Galaktyki spiralne

Typy galaktyk spiralnych

- W zależności od rozmiarów zgrubienia centralnego: Sa, Sb, Sc, Sd
- Ze względu na obecność poprzeczki: SBa, SBb, SBc
- Ze względu na wygląd struktury spiralnej: “wielkoskalowe”, “połamane”, “kłaczkowate”, nieregularne.

Modele powstawania ramion spiralnych

- Fale gęstości w dysku galaktycznym (Lin i Shu 1964, 1966 ..) ramiona są długowieczne
- Stochastyczne wzbudzanie przez lokalne niestabilności. Ramiona istnieją krótko.
- Wzbudzanie ramion przez poprzeczkę
- Wzbudzanie ramion poprzez oddziaływania pływowe pobliskiej galaktyki (a nawet przez niejednorodności rozkładu ciemnej materii).
- Wpływ pól magetycznych?

Rezonanse Lindblada

Zakładamy, że zaburzenie gęstości i zwiazane z nim zaburzenie potencjału rotuje z prędkością kątową Ω_b. Równanie ruchu w układzie cylindrycznym wspólrotującym z zaburzeniem ma postać

$$\ddot{R} - R\dot{\varphi}^2 = -\frac{\partial\Phi}{\partial R} + 2R\dot{\varphi}\Omega_b + \Omega_b^2 R$$

$$R\ddot{\varphi} + 2\dot{R}\dot{\varphi} = -\frac{1}{R}\frac{\partial\Phi}{\partial\varphi} - 2\dot{R}\Omega_b$$

Zakładamy, że zaburzenie jest słabe $\Phi_1/\Phi_0 \ll 1$

$$\Phi(R,\varphi) = \Phi_0(R) + \Phi_1(R,\varphi)$$

$$R(t) = R_0 + R_1(t)$$

$$\varphi(t) = \varphi_0(t) + \varphi_1(t)$$

$$R_0\dot{\varphi}_0^2 = -\frac{d\Phi_0}{dR} - 2R_0\dot{\varphi}_0\Omega_b - \Omega_b^2 R_0$$

$$R_0(\varphi_0 + \Omega_b)^2 = \left(\frac{d\Phi_0}{dR}\right)_{R_0}$$

$$\Omega_0 = \Omega(R_0)$$

$$\Omega(R) = \pm\left(\frac{1}{R}\frac{d\Phi_0}{dR}\right)^{1/2}$$

$$\dot{\varphi}_0 = \Omega_0 - \Omega_b$$

$$\varphi_0 = (\Omega_0 - \Omega_b)t$$

$$\ddot{R}_1 + \left(\frac{d^2\Phi_0}{dR^2} - \Omega^2\right)_{R_0} R_1 - 2R_0\Omega_0\phi_1 = -\left(\frac{\partial\Phi_1}{\partial R}\right)_{R_0}$$

$$\ddot{\varphi}_1 + 2\Omega_0\frac{\dot{R}_1}{R_0} = -\frac{1}{R_0^2}\frac{\partial\Phi_1}{\partial\varphi}$$

$$\Phi_1(R,\varphi) = \Phi_b(R)\cos(m\varphi)$$

zakładamy, że $\varphi_1 \ll 1$

$$\ddot{R}_1 + \left(\frac{d^2\Phi_0}{dR^2} - \Omega^2 \right)_{R_0} R_1 - 2R_0\Omega_0\dot{\varphi}_1 = -\left(\frac{d\Phi_b}{dR} \right)_{R_0} \cos\left[m(\Omega_0 - \Omega_b)t\right]$$

$$\ddot{\varphi}_1 + 2\Omega_0 \frac{\dot{R}_1}{R_0} = -\frac{m\Phi_b(R_0)}{R_0^2} \sin\left[m(\Omega_0 - \Omega_b)t\right]$$

całkujemy drugie równanie

$$\dot{\varphi}_1 = -2\Omega_0 \frac{R_1}{R_0} - \frac{m\Phi_b(R_0)}{R_0^2(\Omega_0 - \Omega_b)} \cos\left[m(\Omega_0 - \Omega_b)t\right]$$

$$\ddot{R}_1 + \kappa_0^2 R_1 = -\left[\frac{d\Phi_b}{dR} + \frac{2\Omega\Phi_b}{R(\Omega-\Omega_b)}\right]_{R_0} \cos\left[m(\Omega_0-\Omega_b)t\right]$$

$$\kappa_0^2 = \left(\frac{d^2\Phi_0}{dR^2} + 3\Omega^2\right)_{R_0} = \left(R\frac{d\Omega^2}{dR} + 4\Omega^2\right)_{R_0}$$

$$R_1(t) = C_1 cos(\kappa_0 t + \phi) - -\left[\frac{d\Phi_b}{dR} + \frac{2\Omega\Phi_b}{R(\Omega-\Omega_b)}\right]_{R_0} \frac{\cos\left[m(\Omega_0-\Omega_b)t\right]}{\Delta}$$

$$\Delta = \kappa_0^2 - m^2(\Omega_0-\Omega_b)^2$$

$$\Delta = \kappa_0^2 - m^2(\Omega_0 - \Omega_b)^2$$

$$R_1(\varphi_0) = C_1 \cos\left(\frac{\kappa_0 \varphi_0}{\Omega_0 - \Omega_b} + \phi\right) + C_2 \cos(m\varphi_0)$$

$$C_2 = -\frac{1}{\Delta}\left[\frac{d\Phi_b}{dR} + \frac{2\Omega\Phi_b}{R(\Omega - \Omega_b)}\right]_{R_0}$$

Dla $C_1 = 0$ mamy orbity zamknięte

R_1 staje się osobliwe dla rezonansu korotacyjnego

$$\Omega_0 = \Omega_b$$

i dla rezonansów Lindblada

$$m(\Omega_0 - \Omega_b) = \pm\kappa$$

ON THE SPIRAL STRUCTURE OF DISK GALAXIES

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ABSTRACT

It is shown that gravitational instability is a plausible basis for the formation of the spiral pattern in disk galaxies An explicit asymptotic formula is obtained for the form of the spiral. It gives reasonable numerical results for the galaxy, and qualitatively satisfactory trends for normal spirals of various types.

I. INTRODUCTION

The mechanism for the formation of the spiral patterns observed in most disk-shaped galaxies has not yet been fully understood. There is little doubt, from the observational data available, that these magnificent manifestations are associated with the interstellar gas and the brilliant young stars born in them. But could the old stars also play an important role in the formation of the spiral structure?

To construct a theory of the spiral structure, one must bear in mind the following important components of a galaxy:

a) *The stars*—with their gravitational forces, circular velocity, and velocity dispersion
b) *The interstellar gas*—with *its* gravitational field and pressure
c) *The magnetic field*—which exerts its influence through the highly conducting interstellar gas.

$$\mu_t + r^{-1}[(r\mu u)_r + (\mu v)_\theta] = 0\ ,$$

$$u_t + uu_r + (v/r)u_\theta - v^2/r = \phi_r\ ,$$

$$v_t + uv_r + (v/r)v_\theta + uv/r = \phi_\theta/r\ ,$$

$$\phi_{rr} + \phi_r/r + \phi_{\theta\theta}/r^2 + \phi_{zz} = -4\pi G\mu(r,\, \theta)\delta(z)\ ,$$

We obtain

$$\mu'_t + \Omega\mu'_\theta + \frac{1}{r}(r\,\mu_0 u')_r + (\mu_0/r)\,v'_\theta = 0\,, \tag{2a}$$

$$u'_t + \Omega u'_\theta - 2\Omega v' = \phi'_r\,, \tag{2b}$$

$$v'_t + \Omega v'_\theta + (\kappa^2/2\Omega)u' = \phi'_\theta/r\,, \tag{2c}$$

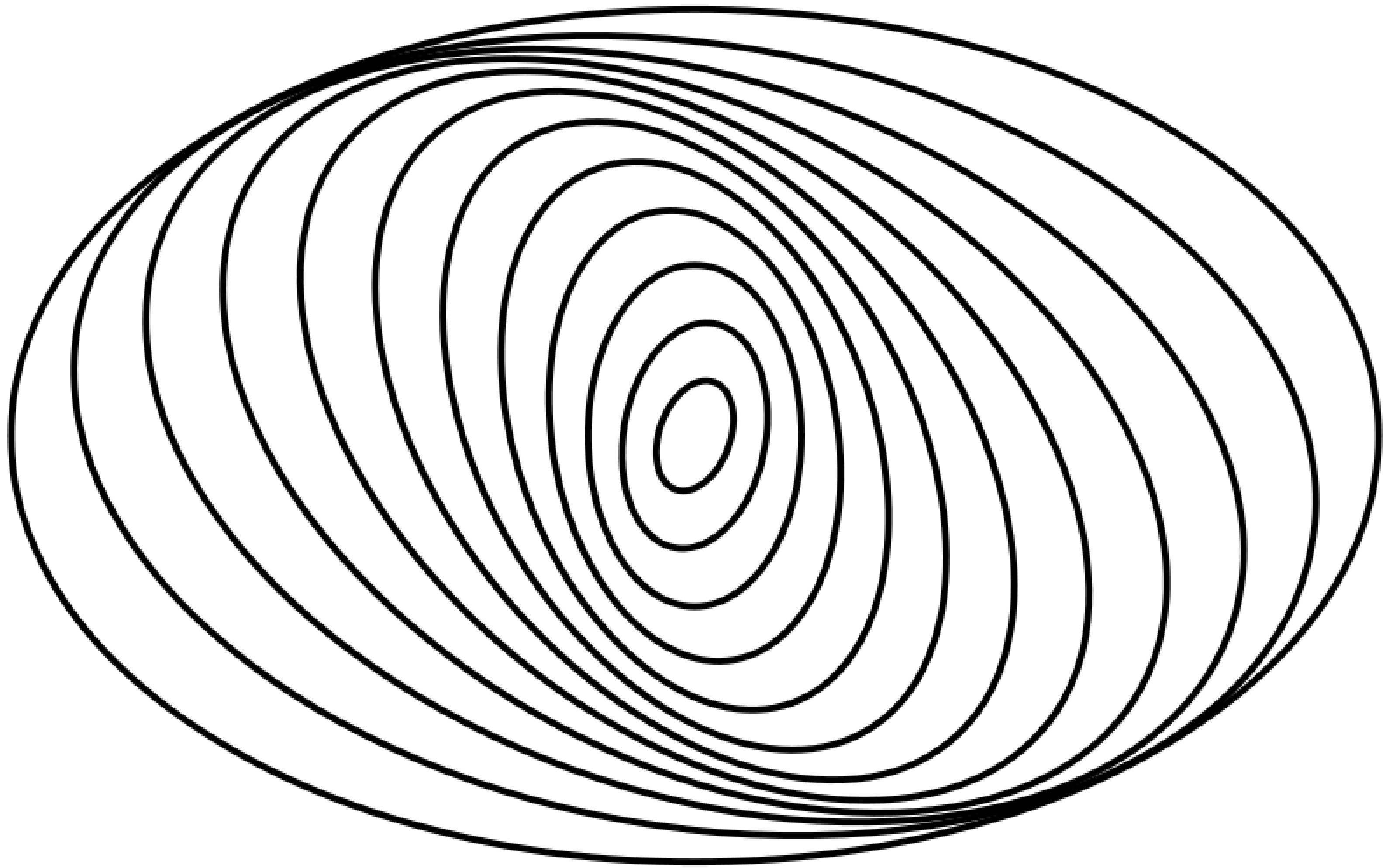
$$\phi'_{rr} + \phi'_r/r + \phi'_{\theta\theta}/r^2 + \phi'_{zz} = -4\pi G\mu'\,\delta(z)\,. \tag{2d}$$

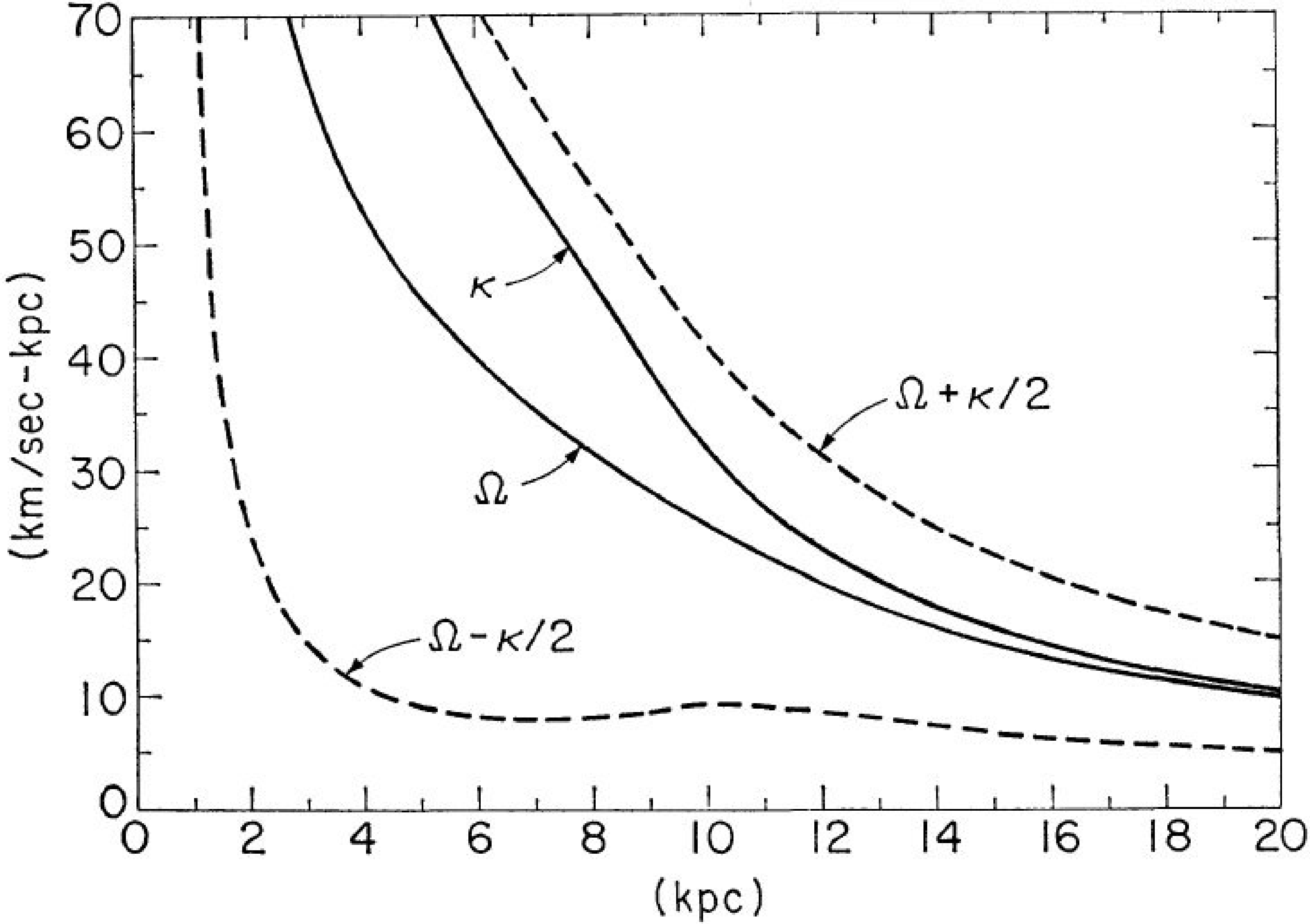
In the above equations, κ is the epicyclic frequency given by

$$\kappa^2 = 4\Omega^2[1 + (r/2\Omega)(d\Omega/dr)]\,. \tag{3}$$

The set of linearized equations (2a–d) admits solutions of the type

$$\mu' = Re\{\mu^{(1)}(r)\exp[i(\omega t - n\theta)]\}\,, \qquad \omega = \omega_r + i\omega_i\,, \tag{4}$$





70
60
50
40
30
20
10
0
(km/sec-kpc)
0
2
4
6
8
10
12
14
16
18
20
(kpc)
κ
Ω
$\Omega+\kappa/2$
$\Omega-\kappa/2$

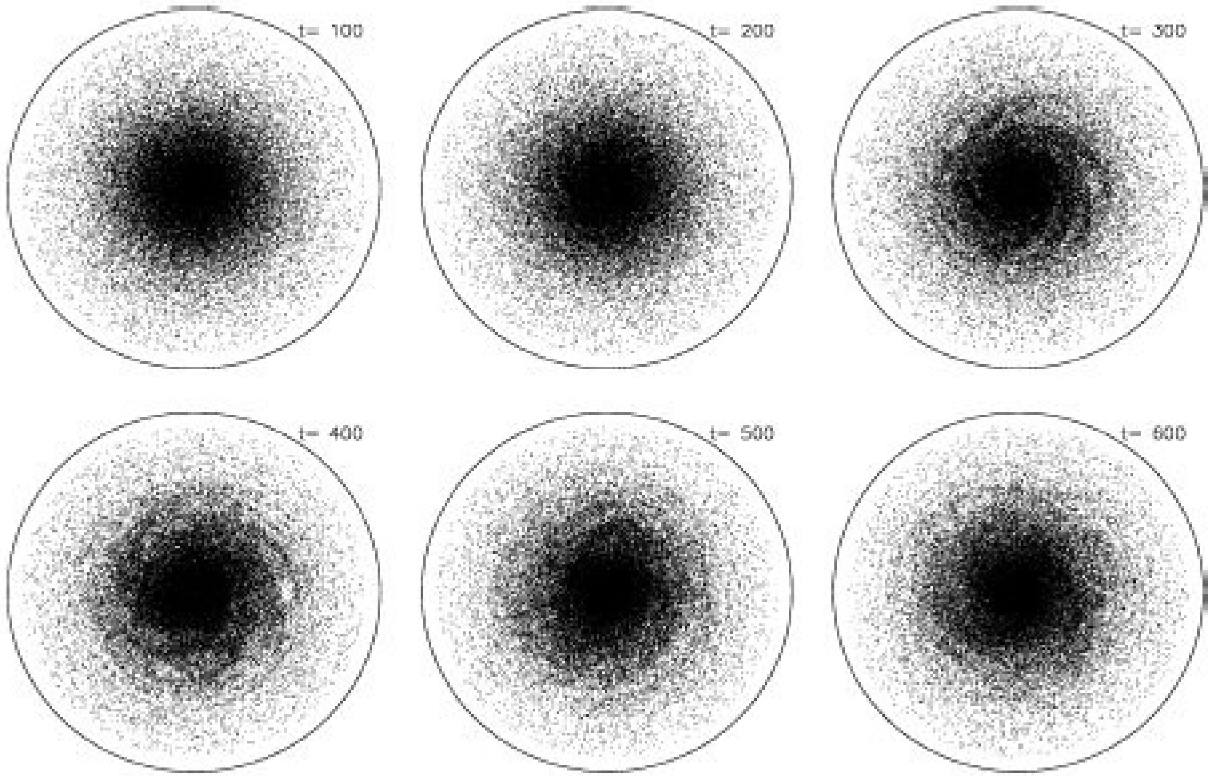


Figure 3. The time evolution of the simulation in which disturbance forces included sectoral harmonics $m > 2$. Only one particle in 400 is plotted in order to avoid saturating the images. Multi-arm patterns appear soon after the start. The grid edge (outer circle) has radius $R = 6.5$ and one rotation at $R = 2$ is 13 time units.

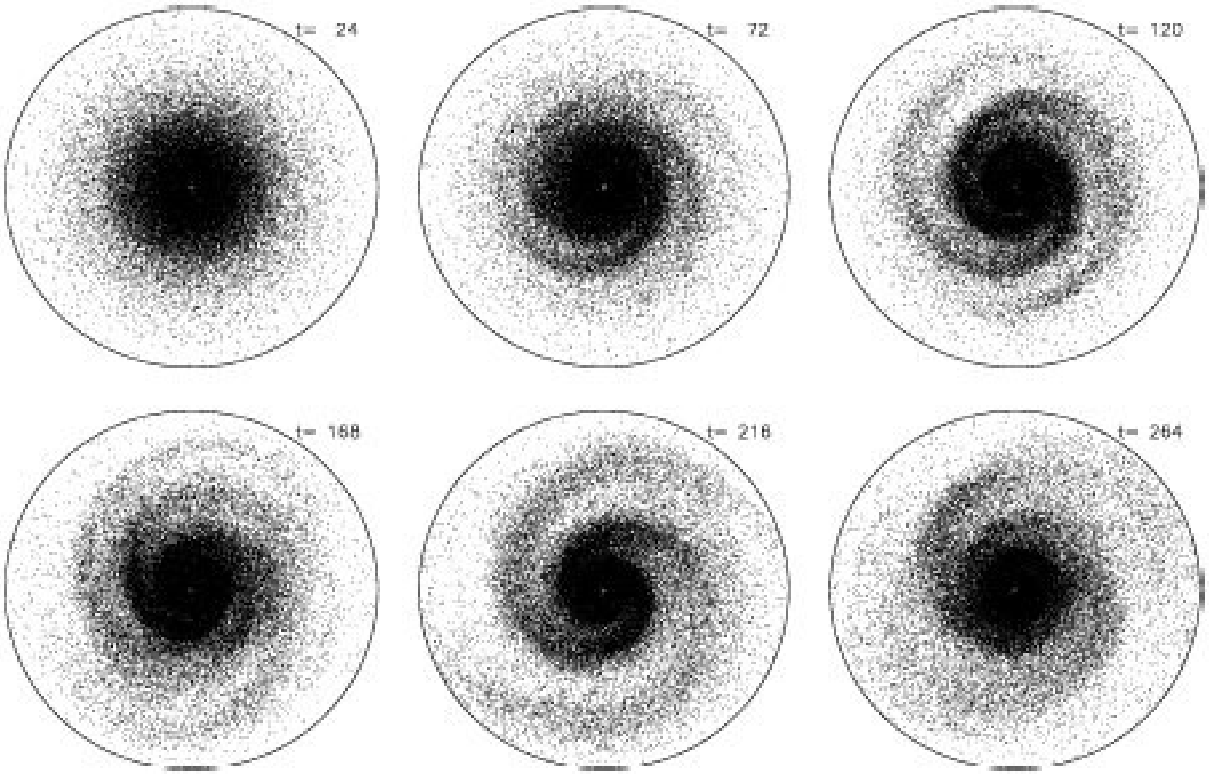


Figure 7. Evolution of the model run to reproduce that reported by DT94 and Z96. The six snapshots, which include one particle in 40, should be compared with those shown in Fig. 2 of both papers. The circle is drawn at $R = 8R_{\rm d}$, although the grid extends to $12.7R_{\rm d}$.