The Spatial Extent of (U)LIRGs in the Mid-Infrared: Nuclear and Extended emission

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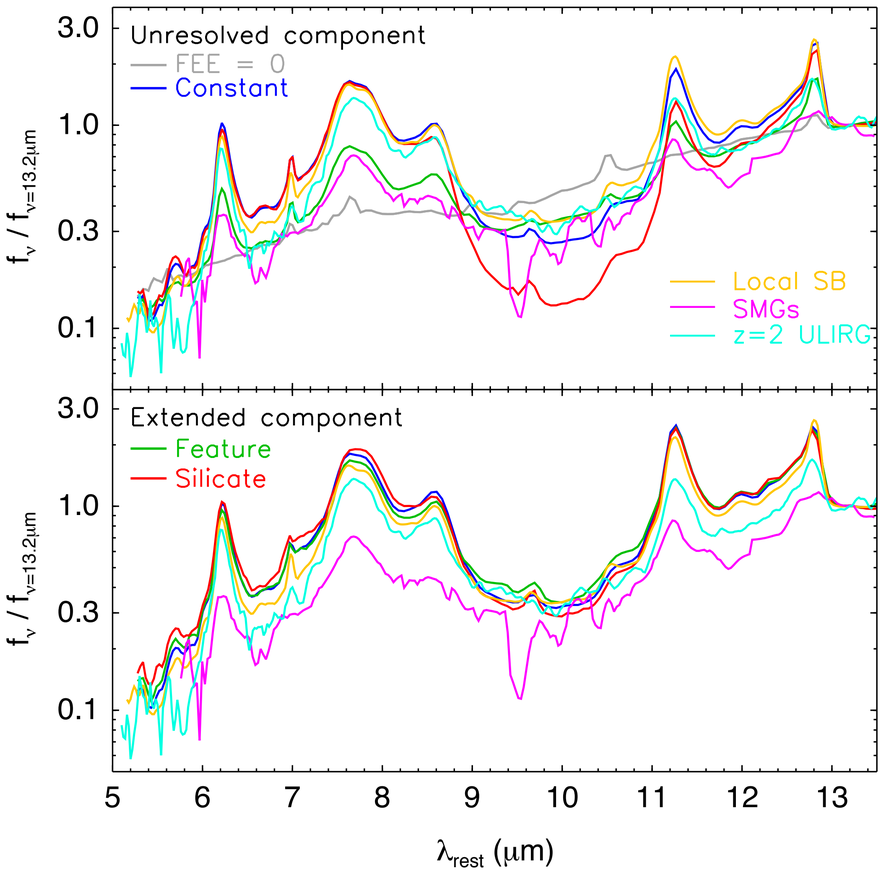
We present results from our analysis of the extended mid-infrared (mid-IR) emission of the Great Observatories All-Sky LIRG Survey (GOALS) sample based on 5-14μm low-resolution spectra obtained with the Infrared Spectrograph on Spitzer. We calculate the fraction of extended emission as a function of wavelength for all galaxies in the sample, FEE_λ, defined as the fraction of the emission that originates outside of the unresolved central component of a source, and spatially separate the mid-IR spectrum of a galaxy into its nuclear and extended components. We find that the [Ne II]12.81 μm emission line is as compact as the hot dust MIR continuum, while the polycyclic aromatic hydrocarbon (PAH) emission is more extended. the 6.2 and 7.7μm PAH emission is more compact than that of the 11.3μm PAH, which is consistent with the formers being enhanced in a more ionized medium. The presence of an AGN or a powerful nuclear starburst increases the compactness of the mid-IR continuum but has a negligible effect on the spatial extent of the PAH emission on kpc-scales. Globally, the 5-14μm spectra of the extended emission component are homogeneous for all galaxies in the GOALS sample, suggesting that the physical properties of star formation occurring at distances > 1.5kpc from the nuclei of (U)LIRGs are very similar, resembling local star-forming galaxies with lower IR luminosities as well as star formation-dominated ULIRGs at z ~ 2. In contrast, the mid-IR spectra of the nuclear component of local ULIRGs and LIRGs are very diverse. These results imply that the observed variety of the integrated MIR properties of local (U)LIRGs arise, on average, only from the processes that are taking place in their cores.

1) The Sample

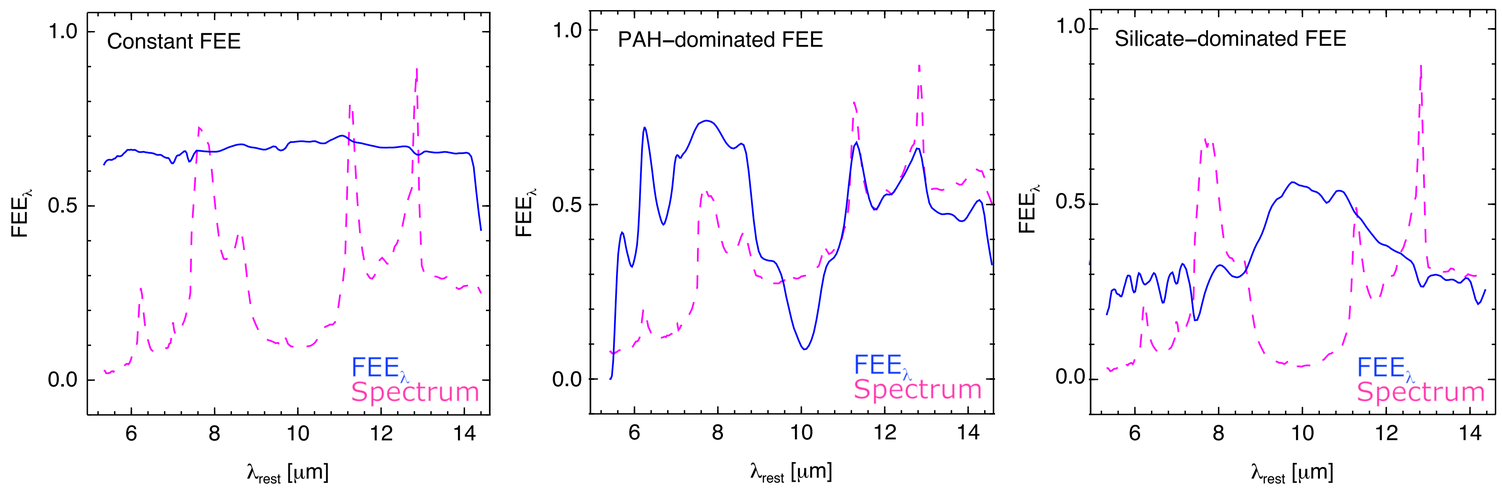
We base our study on the Great Observatories All-Sky LIRG Survey (GOALS) sample (Armus et al. 2009). GOALS comprises a complete, flux-limited sample of (U)LIRGs in the local Universe drawn from the *IRAS* Revised Bright Galaxy Sample. The sample covers uniformly the full range of nuclear spectral types and interaction. A total of 221 galaxies are used for this study. All galaxies in GOALS have been observed in staring mode with *Spitzer*-IRS. Our analysis is based on IRS staring observations, ranging from ~ 5 to 14μm. The median distance of our galaxy sample is 95 Mpc, at which the spatial resolution is 1.7 kpc at 13.2μm. The aim of the study is to separate and quantify the extended emission of (U)LIRGs from the contribution of the unresolved nuclear component. For each wavelength resolution element of IRS, we scale the peak of the spatial profile of a stellar PSF to the maximum of the spatial profile of the galaxy and subtract it. What remains is the the extended emission (EE_λ) of the galaxy at a given wavelength. This quantity, divided by the integrated emission of the galaxy along the slit, for each wavelength, is what we define as the fraction of extended emission (FEE_λ). That is, we define the FEE_λ as the fraction of the emission that originates outside of the unresolved central component of a source:

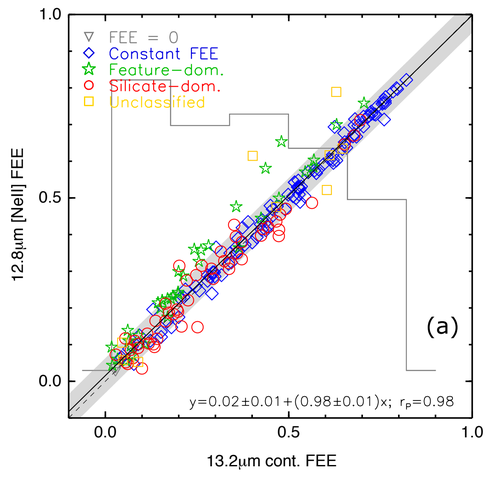
$$FEE_\lambda = \frac{EE_\lambda}{\text{Total emission}_\lambda}$$

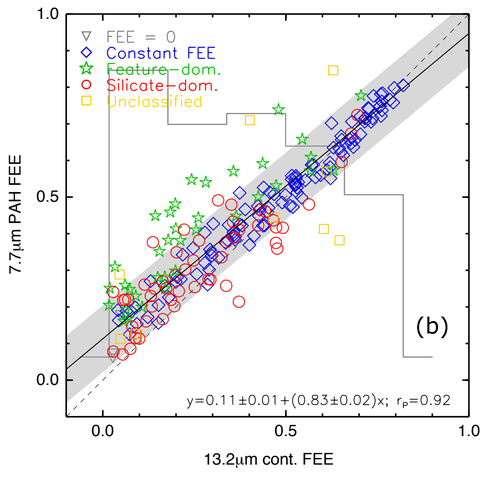
3) Spectra of Nuclear and Extended Emission

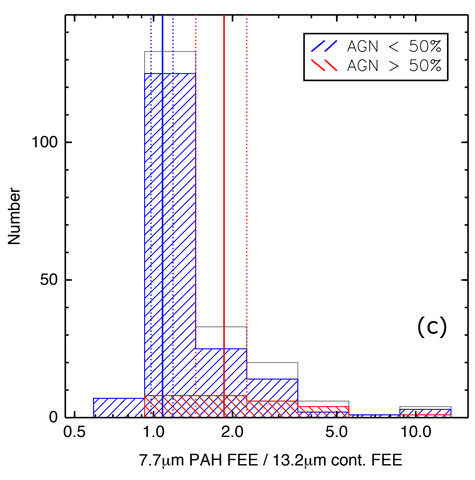


2) FEE types and Compactness at Different Wavelengths



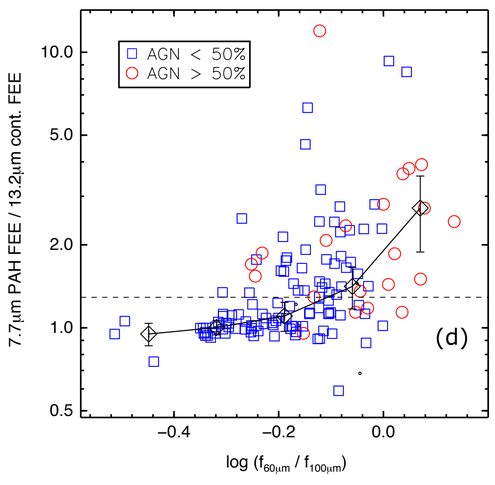






- The intensity of the spectral features (PAHs, emission lines and 9.7 μm silicate absorption) of the extended components are very similar in all FEE_λ types, which suggests that the global physical properties of the star formation in the external parts (disks) of LIRGs (d > 1.5 kpc) are likely the same.
- The averaged spectra of the extended emission of all FEE_λ types resemble that of lower IR luminosity starburst and star-formation dominated ULIRGs at z~2.
- The spectra of the unresolved component are substantially different. Thus, the variety of the integrated mid-IR properties of local (U)LIRGs arise, on average, only from the processes that are taking place in their cores

- (a): The 12.8μm [NeII] line emission is as compact as the 13.2μm continuum implying that the physical processes that are responsible for the [NeII] line and mid-IR continuum are equally concentrated and that, probably, are in fact the same process.
- (b): The 7.7μm (and 6.2μm) PAH emissions are slightly more extended than that of the mid-IR continuum (and the [NeII] emission).
- (c) The presence of an AGN modifies the spatial extent of the hot dust continuum but has a negligible effect on the overall, kpc-scale distribution of the PAH emission. (d) A nuclear, compact starburst also increases the compactness of the mid-IR continuum.



- Armus et al. 2009, PASP, 212, 559
- Diaz-Santos, et al. 2010, ApJ, 723, 993
- Diaz-Santos, et al. 2011, ApJ, in press, arXiv:1107.5958