The dust effects on galaxy scaling relations

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Accurate galaxy scaling relations are essential for a successful model of galaxy formation and evolution as they provide direct information about the physical mechanisms of galaxy assembly over cosmic time. We present here a detailed analysis of a sample of nearby spiral galaxies taken from the KINGFISH survey. The photometric parameters of the morphological components are obtained from bulge-disk decompositions using GALFIT data analysis algorithm, with surface photometry of the sample done beforehand. The method and the library of numerical results previously obtained in Pastrav et al. (2013a,b) are used to correct the measured photometric parameters for inclination, dust and decomposition effects in order to derive their intrinsic (face-on, dust free) values. Galaxy scaling relations are then presented with and without corrections for these effects, at various wavelengths and derived dust opacities. While our sample is rather small, it is sufficient to emphasize the influence of galaxy environment (dust, in this case) when deriving scaling relations.

Motivation

Dust biases all the galaxy structural & photometric parameters (and not only) involved in scaling relations, with other effects having a contribution - inclination and decomposition effects (Pastrav et al. 2013a,b). Not having accurate intrinsic scaling relations can have implications for models of galaxy evolution.

Sample

14 unbarred spiral galaxies from the KINGFISH survey (Kennicutt et al. 2011) - see Table 1

Method

The following steps were followed:

- structural analysis of the sample performing bulge-disk decompositions using parametric functions (exponential+Sersic) available in GALFIT 3.02 (Peng et al. 2010) data analysis algorithm and star-masking routines developed by Richard Tuffs (MPIK)
- surface photometry to derive total integrated fluxes using curve-of-growth method
- derive the central face-on dust optical depth in B band using the correlation between B band face-on dust opacity and stellar mass surface density discovered by Grootes et al. (2013),

$$\log(\tau_B^f) = 1.12(\pm0.11) \cdot \log\left(\frac{\mu_*}{M_\odot\ \mathrm{kpc}^{-2}}\right) - 8.6(\pm0.8) \qquad \mu_* = \frac{M_*}{2\pi r_{e,\mathrm{ss},r}^2}$$

with stellar masses taken from Grossi et al. (2015) (see Table 1)

- the whole chain of corrections presented in Pastrav et al. (2013a, b) for inclination (projection), dust and decomposition effects was applied to the photometric parameters of disks and bulges
(disk scalelength and surface brightness, bulge effective radius and Sersic index, B/D) to obtain the intrinsic (dust-free) values
- intrinsic central surface brightness, apparent and absolute magnitude were derived for each galaxy
- total dust mass and dust-to-star ratio were derived for each galaxy (see Table 1) using eq. (A5) from Grootes et al. (2013); dust-corrected values for these where also derived, with the average values shown in Figs. 1 and 2.

$$\tau_B^f = K\frac{M_{\mathrm{dust}}^{\mathrm{diff}}}{r_{s,d,B}^2} \approx K\frac{M_{\mathrm{dust}}}{r_{s,d,B}^2}$$

Results

Some of the results obtained are presented in Table 1, below.

Table 1. Exponential + Sérsic fits, B band

Galaxy	τ_B^f	$log(M_\star/M_\odot)$	$log(M_d/M_\odot)$	$log(M_d^{corr}/M_\odot)$	$R_s[kpc]$	$R_s^{corr}[kpc]$
NGC0024	2.06 ± 0.32	9.65 ± 0.05	6.75	6.53	1.66	1.29
NGC0628	1.90 ± 0.33	10.08 ± 0.06	7.39	7.22	3.61	2.97
NGC2841	5.85 ± 0.78	10.85 ± 0.06	8.00	7.57	4.15	2.53
NGC2976	3.32 ± 0.33	9.13 ± 0.07	6.25	6.11	0.74	0.63
NGC3190	4.72 ± 0.29	10.58 ± 0.06	7.72	7.42	3.35	2.39
NGC3621	3.38 ± 0.43	10.05 ± 0.06	7.18	6.63	2.11	1.13
NGC3938	3.04 ± 0.28	10.45 ± 0.06	7.57	7.25	3.50	2.42
NGC4254	5.87 ± 0.40	10.60 ± 0.06	7.75	7.32	3.10	1.89
NGC4736	3.80 ± 0.90	10.33 ± 0.06	7.54	6.78	1.35	1.11
NGC4826	3.80 ± 0.82	10.28 ± 0.06	7.46	6.45	1.58	0.87
NGC5055	4.57 ± 0.37	10.62 ± 0.06	7.76	7.32	3.56	2.14
NGC5474	1.55 ± 0.32	9.06 ± 0.05	6.15	6.08	0.96	0.89
NGC7331	4.73 ± 0.34	10.99 ± 0.06	8.13	7.82	5.38	3.75
NGC7793	1.68 ± 0.28	9.47 ± 0.06	6.56	6.30	1.48	1.09

Conclusions

- inclination, dust and decomposition affects all the parameters involved in disk scaling relations, changing the slope of these relations to smaller values, with dust effects having the most significant contribution
- inclusion of these effects changes the dust masses derived for the galaxies in the sample, with a decrease of up to 0.5dex in the total mass
- as a consequence, dust/star ratio is also decreased when considering the above effects, which may have implications for models of dust production and evolution
- the average central face-on dust opacity derived in this study (τ=3.59±0.38) is consistent with the value of 3.8±0.7 found by Driver et al. (2007); the same for the average dust to star ratio value - (1.36±0.02)x10-3, consistent with the value of 0.95x10-3 found by Skibba et al. (2011)

References

Pastrav B.A., Popescu C.C., Tuffs R. J. , Sansom A. E. 2013, A&A 553, A80
Pastrav B.A., Popescu C.C., Tuffs R. J. , Sansom A. E. 2013, A&A 557, A137
Kennicutt R.C., Calzetti D., Aniano G., Appleton P., Armus L. et al. 2011, PASP 123, 1347
Peng C. Y., Ho L. C., Impey C. D., Rix, H.-W. 2010, AJ 139, 2097
Grootes, M.W., Tuffs R.J., Popescu C.C., Pastrav B.,Andrae E. et al. 2013, ApJ 766, 59
Grossi M., Hunt L.K., Madden S. C., Hughes T.M., Auld, R. et al. 2015, A&A 574, A126
Driver S.P., Popescu C.C., Tuffs R.J., Liske J., Graham A.W. et al. 2007, MNRAS 379, 1022
Skibba R.A., Engelbracht C.W., Dale D.A. et al. 2011, ApJ 738, 89

Disk scaling relations

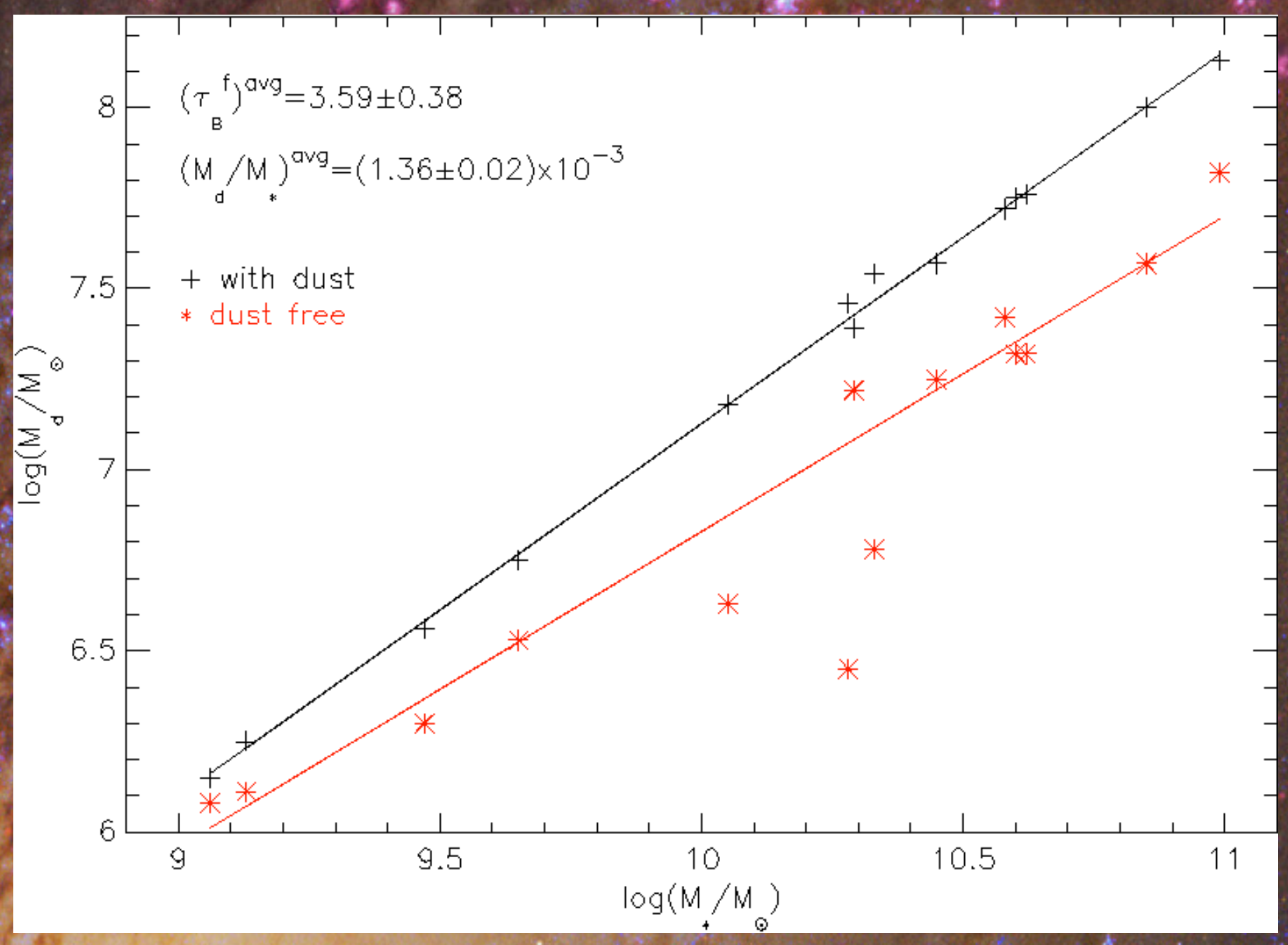

Fig.1 Dust mass vs. stellar mass relation, without corrections for inclination, dust and decomposition effects (black) and the dust-free relation (red).

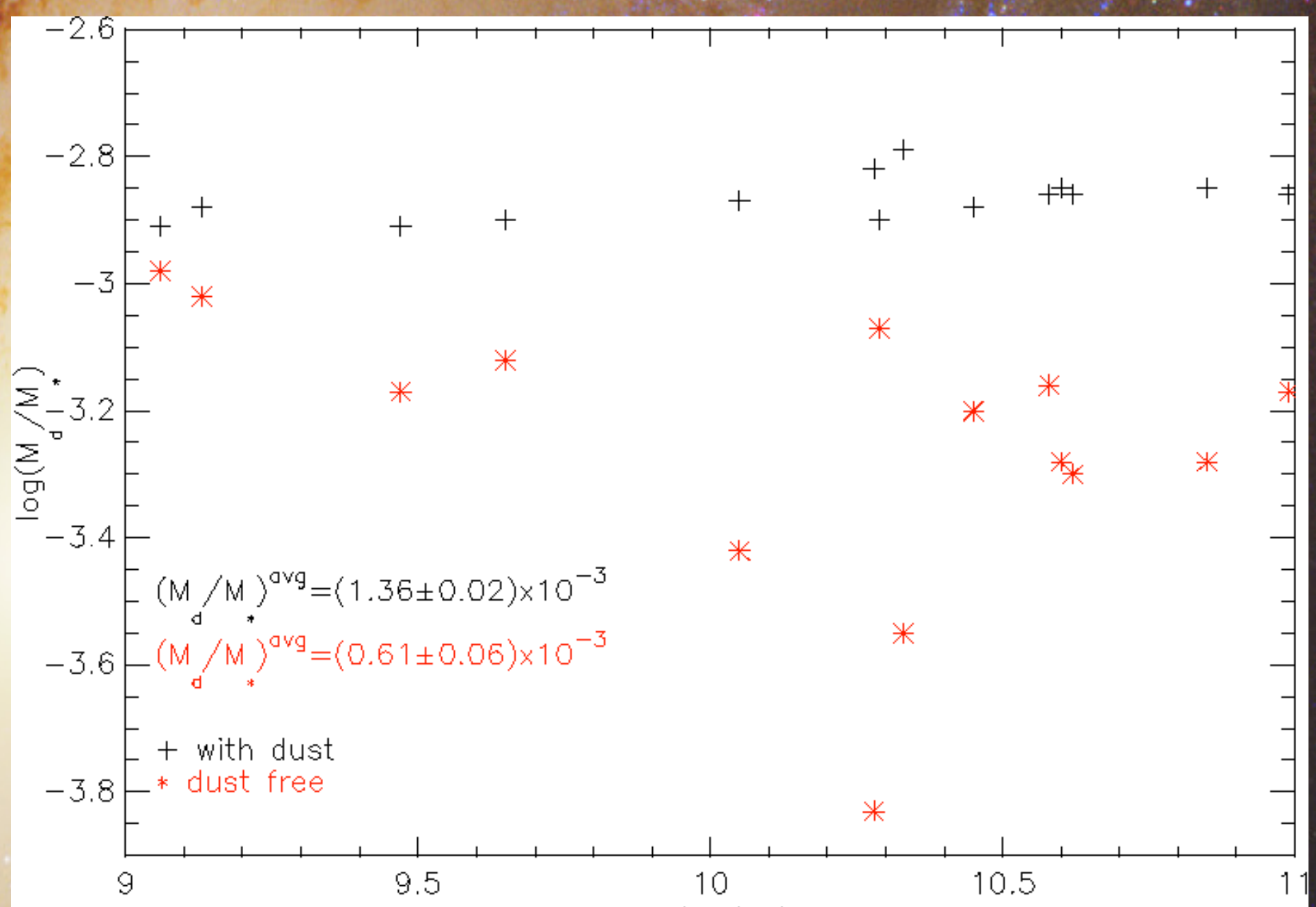

Fig.2 Dust-to-star mass ratio vs. stellar mass. The symbols and colors are similar to the ones in Fig.1.

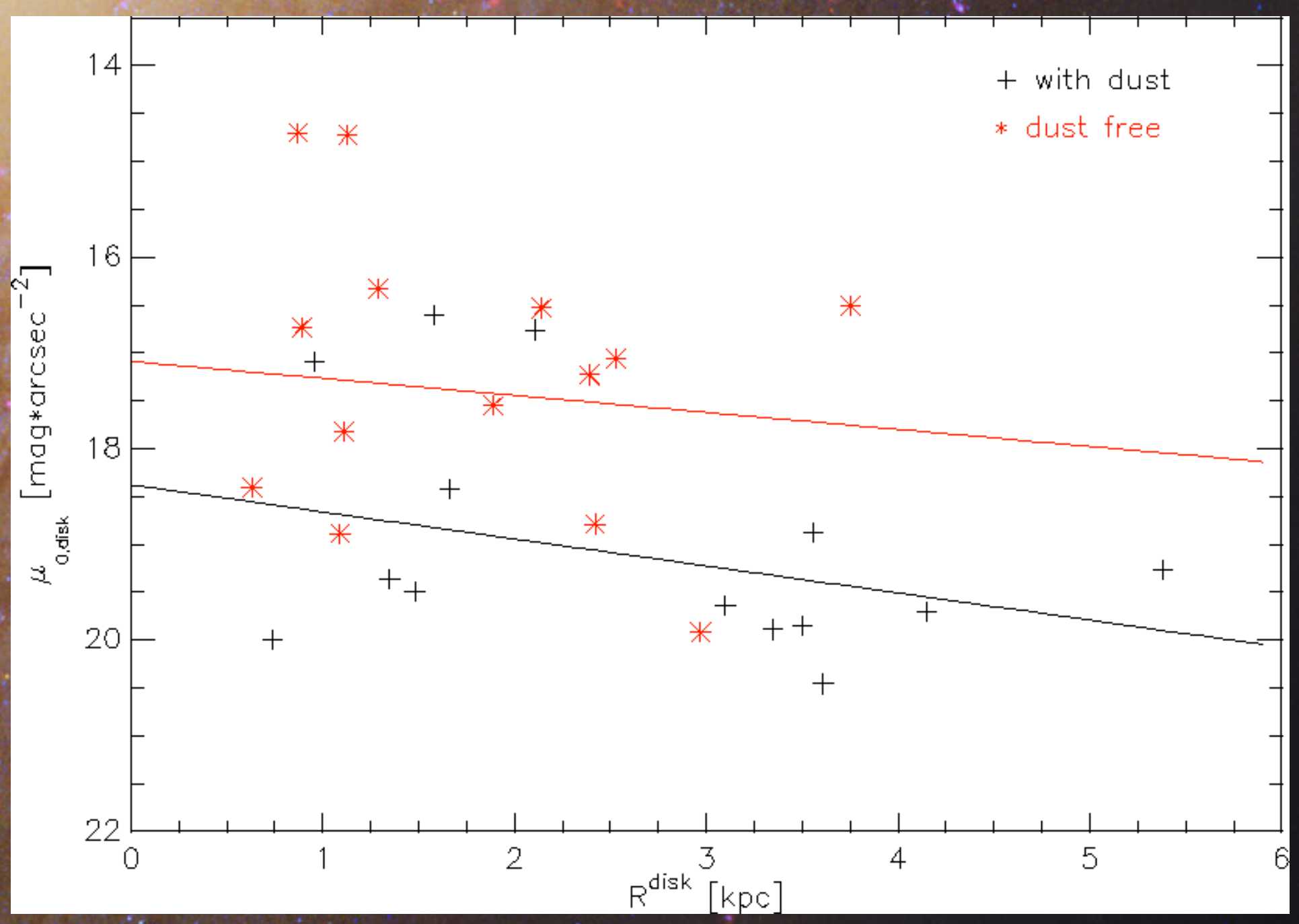

Fig.3 Disk central surface brightness vs. disk scalelength, without corrections for inclination, dust and decomposition effects (black) and with corrections for these effects included (red).

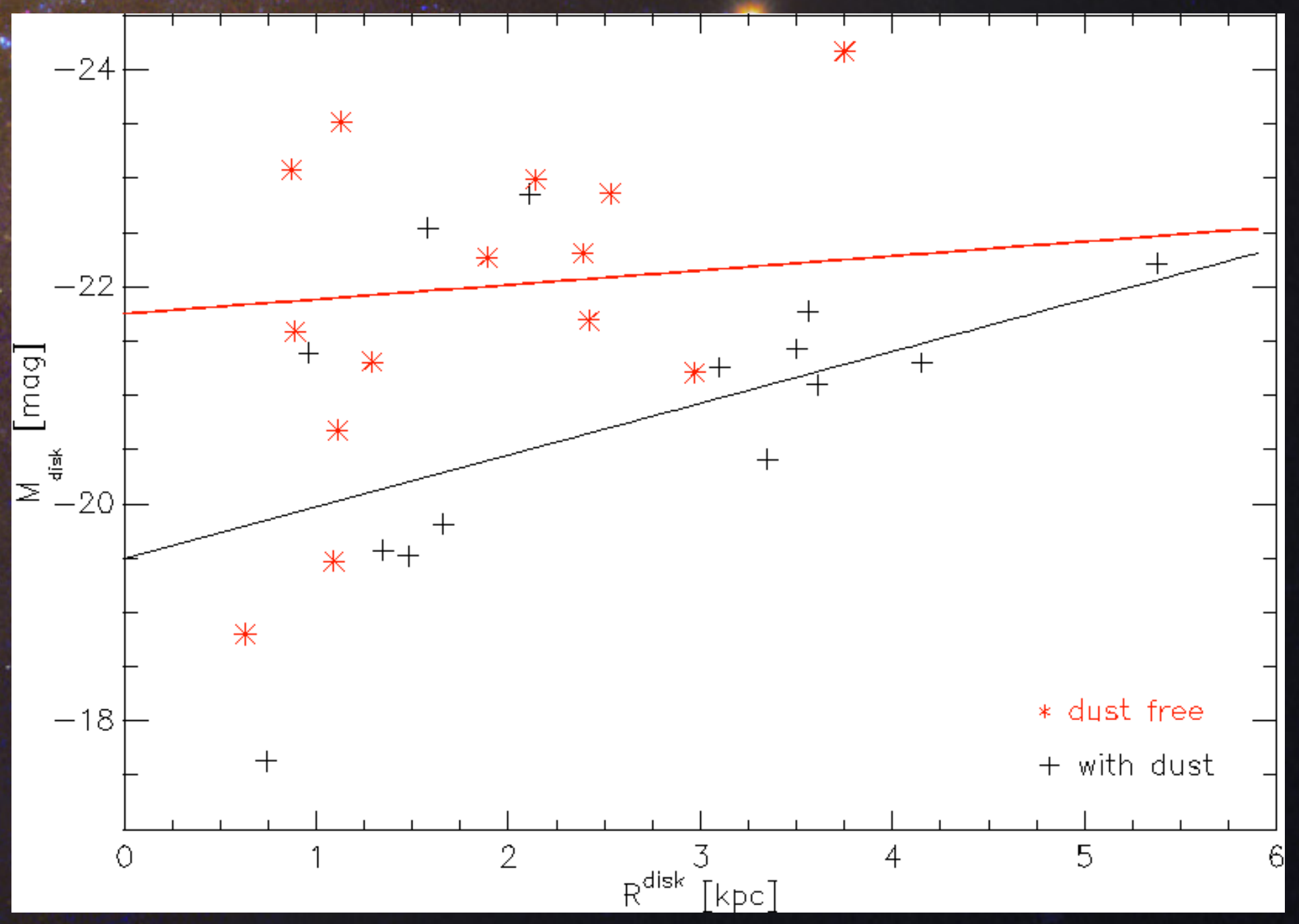

Fig. 4 Disk absolute magnitude vs. disk scalelength (same colors and symbols as for Fig.3).

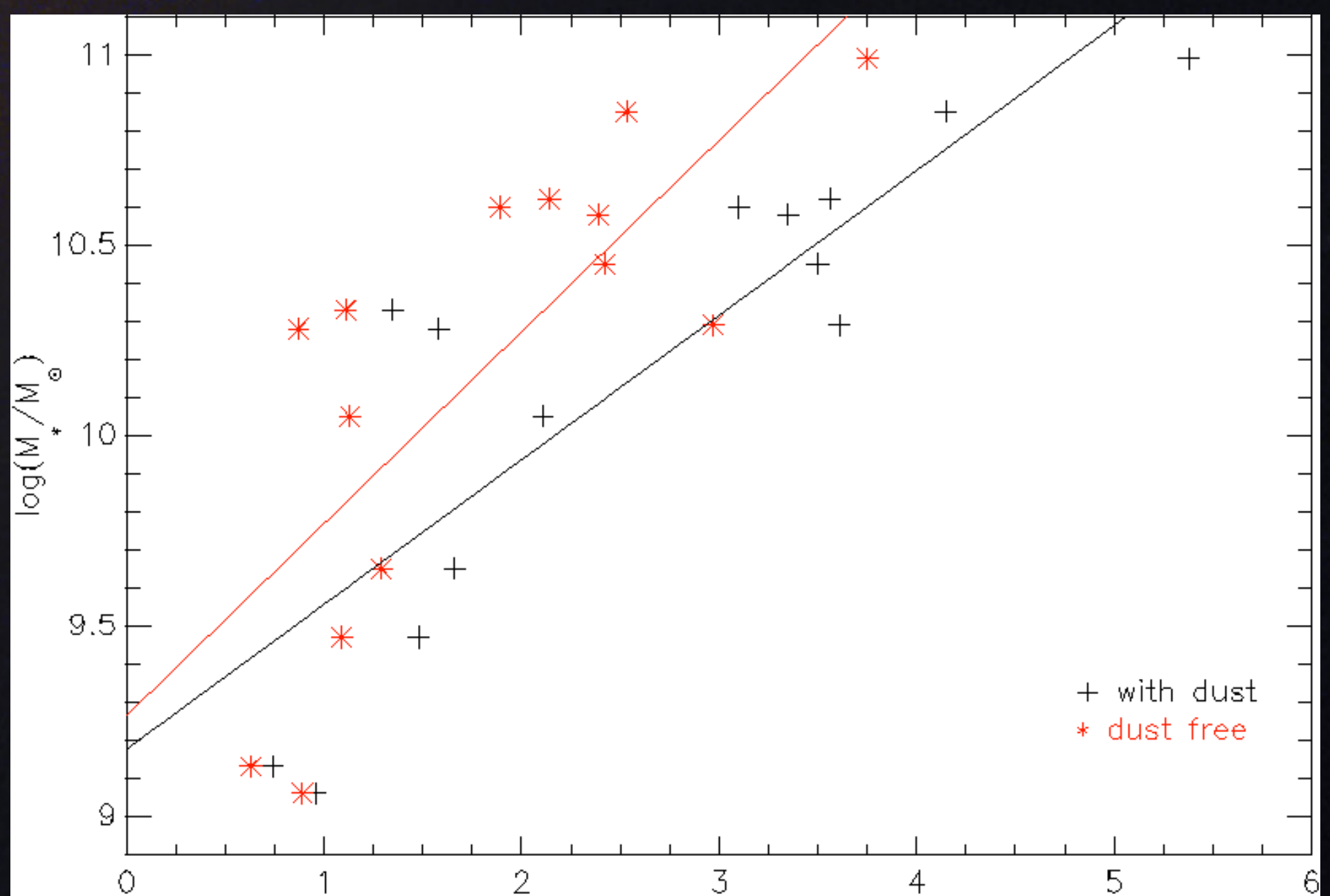

Fig. 5 Stellar mass vs. disk scalelength (same colors and symbols as for Fig.3)

Photo by Robert Gendler, NASA/ESA, Subaru and DSS