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Inner rings in disc galaxies: dead or alive

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ABSTRACT

In this *Letter*, I distinguish "passive" inner rings as those with no current star formation as distinct from "active" inner rings that have undergone recent star formation. I built a sample of nearby galaxies with inner rings observed in the near- and mid-infrared from the NIRS0S and the S^{4}G surveys. I used archival far-ultraviolet (FUV) and Hα imaging of 319 galaxies to diagnose whether their inner rings are passive or active. I found that passive rings are found only in early-type disc galaxies ($-3 \leq T \leq 2$). In this range of stages, 21 ± 3% and 28 ± 5% of the rings are passive according to the FUV and Hα indicators, respectively. A ring that is passive according to the FUV is always passive according to Hα, but the reverse is not always true. Ring-lenses form $30 - 40$% of passive rings, which is four times more than the fraction of ring-lenses found in active rings in the stage range $-3 \leq T \leq 2$. This is consistent with both a resonance and a manifold origin for the rings because both models predict purely stellar rings to be wider than their star-forming counterparts. In the case of resonance rings, the widening may be at least partly due to the dissolution of rings. If most inner rings have a resonance origin, I estimate 200 Myr to be a lower bound for their dissolution time-scale. This time-scale is of the order of one orbital period at the radius of inner rings.

Key words. Galaxies: evolution – Galaxies: kinematics and dynamics – Galaxies: spiral – Galaxies: statistics

1. Introduction

Gas in disc galaxies is redistributed by angular momentum transfer caused by nonaxisymmetries with a given pattern speed such as bars, ovals, and spiral arms. Some of the gas is collected in orbits near dynamical resonances under the influence of the torques caused by the nonaxisymmetries (for a recent review on barred galaxy dynamics see Athanassoula 2012a). Owing to star formation triggered by the high gas density and by gas travelling in intersecting orbits at each side of the resonance, rings and pseudorings are often formed there (Schwarz 1981, 1984). Historically, this picture has been used to explain resonance rings and pseudorings, but recently an alternative model, called the flux tube manifold theory or manifold theory, postulated that at least some of them are caused by gas and/or stars trapped in tubes of orbits that connect the Lagrangian points at the end of the galaxy bars (Romero-Gómez et al. 2006, 2007; Athanassoula et al. 2009b,a, 2010; Athanassoula 2012b). Another alternative ring formation mechanism is that developed by Kim et al. (2012) for nuclear rings (not studied here), where rings are formed due to the centrifugal barrier encountered by gas migrating to inner regions of the galaxy. In this *Letter*, the word rings is used to refer to both rings and pseudorings.

In the classical resonance theory and also in the manifold theory, inner rings in barred galaxies have a diameter slightly larger than the bar length. In the classic resonance theory they are associated to the ultraharmonic 4:1 resonance. In this *Letter*, broad features intermediate between inner lenses and inner rings, called ring-lenses, are accounted for alongside inner rings. Simulations by Rautiainen & Salo (2000) showed that inner rings, although changing in shape and size, are long-lived, provided there is a gas inflow to feed them. In the manifold theory they are also long-lived as long as the galaxy potential does not evolve, or does so slowly (Athanassoula et al. 2010).

"Passive" inner rings are here those not found to host star formation. In the context of nuclear rings, passive rings have also been called fossil rings (Erwin et al. 2001). As opposed to passive features, "active" rings are those with indications of recent star formation. An example of a passive inner ring in the literature is that in NGC 7702 (Buta 1991). Here, I study inner rings identified in two infrared surveys of nearby galaxies, namely the Spitzer Survey of Stellar Structure in Galaxies (S^{4}G; Sheth et al. 2010) and the Near-InfraRed atlas of S0-Sa galaxies (NIRS0S; Laurikainen et al. 2011). The S^{4}G is a survey of 2352 nearby galaxies in 3.6 and 4.5μm using the *Spitzer* Space Telescope and NIRS0S is a K_s-band ground-based survey of 206 early-type galaxies. To investigate whether rings are passive or active, I used archival images in one band and one line that trace recent star formation, namely the far-ultraviolet (FUV) and Hα.

This *Letter* is structured as follows. In Section 2, I present the sample, the data, and the image processing. Then, I present the results in Section 3 and discuss them in Section 4. The conclusions are summarized in Section 5.

2. Data selection and processing

I mainly based my sample of galaxies with inner rings on the classification of S^{4}G galaxies made by Buta et al. (2013) and statistically studied in the Atlas of Resonance (pseudo)Rings As Known In the S^{4}G (ARRAKIS; Comerón et al. 2013). Since the S^{4}G sample is biased against galaxies with a small gas fraction, which are mostly elliptical and S0 galaxies, I also included NIRS0S galaxies with inner rings that matched the S^{4}G selection criteria, namely galactic latitude $|b| > 30^{o}$, radial velocity

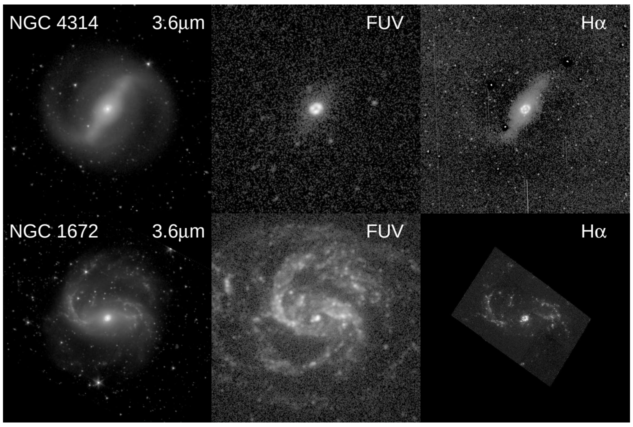

Fig. 1. NGC 4314 (top row) is an (R$'_1$)SB(rl,nr)a galaxy (Buta et al. 2013) with a passive inner ring-lens. NGC 1672 (bottom row) is an (R′)SA$\underline{\text{B}}$(rs,nr)b galaxy (Buta et al. 2013) whose inner pseudoring is still forming stars. In the first case the inner feature does not emit in the FUV and Hα. There is a significant amount of emission in these bands for the active inner feature. The prominent ring feature in NGC 4314 is a nuclear ring. The 3.6 μm images are from the S^{4}G, the FUV images come from GALEX's NGS survey, and the Hα images come from Knapen et al. (2004) and the HLA.

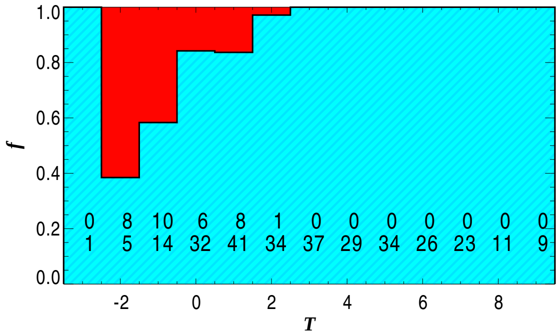

Fig. 2. Fraction of active and passive inner rings (blue hatched and red plain surfaces, respectively) according to the FUV indicator as a function of the galaxy stage for galaxies in the sample with available GALEX imaging. The bottom row of numbers indicate the number of active rings for a given stage and the top row indicates the number of those that are passive.

$v_{\rm r} < 4000\,{\rm km\,s^{-1}}$, angular diameter $D_{25} > 1'$, and integrated blue magnitude $m_{\rm B} < 15.5$ mag (data obtained from HyperLeda; Paturel et al. 2003). S^{4}G and NIRS0S data can be mixed safely because the detection of inner rings in the S^{4}G matches that in NIRS0S very well (Section 5.10 in ARRAKIS). I also included NGC 2950, an S0 non-S^{4}G galaxy appearing in the same frame as a genuine S^{4}G galaxy which also fulfils the selection criteria.

To avoid dust absorption, ring foreshortening, and poor angular resolution problems, I additionally constrained the sample by only selecting disc galaxies (Hubble stage $-3 \leq T \leq 9$) with an ellipticity lower than $\epsilon_{\rm d} = 0.5$ according to the data of the Pipeline 4 of S^{4}G (Salo et al. 2013) and with inner rings with a radius larger than 10″ according to ARRAKIS or NIRS0S. The total number of galaxies fulfilling these conditions is 357.

Two indicators were used to search for recent star formation: the far-ultraviolet continuum and Hα-line emission.

The ultraviolet continuum traces star formation that has occurred in the past 100 Myr (Kennicutt 1998). To study inner rings in that wavelength, I downloaded the deepest available FUV-band image in the GALEX GR6/7 Data Release[1] for each galaxy. Such images were available for 319 out of the 357 galaxies initially included in the sample. These 319 galaxies are the final sample I worked with. For 160 galaxies, the FUV images belong to the GALEX All-Sky Imaging Survey (AIS), which consists of ~ 100 s exposures and can detect point sources down to $\mu_{\rm AB} \sim 20\,{\rm mag\,arcsec^{-2}}$. The other galaxies were imaged in deeper GALEX surveys and were in general exposed for 1000 s or more.

The Hα emission traces star formation that has occurred in the past 20 Myr (Kennicutt 1998). Hα continuum-subtracted images used here come from three sources:

– Images processed for the Atlas of Images of NUclear Rings (AINUR; Comerón et al. 2010). The images in AINUR come mostly from the *Hubble* Space Telescope (HST) Archive[2].
– HST images not processed for AINUR. In these cases, Hα narrow-band images and red continuum images were downloaded from the *Hubble* Legacy Archive[3] (HLA) and were used to produce a continuum-subtracted image using the technique described in Knapen et al. (2004, 2006).
– Continuum-subtracted images in the NASA/IPAC Extragalactic Database (NED)[4].

Hα images were available for 139 out of the 319 sample galaxies.

For each sample galaxy I verified in the FUV and Hα continuum-subtracted images whether the rings detected in S^{4}G or NIRS0S images were visible. A detection was considered to be positive if at least a segment of the ring was seen. In some doubtful cases with shallow AIS FUV images, this was only possible after smoothing the image with a Gaussian kernel with a 3-pixel (4.5″) radius. Positive detections are labelled as "A" for "active" and negative detections are labelled as "P" for "passive" in Table A.1. In doubtful cases, a "?" sign is added to the detection status. From now on, I refer to positive and negative detections as active and passive rings, respectively. This definition means that some rings may be passive in one of the studied indicators but active in the other. Examples of galaxies with passive and active inner rings are shown in Figure 1. A total of 329 inner rings in the 319 sample galaxies were analysed.

3. Results

Out of 329 inner rings, 33 were found not to have FUV emission (Figure 2). All of them are in the stage range $-3 \leq T \leq 2$. The fraction of passive inner rings in this range of stages according to the FUV star formation indicator is 21 ± 3% with the error bar calculated using binomial statistics. Rings hosted in early-type galaxies are more likely to be passive than those in later types (Table 1). I verified whether non-detections may be partly caused by the use of shallow AIS images by recalculating the statistics

[1] http://galex.stsci.edu/GR6/

[2] http://archive.stsci.edu/hst/search.php
[3] http://hla.stsci.edu/hlaview.html
[4] http://ned.ipac.caltech.edu/

Table 2. Fraction of passive and active inner features with a given morphology as classified in Buta et al. (2013) for different star formation indicators in galaxies with $-3 \leq T \leq 2$.

Indicator	rl, rl, rl, r′l, r′l, r′l		r		rs, rs, rs	
	P	A	P	A	P	A
FUV	39 ± 9%	9 ± 3%	33 ± 7%	35 ± 4%	27 ± 8%	56 ± 4%
FUV (Hα)	36 ± 15%	9 ± 4%	36 ± 15%	32 ± 6%	27 ± 13%	60 ± 6%
Hα	32 ± 11%	6 ± 3%	32 ± 11%	33 ± 7%	37 ± 11%	61 ± 7%

Notes. P and A stand for passive and active rings, respectively. FUV (Hα) stands for the FUV statistics assembled from galaxies with available Hα images.

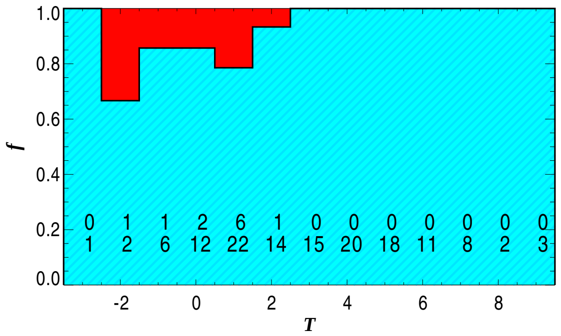

Fig. 3. Fraction of active and passive inner rings according to the FUV indicator as in Figure 2, but now for inner rings in galaxies that have both FUV and Hα imaging available.

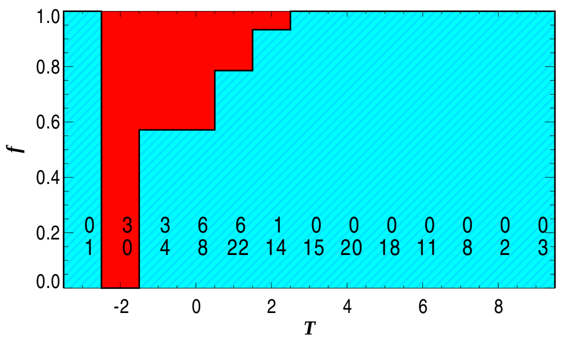

Fig. 4. As Figure 2, but now using Hα emission as an indicator on whether inner rings are passive or active.

with deep GALEX images only (Table 1) and found that the results based on those two samples are compatible within the error bars, which indicates that rings with recent star formation can be detected even in relatively shallow FUV images.

Because Hα imaging is only available for a part of the sample, I reproduced the plot for the FUV inner ring emission in Figure 2 by using only FUV data that correspond to galaxies for which Hα is available (Figure 3 and Table 1). This is used below to compare the fraction of passive inner rings according to the FUV and Hα indicators.

Figure 4 and Table 1 show the fraction of passive inner rings according to the Hα indicator. This fraction is equal to or larger than that of passive rings according to the FUV for all stages ($28 \pm 5\%$ of passive rings in the range $-3 \leq T \leq 2$ where all passive rings are found). This is because none of the rings lacking FUV emission have Hα emission, whereas the reverse is not always true.

Table 1. Fraction of passive rings according to different star formation indicators and for different Hubble stage ranges

Indicator	All types	S0	Early sp.	Late sp.
	$-3 \leq T \leq 9$	$-3 \leq T \leq 0$	$1 \leq T \leq 2$	$3 \leq T \leq 9$
FUV	10 ± 2%	32 ± 5%	11 ± 3%	0%
Deep FUV	13 ± 3%	36 ± 8%	15 ± 5%	0%
FUV (Hα)	8 ± 2%	16 ± 7%	16 ± 6%	0%
Hα	13 ± 3%	48 ± 10%	16 ± 6%	0%

Notes. Deep FUV stands for GALEX FUV imaging excluding images from the AIS survey. FUV (Hα) stands for the FUV statistics assembled from galaxies with available Hα images.

While in the range of stages $-3 \leq T \leq 2$ the fraction of active inner features classified as ring-lenses is one in ten or less, 30 – 40% of the passive inner features are ring-lenses (Table 2). Regarding inner features that are not classified as ring-lenses, inner closed rings are equally frequent among the passive and the active rings (∼ 30 – 40%), but pseudorings are less frequent among passive features than among active ones (∼ 30% vs ∼ 60%).

The passive or active status of a ring does not depend on the family (bar properties) of the host galaxy. Unbarred galaxies (SA) account for ∼ 30% of host galaxies for both passive and active rings in the stage range $-3 \leq T \leq 2$.

4. Discussion

As seen in Section 1, two mechanisms have been proposed for the formation of inner rings, namely the resonance and the manifold ones. I consider the resonance mechanism first.

If inner rings are the consequence of the star formation in gas gathered in orbits near resonances, one may expect that once the gas is exhausted, the ring will fade-out and disappear because of two factors. First, bright stars with a low mass-to-light ratio will die after several Myr. Second, radial migration will cause the ring to widen. Both effects would lower the surface brightness of the ring and will tend to make it indistinguishable from the stellar background of the galaxy. Of course, active rings may also have populations of old stars widened by radial migration, but they are likely to be outshone by the regions with recent star formation and thus would appear very sharp.

One piece of evidence that might indicate that rings become wider as they die is that as seen in Table 2, ring-lenses are roughly four times more frequent among passive features than among active features. It is unclear, however, whether the full width of ring-lenses can be explained by the radial migration of stars in passive rings. Alternatively, ring-lenses may form as a response of the old stellar population to the bar potential.

Under the assumption that the resonance scenario applies, an estimate of the dissolution time-scale of rings can be made from the data presented here and by knowing that Hα emission outlasts star formation by $\sim 20\,$Myr and FUV emission outlasts star formation by $\sim 100\,$Myr (Kennicutt 1998). The subsample of galaxies with both Hα and FUV imaging includes 19 rings without Hα emission. Eleven of those rings have no FUV emission. This means that eight rings stopped forming stars between 20 and 100 Myr ago, and the remainder stopped forming stars longer than 100 Myr ago. Assuming that the fraction of dissolving inner rings has been roughly constant for the past few hundreds of Myr, one can deduce that the ring dissolution time-scale is $\sim 200\,$Myr. This is a time of the order of an orbital period at the radius of inner rings.

However, this $\sim 200\,$Myr estimated dissolution time-scale is a lower limit to the true dissolution time-scale. First, rings may form stars intermittently in recurrent episodes. It is therefore reasonable to assume that some of the passive rings may actually be reactivated at some point by some gas inflow. Such periodic activity has been reported in nuclear rings (Allard et al. 2006; Sarzi et al. 2007). Episodic star formation seems more likely in rings that have stopped forming stars more recently (those without Hα emission but with FUV emission), hence the dissolution time-scale underestimation. Second, Hα surveys may be biased against galaxies with little or no Hα emission. This would bias the surveys against galaxies with passive rings, and especially against those that cannot be reactivated, because if the galaxy still has some gas reserve that can be transferred to the ring, some residual star formation may remain elsewhere in the galaxy. As a consequence, the fraction of inner rings without either FUV or Hα emission might be underestimated.

In the framework of the manifold theory, passive rings are not necessarily dissolving. Indeed, manifolds can trap both stars and gas, and for galaxies with little or no gas, purely stellar rings are expected. However, it is still natural to expect passive rings to be wider. Indeed, stars can easily occupy the whole manifold phase space, but gas collisions would cause it (and also the younger generations of stars) to fill a smaller space and thus make the rings appear thinner (Athanassoula et al. 2009b). Whether this effect is enough to explain the full difference in width between regular rings and ring-lenses is not yet explored.

A large fraction of inner rings with a manifold origin could significantly change the dissolution time-scale estimated before. At the moment, no estimate is available on the fraction of inner rings caused by manifolds. Their existence is nearly certain, however, because the characteristic morphology of all types of outer rings, as well as the statistics of the shapes and sizes of both inner and outer rings in nearby galaxies, can be explained by the manifold theory (Athanassoula et al. 2009b, 2010). On the other hand, a set of ~ 20 N-body simulations with a fixed potential shows that at least in some cases only a minority of ring particles are trapped in manifolds (P. Rautiainen, private communication). This, however, is not the case for the fully self-consistent simulations of Athanassoula (2012b). Additional study, both observational and numerical, is required to reveal whether manifolds can be easily populated and therefore are a widespread mechanism for shaping galaxy morphology.

In either the resonance or manifold frameworks the lack of passive rings in galaxies with $T \geq 3$ is naturally explained because in both cases, gas is available in these late-type galaxies to populate the orbits near resonances and/or the manifold orbits.

5. Conclusions

I used two indicators of recent star formation to check whether inner rings and pseudorings in a set of 319 nearby disc galaxies are passive (without signs of recent star formation) or active (with signs of recent star formation).

I showed that passive rings are only found in galaxies with stages $-3 \leq T \leq 2$. In that range of stages, $21 \pm 3\%$ and $28 \pm 5\%$ of rings are passive according to the FUV and Hα indicators, respectively. When a ring is passive in the FUV, it is also passive in Hα, but the reverse is not always true. I found that $30 - 40\%$ of passive inner rings are classified as ring-lenses in Buta et al. (2013). On the other hand, only $\sim 10\%$ of active inner rings in the stage range $-3 \leq T \leq 2$ are ring-lenses. Although passive rings in both resonance and manifold theories are expected to be wider than their active counterparts, it is still unclear whether these two theories can account for the full transformation of regular inner rings into wide inner ring-lenses.

I estimate that if most inner rings have a resonance origin, a lower boundary for their dissolution time-scale is 200 Myr. This time-scale is of the order of one orbital period at the radius of inner rings.

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Appendix A: Properties of the inner rings in the sample

Table A.1. Properties of the inner rings in the sample

ID (1)	Family (2)	*T* (3)	Kind (4)	FUV (5)	Survey (6)	Hα (7)
ESO 013-016	SB	6	rs	A	AIS	–
ESO 202-041	SB	9	rs	A	AIS	–
ESO 404-012	SAB	3	$\underline{\mathrm{r}}$s	A	AIS	–
ESO 407-014	SA	2	r	A	MIS	–
ESO 420-009	S$\underline{\mathrm{A}}$B	5	rs	A	AIS	–
ESO 422-005	SB	8	r$\underline{\mathrm{s}}$	A	AIS	–
ESO 440-011	SB	6	rs	A	NGS	–
ESO 443-069	SB	8	rs	A	AIS	–
ESO 479-004	SB	7	r$\underline{\mathrm{s}}$	A	GII	–
ESO 482-035	SB	3	rs	A	AIS	–
ESO 508-007	SA$\underline{\mathrm{B}}$	7	rs	A?	AIS	–
ESO 510-059	SB	5	r$\underline{\mathrm{s}}$	A	AIS	–
ESO 532-022	SB	7	r$\underline{\mathrm{s}}$	A	AIS	–
ESO 547-005	SAB	9	rs	A	MIS	–
ESO 548-005	SAB	8	rs	A	AIS	–
ESO 572-018	SA$\underline{\mathrm{B}}$	3	rs	A	AIS	–
ESO 576-032	SB	5	rs	A	AIS	–
ESO 602-030	SB	7	r$\underline{\mathrm{s}}$	A	AIS	–
IC 0749	SB	6	rs	A	AIS	A
IC 1014	SB	9	r	A	AIS	–
IC 1067	SB	3	r	A	GII	–
IC 1265	SA	0	r	A?	AIS	–
IC 1438	SAB	0	r′l	A	AIS	–
IC 1954	SB	6	r$\underline{\mathrm{s}}$	A	GII	–
IC 2969	SA	7	r	A	AIS	–
IC 3102	SAB	0	$\underline{\mathrm{r}}$s	A	GII	–
IC 3267	SA	1	rs	A	GII	–
IC 4214	S$\underline{\mathrm{A}}$B	0	r′l	A	AIS	–
IC 4237	SB	3	r	A	AIS	–
IC 5240	SB	0	r	A	AIS	A
IC 5267	SA	0	r	A	AIS	–
NGC 0150	SAB	2	r$\underline{\mathrm{s}}$	A	AIS	–
NGC 0210	SAB	2	r′l	A	GII	A
NGC 0255	SB	6	rs	A	AIS	–
NGC 0289	SA$\underline{\mathrm{B}}$	2	rs,$\underline{\mathrm{r}}$s	A,A	MIS	–
NGC 0470	S$\underline{\mathrm{A}}$B	2	r$\underline{\mathrm{s}}$	A	MIS	A
NGC 0473	SA	-1	r	A	AIS	A
NGC 0488	SA	1	rl	P	MIS	P
NGC 0600	SB	7	r$\underline{\mathrm{s}}$	A	AIS	–
NGC 0613	SB	3	$\underline{\mathrm{r}}$s	A	AIS	A
NGC 0658	SA	4	r$\underline{\mathrm{s}}$	A	MIS	A
NGC 0691	SA	2	rs,r	A,A	AIS	A,A
NGC 0701	SB	7	$\underline{\mathrm{r}}$s	A	MIS	–
NGC 0718	SAB	1	rs	P?	AIS	P
NGC 0864	SA$\underline{\mathrm{B}}$	4	r$\underline{\mathrm{s}}$	A	MIS	A
NGC 0908	SA	3	rs	A	GII	–
NGC 0936	SB	-1	$\underline{\mathrm{r}}$s	P	GII	–
NGC 0941	S$\underline{\mathrm{A}}$B	5	r	A	GII	A
NGC 0986	SB	2	rs	A	NGS	A
NGC 1022	SAB	0	$\underline{\mathrm{r}}$s	A	NGS	P
NGC 1073	SB	5	rs	A	GII	A
NGC 1079	S$\underline{\mathrm{A}}$B	-1	$\underline{\mathrm{r}}$s	A	MIS	–
NGC 1087	SB	7	r$\underline{\mathrm{s}}$	A	MIS	A
NGC 1097	SB	3	rs	A	NGS	A
NGC 1179	SA$\underline{\mathrm{B}}$	6	r$\underline{\mathrm{s}}$	A	MIS	A
NGC 1187	SA$\underline{\mathrm{B}}$	4	rs	A	GII	A
NGC 1201	SAB	-2	r′l	P?	AIS	–

Table A.1. continued.

ID (1)	Family (2)	*T* (3)	Kind (4)	FUV (5)	Survey (6)	Hα (7)
NGC 1232	SAB	5	rs	A	AIS	–
NGC 1297	SA	-2	rl	P?	MIS	–
NGC 1310	SB	6	rs	A	NGS	–
NGC 1317	SAB	0	r′l	A	NGS	P
NGC 1326	SAB	-1	r	A	NGS	P
NGC 1350	SAB	0	r	A	NGS	A
NGC 1357	SA	0	$\underline{\mathrm{r}}$s	A	AIS	–
NGC 1365	SB	4	r$\underline{\mathrm{s}}$	A	NGS	–
NGC 1367	SAB	0	rs	A	GII	P
NGC 1385	SB	8	r$\underline{\mathrm{s}}$	A	NGS	–
NGC 1398	SB	1	$\underline{\mathrm{r}}$s	A	GII	A
NGC 1433	SB	1	r	A	AIS	A
NGC 1440	SB	-2	$\underline{\mathrm{r}}$s	P?	AIS	–
NGC 1452	SB	0	r	A?	AIS	–
NGC 1493	SB	5	rs	A	GII	A
NGC 1512	SB	1	r	A	NGS	A
NGC 1553	SA	-1	rl	P	NGS	–
NGC 1566	SAB	3	r′l	A	NGS	A
NGC 1640	SB	1	r	A	AIS	–
NGC 1672	SA$\underline{\mathrm{B}}$	3	rs	A	NGS	A
NGC 2460	S$\underline{\mathrm{A}}$B	1	rs	A	AIS	A
NGC 2523	SB	2	r	A	AIS	–
NGC 2604	SB	5	r$\underline{\mathrm{s}}$	A	MIS	A
NGC 2608	SA$\underline{\mathrm{B}}$	3	r$\underline{\mathrm{s}}$	A	MIS	A
NGC 2633	SAB	3	rs	A	AIS	A
NGC 2681	S$\underline{\mathrm{A}}$B	0	$\underline{\mathrm{r}}$s	A	NGS	P?
NGC 2775	SA	-1	$\underline{\mathrm{r}}$s	A	MIS	A
NGC 2780	SB	1	rs	A	AIS	–
NGC 2782	SA	1	rs	A	NGS	–
NGC 2787	SB	-2	r	A	AIS	P
NGC 2805	S$\underline{\mathrm{A}}$B	5	r$\underline{\mathrm{s}}$	A	AIS	A
NGC 2859	SAB	-1	rl	A?	GII	P
NGC 2906	SA	3	rs	A	MIS	–
NGC 2950	SA$\underline{\mathrm{B}}$	-1	r$\underline{\mathrm{l}}$	P	AIS	P
NGC 2962	S$\underline{\mathrm{A}}$B	-1	rl	P	MIS	–
NGC 2964	S$\underline{\mathrm{A}}$B	3	r$\underline{\mathrm{s}}$	A	NGS	–
NGC 2966	SA$\underline{\mathrm{B}}$	1	r′l	A	MIS	–
NGC 2967	SAB	5	rs	A	MIS	–
NGC 2968	SB	-1	r$\underline{\mathrm{s}}$	P	NGS	–
NGC 2974	SA	0	r	A	GII	–
NGC 3031	SA	1	rs,r	A,P	GII	A,P
NGC 3032	SA	-2	rs,r	P	GII	–
NGC 3061	SAB	3	$\underline{\mathrm{r}}$s	A	AIS	–
NGC 3147	S$\underline{\mathrm{A}}$B	3	r$\underline{\mathrm{s}}$	A	NGS	–
NGC 3166	SB	-1	rl	A	GII	–
NGC 3184	SA	4	r$\underline{\mathrm{s}}$	A	AIS	A
NGC 3185	SAB	1	$\underline{\mathrm{r}}$s	A	NGS	A
NGC 3245	SAB	-2	rs	A?	GII	P
NGC 3344	SAB	4	r	A	NGS	A
NGC 3346	SB	6	rs	A	AIS	–
NGC 3351	SB	1	r	A	NGS	A
NGC 3359	SB	7	rs	A	NGS	A
NGC 3368	SAB	-1	$\underline{\mathrm{r}}$s	A	NGS	A
NGC 3380	SA$\underline{\mathrm{B}}$	0	$\underline{\mathrm{r}}$s	A	AIS	–
NGC 3381	SB	8	r$\underline{\mathrm{s}}$	A	AIS	–
NGC 3455	SA	5	rs	A	GII	–
NGC 3485	SA$\underline{\mathrm{B}}$	3	$\underline{\mathrm{r}}$s	A	GII	A
NGC 3486	SAB	5	r	A	GII	A
NGC 3504	SA$\underline{\mathrm{B}}$	1	$\underline{\mathrm{r}}$s	A	AIS	A
NGC 3513	SB	5	r$\underline{\mathrm{s}}$	A	GII	A

Table A.1. continued.

ID (1)	Family (2)	*T* (3)	Kind (4)	FUV (5)	Survey (6)	Hα (7)
NGC 3547	SB	6	rs	A	GII	–
NGC 3583	SAB	3	rs	A	AIS	–
NGC 3611	SA	1	r	A	MIS	–
NGC 3614	SA	4	r	A	AIS	–
NGC 3637	SB	-1	rl	P?	AIS	–
NGC 3642	SA	2	rl	P?	GII	P?
NGC 3664	SB	9	rs	A	MIS	–
NGC 3673	SAB	1	rs	A	AIS	–
NGC 3681	SAB	1	rs	A	AIS	–
NGC 3683A	SAB	4	rs	A	AIS	–
NGC 3687	SAB	2	rs	A	AIS	–
NGC 3691	SB	9	r	A	AIS	–
NGC 3705	SAB	3	rs	A	AIS	A
NGC 3726	SAB	4	r	A	AIS	A
NGC 3729	SB	0	r	A	GII	A
NGC 3780	SA	4	rs	A	AIS	–
NGC 3782	SB	8	rs	A	AIS	A
NGC 3786	SA	0	r	A	AIS	–
NGC 3870	SB	-2	rs	A?	GII	–
NGC 3887	SAB	4	rs	A	GII	A
NGC 3888	SA	3	rs	A	AIS	–
NGC 3892	SAB	-1	r′l	P	AIS	–
NGC 3900	SA	0	r	A	AIS	–
NGC 3945	SB	-1	rl	A	AIS	–
NGC 3949	SAB	5	rs	A	AIS	A
NGC 4030	SA	4	rs	A	MIS	A
NGC 4037	SAB	5	rs	A	AIS	A
NGC 4041	SAB	5	rs	A	GII	A
NGC 4045	SAB	2	rs	A	GII	A
NGC 4050	SAB	1	rs	A	AIS	–
NGC 4051	SAB	3	rs	A	AIS	A
NGC 4067	SB	2	rs	A	GII	–
NGC 4116	SB	7	rs	A	MIS	A
NGC 4123	SB	3	rs	A	AIS	A
NGC 4136	SAB	4	rs	A	GII	A
NGC 4138	SA	-1	r	A	NGS	–
NGC 4141	SB	7	rs	A	AIS	–
NGC 4145	SAB	7	rs	A	AIS	A
NGC 4162	SA	5	r	A?	AIS	–
NGC 4189	SAB	4	rs	A	GII	A
NGC 4212	SA	3	rs	A	GII	A
NGC 4234	SB	9	rs	A	AIS	A
NGC 4245	SB	-1	r	A	GII	A
NGC 4250	SAB	-1	rl	A	AIS	–
NGC 4298	SA	4	rs	A	GII	A
NGC 4303	SAB	5	rs	A	NGS	A
NGC 4309	SAB	-2	rl	A	GII	–
NGC 4314	SB	1	rl	P	NGS	P
NGC 4321	SAB	4	rs	A	GII	A
NGC 4336	SAB	0	r	P	AIS	–
NGC 4339	SA	-2	r	A?	AIS	–
NGC 4340	SB	-1	r	P?	AIS	–
NGC 4371	SB	-2	r	P	DIS	–
NGC 4380	SA	2	r	A	GII	A
NGC 4385	SAB	2	rs	A	AIS	A
NGC 4394	SB	0	rs	A	AIS	A
NGC 4405	SAB	1	rs	A	NGS	A
NGC 4411A	SB	6	rs	A	GII	–
NGC 4412	SAB	4	rs	A	AIS	A
NGC 4413	SB	2	rs	A	NGS	A

Table A.1. continued.

ID (1)	Family (2)	*T* (3)	Kind (4)	FUV (5)	Survey (6)	Hα (7)
NGC 4414	SA	4	rl	A	NGS	A
NGC 4416	SB	8	rs	A	GII	A
NGC 4430	SAB	8	rs	A	AIS	–
NGC 4450	SAB	1	rs	A	AIS	A
NGC 4454	SAB	0	r	A	AIS	–
NGC 4477	SB	1	r	P?	GII	–
NGC 4491	SB	0	rs	P?	NGS	–
NGC 4492	SA	-3	rs	A	AIS	A
NGC 4496A	SB	7	rs	A	AIS	–
NGC 4498	SB	7	rs	A	GII	A
NGC 4501	SA	3	rs	A	AIS	A
NGC 4504	SAB	5	rs	A	GII	–
NGC 4519	SAB	6	rs	A	GII	A
NGC 4528	SB	-2	r	P?	NGS	–
NGC 4531	SA	1	rs	A	NGS	A
NGC 4540	SAB	9	rs	A	AIS	A
NGC 4548	SB	1	rs	A	GII	A
NGC 4567	SA	4	rs	A	GII	A
NGC 4579	SB	1	rs	A	NGS	A
NGC 4580	SA	1	rs,rs	P,A	GII	P,A
NGC 4593	SB	1	rs	A	AIS	–
NGC 4596	SB	0	rs	P	GII	–
NGC 4618	SB	9	rs	A	NGS	A
NGC 4639	SB	2	rs	A	AIS	A
NGC 4643	SB	-2	r	P?	AIS	P
NGC 4651	SA	4	rs	A	GII	A
NGC 4654	SB	6	rs	A	AIS	A
NGC 4680	SAB	3	rs	A	AIS	–
NGC 4698	SA	0	r,r	A,P	GII	A,P
NGC 4713	SAB	5	rs	A	AIS	A
NGC 4725	SAB	1	r	A	AIS	A
NGC 4736	SAB	1	rl	A	NGS	A
NGC 4750	SA	1	rs	A	AIS	A
NGC 4772	SA	0	r	A	MIS	A
NGC 4779	SB	3	rs	A	AIS	–
NGC 4793	SA	5	rs	A	GII	A
NGC 4800	SA	1	rs	A	AIS	A
NGC 4814	SA	4	rs	A	GII	–
NGC 4826	SA	1	rs,r	P,A	CAI	P,A
NGC 4880	SAB	-1	rl	P	AIS	–
NGC 4897	SAB	3	rs	A	GII	–
NGC 4902	SB	3	rs	A	AIS	–
NGC 4941	SA	0	rs	A	AIS	–
NGC 4961	SB	4	rs	A	GII	–
NGC 4995	SAB	2	rs	A	AIS	–
NGC 5033	SA	5	rs	A	AIS	A
NGC 5055	SA	4	rs,rl	A,A	NGS	A,A
NGC 5068	SB	7	rs	A	GII	A
NGC 5101	SB	0	rs	A	AIS	–
NGC 5105	SAB	6	rs	A	AIS	–
NGC 5112	SB	6	rs	A	AIS	A
NGC 5134	SAB	0	rs	A	AIS	–
NGC 5145	SA	-1	r	A	AIS	–
NGC 5194	SAB	4	rs	A	GII	A
NGC 5195	SAB	0	r	P?	GII	P?
NGC 5205	SB	2	rs	A	AIS	–
NGC 5218	SB	1	rs	A	AIS	–
NGC 5300	SAB	5	rs	A	AIS	–
NGC 5313	SA	3	r	A	AIS	–
NGC 5334	SB	6	rs	A	AIS	A

Table A.1. continued.

ID (1)	Family (2)	*T* (3)	Kind (4)	FUV (5)	Survey (6)	Hα (7)
NGC 5339	SB	2	rs	A	AIS	–
NGC 5347	SB	1	rs	A	AIS	A
NGC 5350	SB	3	rs	A	AIS	–
NGC 5364	SA	3	r	A	DIS	A
NGC 5371	SAB	3	rs	A	AIS	A
NGC 5375	SB	1	rs	A	GII	–
NGC 5376	SA	2	rs	A	AIS	–
NGC 5383	SB	1	rs	A	AIS	–
NGC 5426	SAB	5	rs	A	GII	–
NGC 5457	SAB	5	rs	A	GII	A
NGC 5534	SB	1	rs	A	AIS	A
NGC 5595	SAB	6	rs	A	AIS	–
NGC 5600	SB	8	rs	A	AIS	–
NGC 5636	SAB	0	r	A	MIS	–
NGC 5665	SAB	5	rs	A	AIS	–
NGC 5668	SAB	6	rs	A	CAI	A
NGC 5669	SB	7	rs	A	AIS	A
NGC 5678	SA	3	rs	A	AIS	–
NGC 5701	SB	0	rl	P	MIS	–
NGC 5713	SB	2	rs	A	MIS	A
NGC 5728	SB	0	rs	A	AIS	A
NGC 5740	SAB	2	r	A	MIS	–
NGC 5757	SB	2	rs	A	AIS	A
NGC 5768	SAB	4	rs	A	MIS	–
NGC 5770	SAB	-1	r	P	GII	–
NGC 5806	SAB	2	rs	A	GII	A
NGC 5821	SAB	1	r	A	AIS	–
NGC 5850	SB	2	r	A	MIS	A
NGC 5892	SB	6	rs	A	AIS	–
NGC 5915	SA	5	r	A	GII	A
NGC 5921	SB	3	rs	A	AIS	A
NGC 5930	SAB	0	rs	A	AIS	–
NGC 5957	SB	1	rs	A	GII	–
NGC 5962	SAB	5	rs	A	NGS	A
NGC 5964	SB	6	rs	A	GII	A
NGC 6012	SB	2	r	A	GII	–
NGC 6014	SAB	0	rs	A?	AIS	–
NGC 6267	SB	3	rs	A	AIS	–
NGC 6278	SA	-2	r	P?	AIS	–
NGC 6412	SB	6	rs	A	AIS	A
NGC 6902	SAB	1	rs	A	NGS	–
NGC 7070	SB	5	rs	A	AIS	–
NGC 7098	SAB	0	r′l	A	AIS	A
NGC 7107	SB	8	rs	A	AIS	–
NGC 7179	SB	0	r	A	GII	–
NGC 7205	SA	4	rs	A	AIS	A
NGC 7290	SA	3	rs	A	AIS	–
NGC 7378	SA	0	rs	A	AIS	–
NGC 7418	SAB	5	rs	A	NGS	–
NGC 7421	SB	2	rs	A	NGS	–
NGC 7424	SB	6	rs	A	GII	A
NGC 7496	SB	3	rs	A	NGS	–
NGC 7513	SB	1	rs	A	AIS	–
NGC 7531	SAB	1	r	A	GII	–
NGC 7552	SB	1	rs	A	NGS	A
NGC 7716	SAB	2	r	A	MIS	–
NGC 7723	SB	2	rs	A	MIS	–
NGC 7742	SA	-1	r,r	A,A	GII	–
NGC 7743	SAB	1	rs	P	AIS	–
NGC 7755	SAB	4	rs	A	AIS	–

Table A.1. continued.

ID (1)	Family (2)	*T* (3)	Kind (4)	FUV (5)	Survey (6)	Hα (7)
PGC 003853	SB	6	rs	A	AIS	–
PGC 006626	SB	6	rs	A	AIS	–
PGC 012633	SAB	2	rs	A	MIS	–
PGC 012664	SAB	6	rs	A	MIS	–
PGC 032091	SAB	5	rs	A	AIS	–
PGC 038250	SAB	9	rs	A	AIS	–
PGC 044735	SAB	8	rs	A	GII	–
PGC 044952	SA	7	r	A	AIS	–
PGC 047721	SA	2	rs,r,r	A,A?,A?	AIS	–
PGC 048179	SB	6	rs	A	GII	A
PGC 054944	SB	7	rs	A	AIS	–
UGC 01551	SB	6	rs	A	GII	–
UGC 04867	SB	7	rs	A	AIS	–
UGC 06023	SAB	5	rs	A	AIS	A
UGC 06309	SB	5	rs	A	AIS	–
UGC 07184	SB	7	rs	A	MIS	–
UGC 08155	SA	1	rs	A	AIS	–
UGC 09356	SAB	4	rs	A	AIS	–
UGC 09569	SB	5	rs	A	AIS	–
UGC 10054	SB	7	rs	A	AIS	A
UGC 10791	SB	7	rs	A	NGS	–
UGC 12151	SB	7	rs	A	MIS	–

ID (Column 1) refers to the galaxy name, family (Column 2) to its bar classification and and *T* (Column 3) to its stage (from Buta et al. 2013, and NIRSOS). Kind (Column 4) indicates the ring classification by Buta et al. (2013) and NIRS0S. FUV (Column 5) indicates whether a given ring emits in the ultraviolet continuum ("A") or not ("P"). The Survey column (Column 6) indicates to which GALEX survey the FUV images used here belong. Hα (Column 7) indicates whether a given ring is seen in continuum-subtracted Hα images ("A"), or not ("P"). Uncertain detection statuses are indicated by "?" in Columns 5 and 7.