АКАДЕМИЯ НАУК АРМЯНСКОЙ ССР

АСТРОФИЗИКА

ТОМ 9 ФЕВРАЛЬ, 1973 ВЫПУСК 1

A POSSIBLE EVIDENCE FOR THE RECENT PRODUCTION OF MARKARIAN GALAXIES

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Received 19 January 1973

A list of pairs of Markarian galaxies with strong ultraviolet continuum is compiled. The statistical considerations show that most of them are physical. However, the observed differences of radial velocities of components of several pairs strongly suggest that a large proportion of these physical systems have positive energy. If so the kinematical ages of these systems are of the order of 10^8 years, which serves as an argument in favour to the recent production of Markarian galaxies.

Markarian [1—5] published five lists containing 507 galaxies with strong ultra-violet continuum in a 6000 *sq.* degree survey. Markarian has mentioned the existence of pairs of galaxies in his lists. In the present paper we consider some aspects of the statistics of the pairs of Markarian galaxies.

The pairs listed in Table 1 were picked up from Markarian's finding charts. Essentially the list is complete up to at least $r = 8'$. Five of them were already noted by Markarian. We did not include the very close pairs listed under a single Markarian number as those may be different condensations in single galaxies and we carefully checked on the *Palomar Sky Survey* prints that the pairs used here are made up of distinct galactic systems; only two (Ma 30—31, 305—306) may be systems of the NGC 5194-5 type.

According to Table 1 the histogram of Fig. 1 is constructed which gives the number of pairs with angular separation r, per 2 arcmin interval. The number of pairs expected for a random distribution is equal to $0.14\ r$ per $2'$ interval and is represented as a dashed line in Fig. 1. It is clear that the observed number of pairs is much larger and that *most of them are physical pairs.*

Table 1

DATA FOR 18 CLOSE PAIRS AND A TRIPLET OF MARKARIAN GALAXIES

Markarian number	Angular separation (arcmin)	Projected separation (*kpc*)	Radial velocity difference (km/s^{-1})
11 12	5.9	93	—
30 31	0.7	20	350
38 39	0.6	25	230
56 57	5.3	150	310
121 122	2.8	70	—
181 182	2.7	63	—
211 212	3.0	—	5400
220 221	0.6	—	—
232 233*	10.0	—	—
261 262	1.1	40	—
295 296	1.1	20	—
305 306	0.5	11	—
325 326	6.7	92	600
355 356	0.5	18	—
397 398	10.2	—	18900
404 405	10.6	—	—
481 482	6.8	—	—
499 500	1.8	—	—
239	1.9	55	—
240 242	8.9	260	—
(239)	8.1	230	—

* Number 231 in list.

For the pairs of Table 1 with known radial velocities [6—12] the distances and the projected linear separations R were calculated (with a Hubble constant 75 km/s^{-1} Mpc^{-1}). Fig. 2 gives the distribution of R. Fig. 2 shows a large drop, though it is complete up to $r = 8'$; then Fig. 2, though probably incomplete for R larger than a few hundred *kpc*, gives a good approximation to the true distribution up to $R \simeq 200$ *kpc* and the drop it shows is probably real.

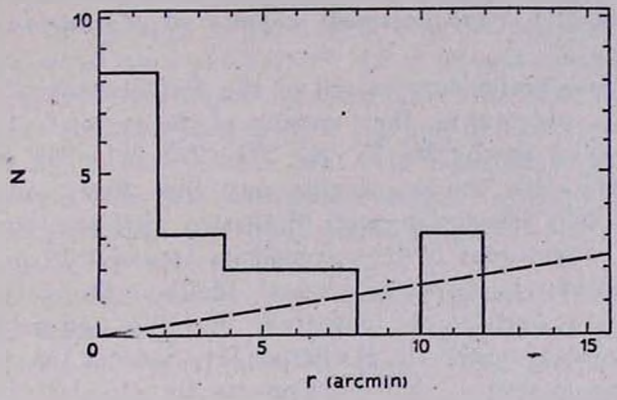

Fig. 1. Histogram of the distribution of pairs of Markarian galaxies versus angular separation r in arcmin. The dashed line is the number expected for a random distribution.

The conclusion that most pairs in Table 1 are physical is strengthened by inspection of the radial velocity differences ΔV between the components. ΔV ranges from 230 to 600 km/s^{-1}, except for Ma 211—212 and 397—398 which may be optical pairs.

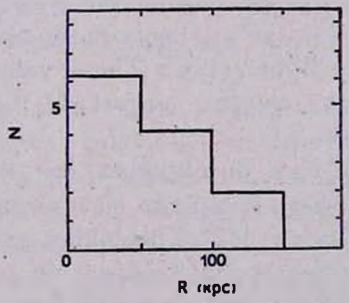

Fig. 2. Histogram of the distribution of the separation R projected on the sky, in *kpc*, between the components in pairs of Markarian galaxies.

We found one triple system: Ma 239—240—242, whose separations are given in Table 1. It is in a group of galaxies around NGC 4973.

The probable number of Markarian galaxies lying within 10′ from the centers of the pairs of Table 1 is 0.12; then the triplet is probably physical. If it is not, our data suggests the possibility of simultaneous pair production of two Markarian galaxies by a parent body.

The drop in Fig. 1 suggests that most of the other Markarian galaxies are singles. Then, if the triplet is physical, the ratios *number of singles (number of pairs) number of triplets* are 468[18]1. There is about a constant 25/1 ratio from one class to the next and this suggests *the production of a random small number of Markarian galaxies by a parent body.*

We made a preliminary search of the *Palomar Sky Survey* prints for anomalous objects in the vicinity of the systems. Possible candidates may exist nearby Ma 38—39, 211—212, 261—262 and 325—326. The most remarkable one is a double very blue fuzzy object 2′ North of Ma 261—262; Iskudarian and Markarian (private communication) estimate the magnitudes of its components to about 19 in the blue.

An important question is to know whether the total energies of the systems are positive or negative. For the two pairs Ma 30—31 and 38—39, already noted by Markarian [1], Sargent [6] estimated the minimum mean masses of their components for circular relative motion to be 3.0 and 1.4×10^{11} $M_\odot$, corresponding to minimum mass to light ratios $M_t/L_{pg} = 20$ and 9 respectively. These last values are close to the mean value derived by Bottinelli et al. [12] from their 21 *cm* line observations of Markarian galaxies: $\langle M_t/L_{pg} \rangle = 12$, where M_t is the *indicative* total mass introduced by N. Heidmann [13]. It is then possible that these two pairs are bound systems.

In addition to the two probably optical pairs Ma 211—212 and 397—398, there are in Table 1 two other pairs with a known ΔV: Ma 56—57 and 325—326. If we make the same estimates for them we obtain 1.7 and 3.9×10^{12} for the minimum mean masses and 230 and 340 for the minimum mass to light ratios. These values are a strong indication of positive energy, as the largest M_t/L_{pg} values obtained by Bottinelli *et al.* is only 80.

Further information may be obtained for the case of the wider pair Ma 7—8 for which there is a mass measurement. Here $r = 26'$ and $R = 340$ *kpc*; $\Delta V = 280$ km/s^{-1} [12]; Khachikian, private communication); on large scale plates Ma 7 and Ma 8 appear to be of strikingly similar morphological types [14] and very probably form also a physical pair. The minimum mean mass for circular relative motion is 3.2×10^{12} $M_\odot$ while the 21-*cm* line observations lead to $M_t = 4.0\times10^{11}$ $M_\odot$ for Ma 7. Therefore, the pair Ma 7—8 has a positive energy.

Then, as out of these five pairs, again without into taking account of the two probably optical pairs, at least three have positive energy, it is likely that *a large proportion of the other physical systems also have positive energy and have their components flying apart.* This conclusion is valid if the mass of the possibly left over parent body is negligible.

In the case of positive energy pairs it is natural to introduce a kinematical age $t = R \langle \tan i \rangle / \Delta V$ where i is angle between the pair line and the plane of the sky; $\langle \tan i \rangle = 1$. For the pairs Ma 7—8, 56—57 and 325—326, we obtain $t = 1.0 \times 10^9$, 4.8×10^8 and 1.5×10^8 years respectively. Thus *the components of these pairs started to depart one from the other quite recently* compared to the age of the universe or even compared to the evolution time which is imparted to galaxies in conventional models. The data presented here give evidence for the recent production of Markarian galaxies and give support to the views proposed by Ambartsumian as early as 1958 [15].

We did not find any clear difference between Markarian galaxies at large and those in pairs for parameters such as strength of UV spectrum, Markarian types, absolute magnitudes, morphological types. But it should be noted that *in Table 1 there is no Seyfert type galaxy* though the expected number for random distribution is four [6—8, 16—21]. From Shramek's and Tovmassian's (private communication) 6-*cm* survey of Markarian galaxies, two or possibly four detected galaxies are in the systems of Table 1, while the expected number for random distribution is two.

The drops in Fig. 1 and 2 suggest *the transformation of at least one of the Markarian components into a galaxy with no ultra-violet continuum to occur within a time of the order of half a billion years.* If the mass of the possibly left over parent body is not negligible the systems may all be bounded and this would account for the drop of Fig. 2.

Correlations between more widely separated Markarian galaxies and between Markarian galaxies, Zwicky [22] galaxies — for which a large proportion of multiple systems have been found by Bertola *et al.* [23] — and normal galaxies are being investigated and more details will be given in a later paper. A thorough investi gation of the systems of of Table 1 may bring up significant contributions to the problem of the origin of galactic systems at large.

This work was done while one of us (J. H.) was on leave from Paris Observatory as a Visiting Astronomer in Byurakan Observatory

under the Exchange Program between the Academy of Sciences of the U.S.S.R. and the C.N.R.S. of France.

It is a pleasure to thank Dr. V. A. Ambartsumian for very valuable discussions.

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ВОЗМОЖНОЕ СВИДЕТЕЛЬСТВО О НЕДАВНЕМ ПРОИСХОЖДЕНИИ ГАЛАКТИК МАРКАРЯНА

Ж. АЙДМАНН, А. Т. КАЛЛОГЛЯН

Составлен список пар галактик Маркаряна с ультрафиолетовым континуумом. По статистическим соображениям большинство пар является физическими. Наблюдаемые разности радиальных скоростей компонентов пар свидетельствуют в пользу того, что большая часть физических пар обладает положительной энергией. Если это так, то кинематический возраст систем порядка 10^8 лет, что говорит о недавнем возникновении галактик Маркаряна как отдельных единиц.

REFERENCES

1. *B. E. Markarian*, Astrofizika, 3, 55, 1967.
2. *B. E. Markarian*, Astrofizika, 5, 443, 1969.
3. *B. E. Markarian*, Astrofizika, 5, 581, 1969.
4. *B. E. Markarian, V. A. Lipovetsky*, Astrofizika, 7, 511, 1971.
5. *B. E. Markarian, V. A. Lipovetsky*, Astrofizika 8, 155, 1972.
6. *W. L. W. Sargent*, Ap. J., 159, 765, 1970.
7. *W. L. W. Sargent*, Ap. J., 173, 7, 1972.
8. *M. A. Arakelian, E. A. Dibay, V. F. Yesipov, B. E. Markarian*, Astrofisika, 7, 177, 1971.
9. *M. A. Arakelian, E. A. Dibay, V. F. Yesipov*, Astrofizika, 8, 33, 1972.
10. *M. A. Arakelian, E. A. Dibay, V. F. Yesipov*, Astrofizika, 8, 177, 1972.
11. *M. A. Arakelian, E. A. Dibay, V. F. Yesipov*, Astrofizika, 8, 329, 1972.
12. *L. Bottinelli, L. Couguenheim, J. Heidmann*, Astron. Astrophys., (in press).
13. *J. Heidmann*, Ap. Lett., 3, 153, 1969.
14. *A. T. Kalloghlian*, Astrofizika, 7, 521, 1971.
15. *V. A. Ambartsumian*, XIème Conférence Solvay, éd. Stoops, Bruxelles, 241, 1958.
16. *E. Ye. Khachikian*, A. J., 73, 891, 1968.
17. *M. A. Arakelian, E. A. Dibay, V. F. Yesipov, B. E. Markarian*, Astron. Circ., No. 568, 1970.

18. *D. W. Weedman, E. Ye. Khachikian*, Astron. Circ., No. 506, 1969.
19. *M. A. Arakelian, E. A. Dibay, V. F. Yesipov*, Astrofizika, 6, 39, 1970.
20. *M. A. Arakelian, E. A. Dibay, V. F. Yesipov, B. E. Markarian*, Astrofizika, 6, 357, 1970.
21. *M. H. Ulrich*, Ap. J., 163, 441, 1971.
22. *F. Zwicky, M. A. Zwicky*, Catalogue of Selected Compact Galaxies and Post-eruptive Galaxies, Calif. Inst. Techn,, 1971.
23. *F. Bertola, F. Lucchin, E. Nasi*, Mem. Soc. Astron. Ital., 42, 517, 1971.