R. Delgado-Serrano

Starburst galaxies in the present and past Hubble sequence

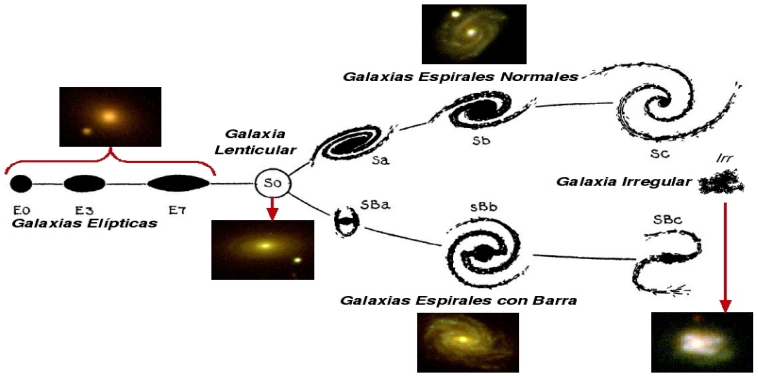
The way galaxies assemble their mass to form the well-defined Hubble sequence is amongst the most debated topic in modern cosmology. One difficulty is to link distant galaxies to those at present epoch. One observational way is at establishing how were the galaxies of the past Hubble sequence (e.g., 6 Gyrs ago). We have intended to derive a past Hubble sequence that can be causally linked to the present-day one. We selected a sample of nearby galaxies from the SDSS and a sample of distant galaxies from the GOODS survey. We verified that each sample is representative of the respective galaxy population. We further showed that the observational conditions necessary to retrieve their morphological classification are similar in an unbiased way. Galaxies are also divided in starburst and quiescent by their [OII]λ3727 EW, larger or smaller than 15 Å, respectively. After morphological classification we have been able to quantify their number fractions. We found an absence of number evolution for elliptical and lenticular galaxies, which strikingly contrasts with the strong evolution of spiral and peculiar galaxies. Spiral galaxies were 2.3 times less abundant in the past, that is exactly compensated by the strong decrease by a factor 5 of peculiar galaxies. It shows that more than half of the present-day spirals had peculiar morphologies, 6 Gyrs ago, and this has to be accounted by any scenario of galactic disk evolution and formation. The past Hubble sequence can be used to test these scenarios as well as to test evolution of fundamental planes for spirals and bulges.

Extreme Starbursts in the Local Universe 2010

l'Observatoire de Paris | GEPI

Galaxies Étoiles Physique et Instrumentation

Starburst galaxies in the present and past Hubble sequence.



R. Delgado-Serrano

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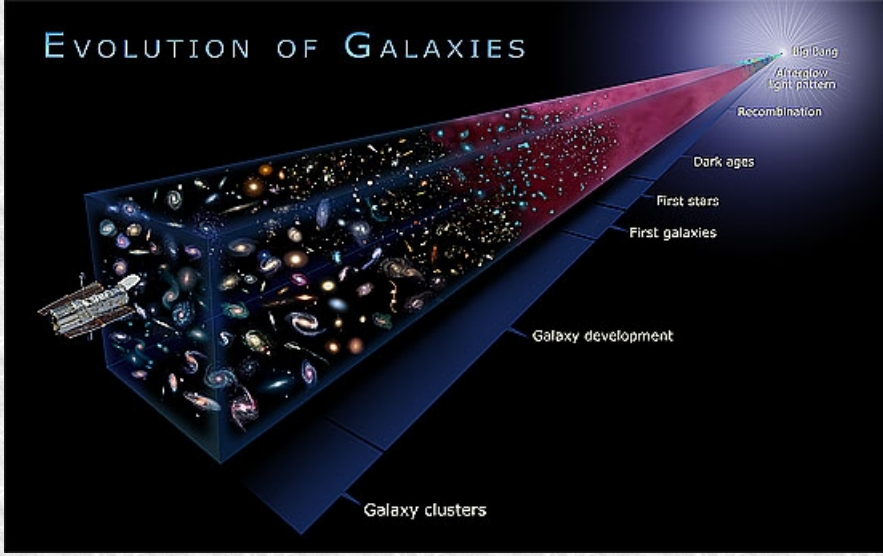
UTP - Technological University of Panama

Team:

F. Hammer, Y.B. Yang, M. Puech, H. Flores, and M. Rodrigues

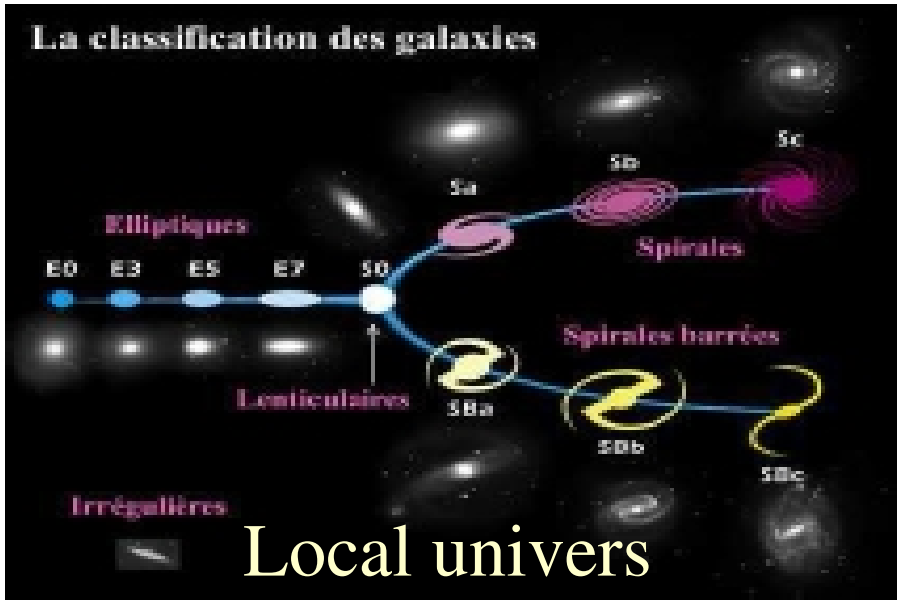
Local and Distant Galaxy Morphology:



- Motivation
- Samples
  - * Selection criteria
  - * Representativeness
- Observations
- Morphological classification methodology
- Results (… in local and distant starburst)
- Conclusions

INTRODUCTION

How were the galaxies of the Hubble sequence 6 Gyrs ago?



Local univers

Evolution?

z~0.65
(6 Gyr ago)

The link between distant and local galaxies is affected by:

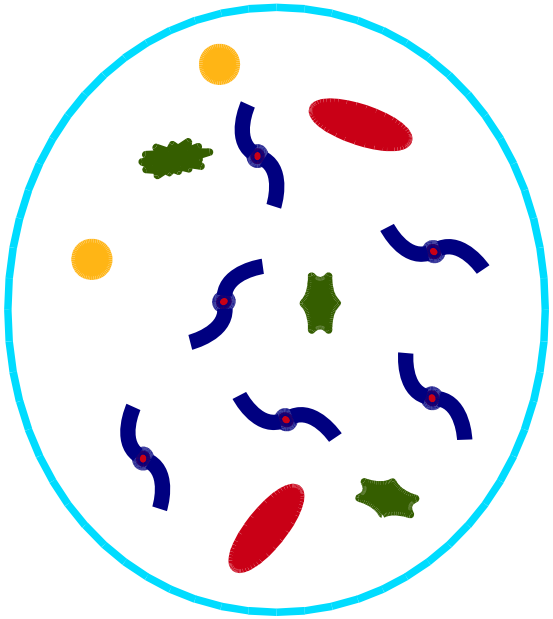
- **The evolution of galaxies: Change of type**
- **The transformation of galaxies: stellar evolution**
- **Selection and observational biases**

Looking for an answer using the SDSS and the CDFS surveys...

Our Samples

SDSS survey

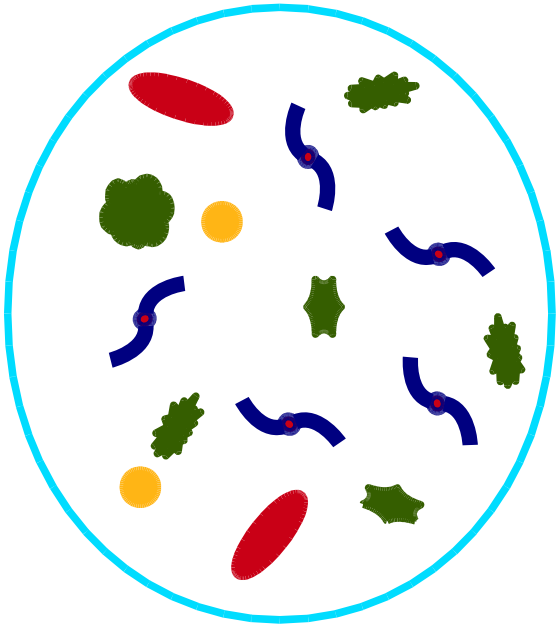
Local



$0.0207 < z < 0.030$

CDFS survey

Distant



$0.4 < z < 0.8$

Criteria for the selection:

- **$M_J(AB) < -20.3$**

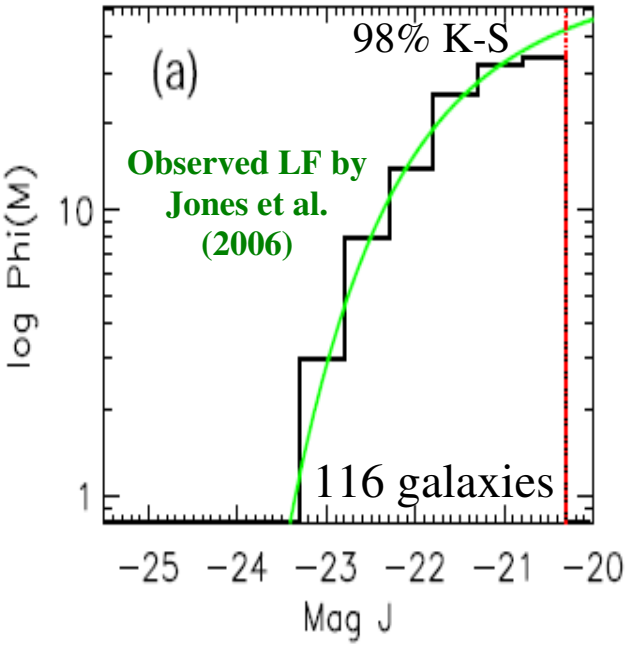
- good quality spectra including [OII] λ3727
- At least three optical bands images (SDSS: u, g, r bands; CDFS: v, i, z bands)

Our Samples

SDSS survey

CDFS survey

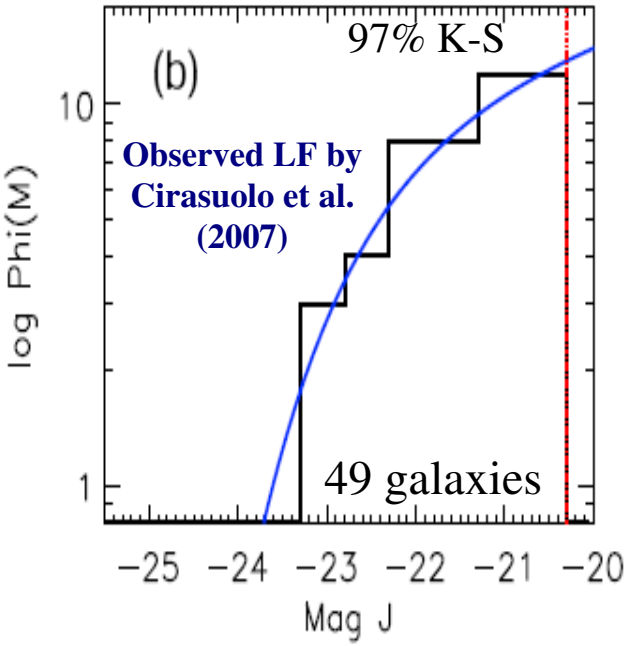
Local



$0.0207 < z < 0.030$

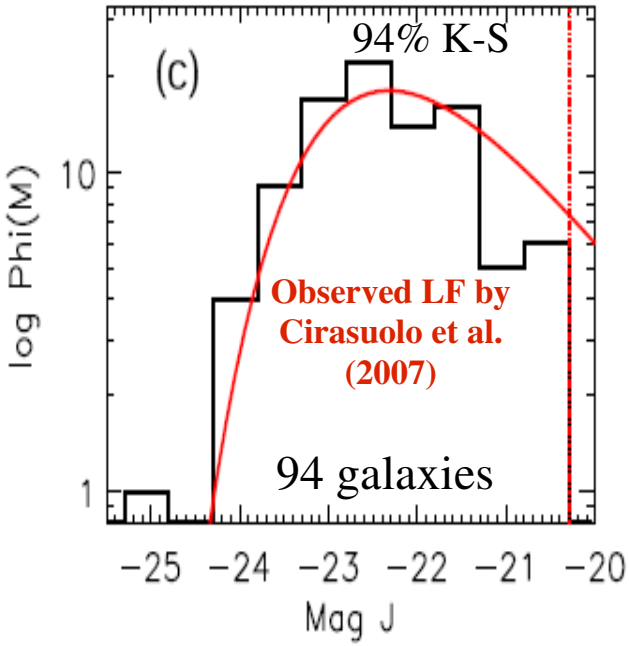
Distant Starburst

EW[OII]>15 Å



Distant Quiescent

EW[OII]<15 Å



$0.4 < z < 0.8$

$$M_J(AB) < -20.3$$

Our Samples

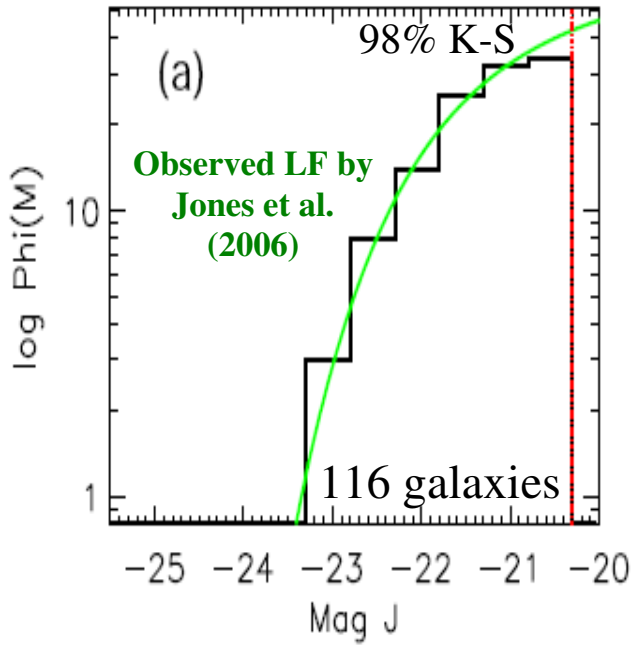
SDSS survey

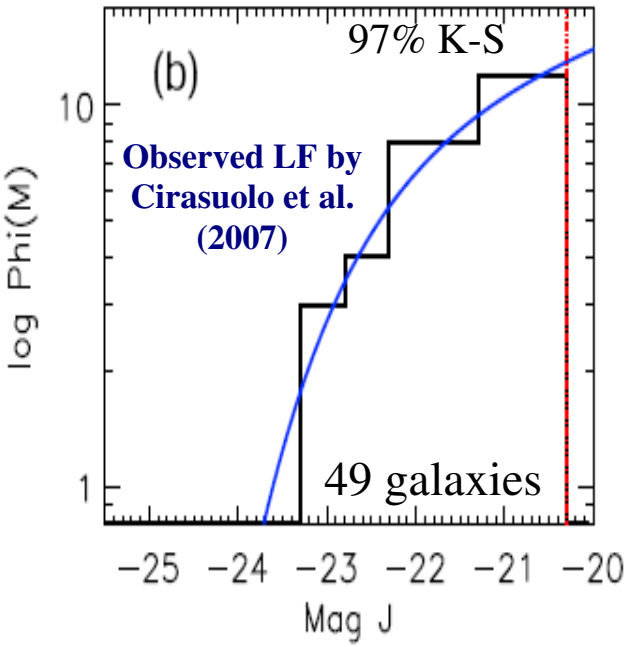
CDFS survey

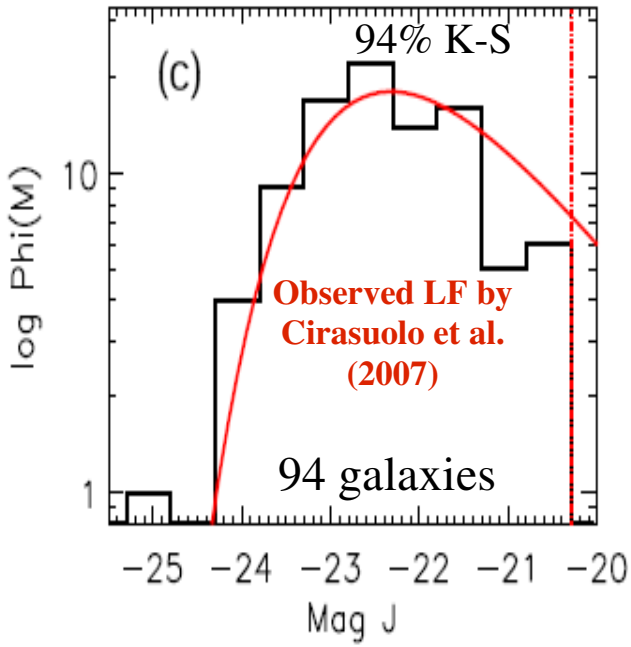
Local

Distant Starburst
EW[OII]>15 Å

Distant Quiescent
EW[OII]<15 Å







$0.0207 < z < 0.030$

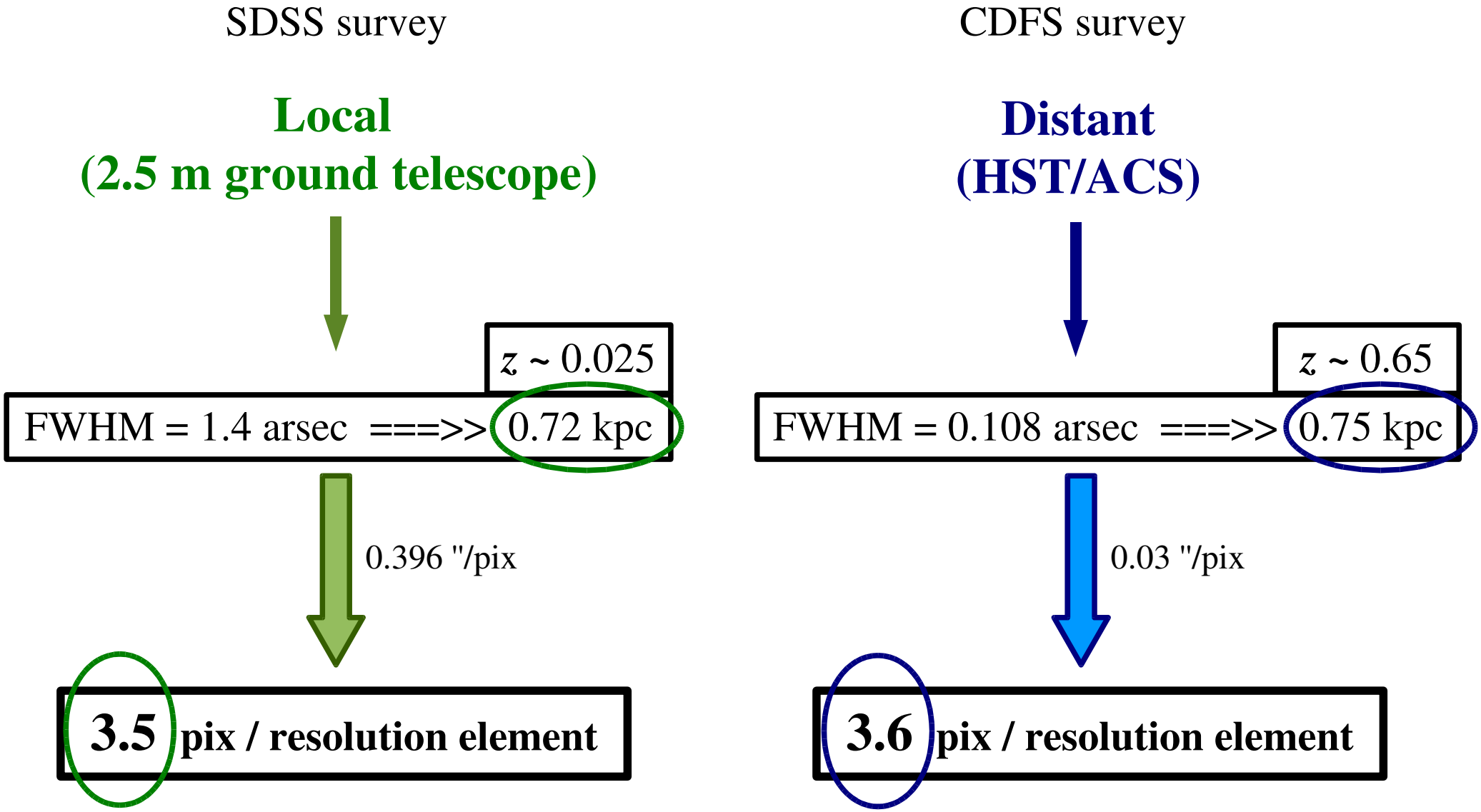
$0.4 < z < 0.8$

2.5 m ground telescope

HST/ACS

...comparing SDSS observations and HST/ACS?

Spatial Resolution



… K-correction, cosmological dimming or instrument differences?

K-correction, cosmological dimming or instrument differences

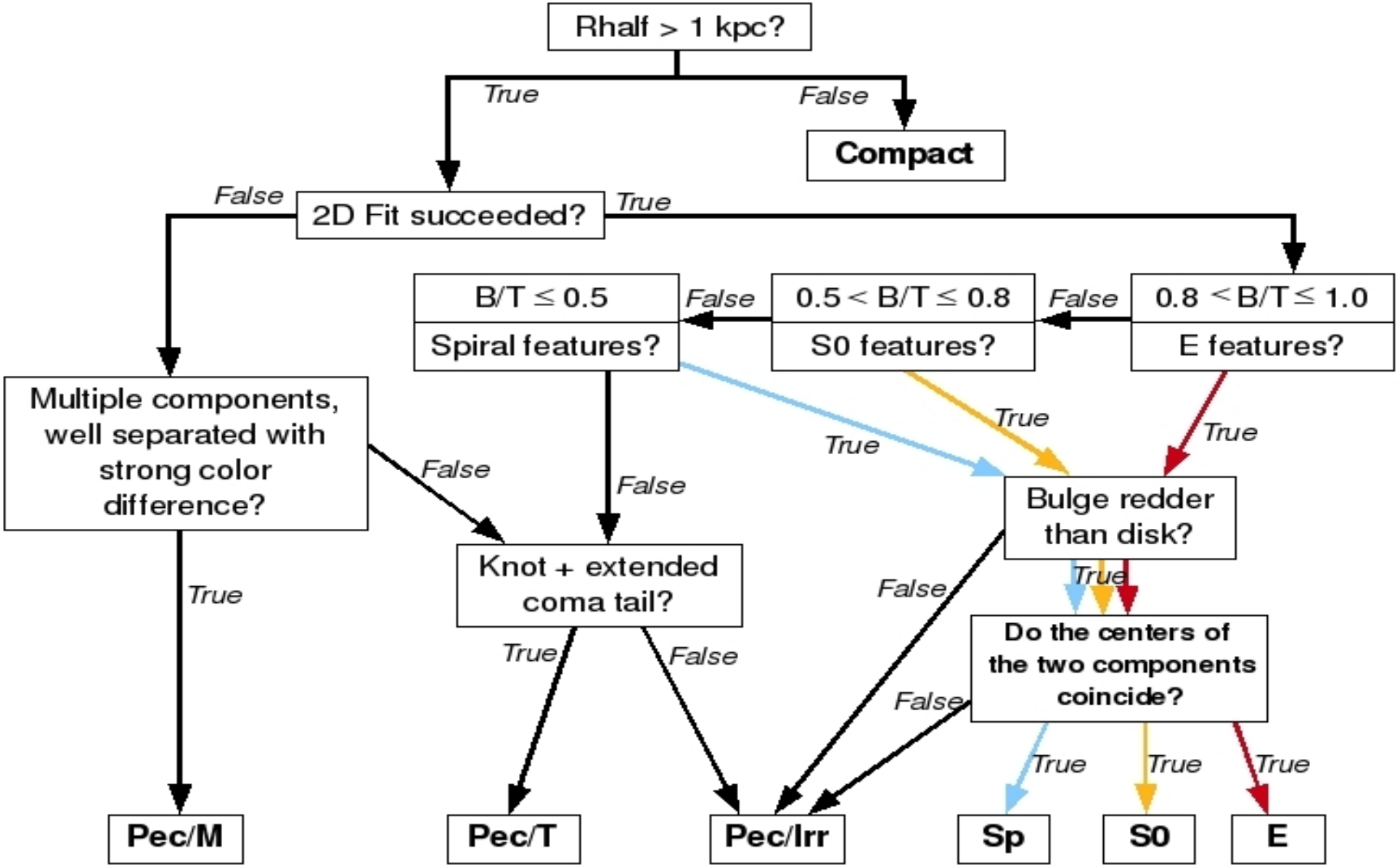
Survey	–	u band	g band	r band	i band	z band
SDSS	–	3551 Å	4686 Å	6165 Å	7481 Å	8931 Å
–	B band	V band	i band	z band	–	–
GOODS	4312 Å	5915 Å	7697 Å	9103 Å	–	–
rest-frame	2582 Å	3542 Å	4609 Å	5451 Å	–	–

	SDSS			GOODS ACS			
D=telescope diameter (m)	2.5			2.4			
Band	**u**	**g**	**r**	**B**	**V**	**i**	**z**
T=Expo-time (s)	53.907456	53.907456	53.907456	7200.00	5450.00	7028.00	18232.00
B=sky background (mag)	22.15	21.85	20.85	23.43	22.74	22.72	22.36
Filter FWHM (Å)	567.00	1387.00	1373.00	728.95	1565.50	1017.40	1269.10
Filter range (Å)	~1000.00	~1800.00	~1500.00	8780.00	2570.00	1910.00	>3080.00

$$\frac{SNR^{HST}}{SNR^{SDSS}} = \sqrt{\frac{FWHM^{HST}}{FWHM^{SDSS}}} * \sqrt{\frac{T^{HST}}{T^{SDSS}}} * \frac{D^{HST}}{D^{SDSS}} * \sqrt{\frac{B^{SDSS}}{B^{HST}}} * \frac{f_{\lambda}^{HST\,T_{z=0.0}}}{f_{\lambda}^{SDSS}} * \frac{1}{(1+z)^5}$$

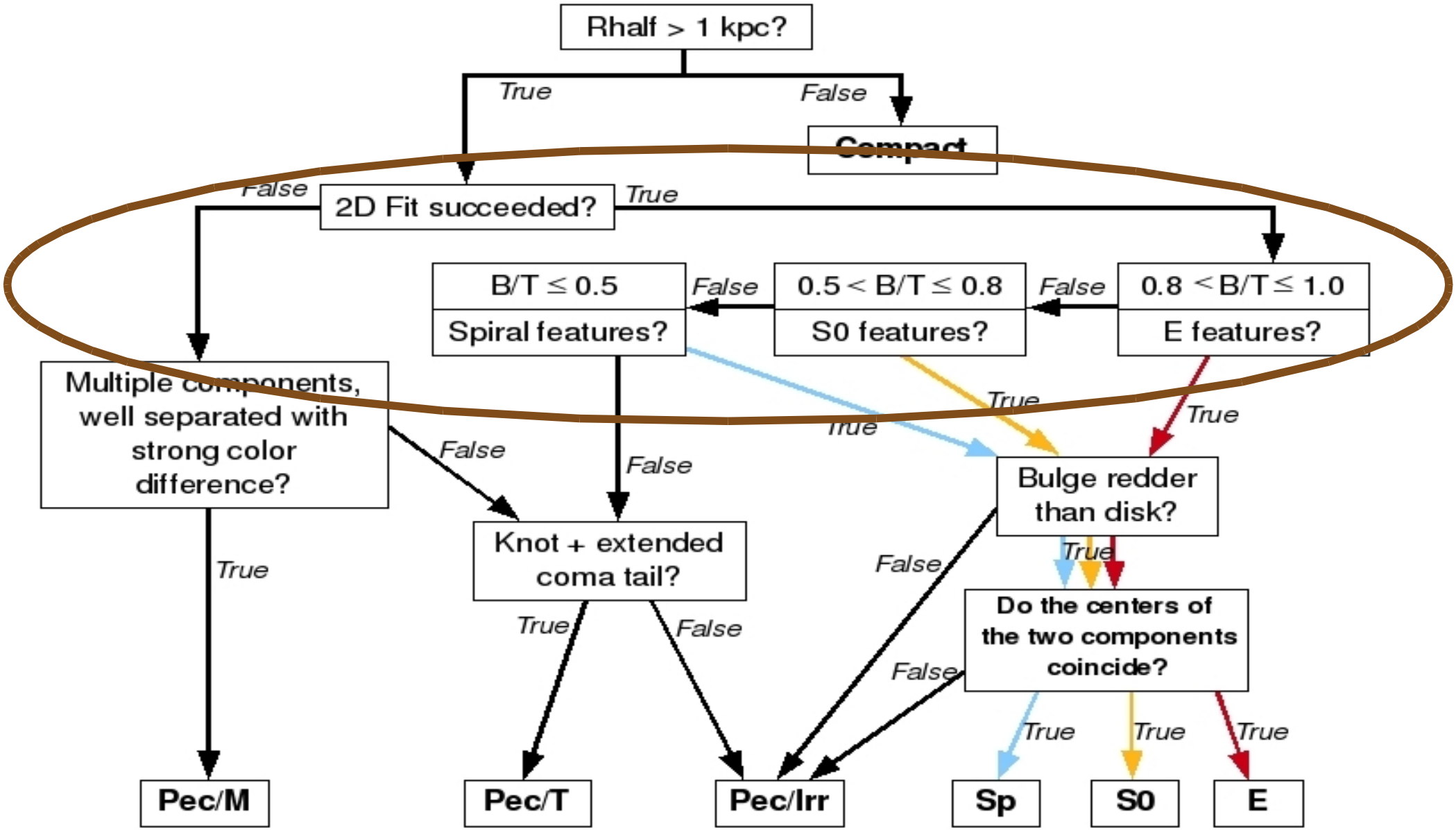
u (V)	0.52
g (i)	0.08
r (z)	1.02

The Method



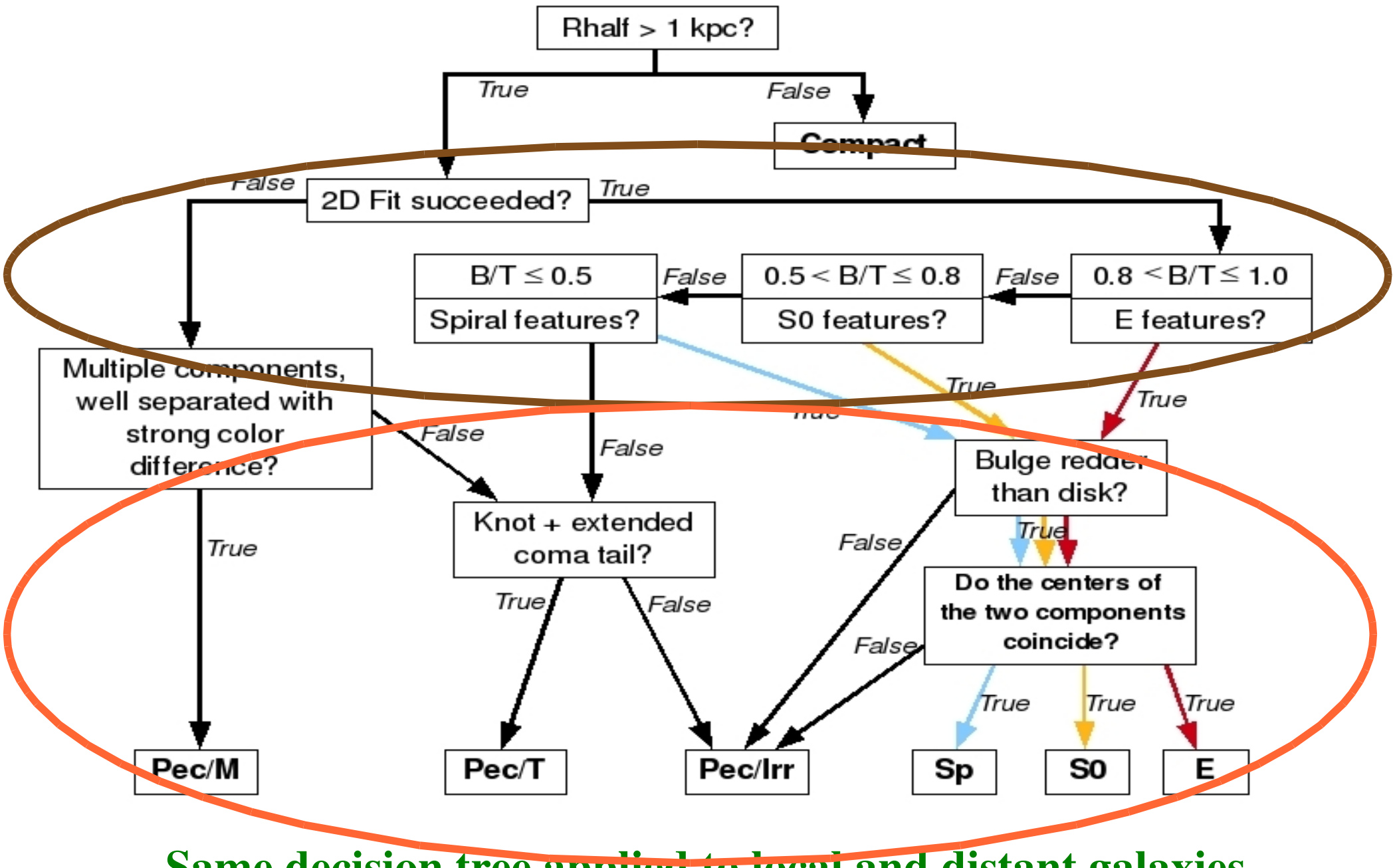
Same decision tree applied to local and distant galaxies

The Method



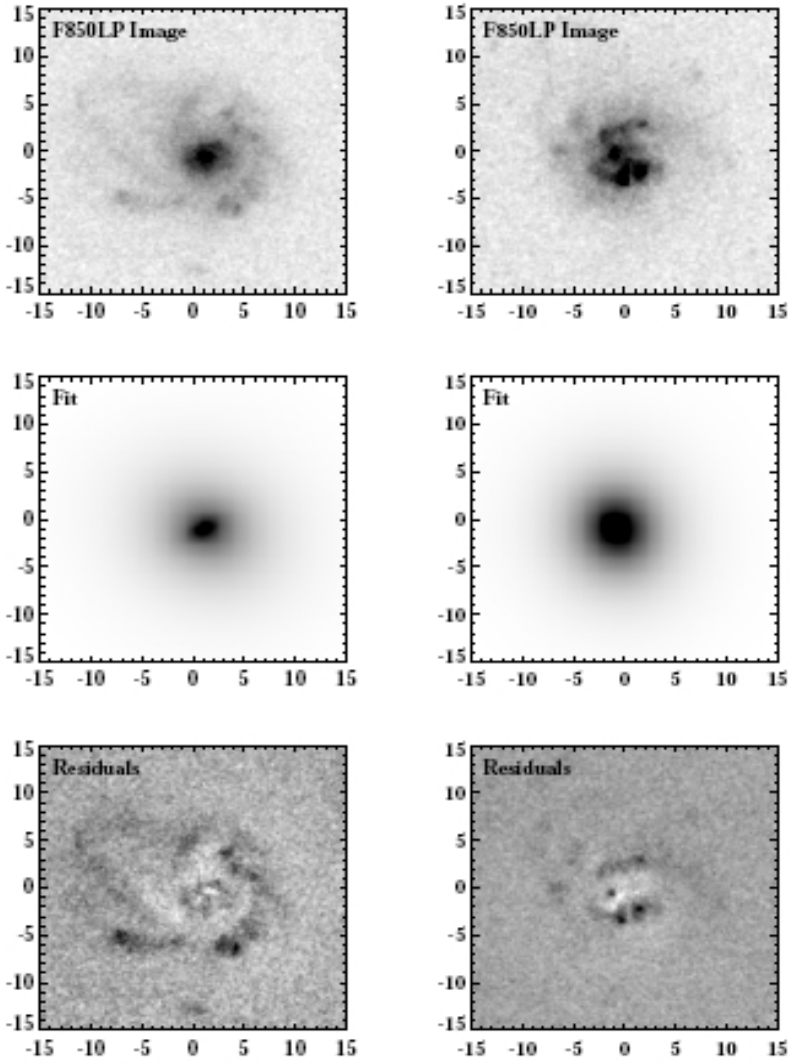
Same decision tree applied to local and distant galaxies

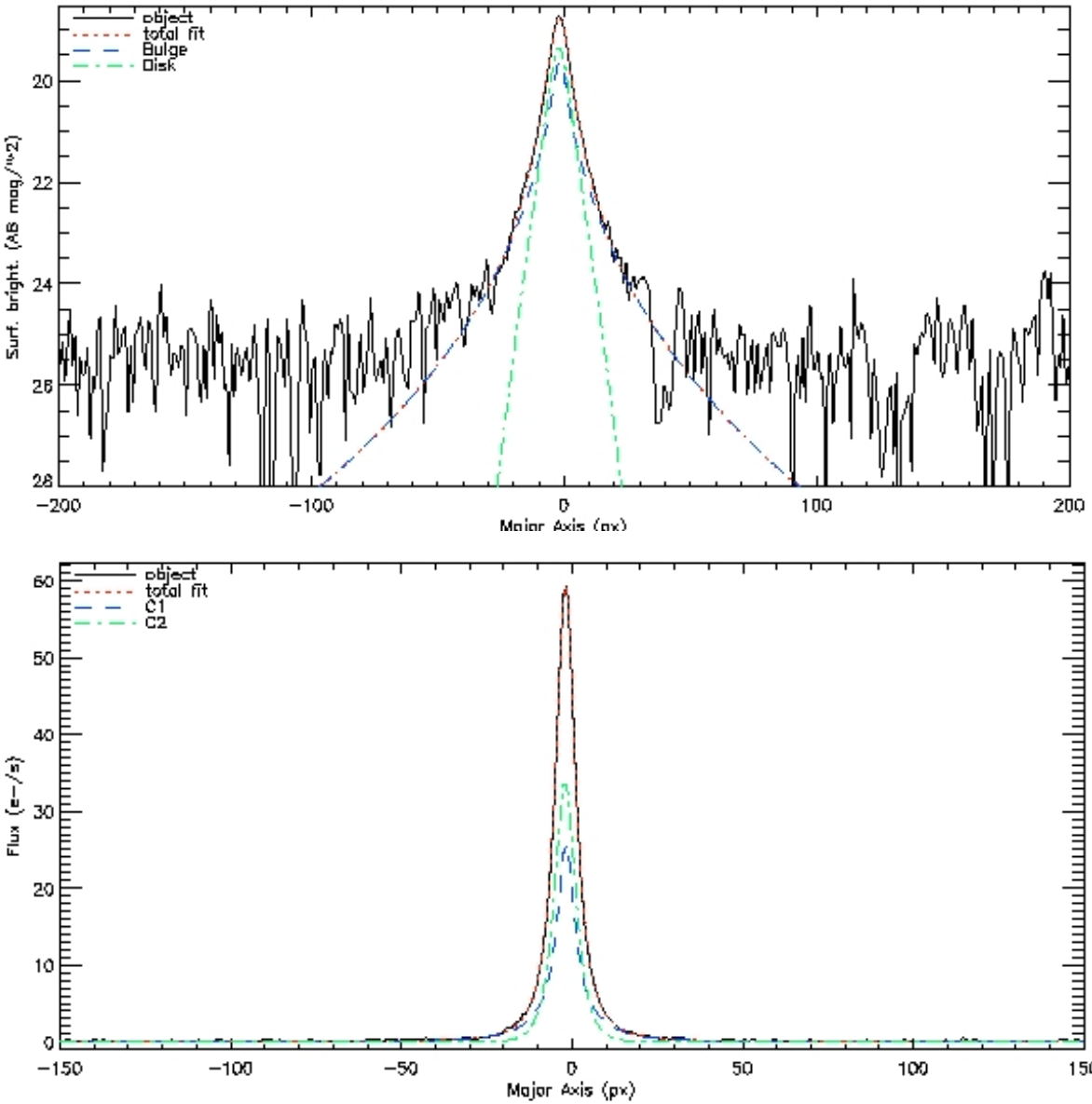
The Method



Same decision tree applied to local and distant galaxies

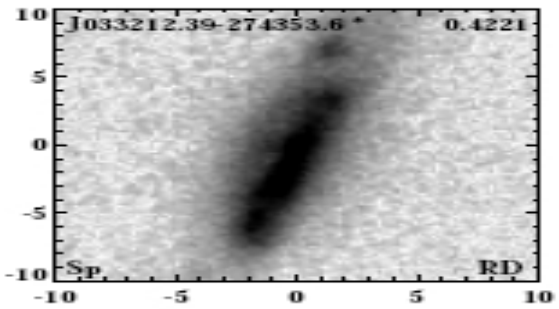
The Method

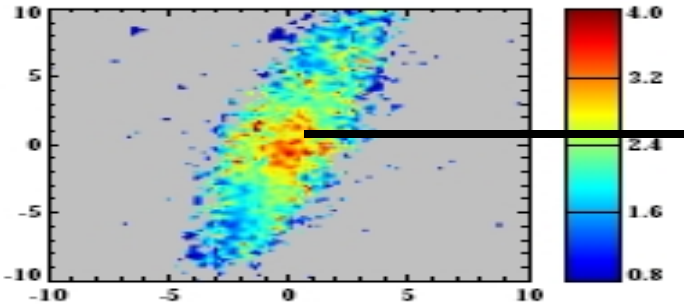




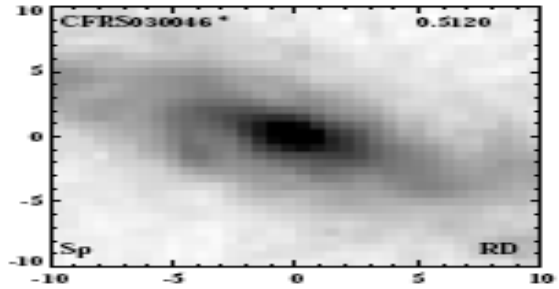
Galfit simulation: Sersic Profiles (Bulge+Disk)

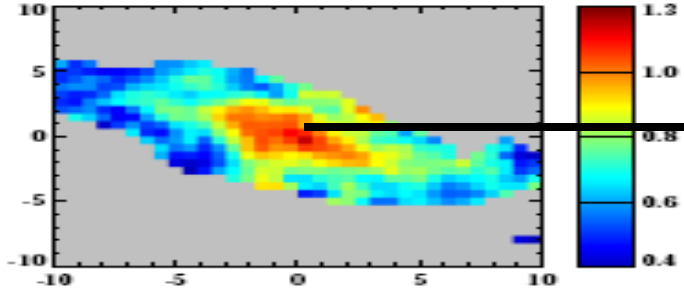
The Method



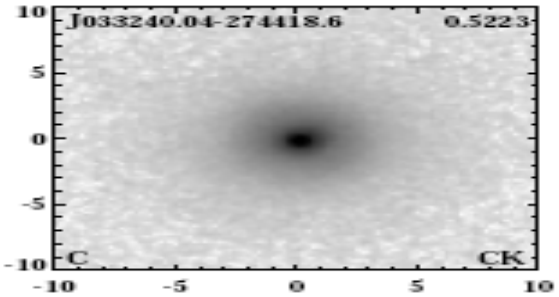


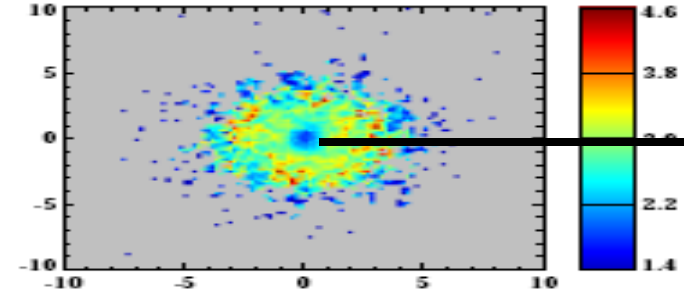
Red center





Red center





Blue center

Color maps

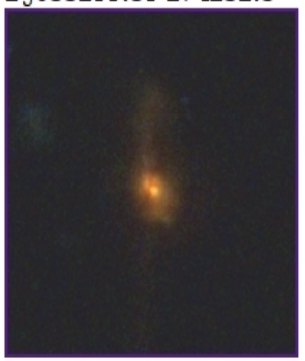
The Method

Color images

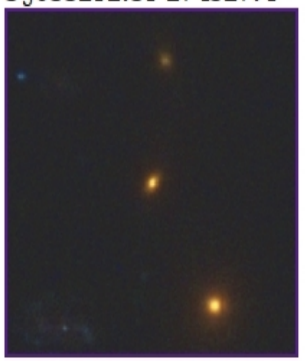
ALL	Pec	Sp	S0	E
80	20	23	27	10

== 80 galaxies ==

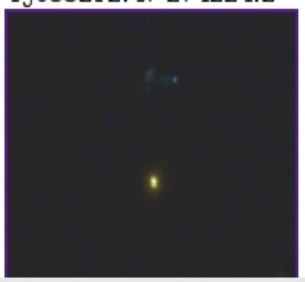
2 J033211.31-274232.5



3 J033212.31-274527.4



4 J033212.47-274224.2



--> Goto Color images

Table 1. General properties

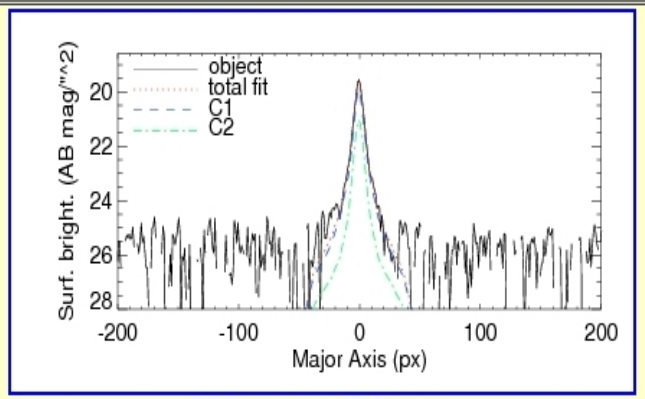
GOODS_ID	redshift	M_B(AB)	$M_{J(AB)}$	R_{half_light} (kpc)
J033246.37-274912.8	0.6810	-19.9516	-21.9901	1.74+/-0.11

morpho-class	EW[OII]	Stellar Mass	SFR_UV	SFR_IR	SFR_TOT	Log(Tsfr)	Flag
7	6.03807	10.7282	0.0730+/-0.0244	0.0000+/-0.0000	5.0365+/-4.9635	10.0261	0

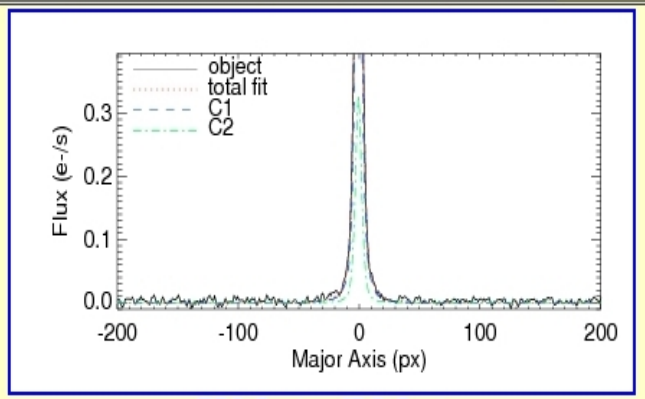
Table 2. Galfit results for all bands

Band	Cp	[x,y]	Magnitude	Radius	Sersic	F_i	b/a	Inc.	P.A.	Chi2/nu
z	C1	[252.33,251.96]	22.22+/- 0.02	3.75+/- 0.11	5.42+/- 0.25	0.69+/- 0.03	0.58	54.55	-35.21	1.24
	C2	[252.00,251.60]	23.08+/- 0.04	8.42+/- 0.15	1.00+/- 0.00	0.31+/- 0.01	0.23	76.70	-40.92	

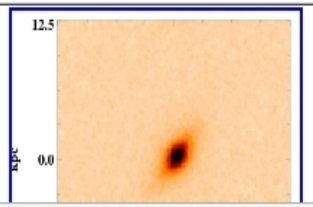
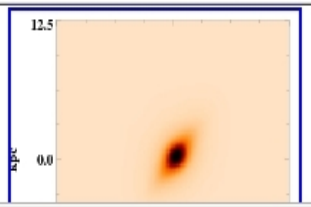
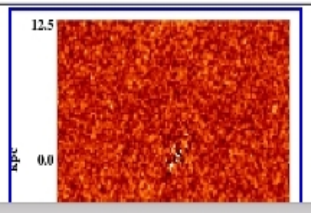
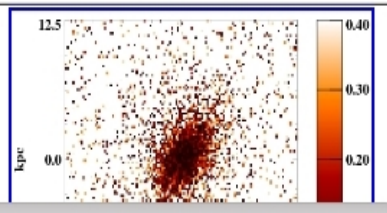
Comments



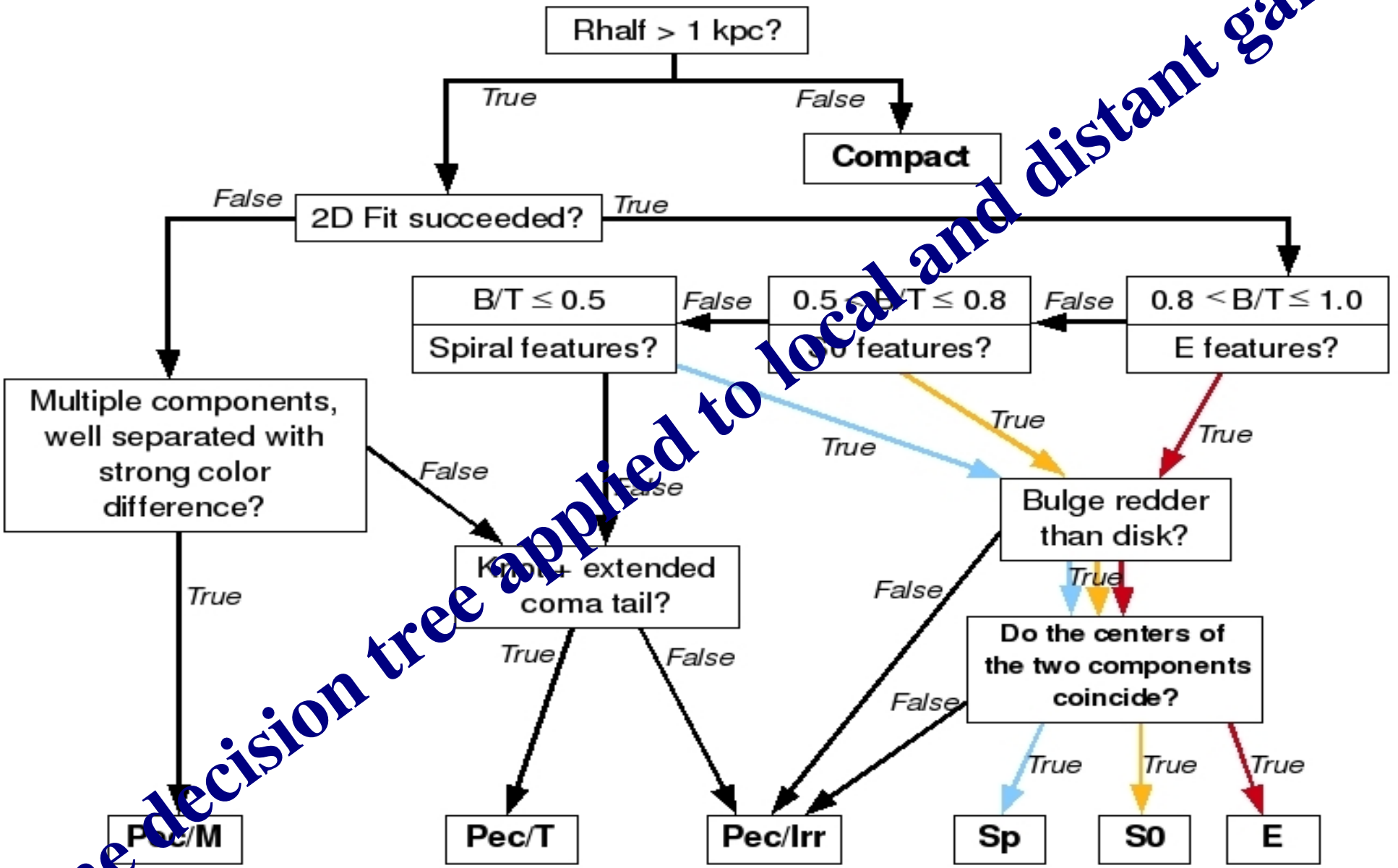
EPS(mag) JPG(mag)



EPS(flux) JPG(flux)

Band	Original	Model	residual	Error(estimate)
z				

The Method



Same decision tree applied to local and distant galaxies

Results

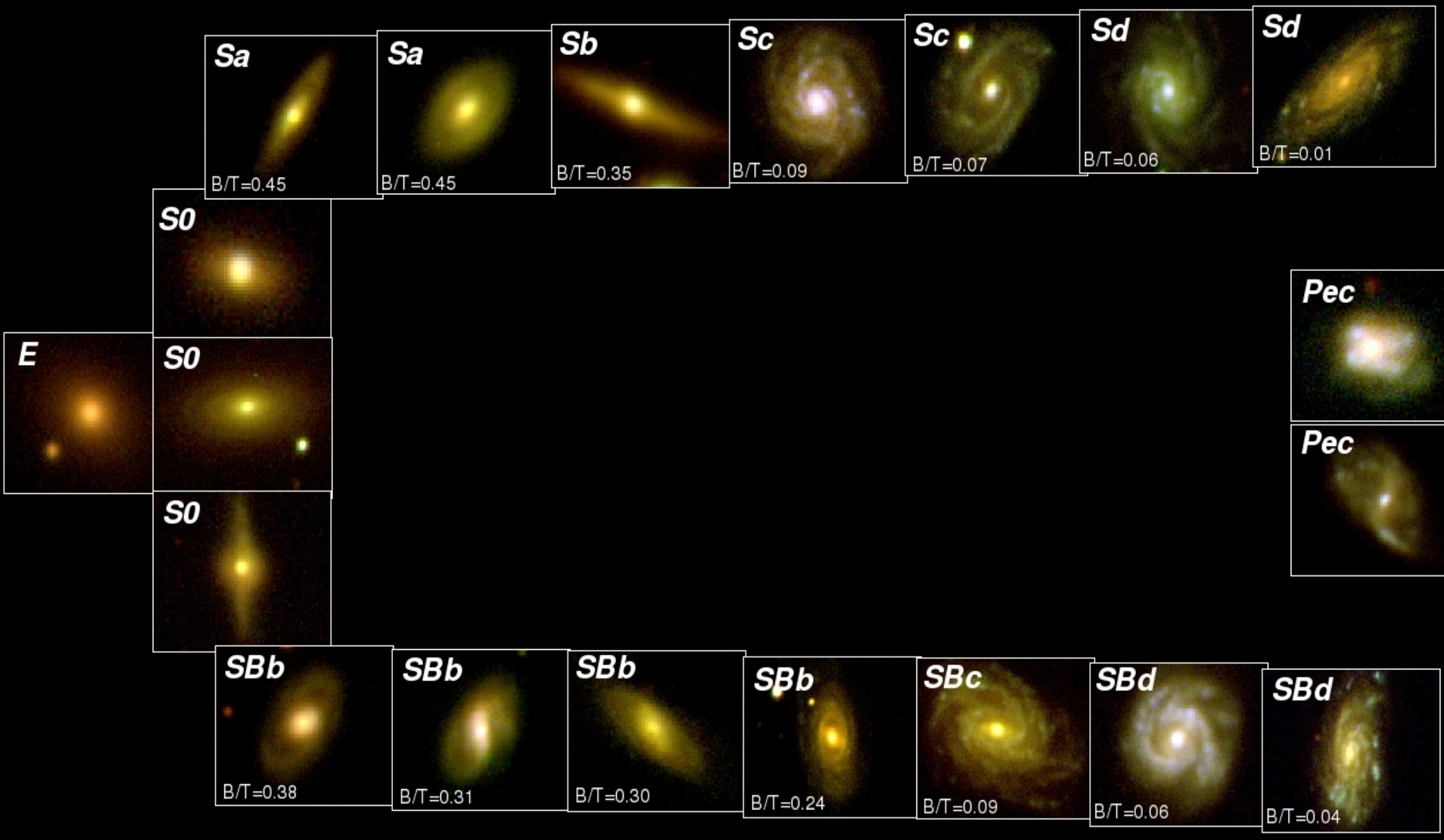
	Local			Distant		
Type	Total (%)	Quiescent (%)	Starburst (%)	Total(%)	Quiescent (%)	Starburst (%)
E	3±1	3±2	0±0	4±1	11±3	0±0
S0	15±4	14±4	20±10	13±2	33±6	0±0
Spiral	72±8	76±10	55±17	31±7	31±6	31±8
Peculiar:	10±3	7±3	25±11	52±9	25±5	69±12
P/Irr	4±2	2±1	15±9	26±7	21±5	29±8
P/Tad	0±0	0±0	0±0	6±3	0±0	10±5
P/Mer	4±2	4±2	5±5	20±6	4±2	30±8
P/C	2±1	1±1	5±5	0±0	0±0	0±0

Delgado-Serrano et al. (2010)

* Recent merging events and star formation histories unlikely affect more than 10% of the galaxies that may be linked together.

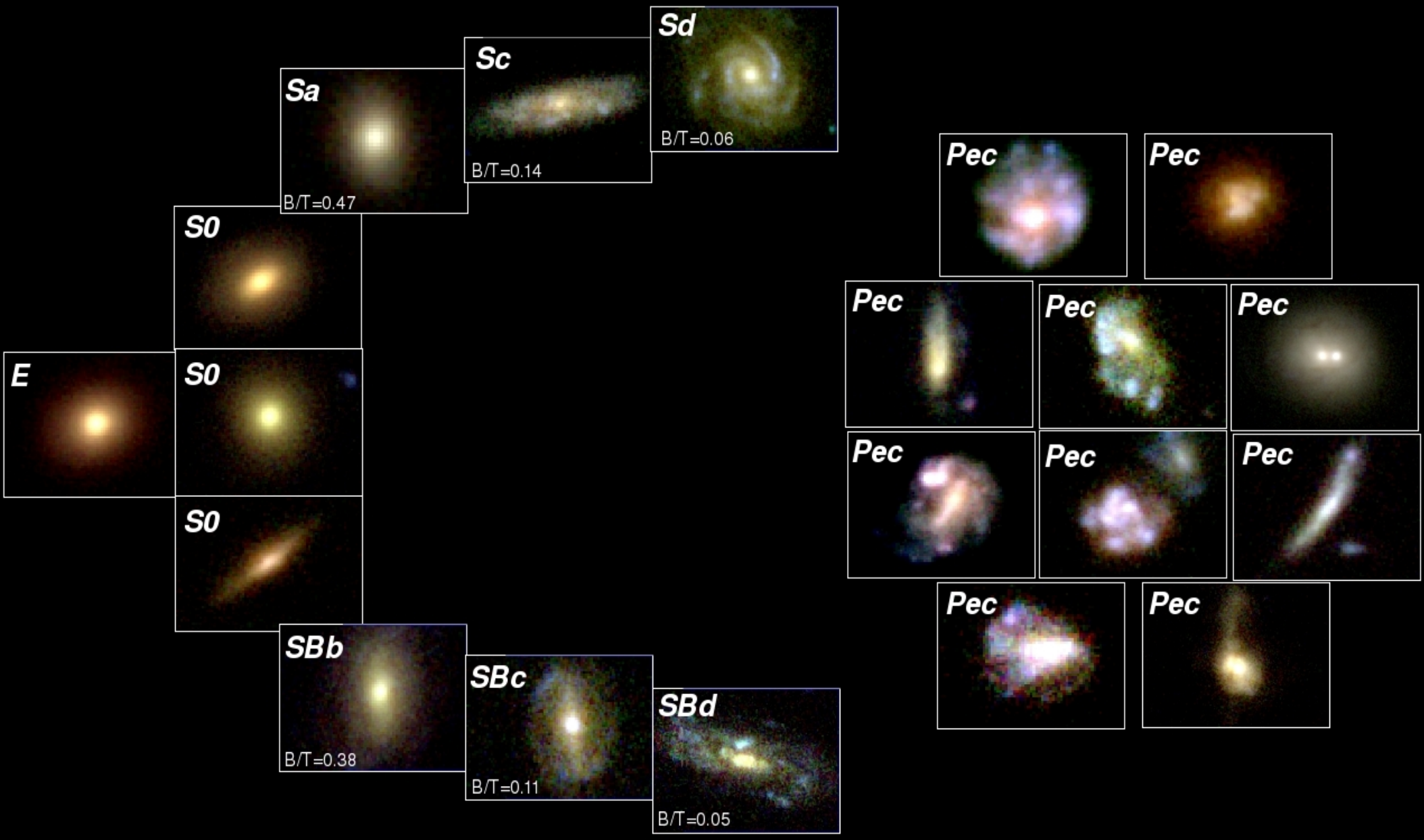
* There is however a need to improve the statistics, since this work is based on numbers slightly over 100 for both distant and local sample.

Local Galaxies



E	S0	Spiral	Peculiar
3%	15%	72%	10%

Distant Galaxies

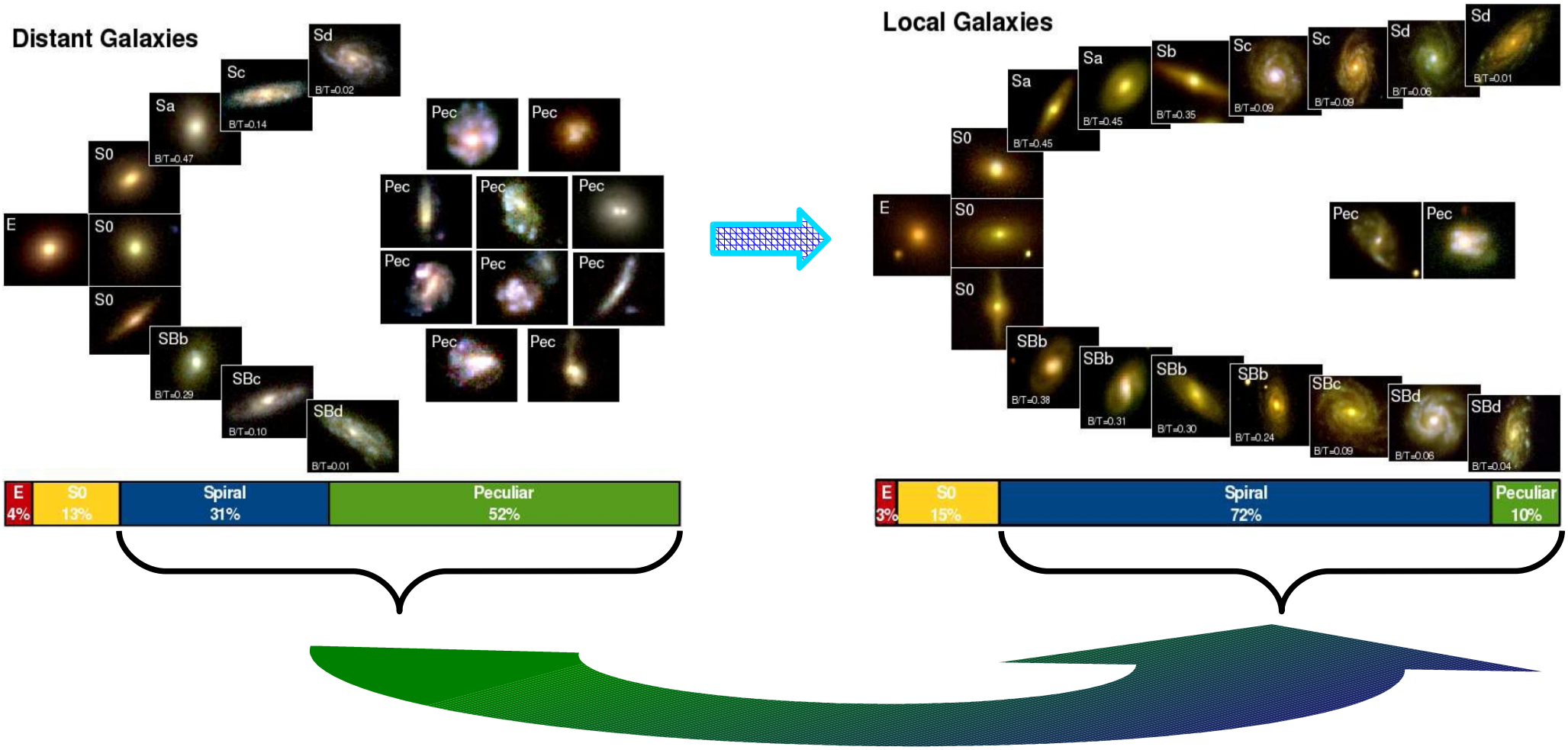


E	S0	Spiral	Peculiar
4%	13%	31%	52%

Hubble sequence evolution

6 Gyrs ago

Present-day



- **2.3 times more regular spiral galaxies**
- **5.2 times less peculiar galaxies**
- **No fraction evolution of E/S0 galaxies**

Results

	Local			Distant		
Type	Total (%)	Quiescent (%)	Starburst (%)	Total(%)	Quiescent (%)	Starburst (%)
E	3±1	3±2	0±0	4±1	11±3	0±0
S0	15±4	14±4	20±10	13±2	33±6	0±0
Spiral	72±8	76±10	55±17	31±7	31±6	31±8
Peculiar:	10±3	7±3	25±11	52±9	25±5	69±12
P/Irr	4±2	2±1	15±9	26±7	21±5	29±8
P/Tad	0±0	0±0	0±0	6±3	0±0	10±5
P/Mer	4±2	4±2	5±5	20±6	4±2	30±8
P/C	2±1	1±1	5±5	0±0	0±0	0±0

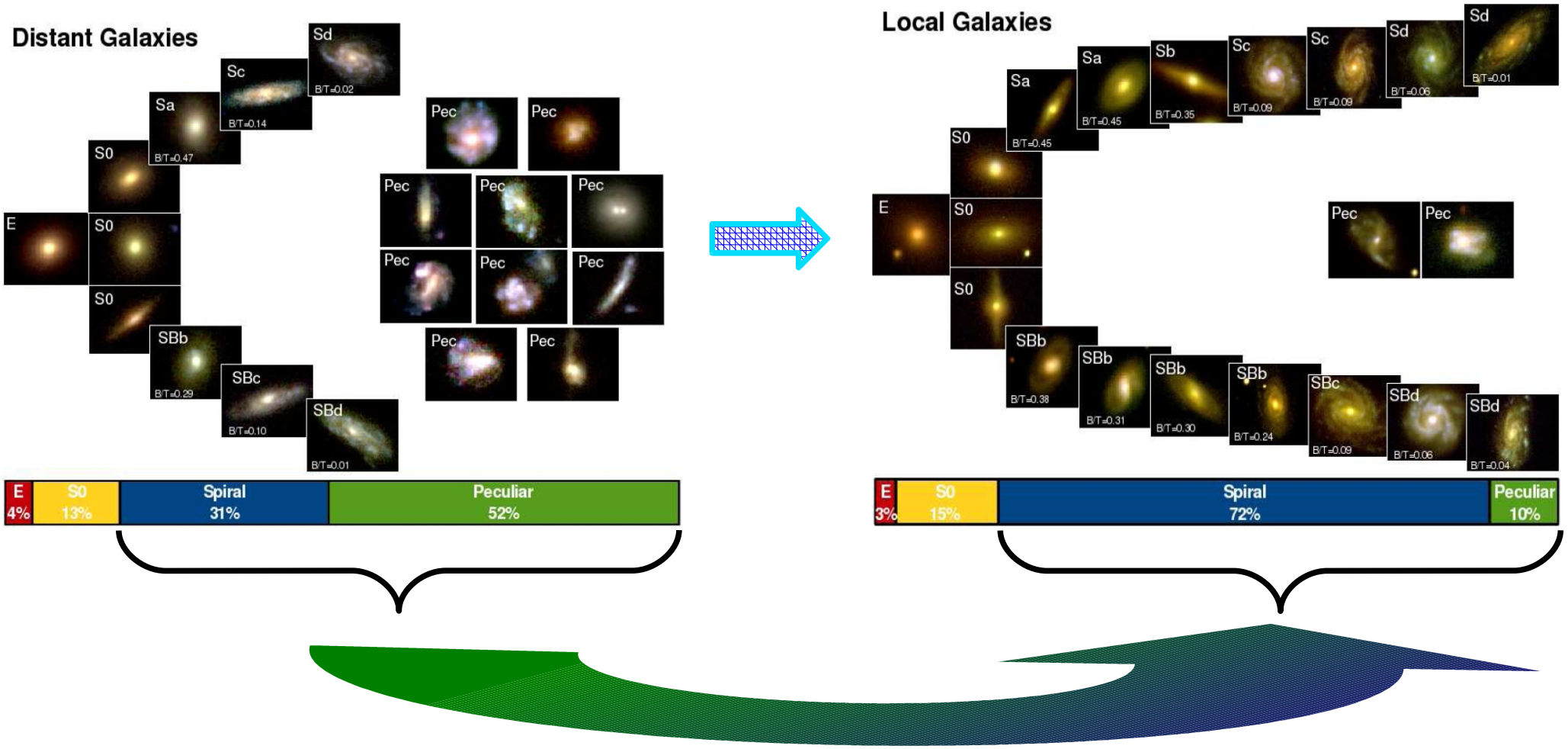
17 %

60 %

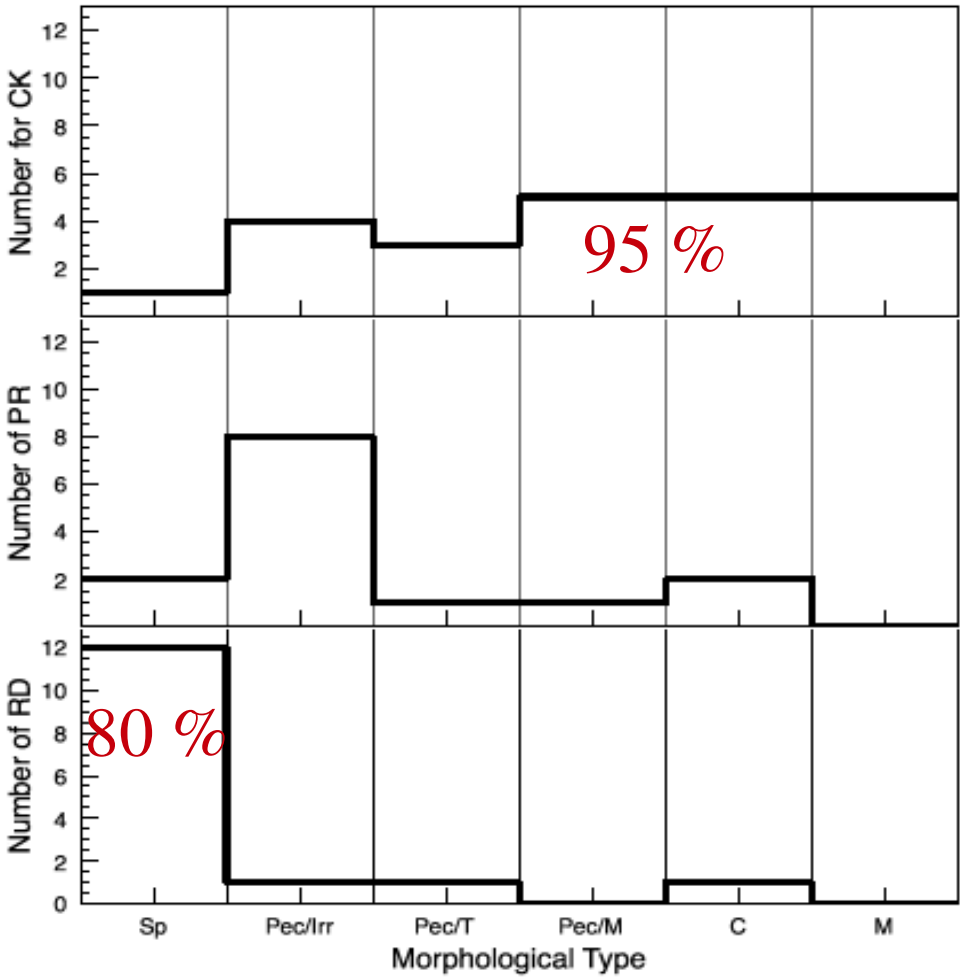
Conclusions

- **We have established a first approximation of what would be the progenitors, 6 Gyrs ago, of the galaxies of the present-day Hubble sequence.**
- **E/S0 galaxy populations show no evidence for a number evolution during the last 6 Gyrs;**
- ***Slightly more than half of the distant galaxies have peculiar morphologies, that is likely associated to anomalous kinematics according to Neichel et al. (2008)*;**
- **The fraction of regular spiral was 2.3 times lower 6 Gyrs ago than at the present epoch;**
- ***Morphology statistics strongly shows that almost all the galaxy evolution, since 6 Gyr ago, is caused by the transformation of galaxies with peculiar morphologies to regular spiral galaxies at present epoch*;**
- ***The transformation of peculiar distant galaxies to regular spiral in the present-day Hubble sequence should be addressed by current scenarios of galaxy evolution and formation.***

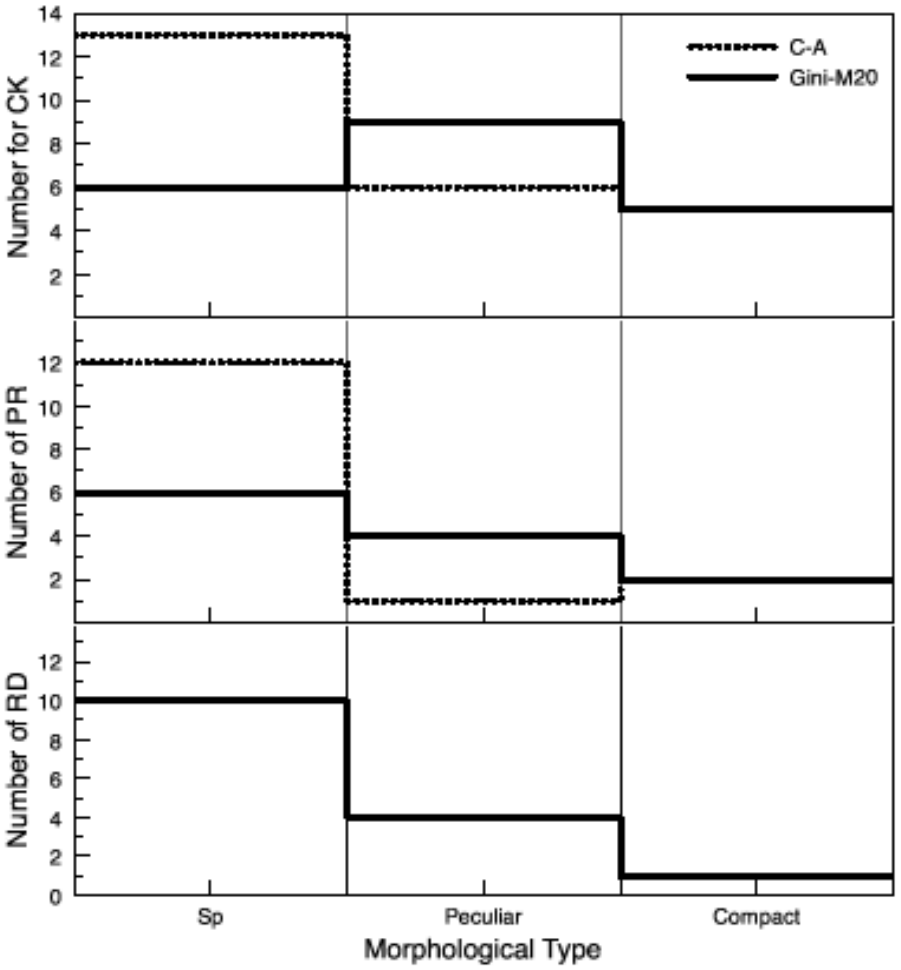
Thank You


Distant Galaxies
Sd
Sc
Sa
S0
E
S0
S0
SBb
SBc
SBd
B/T=0.02
B/T=0.14
B/T=0.47
B/T=0.29
B/T=0.10
B/T=0.01
Pec
Pec
Pec
Pec
Pec
Pec
Pec
Pec
Pec
Local Galaxies
Sd
Sc
Sa
Sb
Sa
S0
E
S0
S0
SBb
SBb
SBb
SBb
SBc
SBd
SBd
B/T=0.01
B/T=0.06
B/T=0.09
B/T=0.09
B/T=0.35
B/T=0.45
B/T=0.45
B/T=0.38
B/T=0.31
B/T=0.30
B/T=0.24
B/T=0.09
B/T=0.06
B/T=0.04
Pec
Pec
E 4%
S0 13%
Spiral 31%
Peculiar 52%
E 3%
S0 15%
Spiral 72%
Peculiar 10%

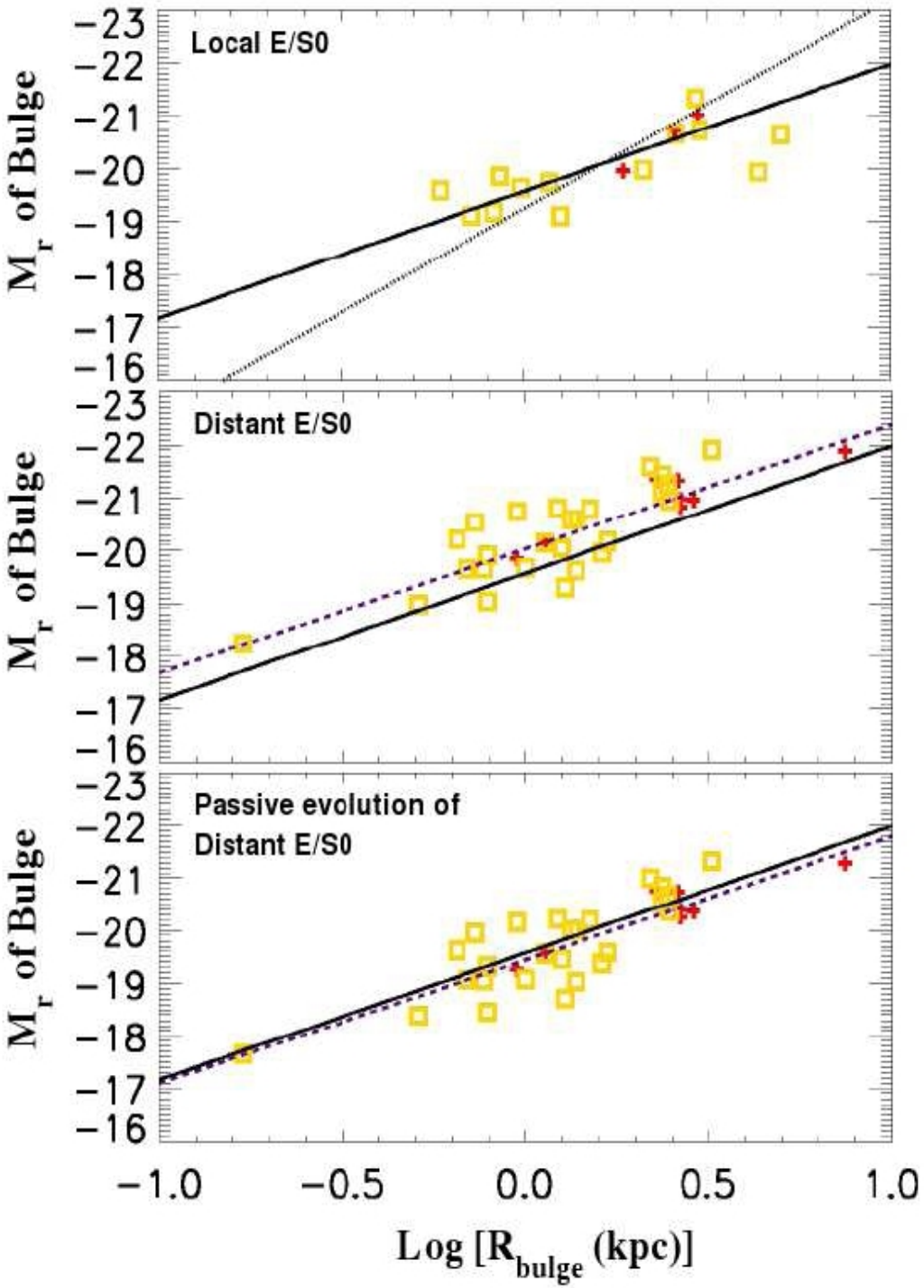
Neichel et al. (2008)



Our morphology classification method and kinematic classification.



Other morphology classification methods and kinematic classification.


Local E/S0
Distant E/S0
Passive evolution of
Distant E/S0
M_r of Bulge
−23
−22
−21
−20
−19
−18
−17
−16
−1.0
−0.5
0.0
0.5
1.0
Log [R_bulge (kpc)]