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A catalog of warps in spiral and lenticular galaxies in the Southern hemisphere

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Abstract. A catalog of optical warps of galaxies is presented. This can be considered complementary to that reported by Sánchez-Saavedra et al. (1990), with 42 galaxies in the northern hemisphere, and to that by Reshetnikov & Combes (1999), with 60 optical warps. The limits of the present catalog are: logr25 > 0.60, $B_{\rm t} < 14.5$, $\delta(2000) < 0°$, $-2.5 < t < 7$. Therefore, lenticular galaxies have also been considered. This catalog lists 150 warped galaxies out of a sample of 276 edge-on galaxies and covers the whole southern hemisphere, except the Avoidance Zone. It is therefore very suitable for statistical studies of warps. It also provides a source guide for detailed particular observations. We confirm the large frequency of warped spirals: nearly all galaxies are warped. The frequency and warp angle do not present important differences for the different types of spirals. However, no lenticular warped galaxy has been found within the specified limits. This finding constitutes an important restriction for theoretical models.

Key words. catalogs – galaxies: structure – galaxies: spiral – galaxies: elliptical and lenticular, cD

1. Introduction

As peripheral features, disc warps are better observed in 21 cm. This has been the preferred observational technique since their discovery by Sancisi (1976) and the study by Bosma (1981) until more recent samples such as those analyzed by García-Ruíz (2001) and García-Ruíz et al. (2000). Optical observations provide an important complementary tool. Even if the relation between optical and radio warps remains unclear (García-Ruíz 2001), the great advantage of optical observations lies in the much larger samples available. Catalogs of warped galaxies have been useful to establish observational restrictions to explain warps. Sánchez-Saavedra et al. (1990) first produced a catalog of 42 optical warps in the northern hemisphere out of a sample of 86 galaxies analyzed. The most noticeable result was that, taking into account the probability of non-detection of warps when the line of nodes lies in the plane of the sky, nearly all galaxies are warped, confirming the suggestion made by Bosma (1981) for HI warps. Warps are therefore a universal feature, common for nearly all spiral galaxies. Even this large frequency is a severe restriction for theoretical models. As Reshetnikov and Combes said: "Differential precession wraps any warp", in contrast with the large frequency of real warped galaxies.

Reshetnikov & Combes (1999) studied 540 edge-on galaxies, from which a sub-sample of 60 warped galaxies was presented. One of the most noticeable new results reported in their work was that warps were more frequent in denser environments. They also found that the warping mechanism is equally efficient in all types of spirals.

Detailed studies of particular warped galaxies in the optical, such as those by Florido et al. (1991) and by de Grijs (1997), the latter including 44 galaxies, are also of great interest, evidently, but the production of catalogs has greater statistical power.

Here, we have examined all the galaxies contained in LEDA, with logr25 (log 10 of axis ratio (major/minor axis)) > 0.60, $B_{\rm t}$ (total B-magnitude) < 14.5, $\delta(2000) < 0°$, $-2.5 < t$ (morphological type code) < 7. The number of galaxies fulfilling these requirements is 276, which is our basis for this work, in which the galaxies were analyzed by means of the DSS. Only discs with a warp angle wa (measured from the galactic center to the last observable point with respect to the galactic plane) larger than 4° are considered to be warped.

To determine the warp angle, wa, and other geometrical parameters of a warp, or even the very existence of a warp, subjective criteria were used in previous catalogs and are in turn used in the present one. Objective procedures (Jiménez-Vicente 1998; Jiménez-Vicente et al. 1998) present some problems when applied to a very large number of galaxies and were

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disregarded. More specifically, in some galaxies it was necessary to apply the automatic star removing procedure to an excessively large number of stars, rendering the map highly distorted. Also the separation of real warps and spiral arms was difficult to define, even for galaxies where this separation is clear to the human eye.

Our work presents 150 warps extracted from 276 edge-on galaxies. The recent study by Reshetnikov & Combes (1998, 1999) extracted 60 warps from 540 edge-on galaxies. It is evident that these authors used stricter criteria to define when a galaxy is definitely warped. Our sample and scope are complementary. The Reshetnikov & Combes sample is limited by coordinates $0^{\rm h} \leq \alpha$ (1950) $\leq 14^{\rm h}$, δ (1950) $\leq -17.5°$; ours by $\delta(2000) \leq 0°$ only. That implies that the study by Reshetnikov & Combes covers 17% of the whole sky, whereas ours covers 50%. This, however, is not strictly true because a large part of the Southern Sky is covered by the Zone of Avoidance due to the large extinction near the galactic plane. Taking into account this Avoidance Zone ($-15° \leq b \leq 15°$) our sample would cover about 40% of the whole sky. Even if based on a smaller number of edge-on galaxies, this large coverage renders the present study more useful for certain statistical tasks, such as the distribution of the orientation of warps.

Another important difference between the work by Reshetnikov & Combes and the present study is that the former only pays attention to the discs of spiral galaxies while ours includes lenticular galaxies. This inclusion is very important from the theoretical point of view because, roughly speaking, lenticulars have a disc but not gas; in other words, the distribution of stars in lenticulars is very similar to that in spiral galaxies. This is an overgeneralisation, because even if the amount of gas in lenticulars is less than in even late-type spirals, lenticulars do process some gas in the outer parts. Another important difference between lenticulars and spirals is that the former have a dominant bulge. This fact makes analysis less simple, as huge bulges could in principle affect the formation of warps. In any case observations of warps in lenticulars have yet to be made and may introduce decisive restrictions on the mechanisms behind warps.

A large number of theories can be found in the literature: non-spherical dark halos misaligned with the disc (Sparke & Casertano 1988; Dubinski & Kuijken 1995), gas infall into the dark matter halo (Ostriker & Binney 1989; Binney 1992) or directly into the disc (López-Corredoira et al. 2002), interactions with companions or small satellites (Weinberg 1998), intergalactic magnetic fields (Battaner et al. 1990), etc. Kuijken & García-Ruíz (2001) recently presented a concise review summarizing several mechanisms proposed to explain warps.

The large fraction of warped galaxies seems to exclude one of the most obvious models, based on interactions, but this hypothesis has been reconsidered by Weinberg (1998), assuming a strong tidal amplification by the gravitational wake of a satellite, although this fact was not confirmed by García-Ruíz (2001) who also argued that the warp of the Milky Way induced by the Magellanic Clouds should have been predicted to have a very different orientation from that observed. Warps are common in merging systems (Schwarzkopf & Dettmar 2001) but it remains unclear whether mergers or interactions can explain all, or at least most, warps.

Warps are more frequent in denser environments (Reshetnikov & Combes 1999). Early $z \approx 1$ warps were considered by Reshetnikov et al. (2002). Early warps were larger, which favors the interaction model. Other models cannot be completely excluded from the observation of early $z \approx 1$ warps. Magnetic fields were also much stronger and the rate of infall of matter onto a galaxy was higher.

García-Ruíz (2001) observed that, even if galaxies with extended discs may be warped, extended discs are less frequent in denser environments.

The observational study of warps in lenticular galaxies is crucial. If warps are absent or are less common in lenticular galaxies which are gas-poor, those models based on gravitation alone would have difficulty in explaining this fact. Models in which a permanent torque acts on the gas of the galaxy would have the preference. For instance, models like that by Kahn & Woltjer (1959) or its more recent version by López-Corredoira et al. (2002) would be favored. Note that neither model requires the assumption that galaxies have a large dark matter halo. The magnetic model, in which intergalactic magnetic fields maintain the warp structure, would acquire additional support from this fact.

It therefore seems that the compilation of large samples of warped galaxies, even if they contain just a few parameters about their position, the parent galaxy and the magnitude and shape of the warping, contributes as much as the detailed examination of the HI maps of a few galaxies.

2. The new catalog

The catalog presented here is shown in Table 1. Column 1 gives the pgc number, Col. 2 the galaxy-name or the alternate name, Cols. 3 and 4 the source position for the epoch J2000, the right ascension (al2000, hours decimal value) and declination (de2000, degrees decimal value), Col. 5 the log 10 of apparent diameter (d25 in 0.1′), Col. 6 the log 10 of the axis ratio (major axis/minor axis) and Col. 7 the morphological type code (*t*), (directly adopted from LEDA). Columns 8–11 are the result of our analysis, with the following meaning:

Column 8, labelled *N/S*, specifies the apparent warp rotation, *S* clockwise, *N* counterclockwise. The *N* and *S* shapes are really two sides of the same galaxy. This difference is therefore completely unimportant from the physical point of view. However, we have kept the information because it is needed when studying the distribution of warps in space, for instance, when considering the orientation of warps in a cluster of galaxies (see for instance, Battaner et al. 1991) *L* means that only one of the two sides of the galaxy is warped. *U* means that the two warps are not antisymmetric, i.e. that the apparent warp rotation on the two sides of the edge-on galaxies has opposite directions. In this column, "-" means unwarped and "?" unclear.

Column 9, labelled *(wa)E–W*, gives the warp angle, defined as the angle between the outermost detected point and the mean position of the plane of symmetry, as defined by the internal unwarped region. *E* indicates the side of the galaxy closer to the

Table 1. Sample of spiral galaxies. In the 8th column "-" means unwarped and "?" unclear; in the 9th column "b" means arms, "c" means corrugated and "0" means unwarped.

pgc	galaxy-name	al2000	de2000	logd25	logr25	t	*N/S*	(*wa*)E–W (°)	β (°)	α_s
43	ESO 293-27	0.00817	−40.48400	1.32	0.60	3.9	*LS*	?	-	-
474	MCG-7-1-9	0.10585	−41.48350	1.53	0.62	6.0	*N*	7–7	30–31	0
627	NGC 7	0.13899	−29.91700	1.39	0.67	4.9	*U*	7–7	31–31	0
725	ESO 241-21	0.17223	−46.41940	1.34	0.62	3.1	*N*	11–10	39–24	0.05
1335	ESO 78-22	0.34918	−63.85740	1.34	0.79	4.3	*S*	6–9	17–31	0.2
1851	NGC 134	0.50616	−33.24550	1.92	0.64	4.0	*N*	11–8	22–31	0.16
1942	ESO 473-25	0.53050	−26.72010	1.41	0.84	4.9	*N*	5–7	-	0.17
1952	ESO 79-3	0.53390	−64.25240	1.45	0.72	3.1	*N*	9–7	27–21	0.13
2228	NGC 172	0.62067	−22.58500	1.31	0.72	4.0	*S*	7–7	-	0
2482	NGC 217	0.69267	−10.02120	1.45	0.65	0.5	*N*	9–10	-	0.05
2789	NGC 253	0.79252	−25.28840	2.43	0.66	5.1	*N*	7–9	22–27	0.13
2800	MCG-2-3-15	0.79624	−9.83460	1.24	0.64	3.1	*U*	7–7	-	0
2805	MCG-2-3-16	0.79641	−9.89970	1.48	0.82	6.7	*S*	14–10	-	0.17
2820	NGC 259	0.80091	−2.77630	1.46	0.65	4.0	*S*	7–9	45–45	0.13
3743	NGC 360	1.04763	−65.60990	1.57	0.89	4.3	*N*	8–7	22–17	0.07
4440	IC 1657	1.23536	−32.65060	1.41	0.65	3.8	*S*	7–11	21–39	0.22
4912	ESO 476-5	1.35492	−22.80050	1.29	0.61	3.9	*N*	10–14	27–34	0.17
5128	NGC 527	1.39947	−35.11520	1.23	0.62	0.1	*N*	7–7	22–22	0
5688	NGC 585	1.52839	−0.93300	1.34	0.66	1.0	*N*	5–3	-	0.25
6044	ESO 297-16	1.63329	−40.06770	1.20	0.61	5.9	*N*	9–7	17–16	0.13
6161	ESO 413-16	1.66594	−28.69710	1.29	0.67	3.9	*S*	8–7	17–16	0.07
6242	ESO 3-4	1.69266	−83.21210	1.28	0.70	4.1	*S*	7–7	22–27	0
6966	MCG-1-5-47	1.88028	−3.44720	1.48	0.87	4.8	*S*	2–7	-	0.56
7298	ESO 245-10	1.94570	−43.97350	1.34	0.61	3.2	?	?	-	-
7306	IC 176	1.94814	−2.01910	1.29	0.68	5.1	*N*	7–7	22–22	0
7427	ESO 297-37	1.97033	−39.54460	1.27	0.67	4.1	*N*	3–7	-	0.4
8326	ESO 30-9	2.17801	−75.03880	1.40	0.61	4.8	*S*	4–5	-	0.11
8581	MCG-1-6-77	2.24055	−7.36840	1.36	0.78	2.7	?	?	-	-
8673	IC 217	2.26957	−11.92660	1.34	0.67	5.8	*U*	5–6	-	0.09
9582	NGC 964	2.51835	−36.03420	1.33	0.60	1.9	*S*	3–6	-	0.33
10645	ESO 546-25	2.81346	−19.97110	1.16	0.73	3.6	-	0–0	-	-
10965	NGC 1145	2.90931	−18.63550	1.47	0.74	5.1	*N*	?–4	-	-
11198	MCG-2-8-33	2.96379	−10.16720	1.45	0.63	0.2	*N*	14–11	22–16	0.12
11595	ESO 248-2	3.08523	−45.96350	1.47	0.69	6.9	*S*	10–10	18–18	0
11659	NGC 1244	3.10866	−66.77640	1.26	0.63	2.1	*S*	6–6	9–9	0
11851	IC 1898	3.17224	−22.40440	1.53	0.77	5.8	*N*	5–3	23–11	0.25
11931	NGC 1247	3.20399	−10.48070	1.54	0.82	3.8	*N*	4–5	-	0.11
12521	NGC 1301	3.34317	−18.71590	1.34	0.66	4.2	*N*	9–6	17–11	0.2
13171	IC 1952	3.55728	−23.71280	1.40	0.66	4.1	*N*	8–6	18–13	0.14
13458	NGC 1406	3.65626	−31.32200	1.59	0.70	4.4	*S*	3–5	20–11	0.25
13569	NGC 1422	3.69191	−21.68240	1.36	0.63	2.4	-	0–0	-	-
13620	NGC 1421	3.70818	−13.48830	1.54	0.60	4.1	?	?	-	-
13646	MCG-2-10-9	3.71559	−12.91570	1.50	0.90	5.0	*N*	7–5	27–18	0.17
13727	NGC 1448	3.74221	−44.64400	1.88	0.65	5.9	S	9–8	45–25	0.06
13809	ESO 358-63	3.77189	−34.94240	1.69	0.64	4.7	*LS*	3–0	-	1
13912	IC 2000	3.81879	−48.85810	1.63	0.74	6.1	*N*	5–5	-	0
13926	ESO 482-46	3.82835	−26.99350	1.55	0.82	5.1	?	c	-	-
14071	NGC 1484	3.90487	−36.97110	1.40	0.69	3.5	*S*	5–5	-	0

Table 1. continued.

pgc	galaxy-name	al2000	de2000	logd25	logr25	t	*N/S*	(*wa*)E–W (°)	β (°)	α_s
14190	NGC 1495	3.97255	−44.46650	1.46	0.73	5.1	*S*	4–9	-	0.38
14255	NGC 1511A	4.00542	−67.80730	1.28	0.63	1.3	*S*	7–7	-	0
14259	ESO 483-6	4.00724	−25.18150	1.43	0.79	3.2	*S*	5–7	-	0.17
14337	ESO 117-19	4.04233	−62.31570	1.31	0.76	3.9	-	0–0	-	-
14397	NGC 1515	4.06748	−54.10270	1.72	0.62	4.0	*N*	5–8	10–10	0.23
14824	IC 2058	4.29847	−55.93440	1.49	0.94	6.6	*S*	4–6	-	0.2
15455	ESO 202-35	4.53769	−49.67520	1.44	0.81	3.3	*N*	5–5	16–11	0
15635	NGC 1622	4.61015	−3.18920	1.52	0.73	2.0	*S*	5–10	13–21	0.33
15654	NGC 1625	4.61841	−3.30340	1.37	0.64	3.1	*S*	6–6	11–?	0
15674	NGC 1628	4.62671	−4.71480	1.27	0.64	3.1	*N*	8–9	11–17	0.06
15749	ESO 157-49	4.66038	−53.01200	1.28	0.66	4.1	*S*	11–11	21–21	0
15758	IC 2103	4.66323	−76.83680	1.28	0.76	4.9	?	b	-	-
16144	IC 2098	4.84561	−5.41870	1.35	0.87	5.9	-	0–0	-	-
16168	MCG-1-13-22	4.85739	−3.12210	1.22	0.60	3.0	*S*	4–4	-	0
16187	IC 2101	4.86165	−6.22970	1.23	0.66	5.0	?	?	-	-
16199	ESO 361-15	4.86601	−33.17860	1.44	0.68	6.1	*S*	7–7	9–17	0
16239	NGC 1686	4.88184	−15.34620	1.25	0.71	4.0	*N*	4–7	–16	0.27
16636	MCG-1-13-50	5.05475	−2.93560	1.39	0.82	3.0	-	0–0	-	-
16849	NGC 1827	5.16768	−36.95890	1.48	0.76	5.9	?	-	-	-
16893	MCG-1-14-3	5.19493	−3.09160	1.16	0.67	3.1	N	7-5	-	0.17
17027	ESO 362-11	5.27748	−37.10210	1.68	0.75	4.1	*N*	6–4	11–6	0.2
17056	IC 407	5.29517	−15.52370	1.24	0.70	4.9	*S*	6–6	-	0
17174	NGC 1886	5.36352	−23.81260	1.51	0.77	3.9	-	0–0	-	-
17248	MCG-2-14-16	5.41515	−12.68870	1.28	0.77	2.0	-	0-0	-	-
17433	NGC 1963	5.55355	−36.39980	1.46	0.78	5.8	?	?	-	-
17969	ESO 555-2	5.84077	−19.72620	1.34	0.74	3.9	*S*	6–6	-	0
17993	ESO 160-2	5.85418	−53.57480	1.26	0.63	3.0	?	?	-	-
18394	ESO 5-4	6.09456	−86.63220	1.58	0.68	2.9	-	0–0	-	-
18437	ESO 121-6	6.12505	−61.80710	1.60	0.75	5.1	*S*	3-3	-	0
18765	ESO 489-29	6.28479	−27.38620	1.52	0.72	3.9	-	0–0	-	-
18833	NGC 2221	6.33750	−57.57740	1.33	0.66	1.1	*U*	7–6	18–11	0.08
19996	ESO 491-15	7.01183	−27.36820	1.35	0.68	5.0	*N*	3–3	-	0
20903	ESO 428-28	7.39406	−30.05070	1.39	0.84	5.3	*U*	-	-	-
21338	ESO 257-19	7.58538	−46.92470	1.40	0.74	6.2	?	b	-	-
21815	ESO 311-12	7.79281	−41.45170	1.57	0.74	0.1	*S*	3–3	6–8	0
21822	ESO 560-13	7.79774	−18.74840	1.48	0.77	4.0	*N*	10–4	18–8	0.4
22174	ESO 35-18	7.91809	−76.41310	1.53	0.65	4.9	-	0–0	-	-
22272	ESO 494-7	7.94852	−24.90810	1.45	0.63	4.3	-	0–0	-	-
22338	ESO 209-9	7.97080	−49.85160	1.80	0.83	6.0	*N*	5–5	9–17	0
22910	ESO 89-12	8.16682	−64.93620	1.41	0.86	4.1	*N*	7–7	15–17	0
23558	ESO 495-12	8.39769	−25.83820	1.27	0.67	3.0	*S*	11–11	14–17	0
23672	IC 2375	8.43881	−13.30300	1.28	0.70	3.0	*S*	17–14	40–27	0.1
23992	ESO 562-14	8.55493	−17.95650	1.15	0.64	3.0	*N*	9–10	34–45	0.05
23997	NGC 2613	8.55626	−22.97330	1.85	0.62	3.2	?	c	-	-
24225	ESO 563-3	8.62196	−20.93980	1.21	0.65	0.4	-	0–0	-	-
24479	ESO 563-14	8.71596	−20.05070	1.38	0.66	6.5	?	c	-	-
24685	ESO 563-21	8.78801	−20.03590	1.48	0.81	4.1	*S*	3–5	-	0.25
25400	ESO 60-24	9.04451	−68.22650	1.46	0.78	2.9	*S*	2–5	-	0.43

Table 1. continued.

pgc	galaxy-name	al2000	de2000	logd25	logr25	*t*	*N/S*	*(wa)*E–W (°)	β (°)	$\alpha_{\rm s}$
25886	MCG-1-24-1	9.18087	−8.88820	1.63	0.63	3.3	S	5-5	-	0
25926	ESO 564-27	9.19844	−20.11760	1.65	0.94	6.1	*S*	2–2	-	0
26561	IC 2469	9.38368	−32.45070	1.75	0.68	1.9	*N*	6–6	11–15	0
26632	ESO 433-19	9.40089	−28.17720	1.15	0.76	0.8	-	0–0	-	-
27135	ESO 373-8	9.55577	−33.03250	1.76	0.81	6.0	-	0–0	-	-
27468	ESO 373-13	9.63908	−33.86110	1.13	0.81	0.2	*U*	4–4	8–8	0
27735	MCG-1-25-22	9.70339	−4.71400	1.28	0.66	4.0	*N*	7–7	16–16	0
27982	NGC 2992	9.76169	−14.32750	1.56	0.62	1.0	?	?	-	-
28117	ESO 499-5	9.78709	−24.84040	1.41	0.64	5.0	*S*	10–15	31–17	0.2
28246	IC 2511	9.82372	−32.84200	1.50	0.65	1.5	*N*	8–10	18–22	0.1
28283	IC 2513	9.83403	−32.88580	1.49	0.60	2.2	-	0–0	-	-
28308	MCG-2-25-20	9.83718	−12.05720	1.25	0.78	6.8	*LS*	7–0	18–	1
28778	ESO 435-14	9.96341	−28.50670	1.40	0.86	4.9	*N*	5–5	11–14	0
28840	ESO 435-19	9.98502	−30.24980	1.53	0.86	4.7	*U*	4–5	8–8	0.11
28909	IC 2531	9.99880	−29.61540	1.83	0.96	5.0	-	0–0	-	-
29096	ESO 316-18	10.04541	−42.09030	1.40	0.85	4.9	*S*	5–6	-	0.09
29691	NGC 3157	10.19515	−31.64220	1.35	0.62	5.0	-	0–0	-	-
29716	ESO 263-15	10.20551	−47.29430	1.49	0.91	5.8	-	0–0	-	-
29743	ESO 436-1	10.21327	−27.83950	1.50	0.80	4.3	*N*	5–5	-	0
29841	ESO 567-26	10.23436	−21.97680	1.32	0.72	4.1	-	0–0	-	-
30716	ESO 375-26	10.45064	−36.22700	1.30	0.74	4.1	-	0–0	-	-
30887	NGC 3263	10.48691	−44.12300	1.78	0.64	5.9	?	?	-	-
31154	ESO 436-34	10.54559	−28.61290	1.35	0.65	3.0	-	0–0	-	-
31426	IC 624	10.60427	−8.33410	1.41	0.61	1.2	*S*	6–3	11–11	0.33
31626	ESO 437-22	10.63830	−28.88600	1.22	0.63	4.0	?	c	-	-
31677	ESO 437-30	10.65422	−30.29910	1.50	0.73	4.0	*LN*	6–0	9–	1
31723	NGC 3333	10.66387	−36.03610	1.32	0.63	4.3	*LN*	6–0	14–	1
31919	ESO 501-80	10.71052	−23.93550	1.36	0.67	5.0	-	0–0	-	-
31995	ESO 318-4	10.73068	−38.26280	1.45	0.63	5.1	*N*	5–5	18–18	0
32271	NGC 3390	10.80110	−31.53260	1.54	0.73	2.7	*N*	3–4	-	0.14
32328	ESO 264-43	10.81209	−45.42020	1.30	0.64	3.1	-	0–0	-	-
32550	ESO 569-14	10.85682	−19.88890	1.54	0.72	6.3	*LN*	8–0	14–	1
35539	NGC 3717	11.52557	−30.30770	1.78	0.64	3.1	?	?	-	-
35861	NGC 3749	11.59794	−37.99470	1.53	0.60	1.0	*U*	14–14	27–27	0
36315	ESO 571-16	11.70260	−18.16960	1.21	0.66	3.9	*N*	6–3	11–8	0.33
37178	NGC 3936	11.87235	−26.90650	1.60	0.73	4.4	-	0–0	-	-
37243	ESO 379-6	11.88444	−36.63820	1.42	0.90	4.9	*N*	3–2	-	0.2
37271	ESO 440-27	11.88987	−28.55320	1.64	0.83	6.7	*S*	4–3	11–11	0.14
37304	IC 2974	11.89692	−5.16780	1.36	0.69	4.7	*S*	5–5	9–9	0
37334	ESO 320-31	11.90167	−39.86450	1.42	0.88	5.1	-	0–0	-	-
38426	MCG-2-31-17	12.11402	−11.09900	1.31	0.77	6.0	S	7–6	16–10	0.08
38464	IC 3005	12.12049	−30.02330	1.38	0.76	5.6	*N*	3–5	6–9	0.25
38841	ESO 321-10	12.19502	−38.54850	1.31	0.83	0.8	-	0–0	-	-
40023	ESO 380-19	12.36725	−35.79230	1.50	0.76	5.8	-	0–0	-	-
40284	NGC 4348	12.39832	−3.44330	1.49	0.70	4.1	*N*	10–11	18–21	0.05
42684	ESO 268-33	12.70824	−47.55780	1.32	0.71	4.9	-	0–0	-	-
42747	UGC 7883	12.71593	−1.22940	1.42	0.61	6.0	*N*	7–11	13–27	0.22
43021	ESO 507-7	12.76168	−26.24320	1.41	0.82	4.0	-	0–0	-	-

Table 1. continued.

pgc	galaxy-name	al2000	de2000	logd25	logr25	*t*	*N*/*S*	(*wa*)E–W (°)	β (°)	α_s
43224	ESO 507-13	12.80150	−27.57800	1.25	0.62	4.1	*N*	6–6	11–11	0
43313	IC 3799	12.81658	−14.39910	1.40	0.88	6.7	-	0–0	-	-
43330	NGC 4700	12.81883	−11.41060	1.47	0.75	4.9	*N*	8–9	11–18	0.06
43342	NGC 4703	12.82187	−9.10850	1.39	0.69	3.1	-	0–0	-	-
43679	MCG-1-33-32	12.87411	−9.75390	1.39	0.92	6.7	-	0–0	-	-
44254	UGC 8067	12.95337	−1.70690	1.28	0.66	3.5	-	0–0	-	-
44271	NGC 4835A	12.95364	−46.37780	1.43	0.62	5.8	-	0–0	-	-
44358	MCG-1-33-60	12.96300	−9.63360	1.51	0.94	6.7	-	0–0	-	-
44409	NGC 4835	12.96883	−46.26320	1.67	0.69	4.0	?	b	-	-
44931	MCG-1-33-71	13.03043	−8.33620	1.45	0.85	4.9	*N*	8–7	8–9	0.07
44966	ESO 381-51	13.03531	−33.11870	1.19	0.70	2.8	-	0–0	-	-
45006	MCG-3-33-28	13.04054	−17.67920	1.42	0.92	4.9	*N*	5–7	11–21	0.17
45098	ESO 443-42	13.05827	−29.82900	1.46	0.83	3.1	*N*	7–5	17–14	0.17
45127	MCG-1-33-76	13.06291	−5.13370	1.27	0.61	4.9	*N*	6–6	11–11	0
45279	NGC 4945	13.09060	−49.47090	2.31	0.67	6.1	*N*	8–8	18–18	0
45487	ESO 508-11	13.12910	−22.85680	1.48	0.79	6.7	-	0–0	-	-
45911	ESO 576-11	13.21811	−19.97810	1.47	0.79	5.7	-	0–0	-	-
45952	NGC 5022	13.22530	−19.54800	1.38	0.69	3.4	-	0–0	-	-
46441	NGC 5073	13.32241	−14.84440	1.54	0.79	5.0	*S*	6–6	17–15	0
46650	ESO 40-7	13.36095	−77.53510	1.46	0.80	5.1	*N*	2–9	4–14	0.63
46768	IC 4231	13.38707	−26.30050	1.25	0.65	4.3	-	0–0	-	-
46928	ESO 382-58	13.42014	−33.65550	1.41	0.73	3.9	?	c	-	-
47345	ESO 383-5	13.48987	−34.27190	1.52	0.72	3.8	*N*	4–8	11–27	0.33
47394	NGC 5170	13.49692	−17.96620	1.91	0.84	4.9	-	0–0	-	-
47948	ESO 509-74	13.59484	−24.07400	1.40	0.72	4.7	*N*	5–5	11–11	0
48359	ESO 220-28	13.67018	−51.14220	1.31	0.75	4.2	-	0–0	-	-
49106	IRAS 13471-4839	13.83850	−48.90490	1.25	0.72	3.6	*S*	25–25	?	0
49129	ESO 383-91	13.84225	−37.28920	1.41	0.81	6.7	*N*	5–9	11–17	0.29
49190	ESO 384-3	13.85615	−37.62870	1.23	0.67	3.0	*S*	10–9	22–14	0.05
49586	NGC 5365A	13.94436	−44.00730	1.45	0.68	3.0	*N*	5–5	11–8	0
49676	IC 4351	13.96504	−29.31490	1.76	0.69	3.2	*N*	6–7	11–14	0.08
49750	NGC 5365B	13.97766	−43.96420	1.21	0.65	2.0	-	0–0	-	-
49788	ESO 325-42	13.98897	−40.06910	1.21	0.63	3.2	*S*	5–5	-	0
49836	ESO 221-22	14.00347	−48.26770	1.37	0.69	6.8	*S*	2–6	4–8	0.5
50676	NGC 5496	14.19388	−1.15890	1.64	0.69	6.5	S	8–9	39–45	0.06
50798	ESO 271-22	14.22487	−45.41360	1.41	0.73	5.9	-	0–0	-	-
51288	IC 4402	14.35379	−46.29830	1.68	0.69	3.2	?	c	17–11	-
51613	ESO 1-6	14.45741	−87.77160	1.48	0.64	5.9	-	0–0	-	-
52410	IC 4472	14.66980	−44.31610	1.35	0.66	5.0	-	0–0	-	-
52411	ESO 512-12	14.66983	−25.77610	1.45	0.82	3.2	*N*	5–5	16–16	0
52824	ESO 580-29	14.79267	−19.76510	1.34	0.80	4.9	*N*	6–6	11–11	0
52991	ESO 580-41	14.84346	−18.15090	1.30	0.70	4.3	-	0–0	-	-
53361	ESO 327-31	14.92637	−38.27700	1.36	0.74	5.0	-	0–0	-	-
53471	MCG-7-31-3	14.96256	−43.13190	1.18	0.70	4.4	?	?	-	-
54348	ESO 581-25	15.22503	−20.67680	1.54	0.70	6.9	?	c	-	-
54392	ESO 274-1	15.23711	−46.81250	2.05	0.76	6.6	-	0–0	-	-
54637	ESO 328-41	15.30663	−38.50690	1.40	0.69	3.1	*S*	5–7	9–11	0.17
56077	IC 4555	15.80448	−78.17830	1.30	0.64	5.9	-	0–0	-	-

Table 1. continued.

pgc	galaxy-name	al2000	de2000	logd25	logr25	t	*N/S*	*(wa)*E–W (°)	β (°)	α_s
57582	UGC 10288	16.24027	−0.20780	1.68	0.94	5.3	-	0–0	-	-
57876	IC 4595	16.34586	−70.14160	1.49	0.75	5.0	-	0–0	-	-
58742	ESO 137-38	16.68135	−60.39340	1.48	0.60	4.4	?	?	-	-
59635	ESO 138-14	17.11666	−62.08300	1.57	0.80	6.7	-	0–0	-	-
60216	ESO 138-24	17.40184	−59.38210	1.30	0.65	4.9	*S*	9–9	17–17	0
60595	IC 4656	17.62894	−63.72950	1.39	0.61	5.0	-	0–0	-	-
60772	ESO 139-21	17.73619	−60.97850	1.32	0.60	3.0	-	0–0	-	-
62024	IC 4717	18.55492	−57.97400	1.22	0.61	3.0	-	0–0	-	-
62529	ESO 281-33	18.88273	−42.53750	1.24	0.61	3.0	?	?	-	-
62706	IC 4810	19.04974	−56.15860	1.57	0.91	6.6	-	0–0	-	-
62722	NGC 6722	19.06100	−64.89480	1.46	0.67	2.9	*S*	5–5	8–8	0
62782	IC 4819	19.11826	−59.46550	1.47	0.73	6.0	*S*	5–2	8–	0.4
62816	ESO 231-23	19.14551	−51.04600	1.25	0.67	3.0	*U*	6–6	11–14	0
62922	IC 4827	19.22261	−60.86010	1.47	0.68	2.0	*LN*	4–0	8–0	1
62938	IC 4832	19.23426	−56.60900	1.37	0.64	1.3	*N*	9–9	17–17	0
62964	IC 4837A	19.25435	−54.13250	1.62	0.73	3.1	*N*	7–7	15–15	0
63161	ESO 184-63	19.39455	−55.06580	1.36	0.72	2.9	*N*	7–6	21–22	0.08
63297	ESO 184-74	19.50854	−57.28420	1.25	0.70	2.9	?	b	-	-
63395	IC 4872	19.59511	−57.51840	1.51	0.76	6.7	*S*	2–3	–11	0.2
63509	ESO 142-30	19.67763	−60.04800	1.26	0.67	4.9	?	b	-	-
63577	IC 4885	19.73113	−60.65150	1.29	0.64	4.9	*S*	7–7	11–11	0
64180	ESO 105-26	20.15782	−66.21610	1.18	0.64	4.2	?	?	-	-
64240	NGC 6875A	20.19888	−46.14380	1.47	0.70	4.2	?	b	-	-
64597	IC 4992	20.39088	−71.56520	1.34	0.88	5.1	*S*	3–3	8–8	0
65665	IC 5054	20.89587	−71.02410	1.32	0.62	1.1	?	?	-	-
65794	ESO 286-18	20.96403	−43.37390	1.42	0.79	3.8	*U*	6–2	9–3	0.5
65915	IC 5071	21.02221	−72.64490	1.53	0.67	4.8	*N*	6–6	39–23	0
66064	ESO 235-53	21.08624	−47.78900	1.39	0.67	3.0	*N*	9–9	22–22	0
66101	ESO 235-57	21.10602	−48.16920	1.37	0.69	3.9	-	0–0	-	-
66530	IC 5096	21.30611	−63.76130	1.50	0.71	4.0	*N*	8–4	18–11	0.33
66545	ESO 145-4	21.31419	−57.64030	1.34	0.61	5.0	?	b	-	-
66617	ESO 287-9	21.35448	−46.15240	1.25	0.73	4.3	-	0–0	-	-
66836	NGC 7064	21.48398	−52.76610	1.52	0.76	5.3	-	0–0	-	-
67045	NGC 7090	21.60794	−54.55740	1.89	0.77	5.1	-	0–0	-	-
67078	ESO 287-43	21.63656	−43.93260	1.30	0.77	6.1	-	0–0	-	-
67158	ESO 531-22	21.67475	−26.52590	1.44	1.02	4.4	*S*	?–4	–11	-
67782	ESO 288-25	21.98822	−43.86700	1.40	0.90	4.1	-	0-0	-	-
67904	NGC 7184	22.04401	−20.81320	1.78	0.65	4.5	*N*	3–3	9–9	0
68223	IC 5171	22.18238	−46.08210	1.38	0.61	3.8	*N*	6–6	11–11	0
68329	NGC 7232A	22.22810	−45.89360	1.33	0.70	2.0	*N*	6–6	14–14	0
68389	IC 5176	22.24848	−66.84810	1.64	0.82	4.3	*N*	3–3	6–6	0
69011	IC 5224	22.50824	−45.99330	1.19	0.61	2.2	-	0–0	-	-
69161	NGC 7307	22.56463	−40.93330	1.55	0.61	5.9	*N*	11–10	31–22	0.05
69539	NGC 7361	22.70498	−30.05800	1.60	0.65	4.6	*S*	5–5	14–14	0
69620	IC 5244	22.73710	−64.04230	1.46	0.73	3.0	*N*	3–2	8–4	0.2
69661	NGC 7368	22.75876	−39.34150	1.48	0.75	3.1	*N*	9–6	18–14	0.2
69707	IC 5249	22.78511	−64.83150	1.59	1.07	6.8	-	0–0	-	-
69967	NGC 7400	22.90582	−45.34670	1.41	0.63	4.0	-	0–0	-	-

Table 1. continued.

pgc	galaxy-name	al2000	de2000	logd25	logr25	t	*N/S*	*(wa)*E–W (°)	β (°)	α_s
70025	NGC 7416	22.92829	−5.49650	1.50	0.68	3.0	*S*	4–4	9–9	0
70070	IC 5269B	22.94356	−36.24970	1.58	0.72	5.6	-	0–0	-	-
70081	IC 5264	22.94796	−36.55430	1.39	0.72	2.4	*N*	5–5	16–16	0
70084	MCG-2-58-11	22.94754	−8.96760	1.31	0.67	4.7	*S*	7–4	16–8	0.27
70142	IC 5266	22.97244	−65.12970	1.24	0.61	3.1	-	0–0	-	-
70324	NGC 7462	23.04623	−40.83400	1.62	0.71	4.1	-	0–0	-	-
71309	ESO 291-24	23.39472	−42.40210	1.22	0.61	5.0	?	?	-	-
71800	IC 5333	23.58140	−65.39590	1.24	0.71	3.4	*LN*	7–0	22–	1
71948	ESO 240-11	23.63039	−47.72630	1.74	0.92	4.8	-	0–0	-	-
72178	ESO 292-14	23.70990	−44.90460	1.43	0.88	6.5	*N*	2–5	6–11	0.43

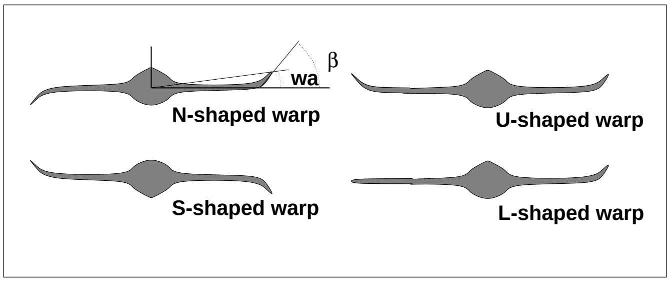

Fig. 1. Definitions of angles and types of warps.

east. *W*, the side of the galaxy closer to the west. In this column, c indicates the presence of noticeable corrugations, and b means that the observed apparent warps could actually be arms. These are not included as true warps.

The angle β in Col. 10 is the angle between the outermost detected point and the point where the warp starts (see Fig. 1).

Finally, Col. 11 gives α_s, the degree of asymmetry, defined as

$$\alpha_s = \frac{|wa(\mathrm{E}) - wa(\mathrm{W})|}{wa(\mathrm{E}) + wa(\mathrm{W})}. \tag{1}$$

The catalog for lenticular galaxies is presented independently in Table 2. In this case, we have considered 26 galaxies with the same limits as those used for spiral galaxies. In addition, galaxies with logr25 > 0.57 were considered. This enlarged the sample by another 12 lenticulars. This sample is complete with the above-mentioned limits.

3. Basic results

Figure 2 gives the distribution of types of warped spiral galaxies, together with the distribution of types for the complete (warped + unwarped) sample. Neither differs significantly from the general distribution of all spirals. The two distributions are so similar, differing only in the size of the sample, that it can be clearly concluded that for spiral galaxies the frequency of warps is completely independent of the type.

The degree of warping is independent of the type, both as defined by the warp angle *(wa)* (see Fig. 3) and the angle β (see Fig. 4). This important property was pointed out by Reshetnikov & Combes (1999).

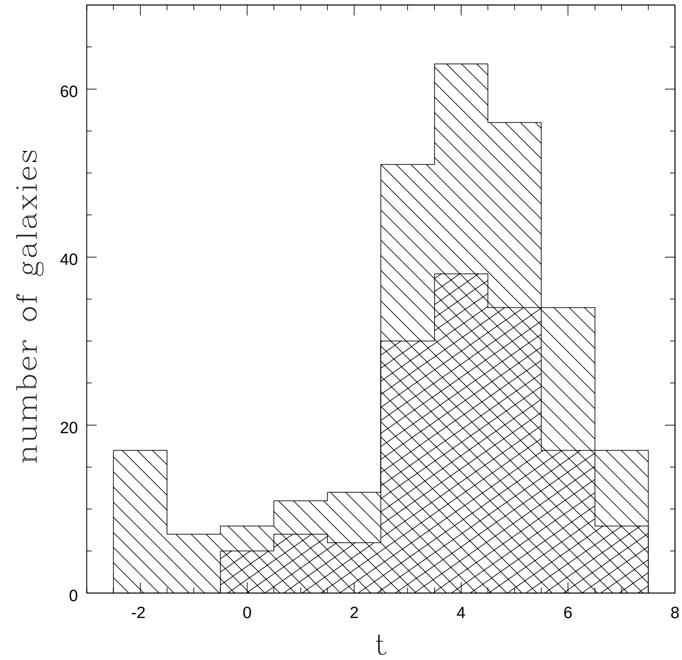

Fig. 2. Distribution of types of warped spiral and lenticular galaxies. Lined shadow area represents all galaxies (warped and unwarped). Squared shadow area represents warped galaxies.

In the case of lenticular galaxies, the result is noticeably different, however. None of the 38 lenticular galaxies in our sample is warped. Warping distorts discs with a similar frequency and amount for $t > 0$, but the transition at $t = 0$ is very sharp for this feature. This fact could be interpreted in two ways.

Firstly, the lenticular dominant bulges could hamper the formation of warps. There is no obvious theoretical argument favoring this interpretation. On the other hand, the fact that all types of spirals have the same warp frequency and as the size of the bulge is a decreasing function of type, the bulge mass seems to have a small influence on the magnitude of the warp. Therefore, it might be suggested that for a galaxy to be warped it must have large amounts of gas.

Figure 5 shows the relation between *wa* and β, which gives some geometrical characteristics of the warp. For moderate warps, there is a clear correlation between *wa* and β, as

Table 2. Sample of lenticular galaxies.

pgc	galaxy-name	al2000	de2000	logd25	logr25	*t*	*N/S*
5210	NGC 530	1.41159	−1.58770	1.24	0.58	−0.3	-
5430	NGC 560	1.45706	−1.91310	1.30	0.57	−2.4	-
6117	NGC 643	1.65349	−75.01100	1.22	0.60	−0.2	-
12662	ESO 301-9	3.38191	−42.18790	1.30	0.69	−1.7	-
13169	NGC 1355	3.55654	−4.99880	1.20	0.61	−2.1	-
13241	ESO 548-47	3.57875	−19.02900	1.40	0.60	−0.8	-
13277	IC 335	3.59187	−34.44660	1.37	0.58	−1.6	-
14495	NGC 1529	4.12195	−62.89900	1.10	0.58	−2.2	-
15388	IC 2085	4.52344	−54.41690	1.35	0.64	−1.2	-
19811	NGC 2310	6.89821	−40.86220	1.62	0.74	−1.9	-
24195	ESO 562-23	8.60971	−20.47010	1.36	0.61	−0.9	-
24966	ESO 371-26	8.90906	−32.93740	1.49	0.68	−1.5	-
25202	ESO 90−12	8.97290	−66.72830	1.34	0.62	−1.8	-
25943	ESO 433-8	9.20360	−30.91120	1.32	0.66	−1.9	-
30177	NGC 3203	10.32623	−26.69820	1.45	0.65	−1.3	-
30792	NGC 3250D	10.46610	−39.81490	1.24	0.71	−1.9	-
30938	IC 2584	10.49771	−34.91160	1.16	0.57	−2.0	-
31369	MCG-2-27-9	10.59093	−14.12990	1.32	0.58	−1.0	-
31504	ESO 437-15	10.61611	−28.17810	1.33	0.58	−2.0	-
36417	NGC 3831	11.72187	−12.87700	1.38	0.60	−0.8	-
37326	NGC 3957	11.90028	−19.56820	1.49	0.64	−1.0	-
42486	NGC 4603C	12.67865	−40.76350	1.24	0.59	−2.0	-
43929	NGC 4784	12.91030	−10.61300	1.19	0.60	−1.8	-
45650	MCG-3-34-4	13.16221	−16.60210	1.35	0.59	−1.0	-
46081	NGC 5038	13.25063	−15.95170	1.19	0.62	−1.9	-
46150	NGC 5047	13.26347	−16.51940	1.43	0.71	−2.0	-
46166	NGC 5049	13.26648	−16.39550	1.28	0.64	−2.0	-
46525	NGC 5084	13.33799	−21.82700	2.03	0.60	−1.8	-
49006	ESO 445-42	13.81359	−31.15510	1.14	0.74	−0.4	-
49300	ESO 445-65	13.87963	−29.92950	1.18	0.62	−2.2	-
49840	ESO 384-26	14.00407	−34.03760	1.19	0.57	−1.9	-
50242	IC 4333	14.08889	−84.27290	1.20	0.62	−1.8	-
62692	NGC 6725	19.03230	−53.86470	1.36	0.65	−2.0	-
63039	ESO 184-53	19.30533	−53.47730	1.10	0.60	−1.8	-
63049	NGC 6771	19.31105	−60.54560	1.37	0.64	−1.0	-
65055	ESO 234-53	20.60682	−49.25780	1.28	0.59	−2.0	-
66908	ESO 47-34	21.52875	−76.48040	1.21	0.66	−2.0	-
69638	NGC 7359	22.74651	−23.68700	1.35	0.58	−1.8	-

expected. However, for very large values of β, wa remains constant. Actually, a threshold value for wa seems to exist at around 14°. The farther away the warp starts, the steeper it rises. Theoretical work should pay attention to this fact.

Asymmetry seems to be unrelated to the morphological type. Figure 6 shows that no large asymmetric warps are found in early types, but as the frequency of these early types is much lower, this result cannot be considered significant.

The frequency of warps is summarized in the following table:

Total frequency of warped spiral galaxies

Total frequency of warps 60%

Within warped galaxies, the frequencies are:

N	*S*	*L*	*U*
50%	38%	5%	7%

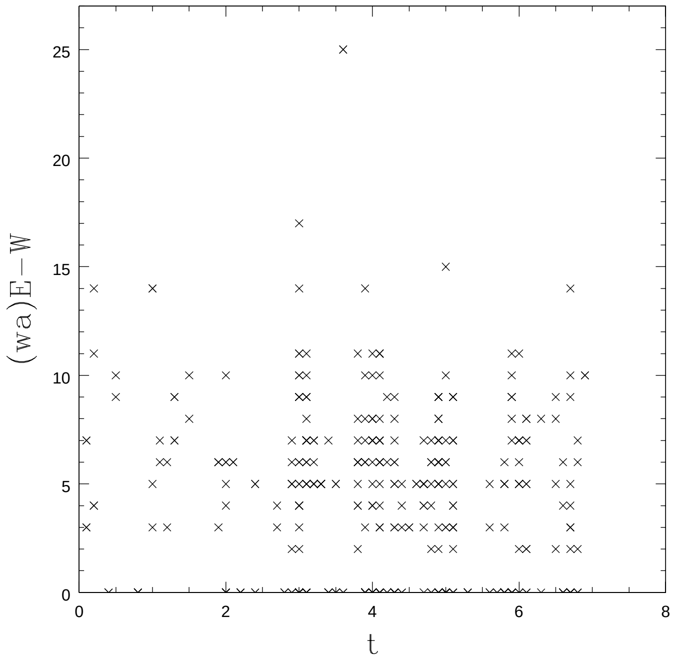

Fig. 3. Warp angle versus type.

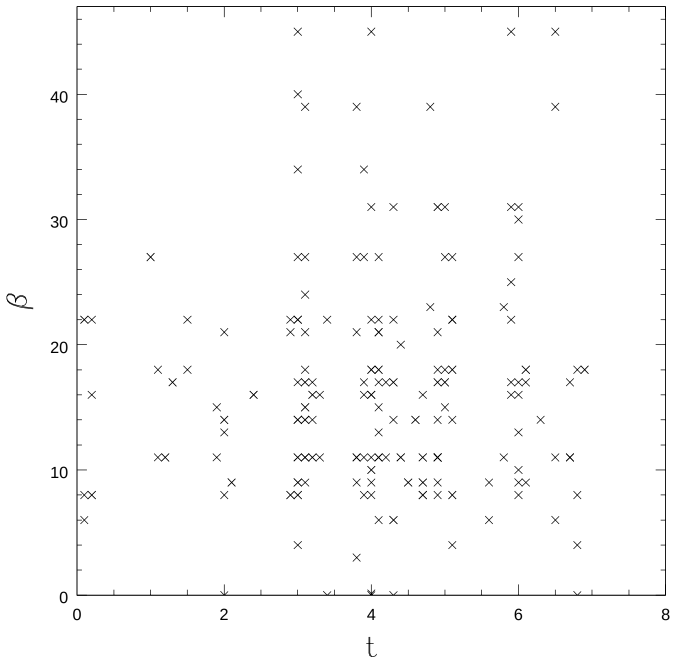

Fig. 4. Angle β versus type.

The N and S frequencies are similar, as expected, as these characteristics depend on the observer rather than on the galaxy. The difference, 50% and 38%, is not significant (it is within the statistical errors). The frequency of U warps is a parameter of theoretical importance, however, the different scenarios predicting different values. As stated by Castro-Rodríguez et al. (2002) an L warp, or even any asymmetric warp can be interpreted as a (N+U) or as a (S+U) warp.

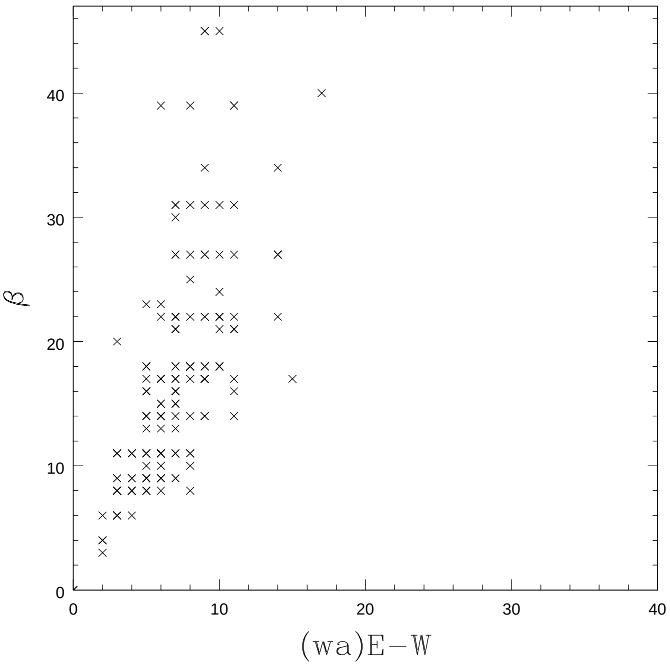

Fig. 5. Relation between wa and β.

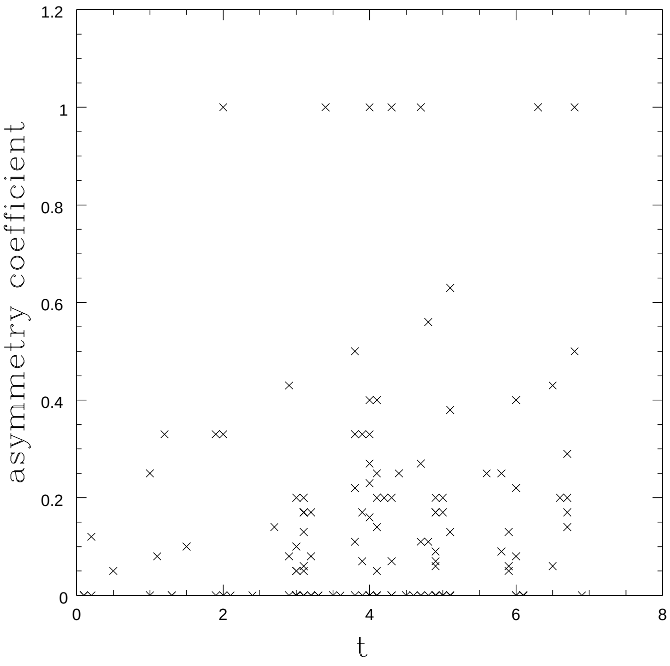

Fig. 6. Asymmetry coefficient versus type.

4. Conclusions

1. This catalog contains a large sample of warped galaxies (150), covering the complete southern hemisphere. We present the whole sample of 250 spirals and 26 lenticulars, with limits logr25 > 0.60, $B_t < 14.5$, $\delta < 0°$, $-2.5 < t < 7$. It is especially suitable for statistical analysis and, indeed, has already been used to study the relation between intrinsic parameters and warps by Castro-Rodríguez et al. (2002). The catalog may obviously be used to choose which galaxies are to be observed in detail.

2. There is the unavoidable problem of the existence of other contaminant effects that could present the appearance of warps. Reshetnikov & Combes (1998) estimated that about 20% of the features assumed to be warps could actually be spiral arms. This value could be applied here. This effect introduces small errors into our calculated frequencies, which should be taken into account in statistical studies.
3. We confirm that warps appear to be a universal feature in spiral galaxies. The frequency of warps is very high (60%), and because of the difficulty (or impossibility) of detecting warps with the line of nodes in the plane of sky, it is concluded that most (if not all) galaxies are warped. Bosma (1981), Sánchez-Saavedra et al. (1990) and Reshetnikov & Combes (1999) previously reached this conclusion.
4. We also confirm, by means of a larger amount of data, the finding by Reshetnikov & Combes (1999) that warps are equally present in all types of spirals. The distribution of warps for the different types of spirals coincides with the distribution of galaxies with type. The maximum observed warp angle either from the center (*wa*) or from the starting radius of the warps (β) has no relation with the type of spiral. We have observed that very large values of β do not correspond to large warp angles of *wa*. Shorter warps are steeper.
5. We found no warped lenticular galaxies at all among the 26 galaxies within our limits, with logr25 > 0.60. We enlarged the sample to reach logr25 > 0.57 and again, none of the 38 lenticulars was warped. There is a sudden transition at $t = 0$. All spirals are warped; no lenticular is warped. The main difference between spirals and lenticulars is probably that the former are gas rich and the latter gas poor. Gas seems to be a necessary ingredient in the warp mechanism. Models based on gravitation alone would have serious difficulties in explaining this.

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References

Battaner, E., Florido, E., & Sánchez-Saavedra, M. L. 1990, A&A, 236, 1
Battaner, E., Garrido, J. L., Sánchez-Saavedra, M. L., & Florido, E. 1991, A&A, 251, 402
Binney, J. J. 1992, ARA&A, 30, 51
Bosma, A. 1981, AJ, 86, 1791
Castro-Rodríguez, N., López-Corredoira, M., Sánchez-Saavedra, M. L., & Battaner, E. 2002, A&A, 391, 519
Dubinski, J., & Kuijken, K. 1995, ApJ, 442, 492
Florido, E., Prieto, M., Battaner, E., Mediavilla, E., & Sánchez-Saavedra, M. L. 1991, A&A, 242, 301
García-Ruíz, I. 2001, Ph.D. Thesis, Groningen University
García-Ruíz, I., Kuijken, K., & Dubinski, J. 2000, MNRAS, submitted, preprint [`astro-ph/0002057`]
de Grijs, R. 1997, Ph.D. Thesis, Groningen University
Jiménez-Vicente, J. 1998, Ph.D. Thesis, Granada University
Jiménez-Vicente, J., Porcel, C., Sánchez-Saavedra, M. L., & Battaner, E. 1998, Ap&SS, 253, 225
Kahn, F. D., & Woltjer, L. 1959, AJ, 130, 705
Kuijken, K., & García-Ruíz, I. 2001, Galaxy Disks and Disk Galaxies, ed. J. G. Funes, S. J., & E. M. Corsini, ASP Conf. Ser., 230, 401
López-Corredoira, M., Betancort, J. A., & Beckman, J. 2002, A&A, to be published
Ostriker, E. C., & Binney, J. J. 1989, MNRAS, 237, 785
Reshetnikov, V., & Combes, F. 1998, A&A, 337, 9
Reshetnikov, V., & Combes, F. 1999, A&A, 138, 101R
Reshetnikov, V., Battaner, E., Combes, F., & Jiménez-Vicente, J. 2002, A&A, 382, 513
Sánchez-Saavedra, M. L., Battaner, E., & Florido, E. 1990, MNRAS, 246, 458
Sancisi, R. 1976, A&A, 53, 159
Schwarzkopf, U., & Dettmar, R. J. 2001, A&A, 373, 402
Sparke, L., & Casertano, S. 1988, MNRAS, 234, 873
Weinberg, M. D. 1998, MNRAS, 299, 499