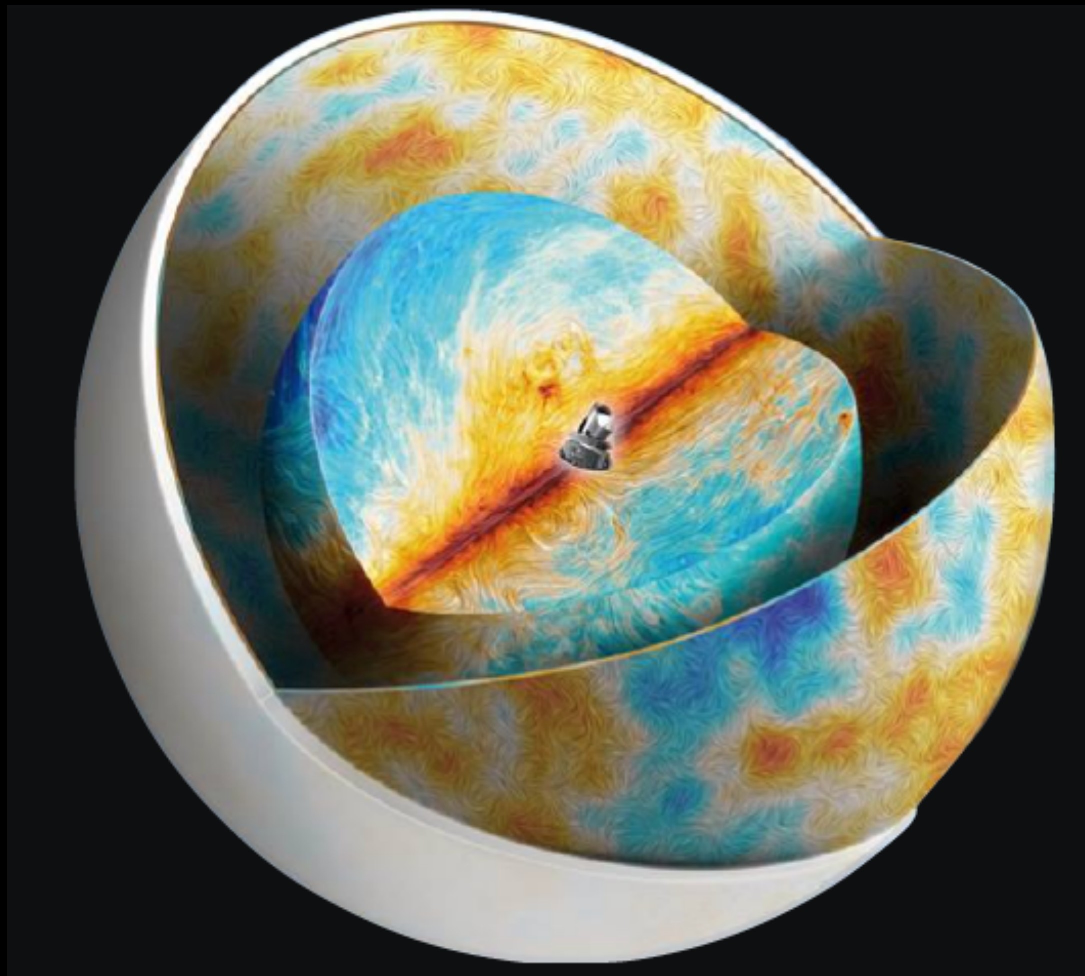
Cosmic Magnetism



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Magnetic fields are the hidden (*dark*) agent of baryon physics across the universe

Two outstanding questions:

★The origin of cosmic magnetic fields

★Their role in the formation of galaxies, stars and planets

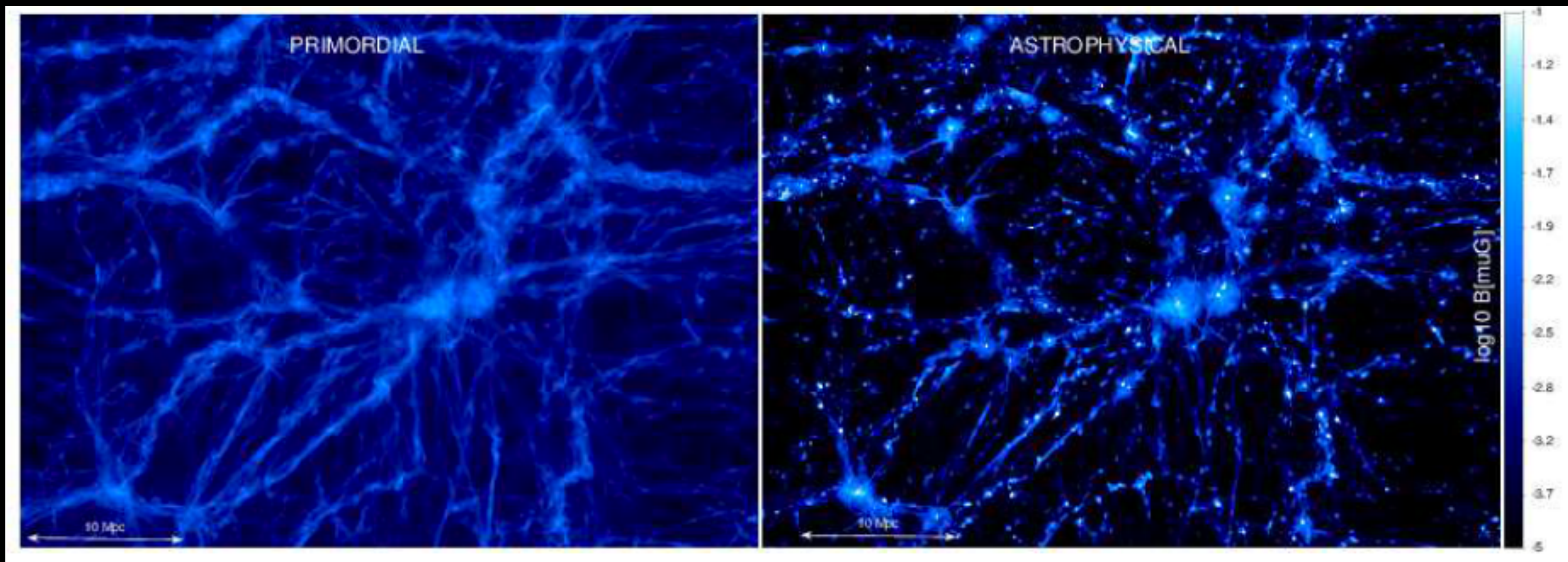
The structure of magnetic fields may be traced with polarization observations from the cosmic web to planets

The Universe shows strong and coherent magnetic fields on all observed scales from proto-planetary discs to clusters.

It implies a set of ubiquitous processes that have amplified and organized a much weaker primordial field

Seed field + Turbulent dynamo

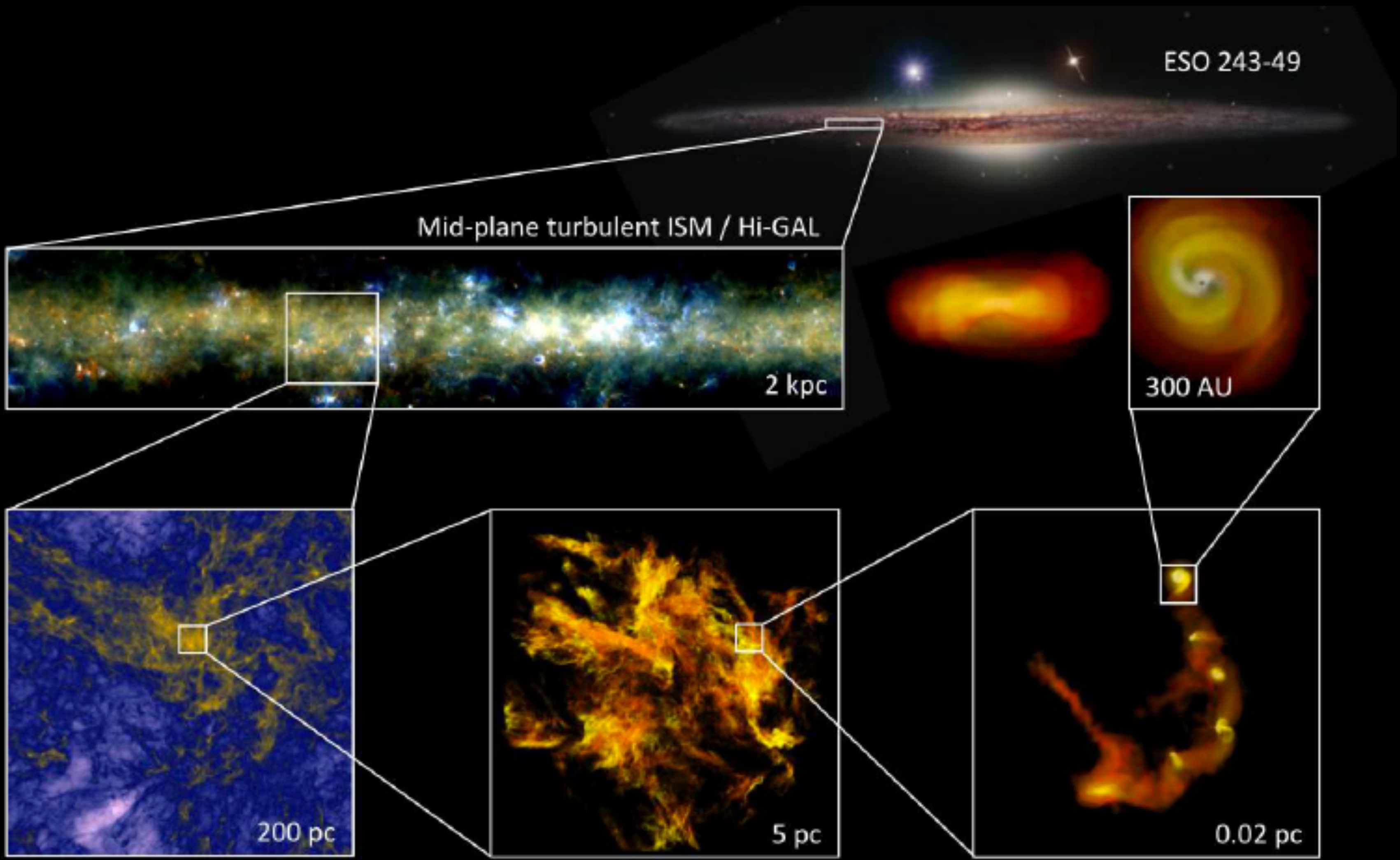
Field diffusion from galaxies



Field strength

Cosmic web z=0.025, Vazza+16

Magnetic fields are dynamically significant on all scales in galaxies



Cosmic magnetism is a highlighted research field of several large observatories

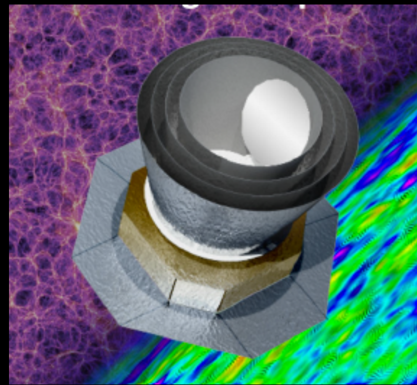
★SKA and its precursors: Synchrotron, Faraday rotation and Zeeman spectroscopy

★ALMA and NOEMA(IRAM) interferometers: Dust polarization and Zeeman spectroscopy

★Stellar polarization surveys + GAIA : Tomography of Galactic dust polarization

A unique perspective from CORE

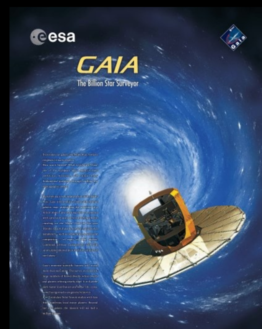
★CORE will have a unique capability to characterize statistically interstellar turbulence: the interplay between matter and magnetic fields in cosmic space



★SKA will be unique to probe magnetic fields in distant galaxies, clusters and the cosmic web.

★ALMA and NOEMA provide the angular resolution to study magnetic fields from pre-stellar cores to proto-stars and their proto-planetary disks

★GAIA astrometry should allow us to build a 3D model of the Milky Way magnetic field on galactic scales

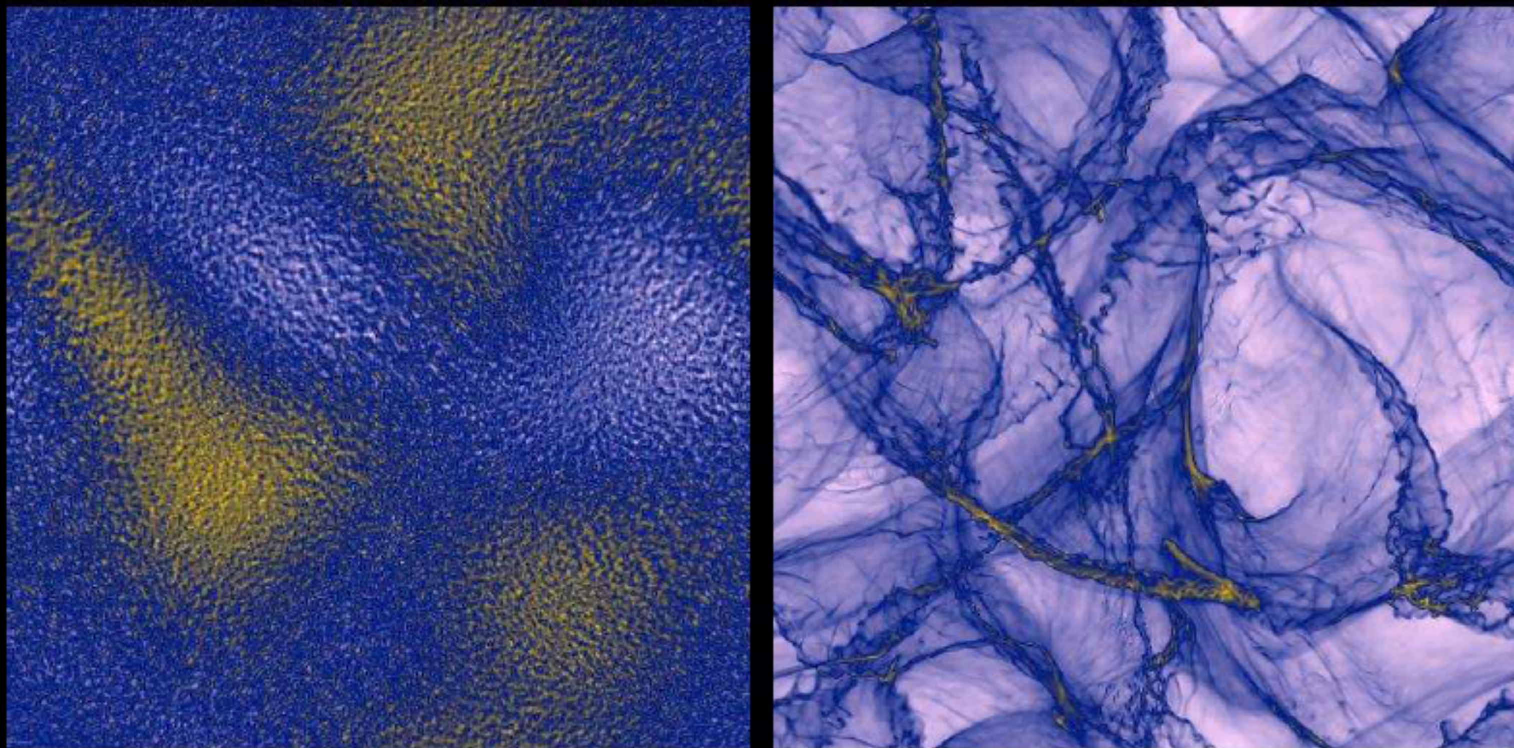


How does turbulence shape the magnetized universe ?

- ★Energy equipartition is observed between kinetic and magnetic energy over a range of scales: in galaxies, the diffuse ISM and star forming molecular clouds
- ★Turbulence creates a range of density structures in interstellar matter and locally the initial conditions for star formation
- ★Turbulence drives the mass, momentum and energy exchange among ISM phases
- ★Interstellar turbulence may not be understood without access to the structure of magnetic field, and its correlation with the density and velocity structure of the gas
- ★The structure of the B-field is also key to model cosmic-ray diffusion and acceleration

Numerical simulations resemble observations in terms of structures and scaling laws, but because of their limited numerical resolution, they cannot reach the very large Reynolds (10^{10}) numbers of interstellar and intergalactic gas flows.

Projected gas density at $t = 2$ Myr (*left*) and at $t = 3$ Myr (*right*) for Model A

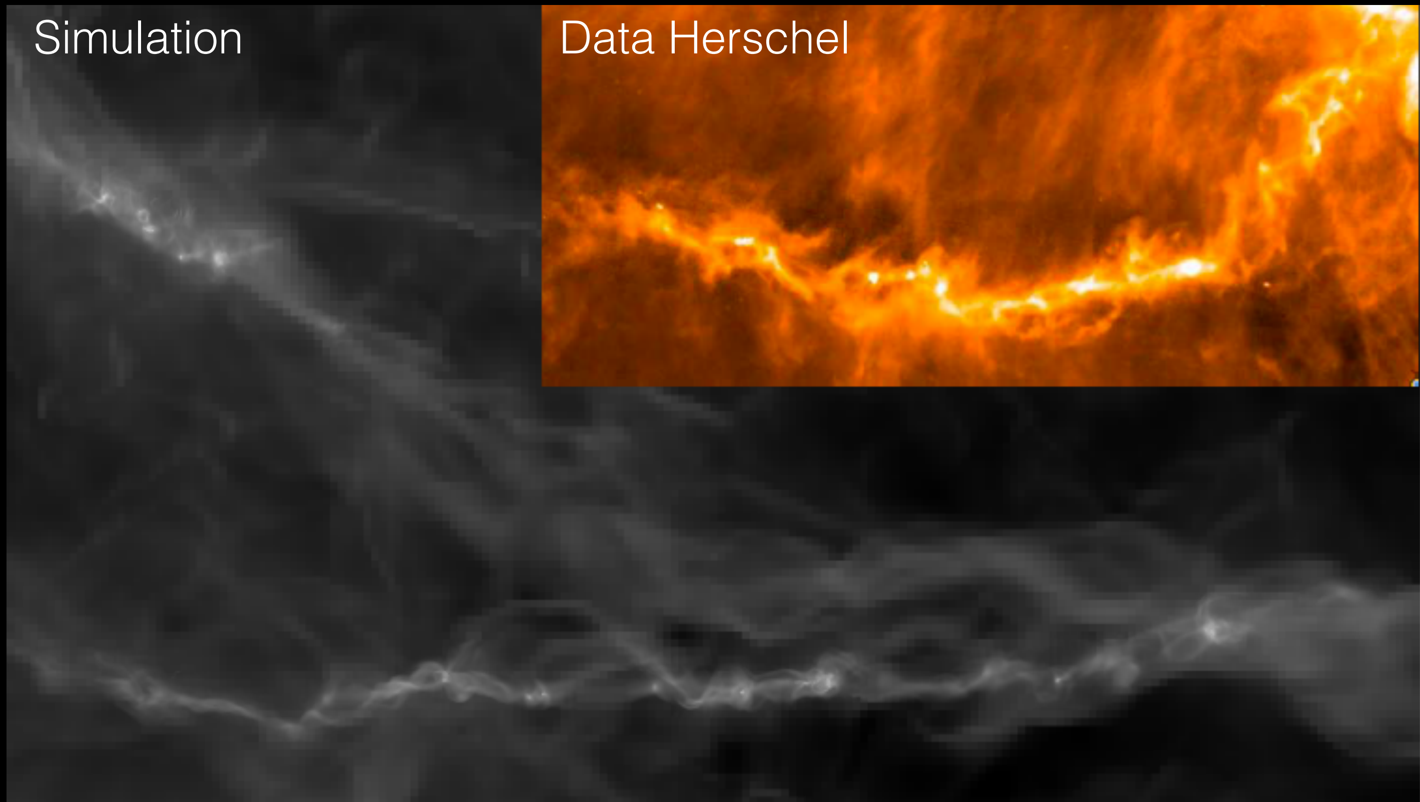


Kritsuk+10

← Two-phase medium right after the forcing is turned ON

Transient “colliding flows” initialize multiphase turbulence →

Simulation yield impressive results but presently they are unable to reveal the inertial range of MHD turbulence



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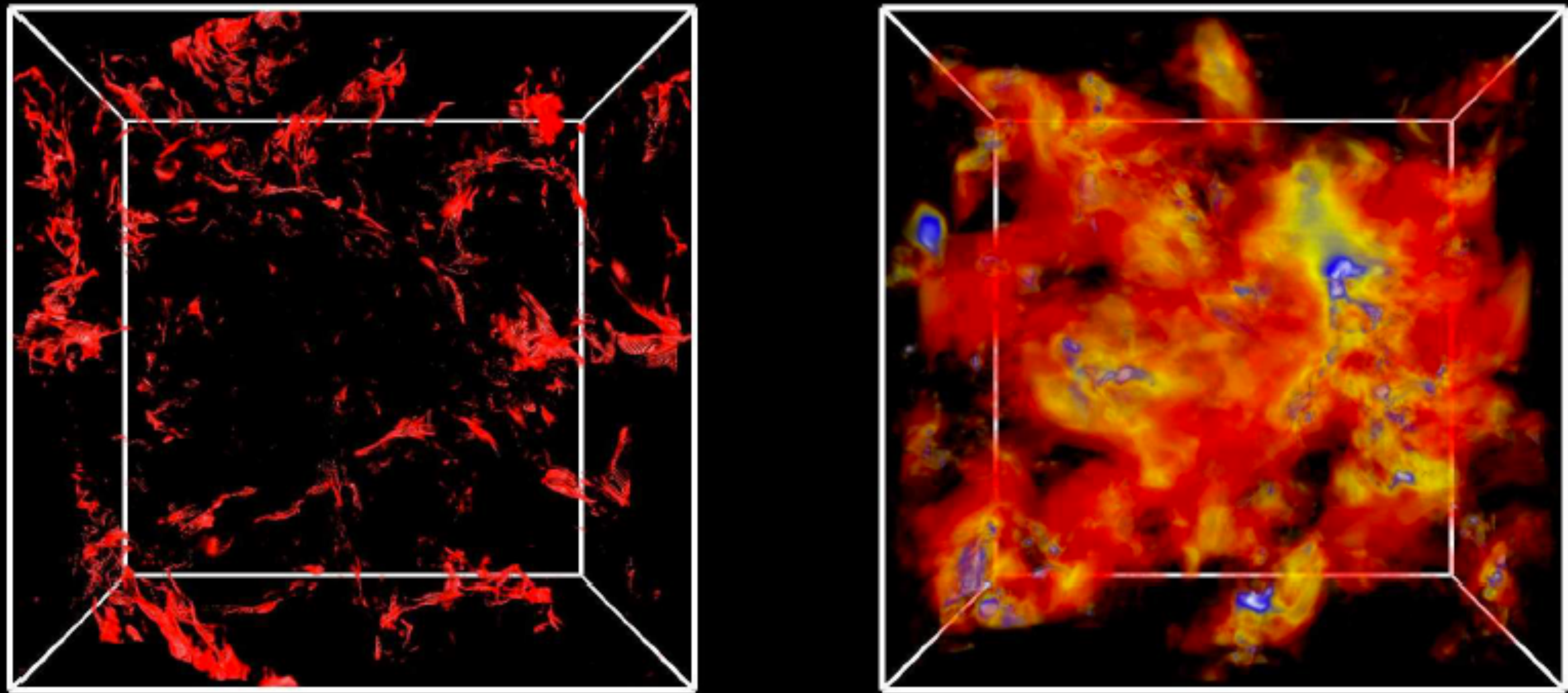
Synergy between observational and numerical studies is essential to make headway.

Statistical studies represent the best hope to bridge theory, simulations and observations.

Magnetic structures

Current sheets (*left*) and regions of high B^2 (blue, *right*) in Model A

Magnetic dissipative structures | Localized enhancement of B-field



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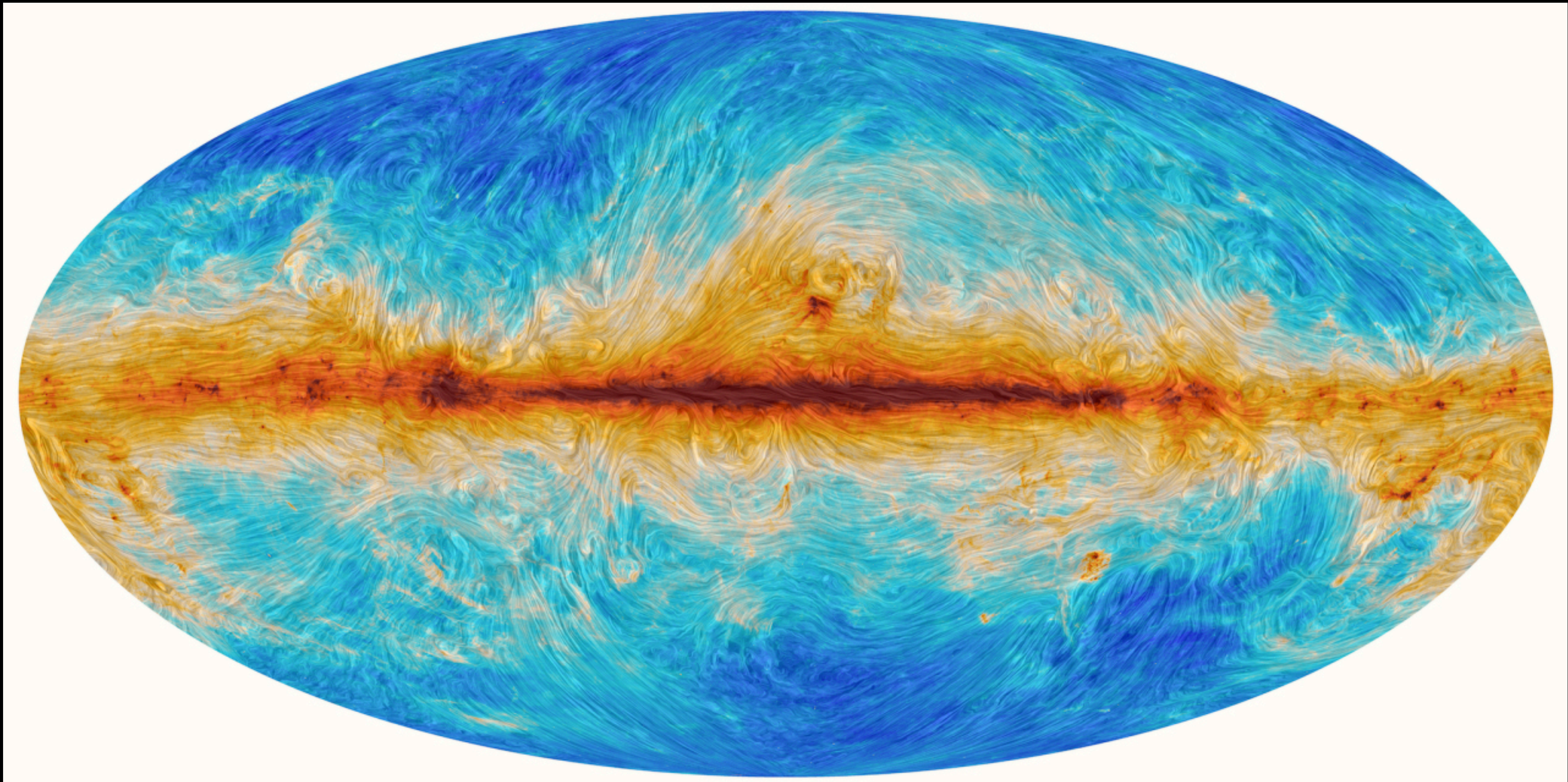
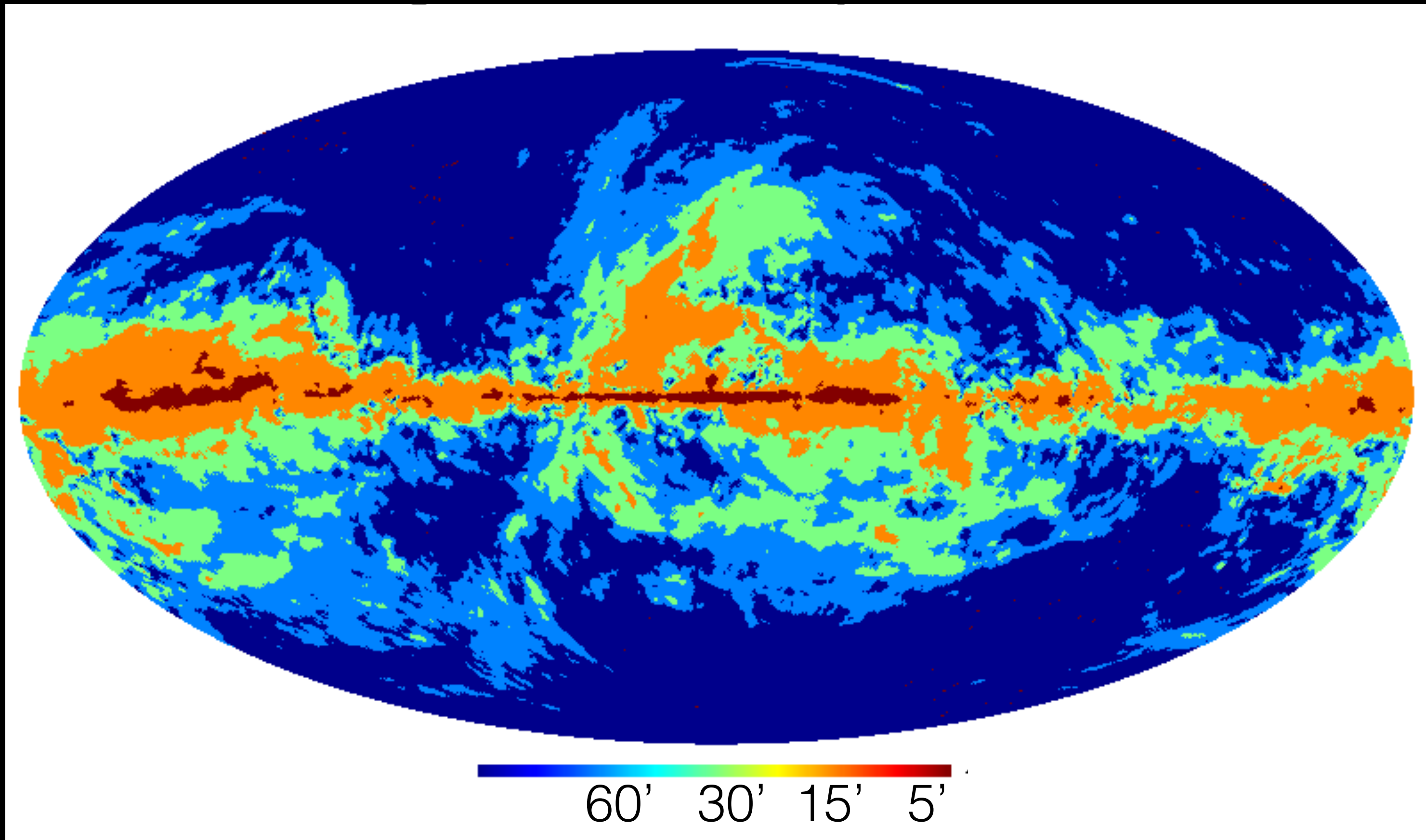
Non-Gaussian excursions => High statistics required



Planck Collaboration - Overview paper 2015

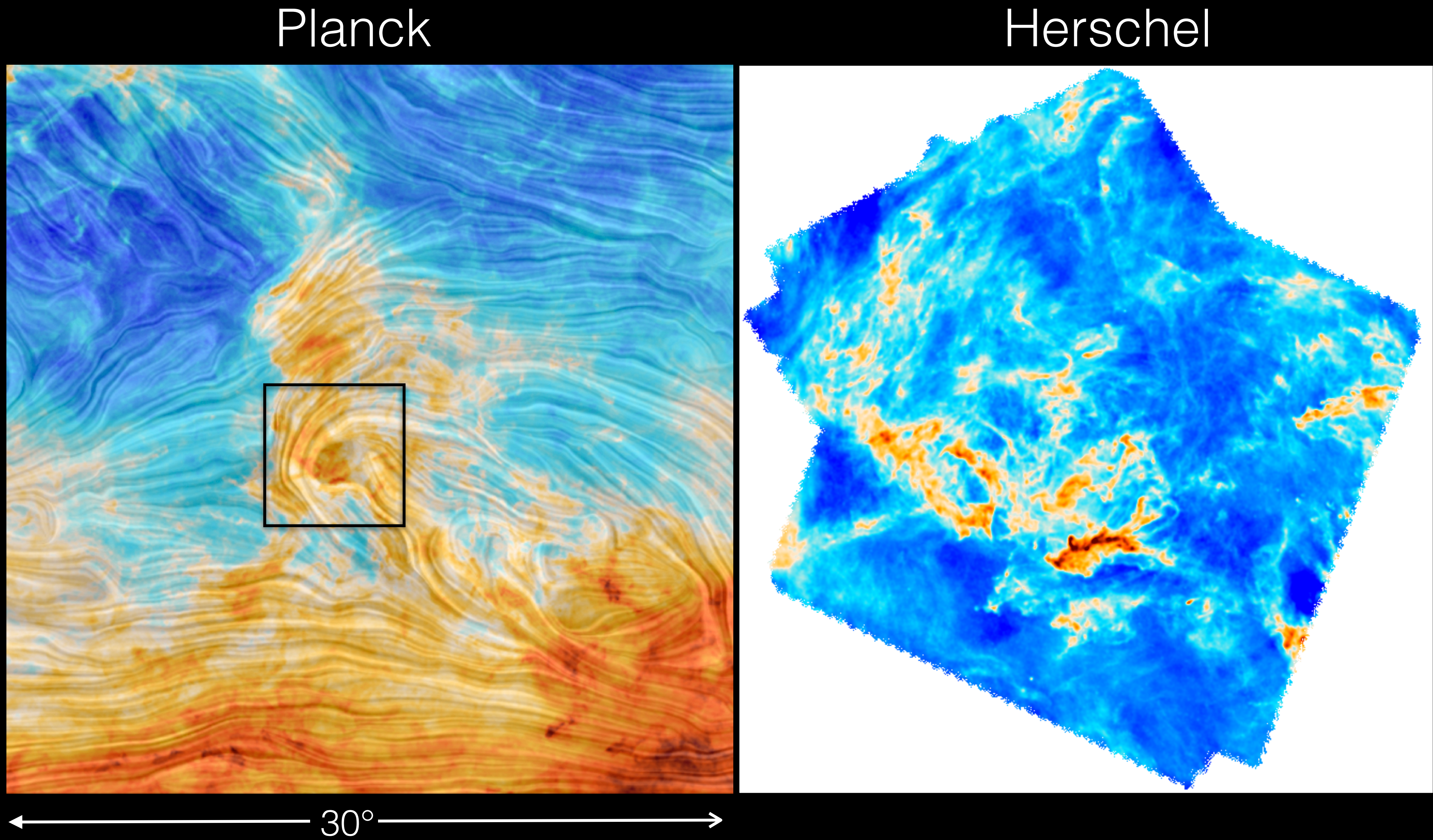
Overcoming Planck limits

Angular scale where EE dust power = Planck noise



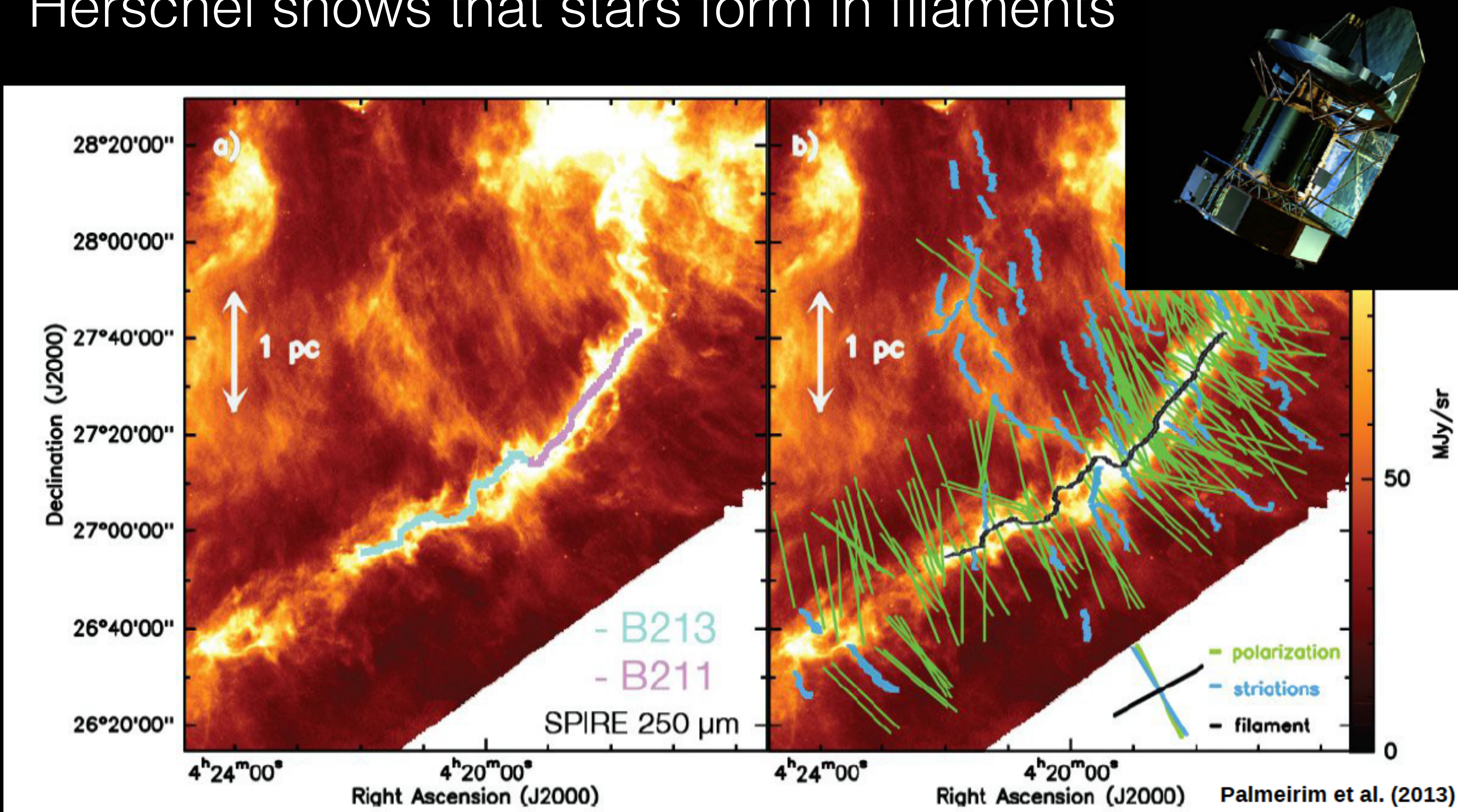
Based on power spectra in Planck intermediate XXX 2014, arXiv 1409.5738

➡ The gain in sensitivity and angular resolution of CORE will increase the data statistics by a factor of 10^3.



➡ CORE will map the magnetic field in similar details to those visible in the Herschel map greatly enhancing the Planck view at the interplay between gas - its density structure and dynamics - and magnetic fields

Herschel shows that stars form in filaments



➡CORE needs to provide the sub-arcminute angular resolution necessary to resolve star forming filaments

Herschel view of the Eagle Nebula

★Massive stars are a main source of energy and momentum injection in the ISM

★They drive turbulence and gas outflows up to galactic scales

★CORE will provide the sensitivity and angular resolution to map the structure of the magnetic field in archetype sources such as the Eagle Nebula.

Summary

★Magnetism is a fascinating facet of our Cosmic Origins to be unveiled

★CORE will provide unprecedented statistics (up to 10^8 modes) to study interstellar turbulence and characterize the interplay between matter and magnetic fields in space

- Access to the inertial range of the turbulent energy cascade
- Characterization of non-Gaussianity of turbulence

★It can uniquely address three key astrophysics questions involving magnetic fields

- How turbulence shapes the magnetized ISM?
- How does gravity becomes the local dominant force to allow for star formation?
- How feedback from massive stars impacts magnetic fields and vice versa?