Dust & Stellar Emission of Nearby Galaxies

in the *Herschel* KINGFISH Survey

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Outline

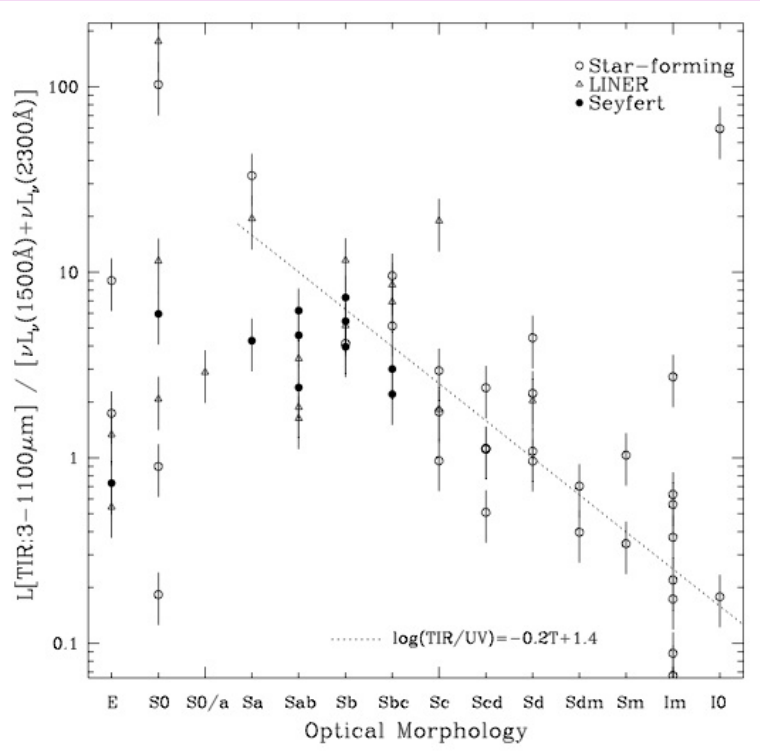
1. Introduction: KINGFISH survey of nearby galaxies
   - successor to Spitzer's SINGS
2. UV-to-submm integrated spectral energy distributions
   - measure precisely how much emission from stars and how much re-radiated by dust
3. Dust/Stellar ratio: estimated empirically from SEDs (including new Herschel data)
4. Analyze correlations with galaxy properties: morphology, metallicity, total IR luminosity, dust mass & temperature, stellar mass, SFR
5. Implications of our results for galaxy evolution

SINGS: Studies of Nearby Galaxies with Spitzer

SINGS: Spitzer IRAC (3.5, 4.5, 5.8, 8.0 μm) and MIPS (24, 70, 160 μm) imaging and low-resolution spectroscopy of 75 nearby galaxies ($d < 30$ Mpc) and high-resolution spectroscopy of their centers and a representative set of extranuclear IR-emitting regions

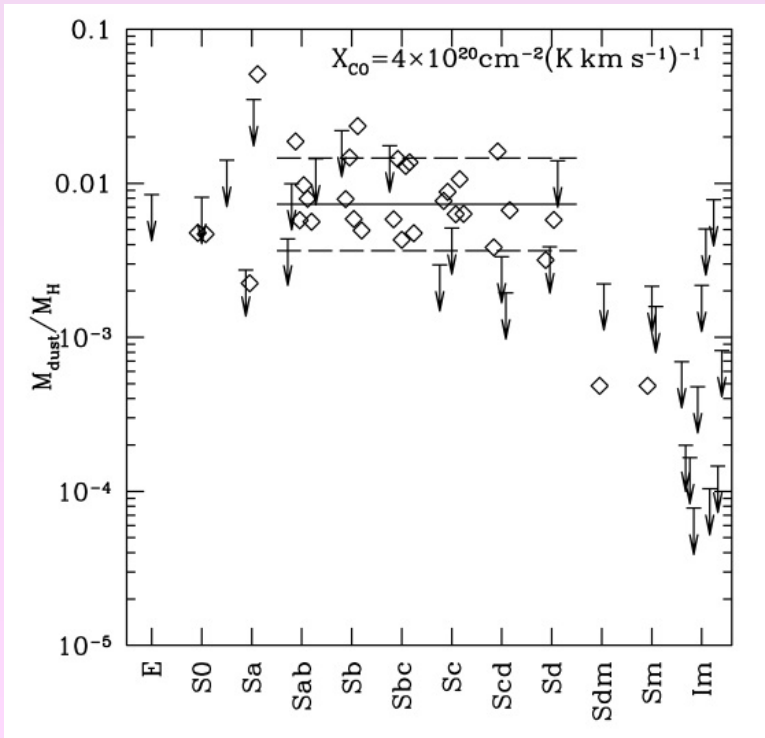
a couple results from SINGS studies involving SED analyses:

IR-to-UV ratio vs. morphology



Dale et al. (2007)

dust-to-gas ratio vs. morphology



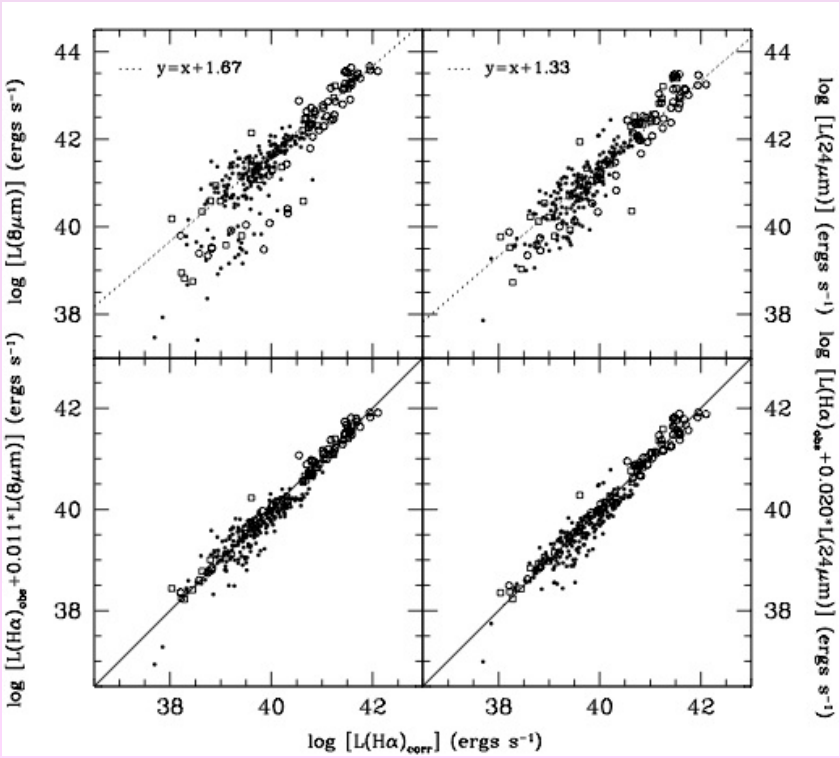
Draine et al. (2007)

SINGS (cont'd): Calibration of SFR Estimators

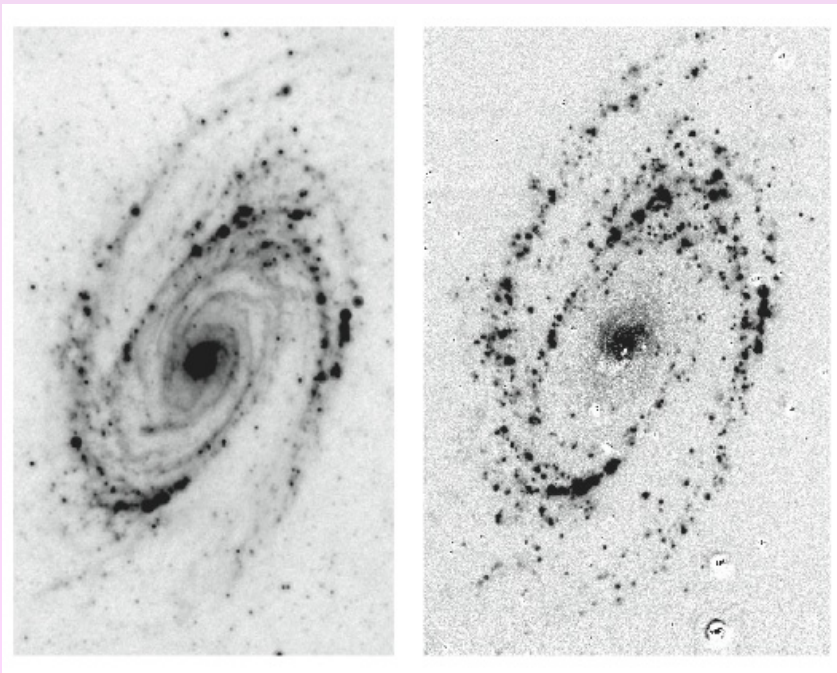
need to account for obscured (in MIR) and unobscured (in $H\alpha$ or UV) star formation

$H\alpha + 24\mu$m in best agreement with attenuation-corrected SFR

MIR+$H\alpha$ calibrations



24 μm & $H\alpha$ images of M81



Kennicutt et al. (2009); see also Calzetti et al. (2007, 2010)

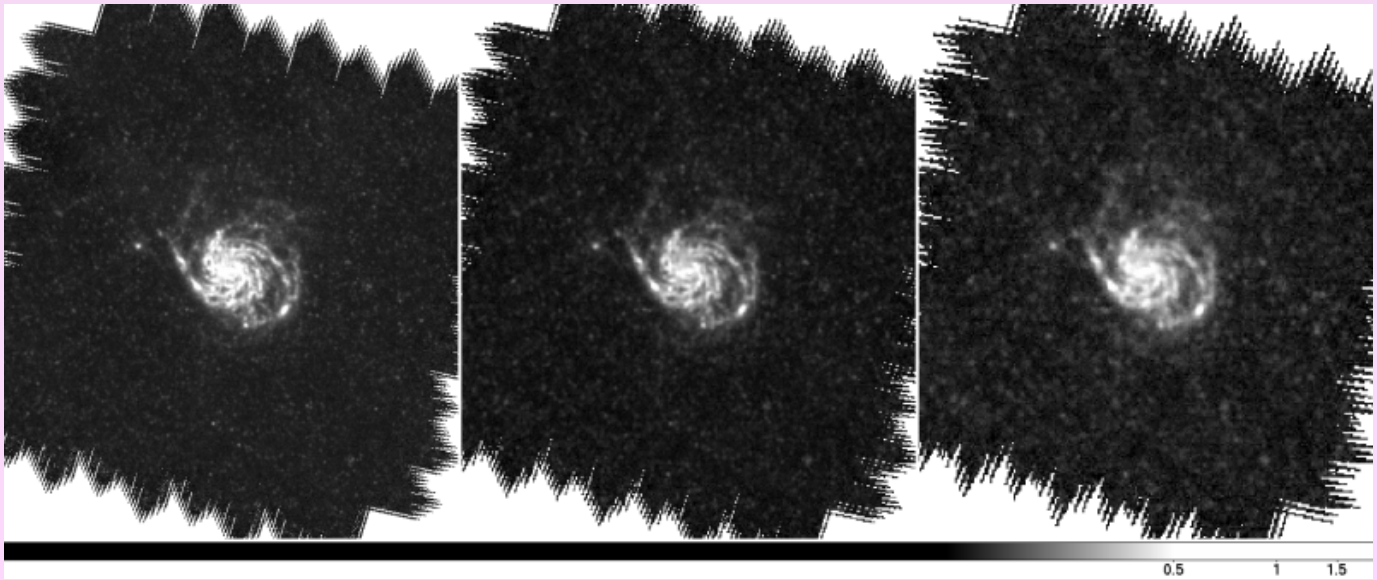
KINGFISH: Herschel's Successor to SINGS

KINGFISH: Key Insights on Nearby Galaxies: a Far Infrared Survey with Herschel; P.I.: R.C. Kennicutt

imaging with PACS (70, 100, 160 μm) and SPIRE (250, 350, 500 μm); plus PACS spectroscopy

61 galaxies covering wide range of morphologies, star formation rates, interstellar medium (ISM) properties, and extragalactic environments

example: SPIRE images of M101 at 250, 350, 500 μm



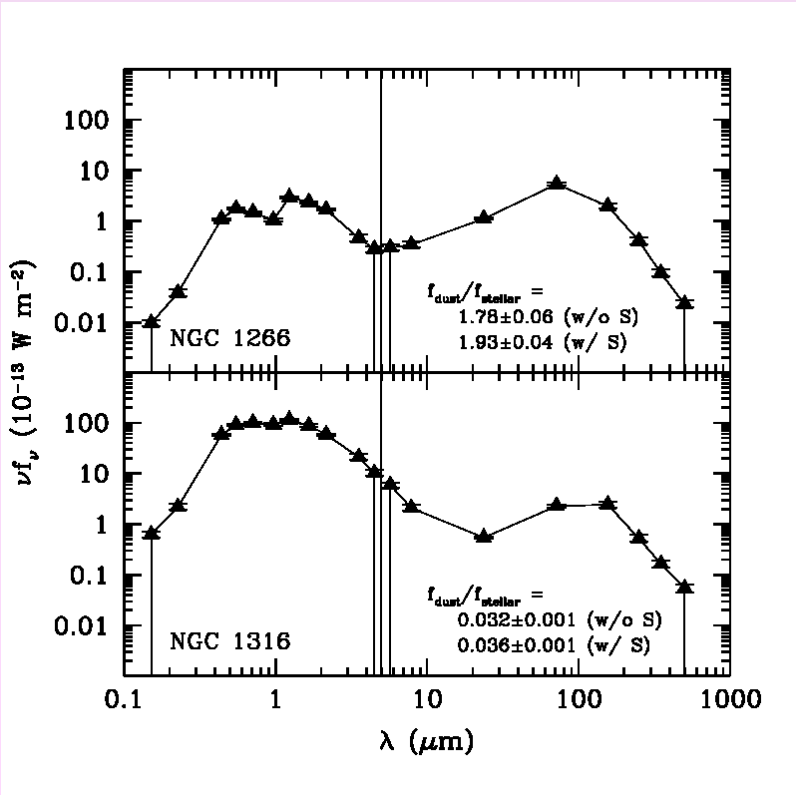
see also posters by KINGFISH people: Pedro Beirao, Alison Crocker, Kevin Croxall, Daniel Dale, Eric Murphy

Dust-to-Stellar Ratio

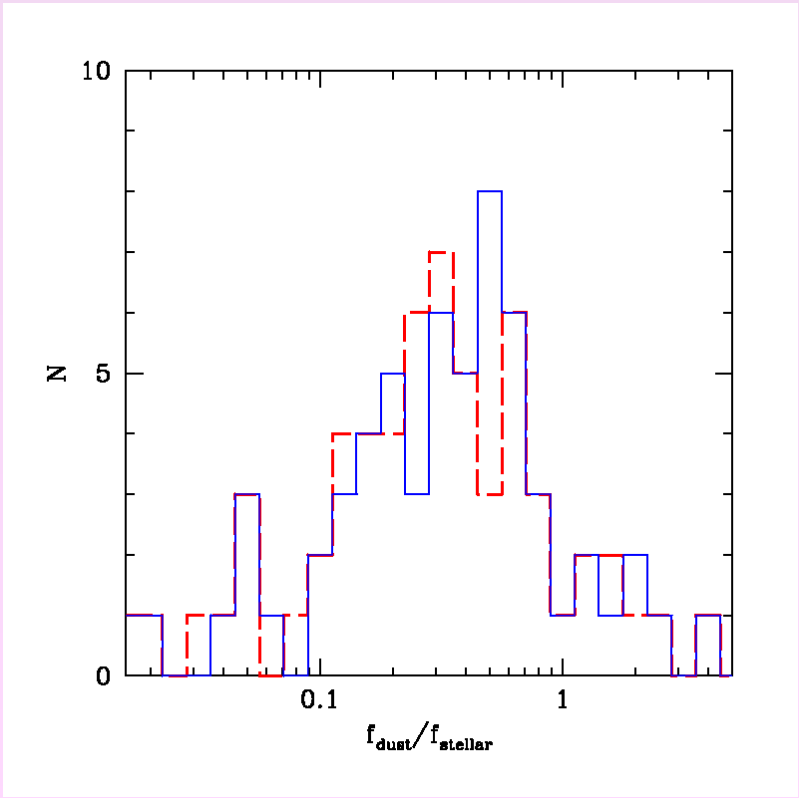
SEDs of 59 galaxies obtained from Dale et al. (2007, 2009) plus SPIRE flux densities

estimate dust/stellar emission ratio by integrating the SEDs, with cut at $\lambda = 5\,\mu$m; quantifies star formation and dust production

example SEDs



dust/stellar distribution

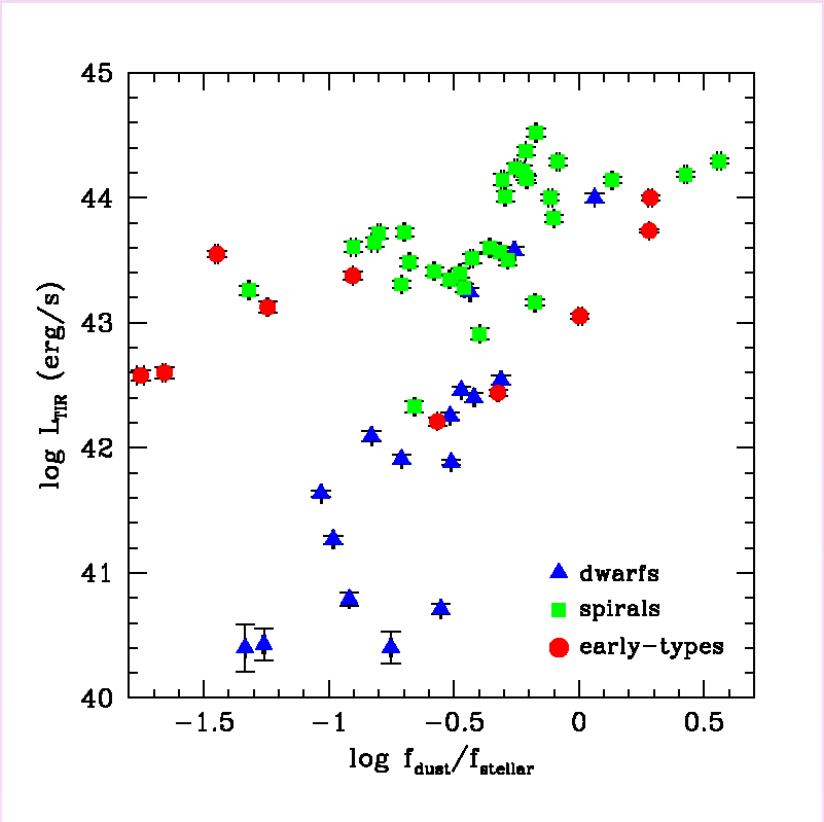


Morphology & Metallicity Dependence of Dust/Stellar

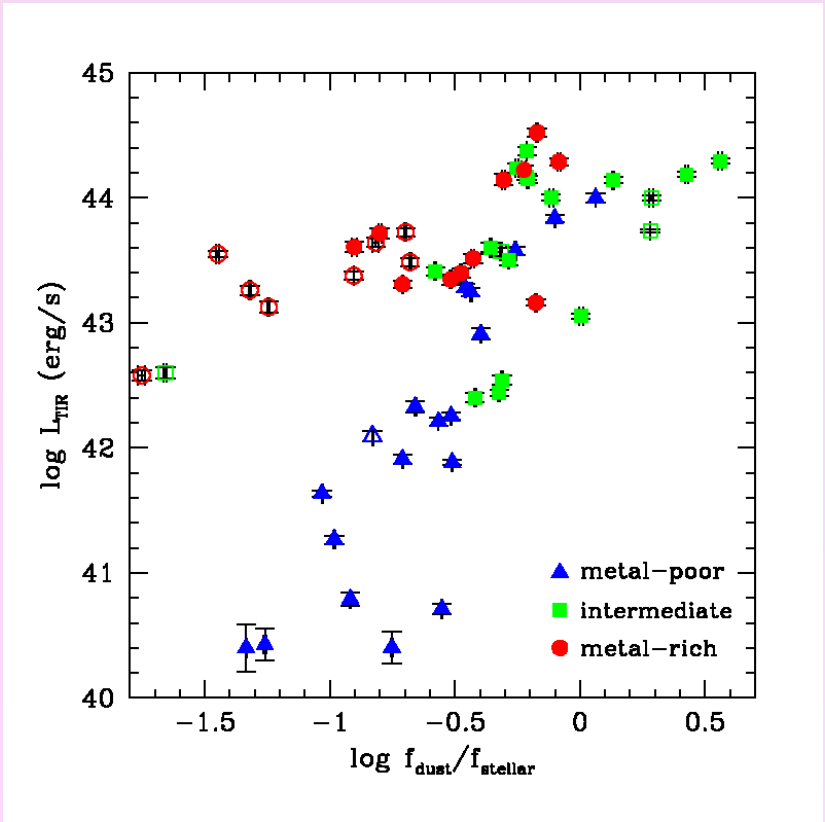
Morphology and metallicity dependence of $L_{\rm TIR}$ vs. dust/stellar flux ratio (morphologies from Buta+ 2010; metallicities from Moustakas+ 2010)

suggestive of an evolutionary sequence for 'typical' galaxies

Morphology dependence



Metallicity dependence



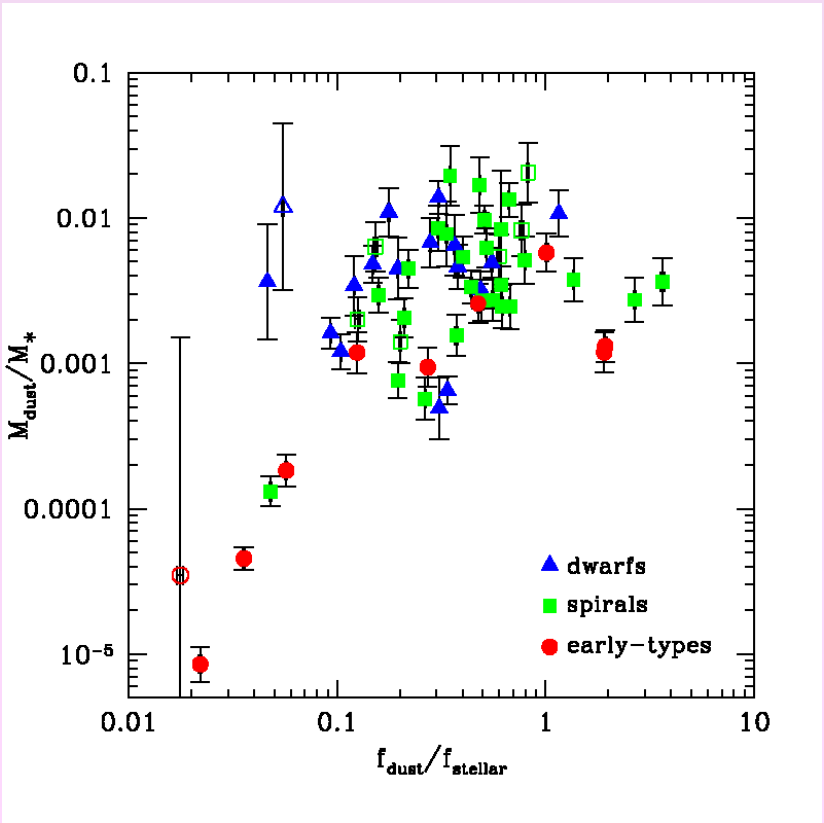
Skibba et al. (in prep.)

Dust and Stellar Masses

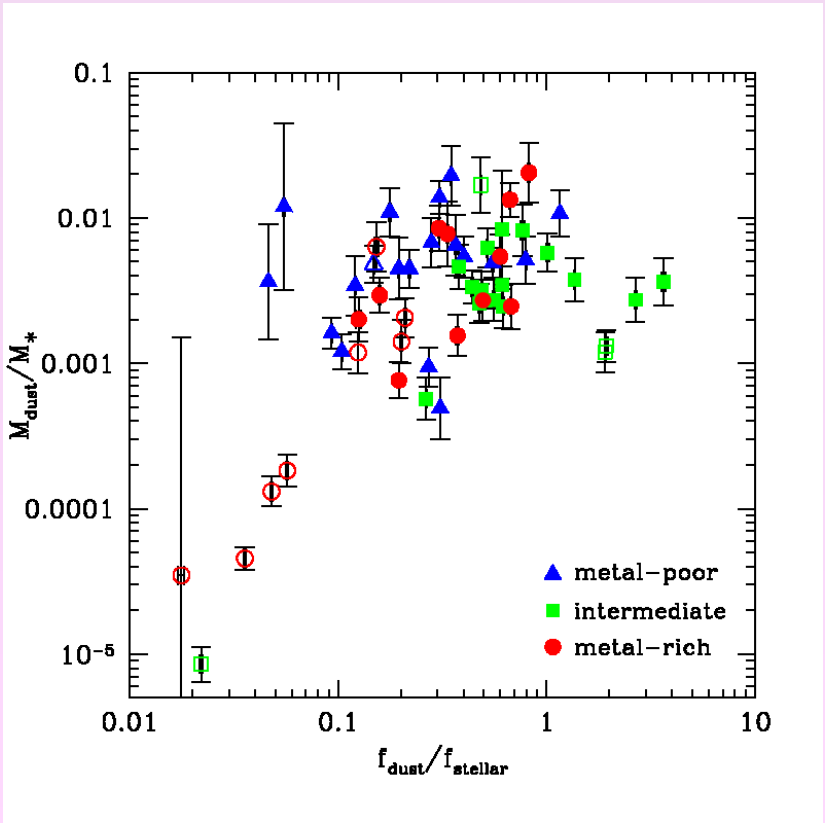
comparison to dust masses (MIPS+SPIRE, Li & Draine 2001 calibration) and stellar masses (H-band & opt. colors, Zibetti et al. 2009 calibration)

dust/stellar mass vs. luminosity: strongest correlation for metal-rich earlier-types

Morphology dependence



Metallicity dependence

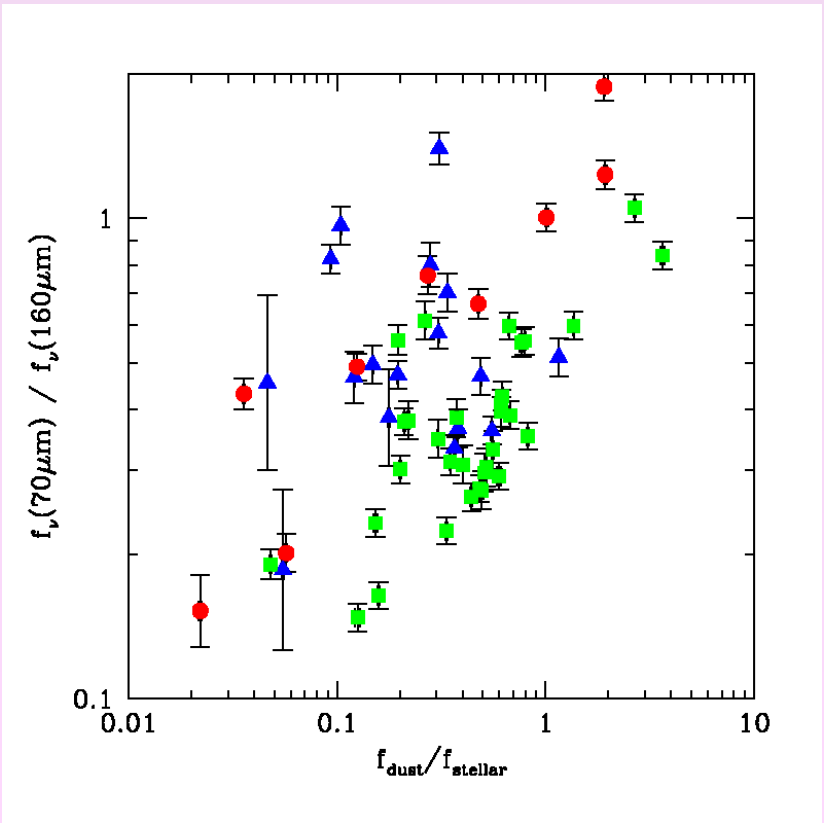


Dust Temperatures

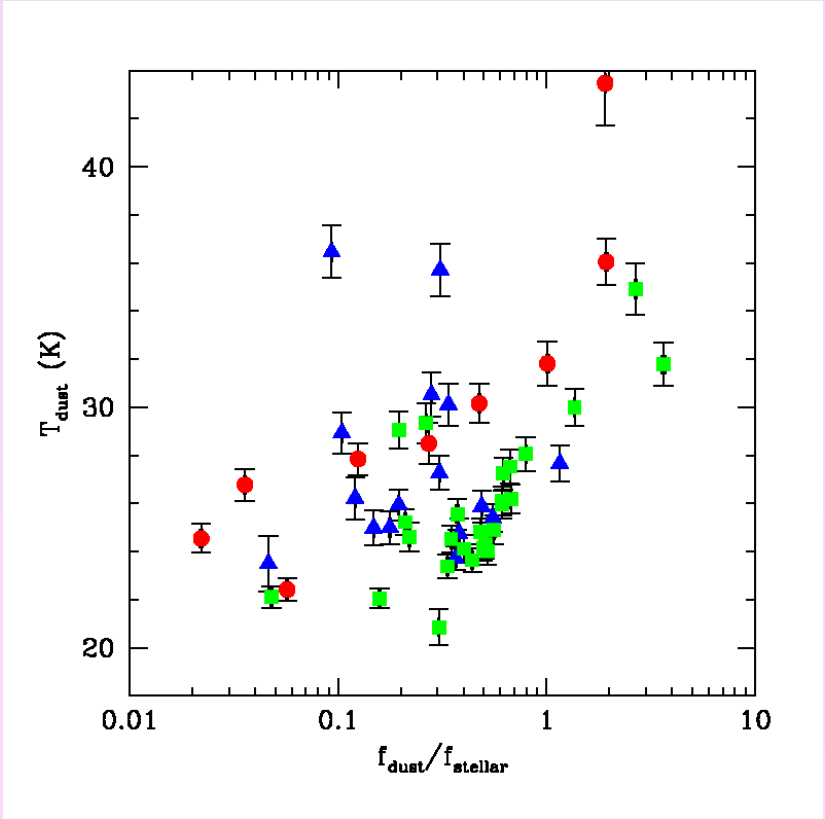
dust temps. estimated from far-IR SED fits (modified blackbody)

early-types & earlier-type spirals with more dust emission have warmer dust temperatures

MIPS $f_\nu(70\mu\mathrm{m})/f_\nu(160\mu\mathrm{m})$



Dust temperature

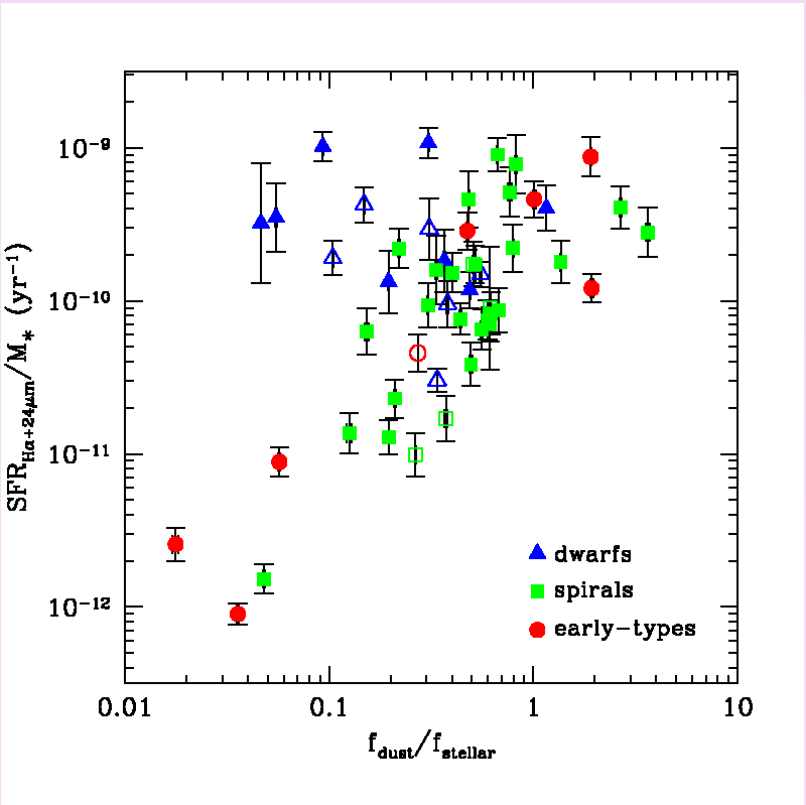


Star Formation Rates

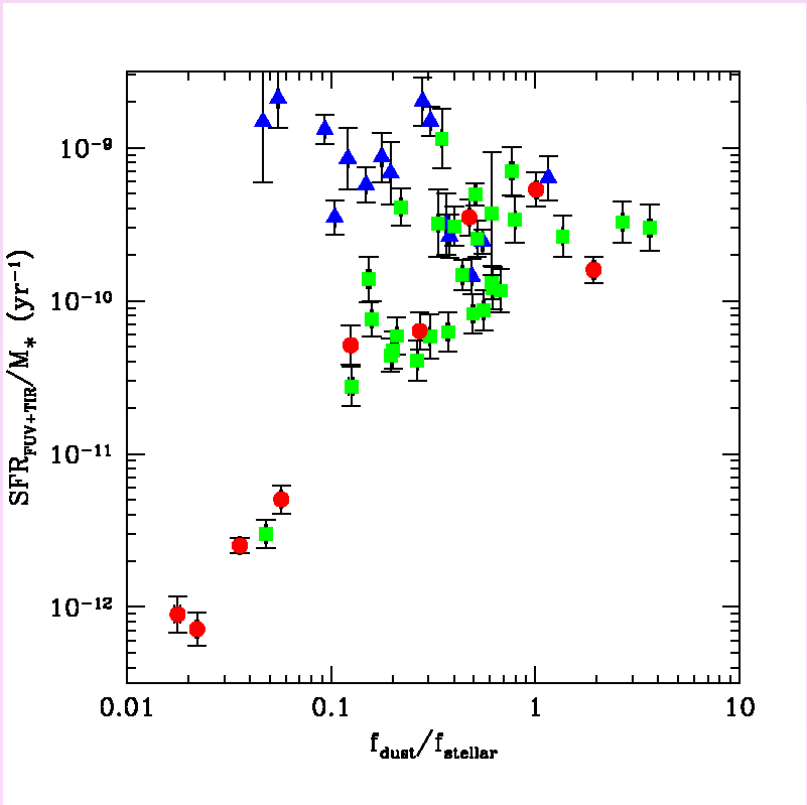
SFRs from Hα+24 μm (Calzetti et al. 2010 calibration) and TIR+FUV (Kennicutt 1998 calibration)

spirals and early-types with more dust emission also have more star formation (which heats dust)

SFR(Hα+24μm)/M_*



SFR(TIR+FUV)/M_*



Skibba et al. (in prep.)

Special or Peculiar Galaxies

NGC 4725 and NGC 1512 are examples of **red spirals** and **passive disks** (see also Skibba et al. 2009; Bundy et al. 2010): *quenched star formation not accompanied by morphological transformation*

NGC 1266 and NGC 1377 are **star-forming early-types** (see also Schawinski et al. 2009): *ongoing star formation in spite of morphological transformation*

NGC 6946 and M101 are **massive 'pseudobulges'** (see Kormendy et al. 2010): *gas-rich galaxies having grown massive without major mergers*

Conclusions

- *Herschel* fills in the far-IR wavelengths of SEDs, allowing us to comprehensively estimate the emission from dust grains and stars in galaxies
- dust/stellar ratio is correlated with total-IR luminosity in a very morphology and metallicity dependent way, **suggestive of an evolutionary sequence**
- dust/stellar mass and luminosity are correlated, but later-types have considerable scatter (why?)
- spirals and early-types with higher dust/stellar have **warmer dust temperatures**
- these galaxies also have **higher specific star formation**; for early-types, little ongoing SF sufficient to heat the dust
- empirical dust/stellar ratios can constrain galaxy formation models