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V4641 Sgr and KV UMa. Two black hole candidates

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Abstract. We have analized the results of processing of the NRAO archive VLA and VLBA data for two star objects titled *V4641 Sgr (J1819-2524)* and *KV UMa (X1118+4802).* Some radio images of both sources for some frequency ranges are presented. Data have been processed with the software project titled *'Astro Space Locator' (ASL for Windows).* The Multi Frequency Synthesis (MFS) method has been used for reconstruction of radio maps. Images of both sources are presented. Any polarization phenomena are not taken into account. We present results of processing of data of RR polarization for all the observational sessions.

Key words. Stars: close bynary systems – Stars: X-ray transients – Stars: variable radio srtucture – Radio Astronomy: VLBA observations

1. Introduction

The objects titled *V4641 SGgr (J1819-2524)* and *KV UMa (X1118+4802)* have been observed sometimes with VLA and VLBA. Particularly, we have taken into account the following observational sessions of VLA : *AM642*, *AH669*, *AR545*, and the following VLBA sessions : *BD087*, *BJ056*, *BH063*, *BO008* for the epoch between 1999 and 2005. Both objects are very weak in optic (the visible magnitude value is more than +10). On the other hand, objects are quite powerful sources of radio emission. Moreover, *KV UMA* is known as soft X-ray transient. A mass function of this close binary system is about *6.3 Solar masses.* Thus, probably, one component of this system is a black hole. Another source, *V4641 Sgr*, is known as a detached binary consisting of an object of a *9 Solar masses* (again, this is probably a black hole) and a star of A0 type. Orbital period of both systems is equal to several days (Halfaris et al. 2005). Distance to *V4641 Sgr* is approximately 10 kpc. Distance to *KV UMa* is conciderably less (about 1.9 kpc) (Martin et al. 2008). It is easy to estimate, that for *V4641 Sgr* 1 milliarcsecond in map corresponds to the linear size of approximately 2 Astronomical Units (1 AU = $1.5 \cdot 10^8$ km). For *KV UMa* 1 milliarcsecond in map corresponds to the linear size of approximately 11 Astronomical Units There are the following reasons of our interest to this object:

- Object is sufficienly weak in all frequency ranges. It is relevant for advancing of calibration procedures implemented into our software project.
- Object is strongly variable in time. Thus, results of processing of radio astronomical data could help us to understand the phys-

Send offprint requests to: A. Chuprikov ical nature and mechanism of their radiation.

- There are some VLA and VLBA data for several epochs in the NRAO archive.

In this paper we analyze results of processing of data of the following observational sessions : *BD087, BJ056, BH063, BO008*. All the data were tranferred from archive of the *NRAO (National Radio Astronomy Observatory, USA)* and processed with with the software project titled 'Astro Space Locator' (ASL for Windows).

2. Method and results of data processing

The data processing consists of the following stages:

- Amplitude calibration of all the data using values from GC and TY tables and some additional information.
- Single band fringe fitting (the primary phase calibration) of all the data. Estimation of the optimum value of solution interval.
- Averaging of all the data over each frequency band.
- Multi band fringe fitting of the atmosphere and ionosphere calibrator data. Estimation of gain values for every frequency and every time interval.
- Application of gains, compensation of atmosphere and ionosphere delay for all the data.
- Self-calibration. Final averaging, editing, and imaging of the data.

Amplitude calibration of the data was made with usage of two standard calibration tables (*'Gain Curve' (GC)* and *'System Temperature' (TY)*) that were established with the VLBA correlator during the primary data processing. The standard procedure of primary phase calibration allows to reconstruct the visibility function phase. Then, we can obtain the dirty map of our source and estimate the signal-to-noise ratio (SNR). For weak sources, such as SS433, SNR depends conciderably on the phase calibration solution interval value. It is necessary, to find the optimal solution interval for every particular data set. In our case, this value changes between 10 seconds and 8 minutes. After phase of visibility function is reconstructed, all the data could be averaged in time and frequency. SNR will be increased due to this averaging. The main difficult stage of the VLBI data processing is usage of phase calibrators for compensation of interferometer model errors as well as for compensation of atmosphere and ionosphere delays. For this goal, it is necessary to include into any VLBI session schedule some additional sources (phase calibrators). There are two criteria for selection of such sources :

- They are close to the main source (at the distance no more than some degrees)
- They are point-like and bright enough

In our case, the sources titled *1820-254, 1744-312* were used as such calibrators for *V4641 SGgr (J1819-2524)*. For *KV UMa (X1118+4802)* the following calibrators were used : *J1110+4403, J1138+4745, J1110+4817, J1153+4931*

As mentioned above, they are used to estimate the gain values for compensation of delays caused by atmosphere, ionosphere and any uncertainties of the interferometer model.

It is known (Martin et al. 2008; Mikolajewska et al. 2002) that a radio structure of both objects is very changeble in time. Figure 1 demonstrates changes in radio structure of *V4641 SGgr (J1819-2524)* in S/X ranges. The litlle ruff is seen clearly in the left picture. Its size is about 10 mas. The length of visible part of jet is approximately 30 mas. The right picture shows the same object at other epoch. Here, the size of ruff seems to be conciderably less. Moreover, it is clear that position angles of jet are strongly different for these two epochs (difference is about 20 degrees) and length of jet in the right picture is about 1.5 times less than in the left picture.

Figure 2 demonstrates changes in radio structure of *KV UMa (X1118+4802)* in the same wavelength range (S/X ranges). It is clear, that this object is much more changeble

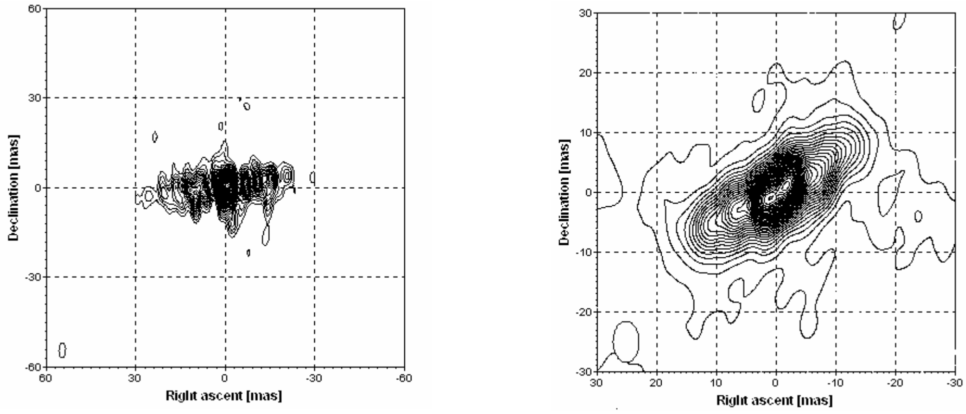

Fig. 1. The S/X range radio images reconstructed for *V4641 SGgr (J1819-2524)*. Session *BH063*, 14/07/1999 (LEFT). Session *BD097*, 13/07/2004 (RIGHT)

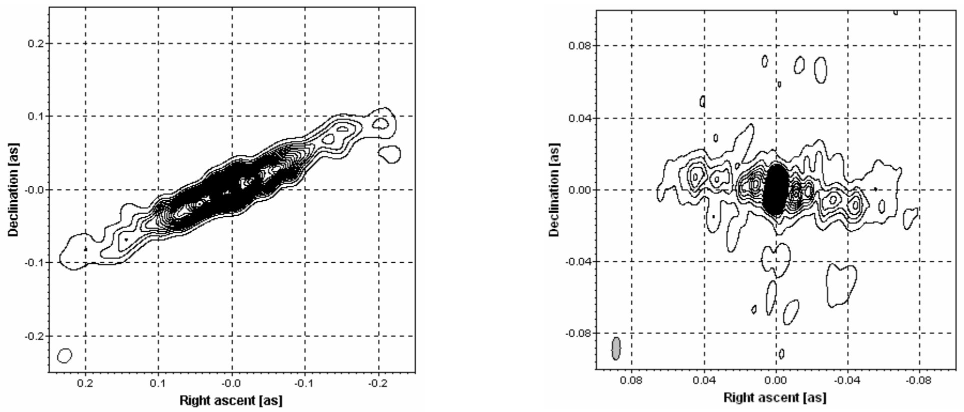

Fig. 2. The S/X range radio images reconstructed for *KV UMa (X1118+4802)*. Session *Bo008*, 14/07/1999 (LEFT). Session *BJ056*, 26/01/2005 (RIGHT)

in this range. The length of visible part of jet is here about 200 mas. Ruff is not seen so clearly in this frequency range. It seems to be visible in the right picture. Again, it is clear that position angles of jet are strongly different for these two epochs (difference is about 40 degrees). In the right picture, length of jet is about 4 times less than in the left picture.

3. Conclusions

We made processing of data of some VLBA observational sessions had been made during 1999 - 2005 *BD087, BJ056, BH063, BO008*. The main goal of this investigation is to reveal the radio structure of bothobjects (*V4641 SGgr (J1819-2524)* and *KV UMa (X1118+4802)*) and its changing in time. Results of these data processing are :

- The radio images reconstucted S/X wavelength range confirms the existence of precessing ruff in radio structure of both objects. The size of the ruff is some tens of AU for this frequency range
- This investigation demonstrates that calibration procedures of 'Astro Space Locator'

are relevant for processing of interferometrical data for weak radio sources

We'll continue our investigations to reveal more detail information of variability of radio structure of (*V4641 SGgr (J1819-2524)* and *KV UMa (X1118+4802)*) during one orbital period as well as the modulation of this variability.

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