ACTIVE GALACTIC NUCLEI: RESULTS AT THE CRIMEAN OBSERVATORY

Yu. S. Efimov, N. I. Merkulova, Yu. I. Neshpor, I. I. Pronik, V. I. Pronik, S. G. Sergeev, N. M. Shakhovskoy, A. A. Stepanian

Crimean Astrophysical Observatory, Ministry of Ukraine for Education and Science
Naukove, 98409 Crimea, Ukraine
e-mail: `vpronik@crao.crimea.ua`

Active Galactic Nuclei (AGNs) are studied at the Crimean Observatory in the spectral range from radio to gamma rays.
The research of AGNs in radio includes the observations of milliarcsecond structure of compact radio sources, extensive monitoring of them and survey of the northern sky at 3.5 cm.
Results obtained in optics concern: continuum variability to reveal the nature of AGNs central sources; connection between the flux variability of broad emission lines and continuum; the nature of the broad line region, its dimension and structure. Optical results are based on data of long time-scale spectral monitoring of AGNs and permit to investigate the evolution of the broad emission line profiles and other spectral characteristics. Data on $UBVRI$ flux variability of the nuclei of Seyfert galaxies obtained through 7 years permit to suspect that different sources caused variability occurred on intranight and extranight time scales.
Photopolarimetric observations of dozen of BL Lac type objects, which have been carried out since the 70s, have revealed the large variations of the polarization degree up to 40% and the position angle of polarization in long (months) and short (days) time scales. These variations confirm the shock wave model of blazar's jets and indicate the long-lived spiral structure of the magnetic field in the inner part of jet. The short-terms variations of the brightness and polarization parameters can be explained by the irregular structure of flux of relativistic electrons penetrating along the jet.
Differences in stellar content of circumnucleus of AGNs and normal galaxies and flux variability of several AGNs were obtained using 1600–3500 Å spectral observations with the scanning spectrometer of Space Station "Astron".
The observations of very high energy gamma radiation from AGNs were carried out at the Crimean Astrophysical Observatory with the aid of ground-based detector. The gamma-ray flux was detected from blazars Mkn 501 in observations in 1997–98 and 3C 66A in observations 1996–1997. The observations of BL Lac carried out in 1998 also show the γ-rays radiation from this object.

INTRODUCTION

The research of AGNs at the Crimean Astrophysical Observatory is carried out in radio, optics, near ultraviolet and γ-rays regions. The working telescopes and topics are following:

Radio – 22-m radio telescope.

– The milliarcsecond structure of compact extragalactic radio sources; extensive monitoring of compact extragalactic radio sources at 3 mm – 2.5 cm; survey of the northern sky at 3.5 cm.

Optics – 1.25-m and 2.6-m telescopes.

– Extensive spectral monitoring of AGNs with CCD spectrograph; brightness monitoring of AGNs; polarimetry of blazars.

Near ultraviolet – Scanning ultraviolet spectrometer of the telescope "Spica" on the Space Station "Astron".

– Spectral energy distribution of AGNs in the region 1600–3500 Å; stellar content of central regions of AGNs; variability of AGNs.

High energy – Telescope with 48 mirrors, each of 1.2-m, for observation of Cherenkov radiation.

– Search high energy extragalactic γ–rays sources; time variations of γ–rays fluxes.

RADIO OBSERVATION

Radio observations are performed since 1967 by I. G. Moiseev, V. A. Efanov, N. S. Nesterov, S. Volvach, *et al.*

Crimean 22-m telescope is a part of International Very Large Base Interferometer (VLBI) which investigate the milliarcsecond structure of extragalactic compact radio sources [1]. Bright radio source 3C 84 (Seyfert galaxy NGC 1275) was the first object investigated in detail. There were revealed two compact components near the bright central source. The evolution of the structure of the radio nucleus was observed during more than 10 years.

3.8 cm – 1.1 mm variability of several dozens of AGNs was monitoring during 20–30 years at the Crimean Observatory together with the Metsahovi Radio Station (Finland). Since 1978 over 4000 observations of some of 40 sources have been obtained with the 22-m telescope of the Crimean Observatory (1.35 cm – 8 mm) and with the Metsahovi 13.7-m telescope (2.5 cm – 3.3 mm) [2]. Data for several dozens sources of extensive monitoring were combined with the other observations to derive separate quiescent and flare component spectra which are crucial to gain an understanding of structure and evolution of compact radio sources. The simple shape and the overall evolution of the flares agree in far greater detail with the shock–in–jet model by Marscher and Gear than it was possible before [3].

The longest series of observations was obtained for the source 3C 84 (NGC 1275). The flux density variation of this source at 3.75 cm – 1.1 mm obtained at the Crimean Observatory and in Finland were compared with the optical V band flux observed by Lyuty [4]. The radio flux curves are exhibited from 1960 till 1993. Two types of variations have been revealed:

1. Outbursts at radio frequencies which occur 5–6 years after the corresponding optical events. These were identified with shocks forming in the radio jet.

2. Variation which is caused by a slowly changing component having a time delay of ∼8 years between radio and optical domains.

Authors proposed that this variation results from a period of enhanced accretion rate in the nucleus, beginning in the 1950s and leading to the growth and subsequent decay of the radio emitting jet.

Survey of the northern sky was obtained at 3.5 cm. The 30% of the Survey sources are newly revealed.

OPTICS

Multicolour photometry of active regions in normal and peculiar galaxies. Observational link between galaxy activity and AGNs

Foundation of section "active galactic nuclei" belongs to the 50s, when V. Ambartsumian introduced for the first time the term "activity of galactic nuclei" to explain numerous peculiar phenomena in galaxies. First main task of astrophysics was an explanation of very strong radio emission of certain radio galaxies. Baade and Minkovski discussed the hypothesis of a realization of the kinetic energy of "colliding galaxies". Instead of this hypothesis Ambartsumian considered activity in nuclei (see review "Observations of active galactic nuclei at the Crimean Astrophysical Observatory" by V. Pronik [5]).

The study of galaxy activity at the Crimean Observatory begins since the fifties when G. Shajn revealed 82 giant H II regions and about 200 high luminosity regions of recent star formations in the spiral branches of the galaxy M33 using H_α filter [6]. G. Shajn first concluded that interstellar matter is dominant by masses inside the complexes of gaseous nebulae and young stars in spiral branches of galaxies. It was an essential leap in the understanding of processes of star formations. This investigation has been prolonged in the 60s with the 2.6-m Shajn telescope under leadership of A. Severny, V. Nikonov and K. Chuvaev. Hundreds regions of recent star formation and giant H II complexes were revealed in several dozens of galaxies, using 5–9 filters in spectral region 3700–7100 Å and image tube in the prime focus of the 2.6-m telescope [7]. Several thousands images obtained for more than 200 extragalactic objects are contained in the archive of the Crimean Observatory.

Using negatives of the Crimean ultraviolet images obtained at the prime focus of 2.6-m telescope V. Pronik and A. Scherbakov revealed optical variability of a jet in the nucleus of peculiar galaxy Virgo A [8].

Multicolour photometry was used by K. Chuvaev and I. Pronik for investigations of starforming activity of normal and barred spiral galaxies [9], by Pronik and Metik to study the circumnuclear regions of Markarian and Seyfert galaxies and its interactions with the starlike objects [10]. It was shown that current star formations in bar galaxies are higher than in normal ones and there is an interaction of Seyfert nuclei with starlike objects which can cause their powering. BVR photometry of starlike objects interacting with the nuclei of Seyfert galaxies was fulfilled by Prokof'eva *et al.* [11]. They showed that starlike objects are complex by nature including stars both of early and late populations. This fact has confirmed an important role of starlike objects in evolution of Seyfert nuclei. Reviews on centers of starformations in the nuclei of galaxies and various levels of galaxy activity were made by V. Pronik and I. Pronik [12, 13].

Spectral observations

The spectral study of galactic nuclear activity at the Crimean Observatory began in 1963 immediately after identifying an unusually large redshift in the spectrum of quasar 3C 273 by M. Shmidt. The large cosmological distance (z = 0.35) and high apparent magnitude of 3C 273 indicated an extremely high luminosity of this object which required an explanation. At the same time, the similarity of its spectrum to the spectra of the nuclei of Seyfert galaxies evidenced a relationship or even an identical nature of these objects. There was a difference only in luminosity which is several orders greater for quasars. But visible brightness of nuclei of the nearest Seyfert galaxies and equivalent widths of emission lines are higher than for quasars. Therefore, it becomes obvious that the key to understanding the nature of quasars should be sought in nuclei of Seyfert galaxies. E. Dibaj and V. Pronik began studies of the physical conditions in nuclei of Seyfert galaxies [14, 15].

The works of Dibaj and V. Pronik were pioneer at that time. The conclusion was made about the presence of two subsystems (two zones) of gas in nuclei of Seyfert galaxies: one emitting narrow lines is more extended region (more than 100 ps) and has a low electron density (10^3–10^4 cm^{-3}) and low velocity dispersion (300–500 km/s); the other emitting broad lines is a small (≤ 10 ps) inner region with high electron density (10^8–10^9 cm^{-3}) and high velocity dispersion of several thousands km/s. They were subsequently called: the narrow–line region (NLR) and broad–line region (BLR). It was suspected that both gas systems are result of successive explosions in the central source of the nucleus responsible for continuum emission.

Obtained spectra of dozens of Markarian galaxies permit to reveal 15 new Seyfert galaxies [16].

V. Pronik (1977) [17] has paid attention that the observed estimates of electron density (n_e) from [OIII] line intensities for almost all galaxies give the same value (2–3)$\times 10^6$ cm^{-3} (critical density for [OIII] lines) despite the large luminosity range about 2–3 orders. It becomes clear that the gas density decreased with radius as r^{-2} and observed large difference of density between BLR and NLR is a result of lack of methods for gas density determination when $n_e \geq 10^7$ cm^{-3}.

Occasional observations of Seyfert galaxies were performing up to the seventies, when principal property of Seyfert nuclei, variability of emission lines and continuum fluxes, became obvious. Since 1971 V. Pronik and K. Chuvaev [18] have begun photographic spectral monitoring of AGNs variability. A line-continuum correlation was established. The method for calibration of spectra by using of [OIII] lines flux was proposed. The Seyfert galaxy Mrk 6 was the first object for which an analysis of systematic spectroscopic observations was made. Variable component in the blue wing of the H_β line of this nucleus was investigated. The changes of Seyfert type was first revealed.

The archive of spectral data created by K. Chuvaev contains photographic spectra for more than 200 Seyfert and Markarian galaxies. More than 20 of them were observed during about 20 years and more than 30 ones during 10 years. The results of long term observations of the H_β and [OIII] line profiles and their intensities in galaxies NGC 7469, NGC 5548, NGC 4151, NGC 1275 have been published in series of papers by K. Chuvaev [19]–[21].

The characteristics of time variability of the hydrogen lines in Seyfert galaxies NGC 1275, NGC 3227 and NGC 7469 have been observed by I. Pronik during 10 years [22]–[24]. Variation of the Balmer $H_\alpha/H_\beta/H_\gamma$ decrement with typical time of 20 days was revealed for the first time.

Seyfert type changes was observed for the nuclei of Mrk 6 [18], NGC 3227 [24], NGC 4151 [25] and NGC 7469 [26] by K. Chuvaev, V. Pronik and I. Pronik with the coauthors.

Special attention was paid to the nucleus of NGC 1275 which contains strong variable radio source. The most wide and complex [OIII] 5007 Å line profile and an extremely strong variations of the nucleus brightness in continuum were observed in 1965–1980. There are numerous gas streams in the vicinity of the nucleus which have a strictly radial motion. The complex structure of the NGC 1275 nucleus was revealed by V. Pronik [27] who investigated burst events by velocities of circumnuclear gas. The attempts to detect the variability of emission line fluxes of H_β and λ 4959, 5007 Å [OIII] have been made by I. Pronik, Merkulova, Metik [28, 29]. There was no common opinion concerning the reality of spectral variations in NGC 1275 (Chuvaev, [30]). The search of such a variability is no void of sense. Suspicion on forbidden line variability was proposed for Seyfert nucleus of the NGC 7469 galaxy too [31]. The theoretical works concerning the possibility of [OIII] lines variability in AGNs were made by V. Pronik and I. Pronik [32, 33].

A fleeting change of the flux in the lines and continuum of the NGC 7469 nucleus over two months was recorded, which led to the temporary disappearance of the broad wings in the H_β and H_α lines (Doroshenko, Sergeev, Chuvaev [34]).

Two reviews on variability of emission lines were published by Lyutyi and V. Pronik [35], and I. Pronik [36].

Since 1988 spectroscopic observations of AGNs have been performing with CCD spectrograph. High accuracy of observations and instantaneous recording of the spectra with their subsequent processing on a PC made possible the permanent monitoring of the behavior of the AGNs spectra on short and long time scales.

The most intensive spectral monitoring over more than 10 years was carried out for NGC 4151, NGC 5548, NGC 7469, Mrk 6, Arp 102-B, 3C 390.3 and other active galaxies by Chuvaev, Malkov, Pronik, Sergeev and Sergeeva. The database containing more than 2000 CCD spectra of AGNs was created. The Crimean Observatory participates in the international programs of spectroscopic and photometric monitoring AGNs (AGN WATCH, see [37]–[39]). The important results concerned the line–continuum correlation and decomposition of broad line profiles for NGC 4151, NGC 5548 and Mrk 6 nuclei were obtained by Malkov, V. Pronik, Sergeev and Sergeeva [40]–[43]. It was shown that the line-continuum diagram for NGC 4151 contradicts to the simplest AGN paradigm where a single central source of continuum caused a steady relation between the visible and ionizing continuum. An explanation of the shape evolution for broad emission line profiles in the NGC 4151 has been given in terms of BLR model with two–component profile [43].

A link between the H_β equivalent width, profile width, the BLR size and optical continuum luminosity have been found from a small sample of well studied AGNs [44]. The radius–luminosity relation of $r \sim L^{0.7}$ and mass–luminosity relation $L \sim M^{1.9}$ have been claimed for AGNs. Different temporal changes of the line–continuum lag in blue and red H_β wings have been found in the spectra of Seyfert galaxy Mrk 6 [45].

The rotational redistribution of matter emitted the broad double-peaked line profiles was revealed in Arp 102B [42]. The model of BLR in Arp 102B represents a great variety of gas clouds rotating predominantly in the same plane. Model explains double-peaked profiles, drift motion of emission details along profile from red to blue wings and observed regular variations of the red-peak-to-blue-peak flux ratio.

Photoelectric brightness monitoring

Since 1982 photoelectric monitoring of flux variation of AGNs with time scale resolution of about 4 min has been performing first at the Crimean Observatory with the 1.25-m telescope by N. Merkulova, L. Metik and I. Pronik. Since 1989 simultaneous *UBVRI* observations of selected Seyfert galaxies have been carried out.

The character of the flux variability was found to be different for different sources. A light curve of the NGC 1275 continuum near λ 5200 Å in 1982–1987 did not show systematical trends of the brightness during 5 years, but several drops of brightness characterized the flux variations. Intranight variations up to 20% were revealed [46]. Extraordinary brightening of the NGC 4151 nucleus during 7.3 years (1989 – 1996) was observed. The amplitudes of the brightening are $2.^m0$, $1.^m5$, $0.^m9$, $0.^m8$ and $0.^m7$ in *UBVRI* bands, respectively [47]. Flares with duration of 10–150 days are revealed overlapped on the smooth light curves. An optical energy distribution for flux excesses on smooth light curve and during the flares can be fitted by the power law form: $F_\nu \sim \nu^\alpha$. Obtained data suggested that the nucleus brightness increasing is caused by the emitting synchrotron radiation clouds ejected from the nucleus during its active period.

Types of processes causing the continuum variability in the optical of the nuclei of Seyfert galaxies are determined using Structure Function (SF) analysis [46, 48]. Complex form of SF for variable flux of the NGC 1275 nucleus, obtained for continuum near λ 5200 Å in 1982–1987 and in the *UBVRI* bands in 1989–1994, allows us to suppose that there are two types of intranight and one type of yearly variations in this nucleus. Obtained data show that there are two sources causing intranight variability and one source of extranight variability in the nucleus of NGC 1275.

SF characteristics of the variable *UBVRI* fluxes of NGC 4151 nucleus exhibit variations with time. The types of processes caused this variability varied on intranight and extranight time scales in different directions during the increasing of the brightness of its nucleus.

Multisources observational picture of variable optical continuum resembles that of complex structure of central radio sources observed with the VLBI. For instance such structure is well known for radio source 3C 84 (NGC 1275).

The photoelectric monitoring of continuum flux variability of AGNs is performing in the frame of international program AGN WATCH too.

Polarimetrical investigations

The high quality photopolarimetric observations of dozen of BL Lac type objects have been provided by Shakhovskoj and Efimov since the 70s with the 2.6-m Shajn and 1.25-m telescopes to study the structure and geometry of the regions of jets where powerful synchrotron radiation arises [49]–[53]. This job is performing in *UBVRI* since 1994 in the frame of the great international program OJ-94 [54]–[59].

The large variations of the polarization degree up to 40% and the position angle of polarization on long (months) and short (days) time scales are revealed. These variations confirm the shock wave model of blazar's jets and indicate the long-lived spiral structure of the magnetic field in the inner part of jet. The short-terms variations of the brightness and polarization parameters can be explained by the irregular structure of the flux of relativistic electrons penetrating along the jet.

NEAR ULTRAVIOLET INVESTIGATION

Since 1983 Space Station "Astron" constructed at the Crimean Astrophysical Observatory under leadership of A. Severny and A. Boyarchuk had operated about ten years [60]. It was found that 1600–3500 Å spectral energy distribution of circumnuclear regions of galaxies containing active nuclei shows excess of regions of recent star formation compare to the central regions of normal galaxies.

UBV variability of Seyfert nucleus of galaxy Mrk 573 obtained by Neizvestny, was confirmed by us in near ultraviolet region being about $0.^{m}75$ during about 2.5 years. Mini Seyfert nuclei NGC 598 (M33) and NGC 5236 (M83) were knowns as variable in the UBV system. Observations with the Space Station "Astron" allow to conclude that amplitude of their near ultraviolet variability is about 1^{m}. The first exhibits flare but the second shows drops of brightness compare to the normal state.

VERY HIGH ENERGY INVESTIGATION

The high energy (HE) γ–rays ($E \geq 100\,MeV$) are observed with satellites because γ–rays of these energy are absorbed in Earth atmosphere. One can observe very high energy (VHE) γ–rays ($E \geq 100\,GeV$) using ground-based detectors. The Cherenkov light emitting by high energy electrons generated due to interaction of gamma ray with Earth atmosphere is used. The narrow angle of Cherenkov radiation along the tracks of primary quanta permit us to find the source of γ–rays. There are about 10 detectors of such a type all over the world. Three of them are located at the Southern hemisphere of the Earth and the others are in the Northern one. One of them is at the Crimean Astrophysical Observatory (CrAO). The CrAO Cherenkov detector (gamma-telescope GT–48) consists of two mounting 20 m apart and has mirrors with total area 54 m^2. The energy threshold is equal to 1 TeV. The details may be found in [61]. During 1996–98, the three blazars were observed: Mk 501, 3C 66A and BL Lac. The results of observations are presented in Table 1. Here L is the power of γ–rays radiation: $L = E{\cdot}F(E)$, where E is the photon energy and $F(E)$ is the spectral density of radiation. All values are estimated on the assumption of isotropy of radiation. According to the current models the total radiation is (with high confidence) connected with high energy electrons, partly with synchrotron radiation and partly with inverse Compton radiation of electrons on lower energy electromagnetic radiation.

Table 1: Energy of radiation of several lacertides

Object	Distance (Mpc)	Optics Log$L$ [ref.] (erg/s)	HE Log$L$ [ref.] (erg/s)	VHE Log$L$ [ref.] (erg/s)
BL Lac	280	44.8 [62]	44.9[64]	44.5 [67]
MK–501	160	44.4 [63]	–	44.5 [65]
3C 66A	1800	46.4 [63]	46.2[64]	46.3 [66]

As it is seen from the table, the value of total power in optical range, in the high energy γ-rays and in the very high energy range are nearly the same for these three objects.

Acknowledgements. We acknowledge L. P. Metik for the help with the manuscript preparing.
The research described in this publication was made possible in part by Award N UP1–2116 of the U. S. Civilian Research & Development Foundation for the Independent States of the Former Soviet Union (CRDF).

REFERENCES

[1] *Kellermann K. I., Jauncey D. L., Cohen M. H., et al.* // Astrophys. J.–1971.–**169**, N 1.–P. 1–24.

[2] *Valtaoja E., Haarala S., Lehto H., et al.* // Astron. and Astrophys.–1988.–**203**, N 1.–P. 1–20.

[3] *Nesterov N. S., Kovalev Yu. Yu., Babak S. V., Larionov G. M.* // Astron. J.–1994.–**71**, N 6.–P. 850–857. (in Russian).

[4] *Nesterov N. S., Lyuty V. M., Valtaoja E.* // Astron. and Astrophys.–1995.–**296**, N 3.–P. 628–632.

[5] *Pronik V.* // Bull. Crim. Astrophys. Obs.–1998.–**94**,–P. 1–6.

[6] *Shajn G. A.* // Izv. Krimsk. Astrofiz. Obs.–1954.–**11**.–P. 3–7. (in Russian).

[7] *Butslov M., Kopylov I. M., Nikonov V. B., et al.* // Astron. J.–1962.–**39**, N 2.–P. 315–322. (in Russian).

[8] *Pronik V., Scherbakov A.* // Astrofizika.–1972.–**8**, N 3.–P. 337–342. (in Russian).

[9] *Pronik I., Chuvaev K.* // External galaxies and Quasi–stellar objects: Proc. IAU Symp. **44** / Ed. D. Evans.– Dordrecht: D. Reidel, 1972.–P. 62–65.

[10] *Pronik I., Metik L.* // Extranuclear Activity in Galaxies: Proc. of Workshop ESO **32** / Eds E. Meurs, R. Fosbury.–1989.–P. 25–29.

[11] *Prokof'eva V., Pronik I., Sharipova L.* // Astron. and Astrophys. Transactions.–1995.–**8**, N 4.–P. 285–290.

[12] *Pronik V.* // Highlights of Astronomy.–1980.–**5**.–P. 223–225.

[13] *Pronik I., Pronik V.* // Transactions of GAISH.–1988.–**60**.–P. 295–314.

[14] *Dibaj E., Pronik V.* // Astrofizika.–1965.–**1**, N 1.–P. 78–90. (in Russian).

[15] *Dibaj E., Pronik V.* // Astron. J.–1967.–**44**, N 5.–P. 952–964. (in Russian).

[16] *Kopilov I., Lipovetski V., Pronik V., Chuvaev K.* // Astrofizika.–1976.–**12**, N 2.–P. 189–194. (in Russian).

[17] *Pronik V.* // Astrofizika.–1977.–**13**, N 1.–P. 51–61. (in Russian).

[18] *Pronik V., Chuvaev K.* // Astrofizika.–1972.–**8**, N 2.–P. 187–196. (in Russian).

[19] *Chuvaev K.* // Pisma v Astron. J.–1980.–**6**, N 6.–P. 323–329. (in Russian).

[20] *Chuvaev K.* // Pisma v Astron. J.–1985.–**11**, N 11.–P. 803–810. (in Russian).

[21] *Chuvaev K.* // Izv. Krimsk. Astrofiz. Obs.–1990.–**81**.–P. 138–148. (in Russian).

[22] *Pronik I.* // Astron. J.–1975.–**52**, N 3.–P. 481–490. (in Russian).

[23] *Pronik I.* // Izv. Krimsk. Astrofiz. Obs.–1980.–**61**.–P. 131–144. (in Russian).

[24] *Pronik I.* // Izv. Krimsk. Astrofiz. Obs.–1983.–**68**.–P. 81–93. (in Russian).

[25] *Lyutyj V., Oknyanskiy V., Chuvaev K.* // Pisma v. Astron. J.–1984.–**10**, N 11.–P. 803–807. (in Russian).

[26] *Chuvaev K., Lyutyj V., Doroshenko V.* // Pisma v Astron. J.–1990.–**16**, N 10.–P. 867–876. (in Russian).

[27] *Pronik V.* // Astrofizika.–1979.–**15**, N 1.–P. 51–57. (in Russian).

[28] *Merkulova N., Pronik I.* // Izv. Krimsk. Astrophys. Obs.–1985.–**85**.–P. 160–174. (in Russian).

[29] *Pronik I., Merkulova N., Metik L.* // Astrophys. and Space Sci.–1990.–**171**, N 1/2.–P. 91–95.

[30] *Chuvaev K.* // Pisma v Astron. J.–1985.–**11**, N 11.– P. 803–810. (in Russian).

[31] *Pronik I., Metik L., Merkulova N.* // Astron. and Astrophys.–1997.–**318**, N 3.–P. 721–728.

[32] *Pronik V., Pronik I.* // Astron. J.–1988.–**65**, N 3.–P. 478–487. (in Russian).

[33] *Pronik V., Pronik I.* // Astron. and Astrophys. Transactions.–1992.–**3**, N 1.–P. 57–62.

[34] *Doroshenko V., Sergeev S., Chuvaev K.* // Astron. J.–1994.–**71**, N 2.–P. 200–215. (in Russian).

[35] *Lyuty V., Pronik V.* // Variable Stars and Stellar Evolution: Proc. IAU Symp., **67** / Eds V. Sherwood, L. Plaut.–Dordrecht: D. Reidel, 1975.–P. 591–604.

[36] *Pronik I.* // Observational Evidence of Activity in Galaxies: Proc. IAU Symp., **121** / Eds E. Khachikian, *et al.*–Dordrecht: D. Reidel, 1986.–P. 169–184.

[37] *Peterson B., Burth A., Berlind P., et al.*// Astrophys. J.–1999.–**510**, N 2.–P. 659–668.

[38] *Dietrich M., Peterson B., Albrecht P., et al.* // Astrophys. J. Suppl. Ser.–1998.–**115**, N 1.–P. 185–202.

[39] *Collier S., Horne K., Kaspi S., et al.* // Astrophys. J.–1998.–**500**, N 1.–P. 162–172.

[40] *Sergeev S., Malkov Yu., Chuvaev K., et al.* // Reverberation Mapping of the Broad Line Region in Active Galactic Nuclei: ASP Conf. Ser. / Eds P. Gondhalekar, K. Horne, B. Peterson.–1994.–**69**.–P. 199–209.

[41] *Malkov Yu., Pronik V., Sergeev S.* // Astron. and Astrophys.–1997.–**324**, N 3.–P. 904–914.

[42] *Sergeev S., Pronik V., Sergeeva E.* // Astron. and Astrophys.–2000.–**356**, N 1.–P. 41–49.

[43] *Sergeev S., Pronik V., Sergeeva E.* // Astrophys. J.–2001.–accepted.

[44] *Sergeev S., Pronik V., Malkov Yu., et al.* // Astron. J.–1999.–**118**, N 6.–P. 2659–2667.

[45] *Sergeev S., Pronik V., Sergeeva E., et al.* // Astrophys. J. Suppl. Ser.–1999.–**121**, N 1.–P. 159–169.

[46] *Pronik I., Merkulova N., Metik L.* // Astron. and Astrophys.–1999.–**351**, N 1.–P. 21–30.

[47] *Merkulova N., Metik L., Pronik I.* // Astron. J.–1999.–**117**, N 5.–P. 2177–2184.

[48] *Merkulova N., Metik L., Pronik I.* // Active Galactik Nuclei and Related Phenomena: Proc. IAU Symp., **194** / Eds Ye. Terzian, D. Weedman, E. Khachikian.–Publisher Astron. Soc. Pacif., 1999.–P. 436-438.

[49] *Efimov Yu. S., Shakhovskoy N. M.* // Izv. Krimsk. Astrofiz. Obs.–1972.–**46**.–P. 3–13. (in Russian).

[50] *Shakhovskoy N. M., Efimov Yu. S.* // Izv. Krimsk. Astrofiz. Obs.–1977.–**56**.–P. 39–51. (in Russian).

[51] *Efanov V. A., Moiseev I. G., Nesterov N. S., et al.* // Izv. Krimsk. Astrofiz. Obs.–1972.–**64**.–P. 91–98. (in Russian).

[52] *Doroshenko V. T., Lyuty V. M., Terebizh V. Yu.* // Astron. and Astrophys.–1986.–**163**, N 1/2.– P. 321–325.

[53] *Doroshenko V. T., Efimov Yu. S., Terebizh V. Yu* // Izv. Krimsk. Astrofiz. Obs.–1987.–**73**.–P. 143–153. (in Russian).

[54] *Valtaoja L., Valtaoja E., Shakhovskoy N.M., et al.* // Astron. J.–1991a.–**101**, N 1.–P. 78–87.

[55] *Valtaoja L., Valtaoja E., Shakhovskoy N. M., et al.* // Astron. J.–1991b.–**102**, N 6.–P. 1946–1955.

[56] *Takalo L. O., Sillanpaa A., Pursimo T., et al.* // Astron. and Astrophys. Suppl. Ser.–1996.–**120**, N 2.–P. 313-321.

[57] *Tosti G., Fiorucci M., Luciani M., et al.* // Astron. and Astrophys.–1998.–**339**, N 1.–P. 41–51.

[58] *Massaro E., Maesano M., Montagni F., et al.* // Astron. and Astrophys.–1999.–**342**, N 3.–P. L49–L52.

[59] *Pursimo T., Takalo L. O., Sillanpaa A., et al.* // Astron. and Astrophys. Suppl. Ser.–2000.–**146**.–P. 141–155.

[60] Astrophysical investigations on the Space Station "Astron" / Ed. A. A. Boyarchuk, 1994.

[61] *Vladimirsky B. M., Zyskin Yu. L., Kornienko A. P., et al.* // Izv. Krimsk. Astrofiz. Obs.– 1993.–**91**.–P. 74–105. (in Russian).

[62] *Nikolashvili M. G., Kurtanidze O. M., Richter G. M.* // Proc. of the OJ-94 annual meeting 1999, Torino, Italy, May 19-21, 1999 / Eds C. M. Raiteri, M. Villata, L. O. Takalo.–P. 33–35.

[63] *Perlman E. S., Stocke J. T., Schachter J. F., et al.* // Astrophys. J. Suppl. Ser.–1996.–**104**, N 2.–P. 251–285.

[64] *Hartman R. C., Bertsch D. L., Bloom S. D., et al.* // Astrophys. J. Suppl. Ser.–1999.–**123**, N 1.–P. 79–202.

[65] *Andreeva N. A., Zyskin Yu. L., Kalekin O. R., et al.* // Pisma v Astron. J.–2000.–**26**, N 4.–P. 243–248. (in Russian).

[66] *Neshpor Yu. I., Stepanian A. A., Kalekin O. R., et al.* // Astron. J.–2000.–**77**, N 9.–P. 723–729. (in Russian).

[67] *Neshpor Yu. I., Chalenko N. N., Stepanian A. A., et al.* // Astron. J.–2001.–**78**, N 4. (in Russian).