# Connecting interacting galaxies with manifolds

M.Romero-Gómez[1] (ICCUB-IEEC) & E. Athanassoula (LAM)

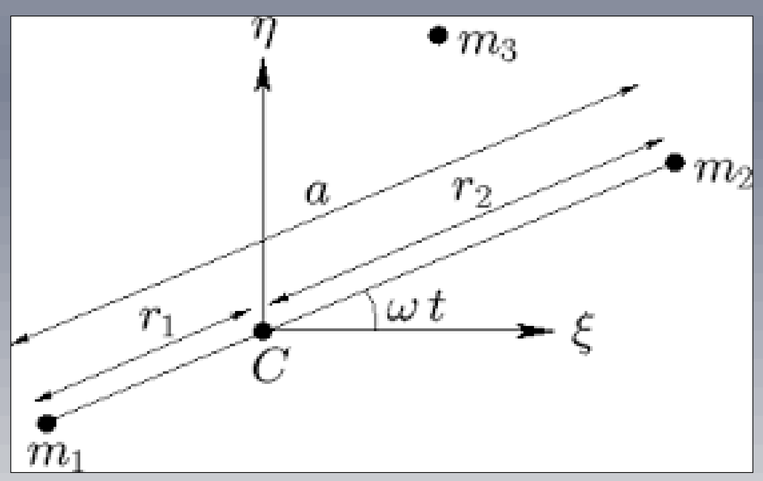
[1]mromero@am.ub.es

## Abstract

It is well known that the interaction between two galaxies generates tidal spiral arms and a connection in the form of a bridge. Here we address the question of the formation of the tidal arms and bridges from a dynamical point of view. We model the bridges and tails observed in interacting galaxies using the invariant manifolds associated to the Lyapunov orbits of the Lagrangian points of the galactic system, when the two galaxies are considered two point masses in a circular orbit.

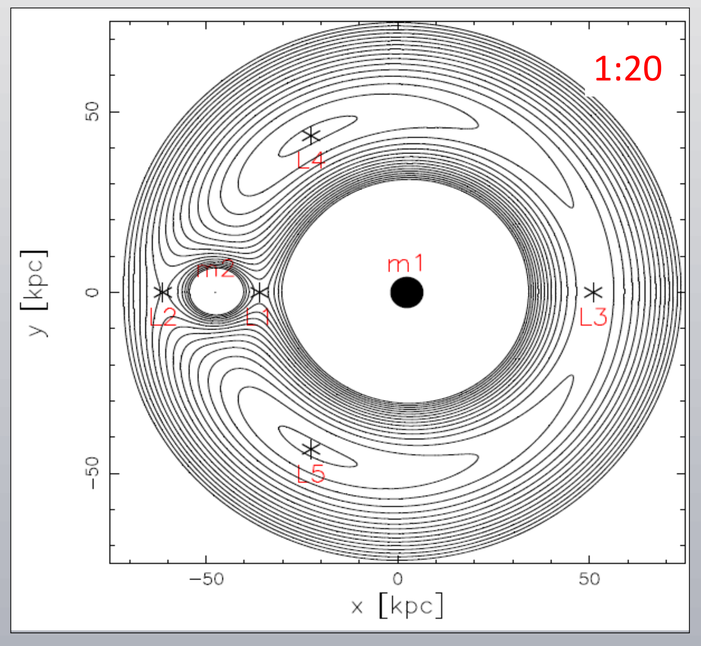
## The model

We model the two interacting galaxies as two point masses and we study the motion of the stars using the Restricted Three Body Problem, i.e. the two mass points are bound and circle around their center of mass.

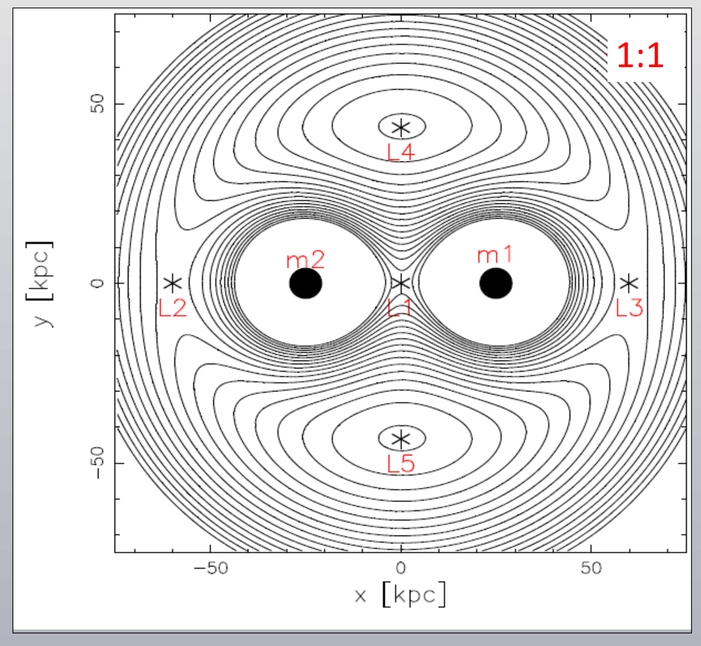



- $m_1$ and $m_2$ are the two interacting galaxies. The two galaxies rotate counter-clockwise around their center of mass (C) at a constant angular velocity (w). $r_1$ and $r_2$ are the distances of the two galaxies to the center of mass.
- $m_3$ represents the mass of a star.
- When we make the problem nondimensional, we are left with only one free parameter which is the mass ratio of the two galaxies: $m_2/m_1$

## The equilibrium points and the effective potential curves



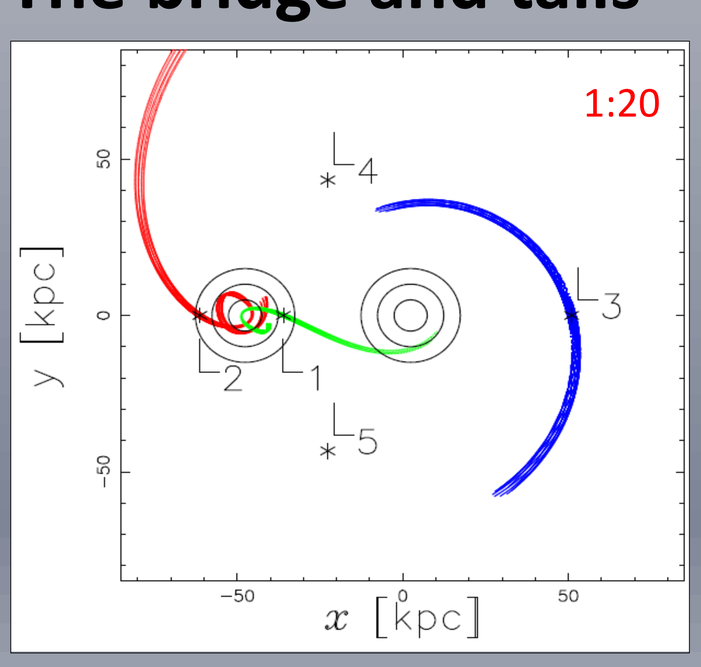

Configuration of a 1:20 encounter

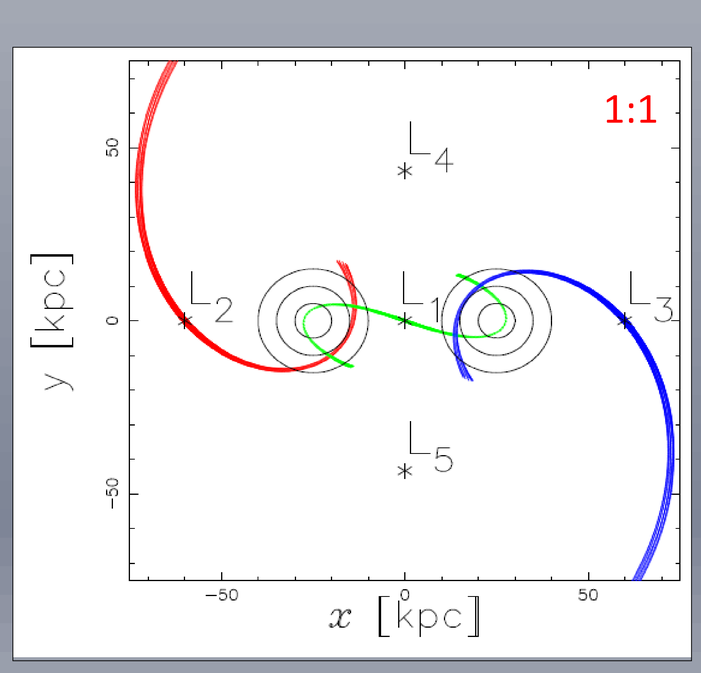



Configuration of a 1:1 encounter

- The position of the two galaxies are marked with filled black dots
- The position of the Lagrangian points is shown by asterisks (*) and labelled accordingly.
- The mass ratio is given in the top right corner.

## The bridge and tails




- The position of the Lagrangian points is marked by asterisks and they are labelled accordingly
- The concentric circles are centered at the position of the two galaxies and have 5, 10 and 15 kpc radii.
- The blue and red curves are the unstable invariant manifolds around L2 and L3 and show the tails of the interacting galaxies.
- The green curves are the unstable invariant manifolds around L1 and show the bridge between the two galaxies.

## Conclusions

- The connection between the bridge and tails and the manifolds is clear for different types of galaxy encounters.
- If we decrease the mass ratio to the range ($10^{-6}$ , $10^{-3}$), then the system models the interaction of a galaxy and a stellar cluster, and the manifolds reproduce well the tidal streams (Romero-Gomez & Athanassoula, 2016).