Hydrodynamical Simulations of the Barred Galaxy NGC 4314: Gas Orbits in the Bar Region

Mariana Ramos & Gilberto C. Gómez
Centro de Radioastronomía y Astrofísica, UNAM
m.ramos@crya.unam.mx, g.gomez@crya.unam.mx

Model

We performed a 2D hydrodynamical simulation using the AMR code RAMSES (Teyssier, 2002). The gas is assumed isothermal and non-self gravitating with $T = 10^4$K. The gravitational potential for NGC 4314 is of the general form:

$$\Phi(r,\theta) = \Phi_0(r) + \sum_{m>0} \Phi_{mc}\cos(m\theta) + \Phi_{ms}\sin(m\theta),$$

where $m = 2, 4, 6$ and the amplitudes of the components in the equation are written in the form $\sum_{n=0}^{8} \alpha_n r^n$ and the values of α_n can be found in Quillen et al. (1994). The gas starts in circular motion in the axisymmetric part of the potential. The perturbation of the bar is introduced gradually during two pattern rotations, (the pattern angular velocity is $\Omega_b = 46\,\mathrm{km\ s^{-1}\,kpc^{-1}}$). From outputs generated with RAMSES, we obtain velocity data of the gas and then with a Runge-Kutta integrator we calculate the orbits in a way similar to that in Gómez et al. (2013).

Conclusion

Comparing our gas orbits with the stellar orbits obtained by Patsis (2006) we found that the gas orbits are very similar to the stellar orbits near the $L_{4,5}$ points, while for gas that lies inside the bar, our results differ, since we obtained regular orbits ($x1$ and boxy-shape) instead of chaotic orbits. From this work, we can conclude that gas shows a different behavior as the stars in the bar region.

References

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Abstract

We report the results of a numerical simulation of the barred galaxy NGC 4314. We start with a gaseous isothermal, non-self gravitating disk, initially in rotational equilibrium, which is perturbed by the gravitational potential of the bar estimated in Quillen et al. (1994) using near infrared observations. We then calculate the gas orbits in the bar region and compare them with stellar orbits obtained by Patsis (2006).

Results

In figure 1, we show the evolution of our model with the inner $m = 2$, inner $m = 4$, corotation, outer $m = 4$ and outer $m = 2$ resonances ($r = 0.25$ kpc, $r = 2.5$ kpc, $r = 3.5$ kpc, $r = 4$ kpc and $r = 5$ kpc respectively). After one pattern rotation (at $t = 140$ Myr), the gas starts to feel the perturbation of the bar and the spiral structure begins to emerge. Once the bar reaches its maximum, we observe some instabilities near corotation and all over the spiral arms. At six pattern rotations, our system reaches a steady state configuration, where the bar starts to dominate the overall shape of the disc. At 1.6 Gyr, we reproduce the morphological features of NGC 4314: the boxy shape at the outer parts of the bar and the weak spiral structure.

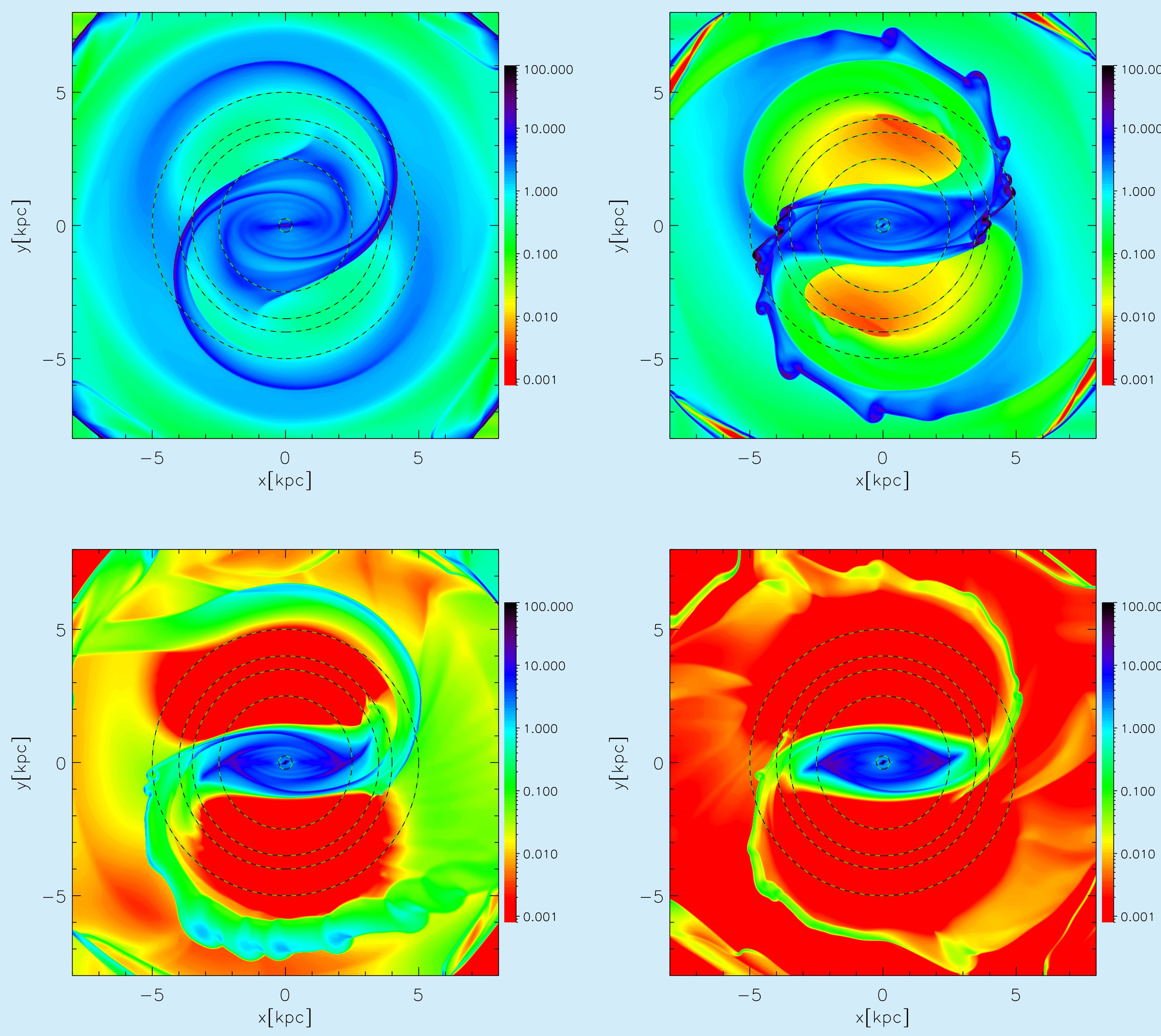

Figure 1: Gas response at $t = 140$ Myr (*top left*), $t = 275$ Myr (*top right*), $t = 815$ Myr (*bottom left*) and $t = 1.6$ Gyr (*bottom right*). The plot shows the gas density in logarithmic scale. The dashed circles denote the inner $m = 2$, inner $m = 4$, corotation, outer $m = 4$ and outer $m = 2$ resonances (from inside out).

Gas orbits

Figure 2 corresponds to the gas orbits of our model. The gas located outside the bar, near the $L_{4,5}$ points, exhibits banana-like orbits. These orbits seems to give support to the spiral structure of our model which contribute to the appareance of the galaxy. These results are in good agreement with the ones found by Patsis (2006) for stellar orbits. The gas in the bar shows two types of orbits: x1 and boxy-shaped orbits. Gas within the inner $m = 4$ resonance moves in x1-orbits that are nearly periodic. Gas located at ~ 0.5 kpc moves toward the center of the galaxy in elliptical motion. Boxy-shape orbits were found for gas that lies between corotation and the inner $m = 4$ resonance. These orbits provide the boxy structure in the outer parts of the bar.

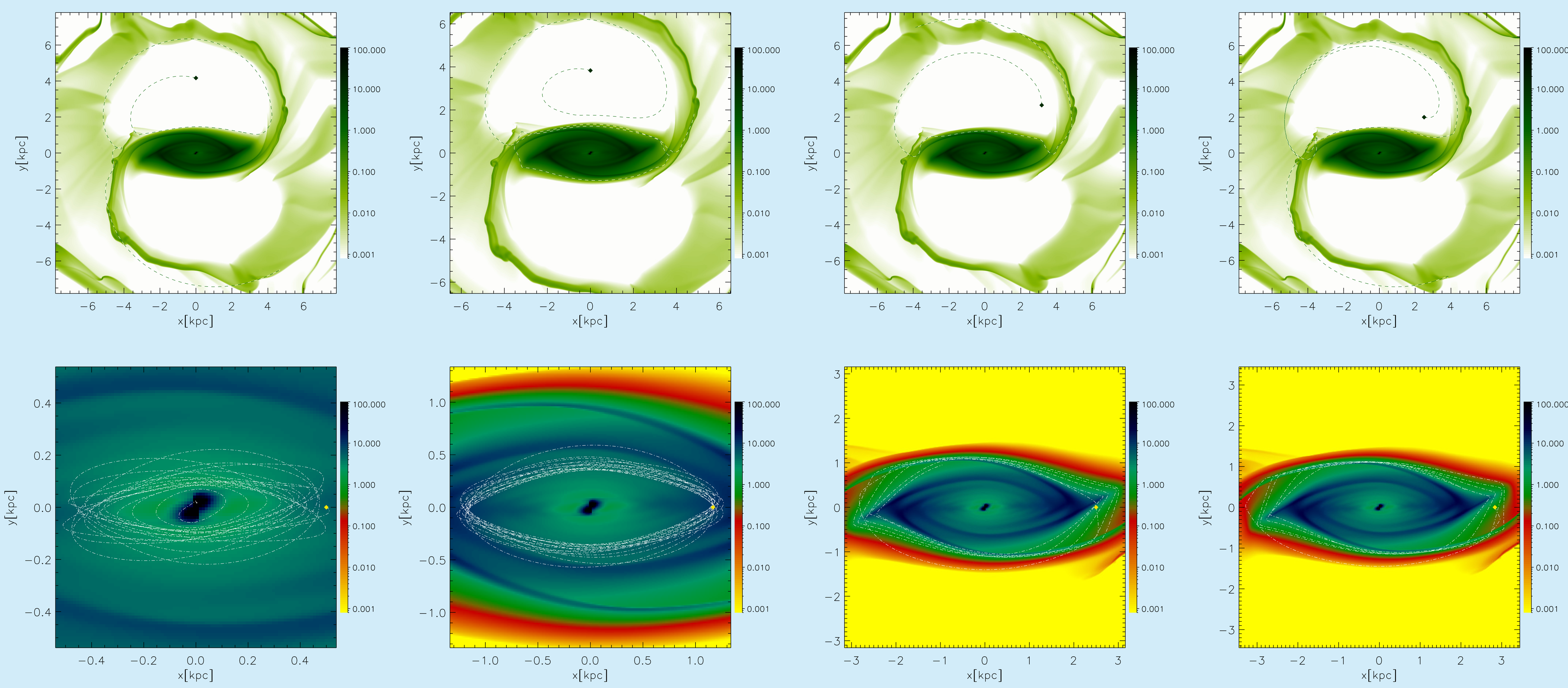

Figure 2: Banana-like orbits associated to the $L_{4,5}$ Lagrangian points (*top row*). Gar orbits in the bar region: $x1$ and box orbits (*bottom row*).