15 Years of Geodetic Experiments at the Simeiz VLBI Station

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Abstract

This report gives an overview about the geodetic VLBI activities during 15 years at the Simeiz station. We summarize briefly the status of 22-m radio telescope as an IVS Network Station.

1. General Information

Figure 1. Crimean Astrophysical Observatory.

The 22-m radiotelescope of the Crimean Astrophysical Observatory participated in the very first intercontinental very long baseline interferometric (VLBI) observations in September 1969 under astrophysical programs. The early narrow-band VLBI observations provided decimeter accuracy and were not useful for geodynamics applications. The telescope was upgraded in 1994: a Mark IIIA data acquisition terminal and a dual-frequency horn were loaned by NASA/GSFC, dual band S/X receivers were supplied by the Institute of Applied Astronomy in Saint-Petersburg, Russia, and a CH-70 hydrogen maser was supplied by the Institute of Space Research in Moscow. Interferometric fringes were obtained in the first test carried out on June 20, 1994. This upgrade enabled the station to join international observing campaigns under both astrophysical and geodynamics programs.

The foundation pit of the telescope is nine meters deep, and it has three meters of crushed stones and then six meters of concrete. The height of the elevation axis above the foundation is 14.998 meters. The telescope is located 80 meters from the edge of the Black Sea. The parameters of the 22-meter radio telescope are presented in Table 1.

Table 1. The antenna parameters of the Simeiz station.

Diameter D	22 m
Surface tolerance (root mean square)	0.25 mm
Wavelength limit	2 mm
Feed System	Cassegrain system or primary focus
Focal length F	9.525 m
Focal ratio F/D	0.43
Effective focal length for Cassegrain system	134.5 m
Mounting	Azimuth-Elevation
Pointing accuracy	10 arcsec
Maximum rotation rate	$1.5°$/sec
Maximum tracking rate	$150''$/sec
Working range in Azimuth (0 to South)	$-270° \pm 270°$
in Elevation	$0°$ - $85°$

The control system of the radio telescope provides the ability to point the antenna and to track the observed source in two modes: autonomous and automatic. All aspects of the radio telescope operation—antenna motion, radiometer readings, and data recording—are controlled from the special host computer in automatic mode. The 2 GHz and the 8 GHz receivers as well as the phase and the amplitude calibration units have been installed at the primary focus of the antenna.

2. Current Status and Activities

RT-22 was equipped with modern Mark 5A and Mark 5B+ VLBI recording systems and a new H-maser. That made it possible to continue astrophysical and fundamental geodetic VLBI observations.

The local geodetic ties between the VLBI, SLR, and GPS reference points of the station Simeiz-Katsively were analysed [1].

A number of relatively small regions of the Earth have been found where the annual periodicity of seismic activity is most prominent: the Balkans and Turkey, the isthmus between North America and South America, Alaska and the Aleutians, and some others. In both hemispheres, these regions are associated with subduction zones or intensely faulted segments of the continental crust [2].

Last year the Simeiz station regularly participated in various radio astronomy programs including VLBI and single-dish observations of quasars and planets.

Table 2. The current projects.

Very Long Baseline Interferometry	Astrophysics, geodesy, astrometry and radar projects with the international networks.
Monitoring of AGN	The regular monitoring at frequencies 22.2 and 36.8 GHz.
Molecular line observations at mm wavelength	Observations in molecular lines of maser sources, star forming regions and other objects have been intensively carried out since 1978 in the range from 1.6 GHz up to 115 GHz.

Catalog of sources for flight program "Radioastron".
Observations of a sample of sources from the preliminary "Radioastron" catalog were obtained at 22.2 and 36.8 GHz with the RT-22 radio telescope of the Crimean Astrophysical Observatory [3]. We determined the distribution of the source spectral indices between these frequencies. The distributions of the spectral indices of the RT-22 sample are more meaningful than in the WMAP catalog (between 23 and 33 GHz) due to the input parameters of the source sample of the "Radioastron" catalog. We have plotted the $log(10dN/N_0) - logS$ dependence down to flux levels of about 0.1 Jy using the survey data of near 22 GHz, where there is a reduction in the density of cosmological sources in relation to the stable Euclidean universe. The variability of individual sources in connection with flare activity was considered.

Evolution of flux density and parsec-scale structure of compact extragalactic radio sources by monitoring at 4.8 – 36.8 GHz and imaging of geodetic VLBI observations.
We present some results on the variability of radio sources which came from continuous monitoring observations made at 4.8 – 36.8 GHz at the Crimean Astrophysical Observatory (Ukraine) and the Michigan Radio Astronomy Observatory (USA), and from international geodetic VLBI observations carried out at 2 and 8 GHz. The combined analysis of integral flux density variations and milliarcsecond scale structures was performed for 32 sources. It was found that, for a number of sources, the flux density bursts at high frequencies are not accompanied by emerging new VLBI jet components, but for some objects the flux density changes occur quasi-simultaneously at different frequencies, and the bursts are accompanied by ejected new VLBI components [4].

Search for radio flashes, caused by collisions of meteoroids with the Moon.
An observing procedure for determining the nature of detected variations of lunar radio fluxes was developed [5]. The probability of detecting a KA SMART-1 impact radio flash was estimated. We estimated the upper limit of the intensity of the radio flashes produced by collisions of sporadic meteoroids with the Moon as 10^{-7} JyJ^{-1} at 3.6 cm.

Binary systems of supermassive black holes in active galactic nuclei.
On the basis of long-term monitoring of active galactic nuclei 3C454.3, 1633+382, and 3C120 observed at the Crimean Astrophysical Observatory from 1985–2008 at 22.2 and 36.8 GHz, we analyzed periodic components of flux variability. The long-period components of the sources' variability (12–14 years) have been determined and are interpreted as the precessional motion of the central body in a double system. The short-period components of the variability (1.5–3 years) have been compared using models for the orbital periods for motion in the central supermassive black holes. The brightest representative active galactic nuclei, observed as non-stationary sources in a broad range of wave lengths, are binary systems of supermassive black holes, residing close to

the coalescence stage of stellar evolution.

The following parameters were determined for the supposed binary black hole system: the masses of the central object and its companion, the radius of the companion's orbit, and the coalescence time. The ratio of the masses of the double systems of all sources is less than 10, which indicates a strong gravitational effect of the central black hole on its companion. The velocity of the central body is a thousand km/sec. This requires an additional calculation to account for the rate of accretion to the central body [6].

The orbital radius of the companion has a close limit, $(4-6)10^{16}$cm, that indicates that the masses of the binary systems have a strong dependency on the orbit sizes and on the energy loss due to gravitational radiation. Shock waves created by the moving companion propagate within the highly dense ($(10^{9}$-$10^{10})$ cm^{-3}) ambient medium surrounding the central body, and some penetrate the central body's accretion disk. In addition, the companion has an elliptical orbit that plunges it into the accretion disk at the disk's pericenter. The fragmentary disruption of the accretion disk due to the moving companion can be accompanied by a powerful release of energy, which is transferred to the accretion disk's outflowing jets by the propagating shock waves.

Subparsec structure of double supermassive black holes in active galactic nuclei. The analysis of long-term multifrequency monitoring of the radio flux of four active galactic nuclei (AGN) of BL Lac type: 3C 120, OJ 287, 1308+326, and BL Lac was carried out. The harmonic components of flux variability on the scale of one to ten years were determined. The observational data were obtained in the Radio Astronomy Laboratory SRI Crimean Astrophysical Observatory (Ukraine) and the Michigan Radio Astronomy Observatory (USA). Based on the observational data, the kinematic model of AGN using the values of the orbital and the precessional periods of binary systems of supermassive black holes (BSBH) were constructed. A narrow range of values (three to four thousand km/s) was obtained for the orbital velocities of the companions. In turn, the orbital radii of BSBH are also in a narrow range ($(10^{17}$-$10^{18})$ cm), which supports the observation that the bright examples of AGN are close enough to double systems. The parameters of the medium in which the companions of double systems move, the rate losses of the orbital moments, and the coalescence times were estimated [7].

3. Future Plans

Our plan for the coming year is to put the VLBI Data Acquisition System DBBC into operation.

References

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