The role of galactic bars on central star formation and AGN

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BAR EFFECTS ON CENTRAL STAR FORMATION AND ACTIVE GALACTIC NUCLEUS ACTIVITY

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ABSTRACT

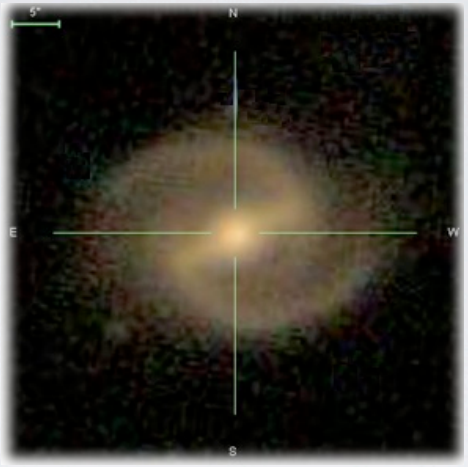
Galactic bars are often suspected to be channels of gas inflow to the galactic center and to trigger central star formation and active galactic nucleus (AGN) activity. However, the current status on this issue based on empirical studies is unsettling, especially regarding AGNs. We investigate this question based on the Sloan Digital Sky Survey Data Release 7. From the nearby ($0.01 < z < 0.05$) bright ($M_r < -19$) database, we have constructed a sample of 6658 relatively face-on late-type galaxies through visual inspection. We found 36% of them to have a bar. Bars are found to be more common in galaxies with earlier morphology. This makes sample selection critical. Parameter-based selections would miss a large fraction of barred galaxies of early morphology. Bar effects on star formation or AGNs are difficult to understand properly because multiple factors (bar frequency, stellar mass, black hole mass, gas contents, etc.) seem to contribute to them in intricate manners. In the hope of breaking these degeneracies, we inspect bar effects for fixed galaxy properties. Bar effects on central star formation seem higher in redder galaxies. Bar effects on AGNs on the other hand are higher in bluer and less massive galaxies. These effects seem more pronounced with increasing bar length. We discuss possible implications in terms of gas contents, bar strength, bar evolution, fueling timescale, and the dynamical role of supermassive black hole.

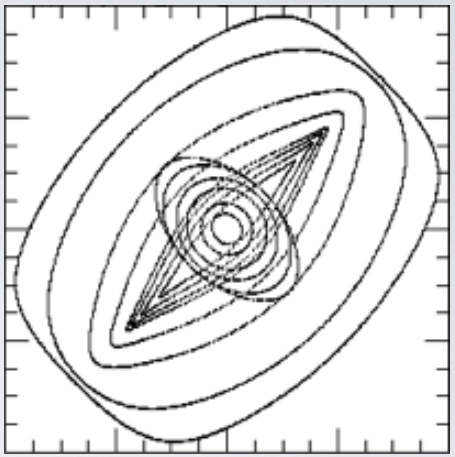
Key words: galaxies: active – galaxies: fundamental parameters – galaxies: nuclei – galaxies: spiral – galaxies: starburst

Hubble Heritage NGC 1300

Yonsei University

INTRODUCTION





- Observations indicate that 60% of bright disk galaxies have bar structures (Knapen et al. 2000; Barazza et al. 2008)
- Bar can be a channel of gas inflow to galactic center (Combes & Gerin 1985; Friedli, Benz & Kennicutt 1994; Englmaier et al. 1997)
- Galactic bars are thought to be related to star formation and AGN

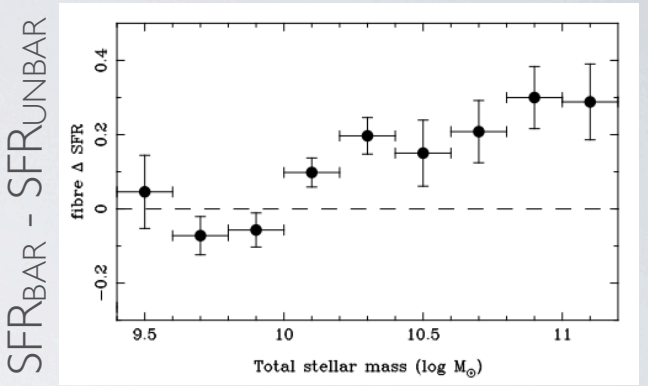
Kraft et al. (2002); Weiss et al.; ESO/WFI; SDSS; Englmaier, & Gerhard (1997)

OBSERVATIONAL EVIDENCES

- Barred galaxies show enhanced radio and far-infrared emissions and higher SFR (e.g., Hummel 1990; Martin 1995; Huang et al. 1996; Hawarden et al. 1986; Ellison et al. 2011)

- Several studies have found an excess of bar in starburst galaxies (e.g., Huang 1996; Ho, Filippenko, & Sargent 1997; Hunt & Malkan 1999; Hao et al. 2009)

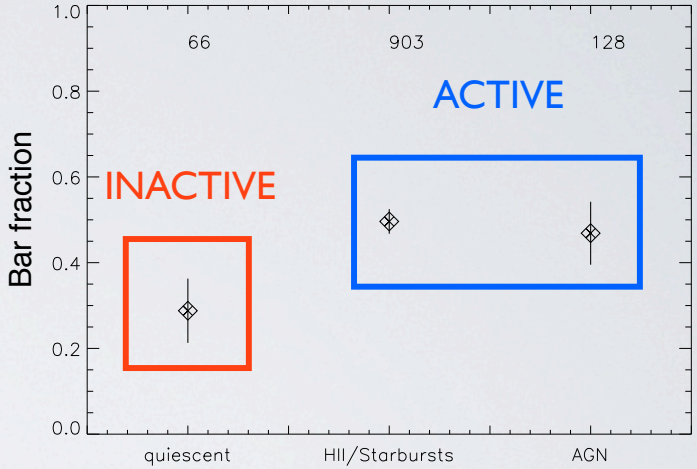
- Some studies reported higher frequency of bars among AGN (Arsenault 1989; Moles, Ma´ rquez, & Pe´ rez 1995; Knapen, Sholsman, & Peletier 2000; Laurikainen, Salo, & Buta 2004), but other studies did not (Mulchaey & Regan 1997; Hunt & Malkan 1999; Martini et al. 2003, Lee et al. 2012)



Ellison et al. 2011

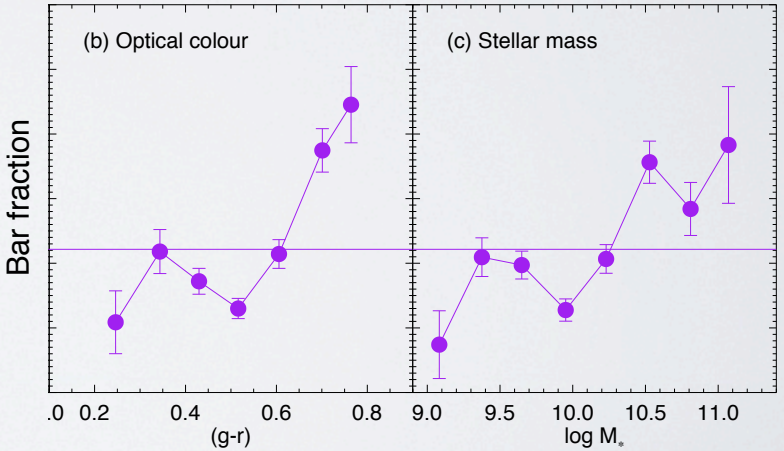
MOTIVATION

- Previous statistical tests are performed by comparing bar fractions between active and inactive galaxies



Hao et al. 2009

- The bar fraction is non-monotonic and varies with change of galaxy properties
  (Odewahn 1996; Elmegreen, Elmegreen, & Hirst 2004; Giordano et al. 2010; Nair & Abraham 2010; Masters et al. 2011; Oh et al. 2012; Lee et al. 2012)



Masters et al. 2012

SAMPLE

- Late-type galaxies in the SDSS DR7

Criterion	Explanation
$0.01 < z < 0.05$	Redshift range for reliable morphological classification without saturation
$Mr < -19.$	The absolute r-band magnitude cut for volume limited sample
Isophotal B/A ratio ≥ 0.7	Exclude edge-on galaxies
Visual inspection	A selection of late-type galaxies which enable to classify their morphology

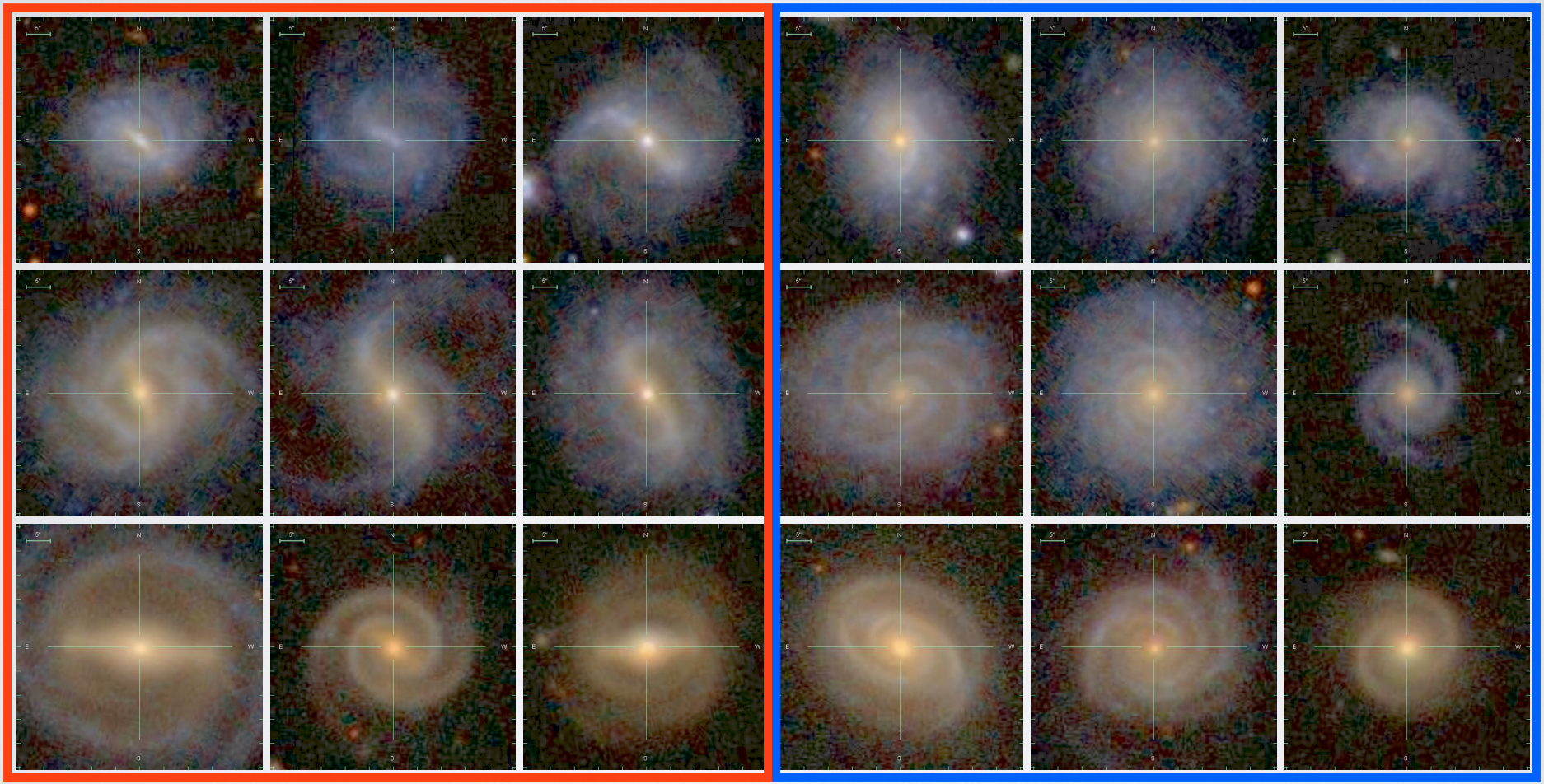
Total (6658)	barred galaxies	2422
	unbarred galaxies	4236

Any morphology indicators are not used

SAMPLE IMAGES

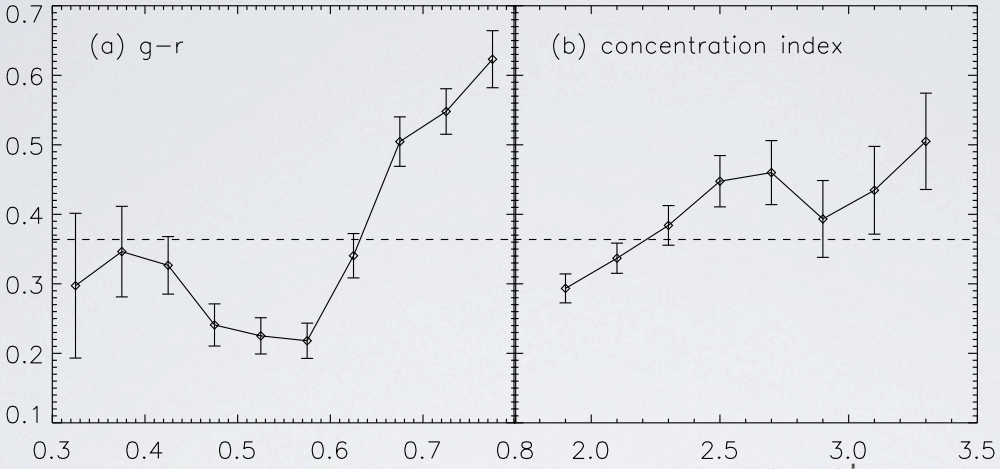
Bar

Unbar



BAR FRACTION

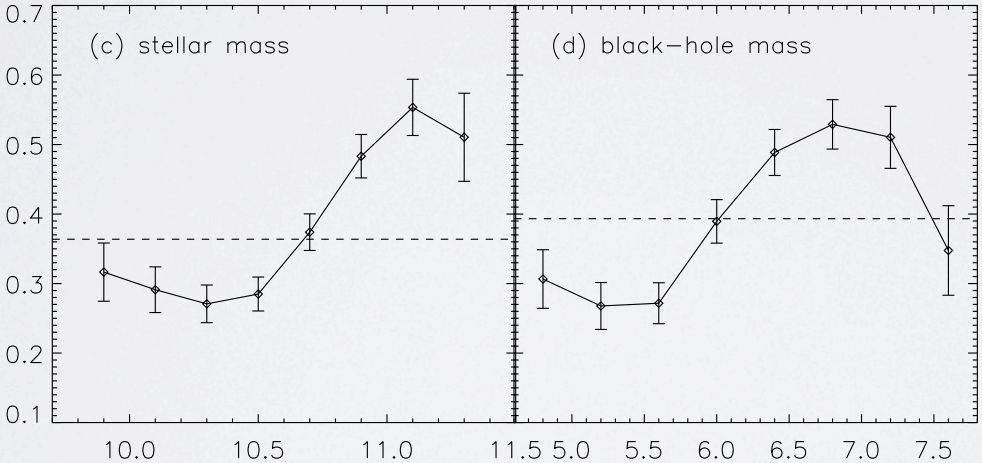
bar fraction



g - r concentration

mean bar fraction is 36%

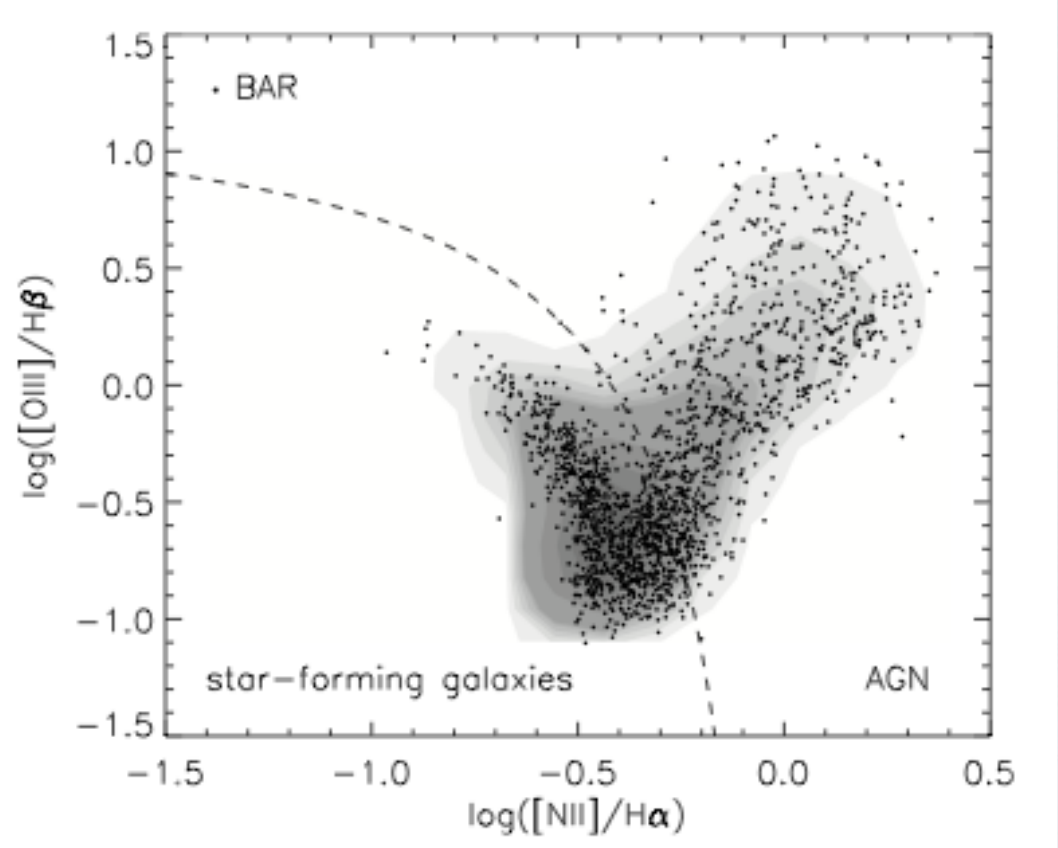
bar fraction



stellar mass black-hole mass

Stellar mass		$\log (M/L)r \sim - 0.306 + 1.097 (g-r)$	Bell 2003
BH mass	Bar	$\log M_{BH} \sim 8.15 + 3.89 * \log (\sigma_e / 200)$	Graham et al. 2011
	Unbar	$\log M_{BH} \sim 8.03 + 3.94 * \log (\sigma_e / 200)$	

CENTRAL ACTIVITIES



- Spectral Line data measured by using GANDALF (Kyuseok Oh et al. 2011)
- Diagnostic(BPT) Diagram
  - Demarkation Line (Kauffmann et al. 2003)

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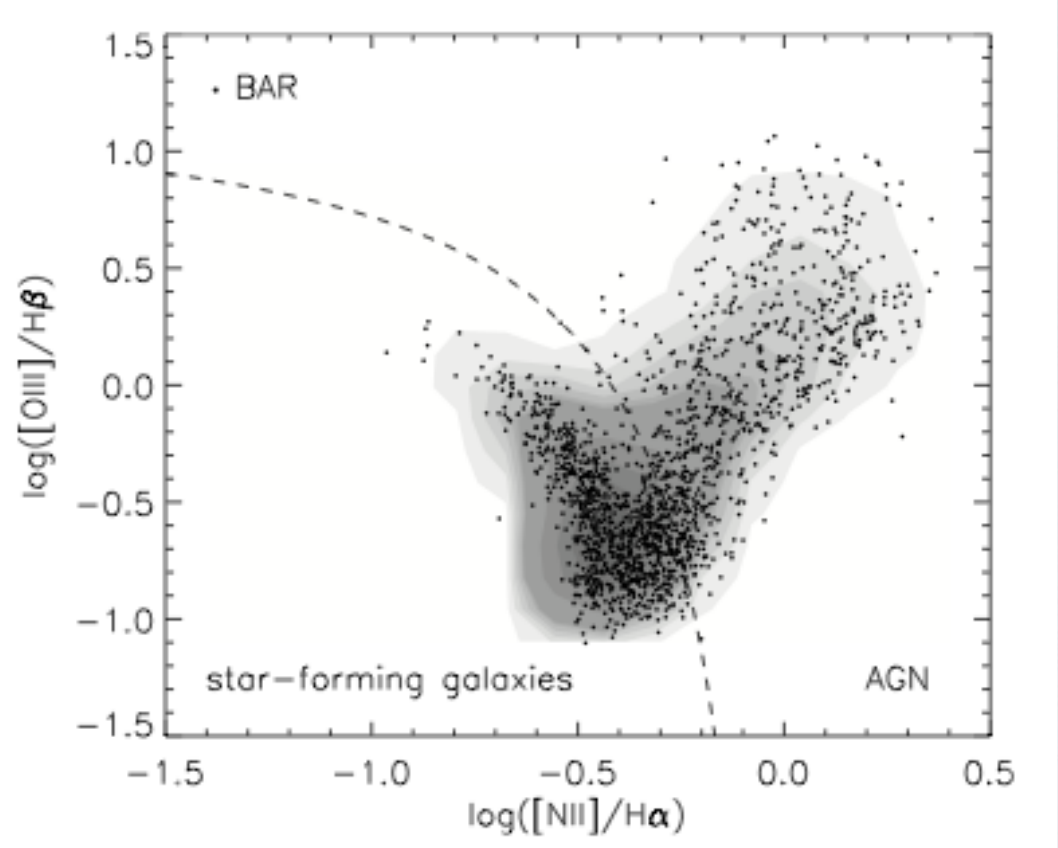

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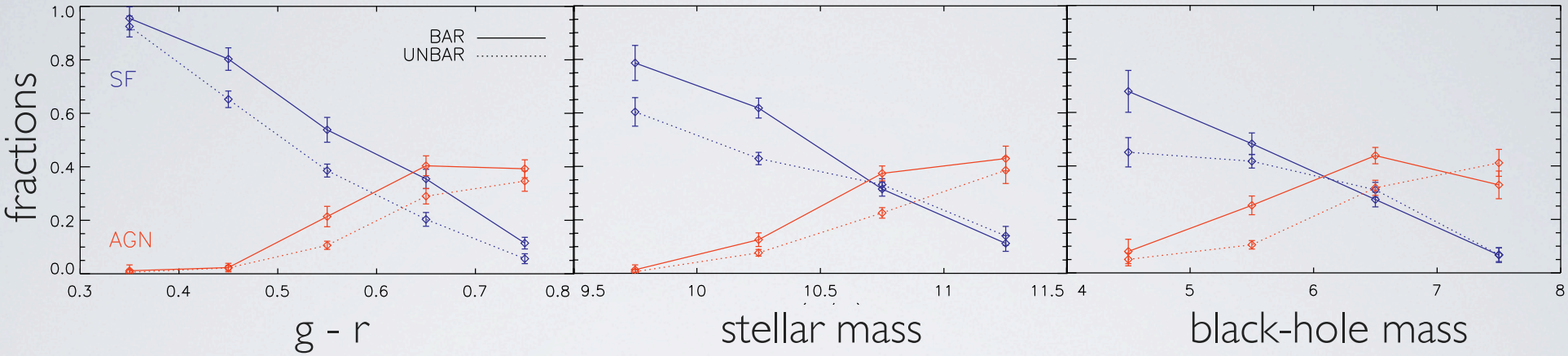
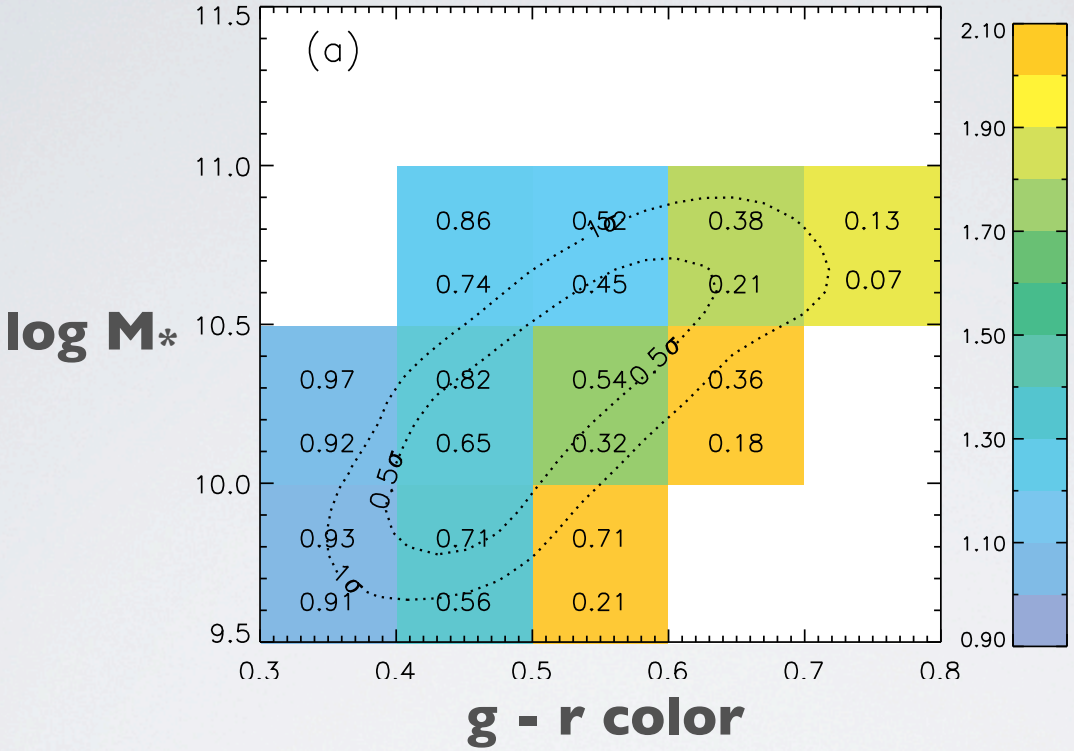
FRACTIONS OF CENTRAL ACTIVITIES



- Bars increase both star-formation and AGN activities for overall colors
- Bar effect is higher on low stellar mass or low black-hole mass among star-forming galaxies
- Bar enhances AGN activities on intermediate stellar mass or low black-hole mass among AGNs

STAR-FORMING GALAXIES



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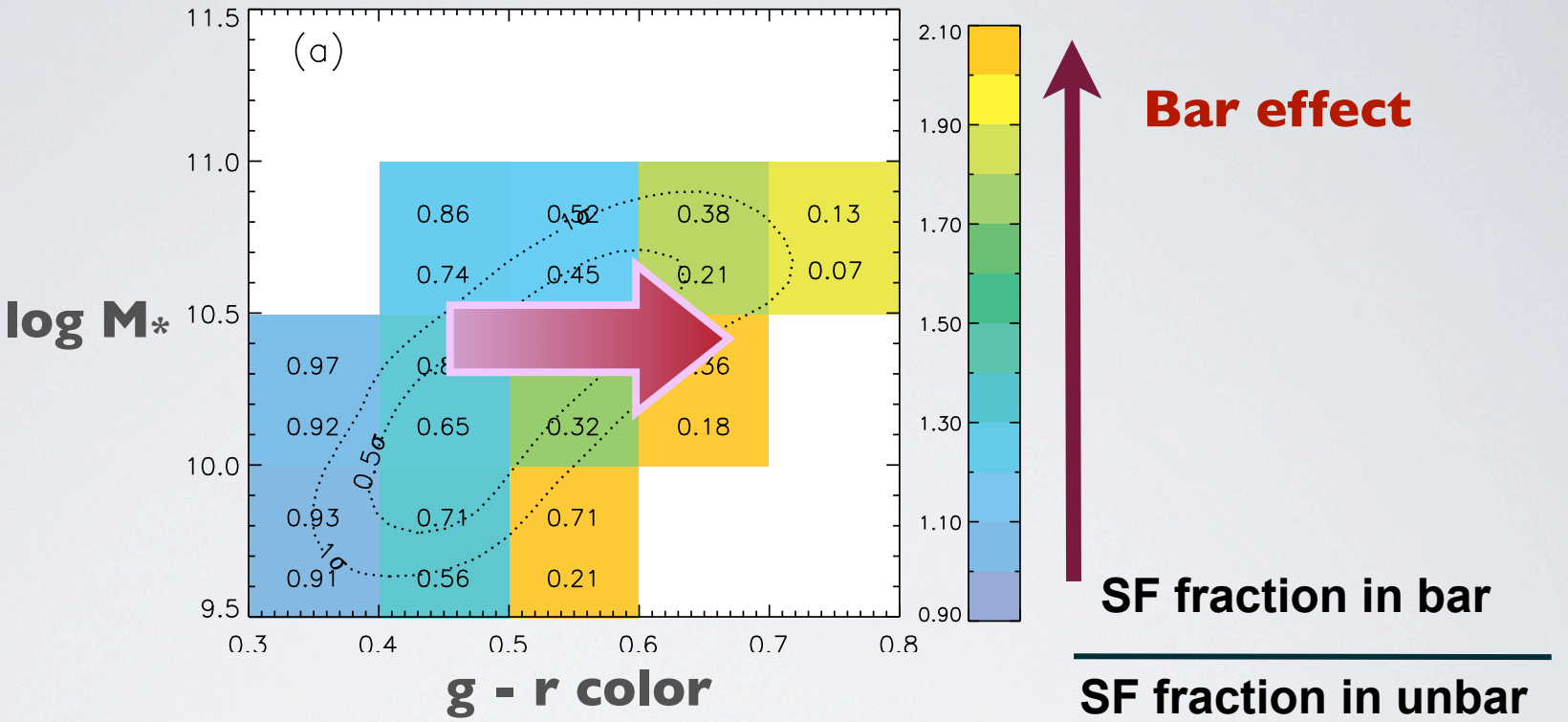
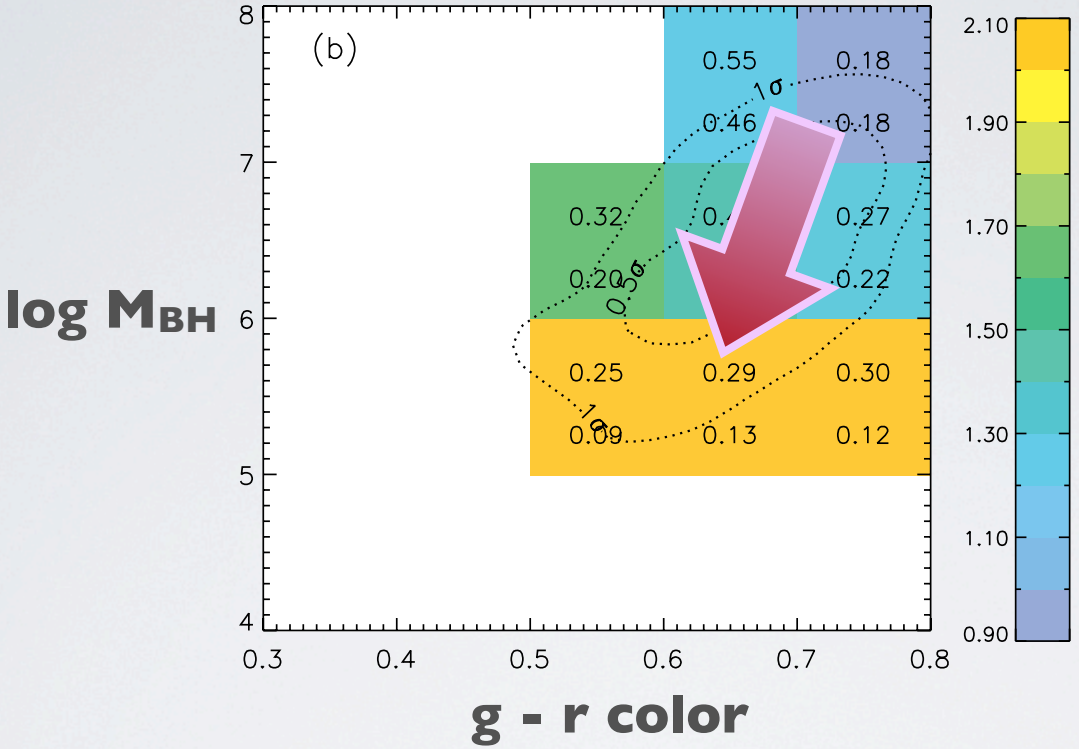


- Bar enhanced central star-formation on red galaxies

AGN



Bar effect

AGN fraction in bar

AGN fraction in unbar

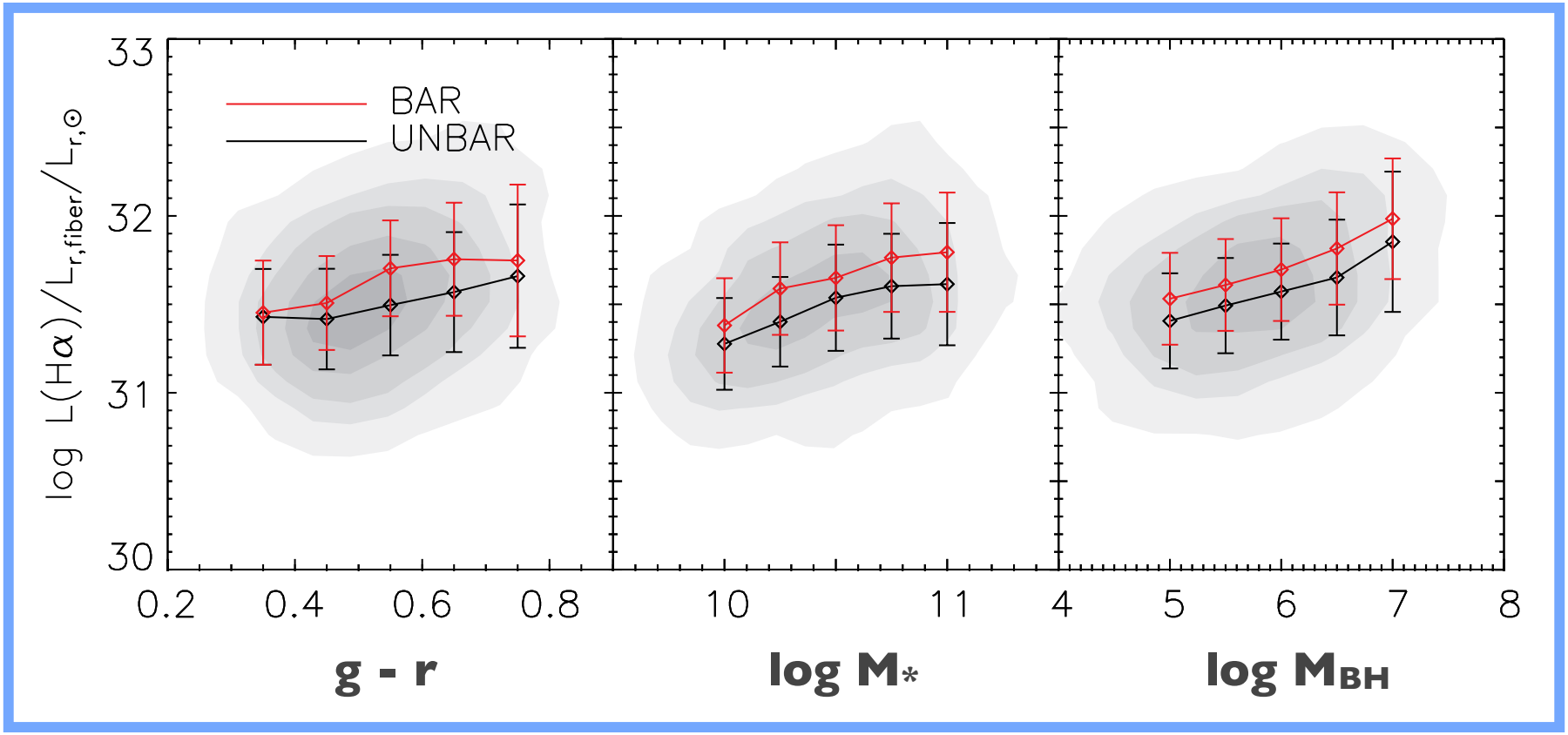
- Bar effects are higher on low BH mass for AGN

STRENGTH OF CENTRAL ACTIVITIES

- Emission lines such as Hα, Hβ, and [O II] arise in H II regions and are indicators of the star formation
- [OIII] and [NII] emission lines are enhanced by higher ionization of AGN
- Emission lines can be an indicator of strengths of central activities
- Specific emission luminosity
  - Emission luminosity / fiber luminosity

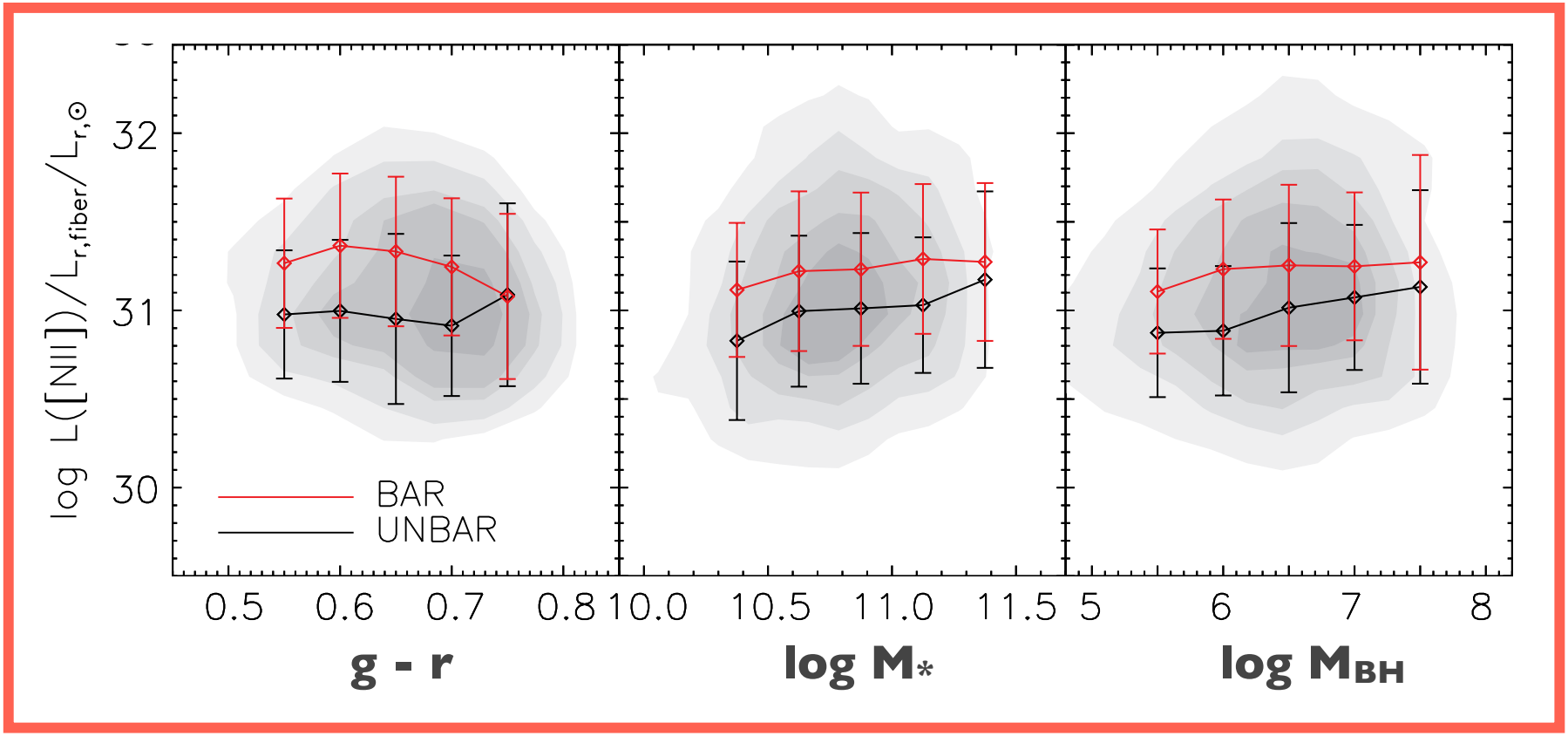
SPECIFIC EMISSION LUMINOSITY

Ha luminosity of star-forming galaxies

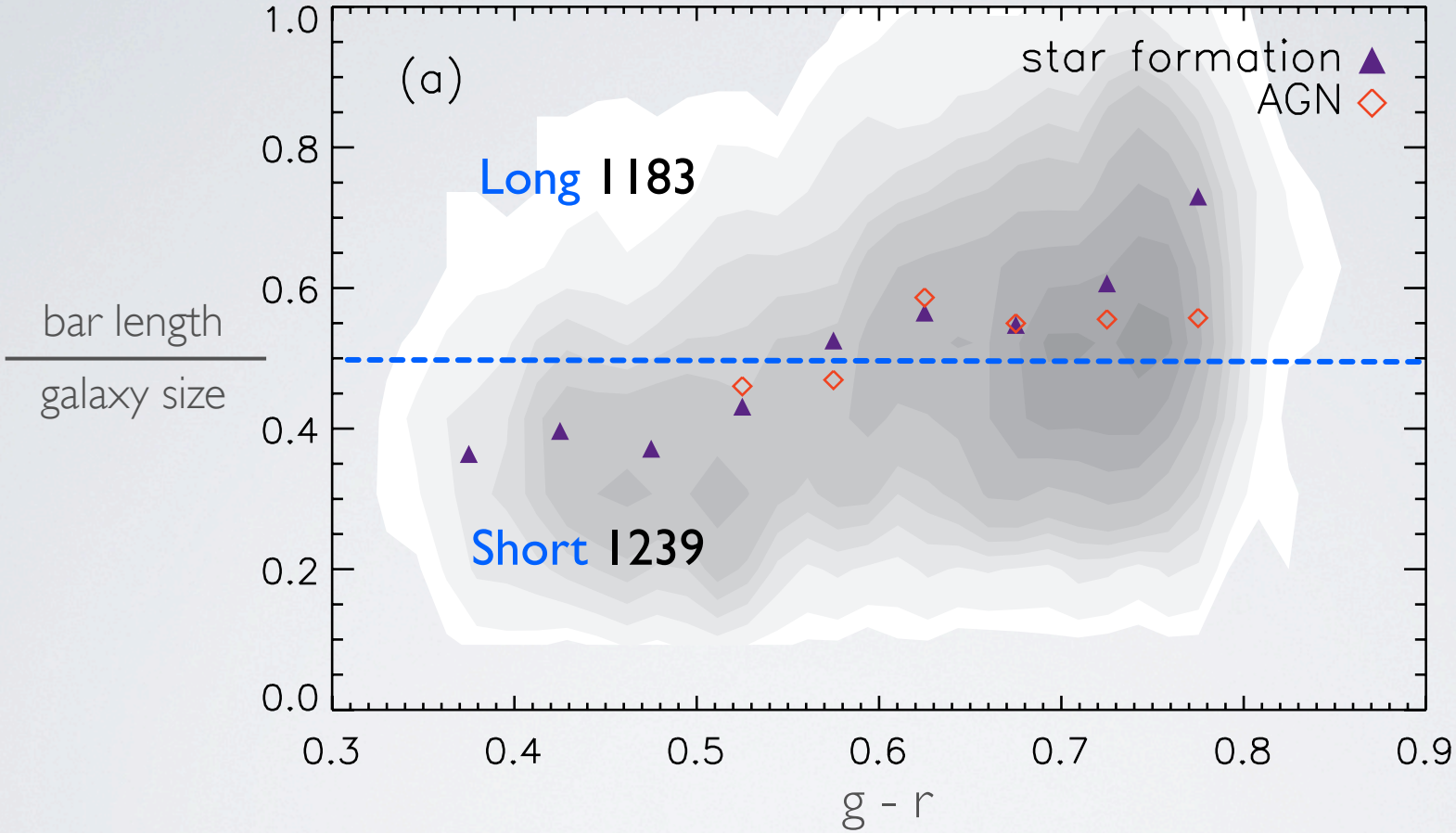


SPECIFIC EMISSION LUMINOSITY

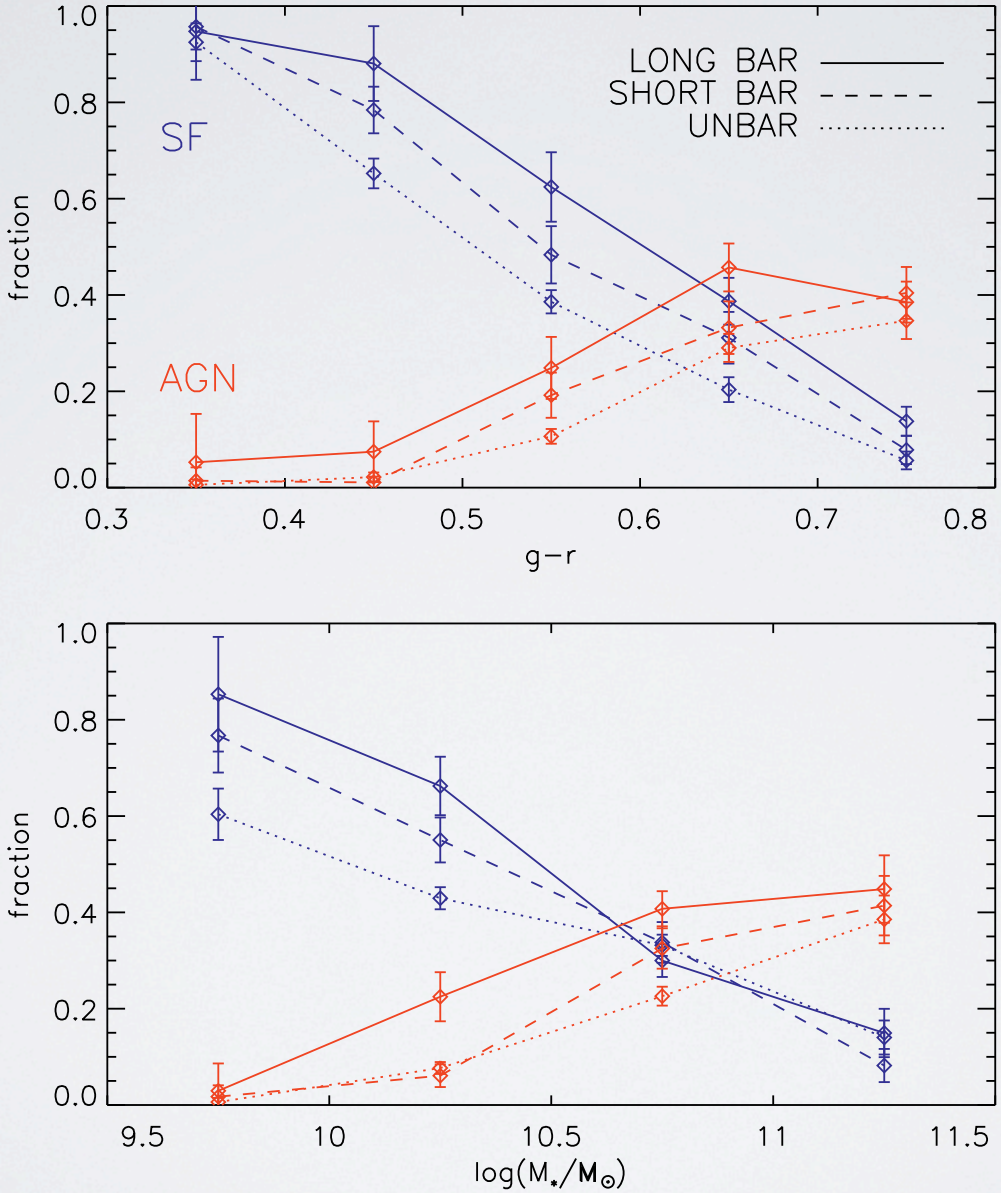
[NII] luminosity of AGN



BAR LENGTH


(a)
star formation
AGN
Long 1183
Short 1239
bar length
galaxy size
1.0
0.8
0.6
0.4
0.2
0.0
0.3
0.4
0.5
0.6
0.7
0.8
0.9
g - r

BAR LENGTH


LONG BAR
SHORT BAR
UNBAR
SF
AGN
fraction
g−r
1.0
0.8
0.6
0.4
0.2
0.0
0.3
0.4
0.5
0.6
0.7
0.8
fraction
log(M*/M⊙)
9.5
10
10.5
11
11.5

SUMMARY

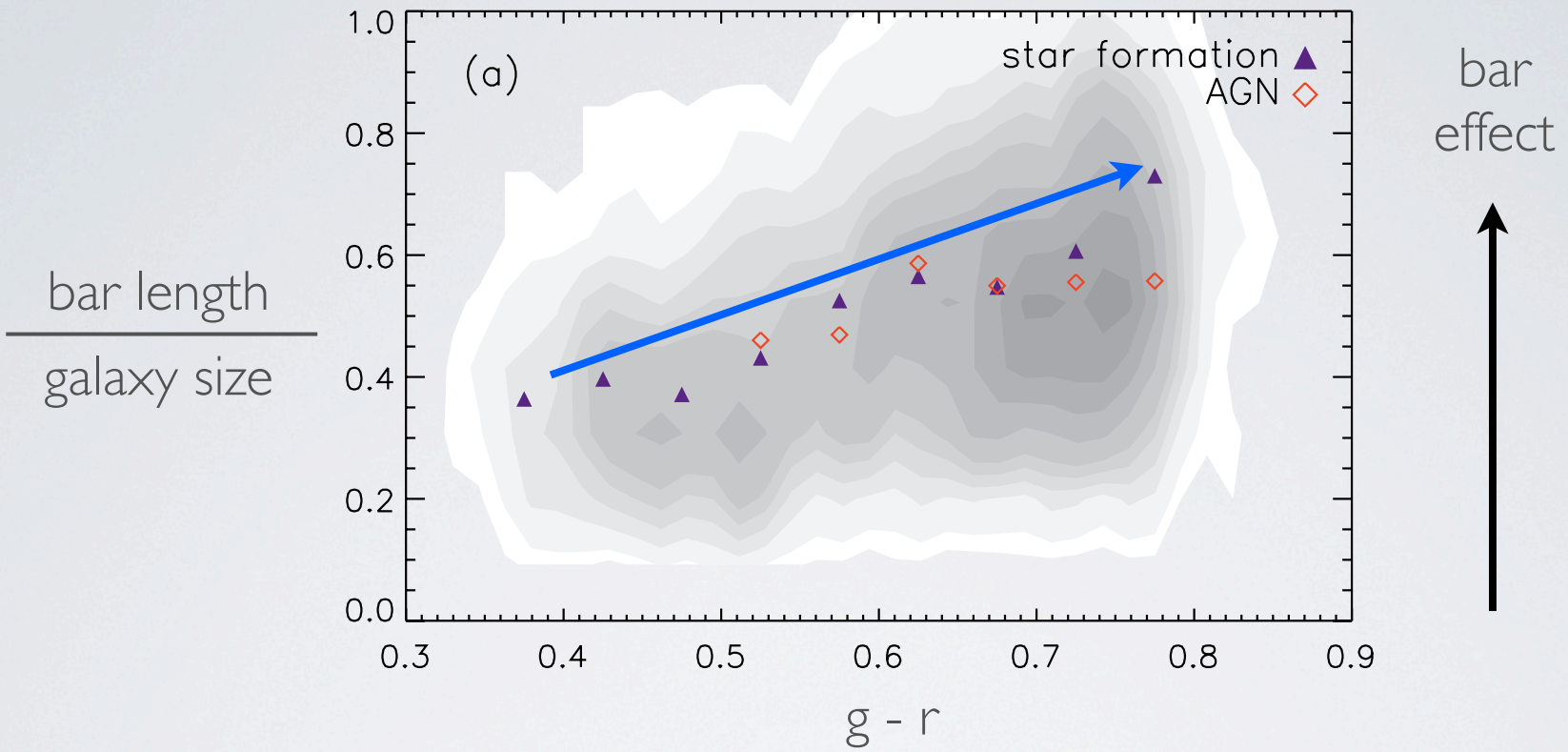
- Infalling gas through bar activates both central star-forming and AGN activities in a certain condition
- Bars mainly enhance central **star formation** in galaxies with **red color**
- Bar effects on **AGN** are shown in galaxies having **low black-hole mass**
- Bars also enhance **strength** of activities
- **Longer bars** are more efficient to supply gas to galactic center

What makes bar effect so complex?

WHY IMPACT ON RED STAR FORMING GALAXIES?

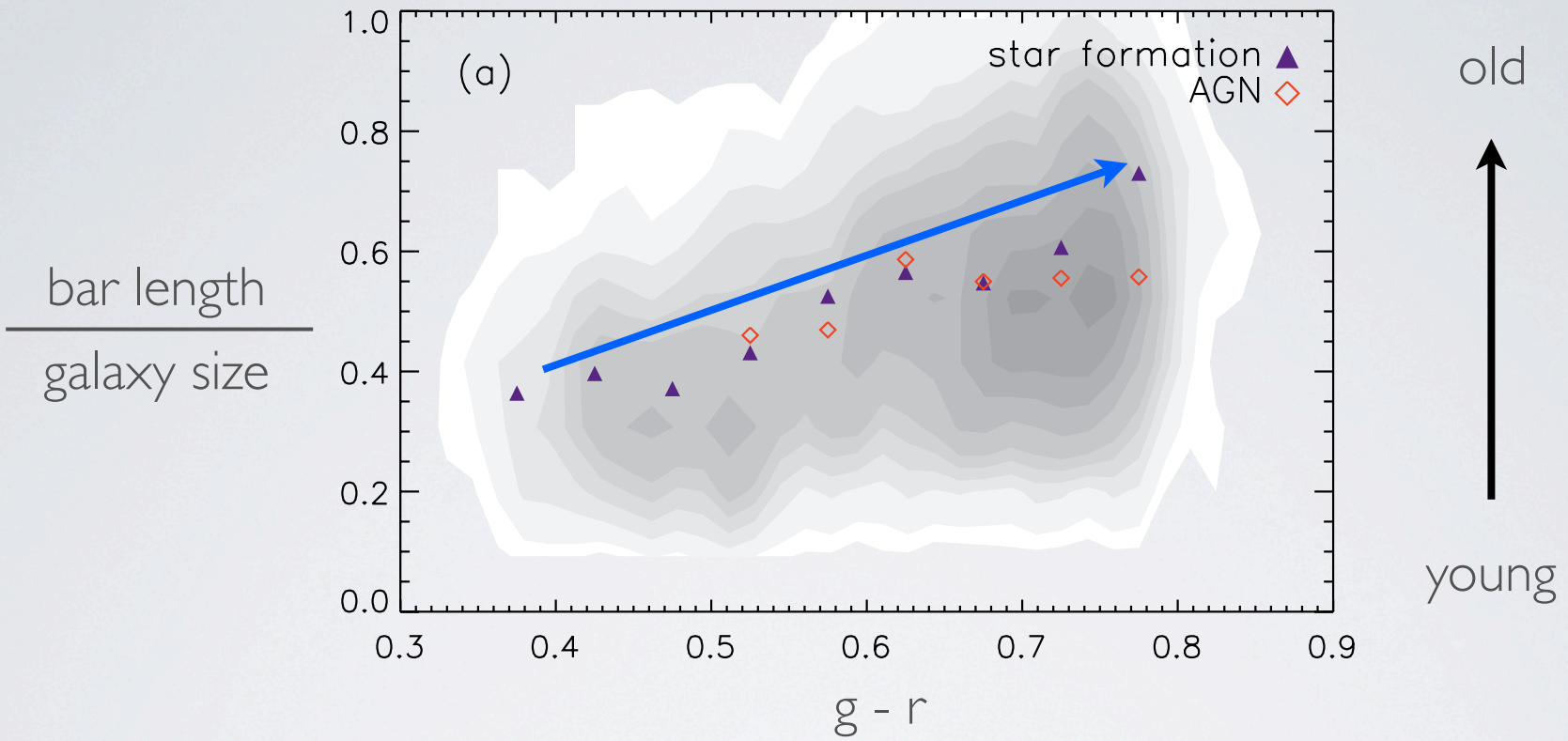
- Amount of Gas
  - Blue - gas rich
  - Red - gas deficient
  - Blue late types already have SF w/o additional gas supply

WHY IMPACT ON RED STAR FORMING GALAXIES?



- Bar strength
  - Long bars are more efficient to supply gas
  - Large portion of red spirals have longer bars

WHY IMPACT ON RED STAR FORMING GALAXIES?



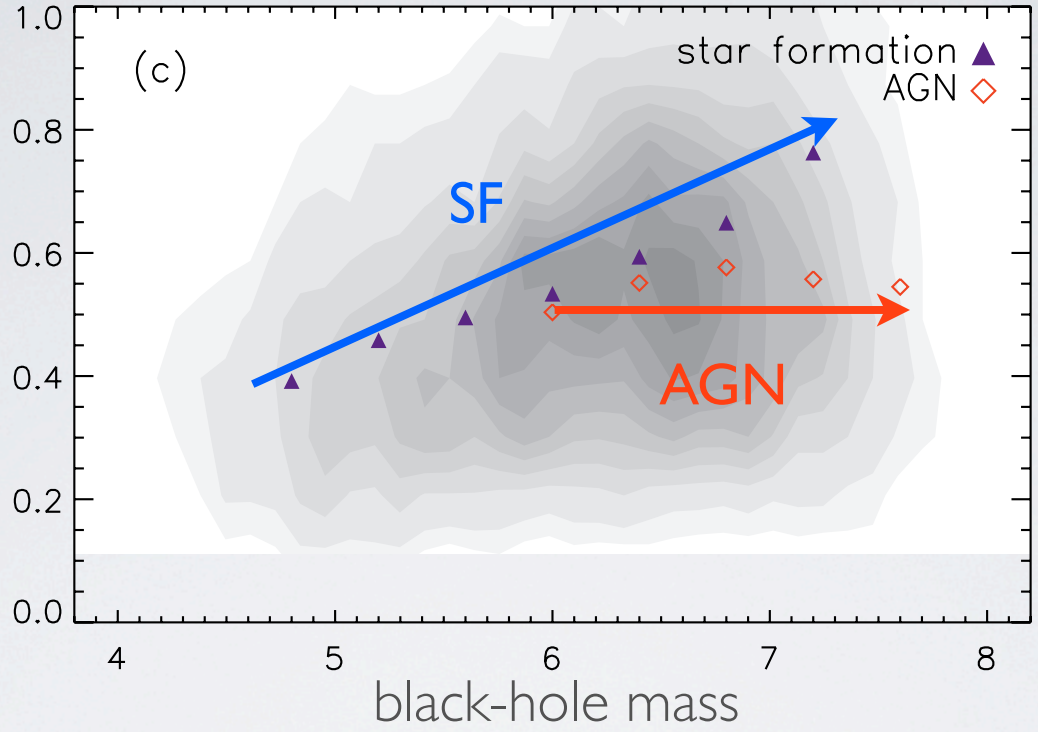
- Bar fueling time-scale
  - Bars grow longer with dynamical age (e.g., Sellwood 1981; Athanassoula 2003)
  - Bar-driven evolution is ~ Gyr scale (Athanassulra 1992; Combes 1999)

WHY NO IMPACT ON AGN HAVING MASSIVE BH?

- Post-starburst phase?
  - Gas might be already consumed by central star formation

WHY NO IMPACT ON AGN HAVING MASSIVE BH?

$$\frac{\text{bar length}}{\text{galaxy size}}$$



- The central concentration like massive black-hole can dissolve bar structures (Friedli et al. 1991; Hasan, Pfenniger, & Norman 1993; Norman, Sellwood, & Hasan 1996)
- Bar length vs BH negative effect
  - For **SF**, bar length increase with BH mass
  - For **AGN**, bar length doesn't change with BH increase

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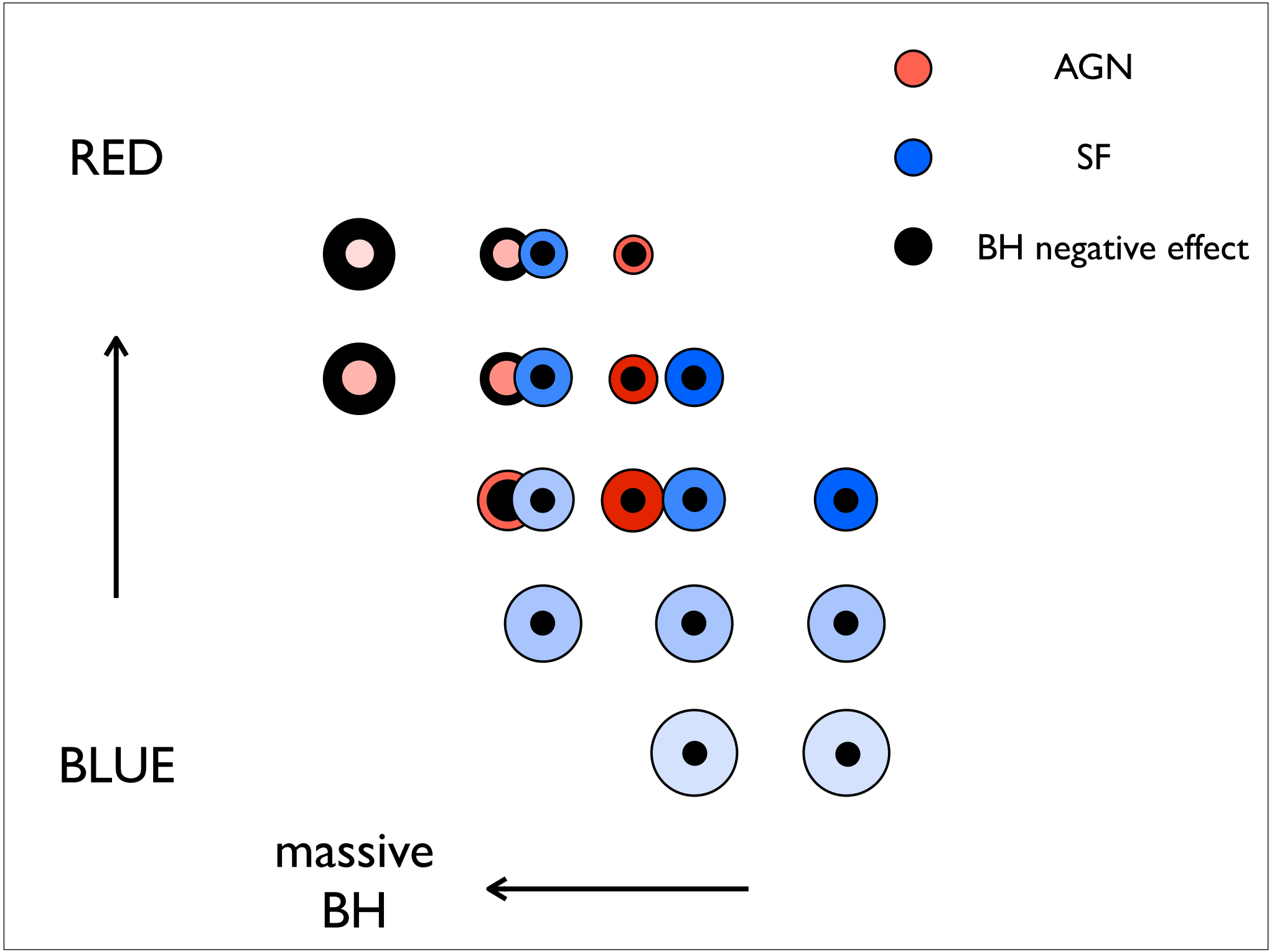
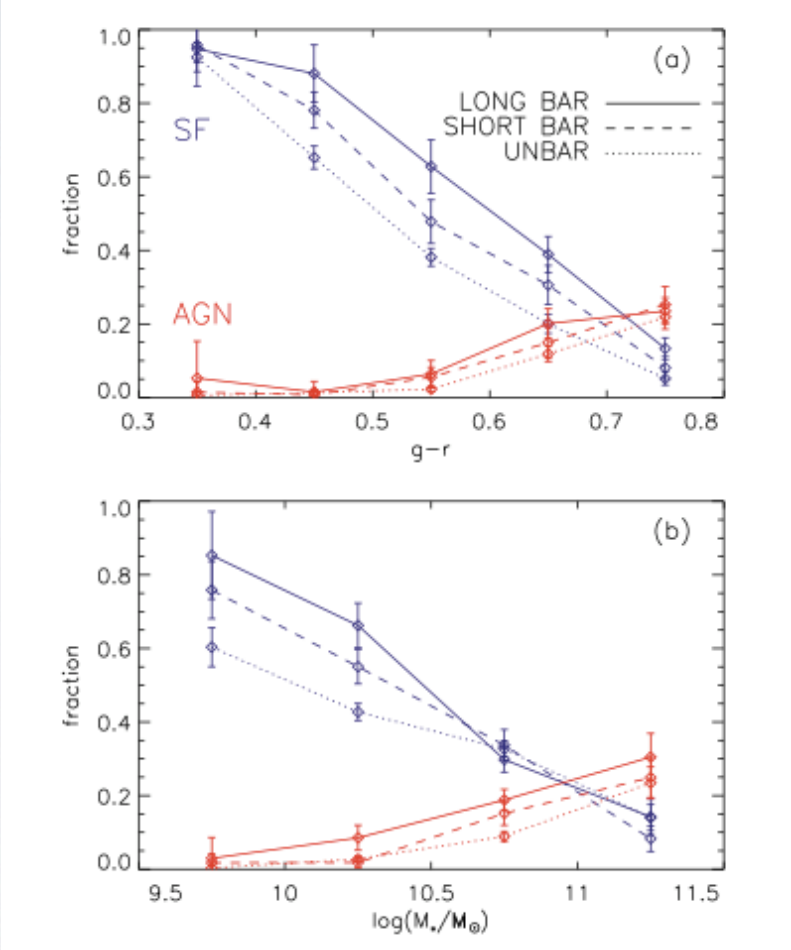

AGN
SF
BH negative effect
RED
BLUE
massive
BH

QUESTIONS

- Why did you put transition objects to AGN
- Did you concerned about LINER-like emission which are not powered by AGN?
- Why did you compare AGN fractions in galaxies w/ or w/o bars
- You might select only strong bars
- Bar fraction is also vary with wavelength.
- Bar length vs bar strength?
- Eddington ratio / accretion rate
- Recent studies Lee et al. 2012
- different M-sigma relation for bar and unbar
- SDSS 3" fiber
- color image

W/O TRANSITION OBJECTS



W(HA) > 3 Å

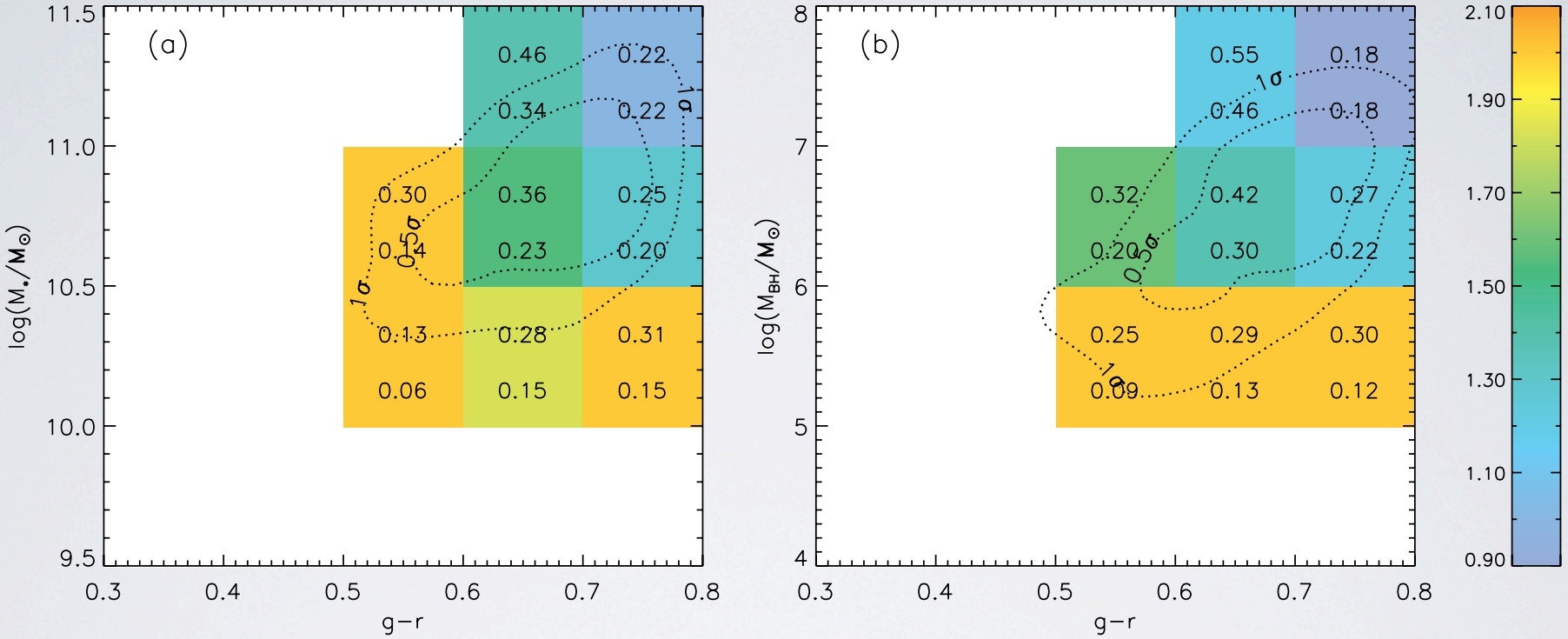
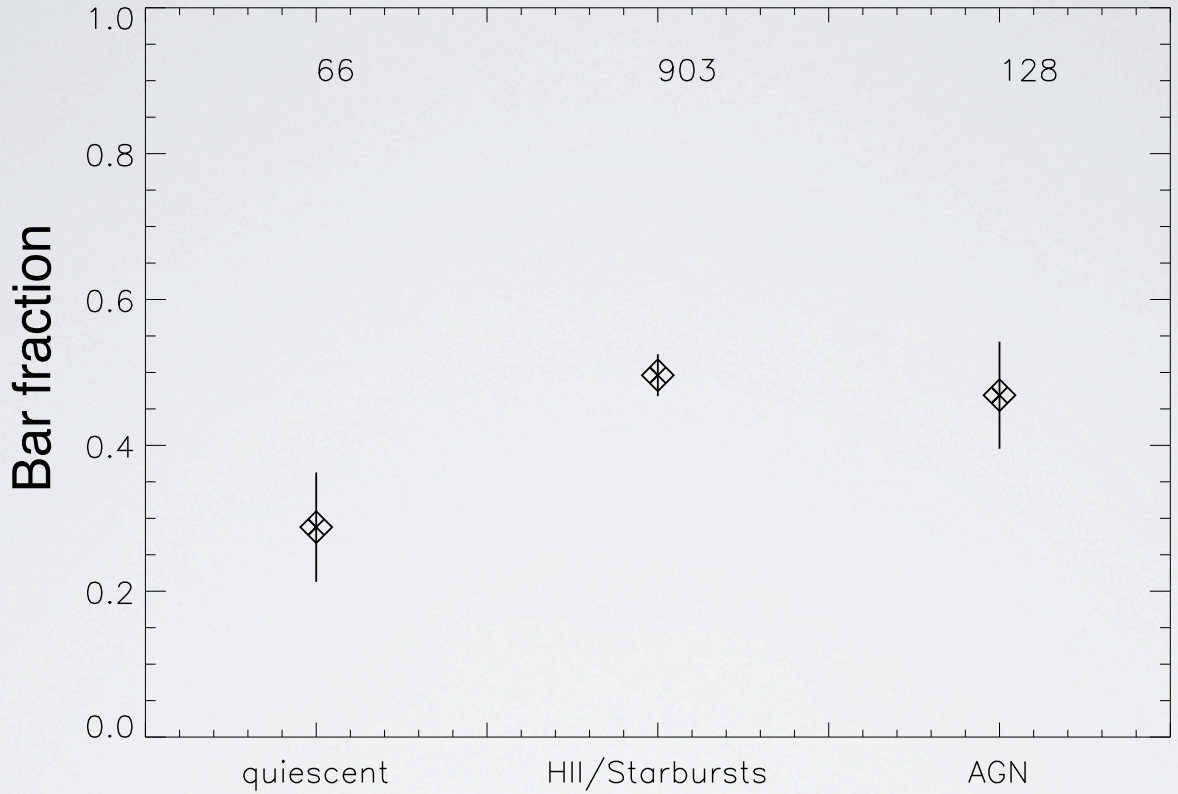


Figure 11. Same as Figure 10, but for AGNs with higher $W(H\alpha)$ than 3 Å.

- AGN could be contaminated by LINER-like emission galaxies powered by old stars (Sarzi et al. 2010; Cid Fernandes et al. 2011)

COMPARING BAR FRACTIONS ?



Hao et al. 2009

MEASUREMENT OF BAR LENGTH

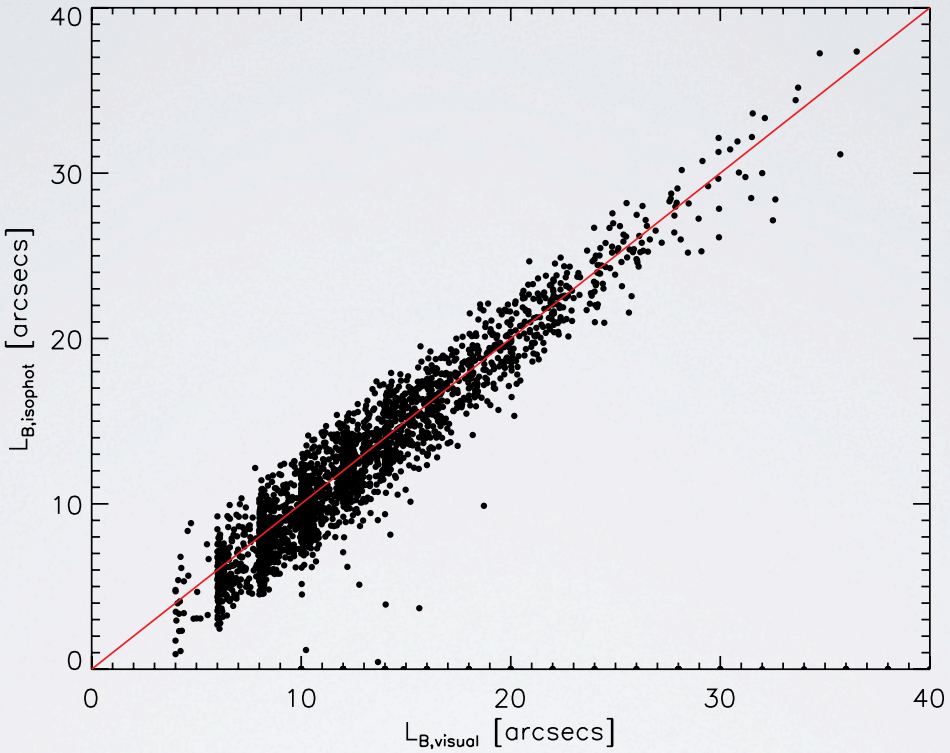
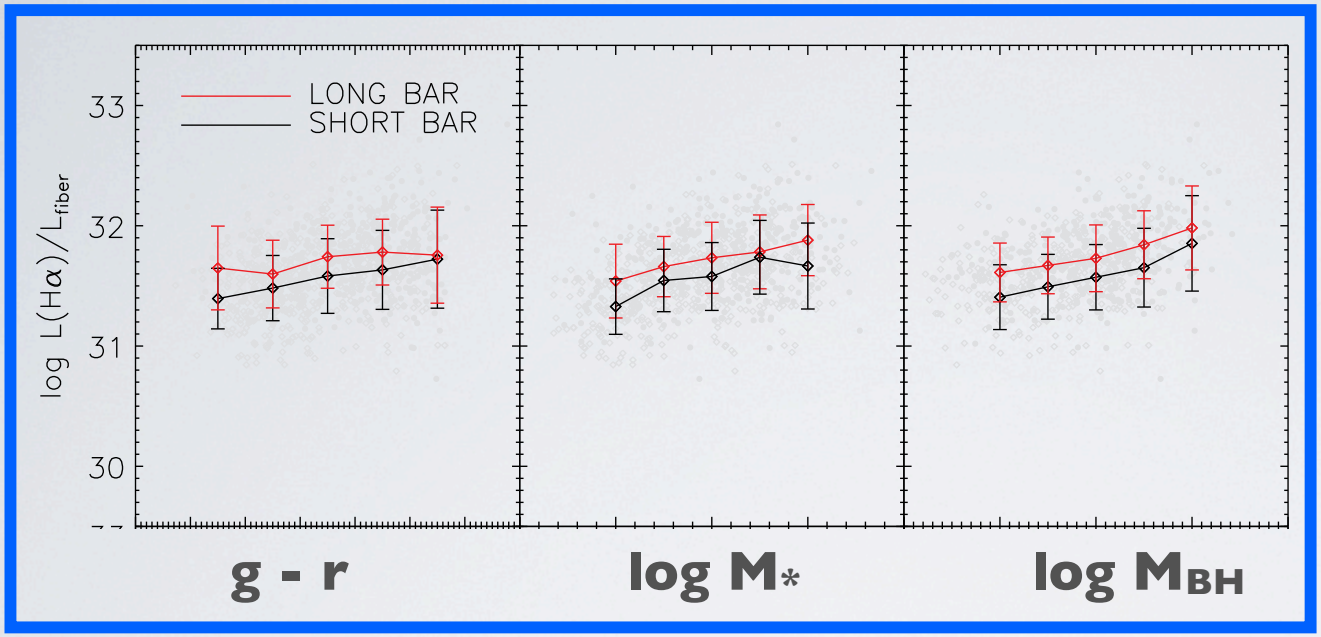


Figure 2. Comparison of bar lengths derived from visual measurement and ellipse fitting (in $''$). Both of them are corrected for the projection effect. The diagonal line indicates one-to-one correlation. Vertical features are due to the unit length of visual measurement, which is $2''$. Bar lengths from the two different methods are in good agreement with each other.

BAR LENGTH

Star-forming



AGN