NESTS OF INTERACTING GALAXIES: WHAT IS IT?

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ABSTRACT. Kinematical and photometric studies of nests of interacting galaxies are described. Velocity fields of 22 nests were obtained using the 6-meter telescope of the Special Astronomical Observatory of Sciences Academy of USSR.UBV-photometry carried out with 125-cm telescope of Sternberg Institute has shown that the majority of nests is blue and undergoes intense star formation.Nests are found to be of different types:among them there are single SB and dwarf Irr galaxies with supergiant HII -regions as well as tight pairs and multiple systems of galaxies. Multiple systems classified as nests are shown to be dynamically stable.

INTRODUCTIONS.

The term "nests" of interacting galaxies has been introduced by B.A.Vorontsov-Velyaminov (1959) for tight groups of interacting galaxies containing more than 2 members.Mostly nest components touch each other and always possess a common envelope.Some systems are observed to have tails.In two parts of the "Atlas of Interacting Galaxies" there are more than two hundred such systems ; they constitute about one fourth of all interacting galaxies. For the first time they were discovered on the Palomar Sky Atlas maps, so their images are often overexposed. The study of their true morphology is one of our main purposes.

Most of nests have small angular sizes. Detailed morphological study of a small sample of the nests has led to the conclusion that some nests can be rather single irregular galaxies with giant compact H II-regions or pairs than multiple systems (Korovyakovskaja 1983, 1984, Korovyakovski 1984). The multiplicity of the system should be proved not only by the morphological method but by the kinematic study as well.

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1. ABSOLUTE PHOTOGRAPHIC MAGNITUDES AND LINEAR DIMENSIONS OF NESTS.

Observations of nests of galaxies were started in 1973 in the Sternberg astronomical institute as a part of the large investigation program on interacting galaxies.Radial velocities of about 100 systems have been obtained by using the 6-meter telescope in the Special Astrophysical Observatory (after 1977) and the 125-cm reflector in Crimean laboratory of the Sternberg institute (Afanasiev et al. 1980, Arkhipova et al.1981a, 1981b).These data were used to determine absolute photographic magnitudes of nests. The luminosity distribution of 103 nests with known radial velocities is shown in fig. 1.

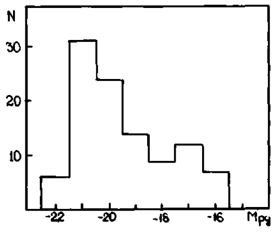

Fig. 1. Luminosity distribution of nests of interacting galaxies.

We assume H=75 km/s Mpc to determine M_{pg}. The observed distribution peak has place at M_{pg}= -21^m which means that nests are high-luminosity galaxies; some excess can be also seen at M_{pg} = -17^m - probably it is caused by the presence of IrrI single galaxies among those classified as nests. The mean luminosity of 103 nests is M_{pg}= -19.7^m.

The data on radial velocities has permitted us to study the linear size distribution of nests. The mean diameter of nest is 21.6 kpc and only 4 systems are larger than 50 kpc.

2.UBV-PHOTOMETRY AND SPECTRA OF NESTS.

Photoelectric UBV-photometry of about 20 bright nests was carried out in the Crimean laboratory of the Sternberg institute by using the 60-cm and 125-cm reflectors (Arkhipova 1982).Apertures of the 10"-68" were used.Mean errors in V and B-V are estimated as $0\overset{m}{.}03$, in U-B as $0\overset{m}{.}06$. In fig.2 two-color diagram U-B, B-V for the nests is presented. The colours in the largest aperture were plotted. They are corrected for the interstellar extinction on our Galaxy but no K-corrections are applied because for all galaxies V_r< 10 000 km/s. Another 10 nests have the published colours however the latter ones were obtained for the inner part of galaxies (as rule) and aren't integrated ones.

On the two-colour diagram the most nests colours are the bluest among normal galaxies colours. Some nests have large ultraviolet excesses so partly the nests were classified as Markarian galaxies. A few

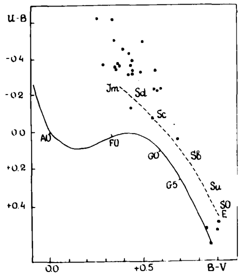

Fig.2. Two-colour diagram for the nests of interacting galaxies. Solid line indicates main-sequence stars colours; dashed line shows the normal galaxies position.

of nests are red as ellipticals and probably consist of E- or SO-components.

Among blue nests some objects are single irregular galaxies - as example we can mention NGC 1156 (or VV 531). However most blue nests have high luminosity and are real tight groups of galaxies (sometimes merged) with large amounts of gas and hot stars. The nests' position on the two-colour diagram indicates star formation bursts caused by the interaction of components. Intense star formation in nests is confirmed by their spectral observations too. In 1977-1984 we have obtained spectra for 54 nests using the 6-meter telescope of the SAO of the Sciences Academy of the USSR. Only 9 objects have spectra without emission lines - less than 20% of the sample. So the majority of nests contains a considerable amount of ionized gas. Nest's emission-line spectrum usually demonstrates strong lines of H and [OIII] and weaker lines [NII], [SII], HeI. The low ratio between intensities of [NII], [SII] lines and H-alpha indicates the radiative mechanism of excitation.

3. INTERNAL KINEMATICS OF NESTS.

Spectral observations of the nests of interacting galaxies were carried out at the primary focus of the 6-meter telescope using the spectrograph UAGS and the three-cascade image tube. The dispersion is about 100 A/mm, the resolution is 3-5 A; the slit sizes are 2"x200". Spectrograms were used to measure radial velocities as the function of y-coordinate along the slit. Having correcting measurements for the field curvature we studied internal kinematics of the 18 nests and of the 4 chains. For all systems rotation velocities and mass estimations are obtained; masses can be underestimated because of uncertain sin i values. As an example we can consider results for two typical nests - VV 141 and VV 731. Their rotation curves are presented in fig.3.

VV 141. The slit has passed across the nucleus of the main component and SW-component. Main galaxy: v_{rot}=120 km/s, mass is equal to $3\cdot10^9\ M_\odot$; SW-component: v_{rot}=140 km/s, the mass is equal to $4\cdot10^9\ M_\odot$. Integrated $M_{pg}=-18^m.2$, mass-to-luminosity ratio is more than 3, the distance between the components is 4 kpc. The system is probably double.

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VV 731.E-component: V_{rot}=125 km/s, the mass is equal $1 \cdot 10^{10} M_{\odot}$. W-component: V_{rot}= 70 km/s, the mass is $2.7 \cdot 10^{9}$ $M_{\odot}$; SW-component: V_{rot} was not determined, only systemic velocity is known. $M_{pg\ int}$= $-21^{m}.0$, D=25 kpc. The system is the nest with three components one of which has a seyfert nucleus.

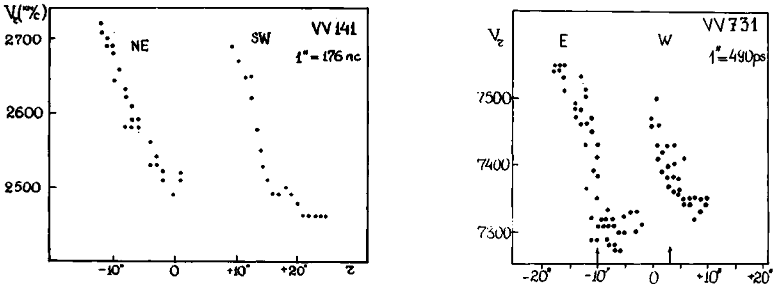

Fig.3 a,b.The rotation curves of VV 141 and VV 731.

Among 17 nests studied by us one half of all objects has $M_{pg} \gtrsim -18$; so among nests there are many dwarf systems.Components of about 50% nests have independent rotation; mostly of them rotate in the same direction. The rest of nests has continuous single rotation curves which indicates the presence of the only rotation body.

Nests, and interacting galaxies in general, have rotation curves of unusual form: linear increase of V_{rot} ("rigid body rotation") can be often observed along all the disk of a galaxy-at least while surface brightness is high enough to provide intense emission lines.The majority of nests components has such rotation curves.

We have not found any indication of dynamical instability in multiple systems. The largest differences of components radial velocities are observed in the nests VV 243 and VV 731 and are found to be 200-250 km/s.Estimations of mass-luminosity ratios haven't also given arguments for the gravitational instability of nests or for the presence of "hidden mass".Mass-luminosity ratios are typical for stellar populations of normal galaxies;the mean M/L for 17 systems is about 5. There are no any discrepancy between M/L estimations for individual components and for systems as a whole under the assumption of dynamical stability though in the latter case M/L can be estimated only very roughly because of unknown space structure of a nest.

In general the nest mass estimation obtained by using a rotation curve is usually a low limit of the mass because a peculiar structure of objects makes it difficult to determine a true inclination of a galaxy. Usually as a first approximation to cos i we used semiaxes ratio for one of the innermost isophots which wasn't distorted by interaction.

The comparison between individual component masses and integrated mass (luminosity) of nest shows that more massive (luminous) nests consist of more massive components. Dwarf nests with integrated absolute magnitude $-17--18^m$ have the mean component mass equal to $4\cdot10^9 M_\odot$ and nests more luminous than -20^m have mean component mass several times higher ($\sim2\cdot10^{10} M_\odot$).

4.SINGLE GALAXIES WITH GIANT HII-REGIONS.

The nests whose components are not kinematically independent have low luminosity as a rule ($M_{pg}>-18$) and may be single galaxies of late types with giant HII-regions. We have found typical diameters of HII-regions in such systems to be as large as 1-1.5 kpc. The presence of supergiant HII regions with high surface brightness and net boundaries has been the cause of misclassification of such galaxies.Kinematics study permit us to separate true nests from false ones. Emission spectra of these supergiant HII-regions resemble typical spectra of gaseous nebulosities in our Galaxy. However all single galaxies misclassified as nests have an interesting morphological feature: a bar-like structure of central parts. Morphology of such galaxies can be defined as SBd or SBm. Rotation curves of many such systems also have a long segment described by a "rigid body rotation" law, and in external parts rotation velocity decrease. Maximum rotation velocity correlates with galaxy luminosity very well.Luminosities and masses of these galaxies are typical for late-type spirals: $M = 1.5\cdot10^{10} M_\odot$, $L = 3\cdot10^9 L_\odot$, $f = 5$.

Unusually large sizes of HII-regions are probably caused by the presence of large star complexes which indicate intense star formation. The fact that only SB-galaxies possess such super-giant star formation regions permits to suppose that bar and star formation rate can be connected.Perhaps star formation is stimulated by bar; but we cannot exclude that there may be external stimulation of this process. We have seen small weak satellites near some "SB-nests" but we have failed to obtain their spectra and so we do not know if their connection with the main galaxies is real.

As for true nests - multiple systems - their star formation rate appears to be high too as implied by their blue colours. Their UBV-colours are typical for recent star formation bursts. Moreover they are very gas-rich objects.A few red nests, on the contrary, are gas-poor because we do not see emission lines in their spectra, and their UBV-colours are typical that of E or SO galaxies. We have not studied kinematics of red nests, this is the task for the future.

5.NESTS AND MERGERS.

Recently a phenomenon of mergers has excited a large interest. Mergers are pairs of galaxies united after collisions. Schweizer (1983) defines several types of mergers related to morphological types of their components: EE, DD, ED etc. Some nests appear to be pairs of galaxies that cannot be separated. For example MCG 1-6-57 classified as a nest consisting of 4 components may be a merger at a certain stage of its evolution. It is illustrated by the direct photo obtained with the 2.6-meter telescope of the Byurakan Observatory and by the kinematic study. The distance between MCG 1-6-57's nuclei is 5.8 kpc as projected on the sky plane. Kinematically it is a single object with peaked rotation curve.We think that there may be many mergers among nests not studied yet.

6. DWARF GALAXIES OF VERY LOW LUMINOSITY.

Finally a small number of nests are found to be very weak dwarf galaxies with $M_{pg}=-12^m$ to -14^m belonged to the nearest groups of galaxies. For example VV 574 is a dwarf belonged to the M 81 group (Arkhipova, Noskova 1983). It has $M_{pg}=-11\overset{m}{.}8$, rotation mass is equal to $3\cdot10^7\ M_\odot$, hydrogen mass $M_{HI}=7\cdot10^6\ M_\odot$, and diameter 0.9 kpc. Maximum HII-regions sizes in VV 574 can be estimated as about 100 pc. HII-regions have net boundaries, and a lack of information on their linear sizes and low resolution gave an impression that this is a nest consisting of several components. We also know such examples of similar galaxies as VV 499 (dwarf member of the M 81 group), VV 558 (the dwarf galaxy belonged to the Local Group) and others. All of them have diameters less than 1 kpc, masses 10^7 - 10^8 and HII-regions as large as 50 - 100 pc diameters.

7. CONCLUSIONS.

The class of nests is very inhomogeneous. Very different physical objects can possess quite similar morphology. Among nests we can see single SB- and Irr-galaxies with extraordinary large HII-regions (superassociations), tight pairs of galaxies possessing large HII-regions too, true nests - tight groups of more than 2 members physically connected. As a rule these blue objects experience very intense star formation. Our intention is to continue the study of these interesting galaxies.

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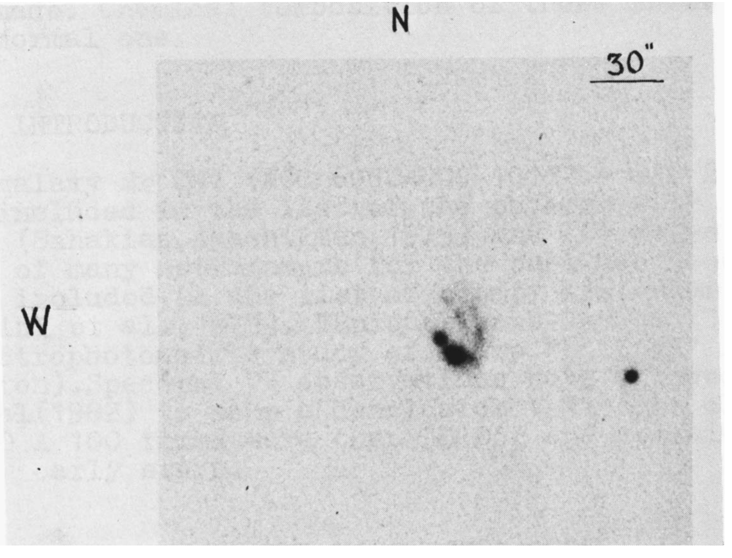

Fig.4. The photograph of the nest MCG 1-6-57. It has been taken with 2.6-meter telescope of the Byurakan Observatory. The exposure is 20 min, 103aO emulsion has been used. The north is to the top, the west is to the left.

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DISCUSSION

FILIPPENKO: What is the typical absolute magnitude of each component in a nest of galaxies?

ARKHIPOVA: The components in the nest W731 have absolute magnitudes about -19 or -19.5m.

JOEVEER: Most of nests of galaxies are quite blue objects. Are some of them included in other lists of blue extragalactic objects, in Markarian lists or others?

ARKHIPOVA: Some nests are also Markarian galaxies. The small number is also in Zwicky's catalogue of compact galaxies.