Deprojection and dynamical modelling of barred galaxies

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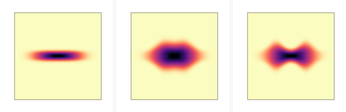
1. Context and problem

- 1/3 to 2/3 of all disc galaxies have bars.
- we see galaxies only in projection and need to reconstruct the 3d shape in order to build dynamical models.
- conventional photometric fitting methods such as Multi-Gaussian Expansion (MGE) are designed for ellipsoidally stratified density profiles, but bars often have boxy or X-shaped structure.
- one can use a boxy or X-shaped model (e.g., a generalized ellipse $(x/a)^n + (y/b)^n = 1$) to fit the projected image, but determining the corresponding 3d shape from it is next to impossible.

2. Our approach

- use the IMFIT program [Erwin 2015], which can deal with arbitrary 3d density components and computes their projected density at any given orientation.
- define a custom family of realistic 3d density profiles of bars with adjustable separation, amplitude and width of peanut-shaped features



3. Results: edge-on fits and deprojection

Apply the method to mock images created from *N*-body snapshots of barred galaxies.
As a first step, explore only the edge-on orientation, with the long axis of the bar rotated at some angle α w.r.t. the image plane.

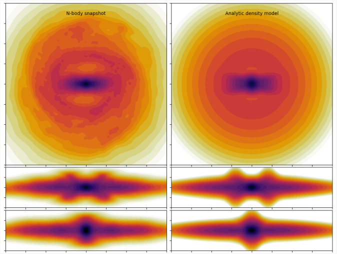


Figure 1: Left: original *N*-body snapshot; right: 3d density reconstructed from an edge-on projection shown in the second row (long axis of the bar lying in the image plane, $\alpha = 0$).
The reconstructed 3d density profile is quite close to the true one.

However, the angle α is not well constrained – a longer bar rotated by $\alpha > 0$ is almost as good as a short bar with $\alpha = 0$. To tell them apart, we need to feed kinematic information (line-of-sight velocity maps) into a dynamical model.

4. Results: dynamical modelling and pattern speed

In addition to photometry, from which the 3d density is reconstructed, use kinematic information (2d maps of line-of-sight velocity distribution represented by six Gauss–Hermite moments, as could be observed by a typical IFU spectrograph) as observational constraints in the dynamical models constructed with the Schwarzschild orbit-superposition code FORSTAND [Vasiliev&Valluri 2020].

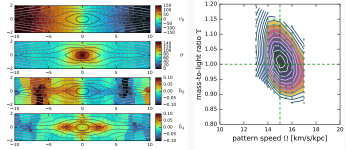


Figure 2: Left: kinematic maps created from the *N*-body snapshot; right: contours of χ^2 as a function of model parameters (pattern speed and stellar mass-to-light ratio); both are well recovered (the minimum of χ^2 is close to the true values marked by green dashed lines).

It appears that dynamical self-consistency (the ability of orbits in the given potential to reproduce the corresponding 3d density profile) already strongly constrains the pattern speed even in the edge-on orientation, in which the simpler Tremaine–Weinberg method is inapplicable.

References

Erwin P., 2015, ApJ, 799, 226
Vasiliev E., Valluri M., 2020, ApJ, 889, 39
Dattathri S., Valluri M., Vasiliev E., in prep.