Inner rings in disc galaxies: dead or alive

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\section*{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\textsuperscript{G}G surveys. I used archival far-ultraviolet (FUV) and H\textalpha{} 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, $21 \pm 3\%$ and $28 \pm 5\%$ of the rings are passive according to the FUV and H\textalpha{} indicators, respectively. A ring that is passive according to the FUV is always passive according to H\textalpha{}, but the reverse is not always true. Ring-lenses form $30 \pm 40\%$ 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.

\section*{Key words.} Galaxies: evolution – Galaxies: kinematics and dynamics – Galaxies: spiral – Galaxies: statistics

\section*{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 {\cite{Athanassoula2012}}. 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 \cite{Schwarz1981,Schwarz1984}. 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, pos- 

\section*{2. Data selection and processing}

I mainly based my sample of galaxies with inner rings on the classification of S\textsuperscript{G}G galaxies made by \cite{Buta2013} and statistically studied in the Atlas of Resonance (pseudo)Rings As Known In the S\textsuperscript{G}G; \cite{ARRAKIS,Comerón2013}. Since the S\textsuperscript{G}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\textsuperscript{G}G selection criteria, namely galactic latitude $|b| \geq 30\degree$. radial velocity...
The ultraviolet continuum traces star formation that has occurred in the past 100 Myr (Kennicutt 1998). To study inner rings in the 319 sample galaxies were analysed. For each sample galaxy I verified in the FUV and Hα continuum-subtracted images whether the rings detected in S^2G 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.

### 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 $21 \pm 3\%$ 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 come mostly from the Hubble Space Telescope (HST) Archive:

1. HST images not processed for AINUR. In these cases, Hα narrow-band images and red continuum images were downloaded from the Hubble Legacy Archive (HLA) and were used to produce a continuum-subtracted image using the technique described in Knapp et al. (2004, 2004).
2. Continuum-subtracted images in the NASA/IPAC Extragalactic Database (NED).

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

### Notes

- Images processed for the Atlas of Images of NUclear Rings (AINUR; Comerón et al. 2010). The images in AINUR

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**Fig. 1.** NGC 4314 (top row) is an (R′)Sb(rLr)a galaxy (Buta et al. 2013) with a passive inner ring-lens. NGC 1672 (bottom row) is an (R′)SAB(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 intervals µ < 4000 km s$^{-1}$, angular diameter $D_{50} > 1′$, and integrated blue magnitude $m_β < 15.5$ mag (data obtained from HyperLeda; Paturel et al. 2003). $S^2G$ and NIRS0S data can be mixed safely because the detection of inner rings in the $S^2G$ matches that in NIRS0S very well (Section 5.10 in ARRAKIS). I also included NGC 2950, an S0 non-$S^2G$ galaxy appearing in the same frame as a genuine $S^2G$ 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 $ε_i = 0.5$ according to the data of the Pipeline 4 of $S^2G$ (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$^4$ 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 $μ_{AB} \sim 20$ 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

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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/
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 ± 5% of passive rings in the range −3 ≤ T ≤ 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.

While in the range of stages −3 ≤ T ≤ 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 ≤ T ≤ 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.

### 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 ≤ T ≤ 2.

| Indicator | r_l, r_H, r_l, r_H | FUV | P | A | r | FUV (Hα) | P | A | Hα | P | A |
|-----------|-------------------|-----|---|---|---|--------|---|---|-----|---|---|
| P         | 39 ± 9%           | 9 ± 3% | 33 ± 7% | 35 ± 4% | 27 ± 8% | 56 ± 4% |
| A         | 36 ± 15%          | 9 ± 4% | 36 ± 11% | 33 ± 7% | 37 ± 11% | 61 ± 7% |

### 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. |
|-----------|-----------|----|-----------|----------|
| 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. P and A stand for passive and active rings, respectively. FUV (Hα) stands for the FUV statistics assembled from galaxies with available Hα images.
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 \citep{Kennicutt1998}. 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 remaining 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 \citep{Allard2006, Sarzi2007}. 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 underestimated. 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 \citep{Athanassoula2009b}. 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 \citep{Athanassoula2009a, Athanassoula2010}. On the other hand, a set of $\sim 20$ N-body simulations with a fixed potential shows that at least in some cases only a minority of ring particles are trapped in manifolds \citep{Rautiainen}. This, however, is not the case for the fully self-consistent simulations of \cite{Athanassoula2012b}. 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 \cite{Buta2013}. 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       | Family | T | Kind | FUV | Survey | Hz |
|----------|--------|---|------|-----|--------|----|
| ESO 013-016 | SB     | 6 | rs   | A   | AIS    | –  |
| ESO 202-041 | SB     | 9 | rs   | A   | AIS    | –  |
| ESO 404-012 | SAB    | 3 | rs   | A   | AIS    | –  |
| ESO 407-014 | SA     | 2 | r    | A   | MIS    | –  |
| ESO 420-009 | SAB    | 5 | rs   | A   | AIS    | –  |
| ESO 422-005 | SB     | 8 | rs   | A   | AIS    | –  |
| ESO 440-011 | SB     | 6 | rs   | A   | NGS    | –  |
| ESO 443-069 | SB     | 8 | rs   | A   | AIS    | –  |
| ESO 479-004 | SB     | 7 | rs   | A   | GII    | –  |
| ESO 482-035 | SB     | 3 | rs   | A   | AIS    | –  |
| ESO 508-007 | SAB    | 7 | rs   | A?  | AIS    | –  |
| ESO 510-059 | SB     | 5 | rs   | A   | AIS    | –  |
| ESO 532-022 | SB     | 7 | rs   | A   | AIS    | –  |
| ESO 547-005 | SAB    | 9 | rs   | A   | MIS    | –  |
| ESO 548-005 | SAB    | 8 | rs   | A   | AIS    | –  |
| ESO 572-018 | SAB    | 3 | rs   | A   | AIS    | –  |
| ESO 576-032 | SB     | 5 | rs   | A   | AIS    | –  |
| ESO 602-030 | SB     | 7 | rs   | 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 | rs   | A   | GII    | –  |
| IC 2969   | SA     | 7 | r    | A   | AIS    | –  |
| IC 3102   | SAB    | 0 | rs   | A   | GII    | –  |
| IC 3267   | SA     | 1 | rs   | A   | GII    | –  |
| IC 4214   | SAB    | 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 | rs   | A   | AIS    | –  |
| NGC 0210  | SAB    | 2 | r'l  | A   | GII    | A  |
| NGC 0255  | SB     | 6 | rs   | A   | AIS    | –  |
| NGC 0289  | SAB    | 2 | rs,rsA,A|MIS | –  |
| NGC 0470  | SAB    | 2 | rs,rsA,A|MIS | –  |
| NGC 0473  | SA     | -1 | r | A | AIS | A  |
| NGC 0488  | SA     | 1 | rl  | P | MIS | P  |
| NGC 0600  | SB     | 7 | rs   | A | AIS | –  |
| NGC 0613  | SB     | 3 | rs   | A | AIS | A  |
| NGC 0658  | SA     | 4 | rs   | A | MIS | A  |
| NGC 0691  | SA     | 2 | rs,r | A,A | AIS | A,A |
| NGC 0701  | SB     | 7 | rs   | A | MIS | –  |
| NGC 0718  | SAB    | 1 | rs   | P? | AIS | P  |
| NGC 0864  | SAB    | 4 | rs   | A | MIS | A  |
| NGC 0908  | SA     | 3 | rs   | A | GII | –  |
| NGC 0936  | SB     | -1 | rs | P | GII | –  |
| NGC 0941  | SAB    | 5 | r    | A | GII | A  |
| NGC 0986  | SB     | 2 | rs   | A | NGS | A  |
| NGC 1022  | SAB    | 0 | rs   | A | NGS | P  |
| NGC 1073  | SB     | 5 | rs   | A | GII | A  |
| NGC 1079  | SAB    | -1 | rs | A | MIS | –  |
| NGC 1087  | SB     | 7 | rs   | A | MIS | A  |
| NGC 1097  | SB     | 3 | rs   | A | NGS | A  |
| NGC 1179  | SAB    | 6 | rs   | A | MIS | A  |
| NGC 1187  | SAB    | 4 | rs   | A | GII | A  |
| NGC 1201  | SAB    | -2 | r'l | P? | AIS | –  |
Table A.1 continued.

| ID     | Family | T | Kind | FUV | Survey | Hr |
|--------|--------|---|------|-----|--------|----|
| 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 | rs   | A   | AIS    |   |
| NGC 1365 | SB     | 4 | rs   | A   | NGS    |   |
| NGC 1367 | SAB    | 0 | rs   | A   | GII    | P |
| NGC 1385 | SB     | 8 | rs   | A   | NGS    |   |
| NGC 1398 | SB     | 1 | r    | A   | AIS    | A |
| NGC 1433 | SB     | -2 | rs   | 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 | SAB    | 3 | rs   | A   | NGS    | A |
| NGC 2460 | SAB    | 1 | rs   | A   | AIS    | A |
| NGC 2523 | SB     | 2 | r    | A   | AIS    |   |
| NGC 2604 | SB     | 5 | rs   | A   | MIS    | A |
| NGC 2608 | SAB    | 3 | rs   | A   | MIS    | A |
| NGC 2633 | SAB    | 3 | rs   | A   | AIS    |   |
| NGC 2681 | SAB    | 0 | rs   | A   | NGS    | P |
| NGC 2775 | SA     | -1 | rs   | 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 | SAB    | 5 | rs   | A   | AIS    | A |
| NGC 2859 | SAB    | -1 | r'l  | A   | GII    | P |
| NGC 2906 | SA     | 3 | rs   | A   | MIS    |   |
| NGC 2950 | SAB    | -1 | r'l  | P   | AIS    | P |
| NGC 2962 | SAB    | -1 | r'l  | P   | MIS    |   |
| NGC 2964 | SAB    | 3 | rs   | A   | NGS    |   |
| NGC 2966 | SAB    | 1 | r'l  | A   | MIS    |   |
| NGC 2967 | SAB    | 5 | rs   | A   | MIS    |   |
| NGC 2968 | SB     | -1 | rs   | A   | NGS    |   |
| NGC 2974 | SA     | 0 | r    | A   | GII    |   |
| NGC 3031 | SA     | 1 | rs,r | A   | GII    | P |
| NGC 3032 | SA     | -2 | rs,r | P   | GII    | A |
| NGC 3061 | SAB    | 3 | rs   | A   | AIS    |   |
| NGC 3147 | SAB    | 3 | rs   | A   | NGS    |   |
| NGC 3166 | SB     | -1 | r'l  | A   | GII    |   |
| NGC 3184 | SA     | 4 | rs   | A   | AIS    | A |
| NGC 3185 | SAB    | 1 | rs   | 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 | rs   | A   | NGS    | A |
| NGC 3380 | SAB    | 0 | rs   | A   | AIS    |   |
| NGC 3381 | SB     | 8 | rs   | A   | AIS    |   |
| NGC 3455 | SA     | 5 | rs   | A   | GII    |   |
| NGC 3485 | SAB    | 3 | rs   | A   | GII    | A |
| NGC 3486 | SAB    | 5 | r    | A   | GII    | A |
| NGC 3504 | SAB    | 1 | rs   | A   | AIS    | A |
| NGC 3513 | SB     | 5 | rs   | A   | GII    | A |
| ID      | Family | T | Kind | FUV | Survey | Hα  |
|---------|--------|---|------|-----|--------|-----|
| 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?   |     |        |     |
| NGC 3642 | SA 2   | rl | P?   | GII |        |     |
| 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   |   | A    | AIS |        |     |
| NGC 3705 | SAB 3  | rs | A    | AIS |        |     |
| NGC 3726 | SAB 4  |   | A    | AIS |        |     |
| NGC 3729 | SB 0   |   | A    | GII |        |     |
| NGC 3780 | SA 4   | rs | A    | AIS |        |     |
| NGC 3782 | SB 8   | rs | A    | AIS |        |     |
| NGC 3786 | SA 0   |   | A    | AIS |        |     |
| NGC 3870 | SB -2  | rs | A?   | GII |        |     |
| NGC 3887 | SAB 4  | rs | A    | GII |        |     |
| NGC 3888 | SA 3   | rs | A    | AIS |        |     |
| NGC 3892 | SAB -1 | rl | P    | AIS |        |     |
| NGC 3900 | SA 0   |   | A    | AIS |        |     |
| NGC 3945 | SB -1  | rl | A    | AIS |        |     |
| NGC 3949 | SAB 5  | rs | A    | AIS |        |     |
| NGC 4030 | SA 4   | rs | A    | MIS |        |     |
| NGC 4037 | SAB 5  | rs | A    | AIS |        |     |
| NGC 4041 | SAB 5  | rs | A    | GII |        |     |
| NGC 4045 | SAB 2  | rs | A    | GII |        |     |
| NGC 4050 | SAB 1  | rs | A    | AIS |        |     |
| NGC 4051 | SAB 3  | rs | A    | AIS |        |     |
| NGC 4067 | SB 2   | rs | A    | GII |        |     |
| NGC 4116 | SB 7   | rs | A    | AIS |        |     |
| NGC 4123 | SB 3   | rs | A    | AIS |        |     |
| NGC 4136 | SAB 4  | rs | A    | GII |        |     |
| NGC 4138 | SA -1  | r  | A    | NGS |        |     |
| NGC 4141 | SB 7   | rs | A    | AIS |        |     |
| NGC 4145 | SAB 7  | rs | A    | AIS |        |     |
| NGC 4162 | SA 5   | r  | A?   | AIS |        |     |
| NGC 4189 | SAB 4  | rs | A    | GII |        |     |
| NGC 4212 | SA 3   | rs | A    | GII |        |     |
| NGC 4234 | SB 9   | rs | A    | AIS |        |     |
| NGC 4245 | SB -1  | r  | A    | GII |        |     |
| NGC 4250 | SAB -1 | rl | A    | AIS |        |     |
| NGC 4298 | SA 4   | rs | A    | GII |        |     |
| NGC 4303 | SAB 5  | rs | A    | NGS |        |     |
| NGC 4309 | SAB -2 | rl | A    | GII |        |     |
| NGC 4314 | SB 1   | rl | P    | NGS |        |     |
| NGC 4321 | SAB 4  | rs | A    | GII |        |     |
| 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 |        |     |
| NGC 4385 | SAB 2  | rs | A    | AIS |        |     |
| NGC 4394 | SB -1  | rs | A    | AIS |        |     |
| NGC 4405 | SAB 1  | rs | A    | NGS |        |     |
| NC 4411A| SB 6   | rs | A    | GII |        |     |
| NGC 4412 | SAB 4  | rs | A    | AIS |        |     |
| NGC 4413 | SB 2   | rs | A    | NGS |        |     |
Table A.1. continued.

| ID      | Family | $T$ | Kind | FUV | Survey | Hα |
|---------|--------|-----|------|-----|--------|----|
| (1)     | (2)    | (3) | (4)  | (5) | (6)    | (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   | rs,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     | Family | T | Kind | FUV | Survey | Hr |
|--------|--------|---|------|-----|--------|----|
| NGC 5339 | SB     | 2 | rs  | A   | AIS    | −  |
| NGC 5347 | SB     | 1 | rs  | A   | AIS    | −  |
| NGC 5350 | SB     | 3 | rs  | A   | AIS    | −  |
| NGC 5364 | SA     | 3 | r   | A   | DIS    | A  |
| NGC 5371 | SAB    | 3 | rs  | A   | AIS    | −  |
| 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 | SB     | 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   | AIS    | −  |
| 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 | rl | 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    | −  |
| ID   | Family | $T$ | Kind | FUV | Survey | H$\alpha$ |
|------|--------|-----|------|-----|--------|-----------|
| 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 $T$ (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. H$\alpha$ (Column 7) indicates whether a given ring is seen in continuum-subtracted H$\alpha$ images (“A”), or not (“P”). Uncertain detection statuses are indicated by “?” in Columns 5 and 7.