A Study of Bars in Low Surface Brightness Galaxies using near-infrared and optical imaging

Honey M

Indian Institute of Astrophysics, Bangalore, India

2017 Asia-Pacific Regional IAU Meeting
Taipei, Taiwan
6th July 2017

Collaborators

Dr. Mousumi Das, IIA, Bangalore, India

Dr. Joe Philip Ninan, Penstate uni

Dr. Manoj Puravankara, TIFR, Mumbai, India

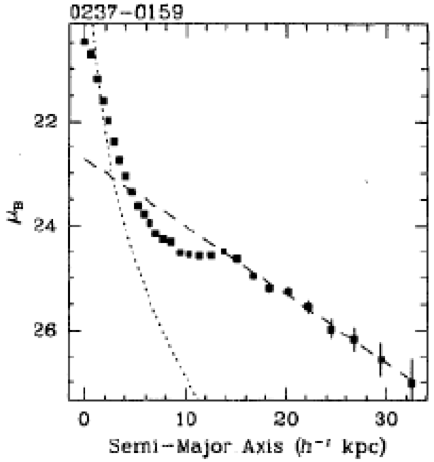
Low Surface Brightness (LSB) Galaxies

- They are optically dim, disk dominated systems. They usually have central disk brightness fainter than 22 magnitude /arcsec^2 in B-band (Sprayberry et al. 1995)
- They are extreme late type galaxies. They can be broadly divided into two groups

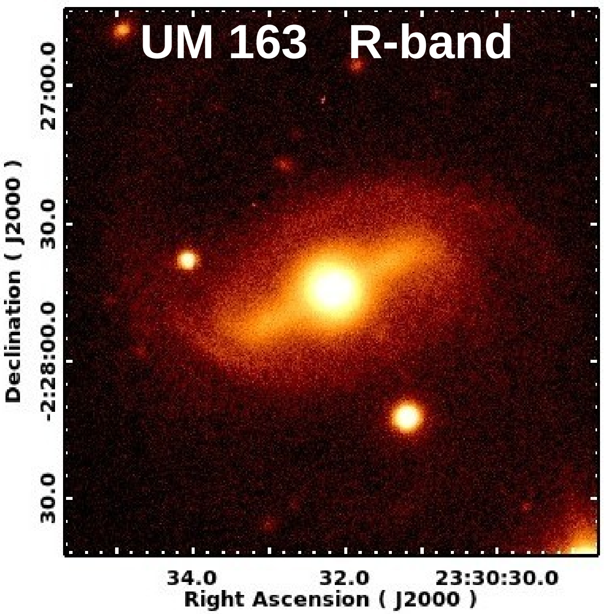
  (i)low surface brightness dwarfs and irregulars

  (ii) large spiral galaxies (Giant LSB galaxies).
- They are rich in HI, but have low star formation rates (Impey and Bothun. 1994).

Image courtesy : SDSS Data Release 12

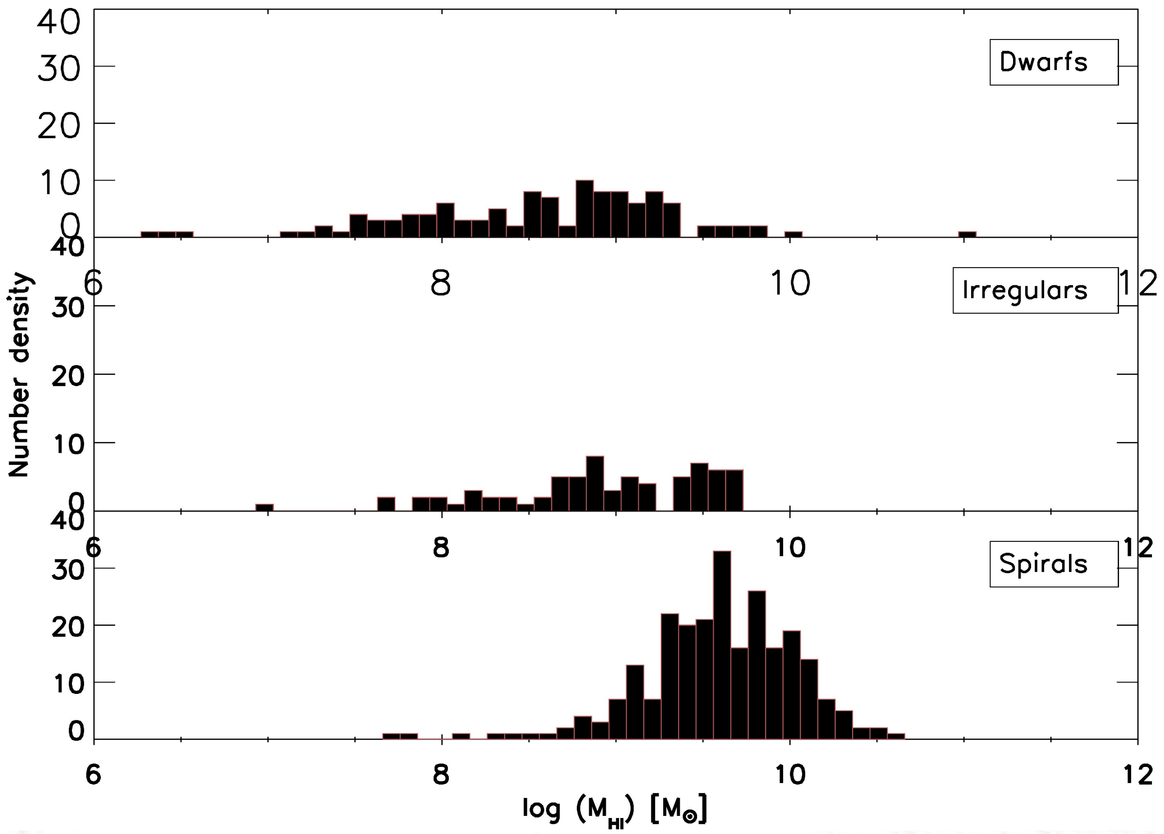


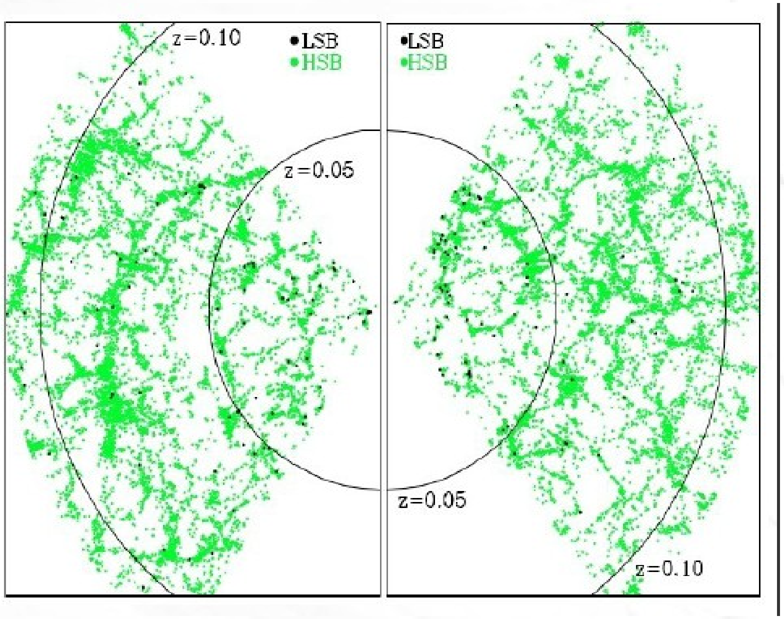
Sprayberry et al,1995AJ,109



Himalayan Chandra Telescope (HCT) image
Honey et al. 2016

- They are Dark matter dominated systems (de Blok et al. 2002).
- They are having diffuse stellar discs
- Molecular hydrogen is rarely found and they are metal poor
- The Giant LSB galaxies are usually seen in isolated environments. They are often found close to the edges of voids.

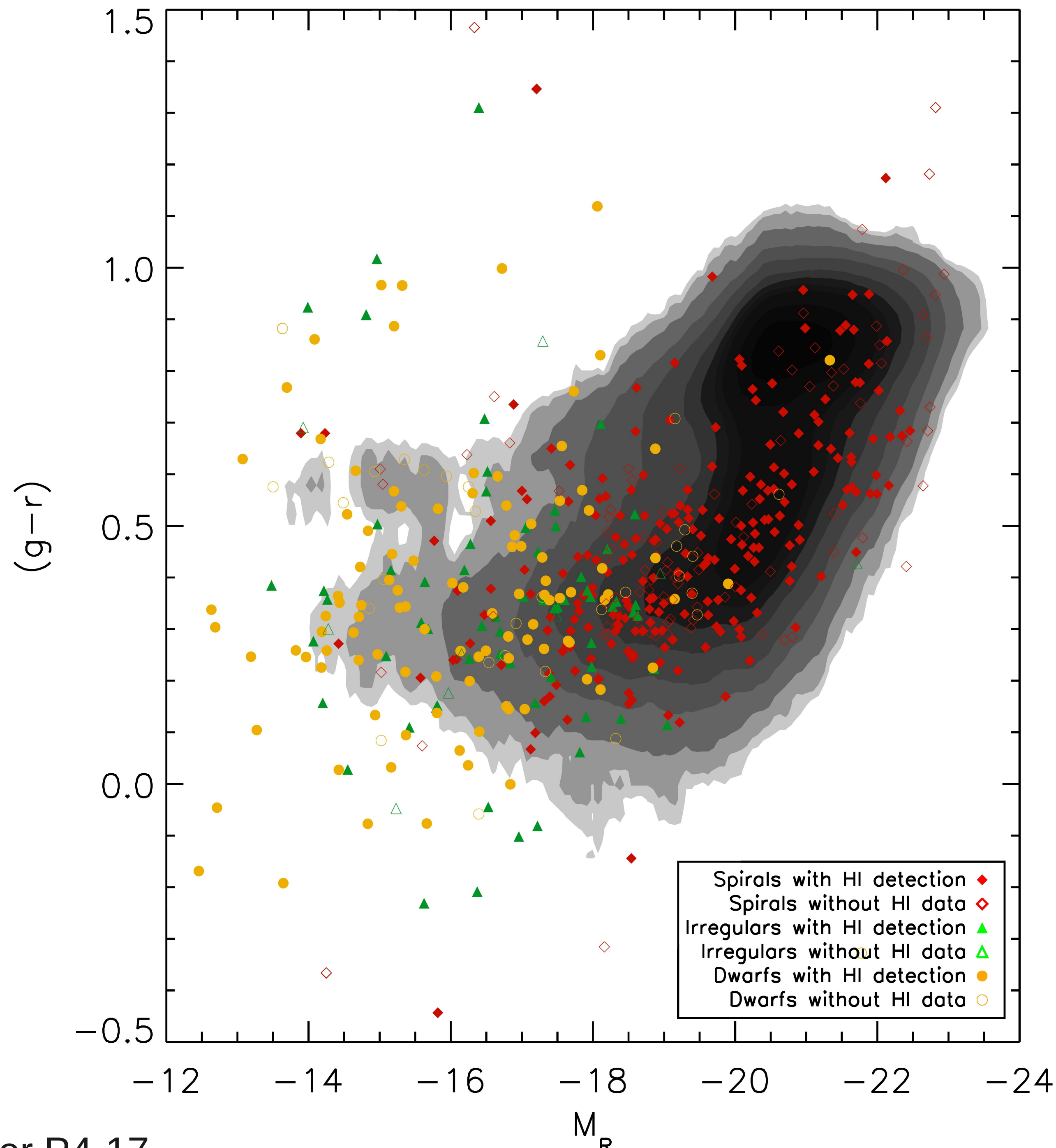




Honey et al. 2017, MNRAS, In preparation

Rosenbaum et al. 2009

Color magnitude diagram of LSB galaxies



Please see poster P4-17

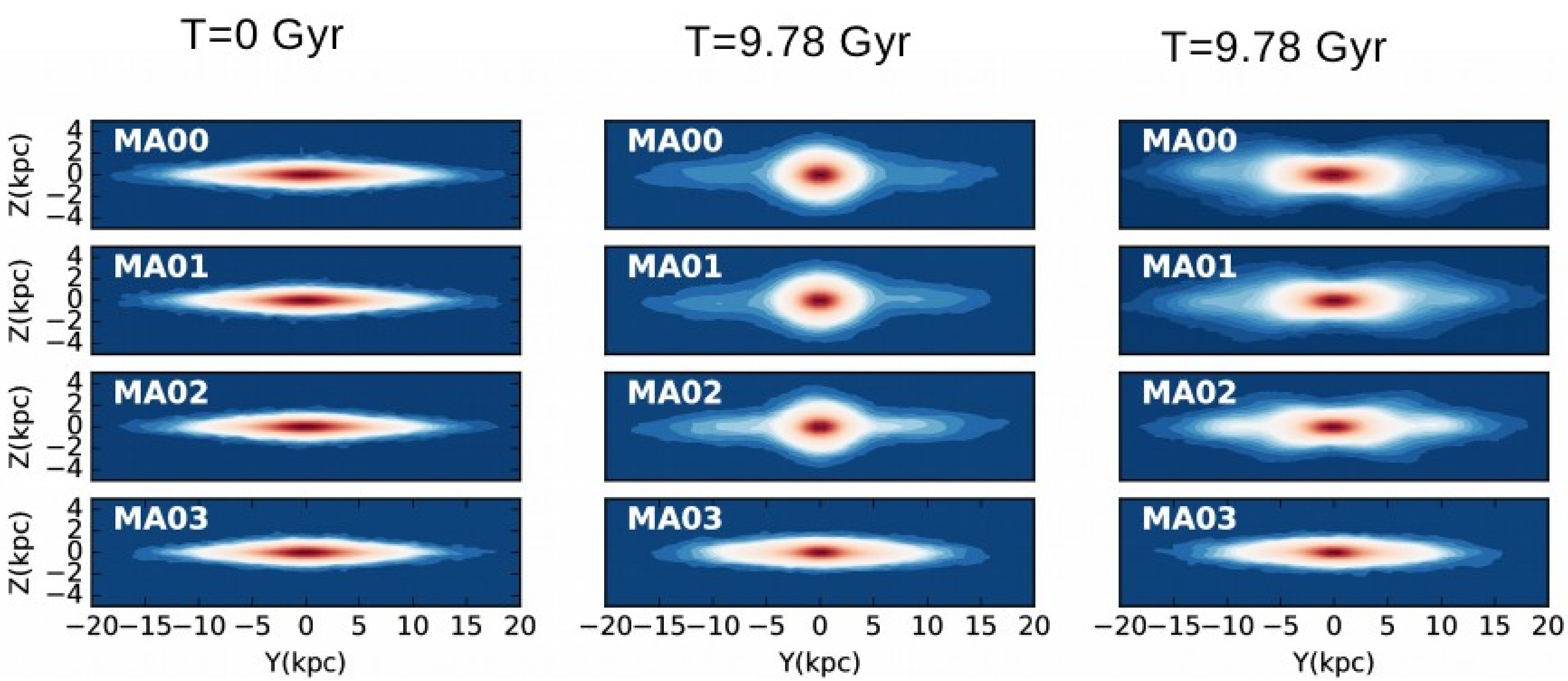
Honey et al. 2017, In preparation

Bars, Spiral arms and disk evolution

- Numerical simulations show that cold, self gravitating disks can become unstable. This leads to the formation of structures like bars and spiral arms.
- Bars and spiral arms trigger star formation in galaxies, leading to disk evolution.
- Observation studies shows about 1/3 of disk galaxies are barred
- In barred galaxies, the bar will drive gas inflow to the center resulting in formation of rings at the resonances (ILR,Co-rotation and OLR) and the build up of central mass concentration.
- Some times bars can become unstable (buckling instability) and form boxy bulges. These are sometimes called pseudobulges.

Secular evolution of spiral galaxies

- Slow internal evolution of galaxies caused by bars, disky bulges, spiral arms and star formation. (Debattista et al. 2005)
- Pseudo bulges are the main signatures of secular evolution.
- To study the secular evolution, the isolated galaxies are the good candidates.



Kataria & Das 2017

How it differs in Dark matter dominated systems ?

- In dark matter dominated systems, the massive halo component suppress the instabilities and structure formation(Hohl. 1976, Mihos et al. 1997, Ghosh et al. 2014).
- LSBs are the ideal candidates for studying the secular evolution in dark matter dominated systems.

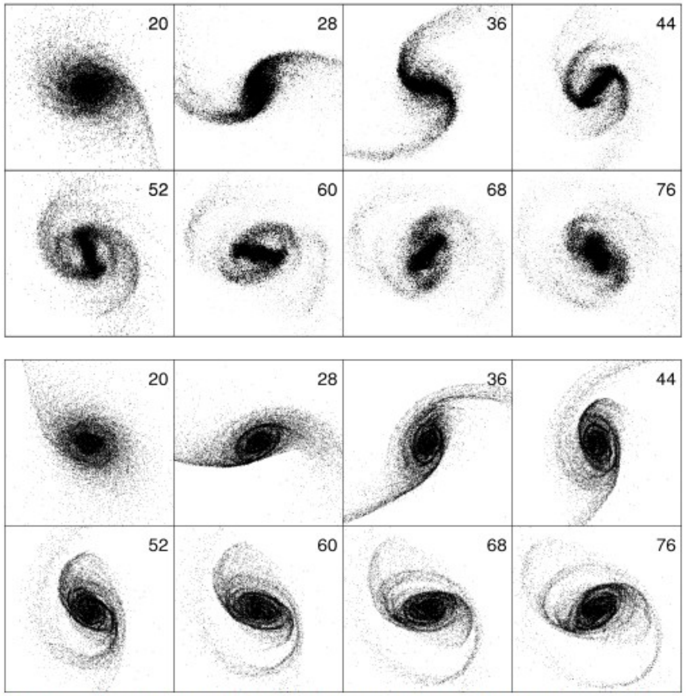


Fig. 2.—Evolution of the HSB (*top*) and LSB (*bottom*) disk during an equal (total) mass galaxy encounter with R_{peri} = 10 scale lengths. Each frame measure 7.5 scale lengths on a side, and time is given in the upper right corner. One half-mass rotation period is roughly 13 time units.

Mihos, McGaugh, & De Blok (see 477, L81)

Mihos et al.1997

Goals of the study

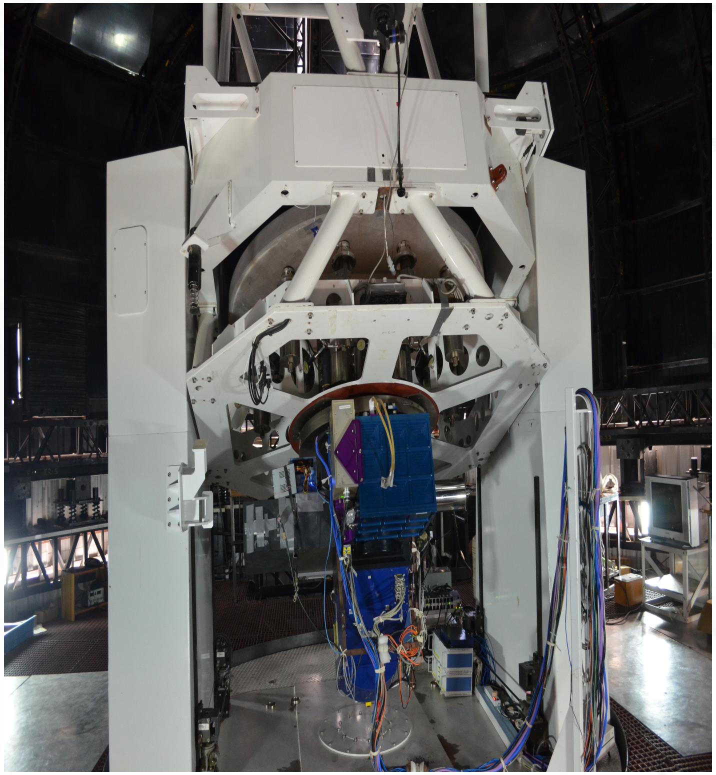
- To examine the strength of the bars in dark matter systems (ellipticity & bar length are directly proportional to bar strength , Laurikainen. et al. 2002)
- Whether their properties are similar to the bars in normal galaxies?
- Structure of bars in GLSB galaxies in NIR and the nature of their isophotes
- How the colour profiles of the bars looks ?
- Do their galactic properties like HI mass, stellar mass and colours showing any correlation with bar parameters?
- Whether the colour is influenced by the gaseous mass fraction

Sample selection

- We have checked for 938 galaxies using four LSB catalogs (Impey et al. 1996 & Schombert & Bothum . 1988, Schombert et al. 1992, Schombert. 1988).
- 836 has visually examined using SDSS DR 12 and HCT images
- We found that only 71 have bars (~ 8.3 %)

NIR observations with TIRSPEC

- Used TIFR Near Infrared Spectrometer and Imager (TIRSPEC), mounted on 2m Himalayan Chandra Telescope (HCT), Hanle.
- Wavelength coverage:1- 2.5μm
- Field of view of 307 x307 arcsec^2

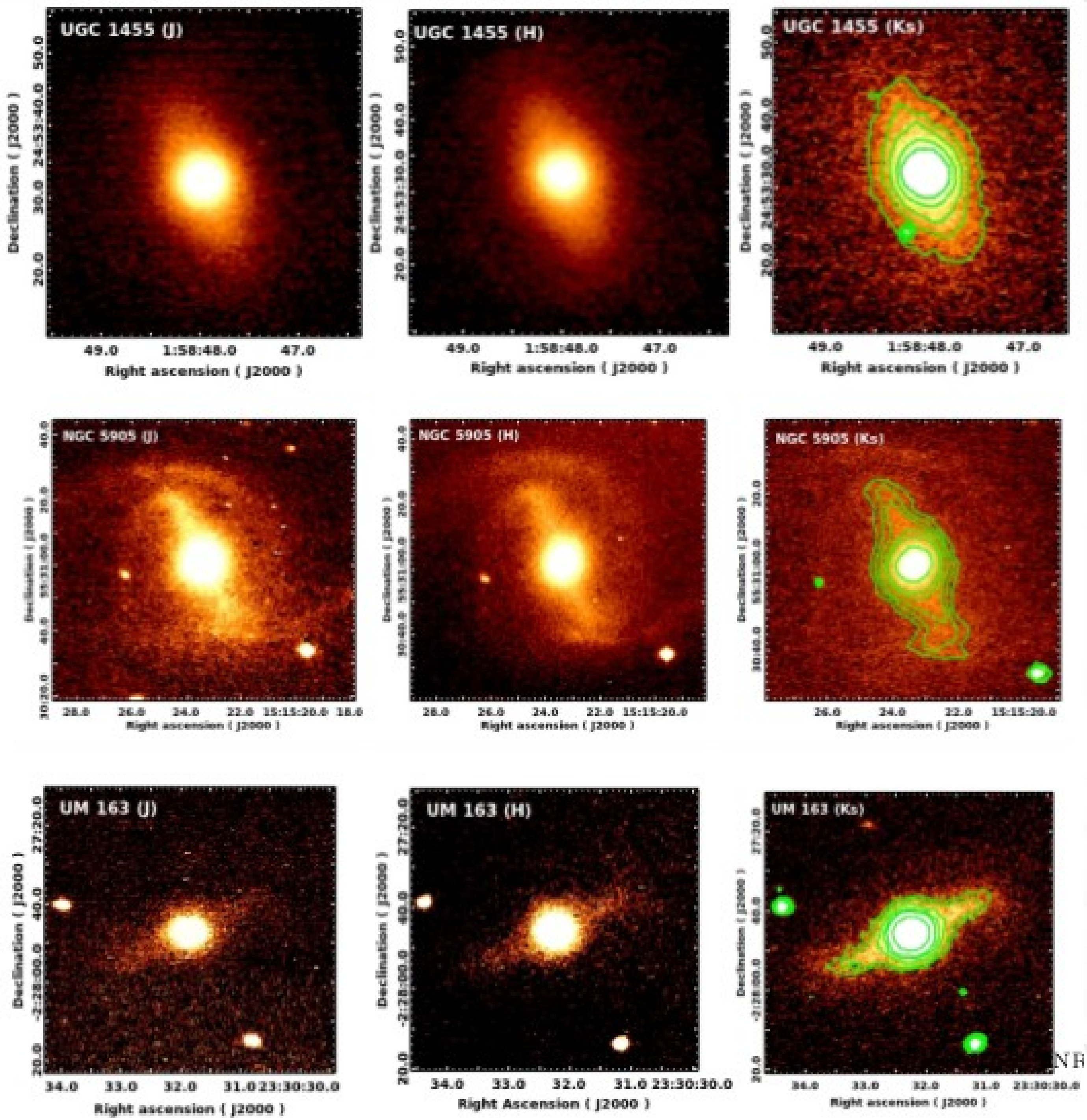


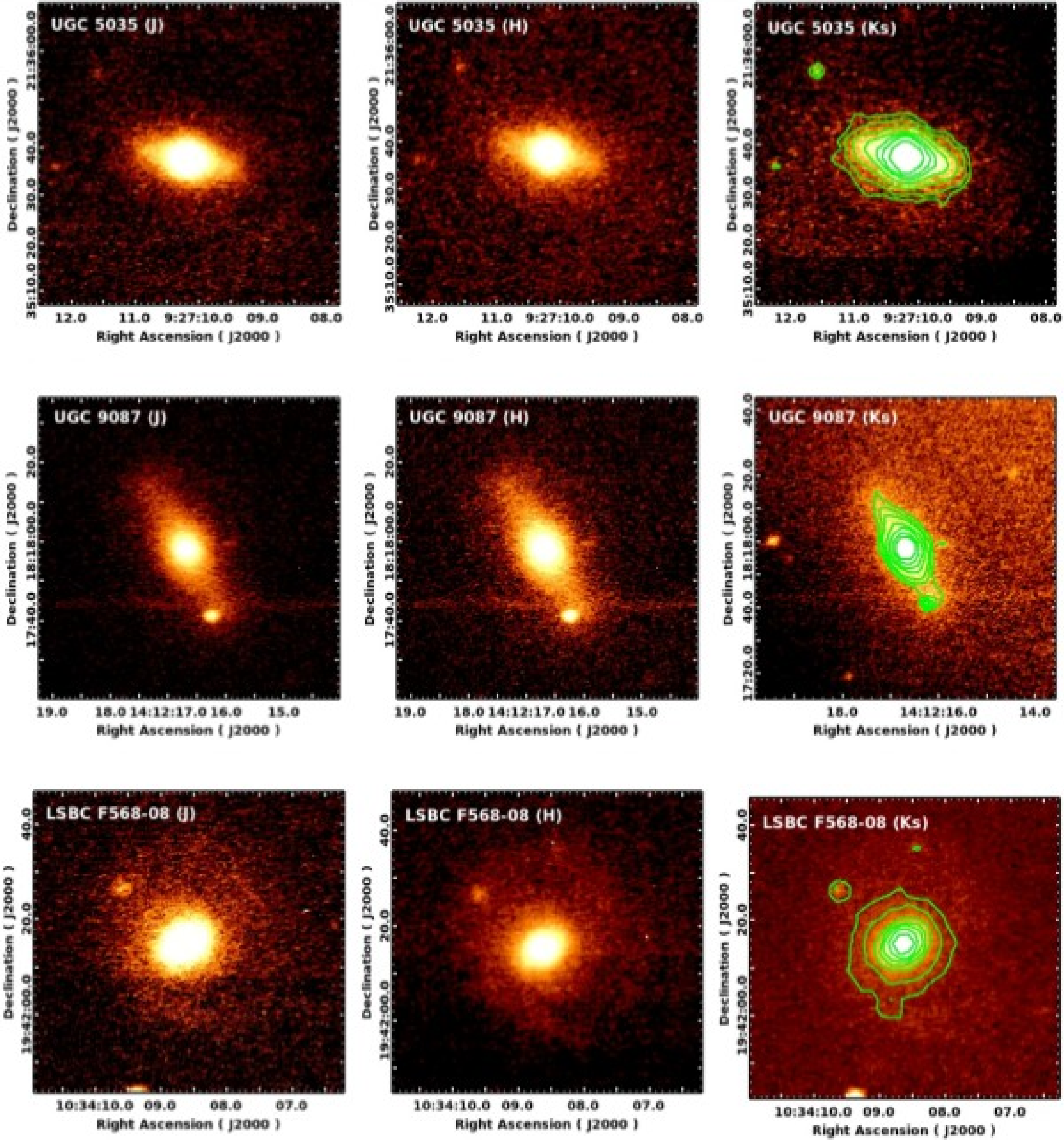
HCT with TIRSPEC mounted on it

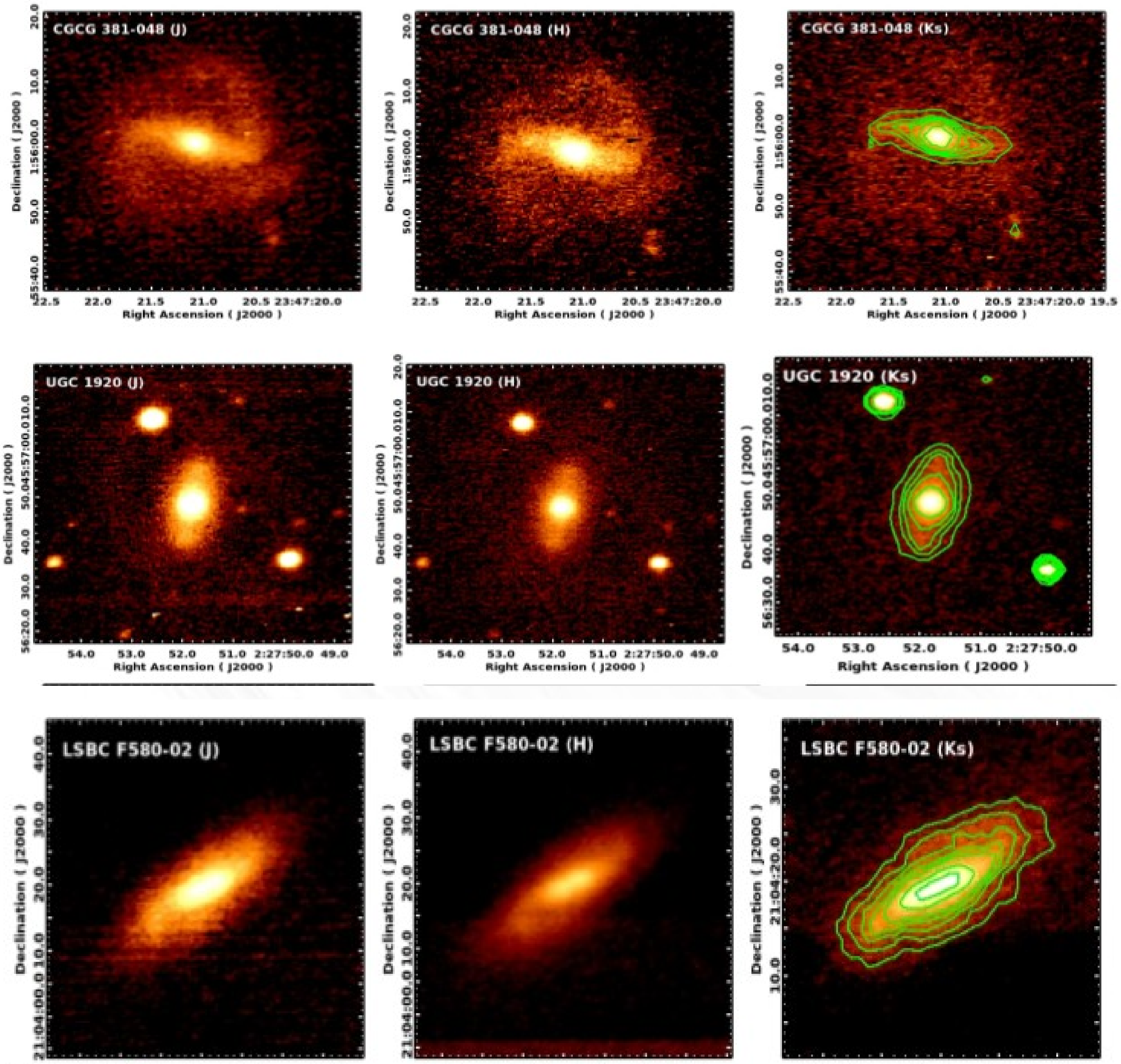
Image courtesy : Joe Philip Ninan

NIR images of LSB galaxies

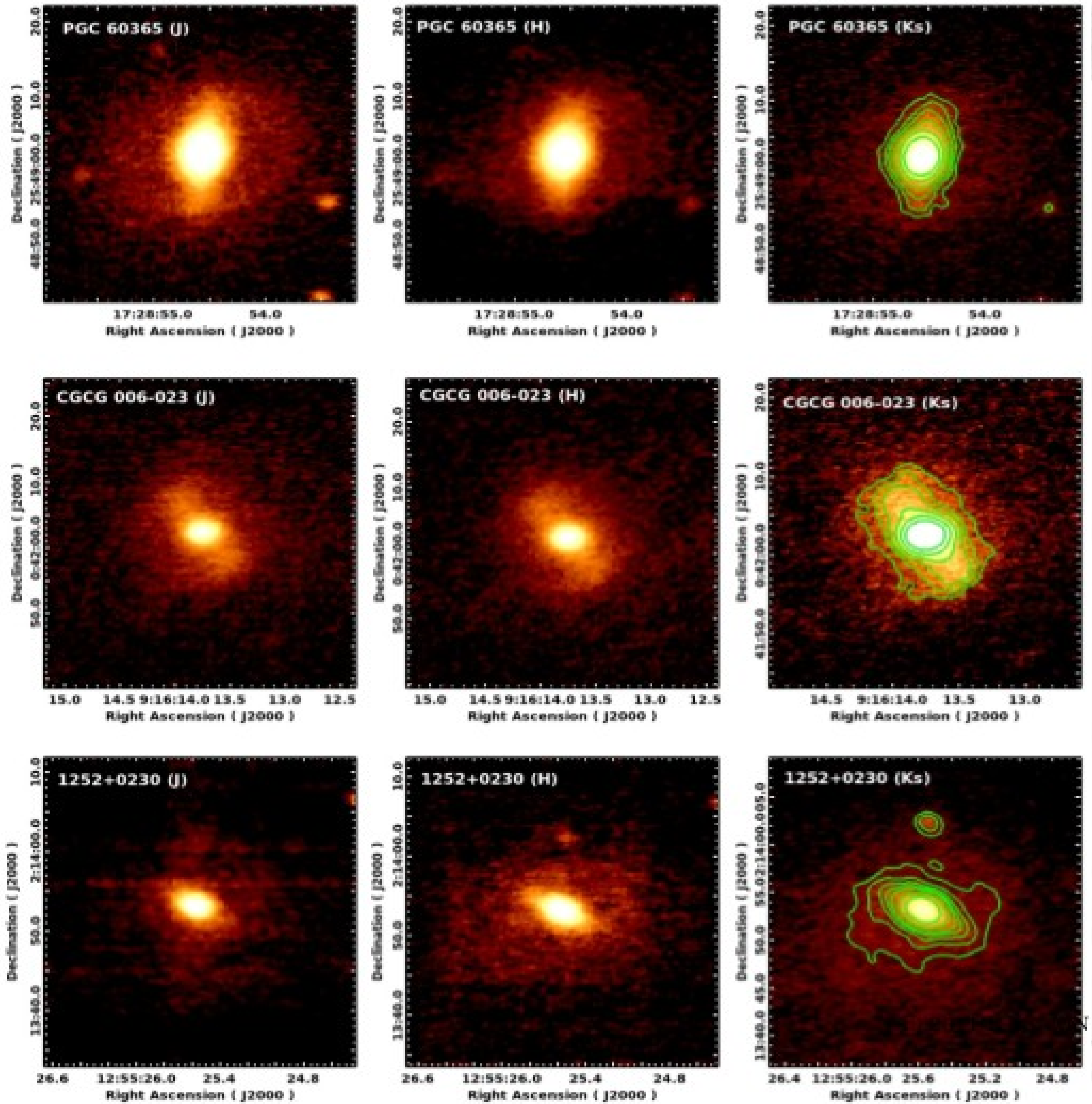
Honey et al. 2016



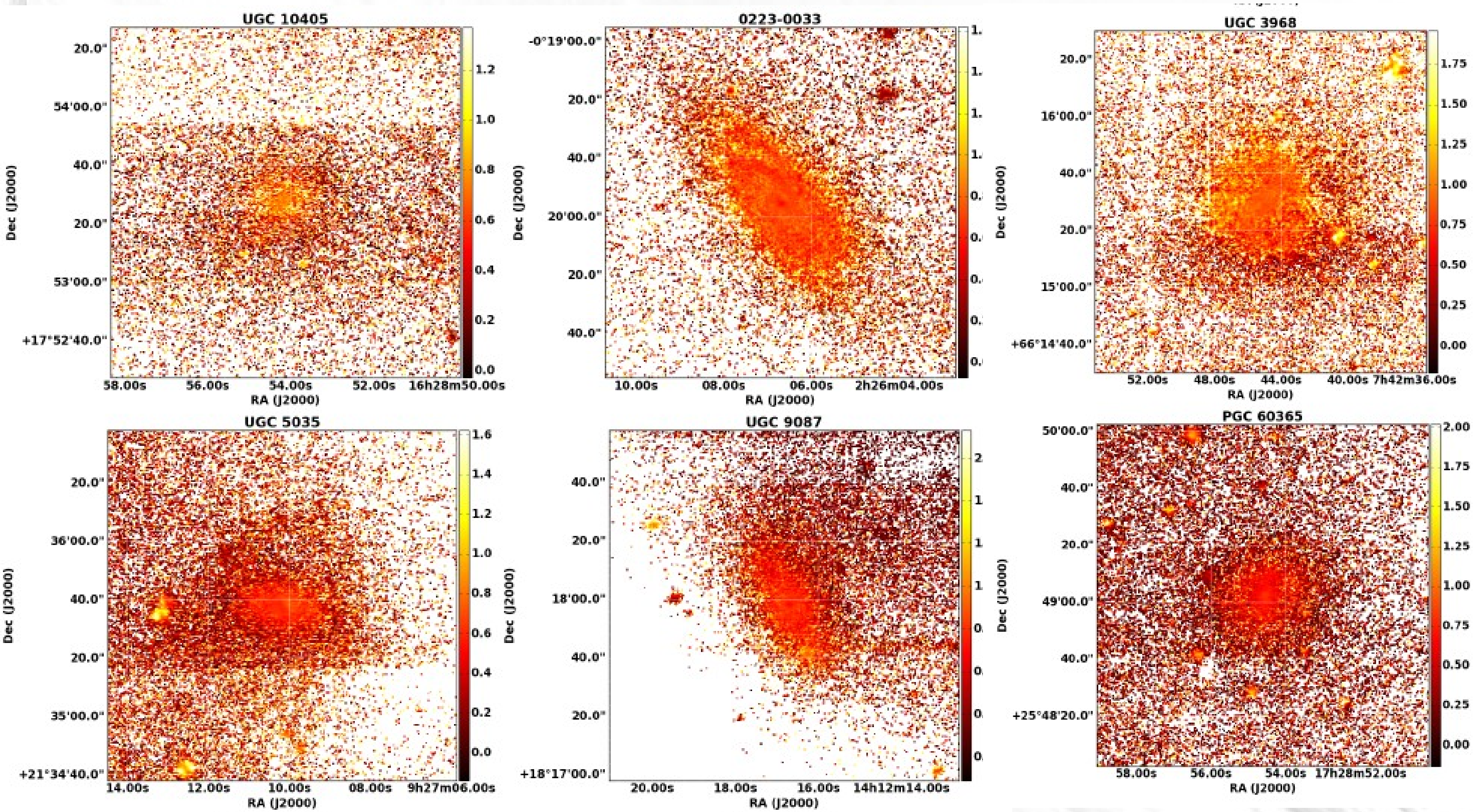

UGC 5035 (J)
UGC 5035 (H)
UGC 5035 (Ks)
UGC 9087 (J)
UGC 9087 (H)
UGC 9087 (Ks)
LSBC F568-08 (J)
LSBC F568-08 (H)
LSBC F568-08 (Ks)
Declination (J2000)
Right Ascension (J2000)
12.0
11.0
9:27:10.0
09.0
08.0
35:10.0
20.0
30.0
40.0
21:36:00.0
19.0
18.0
14:12:17.0
16.0
15.0
14:12:16.0
14.0
17:20.0
17:40.0
18:18:00.0
10:34:10.0
07.0
19:42:00.0



CGCG 381-048 (J)
CGCG 381-048 (H)
CGCG 381-048 (Ks)
UGC 1920 (J)
UGC 1920 (H)
UGC 1920 (Ks)
LSBC F580-02 (J)
LSBC F580-02 (H)
LSBC F580-02 (Ks)
Declination (J2000)
Right Ascension (J2000)
22.5 22.0 21.5 21.0 20.5 23:47:20.0
54.0 53.0 52.0 51.0 2:27:50.0 49.0


PGC 60365 (J)
PGC 60365 (H)
PGC 60365 (Ks)
CGCG 006-023 (J)
CGCG 006-023 (H)
CGCG 006-023 (Ks)
1252+0230 (J)
1252+0230 (H)
1252+0230 (Ks)
Declination (J2000)
Right Ascension (J2000)

J-Ks profiles

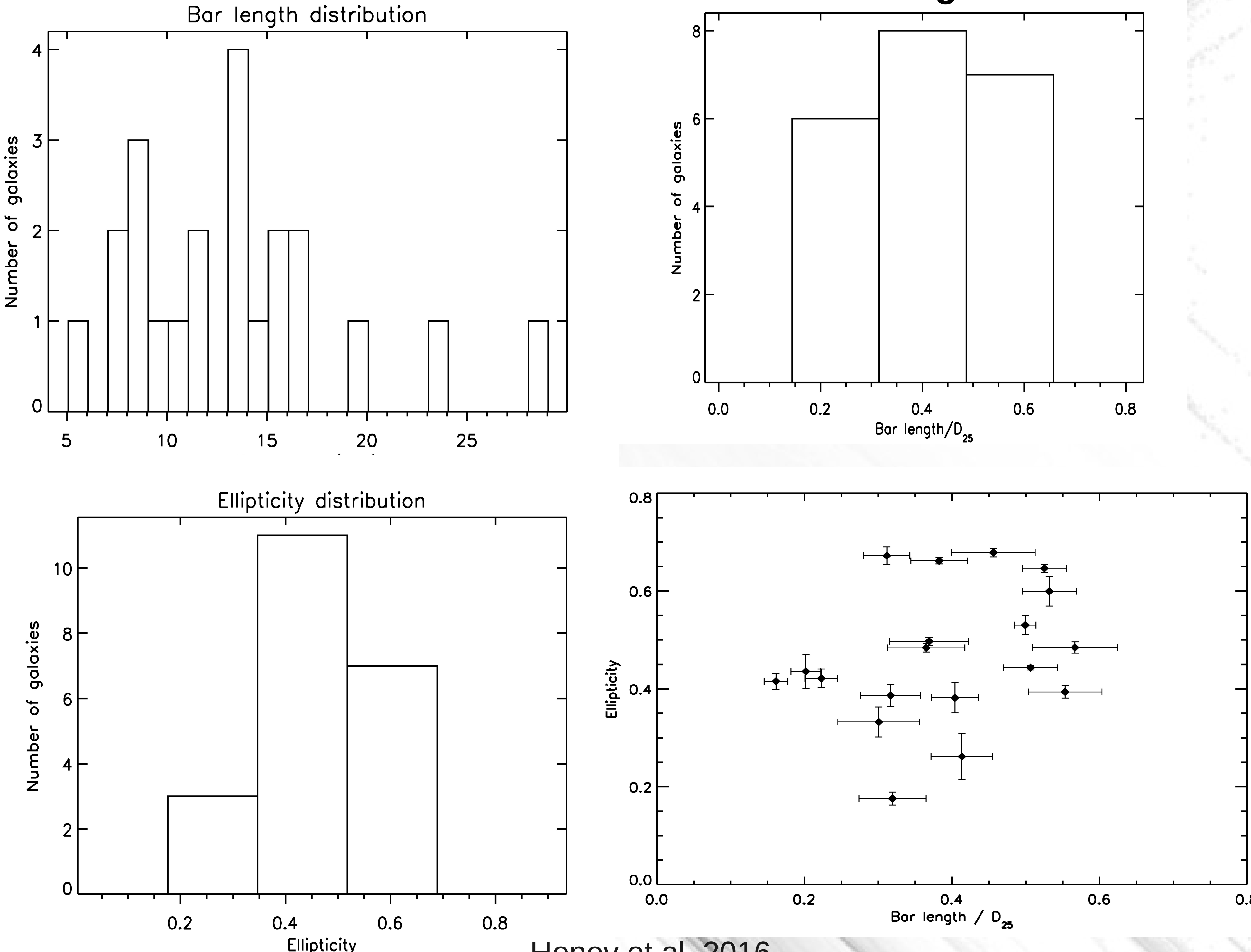


Deprojecting the bar length and ellipticities

- The observed galactic image, that we measured the bar parameters using task ELLIPSE (IRAF).
- The deprojected barlength and ellipticities are calculated analytically
- Most of the bar length lying in the range of 8-17 kpc except for three cases (In normal galaxies the range is 2-28 kpc)
- The distribution of the fraction of barlength with the D_{25} distance is peaking around 0.4-0.6 range (Similar to normal galaxies)
- Ellipticities are lying in 0.4-0.6 range (Similar to normal galaxies - Early type galaxies 0.5-0.75, late types > 0.5)

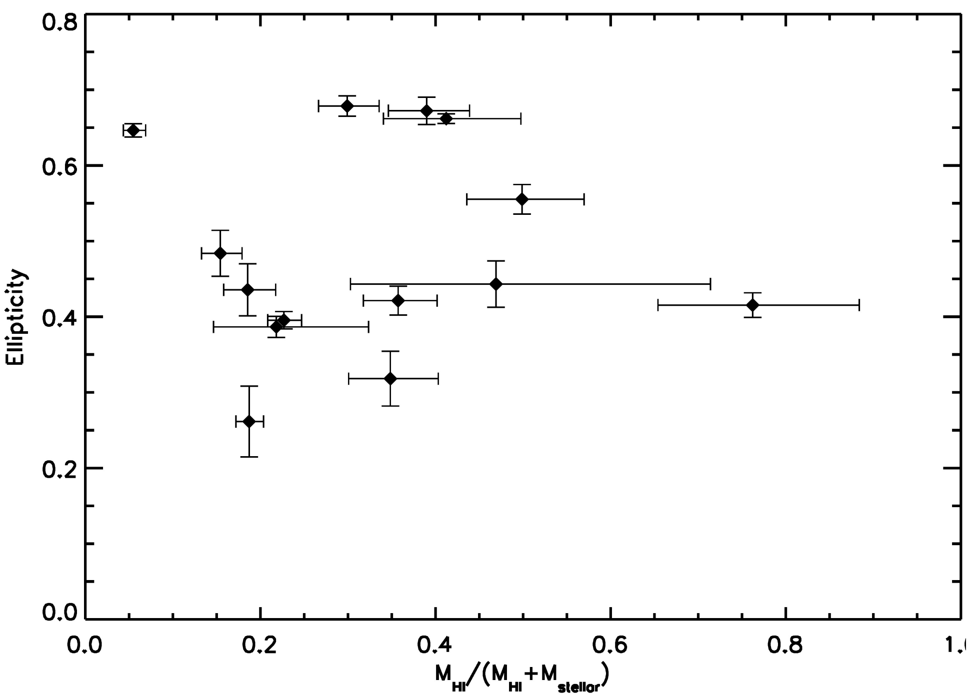
Gadotti et al. 2007;Martin 1995; Marinova & Jogee 2007;Men´ndez-Delmestre et al. 2007

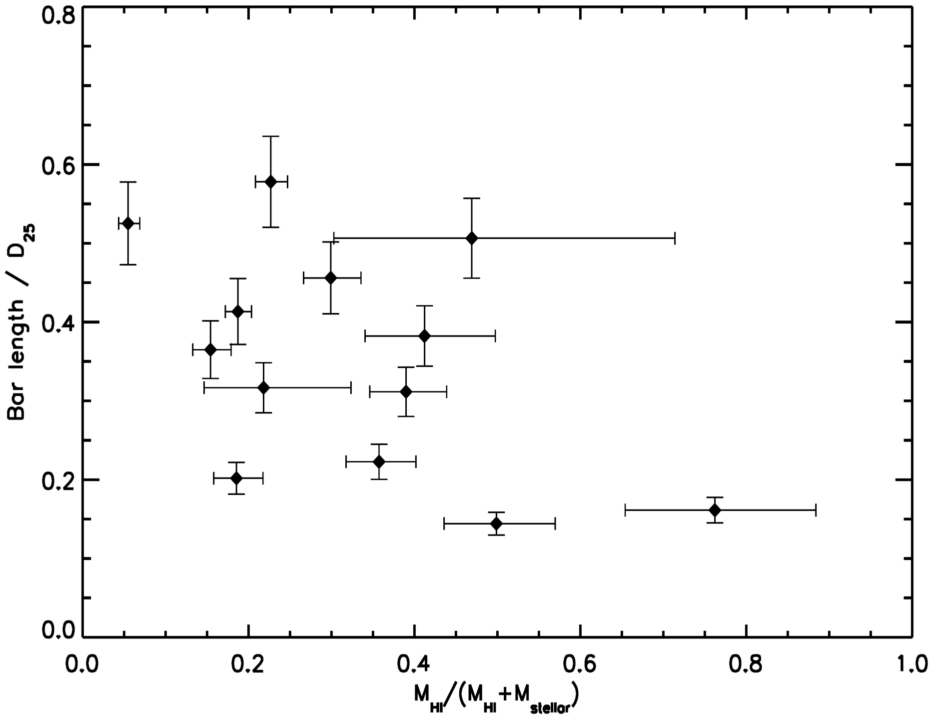
Bar Parameters similar to normal barred galaxies

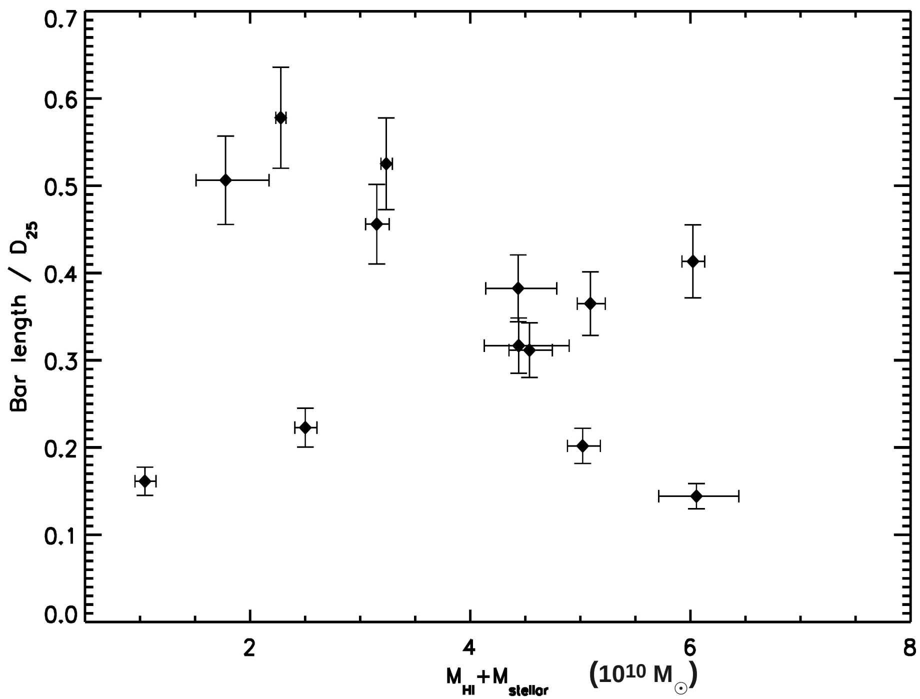


Honey et al. 2016

Do they show any relation with gas mass fraction & total mass ?



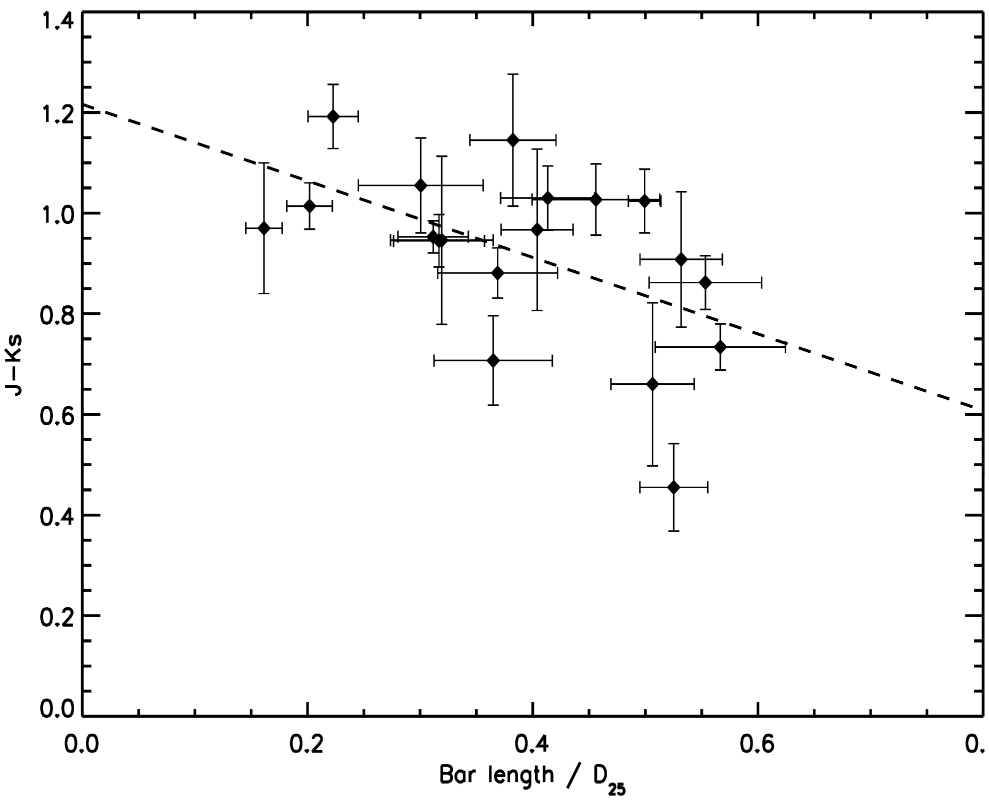




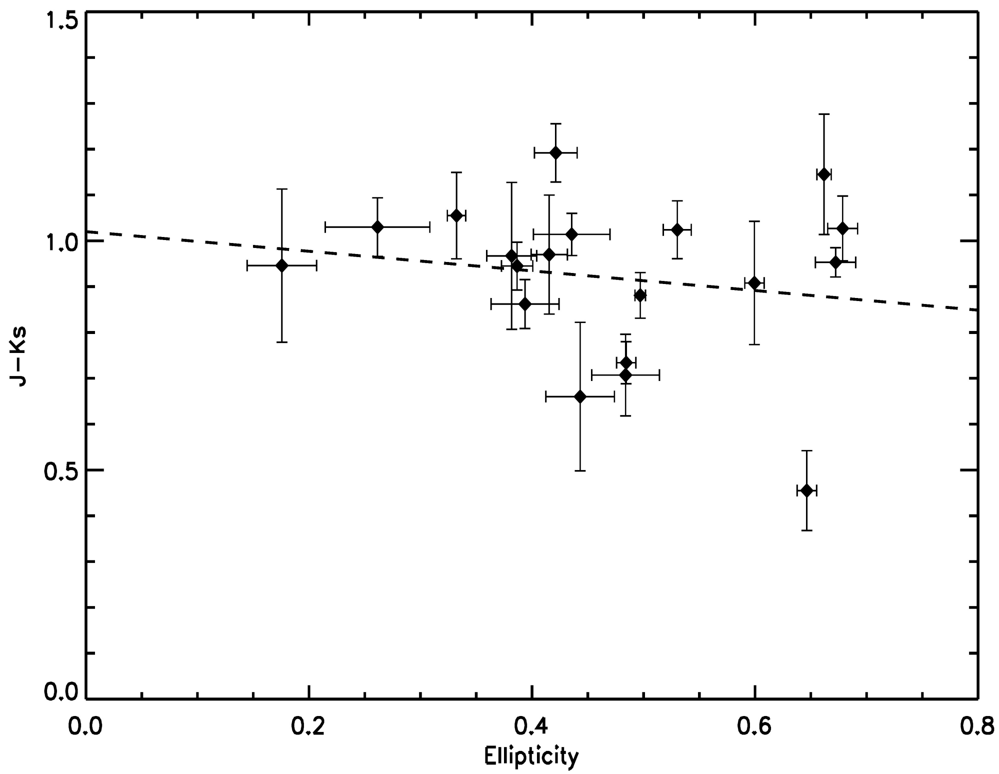
No strong correlation

Honey et al. 2016

J-K $_S$ color vary with bar parameters ?

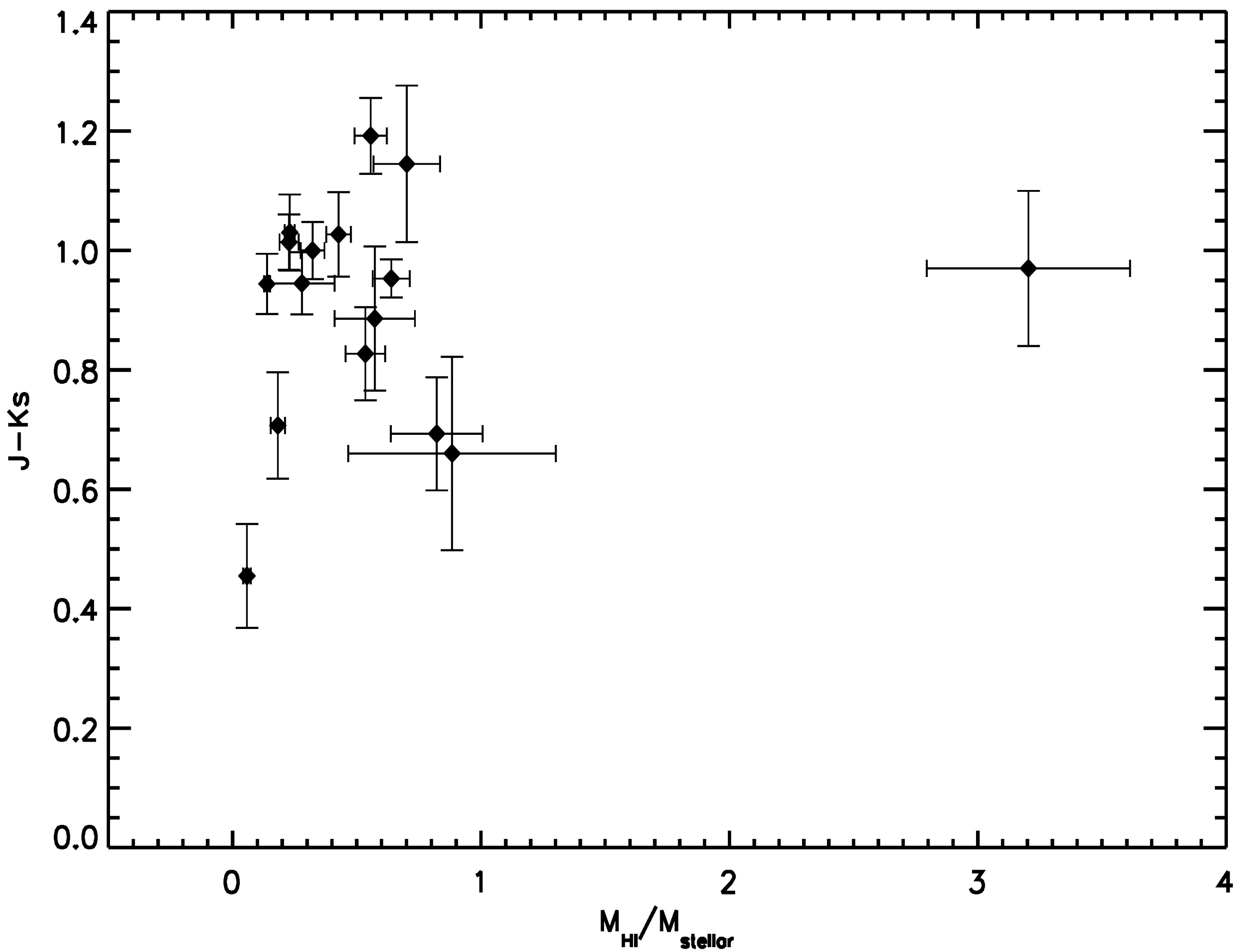


Weakly correlated



Honey et al. 2016

J-Ks color depends gas fraction ?



No correlation

Honey et al. 2016

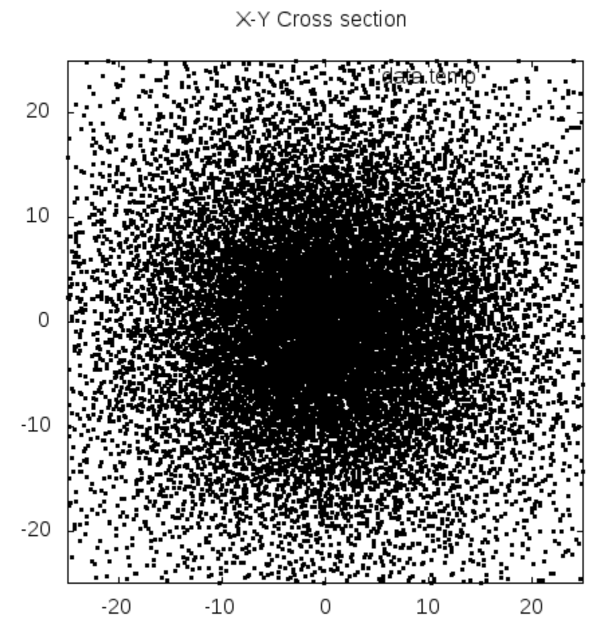
Conclusions from our NIR observations of bars in LSB galaxies

- Fraction of barred candidates in the dark matter dominated LSB galaxies is very small (~ 8.3%)
- The bar parameters have a range of values that are similar to those found in normal galaxies, it clearly show that halo dominated galaxies can host strong bars.
- The J-K_s images are not showing significant color variation between the bar and bulge regions, indicates that they have similar stellar populations.
- The bar parameters are not showing any correlation with the gas mass fraction and total baryonic mass
- Color plots showing weak correlation with bar parameters where as not showing any relation with gas mass fraction, suggesting that star formation triggered by the bar is only to local scale and not on the global disc scale.

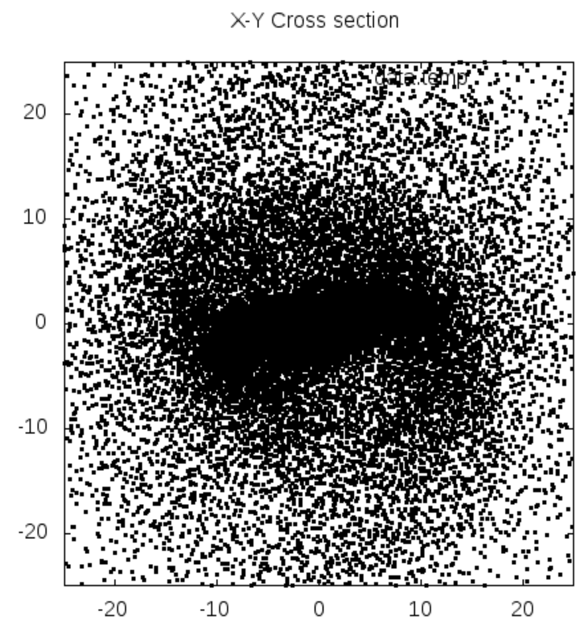
Comparing Observations with Simulations

- Early simulations of halo dominated LSB galaxies have shown that they are usually stable against bar formation but if bars do form, they are smaller than those found in normal galaxies (Mihos. etal. 1997; Wadsley. et al. 2004). The lower fraction of barred LSB galaxies obtained in our sample selection supports these early simulations.
- But our observations clearly show that halo dominated galaxies can host strong bars
- This suggests that it is not just the halo mass that determines whether a bar can form, other parameters such as the halo angular momentum, halo shape and disc surface density can influence bar formation and determine the bar strength and shape (Athanassoula. et al. 2013, Saha. et al. 2013, Kataria & Das 2017).

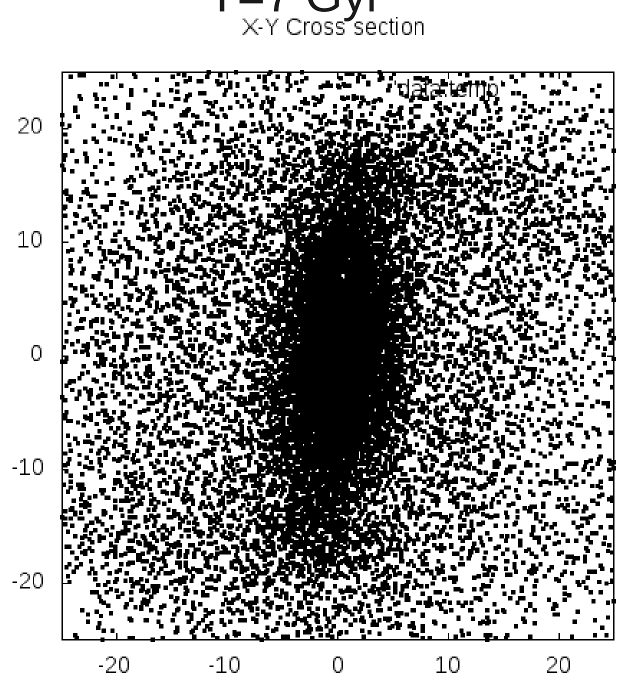
T=0 Gyr



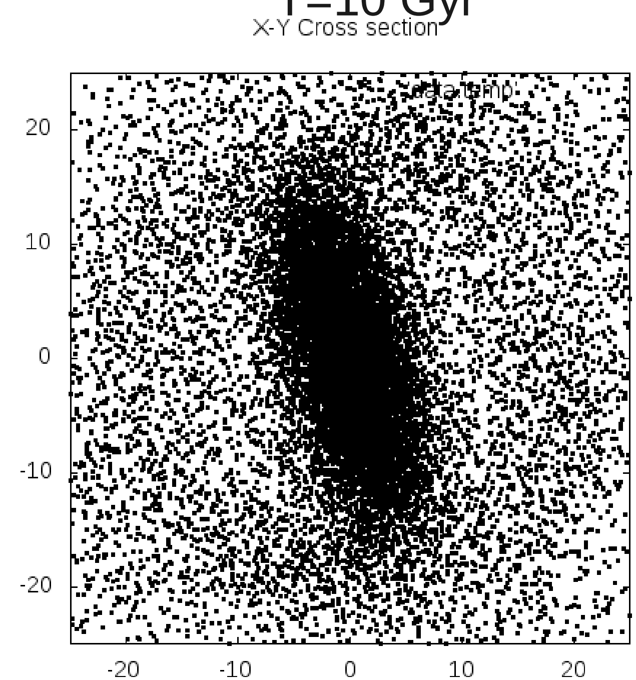
T=3.5 Gyr



T=7 Gyr



T=10 Gyr



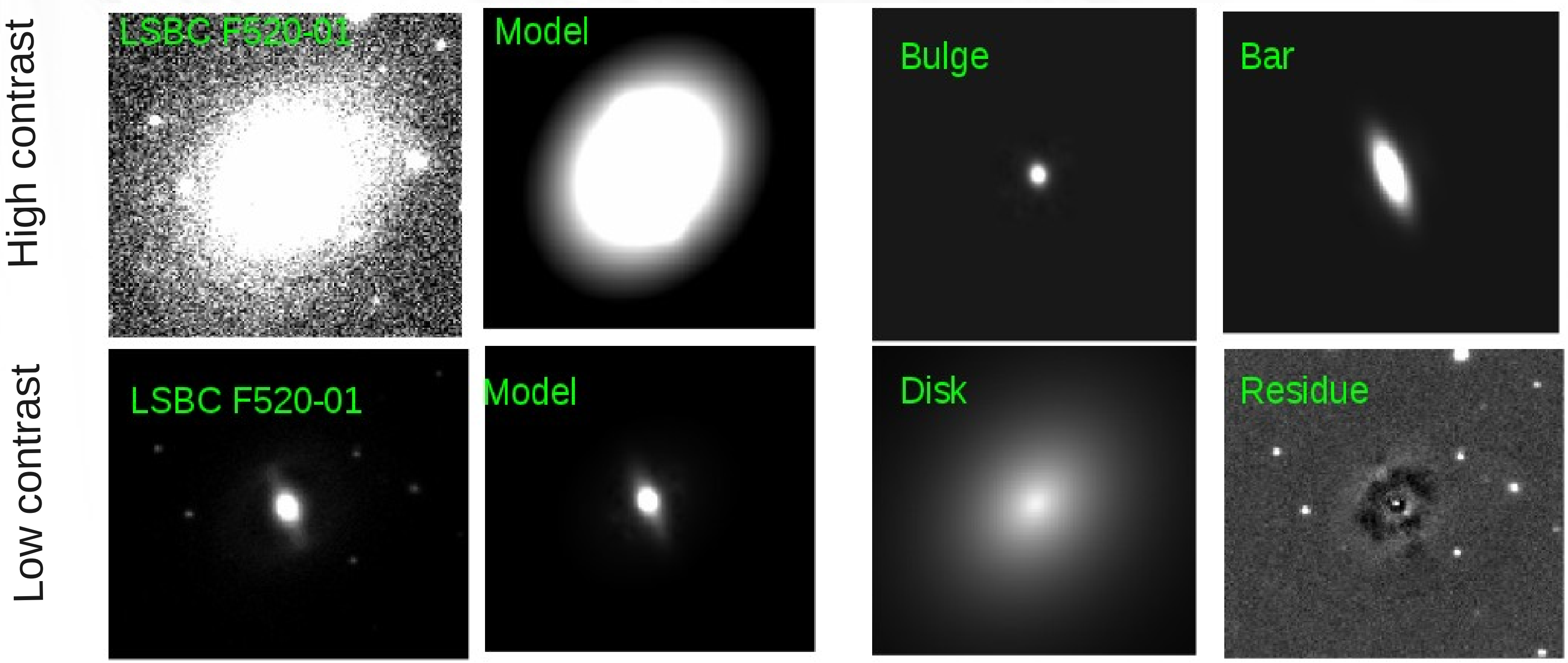
10^5 star particles and 10^6 halo particles, Halo profile is hernquist and disk has exponential profile. (Mass_disk/Mass_Totat)=10% .

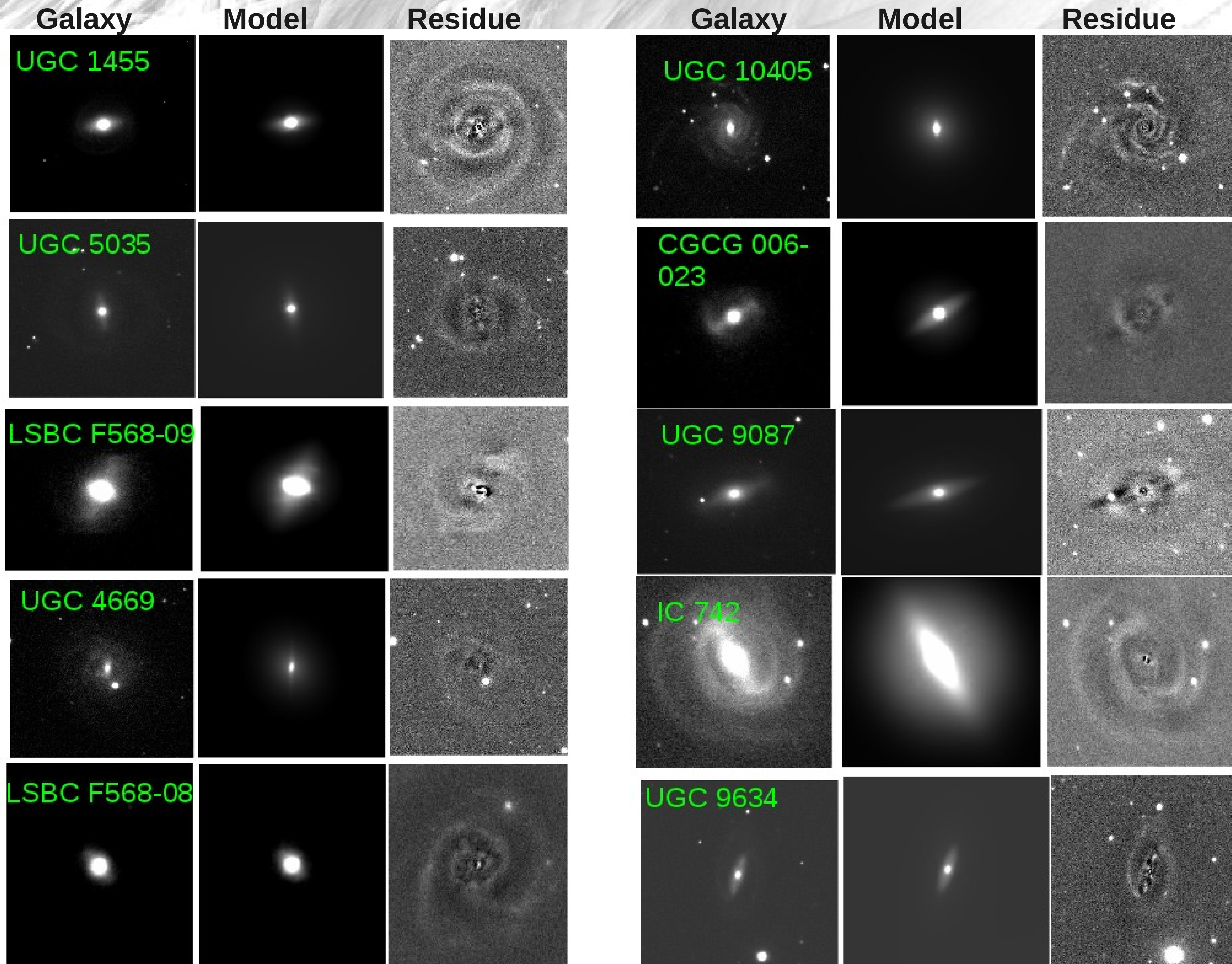
Kataria & Das 2017

Searching for secular evolution in barred LSB galaxies

2-Dimensional decomposition of optical images of barred LSB galaxies using GALFIT

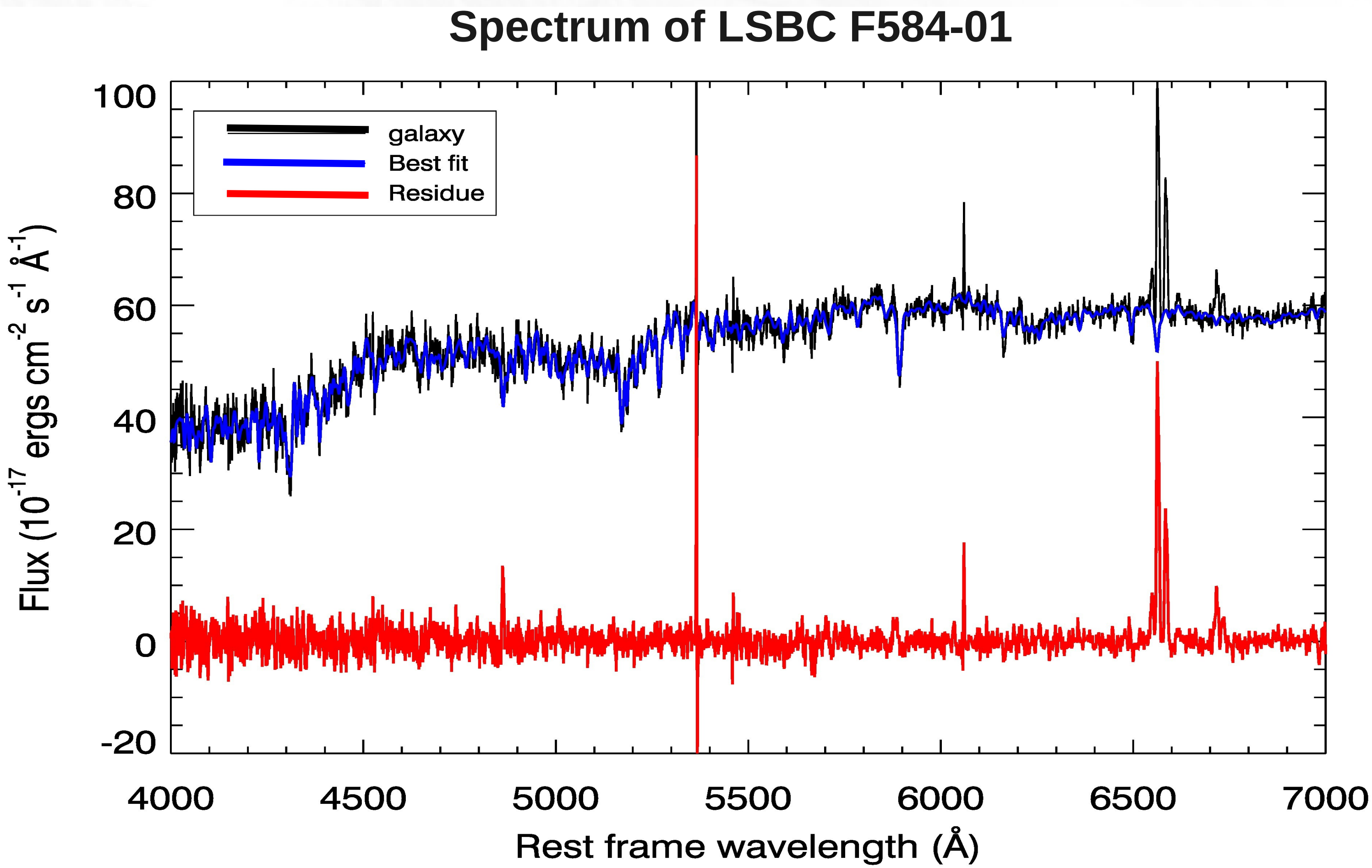
- Do the bars play an effective role in increasing the bulge velocity dispersion (which is related to the central mass concentration)?
- SDSS DR12 I-band images are used
- Image decomposition is done using GALFIT (Peng et al. 2010)



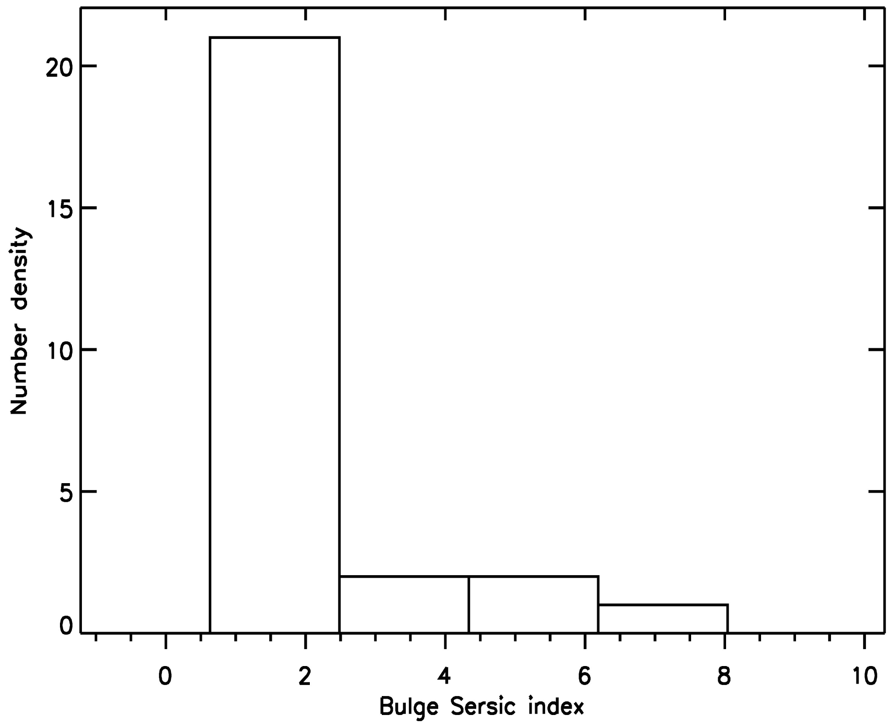

Galaxy
Model
Residue
Galaxy
Model
Residue
UGC 1455
UGC 10405
UGC 5035
CGCG 006-023
LSBC F568-09
UGC 9087
UGC 4669
IC 742
LSBC F568-08
UGC 9634

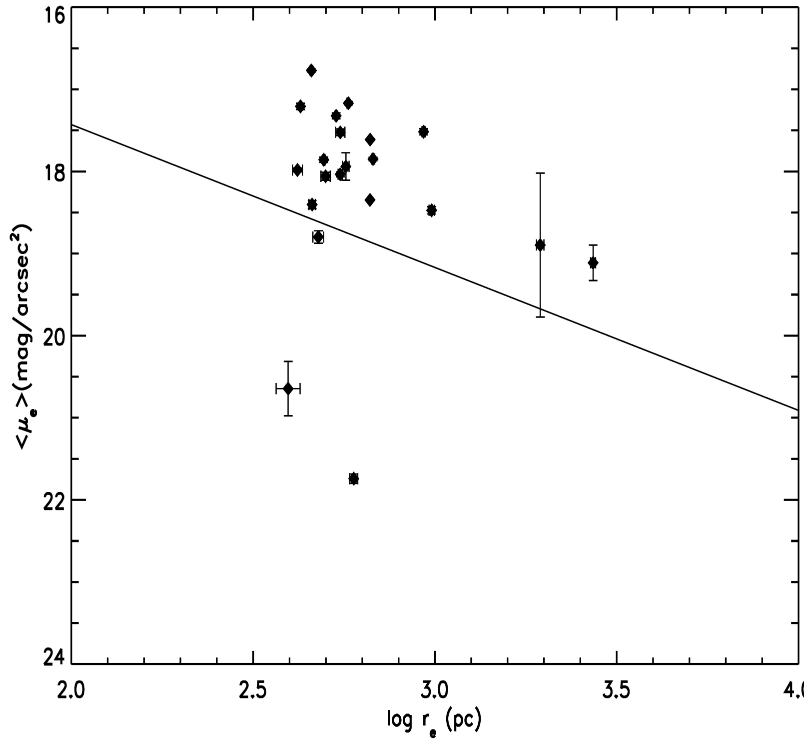
Central velocity dispersion from decomposition of nuclear spectra

- Data : SDSS DR12 spectra
- Code : pPXF for spectral decomposition (Cappellari M., & Emsellem E., 2004)
- Corrected for bulge effective radius and and calculated the bulge velocity dispersion



Nature of bulges in barred LSB galaxies

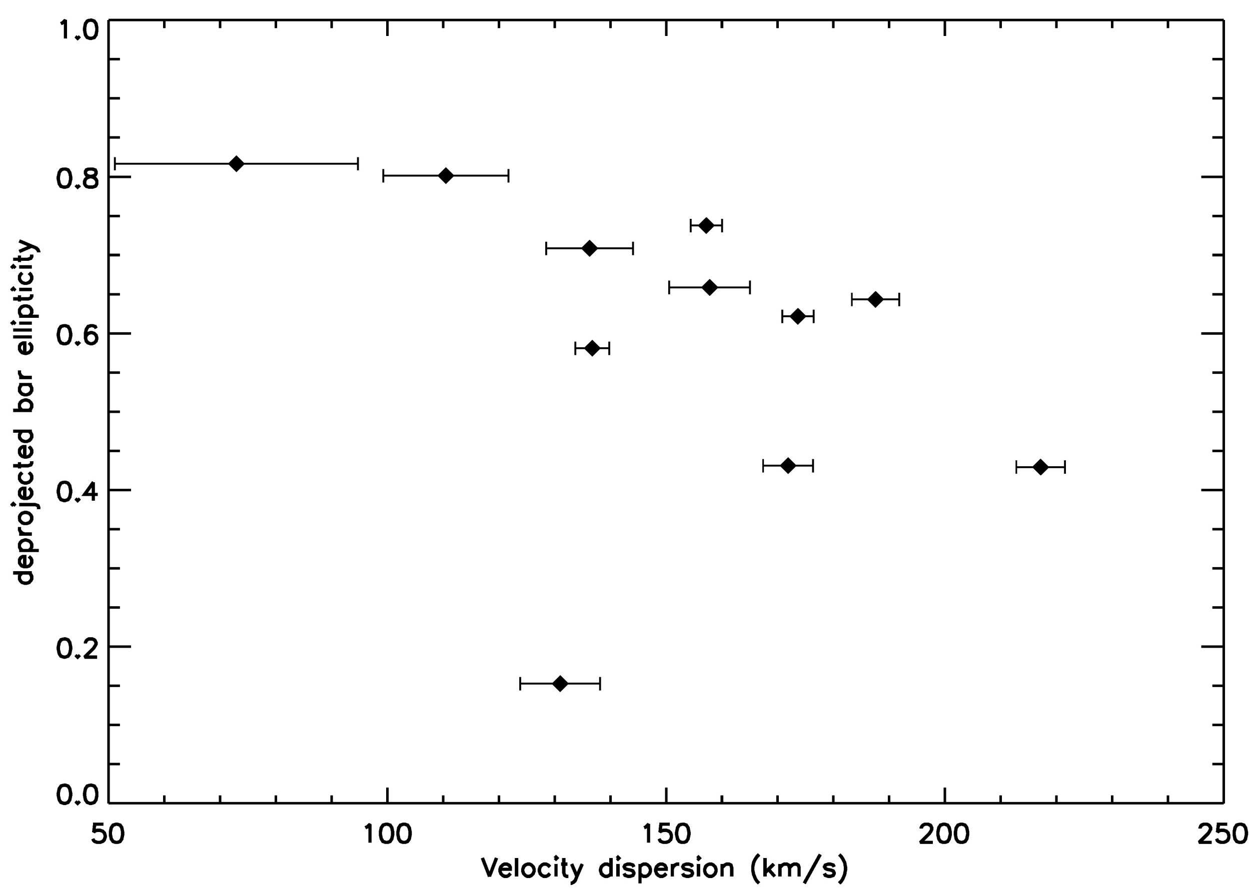




- Sersic index lies between 1-2
- But according to Fundamental plane (Kormendy relation) the bulges are classical.

Honey & Das, 2017, In preparation

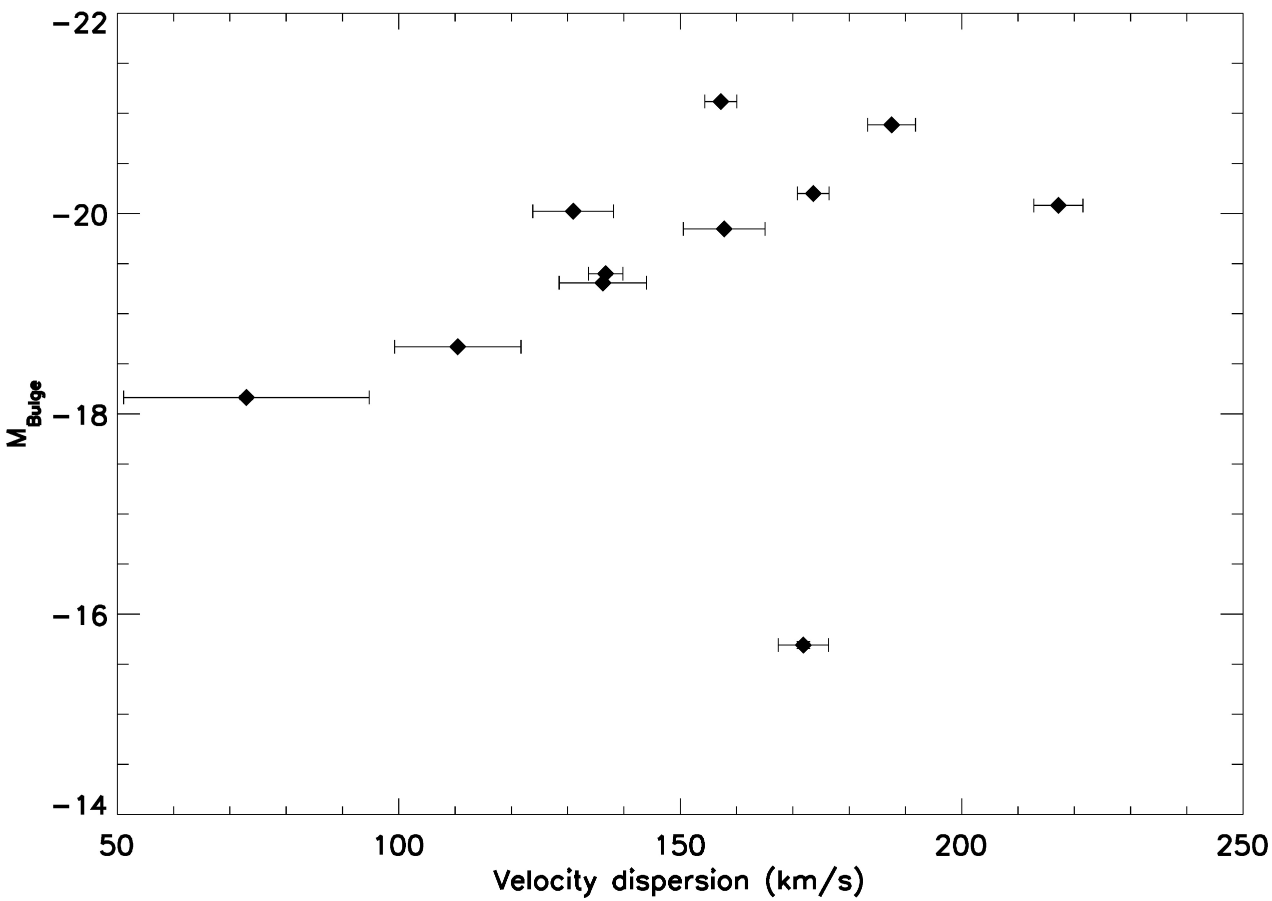
Bar ellipticity Vs Bulge velocity dispersion



• A trend of decreasing bar ellipticity with increasing bulge velocity dispersion

Honey & Das, 2017, in preparation

Bulge magnitude Vs velocity dispersion



Brighter Bulges have larger velocity dispersions

Honey & Das, 2017, In preparation

Results from optical study

- Most of them have bulges with sersic index lies between 1-2, but fundamental plane relations show that they are classical in nature.
- They are not showing the signatures of secular evolution
- The deprojected ellipticity and bulge magnitude are correlated with bulge velocity dispersion.

Summary

- Halo dominated galaxies can host strong bars.
- LSB galaxies have bars that are similar in ellipticity and bar length to normal galaxies.
- Their bulges are mainly classical, do not show signatures of secular evolution