MSISM (The Multi-Fractal Structure of the InsterStellar Medium)
P.I. Davide Elia

MSISM in short…

The structure of the interstellar medium (ISM) appears to be complex, extremely nested and far to be simply described through the shapes of the Euclidean geometry. Furthermore, the appearance of interstellar clouds varies with the wavelength, depending on local conditions. With MSISM we propose an original multi-wavelength (from mid-infrared to radio) study to produce an alternative description of the morphology of the ISM, by:

1) combining observations at different wavelengths, from mid-infrared to radio, to produce maps for a set of observables (column density, far-infrared colours, dust temperature, luminosity/mass ratio, bolometric temperature) probing physical and evolutionary conditions across the whole Galactic plane.

2) developing a metrics for classifying single pixels in these maps. Coherent structures formed by pixels with similar metric will correspond to specific physical conditions in the ISM, and this will allow automatic detection of possible features such as bubble edges, photodissociation regions, star-forming or quiescent filaments/clumps, etc., but also "contaminants" such as post-ZAMS objects, or external galaxies.

3) obtaining a multifractal description of these maps, to establish a link between the morphology of the clouds and the characteristics of their star formation activity.

Used data set

- Hi-GAL (Herschel infrared Galactic plane survey) maps at 160, 250, 350, and 500 µm to derive temperature and column density through greybody fit.
- Hi-GAL maps at 70 µm and Spitzer-MIPSGAL maps at 24 µm to derive, in combination with the aformentioned ones, further bolometric quantities.
- MeerKAT mosaics at 1 GHz to highlight supernova remnants, non-thermal filament complexes, HII regions, etc.

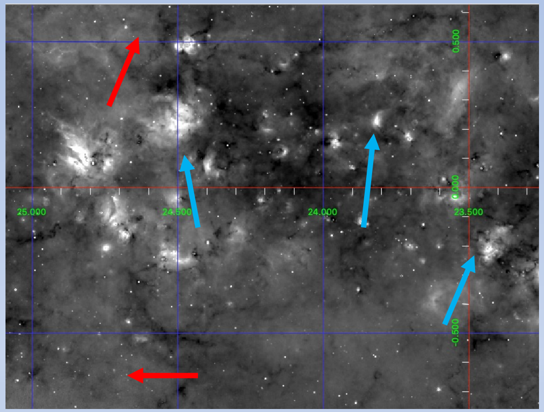

Fig. 1

*M*ap of bolometric temperature obtained for the Galactic plane region delimited by $23.5° \lesssim \ell \lesssim 25°$, $|\, b\,| \lesssim 0.5°$, starting from six infrared maps, from 24 to 500 µm (MSISM product).
Examples of features in common with the MeerKAT radio image, or seen only in MeerKAT map are indicated with blue and red arrows, respectively.

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Achieved goals:

- For the entire Galactic plane (177 Hi-GAL tiles) we produced maps of:
    - [160]-[70], [250]-[70], [350]-[70], [500]-[70], [250]-[160], [350]-[160], [500]-[160], [350]-[250], [500]-[250], [500]-[350] colours.
    - Column density
    - Dust temperature
    - Luminosity / Mass
    - Luminosity / Sub-mm luminosity (λ > 350 μm)
    - Bolometric temperature
- We produced pixel-to-pixel plots for each region by considering different pairs of the aforementioned parameters, and started to identify interesting areas (e.g., in the [160]-[70] color vs MeerKAT intensity plot, the areas corresponding to $x > 10^{-3}$ and $y \lessgtr 0.3$, respectively, for which intense radio emission corresponds to a less/more advanced evolutionary stage, respectively).

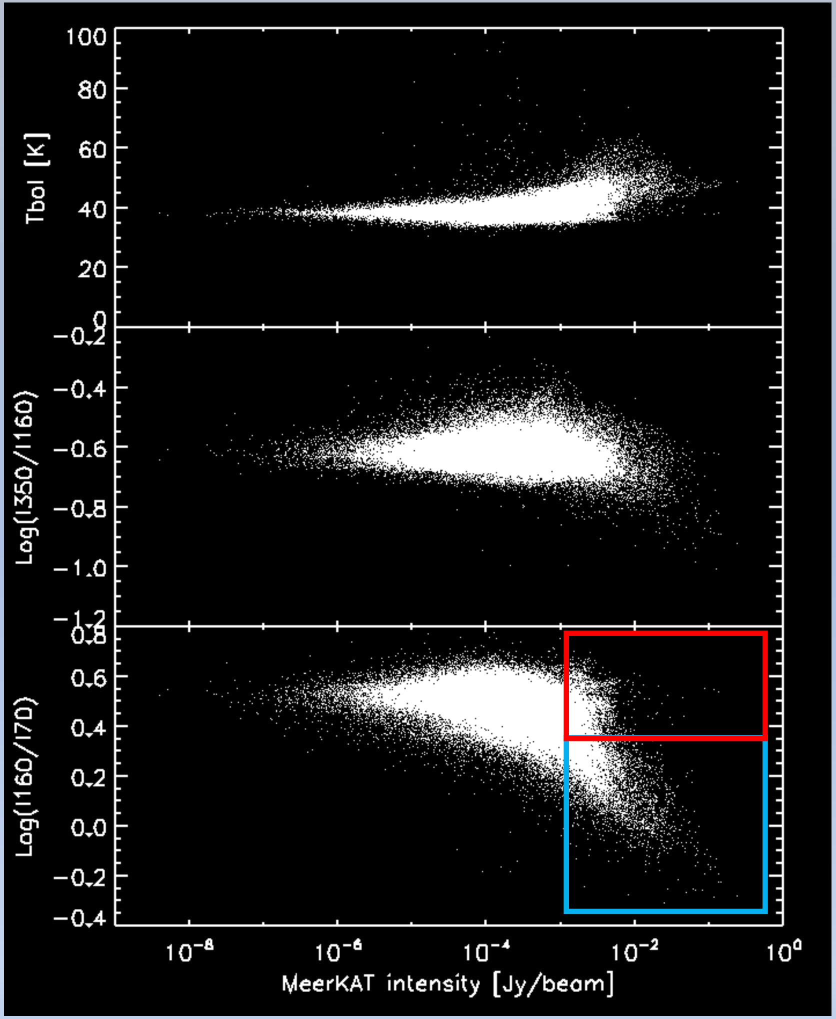

Fig. 2
Pixel-to-pixel plots of three distance-independent parameters (*top*: bolometric temperature, *middle*: [350]-[160] color, *bottom*: [160]-[70] color, respectively) obtained in the same field shown in Fig. 1, vs MeerKAT intensity regridded to the resolution of other maps (i.e. the one of Hi-GAL 500 μm observations). For $x > 10^{-3}$, the blue and red boxes indicate $y < 0.3$ and $y > 0.3$ areas, respectively.

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Achieved goals:

- We cross-correlated our data set with the HII region catalog of Anderson et al. (2014), and got the statistics of pixels encompassed within their boundaries.
- We obtained multifractal spectra for all Hi-GAL column density maps using the thermodynamical formalism of Chhabra & Jensen (1989).

To do:

- To cross-correlate our data set with catalogues of Infrared Dark Clouds (Peretto 2009, Pari & Hora 2020) and filaments (Schisano et al. 2020).
- To complete a metrics within which characterizing pixels belonging to different physical and evolutionary conditions.
- To obtain multi-fractal spectra for all Hi-GAL column density maps using the wavelet transform modulus maxima (WTMM) method.
- To compare (multi-)fractal properties of ISM maps and pixel statistics for different physical parameters.

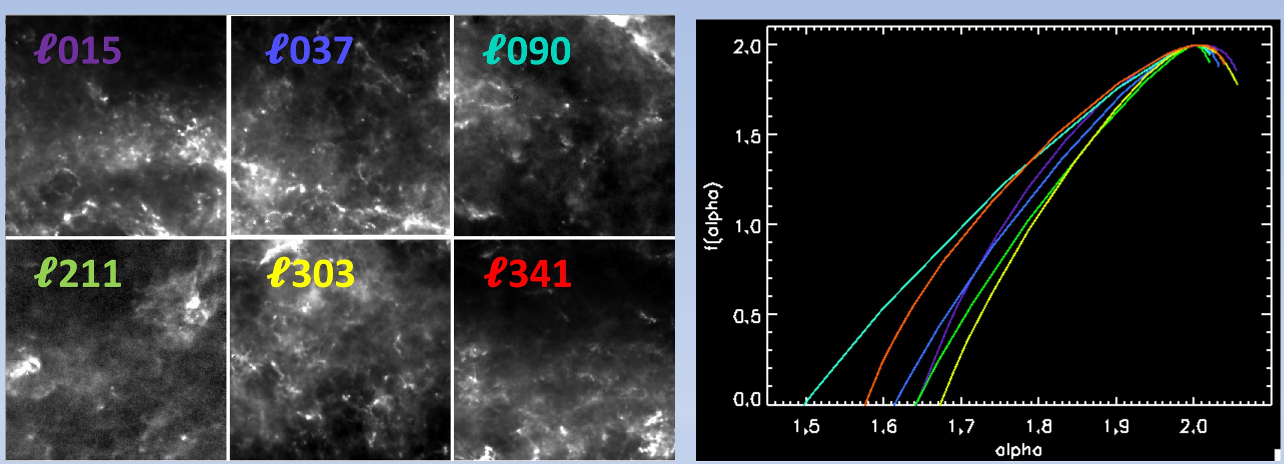

Fig. 3
Left: six column density maps obtained from Hi-GAL tiles, shown here an example of multi-fractal analysis. The tile name represents the approximate central longitude of the tile (so that four of them belong to the inner Galaxy, and two in the outer one). *Right*: singularity spectra computed for the tiles in the left panel (color coding is the same used for the tile names). See Elia et al. (2018) for an introduction to multi-fractal analysis of images, and for the concepts of singularity spectrum, α, and $f(\alpha)$.