Galactic science

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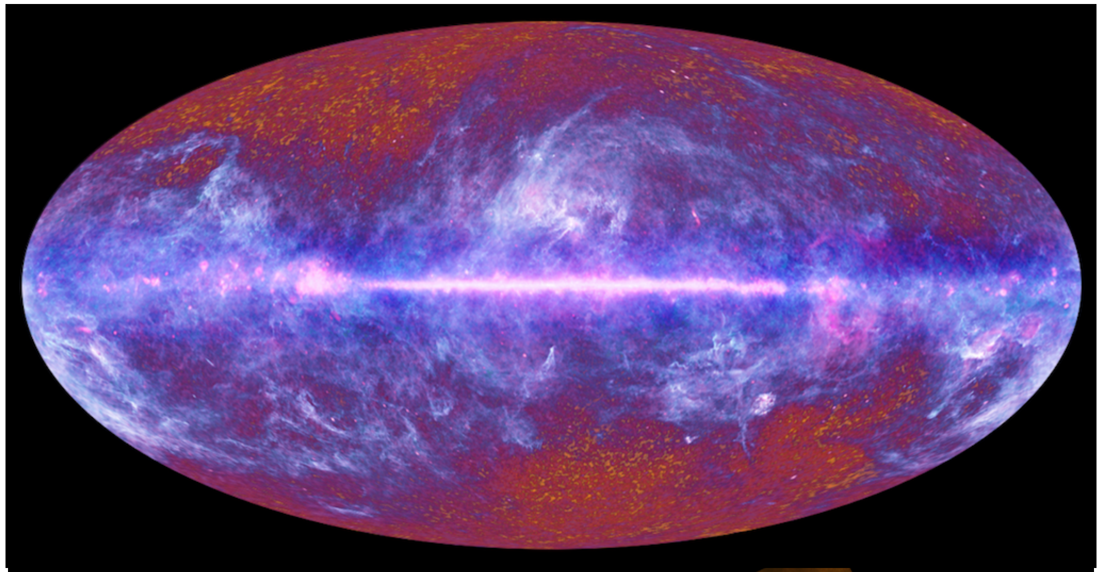
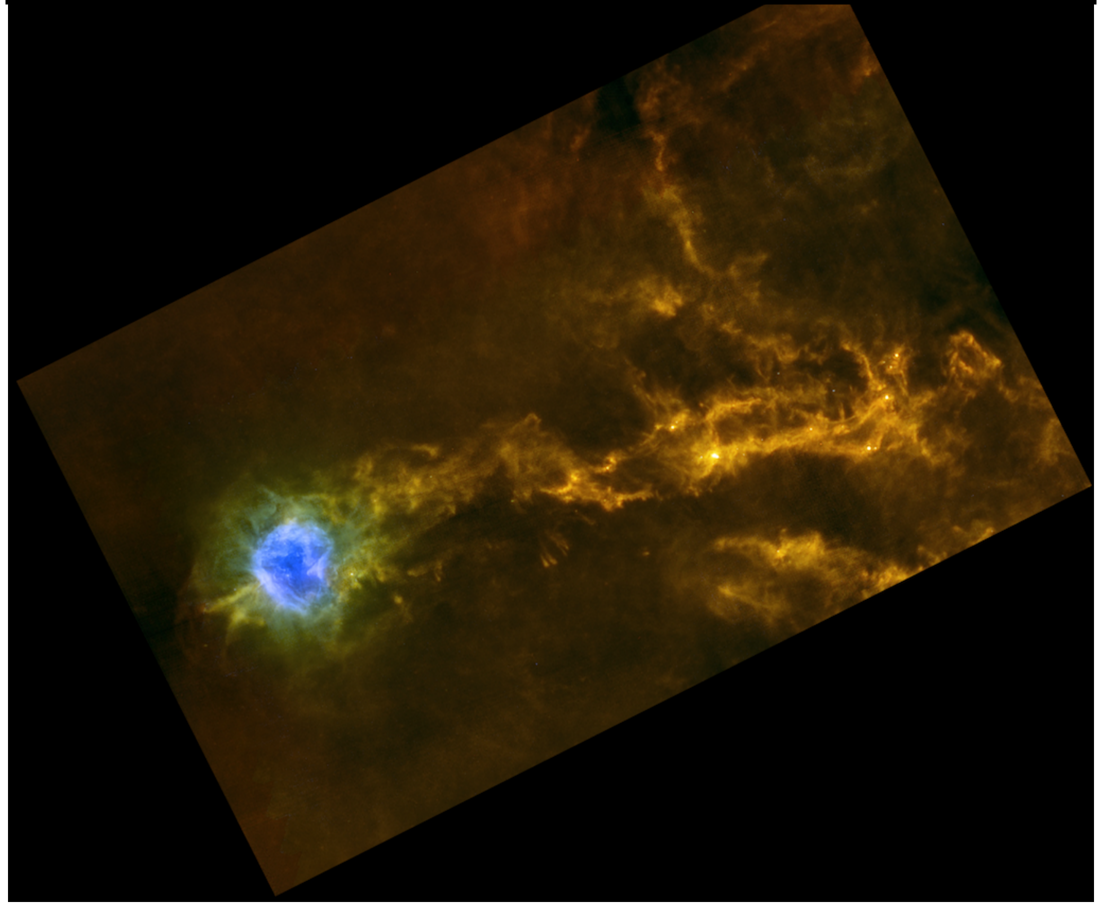
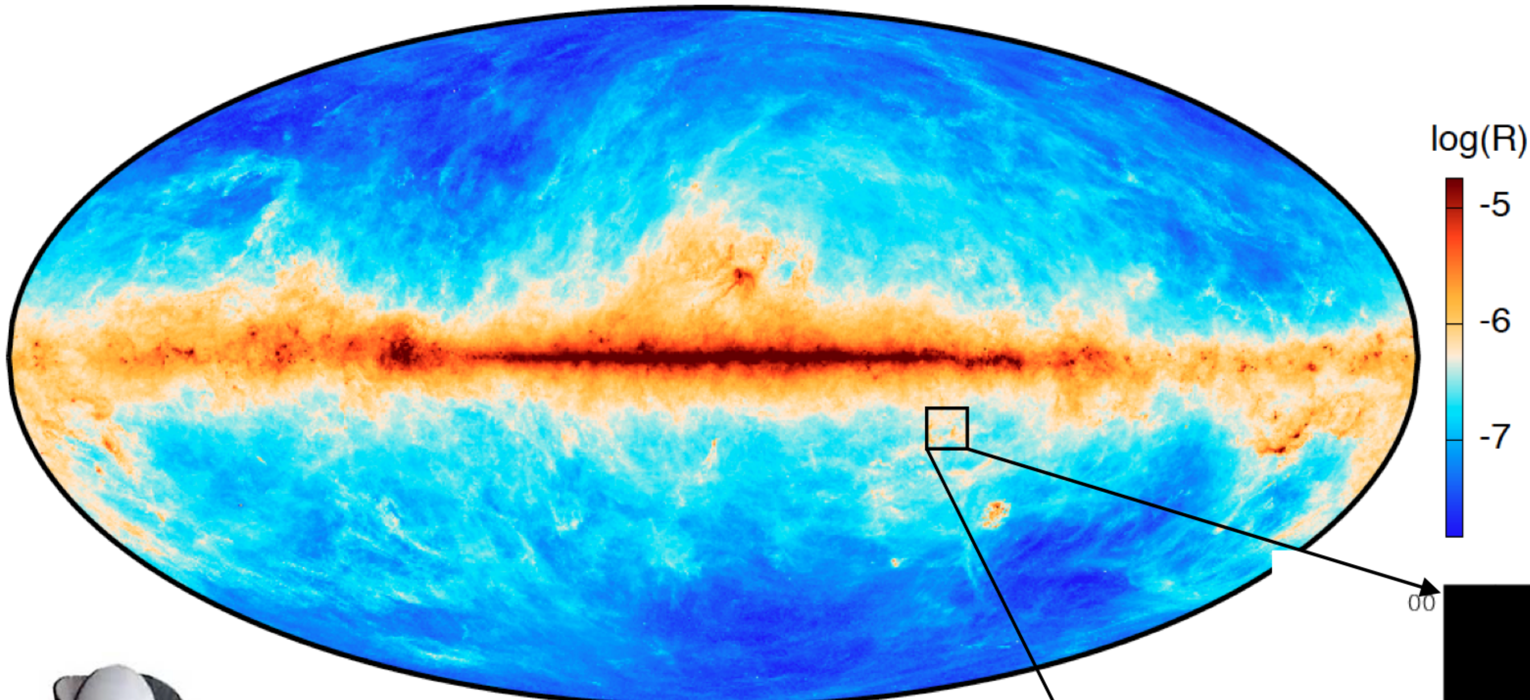
Context

- **Main scientific context : formation of structures**
  - Physical processes involved in the formation of cold structures, stars and planets
  - Complex (dirty) physics : combination of MHD turbulence, thermal, gravitational and chemical instabilities
    - Heating and cooling processes
    - MHD dynamics
    - Radiation-matter and CR-matter interactions
- **The status now :**
  - Herschel brought a new picture of ISM structure : filamentary and clumpy
  - Planck is providing a revolution in dust physics : no current model can fit the data
  - Role of magnetic field and ambipolar diffusion is studied in details : Planck polarization data are crucial
- **The road ahead :**
  - Apply what is learned from the formation of clouds and stars in the Milky Way to extra-galactic systems with the help of the increase of angular resolution (ALMA, SKA, JWST)
  - Galactic science should be seen as a way to zoom at properties of extra-galactic systems

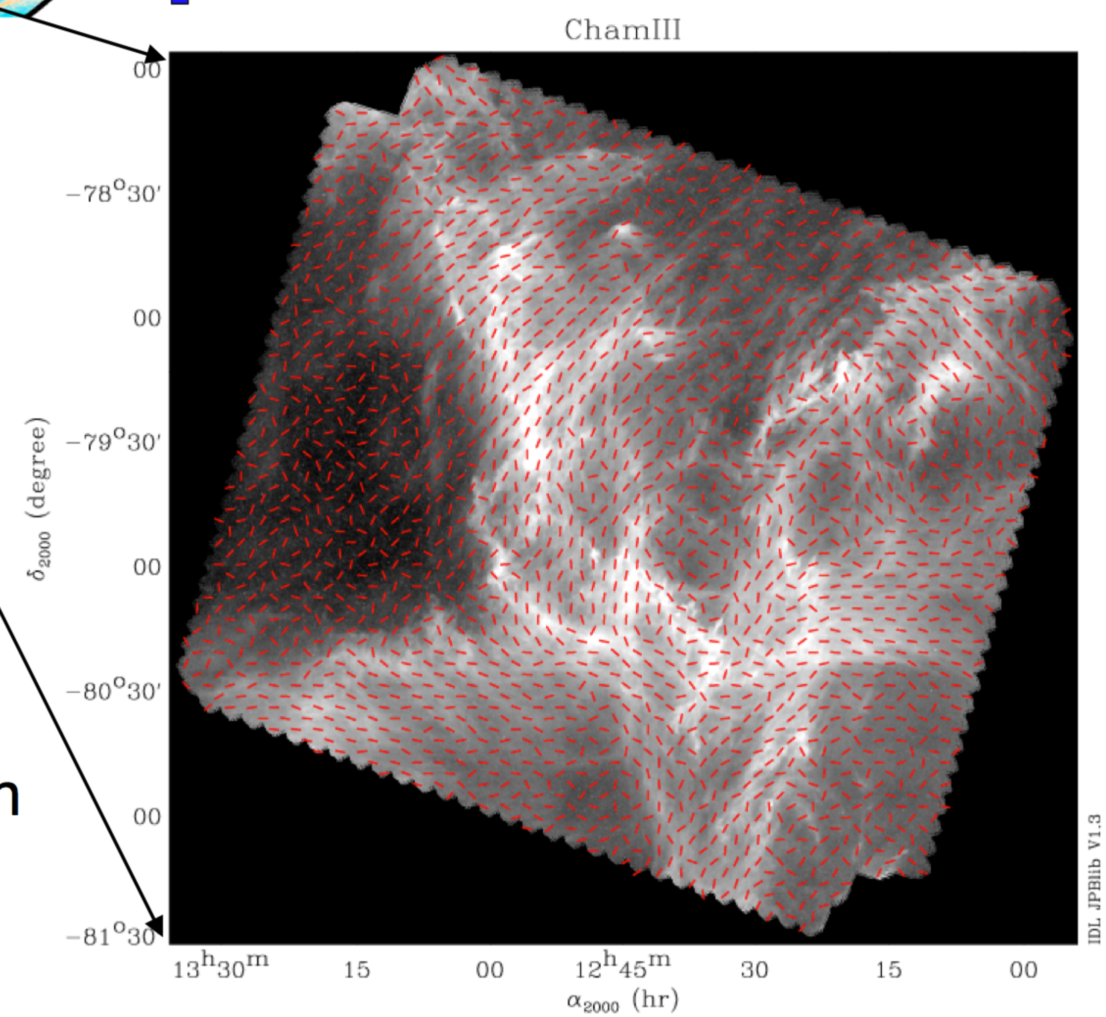




Structure of the ISM using dust emission



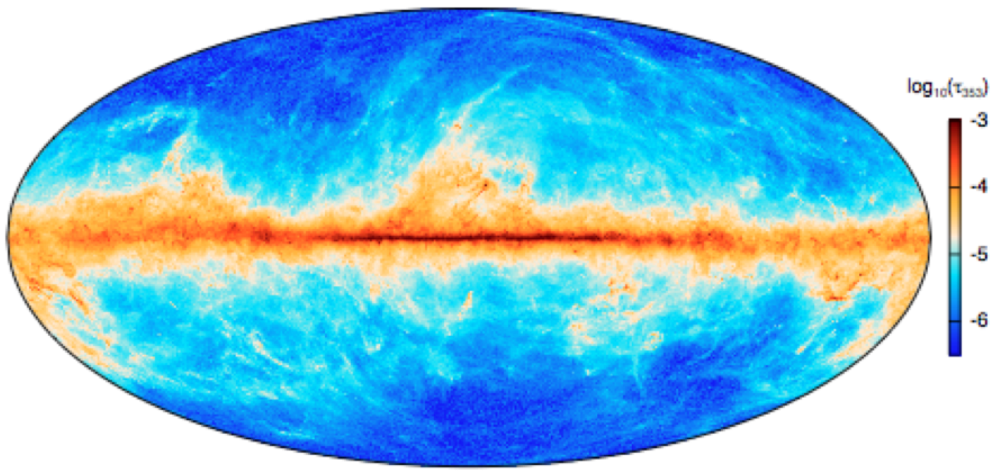
Herschel
Emission

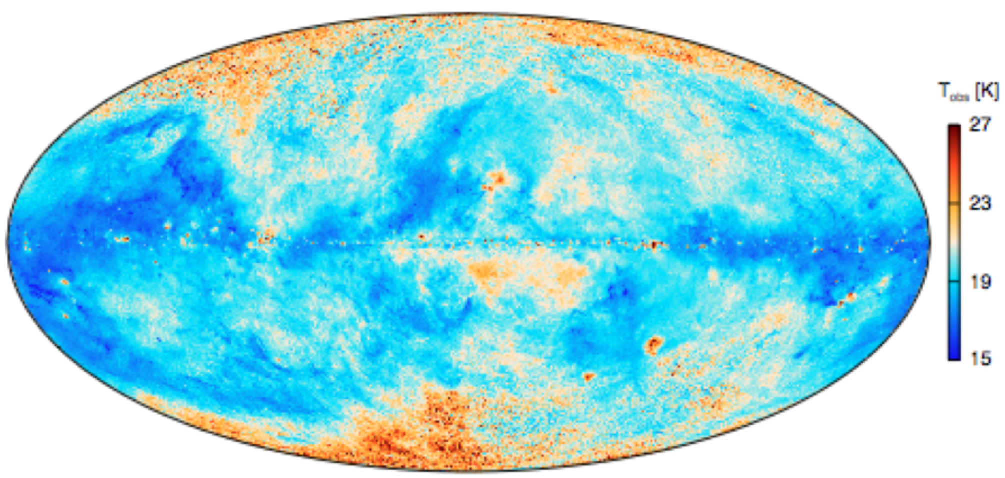


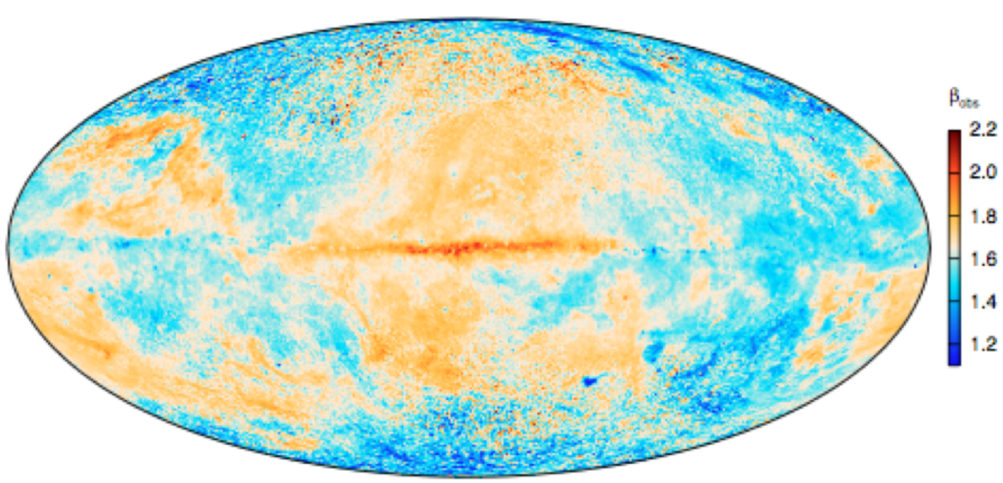
Planck maps
the field structure
with a tracer of the ISM structure
unlike synchrotron and Faraday rotation

- Preferred alignment between the ISM structures and the magnetic field direction in the diffuse interstellar medium

All-sky model of dust emission from Planck

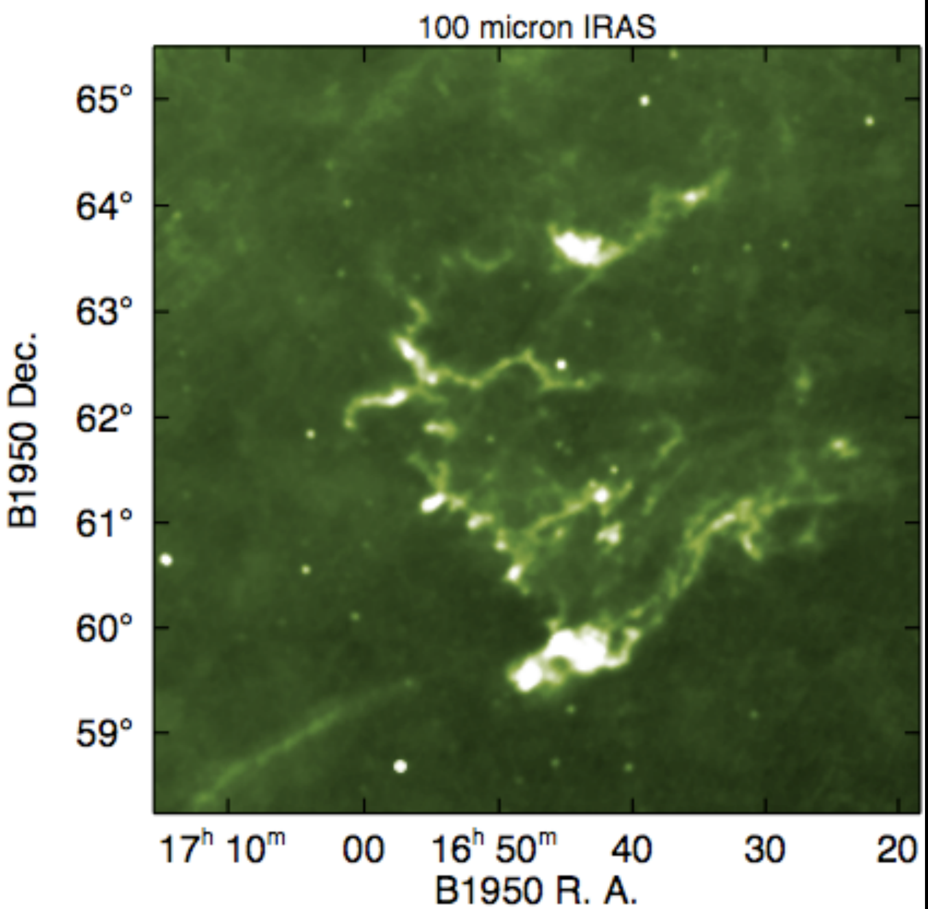


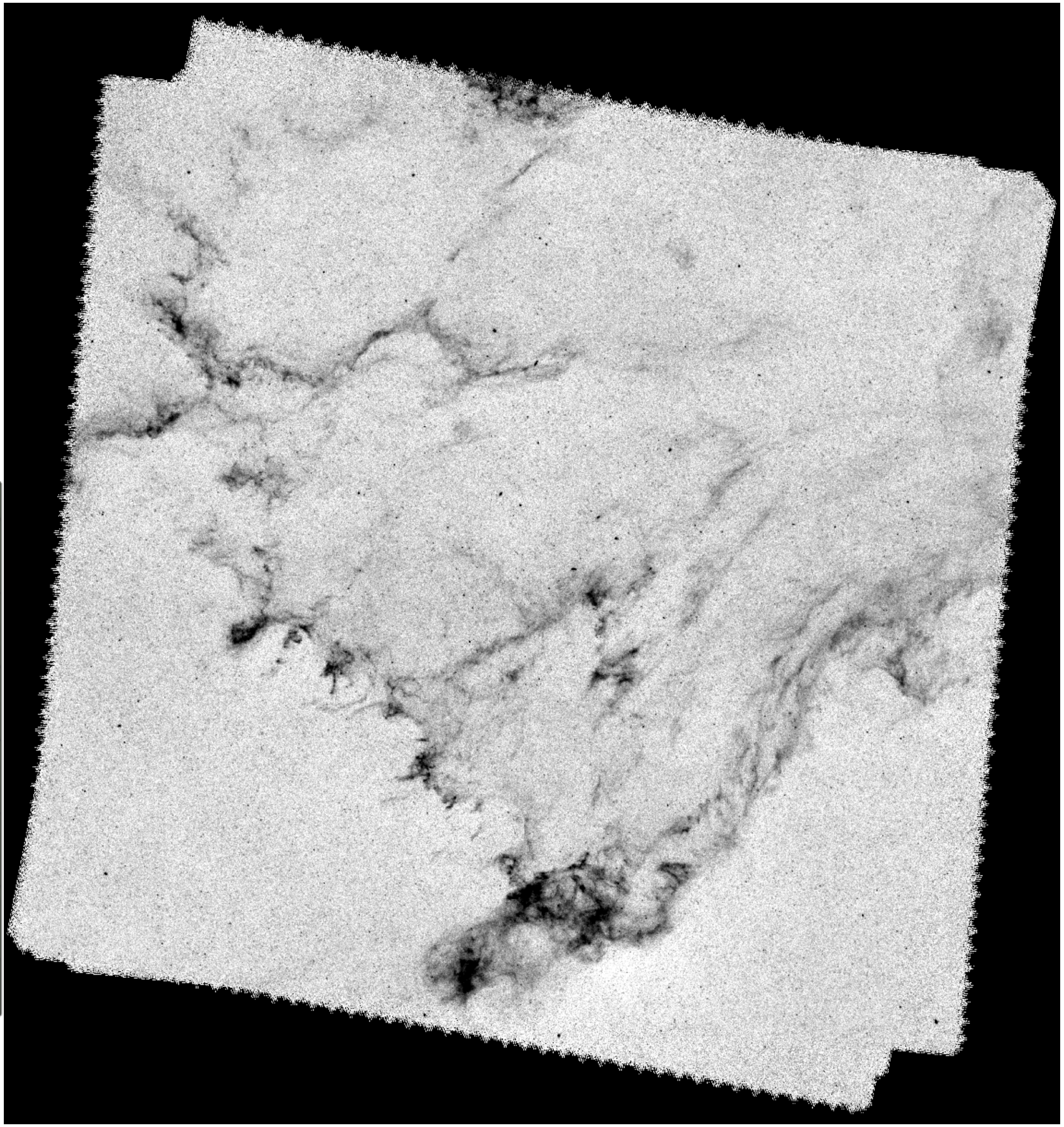




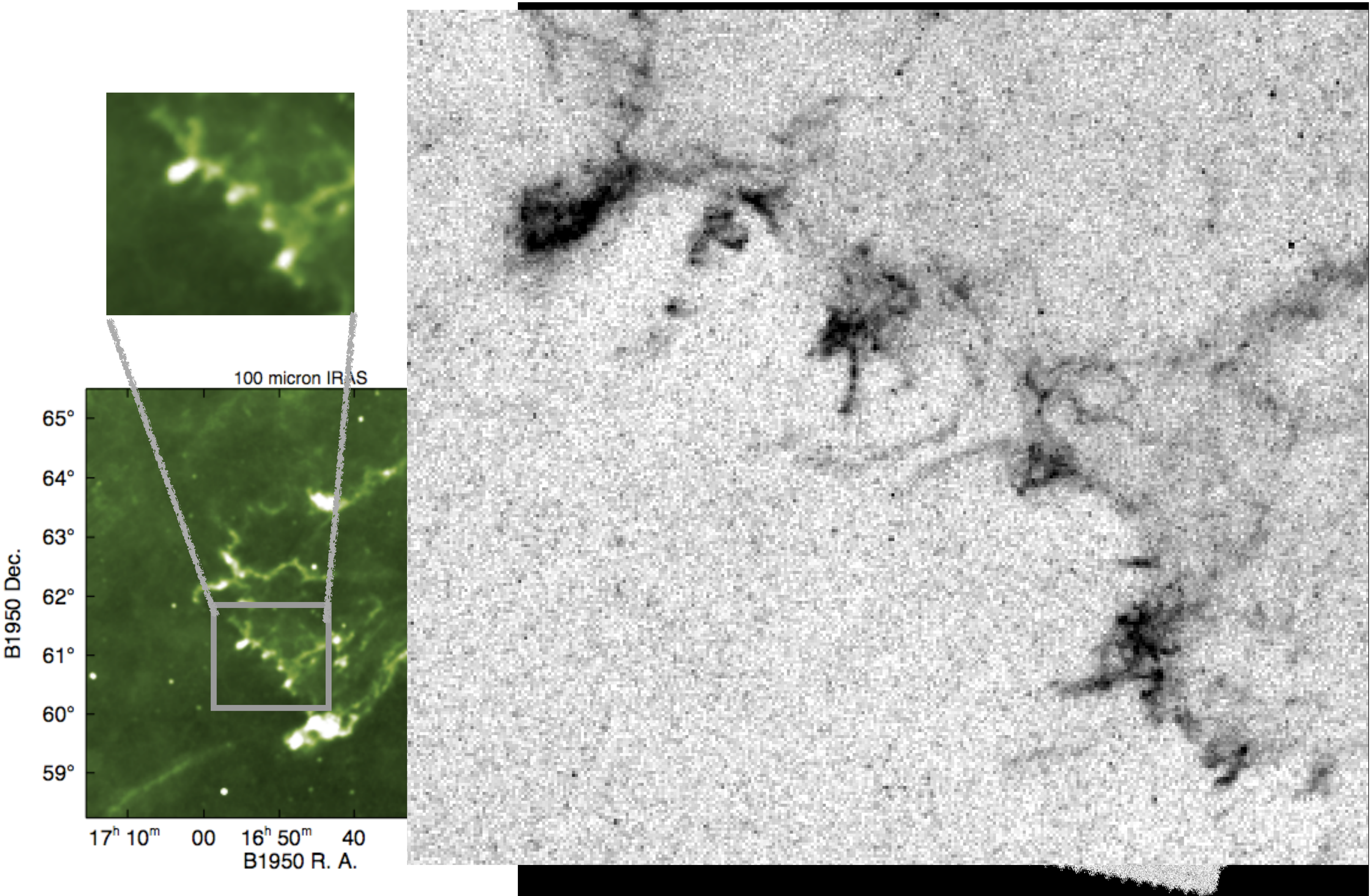
- Structure of diffuse matter : separating the effect of dust emission spectrum and column density
  - Flattening of dust power spectrum compared to previous estimate (-2.5 compared to -2.8), revealing cold small-scale structures (c.f. Planck cold cores/ clumps)
- First estimation of dust spectrum in the CMB range
  - Flattening of the spectral index at nu < 353 GHz
- Dust physics
  - Evolution of grains are now seen in all environments
  - The Planck data are challenging dramatically the modelling of dust

Small scale structure

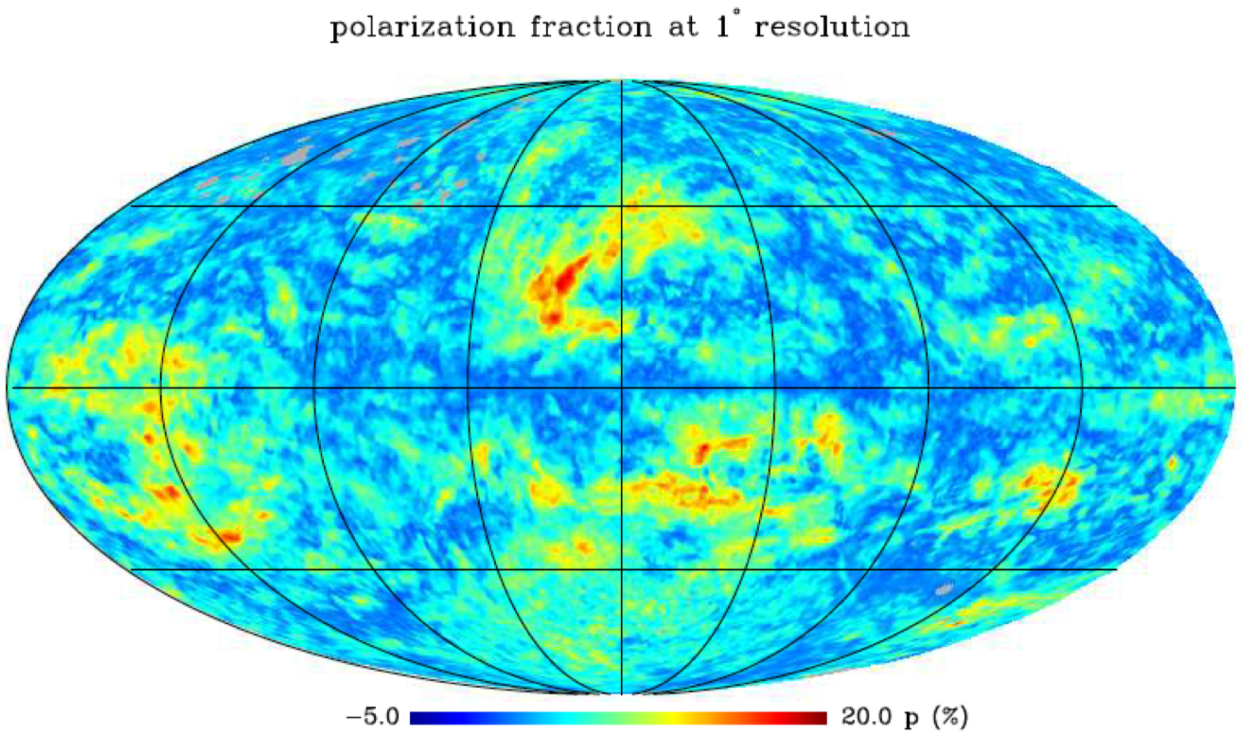




Small scale structure

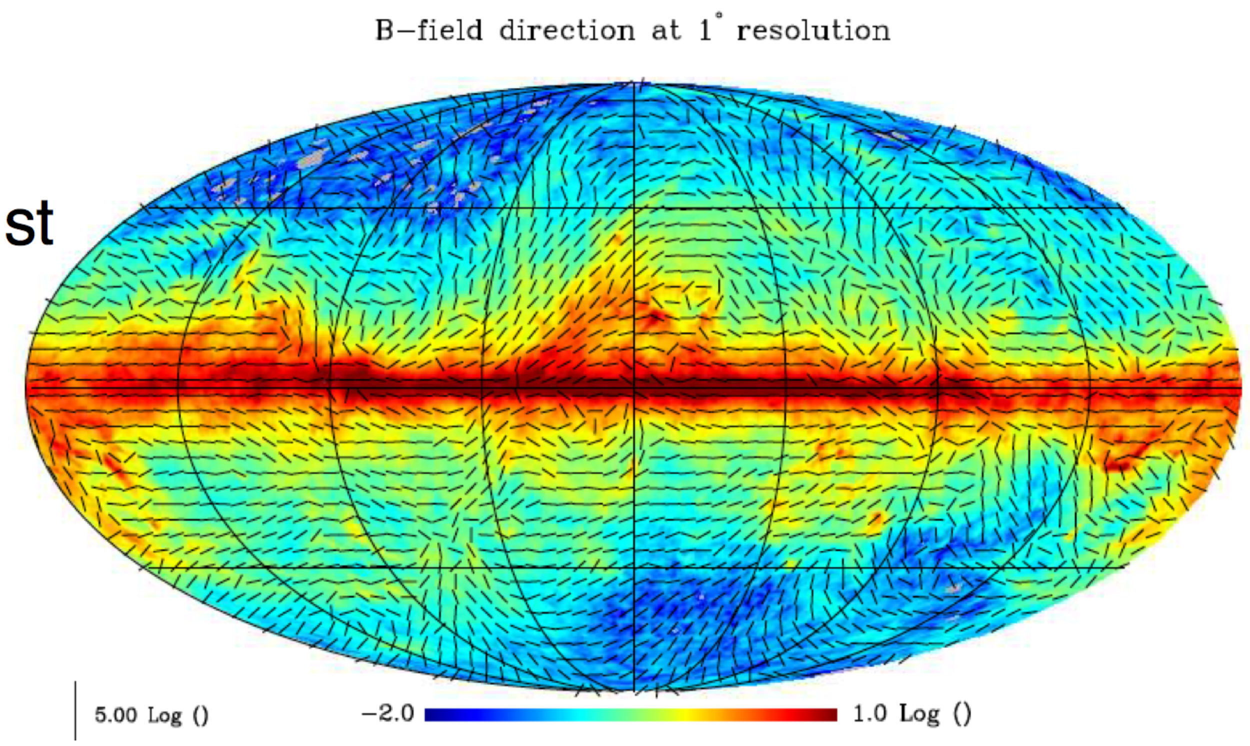


Polarization of the ISM dust emission with Planck



First maps of dust polarization

Dust polarization detected over the whole sky

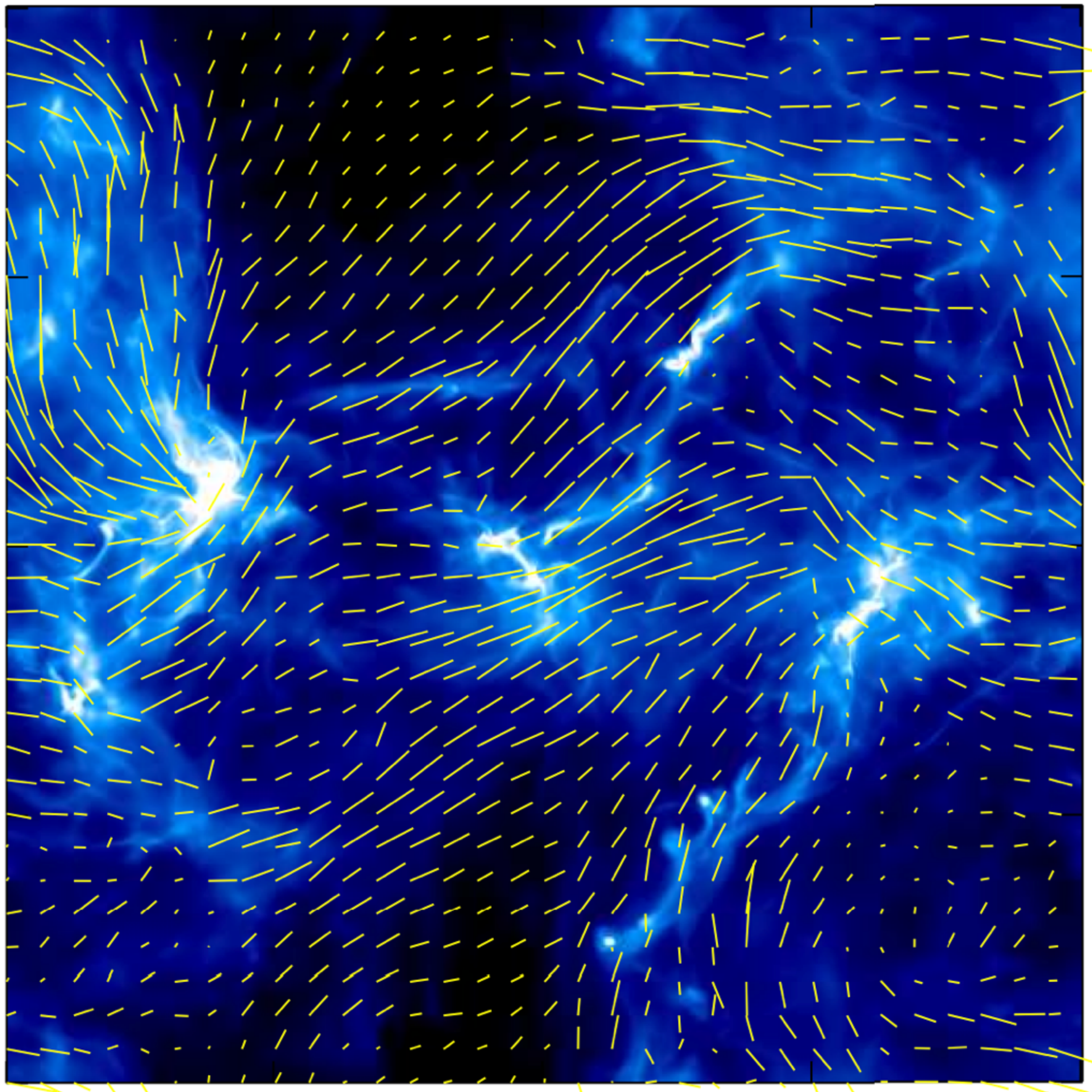


A new perspective on interstellar dust and on the turbulent component of the magnetic field within interstellar matter.

Main polarized foreground to the search of B mode CMB polarization

The Galactic magnetic field

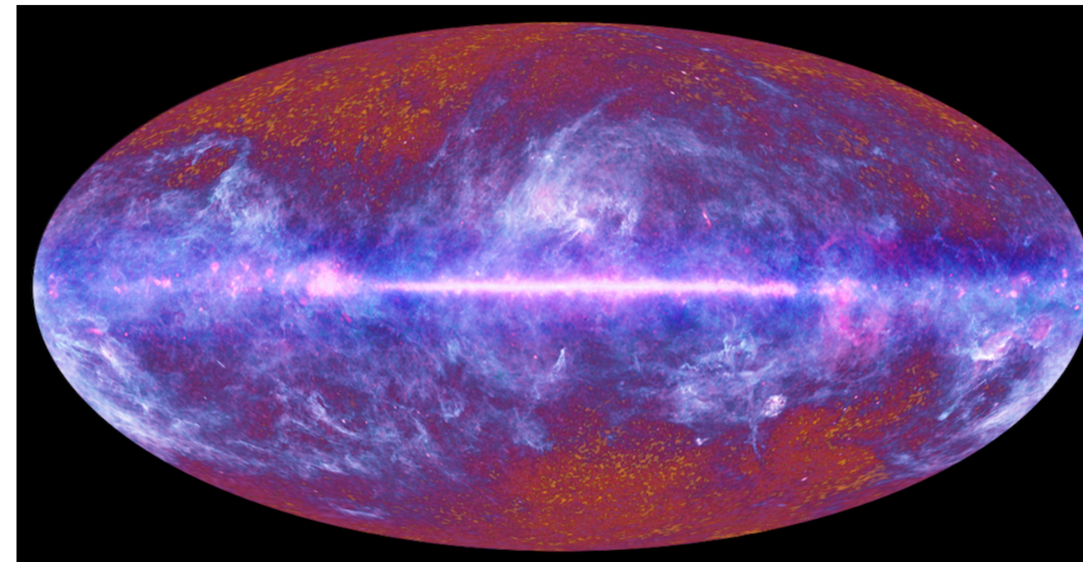
- The magnetic field is crucial in the understanding of the structure formation process: gravity, turbulence and magnetic field are equally important in the structure and evolution of clouds.
    - Polarization observations are lacking: it is one of the rare field in astrophysics where numerical simulations are ahead of the observations.
- Interest in a project that would have the resolution and sensitivity to map the projected structure of the Galactic magnetic field over the whole sky, down to sub-arcmin resolution
    - Planck measures it over the whole sky in only one frequency, with limited sensitivity and 5 arcmin resolution
    - Ground based (e.g., ALMA) can achieve high resolution but on specific targets only
    - Observing the whole sky is important to understand the MHD turbulence cascade and the connection of the field to the local spiral arm.

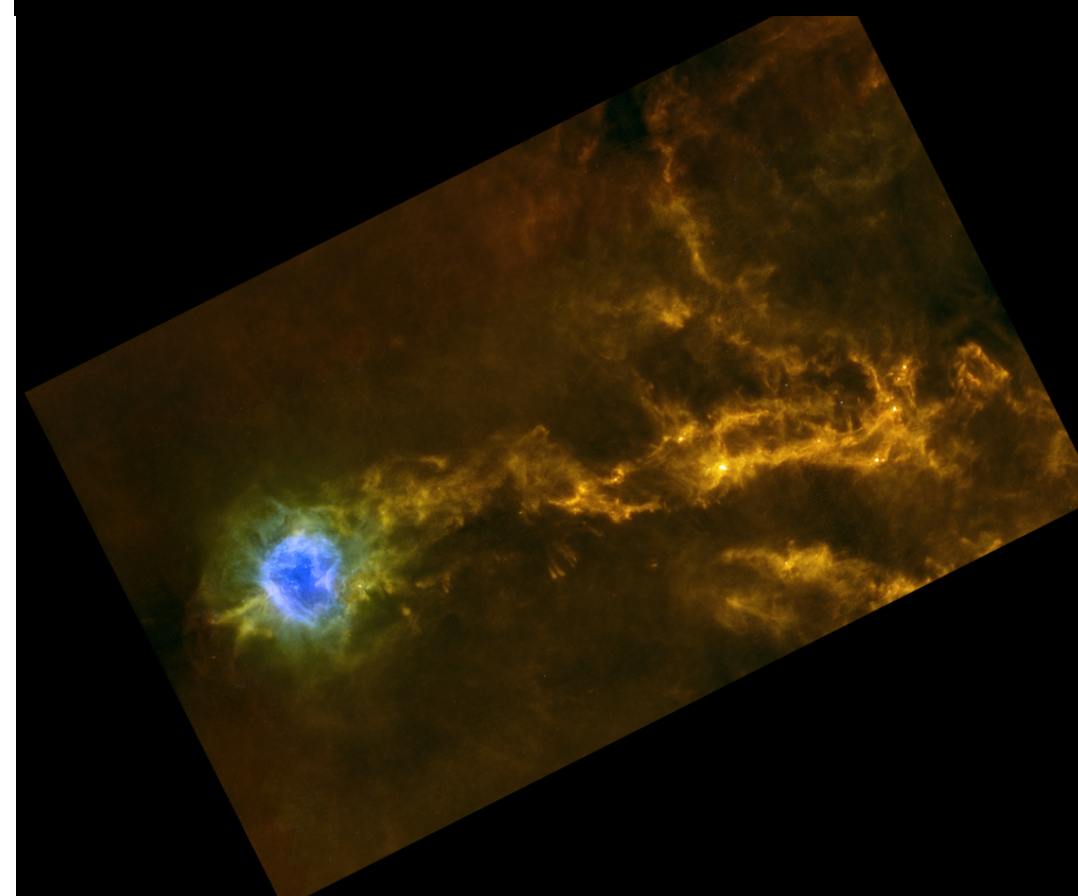


MHD simulations: link between structure and magnetic field in a molecular cloud.
Soler et al. (2013)

What a 4th generation CMB experiment can bring to Galactic science ?

- Planck and Herschel had both a strong impact on the Galactic ISM physics, one with its all-sky view of interstellar emissions, the other with its high angular resolution observations of the dust emission of chosen clouds
  - An experiment that would combine the power of these two experiments would allows us to go much further.
- CORE type mission would provide all-sky maps at Herschel resolution of
  - Dust and synchrotron emission, in intensity and polarization, tracing the density and magnetic field structures of the ISM.
- CORE type mission will address three fundamental questions in Galactic astrophysics
  - What are the processes that structure the interstellar medium ?
  - What role does the magnetic field play in the star formation process ?
  - That are the processes that determine the composition and evolution of solids in space ?
- No project provides a comparable perspective on the understanding of the processes involved in the formation of structures





Beyond Planck

- Current limitations
  - **<u>Model of foregrounds is still not satisfactory in the CMB range.</u>** Flattening of the spectral index at nu < 353 GHz : no all-sky model for now, limited by CMB contamination.
  - Separation of dust and CIBA : more channels could help (to be demonstrated).
  - Limited resolution : lots of structure and physics at small scales
  - Gain in sensitivity is an issue for Galactic emission in polarization
  - More channels would improve the parametrization of the dust spectrum : now we fit 3 parameters with 4 channels….

- What would be needed to make progress after Planck
  - Increase angular resolution to trace the formation of cold structures
  - Increase sensitivity in polarization to understand the MHD energy cascade
  - Increase number of channels to separate foregrounds

- By mapping the whole sky, a CORE-type mission fills a niche on the physics of the formation of structures that no other experiment will do