Mass loss of AGB stars and RSGs in the Magellanic Clouds

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Overview Talk

- AGB/RSG in the MCs: IRAS and ISO times
- AGB/RSG: Spitzer era

  -Imaging

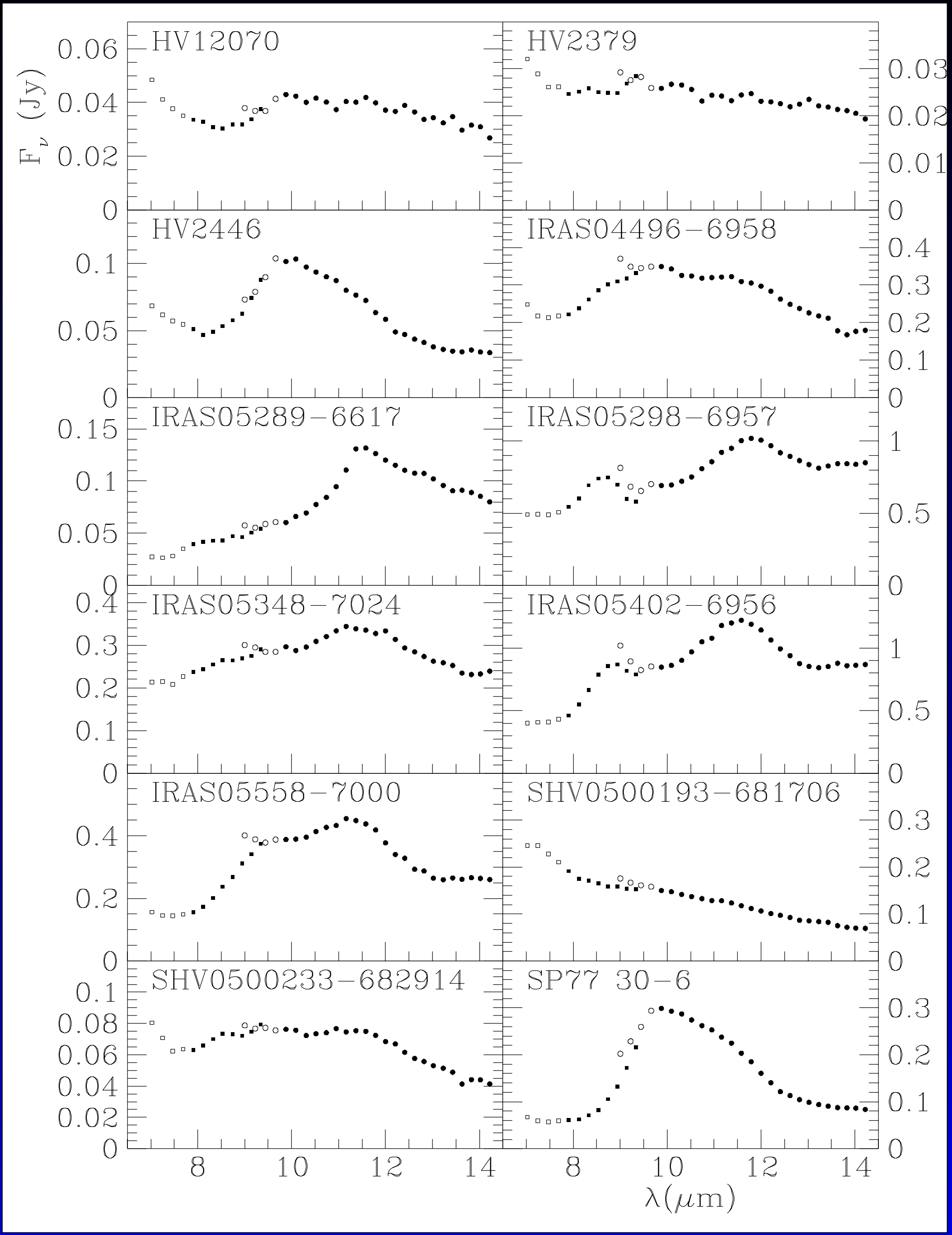
  -Spectroscopy
- SED fitting (Sloan, Soszyński)

The beginning

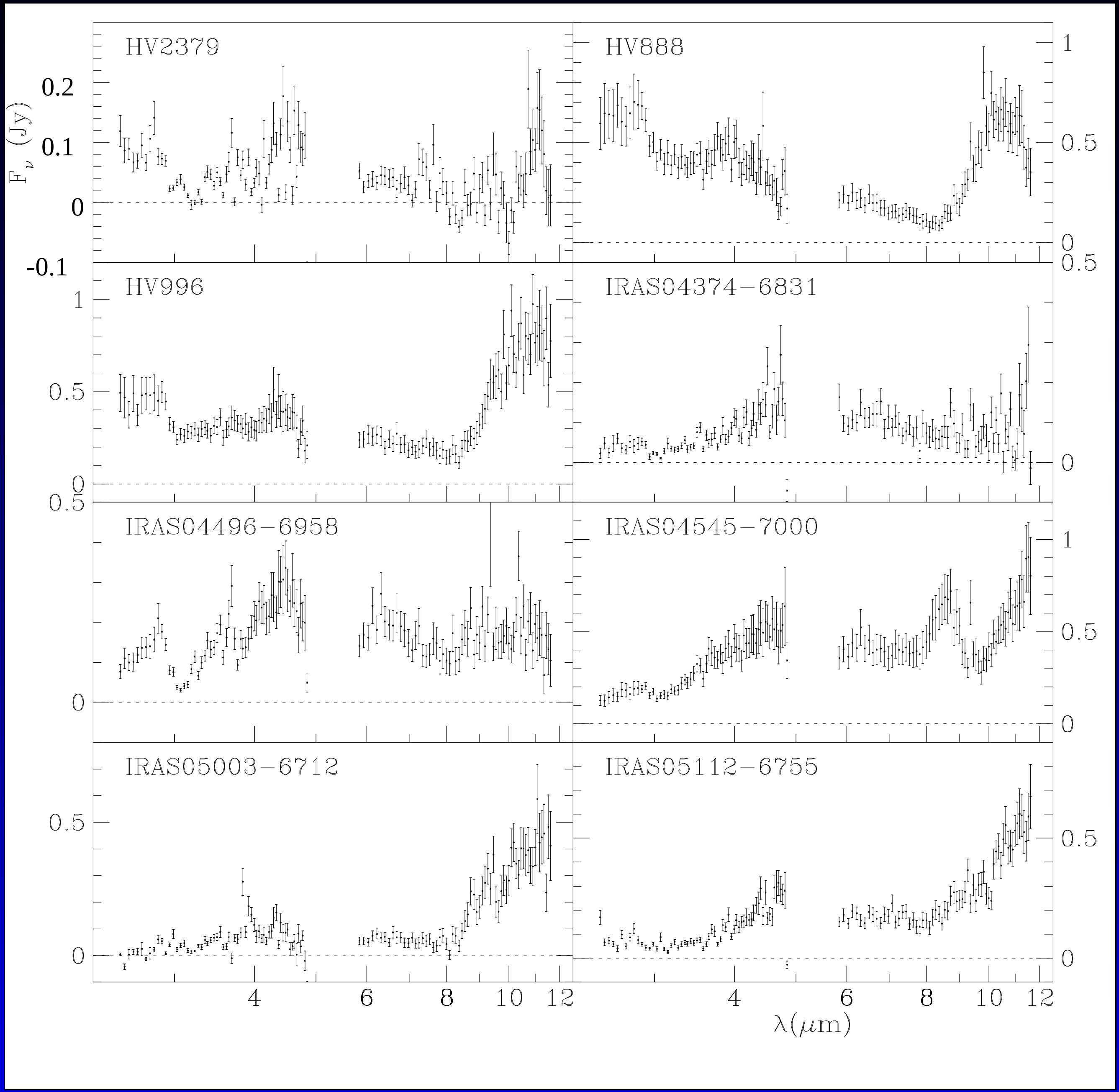
- Reid et al. (1990): combined IRAS with I-plates
- Wood et al. (1992): monitored bright IRAS sources, detected OH emission, $M_{\rm bol}$= -6.5 to -9.1
- Loup et al. (1997)

- Zijlstra, Trams, van Loon, Whitelock, Groenewegen & Blommaert (1998) NIR photometry, N-band images
- ISO: multi-band photometry and spectroscopy. Mosty follow-up of IRAS, or known HV.

  Loup (ISOCAM survey, combined with DENIS).

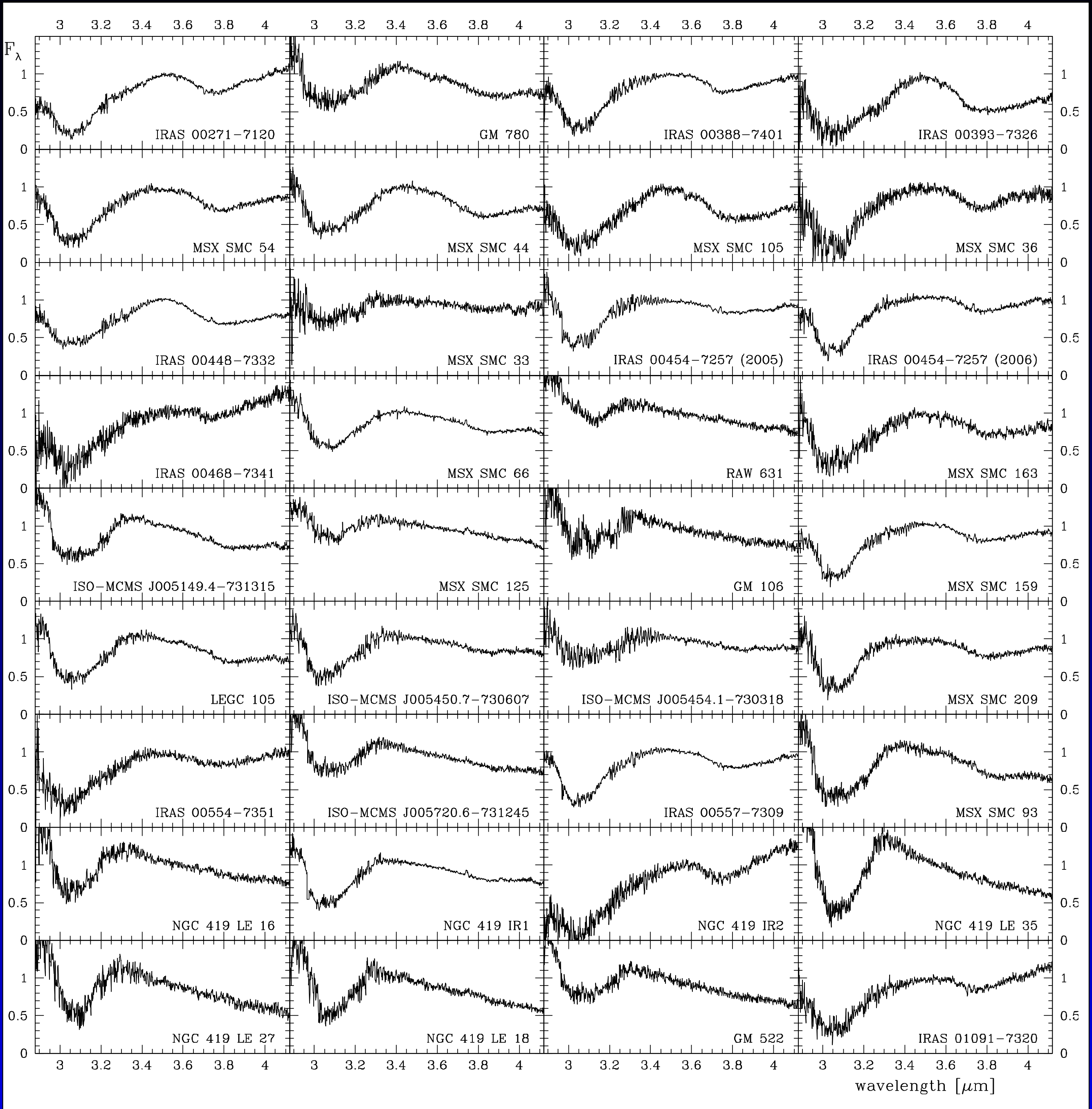


ISOCAM CVF spectra (Trams et al. 1999)



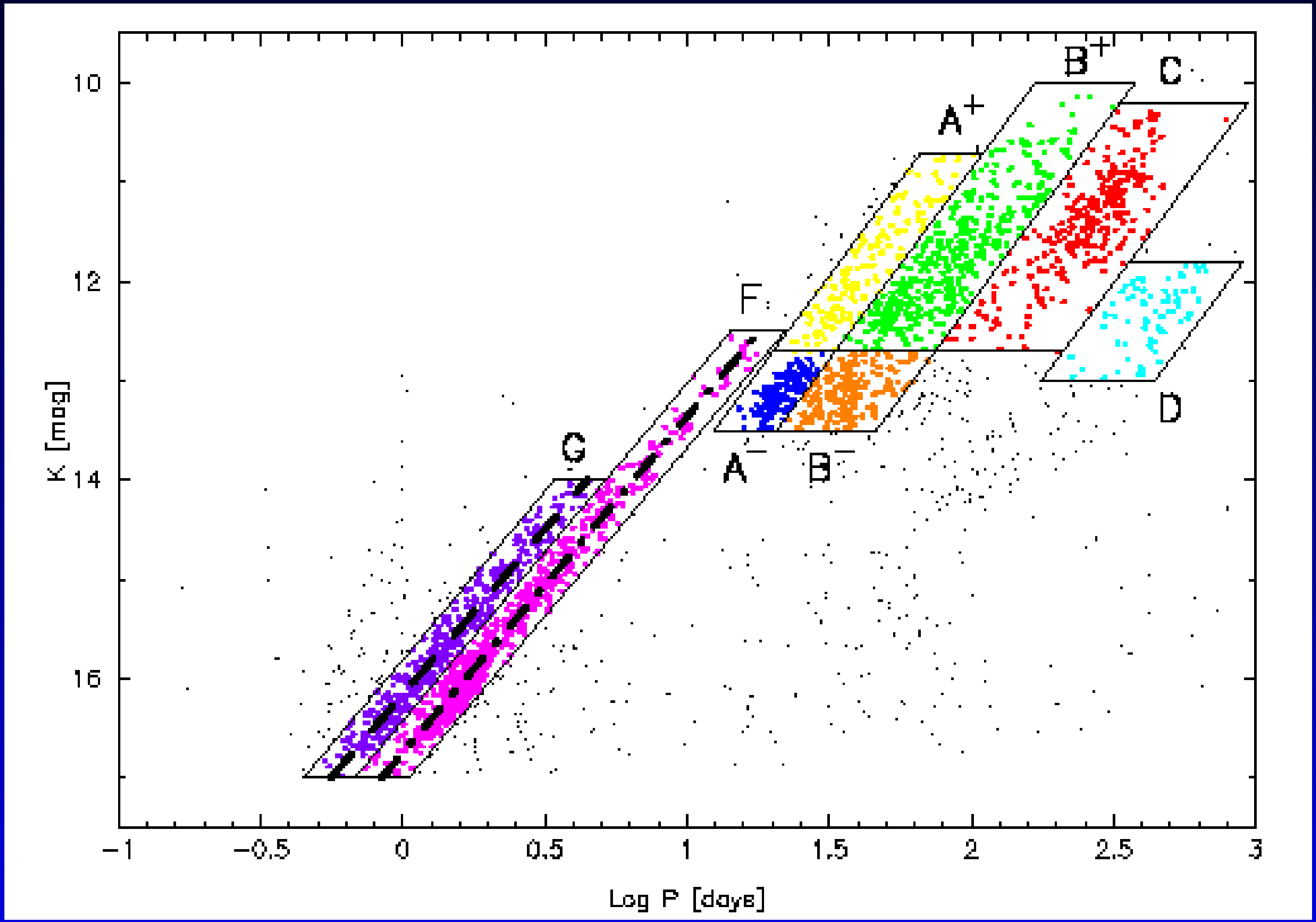
ISOPHOT-S spectra (Trams et al. 1999)

- NIR Monitoring: Whitelock et al. (1993), Wood et al. (1998)
- OGLE/MACHO:
  Wood, Cioni, Groenewegen, Ito, Fraser
- van Loon et al. (2008) molecular bands

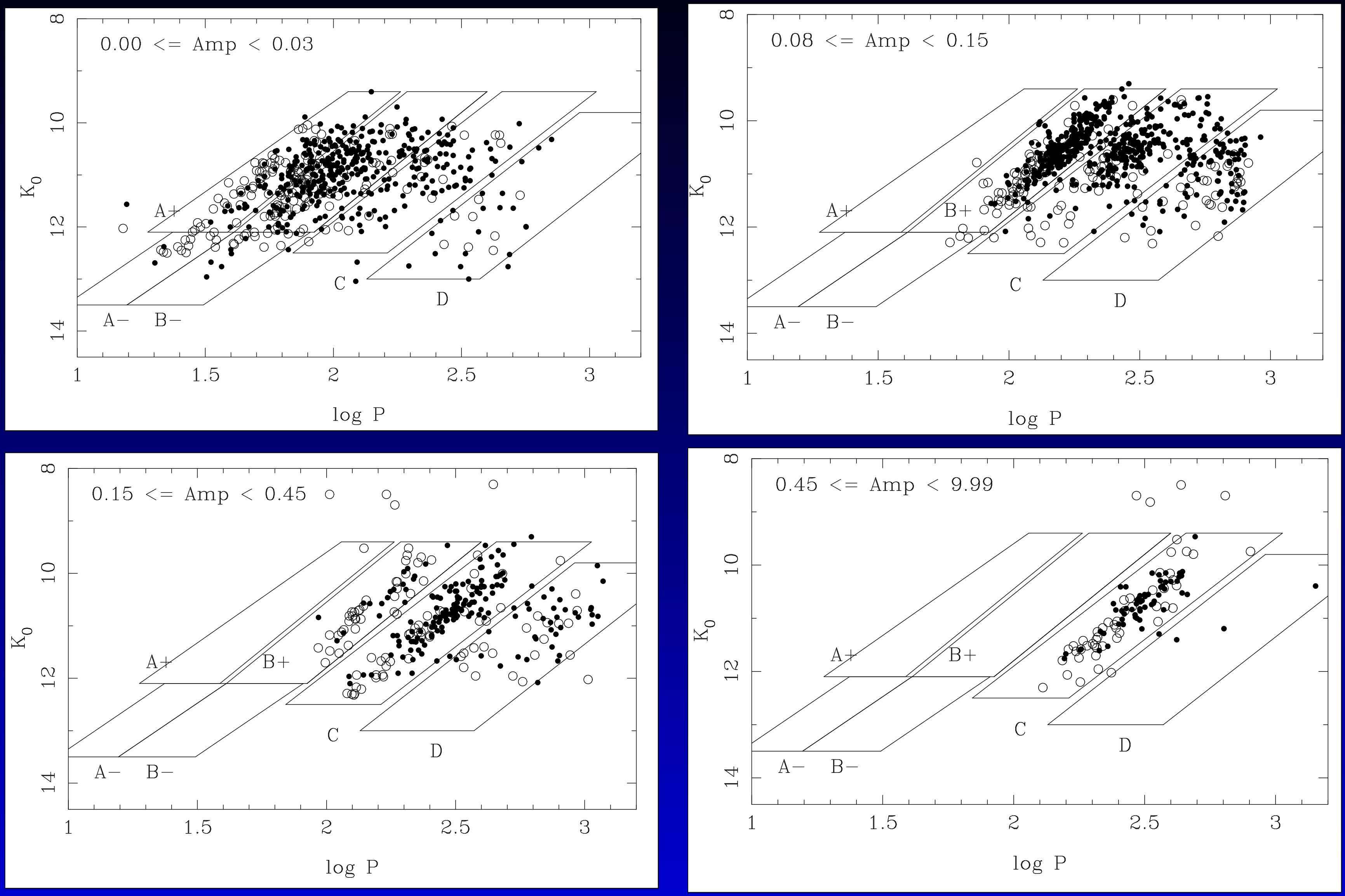


ISAAC 3 μm spectra of C-stars (van Loon et al. 2008)

Pulsation



Ita et al. (2003)



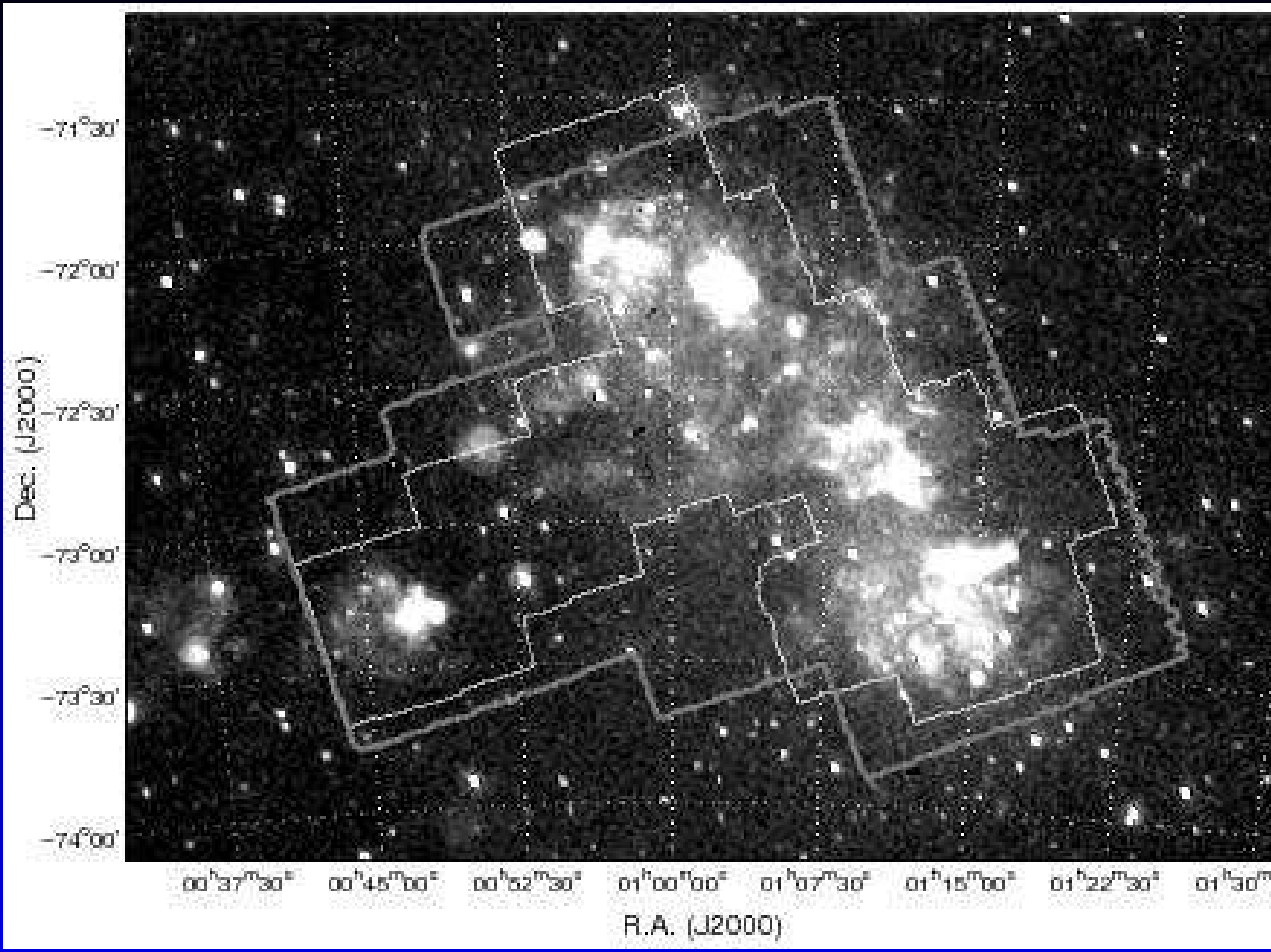
LMC LPVs from Groenewegen (2004)
$PL(K)$-relation for different cuts in amplitudes
Known C/M-stars in filled/open symbols

Spitzer SAGE and S3MC

S^3MC Bolatto et al. (2007) IRAC+MIPS

4 square degree.

400 000 sources
catalog available on the web (Aug 2006).



S^{3}MC coverage (Bolatto et al. 2007)

Spitzer SAGE and S3MC

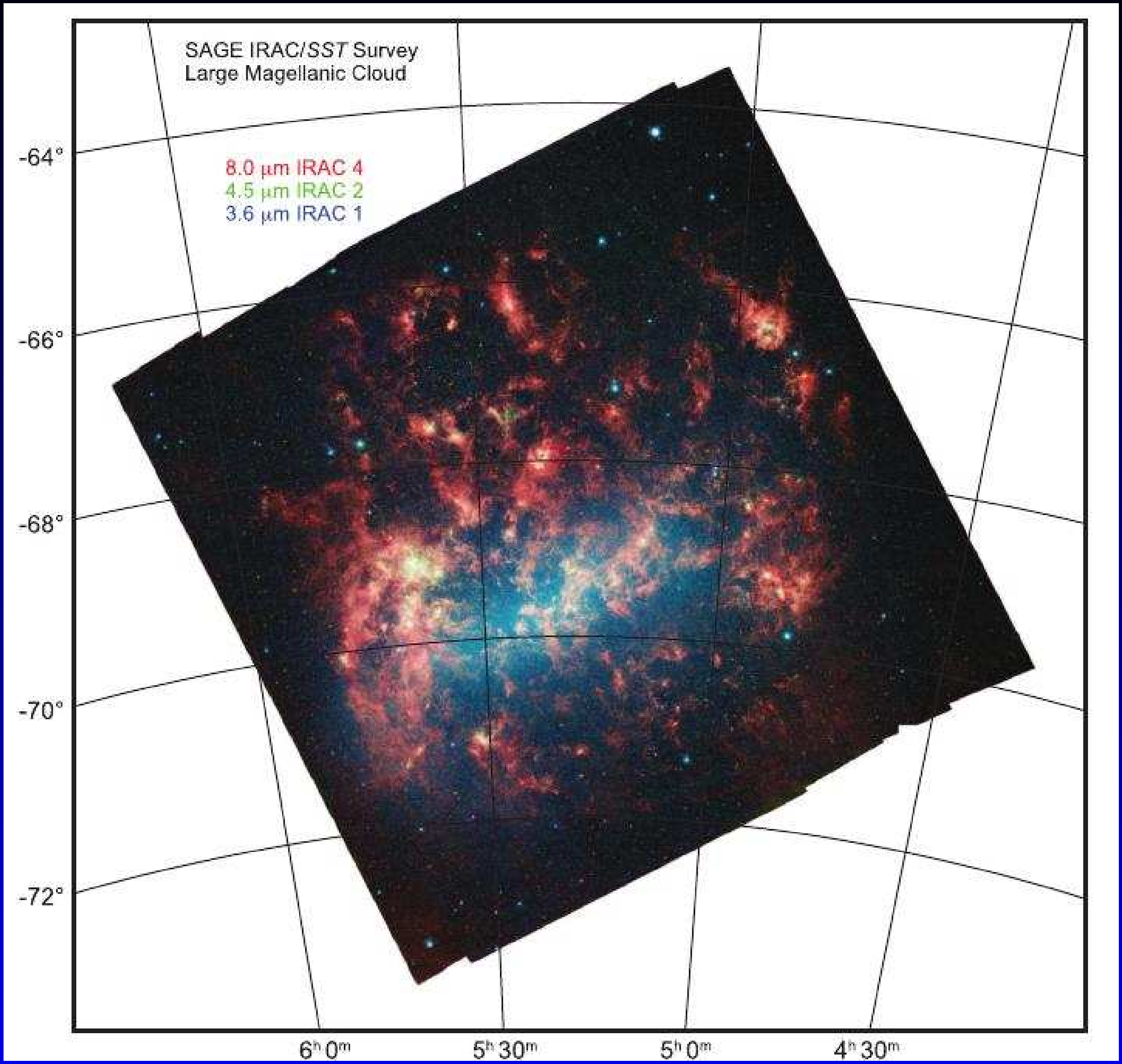
SAGE (Surveying the Agents of a Galaxy's Evolution)
Meixner et al. (2006)

SAGE-LMC (2 epochs) 4 million sources

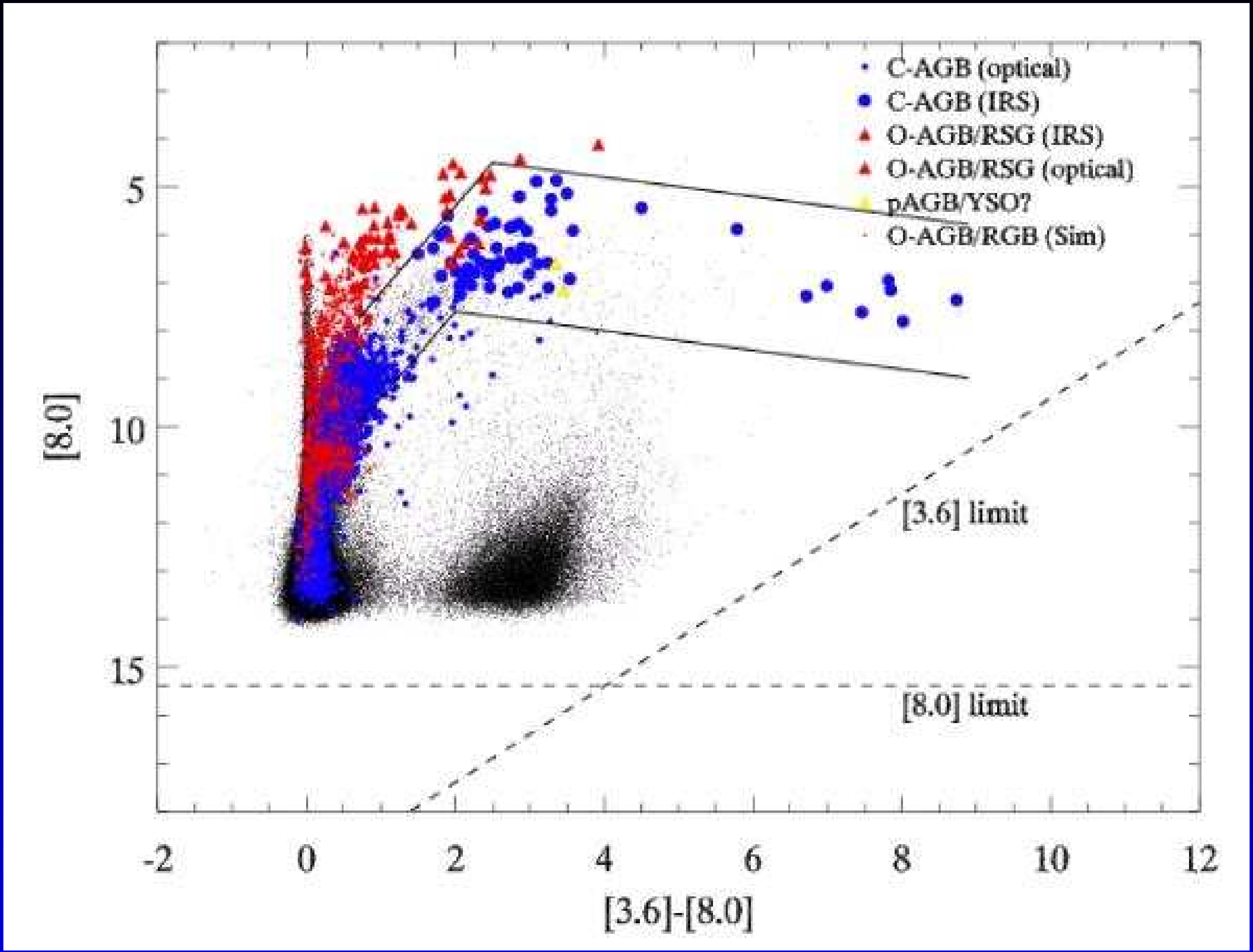
SAGE-SMC (2 epochs, 33 sq.deg.)

SAGE-SPEC

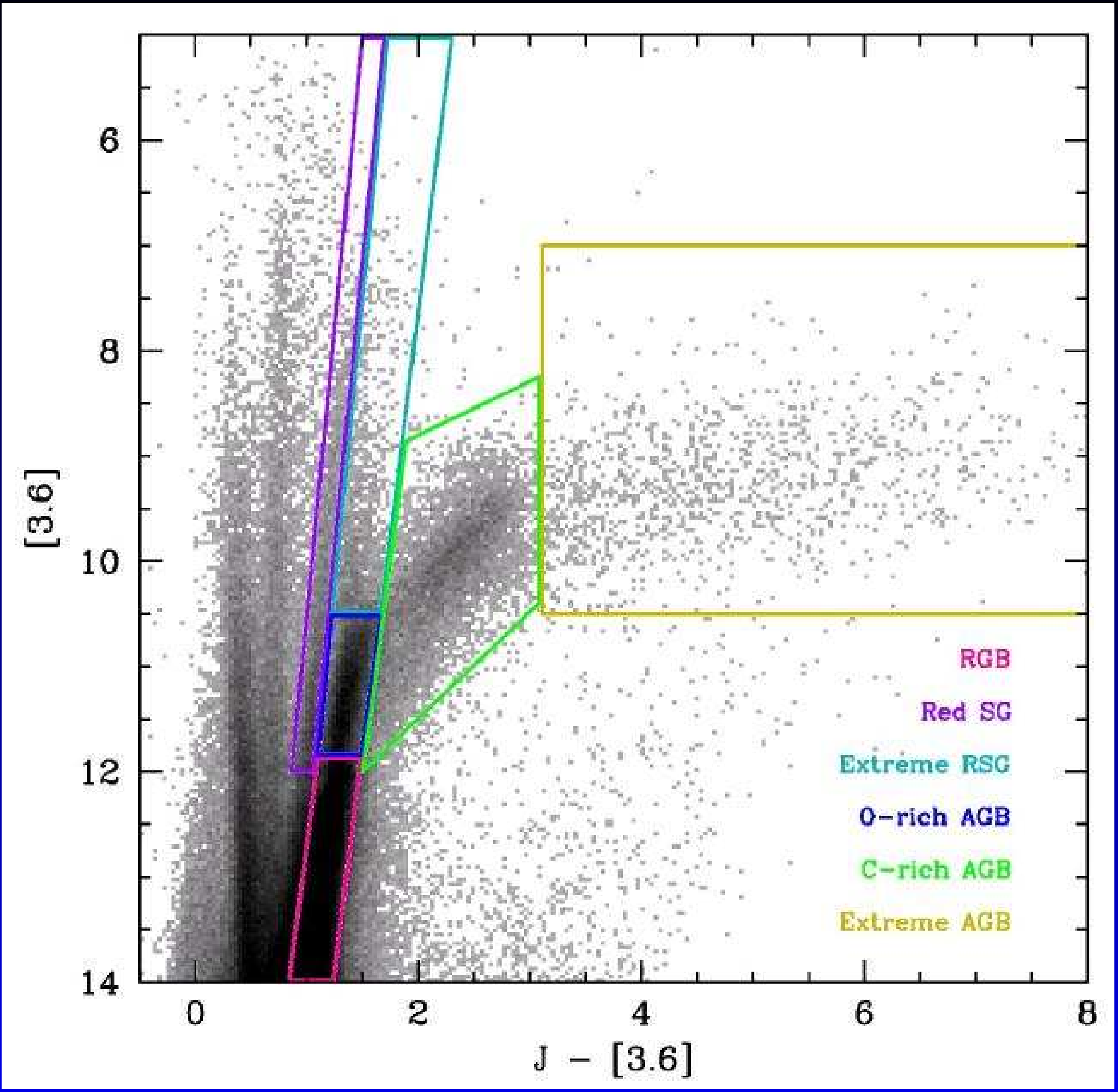
SMC-SPEC



SAGE coverage (Meixner et al. 2006)



Matsuura et al. (2009)



Harris et al. (2009)

Spitzer IRS program

200 (P.I. J. Houck), Sloan et al. (2008)

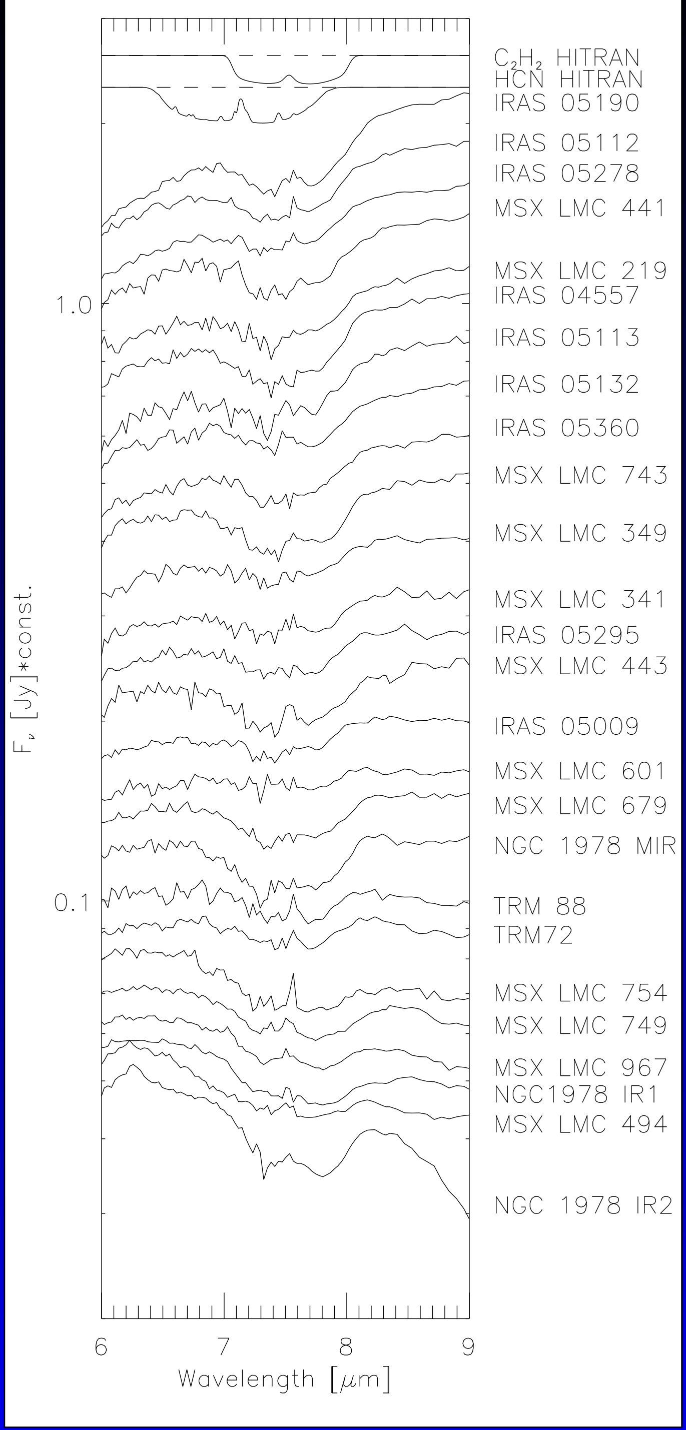
3277 (P.I. M. Egan), Sloan et al. (2006)

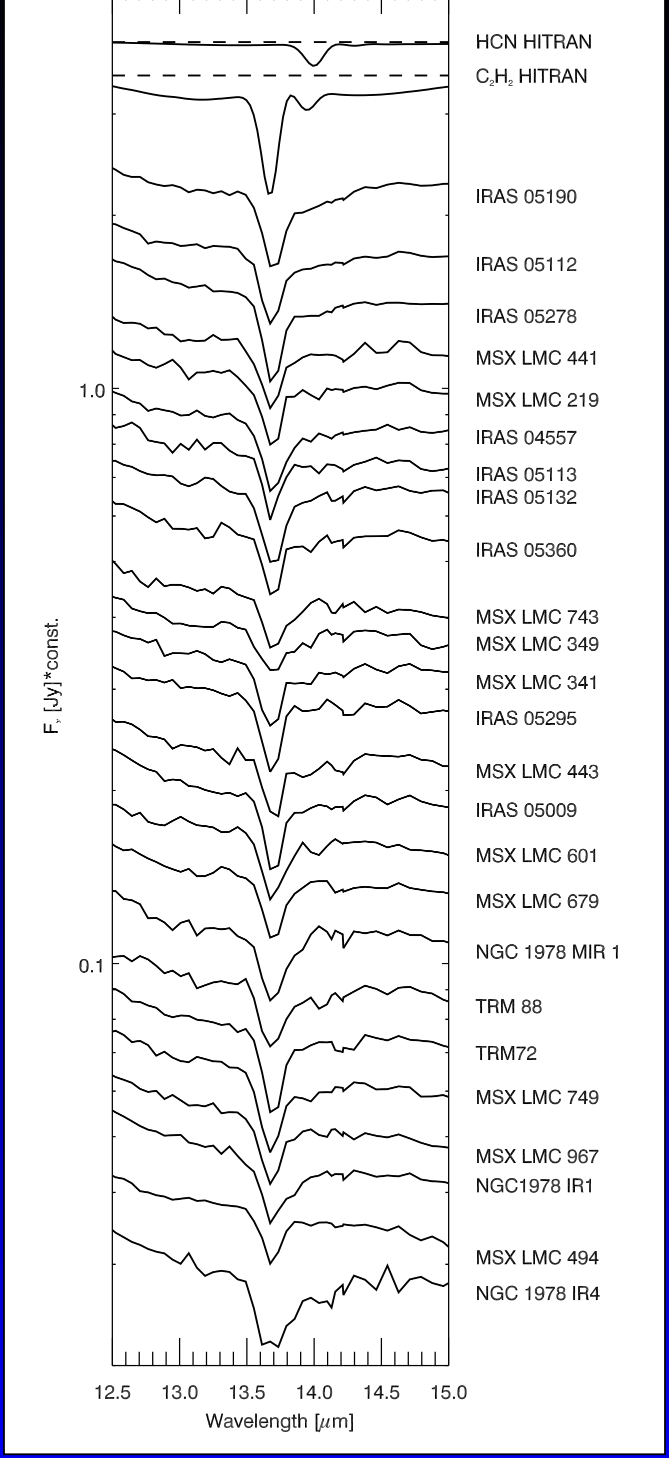
3426 (P.I. J. Kastner), Buchanan et al. (2006)

3505 (P.I. P. Wood), Zijlstra et al. (2006) and Lagadec et al. (2006)

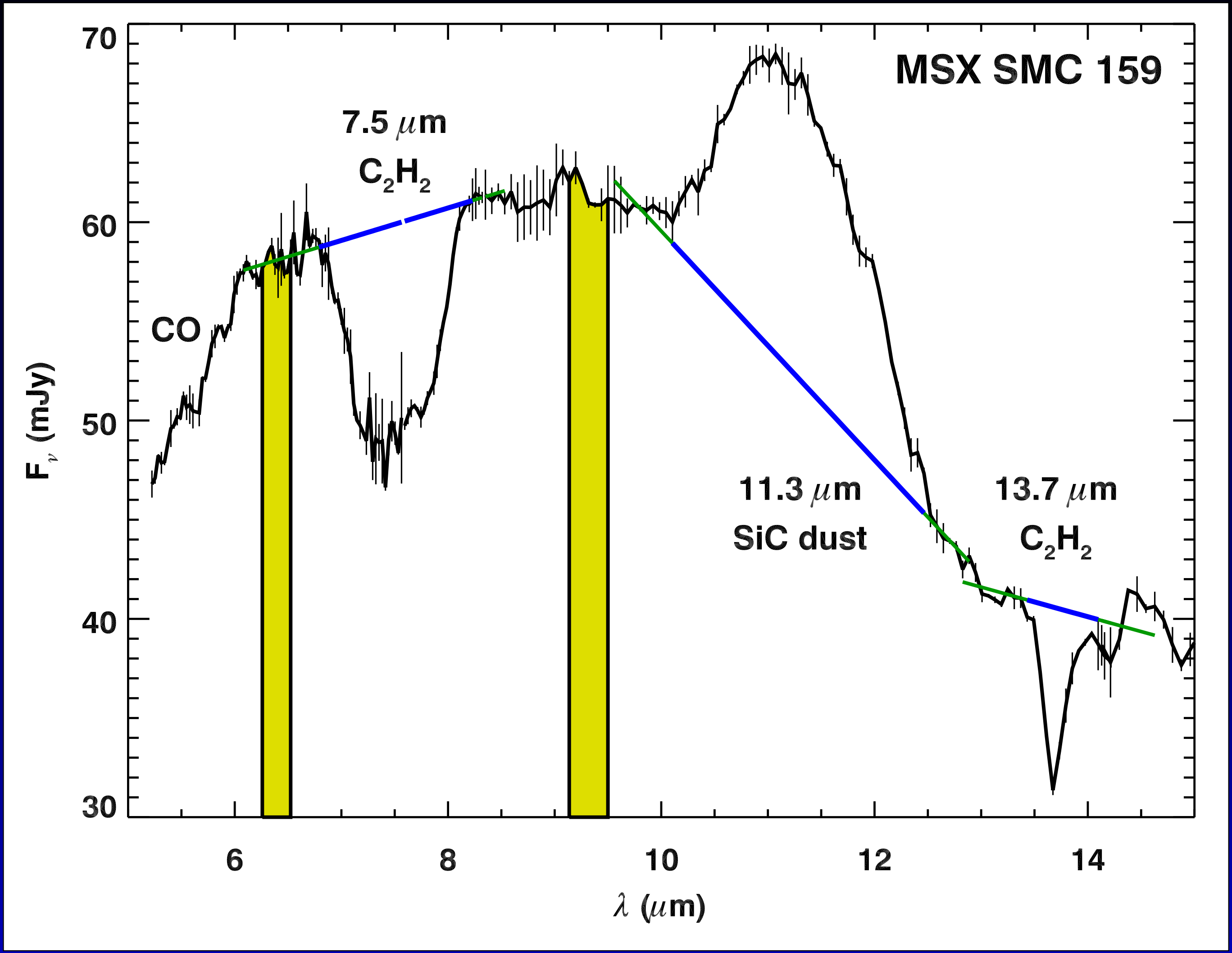
3591 (P.I. F. Kemper), Leisenring et al. (2008)

+ others ongoing





Matsuura et al. 2006

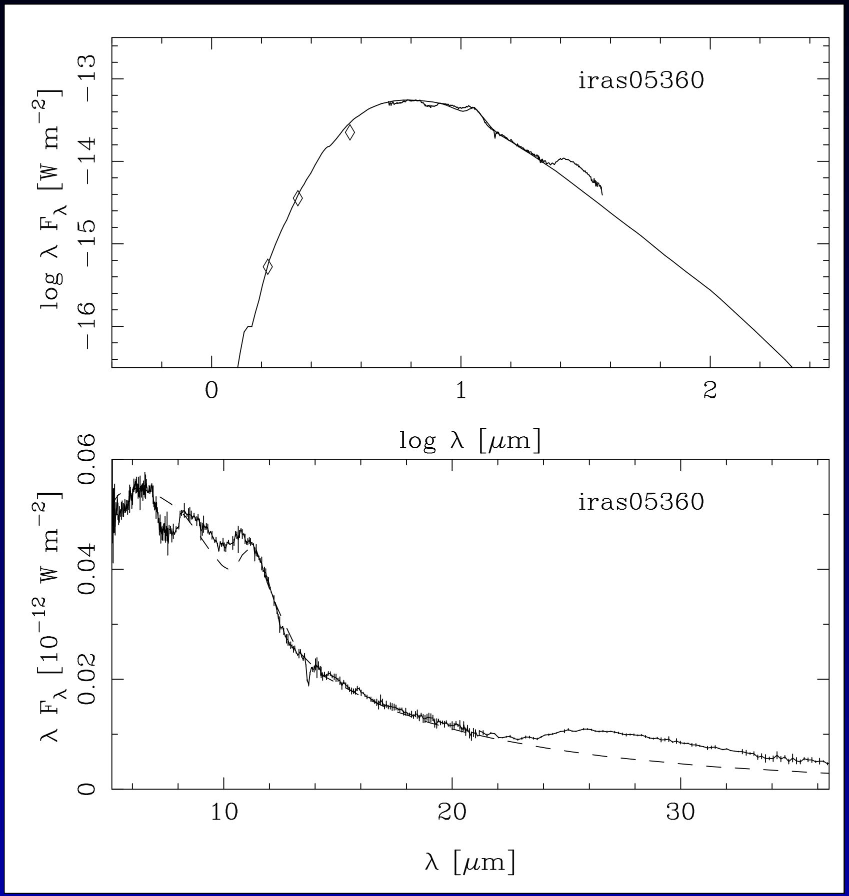


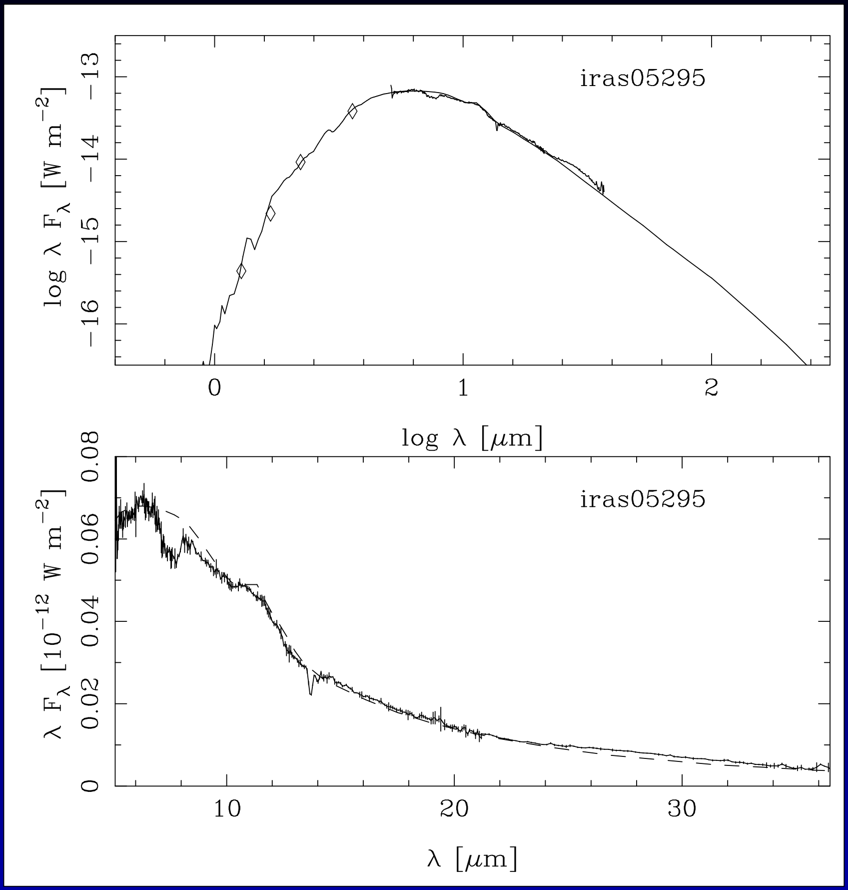
Sloan et al. (2006)

"At lower metallicity, C-stars with similar amounts of amorphous carbon in their shells have stronger absorption from C_2H_2 and weaker emission from SiC and MgS"

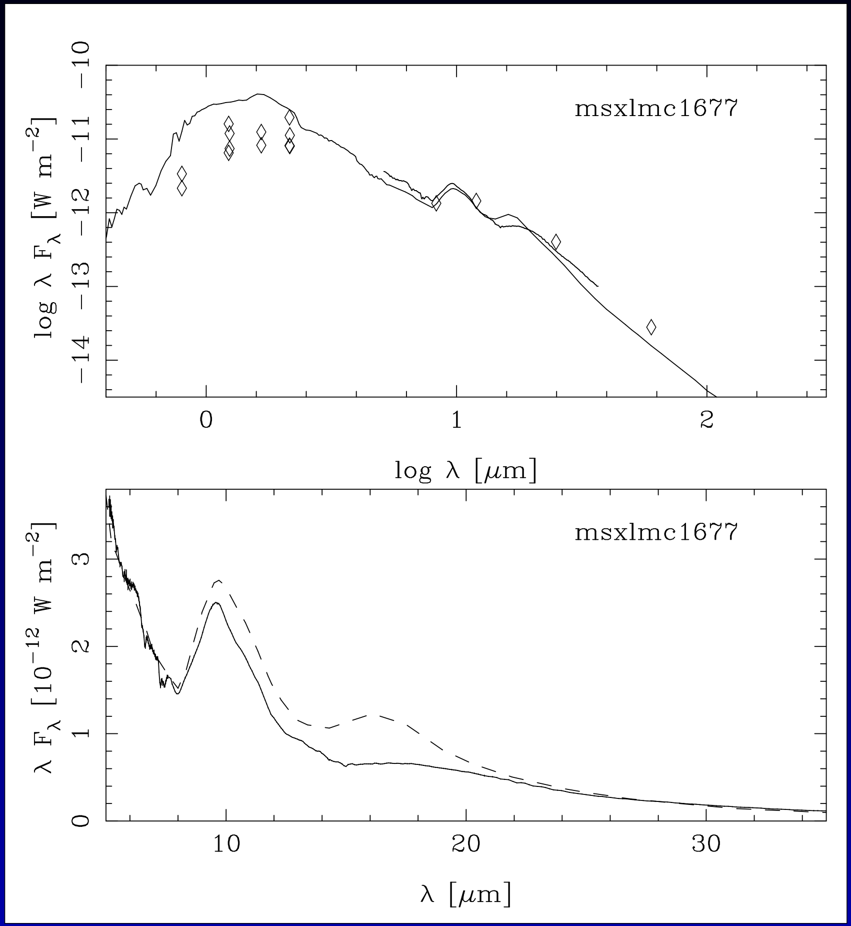
SED fitting

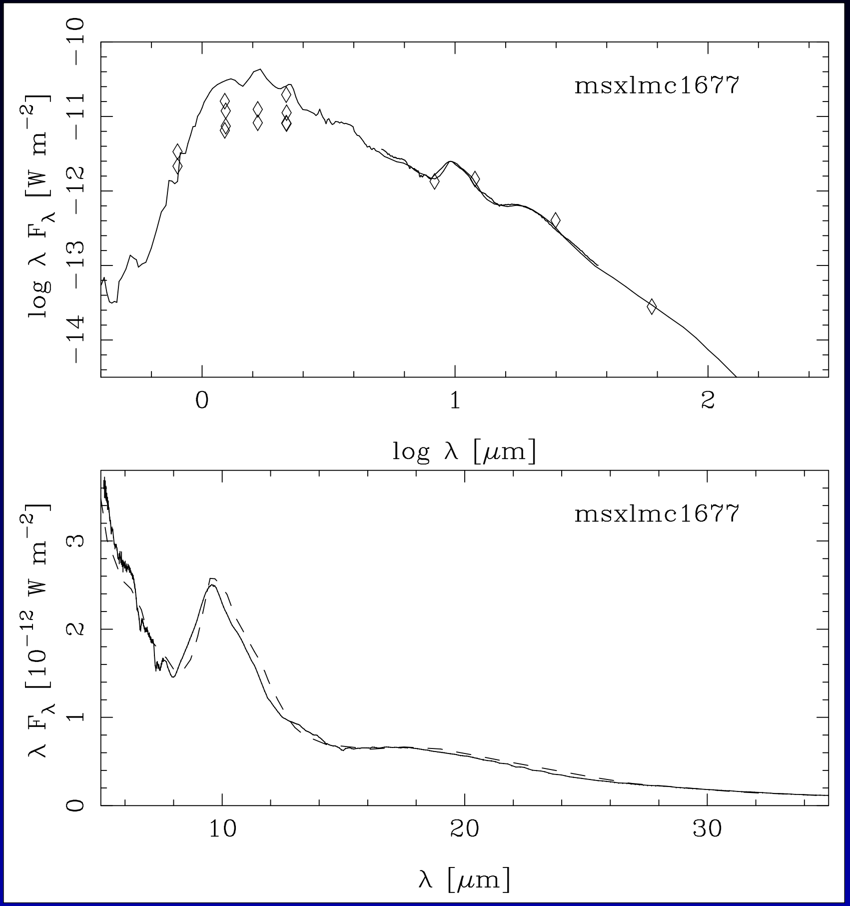
- 103 C-stars,
  88 O-stars (10 FG, 41 RSG, 37 O-AGB)
- 1D dust radiative transfer model
  (Groenewegen 1995)
- Included as subroutine in minimalisation routine
  Runs on HPC $\Rightarrow$ fits L, T_c, $\dot{M}$
- Model atmospheres:
  Fluks et al. (M), Loidl et al. (C)
- Different types of dust
- Assumptions:
  Dust-to-gas ratio of 0.005
  Dust expansion velocity of 10 km/s



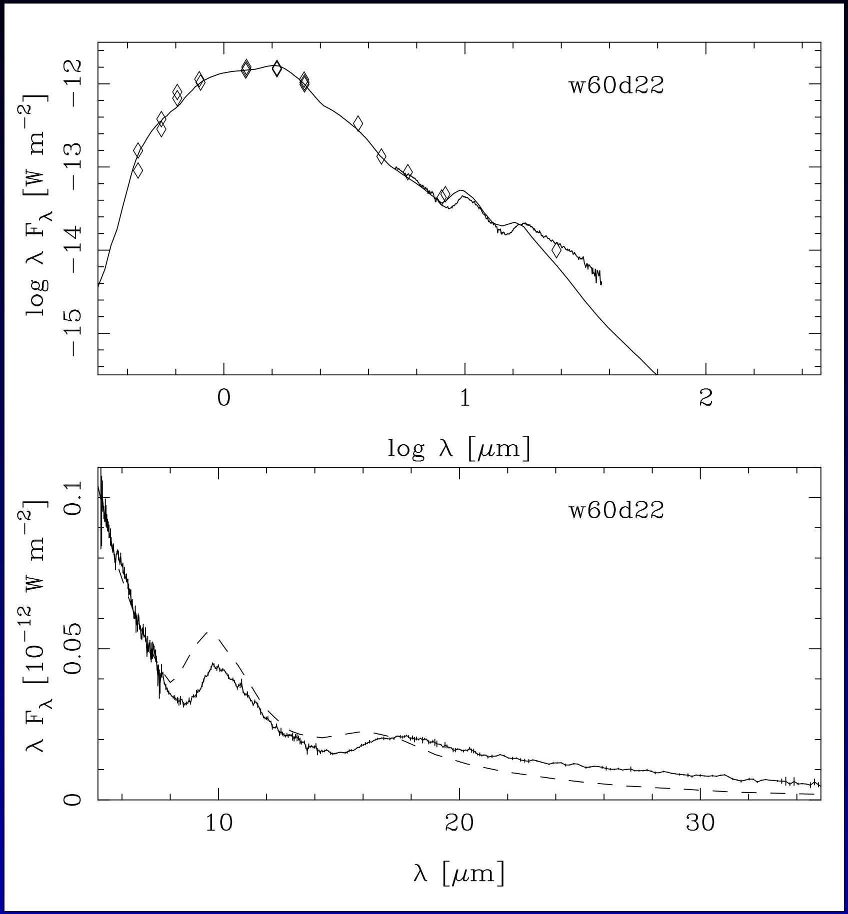


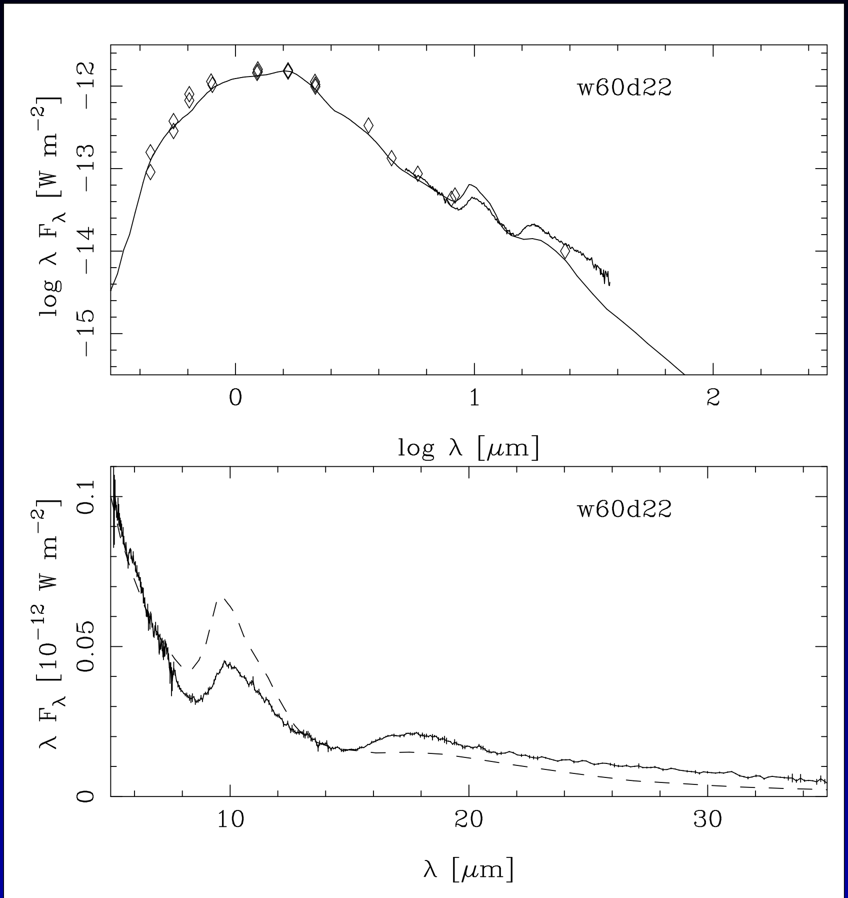
Example C-stars





Example O-stars. Lab versus Astronomical silicates



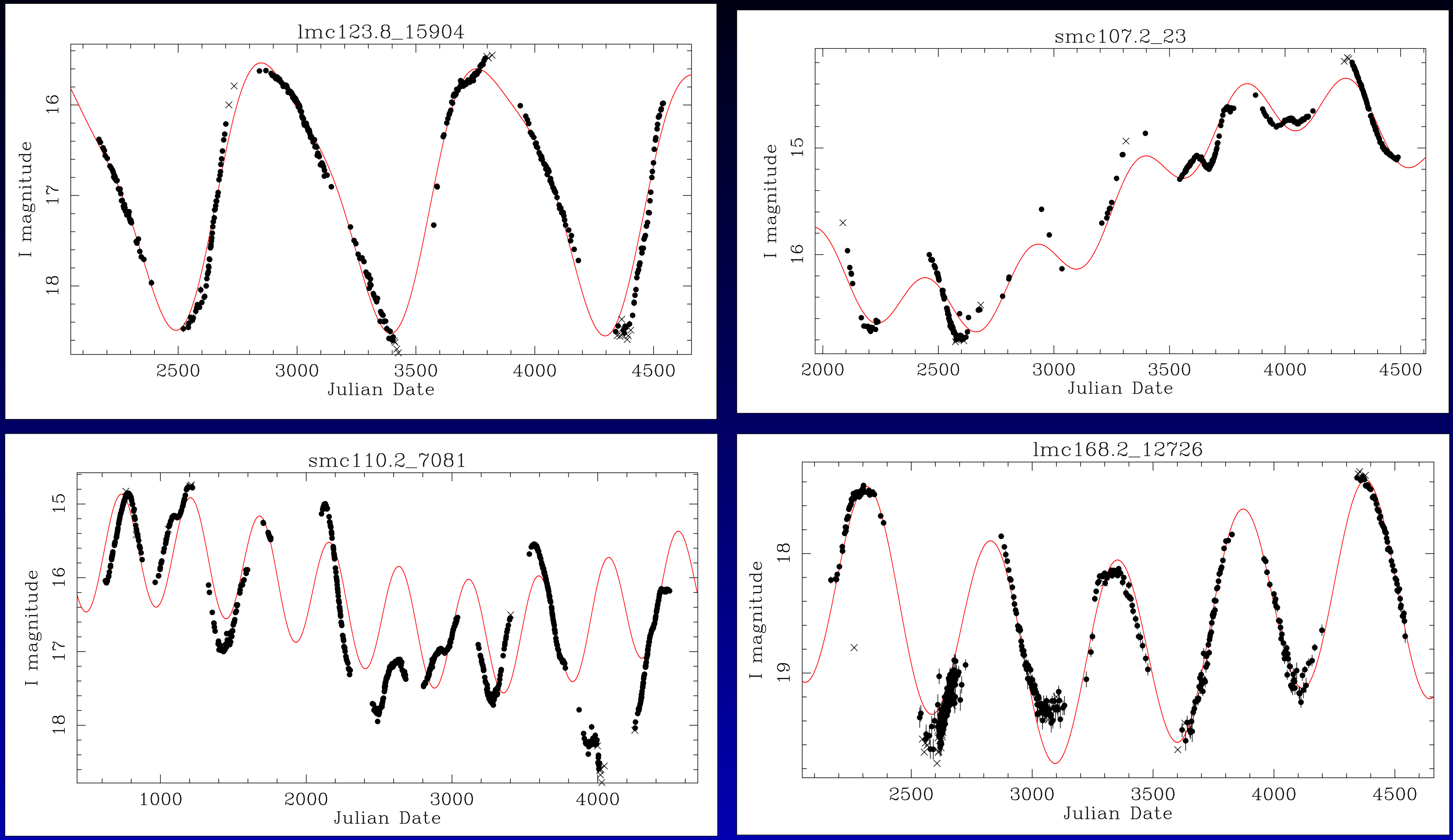


Example O-stars. Lab versus Astronomical silicates

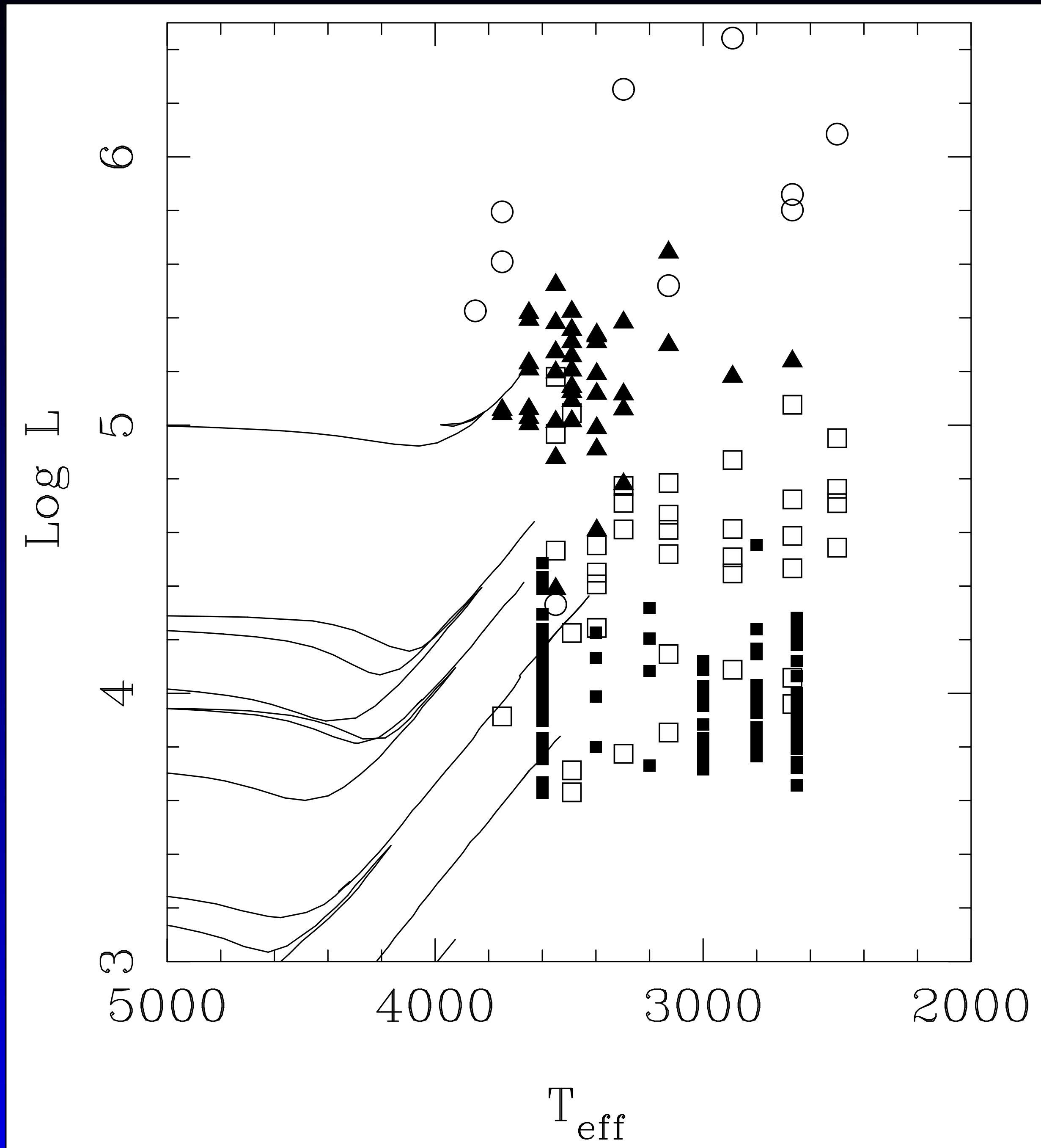
Astronomical Silicates typically fit better.

Depends on assumptions in calculating Q from (n, k)

CDE, or grains of order 1 μm, show better results



Example of OGLE II + III *I*-band lightcurves

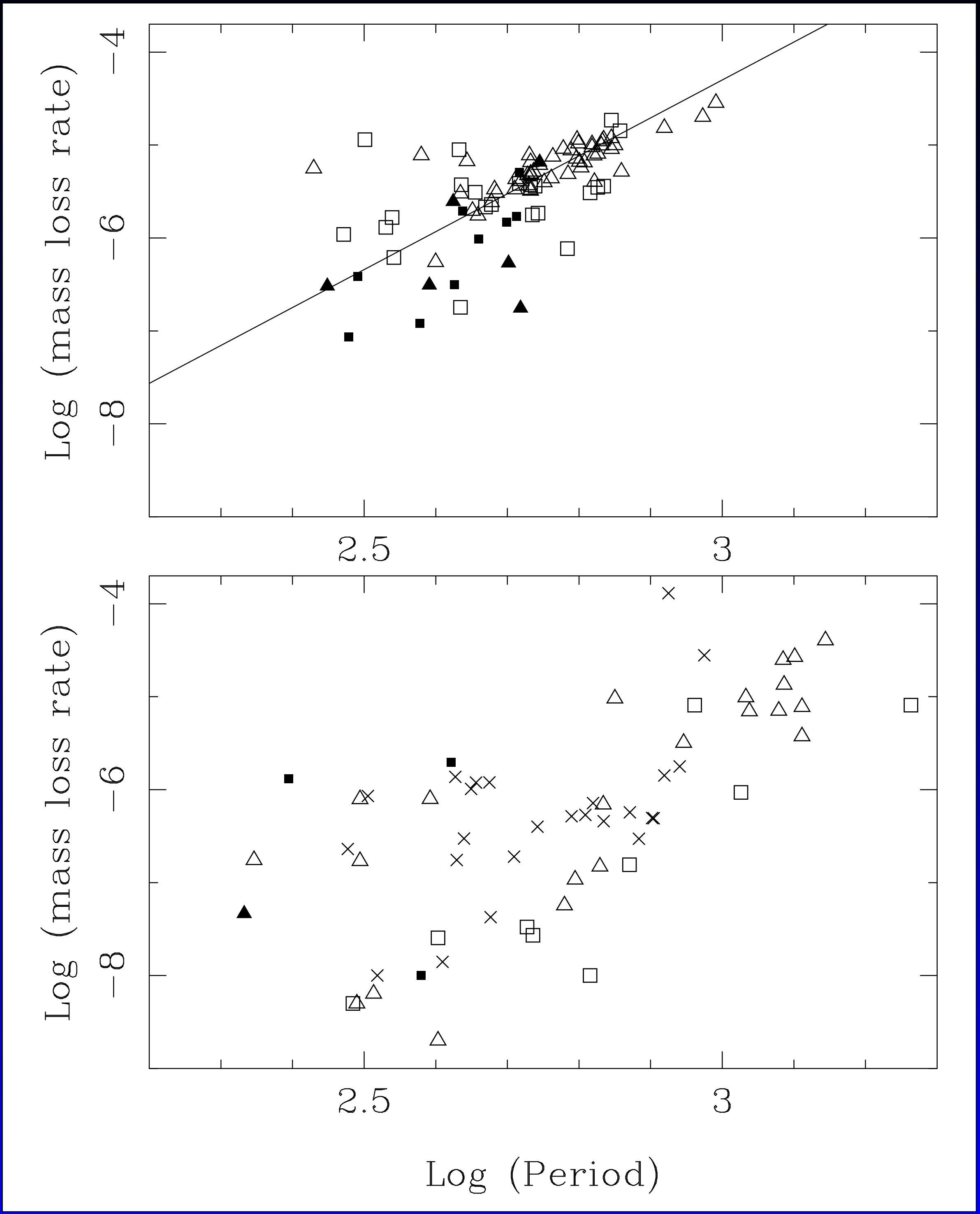


C = filled ■

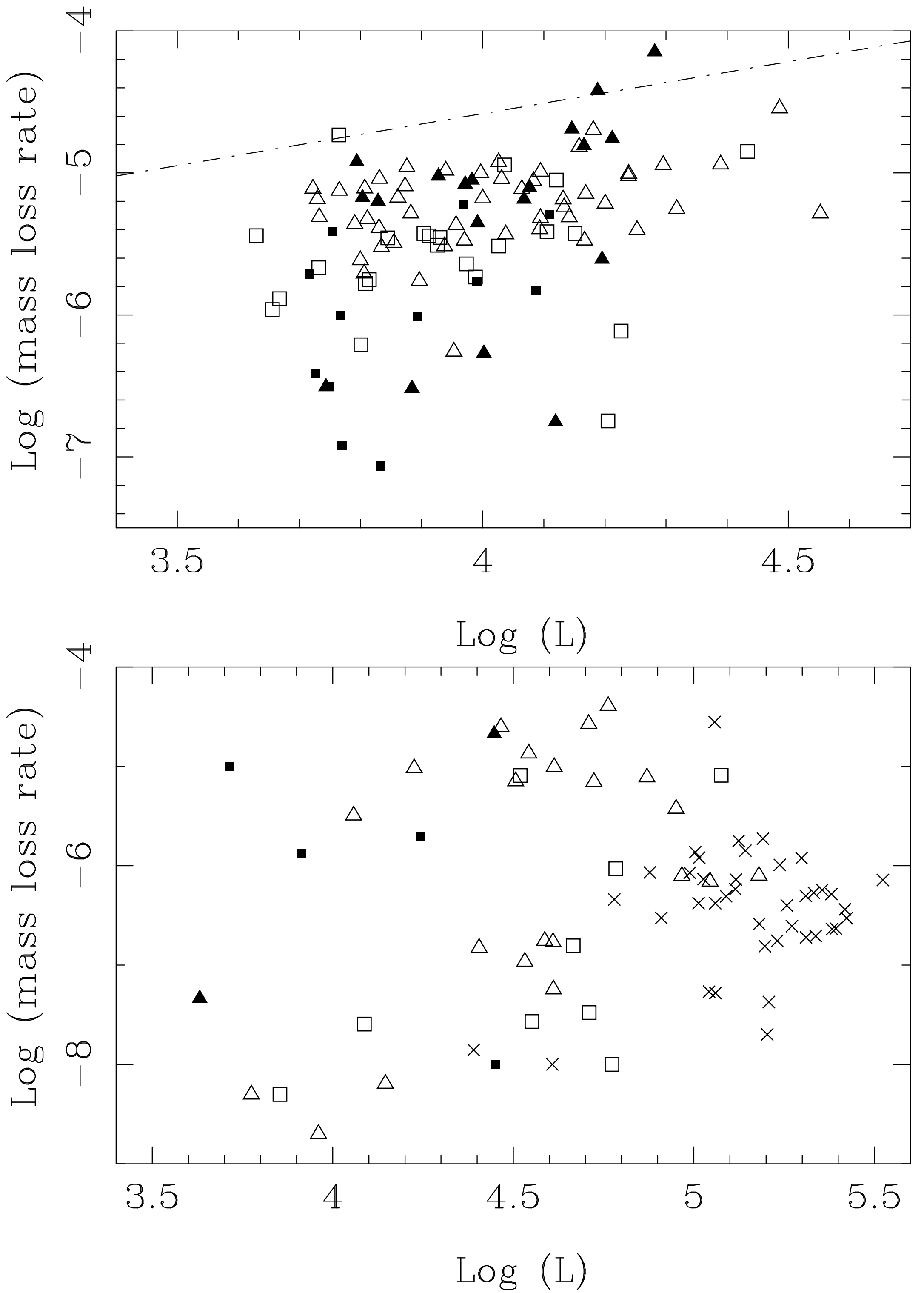
M-AGB = □

Foreground = ○

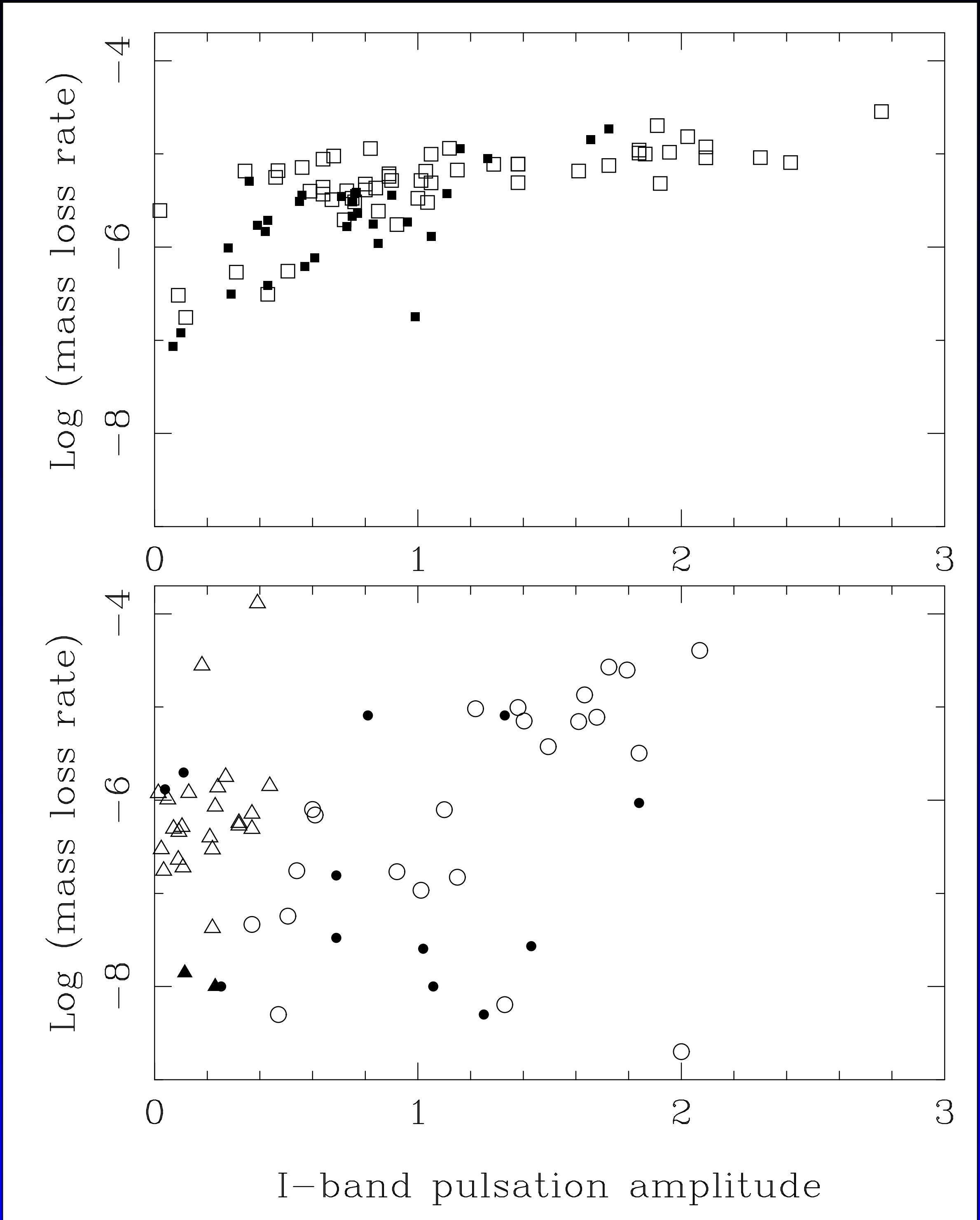
RSG= filled △



SMC = □
LMC= △
Mira= open symbols
RSG= x

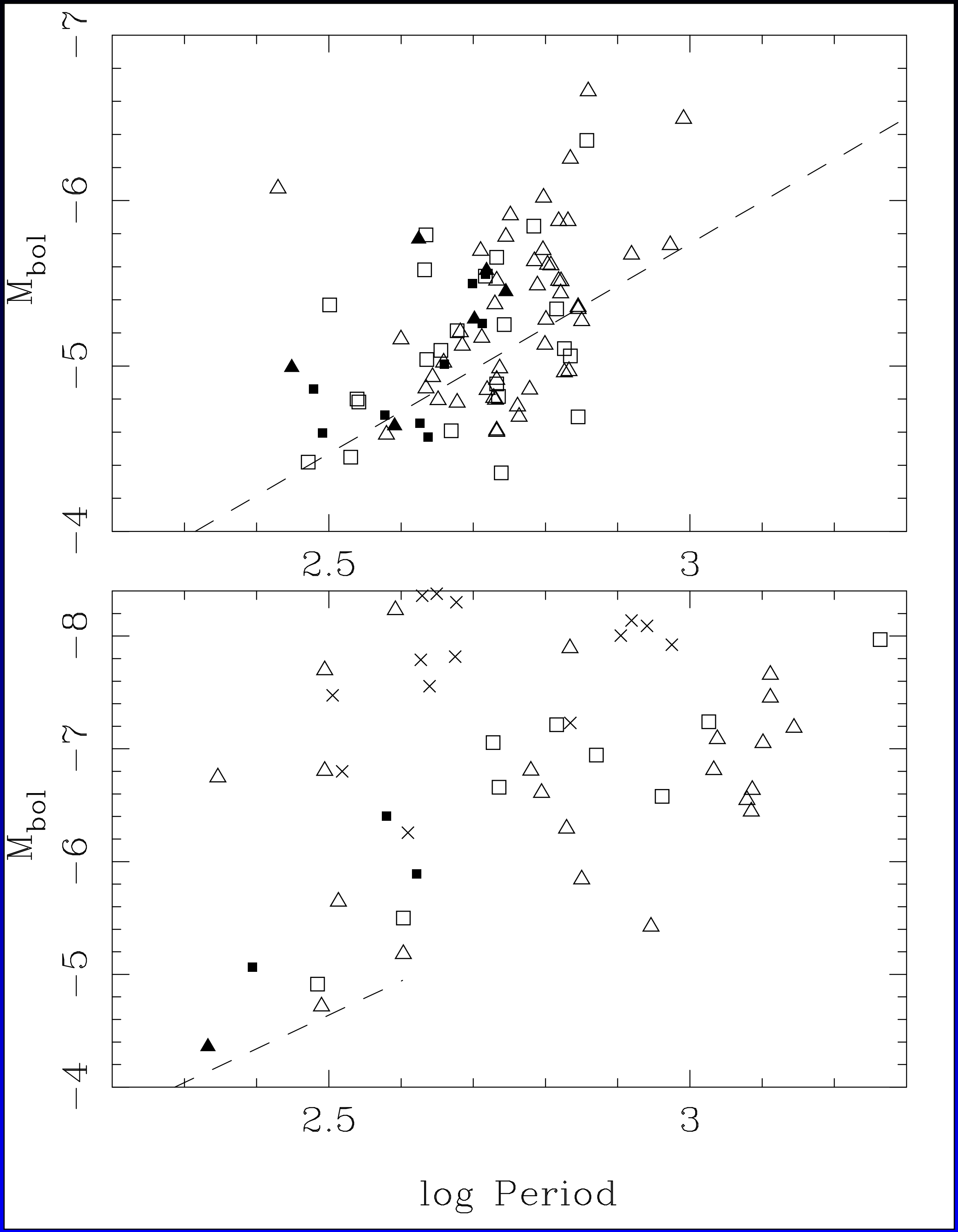


SMC = □
LMC= △
Mira= open symbols
RSG= x



SMC = filled
LMC= open

M-AGB= o / • RSG= △



SMC = □
LMC= △
Mira= open symbols
RSG= x

Link to theory

Hydrodynamical Dust driven wind models
Wachter/Winters/Sedlmayer Höfner/Mattson/Wahlin

For a given C/O value,
similar $\dot{M}$, larger v_∞, larger Ψ

$v_{\mathrm{GAL}}/v_{\mathrm{LMC}} = 2$, $v_{\mathrm{GAL}}/v_{\mathrm{SMC}} = 4$
$\Psi_{\mathrm{GAL}}/\Psi_{\mathrm{LMC}} = 1.3$, $\Psi_{\mathrm{GAL}}/\Psi_{\mathrm{SMC}} = 2.3$

Larger C/O, larger $\dot{M}$, v_∞, Ψ

Wahlin / Abia / de Laverny

The Future

Spitzer-IRS $\Rightarrow$ more spectra

Spectroscopy/abundance studies $\Rightarrow$ C/O abundances

ALMA $\Rightarrow$ CO lines in MCs $\Rightarrow$ v_∞, $\dot{M}$, Ψ,
test dust driven wind theory

THE END