Morphology of local Luminous InfraRed Galaxies (LIRGs)

Alexandros Psychogyios[1,2]

V. Charmandaris[1,2], L. Armus[3], T. Diaz-Santos[4]

(1) Department of Physics, University of Crete, Greece
(2) National Observatory of Athens, Greece
(3) SSC/Caltech, USA
(4) Diego Portales University, Santiago, Chile

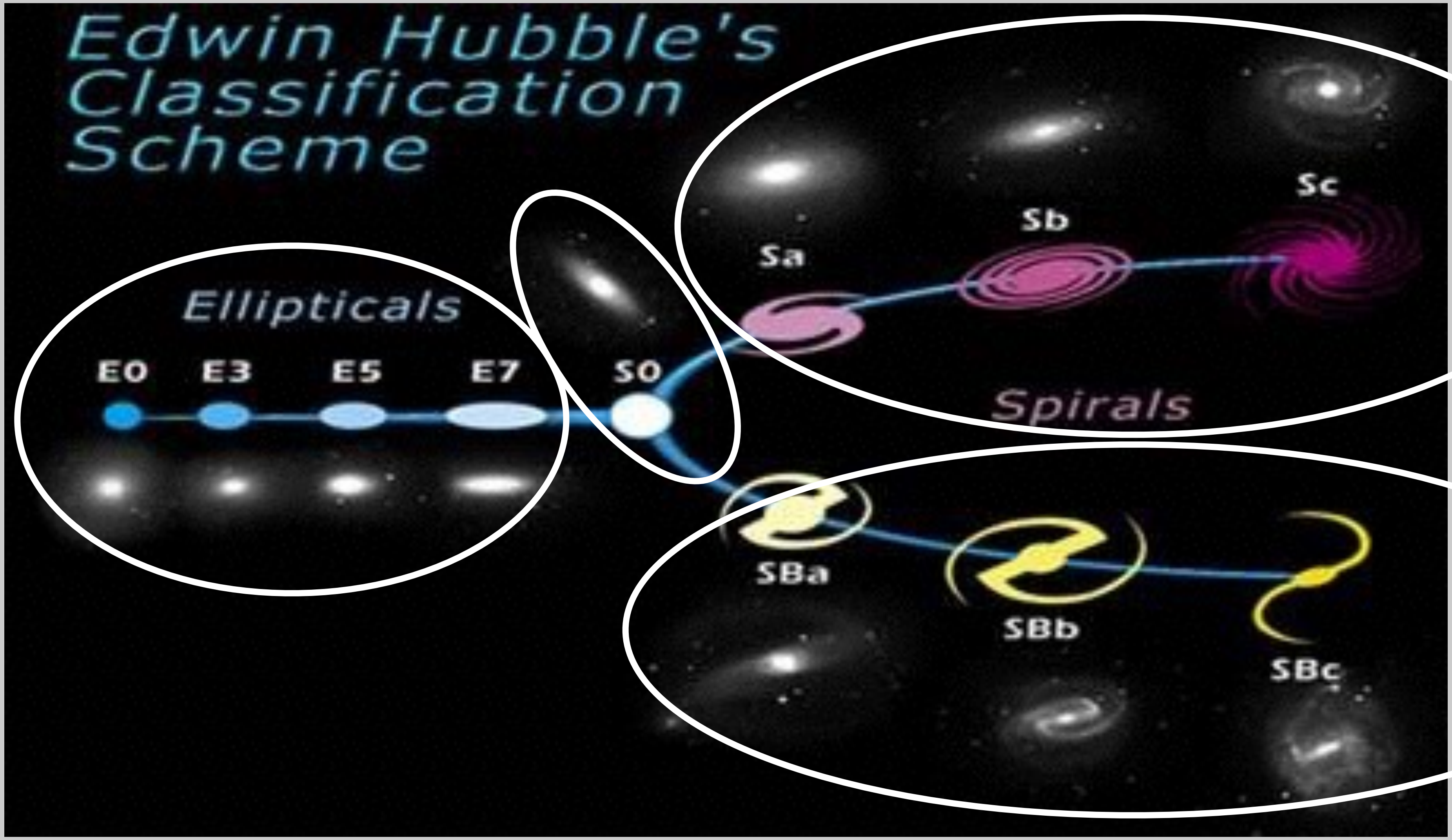
Psychogyios et al. 2016 , A&A 591, A116 (2016)

Content

- introduction
- analysis
- results
- summary

Historical overview

- 18th century : William Herschel search for 'nebulae'.
- 1888 : Issac Roberts (nebular photography)
- Hubble (1926) "Hubble tuning fork"



- Sandage, De Vaucouleurs, van den Bergh (tuning fork revision)

Introduction

extragalactic studies

how matter in the universe assembled into the structures

↓

study the formation and evolution of galaxies

(luminous beacons of the baryon content of the Universe)

why morphology

strongly related with $M_\star$ and *SFH* of galaxies.

property key to unveil the evolution of galaxies.

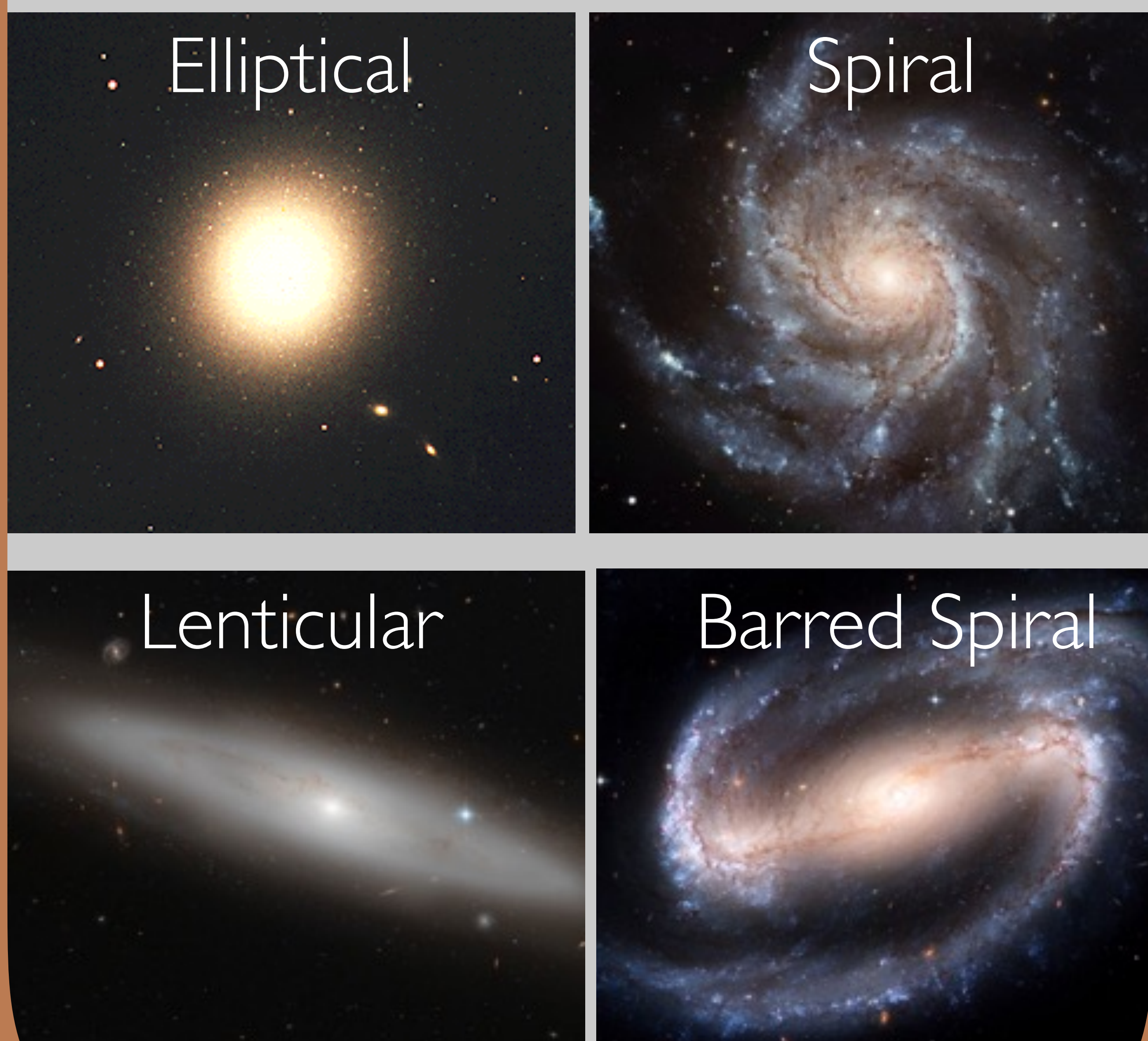
what is morphology

describes how the galaxy's electromagnetic emission,
as it is projected along the line of sight and at a specific wavelength,
is distributed on an image.

Introduction

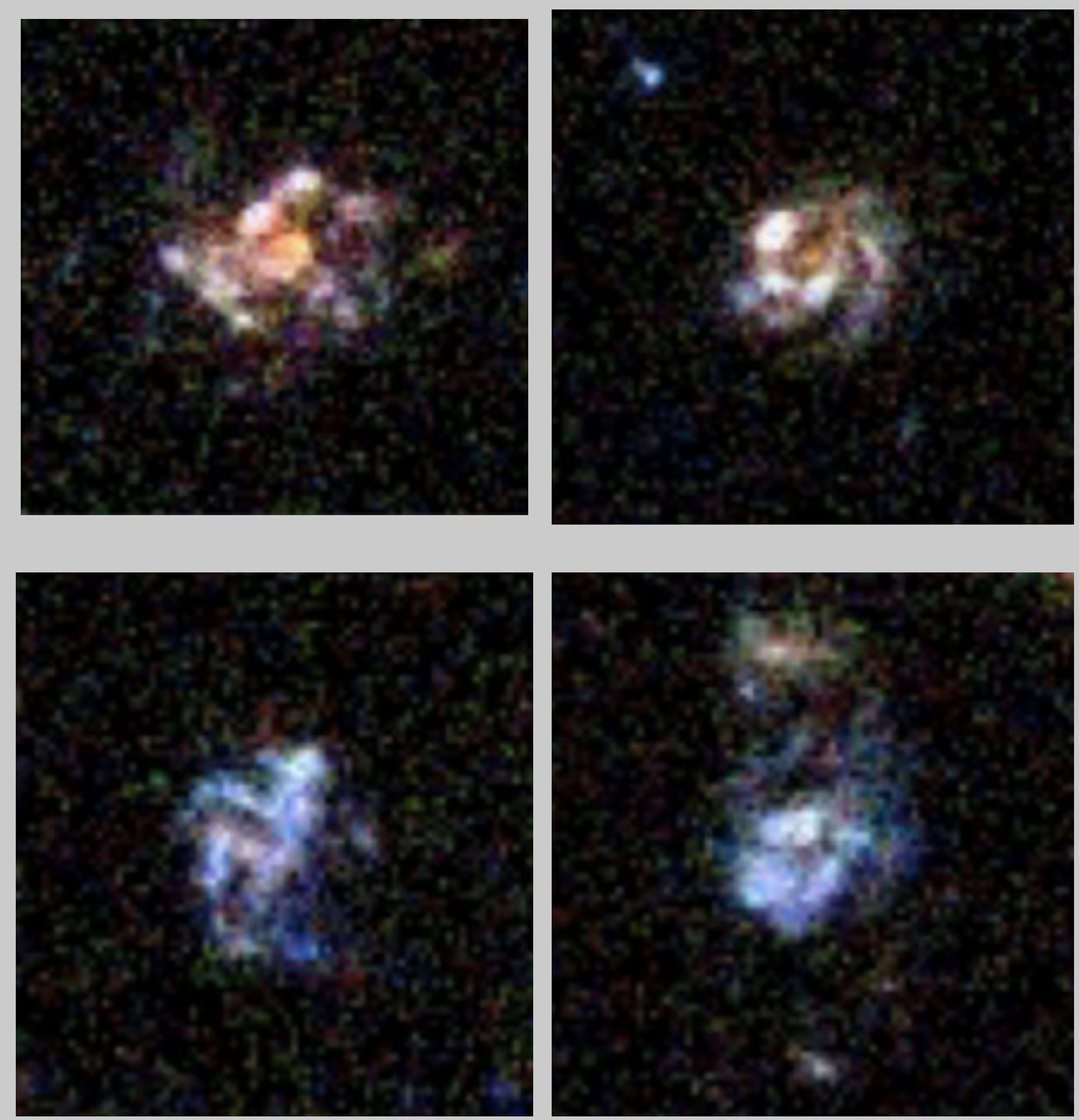
local Universe

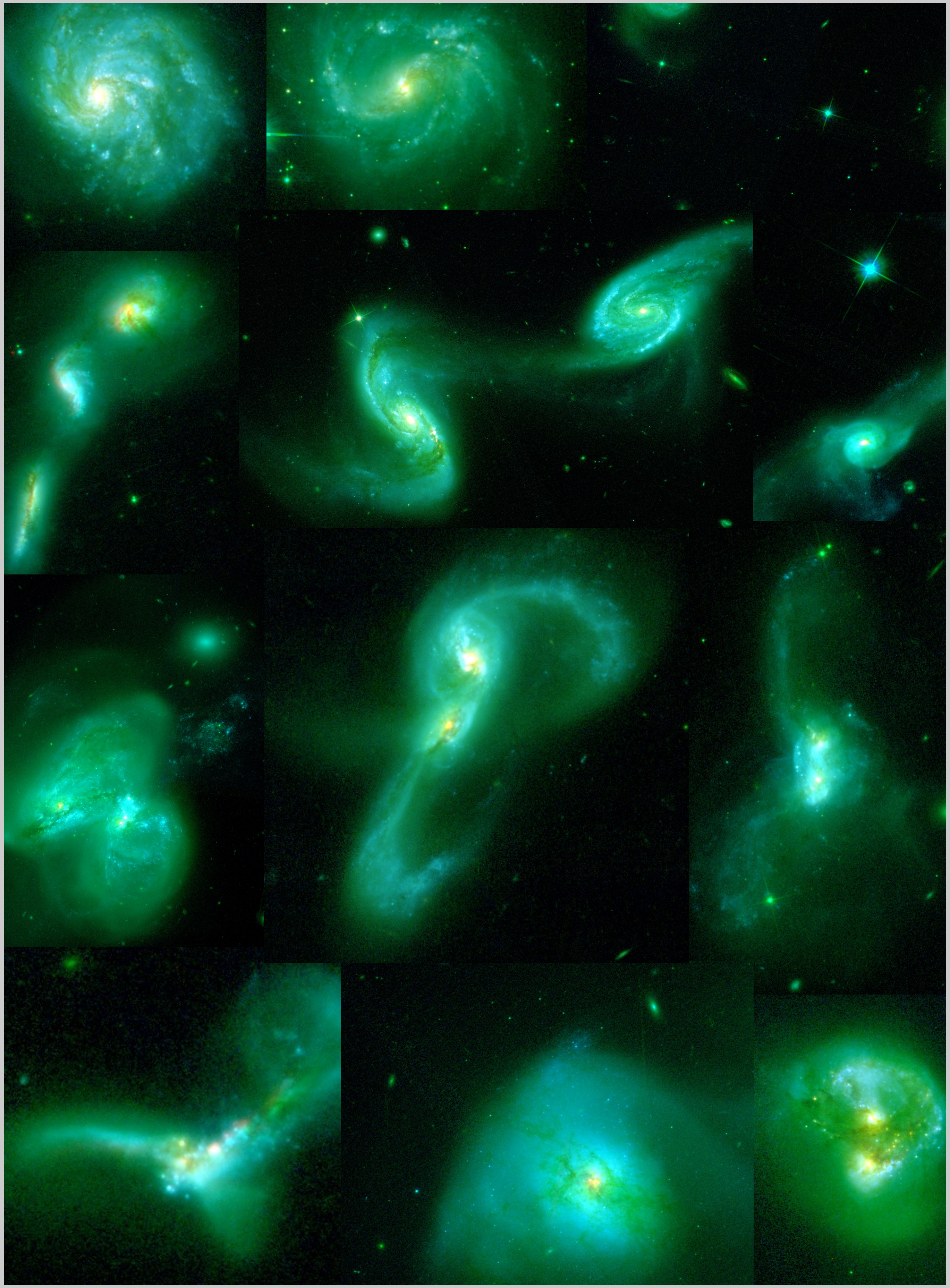
(Hubble Tuning-fork)



high-z Universe

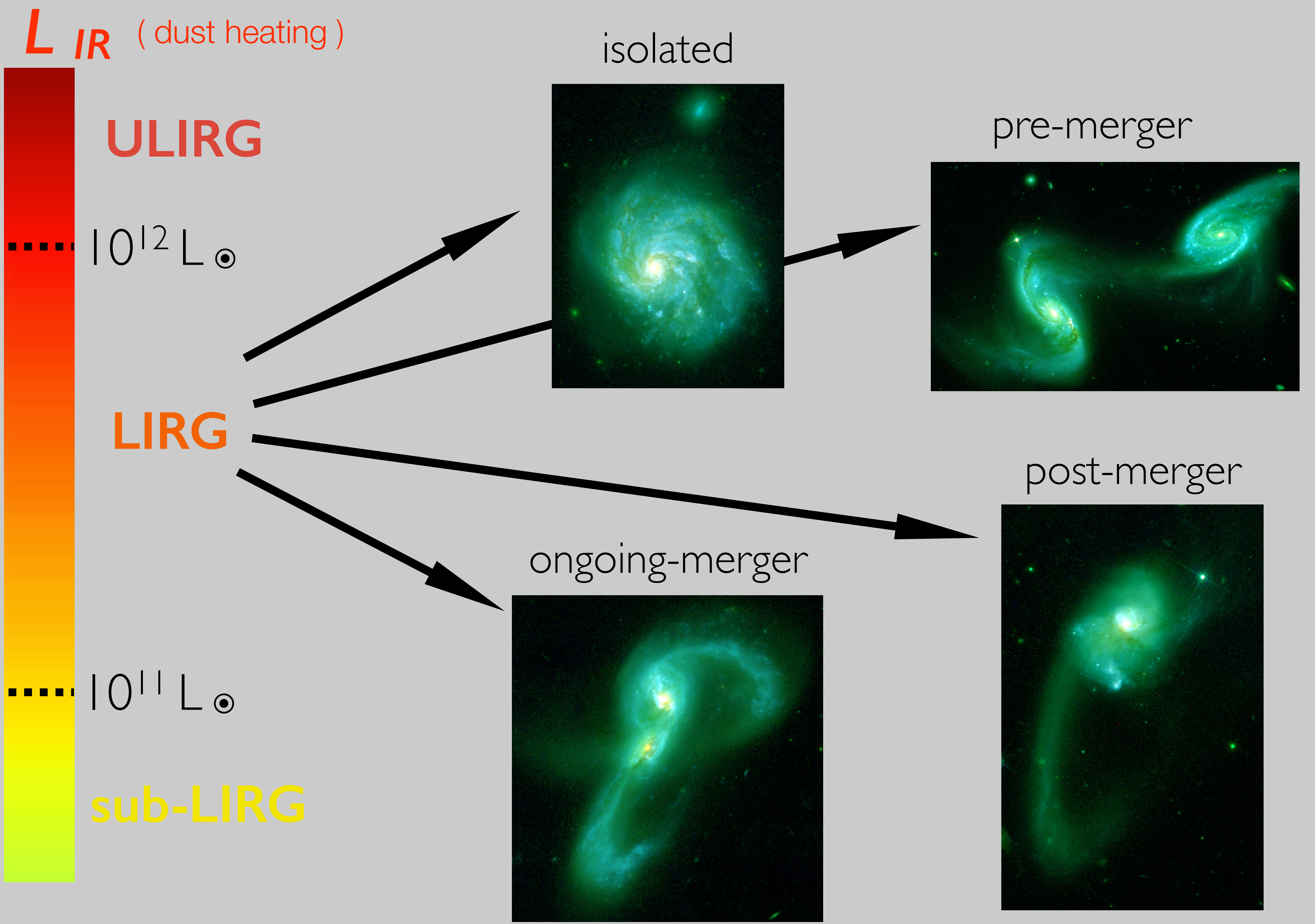
irregular shapes





(U)LIRGs

- Emit in the FIR spectrum (Sanders & Mirabel 1996)
- Dominate the SFRD at z ~ 1 and at z ~ 2 (peak of galaxy assembly) Magnelli et al. 2013, Le Floc'h et al. 2005
- Strongly related to the formation of massive ellipticals (Hopkins et al.2009)
- Rare in local Universe but thousand times more common at high-z.


L IR (dust heating)
ULIRG
10^12 L⊙
LIRG
10^11 L⊙
sub-LIRG
isolated
pre-merger
post-merger
ongoing-merger

Quantify Morphology

Visual classification

i.e. Galaxy Zoo

Automatic
(coefficients)

parametric
(analytic function)

Sersic function (Sersic 1963)

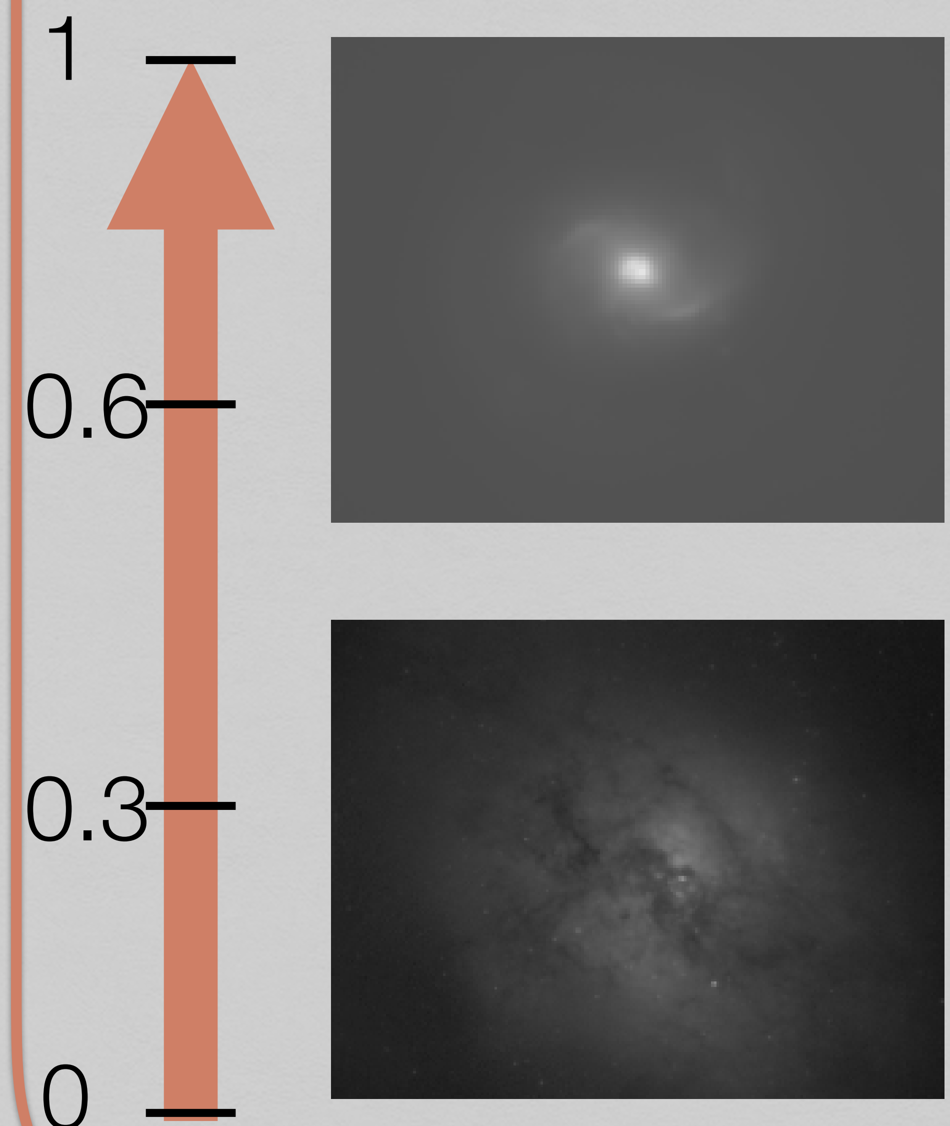
non-parametric

CAS (Conselice 2003)
Gini (Abraham et al 2003)
$\mathbf{M_{20}}$ (Lotz et al. 2004)

Interpreting non-parametric coefficients

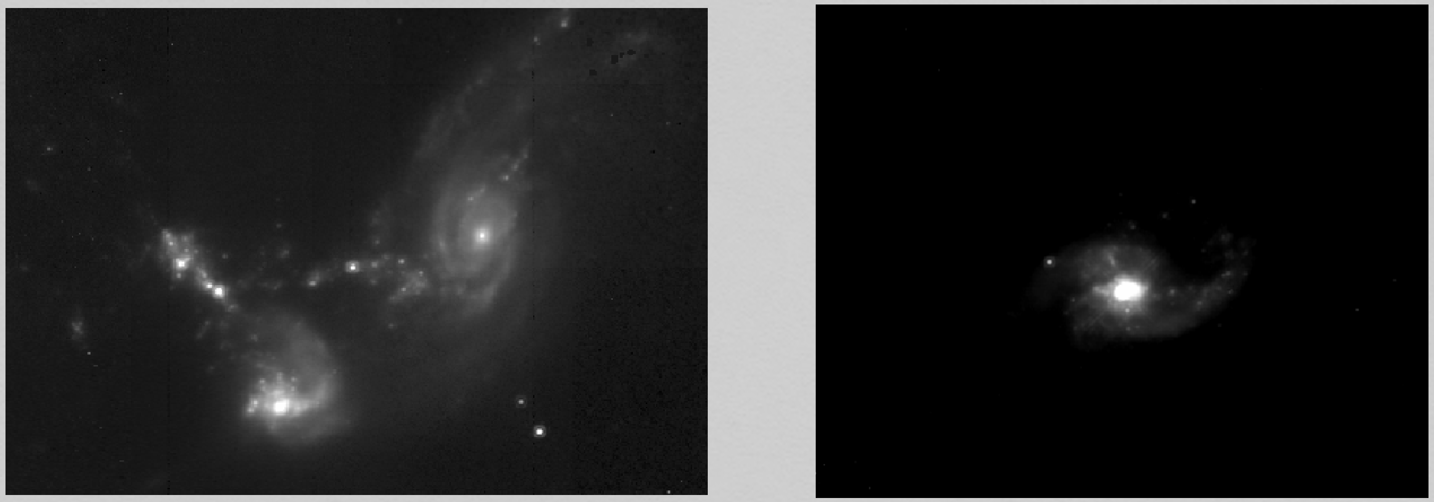
Gini

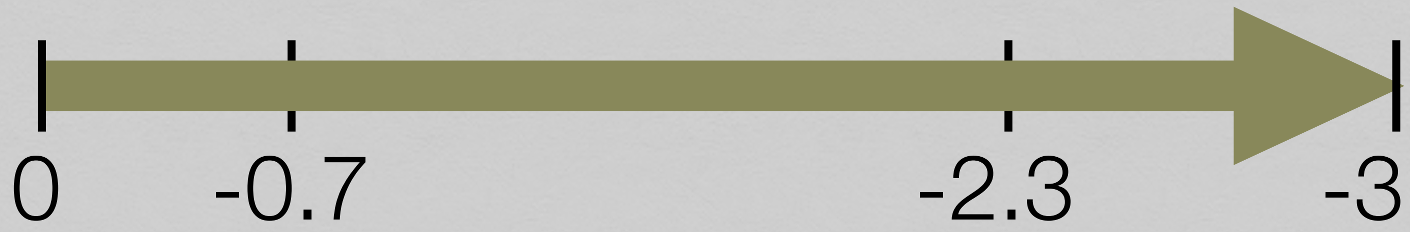
indicates the relative distribution of galaxy pixels



M_{20}

traces the spatial distribution of any bright region





Sample

89 galaxies from GOALS (Armus et al. 2009)

17 ULIRGs

65 LIRGs

7 sub-LIRGs

$0.009 < z < 0.088$

B,I and H-band ***HST***

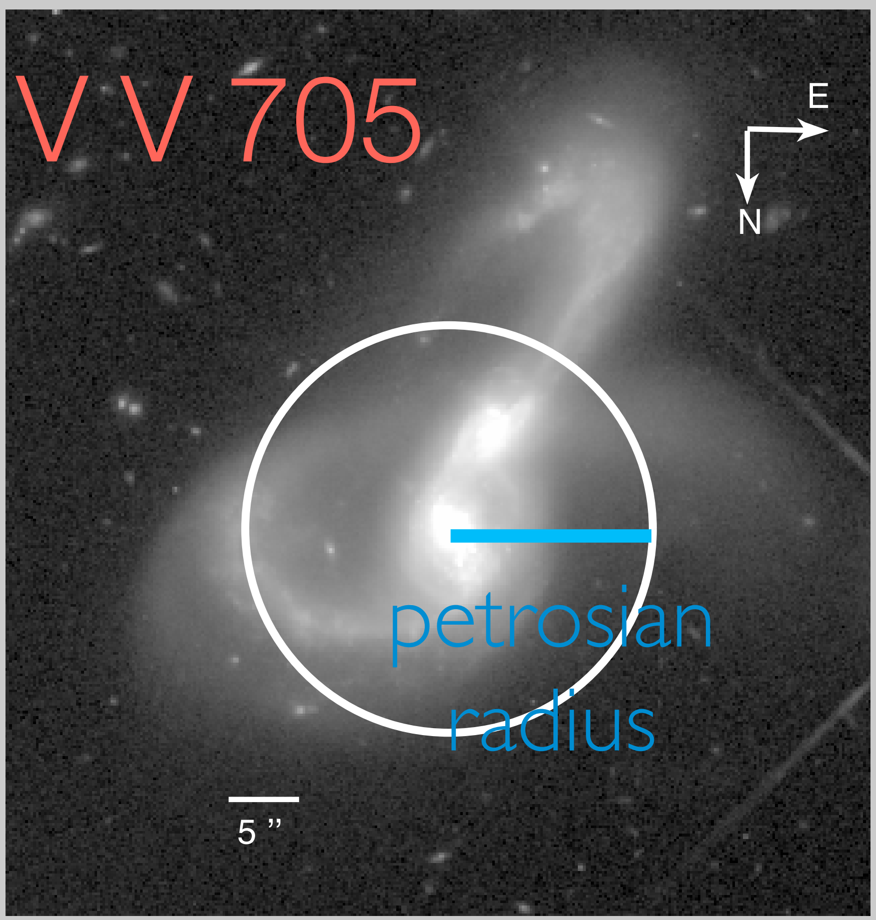
5.8μm IRAC ***Spitzer***

Method

constructing the segmentation map of a LIRG

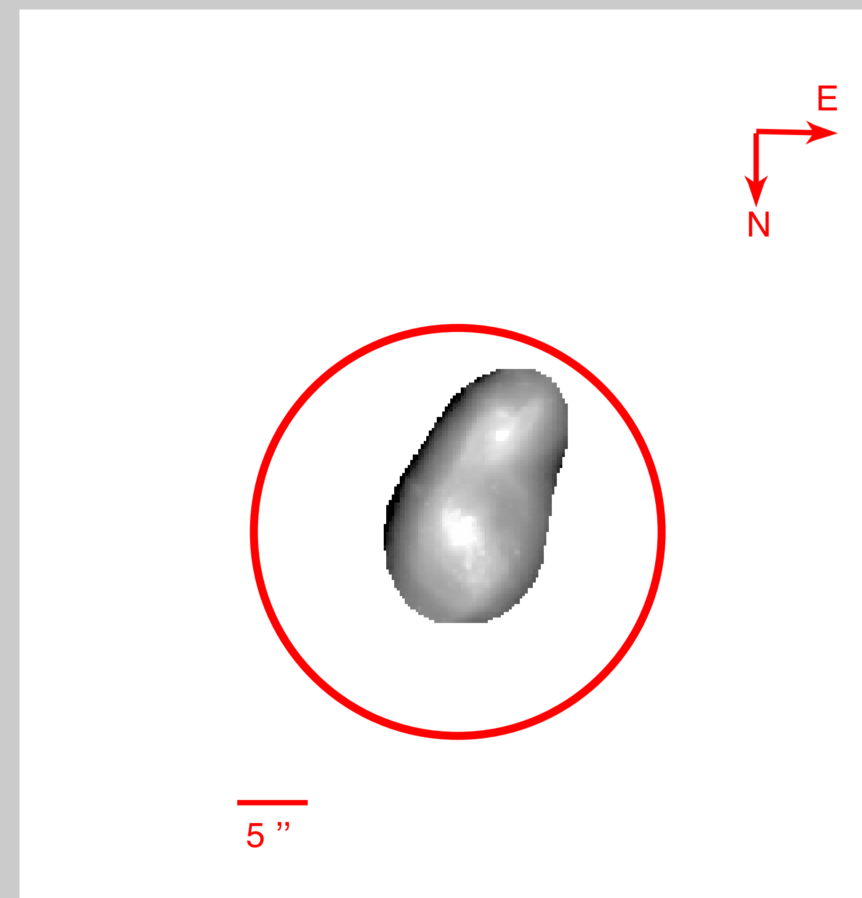
Petrosian : $sb = 20\% \, sb_{circle}$

initial image



analysis

segmentation map



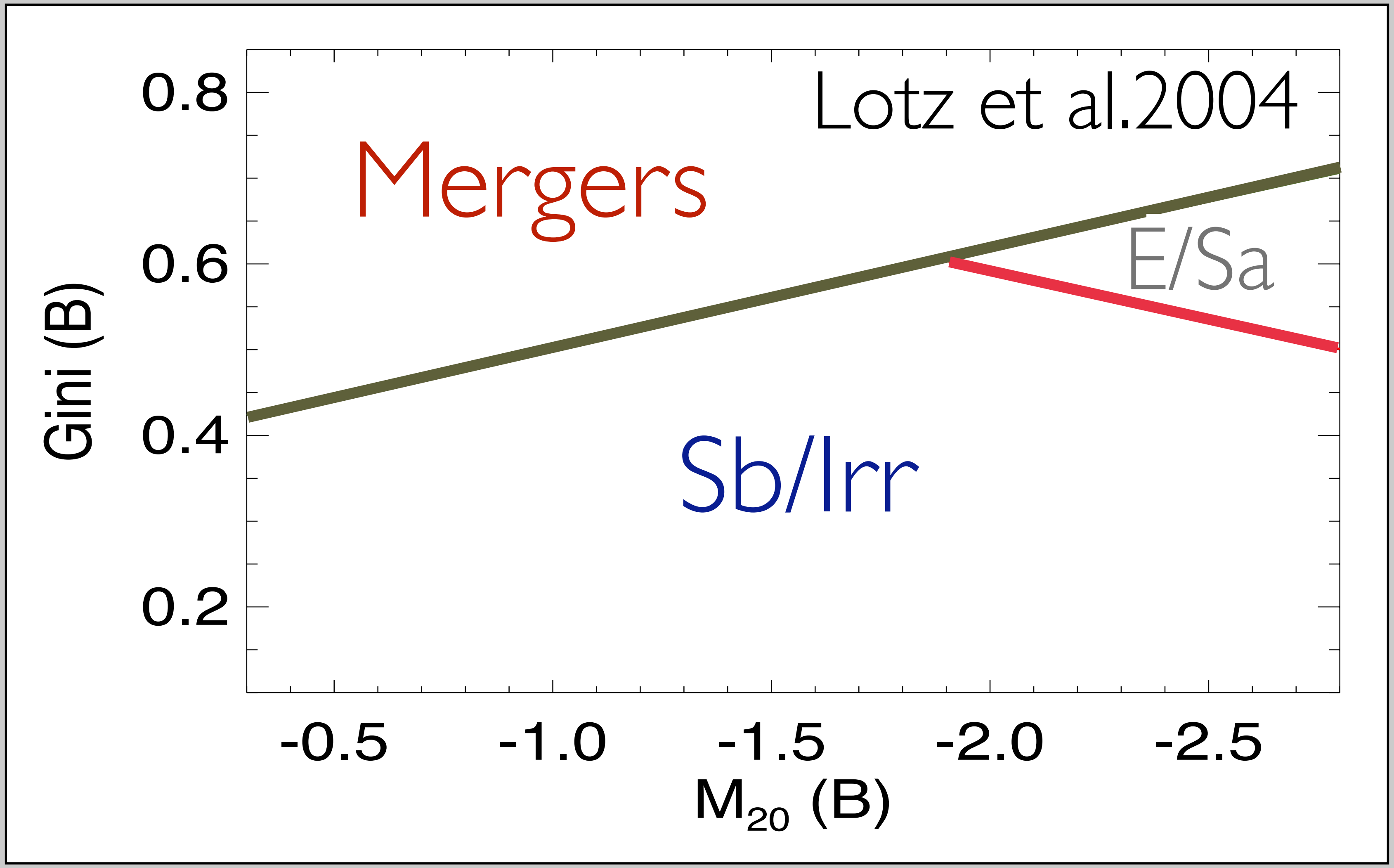
Motivation

- Quantify the morphology of local (U)LIRGs using HST optical to NIR imaging and search for clues of merging signatures via non-parametric coefficients.

- Reliability of non-parametric coefficients as a function of λ. (optical to NIR)

- Exploring correlations between the morphological indicators and properties of galaxies (sSFR).

Gini - M_{20} plane



Visual classification of our sample (Haan et al. 2011)

Expectation :

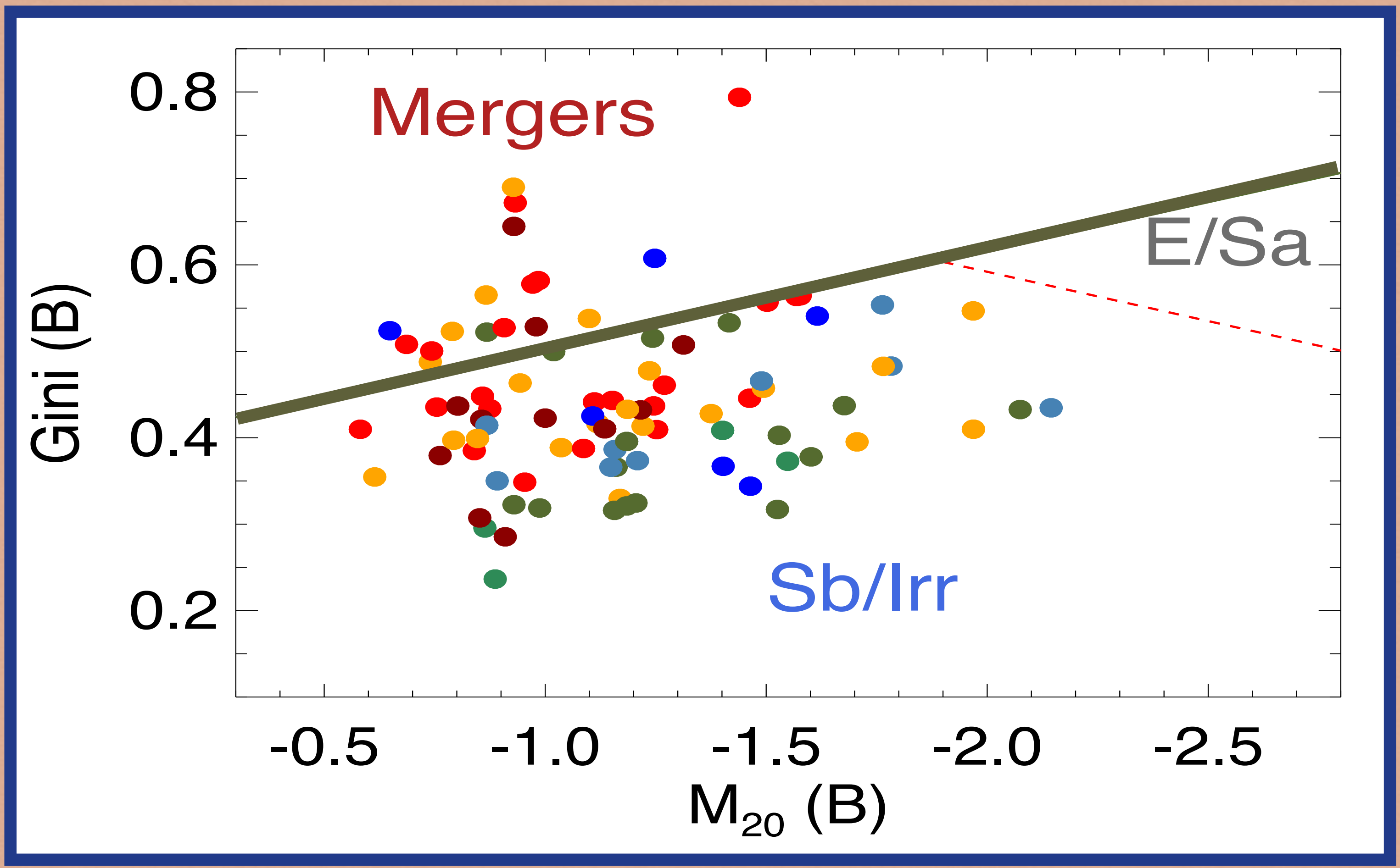
most of our galaxies should lie in the Mergers region according to their interacting morphologies

Results

Gini - M_{20} plane in B-band

more flux in fewer pixels

smooth distribution



spatially extended → compact

pre mergers

- undisturbed isolated galaxies
- distinguishable galaxies disks

on-going mergers

- separate galaxies, symmetric disks
- two nuclei in common envelope
- double nuclei plus tidal tail

post mergers

- single or obscured nucleus with long tails
- single nucleus with central morphology

B-band

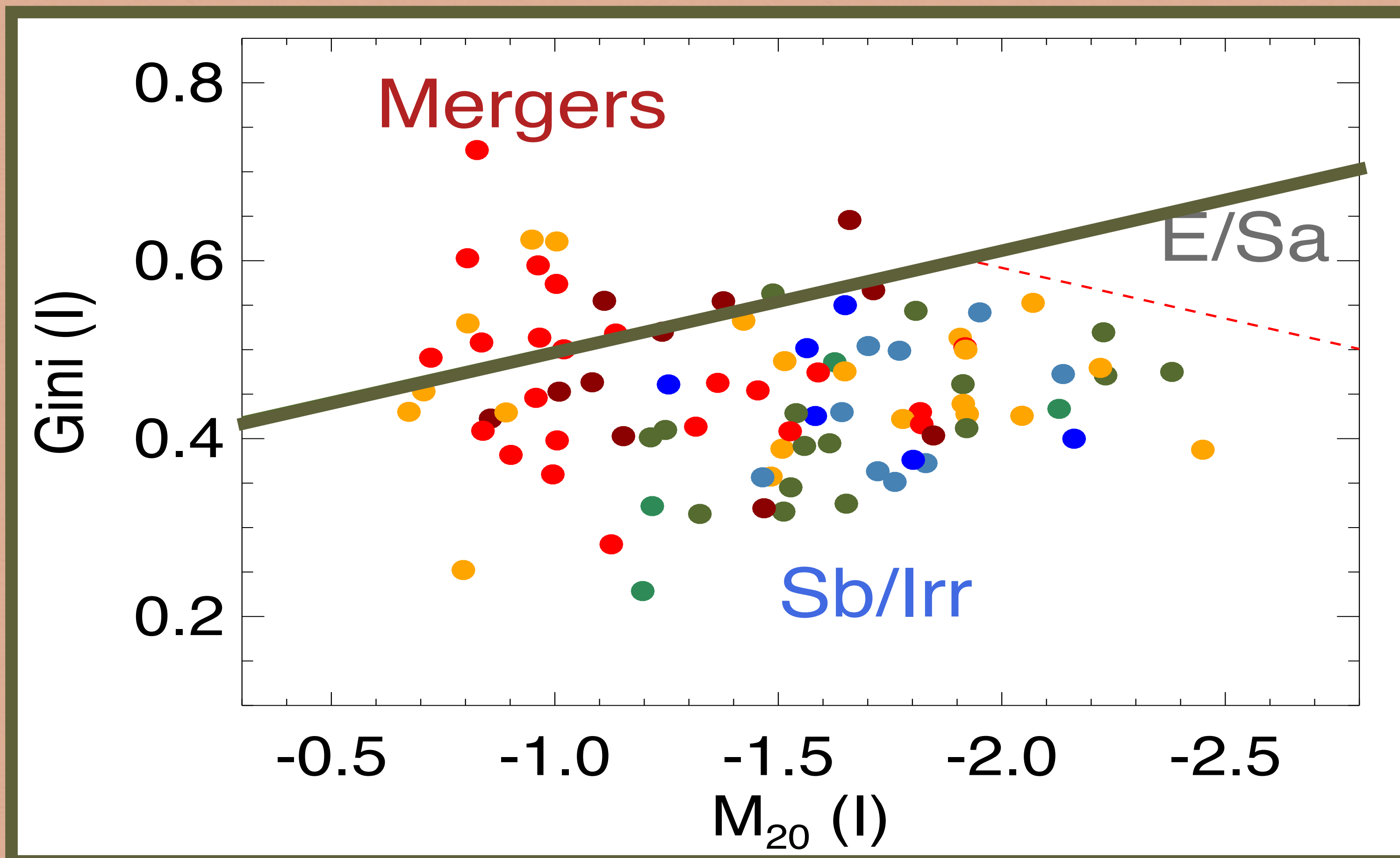
unobscured young stars
star forming regions

Most of galaxies are below the **Merger** line

Gini - M_{20} plane in I-band

more flux in fewer pixels

smooth distribution



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I-band

evolved stars

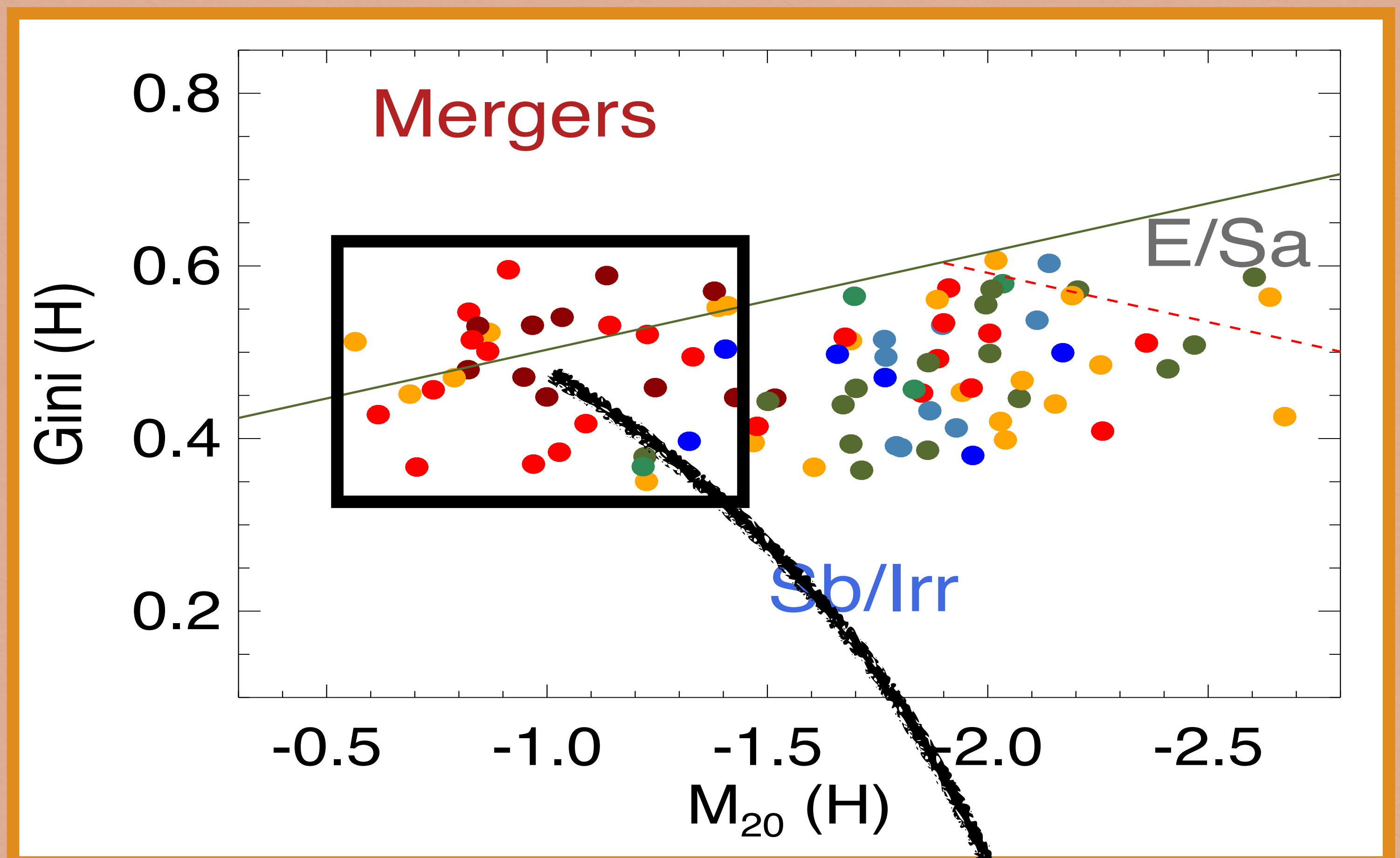
Median M_{20} ↓

some LIRGs tend towards more compact morphologies

Gini - M_{20} plane in H-band

more flux in fewer pixels

smooth distribution



pre mergers

- undisturbed isolated galaxies
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on-going mergers

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post mergers

- single or obscured nucleus with long tails
- single nucleus with central morphology

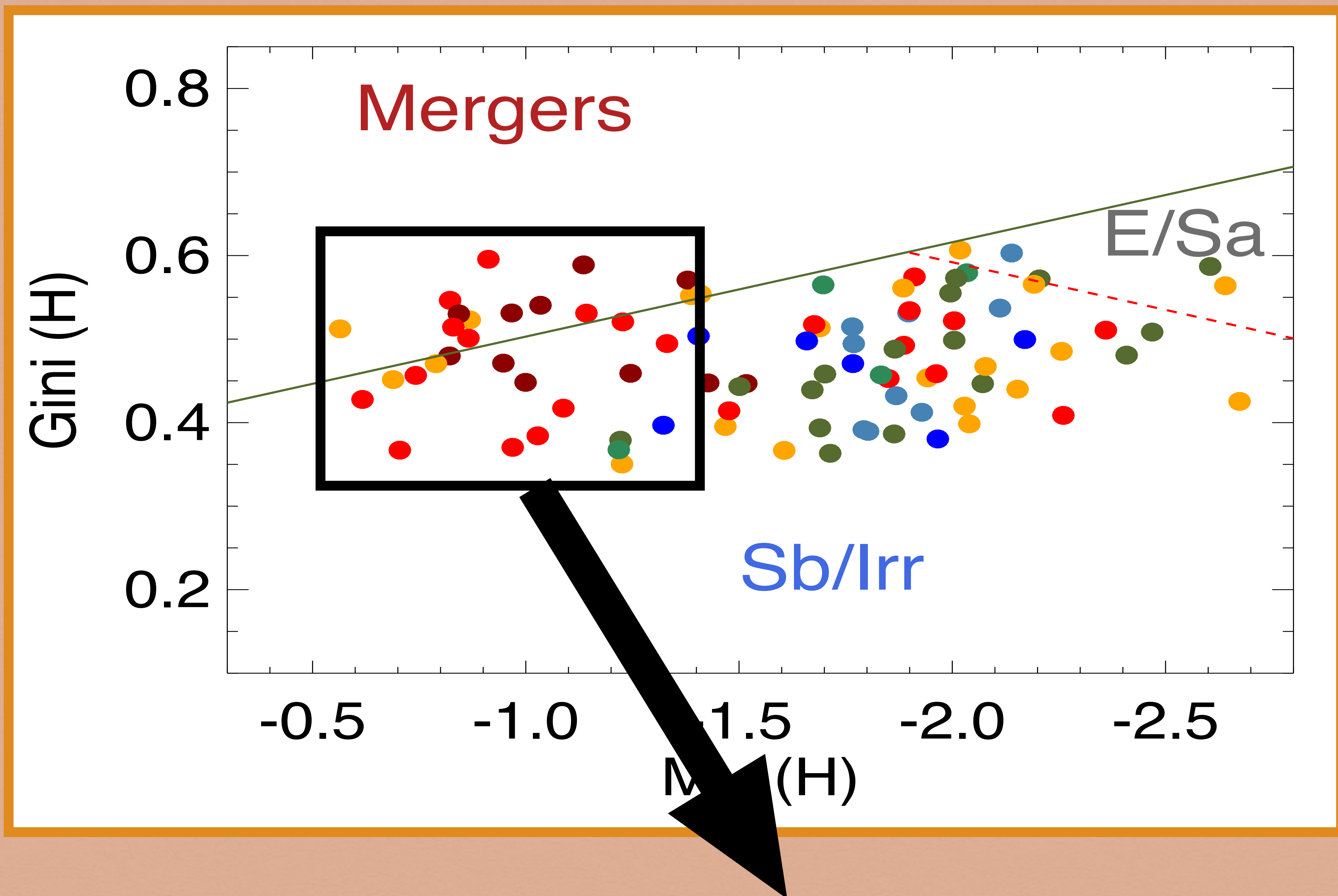
spatially extended → compact

H-band

nuclei, K stars,
not affected by dust

They lie inside the left part of Gini-M_{20} plane regardless of the band.

Gini - M_{20} plane in H-band



H-band

galaxies that undergoing
an ongoing merger event

Gini - M_{20} plane in L_{IR} bins

ULIRGs

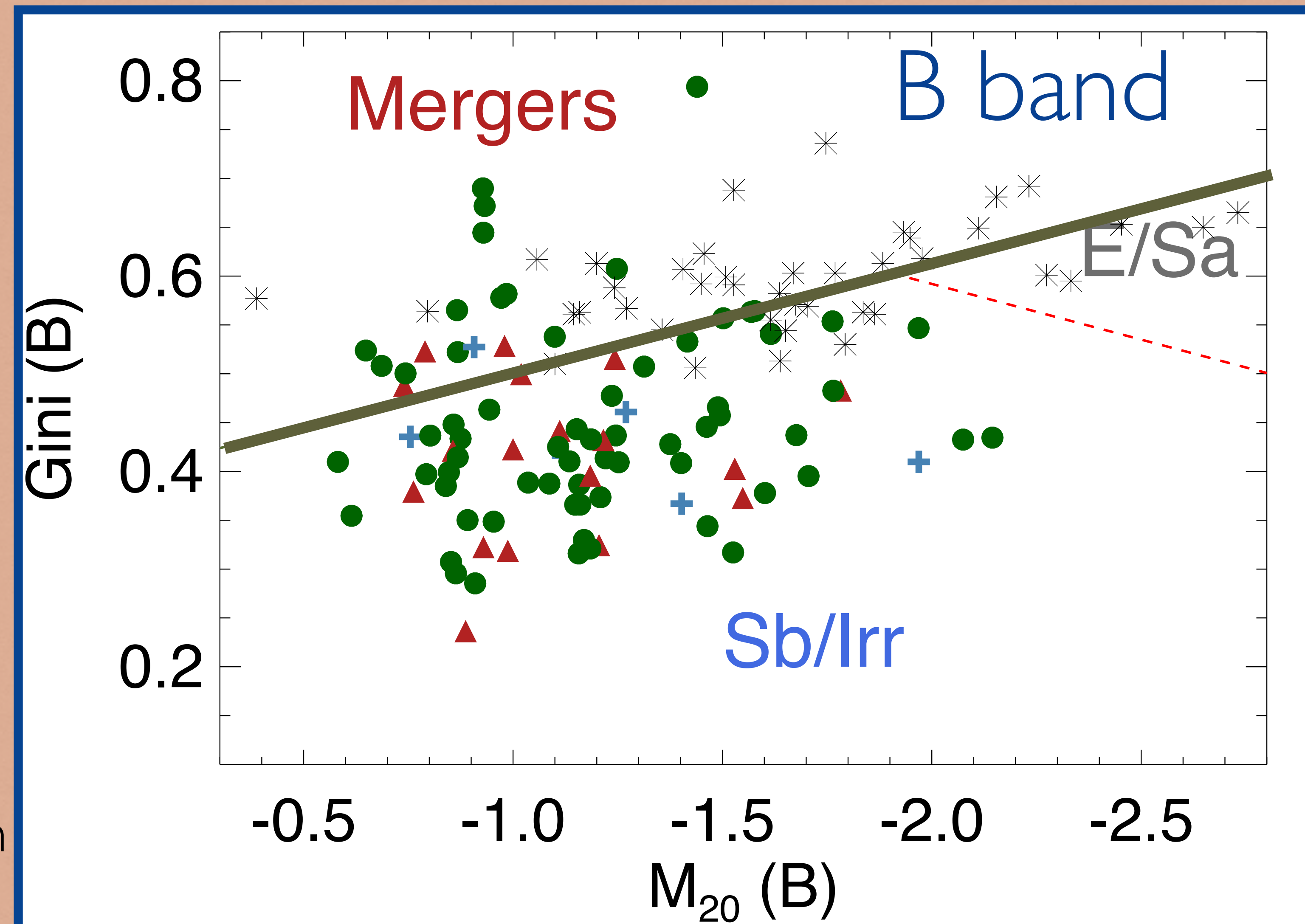
LIRGs

sub-LIRGs

Lotz et al.2004 ULIRGs

more flux in fewer pixels

smooth distribution



spatially extended → compact

- ULIRGs lie below the merger line in all bands

L_{IR} is not a defining physical quantity that controls where the (U)LIRGs lie in Gini-M_{20}

Gini -M_{20} plane
(aperture dependence)

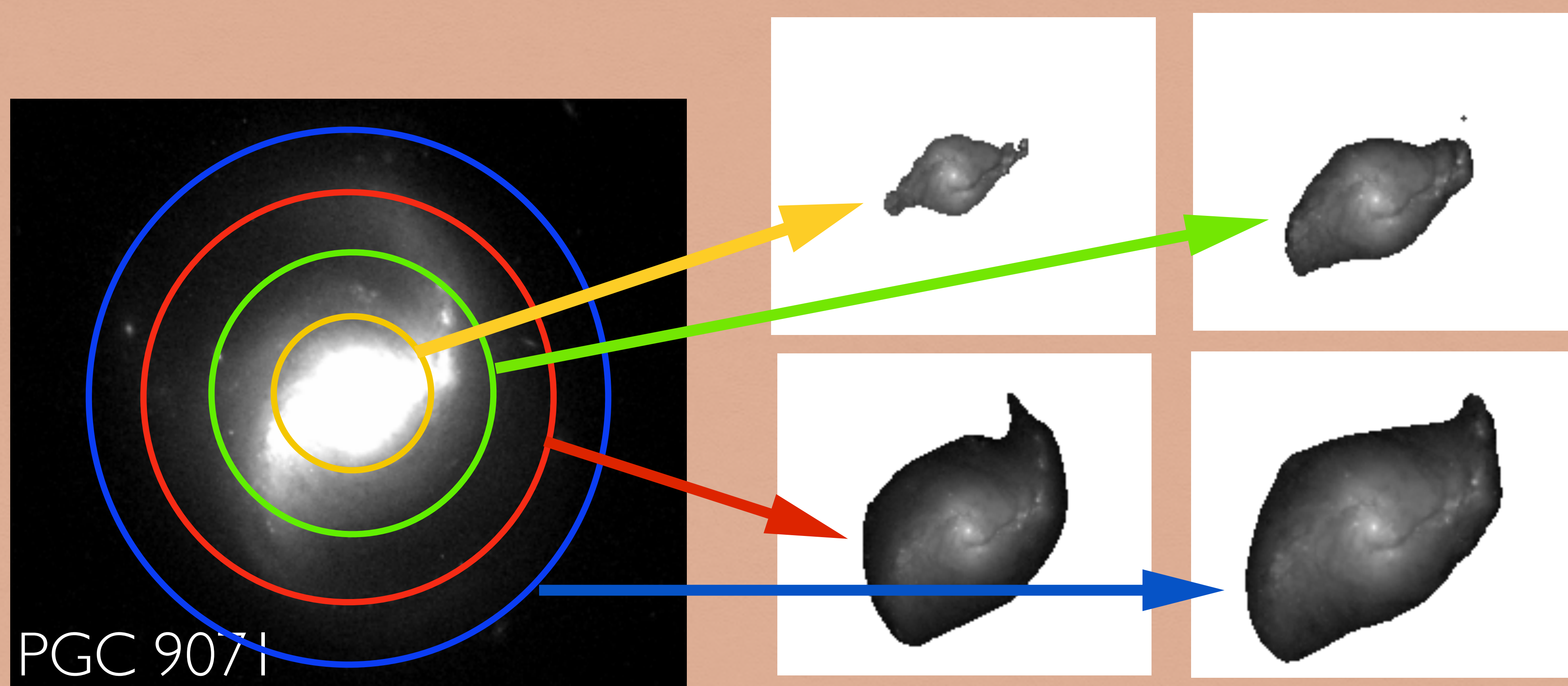
Why the majority of (U)LIRGs don't lie inside the **Mergers** region
as Lotz et al. 2004 suggested ?

studies used Gini-M_{20} to describe galaxy morphology
i.e. Lotz et al. 2004 , Abraham et al. 2003, Hung et al. 2014

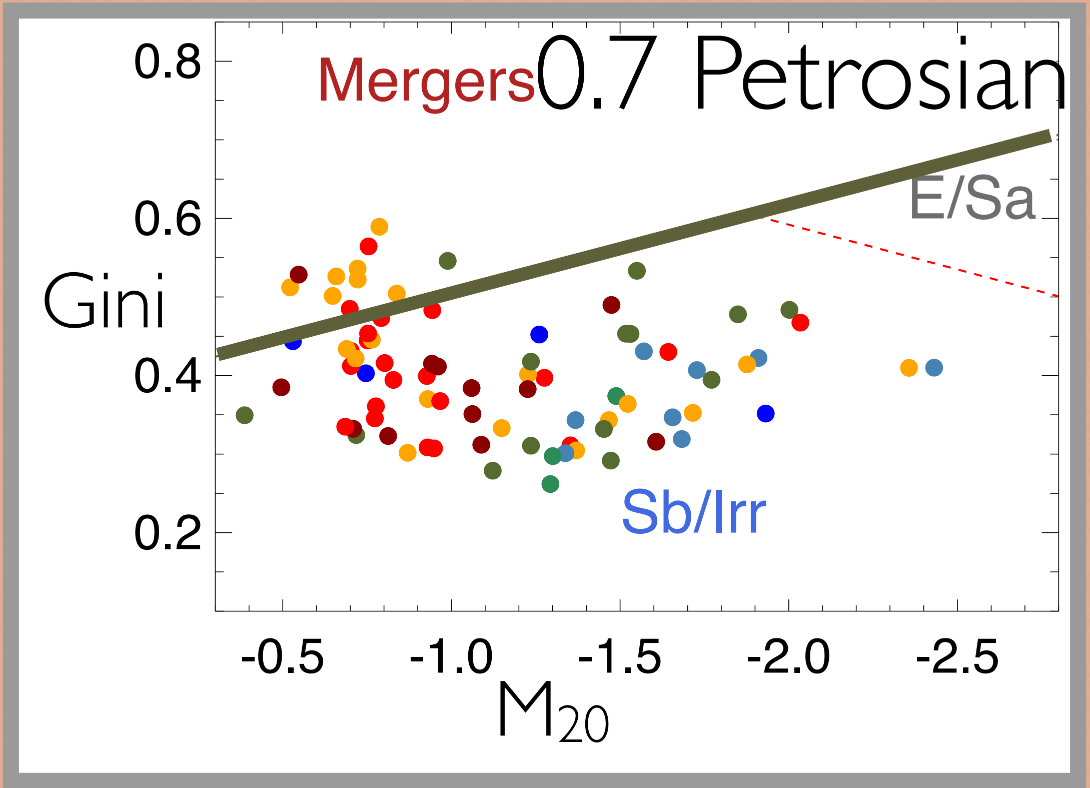
main difference : choice of the characteristic aperture to construct the segmentation map

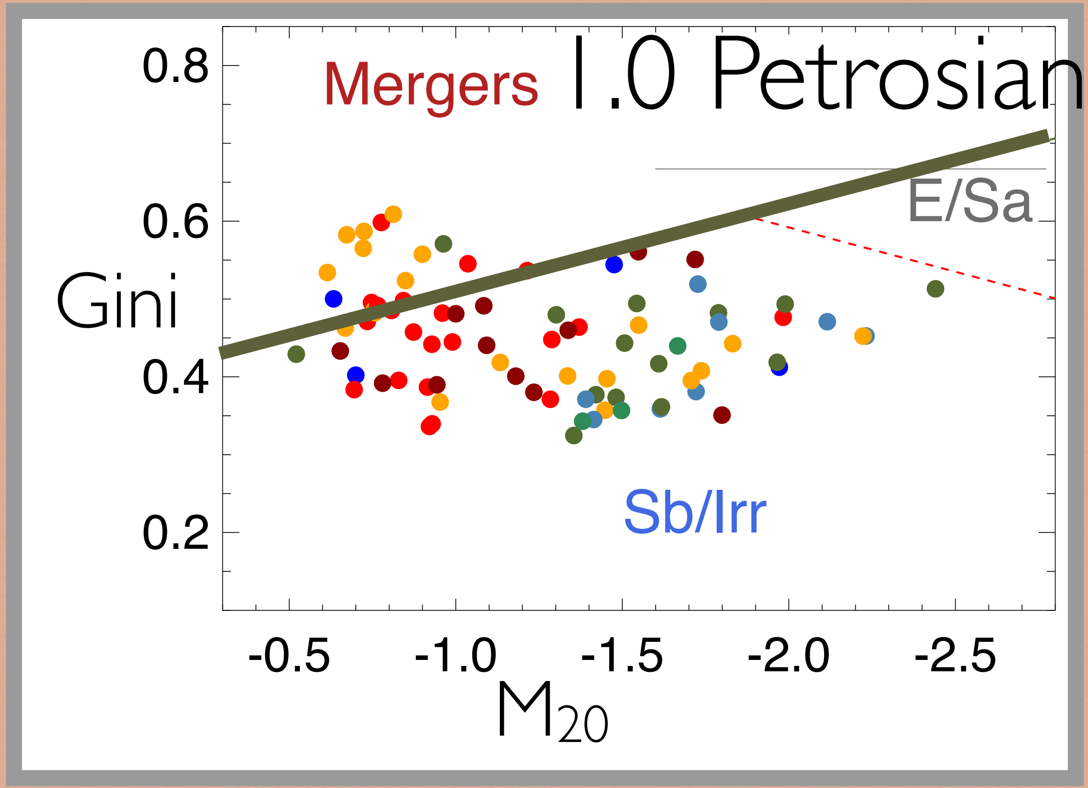
aperture used
to construct
the segmentation map

0.7
1.0 **Petrosian**
1.5 **radius**
2.0

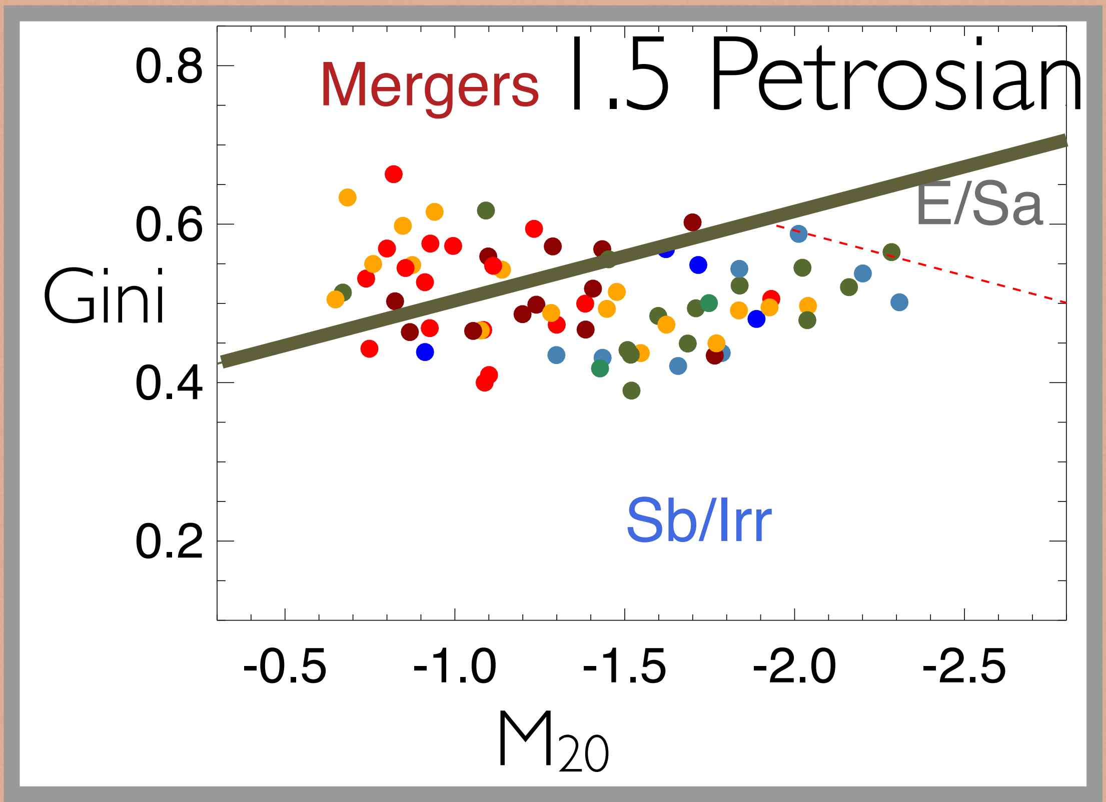


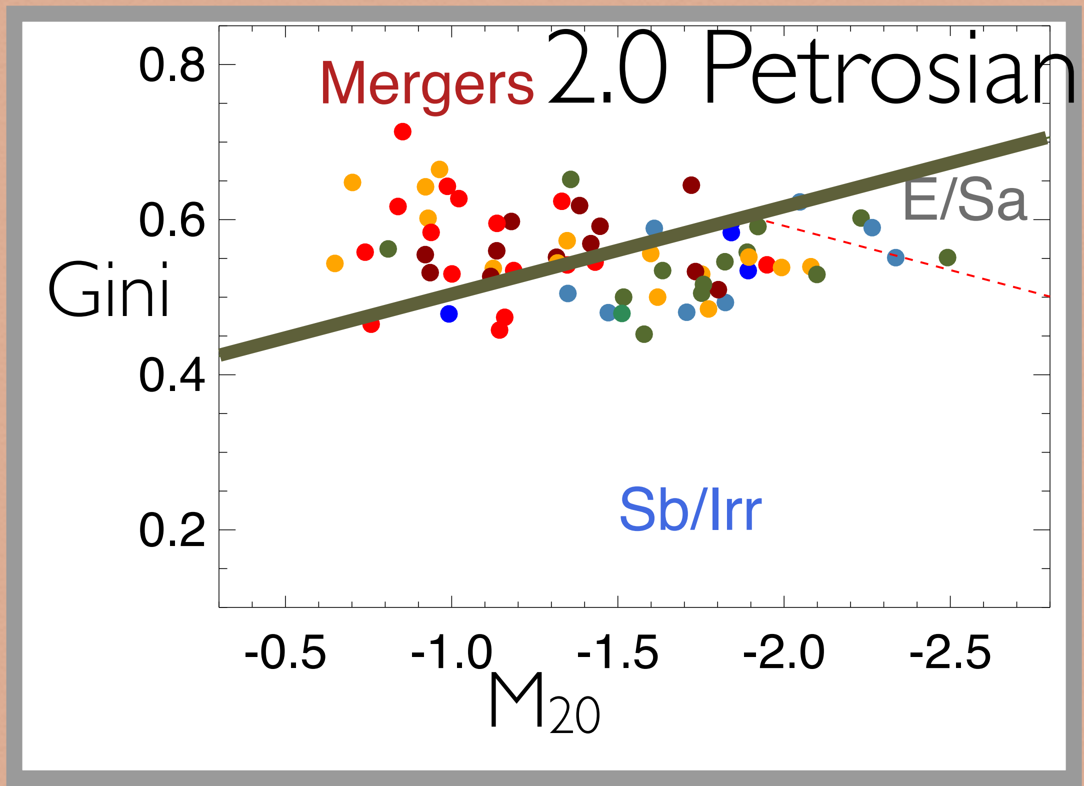
Gini -M_{20} plane as a function of Petrosian radius





I-band





Gini -M_{20} plane

- aperture dependence on the Gini-M_{20} plane

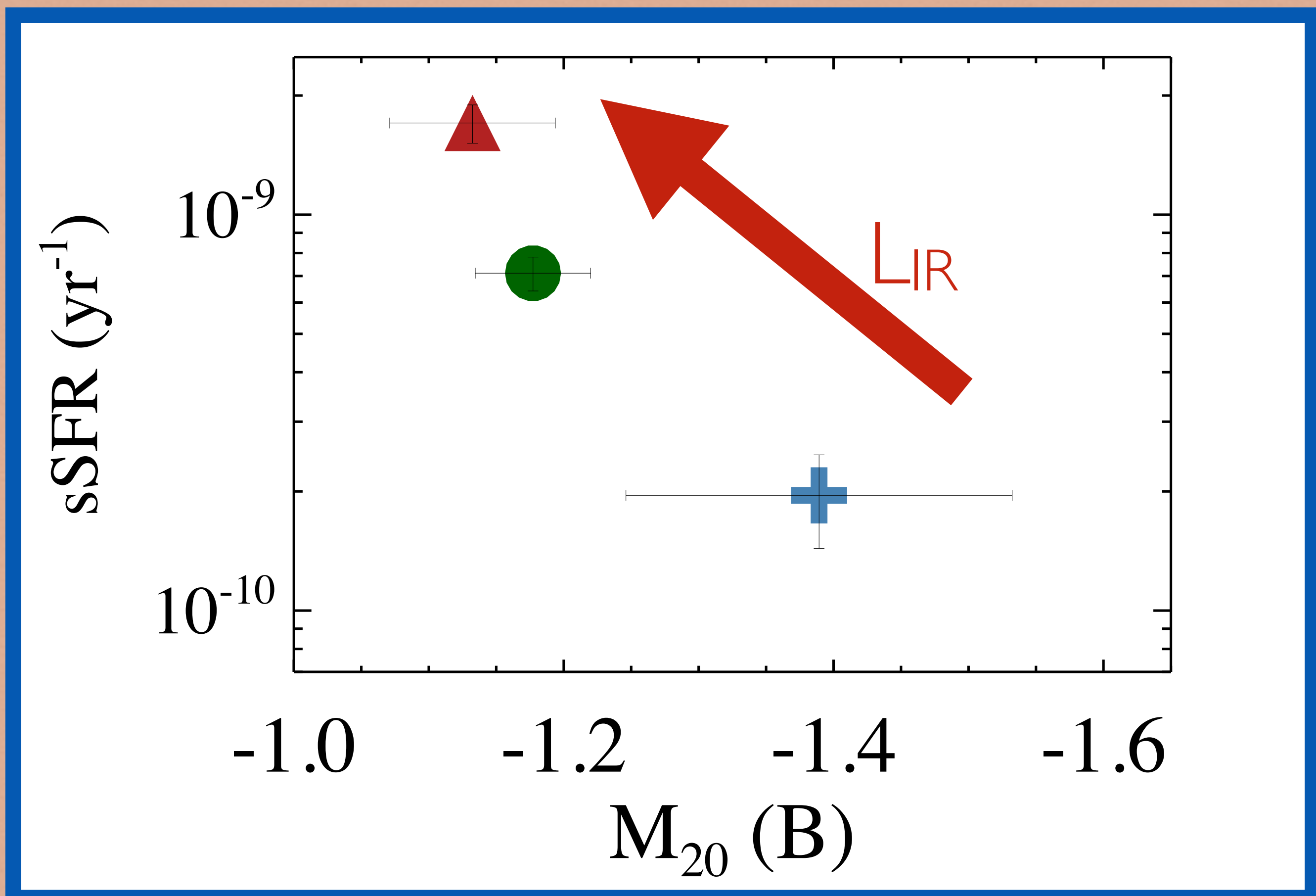
- Be careful with the choice of the characteristic radius.
- The lines of the Gini-M20 plane should be modified according to the sample that we use.

Morphology and physical properties

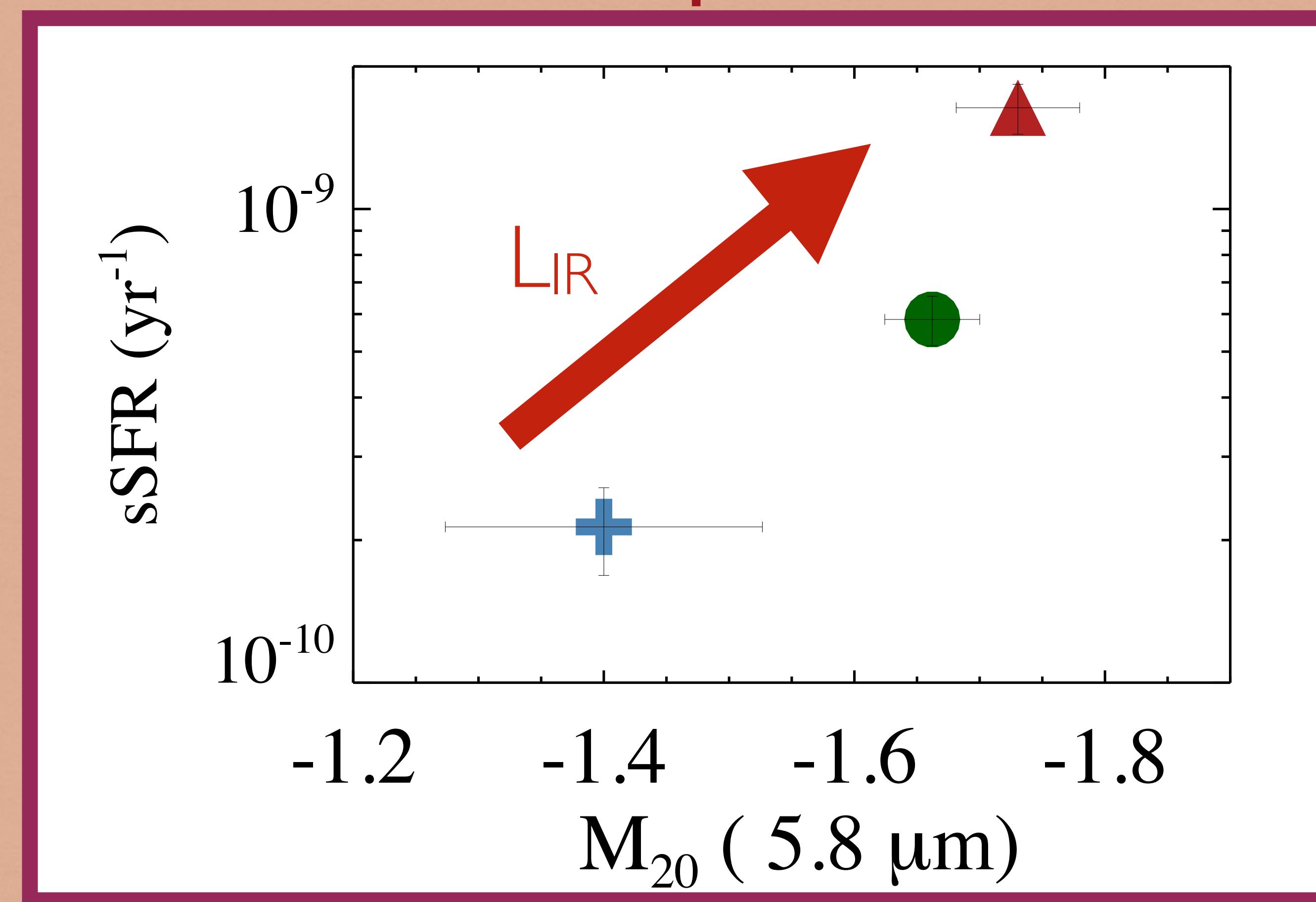
Morphology and sSFR

sSFR = SFR / M★ (instantaneous SFR)

B-band



5.8 μm



ULIRGs

LIRGs

sub-LIRGs

ULIRGs & LIRGs (highest sSFR) appeared extended in the B-band in contrast to MIR where they are more compact than the sub-LIRGs.

- The physical size of dusty galaxies, (U)LIRGs measured in optical, are highly dependent on the geometry of dust distribution and can be significantly overestimated.
- Application to high-z surveys of dusty galaxies

Conclusions

1. Moving from the optical to NIR, we find that the median values of Gini increases while median values of M_{20} become more negative.

2. M_{20} can distinguish better systems formed by multiple galaxies from isolated and post-merger LIRGs, and its effectiveness increases with increasing wavelength. In fact, our multi-wavelength analysis allows us to identify a region in the Gini-M_{20} parameter space where ongoing mergers live, regardless of the band used to calculate the coefficients.

3. L_{IR} is not a defining physical quantity that controls where the (U)LIRGs lie in Gini-M_{20}

4. The choice of the characteristic radius for the construction of the segmentation map is crucial for the Gini-M_{20} plane.

5. The sSFR is positively correlated with the M_{20} that is measured in the mid-IR;

–starbursting galaxies appear more compact than normal ones – and it is anti-correlated with it if measured in the B band.

We interpret this as evidence of the spatial decoupling between obscured and unobscured star formation, whereby the ultraviolet/optical size of LIRGs that experience an intense central starburst is overestimated owing to higher dust obscuration towards the central regions.

Psychogyios et al. 2016
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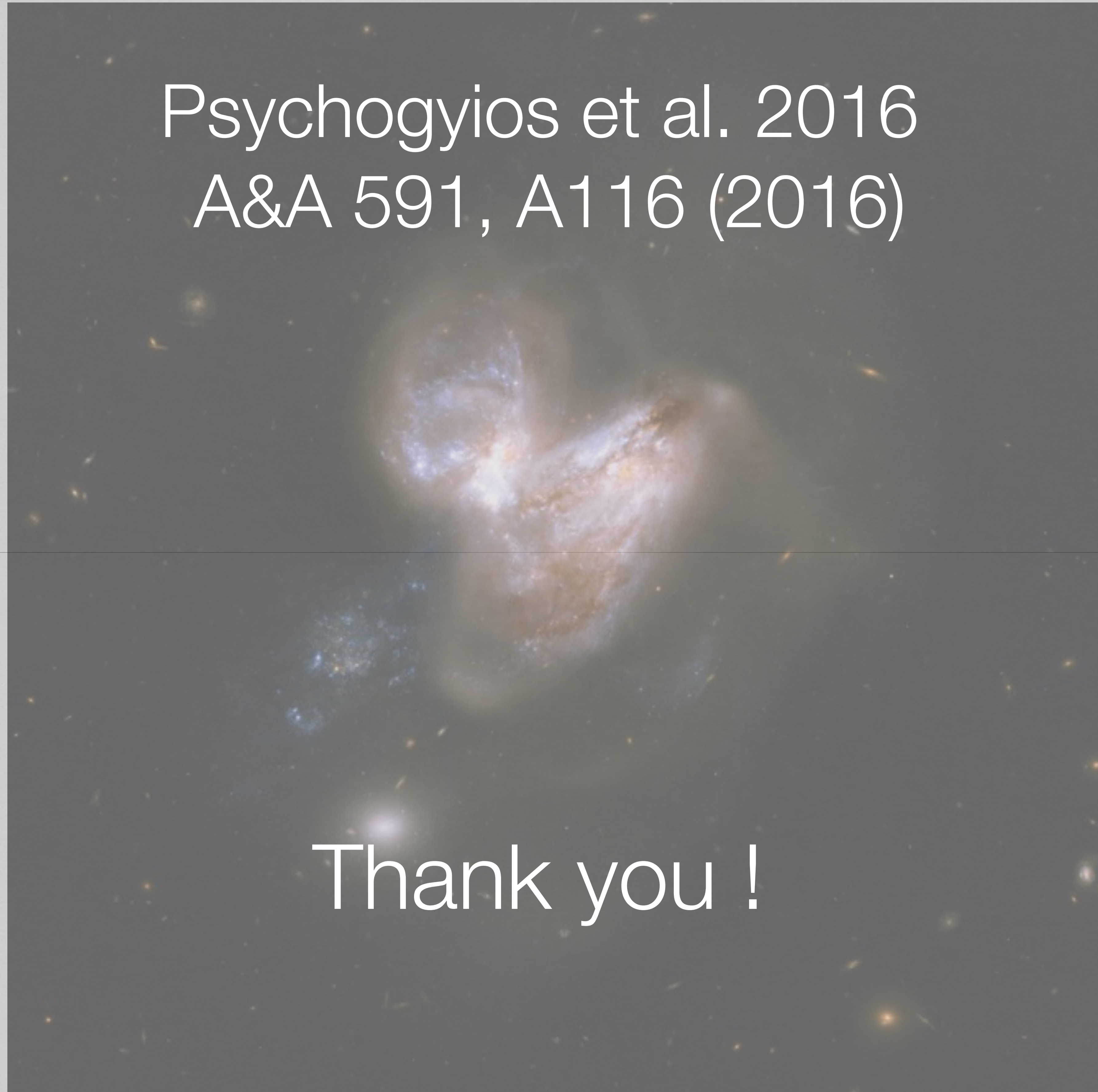

Thank you !

Extras

Petrosian radius (R_P)

independent-distance way to describe the radial profile

$$sb_{annulus} = 20\% \text{mean } sb_{\text{ inner circle}}$$