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Beyond the sphericity assumption in dynamical HI models

Pieter Buyle[*]
Ghent Univ., Belgium
E-mail: Pieter.Buyle@UGent.be

Herwig Dejonghe
Ghent Univ., Belgium
E-mail: Herwig.Dejonghe@UGent.be

Gianfranco Gentile
SISSA, Italy
E-mail: gentile@sissa.it

It is generally agreed that the rotational velocities of spiral galaxies indicate that a lot of matter is unseen. Hitherto, the majority of these mass models are all based on spherical symmetry, although this assumption is obviously not the one that is closest to reality. We present a new method to derive dynamical mass models from HI-data based on an axisymmetric geometry. To validate our method, we started a project with the aim to create such models from a combined sample of late-type Low Surface Brightness galaxies and early-type High Surface Brightness spiral galaxies. The whole sample spans a wide range of bulge-to-disk ratios and will ultimately allow us to investigate the orbital distribution as a function of morphology.

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[*]Speaker.

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1. Introduction

Since the first observations of neutral hydrogen in our own galaxy were made, dynamical HI models have only gained importance. Because the radiation of HI is not affected by dust, it became the primary tool to map the kinematics of galaxies, even beyond the optical radius. This has lead to the dark matter paradigm, as the observations showed that one had to invoke a lot of unseen matter to explain the flattening of the rotation curves at high distances from the centre. Although it is clear that this extra matter should be present (in the Newtonian world view, that is), the amount and location may also depend on the used dynamical mass modeling. The majority of these models are based on spherical symmetry, which is probably not the most suitable representation of the mass components in galaxies, e.g. CDM simulations and observations suggest that the dark matter haloes are triaxial ([2] [4] [6] [7] [8] [9] [10]). We aim to improve on the modeling part by creating axisymmetric mass models of our mixed sample of late-type Low Surface Brightness (LSB) galaxies and early-type High Surface Brightness (HSB) spiral galaxies that were recently observed at 21cm.

2. Sample selection

We compiled a sample of 12 spiral galaxies along the Hubble sequence that span a wide range in bulge-to-disk ratios. For the late-type galaxies we preferred LSB galaxies above HSBs since many investigations have shown that LSBs are dark matter dominated and thus form the ideal objects for this project. On the contrary, for the early-type sample we prefer HSB galaxies rather than LSB galaxies, since early-type LSB galaxies are very rare and contain even less neutral hydrogen than their HSB counterparts making them much more difficult to observe at 21cm. The LSB galaxies were selected from the LSB catalogues from Morshidi-Esslinger (1999) and Monnier-Ragaigne (2003) on basis of their morphology, angular size, velocity width and HI emission. The early-type galaxies are taken from the HSB catalogue of D'onofrio et al. (1995) according to the same criteria.

3. Observations

On 26, 28, 29 May and 1 June 2004 we observed the 4 LSB galaxies LSBGF300-026, NGC4965, IC4366 and IC2147 with the Australia Telescope Compact Array (ATCA) in the 1.5B configuration. Because our spectral line widths were smaller than 150 km s^{-1} we selected a correlator setup which yielded a bandwidth of 4 MHz divided over 1024 channels, hence giving a channelwidth of 3.9 KHz. Each galaxy was observed for 12h to cover the whole U-V plane. Standard data reduction was performed in the MIRIAD software package. Final datacubes were made with a velocity resolution of 3.3 km s^{-1}, though for IC4366 we performed Hanning smoothing an additional time (yielding a velocity resolution of 6.6 km s^{-1}) in order to increase the S/N ratio. The properties of the final observations are listed in Table 1. The 8 other galaxies will be observed in December 2004 and January 2005.

Galaxy name	LSBF300-026	NGC4965	IC4366	IC2147
RA	03h09m37.8s	13h07m09.4s	14h05m11.5s	05h43m28.0s
Dec	-41°01’50”	-28°13’41”	-33°45’36”	-30°29’42”
# channels	512	512	512	512
Channel seperation (KHz)	7.8	7.8	7.8	7.8
Synth. beam (arcsec)	35×22	47×24	43×23	43×21
Synth. beam (kpc)	2.2×1.4	7.0×3.5	12.9×7	3.7×1.8
Noise (mJy beam^{-1})	1.7	1.9	1.7	1.9

Table 1: Observational parameters

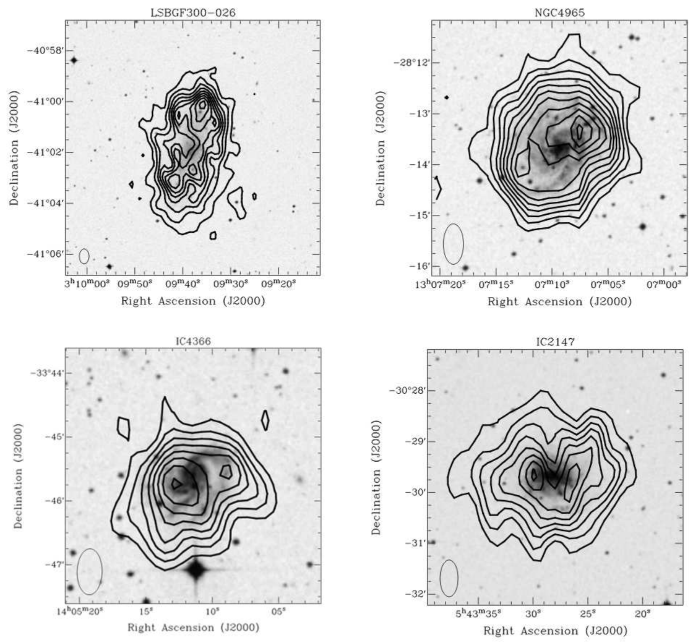

Figure 1. *The total-intensity maps (contours) superimposed on optical DSS images (gray-scale). The outermost contour corresponds to 3σ. The beam is plotted in the lower left corner.*

4. Axisymmetric models

In order to construct axisymmetric models, one must assume the fact that the data are compatible with an axisymmetric geometry. Hence, the final datacubes we derived after datareduction were slightly modified into an axisymmetric data set. An example of the result of this process is shown in Figure 2, where it appears that axisymmetric systems do in fact fit well to the observed data especially in the outer regions. The inner regions are more distorted due to the effect of spiral arms and star formation. Once a final axisymmetric data set has been created, a density function must be obtained from the total-intensity map. This will be done by quadratic programming deprojection on a space of suitable basis functions for which the gravitational potential can be calculated in a convenient way[3]. Additionally it is assumed that 1 $M_\odot$ of HI has an emissivity of

$$\varepsilon = \frac{h\nu_0}{4\pi}\frac{3}{4}N_H A_{10}\phi(\nu) \;=\; 1.913 \times 10^{17}\phi(\nu)\ \mathrm{W/Hz} \tag{4.1}$$

where $\phi(\nu)$ is a function of frequency and selfabsorption of the HI-emission is neglected. This density - potential pair is usually compatible with a vast number of distribution functions (which distributes the gas and stars in a system). However, quadratic programming allows us to χ^2-fit the moments of the distribution function to the observed kinematics derived from the full datacube.

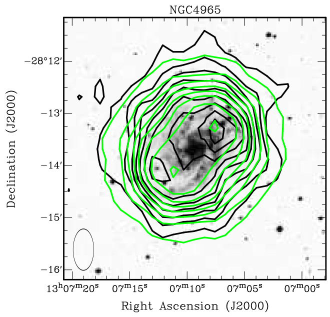

Figure 2. *The axisymmetric representation from the datacube of NGC4965. The green contours are the model, while the black shows the real datacube, superimposed on an optical image (gray-scale). The contourlevels are the same for the model and datacube.*

5. Future

The mass decomposition of the axisymmetric models relies on the combination of HI-data and optical imaging. To trace the light of the stars in our systems, we proposed deep H- and K-band imaging with the NTT-telescope at ESO. When the final axisymmetric models of our sample are constructed, we plan to investigate the orbital distribution as a function of morphology. Additionally, the models will enable us to examine the link between the putative central supermassive black hole and dark matter which is suggested by the recently found v_c-σ relation ([5] [1]).

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