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The annual parallax of cataclysmic binary system AM Herculis with the e-EVN

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AM Herculis is a prototype of the class of magnetic cataclysmic variables called "polars". The white dwarf magnetic field is strong enough to synchronize the rotation of the white dwarf with the binary orbit in these close binaries. In such a case only accretion stream is present and the accretion flow is directed onto the magnetic pole (or poles) of the white dwarf. The precise estimation of the distance to polars is crucial in better understanding of physical parameters of these very interesting stellar systems. Here we present results of our astrometric project conducted with the e-EVN at 5 GHz.

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1. Introduction

Cataclysmic variables (CVs) are very interesting short-period, close binaries consisting of a white dwarf primary component and a low-mass main-sequence star (red dwarf) as the secondary component. The white dwarf accretes material from the red dwarf via the inner Lagrangian point (L1) to form an accretion disc, or a magnetically channeled accretion stream, or a combination of both. Magnetic CVs (MCVs) are defined to be those CVs which include white dwarfs with the very strong magnetic fields. In this case the magnetic field is strong enough to direct the flow of accretion onto the magnetic pole (or poles) of the white dwarf. If magnetic field also is capable to synchronize the rotation of the white dwarf with the orbital period, then the system is called an AM Herculis type binary or "polar". In such a case only accretion stream is present and strong optical-IR polarization is usually observed from the object. Radio detections of some MCVs are documented in the literature. Variable radio emission at level of $\sim$1 mJy was reported for polars AM Her, V834 Cen, AR UMa and ST LMi (e.g. [4]).

The distance estimation of MCVs is fundamental for the interpretation of existing observations and physical models. However, the direct measurements of the trigonometric parallax based on the optical astrometry were done only for a few closest CVs and MCVs so far [7]. In the other cases, usually so–called K–band surface–brightness method is used (e.g. [1]).

AM Her is a prototype of polars and the first discovered member of the polar class. This system was also the first to be deteced as a radio source [3]. AM Her was observed to exhibit non–thermal emission in the range $\sim$0.3 – 0.7 mJy [3] as well as a single 100% circulary polarized flare (9.7 mJy, [4]), both at C–band. The quiescent emission appears to be nearly always present in the range $\sim$0.2 – 0.7 mJy. The magnetic field strength was derived 14.5 MG for the primary component [2]. In 1981 the M4V secondary was detected and the distance $d = 71 \pm 18$ pc was estimated assuming a radius typical of a main sequence star for the secondary component [9]. [6] using the K–band method estimated $d = 91^{+18}_{-15}$ pc and recently [8] using optical astrometry has given $d = 78^{+7}_{6}$ pc.

Date	RA (J2000)	ΔRA (mas)	Dec (J2000)	ΔDec (mas)	S_{5GHz} (μJy)
10.01.1998*	18 14 58.55735	67	49 50 56.1261	41	549 ± 96
17.10.2003*	18 16 13.23569	35	49 52 04.9571	48	597 ± 88
05.12.2012	18 16 13.19282	0.2	49 52 05.1122	0.3	290 ± 31
06.02.2013	18 16 13.19321	0.2	49 52 05.1193	0.2	438 ± 43
02.05.2013	18 16 13.19224	0.3	49 52 05.1300	0.3	390 ± 63
17.09.2013	18 16 13.18830	0.4	49 52 05.1453	0.4	172 ± 43
17.09.2013	18 16 13.18834	0.2	49 52 05.1464	0.2	394 ± 37
03.12.2013	18 16 13.18806	0.3	49 52 05.1408	0.2	285 ± 36

Table 1: Estimated positions and fluxes of AM Her during our astrometric survey. Errors in the position are errors from fitting and do not include any systematic effects. * – VLA archival observations at 8.4 GHz

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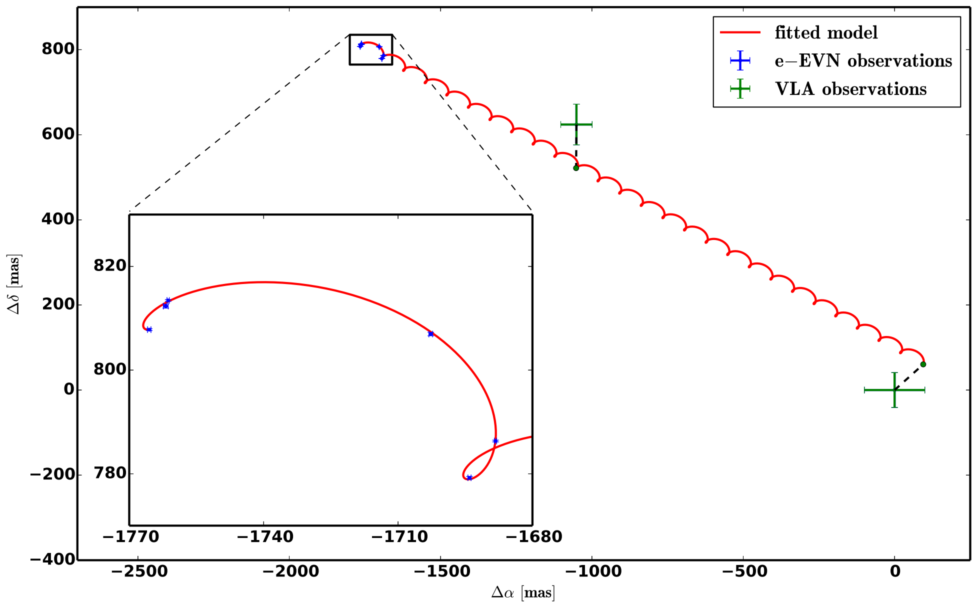

Figure 1: The comparison of our astrometric measurements with the model of the annual parallax and proper motion. The figures shows position offsets of AM Her relative to the first epoch of observations.

2. Observations and results

In order to make a new, more precise distance estimation we conduced a new astrometric survey with the e–EVN at 5 GHz. Multi–epoch phase–referencing observations were performed during 12 months and started in December 2012. The data reduction process was carried using standard NRAO AIPS[1] package. Maps of the phase calibrator J1818+5017 were created and used as a model for final fringe–fitting. The IMAGR task was used to produce the final total intensity images. We were able to detect AM Her in all epochs of observations. Our observations with estimated AM Her fluxes and positions are presented in Tab. 1. We also added positions from two archival VLA observations at 8.6 GHz to our sample in order to expand the time span of observations and made more precise estimation of AM Her proper motion. The astrometric model of AM Her fitted to our data gives a new distance estimation $d = 88.5 \pm 2.8$ pc ($\pi = 11.30 \pm 0.35$ mas, $\mu_{RA} = -71.44^{+1.35}_{-1.37}$ mas and $\mu_{Dec} = 28.82^{+0.72}_{-0.73}$ mas). We conducted calculations using the EMCEE package [5]. Our new astrometric model of AM Her is presented in Fig. 1 and the posterior probability distributions of the fitted astrometric parameters is shown in Fig. 2. This new estimation of the distance to AM Her put this object in the upper limit of the known values from the literature.

Acknowledgement

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[1] http://www.aips.nrao.edu/index.shtml

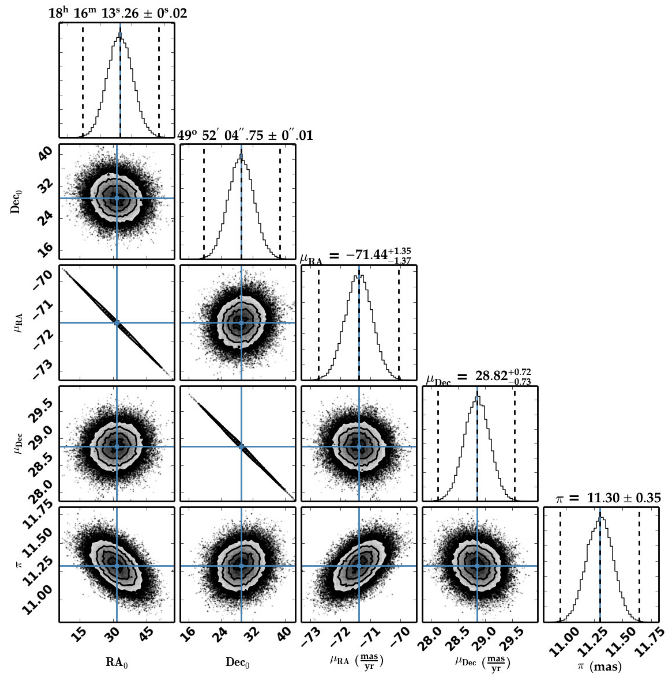

Figure 2: The corner plot presents two-dimensional projections of the posterior probability distributions of the fitted parameters with 3σ measurements uncertainties (EMCEE package, [5]). The correlation between $\mu_{RA}-\mathrm{RA}_0$ and $\mu_{Dec}-\mathrm{Dec}_0$ is caused by large errors from VLA observations.

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