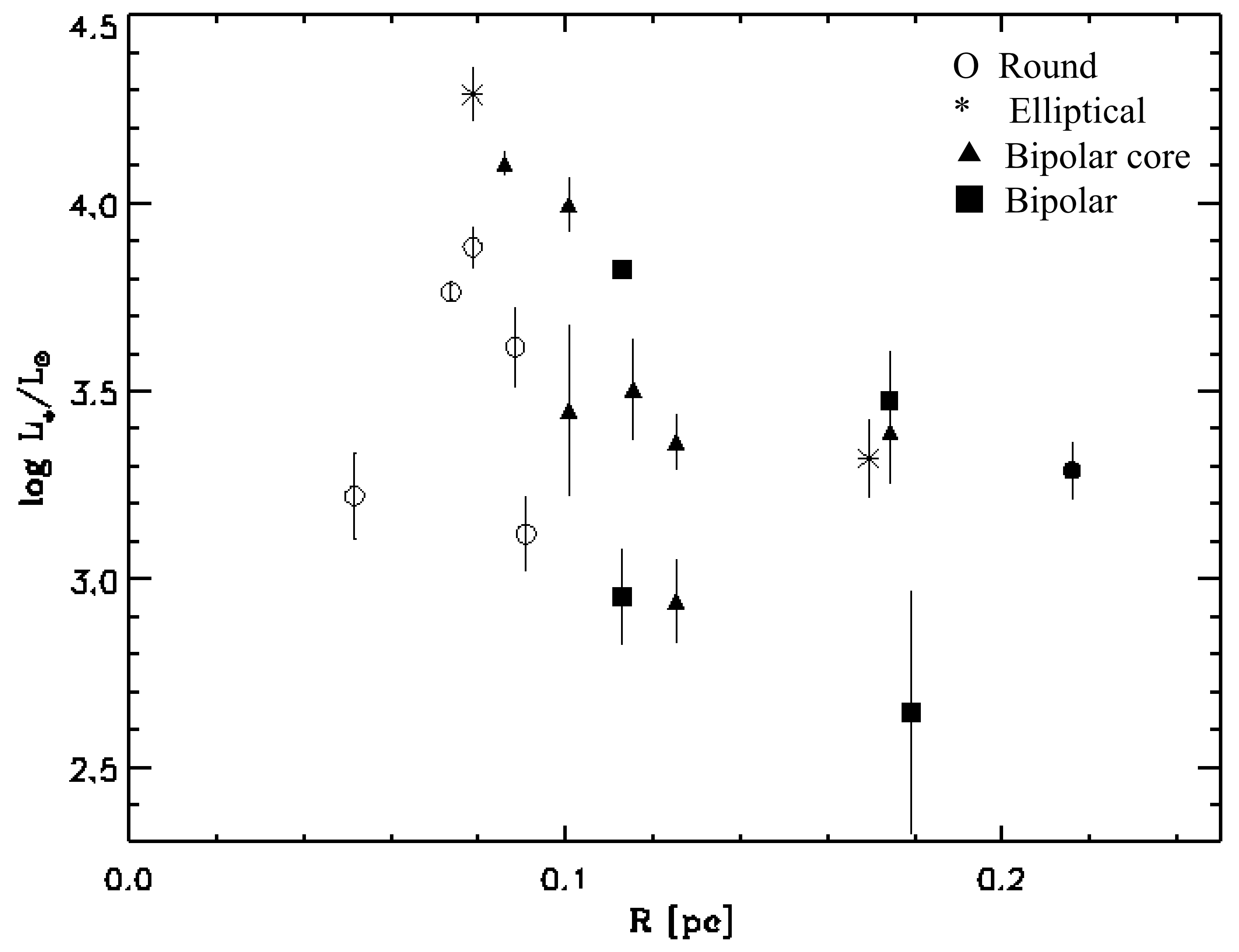
Wind driven by radiation pressure on resonance lines (Pauldrach et al. 1988):

$$M_{LR} \alpha M^{-1/2} L^{5/4} T_{eff}^{-0.85}$$

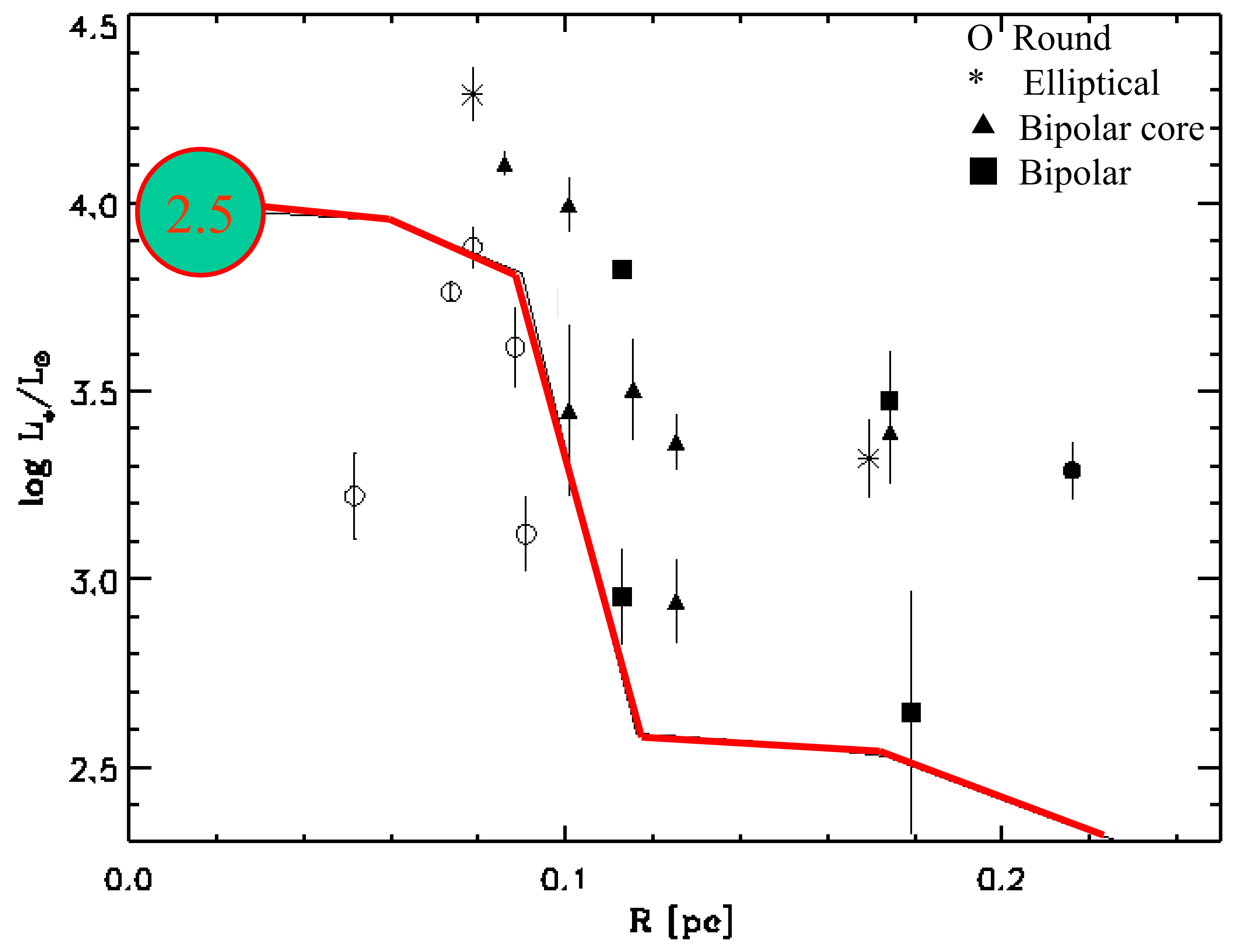
$$v_{\propto} \alpha M^{1/2} L^{-1/4} T_{eff}^{1.52}$$

Number of Ionizing photons:

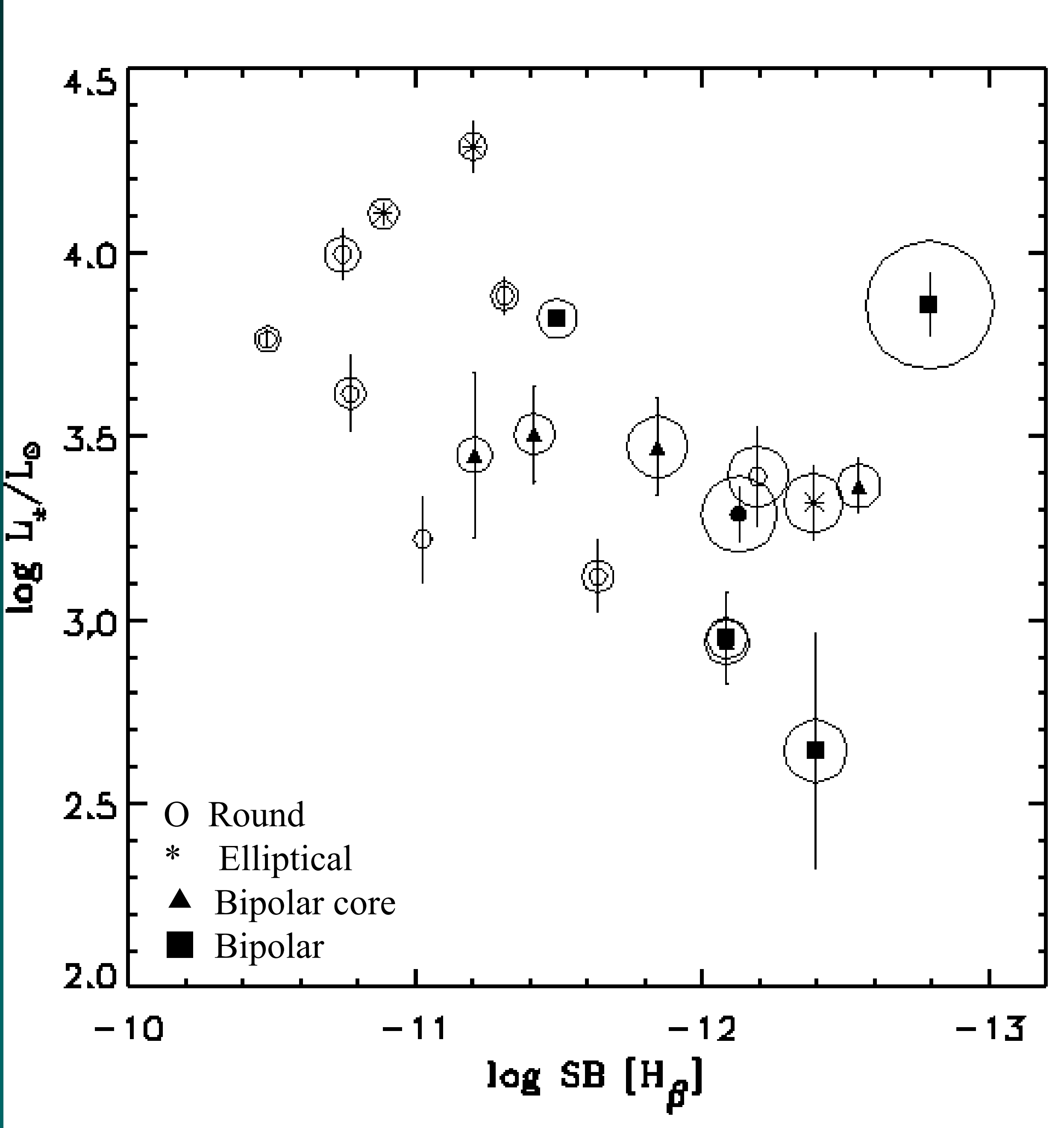
$$Q_o \alpha L \; T_{eff}^{-1} \int f(T_{eff})$$



Villaver, Stanghellini & Shaw, 2003, ApJ, 597, 298

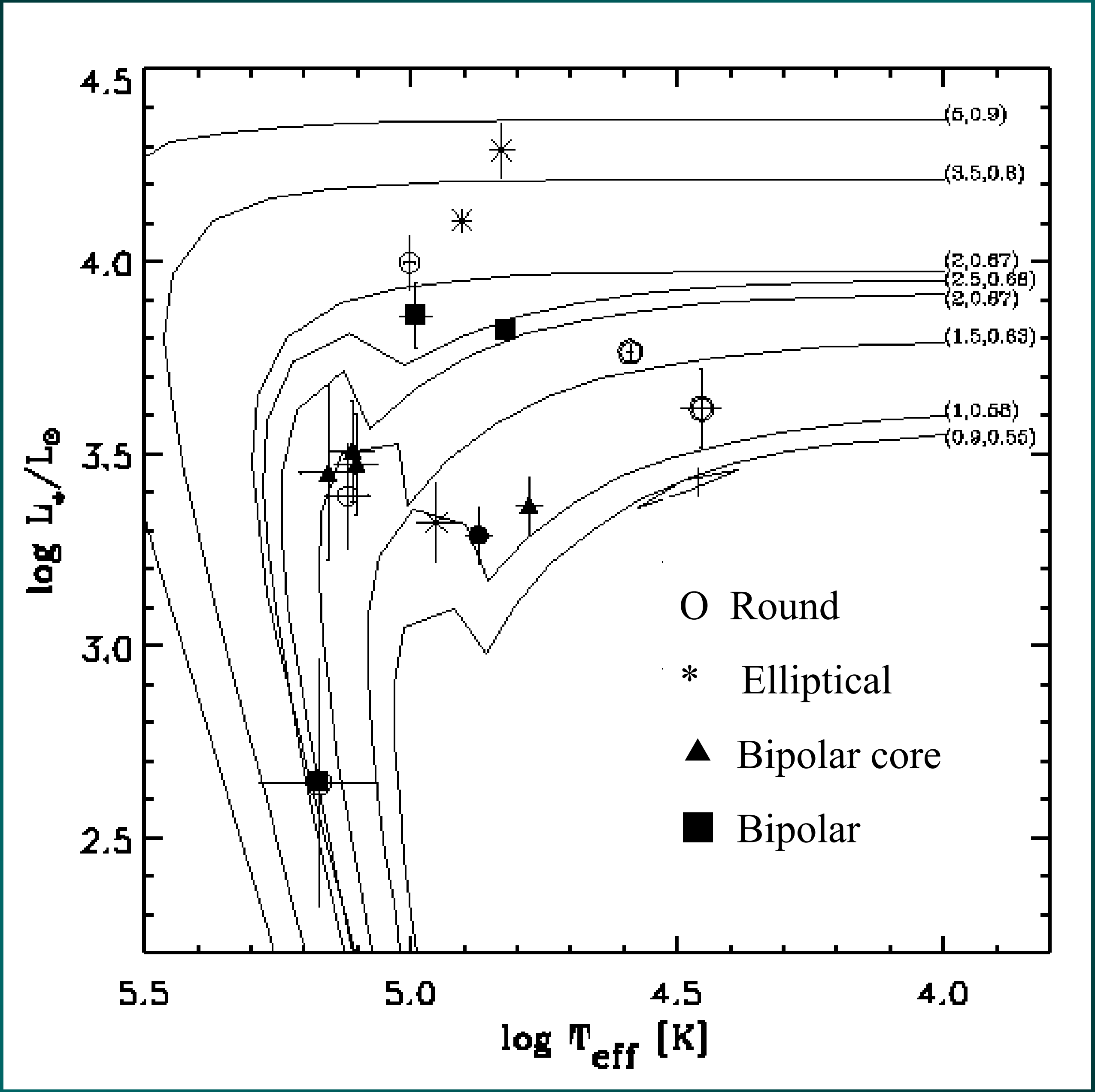


Villaver, Stanghellini & Shaw, 2003, ApJ, 597, 298
Models from Villaver, Manchado, & García-Segura 2002, ApJ, 581, 1204



Villaver, Stanghellini & Shaw, 2003, ApJ, 597, 298

LMC



Tracks from Vassiliadis & Wood 1994 for LMC metallicity

Villaver, Stanghellini & Shaw, 2003, ApJ, 597, 298

Light contamination due to a stellar companion

PN SMC	%	V	Sp *	M (M_{Θ})	V	T_{eff} $(10^3 K)$	Log L/L_{Θ}	Mc (M_{Θ})	Mi*** (M_{Θ})
SMP 1	50	17.55	B3	7.6	17.75	33.2	3.64	0.59	1
	90	16.92	B3	7.6	19.44	48.9	3.42	0.56	0.89
	95	16.89	B3	7.6	19.70	52.4	3.40	0.56	0.89
SMP 20	50	20.57	A4	2.3	21.17	114.5	3.74	0.64	1.5
	90	19.93	A3	2.3	22.89	236.4	3.91	0.69	2.5
	95	19.87	A3	2.3	23.64	331.0	4.01	0.86	3.5

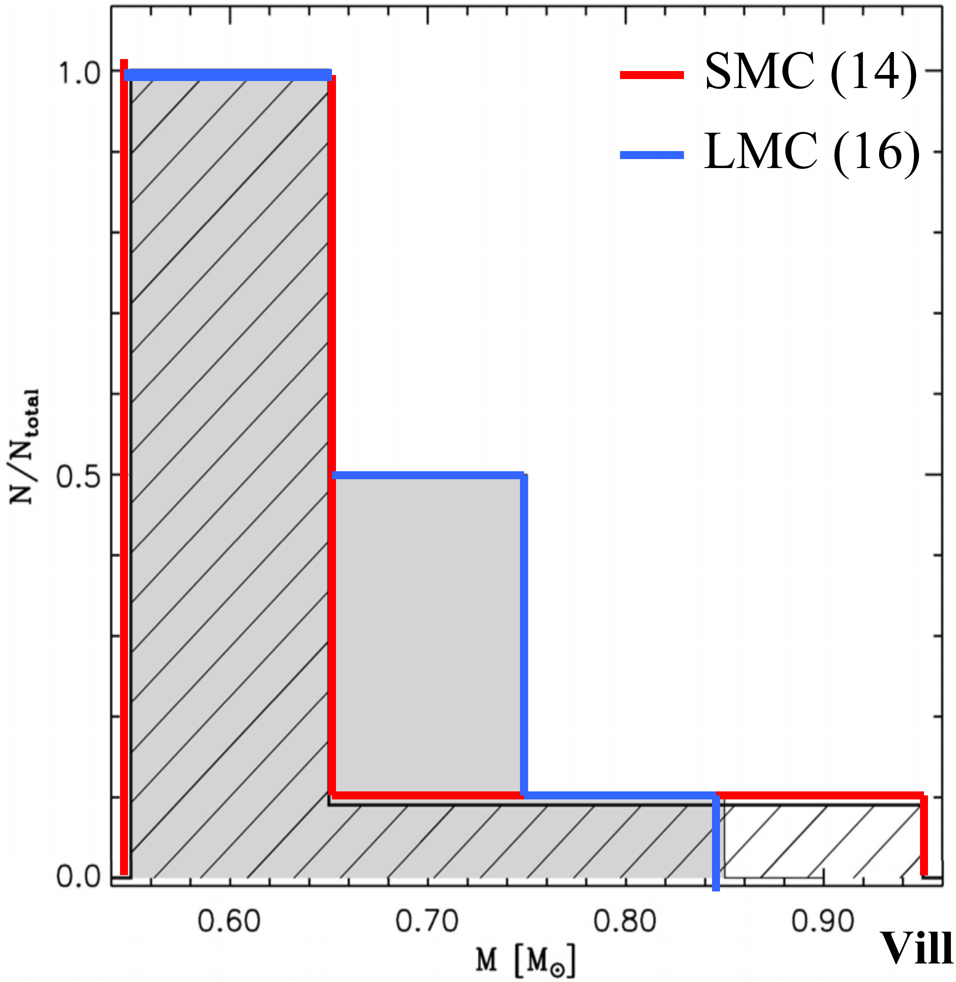
*From Cox (2000) **Assuming a MS companion *** From Vassiliadis & Wood (1994)

SMP 20: EC derived for the nebula is inconsistent with the CS Teff

Villaver, Stanghellini & Shaw, 2004, ApJ, Submitted

Comparison of the LMC and SMC CS masses:

-Similar sizes sample
-CS detection rate



K-S test gives a P = 0.12. P = 1 implies that two distributions are identical.

Mass	MEAN	MEDIAN
SMC	0.63	0.59
LMC	0.65	0.63

Villaver, Stanghellini & Shaw 2004, ApJ, Sub

- We find a difference in the mass distribution of the LMC and SMC CSs:
  - The SMC PN population hosts slightly lower mass CSs compared to the LMC.
- If we assume the same initial mass distributions in the two galaxies we would expect to find the opposite due to the reduced mass-loss rated expected in a lower metallicity environment. IMF do not change with Z (Salpeter 1995; Scalo 1998).
- Well establish that the star formation history of the LMC and SMC are different (Olszewski, Suntzeff & Mateo 1996).
- Can the star formation history explain the mass distributions observed?
  - LMC Experience a burst of star formation 3-5 Gyr ago (Bertelli et al. 1992)
  - SMC Constant star formation over the last 2-12 Gyr (Dolphin et al. 2001)

  Stars with ages between 8 to 3 10^8 yr are abundant in the LMC but are missing in the SMC

- Dopita, Lawrence, Ford & Webster (1985) found that the kinematics of the SMC PNe is that of a spheroidal population without rotation. Studies of carbon stars (Hardy et al., 1989, Hatzidimitriou et al. 1997) affords a similar scenario. SMC PNe are kinematically old.
- From Vassiliadis & Wood (1994) initial-to final-mass relation, the peak of the SMC mass distribution is ~1.5 M translate into an age of ~3 Gyr.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The most massive CSs in the SMC (lower limit to the age of the SMC PNe population ~10^8 yr) are located where Dopita et al. (1985) found the kinematically younger PN population to be concentrated. Crowl et al. (2001) contain younger and more metal rich clusters. Our estimated ages are consistent with other studies of low- and intermediate mass populations.

Summary:

- We have determined the CS parameters for two samples of CSs in the LMC and SMC. HST resolution allows to directly measured the stellar continuum removing the dependency of photoionization models in the determination of the stellar flux. Teff still subject to uncertainty but we mostly use HeII Zanstra.
- We propose the LMC and SMC PNe as excellent probes to study the gasdynamic processes and wind injection rates. Ideal to constrain wind-driven mechanism during the post-AGB phase.
- We suggest differences in the star formation histories between the SMC and LMC as a plausible explanation for the observed mass distribution. Mass-loss rate dependency with Z alone cannot account for the observations.