Project RISARD - linking the EVN and GAIA stellar astrometry

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ABSTRACT

The stellar astrometry based on the Very Large Baseline Interferometry (VLBI) is a well established observational technique that may be useful for validating astrometric measurements of the ongoing GAIA mission. A careful comparison of astrometric models for particular, well defined targets may help to identify statistical biases in the data sources. In 2011, we initiated a Radio-Interferometric Survey of Active Read Dwarfs (RISARD) with the European VLBI Network (EVN). This project is devoted to young, magnetically active red dwarfs placed in the close Solar neighbourhood, between 10 and 15 pc. We systematically observed a sample of carefully selected active M-dwarfs at 6cm radio band during last 7 years. We used the well-known phase-referencing mode of observations, when a weak radio signal is compared with a strong source of radio emission (quasar) that is placed in the cosmological distance. We report on our final EVN results for two active red dwarfs from our sample, TVLM 513-46546 and V596 Cas. V596 Cas is included in GAIA Data Release I. We also observed AM Her, the interacting compact binary system. We present the astrometric model and its Bayesian optimization. We compare the derived absolute parallax and proper mean motion of V596 Cas with results from the GAIA Data Release 1.

INTRODUCTION

Magnetically active young M-dwarfs produce weak, variable radio emission at cm wavelengths. The VLBI technique has been successfully used for the observations of low-mass active M-dwarfs or even brown dwarfs (e.g. Güdel et al. 1993). The recent development of the VLBI systems improved significantly the sensitivity and opened a new observational window for stellar astrophysics. This also should allow for direct comparison of the VLBI and GAIA astrometry results.

OBSERVATIONS & DATA REDUCTION

We carried out interferometric observations of selected M-dwarfs at the 5 GHz radio band from March 2011 to June 2016. We performed the observation with the EVN in the e-VLBI mode, using the phase-referencing technique (proposals EG053, EG065 & EG082). AM Her also was observed with the use of the EVN. The reduction of the interferometric data was carried out with the standard NRAO AIPS procedures. The final total intensity radio images with the natural weighting of *uv-data* for all observed sources. Position of radio images were then measured by fitting Gaussian models to radio images of observed stars. In the case of TVLM 513-46546 we also added archival positions obtained with the use of VLBA observations (Forbrich et al. 2013).

ASTROMETRIC MODEL & ITS OPTIMIZATION

We used the canonical 5-element model for the ICRF astrometric place of an isolated target. To avoid correlations between the zero-epoch position and the proper motion components we adopted the initial epoch as the mean of all observational epochs weighted by their uncertainties. Understanding sources of uncertainties of astrometric VLBI observations is crucial for their correct estimation. We proposed a new, systematic statistical approach to the proper optimization of astrometric model in the presence of unspecified error factors. It is based on the maximal likelihood function and Markov chain Monte Carlo (MCMC) exploration of the parameters space (see for details Gawroński et al. 2017). The error floor (σ_f) estimated in this way accounts for different systematic effects, from spanning atmospheric phase effects to the motion of unseen, low-mass companions. The sky-projected astrometric model and the posterior probability distribution for free parameters are shown on Fig.1 and Fig.2, respectively. The astrometric models for TVLM 513-46546 and AM Her are presented in Tab. 1, and the differences between VLBI astrometry and GAIA DR1 results for V596 Cas are given in Tab.2 The noted discrepancies between VLBI and GAIA results are in agreement with median position offsets ~2.2 mas between the GAIA DR1 and the VLBI positions for bright, compact radio sources (Petrov & Kovalev, 2017)

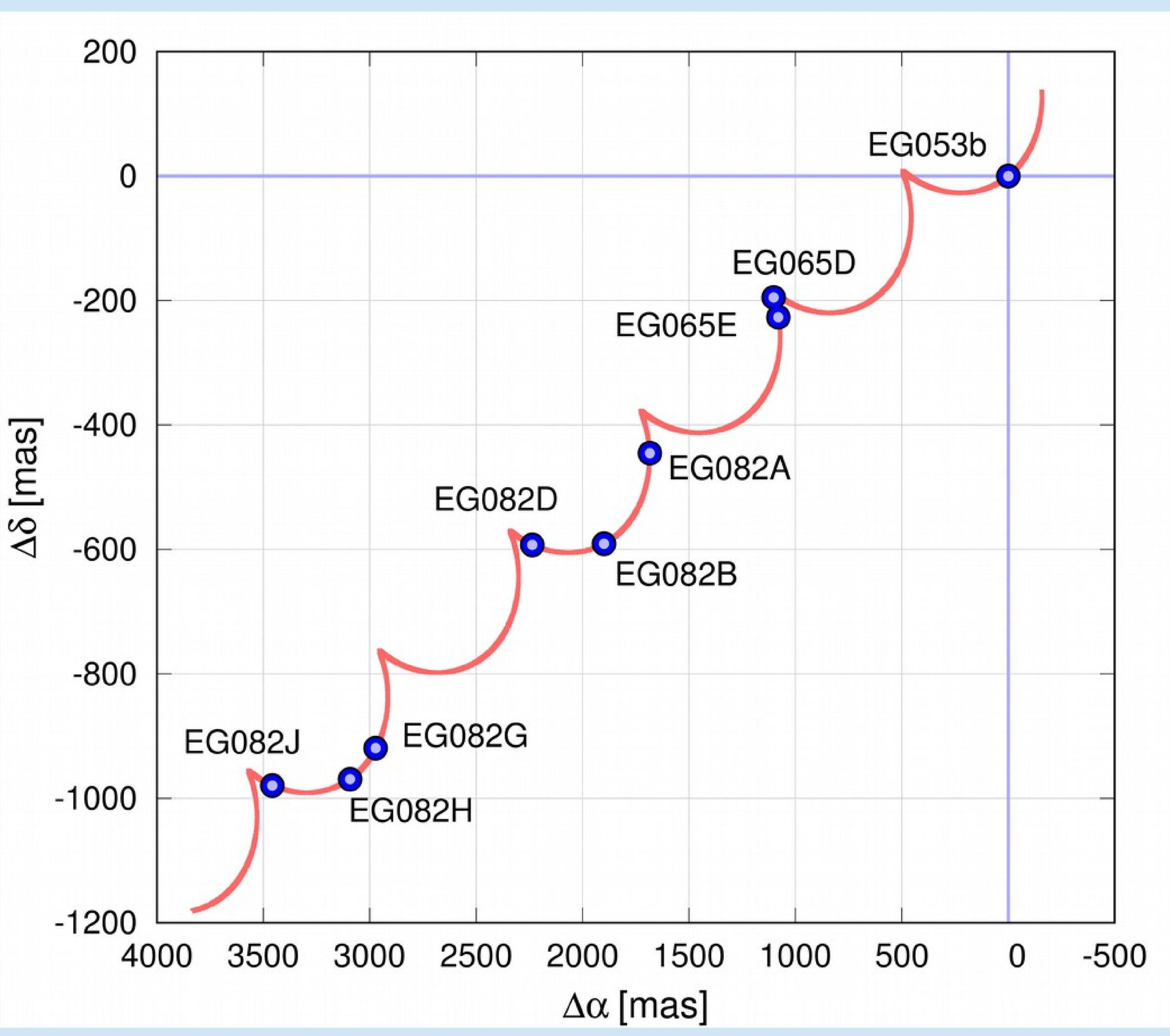

Fig.1 Sky-projected, 5-parameter astrocentric model of V596 Cas over-plotted with e-EVN detections.

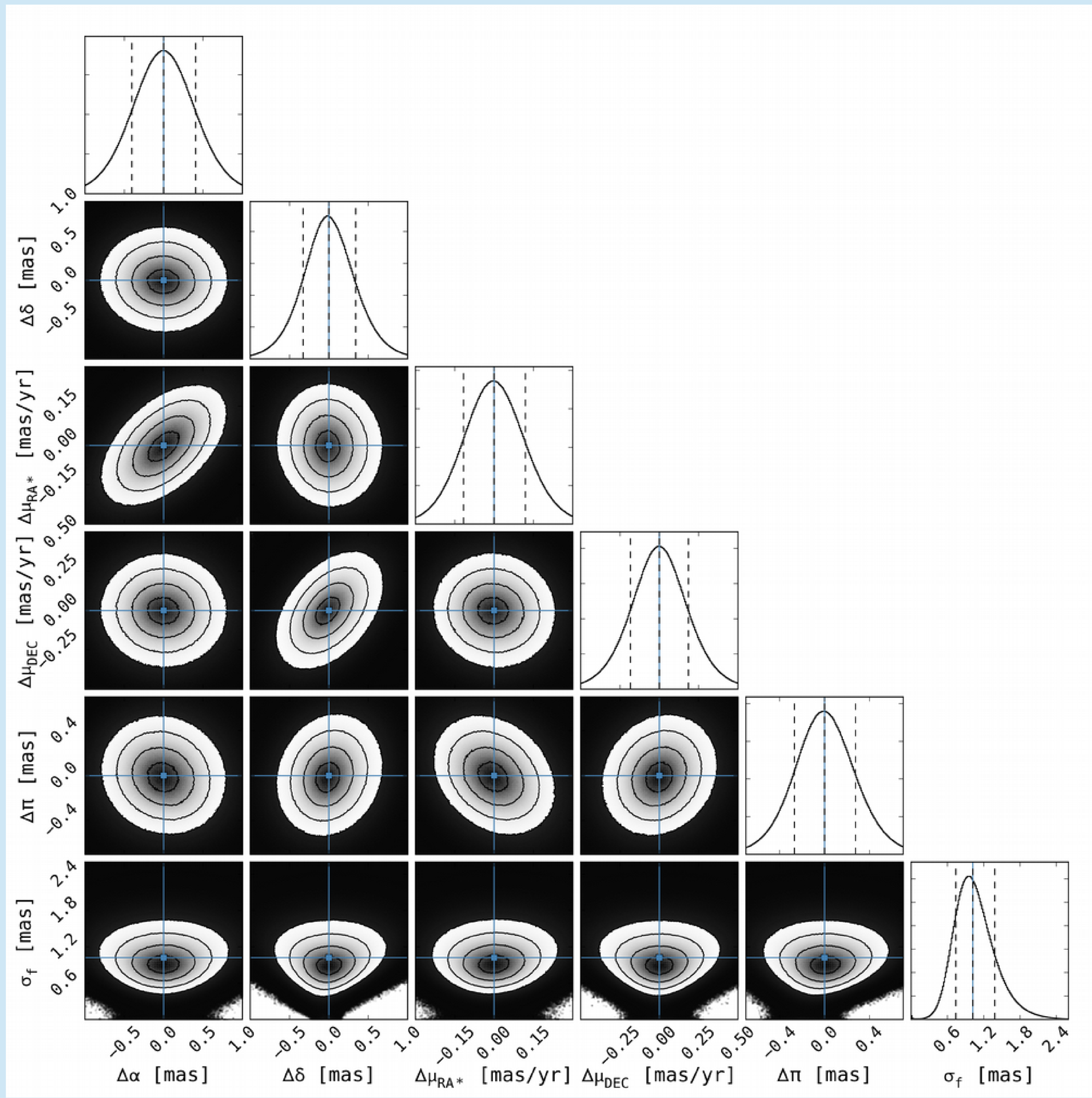

Fig.2 One- and two- dimensional projections of the posterior probability distribution for all free parameters of the astrometric 5-elements model. Contours indicate 16th, 50th, and 84th percentiles of the samples in the posterior distributions.

Parameter	TVLM 513-46546	AM Her
epoch [JD]	2455424.2	2456457.5
α_0	$15^h01^m08^s.15219^{+9}_{-10}$	$18^h16^m13^s.19074^{+1}_{-1}$
δ_0	$22°50'01''.42470^{+75}_{-70}$	$49°52'05''.13684^{+6}_{-6}$
μ_α [mas yr^{-1}]	-43.23^{+8}_{-7}	-46.02^{+22}_{-22}
μ_δ [mas yr^{-1}]	-65.60^{+8}_{-7}	28.83^{+18}_{-18}
parallax π [mas]	93.17^{+21}_{-20}	11.29^{+8}_{-8}
σ_f [mas]	0.43^{+10}_{-12}	0.17^{+19}_{-13}

Tab.1 Parameters of the best-fitting solution at the for all e-EVN epochs. Uncertainties are shown at last significant digits.

Parameter	e-EVN	(e-EVN)-(GAIA DR1)
α_0	$01^h59^m24^s.127661^{+23}_{-23}$	-1.36 mas
δ_0	$58°31'13''.214295^{+13}_{-13}$	-1.20 mas
μ_α [mas yr^{-1}]	320.81^{+7}_{-7}	0.10 mas
μ_δ [mas yr^{-1}]	-192.88^{+6}_{-6}	-0.26 mas
π [mas]	75.38^{+9}_{-9}	-1.16 mas

Tab.2 Parameters of the best-fitting solution for the V596 Cas at the GAIA DR1 epoch J2015.0, and absolute differences between our solution and the GAIA DR1 catalogue. Uncertainties are shown at last significant digits.

ACKNOWLEDGEMENTS

We are grateful to the Polish National Science Centre for their support (grant no. 2011/01/D/ST9/00735). The EVN is a joint facility of European, Chinese, South African, and other radio astronomy institutes funded by their national research councils.

REFERENCES

Forbrich, J. et al., 2013, ApJ, 777, 70
Gawroński, M.P. et al., 2017, MNRAS, 466, 4211
Güdel, M. et al., 1993, ApJ, 415, 236
Petrov, L. & Kovalev, Y.Y., 2017, MNRAS, 467, L71