COLOR SEPARATION OF GALAXY TYPES IN THE SLOAN DIGITAL SKY SURVEY IMAGING DATA

Strateva et al. 2001, AJ, 122, 1861

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Outline

- **Abstruct**

  : roughly
- **Introduction**

  : background about molophology of galaxy and SDSS
- **Samples**

  : somewhat complecated.....(for me)
- **Color distribution and morphology**

  : main claim of this study!
- **Other parameters except color**

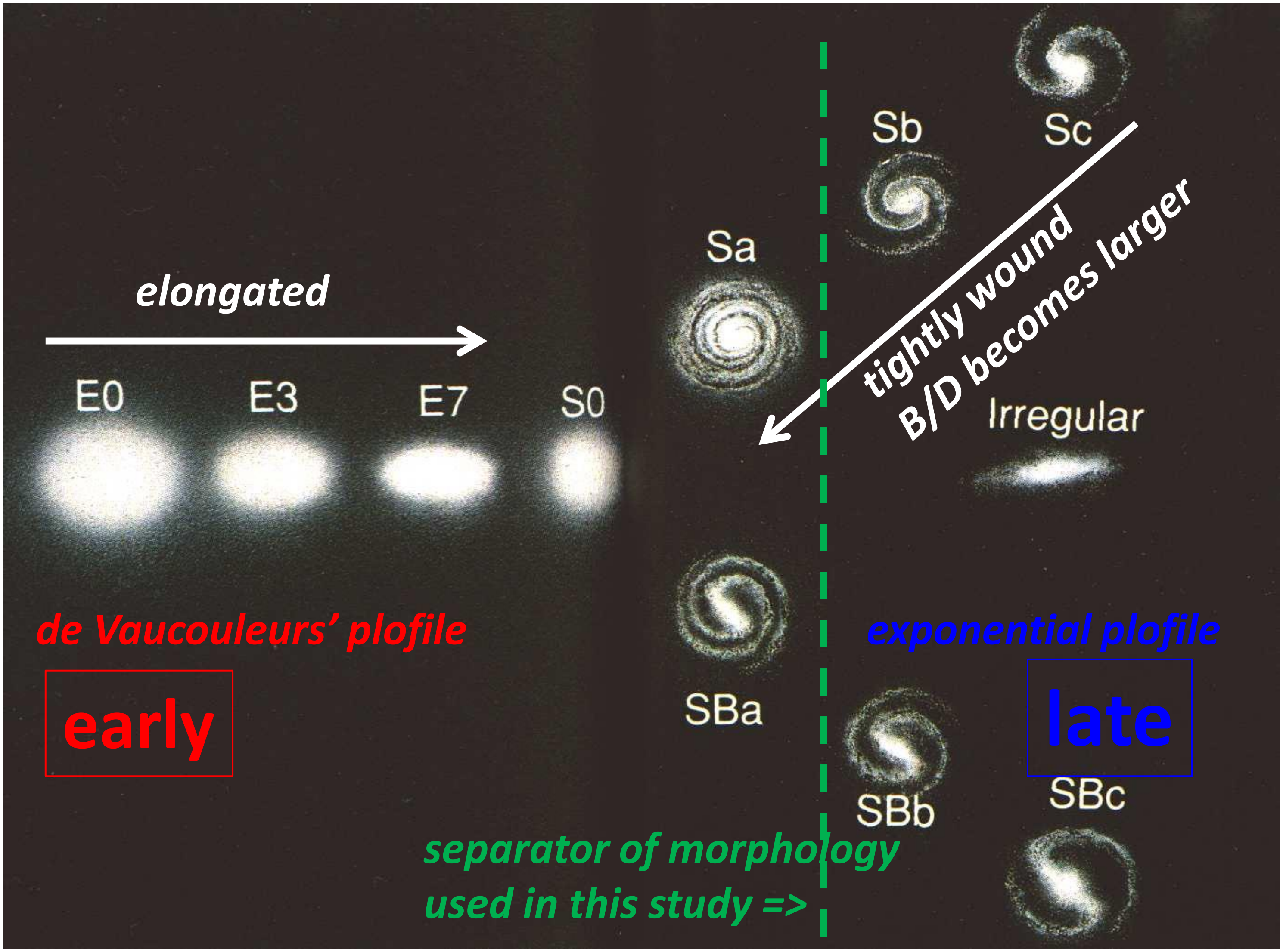
- **Conclusion**

Abstruct

- They mainly study the correlation between the optical colors and morphology of galaxies.

  (using ***147,920*** galaxies brighter than g* = 21 from ***SDSS data***)
- The galaxies can be separated clearly with an optimal color separator of ***u*- r*=2.22*** in both of the color-color diagram and the color-mag diagram.
- It is found that ***red***/***blue*** ***galaxies correspond roughly to early***/***late***-***type galaxies!!***
- Other parameters, Profile likelihoods and concentration index are correlated with color, but not strongly.
- Color (and other parameters) are more accessible and beneficial as indicators of morphology than Hubble sequence.

Introduction(1):morphology



Introduction(1):morphology

- Since the late 1930s several studies that seek correlation between color and morphology of galaxies have been conducted.

- ***Spectral type of stars*** that dominate the system affect ***the morphology*** of the system.(Morgan & Mayall, 1957)
- There seem to be some relation between ***the colors, molophological types, shapes, and luminosity*** of galaxies.(Fioc & Rocca-Volmerange, 1999)
- ***Strength of galaxy clustering*** is strongly dependent on ***color***, with red galaxies more strongly clustered than blue galaxies.(Brown, Webster, & Boyle, 2000)

Introduction(2):SDSS

- ***SDSS(Sloan Digital Sky Survey)***

(i) is a digital photometric and spectroscopic survey,

(ii) ***cover the very wide area***(the survey sky coverage of 10,000 square degree),

(iii) have the five bands for imaging; ***u,g,r,i,z*** (λ~3543,4770,6231,7625,9134)

(iv) use the ***fiber-fed spectrographs***, which have 640 optical fibers of ***3'' entrance diameter***,

(v) leads ***photometric measurements of*** $\sim\mathbf{5\times10^{7}}$ galaxies and $\sim\mathbf{10^{6}}$ ***spectra.***

Samples

- Three galaxy samples are made as follows,

➢ ***photometric***

: ***147,920*** galaxies which have magnitude of ***g*<21*** and the spatial coverage of 101.4deg^2.

This samples are used to study the color distribution.

➢ ***spectroscopic***

: composed of ***500*** galaxies which havs magnitude of $\boldsymbol{r_{petr}}$****<17.8*** and the spatial distribution of 1.7 deg^2.

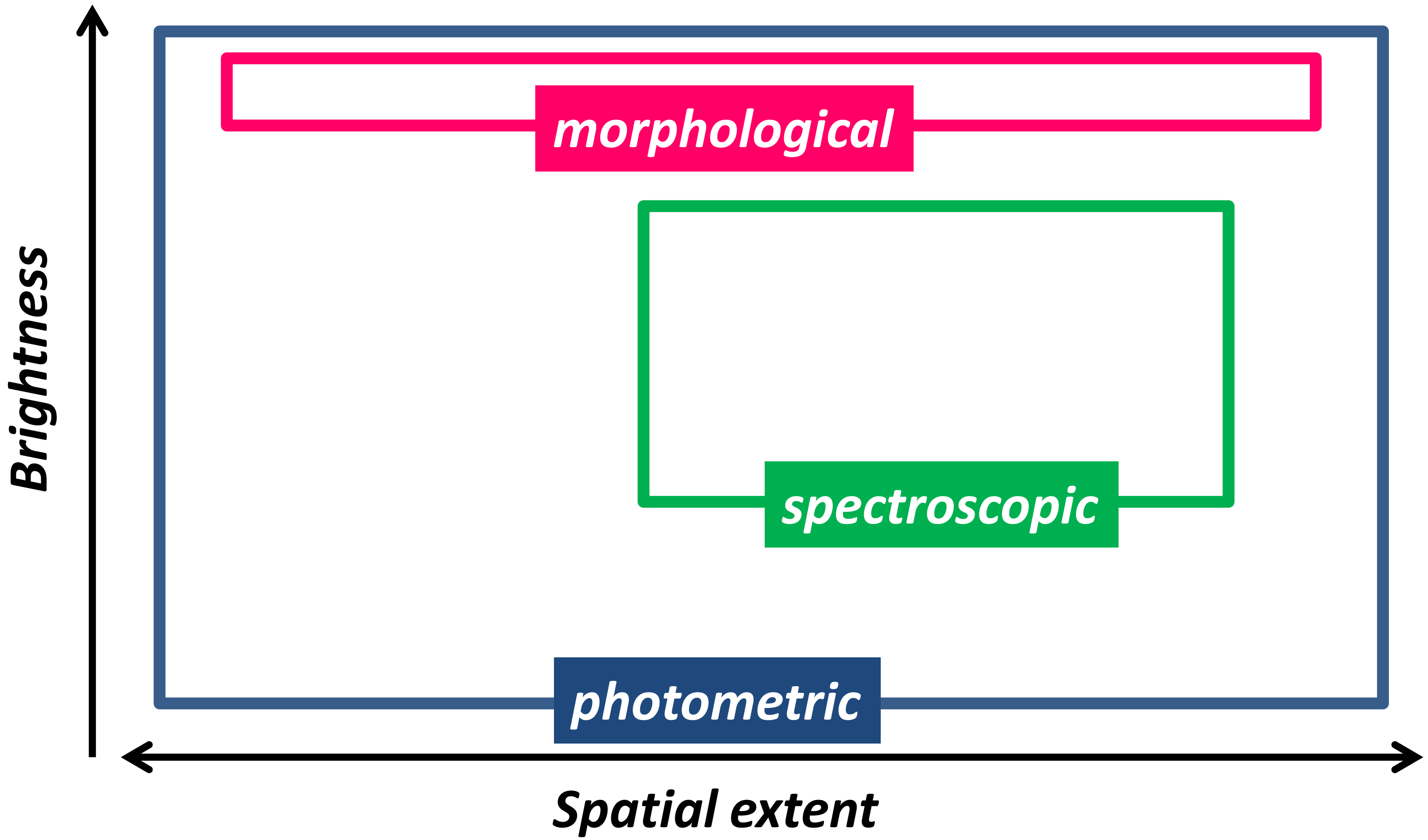
This samples are used for morphological classification.

➢ ***morphological***

: composed of ***287*** bright galaxies(***g*<16***).

For morphological classification by visual inspection.

Samples


morphological
spectroscopic
photometric
Brightness
Spatial extent

Galaxy Color Distribution

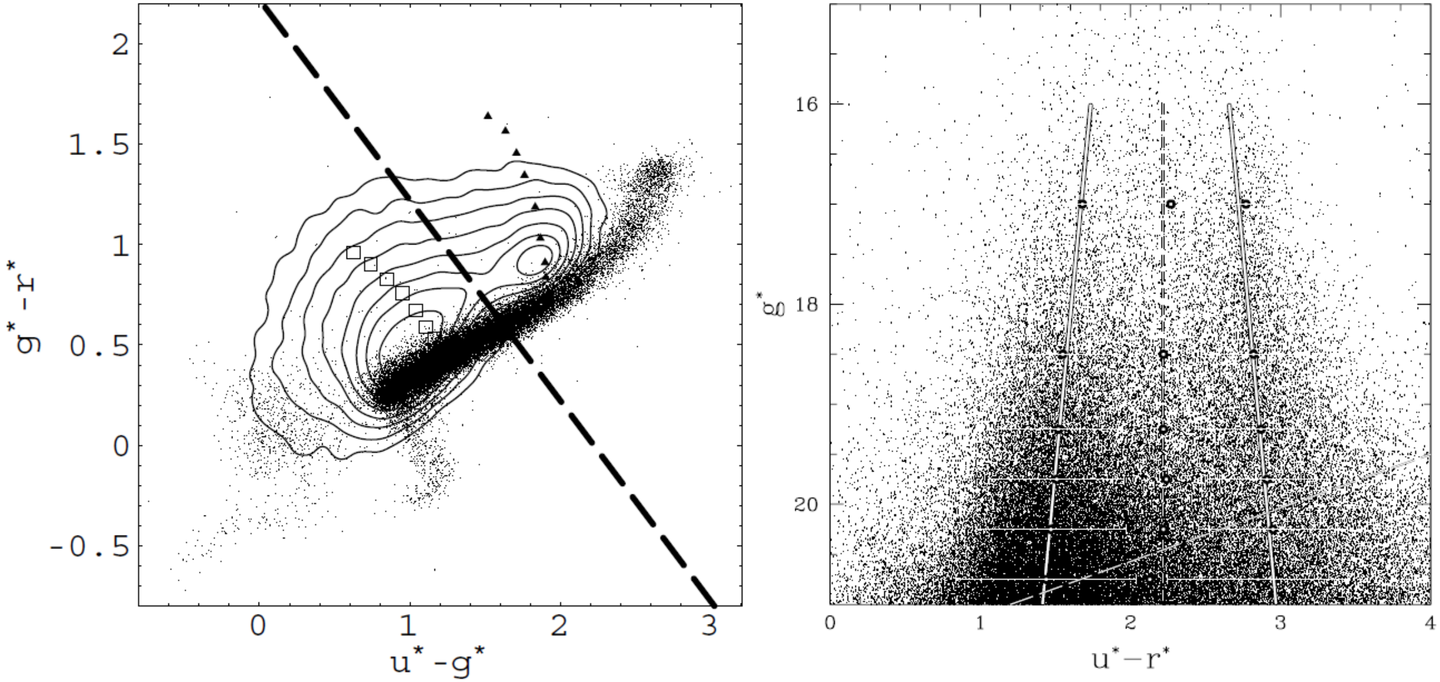


FIG. 1.—*Left*: Distribution of galaxies (*contours*) and stars (*dots*) in the u^*-g^* vs. g^*-r^* color-color diagram. The contours enclose $\sigma/4$ (20.8%) to 2 σ (95.5%) of all galaxies, in steps of $\sigma/4$ (σ corresponds to the equivalent Gaussian distribution). The dashed line is the $u^*-r^* = 2.22$ separator. The evolution of spiral (*squares*) and elliptical (*triangles*) theoretical colors are given for $0 < z < 0.4$ at every 0.05 in redshift. *Right*: u^*-r^* vs. g^* color-magnitude diagram of the photometric sample. Circles show positions of the red and blue peaks and the separator at each mean g^* of six subsamples (see text). Solid lines give linear regressions to the variation of each peak, while the dashed vertical line is the $u^*-r^* = 2.22$ separator. The slanted dashed line is a $u^* = 22$ cut.

- ***Clearly there exists double populations "blue" & "red" with separator of constant u*-r*(2.22).***

Galaxy Color Distribution

- Two trends in the u*-r* color distribution are visible

(i) a shift of ***the blue peak toward bluer*** and ***the red peak toward redder*** with fainter mag end

- ➢ This shift is due to the fact that ***galaxies at increasing redshift are sampled when selecting fainter mag cuts***.
- ➢ *K-correction* dominate the change of the color for the red galaxies.
- ➢ *galaxy evolution (stellar population and SF activity)* explain the change of the color for the blue galaxies.

(This suggest the red/blue galaxies correspond to passive early/young late type galaxies, I thought….)

Galaxy Color Distribution

(ii) ***an increase of the blue galaxies relative to the red***

- ***caused by real evolutionally effect***, not the instrumental effects.

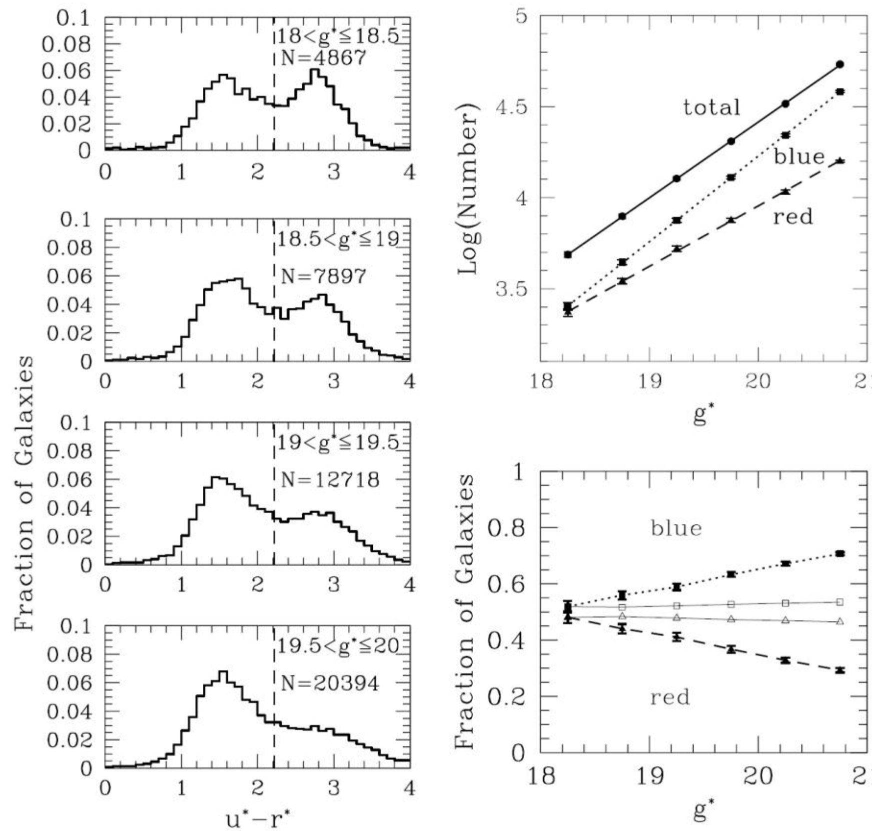


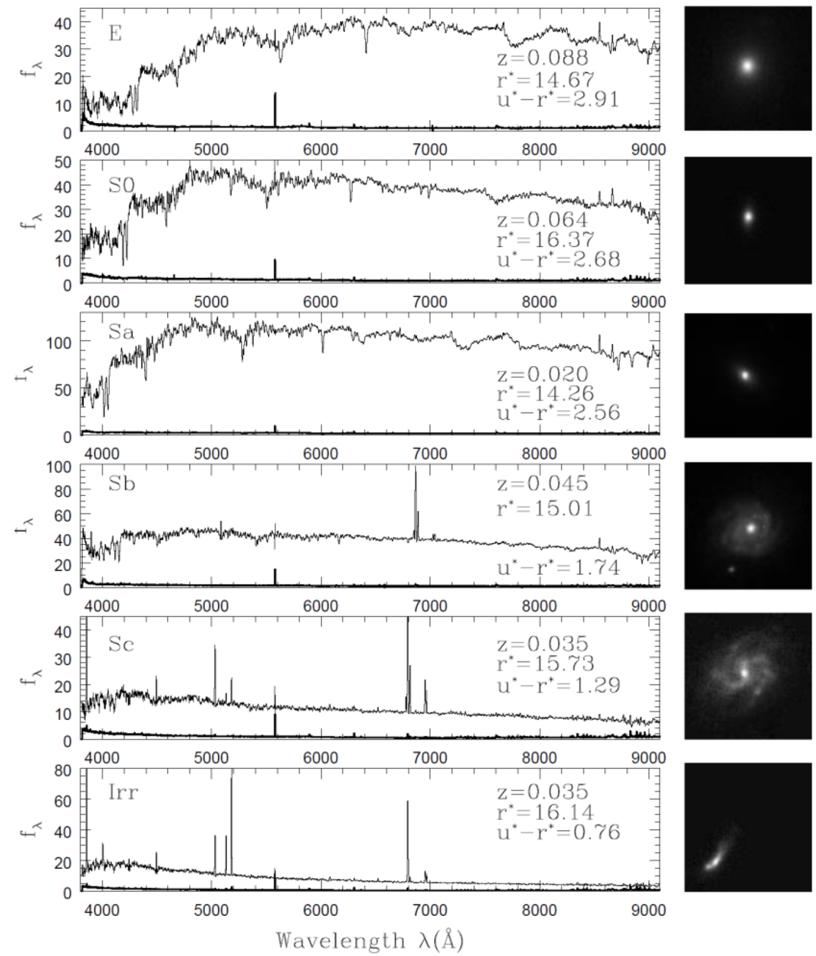
FIG. 2.—*Left*, color distribution $u^* - r^*$ as a function of g^* magnitude of the galaxy sample; *top right*, fraction of blue galaxies (*filled squares*) increasing relative to the red (*filled triangles*) for fainter g^* samples; *bottom right*, photometric errors cannot account for the dependence of the red and blue galaxy fractions on magnitude cut. The open symbols correspond to the predicted fraction (assuming only photometric errors change with magnitude), the filled symbols to the observed.

Correspondence between Color and Morphology

- **Morphological classification**

➢ For bright galaxies(g*<16), they use ***visual appearance*** of g* image.(morphological sample)

➢ For fainter galaxies($r_{petr}* < 17.8$), they classified spectroscopic samples(500) by ***visually compa-ring*** their spectra.



Note!: Here fiber-fed specrograph was used, and their aperture of 3'' may misclassify large late-type as early-type. (6% of the samples are expected to be misclassified.)

Correspondence between Color and Morphology

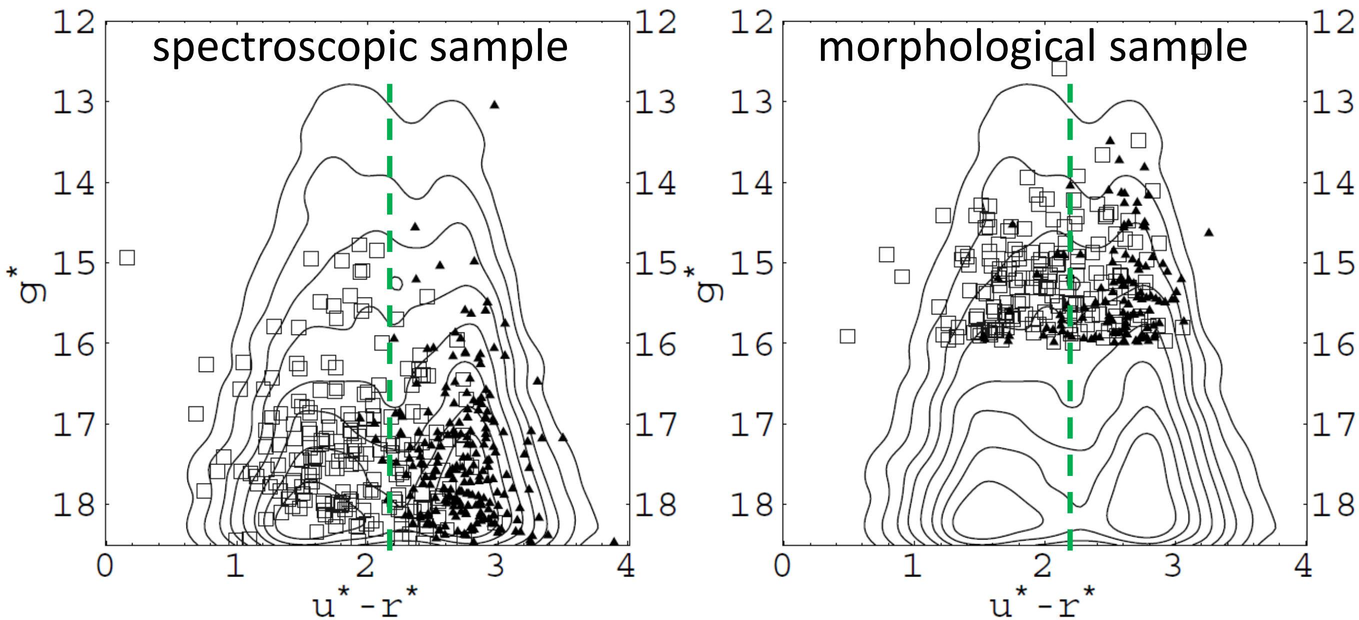


FIG. 6.—Bimodality in the photometric galaxy sample (*contours*) corresponds to early (*triangles*) and late (*squares*) types of galaxies. The 500 galaxies at left are classified spectroscopically; the 287 bright galaxies at right are classified by visual inspection of images.

- ***Most galaxies classified as early types***(E,S0,Sa) have color of u*-r*>2.22, which ***correspond to "red" galaxies***.
- ***Late type galaxies(Sb,Sc,Irr)*** also have u*-r* color ***corresponding to "blue" galaxies***, but ***with more scatter***. There are still a small number of the late-type with u*-r*>2.5.

Correspondence between Color and Morphology

broken samples into more detailed classes…

Some fraction of Sb galaxiess have redder u*-r* color,
which cause the scatter of the color distribution for late-types,
I thought….?

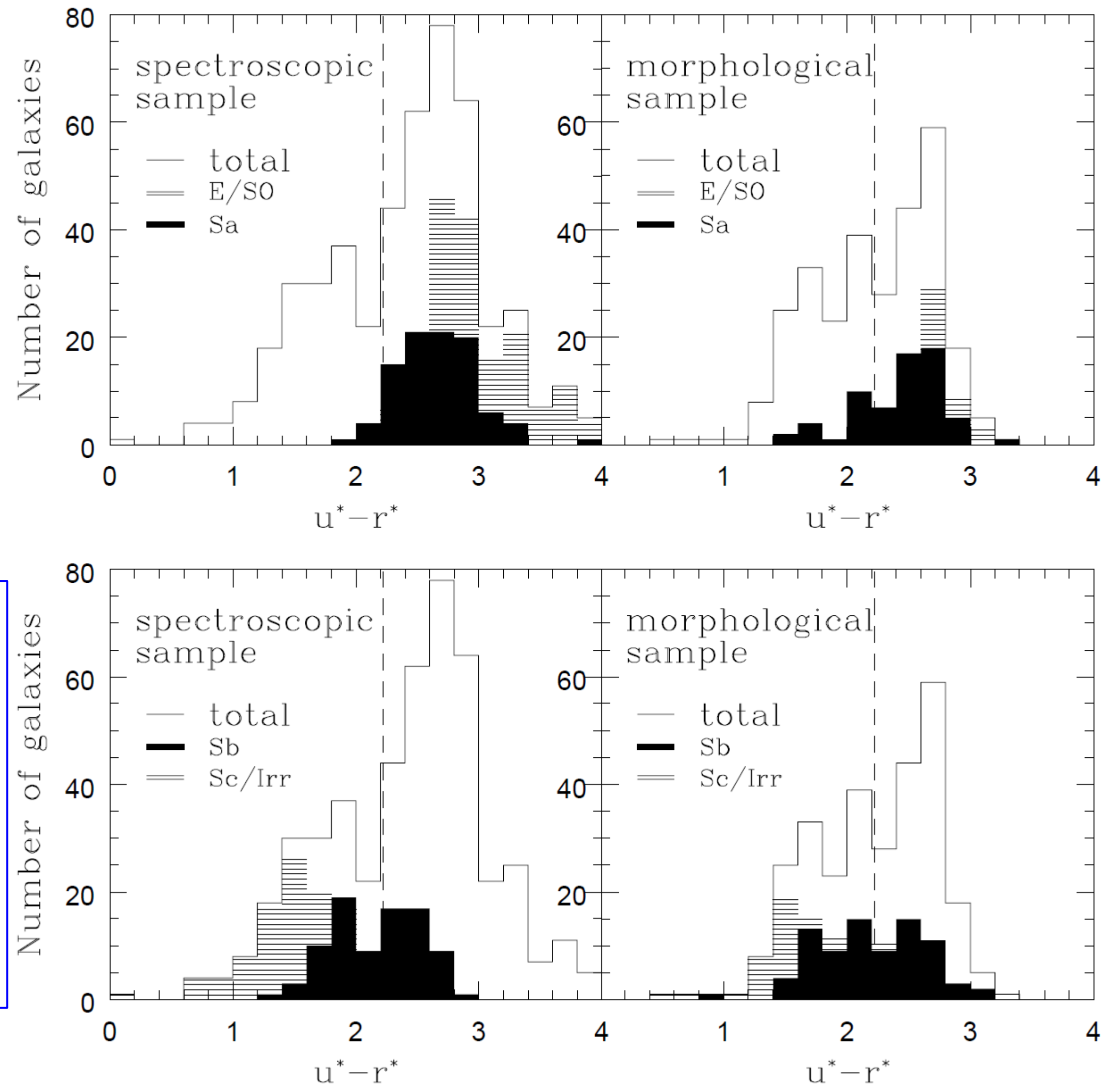


FIG. 7.—*Left*, Spectroscopic classification and $u^* - r^*$ color; *right*, morphological classification and $u^* - r^*$ color; *top*, histograms of early-type galaxies (E/S0 or Sa); *bottom*, those for late types (Sb or Sc/Irr).

Other Parameters Sensitive to Morphology

- The following two parameters correlate well with morphology.

➢ ***Profile likelihood ($P_{exp}/P_{de\ V}$)***

: This quantifies whether radial profile looks like exponential profile or de Vaucouleurs' profile.This is calculated ***in r*-image***.

$P_{exp} > P_{de\ V}$ ***=> late type?*** $P_{exp} < P_{de\ V}$ ***=> early type?***

At very bright end(g*<16), profile likelihoods are calculated incorrectly.(caused by flaw in *PHOTO pipeline*)

➢ ***Concentration index (C)***

: This is defined as the ratio of the radii containing 90% and 50% of the total galaxy light; $C \equiv r_{p90}/r_{p50}$

"These parameters require spatially resolved image…"

Other Parameters Sensitive to Morphology

Spectroscopic sample are divided using ***profile likelihoods*** or ***concentration parameters***.

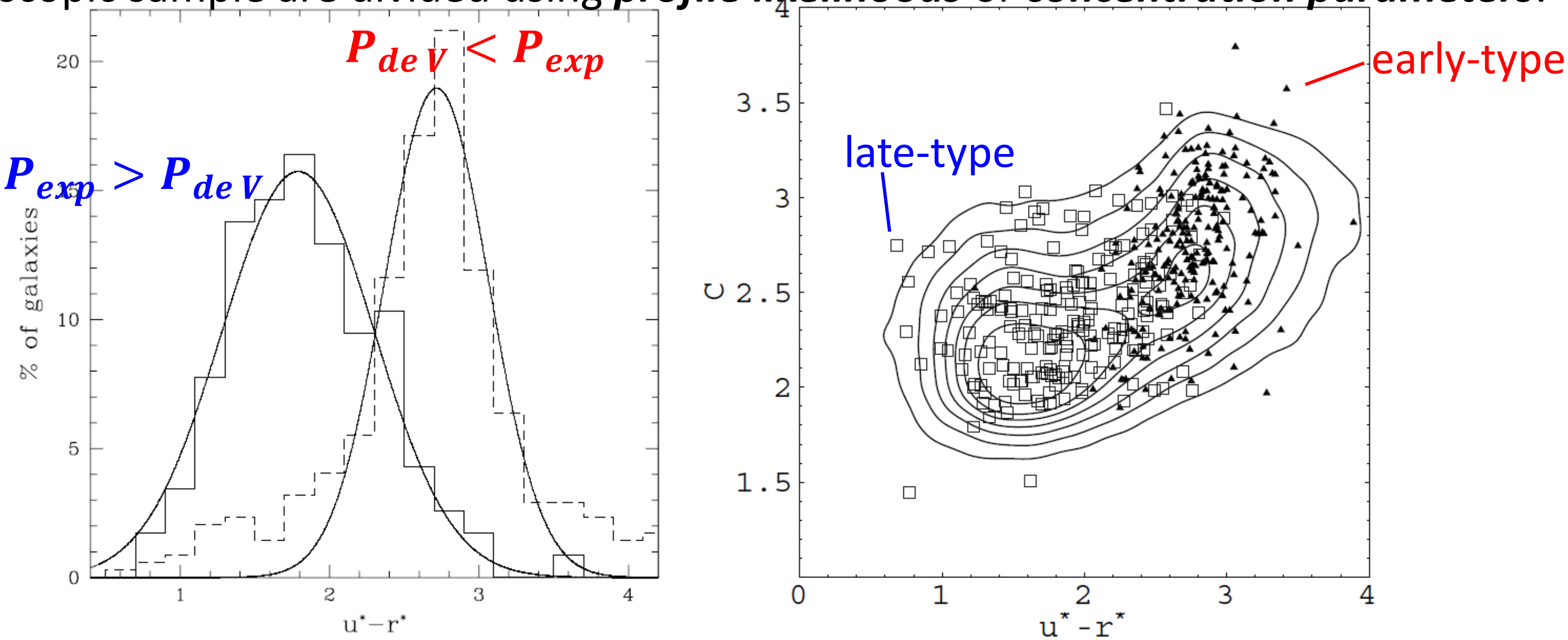


FIG. 8.—Correlation of $u^* - r^*$ color with profile likelihoods and concentration index. *Left*: Spectroscopic galaxy sample $u^* - r^*$ histograms separated into objects with $P_{\rm deV} > P_{\rm exp}$ (early type; *dashed lines*) and $P_{\rm deV} < P_{\rm exp}$ (late type; *solid lines*), showing the same bimodality as does galaxy $u^* - r^*$ color. Gaussian fits to the two histograms are given as a guide to the eye. *Right*: Concentration index vs. $u^* - r^*$. The photometric sample is given as contours enclosing $\sigma/4$ (20.8%) to 2 σ (95.5%) of all galaxies with $g^* \leqslant 20$, in steps of $\sigma/4$ as in Fig. 1. The triangles correspond to early spectroscopic sample galaxies (E, S0, and Sa) and the squares to late spectroscopic sample galaxies (Sb, Sc, and Irr); early-type galaxies have higher concentration index than late types.

- Profile likelihoods shows the same bimodality as u*-r* color.
- The dependence of concentration index on morphological type is weak, with large scatter.

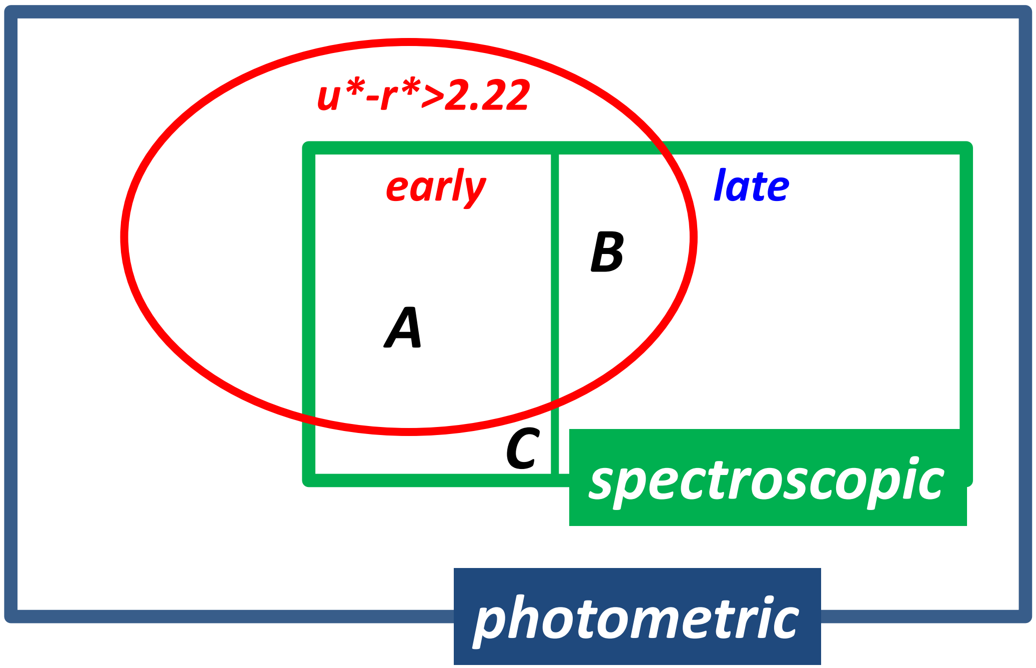
Other Parameters Sensitive to Morphology

Which method is the best as indicator of morphology?

- **Reliability and Completeness of each classification method**

fraction of ***real sample*** in ***sample selected by one method***

fraction of ***sample selected by one method*** in ***real sample***



For example,
The reliability of the u*-r* color selection method for early-types is ***A/(A+B)***,

and

The completeness of the method is ***A/(A+C)***

Other Parameters Sensitive to Morphology

Comparison between Classification Methods for the Spectroscopic Sample

Selection Rule	Completeness	Reliability
$u^* - r^* \geqslant 2.22$	98%	83%
$P_{\mathrm{deV}} > P_{\mathrm{exp}}$	96%	76%
$C > 2.6$	68%	81%
$u^* - r^* < 2.22$	72%	96%
$P_{\mathrm{exp}} > P_{\mathrm{deV}}$	55%	90%
$C < 2.6$	77%	64%

Comparison between Classification Methods for the Morphological Sample

Selection Rule	Completeness	Reliability
$u^* - r^* \geqslant 2.22$	80%	62%
$P_{\mathrm{deV}} > P_{\mathrm{exp}}$	99%	42%
$C > 2.6$	84%	75%
$u^* - r^* < 2.22$	66%	83%
$P_{\mathrm{exp}} > P_{\mathrm{deV}}$	6%	91%
$C < 2.6$	81%	88%

- **The Concentration index(C)** is better criterion ***at the very bright end(g*<16)*** than other two criteria.
- ***The profile likelihood criterion(P)*** cannot be applicable except to galaxies ***at intermediate magnitudes(16<g*<18)***.
- ***The color criterion*** can be used ***for all mag ranges***, and is specifically ***recommended for fainter samples(g*>18)***.

(because C and P rely on spatial information hard to obtain at the faint end.)

Conclusion

- Galaxies have a ***bimordal u*-r* color distribution corresponding to early and late*** morphological types.
- The separation of two peaks in u*-r* is much larger than other color combinations (r*-i*, i*-z*,g*-r*, u*-g*) because the u* and r* filters always bracket the Balmer break.
- Profile likelihoods and concentration correlate morphology too.
- ***Color/P/C is quantitative indicators of morphology.***

(Physical interpretation)

- u*-r* is connected to SFR, P and C connected to mass distribution of galaxies. ***SFR and mass distribution are not strictly independent with morphology, and each other***, which is the reason for the several correlations found.