ANIR Key Project

Paα LIRGs Survey

●Ken Tateuchi, Kentaro Motohara, Masahiro Konishi,
Hidenori Takahashi, Natsuko Kato, Yutaro Kitagawa
(IoA, University of Tokyo)

and TAO Project Team

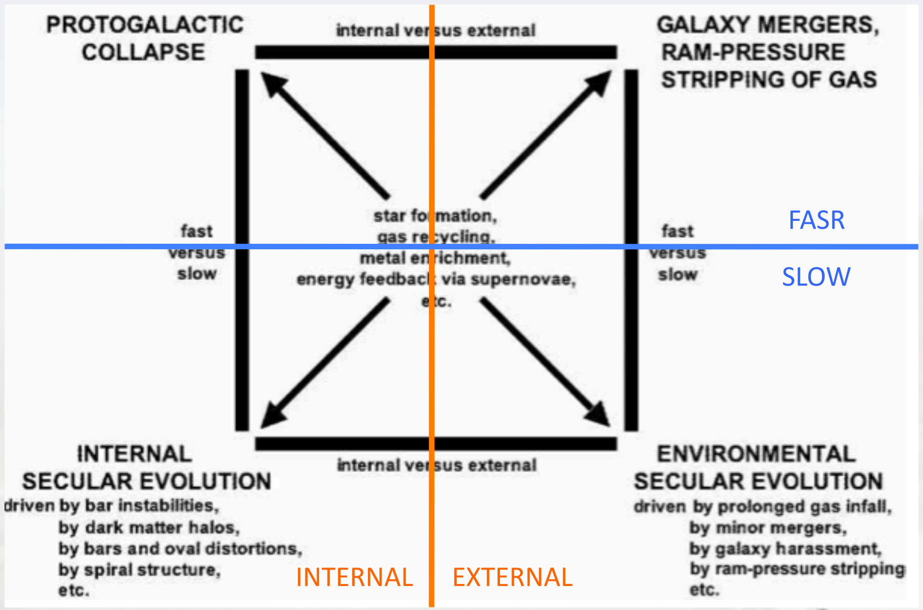
Physical Morphology

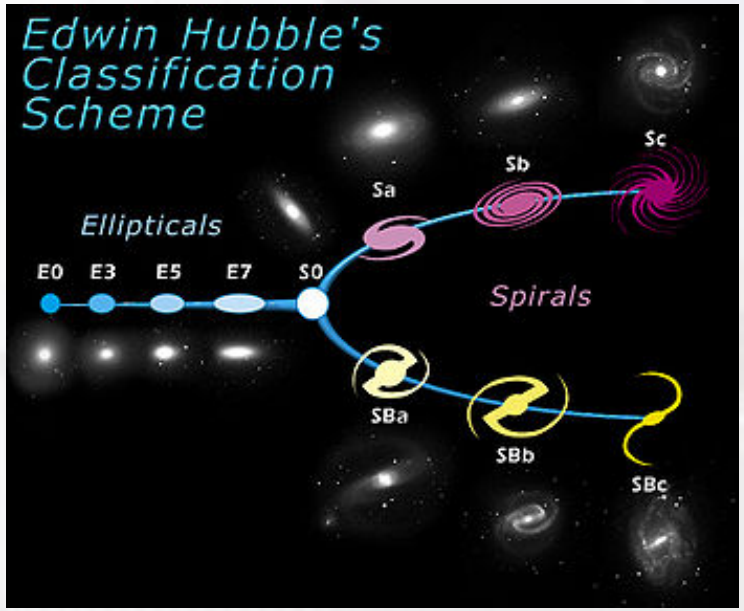
- *Hubble-Sandage de Vaucouleurs classifications*
  → one of the most famous as “visual appearance” morphological classification

  Are bulges of early-type and late-type spirals different?
  Are their formation scenarios different? (Fathi & Peletier 2003)

  → YES !
  Their differences are not recognized in classical morphology
  (Kormendy & Kennicutt 2004)

- Physical Morphology (Zwicky 1957)





Classcical- and Pseudo- Bulge

Theoretical Prediction

Major Merger → Elliptical Galaxy

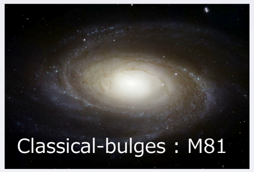
Minor Merger → Late Type (Disk) Galaxy

Secular Evolution →

- with classical bulge
- with Pseudo bulge

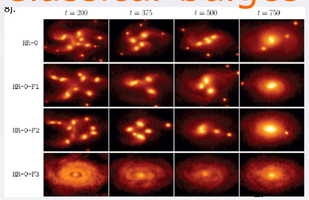
・Elliptical, coreless : dry dissipationless mergers ?
core : wet dissipative mergers? (Kormendy et al. 2009)

High Sersic Index



Classical-bulges : M81

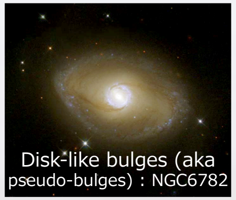
・Classical-bulges



: major mergers? (Kormendy et al. 2004)
giant clumps in primordial disks? (Bournaud et al. 2007)

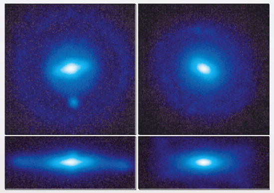
- elliptical like bulge
- mostly old stars
- Kinematically hot, i.e. dynamically supported by stellar velocity dispersion σ

Low Sersic Index



Disk-like bulges (aka pseudo-bulges) : NGC6782

・Pseudo-bulges



: minor merger? (Scannapieco et al. 2010)
Secular evolution? (Kormendy et al. 2004)

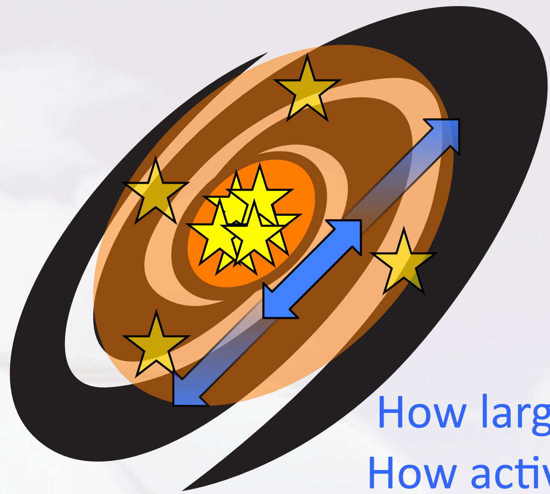
- mostly young stars
- Kinematically cold, i.e. dynamically supported by stellar rotatioin

Observational Prediction

1. Fabricius et al. (2012) show that bulges with low Sérsic index have colder stellar kinematics.
2. Fisher & Drory (2008) show that bulges with lower Sérsic index are more likely to be flatter.
3. Fisher (2013) shown that bulges with low Sérsic index have higher gas densities.

Few things have been cleared by observation !

Link of Morphology and Activity



How large?
How active?

MORPHOLOGY
stellar population
gas distribution

MISSING LINK !!

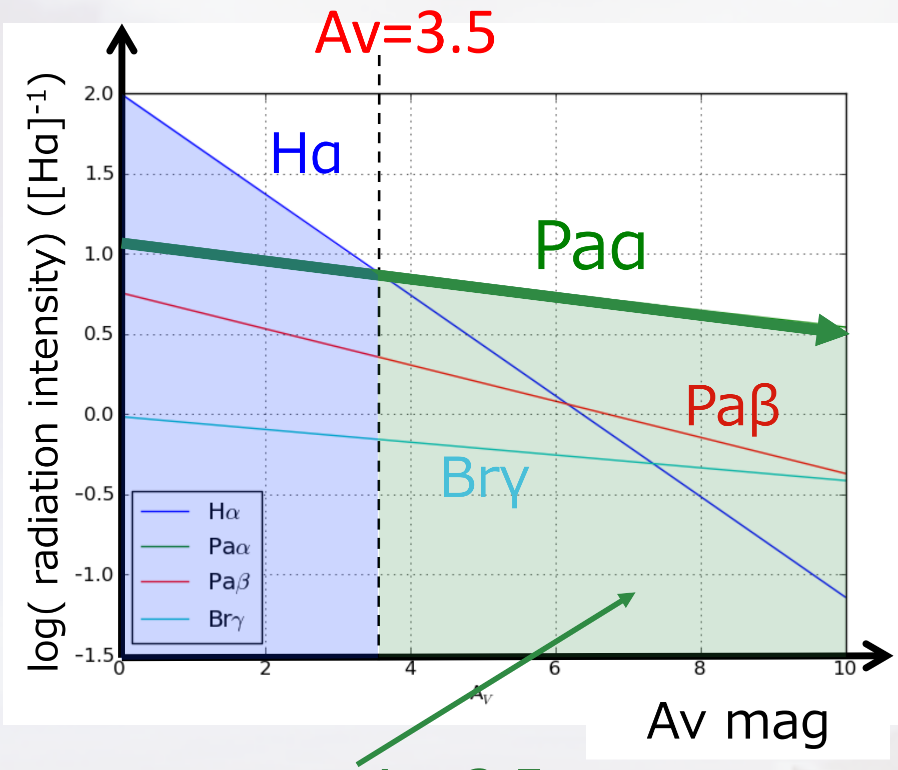
Dynamical (Physical) mechanism
- Environmental effect ?
  → merging,⋯
- Initial condition ?
  → initial stellar/gas mass,⋯

ACTIVITY
star formation
AGN
size of SF

We hypothesize that
<u>the morphology is associated with the activity</u>

So, we need accurate star formation tracer...

Paα Emission line (1.875μm)



$A_V > 3.5$

Paα is the strongest emission

※Assuming Case-B @T=10000K

The advantages of Paα emission line

① Far less affected by dust extinction
→ Suitable for U/LIRGs (Av>3mag)
(Alonso-Herrero ea. 2006)

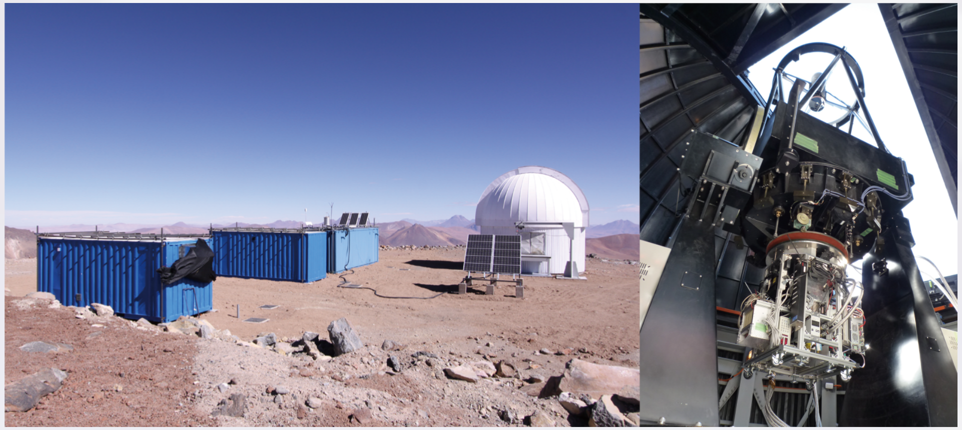
② One of the STRONGEST hydrogen re-combination lines @ near-IR

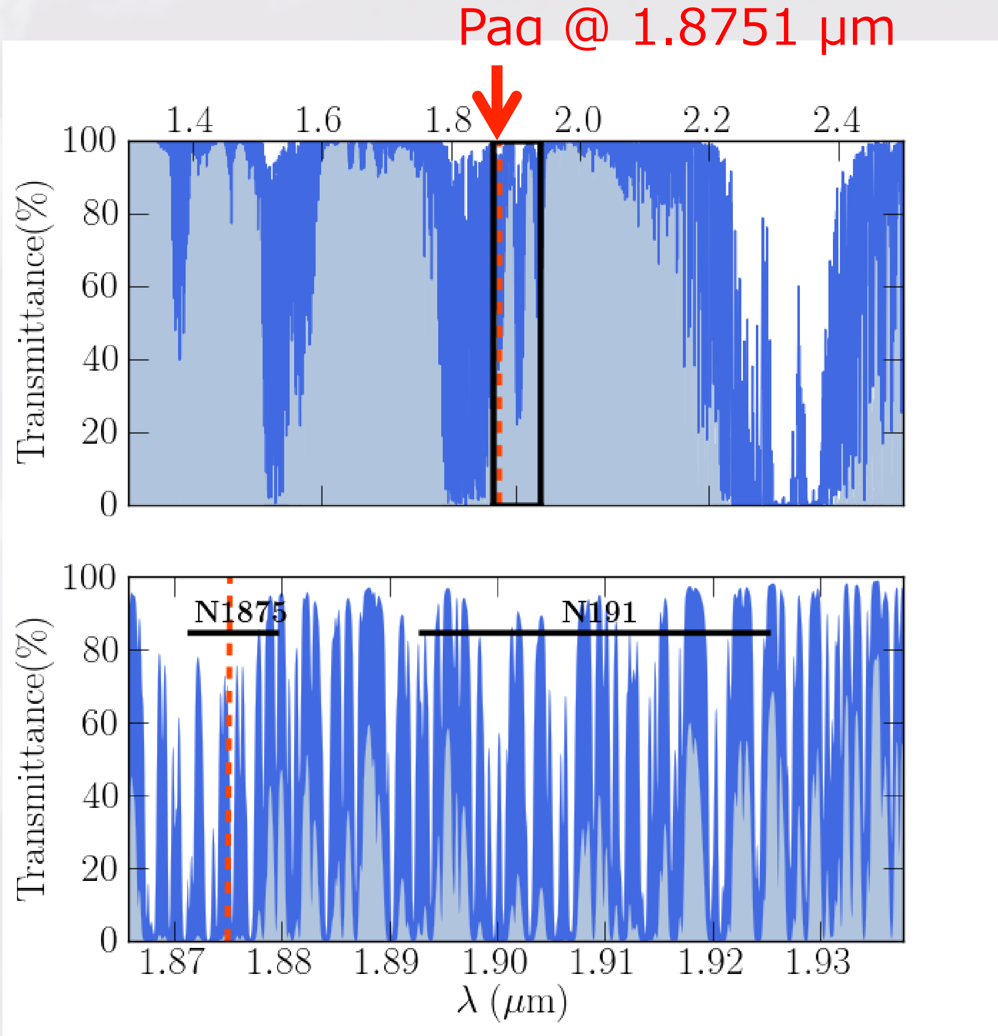
③ Unbiased tracer of the current SFR
→ Over a timescale of about 10 Myr

④ High spatial resolution
→ Compared to far-IR and mid-IR

Paα is strongly affected by atmospheric absorption !!

The Univ. of Tokyo Atacama Obs.

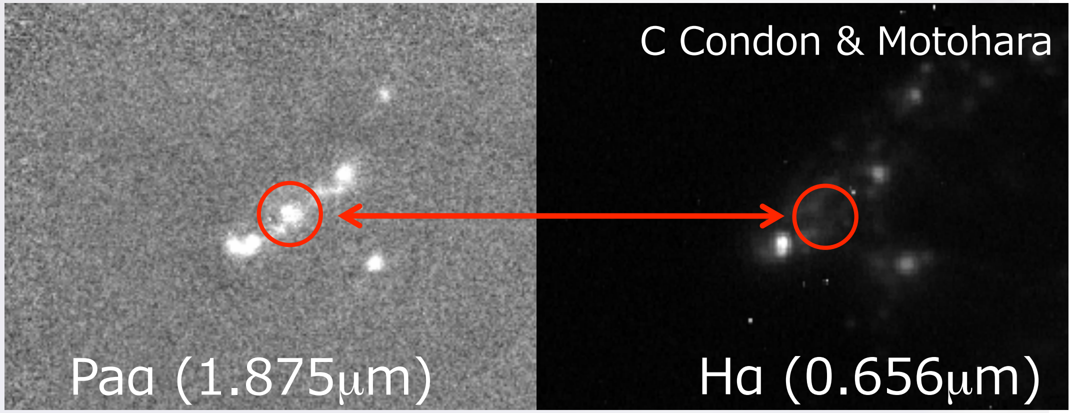




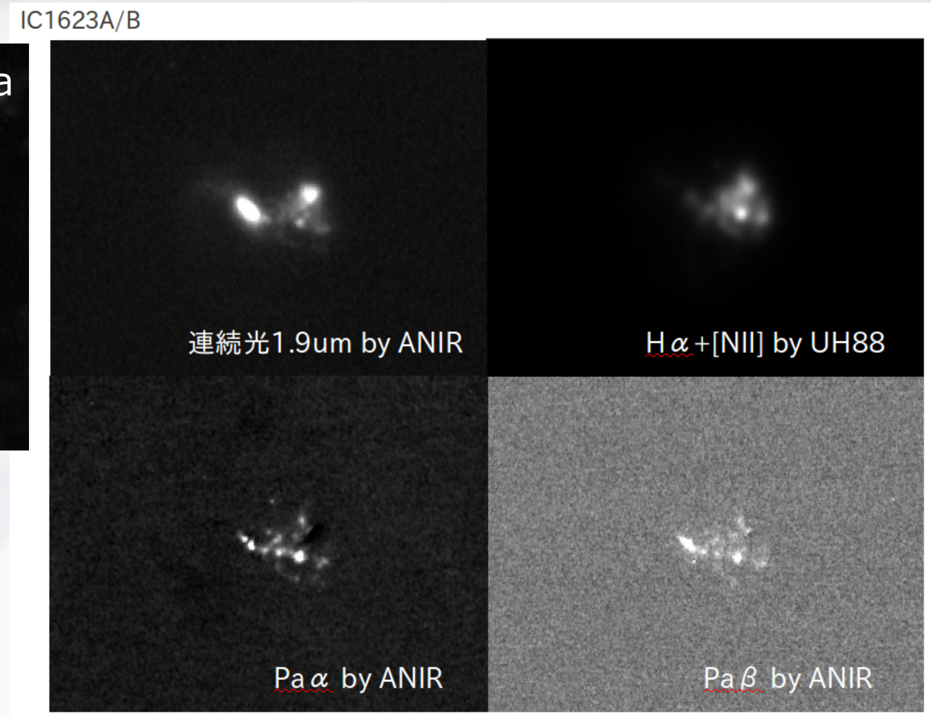
- √ The Univ. of Tokyo Atacama Observatory 1m Telescope → miniTAO
- √ Installed at the summit of Co. Chajnantor in northern Chile (5640m altitude, PI:Yoshii et al. 2010)
- √ Good performance for near-IR observation → low PWV, good weather, clear sky, …
- √ HST/NICMOS → has been decommissioned in 2010, so…

ONLY miniTAO/ANIR can observe Paα !

Paα Emission line w/ ANIR



VV254 Komugi & Tateuchi et al. 2012



√ Larger FOV (5′x5′) than NICMOS
→ Covering the whole galaxy

√ Better Detector Performance (NICMOS3 ⇒ HAWAII2)

√ Good spatial resolution (~0.7″)

√ New data reduction and calibration method
→ Tateuchi et al. 2012 SPIE.proc. , Konishi et al. in prep

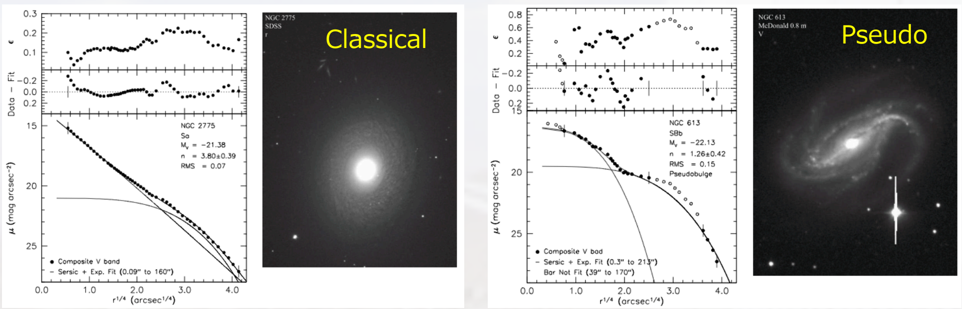
Analysis strategy

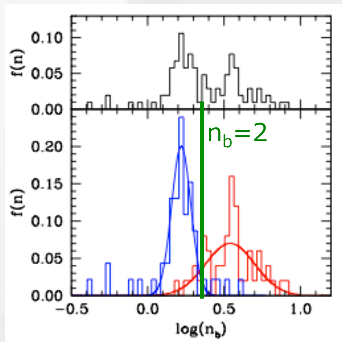
Focus on the bulge shape and activity

√ Merger, non-merger
→ previous study, Gini/M20

√ Star formation activity and size
→ ANIR/Paα, (size = half light radius)

√ Bulge shape
→ bulge and disk decomposition with ANIR/Ks





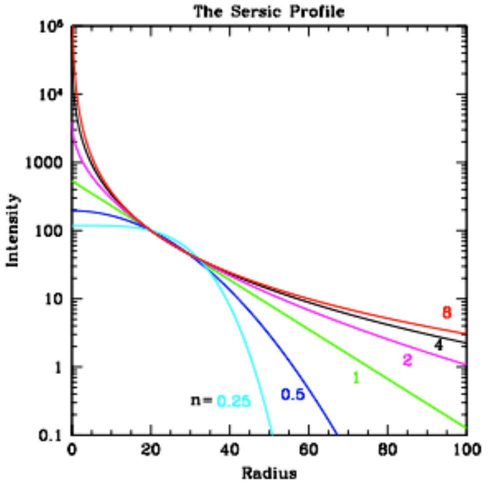
Pseudo (Blue) and classical (red) bulges is bimodal in the Sersic index
(Fisher et al. 2008)

How is the morphology (Ks,bulge) associated with the activity (Paα) ?

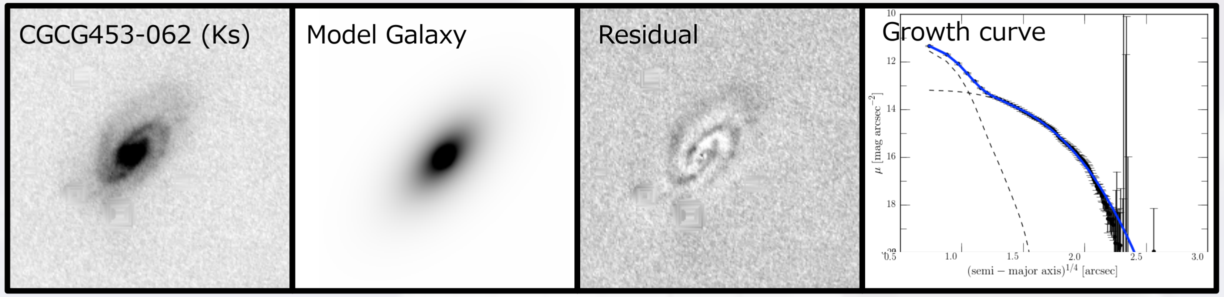
Bulge and Disk Decomposition

Sersci Index of Bulge

$$I(r) = \underbrace{I_0 \exp\left[-(r/r_0)^{1/n_b}\right]}_{\text{Bulge (Sersic Function)}} + \underbrace{I_d \exp\left[-(r/h)\right]}_{\text{Disk (Exponential Function)}}$$



Peng et al. 2010

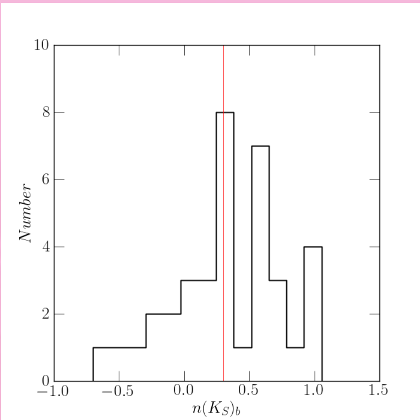


Decompositon w/ GALFIT (※ GALFIT; Peng et al. 2002)

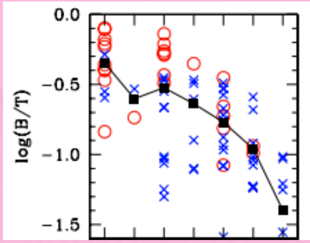
Sersic Index

n_b : 0~2
Pseudo bulge
n_b: 2~10
Classical bulge

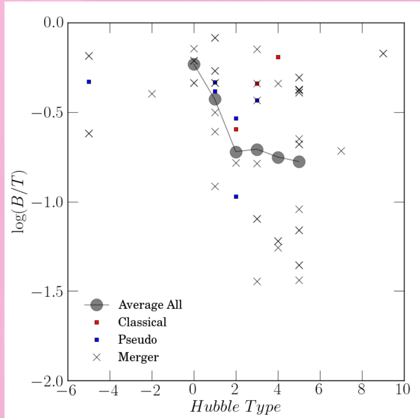
Peak at
n_b = 2 ?, 4 ?



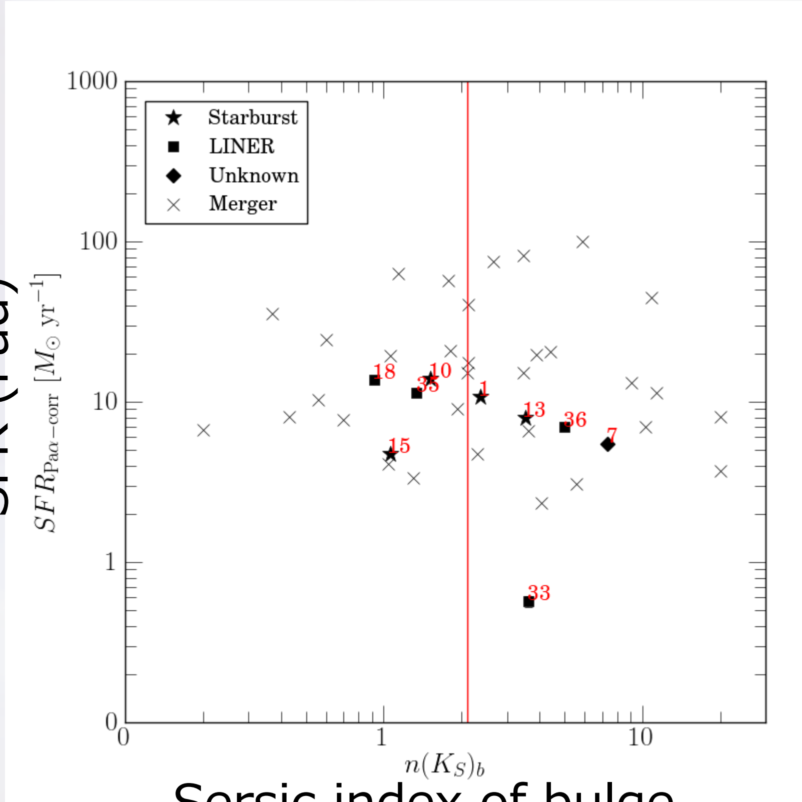
Hubble Type

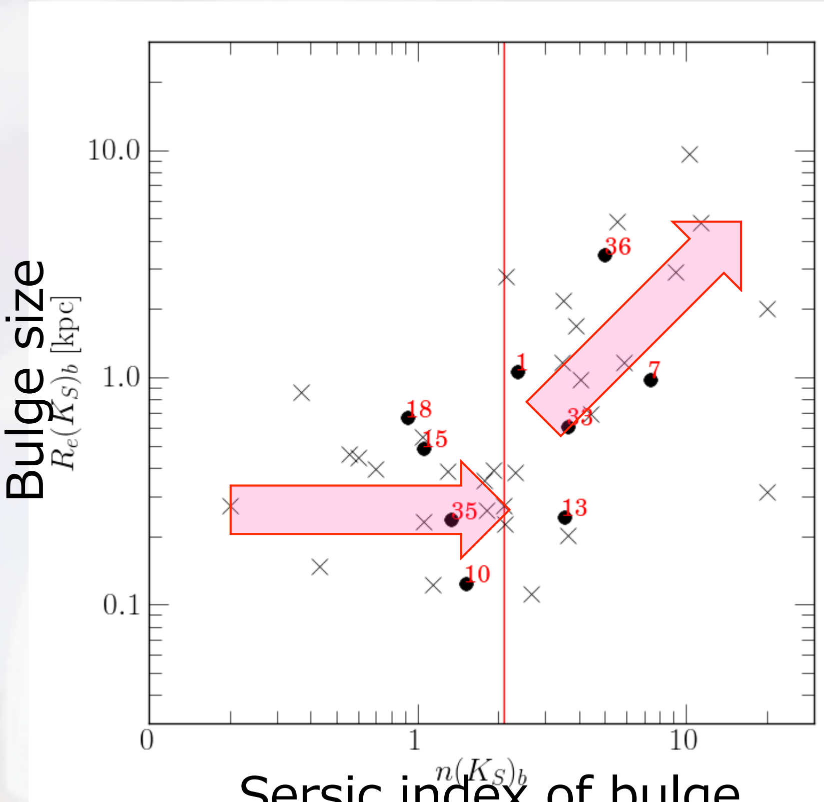


Fisher et al. 2010



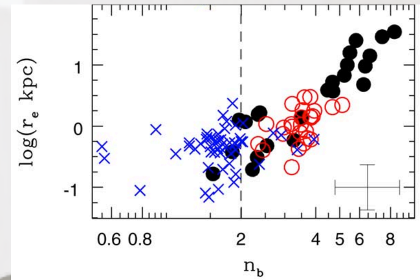
Size and activity



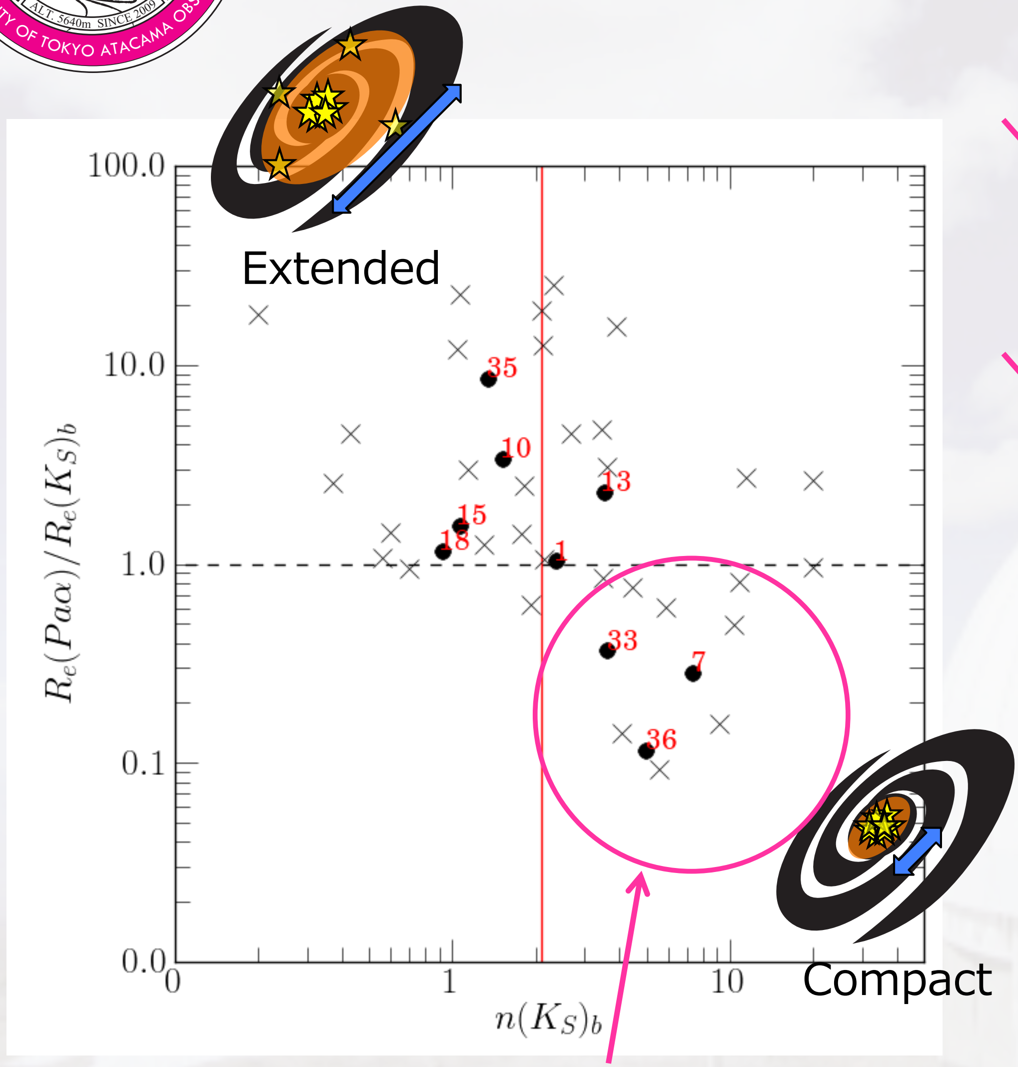


- No correlation?
  → luminosity selection bias?

- similar as previous works
  Fisher et al. (2008)



Size and bulge morphology



✓ Y-axis
Paα size / Ks bulge size
→ 1 = almost same size

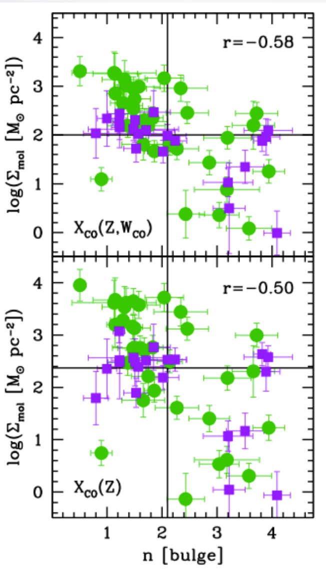
✓ X-axis
Bulge Sersic index (Ks)
→ classiacal- pseudo- bulge

How is the morphology (Ks,bulge) associated with the activity (Paα) ?
↓
Classical like bulge : compact SF
Pseudo like bulge : extended SF

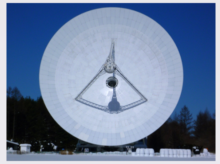
However, we do not know how they can be active?
How about gas motion?...

Future works I -Molecular Gas-

Molecular Gas Survey



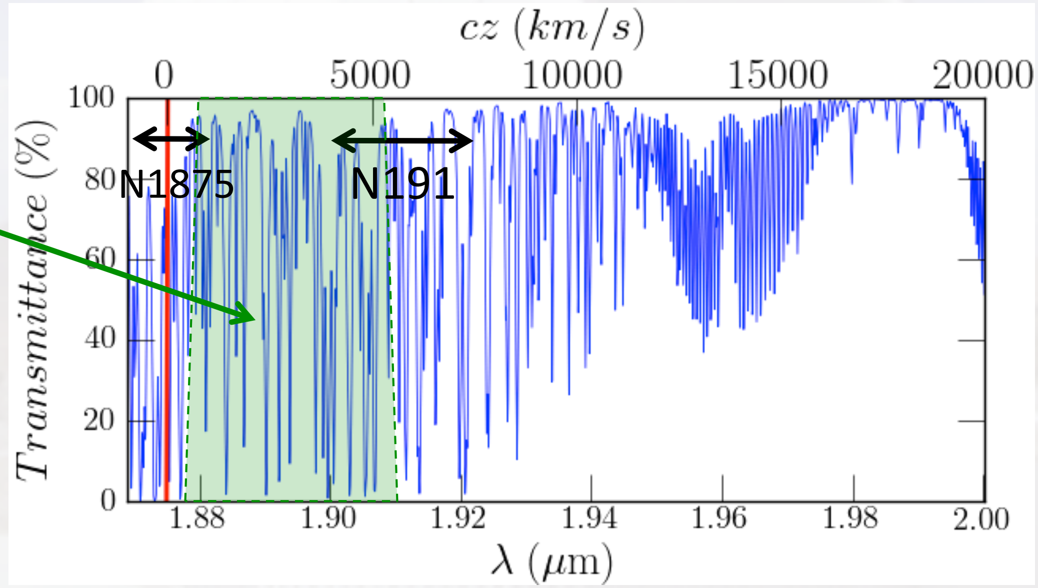
molecular gas distribution (Merger, pseudo- and classical- bulge)
- CO(1-0) & Paα → star forming efficiency

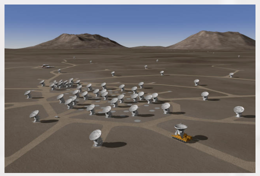


- COMING (P.I. Sorai) : NRO 45m (North) → Kaneko-san's talk
  - CO multi-line observation ~ 200-300 objects

- COMING^{PLUS} (P.I. Tateuchi) : Mopra 22m (South)
  - CO(1-0) pointing survey ~ 130 objects (110h)
  - Amount of molecular gas

We would like to install the new NB filter (for nearby galaxy's Paα) , but ...





Towards ALMA...

Bulge-disk decomposition by Gas tracer with high resolution !!

Future works II -Merger-

- Merger sample
  - merger stage...

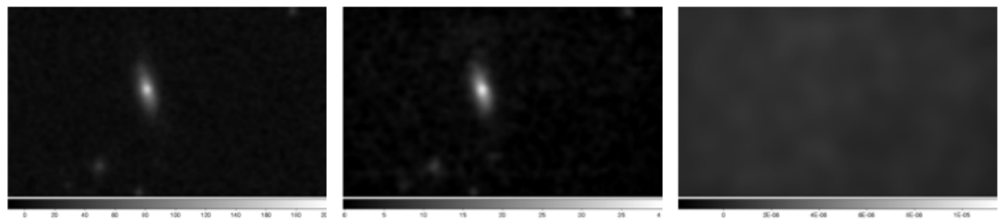


Figure 4.1. Ks　**Figure 4.2.** N207　**Figure 4.3.** Paα-LINE

Z=0.1 AKARI source (LIRG); No detection (1h)

- Middle-Redshif (U)LIRG Survey
  - cz>1000 km/s
  - High star forming mechanism

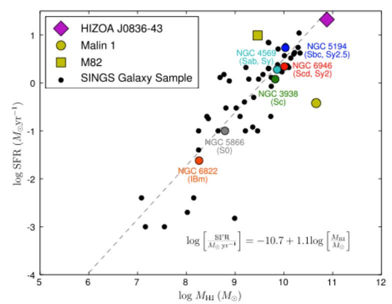
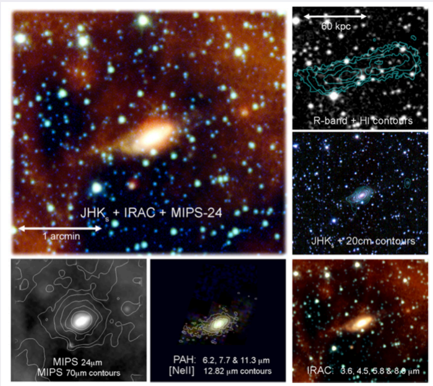
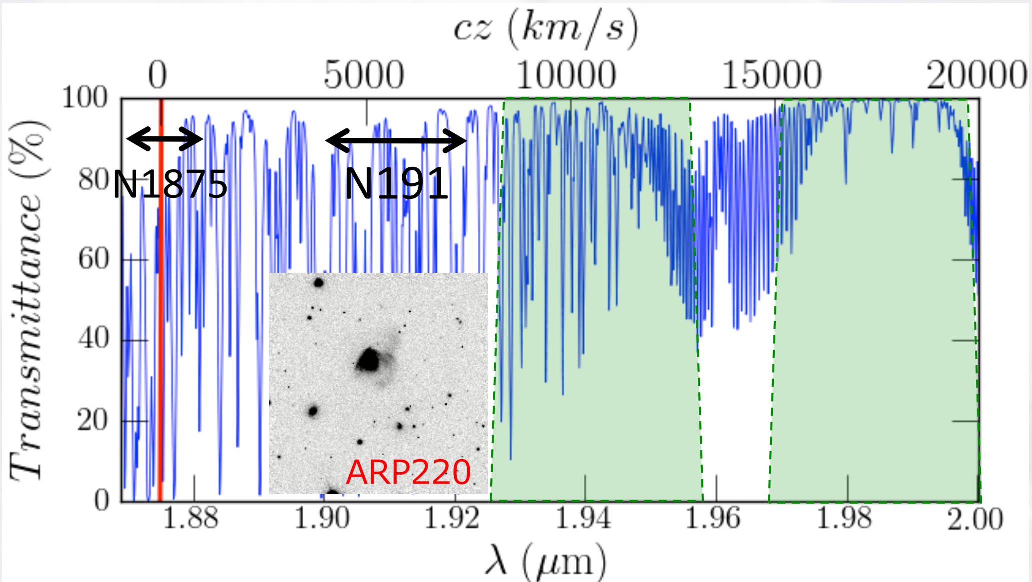


Figure 7. SFR vs. H I mass for HIZOA J0836-43 and SINGS galaxies. The SFRs for the SINGS galaxies are calculated from their Hα emission (Kennicutt et al. 2003). The SFR of Malin 1 is from Rahman et al. (2007) and its H I mass from Pickering et al. (1997). The M82 data are from Yun et al. (1993) and Sanders et al. (2003) for the H I and SFR, respectively.





- HIZOA J0836-43@ cz=10687 km/s
  → HI-massive disk galaxy
  Survival of high-z sBzk ?
- miniTAO can not detect high-z galaxies ?
  → TAO 6.5/SWIMS or Subaru/SWIMS ?