The role of Galaxy Interactions and Stellar Bars

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ICTP: Interacting Galaxies
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Collaborators

- Sara Ellison, Dave Patton, Luc Simard
- Bob Abraham, Sidney van den Bergh
Two modes to assemble and redistribute mass

according to epochs and environment

Secular evolution

Internal slow evolution

Cosmological or Hierarchical scenario

Spheroids form through major spiral mergers

Gas accretion can then reform disks
2 main mechanisms for gas inflow to build bulge.

- **Galaxy-galaxy mergers** (e.g. the mice)
- **Galaxy bars** (e.g. NGC 1300)
Theory vs. Observations for pairs

- Close pair interactions should show enhanced star formation rates.
  - depends on pair separation?
  - depends on mass ratio? (Cox et al. 2008, Ellison et al. 2008)
  - 30% - 200%
- Level of SFR enhancement is the same out to $z \sim 1$. (Jogee+ 2009, Robaina + 2009)
- Shallower metallicity gradients. (Rupke et al. 2010, Kewley et al. 2010)
- Central metallicities are lower in close pair galaxies - (0.05 dex to 0.1 dex decrement).
- AGN triggers? (talks by Sara Ellison, John Silverman)
- Bar triggers? (this talk, if I have the time)
Why are stellar bars important?

1. Redistribute angular momentum between baryonic and dark matter components
   - cusp/core problem
   - black hole mass vs. bulge mass correlation
5. Metallicity gradients
6. Drive spiral arms and rings
7. Up to 70% (?) of disk galaxies are barred.
   Bars are 'normal'.

PROBLEMS
- fractions (?)
- timescales (?)
- destruction mechanisms? (?)
- Found in mature disks (?)
- Triggered in unstable disks?
- contribution to star formation rate density, AGN fraction or bulge growth(?)
Role of bars

• Why is it hard to determine bar fractions?
• Are barred galaxies different from unbarred galaxies?
• Can they be triggered by close pair interactions?
Barred vs. Unbarred
- Sample drawn from SDSS Data Release 4 to match high-z galaxies
- $g < 16$ and $0.01 < z < 0.1$
- ~15,000 galaxies
- visually (T-types) and quantitatively (A,C,G,M20,E, etc) classified

Catalog is public.
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<td>2520 (25%)</td>
<td>532 (5%)</td>
<td>4112 (29%)</td>
<td>2719 (19%)</td>
<td>421 (3%)</td>
<td>969 (7%)</td>
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• Visual catalog of Nair & Abraham 2010.

• $0.02 < z < 0.1$

• S/N>5 in [OII], H_beta, [OIII], H_alpha, [NII]

• AGN are excluded.

• 311 barred galaxies and 806 unbarred galaxies.

Ellison et al. 2011
Properties of Barred Galaxies

- Star Formation Rates

~ No broad star formation rate enhancement.

Ellison et al. 2011
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Ellison et al. 2011

~ No broad star formation rate enhancement.

Central star formation rate does show enhancement

Ellison et al. 2011
Properties of Barred Galaxies

- Metallicities

- Barred galaxies more metal-rich at all masses.

- Bars sufficiently long lived to show enrichment, even after burst of SF.

0.06 dex enhancement
So while there is metallicity enhancement below Log M~10, there is no enhancement in SFR.
Quick Detour: Bar Fractions (SDSS)
Bar Fraction vs. Stellar Mass

- Bar Fractions strongly depend on mass.
- Bar Fractions are bimodal.
- The also depend on the central concentration of a galaxy.

- So, on average strong bar fraction in disk galaxies is ~30%.
- For all galaxies including ellipticals and no i cut, average bar fraction ~ 15%
Properties of Barred Galaxies

- Contributions of bars and CP to SF

\[ \frac{\epsilon_{b/p}}{\epsilon_{p}} = \frac{f_{b}}{f_{p}} \times \frac{f_{b,*}}{f_{p,*}} \times \frac{10^{\Delta SFR_{b}}}{10^{\Delta SFR_{p}}} \]

Ratio of enhanced star formation coming from bars and pairs.

Ratio of bar and pair fraction in galaxy population.

Ratio of bar and pair fraction in star-forming sample.

Ratio of SFR enhancements bar and pair star-forming sample (this ratio \(\sim 1\)).

\( \epsilon_{b/p} \geq 3 \), i.e. at least 3.5 times more central star formation comes from bars than pairs.

Ellison et al. 2011
Properties of Barred Galaxies

- Contributions of bars and CP to SF

So from SDSS, bars cause the same level of SFR enhancement as close pairs. Maybe because close pairs trigger bars which cause the gas inflow.

Ellison et al. 2011

\[ \frac{\varepsilon_{b/p}}{3} > 3, \text{i.e. at least 3.5 times more central star formation comes from bars than pairs.} \]
Back to Bar Fractions

- From SDSS, bar fractions are bimodal.

- For the low mass peak, bar fractions at a given stellar mass decreases as concentration increases.

- Bar fractions decrease with increasing stellar mass.

- Central concentrations are expected to destroy bars, but only for more massive galaxies.
Back to Bar Fractions

- For the high mass peak, bar fractions at a given stellar mass increase as concentration increases.

- Bar fractions shows no dependence on stellar mass.

- Bulges may be stabilizing bars.
So central concentration is important to bar fractions. But it depends on the stellar mass and morphology of the galaxy!
Do Close Pairs Trigger Bars?

Talk to me offline.
Conclusions from SDSS

• Fiber metallicities of barred galaxies are uniformly higher by 0.06 dex.

• Fiber star-formation rates of barred galaxies are higher by 60%.

• Bars account for 3.5 times more triggered central star formation.

• Bar Fraction strongly depend on the mass and morphology of a galaxy