The Role of the IILR in the Structure of the Central Gaseous Discs

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Abstract. Recent NICMOS observations of the central regions of nearby barred galaxies, NGC5383, NGC1530 and NGC1667 by Regan, Sheth and Mulchaey (1999), all show, in the unsharp mask map, a pair of distinct trailing spirals which can be followed all the way to the center. This result is in apparent conflict with the density wave theory. In this report, we argue that this difficulty may be removed if we take the self-gravitation of the disc into consideration, or the IILR does not exist in these galaxies.

1. Introduction

There are two types of rotation curves, one rising rapidly and the other relatively slowly from the center. The fast rising rotation curve usually can host two Lindblad resonances, the outer and the inner (OLR and IILR). The slowly rising rotation curve, however, can host one extra inner Lindblad resonance. Thus we have an outer inner Lindblad resonance (OILR) and an inner inner Lindblad resonance (IILR). The importance of these Lindblad resonances lies in the fact that spiral density waves can be excited there by a rotating bar potential. These waves dominate the structure and the evolution of the galactic discs.

Recent NICMOS observations of the central regions of nearby barred galaxies of NGC5383, NGC1530 and NGC1667 (Sheth et al 1999; Regan et al 1999, Mulchaey and Regan 1997), all show, in the unsharp mask map, a pair of distinct trailing spirals in the very center (within $\sim500$ pc), which can be traced as originating from the OILR located at a radius of a few kpc from the center.

Preliminary analysis of the rotation curve according to the BIMA observations (Sheth et al 1999) suggests that NGC5383 has an IILR. If this is indeed the case, the inner spiral structure should be leading and separated from the exterior spiral structure. The fact that it has a pair of distinct trailing spiral, and is connected continuously to the OILR spirals, poses a challenge to the theory. Two explanations are possible: (1) the IILR is ineffective because its Q-barrier may either be too close to the center or not exist, and (2) the rotation curve of NGC5383 close to the center may not guarantee the existence of an IILR. We shall examine both cases here.
2. The Role of the IILR

The effectiveness of the IILR in exciting spiral density waves depends heavily on the location of the Q-barrier, which, in turn, depends on the self-gravitation of the disk. The self-gravitation will shift the IILR Q-barrier toward the galactic center or even into non-existence. In the case of NGC5383, a typical disc mass, say, of $200 \, M_\odot \, pc^{-2}$ and typical sound speed of $8 \, km/s$, can shift the Q-barrier of the IILR from 0.5 kpc to 0.2 kpc. If the surface density is a little higher and the disc is a little cooler, the Q-barrier could be moved "beyond" the center, i.e., non-existence.

Under such a circumstance, the long leading waves excited by the bar potential at the IILR may never get reflected or refracted at the Q-barrier. Therefore, there would be no reflected short leading spirals to be observed. For the same reason, the incoming trailing spirals generated at the OILR cannot find the Q-barrier associated with the IILR, hence they can go to the center (Yuan and Kuo 1997).

Furthermore, if the Q-barrier were moved to 0.2 kpc, the disk thickness would be comparable to the the disk radius (as well as the wavelengths of the density waves). Strong coupling between the disc and the thickness would result in strong damping of the waves and lead to the effective wave absorption. Again, it would diminish the Q-barrier’s role of reflecting waves, hence no short leading spirals.

3. The Rotation Curves near the Center

It is well known that the rotation curves near the center of a disc galaxy cannot be determined accurately, either because of the large velocity dispersion in the central region or because of lack of angular resolution. Yet the Lindblad resonances sensitively depend on the derivative of the rotation curve. Although crude observation data often suggest a rigid body rotation near the center, thus the existence of an IILR, it is not yet possible to rule out a Keplerian disk, which has no IILR. It is entirely possible that NGC5383 does not have an IILR. Thus the waves generated at the OILR, can (if viscosity is reasonably small) freely march all the way to or close to the center.

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