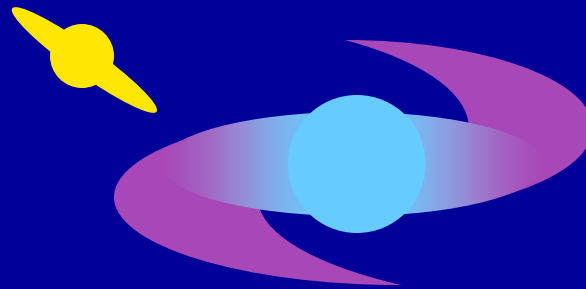


Forming Young Bulges within Existing Disks: Statistical Evidence for External Drivers



*Sheila Kannappan (UT Austin)
with Rolf Jansen (ASU) & Elizabeth Barton (Arizona)*

Forming Young Bulges within Existing Disks

Many bulges are younger & diskier than expected.

- Colors

surprisingly blue bulges, correlated bulge/inner-disk colors
(e.g. Peletier, Balcells, et al, Carollo et al, Ellis et al)

- Structure

exponential light profiles, correlated bulge/disk scale lengths
(e.g. Andredakis et al, MacArthur, Courteau, et al)

- Kinematics

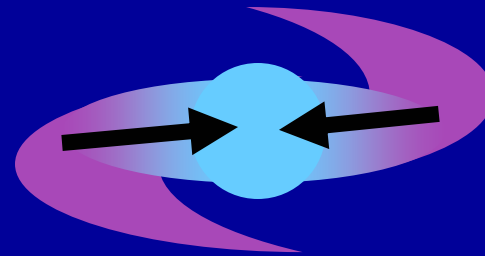
disky v/σ ratios, Faber-Jackson outliers *(Kormendy & Illingworth)*

Forming Young Bulges within Existing Disks

Bulges must evolve late, within & together with disks.

Secular Scenario:

- Bar instability
- Disk gas inflow
- Central starburst
- Dissolution of bar



*e.g. Pfenniger & Norman,
Friedli & Benz*

Forming Young Bulges within Existing Disks

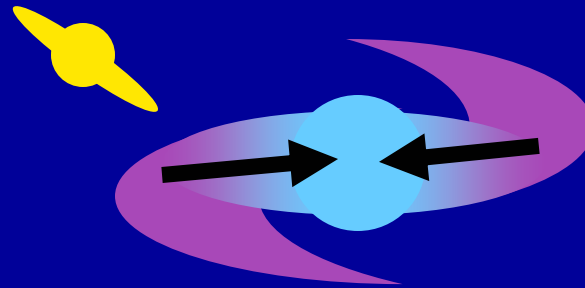
Bulges must evolve late, within & together with disks.

Secular Scenario:

- Bar instability
- Disk gas inflow
- Central starburst
- Dissolution of bar

Triggered Scenario:

Just add neighbor.

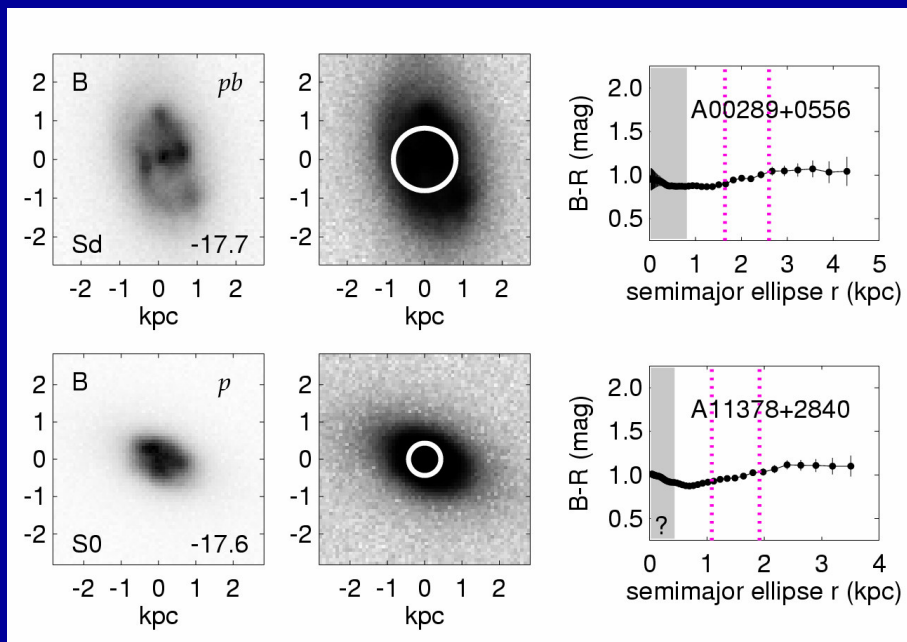


*e.g. Pfenniger & Norman,
Friedli & Benz, Hernquist & Mihos....*

Breaking the Degeneracy

Kannappan, Jansen & Barton 2003

Strategy: catch bulges in the act of forming...



blue center criterion :

$$\Delta(B-R) > 0$$

(outer color – inner color)

“inner” = inside 50% radius

“outer” = from 50% to 75%

...and test for
outside influences

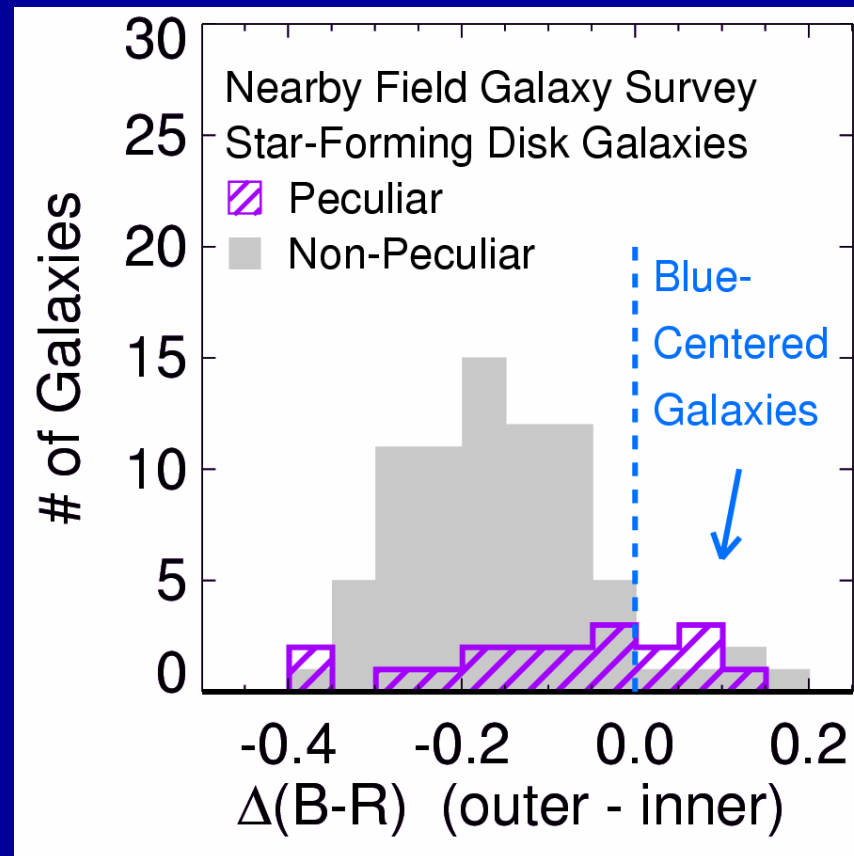
Statistical Evidence for External Drivers

Blue centers correlate with evidence for interactions and mergers.

peculiarity:
99% confidence

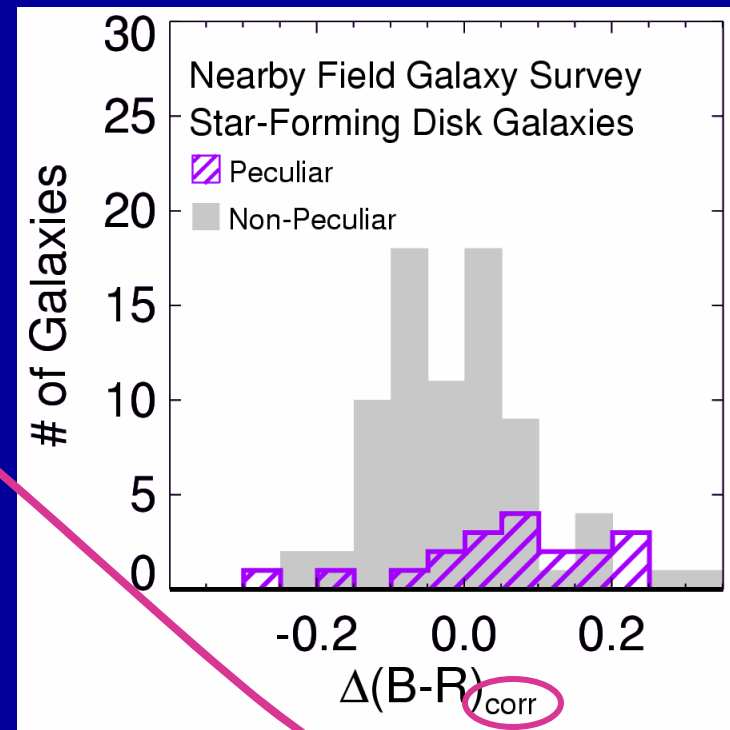
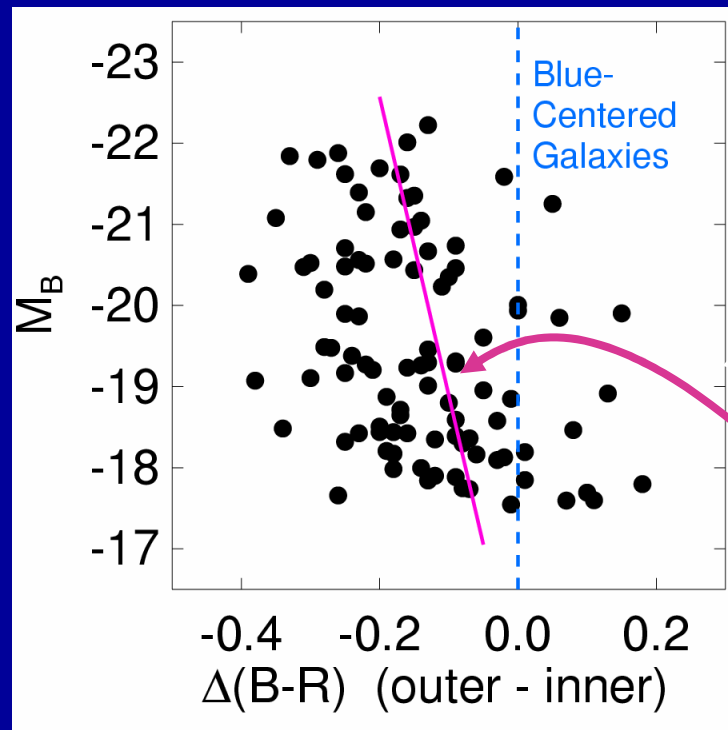
UZC companion:
95% confidence

some evidence:
all 11 galaxies



Statistical Evidence for External Drivers

Peculiarity result does not reflect luminosity trend.



(also Tully et al 1996, Jansen et al 2000)

Statistical Evidence for External Drivers

KEY POINT

Not just:

interactions & mergers can cause blue centers

But:

in a statistically fair sample, blue centers
usually reflect interactions & mergers

Forming Young Bulges within Existing Disks

Blue-centered galaxies plausibly reflect an important mode of bulge growth within disks.

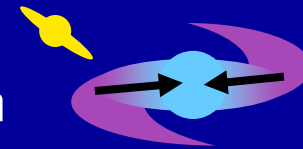
- central growth → bulge growth
(spatial scales match)
- growth within disks
(non-destructive interactions: small companions)
- substantial growth
(pop. synth. model galaxies: bulge sizes ~double after fading)
- life stage for most disk galaxies (bright galaxies masked?)
(10% of sample and 1-2 Gyr duty cycle → > 50% of disk galaxies)

*see paper
for details*

Forming Young Bulges within Existing Disks: Statistical Evidence for External Drivers

The Big Picture (A Suggestion):

Late-epoch bulge growth within disks =
“high-resolution” hierarchical galaxy formation



Open Questions:

- Does the luminosity trend reflect “downsizing”?
 - high-z analogues, bulge rejuvenation (*Ellis et al.*)
- Will bulges formed in this way be “disky”?
 - exponential profiles and/or disky kinematics
(*Scannapieco & Tissera simulations say yes...*)