

# Synthetic AGB evolution

Martin Groenewegen

groen@ster.kuleuven.ac.be

K.U.Leuven

Paola Marigo

marigo@pleiadi.pd.astro.it

Padua

# Synthetic AGB evolution: outline

- Why ?
- History
- Synthetic AGB evolution
  - Key relations
  - Population synthesis
  - Observational constraints
- Future directions

# Why ?

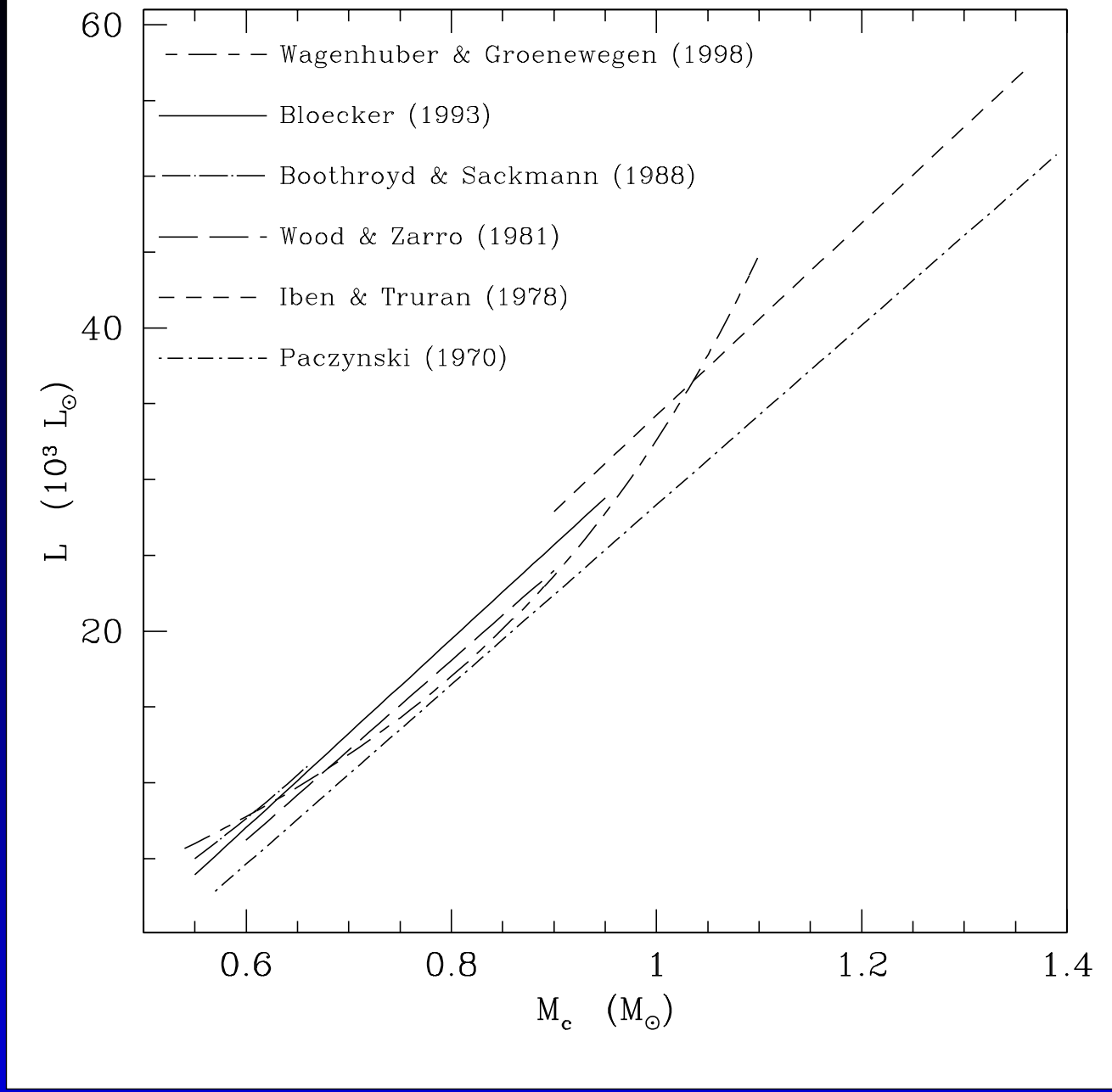
- Computationally fast
- Flexibility
- Population synthesis
- **RETURN:**
  - Insight in dredge-up efficiency and mass loss
  - “Stellar Yields”  
for Galaxy Chemical Evolution Models

# History

- Iben & Truran (1978), Iben & Renzini (1983)  
“uncalibrated”, massive st.evol. models
- Bedijn (1988), Bryan, Volk & Kwok (1990)
- Groenewegen, de Jong, van den Hoek, Wagenhuber (1993-1998)  
“calibrated”, all st.evol. models, luminosity dip, metallicity, first pulses
- Marigo, Girardi, Chiosi, Bressan (1996-2003)  
idem; emphasis on nucleosynthesis

# Key features

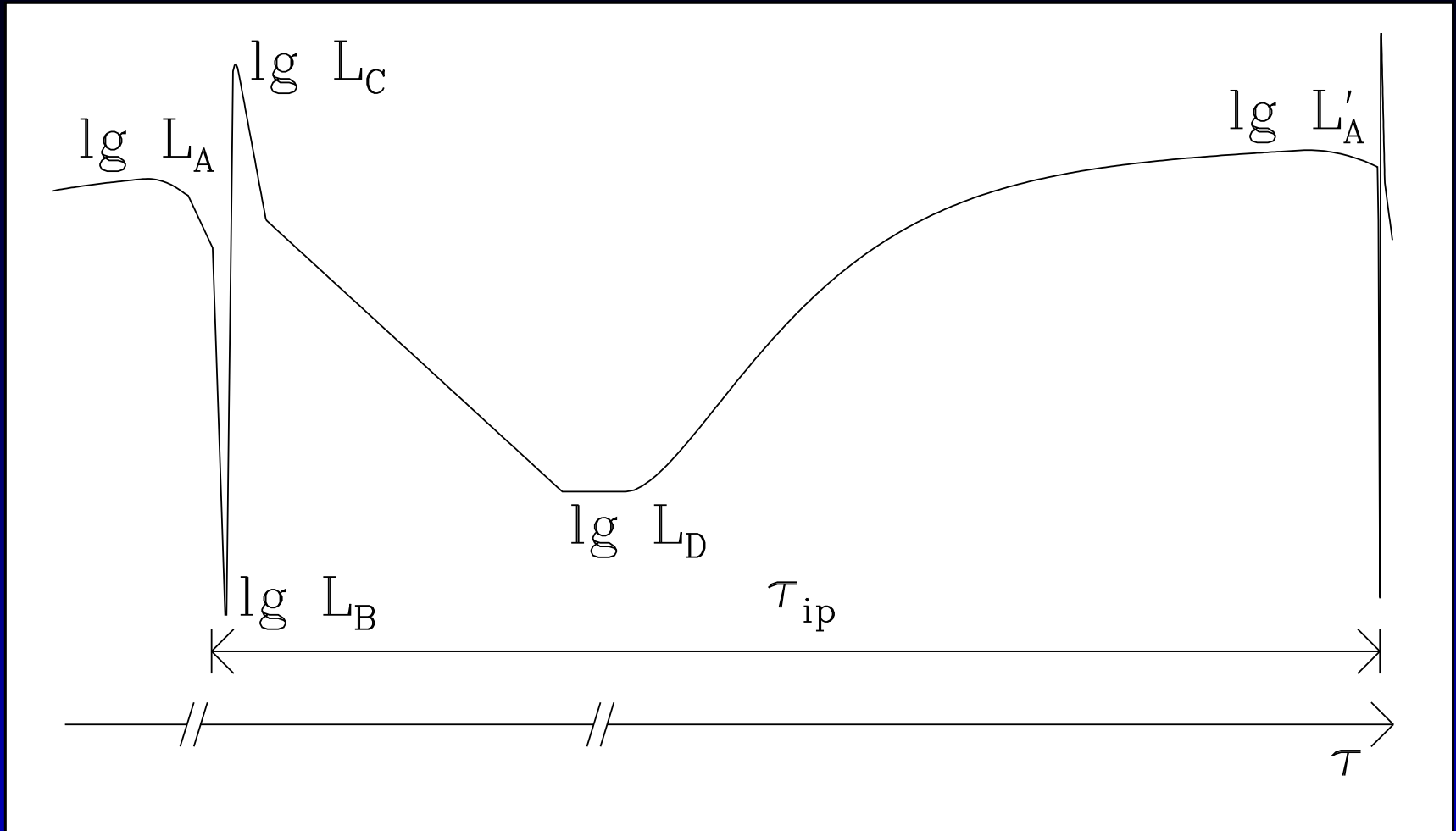
- Core Mass - Luminosity relation
- Core Mass - Interpulse time relation
- “Luminosity dip”
- Description of dredge-up:  $M_c^{\min}$ ,  $\lambda$ , composition,  $T_b^{\text{dred}}$
- Description of mass-loss
- $\frac{dM_c}{dt} = \frac{q}{X} L_H$



## Core Mass - Luminosity relation

# Key features

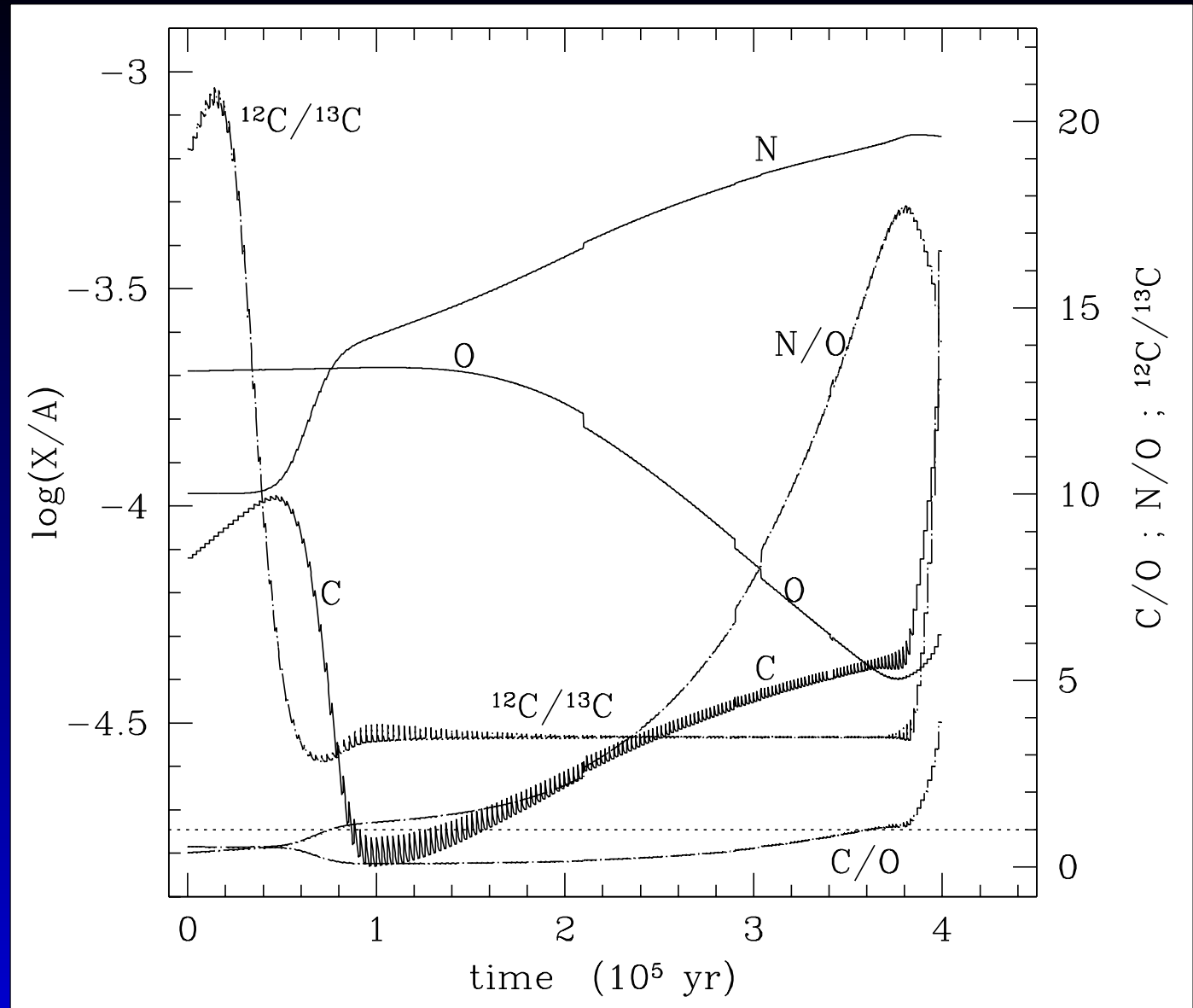
- Core Mass - Luminosity relation
- Core Mass - Interpulse time relation
- “Luminosity dip”
- Description of dredge-up:  $M_c^{\min}$ ,  $\lambda$ , composition,  $T_b^{\text{dred}}$
- Description of mass-loss
- $\frac{dM_c}{dt} = \frac{q}{X} L_H$



The thermal-pulse cycle  
(Wagenhuber & Groenewegen 1998)

# Key features

- Core Mass - Luminosity relation
- Core Mass - Interpulse time relation
- “Luminosity dip”
- Description of dredge-up:  $M_c^{\min}$ ,  $\lambda$ , composition,  $T_b^{\text{dred}}$
- Description of mass-loss
- $\frac{dM_c}{dt} = \frac{q}{X} L_H$



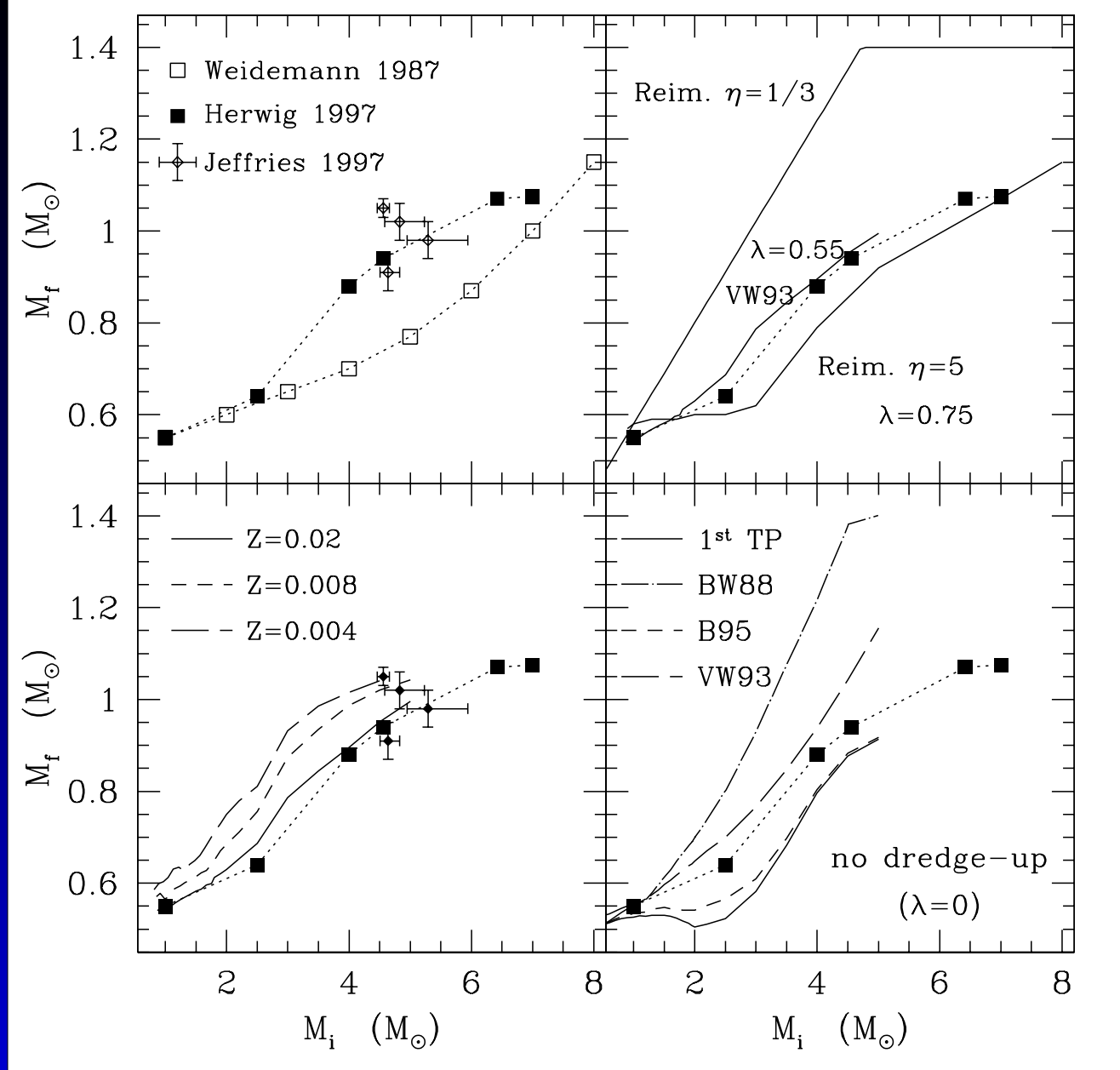
## Chemical evolution (Marigo 1998)

# Population synthesis

- Evolution of one star
- $N(M)dM \sim \phi(M) \psi(T_G - \tau(M, Z)) t_{\text{AGB}}(M, Z)$
- Initial Mass Function,  $\phi(M)$
- Star Formation Rate,  $\psi(t)$
- Age Metallicity Relation, AMR(t)

# Observational constraints

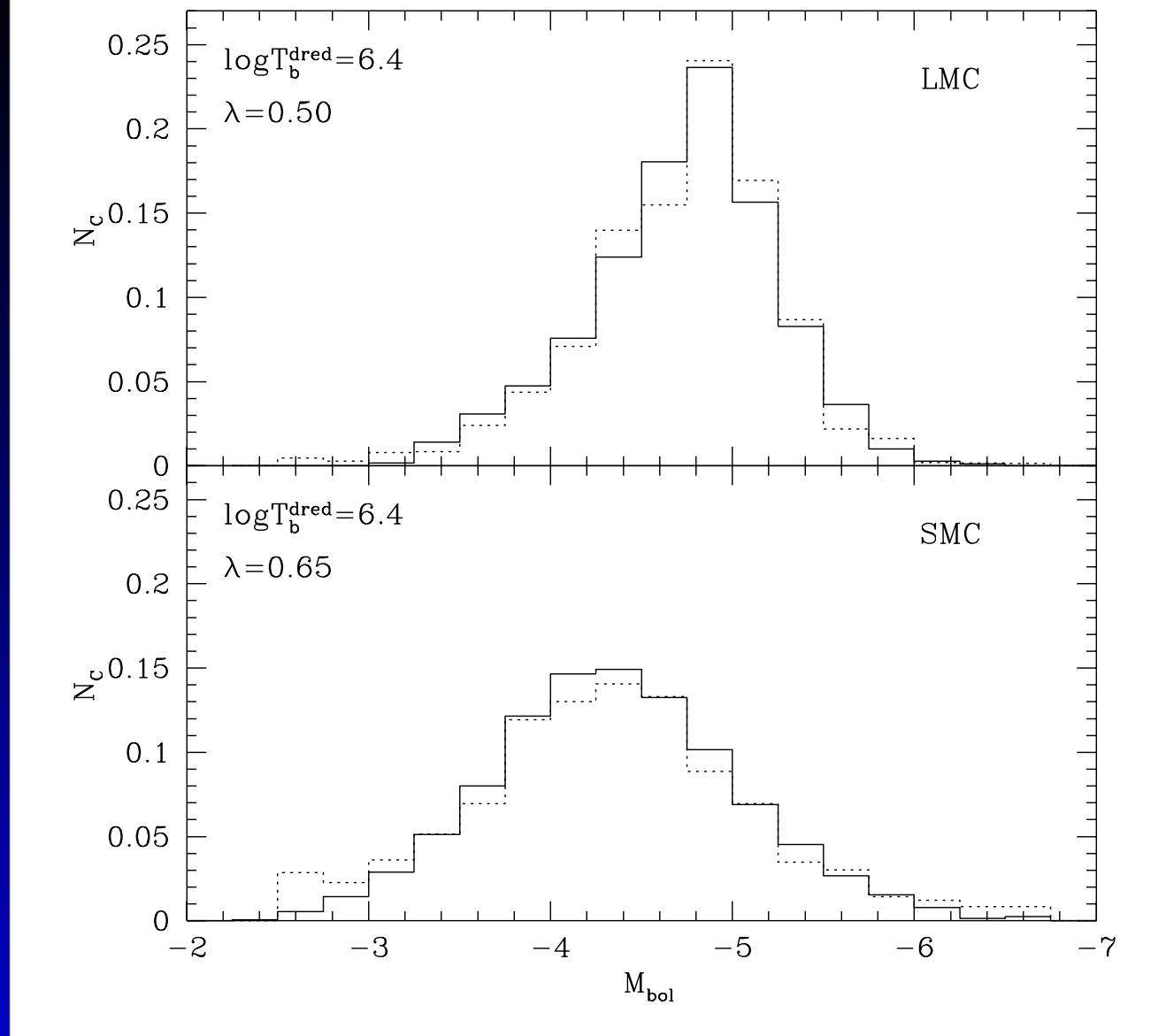
- Initial - Final Mass relation
- Luminosity Function (carbon stars)
- $N_C/N_M$ -ratio
- Abundances of PNe
- Effective Temperatures
- Pulsation Properties



## Initial-Final mass relation

# Observational constraints

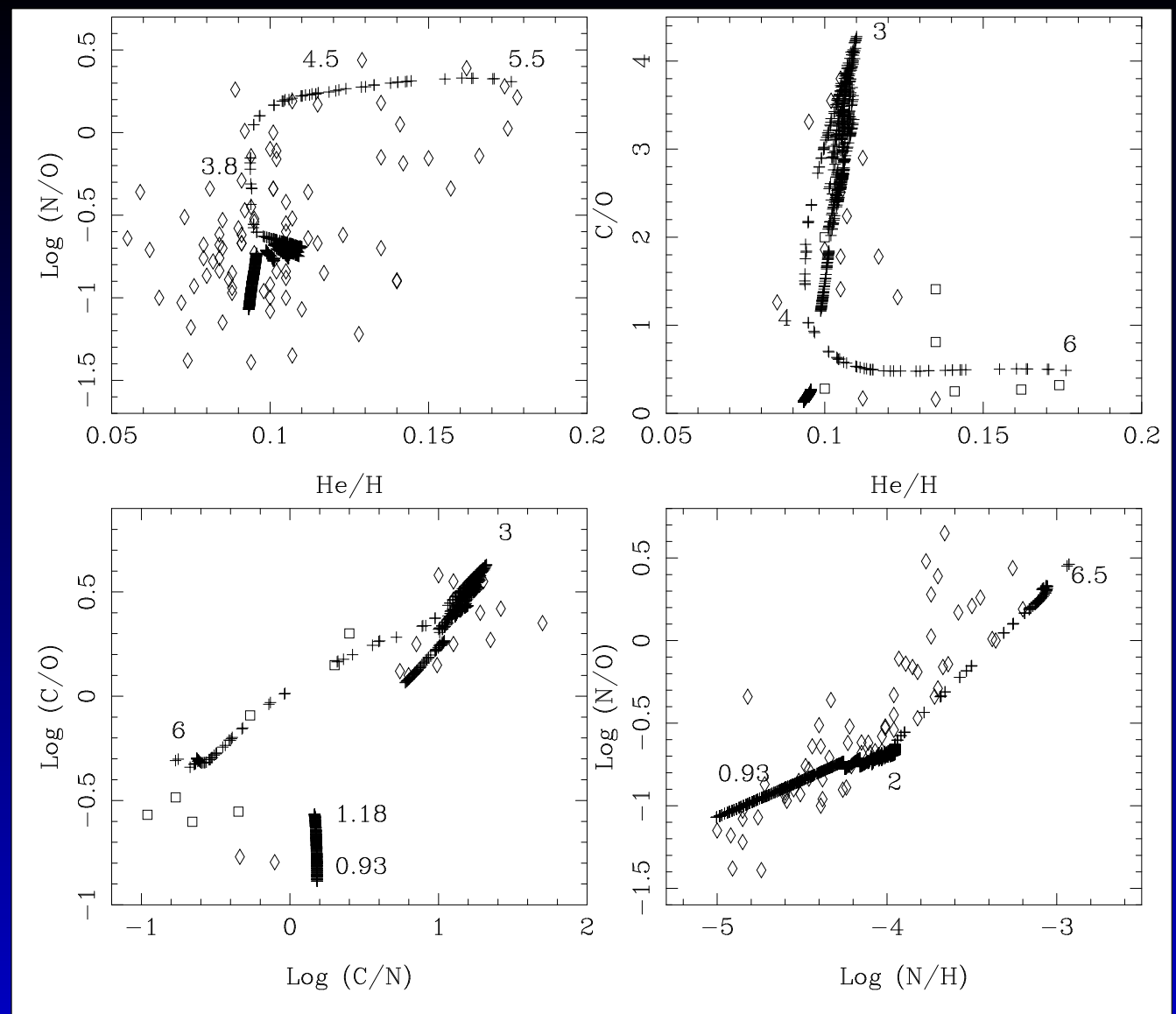
- Initial - Final Mass relation
- Luminosity Function (carbon stars)
- $N_C/N_M$ -ratio
- Abundances of PNe
- Effective Temperatures
- Pulsation Properties



## Carbon star LF (Marigo et al. 1999)

# Observational constraints

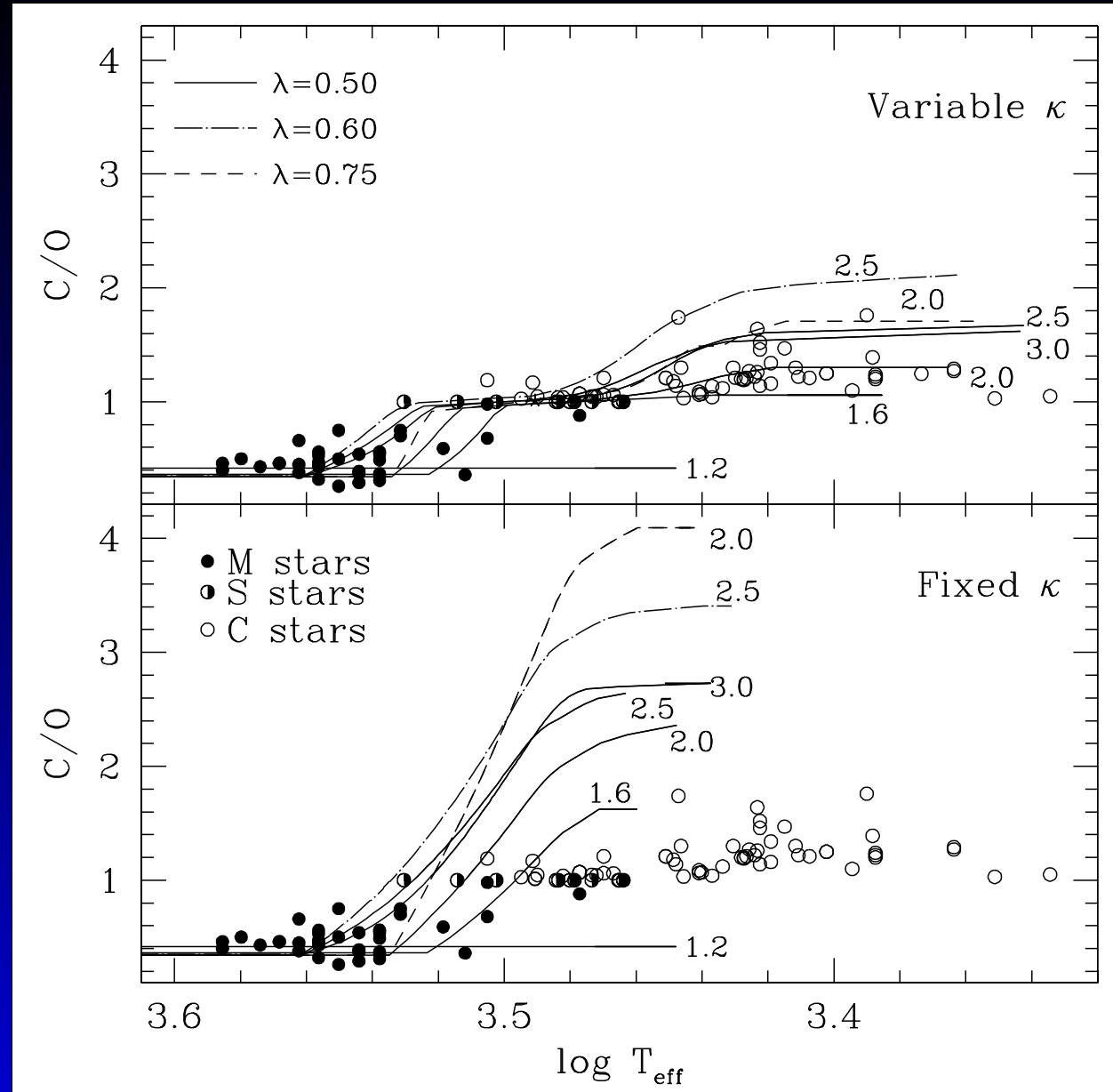
- Initial - Final Mass relation
- Luminosity Function (carbon stars)
- $N_C/N_M$ -ratio
- Abundances of PNe
- Effective Temperatures
- Pulsation Properties



## PNe abundance patterns (Groenewegen 1994)

# Observational constraints

- Initial - Final Mass relation
- Luminosity Function (carbon stars)
- $N_C/N_M$ -ratio
- Abundances of PNe
- Effective Temperatures
- Pulsation Properties



## The effect of opacity (Marigo 2002)

# Future Directions

- Pulsational properties: MACHO, OGLE, EROS.  
Links between SR and Mira?  
Test different hypothesis on evolution.
- Coupling of (full) population synthesis models to radiative transfer models to predict numbers *and* FIR fluxes (Herschel, SIRTf)
- Fit C-star LF and  $N_C/N_M$ -ratio in LG galaxies

THE END