A Local Reference for Bar Studies in the Distant Universe

Bar Properties as a function of wavelength

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S4G

Spitzer Survey of Stellar Structure in Galaxies

Why do we care about bars?

Disks like forming bars!

– A galaxy disk will naturally form a bar in a couple of Gyrs unless it is dynamically hot or is dominated by dark matter (Athanassoula+)

→ The presence of a bar allows us to gauge disk "maturity"

Bars transform their hosts!

- The gas transport triggered by a bar can affect significantly its host

→ wash out metallicity gradient across galaxy (Martin & Roy 2004; but Sánchez-Blázquez+11)

→ central accumulation of molecular gas (e.g., Sheth+05)

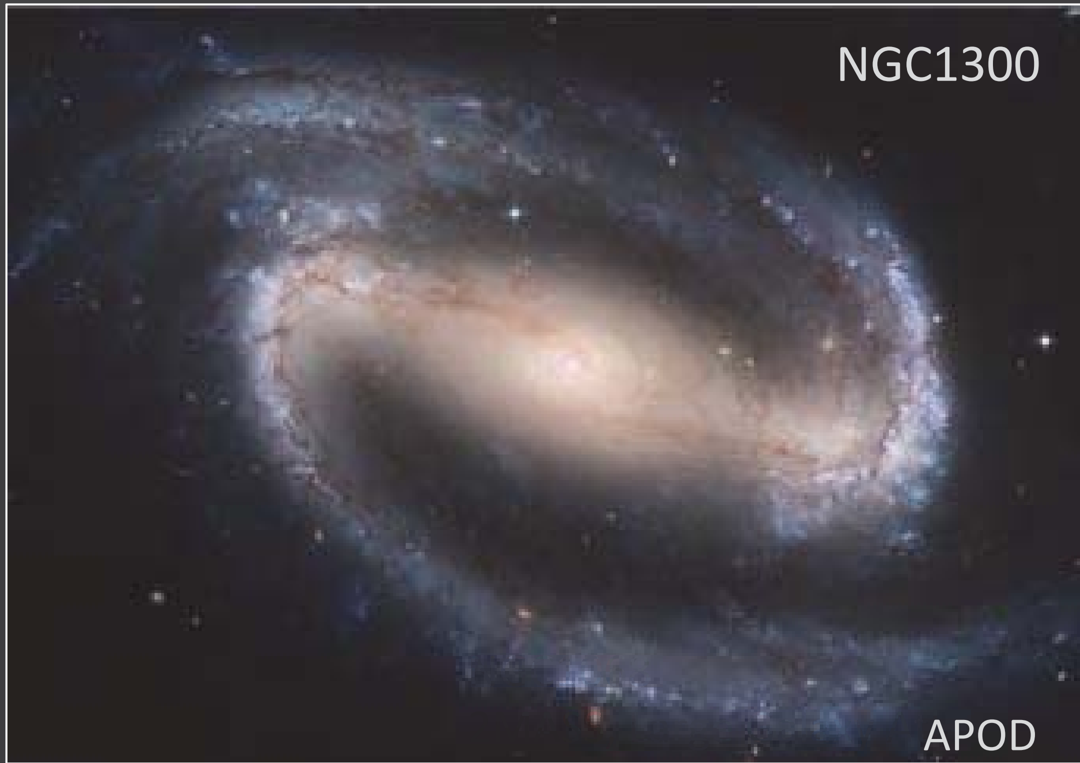
→ triggering nuclear starbursts

→ leading to the formation of pseudobulges (e.g., Kormendy & Kennicutt 04)

→ perhaps even feeding an AGN

Morphological classification of local galaxies – it all started in the optical…

- Morphological classification of galaxies in the optical
  → ~2/3 of spirals are barred (de Vaucouleurs+63)



Morphological classification of local galaxies – look in the infrared!

- Morphological classification of galaxies in the optical
  → ~2/3 of spirals are barred (de Vaucouleurs+63)
- Case studies in the IR showed bars unseen in the optical
  - IR traces old, low-mass stars (e.g., Scoville+88)
  - Bars are dominated by old stars

→ Are all galaxies barred and we just need to look in the IR?

The quest for the bar fraction

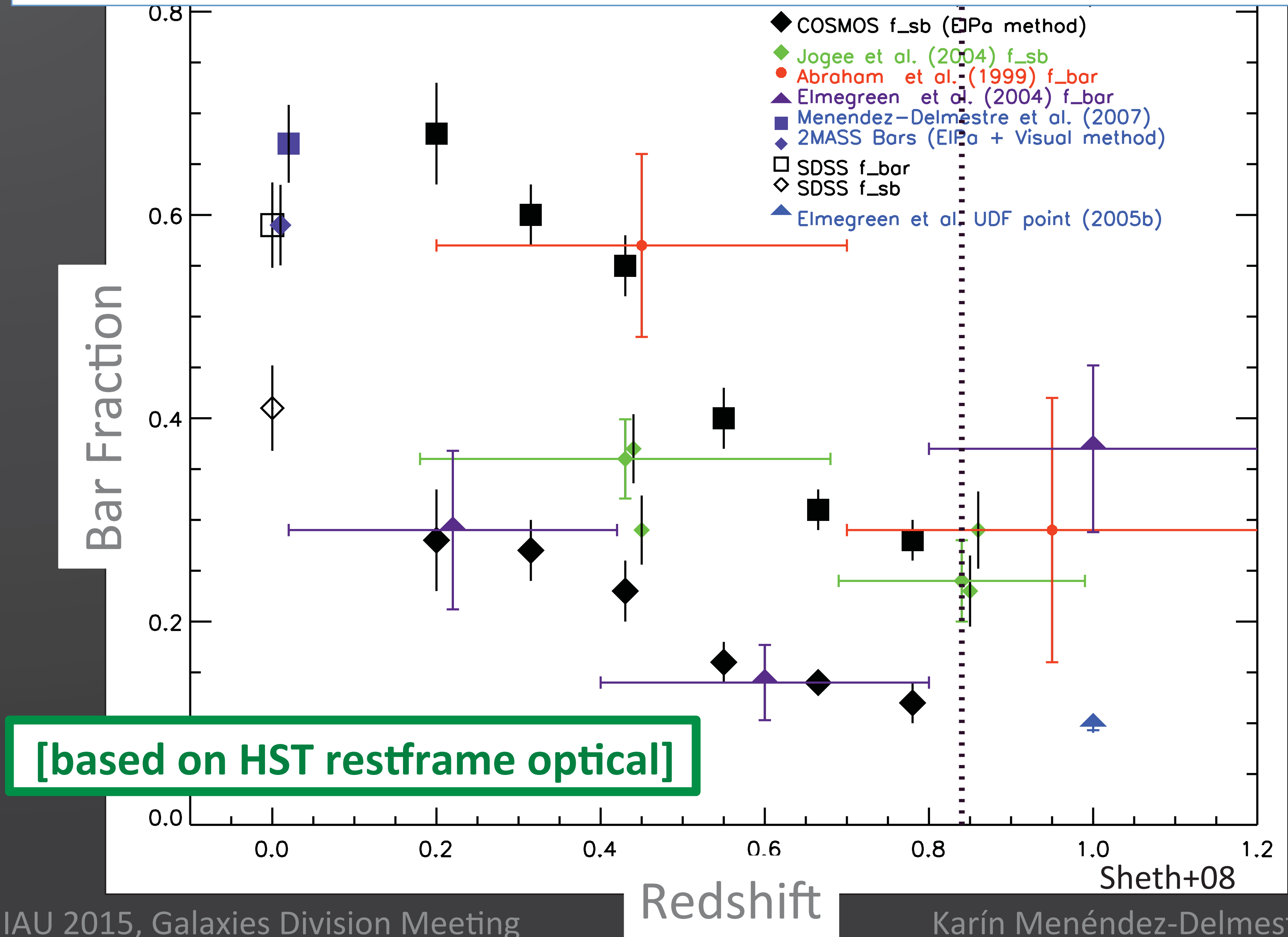
- The *Two-Micron All-Sky Survey* (2MASS; Skrutskie+05)
  - Large Galaxy Atlas (LGA; Jarrett+03)
    - > 500 large (~2′ to 2°) galaxies
    - J, H, Ks

- The bar fraction stays constant across wavelengths from optical to near-IR

  (e.g., Menéndez-Delmestre+07)

  - Why is this interesting?
    - We can trace the evolution of the bar fraction with redshift (→ disk maturity!), safe from band-shifting effects!

Redshift Evolution of the Bar Fraction



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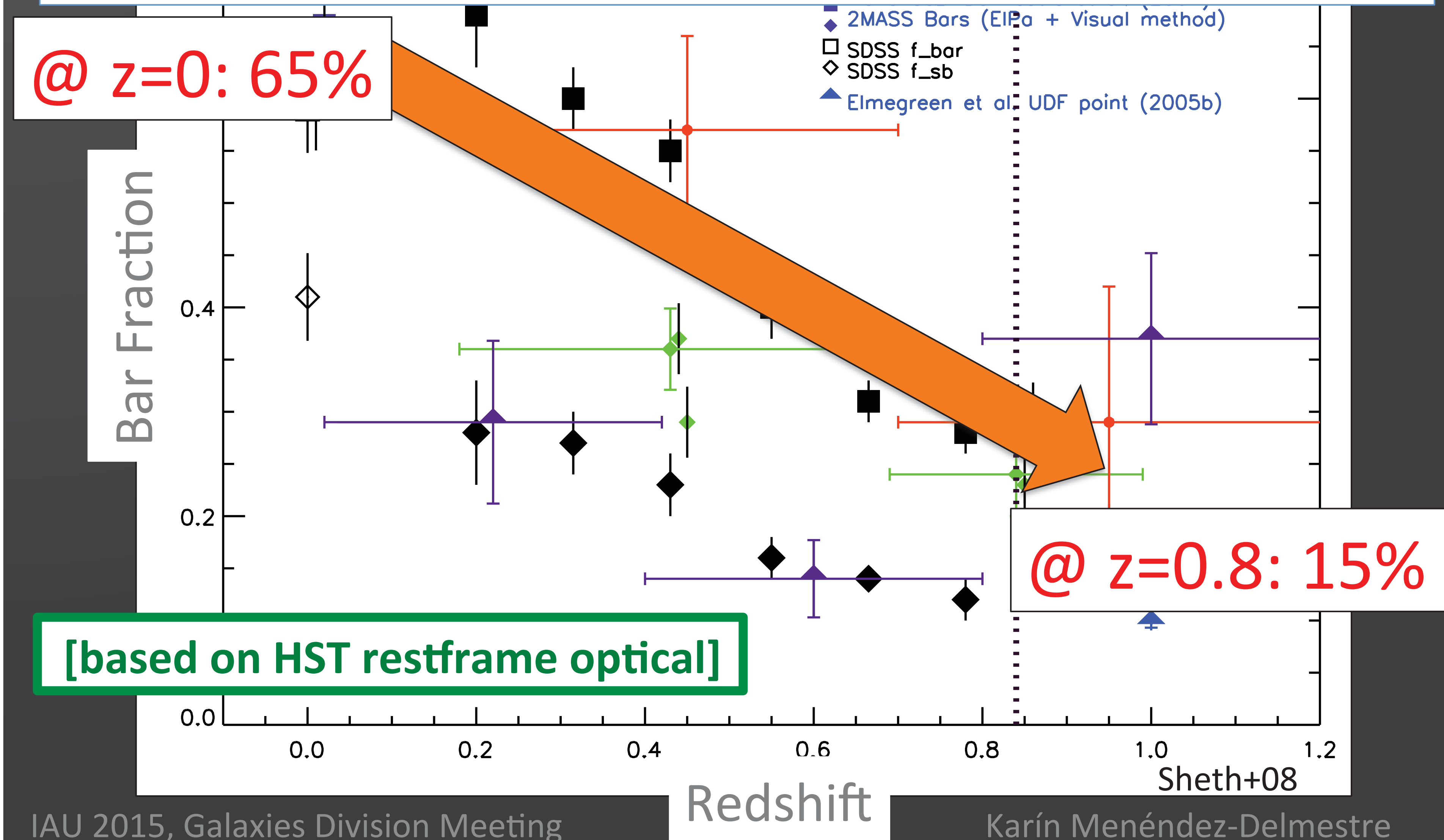
Redshift Evolution of the Bar Fraction: Decreases beyond z~0.4



The quest for bar characterization – do bars change over cosmic time?

- Band-shifting from near-IR to optical does not hamper (significantly) the ability to *recognize* bars

→ So we can trace the evolution of the bar fraction based on the huge amount of high-resolution optical imaging available (HST)

How about our ability to trace bar properties?

- Several studies have looked at bar properties locally (e.g., Erwin+05+13, Laurikainen+07, Gadotti+08, Hoyle+11)

2MASS median bar:

- a_{bar} = 4.2kpc
- ε_{bar}=0.5

Menéndez-Delmestre+07

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How about our ability to trace bar properties?

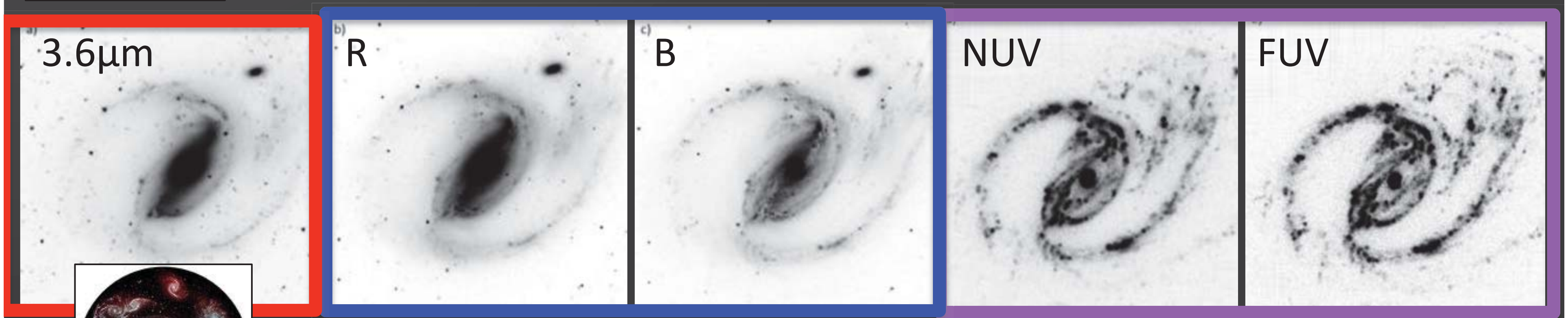
- Several studies have looked at bar properties locally (e.g., Erwin+05+13, Menéndez-Delmestre+07, Laurikainen+07, Gadotti+08, Hoyle+11)

- Although some studies on bar properties have ventured to higher redshifts (Barazza et al. 2009), band-shifting effects on the bar morphology have not been explored. (Q_b: Speltincx+08)

Bar Morphology at high z: need a local reference on how bar properties change with wavelength

We look at bar properties as a function of waveband in a sample of 16 local barred spirals with deep multi-band imaging from UV – opt –IR, based on GALEX, SINGS and S4G imaging.

NGC1097



Spitzer Survey of Stellar Structures in Galaxies (PI Kartik Sheth)
Legacy Survey of the Warm Spitzer Mission
IRAC 3.6/4.5um of >2300 local galaxies

http://s4g.caltech.edu

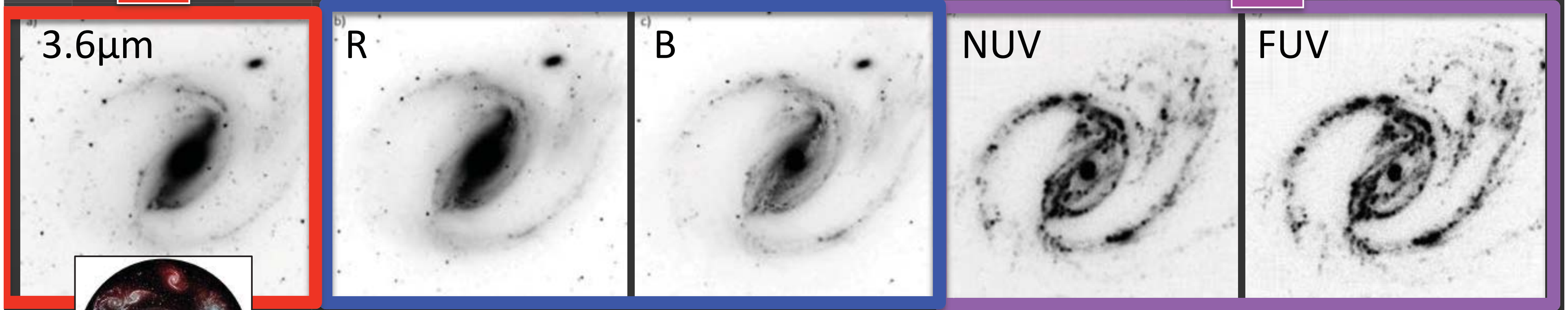
Bar Morphology at high z: need a local reference on how bar properties change with wavelength

mid-IR: optimal window for stellar structure → provides a "canonical measure" of bar properties

UV: explore band-shift out to z>0.8

n of ... and ... based on GALEX, SINGS and S^{4}G imaging.

NGC ...7



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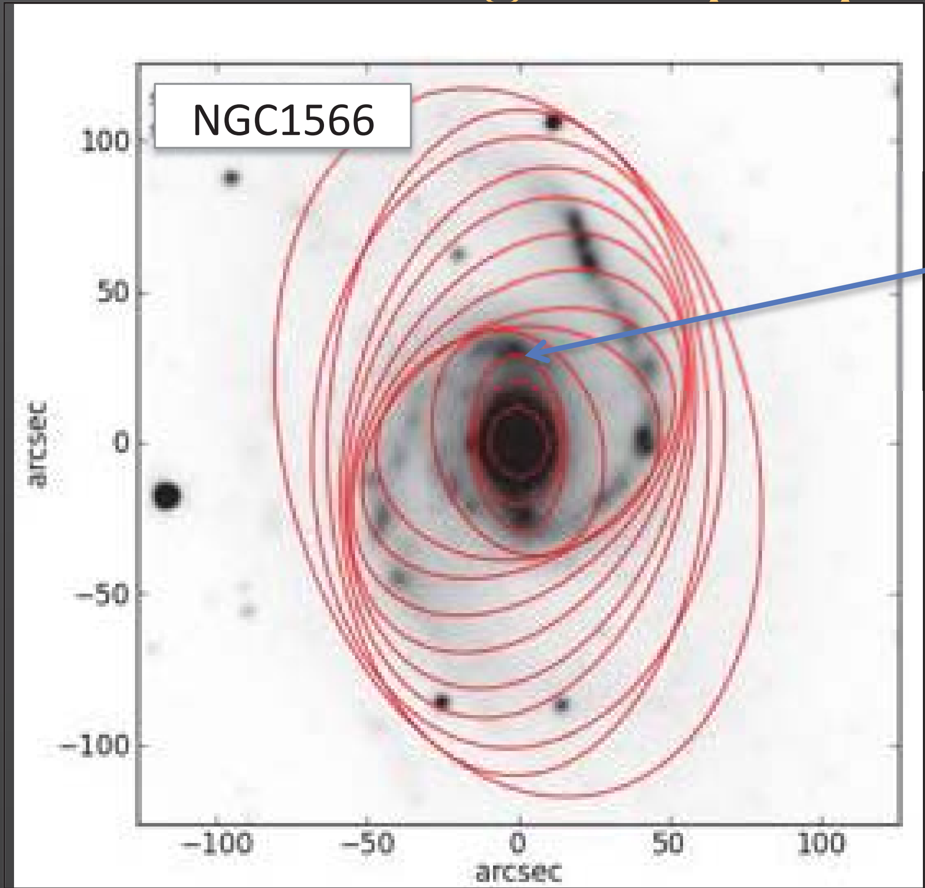
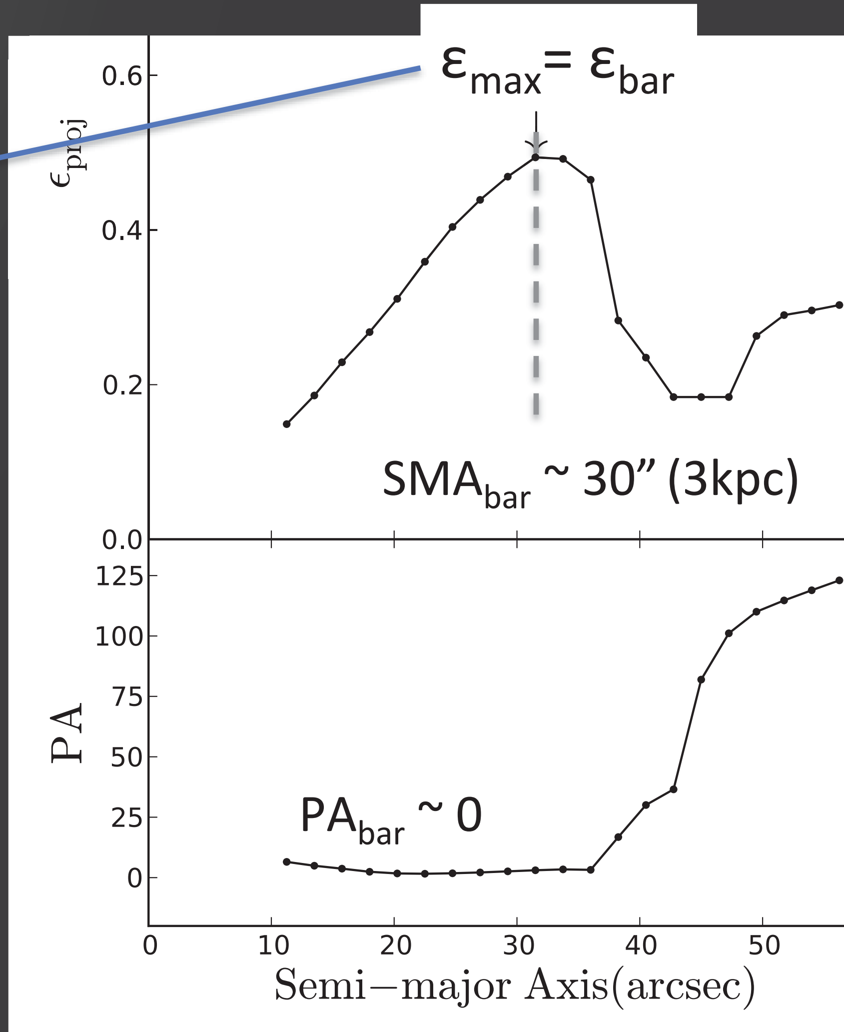
Measuring bar properties – our approach

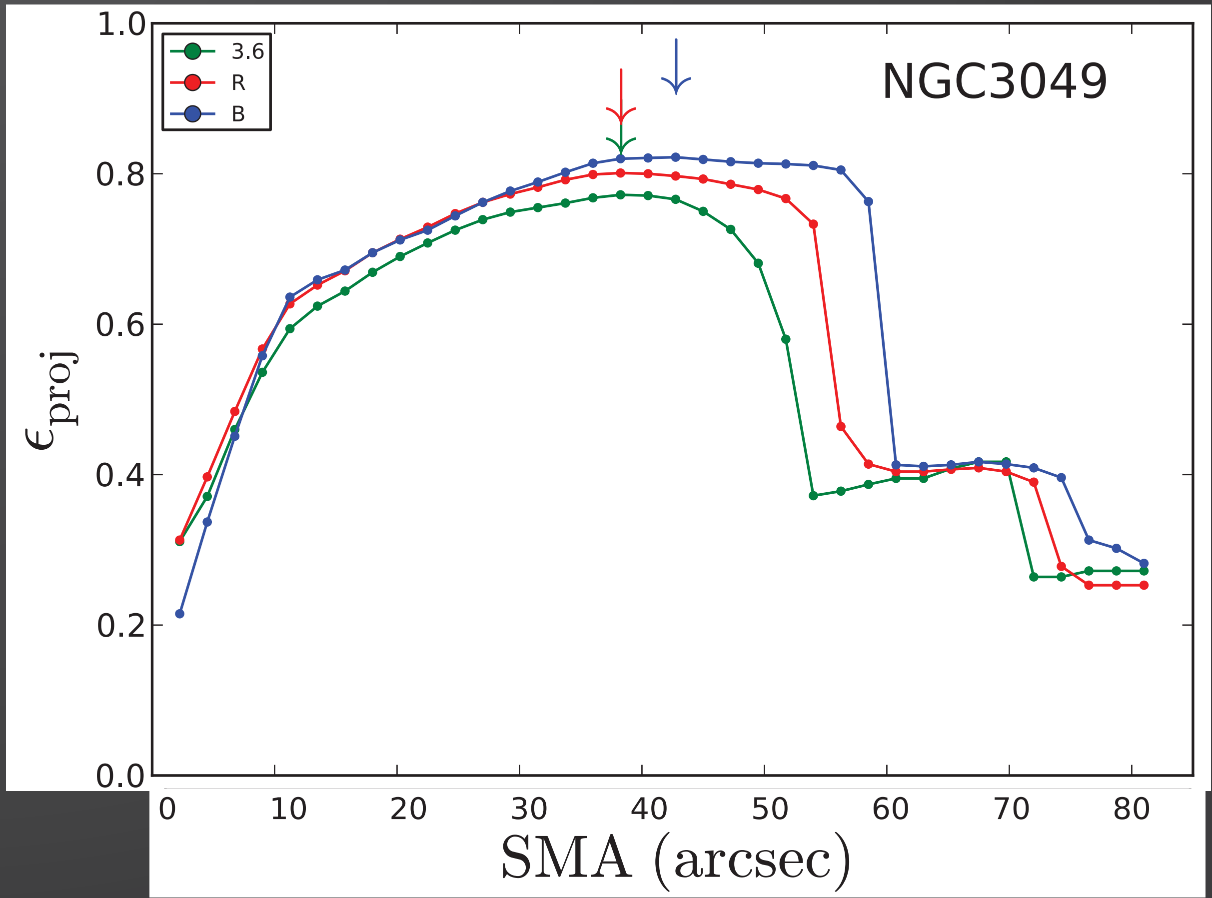


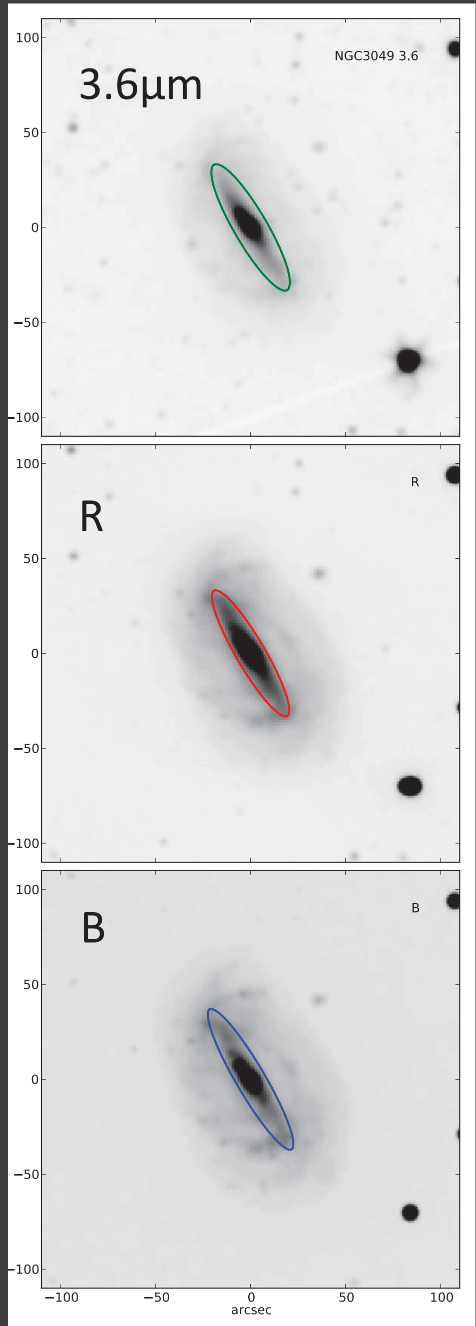


- widely-used ellipse-fit technique

KMD+15

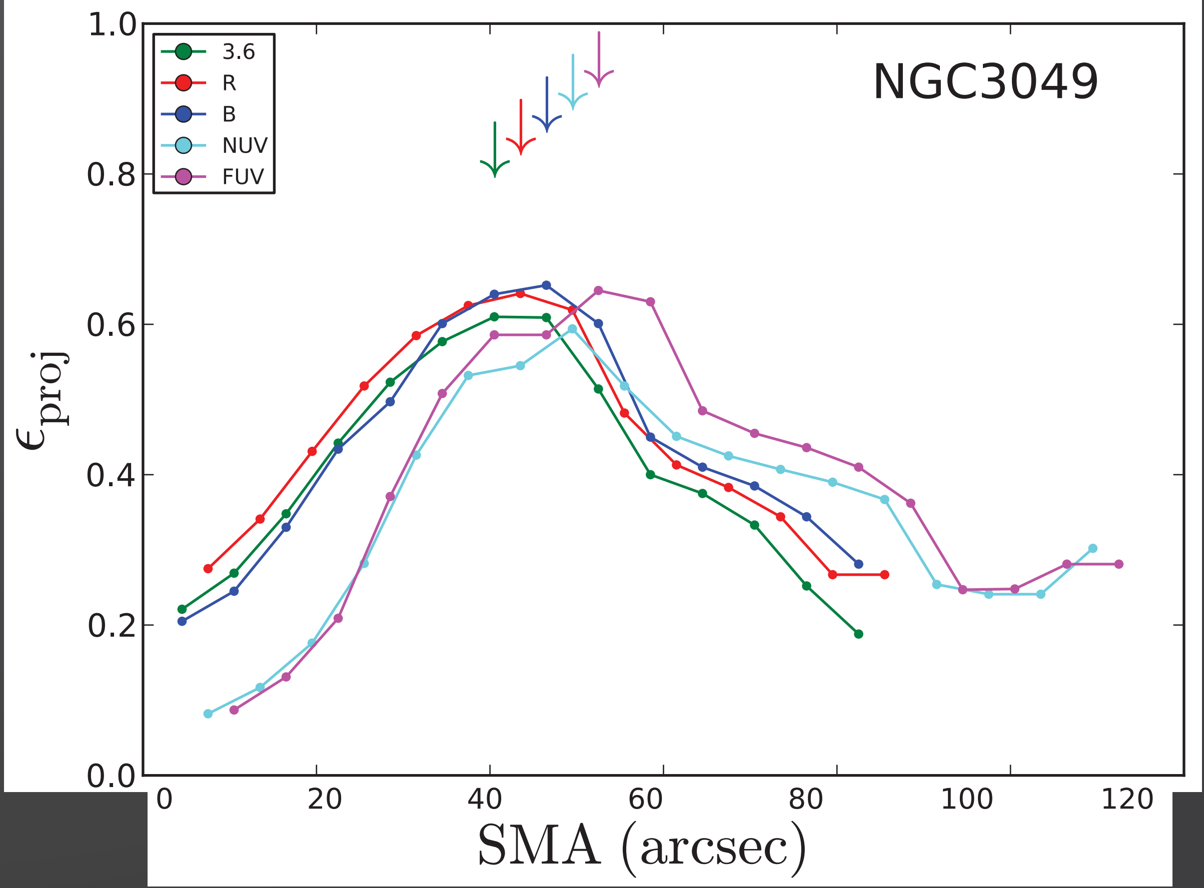
Bars properties: from optical through IR

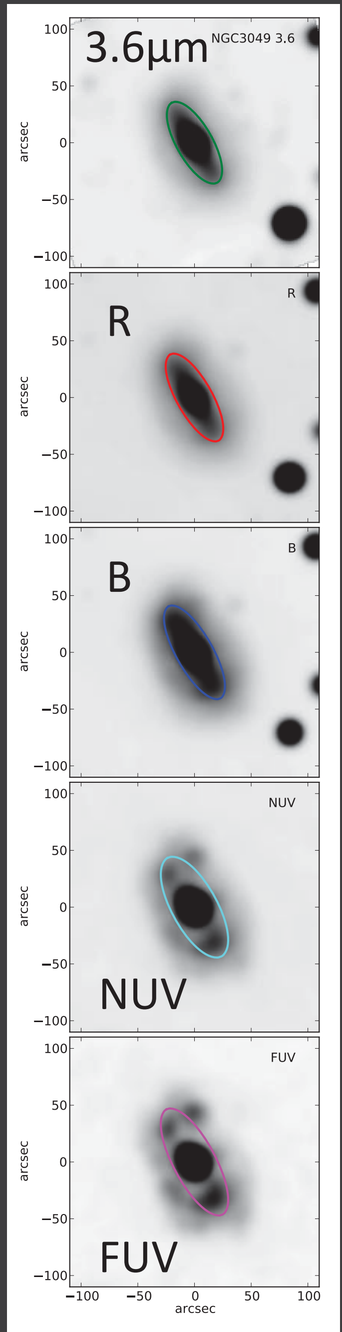




- Based on SINGs ancillary B, R and S^4G 3.6µm IRAC/Spitzer images
- Angular resolution ~1-2"

Bars properties: from UV through IR





- Including GALEX NUV [2267 Å] and FUV [1516 Å]
  - To address high-z (z>0.8) studies based on optical imaging
  - Angular resolution ~6”

1st result:

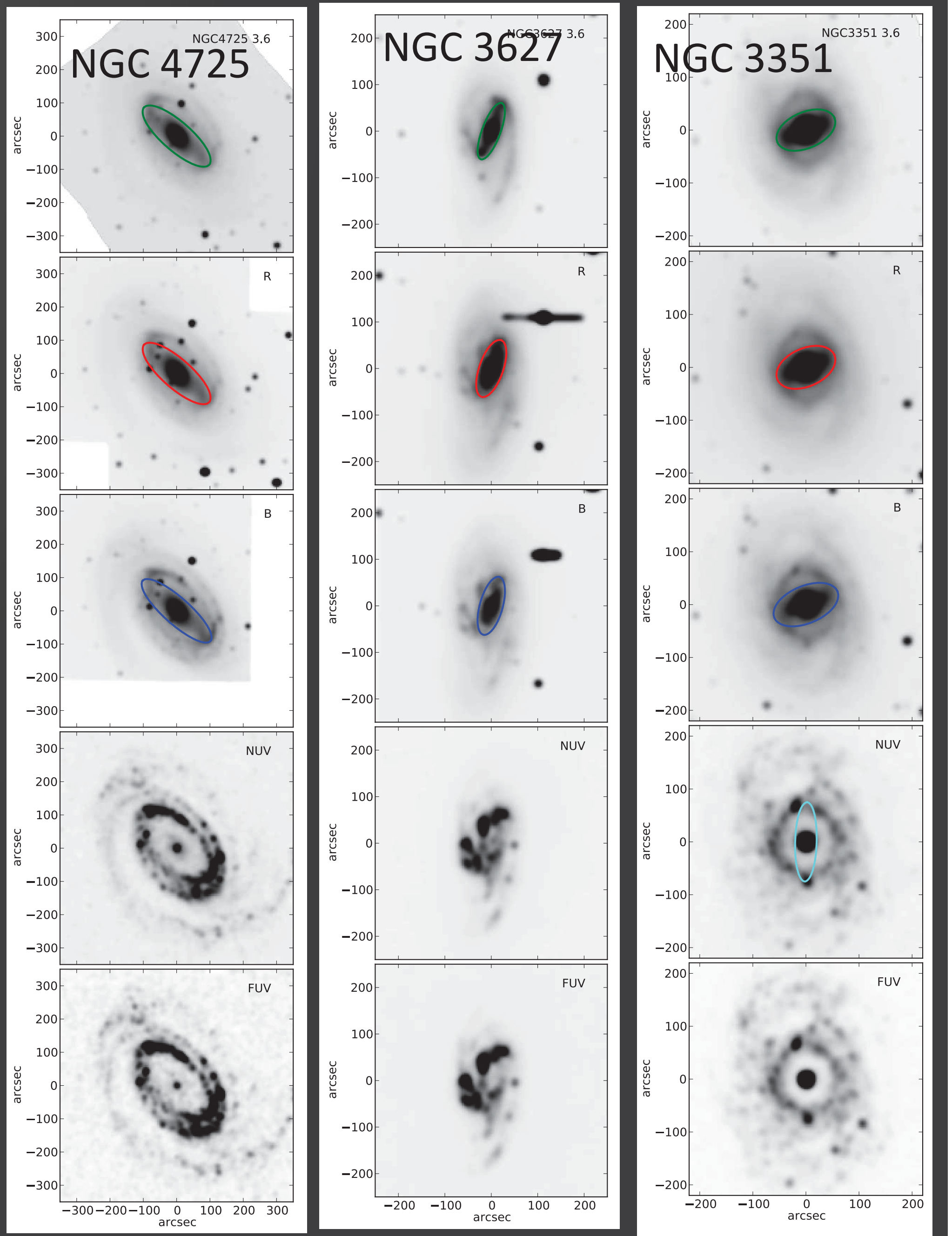
we lose bars in the UV_{rest}

- We lose ~50% of all bars in the NUV/FUV bands

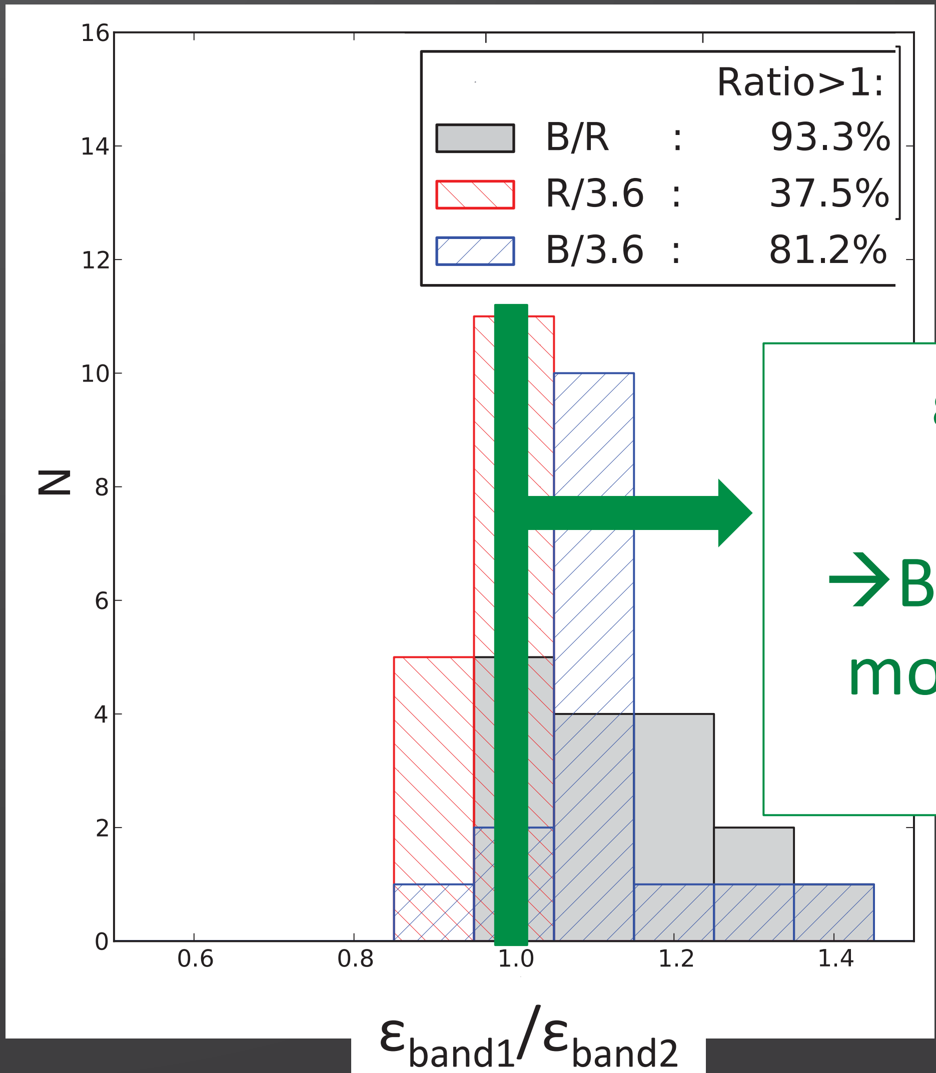
- Band shifting is an issue when going shortwards of the Balmer break (Sheth+08)

→ Studies of bars at high redshift – beware!

→ HST optical data beyond z~0.8 traces emission bluewards of the Balmer break



2nd result: bars look thinner in bluer bands

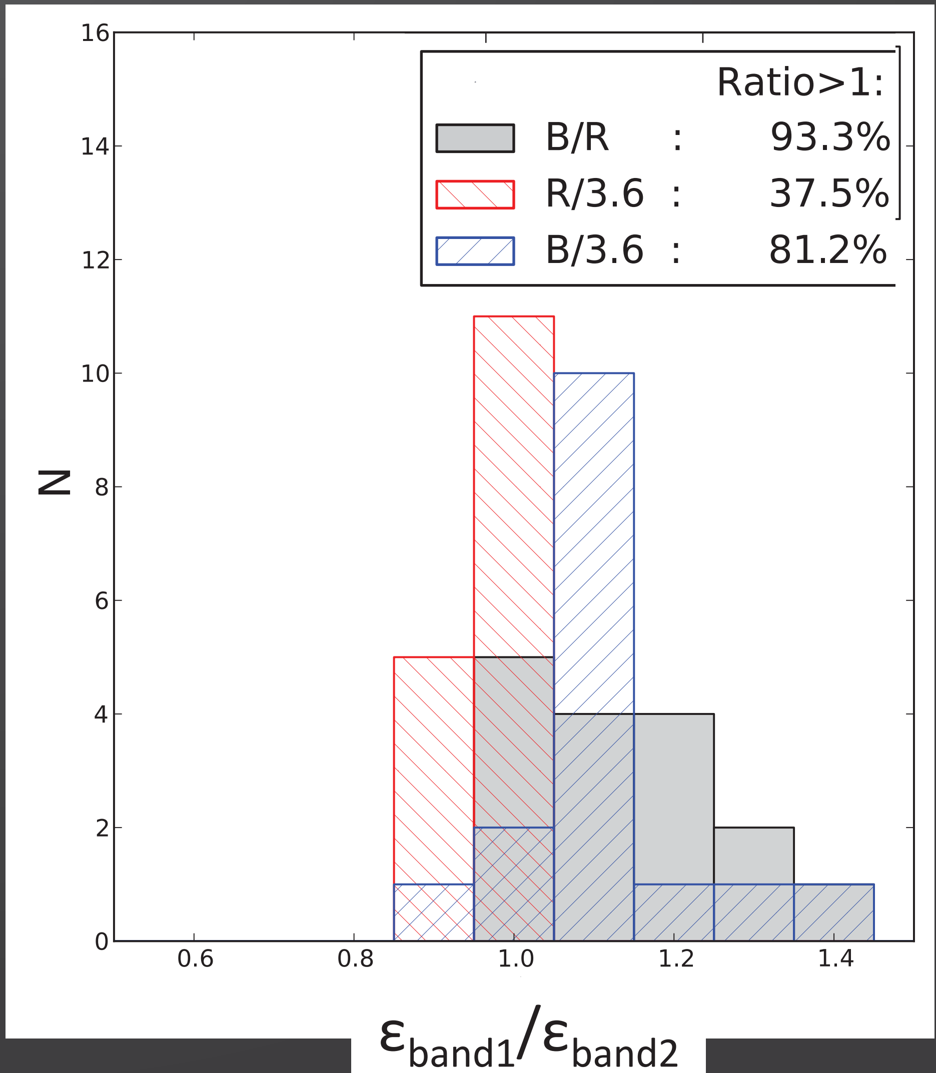


- ε_{max} is higher in the optical bands, compared to the mid-IR

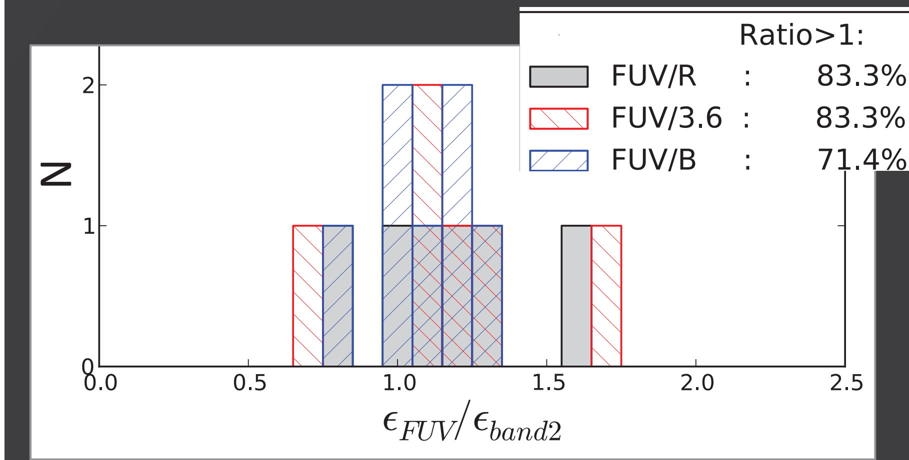
$\varepsilon_{band1}/\varepsilon_{band2} > 1$

→Bar measured to be more elliptical in the bluer band

2^{nd} result: bars look thinner in bluer bands



- ε_{max} is higher in the optical bands, compared to the mid-IR
- This result extends to the UV



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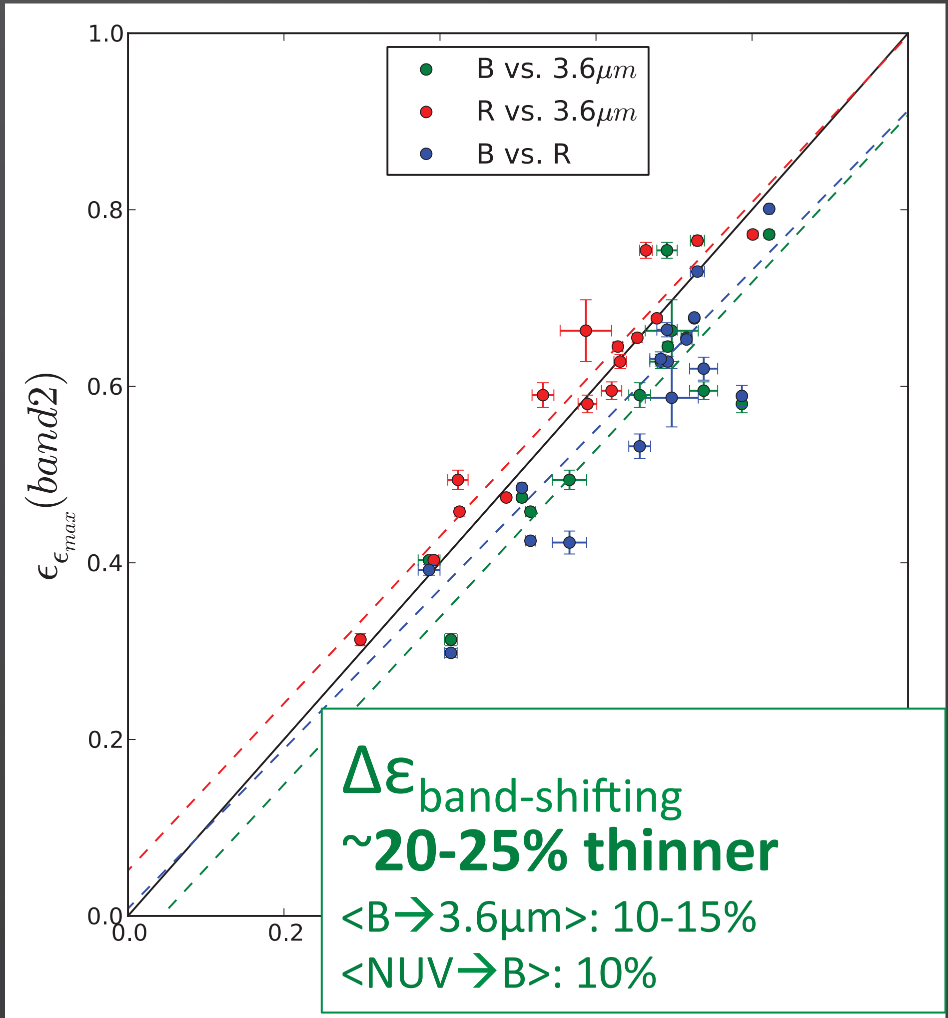
2nd result: bars look thinner in bluer bands



- **Driven by bulge sizes:**
  - Bulge looks bigger in redder bands → smaller in the blue
    - Limits the size of the bar semi-minor axis

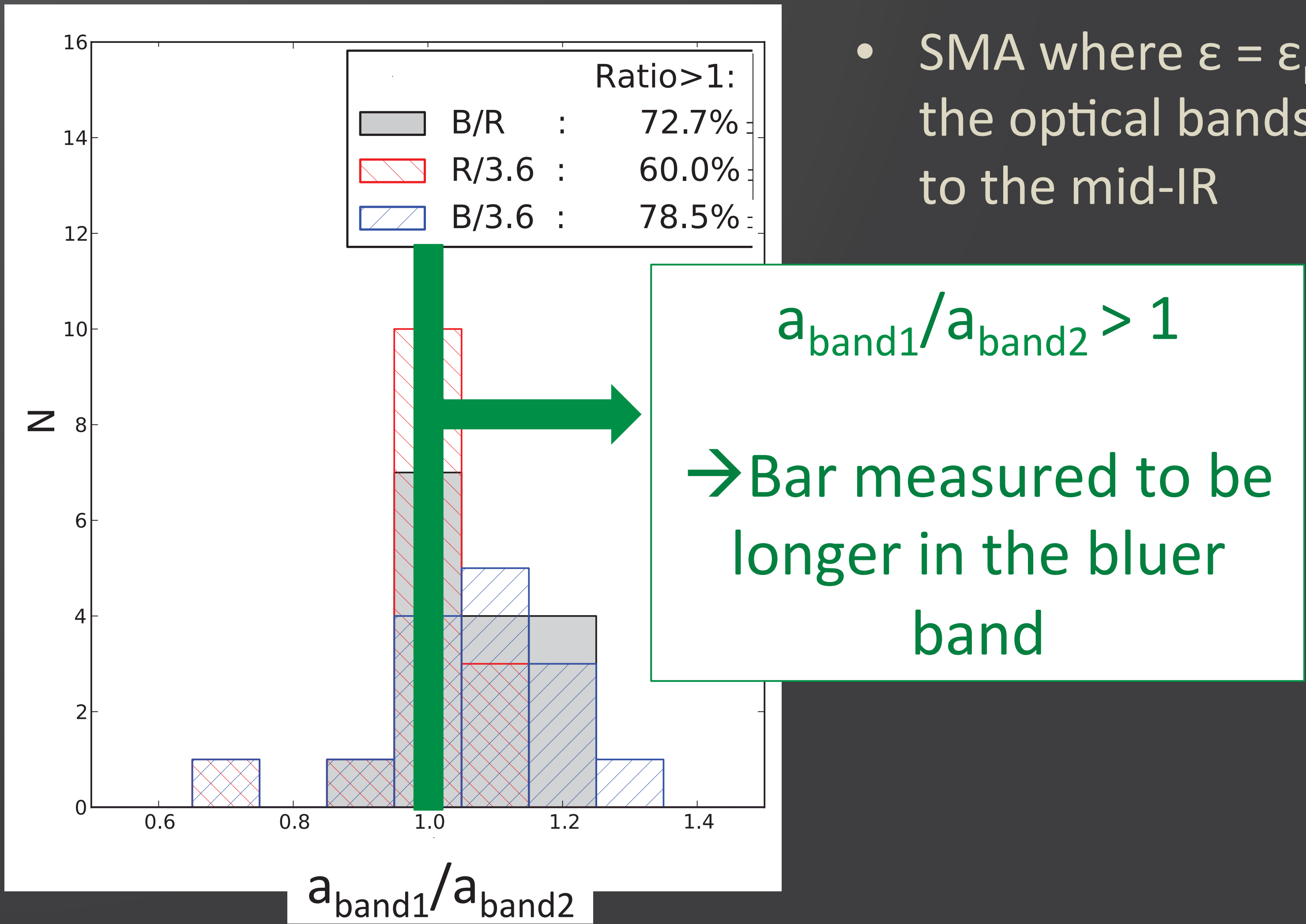
    → Bar looks thinner

Speltincx+08:

- Similar increase of ~25% in bar strength from H to B
  - OSUBSG survey
- Q_b: gravitational bar torque method
  - the maximum tangential force normalized by the radial force

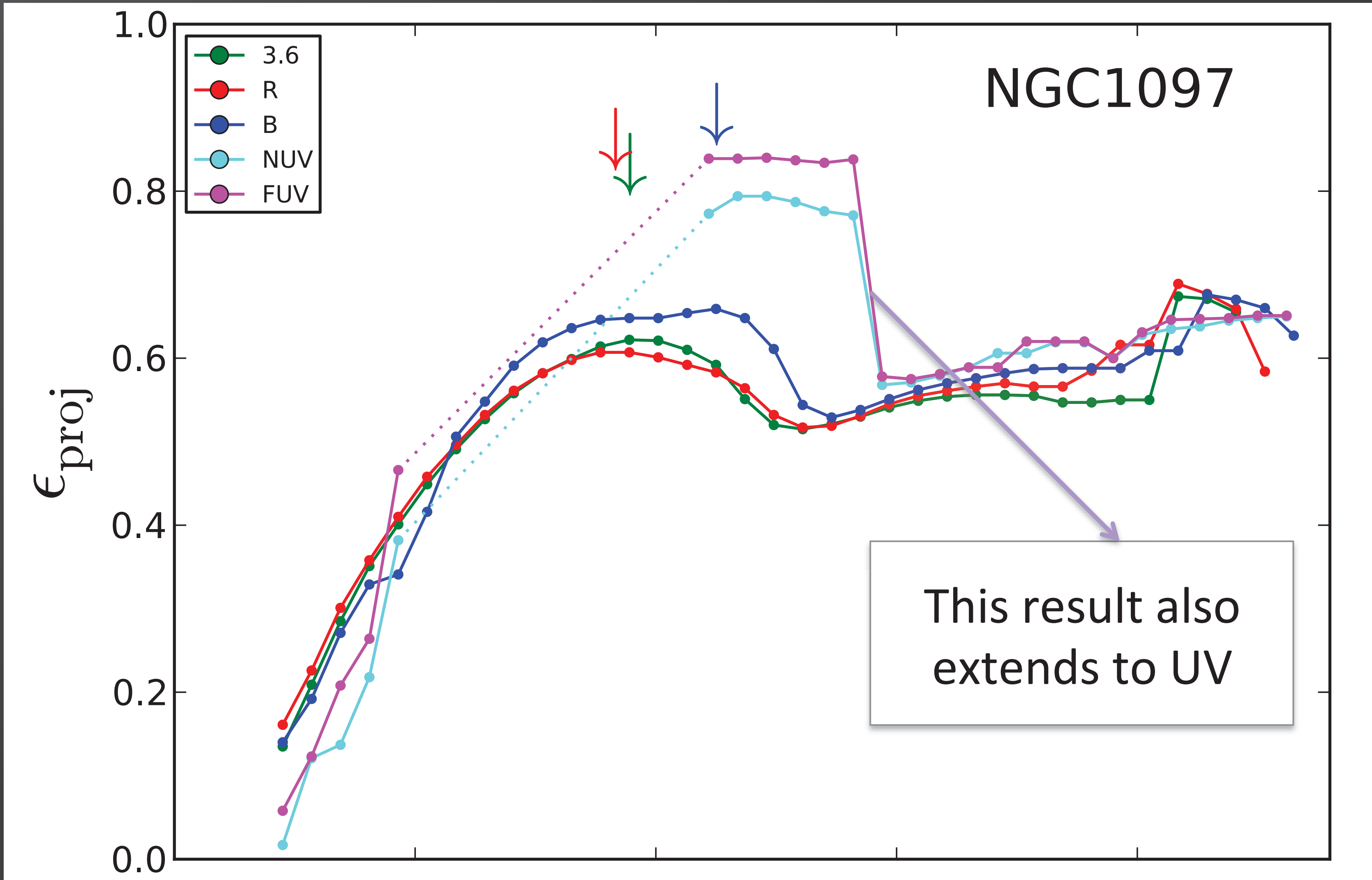
The bluer the restframe band, the thinner the bar!

3rd result: bars look longer in bluer bands



- SMA where $\varepsilon = \varepsilon_{max}$ is larger in the optical bands, compared to the mid-IR

3rd result: bars look longer in bluer bands



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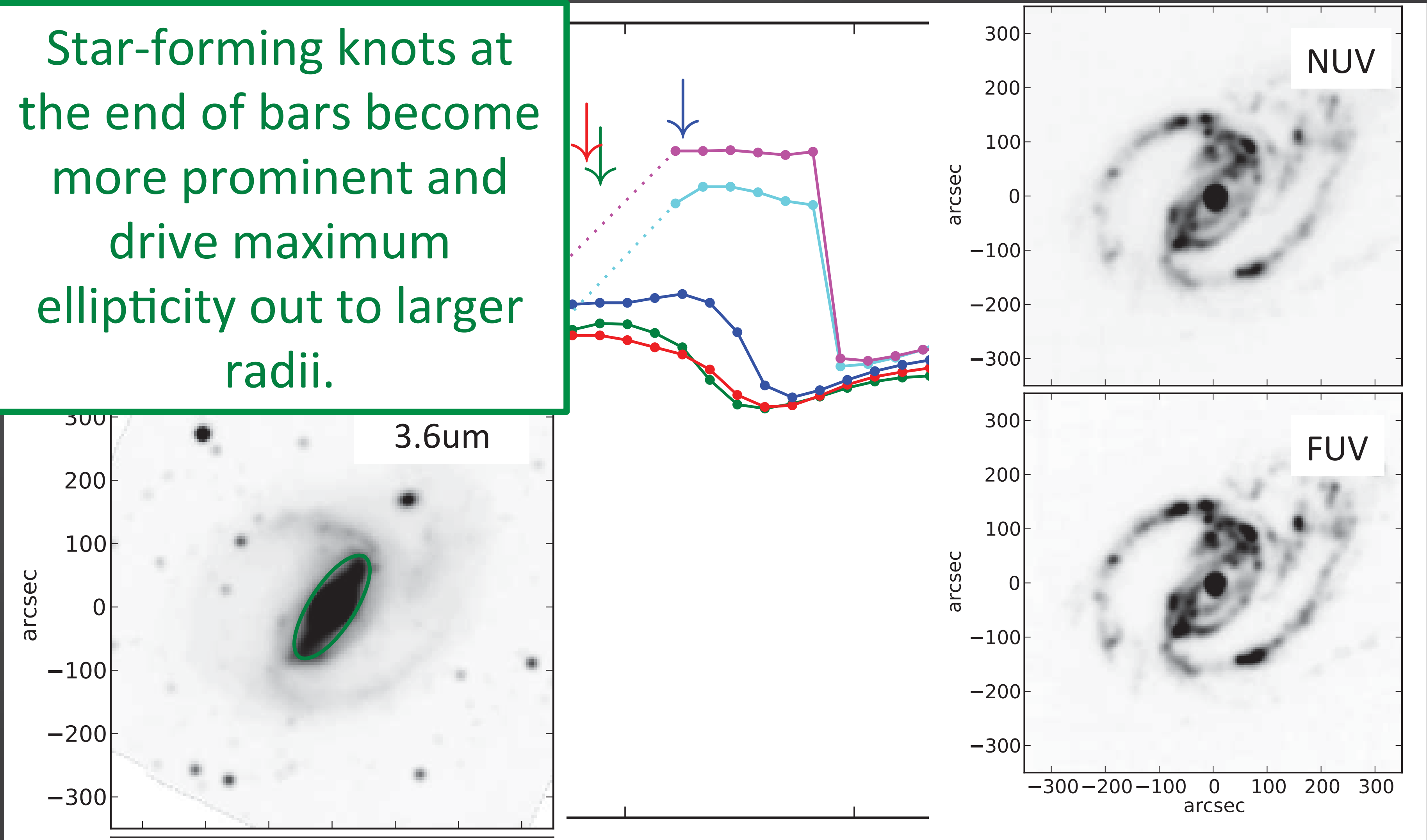
3[rd] result: bars look longer in bluer bands

Star-forming knots at the end of bars become more prominent and drive maximum ellipticity out to larger radii.



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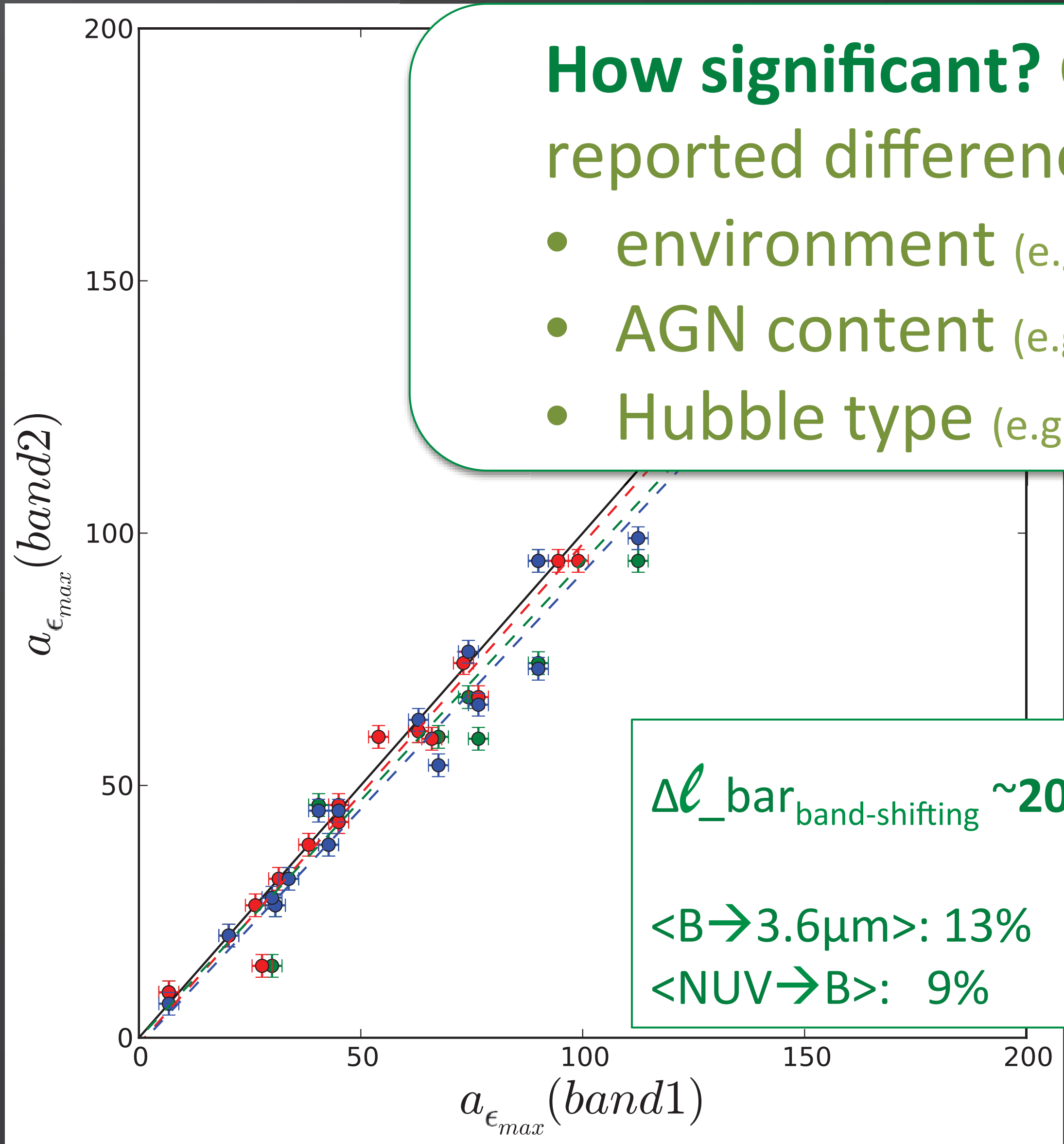

How significant? Comparable to reported differences with respect to:

- environment (e.g., Barazza+09)
- AGN content (e.g., Laurikainen+02)
- Hubble type (e.g., Menéndez-Delmestre+07)

$\Delta\ell$_bar$_{\text{band-shifting}}$ **~20-30% longer**

<B→3.6μm>: 13%
<NUV→B>: 9%

Take away points…

- As we extend bar studies out to high redshifts, our single-band studies are inevitably subject to band-shifting effects:
  - We lose 50% of bars in the UV → need to stick to the red side of the Balmer break in order to reliably detect bars
  - Bars change in shape as we go bluer; even in the restframe opt:
    - *Bars look thinner*, due to apparent bulge size
    - *Bars look longer*, as star-forming knots become prominent
  - Need to consider this when comparing bar morphologies as a function of galaxy properties!
  - These band-shifting effects may affect the "ease" to detect bars
- Refraining from going bluer than B-band may be good enough to study bar fraction out to z~0.8… but not bar properties!
  - Need to correct for band-shifting effects even in the optical!