Title: Lentiptical galaxies

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Early-type galaxies are quiescent galaxies, with little or no star formation activity. The majority of early-type galaxies are made of two principal components: a spheroid (or bulge) of stars with random motion and a rapidly rotating stellar disk (1 krajnovic). The relative importance of these two components determines the morphological classification of early-type galaxies into two types: elliptical galaxies are spheroid-dominated systems, whereas lenticular galaxies are composed of a small bulge of stars encased in a larger stellar disk. When perfoming bulge/disk decomposition, the spheroidal component is typically described with a Sérsic profile (2 sersic), while the disk is fit with an exponential function. Theoretically, the bulge-to-disk ratio, which describes the relative importance of the spheroidal component over the disk component, can assume any positive value. However, several studies have taken into account only bulge/disk decompositions in which the exponential function neatly dominates over the Sérsic profile at large galaxy radii, and rejected those decompositions in which the exponential function remains "embedded" within the Sérsic profile, considering such decompositions as unphysical. Here we show that these rejected models correctly reproduce the kinematics of a class of early-type galaxies, that we name *lentiptical*. Lentiptical galaxies have often been confused with lenticular galaxies and, consequently, their bulge luminosities

have been largely underestimated. This surprisingly common mistake has led to some wrong conclusions, such as the claim that a number of lentiptical galaxies host a central black hole whose mass is abnormally large compared to expectations from its (underestimated) bulge luminosity.

Our results demonstrate that there is no bimodality in the distribution of the bulgetodisk that the claimed bimodality is artificial

we show that the ell profile is enough to estabilish if the disk is embedded or not

1 Introduction

There are currently two well-known types of stellar disks in galaxies. The first are the large-scale disks (with sizes of a few kpc) that dominate at large radii in spiral and lenticular galaxies; the second are the small (tens to a couple of hundred parsec) nuclear disks observed in both early- and late-type galaxies (e.g. **????**). The origin of the nuclear disks has been speculated to arise from the infall of small satellite galaxies or gas clouds **refs**. The origin, or at least the on-going feeding and growth, of the large-scale disks has been attributed to cold gas flows, gas rich mergers and halo accretion events (e.g. **??????**). A thorough review can be found in Combes (arXiv:1309.1603 and 1405.6405).

A puzzling question, which has been unspoken for decades, is why are there not intermediate-sized disks; why are there not accretion events which create disks larger than the typical nuclear disks but which are not large enough to dominate at large radii? Here we report on the existence of these intermediate-sized stellar disks.

The existence of such disks is not only important for our understanding of disk growth in general, reducing or eliminating an old mystery, but accounting for such structure will impact on our galaxy scaling relations and surely see the reclassification of many "disky" elliptical galaxies and lenticular galaxies as *lentiptical* galaxies with intermediate-sized stellar disks that do not dominate at large radii.

It is well known to the astronomers that identifying a face-on, featureless stellar disk in an early-type galaxy only by looking at the galaxy image is a very challenging if not even impossible task. Luckily, the majority of such disks are observed by us with some level of inclination, which makes them appear as flat, elliptical components, and helps us distinguishing them from the more spherical galaxy bulges. A more subtle and overlooked issue is the difficulty in identifying the extent of these disks with respect to their bulge.

Kinematic maps, obtained from IFU spectroscopy, constitute an extremely powerful instrument to this purpose. **However, xxxSLUGGS have shown that the limited FOV of the atlas3d maps is not enough to get the full picture, and more extended maps are needed to reveal which galaxies display a FR behaviour all the way out and which ones become SR at large radii.** Unfortunately, kinematic maps are not yet available for a large sample of galaxies in the local Universe. Notwhithstanding, there is another powerful instrument that can help identify the extent of stellar disks in early-type galaxies, and that has the advantage of requiring only galaxy images (even photometrically uncalibrated), which are cheaper to acquire in terms of telescope time than IFU observations. This instrument is the ellipticity profile of a galaxy's isophotes, that can be easily obtained from a 1D isophotal analysis of the galaxy image, using for example the IRAF task `ellipse`.

The toy model shown in Figure 1 illustrates the typical ellipticity profile for a large-scale disk that encases a bulge, as in lenticular (S0) galaxies, for an intermediate-scale disk embedded in a larger spheroid, that we name lentiptical (E/S0) galaxy, and for an elliptical (E) galaxy featuring a nuclear stellar disk. Note that, in the case of an intermediate-scale disk, the maximum of the ellipticity profile corresponds to the minimum difference between the light profile of the bulge and that of the disk (vertical dashed line in Figure 1). Galaxy modellers that attempt to perform bulge/disk decomposition of lentiptical galaxies should always check that their model correctly reproduces this important signature.

The **realization, coscienza, not-knowledge** that many "elliptical" galaxies actually contain embedded stellar disks dates back at least three decades (**?????????????**) and, more recently, intermediate-scale disks were all but unfamiliar to **?**. However, the class of lentiptical galaxies has been missed out by many galaxy modellers, who labelled as "unphysical" the idea that an intermediate-sized stellar disk can exist fully embedded in a larger spheroidal component. This unspoken bias has led them to reject any bulge/disk decomposition with an outcome similar to that illustrated in the middle panel of Figure 1. Unsurprisingly, some studies have found that the b/t ratio of S0s is less than...

Examples of lentiptical galaxies are the galaxies MRK 1216, NGC 1271, NGC 1277, NGC 1332, NGC 3115, NGC 3377 (see Figure 1) and NGC 4621. All of these galaxies can be easily described and explained with a simple two-component model: an outer Sérsic bulge plus an embedded, intemediate-sized exponential[1] disk. Models that "forzatamente" describe the galaxy with an inner Sérsic bulge encased within a large-scale exponential disk can produce acceptable fits ???? statistically decent?? only in two cases: either the data are shallow, thus they are not probing the re-rise of the bulge, or an outer Sersic halo is added to the model to account for the outer light (n3115 and n3377 lasker).....

show vel map? + ell profile, explain shape

our models are physically motivated and produce bulge luminosities which make these galaxies no longer outliers btw they are not outliers on the M-Mgal relation, which suggests poor bulge/disk decomposition

people that do only 2d decompositions, should still perform a 1d isophotal analysis to check extent of disk

The existence of intermediate-scale stellar discs suggests that a continuum of disc sizes may exist, rather than a dichotomy of nuclear vs. large-scale discs. In a somewhat similar vein, it

[1]Given its close-to-edge-on inclination, the stellar disk of NGC 1332 is better described by a Sérsic profile with Sérsic index $n < 1$ (**??**).

was previously thought that bulges came in just one of two flavours: classical bulges with n=4 light profiles and pseudobulges with n=1 light profiles (e.g. Carollo et al. 1998-2002?). Although many works still advocate this bulge dichotomy based on their light profiles, Graham & Worley (2008) have revealed no evidence for a bimodality in the distribution of their Sersic indices from a sample of 400 disc galaxies[2]. The presence of intermediate-scale discs blurs the distinction between elliptical and lenticular galaxies and it may be that our E vs S0 classification for galaxies without spiral arms could be better represented by a range of bulge-to-disc (luminosity and size) ratios.

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[2]The co-existence of classical and pseudo bulges in the same galaxy (e.g. Erwin et al. 2003, ApJ, 597, 929) further blurs claims for galaxies having either a classical bulge or a pseudobulge.

Figure 1 Illustration of the typical light profile (top plots) and ellipticity profile (bottom plots) of a galaxy featuring a stellar disk with varying size. For simplicity, we show separately the light profile of the bulge (or spheroid) in red and that of the disk in blue. The sum of these two contributions gives the galaxy's light profile (not represented here). The left panel shows the case of a large-scale disk, **prototipico** of a barless lenticular galaxy. The right panel displays the case of an elliptical galaxy with a nuclear stellar disk. The middle panel presents the case of a lentiptical galaxy with an inermediate-sized disk. Stellar disks typically have fixed ellipticity, dictated by their inclination to our line of sight. Bulges, instead, can have their ellipticities varying with radius, but they are usually rounder than inclined disks, thus their average ellipticity is lower than that of an inclined disk. If the ellipticity profile of a galaxy increases with radius, this can be ascribed to an inclined disk that becomes progressively more important over the bulge, whereas a radial decrease of ellipticity signifies the opposite case. Therefore the "shape" of the ellipticity profile can be decisive to distiguish between large- and intermediate-scale disks.

Figure 2