

Long Period Variables in the Magellanic Clouds: The OGLE/MACHO/2MASS/DENIS view

Martin Groenewegen
groen@ster.kuleuven.ac.be

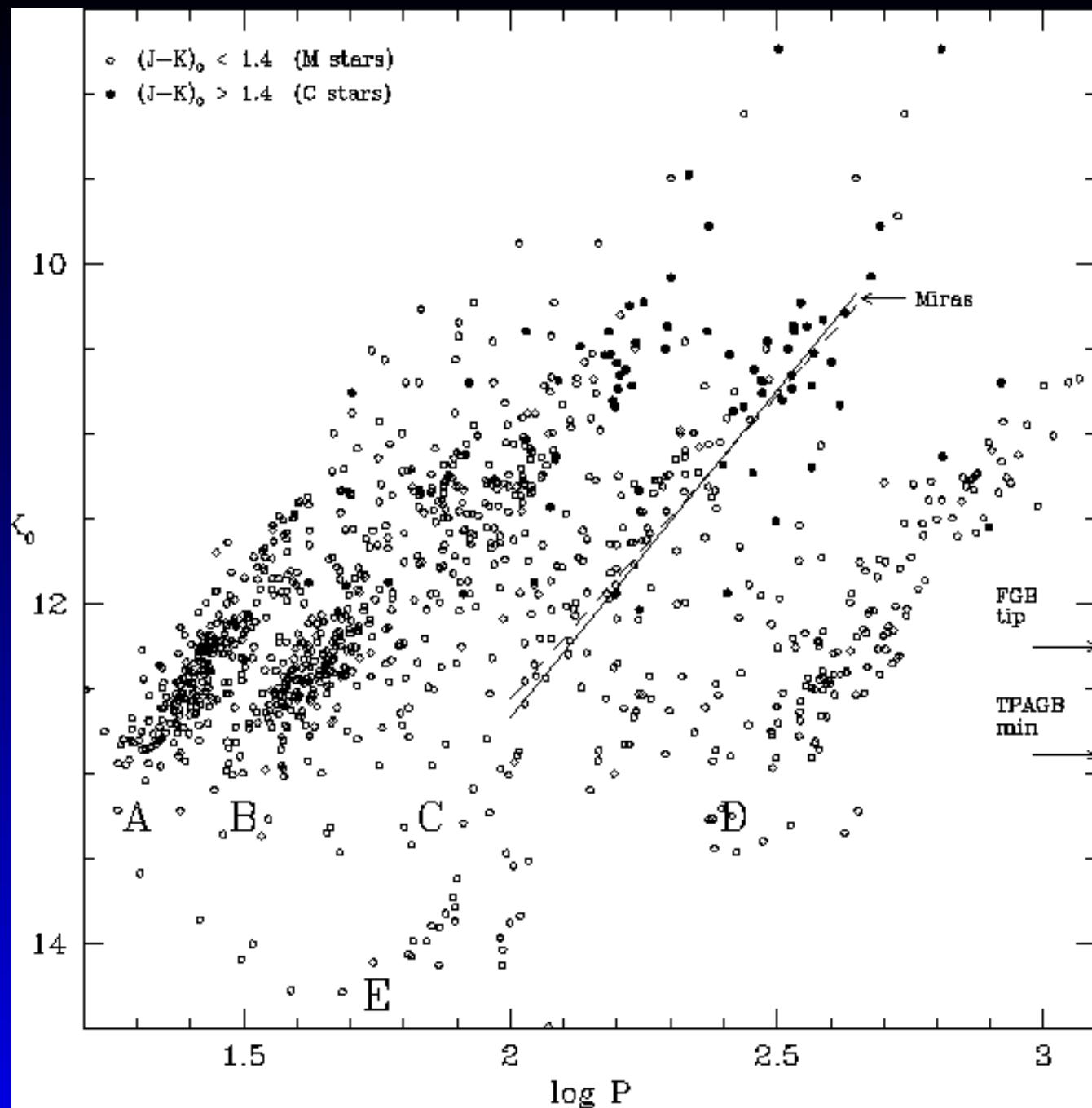
K.U.Leuven

LPVs in MCs: outline

- Historical perspective
- Lightcurve classification
- Comparison between authors/surveys
- Combining MACHO & OGLE
- Future directions

History

- Wood et al. 1999, Wood 2000
($0.25 \square^2$ LMC-bar; 1430 red variables;
MACHO + IR)
- Cioni et al. 2001
($0.5 \square^2$ LMC-OC; 240 M+SR; EROS + DENIS)
- Noda et al. 2002
(14 \square^2 LMC; 146 LPV; MOA + DENIS)
- Lebzelter et al. 2002
($0.25 \square^2$ LMC-bar; 470 red variables;
AGAPEROS + DENIS)
- Cioni et al. 2003
($0.25 \square^2$ ISO-sample SMC-bar,
458 red variables; MACHO + DENIS/2MASS)

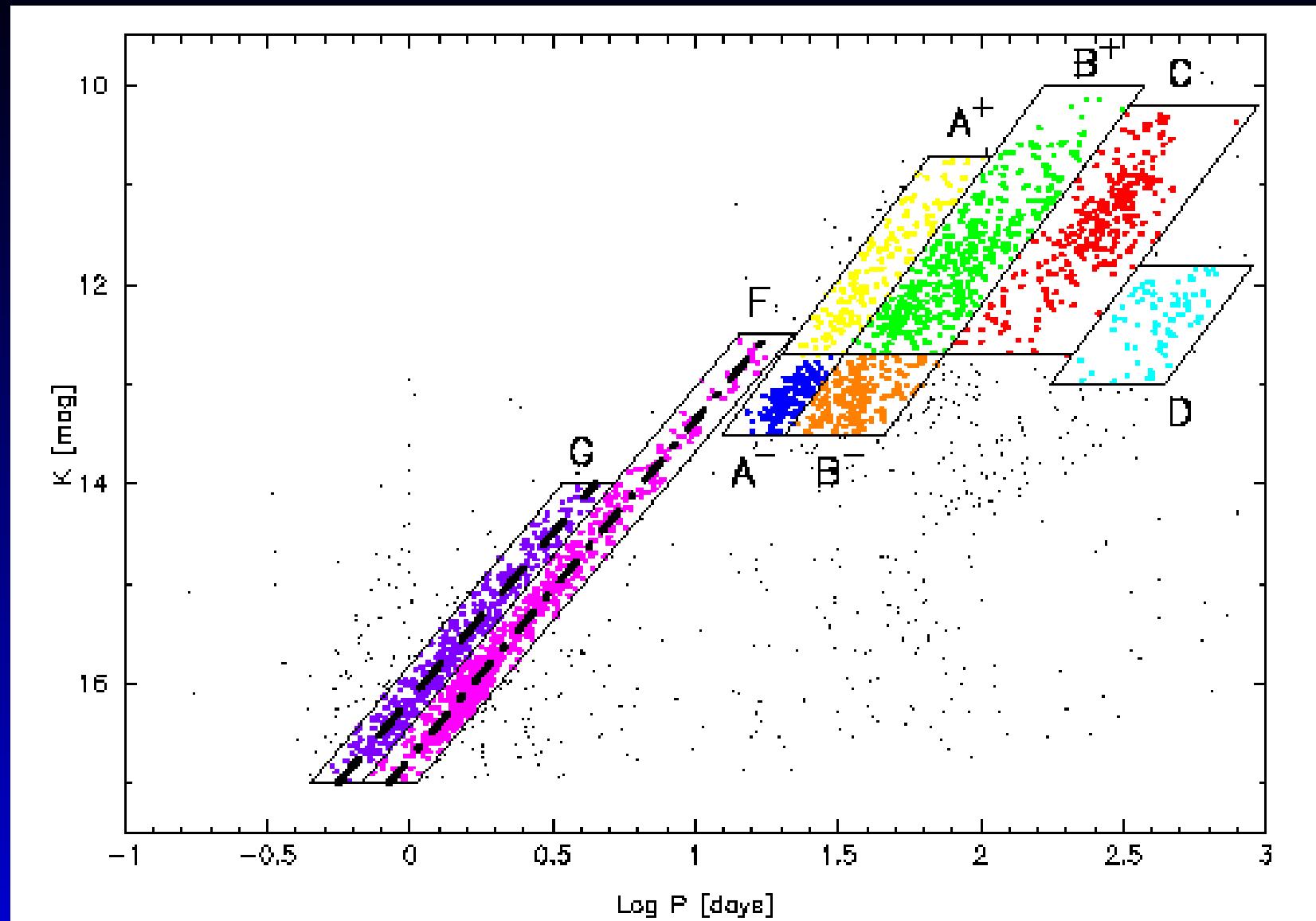


History

- Wood et al. 1999, Wood 2000
($0.25 \square^2$ LMC-bar; 1430 red variables;
MACHO + IR)
- Cioni et al. 2001
($0.5 \square^2$ LMC-OC; 240 M+SR; EROS + DENIS)
- Noda et al. 2002
(14 \square^2 LMC; 146 LPV; MOA + DENIS)
- Lebzelter et al. 2002
($0.25 \square^2$ LMC-bar; 470 red variables;
AGAPEROS + DENIS)
- Cioni et al. 2003
($0.25 \square^2$ ISO-sample SMC-bar,
470 red variables; MACHO + DENIS/2MASS)

History

- Ita et al. 2003
($1.0 \square^2$ SMC-centre; ~ 1800 red variables;
OGLE + SIRIUS)
- Kiss & Bedding 2003
(~ 23000 red variables LMC;
OGLE + 2MASS with $J - K > 0.9$)
- Groenewegen
SMC+LMC; OGLE + 2MASS/DENIS



Ita et al. (2003)

Procedure

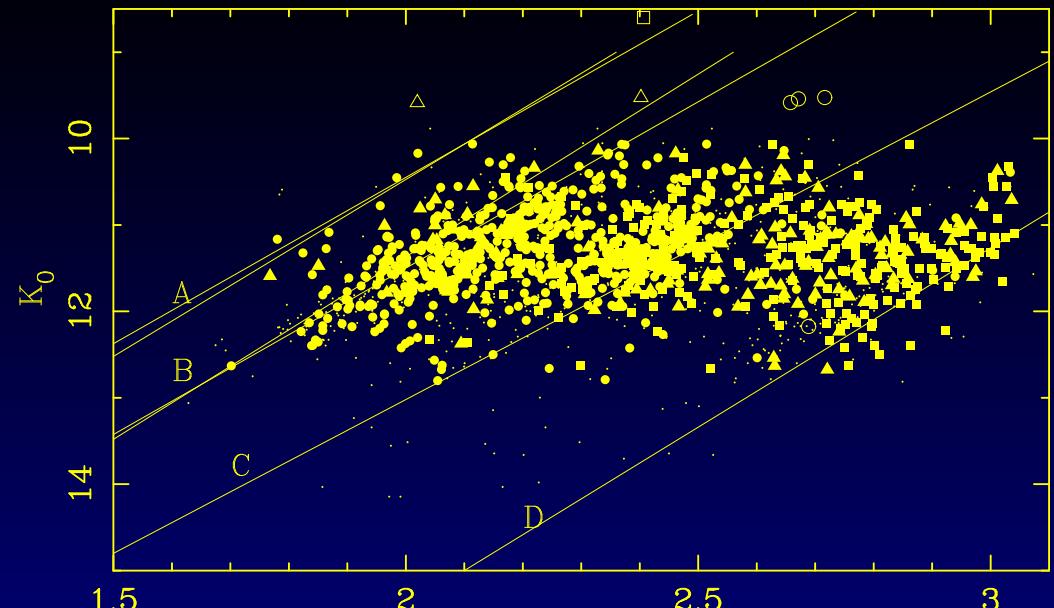
Step 1: Fitting

- Subtract best fit so far
- Fourier transformation (FASPER)
- Linear LSF
$$I(t) = I_0 + \sum_{i=1}^{i=n_{\max}} (A_i \sin(2\pi t \omega_i) + B_i \cos(2\pi t \omega_i))$$
- Stop: $n = 3$, or no significant frequency

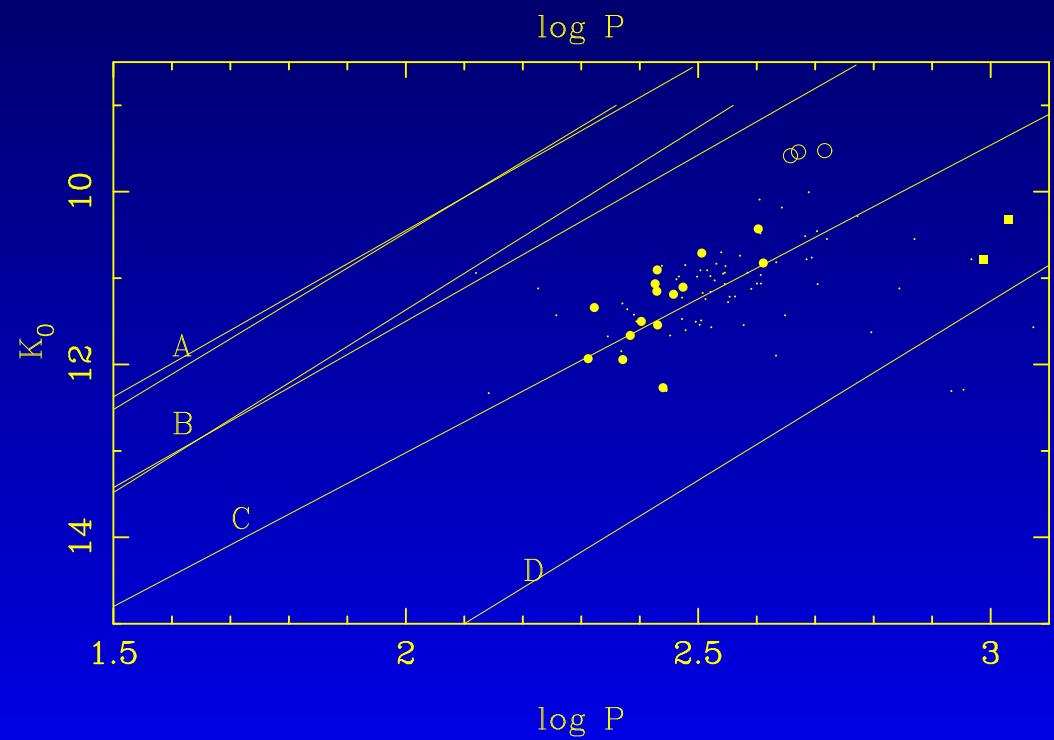
Procedure

Step 2: Correlation and Selection

- Correlate:
68193 OGLE \Rightarrow 50129 2MASS & 40793 DENIS
 - Using thousands of least variable stars:
 $K_{\text{2mass}} = K_{\text{denis}} + 0.14$
 $J_{\text{2mass}} = J_{\text{denis}} + 0.08$
 $I_{\text{ogle}} = I_{\text{denis}} + 0.02$
- AGB selection for SMC: $I < 16.8$,
any $P > 50$ days; any amplitude > 0.05 mag
- SIMBAD (spectral type; known non-AGB)
- visual inspection
- 975 objects: 575 C, 7 M, 0 S



all

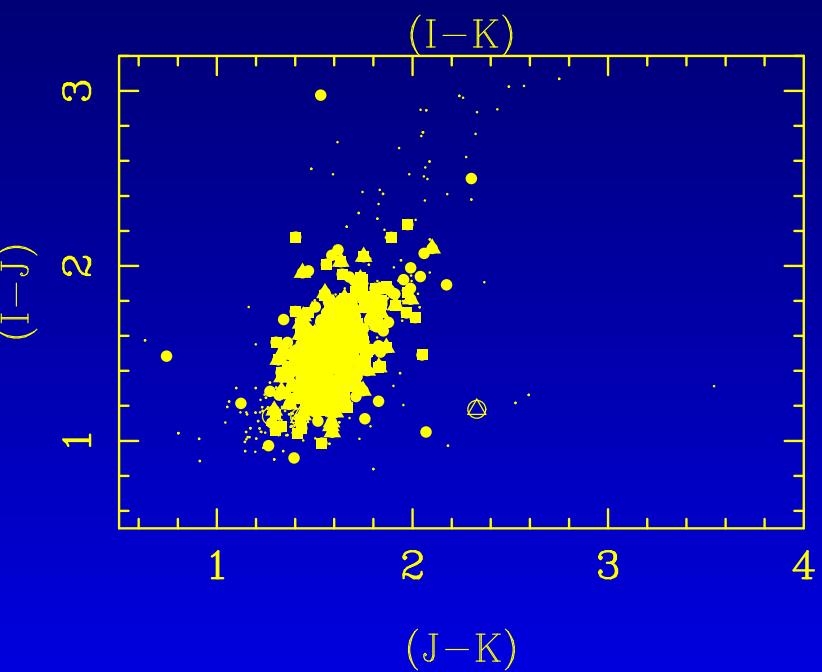
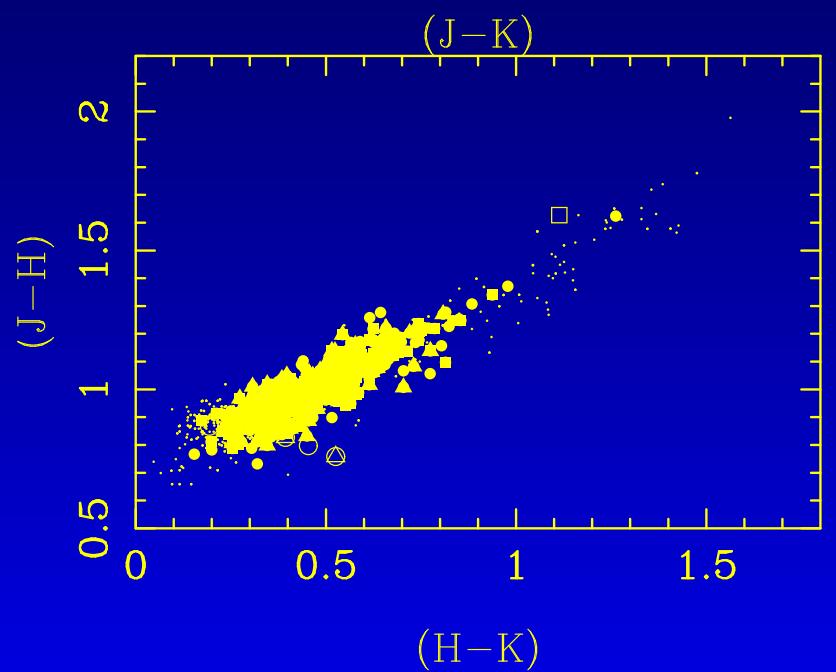
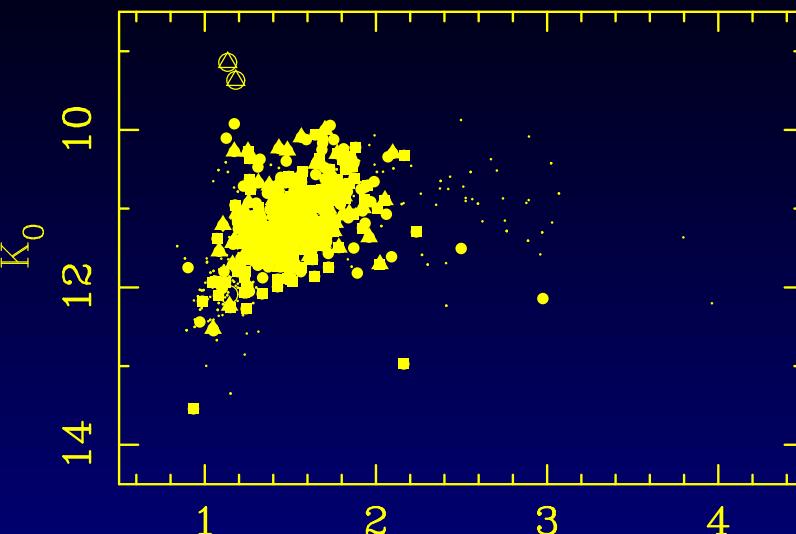
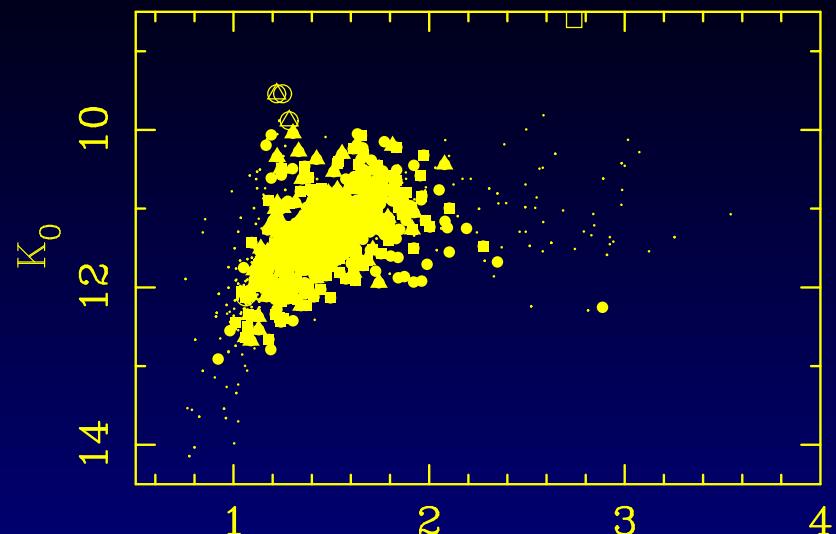


I-band
amplitude
 > 0.45 mag

SMC $PL(K)$ -relation
Known C/M-stars in filled/open symbols

2MASS

DENIS



Colour-Colour & Colour-Magnitude diagrams

Comparison

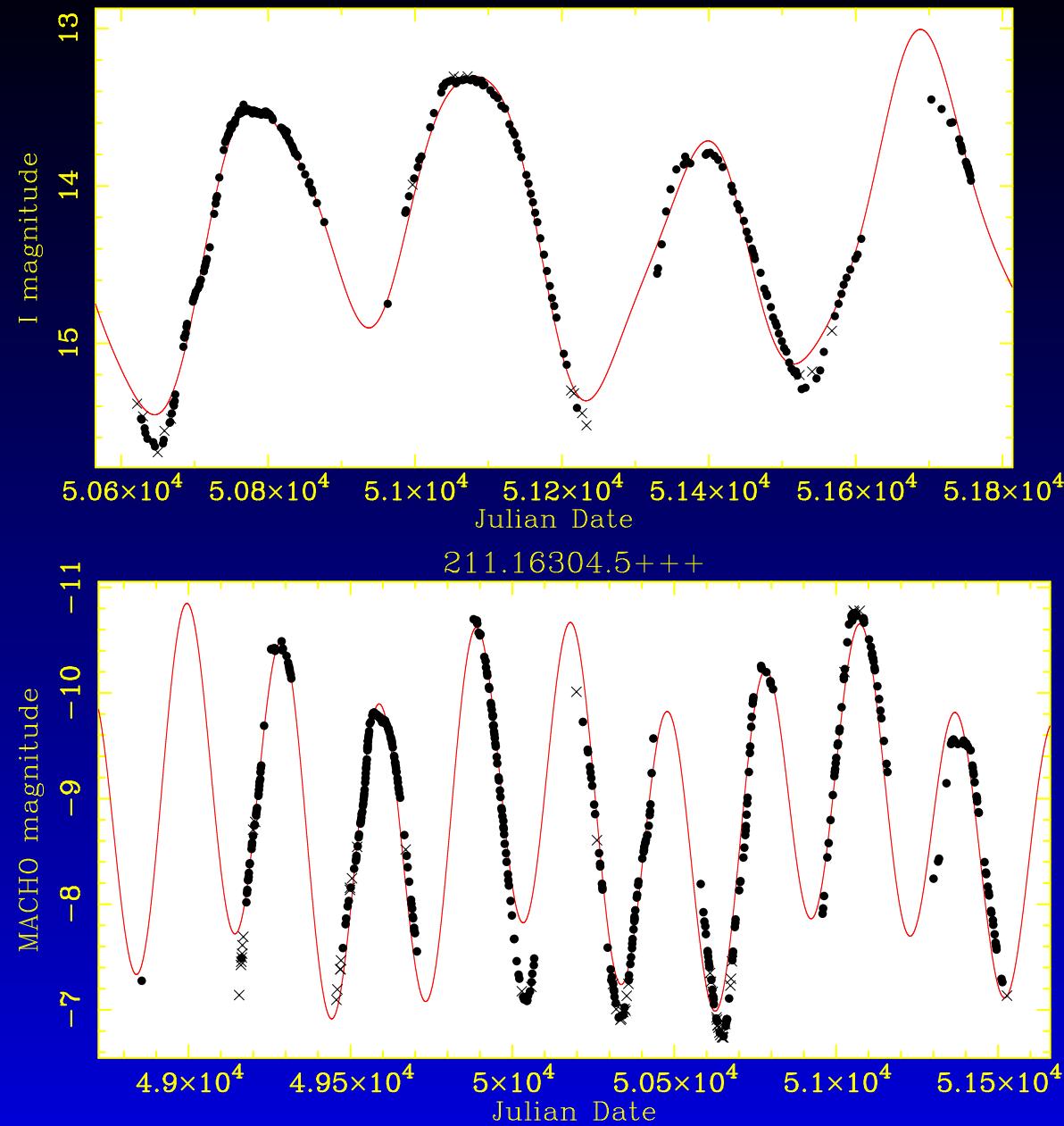
- with Cioni et al. [MRC] for SMC objects
- with Wood [PW] for $P < 25^d$ LMC objects on Seq. “A”

in following plots:

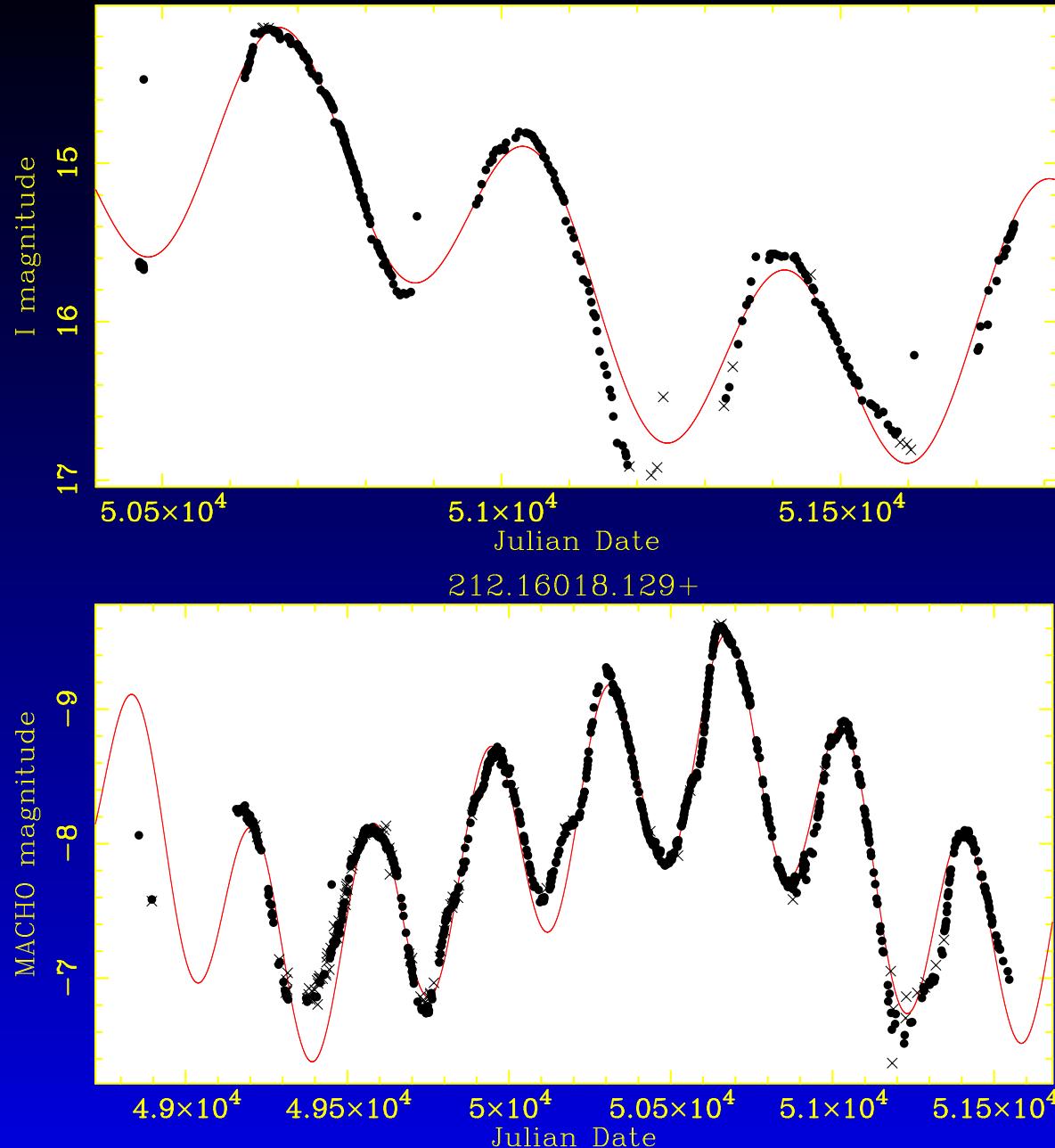
top: my fit to OGLE data

lower: my fit to MACHO data

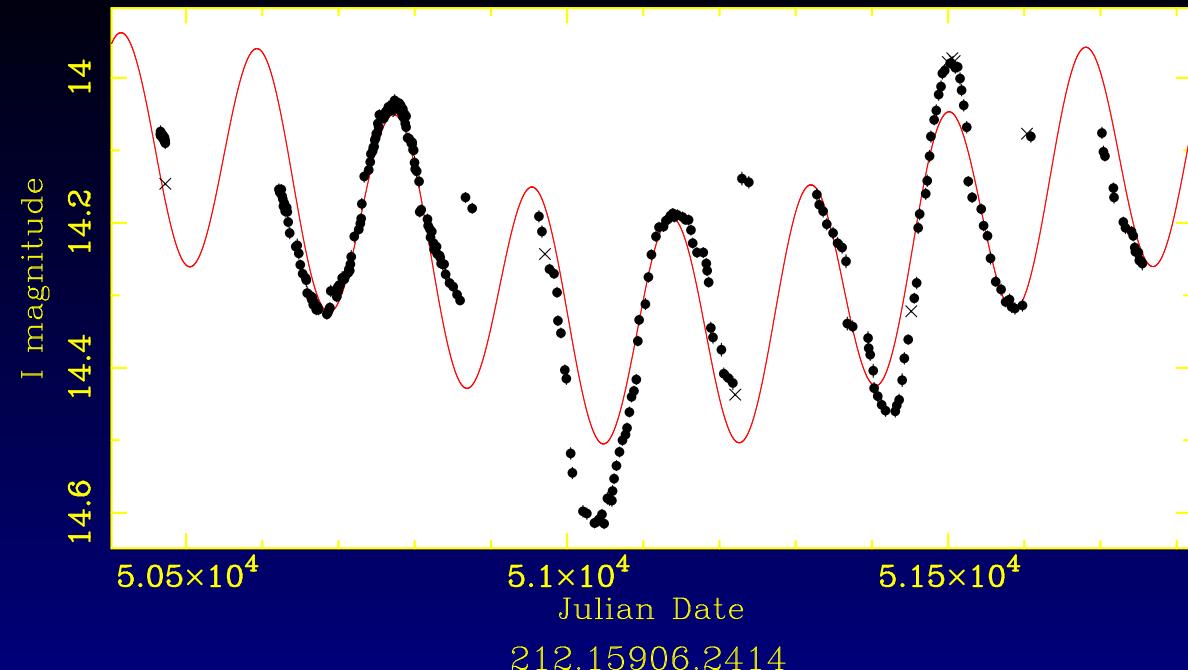
period by MRC or PW; period(s) found by me
(periods in days)



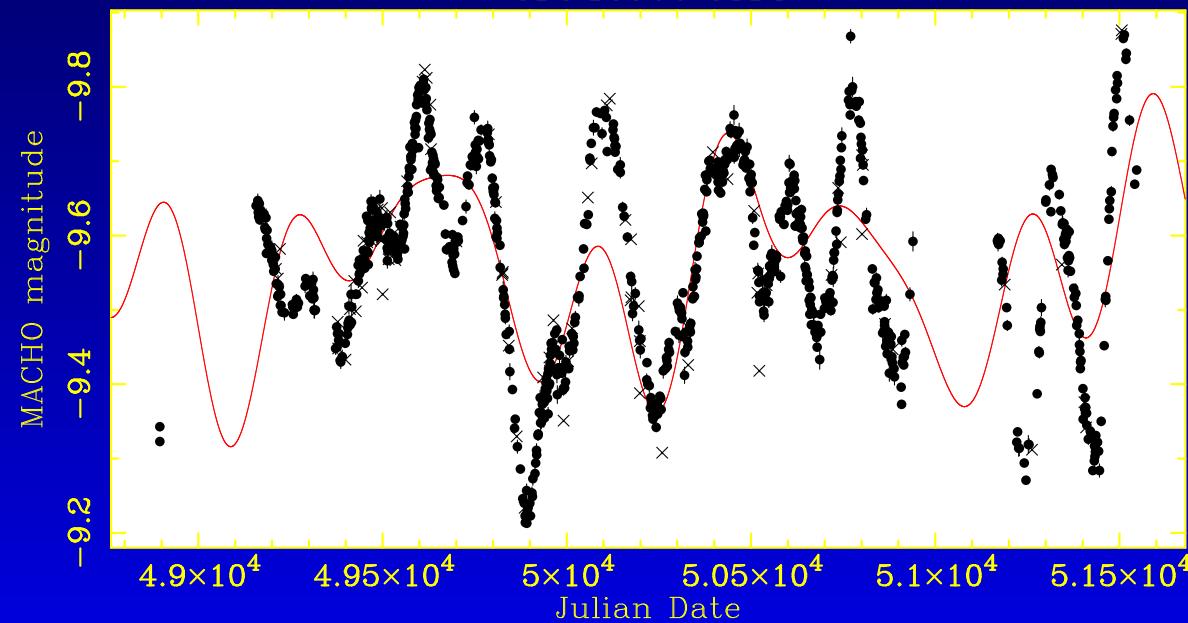
HV 1645: MRC: 296 (1), MACHO: 294, OGLE: 301



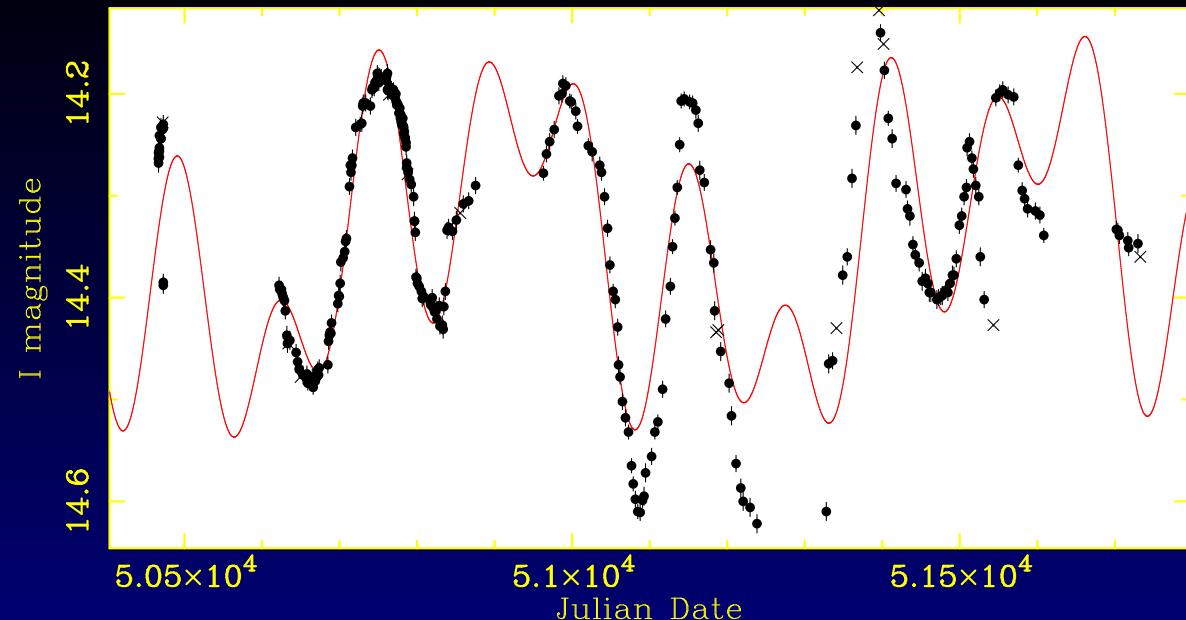
MRC: 2600 (5), MACHO: 364 + 2145,
OGLE: 373 + 1640



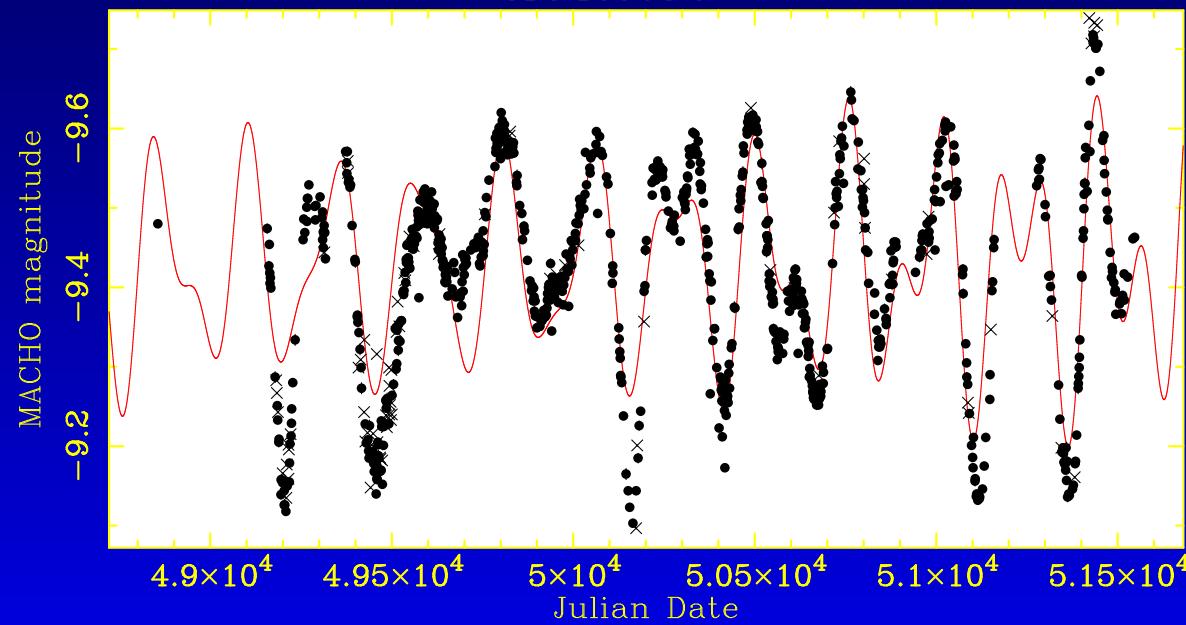
212.15906.2414



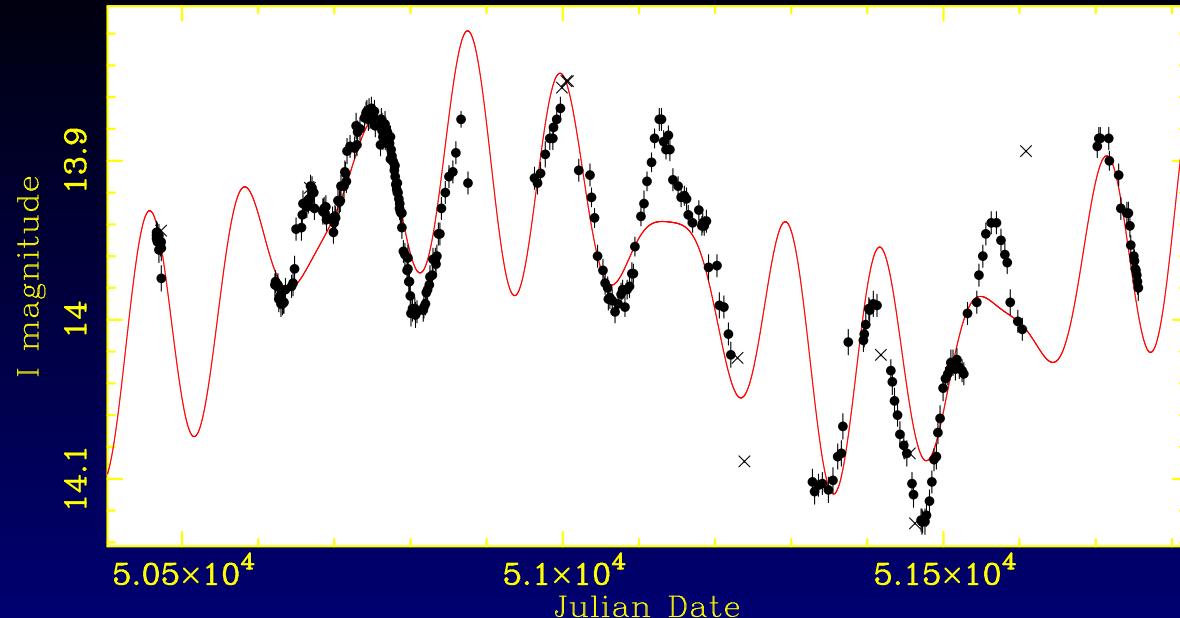
MRC: 1047 (6), MACHO: 386 + 1002,
OGLE: 181 + 1350



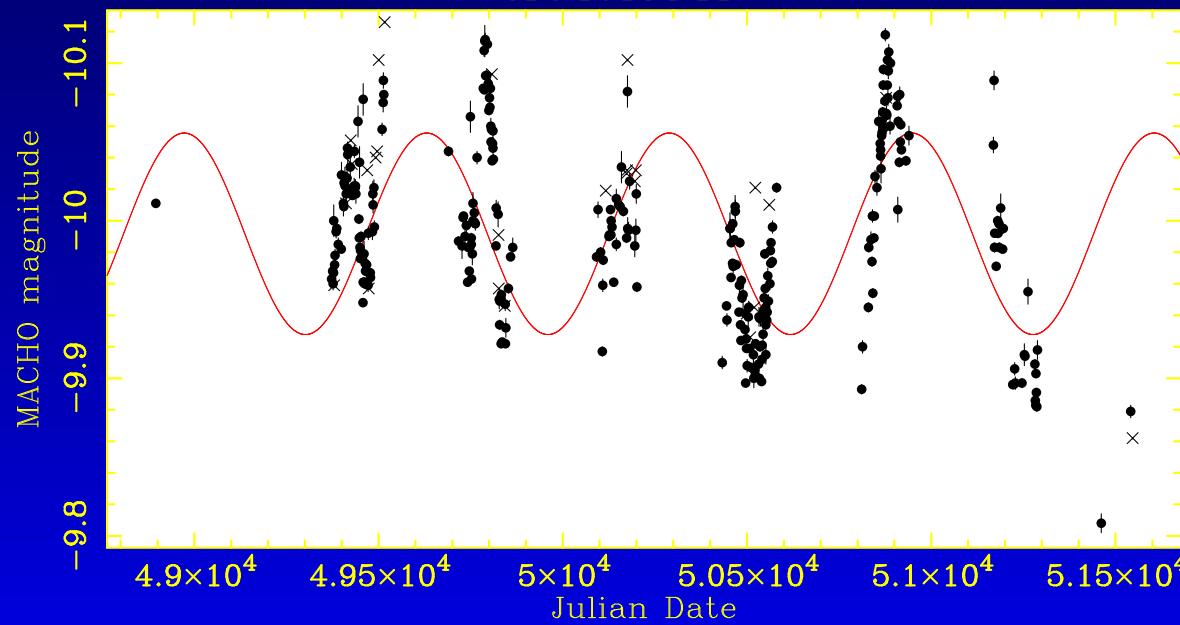
212.15903.9+++



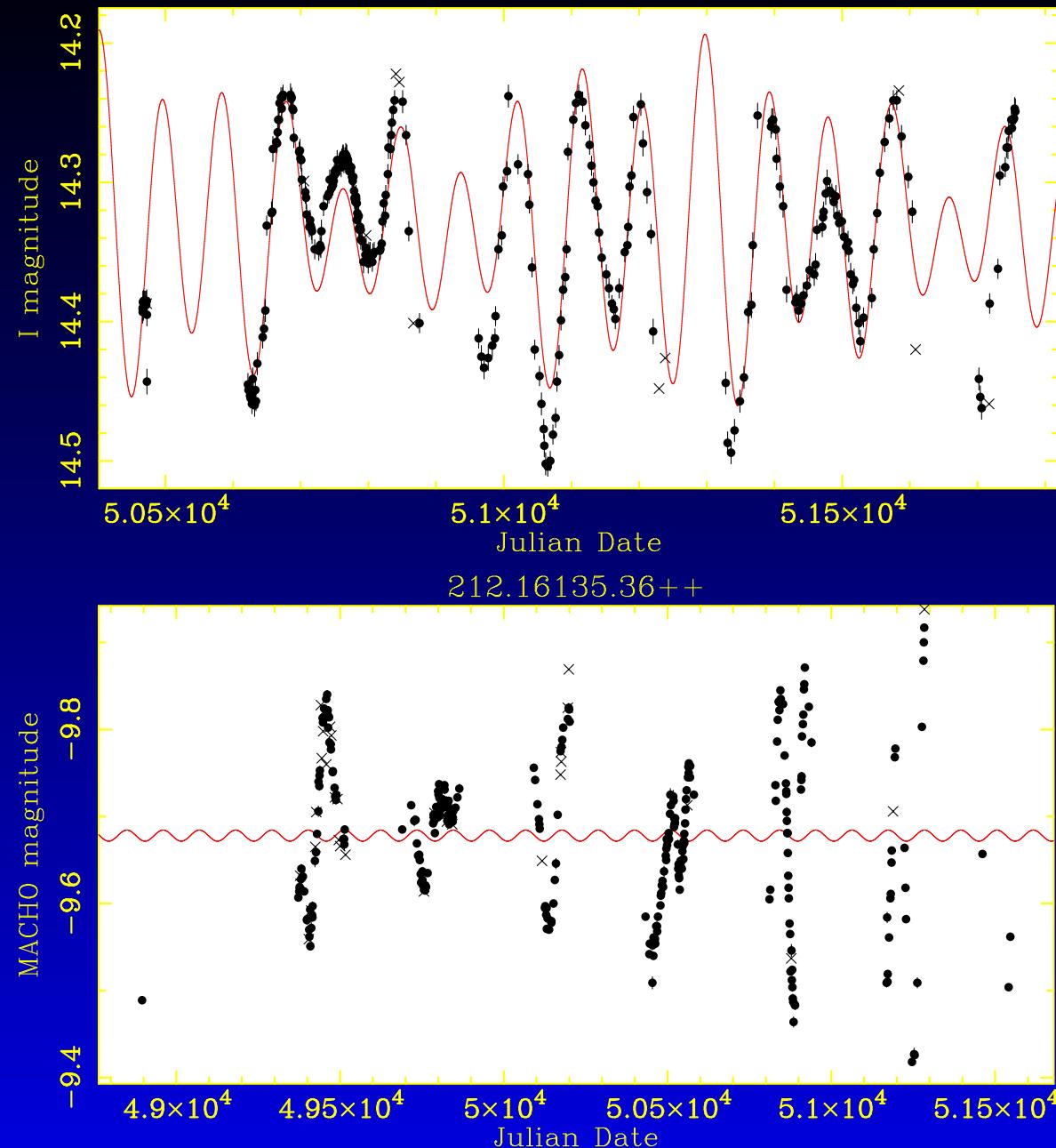
MRC: 239 (1), MACHO: 237, OGLE: 132



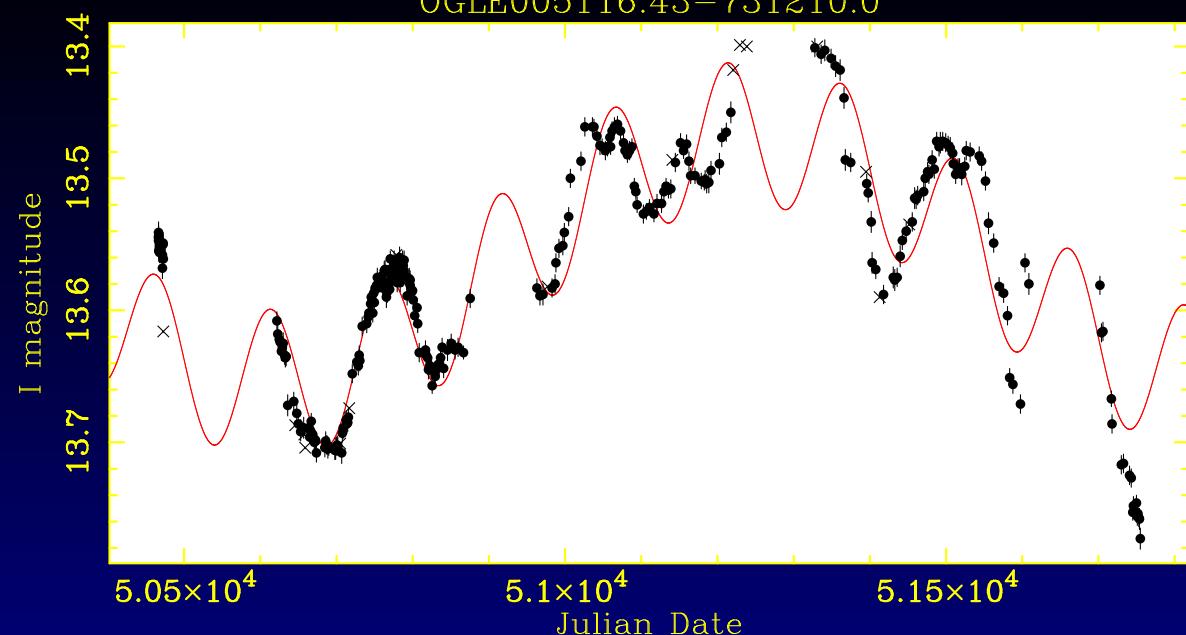
212.16134.11++



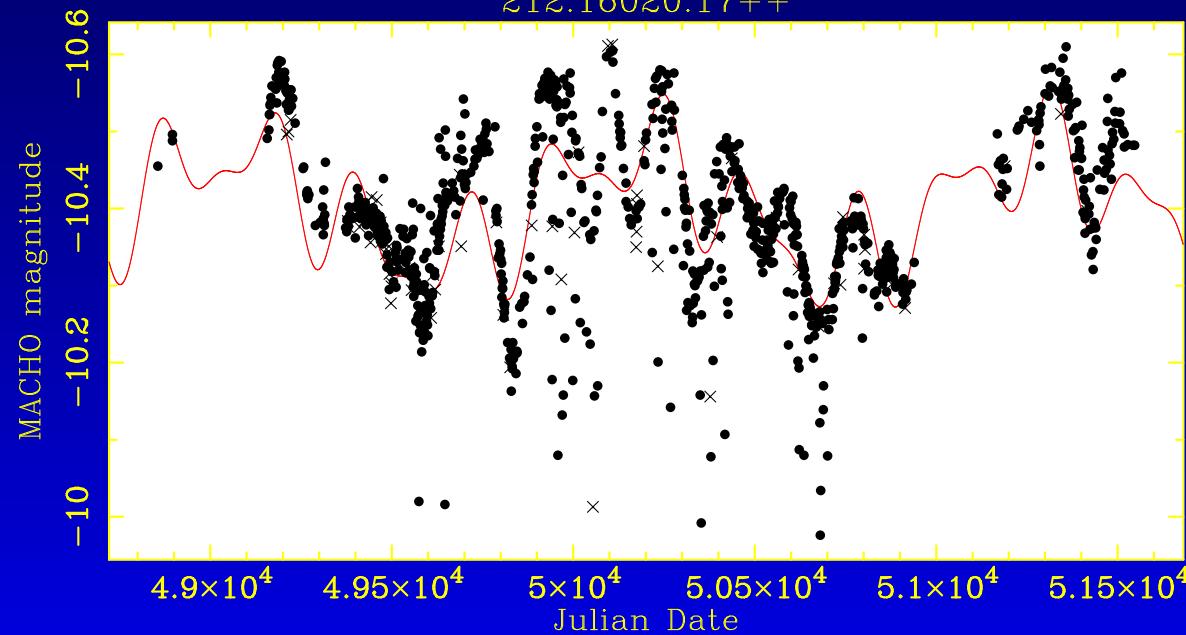
MRC: 1224 (5), MACHO: 658, OGLE: 138 + 1100



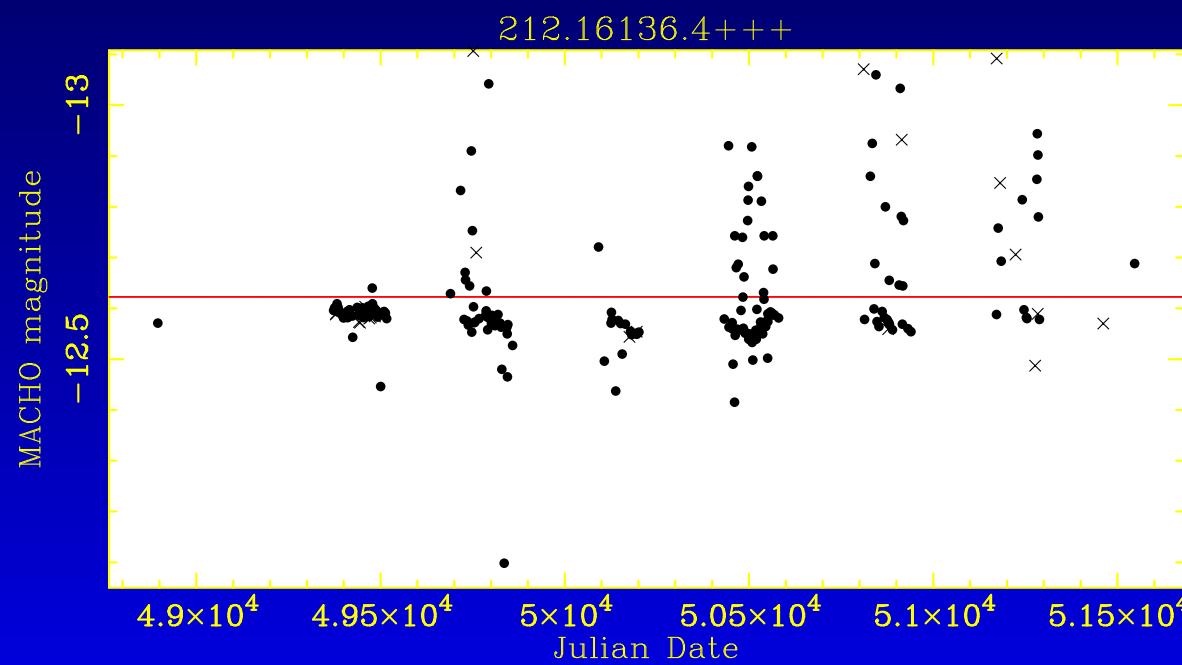
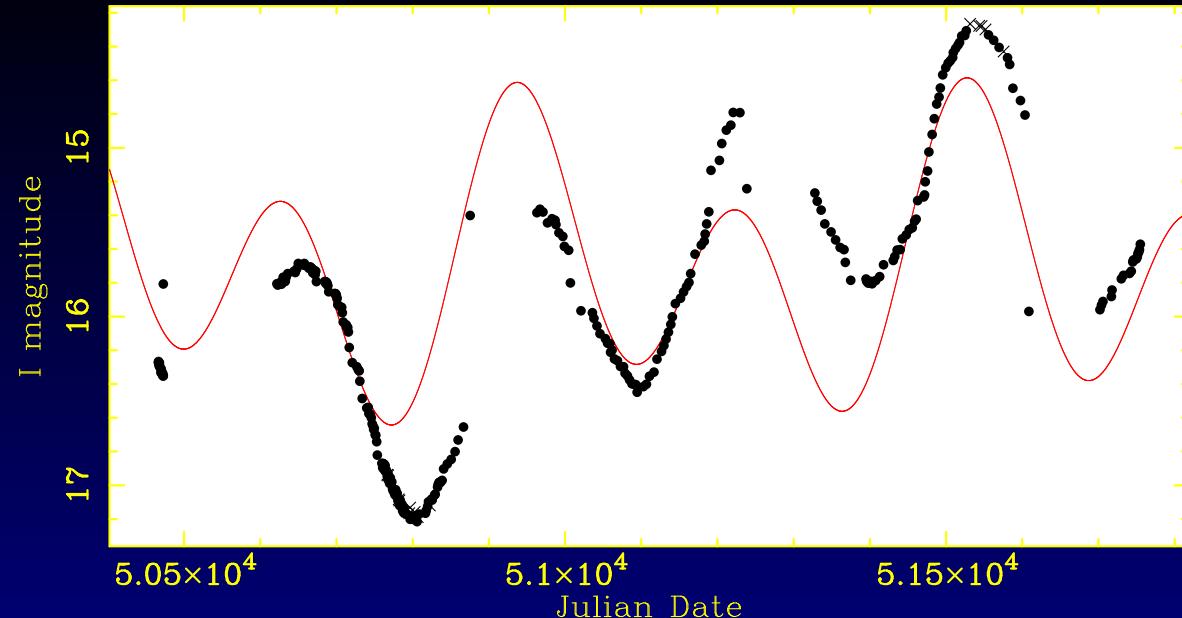
MRC: 182 (1), MACHO: 92, OGLE: 89



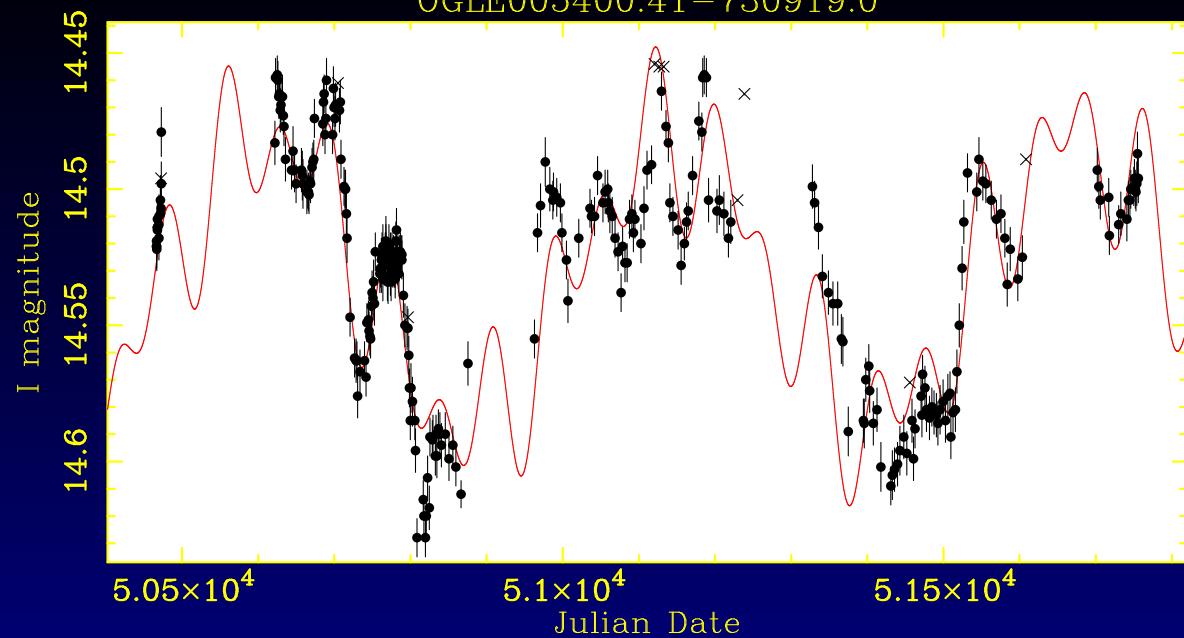
212.16020.17++



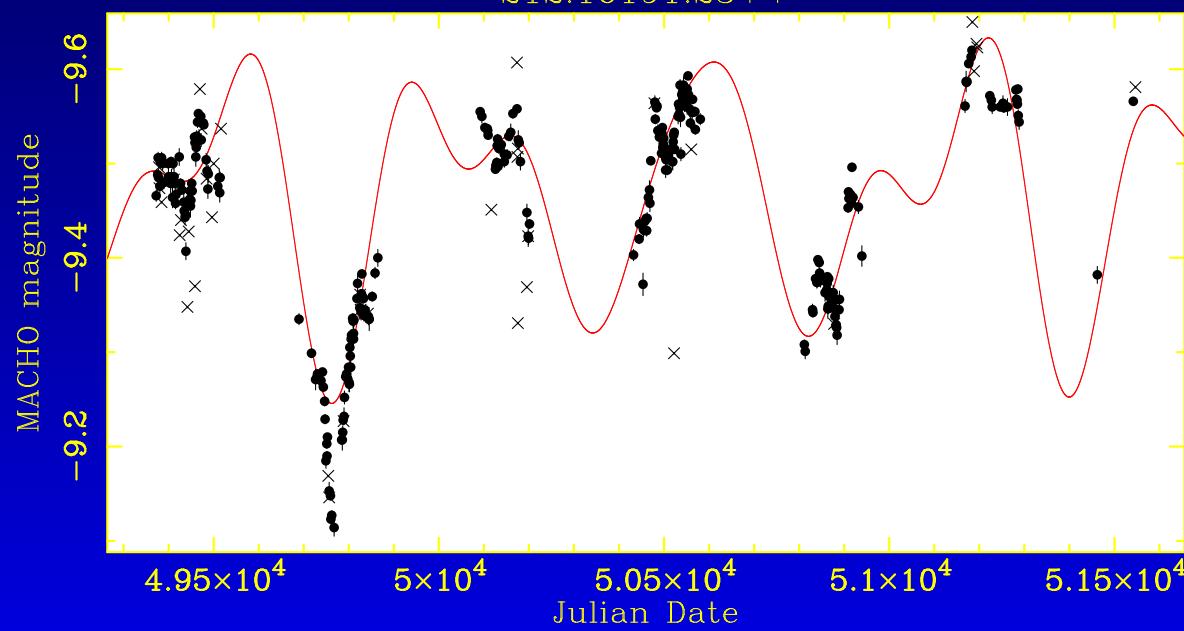
MRC: 1070 (6), MACHO: 1116 + 269 + 177,
OGLE: 150 + 1253



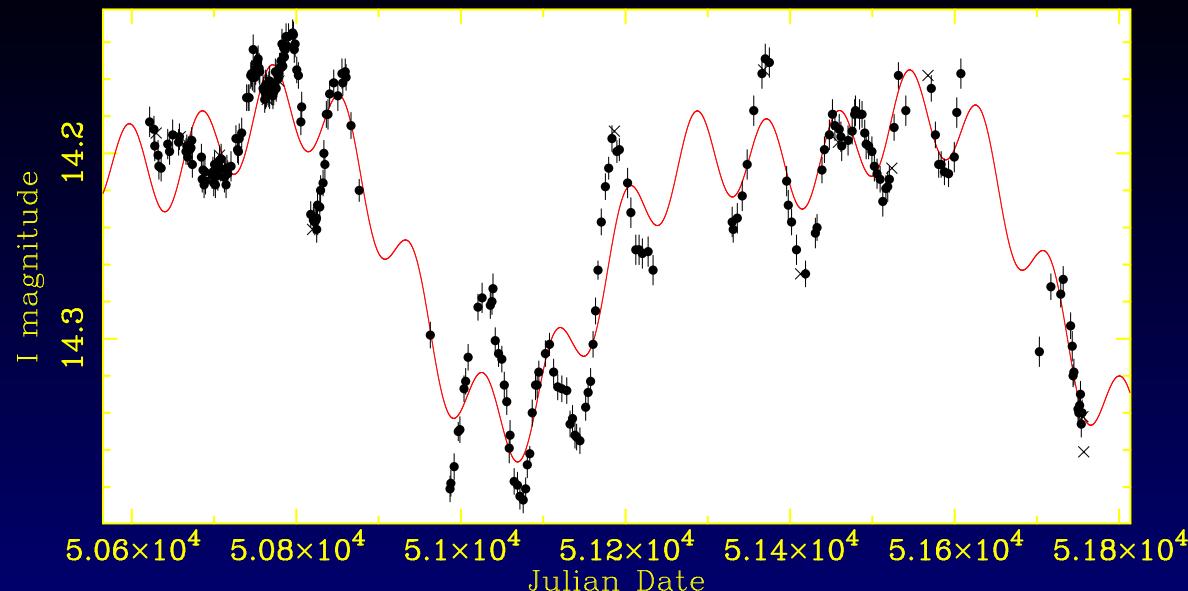
MRC: 14 (5), MACHO: none,
OGLE: 297 ; FAILURE



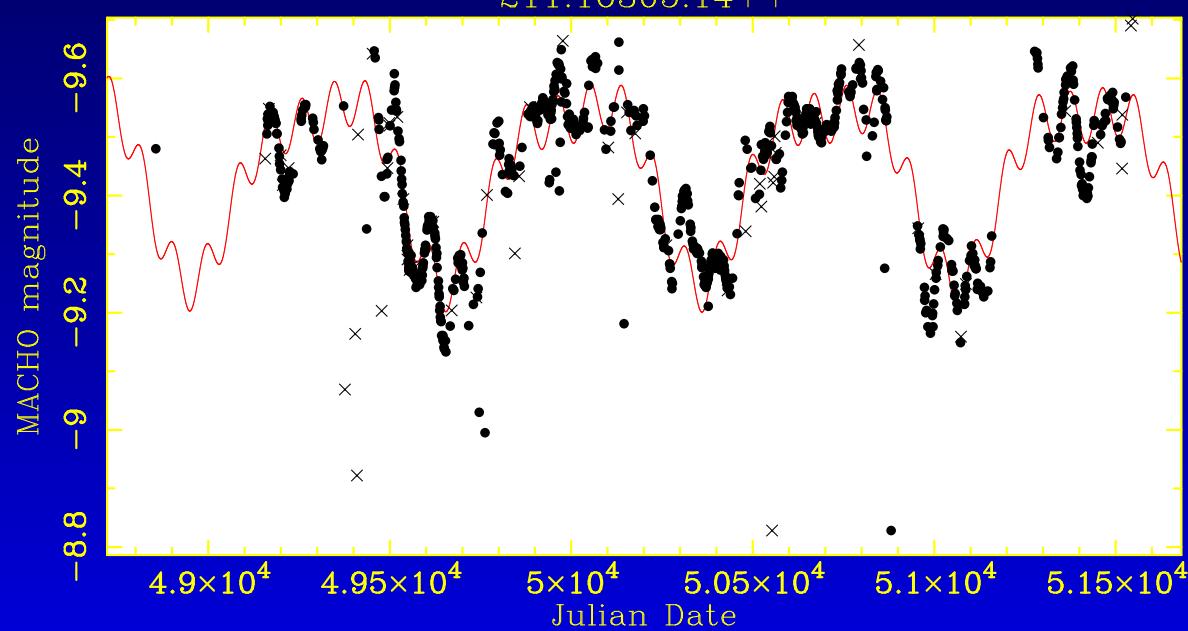
212.16191.23++



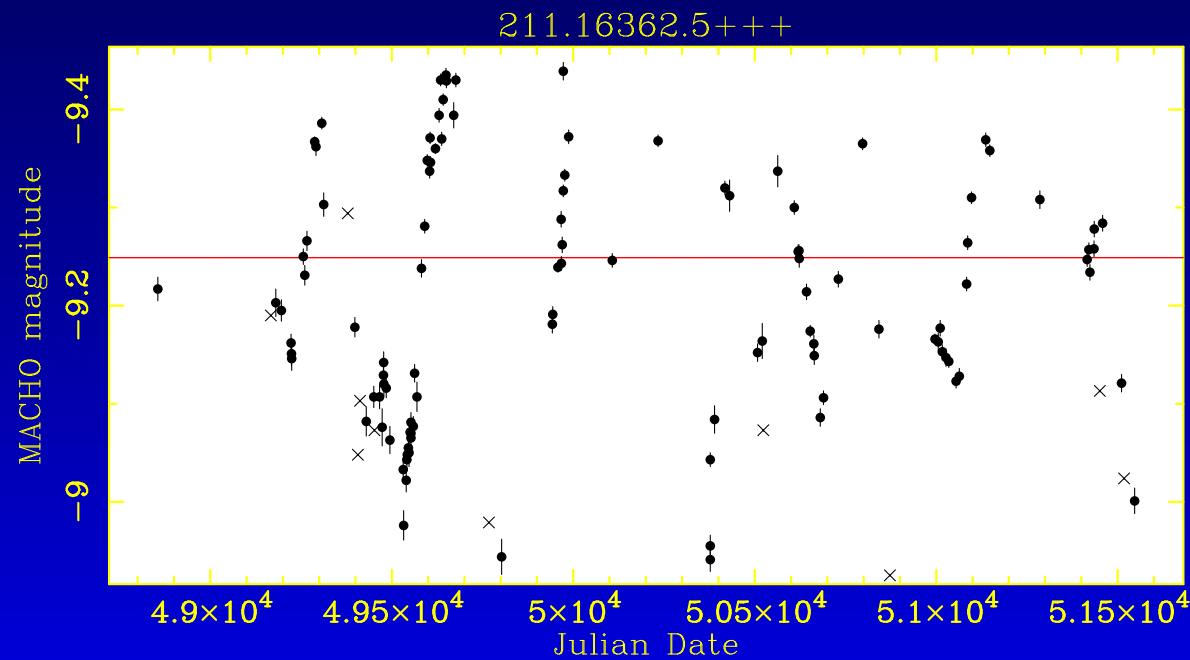
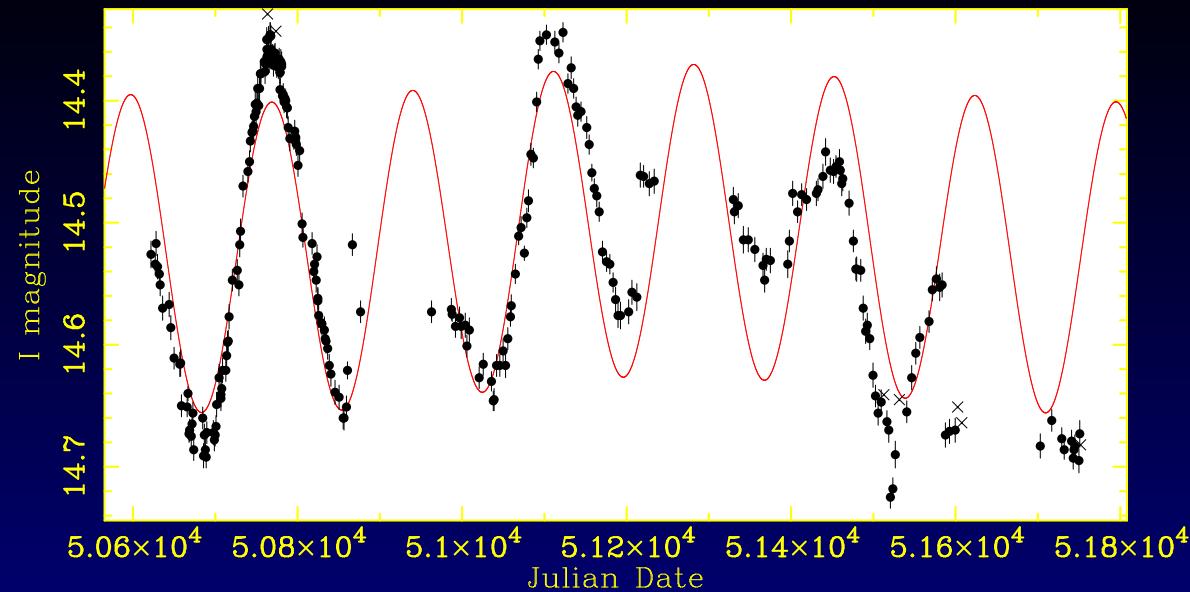
MRC: 550 (1), MACHO: 549, OGLE: 71 + 532



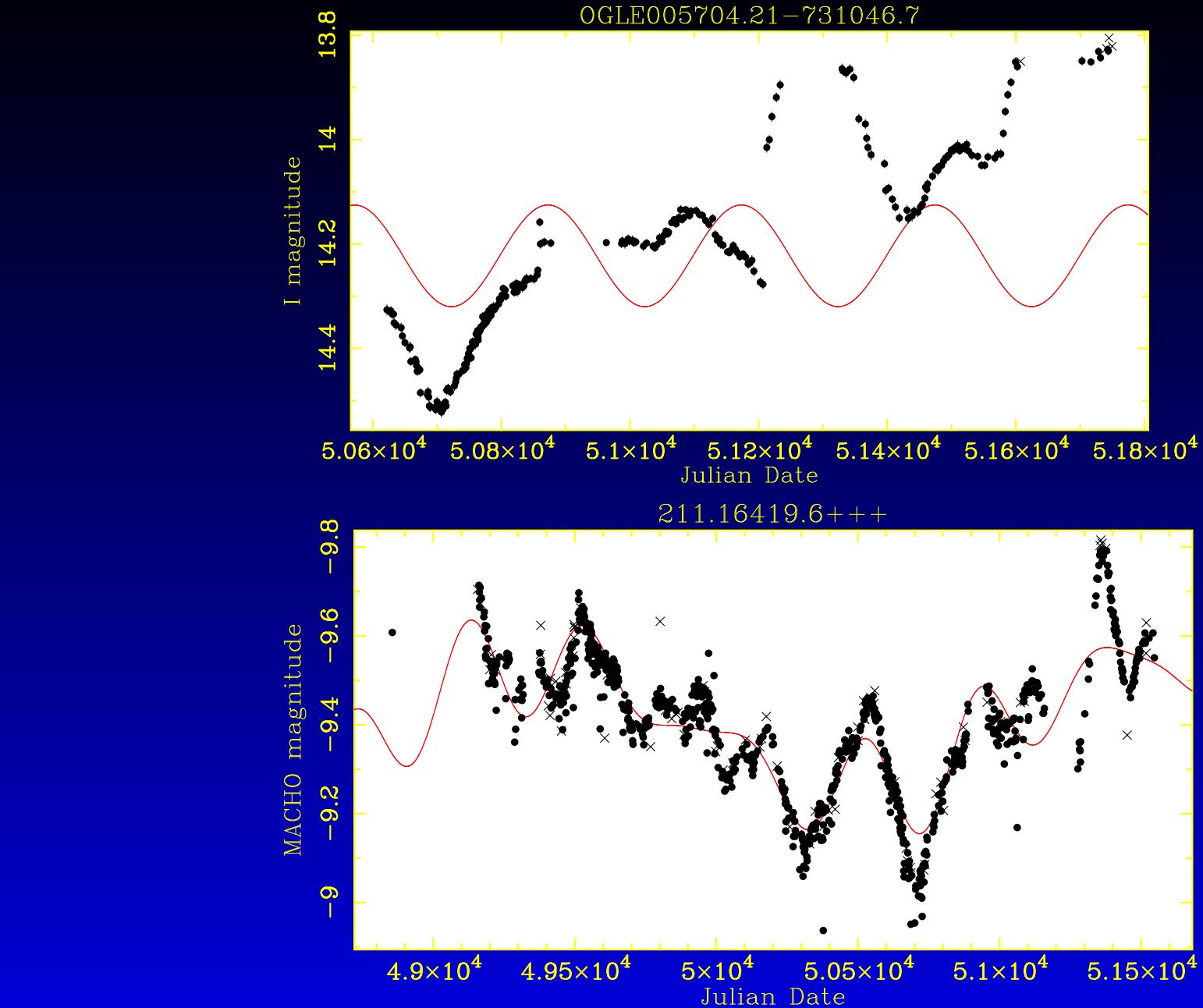
211.16305.14++



MRC: 697 (6), MACHO: 88.2 + 699,
OGLE: 86.1 + 765

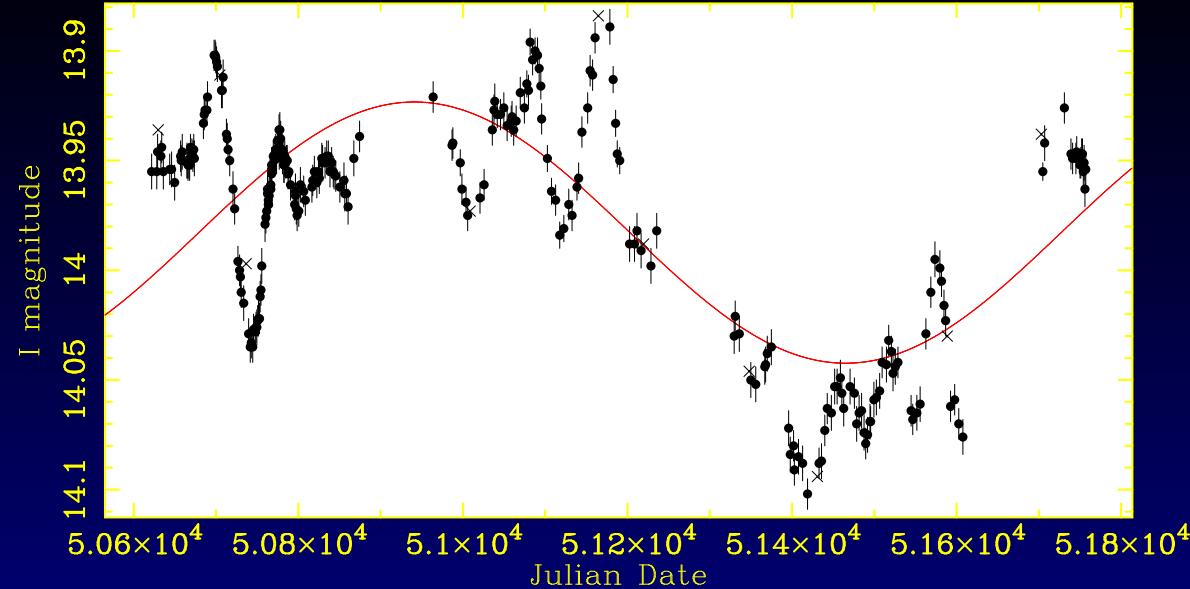


MRC: 284 (6), MACHO: none, OGLE: 171

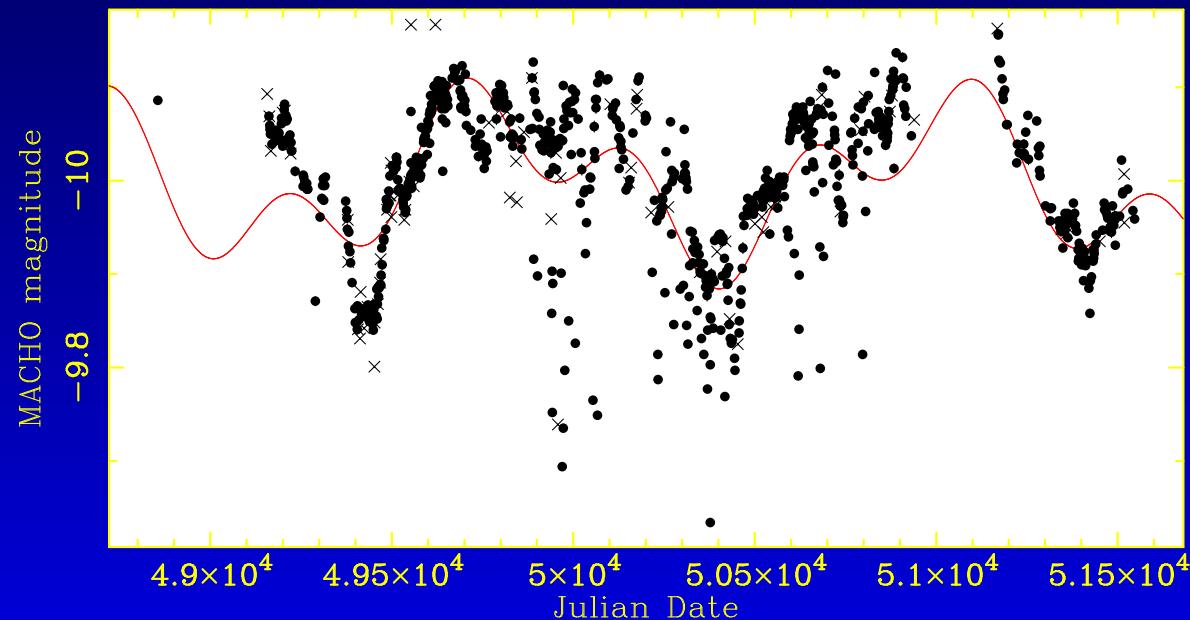


MRC: 2200 (5), MACHO: 2161 + 458 + 355,
OGLE: 300

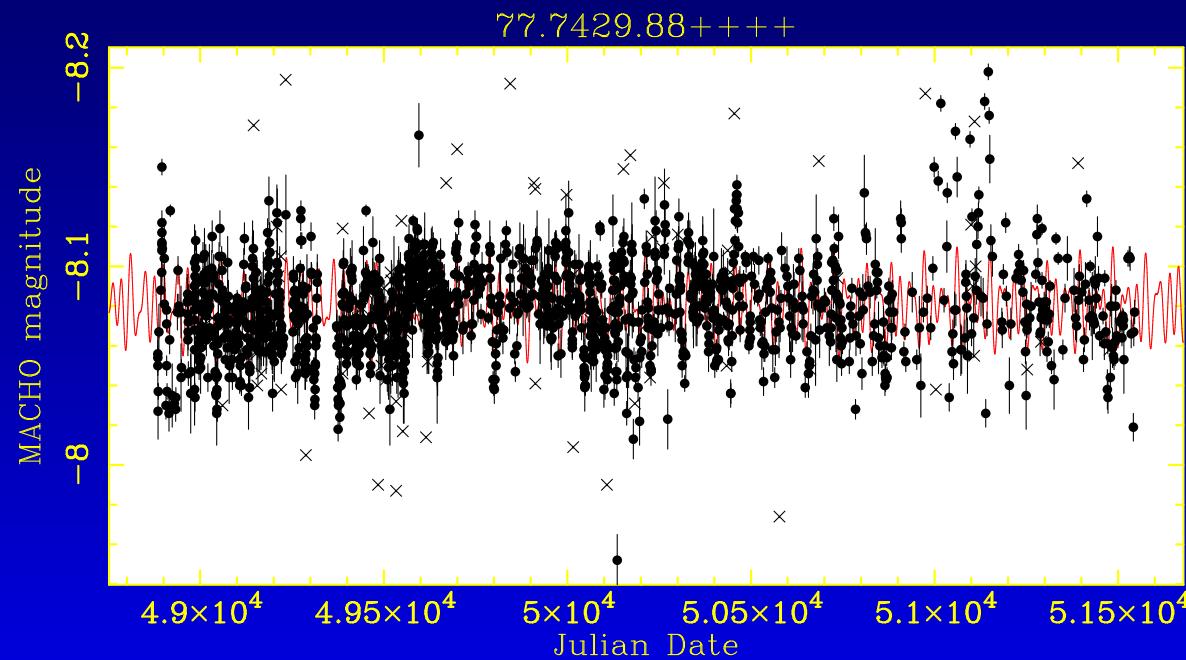
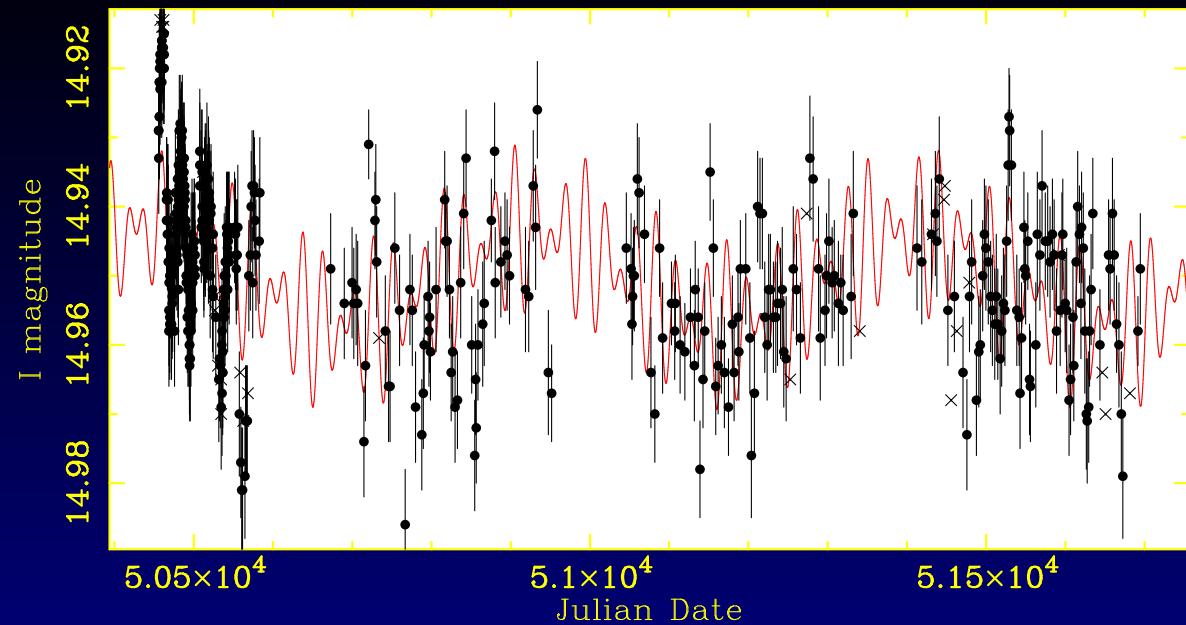
OGLE010043.20-725746.4



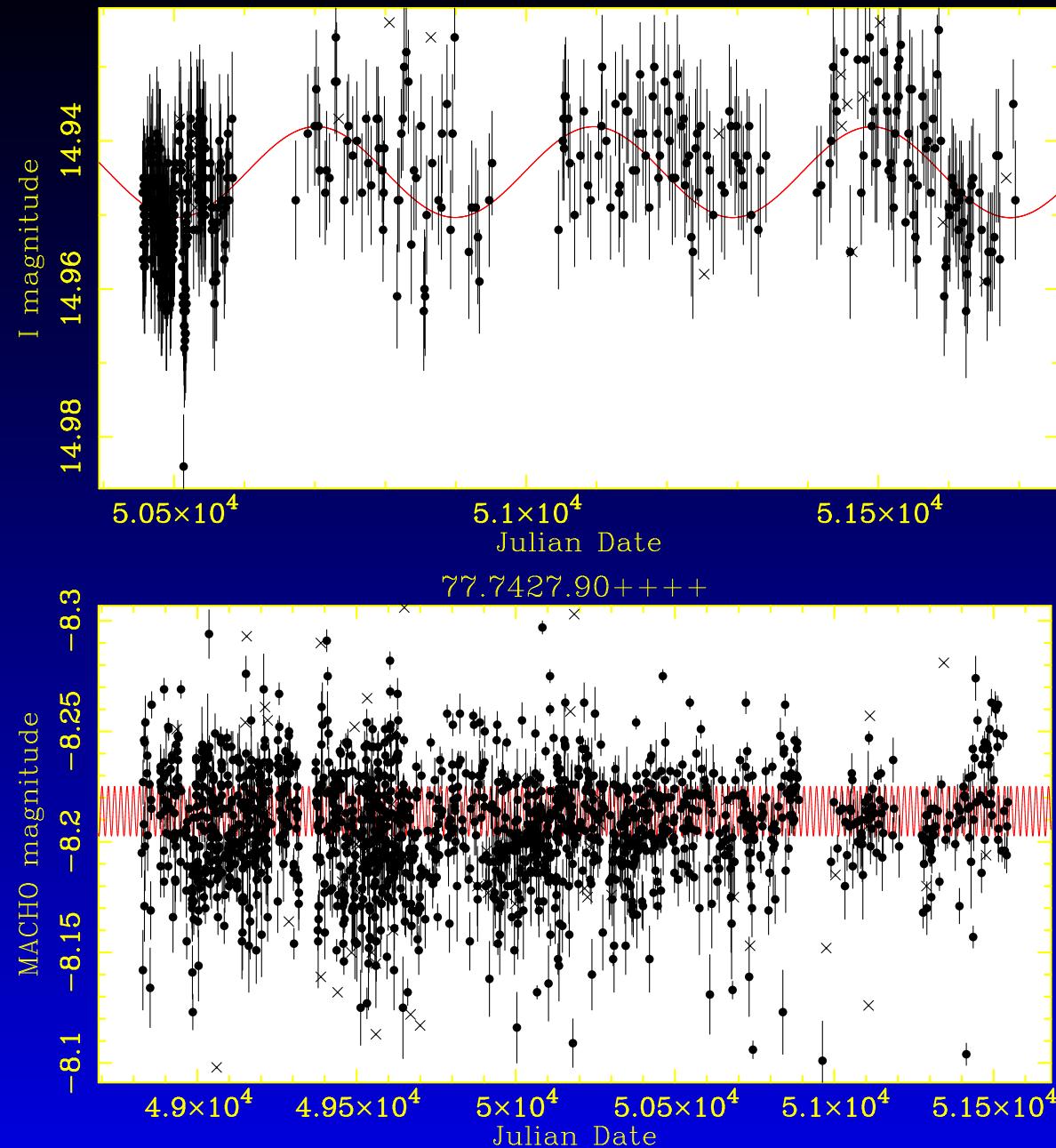
211.16650.6+++



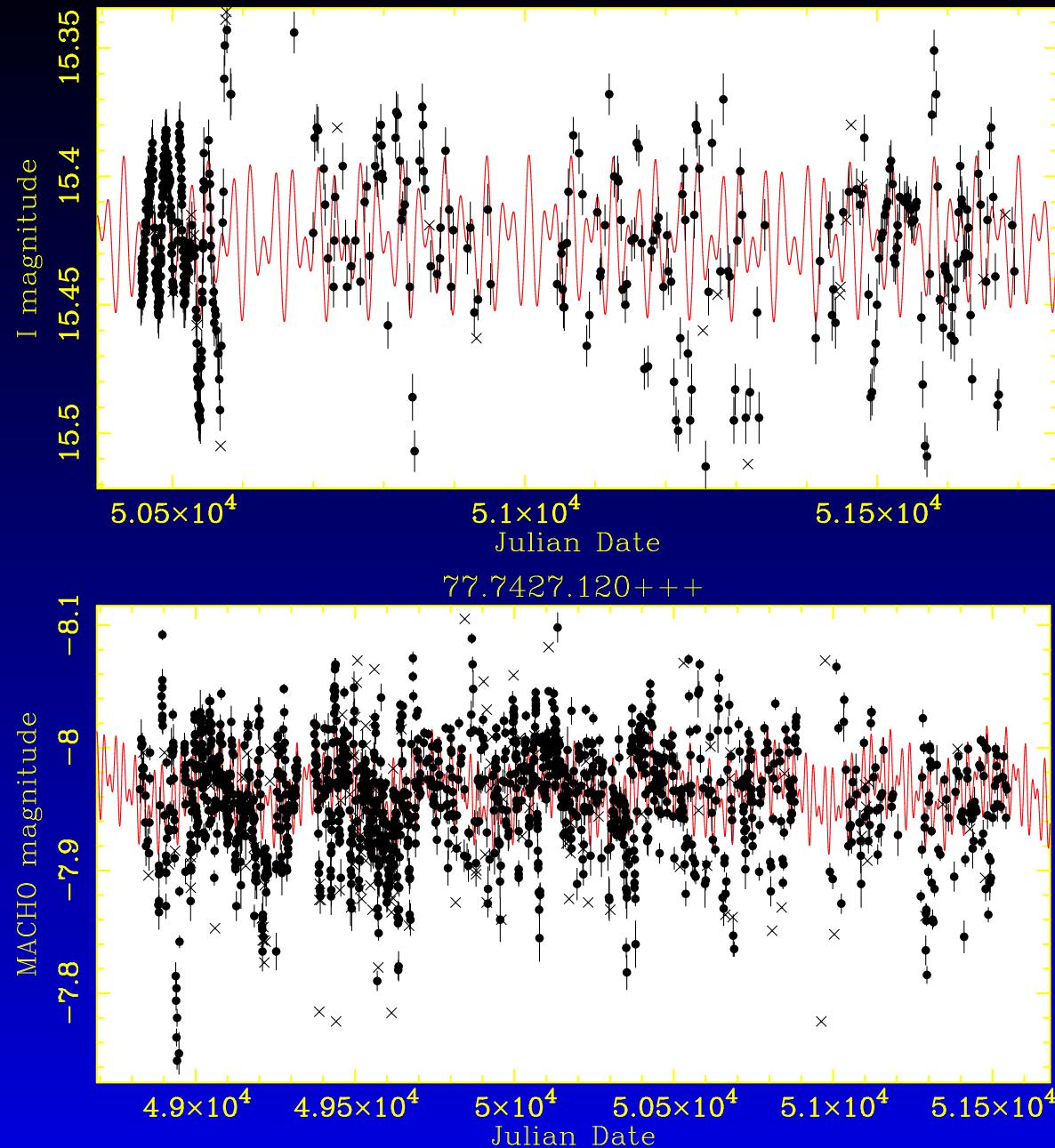
MRC: 991 (6), MACHO: 475 + 1205,
OGLE: 1056



PW: 22.32, MACHO: $11.31 + 30.4 + 42.8$
 OGLE: $29.84 + 480 + 22.24$

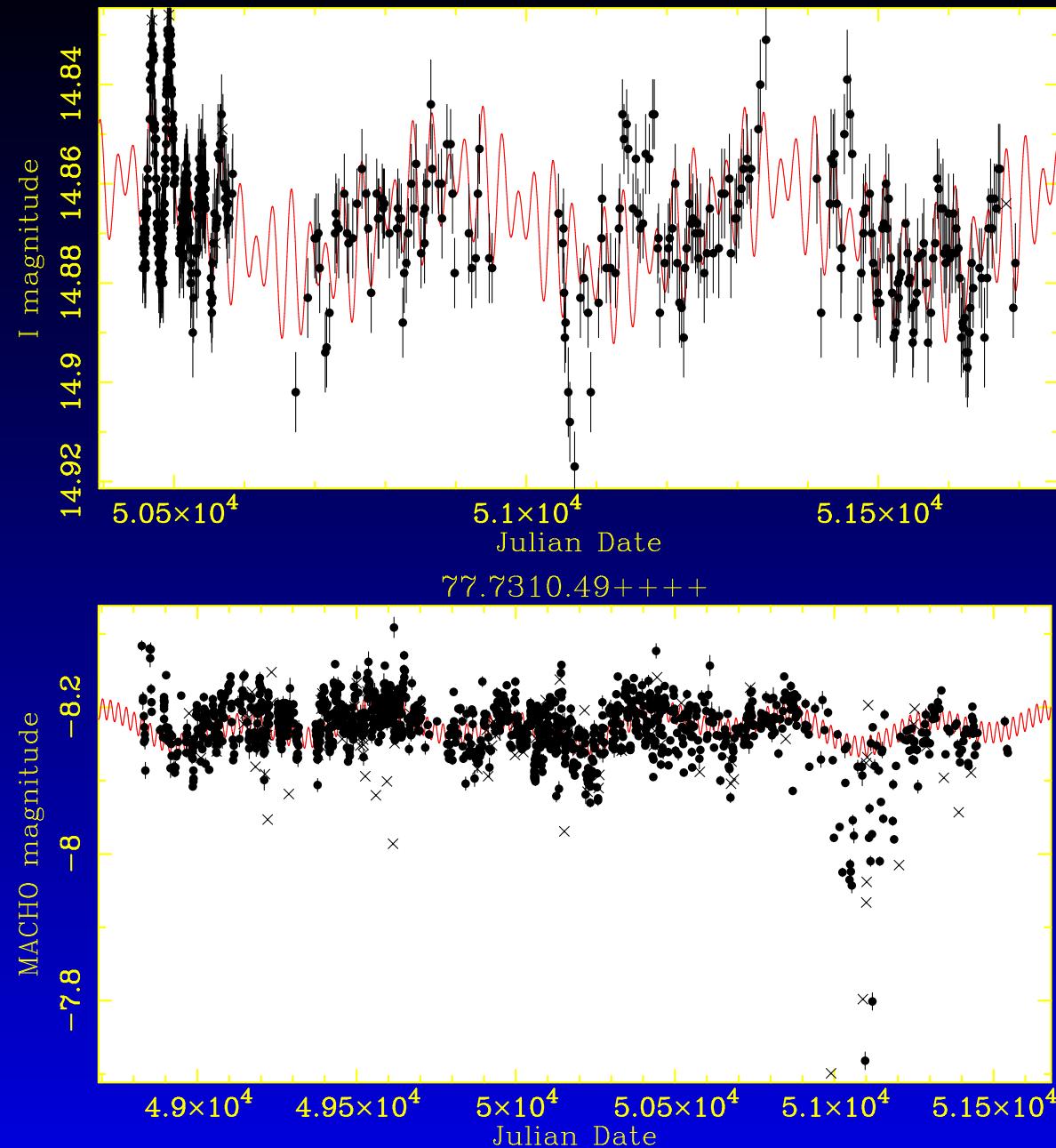


PW: 19.66, MACHO: 19.68, OGLE: 394



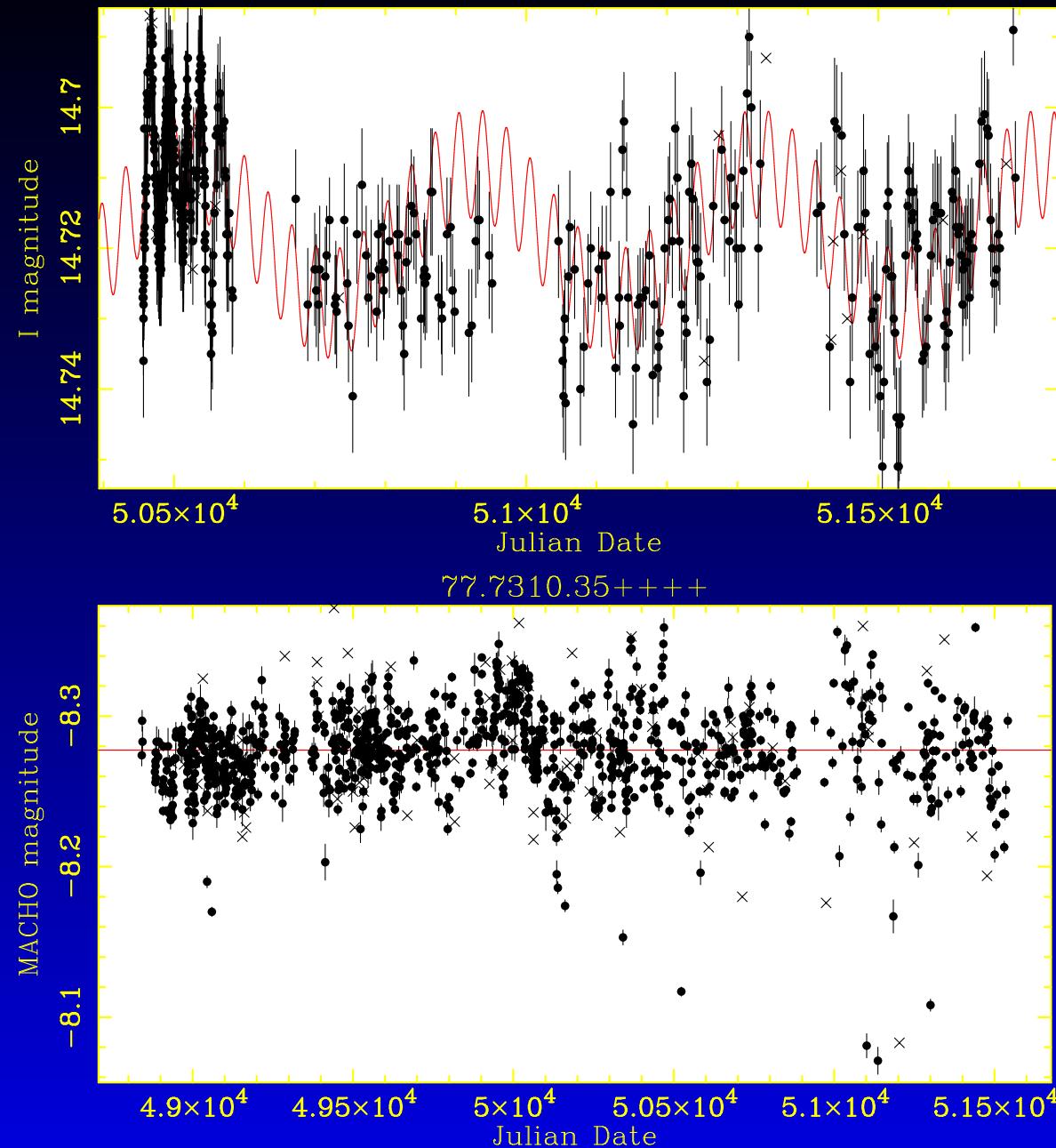
PW: 20.21, MACHO: $30.1 + 20.22 + 350$

OGLE: $19.84 + 30.2$

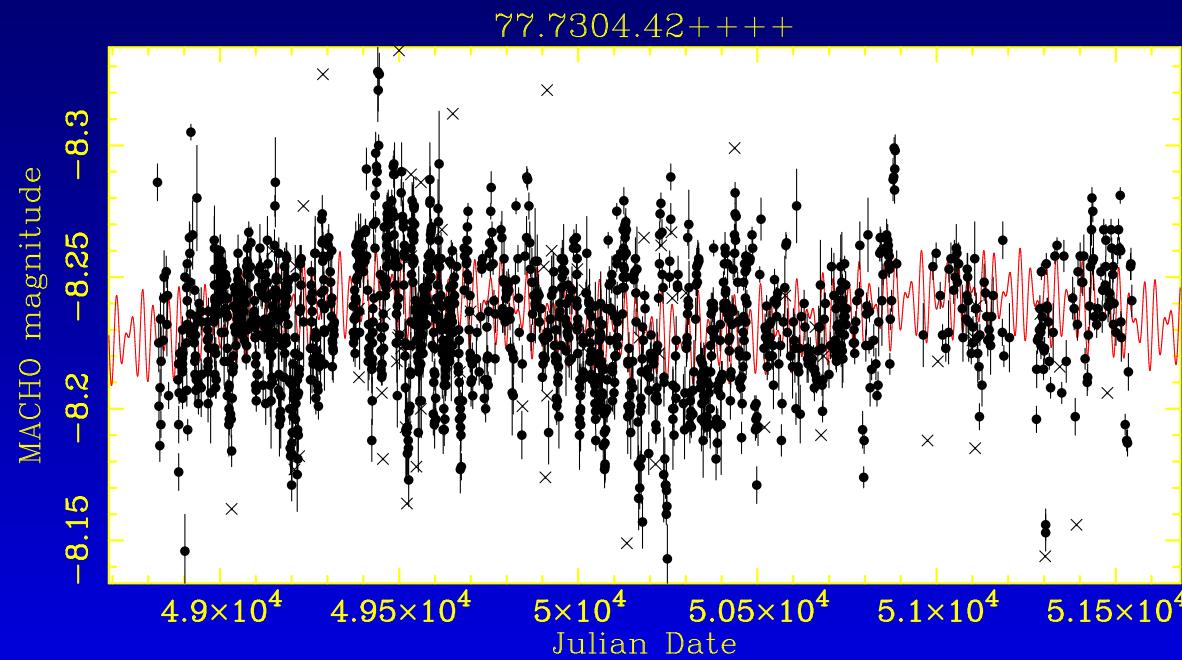
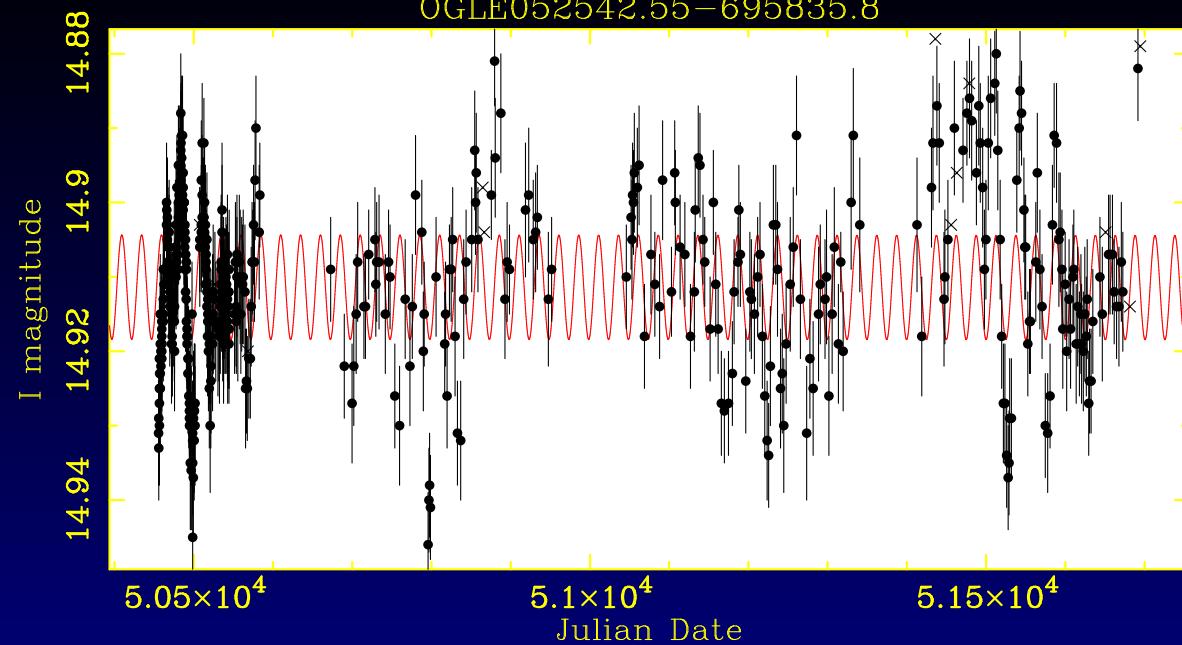


PW: 24.45, MACHO: $430 + 1023 + 24.86$

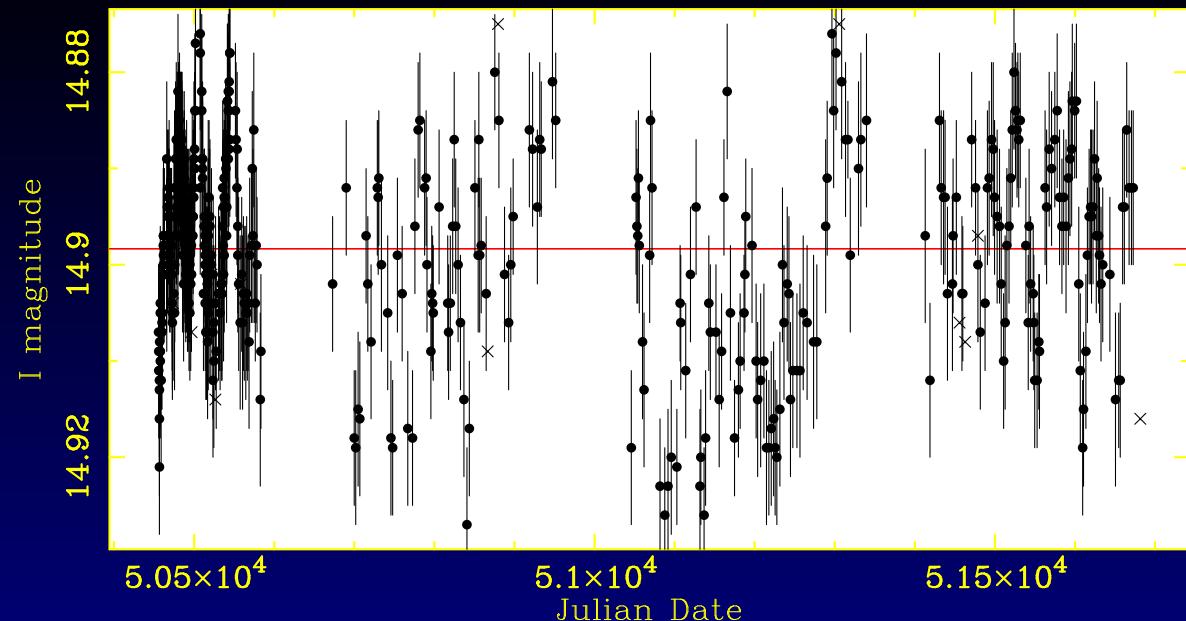
OGLE: $24.79 + 445 + 33.7$



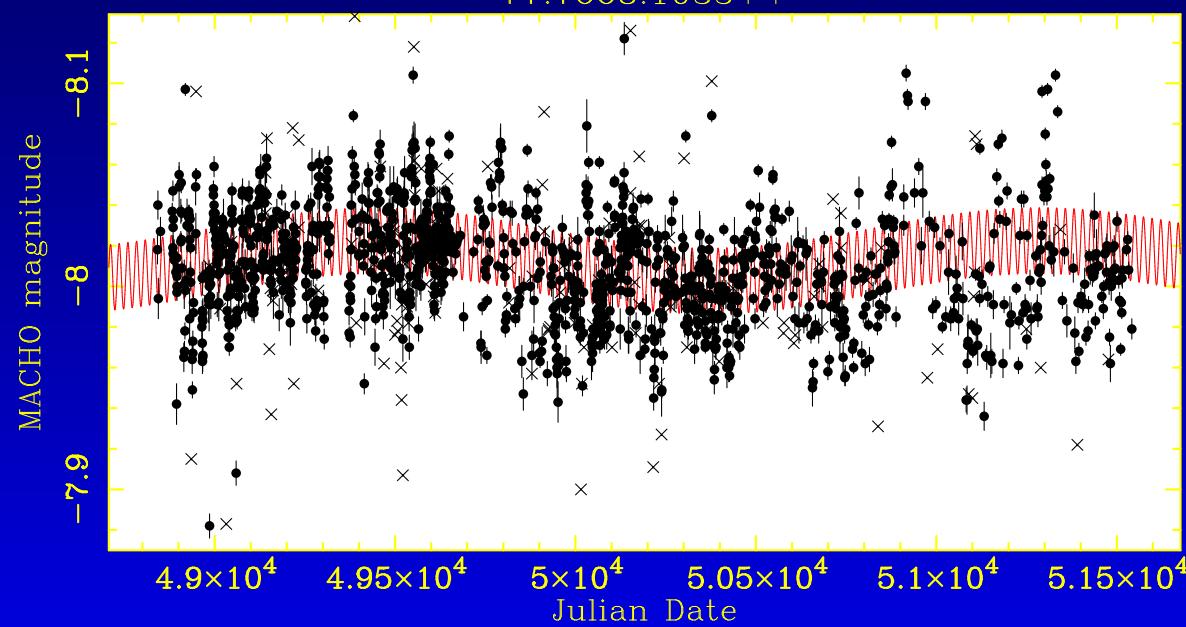
PW: 24.52, MACHO: none, OGLE: 33.8 + 404



PW: 24.88, MACHO: $24.99 + 30.50 + 1591$,
OGLE: 25.08



77.7668.1033++



PW: 24.05, MACHO: 24.05 + 1834

OGLE: none

Combine OGLE & MACHO ?

$$R(t) = M_R + A_R \cos(\omega_R t + \phi_R)$$

$$I(t) = M_I + A_I \cos(\omega_I t + \phi_I)$$

IF $\omega_R = \omega_I = \omega$ $\phi_R = \phi_I = \phi$ THEN

$$R(t) - I(t) = (1 - A_I/A_R) R(t) + (M_R - M_I)$$

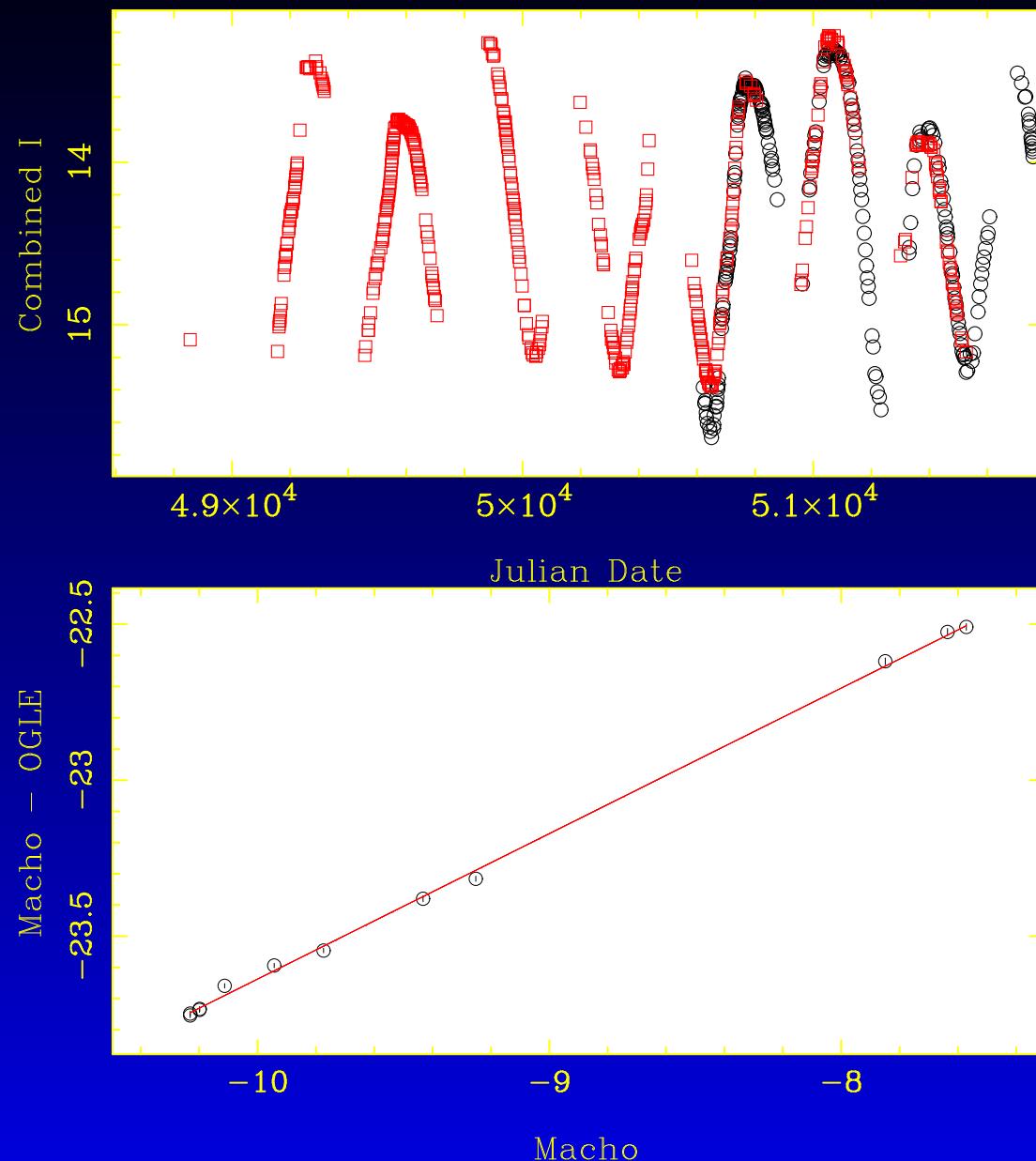
$\Delta t = 0.1 - 0.3d$ to get >40 points together in time +
subsequent rejection of outliers

Next plots:

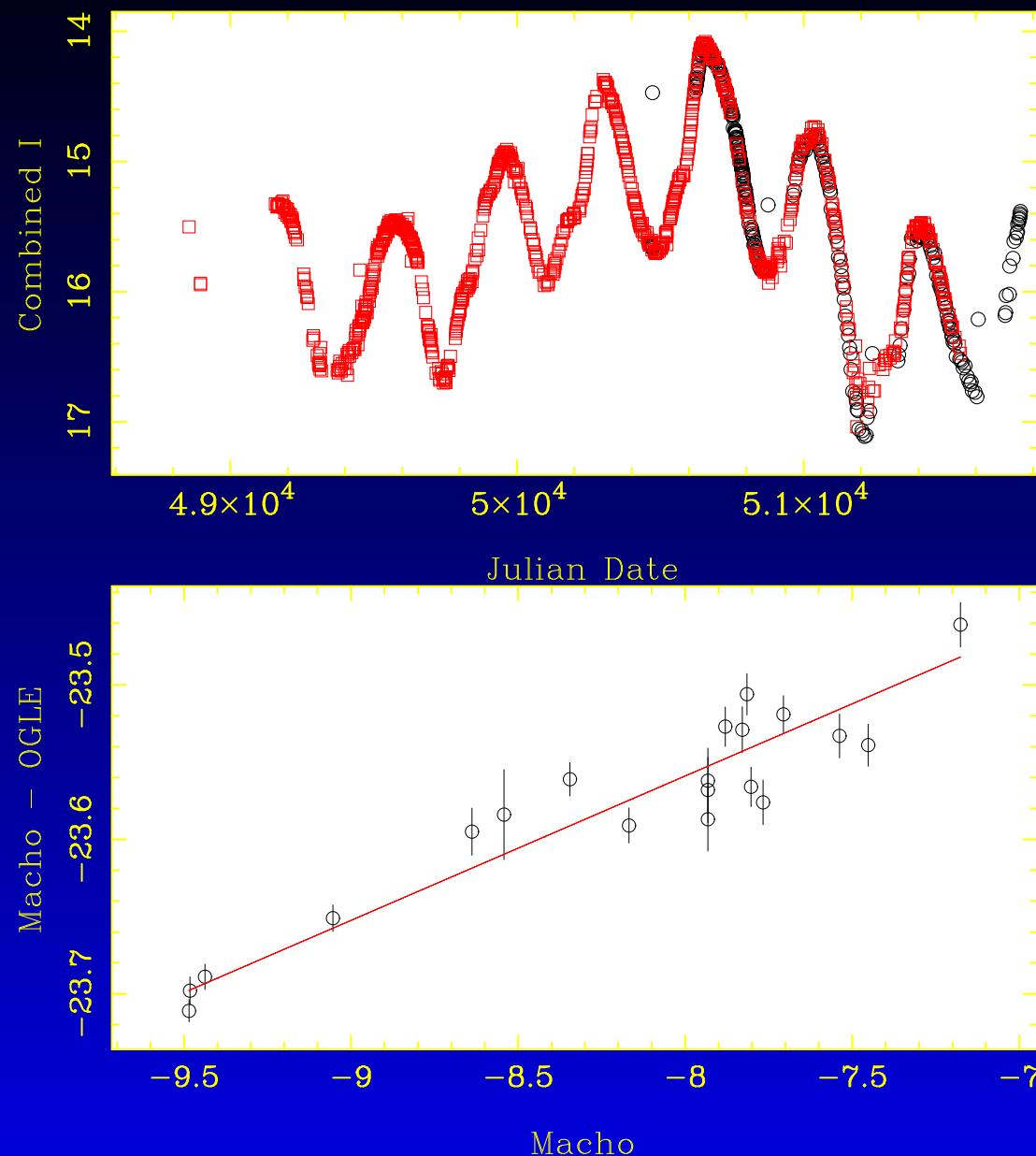
top: OGLE + MACHO transformed to I -band

lower: the expected linear relation

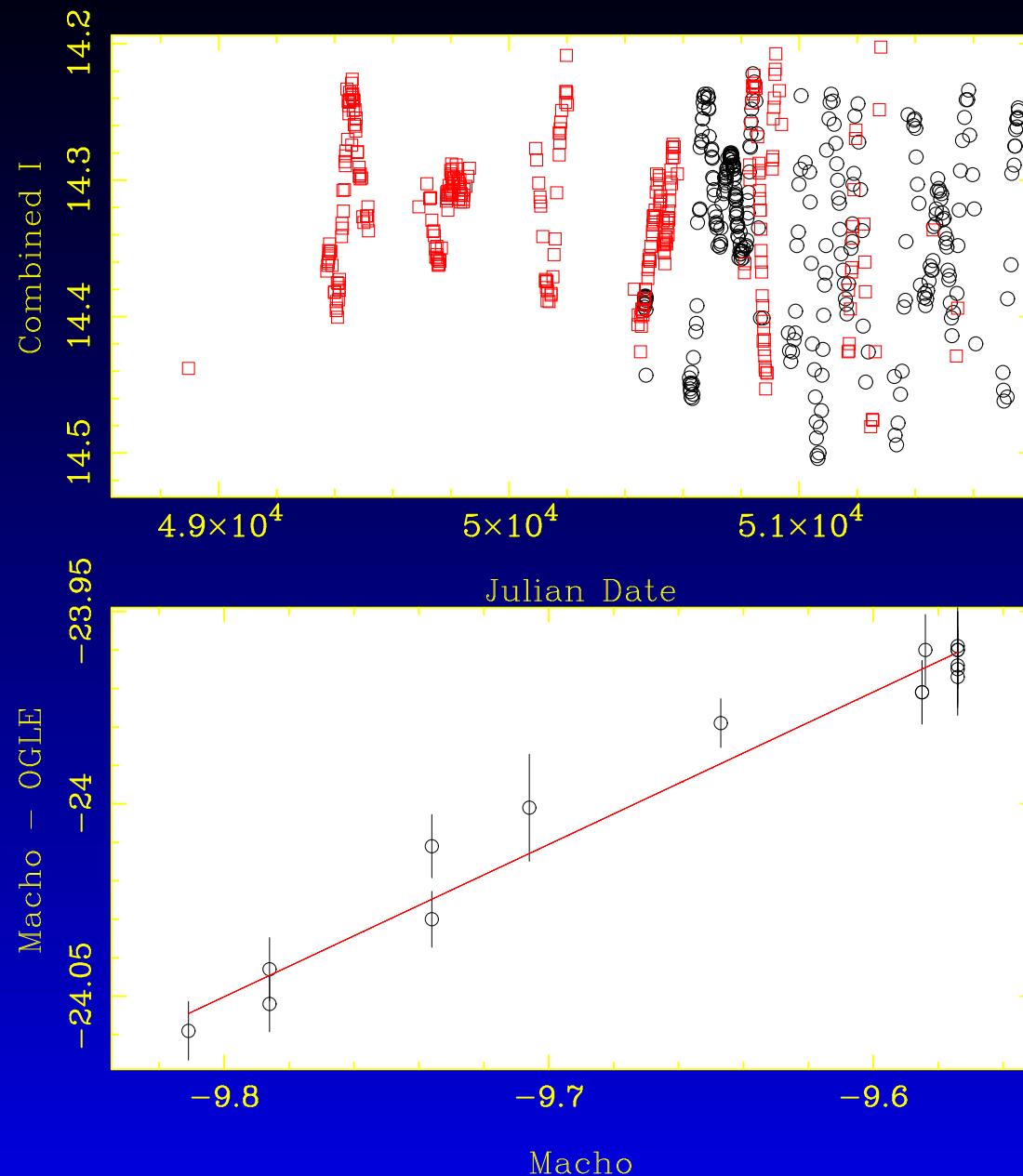
periods, including from combined dataset (M+O)



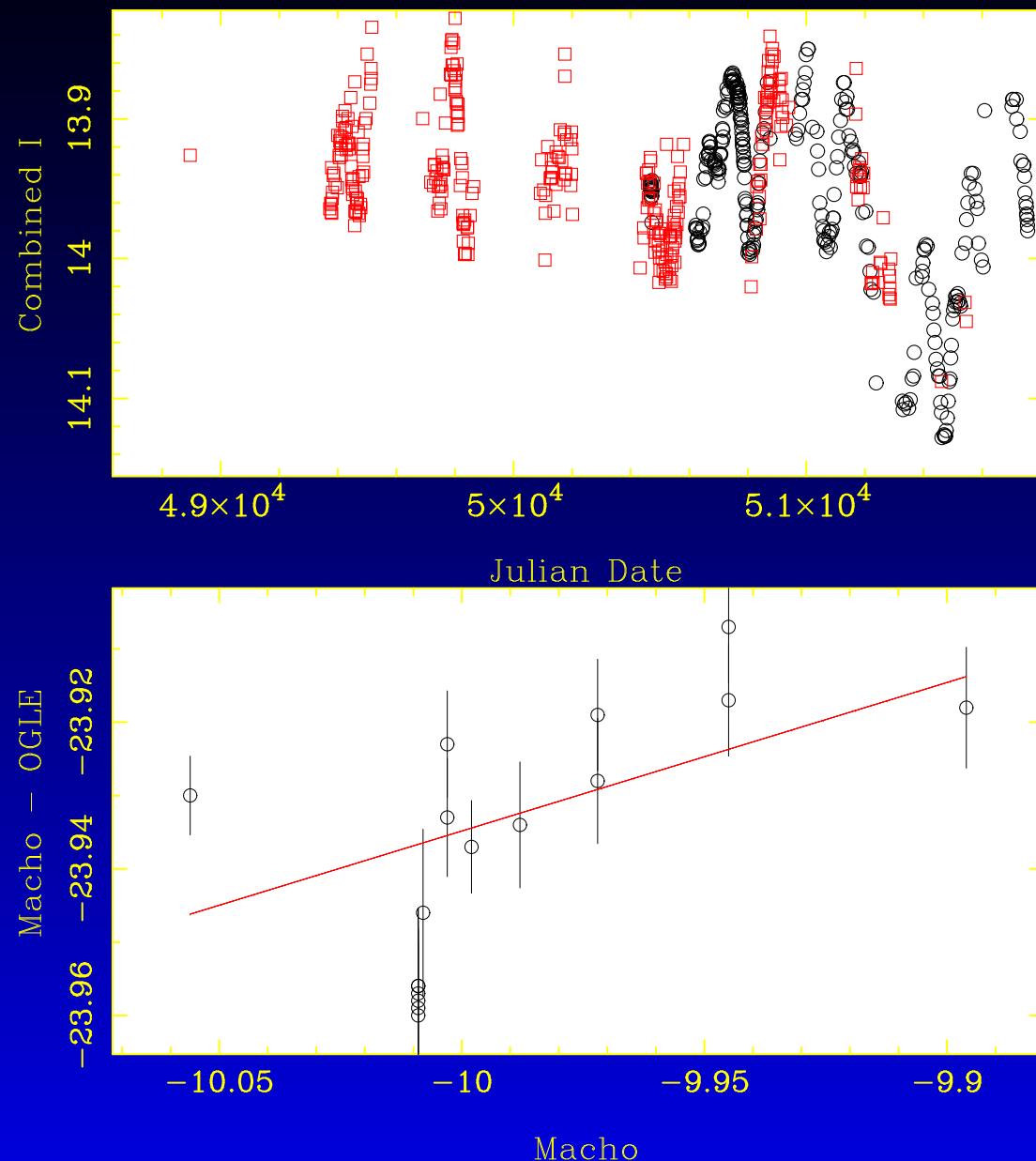
HV 1645: MRC: 296 (1), MACHO: 294,
OGLE: 301 ; M+O: 296



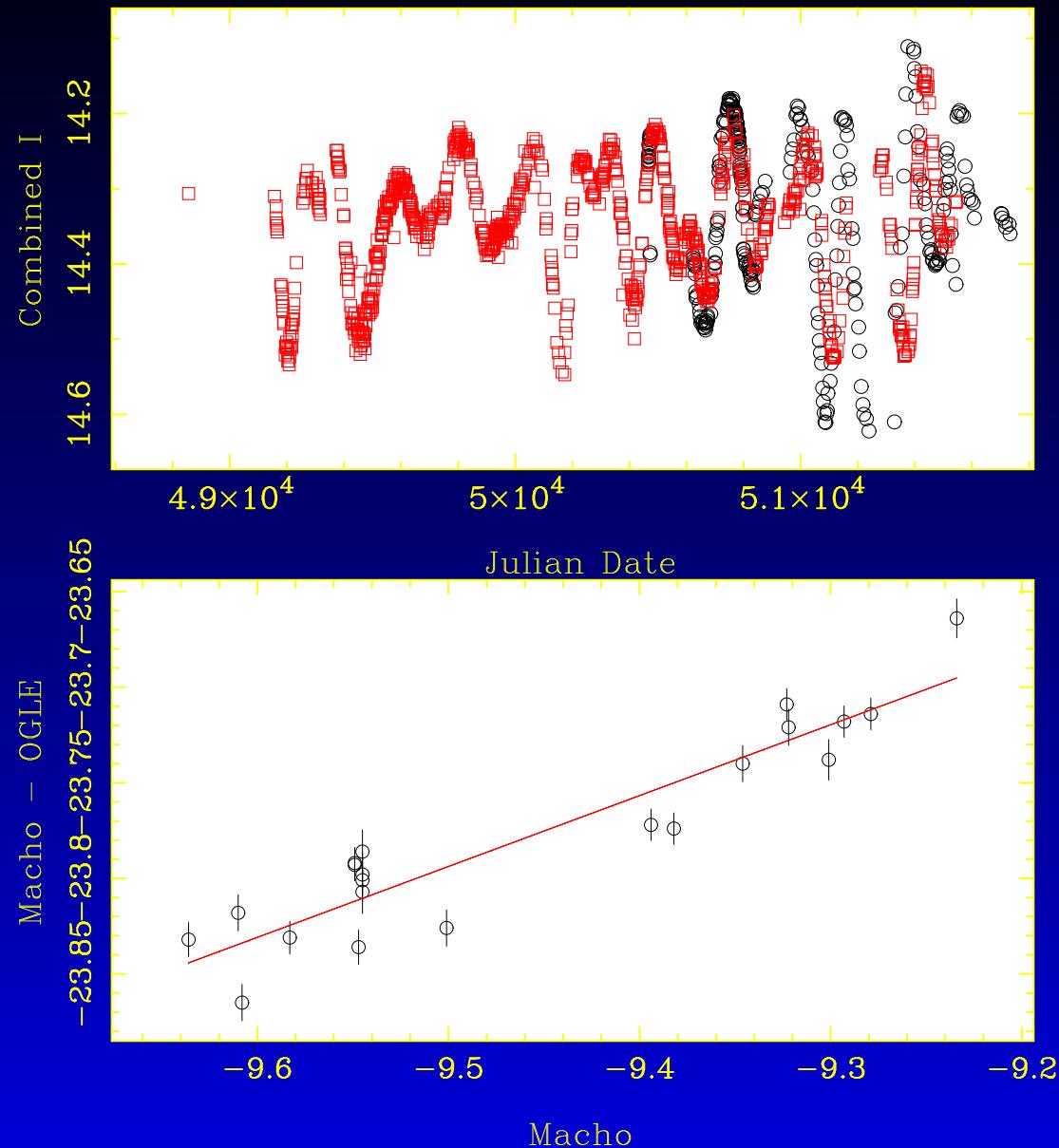
MRC: 2600 (5), MACHO: 364 + 2145,
OGLE: 373 + 1640; M+O: 2029 + 367



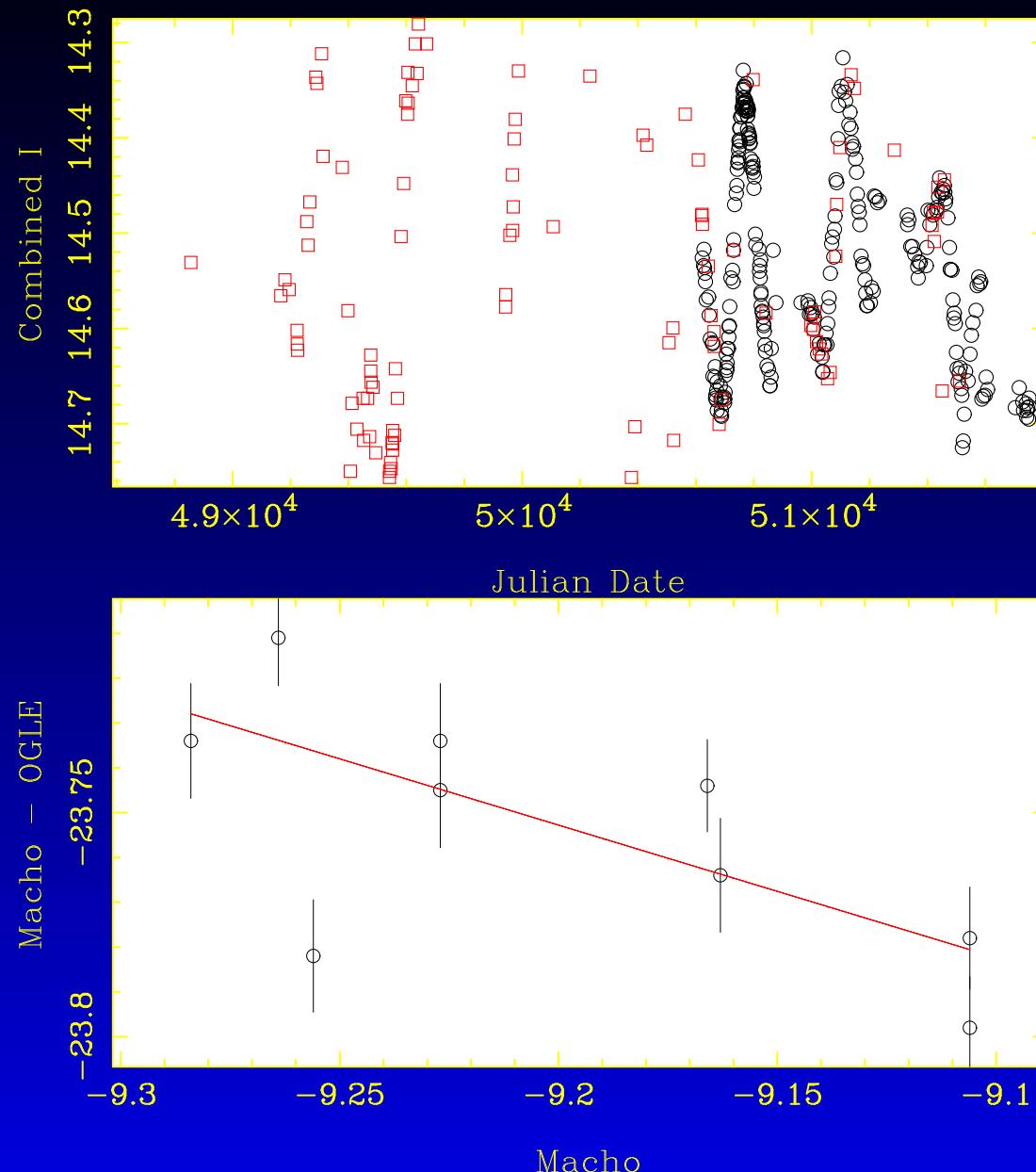
MRC: 182 (1), MACHO: 92, OGLE: 89;
M+O: 87 + 94



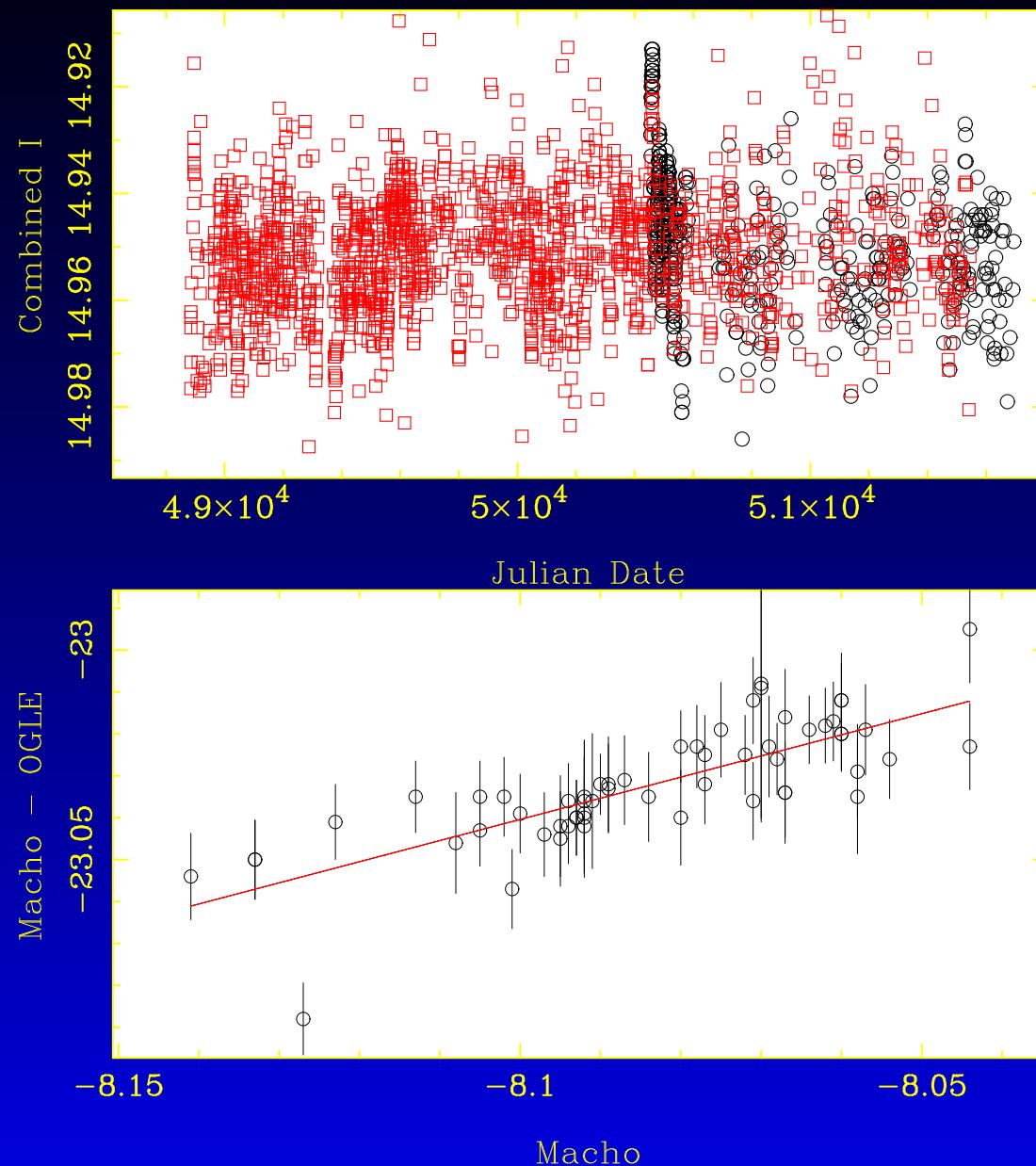
MRC: 1224 (5), MACHO: 658,
OGLE: 138 + 1100; M+O: 887 + 1041 + 135



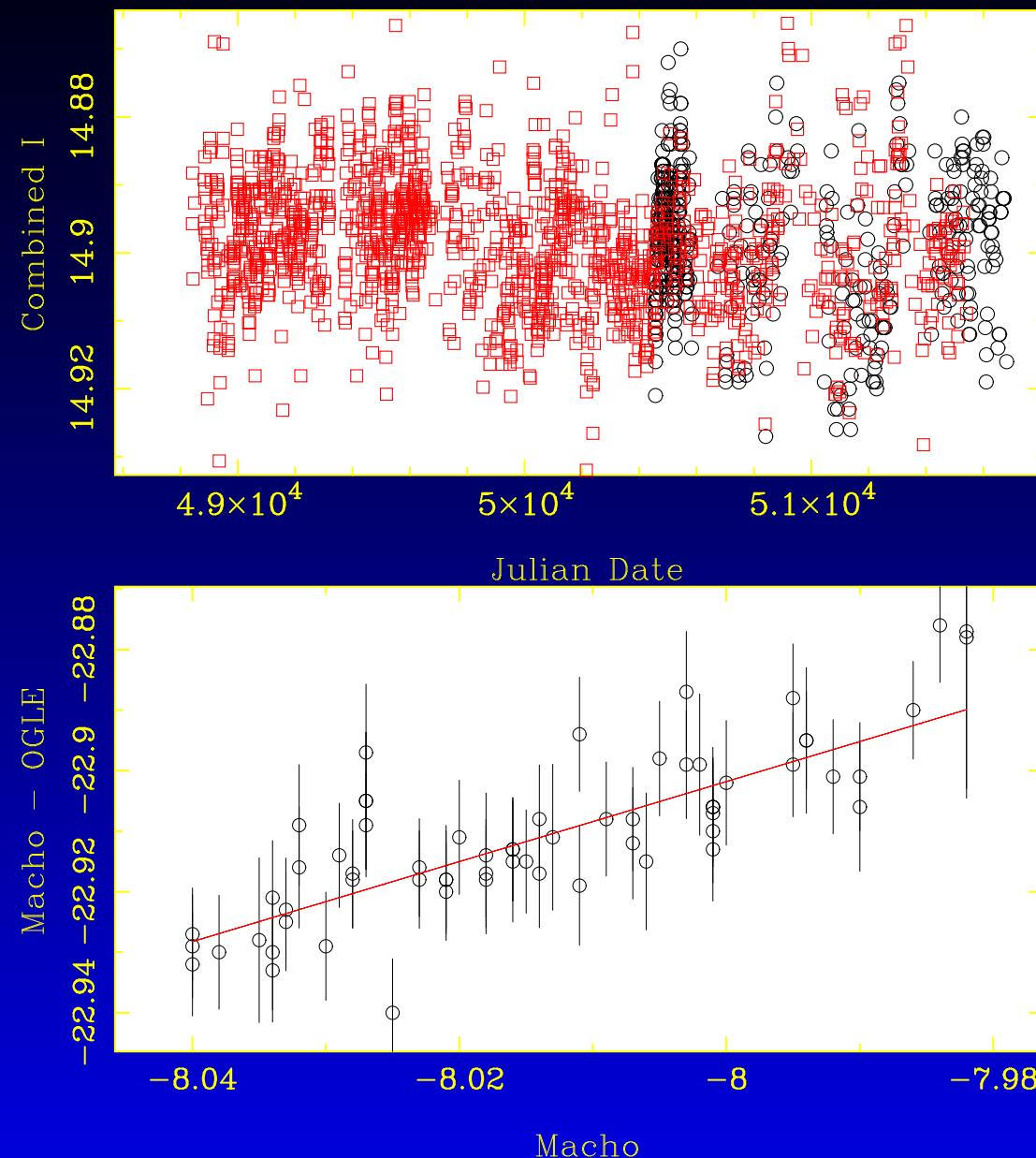
MRC: 239 (1), MACHO: 237,
OGLE: 132; M+O: 233 + 134



MRC: 284 (6), MACHO: none,
OGLE: 171; M+O: 171 + 287



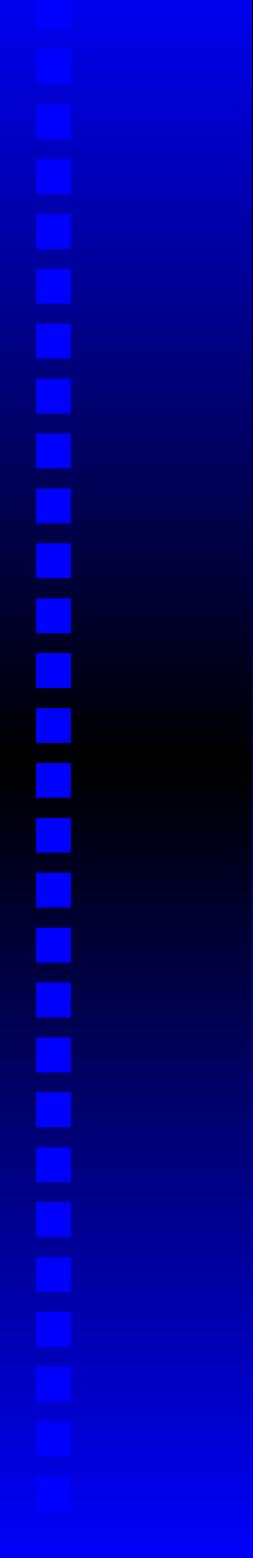
PW: 22.32, MACHO: $11.31 + 30.4 + 42.8$
 OGLE: $29.84 + 480 + 22.24$; M+O: 22.3



PW: 24.05, MACHO: 24.05 + 1834
 OGLE: none ; M+O: 24.1

Summary

- SMC/LMC/BULGE; OGLE + 2MASS/DENIS
 - SMC: 11 fields, $2.4 \square^2$, 15 000 variables
 - LMC: 21 fields, $4.5 \square^2$, 53 000 variables
 - BUL: 49 fields, $11. \square^2$, 221 000 variables
- Comparison: in individual cases OGLE or MACHO can be superior over the other
- Combining: seems to work reasonably well



THE END