

# Mass-losing and Pulsating AGB stars in the Magellanic Clouds

Martin Groenewegen

Instituut voor Sterrenkunde - K.U.Leuven

# Overview

- General Overview
  - History
- Some New Results
  - PL-relation
  - Whitelock, Cioni, Wood

# Overview: Mass-losing Stars

- pre-IRAS
- IRAS

Whitelock et al. 1989: 5 SMC

Reid et al. 1990: 13 LMC AGB candidates

Reid 1991: NIR on 13 LMC

Wood et al. 1992: 6 OH/IR

Tanabe et al. 1997: NIR of 9 MC clusters

Loup et al. 1997: 198 candidate AGB stars

Zijlstra et al. 1996: 60 JHKLN

van Loon et al. 1997, 1998: JKN of 30 LMC

Groenewegen & Blommaert 1998:

JHK photometry of 30 SMC IRAS objects

# Overview: Mass-losing Stars

- ISO

Trams et al. 1999: 57 IRAS LMC sources  
12  $\mu\text{m}$  (CAM/PHT), 25 & 60  $\mu\text{m}$  (PHT),  
LRS (CAM-CVF/PHT-S)

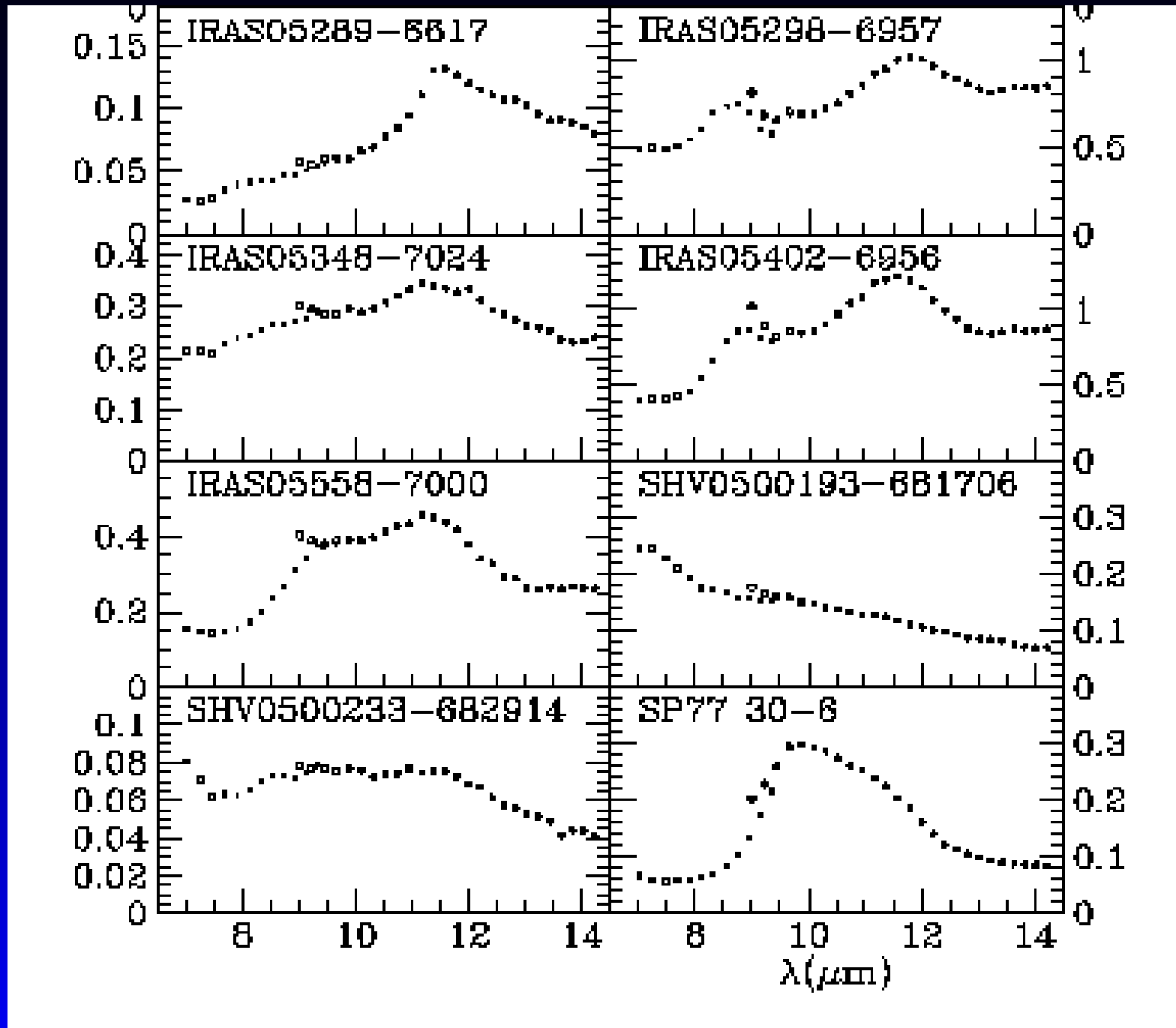
van Loon et al. 2000: modelled SEDs, to derive  
mass loss rates

Loup et al. 2002: “minisurvey”, observed  
0.3 sq.deg in SMC, LMC in CAM LW2, LW10

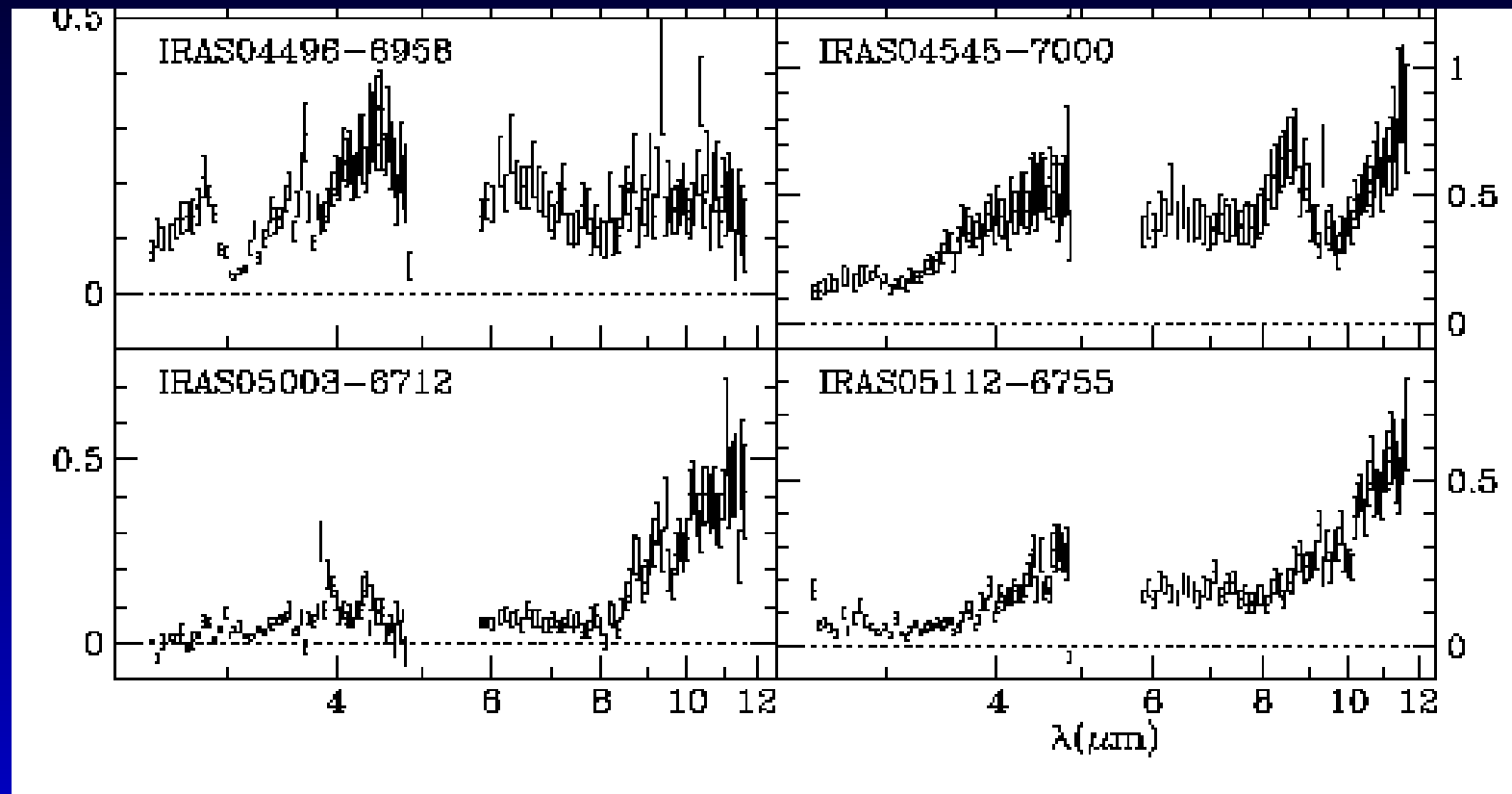
Kucinkas et al. 2000: 3 SMC, 8 LMC clusters

Blommaert et al. 2002: 24 IRAS SMC sources  
CAM/PHT

# Trams et al. 1999



# Trams et al. 1999



# Overview: Mass-losing Stars

- post-ISO

2MASS: 2nd incremental data release

DENIS: Cioni et al. 2000:

PSC (1.3M LMC, 0.3M SMC)

SIRTF: follow-up, new larger survey

# Overview: Pulsating Stars

- pre-IRAS (optical/IR Monitoring)

Payne-Gaposchkin: Harvard survey

Wood et al. 1985: 33 LPVs, LMC Bar;  
JHK + spectra

Glass & Reid 85; Reid, Glass & Catchpole 1988:  
126 LPVs, JHK

Hughes & Wood 1989, 1990: 471 M, 572 SR in  
30 sq.deg. LMC. I-band + NIR

Reid et al. 1995: I-band 16 sq.deg. LMC + NIR,  
300 periodic variables

# Overview: Pulsating Stars

- IRAS-related

Wood et al. 1992: 9 LMC,  $P = 930 - 1390$

Wood 1998: 12 LMC, 9 AGB,  $P = 565 - 1295$

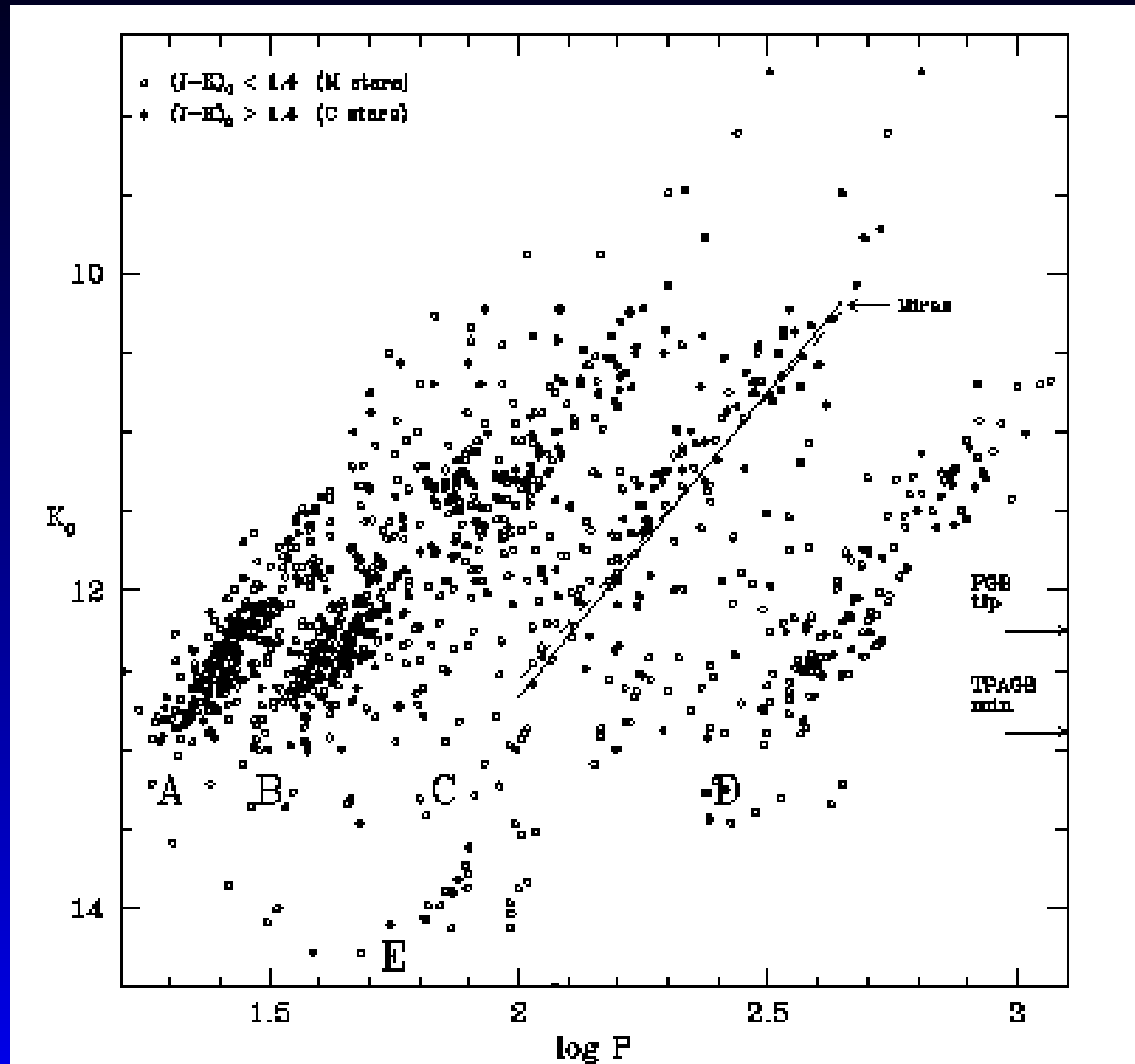
Whitelock et al. 2002: LMC, SMC

- MACHO, OGLE, EROS, MOA

Wood 1999, Wood 2000: MACHO, 0.5 sq.deg in LMC Bar, 1400 variables

Cioni et al. 2001: DENIS+EROS, 0.5 sq.deg in LMC Bar, 330 variable objects detected in K

Noda et al. 2002: 146 LPV in LMC from MOA



# New Results

- SMC

## MACHO & OGLE & 2MASS

sources in Groenewegen & Blommaert 1998  
selected sources in Loup et al. 2002

- LMC

## ISO

sources in Groenewegen et al. 2000,  
van Loon et al. 2000  
all IRAS-LMC sources with known periods

# Procedure

Cross-correlate NIR positions with 2MASS/DENIS

- ID secure based on  $K$  and  $J - K$

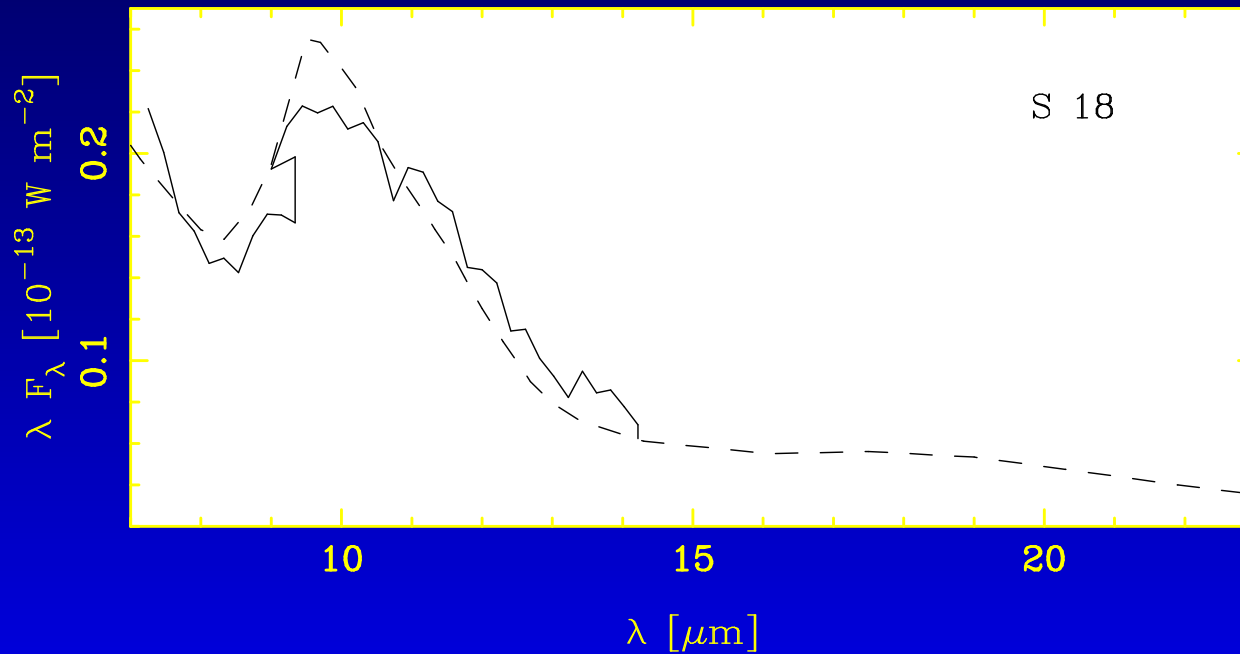
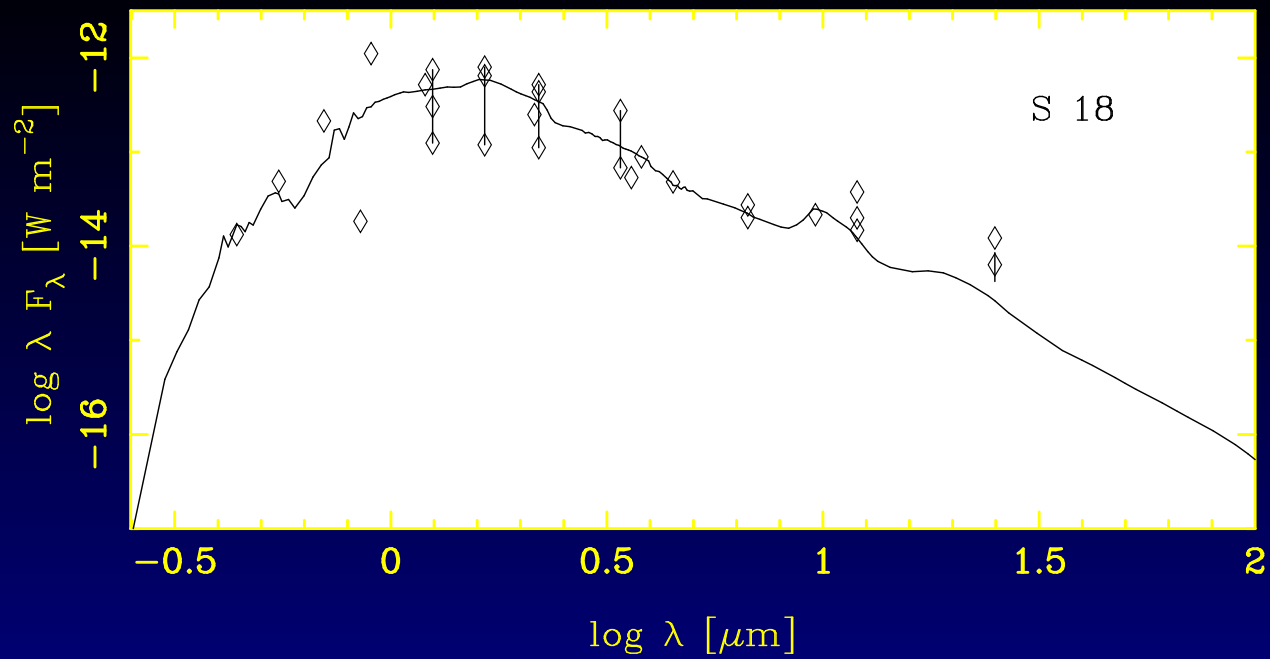
Cross-correlate improved positions with OGLE & MACHO

- ID less secure: position, lightcurve, period, color

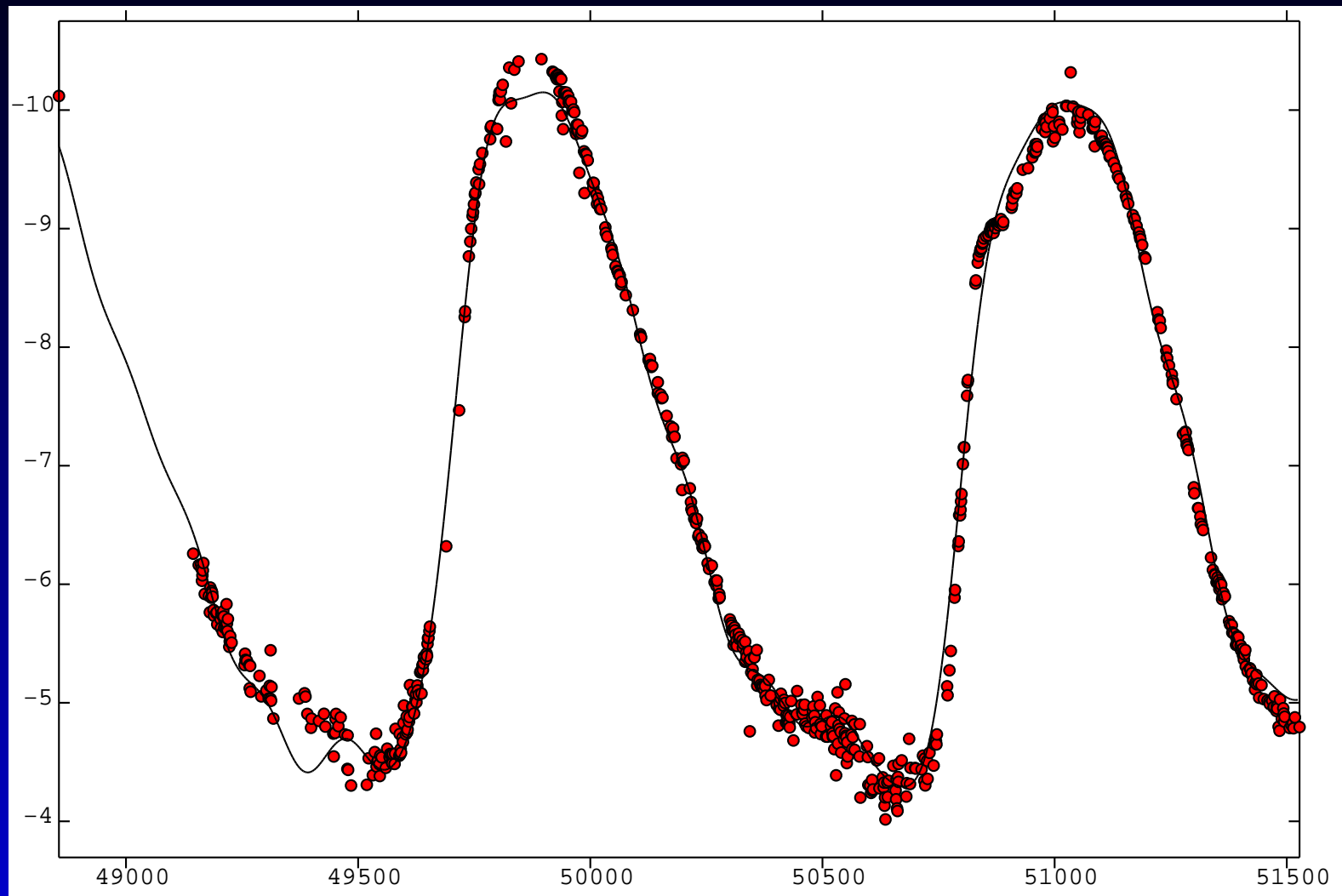
Dust radiative transfer fits to SED

- Carbon-rich central star spectra have become available (Loidl et al. 2000)

- C-/O-rich stars can be distinguished because of different dust properties

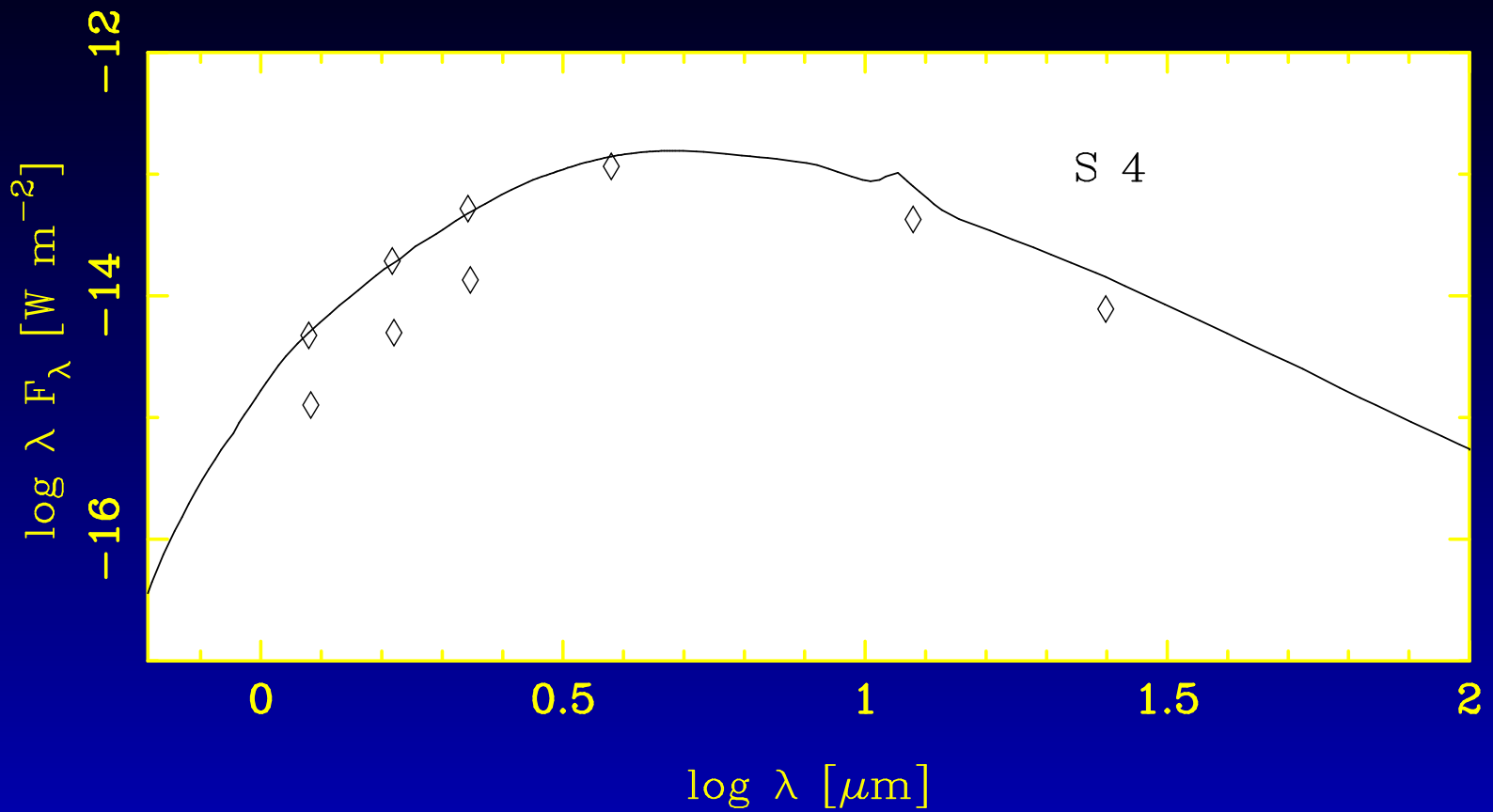


SMC 18:  $L = 77\,000 L_\odot$ ,  $\dot{M} = 3.0 \cdot 10^{-8} M_\odot \text{yr}^{-1}$

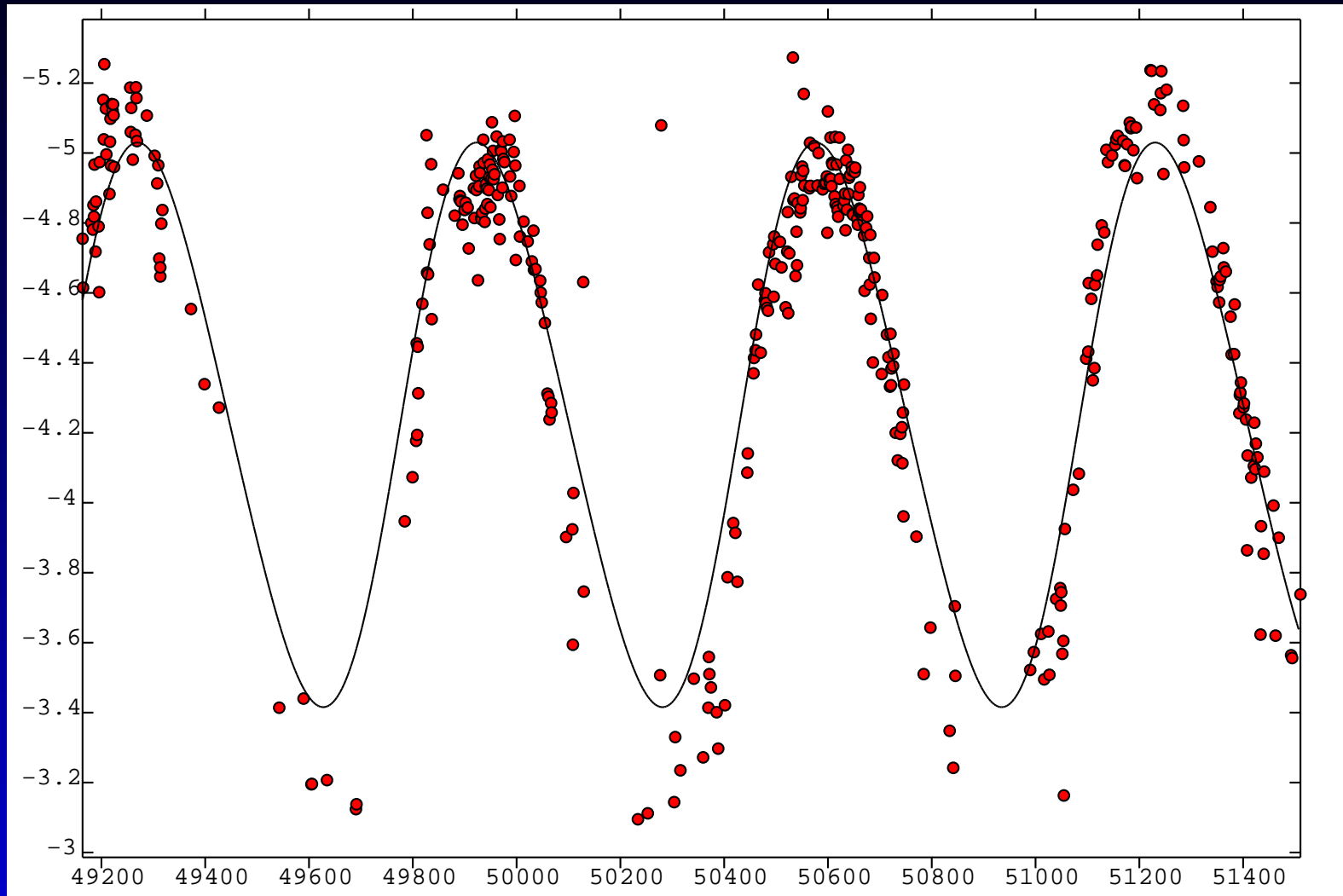


SMC 18:  $P = 1110$  d  
567, 355, 258 d

MACHO-Blue

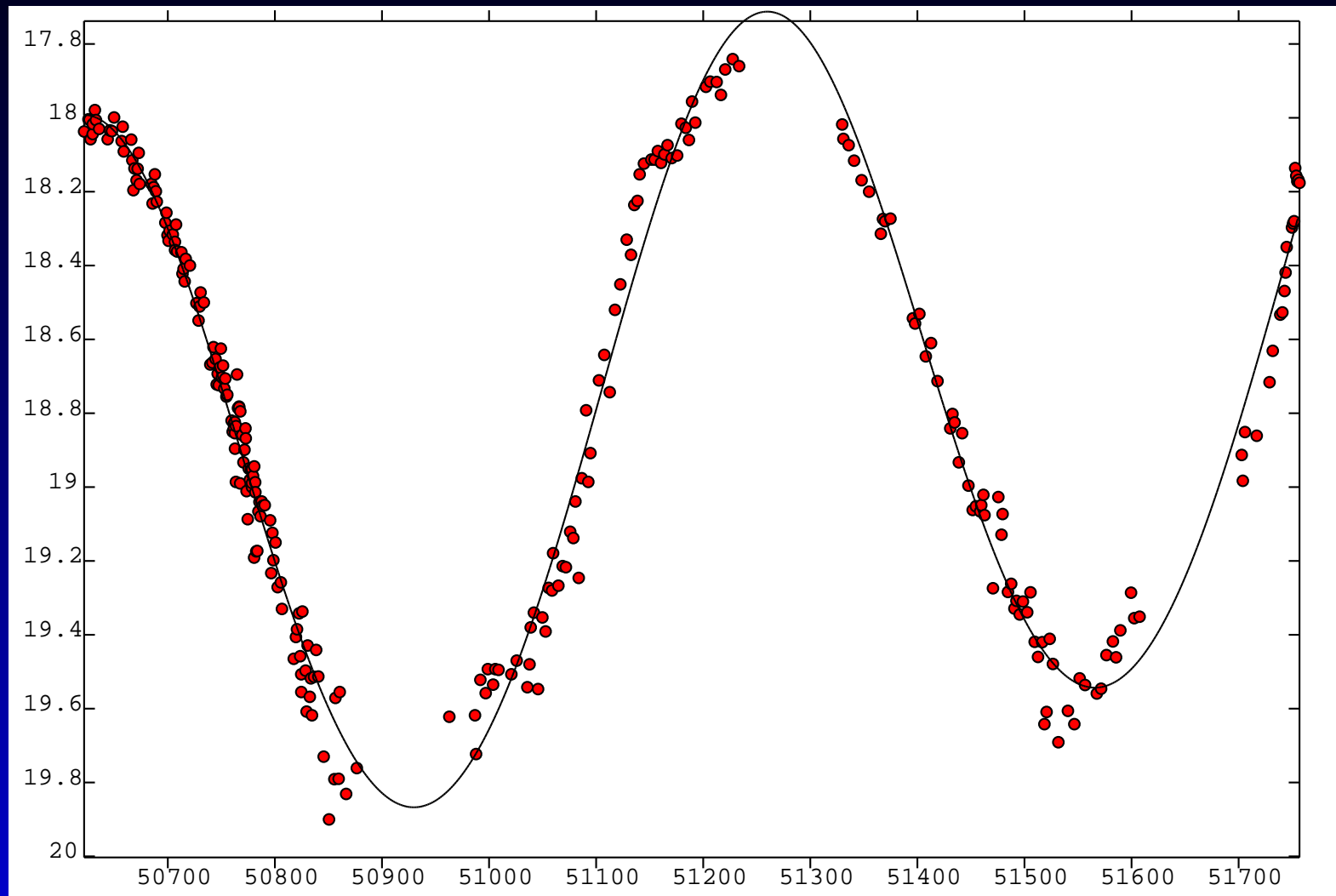


SMC 4:  $L = 30\,000 L_\odot$ ,  $\dot{M} = 1.0 \cdot 10^{-5} M_\odot \text{ yr}^{-1}$



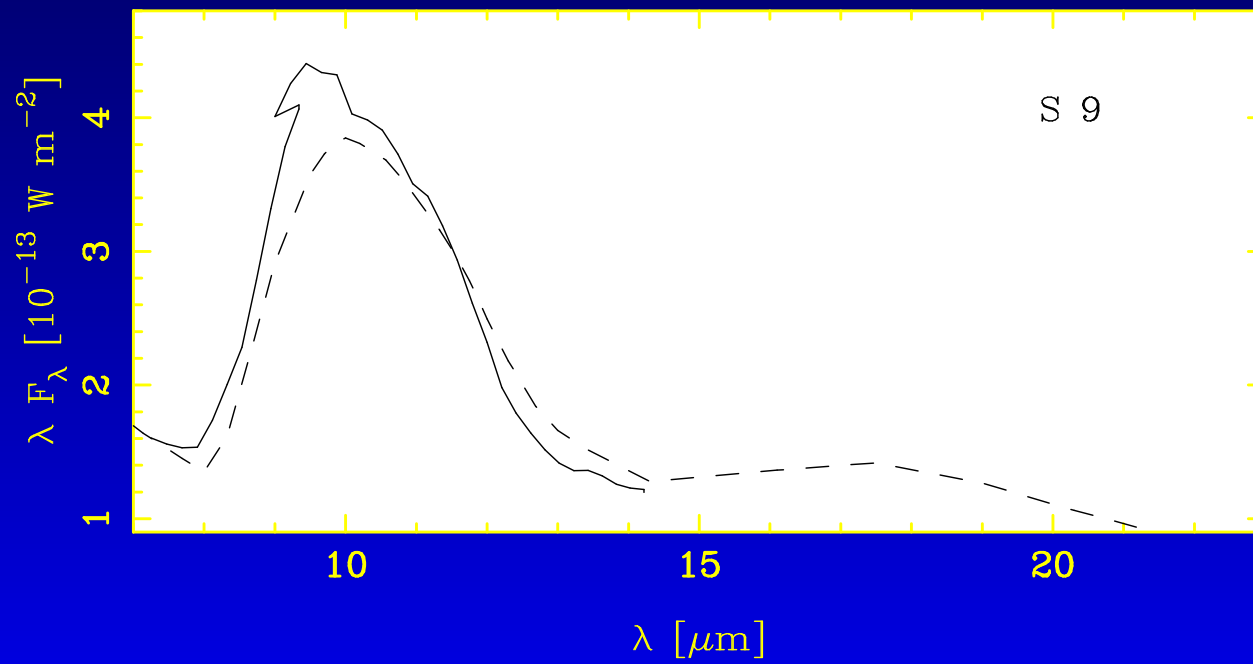
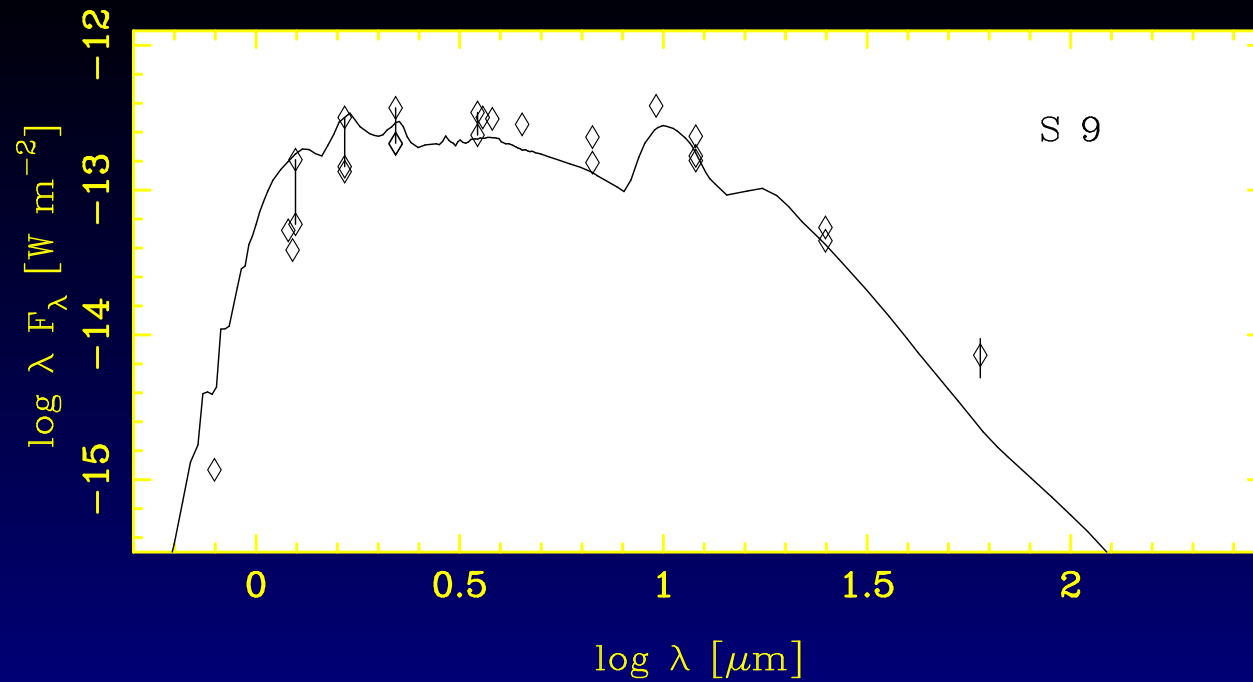
SMC 4:  $P = 654$  d  
326 d

MACHO-Red

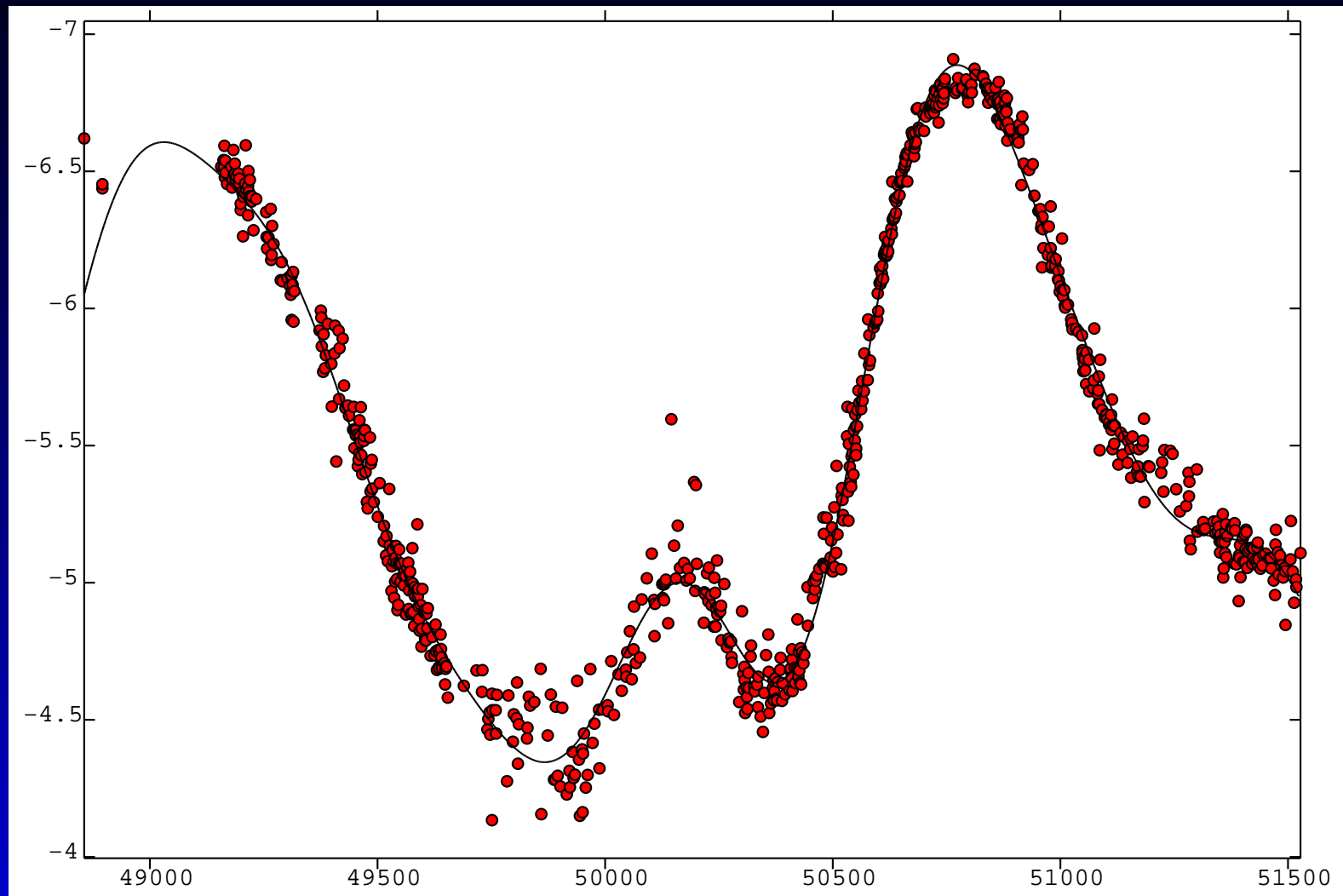


SMC 4:  $P = 636$  d

OGLE

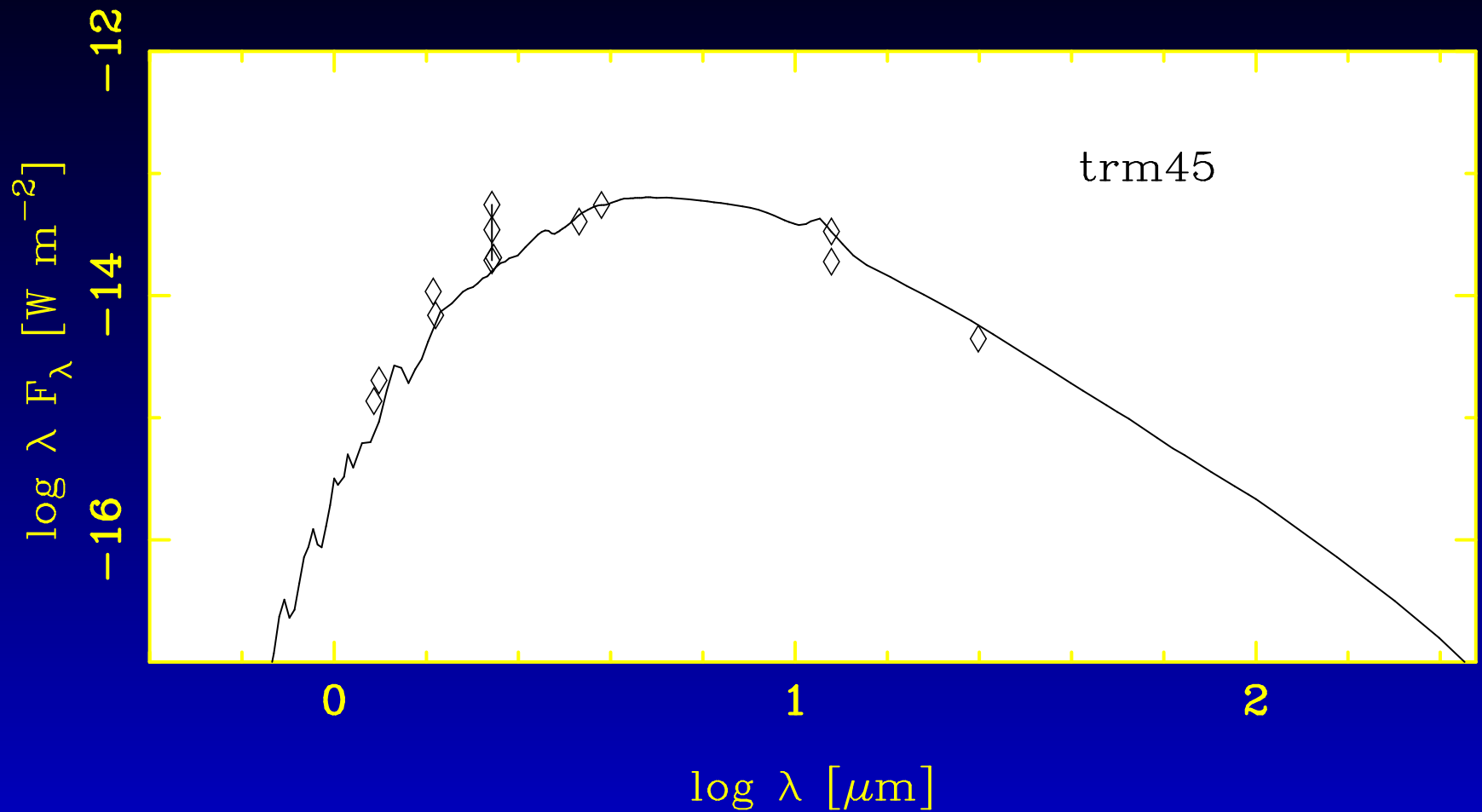


SMC 9:  $L = 72\,000 L_\odot$ ,  $\dot{M} = 6.0 \cdot 10^{-6} M_\odot \text{yr}^{-1}$



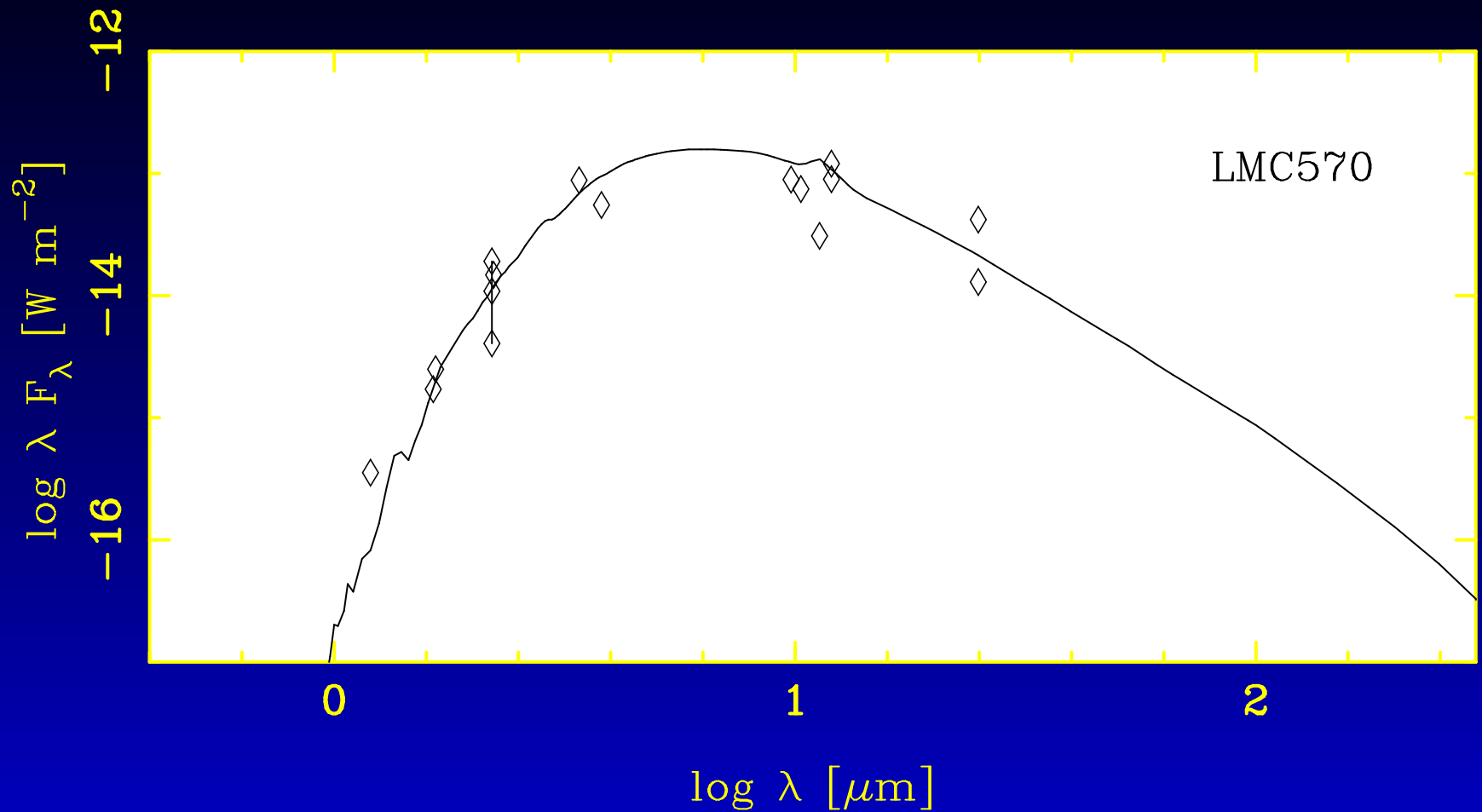
SMC 9:  $P = 1780$  d  
830, 620, 447 d

MACHO-Red



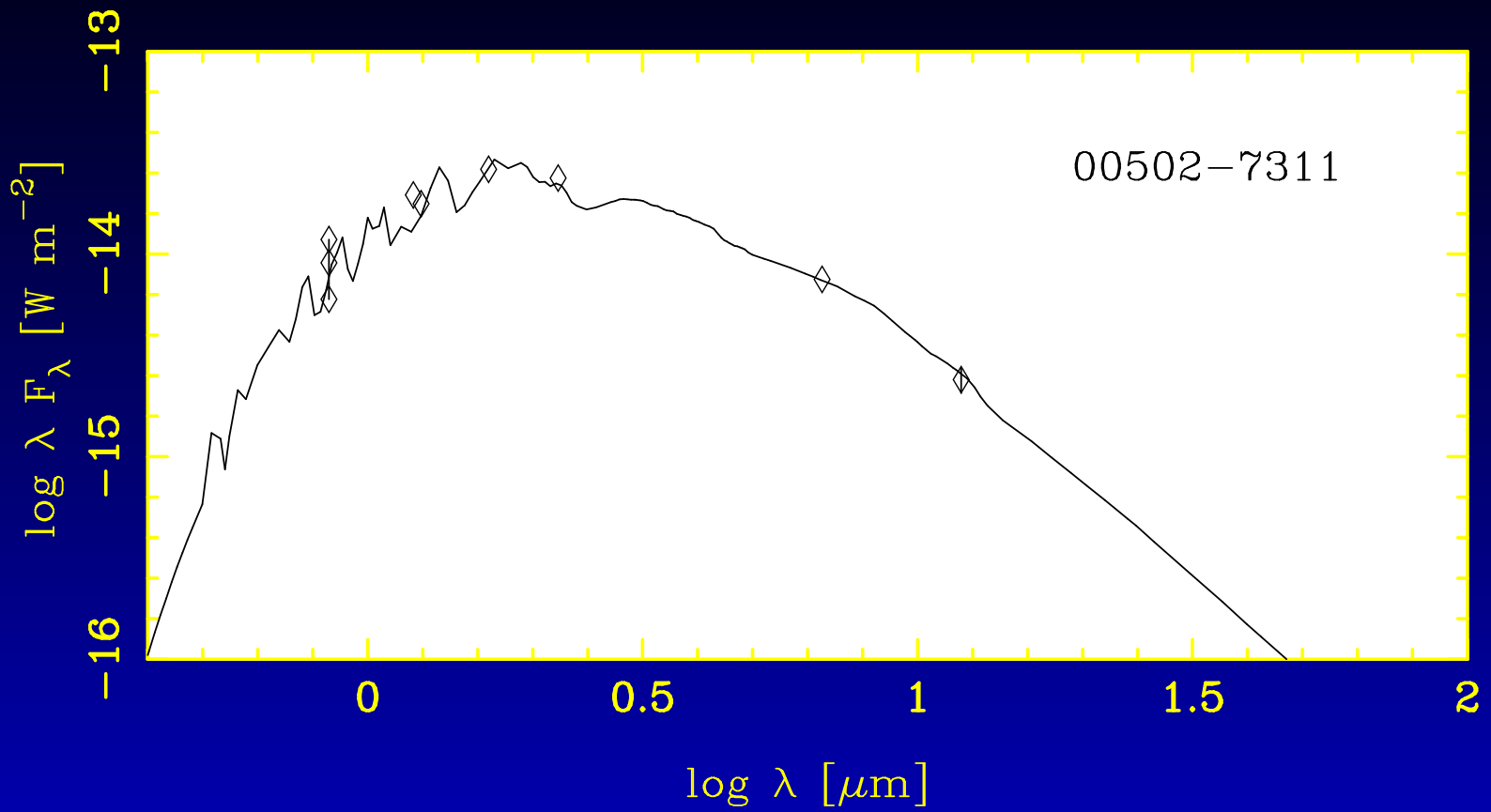
TRM 45:

$$L = 7600 L_\odot, \dot{M} = 5.2 \cdot 10^{-6} M_\odot \text{ yr}^{-1}, P = 570 \text{ d}$$

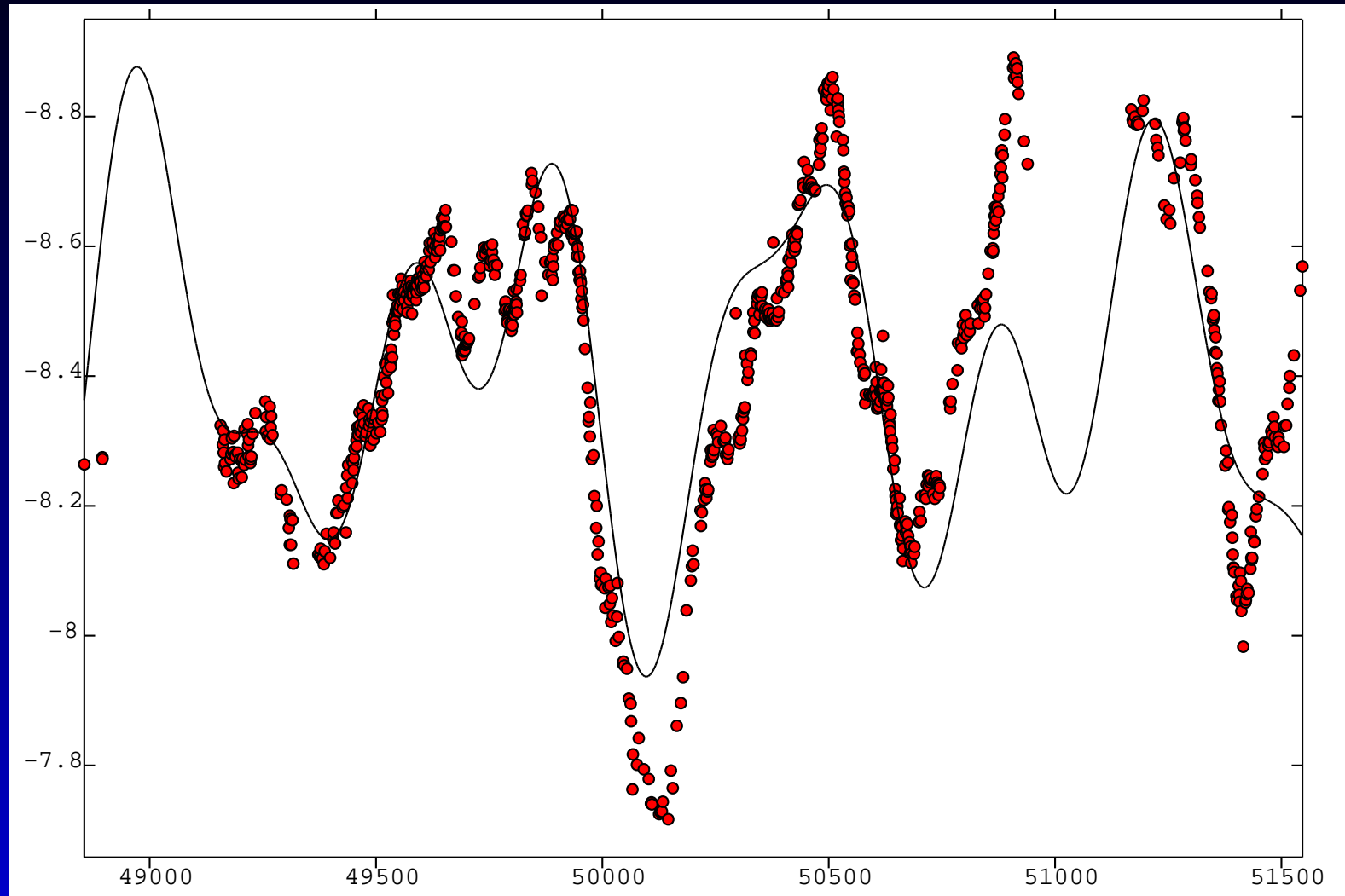


LMC 570/TRM 4:

$L = 18000 L_{\odot}$ ,  $\dot{M} = 1.3 \cdot 10^{-5} M_{\odot} \text{ yr}^{-1}$ ,  $P = 900 \text{ d}$

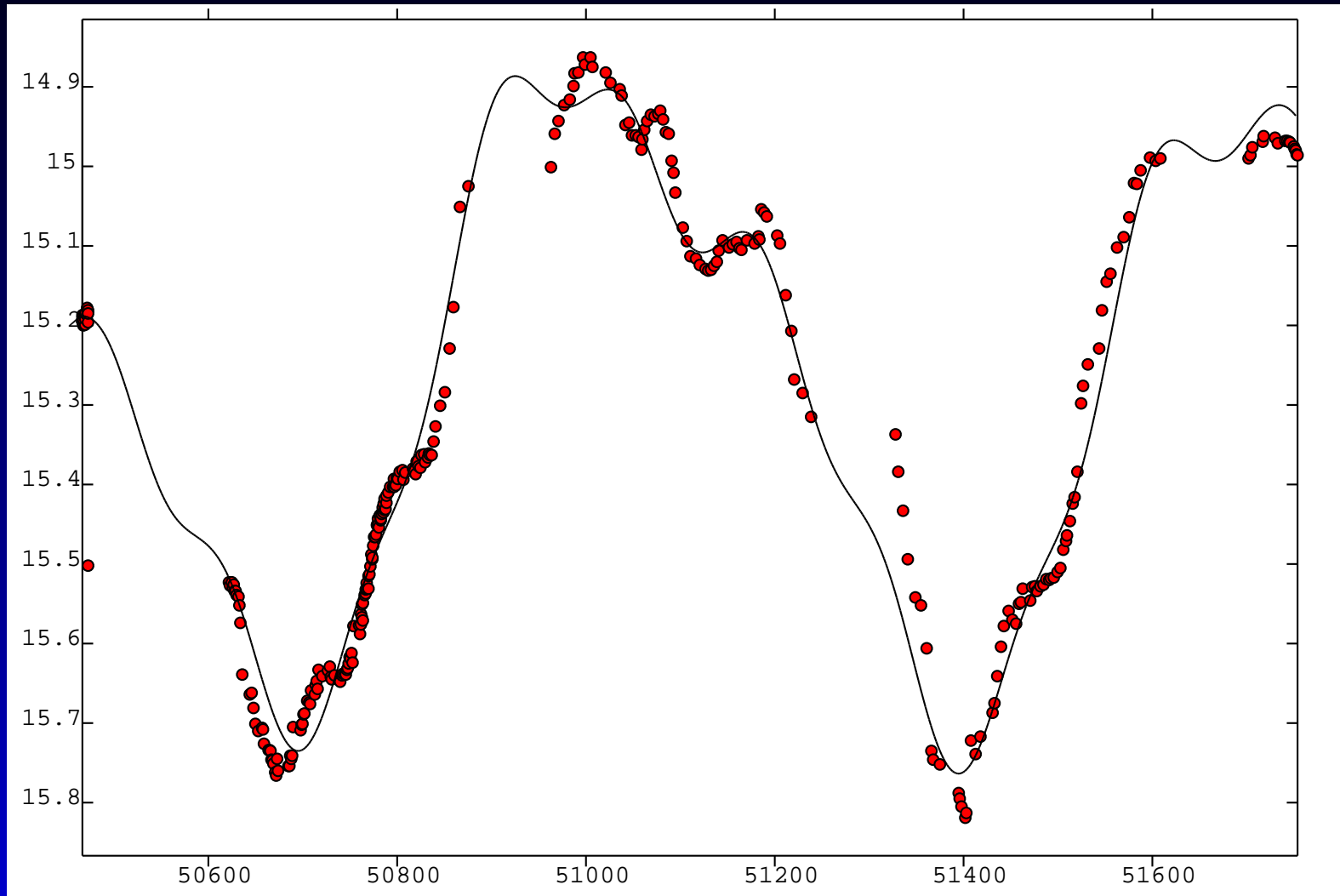


$$L = 5000 L_\odot, \dot{M} = 4.0 \cdot 10^{-7} M_\odot \text{ yr}^{-1}$$



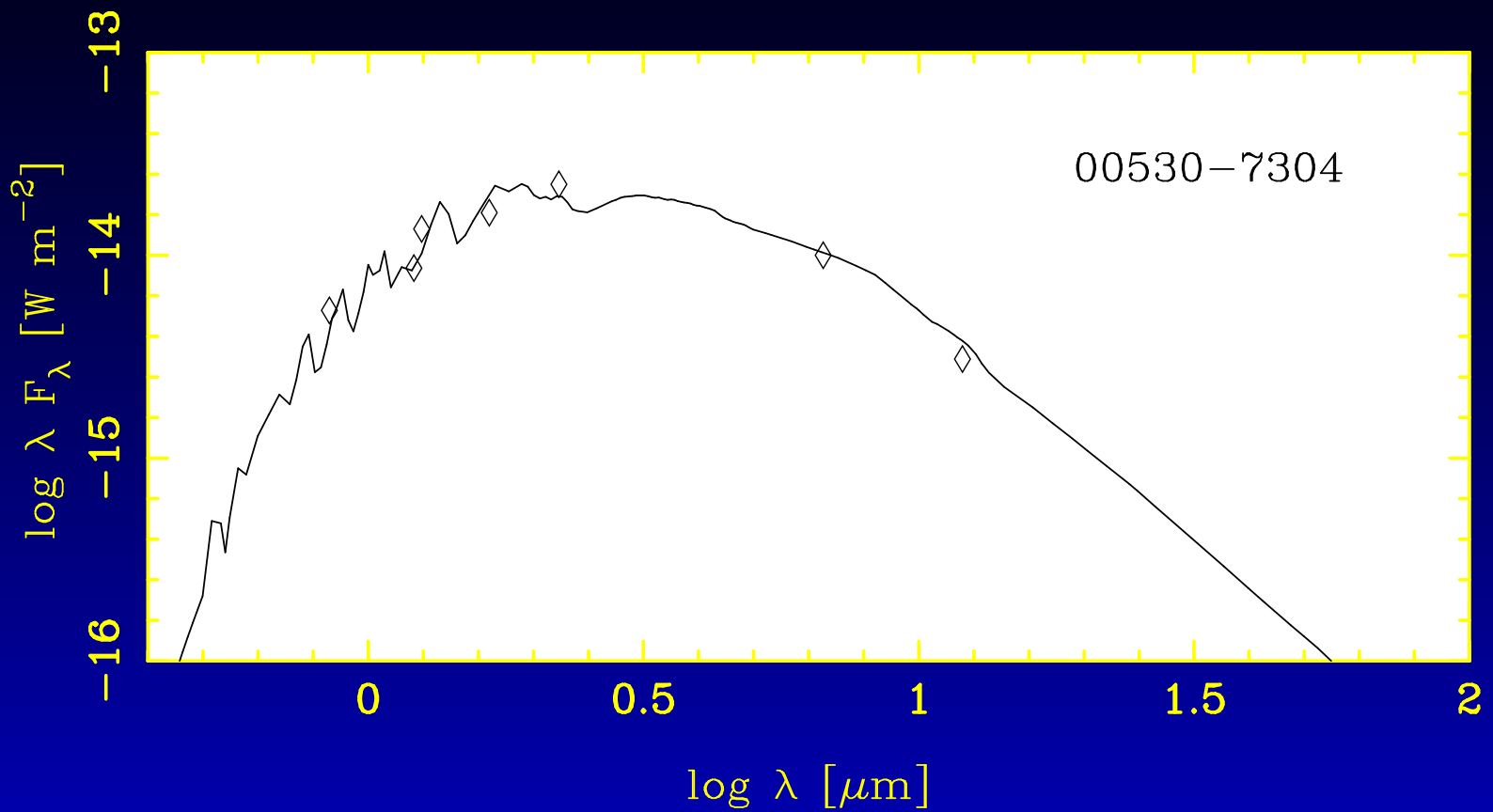
$P = 717 \text{ d}$   
 $464, 322 \text{ d}$

MACHO-Red

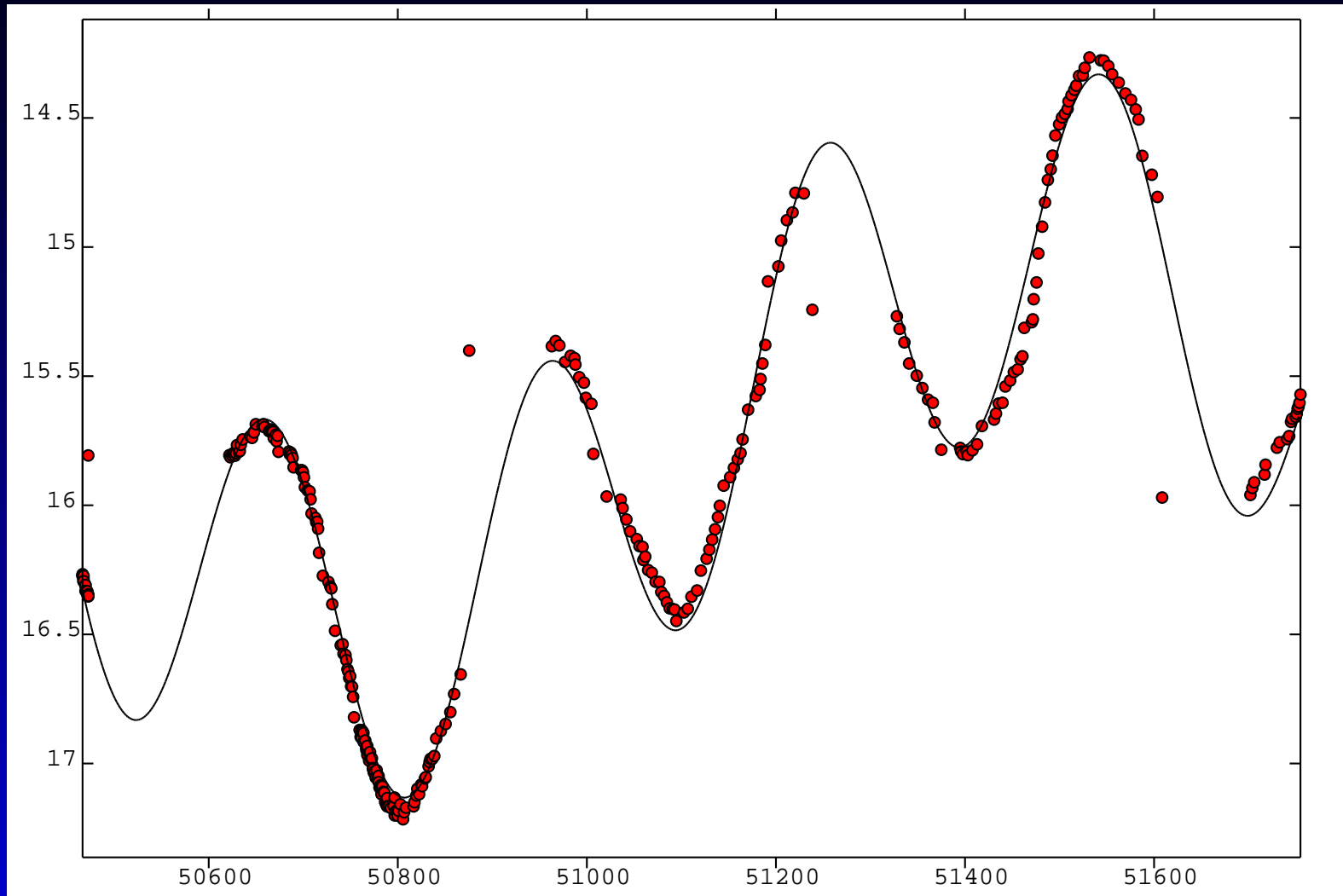


$P = 725 \text{ d}$

OGLE

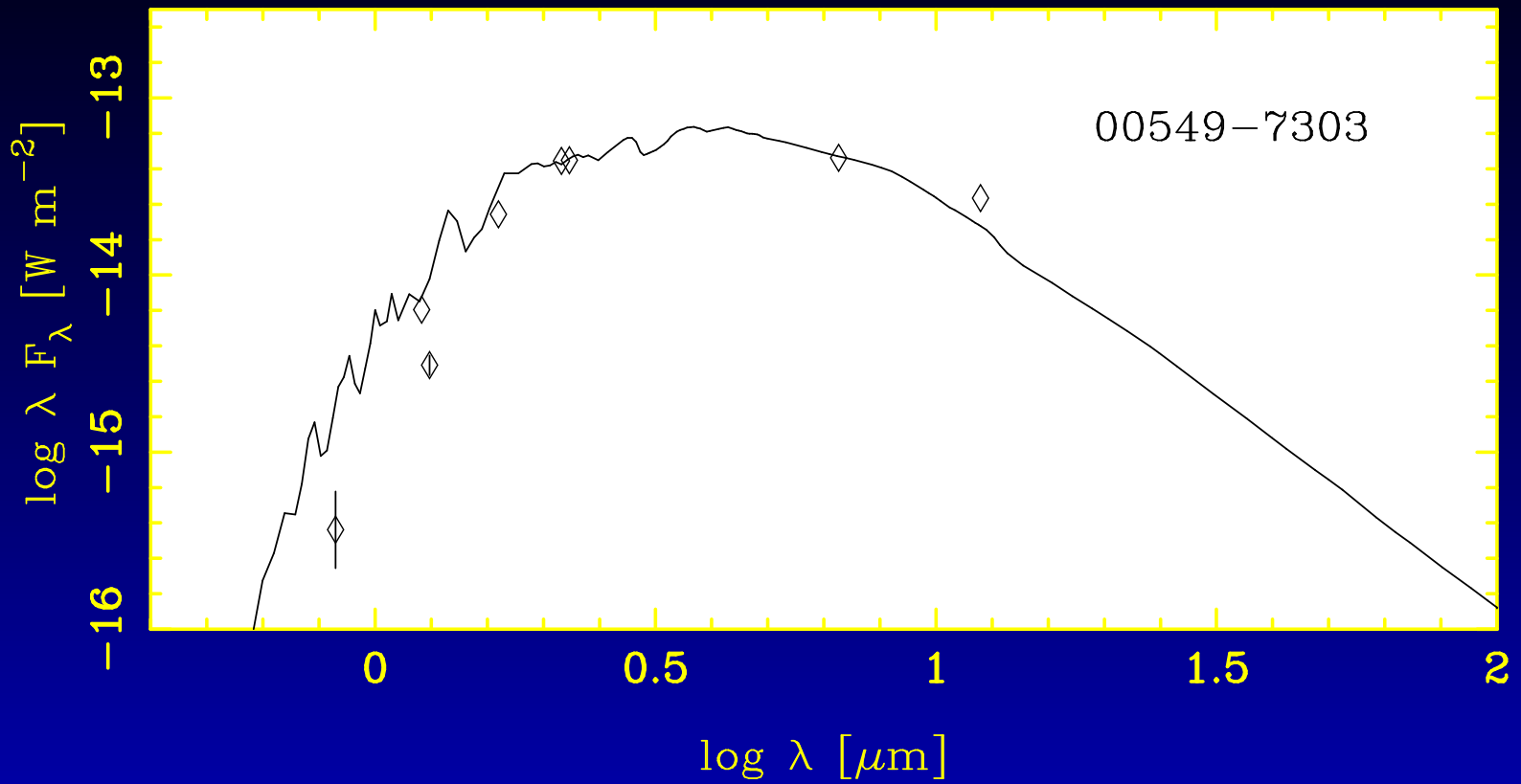


$$L = 4700 L_\odot, \dot{M} = 7.3 \cdot 10^{-7} M_\odot \text{ yr}^{-1}$$

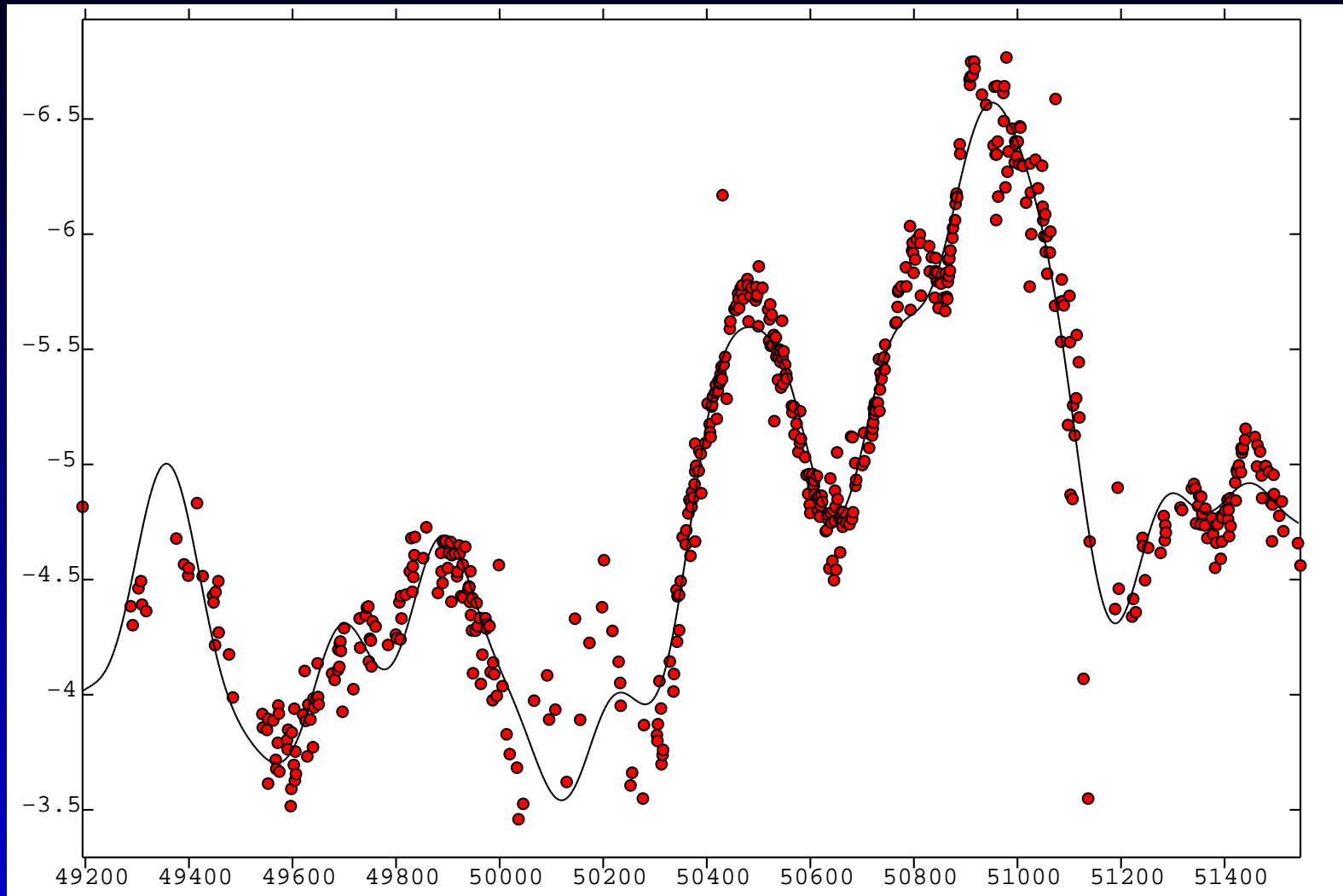


$P = 292 \text{ d}$   
 $1448 \text{ d}$

OGLE

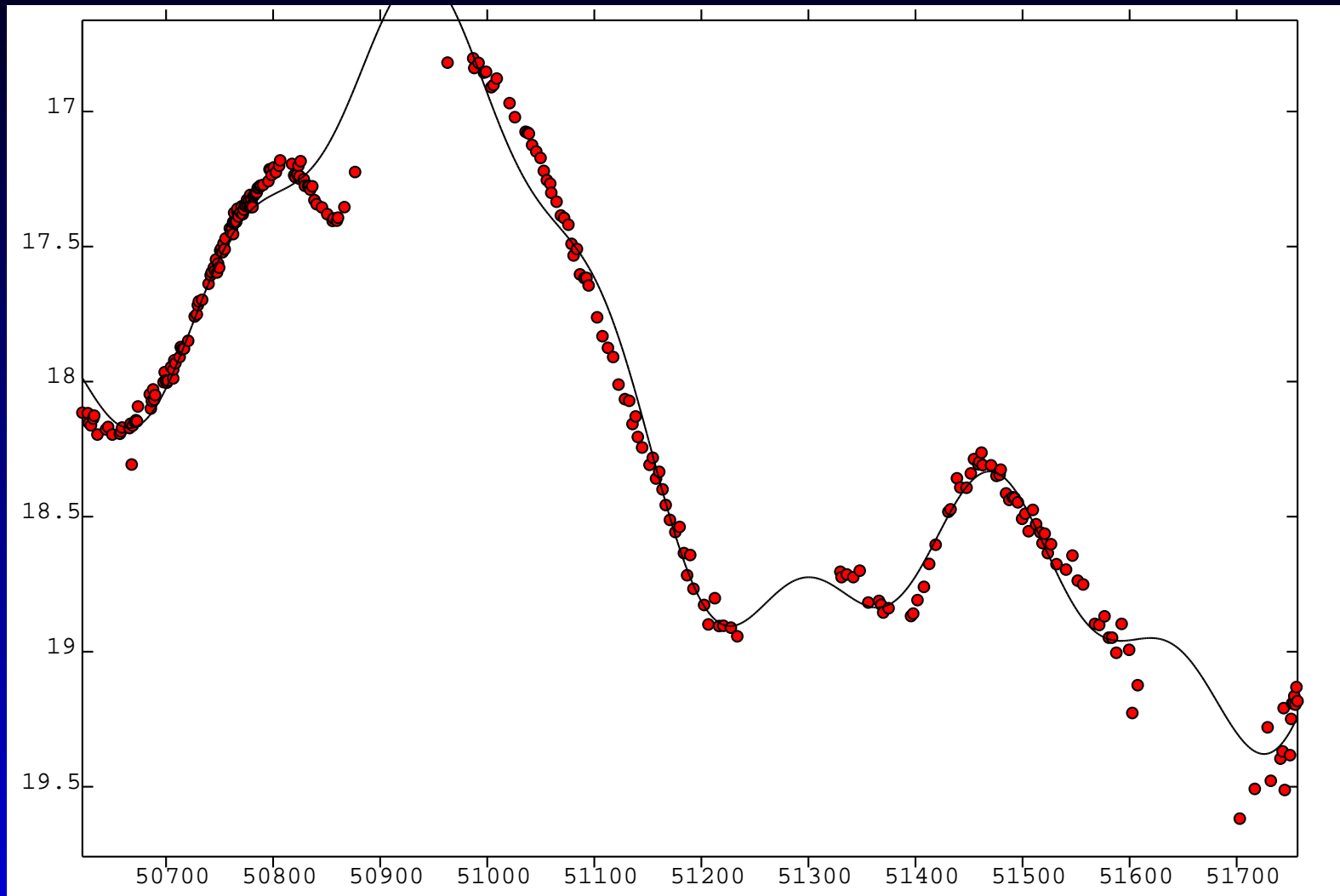


$$L = 13700 L_\odot, \dot{M} = 2.8 \cdot 10^{-6} M_\odot \text{ yr}^{-1}$$



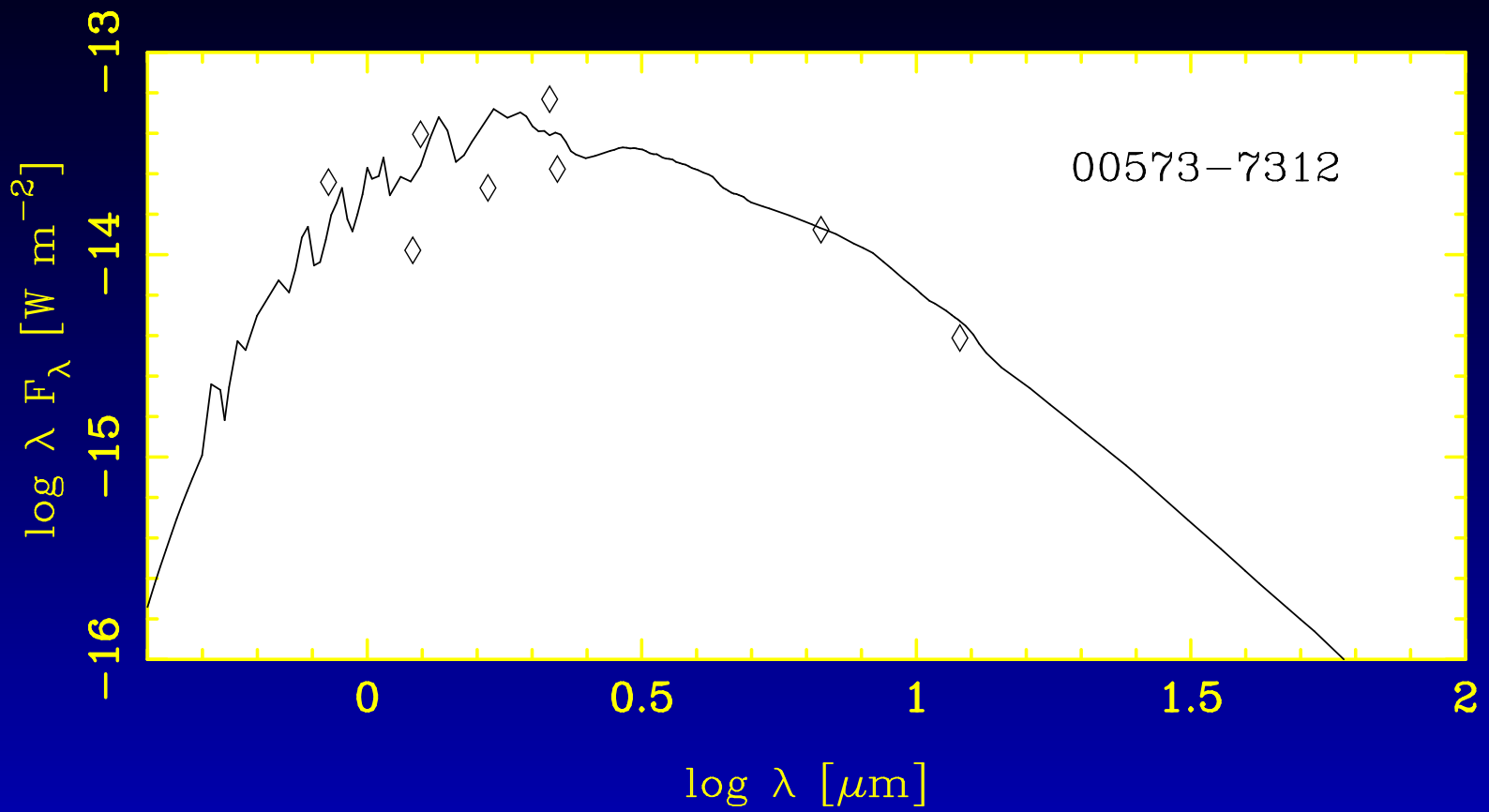
$P = 536$  d  
1192, 2525, 417, 272 d

MACHO-Red

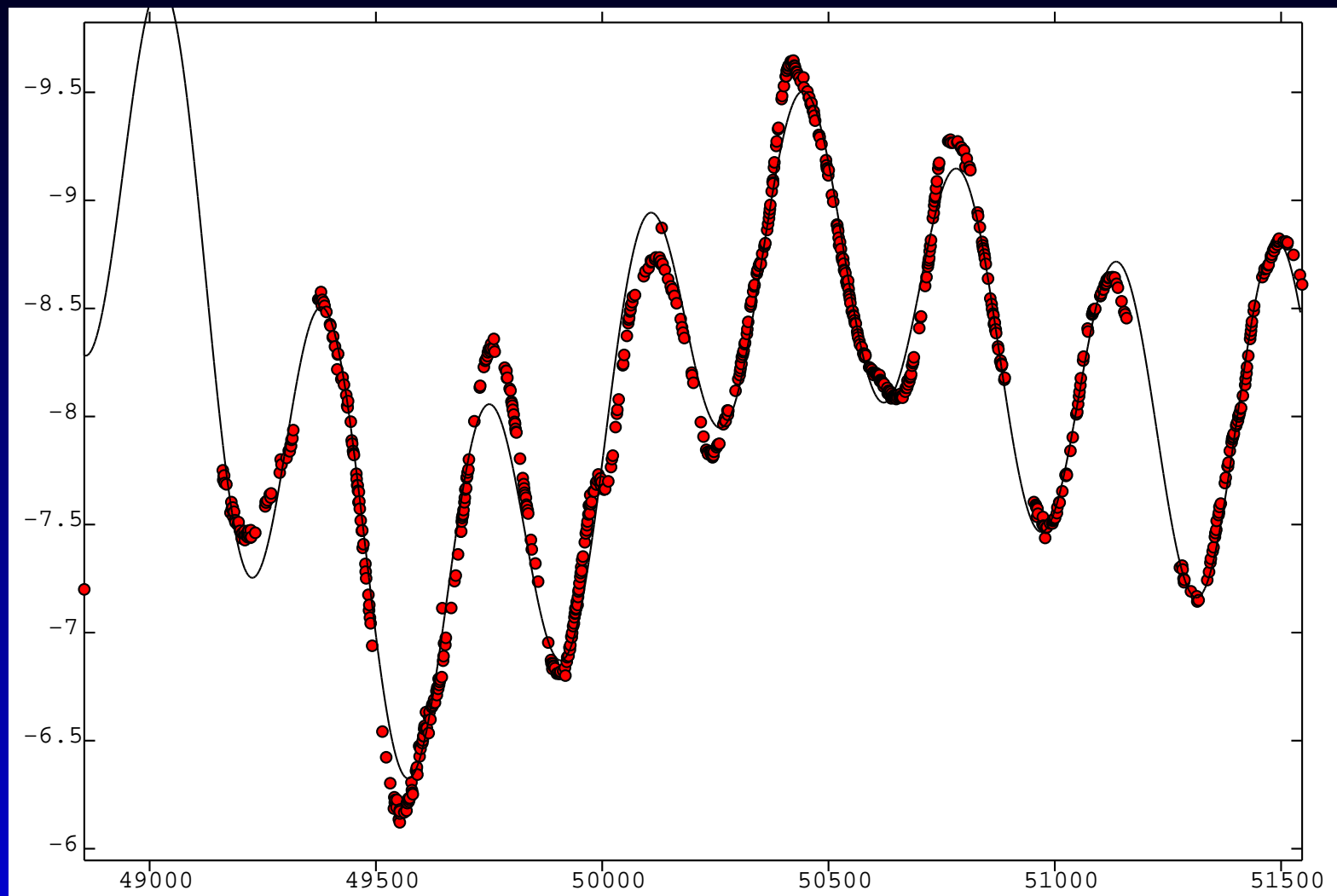


$P = 524 \text{ d}$

OGLE

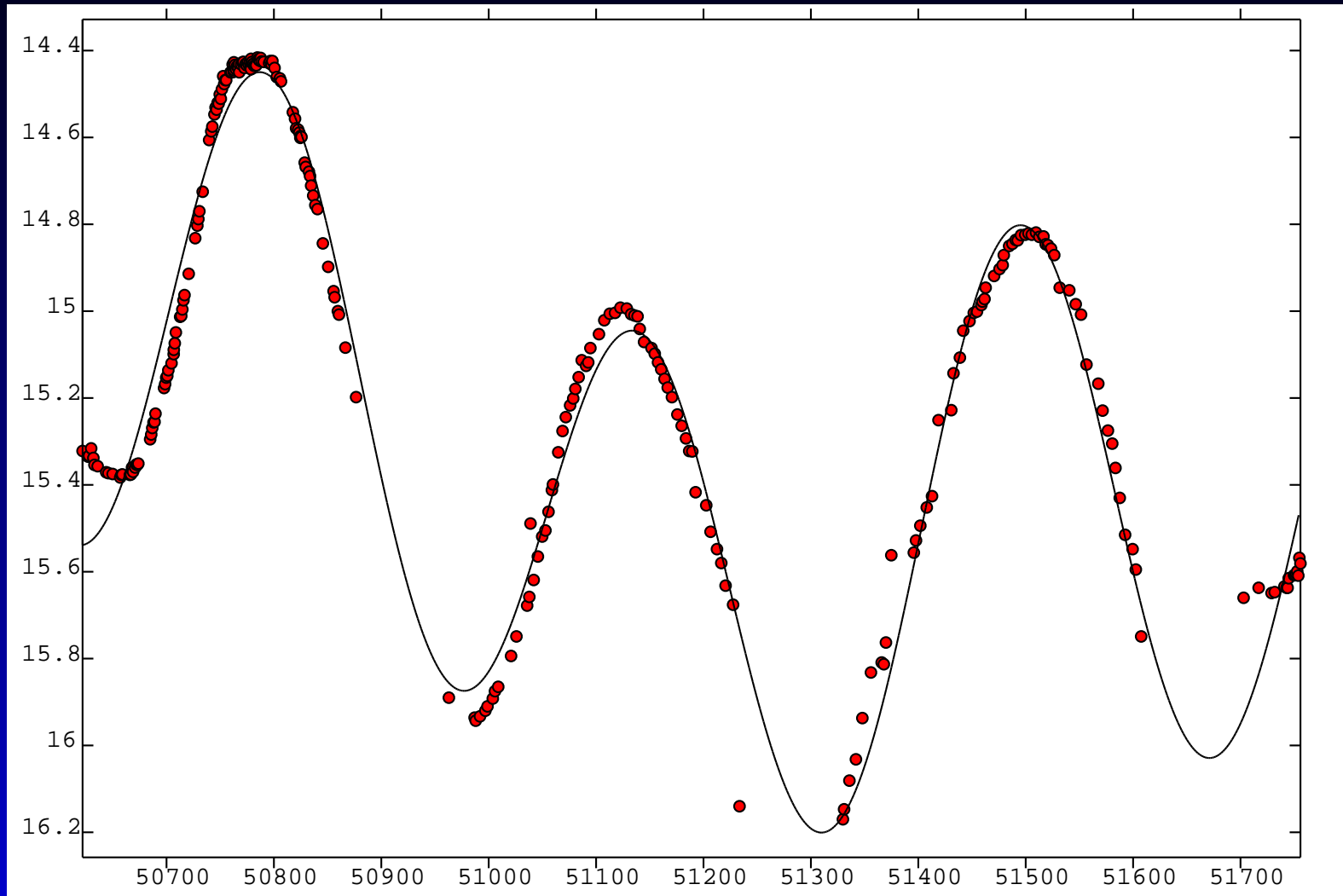


$$L = 9000 L_{\odot}, \dot{M} = 5.5 \cdot 10^{-7} M_{\odot} \text{ yr}^{-1}$$



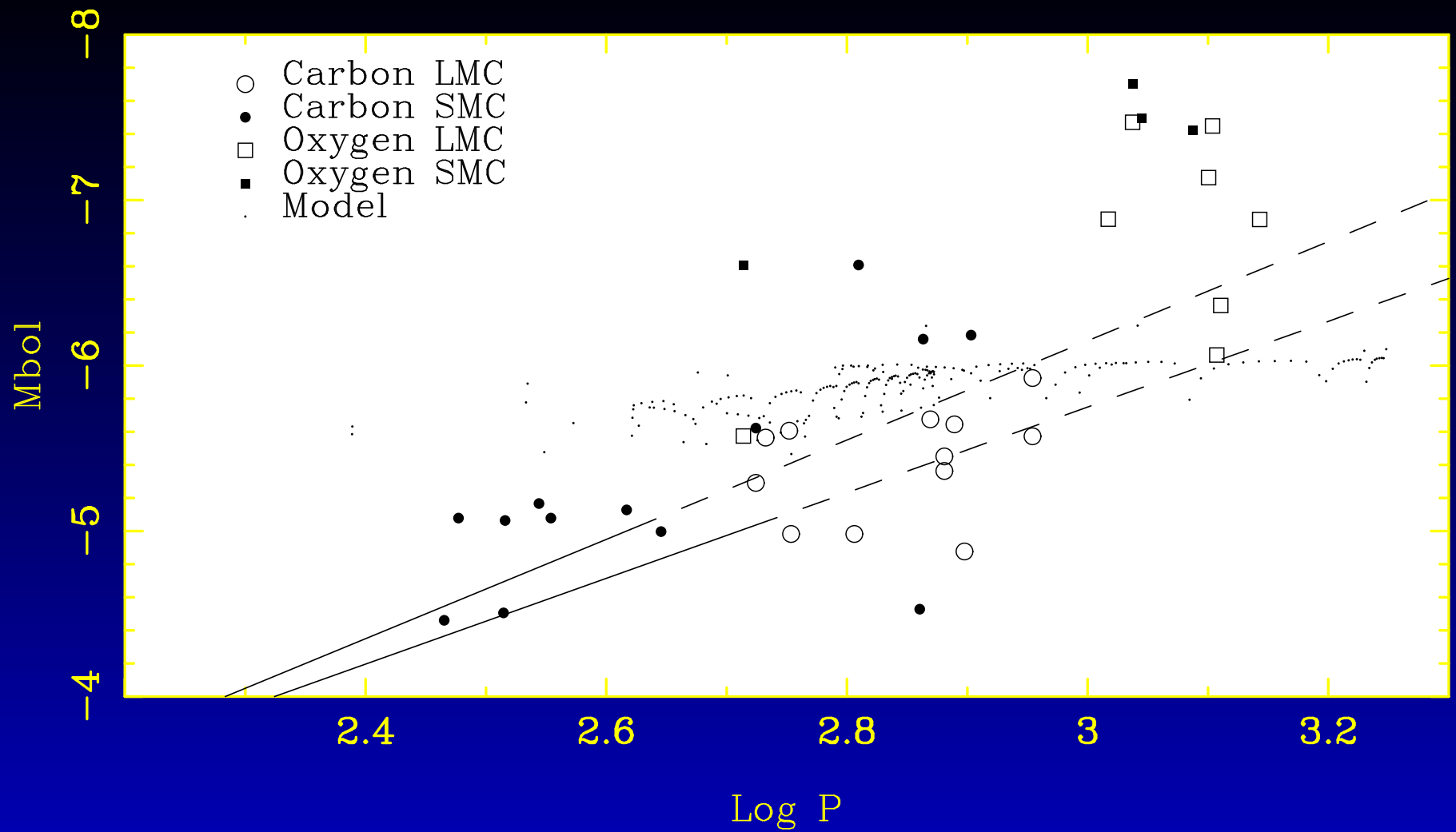
$P = 349 \text{ d}$   
2163, 1420 d

MACHO-Red



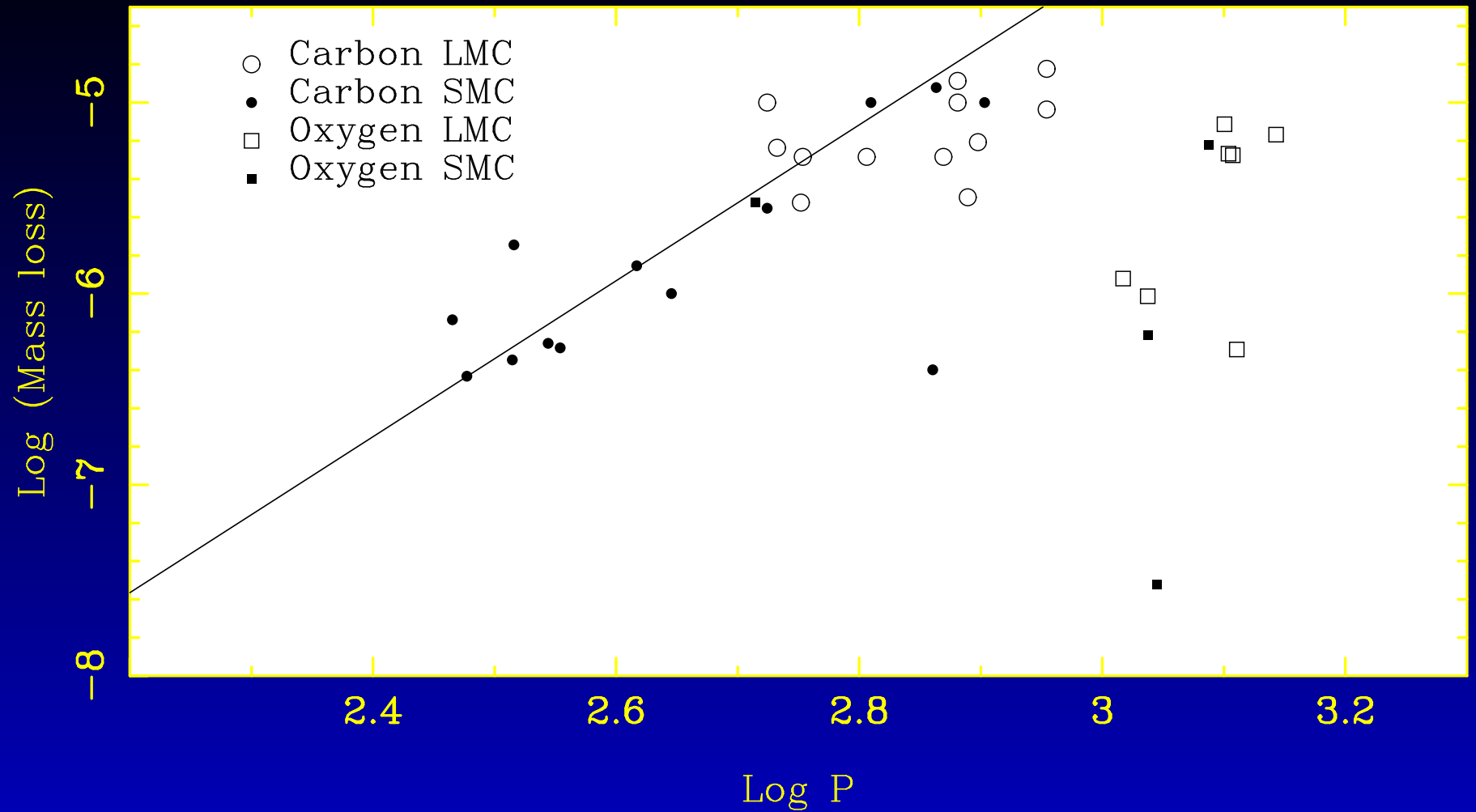
$P = 352 \text{ d}$

OGLE



Model: synthetic AGB evolution model of  
Wagenhuber & Groenewegen (1998)

PL-relations of Groenewegen & Whitelock (1996),  
Feast et al. (1989)



Relation of Groenewegen et al. (1998)

# Conclusions

Carbon-star model spectra

- missing opacity, or,  $T_{\text{eff}} < 2600\text{K}$

Lightcurves

- non-Sinusoidal behaviour seems to be the norm

$P - L$ -relation

- Scatter

$P - \dot{M}$ -relation

- Carbon stars seem to follow Galactic relation