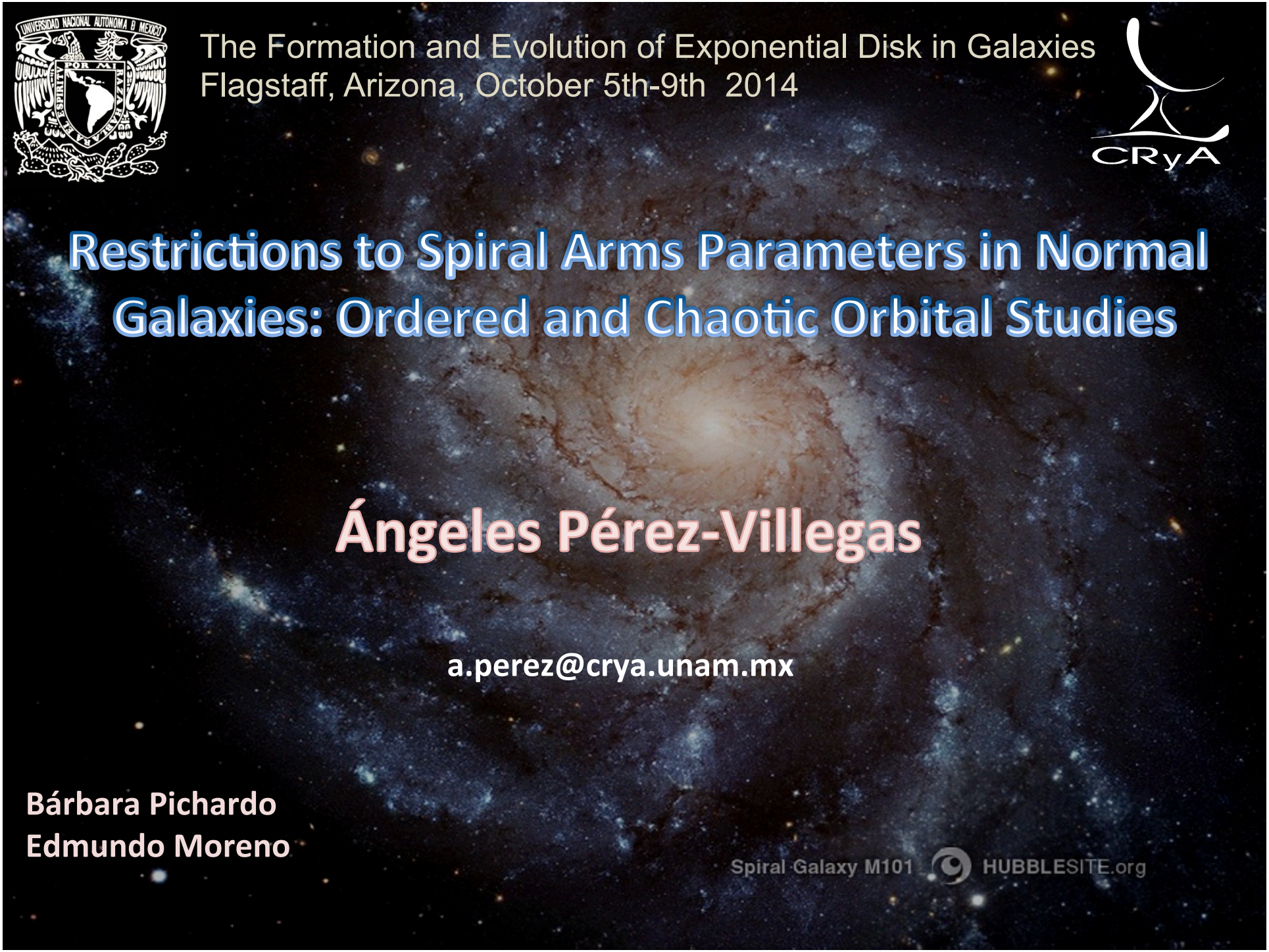
The Formation and Evolution of Exponential Disk in Galaxies
Flagstaff, Arizona, October 5th-9th 2014
CRyA
Restrictions to Spiral Arms Parameters in Normal Galaxies: Ordered and Chaotic Orbital Studies
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INTRODUCTION

- In “real life”, the Hubble scheme is not closely followed by galaxies, i.e. Structural and dynamical parameters present a large scatter among galaxies catalogued with the same morphological type. This considers only galaxies with redshift z<0.5, where Hubble morphological classification is satisfactory (van den Bergh 2002).

- However, as a first approximation we adopted the ideal Hubble morphological scheme to study the effects on the orbital structure in different spiral galaxies.

- The pitch angle is the parameter with widest scatter, going from about 4°to 50° (Kennicutt 1981; Ma et al. 2000; Davis et al. 2012).
- This work is devoted to structural and dynamical parameters of spiral arms: the **pitch angle, mass and angular speed.**
- To elucidate the influence of spiral arms on different morphological types of galaxies, as we going from early to late types.
- To provide some restrictions to structural and dynamical parameters of galaxies.
- To produce a set of parameters for "allowed spiral models", self-consistent from an orbital (periodic orbits) point of view, with good probabilities of being long-lasting structures, and mild or quiet chaotic nature.

Methodology

- Poincaré Diagrams
- Periodic orbits and maximum density response

Equations of motion:

$$\frac{dx}{dt} = \dot{x}, \frac{dy}{dt} = \dot{y}, \frac{dz}{dt} = \dot{z}$$

$$\frac{d\dot{x}}{dt} = -\frac{\partial \Phi}{\partial x}, \frac{d\dot{y}}{dt} = -\frac{\partial \Phi}{\partial y}, \frac{d\dot{z}}{dt} = -\frac{\partial \Phi}{\partial z}$$

$$\Phi = \Phi_0 + \Phi_{Arm}$$

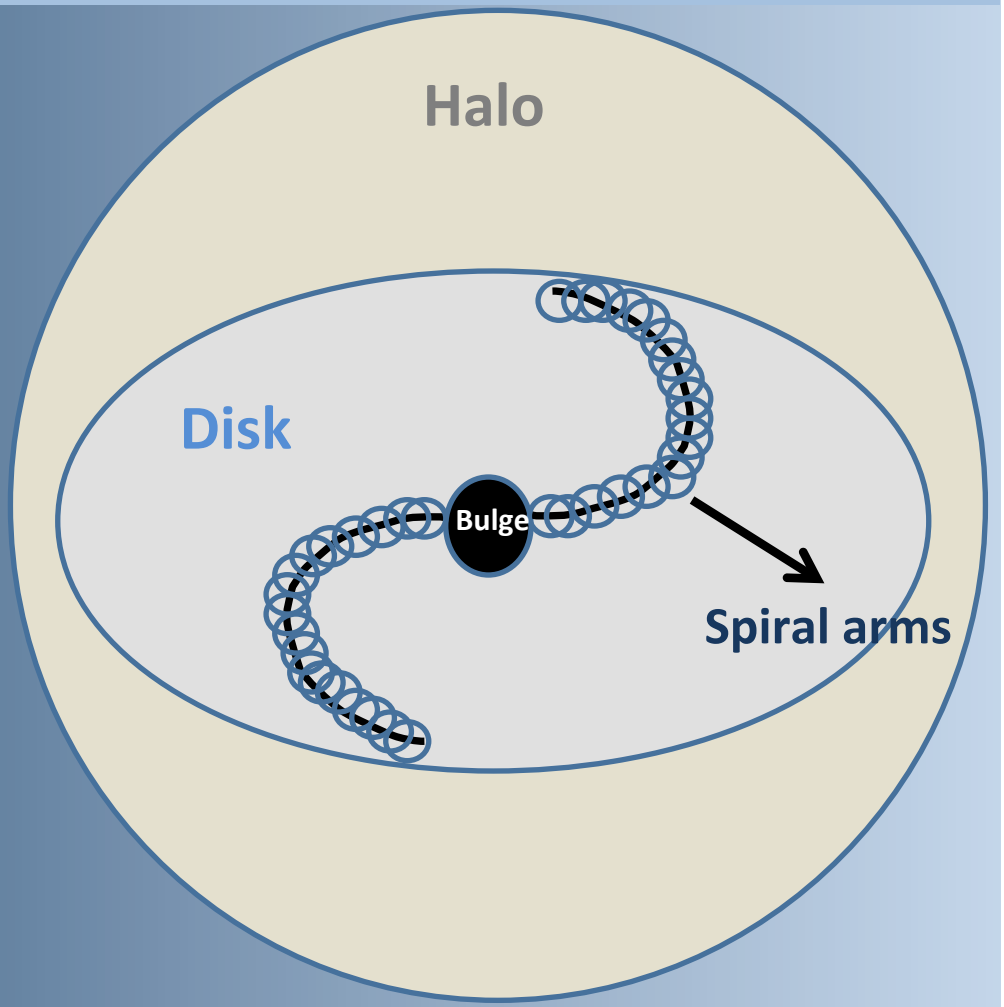
Reference system: non- inertial

$E_J = 1/2\ v'^2 + \Phi_0(r') + \Phi_{BR}(r') - 1/2|\Omega_P \times r'|^2$

Error in E_J is 10^{-13}

PERLAS Model

- PERLAS model by Pichardo et al. (2003) .
- The model is superimposed on an axisymmetric background*.
- This model is made by a superposition of oblate spheroids as building blocks along of a given locus.



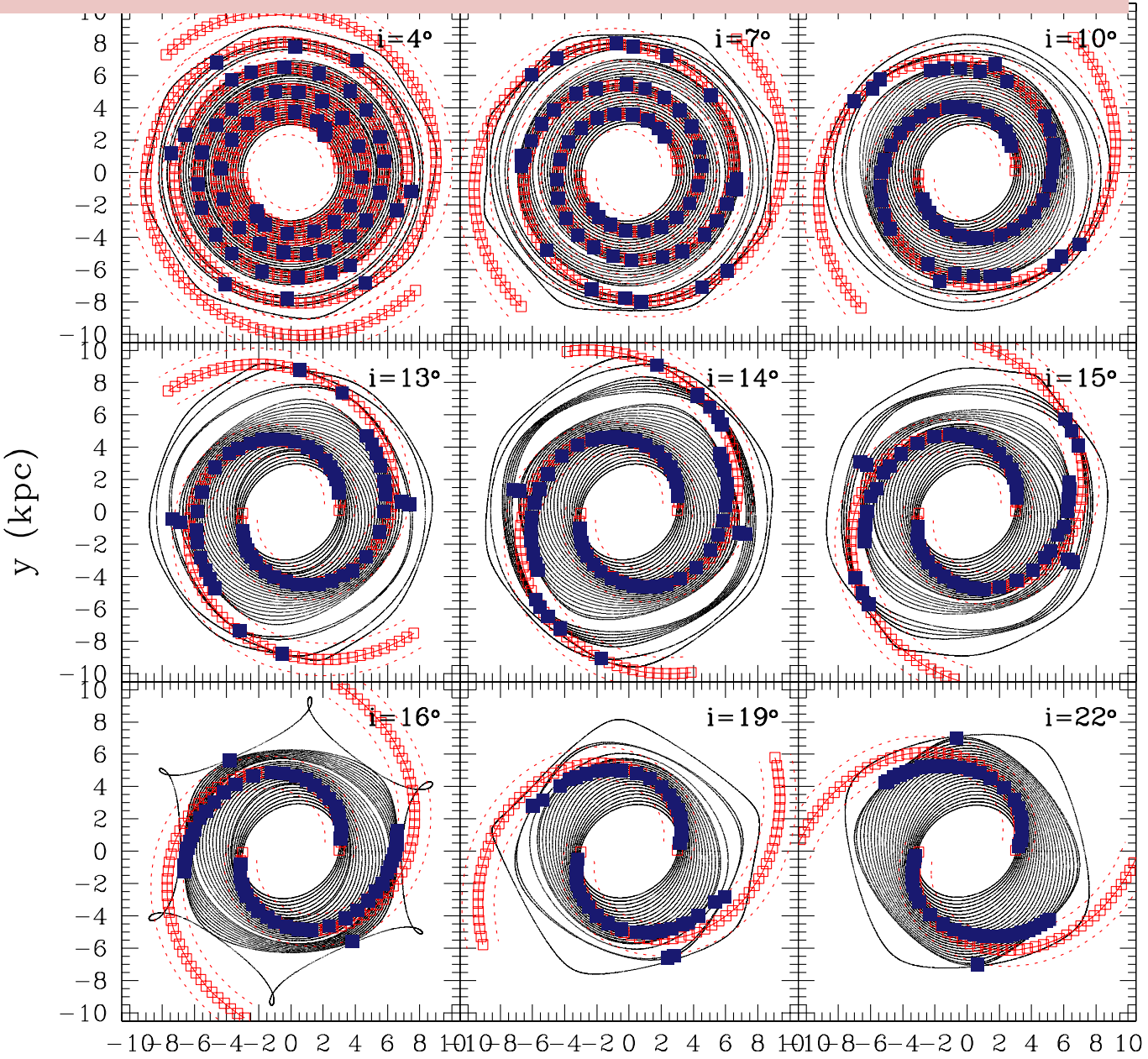
*Bulge: Miyamoto Nagai (1975).
Disk: Miyamoto Nagai (1975).
Halo: Massive spherical

Parameters of the model

Parameter	Value			Reference
Spiral Arms				
Morphological type	Sa	Sb	Sc	
Locus	Logarithmic			Grosbøl & Patsis 1998; Pichardo et al. 2003
Arms number	2			Drimmel et al. 2000
Pitch Angle	4– 40 °	8 – 45 °	10 – 60 °	Kennicutt 1981; Ma et al. 2000
M_{spiral}/M_{disk}	1 - 10 %			
Scale-length Disk based	7 kpc	5 kpc	3kpc	Pizagno et al. 2005; Weinzirl et al. 2009
Pattern speed (Ω_{sp}) (clockwise)	10 - 60 km s^{-1} kpc^{-1}			Grosbøl & Dottori 2011 Grosbøl & Patsis 1998; Patsis et al. 1991
Inner Limit	Depend on angular velocity			ILR position based
Outer limit				Corotation position based

Restrictions Based on Ordered Behavior.

Periodic Orbits



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Restrictions Based on Chaotic Behavior.

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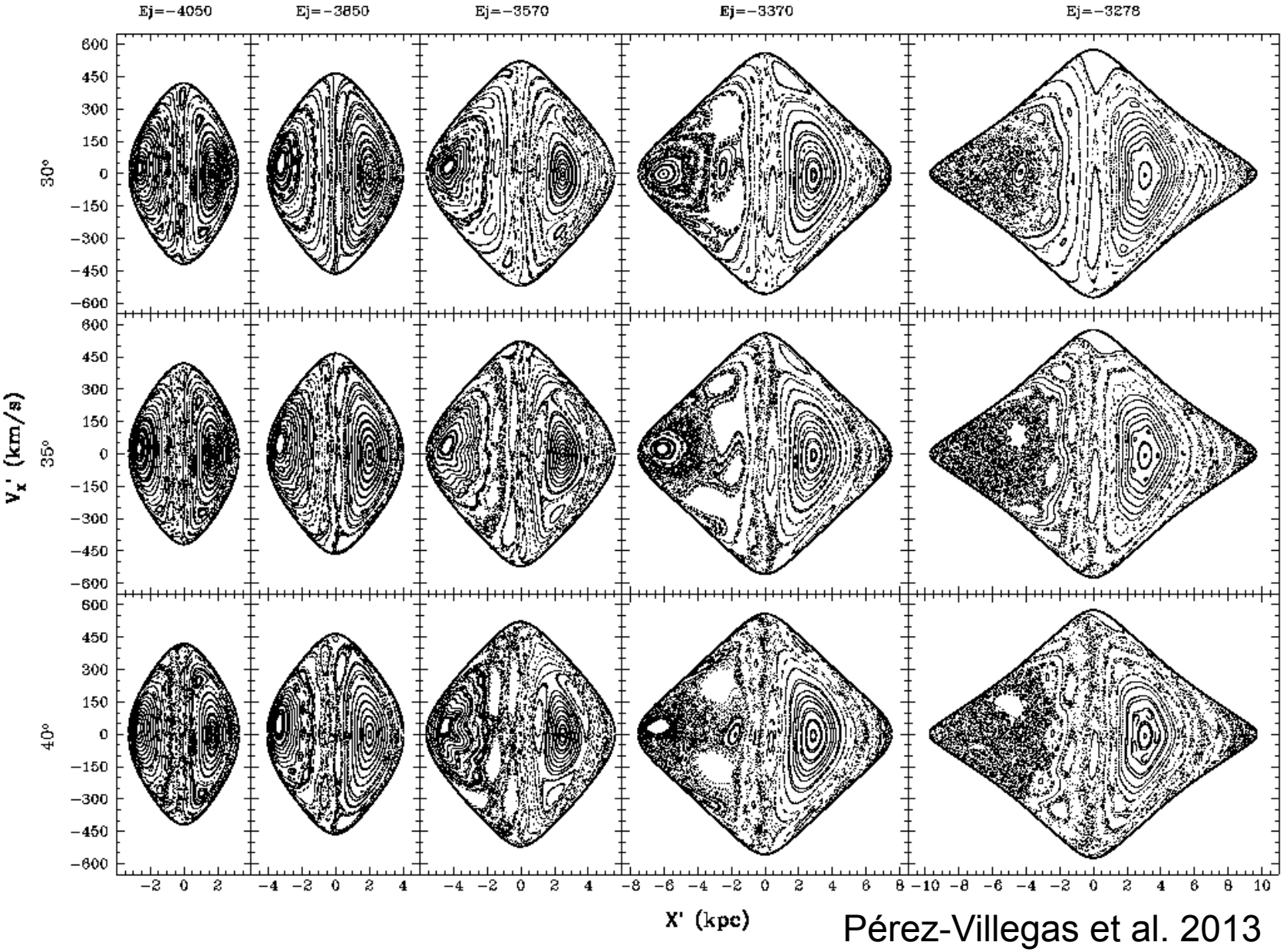
Phase space diagrams



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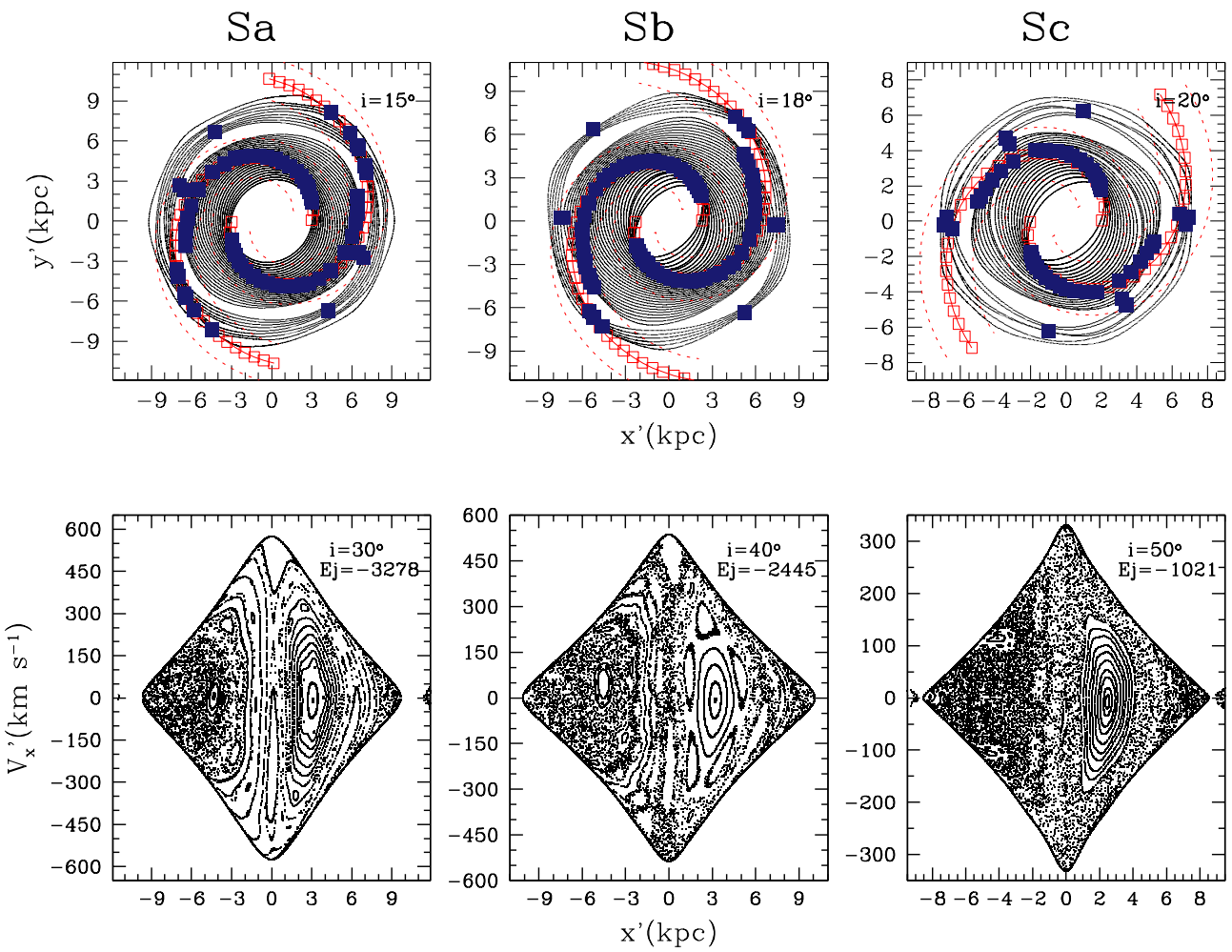
Restrictions Based on Ordered and Chaotic Behavior.

- **Pitch Angle**

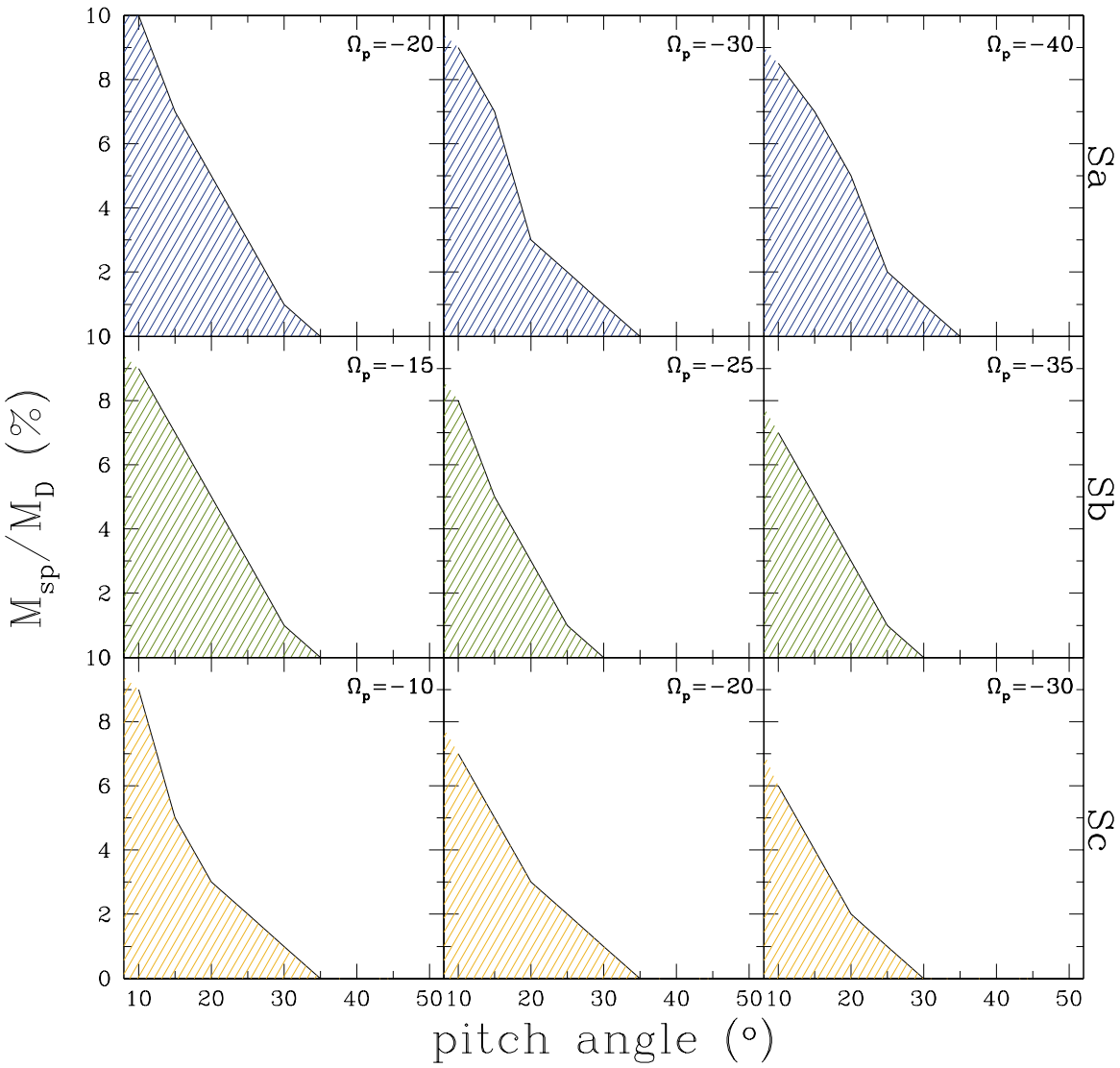


Restriction based on ordered behavior. Nature of spiral arm: long-lasting or transient.

Restriction based on chaotic behavior: Before the dominion of chaos.

Valid Structural and Dynamical Parameters for Spiral Arms

Transient or Long-lasting Spirals



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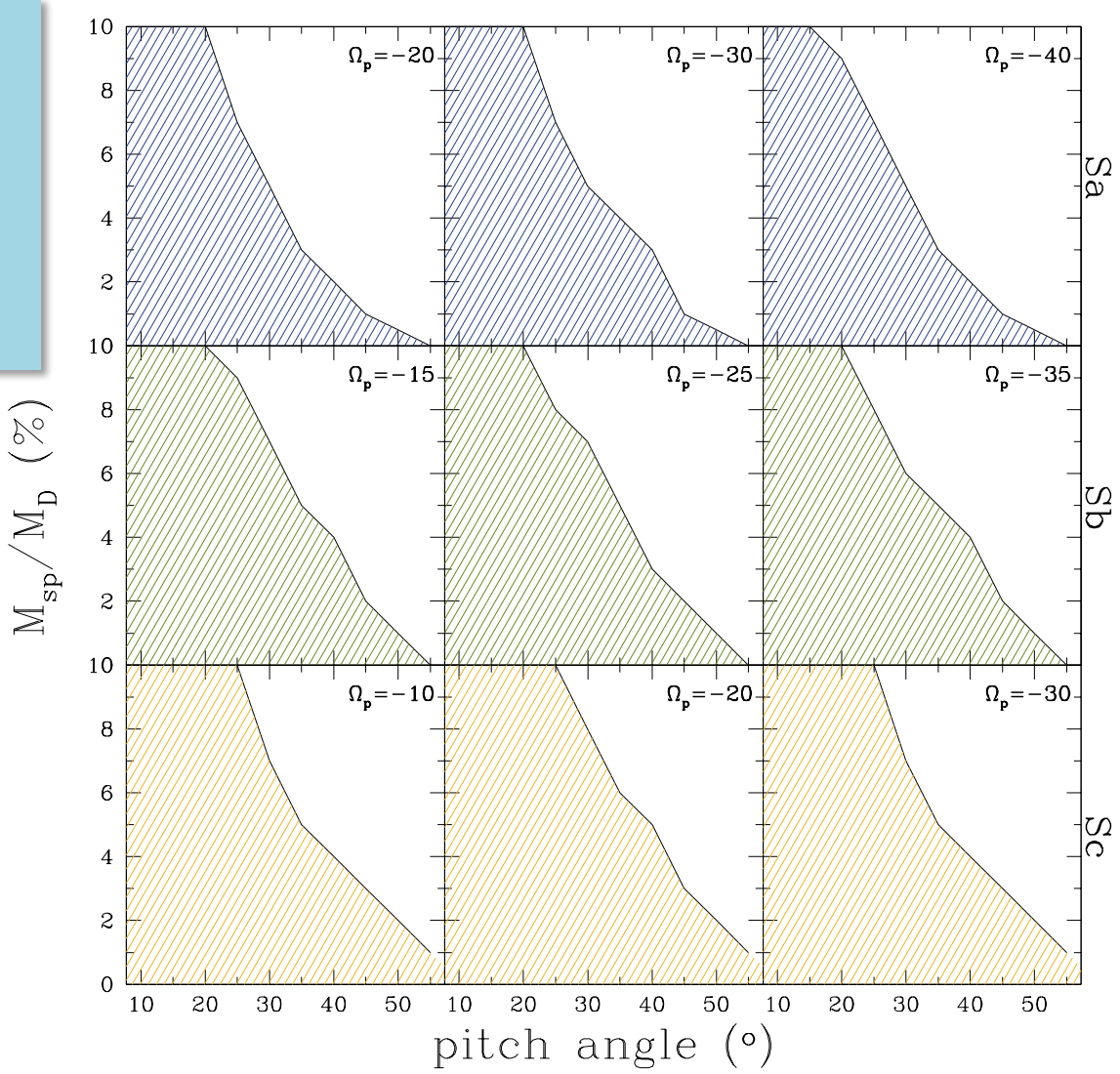
Maxima Values Before the Dominion of Chaos



Pérez-Villegas et al. in prep.

Conclusions

- With the use of a steady physical model to simulate normal spiral galaxies, we studied the disk dynamics as we vary structural and dynamical parameters: the pitch angle, mass and angular velocity.
- Based on ordered behavior, we found a limits for spiral arms parameters where spiral arm could be a long-lasting structure or would be explained as a transient feature.
- Based on chaotic behavior, we found limits where spiral arm is destructed, because chaos becomes pervasive, destroying all orbital support.
- In these studies, we noticed the effect that spiral arms induces to the disk dynamics, when we vary the pattern speed or the mass of spiral arms is strongly linked to the pitch angle.
- M_{sp}/M_D rate in early spiral galaxies could be larger than in late spiral galaxies, without compromising the stability, i.e., if the pitch angle is smaller, the limit of the mass of spiral arms could be higher.
- The effect of angular speed is almost negligible. However, this is an important parameter because it establishes the extension of spiral arms, therefore the angular velocity would not be too fast or slow.

¡MUCHAS GRACIAS!

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