THE CATALOGUE OF SOUTHERN RINGED GALAXIES (CSRG)

R. Buta
University of Alabama
Box 870324
Tuscaloosa, AL 35487

ABSTRACT. The CSRG is a comprehensive compilation of diameters, axis ratios, relative position angles, and morphologies of inner, outer, and nuclear rings in 2,300 southern galaxies. This paper describes the motivation for this survey, its present status, and early results and implications from the analysis of its contents.

1. Introduction

Sixteen years ago, P. O. Lindblad (1974) made the following comment in a review article for IAU Symposium No. 58: "It would be of the utmost importance for our understanding of density waves if we could identify the different resonance regions in the galaxies observed." The *Catalogue of Southern Ringed Galaxies*, or CSRG, is an attempt to address this problem statistically. The motivation for it came mainly from theoretical n-body work by Schwarz (1979, 1981) which clarified a long suspected link between observed galaxy rings and orbital resonances in a disk galaxy perturbed by a non-axisymmetric potential, such as a bar. This work not only demonstrated how ring formation might take place, but also made several interesting predictions about resonance rings with regard to morphology, intrinsic shapes, and intrinsic orientations with respect to bars. These predictions are testable with a large sample of ringed galaxies, and this led me in 1984 to explore the possible use of the large southern sky surveys, then being produced at the UK Schmidt and at ESO, to prepare a statistically significant data base on rings.

2. The Survey

The CSRG is the result of a long-term search for rings of all types on the UK Schmidt SRC IIIa-J Southern Sky Survey. Rings on these charts as small as 0.'2 in apparent size are measureable, and outer rings and pseudorings are detectable in many galaxies where these features would be difficult to discern on the ESO B or R charts or on the Palomar Sky Survey (PSS). The principal limitation of the SRC charts is that many galaxies are overexposed in the crucial inner regions; however, these regions are often clearly distinguishable on the other survey materials, which are used when needed.

The basic data derived from the charts concern morphology, ring diameters and axis ratios, relative bar/ring position angles, bar diameters, spiral arm multiplicity, and local environment. The apparent distributions of axis ratios and bar/ring position angles provide information on the intrinsic axis ratios and ori-

F. Combes and F. Casoli (eds.), Dynamics of Galaxies and Their Molecular Cloud Distributions, 251–253.

entations of rings. The ubiquity of ringed galaxies and the desire for statistical reliability has made the CSRG a long–term project that is still in progress.

3. Early Results

3.1 INVENTORY

Table 1 gives an inventory of the contents of the preliminary CSRG. The catalogue currently contains 2,300 entries with inner rings ranging from 0.′2 to 3.′2 (median = 0.′47) and outer rings ranging from 0.′4 to 8′ (median = 0.′90) in diameter. The statistics demonstrate a clear preference for barred galaxies. Some 1,026 inner rings and 520 inner pseudorings are included, while the 313 (s)-variety systems are mostly associated with outer pseudorings. The catalogue also distinguishes lenses from rings using notation suggested by Kormendy (1979), with subtle ring enhancements being denoted (rl) or (RL). About 250 lens or ring/lens features are recognized. For 665 CSRG spirals, the multiplicity of the spiral pattern was also estimated for reasons discussed by Buta (1984).

The distribution of rings by stage is shown in the right half of Table 1, where (r) and (R) refer to both rings and pseudorings in this case. Inner and outer rings are observed over a wide range of the Hubble sequence. At least 528 objects are double-ringed, showing both inner and outer rings or pseudorings.

TABLE 1. Inventory by Family and Variety (left) and by Stage (right)

Category	N	Category	N	Stage	N	N(r)	N(R)	N(r+R)
SA	376	(rl)	92	S0°	71	11	25	2
SAB	90	(rl)	32	S0$^+$	288	146	165	64
SAB	336	(R)	409	S0/a	242	152	124	58
SAB	92	(R′)	665	Sa	515	325	344	181
SB	1268	(r) but no (R)	1110	Sab	258	184	147	80
(r)	1026	(L), (RL)	47	Sb	372	306	174	110
(rs)	164	(R_1R_2')	31	Sbc	233	201	53	15
(rs)	304	(R_1) or (R_1')	163	Sc	168	147	29	13
(rs)	52	(R_2) or (R_2')	109	Scd	32	31	4	2
(s)	313	(nr)	12	Sd	27	26	3	2
(l)	72	(r) or (R)?	44	Sdm	12	10	3	0
(rl)	11	peculiar	162	Sm	4	3	1	1

3.2 STATISTICS

A discussion of the inferences about ring properties from an analysis of the distributions of apparent axis ratios and relative bar/ring position angles has been given by Buta (1986; see this paper also for a discussion of selection effects). Although the present CSRG sample is twice that used before, the revised distributions are little changed, and my conclusions now are essentially the same as those in Buta (1986). A few results are: (1) the distributions of axis ratios for inner and outer rings in SB galaxies both show a clear deficiency of apparently round rings, implying that on average the intrinsic shapes are non-circular. The deficiency is greater for inner rings, implying that on average these are more elongated than outer rings; (2) Inner SB rings show a significant excess of objects having angles near 0° with respect to

the bar in projection, while outer SB rings show excesses of objects having angles both near 0° and 90°. This implies that most inner rings must be intrinsically aligned parallel to the bar, while the outer ring population includes two preferred alignments: parallel and perpendicular (see Buta 1986).

3.3 MORPHOLOGY

Outer rings and especially pseudorings show two distinct morphologies consistent with the Schwarz patterns which develop near outer Lindblad resonance (OLR; see Crocker and Buta, this conference). The CSRG currently includes about 270 examples of these, which were called R_1' and R_2' by Buta (1986), and they comprise about 30-40% of the outer pseudorings. A combined type called R_1R_2', not predicted by Schwarz, is found at the 5% level; such a morphology currently can only be explained in terms of the OLR, but not by pure gas dynamical models. Inner rings sometimes show breaks near their minor axis and, in spirals, a four-fold symmetry as in Schwarz's 4:1 resonance rings. Pointy, rectangular, or hexagonal shapes are also seen. Cases where a bar enveloped by an inner ring does not fill the ring were noted; the CSRG currently includes 92 of these, some of which may have important implications for the resonances which limit bar extent.

4. Implications

Information on the shapes, alignments, and morphologies of rings from the CSRG support the resonance interpretations proposed by Schwarz, at least in the case of barred galaxies. However, while the CSRG has in many respects helped to address the problem posed by Lindblad, it has been restricted to a narrow class of objects whose properties need to be accurately tied into the general scheme of galaxy structure. Resonances may be a necessary but not sufficient condition for ring formation, as we can judge from analysis of some pure spirals (see, e.g., Elmegreen and Elmegreen 1990), and thus follow-up work on a large sample of CSRG galaxies is essential if we are to use rings to understand density waves.

5. Status of the CSRG

The CSRG is currently about 80% completed. The final analysis of the data will take into account all independent sources of ring axis ratios and angles as well as observational errors. It is anticipated also that the survey will be extended into the zones north of $\delta = -17°$ when the northern Palomar II and SRC Equatorial Sky Surveys become available.

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