2MASS photometry of edge-on spiral galaxies

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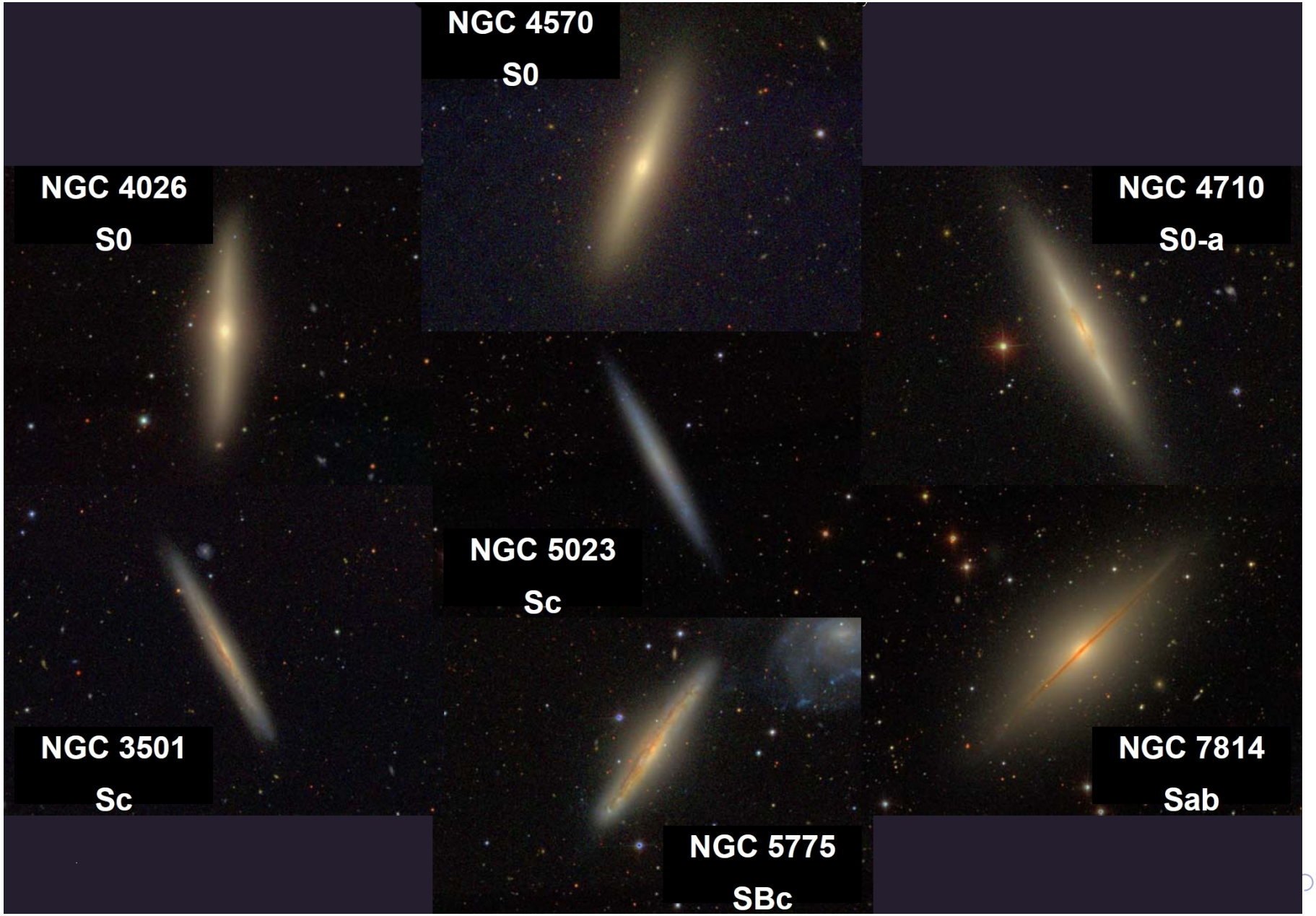

NGC 4570
S0
NGC 4026
S0
NGC 4710
S0-a
NGC 5023
Sc
NGC 3501
Sc
NGC 7814
Sab
NGC 5775
SBc

These objects are of considerable interest for several reasons

They provide the possibility to investigate

(1) the radial and vertical structure of their discs simultaneously;

(2) peculiarities in outer regions (disc's truncutions, warps);

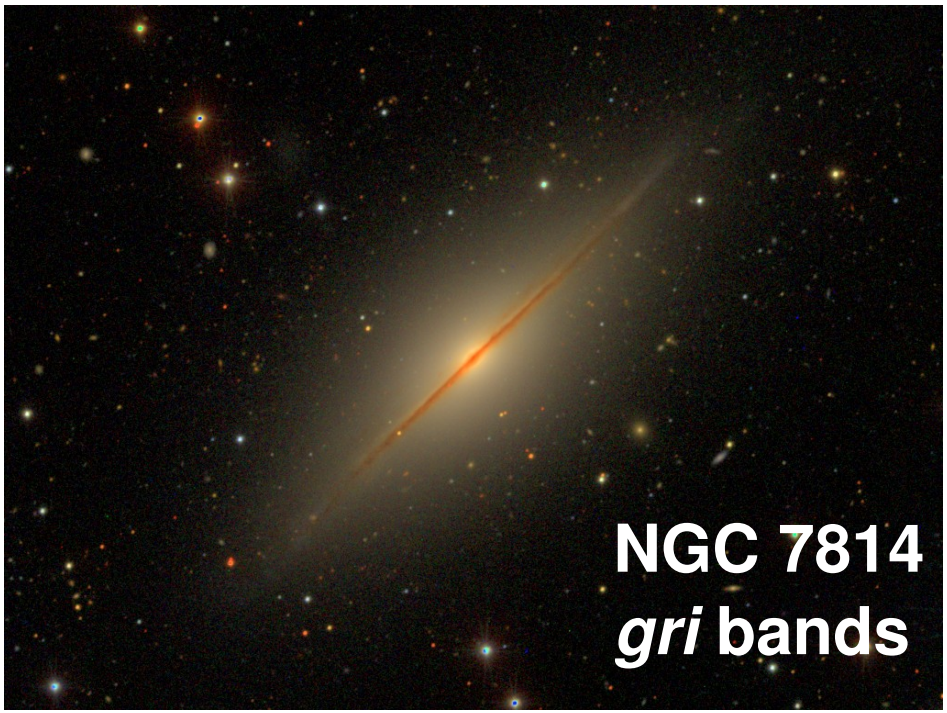
(3) the structure of dust lanes;

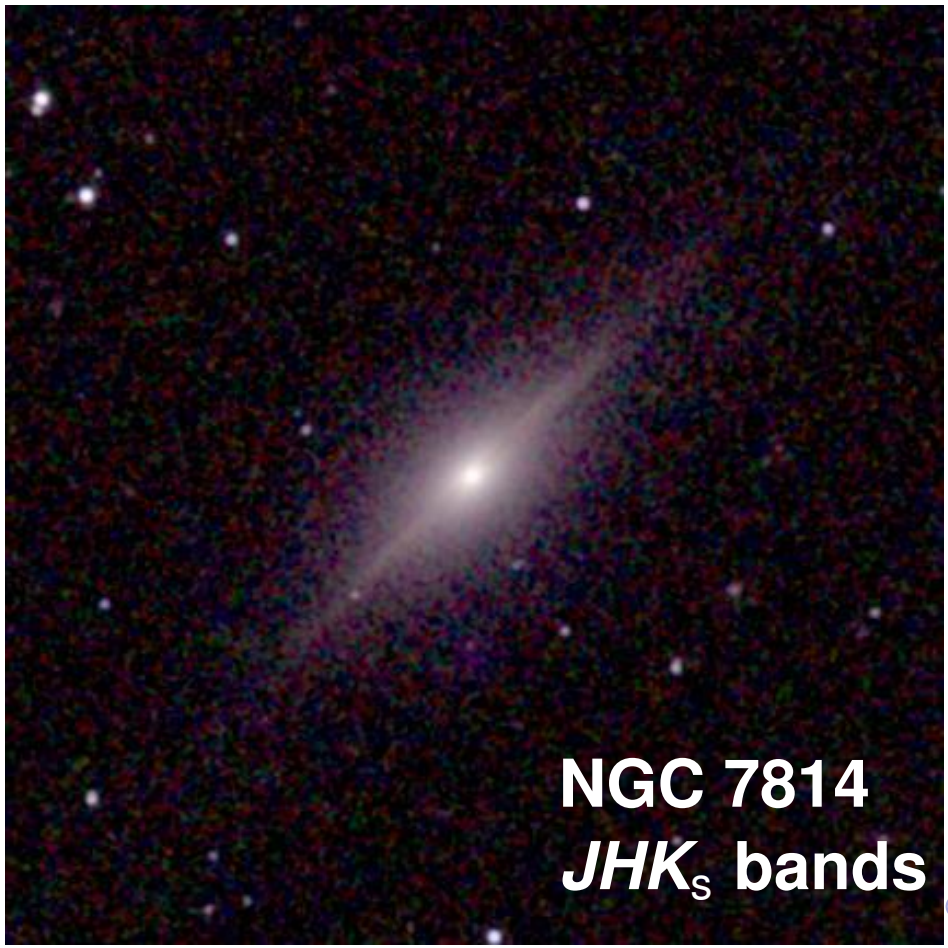
(4) the structure and the shape of bulges.

Difficulties

It is needed to take into account the influence of dust and the fact that we get emission integrated along the line of sight.

$\Longrightarrow$ **IR**





Motivation

The aim: is to investigate statistically the photometric structure of various morphological type edge-on galaxies in IR bands.

Motivation

The difference from previous works:

(Roelf de Grijs, 1997; Dmitri Bizyaev & Sophia Mitronova, 2002, 2010)

– we compiled a large volume sample: **175 galaxies**;

– we chose galaxies of various morphological types: **from S0 to Sd**;

– we used **2D decomposition** instead 1D cuts;

– we determined the structural parameters not only of **discs** but also of **bulges**.

Source of image data

2MASS survey (Two **M**icron **A**ll **S**ky **S**urvey)

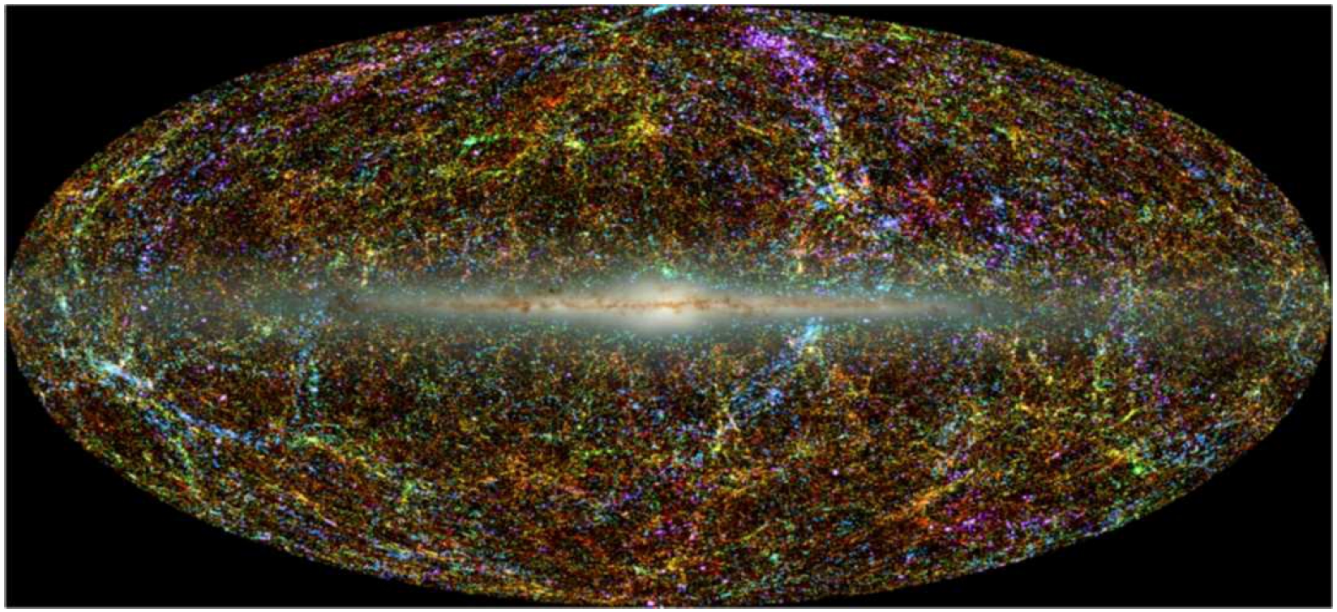
Two 1.3m automatic telescopes

Covers the whole sky in three IR bands:

J (1.25 μm), H (1.65 μm), K_s (2.17 μm)

$\sim$ **3 billion** galaxies brighter than $K_s = 14^m.5$

`http://www.ipac.caltech.edu/2mass`



Source of objects

2MFGC (**2M**ASS-selected **F**lat **G**alaxy **C**atalog)

Mitronova et al. 2003

Contains **18 020** disc-like galaxies covering all the celestial sphere

The objects were selected from the Extended Source Catalog of the 2MASS (XSC 2MASS) according with their 2MASS axial ratio $\boldsymbol{a/b > 3}$

Selection criteria

- axial ratio for the combined $J + H + K$ image, $\boldsymbol{b/a < 0.2}$
- K-band fiducial elliptical Kron radius, $\boldsymbol{R_K > 30''}$
- Hubble type ranging from **S0-Sd**
- **non-interacting** galaxies

175 galaxies – K_s-filter
169 galaxies – H-filter
165 galaxies – J-filter

Type	Number	Percentages
S0, S0-a	41	23.4
Sa	11	6.3
Sab	15	8.6
Sb	47	26.9
Sbc	21	12.0
Sc	36	20.5
Scd	4	2.3
Total	175	100

The full sample is uncomplete but the subsample of galaxies with angular radius $r > 60''$ is **complete** (**92** galaxies)

Decomposition

Photometric model

DISC:

$$I(r,z) = I(0,0)\, e^{-r/h}\, \mathrm{sech}^2(z/z_0)$$

for edge-on galaxies:

$$I(r,z) = I(0,0)\, \frac{r}{h}\, K_1\left(\frac{r}{h}\right)\, \mathrm{sech}^2(z/z_0)$$

BULGE (Sérsic law):

$$I_{\mathrm{b}}(r) = I_{0,\mathrm{b}}\, e^{-\nu_{\mathrm{n}}[(r/r_{\mathrm{e,b}})^{1/n}]}$$

BUDDA (**BU**lge/**D**isc **D**ecomposition **A**nalysis) – 2D analysis of an image (de Souza et al. 2004)

Decomposition

Parameters

DISC: $\mu_{0,d}$, M_d , h , z_0 , h/z_0

BULGE: $\mu_{e,b}$, M_b , $r_{e,b}$, n , $q_b (= b/a)$

$n = 1$ – **exponential law**

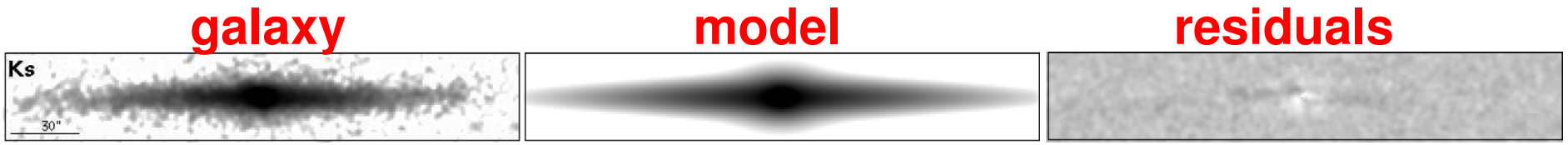
$n = 4$ – **de Vaucoulers' law**

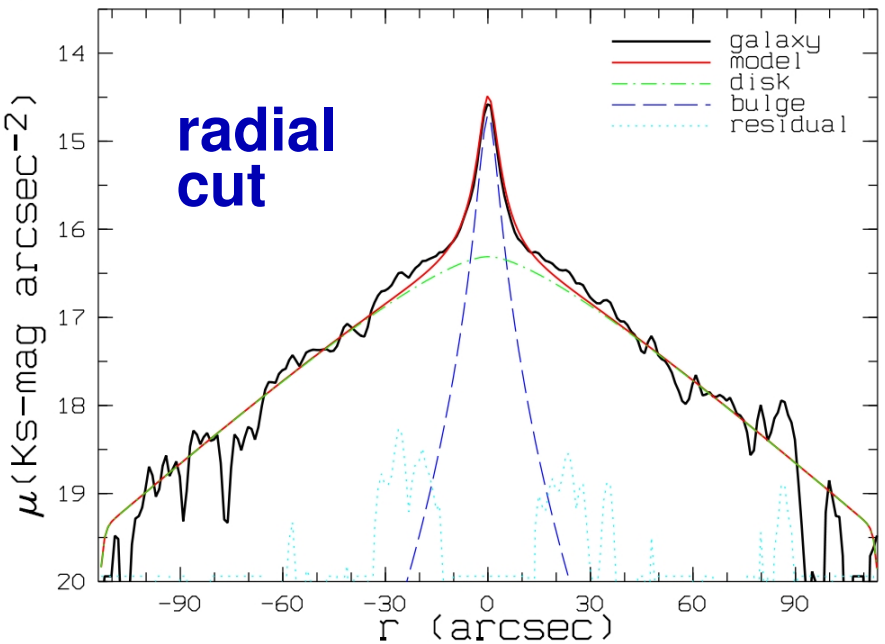
GALAXY: B/D , m_{gal} , M_{gal} , $+v_{rot}$

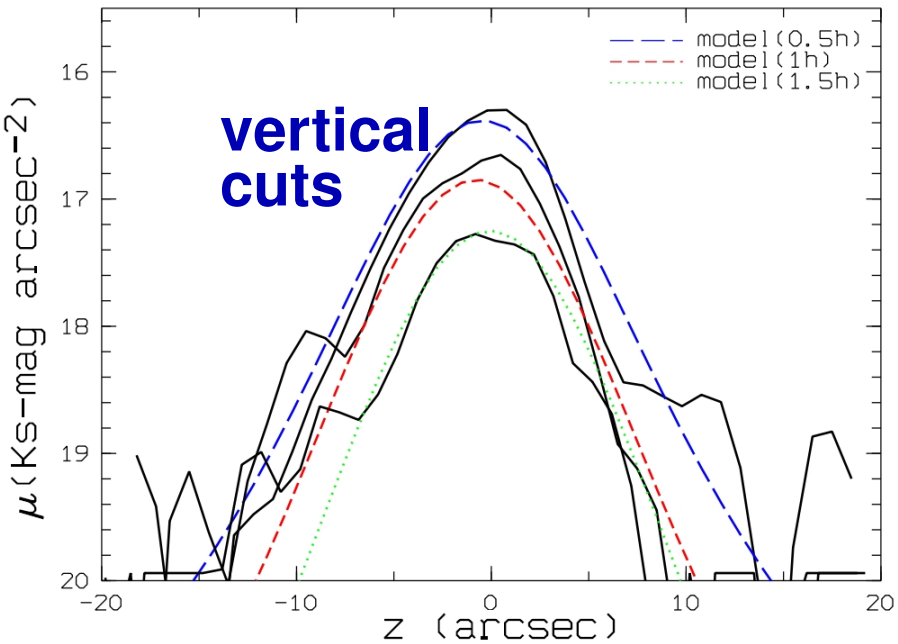
Decomposition

An example

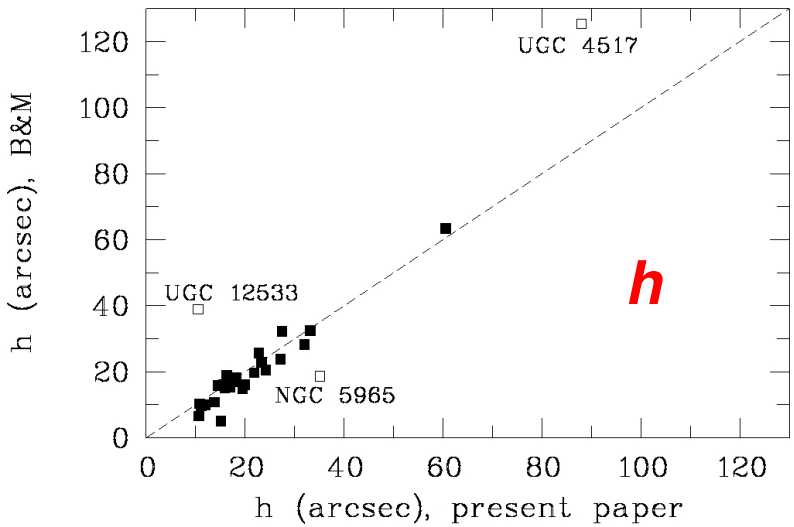
ESO-240-G011, K_s-band

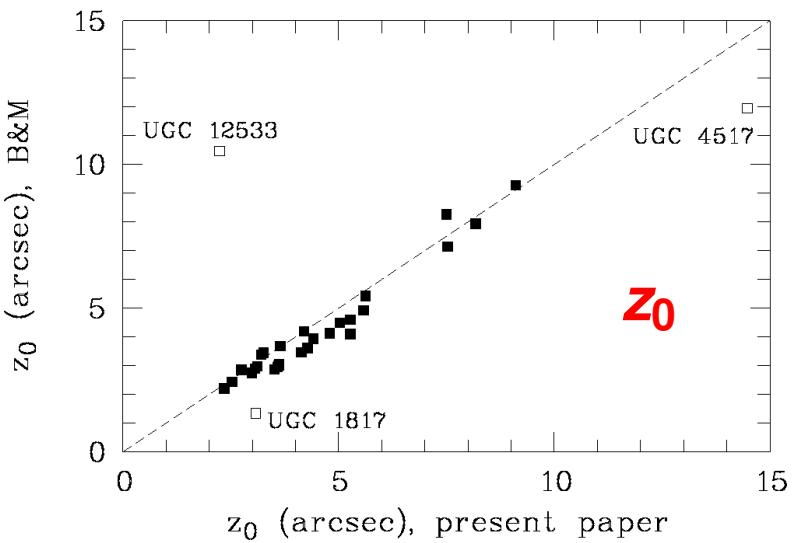




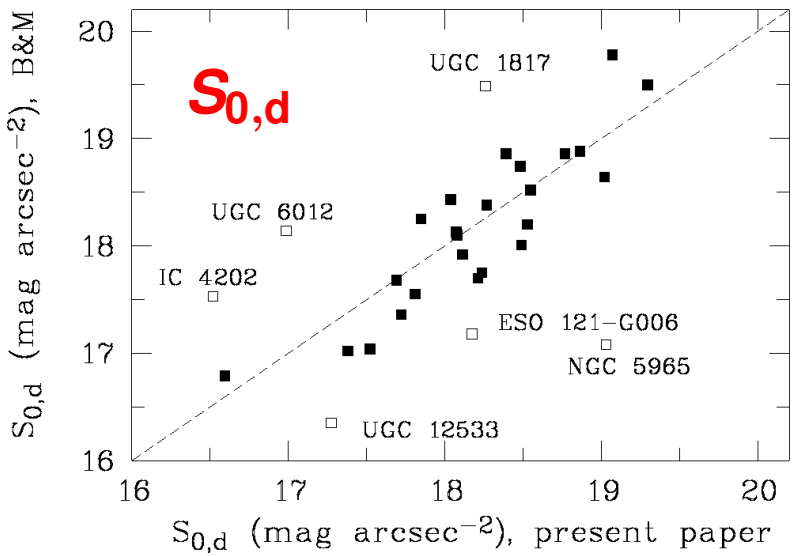


Comparison with previous works

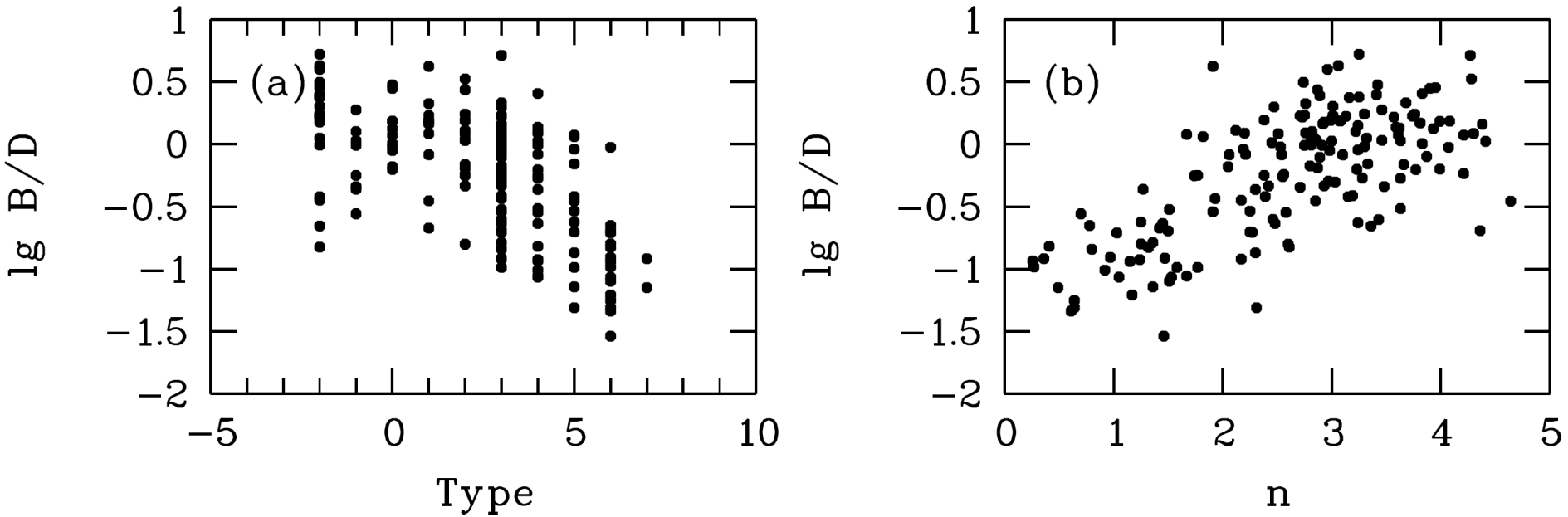




30 galaxies in common with the sample of Bizyaev & Mitronova 2002



Morhological type vs Sérsic index



Classical bulges

- $n \geq 2$
- dynamically hot
- relatively featureless
- red colors
- same or similar FP relations as for ellipticals
- appear to be similar to E-type galaxies

Possible origins:

hierarchical clustering via minor or major mergers

Pseudobulges

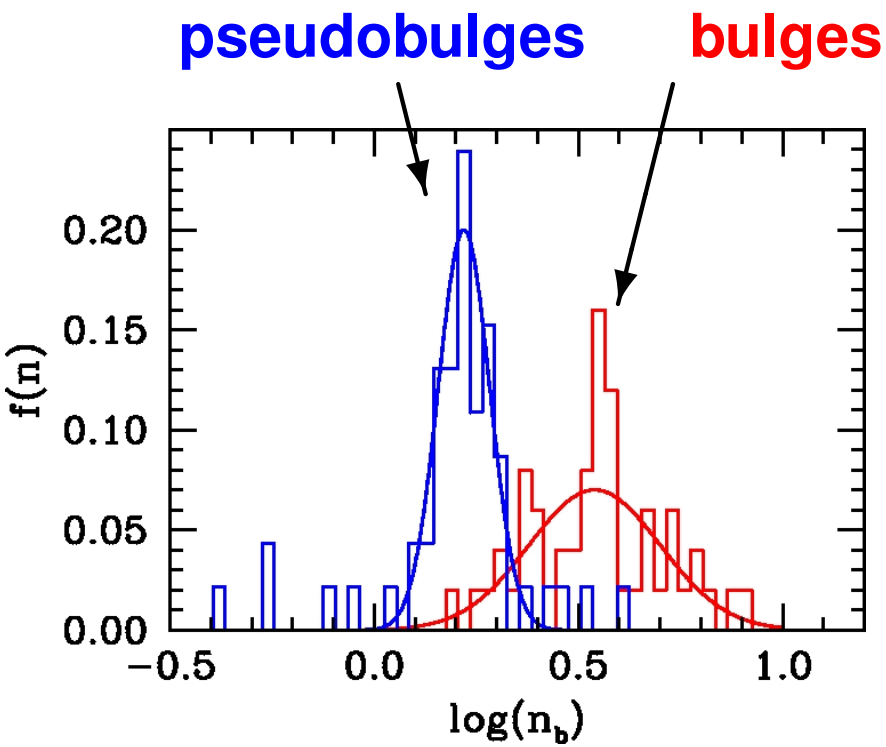
- $n \leq 2$
- kinematics dominated by rotation
- flattening similar to that of their outer disk
- nuclear bar, ring and/or nuclear spiral

Possible origins:

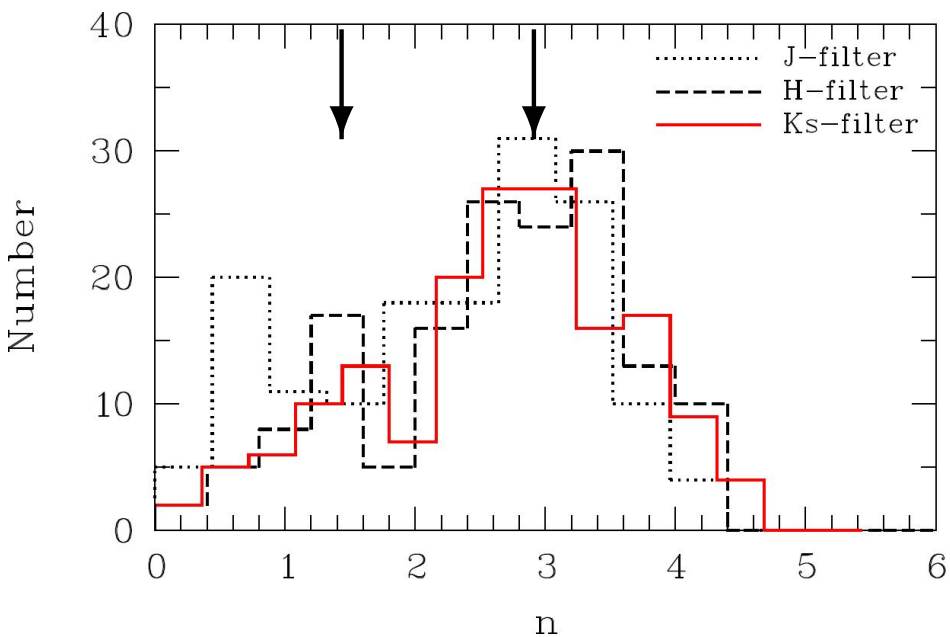
secular evolution – long-term dynamical evolution (bar formation, vertical and radial transport, disk heating, new star formation, bar destruction?)

Bimodality of the distribution over Sérsic indices

Fisher & Drory 2008



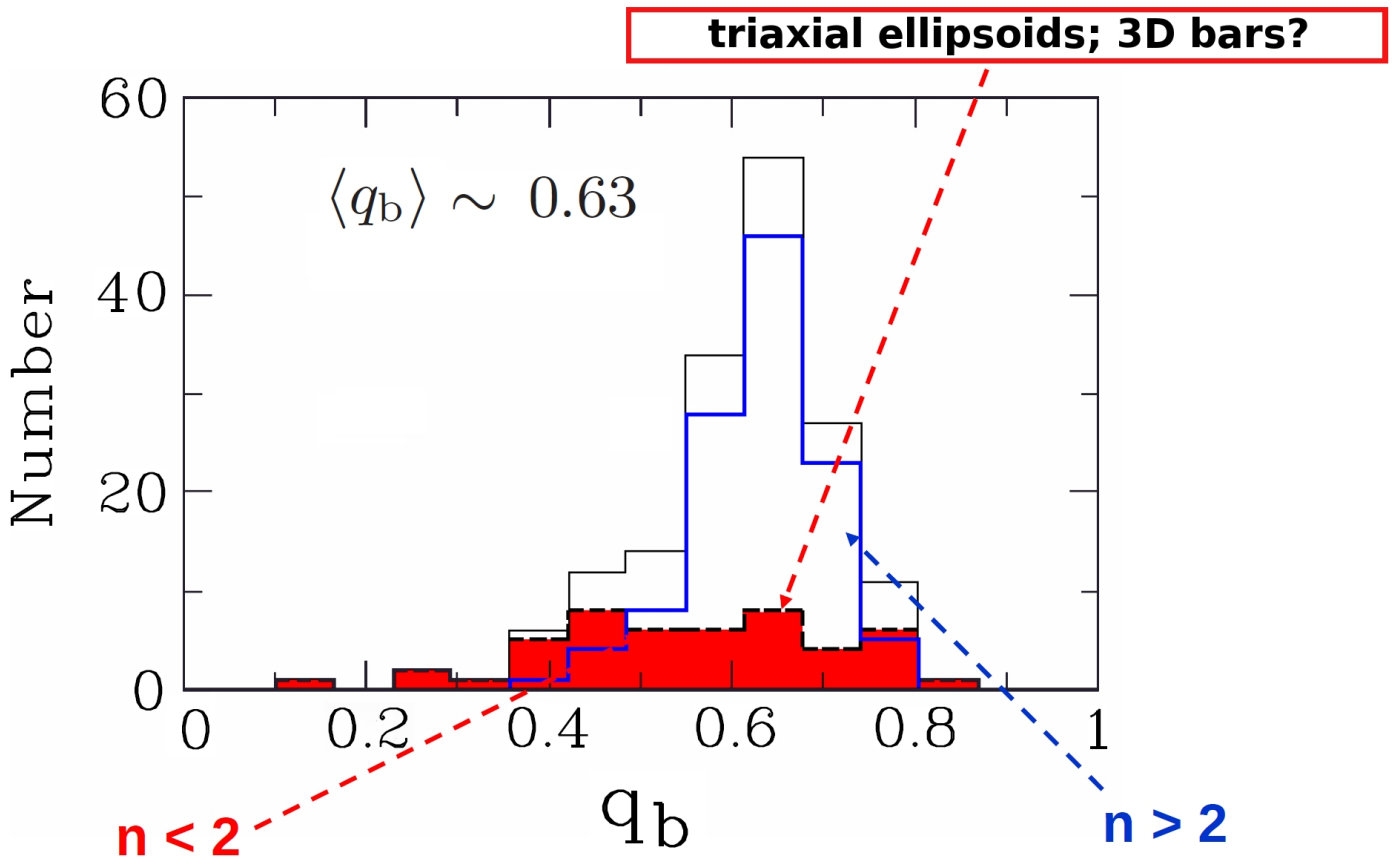
Our sample



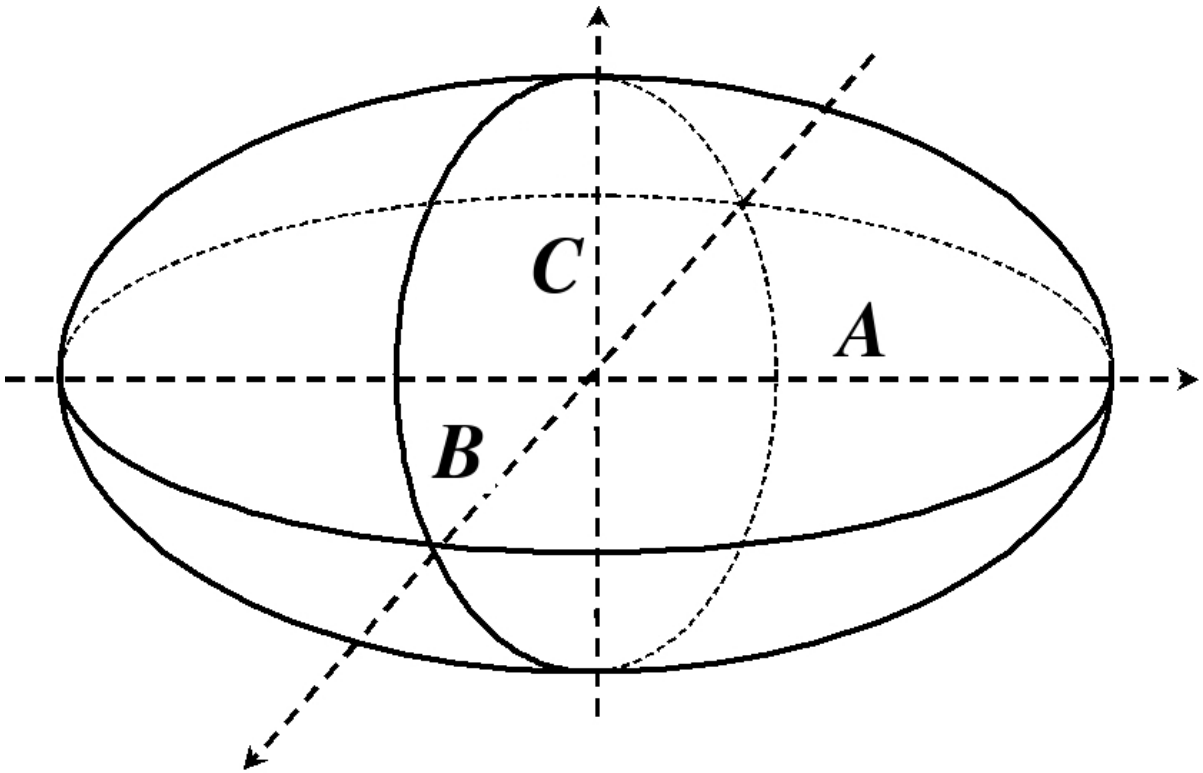
The intrinsic shape of bulges

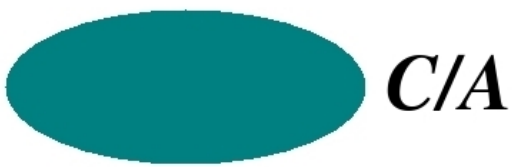
$q_b = b/a$

a, ***b*** are apparent semi-major and semi-minor axes of a bulge



The intrinsic shape of bulges





The intrinsic shape of bulges

$n \geq 2$ (classical bulges)

The distribution over q_b has a rather **narrow peak** at $q_b \approx 0.65$.

It is consistent with a suggestion that bulges in early-type spirals are nearly **oblate** spheroids with moderate flattening.

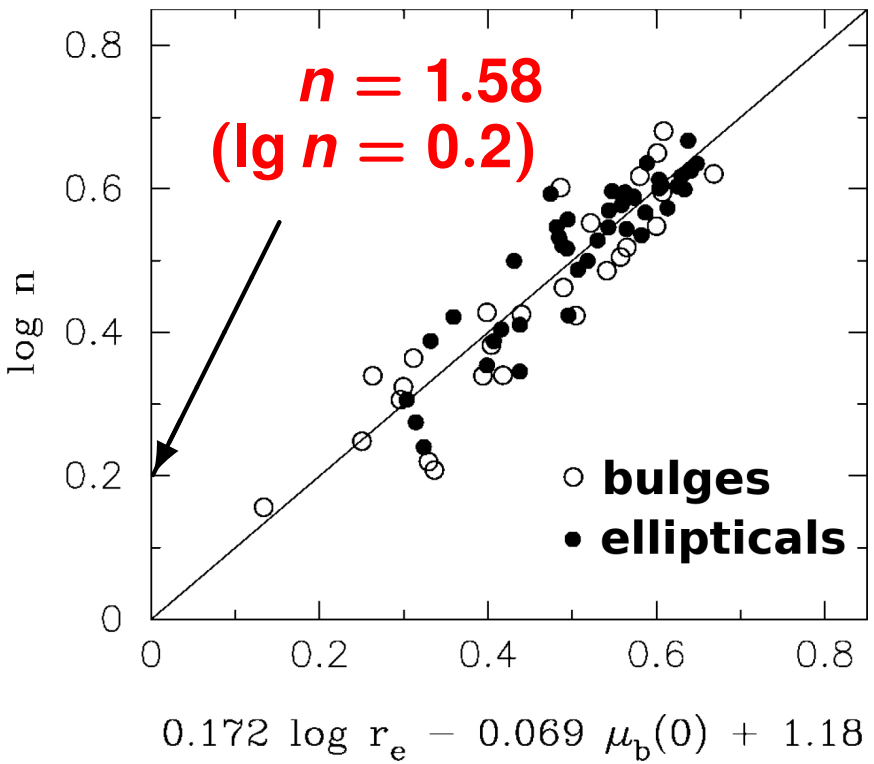
$n \leq 2$ (pseudobulges)

The distribution over q_b is very **wide**, spreading from flat bulges up to nearly spherical ones.

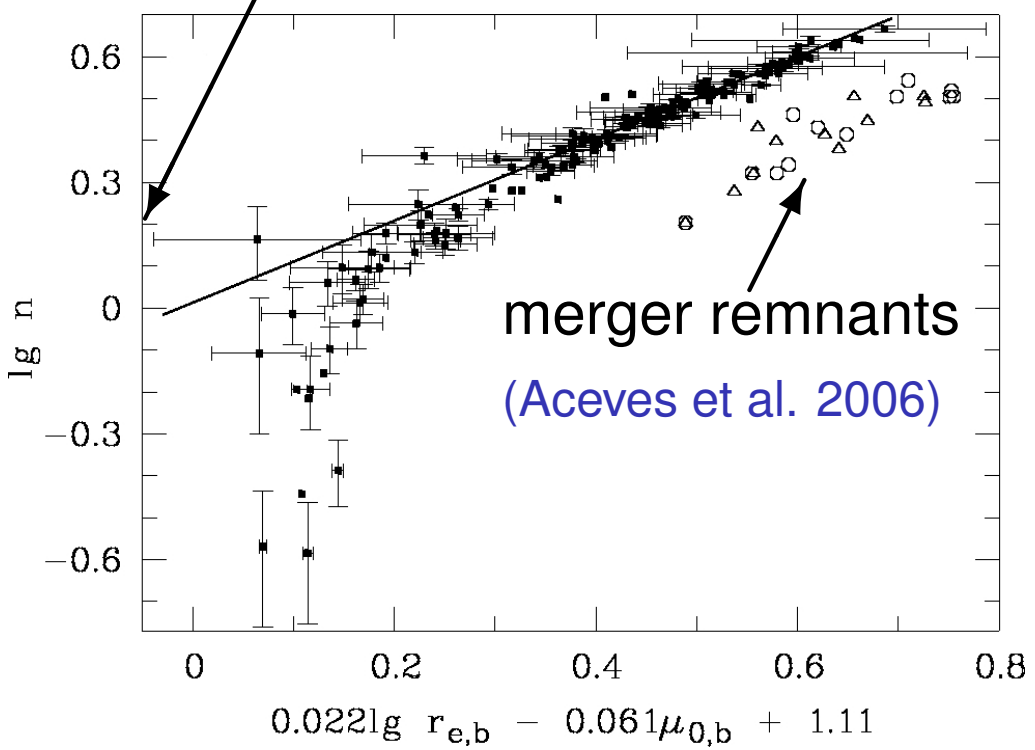
It may be attributed to **triaxial, near prolate** bulges that are seen from different projections – along the major axis and perpendicular to it.

Photometric plane for bulges

Khosroshahi et al. 2000 (***K*-band**)
26 early-type galaxies

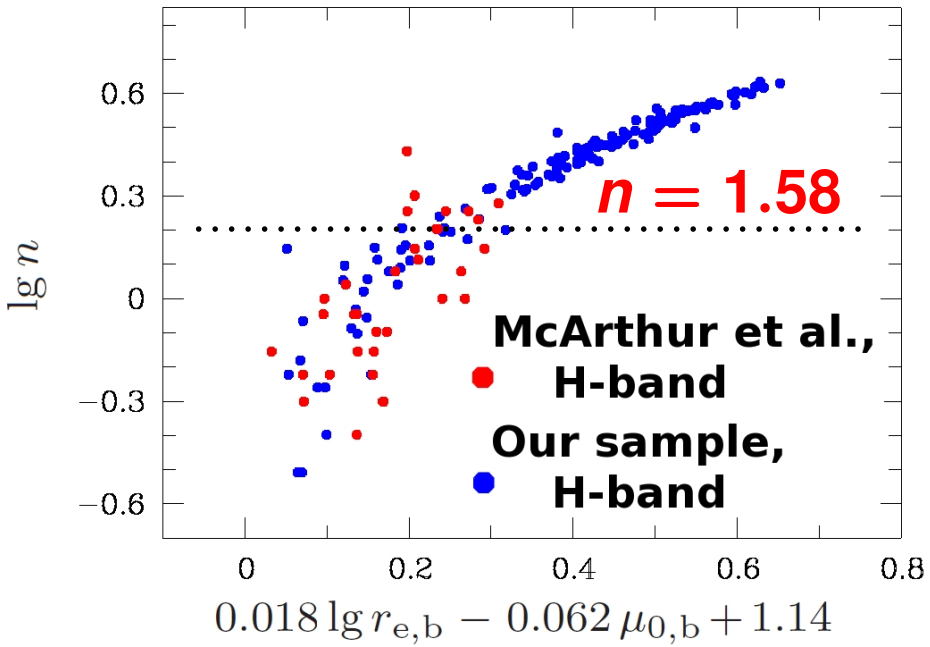


Our sample (***K*$_s$-band**)
$n = 1.58$ ($\lg n = 0.2$)

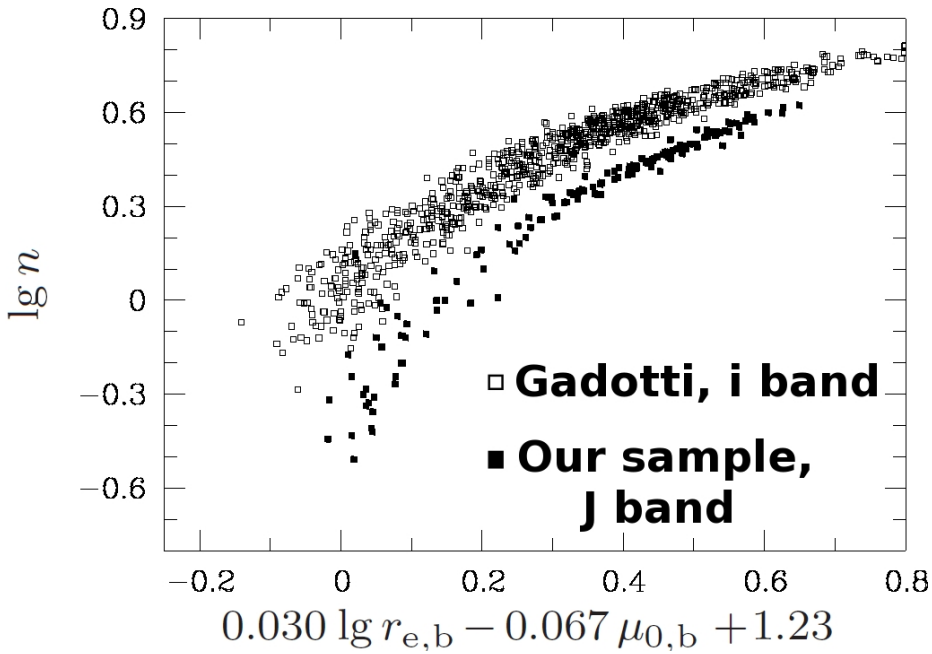


Photometric plane for bulges

data from MacArthur et al. 2003
***H*-band**
121 face-on and moderately inclined late-type spirals



data from Gadotti 2009 (***i*-band**) 2D bulge/bar/disc decompositions of $\sim$ **1000** galaxies from the SDSS



Photometric plane for bulges

$n \geq 2$ (classical bulges)

The galaxies with $\lg n \geq 0.2$ lying on the PhP, that is built for these galaxies, has a **small scatter**.

The model of **collisionless merging** fairly well reproduce the slope of the PhP.

$n \leq 2$ (pseudobulges)

The galaxies with $\lg n \leq 0.1$ do not correspond to the main PhP and form their own plane with a **large scatter**.

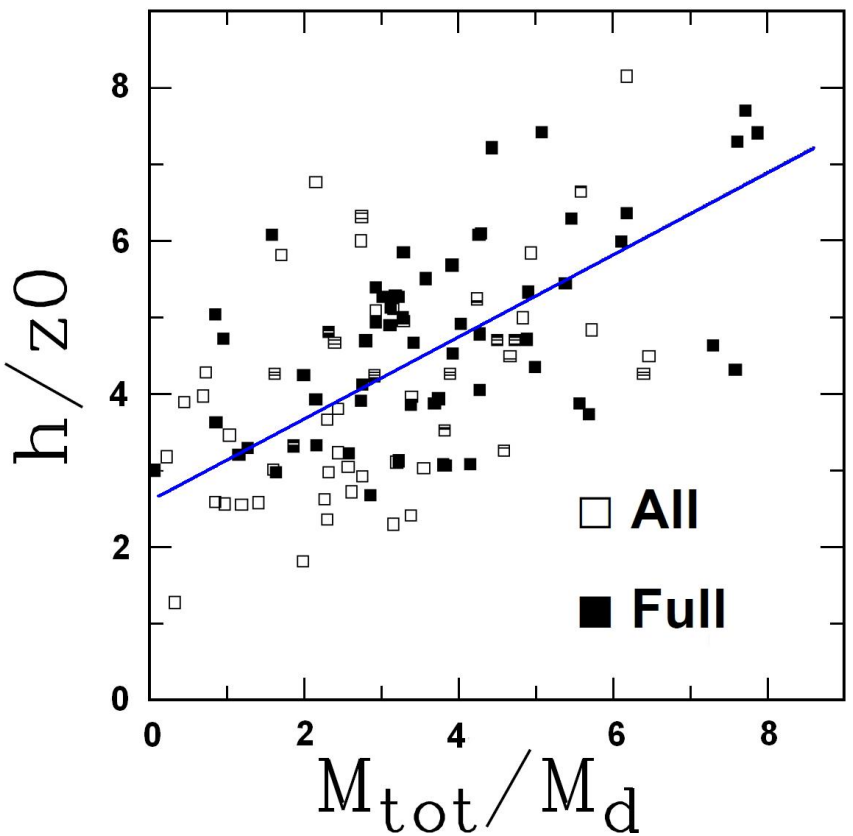
The curvature of the PhP towards small values of n may reflect the quite different nature of such bulges, formed, for example, via **secular evolution** of discs.

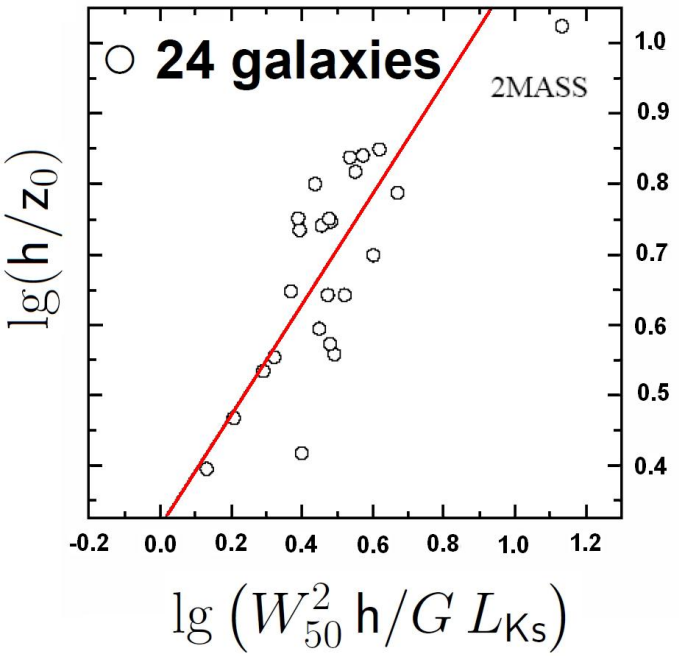
The Dark halo and disc flattening

Our sample

All type galaxies

115 galaxies





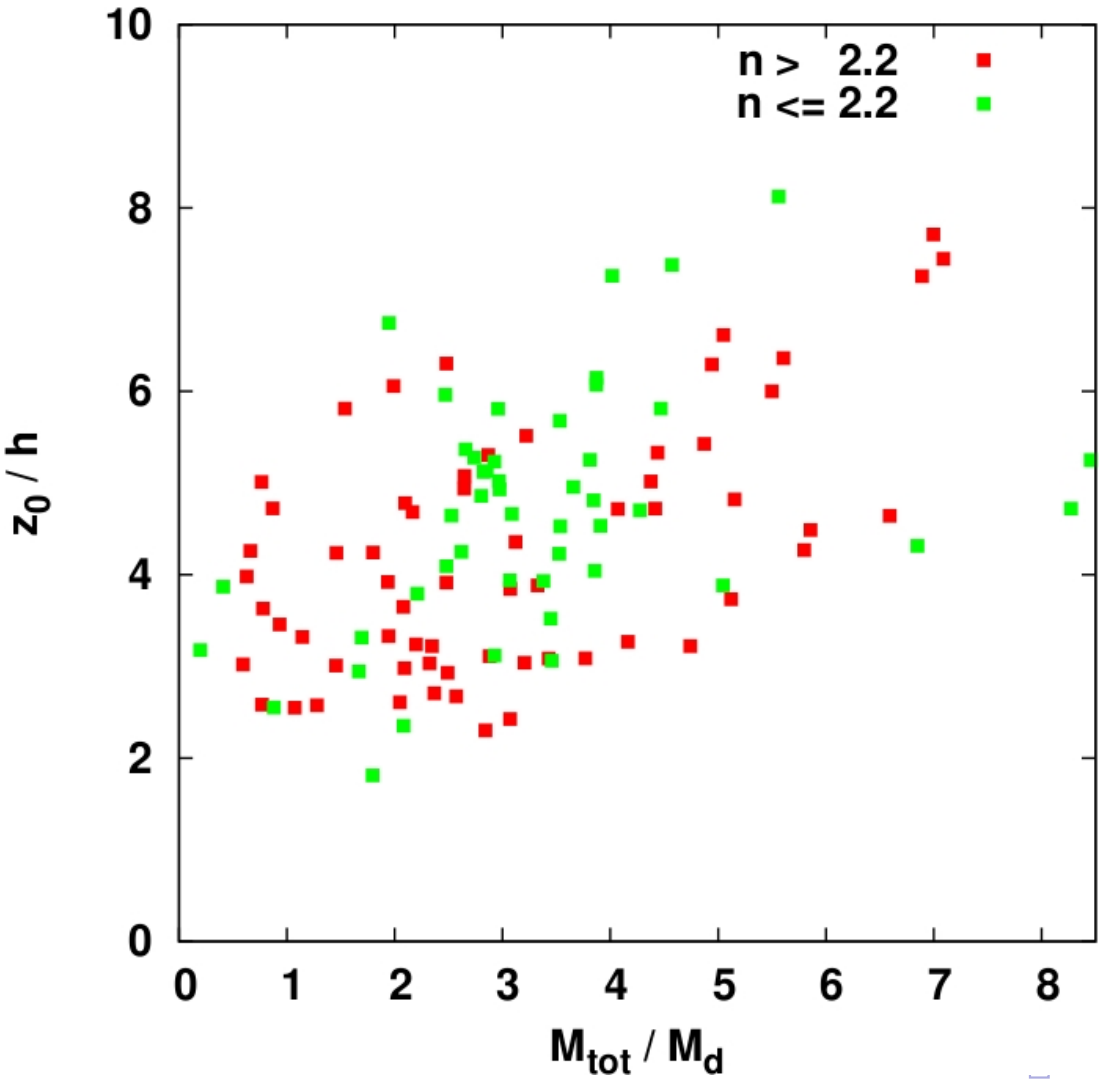
Zasov et al., 2002

Bulgeless galaxies

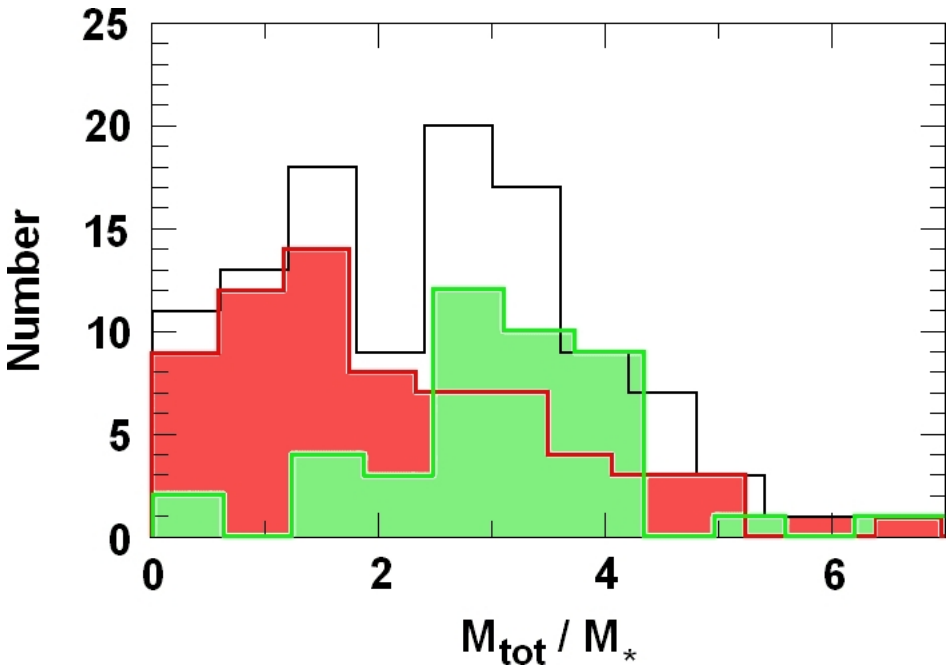
$$M_{\rm tot} = 4\,h\,v_m^2/G$$

$$M_{\rm d} = (M/L)_{\rm Ks}\; L_{\rm d}^{\rm Ks}$$

The Dark halo and disc flattening



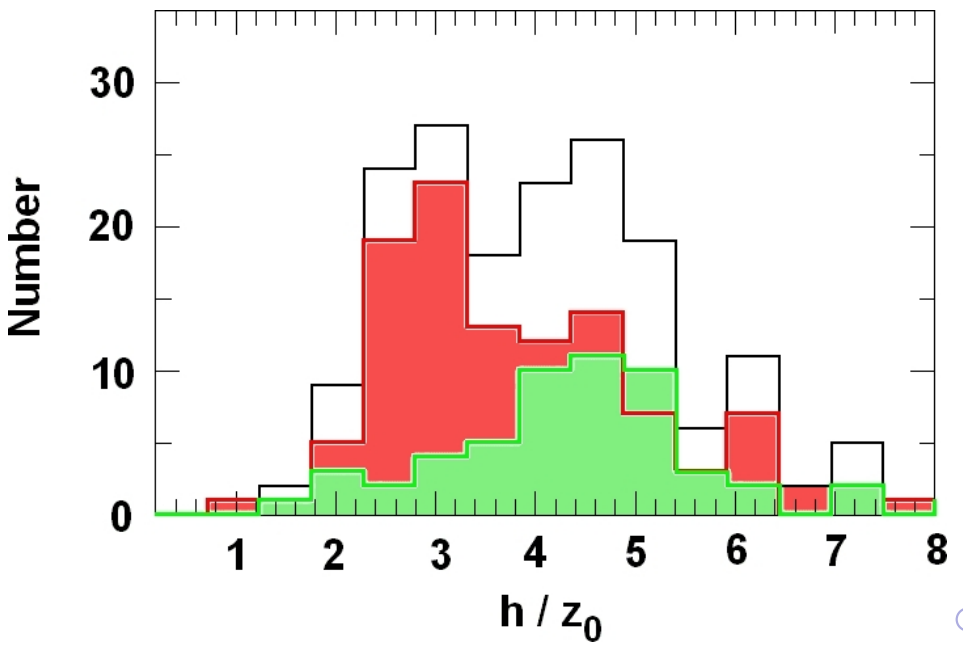
The Dark halo and disc flattening



all

n $\leq$ **2**

n $\geq$ **2**



all

n $\leq$ **2**

n $\geq$ **2**

Conclusions

(1) We compiled a large sample of edge-on spiral galaxies with performed 2D bulge/disc decomposition of 2MASS galaxies images in *J*, *H* and *K*s passbands.

(2) We considered main relations between global structural parameters of discs and bulges.

(3) We obtained several new evidences in favour of existence of two quite different populations of bulges in spiral galaxies – classical bulges and pseudobulges.