DO GALAXIES EVOLVE ALONG THE $R-\omega$ SEQUENCE?

WILLIAM C. SASLAW

Berkeley Astronomy Dept., University of California, and Institute of Theoretical Astronomy, University of Cambridge, and Center for Advanced Studies, University of Virginia

Abstract. The stellar contents of Sb and Sc galaxies do not appear to be related to their rotation properties. This lack of correlation suggests that the position of a galaxy on the $R-\omega$ sequence is determined to a large extent by the environment in which the galaxy formed, rather than by subsequent evolution.

Suppose we are given some physical property of a galaxy, such as its rotation curve. It may then be asked how quickly this property changes with time. If the change is very rapid, then the property can be used to set up an evolutionary sequence for an ensemble of galaxies. If the change is sufficiently slow, then the property is the remnant of initial conditions when the galaxy formed. We consider the internal rotation of Sb and Sc spiral galaxies from this point of view. For further discussion see Saslaw (1970, 1971a, 1971b).

Nineteen rotation curves for fairly normal Sb and Sc galaxies have been measured, mainly by the Burbidges and their collaborators. These rotation curves generally have a spatial resolution of about 6 or 7 arc sec, which is sufficient to determine average dynamical properties of the galaxy. *To a first approximation*, the curves have an inner region of solid body rotation and an outer region of constant rotational velocity. We can estimate the linear extent, R, and angular velocity, ω, of the central region of each galaxy. These show an approximate correlation of the form $R \sim \omega^{-1}$. Possibly the Sb's have a different correlation from the Sc's, but the present observational uncertainties make this difficult to determine. An alternative statement of the $R \sim \omega^{-1}$ correlation is that the rotational velocity at which the curve turns over is generally 200 ± 50 km s^{-1}, even though values of both R and ω can vary by more than an order of magnitude.

The position of a spiral galaxy on the $R-\omega$ sequence gives us a direct measure of its dynamical properties. This measure is purely observational and independent of any model for the mass distribution of the galaxy. Of course, when such a model is available we can use the rotation curve to derive the mass $M(R)$ interior to R. A very crude illustrative model, supposing the mass $M(R)$ to be collected at the center, would give $M \sim R^3 \omega^2$. To obtain $R \sim \omega^{-1}$ would require $M(R) \sim R$. Thus the $R-\omega$ sequence can also be viewed as a mass sequence. However, this would introduce new uncertainties.

We ask whether galaxies evolve along the $R-\omega$ sequence, or whether this sequence is a relic of initial conditions. To search for observational hints, we ask more specifically whether there is a relation between a galaxy's location on the $R-\omega$ sequence and the stellar content of its nucleus. If among many galaxies there were a monotonic relation between the dynamical properties and the stellar content, for example, the smaller the solid body region the older its stars, this would suggest that the galaxies

D. S. Evans (ed.), External Galaxies and Quasi Stellar Objects, 93–96.
All Rights Reserved. Copyright © 1972 by the IAU.

https://doi.org/10.1017/S0074180900005374 Published online by Cambridge University Press

began from similar initial conditions, but that R decreases with time. On the other hand, if there is a random relation between dynamical properties and stellar content, it would suggest that initial conditions still dominate the observed properties of the dynamics, the stellar content, or both. This second situation, in fact, appears to be the case.

To begin examining this question, Spinrad and I have scanned selected blue wavelengths of nine galaxies at the Lick 120-in. prime focus. The galaxies are selected to have bright, fairly compact nuclei, and the wavelengths are chosen to give line indices which are sensitive to the stellar content (Tables I and II).

TABLE I

Rest wavelength (Å)	Feature	Line index
4040	Continuum	–
4100	Hδ	(4040)/(4100)
4200	CN λ4215	(4040 + 4500)/2(4200)
4300	CH λ4313	(4040 + 4500)/2(4300)
4340	Hγ	(4040 + 4500)/2(4340)
4500	Continuum	–
	Blueness	(4040)/(4500)

The notation (λ) denotes the intensity at wavelength λ.

TABLE II

NGC	Type	Observed systemic velocity km s^{-1}	Distance Mpc	R_{turnover} arc sec	kpc	ω km s^{-1} kpc^{-1}
157	Sc	1710	24	50	5.8	30
224	Sb	– 300	0.67	2100	6.5	45
1084	Sc	1465	19.2	22	2.0	65
1832	Sb	1935	25.3	7	0.7	170
2903	Sbc	600	7.9	70	2.1	100
3521	Sb	815	8.5	38	1.6	150
5055	Sb	560	10.3	30	1.5	150
5248	Sc	1190	15.4	10	0.75	200
6181	Sc	2350	32.9	6	0.9	210

Differences of line indices among galaxies are caused mainly by differences in stellar population. To make absolute quantitative models of the stellar content of these nuclei we need much more data. However, here we are concerned with the trend of relative differences among nuclei, and this can be estimated qualitatively directly from the line indices. Figures 1 and 2 show the results. Error bars show the standard deviations for several scans of a given line index.

https://doi.org/10.1017/S0074180900005374 Published online by Cambridge University Press

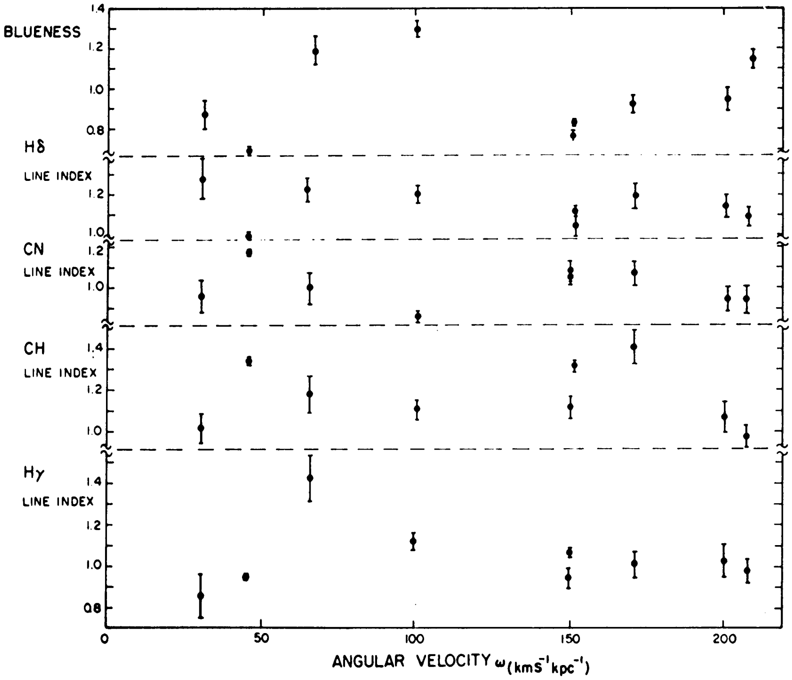

Fig. 1. Angular velocity vs spectral line indices for spiral galaxies.

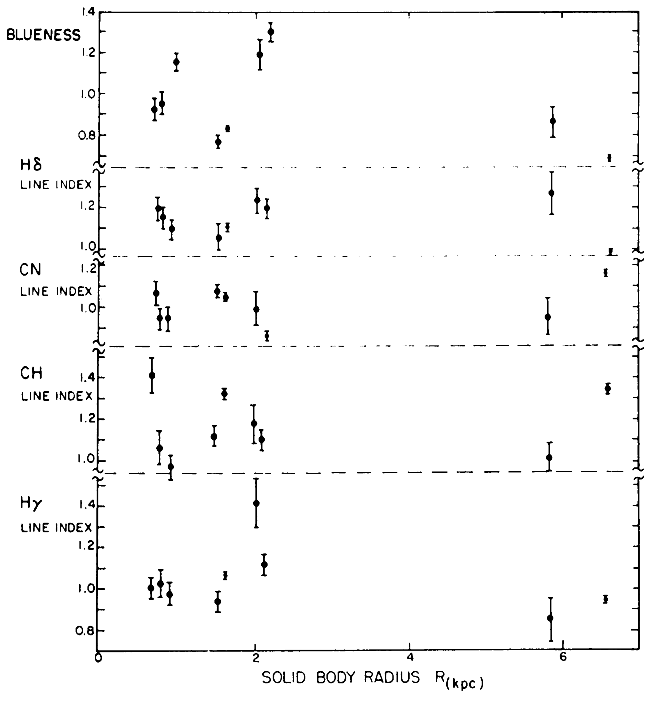

Fig. 2. Solid body radius vs spectral line indices for spiral galaxies.

https://doi.org/10.1017/S0074180900005374 Published online by Cambridge University Press

The various indices appear to vary quite randomly with R and with ω. This is especially true of the blueness index, which turns out to be a useful rough measure of stellar content for these galaxies.

The lack of correlation between dynamical properties and stellar content suggests that different degrees of evolution, starting from the same initial conditions, cannot explain what we observe, even for galaxies of similar type. It also suggests that the position of a galaxy on the $R-\omega$ sequence (and perhaps the stellar content as well) is governed to a large extent by the environment in which the galaxy formed.

There is another, indirect, line of evidence which also tends to support this conclusion. Turbulent and dusty galaxies do not appear to cluster in any particular region of the $R-\omega$ sequence. If these qualities indicate either young or old galaxies, but not both, this result also argues against a predominantly evolutionary interpretation. Therefore, in rotation curves we may find new clues to the origin of the galaxies.

References

Saslaw, W. C.: 1970, *Astrophys. J.* **160**, 11.
Saslaw, W. C.: 1971a, *Astrophys. J.* **163**, 249.
Saslaw, W. C.: 1971b, *Monthly Notices Roy. Astron. Soc.* **152**, 341.

Discussion

Ozernoy: A simple argument against any evolution along the Hubble sequence is that, according to Holmberg's data, the mean mass of a galaxy increases from irregulars to ellipticals. Apparently the same is valid for the spiral subsequence.

https://doi.org/10.1017/S0074180900005374 Published online by Cambridge University Press