The interstellar medium (ISM) is the amount of gas, dust, energetic particles, and magnetic fields that lie in the vast interstellar spaces between the stars. It plays a fundamental role in the evolution of stars and galaxies.

The physical conditions in the ISM cover an enormous range, from cold molecular clouds to hot ionized gas. In addition, there are relativistic particles, magnetic fields and dust grains of varying size and temperature.

This huge range in the physical conditions means that the characteristics of the radiation emitted by the ISM also vary enormously: the ISM is a powerful source of radiation throughout the whole electromagnetic spectrum, from radio to gamma rays.

Observations of spiral galaxies have revealed correlations between different properties of the ISM.

The tightest one is certainly that between the far-infrared (FIR) and radio-continuum (RC) emission (e.g. Yun et al. 2001), usually explained invoking massive-star formation. Furthermore, it has been established that the CO line emission, used as tracer of molecular content in galaxies, is well correlated with the RC emission on global and intermediate scales (Rickard, Turner & Palmer 1977; Israel & Rown-Robinson 1984; Adler, Allen & Lo 1991; Murgia et al., 2002).

What is most extraordinary of these correlations is that they couple emissions produced by completely different processes. The RC at centimeter wavelengths is, for the most part, non-thermal synchrotron radiation of the relativistic electrons interacting with the ambient magnetic field in which they diffuse.

The FIR emission arises from dust heated by massive stars. The CO emission is produced from giant, turbulent, cloud complexes and traces the bulk of molecular gas in
which star formation occurs.

The usual explanation of these correlations invokes massive-star formation in giant molecular clouds, which accounts for the non-thermal radio luminosity via supernova events, and for the FIR luminosity by means of massive stars heating the dust (Wunderlich & Klein 1988). Giving the many disparate steps, the completely different physics, and the different time scales for the various processes, the tightness of the correlations is surprising indeed.

For instance we know that the relativistic electrons diffuse from their birthplaces, and thus we would expect that the spatial correlation of the RC and FIR or CO emission breaks down below the characteristic diffusion scale-length of the radiating electrons, which is of order of few kiloparsecs.

The remarkably tight correlation between CO, radio-continuum and Far-infrared emissions in galaxies has always been a puzzle.

Until now, these correlations were essentially known globally over galaxies. Thanks to new interferometric images at cm and mm-wavelengths and new infrared satellite data it has been possible to extend these studies down to sub-kpc scale. We have investigated the behaviour of spatially resolved correlations down to scale of \(~100\) pc (Murgia et al., 2005; Paladino et al., 2006) in a sample of 22 spiral galaxies belonging to the BIMA SONG sample (see Figure 1).

The BIMA (Berkeley Illinois Maryland Association) SONG (Survey of Nearby Galaxies) is a systematic imaging study of the 3 mm CO molecular emission within the centers and disks of nearby spiral galaxies.

This survey represents a significant improvement with respect to the previous CO extragalactic survey, since in each galaxy a large area can be mapped at high resolution.

Comparing these images with VLA array observations we found that a strong correlation between CO and RC emission persists down to scale of \(~100\) pc in a sample of 22 spiral galaxies (see Figure 1).

We investigated the behaviour of the correlation scatter as a function of the linear resolution, the scatter systematically increases with increasing the resolution, we cannot recognize any discontinuity on the trend that can be associated to a characteristic scale for the decorrelation.

Furthermore, for six galaxies of the sample have been recently released Spitzer IR high resolution images. In particular mid-IR 24 \(\mu\)m observations provide a resolution of about 6 arcseconds comparable to that of the CO and RC images.

For these galaxies it has been possible to analyze the behaviour of all the three emissions at sub-kpc scales.

It results that the scatter of the RC-mid-IR correlation is even lower than that of the RC-CO and mid-IR-CO correlations.

This result indicates either that we have not yet probed the spatial scales at which the correlations break down or that there is a mechanism of regulation that compensate the electrons diffusion.
Figure 1. Correlation between RC and CO emission in 22 galaxies.

Figure 2. (Left panel): Spectral index image of M51 measured between 4.9 and 1.4 GHz at resolution of ~16 arcsec s (Right panel): Image of the ratio between the FIR and RC emissions taken from Murphy et al. (2006).
Note that spiral arms are visible in both images, indicating that they have an excess of FIR and a spectral index flatter than the underlying disk.
A way to test these two possibilities is to study images of the RC spectral index, obtained combining radio observations at two different wavelengths.

We found a relation between the RC spectral index and the FIR emission: namely the radio spectrum flattens in regions of high FIR emission, see Figure 2.

This indicates that electron diffusion is efficient in these regions of high star formation rate.

Indeed a mechanism compensating the leakages of the synchrotron electron should exist. A possibility is that the galaxy magnetic field is higher in molecular clouds.

REFERENCES


