On the variation of the energy scale 16

Hoag's object; ring galaxies; shell galaxies

by

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Sat 5th May 2018
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Summary

Hoag's object is a ring galaxy with a central nucleus of old stars separated from a detached ring of young stars. Rings and shells are observed in a small number of galaxies. The mechanisms for forming these are not fully understood. Currently they are thought to be formed through interaction with another galaxy.

It has been proposed that the energy scale can vary from location to location. Such variations can explain a number of observations including the flat rotation curves of spiral galaxies, without the need for any dark matter. A simple change to the width of the energy scale variation in a disk galaxy leads naturally to a central condensation and a detached ring of material, exactly as observed in Hoag's object. Other changes to either the height or the width of the energy scale variation also lead to patterns of rings within disk galaxies. So rings can be formed without interaction from another galaxy and without the involvement of dark matter.

1 Introduction

1.1 Hoag's object

Figure 1 shows the Hubble image of Hoag's object, a ring galaxy discovered by Art Hoag in 1950.

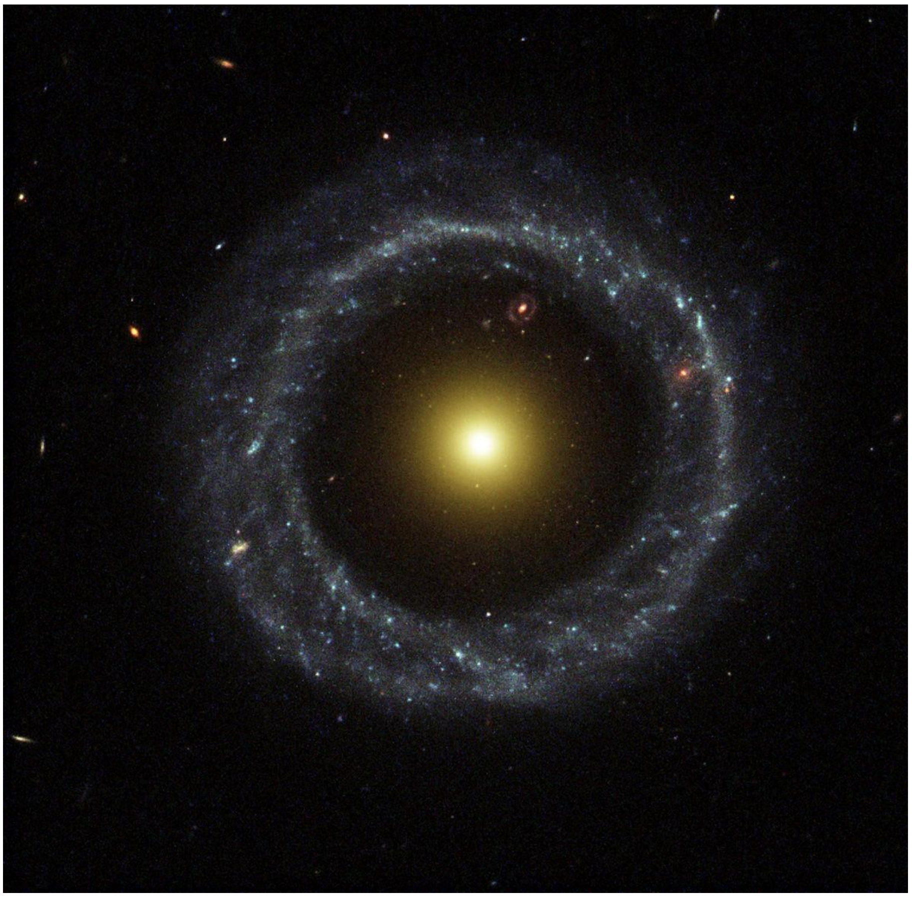

Figure 1. Hoag's object. Hubble image. NASA and The Hubble Heritage Team (STScI/AURA); Acknowledgment: Ray A. Lucas (STScI/AURA) -

1.2 Hoag's object is a ring galaxy. It has a central nucleus that is yellow in colour and made up of old stars. Detached from the nucleus is a wide ring that is blue in colour and made up of young stars.

1.3 Ring galaxies are thought to be formed when another galaxy passes through the disk of the galaxy; the ring being formed as a ripple effect. No second galaxy can be found near Hoag's object, which leaves the formation of the ring a puzzle.

1.4 The paper "On the variation of the energy scale: an alternative to dark matter" (Jo.Ke, 2015) is referred to in this paper as simply "JoKe1". This paper introduced the idea of variations of the energy scale to explain the rotation curves of spiral galaxies. It used the simple model of a galaxy point mass and a Gaussian energy scale variation. This was improved in JoKe2 (2015) to use a Gaussian density distribution and a Gaussian variation in the energy scale. And JoKe3 (2015) applied the model to a large sample of 74 spiral galaxies.

1.5 Other papers in this series have dealt with: clusters of galaxies; collisions between clusters of galaxies; galaxy interactions; gravitational lensing; primordial density perturbations; cosmology.

1.6 Papers JoKe6 (2016) & JoKe15 (2018) looked at near-miss collisions between galaxies and suggested there could be differences in the tidal effects between dark matter and variations in the energy scale.

1.7 This paper looks at how changes in the energy scale variation within an isolated galaxy can give rise to rings and shells.

2 Gravity

2.1 The radial acceleration, $\boldsymbol{g}$, for Newtonian gravitation is

$$\boldsymbol{g = -\frac{G\,M}{r^2}} \tag{1}$$

where $\boldsymbol{G}$ is the gravitational constant; $\boldsymbol{M}$ is the mass of the attracting galaxy; $\boldsymbol{r}$ is the distance from star to galaxy centre.

2.2 Following previous papers in this series (JoKe1, 2015) the radial acceleration for a Gaussian variation in the energy scale is

$$\boldsymbol{g = -\frac{G\,M}{r^2}\,\frac{\xi(0)}{\xi(r)}} \tag{2}$$

where the scalar function, $\boldsymbol{\xi(r)}$, is given by

$$\boldsymbol{\xi(r) = 1 + \beta\, exp\{-r^2/\alpha^2\}} \tag{3}$$

where $\boldsymbol{\beta}$ is a pure number (of order 5); $\boldsymbol{\alpha}$ is a characteristic distance (or order 10kpc for a galaxy).

2.3 Near the galaxy centre, $\boldsymbol{r<\alpha}$, $\boldsymbol{\xi(r) \approx \xi(0),}$ and equation (2) reduces to equation (1). This means there are no differences in motions near the galaxy centre.

2.4 At large distances, $\boldsymbol{r>\alpha}$, $\boldsymbol{\xi(r) \approx 1}$, and equation (2) reduces to Newtonian gravitation (inverse square law) but at a higher level with $\boldsymbol{M\,\xi(0)}$ replacing $\boldsymbol{M}$.

2.5 At intermediate distances, $\boldsymbol{r \simeq \alpha}$, equation (2) gives rise to flat rotation curves that closely match those observed in real galaxies (JoKe3, 2015). The variation in the energy scale gives flat rotation curves without the need for any dark matter.

2.6 For circular orbits the centripetal acceleration is balanced by the gravitational attraction. This leads to the orbital velocity, $\boldsymbol{v}$, being given by

$$\boldsymbol{\frac{v^2}{r} = \frac{G\,M}{r^2}\,\frac{\xi(0)}{\xi(r)}} \tag{4}$$

2.7 When it comes to the numerical simulation of disk galaxies equation (2) can be written in component form as:

$$\ddot{x} = -GM \frac{\xi(0)}{\xi(r)} \frac{x}{r^3} \tag{5}$$

$$\ddot{y} = -GM \frac{\xi(0)}{\xi(r)} \frac{y}{r^3} \tag{6}$$

3 The model

3.1 The model consists of a central area which contains all the mass. Surrounding this is a disk of massless particles.

3.2 The particles start in circular orbits around the central mass. The particles, which are massless, do not interact with one another, only with the central mass.

3.3 The particles start in circular orbits and the initial orbital speed is determined by equation (4).

3.4 The model is advanced from one time step to the next using the Runge-Kutta-Nystrom (RKN) method for integrating the second order differential equations for the gravitational acceleration, equations (5) & (6).

3.5 The model is run for 100 time steps before any change is made to the parameters defining the energy scale variation. This is sufficiently long to demonstrate that the model is stable and that the particles correctly move around the centre in circular orbits.

3.6 At time step 100 a change is made to the energy scale variation; either to the height or to the width. The model is run with the new settings for 700 time steps, up to time step 800.

3.7 At time step 800 the change is undone and the energy scale variation reverted back to its original settings. The model is run for a further 700 time steps, up to time step 1500.

4 Hoag's Object

4.1 Figure 2 shows 6 time steps during the model simulation. The similarity to Hoag's Object is clear.

4.2 At time step 100 the width parameter, α, is doubled from 100 to 200.
At time step 800 the width parameter, α, is changed back to 100.

4.3 The ring is formed by inner material moving outwards. In a real galaxy this would be a compression wave, which would be expected to trigger star formation. This would naturally lead to the ring containing a large number of young stars compared to the central galaxy containing predominantly old stars.

4.4 The position of the outer boundary of the ring is essentially unchanged. The change in the width of the energy scale variation has a negligible effect.

4.5 The model demonstrates that it is possible to form a ring galaxy without the involvement of a separate interacting galaxy.

4.6 However, some agent or instability is still required to trigger the change in the energy scale variation.

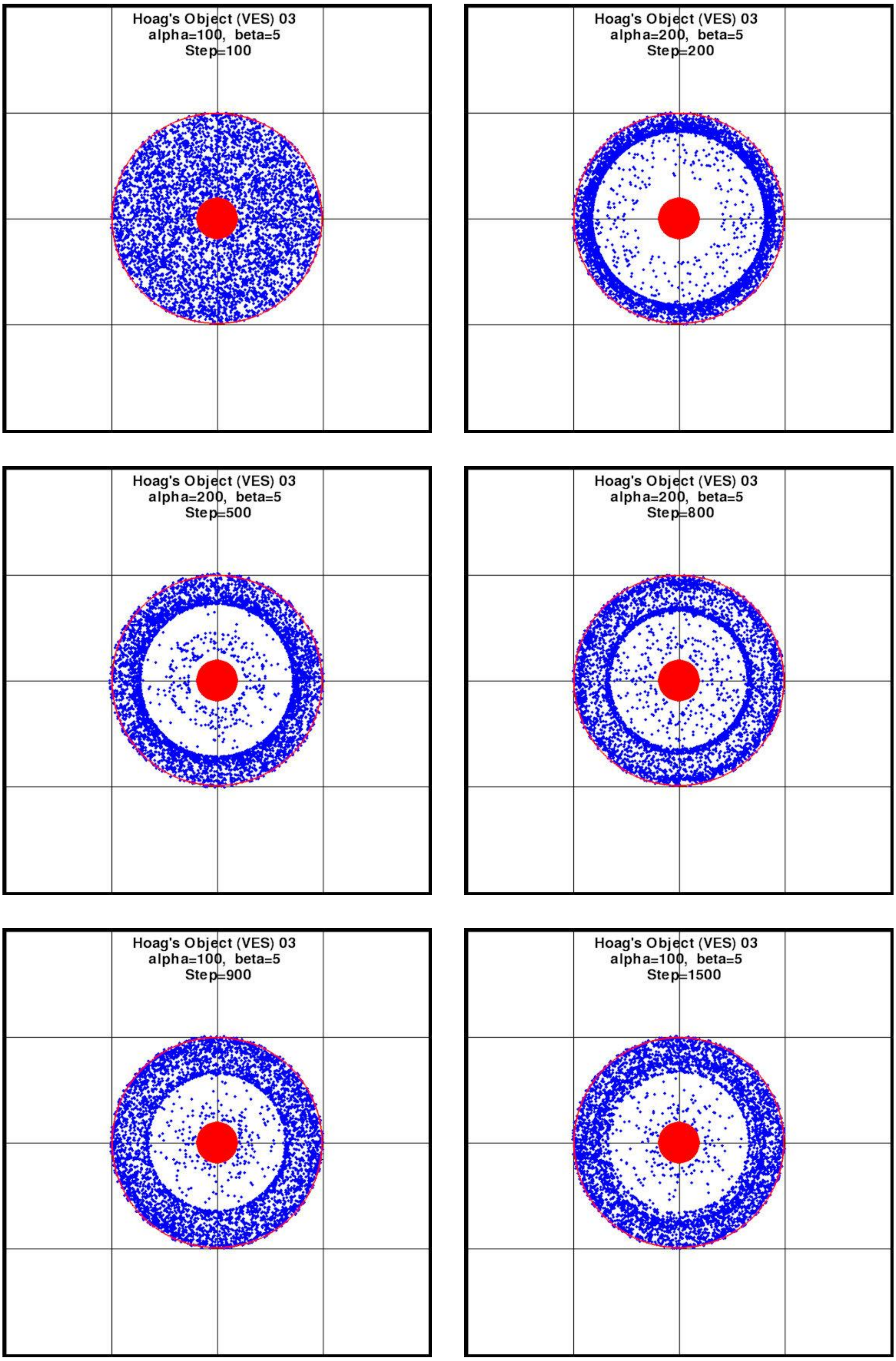

Figure 2. Numerical simulation of a disk galaxy with an energy scale variation that changes. The parameter α doubles at time step 100 and reverts back at time step 800. The creation and persistence of a ring structure is apparent.

5 Rings and Shells

5.1 Having come up with an explanation for the formation of Hoag's object we can take a more systematic approach to changes in the energy scale variation. A Gaussian shaped energy scale variation is defined by just two parameters: (a) the 1/e-width, and (b) the height.

5.2 There are four simple models that we can examine:

(A) Decrease the 1/e-width and then increase it back to its original size,
(B) Increase the 1/e-width and then decrease it back to its original size,
(C) Increase the height and then decrease it back to its original value.
(D) Decrease the height and then increase it back to its original value,

We use the same model as for Hoag's object, as described in section (3) above.

5.3 Model A. Width: shrink then expand

This is shown in Figure 3. The sequence is as follows

(a) Start at time step 0 with α=100, β=5.0
(b) At time step 100 set α=50, β=5.0
(c) At time step 800 set α=100, β=5.0
(d) Stop at time step 1500.

In this model there is almost no formation of any rings. When the 1/e-width is shrunk the innermost part of the disk is sucked into the galaxy centre where it is lost. When the 1/e-width returns to its original size the disk material moves out again leaving an empty inner zone.

5.4 Model B. Width: expand then shrink

This is shown in Figure 4. The sequence is as follows

(a) Start at time step 0 with α=100, β=5.0
(b) At time step 100 set α=150, β=5.0
(c) At time step 800 set α=100, β=5.0
(d) Stop at time step 1500.

In this model there is a lot of ring formation. When the 1/e-width is increased the material in the disk moves out and a number of peaks and troughs are created; these appear as rings. When the 1/e-width returns to its original size the disk material starts to move back in; the rings evolve and new peaks & troughs appear. There are no permanent rings, they continue to appear and disappear with time.

5.5 Model C. Height: raise then lower

This is shown in Figure 5. The sequence is as follows

(a) Start at time step 0 with α=100, β=5.0
(b) At time step 100 set α=100, β=6.0
(c) At time step 800 set α=100, β=5.0

(d) Stop at time step 1500.

In this model there is a lot of ring formation. When the height is increased the disk contracts slightly, material moves in and a number of peaks and troughs are created; these appear as rings. When the height returns to its original size the disk expands well beyond its original size; the rings evolve and new peaks & troughs appear. There are no permanent rings, they continue to appear and disappear with time. The disk slowly returns to its original size.

5.6 Model D. Height: lower then raise

This is shown in Figure 6. The sequence is as follows

(a) Start at time step 0 with α=100, β=5.0

(b) At time step 100 set α=150, β=4.0

(c) At time step 800 set α=100, β=5.0

(d) Stop at time step 1500.

In this model there is a lot of ring formation. When the height is decreased the disk expands, material moves out and a number of peaks and troughs are created; these appear as rings. When the height returns to its original size the disk contracts to its original size and then expands back out again. The rings evolve and new peaks & troughs appear. There are no permanent rings, they continue to appear and disappear with time. The disk retains its expanded size.

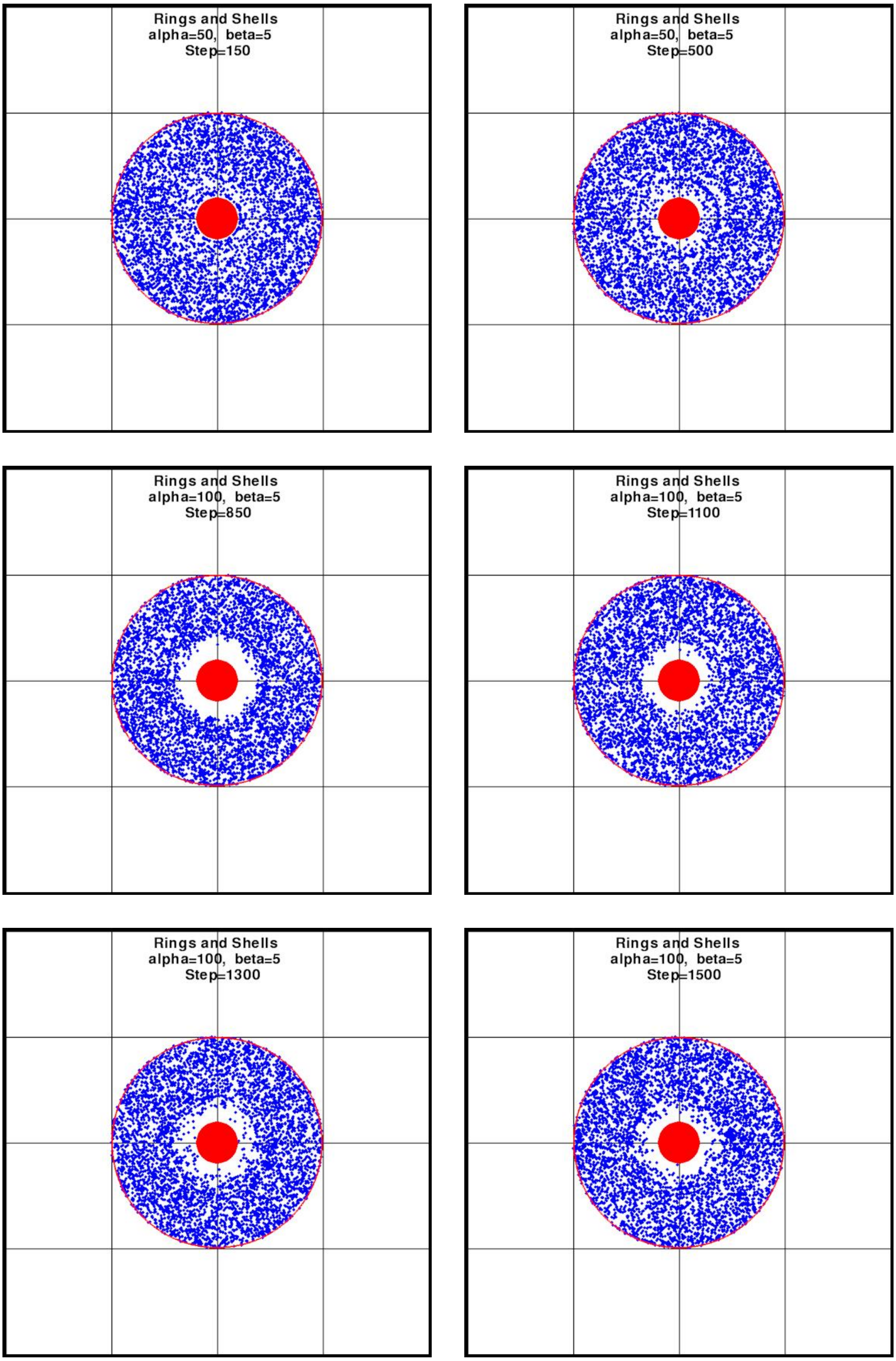

Figure 3. Width: shrink then expand.

Change in the disk of a galaxy when the width of the energy scale variation is shrunk and then expanded.

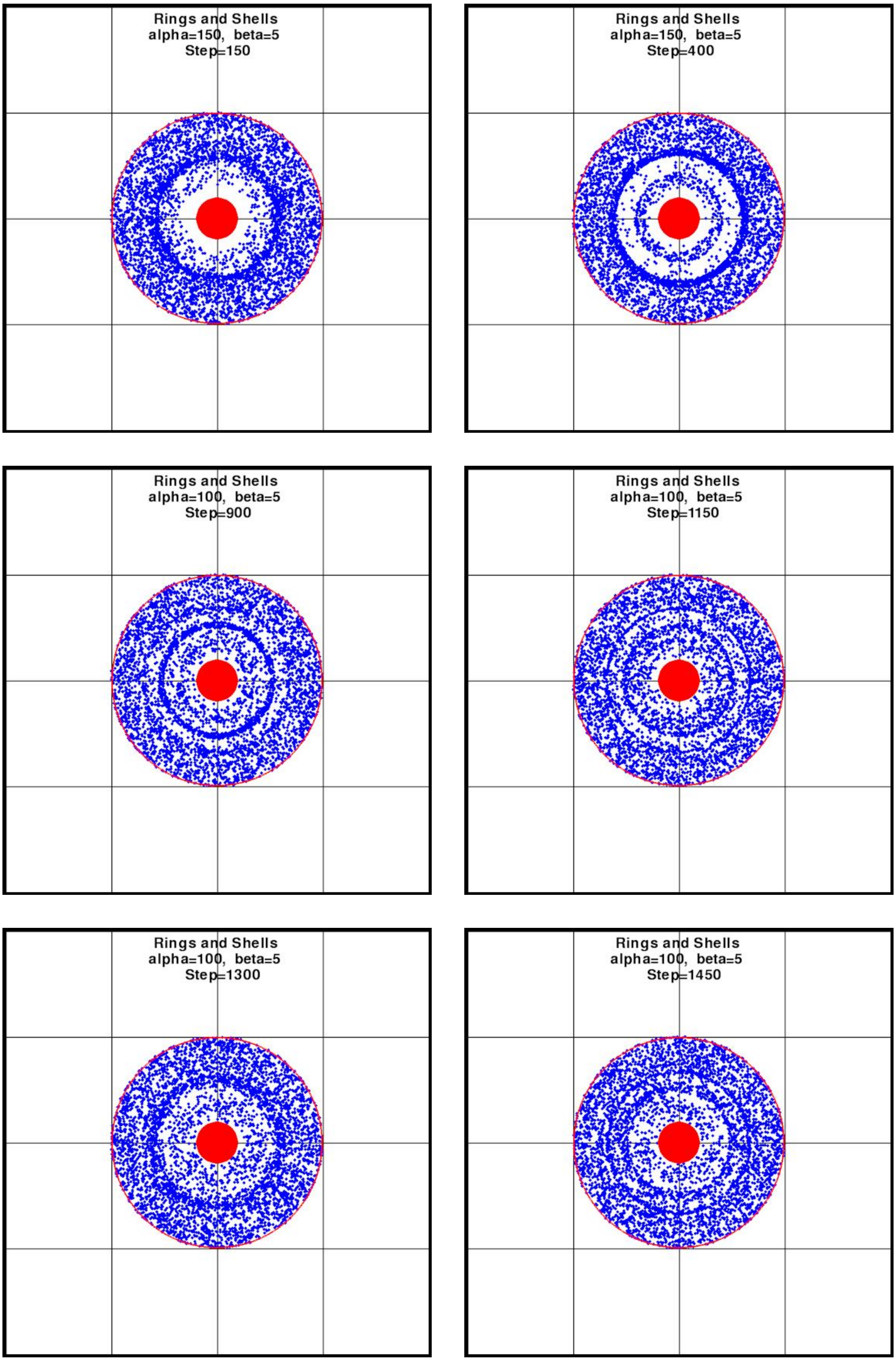

Figure 4. Width: expand then shrink.

Change in the disk of a galaxy when the width of the energy scale variation is expanded and then shrunk.

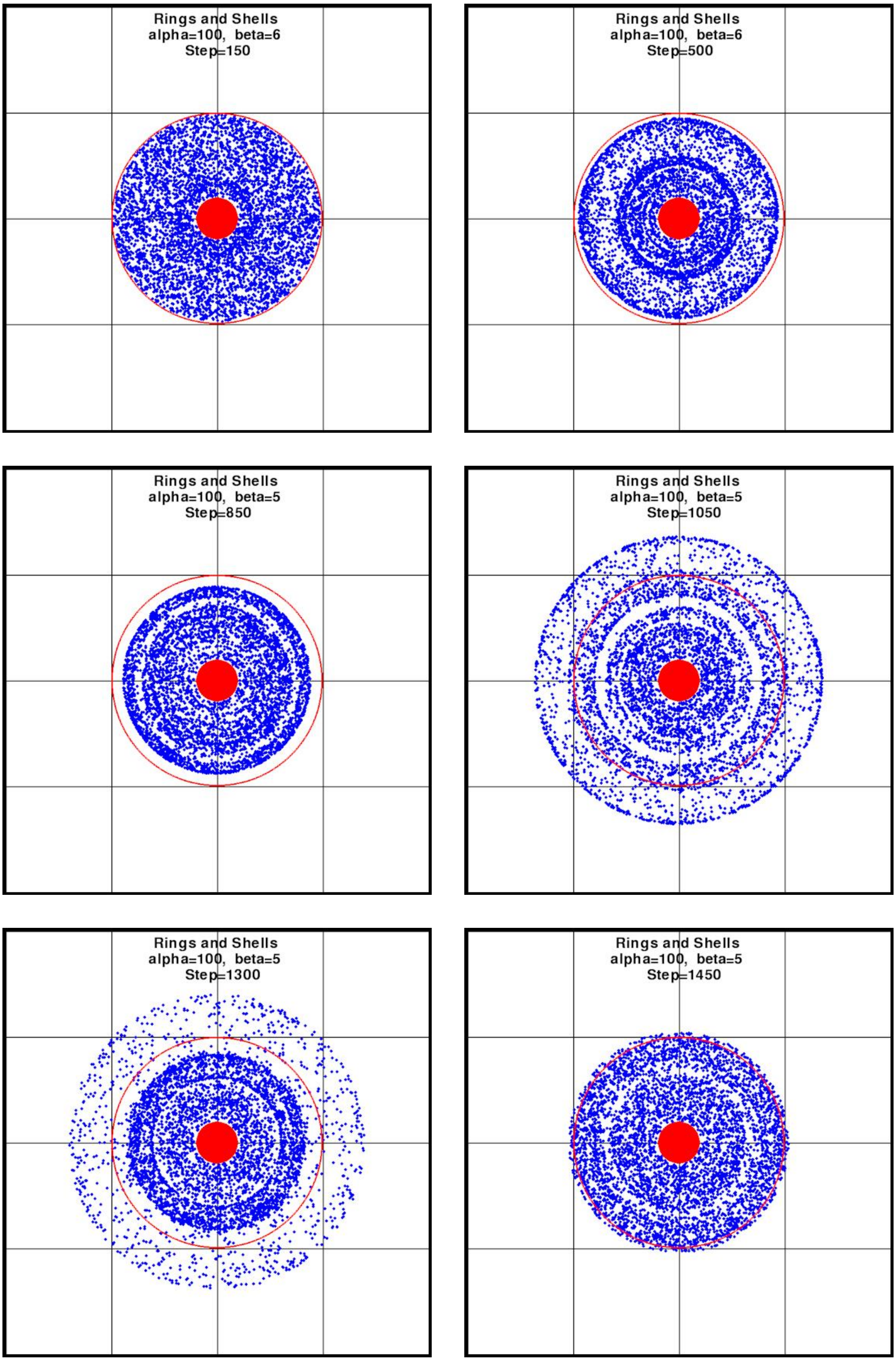

Figure 5. Height: raise then lower.

Change in the disk of a galaxy when the height of the energy scale variation is raised and then lowered.

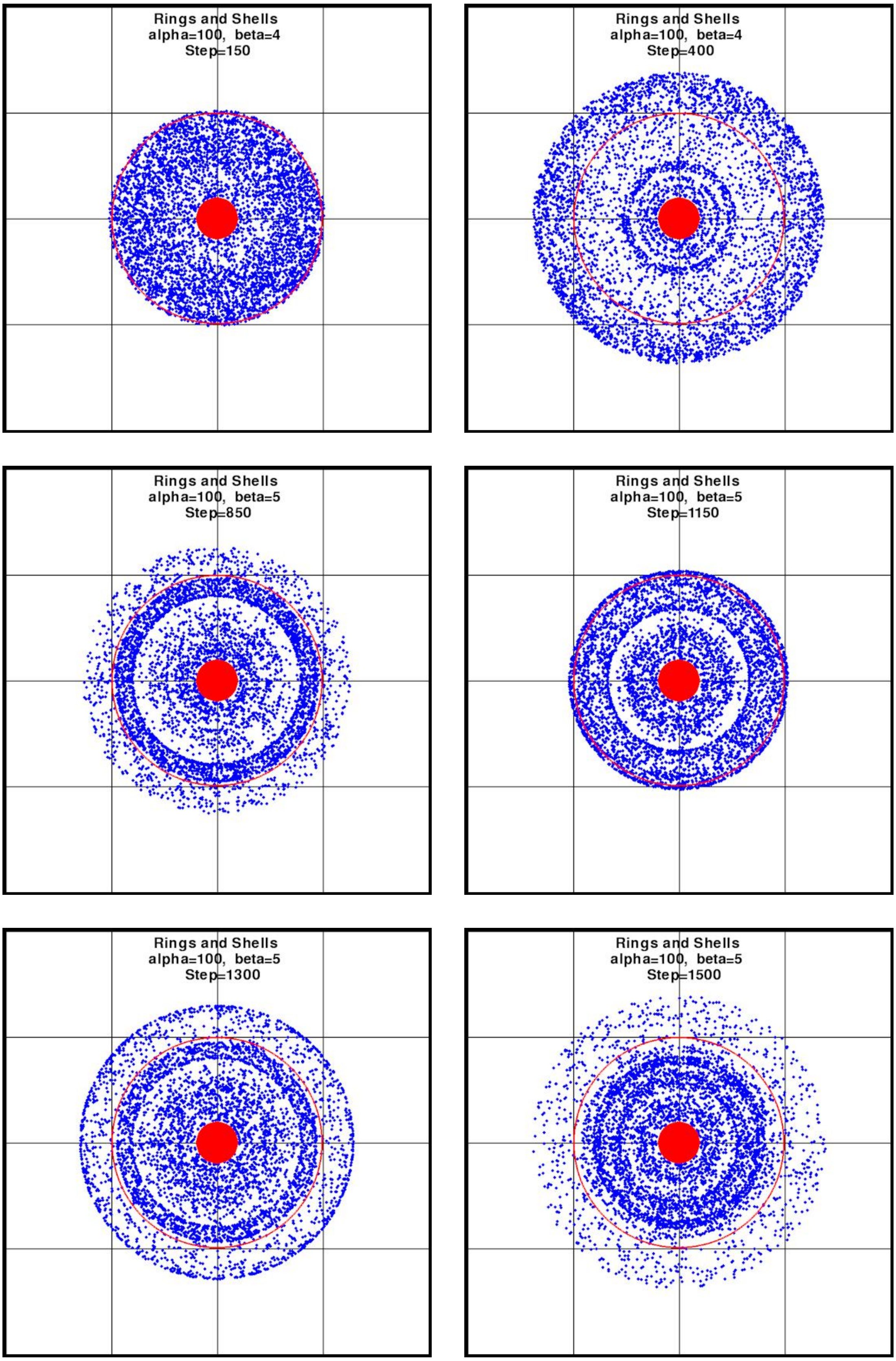

Figure 6. Height: lower then raise.

Change in the disk of a galaxy when the height of the energy scale variation is lowered and then raised.

6 Discussion

6.1 The simple models described in the previous sections demonstrate that rings in galaxies (and by extension shells) can be formed by changes in the underlying energy scale variation.

6.2 However, it is clear that most observations of rings and shells have been triggered by the disturbances caused by a second interacting galaxy. There is usually an obvious galaxy in the neighbourhood that has been involved in a recent interaction. So we are not claiming that changes in the energy scale variation completely obviate the need for an interacting galaxy.

6.3 The galaxy interaction may not be sufficient, of itself, to account for all the rings and shells. The interaction may well trigger changes in the energy scale variation that then lead to an enhanced creation of rings and shells.

6.4 Nevertheless, there may be cases of isolated galaxies where some instability causes a change in the energy scale variation with the subsequent appearance of rings. In these rare cases there is no involvement from a second interacting galaxy. This is probably what is happening in Hoag's object.

6 References

JoKe1. "On the variation of the energy scale: an alternative to dark matter". (Sep 2015). www.varensca.com

JoKe2. "On the variation of the energy scale 2: galaxy rotation curves". (Nov 2015). www.varensca.com

JoKe3. "On the variation of the energy scale 3: parameters for galaxy rotation curves". (Nov 2015). www.varensca.com

JoKe6. "On the variation of the energy scale 6: galaxy interactions". (Aug 2016). www.varensca.com

JoKe15. "On the variation of the energy scale 15: galaxy interactions". (Feb 2018). www.varensca.com