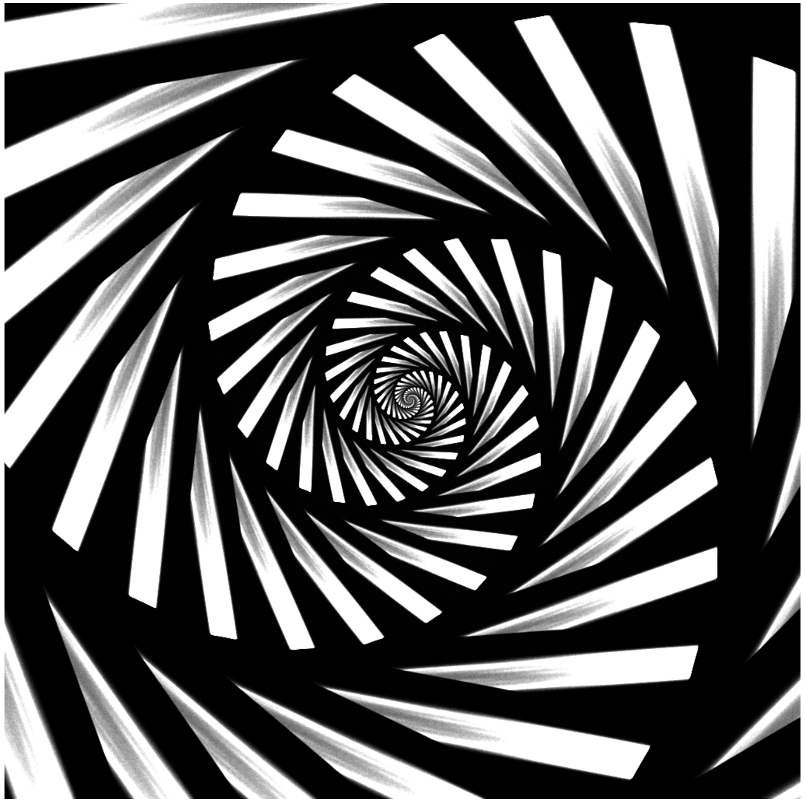
THE FUNDAMENTAL MANIFOLD OF SPIRAL GALAXIES

ORDERED vs RANDOM MOTIONS
AND THE MORPHOLOGY DEPENDENCE
OF THE TULLY-FISHER RELATION



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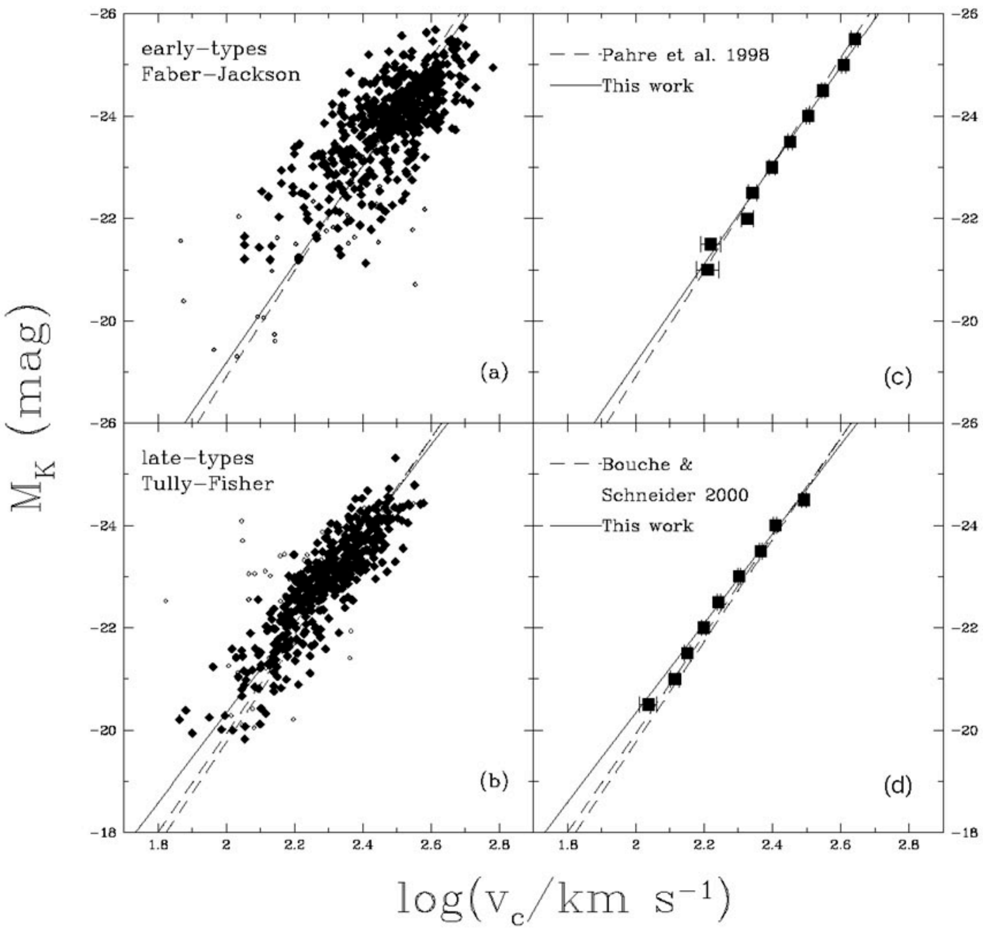
Swinburne

GALAXY SCALING RELATIONS

The simple picture:



Faber-Jackson

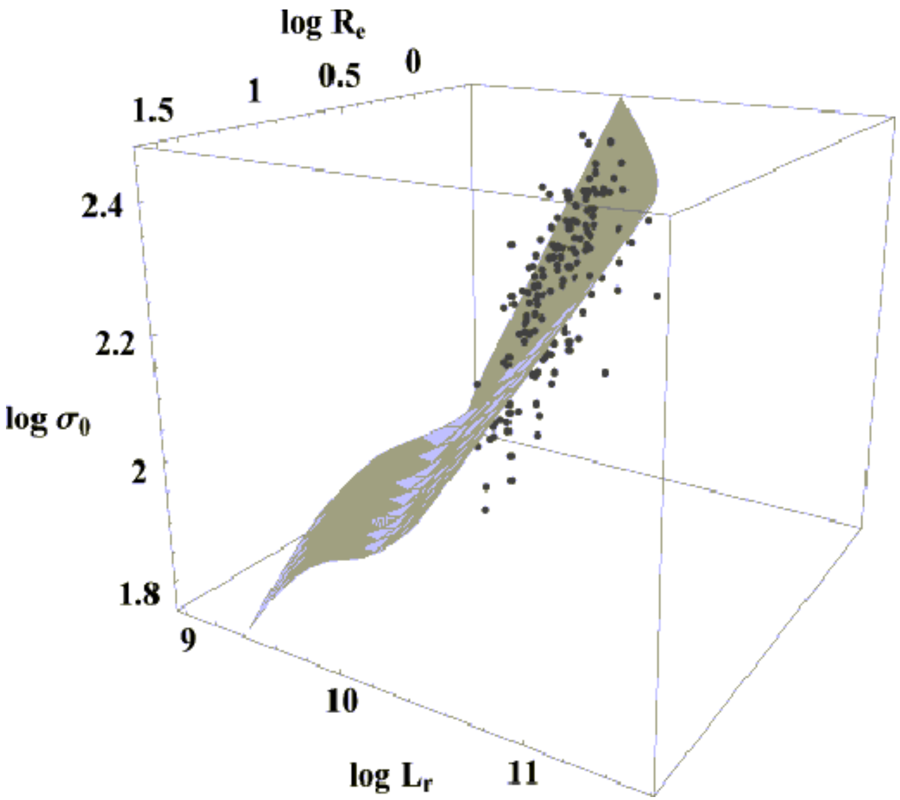
Tully-Fisher

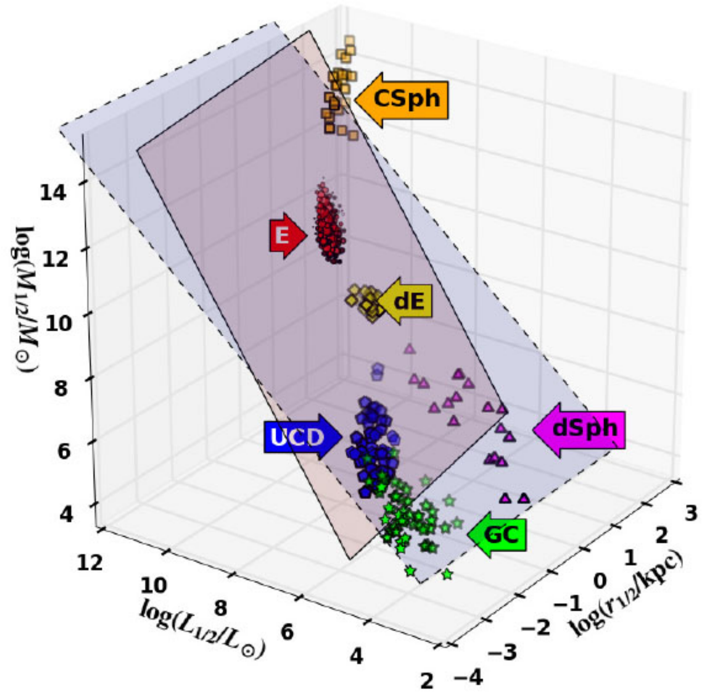
Kochanek et al. 2001

1 parameter rules galaxy evolution: galaxy mass

THE FUNDAMENTAL PLANE OF ELLIPTICALS

higher dimensions: galaxies have "shapes"

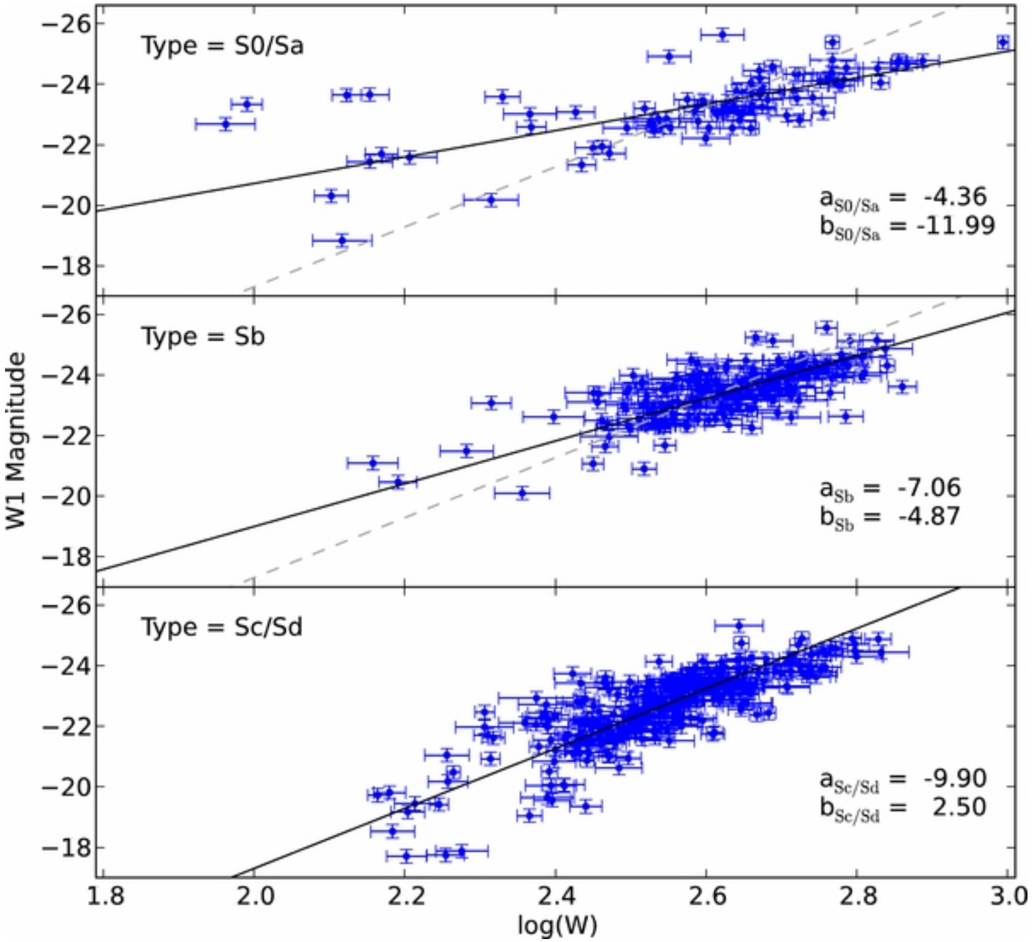




There is another parameter governing the galaxy structure: angular momentum

SPIRALS MISBEHAVE

The "vanilla" Tully-Fisher relation is broken by morphology differences



Another parameter beside mass is at play. Something that defines a "shape"

Can we extend the TF into a 3D spiral manifold?
What parameter can we use?
Is it 'angular momentum-like'?

Lagattuta et al. 2013

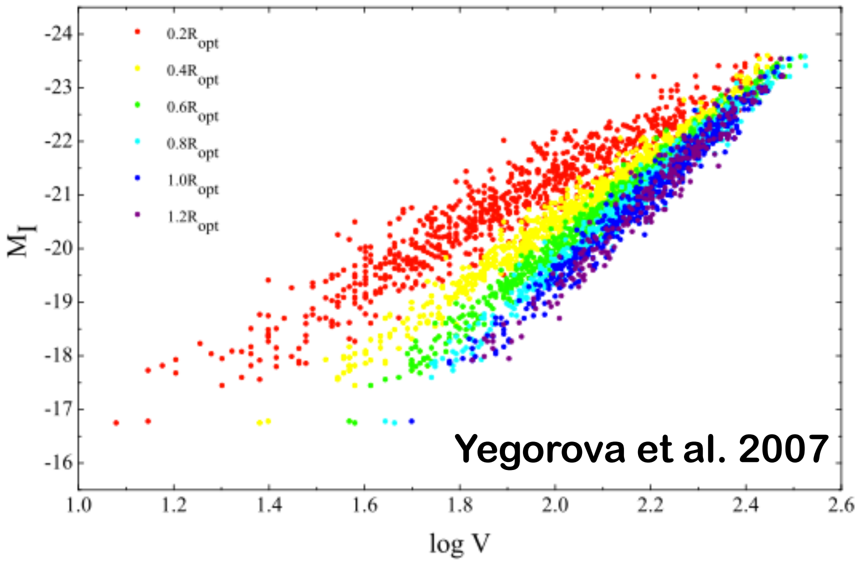
THIS WORK

Data sample:
HI circular velocity: GASS (GALEX Arecibo SDSS), DR 3 (Catinella et al. 2013)
Central velocity dispersion: SDSS DR 9
K-band magnitudes: 2 MASS

Model:
hierarchical semi-analytic model based on Croton et al. (2006)
We use the model to analyse the data

Questions:
- is there a third (physical) parameter that characterises spiral galaxies, that connects the galaxy 'shape' with the slope of the TF relation?
- can we use this parameter to classify galaxy morphology, for instance at high redshift or for large surveys, when visualisation is not available or impractical?

ROTATION CURVES



$$V^2 = V_D^2 + V_B^2 + V_H^2$$

$$r = 2.2 R_D$$

the slope of the TF depends on the radius where V is measured

$$V_{H,B}^2 = G\frac{M(r)}{r}$$

spherical potential profiles; velocity dispersion traced by bulge stars

$$V_D^2 = \frac{GM_D}{R_D}\left(\frac{r}{R_D}\right)^2 [I_0K_0 - I_1K_1]_{\frac{r}{2R_D}}$$

disky potential profile

$$\boxed{R_{D_{new}} = R_{D_{MMW}}\left(1 + (1-f)\frac{M_{bulge}}{M_{disk}}\right)}$$

scale of equivalent angular momentum

CT et al. 2011, Dutton et al. 2007

THE MEANING OF MORPHOLOGY

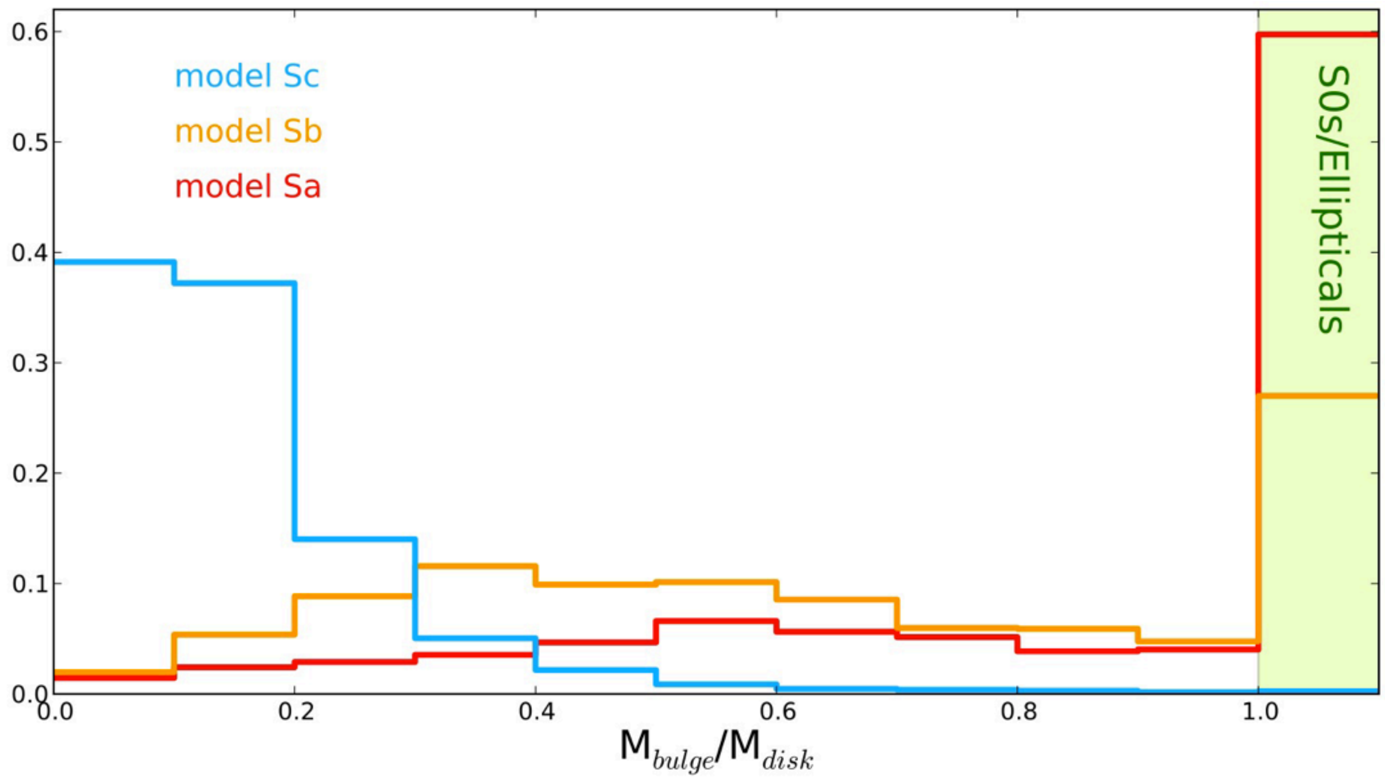
photometric classification (ex. Simien & De Vaucouleurs 1986)
B-band luminosity ratio

$$\mu_B = M_B(bulge) - M_B(total)$$

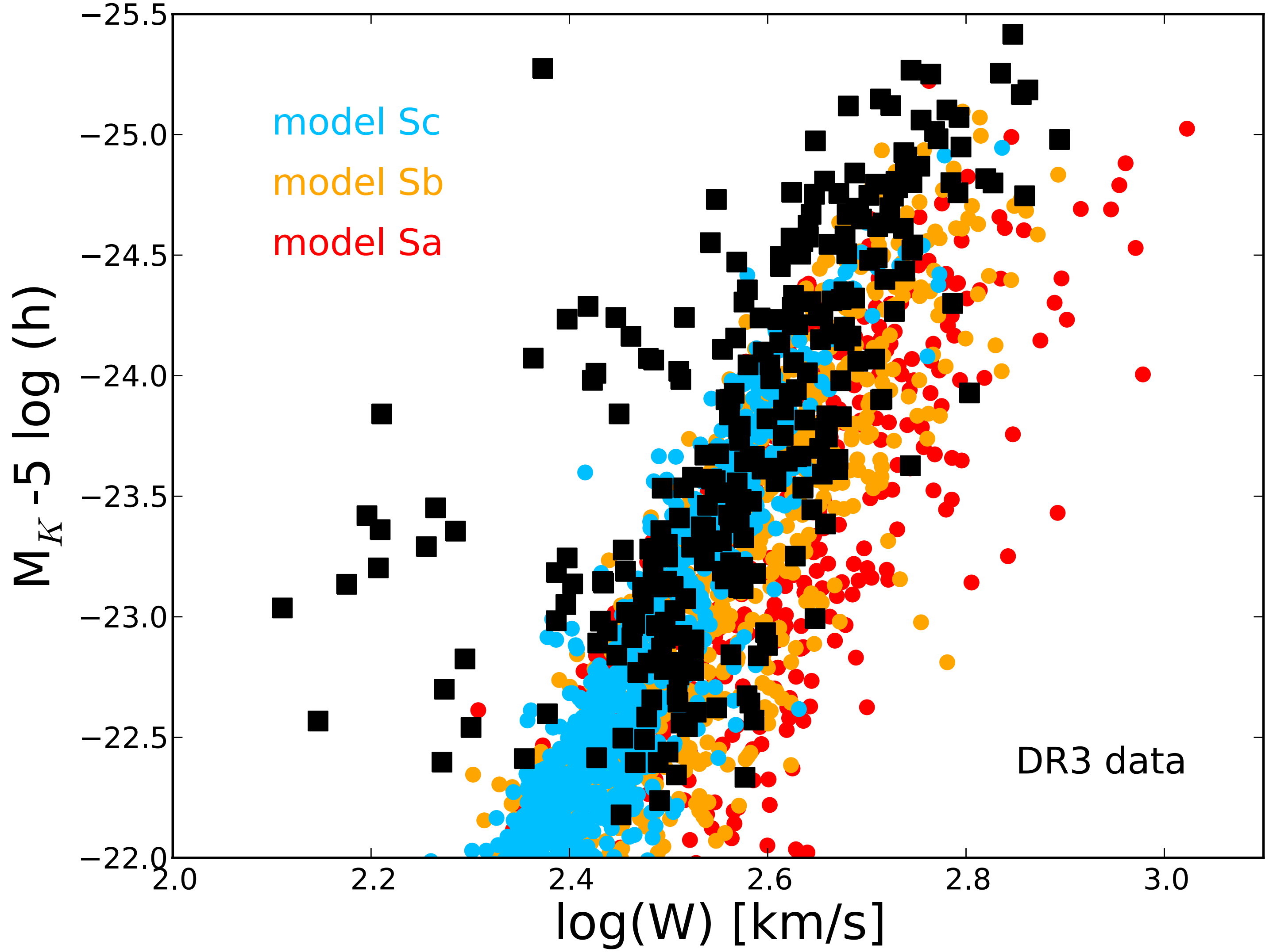
$$Sa: \ \ 0.8 < \mu_B < 1.23$$

$$Sb: \ \ 1.23 < \mu_B < 2.01$$

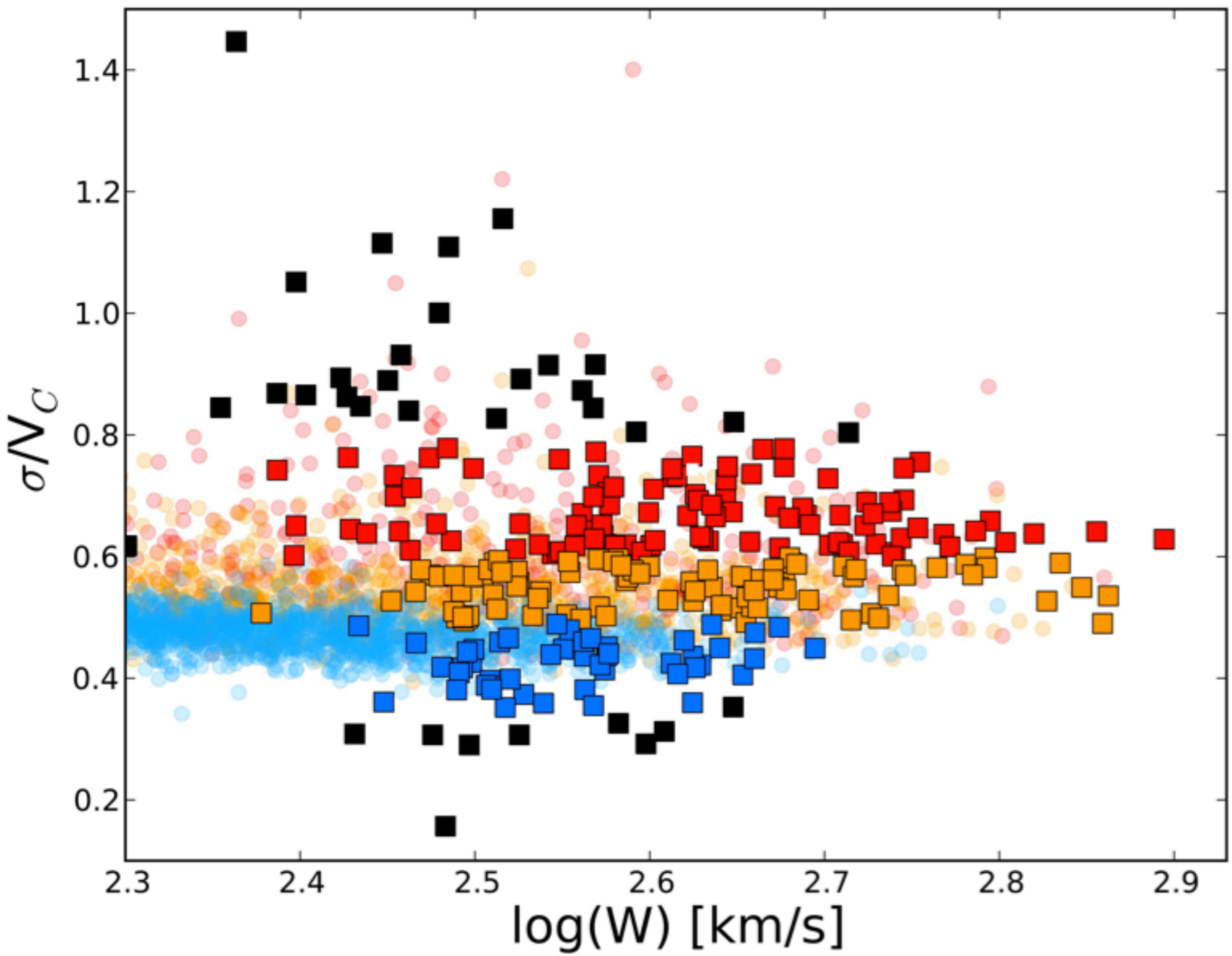
$$Sc: \ \ 2.3 < \mu_B < 4.15$$



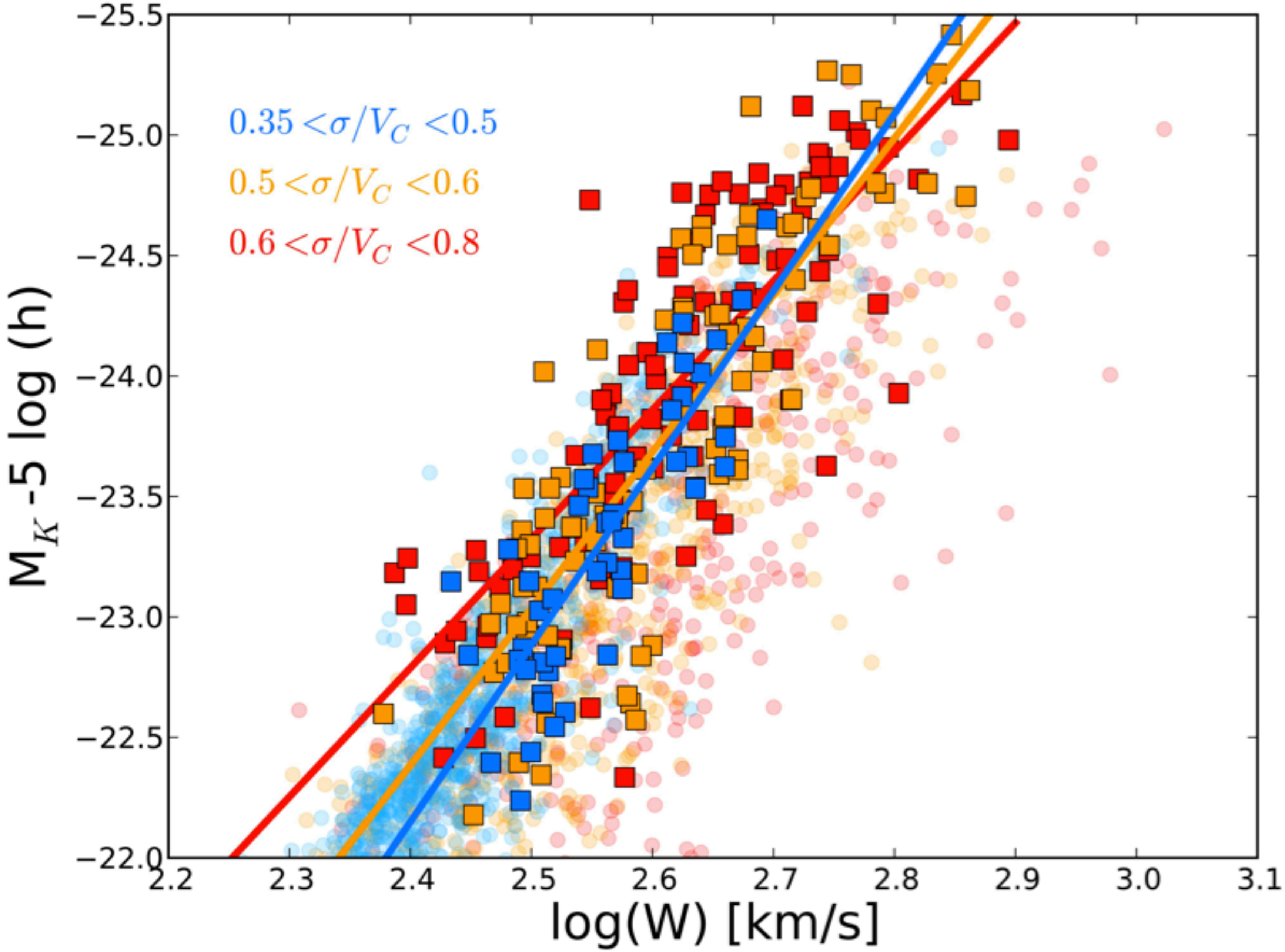
THE TF RELATION



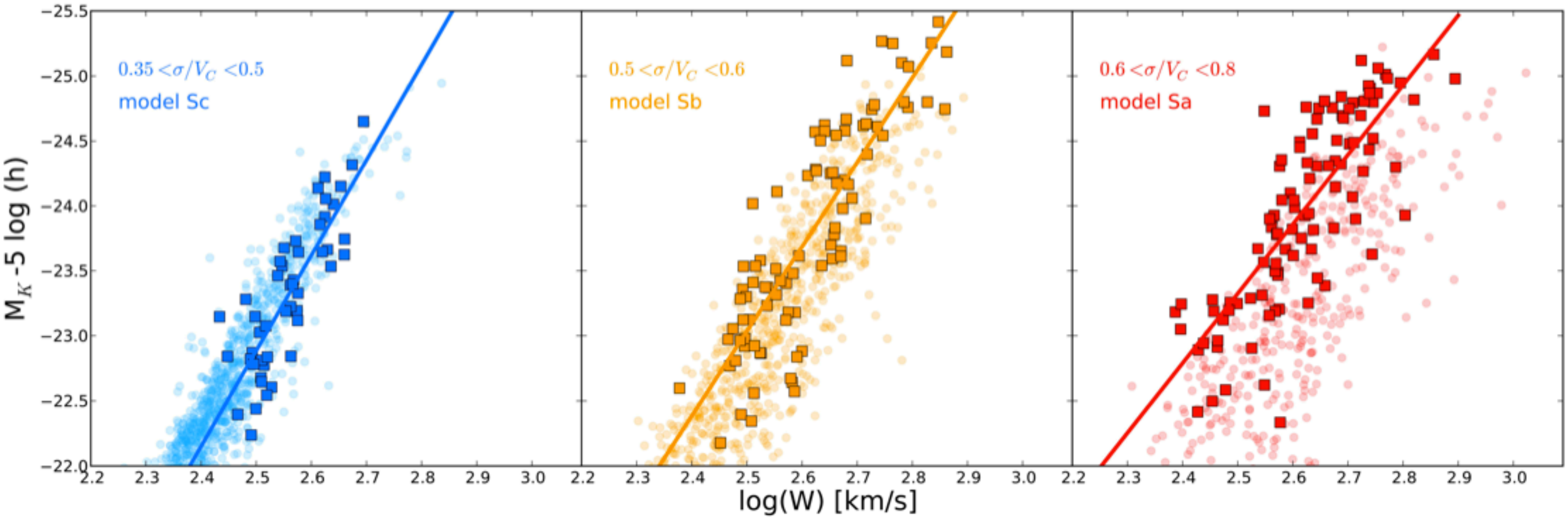
DYNAMICAL RATIOS



THE TF IN CLASSES OF DYNAMICAL RATIO



THE TF IN CLASSES OF DYNAMICAL RATIO: MORPHOLOGY PROXY



sigma/V ratio from model
→ classify observed galaxies based on sigma/V
→→ TF slope depends on sigma/V: the spiral scaling relation has a third dimension
slopes consistent with photometric morphology subclasses

CONCLUSIONS

the TF in model and data agree pretty well; the model shows a morphology-dependent TF, with a photometric classification

the model predicts a link between sigma/V and photometric morphology

we compare the ratio of the velocity dispersion over total circular velocity between model and data, and classify the oberved galaxies in classes of sigma/V

different classes of sigma/V produce TF relations with different slopes; such TF relations correspond well to the established morphology-dependent TF

sigma/V is a good proxy for galaxy morphology, useful at high redshift and for large surveys

sigma/V is a good physical parameter to characterise the structure of spirals and expand their scaling relations into a 3D manifold: {Vc, M, sigma/V}