Dynamical models for dusty disk galaxies

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Abstract. Disk galaxies contain a large amount of interstellar dust, which affects the projection of kinematic quantities. We investigate in detail the effects of dust extinction on the mean projected velocity and the projected velocity dispersion. We use our results to construct a general strategy to determine the dynamical structure of disk galaxies, with the aim to constrain their mass distribution and dynamical history.

1. Introduction

The knowledge of the dynamics of disk galaxies is essential in order to understand their structure and history. Unfortunately, disk galaxies are difficult systems to model dynamically, for several reasons. One of them is the presence of a large amount of interstellar dust, which obscures the light along the lines-of-sight. Using extended radiative transfer models it is nowadays possible to recover quite accurately the three-dimensional light and dust distribution in disk galaxies (Kylafis & Bahcall 1987, Xilouris et al. 1999). But also the observed kinematics are affected by dust obscuration. Indeed, each element along a line-of-sight carries its own kinematic information, and the projected kinematics are a weighted mean of all these contributions. We adopt the technique outlined in Baes et al. (2000a,b) in order to investigate in detail the effects of dust extinction on the mean projected velocity \( \bar{v}_p \) and the projected velocity dispersion \( \sigma_p \).

2. The modelling and results

We adopt a galaxy model which consists of a double exponential disk and a de Vaucouleurs bulge. We construct a dynamical model (i.e. a potential and a phase-space distribution function) for this galaxy. We choose a potential that gives rise to a flat rotation curve and represents a halo-disk structure (Batsleer & Dejonghe 1994). Using the Quadratic Programming modelling procedure (Dejonghe 1989) we then construct a two-integral distribution function that is consistent with the light density. We add a double exponential dust disk to this model. Finally, the dust-affected \( \bar{v}_p \) and \( \sigma_p \) can be calculated for various values of the inclination and optical depth.

For galaxies which are face-on or moderately inclined, the effects of dust extinction on \( \bar{v}_p \) and \( \sigma_p \) are negligibly small. In the edge-on case, the dust-affected \( \bar{v}_p \)-profile tends to apparent solid body rotation, as we only see the
stars moving on the outer near edge of the disk. In meanwhile, the projected dispersion decreases drastically as a function of optical depth for the inner lines-of-light, as dust obscuration strongly reduces the contribution of the high random motions of the bulge stars. Both effects are critically dependent on inclination, and they are already much weaker for galaxies which are only a few degrees from exactly edge-on (see also Bosma et al. 1992).

3. Conclusion: dynamical modelling of disk galaxies

From our results it is clear that the effects of dust obscuration on \( \bar{v}_p \) and \( \sigma_p \) are negligible for moderately inclined galaxies. Hence it is quite safe to neglect dust extinction in the interpretation of projected kinematics. This leads us to propose the following strategy to construct dynamical models for disk galaxies. Intermediately inclined disks are the best choice, as spectra at different position angles will then show different projections of the velocity ellipsoid.

First, one should determine the three-dimensional light distribution of the galaxy, using deprojection techniques which take the dust into account. The accuracy of the results can be tested by comparing models in different wavebands with the galactic extinction curve (Xilouris et al. 1999) or by comparing the derived extinction profile with FIR/submm emission (Alton et al. 2000). Then, a set of potentials which are consistent with the rotation curve and the light distribution need to be determined. For each potential a three-integral model can be constructed. Input for the fit should be the light density and the projected kinematics along (at least) both major and minor axes. The goodness of fit of the different models can then be used to constrain the set of possible potentials, which will reveal the mass distribution in the galaxy. The velocity field can then be analysed, in particular the behaviour of the velocity ellipsoid. This can shed a light on the mechanism responsible for the dynamical history of the disk (Jenkins & Binney 1990, Gerssen et al. 1997, 2000).

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