======================
Astro Space Center
RadioAstron Newsletter
Number 29
18 July 2015
======================

Four years since the launch

Today is the fourth year birth day of the RadioAstron Space Radio Telescope Spektr-R! We would like to express our congratulations and deep thanks to all the institutions and individuals involved in the mission's operations and science.
Several weeks ago AO3 observations have started.

Ultra-high spatial resolution image of nearby radio galaxy 3C 84 at 22 GHz

The RadioAstron Key Science Program on imaging nearby active galactic nuclei has successfully produced an ultra-high spatial resolution space-VLBI image of 3C 84, a radio source located in the giant elliptical galaxy NGC 1275 in the Perseus Cluster at a distance of 75 Mpc. At this distance, an angular size of 1 milliarcsecond corresponds only to ~ 0.3 parsec linear size. Because of its proximity and bright, relatively compact radio emission, 3C 84 is one of the best candidates for studying the inner jet at very high spatial resolution and it was selected as an ideal target for space-VLBI imaging with RadioAstron. The ultra-high resolution images of 3C 84 will help us to understand the AGN jet formation and evolution within the innermost parsec from the central engine.

The 22-hour long imaging experiment was carried out on 21-22 September 2013. Observations were obtained at the same time at 5 and 22 GHz using the dual-band observing mode of the Space Radio Telescope. The ground array data comes from 25 telecopes including the European VLBI Network together with the Russian Kvazar network, the Korean VLBI Network, Kalyazin and the NRAO telescopes Very Long Baseline Array, the Green Bank Telescope, and the phased Very Large Array. Part of the ground array observed at 5 GHz and a part at 22 GHz with Effelsberg switching between the two. The data presented here were correlated at the Max-Planck-Institut für Radioastronomie, Bonn. Space-to-ground fringes were detected from 0.2 Earth Diameters (ED) up to ~ 7 ED at both frequencies. The Figure 1 shows the resulting 22 GHz space-VLBI image after the full data calibration and deconvolution.

At sub-mas scale, the central region of 3C 84 is resolved in a complex structure. The most prominent features are the core at the northern end of the jet and a bright component South of the core, which moves at sub-luminal speed along a curved trajectory connected to the core by a limb-brightened jet. The RadioAstron image shows substructure in these features at an unprecedented detail. For the first time a counter-jet is clearly visible at sub-parsec scale. The core is elongated in East-West direction implying a resolved structure at the angular resolution of about 50 μas, corresponding to about 500 Schwarzschild radii. The limb-brightened, well-resolved jet and counter-jet can be seen right from the beginning. The bright spot inside the southern component is identified with the end of the limb-brightened jet. Its compactness indicates a very high brightness which is unusual for sub-luminal jets being observed at a large angle.

Probing the cosmic plasma with a pulsar's radio pulses and an "interstellar interferometer"

Radio pulsars provide a powerful tool for studying the ionized interstellar medium. Pulsar B1933+16 was observed with Radioastron on August 1 2013 for 1.5 hours at two wavelengths simultaneously: 92 and 18 cm. This was the first experiment to use Green Bank tracking station, the 45-m antenna of NRAO (USA). The observations were supported by several ground radio telescopes: the 300-m telescope in Arecibo, the array of 14 telescopes in Westerbork (WSRT), the 32-m radio telescope in Torun, one 25-m dish of the VLBA system in Saint-Croix (USA), and one 32-m telescope of the Russian system QUASAR in Svetloe. The pulsar is located in the Sagittarius Arm at a distance from 3 to 10 kpc, with the most probable value of 3.7 kpc. The direction to the pulsar goes along this spiral arm, and such circumstances provide possibility of compelex structure of interstellar medium on the light of sight.

We measured angular diameter of the scattering disk at 92 cm from the decrease of amplitude of interferometric visibility with the increasing baseline. Figure 2 illustrates the method. The diameter of the scattering disk was found to be equal to 17 mas at 92 cm. A scattering disk size is proportional to lambda squared, and at wavelenght of 18 cm we expect scattering disk to be about 0.7 mas in diameter. This value can be measured at the maximum RadioAstron baselines, but not in the August 2013 configuration. Scattering of radio waves on the inhomogeneties of interstellar plasma causes the mutual interference of scattered waves at the observer position, thus forming an "interstellar interferometer" with a baseline equal to the distance between scattering rays at the effective screen. This can reach values of several astronomical units. In figure 3 we present an interferogram (delay-fringe rate diagram) of these scattered rays obtained for pulsar B1933+16 using data recorded with the Arecibo radio telescope for our observing session. The diagram is also called a secondary spectrum, since it is obtained as a 2-d Fourier transform of the dynamic spectrum. One can see parabolic features in the diagram. Such features were discovered by Stinebring in 2001 and they are called scintillation arcs. Each scintillation arc corresponds to separate scattering screen, and the curvature of the arc is related to the distance of the given screen. Dashed white lines going through arcs in the figure represent our approximations, that give us values for the two screen position as 0.27 and 0.73 of the distance to the pulsar. Comparing these values with the large scale structure of the spiral arm, we can in principle improve the estimate of the pulsar distance as well.

RadioAstron study of galactic water masers with ultimate angular resolution

Recent observations of the most luminous water maser source in the Galaxy, star-forming region W49 N, resulted in a successful detection updating the RadioAstron record in angular resolution achieved in observations of cosmic masers. W49 N is located at a distance of about 11 kpc from the Sun in a distant part of the Perseus arm near the Solar circle. A correlated signal was obtained on 27 April 2015 between the space antenna and the two sensitive European ground facilities taking part in the experiment: the 100-m radio telescope in Effelsberg (Germany) and the 43-m radio telescope in Yebes (Spain). Projected baselines of the space-ground interferometer in the experiment reached up to about 9.7 Earth diameters, achieving a fringe-spacing resolution of $\sim$23 μas. The collected data on water masers are used to study structure and physical characteristics of the star forming regions in our Galaxy, impose tight limits on the sizes of individual maser spots, estimate brightness temperatures and provide the necessary input for the studies of their pumping mechanisms.

Nikolai Kardashev (nkardash@asc.rssi.ru)
Yuri Kovalev (yyk@asc.rssi.ru)

The RadioAstron project is led by the Astro Space Center of the Lebedev Physical Institute of the Russian Academy of Sciences and the Lavochkin Scientific and Production Association under a contract with the Russian Federal Space Agency, in collaboration with partner organizations in Russia and other countries.

To subscribe or un-subscribe to the Newsletter, use:
http://asc-lebedev.ru/index2.php?engdep=22

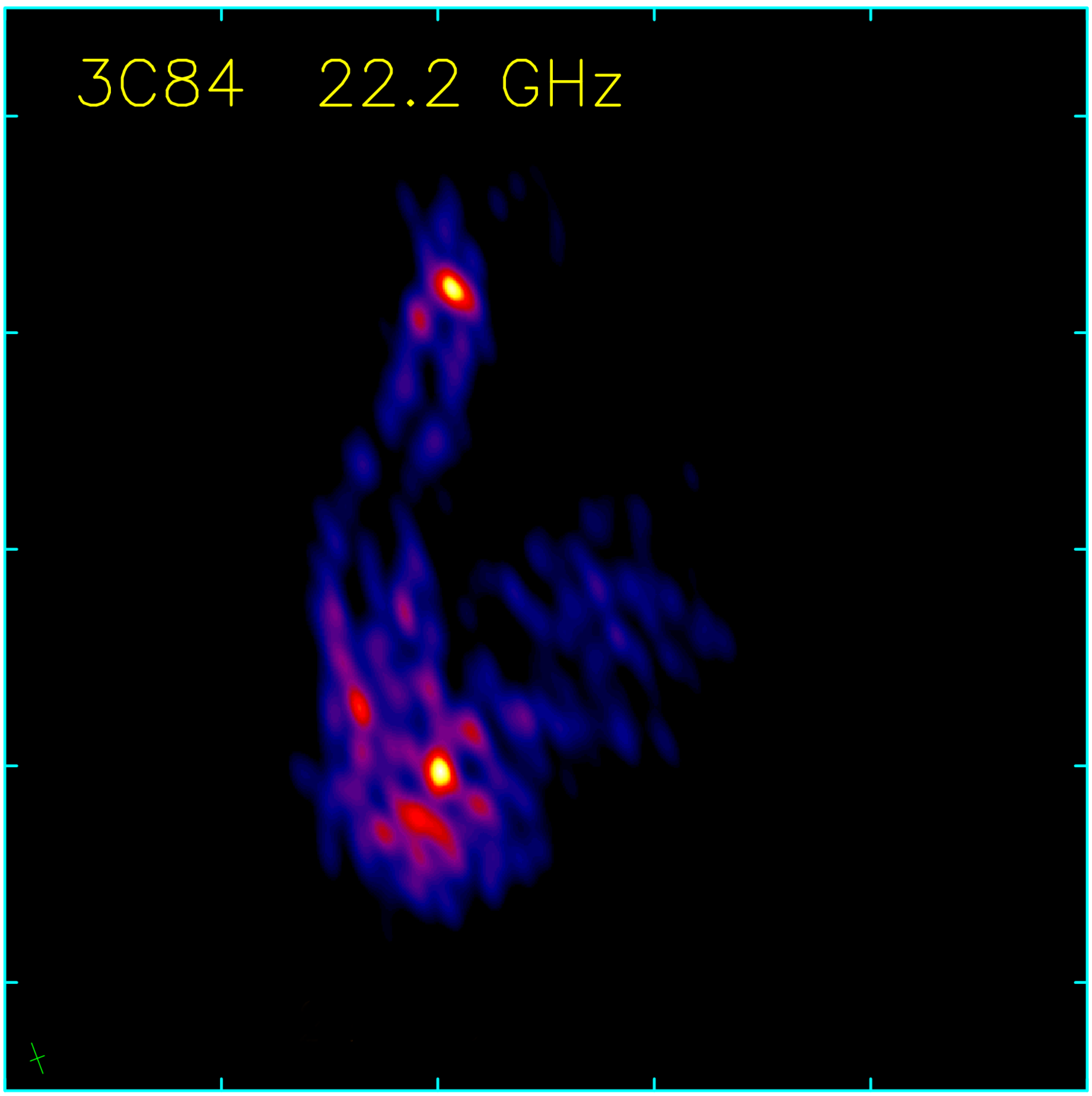

Figure 1: RadioAstron total intensity image of a nearby radio galaxy 3C 84 at 22 GHz. The restoring beam size is $150 \times 70\,\mu$as at an angle of 21° (shown in the lower left corner). The peak flux density is 1 Jy/beam. Tick marks have a 1 mas separation. The whole North-South extent of the visible jet structure is just ~ 1.2 pc in linear scale (projected).

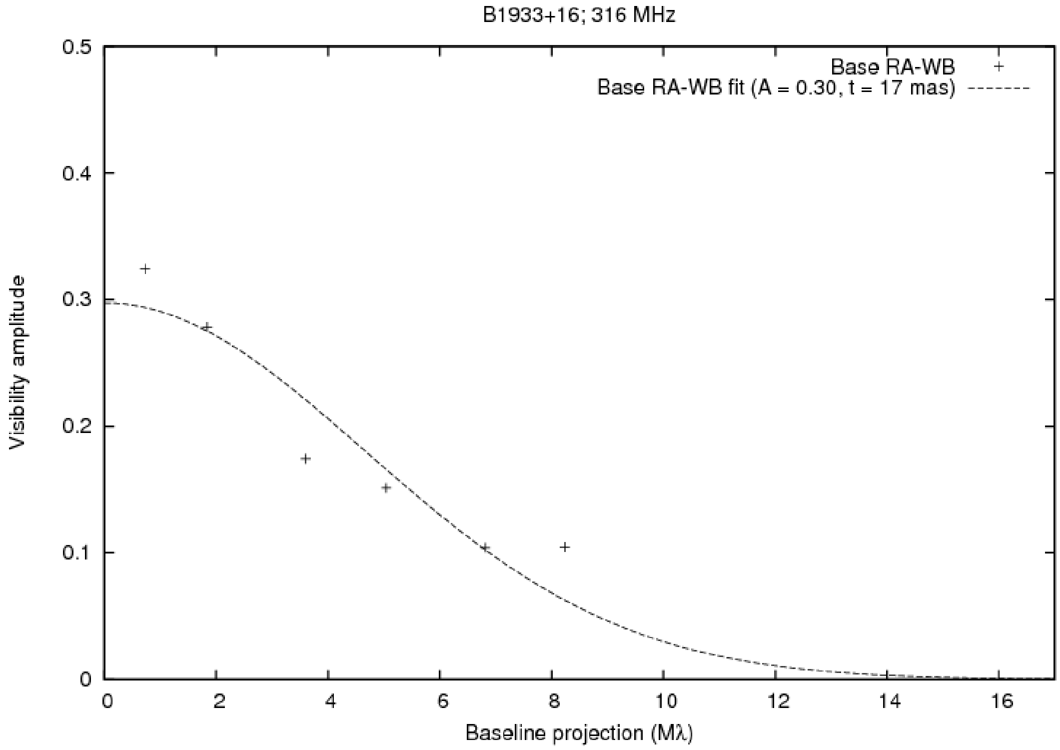

Figure 2: Amplitude of visibility versus projected baseline between Westerbork and space radio telescopes. Dashed line corresponds to a circular scattering disk with the diameter of 17 mas.

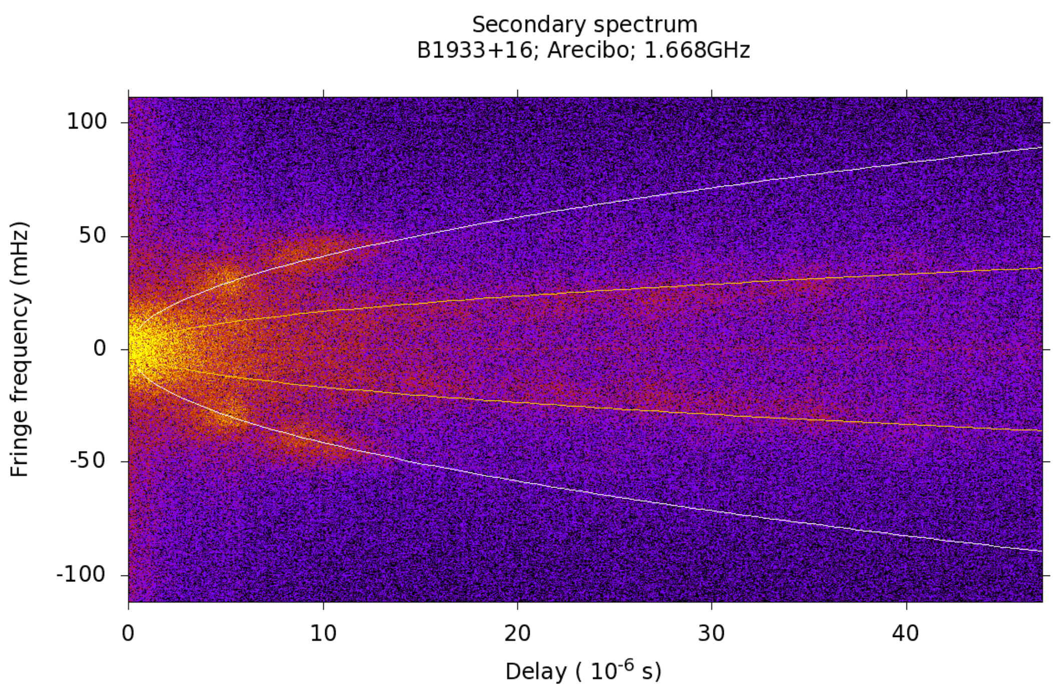

Figure 3: PSR B1933+16 secondary spectrum. The data were taken with Arecibo radio telescope at 18 cm wavelength. Bright features form as a result of interference between scattered rays at two separate screens, located at 0.27 and 0.75 of the total distance to the pulsar. Dashed lines represent our approximations for two parabolic arcs seen in the figure.