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# MODELLING THE INNER PARTS OF THE MILKY WAY USING INVARIANT MANIFOLDS

M. Romero-Gomez,[1] E. Athanassoula,[2] T. Antoja,[3] O. Valenzuela,[4] F. Figueras,[1] and B. Pichardo[4]

RESUMEN

En una serie de artículos propusimos una teoría que puede explicar la formación y propiedades de tanto los anillos como los brazos espirales en galaxias barradas. Los bloques principales de estas estructuras son órbitas atrapadas por las variedades invariantes de las órbitas periódicas alrededor de los puntos Lagrangianos inestables situados al final de la barra. Aquí presentamos una comparación de la morfología de las espirales observadas y de las teóricas. Describimos el mecanismo de formación usado para obtener estas estructuras y comparamos tanto la morfología como la cinemática de los anillos y espirales teóricos con los datos observacionales. Finalmente, introducimos el trabajo reciente para modelizar brazos espirales de la Vía Láctea usando esta aproximación.

ABSTRACT

In a series of papers we proposed a theory to explain the formation and properties of rings and spirals in barred galaxies. The building blocks of these structures are orbits trapped by the invariant manifolds of the periodic orbits around the unstable Lagrangian points located near the ends of the bar. Here, we will first present a comparison of the morphology of observed and theoretical spirals and rings. We will describe the mechanism used to obtain these features and then we will compare the morphology and kinematics of the rings and spirals obtained with the ones from observations. Finally, we will introduce the work done to model the spiral arms of the Milky Way using this new approach.

*Key Words:* galaxies: kinematics and dynamics — galaxies: structure — Galaxy: kinematics and dynamics — Galaxy: structure

## 1. INTRODUCTION: WHAT ARE THE INVARIANT MANIFOLDS?

Here we present the results from modelling the spiral arms and rings of barred galaxies using invariant manifolds. This is a summary of the main results given in Romero-Gómez et al. (2006, 2007), Athanassoula, Romero-Gómez, & Masdemont (2009), and Athanassoula et al. (2009, 2010). The invariant manifolds can be described as flux orbits that guide the motion around the unstable Lagrangian points $L_1$ and $L_2$. This is an alternative way different from the density wave theory to explain the spiral arms and rings in barred galaxies.

To compute the invariant manifolds, we will consider a galactic potential composed of an axisymmetric component plus another bar-like. In the rotating reference frame, the bar is fixed and along the $x$-axis, the effective potential has five equilibrium points: $L_1$ and $L_2$ are located along the semi-major axis of the bar and are saddle points, $L_3$ is located at the centre of the galaxy, $L_4$ and $L_5$, along the semi-minor axis of the bar, and are stable elliptic points. There exists a family of unstable periodic orbits around $L_1(L_2)$, starting with the energy of the equilibrium point. These orbits cannot trap material around them, however, there exists another family of orbits linked to the periodic orbits called invariant manifolds. Roughly speaking, the invariant manifolds are a set of orbits that depart (unstable branches) or approach (stable branches) the periodic orbit of the saddle point. Each of the manifolds has two branches: one going to the inner parts of the galaxy and the other, to the outer parts of the galaxy. The general view of the manifolds has an $x$-shape, describing the typical behaviour of the saddle point.

In our previous work, we vary the main free parameters, that is, the bar mass/amplitude and the

[1]Dept. d'Astronomia i Meteorologia, Institut de Ciències del Cosmos, Universitat de Barcelona (IEEC-UB), Martí i Franquès 1, E08028 Barcelona, Spain (mromero@am.ub.es).

[2]Laboratoire d'Astrophysique de Marseille, UMR6110, CNRS/Université de Provence,Technopôle de Marseille Etoile, 38 rue Frédéric Joliot Curie, 13388 Marseille Cédex 20, France (lia@oamp.fr).

[3]Kapteyn Astronomical Institute, University of Groningen, PO Box 800, 9700 AV Groningen, The Netherlands (antoja@astro.rug.nl).

[4]Instituto de Astronomía, Universidad Nacional Autónoma de México, Apdo. Postal 70-264, 04510, México, D.F., Mexico (octavio@astro.unam.mx).