Mapping κ_d in Nearby Galaxies

Chris Clark
Pieter De Vis
Jon Davies
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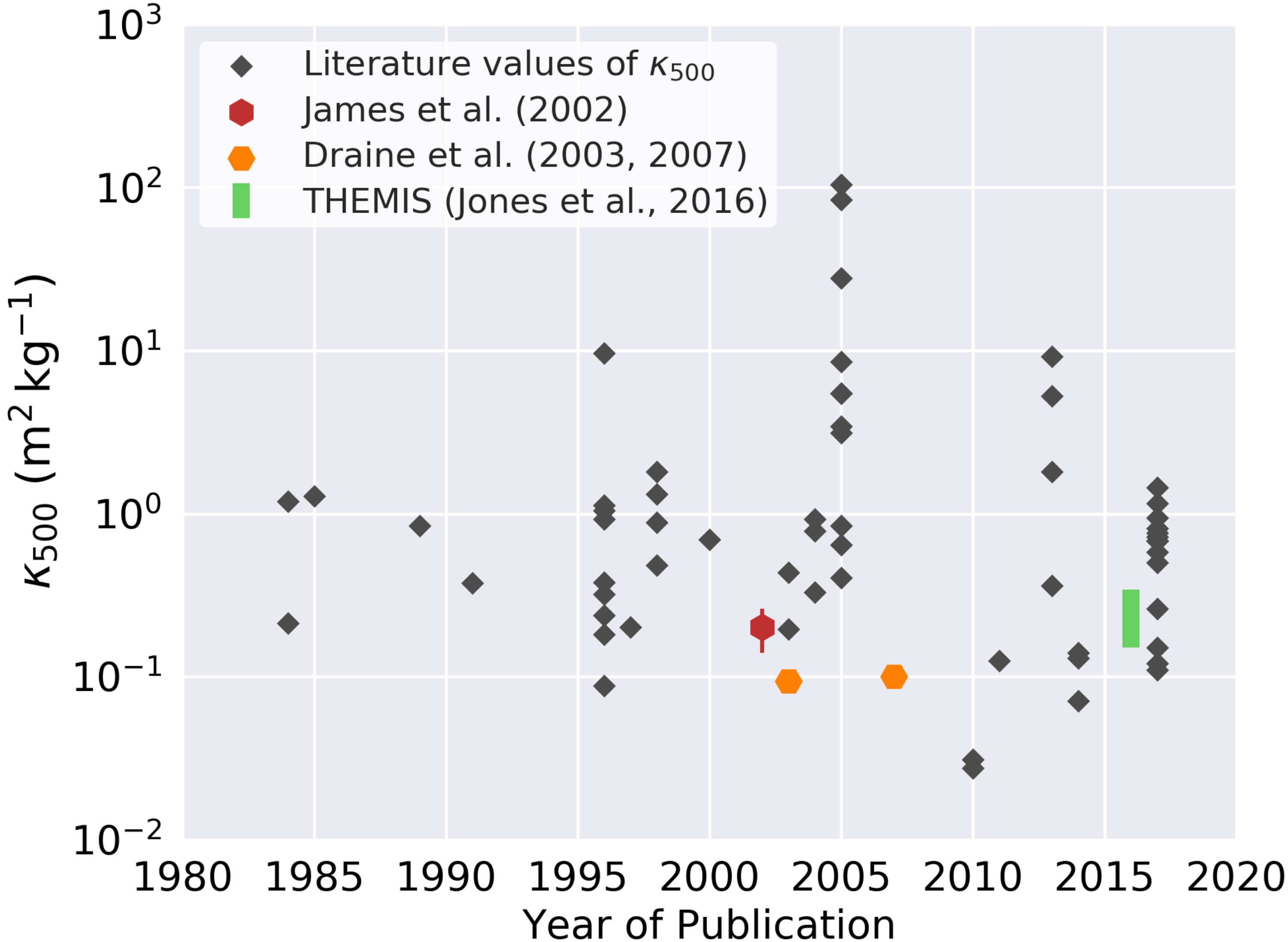
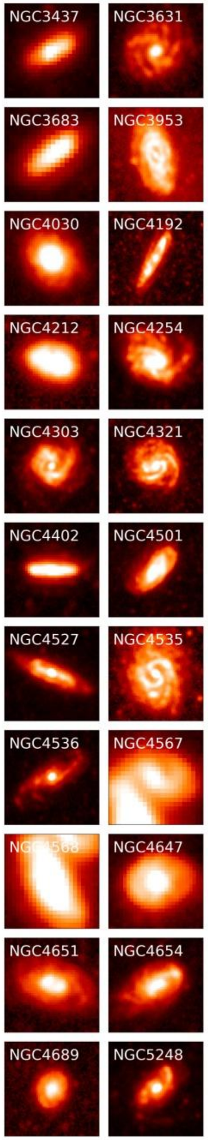
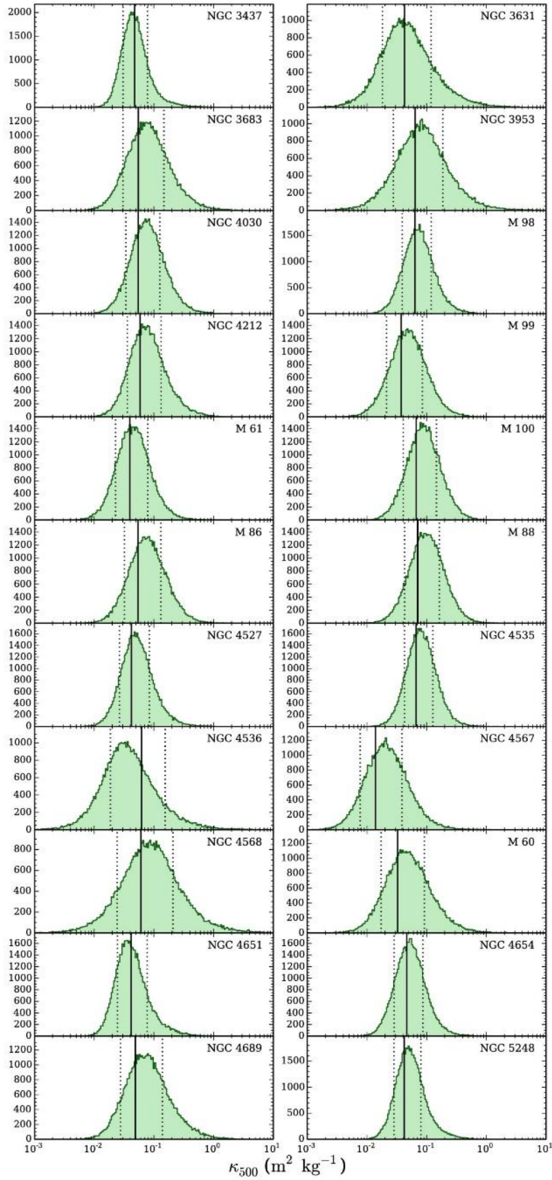
Literature Values for κ_d



Alton+ (2004); Demyk+ (2013); Köhler+ (2015); Clark+ (2016); Jones+ (2017); Clark+ (*in prep.*)

Estimating κ_d with the HRS

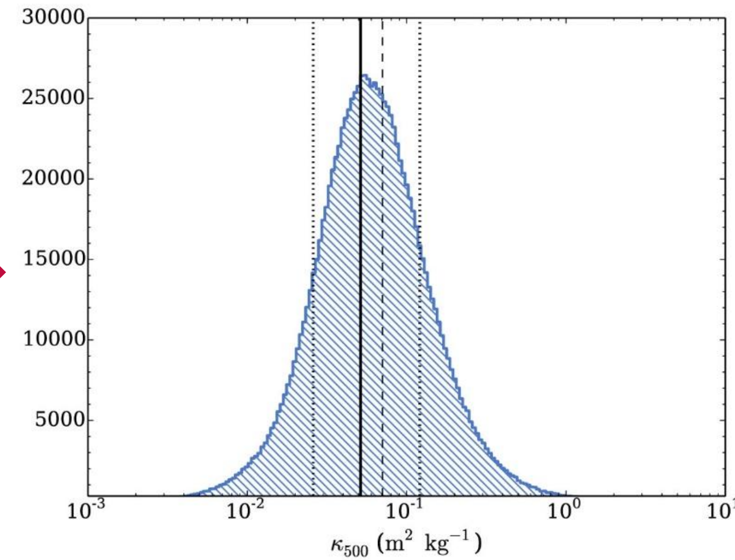




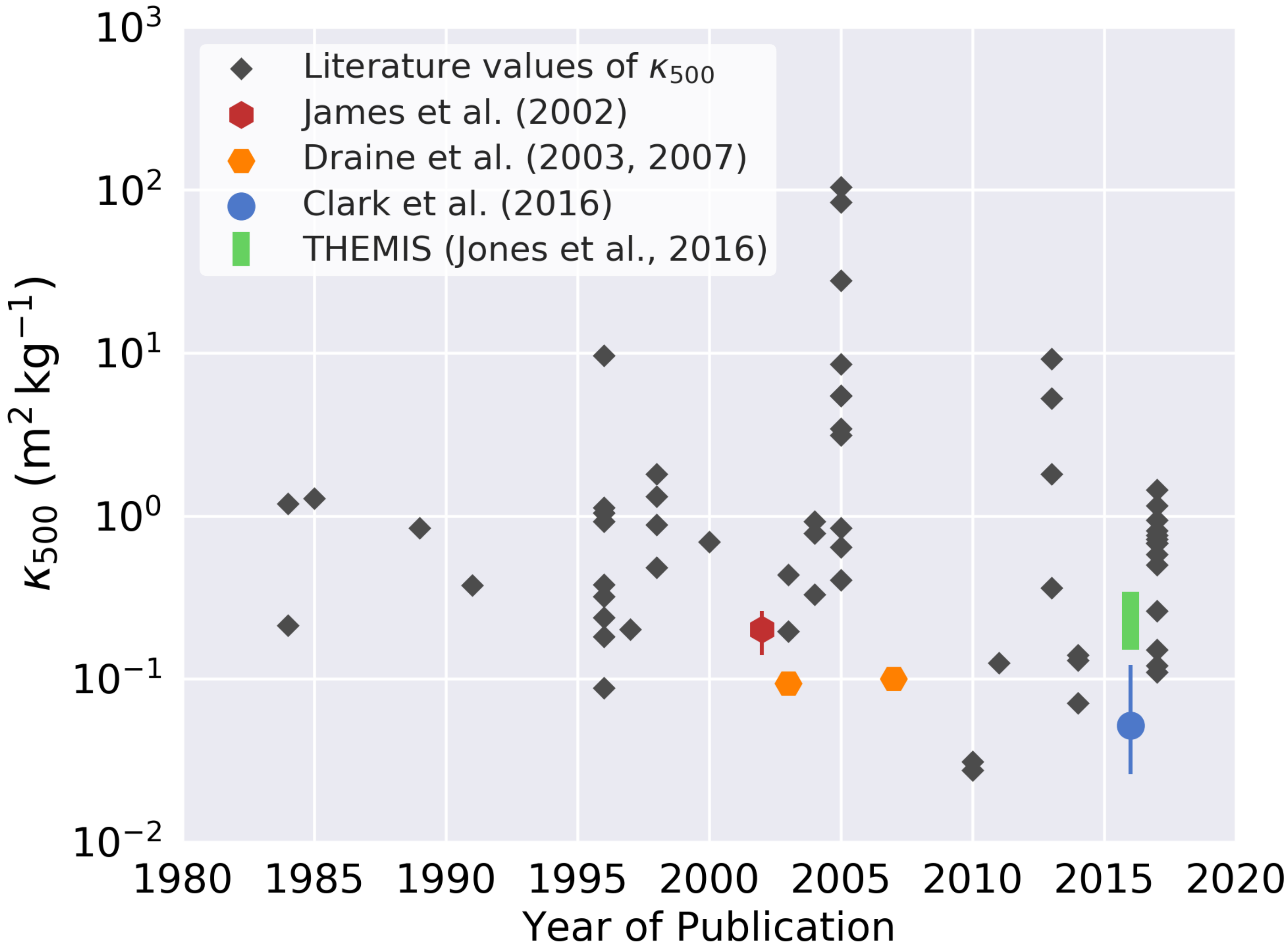
$$\kappa_\lambda = \frac{D^2}{\xi(M_{HI} + M_{H_2})\varepsilon_d f_Z}\left(\frac{S_{\lambda_w}}{B_\lambda(T_w)} + \frac{S_{\lambda_c}}{B_\lambda(T_c)}\right)$$

κ_{500} = 0.051 m^2 kg^{-1}

(± 0.24 dex)



Literature Values for κ_d



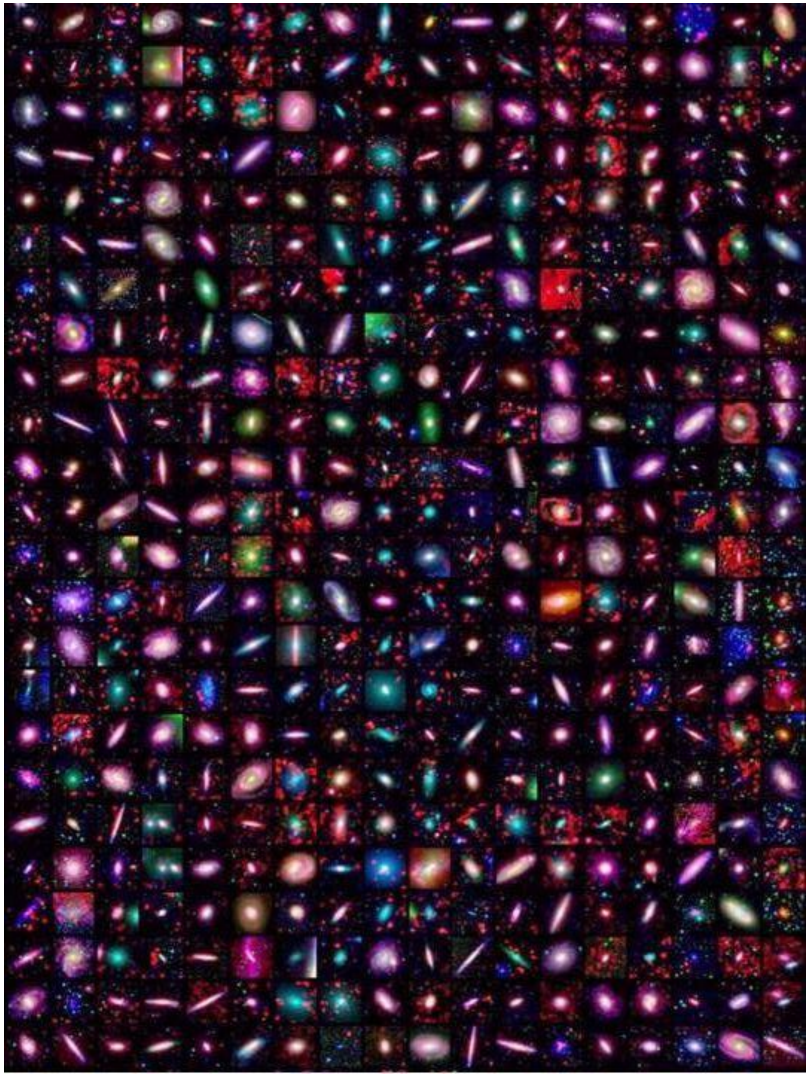
Alton+ (2004); Demyk+ (2013); Köhler+ (2015); Clark+ (2016); Jones+ (2017); Clark+ (*in prep.*) **Chris Clark**

Mapping κ_d Across a Galaxy

UV-NIR image of M83

FIR-submm image of M83

The DustPedia Database

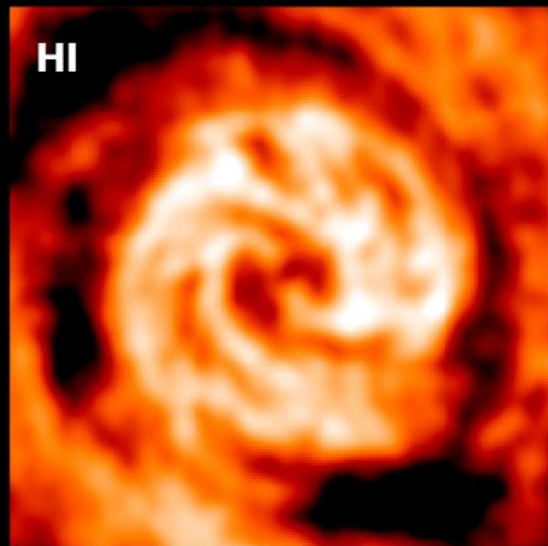


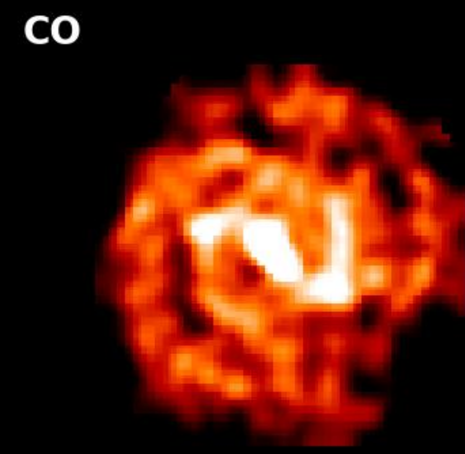
UV-NIR-FIR montage of some of the galaxies in the DustPedia database

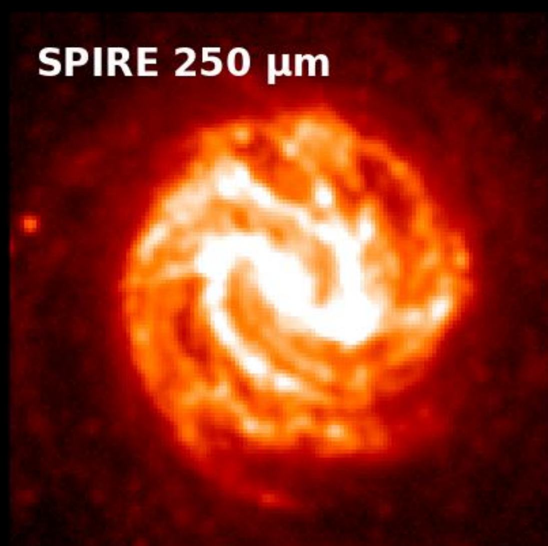
- The DustPedia (Davies+, 2017) covers all 875 nearby (D<40 Mpc) extended (1' < D25 < 1°) galaxies observed by *Herschel*.
- Standardised imagery & photometry spanning 42 UV–microwave bands (Clark+, 2018).
- Homogenised atomic & molecular gas values for 764 & 255 DustPedia galaxies respectively (Casasola+, *in prep.*; De Vis+, *in prep.*).
- 10000 consistently-determined gas-phase metallicity datapoints (from IFU, slit, and fibre spectra) for 492 DustPedia galaxies (De Vis+, *in prep.*).

DustPedia.com

ISM Observations for M83

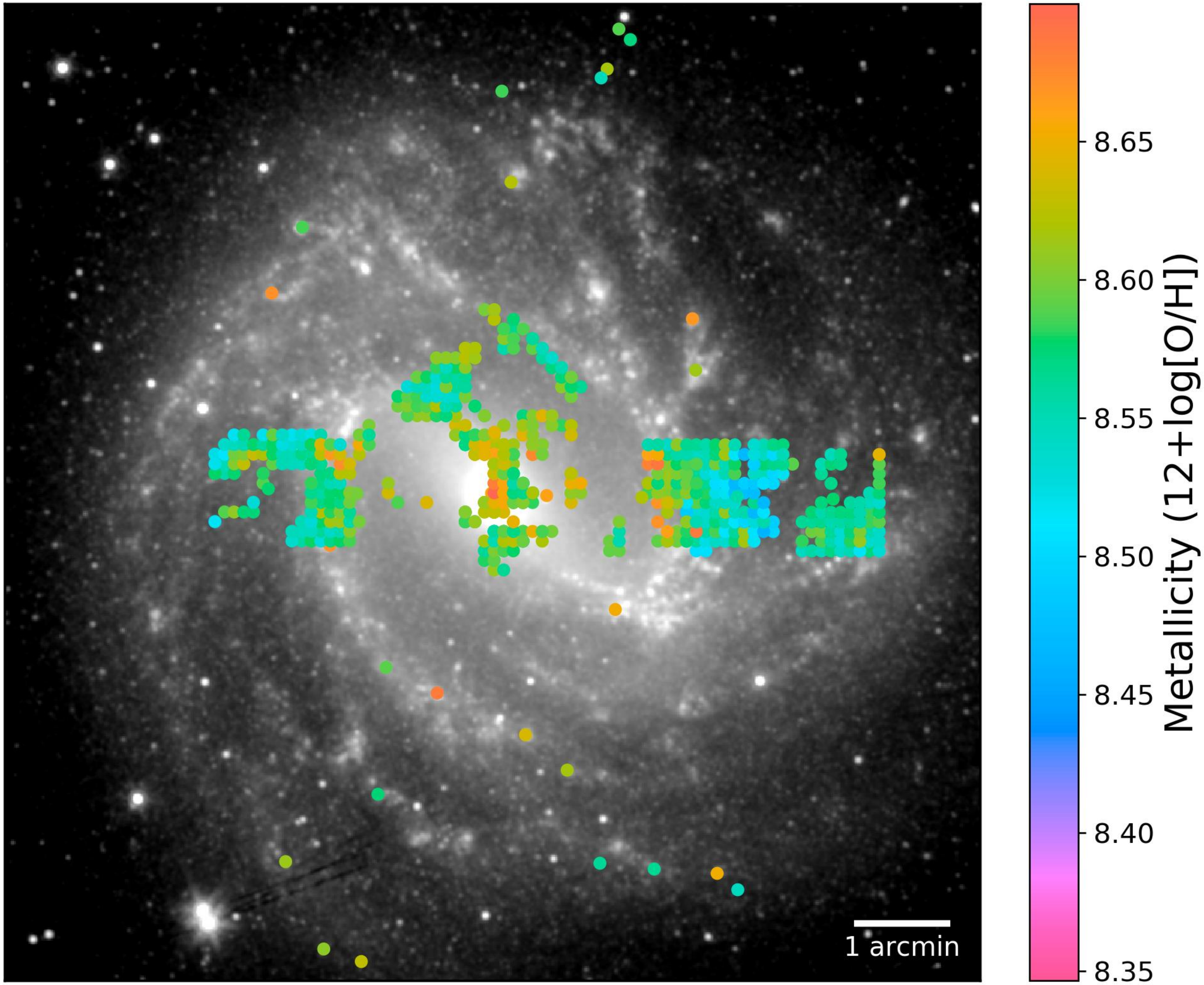






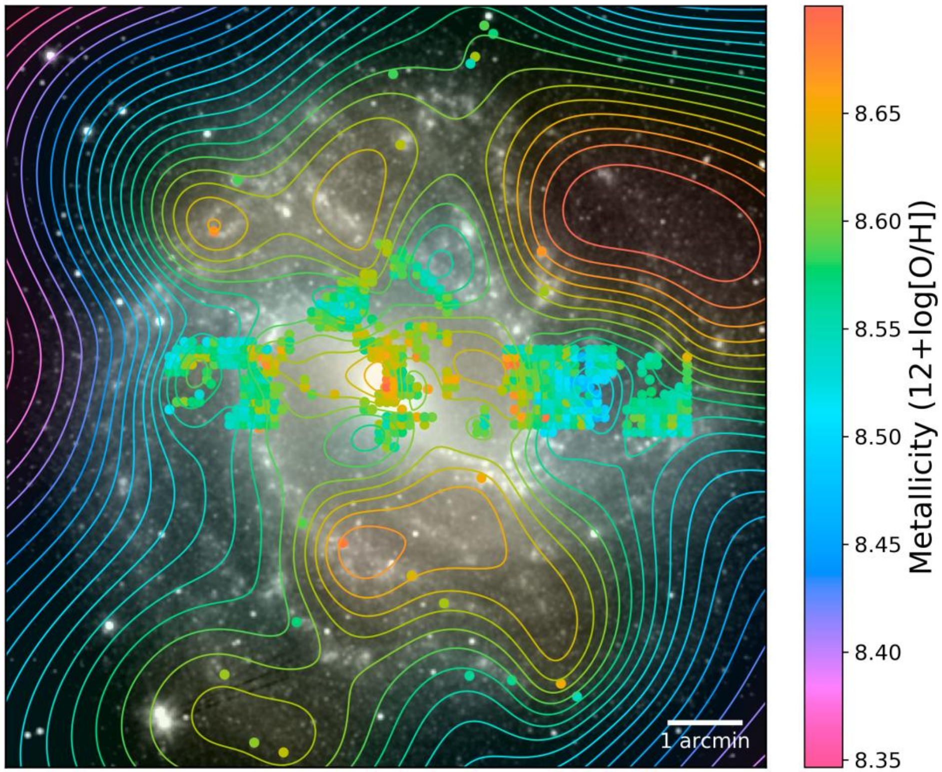
Metallicity...?

Metallicity Points for M83

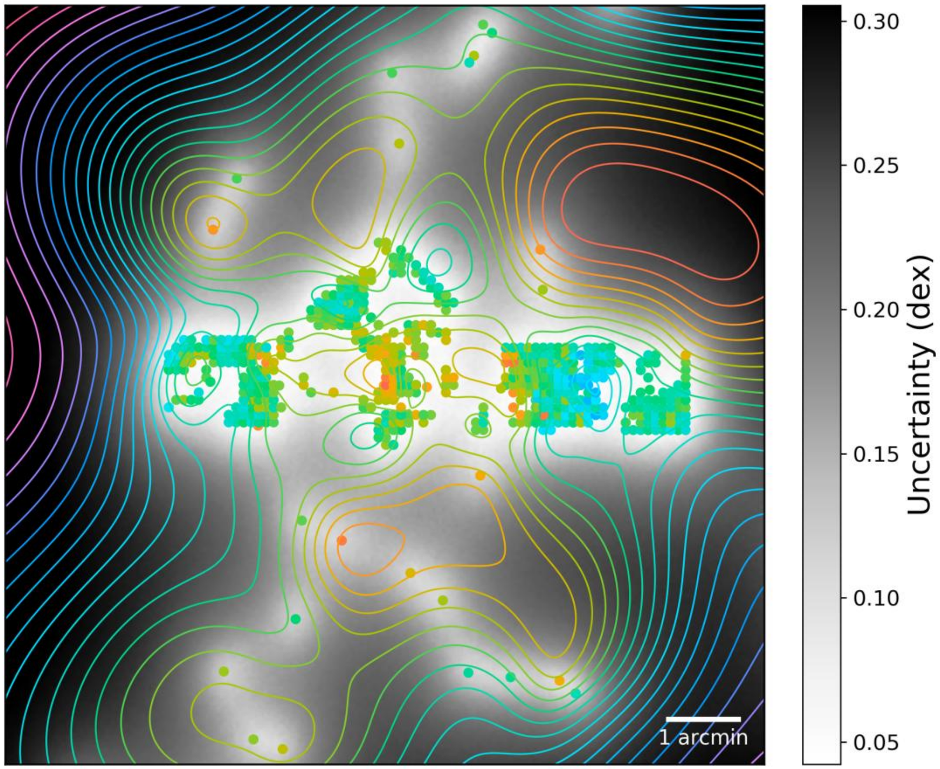


Optical map with metallicity data points overlaid.

Gaussian Process Regression

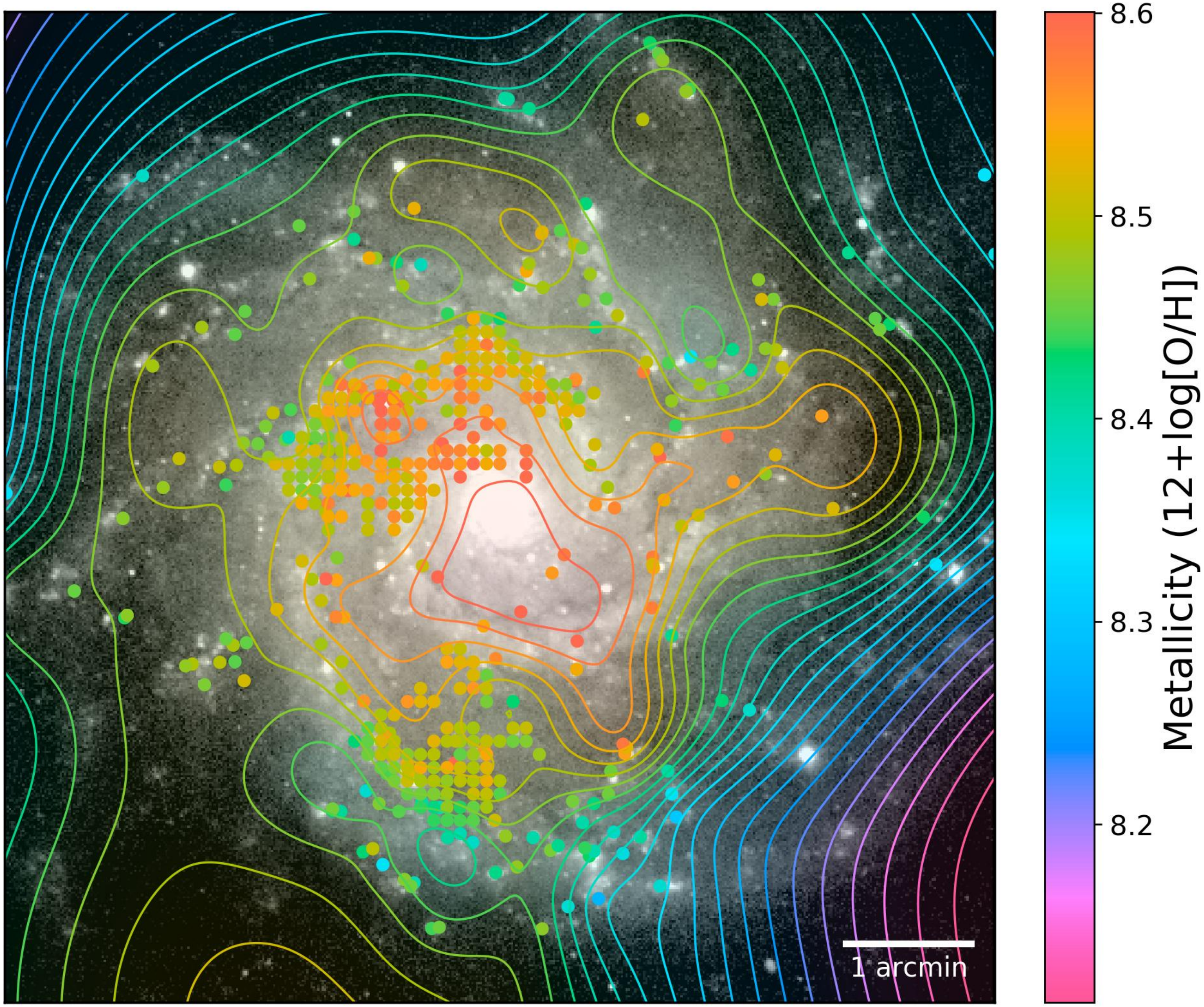


Background: optical image
Coloured points: spectra metallicities
Coloured contours: GPR metallicity map

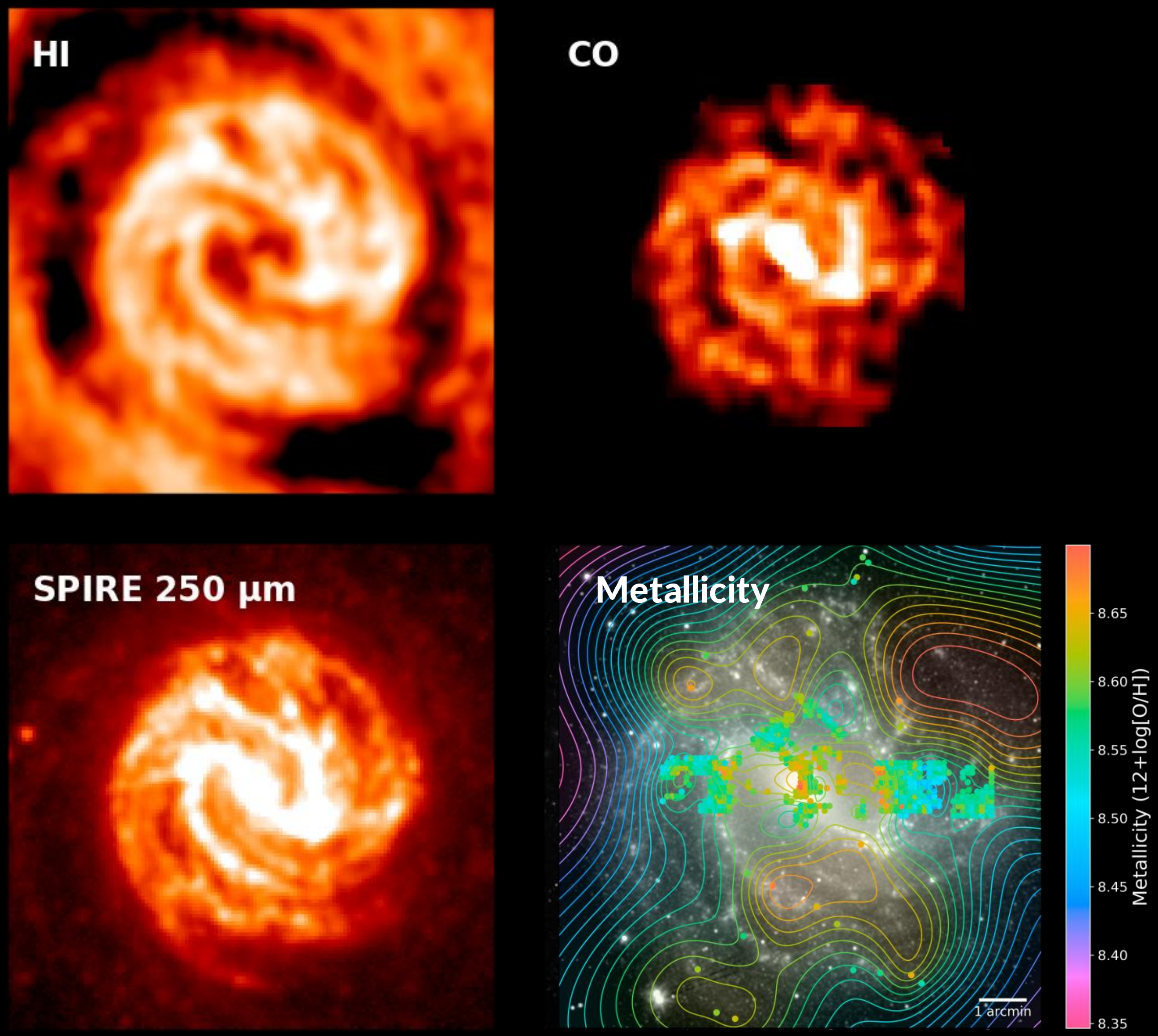


Background: uncertainty on GPR
Coloured points: spectra metallicities
Coloured contours: GPR metallicity map

Aside: GPR Metal Map of M74



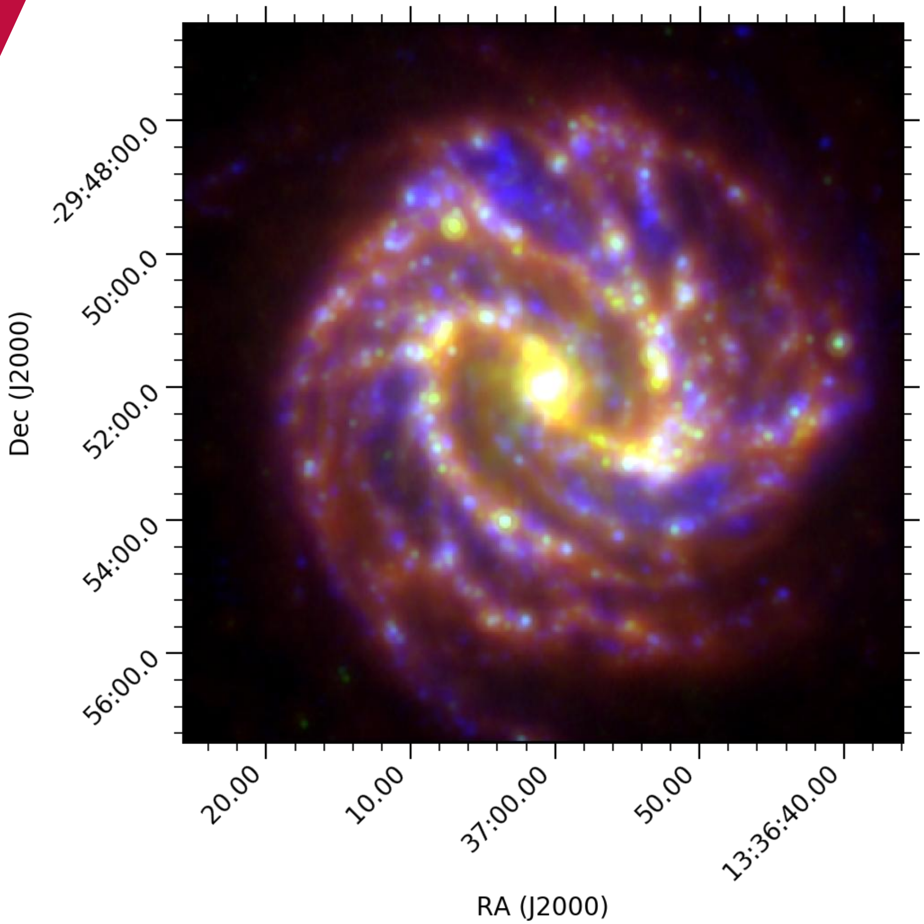
ISM Observations for M83



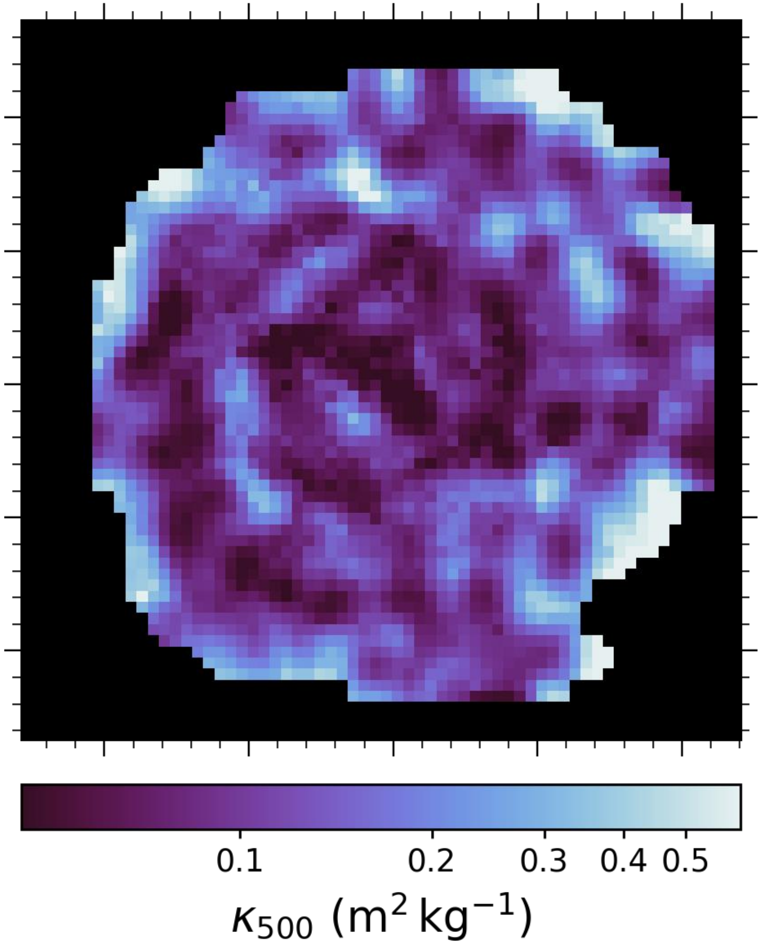
Casasola+ (2017); Clark+ (2018); Clark+ (*in prep.*)

Chris Clark

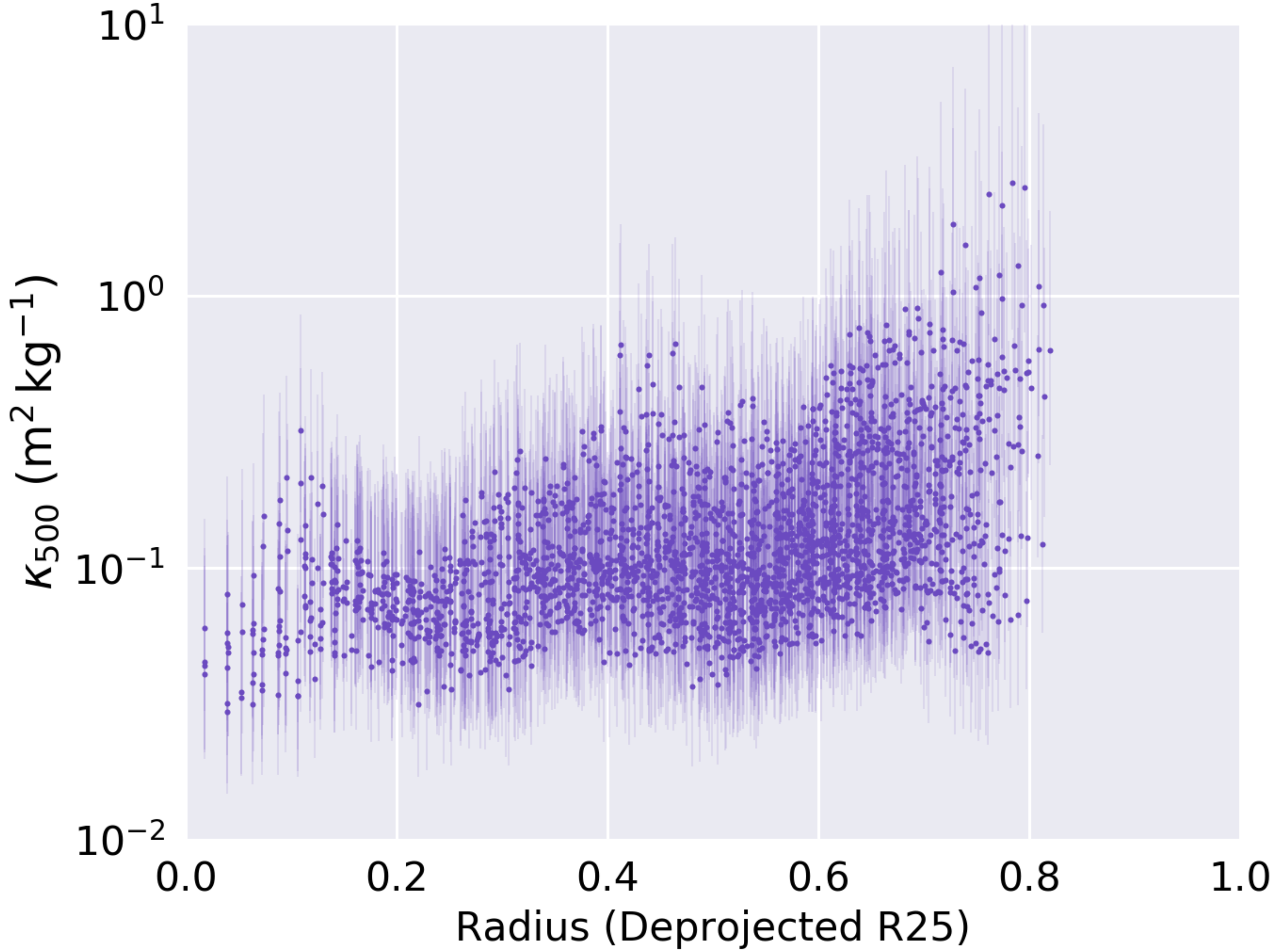
Map of κ_d across M83



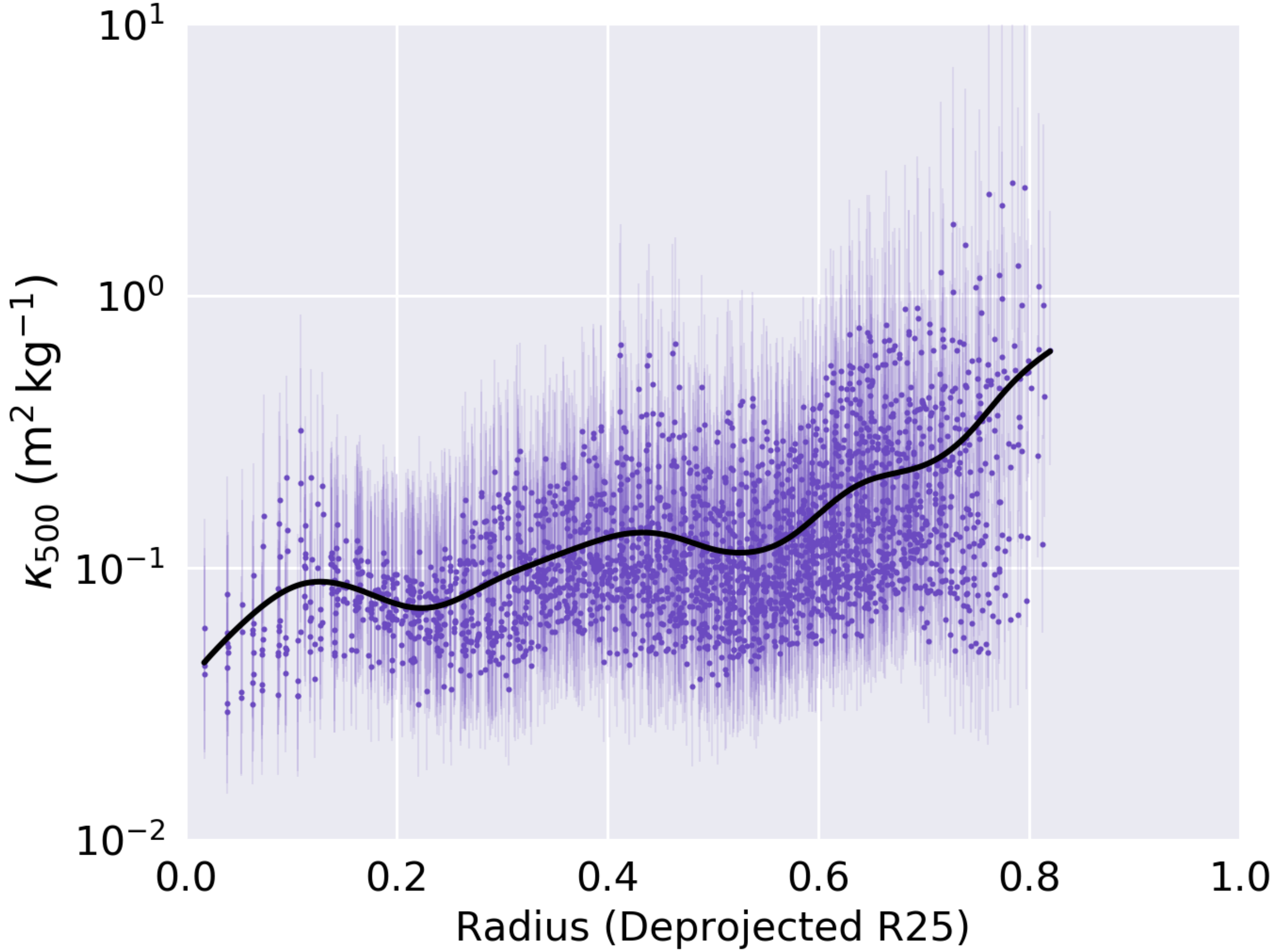
FIR-MIR-UV three-colour image of M83



κ_d vs Radius



K_d vs Radius

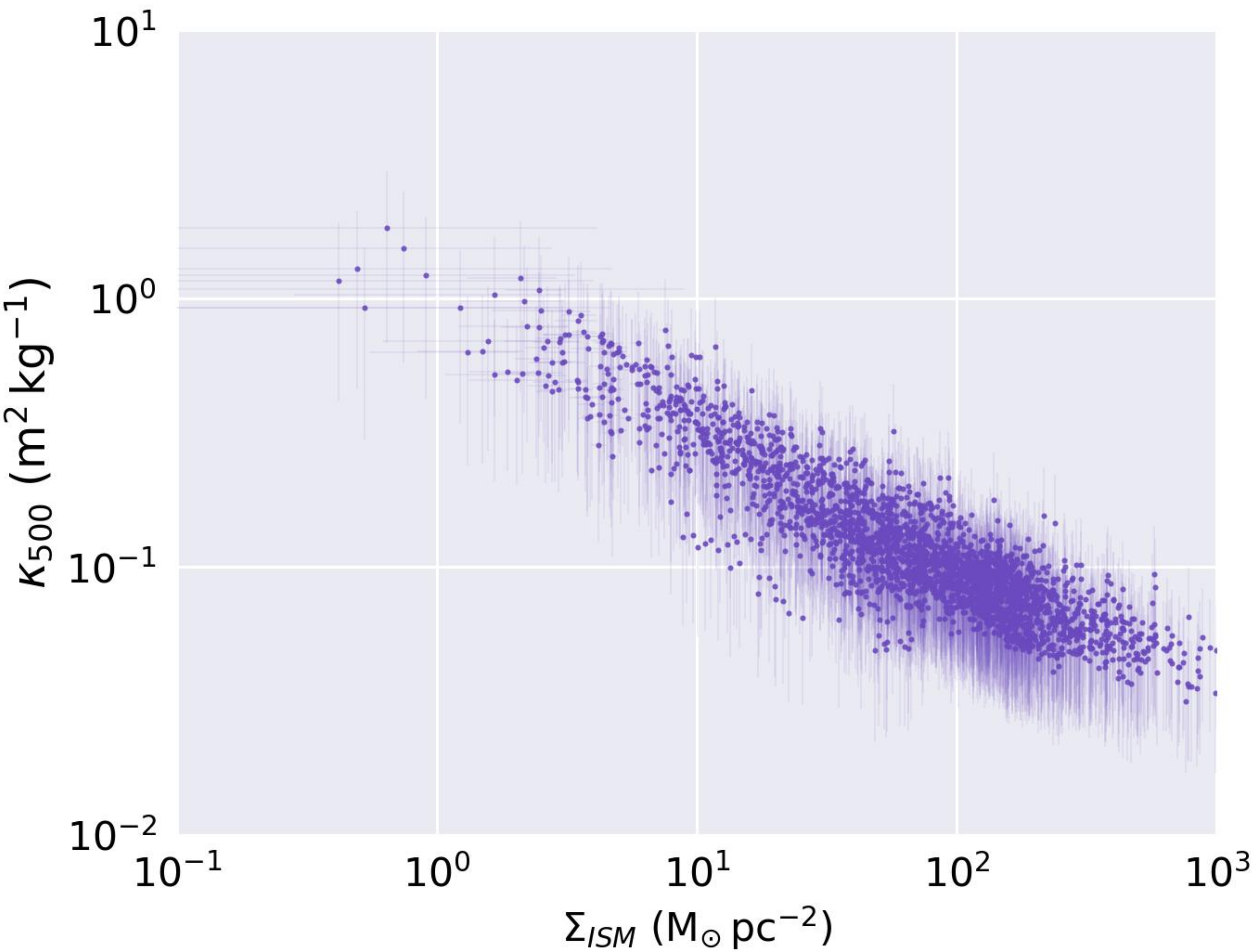


Mean K_{500} for inner 20%: **0.0902** ± 0.001 $m^2\ kg^{-1}$

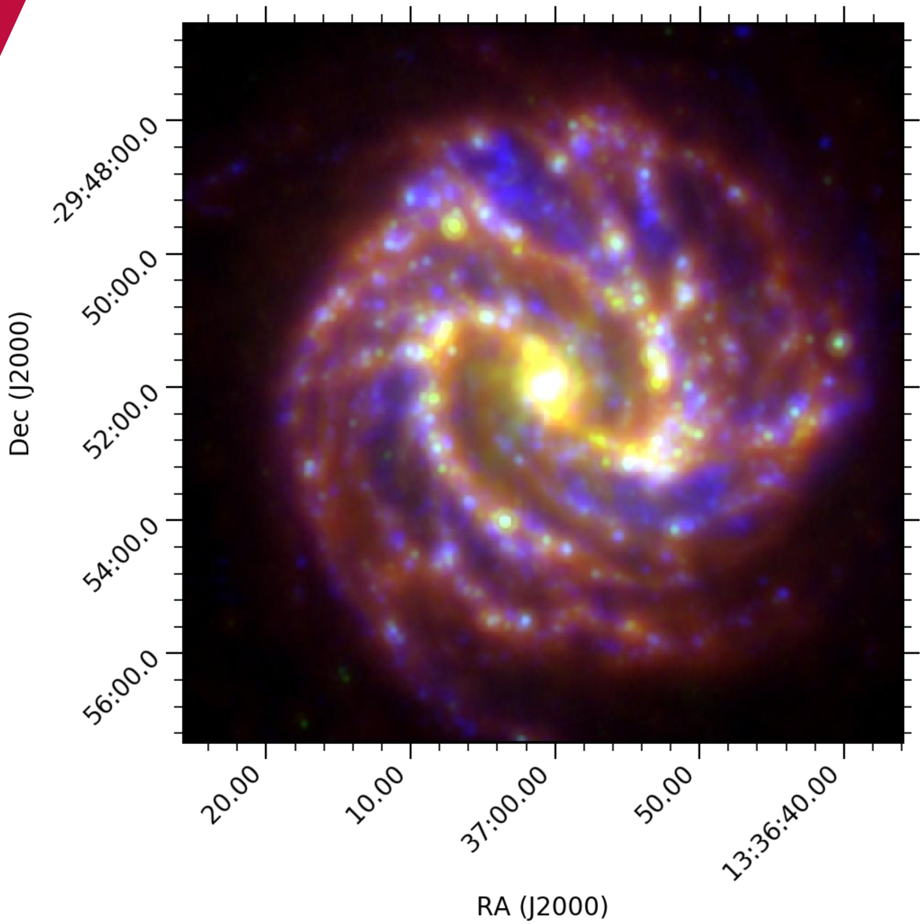
Mean K_{500} for outer 20%: **0.556** ± 0.013 $m^2\ kg^{-1}$

(± values give standard error on the mean)

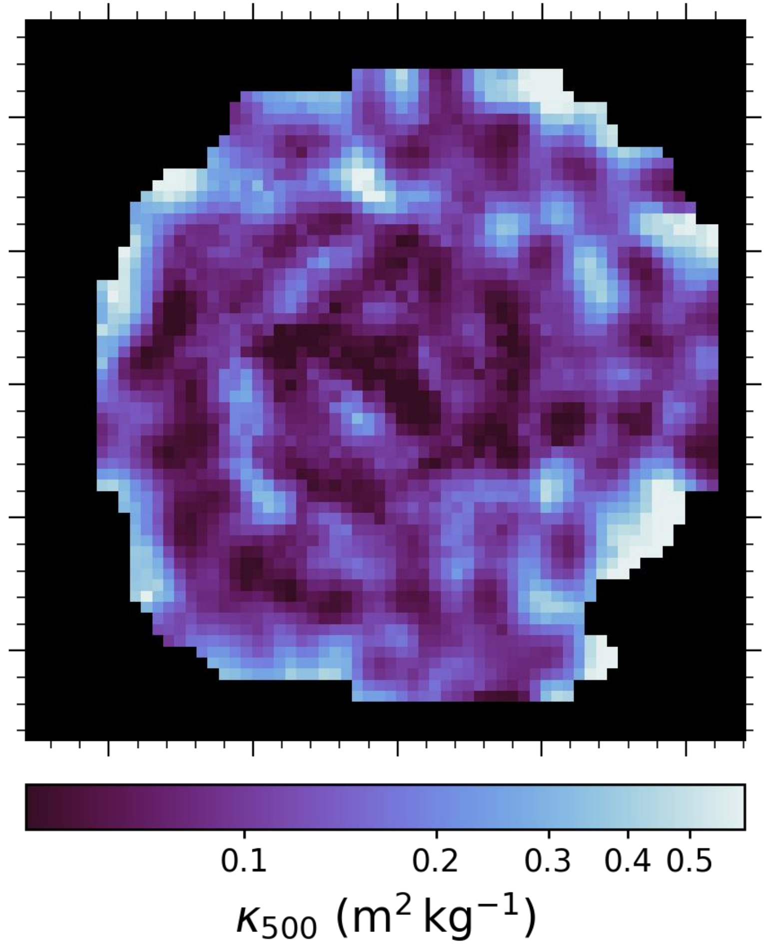
κ_d vs ISM Surface Density



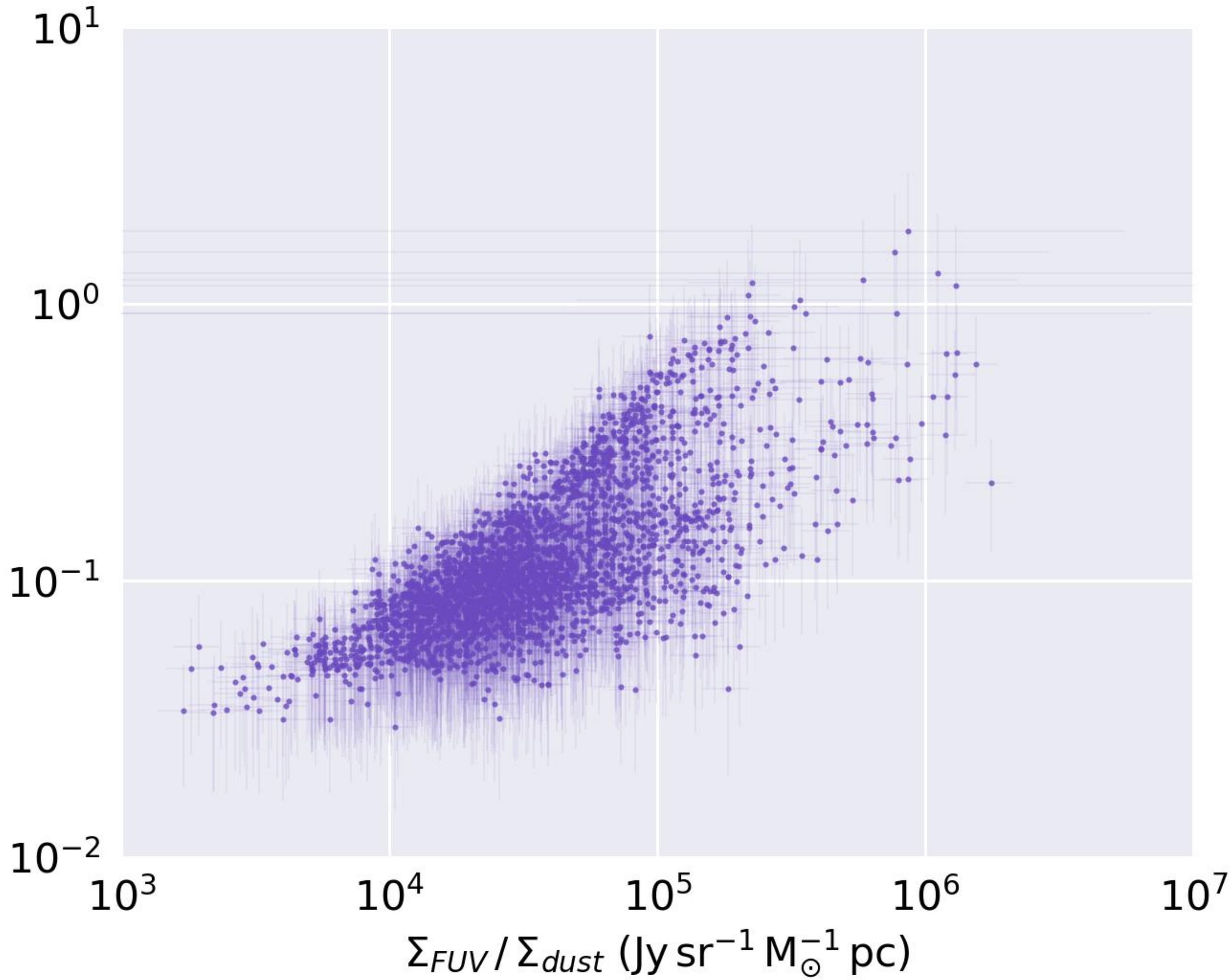
Map of κ_d across M83



FIR-MIR-UV three-colour image of M83



κ_d vs UV-per-Dust



But...

How reliable are these findings, given that the method assumes a *constant* dust-to-metal ratio?

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Dust-to-Metals via Depletions

- Wiseman+ (2016) and De Cia+ (2016) find DTM varies with metallicity, from DLA depletions; but for metallicities of >0.1 $Z_{\odot}$ this variation is less than factor of ***≲2***.
- Jenkins+ (2009) find Milky Way variation of factor ***≲2.7***.

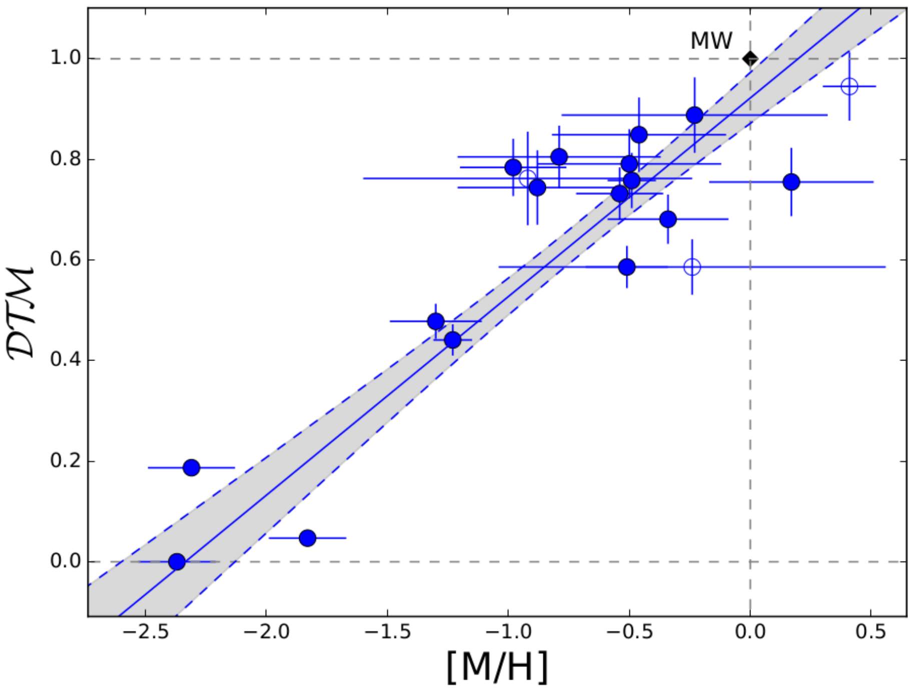


Figure 7 from Wiseman+ (2016)

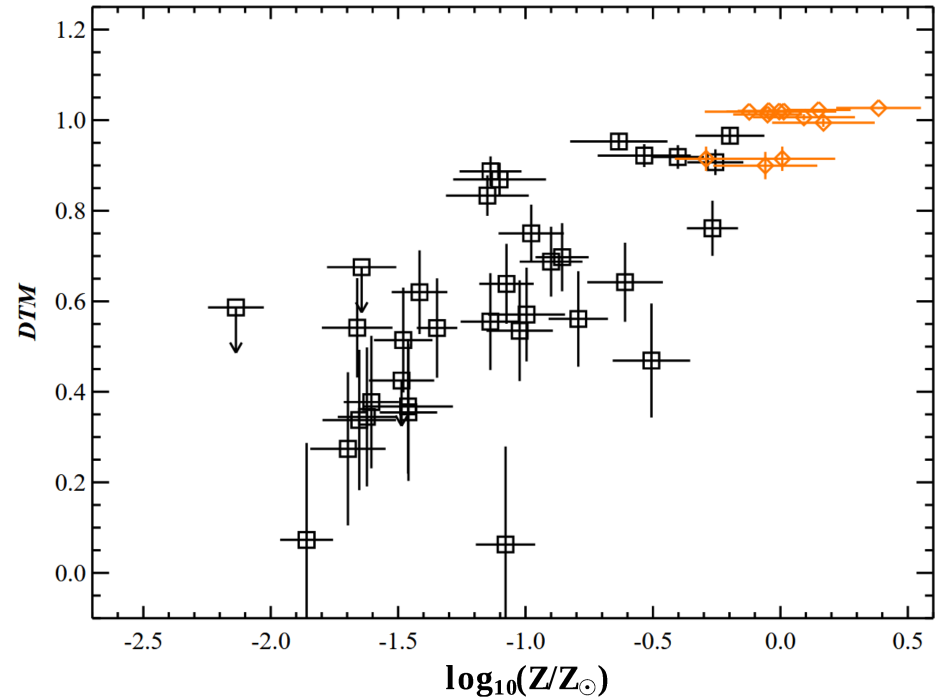


Figure 15 from De Cia+ (2016)

Dust-to-Metals in Simulations

- Popping+ (2017) find DTM varies by factor of ***<4*** at metallicities >0.1 $Z_{\odot}$ in semi-analytic models.
- McKinnon+ (2016) find DTM varies by factor of ***≤3.5*** at z<0.5 in hydrodynamical zoom-in simulations.

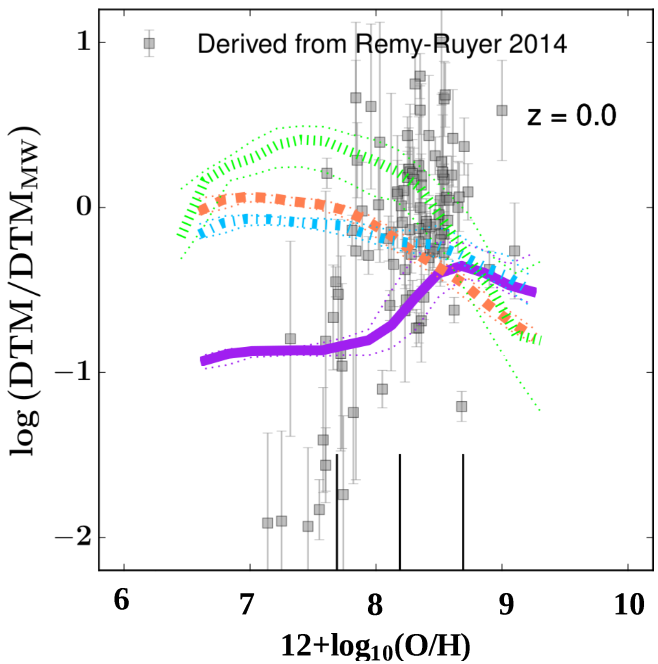


Figure 5 from Popping+ (2017)

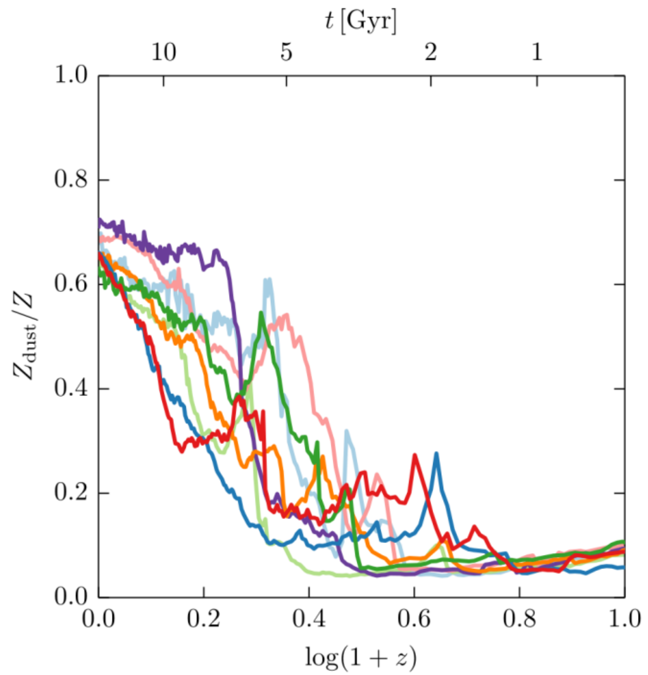


Figure 15 from McKinnon+ (2016)

Dust-to-Metals in THEMIS

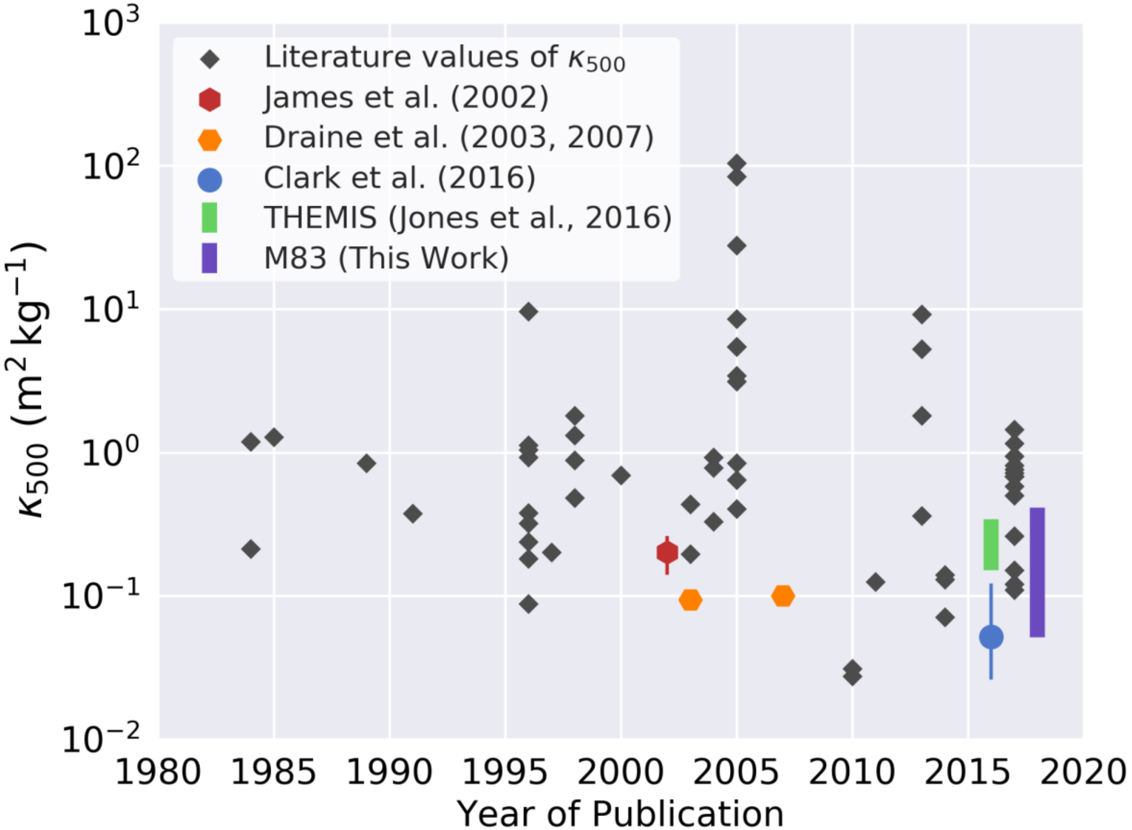
- Dust-to-metals expected to vary by factor of ***~3.6*** in THEMIS dust model (Jones+ 2017;2018).
- However, Jones+ predicts *larger* DTM in denser environments – which would actually *increase the variation in κ_d* compared to what we get from fixed DTM!

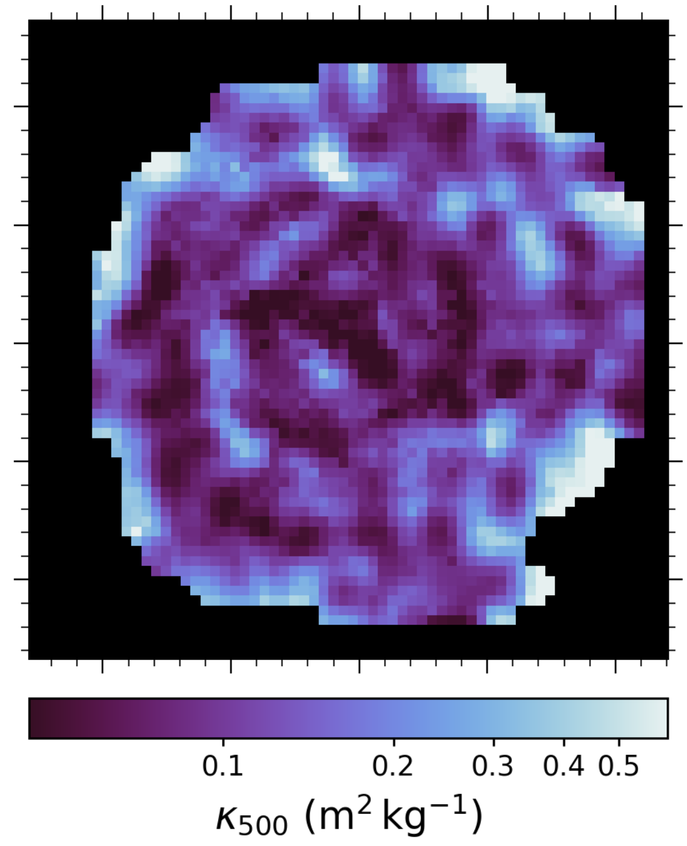
Table 3. The gas-to-dust mass ratios (G/D), dust mass relative to hydrogen, dust mass relative to the available metals, carbon and oxygen abundances, [C] and [O], in dust (in parts per million, ppm) and the percentage by volume of carbonaceous matter in dust, $V_{f,\mathrm{C}}$. This is shown as a function of the ISM environment and the corresponding dust model, where: DISM indicates the standard diffuse ISM dust model, C (O) carbon (oxygen) atom accretion from the gas and ice the presence of ice mantles. Fractional variations from the standard diffuse ISM abundances of carbonaceous nano-particles (big grains) $\frac{1}{n}\mathrm{C_{np}}$ ($\frac{1}{n}\mathrm{C_{bg}}$) or no contribution at all (0×). Low Z indicates sub-solar, low metallicity environments.

Environment	$\approx n_\mathrm{H}$ (cm^{-3})	$\approx T_\mathrm{gas}$ (K)	Dust type	G/D	$\frac{M_\mathrm{dust}}{m_\mathrm{H}}$	$\frac{\mathrm{dust}}{\mathrm{metal}}$	[C] (ppm)	[O] (ppm)	$V_{f,\mathrm{C}}$ (%)
dense	10^4	15	DISM+C+O+ice	55	0.0184	0.88	406	566	41
translucent	1500	20	DISM+C+O	81	0.0124	0.60	406	270	74
translucent	1500	20	DISM+C	102	0.0098	0.47	406	110	65
diffuse	50	100	standard DISM	135	0.0074	0.36	206	110	47
diffuse	50	100	$\frac{1}{2}\mathrm{C_{np}}$	153	0.0066	0.32	135	110	36
diffuse	50	100	$\frac{1}{10}\mathrm{C_{np}}$	170	0.0059	0.28	77	110	23
diffuse	50	100	$\frac{1}{10}\mathrm{C_{np}}$, $\frac{1}{2}\mathrm{C_{bg}}$	180	0.0056	0.27	52	110	17
energetic	0.25	10^4	$0\times\mathrm{C_{np}}$, $\frac{1}{2}\mathrm{C_{bg}}$	185	0.0054	0.26	38	110	13
energetic	0.25	10^4	$0\times\mathrm{C_{np}}$, $0\times\mathrm{C_{bg}}$	196	0.0051	0.25	13	110	5
energetic	0.25	10^4	bare a-Sil	202	0.0049	0.24	0	110	0
low Z/x-ray	0.01	10^6	$\frac{1}{3}$ a-Sil	613	0.0016	0.08	0	36	0
low Z/x-ray	0.01	10^6	$\frac{1}{30}$ a-Sil	6742	0.0002	0.01	0	4	0

Table 3 from Jones+ (2018)

Results Summary





SED-Fitting Example