The Radial Tully-Fisher relation in Dwarf Disk galaxies

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Summary

- Relation between the absolute magnitude in a specific band and velocities. Links photometry to kinematics in galaxies .
- Brent Tully and Richard Fisher in 1977 [Tully and Fisher, 1977]. First established as a distance indicator (and still used).
- Historically defined as : $M = a log(V_{max}) + b$
- Calibrated for Local Group and M81 galaxies, average central surface brightness ($\langle \mu_{0,B} \rangle \approx -23.5$). Then studied for Virgo and Ursa Major cluster.
- $a = 4$ for the original Tully-Fisher relation. Departure of this slope can be achieved if we consider other TF relations in different photometric bands (in B band or in IR in K, R or I band for instance). For instance $a_I = 10$, $a_B = 7.7$, the more infrared the steeper the slope of TF relation ([Yegorova and Salucci, 2007] and references therein).
- Can be used as a way to determine H_0 [Salucci and Frenk, 1988, Salucci et al., 1993]
- Average scatter of 0.3 dex

Summary

- Proposed by Yegorova and Salucci in 2007 for regular spirals [Yegorova and Salucci, 2007].
- Set of 6 relations of type :

$$M_I = a_n log(V_n) + b_n \quad (1)$$

- a_n and b_n fit parameters obtained by least-square fitting
- $V_n = V(R_n)$ where R_n centers of each of the 6 bins.
- Small rms scatter and increase of the slope with respect to radius
- Increase of the slope : implication for the dark matter component
- Studied from 0.2 R_{opt} to 1.2 R_{opt}

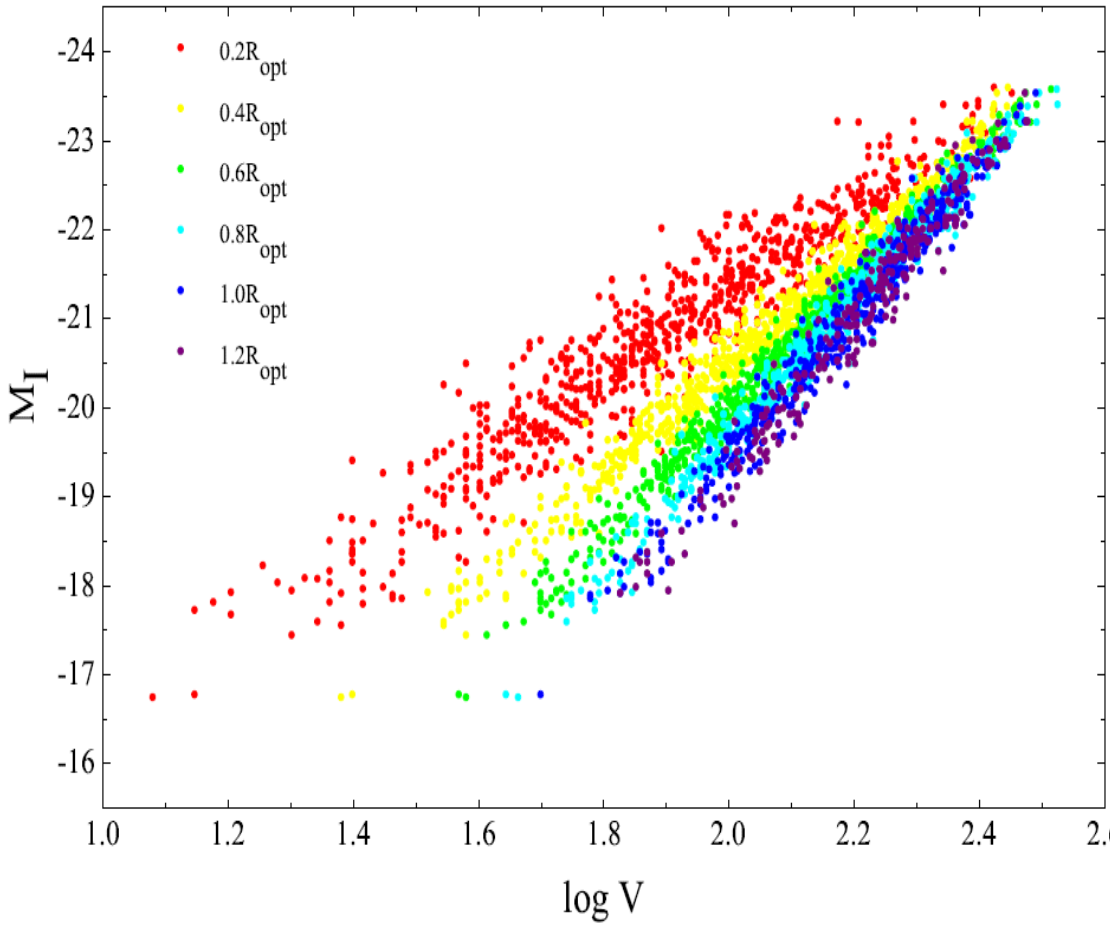
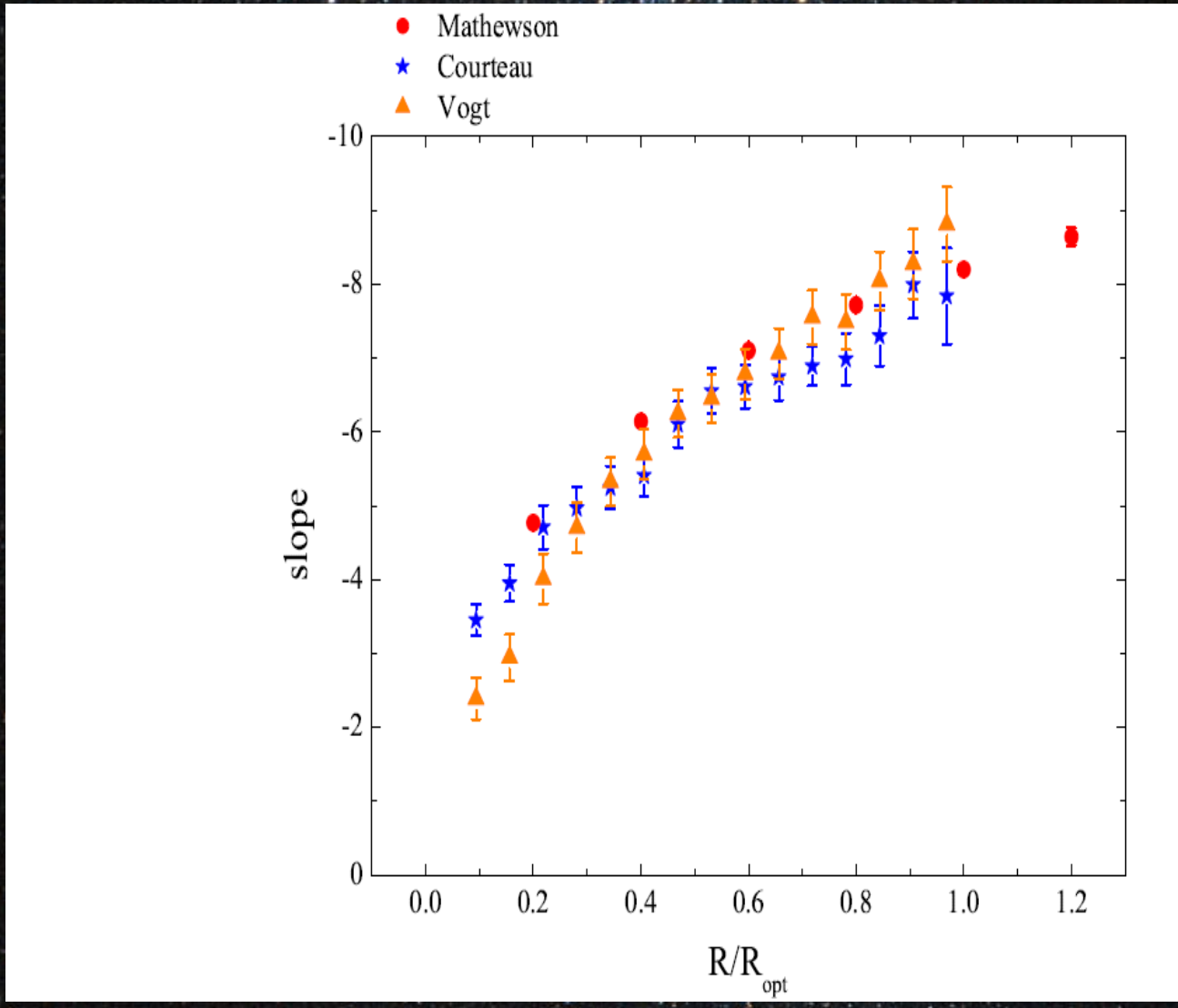
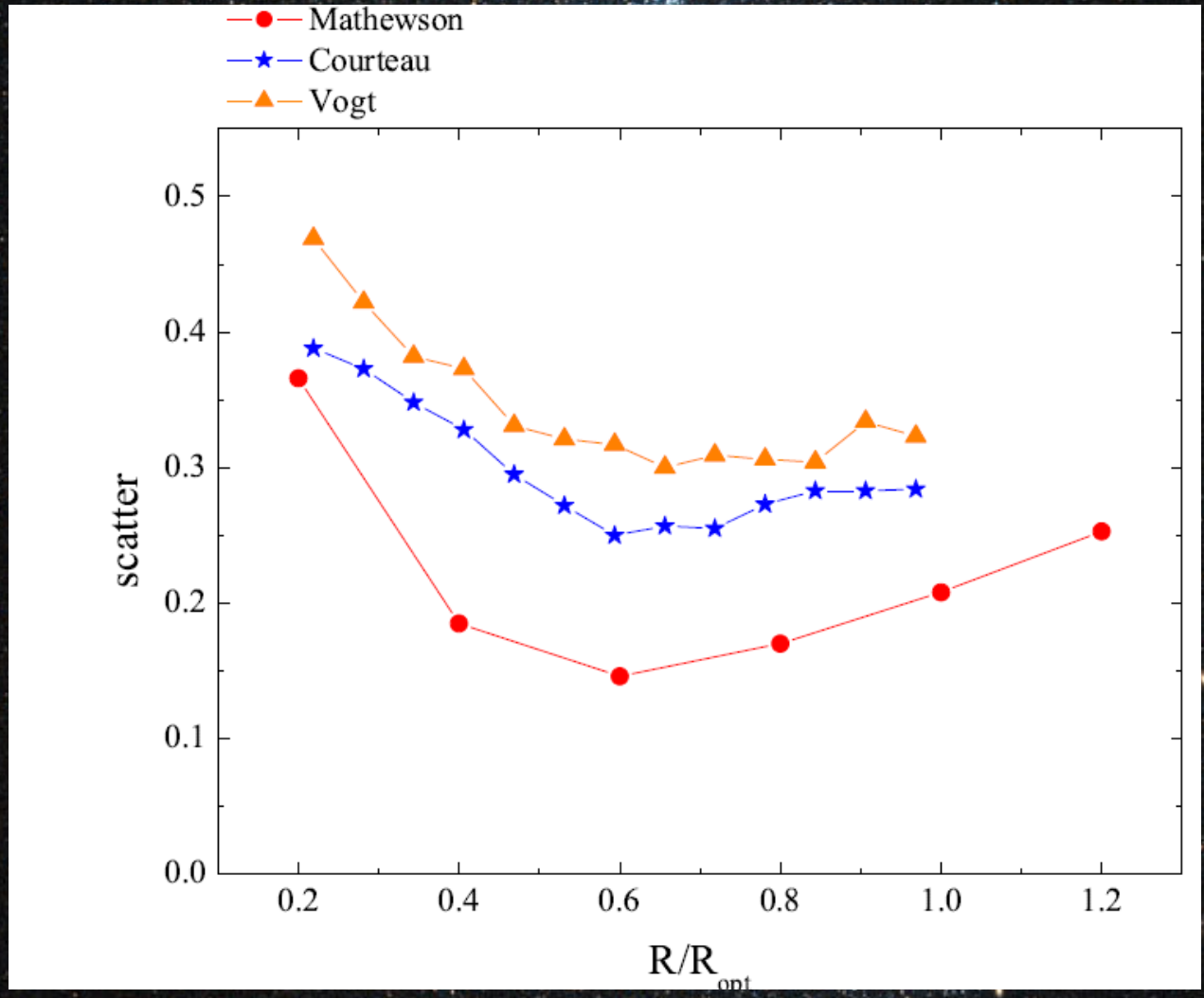


Figure 2. The Radial Tully-Fisher relations for the PS95 sample. Each one of the 6 relations is indicated with different color.


Mathewson
Courteau
Vogt
-10
-8
-6
-4
-2
0
slope
0.0
0.2
0.4
0.6
0.8
1.0
1.2
R/R opt

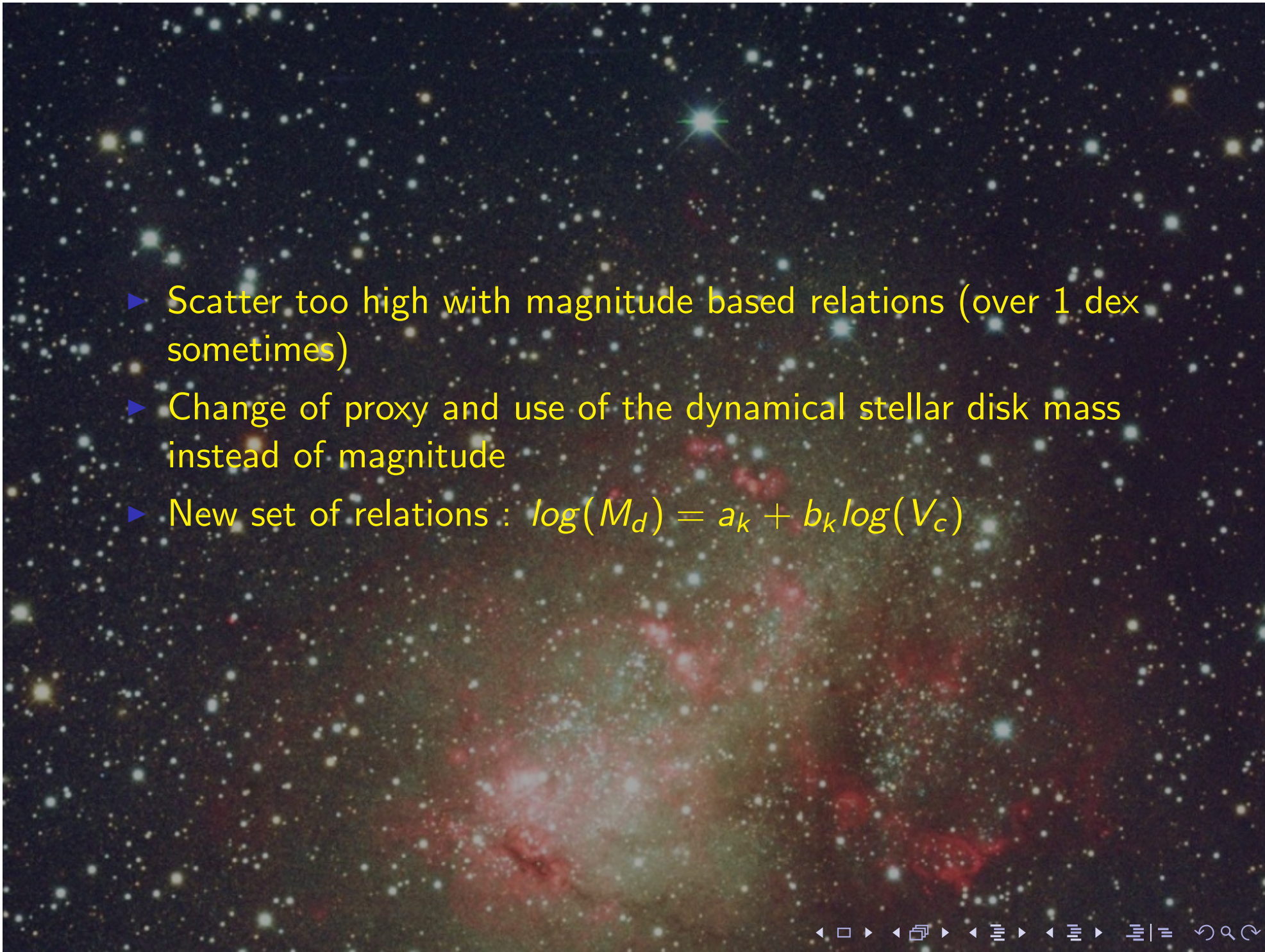

Mathewson
Courteau
Vogt
scatter
0.0
0.1
0.2
0.3
0.4
0.5
0.2
0.4
0.6
0.8
1.0
1.2
R/R_opt

Summary

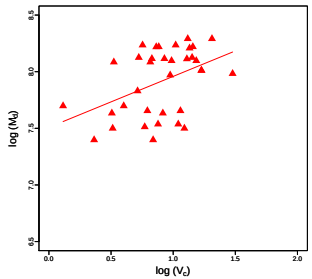
- Dwarf galaxies : more than 90 % dark matter dominated. Also dark matter dominated in the innermost regions.
- For our work, DM halo follow Burkert distribution, best fit for the mass modeling as shown in [Burkert, 1995] :

$$\rho_B(r) = \frac{\rho_0}{\left(1 + \frac{r}{r_0}\right)\left(1 + \left(\frac{r}{r_0}\right)^2\right)} \tag{2}$$

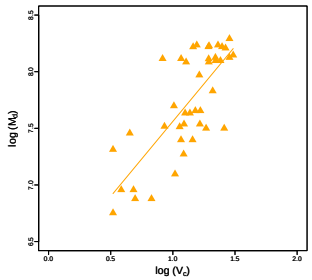
- Not too low luminosities, $M_B < -14$, not pressure supported galaxies, RC decomposition possible [Kormendy and Freeman, 2016]
- Sample from Karachentsev catalog [Karachentsev et al., 2013] and taken from Karukes in [Karukes and Salucci, 2017]. 36 dwarf disk galaxies from which BCDs and Irr.



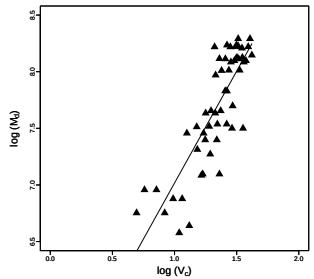
- Scatter too high with magnitude based relations (over 1 dex sometimes)
- Change of proxy and use of the dynamical stellar disk mass instead of magnitude
- New set of relations : $log(M_d) = a_k + b_k log(V_c)$



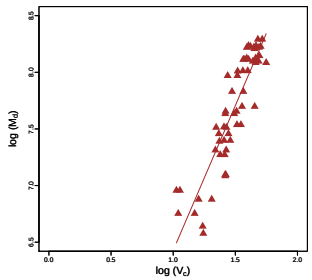
(a) $V_{0.10R_{opt}}$



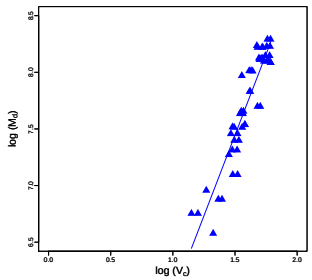
(b) $V_{0.22R_{opt}}$



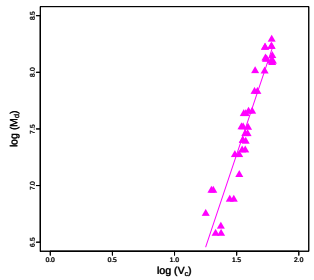
(c) $V_{0.38R_{opt}}$



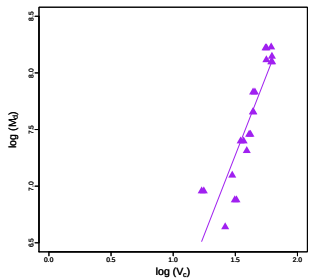
(d) $V_{0.64R_{opt}}$



(e) $V_{0.94R_{opt}}$



(f) $V_{1.25R_{opt}}$



(g) $V_{1.52R_{opt}}$

Figure : Disk mass based TFR relations, bins 1 to 7

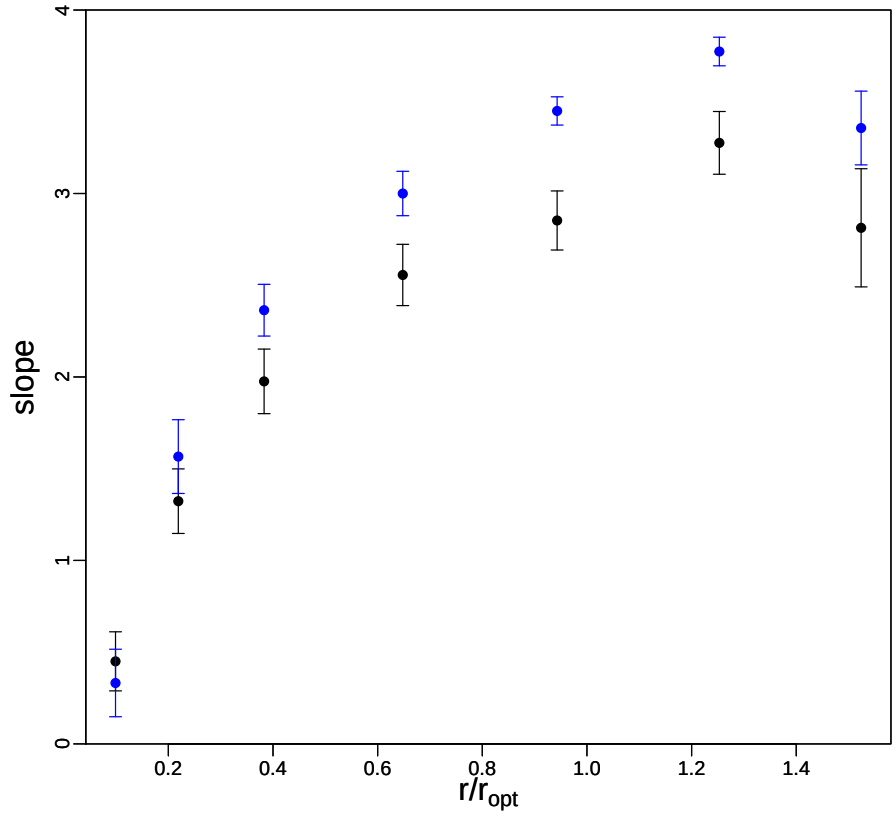


Figure : Slope versus normalized radius for TFR-disk mass and TFRC (black and blue respectively)

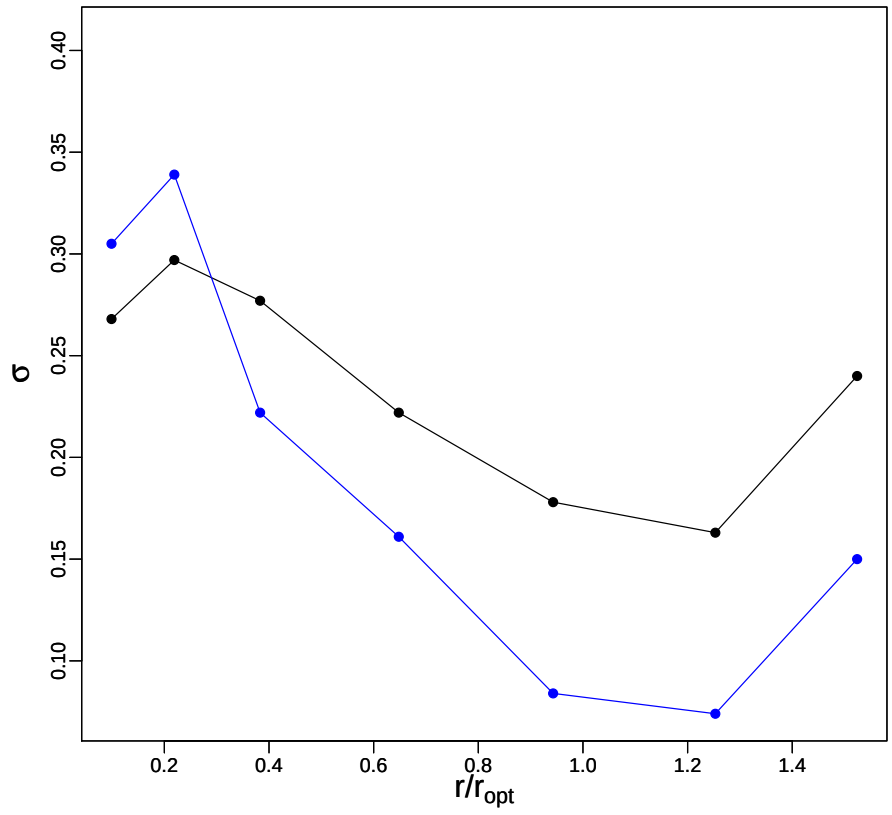


Figure : rms versus normalized radius for TFR-disk mass, TFRC (black and blue)

- Scatter less important (need to rescale since factor 2.5 between magnitudes and masses) than for TFR-Kmag but still important
- Another parameter important to describe dwarf disks, compactness (see Karukes et al. [Karukes and Salucci, 2017])

$$C = \frac{R_d(M_d)}{R_d} \tag{3}$$

$$log(R_d(M_d)) = -3.64 + 0.46 log(M_d) \tag{4}$$

- New set of TF-like relations (TFRC) : $log(M_d) = a_k + b_k log(V_c) + d\ log(c)$
- c is a property of the disks (like M_d)
- Physical interpretation: quantifies differences of the sizes of the stellar disks in galaxies with the same stellar mass.

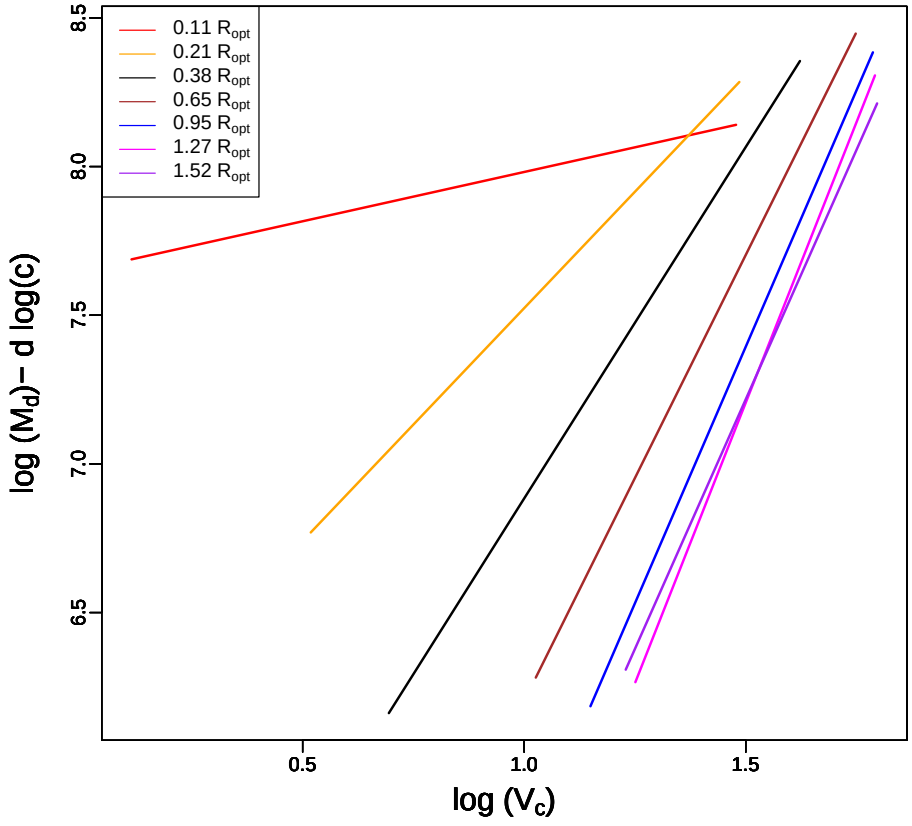
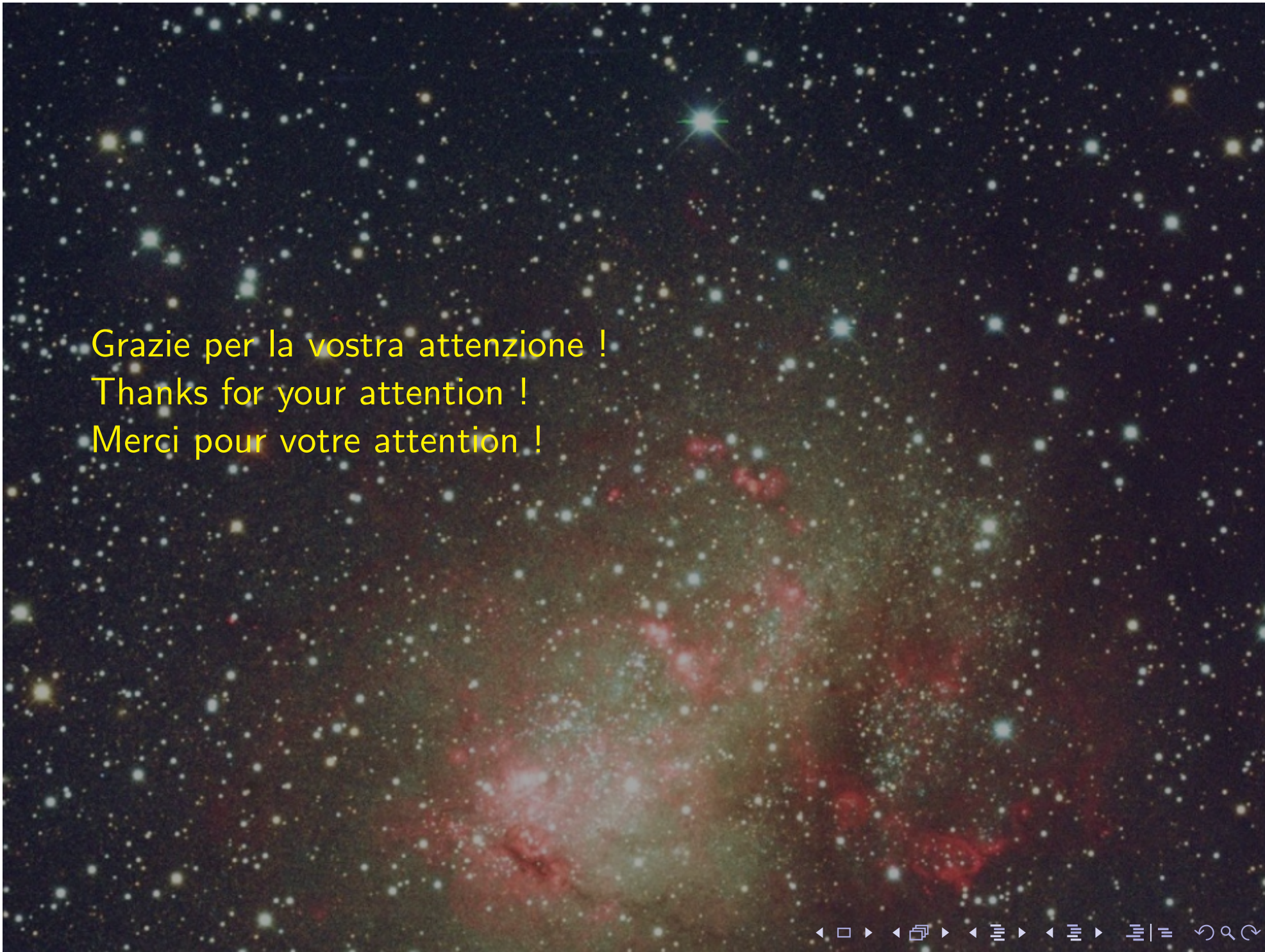


Figure : TFRC relations based on dynamical mass

- Adding compactness has an effect on rms scatter, except on the innermost regions $0.03 < \frac{r}{R_{opt}} < 0.27$
- Room of improvement : change dynamical disk masses ot photometrical disk masses, using data from ALFALFA for instance [Papastergis et al., 2016]
- Thorough study of TFRCHI, for that we need an accurate estimate of both disk mass and gas mass (HI mostly)
- Investigation of possible non linearity in the TFR(C)

Summary

- Study of a set of radial Tully-Fisher like relations from reduced radii from 0.03 to 1.6 R_{opt}
- In each case, magnitude based, disk mass based, increase of the slope of the relations with radius
- Tend to prove the existence of a dark component in these galaxies as discussed in [Yegorova and Salucci, 2007]
- For magnitude based, too high rms scatter
- Lowest scatter obtained for disk mass based relations with compactness parameter (TFRC)


Grazie per la vostra attenzione !
Thanks for your attention !
Merci pour votre attention !

Basic assumptions under TF relation

- Disks of galaxies are modelled using a Freeman exponantial disk of type : $\mu = \mu_0 exp(-\frac{r}{R_D})$ where R_D disk length scale (related to R_{opt} the radius encompassing 83 % of the light)
- Central surface brightness μ_0 is constant
- $\left(\frac{M}{L}_*\right) = \text{cst}$
- disks are self gravitating : $V^2(r) \propto \frac{M_d}{r}$

Interpretation of high scatter for innermost regions

- Dwarfs irregulars : most important type of galaxies in our sample, and HI dominated. HI domination in the outermost regions (after 1.6 R_{opt}).
- Need to take into account SFR since galaxies are starbusting.

TFRCHI-relations

$$M_{bar} = a_k + b_k log(V_c) + dlog(C) \text{ with } M_{bar} = M_d + M_{HI}$$

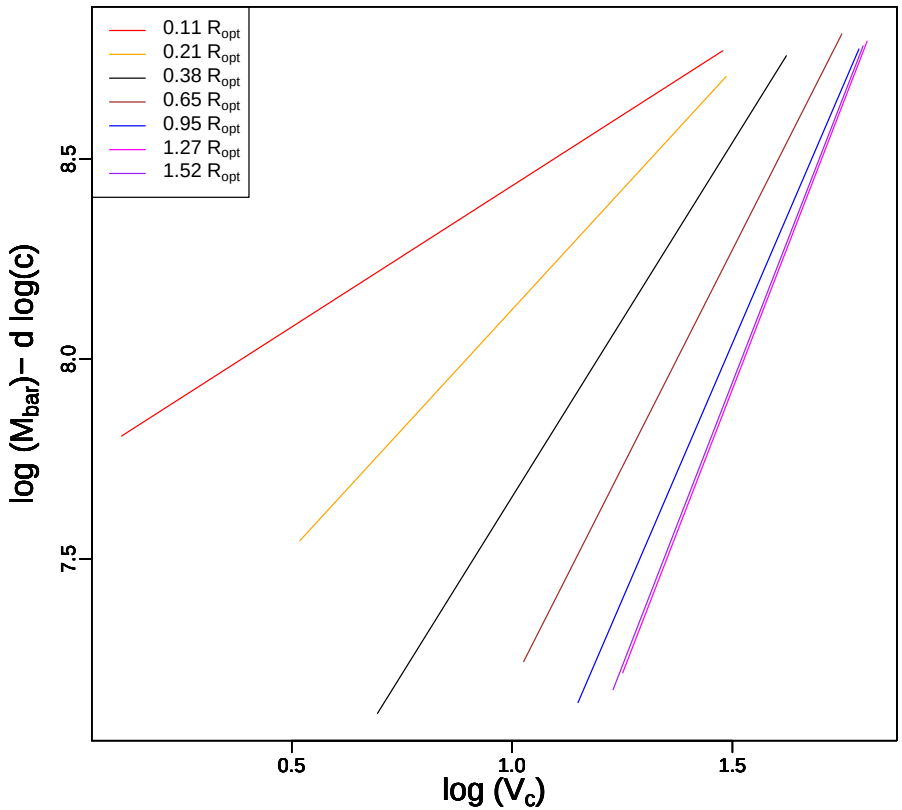
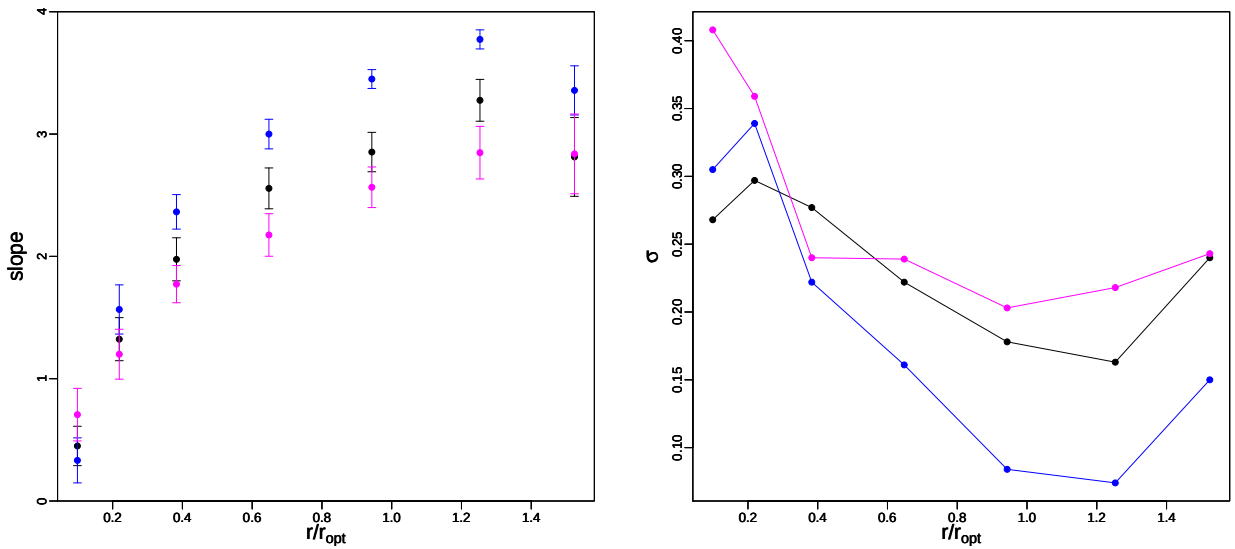


Figure : TFRCHI relations based on dynamical mass

TFRCHI-scatter and slope



(a) $V_{0.10R_{opt}}$ (b) $V_{0.22R_{opt}}$

Figure : Slope and rms versus normalized radius for TFR-disk mass, TFRC and TFRCHI (black, blue and magenta respectively)

Criteria for the original Tully-Fisher calibrators

- Sample of calibrators selectionned originally according to few criteria : well determined distance, known photometric properties, known HI profile width and sufficient inclination ($> 45^o$ from face-on)
- galaxies studies photometrically by Holmberg (1956), within 6^o of the center of the cluster, late type spirals (Sb,Sc), inclination from 45^o to 85^o, sufficiently isolated.

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1. to avoid any appreciable error in correcting HI profile for projection effects
2. severe type and absorption uncertainties above 85°, no confusion for disentangling HI profiles.

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