ASTRONOMY & ASTROPHYSICS
SUPPLEMENT SERIES

JULY 1991, PAGE 159

Astron. Astrophys. Suppl. Ser. **89**, 159-184 (1991)

Analysis of the distribution of HII regions in external galaxies. I. Position and inclination angles

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Received July 23; accepted December 10, 1990

Abstract. — We have compiled a sample of galaxies with published catalogues of HII regions forming the basis for subsequent studies of the HII region distribution in spiral galaxies. As a first step we address the problem of the deprojection of a galaxy image as seen on the sky. We have devised two methods to do this, based on the HII region distributions themselves, and apply them to our sample. The results are compared with the ones obtained using several other methods and we find that our new methods are capable of obtaining good values for the position and inclination angles of the galaxies.

Key words: galaxies — structure — spiral galaxies — interstellar medium : HII regions.

1. Introduction.

In the past few years catalogues of HII region positions and, occasionally, intensities have been published for many nearby galaxies. These catalogues contain a lot of information about the structure of the underlying galaxies. For example one can study the form and scalelength of the HII region radial profiles, give a measure of the clumpiness of their distribution, the extent of their concentration in the spiral arms or other substructures, etc. Further information can be obtained with the help of Fourier analysis. This involves first decomposing the observed distribution into components of a given angular periodicity. Then each component can be analysed into a superposition of logarithmic spirals. One can thus obtain the power in each angular periodicity, the pitch angle of the arms, their amplitude etc., and compare with other spiral tracers. Such studies are particularly interesting if done homogeneously for a sufficiently large sample, since this will give mean or "standard" values, as well as allow correlations with Hubble type, luminosity class, or environment, thus perhaps leading to a more quantitative classification of galaxies. Last but not least one could try confrontations with theoretical predictions.

Though several such studies have been made in the past, they were mostly applied to only a few galaxies, so that no general picture is so far available. Hodge (1982) reviewed the optical surveys of HII regions in external galaxies. Hodge (1975a, 1975b) also presented data for and discussed the HII regions in irregular and in interacting galaxies. Hodge (1969b, 1969c) and Hodge & Kennicut (1983) examined the radial distribution of HII regions in the rectified planes of 27 and 37 galaxies repsectively. Van den Bergh (1981) and Hodge (1983, 1987) discussed the distribution of HII region diameters. Studies of the HII regions in the individual galaxies NGC 300, 628, 1566, 2997, 3631, 4321; 5236 and 6946 given by Deharveng *et al.* (1988), Boeshaar & Hodge (1977), Sersic & Calderon (1978), Comte & Duquennoy (1982), Hodge (1976), Kennicutt & Hodge (1976, 1980), Anderson *et al.* (1983), Rumstay & Kaufman (1983), Bonnarel *et al.* (1986). Kalnajs (1975) pioneered the use of Fourier analysis applying it to M31, and Considère & Athanassoula (1982) presented the results for the HII region distributions in M31, M33, M51 and NGC 2997. Unfortunately no global and homogeneous analysis has been made of these data. We will thus in this and subsequent papers undertake a homogeneous analysis of the material at our disposal. In this paper we will present the information on the deprojection parameters, i.e. position and inclination angles, a necessary first step for all the analyses described above. In the next papers we will study the radial distribution of the HII regions, apply the Fourier analysis to the galaxies in which the HII regions trace some spiral structure, and finally we will look for possible subclustering of the HII regions in the arms. We present the sample in Sect. 2, a brief summary of the mathematical analysis in Sect. 3 and discuss the various methods used for measuring position and inclination angles in Sect. 4. Notes on individual galaxies are given in Sect. 5, while the discussion of the main results of this paper is in Section 6.

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2. The sample.

Our sample consists of 64 spiral galaxies with a distribution of HII regions not too irregular and with an inclination angle of less than 80° for which catalogues with more than 50 HII region positions are available in the literature. They are listed in Table 1. Column 1 gives the galaxy name, Column 2 the number of HII regions in the published catalogue and Column 3 gives a number referencing to the source of the catalogue. For 8 galaxies two catalogues were available and for 2 galaxies three. Columns 4 and 5 give the type of the galaxy according to the Second Reference Catalogue (de Vaucouleurs *et al.* 1976, hereafter RC2) and to the Shapley-Ames catalogue (Sandage & Tamman 1981, hereafter SA).

Depending on whether the HII regions outline what could be called a grand design spiral, or not, we have classified the galaxies in our samples as Y or N. Intermediate cases, i.e. when the galaxy has some trace of spirality but of short extent or badly defined, are labelled R in Column 6. The arm type classification of Elmegreen & Elmegreen (1987) is given in Column 7, while Column 8 mentions whether there is flux information in the catalogue.

It is obvious that a better analysis can be made of galaxies for which the catalogue contains many HII regions, yet some information can be obtained with as low as 50 HII regions. We have thus grouped galaxies according to the number of HII regions in their catalogue in Table 2. This shows that a complete study, including the analysis of the spiral structure whenever existent, can be made for the 19 galaxies with more than 200 HII regions, while a reasonable one for the 21 galaxies with $100 \leq N \leq 200$.

Figure 1 shows a histogram of the number of galaxies of a given type, as classified in the RC2. We note that more than half of our sample are of type bc or c. This is due on the one hand to the lack of HII regions in early-type galaxies and on the other to the preference of observers to "pretty" galaxies and to the relative scarcity of large angular diameter in very late-type galaxies.

Our galaxies were classified as Y, N or R based on their HII region distribution, not the galaxy image as for the classification of Elmegreen & Elmegreen (1987). It is thus of interest to compare the two classifications. For this we plot in Figure 2 histograms of the number of galaxies of a given Elmegreen & Elmegreen arm class. We have done this for all our sample (a), the Y ones (b), the R ones (c) and the N ones (d) separately. We note that the correspondence is very good. There are no galaxies with arm classes higher than 7 in our N subsample, while most galaxies in our Y subsample have arm class larger or equal to 5* One galaxy, NGC 925, is in our Y subsample, while being classified as chaotic by Elmegreen & Elmegreen. However the difference is not between the blue light and the HII region distribution, but rather between the classifiers, since we would say that this galaxy has a structure.

* Class 5 according to Elmegreen & Elmegreen (1987) corresponds to galaxies with two symmetric, short arms in the inner regions and with irregular outer arms and class 6 to galaxies with two symmetric inner arms and feathery ringlike outer structure.

3. Analysis.

The mathematical formulation of the decomposition of a given distribution of coplanar points, (in our case HII regions), has been given by Considère & Athanassoula (1982). We will only recall here the essential information briefly. Let (r_j, θ_j) be the radii and angles of the individual HII regions, and $u_j = \ln r_j$. Their distribution can be written in terms of δ-functions:

$$\mu(u, \theta) = \frac{1}{N} \sum_{j=1}^{N} \delta(u - u_j)\ \delta(\theta - \theta_j) \tag{1}$$

Its Fourier transform can then be written:

$$A(p, m) = \int_{-\infty}^{+\infty} \int_{-\pi}^{+\pi} \frac{1}{N} \times \sum_{j=1}^{N} \delta(u - u_j)\ \delta(\theta - \theta_j)\ \mathrm{e}^{-i(pu_j + m\theta)}\, \mathrm{d}u\, \mathrm{d}\theta = \frac{1}{N} \sum_{j=1}^{N} \mathrm{e}^{-i(pu + m\theta_j)}. \tag{2}$$

The $m = 0$ term corresponds to the axisymmetric component, $m = 1$ to the one-armed one, $m = 2$ to the two-armed etc. In this notation an m-armed logarithmic spiral is given by $r = r_0 \exp(-m\theta/p)$ and its pitch angle i, by $tan(i) = -m/p$.

As the galaxy is projected on the sky its axisymmetric component is elliptical in shape and contributes a spurious $m = 2$ component around $p = 0$ which is added to the real $m = 2$ due e.g. to spiral arms or a bar. If the galaxy had been observed face-on, instead of this spurious $m = 2$ one would have seen an axisymmetric component. Thus a way of finding the position angle and inclination angle (hereafter PA and IA respectively) is to find the values for which the $m = 0$ component is maximum with respect to the other components, i.e. if we define:

$$B(m) = \int_{-\infty}^{+\infty} |A(p, m)|\, \mathrm{d}p \tag{3}$$

then we have to find the values of the angles that maximize the ratio

$$\frac{B(0)}{\sum_{m=1}^{M} B(m)} \tag{4}$$

We used in this work $M = 6$ while omitting $m = 5$. A similar method has been proposed by Iye *et al.* (1982) not for the HII regions but for digitized images of the galaxy. The main difference is that Iye *et al.* take the Fourier transform of the density $\sigma(r,\theta)$ while the sum in (1) gives a "mass" $\mu(r,\theta) = r^2\sigma(r,\theta)$. Thus Iye *et al.*'s transformation will give more weight to the inner parts than ours will.

4. Measuring position and inclination angles.

Several, more or less independent, ways of measuring the position and inclination angles, of galaxies have been proposed and used so far:

i) Large-scale kinematics. Assuming that the emitting material is in a thin planar disk and is in circular motion around the center of the galaxy, one can minimize, e.g. by least squares, the departures from such a flow (Warner *et al.* 1973). This method is well adapted to HI velocity fields, provided the galaxy is not too perturbed, and has been widely used in such studies (e.g. Bosma 1981). If the above mentioned assuptions are met, it is the safest of all methods, at least as far as the P.A. is concerned, since it involves data from all the surface of the galaxy and it is not too hindered by noise. This method has been lately (e.g. Pence *et al.* 1990) applied to optical data which present a sufficiently good coverage of the surface of the galaxy.

ii) From photometry the position and inclination angles are measured traditionally by fitting ellipses to the outermost isophotes which are not too perturbed by noise and background (e.g. Boroson, 1981, etc).

iii) Grosbol (1985, hereafter G85) used a variant of the above method. He applied one dimensional Fourier transforms to the intensity distribution in the outer parts and adopted the deprojection angles that minimised the bisymmetric Fourier component.

iv) Kent (1985) used the photometric data all through the galaxy and did not limit himself to the outer parts. He assumed that the galaxy consists of two components, a bulge and a disk, the former being considered spherical, and fitted the intensity profiles on the major and minor axes.

v) Iye *et al.* (1982) calculated the projection angles of NGC 4254 by maximizing the power in the axisymmetric component of the deprojected intensity distribution.

vi) Considère & Athanassoula (1988, hereafter CA88) used the $m = 2$ spectrum to ensure that there was no contribution from a wrongly deprojected disk and that the signal of the spiral stood out well.

vii) Another method related to the above one consists of plotting the positions of the HII regions in a $\log(r) - \theta$ plane and fitting a straight line to the arms, thus ensuring that the spirals are logarithmic.

viii) Danver (1942, hereafter D42) obtained visual estimates for 202 galaxies by rotating their images with the help of a special display table, until the galaxy image was circular.

The methods of Iye *et al.*, Considère & Athanassoula, and Danver, i.e. methods v, vi and viii, can be suitably modified so as to apply to HII region distributions. We have refrained from applying method viii, because it is highly subjective, although in the discussion of the individual galaxies that follows, in a few cases, when discordant values are found by the various methods, we will make note of which values gave more reasonable looking results. Method vi necessitates a clear spiral structure, giving a clear signal-to-noise ratio in the $m = 2$ spectrum. This is often the case when the whole image of the galaxy is being analysed, but seldom in an HII region distribution. Considère & Athanassoula (1982) have already applied it to the HII region distribution of M51 and given a discussion on the results. We have not used this method since very few galaxies in our sample have a spiral structure as clearly delineated as that of M51

Finally method v cannot be applied as such but rather as described in the previous section. It will be referred to hereafter as our first method. It can of course be applied only to galaxies whose HII region distribution delineates the axisymmetric component. If the HII regions are found only in the spiral arms, i.e. their distribution delineates mainly some $m > 0$ component, another method should be applied (see next paragraph). Thus all galaxies marked by a Y in Column 6 of Table 1 were found difficult, or impossible to analyse by our first method. Its main disadvantage is that, depending on whether one uses the density, mass or any other form $r^\alpha\sigma(r,\theta)$, one gives more or less weight to the inner compared to the outer parts of the distribution. Giving weight to the inner parts should give wrong results in the case of B or AB galaxies (respectively 8 and 28 galaxies in our sample according to the RC2), and could falsify the results for galaxies with a slight oval component, if this was reflected in the HII region distribution. Favouring the outer parts does not seem to introduce any obvious biases, but could introduce errors in galaxies with asymmetric outer parts.

We have thus deviced another method, which we will hereafter refer to as our second method, which does not present the above problem. If we cut an axially symmetric galaxy into N equal sectors, like parts of a cake, then each part should have a roughly equal number of HII regions, but these sectors are not equal in a projected galaxy, and the size of each sector depends on the values of PA and IA. For given values of PA and IA we can deproject the HII region distribution, cut the surface into sectors and then count the HII regions falling in each sector. If the deprojection angles chosen are the correct values, the number in each division must be roughly equal and the dispersion around the mean minimal. Thus the correct PA and IA should minimize the dispersion of the number of HII regions in each angular slice from this mean value. Of course this method will not work for the case of strongly barred galaxies and will present more than one minimum in the (PA, IA) plane in the case of ovals, spirals or other structures. Mercifully, most of the time, these minima are relatively wide apart, so that visual inspection of the deprojected distribution or a very rough knowledge of the deprojection angles are enough to tell the relevant minimum. We have also tried to eliminate the effect of asymmetries by adding the contents of two sectors which are symmetric with respect to the center. An important advantage of this method is that the calculations require very little computing time compared to the first method.

We have tested our second method with the help of many random number realisations of axisymmetric inclined disks. We found that this method, like most others, works better with more inclined galaxies than with less inclined ones since for the former the PA stands out better. Of course the larger the number of points the better the method works. It also works less well for very centrally concentrated distributions or distributions having most regions in the outer parts, i.e. the method favours more uniform coverages.

For most of our test, we used an $N(r) = re^{-r}$ profile which, as will be shown in a forthcoming paper, is a realistic representation of the HII region number distribution in a fair fraction of galaxies. Realisations with a relatively large number of points have a minimum in the (PA, IA) plane clearly showing the correct values of the deprojection angles. For a low number of points, i.e. less than 200, one often gets more than one minimum. Since many of our galaxies have less than 200 catalogued HII regions, we have made tests to assess the possibilities of the method in such cases. Fifty different realisations of 150 points were made and projected with PA = 120° and IA = 60°. Our second method was then applied to each of them. In 37 realisations the primary minimum was within ± 5° from the right position, and in 47 within ± 10°. The mean for the PA values for the primary minimum is 120° ± 6°, and for the inclination angle 59° ± 5°. We repeated this for an inclination of 45° which, as discussed above, is less favourable to this method. We found a mean of 122° ± 13° and 43° ± 7° for the primary minima.

We applied the same test to our first method, but now with forty realisations of each distribution since this method is more CPU intensive. In all cases there was only one minimum, however it corresponded to values of the PA and IA further away, in the mean, from the correct values than those predicted by the second method. When the correct values were PA = 120° and IA = 60°, it gave PA = 118° ± 9° and IA = 59° ± 6°. Similarly for PA = 120° and IA = 45° it gave PA = 122° ± 20° and IA = 46° ± 9°.

These tests gave an estimate of the expected errors in the case of an axisymmetric distribution of points. However we expect bigger errors in the cases where a considerable number of points are in a spiral. Furthermore the influence of the spiral structure on the errors might be different for the two methods. In order to test this we made 10 different realisations of two "spiral" galaxies. In the first case 100 points were drawn from an axisymmetric distribution and 50 were in spiral component. The numbers were inversed in the second case. Initially we tried drawing numbers from a spiral with a cos 2θ component and a reasonable radial distribution. However this gave a spiral structure which was too broad and not at all reminiscent of the distribution shown e.g. in Figure 3. We thus discarded this as unrealistic and preferred to generate the spiral as follows. We placed the points initially equidistantly on a logarithmic spiral with pitch angle $i = 15°$ and then gave to each of them two random nudges, in x and y, between 0 and 0.1 times the maximum radius of the axisymmetric distribution. The result of this *ad hoc* method looks much more realistic than that of the previous one. Since the amplitude of the spiral does not decrease with radius in these examples, we expected, and got, an important Stocke's effect (Stocke 1955). However, as there are distributions of HII regions with this characteristic and since these were often amidst the most difficult to treat, we have thought it realistic to leave this effect in the random distribution as well. We then applied the same test as above to these two test distributions and found, as expected, bigger deviations in the mean from the correct value than before.

The first method was, in general, more affected by the nonaxisymmetry of the distribution than the seond one. Thus for 10 realisations with 100 points in the disc and 50 in the spiral we obtained for the first method PA = 129° ± 6° and IA = 60° ± 3°, and for the second PA = 122 ± 7° and IA = 49° ± 5°, instead of the correct 120° and 45°. However the values of the departure depend not only on the ratio of points in the spiral to that in the disc, but also on the phase of the spiral with respect to the adopted PA. Thus the values we have given are only indicative.

With the help of the computerised bibliography of the Centre de Données Stellaires in Starsbourg (France) we made a literature search for the PAs and IAs obtained by other methods. Most galaxies had several independent determinations, but not all were judged to be equally reliable.

Our results are summarized in Table 3. The name of the galaxy is given in Column 1. An I in Column 2 means that the HII region distribution is irregular, and a II that it is very irregular. Columns 3 and 4 give the PA and IA obtained by our first method (similar to Iye *et al.*'s method) and Column 6 the step in degrees (ΔPA, ΔIA) used in the partitioning and scanning of the (PA, IA) plane when searching for the minimum. Column 5 gives the weight we have assigned to this result. The values of the PA and IA obtained from our second method are given in Columns 7 and 8 and the weight we have assigned to this result in Column 9. A 20, or 40 in Column 10 means that the galaxies were divided into 20, respectively 40, equal sectors. An * was put in Column 11 when the adopted minimum was not the deepest but a secondary one. For this method the angles ΔPA and ΔIA which we used when looking for the minima were always 5°. Thus the error bars of the values we have determined are at least half this step, or half the number given in Column 6 for our first method. However they can be considerably higher if certain structures or associations of points interfere with our methods. In Columns 12 and 13 we give the weighted means of the PAs and IAs obtained by means of our two methods.

Columns 14 and 15 give PA and IA values obtained by other methods, as given in the literature, and Column 16 the weight we have assigned to these values. Column 17 gives the number of the reference from which these values were taken. The references are numbered at the end of the table. It was obviously impossible to mention all previously obtained values. We have thus given only the most trustworthy or most noteworthy values, in our opinion, trying at the same time to include determinations by different methods. Since some galaxies in our sample have been very little studied, we have included for them values less safe than for the best studied cases. The weights were assigned according to the following rules. We consider *a priori* that the kinematical method based on a complete velocity field is the most accurate one (see also Section 6), so the corresponding values got a weight of 5 (or 3 if the data were of not too high quality). For the photometric values, in the case were the authors presented a convincing isophotal map, the values took a weight of 3, in all the others cases they took a value of 2. The rest of the values, coming from different methods, took a value of 1. For the methods based on the HII regions the weights were ascribed on a subjective basis. The criteria that entered into consideration included the uniqueness of the minimum, the plausibility of the solution (whether it was in agreement with the literature values), the number of HII regions, the regularity of the distribution and whether the HII regions were mostly in the axisymmetric background or rather, delineated a structure like spiral arms or a bar etc.

Finally the adopted PA and IA values are given in Columns 18 and 20 and the corresponding dispersion in Columns 19 and 21. They have been obtained as the weighted means of the values obtained by the different methods. These values have been used to obtain deprojected images, shown in Figure 3, and all other properties of the HII region distributions which will be discussed elsewhere. In figure 3 we show first galaxies with a large number of HII regions in their catalogues and then the ones with fewer, in a smaller format.

5. Notes on individual galaxies.

NGC 157: There is a reasonable agreement between our results and the literature.

NGC 224: All methods agree beautifully. From the literature values we mention for brevity only that of Brinks & Burton (1984), but there are several more with exactly the same value. We assign to them globally a very high weight.

NGC 300: This is a well studied galaxy. The PA and IA given by photometric methods (Carignan 1985) are in good agreement with the values given by the study of the HI velocity fields (Shobbrook & Robinson 1967 and Rogstad *et al.* 1979) and from the spiral structure analysis (CA88). The PA given by optical kinematics studies (Marcelin *et al.* 1985) does not agree so well. In this case both our methods do not give good results and thus get zero weight. This is probably due to the fact thay the HII region distribution does not delineate sufficiently the axisymmetric component, since the distribution deprojected by the values given by our second method looks rounder than when deprojected with the literature values.

NGC 470: There is general agreement between the results obtained by our two methods and photometry (G85). Since for this galaxy the number of HII regions is small and their distribution is not very regular, we put a rather low weight to our first method.

NGC 598: The kinematic and photometric determinations are of high quality and agree well between them. They are thus assigned a high weight. Our first method fails as the HII regions do not delineate the disc but rather the spiral arms. The second method is in rough agreement with the photometry and kinematics. It should be mentioned that Danver (D42) found quite different values (49°, 40°), while the spiral structure analysis does not give sufficient variations of the signal-to-noise ratio to be of much weight, while still disfavouring the photometric and kinematic value (Considère & Athanassoula 1982). On the other hand Sandage & Humphreys (1980) find that for the spirals to be strictly logarithmic the galaxy's plane has to warp, even within the optical image.

NGC 628: Since the galaxy is quite face-on, neither our methods nor photometry can give accurate values for the PA. The double weights (i.e. different for the PA and IA) given are a result of this.

NGC 772: The shape of the HII region distribution is very irregular, while the optical image shows a strong arm which could bias the photometrically determined values (G85). Thus none of the values are very reliable.

NGC 925: There is a very good agreement between the values obtained by the HI studies (Gottesman 1980; Wevers *et al.* 1986) and the photometric results (G85). Unfortunately, the strong concentration of the HII regions in the arm makes this galaxy ill-suited for our methods, which thus get zero weight.

NGC 1073: This is a ringed barred galaxy. Our two methods and the HI kinematics (England *et al.* 1990) agree well, as far as the PA goes, while Grosbol's photometry might be influenced by the bar. The values of the inclination angle vary between 20° and 40°. For lack of any clear criterion we give to all inclination values the same weight. We repeated our first method omitting the five HII regions in the bar, but the result stayed the same.

NGC 1084: Our methods are in general agreement, but we think that the HII region distribution is too poor to give reliable results. The two photometric results agree very well between them (Bernacca & Bertola 1969 and Blackman 1979).

NGC 1232: There is a general agreement between the results of our two methods and photometry (G85). We repeated the first method after omitting roughly the innermost quarter of the HII regions, and the values of the deprojection parameters found were the same.

NGC 1313: This galaxy is asymmetric and one cannot unambiguously assign its center (Marcelin & Athanassoula 1982). The deprojection parameters depend on whether one considers the southern appendage or not and where one places the center. We thus give no values in Table 3.

NGC 1566: This galaxy has an oval dominating the inner parts. Both our methods tend to circularize this and thus give wrong results. If we omit the HII regions in the oval there are too few left for our first method to work. On the other hand, our second method does not seem to be hindered by the low number of regions and gives values in good agreement with the kinematics and photometry.

NGC 1832: The HII region distribution does not delineate the axisymmetric component, but is rather concetrated in the ring and surrounding spiral. The galaxy is barred and the ring could be oval. Both our two methods might be affected by this fact, so we give a higher weight to the G85 values.

NGC 2276: ARP 25 shows an important $m = 1$ asymmetry which could bias the photometric and/or our results.

NGC 2403: This is a well studied galaxy. If all the regions are used, then our first method gives (125°, 38°). The deprojected distribution shows that the low value of inclination is due to the outermost 53 regions. Omitting these we find (115°, 50°), i.e. a much better agreement with Begeman's (1987) values. Our second method is not influenced by these outermost regions and gives with them or without them (120°, 50°), in good agreement with the kinematics.

NGC 2805: NGC 2805 is member of a small group of galaxies and thus its outer parts are heavily perturbed and its light and HII region distribution asymmetric, similarly to M101. The inner velocity field does not look perturbed and we therefore give highest weight to the PA obtained by Bosma *et al.* (1980). The HII region distribution obtained after deprojection with the values given by our first method is the least satisfactory and thus has been given zero weight. We repeated the evaluation after omitting the HII regions in the arc but the result remained the same.

NGC 2835: This is a strongly barred ringed galaxy with a strong outer spiral for which no HI studies have been published. Since the HII regions do not delineate any axisymmetric component, our first method cannot be expected to work. We get results in good agreement with the literature values using our second method.

NGC 2841: This is a well studied galaxy. Both our methods are in agreement with the HI results by Begeman (1987) and Bosma (1981) and the photometric ones by Boroson (1981) and Van der Kruit (1979).

NGC 2903: This is also a well studied galaxy. The HII regions concentrate in the two strong arms, cleary visible in the optical photographs, a fact which should handicap both our methods. Nevertheless they give good agreement with the kinematics from Begeman (1987), Marcelin *et al.*(1983) and Wevers *et al.* (1986).

NGC 2976: This galaxy has an HII region distribution which is well suited for both our methods. They give results in agreement between them and the, unfortunately, very poor values in the literature we can compare with.

NGC 2997: Our two method give results in good agreement betwwen them and with the kinematical studies by Peterson (1978), the spiral analysis by Milliard & Marcelin (1981) and the photometric values from G85. The same values were found for the first method after evicting the central region.

NGC 3031: Due to the strong arms our two methods are not expected to do well. On the other hand omitting the HII regions in the arms we find a good agreement between the values they give and the literature values.

NGC 3184: It is a very regular galaxy as showed in the optical images, and seems to be nearly face on. Due to the concentrations of HII regions our first method does not work well, even after evicting the center. With the second method we obtain a value in reasonable agreement with G85.

NGC 3310: This is a peculiar galaxy (Arp 217) with a very strong emission at the center. There is reasonable agreement between our two methods, the kinematical study of the central part by Van der Kruit (1976a) and photometry (G85) about the PA. However the spread in inclinations is large (33°-51°). The values given for the second method change by only 5° for the PA if we omit nine regions in a sort of straight outer feature (see Fig. 3) while the values of IA remain unchanged.

NGC 3344: Our results for the PA are in agreement between them and with the ones from G85, but not with the ones from the spiral structure analysis (CA88). This is probably due to the low inclination of the galaxy. The spread in inclination value is again large (15°-36°).

NGC 3351: This galaxy is strongly barred and has an inner ring. Our methods are in excellent agreement with each other and with the PA obtained from photometry (G85) and the Hα kinematics from Buta (1988), and in good agreement with the IAs of those two methods.

NGC 3486: This is a galaxy with a rich spiral structure. Thus, our first method does not work due to the concentration of HII regions in the arms. Our second method, however, gives good agreement with G85 and other values found in the literature.

NGC 3521: Our methods are in good agreement between them, while their inclination values are 10° higher than that found by Kent (1985).

NGC 3627: There is a great dispersion of the values of PA found by different methods, which seem to depend on radius, as can be seen in the photometric study by Burkhead & Hutter (1981). On the other hand there is a general agreement on the inclination values, as found in the literature and with our second method. Our first method does not work in this case due to the small number of HII regions, which are, furthermore, to a very large extent placed in the arms.

NGC 3631: This is a galaxy with a well defined spiral structure, and nearly face on, so large uncertainties can be expected in the values of PA. Indeed a wide spectrum is found.

Our first method is hampered by the fact that the HII regions are concentrated in the arms.

NGC 3938: This galaxy also is nearly face-on, so a comment similar to that for the previous galaxy can be made about the values of PA. Our first method does not work at all, affected by the concentration of the HII regions in the spiral. The second method is in agreement with the kinematical values from Van der Kruit & Shostak (1982) and Foster & Nelson (1985). Note however the very different value of the PA given by G85, who might be biased by a spiral feature in the outer parts.

NGC 3992: There is a good agreement between our two methods, the kinematically obtained values from Gottesman *et al.* (1984) and the photometric values from G85.

NGC 4254: With the second method we get results in agreement with the kinematics from Guhathakurta *et al.* (1988). The strong external arm may bias both our first method and photometry (G85).

NGC 4298: Our first method gives a deprojected distribution which is not pleasing to the eye and a too high value of IA. With the second method we obtain results in agreement with the values from Boroson *et al.* (1983) and G85.

NGC 4303: The small inclination angle of this galaxy makes its position angle badly defined for all methods except kinematics. Our first method finds a broad minimum so that any PA between 95° and 140° is acceptable.

NGC 4321 : The value found by our first method is near that found by G85, but these results differ a lot from the kinematical ones by Guhathakurta *et al.* (1988, hereafter GGKB88). The value given by our second method is the principal minimum. However a valley of relatively low values is obtained near the kinematical values. Our second method thus gets a low weight.

NGC 4535 : Our methods are in good agreement with the photometry from G85 and the kinematical values from GGKB88.

NGC 4559 : No reliable photometric or kinematic values for PA and IA were found in the literature, but both our methods are in reasonable agreement between them.

NGC 4568 : This galaxy is in interaction with NGC 4567. Our two methods agree between them and with the inclination given by Fraser (1977), (the deprojected distribution is more pleasing to the eye with the values obtained with the second method). GGKB88 find a considerably smaller inclination.

NGC 4654 : There is very good agreement between the PAs of our two methods and those found by G85 and between the IAs of our second method and that of G85. The inclination angle of our first method deviates considerably, perhaps due to the irregularity of the HII region distribution at large radii.

NGC 4689 : There is good agreement between the results from photometry (G85) and kinematics (GGKB88). The first method did not converge, and the second gave more than one minimum, perhaps due to the irregularity of the HII region distribution in the northern part.

NGC 4736 : Our first method agrees well with the kinematical values derived by Van der Kruit (1976b) and Bosma *et al.* (1977). The photometric values (Boroson 1981, G85) give a different PA.

NGC 4939 : Our methods are in agreement between them but no reliable values were found in the literature.

NGC 5055 : Our two methods agree with the values derived for the optical part of the galaxy as obtained by HI mapping (Bosma 1981), with the photometry from Grosbol (G85), and the spiral structure analysis by CA88.

NGC 5128 : All methods agree well.

NGC 5194 : The values obtained for this galaxy by the different methods are very discordant. Preliminary values from the high resolution HI study by Rots *et al.* (1990) for the PA agree with those of Tully (1974), Shane (1975) and Goad *et al.* (1979). Thus the kinematical studies agree between them (170°) and with the 160° adopted by Elmegreen & Elmegreen (1984). On the other hand photometry by Boroson (1981) and by G85 and spiral structure analyses (Considère & Athanassoula 1982 and CA88) give correspondingly 37°, 27° and 30°. Thus there seems to be two disagreeing groups, each with good internal agreement. For the inclination Tully (1974) gives 20° while all the others between 30° and 40°. In particular Shane (1975) gives 30°, Boroson (1981) 33°, Goad *et al.* (1979) 35°, G85 and CA88 37° and Considère & Athanassoula (1982) 40°. On the other hand the simulations of Toomre & Toomre (1972) favour values around 15° and place an upper limit to 25° for the fits to be acceptable. However if a sizeable halo is included even high inclination angles may give a bound orbit for the companion.

It is very difficult to come to any conclusion about this complicated case. Athanassoula (1990) showed with the help of numerical simulations that during a strong interaction the outermost isophotes could become oval. It could of course be argued that the kinematics would have equally suffered. However there is no obvious change of PA with radius in NGC 5194, except perhaps in the innermost part where there could be an oval as discussed by Pierce (1986). We will thus favour the kinematical values, to which we give the highest weight, and put no weight to the other values.

NGC 5236 : Kinematical values (Rogstad *et al.* 1974 and Comte 1981) agree very well with the second method. Our first method is hampered by the concentration of the HII regions in the arms and oval. G85 values do not agree with the rest.

NGC 5248 : The various methods are only in rough agreement.

NGC 5457 : The first method does not converge, presumably due to the fact that the HII regions delineate more the arms than the axisymmetric component. After omitting the outer asymmetric part it still does not converge to a plausible maximum. The second method gives too high a value for the IA and a good agreement with the PA obtained by the kinematics from Comte *et al.* (1979) and Bosma *et al.* (1981).

NGC 5678: Good agreement of all methods.

NGC 5921: Our two methods are in reasonable agreement between them and in rough agreement with the photometry (G85). The values found by Grosbol (1980) are quite different, presumably biased by the bar and ring region.

NGC 5962: Very good agreement found between our second method, photometry (G85) and the inclination angle found by the first method. The inclination angle found by Kent (1985) and the PA of the first method are more discordant. The distribution deprojected with the values of the first method is less convincing than that with the second method.

NGC 6015: No kinematically derived values exist. In order for our second method to work we had to omit the outermost four regions.

NGC 6384: Our first method does not converge to a plausible value, even after omitting the outermost HII regions (the value in Table 3 corresponds to the latter case). Our second method is only in rough agreement with the photometric results (G85).

NGC 6503: The values obtained by our two methods are in very good agreement with the kinematical values of Shostak *et al.* (1981). Cutting out the outermost 11 HII regions gives exactly the same values for our first method and a very small difference for our second one. The optical kinematics from de Vaucouleurs & Caulet (1982) give a somewhat smaller inclination.

NGC 6643: There is only a rough agreement between the different methods. No values from a complete velocity field have been published so far for this galaxy.

NGC 6946: The galaxy has an oval and strong spiral arms, which could bias all methods. There is an agreement between the inclination values of all methods, while the PA range between roughly 60° (kinematical methods) to 80° (photometry), while our two methods and the spiral structure analysis (CA88) give intermediate values.

NGC 7331: Excellent agreement between our two methods and the values from photometry, (Boroson 1981), kinematics (Begeman 1987) and spiral structure analysis (CA88). We note that this is often the case for very inclined galaxies where the outer oval shape is well outlined.

NGC 7479: This is a barred galaxy and the HII regions are essentially in the bar and the arms. Thus our first method should not be reliable. Photometry of this galaxy was carried out by G85, Baumgart & Peterson (1986) and Okamura (1978).

NGC 7741: As in the previous case, the HII regions are essentially in the bar and the arms. Thus our first method does not work, while our second one gives more than one minimum between which it is difficult to choose. Table 2 gives the one nearest to the literature values.

NGC 7793: There is a very good agreement between all methods for the inclination angle of this galaxy. The PA values range between roughly 90° (our first method) and 108° (kinematics by Davoust & de Vaucouleurs 1980), with intermediate angles by the photometry (de Vaucouleurs & Davoust 1980 and Carignan 1985) and our second method.

IC 342: The kinematically obtained values of the PA (Newton 1980b) is the only reliable one because of the galaxy's low inclination angle. There is a rough agreement for the value of the IA. Our second method is hampered by a clump of HII regions at the NE part of the galaxy and the minimum found is secondary.

IC 5325: No literature values were found, and only our second method gave reliable results.

6. Discussion

A global comparison of the results of the different methods may allow us to assess them. This is particularly important for our two methods for which no other comparison or discussion can be found in the literature. We will consider: values from our second method, from our first method, from global HI kinematical studies, from Grosbol's (G85) photometric study, from Considère & Athanassoula's (CA88) spiral structure analysis and from Danver's (D42) eye estimates. We have plotted in figure 4 the PA obtained with each of these methods *versus* the values obtained by the other methods. Figure 5 gives the same plots for the cosine of the IAs. We have plotted the cosines rather than the angles since these are more uniformly distributed. The comparison is of course not for all galaxies ever measured by a given method but rather only for the galaxies in the present sample. We have also omitted M51 from these comparisons as the different methods give very very discrepant results (see previous section). The solid line gives the least squares fit to the points and the dashed one the diagonal. The correlation coefficients are given in the first line of each entry in Table 4, and their 90% confidence level in the second line. We have included in this Table two entries per correlation. In nearly all cases the two entries are the same yet we kept them both to facilitate the reading of the table. The independent variable is always in the column and the dependent one in the line. In the third line we find the value of spearman's rank correlation coefficient and in the fourth line the two-sided significance level of its deviation, using a student's distribution. In the last line is the number of galaxies in each of the observations.

From figures 4 and 5 and Table 4 we note that the PAs are in general much better correlated than the IAs. Indeed the mean of the rank correlation coefficients from the PAs in Table 4 is 0.90 ± 0.07, while the same quantity for the IAs is only 0.76 ± 0.15. (From Figs. 4 and 5 one could have thought that the difference was even larger. However this is partly due to the fact that, since PAs can reach values twice as large as IAs, the scales on the figures are not the same, but even so the difference is significant). It reflects the fact that the PAs are easier to measure and are riddled with less errors than the IAs. Furthermore, for some methods, an error in PA will produce a systematic error in IA. For the case of large scale kinematics, the PAs can be measured fairly accurately, whereas IAs can only be obtained from the measurement of Vsin i. In photometry the IAs are influenced by the Stocke effect (Stocke 1955), which is important only for galaxies with high amplitude spirals and whose disk does not extend much beyond the region of the spiral. On the other hand the inclination angles are influenced for all galaxies by the thickness of the disk, or even, in the case of intermediate inclination galaxies with large bulges, by that of the bulge. Finally in Danver's method it is difficult to discuss the errors, since the method is purely subjective. However it seems to us that the eye can measure position angles more accurately than inclination angles. The main conclusion that can be drawn from Table 4 is that there is no bad, inadequate or even second rate method. That is particularly important for the two methods we introduced in this paper, since they had not been tested before. Their correlation coefficients are as good as those of the other methods. Table 4 together with Figs. 4 and 5 show that they are devoid of systematic errors and that their mean errors are not higher than those of the other methods. Thus, provided that a given catalogue does not contain systematic errors and contains a sufficient number of HII regions describing reasonably well the disk, then it can be used with confidence for estimating the position and inclination angles of a galaxy.

One should not try from Table 4 to rank the various methods. The differences between most of the correlation coefficients are not significant as can be seen be carefull inspection of Table 4. Furthermore different kinds of perturbations (like ovals, asymmetries in the outer parts, spiral structure, etc) influence the various methods in different ways. Unfortunately these effects can not be found by statistical studies as the present one. Only rather elaborate modelling may help us to untangle them.

Acknowledgements.

We would like to thank the referee, P. Grosbol, for interesting comments on the first version of this paper, A. Bosma for many helpful discussions on the galaxies in our sample and P. Hodge for sending us a copy of "An Atlas of HII regions in 125 Galaxies" (Hodge & Kennicut 1982) which contains a number of otherwise unpublished catalogues of HII regions. M. Gerbal typed in about a third of these catalogues. Our literature search was based on SIMBAD data retrieval system, database of the Strasbourg, France, astronomical Data Center. C. G.-G. acknowledges his financial support by a grant under the contract by the I.N.S.U. and the I.A.C. for the installation of the Themis telescope.

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TABLE 1.

Galaxy Name	Number of HII region	Reference Number	RC2 Type	Shapley Ames type	Spiral structure	Arm type	Flux information
N 157	84	3	4	Sc(s)I-II	R	12	
N 224	688	4	3	SbI-II	Y	-	Y
N 224	960	5	3	SbI-II	Y	-	Y
N 300	176	6	7	ScII.8	R	5	Y
N 470	51	3	3	Sbc(s)II.8	N	3	
N 598	101	7	6	Sc(s)II-III	Y	5	Y
N 598	779	8	6	Sc(s)II-III	Y	5	Y
N 598	748	9	6	Sc(s)II-III	Y	5	Y
N 628	193	1	5	Sc(s)I	Y	9	
N 628	730	10	5	Sc(s)I	Y	9	Y
N 772	62	3	3	Sb(rs)I	N	4	
N 925	99	1	7	SBc(s)II-III	Y	1	
N 925	132	3	7	SBc(s)II-III	Y	1	
N 1073	74	3	5	SBc(rs)II	N	5	
N 1084	46	3	5	Sc(s)II.2	N	5	
N 1232	130	1	5	Sc(rs)I	Y	9	
N 1232	529	3	5	Sc(rs)I	Y	9	
N 1313	375	23	7	SBc(s)III-IV	Y	5	Y
N 1566	267	11	4	Sbc(s)I.2	Y	12	Y
N 1566	476	12	4	Sbc(s)I.2	Y	12	Y
N 1832	57	3	4	SBb(r)I	N	5	
N 2276	72	3	5	Sc(r)II-III	N	2	
N 2403	109	1	6	Sc(s)III	N	4	
N 2403	52	14	6	Sc(s)III	N	4	Y
N 2403	605	3	6	Sc(s)III	N	4	
N 2805	118	3	7	-	R	5	
N 2835	124	3	5	SBc(rs)I.2	Y	9	
N 2841	61	3	3	Sb	N	-	
N 2903	74	2	4	Sc(s)I-II	N	7	
N 2903	75	14	4	Sc(s)I-II	N	7	Y
N 2976	74	3	5	SdIII-IV	N	3	
N 2997	382	15	5	Sc(s)I.3	R	9	Y
N 3031	801	3	2	Sb(r)I-II	Y	12	
N 3031	492	16	2	Sb(r)I-II	Y	12	Y
N 3184	56	1	6	Sc(r)II.2	R	9	
N 3184	144	3	6	Sc(r)II.2	R	9	
N 3310	86	3	4	Sbc(r)tide	N	I	
N 3344	151	3	4	Sbc(rs)I.2	R	9	
N 3351	102	2	3	SBb(r)II	N	6	
N 3351	112	3	3	SBb(r)II	N	6	
N 3486	81	1	5	Sbc(r)I.2	R	9	
N 3486	153	3	5	Sbc(r)I.2	R	9	
N 3521	149	3	4	Sbc(s)II	R	3	
N 3627	62	2	3	Sb(s)II.2	Y	7	
N 3631	222	13	5	Sbc(s)II	Y	9	Y
N 3938	160	3	5	Sc(s)I	R	9	
N 3992	394	25	4	SBb(rs)I	Y	9	Y
N 4254	10	2	5	Sc(s)I.3	Y	9	
N 4254	214	3	5	Sc(s)I.3	Y	9	
N 4298	87	3	5	Sc(s)III	N	2	
N 4303	131	2	4	Sc(s)I.2	Y	9	
N 4303	289	3	4	Sc(s)I.2	Y	9	
N 4321	56	2	4	Sc(s)I	R	12	
N 4321	289	3	4	Sc(s)I	R	12	
N 4321	437	20	4	Sc(s)I	R	12	Y
N 4535	221	3	5	SBc(s)I.3	Y	9	
N 4559	78	3	6	Sc(s)II	N	-	
N 4568	65	3	4	Sc(s)II-III	R	-	
N 4654	107	3	6	SBc(rs)II	N	4	
N 4689	68	3	4	Sc(s)II.3	N	3	
N 4736	54	3	2	RSab(s)	N	3	
N 4939	107	3	4	Sbc(rs)I	R	12	
N 5055	138	3	4	Sbc(s)II-III	R	3	
N 5128	107	3	-2	SO+S pec	R	-	
N 5194	109	17	4	Sbc(s)I-II	Y	12	
N 5194	88	3	4	Sbc(s)I-II	Y	12	
N 5236	60	24	5	SBc(s)II	Y	9	Y
N 5236	296	18	5	SBc(s)II	Y	9	Y
N 5248	97	3	4	Sc(s)I-II	R	12	
N 5457	190	1	6	Sc(r)I	Y	9	
N 5457	471	3	6	Sc(r)I	Y	9	
N 5678	58	3	8	Sc(s)II-III	N	I	
N 5921	85	2	4	SBbc(s)I-II	R	8	
N 5962	112	3	5	Sc(rs)II.3	N	2	
N 6015	105	2	6	Sc(s)II-III	N	-	
N 6384	142	3	4	Sb(r)II.2	R	9	
N 6503	101	2	6	Sc(s)II.8	N	-	
N 6503	125	19	6	Sc(s)II.8	N	-	
N 6643	93	2	5	Sc(s)II	R	5	
N 6946	40	1	6	Sc(s)II	Y	9	
N 6946	540	3	6	Sc(s)II	Y	9	
N 6946	643	21	6	Sc(s)II	Y	9	Y
N 7331	124	3	4	Sb(rs)I-II	R	-	
N 7479	66	3	5	SBbc(s)I-II	R	9	
N 7741	85	3	6	SBc(s)II.2	Y	5	
N 7793	35	1	8	Sd(s)IV	N	2	
N 7793	132	22	8	Sd(s)IV	N	2	Y
I 342	666	3	6	-	N	-	
I 5325	93	3	4	Sc(s)II-III	N	-	

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TABLE 2.

NUMBER OF HII REGIONS DETECTED	NUMBER OF GALAXIES
$50 < N \leq 100$	24
$100 < N \leq 150$	17
$150 < N \leq 200$	4
$200 < N \leq 250$	3
$250 < N \leq 300$	3
$300 < N \leq 400$	3
$400 < N \leq 500$	2
$500 < N$	8

TABLE 3.

Name		First.				Second.					HII.		Bibliography.				Adopted.			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
N0157		46.	40.	2	2	40.	40.	1	20	*	44.	40.	35.	45.	2	1	40.	6.	42.	3.
N0224		38.	77.	3	2	38.	77.	2	40		38.	77.	38.	77.	5	6	38.	0.	77.	0.
N0300		99.	28.	0	2	120.	60.	2	20		120.	60.	108.	45.	3	2	110.	5.	47.	7.
													106.	42.	3	42				
													110.	43.	2	8				
N0470	I	144.	46.	1	2	150.	50.	2	20		148.	49.	151.	55.	2	1	149.	3.	51.	4.
N0598	I					35.	55.	1	20	*	35.	55.	22.	54.	5	48	24.	4.	55.	2.
													23.	54.	3	54				
													23.	58.	2	8				
N0628		160.	25.	0	2	25.	15.	1	20	*	25.	15.	25.	6.	5	50	23.	6.	8.	5.
														0.	0,1	7				
													84.	21.	0,1	1				
													26.	6.	5	54				
													10.	15.	2	8				
N0772	II	148.	40.	1	2	135.	40.	2	20		139.	40.	120.	43.	2	1	132.	12.	41.	2.
N0925	I	89.	63.	0	2	95.	70.	0	20				102.	53.	4	3	102.	1.	54.	3.
													104.	60.	1	1				
N1073		168.	43.	2	2	155.	30.	2	20		162.	37.	23.	29.	0,2	1	163.	5.	30.	9.
													164.	19.	4,2	34				
N1084		26.	66.	1	2	30.	50.	1	20	*	28.	58.	31.	55.	2	4	30.	2.	57.	7.
N1232		84.	26.	1	2	85.	30.	2	20		85.	29.	87.	39.	2	1	86.	1.	33.	6.
N1313	I					20.	45.	0	20	*			4.	38.	0	1				
													15.	39.	0	43				
N1566						55.	25.	1	20	*	55.	25.	50.	30.	3	19	47.	6.	28.	2.
													41.	27.	3	14				
N1832	I	35.	50.	1	2	30.	45.	1	20		33.	48.	0.	41.	2	1	16.	19.	44.	4.
N 2276		42.	25.	1	2	35.	30.	1	20	*	39.	28.	34.	33.	1	1	37.	4.	29.	4.
N2403		115.	50.	2	5	120.	50.	2	20		118.	50.	127.	54.	2	8	121.	4.	55.	5.
													122.	60.	5	53				
N2805		143.	48.	0	2	130.	40.	1	20	*	130.	40.	110.		3	9	116.	9.	39.	1.
														38.	1	10				
													120.	40.	1	1				
N2835						165.	40.	2	20		165.	40.	170.	43.	2	1	168.	3.	42.	2.
N2841		150.	72.	2	2	155.	70.	2	20		153.	71.		66.	2	7	151.	2.	70.	3.
													152.	72.	5	53				
													148.	65.	2	8				
N2903		23.	58.	2	2	15.	60.	2	20		19.	59.	22.	65.	3	45	21.	3.	61.	3.
													22.	60.	5	53				
N2976		147.	66.	2	2	135.	60.	2	20		141.	63.		61.	1	12	141.	7.	63.	3.
N2997		95.	46.	2	2	110.	45.	1	20	*	100.	46.	92.	46.	2	1	99.	9.	45.	2.
													110.	40.	1	18				
N3031		150.	60.	2	5	145.	55.	2	40		148.	58.	152.	59.	5	13	150.	3.	58.	2.
													147.		2	46				
													150.	55.	3	8				
N3184		121.	43.	0	2	90.	5.	2	20		90.	5.	90.	21.	2	1	90.	0.	13.	9.
N3310	I	170.	51.	1	2	160.	50.	2	20		163.	50.	163.	38.	2	1	166.	5.	42.	8.
													172.	33.	2	47				
N3344		170.	36.	2	2	165.	30.	1	20	*	168.	34.	175.	24.	2	1	164.	18.	28.	8.
													128.	15.	1	8				
N3351		13.	34.	2	2	15.	35.	1	20	*	14.	34.	13.	40.	3	15	13.	1.	39.	5.
													11.	46.	2	1				
N3486						80.	40.	2	20		80.	40.	79.	43.	2	1	80.	1.	42.	2.
N3521		167.	68.	1	2	165.	70.	2	20		166.	69.		59.	3	17	166.	1.	64.	6.
N3627	II	7.	54.	0	2	175.	65.	1	20	*	175.	65.	155.		2	20	162.	12.	67.	2.
														68.	3	17				
N3631		68.	26.	0	2	120.	20.	1	20	*	120.	20.	126.	32.	2	1	124.	3.	28.	7.
N3938						20.	5.	1	20	*	20.	5.	22.	10.	5	21	24.	9.	10.	6.
													52.	30.	1	1				
													20.	8.	5	54				
N3992		75.	60.	2	5	70.	55.	2	20		73.	58.	72.	58.	2	1	75.	4.	56.	3.
													79.	53.	5	36				

TABLE 3. *(continued)*

N4254		38.	44.	0	2	55.	30.	1	20	*	55.	30.	62.	27.	4	22	61.	3.	30.	5.
													62.	40.	1	1				
N4298		143.	70.	1	2	135.	50.	2	20		138.	57.	134.	60.	3	33	136.	3.	58.	7.
													138.	55.	2	1				
N4303		120.	30.	2	5	150.	25.	2	20		135.	28.	138.	27.	5	22	135.	10.	29.	4.
													127.	35.	2	1				
N4321		45.	32.	0	2	110.	35.	1	20		110.	35.	153.	27.	5	22	146.	18.	28.	3.
													58.	25.	0,1	1				
N4535		182.	45.	2	2	180.	45.	2	20		181.	45.	177.	40.	3	22	181.	3.	44.	3.
													185.	48.	2	1				
N4559		149.	72.	1	2	135.	65.	2	20		140.	67.					140.	8.	67.	4.
N4568		27.	70.	2	2	20.	60.	2	20		24.	65.	32.	43.	4,2	22	28.	5.	58.	10.
														59.	2	23				
N4654		128.	39.	0	2	120.	55.	2	20		120.	55.	120.	56.	2	1	120.	0.	56.	1.
N4689						160.	30.	1	20	*	160.	30.	163.	27.	3	22	163.	1.	31.	4.
													163.	36.	2	1				
N4736		119.	34.	2	2	110.	45.	1	20	*	116.	38.	122.	35.	5	24	108.	15.	37.	3.
													89.	40.	3	7				
													92.	37.	2	1				
N4939	I	4.	64.	1	2	10.	60.	2	20		8.	61.					8.	3.	61.	2.
N5055		106	60.	2	2	115.	60.	2	20		111.	60.	99.	55.	5	11	103.	6.	58.	2.
													100.	58.	2	1				
													100.	60.	2	8				
N5128		115	60.	2	2	125	60.	2	20		120.	60.	120.	73.	1	25	120.	5.	64.	6.
													122.	72.	1	26				
N5194		137	30.	0	2	165.	20.	0	20	*			170.	20.	5	27	170.	0.	20.	0.
													37.	33.	0	7				
													27.	37.	0	1				
													30.	37.	0	8				
N5236		70	26.	0	2	45.	25.	2	20		45.	25.	45.	24.	5	28	45.	0.	24.	0.
													45.		3	29				
													87.	16.	0	1				
N5248		152	65.	2	2	145.	70.	2	20		149.	68.	142.	52.	2	1	146.	5.	61.	7.
														57.	3	17				
N5457						40.	35.	2	20		40.	35.	39.	18.	5	30	38.	2.	24.	7.
													35.	27.	2	49				
N5678		5	67.	2	2	5.	60.	2	20		5.	64.		57.	3	17	5.	0.	61.	4.
N5921		155	45.	1	5	155.	35.	2	20		155.	38.	28.	36.	0	31	149.	9.	36.	5.
													139.	33.	2	1				
N5962		135	45.	1	5	115.	45.	2	20		122.	45.	111.	46.	2	1	117.	10.	43.	3.
														39.	3	17				
N6015		18	57.	1	2	15.	55.	2	20		16.	56	27.		2	32	20.	6.	56.	1.
N6384		60	35.	0	5	50.	45.	2	20		50.	45.	31.	50.	2	1	41.	11.	48.	3.
N6503		125	70.	2	2	125.	70.	2	20		125.	70.	121.	74.	5	58	123.	2.	70.	4.
													125.	64.	3	35				
N6643		55	55.	2	5	40.	60.	2	20		48.	58.	40.		2	32	44.	8.	57.	3.
													35.	57.	1	51				
N6946		70	35.	1	2	65.	25.	1	20	*	68.	30.	58.	32.	3	37	64.	7.	34.	4.
													81.	32.	1	1				
													69.	34.	2	8				
													60.	38.	5	16				
N7331		164	75.	2	2	165.	75.	2	20		165.	75.	170.	74.	2	7	167.	2.	74.	2.
													165.	70.	2	8				
													168.	75.	5	53				
N7479		72	52.	0	2	35.	40.	2	20		35.	40.	37.	45.	3	38	37.	2.	44.	2.
													39.	45.	2	1				
N7741		143	41	0	2	165.	45.	1	20	*	165.	45.	160.	47.	2	39	162.	2.	43.	5.
													163.	38.	2	1				
N7793		87	52.	2	2	100.	50.	2	20		94.	51.	108.	53.	3	40	100.	8.	53.	2.
													99.	54.	3	42				
I0342		25	30.	1	5	5.	0.	1	40	*	15.	15.	39.	25.	5	41	32.	13.	22.	8.
													97.	20.	0,3	52				
I5325						40.	35.	2	20		40.	35.					40.	0.	35.	0.

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TABLE 4a.

	SECOND	FIRST	KINEMATICS	GROSBOL	CONS. & ATHA.	DANVER
SECOND		0.95 (0.92 , 0.97) 0.94 0.1E-25 54	0.96 (0.92 , 0.98) 0.93 0.8E-12 28	0.93 (0.87 , 0.95) 0.95 0.7E-18 37	0.97 (0.89 , 0.99) 0.91 0.3E-3 10	0.95 (0.90 , 0.97) 0.92 0.2E-10 27
FIRST	0.95 (0.93 , 0.97) 0.94 0.1E-25 54		0.93 (0.84 , 0.97) 0.96 0.4E-10 19	0.89 (0.81 , 0.94) 0.88 0.5E-9 28	0.88 (0.57 , 0.97) 0.80 0.2E-1 8	0.86 (0.72 , 0.93) 0.85 0.4E-6 22
KINEMATICS	0 , 96 (0.93-0.98) 0.93 0.8E-12 28	0.93 (0.84 , 0.97) 0.96 0.4E-10 19		0.86 (0.74 , 0.95) 0.92 0.6E-6 16	0.98 (0.93 , 0.99) 0.99 0.9E-7 10	0.95 (0.88 , 0.97) 0.83 0.7E-5 20
GROSBOL	0.93 (0.87 , 0.95) 0.95 0.7E-18 37	0.89 (0.81 , 0.94) 0.88 0.5E-9 28	0.86 (0.74 , 0.95) 0.92 0.6E-6 16		0.79 (-0.1 , 0.97) 0.70 0.19 5	0.80 (0.59 , 0.91) 0.86 0.4E-5 18
CONS. & ATHA.	0.97 (0.89 , 0.99) 0.91 0.3E-3 10	0.88 (0.57 , 0.97) 0.80 0.2E-1 8	0.98 (0.93 , 0.99) 0.99 0.9E-7 10	0.79 (-0.1 , 0.97) 0.70 0.19 5		0.98 (0.93 , 0.99) 0.99 0.9E-7 10
DANVER	0.95 (0.90 , 0.97) 0.92 0.2E-10 27	0.86 (0.72 , 0.93) 0.85 0.4E-6 22	0.95 (0.88 , 0.97) 0.83 0.7-5 20	0.80 (0.59 , 0.91) 0.86 0.4E-5 18	0.98 (0.93 , 0.99) 0.99 0.9E-7 10	

TABLE 4b.

	SECOND	FIRST	KINEMATICS	GROSBOL ATHA.	CONS. &	DANVER
SECOND		0.84 (0.76 , 0.90) 0.81 0.6E-13 54	0.90 (0.78 , 0.95) 0.84 0.3E-7 28	0.77 (0.66 , 0.87) 0.77 0.4E-7 37	0.92 (0.74 , 0.97) 0.84 0.2E-2 10	0.83 (0.69 , 0.90) 0.77 0.3E-5 27
FIRST	0.84 (0.76 , 0.90) 0.81 0.6E-13 54		0.85 (0.68 , 0.93) 0.77 0.1E-3 19	0.70 (0.49 , 0.83) 0.61 0.6E-3 28	0.91 (0.65 , 0.98) 0.88 0.5E-2 8	0.80 (0.62 , 0.90) 0.78 0.2E-4 22
KINEMATICS	0.90 (0.81 , 0.95) 0.84 0.3E-7 28	0.85 (0.68 , 0.93) 0.77 0.1E-3 19		0.86 (0.68 , 0.94) 0.66 0.5E-2 16	0.97 (0.90 , 0.99) 0.88 0.7E-3 10	0.86 (0.71 , 0.93) 0.82 0.7E-5 20
GROSBOL	0.79 (0.66 , 0.87) 0.77 0.4E-7 37	0.70 (0.49 , 0.83) 0.61 0.6E-3 28	0.86 (0.68 , 0.94) 0.66 0.5E-2 16		0.99 (0.93 , 1) 0.87 0.6E-1 5	0.47 (0.09 , 0.73) 0.29 0.243 18
CONS. & ATHA.	0.92 (0.75 , 0.97) 0.84 0.2E-2 10	0.91 (0.56 , 0.98) 0.88 0.5E-2 8	0.97 (0.90 , 0.99) 0.88 0.7E-3 10	0.99 (0.93 , 1) 0.87 0.6E-1 5		0.85 (0.57 , 0.95) 0.83 0.3E-2 10
DANVER	0.83 (0.69 , 0.91) 0.77 0.3E-5 27	0.80 (0.62 , 0.90) 0.78 0.2E-4 22	0.86 (0.71 , 0.93) 0.82 0.7E-5 20	0.47 (0.09 , 0.73) 0.29 0.243 18	0.85 (0.57 , 0.95) 0.83 0.3E-2 10	

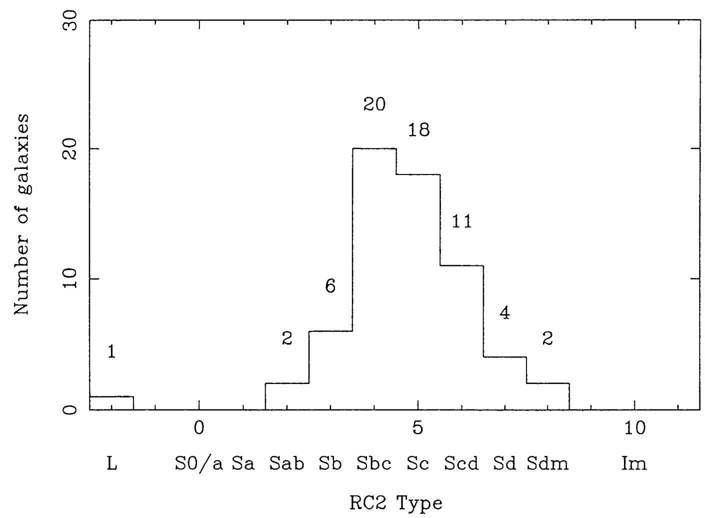

FIGURE 1. Histogram of the number of galaxies as a function of type according to the second reference catalogue. The number of galaxies is given also on top of each bin.

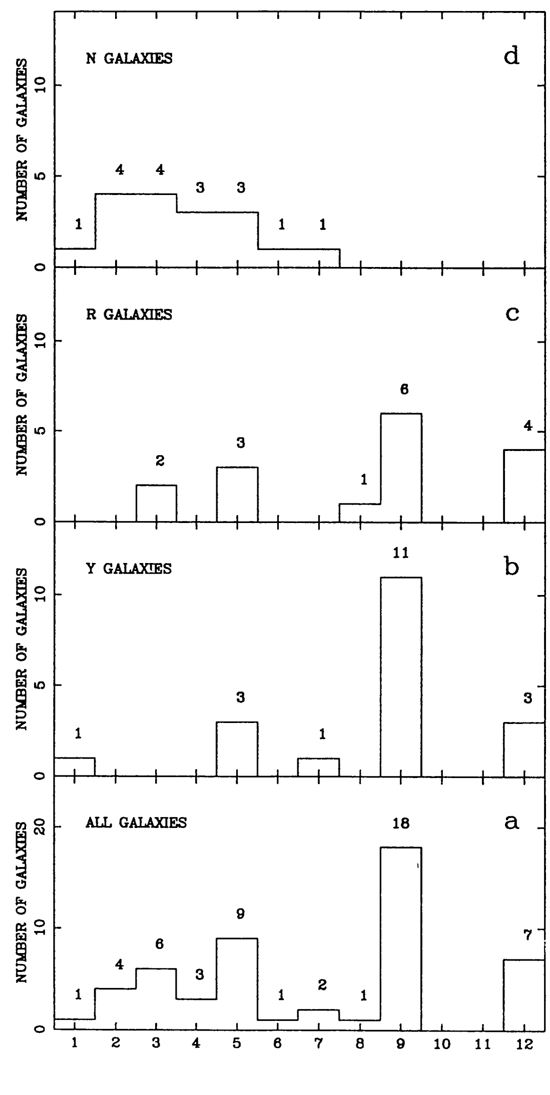

FIGURE 2. Histogram of the number of galaxies as a function of arm class according to Elmegreen & Elmegreen (1987). a) All galaxies in our sample, b) galaxies with clear structure in their HII region distribution, c) intermediate cases,d) galaxies with no structure in their HII region distribution.

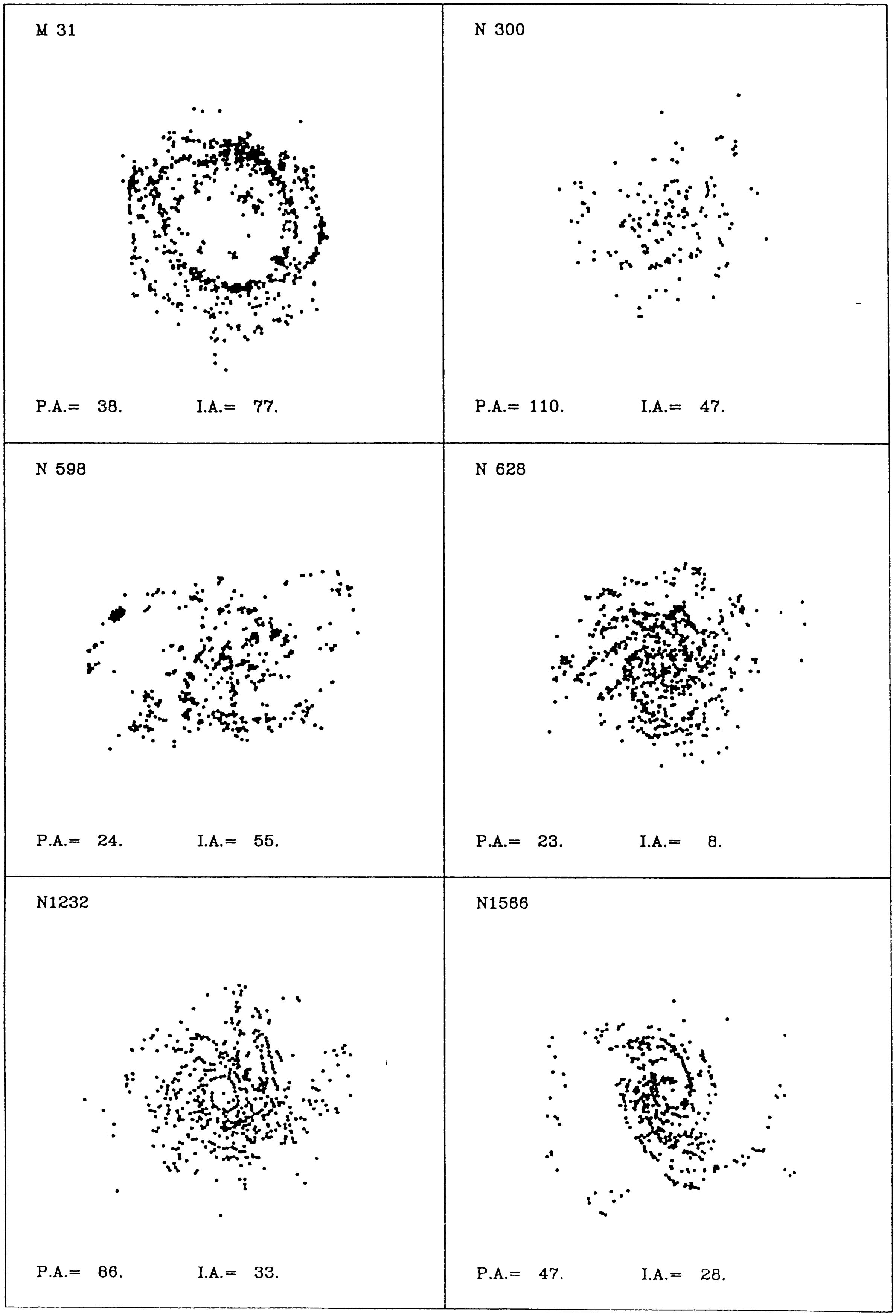

FIGURE 3. Deprojected HII region distributions of all galaxies in our sample.

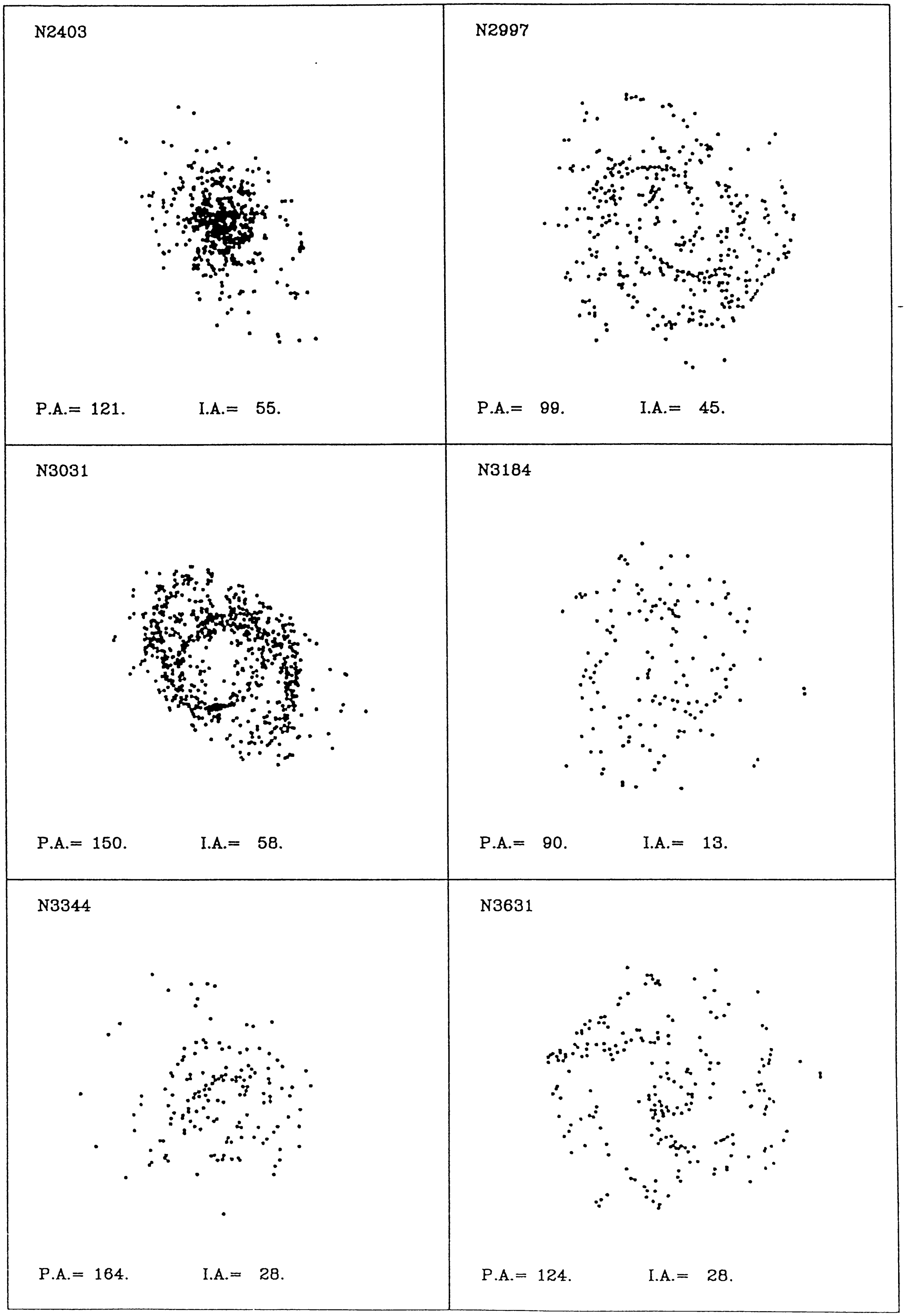

FIGURE 3 (*continued*)

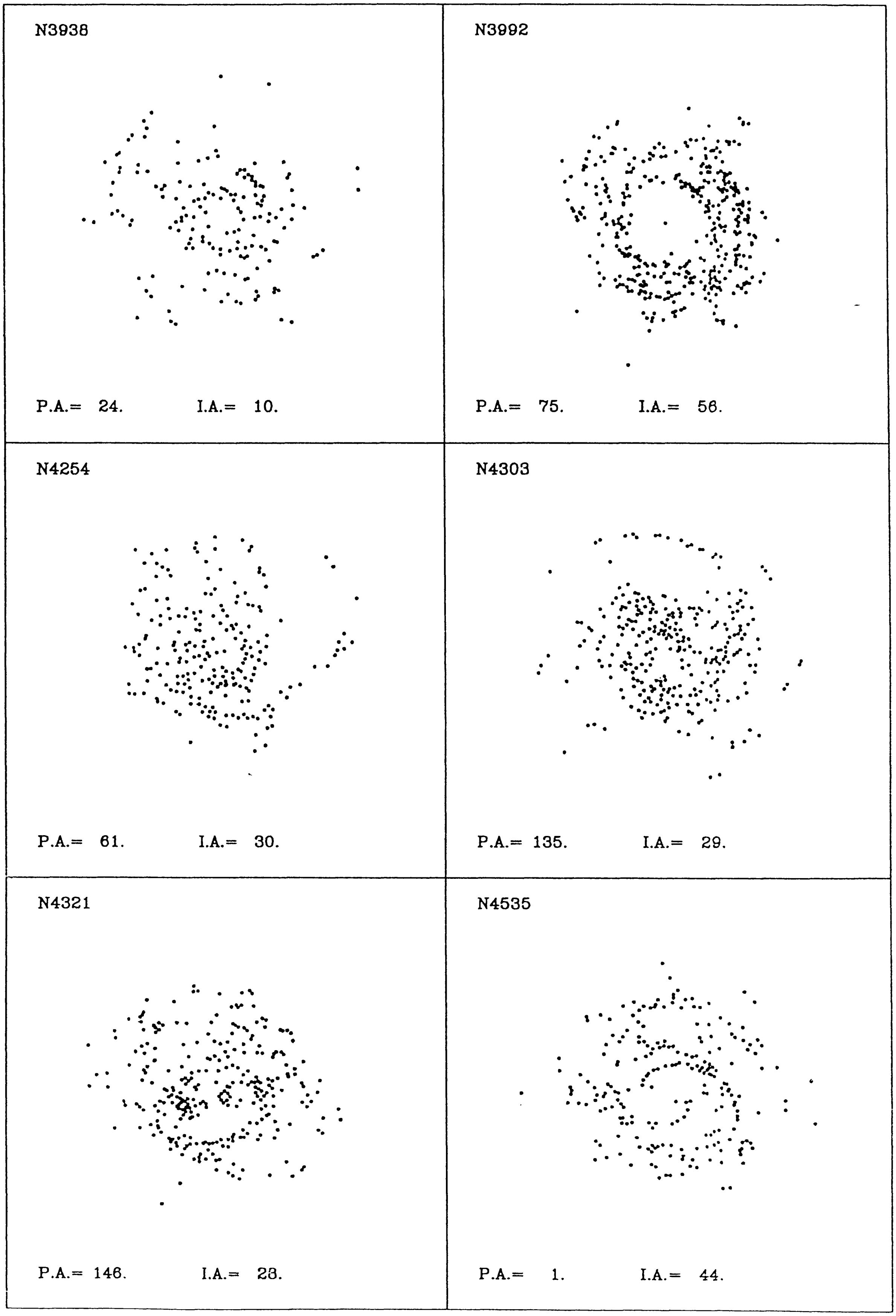

FIGURE 3 (*continued*)

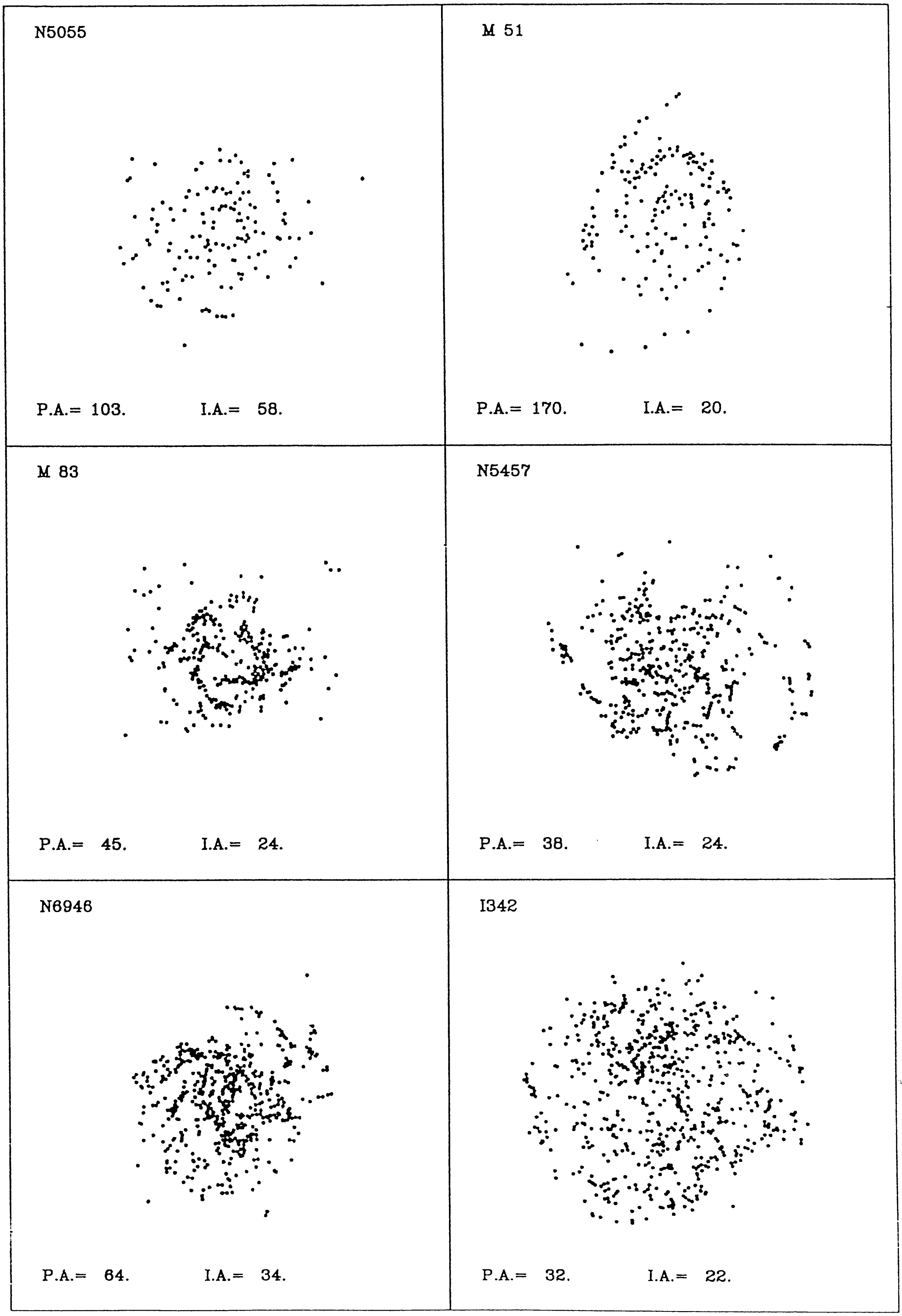

FIGURE 3 (*continued*)

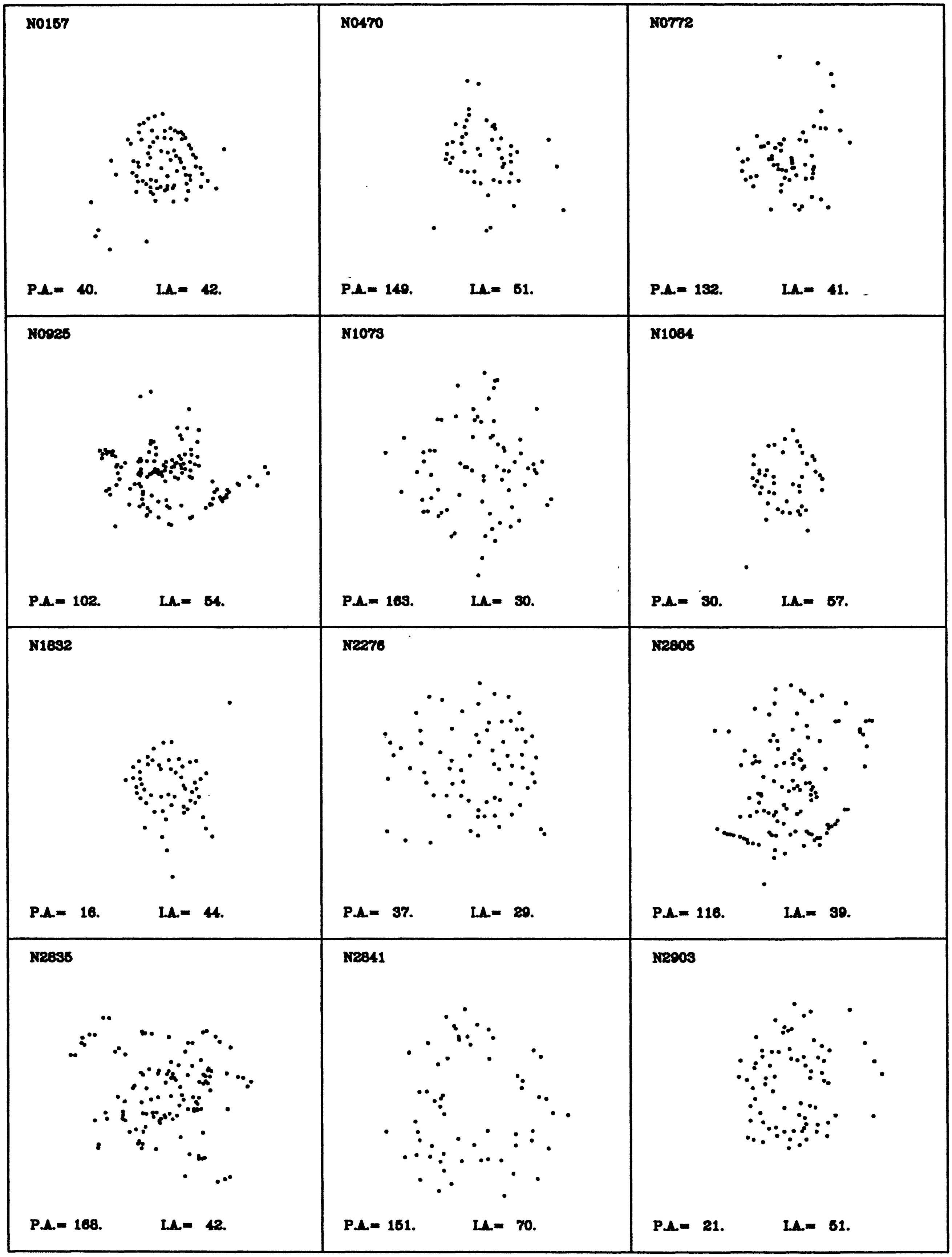

FIGURE 3 (*continued*)

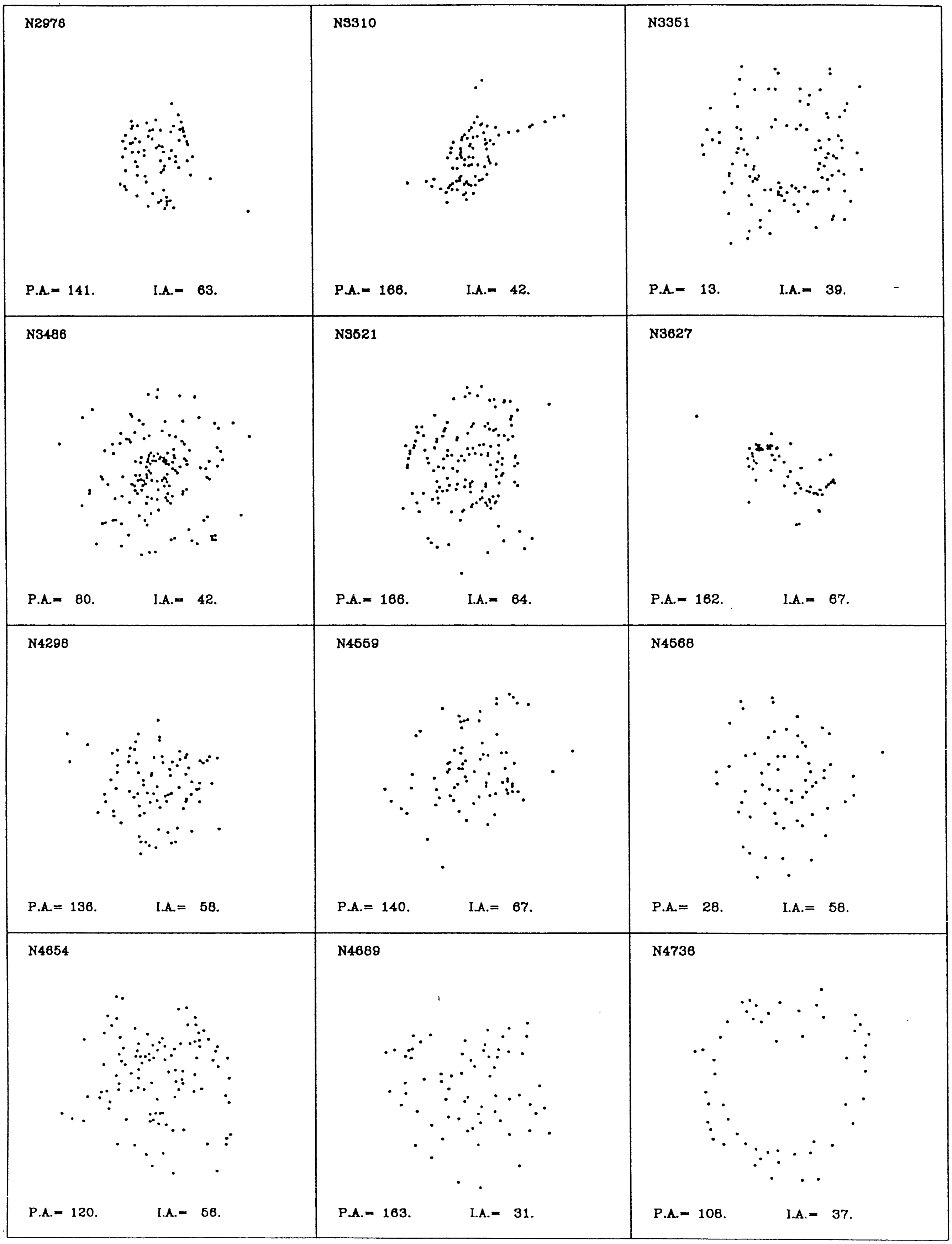

FIGURE 3 (*continued*)

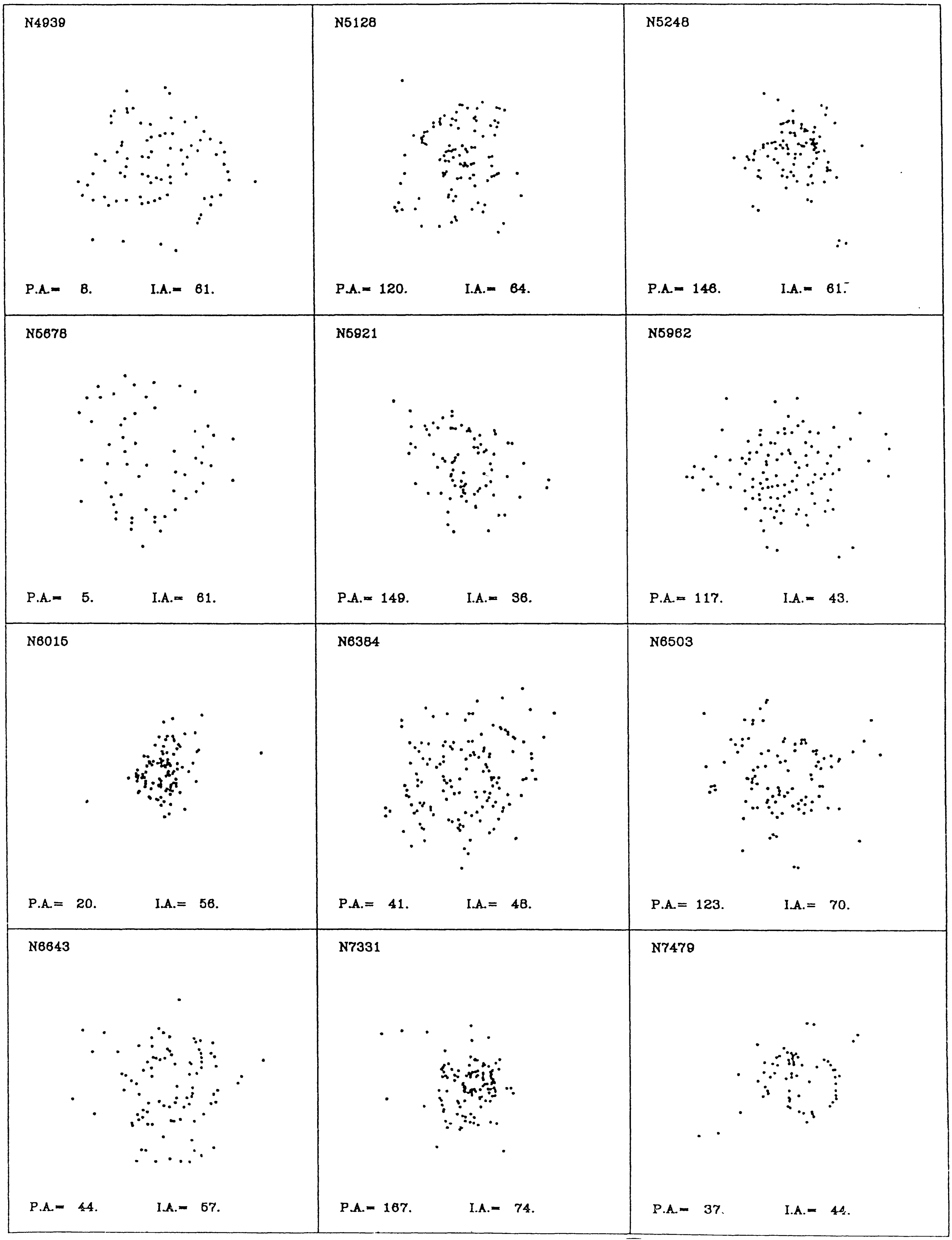

FIGURE 3 (*continued*)

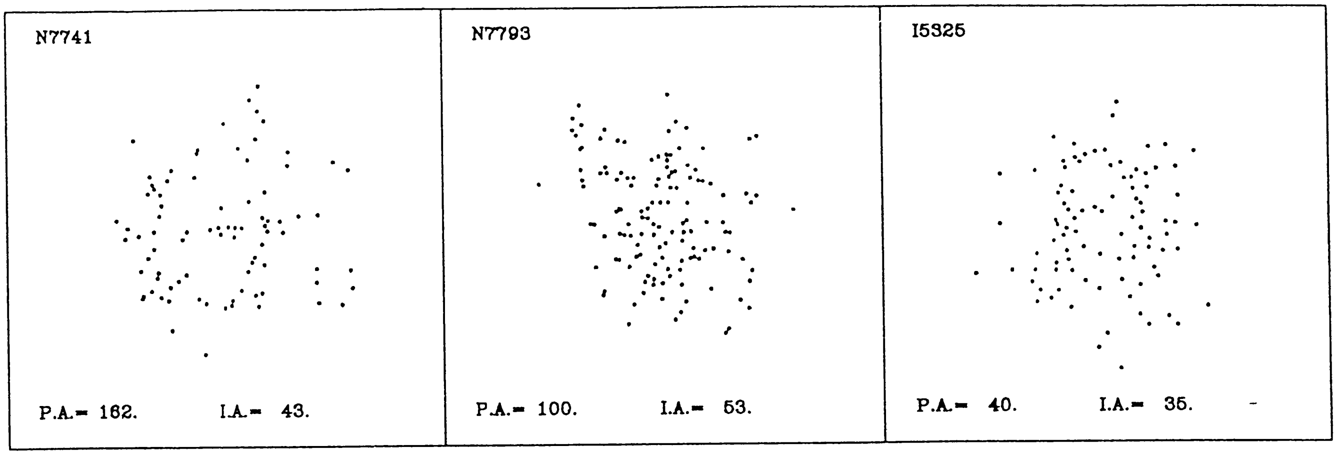

FIGURE 3 (*continued*)

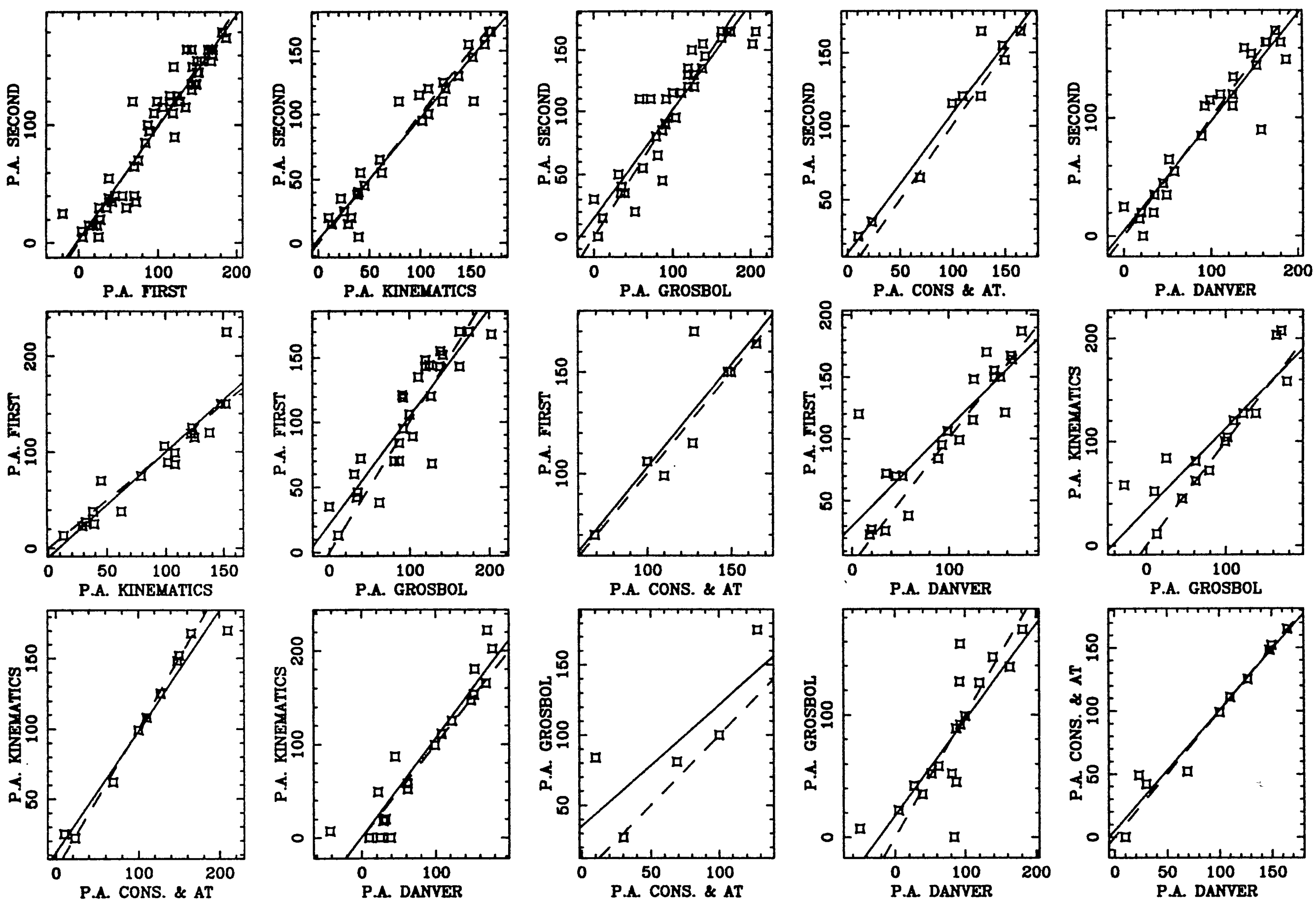

FIGURE 4. Correlations between the values of the PA found by various methods.

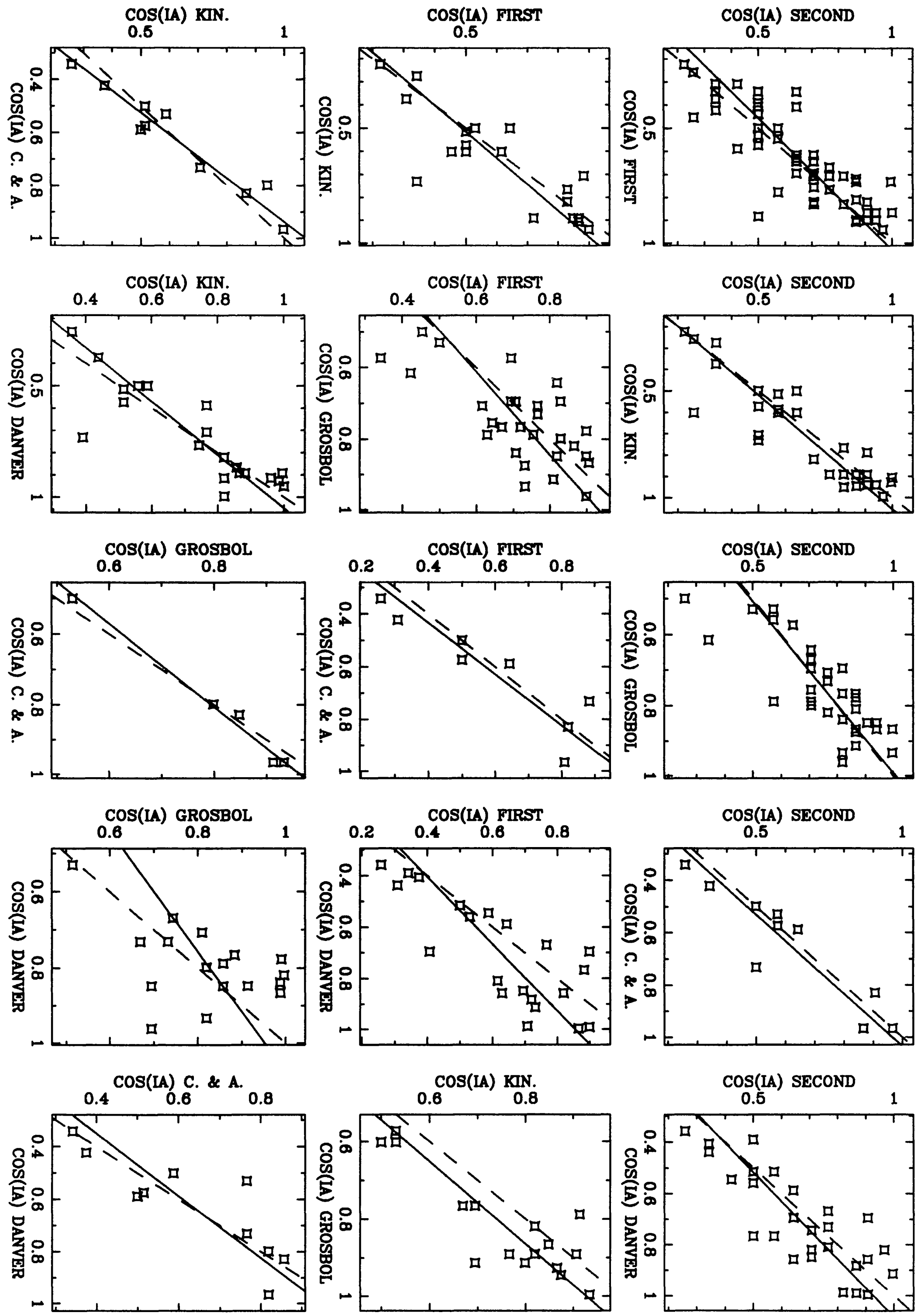

FIGURE 5. Correlations between the values of the cos (IA) found by various methods.