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Photon dominated regions in the spiral arms of nearby galaxies

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Abstract. We present [CII] $^3P_1$–$^3P_0$ spectra at four spiral arm positions and the nuclei of the nearby galaxies M83 and M51 obtained at the JCMT. The spiral arm positions lie at galactocentric distances of between 2 kpc and 6 kpc. This data is complemented with maps of CO 1–0, 2–1, and 3–2, and ISO/LWS far-infrared data of [CII] (158 μm), [OI] (63 μm), and [NII] (122 μm) allowing for the investigation of a complete set of all major gas cooling lines. From the intensity of the [NII] line, we estimate that between 15% and 30% of the observed [CII] emission stem from the dense ionized phase of the ISM. The analysis indicates that emission from the diffuse ionized medium is negligible. In combination with the FIR dust continuum, we find gas heating efficiencies below $\sim$ 0.21% in the nuclei, and between 0.25 and 0.36% at the outer positions. Comparison with models of photon-dominated regions (PDRs) of Kaufman et al. (1999) with the standard ratios [OI](63)/[CII]$_{\rm PDR}$ and ([OI](63)+[CII]$_{\rm PDR}$) vs. TIR, the total infrared intensity, yields two solutions. The physically most plausible solution exhibits slightly lower densities and higher FUV fields than found when using a full set of line ratios, [CII]$_{\rm PDR}$/[CI](1–0), [CI](1–0)/CO(3–2), CO(3–2)/CO(1–0), [CII]/CO(3–2), and, [OI](63)/[CII]$_{\rm PDR}$. The best fits to the latter ratios yield densities of 10^4 cm^{-3} and FUV fields of $\sim$ G_0 =20–30 times the average interstellar field without much variation. At the outer positions, the observed total infrared intensities are in perfect agreement with the derived best fitting FUV intensities. The ratio of the two intensities lies at 4–5 at the nuclei, indicating the presence of other mechanisms heating the dust. [CI] area filling factors lie below 2% at all positions, consistent with low volume filling factors of the emitting gas. The fit of the model to the line ratios can be significantly improved by assuming that [CI] stems from a larger region than CO 2–1. Improved modelling would need to address the filling factors of the various submm and FIR tracers, taking into consideration the presence of density gradients of the emitting gas by including cloud mass and size distributions within the beam.

Keywords. galaxies: ISM, galaxies: individual (M83, M51), submillimeter, infrared: galaxies