The Number of Tidal Dwarf Satellite Galaxies in Dependence of Bulge Index

López-Corredoira & Kroupa (2016, ApJ, 817, 75)

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Standard Model:predictions

A dark matter host halo contains many satellite sub-halos spherically distributed, many of which are constantly decaying toward the center through dynamical friction while new sub-halos enter.

The number of satellite galaxies (dSph) is predicted to increase monotonically with the mass of the host dark matter halo (Moore et al. 1999; Kroupa et al. 2010; Klypin et al. 2011; Ishiyama et al. 2013).

Bulges or pseudo-bulges explained from galaxy evolution.

NASA, ESA, AND T. BROWN and J. TUMLINSON (STSCI)

Milgromian (MOND) and generalized gravitation models (no dark-matter): predictions

Encounters between galaxies draw out long tidal arms that fragment forming populations of star clusters and dwarf galaxies (Tiret & Combes 2008; Pawlowski et al. 2011; Yang et al. 2014).
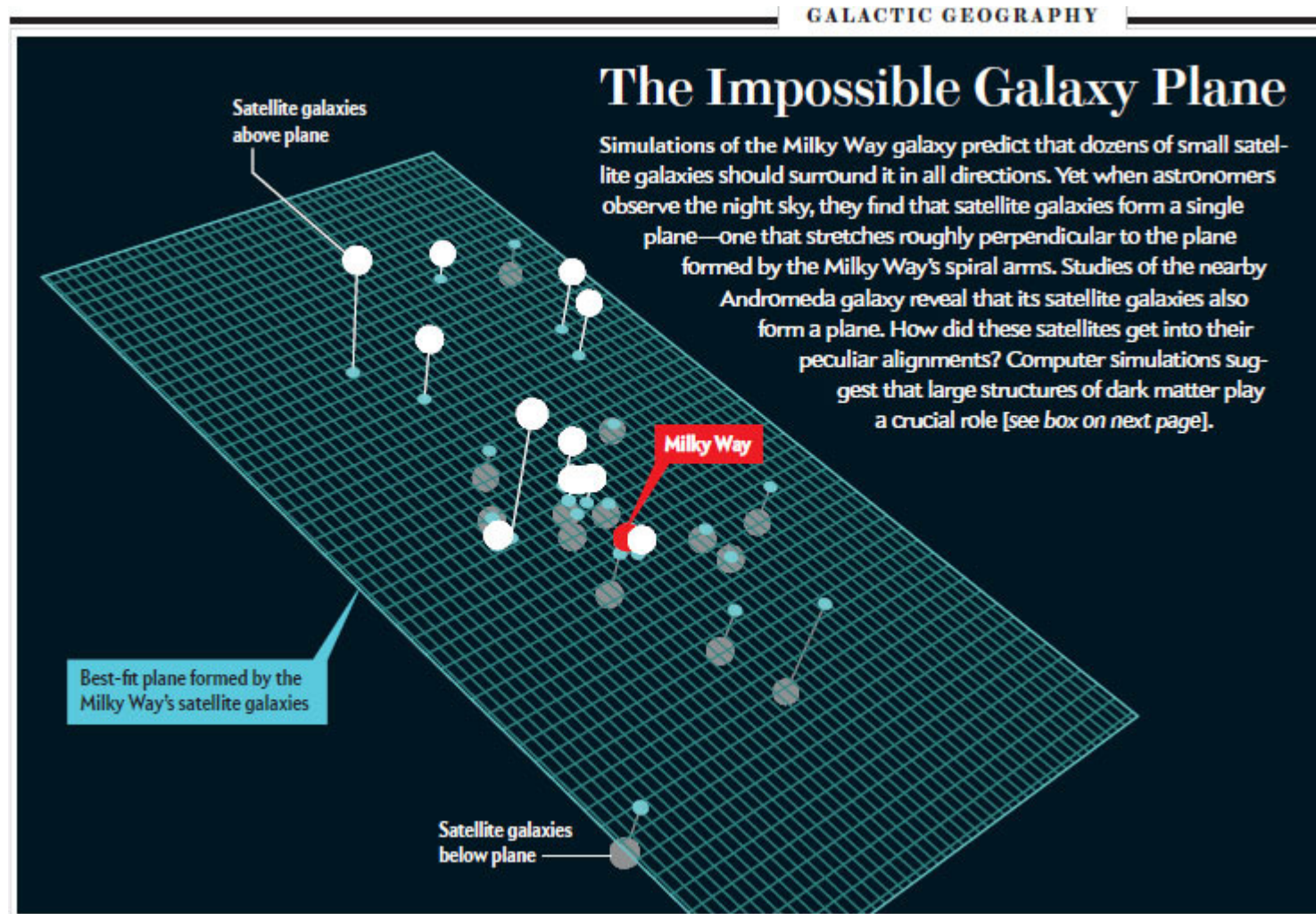dSph are old Tidal Dwarf Galaxies (TDGs)

Phase-space correlated TDGs [OBSERVED]

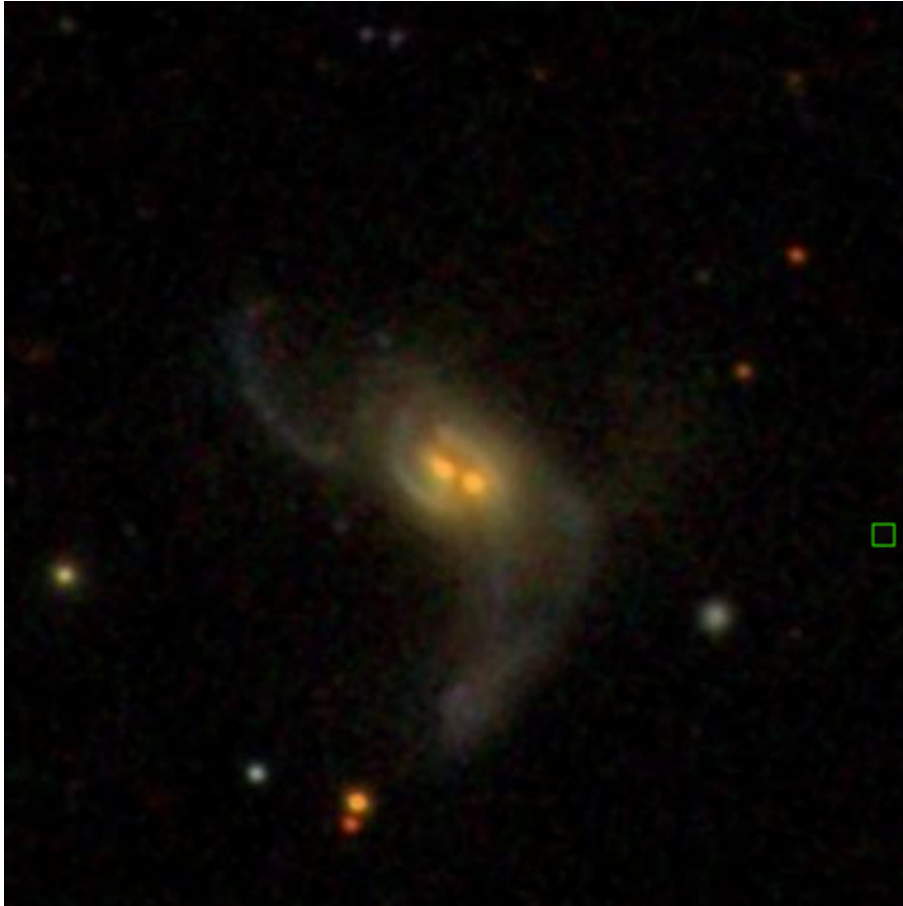Number of TDGs → degree of encounters a given host has experienced.

Classical and pseudo-bulges typically form in a galaxy after it experiences a tidal perturbation → **number of TDGs scales with the bulge size**

Formation and evolution of structures and galaxies

(Libeskind 2014, Pawlowski et al. 2013)

Tidal Dwarf Galaxies

Tidal dwarfs are dwarf galaxies that form from the tidal debris of baryonic material liberated from giant galaxies by interactions with other galaxies

<u>SDSS image</u>: SDSS J094940.42+382018.9, z=0.061

Tidal Dwarf Galaxies

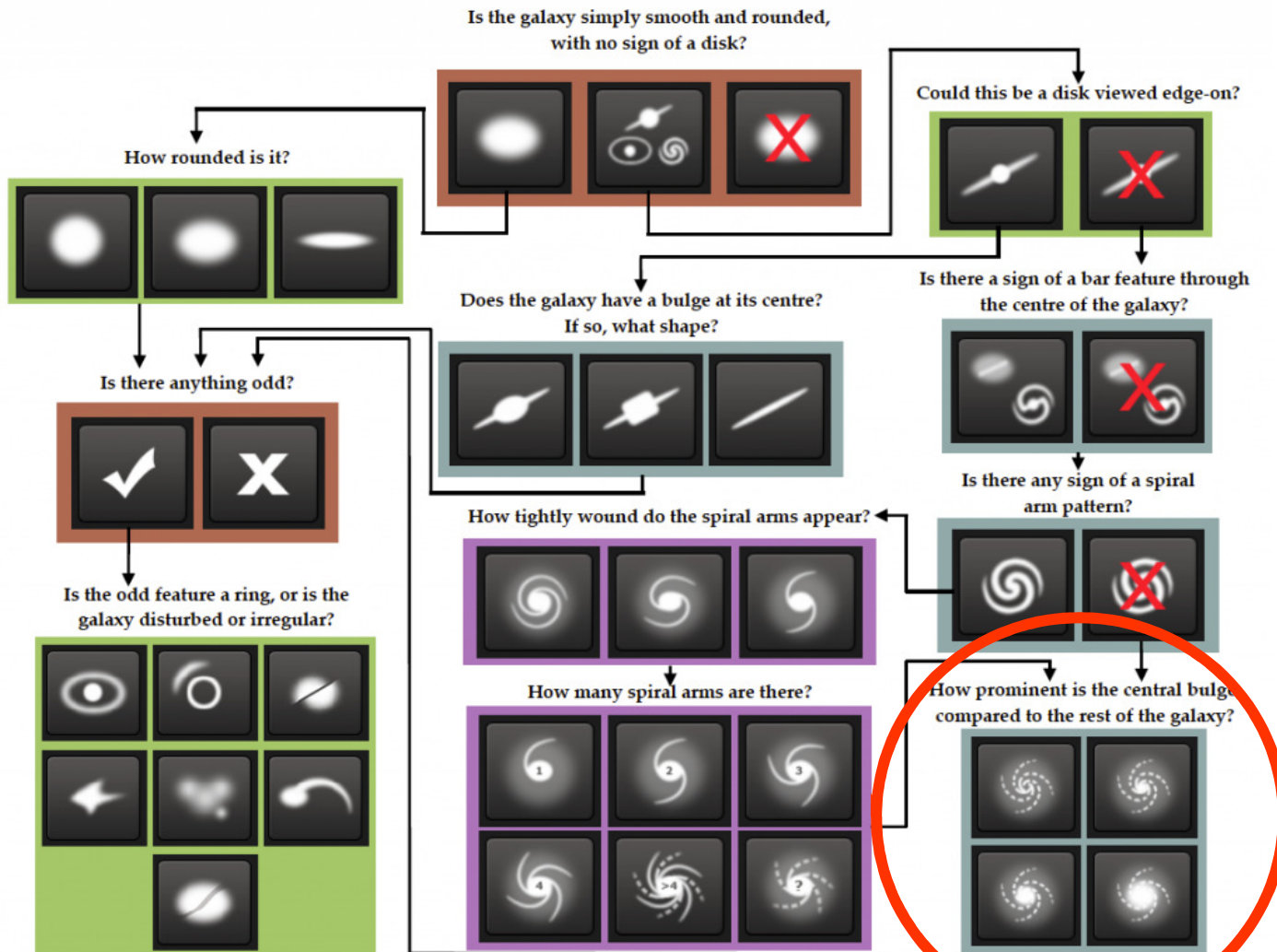## Kaviraj et al. (2012) TDGs catalogue:

SDSS-DR6

z < 0.10

$-20 < M_r < -12$

$6 < \log_{10}(\text{Stellar Mass}) < 10$

1644 TDGs; 508 of them with high confidence detection

Galaxy Zoo 2

Willett et al. (2013), Fig. 1

Galaxy Zoo 2

BULGE INDEX:

0: no bulge
1: just noticiable bulge
2: obvious bulge
3: dominant bulge

We take the average and rms
of all the "debiased" votes of
a galaxy

How prominent is the central bulge,
compared to the rest of the galaxy?

Galaxy Zoo 2

GALAXY ZOO 2 (Willett et al. 2013):

A citizen science project with more than 16 million morphological classifications of 304,122 galaxies drawn from the SDSS-DR7, with m_r<17, in addition to deeper images from SDSS-Stripe 82

From this catalog, we select only the sources with redshift z < 0.10, with clean flags(=1) for the classification as disk galaxy. Moreover, we restrict our sample to galaxies with 4 or more votes, rms_B < 0.5 and -20 > M_r > -23.
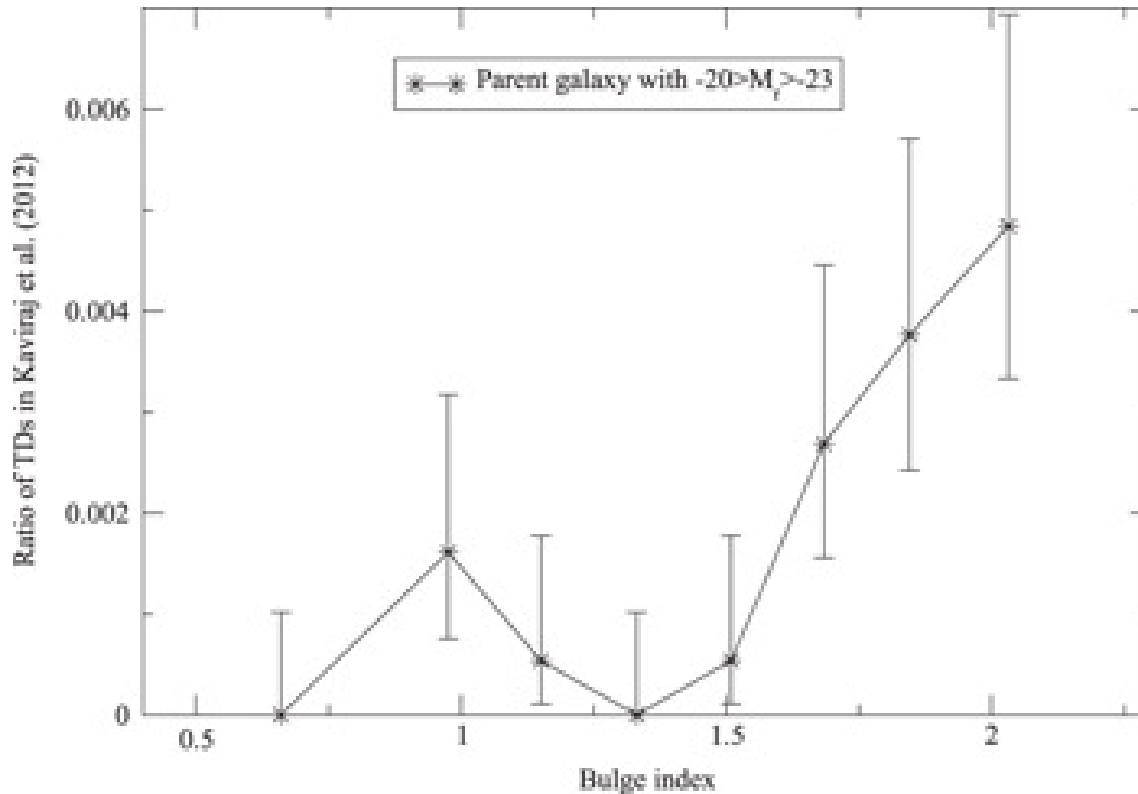This gives a total of 14,878 galaxies.

Correlation
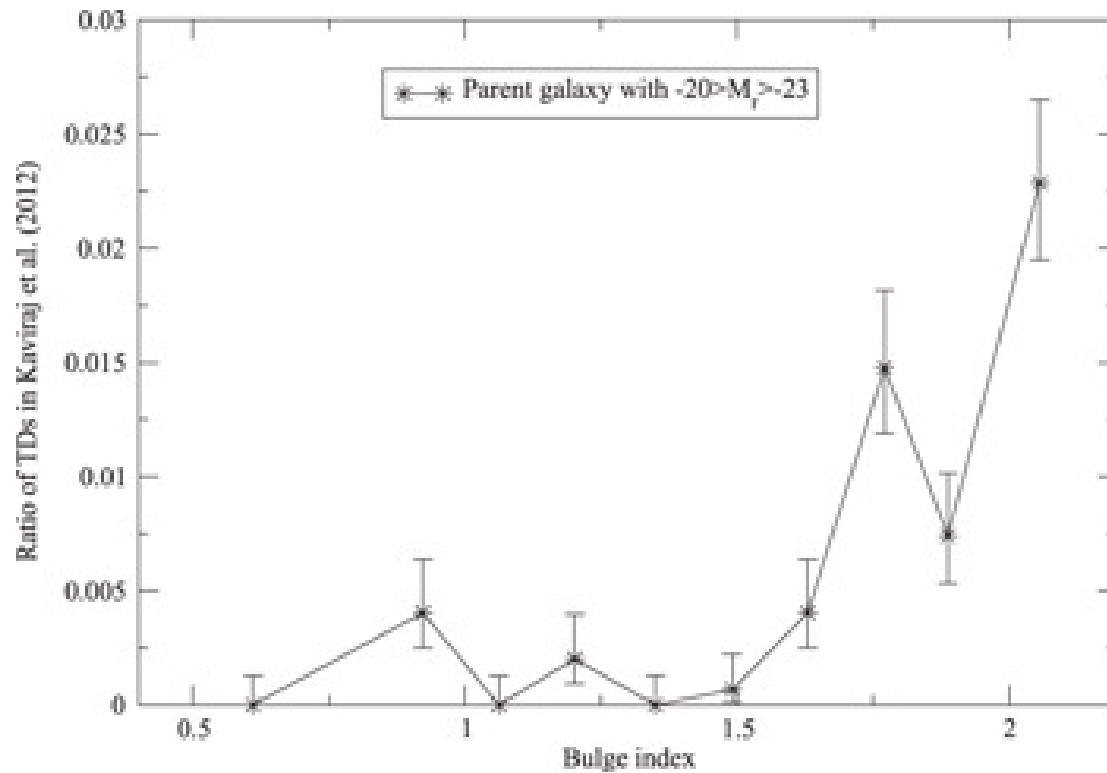
Constant ratio excluded at **5σ**

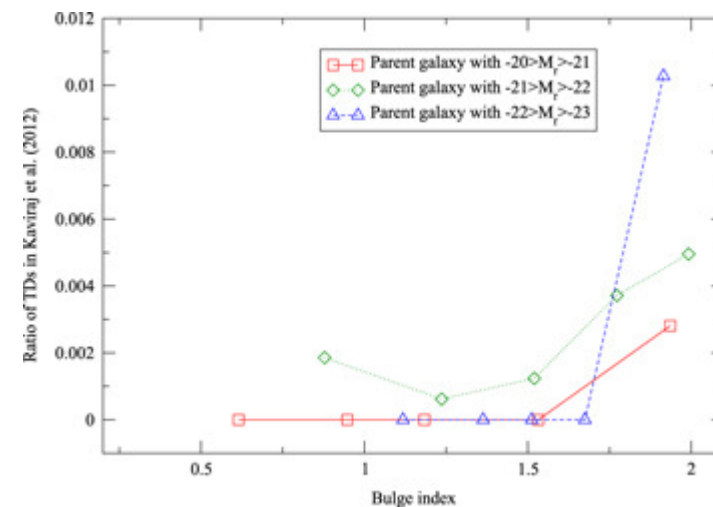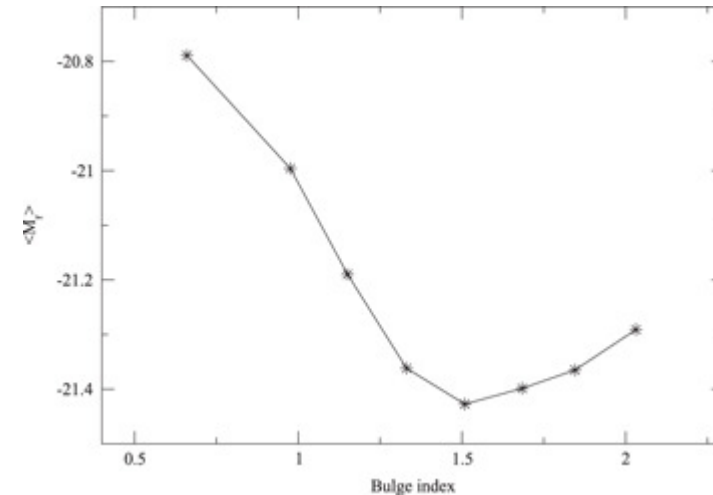With all of the 1644 TDGs of Kaviraj et al. (2012) catalogue

Correlation

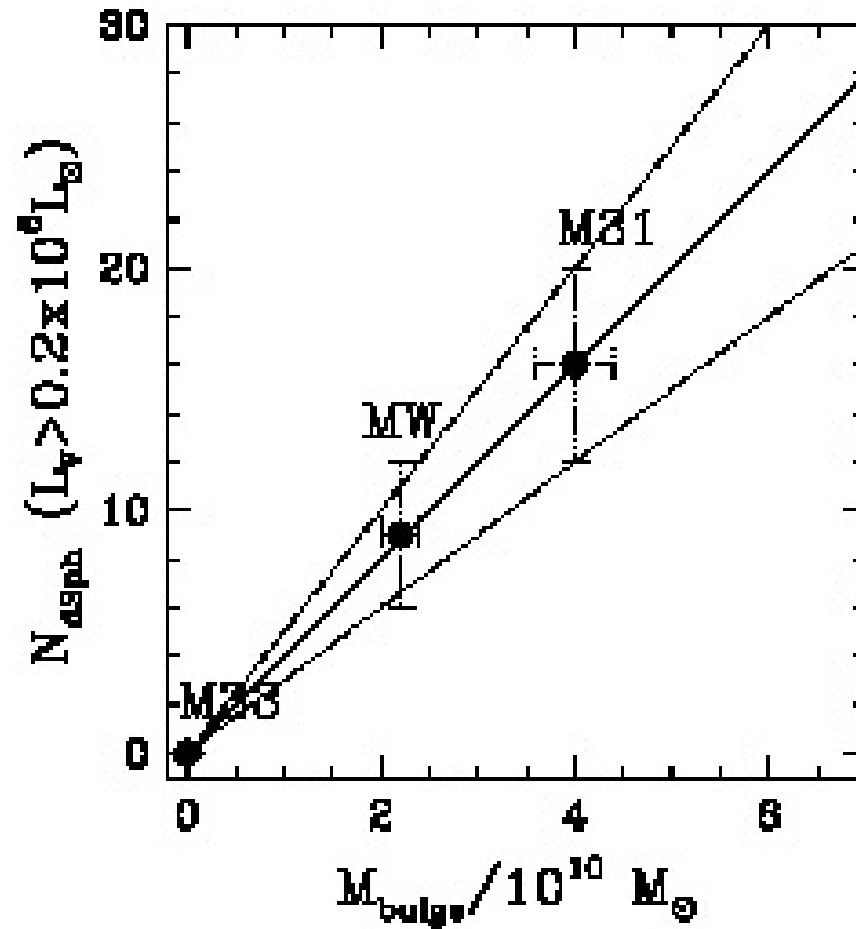Constant ratio
excluded at **3σ**

With 508 TDGs with high confidence of correct identification
of Kaviraj et al. (2012) catalogue

Correlation

- Compatible trends with different parameters (rms_B, mínimum number of votes, M_r range, flags).

- The average M_r is very slightly dependent on Bulge Index.

Correlation: Local Group with dSphs

Kroupa et al. (2010)

Can Standard Cosmology explain the correlation?
(is the bulge/disk ratio correlated with the halo mass?)

- Higher bulge index (lower Hubble stage) → lower or equal ratio of the dark-to-luminous mass (Tinsley 1981; Jablonka & Arimoto 1992) → less interaction to form TDGs?

- No trend toward higher halo masses for barred galaxies (López-Corredoira 2007).

- ANY WAY TO EXPLAIN IT? POSSIBLY, BULGE FORMATION SCENARIO RELATED TO INTERACTION BETWEEN GALAXIES

CONCLUSIONS

- Up to 5σ correlation between nr. of TDGs and bulge index.

- This is a succesful confirmation of a prediction given by modified gravity theorists.

- The explanation of the correlation with the standard model requires to understand the connection between bulge formation and TDGs, which is not clear yet.