A Multi-Scale Study of IR and Radio Emission from M33

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Abstract. The origin of the tight radio–IR correlation in galaxies has not been fully understood. One reason is the uncertainty about which heating sources (stars or diffuse interstellar radiation field) provide the energy that is absorbed by dust and re-radiated in IR. Another problem is caused by comparing the IR emission with the thermal and nonthermal components of the radio continuum emission separated by simplistically assuming a constant nonthermal spectral index. We use the data at the \textit{Spitzer} MIPS wavelengths of 24, 70, and 160 $\mu$m, as well as recent radio continuum map at 3.6 cm observed with the 100–m Effelsberg telescope. Using the wavelet transformation, we separate diffuse emission components from compact sources and study the radio-IR correlation at various scales. We also investigate the IR correlations with the thermal and nonthermal radio emissions separated by our developed method. A H\textalpha map serves as a tracer of star forming regions.

1. Wavelet Analysis of MIPS

The 2D-wavelet transformation is a useful tool to separate diffuse emission from that of compact sources (e.g. Frick et al. 2001). A comparison of the wavelet-decomposed images of MIPS (Hinz et al. 2004) indicates that the 24 and 70 $\mu$m emission emerge mostly from the compact structures corresponding to star forming and HII regions. The 160 $\mu$m emission emerges from both compact and extended structures. The 160 $\mu$m wavelet spectrum (Tabatabaei et al. 2005, 2007a) shows an increase when it reaches the scale of complexes of dust and gas clouds of $\sim 1$ kpc, and a second increase in transition to the large-scale structures of diffuse dust emission.

2. Radio ($\lambda$3.6 cm)- FIR and H\textalpha Correlations

The 3.6 cm emission from M33 (Tabatabaei et al., 2007b) shows better correlations with warm than with cold dust at scales smaller than the width of the spiral arms (1.6 kpc). The results were compared before and after subtracting the 11 brightest HII regions. Comparing with the H\textalpha map, the role of star forming regions in heating the dust, even the cold dust, is generally important at scales up to 4 kpc.

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After separating the thermal and nonthermal components of the radio continuum emission (using the de-extincted Hα map as a thermal emission template, Tabatabaei et al. 2007c), not only the stronger warm dust–thermal radio than the cold dust–nonthermal radio correlation is proved, but also a stronger warm dust–nonthermal radio than the cold dust–nonthermal radio correlation is found (Fig. 1). It is also found that the cold dust has a better correlation with the thermal than with the nonthermal emission. The IR–nonthermal radio correlation is better at scales between 0.8 and 2 kpc, scales including giant molecular clouds, spiral arms, and the central extended region of M33.

3. Conclusions

- HII regions influence the IR emission with a strength inversely depending on wavelength: more influence at 24 µm and less influence at 160 µm.
- The nonthermal radio emission correlates well with the thermal radio and Hα emission out to the scale of the central extended region, 2.5 kpc.
- The warm dust–thermal radio correlation is much stronger than the cold dust–nonthermal radio correlation at scales smaller than 4 kpc.
- At these scales, the role of UV photons from O/B stars in heating the cold dust is more significant than of other energy sources.
- The better correlation of the nonthermal emission with the 24 µm than with the 160 µm indicates that magnetic field is stronger in the star forming regions. However, there is no indication that the magnetic field is enhanced at scales of the HII complexes.

References

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