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OBSERVATIONAL EFFECTS OF INTERACTION IN THE SEYFERT GALAXY NGC 7469

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ABSTRACT. Some pecularities of the circummucleus of the Seyfert galaxy NGC 7469 were revealed, plausibly caused by interaction with the satellite IC 5283 and a starlike detail, situated on the edge of the west spiral branch 14" from the nucleus. Shock excited HII regions were noted in the part of NGC 7469 turned toward the satellite IC 5283. The galaxy's central radio structure ($\lambda \sim 6$ cm) stretches in the direction toward the satellite IC 5283 and the starlike detail. The spectum and color index of the starlike detail suggest that it is a cluster of early type stars ($M_V = -19^m$) and dust clouds ($A_V = 3^m$), in NGC 7469.

NGC 7469 = MGC I-58-25 = Arp 298 is the main member of the pair Holmberg 803, having as a satellite the irregular galaxy IC 5283 (see Figure 1). Its morphological type is Sa (Humason et al., 1956), z = 0,0170 (Burbidge et al., 1963), $M_V = -21^m$ (DeRoberts and Pogge, 1986). We take 1" at the distance of NGC 7469 to be 325 pc. Interstellar absorption in our Galaxy in the NGC 7469 region is not high - $A_V = 0{,}25^m$ (Weedman, 1973). NGC 7469 has two spiral structures - the inner bright and outer faint, dimensions of which are 33" or 11 kpc and 100" or 33 kpc correspondingly. Position angle of the line of nodes is equal to 121° (Burbidge et al., 1963) and 1350 (DeRobertis and Pogge, 1986).

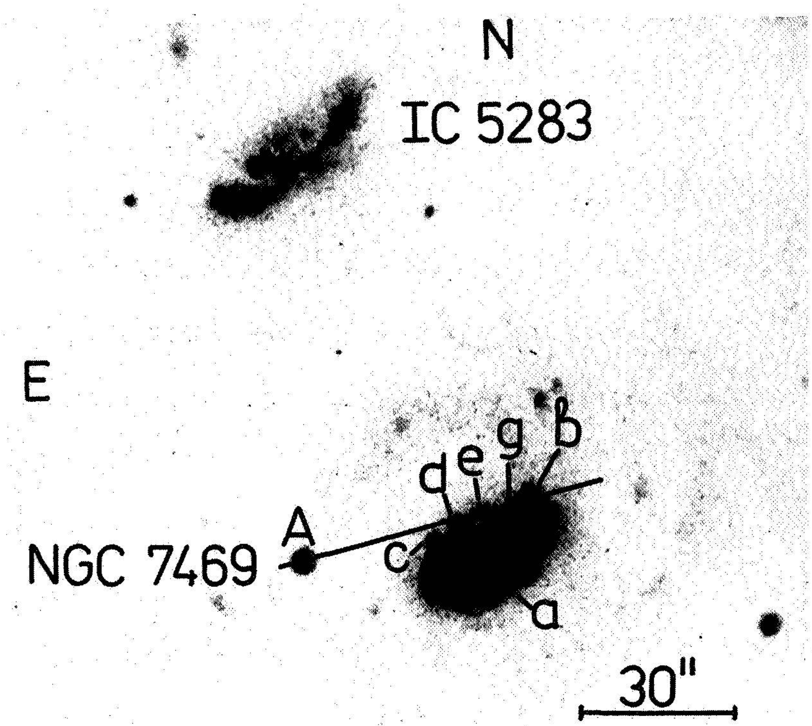

Figure 1. Holm.803 pair photo according to Burbidge et al. (1963). a - nuclear region, b, c, d, e, - details of NGC 7469. Ab - shows direction of spectrograph slit (see text).

Figure 1 shows that both galaxies of the pair are oriented in such a way, that a large part of each galaxy surface turns toward its neighbor. The projected distance between the members of the pair is 1,2 or 23,5 kpc. This distance is less than the dimension of the outer spiral structure of NGC 7469. The difference in radial velocities of the pair members is 68 km/s (de Vaucouleurs and de Vaucouleurs, 1964). So it is very possible that effects of tidal action will be noticeable. Published and our data confirm this supposition as applied to the inner spiral structure.

The inner spiral structure of NGC 7469 surrounds its central region containing a typical Sy I nucleus (Khachikian and Weedman, 1974), widths of permitted lines being 10 - 15 000 km/s (Pronik, 1975). This nucleus has large UV excess (Lyutyi, 1972), bright X-ray emission (Marshall et al., 1981; Petre et al., 1984). Figure 1 shows that inner spiral structure is more regular in the southern part of the galaxy opposite the satellite IC 5283. Its amorphous structure is turned toward the satellite. Spiral arms come to an end on starlike details "b" and "c", between which amorphous details "d" and "e" are seen. One can suppose that tidal forces do not permit the formation of regular spiral structure toward IC 5283 side. DeRobertis and Pogge (1986) supposed that detail "b" is a star of our Galaxy. While analyzing published data we have noticed that detail "b" is connected with the circumnuclear structure of NGC 7469. Figure 1 shows that the western spiral arm makes an abrupt turn to the "b" detail and a jet-like filament "g" is directed from the nucleus to this detail. One can see that NGC 7469 interacts not only with the satellite IC 5283, but also with the detail "b".

Let us consider Figure 2, which illustrates that in the 6-cm radio on 6 cm of NGC 7469 there are three directions of extension: (1) along the line of nodes, (2) toward object "b", and (3) toward IC 5283. Thus the radio sources are located along the direction of the greatest stellar space density in the galaxy and in two directions, fixed by the satellite and the starlike object "b".

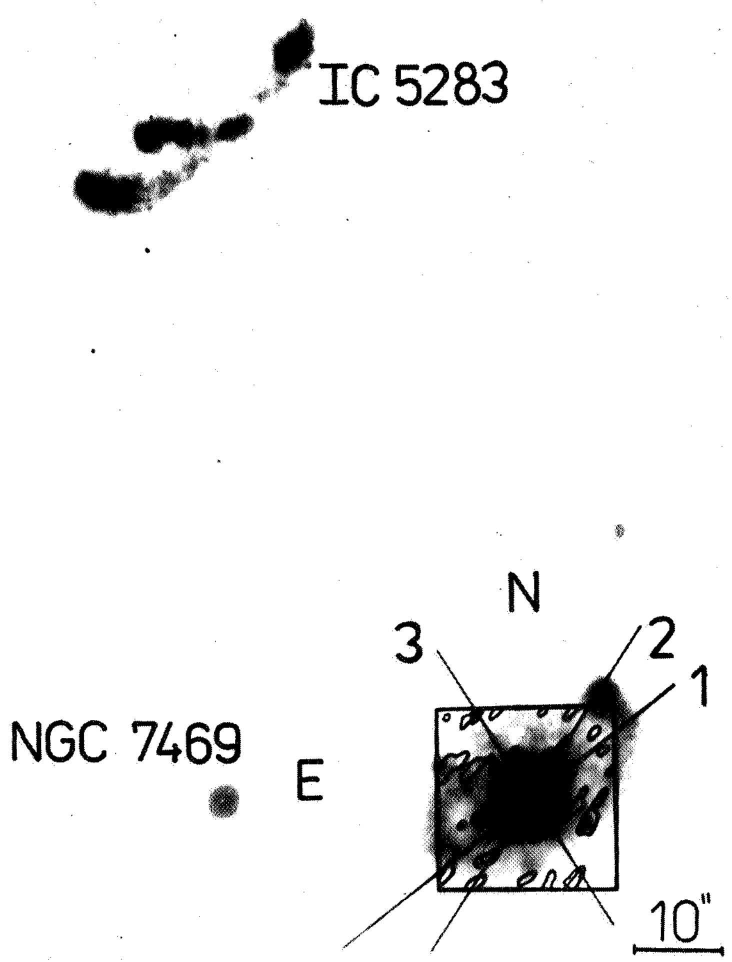

Figure 2. Radio isophotes of central region of NGC 7469 at 6 cm according to Ulvestadt et al. (1981) projected on the photo of the galaxy. 1,2,3 - directions of radio isophotes stretching.

The Seyfert nucleus of NGC 7469 is surrounded by large numbers of young stars and HII regions, as shown by spectral, photometrical, IR, and radio investigations. Humason et al. (1956) estimated the spectral type of the central region of NGC 7469 as F5, Cutri et al. (1984) observed the galaxy in CO band, 3,2 μ and calculated, that the heating of observed dust to T = 300 K can be made by centers of star formation. Active star formation here is confirmed by radio observations at 6 cm within a 10" region (Ulvestad et al., 1981). Wilson et al. (1986) estimated the lower limit of bolometric luminosity of central group of young stars as $10^9 - 6.10^{10}$ $L_{\odot}$. Together with the young blue stars in the central part of NGC 7469 there are extensive gaseous nebulae with various mechanisms of excitation. According to Burbidge et al. (1963), H_α + [NII] emission is observed to 10" from the center. Now together with H_α + [NII] and λ 5007 A [0111] emission of H_α, 2,12 μ, and CO 2,6 mm is observed in the 7".5 diameter. HII regions are partly divided by mechanisms of excitation if they are located on the satellite side or on the opposite side. In Figure 3 one can see boundaries of HII regions according to DeRobertis and Pogge (1986) data. Gaseous fields, having high and low $I_\beta/I_{[o111]}$ relations are shown by thick and dotted lines correspondingly. The first are the regions where hot stars are responsible for hydrogen excitation. They are concentrated in the central and south part of the galaxy. The second regions can be excited by collision. They prefer the satellite side of the galaxy. It is interesting that both types of HII regions avoid the surroundings of detail "b".

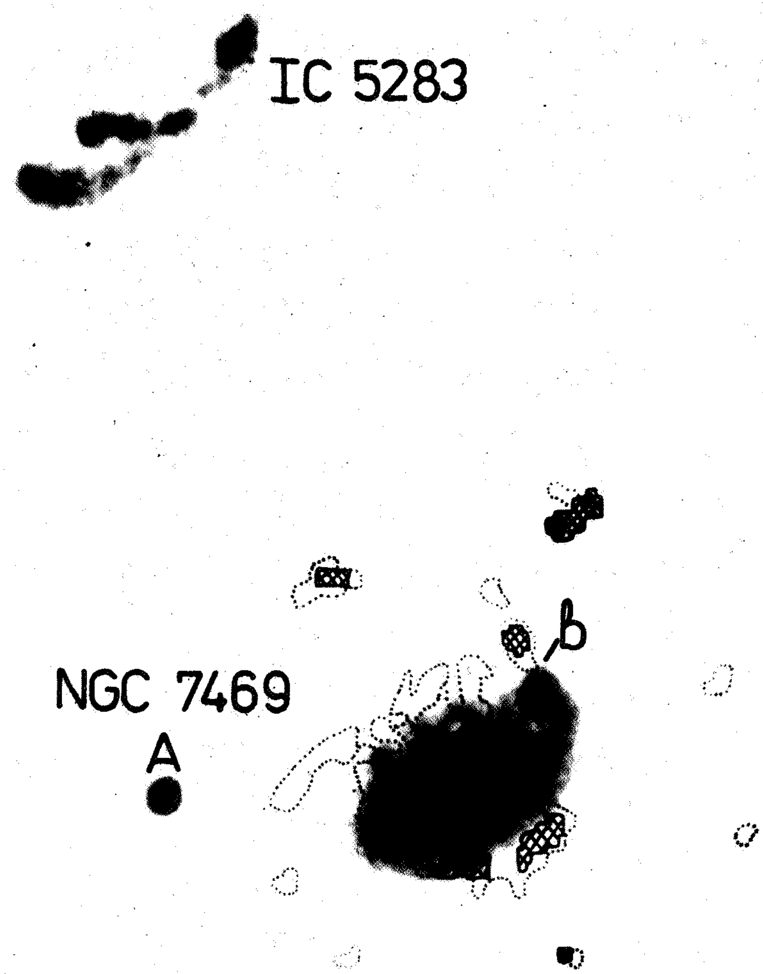

Figure 3. Boundaries of HII regions of different relations $I_{\beta}/I[0111]$ according to De Robertis and Pogge (1986) projected on the photo of the galaxy: solid lines and shaded regions - $I_{\beta}/I_{[0111]}$ being high, dotted lines - $I_{\beta}/I_{[0111]}$ being low.

In order to investigate this phenomenon, we obtain spectra at 6-m telescope with dispersion 95 A/mm and scale 17"5 per mm, and direct images with the glass filters at the TV MTM-500 telescope of the Crimean Observatory. Unwidened spectra were obtained with slit width 0"8 and 10 min exposures. Seeing was 1"5. The slit crossed details "b", "c", "d", and "e" simultaneously. Figure 4 shows two spectral regions for the details. In the spectrum of detail "b" there are no bright emission, or absorption, lines. According to the spectrum of detail "c" it is a typical HII region excited by hot stars: H_β line is brighter than [OIII], H_α is brighter than [NII]. Quite different relations of forbidden and permitted line intensities show in the spectra of details "d" and "e": here the forbidden lines are almost equal in intensity to the neighboring permitted lines. The relative intensities of these lines are shown in the Table. Errors obtained from doublet members' intensities are equal to ±8%. So the spectral data confirm the supposition that HII regions on the satellite side may be excited by collisions.

TABLE

Relative Intensities of Emission Lines in the "d" Detail Spectrum

$I_{\lambda 1}/I_{\lambda 2}$	Theory	Observations
5007/4959	2,96	2,94
4959+5007/H_β		1,45
6583/6548	3,00	2,54
6583+48/H_α		1,08

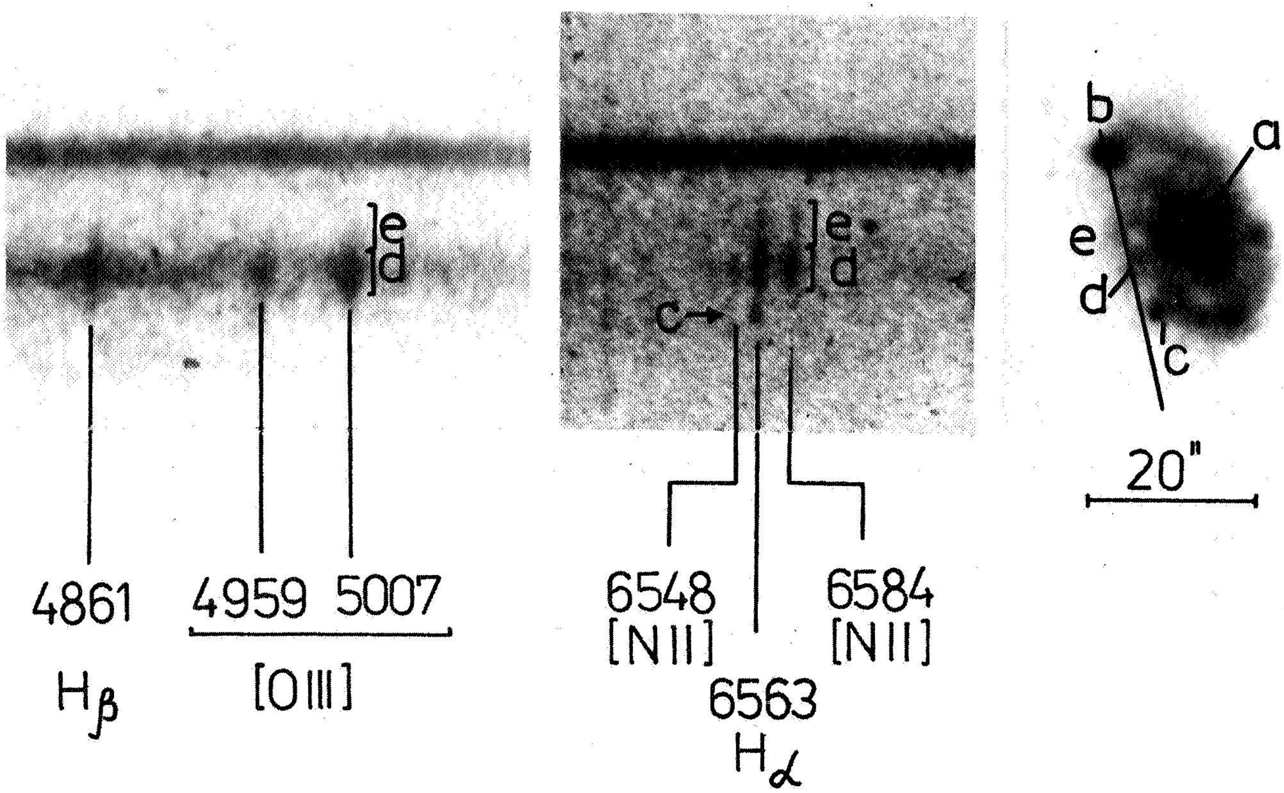

Figure 4. Right - photo of NGC 7469 with the details as on Figure 1. Left - spectrum of the regions obtained with the slit position Ab.

What is the nature of object "b" according to its spectrum? In the spectral region 4000-7000 A there are but three prominant emission lines, which in the scale of laboratory wavelengths coincide with λ 5050 A, 5100 A, and 6800 A. There exist also some weak absorption and emission details. We tried to identify these spectral details and were forced to assume that they belong to the gas systems of different radial velocities (see Figure 5). If our assumption is correct, then the galaxy NGC 7469 contains three gas systems with different radial velocities: 5075, 6300, and 10,800 km/s. It is well known that there exist two gas systems of different radial velocities in NGC 1275: 5000 and 8000 km/s (Minkowski, 1957). It is worth noting that the gas systems of NGC 7469 are markedly weaker and smaller than those of NGC 1275. It is interesting to note that the gas of the lowest velocities in both galaxies contains more or less extensive regions of shock excitation. On Figure 6 one can see relative intensities of emission lines of several know low velocity gas spectra; they correspond more to the status of gas in the Cygnus Loop (a known supernova remnant, the mechanism of excitation being of shock origin), than to regular gaseous nebulae in spiral arms of galaxies.

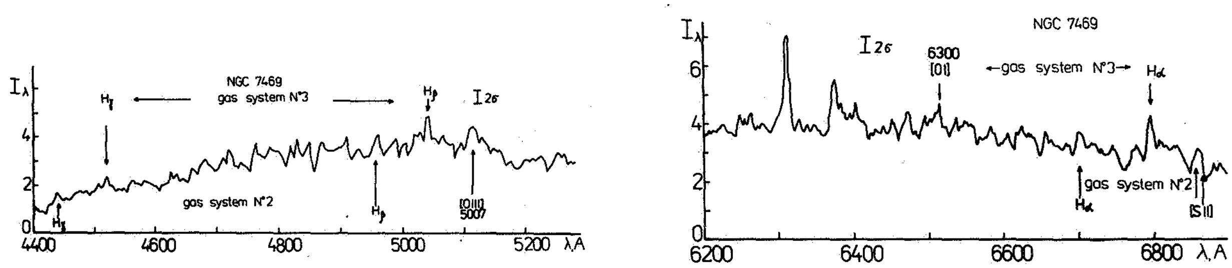

Figure 5. Spectrum tracing of object "b" in the blue (a) and red (b) with the proposed identification of emission lines (see text).

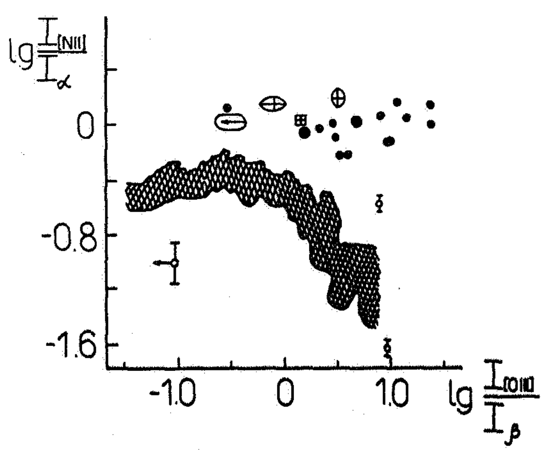

Figure 6. Relative intensities of emission lines for HII regions of spiral galaxies (shaded arc and circles), gas of low velocity in NGC 1275 (ovals) and in NGC 7469 (square) and Cygnus Loop (points) (Metik and Pronik, 1990).

Results of BVR photometry of object "b" are shown on Figure 7. Its position on two-color diagram shows that if it is a star of our Galaxy, then it belongs to K2-K5 spectral class. But the spectrum of the object does not show the typical blend in the region 5000 - 5200 A - MgI + MgH band. Therefore we assume that this object is a group of early stars and dust where the absorption is not less than $A_V = 3^m$ (see Figure 7).

If the object "b" really belongs to NGC 7469, it must be a huge compact group of stars with absolute magnitude $M_V = -19^m$. It contains a lot of early stars and dust but is almost free from gas. Such huge star cluster must be responsible for perturbation, leading to gravitational instability of the galaxy disc, thus causing a reason of matter to fall toward the center of the galaxy (Sotnikova, 1988). Gas accumulation in the center of galaxy creates there the conditions for recent star formation and generation of Seyfert nuclei.

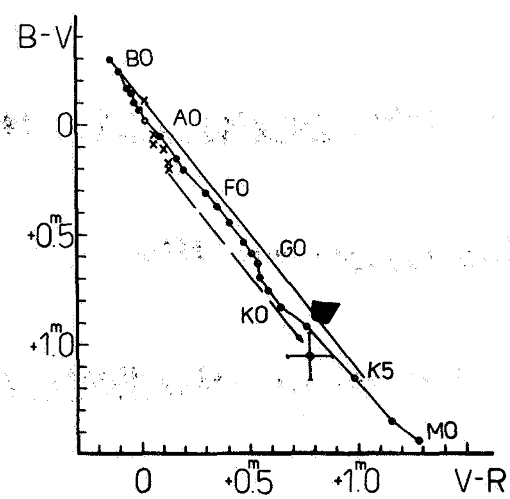

Figure 7. Two-color diagram for MS stars (Straizys, 1977), NGC 7469 object "b" (cross) and details of NGC 1433 SBab galaxy (shaded quadrangle - Buta, 1986). The arrow shows the line of reddening.

REFERENCES

Burbidge E. M., Burbidge, G. R., and Prendergast K. H. 1963, Astrophys. J., 137, 1022.

Buta, R. 1986, Astrophys. J. Suppl. Ser., 61, 631.

Cutri, R. M., Rudy, R. J., Rieke, G. H., Tokunaga, A. T., and Willner, S. P. 1984, Astrophys. J., 280, 521.

DeRobertis, M. M., and Pogge, R. W. 1986, Astron. J., 91, 1026.

deVaucouleurs, G., and deVaucouleurs, A. 1964, Reference Catalogue of Bright Galaxies, The University of Texas Press, Austin.

Humason, M. L., Mayall, N. U., and Sandage, A. R. 1956, Astron. J., 61, 97.

Khachikian, E., and Weedman, D. 1974, Astrophys. J., 192, 581.

Lyutyi, V. M. 1972, Russian Astron. J., 49, 930.

Marshall, N., Warwick, R., and Pounds, K. 1981, Monthly Not. Roy. Astron. Soc., 194, 983.

Metik, L. P., and Pronik, I. I. 1990, Izv. Krimsk. Astrofiz. Obs., 82, in press.

Minkowski, R. 1957, "Radio Astronomy," Proc. IAU Sum. No. 4, ed. H. C. Van der Hulst, Cambridge, Cambridge University Press, p. 107.

Petre, R., Mushotzky, R. F., Krolik, J. H., and Holt, S. S. 1984, Astrophys. J., **280**, 499.

Pronik, I. I. 1975, "Variable Stars and Stellar Evolution," Proc. IAU Sym No. 67, 605.

Sotnikova, N. Y. 1988, Avtoreferat Kandidat. Dissertation, Leningrad.

Straizys, V. L. 1977, "Multicolor Photometry of the Stars," Mokslas, Vilnius, p. 105.

Ulvestadt, J. S., Wilson, A. S., and Sramek, R. A. 1981, Astrophys. J., **247**, 419.

Weedman, D. 1973, Astrophys. J., **183**, 29.

Wilson, A. S., Baldwin, J. A., Sun Sze-Dung, and Wright, A. E. 1986, Astrophys. J., **310**, 121.