Herschel-ATLAS: Understanding tracers of dust and gas

A CO survey of local sub-mm selected galaxies

Nathan Bourne and the H-ATLAS team

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

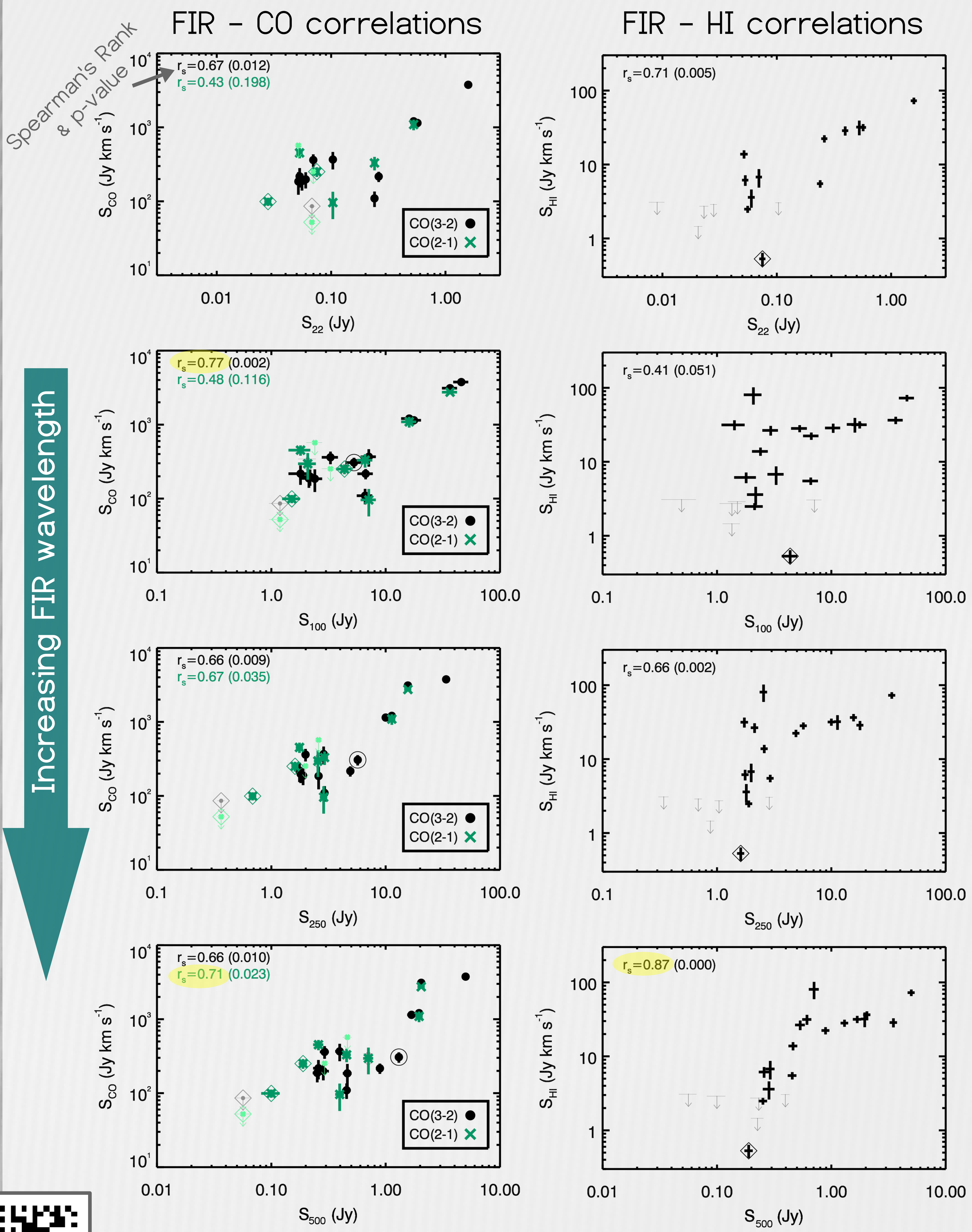
nbourne22@gmail.com

Introduction

We present an analysis of the relationships between different components of the interstellar medium (ISM), in a novel sample of **20 dusty spiral galaxies and early types** selected at 500 microns in the local Universe. Using extensive photometric coverage of the far-infrared (FIR) spectral energy distribution (SED), we measure correlations between the continuum flux at various wavelengths and various spectral line tracers of the ISM.

We have mapped the 500-micron selected galaxy sample in the CO(3-2) and CO(2-1) lines using JCMT observations, and we use archival 21cm spectra from HIPASS for HI line measurements. The motivation for this work is to understand whether FIR and sub-mm photometry are reliable tracers of the ISM and/or star formation rate (SFR) in cold-dust dominated galaxies.

Figure 2 How well do CO/HI and FIR fluxes correlate?

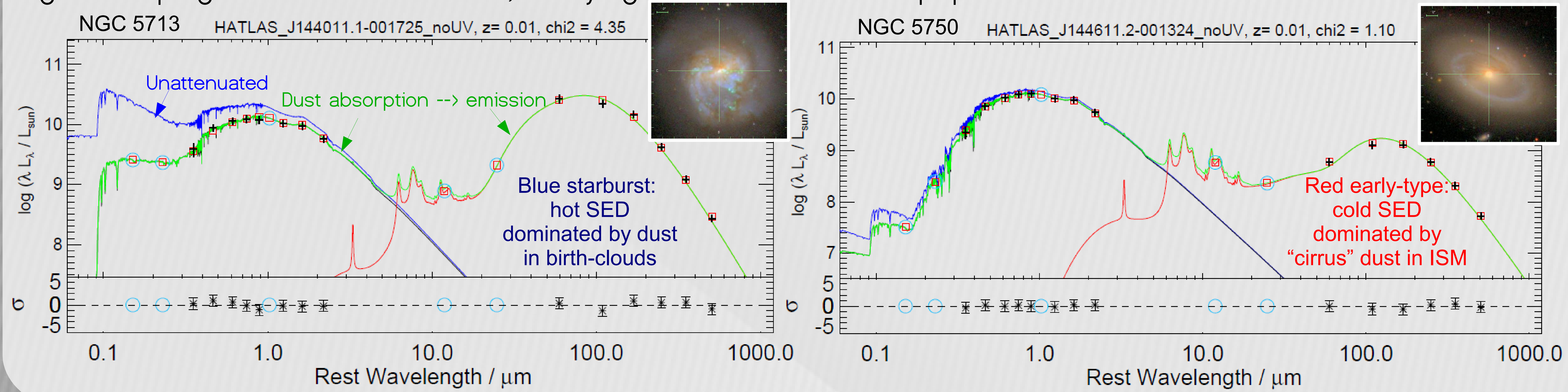


CO(3-2) (black) best correlated with FIR flux near the SED peak ~100μm

HI is better correlated with sub-mm flux at 500μm

Figure 1 The spectral energy distribution of dust emission:

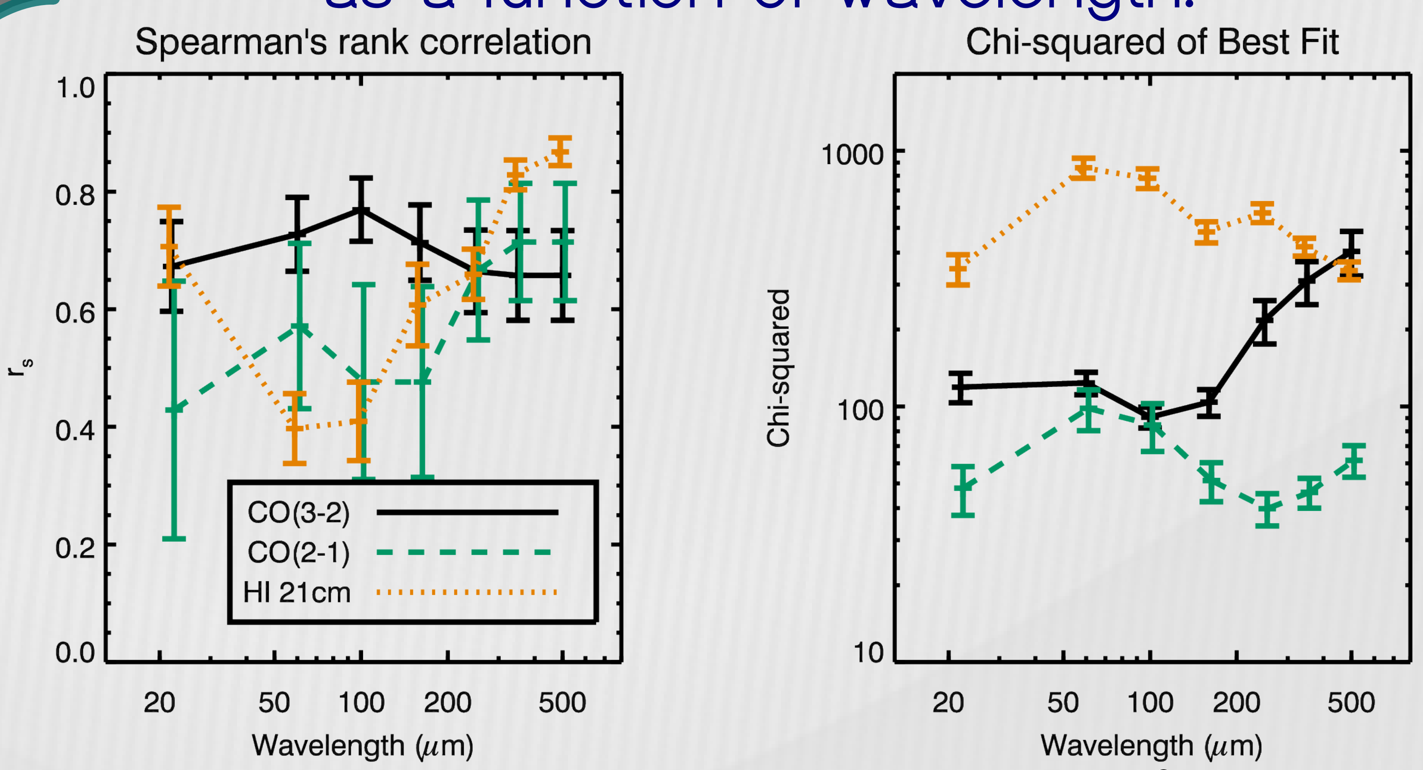
These example SEDs (fitted to galaxies in our sample using Magphys[1,2]) illustrate that thermal dust emission at λ>20μm can take different forms depending on the relative contributions from dust in different phases of the ISM. Emission near the ~100μm peak of the SED is dominated by dust in stellar birth-clouds heated by young stars, and is correlated with the SFR[3]. Longer (sub-mm) wavelengths are dominated by cold dust in the large-scale ISM: this may be heated by UV light escaping from the birth-clouds, or by light from older stellar populations.[4,5,etc]



Gas Tracers

Molecular gas (H_2) in galaxies is commonly traced by the more readily observable rotational CO emission lines. High excitation lines such as CO(3-2) trace the warmer, denser gas that is the direct fuel for star formation. The lower excitation temperatures of the CO(1-0) and CO(2-1) lines mean that they are better tracers of the total H_2 mass.[6]

Figure 3 The FIR-CO and FIR-HI correlations as a function of wavelength:



- We measured Spearman's rank (r_S) and χ^2 for correlations with 22-500μm fluxes from WISE, IRAS, & Herschel.
- Spearman's rank for CO(3-2) is highest for λ=100μm and declines towards both shorter and longer wavelengths.
- For HI the trend is reversed.
- CO(2-1) appears to follow the same trends as HI at λ>60μm, but more data are needed to confirm this.
- Analogously, the scatter (χ^2) in the correlations follows the opposite trends to r_S

Conclusions

Our results have implications for the relationships between different dust and gas phases in the ISM:

- From Figure 3 we deduce that dense molecular gas [responsible for CO(3-2) emission] is more strongly associated with warm dust (which dominates at λ~100μm) than cold dust (which dominates at λ≳250μm). This is consistent with the notion of dense gas being the fuel for ongoing star formation, which is directly traced by emission from warm dust.
- On the other hand, if CO(2-1) and HI trace the molecular and atomic gas masses respectively, we would expect them to be correlated with the warm dust (~SFR) as a result of the Schmidt-Kennicutt law[7,8], yet the correlation at λ~100μm is poor. These tracers are better correlated with the sub-mm, suggesting that the gas mass is more closely linked to the total dust mass via the dust/gas ratio.
- The high level of scatter in the correlations between dense CO and the sub-mm suggests that the sub-mm does not directly trace SFR, but rather diffuse dust (and gas) which is not associated with star formation.
- The 22 & 60μm fluxes correlate worse with CO(3-2) and better with HI compared with 100μm, suggesting an emission component that is uncorrelated with SFR. This is likely to be very-small grain emission, which appears to be better correlated with the diffuse phase of the ISM than with dense molecular clouds.[9,10]

References

1 Da Cunha et al. 2008, MNRAS, 388, 1595
2 Smith, D.J.B. et al. 2012, MNRAS, 427, 703
3 Kennicutt 1998a, ARA&A, 36, 189
4 Walterbos & Greenawalt 1996, ApJ, 460, 696
5 Bendo et al. 2010, A&A, 518, L65
6 Young & Scoville 1991, ARA&A, 29, 581
7 Schmidt 1959, ApJ, 129, 243
8 Kennicutt 1998b, ApJ, 498, 541
9 Draine & Anderson 1985, ApJ, 292, 494
10 Compiegne et al. 2011, A&A, 525, A103