VERAによる長周期変光星のVLBI位置天文観測

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Abstract
太陽の1－8倍の質量を持つ長周期変光星(LPV)は質量放出が激しく、宇宙の化学組成を考えるうえで重要である。明るさと変光周期の間に周期光度関係（Peirod-luminosity relation ; PLR）が知られており、この関係を我々の天の川銀河独自で確立することがVERAの目標の一つである。同時に得られる星周物質の運動も質量放出の理解につながる。その導出法としてHIPPARCOSによる計測との差分を用いる手法を試みた。この際バイナリーの可能性を検討する必要がある。本解析からはバイナリ―に関する強い制限を加えることは難しかったが、少なくとも0.5km/s/yr より大きなメーザー群の加速度は検出できなかった。運用中のGaiaや2017年12月に打ち上げ予定のNano-JASMINEには近傍(距離=数百pc)のLPVの固有運動測定が期待される。VERAによるメーザーの位置天文結果と結びつけることで内部運動やバイナリー運動についてより精度の高い議論が期待できる。

1 Source selection and VLBI observation

For the sake of construction of the PLR of Galactic source, we have selected ~80 LPV targets which show maser emission. Miras, Semiregular, and OH/IR stars are included in this target list. Figure 1 shows a period distribution of ~800 Miras in Feast et al. (2000) and our ~80 targets. Period average of ~80 Miras with water maser emisison is 407 day (LogP = 2.61), which is longer than that of 338 day (LogP = 2.53) of the sources in Feast et al. (2000). We conduct phase referencing VLBI observation at 22 GHz with typical duration of 1.5 - 2.0 years. Interval is ~1 month.

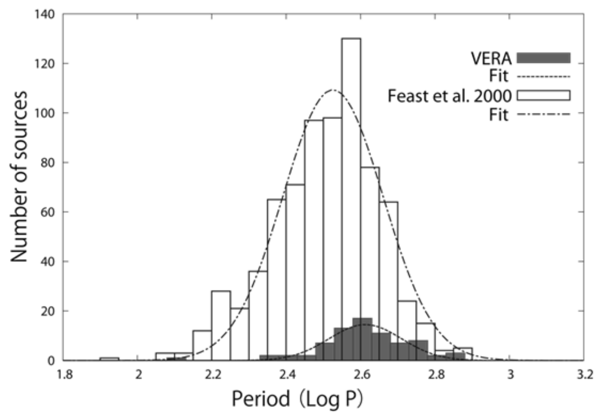

Fig.1 Period distribution of Miras in Feast et al. (2000) (white) and our targets (filled).

2 PLR of Galactic LPVs revealed by VLBI observations

In the last decade, astrometric VLBI has been played an important role for determining annual parallaxes of the Galactic LPVs. Accurate distance measurements were achieved with VERA and VLBA using H2O, OH, and SiO masers. In the upper panel of figure 2, we show a distribution of the Galactic LPVs on absolute magnitude Mk - LogP plane. A solid line indicates a PLR determined in our previos work (Nakagawa et al. 2014). Result by Ita et al. (2004) is superposed to find sequences for several types of variables. Errors of absolute magnitude are based on their distance errors. We can find there are some LPVs representing Mk of −11 mag. They are classified as red supergiants. PLR for this kind of stars can be an additional aim of our program.

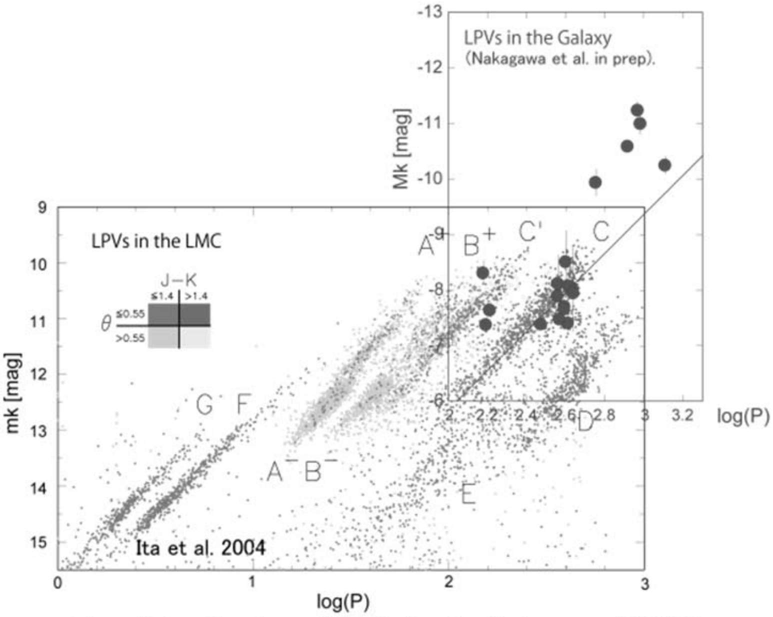

Fig.2 Distribution of LPVs in the Galaxy and LMC (Ita et al. 2004) on Mk - LogP plane. Distance of 49.89 kpc is assumed to the LMC.

3　Observation of a Mira tyoe variable “R UMa”

3.1　Parallax measurement

Using 12 maser spots, an annual parallax of R UMa was determined to be 1.92±0.05 mas, corresponding to a distance of 520±14 mas. Figure 3 shows parallactic motions in R.A. and Dec.

3.2　Maser spot distribution

Distribution of the maser spots around R UMa (Figure). Color indicate radial velocity. A cross mark is an estimated positon of central star from a consideration of the distribution. The map is 146 au square. An estimated shell with a radiusof 85 mas is presented with a dotted circle.

3.3　Maser internal motion revealed from VERA and HIPPARCOS astrometry

Kinematics of circumstellar matter from VLBI method is constructed on "pattern matching". Since we can not directly see photosphere, we estimate internal motions of maser spots by subtracting "average motion" of the maser spots. Sometimes, it is very difficult to derive the average motion. We tried to reveal ths internal motion using two independent astrometric measurements, one from

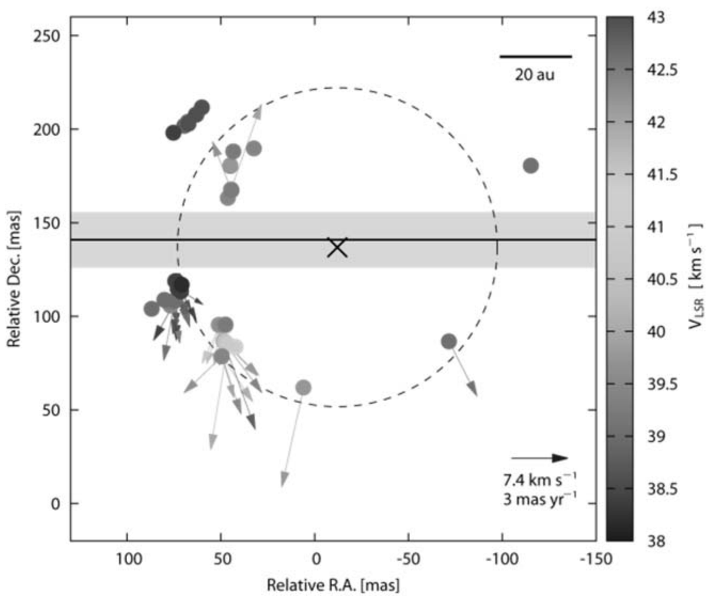

Fig.3 Distribution of water masers in R UMa. A cross mark indicate an estimated star posion.

VERA and another from Hipparcos. In figure 3, we derived the internal motions by subtracting HIPPARCOS proper motion (μx, μy) = (-40.51, -22.66) mas/yr from our VLBI measurements of each maser spot. VLBI proper motion accuracy of the spots was~0.2mas/yr. This can give a grobal picture of the circumstellar matter of the star.

3.4 Constraint on binary scenario

Actually, we have to pay attention to effects of "binary system". The μ_bin and μ_bin' indicate velocity vectors of binary motion on Hipparcos and VERA observation dates.

$$
\begin{aligned}
\mu\_\mathrm{VERA} &= \mu\_\mathrm{sys} + \mu\_\mathrm{bin}' + \mu\_\mathrm{int} \\
-)\ \mu\_\mathrm{HIP} &= \mu\_\mathrm{sys} + \mu\_\mathrm{bin} \\
\hline
\mu\_\mathrm{VERA} - \mu\_\mathrm{HIP} &= \Delta\mu\_\mathrm{bin} + \mu\_\mathrm{int}
\end{aligned}
\qquad (\Delta\mu\_\mathrm{bin} = \mu\_\mathrm{bin}' - \mu\_\mathrm{bin})
$$

Time differential of μ_VERA-μ_HIP include an acceleration of binary system. In next section, we consider the effect of binary motion, and try to give a constraint on binary scenario of R UMa. Since we did not detect difference of systematic motions between HIP and VERA larger than ~2 mas/yr (=~5 km/s), an acceleration due to a binary motion can be estimated to be < 0.5 km/s/yr (5 km/s was divided by an interval of 10 yr between HIP and VERA). In a radial velocity, we could not find any difference in Vslr of R UMa from literatures.

Gray scale of figure 6 gives a companion mass in unit of Msun as a function of orbit semimajor axis and acceleration. If we assume the acceleration of 0.5 km/s/yr as an upper limit, and also assume a companion mass larger than 0.5 Msun, a semimajor axis should be larger than ~14 au. Of course, we can not reject a single star scenario.

For very bright stars, like nearby Milas, Nano-JASMINE will be a powerful and promising telescope to determine their proper motions. In near future, more accurate proper motions from new satellites will be tied up with VLBI measurements of maser spots. With the same method as this study, circumstellar dynamics and binary scenario of many sources can be studied.

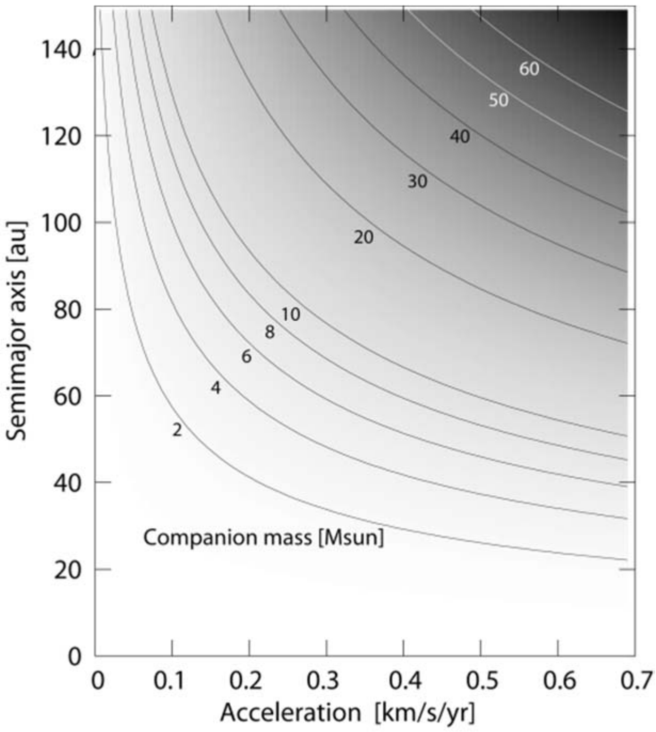

Fig.4 Biary orbit semimajor axis, acceleration of binary motion and companion mass.