VLBI Phase–Referencing Observations of the OH Masers in U Her and R LMi; toward Parallax Distance Measurements

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Abstract. We report preliminary results of our campaign to measure proper motions and annual parallaxes of the nearby Mira variables U Her and R LMi. The stellar positions are measured by means of the circumstellar 1667 OH maser. The assumption is that the brightest peak in the maser represents the amplified stellar image.

1. Observations

We selected U Her and R Lmi for a phase referencing campaign, because they are amongst the nearest maser emitting Miras (296–457 and 350 pc respectively, Engels 1979, Sivagnanam et al. 1987) and at complementary hour angles. For both stars two close compact radio sources are available as phase reference sources. These objects range in flux from 150–300 mJy and lie between $1^{\circ}\!.1$–$3^{\circ}\!.5$ from the targets. Since the reference sources are relatively weak, a large bandwidth is required to detect these sources. For the masers a smaller bandwidth, that resolves the lines, yields the optimal sensitivity. Hence the observations were carried out in mixed bandwidth mode with 6×2 MHz and 2×500 kHz.

Two sets of VLBA observations have so far been performed. The first on July 22 1994, the second on March 6 1995. Observations included bright extragalactic sources to calibrate instrumental effects and cycles of calibrator–source–calibrator of typically 6 minutes. A simple AIPS task was written to interpolate the wide–band continuum delay and rate solutions to the line data. Without further corrections such a calibration scheme produces convincing results.

The calibration method described above yields relative positions with respect to the reference sources. These were obtained from the astrometric catalogue of Patnaik et al. (1992) and are probably accurate to 12 mas. More importantly, the position information depends on the level of sophistication of the correlator model. In the VLBA correlator most of the necessary model

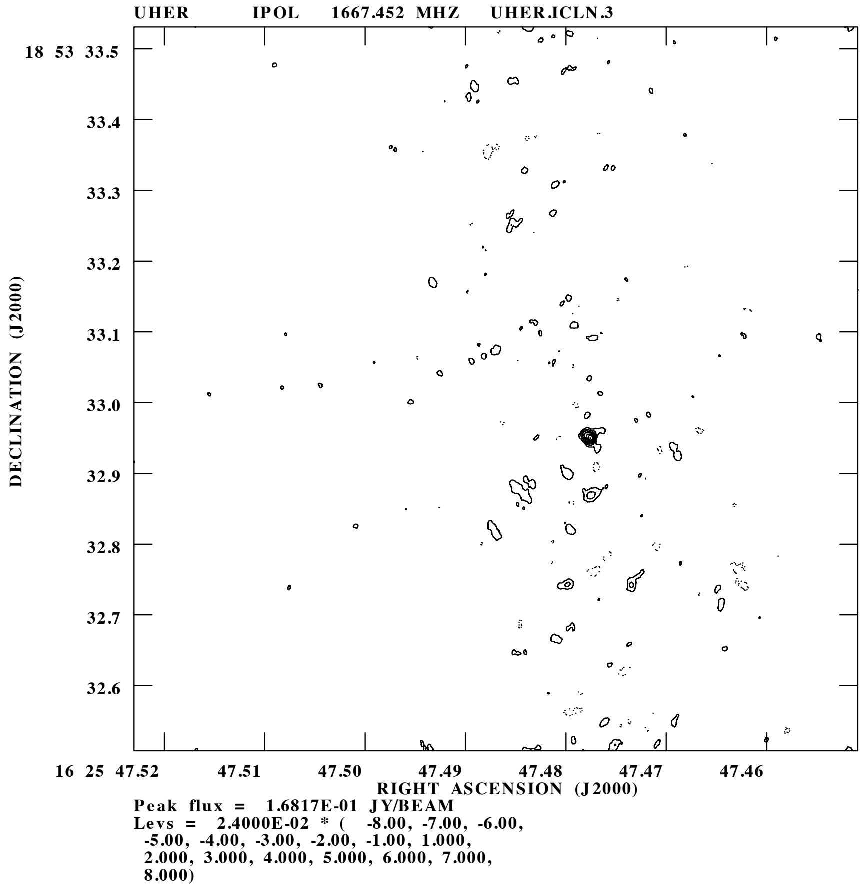

Figure 1. Map of the blue–shifted 1667 OH maser emission in U Her and R LMi. The image was obtained without self–cal.

components are included, so that there is some hope to do relative astrometry without further special software. The most important limiting factor at 1.6 GHz is the ionosphere. The first epoch was taken at night, the second during the morning. Both epochs were during solar minimum when the ionosphere is relatively quiescent.

The map in Fig. 2 was obtained without further phase calibration. Although it is limited in dynamic range, it can be seen that referenced calibration worked quite well. Note that no self–cal and no ionospheric modeling was applied. Self–cal improves the appearance of the image, but position information is lost in the process. The sources appear resolved, both in frequency and spatially. Work is in progress to study the maser in detail. Because we do not have to rely on self–cal and we have unprecedented spectral resolution this technique promises to be very useful.

2. Discussion

The basic assumption for the parallax measurements is that the brightest peak reflects the stellar position. The theoretical idea behind this is that on this line of sight the maser cascade is started by photons from the stellar continuum (e.g. Van Langevelde & Spaans 1993). In many objects the peak brightness temperature is in the most blue–shifted emission peak (e.g. Norris et al. 1984).

The best proof for this mechanism was presented for U Her by Sivagnanam et al. (1990), who showed that the brightest blue shifted peak was coincident for simultaneous measurements of the 1667 and 1665 maser lines. Although we did not aim to spectrally resolve the 1665 MHz line, the 1665 maser for U Her can be detected in our wide–band data. The positions are consistent to 3 mas. The estimates for the stellar radius of U Her are ≈ 10 mas, thus we confirm the results by Sivagnanam et al. (1990).

Second epoch observations were obtained 226 days after the first observations. After correlation it was discovered that a small improvement in the correlator model hampered the comparison between the two epochs. The effects of this are now understood and can be corrected. The same position was found within 12 mas for U Her from both epochs. This is about the amount expected for intrinsic motion on the sky, but we cannot yet rule out any systematic effects that were left uncorrected.

R Lmi could not be detected during the second epoch. Either the day time observations have suffered from an unstable ionosphere, or the known variability caused the target to be too weak.

3. Conclusions

The short slew times and the high accuracy of the correlator model, make the VLBA very suited for phase referencing. Without special software we readily derived 10 mas accurate positions. Our observations seem consistent with the hypothesis that the brightest peak in the blue–shifted emission is indeed the stellar image, amplified by the maser mechanism.

A parallax determination accurate to 1 mas appears to be possible, although further investigation of systematic effects is required. The fundamental limitation is however, the fact that the maser spot is resolved on 10 mas scales. These two stars will be a valuable link between the optical and radio reference frame. Many more Miras for which this comparison can be done are available.

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