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ATLAS OF INTERACTING GALAXIES, PART II AND THE CONCEPT OF FRAGMENTATION OF GALAXIES

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This is a further publication of the photographs of some of the 1500 interacting galaxies found by the author on the Palomar Sky Atlas, recognized and described by him in the "Morphological Catalogue of Galaxies" mostly before 1964. They are given with a magnification of 30 times. Some of the photographs have been taken from the excellent large-scale photographs of these objects made or collected by Arp. This is also the case for some of the objects published in 1959 on a smaller scale in part I of our atlas and since then studied in more detail. These are identified by numbers below 356. Altogether, 700 photographs of 600 objects are presented here, of which 500 photographs are reproduced for the first time, although nearly all were already found and recognized and described long ago in MCG. It is essential that the images are arranged here and discussed from the point of view of fragmentation of galaxies and compared to the models of the theory of tidal perturbations.

Key words: atlas – interacting galaxies – evolution of galaxies – morphology of galaxies

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INTRODUCTION

Some very peculiar galaxies noticed by Herschel and later by Zwicky did not attract attention until we (Vorontsov 1959) published the first part of the "Atlas and Catalogue of Interacting Galaxies". Referred to below as Atlas I, it contained the photographs of 355 systems. Apparently, this stimulated the publication of the first Atlas of 175 regular galaxies (Sandage 1961) which for a long time remained in preparation by Hubble. By interacting galaxies we understand a) systems, where the regular shapes are perturbed, apparently as a consequence of interaction with another galaxy, or b) systems where the galaxies are imbedded in a common luminous haze. They are distinguished from peculiar galaxies in that they involve at least two stellar systems, or, in extreme cases, lead to the suspicion that one system in fact consists of two or more in a contact or penetrating each other.

The Burbidges and Hoyle (1963) have stated: "Extragalactic research has tended to be focused on the regular spiral and elliptical galaxies. Hubble put into the category "irregular" all the galaxies which could not be fitted into his fundamental classification scheme..."

A new line of investigation was opened with the publication by Vorontsov-Velyaminov (1959) of his "Atlas of Interacting Galaxies".

The Burbidges were the ardent pioneers who studied the interacting galaxies by photographing them on a larger scale and investigating their spectra. Some spectroscopic studies, the most efficient, were made also by Carpenter, Zwicky and Humason, Bertola, Page, Arp and others.

Unfortunately, soon after the first years of researches, the energy of spectroscopists was engulfed by the newly discovered quasars, Seyfert galaxies and later by the Zwicky's compact galaxies and Markarian's blue galaxies. This fashion lasts. The red shifts of these objects are measured repeatedly without good reason*. However, the fainter interacting galaxies have been observed only if they were lucky enough to be included (under "disguised" names, – "disguised" because their initial (MCG) numbers were not given by the observers) in the lists of compact or blue galaxies compiled later. However, a negligible number of spectra of fainter interacting galaxies observed have emission lines, and 8 of them have Seyfert spectra. Most are composed of members connected by filaments in a chain.

In compiling MCG (the "Morphological Catalogue of Galaxies") (Vorontsov *et al.* 1961) we paid much attention to the discovery and description of interacting pairs of galaxies. The first three of the five volumes of MCG before 1964 covered the northern hemisphere. 1449 interacting pairs of galaxies were recognized, registered, measured and described. To emphasize this and to draw attention to them, besides listing them in the proper places, each volume of MCG was completed by the list of interacting galaxies found. The publication of selected photographs of these galaxies was postponed until the publication of all fields of the "Palomar Sky Atlas". MCG was based on it, and our Atlas I gave mostly 17 fold magnifications from these sky photographs of excellent definition. Unfortunately, we were able to publish our Atlas I only photographically and in a miserable quantity of 100 copies. (In the typographical reproduction, nearly all faint details in the tiny images became lost).

Arp (1966) published his "Atlas of Peculiar Galaxies" typographically as well as photographically. Of his "portraits" one half are the larger and the more interesting objects of our Atlas I. These were correctly referred to in his table by the letters VV. However he made no reference to MCG in the case of those objects (most of the remaining 160!) which for the first time were recognized as interacting or peculiar, which were measured and described in detail in the first three volumes of MCG published in 1962–1964 (with δ above $-9°$). They were moreover listed once again at the end of each volume.

In the second part of our Atlas II some, mostly more southern, objects were added from various sources. The aim of Atlas II is principally to show that whatever the origin of galaxies (from diffuse or from superdense matter), their fragmentation occurs at the present epoch. This is illustrated by dwarf satellites originating inside the larger systems, gemmating from them and connected to them at the beginning by filaments or by

* No. 626 (plate 41), 402 (plate 6); 261 (plate 25), 831 (plate 67) are examples.

spiral arms which cannot be produced tidally by the negligible masses of the satellites. Particular attention is drawn to nests of galaxies (our term for three or more galaxies in a more or less tight contact) and to their version in the form of "minichains", consisting of galaxies in a line in contact or connected by a blue filament. Therefore, several hundred more commonly distorted pairs were left out.

The new arrangement of objects, the wish to recall some objects important for our purposes or objects for which new important data or much better photographs were obtained, resulted in the inclusion of some 90 objects from Atlas I. They are quoted as VV with their former numbers which go from 1 to 355. In view of bibliographic rarity of Atlas I, it is in any case useful to print again some of the photographs on a larger scale and with an improved quality. Some of the excellent photographs of our objects presented by Arp play an important part in our discussion. They are given here with the correct reference as Arp (A) using his identification numbers. The photographs of 500, out of nearly 2000 interacting objects, mostly found by us, and described in the five volumes of MCG, which were not in our Atlas I, are numbered here as a continuation of the latter. These are objects no. 356 to 852. There are therefore altogether about 600 objects, but 700 images, because we reproduce some red photographs, besides the blue ones, sometimes differently printed from the negatives, sketches, etc.

Contrary to the preface to Zwicky's catalogue of compact and "post-eruptive" galaxies (1971), only a few percent of the galaxies, compact or interacting, described for the first time and published in the first 4 Volumes of MCG between 1961 and 1967 north of $\delta = -33°$ were actually referred to. Instead only his own later designations are given by Zwicky.

It is worth-while recalling some facts concerning the MCG. Firstly, that in a review by Kimball Hanzen (1971), the Editors inform the readers that they can furnish the English translation of the complete preface to MCG. Secondly, the approximate coordinates are evident from the reference number of the MCG galaxies. The number of the zone multiplied by 6° gives δ with an error of less than 3°. The zones with $\delta < \pm 45°$ contain from 60 to 56 fields and α is easily calculated from the number of the field.

For the larger images the arrow indicates the North, West being to the right of it. On the photographs by the Burbidges (white on a black background) West is to the left. The scale of the magnifications from the "Palomar Atlas" is 2″ per mm (30 fold magnification). The scale of Arp's photographs, as they are given here, can be taken from the table in his Atlas, taking into account the change of scale in our reproduction.

The colours and radial velocities (expressed in kms^{-1}), and in most cases reduced by the observers to the local centre of rest, are designated V_0 and are taken from MCG with addition of new data. For faint galaxies with large redshifts the correction for the rotation of Galaxy is unimportant. Quoting the distances and absolute magnitudes M, we use the Hubble's constant $H_0 = 50\ \mathrm{kms}^{-1}\ \mathrm{Mpc}^{-1}$.

The symbol V must be retained for the V magnitudes. Therefore for the radial velocities we adopted the symbol V_0, although in some cases it was not known if the observer had corrected his values for the solar motion. In most cases V_0 is the corrected value, the value of solar velocity being taken as 300 kms^{-1}, V_0 being taken from the Vaucouleurs' (1964) "Reference Catalogue" designated in these cases as (R), or from the calculations of Arhipova of average velocities taking account of the probable errors given by the observers and also reduced to the Local Group of galaxies. The observers who contributed to the average in these cases are noted in parentheses by letters. The corresponding references are given in the next table.

A	= Arp (1967)
B	= Burbidge *et al.* (1964)
C	= Carranza (1967)
D	= Denisjuk (1971, 1974)
E	= Evans (1965)
K	= Kintner (1971)
d'O	= d'Odorico (1970)
P	= Page (1970)

Pr = Pronik
R = Reference Cat. B.G. (1964)
Sr = Sargent (1970, 1971, 1972)
T = Turner (1976)
V = Vaucouleurs (1972)
Z = Zwicky

It is very important to know the value of ΔV_0 – the velocity difference between the components of systems. We suppose that owing to systematic errors, the value of ΔV_0 given by one observer is more reliable than that deduced from a comparison of the averaged values, especially when different observers enter into the averages. It appears that most of the systems are bound, as might be expected.

The *UBV* values we give without references for brevity, and also because we do not know the diaphragm diameter with respect to the face-on diameter of galaxies. The latter besides must be known on the uniform system. Even the sizes of the diaphragm are not always known. In the case of the observations of Arhipova and Savelieva, which they kindly passed to us, we give the largest value of the diaphragm used.

The detailed compilation of heterogeneous velocity differences and of colour observations is in progress. Cases of strong radio emission are mentioned in the description of the plates. In the case of several interacting galaxies mentioned in a "disguised form" (as Markarian or Zwicky galaxies with their designations), some data about HI emission were obtained by the French team Heidmann, Bottinelli, Gougenheim, Balkowski (Bottinelli *et al.* 1973a, 1973b and Heidmann 1973).

Considerable additional bibliography concerning the physical observation of galaxies included here may be obtained from Brosche *et al.* (1974) and from MCG.

Speculations about interacting galaxies in corporae must take into account the fact that they do not favour clusters (that is, they are not chance encounters) and that relative to all galaxies, their fractional contribution is 7% on the average (from 0 to 30%).

Statistics must be based on reliable magnitudes, and these are lacking. Most of the objects presented have Zwicky *et al.* estimates; their limit is $15^{m}.7$. Apparently, our limit for interacting systems in MCG is lower.

For the nests and very close objects, partly due to their intricate nature and partly to the existence of only one photograph, often overexposed, our interpretation may sometimes be erroneous. Certain "nests" in the future may be reduced to a pair, or a pair may turn out to be a nest etc. We believe that the statistic is still valid: some objects may turn out not to be interacting, while many overexposed images may belong to complicated systems. To have a clear idea how necessary it is to have much different exposures and how difficult it is to understand the true structure of a particular object we draw attention to plate 26 – figures 123 and to plate 57 no. 783.

Radio observations of interacting galaxies are rare. Occasionally, they were observed amid normal galaxies. Wright (1974) has more extensive observations. Heeshen and Wade (1964) detected radio emission exceeding 0.3 x 10^{-26} Wm^{-2} Hz^{-1} at 750 and 1400 MHz from 7 of the 24 interacting systems. Caswell and Wills (1967) identified several of the 4C radio sources as interacting systems. Allen *et al.* (1973) investigated nine interacting systems at 1400 MHz with high resolution. For six systems they found the emission to be localized in the nucleus of one of the components. More variegated results upon the localization of the emission were obtained by Burke and Miley (1973). Their results are reproduced in the atlas. Sulentic and Kaftan-Kassim (1973) investigated six close groups of galaxies with the giant Arecibo telescope at frequencies from 318 to 606 MHz. In NGC 379/388 and Stefan's Quintet they found strong radio sources. They concluded that the lack of excess of a radio emission in young groups of galaxies is hard to reconcile with the ejection hypothesis. The radio maps around five peculiar spirals shown by Arp (1972), form a separate class from these observations: he finds a higher frequency of radio sources near such galaxies.

Wright (1974) made the first more extensive specialized observations at Parkes at frequencies of 2700 and 5000 MHz. He observed 44 southern systems brighter than 14^{m} from our Atlas I with the 64 m telescope.

Radio emission was detected from 26 systems. For comparison, Wright observed 240 normal bright galaxies. He constructed radio spectra and studied the results from different points of view. Wright concludes that the fraction of radio-emitting galaxies is somewhat greater for interacting systems than for the normal ones. Their relative frequency may be as great as 2, but he concludes: "there is no evidence to suggest that the interacting systems are in any way abnormal with regard to their radio properties ... in agreement with the ... previous investigators (Purton and Wright 1972 and Allen *et al.* 1973) and ... deformations ... do not arise from violent nuclear events ...".

We do not know whether somebody has suggested that the violent nuclear events are the cause of galactic disturbances in pairs. We do not deny the existence of tides, but it will be shown that the existing models considered in the tidal theory do not suffice to explain all cases observed. On the other hand, the interacting galaxies present a variety of systems possibly of different origin and age. Even if on the average they do not greatly differ from normal galaxies, this does not mean that they do not deserve special attention. Their study is most important for understanding the evolution and origin of galaxies in general. Furthermore, it is necessary to find out which variety of interacting galaxies is more frequently connected with radio emission. For example, we should expect that those with Seyfert spectra would show larger radio emission. Below is given the list of systems with radio emission measured by Wright at 2700 MHz, their flux expressed in 10^{-26} Wm^{-2} Hz^{-1} units.

MCG	S_{2700}	MCG	S_{2700}	MCG	S_{2700}
4–29–6, 7	250	2–29–19, 20	320	–1–3–21, 22	[670]
4–38–22	<50?	2–32–64, 65	160	–1–36–3, 4	100
3–27–15, 16	70	2–32–151, 152	84	–1–58–9, 10, 11	[180]
3–30–37, 39	[70]	2–33–1, 2	53	–2–9–11, 12	90
3–33–1	[1800]	1–4–52	100	–2–33–50, 51	4500
3–40–5, 6	65	1–6–3, 4	500	–3–31–7, 8	120
3–40–38, 39	[260]	1–59–80, 81	140	–3–31–14, 15	400
3–59–38	<50	0–35–15, 16	41	–7–22–10	420
2–5–36, 38	[320]	0–59–46, 47	75	VV 297	70
		0–60–17, 18	180	VV 304	73

The following 8 interacting galaxies were found to have Seyfert spectra:

VV 144 = 9–19–76 minichain (plate 23)
VV 150 = 9–19–111 minichain (plate 21)
VV 209 = 3–27–15, 16 in a pair, plate 17 (NGC 3227)
VV 220 = 3–41–104 chain IC 1182 (plate 23)
VV 285 = –2–7–35 deformed ring (plate 60)
NGC 1410 = 0–10–12 starlike? (plate 52)
I Zw 1 $0^h51^m.0 + 12°25'$ starlike in a pec. halo
VV 517 = I Zw 96 with a thin long jet.

The last three were recognized by Sargent (1970). The last one with faint forbidden emissions has no visible hydrogen lines and may be of Seyfert type. The photographs of the two preceding were published by Sargent (1970).

We have tried to arrange the images in plates illustrating the definite types or events in order to present the fragmentation phenomena. Thus, we have the sequence:

	Plate
Strong asymmetric, peripheral distribution of the HII regions	1
Large inner subsystems	2
Radionests of spherical galaxies	3

Since the objects and their photographs have various sizes, and since there is only a limited number of objects of a given definite kind, etc., it was not possible to arrange the images in the plates strictly as we would have liked. Some objects equally well represent the two different features and therefore they were placed into two plates. In dealing with several thousands of prints (different versions and stores included) some lapses resulted: a given object occasionally received two different numbers, or one number was given to two different objects, which were then distinguished by an index.

The manipulation of the photographic material was made by the aid from the photographic laboratory directed by Dokuchaieva, and her collaborators Zaitzeva and Trubinsky. We received inestimable aid in the reproductions and preparation for print of the Atlas from our collaborators Arkhipova, Savelieva, Noskova and lastly, particularly from my wife Vorontsova-Velyaminova. I thank them all heartily for their immense labour. I am also much indebted to amiable encouragement and help from Heidmann of the Paris Observatory.

FRAGMENTATION OF GALAXIES AND INTERACTING GALAXIES

It is well known that large systems contain the smaller systems which were hence formed there: irregular clusters, HII regions and globular clusters. It is less known that there exist much larger inner systems comparable to the dwarf galaxies and even comparable to the systems themselves. There are common double galaxies of various and of equal sizes, connected by filaments (bridges) and in contact, even interpenetrating. There exist satellites of various masses and at various distances up to contact. There are intergalactic clusters which could be members of our Galaxy, but may also be stray objects, or may belong to another smaller galaxy. There is therefore a complete spectrum of mutual distances, and of relative sizes of companions and inner systems. Such a situation could easily be due to fragmentation. Larger and more massive objects are formed less often. It is easy to believe that, at least in part, the smaller systems originate at the expense of the larger ones. There exists the most feasible hypothesis of creation of very close binary systems by fission. The fragmentation of large gaseous masses is universally accepted, although no clearly pertinent facts have been observed. Stellar systems are often considered as liquid bodies or as gaseous masses. This meets no objections. Why then should they not undergo fragmentation in their present form at our epoch of development in Metagalaxy? This concept not only easily conforms to the picture sketched above, but also has observational confirmations.

Smaller inner systems are more common. It is evident that systems which are close to the periphery of the massive system have a better chance of moving away or of acquiring a highly eccentric orbit. Perhaps in most cases there is no question of instability. If a peripheral object recedes to a distance comparable to the diameter of the parent galaxy, it will appear to be an independent, intergalactic entity. Our plate 1 shows interacting and single galaxies with many HII regions; as well as being very crowded, they are on either side of the edge of the corresponding galaxies. In the same way as peripheral globular clusters, some of these HII regions can acquire a velocity exceeding the circular one, sufficient to make of them the intergalactic cluster or the isolated HII region studied by Sargent and Searle (1970). The latter objects I Zw 0930+55 and II Zw 0553+03, with diameters of 246 and 147 pc and $M=-13.8$ and -11.8 respectively, are versions of dwarf irregular galaxies or companions. Inside larger galaxies, such subsystems were studied by Ambartsumian and his colleagues (1963) under the name of superassociations. They found superassociations up to $M=-17$! 30 Doradus in the LMC is an HII region (with many hot stars) 600 pc in diameter. It equals the HII complex in M101 (Sandage and Tamman 1974), where Allen (1973) finds an HI complex 1500 pc in length to be coinciding with the optical condensation (see plate 15 here). In NGC 2535–6 we have two gigantic HII regions, the larger being nearly 300 pc long (Vorontsov *et al.* 1974b). It can be seen plainly in the Hα photograph by Arp (1970). This feature cannot be due to distortion produced by the Hα camera, because from the same photograph many other HII regions, many times smaller, are seen to be perfectly round. Our plate 2 shows various forms of inner systems comparable in size to the principal one, and also near to the periphery or on the verge of separation.

It would therefore appear that the peripheral clusters, superassociations and HII regions can separate and gradually recede from a large system, thus transforming into the category of satellites, intergalactic dwarf irregulars, dwarf ellipticals, isolated HII regions etc. To them may be related the intergalactic HI clouds with masses of 10^6–10^7 $m_\odot$ recently reviewed by Davis (1975). Such a process may well be responsible for the saturation of the Local Group of galaxies and of the other groups of large galaxies by all kinds of dwarfish systems. It would be expected that in the initial phase of separation the companion might drag with itself some filament from the matter belonging to the principal system. This phenomenon of a decaying filament, a kind of umbilical cord present at the birth of a satellite by fragmentation, is seen in plates 4–7 in the form of satellites "on a stem". Also noteworthy are the forms reminiscent of Jeans' a p i o i d s – theoretical figures of rotation of fluid bodies (plate 4, figure 369 and perhaps others on plate 6). The connecting filaments in this case cannot be produced tidally, since the satellites have negligible masses and have no tails. The twin dwarf satellites, both on one side of the galaxy, show how little we know still of the nature of galaxies and of their evolution.

Particular ways in which satellites can be formed are exhibited by systems of the M 51 type (plates 8–18). The satellite, which ranges from a considerable to a most dwarfish size and mass ripens at the tip of one, or two (!) spiral arms and then gemmates with a moderate velocity, becoming finally a detached companion. Details of this, as well as of the other particulars of our concept of fragmentation, are given in the appropriate places. Of course, satellites can also form in other ways.

How does the inner subsystem acquire a velocity corresponding to a larger, more eccentric, or even parabolic orbit? Two answers can be given. We recall that the Ambartsumian's hypothesis of ejection of satellites and companions from galactic nuclei with velocities of thousands kms^{-1} requires unknown sources of energy. The Heidmann and Kalloghlian (1973) hypothesis for the formation of double Markarian blue galaxies involves average velocities of 1000 kms^{-1}. We suppose that the gemmation of a ready-made small mass companion can proceed quite easily at velocities of a few dozen kms^{-1}. However, one should obtain from observations what these velocities of gemmation really are. Unfortunately we expect them to be so small that with the present accuracy of redshift measurements, they can hardly be determined reliably.

Now, deviations of up to 100 kms^{-1} from circular motion are often recorded among the stars and gas of galaxies. Radial velocities of comparable size have also been recorded along the bars. Objects accelerated by some cause, by a neighbouring galaxy or by a nearby compact mass, to some 100–200 kms^{-1} serve our purpose when the circular velocities are not much larger than these. In the case of a mass rotating with the primary at a distance equal to the radius of the spiral system, the mechanical and magnetic torques will induce the mass to recede with the above velocity during a cosmogonically reasonable period. This has been shown by Starr and Newall (1963) and by Hoyle and Ireland (1960). If the ejection of relativistic gases with masses $\sim 10^7$ $m_\odot$ with velocities of over 3×10^4 kms^{-1} are considered to be reasonable, the corresponding kinetic energy suffices to provide to separate the halves of the dividing galaxy, of a mass say $\sim 10^{10}$ $m_\odot$ with velocities in excess of 10^2 kms^{-1}. Even lower values of the energy needed for fragmentation are sufficient.

Apparently the cases of breaking apart of the galaxies into two we observe in the figures 246 and 30 (plate 1) 313 (plate 2) and 42 (plate 66).

The rupture seems to be recent and followed by some twisting. Note that there are traces of the bridges but no traces of the tails, which as the tidal theory predicts, must be more frequent than the bridges in the case of a temporary close passage of a companion or of a chance galaxy.

In plate 3 we meet a giant radio dumbell. Before the tidal theory of the formation of intergalactic bridges and tails can be posed the question: why pairs of similar galaxies (only ellipticals?) are connected by bright bridges but show no tails? This is the same phenomenon as in the case of small companions on plates 4–7. Again fragmentation of a single galaxy by rotation or otherwise is in these cases more probable than the close encounter of two galaxies in a very eccentric orbit. The presence of strong emission is considered as an indication of an early stage of evolution. In Atlas I we gave pictures of many dumbells. We have many more in store. The same plate 3 shows a radio nest of spherical galaxies. It has not been recognized that it is a fine example of a nest, and perhaps the nearest to us. With an appropriate exposure three of the four elliptical-like galaxies here overlap each other. It is a typical nest. It is the central D galaxy in a cluster. So it is possible that QSS were the progenitors of clusters of galaxies, but at the present time they produce the groups of galaxies (Vorontsov 1969). The multiple absorption lines belonging to the components could well be the result of fragmentation. NGC 6166 is then the later stage of the further evolution of a QSS.

In the realm of stars multiples are less frequent the larger is their multiplicity. Similarly among the galaxies there are many doubles (dumbells in the early phases of fragmentation), often radiogalaxies (if of large mass). Triples and multiples are rare objects. In plates 19–25, we show long formations in all stages of gravitational (?) instability leading in most cases to "minichains" (which consist of three galaxies), which in the early phase are connected by bright blue bridges. But these are real chains, more interesting than the hypothetical chains of many galaxies, arranged in zigzags – apparently flat systems seen edgewise (at best).

From minichains we pass to other types of nests, which more often than not are only mininests, of 3 galaxies. These are shown in plates 26–58, merging with minichains in different stages of disruption and dispersion. They probably pass through the stages of Seyfert and Stefan groups. The latter are the most dispersed of the nests which interest us, but they are the tightest among the groups studied already. The close encounter of two galaxies is not very probable. The exact interpretation at the encounter of 3 or more galaxies, many cases of which are presented here, is a sheer impossibility. The tidal effects here may arise once only during the mutual separation of the components.

Plates 59–63 show some enigmatic systems – thin elliptical rings with a galaxy nearly at a ficus, rings which are nearly empty inside (plate 60), comet-like galaxies comparable to the radio comet-like galaxies etc.

In plates 64–68 we collect some of the forms still unexplained by the tidal theory: double bridges, very thin bridges (hardly ensuing from edgewise projection, broken bridges, tails without a perturbing body (ejections?), asymmetric mists, though the asymmetric enveloping halo is also beyond the tidal theory.

The general idea of fragmentation of galaxies was first advanced by Ambartsumian (1958). Sersic (1968), on the mass-radius diagram has found two groups of E galaxies which he considered to be a result of fragmentation, and he presented a model of fragmentation by explosion. He discussed the energies involved.

He compared the results to observation. His work was criticized (Genkina 1969). In an important paper, Karachentsev and Terebizh (1970) presented the numerical statistical confirmation of the probability of fragmentation of galaxies.

Ambartsumian believes that fragmentation begins by a splitting of the nucleus. We have given (Vorontsov 1966) a list of the nuclei which on the "Palomar Sky Atlas" appear to be double or triple. On a larger scale, the same phenomenon was recently demonstrated without comments by Osmer *et al.* (1974). Some of their double nuclei are shown in figures 824–826 (plate 66). Can they be ascribed to the chance penetration of some outer object into the heart of a galaxy? We doubt it.

A preliminary discussion of our ideas we presented in extenso (Vorontsov 1974c and 1974b).

We suggest the following programme of investigation:

1. To determine the *UBV* magnitudes of the components, or at least the reliable photographic ones. The magnitudes of close companions may be estimated relatively.

2. To determine the redshifts of many objects of various type and to compare the general trends to those found by Sargent (1970, 1972) for the compact and Markarian galaxies.

3. To study the relative motions of the components, especially in nests and chains. Galaxies of the lesser

central condensation are studied the least. Variable exposures for direct photography must be made on a large scale. Steps in this respect were recently undertaken by Casini and Heidmann as well as by the observers at the 6 m telescope of the USSR.

COMMENTS TO THE PLATES AND IDENTIFICATIONS

Plate 1 Peculiar Distribution of Large HII Regions

357 9–20–89 = NGC 4088 = A 18; $11^{m}03$, $V_0 = +812$ (R), $B-V=0.67$, $U-B=0.08$. Outer part of one arm apparently receding. The outer figures represent large HII regions concentrated at one side (VV 331, 272, 266), or on the opposite sides (VV 142, 356, 246, 30). The latter two, as well as VV 42 on plate 66 and 313 on plate 2, plainly show that they are ruptured, receding systems, but not accidental encounters, since the structures of the components are identical to the primary. HII regions are on the periphery and on the sides facing each other. No curved bridges, no tails predicted by the tidal theory. Short bright spiral arms of 246 exist from the beginning. For the idea that the regular massive arms are generally not of tidal origin see Vorontsov (1975d). At the IAU Symposium no. 58 a question arose whether the "bridges", or filaments between the galaxies, show young stars. This would be important for the discussion of the role of tidal events. No clear answer was given. However we can answer definitely that the structures of connecting filaments vary as much as the structures of spiral arms themselves – from smooth to patchy, presumably from red to blue.

In figures 246, 51a (plate 34, strong radio emitter according to Wright (1974)), 150 and 21 (plate 64) HII regions (ergo the hot, young stars as well) are seen in the space between and on the opposite side, or in the tail.

331 0–8–47, 48 = VV 331 = A 118 = NGC 1143, 44; total $V=12.43$. The gigantic loop of gigantic HII regions cannot be due to a perturbation by the elliptical galaxy, but must come from mixing with another spiral (the overexposure makes the picture confused). Total $B-V=0.94$, $U-B=0.30$. $V_0 = +5814$ (FV).

272 –2–1–25 = VV 272 = A 144 = NGC 7828, 29; 14^{m}. The spiral or a pair of galaxies are perturbed by a compact elliptical galaxy.

266 6–28–39 = VV 266 = A 265; 17^{m}. Very peculiar. Possibly consists of two bodies.

142 6–32–2 = VV 142 = A 69 = NGC 5579, 5580; $14^{m}7$. In this system a group of large HII regions at the upper left hand corner, and a larger group below at the left, are remarkable peripheral objects likely to transform into numerous irregular companions or "isolated HII regions".

356 9–18–8 = NGC 3310 = A 217; $11^{m}0$, $V_0 = +1075$ (R). First published and discussed by Vorontsov *et al.* (1964, 1966). Two large groups of big HII regions on opposite sides. At one side, there is a long arc transfixed by a jet which emerges from the location of the HII regions. Here, this bow and arrow is underexposed. Rotation and mass studied by Bertola (1964), then by Walker and Chincarini (1967), who ignored the former author. They published an excellent series of photographs with exposures from 5^{s} to 10^{m} $M_{ph} = -20.0$.

Another view of 356 is given on plate 7, labelled no. 406, where another peculiar feature is apparent.

246 6–24–17, 18 = VV 246 = A 270 = NGC 3395; $12^{m}1$, $V=12.17$ (principal) NGC 3396; $12^{m}6$, $V=12.51$; for the brighter $B-V=0.31$, $U-B=-0.25$; for the fainter $B-V=0.41$, $U-B=-0.21$; $V_0 = +1607$ (R, O) and +1635 (R, O), respectively. Studied by d'Odorico (1970) who gave emission intensities. Dust in the nucleus of the primary, rotation, $m \sim 1{,}2 \times 10^9\, m_{\odot}$. Companion does not show rotation but is orbiting. Compare to VV 30.

30 7–26–13, 14 = VV 30 = A 269 = NGC 4490; $10^{m}09$, $V=10.21$, $V_0 = +632$ (B. R, G), $B-V$ 0.38, $U-B=-0.16$ (Primary); NGC 4485; $12^{m}24$, $V=12.03$, $V_0 = +838$ (R), $B-V=0.34$, $U-B=-0.23$. There are other measurements (Karachentsev, in preparation). Bertola (1968) finds the system to be unbound. Relative velocities $\Delta V_0 = 155$ found by Page (1970) and confirmed by Demulin at a distance of 200″ exceeds the escape velocity. Bertola found $m = 1{,}5 \times 10^9\, m_{\odot}$ and m: $L=0.4$, $M=-19.7$ and -17.6. VV 313 (plate 2) is similar.

357 9–20–89 = NGC 4088 = A 18; $11^{m}03$, $B-V=0.67$, $U-B=0.08$, $V_0 = +812$ (R). A large chunk of her arm apparently is receding. 360 in the plate 2 is similar, as well as figure 42 in the plate 66, though the latter is a dwarf.

Plate 2 Large Inner Subsystems

313 1–33–22, 23 = VV 313 = A 277 = NGC 4809 (primary); /$13^{m}_{.}1$/, $14^{m}_{.}8$, 4810 /$13^{m}_{.}2$/, $14^{m}_{.}9$, CI = 0.46, belongs to the group of torn galaxies 30 and 246 of plate 1. NGC co-ordinates erroneous. $V_0 = +854$ and +794 (R), +803 (Page 1970) for the component and $\Delta V_0 = 57$. The larger may be composed of two bodies – VV 313 would then be a nest. Many HII regions, short bridge of hot stars.

363 9–19–47 = A 27 = NGC 3631; $10^{m}_{.}91$, $V_0 = +1162$ (R), CI = 0.46. At the right is a fine superassociation and a straight long subsystem diverging from the spiral arm. The first one is about 44″ or 5000 pc in diameter.

358 4″ per mm. 12–10–9 = NGC 3027; $12^{m}_{.}31$, $V_0 = +1226$ (R). Only one arm enormously developed. Consists of large HII regions. Asymmetry is dangerous for stability. The arm can separate from the main body.

359 4–55–17 = A 28 = NGC 7678; $12^{m}_{.}7$, $V_0 = 3680$ (R), V = 12.58, $B-V = 0.65$, $U-B = 0.02$. One enormously developed massive arm might be considered as another galaxy if it was not exactly matching its spiral.

360 8–17–70; $14^{m}_{.}9$. Massive link of one arm is severed and is apparently receding from it, which makes the object similar to 357 (plate 1). Was recognized by us as peculiar or interacting and as such described completely in 1962 in MCG Vol. I; Arp (1969) reproduced its photo on a larger scale (presented here) typically for him avoiding to consult MCG. Here 1 mm = 2.4″.

362 1–6–62 = A 10; $14^{m}_{.}2$. An enormously developed massive part of the ring with an embryonic spiral may lead to nonstability.

361 –2–3–63, 64 = A 59 = NGC 341; 13^{m} and 15^{m}. Apparently SBa of the M 51 type. Companion just tearing itself away. Both galaxies are of similar texture. It is doubtful if the companion can be an E galaxy. Unusual condensation at the base of another arm. No other objects of this kind were found anywhere along the arm.

Plate 3 Radio Nests of Spherical Galaxies

General Three or more galaxies nearly touching each other we have called "nests". Zwicky adopted this term. Many of them were shown in Atlas I, but very few were studied. Their extreme importance is still not recognized. Some astronomers obstinately continue to call them irregulars! However, irregular galaxies as a class are only of moderate luminosity and dimensions.

364 7–34–60 = NGC 6166; $12^{m}_{.}79$, the brightest member of the cluster A 2199 is a well known radio galaxy 3 C 383, its radio luminosity being comparable to that of Virgo A. 364a gives its position in the cluster, b, c and d frames, (scale 1 mm = 5″.7), obtained by Minkowski (1961) and the Burbidges (1962), using decreasing exposures to show the structure of 364. Most interacting galaxies, especially nests, should be studied in a similar way. 364 is a "mininest" composed of three galaxies. Minkowski (1961) studied this object photometrically and spectroscopically and states: "The bright nuclear region typical for galaxies of types E and SO is absent. Traces of structure or dust in the central mass on the southern side. It has a semistellar nucleus that emits moderately strong [OII] lines and therefore is bluish. Otherwise the spectra and absorption are normal". Minkowski holds the remote object to be the fourth member of the group and gives the following data, corrected for absorption and for solar motion. Data reduced to $H = 50$ kms^{-1} Mpc.

Component	Aperture	B_0	$(B-V)_0$	V_0 kms^{-1}	M_B
All	1′	13.24	+0.85	–	–
All	2′.5	12.79	+0.83	+9082	–22.9
A		13.1		+9480	–22.6
B		14.5		+7960	–21.2
C		16.0		+10050	–19.7
D		17.5		–	–18.2

The main members are supergiants with completely overlapping atmospheres, especially if taken up to the surface brightness of 27.5 mg per 1″ square, not to 25^m as here. From the virial theorem, the mass of the system is $3 \times 10^{13}\ m_\odot$ and $m: L = 7.5$.

The nest 364 must be younger than the other galaxies in a cluster. The central supermassive object has undergone fragmentation. Strong radio emission is a complimentary indication of the younger age.

We stress that E like galaxies, which seem somewhat irregular as a consequence of their tight multiplicity, and surrounded by an unusually large halo, were discovered by us (Vorontsov and Rrasnogorskaya 1961) while compiling the MCG. They were clearly described there and it was shown that many of them (not all!) are the brightest, central objects of clusters. There exist isolated objects of this type.

This discovery was falsely and repeatedly ascribed to the Matthews, Morgan and Schmidt (1964) (in fact, to Morgan). Although we did remonstrate (Vorontsov 1965), the unjust wrong statement lives on. In fact, Morgan only designated the type of galaxies, which we have discovered, by cD thereby causing confusion, because he had previously used D for the disc galaxies. mE (multiple E) would be a better symbol.

In MCG it was stated that 2–7–17, 2–27–4, 2–29–20, 2–58–21, 2–59–35, 1–39–9, 5–38–5, 3–41–78 and 6 others belong to the same type. We showed that, even by the eye estimate, with $H_0 = 75$ kms^{-1} Mpc^{-1} NGC 7469 has a diameter of 60 000 pc. NGC 1275 possibly is also a very young tight nest of spheroidal peculiar giants. At the 1973 IAU Symposium it was said that the nest NGC 6166 could have been formed in the cluster by captures! Nobody recalled that we showed in MCG that such nests (cD) also exist as isolated entities, consequently the capture theory is as unvalid here as it is in the case of numerous isolated nests!

201 –2–33–50, 51 = VV 201 = NGC 4782–3; /$12^m.8$/ and /$13^m.2$/, $V_0 = +3853$ (R, P) and $V_0 = +4502$ (R, P), $M_p = -22.4$ and -22.0 respectively. Velocity difference measurements in good agreement by Greenstein (1961, 1962) and Page (1958) $\Delta V_0 = 650$ kms^{-1}, the first galaxy being the slower. This is a strong radio galaxy 3 C 278. The Burbidges and Crampin (1964) carried out photographic photometry. 201b – isophotes, 201c – luminosity profile along the connecting line. (One is reversed relative to the other). The brighter component is much less condensed, the isophotes are distorted and compressed due to interaction and possible rotation. There is an inner Lagrangian point of the zero velocity surface. The authors evaluate from these data that $m_1 : m_2 = 1.44$ and $L_1 : L_2 = 1.45$, $m_1/L_1 = m_2/L_2 \geq 6.2$, where the index 1 refers to NGC 4182. $m_1 + m_2 \geq 5 \times 10^{11}\ m_\odot$ with H = 75 kms^{-1} Mpc. The most probable mass, due to the unknown inclination of the system, is five times larger (Greenstein 1962). There must be an exchange of stars and some losses from the Lagrangian points.

201 is a prototype of the “Dumbell” forms frequent among radio galaxies. NGC 750–1 and other dumbells are collected in our Atlas I, but are not radio galaxies. It seems that 201 is also a nest. At any rate our enlargement from the “Palomar Sky Atlas” shows a small companion attached to the large elliptical galaxy by a stem. (Two other objects nearby are stars). In the plate 66 no. 42, 818 and 820 are in a stage of fragmentation, somewhat earlier than VV 201.

Using the statistical methods of Holmberg and Page, Jenner (1973 and 1974) estimated that the mass of a component in the “multiple” and “Dumbell” systems is $1.1 \times 10^{13}\ m_\odot$. In fact he studied only doubles, probably loose pairs, not multiple galaxies. The real nests, close multiple E-like galaxies, discovered by us still await a detailed study.

Plates 4–6 Satellites “on a Stem”. Bottle Forms

General Plates 4–6 show dwarf satellites connected to the primary by a short thin filament, mostly normal to the surface of the latter. This recalls a mushroom sitting on its stem. It is noteworthy that most primaries appear to be spheroidal, not spiral. Typical objects are 365, 367, 347, 368 (upper left corner), 376. In 366, 371, 383 the satellites appear to have broken the link and to be receding. None of these 25 companions show a tail, although according to the tidal theory, tails are easier to form than bridges. This, together with their insignificant masses, makes it improbable that the stems are produced by tides.

Here again, it is more probable that the phenomenon is due to the viscosity of galactic substance in the process of gemmation, or to ejection of satellites.

Of exceptional interest is 369, which recalls us of the famous figure of rotation of a liquid body – the apioid, a pear-shaped body studied by Darwin and Jeans. It was supposed that the rupture of such a rotating figure might have created the Earth-Moon system and close binaries. Bottle forms may represent the earlier stages of this figure. Rotation of the companions could produce the longer curved filaments and filaments oblique to the surface of the primary. Objects 386, 390, 391 are probably triple. Enigmatic are fan-shaped primaries 365 and 347. The latter, interacting with a compact E galaxy on the further side, has a fan of filaments such that each is terminated by an HII region.

Plate 7 Ejection of the Twin Satellites

The 15 cases in plate 7 present a puzzle: twin blue satellites ejected or gemmated. 392, 393 and 396 may be the disruption phase of the connecting link. In 404, the two objects appear perfectly stellar. However, their unmistakable connection with the large galaxy makes probable their identification with the satellites. Similar twin ejections appear in NGC 3310 (figure 406) and in the nuclei of 30 Doradus in the LMC (figure 399) and of M 51 (figure 406). The latter two are reproduced from the blue photographs by Peimbert (1974) and by Benvenuti *et al.* (1973).

No. 395 can be compared with its red image in plate 38.

Identifications for Plates 4–7

365 13–9–41; 15^m.
366 1–33–20 = NGC 4765; 13^m.
367 4–28–59; $14^m.1$; $V_0 = +3600$ (AES 1976).
347 2–4–21, 22 = VV 347 = A 119; 15^m and 15^m.
368 VV 679 = 11–22–46; $14^m.2$; $V_0 = +4457$ and $+4630$ (Kopilov *et al.* 1974*).
369 5–33–12; /$14^m.4$/, 15.6.
370 0–41–8; $15^m.4$.
371 4–34–31; $14^m.7$.
372 –3–57–15; 14^m.
373 2–25–56; $15^m.3$.
374 1–38–25; $15^m.1$.
375 –4–5–4; $15\frac{1}{2}^m$.
376 –6–47–11; $15\frac{1}{2}^m$.
329 0–59–46, 47 = NGC 7679, 7682 = Mrk 534 = A 216; $13^m.2$ and $14^m.0$, $V_0 = +5378$ (R, T), $+5350$ (R,T); $\Delta V_0 = 28$; $V = 12.96$, $B-V = 0.58$, $U-B = -0.01$.
377 2–4–11; $15^m.7$.
378 2–31–29; $15^m.1$.
379 –2–6–20; 15^m.
380 4–38–38 = NGC 6075; $15^m.3$.
381 –1–30–10; $15^m.5$.
382 2–4–10; $15^m.7$.
383 1–8–39; $15^m.3$.
384 3–31–20; $14^m.4$.
385 9–20–47; 17^m.
386 –2–3–68; 15^m.
387 10–11–56; 15^m.

*No. 368 relates to the companion on a stem (at the left). On the list 45 no. 679 relates to the whole group.

388 9–15–46; 16^m.
58 13–7–30 = VV 58 = A 207; $15^m.4$.
389 4–41–14; $15^m.5$.
390 –2–56–21; 15^m.
391 4–6–44; $15^m.7$, $V_0 = +9867$, (Sargent 1970), abs. H.
392 –4–32–52; 16^m.
393 3–27–64 = VV 755; $15^m.5$ and $15^m.5$.
394 9–23–30; 15^m.
395 –2–3–70 = VV 602; 15^m.
396 1–27–15; 14^m.
397 4–36–9; 15^m.
398 –4–4–5; 15^m.
399 30 Doradus.
400 4–55–29; $14^m.5$.
401 4–26–32; 15^m.
402 9–19–34, 35 = Mrk 39; $15^m.2$ summarily. For 34 $V_0 = +10730$ Hyd. abs., em. 3727 A; for 35 $V_0 = +10960$ dS1e (Sargent 1970). $M = -20.9$, $D = 23$ kpc, $m \geq 3 \times 10^{11}$ $m_\odot$, m: $L \geq 9$ (Heidmann and Kalloghlian 1973).
403 M 51 nucleus.
404 4–41–11; $15^m.3$.
405 6–48–10; $14^m.9$.
406 9–18–8 = NGC 3310 = A 217; 11^m, $V_0 = +1090$ (R). On plate 1 it is = no. 356 – another appearance.

Galaxies of the M 51 Type – Plates 8–18

General We were the first to show that systems with a satellite at the end of one of the spiral arms, such as M 51, are not due to chance (Vorontsov 1957). We also gave this as the evidence that the intergalactic filaments, like the spiral arm, consist of stars and gas and are not purely gaseous, as was supposed at the time. An important contribution to the study of such systems was given by the spectroscopic work of Arp (1970), who however believes that the companion is violently thrown from the nucleus. The role of the spiral arm in his scheme is not clear. Our present concept is that the companions are somehow quietly formed at the ends of spiral arms and at a later epoch the smaller stellar system gemmates from the parent galaxy with a moderate velocity of several tenths kms^{-1}. It drags with it a part of the material of the arm resulting in its straightening before the final break. This sequence can be easily visualized by comparing the objects presented here, more particularly in plate 14 and in Vorontsov (1974c). We have shown (Vorontsov 1975c) that 160 systems of the M 51 type have in the main, satellites of the same gaseous-stellar structure as that of the spiral arms. They resemble irregular galaxies (or HII regions or superassociations) of various dimensions. They are not of the E type. This is evident from our plates. In most cases, the masses of the satellites are so negligible that it is absolutely impossible for them to produce by tidal mechanism the spiral arms of the large galaxy. Chance projection of satellites may only on rare occasions coincide with the tip of a spiral arm even in the case of tidal arms. A detailed investigation shows that even the special case of M 51 presents doubts in this respect (Vorontsov 1975b). This latter work has led to the discovery that straight streams of stars and dust lead to the companion at right angles to the northern spiral arm, and to the discovery of absorption possibly produced by the companion on the northern part of the spiral. This feature and other examples of straight streams of matter leading to the companion, effects not anticipated by the tidal theory, are shown and commented on plate 12. Plates 15 and 16 present examples of systems where both spiral arms appear to have companions on their tips. This completely excludes the possibility of chance projections, and confirms that the formation of a satellite at the tip of a spiral arm is an intrinsic phenomenon. About 7% of spiral arms are favourable for the development of such condensations. Other tidal models are compared to the photographs on plate 58.

Tidal interactions must of course exist, but perhaps not exactly in the way in which they have been modelled. However they must be associated with companions (seldom stray galaxies) of comparable mass. Perhaps the cases such as these are in plate 17. Only among these relatively bright and large companions do we meet with elliptic galaxies. We are faced possibly with a problem analogous to that of ascribing to a particular lunar crater a meteoric or volcanic origin. It is difficult to draw a borderline between the tidal and non-tidal intergalactic filaments.

On plate 18, we have collected systems where relatively large single components do not apparently fit one of the above categories, and are peculiar by some twist of the filament attached. They seem not to be related to the system of spiral arms.

The particulars are given in the identification columns. Important comments are given to plate 12.

It seems to us that the perturbation produced by the companion of M 51 on the primary is evident in the slight change of curvature of the ends of its spirals. They deviate as would have deviated the streams of a liquid or an elastic band under perturbing force. The defect of the modern tidal models is to consider that mass probes revolve about the nucleus of galaxy without interaction. The viscosity of a spiral arm is not negligible. These models would apply rather to the still more distant parts of the discs where there is no compact spiral structure. There, the particles are not so strongly bound and form the straight bridges whose luminosity is well below that of the spiral arms. A 84 and A 87 may present a physical pair, but companions appear to be not connected materially with the primary.

Plate 8 Galaxies of the M 51 Type. I

407 1–60–37 = A 68 = NGC 7757; /13^{m}2/. Very rich with HII regions. Small spiral to the left is a chance projection. NGC 7756, 15^{m}1 at a distance 4$'$5 is a star.

408 1–37–12 = NGC 5619; /13^{m}7/, 14^{m}.

409 2–56–15; 15^{m}2. 3 chance stars.

410 –3–28–1; 14½^{m}.

411 –7–40–3; 14½^{m}. Companion is a binary.

412 1–37–24 = A 49 = NGC 5665; 12^{m}6. $V_0 = +2250$ (V). The starlike object is an HII region = companion on the tip of the spiral arm as shown by its spectrum. ΔV_0 of the companions is 60 kms^{-1}.

413 3–22–17 = A 58; 14^{m}9. Starlike object (upper right) connected to the spiral is also an HII region. $V_0 = +11265$ (A), ΔV_0 of the companions 84 kms^{-1}. Cases 412 and 413, where Arp (1970) has shown that the starlike objects at the tips of the spiral arms are small companions with the spectra of HII regions, are most important as indicating that these arms could not be formed tidally.

4 5–32–38 = VV 4 = A 36; 15^{m}5. SB with a double companion at the end of a single developed arm.

414 NGC 6786 (19^{h}12^{m}0 + 73°19$'$). Both galaxies 14½^{m} of the M 51 type. ($V_0 = +8260$ (K PrCh)).

415 –7–26–1, 3; 17^{m} and 16^{m}. "Syphon" has a companion at the end of a spiral arm to the bottom left, or it is a companion which gemmated long ago.

Plate 9 Galaxies of the M 51 Type. II

416 –6–27–18; 14^{m}. Photo by Sersic (1968).

417 9–22–32; 16^{m}.

418 7–27–12; 15^{m}.

419 –5–5–3; 14½^{m}.

420 –2–12–6; 14½^{m}.

421 –2–22–26; 15½^{m}.

422 2–35–16; 15^{m}1.

423 –2–7–66; 14^{m}.

424 5–28–63 = A 305 = NGC 4017?; $13^{m}.5$.
425 5–5–36; $14^{m}.5$.
426 5–42–2, 3; $14^{m}.4$ (42–2 is larger. The smaller itself is an interacting pair).
427 7–32–10; 14^{m} (1 mm = 4″).

Plate 10 Galaxies of the M 51 Type. III

By analogy with 412 and 413 (plate 8), the starlike objects in 2, 428 and 28 may be components.
2 9–23–64 = VV 2 = A 45; $15^{m}.5$.
428 6–5–78 = II Zw 170; $13^{m}.1$ and $16^{m}.9$. Zwicky holds the object $16^{m}.9$ to be an elliptical companion.
429 1–29–5; $15^{m}.2$.
430 5–4–10, 14^{m}. $V_0 = +5969$ (KPCh).
28 –3–23–9 = VV 28 = A 7; $14\frac{1}{2}^{m}$.
431 1–31–40; $13^{m}.33$, C I = 0.56. In a pair with 1–31–41? Very peculiar. “Bar” seems to be a chain.
432 2–31–80, /$14^{m}.2$/, 15^{m}. Edge on.
433 2–2–26, 27, 16^{m} and 16^{m}. M 51 type is below.
434 –2–33–73, 14^{m}. Maybe it is a nest.
435 3–38–14 = A 47, $15^{m}.4$.
436 NGC 1313, $9^{m}.5$ $3^{h}17^{m}.6$. $-66°40'$, $V_0 = +47$ (R). Photo and photometry by Sersic (1968), $M = -18.7$, $D = 4.5$ Mpc, SN 1962.

Plate 11 Galaxies of the M 51 Type. IV

82 6–21–67 = VV 82 = A 63 = NGC 2944, $15^{m}.5$ and 16^{m}. Companion is Irr. May be rather a ruptured galaxy (as in plate 1).
298 3–34–12, 13 = VV 298 = A 57, $15^{m}.5$.
438 6–29–64, $15^{m}.4$. Faint ring is a defect.
439 12–8–13 = Mrk 12. Photo from Casini (1974). 13^{m}, $V_0 = +4100$ (Sr, D).
440 –7–47–28 = NGC 7552, $11^{m}.50$. Photo from *Handb. Phys.* **53**, 294 (1959). Peculiar nucleus. $V_0 = +1644$, $(B-V)_0 = 0.73$, $(U-B)_0 = 0.09$ (Shobbrook 1966). Early spectrum with emissions of Hand [OII]. $V_0 = +1689$ (R, C, E).
441 5–3–1, $14^{m}.1$ (1 mm = 4″).
442 3–43–10, $14^{m}.6$.
443 NGC 646, $1^{h}35^{m}.8$ – 65°09′, 15^{m}, $V_0 = +8060$, $\Delta V_0 = 107$ (Danziger and Schuster 1974). The arm connecting this spiral to the companion (to the extreme left) is very uniform and excessively faint, completely underexposed. Condensations in the arm as strong as in 438, 439. The authors hasten to relate the object to the tidal theory. However the relative surface of companion is only 2%, ergo its m is less than 2% of the primary! Condensations on the bright arm are comparable to the companion.
12 3–6–4 = VV 12 = A 56; $14^{m}.8$.
286 7–25–2 = VV 286 = A 62; $14^{m}.2$.

Plate 12 Galaxies of M 51 Type. V

1 8–25–12, 14 = VV 1 = A 85 = M 51 = NGC 5194,5; $8^{m}.88$ and $10^{m}.47$, CI = 0.53 and 0.98, $V_0 = +546$ and +552 (R). However in various sources ΔV_0 vary from 15 to 300! $B-V = 0.73$, $U-B = 0.06$.
1a Summary view from the Palomar diapositive printed by our method which compares inner and outer isophotes.

1b is the stream of stars and dust leading directly to the companion above. Was overlooked by everybody. **1c** is the structure of the centre of the SBO/a companion. **1d** is the tidal model of M 51 calculated by Toomre (1972). None of the filaments at the companion which are predicted by the theory are observed*, however the direct streams to it (which are not predicted) are observed. From **1a** it appears that it is rather the companion which absorbs the light of the "horizontal" (on the picture) spiral arm. Consequently the companion cannot be below the left spiral arm at the distance of 11 kpc, as claims the theory. The velocity field was studied by the Burbidges (1964), Tully (1972) and others. Tully declares the inner parts of the spiral arms to be primordial but the outer parts (of the same arms!) to be formed by the tides. Such is the strength of blind faith. Not only do unprejudiced observers not see here the two separate spiral systems, but theoretically it is more than improbable that the origin of the tidal arms would exactly coincide with the ends of the original arms. It can be seen that, as a rule, the tidal filaments are much more open and begin from arbitrary points of galaxies with no relation to original spiral system. The latter even often remains unperturbed: figures 301, 244, 209 (plate 17), no. 90 in Arp's Atlas etc. For detailed review of all data concerning M 51, see Vorontsov (1975b and 1975d). Other examples of direct streams between two galaxies are given below: objects 19 and 20.

19 9–22–101, 102 = VV 19 = A 239 = NGC 5278–9 = Mrk 231 = "Telephone receiver", total $13^{m}.6$, $V_0 = +7708$ and for the fainter 15^{m}, $V_0 = +7665$, $\Delta V_0 = 43$ (Page 1970); $V_0 = +7800$ and $+7500$ (ADEv), $\Delta V_0 = 300$. Spectrum d3e with bright Hα, Hβ, N_1, equiv. width (Arakelian *et al.* 1971). One particularly strong arm connected with a strong arm of the smaller galaxy which is wound in the opposite direction. However apart from this, a conical amorphous stream directly emerges from the "agressor" and connects it to the "victim" (Toomre's terminology).

20 1–59–47 = VV 20 = A 150 = NGC 7609; $14^{m}.5$. Here, the two small galaxies are in contact and let out only one tail perpendicular to the line which connects them. Besides, they cast a strong arc – "the curved bridge" toward the large E galaxy and, furthermore, – also a "straight thin bridge" directly to the latter.

444 13–12–26 = A 38 = NGC 6412; $12^{m}.19$, $V_0 = +1751$ (R), $V = 12.72$, $B–V = 0.67$, $U–B = -0.02$. One of the rare cases where the companion at the end of a spiral arm is also a spiral. Here, a chain of HII regions encircles the massive condensation thus forming a small spiral ripening at the periphery of the larger one and liable to gemmate.

445 $1^{h}16^{m}.5 + 12°13'$ = A 88; 16^{m}. Another example: a later phase of the case just described. Small spiral at the end of a large spiral arm.

89 10–24–107 = VV 89 = A 32; $14^{m}.3$. A pair perhaps similar to the ruptured galaxies in plates 1, 2 and 11.

Plate 13 Galaxies of the M 51 Type. VI

VV 5 and VV 9 are shown in the blue (a) and in Hα light (b) (Arp 1971) and no. 446 in blue (a) and in red (b) light.

446 –3–37–12 = NGC 5595–5597; $12^{m}.4$ and $12^{m}.6$ or /12.4/ and /13.3/, for the brighter $V = 12.50$, $B–V = 0.56$, $U–B = -0.17$, $V_0 = +2550$ for –3–37–1 (AES 1976).

9 4–20–4,5 = VV 9 = A 82 = NGC 2535–6; $13^{m}.5$ and $14^{m}.8$, $V_0 = +3961$ and $+3957$ with $\Delta V_0 = 4$ (Page 1970), but Arp (1970) has found $\Delta V_0 = 90$ with a dispersion ± 90, $V_0 = +4110$ and $+4200$. Other measurements are given by Karachentsev (1972). A good example of the poor reliability of ΔV_0 measurements, even for the bright pairs. In the blue the companion looks like a spiral, but in Hα its central part is a gigantic HII region. In the large galaxy the two major HII regions are not less than 2000 pc in length (Vorontsov *et al.* 1974b).

5 5–56–4,5 = VV 5 = A 86 = NGC 7752–3; (the latter is the principal object $14^{m}.3$, /$13^{m}.6$/ and $13^{m}.2$, /$12^{m}.6$/). With an overexposure, the companion looks like an E galaxy with a sharp edge. In Hα its central part consists of 3–4 HII clouds. $V_0 = +4845$ and $+4868$ (R), but according to D'Odorico and Bertola (1973), the above velocities should be inverted. They themselves found $V_0 = +5206$ for the main component. $\Delta V_0 = 341$, $m = 6.4 \times 10^{10}\ m_\odot$, $m_2 : m_1 = 0.1$, the system is not bound. For V_0 see Karachentsev *et al.* 1975 with V_0 up to $+5668 \pm 90$!

* At least on the photographs published so far.

Plate 14 Stages of Gemmation and "Twice M 51 Type Galaxies". I

The middle row presents the successive stages of gemmation of a companion. Perhaps a better sequence was given in Vorontsov (1974c).

The other galaxies start the expulsion of companions at the ends of both spiral arms, which again speaks against chance simultaneous projections moving in different planes in very eccentric orbits, which is necessary for the tidal theory of intergalactic filaments.

23 –4–9–17 = VV 23 = NGC 1347 = A 39; 13^m.

447 8–33–14; 16^m.

448 8–22–104 = NGC 4258; $8^m.90$ in Hα (van de Kruit 1974). Strong HII condensations at the extremities of the arms. $V_0 = +530$ (R); $V = 9.61$, $B-V = 0.82$, $U-B = 0.24$.

449 –1–7–15; 15^m.

450 6–29–59; 15^m (1 mm = 1''.5).

451 6–29–60; 15^m (1 mm = 1''.5).

452 3–41–34; $15^m.2$.

453 –1–7–7 = A 54; $15\frac{1}{2}^m$.

454 7–25–33 = NGC 4137; 15^m and 15^m; $V_0 = +9300$ (AES 1976).

455 9–19–189 = NGC 3888 = Mrk 188; 12^m, $V_0 = +2500$, Ca II abs, sd 3, $M = -21.2$ (Sargent 1972), $V = +2400$ (Arakelian *et al.* 1972). First published (Vorontsov 1960) as an example where the arms are wound in opposite directions. Rich in HII regions. a – blue image, b – red.

Plate 15 "Twice M 51 Type Galaxies". II

456a 9–23–28 = M 101 = NGC 5457. 456b – the same object, on which HI isodensity contours have been drawn. The largest condensations coincide with optical features at the end of the arms marked by NGC numbers, 600 to 1500 pc in length (Allen *et al.* 1974). $V_0 = +415$ (R), $B-V = 0.75$, $U-B = 0.21$.

457 –1–30–43; 14^m. Very nice specimen. AES (1976) give $V_0 = +1470$.

458 1–37–34, 35, 36 = A 274 = NGC 5679 a, b, c; $14^m.5$, $14^m.5$.

459 9–19–123 (1 mm = 4'') = NGC 3733; ($13^m.1$).

460 5–31–144 = NGC 5000; 14^m, $V_0 = +5643$ (Kintner 1971), SBb? with extremely thin fine arms. The object to the right can be a star.

461 –2–59–14; 16^m. The lower bright object is a star.

462 1–31–9; $14^m.9$.

463 1–28–29; $15^m.1$. Objects at the upper right corner seem to be connected, the left one is starlike.

Plate 16 "Twice M 51 Type Galaxies". III

464 10–14–20; $15^m.2$.

141 12–8–1 = VV 141; 15^m.

465a 8–23–89; $15^m.2$ in the red.

465b the same in the blue.

466 –2–28–21; $14^m.5$.

467 –4–5–27; $14\frac{1}{2}^m$ or a minichain. Similar to 503 plate 21.

468 –2–12–38; 15^m.

469 4–35–14; $15^m.2$.

470 1–60–7; 13^m.

471 3–38–7 = A 64; $15^m.1$.

472 9–27–40 = A 66; 14^m, $V = 14.29$, $B-V = +0.78$, $U-B = 0.31$.

473 5–21–13; $15^m.5$, $V_0 = +8050$ (U).

474 5–31–154; 15½^m, $V_0 = +6877$ (T).
25 –2–1–7 = VV 25 = A 50; 14½^m.
475 –4–20–3 = NGC 2559; 13^m.

Plate 17 Spirals with Elliptical (?) Components

Rare objects, certain only among the brighter pairs. In 476–478, the objects are compact. Note that in 476, 477, 301, 209 and 244, the "bridge" has no relation to the normal spiral arms which are wound more tightly.

476 II Zw 101, 102; 21^{h}05^m.2 + 3°40′, $\rho = 70''$; 15^m.3 and 15^m.3. $V_0 = +7680$ hydrogen abs., λ 3727 A in em. (Arp 1969). $V_0 = +8069$ and $+7983$ (KPCh, Sr, Z).
477 –3–30–10 = NGC 3836; 13½^m.
478 –1–4–25; 14½^m.
479 5–54–29; 15^m.
13 5–29–10, 11 = VV 13 = A 97; 15^m.7 and 15^m.6. $V_0 = +7010$ for E0 G5 abs., for S a/o, $V_0 = +6952$ em. Hγ, [OII], $m = 8 \times 10^{10}\, m_\odot$ (Zwicky and Humason 1960).
301 5–4–66, 67 = A 98; 15^m, $V_0 = +12733$ and $+12758$, $\Delta V_0 = 35$ (Chincarini and Rood 1972).
120 6–31–45 = A 111 = NGC 5421 = Mrk 665; /14^m.5/, 14^m.3. $V_0 = +8123$ (Karachentsev *et al.* 1975).
209 3–27–15, 16 = A 94 = NGC 3226 (E), 3227 (S) – Seyfert galaxy; 12^m.6 and 11^m.3 or 13^m.3 and 12^m.2. $V_0 = +1233$ and $+1006$ (R), $V_0 = 11.79$, $B-V = 0.82$, $U-B = 0.29$.

The velocity field and the physical conditions studied by Rubin and Ford (1968). Gas in the tidal arm connected with the deformed elliptical companion has $\Delta V_0 = -700$ kms^{-1} relative to the mean velocity of the system: $(1069 + 1243) \times 0.5 = 1156$ kms^{-1}.

244 3–40–5, 6 = VV 244 = A 91 = NGC 5953 (E?), 5954 (S); /13^m.2/ and /13^m.1/. $V_0 = +2188$ and $+2228$ (R) and Page (1970) gives $+2211$ and $+2252$, $\Delta V_0 = 40$. Many emissions.

Plate 18 Transport out of Large Companions

In these systems the companions apparently are not related to the spiral systems, yet are transported out by means (seemingly) of a massive filament. All are overexposed and some may be misinterpreted.

480 –1–60–23; /13^m.7/, 14½^m.
481 4–22–6 = NGC 2738; 13^m.8.
482 –2–8–19 = NGC 1140; 12^m.7, $V_0 = +1511$ (R), F 2 e, $V = 12.82$, $B-V = 0.39$.
483 3–57–2; 15^m.
484 –5–3–10 = NGC 289; (12^m.1), $V_0 = +1907$ (R).
485 –3–34–70, 71; 14^m and 15^m.
486 –1–3–78 = NGC 356; 13½^m.
487 10–22–28; 16^m.

Plate 19 Predecessors of Chains

We have found a number of long thin formations never observed formerly and showing evident symptoms that they are ready to break apart, thus forming the chains of galaxies in contact. The rupture must be the result of their gravitational instability. The symptoms of rupture and transformation of these predecessors into minichains containing 3–4 members, presumably sometimes into only two, generally progress from plate 19 onward. The predecessors and the chains themselves are often blue or surrounded by an intensely blue haze which apparently consists of young blue hot stars and of λ 3727 A [OII] emission. Among the negligible number of such objects observed, two (VV 150 and VV 144, plates 21 and 23) displayed the Seyfert spectra-tokens of youth and instability. However observers pay small attention to observation of interacting galaxies.

Chains are the simplest and the most obvious kind of nests and of fragmentation.
5 of the youngest formations are presented here; four of them are in a) blue and b) red light.
488 –2–58–11 a and b, 14^m.
489 5–38–36 a and b, $15^m.2$.
490 –2–59–4, 5, $14^m.5$.
491 –2–9–35, $15\frac{1}{2}^m$.
492 0–59–42, $15^m.6$.
493 8–23–85 a and b, $15^m.4$.
It is remarkable that very rare objects 488 and 490 are situated in the sky close to each other.

Plate 20 Chains in the Making

243 6–20–12 = VV 243 = A 195; 15^m. a and b differently printed. 3 or more components in contact and 3 adjoining dwarfs. Similar to 495 (here) and 519 (plate 24).

147 3–31–69 = VV 147; 16^m. 2–4 components in contact. Similar to VV 150 in the plate 21.

494 –4–52–31; 14^m a) blue, b) red. Two large components in contact. Linked by a broad "bridge" to the third one. Three faint blue knots in the tail.

495 0–10–9 = A 219; $14^m.5$. 3–4 components in a contact. The far components elongated. Remarkably large arc. $V = 14.62$, $B–V = 0.76$ 50″ (AES 1976).

496 –4–53–28; $15^m.5$ 5 components. The larger one might consist of two coalescent objects.

497 9–20–113; 15^m a) blue, b) red. The three components still not completely separated.

The photographs obtained at the 6 m telescope by Korovjakovsky and Shabanov show that in fact VV 497 is a multinominal chain (but one of the larger members, as it appeared on the "Palomar Atlas", is a star). But the supposed middle member in reality presents the three smaller members in contact. The two objects below and to the right may form a prolongation of the chain, though one of them may be a star. The extended haze below has diffuse condensations. The scale is 2″ per mm. Our prints show how the successive prints make evident the real structure of complicated interacting objects. See plate 69.

498 4–27–47; 15^m. a) blue, b) red. Disruption barely begins.

Plate 21 Young Minichains

150 9–19–111 = VV 150 = A 322 = Mrk 176; total $14^m.7$. A chain of four members (150b) overlapping each other (150c). 150a is an inverted photo by Burbidge (1959) who has found (Burbidge 1961) that the brightest elongated member is a Seyfert galaxy with $V_0 = +7900$ and line breadth 800 kms^{-1}. Another member has $V_0 = +6700$ and the third, blue, shows only a continuum. The cross on 150d shows the position at 1415 MHz of a radiosource (Burke and Miley 1973). Zwicky put this object in his 1971 catalogue, but said nothing concerning the data given above. Sargent (1972) observed it only as "Markarian galaxy" and classified it s d 2 e. For the group the average $V_0 = +8080$; from the dispersion of velocities he has found $m:L = 38$. In a private letter Arp gives $V_0 = +7900$, 8000, 8100, 8300, but does not specify the members.

499 11–11–13, 15^m. A chain or a nest disrupted into a large group of very blue dwarf galaxies (or clouds of gas?) a – blue, b – red.

500 –5–47–17, 16^m.

501 7–34–127 = A 125, $15^m.5$. Chain of four galaxies in common envelope recalling the comet-like galaxies (plates 62 and 63). $V_0 = +8572$, and for the companions V_0 varies from +8000 to +10000, being +8118 on the average. Spectrum absorption with [OII] (Arp 1967).

502 7–1–5, $15^m.5$. Three galaxies and a dwarf (or jet) in contact: a – red, b – blue.

503 2–59–34, $15^m.5$. Three galaxies in contact and bright haze.

Plate 22 Chains

504 –4–31–37, 15^m. Near a bright double star 3 galaxies nearly in contact. The common haze is only to one side, a – blue, b – red.

505 2–32–192, $15^m.3$. 5 galaxies in a chain of which 4 are dwarfs on both sides of the principal one.

506 5–38–31, $15^m.5$. 5 galaxies of which 4 are dwarfs on an arc to one side of the larger one.

507 9–28–14, 16^m. 4 galaxies in a row, the largest being in the middle: a – red, b – blue. The row is in a very bright blue haze.

508 0–54–7, $15^m.1$. 4–5 in a tight row. The principal object is in the centre of two coalescent galaxies.

509 0–4–111, $15^m.5$. 5 in a row. One of them merges with the largest.

510 1–29–35, $14^m.9$. 2 dwarf satellites on an arc emerging from the centre of the principal galaxy.

511 2–32–56, $15^m.6$. Faint not disrupted progenitor. In its tail 3 diffuse companions in a blue haze.

512 2–4–55, $15^m.6$. Just disrupted into three galaxies in contact, with "bridges". Farther on may be the fourth one.

513 2–34–13, $15^m.6$. A band disrupting into a spindle, a compact and a spheroidal member.

514 1–28–2; $15^m.3$. Near the large compact is a chain of 3 members diminishing in size.

515 5–26–34; 16^m. Three still receding with a bright haze to one side, as happens in many similar groups.

516 2–7–21, 22 = III Zw 51; $15^m.7$. It is a disrupting system with a jet (?) of blobs. Possibly a $16^m.5$ star overlaps. Apparently interacts with compact (2–7–21) 65″ = 80 kpc in projection to the West. $V_0 = +13305$, $D = 10'' = 13$ kpc (Sargent 1970).

Plate 23 Chains nearly Disrupted

220, 237 and 517 recalling jets are taken from IAU Symposium no. 44, p. 380.

220 3–41–104 = IC 1182, $15^m.2$. Two of her companions are on a jet. Photo from Arp (1972) and Stockton (1968). $B = 16.20$, $B - V = 1.01$, $U - B = -0.09$, $V_0 = +10350$, Sy2, $M_v = -21.7$ (Weedman 1973), $V_0 = +10200$ S 2 e with [SII] and [NII], Hβ 55 A wide, Seyfert galaxy with narrow nebulium lines (Arakelian *et al.* 1971).

237 5–27–10, 11 = A 105 = NGC 3561; a – complete chain, b – main members; Photo Arp (1972). See also plate 50 for the details. A chain and a tail 3′ long. Average $V_0 = +8730$, [OII]. At the end and near to the brighter galaxies may be dwarf ones. In detail studied by Zwicky and Humason (1961), ΔV up to 253 kms^{-1}.

517 I Zw 96 $14^h43^m.3 + 51°35'$, $14^m.8$. $V_0 = +27100$ (Sargent 1970) from absorptions of H and [OII] in emission along the major axis. Bright emission in a knot on the east side (Sargent 1970). Photo by Stockton in Arp (1972). Scale 1 mm = 1″.

518 The Burbidges' chain (1963). a – general view. Bright members: –4–3–10, Sc 14^m and –4–3–13, Sc, $14\frac{1}{2}^m$. $V_0 = +6270$, $+6164$ for the northern and $+6308$ for the southern from the single visible Hα line. In between are two faint 16^m and 17^m "members". However they both are interacting pairs. Thus the small spiral components shown in 518b and 518c are much fainter and so must belong to the far background. The chain must be optical and is just a wide pair. Balkowski and Chamaraux (1976) studied HI in this pair. They found the distance to agree with the cosmological one of the brighter members.

172 12–11–28 = VV 172 = A 329, $15^m.2$. This was the first galaxy containing 5 members in contact which we found. Their radial velocities are shown on the photo (Sargent 1968). The smallest compact has a velocity deviating by 21000 kms^{-1} from the average for the chain. Therefore it must be a chance projection as in the case of 518 (above). Therefore, contrary to probabilistic calculations, chance projections do occur in some cases and are indeed not very exceptional.

144 9–19–73 = VV 144 = A 151 = Mrk 40, 15^m. $V_0 = +6232$. 24 kpc in length, with Seyfert nucleus (Burbidge 1964). Confirmed by Sargent (1970): hydrogen width 4000 kms^{-1} [OII], [OIII] and [NeIII] below 800 kms^{-1}. Second galaxy has $V_0 = +6472$ abs. Spectrum of the "bridge" and "tail" unknown. Weedman (1973) with a 15″ diaphragm gives for the brighter member: $B = 16.21$, $B–V = 0.82$, $U–B = -0.23$, $V_0 = +6150$, Sy1, $A_V = 0.21$, $M = -20.3$.

Plate 24 Prechains and Chains of Different Age

519 12–9–13 = A 80 = NGC 2633; $12^{m}.8$. 3 or more galaxies with one and two "bridges" (at the left). All nearly in contact. Bordered by an arc above and below and still further above by a wide spiral arm. Similar to 243 and 495 in the plate 20. The upper arc is terminated by zigzags, or by a chance projection of a remote nest. Somewhat akin to the M 51 type. $V_0 = +2382$ (R).

167 –4–52–14 = VV 167 = A 325; $14\frac{1}{2}^{m}$. 5 members of a probable chain.

520 1–31–29; $13^{m}.8$. The lower end begins to disrupt.

521 4–3–7 to 9; $14^{m}.7$. Young group of 4 compacts. Remnants of a haze. Two very remote pairs in contact are visible – altogether three on a surface of 4′ square!

522 –5–14–9; 15^{m}. Chain with 5 members of which 4 are still bound materially and a perturbed haze.

523 6–26–60 = Haro 5 = NGC 3991; V = $13^{m}.19$. For the bright component $V_0 = +3298$, for the faint +3033, emissions lines of Balmer series, [OIII], [NeIII], [NII], [OII] (Page 1970). B–V = 0.31, U–B = –1.14, also B–V = 0.43, U–B = –0.50. $\Delta V_0 = 265$ kms^{-1}. The image in the "Palomar Atlas" is very overexposed.

The photography of VV 523 on plate 69, added at the last moment was obtained on the large 6 m telescope of USSR and shows an excellent multinominal chain. Four of the members are in contact and were considered by Page to be the "faint component", but between them and the principal compact companion there is a "bridge", or rather two fainter members in contact. On the whole the chain contains from 5 to 7 members (the last one is double). That the leading member is compact and the brightest is typical for tight chains. VV 523 is the remote member of a triple system, which contains also the pair VV 249: the very compact peculiar spiral NGC 3994 (the brightest of the three) and a very distorted large spiral NGC 3995. All objects are very blue, young, with nearly equal velocities. The centre of NGC 3995 is akin to NGC 4038/39 and their photographs are reproduced in plate 70. All 6 m telescope photographs were kindly obtained by Shabanov and Korovjakovsky. Both objects were discussed by Vorontsov (1976).

Plate 25 Chains/Nests

251 1–29–41 = VV 251 = A 5 = NGC 3664; $13^{m}.6$. Similar here are 140, 524, 242, 525: straight but disrupting formations. $V_0 = +1253$ (R) bright [OII], [OIII] and hydrogen lines, inclined. Here is a nest of one larger, several irregulars in contact and many dwarfs, of which 5 form a chain.

143 3–7–37, 38 = VV 143 = A 258; $14^{m}.6$, $V_0 = +4122$ (R). Differs from the preceding one only by the lack of dwarfish chain.

140 –2–38–16, 17 = VV 140 = A 261; 15^{m} and $13^{m}.9$, a – photo by the Burbidges (private letter) shows the fragmentation of the lesser chain better. b – shows the connecting arc better. In the arc of these "trailers" there are HII regions, – that is the young hot stars. For the brighter $V_0 = +1833$ (R).

261 9–20–119 = VV 261 = A 160 = NGC 4194 = Mrk 201; 13^{m}. a and b show structure. Of this "Medusa", the structure of the "head" is as yet unresolved. In this case, three galaxies apparently are coalescent. "Behind", the dwarfs begin to separate. The impression is that the right hand side is advancing with some resistance, while the left hand side recalls us of chips lagging behind the motion. $V_0 = +2585$ and +2522 from Hβ and [OIII] (Arp 1967); +2684; +2480 ds2e (Arakelian *et al.* 1971); Weedman (1973): $B = 13.79$, B–V = 0.49, U–B = –0.25, $M_v = -20.3$. The photographs obtained with the 6 m telescope by Korovjakovsky and Shabanov (plate 69) reveal the fantastic structure of this enigmatic object. Its source (core) consists simply of two coalescent compact bodies. Its envelopes become more and more complicated as more fainter parts are recorded on the plate. Its whole diameter is 25 kpc.

242 5–52–10, 11 = VV 242 = A 278 = NGC 7253; $14^{m}.4$. One part of the group was believed to be a pair. However besides the interaction, the lower one proves to be a chain of 3 members in contact. The upper galaxy also shows traces of disruption. $V_0 = +2545$, width of the lines 190 kms^{-1}, flux 1.4×10^6 $m_{\odot}$ M^{-1} (Bottinell *et al.* 1973a) from λ = 21 cm.

525 –2–7–7; 14^m. Similar to 251: they both recall a SBd galaxy of small surface brightness, but it clearly disrupts.

126 6–26–62 = VV 126 = A 194: $13^m.9$. The middle part of the two interacting galaxies reminds us of the disrupted "bridge" – a chain.

524 –1–13–45 = A 259 = NGC 1741; 14^m. In this blue photograph by Arp (1966), the high resolution showing fine structure, the object is somewhat intermediate between the pure chainlike structure and the nests. On plate 34 the same object is given the number 565: a – in the red and b in the blue light, where its blue nature is evident. In comparing figures 524 and 565, one can doubt that they are identical objects; and this led to their separate numbering. $V = 13.57$, $B–V = 0.39$, $U–B = -0.53$, $V_0 = +3872$ (R).

Plate 26 Nests. I

These are the first two objects recognized by us as nests. Since that time they have been studied further.

117 7–16–16, 17 = VV 117 = NGC 2444–5; $13^m.1$. 7–16–16 is E, its $V_0 = +3950$ (Burbidges 1959), the remaining 8 small members are enveloped in the bright filaments of hydrogen. They delineate the principal part of the remaining formation which is at a distance of 82 kpc ($1'' = 410$ pc). The whole system with the tail of the E galaxy is 53 kpc in diameter (!), larger than M 31 and has nothing to do with the irregular galaxies as a type. (As we see here, the E galaxies can have tails, while no very massive "agressor" is present, and do not show a tail being confronted to an equally large mass as is the case in plate 3 and many others). Some of the 8 "condensations" are sharp starlike nuclei surrounded by a gas with evident turbulence and traces of spiral structure. Using the photographs made by the Burbidges (1959) and by Sandage (1959) we considerably enlarged the objects for plate 27. Perhaps the condensations are the nuclei of the future small spiral galaxies. The broad bright "bridge" toward E may belong to the group, but the tail belongs to E. The Burbidges were the first to resolve the object on a large scale photograph and measured the velocities shown in the frame 117b. Frame b gives the photo by Sandage (1959) in λλ 6100–6900 Å, frame d is in the yellow, a – in the blue (by the Burbidges). They noticed that the spectrum of f overlaps that of a foreground star. Please notice that many of the remaining centres contain starlike images and some appear double. It is important to check whether a foreground star is superimposed near the nucleus in all cases. E is a giant with $M_B = -20.8$. The gaseous turbulent condensations are ~6 kpc across. Sandage measuring with a diaphragm 70″ gives for $(E–V) = 13.26$, $(B–V)_0 = 1.00$, $(U–B)_0 = 0.43$, and for d, which he calls "the nucleus of the spiral", $V = 15.69$, $(B–V)_0 = 0.68$, $(U–B)_0 = 0.04$. On the frame 117d the white cross marks the position of radio emission at 1415 MHz (Burke and Miley 1973).

123 12–7–35 = VV 123; $13^m.7$. $V_0 = +2766$ (Kintner 1971), +2516 (Arp 1967), +2996 (the Burbidges according to Sandage (1959). The latter with a diaphragm 70″ measured for the E galaxy $V = 13.32$, $(B–V)_0 = 0.80$, $(U–B)_0 = +0.23$, $M_B = -19.9$. For the "spiral" $V = 16.5$, $(B–V)_0 = 0.35$, $(U–B) = -0.05$. Frame a is the blue, c and b in yellow light. Here, the large body appears in the form of a sickle with a handle. The latter with shorter exposure is resolved into the E galaxy, a spiral and a very large complicated formation. Photo by Arp (1967) shows that the "spiral" is in fact still more complicated.

Plate 27 Nests. II

117 117e and 117b – see the list 26.

155 8–17–65 = VV 155 "grasshopper"; $14^m.9$. $V_0 = +11773$ (Arp) abs. and [OII]. Photo from Arp (1967). The main body consists apparently of three parts. Its length $40'' = 44$ kpc! The tail with three "condensations" is 3×5 kpc (of galactic dimensions). $M = -22.0$ (absorption not accounted for).

526 1–21–15; $14^m.6$. Two large coalescent galaxies. Below, connected to them in the blue light are 3 dwarfs.

Plate 28 Nests – Evident and Possible

Photographs made on a larger scale by Arp confirm our classification that these objects are tight interacting systems. Of course in many cases the interpretation of complicated patterns is tentative.

118 10–17–2, 2a, 3, 5 = VV 118 = A 299 = NGC 3690 + IC 694 = Mrk 171; 11$^m_.$8. b – photo by the Burbidges (their gift to us), c – photo by Panomareva who used a 50 cm Maksutov camera in Crimea. Two large coalescent galaxies, the third in contact. With them are 3–4 dwarfs and one E? For the principal component a $V_0 = +3097$, for the b +3212 (Karachentsev 1972); +3085 for b (Ulrich 1971) and +3101 for the compact companion 1$'_.$5 to the North (Fairall 1971). Identifications of V_0 with details inside this complicated system are doubtful because the appearance depends on the scale and exposure. Here the scale was taken from Arp 299.

527 6–26–16, 17; 13$^m_.$6 and 15$^m_.$6. Several coalescent galaxies of various dimensions. Strong perturbations. Total: $V = 13.45$, $B-V = 0.72$, $U-B = -0.12$, 68″ (AES 1976).

528 6–17–2; 13$^m_.$7. Overexposed. Not less than 3 members.

529 1–28–4; 14$^m_.$3. $V = 13.58$, $B-V = 0.60$, $U-B = -0.08$, (68″) $V_0 = +15800$ (AES 1976). "Armoured motor car" as seen from above. Several companions are in the stage of gemmation, nearly coalescing with the main body.

530 –3–37–1 = NGC 5595; (12$^m_.$4). Disrupting nest of 5–6 galaxies or a disrupted spiral. $V_0 = +1550$ (AES 1976).

86 4–38–22 = VV 86 = A 209 = NGC 6052 = Mrk 297; 14$^m_.$1 (13$^m_.$1), $V = 12.99$, $B-V = 0.44$, $U-B = -0.30$. $V_0 = +4803$, many emissions (Vaucouleurs 1967). There are other measurements. Coalescent galaxies and a chain of three dwarfs. The reference in MCG concerning its photo in *Astron. J. USSR* was wrong.

95 3–27–25 = VV 95 = A 263 = NGC 3239; 12$^m_.$8, $V_0 = +761$ (R). $c'_p = 0.32$. 3 or more coalescent. Karachentsev (1972) gives for the two components $V_0 = +816$ and +894.

531 4–8–6 = NGC 1156, 11$^m_.$85. $V_0 = +495$ (MCG), +405 (Zwicky 1972), emissions. Recalls NGC 4449 Ir, but includes dwarf galaxies and therefore is a nest. $V = 12.70$, $B-V = 0.45$, $U-B = -0.43$.

532 5–42–11; 15$^m_.$6. 3 galaxies in contact and a compact below.

533 9–17–34, 36; 14^m and to the right 16^m. From the first, large object, 5–6 companions gemmate, and is itself possibly made up of two bodies.

Plate 29 Possible Bright Nests

119 7–21–7 = VV 119 = A 264 = NGC 3104; 14$^m_.$2. Clearly a nest with many gemmating companions. a and b differ by the printing. $V_0 = +718$ (Vancouleurs 1967).

534 4–42–12; 14$^m_.$9. Rather a nest than IrI.

535 3–5–17; 14$^m_.$5. Three coalescent.

536 0–40–11; 15^m. Two coalescent. A dwarf to the right.

537 2–46–8 = NGC 6570; 13$^m_.$2 ≥ 3 bodies.

538 6–24–16; 15^m. a – blue, b – red. 4 dwarfs gemmating from the principal. Below to the left a double defect.

539 12–8–5; 14$^m_.$8. 4 galaxies receding from each other.

540 4–37–5 = A 220; 14$^m_.$4. Overprinted. Very probably more than two galaxies.

78 –7–9–2 = VV 78 = NGC 1487; (12$^m_.$6). 3–4 coalescent. Isophotes given by Sersic (1961). Compare this photo from "Palomar Atlas" to no. 78 in plate 36. $V = 12.33$, $B-V = 0.44$, $U-B = -0.32$.

Plate 30 Nests. III

541 4–22–12 = NGC 2750; 12$^m_.$7. Spiral and a small flat galaxy. Perhaps there are more members.

542 5–24–4; 15$^m_.$2. One or two coalescent. In their tail there are 3 very blue dwarfs and a counterjet.

543 5–32–67 = NGC 5275; 15$^m_.$4. In a cluster 4 galaxies in contact and in common haze.

544 –1–30–22, 13½^m "Zigzag". Enigmatic object first published by Vorontsov (1975a). 2 or 4 galaxies? It cannot be SB, the "arms" being brighter than the "bar".

545 –3–16–14, 15; 13½^m and 15^m. 3 coalescent in a very disturbed haze.

546 –2–53–1; 14½^m. Large galaxy and 3–5 dwarfs in a common haze.

Plate 31 Blue Nests. I

This title does not mean that the other nests are not blue. Simply there we have reproduced a number of specimens: a – blue and b – in red light.

547 2–25–21, 22; $13^{m}75$. a – very blue, form an arc, b – red.
548 –2–2–64; 14^{m} 3–4 objects. $V=15, 21$, $B–V=0.53$.
549 –2–24–4; $15\frac{1}{2}^{m}$ 3 galaxies.
550 4–37–37; $15^{m}1$. Two pairs. The other pairs of pairs are on plate 54.
551 11–9–16; $15^{m}6$. 4–5 galaxies.
552a 8–14–7; $15^{m}3$. Only in the blue, 3–4 galaxies.
552b 5–26–47 = A 21; $14^{m}7$, in the blue. Several galaxies.
149 1–28–23 = VV 149 "The Ant"; $14^{m}9$. 4 galaxies in contact. In blue light only.

Plate 32 Blue Nests. II

a – in the blue, b – in the red.
553 4–23–10; $15^{m}3$ 2–3 coalescent, $V_0=+7800$ (AES 1976).
554 7–2–20; $14^{m}6$ 5–6 galaxies, the small ones blue. $V=15.25$, $U–B=0.45$.
130 –3–38–21; $14\frac{1}{2}^{m}$. 3 large and 4 dwarfs.
555 1–12–6; $15^{m}5$ 7 galaxies dispersing.
556 3–46–2; $15^{m}0$. 2–4 galaxies.
557 4–34–14; $15^{m}4$. 5 members $V_0=+2520$ (AES 1976).

Plate 33 Blue Nests. III

a – in blue light, b – in red light.
558 2–33–41; $15^{m}3$ 7–8 galaxies. "Imprint of a foot".
128 3–31–77 = VV 128 = A 260; $14^{m}8$ 2–5 galaxies.
559 4–31–14; $14^{m}8$, Enigmatic object "Apparition". 6 galaxies? First published by Vorontsov (1975a).
560 2–42–6; $15^{m}2$ 5–6 galaxies.
561 9–23–34; $14^{m}5$ 4(?) galaxies in a very bright blue haze.
562 2–42–4; $15^{m}3$. "Bandy-legged galaxy".

Plate 34 Blue Nests. IV

51 0–60–17, 18 = VV 51 = A 284 = NGC 7714–5; ($14^{m}3$) and ($13^{m}4$).

a – whole system, b – principal member in a group of 3–5 components. $V_0=+3001$ and $+2963$. Widely dispersed chain of small HII regions along the "bridge"; $\Delta V=38$.

563 2–32–125; $13^{m}5$ a – in red light, b – blue. 5–7 galaxies, $V_0=-240$ (AES 1975). V_0 needs verification.

564 3–32–80 = A 149; $15^{m}3$ a – in red light from the "Palomar Atlas", b – in blue light, Arp's Atlas. 4 galaxies.

565 = 524. –1–13–45 = A 259; 15^{m}. Here, both photos are from the "Palomar Sky Atlas", a – in red light, b – in blue light. Compare them to the same object numbered as no. 524 in plate 25.

$V_0=+3872$ (R), $V=13.57$, $B–V=0.39$, $U–B=-0.53$.

Plate 35 Nests. IV

566 7–3–5; $15^{m}6$, 3 in contact?
567 1–36–28; $14^{m}6$, /$13^{m}5$/. Two or more.

568 4–5–48; $14^{m}.7$, a – blue, b – red. 3–4 in contact.
569 5–43–14; $14^{m}.6$, a – blue, b – red. 3–4 in contact. $V=15.29$, $B-V=0.86$.
570 –2–2–43; 15^{m}, a – blue, b – red. 3 in a haze.
571 3–32–76 = NGC 4561, $12^{m}.7$. Has some resemblance to the "Zigzag" –1–30–22 (plate 30). 3 coalescent?
572 3–56–4; $14^{m}.8$. Three? For two of the parts, $V_0=+8155$ and $+8272$ (Karachentsev *et al.* 1975).
573 6–23–16, 17; 15^{m} and $15\frac{1}{2}^{m}$. 5 compacts.
574 13–8–58; $14^{m}.7$ 3 in contact, perturbed. $V=14.96$, $B-V=0.37$, $U-B=-0.30$ (68″) (AES 1975).
575 5–28–5; $15^{m}.7$ 4 in contact.
576 –5–16–4; 15^{m}. Six.
577 –6–4–34; 14^{m}. Three.

Plate 36 Nests. V

578 –7–3–16, 15^{m} "Boomerang". Photo Sersic (1961). 6–7 galaxies forming a right angle. Chance encounter impossible. Could the fragmentation have just begun to produce this figure? $V=12.33$, $B-V=0.44$, $U-B=-0.32$.
78bis –7–9–2 = VV 78 = NGC 1487; $12^{m}.9$. Photo from the European Southern Obs. Compare with 78 (plate 29).
579 4–55–24, $15^{m}.6$ 3 in a haze.
580 –7–26–35–36, $15\frac{1}{2}^{m}$ and $14\frac{1}{2}^{m}$. 3 in contact.
581 –6–48–8, $14\frac{1}{2}^{m}$. 3 members. 2 in contact.
582 –5–2–4, 15^{m}. 2–4 members.
583 –4–6–1, $14\frac{1}{2}^{m}$. 3–5 members a – blue, b – red.
137 –3–38–26 = VV 137, $14\frac{1}{2}^{m}$. 4–5 members, a – blue, b – red.
584 $11^{h}16^{m}.9$ $-2°49'.5$ A 132, $14^{m}.9$. 4 members in contact.
585 –4–35–17, $14\frac{1}{2}^{m}$. 3–5 members, Bright haze.
586 –6–21–8, 9, 16^{m} and $16\frac{1}{2}^{m}$. 3–5 galaxies.
98 –2–38–4 = VV 98, $14\frac{1}{2}^{m}$. 3 in contact.
587 –1–9–19, 15^{m}. Faint member of the pair A 279. The bright member is 1–9–18. There are 5 components with a gigantic tail.

Plate 37 Nests. VI

588 1–7–25 = Mrk 596, 15^{m} 3+2?
589 2–56–2 15^{m}. 2 small companions on filaments.
590 1–5–6 15^{m} About six galaxies, three blue of them are in a line. This is typical.
591 3–53–7 15^{m}. Coalescent companions. Principal is difficult to interpret.
592 –5–24–10, 14^{m}. 2 or 3.
75 1–28–33 = VV 75 = A 335 = NGC 3509, $11^{m}.8$. Nest/chain? No less than 5 formations. $V_0=+7440$ (The Burbidges *et al.* 1963). Emission lines. 67 kpc in length! Rotation, motion of components.
593 8–17–68, $14^{m}.8$. Two with a jet?
594 4–27–38, $14^{m}.8$. More than 5.
235 9–22–55, 56 = VV 235, $15^{m}.6$. Three (one is double).

Plate 38 Remote Nests with Haze

595 –3–27–18, 15^{m}. 3–4 components.
596 6–14–2, 17^{m}. 3 in contact in haze, one aloof.
597 6–4–32, $15^{m}.6$. 3–5 components. Supernova 1967. $D=66$ M_{pc} $M=-19.0$ (Vorontsov 1974b).

598 3–60–14; 14^m. 2 large, 3 small members.
599 –7–12–4; $15\frac{1}{2}^m$. 4 members.
600 5–4–25; $15\overset{m}{.}2$. 3 components.
601 8–11–12; $15\overset{m}{.}7$. 3 components.
336 –3–8–25; 26 = VV 336 = A 131, 15^m. Faint component of a pair, 2 large, 2 small?
602 = VV 395. –2–3–70; 15^m. In the red. 2 blue satellites.
603 9–18–78; 16^m. Three bodies?
604 –5–46–2; 15^m. Three or two plus a star.
605 11–16–8 = Mrk 238; $15\overset{m}{.}2$ 3+?, $V_0 = +15000$ d3nd3 (Arakelian 1972).
606 2–8–25; $14\frac{1}{2}^m$. Chain of three and 2–3 in a haze.
607 6–30–103; 16^m. The complicated haze speaks in favour of more than 2 objects.
148 9–19–140 = VV 148; $15\overset{m}{.}5$. Three?

Plate 39 Nests and Possible Nests

608 –5–23–10; $14\overset{m}{.}6$: several members of low surface brightness.
609 5–31–99 = NGC 4922; $14\overset{m}{.}2$. Three coalescent. $V_0 = +7376$ (R).
610 –5–9–22; 14^m. $x+2$ small.
611 7–33–31; $14\overset{m}{.}5$ $x+2$ or 4.
612 3–23–31; $13\overset{m}{.}7$ three $+x$, $V_0 = +3324$ (R).
613 0–59–38; 14^m three and a small one.
614 2–31–88; $14\overset{m}{.}9$. Three objects?
615 –1–36–14 = NGC 5534; $15\overset{m}{.}7$. Three $+x$; $V = 13.17$, $B-V = 0.66$, $U-B = -0.19$.
616 6–29–65 = Mrk 450; $14\overset{m}{.}9$, three $+x$. $V_0 = +870$ (Denisjuk 1974).
617 0–43–4; $14\overset{m}{.}7$. Three objects.
618 8–18–51; $14\overset{m}{.}4$. 5 or 6 members of which two are flat.
138 8–15–50 = VV 138 = A 6; $11\overset{m}{.}7$. Rather three irregulars in a nest than SBd. $V_0 = +423$ (R, D, AED). $B-V = 0.66$, $U-B = -0.16$, $V = 11.72$.

Plate 40 Nests – Probable and Possible

619 4–55–14, 15 = IV Zw 149 = Mrk 325–326 = NGC 7673, 7677. $12\overset{m}{.}7$, $13\overset{m}{.}9$; a and b – two isodensitograms made by Chincarini (1974). 4–5 members. $V_0 = 3500$ and $+3890$ (Srg, ADE, KPCh). $V = 12.86$, $B-V = 0.47$; $U-B = -0.25$. Sargent gives the direct photograph of a very elongated object. Something must be wrong with the identifications.
620 0–25–21, 22, $13\overset{m}{.}5$. More than five members.
621 0–52–33 = NGC 6926, $13\overset{m}{.}$ Difficult to interpret.
622 4–2–18, $14\overset{m}{.}7$. a – blue, b – red. 2 large and 3 blue companions.
623 3–45–37; $15\overset{m}{.}2$. 5–6 members in the blue.
624 5–38–17; $14\overset{m}{.}4$. 3 members or an ellipse in a ring edge on?
625 5–39–5; $14\overset{m}{.}2$ 5–8 members.

Plate 41 Nests – Early Stages of Fragmentation

626 9–26–64 = Mrk 496. Three; $V_0 = +8920$ (ADE, Z, D, KPCh, T) emissions of Hα, NII, SII.
627 10–16–44; $15\overset{m}{.}2$. Three objects.
628 10–16–25; $15\overset{m}{.}7$. Three + 1 or 2.
629 10–23–38; $14\overset{m}{.}5$. a – blue, b – red, $V = 14.57$, $B-V = 0.48$, $U-B = -0.39$.

630 =VV 225; 1–14–34, 35; $14^{\mathrm{m}}.9$. Three.
631 –4–32–33; 15^{m}. Three?
632 10–12–77; $14^{\mathrm{m}}.2$, 15^{m}, $16\frac{1}{2}^{\mathrm{m}}$. Three. Total: $V=13.45$, $B-V=1.01$, $U-B=0.61$ (50″) (AES 1976).
633 6–29–76; $15^{\mathrm{m}}.1$. Three.
634 1–2–1, 2; 15^{m} and 15^{m}. Three. $V=14.46$, $B-V=0.92$.
635 "Heart" $22^{\mathrm{h}}07^{\mathrm{m}}.6+29°40'$ 14^{m}. Three objects.
636 V Zw 255; $2^{\mathrm{h}}31^{\mathrm{m}}.0+31°45'$, $15^{\mathrm{m}}.5$. Three.
637 0–26–13; $15^{\mathrm{m}}.6$. "Revolver". Three in the red.
638 0–30–12; $15^{\mathrm{m}}.4$. Three. In the red.
639 10–15–103; 15^{m}. Three.

Plate 42 Nests Beginning to Disperse

640 VII Zw 130 $7^{\mathrm{h}}08^{\mathrm{m}}.7+67°08'$; $15^{\mathrm{m}}.6$. Three members.
641 0–60–53; $15^{\mathrm{m}}.2$. 4–5 members.
642 –1–3–2, 3=A 231; $14\frac{1}{2}^{\mathrm{m}}$. Three.
643 4–18–26; $14^{\mathrm{m}}.7$. 5 members?
258 –3–4–28, 29=VV 258; 15^{m} and 16^{m}. Three.
644 12–7–41=Mrk 8; $13^{\mathrm{m}}.8$. Three. Weedman (1973) gives: $V=15.28$, $B-V=0.46$; $U-B=-0.52$. $M_v=-19.3$, $V_0=+3556$ (R, W) for both components. Heidmann and Kalloghlian (1973) consider Mrk 8 in pair with Mrk 7 with a separation of $26' \geq 500$ kpc. See also Weedmann and Khachikian (1973). Studied in detail by Bürgen and Kalloghlian (1974).
645 3–23–30; $14^{\mathrm{m}}.3$. "Browning". Three?
646 8–15–2, 3; $15^{\mathrm{m}}.4$. Three.
647 –5–11–11; $15\frac{1}{2}^{\mathrm{m}}$. 3+2?
648 0–7–70, 71; 16^{m}. 3 or 4.
649 5–55–9; $15^{\mathrm{m}}.5$. Three?
650 6–5–94; $15^{\mathrm{m}}.7$. Three?
651 –3–27–17; 15^{m}. 2–3.
652 –4–7–21; $14\frac{1}{2}^{\mathrm{m}}$. 3–4.
653 8–21–78, 79; $15^{\mathrm{m}}.1$. 2 pairs both with a "bridge".

Plate 43 Disruption of Compact Groups

654 9–13–55; 16^{m}. Many faint to the left.
655 0–32–13; 15^{m}. Three.
656 10–17–128; 130, 17^{m} and 17^{m}. Three? +2.
657 8–30–17; 15^{m}. Three of five.
658 $2^{\mathrm{h}}22^{\mathrm{m}}.1+26°08'$; $15^{\mathrm{m}}.6$. Three.
659 $9^{\mathrm{h}}36^{\mathrm{m}}.5+23°48'$; $15^{\mathrm{m}}.6$. Three.
660 8–21–37; $15^{\mathrm{m}}.3$. Three.
661 –2–2–48; 14^{m}. Three.
662 9–13–24; $15^{\mathrm{m}}.2$. Three or four.
663 0–22–24; $15^{\mathrm{m}}.7$. Three or four. Wonderful connection.
664 4–26–29; $15^{\mathrm{m}}.7$, /$14^{\mathrm{m}}.8$/. Three?
71 3–27–66=VV 71=A 192; $14^{\mathrm{m}}.5$. a – centre, b – faint parts. Northern companion $V_0=+6208$, Southern: +5951, both with emission lines (Kintner 1971).
665 1–13–1, $14^{\mathrm{m}}.8$. Four? $V=13.24$, $B-V=0.56$, $U-B=-0.27$, 68″ (AES 1976).
666 –4–33–24, 25, 26; 15^{m}. 16^{m}. 15^{m}. Birth of spirals?

Plate 44 Disruption of Chainlike Nests

667 8–30–24 to 27; 15^m. Group of more than 8 members.

668 0–53–14, 15; 4 members + ? The largest consists of four? For two members $V_0 = +6089$ and $+6074$ (Kopylov *et al.* 1974).

197 8–31–4, 5, 6 = VV 197 = A 312; $15^m.4$ and $15^m.7$. Two with a "bridge" and three aloof.

669 –3–59–8; $14^m.4$. a – blue, b – red. From the large galaxy a filament to the left and a blue loop of the haze with three companions.

670 $0^h36^m.6$ – 8°09′. Each 16^m. Three in a row and three joining up with the middle one in the red light.

671 –6–29–9; $15^m.5$. 10 galaxies, three in contact.

672 11–22–55, 56, 57; $13^m.6$. To the left 2–4 in contact, to the right two large objects, the left has a satellite "on a stem".

673 6–26–38, 39; /$14^m.7$/, 15^m and /$14^m.9$/, 16^m. A pair of pairs in contact. The other "pairs of pairs" are in plate 54.

Plate 45 Disruption into Groups of 3–4

674 –2–3–37 = A 251; 15^m. Is it possible that after a chance encounter the tidal appendages join as precisely as can be seen here?! Or has this been produced in another way?

675 10^h22^m, +48°05′; 17^m. "Corona" of 5–6 compacts. To the left a pair in contact.

676 1–33–38; $15^m.3$. "Trapezium" of four, the fifth is aloof.

677 –7–43–28, 29 every one 16^m. "Square" of 4–5.

678 3–34–39; $15^m.7$. A nest of 3–4 very compact. With a small contraction of the companions, they would coalesce into one object. Or will they disperse?

116 –1–25–8 to 12 = VV 116 = A 321; components: 15^m, $14^m.5$, 15^m, $15^m.5$. As a whole, the group can be seen in plate 47. At first sight there are two nearly edge on spirals connected to an elliptical. However the abrupt break and distribution of luminosity in the upper "bridge" are improbable for a bridge. It is more likely that there is another small (far?) spiral and an irregular also edge on, and the same way may be in the case of the lower "bridge". The contact of their ends to the elliptical galaxy can be a chance projection.

679 = VV 368 = VII Zw 790; 11–22–46, 47; $14^m.2$. Two tight pairs. To the left a spiral and a round object with a jet? Or is it thus a chance projection of a very distant spiral? To the right from one (or from two coalescent?) galaxies emerges a satellite "on a stem". It was shown as no. 368 in plate 4. $V_0 = +4457$ and $+4630$, $\Delta V_0 = 173$ kms^{-1} (KPLCh).

680 –1–33–64a; 17^m. A pair (?) and three in a contact.

681 8–34–17, 18. Every one 17^m. Three with a bridge and a contact.

682 NGC 6438 $18^h09^m.4$ – 85°26′; $11^m.2$. Elliptical galaxy and two very perturbed. To the right – two dwarfs. Photo by Sersic (1968a).

683 –1–6–81; $15\frac{1}{2}^m$. 3–4 coalescent and to the right an S0 edge one.

684 –1–12–12; $15\frac{1}{2}^m$. 2 in contact, the third aloof.

Plate 46 Tight Groups of Stefan and Seyfert

These are the most dispersed, the least dense, and have a small number of compact members.

288 6–49–38 to 42 = VV 288 = A 319 = Stefan's group. a – general aspect in the blue with the structure visible, b – photo by Arp (1973) in Hα with the numbered HII regions, c – contours of radio emissions over the blue photo (Allen and Hartsuiker 1972). The cross marks the radio source in the NGC 7319. Maximum is at the side of NGC 7318b SBb, where are gigantic HII regions, d – is an isodensitogram obtained by Arp, e – shows the NGC numbers and the red shifts obtained (Burbidges 1961). There is an extensive literature with a discussion about the relative and absolute distances of the members. It is just the cosmological distance of NGC 7318b that is consistent with the maximum of radio emission there and the size of its HII regions. The discussion was raised because of the considerably deviating red shift of NGC 7320. The magnitudes of the members are: NGC 7317 – 15ᵐ.3, 7318 – 14ᵐ.9, 7318 – 14ᵐ.4, 7319 – 14ᵐ.8, 7320 – 13ᵐ.8. *UBV* surface photometry Kalloghlian (1967), λ21 cm observations Balkowski *et al.* (1974), Shostak (1974).

115 4–38–5 to 10 = VV 115 = NGC 6027 = Seyfert's Quintet; 14ᵐ.7 to 16ᵐ.9. a – general view and the contours of radioemission in 1415 MHz (Bürke and Milley 1973). The cross denotes the localization of the maximum – which is in elliptical galaxy. b – gives the designation of the components and their red shifts (Chincarini and Rood 1972).

The literature concerning the stability of the groups is outside the scope of the Atlas.

Plate 47 Groups VV 116, VV 166 and NGC 7204

116 –1–25–8 to 12 = VV 116 = A 321; 15^m. a – general view, b – designation of members and their red shifts (Burbidges 1961). Notes concerning the three members on the right are in the list 45. Magnitudes (taken from MCG) range from 14½^m to 16^m.

166 5–1–64 to 71 = VV 166; a – general view on the "Palomar Atlas". Three principals, – a large spiral with many arms and the two ellipticals overlap. Studied by Kormendy and Sargent (1974) who gave the red shifts (shown in b) and the isodensitogram (shown in c). They have found dispersion of velocities 404 and 240, excluding NGC 68 which deviates from the average by 1000 kms^{-1}. In the last case m: L=51 is normal for a mixture of S and E galaxies. The absence of distortion in NGC 68 they take to indicate its remoteness from the group. However NGC 71 also is not perturbed and the influence of tides on the E galaxies has not been studied. Types and mg: F 15.7 E5, B 14ᵐ.5 E1, E 15ᵐ.7 E0, A 14ᵐ.5 Sc, C 14ᵐ.8 E1, D 15^m SBa, H (16^m) E, G (16^m) E5.

685 –5–52–29 = NGC 7204; 13ᵐ.5. In MCG the object is overexposed and appears to consist of two objects, both 14^m, flat, one of them nearly edge on, coalescent. The elongated object may consist of two or three galaxies coalescing into a chain. Very faint haze surrounding. This proved exactly to be the case as shows the short exposure made by Rubin (1974). This photograph is reproduced here with the radial velocities found by her for different parts of this group, rather a nest, of which the right part E – W is a chain. The east knot has a blue continuum, otherwise faint. Emission lines of H, [NII], [SII], [OII], [OIII] are present with a velocity gradient 200 kms^{-1} in 7 kpc. Central V_0 = +2630, practically the same as of a group NGC 7172–74, 76 also studied by Rubin at a distance 78′, which is 820 kpc. The chain on the photo here is 33″ long.

Plate 48 Some Triples and Coalescents

686 5–27–46; 15ᵐ.7, /14ᵐ.4/. Three coalescent.

687 8–30–21; 16^m. Three?

688 5–33–28; 29 = Mrk 280, 15ᵐ.2, V_0 = +11200 ds2e and +10980 (Denisjuk 1974).

689 3–26–16; 15ᵐ.6. a – blue, b – red. Curious object. Two elongated objects coalescent obliquely and between their protruding ends is the third galaxy and from the opposite side in the blue light emerges the faint gamma form.

690 –3–9–46 = Haro 21 = NGC 1345; V = 13.9. Three? $B-V$ = 0.53, $U-B$ = –0.14, V_0 = +1540 (du Puy 1970), V_0 = +1523, $m_{HI} = 1.1 \times 10^9$ $m_\odot$, $m_T = 9.6 \times 10^9$ $m_\odot$, m_T: L=4.6 (Bottinelli *et al.* 1973).

691 –1–36–6; 14½^m. Two or three.

692 1–39–8; 15ᵐ.6. Two and the third on a "bridge".

693 –5–32–40; 41. All are 15^m. Three or four.

694 –5–55–27; 15^m. Large compact image can be a compact galaxy.

695 –1–53–1, 3; 14½^m and 18^m. Three or four.

696 9–19–201, 202; 15ᵐ.7. Four spirals in the making?

697 4–1–2, 3, 4. Each one 15^m.

698 –5–52–8, 10, 11 = NGC 7173, 74, 76. Each one 13^m. In 1968 it was described in MCG as an interacting group. The two last coalescent (S + E compact).

Rubin (1974) refers to it however as a Clemola (1969) group, though she used mg and α, δ from MCG (1968). She reproduced a small-scale photograph of the group and supplemented the list of the red shifts known formerly. She concludes that the group is real with V_0 from +2520 to +2777.

699 –2–13–27, 28, 30. Every one 15^m.

The groups 688, 695–699 appear to be compact objects liable to expand by emanating the embryonic spiral arms simultaneously with the expansion of the group as a whole. In tight groups, the components rarely display the spiral arms.

Plate 49 Triples with a Tight Pair. I

700 –5–52–34, 35, 36; 12^m, 15^m and 14^m. A spiral, apparently SB and a compact companion in contact.

701 I Zw 106 $1^h44^m.0 + 34°32'$; $15^m.2$.

702 1–41–8; $14^m.7$. E and S coalescent.

703 9–15–25; 15^m.

704 8–24–79, 80; $15^m.5$.

705 $15^h16^m.3 + 43°03'$; 15^m? Found by the Burbidges (1963). Bright nuclei with bright line spectra. $V_0 = +12270$. $M < -22.0$.

706 14–8–24, 25; $14^m.3$ and 17^m. Two with compact companions "on a stem" and a faint spiral.

707 4–22–20; $15^m.3$ and $15^m.2$.

708 9–31–33, 34 = Mrk 221; $14^m.1$. Two coalescent. $V_0 = +4920$ (Denisjuk *et al.* 1974), +4998 (Sargent 1970) for every companion.

709 10–13–59; $15^m.5$. Two coalescent.

Plate 50 Triples with a Tight Pair. II

10 8–31–41, 42, 43 = VV 10 = A 102; $15^m.5$, $14^m.9$. Studied by Zwicky and Humason (1961). a – their sketch, c – Arp's photo (1966), b – main double member from "Palomar Atlas" 1 mm = 2″. No. 42, $14^m.7$, $V_0(B) = +7182$, A: E0 $14^m.9$, $V_0 = +7250$ with $M \sim -21.0$ for both. $m \sim 8 \times 10^{10}\, m_\odot$ and $m{:}\,L = 5$.

710 8–31–3, 3a = A 103; $15^m.4$ and 16^m. Studied by Zwicky and Humason (1961). a – their sketch, b – Arp's photo. A: S0 abs. spectrum G2, $V_0 = +9418$, $15^m.5$; B: Sa abs. spectrum with [OII], $V_0 = +9405$, $15^m.1$. C: SO abs. spectrum, $V_0 = +9449$, $16^m.5$, $m = 2.3 \times 10^{10}\, m_\odot$, $m{:}\,L = 1.0$.

237 5–27–10, 11 = VV 237 = A 105 = NGC 3561; $14^m.7$. Studied by Zwicky and Humason (1961). a – their sketch, b – photo of its right part. They gave: A: Sb or S0, spectrum G0, bright in the blue, $V_0 = +8803$. B: spectrum K0 and redder, $V_0 = +8550$. C – "Ambartsumian's knot" very blue. In its spectrum only [OII], $V_0 = +8839$. The system is in a cluster. As a chain it was also placed in plate 23. Magnitudes: A – $14^m.4$, B – $14^m.7$, C – $18^m.5$.

79 4–21–9 = VV 79 = A 243 = NGC 2623; $14^m.4$. Two or more bodies in contact. To interpret the central part better is difficult whatever the exposure. $V_0 = +5342$ A5. Spectrum of A type with emission lines described by Minkowski (1957) $m = 7 \times 10^{11}\, m_\odot$, $m{:}\,L = 10$.

Plate 51 Pairs of Coalescents. I

711 5–43–13; $15^m.2$.

712 5–43–1; $15^m.4$.

713 9–24–35; 14^m. $V_0 = +9410$ (Denisjuk and Dostal).

714 –7–44–26; $14\frac{1}{2}^m$.

715 –7–48–27; 13^{m}, ($12\overset{m}{.}8$), $V=12.46$, $B-V=0.38$, $U-B=-0.31$.
716 9–16–22; 15^{m}.
717 3–37–18; $15\overset{m}{.}2$.
718 5–43–3; $14\overset{m}{.}8$.
719 3–35–36; $15\overset{m}{.}6$.
720 8–28–38; $15\overset{m}{.}2$, $V_0=+789$, $M=-16.2$ (Sargent 1971).
721 –1–1–65; $13\frac{1}{2}^{m}$, a – blue, b – red.
722 0–26–25; /$14\overset{m}{.}7$/, $15\overset{m}{.}2$.
723 0–40–3; $14\overset{m}{.}5$.
724 –1–29–8, 9; $15\frac{1}{2}^{m}$ and $16\overset{m}{.}1$.

Plate 52 Pairs of Coalescents. II

725 –4–12–17; $14\frac{1}{2}^{m}$.
726 $17^{h}07\overset{m}{.}7+63°43'$; $13\overset{m}{.}1$.
727 5–26–6; $14\overset{m}{.}4$.
728 –3–3–3 = Haro 14 = NGC 244; 13^{m}, $V_0=+1021$ (Vaucouleurs 1967), +910 (du Puy 1970), +971 (R); +941 (Bottinelli *et al.* 1973), $m_H=4{,}6\times10^8\ m_\odot$, $m_T=4.4\times10^9\ m_\odot$, m: $L=2.2$, $B-V=0.43$.
730 1–4–44; $15\overset{m}{.}2$.
731 –1–59–17; = NGC 7592; $14\frac{1}{2}^{m}$, $V_0=+7440$ (R).
732 3–37–27; $15\overset{m}{.}2$.
733 –1–6–18; 14^{m}.
734 $17^{h}23\overset{m}{.}2-62°46'$ = NGC 6300. Photo Sersic (1968).
735 5–29–45; $14\overset{m}{.}6$. $V_0=+7830$ (Denisjuk and Dostal 1976).
736 $8^{h}27\overset{m}{.}7+18°22'$; $15\overset{m}{.}5$.
737 8–23–38, 39 = Mrk 212; $14\overset{m}{.}8$. Every one 16^{m}, $V_0=+7200$ and +6900 (Arakelian *et al.* 1970).
738 3–58–30; 15^{m}.
739 5–34–30; $15\overset{m}{.}5$. "Segner's wheel".
729 0–10–11, 12 = III Zw 55 = NGC 1409–10; $14\overset{m}{.}7$. Both separately $15\overset{m}{.}4$. From "Palomar Atlas". Another photo made with 200″ telescope by Sargent (1970) has the same appearance. The upper compact has a Seyfert spectrum, – if its hydrogen lines are not visible due to their great width. In the identification of NGC 1409 is some confusion. Vorontsov and Arhipova (1963) identified with 0–10–12 the northern very compact component NGC 1410 and with 0–10–11 NGC 1409 – the southern with a halo. Zwicky (1971) calls the northern "blue elliptical" companion NGC 1410 in contrast to NGC 1409 "red, patchy, ... halo". For a Seyfert spectrum, the blue, compact object which both observers call the northern NGC 1410 is more "suitable". But Sargent says: "the northern stellar component NGC 1409, appears stellar at the telescope. On the original plate, it is seen to consist of three condensations. ... the central stellar knot of NGC 1409 ...". However on his photo obtained with the 200″ telescope and on our reproduction from "Palomar Sky Atlas", the whole object appears to consist of three condensations, the third being very small and faint, – the most northern detail, and then the stellar (or very compact component) is at the centre of the whole system. Sargent (1970) measured for the northern component $V=15.22$, $B-V=0.84$, $U-B=0.17$, and for the southern $V=14.72$, $B-V=1.18$, $U-B=0.93$, $V_0=+7378$. For the northern (?) component $V_0=+7576$ (K, L, P, Ch).

Plate 53 Pairs in Contact

65 –7–22–10 = VV 65 = NGC 3256; $B=12.42$, $V=11.62$. Photo by Sersic (1968a). Nearly the same appearance in "Palomar Atlas". Principal body apparently is double. Nucleus red and complicated. $V_0=+2539$ (R), +2665 (Carranza 1967); Allen (1974) quotes Vaucouleurs $V_0=+2868$, himself finds $V_0=+2800\pm20$ and believes V_0 to be variable. $M_v = -22$. There is radio emission. In MCG $(B-V)_0 = 0.43$, $(U-B)_0 = -0.55$, Vaucouleurs and Vaucouleurs (1972) give $(B-V)_0 = 0.36$, $(U-B)_0 = -0.39$.

740 9–16–60, 61; 15^m.
741 –2–25–26; 15^m.
742 –1–1–62, 63; 15^m and $15^m.5$.
743 –6–31–27, 28; 15^m and $15\frac{1}{2}^m$.
744 3–36–97; $15^m.4$.
745 0–39–25; 15^m and $15^m.3$.
746 5–31–135 = A 139; $15^m.5$, $V_0 = +11420$ (A).
747 6–24–38; $15^m.5$.
748 2–54–8, 9; $14^m.6$ and $15^m.4$.
749 1–22–11; $14^m.7$.
750 –4–48–29. Both 15^m.
264 5–34–83 = VV 264 = A 241; 15^m "Segner's wheel". $V_0 = +11326$ (Arp 1967), $+11517$ (Tifft and Gregory 1973) abs. and [OII].
751 3–6–12; $14^m.6$.
752 4–35–4; $15^m.4$.

Plate 54 Pairs of Tight Pairs

Analogous to the ε Lyrae type systems.

753 6–26–38, 39; /$14^m.7$/, $15^m.4$ and /$14^m.9$/, 16^m.
754 1–30–3, 4; /$14^m.3$/ and $15^m.3$, 15^m.
755 3–27–64; $15^m.5$. Both are rather triple. = VV 393.
303 5–34–76, 77, 78 = VV 303 = A 95; $15^m.3$. Further fragmentation of both seems to have started.
756 8–21–78, 79. Both 16^m and a smaller pair with a thin bridge in the upper right. It is VV 653 in plate 42.
757 9–13–5a, 5b, 6. Bright pair, $15^m.7$, faint system is 17^m and triple in contact.
758 –1–30–19; 16^m.
759 –1–32–5; 16^m.
760 –1–12–5, 6; $15\frac{1}{2}^m$.
761 10–13–38; $15^m.6$.
762 $14^h33^m.5 + 24°55'$. Total 15^m. The right one is triple.
763 2–8–43; $15^m.3$. The left system may be triple.
764 –4–49–15, 16; 14^m and 16^m. Both may be triple.
765 8–16–36 to 39; 13^m, 16^m, 16^m, 17^m, 16^m.
766 3–38–50; $15^m.6$. Frame 766 above contains doubles in contact. The largest has an appendix downward. Companions to the right. Below is another pair.

In order to understand the origin of galaxies it is more important to study such accumulations of pairs than to study complicated deformations in single pairs.

Plate 55 Parallel Flat Systems

With references to the question of complanar galaxies and orbits.

767 –4–48–11, 12. Both 15^m.
768 –6–21–5, 6; 16^m and 17^m.
769 8–3–11, 13; $15^m.1$ and $14^m.6$.
321 8–18–52, 53 = VV 321; $15^m.6$ and 15^m.

770 –6–4–30, 31; both 15^m.

771 –7–47–20 = NGC 7496; $12^m.19$. $V_0 = +1446$ emissions (Shobrock 1966). Photo by Sersic (1968a). $V = 12.35$, $B - V = 0.58$, $U - B = 0.00$.

772 –1–8–16, 17; 17^m and 17^m.

773 2–52–8; 15^m.

52 –1–25–31, 32 = VV 52 = A 253. Both 15^m. $V_0 = +1723$, emissions Hα, N 1 (Vaucouleurs 1972).

Plate 56 Flat Systems Forming Angles

With references to the questions of non-complanar galaxies and orbits.

774 $16^h10^m.6 + 27°27'$; $15\frac{1}{2}^m$.

775 6–32–58, 58a; $15^m.2$.

228 5–28–8, 9 = A 294 = NGC 3786; /$13^m.2$/, $13^m.5$ and /$12^m.6$/, $13^m.2$, $V_0 = +2737$ and 2327 (R); +2723, +2308 (Page 1970).

776 –5–10–10, 11; 15^m and 16^m.

777 4–10–18; $15^m.7$.

778 1–44–8; $15^m.2$. A case of connection of two galaxies through a knot which we have encountered several times.

779 –3–4–40, 41; both 14^m.

780 –7–31–1, 2, 3; 15^m, 17^m, $14\frac{1}{2}^m$.

781 –3–4–52, 53; both 14^m.

782 2–36–32; $15^m.1$.

Plate 57 Enigmatic VV 783 = 6–4–18 = NGC 523

Excellently studied by Chincarini and Gecathorn (1973) and Chincarini (1973), but still enigmatic. It is $13^m.5$. a – cometlike seen as one body – a good example of how multiple systems can remain unrecognized on the "Palomar Sky Atlas". b, c, and d – different prints made by us from the picture obtained by the authors at the Cassegrain focus of the 82" telescope using an image converter. Densitograms d and g are oriented in opposite directions. f and i – the velocity curve at different settings of the slit along the system. Zwicky (1971) described it as "posteruptive, three blue compact knots connected by a fanlike bright bar, fanlike jets and haze".

How Zwicky managed to see here three compact objects is not clear. From the text of the first authors it appears that there is only one knot, because they write that the western one is a foreground star, while the central elongated feature was barely seen in the telescope. In agreement with this, the authors discuss in detail the isophotes of the eastern knot only. However, further on they mention unexpectedly two dwarf galaxies and the intervening band considered to be the "bridge". Perhaps the second compact object coincides with the star? This would be more eligible for the isophotes presented. From our experience, since this is a very complicated picture (in projection) the system must be at least triple. The small object seen in the frame e may be related to the system. $V_0 = +4840$ and $1'' = 450$ pc. This dwarf is less than 6 kpc in diameter. From the velocity curves, the authors suppose rotation to be present. Spectrum is in absorption, and in the blue-yellow part of the spectrum only λ3727 A is bright.

Plate 58 Toomre's Tidal Models for Galaxies

Toomre's model for M 51 is reproduced in the plate 12. Here, we compare with photographs some more successful models of very astonishing systems.

224 5–30–76, 77 = VV 224 = A 242; /$14^m.7$/, /$14^m.4$/, "Mice", summarily $14^m.1$. It is not correct to call it NGC 4676, because before our communication this NGC number was unknown and NGC 4676 was catalogued as a single object. Later, it was labelled as IC 819–820 but with very wrong co-ordinates. a – photo by the Burbidges (their gift to the author). It gives an idea of the inner structure. b – shows the faint appendages (as in our Atlas I). c – the location of radio emission (Bürke and Miley 1974). d – is the Toomre's model. It imitates the object very well by an ingenious choice of the appropriate orbital and collisional parameters – its moment and projection for the observer. The second spectral check of the intrinsic velocities (Stockton 1974) gave results not contradicting the velocities expected from the tidal theory of the case. For component A (with a strong tail) $V_0 = +6640$, and for $B - V_0 = +6560$, while the Burbidges (1961) obtained +6500 and 6605, respectively: this meant that B is receding from A. This contradicts the theory because it is impossible to produce a good tail if the "galaxy's spin is counter to its relative orbit about its companion". Theys *et al.* (1972) confirmed the direction of rotation obtained by the Burbidges, but Stockton (1974) turned over the direction of rotation of the components and in his abstract said that he removed the principal contradiction with the theory. However in the text, he said that the difference of velocities along the bright tail still amounts to 250 kms^{-1} at 90″ from the centre. This presents some difficulty for the theory. Moreover, $\Delta V_0 = 80$ kms^{-1} for the components is also difficult to reconcile with the motions in the tail on the basis of gravitational interaction. He says that the A type spectrum along the tail and inside the galaxy A itself indicates a violent star formation, which agrees with our inferences from the observation of galaxies which have been torn apart (text to plates 1, 2). Stockton arbitrarily chose the centres of galaxies and it influences the value accepted for ΔV_0.

245 –3–31–14, 15 = VV 245 = A 244 = NGC 4038–9; 15^m and 13^m. These enigmatic formations are better presented in our Atlas I, than in 245a. They are considered as two coalescent galaxies with two long and very faint arcs called antennae (as in the case of certain insects). Their form is well reproduced by Toomre on 245b in the plane (above) and in the visible projection (below). The velocity field in their brighter part was studied by the Burbidges (1966), Rubin *et al.* (1970), who gave also the intensities of numerous emissions. $V_0 = +1636$, $\Delta V_0 = 235$ in the regions of emissions. Rotation was not very evident. From V_0, sizes of HII and from SN 1921, the distance is 9 Mpc. For NGC 4039, $V = 12.49$, $B - V = 0.78$, $U - B = -0.06$.

Very similar structure is displayed by the central part of NGC 3995 (in the pair VV 249). Both objects are shown in Plate 70 together with the velocity field of NGC 4038/39 which is difficult to interpret. Huchtmeier and Bohnenstengel (1975) gave results of their observations of HI in "antennae". Their total mass is $2{,}8 \times 10^9$ $m_\odot$ with 30% of HI and the mass of the whole system may be $10^{10} - 10^{11}$ $m_\odot$. The most probable distance must be derived from the redshift: 33 kpc. (The HII regions here are too large to be compared in size to the usual ones. They are exceptionally large as is shown by the similar NGC 3995, for which the distance from the redshift is very reliable.) With distance 33 Mpc the diameters of the HII regions amount here to 1500 pc. The loop of HII regions is 138″ or 23000 pc in diameter, and the size with antennae is 180000 pc. The magnitude of Supernova which appeared there in 1921 was not known.

The velocity field and better photographs of VV 245 are presented on plate 70. The central region of NGC 4038/39 is most peculiar because there is no evidence of the nuclei of two galaxies nor of the discs used by Toomre in his models which well explain the big antennae. Instead there are complicated gigantic loops of enormous HII regions. Hitherto this did not attract attention. NGC 4038/39 is a faint radio galaxy (flux 0,65 f.u. at 1420 MHz) known from 1958 and is somewhat stronger than M 82. Burke and Miley (1973) have found that the source of continuum radiation is midway between the two galaxies. This point in figure 245 is just below the crest of the chain of gigantic HII regions. The boundaries of the faint luminous matter produce the impression that there really are two galaxies – hence the mention of two galaxies in NGC and in later references. But there are no two discs characteristic for spirals. The enormous chain of gigantic HII regions forms a deformed ring with a hook. Central region of NGC 3995 (plate 70) is similar. It is ascribed to one galaxy.

34 –1–60–21, 22 = VV 34 = A 295; both $14^m\!.5$. This is Zwicky's famous system in Pisces, which has the longest and thinnest "bridge" ever observed between two spirals. One of them also has a very thin and long tail, but the other galaxy does not. Humason (Zwicky 1956) measured the difference of velocities in the pair

$\Delta V_0 = 239$; this is too large for the Toomre's model. Stockton (1974) obtained for the larger, southern galaxy A $\Delta V_0 = +6860$ and for the lesser $+6960$, so that $\Delta V_0 = 100 \pm 20$. He estimated m_A: $m_B = 3.5$ and obtained the rotation velocity curves, but not the masses. He concluded that the system is bound and that Toomre's model 34b (shown here in several projections) meets no objections. Arp (1962) communicated that in the "bridge" he had found considerable polarization which is impossible if the "bridge" consisted of stars. This observation needs confirmation, but nothing prevents gas from flowing with the stars into the "bridge" and producing polarization. Biver *et al.* (1974), using a new technique, measured the surface brightness of this extremely faint bridge and found it to be $25^{m}_{.}9$ from 1″ square and $B-V=1.00$. One point in the tail has the same colour but slightly smaller brightness.

231 1–4–52 = VV 231 = A 157 = NGC 520; $12^{m}_{.}35$. Hodge (1963) obtained: $(B-V)=0.70$, $(U-B)=0.21$, CI = 0.81, but Khachikian (1973) in a detailed survey found very patchy and variegated contents. The colour changes considerably from place to place. On the 200″ spectrograms with adispersion of 85 Å/mm, he followed the [OII] line out to 5400 pc. He measured the equivalent width of lines, and found a super-association 750 pc in diameter. Absorption spectrum of an early type, giants $B_1 - B_2$ are suspected. In many places the absorptions are shifted relative to emissions by 250 kms^{-1}, but in the southern part only by 120. He postulates that NGC 520 suffered an explosion similar to M 82 although it is rich in hot stars. We believe that the strong traces of perturbations and appendages are due to the double nature of the system. One of the components may be sliding along the other at right angles to our line of vision. Mayall and de Vaucouleurs (1962) found for the bright half $V_0 = +2422$, and for the faint one $+2857$, which confirms the double nature. The former values were $V_0 = +2177$ and 2320 (R) for the whole object. Kreinke (1975) from his multicolour photometry confirms the double nature of VV 231.

Plate 59 Enigmatic Forms. I

786 $11^{h}41^{m}_{.}9$ – 40°27′, "Lemon"; 17^{m}. It looks like a lemon on the normally printed image (photo b). On a the image is strongly intensified, showing better the band which intersects it obliquely. At the left two galaxies are coalescent. The author (Vorontsov 1975a) already drew attention to this enigmatic object.

Further we confront the three objects: elliptical rings with eccentric nuclei of which the two: 784 and 785, we (Vorontsov 1976) discussed formerly. The third one, discovered by Herzog, and designated II Hz 4, was made known only from two preprints named below, but too late to be inserted in the present atlas. We believe that these elliptical rings are closely related to the sequences of circular rings with a central nucleus, which we discovered 16 years ago (Vorontsov 1960 and elsewhere). We discovered that there exist two sequences of pure ring and pure disc galaxies parallel to the Hubble sequences of S and SB galaxies. They differ from the flat S0 galaxies having all degrees of patchiness, of condensations typical for spiral arms with different rates of star-birth. They have no spiral arms, nor bars, but there are forms with the hint of a bar, and of complicated structure of the nucleus. There are also intermediate forms: discs with a ring effect – more or less pronounced. Diameter of the nucleus compared to the diameter of the ring vary, as well as the relative thickness of the ring. The same we notice among the three elliptic rings. The ring of II Hz 4 is smooth, as in Sab galaxies, in the picture VV 785 the texture is more like Sb, and in VV 784 it is as in Sc, with the smallest nucleus, and a faint disc (with spirals), which is barely evident in the two other objects. The apparent relative thickness of the ring depends also on the exposure and scale – compare 784a and 784b. Ratio of the diameter of the nucleus to the largest diameter of the ring of II Hz 4, on the three photographs made by Lynds at the 4 m telescope, increases from 0.3, through 0.5, to a complete blending of the nucleus with the ring.

In what respect the new elliptical rings with a nucleus differ from the pure ring galaxies presented and described in 1960? The rings, as we called them, are also differently transformed into ellipses. Perhaps the sole difference is in the not central localization of the nucleus. But the same we have in MCG 0–27–15 (IC 614) which at the time we considered to be the projection of a ring. Maybe it belongs to the new group considered here. The nuclei of the circular rings sometimes are of unknown, but complicated structure. The nucleus of Zwicky's ellipse on the photo with the better resolution shows that there is a smaller elliptical ring, the nucleus itself is much smaller, much elongated and also is not in the centre of the small elliptical ring.

The II Hz 4 object was studied by Lynds and Toomre (1976). These authors, as well as Theys and Spiegel (1976) and Freeman with Vaucouleurs (1971) developed different versions of a theory that the ellipses with eccentric nucleus of this paragraph are a result of drastic direct, mostly central, collisions of one spiral or S0 galaxy with another one, or with an intergalactic cloud of neutral hydrogen. In their theories they discuss, jointly with these objects, the pure ring galaxies, without traces of a nucleus and some other forms presented in the next paragraph. The complicated inner features in the Zwicky ellipse were not discussed in these theories.

Because the objects of this paragraph seem intimately connected to the most numerous ring galaxies, discovered in 1960, and the latter link to the common S and SB galaxies, we think it possible that, after all, these unusual objects could have developed in a more peaceful, ordinary way which must have produced the common S and SB galaxies.

Below are the data concerning the individual objects discussed above.

784 –6–2–22a = "Zwicky's ellipse"; $13^{m}_{.}4$. a – from Zwicky (1941), b – from the "Palomar Atlas". A photograph with better resolution is given by Theys and Spiegel. As well as the object discussed below (no. 785) the ellipse is remarkable in that the nucleus is not at its centre, which is therefore not in the plane of a ring, whose projection could be this ellipse. The ring is amazingly thin. From the nucleus, which is surrounded by a small, inner ring, emerge 3–4 faint spiral arms! Some arms reach the larger elliptic ring. To the right there are two galaxies in contact. They are compact and probably are much farther from us. Attention to this ellipse has been recently drawn (Vorontsov 1975a).

785 $6^{h}43^{m}_{.}5$–74°14′ (1975) – "Southern ellipse" was found by Lindsay and Shapley (1960) and recently studied by Graham (1974). It is 95″ × 50″, but Graham considers that it is a spiral single arm, which makes 1½ turns. The nucleus is overexposed and its structure is unknown. It looks like an E galaxy. It differs from Zwicky's ellipse by the absence of an inner disc and of spiral arms. It has much greater eccentricity. The sketch shows the red shifts of the nucleus and of the neighbouring galaxies of the group. Magnitudes, colours and luminosities are given below:

	V	$B–V$	M_v
A	$13^{m}_{.}04$	0.92	–21.6
B	$13^{m}_{.}82$	1.04	–20.8
C	$14^{m}_{.}59$	0.96	–20.0
D	$13^{m}_{.}96$	0.98	–20.6

In the bright part of the ellipse Hα, Hβ [OII] lines are in emission. Their red shifts are identical with that of the nucleus which has an absorption spectrum. Diameter of the ellipse is 60 kpc!

Plate 60 Rings and Pseudo-Rings

Vorontsov (1972) attracted attention to the fact that there exists a class of double objects in which a non-elliptic galaxy is accompanied at a close distance by a ring of galactic dimensions but without a nucleus (which is the most enigmatic). There is no proof that there are no stars in the ring. They are necessary to excite the luminescence of the gaseous ring. We know and reproduce here four such rings in pairs: 32, 787, 788, 790. Theys and Spiegel (1976) in an extensive paper denote such galaxies RE, and those described above as RN, N meaning the presence of a nucleus. They denote some other galaxies, probably akin to these above, as RK. Of them here is reproduced 790b, 789, 285. They, as well as two teams of astronomers mentioned above, tend to consider them also as ring galaxies but with their nuclei (or nuclei of the "attacking" galaxy) to be disposed, or projected on the ring itself – due to the circumstances of encounter or of projection. It seems to us that rather the photographs 789, 285 and 791 represent the one-armed spirals with the arm returning back to the principal body. Such galaxies (and those with two arms returning back) are not uncommon among the descriptions in MCG. In all these cases the supposed nucleus of the ring is exceptionally large compared to the diameter of the ring. Besides it is improbable that, against the three cases of internal location of the nucleus, there are more cases when the nucleus projects exactly on the ring. More likely one, or two arms emerge from the main body. In VV 791 there is even a gamma-form emerging from one end of it. Objects 790a and 790b may be pairs of coalescent galaxies. Of rings there is not much to see. So, probably, the RK group unites the pseudo rings: "stirrups", in the last line of plate 60, and chance peculiar objects. They are not related to the elliptical rings with a nucleus or without it. The pure ring galaxies without nucleus inside, which have a close companion (VV 32, 787, 788, 790) are more likely candidates to represent the result of galactic encounter. Lynds and Toomre (1976) by means of a strong intensification, obtained a very faint detail near II Hz 4 which they consider to be the elliptical ring, which touches the bright ring with a nucleus discovered by Herzog and described above. On ordinary photograph one sees a slightly elongated companion nearly in contact with the bright ring. From the companion emerges a tail in the direction opposite to the direction toward the nucleus of the bright ring. This must be the result of tidal interaction between two nuclei. The tidal theory of such tails was brilliantly developed by Toomre. Strangely enough he does not even mention this tail. Instead he considers it apparently to be a part (and enormously bright part indeed) of the faint ring which the authors discern to the north of the bright ring. The companion they consider to be the nucleus of the faint northern ring. The existence of two wonderful rings in a contact has some chance to be of spurious nature. The left (east?) part of the faint ring abruptly transforms into a very bright end of a tail mentioned above. And at their junction they make an acute angle, unsuitable for the ring. The reason of it may be, that exactly here passes one of the diffracting rays of the bright star seen to the north. The upper right part of the ring may be in fact but another filament of tidal interaction emerging from the bright ring or from one of the two galaxies.

Theys and Spiegel (1976) contributed the new red-shifts and the first *UBV* data for some ring galaxies. They are inserted below, but owing to the complicated structure and a specific interest about the colours of different parts of these systems, one needs to inspect closer the source of information.

32 7–23–19 = VV 32 = A 148; V = $14^{m}_{.}29$. "Mayall's object". a and b – photo by Burbidges (1964), c – from Arp (1966). The main body appears to consist of the two coalescent objects or of two in projection. Studied by Burbidge (1964). Vaucouleurs (1961) gives $V_0 = +10355$, $B-V = 0.88$, $U-B = -0.08$. In the spectrum of the main body there are emission lines Hα and [NII], but in the nucleus only Hα, $V_0 = +10374$ and differs from the velocity of the ring by 240 kms^{-1} on the average. The ring is 14700 pc in diameter. The main body seems to rotate. Vorontsov's (1970, 1972) estimate of its mass is about 8×10^9 $m_\odot$. Theys and Spiegel give: $B-V = 0.65$, $U-B = -0.02$.

787 0–9–15 = A 147; $15^{m}_{.}1$. Studied by Sargent (1970). In the spectrum of the spiral (seen nearly edge-on) a blue continuum, H and K in absorption and emission of λ 3727 A. Knots in the ring have bright emissions. $V_0 = +9424$, $M = -21.5$. Theys and Spiegel (1976) give $V_0 = +9660$.

790 $0^h05^m_{.}0 - 6°54'$ = Arp 146; $14^{m}_{.}66$. Discovered by Dewhirst. Not studied. Theys and Spiegel (1976) give

for the ring:	$M_v = -21.3$,	$B-V = 0.41$,	$U-B = -0.24$;
for the companion:	-21.7	1.08	0.66.

788 VII Zw 466 ($12^h29^m_{.}8 + 66°40'$). Photo and isodensitogram by Chincarini and Hecathorn (1974). See also Chincarini 1973.

789 6–28–37 = NGC 4774 = I Zw 45; $14^{m}_{.}6$. Photo by Cannon *et al.* (1970) who named it I Zw 44 by mistake. Theys and Spiegel give: $V_0 = +8390$, $M_v = -21.2$, $B-V = 0.58$, $U-B = -0.13$.

790a 3–5–13 = III Zw 33; = Mrk 360; $14^{m}_{.}7$. Studied and photographed by Sargent (1970). $V_0 = +8036$ CaII and hydrogen in absorption; sharp emission lines.

790b II Zw 28; $4^h59^m_{.}0 + 3°30'$; $14^{m}_{.}9$. Studied by Sargent (1970). $V_0 = +8548$ hyd. abs., sharp emission. His photo, much enlarged by us, as well as is also the preceding one. Can be expanding or rotating, as indicates the tilt of the lines. Theys and Spiegel (1976) give: $M_v = -20.7$, $B-V = 0.30$, $U-B = -0.15$.

285 –2–7–35 = NGC 985. Spectroscopically studied by the Vaucouleurs (1975), who have found $V_0 = +13000$ and a Seifert nucleus. Line half width 5500 kms^{-1} for hydrogen and <200 kms^{-1} for [OIII]. M_{ph} is about -23!

791 4–40–1 = VV 846; $15^{m}.5$. Zwicky *et al.* in their catalogue consider the loop which makes a half turn to be a jet.

791a –3–2–24 = NGC 175; $12^{m}.8$. An SB. The ring is not complete and forms also a stirrup.

Plate 61 Enigmatic Forms. II

792 10–20–52; $15^{m}.6$. An amazing arc. Haze. Very blue object. a – blue, b – red.

793 13–4–3; $15^{m}.2$. A nest of dwarf galaxies?

794 6–24–6 "A Spider"; $15^{m}.1$. a – blue, b – red. Galactic latitude $+62°$. The two last objects have already been published (Vorontsov 1975a).

795 1–29–30. "A flying bird", $14^{m}.4$.

Plate 62 "Comets" in the Optical Domain and Radio. I

796 –5–24–28 = NGC 3175; $12^{m}.1$; $V=11.65$, $B\text{–}V=0.93$, $U\text{–}B=0.26$.

797 6–29–3 = A 266 = NGC 4861 = Mrk 59 = I Zw 49; $12^{m}.8$. Studied by the Burbidges and Hoyle (1963). The head is roughly round, but this is not an elliptical galaxy. The spectral continuum is blue. Many emissions with [SII], [NII]. $V_0=+770$ (W, K). The length is not less than 15 kpc. $M=-18.3$. HI content is normal (Carozzi *et al.* 1974).

798 12–9–11 = IC 2389; /14^{m}/, $C'_p=0.61$, $V_0=+2782$ (R).

799 4–32–37; $15^{m}.2$.

800 –4–51–11; 14^{m}.

801 3–28–17; 15^{m}, a – blue, b – red.

A – Radiophotography of the source 3 C 129 at the frequency 1415 Mg H.

B – Radiophotography of the source 3 C 1265. The scale here is $8'.4$ per mm.
The length of the latter was estimated above 400 kpc. Both pictures from Miley and van der Laan (1973).

Plate 63 "Comets" in the Optical Domain and Radio. II

255 3–1–3, 4 = VV 255 = A 262; $14^{m}.5$.

The other types are reproduced for comparison.

802 –3–34–48, 49, both 15^{m}. Distance 105 Mpc, $M=-20.1$ (Vorontsov and Baranova 1974c).

250 10–19–56, 57 = VV 250 = A 238; $14^{m}.4$, $V_0=+9623$ and $+9393$ (KPCh).

172bis 12–11–28 = VV 172 = A 329; $15^{m}.2$. From plate 23.

783e bis 6–4–18 = A 158 = NGC 523; $13^{m}.5$. $V_0=+4940$ (Z). It is completely shown in plate 57.

803 5–35–23; $15^{m}.3$.

804 5–25–25 = A 267; $15^{m}.6$.

The rest are radiophotographs of the sources from Miley and van der Laan (1973).

C 3C 465	E 3C 66	G 3C 61.1
D 3C 402	F 3C 274.1	H 3C 390.3.

Plate 64 Tidal Streams besides the Spiral Arms

50 7–19–55, 56 = VV 50 = A 283 = NGC 2798–9; $12^{m}.9$ and $14^{m}.4$, $V_0=+1699$. NGC 2798: $V=12.78$, $B\text{–}V=0.76$, $U\text{–}B=0.01$ 50″ (AES 1976).

21 –1–36–3, 4 = VV 21 = A 271 = NGC 5426,27; $12^{m}.71$ and $11^{m}.98$. Double thin "bridges". One of them at right angle to the spiral arm. Contains HII regions. It would seem highly unlikely that they can be produced by the tides. $V_0=+2452$ and $+2356$ (R, P), $B\text{–}V=0.46$ and 0.64, $U\text{–}B=-0.01$ and -0.06, [OII] bright in both.

805 5–40–34 = Mrk 700; $15\overset{m}{.}4$. A jet?

806 4–1–13 = Mrk 334; $14\overset{m}{.}4$. Can the jet curve backwards? Or is it a single arm? $V_0 = +6900$ (ADE).

55 0–35–15, 16 = VV 55 = A 240 = NGC 5257–58; /$12\overset{m}{.}9$/, $13\overset{m}{.}7$ and /$13\overset{m}{.}3$/, $13\overset{m}{.}8$. One arm of the upper galaxy intrudes perpendicularly into the spiral arm of the lower galaxy. Both branches are curved, but there are no special tidal tails. $V_0 = +6693$ and $+6572$ (R, T).

247 11–22–30, 31 = VV 247 = A 81 = NGC 6621–2; $13\overset{m}{.}6$. Photo by the Burbidges (presented to the author). The spiral with unscathed arms of one galaxy barely touches the small irregular galaxy. Between them is a bright cloud and the tail of the spiral begins independently from the arms and is too massive. Total $V_0 = +6490$ (R), (KLCh) give $V_0 = +6454 \pm 85$ and $+6201 \pm 15$, $V = 13.17$, $B-V = 1.01$, $U-B = 0.29$ total.

807 4–39–8; $16^h27\overset{m}{.}8 + 24°32'$; $15\overset{m}{.}5$. In the red the round part is sharper. If it is a star, then instead of a jet we have here a ring partly masked by this star.

33 11–17–4,5 = VV 33 = A 104 = NGC 5216–18; $13\overset{m}{.}1$ and 14^m, Keenan's system. One of the thinnest "bridges" known perpendicular to the spiral arm. It seems amazing that apparently from an elliptical galaxy, besides a compact, emerges a long tail, although the high density of a galaxy must make it difficult to deform. $V = 13.02$ and 12.52; $B-V = 0.92$ and 0.84, $U-B = 0.47$ and 0.32.

Plate 65 Breaking of Bridges

– Another phenomenon hardly explicable by tides.

808 3–25–8; $14\overset{m}{.}9$.
809 0–12–26, 27; $14\overset{m}{.}9$.
810 0–22–17, 18; both $14\overset{m}{.}7$.
811 5–39–6; $15\overset{m}{.}3$.
471bis 3–38–7; $15\overset{m}{.}1$.
812 2–56–5; 16^m, $V_0 = +8400$ (KLPrCh).
813 3–25–20; $15\overset{m}{.}7$.
814 7–25–46; /$14\overset{m}{.}4$/, $15\overset{m}{.}3$, $V_0 = +1886$ (KLPrCh).
815 0–38–10; $15\overset{m}{.}2$ in the red.
816 9–26–21; 16^m.
817 –2–7–27; 16^m.

Plate 66 Not Tidal Phenomena. I

818 8–33–29, 30; $14\overset{m}{.}8$. A nest recalling us of radio galaxy VV 201 on the plate 3.

42 7–26–33, 34 = VV 42 = A 211; 17^m and 16^m. Is this a chance head-on collision of amazingly similar galaxies, or a quiet framgentation of one galaxy into two halves? Collisions head on are extremely rare, and for the equal components of an isolated pair impossible. The same event apparently takes place with 820, and on a larger scale with 201 (plate 3).

819 IV Zw 14 $00^h\ 18\overset{m}{.}0 + 34°05'$; $16\overset{m}{.}2$.

820 0–43–3; $14\overset{m}{.}9$.

821 IC 883 = A 193; $14\overset{m}{.}8$. $13^h18\overset{m}{.}3 + 34°24'$. Studied by Burbidge (1964) following to recommendations by Hoyle. In the spectrum of the main body Hα and [NII] are bright. $V_0 = +6967$ (Z, Sr, B), the length is 20 kpc, with tails and the faint "fan" 36 × 30 kpc. Along the main body there is a velocity gradient 100–140 $\mathrm{km\,s^{-1}}$.

822 –1–13–34 = A 180; 16^m.

823 7–32–6,7 = A 90 = NGC 5929–30; /$14\overset{m}{.}1$/ and /$13\overset{m}{.}6$/. $V_0 = +2868$ (R). For comparable masses and a flat structure which would appear to be the case here, one may expect tidal phenomena. However the arms of the larger are not perturbed. Instead, it is enveloped in a broad band as in a shawl, whose end envelopes the smaller galaxy. Does not resemble the sketches of the tidal theory.

824, 825, 826 Nuclei of peculiar emission line galaxies photographed by Osmer *et al.* on a large scale (1974). Their NGC numbers are on the photographs. Such double structure may be caused only by splitting, as predicted by Ambartsumian. It can be the beginning of the division of the galaxy as a whole.

Plate 67 Not Tidal Phenomena. II

Here are collected the "bridges" and the very thick "tails" too, pairs of very similar galaxies with only one tail, with the bright haze along the whole system, as if blown off to one side (in the right column), the tails at right angle to the connecting line, forms such as 829, 830 and so on.

827 –7–3–13, 14; both 15^m.

828 9–22–82 = NGC 5238; $13^m.7$ and $14^m.2$.

829 8–31–38; 16^m.

830 –4–2–40; $14\frac{1}{2}^m$.

831 5–32–20 = Mrk 454; $15^m.1$. $V_0 = +7020$ sd2e (Denisjuk and Lipovetsky 1974), +6900 (Arakelian *et al.* 1973).

832 –5–53–14; $13^m.42$. Such a thin and twisting filament to a small satellite could not be produced by tides. It could be produced by separation or ejection from a tenacious mass.

833 5–8–6; 16^m.

834 8–19–16; $15^m.6$.

835 –5–29–16, 17; both 16^m.

836 4–36–7; $15^m.7$.

221 2–8–15 = VV 221 = A 190; 15^m.

837 –1–2–13; 17^m.

838 5–38–8,9 = Mrk 494; $15^m.2$. $V_0 = +9510$ ds2e (Denisjuk 1974).

839 5–34–64; $15^m.7$.

840 4–35–16, 17 = A 177; 17^m and 16^m.

112 2–27–42 = VV 112 = A 291; $13^m.8$.

841 5–31–133; 15^m.

842 5–35–12, 13; total $15^m.3$. Very blue haze completely to one side, no tails. In the red light each of the two objects is a double. Four galaxies in a line.

843 5–20–2; $15^m.4$.

Plate 68 Jets and Tails without Visible Cause

234 –2–2–23 = VV 234 = A 100; 15^m.

844 –1–32–31; 17^m.

845 9–17–71; 16^m.

846 = VV 791; 4–40–1; $15^m.3$.

847 0–39–23; $15^m.3$.

848 –1–15–2; 17^m.

849 6–20–34; $15^m.2$.

850 –2–1–32; $13\frac{1}{2}^m$.

318 3–41–69, 70 = VV 318 = A 101; $15\frac{1}{2}^m$ and $15^m.2$.

851 9–23–4; $15^m.0$, $V = 13.25$, $B-V = 0.63$, $U-B = -0.02$.

852 4–40–7; $14^m.8$, $V_0 = +11800$ (ADE, AES 1976), $V = 14.50$, $B-V = 1.00$, $U-B = -0.06$.

Plate 69 Additional Data. I

Delivered by the 6 m telescope from the negatives obtained by Koroviakovky and Shabanov.

523 6–26–60 = NGC 3991 = Haro no. 5. b, c, d, e – the successive exposures from the negative. They show the structure of this excellent young chain.

497 9–20–113. A chain. Successive exposures. Compare to plate 20.

261 9–20–119 = NGC 4194 = Arp 160 = Mrk 201. Successive exposures. Compare to plate 25. The whole fantastic structure originates from the coalescent compact bodies.

Scale of all photographs is 2″ per mm.

Plate 70 Additional Data. II

245c NGC 4038/39. Chain of gigantic HII regions in its center. From Burbidge (1966). Scale 1 mm = 3″.7. Compare to plate 58.

245d The velocity field from Burbidge *et al.* (1966).

245e The velocity field from Rubin *et al.* (1970).

249 II NGC 3994. Peculiar gigantic very compact spiral, $M = -21.6$, visual surface brightness $19^m.7$ per square second of arc. Here and in 249 Ia and Ib the scale is 2″ per mm. These three photos are made with the 6 m telescope.

249 I NGC 3995 gigantic peculiarly disturbed spiral with $M = -20.2$ 46 kpc in diameter. a – the inner region of HII regions without distinct nucleus, b – compare to VV 249 as given in our Atlas I.

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Table 1 Finding list of VV numbers

VV	Plate	VV	Plate	VV	Plate	VV	Plate
1	12	52	55	126	25	221	67
2	10	55	64	128	33	224	17,58
4	8	58	6	130	32	225	41
5	13	65	53	137	36	228	56
9	13	71	43	138	39	231	58
10	50	75	37	140	25	234	68
12	11	78	29	141	16	235	37
13	17	78bis	36	142	1	237	50,23
19	12	79	50	143	25	242	25
20	12	82	11	144	23	243	20
21	64	86	28	147	20	245	58,70
23	14	89	12	148	38	246	1
25	16	95	28	149	31	247	64
28	10	98	36	150	21	250	63
30	1	112	67	155	27	251	25
32	60	115	46	166	47	255	63
33	64	116	45, 47	167	24	258	42
34	58	117	26, 27	172bis	63,23	261	25,69
39	55	118	28	197	44	264	53
42	65	119	29	201	3	266	1
50	64	120	17	209	17	272	1
51	34	123	26	220	17,23	285	60

VV	Plate	VV	Plate	VV	Plate	VV	Plate
286	11	438 - 443	11	563 - 565	34	784 - 786	59
288	46	444 - 445	12	566 - 577	35	787 - 791	60
298	11	446	13	578 - 587	36	792 - 795	61
301	17	447 - 455	14	588 - 594	37	796 - 801	62
303	54	456 - 463	15	595 - 607	38	802 - 804	63
313	2	464 - 475	16	608 - 618	39	805 - 807	64
318	68	476 - 479	17	619 - 625	40	808 - 817	65
321	55	480 - 487	18	626 - 639	41	818 - 826	66
329	5	488 - 493	19	640 - 653	42	827 - 843	67
331	1	494 - 498	20	654 - 666	43	844 - 852	68
336	38	499 - 503	21	667 - 673	44	497	69
347	4	504 - 516	22	674 - 684	45	523	69
356 - 357	1	517 - 518	23	685	47	249	70
358 - 363	2	519 - 523	24	686 - 699	48		
364	3	524 - 525	25	700 - 709	49		
365 -372	4	526	27	710	50		
373 - 383	5	527 - 533	28	711 - 724	51		
384 - 391	6	534 - 540	29	725 - 739	52		
392 -406	7	541 - 546	30	740 - 752	53		
407 - 415	8	547 - 552	31	753 - 766	54		
416 - 427	9	553 - 557	32	767 - 773	55		
428 - 437	10	558 - 562	33	774 - 783	56		

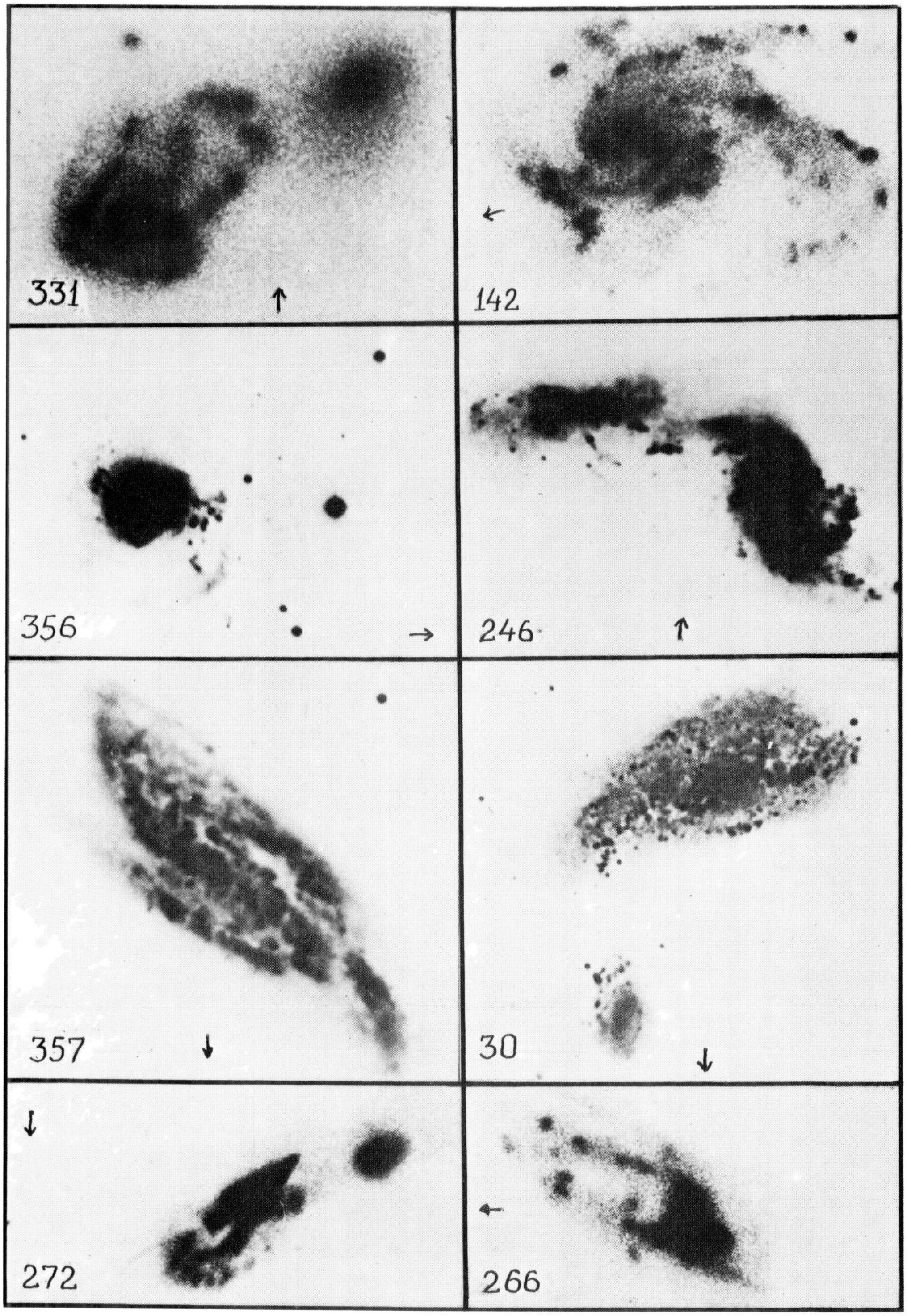

Plate 1 Peculiar distribution of large HII regions.

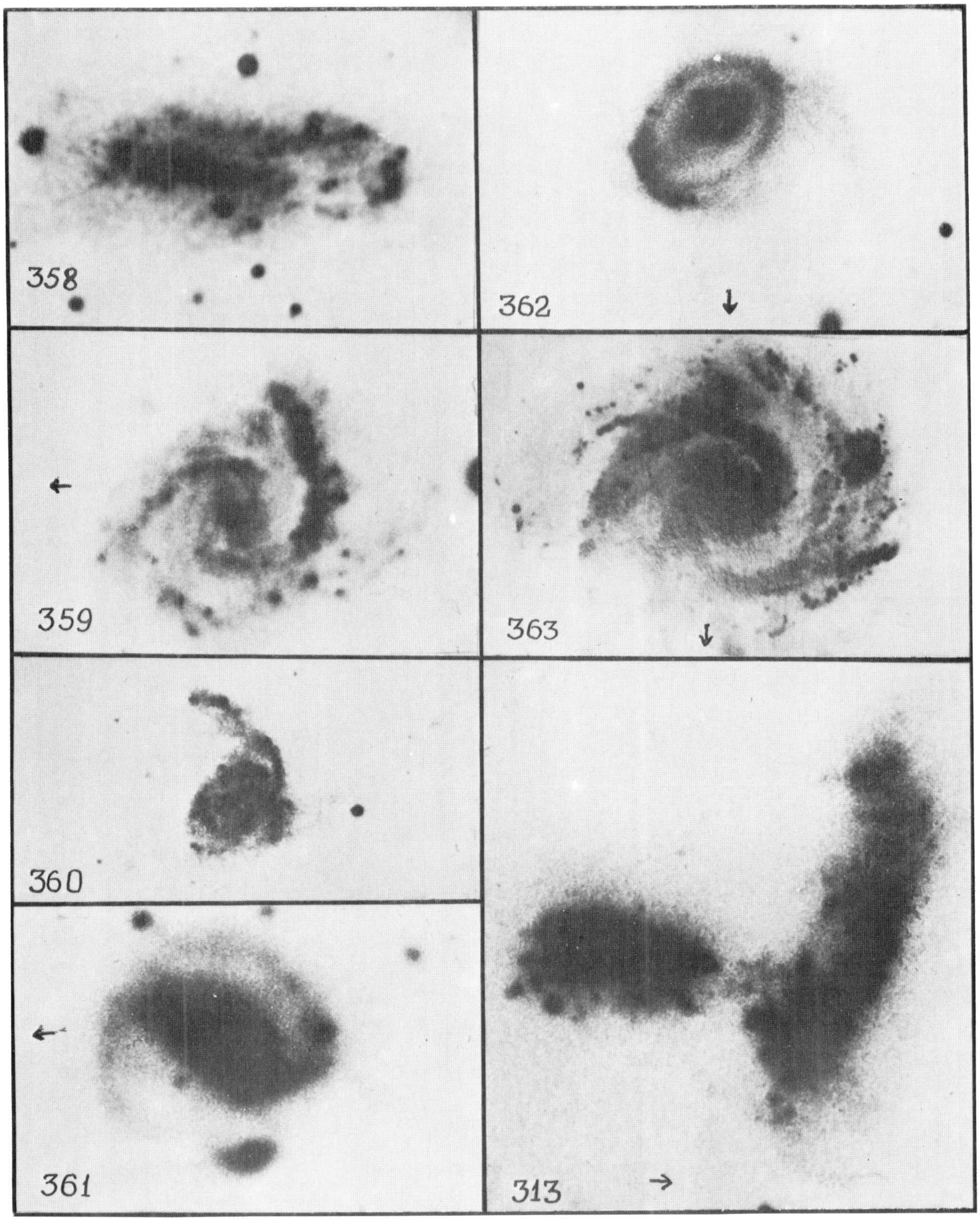

Plate 2 Large inner subsystems.

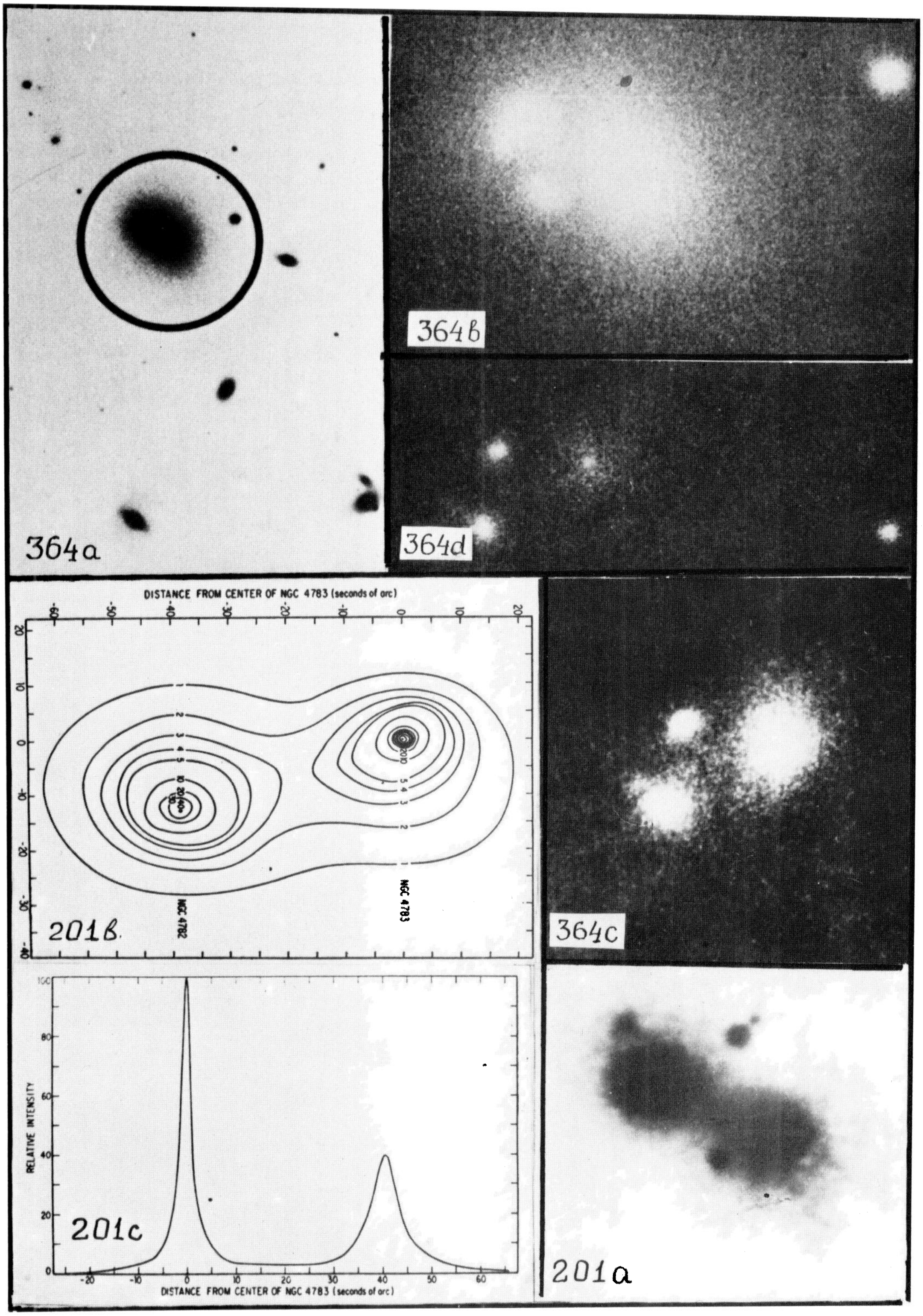

Plate 3 Radio nests of spherical galaxies.

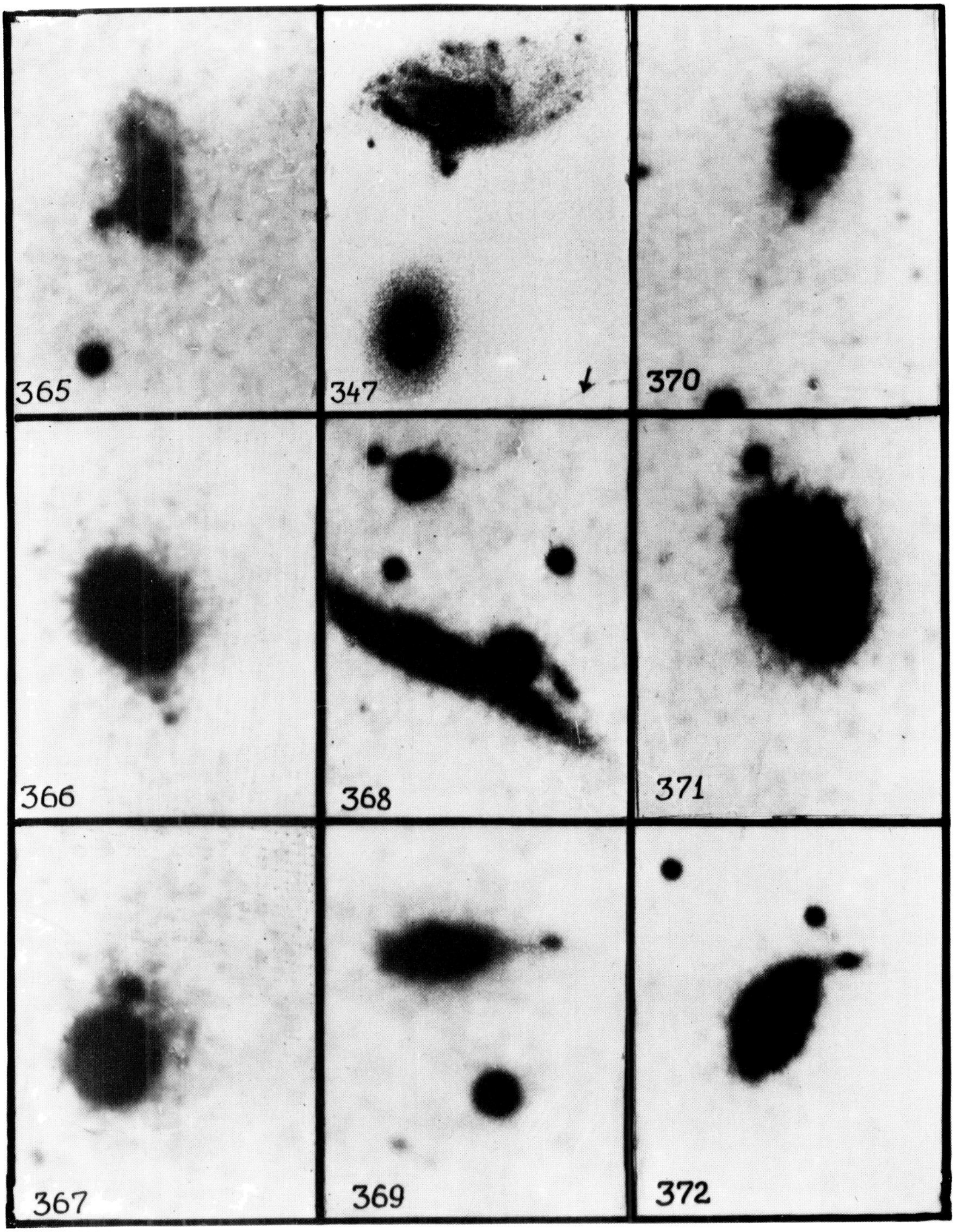

Plate 4 Satellites "on a stem". Bottle forms. I.

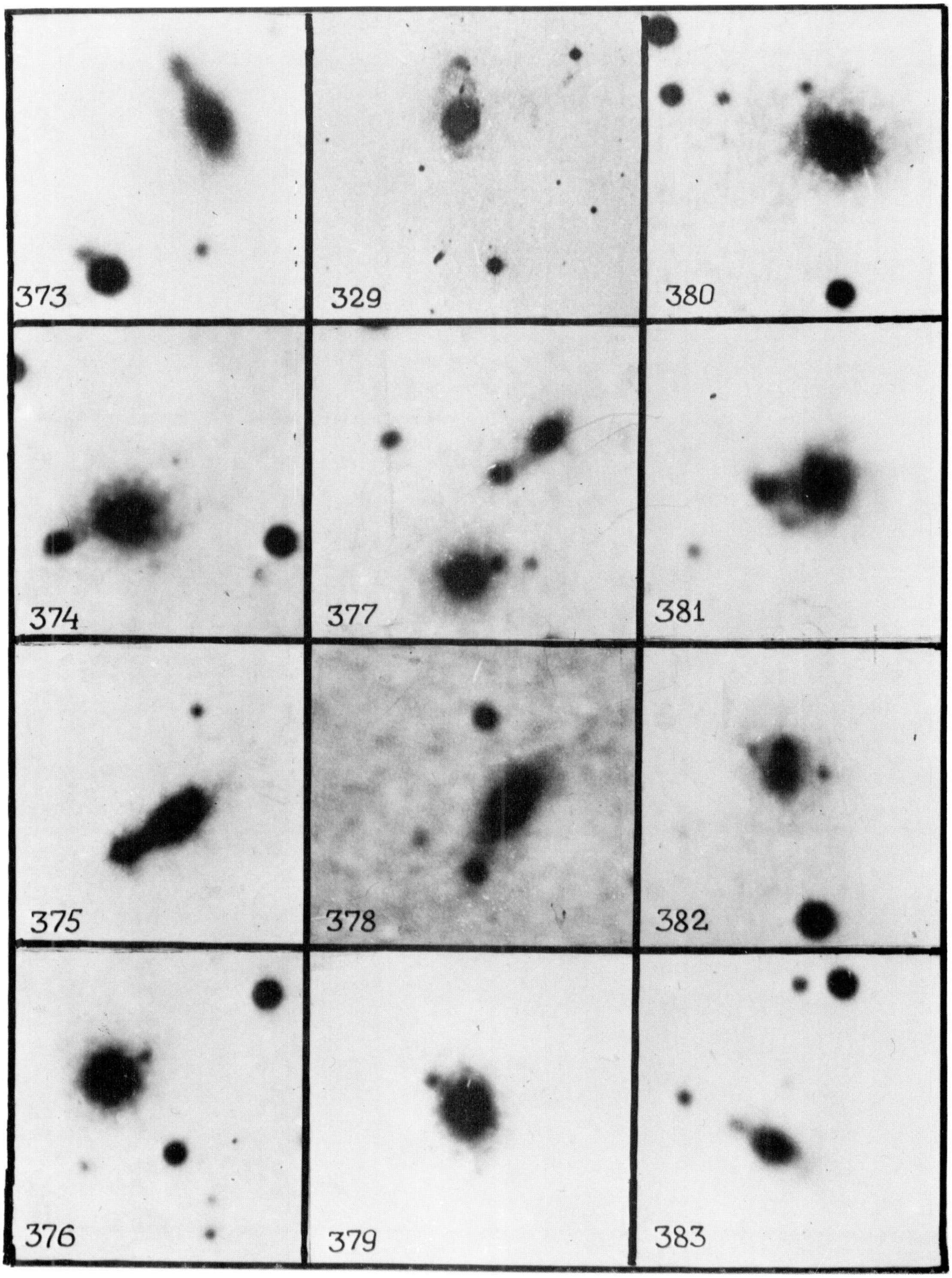

Plate 5 Satellites "on a stem". Bottle forms. II.

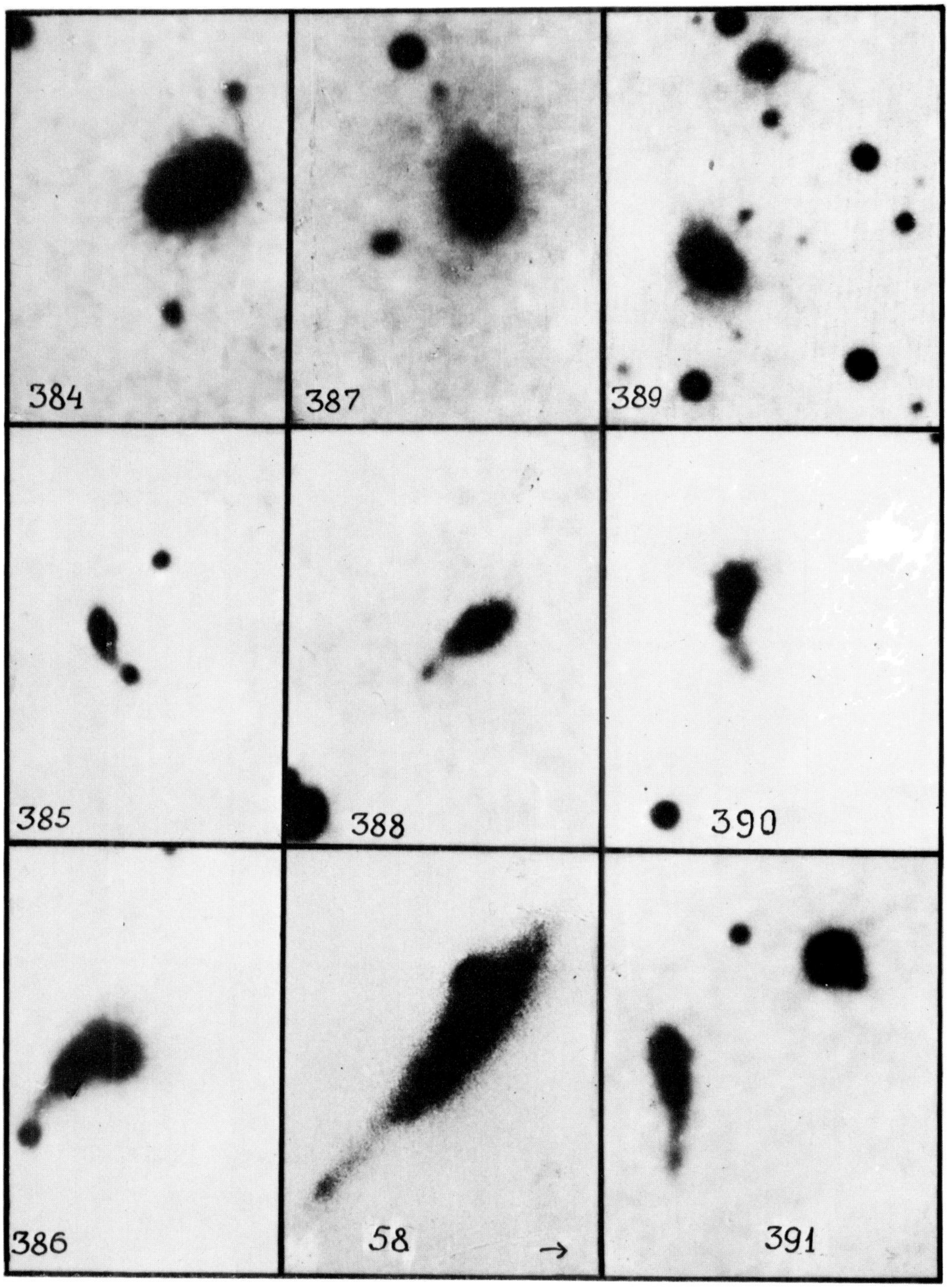

Plate 6 Satellites "on a stem". Bottle forms. III.

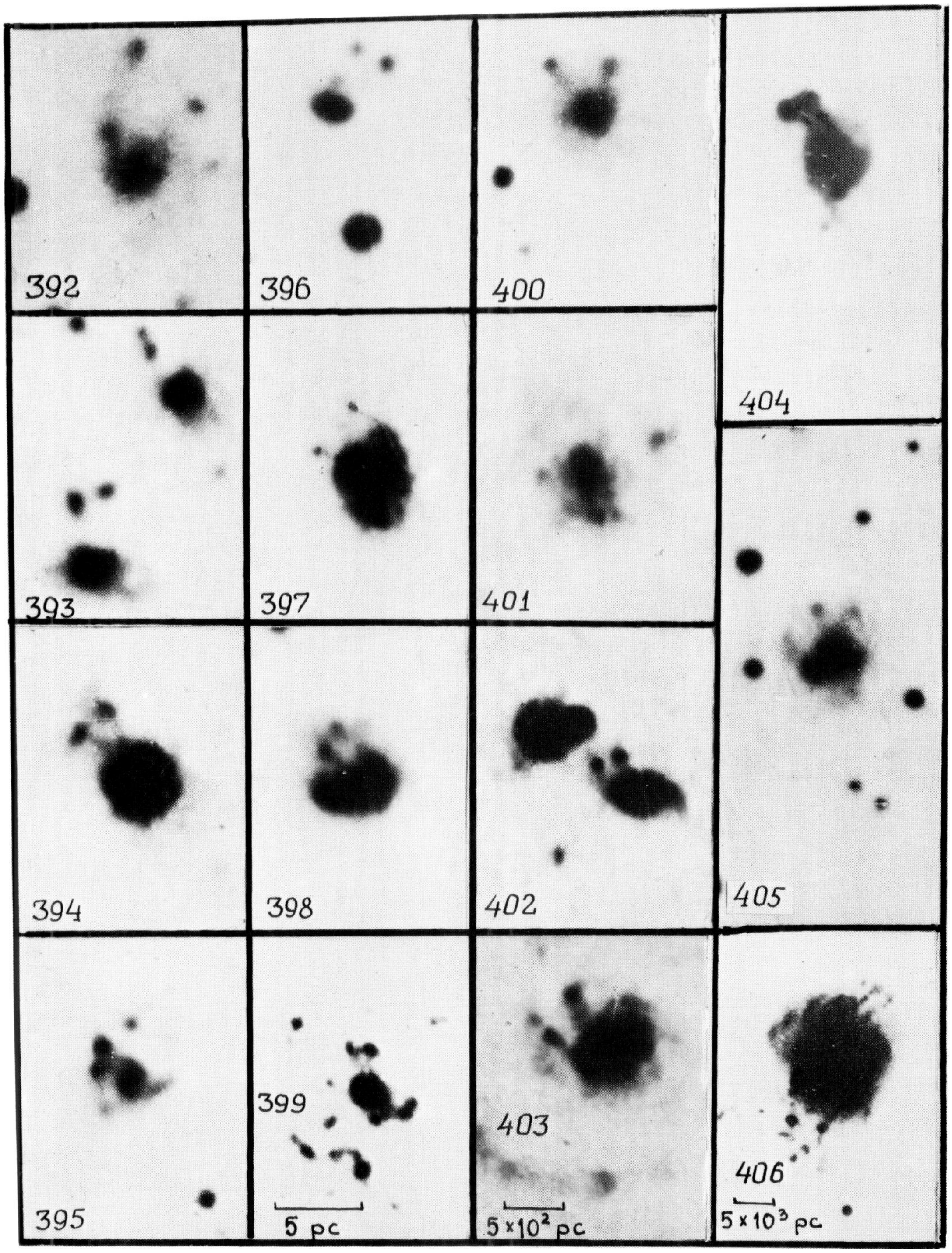

Plate 7 Ejection of the twin satellites.

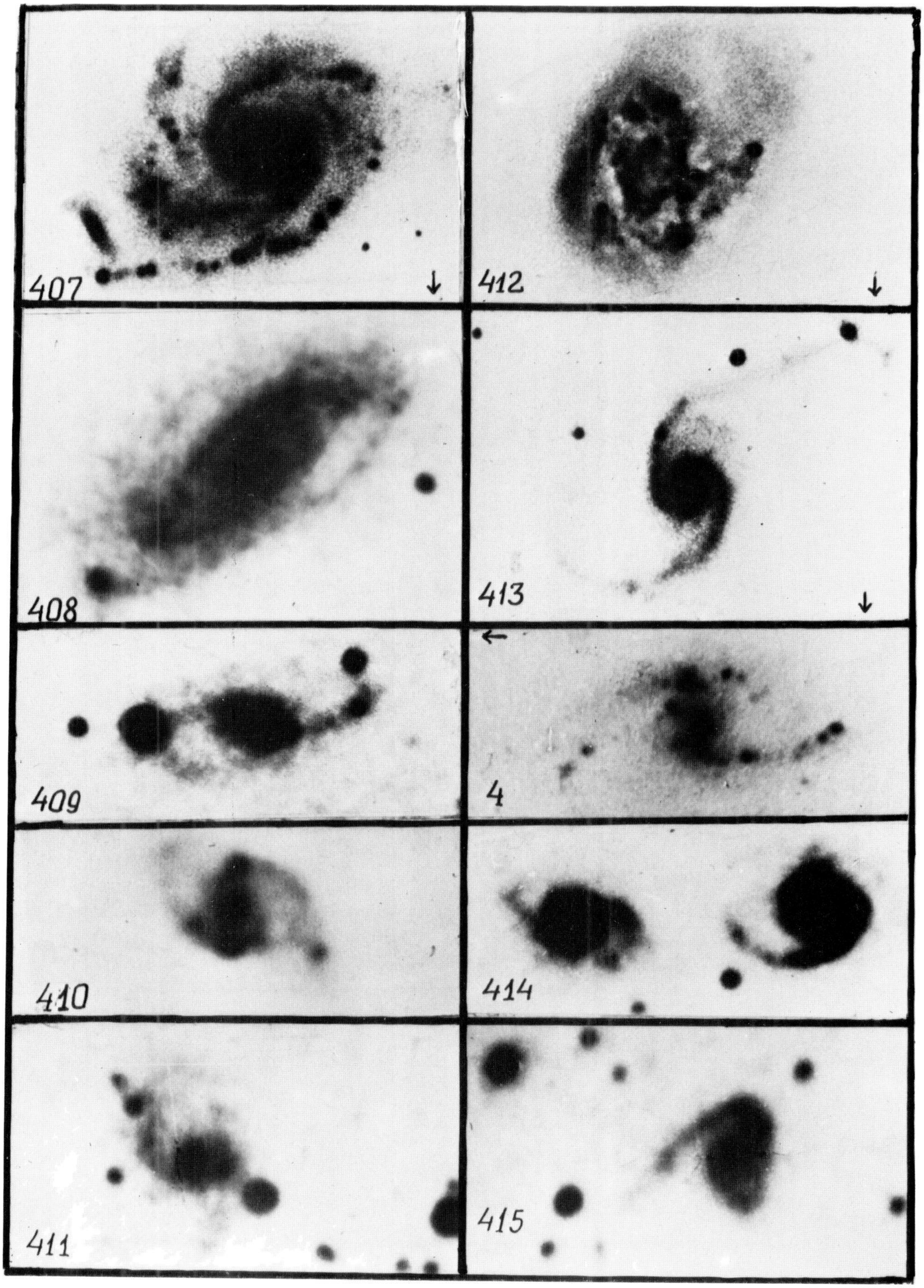

Plate 8 Galaxies of the M 51 type. I.

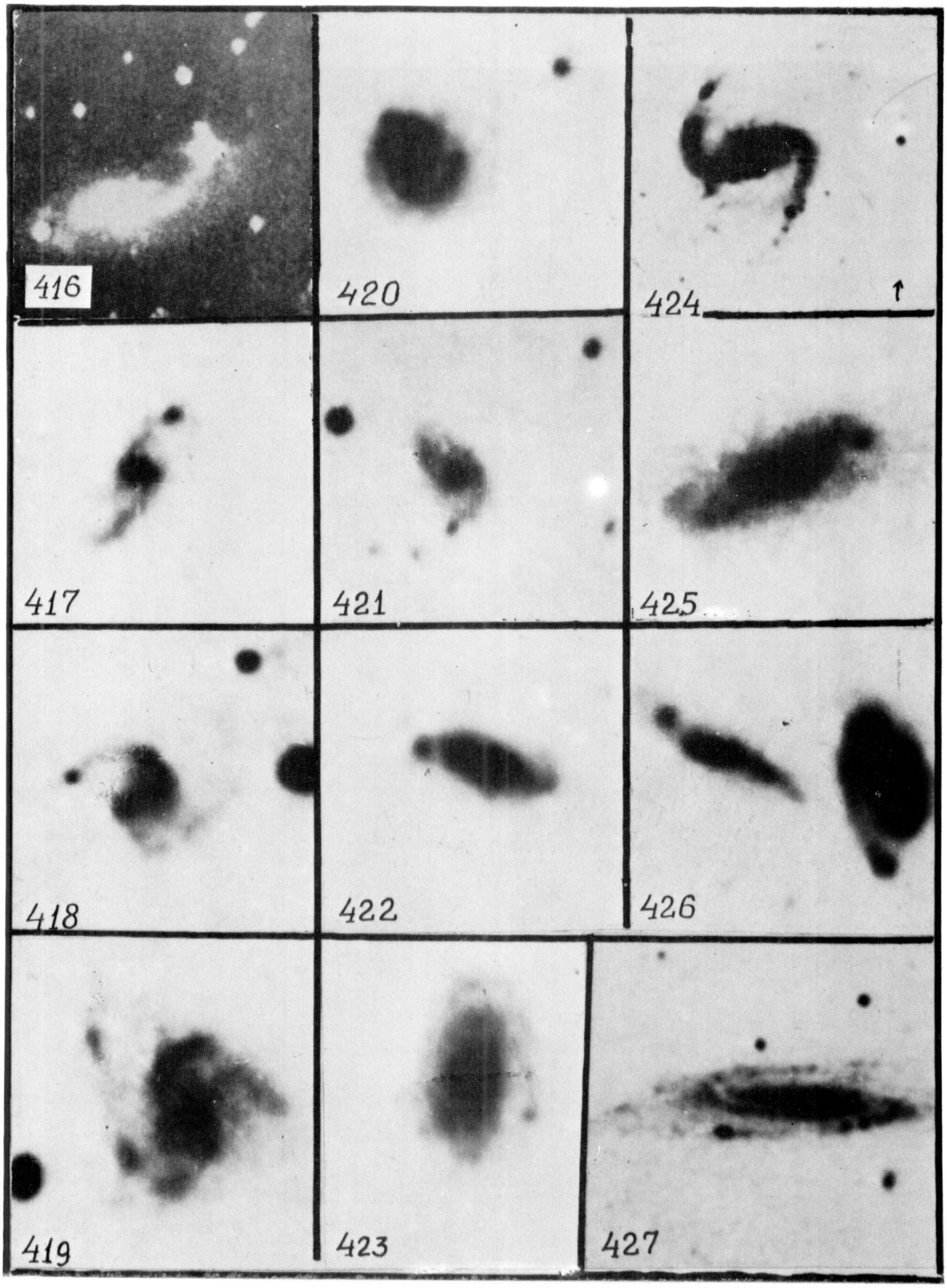

Plate 9 Galaxies of the M 51 type. II.

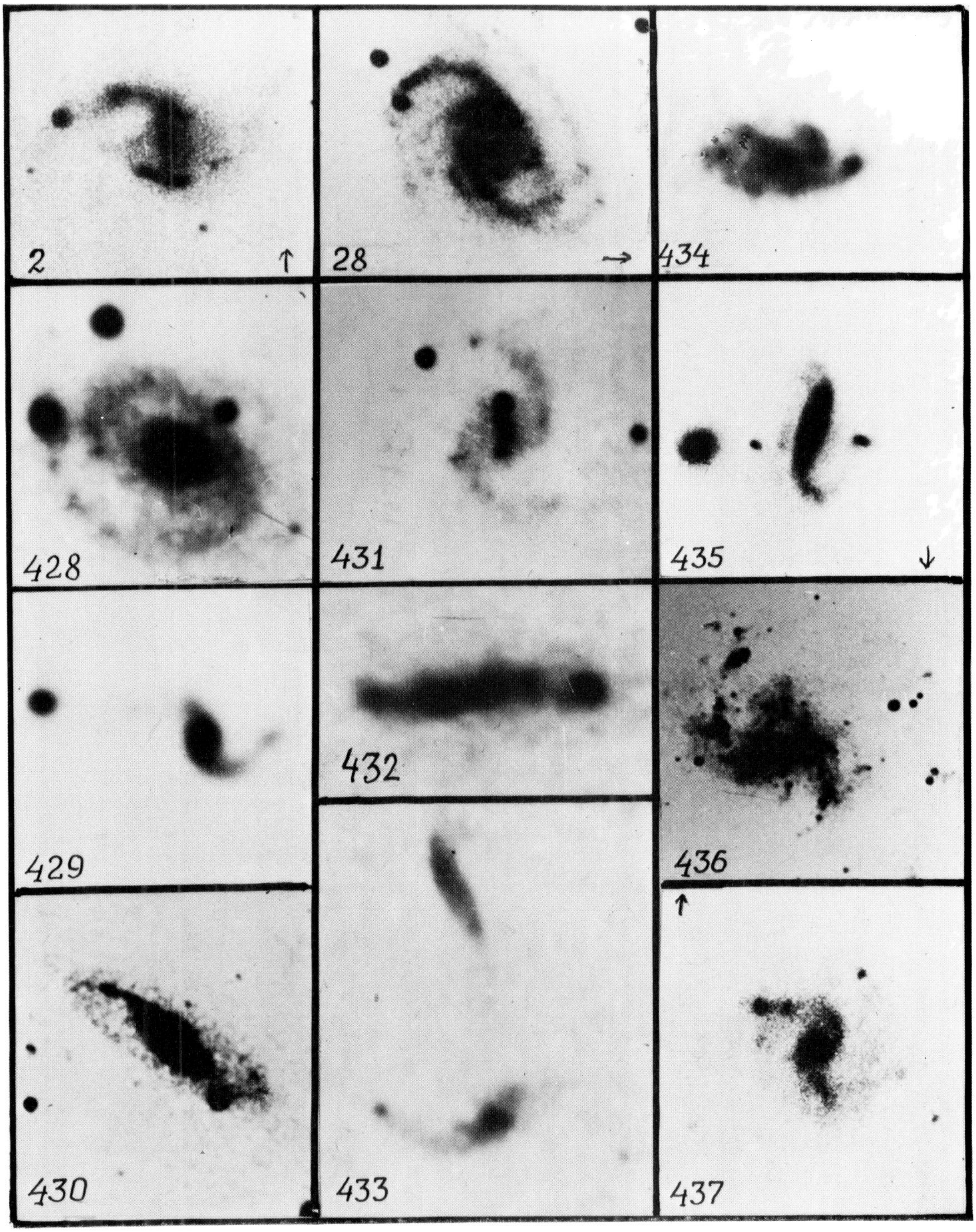

Plate 10 Galaxies of the M 51 type. III.

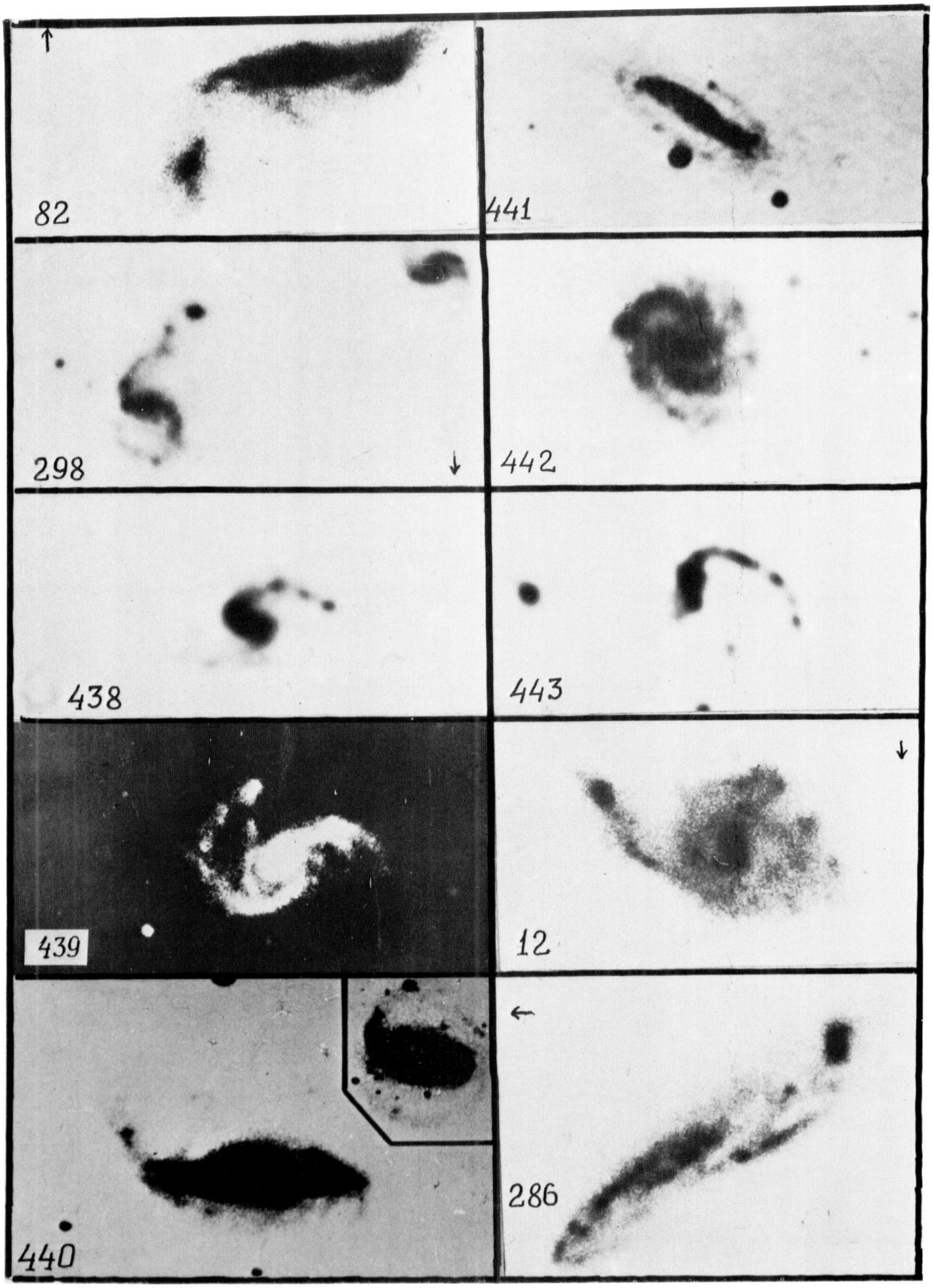

Plate 11 Galaxies of the M 51 type. IV.

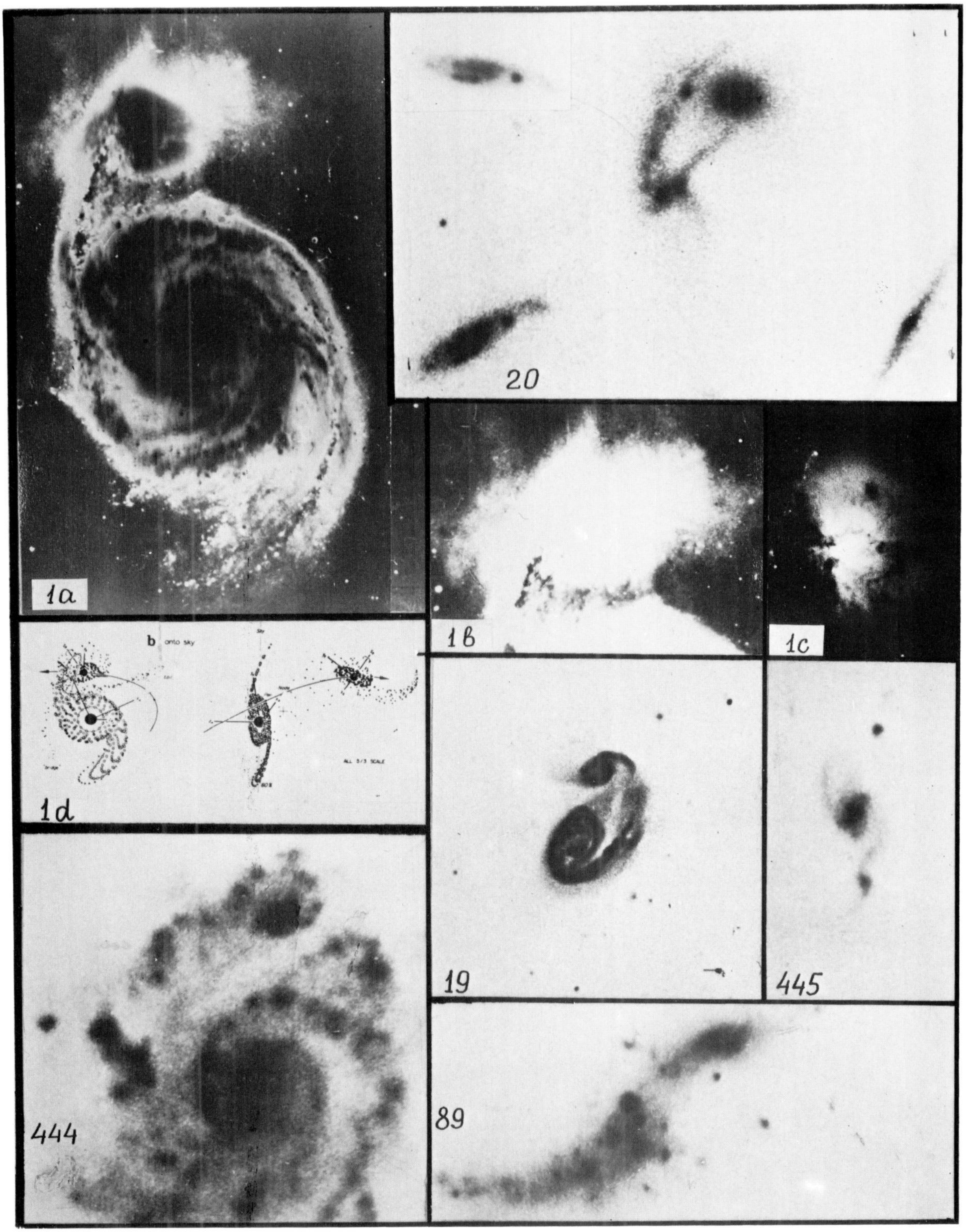

Plate 12 Galaxies of the M 51 type. V.

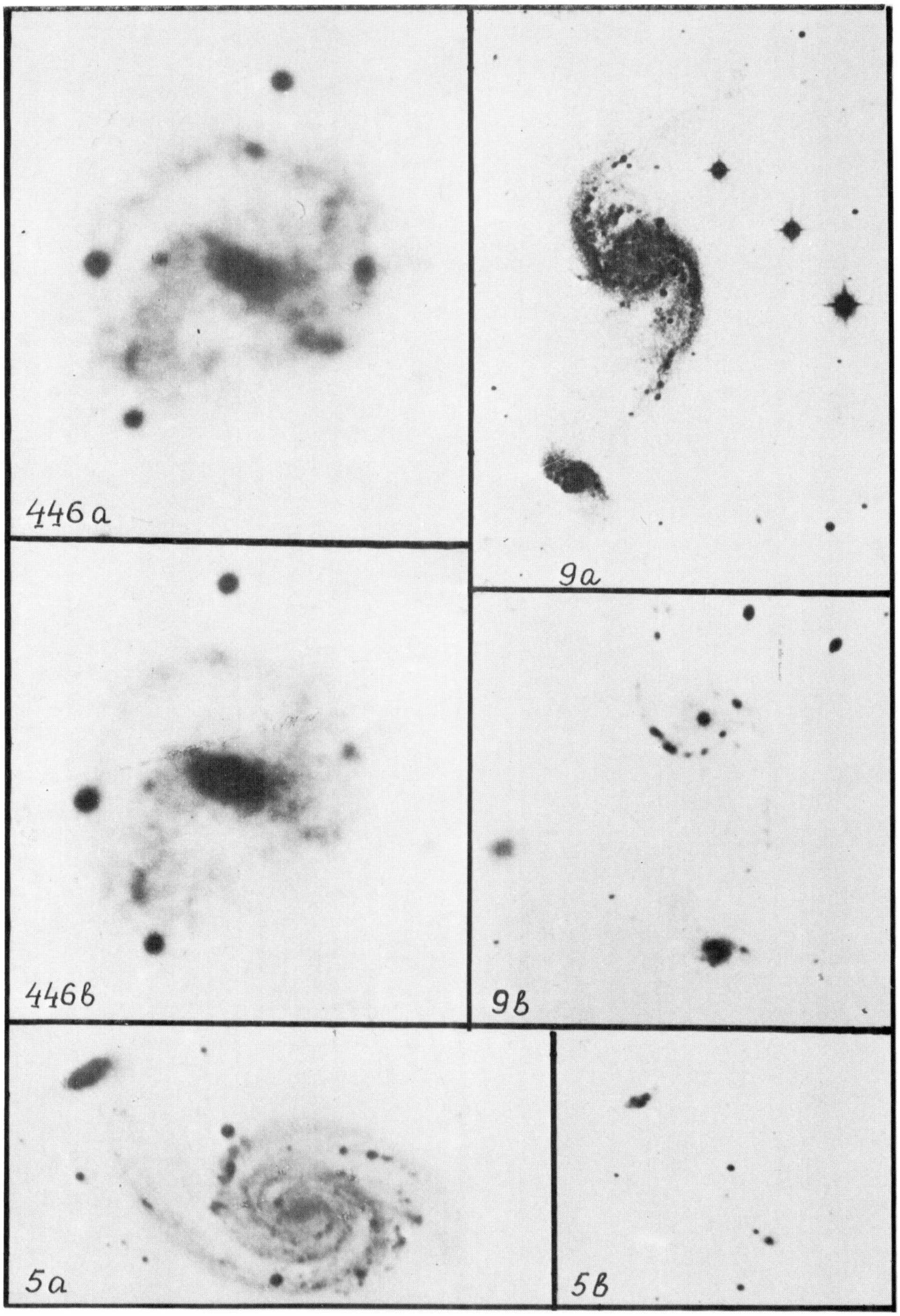

Plate 13 Galaxies of the M 51 type. VI.

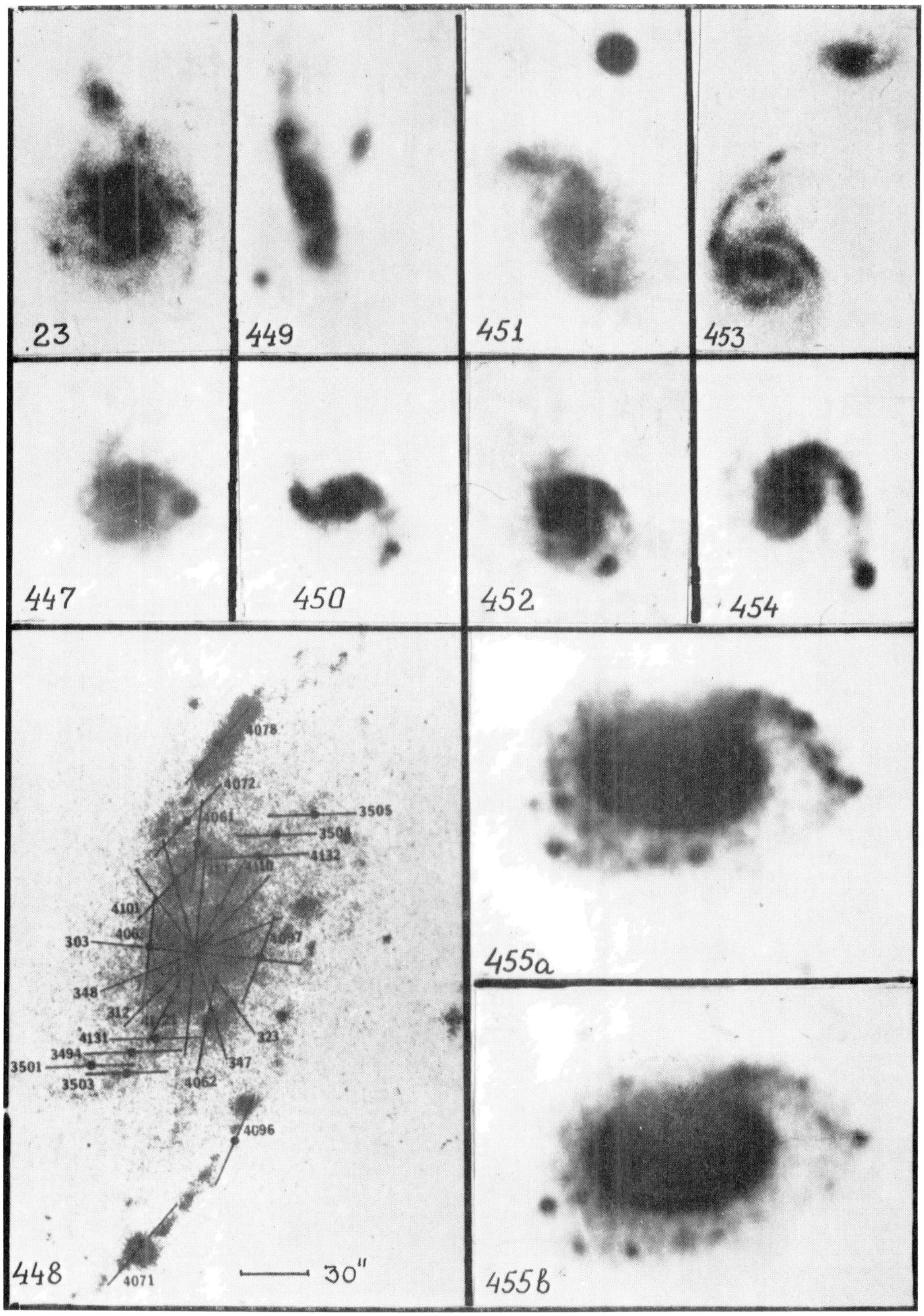

Plate 14 Stages of gemmation and "twice M 51 type galaxies". I.

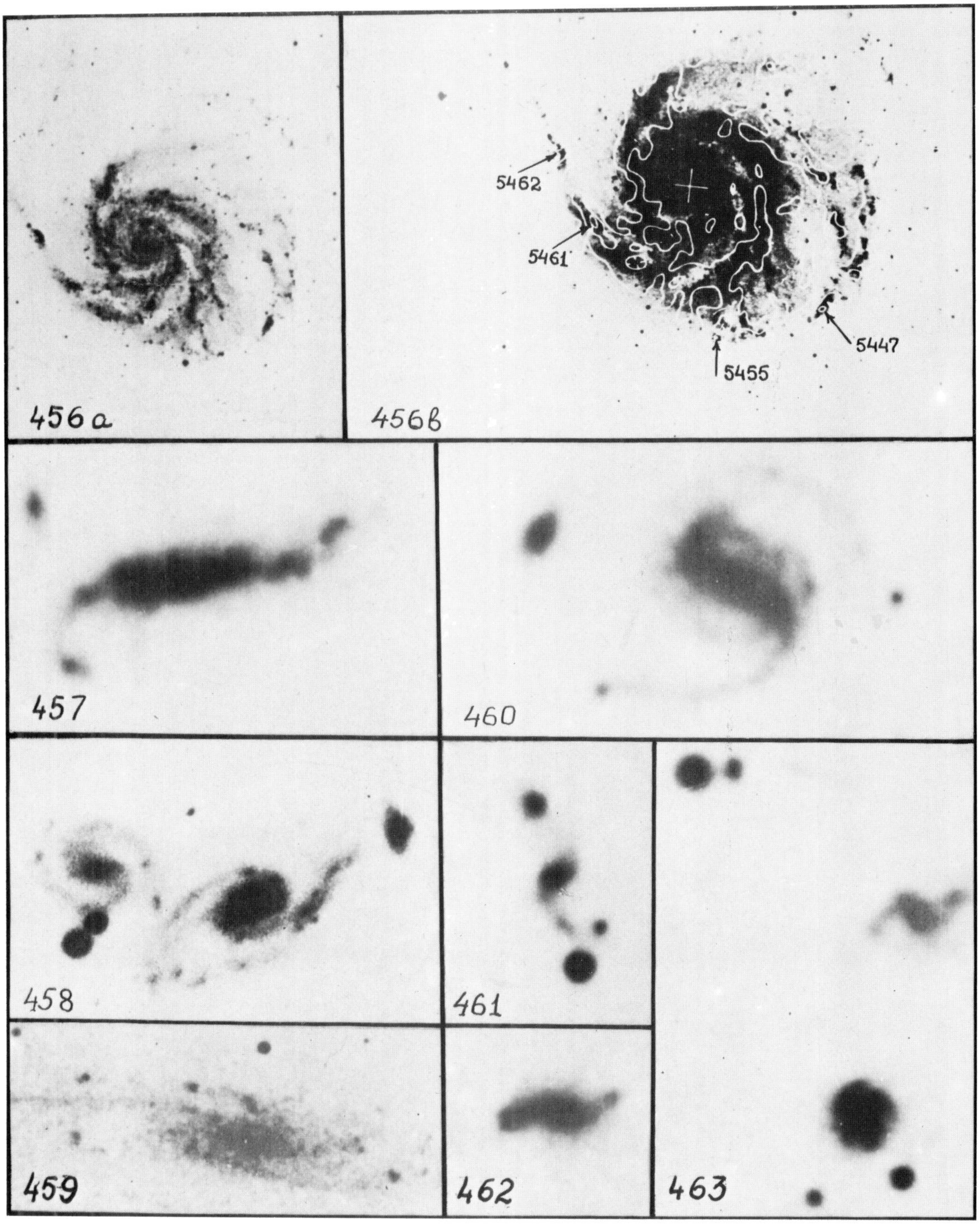

Plate 15 "Twice M 51 type galaxies". II.

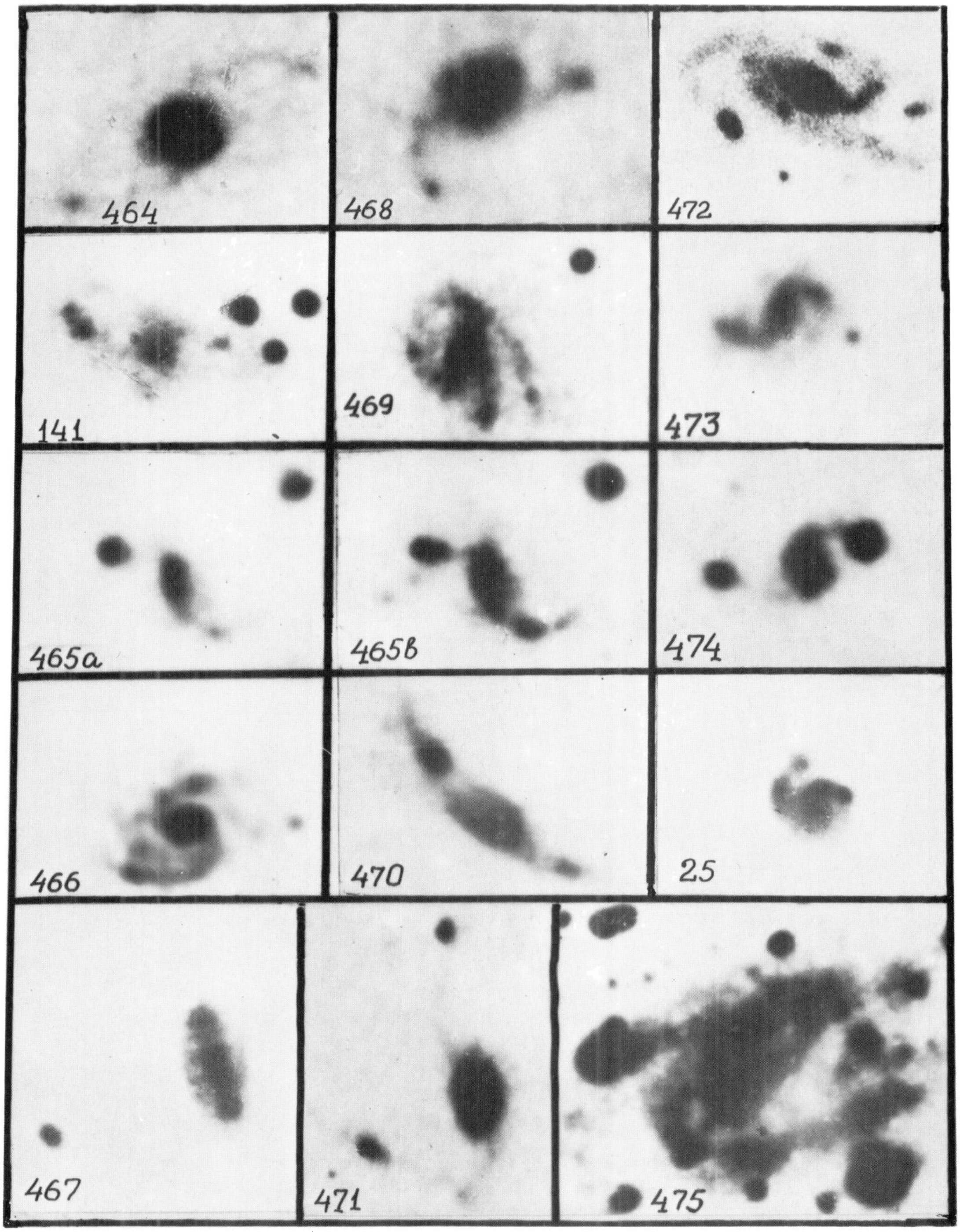

Plate 16 "Twice M 51 type galaxies". III.

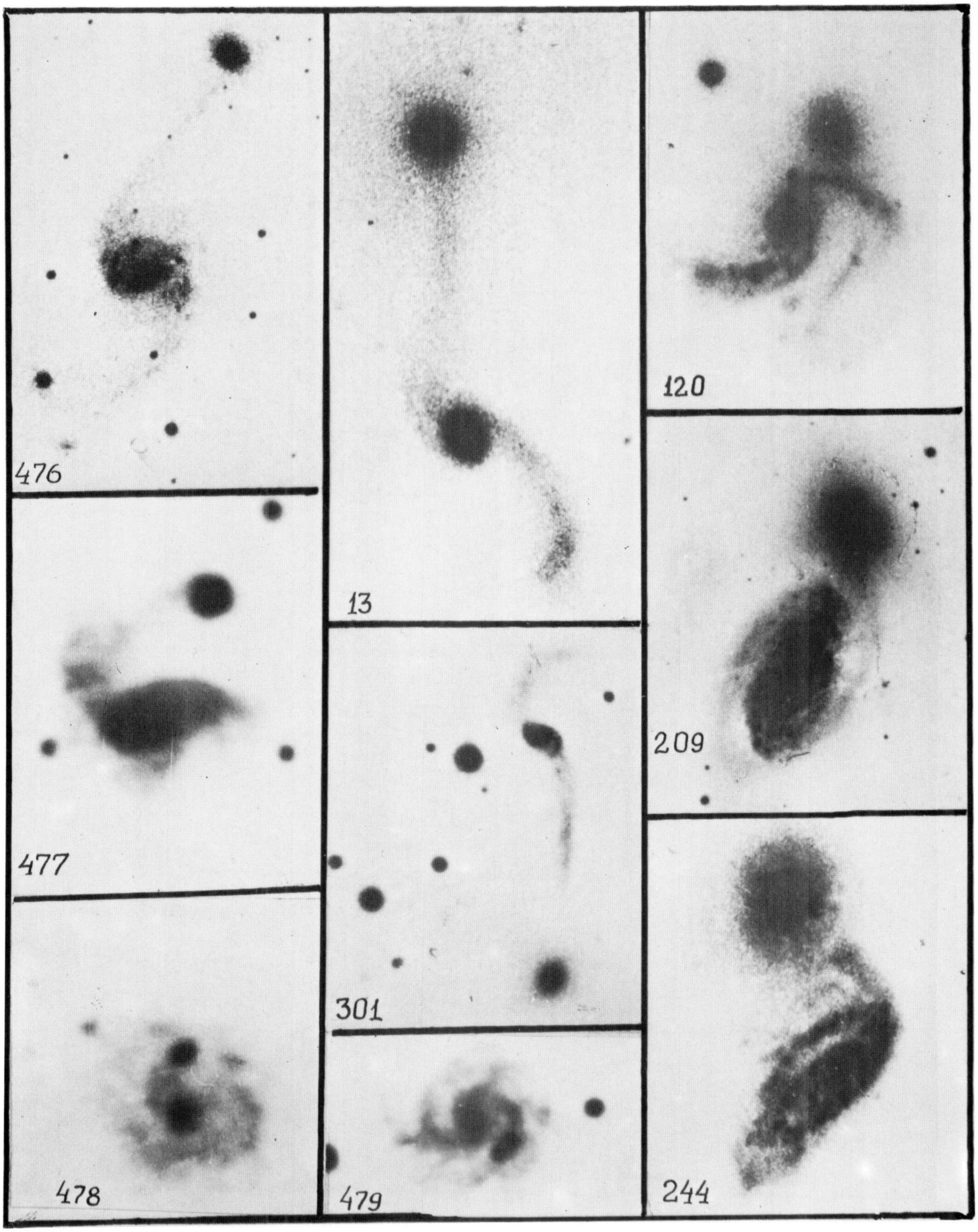

Plate 17 Spirals with elliptical (?) components.

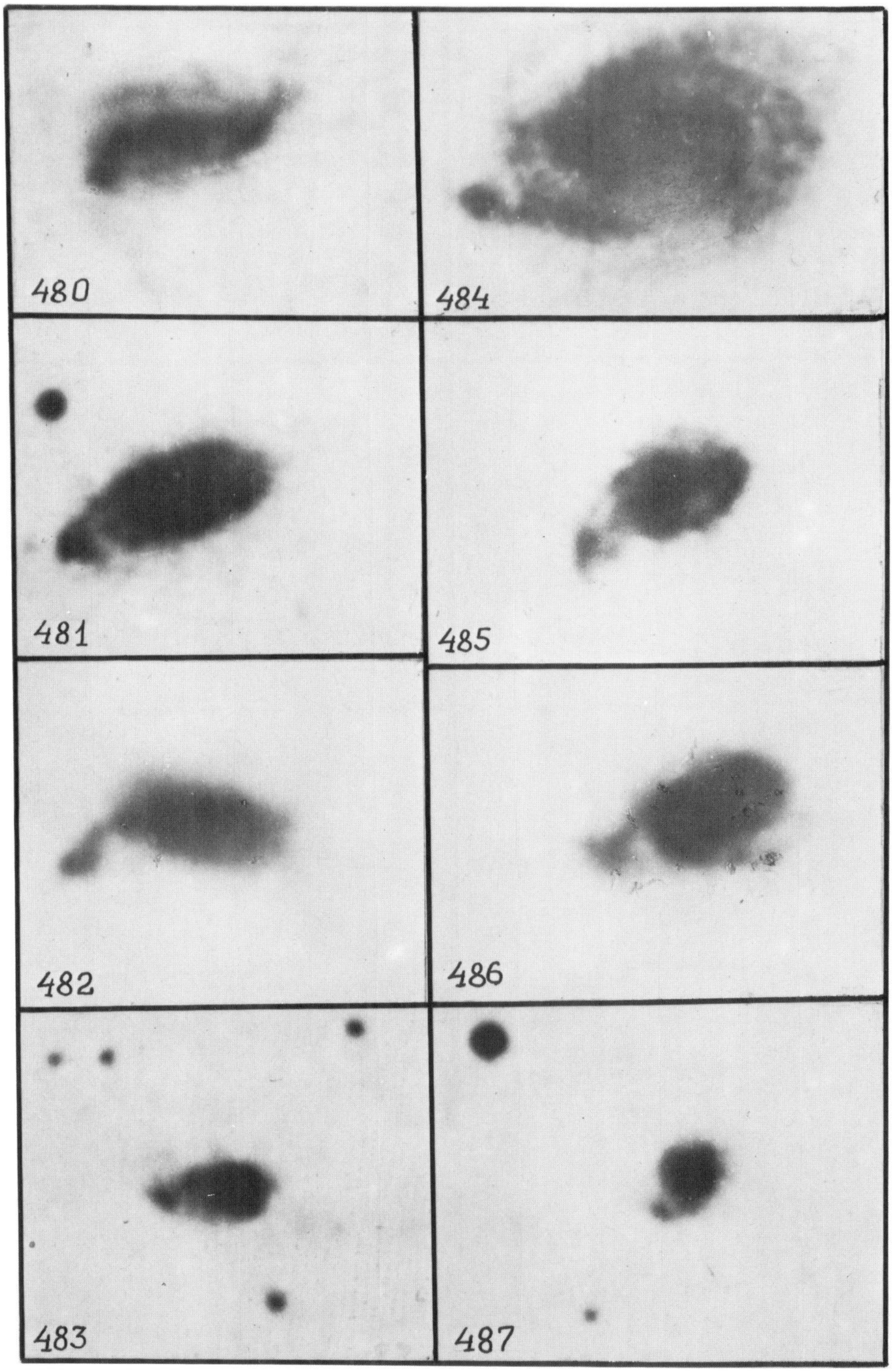

Plate 18 Transport out of large companions.

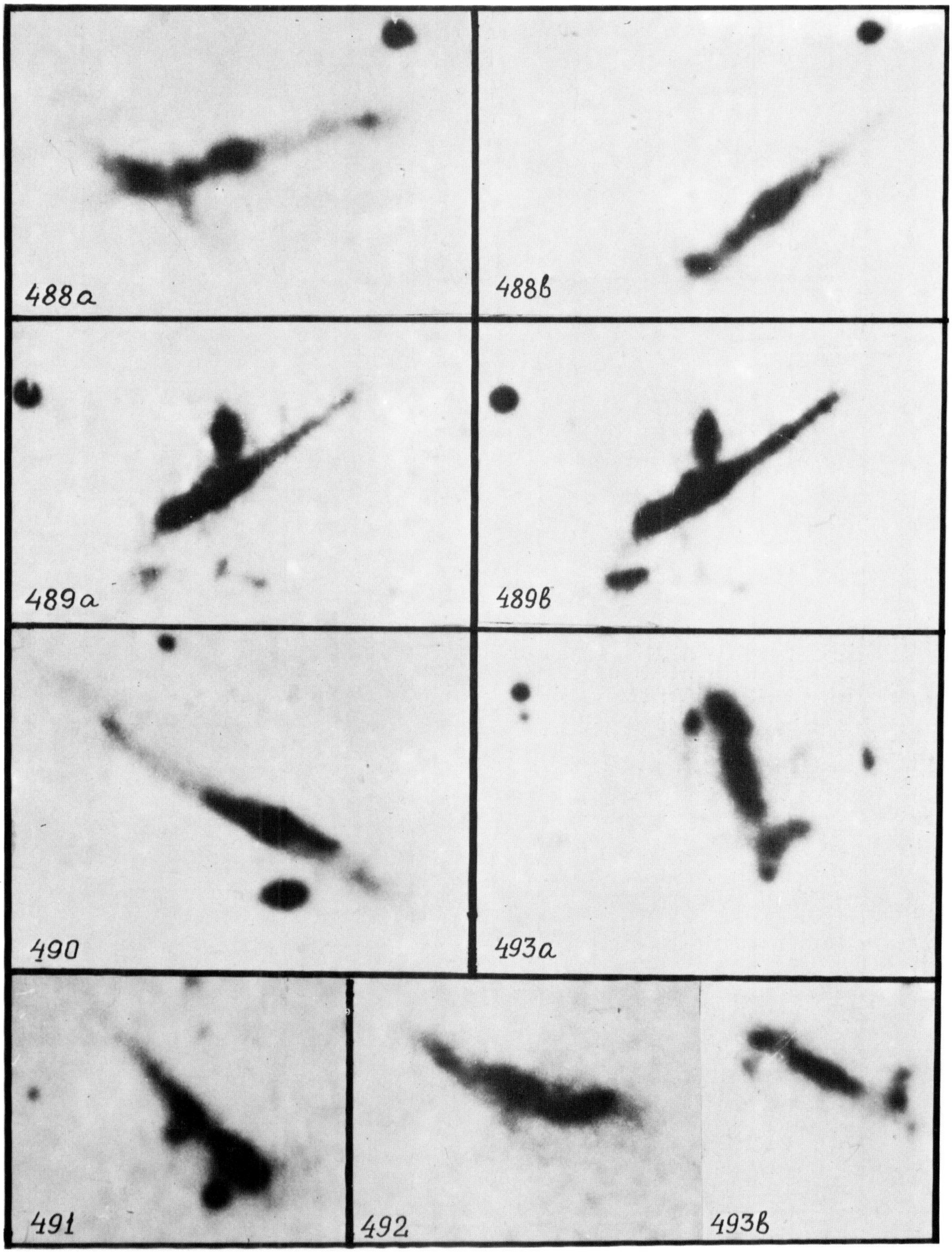

Plate 19 Predecessors of chains.

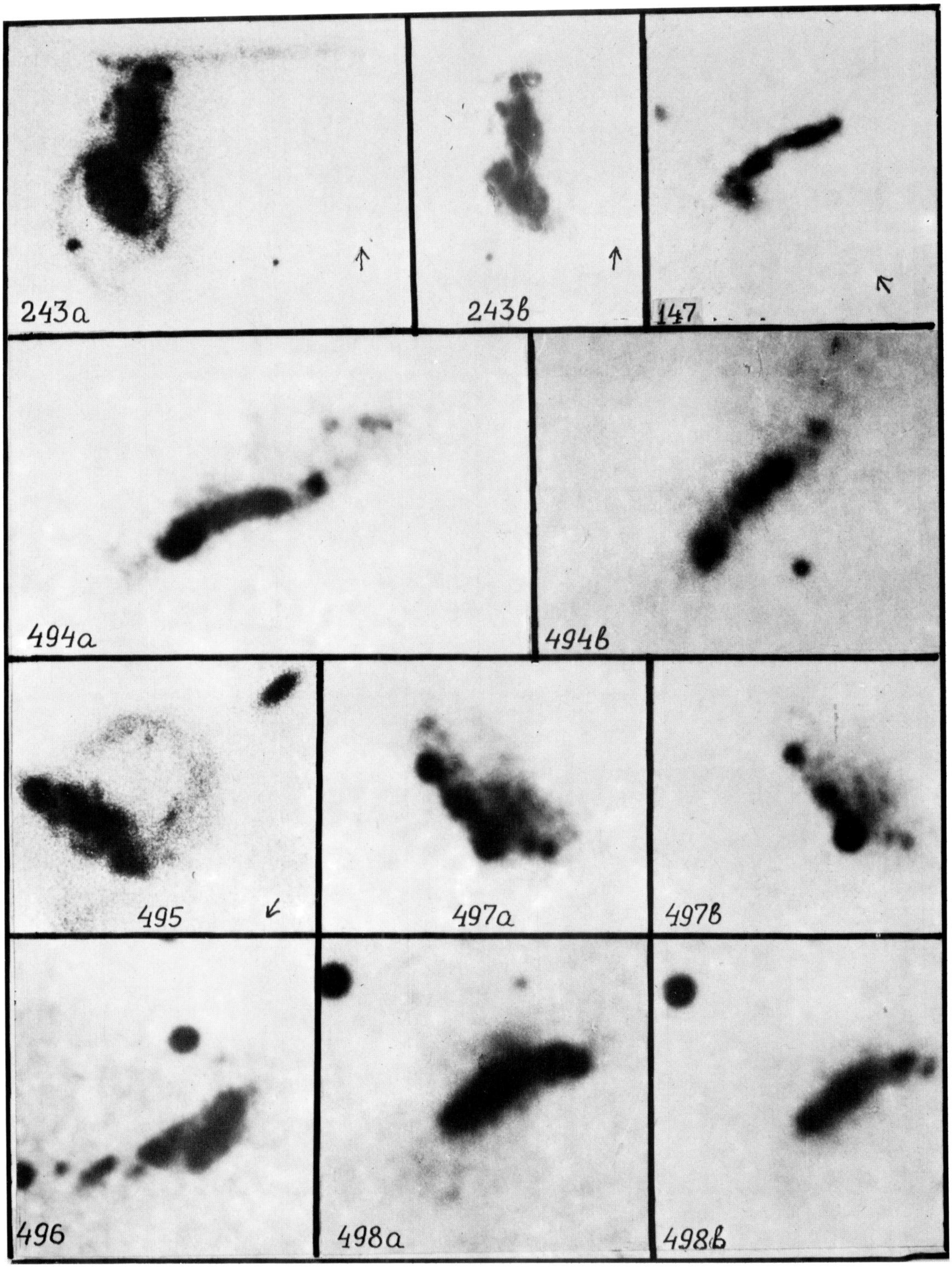

Plate 20 Chains in the making.

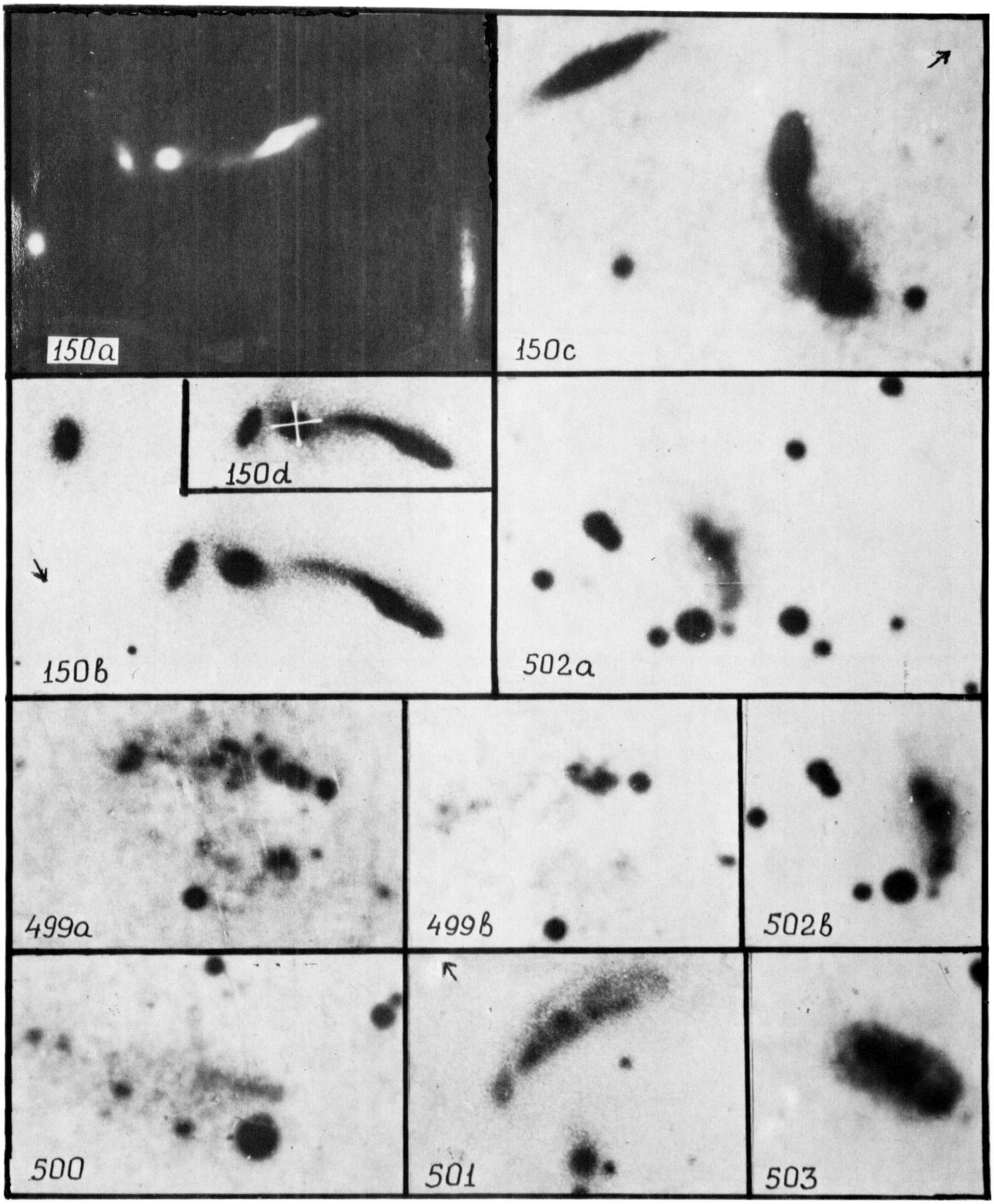

Plate 21 Young minichains.

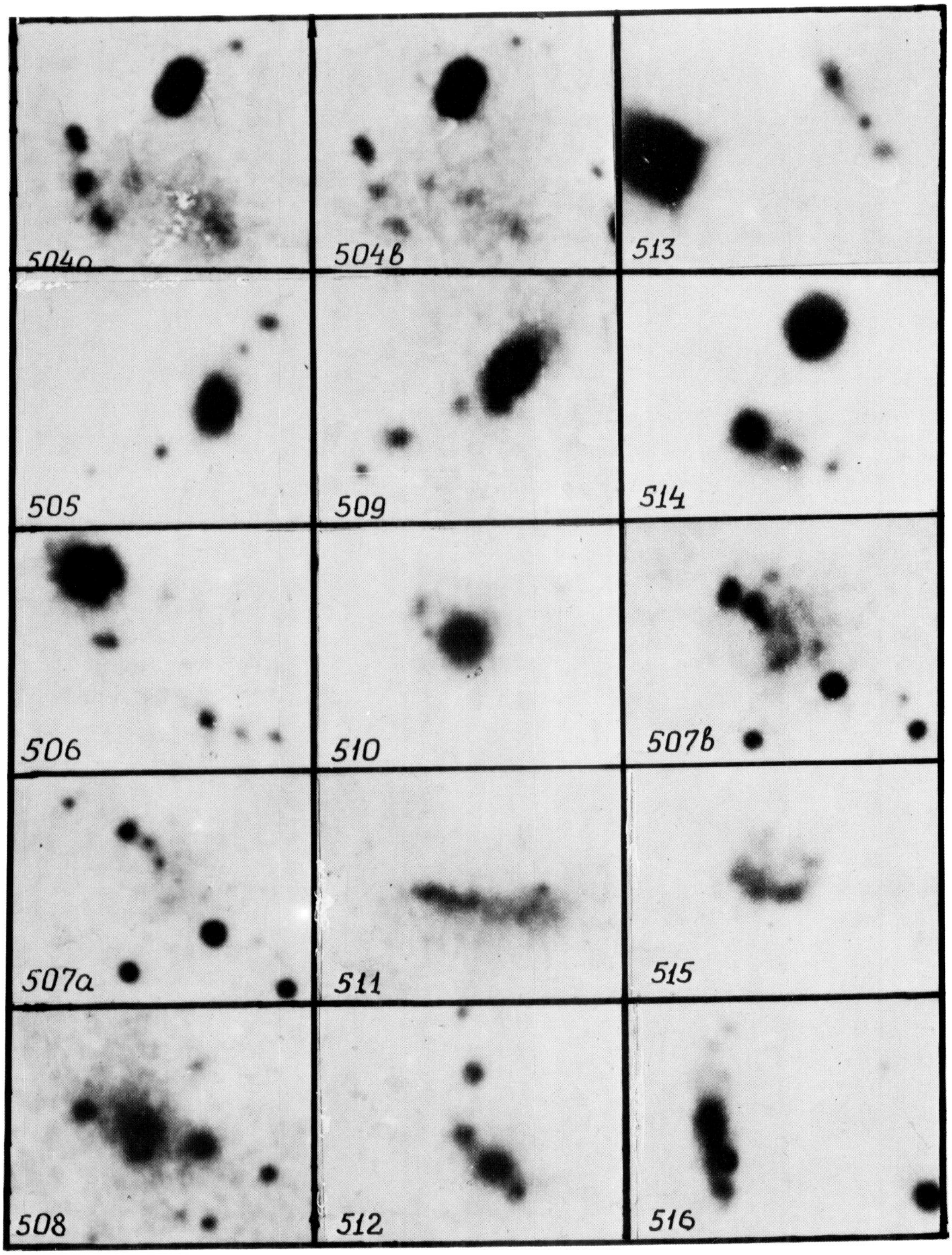

Plate 22 Chains.

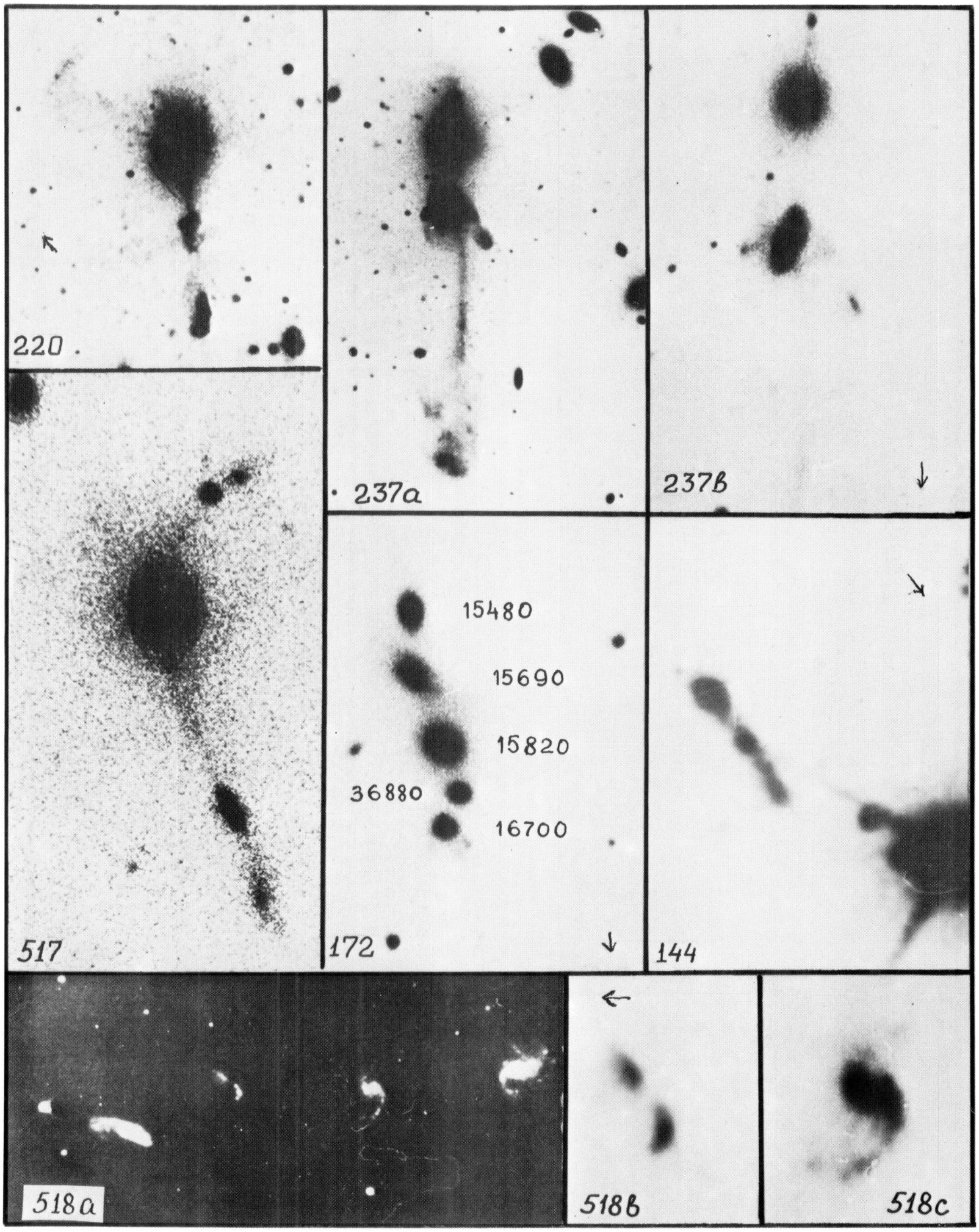

Plate 23 Chains nearly disrupted.

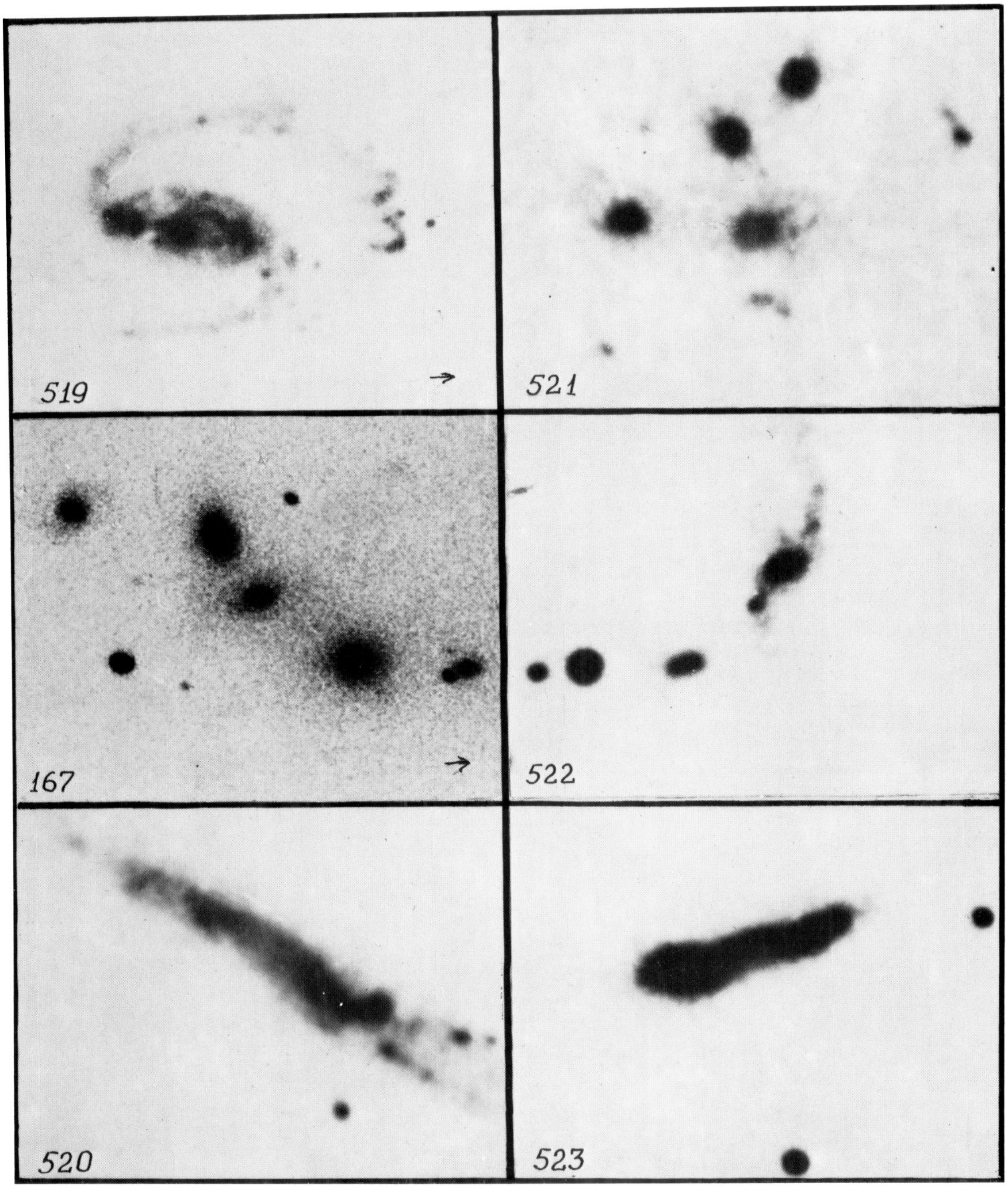

Plate 24 Prechains and chains of different age.

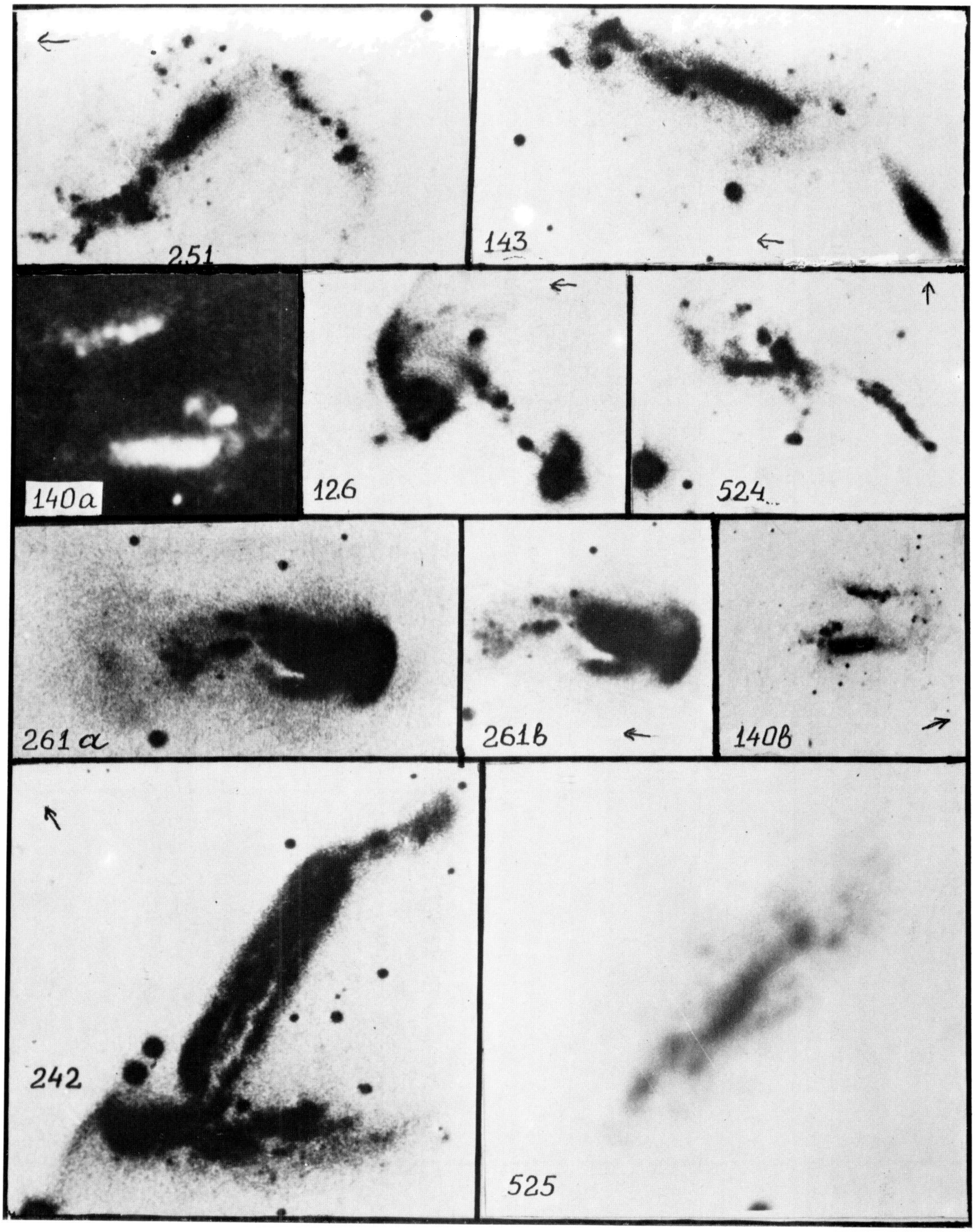

Plate 25 Chains/nests.

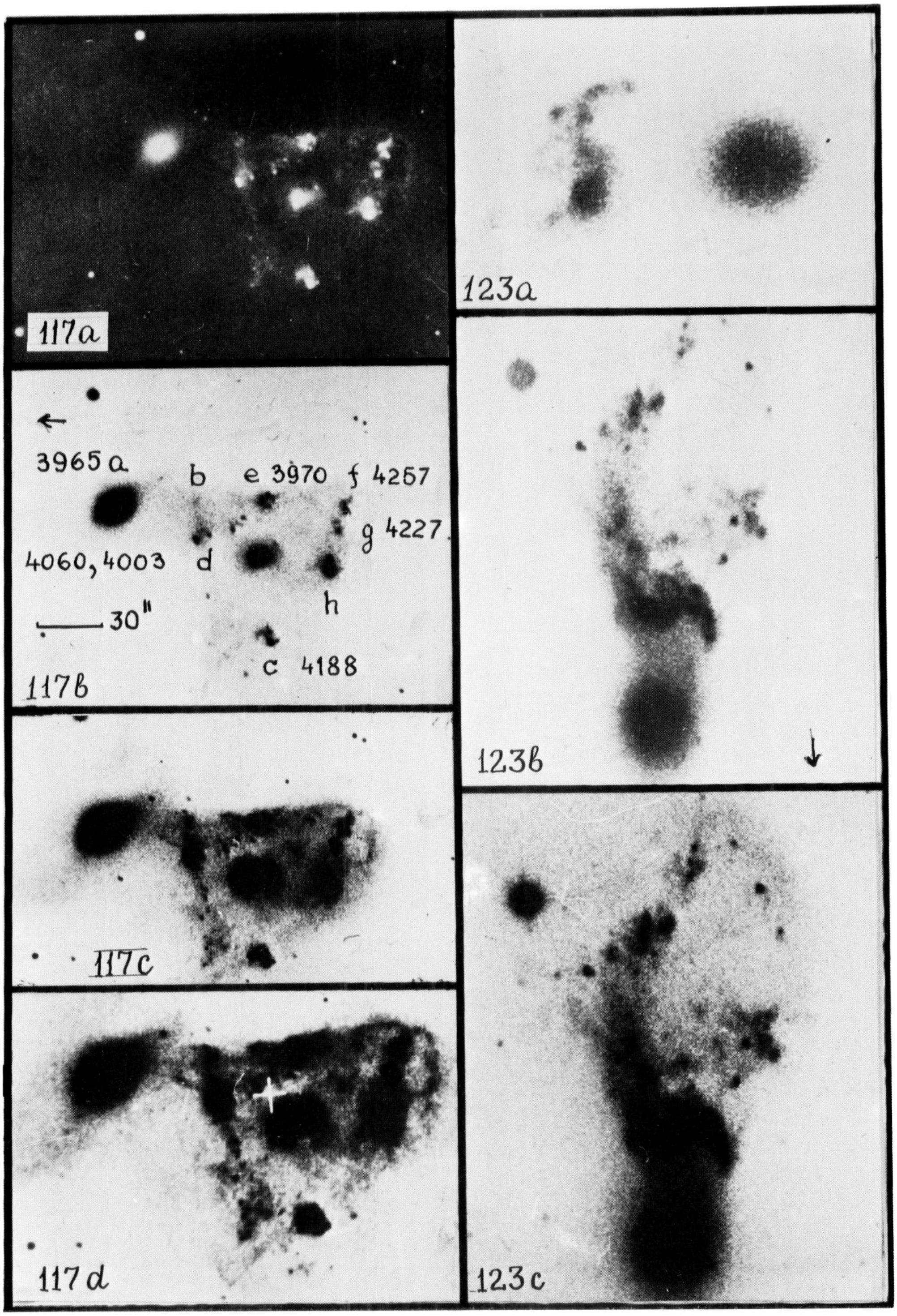

Plate 26 Nests. I.

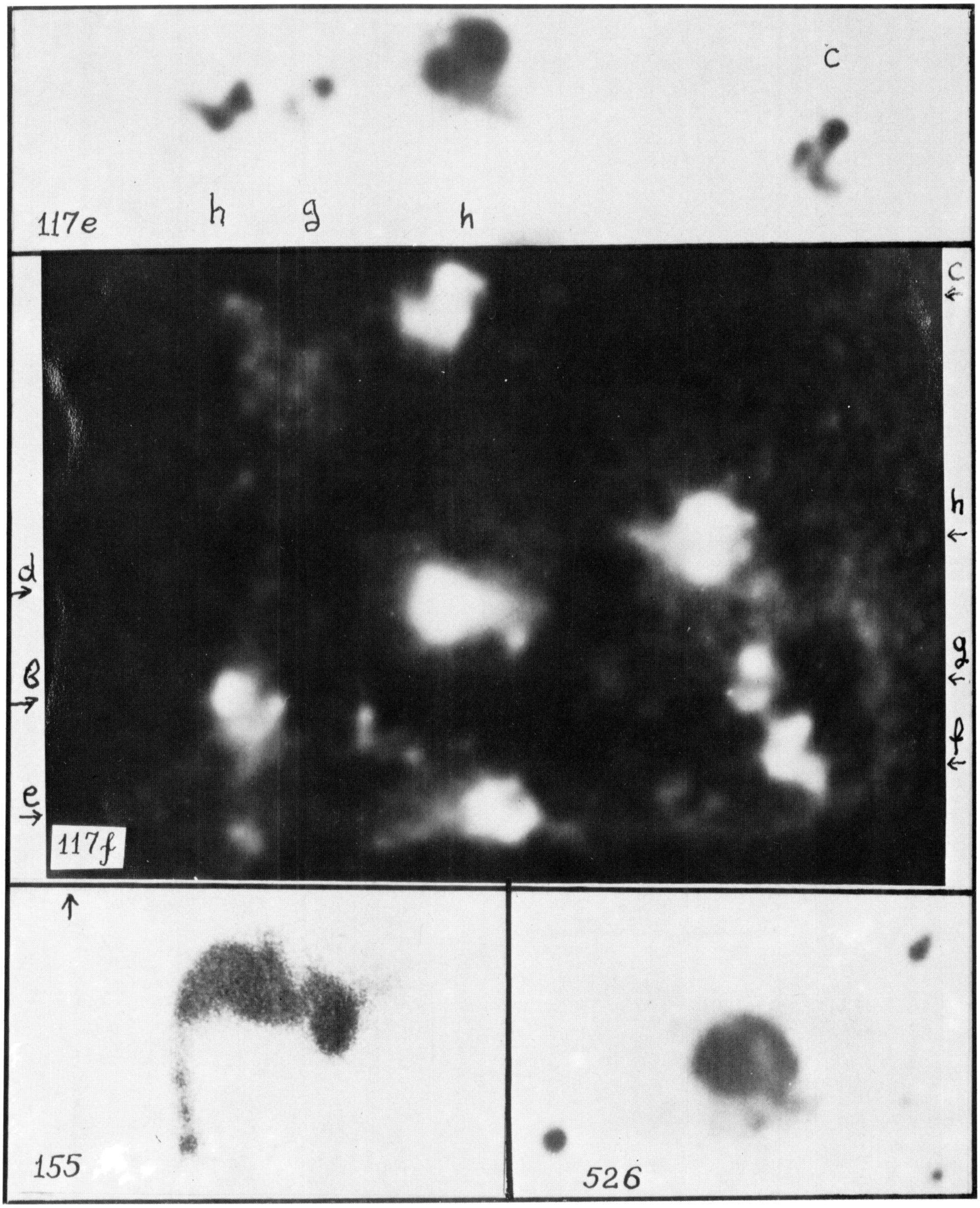

Plate 27 Nests. II.

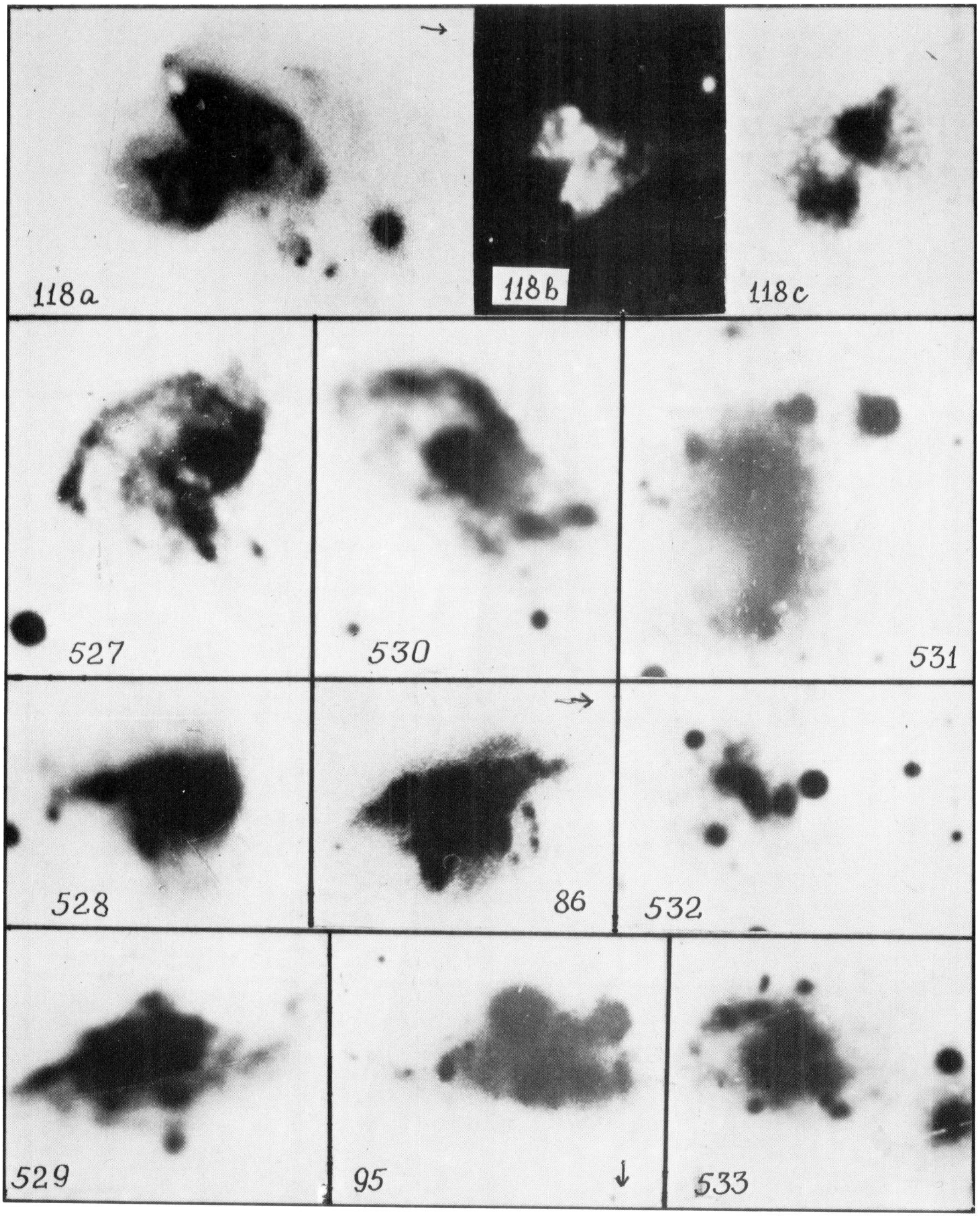

Plate 28 Nests – evident and possible.

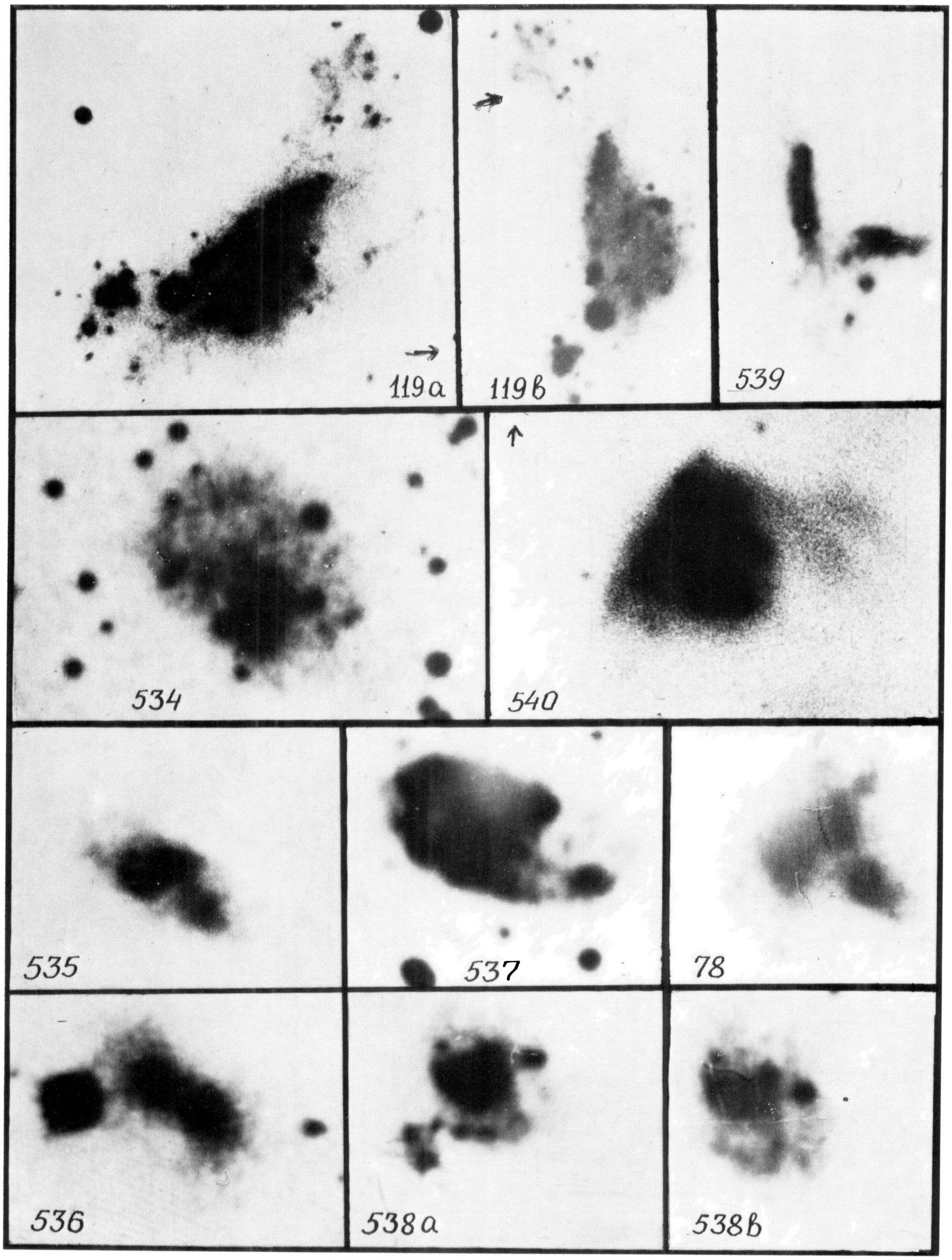

Plate 29 Possible bright nests.

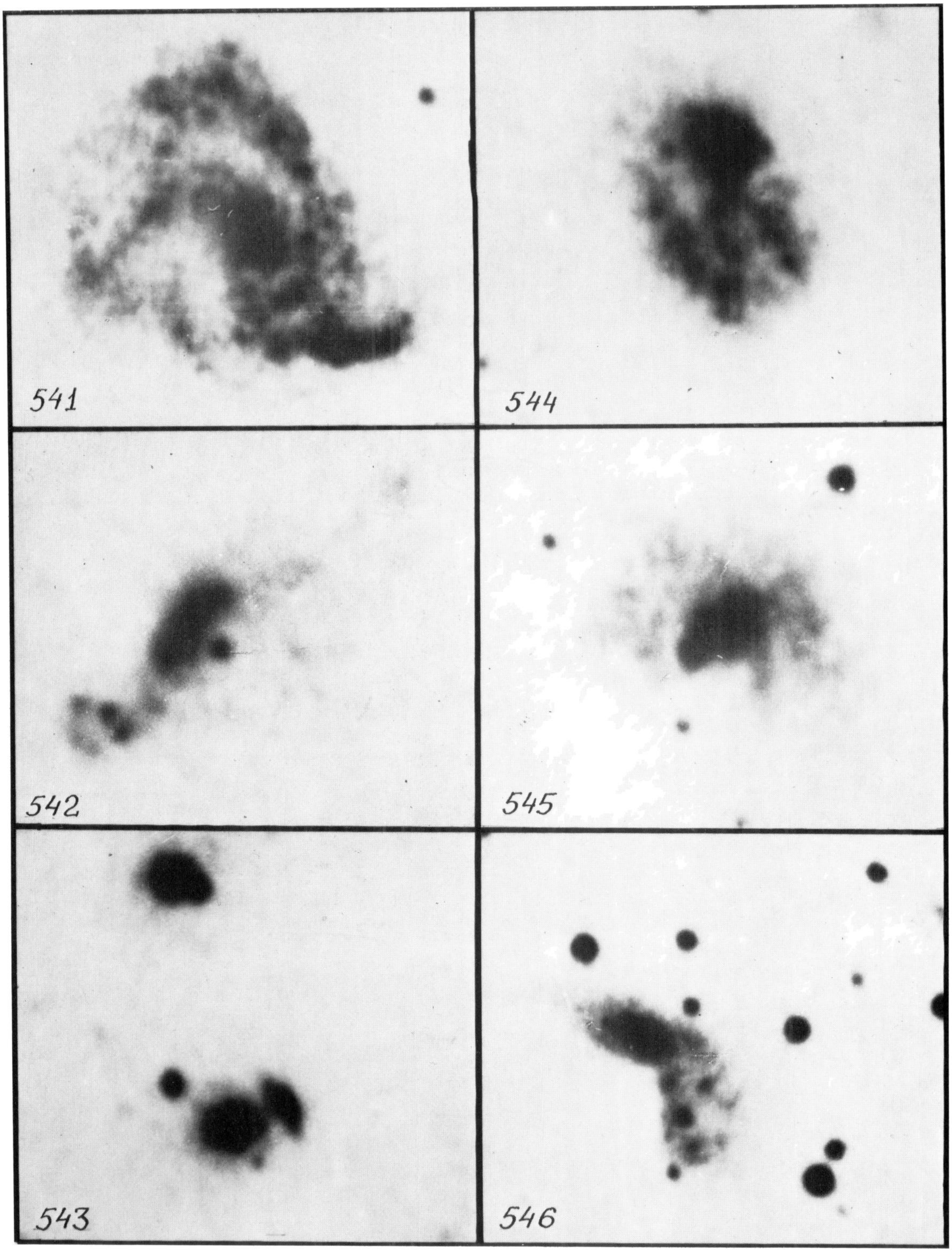

Plate 30 Nests. III.

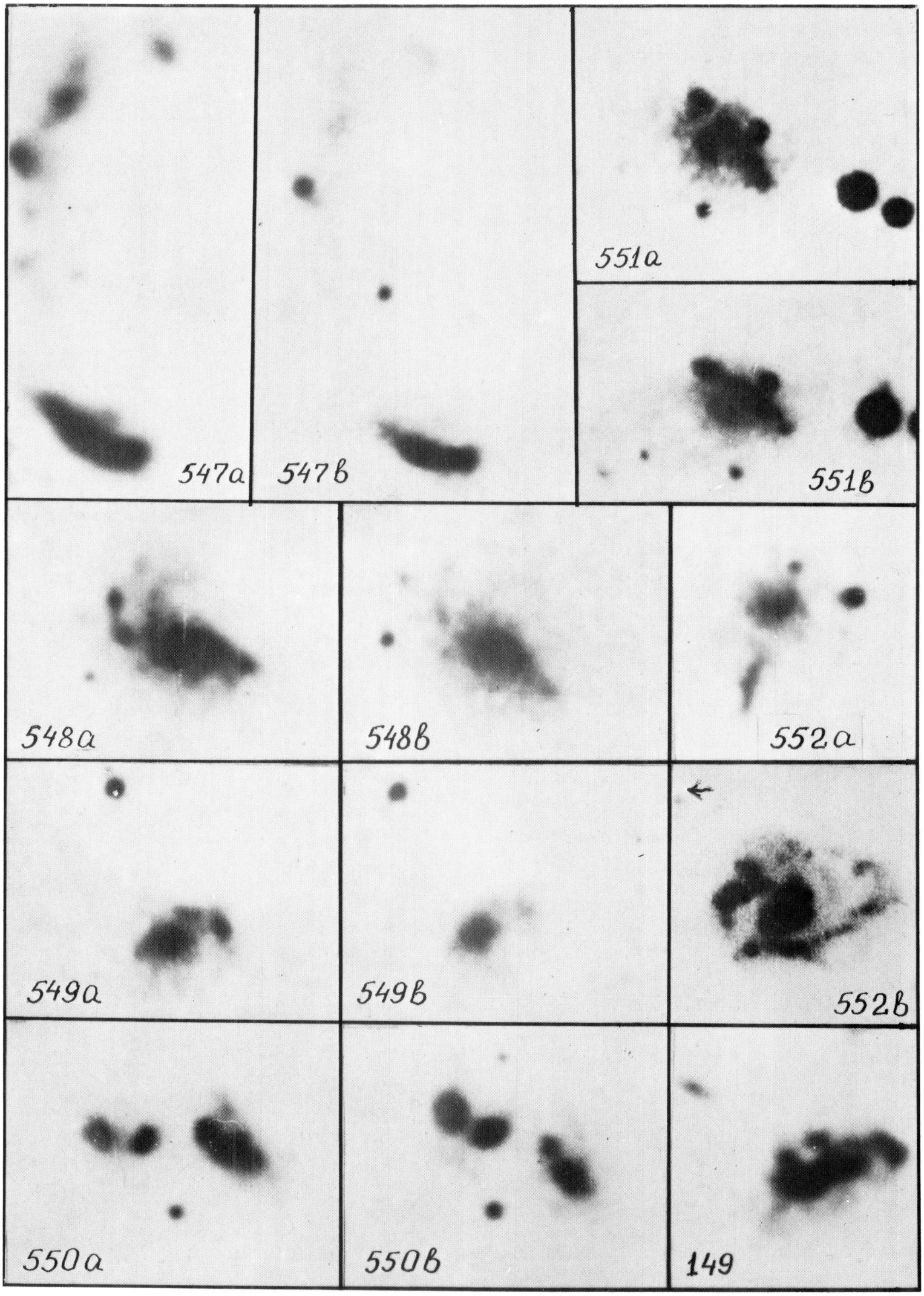

Plate 31 Blue nests. I.

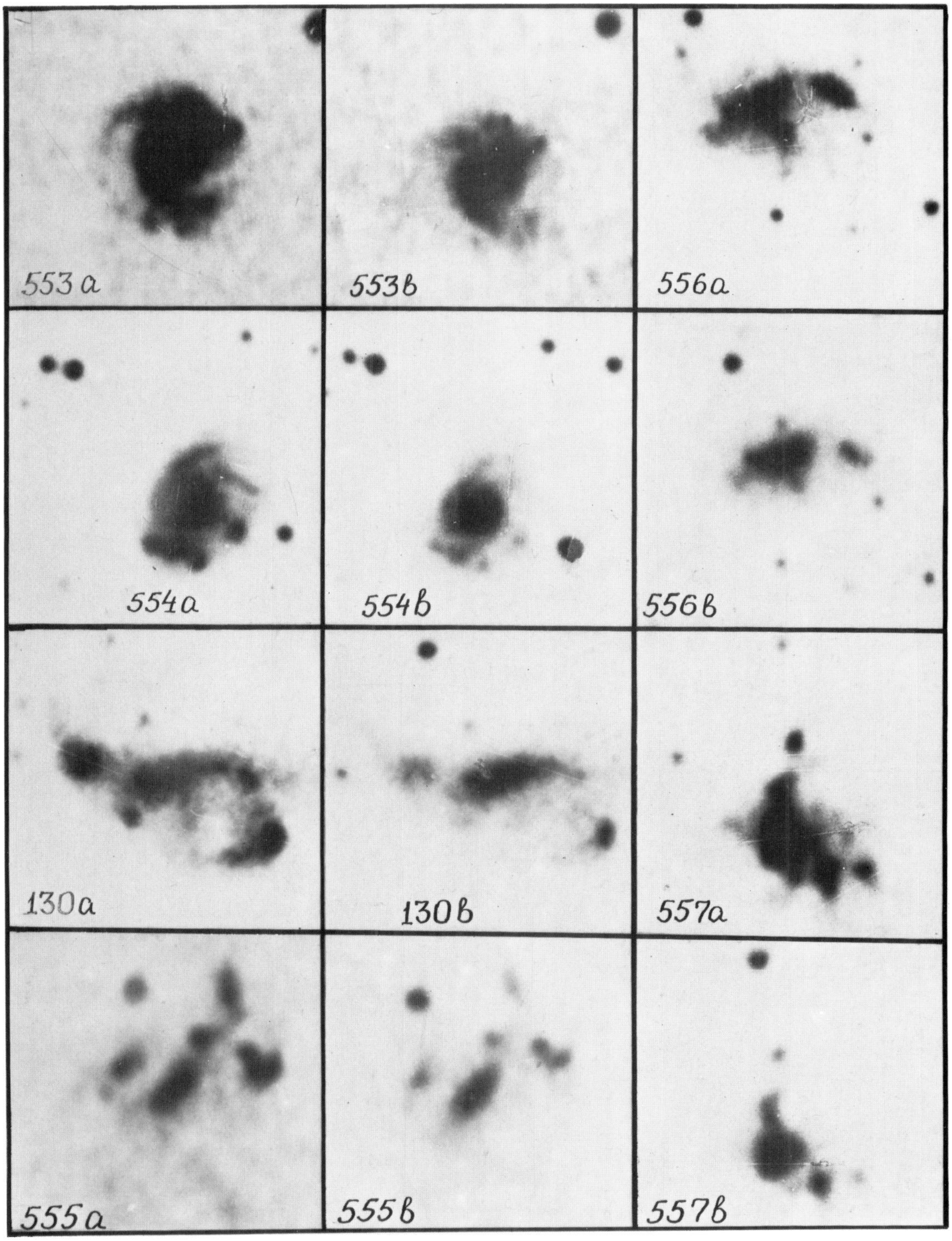

Plate 32 Blue nests. II.

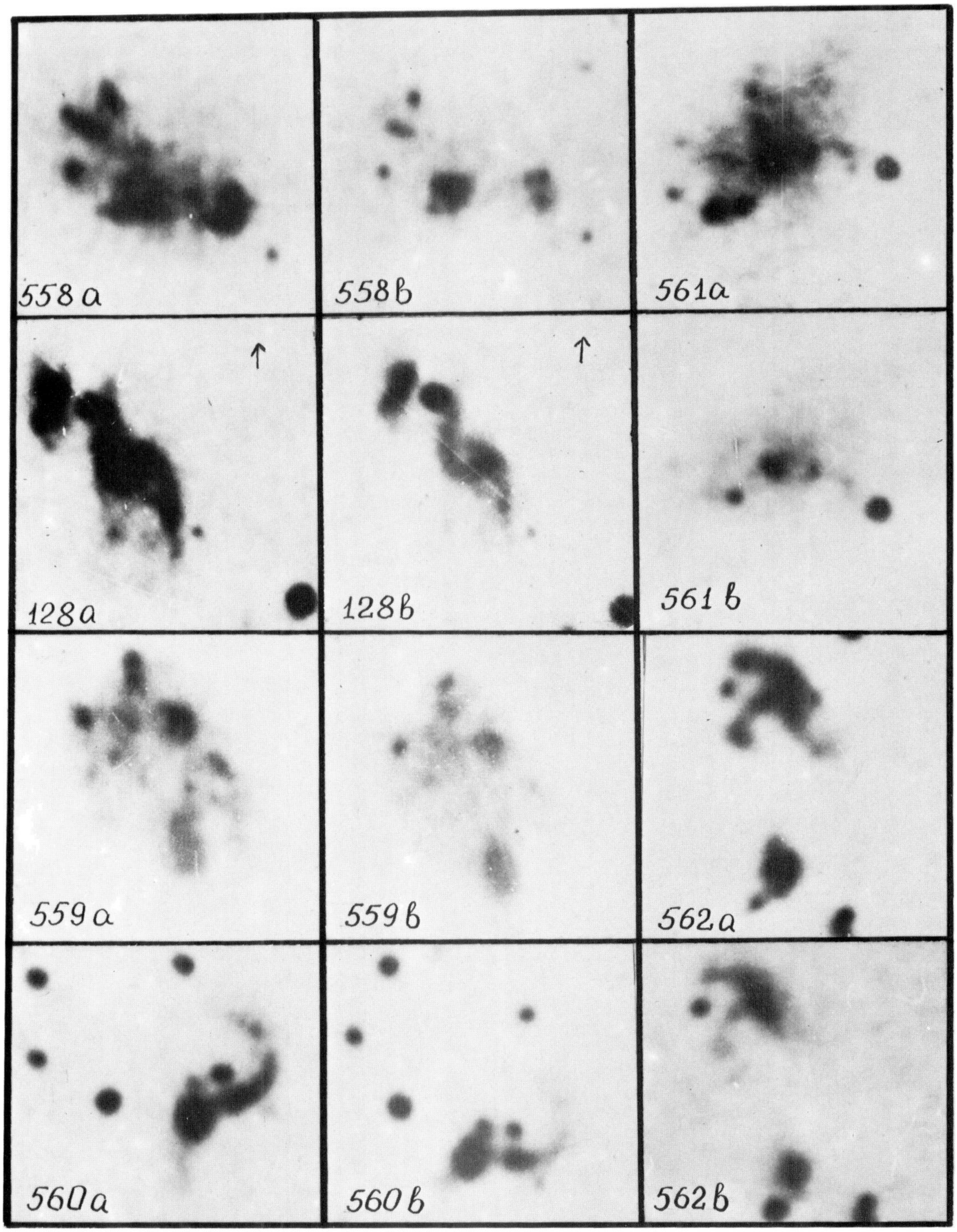

Plate 33 Blue nests. III.

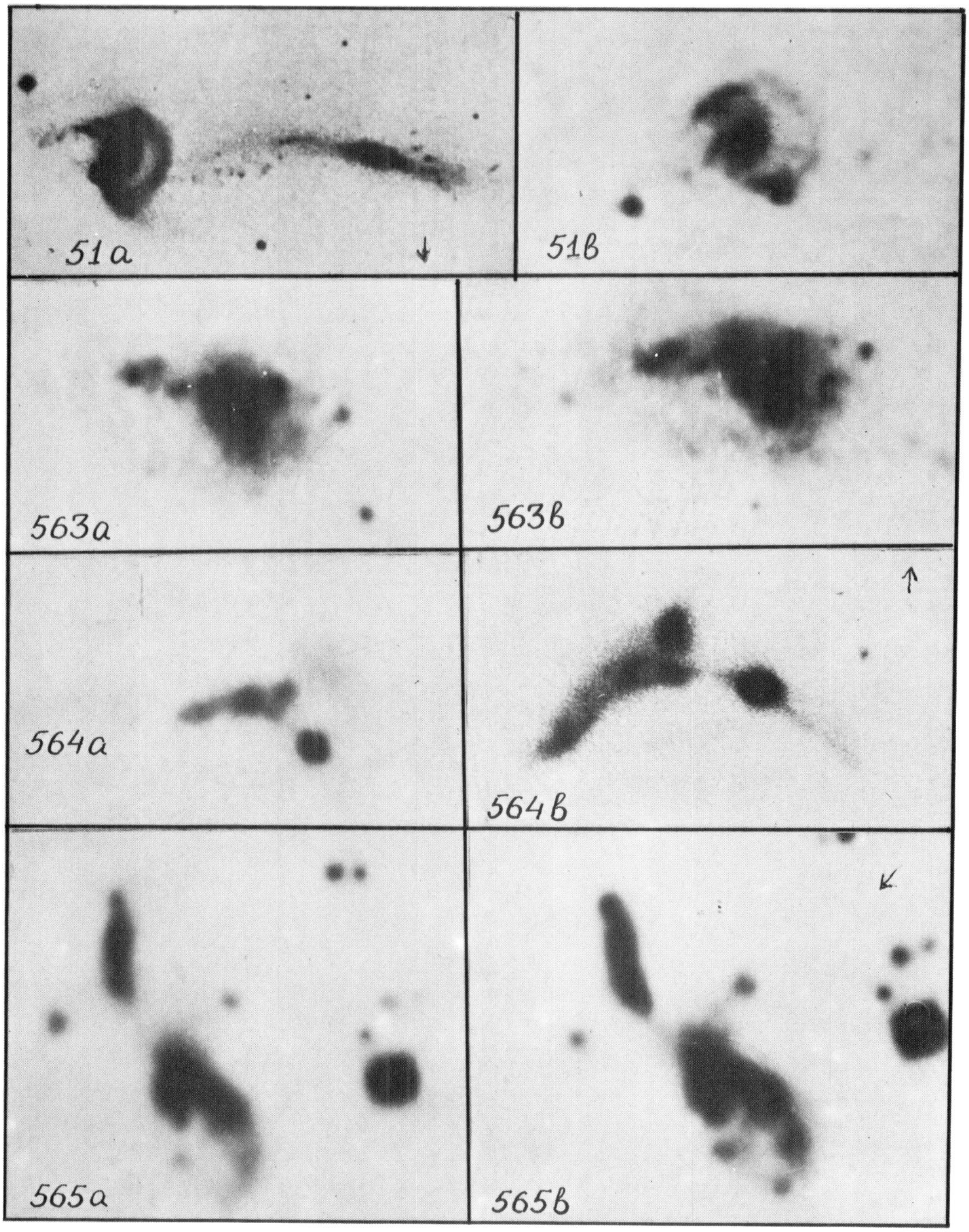

Plate 34 Blue nests. IV.

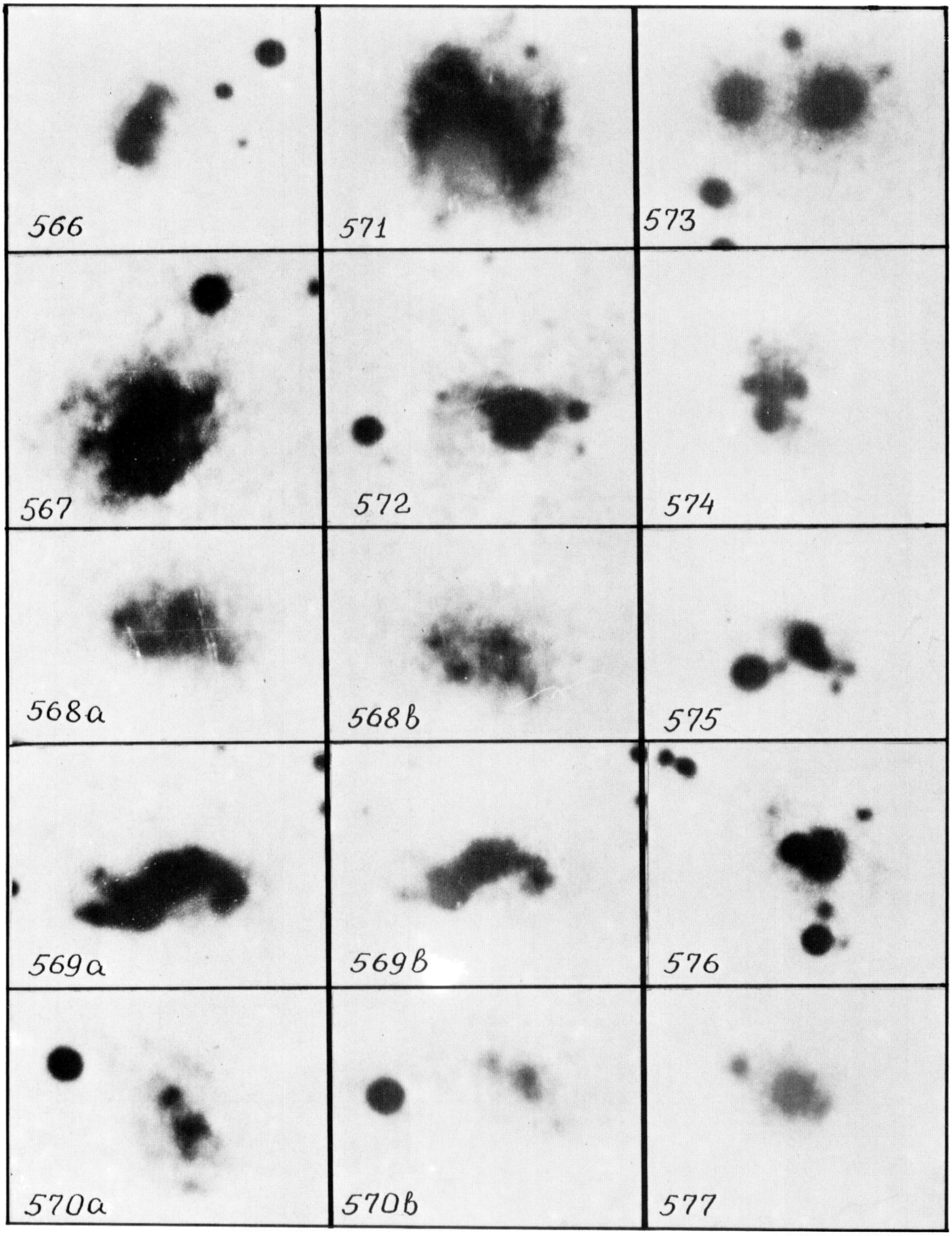

Plate 35 Nests. IV.

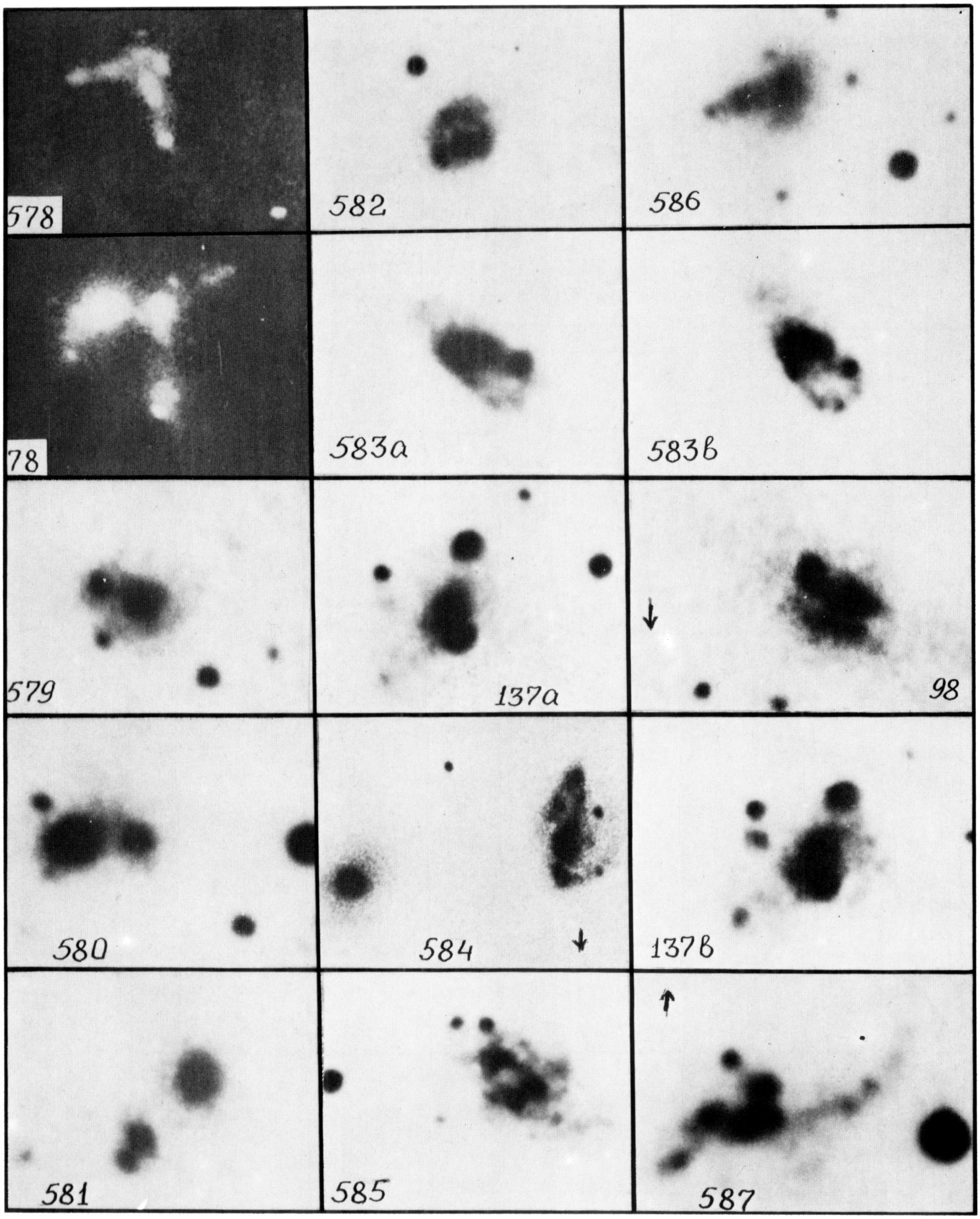

Plate 36 Nests. V.

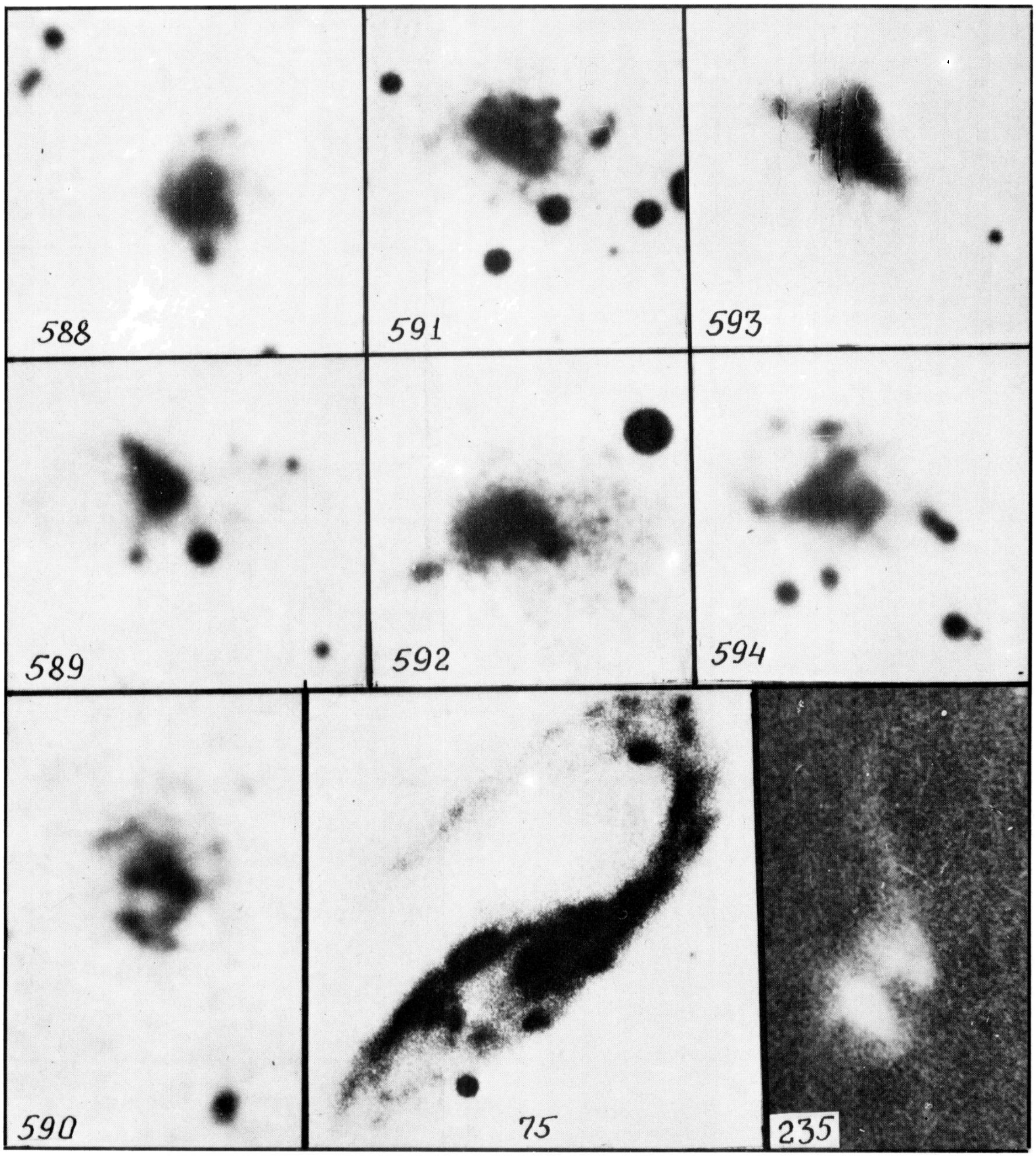

Plate 37 Nests. VI.

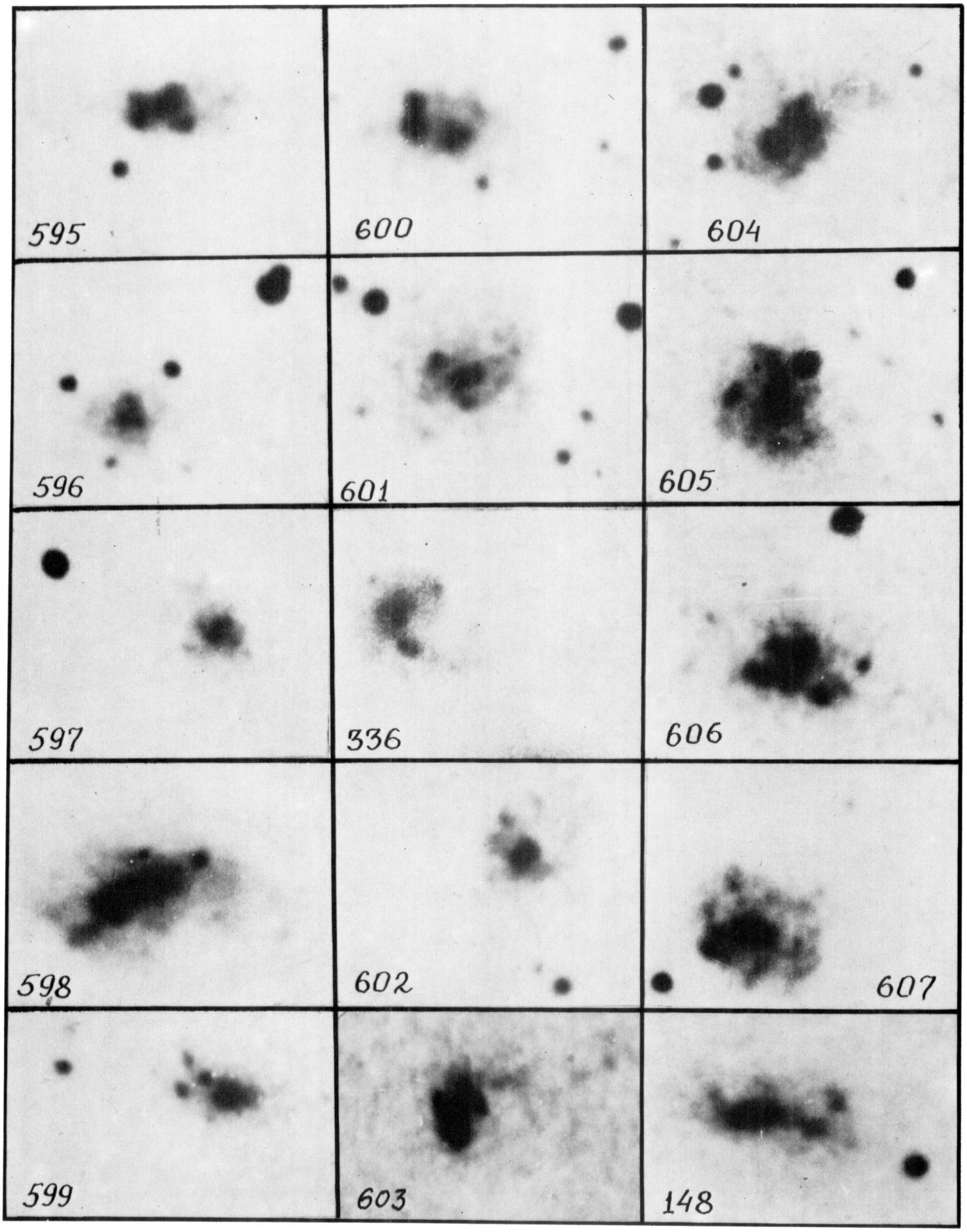

Plate 38 Remote nests with haze.

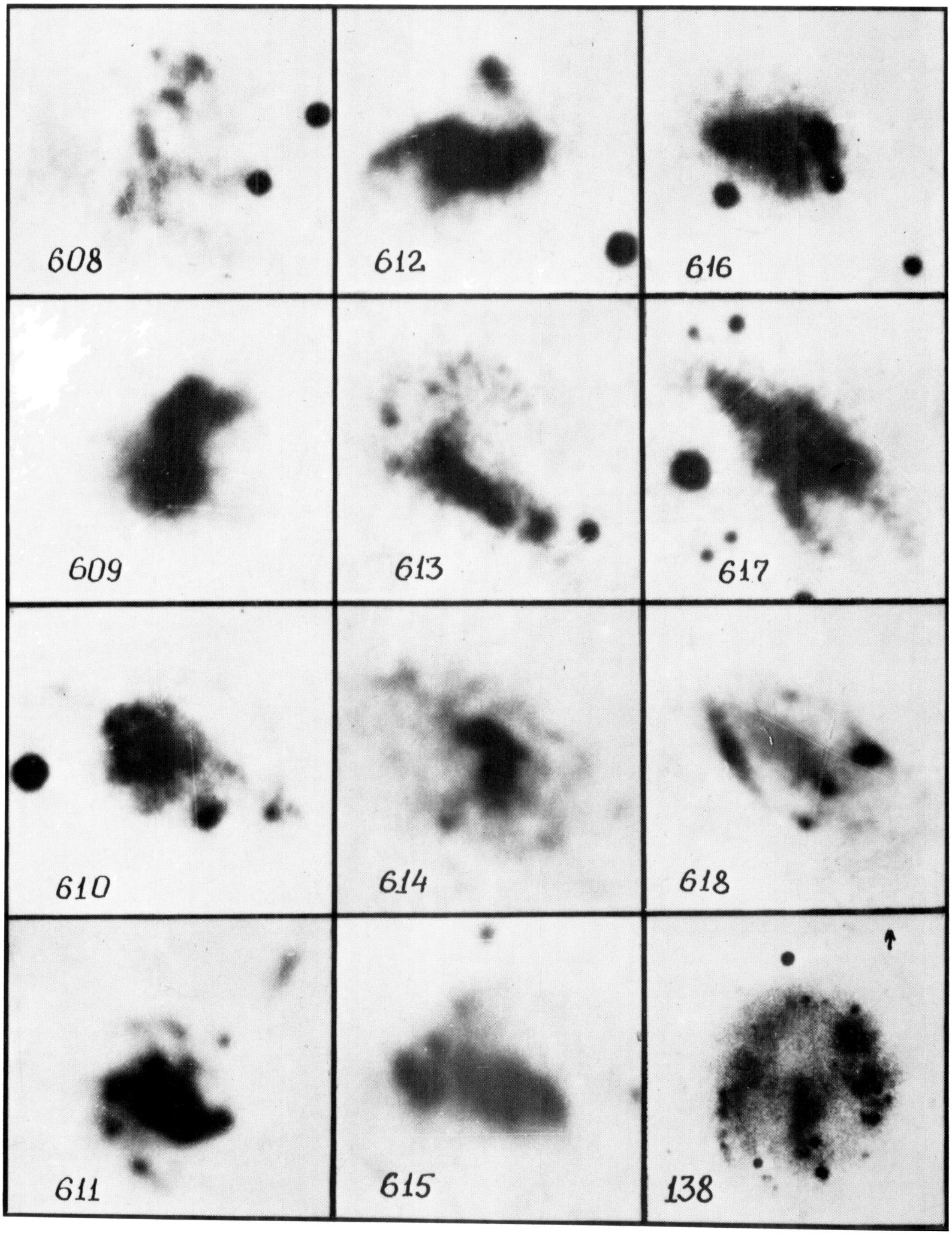

Plate 39 Nests and possible nests.

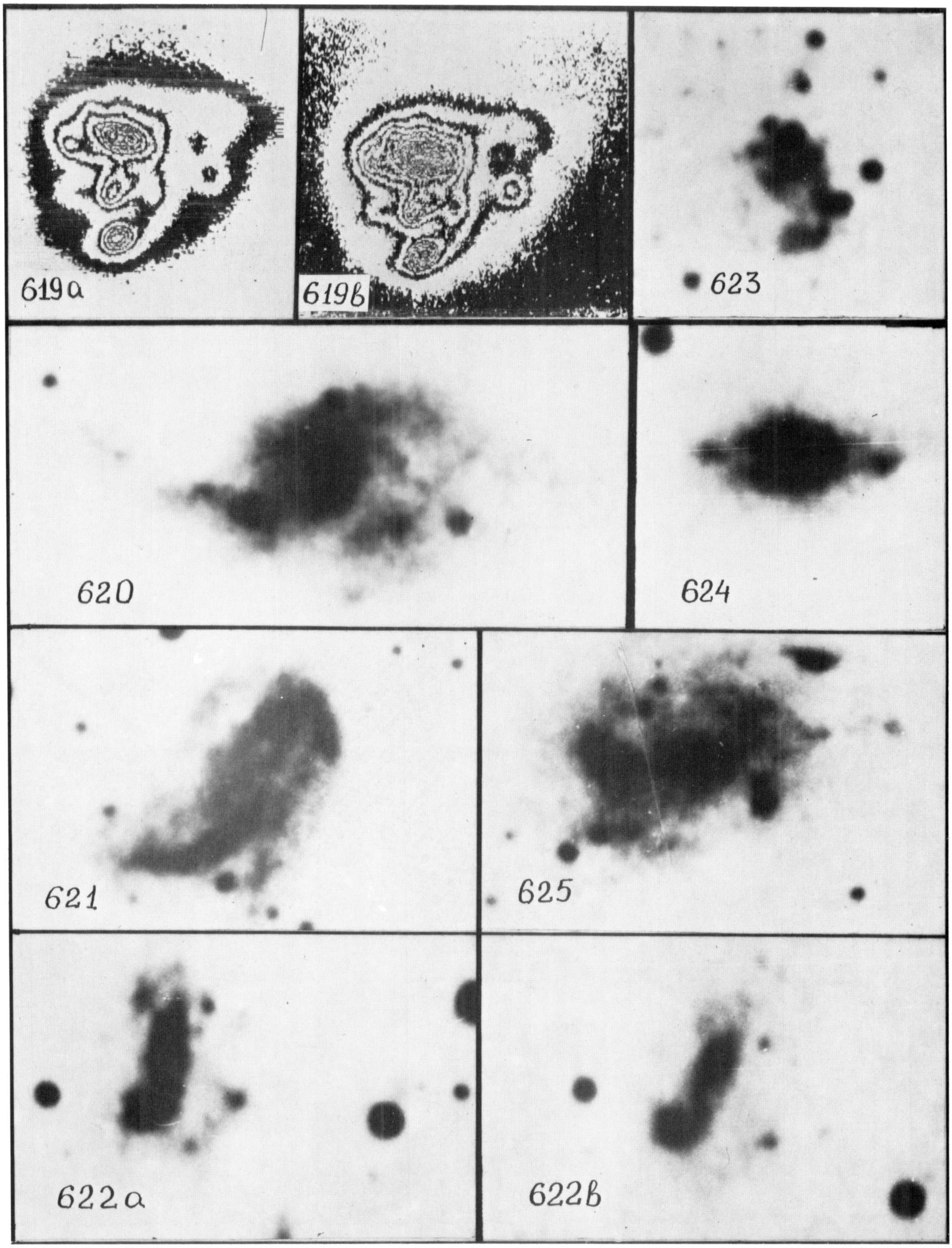

Plate 40 Nests – probable and possible.

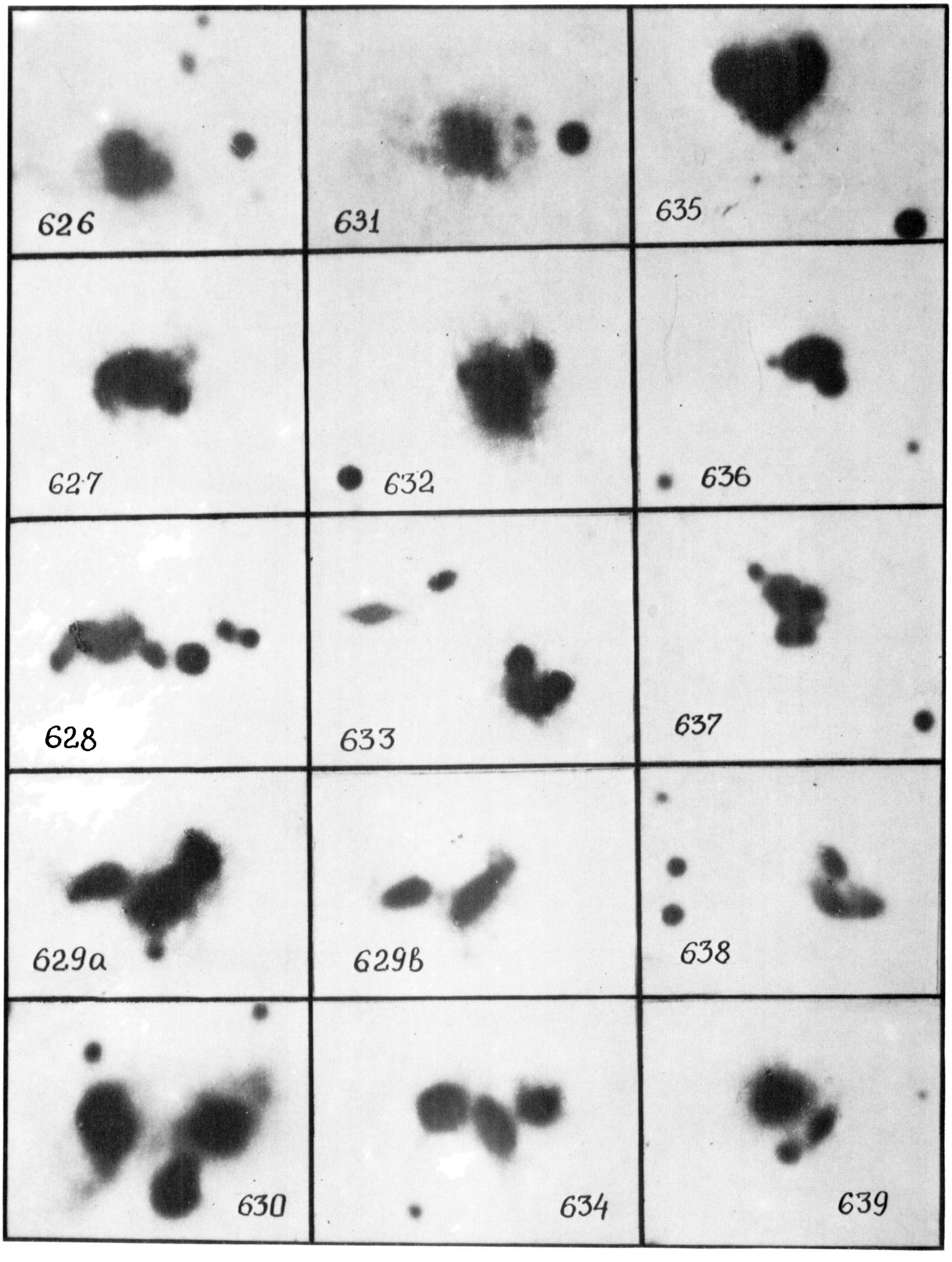

Plate 41 Nests – Early stages of fragmentation.

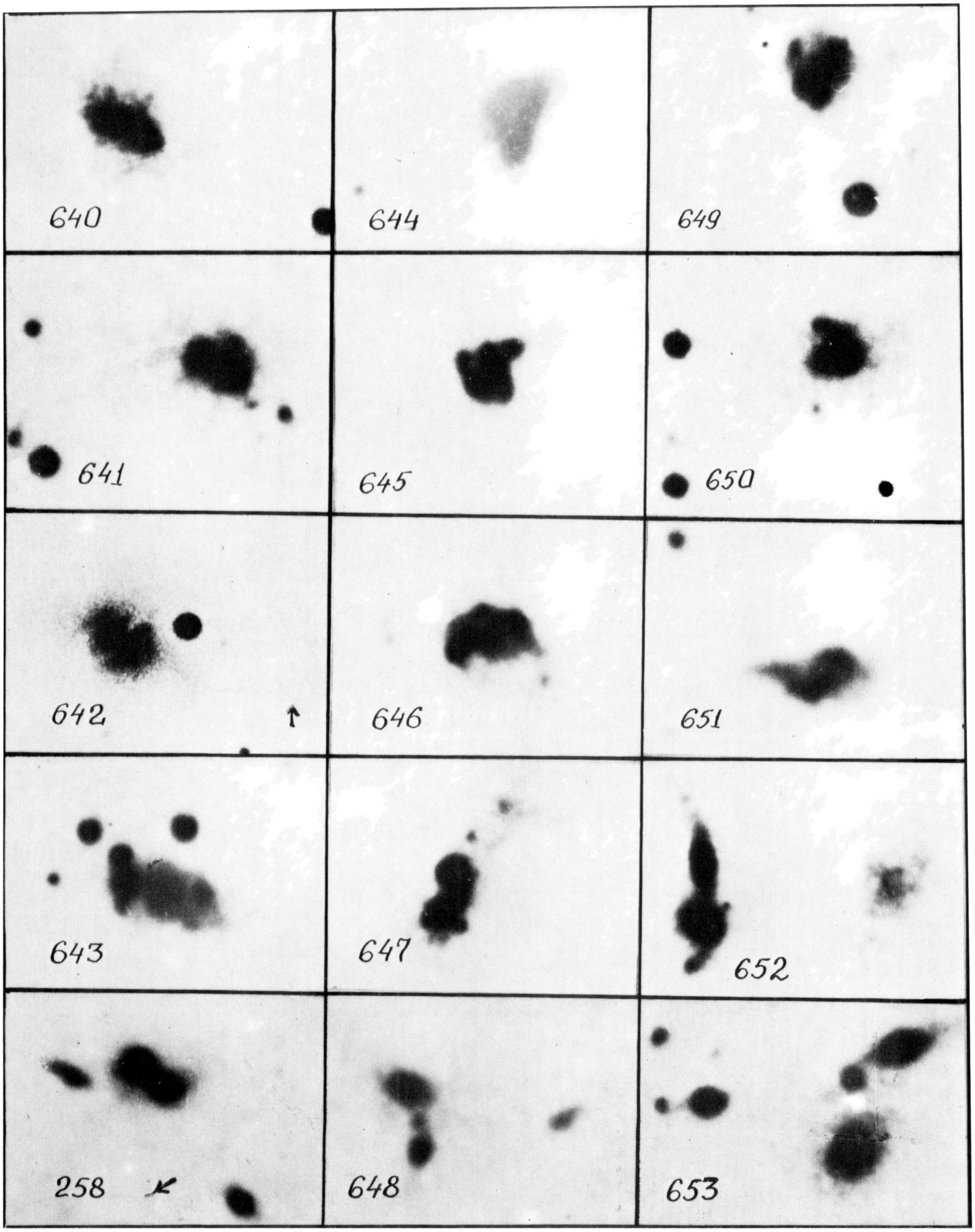

Plate 42 Nests beginning to disperse.

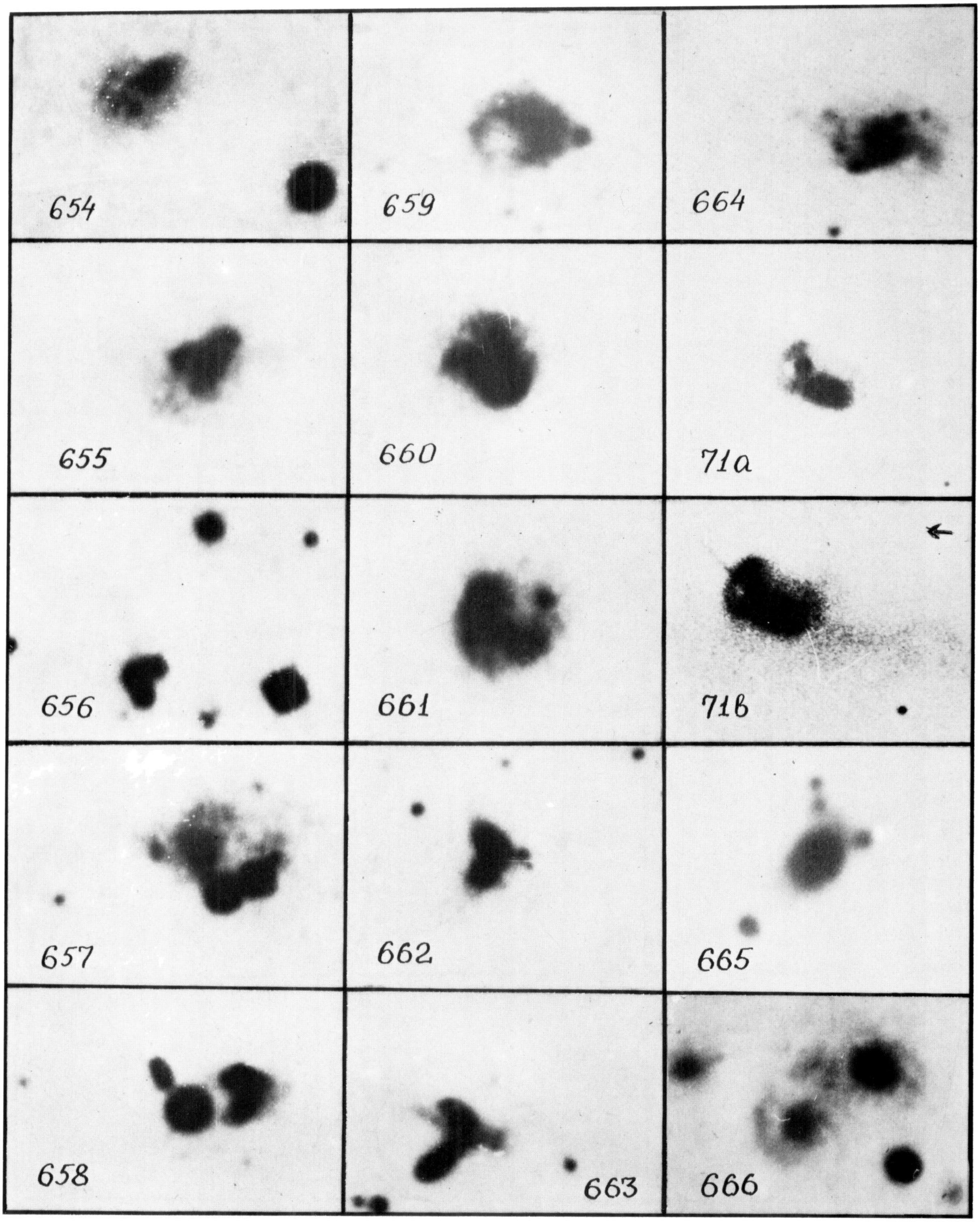

Plate 43 Disruption of compact groups.

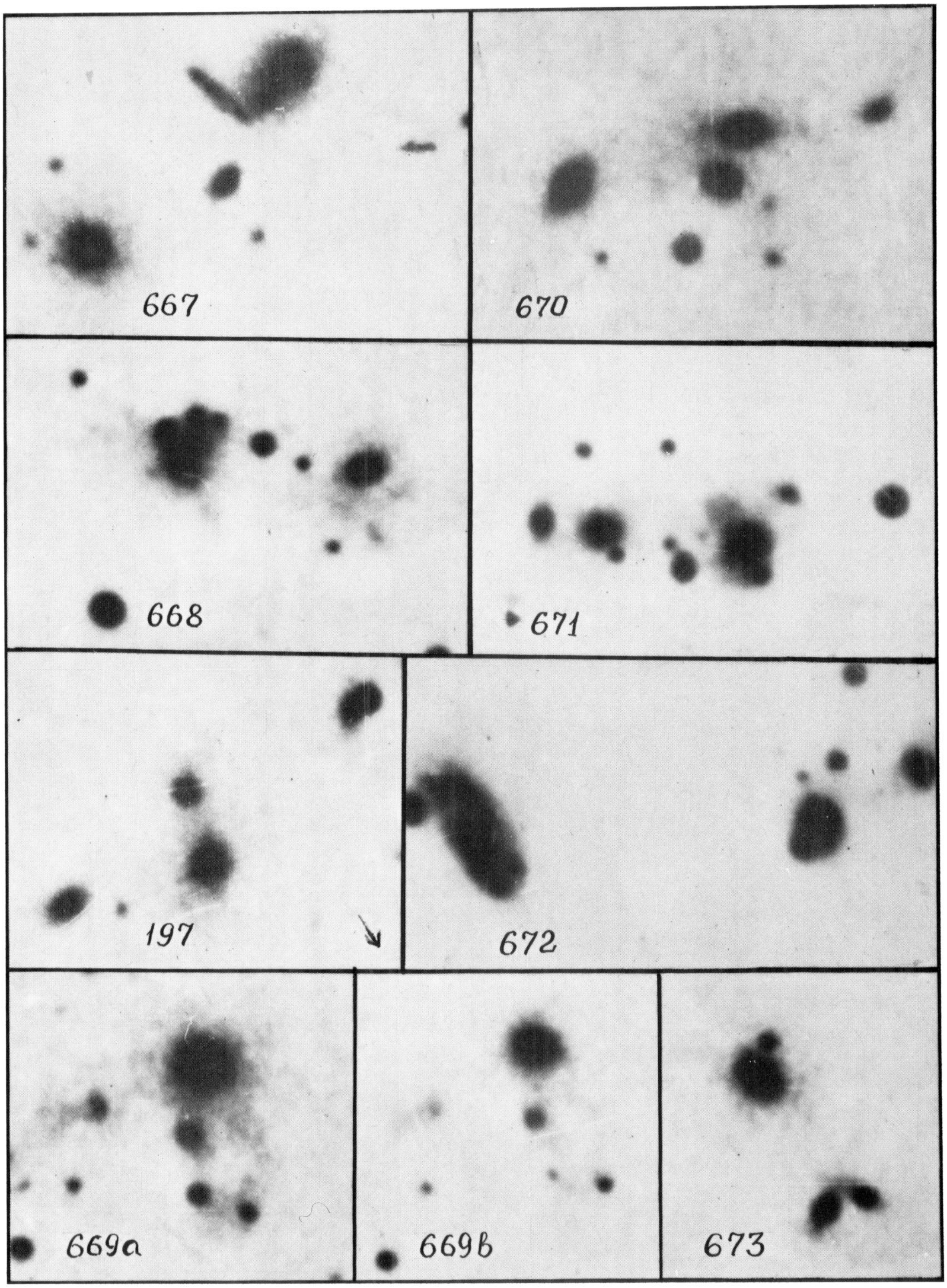

Plate 44 Disruption of chainlike nests.

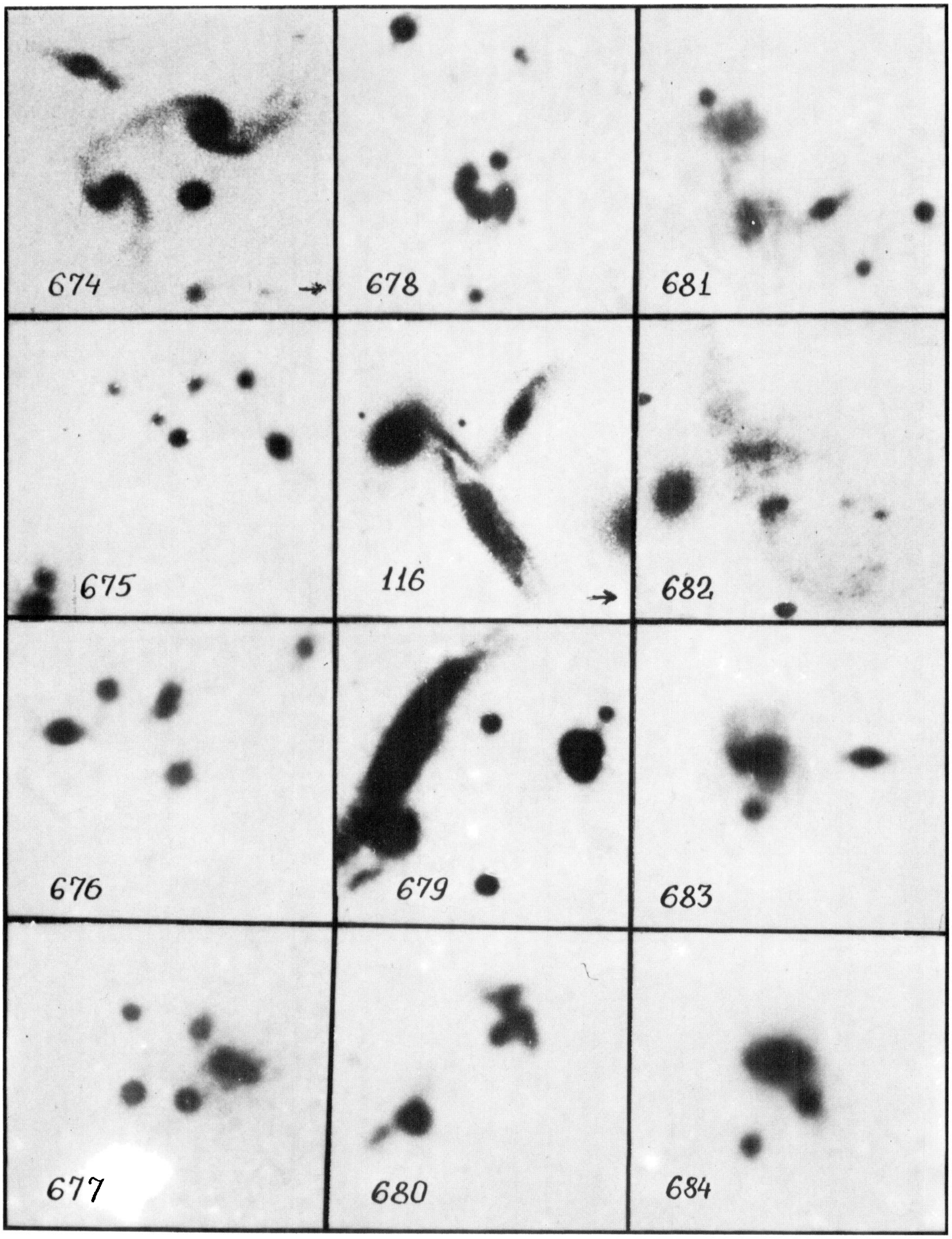

Plate 45 Disruption into groups of 3–4.

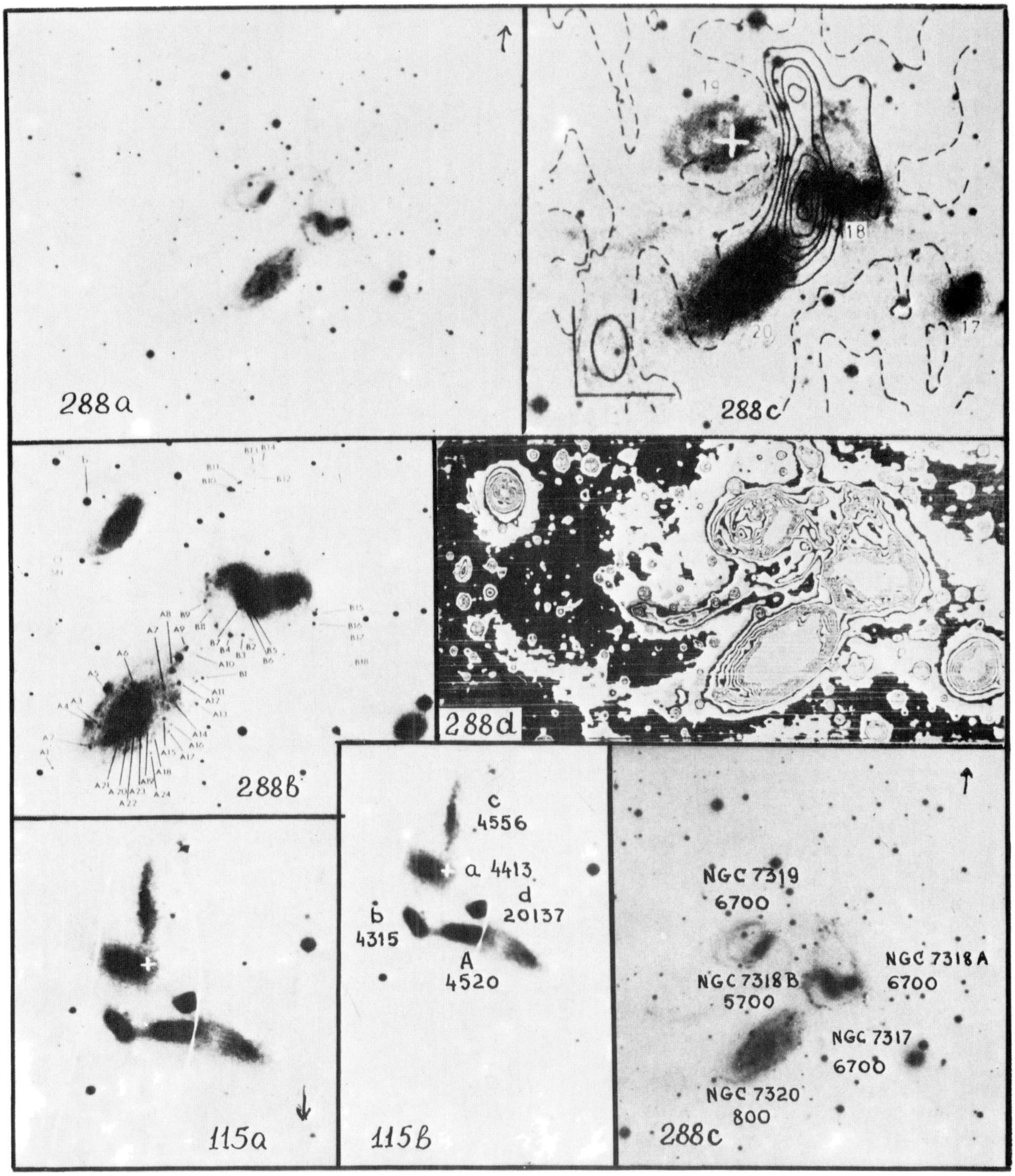

Plate 46 Tight groups of Stefan and Seyfert.

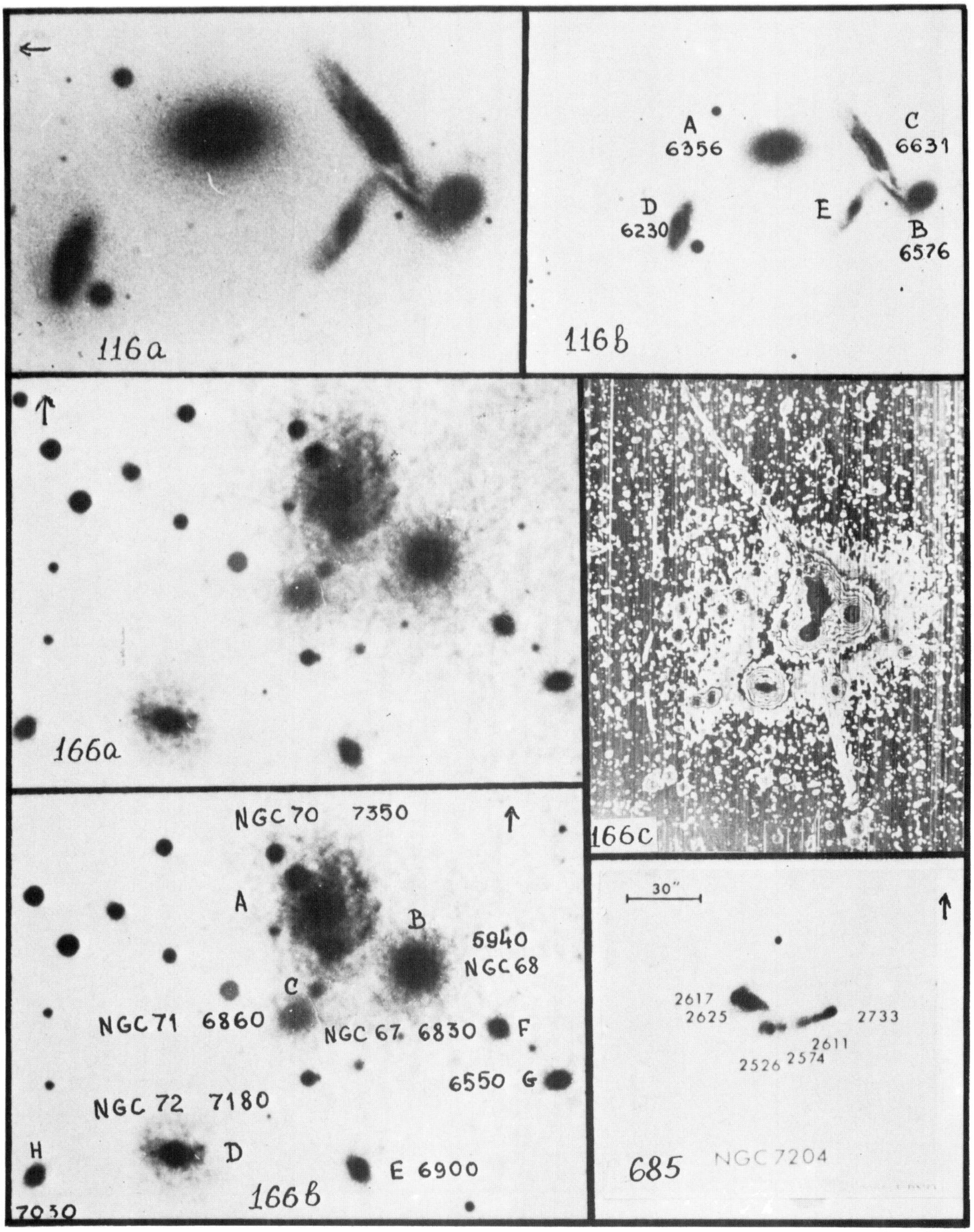

Plate 47 Groups VV 116, VV 166 and NGC 7204.

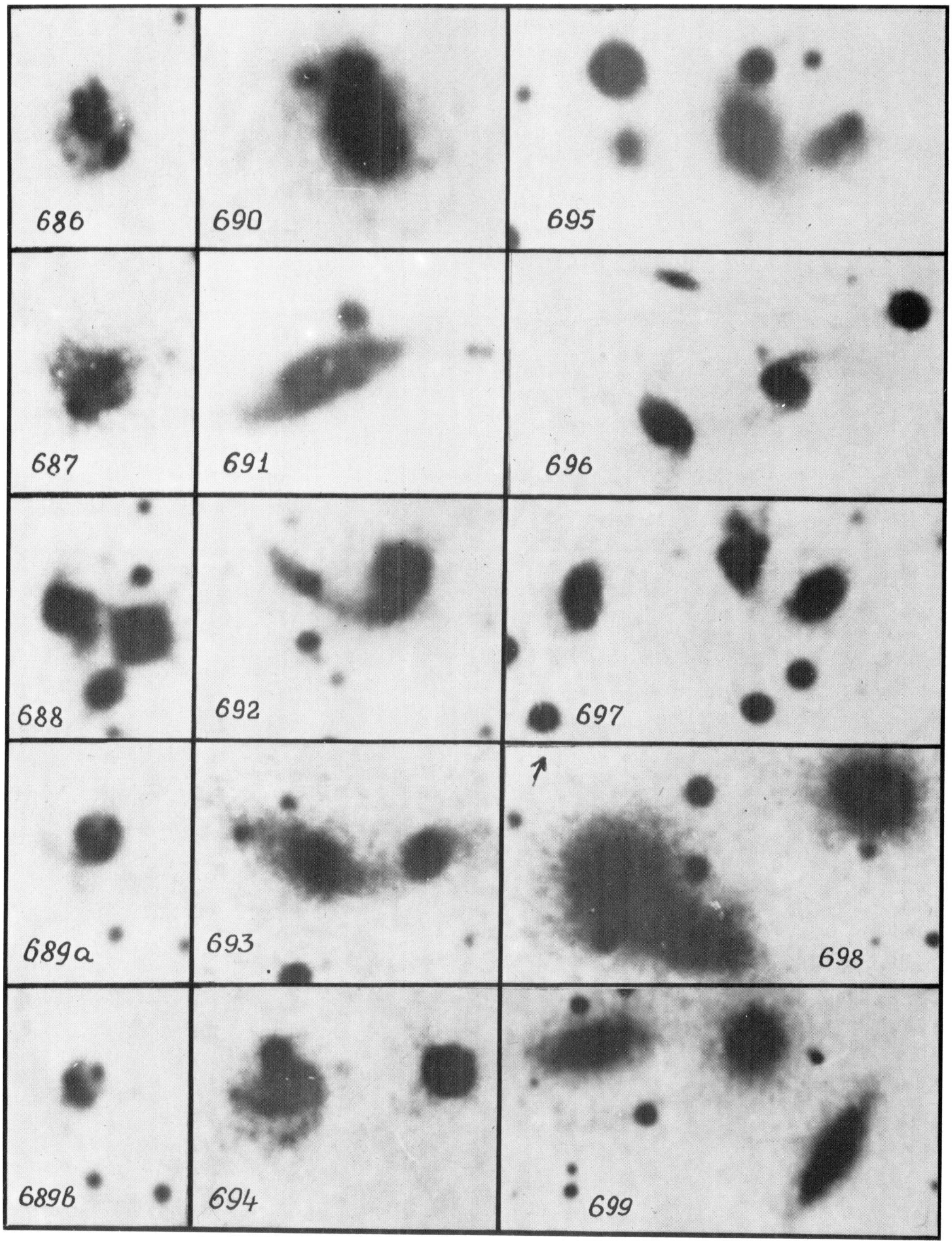

Plate 48 Some triples and coalescents.

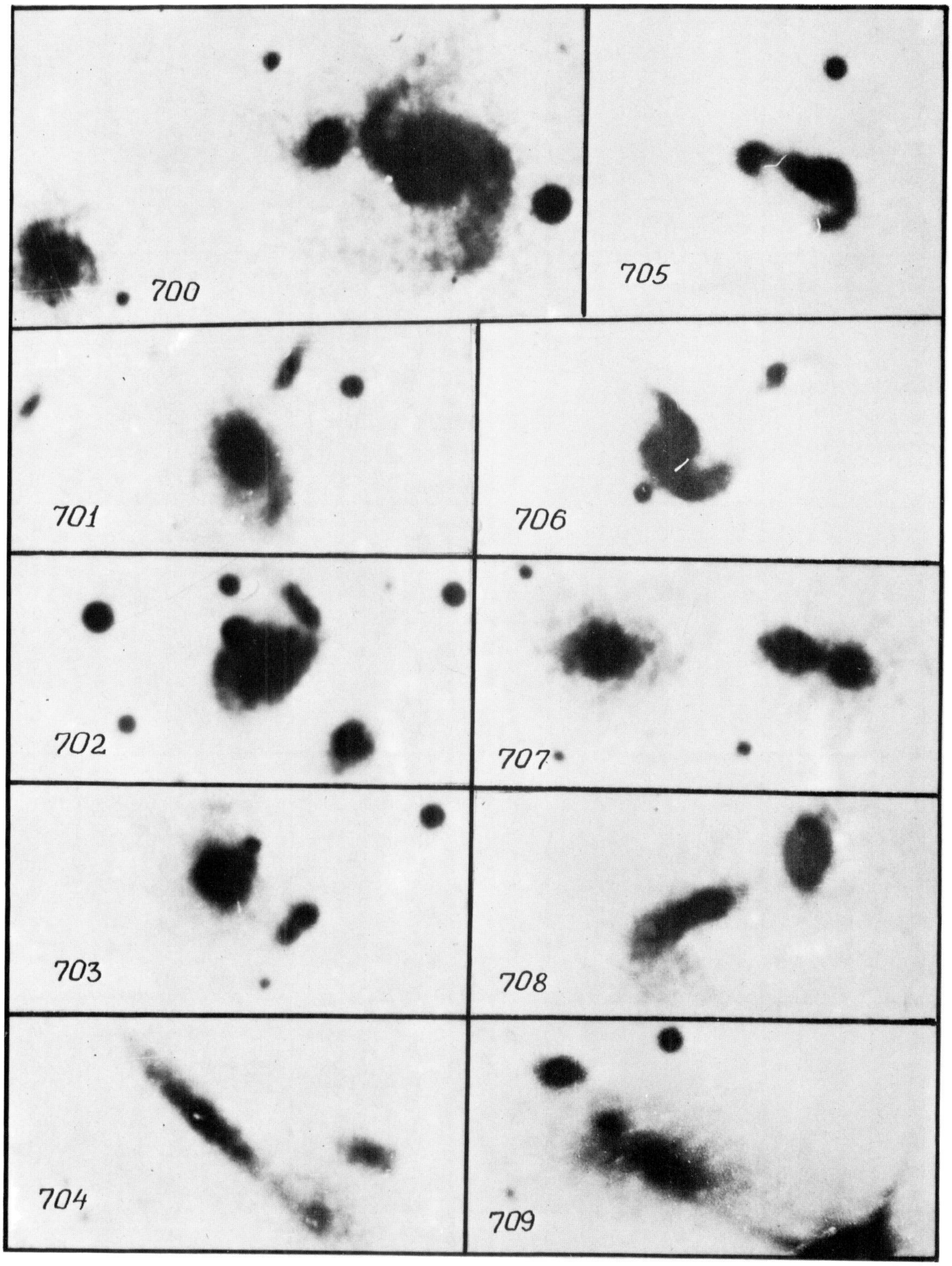

Plate 49 Triples with a tight pair. I.

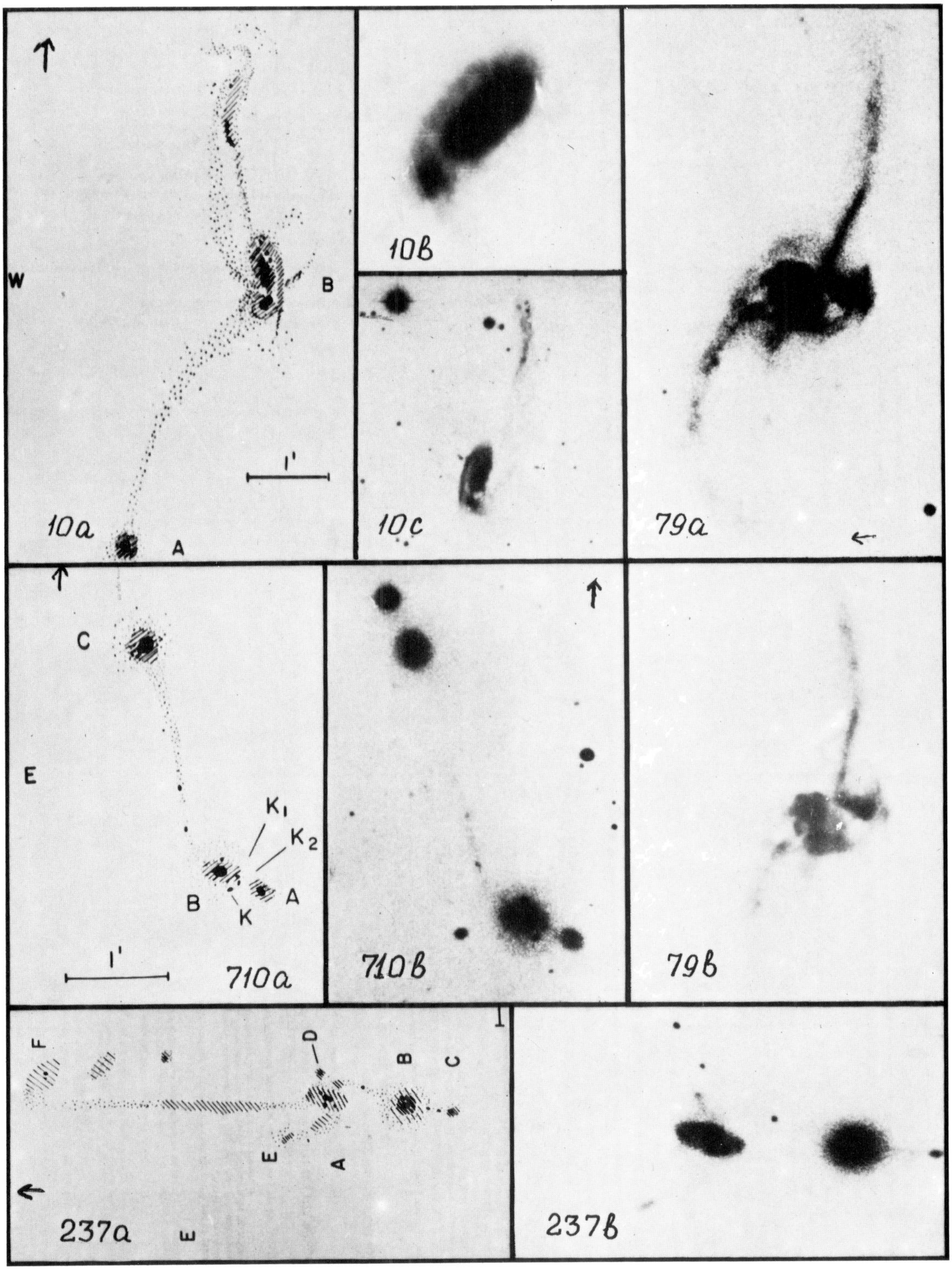

Plate 50 Triples with a tight pair. II.

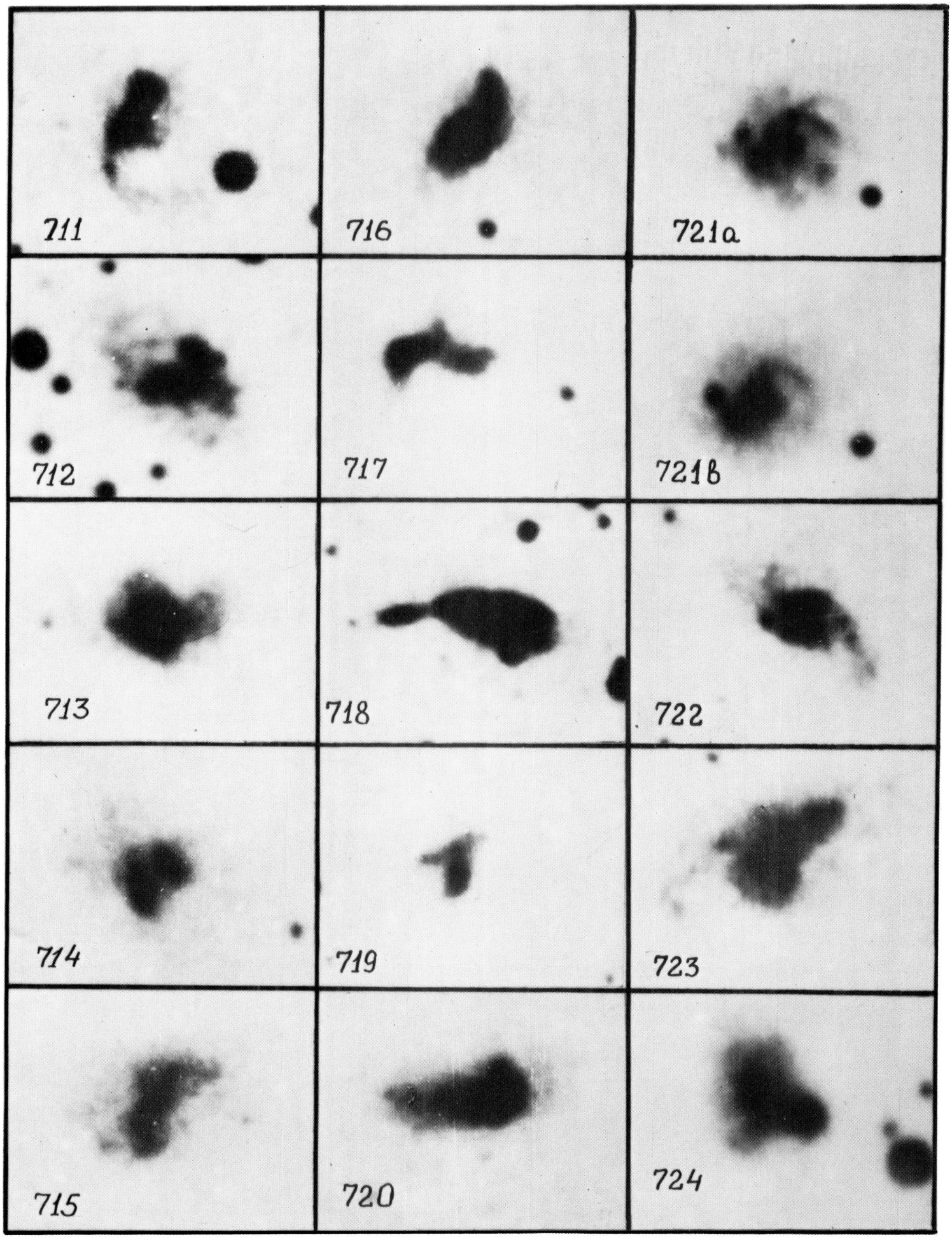

Plate 51 Pairs of coalescents. I.

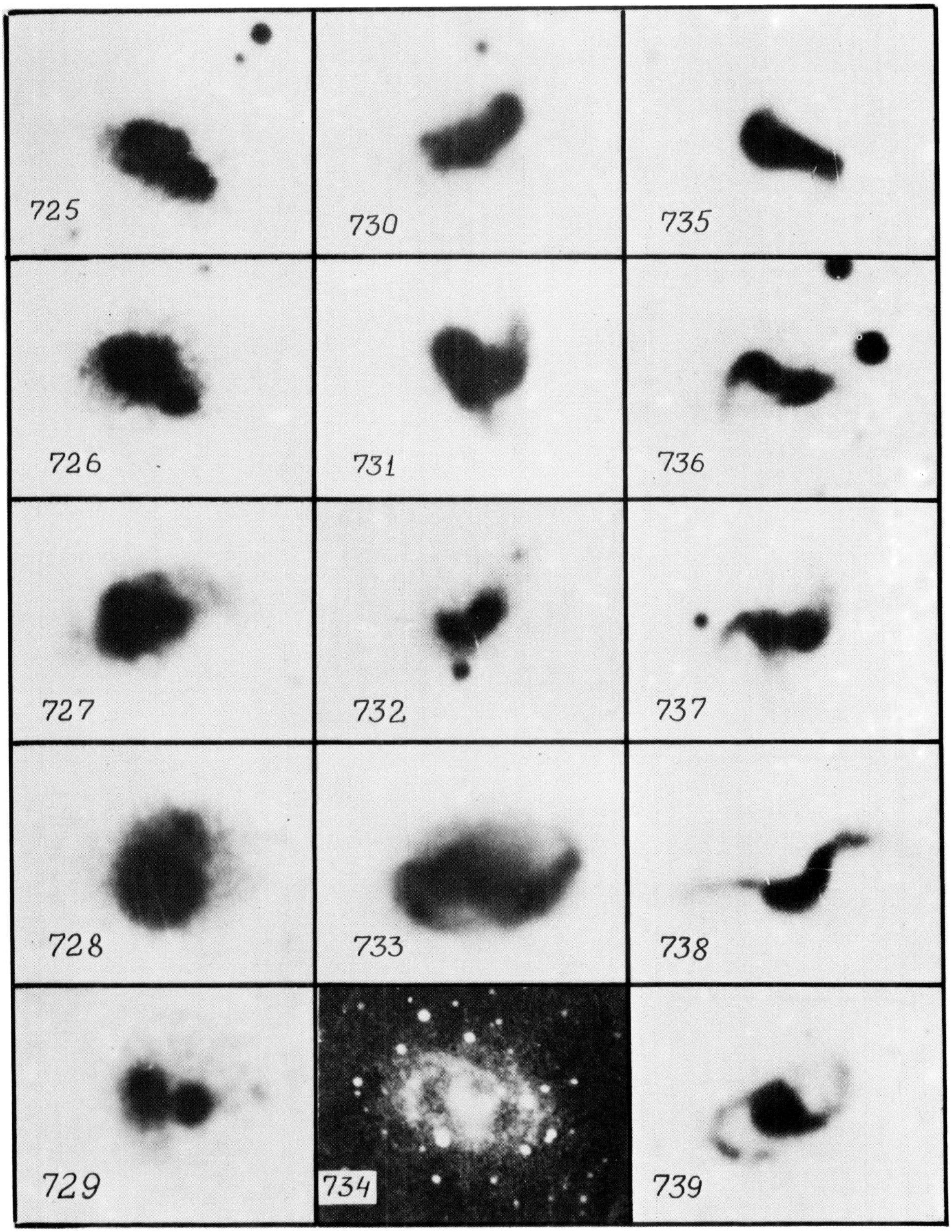

Plate 52 Pairs of coalescents. II.

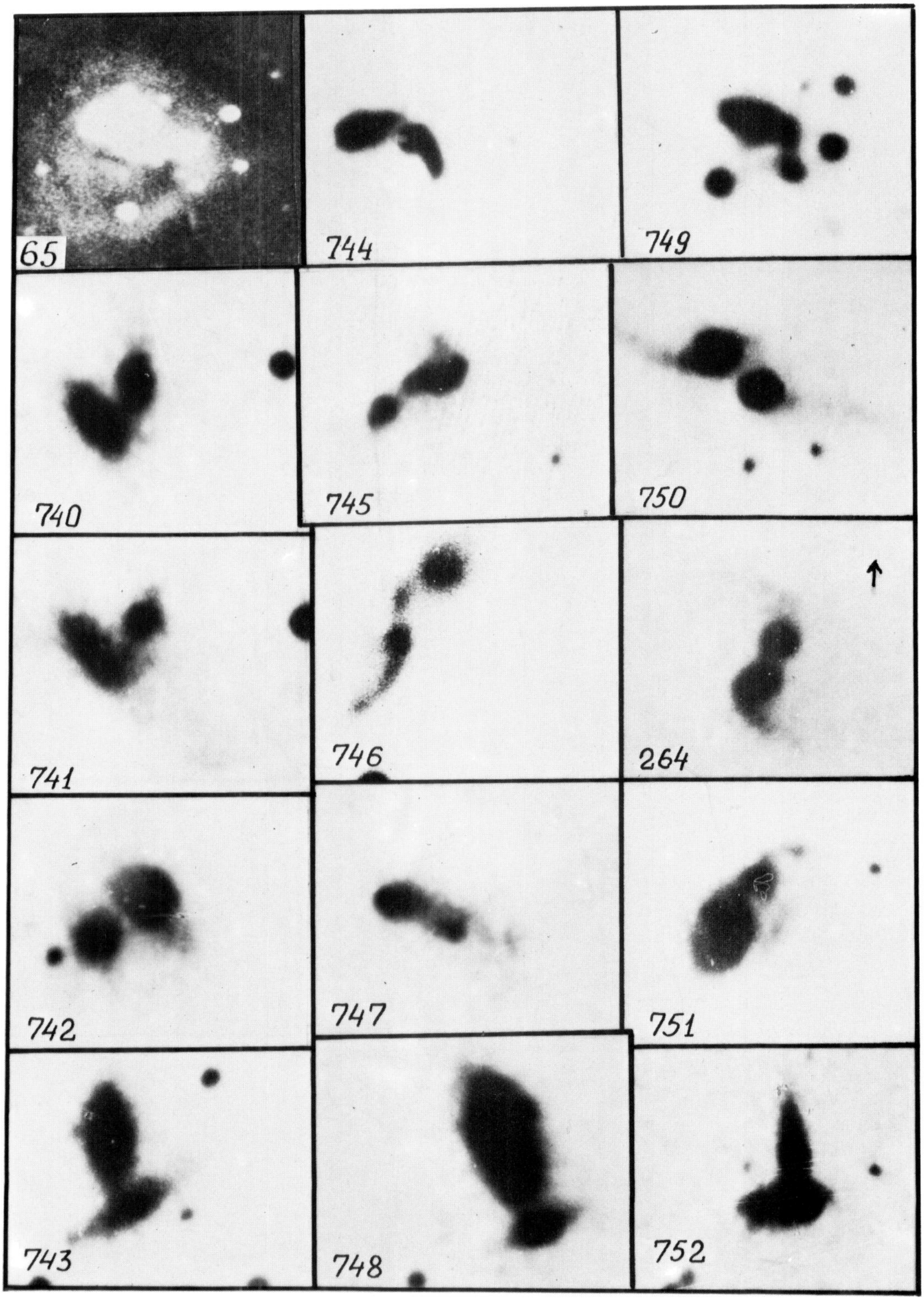

Plate 53 Pairs in contact.

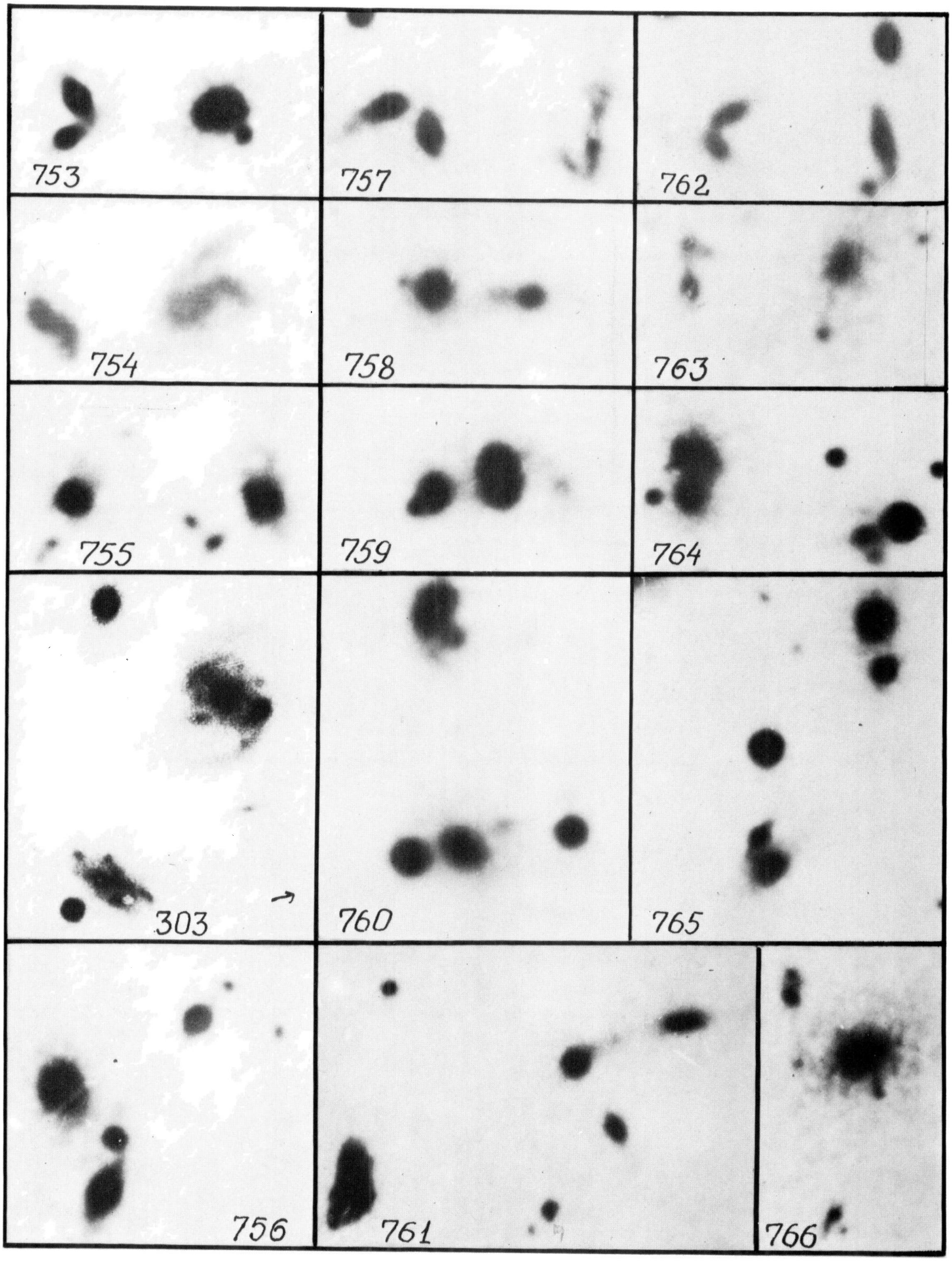

Plate 54 Pairs of tight pairs.

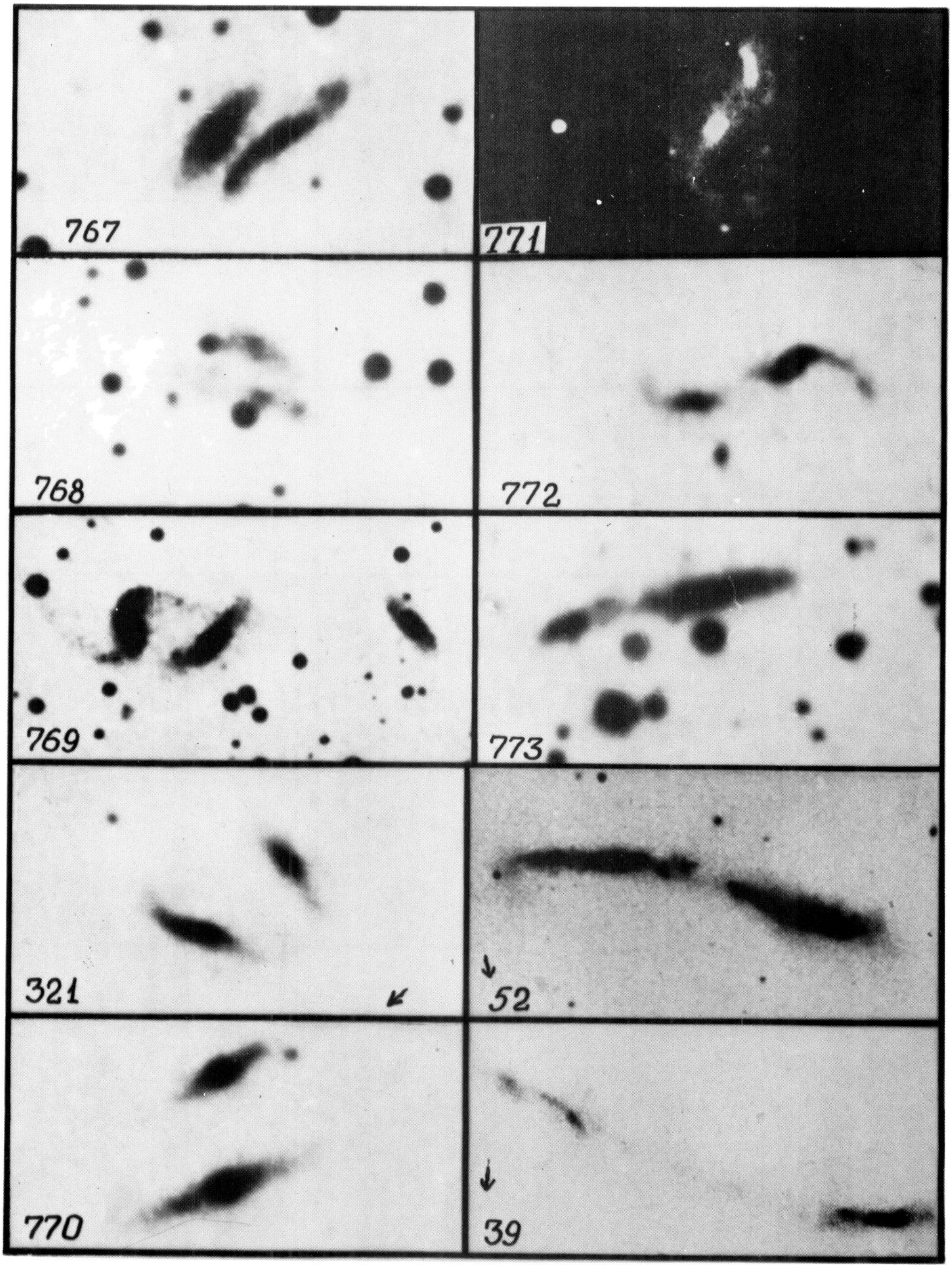

Plate 55 Parallel flat systems.

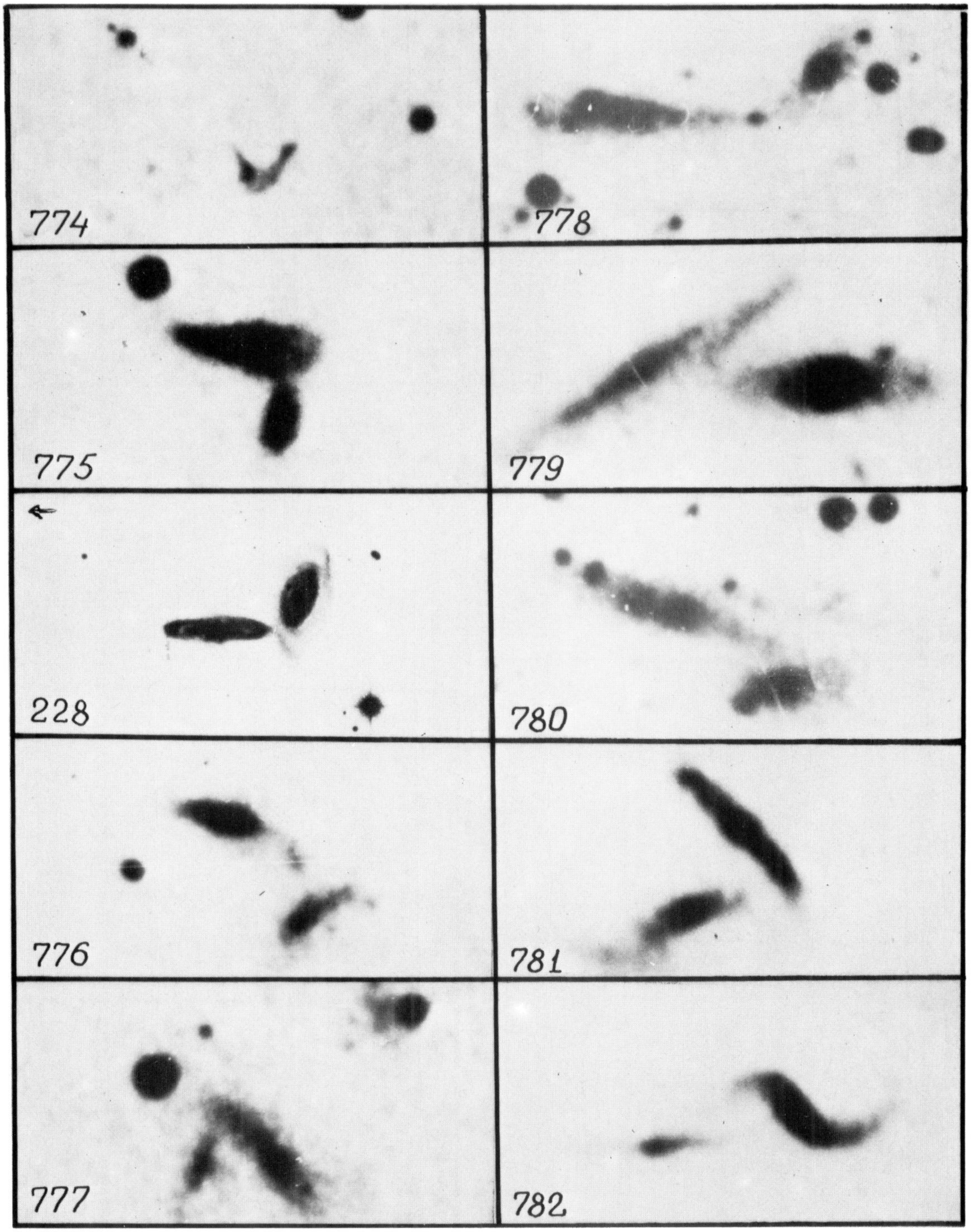

Plate 56 Flat systems forming angles.

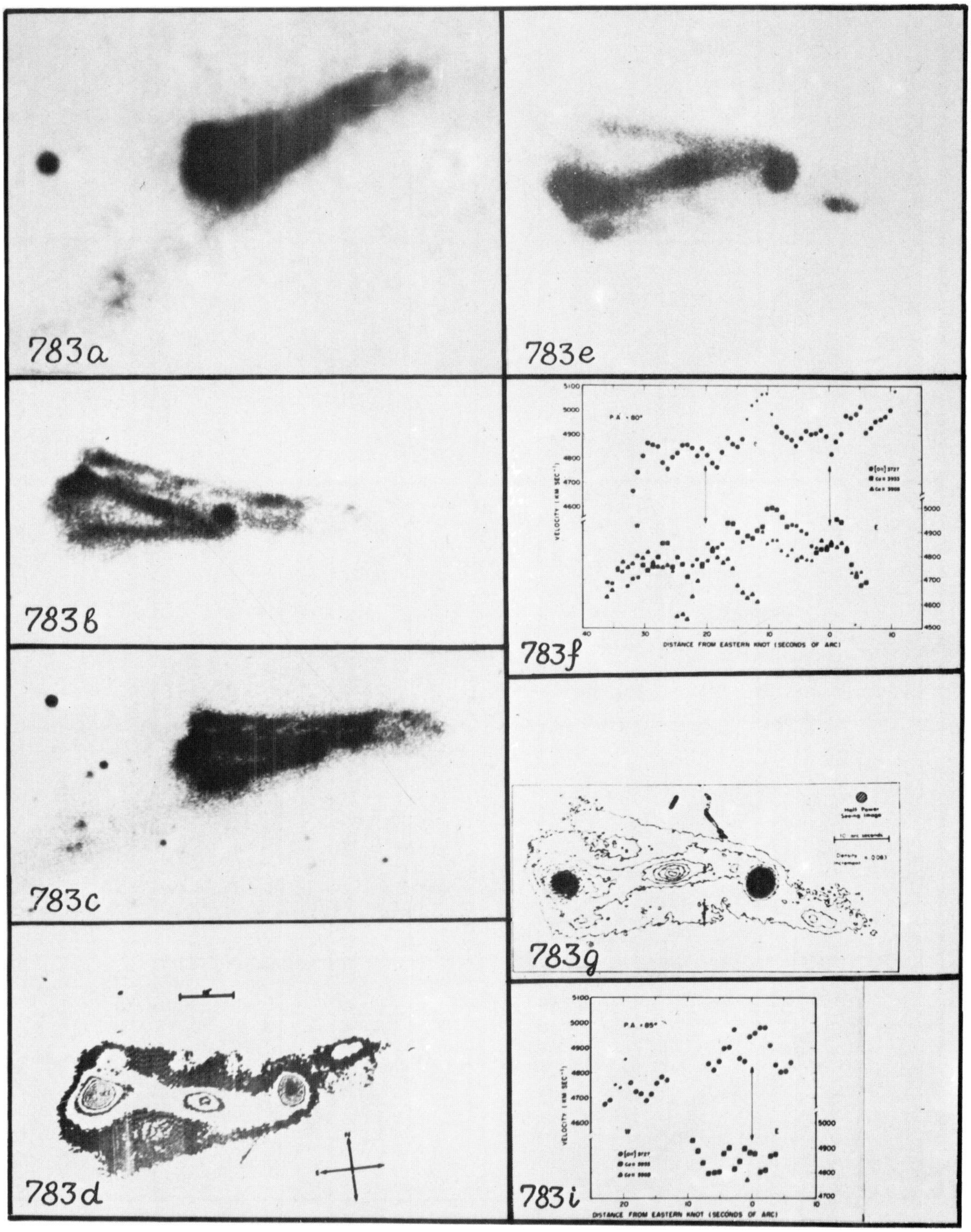

Plate 57 Enigmatic VV 783 = 6–4–18 = NGC 523.

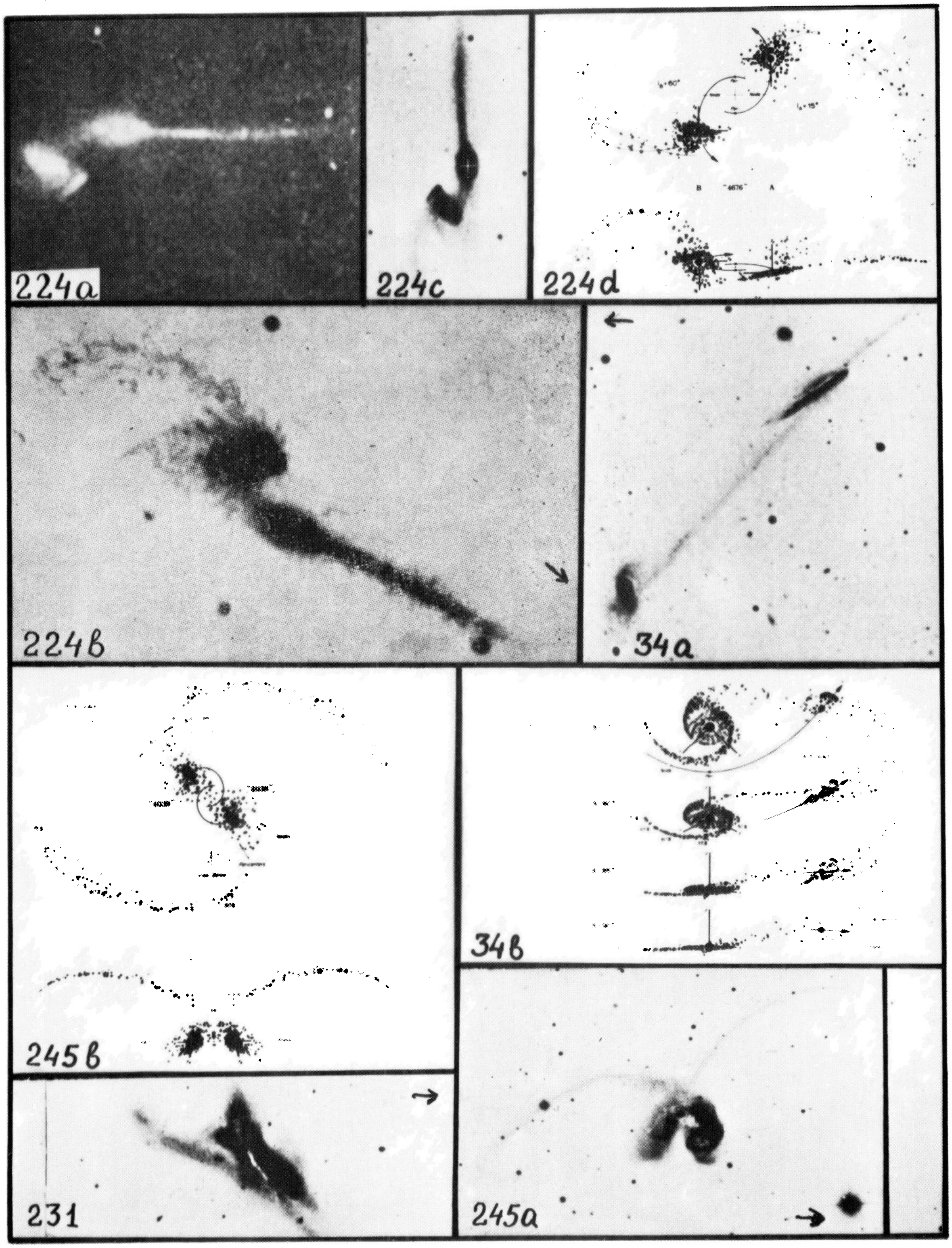

Plate 58 Toomre's tidal models for galaxies.

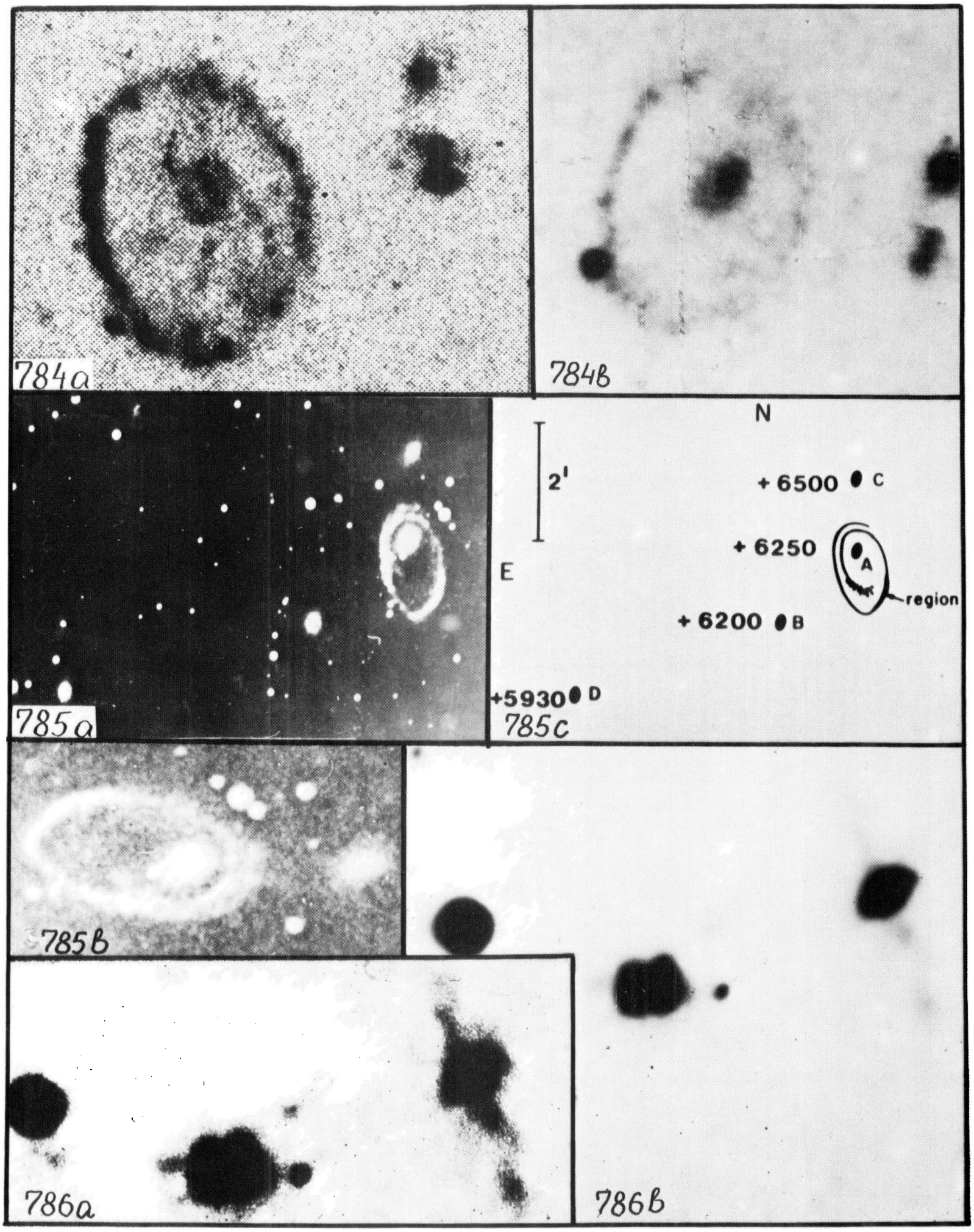

Plate 59 Enigmatic forms. I.

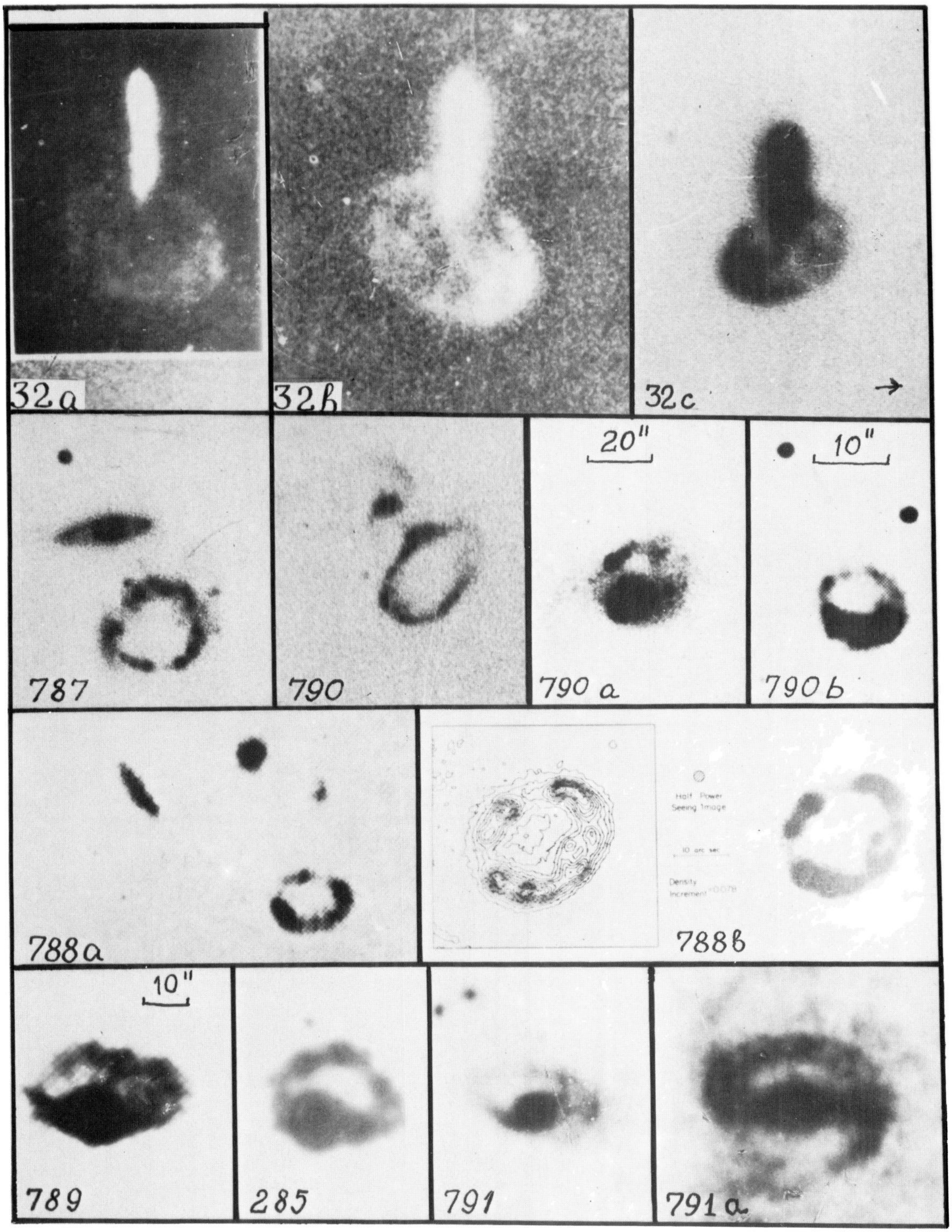

Plate 60 Rings and pseudo-rings.

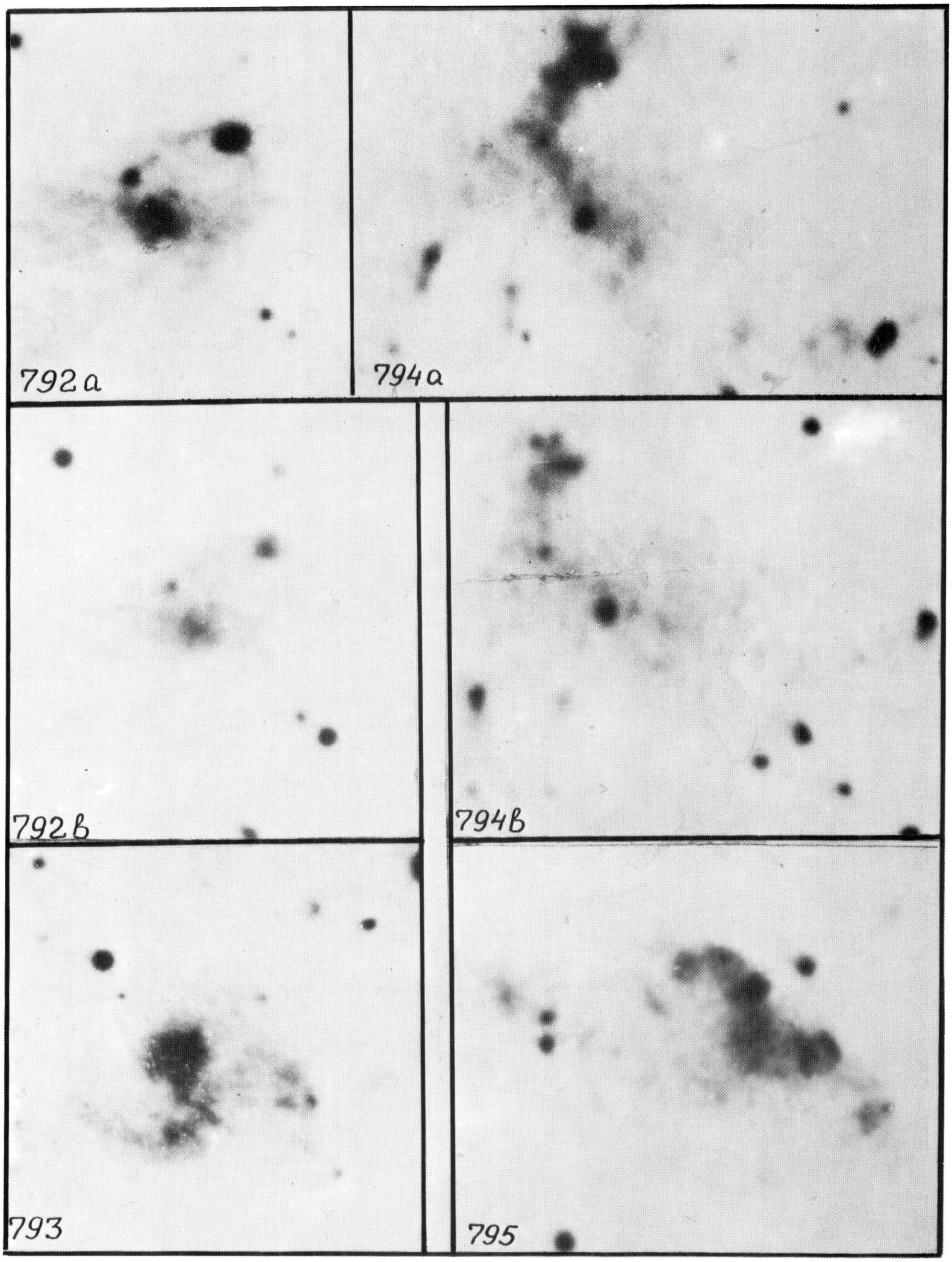

Plate 61 Enigmatic forms. II.

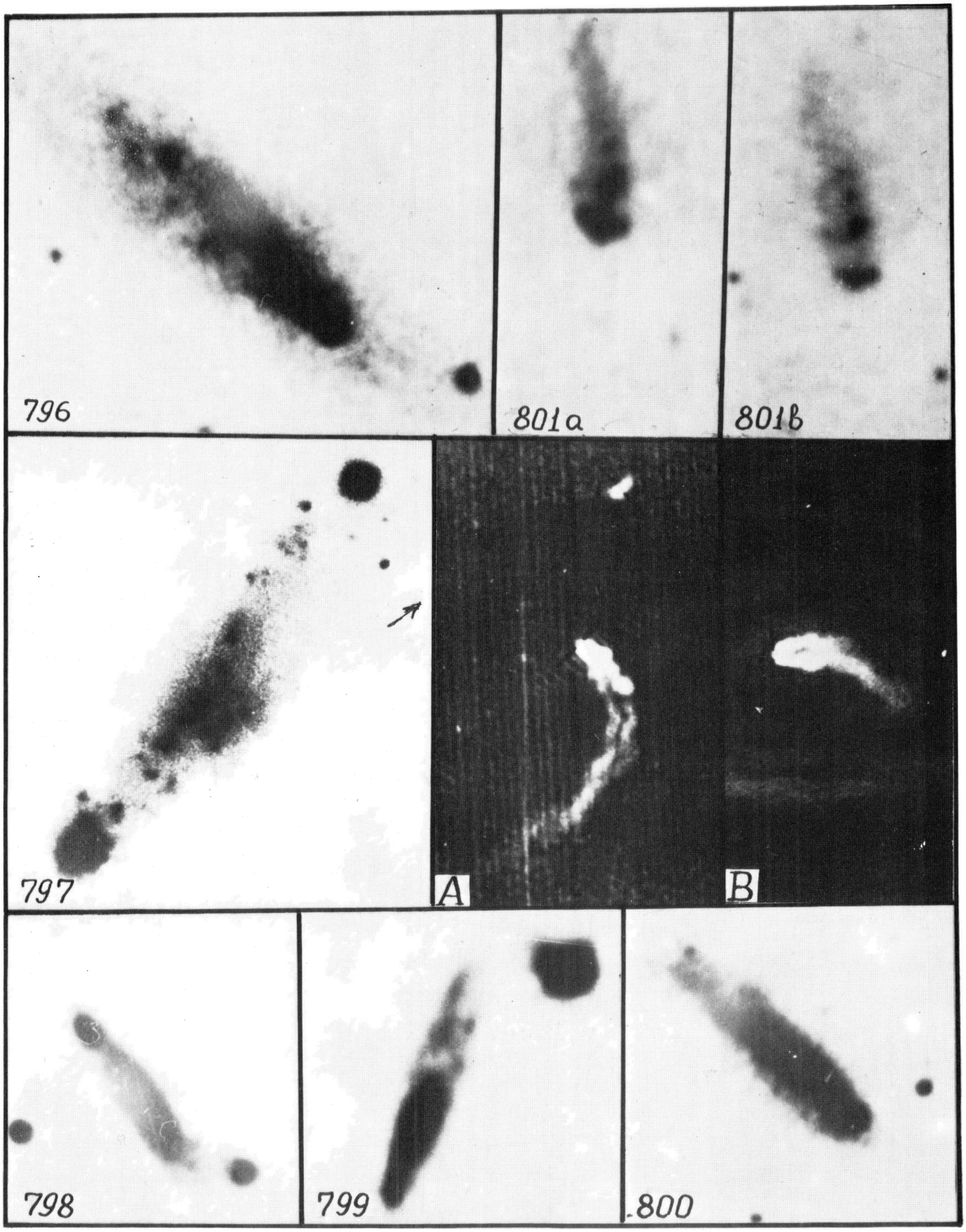

Plate 62 "Comets" in the optical domain and radio. I.

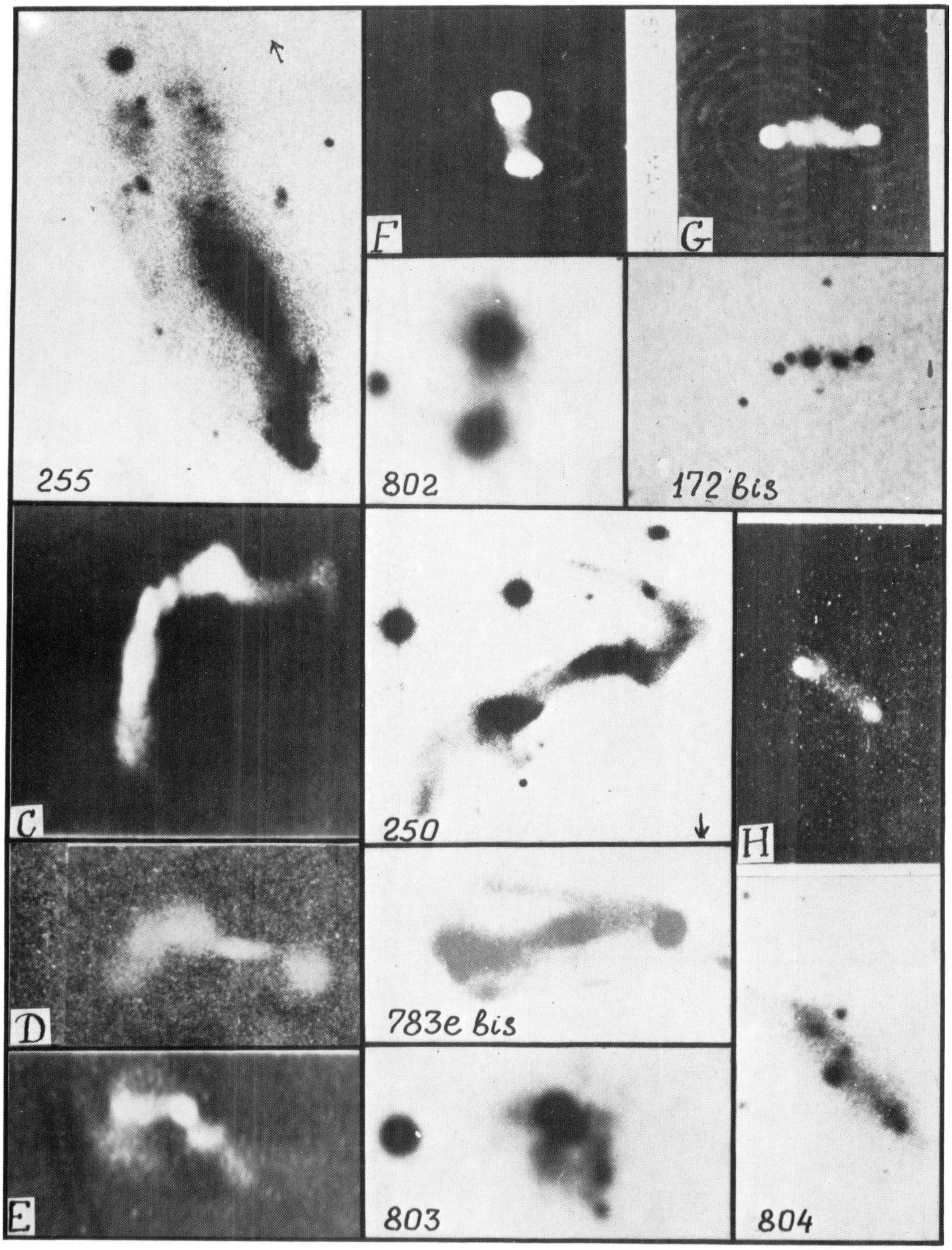

Plate 63 "Comets" in the optical domain and radio. II.

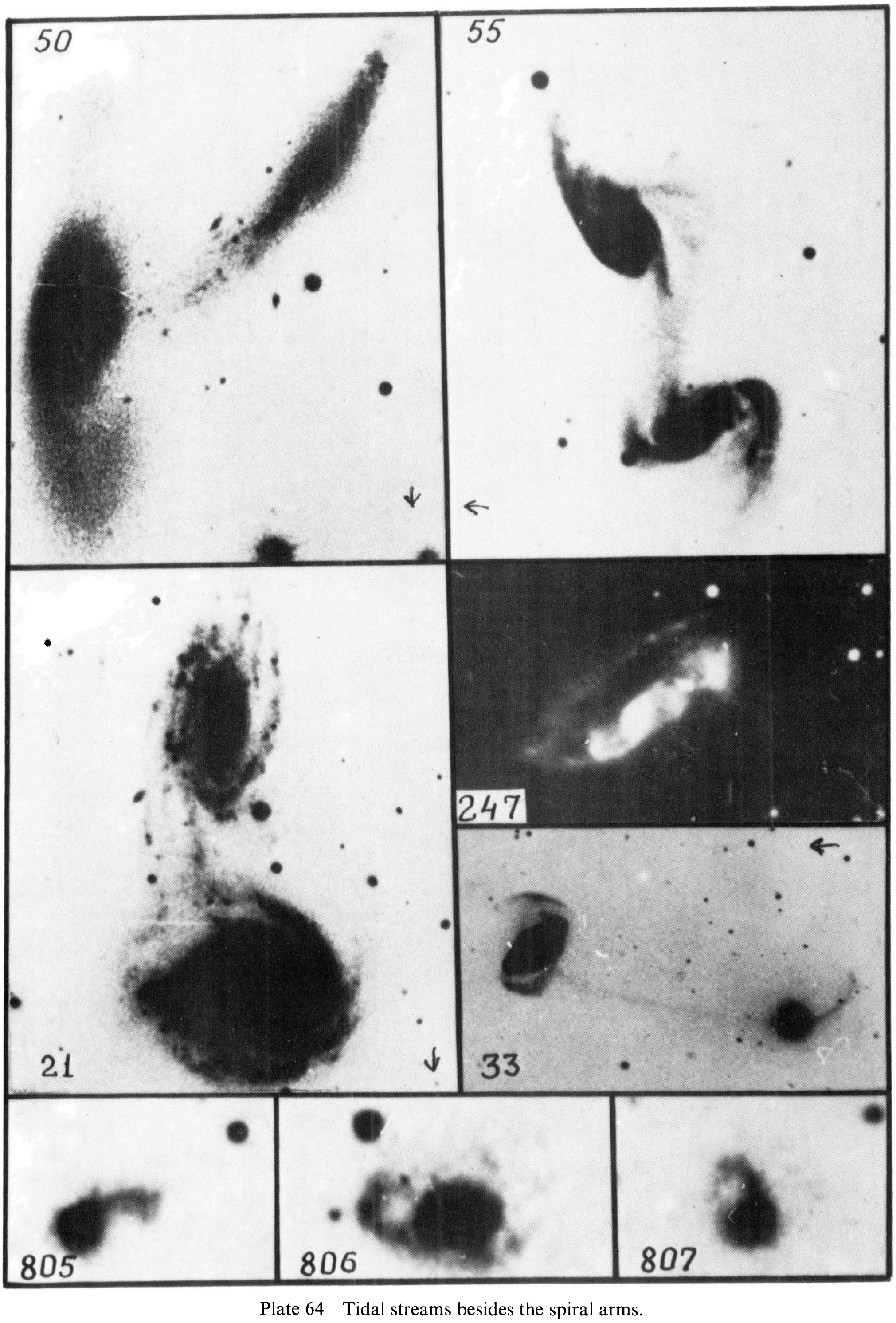

Plate 64 Tidal streams besides the spiral arms.

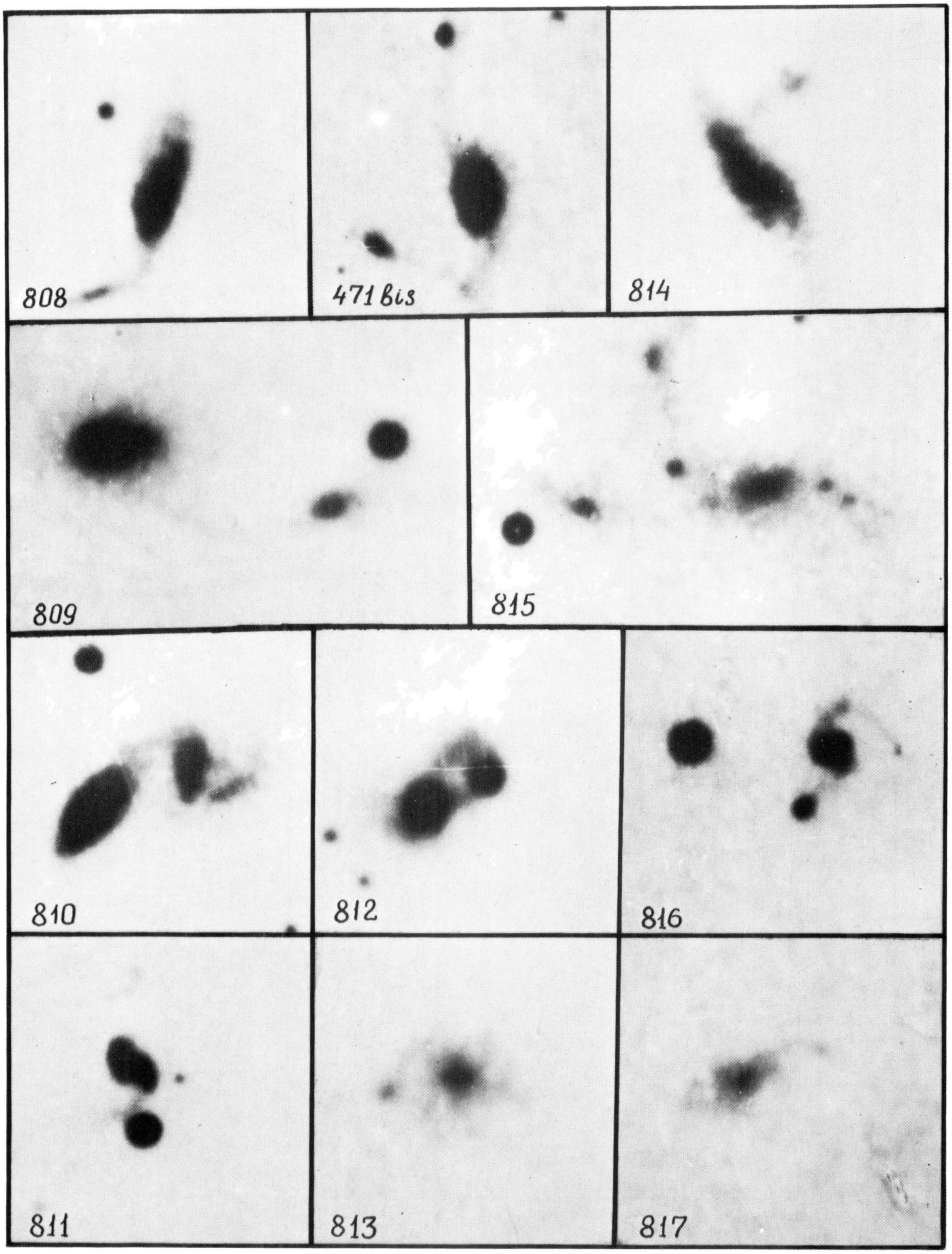

Plate 65 Breaking of bridges.

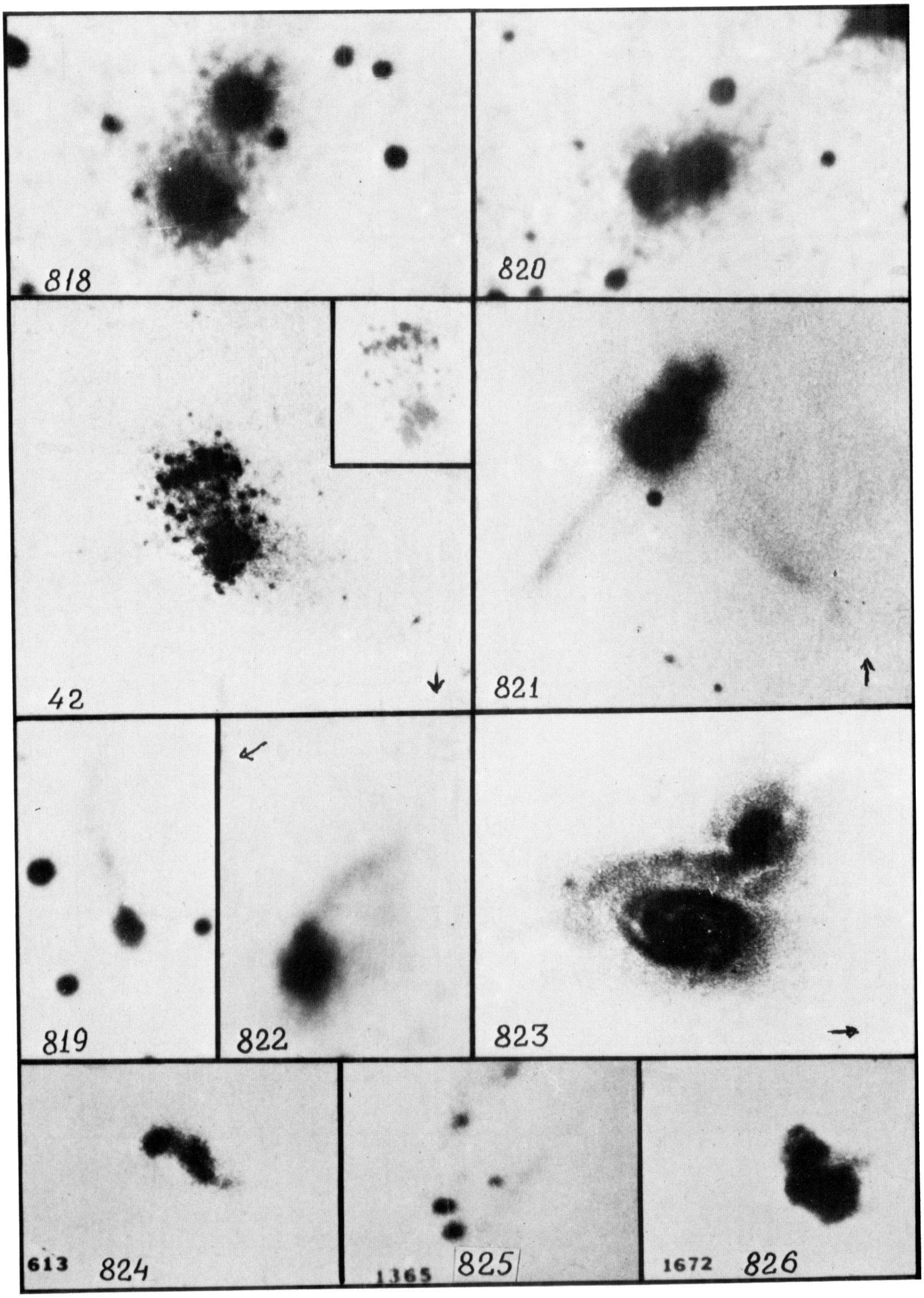

Plate 66 Not tidal phenomena. I.

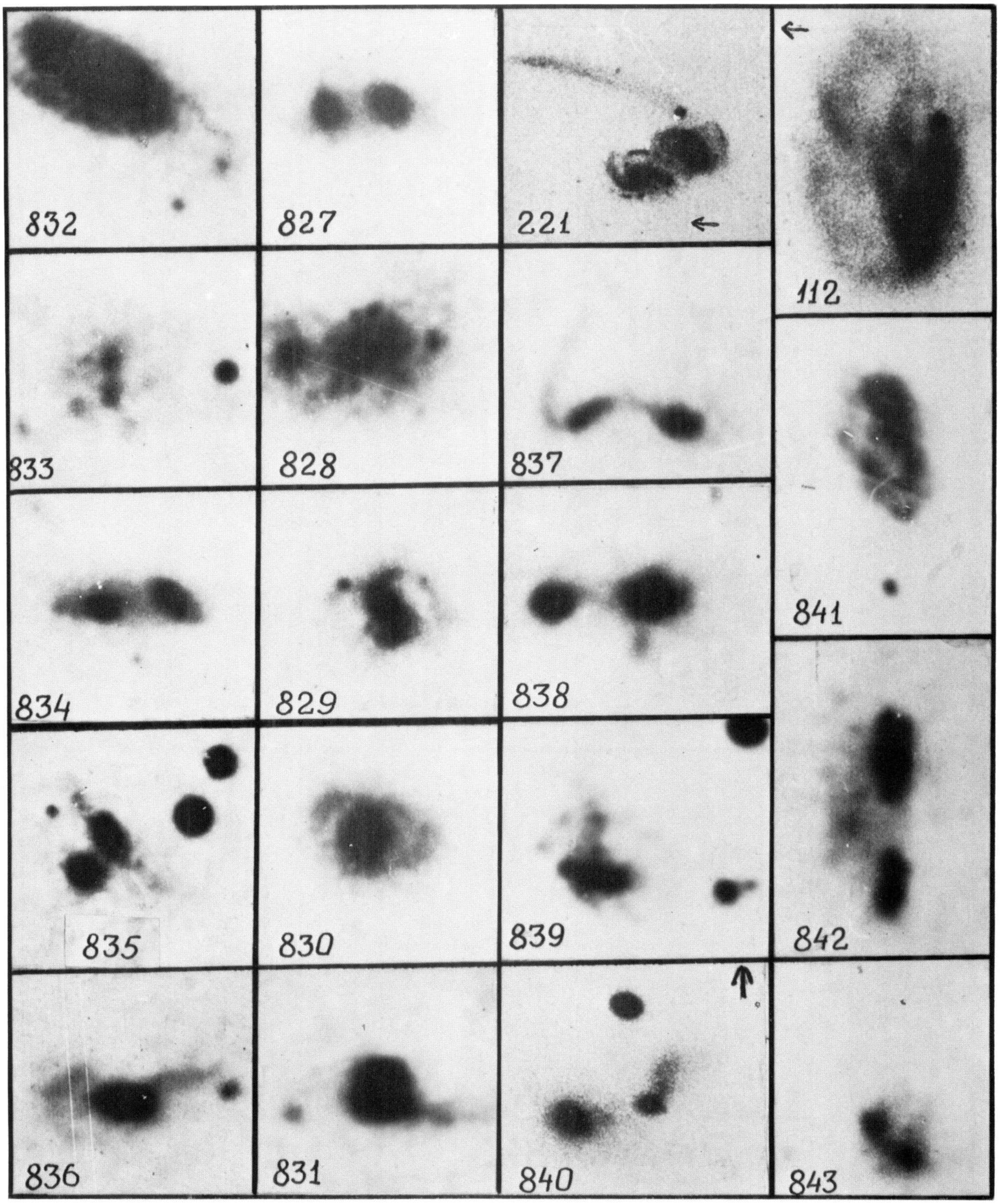

Plate 67 Not tidal phenomena. II.

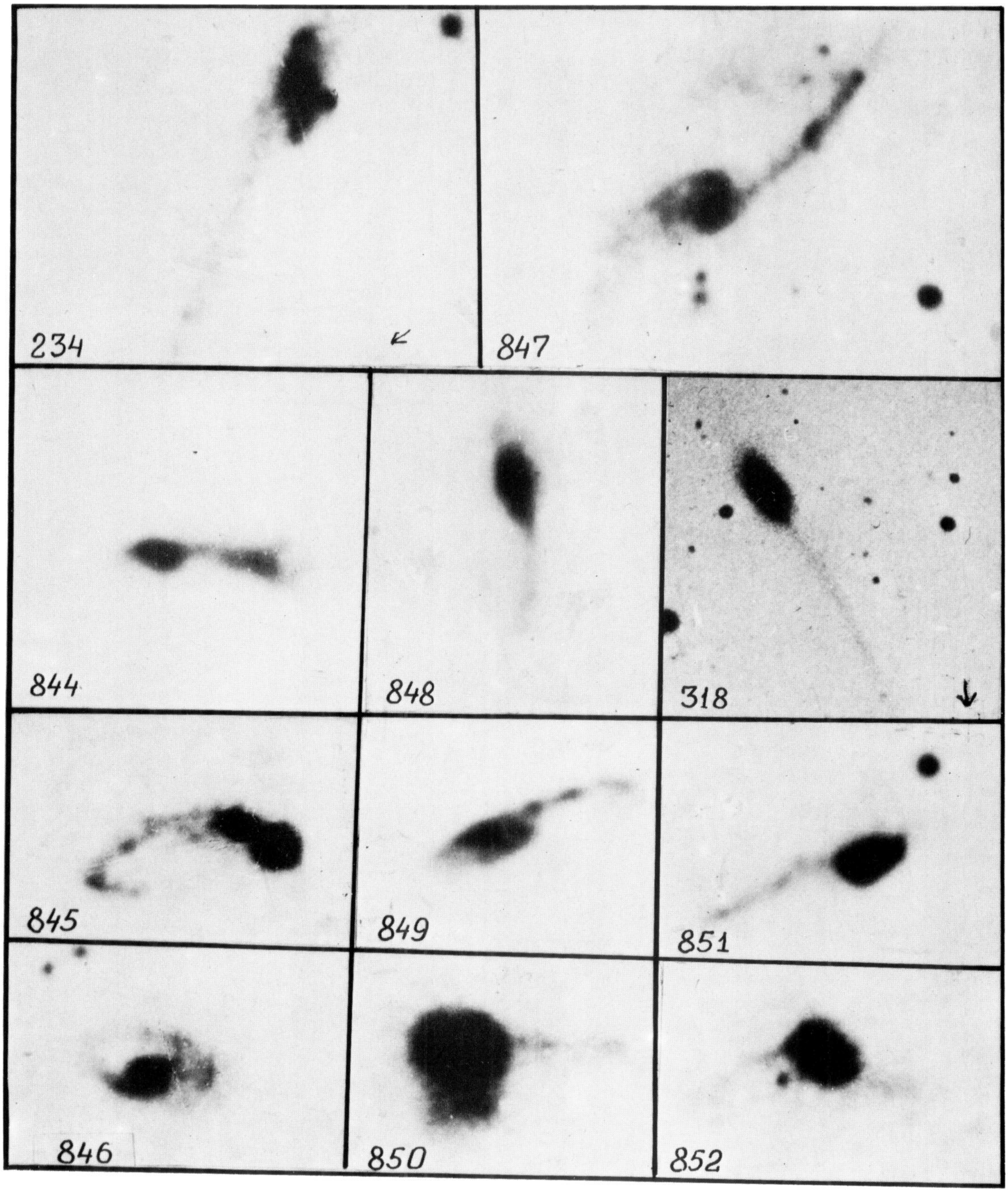

Plate 68 Jets and tails without visible cause.

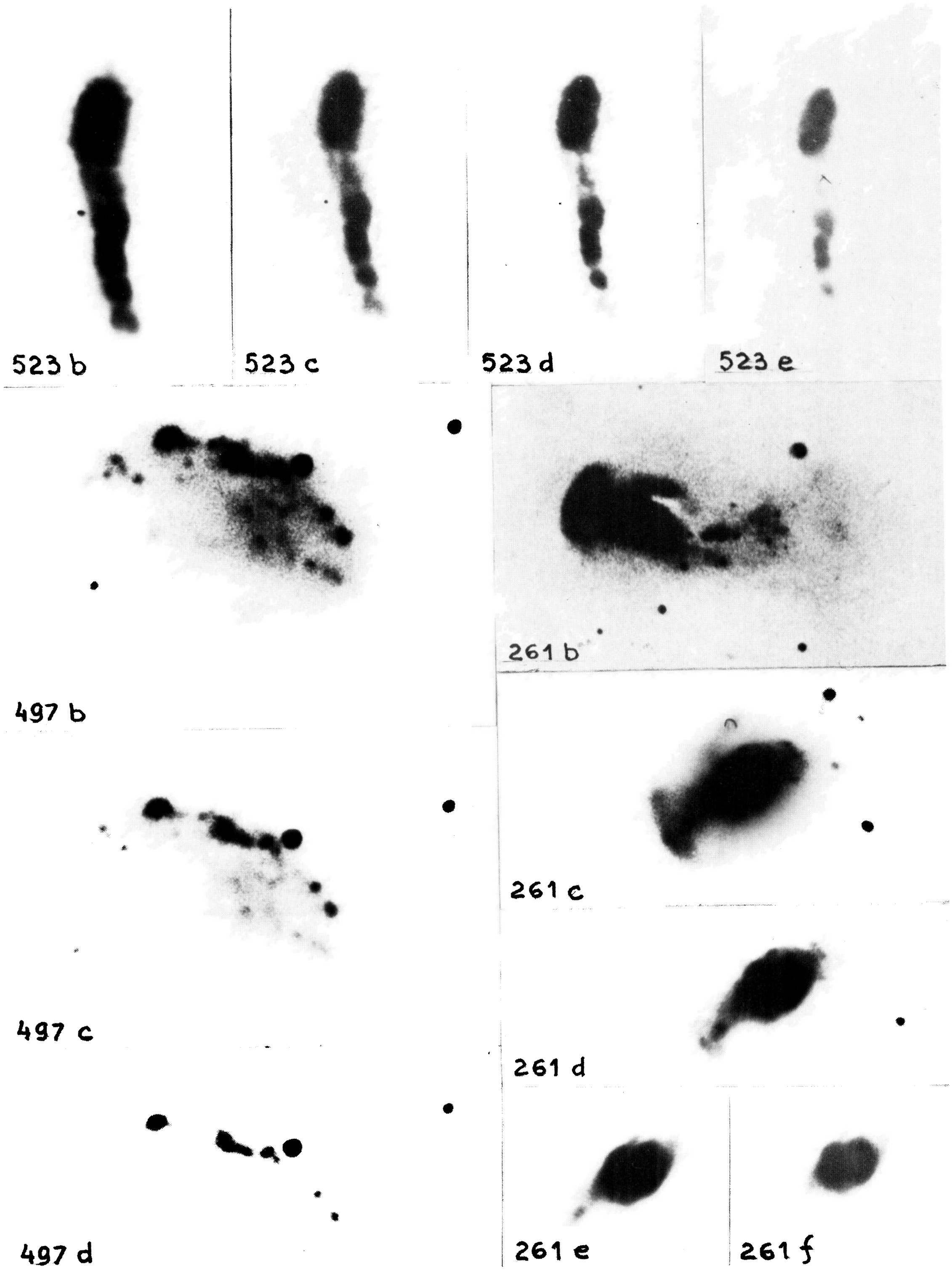

Plate 69 Additional data. I.

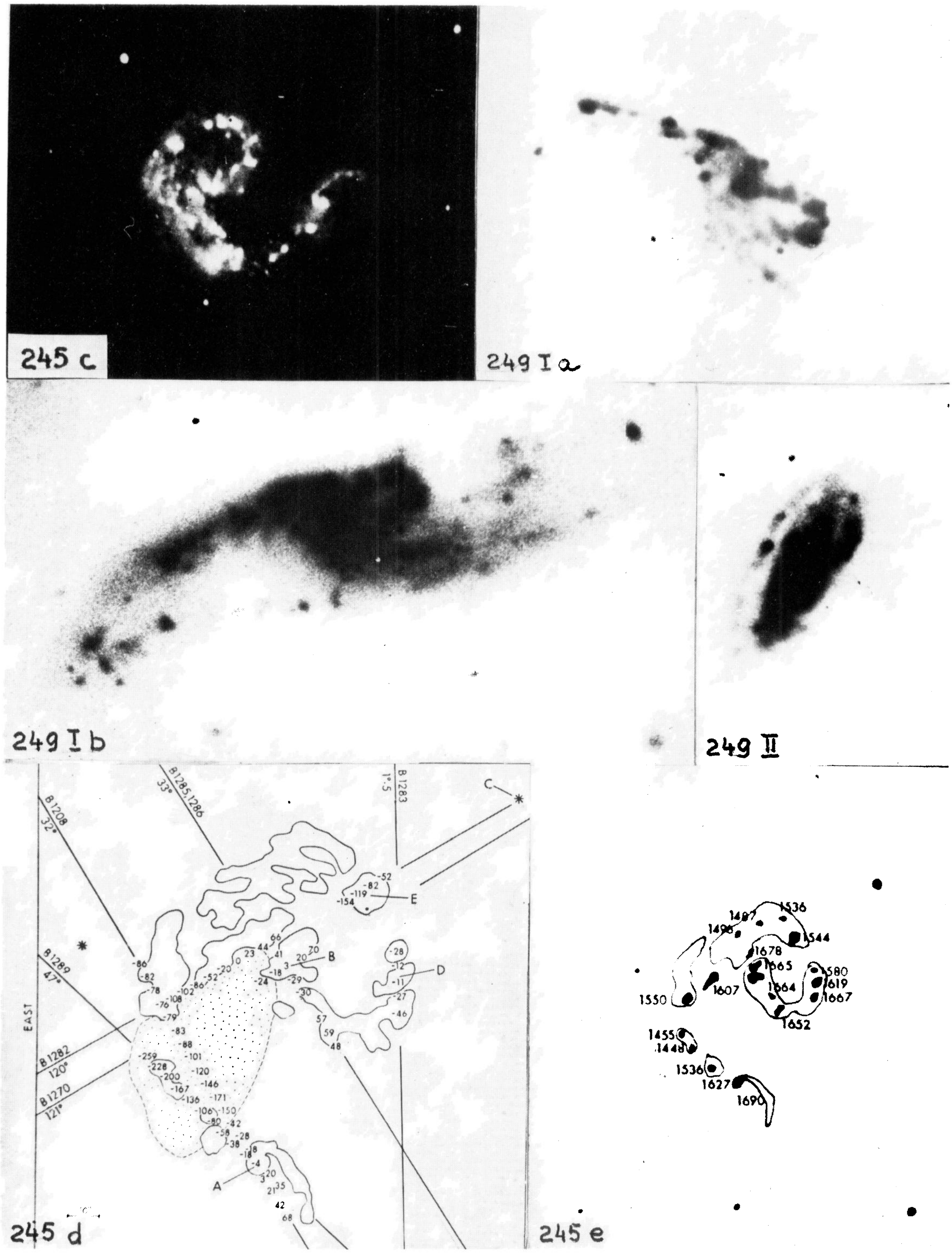

Plate 70 Additional data. II.