Part 1

Optical Surveys for AGN

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Jivan Stepanian describing the 1m Schmidt Telescope

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Markarian's First Survey (FBS) – Some Most Interesting Objects

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Abstract.
In this review I try to show the important role of the Byurakan Observatory in the discovery and detailed investigations of ultlaviolet excess (UV) galaxies, which are now the center of attention of many observatories. Most new Seyfert (Sy) galaxies by the end of the 1960s, when no more than ten of this type of galaxy were known, were discovered among UV galaxies. In addition, many unusual and interesting galaxies were also discovered among UV galaxies: double and multiple nucleus galaxies, double nucleus Sy galaxies, galaxies with jets, galaxies consisting only of Superassociations (giant HII regions), Sargent-Searle objects, BL Lacs and QSOs possessing a different type of activity according to Ambartsumian. The material presented here overlaps considerably that of some other talks delivered by the author in IAU Symposia Nos. 121 and 194.

1. Brief History

Markarian was born on November 29, 1913. In 1938 he graduated from the Yerevan State University in mathematics. Until 1941 he was a post–graduate student of Prof. V. Ambartsumian. In 1944 he defended his thesis; he continued his scientific work in the Byurakan Observatory until his death on September 29, 1985. During 1976-1979 he was the President of IAU Commission 29 "Galaxies".

It is well known that the idea of Activity of Galaxies and their nuclei was suggested by Ambartsumian in the middle 1950's and reported at the Solvay Conference in 1958. This idea was based on the following astronomical observations and discoveries:

Radio-sources (1949), which were later (1954) identified mainly with double-nuclei galaxies (Radiogalaxies),

Seyfert galaxies (1943),

Haro blue galaxies (1956).

Ambartsumian identified different forms of activity, which are well-known among astronomers, but many of them, especially young ones, do not imagine that Ambartsumian was the first to describe these forms. At the same time in Byurakan Observatory Ambartsumian started with co-workers the quest for blue objects connected by filaments or jets with nearby elliptical galaxies. As a result, a number of blue low luminosity galaxies but brighter than dwarf galaxies were detected. In 1968 Allan Stockton obtained the spectra of some of these objects, which turned out to be emission-line galaxies just like Haro galaxies. I should like to note here Markarian's article (1963), published in the Contributions of

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the BAO and very rarely cited, where he described a number of bright galaxies having earlier type spectral characteristics, which do not correspond to their integrated colors or morphological types. So, it was natural to ask: is it possible to find blue galaxies with UV excess among fainter ones? For the solution of this problem Ambartsumian ordered for the 1-m Schmidt telescope three objective prisms of the same size and with refraction angles: 1.5, 3.0 and 4.0 degrees. Then he made Markarian an offer to search for blue galaxies. In 1965 Markarian began this job and in 1967 the first list of so-called UV-excess galaxies had already been published in the journal "Astrofizika".

Markarian used the 1.5-degree prism, which gives on the plate about 2500 Angstrom/mm near $H\beta$ and about 1800 Angstrom/mm near $H\gamma$. The first list contains 70 UV-excess objects. On the basis of a general view of the spectra, Markarian divided the objects into two main groups: "s" and "d". "s" objects have narrow and sharp spectra like those of stars. "d" objects have diffuse spectra with weak continuous spectra like compact associations of blue stars and gaseous nebulae. To describe the intensity of the continuum, he used the number 1 for the strongest ones and the number 3 for the weakest. Differently mixed symbols have also been used. If Markarian guessed the presence of emission lines, he noted it by the letter "e". The FBS is the most famous work done with the 1-m Schmidt telescope. More than 2000 photographic plates covering about 17,000 square degrees of sky were obtained. Each plate (approximately $4\overset{\circ}{.}1$ x $4\overset{\circ}{.}1$) contains low dispersion spectra of more than 15,000 objects. The FBS covers completely the northern part of the sky and also part of the southern ($\delta > -15^o$). The limiting visual magnitude of UV galaxies in the FBS is about $17\overset{m}{.}0 - 17\overset{m}{.}5$).

The selection of UV objects was carried out by the gap in the continuum objective prism spectrum near 5300 Å/ thanks to the observing technique. This gap divides the spectrum into two parts: blue and red. By means of the brightness of blue part of the spectrum Markarian could choose the UV excess galaxies. In all, during 15 years about 1500 UV-excess objects (including blue stars as it became clear later) were discovered. Because of the low dispersion, it was very difficult for Markarian to distinguish important details in the spectra, estimate the intensity of lines, their widths, the redshifts of objects and so on. Without these data it was very difficult to judge (understand) the physical nature of UV-excess galaxies. It was necessary to observe these interesting objects with a slit spectrograph and higher dispersion.

2. Spectroscopy

I was lucky to be the first to observe almost all the galaxies from the first list of UV galaxies with the largest optical telescopes in the USA (1967-68). I was double lucky when it became clear that numbers 1, 3, 6, 9, 10, 42 and 67 turned out to be Seyfert galaxies! I would like to emphasize once more that the detailed spectral investigation of Markarian objects indicated (Khachikian 1968, Weedman & Khachikian 1968, 1969) that *over 85% of them have emission lines with their intensity being directly dependent on the value of the UV excess. One can conclude that the presence of strong UV continuum is closely associated with the formation of the emission spectrum and the more intense the continuous*

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spectrum in the visible ultraviolet is, the more intense are the emission lines. It also became evident that the spectra of those objects differ, nevertheless, essentially from each other as to the excitation degree of the emission lines and their widths. On the basis of slit spectra, Markarian objects have been classified into five groups (Khachikian 1968):

–Narrow line spectra both in emission and absorption.
–Narrow, strong emission lines only.
–Strong and diffuse emission lines, [OIII] lines much stronger than the hydrogen lines (now - Sy2).
–Very broad H lines, narrow forbidden lines (Sy1),
–No strong emission lines (probably BL Lac type).

The most important result from the study of UV objects probably was *the discovery of Seyfert type galaxies among them. About 10% of UV objects turned out to be Seyfert galaxies.* ***In the first list of UV-excess galaxies alone (70 objects) there are 7 Sy type galaxies (Khachikian & Weedman, 1971a).***

Thanks to that the number of Seyfert galaxies increased very quickly, which gave Dr. Weedman and me the possibility to divide them into two types (Khachikian & Weedman 1971a):

1. Galaxies with broad hydrogen lines and narrow forbidden lines (Seyfert 1).
2. Galaxies with hydrogen and forbidden lines both broad (Seyfert 2).

Besides that, the intensity ratio of the [OIII] ($\lambda(5007, 4959)$) lines to $H\beta$ for Sy1 is < 1, and for Sy 2 > 10. So we suggested a very simple method to distinguish Sy1 from Sy2: it is necessary to observe only the [OIII] lines ($\lambda(5007, 4959)$) and $H\beta$. As they are situated practically in the same spectral region, you don't need to determine the spectral sensitivity of the system. The systematic observations of UV objects from the Markarian lists with the purpose of measuring their redshifts and clarifying the activity type were done by Arakelian et al. (1970). They confirmed most of the results obtained by Weedman and Khachikian.

3. Morphology

Among UV galaxies there are all Hubble types, but still, in many cases, unusual forms: Zwicky galaxies, Sargent-Searle objects, radio, X-ray and gamma-ray sources. But as it is now clear, most important is to study the strucure of the central parts of UV galaxies. The morphology of the central parts can be divided into the following groups:
Starlike galaxies, Galaxies with star-like nuclei (in general, spirals), Double nuclei galaxies, Multi nuclei galaxies, Galaxies with bulges, A few galaxies show jets starting from the nucleus. (see Figs. 1–6 in Khachikian, 1987)

4. Some Most Interesting Objects

Markarian 1,3,6: the first Sy2 galaxies discovered in the FBS. It is interesting to note that Mark 6 was the classical Sy2 galaxy before 1968. The appearance of additional new emisson components of the hydrogen lines in the spectra of

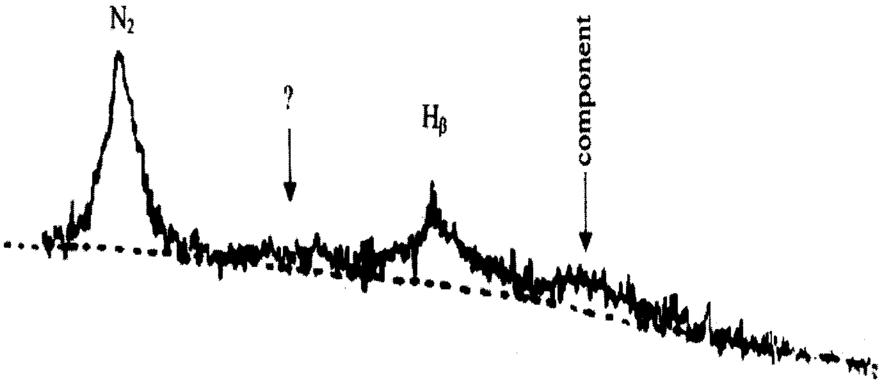

Figure 1. Spectrum of Mark 6, with blue-shifted velocity components apparent.

AGN was first discovered in Markarian 6 in 1969 (Khachikian & Weedman, 1970, 1971). During one year (between February, 1968, and January, 1969) in the spectrum of this galaxy new broad emission components of $H\alpha$, $H\beta$ and $H\gamma$ were detected. Their blue-shifted velocity is 3000 km/sec. What do they look like now? You can know from the posters of Asatrian et al. in this volume (and in Asatrian et al. 1999a,b). The high dispersion (28 Å/mm) spectrum of Mark 6 is shown for the first time in Fig. 1, where the blue-shifted component is well seen.

After the explosion in the nucleus of this galaxy, it was classifed as Sy 1.5, but actually it is probably just a short event in the history of a Sy2 galaxy. Therefore, there are very few of this type of Sy galaxy. So this "new" classification is nonsense. The nature of this type of explosion is still a puzzle. One of the possible new models is suggested in Ambartsumian et al. 1998.

Markarian 7 and 8. Probably a physical pair of very unusual galaxies that very much look like the same shape and consist of five bright superassociations (SA) (Khachikian 1972, Khachikian & Burenkov 1990) forming two almost rectilinear segments in a figure resembling the letter "V" (Mark 8) and an upside-down letter "V" (Mark 7). Actually they are nests of SA, namely, star formation regions, each included in the diffuse envelope. The absolute magnitude of the brightest SA in Mark 8 is M= -18 and in Mark 7 M= - 16.4. Similar morphological structures are in **Markarian 35** (Burenkov & Khachikian, 1986), Mark 297 (Burenkov 1987), Mark 325 (Burenkov, Khachikian, & Nazarova, 1990). All these galaxies show at the same time very interesting dynamical properties.

Markarian 9 and 10 are the first Sy1 galaxies discovered among Markarian galaxies (Khachikian 1968). The most important property of these galaxies is their very high brightness M_V= -21.6 and M_V = -21.3, which filled in the gap in brightnss between giant normal galaxies and QSOs.

Markarian 94. In the second list of UV galaxies, this object was classified as d1e. The spectral and photometric investigation of this object (Arp & Khachikian, 1974) showed that **Mark.94 is not the nucleus of a galaxy, but just the SA in III Zw 0834 +51**. The redshift of this galaxy (z = 0.0022) is about equal to that of Mark 94, z = 0.0025 (Sargent 1972) and z = 0.0030 (Arp & Khachikian, 1974). The prime-focus photograph taken with the 200-inch Hale telescope shows (Arp & Khachikian, 1974) that Mark 94 is located in an area of disordered spiral structure on the edge of the bar of the galaxy. The integrated absolute magnitude of the galaxy is M_{pg} = -16.6, and for Mark 94 M_B = -13.5. The diameter of Mark 94 is about 600 pc. The most interesting is, as became clear later on (Sahakian & Khachikian, 1975), that **Markarian 94 is the prototype of a new class of objects (more than 50 among the UV galaxies from the first six lists of the FBS)**. Representatives of this type of object are Mark 40, 49, 59, 71, 86, 108, 201, 256, 295, 325, 330, and so on. The brightness of these objects falls in the range from -11.4 to -18.7. The majority of them are connected with irregular galaxies (more than 65%). Another important characteristic of this type of object is their quite different spectra: i) both strong continuous spectrum and emission lines; ii) strong continuum and weak emission lines; iii) weak continuum and strong emission lines; iv) both weak continuum and emission lines. The location of these objects in the galaxy also varies (Sahakian & Khachikian, 1975). They can be the nucleus of the UV galaxy; a part of the galaxy (like Mark 94, 59, 298); an isolated UV galaxy (Mark 116= I Zw 18), which is almost the same category as a Sargent-Searle object. All these facts are not understandable completely.

Markarian 231. A unique object, and according to D. Weedman, Mark 231 is the prototype that includes all physical processes associated with active galaxies: it contains both a starburst and an AGN which are highly obscured by dust; its luminosity at various wavelengths shows how such a galaxy would appear at high redshift. Mark 231 provides an excellent example for comparing low redshift and high redshift phenomena. (Weedman, 1999).

Markarian 273. The unique ULIRG double Sy type nucleus galaxy with a long jet to the south (about 40 kpc), which originates from the southern nucleus (Khachikian et al., 1985). The separation of the main bright nuclei is about 800 pc. But the most interesting peculiarity of this galaxy is the double structure of the northern nucleus: the separation between them is only 70 pc! (Knapen et al. 1998). More detailed optical observations suggest that there are multiple nuclei in this galaxy (Koroviakovskii et al., 1981; Mazzarella & Boroson, 1993). The galaxies Mark 423 with a starlike nucleus and multinucleus Mark 773 have jets. Fig. 2 presents a picture of this galaxy obtained with the Keck Telescope in the K-band and kindly given to me by Dr. B. T. Soifer.

Markarian 266. The unique double Seyfert type nucleus galaxy, with unusual physical properties. The detailed spectrophotometric investigation of this galaxy first was presented in Khachikian et. al. (1980). Now there are a lot of new observations of Mark 266. I should like to note the important work of Mazzarella et al. in 1988 and 1993 on Markarian galaxies. It was shown that Mark 266 is a radio source: both optical nuclei are radio sources, at the same time, just in the center of the galaxy between the two optical nuclei there are two radio sources (Fig. 3). The orientation of these two radio nuclei is very interesting: they are elongated in the direction perpendicular to the direction of optical nuclei!

The distance between them is less than one arcsecond. **But the most interesting is that the spectrophotometric investigation of Mark 266**

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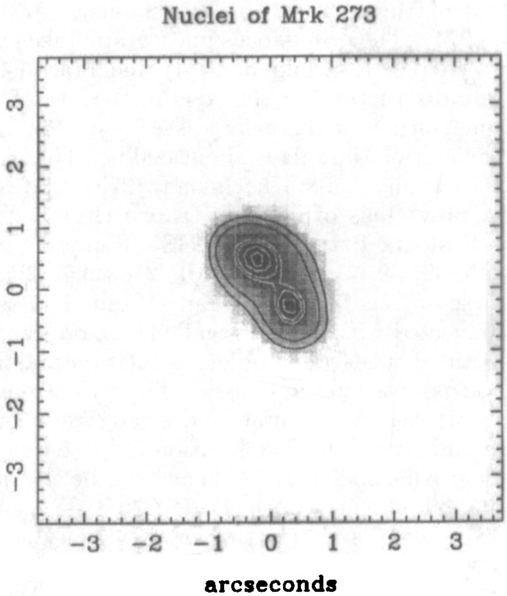

Figure 2. Keck K-band image of Mark 273.

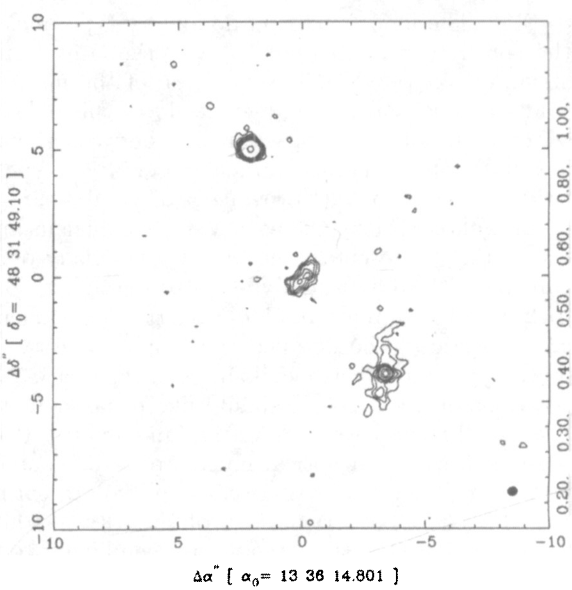

Figure 3. VLA image of the central region of Mark 266 showing the double radio nuclei.

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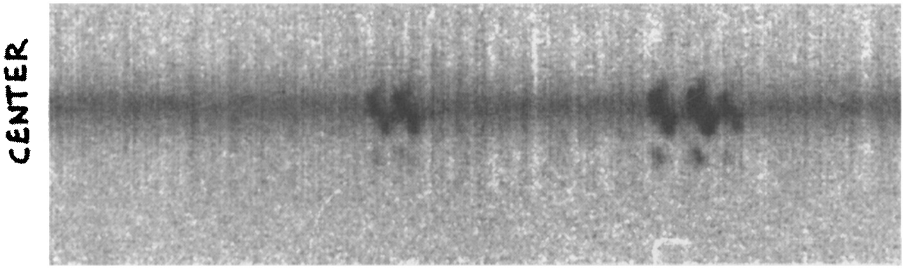

Figure 4. Spectrum of Mark 266. The P.A. of the slit is 120 and crosses the center of the galaxy just between the optical nuclei.

carried out with the Palomar Observatory 5-m by Terzian, Nortgren and me (not yet published) shows that just in the same direction symmetrical to both sides of these radio sources there are two condensations discovered by means of emission lines! (Fig.4).

The distance between these objects is about 15 arcsec. Figs. 5–7 show the results of recent observations with the 2.6m telescope of BAO of Mark 266 in an Hα filter and the field of radial velocites obtained with the "Tiger" system in the $H\alpha$ and [N II] lines, respectively. One can see the variations in the profiles of these lines over the central part of Mark 266. The difference of radial velocities of these two new objects is about 500 km/s, which shows that they rotate around the center of Mark 266. More detailed discription of the results of this investigation of Mark 266 will be published elsewhere.

5. Concluding Remarks

There are many other interesting objects among UV-galaxies (Mark 116 = I Zw18 - probably one of the most metal-deficient objects; Mark 64 - first quiet QSO; Mark 421 and 501- BL Lac objects; Mark 205 and 474 - Sy 2 galaxies, very much looks like Mark 9; Mark 5,13,19 and others - galaxies with bright and narrow emission lines; Mark 11, 26, 41, 292 - without any strong emission lines; Mark 133- without N1, N2 lines; double systems - Mark 220 and 221, Mark 261 and 262, Mark 305 (BL Lac object) and Mark 306 (with very strong emission lines) and so on. But because of the limits of space I have no possibility to continue the list of interesting objects from the FBS. I would just like to stress that about 10% of UV galaxies are double and multi-nuclei galaxies. The number of this type of active galaxy is now so high that the majority of them, no doubt, are real double or multi-nucleus galaxies, but not double or multi galaxy systems. Therefore **they are not a result of colliding or interaction of two or more independent galaxies**. The fact that the majority of double nuclei show either form of activity also speaks in favor of this opinion. I would like to finish my review with the following words of Margaret Burbidge: "It is

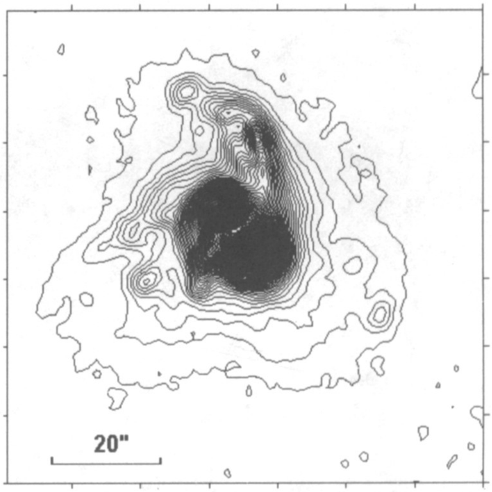

Figure 5. Hα contour image of Mark 6.

very fashionable at the moment to talk about "mergers" of galaxies to explain unusual morphology, but it seems to me that there are too many of these double nuclei for them ever to be accounted for as "mergers" of previously separate galaxies." (Khachikian 1988).

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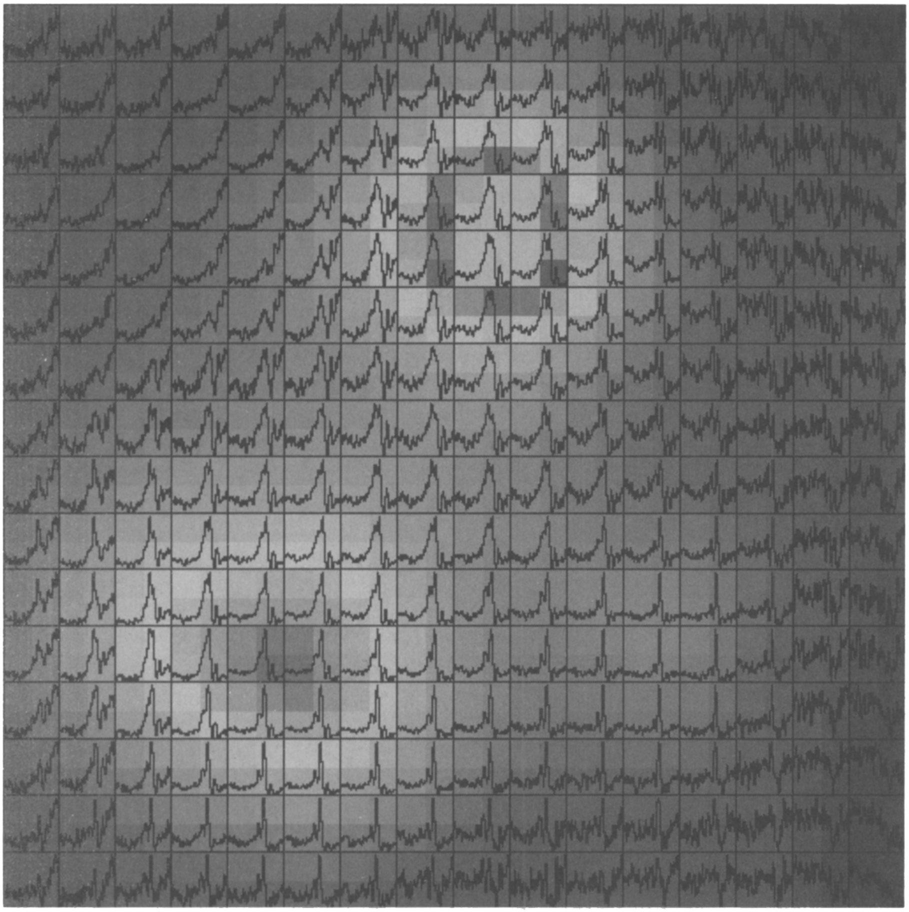

Figure 6. Multi-pupil Hα + [N II] observation of Mark 6.

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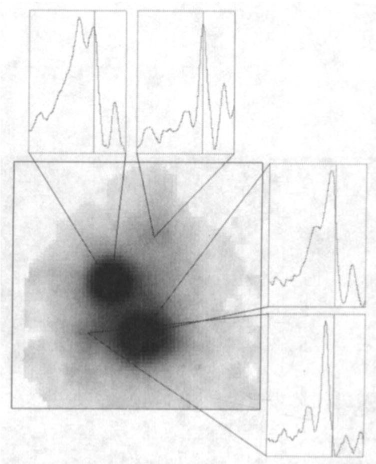

Figure 7. Averaged profiles of 4 regions of Mark 266. The vertical line corresponds to λ6750Å.

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