A multi-wavelength exploration of the [C II] deficit in *H*-ATLAS/GAMA galaxies out to $z = 0.2$

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Abstract

We explore the behaviour of [C II] $\lambda 157.74\,\mu$m forbidden fine-structure line observed in a sample of 28 galaxies selected from $\sim 50\,\mathrm{deg}^2$ of the *H*-ATLAS survey. The sample is primarily constructed using galaxies with $160\,\mu$m flux densities higher than 150 mJy and optical spectra from the GAMA survey. Far-IR spectra centred on this redshifted line were taken with the Photodetector Array Camera and Spectrometer (PACS) on-board the *Herschel Space Observatory*. The galaxies span $0.02 < z < 0.2$, with $10 < \log(L_{\rm IR}/\mathrm{L}_\odot) < 12$ (where $L_{\rm IR} \equiv L_{\rm IR}[8-1000\mu\mathrm{m}]$) and $7.2 < \log(L_{\rm [CII]}/\mathrm{L}_\odot) < 9.4$, covering a variety of dust-emitting galaxy morphologies, including face- and edge-on disks, ellipticals and irregulars. The sample exhibits the so-called [C II] deficit at high IR luminosities ($L_{\rm IR}$), i.e. $L_{\rm [C\,II]}/L_{\rm IR}$ (hereafter [C II]/IR) decreases at high $L_{\rm IR}$. We find significant differences between those galaxies presenting [C II]/IR $> 2.5 \times 10^{-3}$ with respect to those showing lower ratios. In particular, we find that galaxies with high ratios tend to have: (1) $L_{\rm IR} < 10^{11}\,\mathrm{L}_\odot$; (2) colder dust temperatures, often $T_{\rm d} < 30\,\mathrm{K}$; (3) the presence of disk-like morphologies in SDSS r-band images; (4) *WISE* colours in the range $0.5 < S_{12\mu\mathrm{m}}/S_{22\mu\mathrm{m}} < 1.0$; (5) low surface brightness $\Sigma_{\rm IR} \approx 10^{8-9}\,L_\odot\,\mathrm{kpc}^{-2}$, (6) and a wide range of specific star-formation rates, $\mathrm{sSFR} \approx 0.01-3\,\mathrm{Gyr}^{-1}$. We suggest that the main parameter responsible for controlling the [C II]/IR ratio is the strength of the far-UV radiation fields ($<G_{\rm O}>$). It is possible that relatively high $<G_{\rm O}>$ create a positively charged dust grain distribution, impeding an efficient photo-electric extraction of electrons from these grains to then collisionally excite carbon atoms. We find that within the brighter IR population, $11 < \log(L_{\rm IR}/\mathrm{L}_\odot) < 12$, the [C II] deficit is unlikely to be produced by [C II] self absorption or controlled by the presence of a moderately luminous AGN (identified via the BPT diagram).