Evolution of Bars in Galaxies

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Background: Bar formation

- Roughly 60% of spiral galaxies have bars (Buta et al., 2010)
- Significant proportion of all galaxies
- The Milky Way and Andromeda both have bars

- Bar formation is a cornerstone of galaxy evolution
- Bars form when instabilities cause deviation of orbits from circular paths (Athanassoula, 2005)
$N$-body simulation specifics

- $N$-body model used was developed by our collaborator Lia Athanassoula
  1. Luminous disk, 200,000 particles
     - Initialized w/ exponential drop-off radially, and a sech$^2$ drop-off in the z-axis
  2. Dark matter halo, 1,000,000 particles
     - Parameterized by halo scale lengths with a drop-off with radius squared

- Looking for kinematic signatures of a bar in the buckling phase, which is when the bar begins extending out of its galactic plane
- Want to eventually catch a bar buckling, observationally
How do bars form?

From 3D $N$-body simulations:

1. A weak, thin bar forms and sits within its galactic plane
2. The bar becomes unstable: it buckles and settles with an increased thickness and velocity dispersion
   A. During the buckling process, the bar is N/S asymmetric
   B. The N and S portions do not necessarily buckle at the same time
3. When seen edge-on, the bar is visibly thicker than its galactic plane, and appears boxy or peanut shaped

Edge-on
Edge-on

- Martinez-Valpuesta et al., 2006.
Signatures of the buckling instability

Face-on

Buckling

Stable
2D plots of line-of-sight velocity

Edge-on

Face-on
Observations

- MaNGA: Mapping Nearby Galaxies at APO, survey of 5000 galaxies, 800+ barred spiral galaxies
- \( \approx 30 \) almost exactly face-on barred galaxies, statistically
- \( \approx 350 \) that are ‘close enough’ to face-on

Image: Dana Berry / SkyWorks Digital Inc., David Law, and the SDSS collaboration
Face-on, simulation

Stable - 2.5 Gyr

Buckling - 3.53 Gyr

Stable - 4.5 Gyr

Distance: 150000 kpc
Inclination: 0°
Observations & Unsharp Masking (cont’d)
Thank you!
15 degrees inclination

**Buckling**

**Stable**

**Mean**

**Sigma**

**Skew**

**Counts**