Mass-losing and Pulsating AGB stars in the Magellanic Clouds

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Overview

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

Overview: Mass-losing Stars

- pre-IRAS
- IRAS

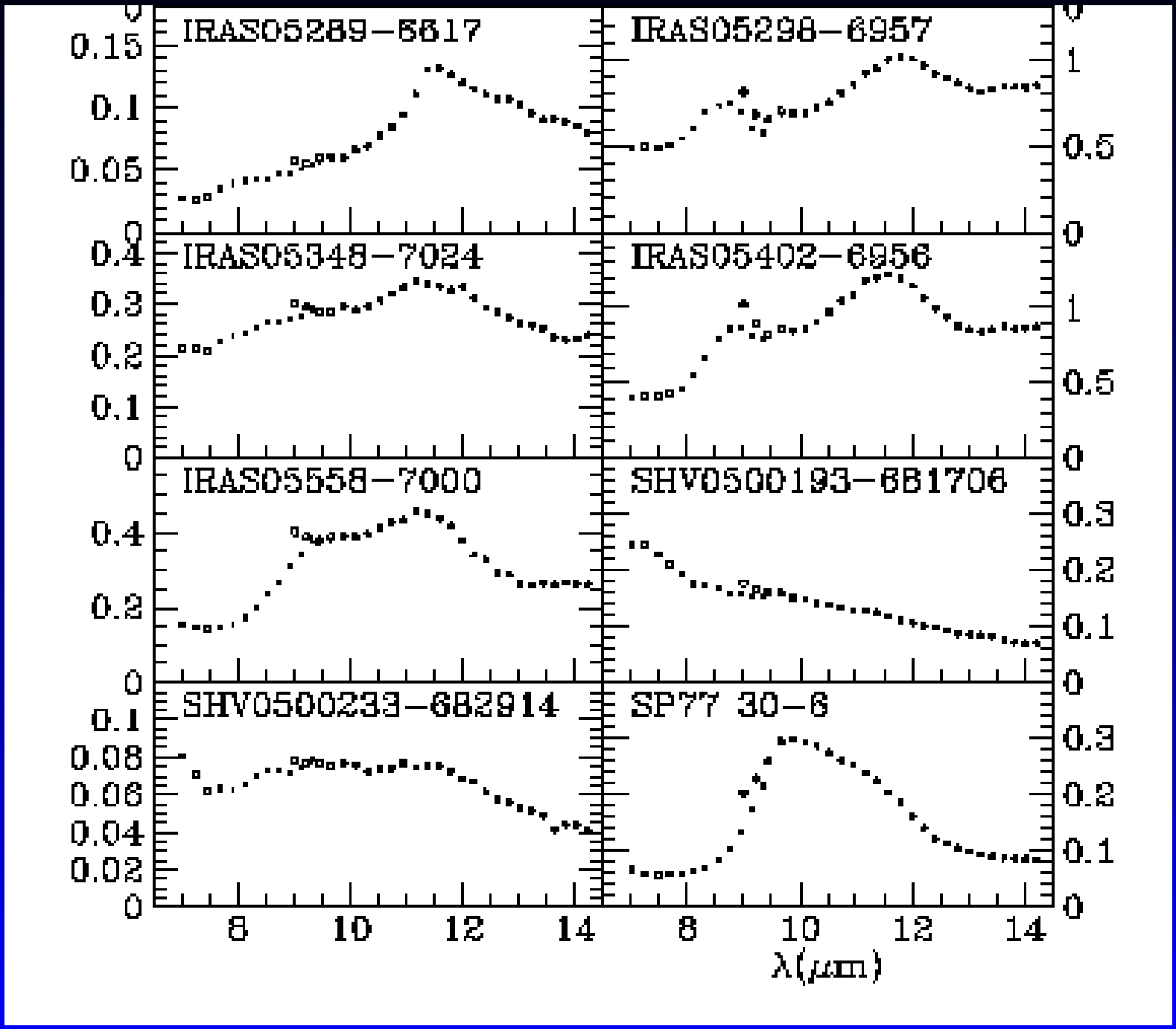
  Whitelock et al. 1989: 5 SMC
  Reid et al. 1990: 13 LMC AGB candidates
  Reid 1991: NIR on 13 LMC
  Wood et al. 1992: 6 OH/IR
  Tanabe et al. 1997: NIR of 9 MC clusters
  Loup et al. 1997: 198 candidate AGB stars
  Zijlstra et al. 1996: 60 JHKLN
  van Loon et al. 1997, 1998: JKN of 30 LMC
  Groenewegen & Blommaert 1998:
  JHK photometry of 30 SMC IRAS objects

Overview: Mass-losing Stars

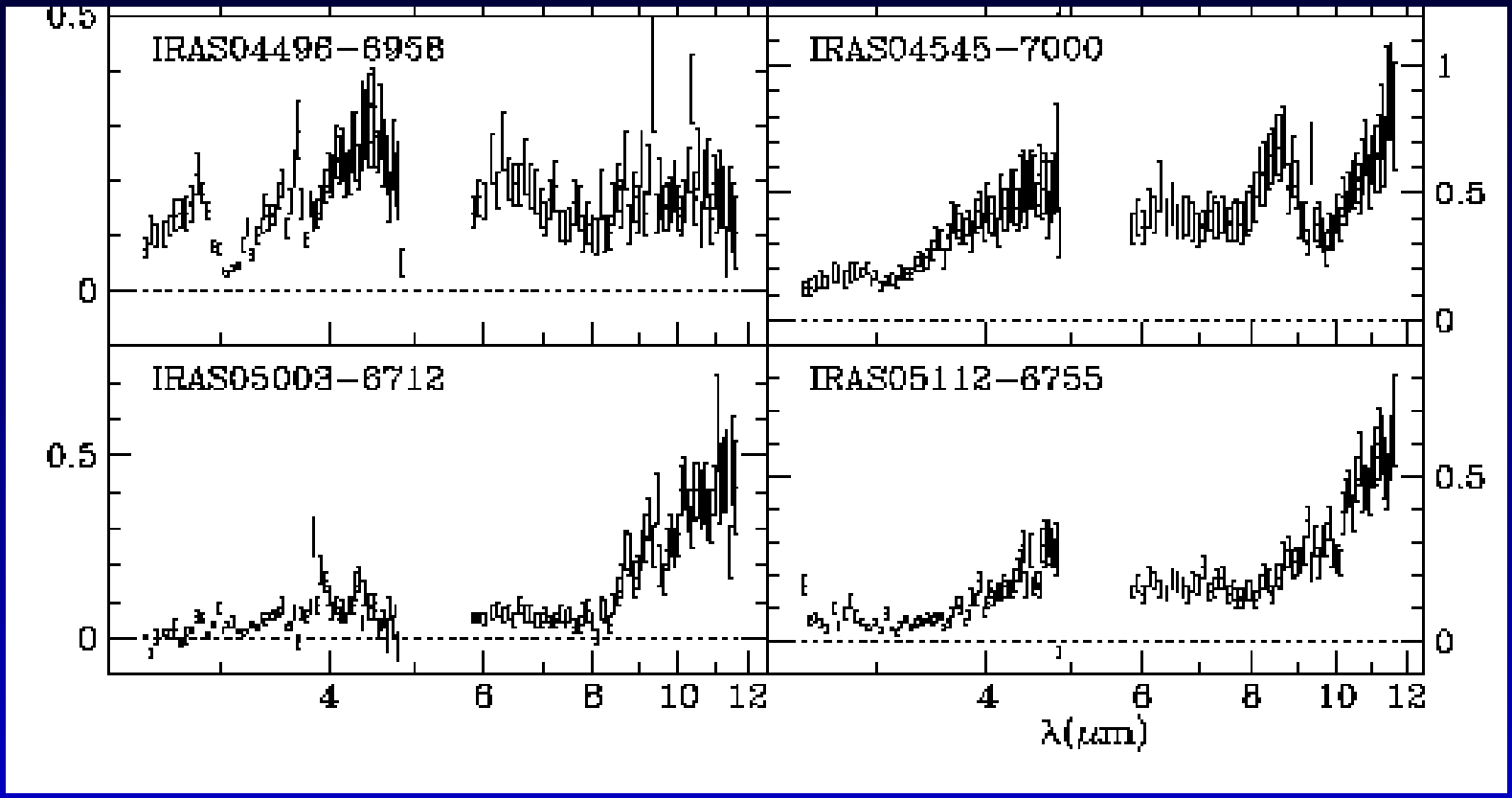
- ISO

  Trams et al. 1999: 57 IRAS LMC sources
  12 μm (CAM/PHT), 25 & 60 μm (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
  Kucinskas 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 suvey

Overview: Pulsating Stars

- pre-IRAS (optical/IR Monitoring)

  Payne-Gaposhkin: 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

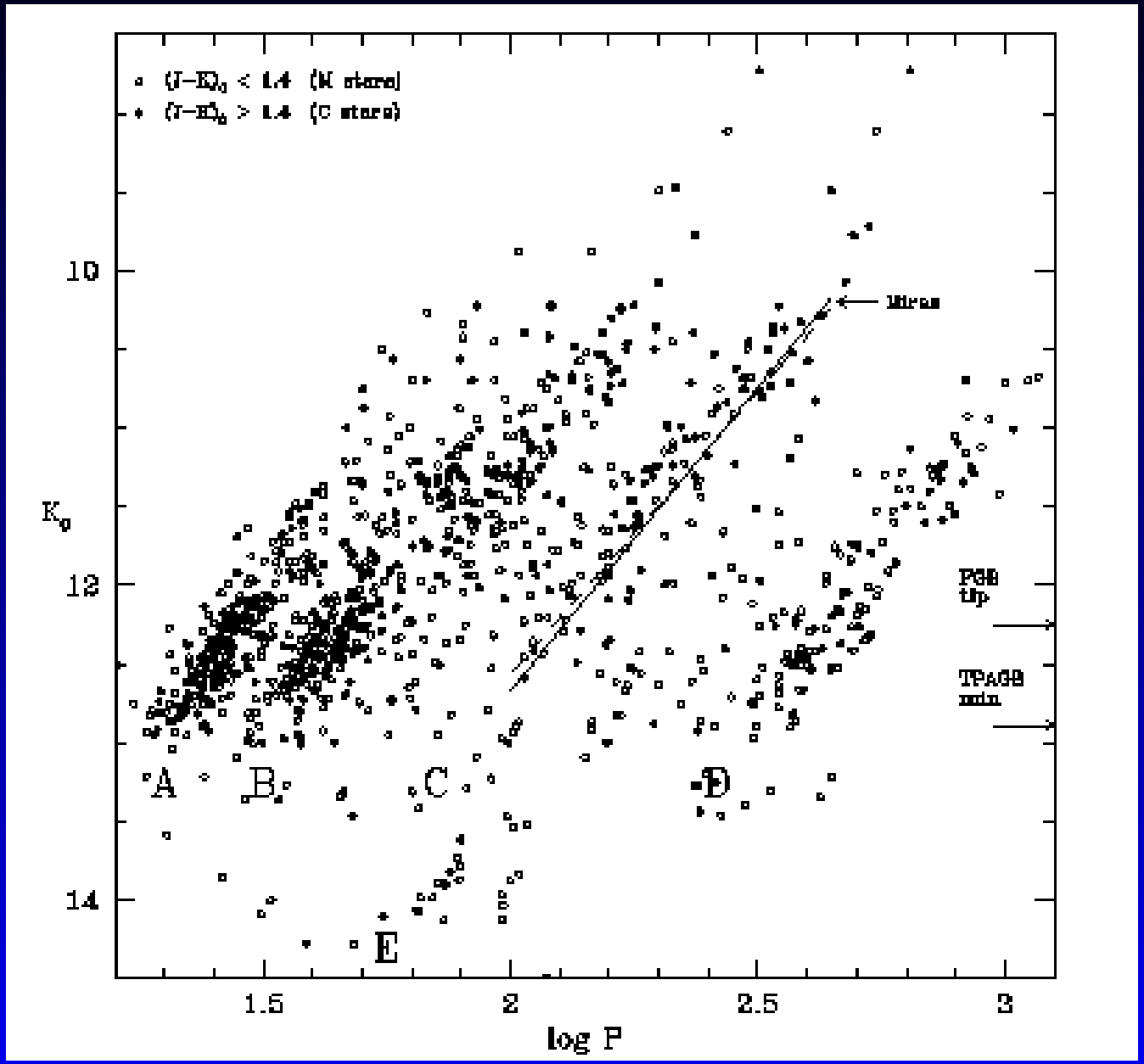
- IRAS-related

  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

Wood 2000


(J−K)0 < 1.4 (M stars)
(J−K)0 > 1.4 (C stars)
Mira
PAGB tip
TP-AGB bottom
A
B
C
D
E
10
12
14
K0
1.5
2
2.5
3
log P

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 $J-K$

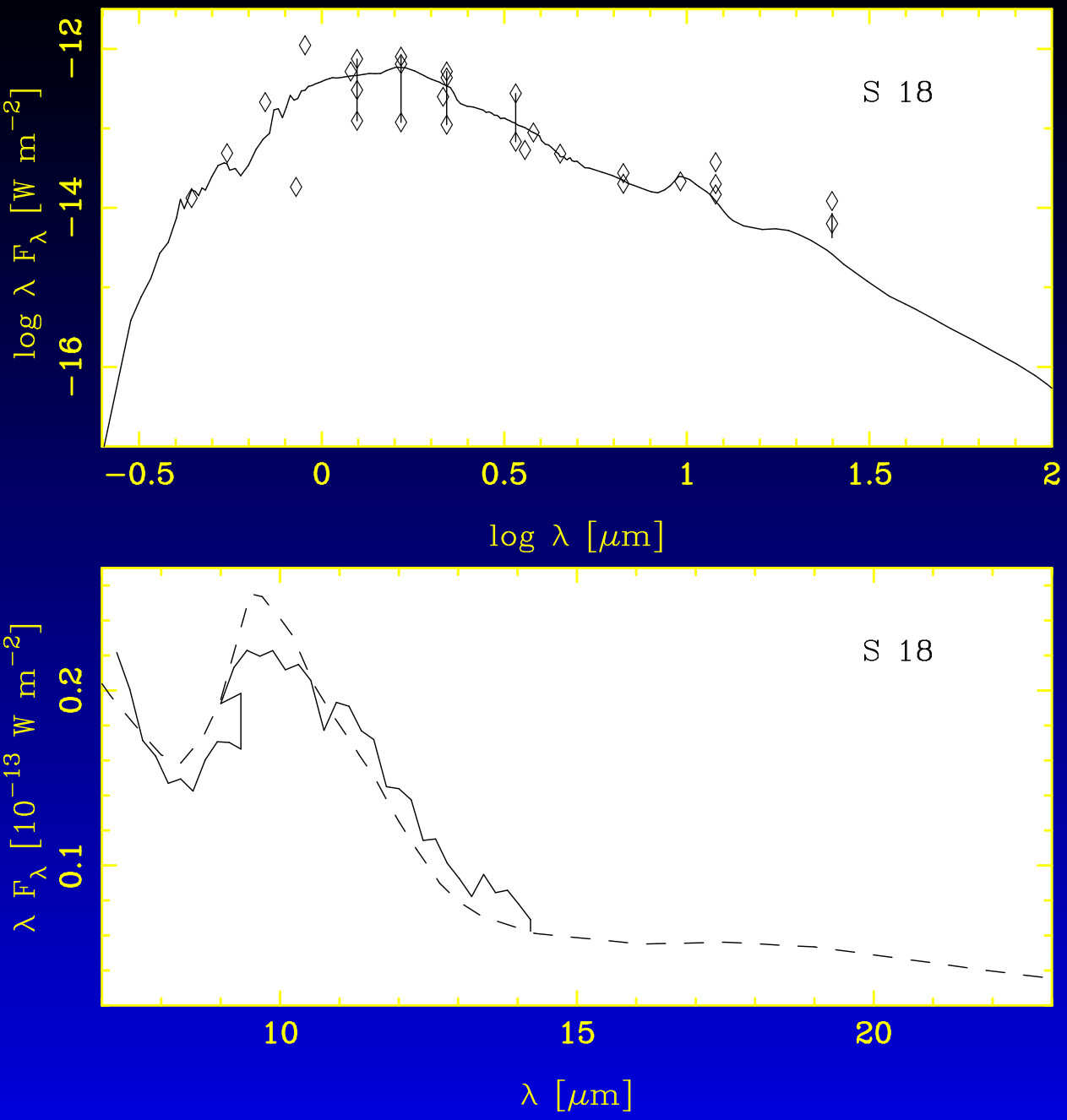
Cross-correlate improved positions with OGLE & MACHO

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

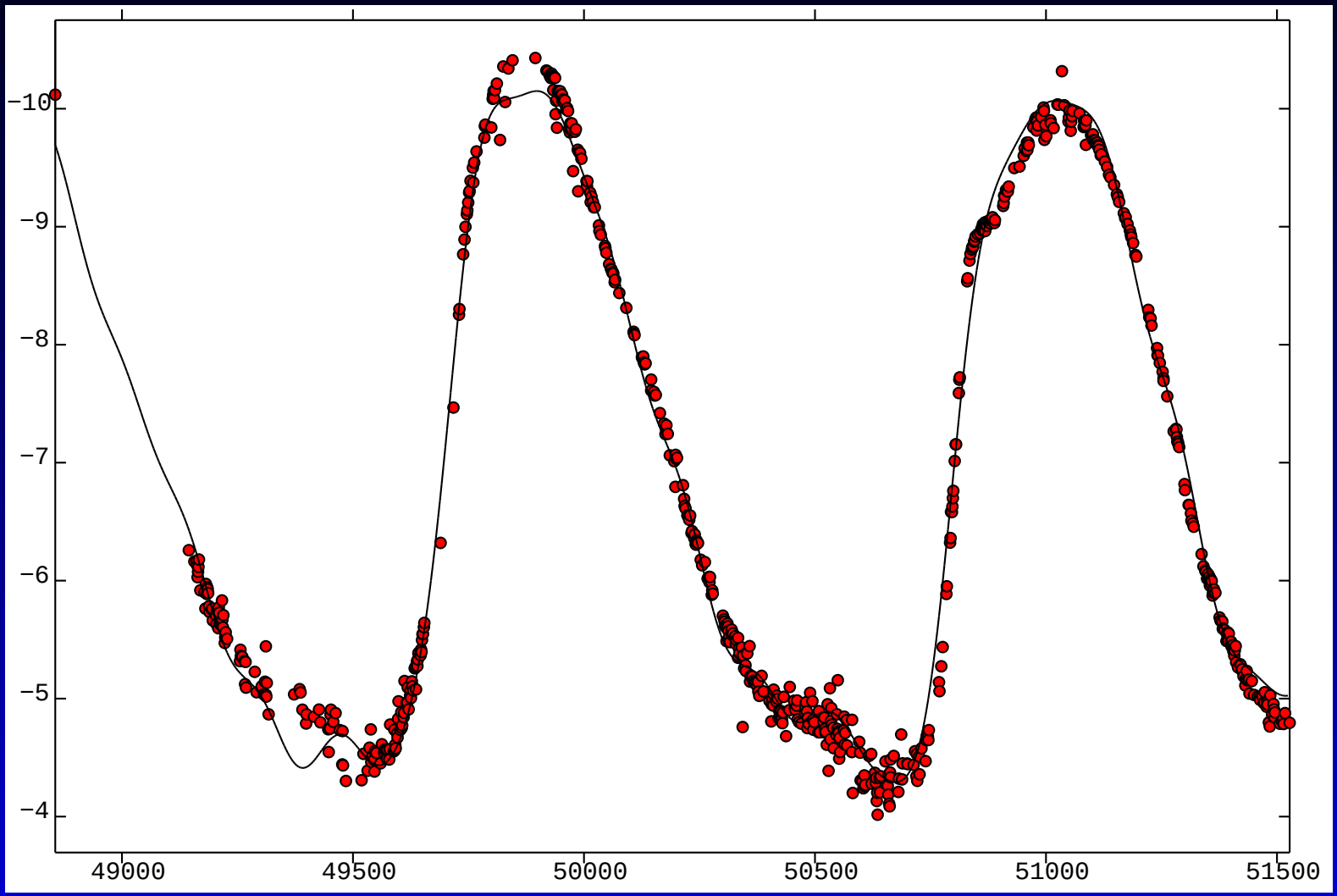
Dust radiative transfer fits to SED

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

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

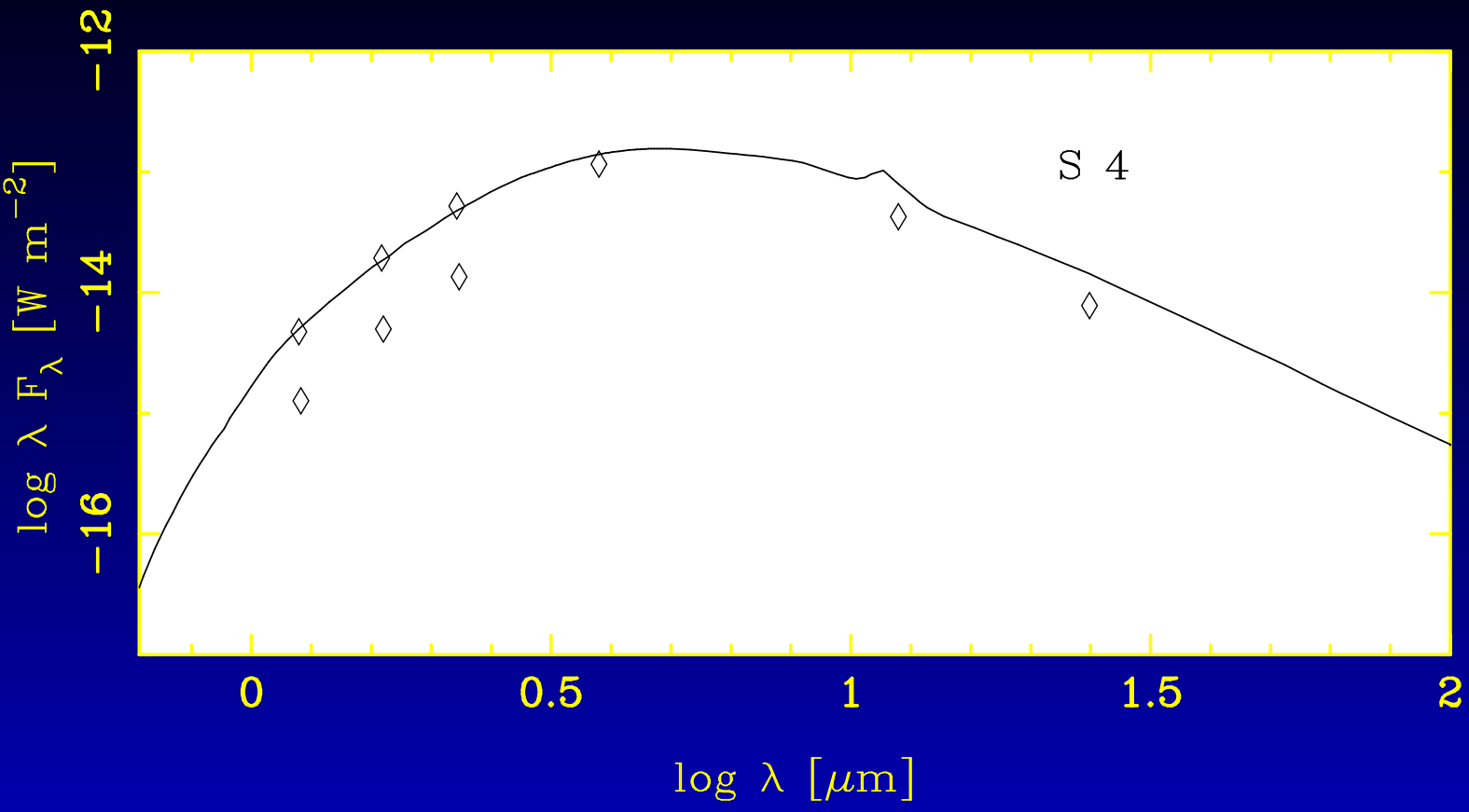


SMC 18: L = 77 000 $L_\odot$, $\dot{M}$= 3.0 $\cdot 10^{-8}$ $M_\odot$ yr^{-1}

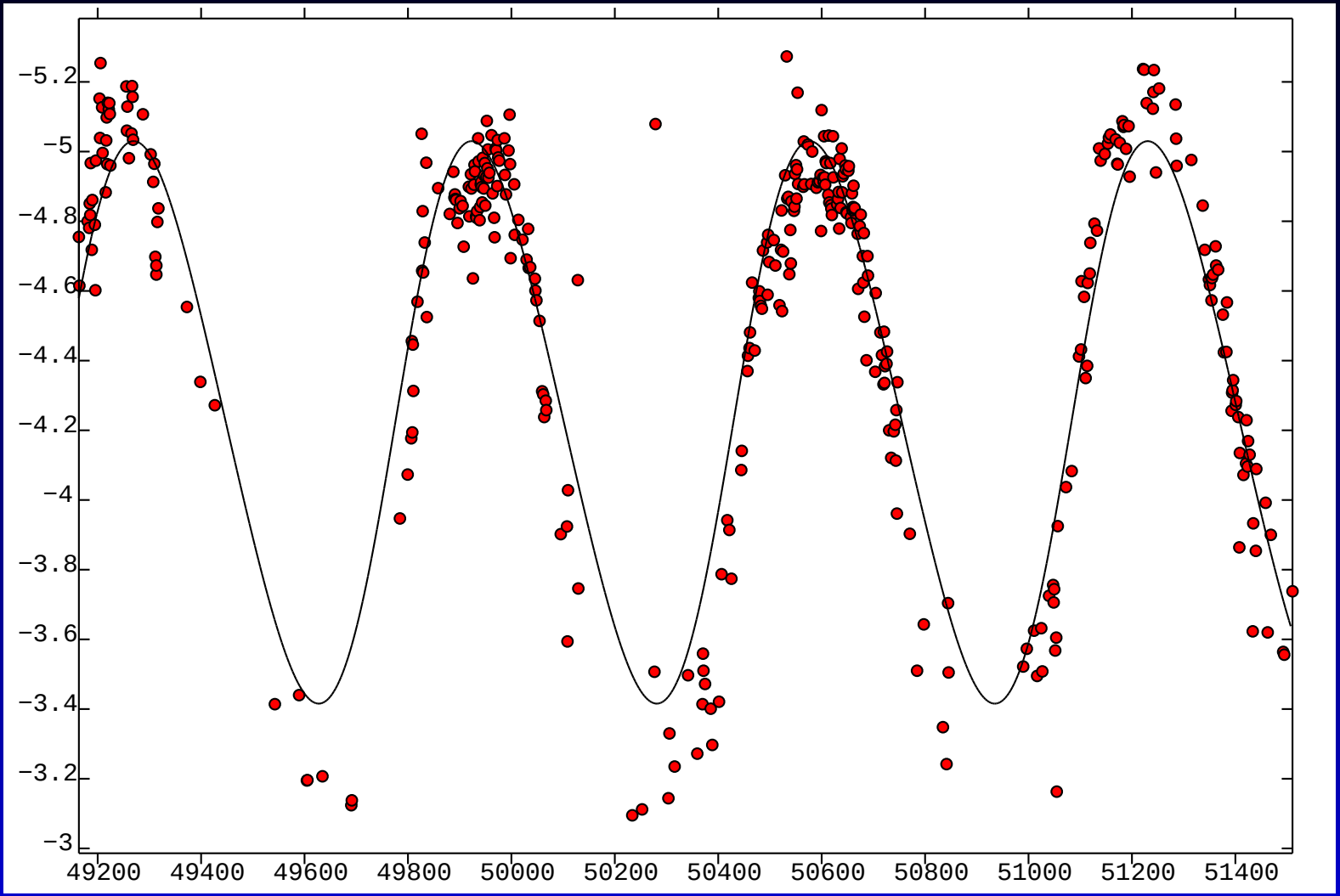


SMC 18: P = 1110 d
567, 355, 258 d

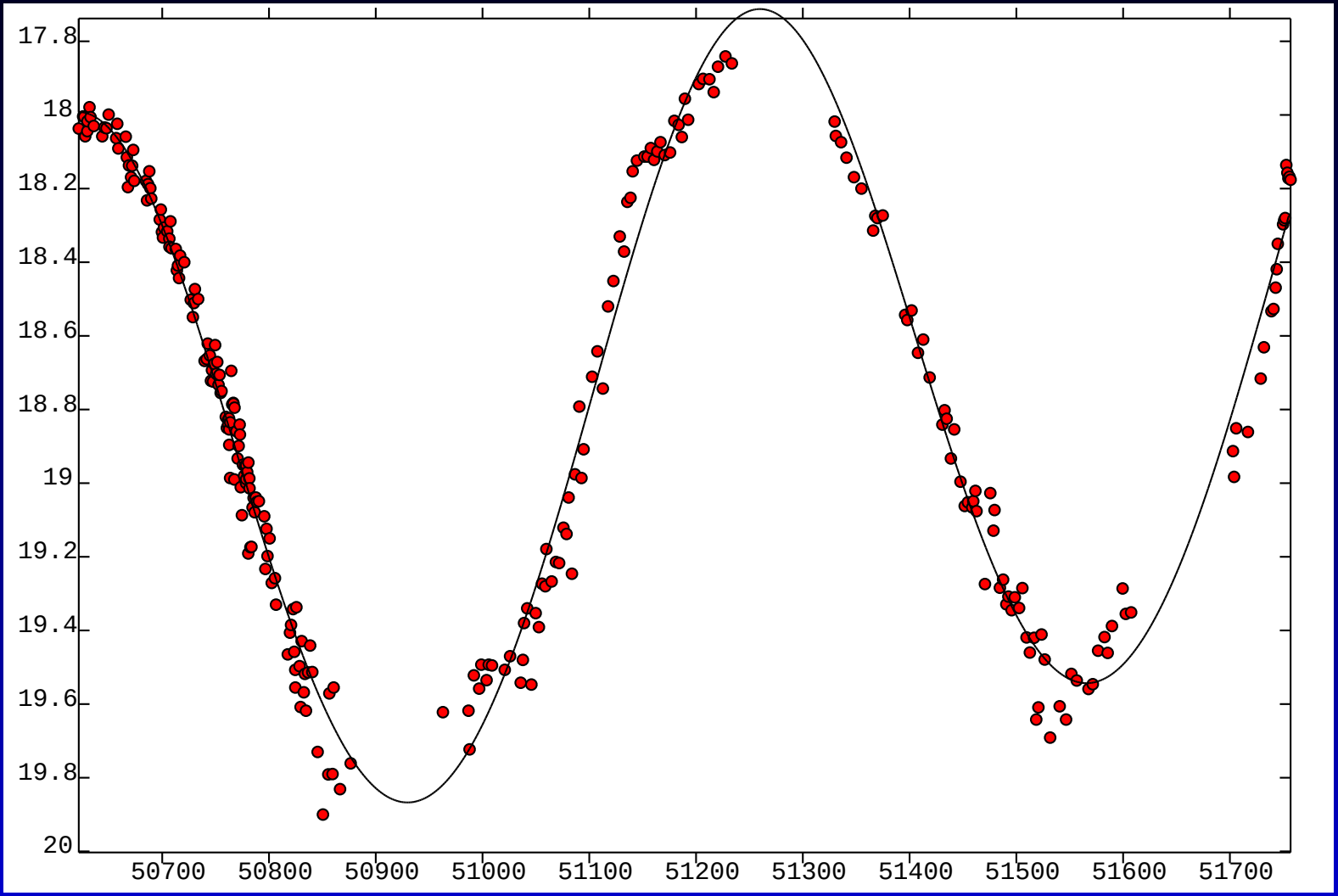
MACHO-Blue



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

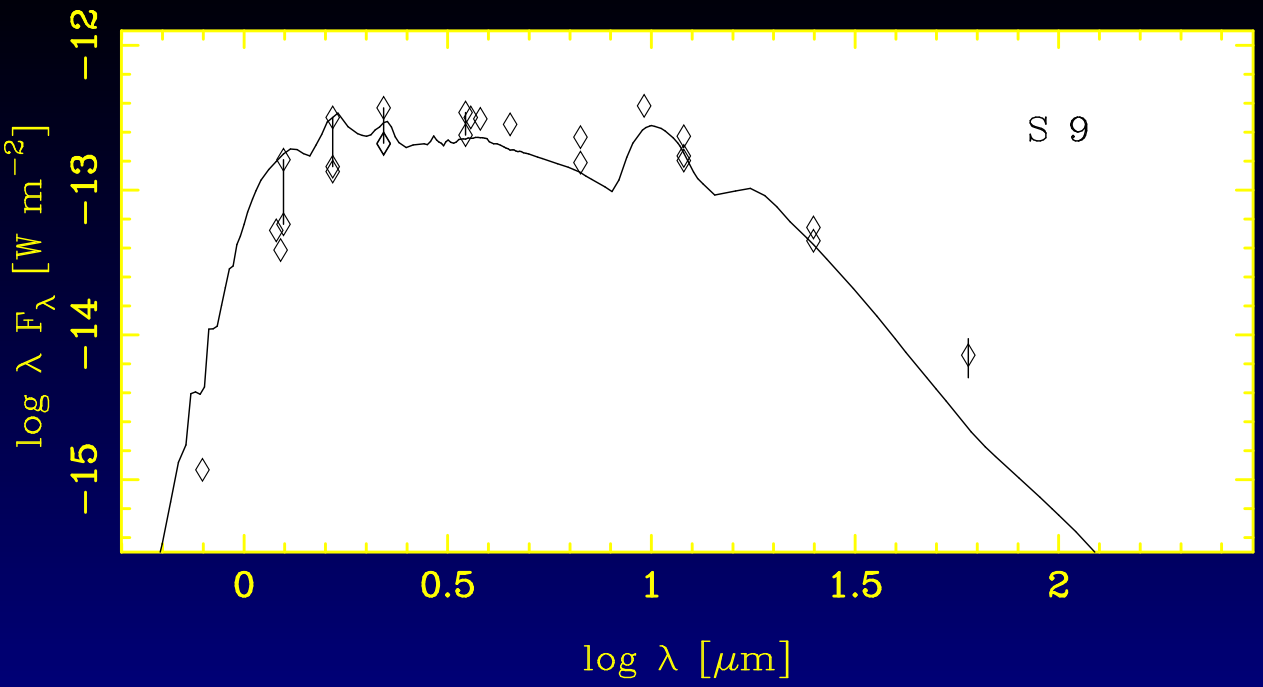


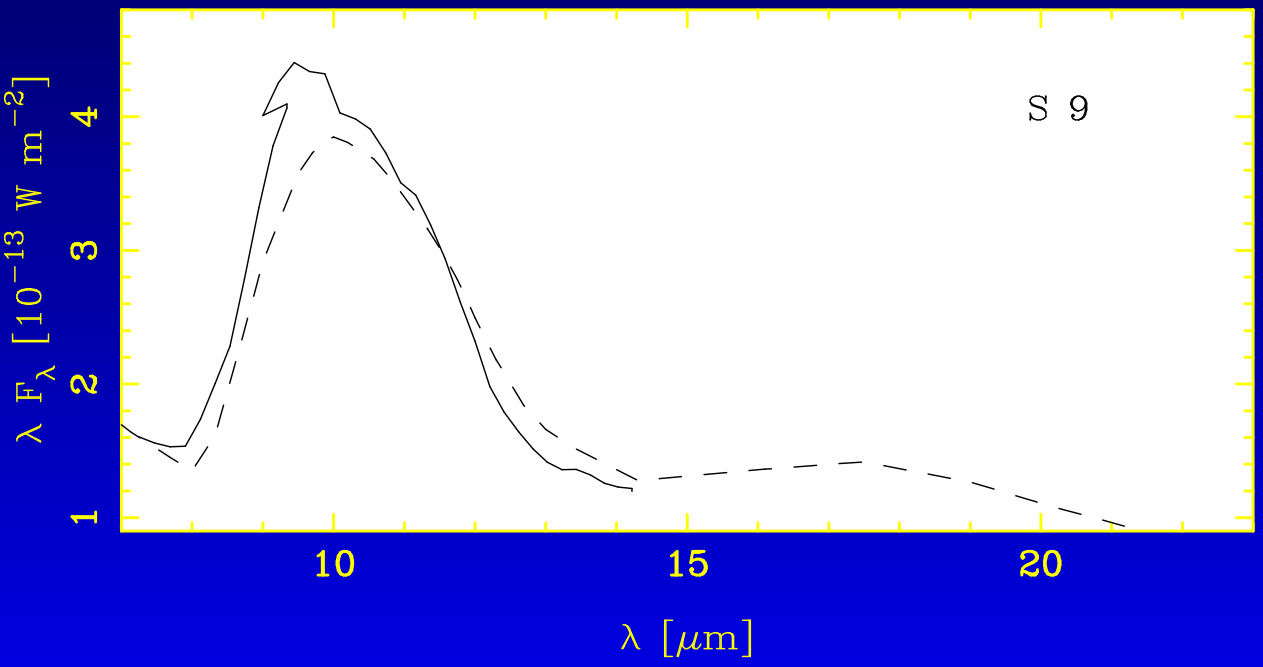
SMC 4: P = 654 d MACHO-Red
326 d



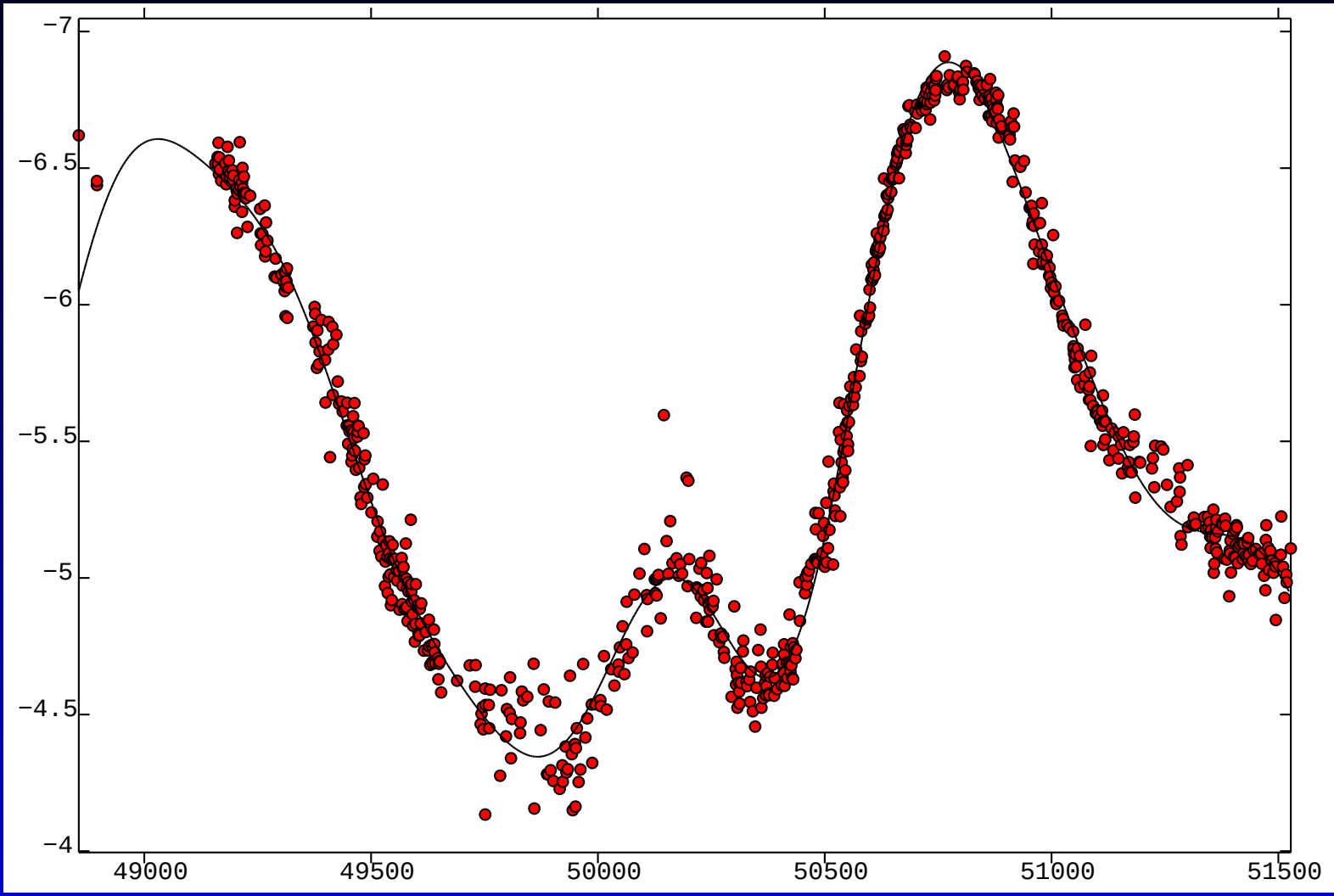
SMC 4: P = 636 d

OGLE



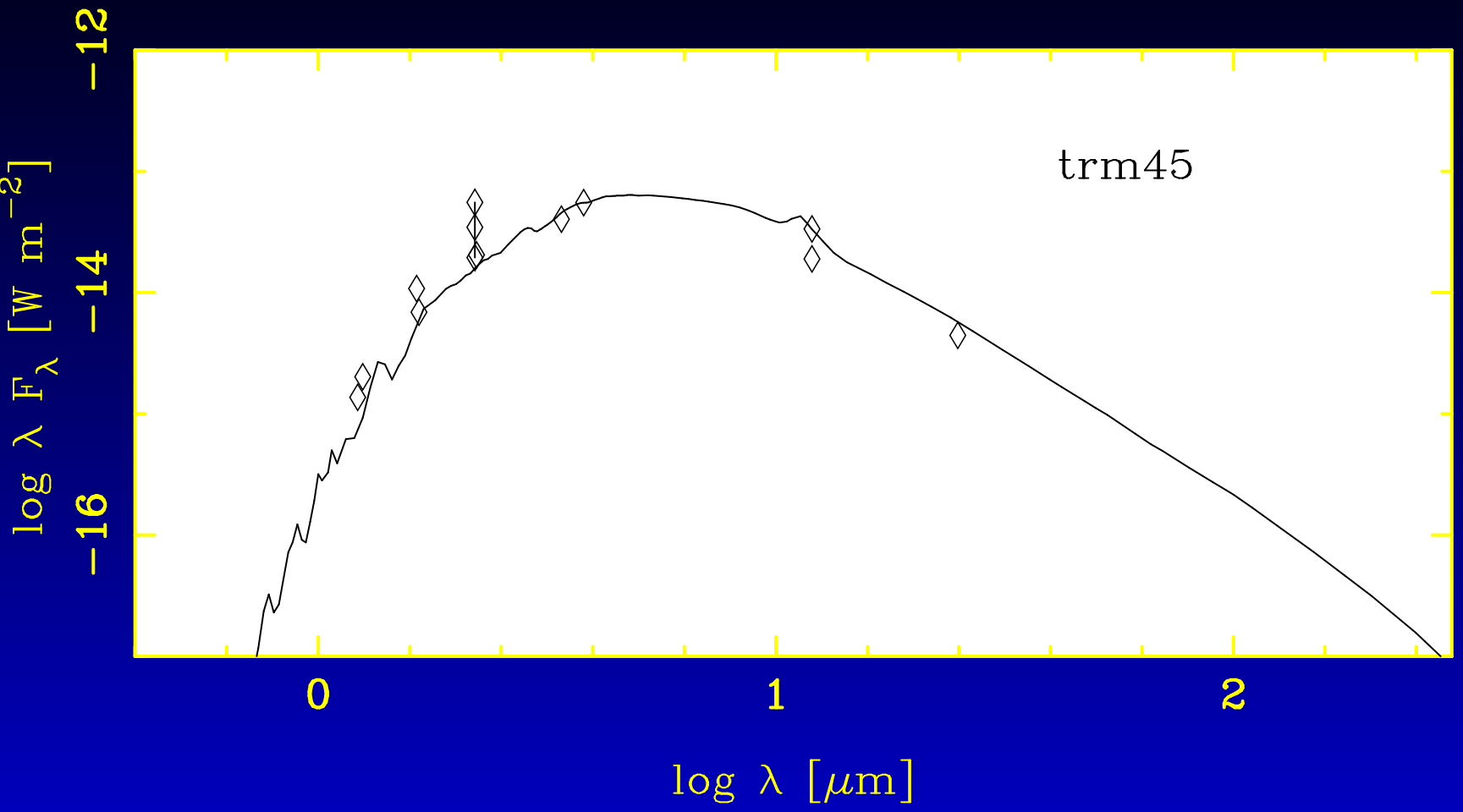


SMC 9: L = 72 000 $L_\odot$, $\dot{M}$= 6.0 $\cdot 10^{-6}$ $M_\odot$ yr^{-1}

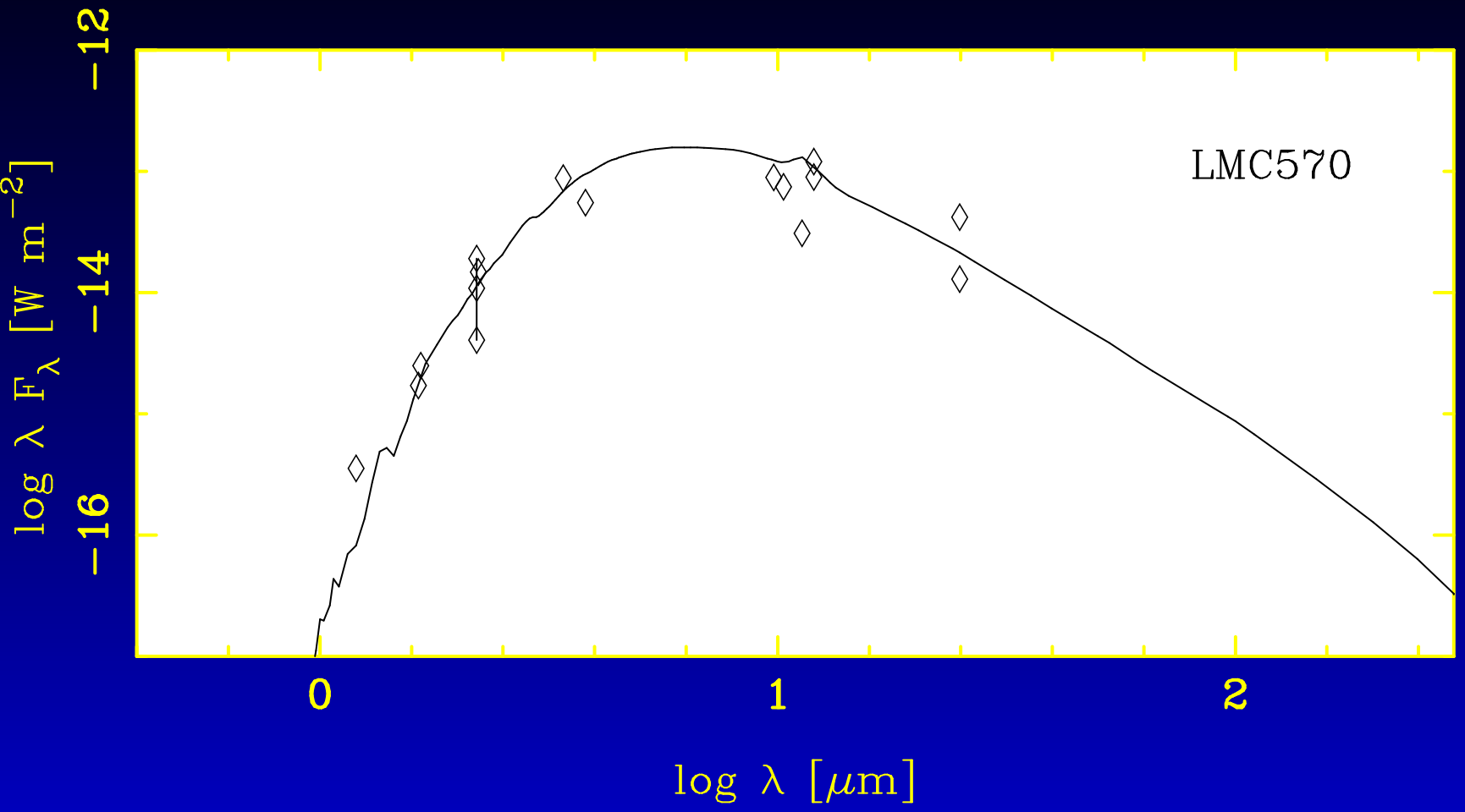


SMC 9: P = 1780 d
830, 620, 447 d

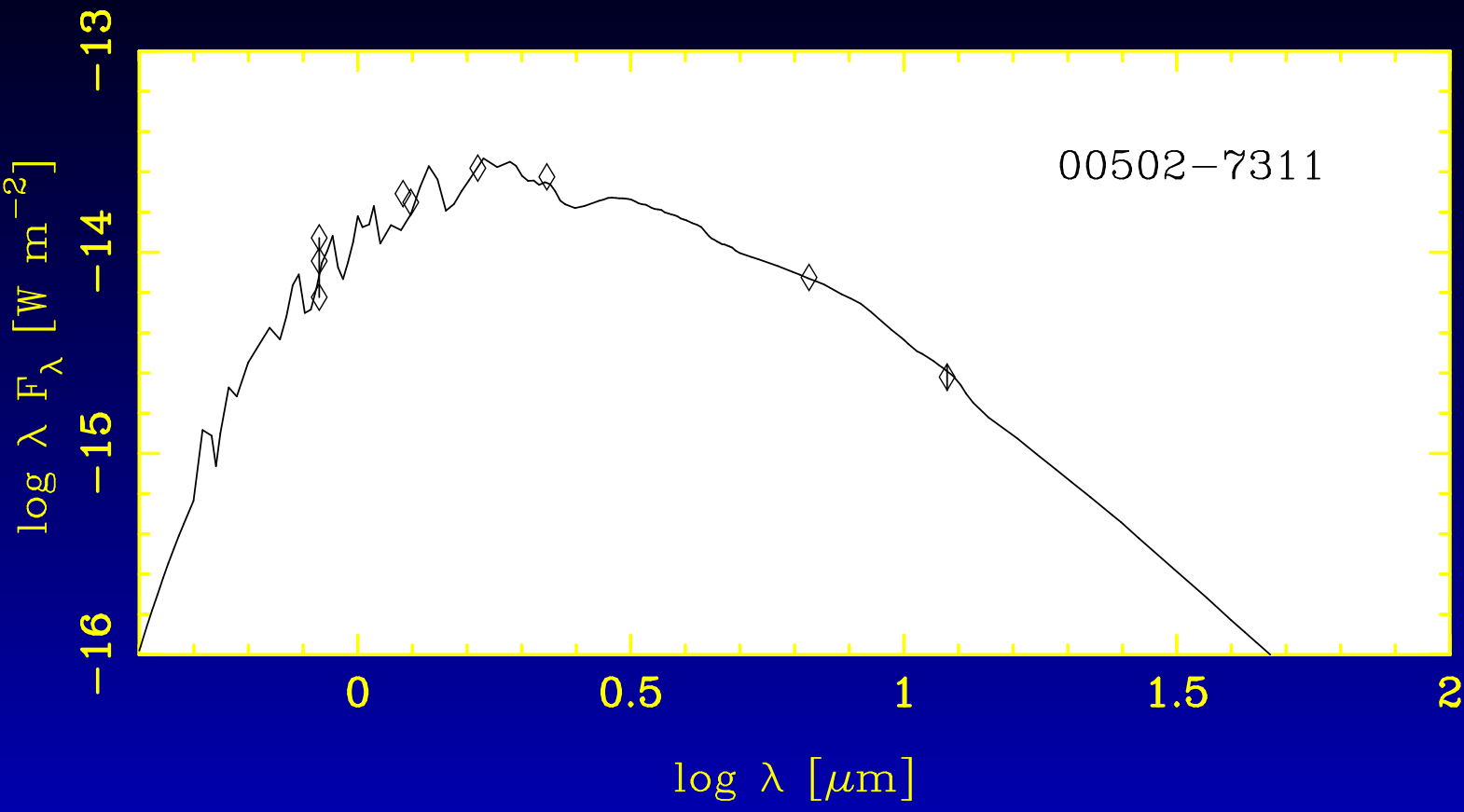
MACHO-Red



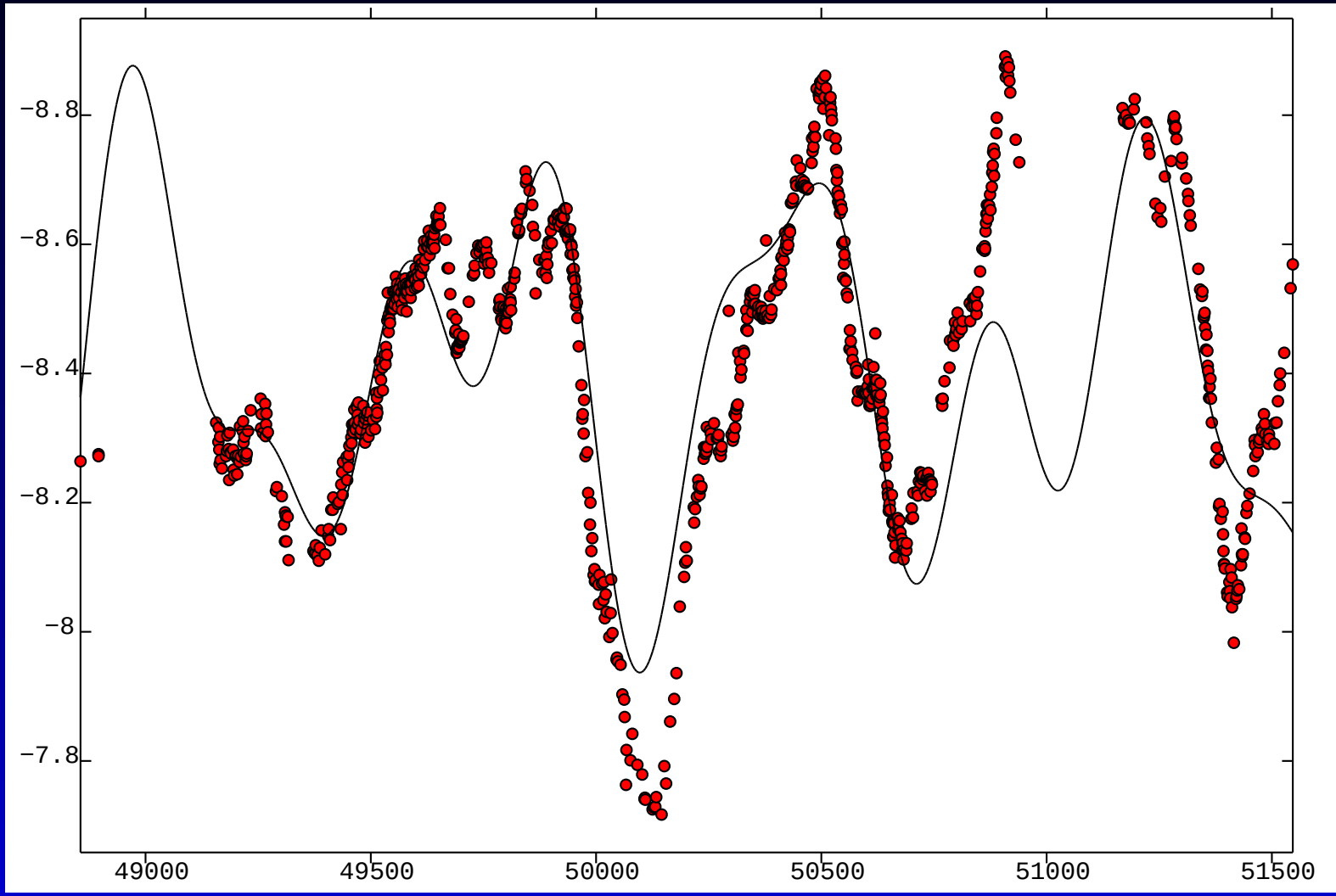
TRM 45:
L = 7600 $L_\odot$, $\dot{M}$= 5.2 ·10^{-6} $M_\odot$ yr^{-1}, P = 570 d



LMC 570/TRM 4:
L = 18000 $L_\odot$, $\dot{M}$= 1.3 ·10^{-5} $M_\odot$ yr^{-1}, P = 900 d

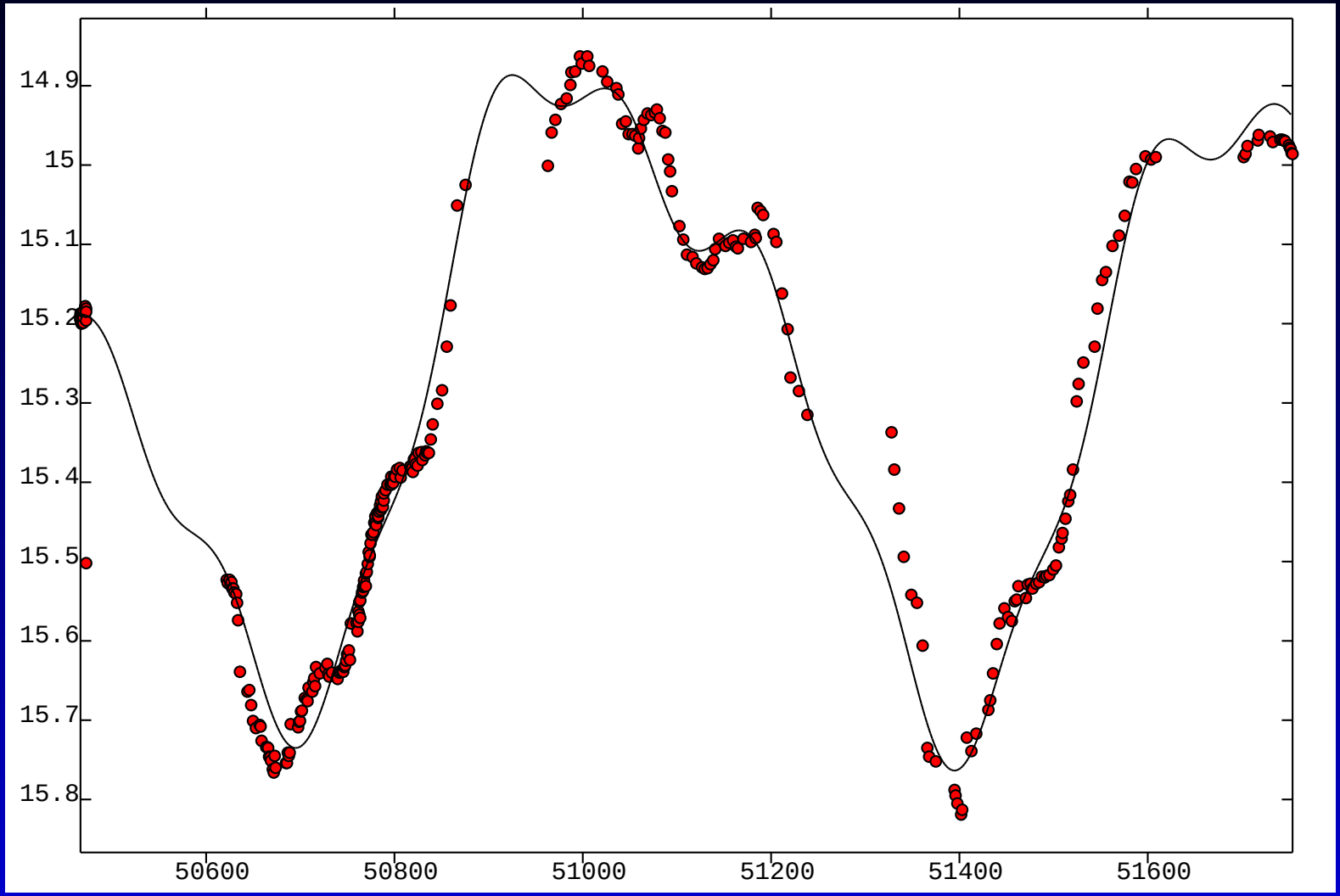


L= 5000 $L_\odot$, $\dot{M}$= 4.0 $\cdot 10^{-7}$ $M_\odot$ yr^{-1}



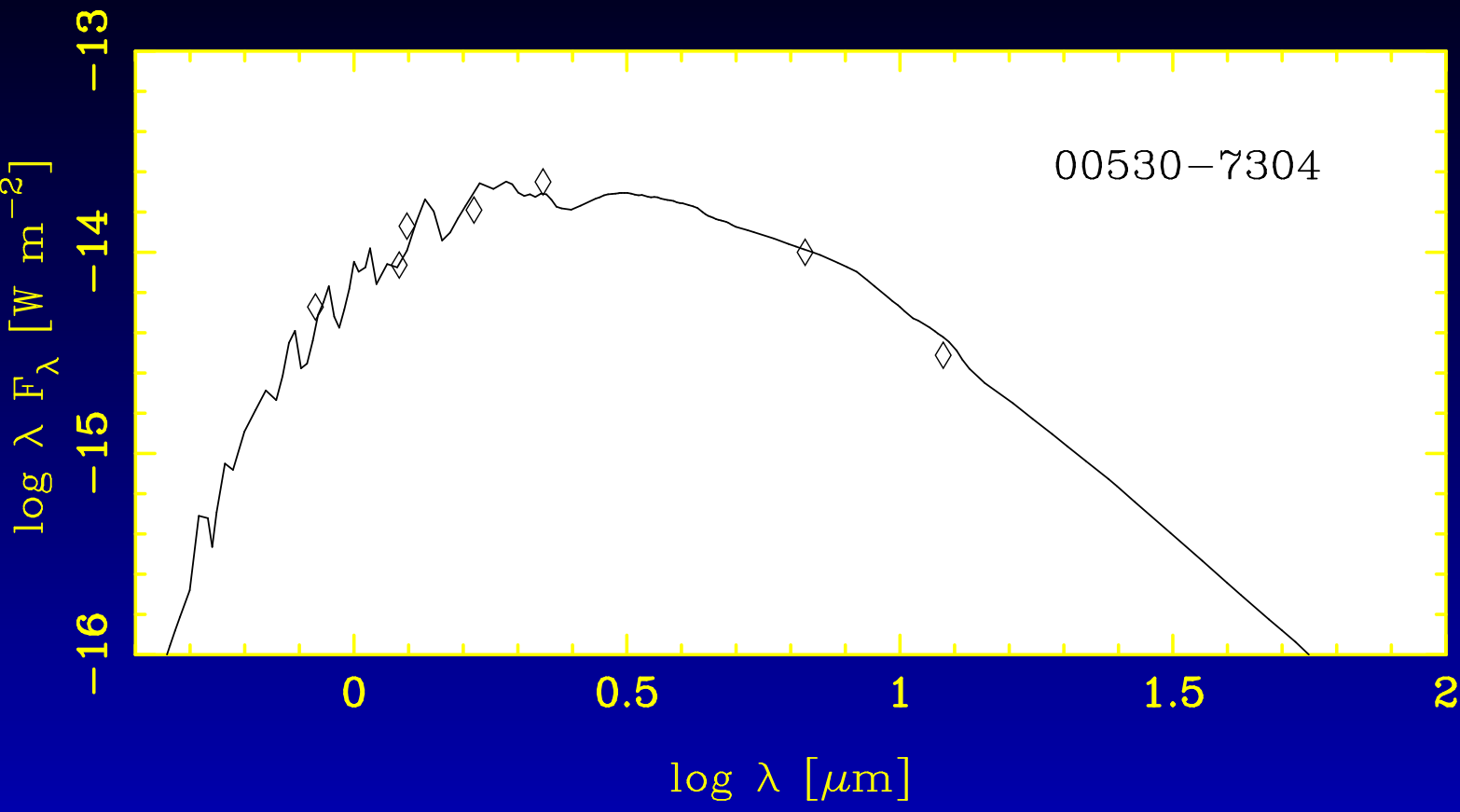
P = 717 d
464, 322 d

MACHO-Red

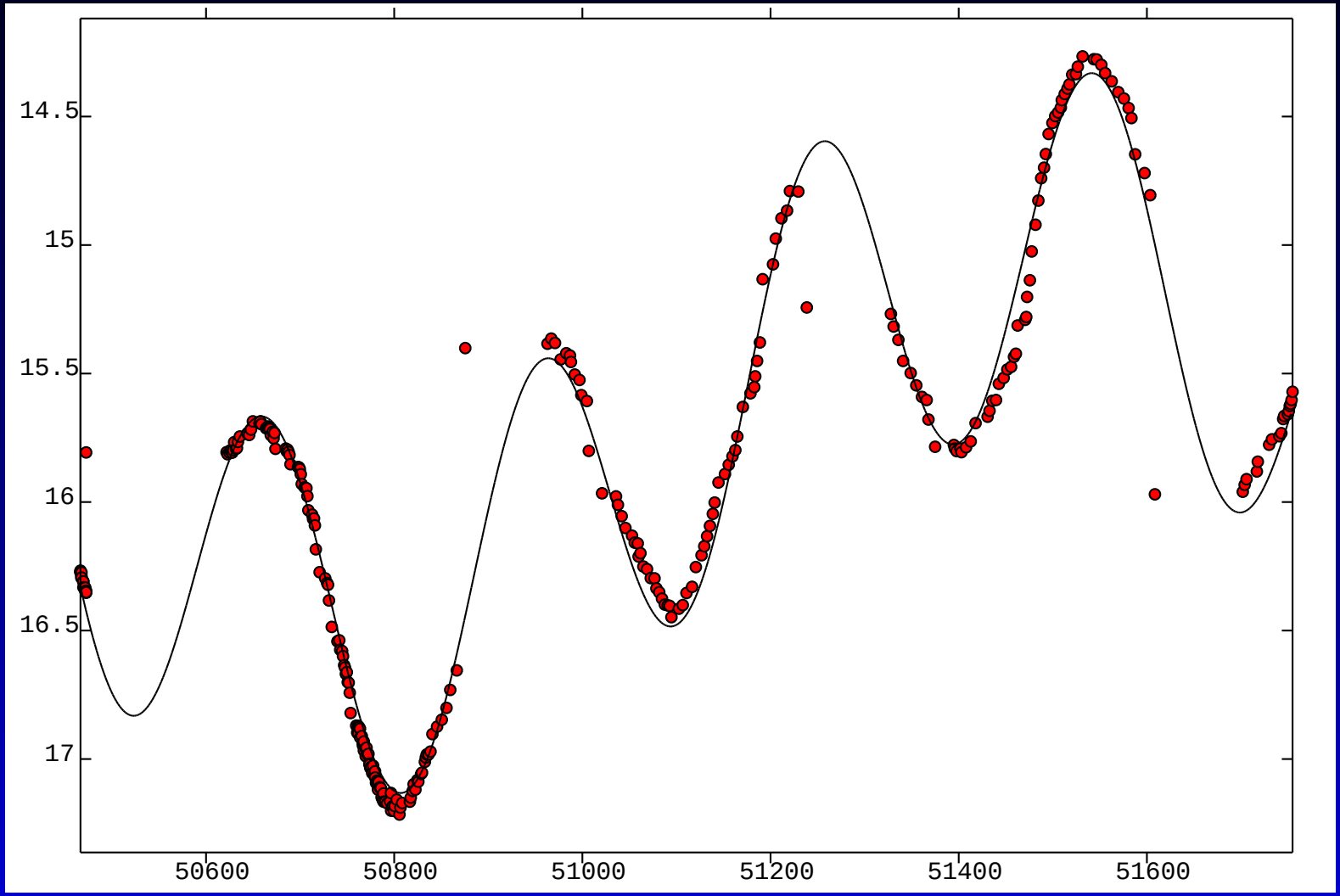

14.9
15
15.1
15.2
15.3
15.4
15.5
15.6
15.7
15.8
50600
50800
51000
51200
51400
51600

P = 725 d

OGLE

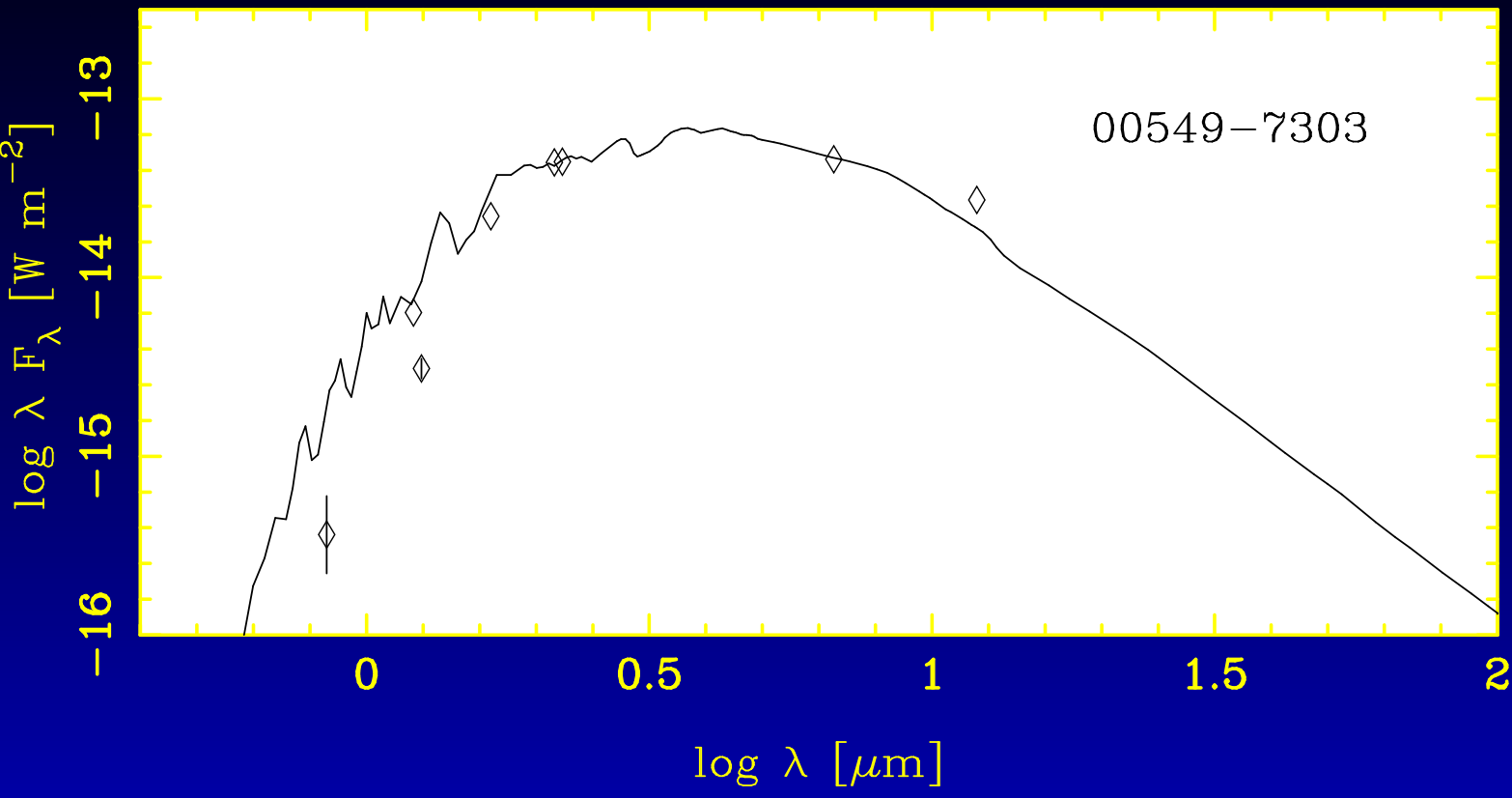


L= 4700 $L_\odot$, $\dot{M}$= 7.3 $\cdot 10^{-7}$ $M_\odot$ yr^{-1}

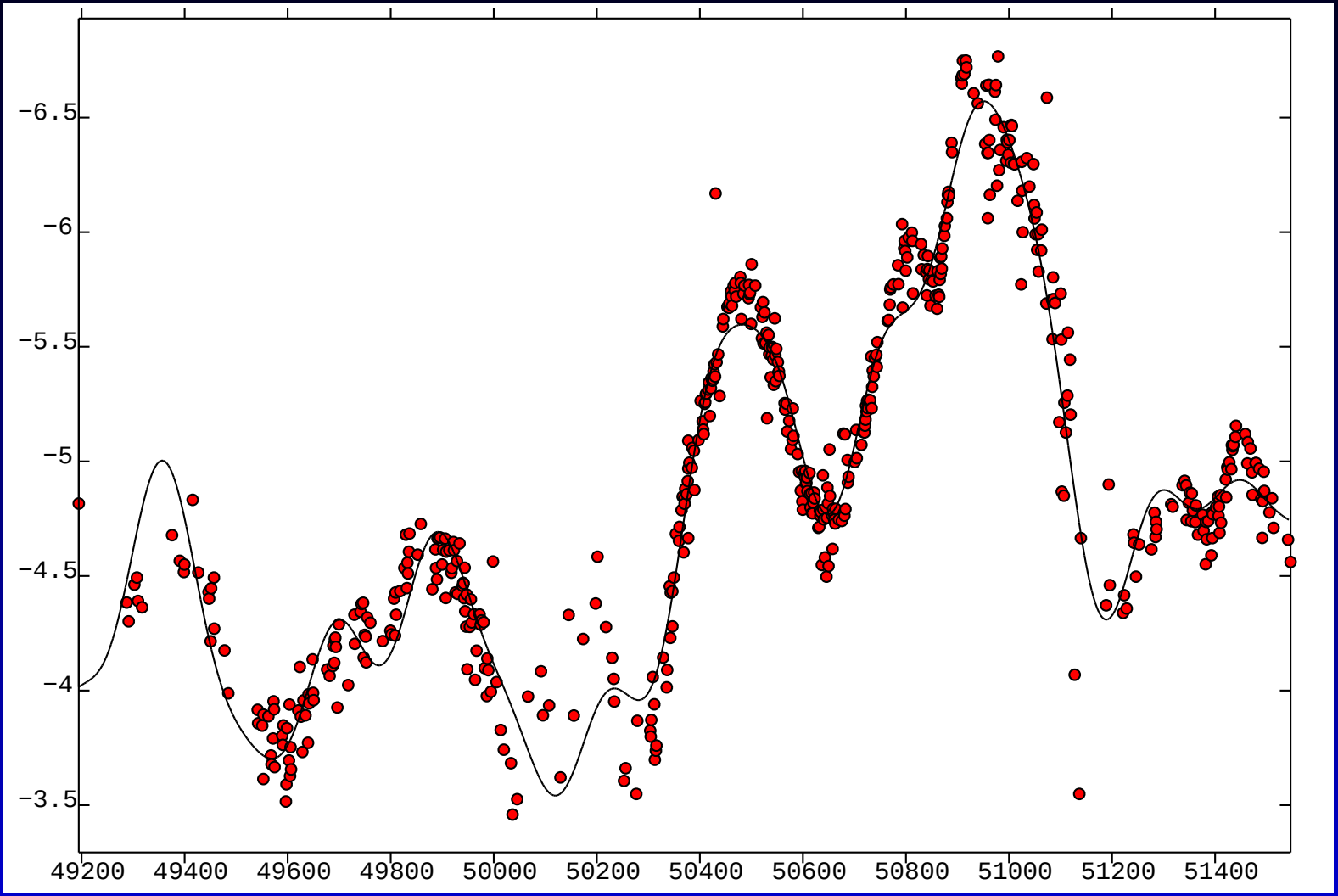


P = 292 d
1448 d

OGLE



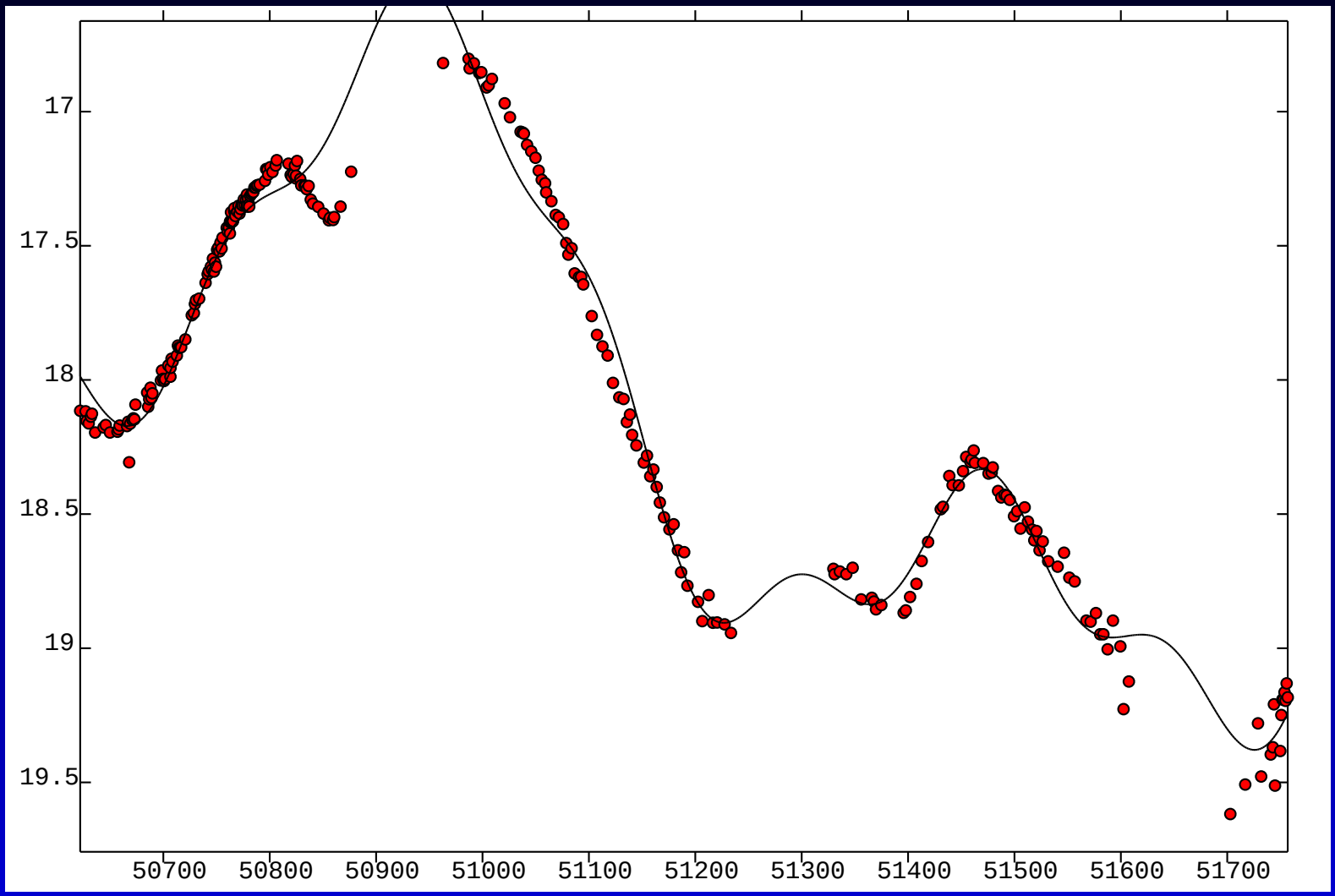
L= 13700 $L_\odot$, $\dot{M}$= 2.8 $\cdot 10^{-6}$ $M_\odot$ yr^{-1}



P = 536 d

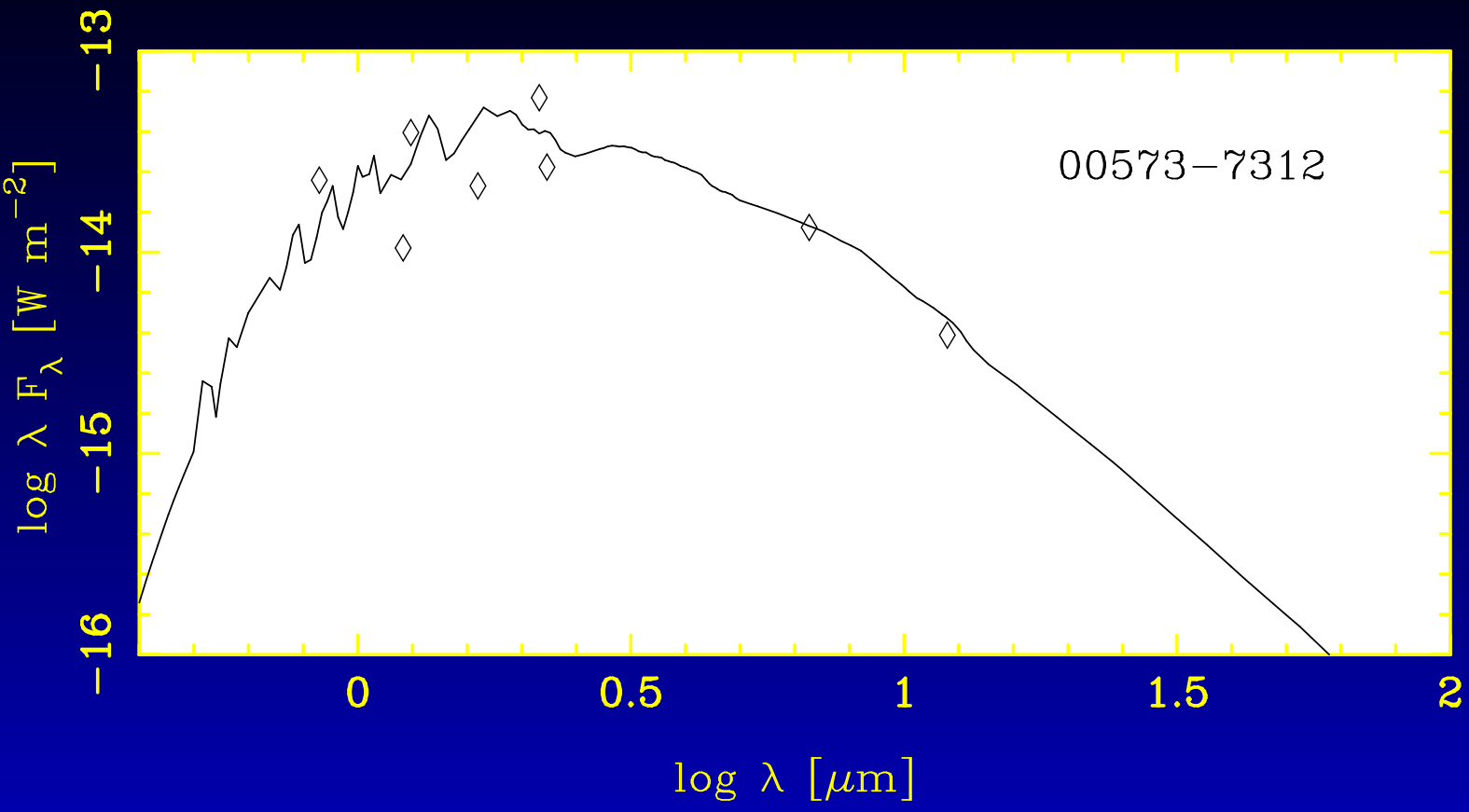
1192, 2525, 417, 272 d

MACHO-Red

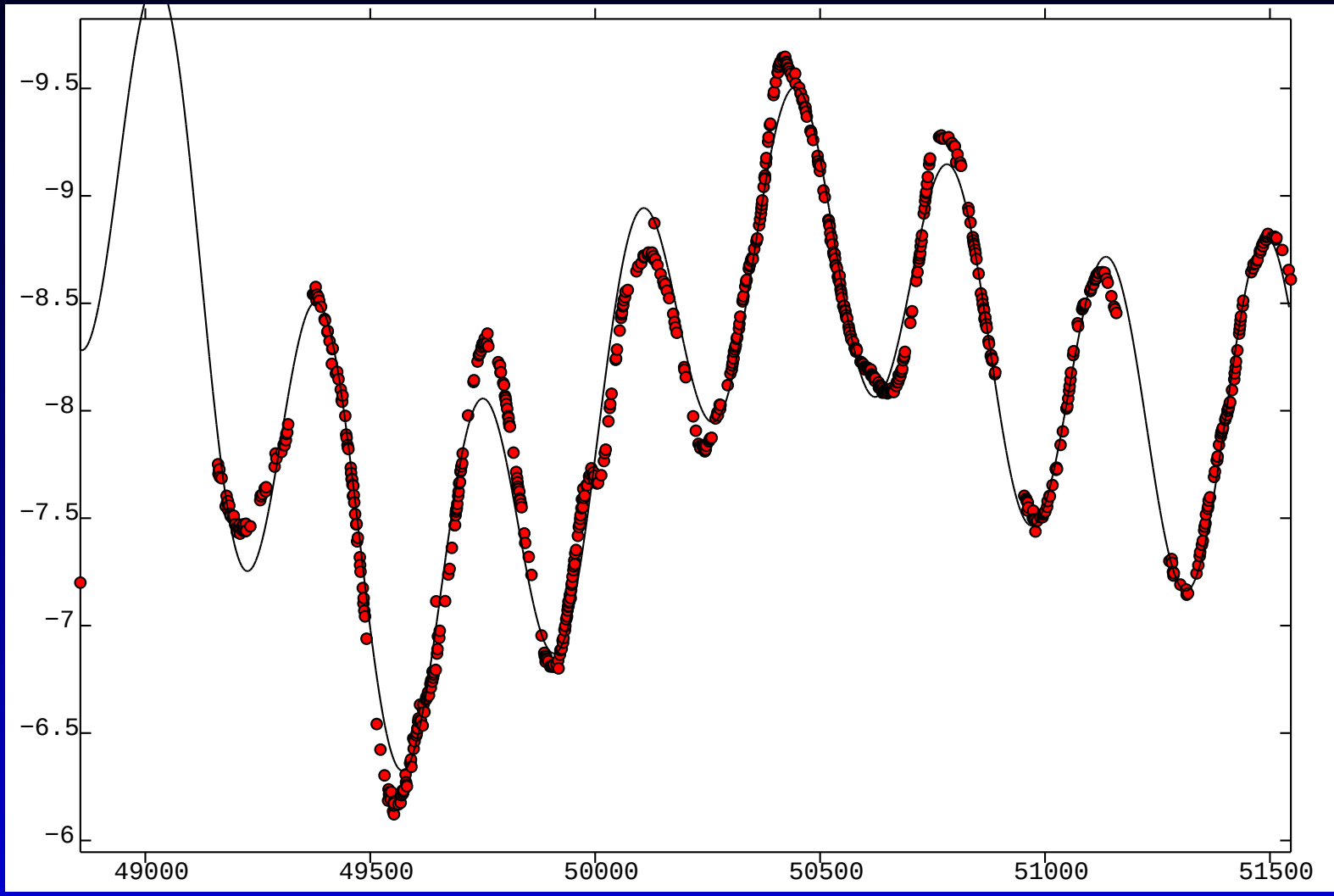

17
17.5
18
18.5
19
19.5
50700
50800
50900
51000
51100
51200
51300
51400
51500
51600
51700

P = 524 d

OGLE

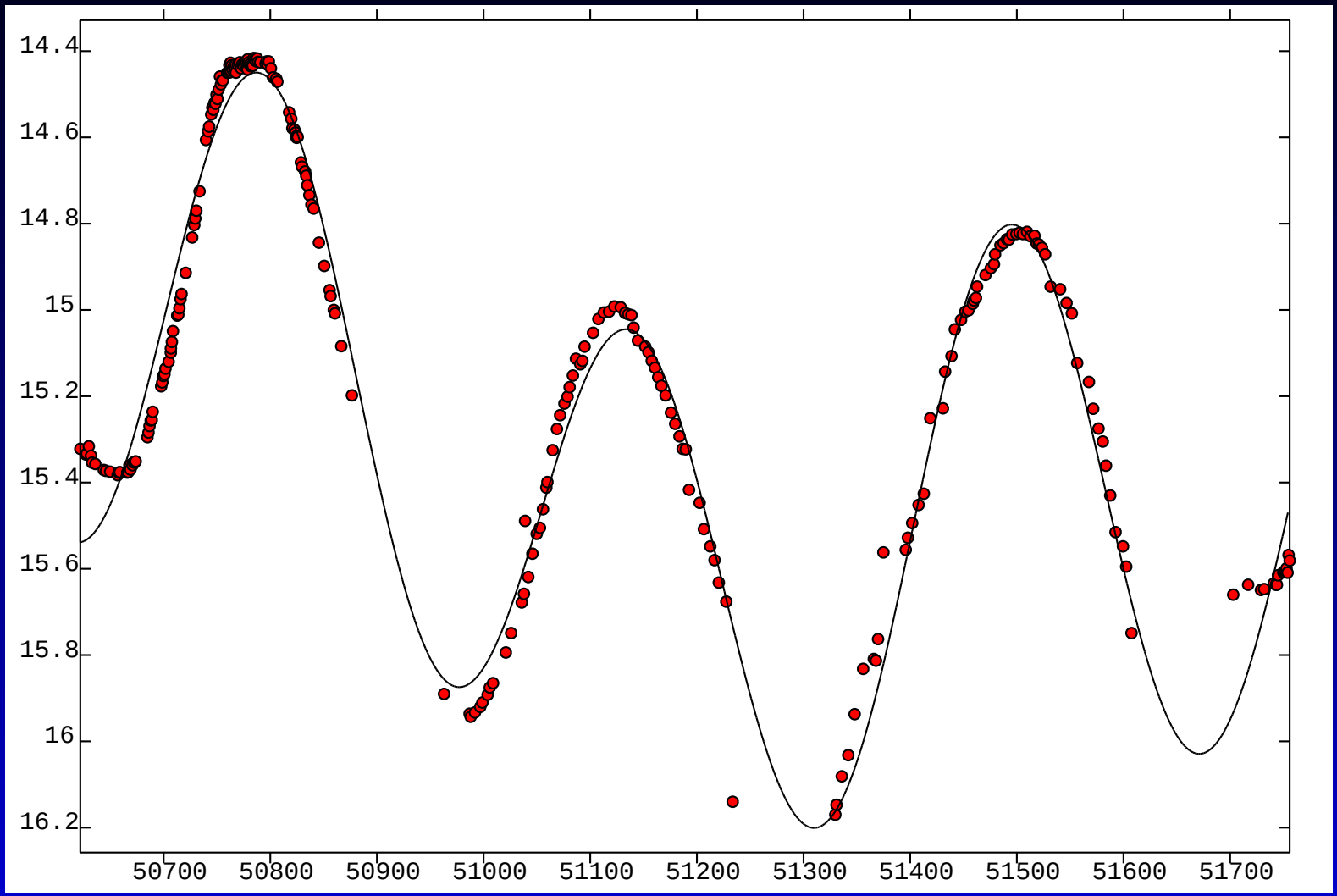


L= 9000 $L_\odot$, $\dot{M}$= 5.5 $\cdot 10^{-7}$ $M_\odot$ yr^{-1}



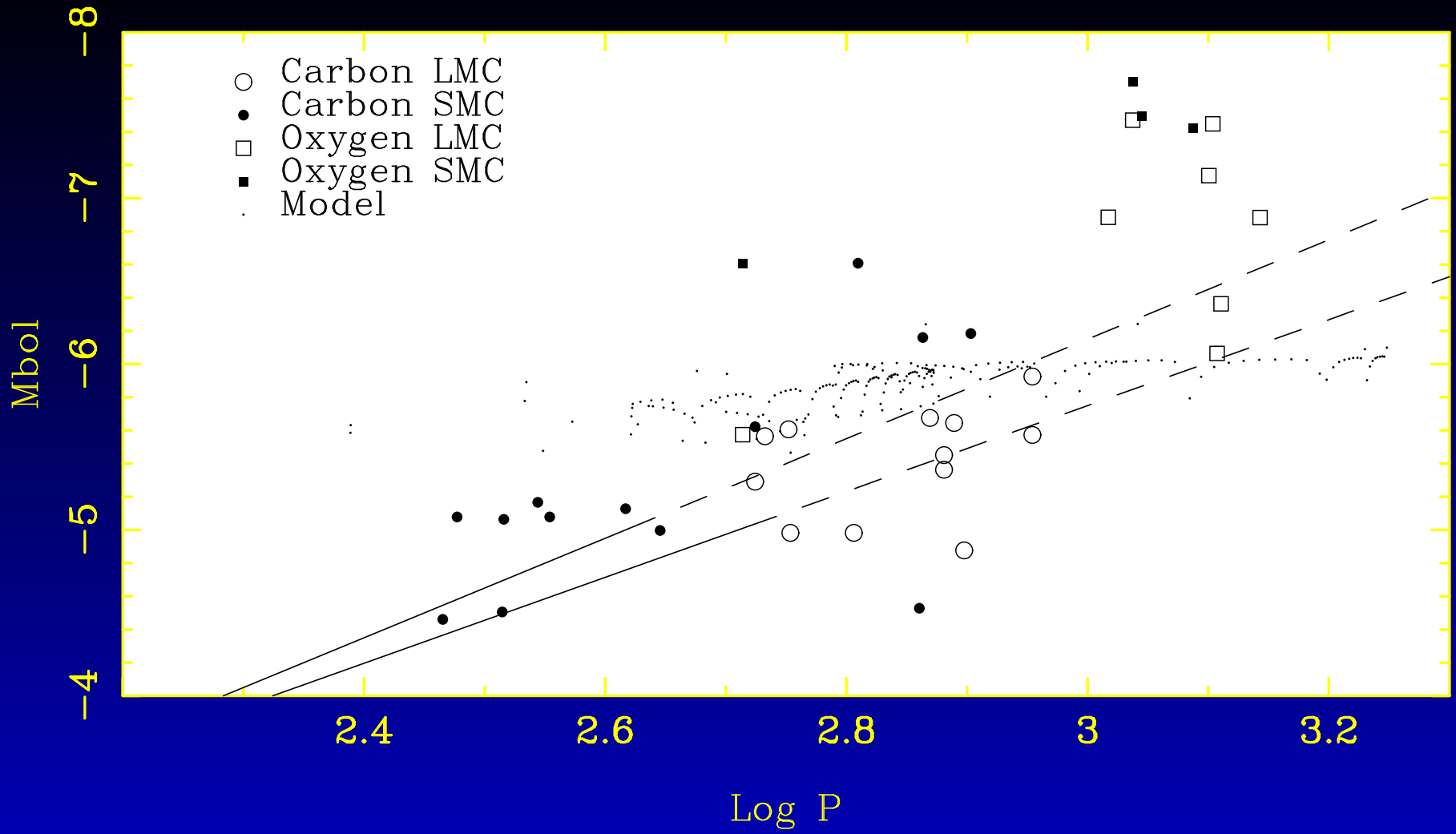
P = 349 d
2163, 1420 d

MACHO-Red


14.4
14.6
14.8
15
15.2
15.4
15.6
15.8
16
16.2
50700
50800
50900
51000
51100
51200
51300
51400
51500
51600
51700

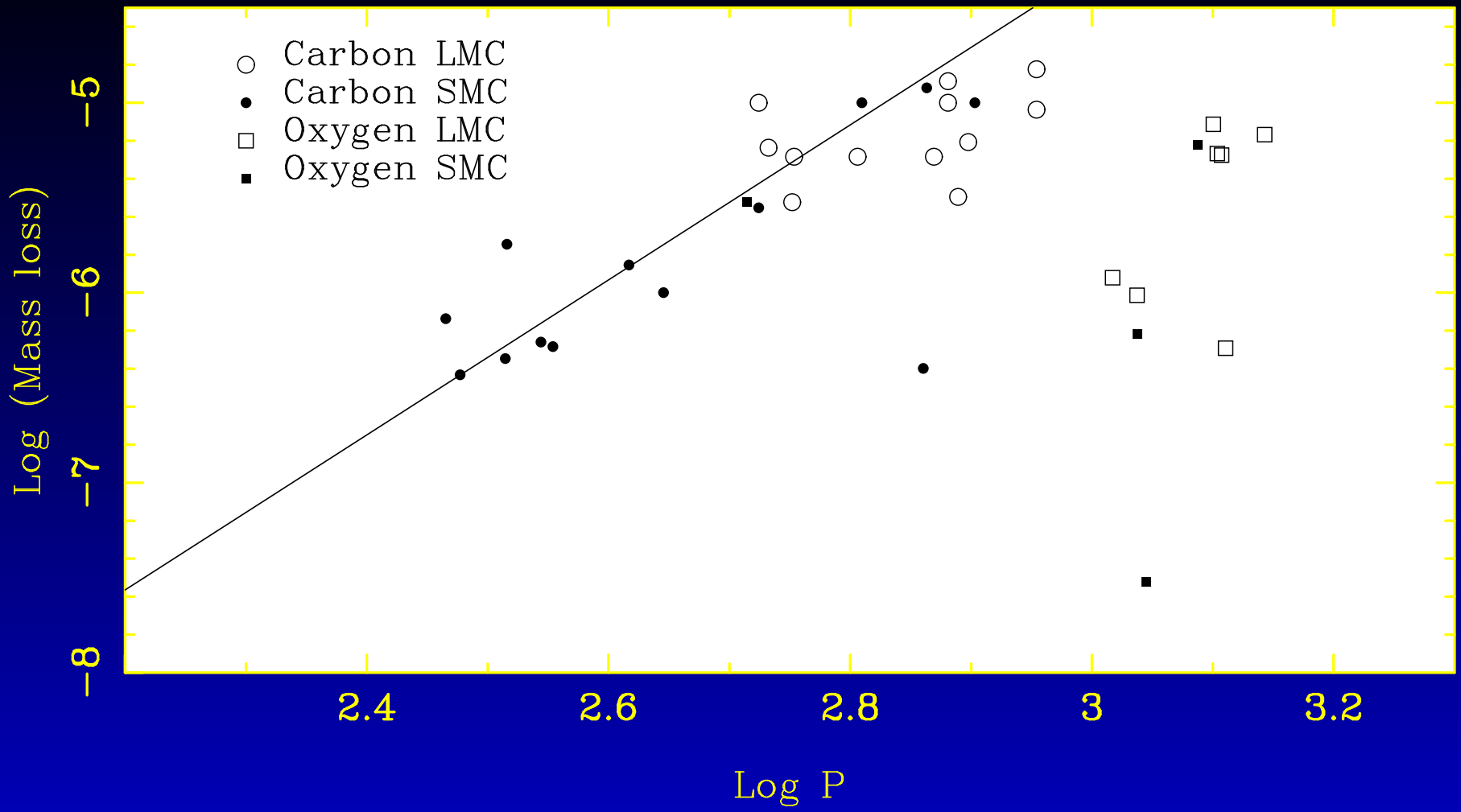
P = 352 d

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, $T_{\rm eff} < 2600$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