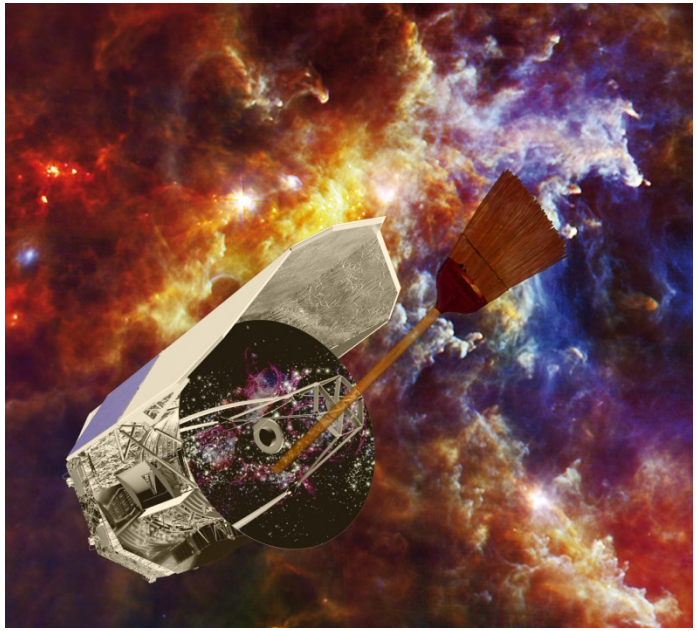
Dust, Star Formation and The ISM in the Outskirts of Galaxies



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Star Formation Through Space and Time

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Herschel Legacy Projects

- Two new EU funded (FP7) projects to provide legacy data for the community (i.e., radiative transfer modelling,

- HELP – Herschel Extragalactic Legacy Project
  - Taking data from many large Herschel surveys (HerMES, H-ATLAS, GOODS etc…)
  - HELP will assemble the largest coherent database of galaxies in the distant Universe

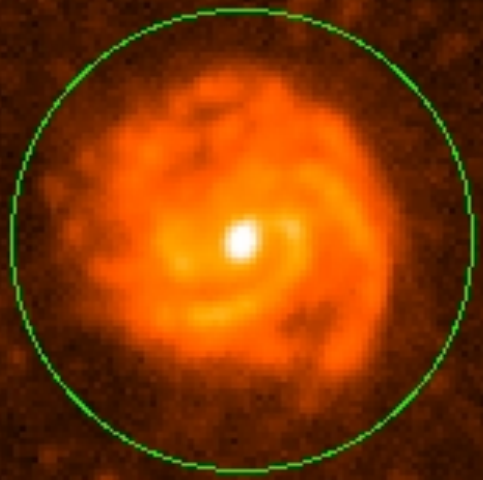
    (part of my work is funded through HELP)
- DustPedia
  - Study in detail 3045 local-galaxies.

No logos for either yet!

Extended Dust

- While reading Herschel proposals from my thesis many aimed to find cold dust in outskirts of galaxies.
- 850μm (e.g. Scuba) from ground struggles to measure local galaxies
- IRAS/ISO/Spitzer not enough resolution and only hot dust
- Virgo cluster survey wanted to find Inter-Cluster Dust
- Dust could be driven out or formed in the outer disk.
- Has been detected by quasar absorption (Menard et al. 2010) – see next slides.
- Not been possible to detect emission before as dust is cold (long wavelengths) and very low surface brightness.

The Typical View



What About Other Phases?

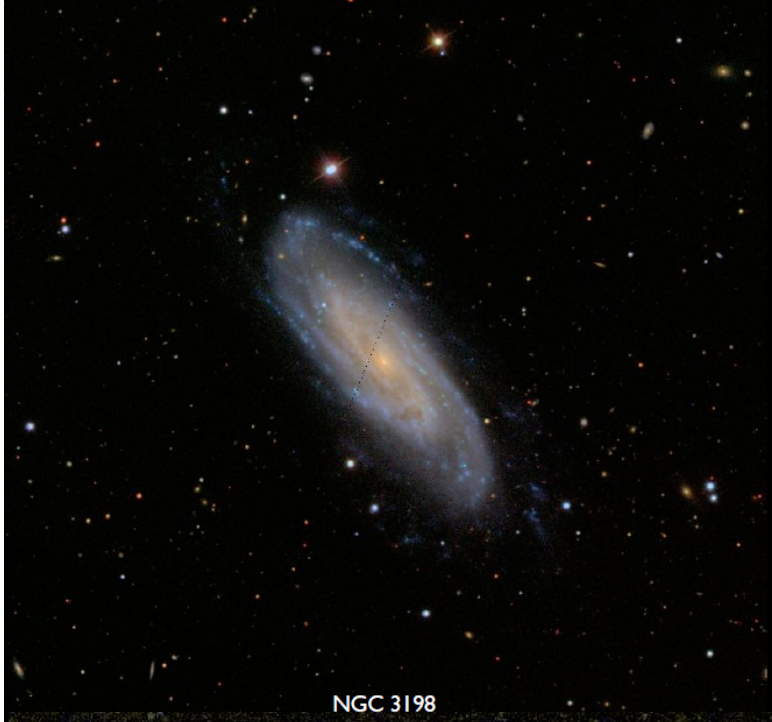
- HI disks are often found to be far more extended than optical

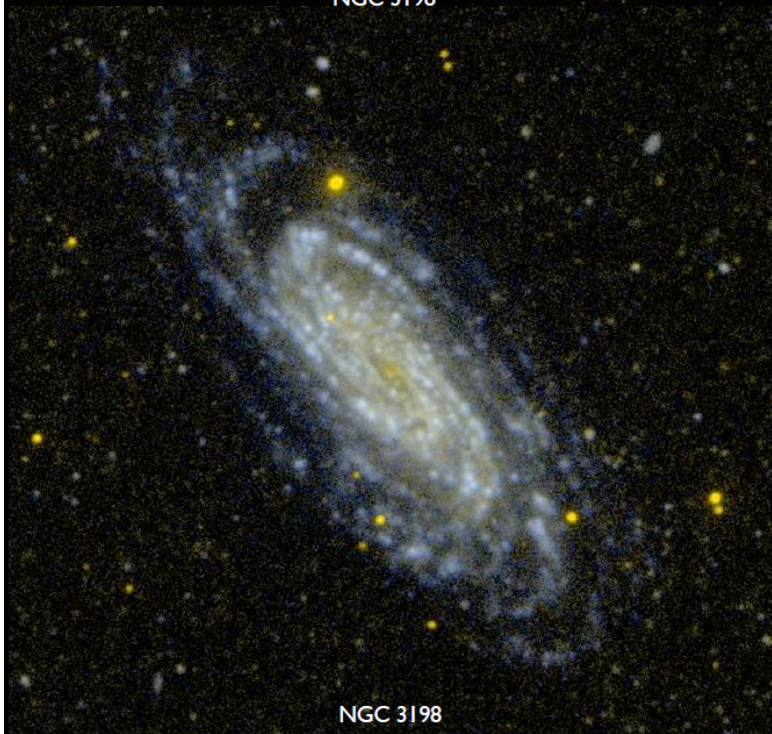
M83

HI+UV+Optical composite by Angel Lopez-Sanchez

Extended UV Disks

- 10 – 30% of galaxies contain extended UV disks.
- Normal spirals though do not have a cut-off radius

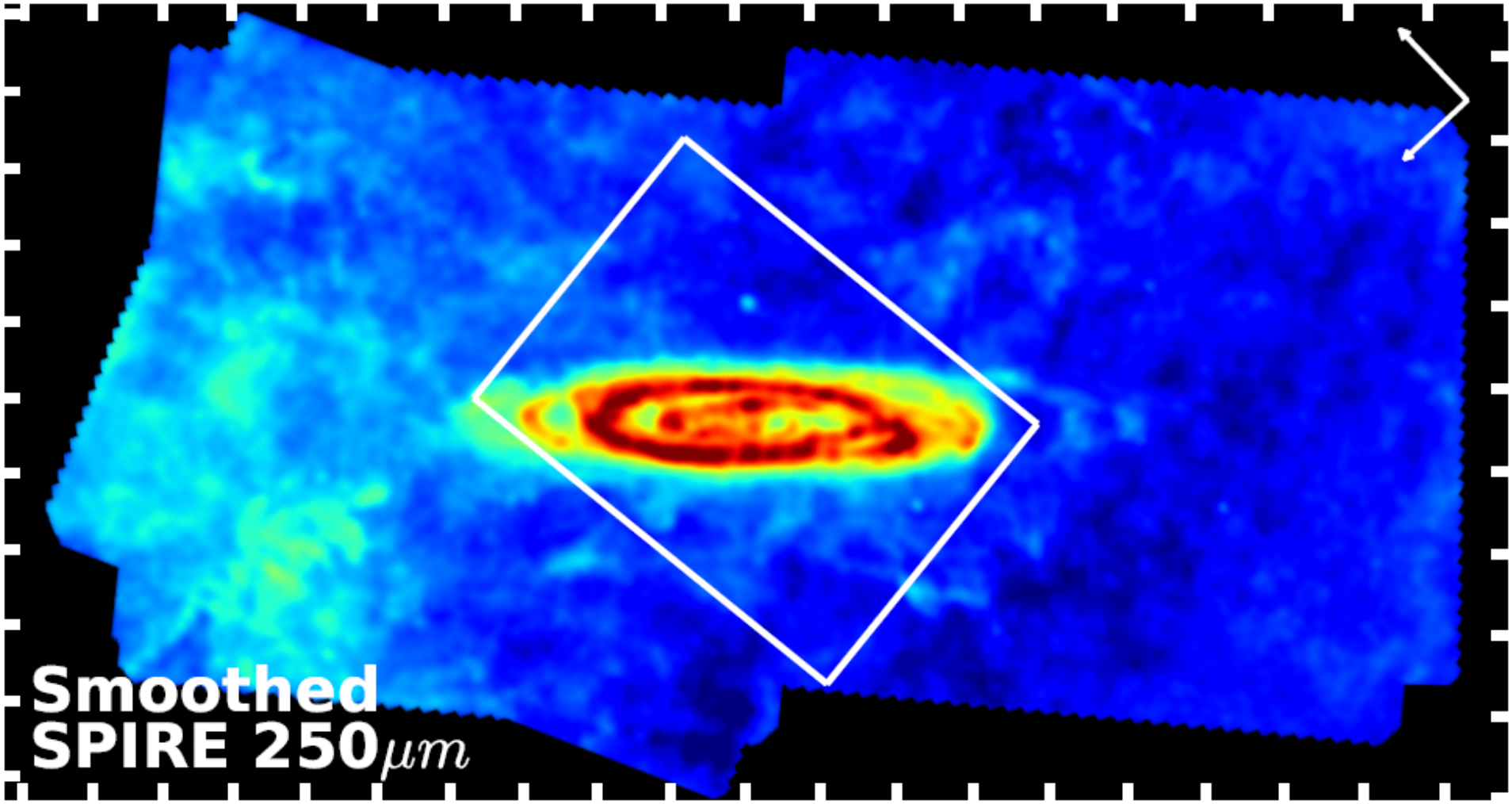




Images from talk of David Thilker. For more information see Thilker et al. 2007

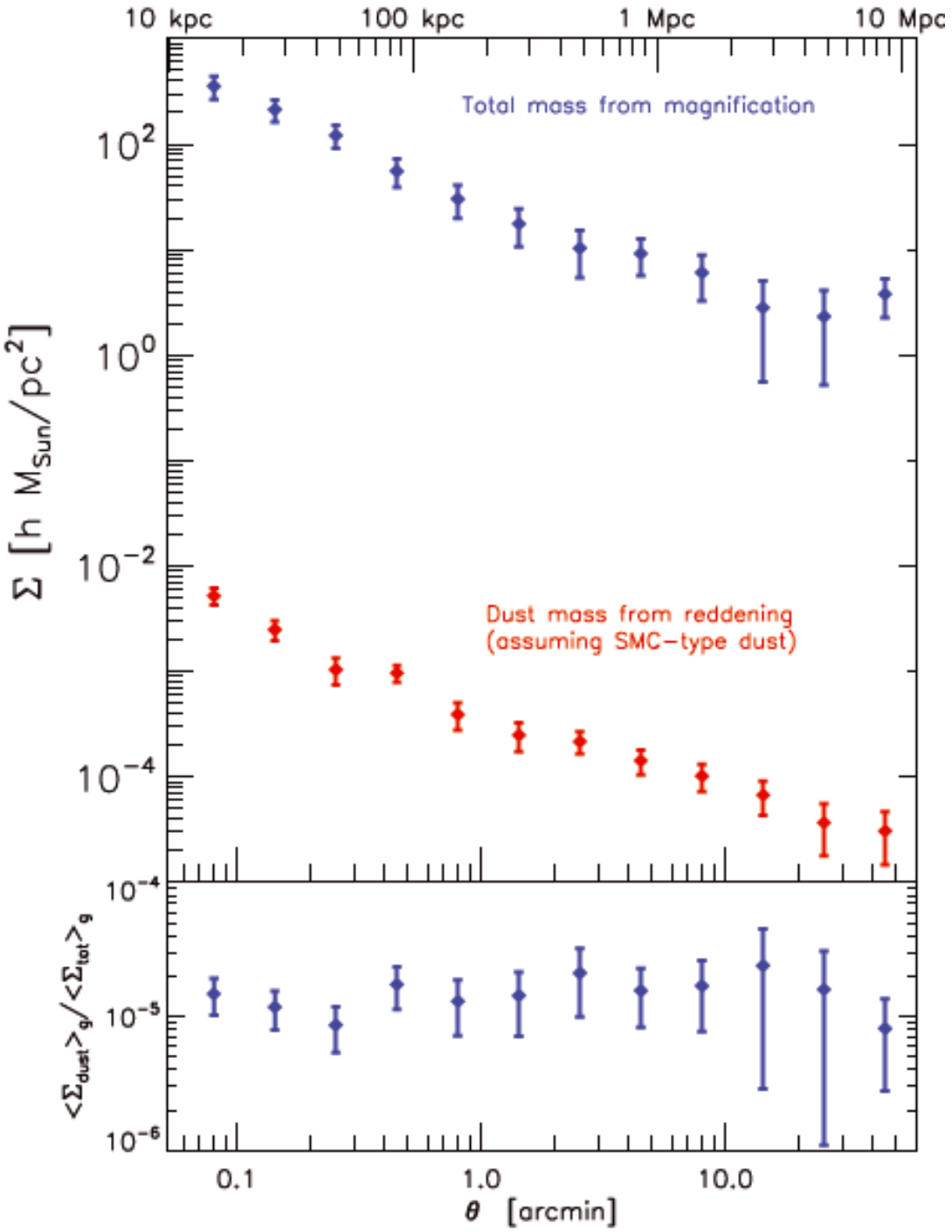
Possibility of Dust

more info see Fritz et al. 2012
and other HELGA papers



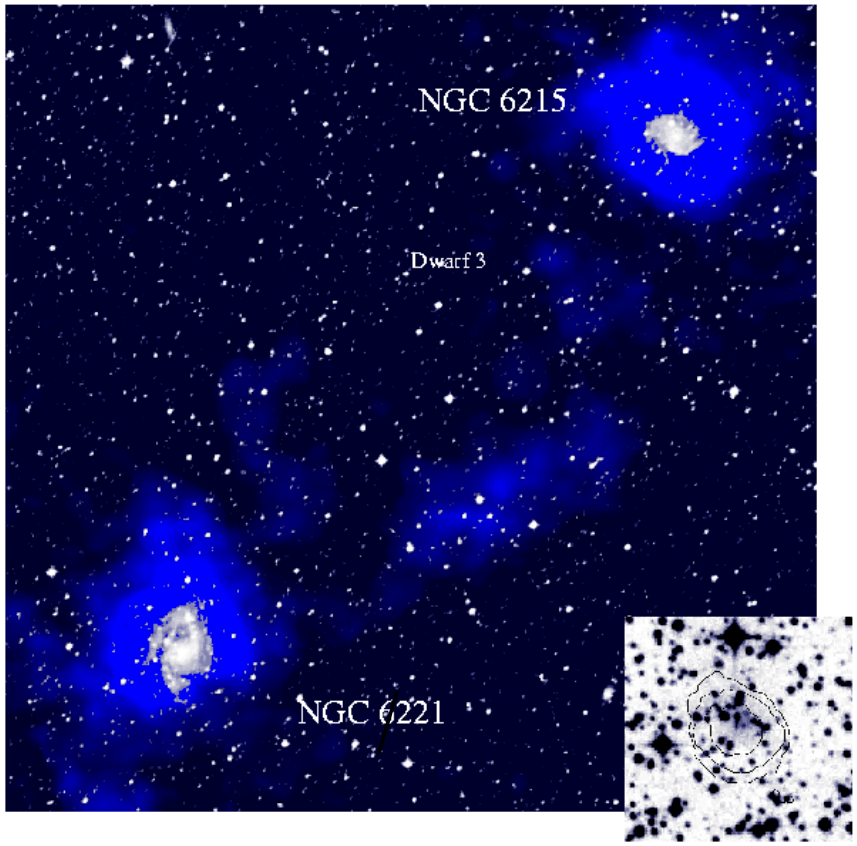
Menard et al. 2010

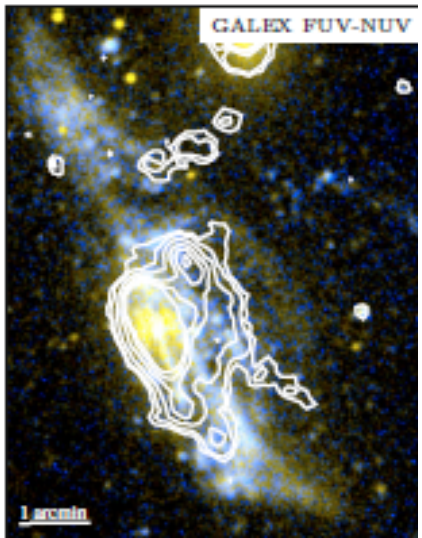
- uses SDSS
- ~85,000 quasars at $z > 1$
- Correlated with 24 million galaxies at $z \sim 0.3$
- Find reddening and magnification
- Half of dust is outside galaxies
- Shallow gradient

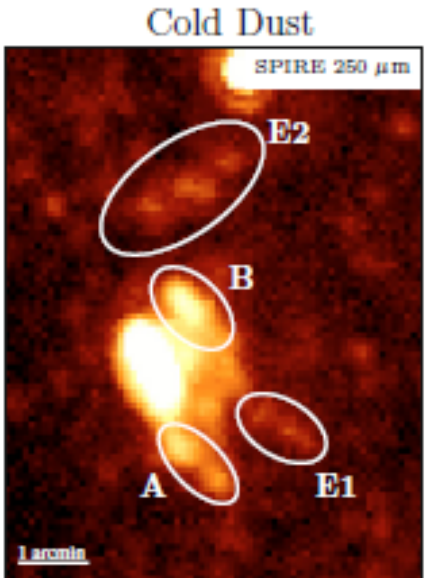


ISM on galaxy scales

- Galaxies known to have HI streams in galaxies
- Cluster galaxies are HI deficient (ram-pressure stripping, thermal evaporation, starvation strangulation)

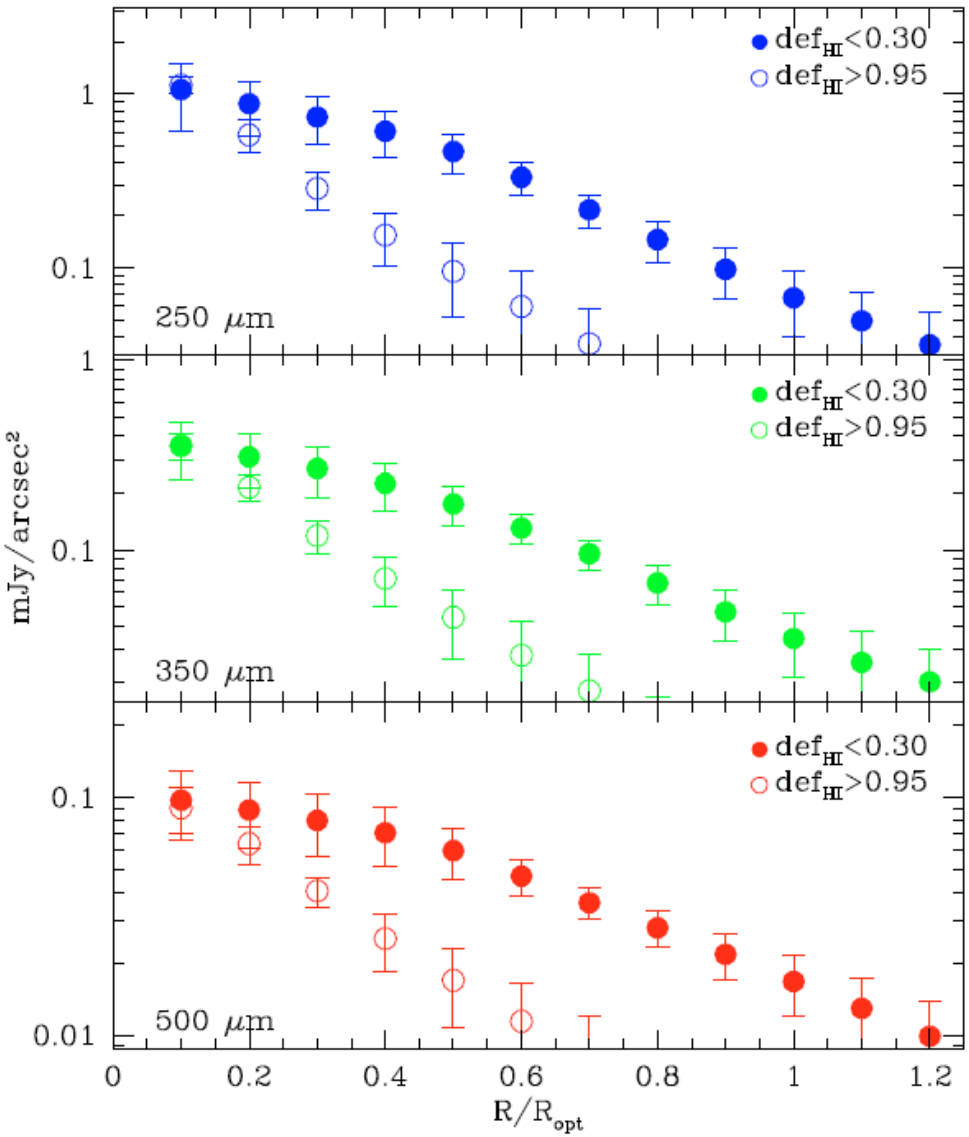






- Dust been seen to also be affected Cortese 2010a/b

Environment



Dust Disks:

- Know dust is affected along with gas (Cortese et al. 2010)

Early Type Galaxies:

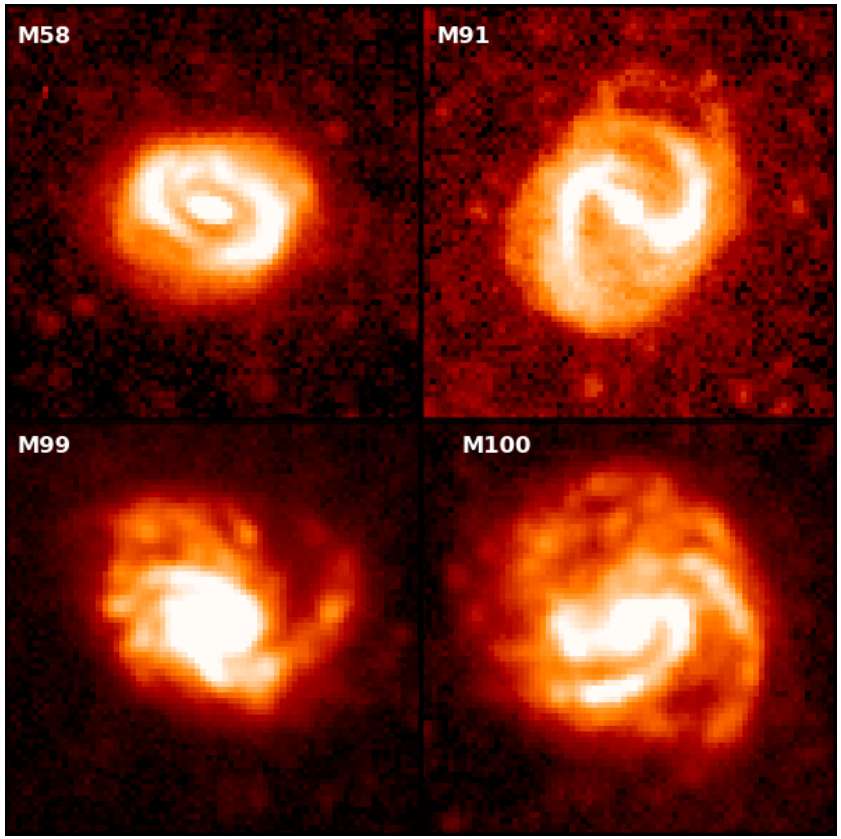
- In Virgo
  - 53% S0
  - 29% E
- Outside Virgo
  - 89% S0
  - 33% E
- Other than S0s not enough objects to be statistically significant (more objects to come)

HRS ETG Paper:
Smith et al. (2012)

Extended Dust (2)

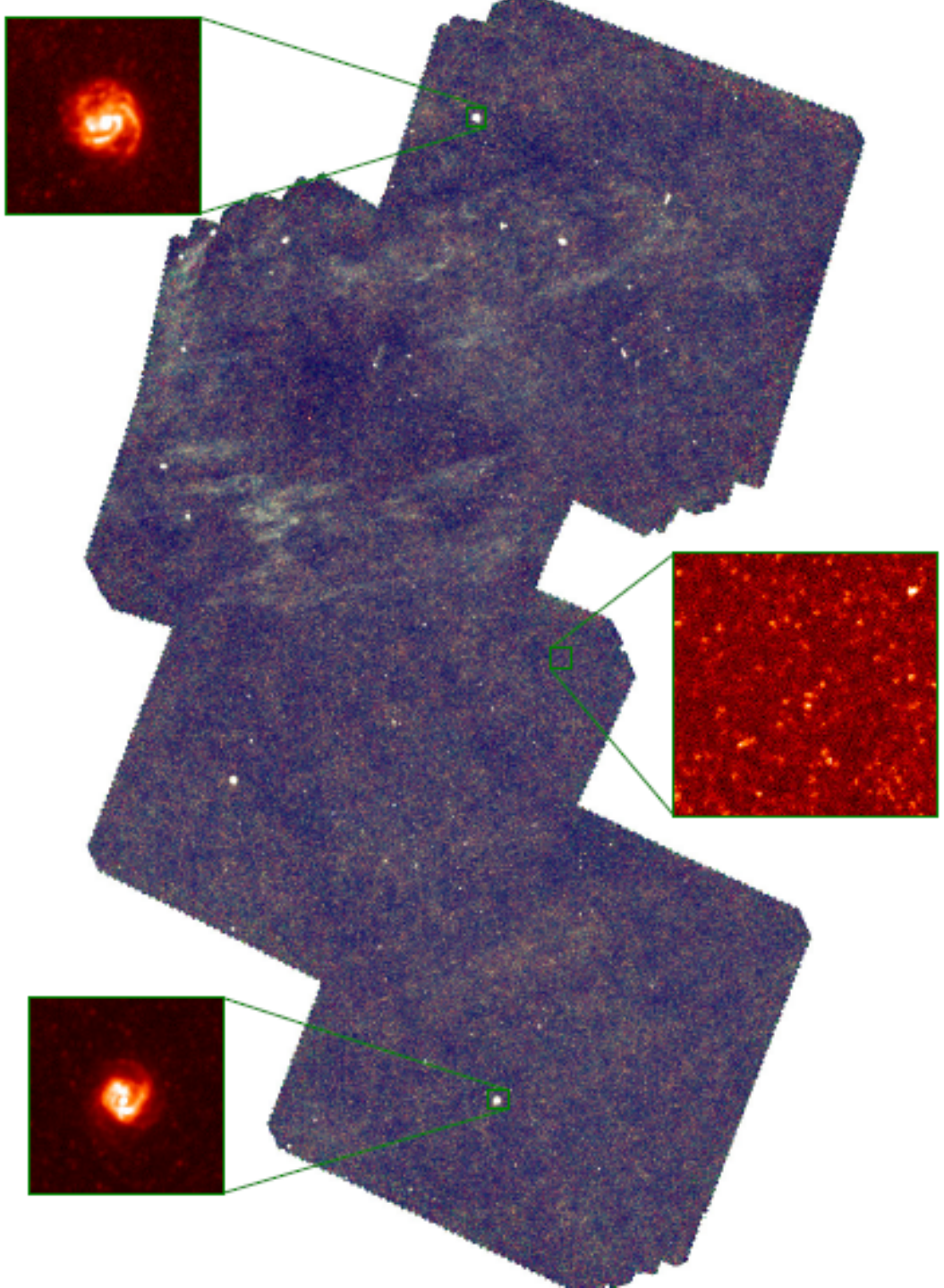
- Potential Questions?
  - How far can we detect dust emission
  - What are the properties of the dust at these wavelengths
  - How does the dust compare to other galaxy tracers?
  - Extreme environment for SF

Herschel Reference Survey



Largest Targeted Survey of galaxies with Herschel

- Statistically complete sample of 322 galaxies
- PI – Steve Eales
- Volume Limited 15 – 25 Mpc
- Very accurate Morphologies
- K-band selected
  - Avoid dust extinction
  - Good measure of stellar mass
  - Late-type $K_{stot} \leq 12$
  - Early-types $K_{stot} \leq 8.7$
- OT2 PACS program
- Use custom pipeline SPIRE pipeline BriGAdE



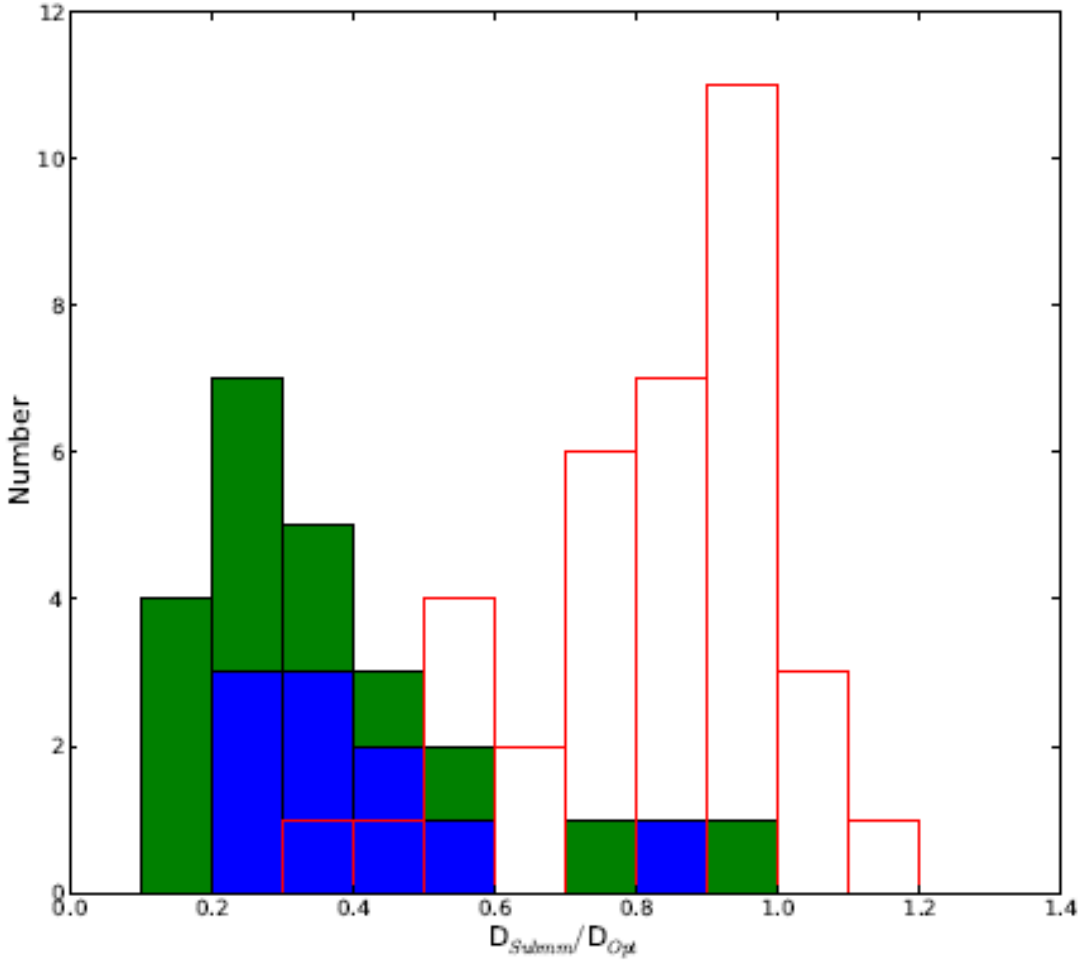
HeViCS

- PI – Jon Davies
- Otherwise known as DAVIES
- 8 parallel scans
- 100, 160, 250, 350 and 500μm
- 80 sq. deg
- Very deep compared to survey like H-ATLAS
- Noise ~ 0.3 × confusion for SPIRE

Stacked Radial Profiles

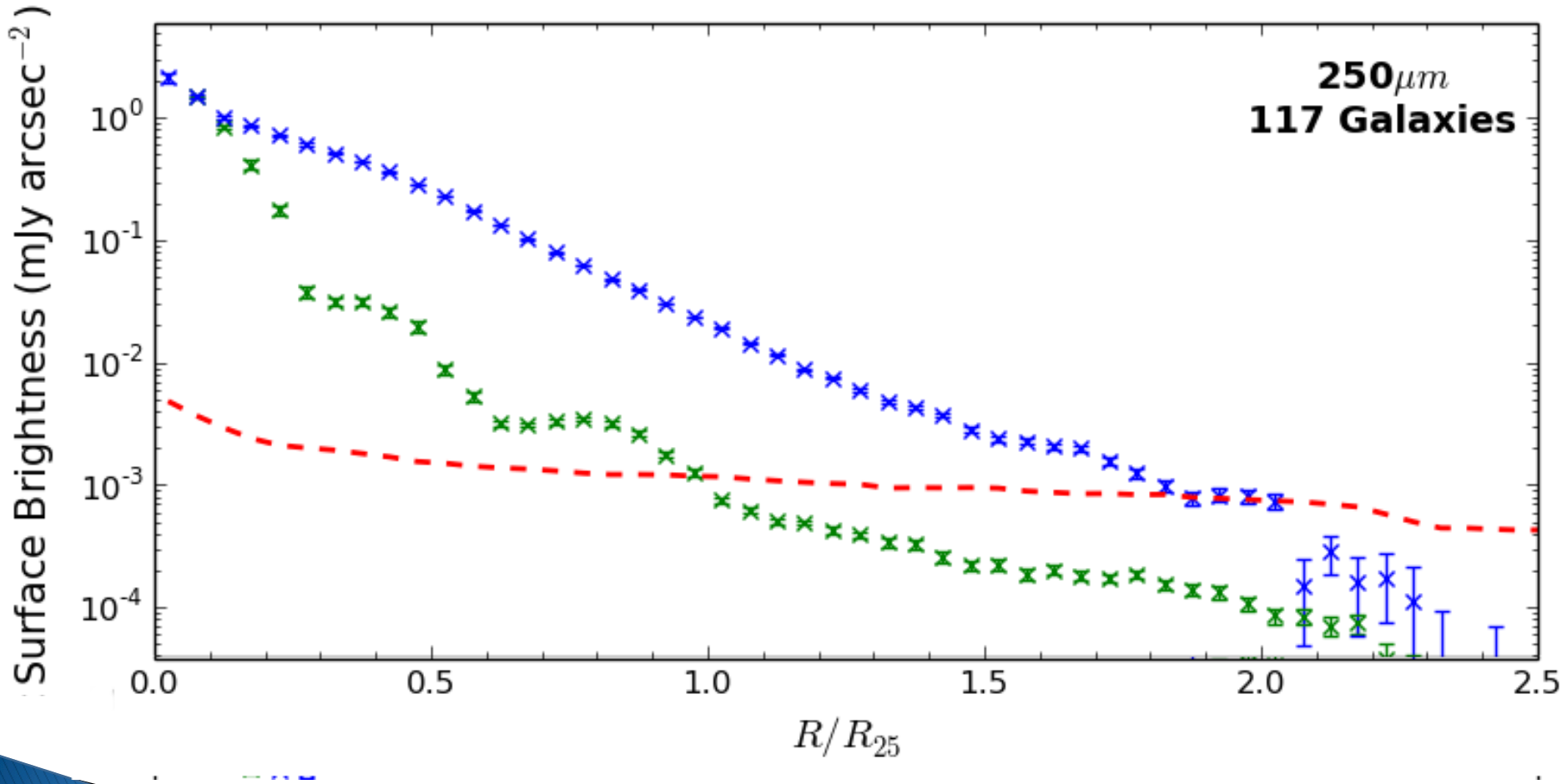
HRS object Criteria:

- Late-type galaxies
- Indentified as detection
- Extended Source
- No other bright contaminating object
- No heavy cirrus contamination
- Inclination < 60°

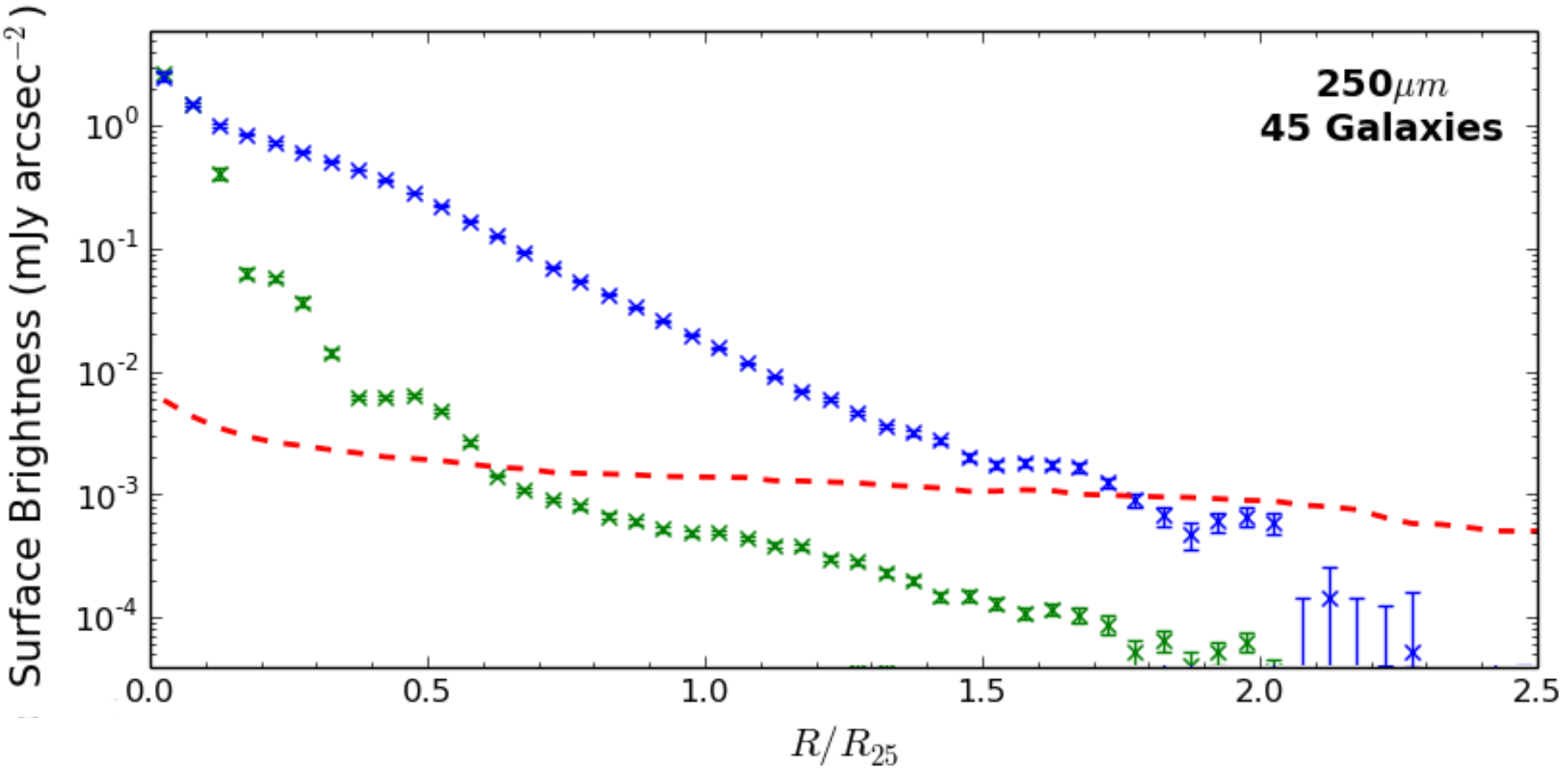


Smith et al. 2012

Stacked Radial Profiles (2)

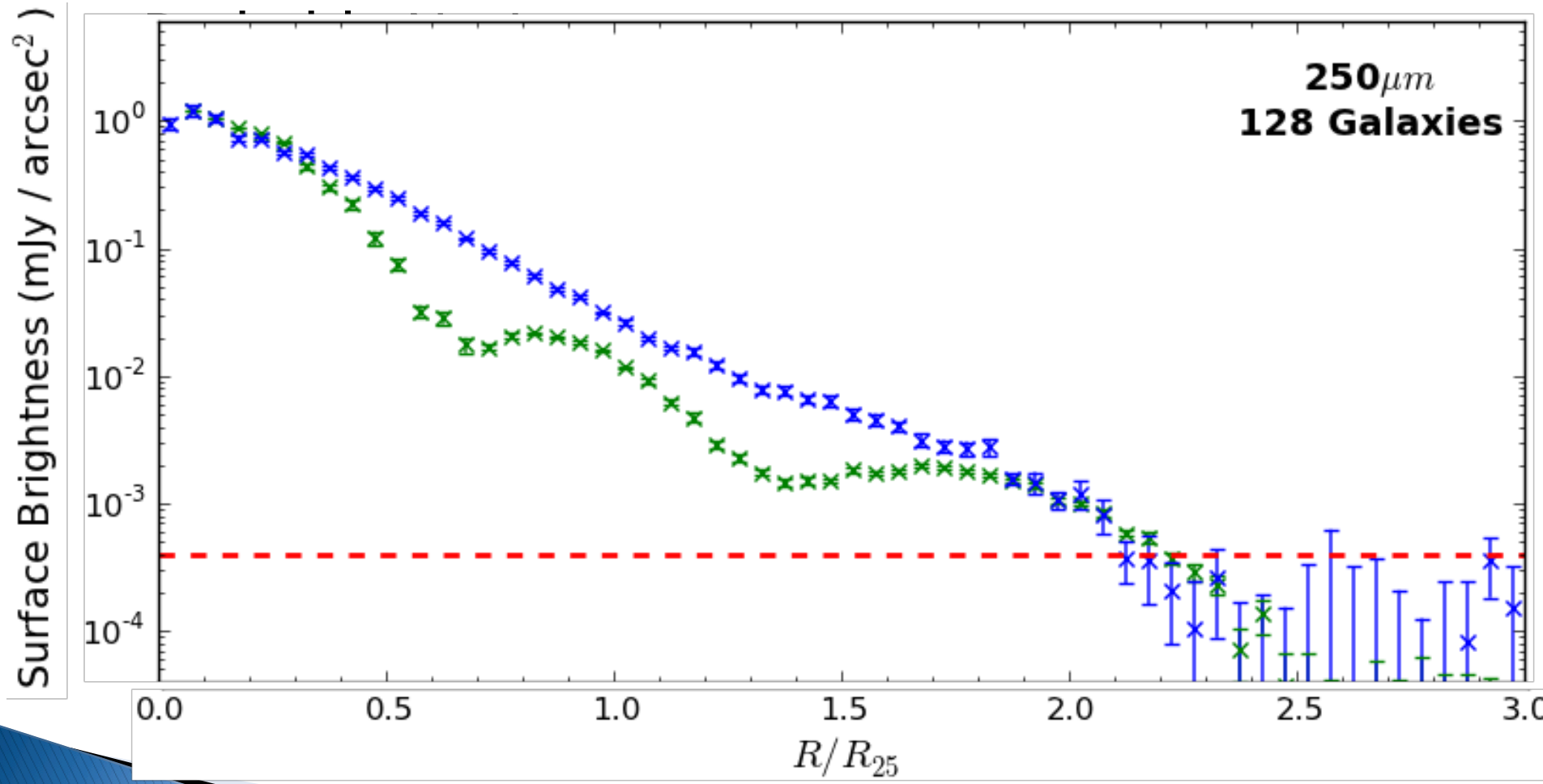


Stacked Radial Profiles (2)



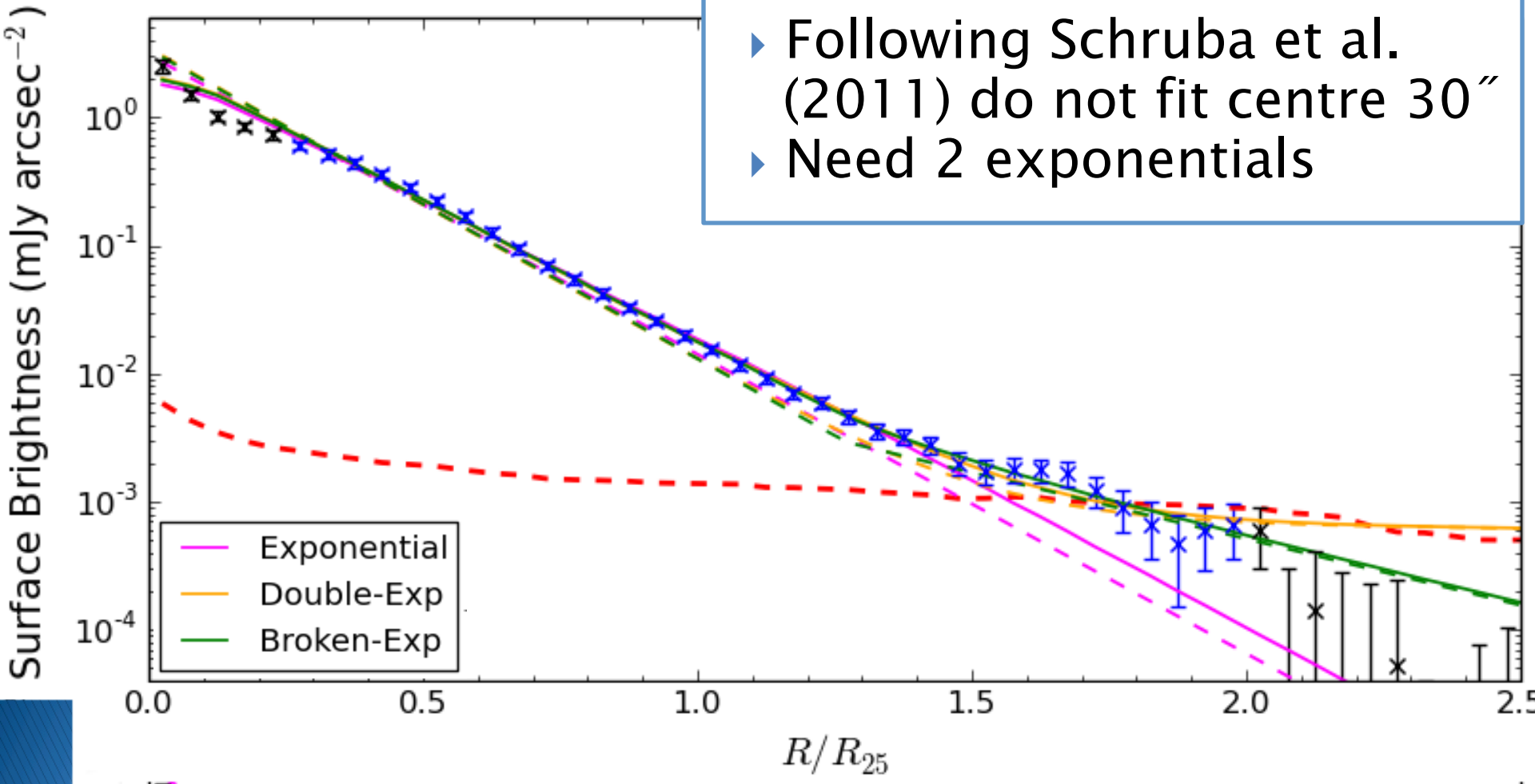
- Restricted to galaxies with D25 > 3´
- Median R25 corresponds to 10.3 kpc

Can other Surveys do better?

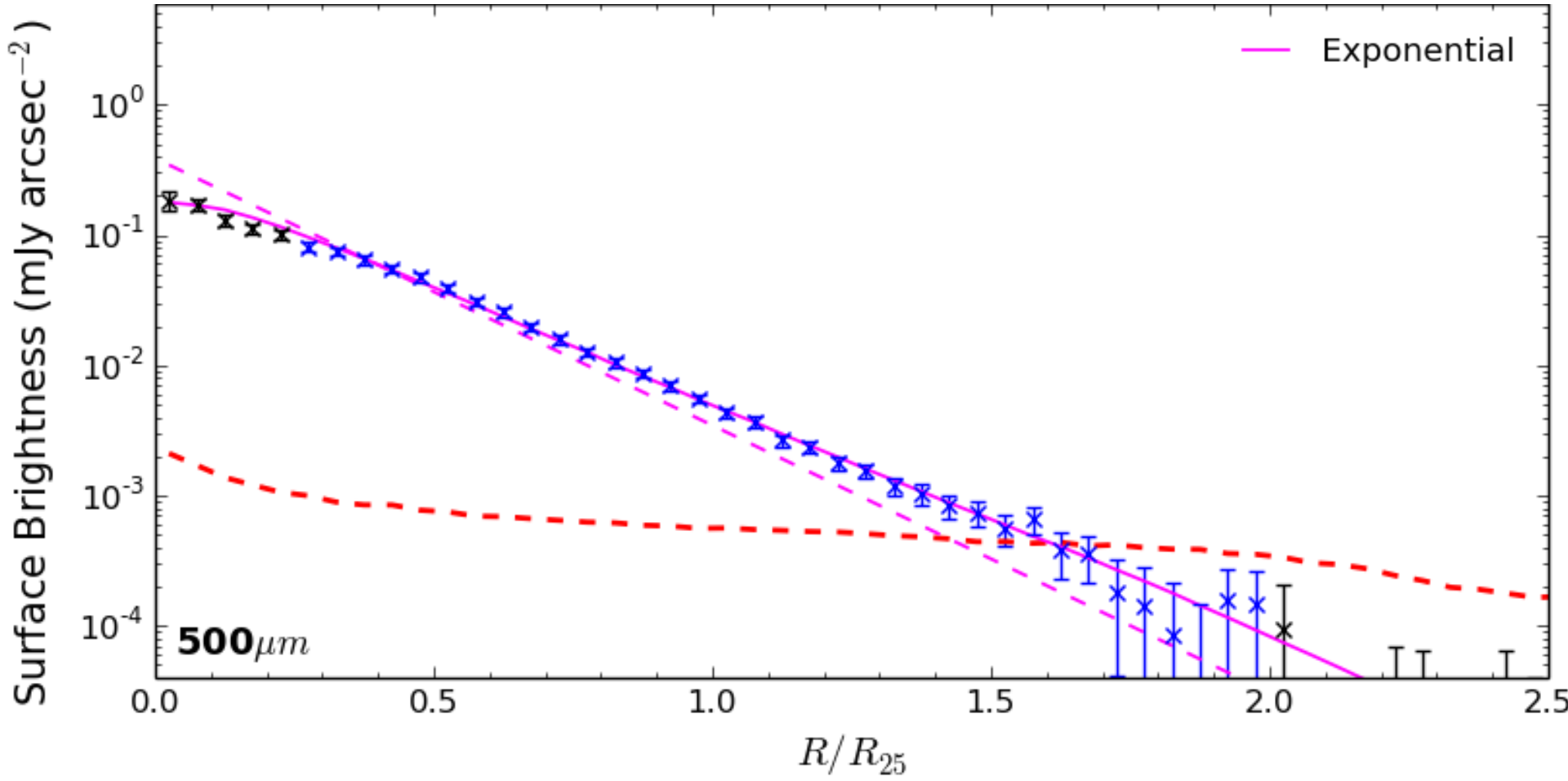


Best-Fit Model 250μm

- Minimise χ^2 model by:
  - Trial Model
  - Convolving it with beam
  - Calculate χ^2
  - Originally done 1D but found had to do it in 2D
- Following Schruba et al. (2011) do not fit centre 30″
- Need 2 exponentials



Best-Fit Model 500μm

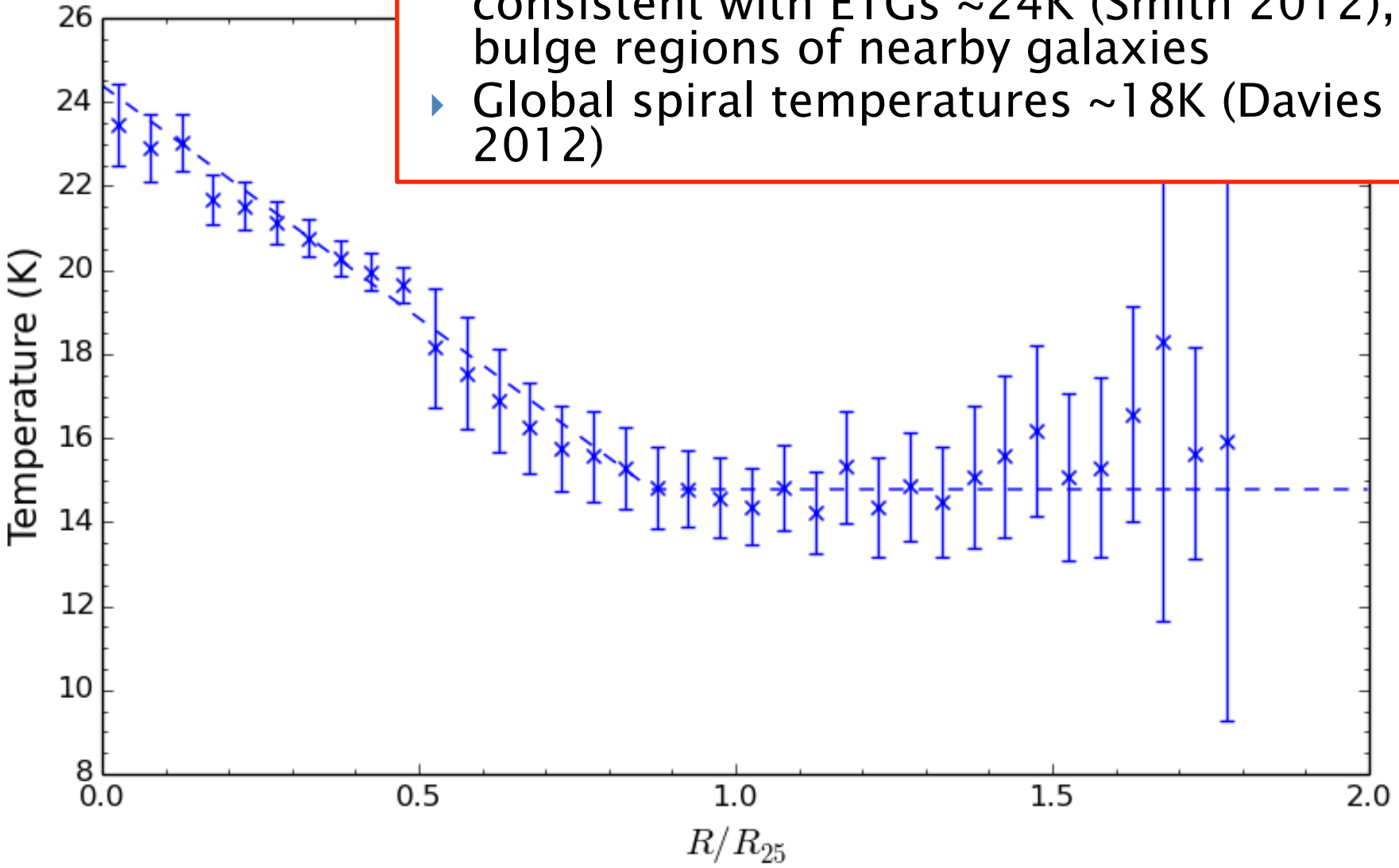


SED fitting

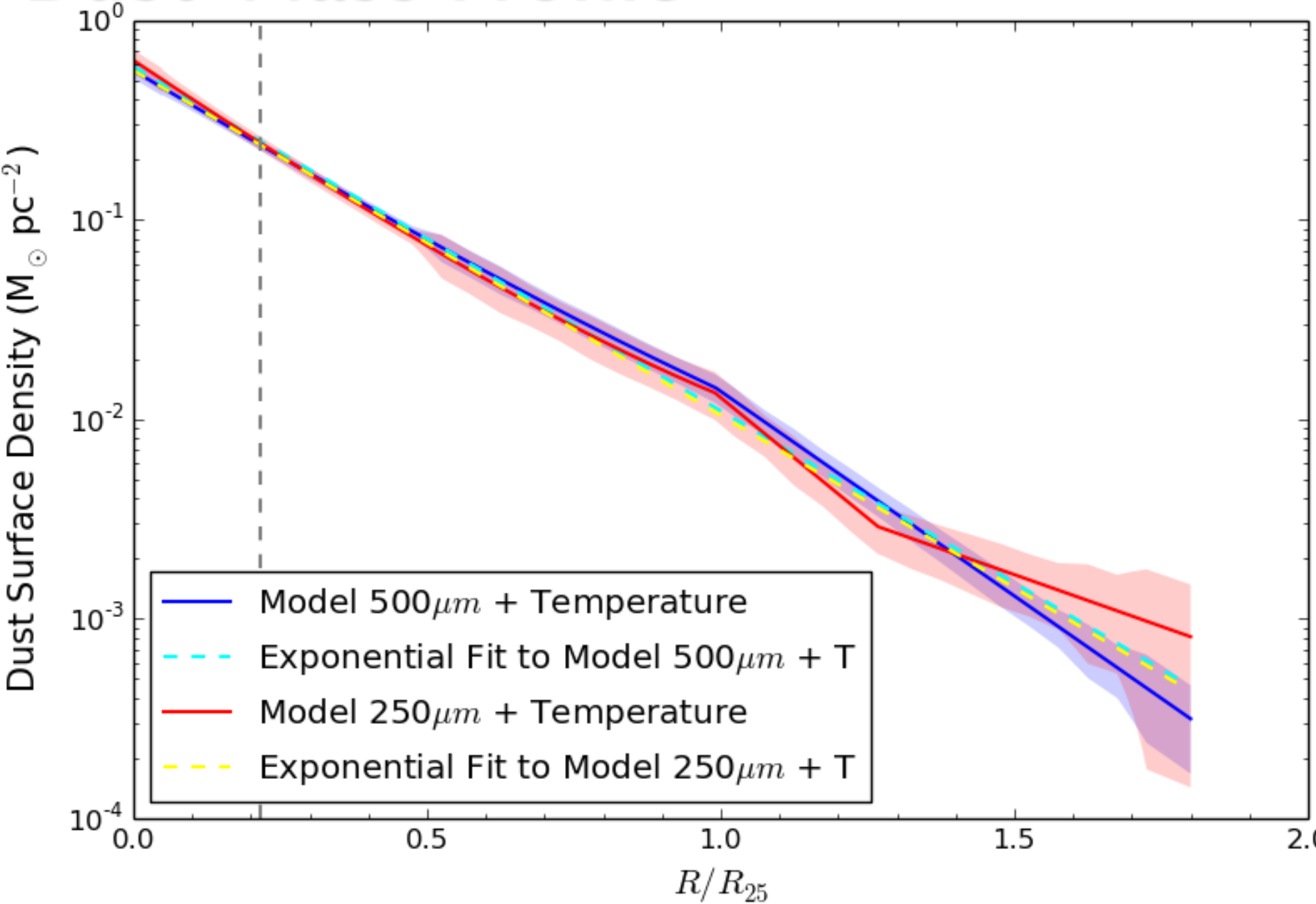
- SED fitting PACS + SPIRE data:
  - PACS data only received recently
  - Match PSFs and pixel sizes to 500μm (can't just use Gaussians)
  - PACS data particularly dominated by beam + background issues so limit to $0.5R_{25}$
  - Use a 1 component modified blackbody, most SPIRE only so cant be more complicated
- Is a fixed dust emissivity index justified?

Temperature Results

- Temperature reaches a minimum ~15K
- Rise in centre, the central temperature consistent with ETGs ~24K (Smith 2012), bulge regions of nearby galaxies
- Global spiral temperatures ~18K (Davies 2012)



Dust-Mass Profile



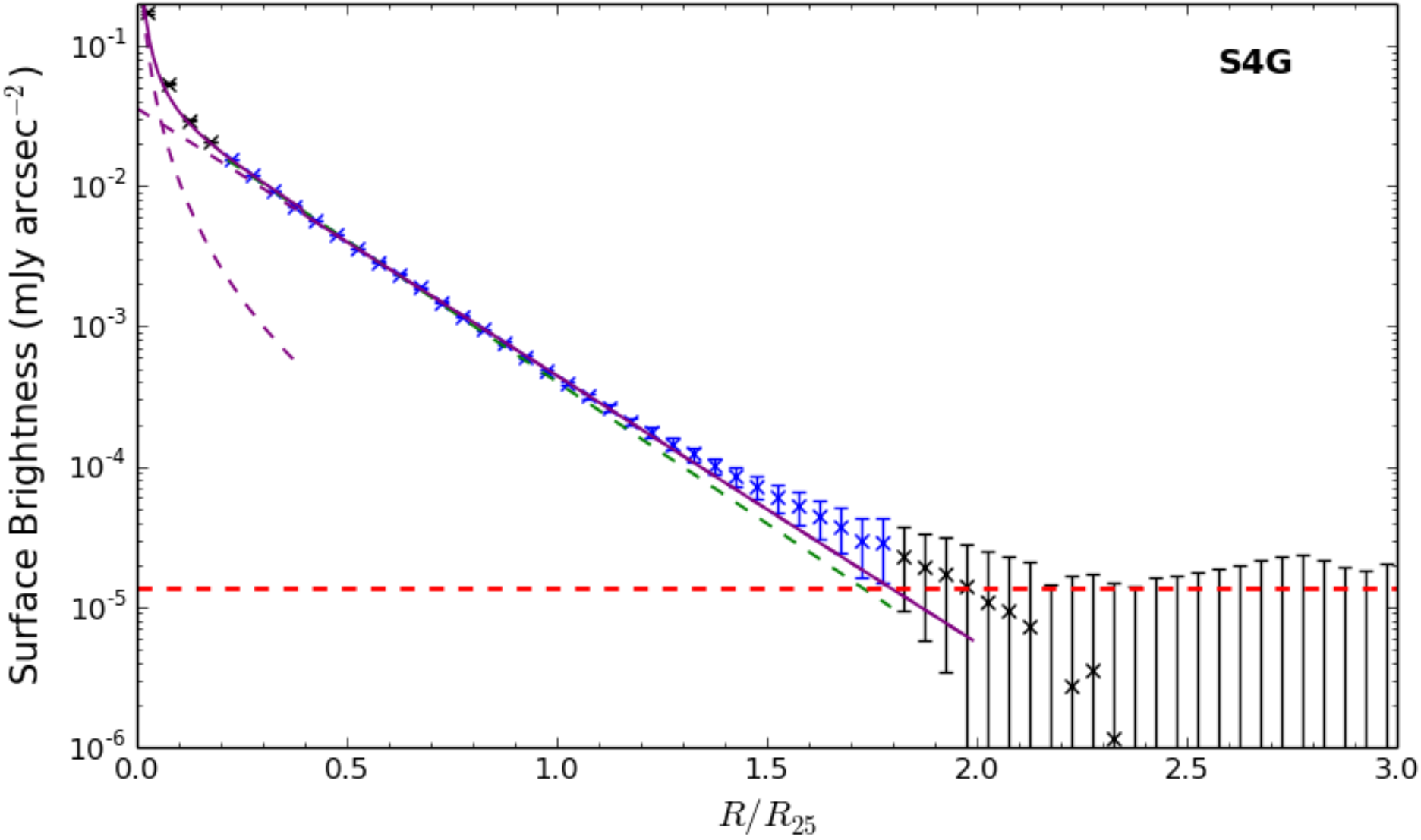
Stacked Radial Profiles (3)

- Fraction of dust emission between 1-2 R_{25} is 4.2, 5.6 and 7.6% for the 250, 350 and 500μm band. (un-beam corrected)
- If integrate the dust mass profile from $R_{25} \dashrightarrow \infty$ find that 4% of dust mass
- Rough agreement with 15kpc Menard value but I need to redo this.

Other Info Bands:

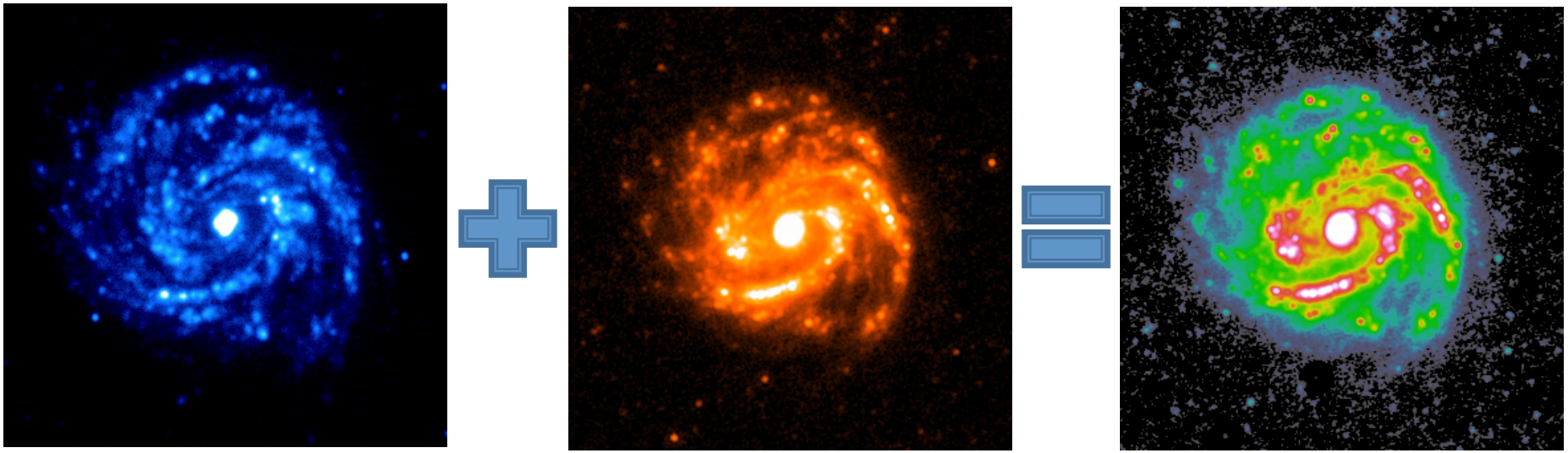
- Stars
  - The Spitzer Survey of Stellar Structure (S^4G)
  - 2 and 3.6μm IRAC imaging
  - 46 of the 48 large HRS objects
- Star Formation (Obscured and Un-obscured)
  - Obscured – MIPS 24μm
    - 28 Galaxies of the large HRS sample
  - Obscured – WISE 22μm
    - Entire Sample
  - GALEX – NUV
    - Only NUV data deep enough as FUV channel failed
    - 44 Galaxies of the large HRS sample
- Gas
  - HI (see slide)
  - CO (see slide)

Stellar Profile



Star Formation Rate

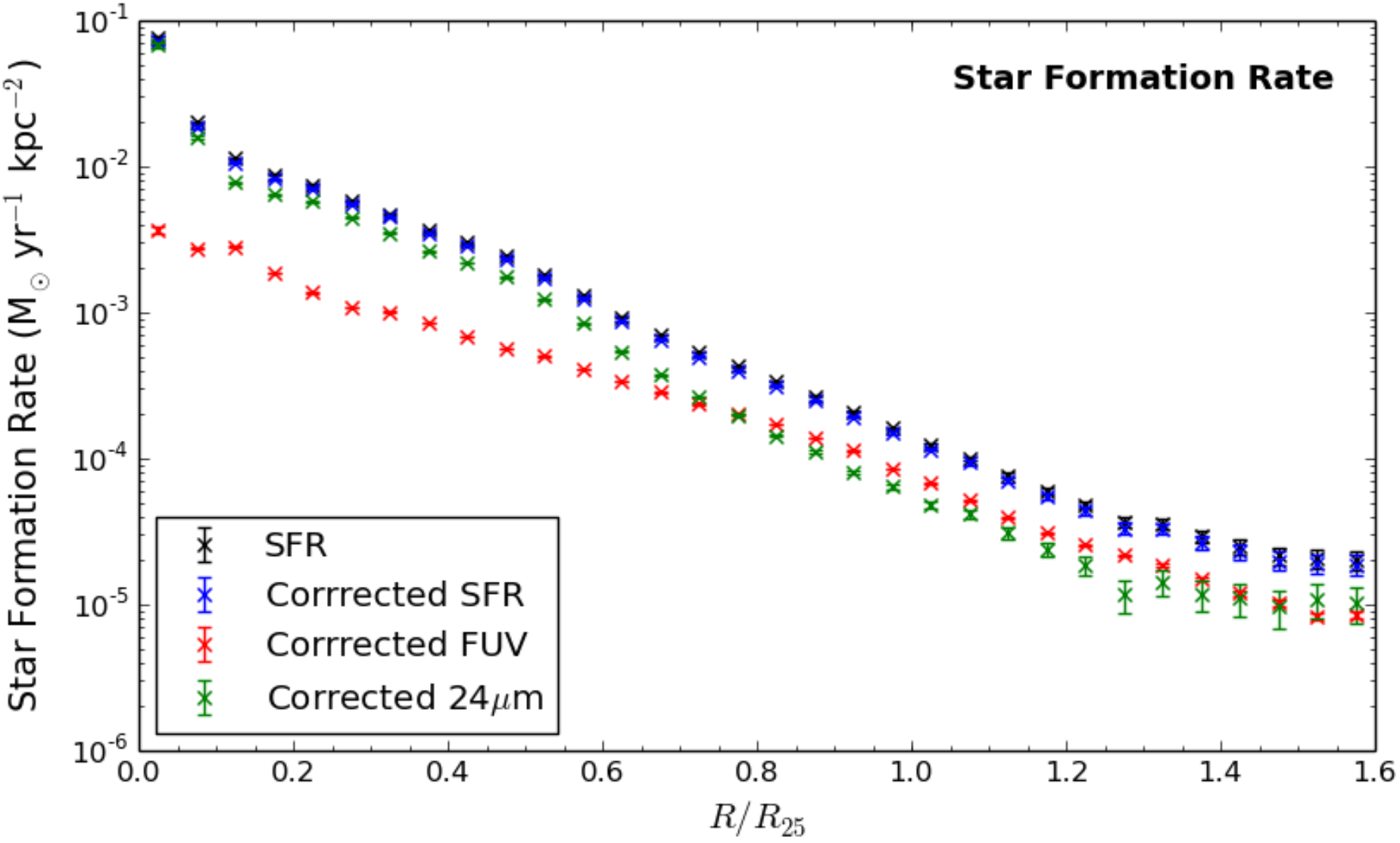
NUV + MIPS 24μm = SFR



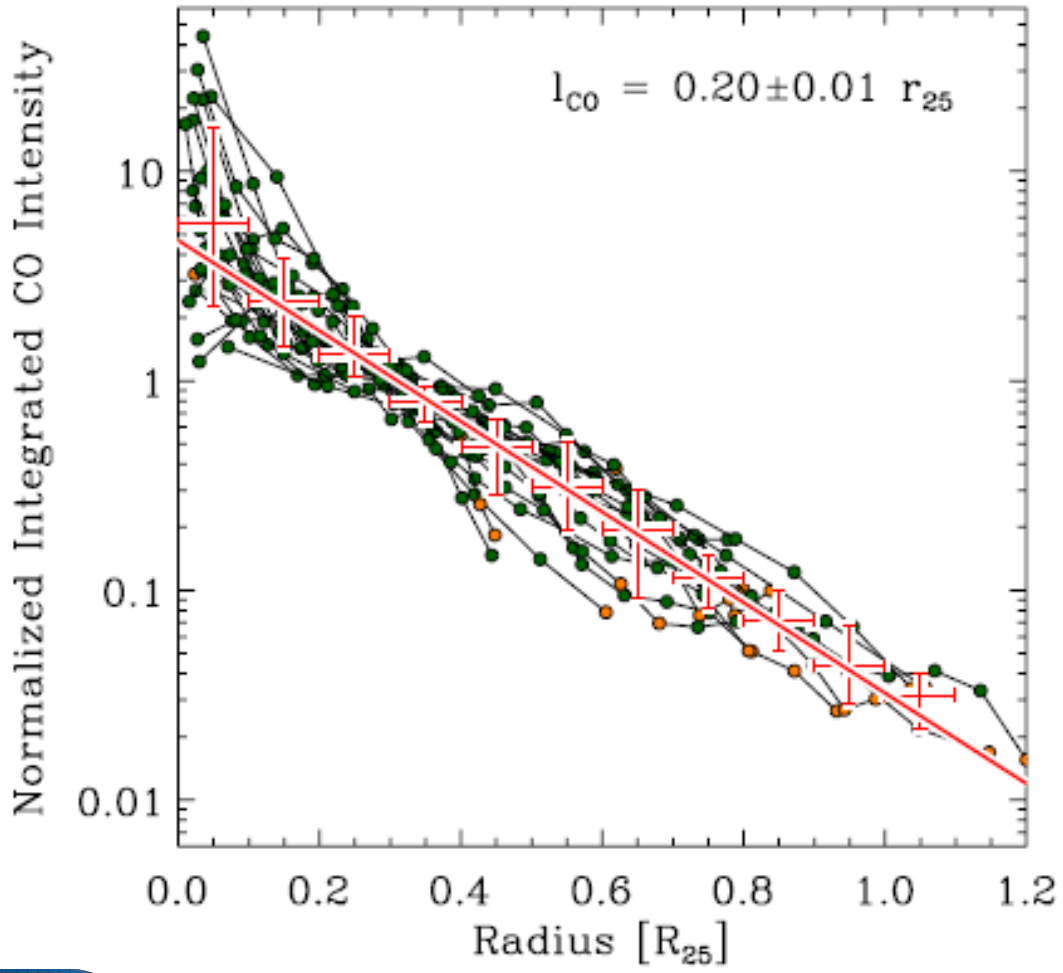
- Method of Leroy et al. (2008)
- Only 29 galaxies have usable MIPS 24μm
- So we also do the same with WISE 22μm (similar resolution to SPIRE and use the same methods

Star Formation Rate

- Method that of Leroy et al. (2008)



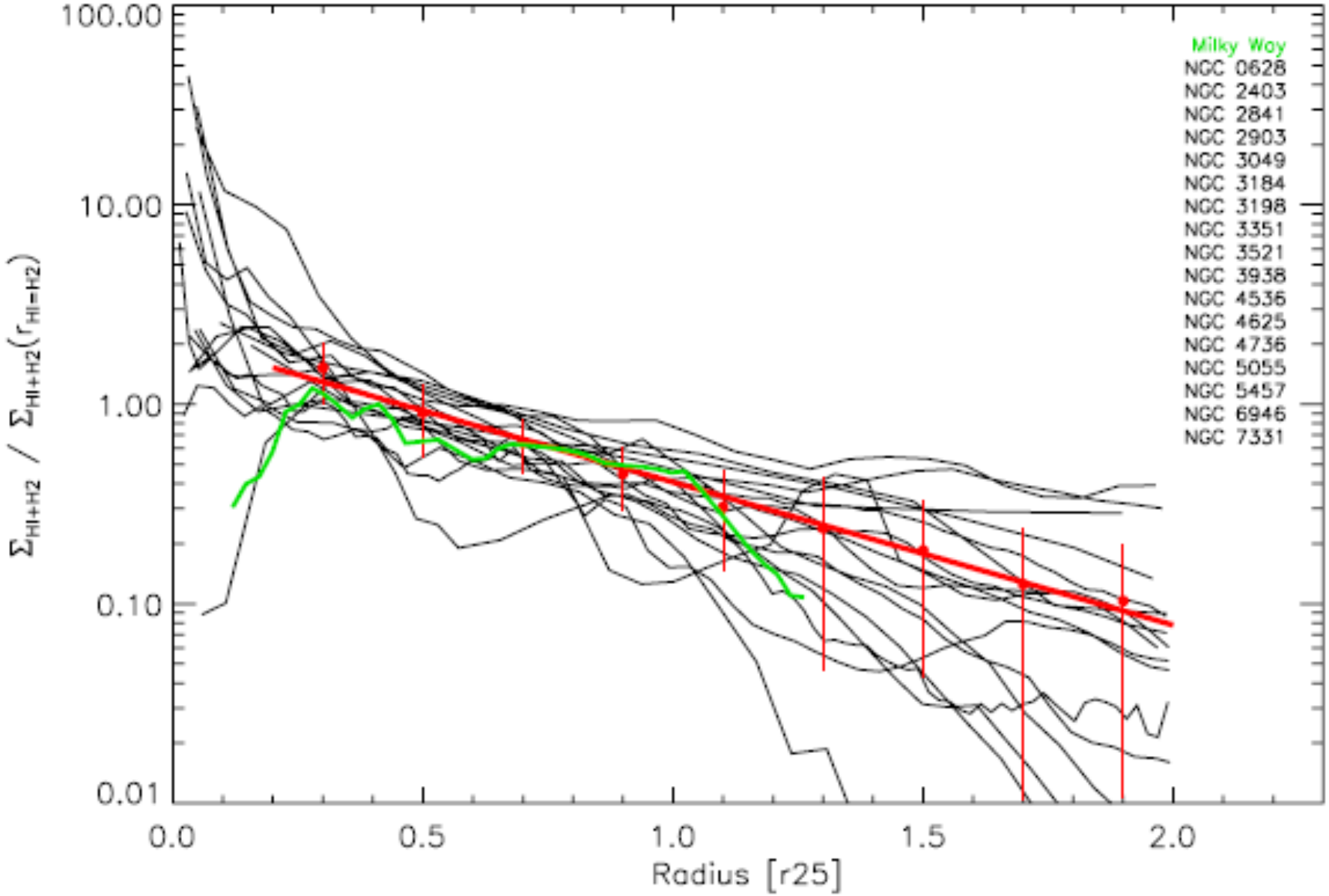
Molecular Gas



- Paper by Schruba et al. (2011)
- Use the HERACLES survey
  - Deep CO (*J*=2–1) of nearby galaxies
  - Targets THINGS/SINGS galaxies
- Cool stacking method:

Atomic/Total Gas

- Bigiel & Blitz 2012

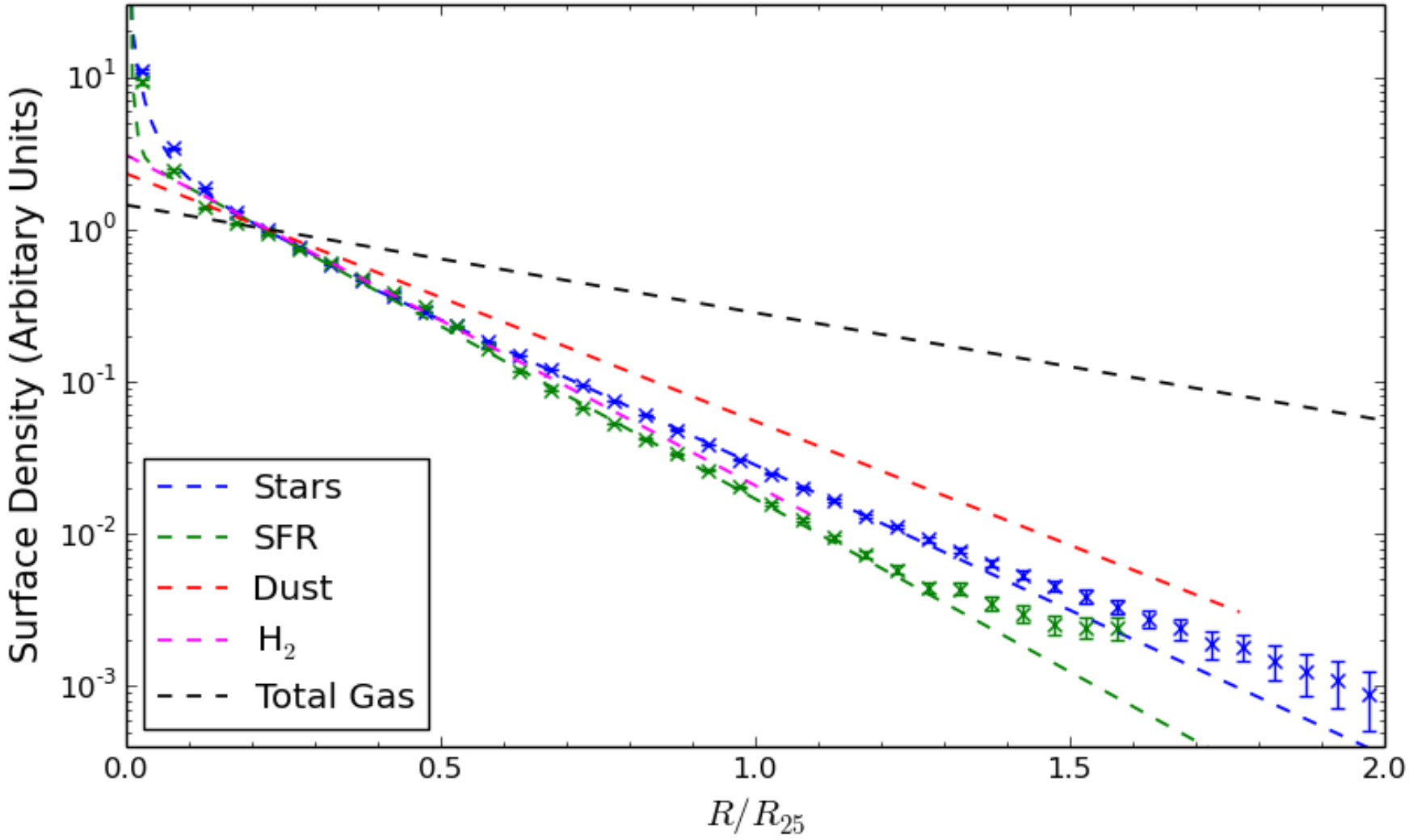


The Gradients:

- Provisional Numbers
- Simulations finished yesterday for other bands
- Repeating by smoothing the high-resolution data to SPIRE resolution and use same procedure

	Gradient (dex R_{25}^{-1})	Error
Stellar	-1.91	0.02
SFR	-2.27	0.03
CO	-2.17	?
HI +H_2	-0.71	?
Dust	-1.63	0.01

The Gradients (2)



Interpretation

- We don't really know yet…
- Dust sources are thought to be either from AGB stars or from Supernova
- Potential Solutions
  - Radial movement of dust – radiation pressure?
  - Star-formation history?
  - Grain-growth in the ISM?
- Grain-growth in the ISM

Conclusion

- Herschel is enabling us to constrain the mass, temperature, composition, origin and extent of dust in galaxies
- Dust seems to keep on going (just like all the other phases we've heard about).
- Gradient of dust seems more extended than stars and star-formation.

THANK YOU FOR LISTENING