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VLBI Monitoring of Mira variables with VERA†

A. Nakagawa*1, T. Omodaka*1, K. M. Shibata*2, T. Kurayama*2, H. Imai*1, S. Kameno*1, M. Tsushima*1, M. Shintani*1, N. Matsumoto*1, M. Matsui*1, S. Oizumi*1, T. Yasuda*1, T. Arao*1, VERA project. (*1 : Kagoshima university, *2 : NAOJ)

Related presentation : M. Honma, 15 March Session 6, "Galactic rotation measurements based on water maser astrometry with VERA"

Abstract

We have started a 22 and 43 GHz VLBI monitoring program for Asymptotic Giant Branch (AGB) stars incorporate with the VLBI Exploration of Radio Astrometry (VERA) project for precisely obtaining the period-luminosity (PL) relation of the Galactic Mira variables. Using accurate distances measured with VERA, we reveal PL relation in the Galaxy based on the absolute magnitudes of the sources. We have selected ~20 sources for the VLBI monitoring so that they have a good coverage of various pulsation periods. Associated with this VLBI program, photometry in infrared J, H, and K bands for ~400 AGB stars has started since 2003 with the 1m telescope of Kagoshima university to obtain the pulsation periods and magnitudes of the sources. Current analysis of multi-epoch phase referencing VLBI observations of S Crt shows that the parallax is 2.3±0.2 milliarcsec (mas) which correspond to the distance of 435^{+41}_{-35} pc. From the infrared monitoring data, we obtained pulsation periods and magnitudes in K band for 211 sources.

Introduction

Mira variables are pulsating stars with periods in the range 100 to 1000 days, showing rapid mass loss before ejecting their outer layers as planetary nebula shells. Although a narrow PL relation for Miras in the Large Magellanic Cloud (LMC) was found (Figure 1), the same relation for the Galactic Miras has not been precisely obtained because of large errors (Figure 2). Such large errors arise from the ambiguities of absolute magnitudes deduced from inaccurate distances to each object. Using absolute magnitudes deduced from accurate distances purely geometrically measured with VERA, we can investigate precise PL relation of the Galactic Miras. Furthermore, this program is important in a sense that once we have provided a calibration to the PL relation as the use of relative distance estimator, we can convert the relative distance measurements to an absolute scale. For example, distance to the LMC, which is a fundamental quantity in astronomy, can be obtained.

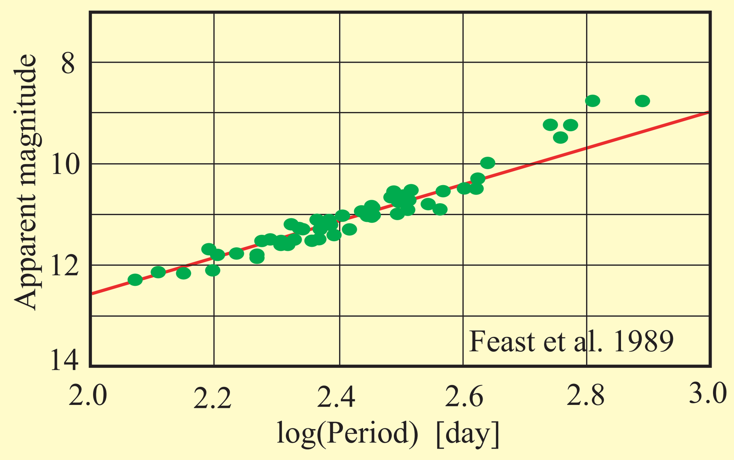


Figure 1. PL relation of Mira variables in LMC. Apparent magnitudes of each source can be used in considering the relation.

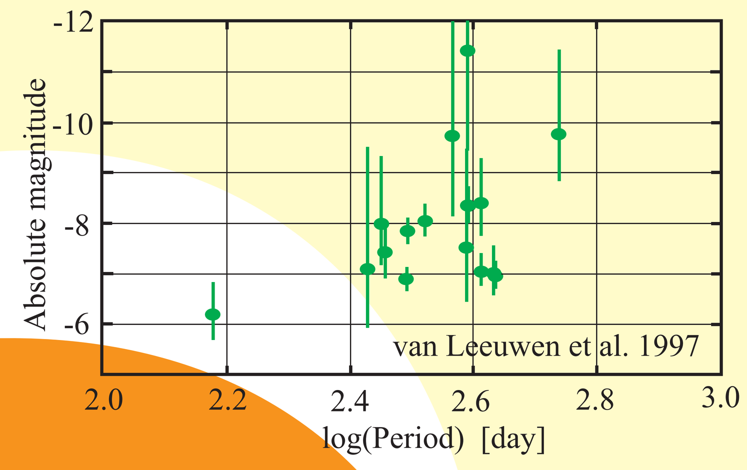


Figure 2. Pulsation periods vs absolute magnitudes of the Galactic Mira variables. We can't obtain a precise PL relation because of large errors in absolute magnitudes.

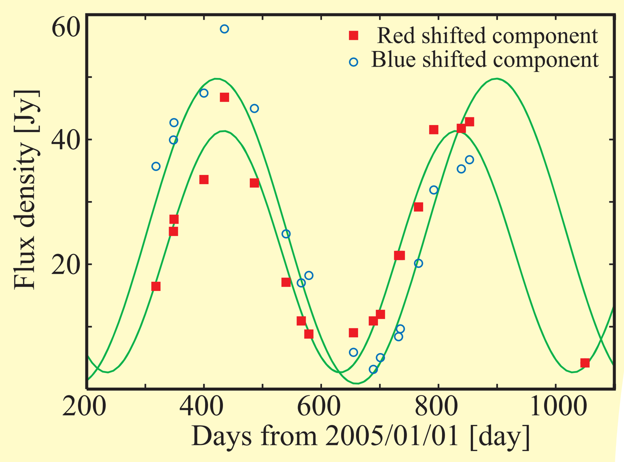
Observations in radio and infrared

We organize three observational techniques so that we can effectively go ahead with this monitoring program (Figure 3).

< A : Single Dish monitoring >

Flux monitoring at 22and 43GHz in order to grasp the radio bright state of the targets are in progress. Total number of sources amounts to ~500. One third of these samples are monthly observed at 22GHz.

Figure 4. The 22GHz radio variability of the water masers in IRC+60169 are presented with sinusoidal fits.



< B : VLBI monitoring >

We set monthly VLBI observations when the sources are so bright that we can expect successful detection of fringes. With the dual beam system uniquely installed in VERA, we observe target maser and extragalactic reference sources simultaneously.

— Selection criteria for VLBI —

1. Target sources : Flux > 20 Jy at 22 GHz
   : Flux > 20 Jy at 43 GHz
2. Reference source : Flux > 100 mJy at 22 GHz
   : Flux > 300 mJy at 43 GHz
3. 0.3° < Separation between target and reference < 2.2°

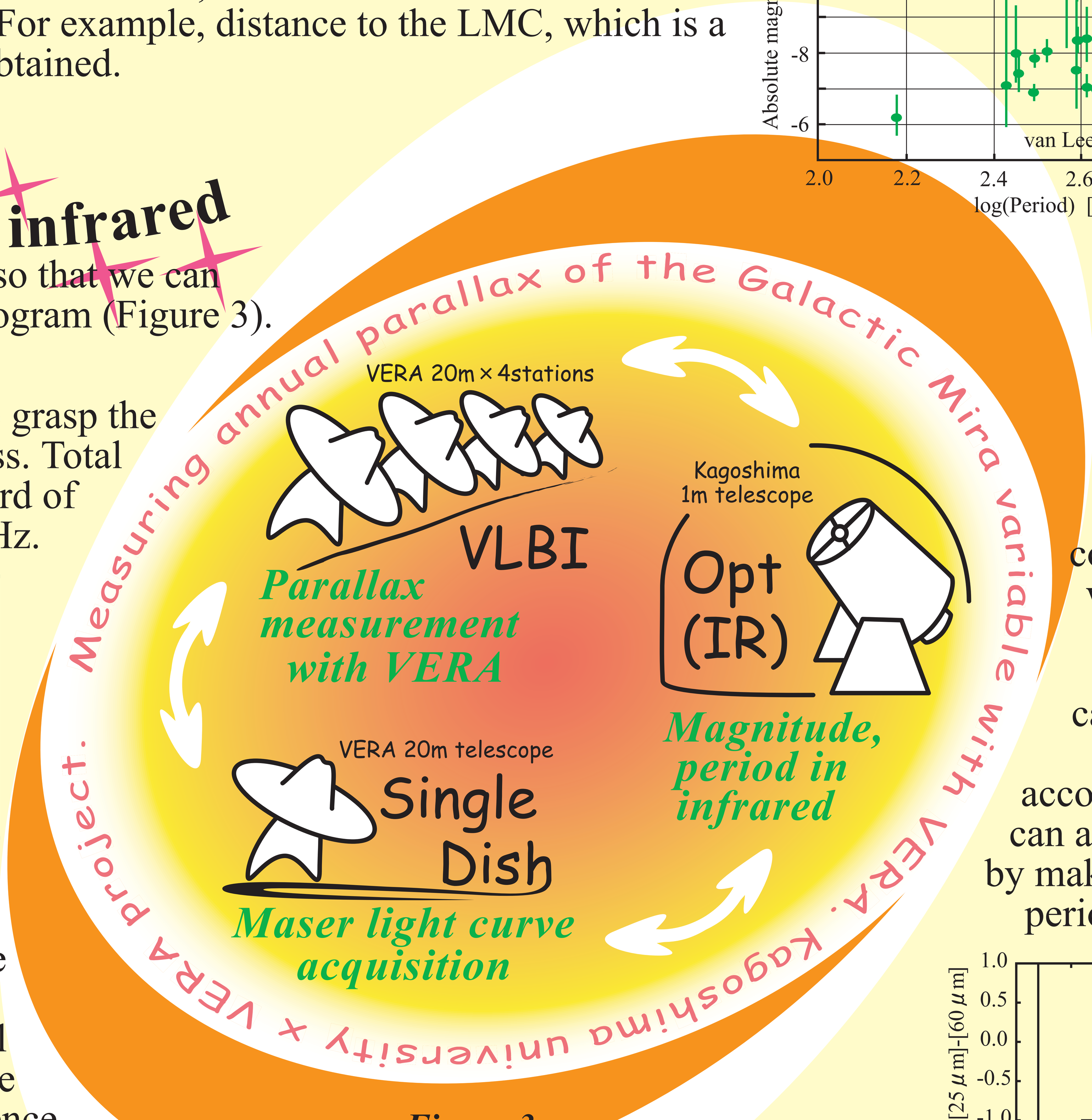
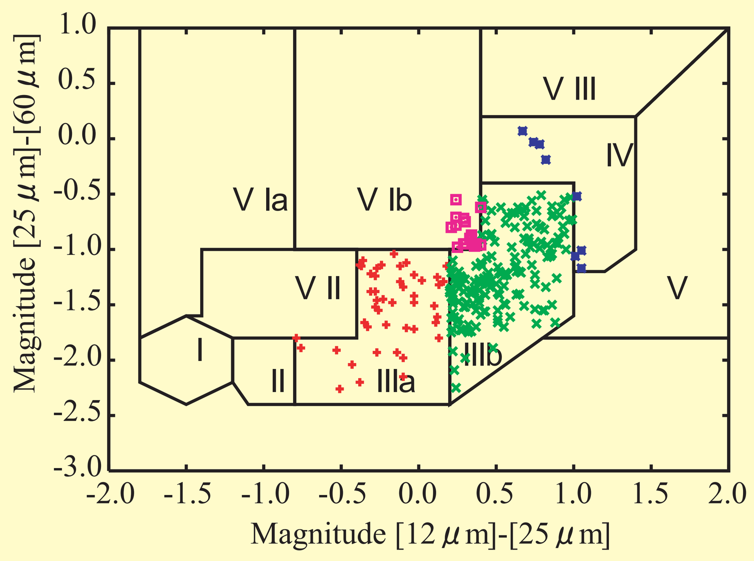


Figure 3. The strategy of our program is shown schematically in this figure. We investigate PL-relation of the Galactic sources by utilizing three observation techniques. Single Dish monitoring is carried out for obtaining the maser light curves. The 1m infrared telescope is used for obtaining magnitude and pulsation period. Accurate measurement of annual parallax will be achieved with VERA array (VLBI).

< C : Infrared monitoring >

Photometry on infrared J(λ =1.2 μm), H(1.6 μm) and K(2.2 μm) bands for ~400 AGB stars has started since September 2003 in order to obtain their pulsation periods and magnitudes. Sources are collected mainly from the samples classified within IIIa, IIIb, IV, and VIb regions of the two-color diagram (van der Veen and H. J. Harbing 1988) of the IRAS point source catalog, wherein the sources have high mass loss ratio and they are expected to be accompanied by H_2O/SiO maser emissions. We can also study physical properties of the sources by making use of the period-amplitude relation or period-color relation of the monitored sources.



(Specifications)
Field of view : 5.5 min x 5.5 min
CCD : 512 x 512 pixel
Filter : Infrared – J, H, K
Optical – V, R, I

Figure 5. Distribution of the monitored sources on IRAS two-color diagram. The 248 sources to which we could successfully measure magnitudes are represented.

Current Results

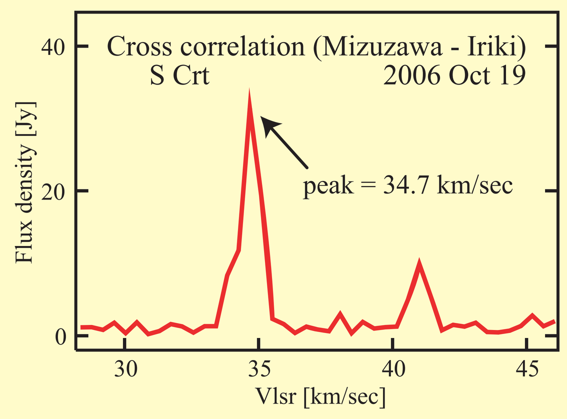
< Radio > S Crt is a semiregular variable with the pulsation period of 155 day. Multi-epoch phase referencing VLBI with VERA revealed the absolute motion of a maser spot (V_{lsr} = 34.7 km/sec) in S Crt.

Parallax 2.3±0.2 mas → 435^{+41}_{-35} pc

cf : Distance of S Crt in previous reports and adopted methods in each study.

1. 420 pc (Bowers 1994) — PL-relation in IR
2. 285 pc (Nimesh 1992) — PL-relation in IR
3. 500 pc (Hipparcos) — Parallax

Figure 6. Correlated spectrum of S Crt at 22 GHz. Two major components had been observed throughout all VLBI observations. We traced the motion of the brightest component.



Coordinates	RA	Dec
S Crt (target)	11h 52m 45.0981s,	–07d 35' 48.072"
J1147–0724 (reference)	11h 47m 51.554035s,	–07d 24' 41.14109"

Separation is 1.23° along the position angle of –85°.

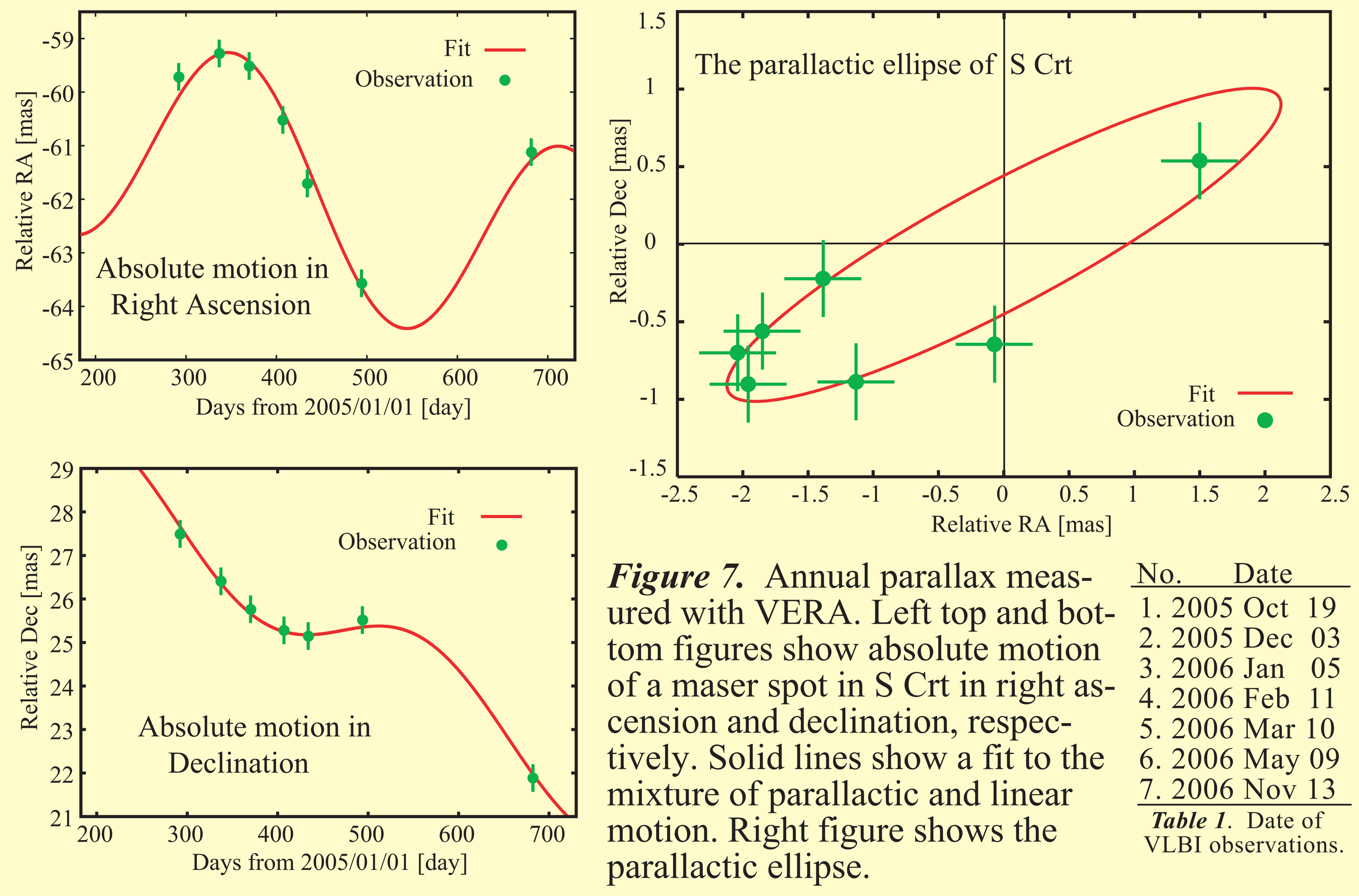


Figure 7. Annual parallax measured with VERA. Left top and bottom figures show absolute motion of a maser spot in S Crt in right ascension and declination, respectively. Solid lines show a fit to the mixture of parallactic and linear motion. Right figure shows the parallactic ellipse.

No.	Date
1.	2005 Oct 19
2.	2005 Dec 03
3.	2006 Jan 05
4.	2006 Feb 11
5.	2006 Mar 10
6.	2006 May 09
7.	2006 Nov 13

Table 1. Date of VLBI observations.

< Infrared > Light curves obtained by infrared monitoring were fitted with sinusoids. We have found the pulsation periods and magnitudes for ~200 sources at present analysis.

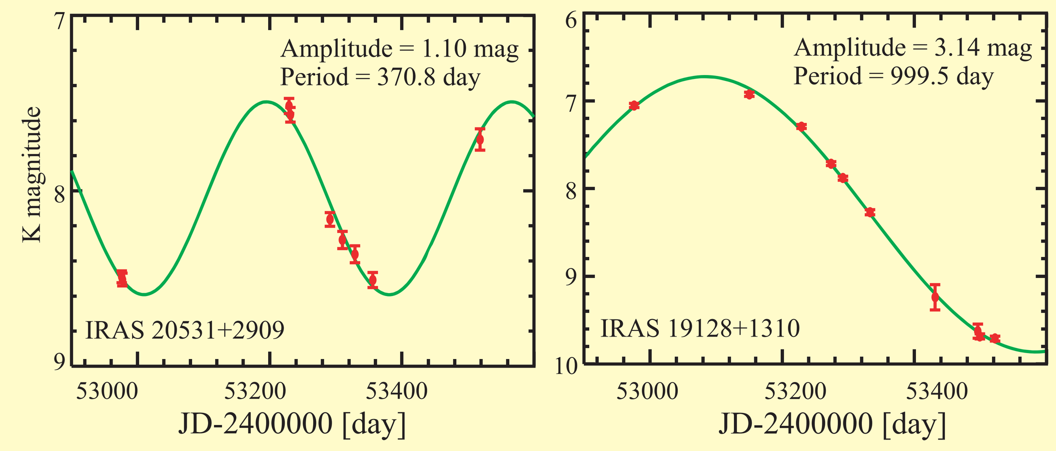


Figure 8. Light curves in infrared (K band). Left : Light curve of IRAS 20531+2909 presenting the pulsation period of 370.8 day. Right : IRAS 19128+1310 presenting the period of 999.5 day.

Continuous works

< 1 > We will continue this program based on the strategy explained in this presentation.
< 2 > Monthly VLBI observation with VERA and data reduction are in progress (IRC+60169, R UMa, Z Pup, WX Psc, T Lep, etc.).
< 3 > Zenith atmospheric delay residuals should be considered to explain the deviations of data from parallactic ellipse.
< 4 > In order to find new VLBI target, we are planing a radio survey at 22 GHz for the sources from which we newly derived a pulsation period and magnitude in infrared. The number of these potential target is ~150.
< 5 > Radio survey at 43 GHz is also necessary for astrometry using SiO maser emissions.

† New japanese VLBI array dedicated for phase referencing VLBI. Each element antenna (Mizusawa, Iriki, Ogasawara, Ishigaki) has two receivers for simultaneous observation of two sources. Data recording rate is 1Gbps.