VERAによるミラ型変光星の周期光度関係の確立

Period-Luminosity relation of Mira variable stars

中川亜紀治、面高俊宏、亀崎達也、半田利弘（鹿児島大学）
倉山智治（帝京科学大学）、国立天文台VERAグループ

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・目的
・これまでの観測状況
・現在までの結果
・今後の課題

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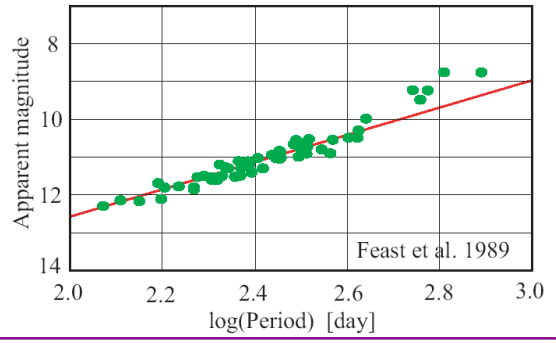
Introduction: Period-Luminosity Relation (PLR)

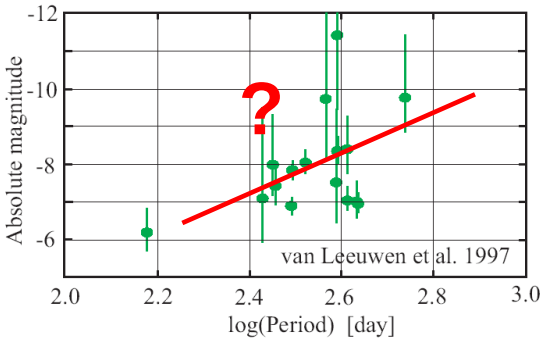
PLR of LMC Miras

- Based on apparent magnitudes



PLR of the Galactic Miras

- Absolute magnitude obtained with Hipparcos data
- Large error of absolute magnitudes



- 目的: Establish a PLR for the Galactic Miras → Distance estimator
- 手法:
  - (1) Distance measurements using annual parallax (VLBI astrometry)
  - (2) Convert apparent magnitudes(m_k) to absolute magnitudes(M_k)

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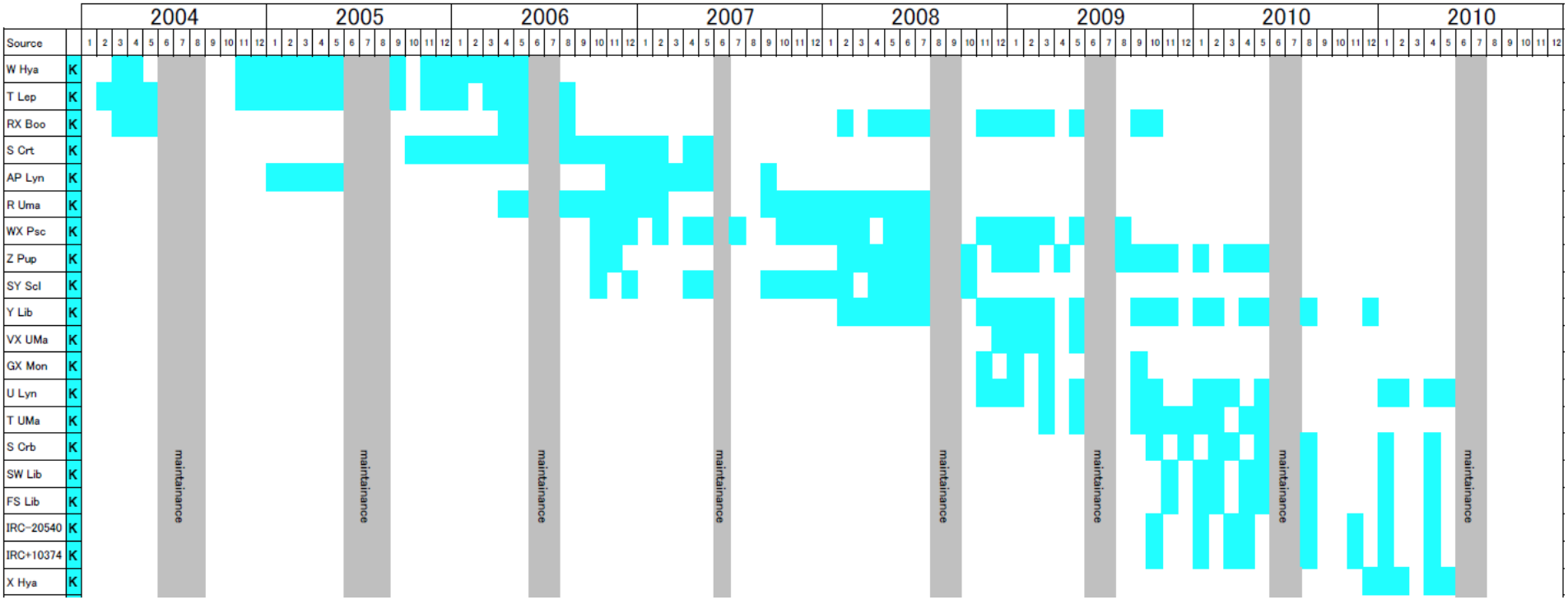
Observation: Source selection

水メーザーを伴うミラ型変光星　約40天体を選定



W_Hya, T_Lep, RX_Boo, S_Crt, AP_Lyn, R_Uma, WX_Psc, Z_Pup, SY_Scl, Y_Lib, VX_UMa, GX_Mon, U_Lyn, T_UMa, S_Crb, SW_Lib, FS_Lib, IRC-20540, IRC+10374, X_Hya, R_Cnc, FV_Boo, RU_Ari, RW_Lep, Y_Cas, BW_Cam, BX_Cam, U_Ori, QX_Pup, RS_Vir, V391_Cyg, SY_Aql, V2250_Cyg, SV_Peg, ...

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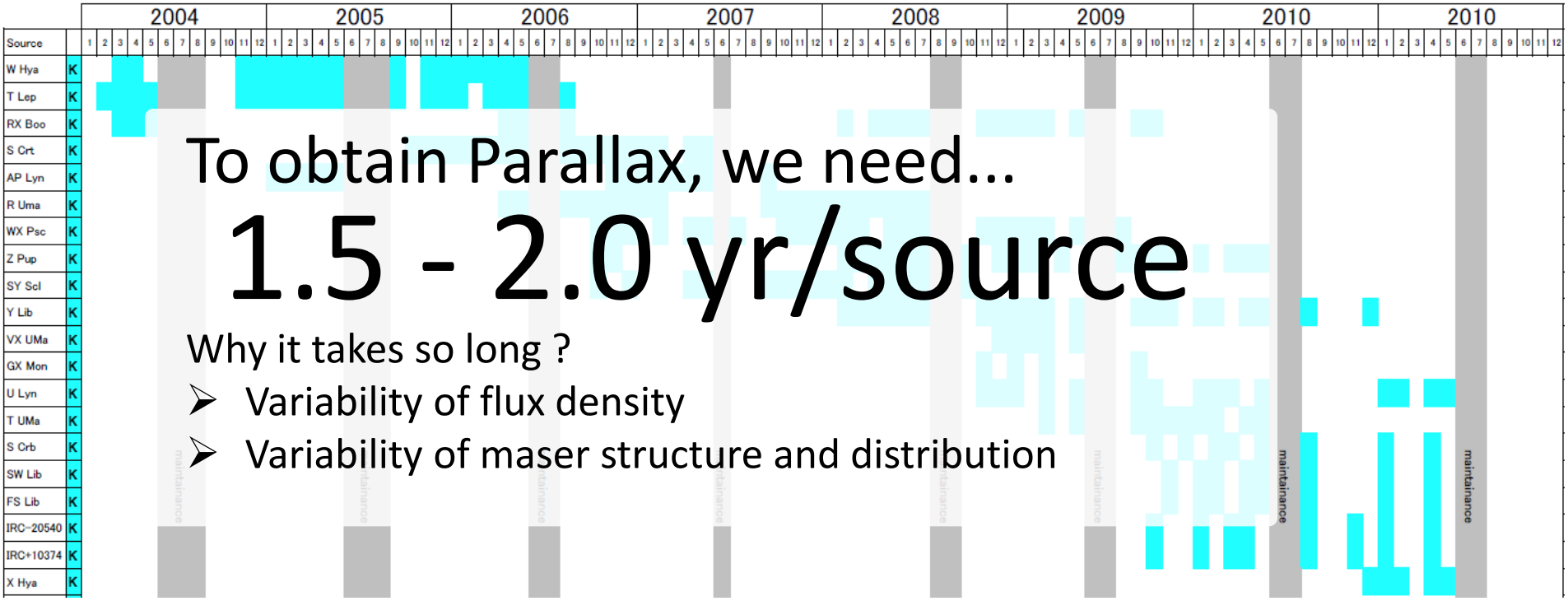
Observation: Source selection

水メーザーを伴うミラ型変光星　約40天体を選定



To obtain Parallax, we need...

1.5 - 2.0 yr/source

Why it takes so long ?

- Variability of flux density
- Variability of maser structure and distribution

W_Hya, T_Lep, RX_Boo, S_Crt, AP_Lyn, R_Uma, WX_Psc, Z_Pup, SY_Scl, Y_Lib, VX_UMa, GX_Mon, U_Lyn, T_UMa, S_Crb, SW_Lib, FS_Lib, IRC-20540, IRC+10374, X_Hya, R_Cnc, FV_Boo, RU_Ari, RW_Lep, Y_Cas, BW_Cam, BX_Cam, U_Ori, QX_Pup, RS_Vir, V391_Cyg, SY_Aql, V2250_Cyg, SV_Peg, ...

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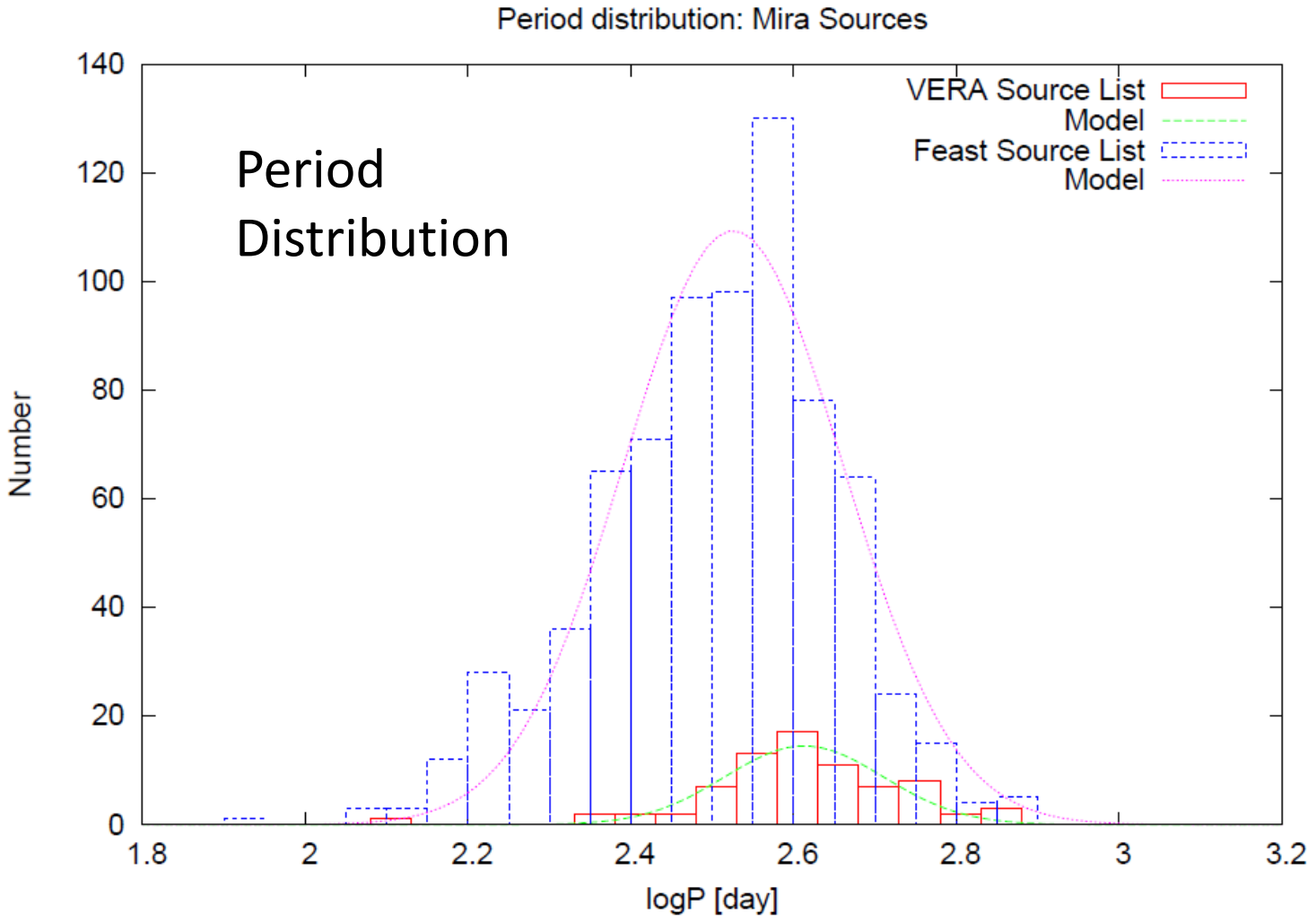
Observation: Source selection

光学観測から同定されたミラ型変光星のリスト約800天体（Feast et al. 2000）の周期分布と、水メーザーを伴うミラ型変光星の周期分布には違いがある。



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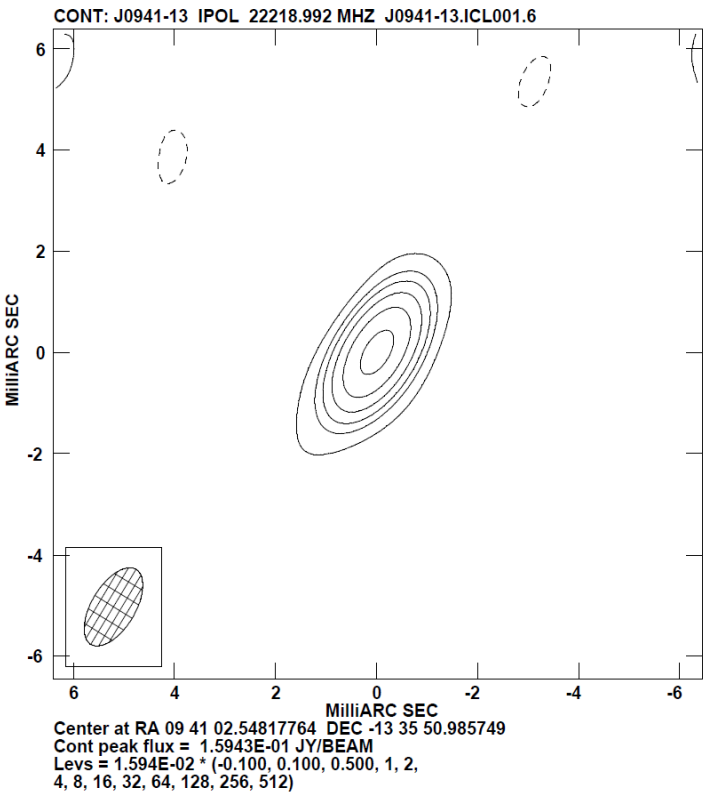
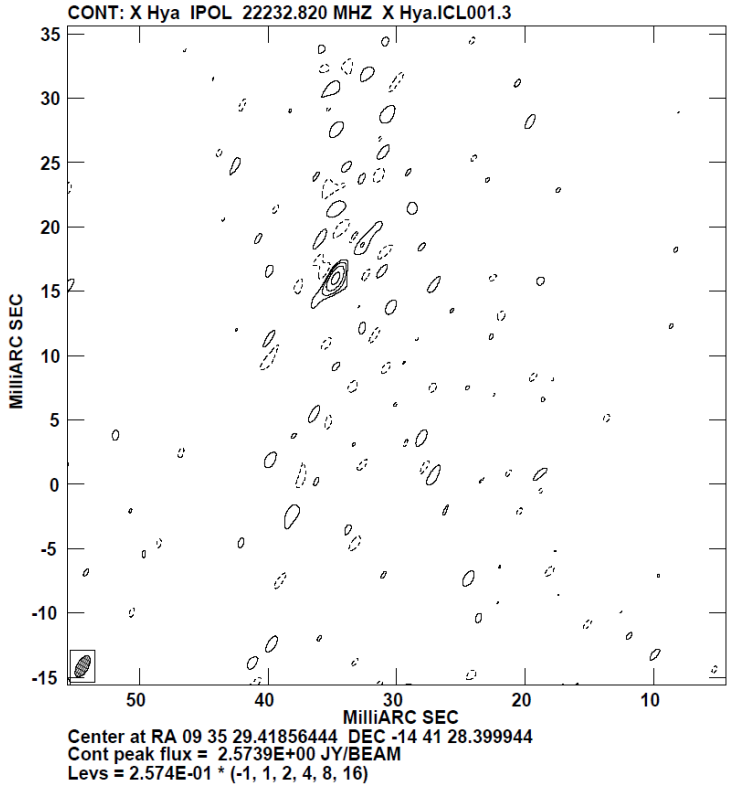
位相補償マップの一例　X Hya





参照電波源　J0941-1335;

R.A.　09h　41m　02.549496s
Dec.　-13d　35'　50.98531"

ミラ型変光星 X_Hya（メーザー源）
Nominal Coordinate
R.A.　09h　35m　29.42s
Dec.　-14d　41'　28.4"

⇩

Accurate Coordinate from The Phase Referencing Analysis
R.A.　09h　35m　30.223s
Dec.　-14d　41'　28.72"

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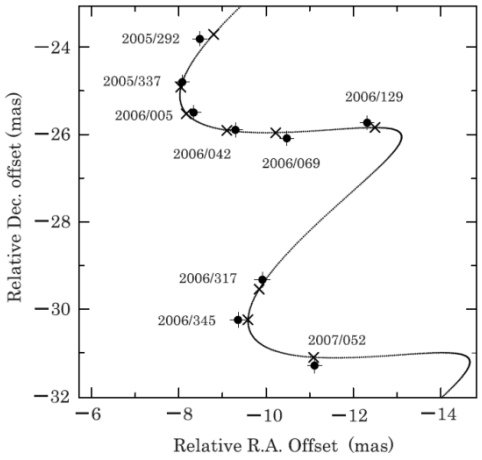
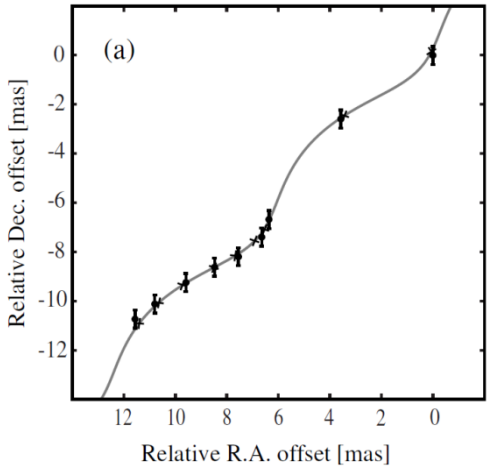
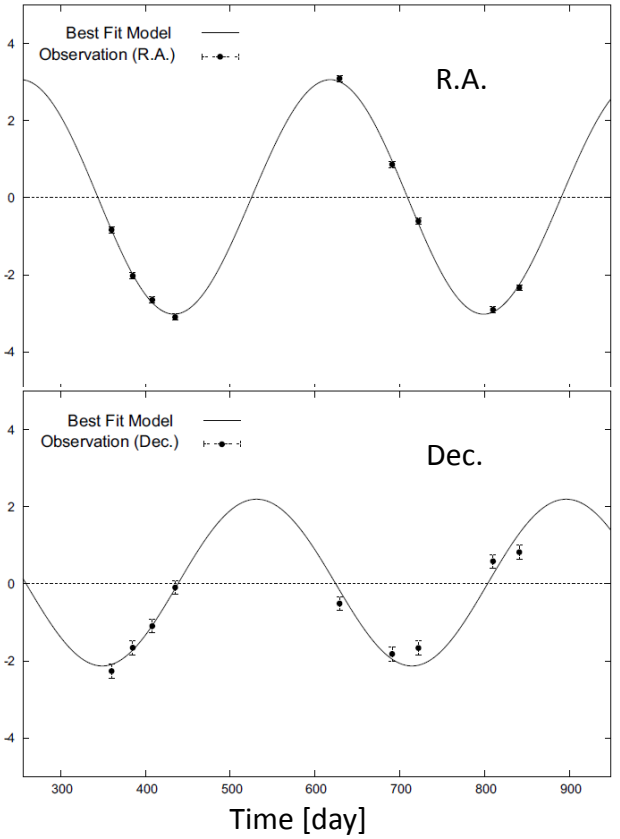
Result : S Crt, SY Scl, RX Boo, T Lep
年周視差の測定結果



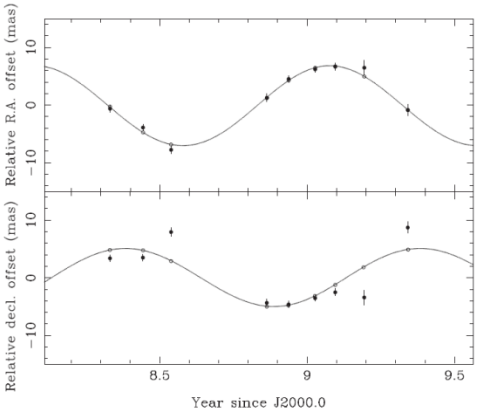
S Crt : Nakagawa et al. 2008



SY Scl : Nyu et al. 2012



T Lep : (Nakagawa in prep.)



RX Boo : Kamezaki et al. 2012

Source	Parallax [mas]	err [mas]	err [%]	D [pc]
S Crt	2.33	0.13	5.6	429
T Lep	3.058	0.042	1.4	327
R UMa	1.72	0.09	5.2	581
SY Scl	0.75	0.03	4.0	1333
RX Boo	7.31	0.5	6.8	137
Y Lib	0.87	0.08	9.2	1149
RW Lep	1.62	0.16	9.9	617
U Lyn	1.29	0.08	6.2	775
R Aqr	4.7	0.8	17	213

: Semiregular

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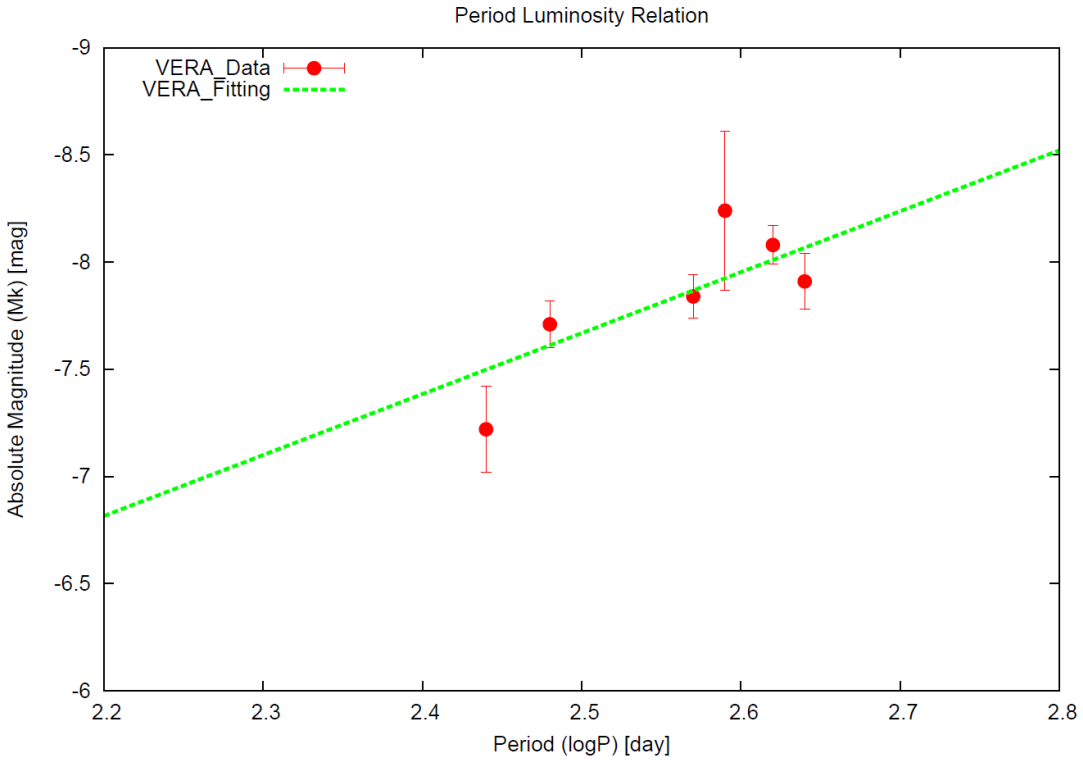
Preliminary Result : PLR

ミラ型変光星6天体を利用して、PLRの傾きとゼロ点を同時に推定した結果

$M = \rho\,(\mathrm{Log}P - 2.56) + \delta$

- 6 Mira sources
- Solve ρ and δ

Source	Type	D [pc]
S Crt	SR	429
T Lep	Mira	327
R UMa	Mira	581
SY Scl	Mira	1333
RX Boo	SR	137
Y Lib	Mira	1149
RW Lep	SR	617
U Lyn	Mira	775
R Aqr	Mira	213



ρ & δ　　$M = -2.85 \pm 0.91\,(\mathrm{Log}P - 2.56) - 7.84 \pm 0.06$

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Preliminary Result : PLR

Whitelock et al. 2008 の結果（図中の青線）と比較

$M = \rho (\mathrm{LogP} - 2.56) + \delta$

- 6 Mira sources
- Solve ρ and δ
- Whitelock et al 2008

Source	Type	D [pc]
S Crt	SR	429
T Lep	Mira	327
R UMa	Mira	581
SY Scl	Mira	1333
RX Boo	SR	137
Y Lib	Mira	1149
RW Lep	SR	617
U Lyn	Mira	775
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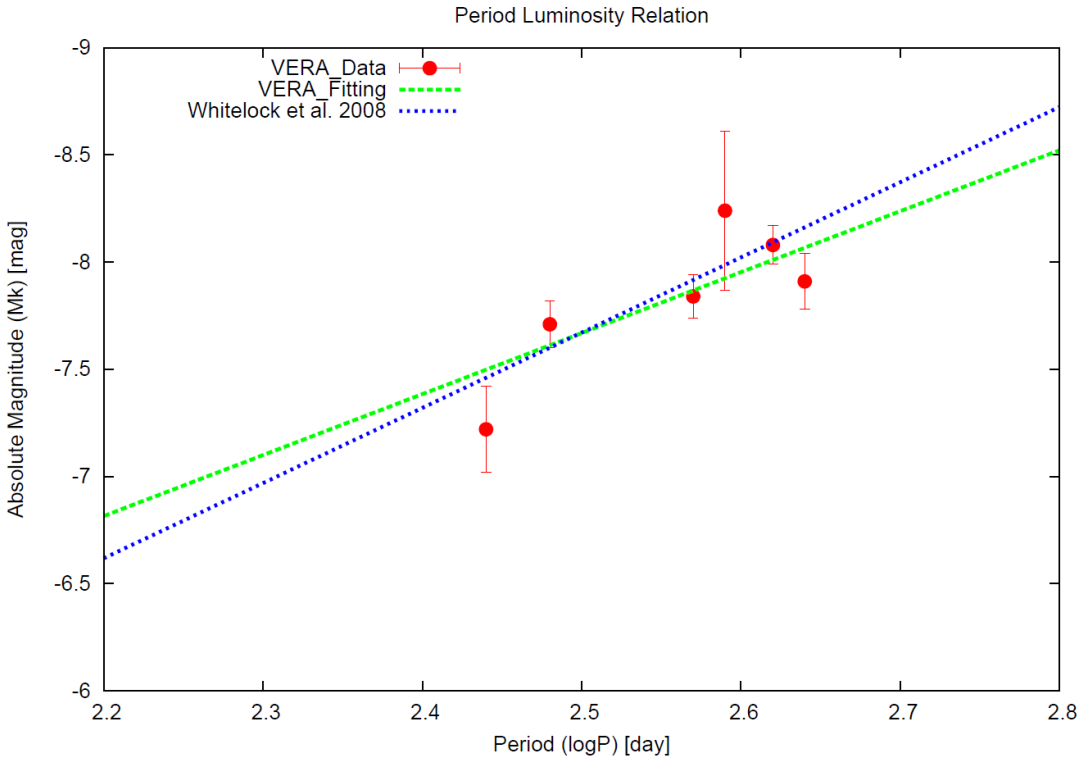

ρ & δ　　$M = -2.85 \pm 0.91\ (\mathrm{LogP} - 2.56) - 7.84 \pm 0.06$

Whitelock et al 2008　$M = -3.51\ (\mathrm{LogP} - 2.56) - 7.88$

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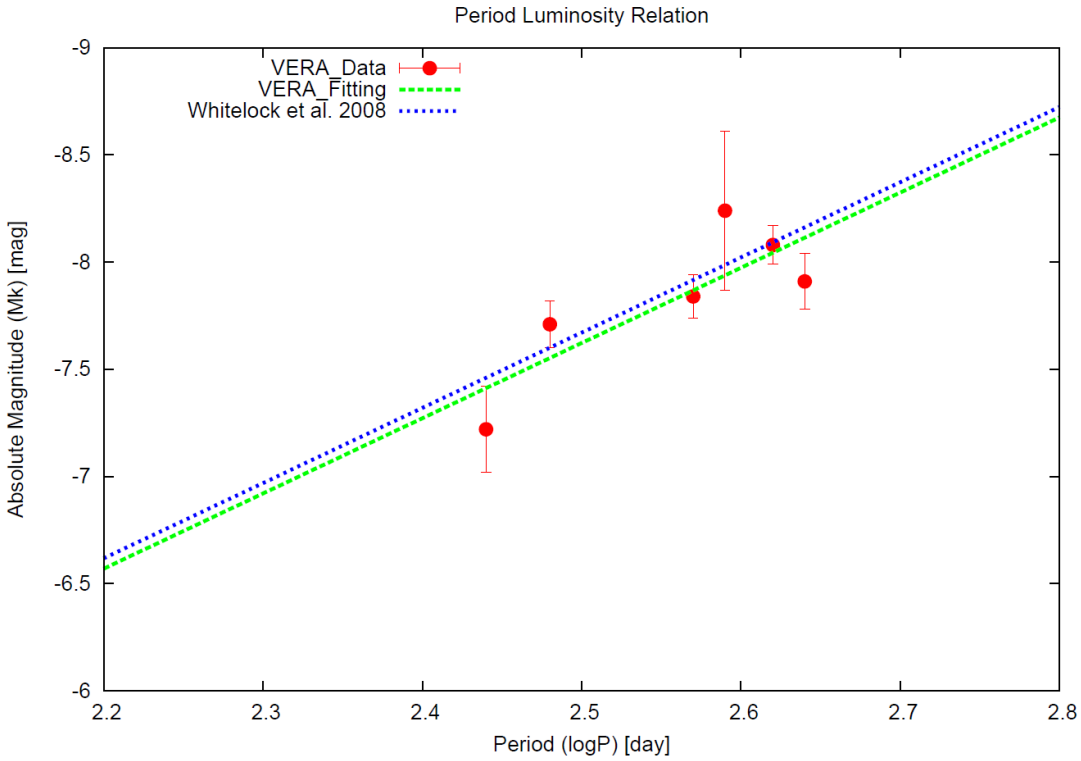
Preliminary Result : PLR

ミラ型変光星6天体を利用して、ゼロ点のみを推定した結果

$M = \rho (\mathrm{Log}P - 2.56) + \delta$

- 6 Mira sources
- Solve δ only
- Whitelock et al 2008

Source	Type	D [pc]
S Crt	SR	429
T Lep	Mira	327
R UMa	Mira	581
SY Scl	Mira	1333
RX Boo	SR	137
Y Lib	Mira	1149
RW Lep	SR	617
U Lyn	Mira	775
R Aqr	Mira	213



ρ & δ　　$M = -2.85 \pm 0.91 (\mathrm{Log}P - 2.56) - 7.84 \pm 0.06$

Whitelock et al 2008　$M = -3.51 (\mathrm{Log}P - 2.56) - 7.88$

δ　　$M = -3.51 (\mathrm{Log}P - 2.56) - 7.83 \pm 0.06$

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How many sources we need to determine the PLR ?

— Simulation study —

Source number (N) dependence of estimation error.

Fit PLR to the test data.

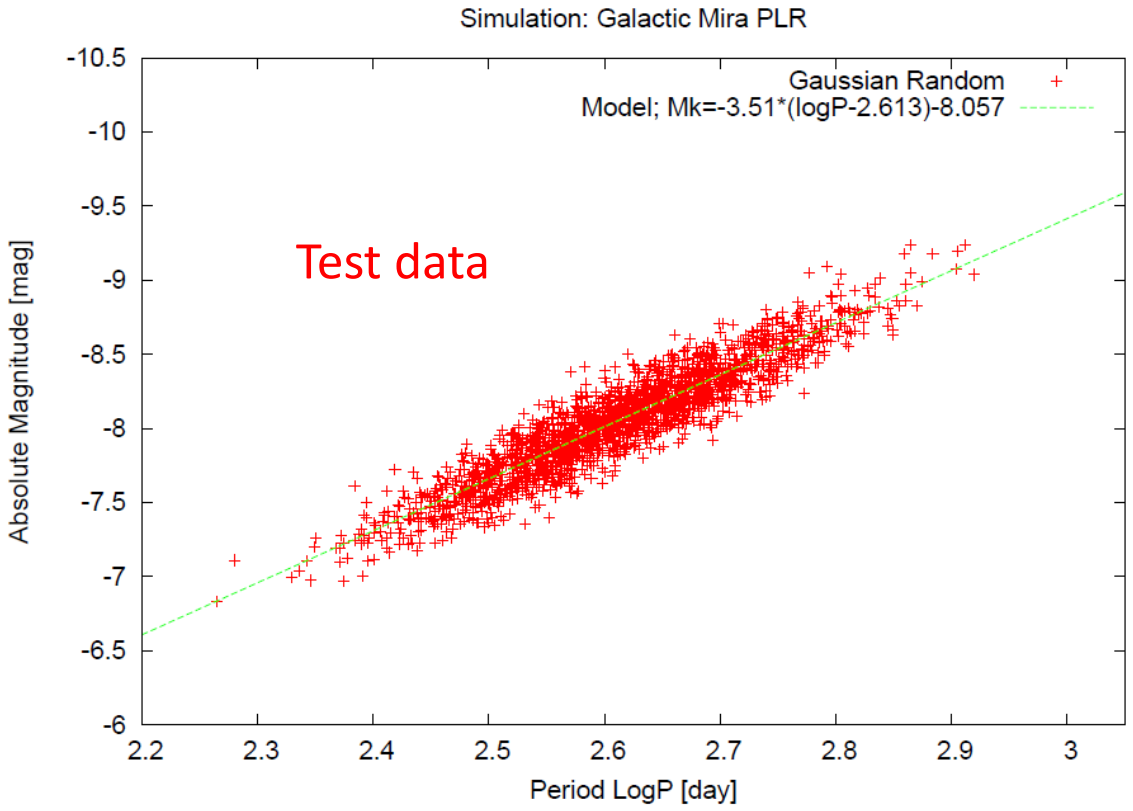
⇩

Estimate ρ and δ.

$M = \rho(\mathrm{LogP} - P_0) - \delta$

＜Model＞

- Mk = −3.51（LogP−2.61）−8.057
  - σ_ρ = 0.14
    （Whitelock et al. 2008, O-rich Mira）
  - σ_δ = 0.098
    （VERA Project Source List）
- Error of Mk 0.1 [mag]



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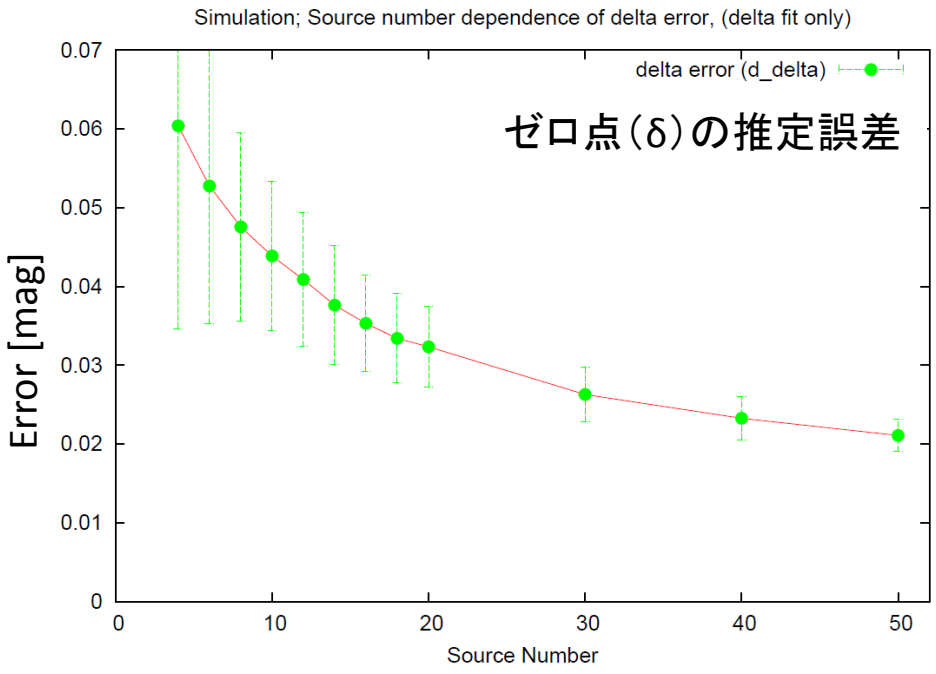
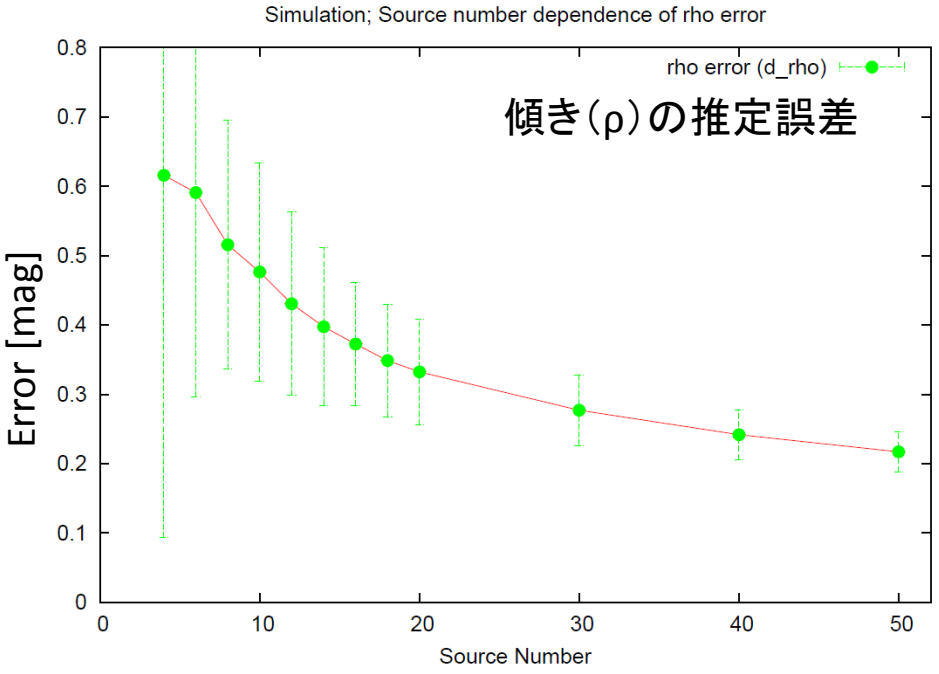
N dependence of ρ and δ error.

- 観測天体数と、ゼロ点（δ）および傾き（ρ）の推定誤差の関係



N (Source Number)



N (Source Number)

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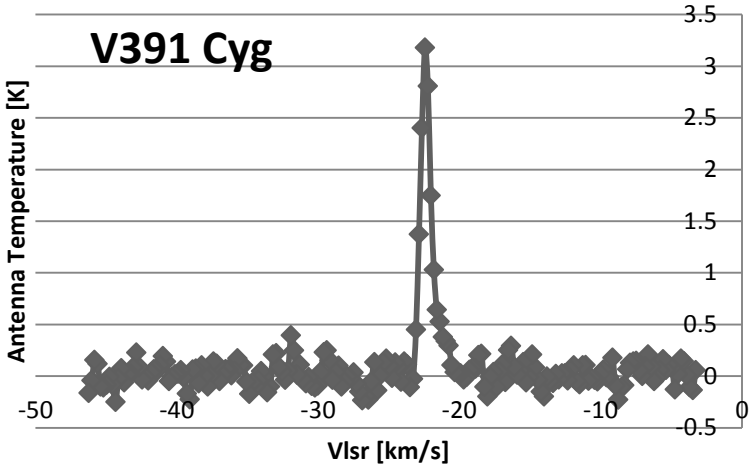
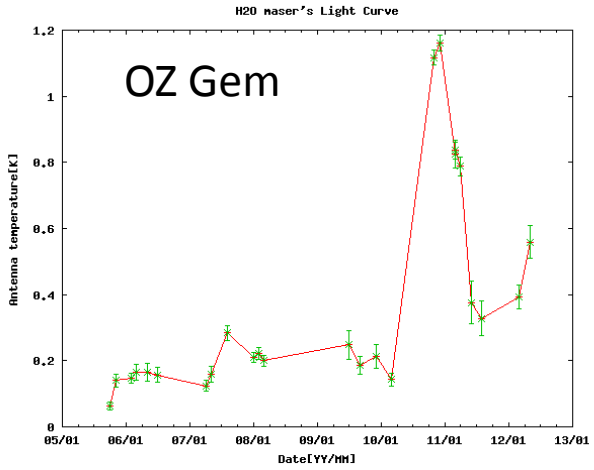
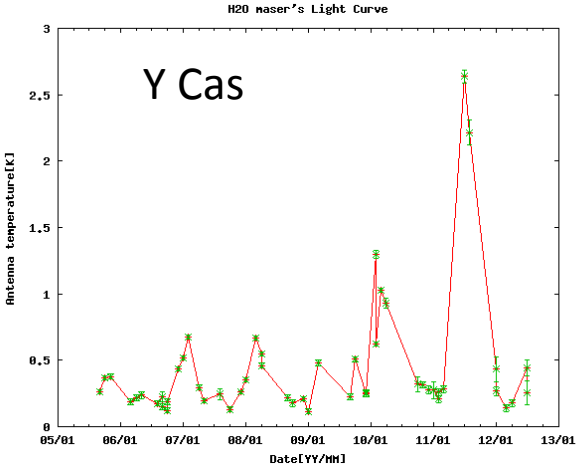
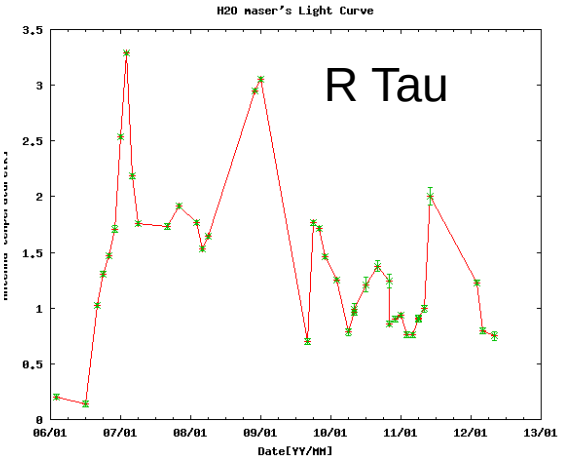
New sources Winter 2012



Single-Dish monitoring at IRIKI







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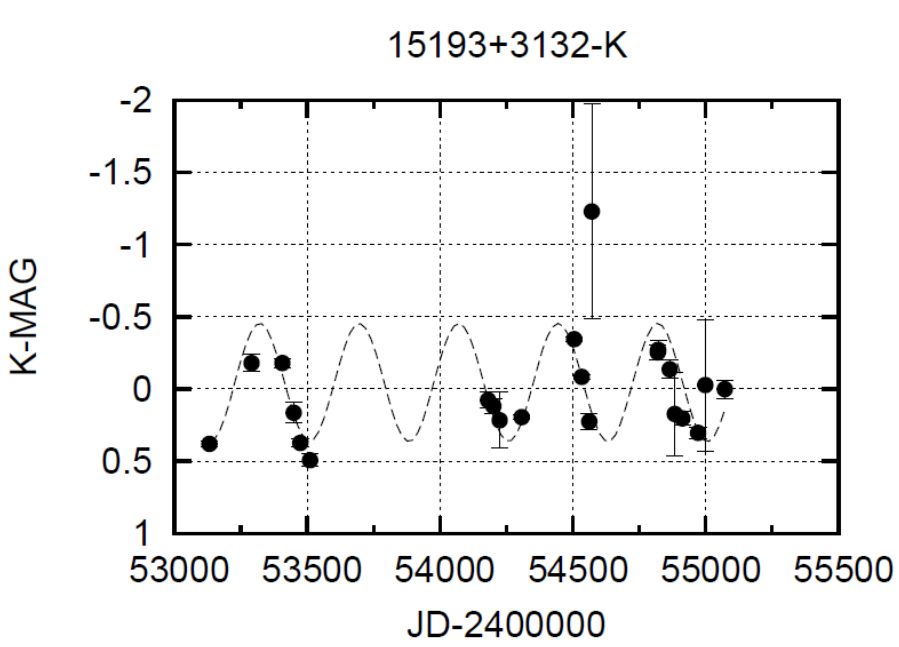
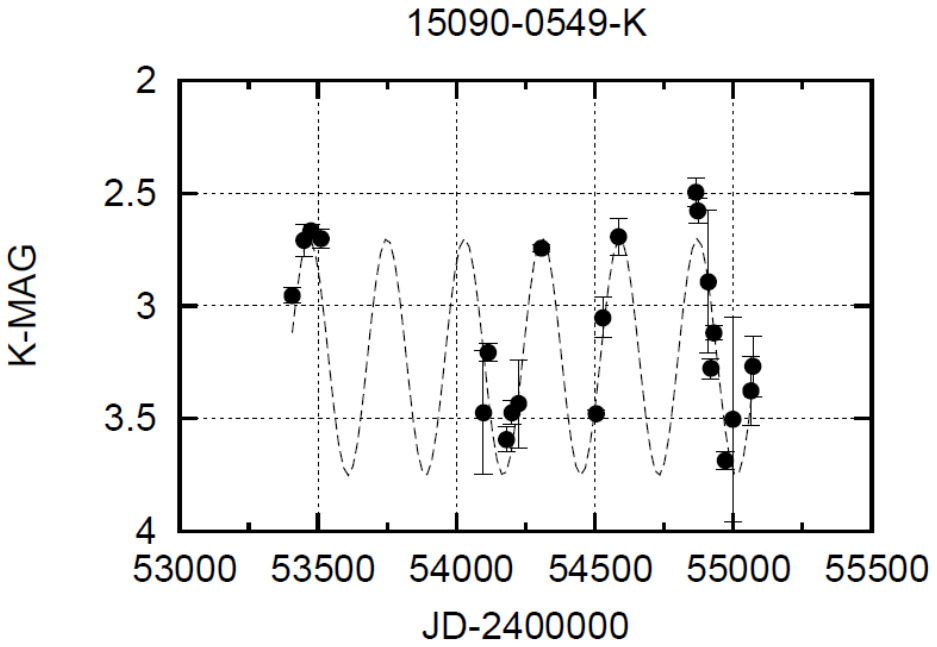
Infrared (K) observation

S-CrB (IRAS 5193+3132)
Period 374.1 day
Mk -0.045 mag
σMk 0.027 mag

Y-Lib (IRAS 15090-0549)
Period 280.3 day
Mk 3.23 mag
σMk 0.031 mag





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今後の課題

- PLRの精密化を丁寧にすすめる
  - 距離の決定精度の向上（右表：誤差の距離精度依存性）
  - 目標天体数の目安に向けた観測計画
  - ゼロ点の精度　→　距離尺度の高精度化
- 見かけ等級の誤差の最小化は重要
  - 赤外線観測データの正確な取り扱い
    - 見かけ等級決定の精度：0.2～0.3 mag
    - 星間減光：D > 1kp
    - 星周減光：長周期で影響あり？
  - カラーと減光の関係などに先行研究の分析
- MiraのPLRの本質的な幅が見えるか
- LMCのPLRはLMCの厚みの分ボケている
  - LMCの厚みが見える？
    （どこまで精度を追い込めば見えるか？）

距離の精度が
等級に与える影響

Distance Error [%]	σ Mk [mag]
1	0.02
2	0.04
3	0.07
4	0.09
5	0.11
6	0.13
7	0.15
8	0.17
9	0.20
10	0.22
11	0.24
12	0.26
13	0.28
14	0.31
15	0.33