Non-parametric morphological classification of LIRGs

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Introduction

Why Morphology ?

Property key to unveil the evolution of galaxies.

Local Universe → Hubble's Tuning-fork

high-z Universe → irregular shapes

Why LIRGs ?

Dominate the SFR at z ~ 1 and z ~ 2 (peak of galaxy assembly).

Rare in local Universe but thousand times more common at high-z.

Strongly related to the evolution of massive ellipticals.

Motivation

Quantify the morphology of LIRGs (GOALS, Armus et al. 2009) 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 . B-band (young stars) up to H-band (older stars)

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

Develop a robust and automated method to also classify in a consistent manner the morphologies of high-z systems.

What are LIRGs ?

L_{IR}

ULIRGs

$10^{12}\ L_{\odot}$

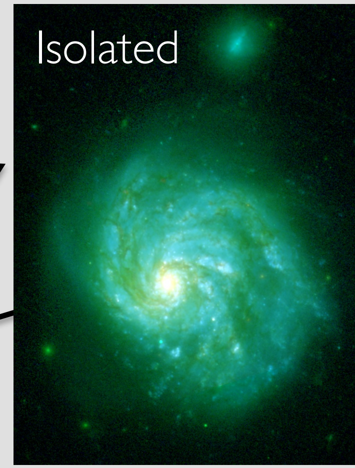
LIRGs

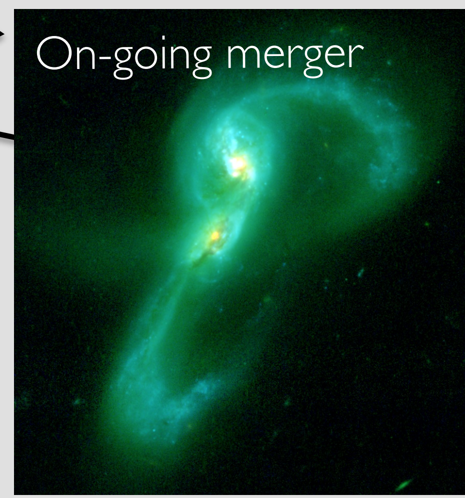
$10^{11}\ L_{\odot}$

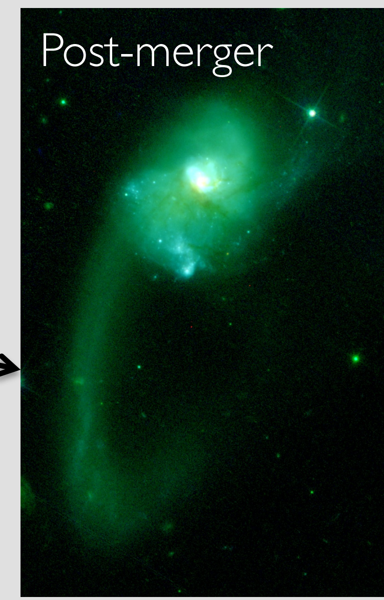
Sub-LIRGs

90 local galaxies

wide range of morphologies







L_{IR} due to dust heating from an intense starburst within giant molecular clouds

Measuring galaxy Morphology

Visual classification

Parametric coefficients

i.e. Sersic index, n

Require a prescribed analytic function

$$I(r)=I_0 e^{-(r/a)^{1/n}}$$

Non-parametric coefficients

- Applied to Hubble types or interacting types
- Are measurable out to high-z

$$Gini = \frac{1}{|\bar{f_i}| N(N-1)} \sum (2i - N - 1)|f_i|$$

$$M_{20} = \log\left(\frac{\sum M_i}{M_{total}}\right)$$

while $\sum M_i < 0.2 f_{total}$

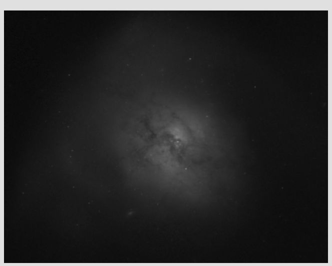
Interpreting non-parametric coefficients

Gini

Indicates the relative distribution of galaxy pixels

1

Centrally concentrated light distribution

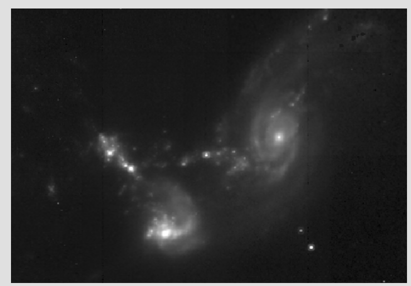


more equal flux distribution

0

M_{20}

Traces the spatial distribution of any bright region



extended object

compact object

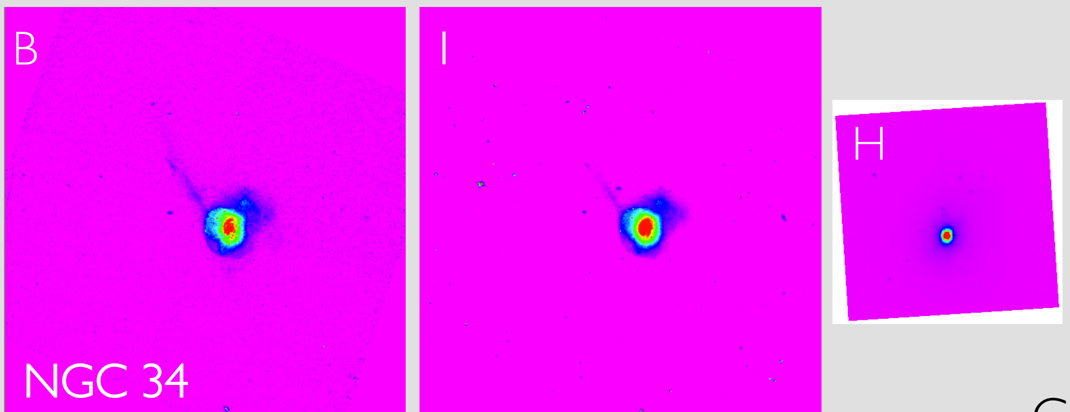
0

-3

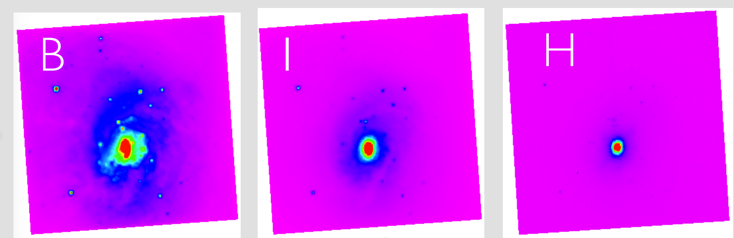
Method

Select the emitting region by creating a segmentation map

Input HST images

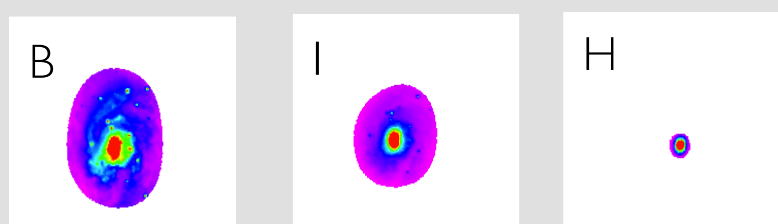


Crop, De-convolve,
Rebin, Convolve



Calculate the flux limit using the value of one Petrosian radius

Segmentation maps



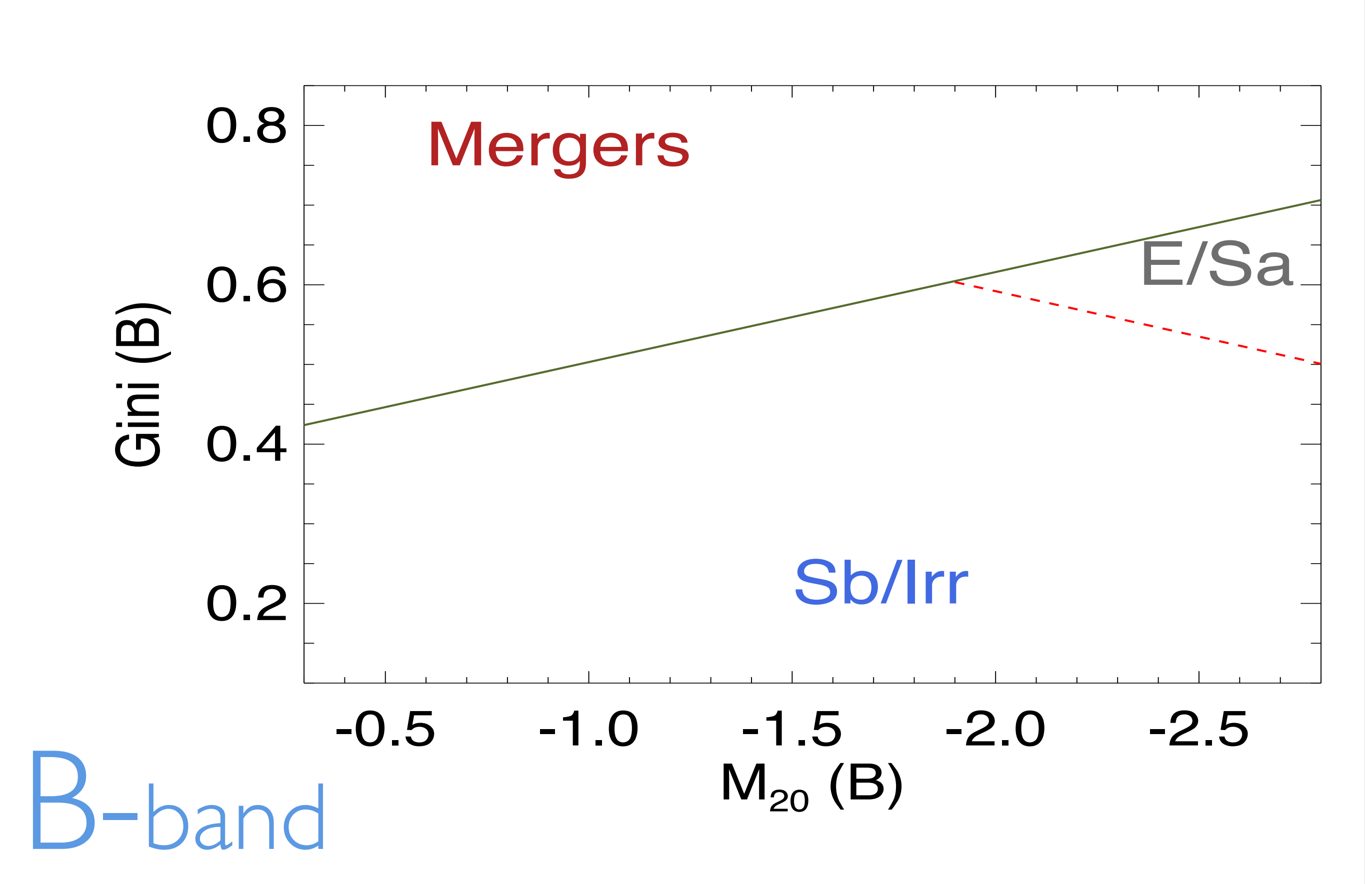
calculate

Gini

M_{20}

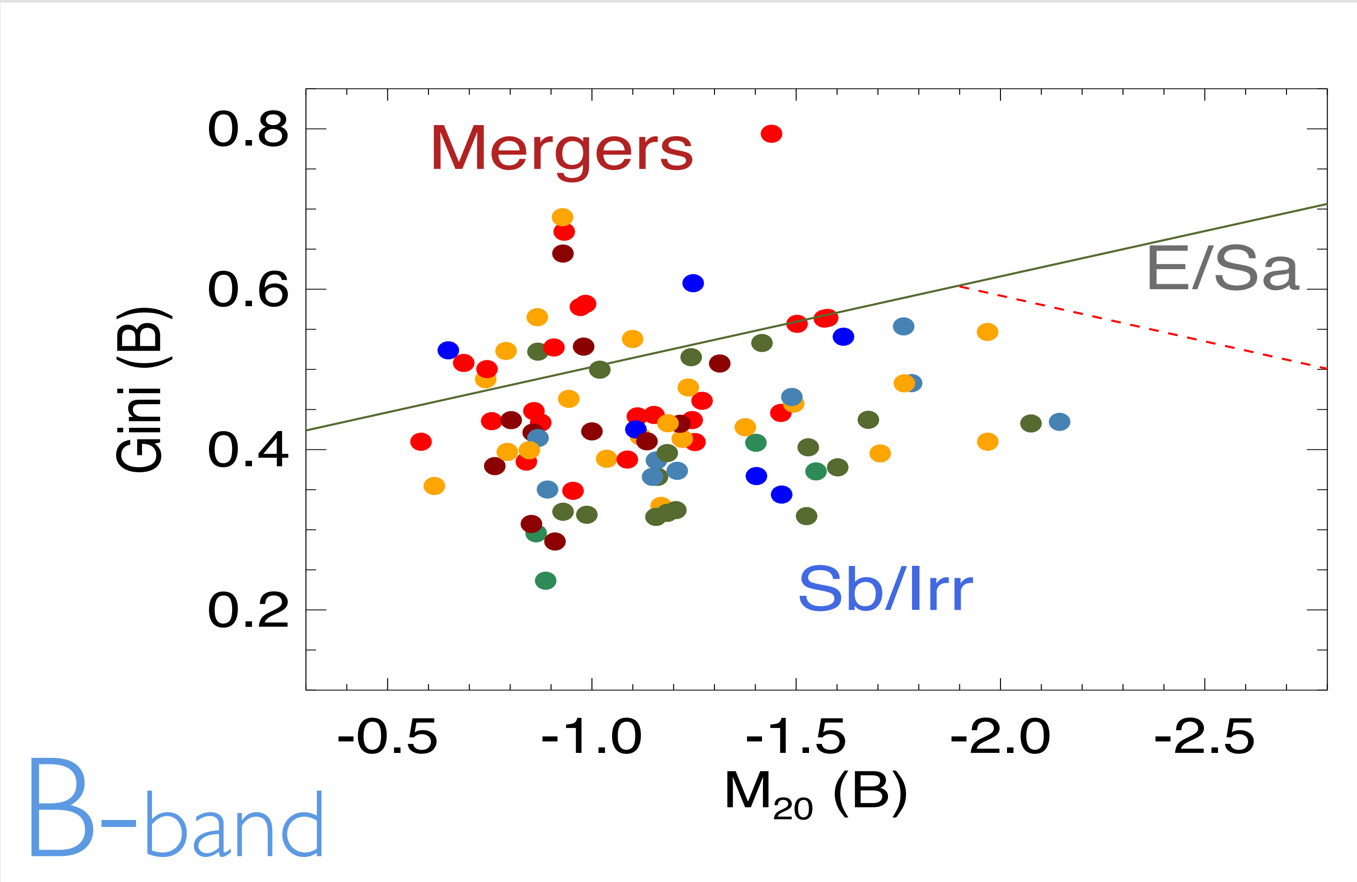
The Gini-M_{20} plane

Lotz et al.2004



Expectation : most of the LIRGs should lie in the Mergers region

Classifying the morphologies



Most of LIRGs are below the merger line

pre mergers

- undisturbed isolated galaxies
- distinguishable galaxies symmetric or amorphous disks and/or tidal tails

on-going mergers

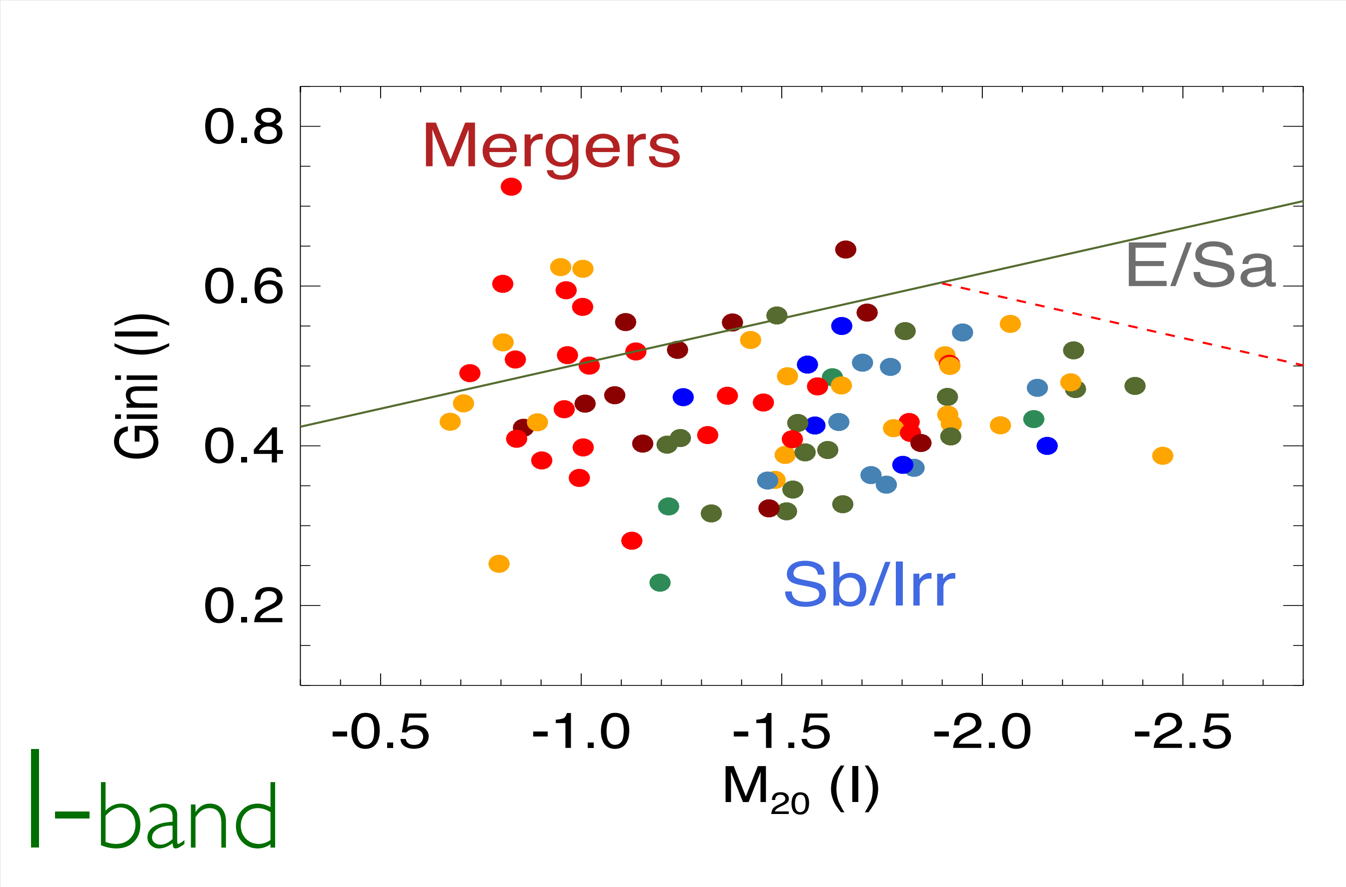
- separate galaxies, symmetric disks no tidal tails
- two nuclei in common envelope
- double nuclei plus tidal tail

post mergers

- single or obscured nucleus with long prominent tails
- single nucleus with disturbed central morphology and short faint tails

Haan et al. (2011)

Classifying the morphologies



Median M_{20}

LIRGs tend towards more compact morphologies

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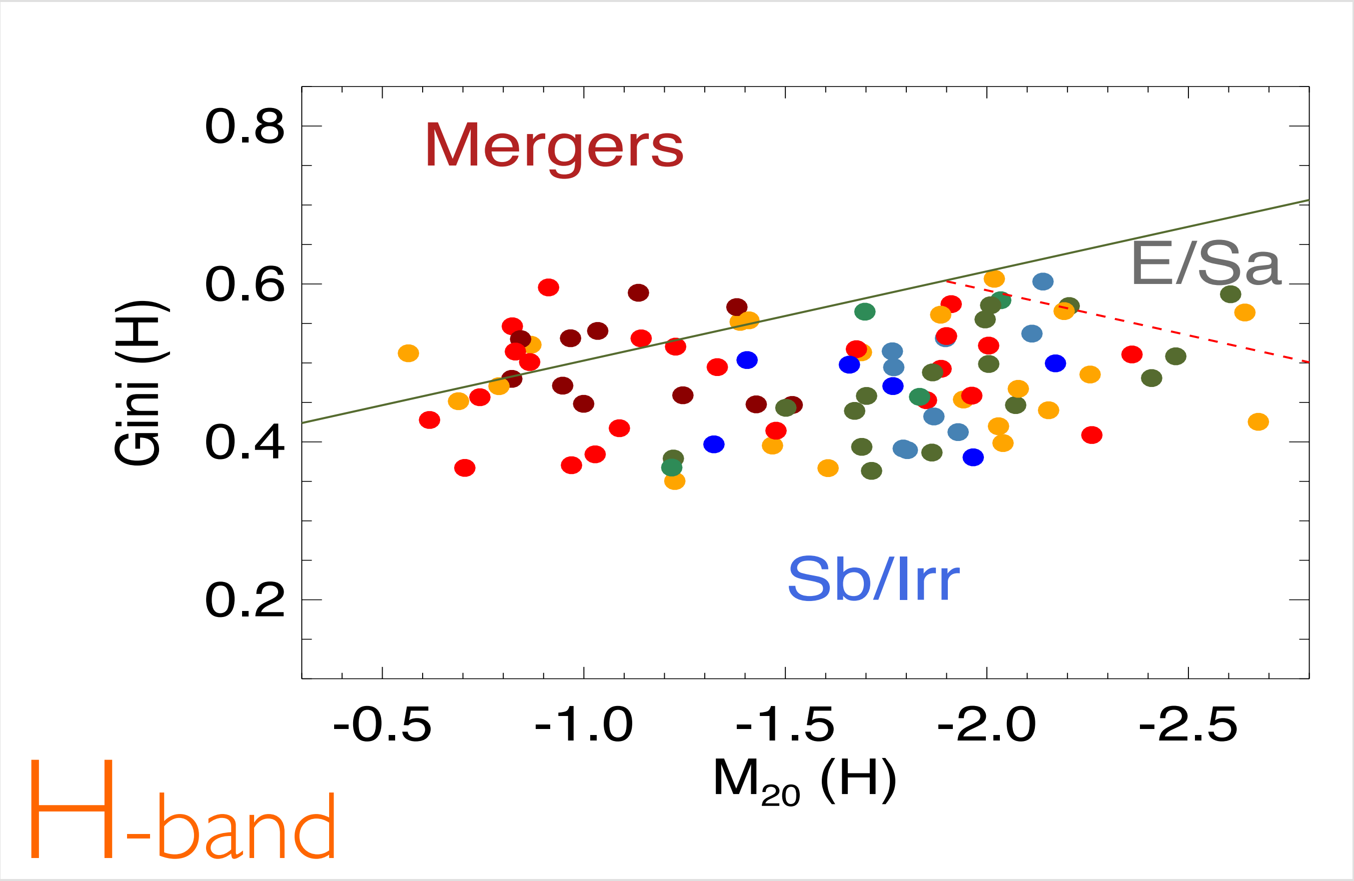
Classifying the morphologies



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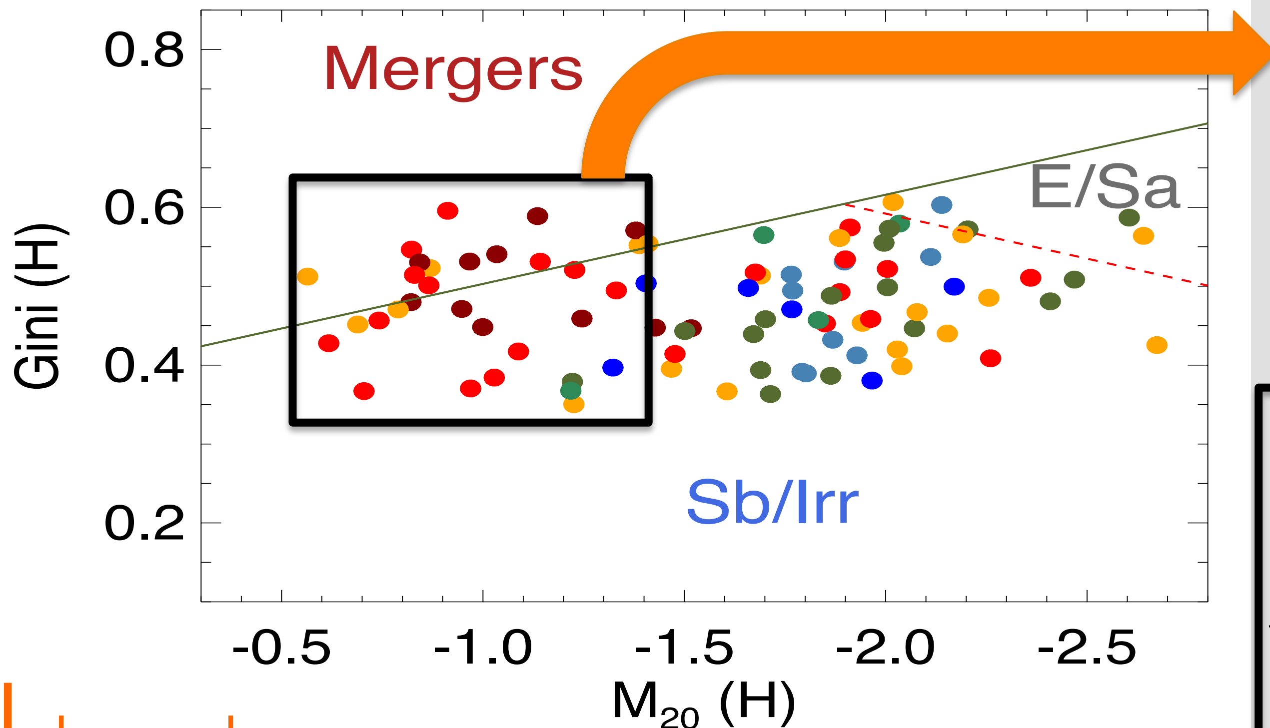

H-band

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

B,I-band not useful.
H-band : the majority of LIRGs fall inside the box are classified as on-going mergers.

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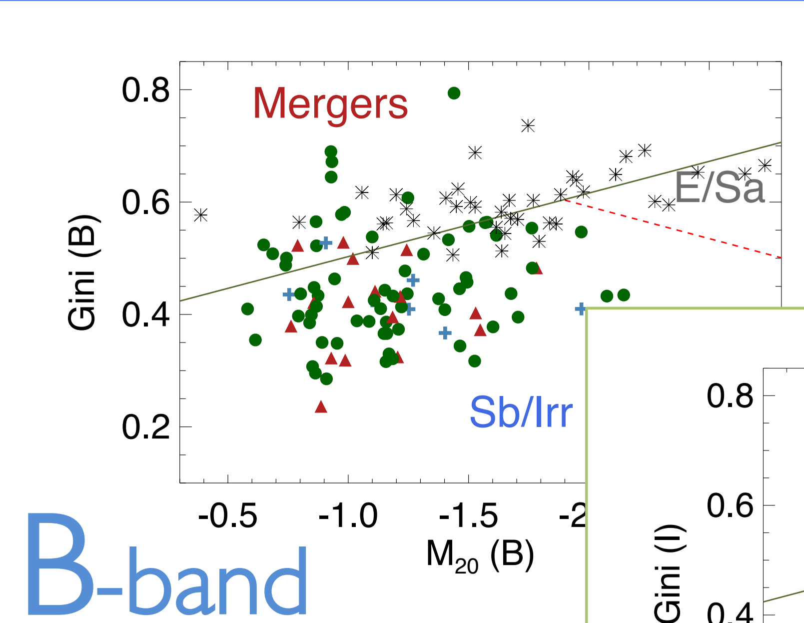
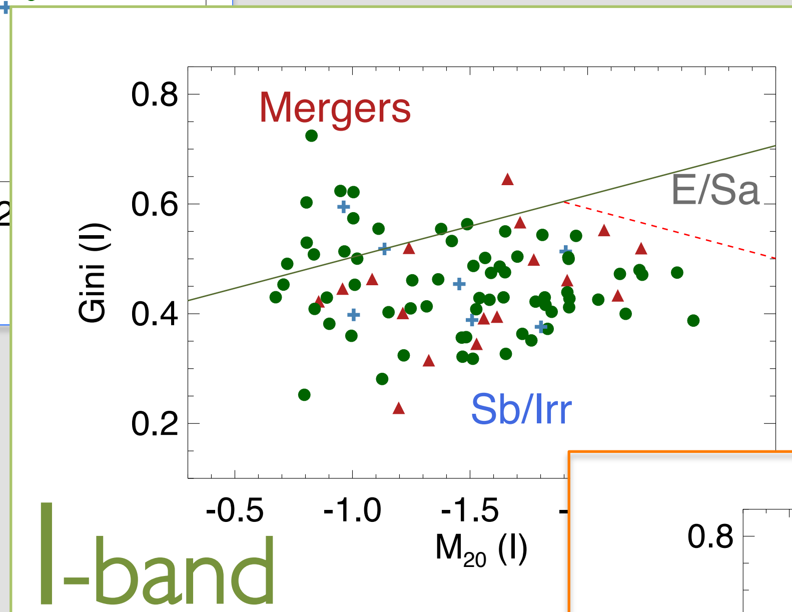
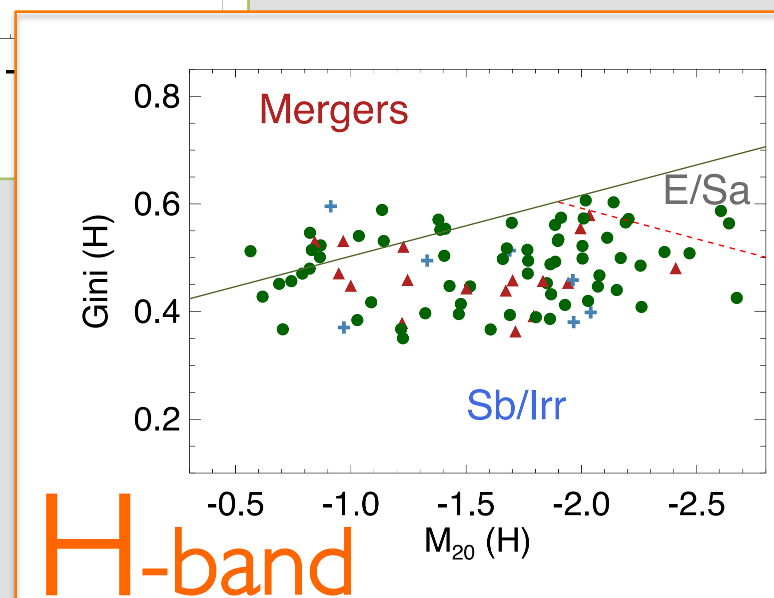
Gini vs M_{20} in L_{IR} bins







ULIRGs lie in the Sb/Irr region in all bands. (below the merger line)

ULIRGs

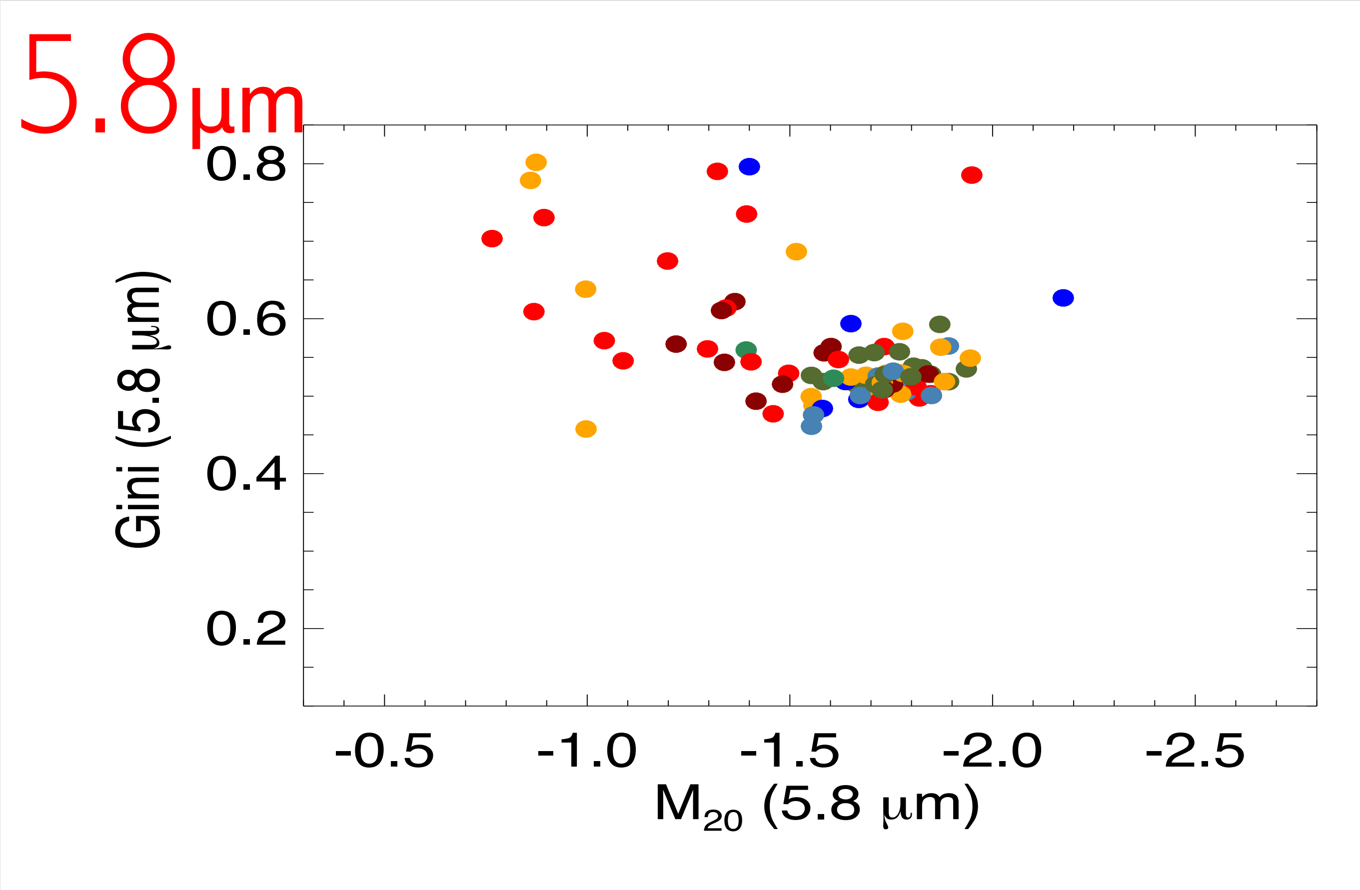
LIRGs

sub-LIRGs

LPM04 ULIRGs

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

Classifying the morphologies



Traces the obscured star-forming regions

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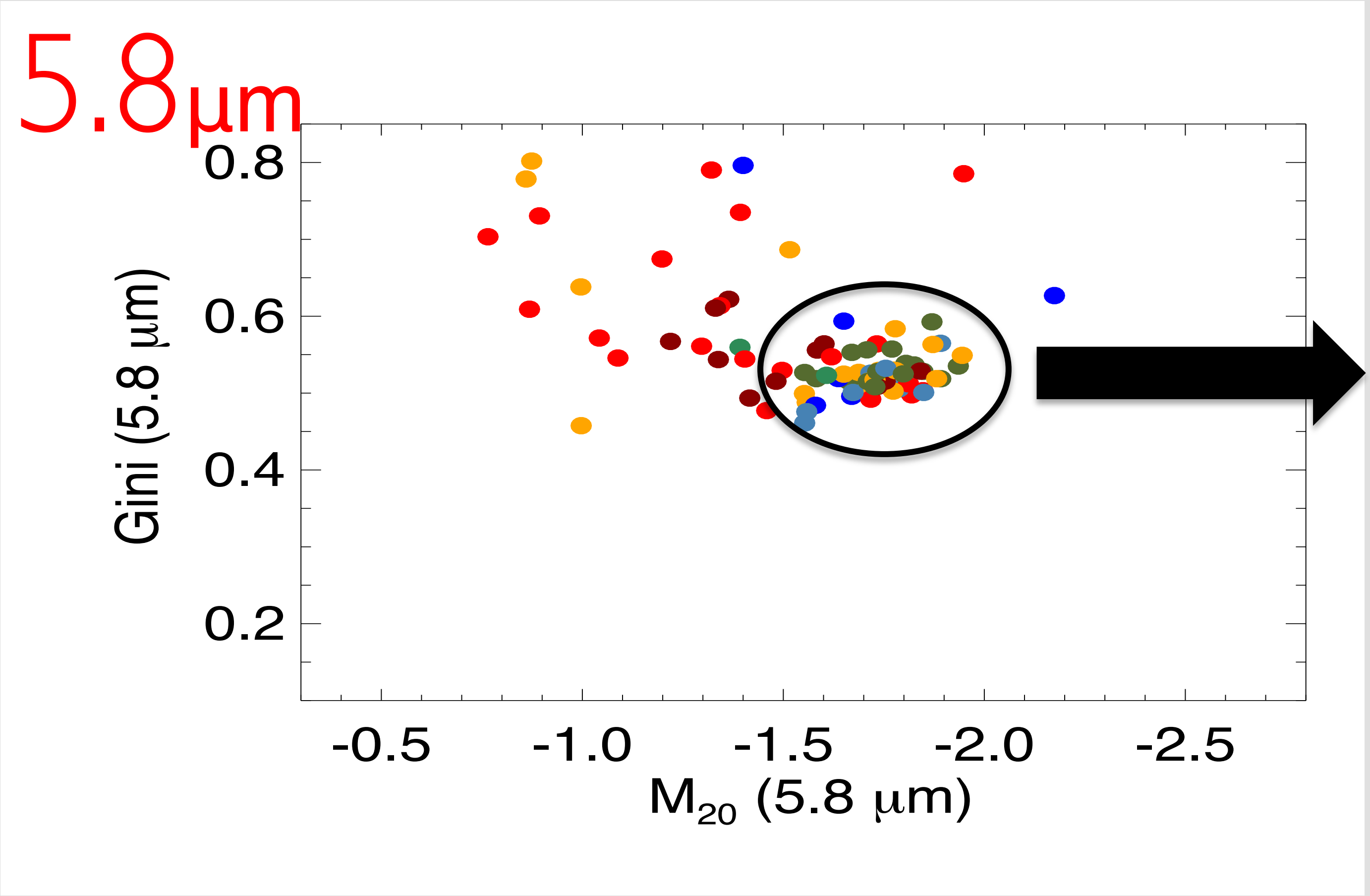
Classifying the morphologies



Most of the LIRGs are unresolved sources.

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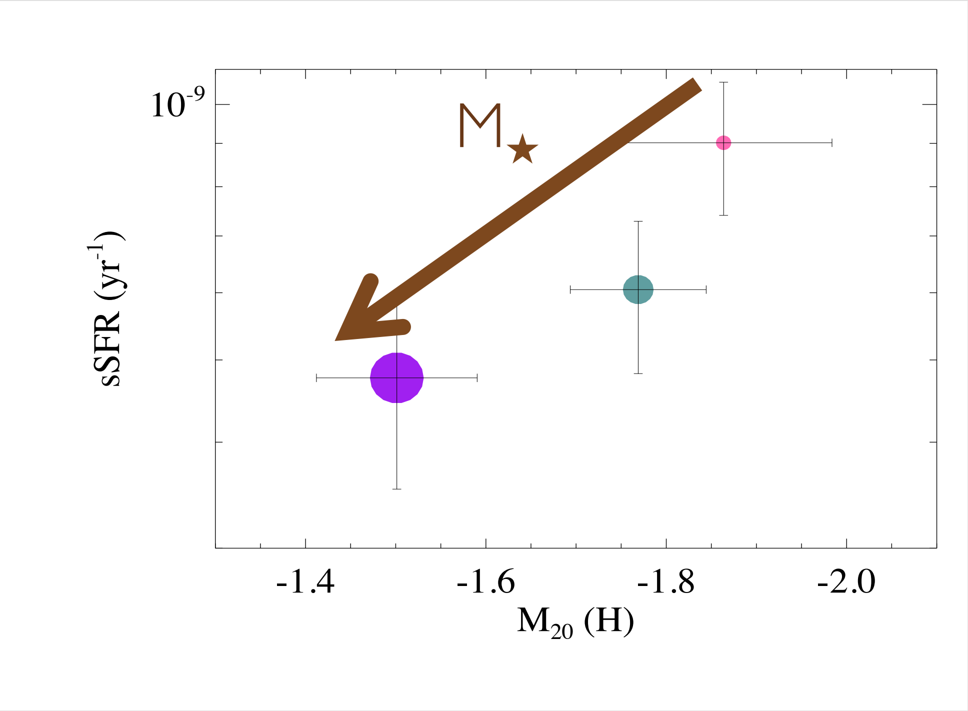
sSFR vs M_{20}



massive LIRGs

moderate mass LIRGs

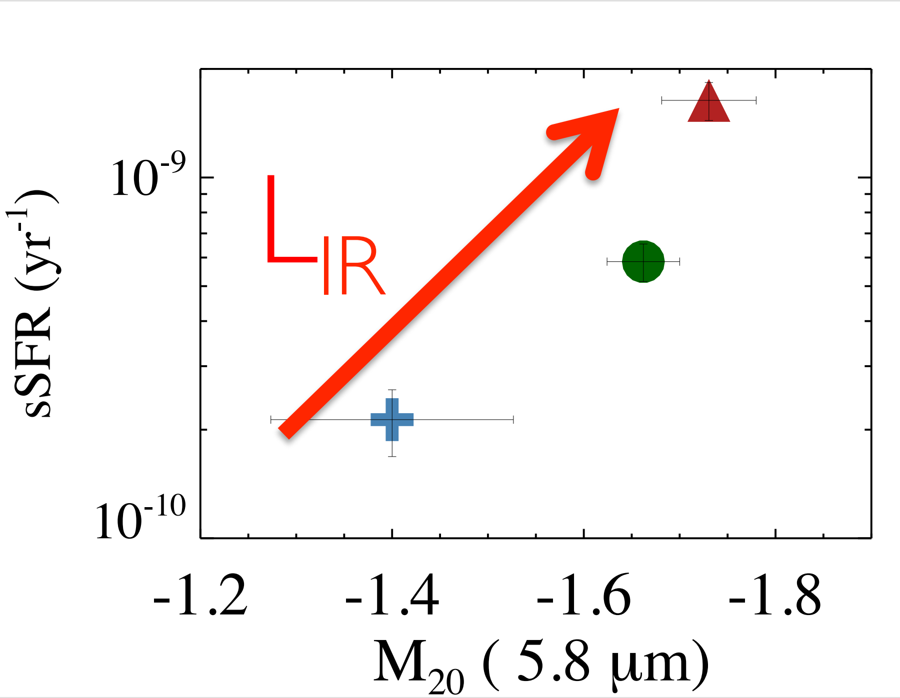
low mass LIRGs

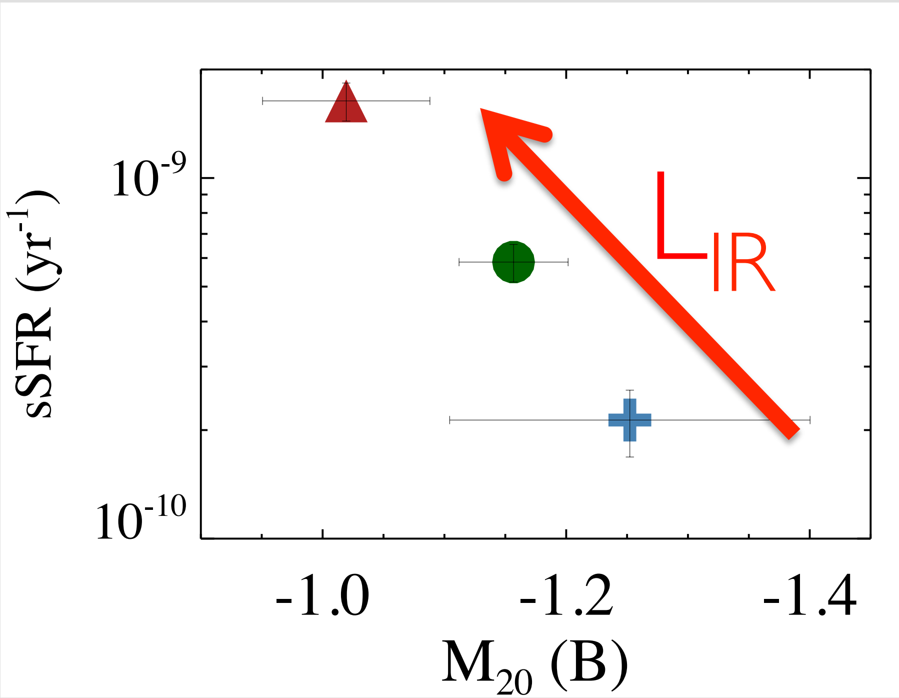
H-band

We confirm that :
massive LIRGs have low sSFR
(already evolved)

The more massive the LIRG,
the more extended the object
because the stellar mass is distributed
over a larger area.

sSFR vs M_{20}





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.

Never use optical emission to measure the size of the starburst in dusty galaxies

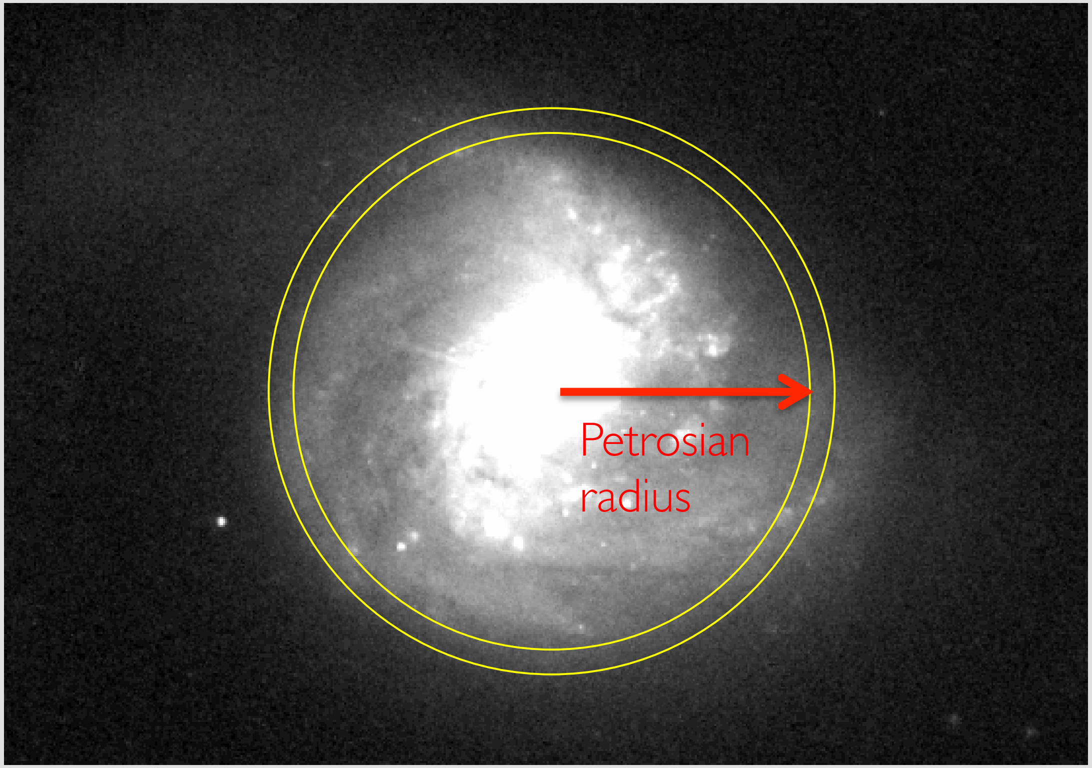
Summary

- Classifying the morphology of LIRGs in these 4 bands is not straightforward and the Gini-M_{20} plane presents a number of degeneracies.
- M_{20} separates well the double systems from isolated galaxies and is a better morphological tracer than Gini.
- The more massive the LIRG, the more extended the object.
- Not accurate to measure the size of dusty galaxies using optical observations.

Extras

Petrosian radius

Distance-independent way to describe the radial profile

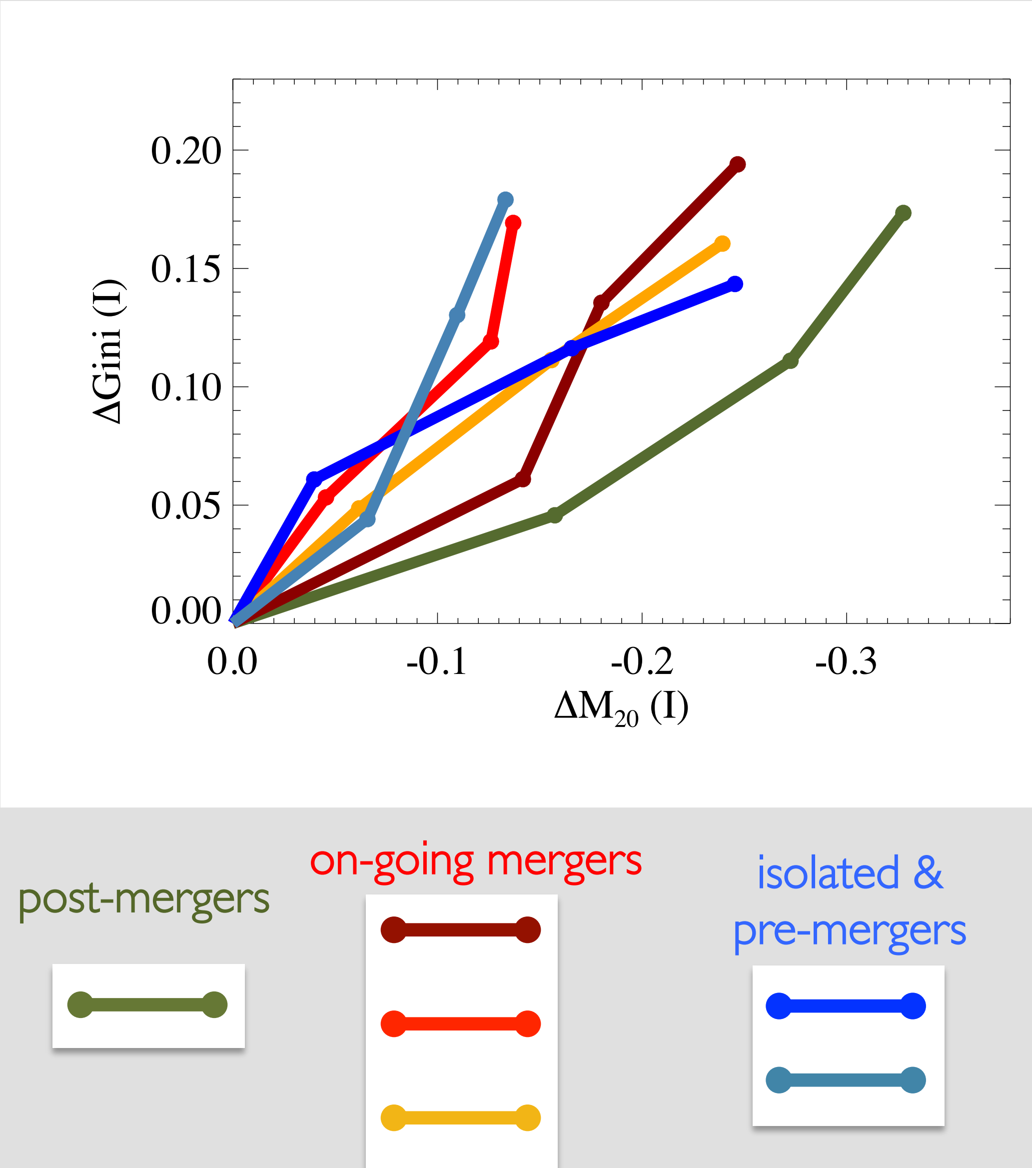


Can't measure the radial profile of a galaxy out to arbitrarily large radii because, at some point, the light from the galaxy disappears into the noise of the background sky.

Surface brightness of the annulus
=
20% of mean surface brightness of the inner circle

In order to compare galaxies to each other fairly, we must find some description which doesn't depend on distance

Gini, M_{20} in different Petrosian radii



I-band

There is a trend of increasing the Gini and decreasing the M_{20} as we enlarge the emitting area of LIRGs.