Formation of Various Shapes of Galaxies

Based on the Energy Circulation Theory

Version-2023.01

Galactic seed separation completed ⇒ **stellar seed release** starts.

Inclined flat separation of a local intrinsic energy of a galactic seed

Types of stellar seed releases from a galactic seed:

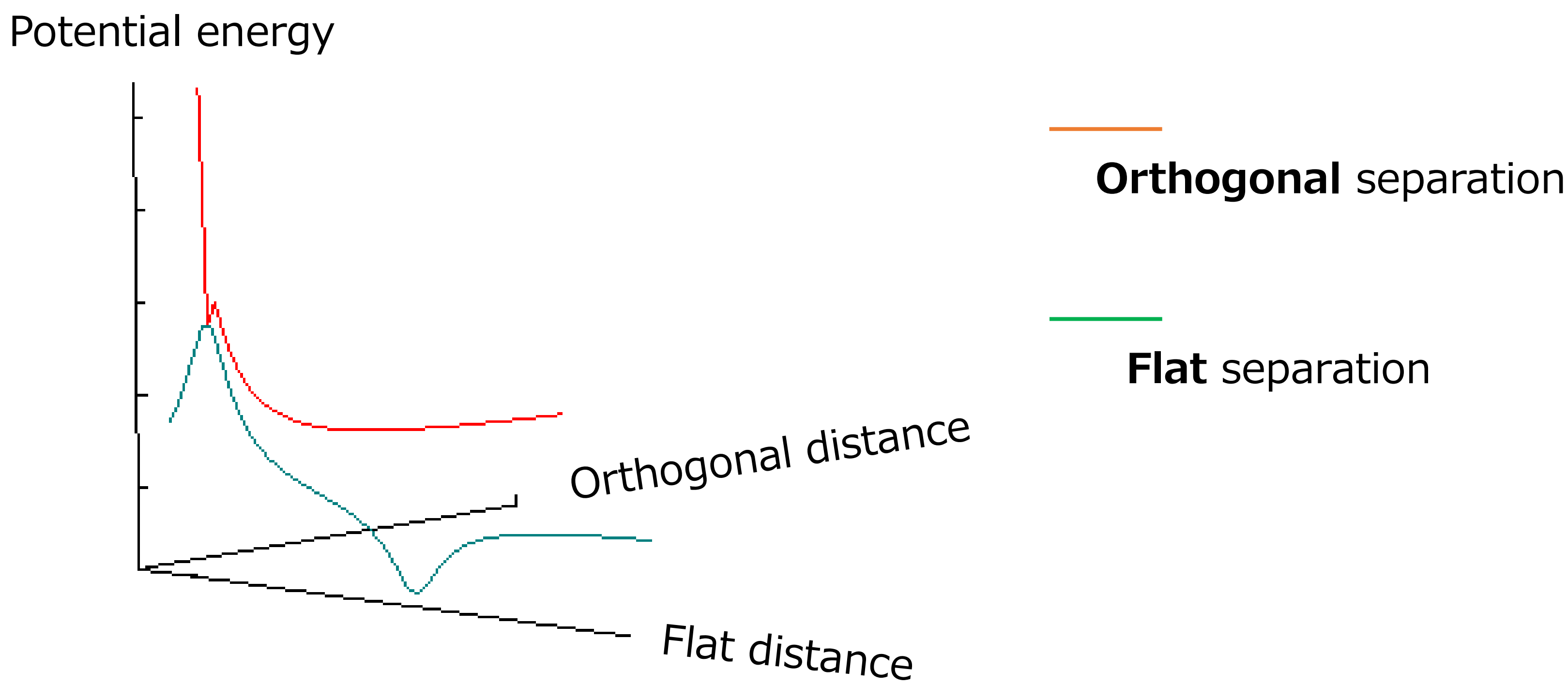
1. **Linear release**
   - Randomly and continuously stellar seeds are released.
   - Flat release and orthogonal release
2. **Ring release**
   - Simultaneous flat releases on the entire circumference

     Stellar seeds in a ring ----- **intra-circulation force** works

     Continue to circulate as the radius expands by space expansion.
   - A ring of stellar seeds is released intermittently.

Classification of galactic seeds to release stellar seeds:

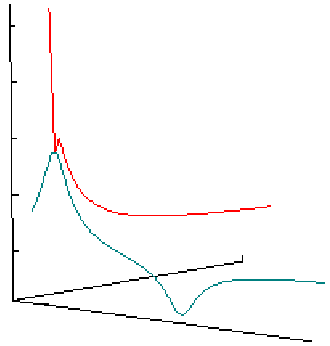
Use the same one for **gamma-ray bursts**



Change of **potential energy** in a **galactic seed separation**

released as radiation (**gamma-ray burst**, gravitational wave)

Galactic seeds after a galactic seed separation:



Type-1 GRB:

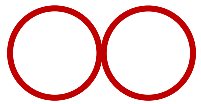
- Enough receding speed at the energy trough of orthogonal separation.
- Consists of only an orthogonal separation.
- **Two seeds continue to recede**.

Type-2 GRB:

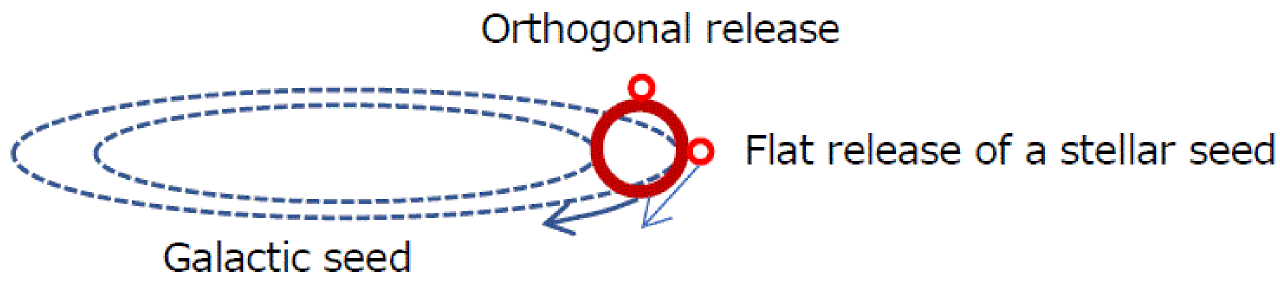
- The distance vibrates around the trough and gets static.
- From the trough of orthogonal division, subsequent flat separation starts.
- If the speed at the trough of flat separation is high, the distance continues to increase or **gets constant without a contraction**.

Type-3 GRB:

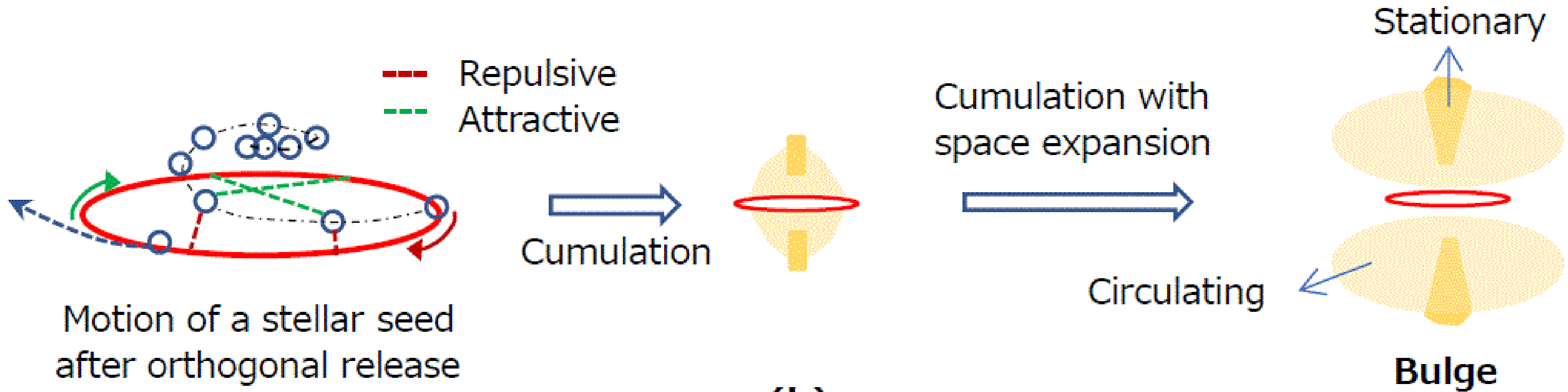
- The receding speed is not enough in flat separation.
- The distance vibrates around the trough and releases radiations. Then, two seeds get static.
- Results in **attached two galactic seeds.**



Type-1: galaxy formed from a **single galactic seed**



(a)



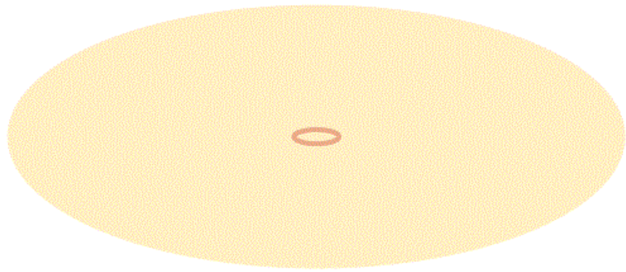
(b)

Linear releases of stellar seeds

Flat and intermediate releases ⟶ form an elliptical galaxy or halo

Orthogonal releases ⟶ form a bulge structure

Type 1-1: By independent linear releases



(a) **Elliptical galaxy**

Simulation using an exponential time unit:

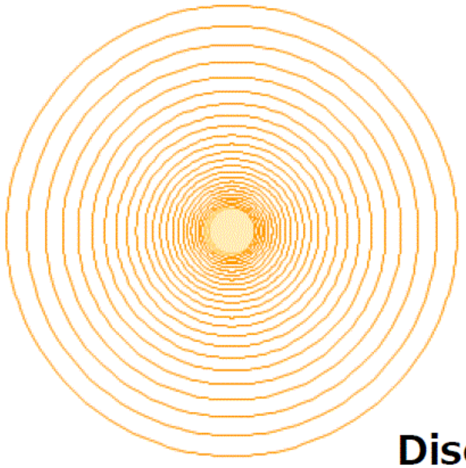
For $T_{1.1} = m$, the space expands by 1.1^m times. Present: $m = 0$

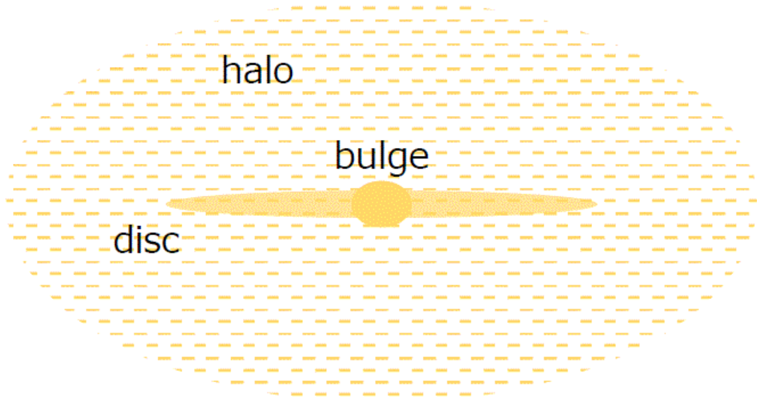
$r_0 = 1.1^m r_m$, r_m: radius at $T_{1.1} = -m$

Ring releases: occur intermittently once per $T_{1.1} = 1$

(Reported 42 shells of NGC 3923 show this interval.)

Type 1-2: By simultaneous flat releases in a ring (**ring release**)





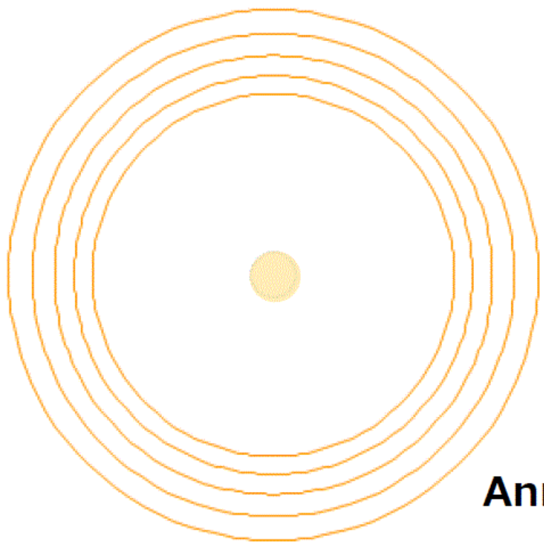
NGC 3923

NGC 691

Disc galaxy (disc + bulge)

(b) Intermittent ring releases once per $T_{1.1} = 1$ ($T_{1.1} = -24$ to 0)

$$[x_m, y_m] = R_m[\sin t, \cos t], R_m = 1.1^m \quad (0 \le t \le 2\pi)\ (m = 0 \text{ to } 24)$$



Hoag's Object

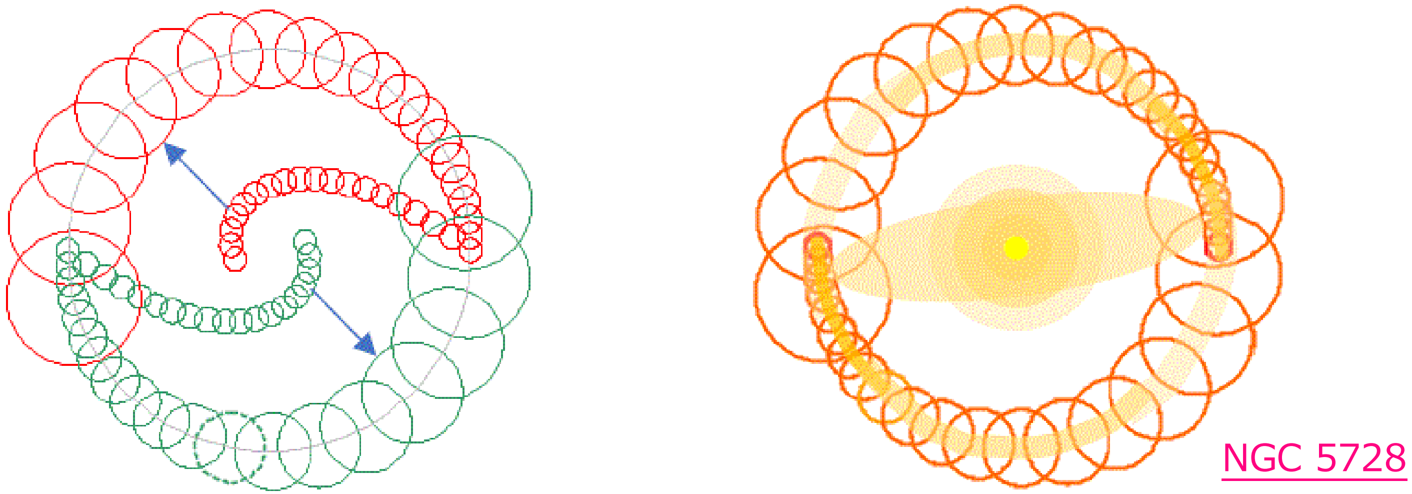
Annulus galaxy (rings+ bulge)

(c) Galactic seed released rings then exhausted ($T_{1.1} = -26$ to -22).

Type-2: galaxy formed from **rotating binary galactic seeds**

Type 2-1: By intermittent **ring releases**

Type 2-1: By intermittent ring releases from rotating binary galactic seeds



(a) Intermittent ring releases

(b) **Barred ring galaxy**

$$T_{1.1} = -18 \text{ to } 0\text{: } r_m = 1.1^m.\ R_0 = 3 * 1.1^{18},\ \theta_m = 0.236\pi(1.1^m - 1)$$

$$R_m = 3 * 1.1^{18-m} \quad , \quad m = 0 \text{ to } 18$$

Galactic seeds:

$$[x_m, y_m]_1 = [\sin t + R_m \cos\theta_m\,, \cos t + R_m \sin\theta_m]$$

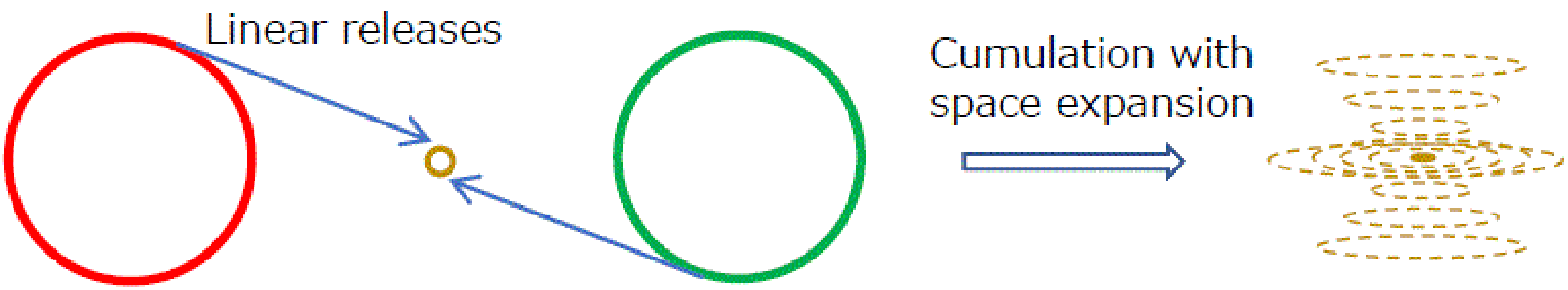
$$[x_m, y_m]_2 = [\sin t - R_m \cos\theta_m\,, \cos t - R_m \sin\theta_m]$$

Released rings:

$$[x_m, y_m]_1 = [r_m \sin t + R_0 \cos\theta_m\,, r_m \cos t + R_0 \sin\theta_m]$$

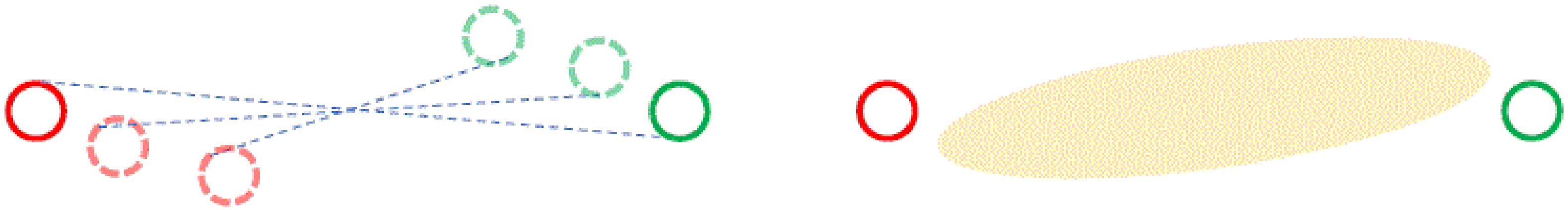
$$[x_m, y_m]_2 = [r_m \sin t - R_0 \cos\theta_m\,, r_m \cos t - R_0 \sin\theta_m]$$

Formation of a **bar-bulge**



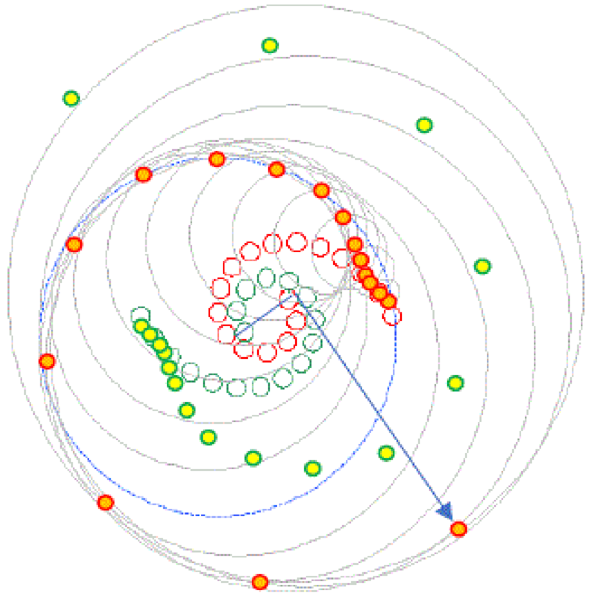
(c) Formation of a “**bar-bulge**” of stellar seeds

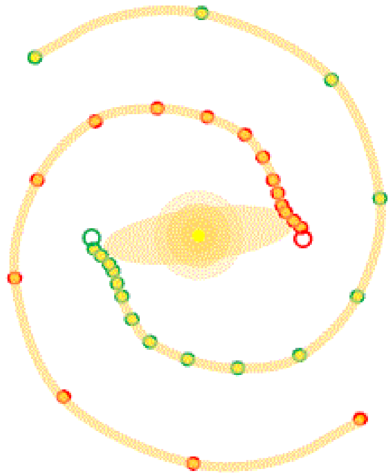
Circulations are formed not limited at the center, spreading on the line.



(d) Distribution of **bar-bulges**

Type 2-2: By **linear releases** from two outer-ends of rotating binary galactic seeds





NGC 1300

(b) **Barred arm galaxy** (with bar-bulge)

(a) Released stellar seeds from two ends move linearly.

$$T_{1.1} = -16 \text{ to } 0: \ V_{1.1} = 1.2, \ R_m = 3 * 1.1^{(16-m)}, \ \theta_m = 0.613\pi(1.1^m - 1)$$

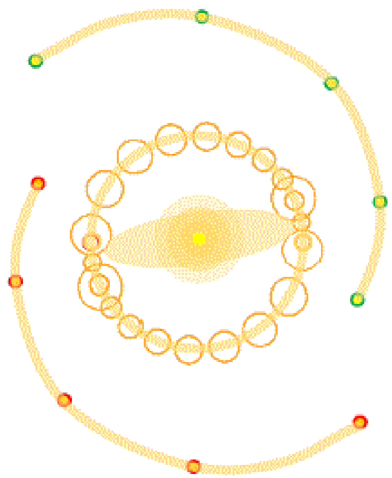
Short duration of linear releases:

$T_{1.1} = -16\ to - 12$: Linear releases

$T_{1.1} = -11\ to\ 0$: Ring releases

$r_m = 1.1^m, R_0 = 3 * 1.1^{16}$

$\theta_m = 0.613\pi(1.1^m - 1)$



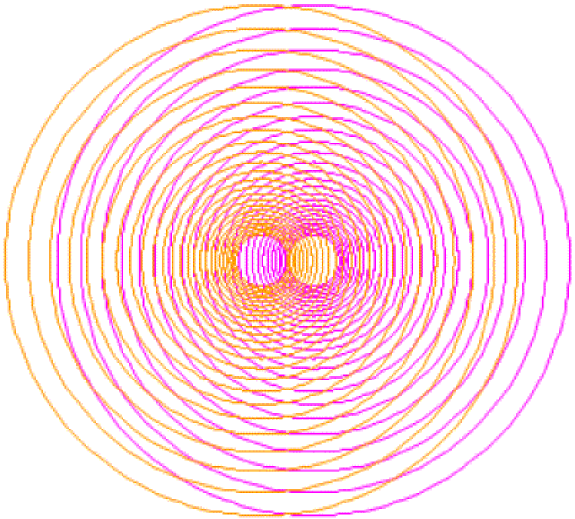
NGC 2217

(c) **Barred ring-arm galaxy**

Type-3: galaxy formed from **two attached galactic seeds**

Type 3-1: By **intermittent ring releases** from two attached galactic seeds

Rings are released once per $T_{1.1} = 1$ from $T_{1.1} = -24$ to 0: **Double-disc galaxy**



Andromeda Galaxy

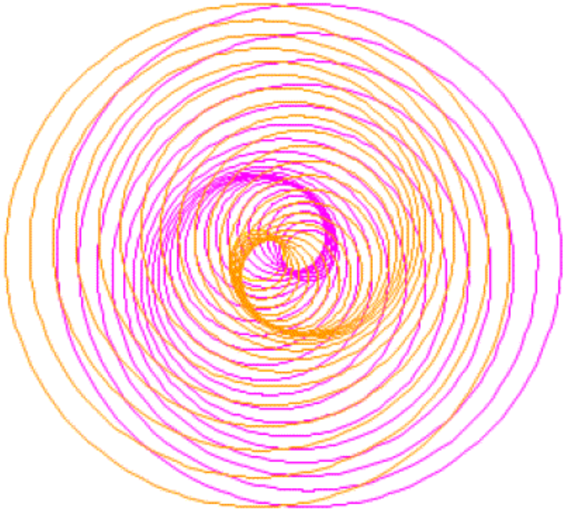
(a) No rotation of galactic seeds $\Omega_{1.1} = 0$

$$[x_m, y_m]_1 = [r_m \sin t + \cos(m\Omega_{1.1}), r_m \cos t + \sin(m\Omega_{1.1})]$$

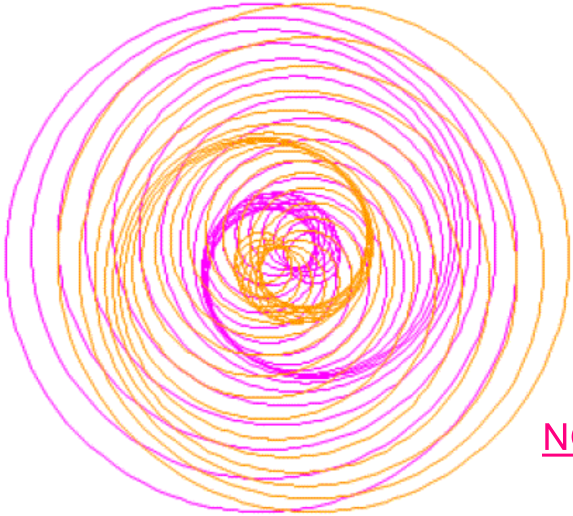
$$[x_m, y_m]_2 = [r_m \sin t - \cos(m\Omega_{1.1}), r_m \cos t - \sin(m\Omega_{1.1})]$$

$$r_m = 1.1^m, \qquad \Omega_{1.1} = 0\ (a), \frac{\pi}{12}\ (b), \frac{\pi}{8}\ (c), \frac{\pi}{6}\ (d) \text{ or } \frac{\pi}{4}\ (e)$$

$$m = 0 \text{ to } 24, \qquad 0 \le t \le 2\pi$$

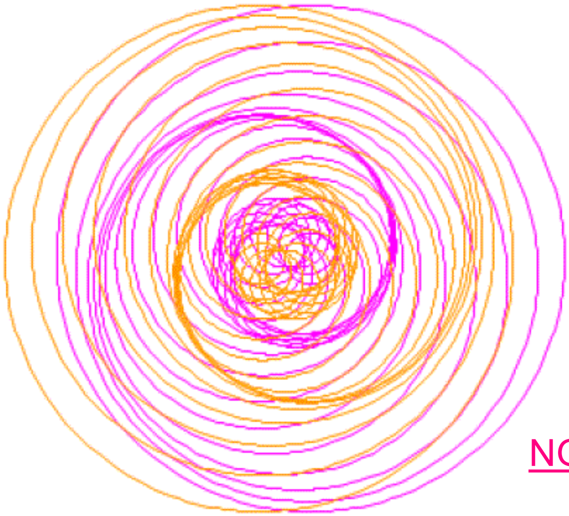


(b) Rotation by $\Omega_{1.1} = \pi/12$



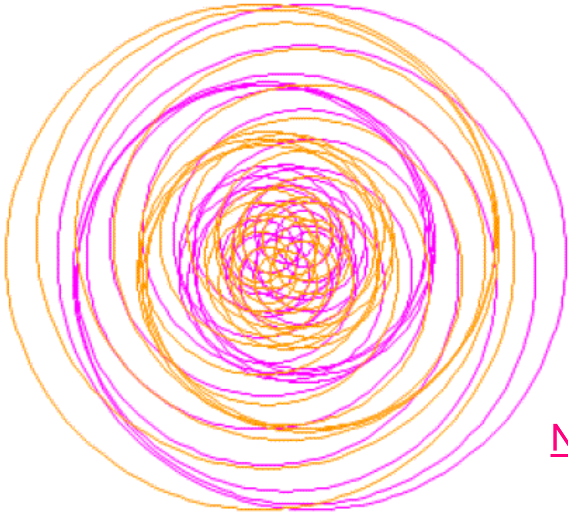
NGC 5861

(c) Rotation by $\Omega_{1.1} = \pi/8$



NGC 6384

(d) Rotation by $\Omega_{1.1} = \pi/6$



NGC 3147

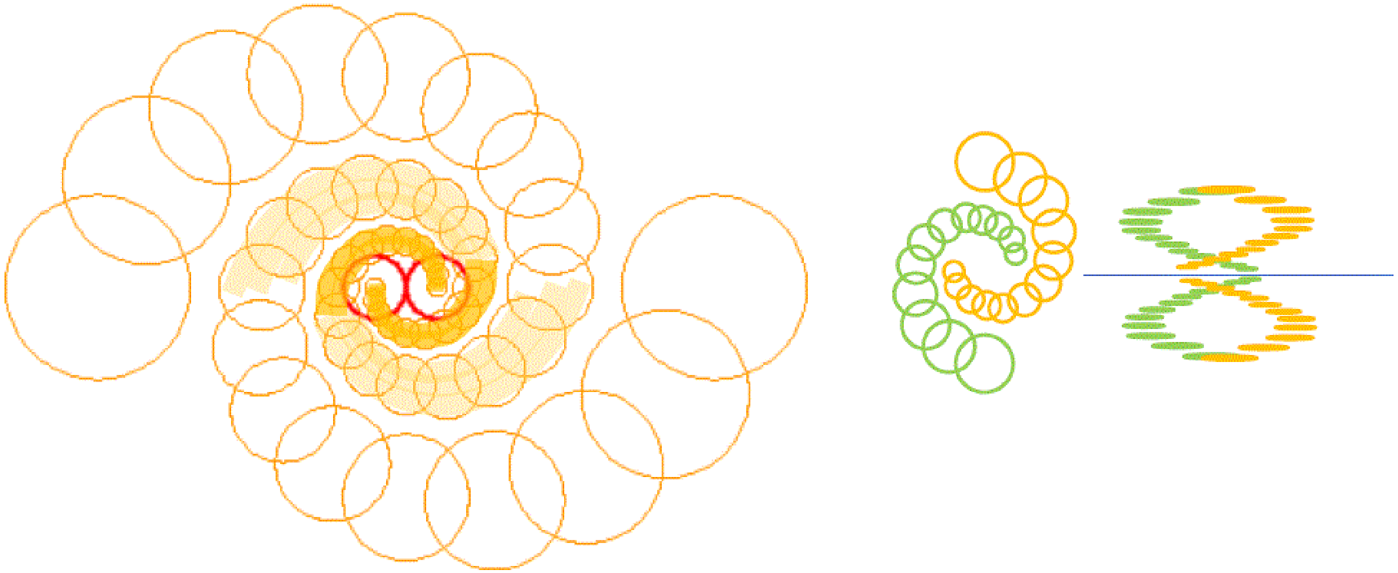
(e) Rotation by $\Omega_{1.1} = \pi/4$

Double-disc galaxy showing spiral arms: **Spiral double-disc galaxy**

Bulges of non-rotating attached galactic seeds:

Respectively remain over/under the two galactic seeds.

Bulges of a spiral double-disc galaxy:



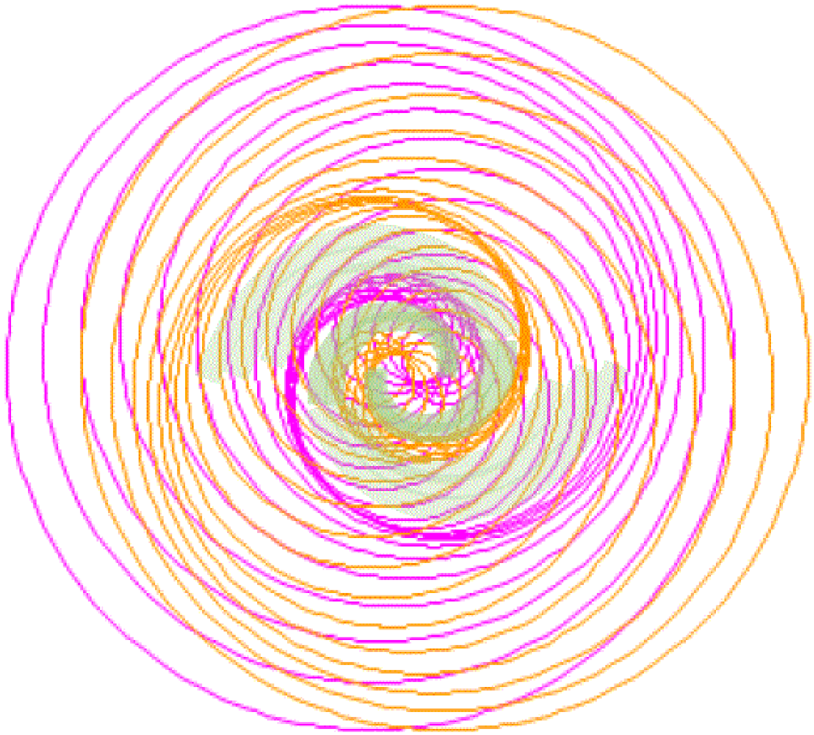
(a) Bulge: $T_{1.1} = -24$ to 0 , $\Omega_{1.1} = \pi/8$, $r_{bulge} = 0.3$

$$[x_m, y_m]_1 = [r_m \sin t + R_m \cos(m\Omega_{1.1}) \,, r_m \cos t + R_m \sin(m\Omega_{1.1})]$$

$$[x_m, y_m]_2 = [r_m \sin t - R_m \cos(m\Omega_{1.1}) \,, r_m \cos t - R_m \sin(m\Omega_{1.1})]$$

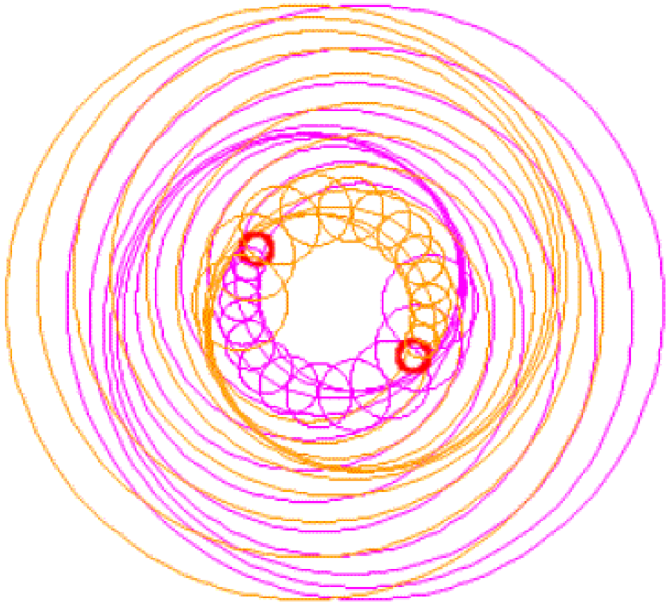
$$r_m = 0.3 * 1.1^m \,, \qquad R_m = 1.1^m \,, \qquad \Omega_{1.1} = \pi/8$$

Overall appearance of the galaxy (double-disc + bulge)

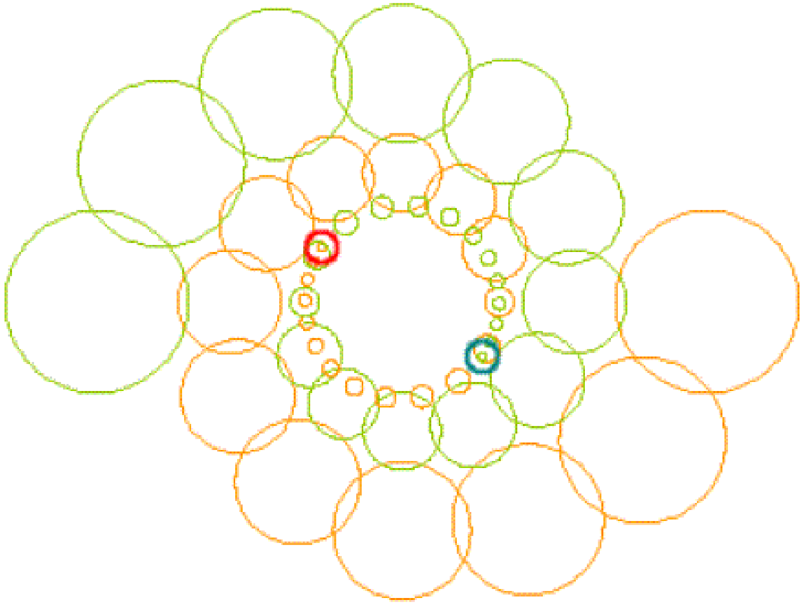


(b) **Spiral double-disc galaxy** ($T_{1.1} = -24$ to 0 , $\Omega_{1.1} = \pi/8$)

Type 3-2: By ring releases from rotating two galactic seeds firstly attached then receding by the space expansion



(a) Disc by ring releases



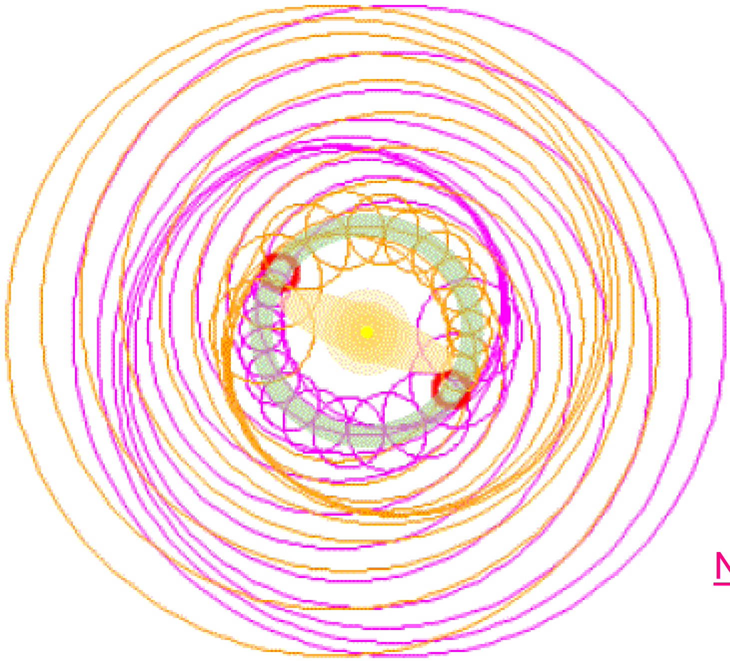
(b) Bulge by orthogonal releases

(1) $T_{1.1} = -24$ to -13 : $r = 1$, $R = 1$, $r_{bulge} = 0.3$, $\Omega_{1.1} = \pi/6$

(2) $T_{1.1} = -12$ to 0 : $r = 0.5$, $R_m = 1.1^m$, $R_0 = 1.1^{12} = 3.14$, $r_{bulge} = 0.15$,

$$\theta_m = 0.557\pi(1.1^m - 3.138)$$

Overall appearance of the galaxy (double-disc & ring + bulge + bar-bulge)



NGC 105

(c) Barred ring & double-disc galaxy

Published paper:

S. Nagao, Formation of Major Types of Galaxies Based on the Energy Circulation Theory, *Rep. Adv. Phys. Sci.* **6** (2022) 2250004.

https://doi.org/10.1142/S2424942422500049

Website:

Energy Circulation Theory (ECT) home

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