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Abstract: In this work, we use the first Herschel Science Demonstration Phase maps provided to the Hi-GAL consortium (Galactic longitude $l=59^\circ$ and $l=30^\circ$). The power spectra slopes vary from one wavelength (160, 250, 350 and 500 microns) to the other, -2.96 to -2.57 . These are similar to what was obtained in the past from IRAS data (100 microns), about -2.9 . Since it is believed that dust particles should be well mixed with the gaseous components of the ISM, we chose to compare the dust power spectra with the HI column density power spectra over the same galactic regions. The HI slope is approximately -3.3 . Both components have significantly different slopes. We provide tentative explanations to account for these differences. In the long run, we wish to evaluate whether the power spectra is an appropriate tool to check the algorithms used to decompose the ISM into its different components.

Introduction

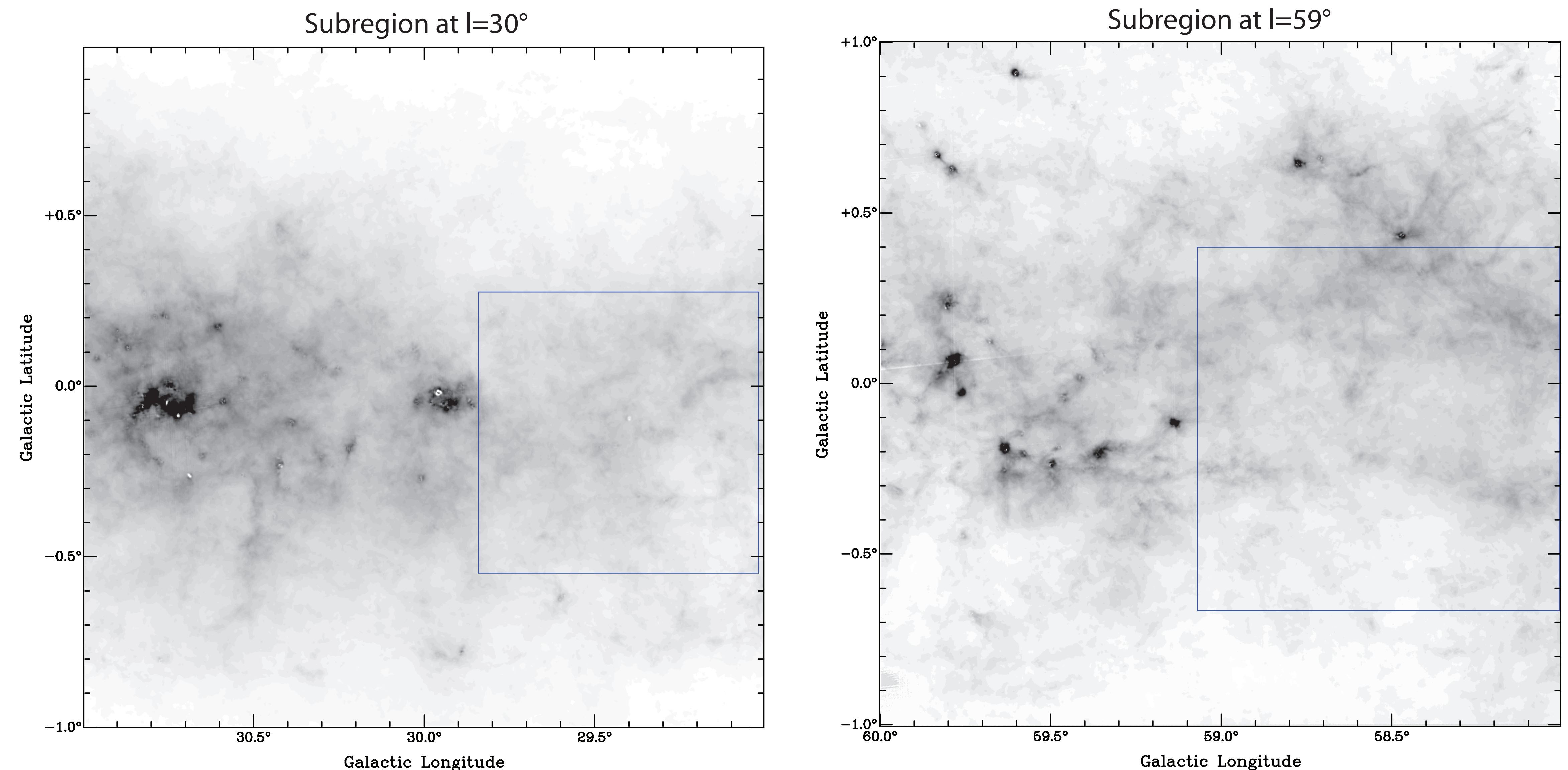
Power spectrum analysis of interstellar medium (ISM) emission (line and continuum) has been going on, on and off, for three decades. The first such study dates back to 1983 and was done for HI emission at 21 cm. The first (1991) of seven studies done so far on dust emission awaited IRAS data. Although a relatively small number of analysis of this type (whatever the ISM component) were published, a theoretical framework now exists. The slope of the power spectra can be related to (1) the scale of energy injection in the ISM, (2) turbulent behavior and/or (3) different aggregation of matter. Kolmogorov-like turbulence is the reference template for power spectra analysis since it is accepted by most researchers that the ISM is turbulent. We base our analysis and interpretation on the following premises:

- 1) Turbulence is a structuring process affecting a wide range of scales (inertial range).
- 2) The ISM is violent. Stellar winds, supernovae, spiral density waves also structure the ISM but at given scales.
- 3) Power spectra as an analyzing tool partitions the fluctuation power of the field into its various scales.
- 4) The slope of the power spectra can be related to a physical process (e.g. turbulence) but there is no unicity.
- 5) Dust is present within most phases of the ISM (CNM, WNM, WIM).
- 6) The Herschel data samples all three phases but in different proportions.

Our preliminary goals are to determine if the dust is well mixed with the other components of the ISM and if the dust is affected the same way as the gas by turbulence and the violent processes of the ISM.

The Subregions

The calculation of the power spectra is not done over the entire $2^\circ \times 2^\circ$ field of the Science Demonstration Phase maps. High contrast regions exist in both fields at $l=30^\circ$ and $l=59^\circ$ and those regions, even if the calculation is done with the point source-subtracted maps, can behave like point sources in a Fourier transform operation and thus contaminate the ISM power spectrum. Point sources induce an underestimation of the true slope of the power spectrum.

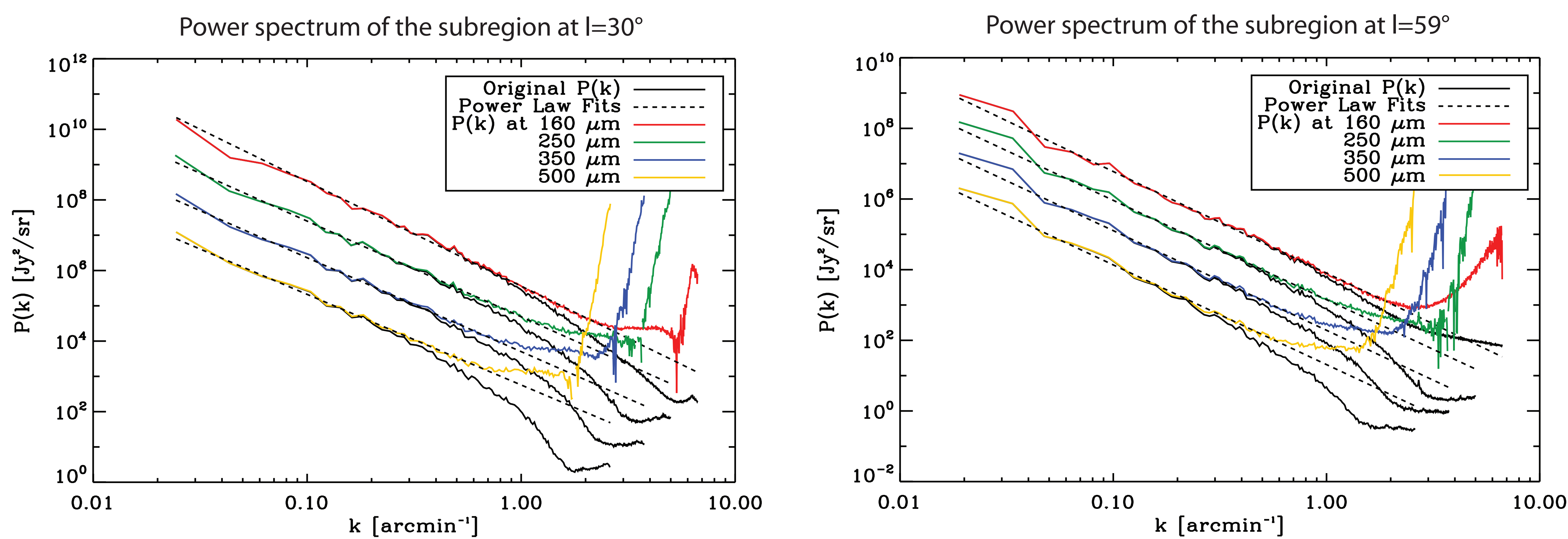


Dust Power Spectra

The dust power spectra are produced with the technique described in Miville-Deschênes et al. 2002 and Roy et al. 2010. The total power spectrum of the statistically uncorrelated components of a signal can be written as: $P(k) = \Gamma(k)[P_{\text{ISM}} + P_{\text{source}}(k) + P_{\text{CIB}}(k)] + N(k)$ where $N(k)$ is the noise and $\Gamma(k)$ is the PSF of the instrument. This function can be estimated by a Gaussian:

$$\Gamma(k) = \exp\left(-\frac{k^2}{2\sigma^2}\right)$$

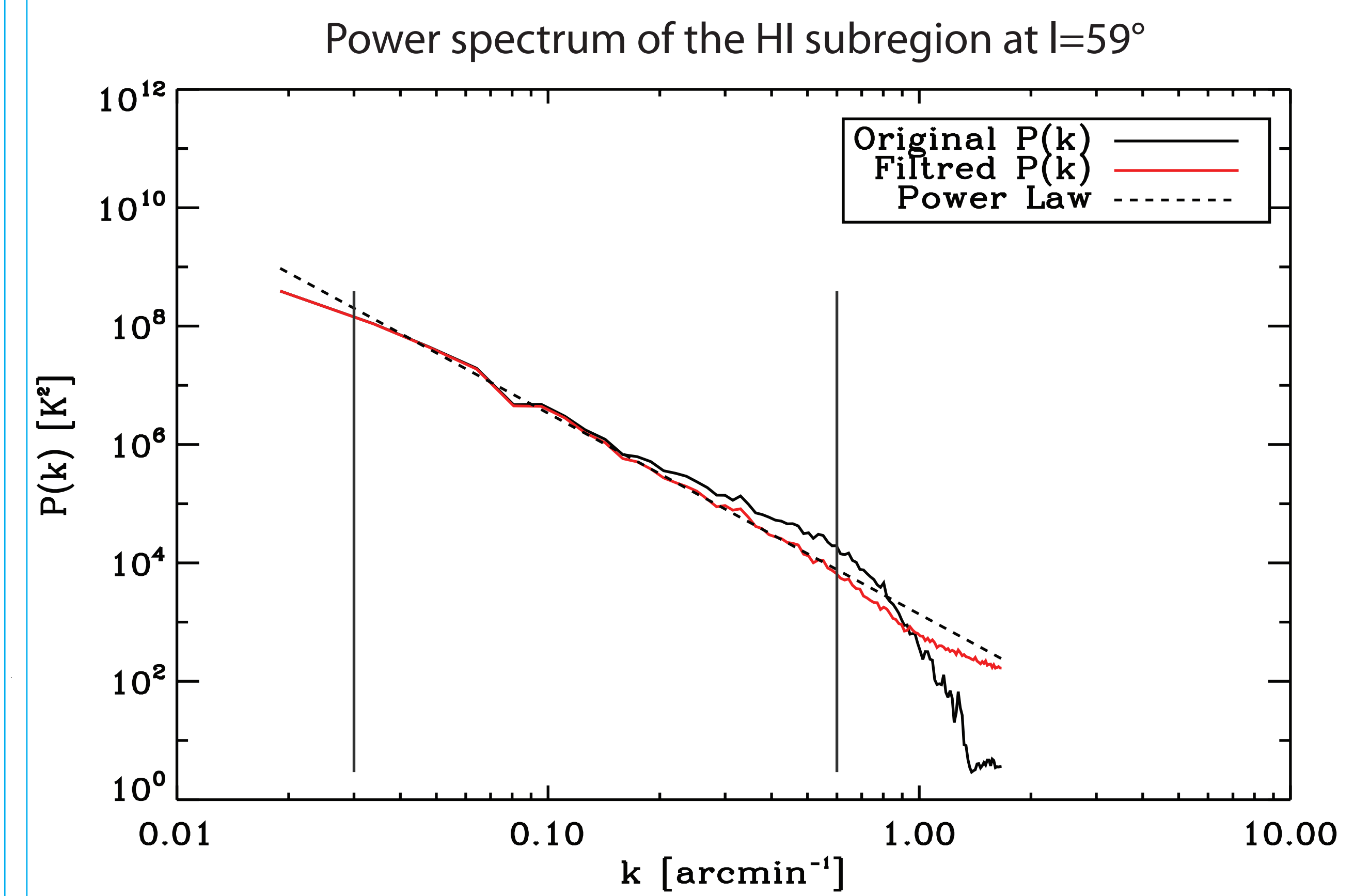
Here, the calculation is done on point source-subtracted maps. Furthermore, the cosmological infrared background (CIB) can be neglected on these maps where the dust emission is relatively high.



HI Power Spectra

The HI power spectra are produced with the technique described in Miville-Deschênes et al. 2003. In order to increase the signal-to-noise ratio, each HI map is filtered with a wavelet transform based filter. This filter also decreases the beam signature in the power spectrum.

Power Spectra are evaluated on column density maps of HI data. At $l=30^\circ$, data are integrated from 126.33 to -50.93 km/s. At $l=59^\circ$, data are integrated from 59.55 to -91.51 km/s.



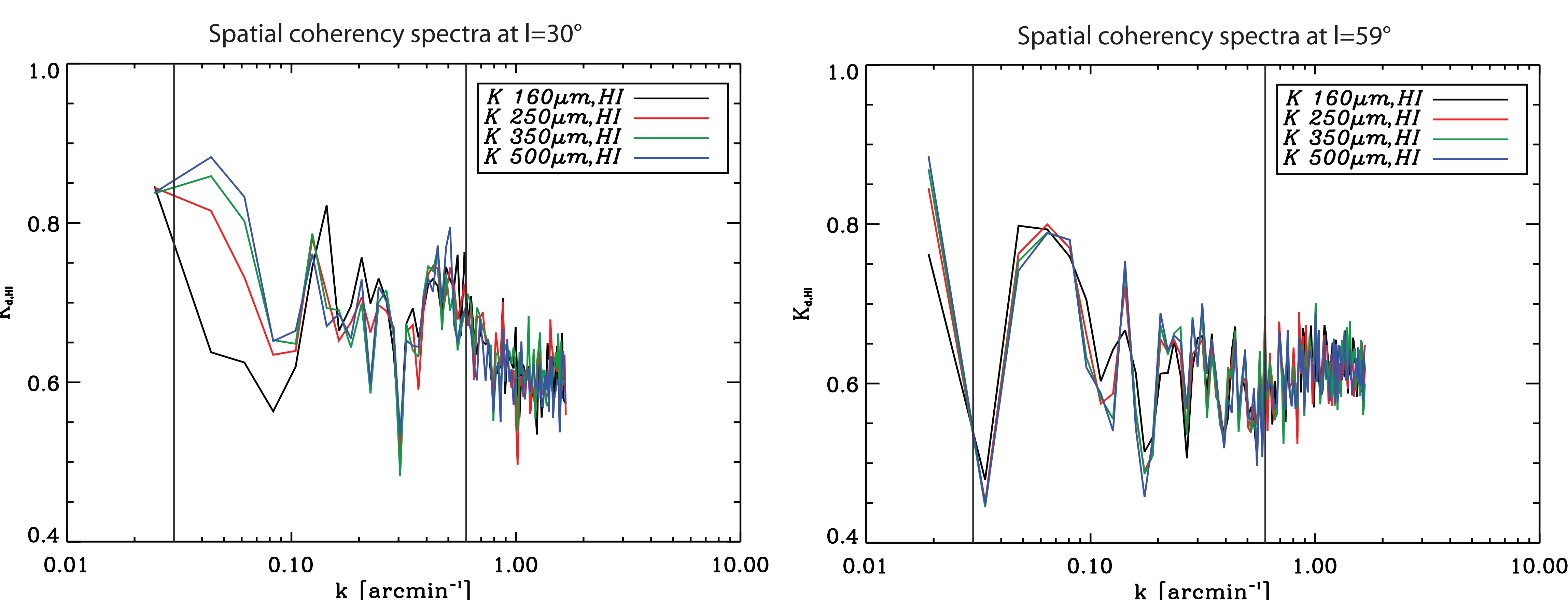
Power Laws

Longitudes	Wavelengths				
	160 μm	250 μm	350 μm	500 μm	21 cm
30°	-2.96 ± 0.02	-2.71 ± 0.03	-2.66 ± 0.03	-2.57 ± 0.03	-3.24 ± 0.07
59°	-2.87 ± 0.01	-2.81 ± 0.02	-2.82 ± 0.03	-2.82 ± 0.04	-3.38 ± 0.03

Spatial Coherency Spectra

In order to compare the dust grain and the HI power spectra on a statistical point of view, we evaluated the correlation with a cross spectrum (Stanimirovic et al. 2000). The cross spectrum is defined as $C_{d,HI} = \langle X_d X_{HI}^* \rangle$ where X_d and X_{HI} are the Fourier transform of the dust and HI map respectively. From the cross spectrum, we can calculate the spatial coherency spectrum:

$$K_{d,HI}(k) = \frac{|C_{d,HI}(k)|^2}{P_d(k)P_{HI}(k)}$$



Discussion

Some implications derived from the analysis:

- 1) There are no preferred angular scales of dust emission for any wavelength.
- 2) There are no preferred angular scales of HI column density.
- 3) There is a significant trend in the power law slope as the wavelength increases at $l=30^\circ$. Why?
- 4) The differing slopes between the HI column density and dust emission may imply that dust reacts differently from gas to the structuring processes of the ISM. However one must keep in mind that dust emission depends on its temperature and composition, it may vary along the line of sight.
- 5) The differing slopes (HI vs dust) may simply mean that dust emission carries information from all phases not only the WNM which is mostly what HI provides.
- 6) The cross spectrum between dust and HI with its mean value of about 0.6-0.7 shows a lukewarm correlation. Whatever happens along the line of sight (different processes, different morphology of the environment,...) there is a minimal similarity in the repartition of the fluctuations (no randomness). Turbulence could be that "basic principal".
- 7) The spatial coherency spectrum has its largest variations (0.85 to 0.45) at large scales. The imprint of the violent ISM?

CONCLUSION: more thinking and some modeling are obviously needed!!!

References: Miville-Deschênes, M. et al. 2003, A&A 411, 109
Miville-Deschênes, M., Lagache, G., & Puget, J. 2002, A&A 393, 749
Roy, A. et al. 2010, ApJ 708, 1611
Stanimirovic, S. et al. 2000, MNRAS 315, 791