Relationships between Gas and Dust in Local Dusty Galaxies

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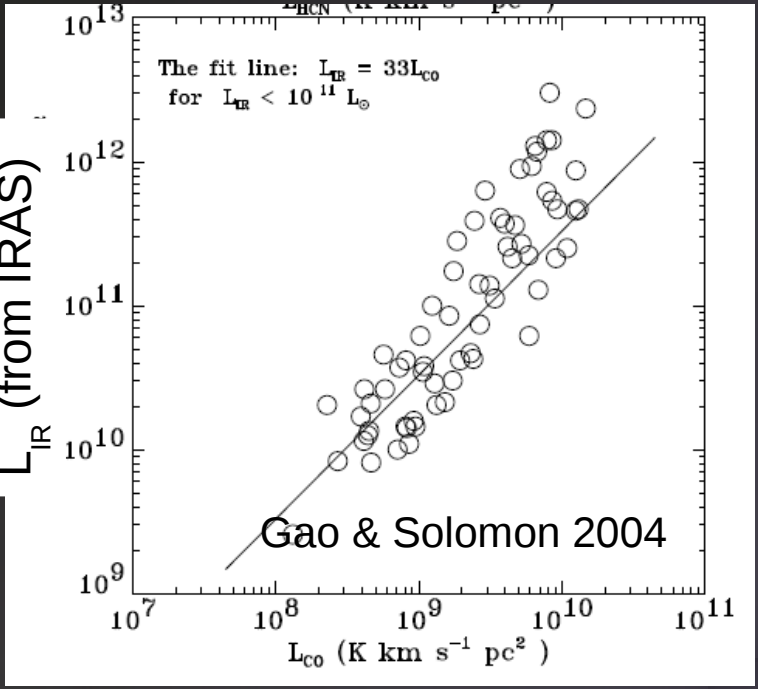
Does sub-mm dust emission trace cold gas?



- We know there are links between the dust and molecular & atomic gas phases in galaxies
- Dust also exists in several "phases" of the ISM:

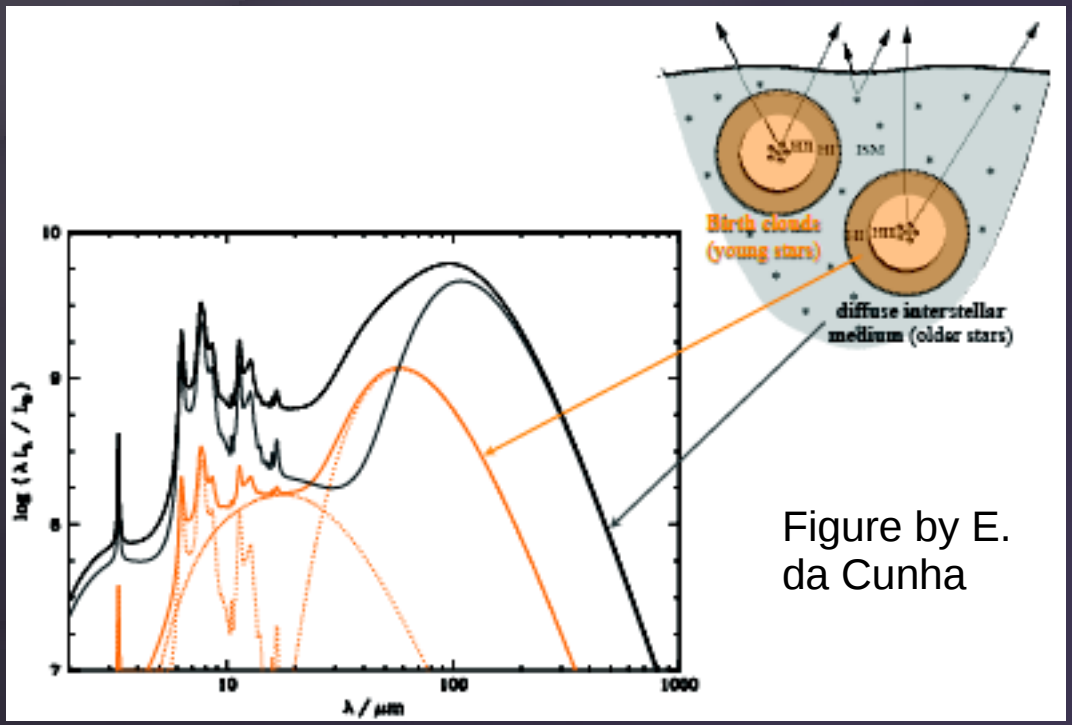


Figure by E. da Cunha

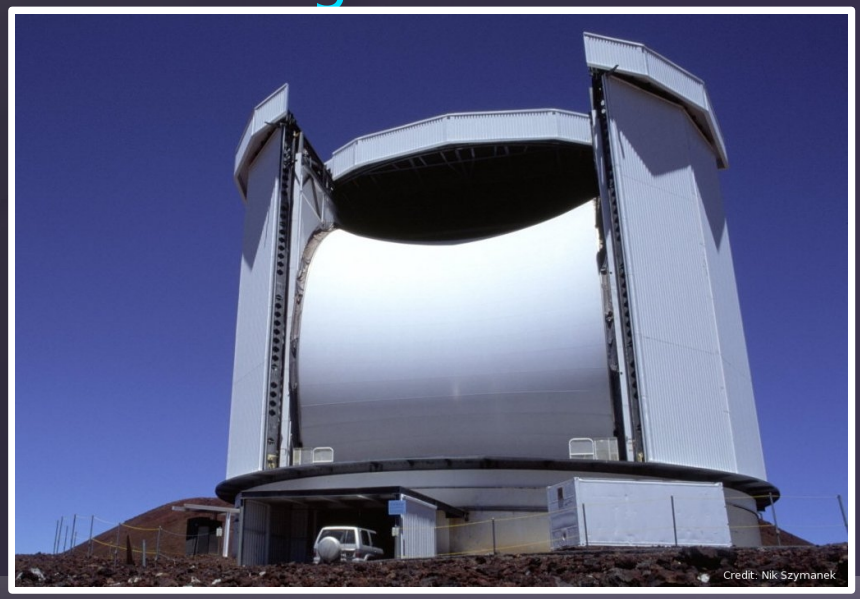
- Does Herschel detect dust heated by young stars?
- Does it trace the SFR?
- A long-running debate - e.g. Lonsdale Persson & Helou 1987; Walterbos & Greenawalt 1996;
- Recent evidence – e.g. Bendo et al. 2011; Boquien et al. 2011; Totani et al. 2011; Boselli et al.2012; etc etc

Sample and observations

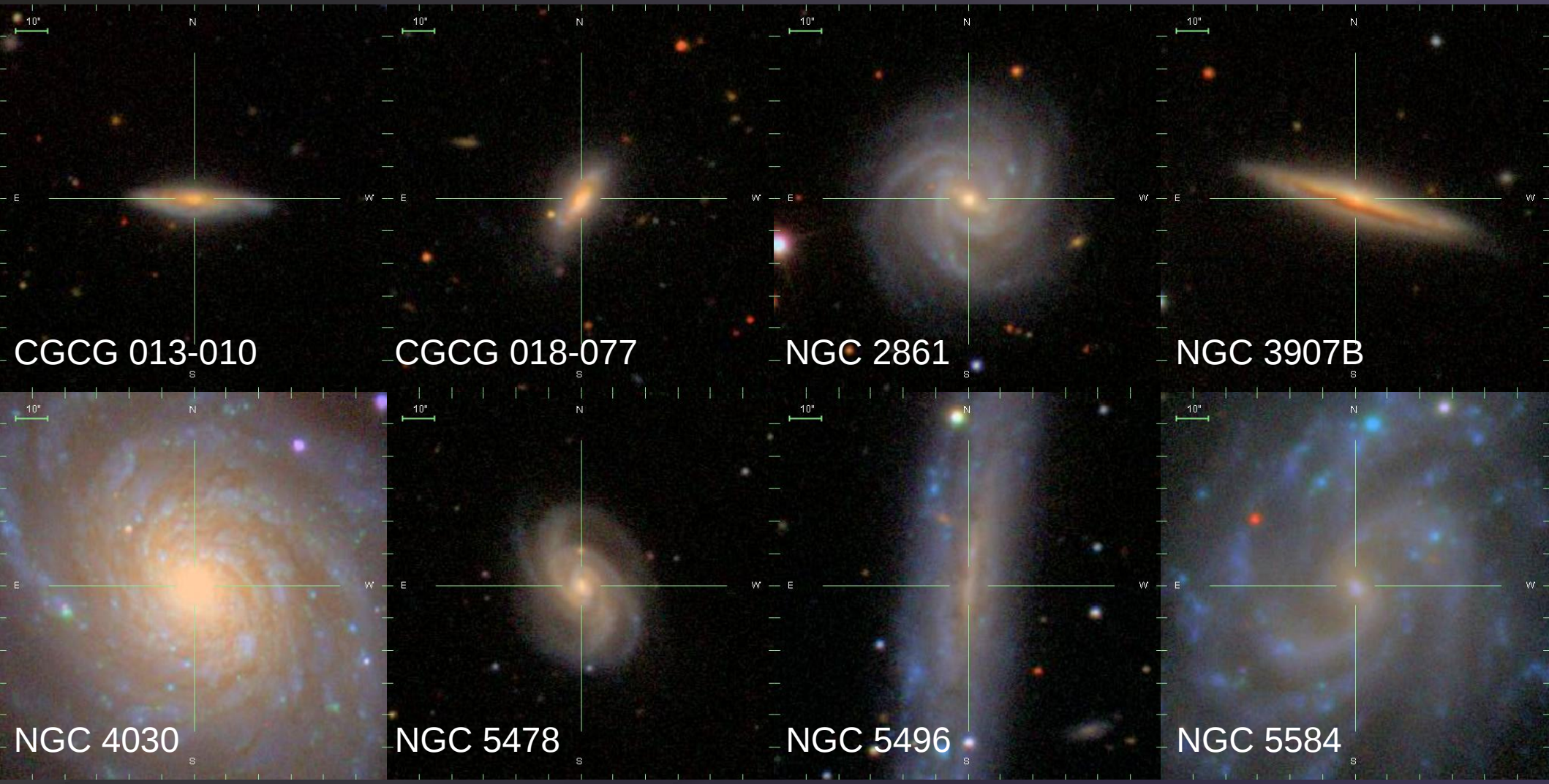
- 17 local (z<0.05) galaxies from H-ATLAS equatorial fields
- 500μm flux-limited sample
- FIR data covering the peak of the SED
- Cold SEDs – not bright IRAS sources, but (mostly) spirals whose gas and dust content have not been studied previously
- The dustiest galaxies in the local Universe

Need to test the correlation between sub-mm flux and CO tracers of the dense molecular gas

- CO observations at JCMT:
  - CO(3-2) on HARP
  - CO(2-1) on RxA
- Detecting total extended flux from CO in each of the galaxies
- Archival HI data from HIPASS

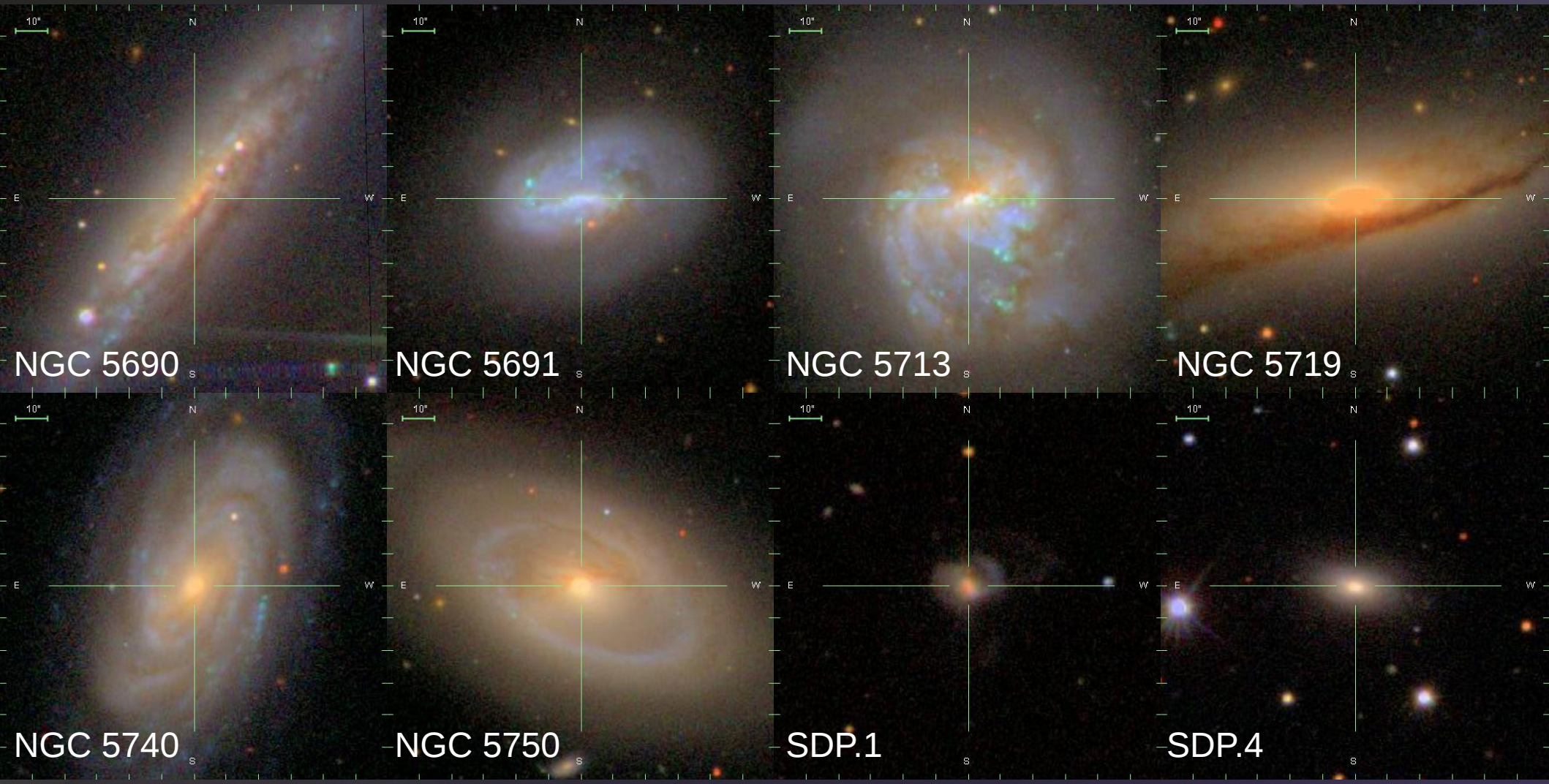


500μm-selected galaxies



- Blue and dusty spirals; extended sources; generally isolated
- Also included the three brightest early-types in SDP from Rowlands et al. 2012.

500μm-selected galaxies



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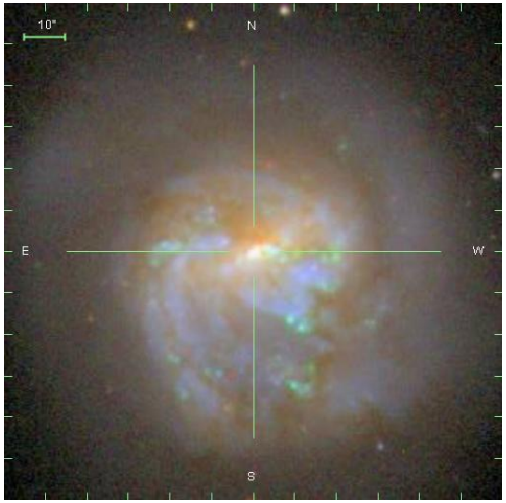
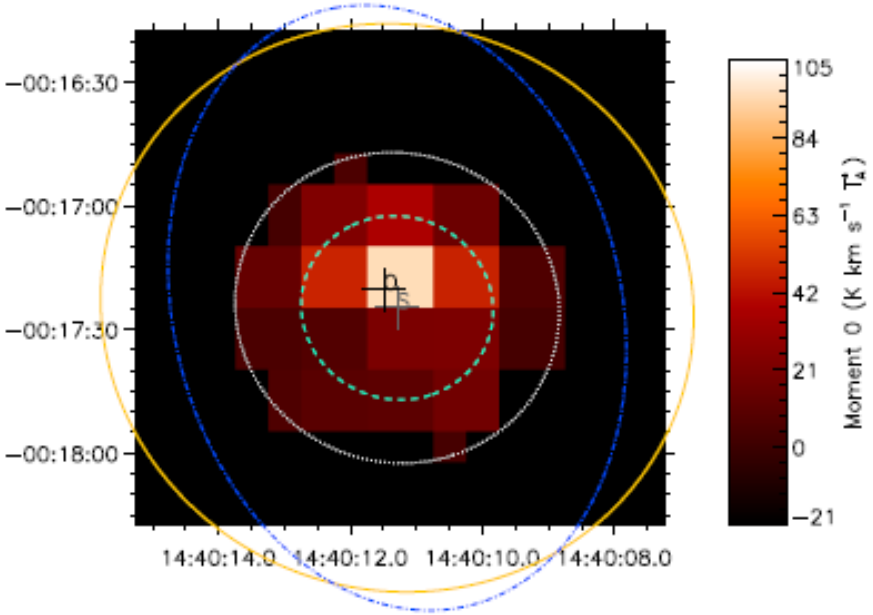
- Also included the three brightest early-types in SDP from Rowlands et al. 2012.

e.g. NGC 5713

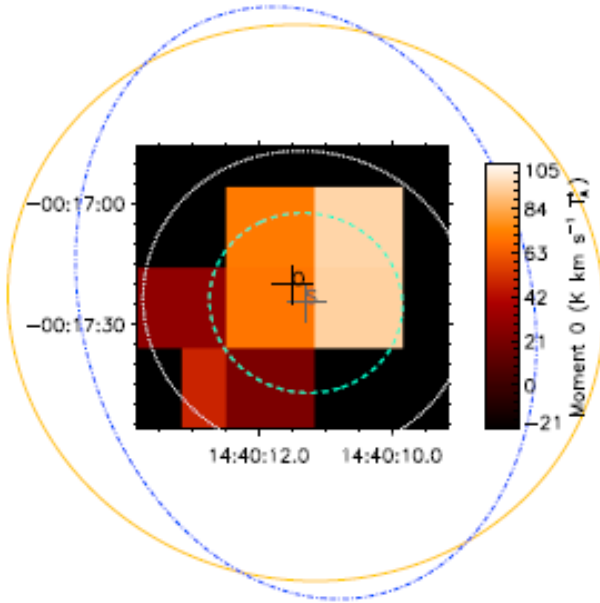
Sloan

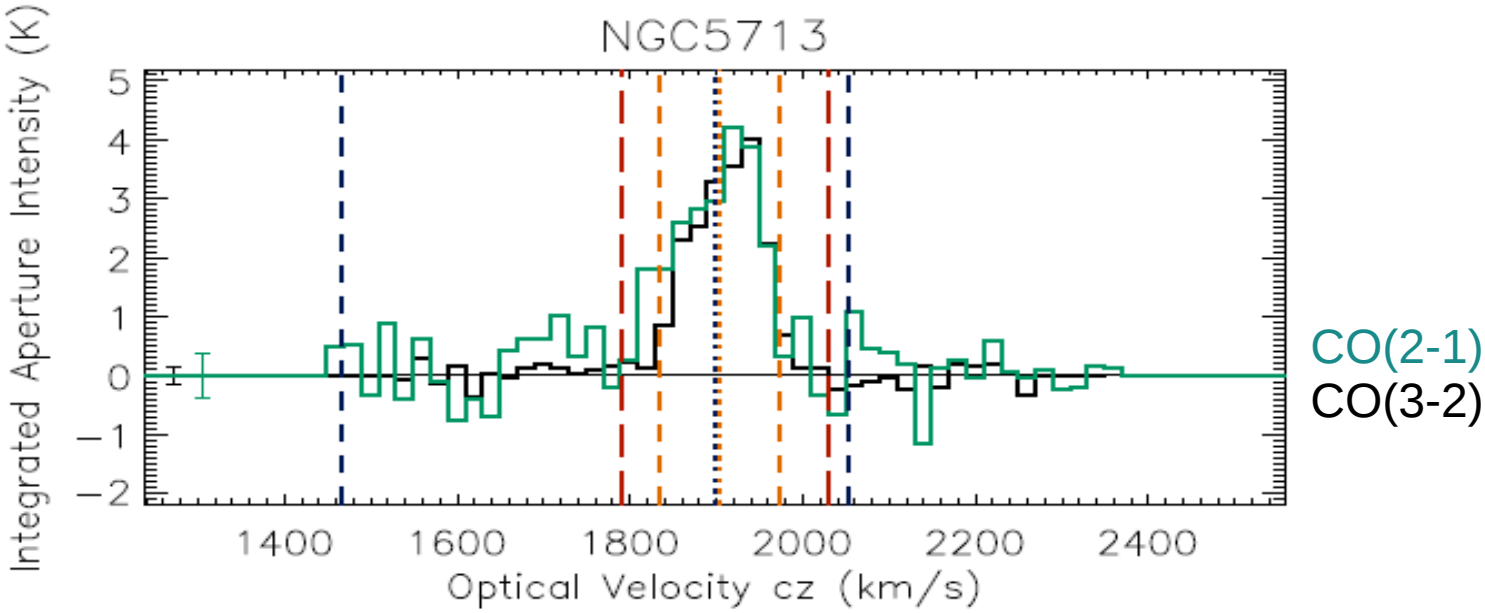


CO(3-2)



CO(2-1)

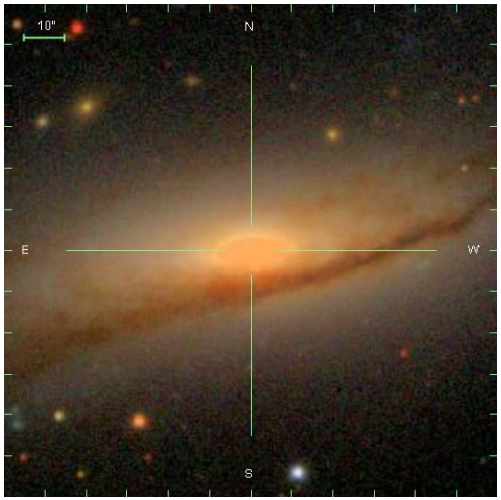




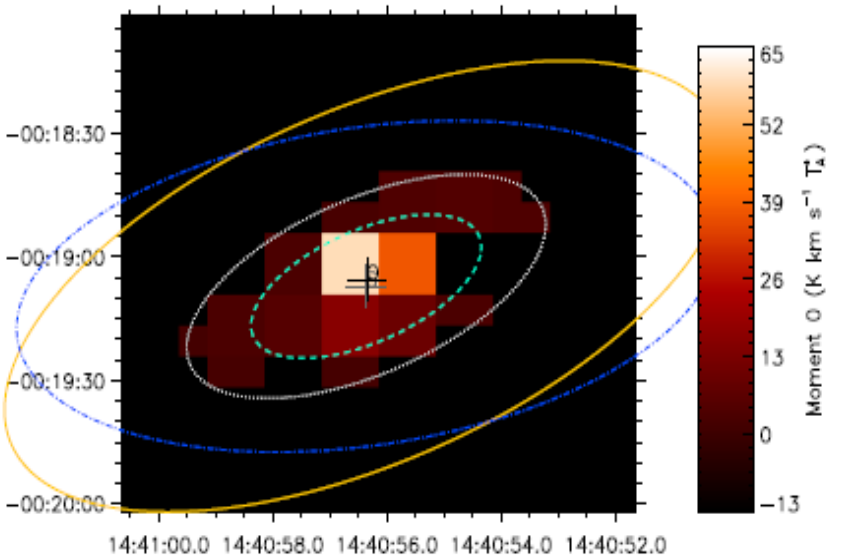
CO(2-1)
CO(3-2)

e.g. NGC 5719

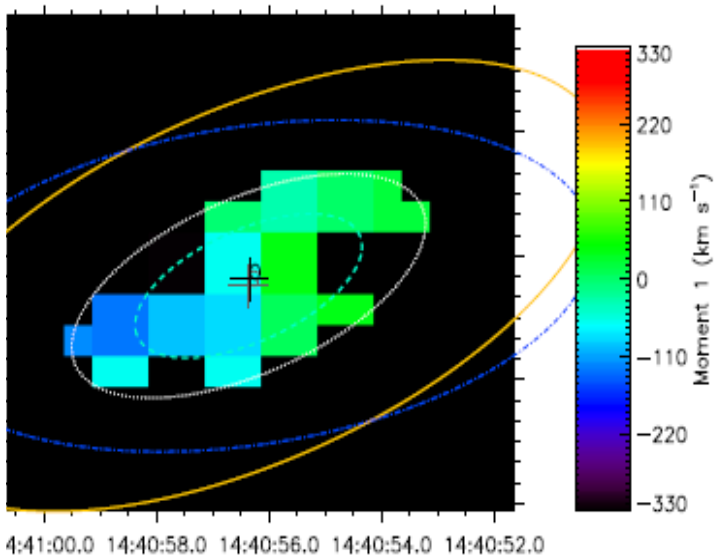
Sloan

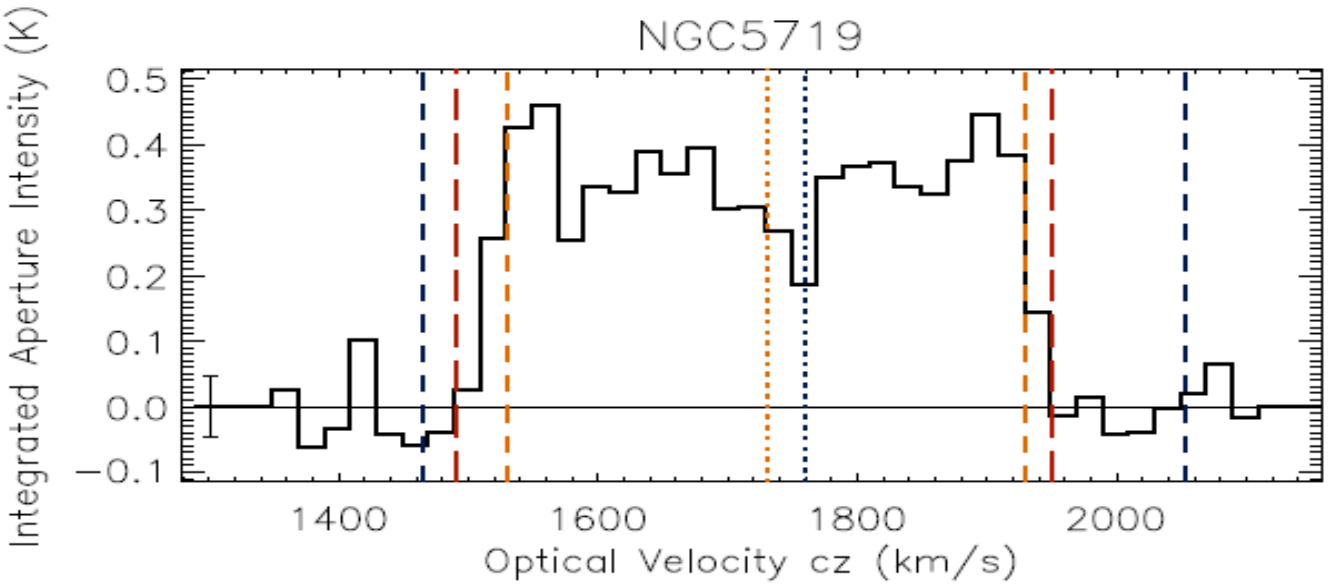


CO(3-2) moment 0



CO(3-2) moment 1

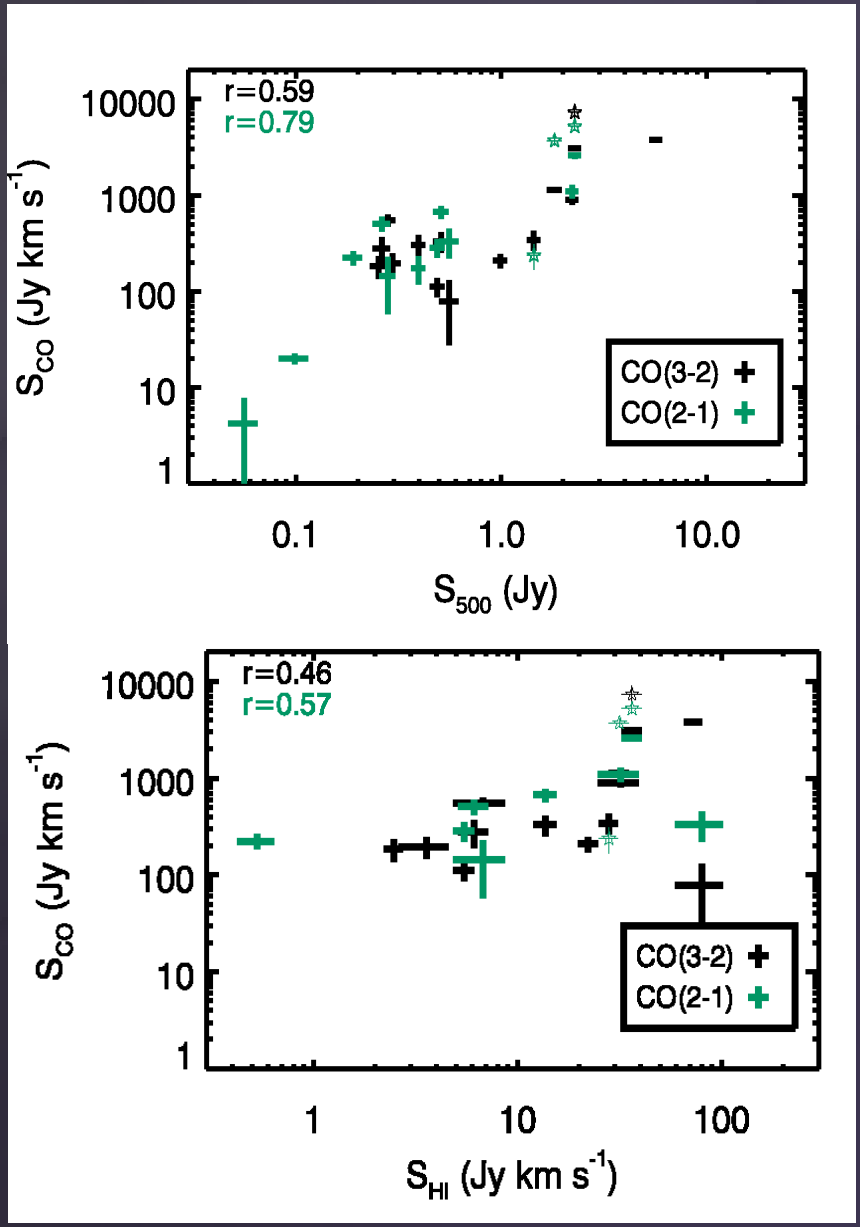




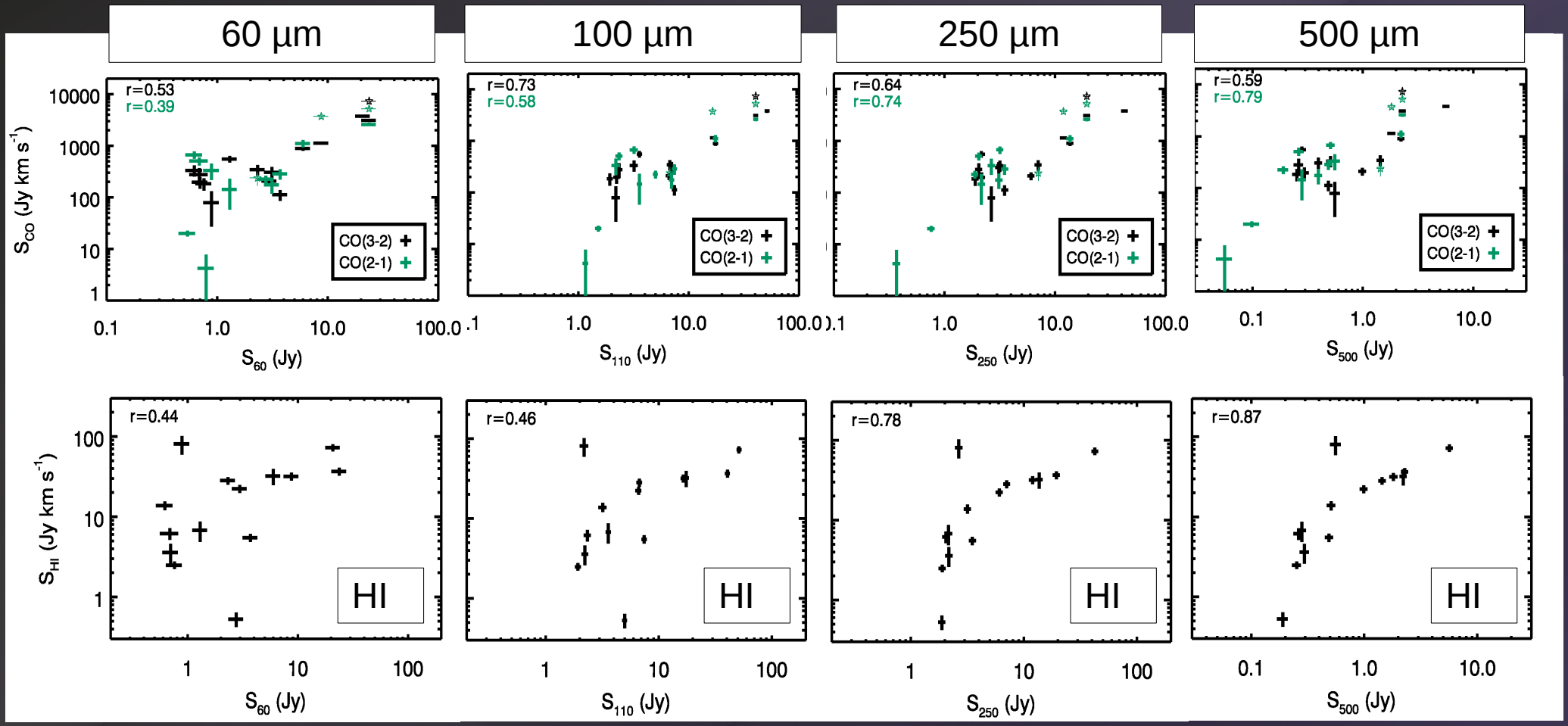
CO(3-2)

Looking for correlations in the results

- Total CO fluxes
  CO(3-2) → warm, dense H_2
  CO(2-1) → cooler, more diffuse
  H_2 ; total molecular mass
- HI from HIPASS
  → total atomic mass
- 60, 100μm from IRAS (Scanpi)
  → warm dust; total L_{IR}
- 100,160μm from PACS
- 250, 350, 500μm from SPIRE
  → cold dust; total dust mass

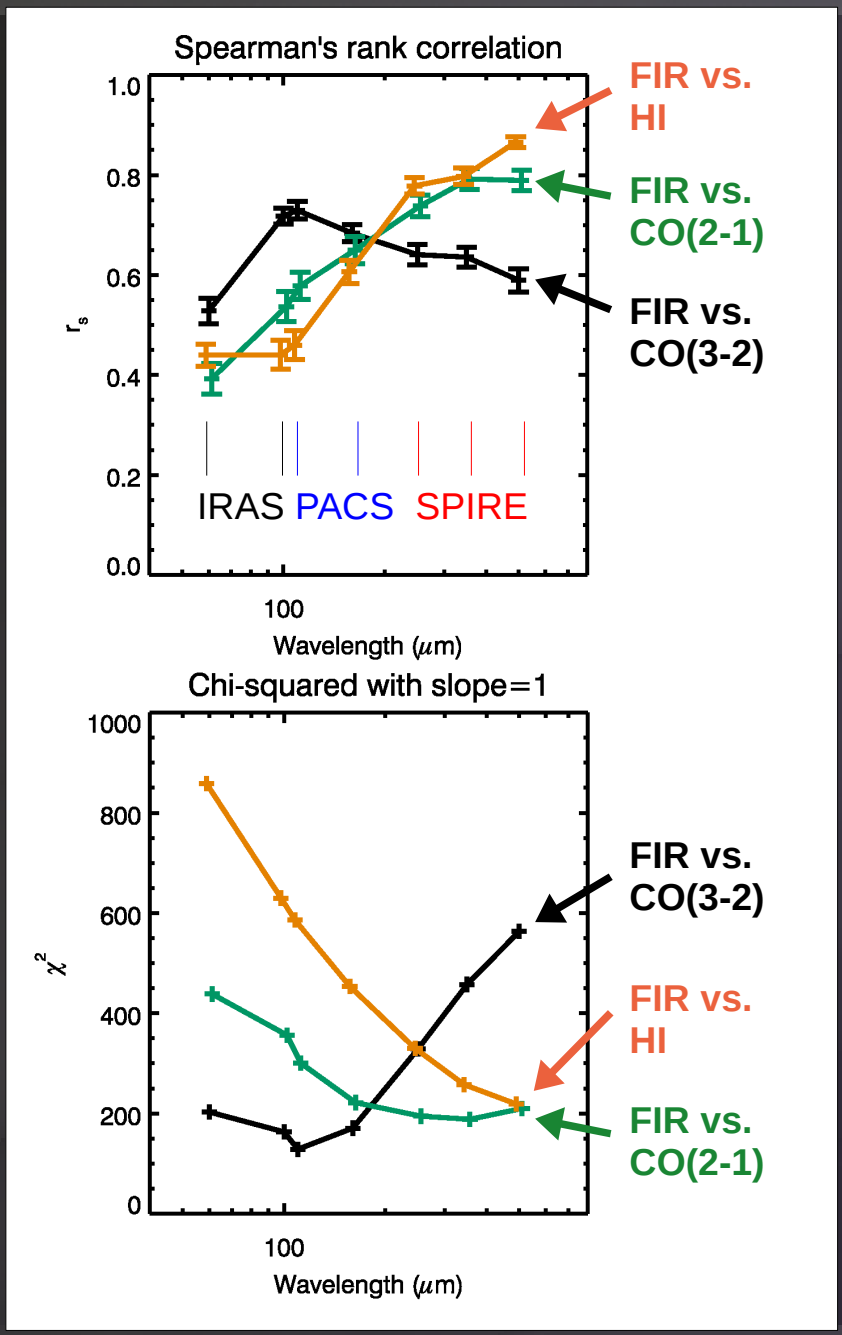


Longer wavelengths are less correlated with dense CO



… but are better correlated with HI

100μm traces dense gas; >250μm traces diffuse?



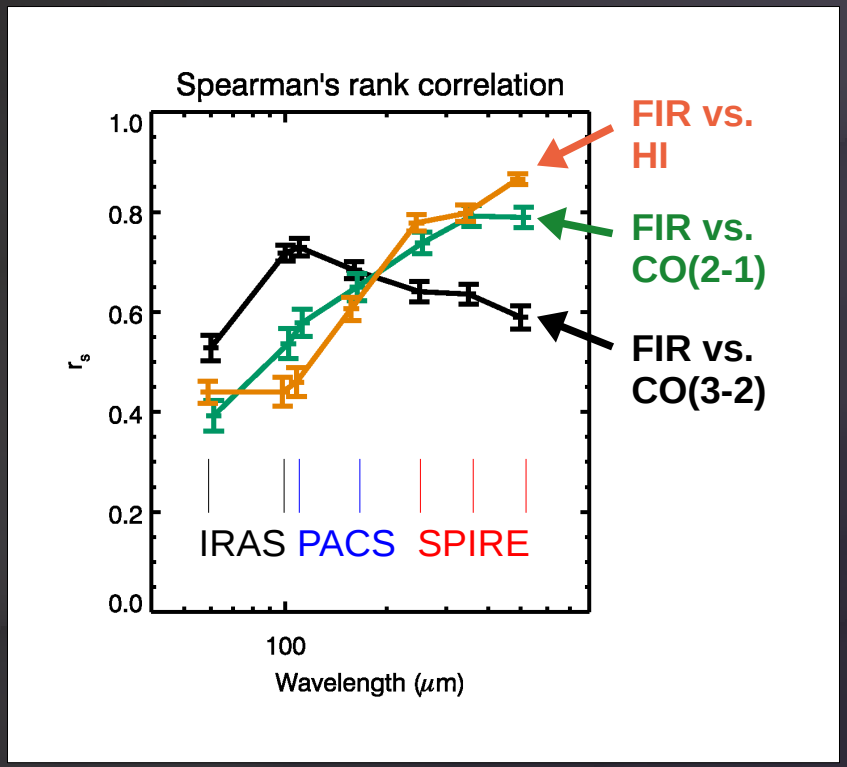
- CO(3-2) flux correlates best with 100μm
- CO(2-1) AND HI fluxes correlate better with flux at longer wavelengths
- Global sub-mm fluxes (>250μm) trace total gas mass
- But they are a poor tracer of dense molecular gas that fuels star formation
- Does this mean the cold dust is heated by evolved stars instead of young ones?

Cold dust heating by evolved stars

- Consistent with results from FIR colours in galaxies...
  - HRS galaxies – Boselli+2012
  - M33 – Boquien+2011 (HERM33ES) and Komugi+2011
  - JCMT Nearby Galaxies Legacy Survey (NGLS) – Bendo+2012
  - M31 – Smith+2012 (HELGA) , see also modelling by Groves+2012
- And recent results on the FIR – CO relationship in other samples
  - Virgo cluster spirals – Corbelli+2012 (HeVICS)
  - HI-selected galaxies in NGLS - Wilson+2012

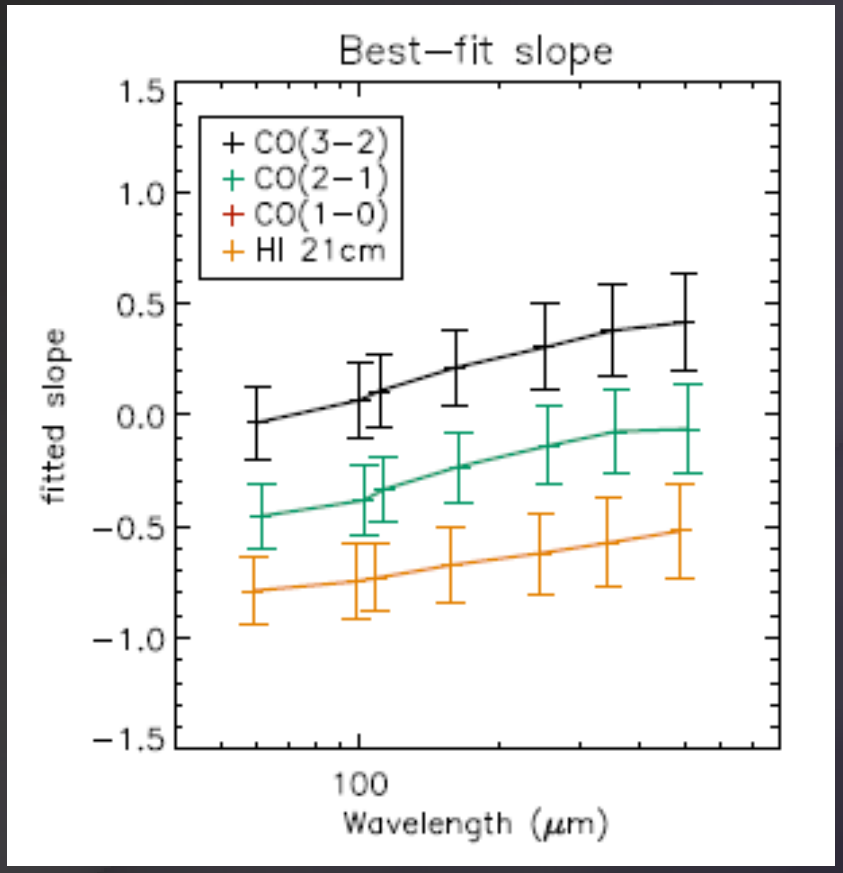
Conclusions

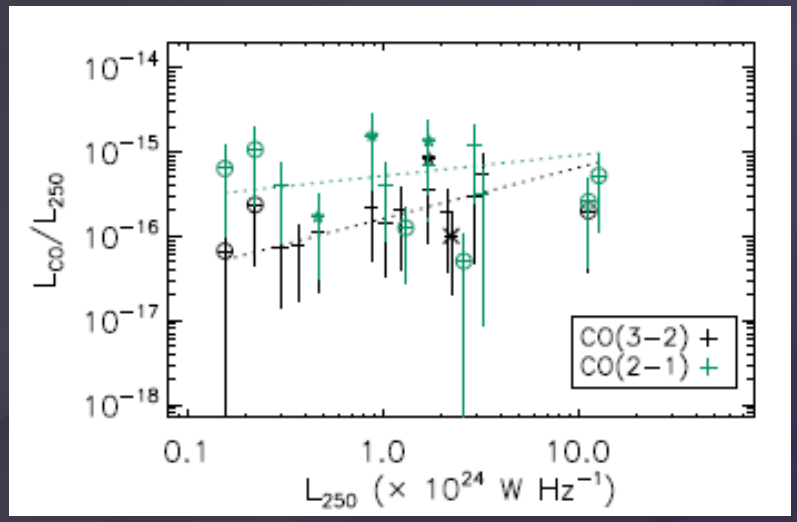
- A first look at the gas content of sub-mm selected galaxies in the local Universe
- CO is detected in most but the galaxies appear to be dominated by atomic gas: H2/HI in the range 0.05-0.9 (though uncertainty due to CO-to-H2 conversion)
- Dust/gas mass ratios in the range 0.002-0.009



- Scatter in the correlation between dust and gas tracers varies:
- CO(3-2), i.e. dense gas, is better correlated with 100µm
- CO(2-1), tracing cooler diffuse gas, is better correlated with 250-500µm
- HI is also better correlatd with sub-mm (although HI and CO(2-1) are poorly correlated)
- All consistent with cold dust being uncorrelated with SFR, and being heated by older stellar populations

Slope of the CO-FIR relation

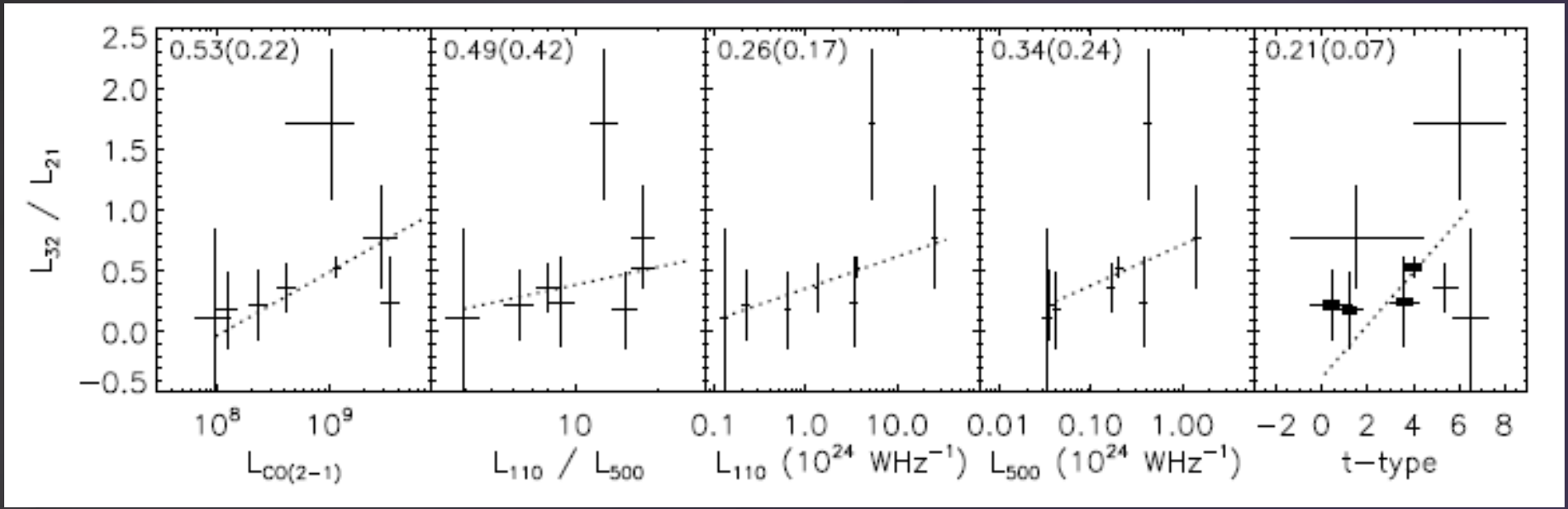




- Look at the ratios L_{CO}/L_{FIR} and L_{HI}/L_{FIR} versus L_{FIR}
- Fitting for the slope:
  - Steeper slopes for longer wavelengths
  - And for denser gas tracers

Line ratios

- CO(3-2) / CO(2-1) in the range 0.0-1.0 – apart from one outlier
- No strong correlations with any luminosities or morphological type



Gas and dust masses

- Most galaxies appear to be HI-dominated
  - H2/HI in the range 0.05-0.9 - based on CO(2-1) where available
- Dust/gas mass ratios in the range 0.002-0.009
- Total gas masses ~10^{9}-10^{10} M_{sun}
- Total dust masses ~10^{7}-10^{8} M_{sun}

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- Total gas masses ~10^{9}-10^{10} M_{sun}
- Total dust masses ~10^{7}-10^{8} M_{sun}
- Cold dust temperature correlated with CO luminosity and gas/dust?