Dust (total) emission of the ISM as seen by *Planck*

Signature of the magnetic field geometry of interstellar filaments in dust polarization maps

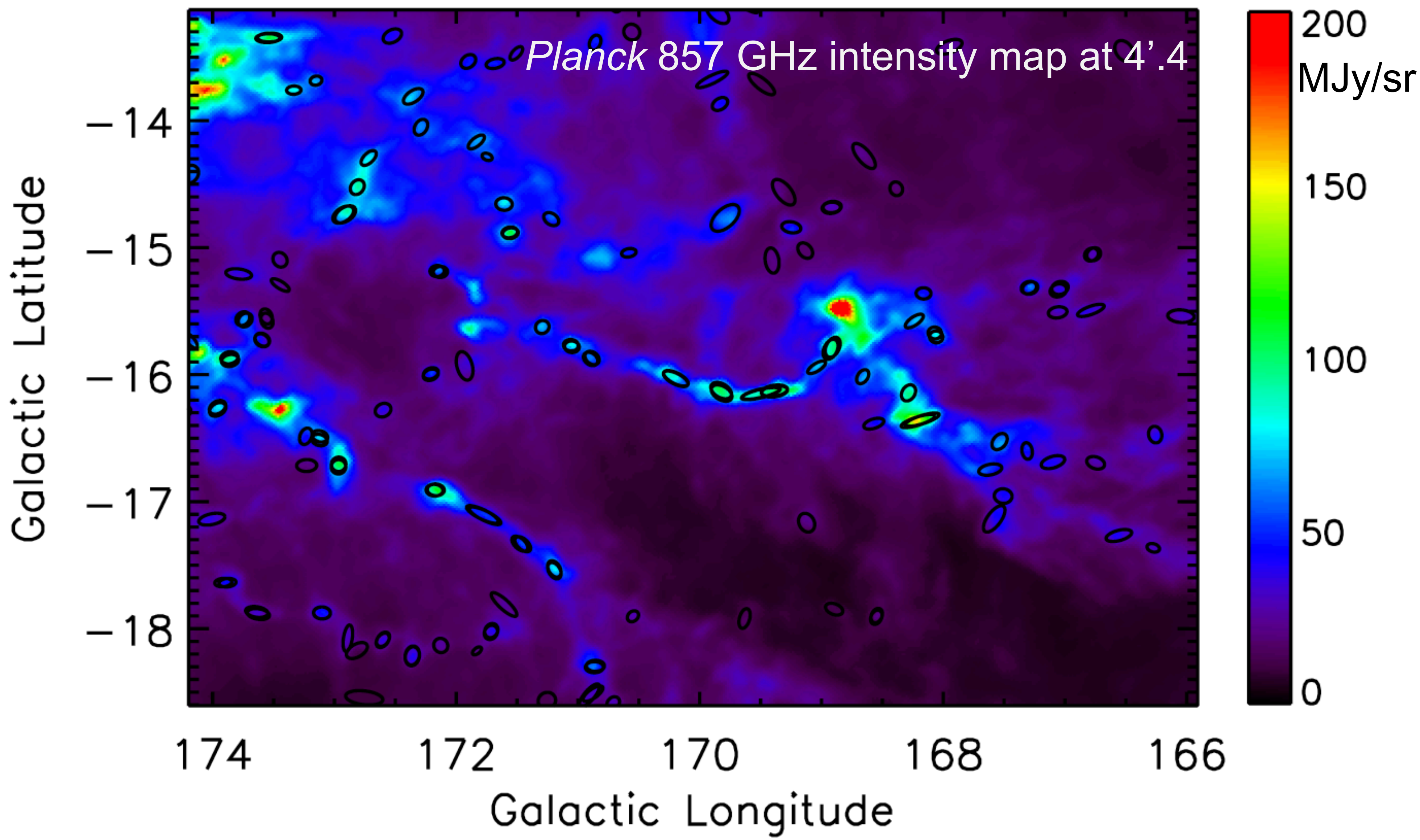
Doris Arzoumanian (IAS, Orsay)
On behalf of the *Planck* Collaboration

The microwave sky in temperature and polarization
Planck 2014 - Ferrara - 2/12/2014

Link between the filamentary structure and the distribution of cold clumps in the interstellar medium (ISM)

Dense filaments are observed to be the main sites of star formation in molecular clouds

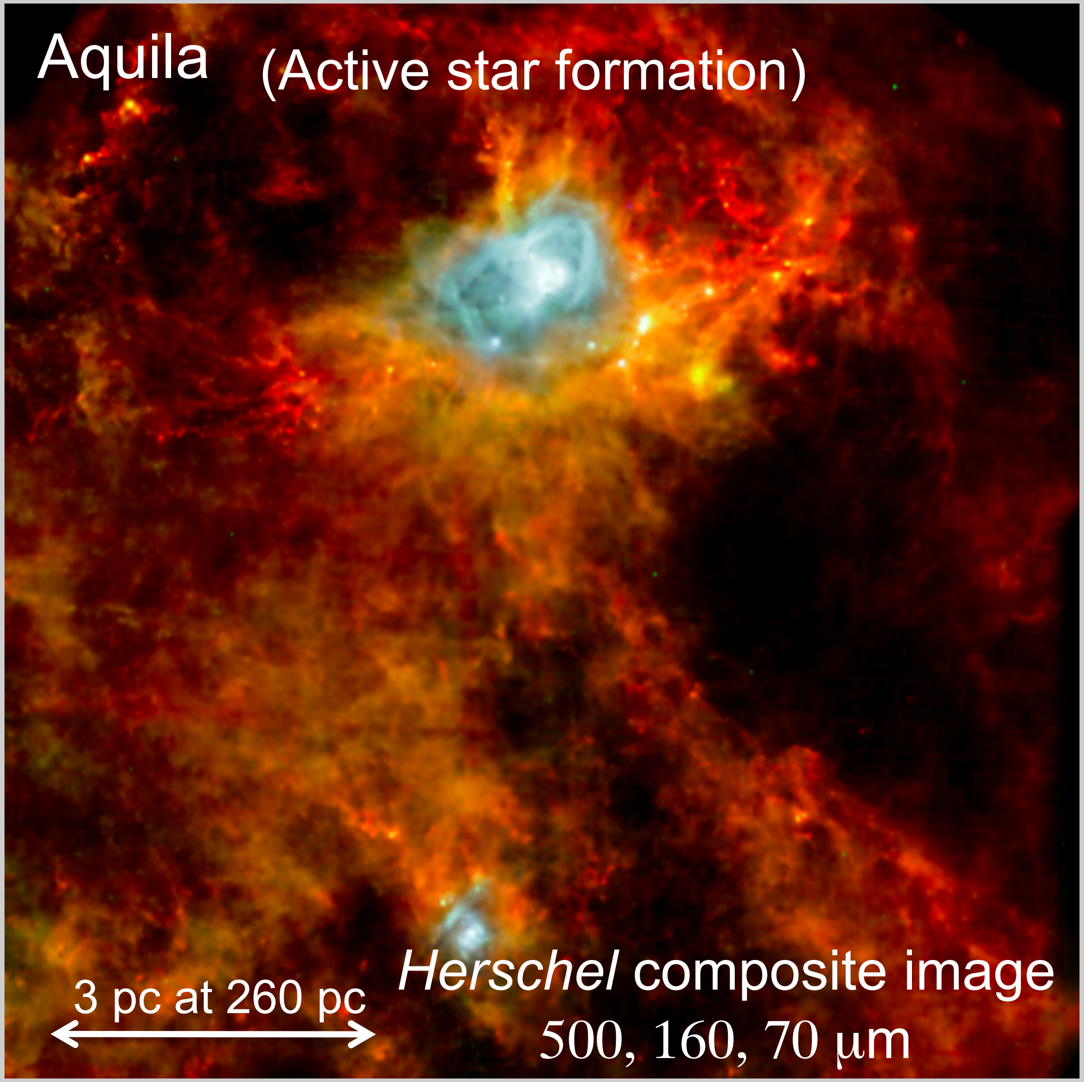
Planck Cold clumps (C3PO catalogue) seen in the Taurus star forming region

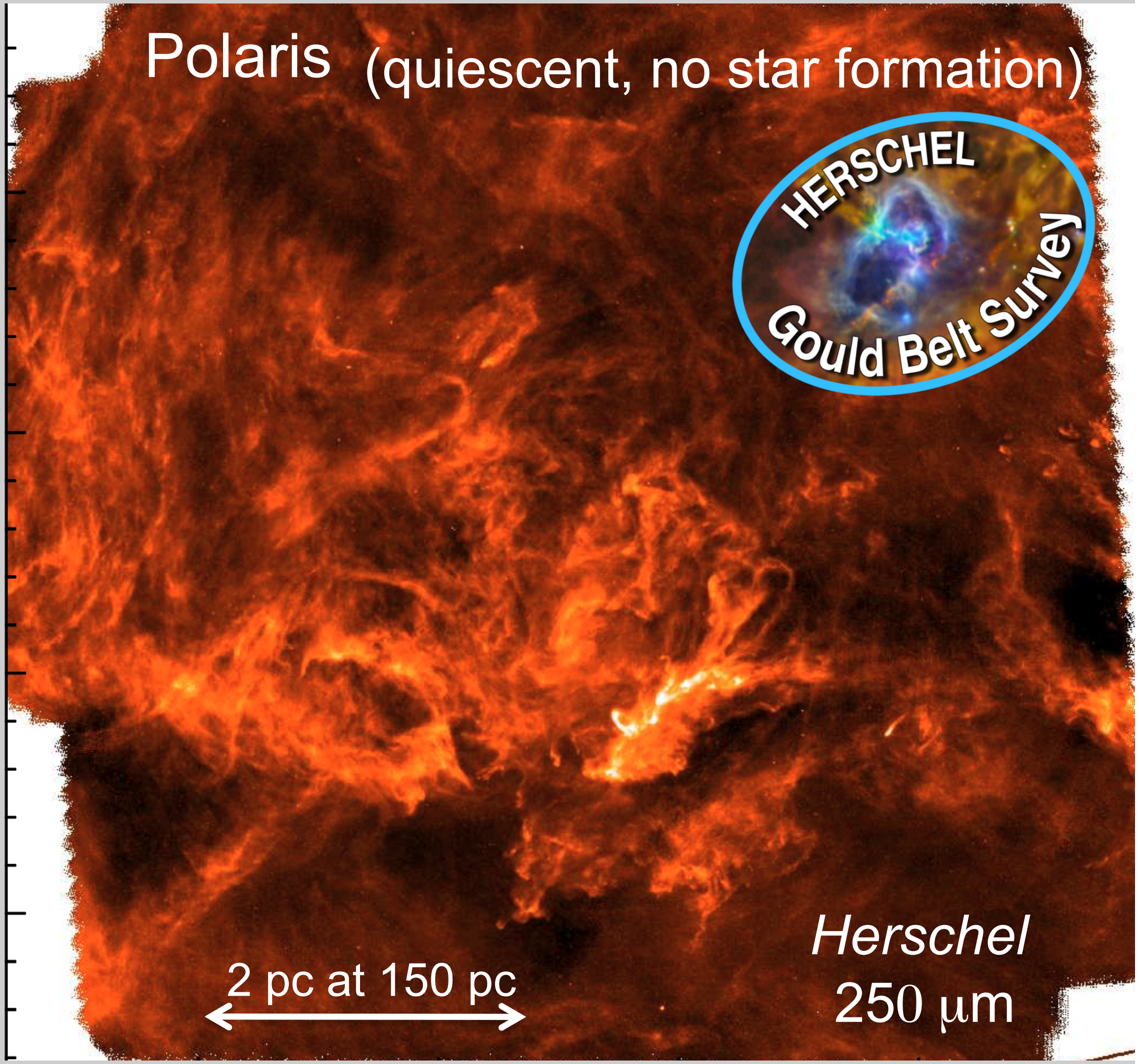


Planck early results XXIII 2011

Omnipresence of filamentary structures in star forming regions, quiescent clouds, and the diffuse ISM

Filament formation in the ISM from an interplay between
turbulence, gravity, and magnetic fields
What is the role of these various processes?



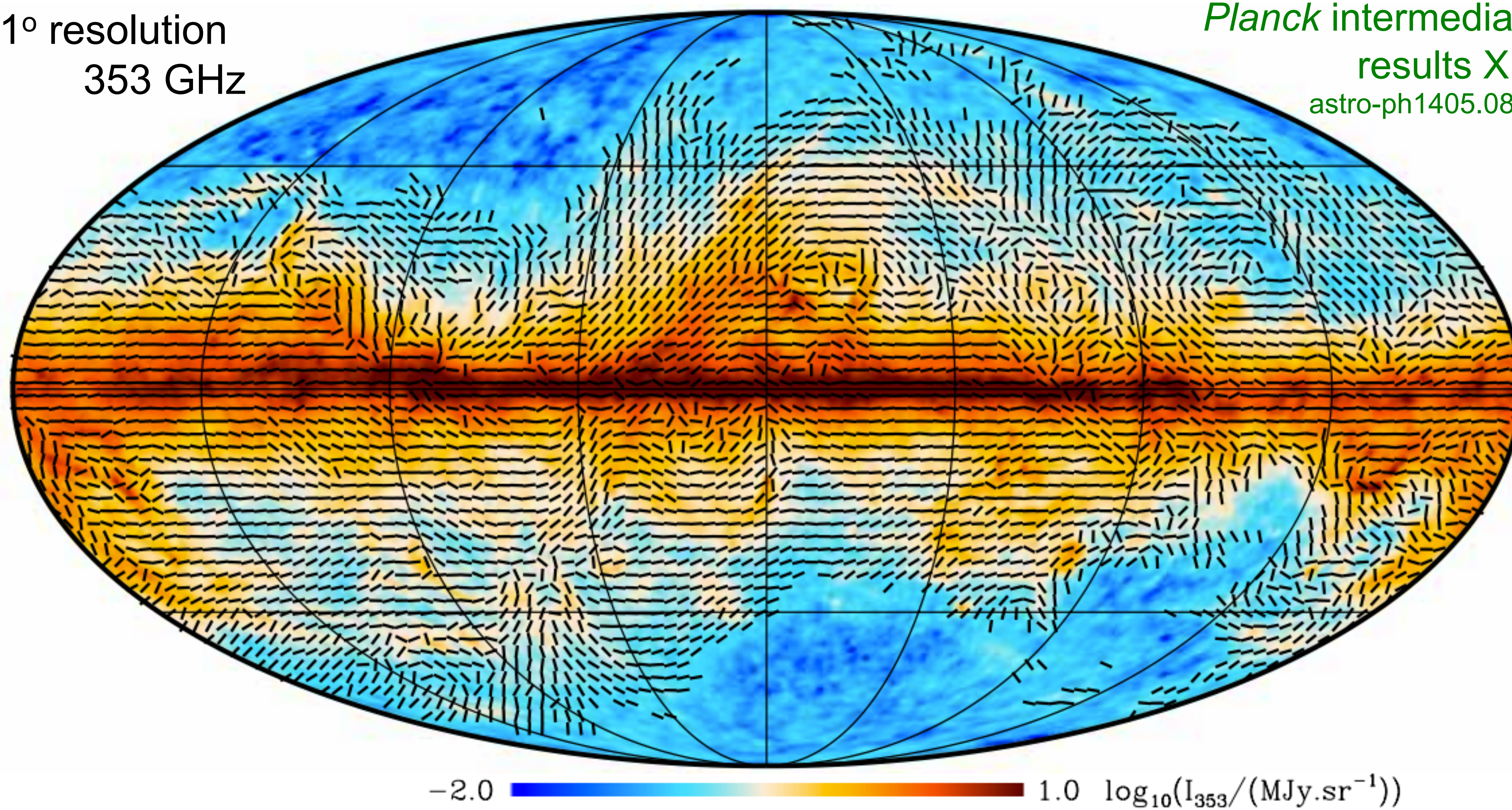


André et al., Bontemps et al., Könyves et al., Men'shchikov et al., Miville-Deschênes et al. 2010

Planck polarization observations reveal the link between the magnetic field structure and the distribution of the interstellar matter

1° resolution
353 GHz

Planck intermediate results XIX
astro-ph1405.0871

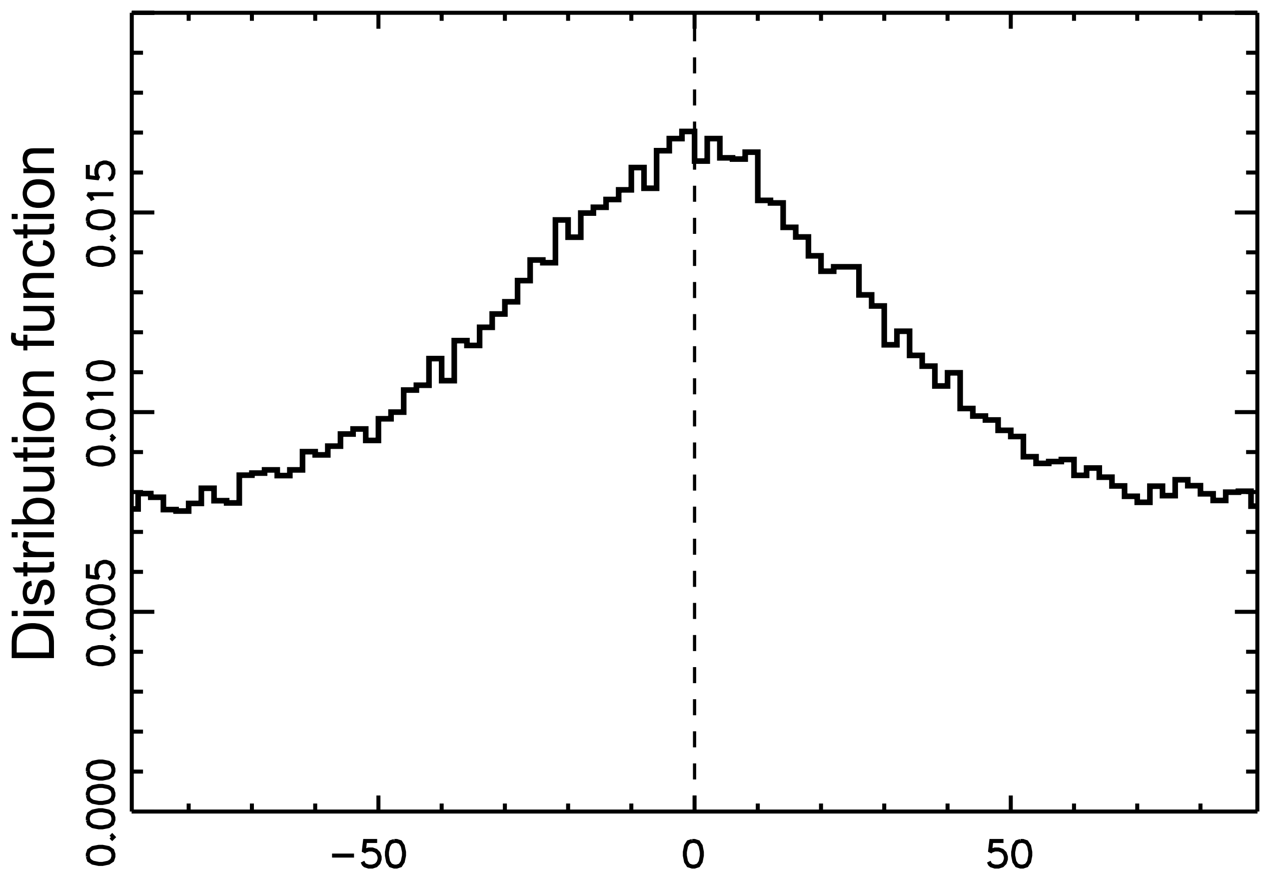


Total intensity at 353 GHz, with plane-of-the-sky magnetic field (B_{POS}) orientation (segments with normalized length)

Statistical analysis of the relative orientation between magnetic field and interstellar filaments observed by *Planck*

In the diffuse ISM, filaments are preferentially aligned with the local B_{POS}

Planck intermediate results XXXII and Poster by Andrea Bracco



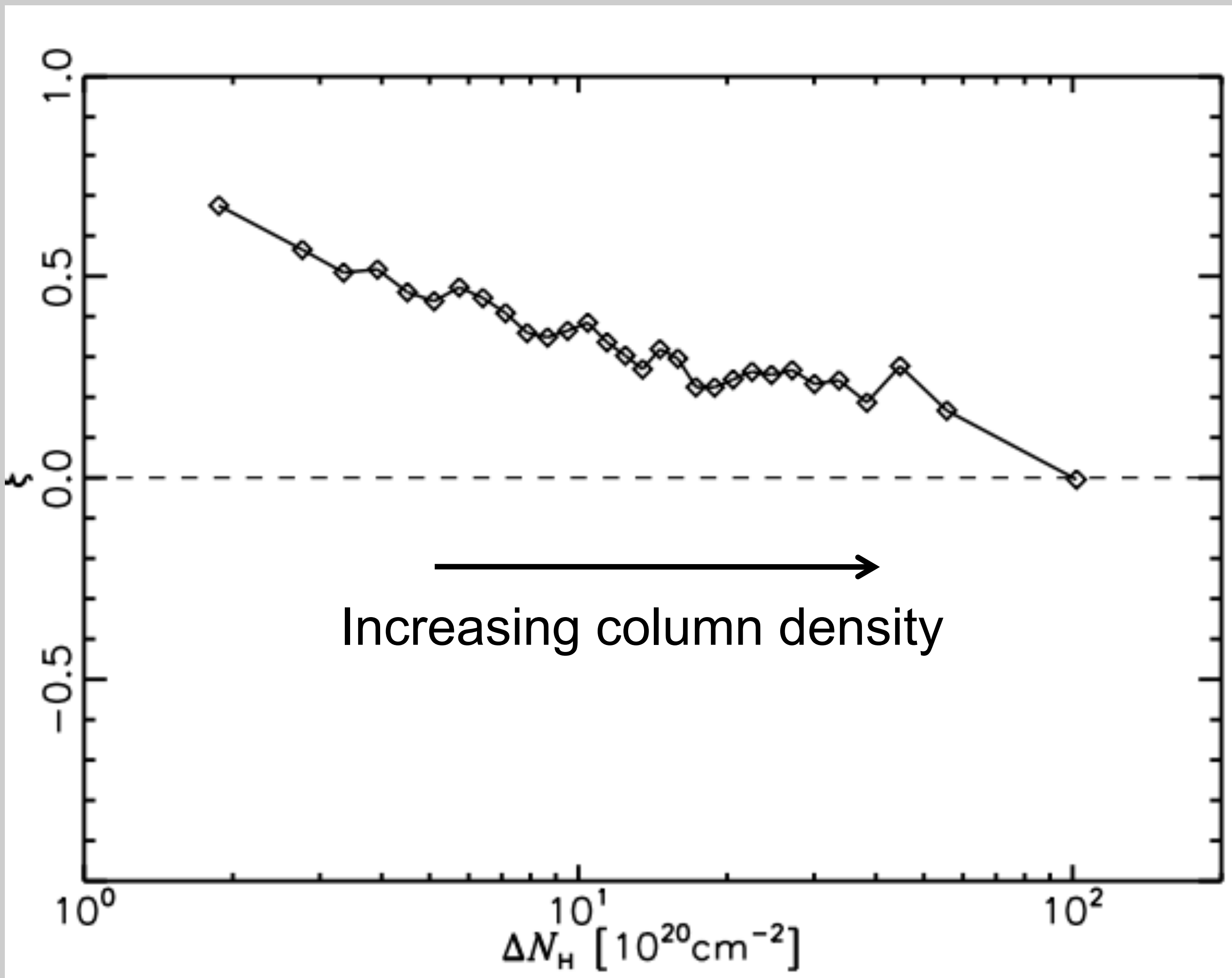
Difference between the orientations of B_{POS} and of interstellar filaments (Distribution dominated by diffuse filaments)

Statistical analysis of the relative orientation between magnetic field and interstellar filaments observed by *Planck*

In the diffuse ISM, filaments are preferentially aligned with the local B_{POS}
While filaments perpendicular to the field appear in molecular clouds

Planck intermediate results XXXII and Poster by Andrea Bracco

Smaller dispersion of the relative orientation



See also Clark et al. 2014, McClure-Griffiths 2006, Chapman et al. 2011, Pereyra & Magalhães 2004

Statistical analysis of the relative orientation between magnetic field and interstellar filaments observed by *Planck*

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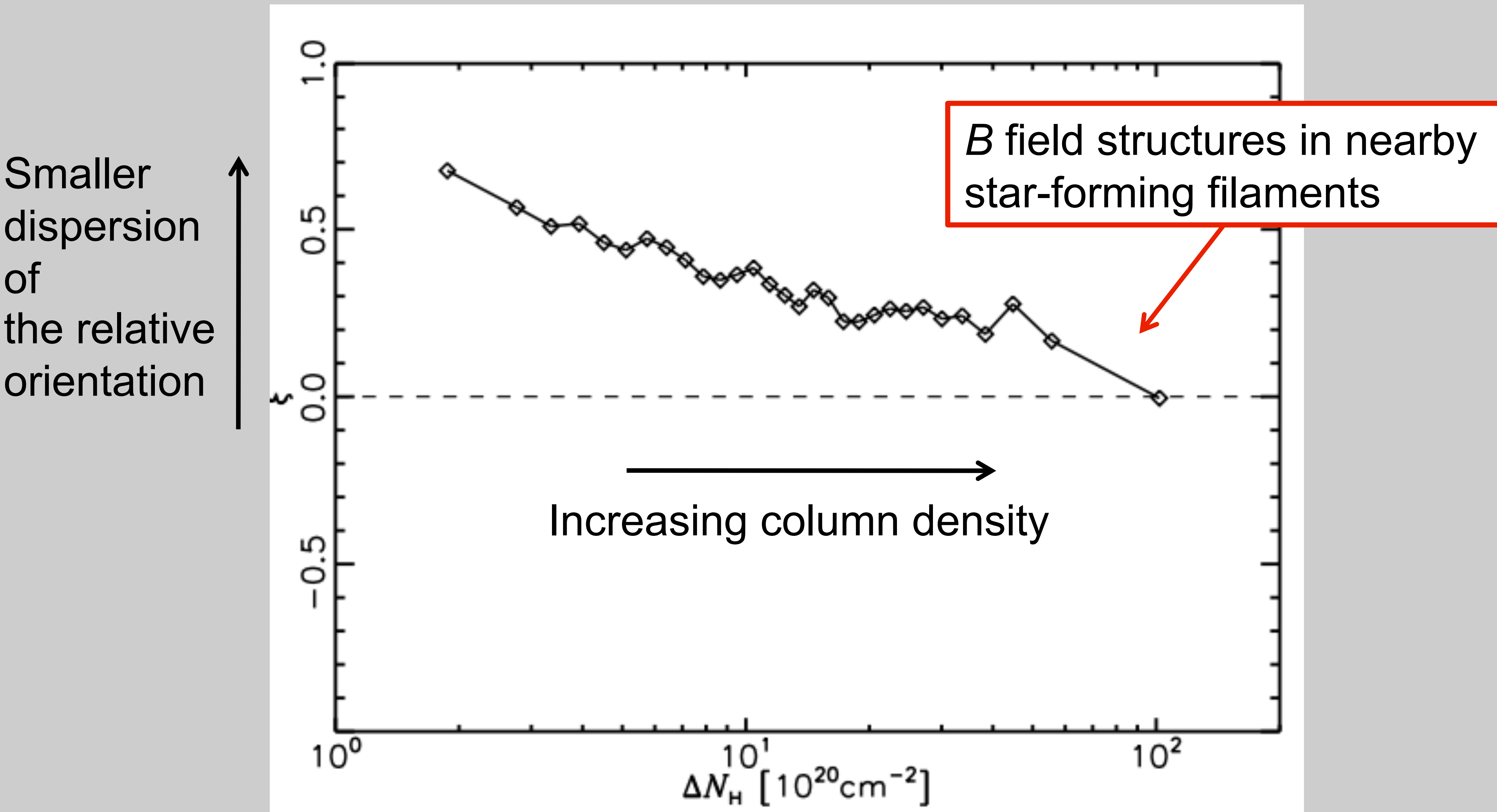
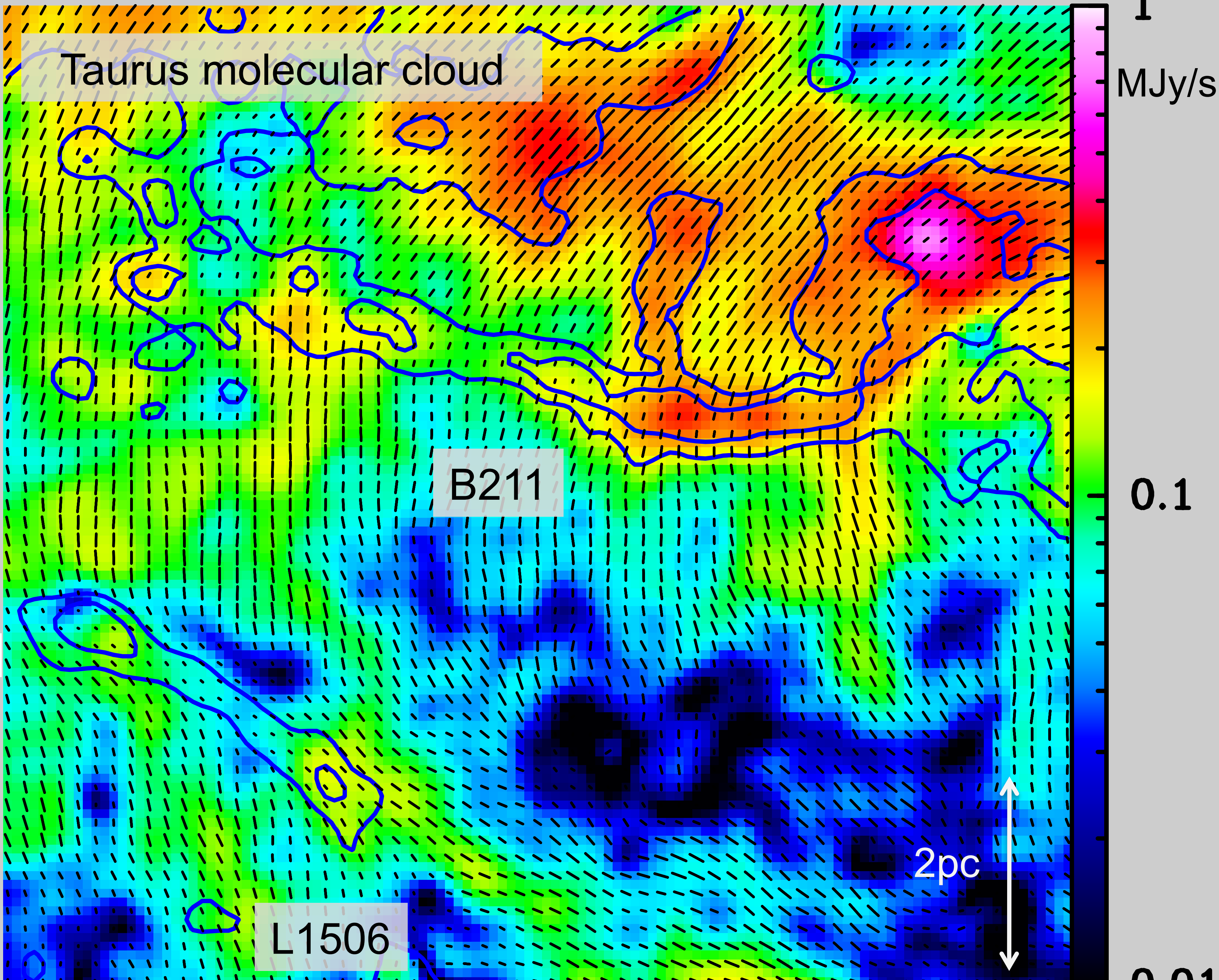
Planck intermediate results XXXII and Poster by Andrea Bracco



See also Clark et al. 2014, McClure-Griffiths 2006, Chapman et al. 2011, Pereyra & Magalhães 2004

Polarized emission and magnetic field orientation as observed by *Planck*



Polarized intensity

$$P = \sqrt{Q^2 + U^2}$$

Polarization fraction

$$p = P/I$$

Polarization angle

$$\psi = 0.5 \arctan(-U, Q)$$

+ 90°
orientation of ***B***
projected on
the plane of the sky

Resolution: 10',
0.2pc at 140pc
blue contours: *I* 353GHz (3 & 6 MJy/sr),
black segments: B_{POS} length ~ polarization fraction

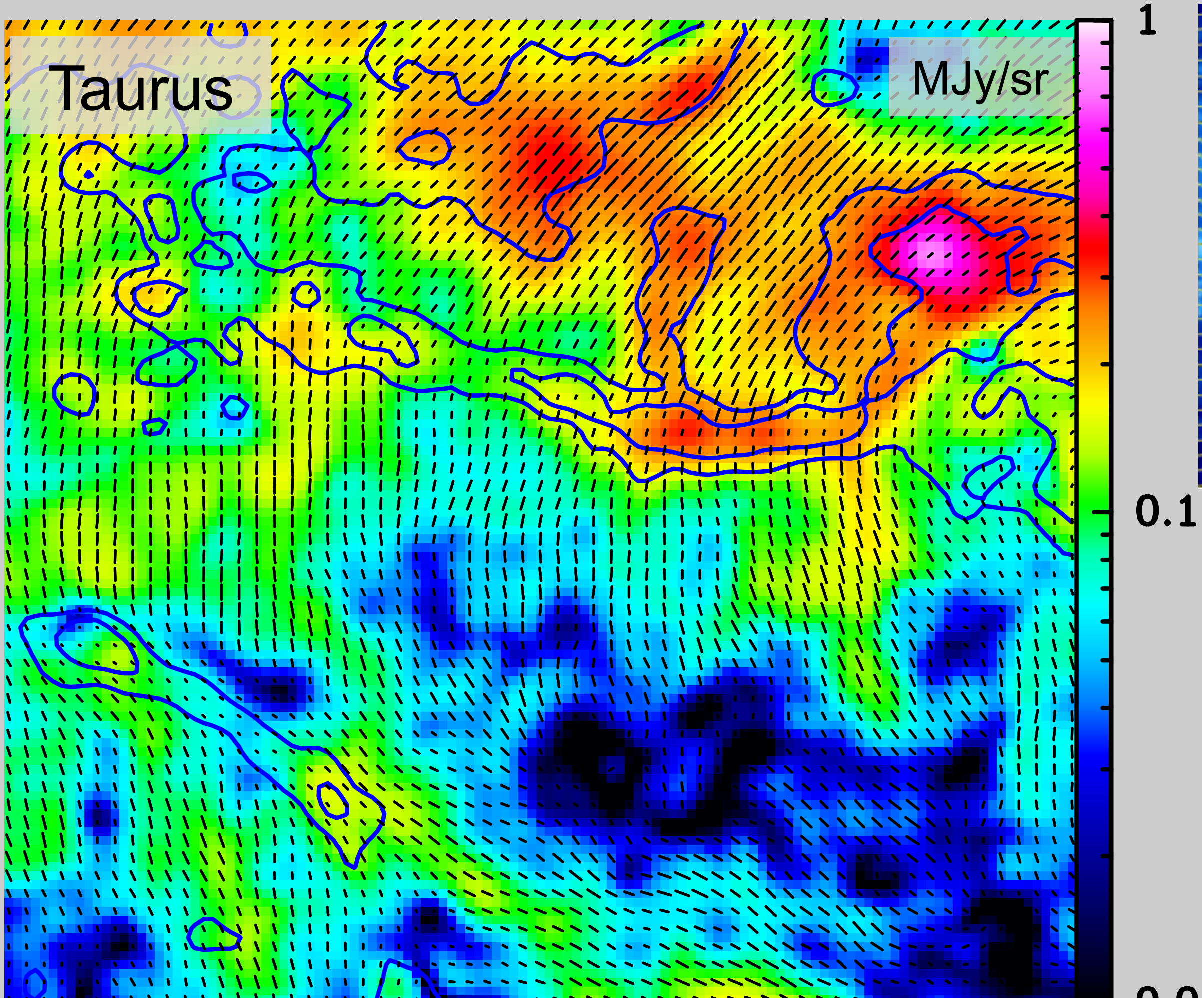
Planck intermediate results XXXIII

Ordered magnetic field structure in molecular clouds

The observations suggest that, at the scales probed by *Planck,* the magnetic field is dynamically important in the formation of density structures such as filaments (preliminary)

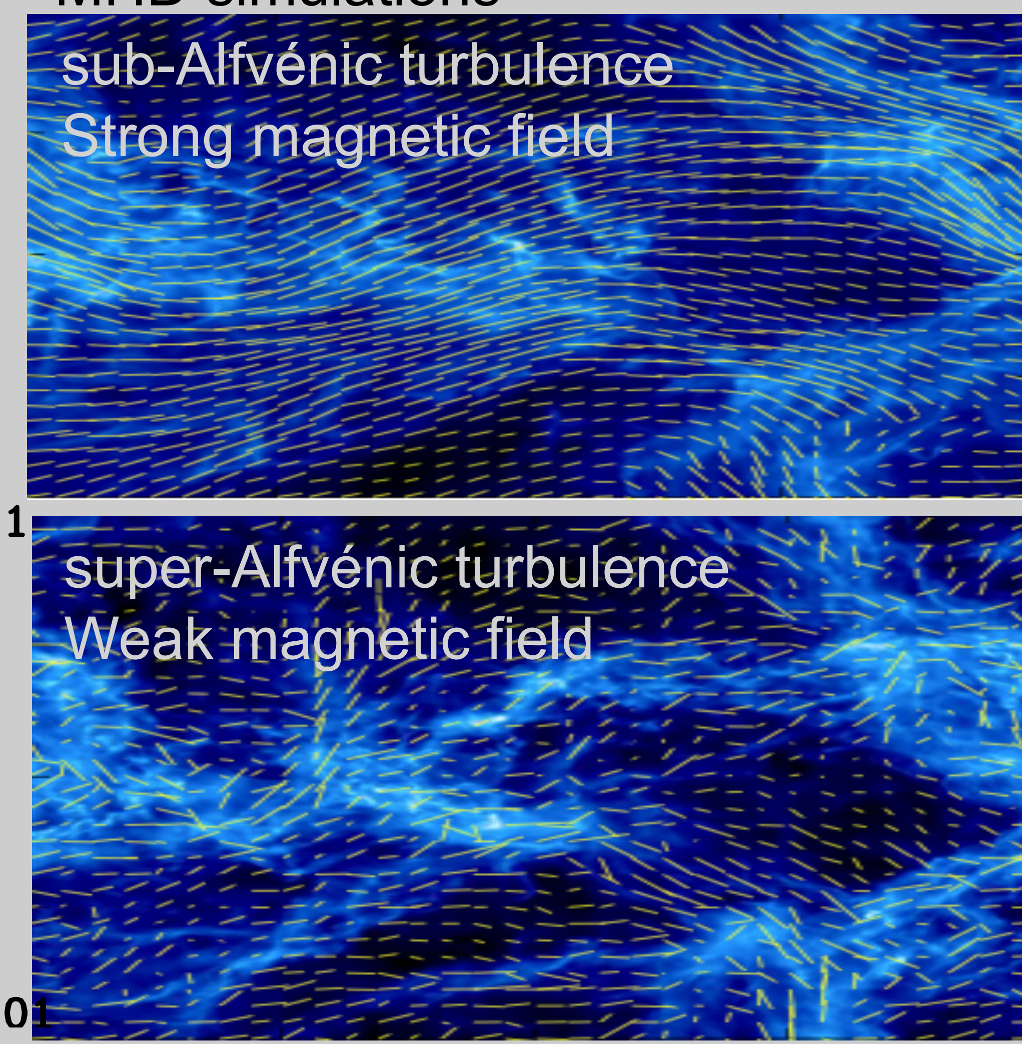
Comparison with MHD numerical simulations (e.g., Falceta-Gonçalves et al. 2008, Soler et al. 2013) and with estimates of field strength from Chandrasekhar-Fermi method (e.g., Chapman et al. 2011)

Planck observations



MHD simulations

Soler et al. 2013

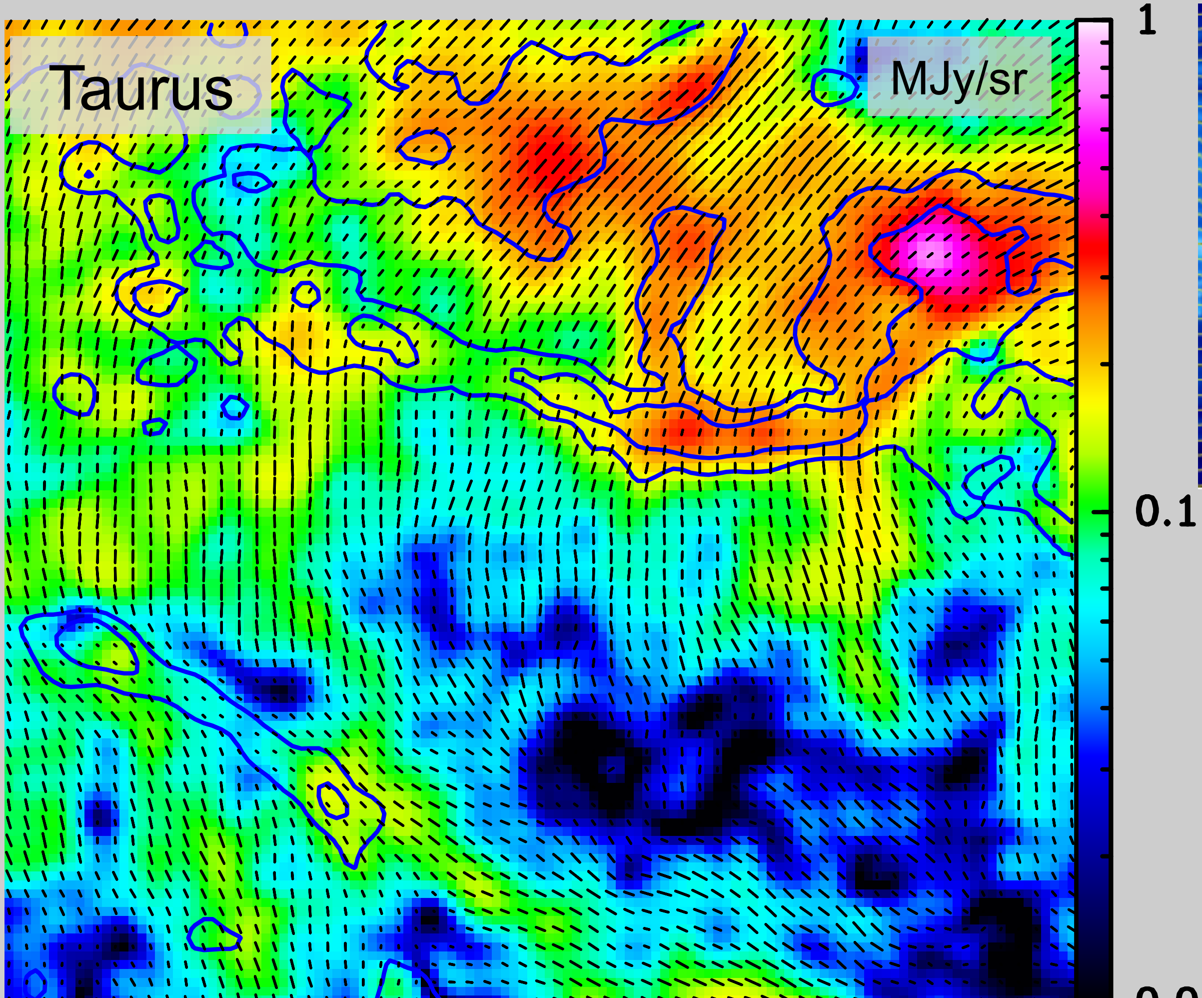


Poster presented by Juan Soler

Probing the role of the magnetic field in the formation of molecular clouds

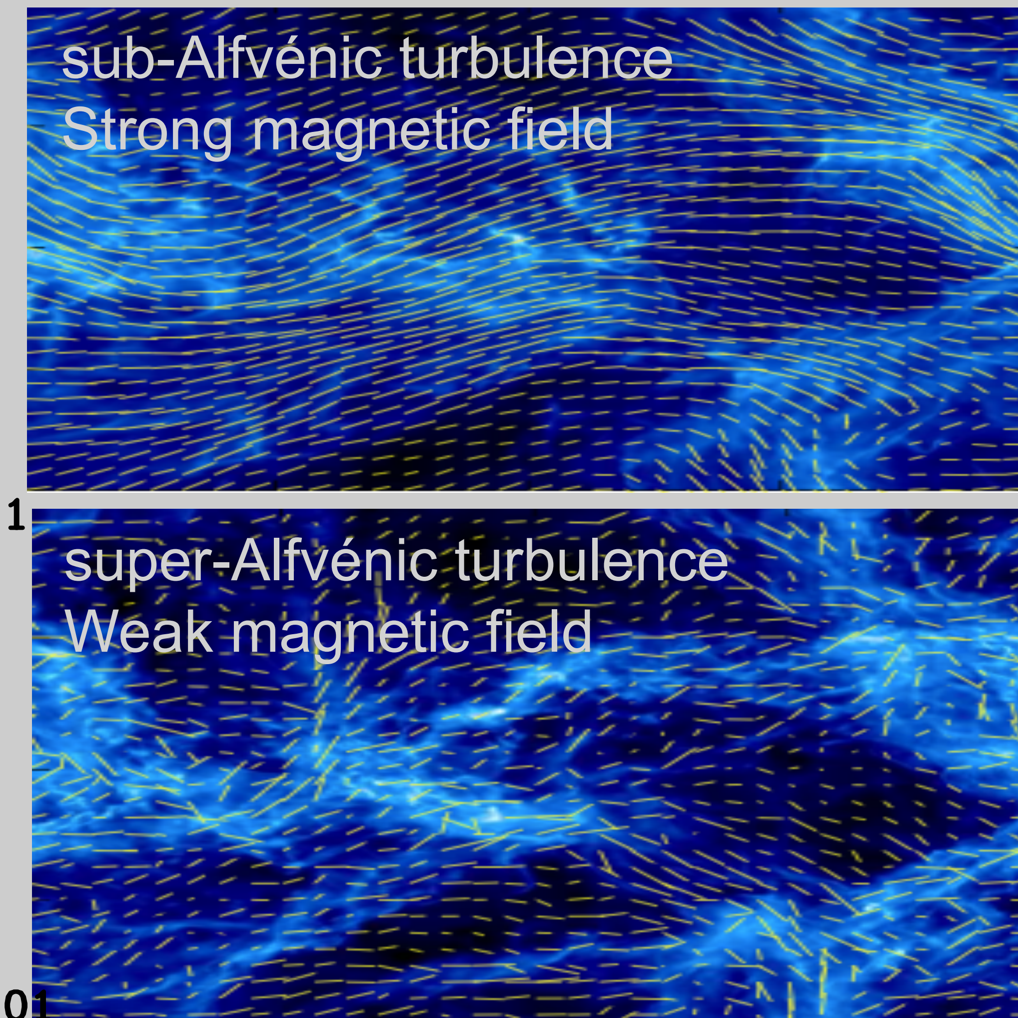
Juan Diego Soler (IAS, Orsay) on behalf of the PLANCK collaboration

Planck observations



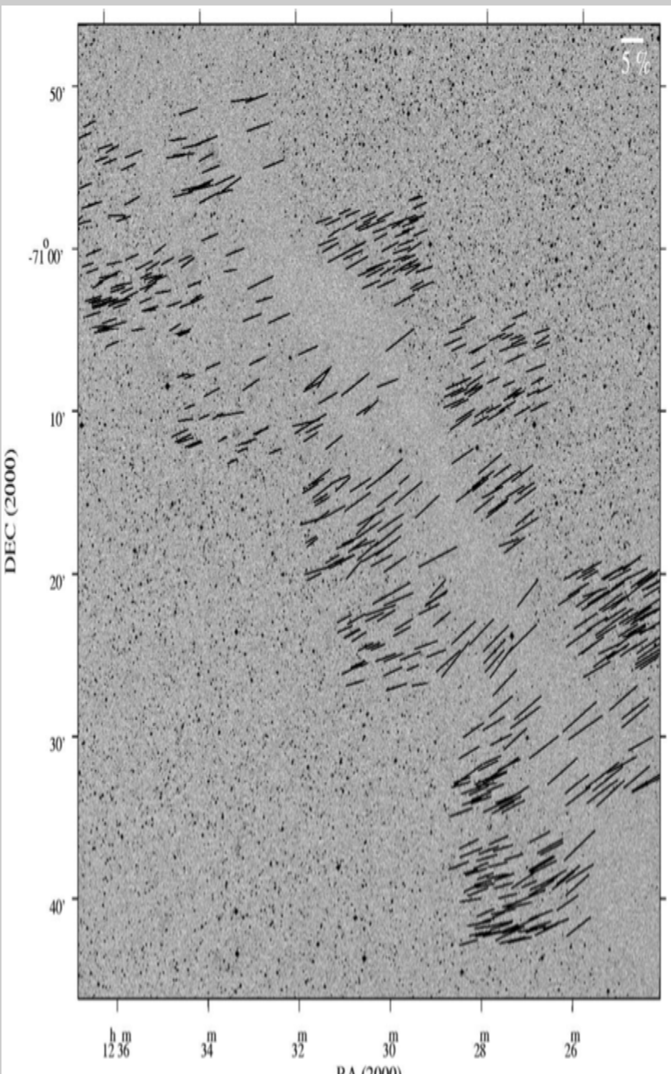
MHD simulations

Soler et al. 2013

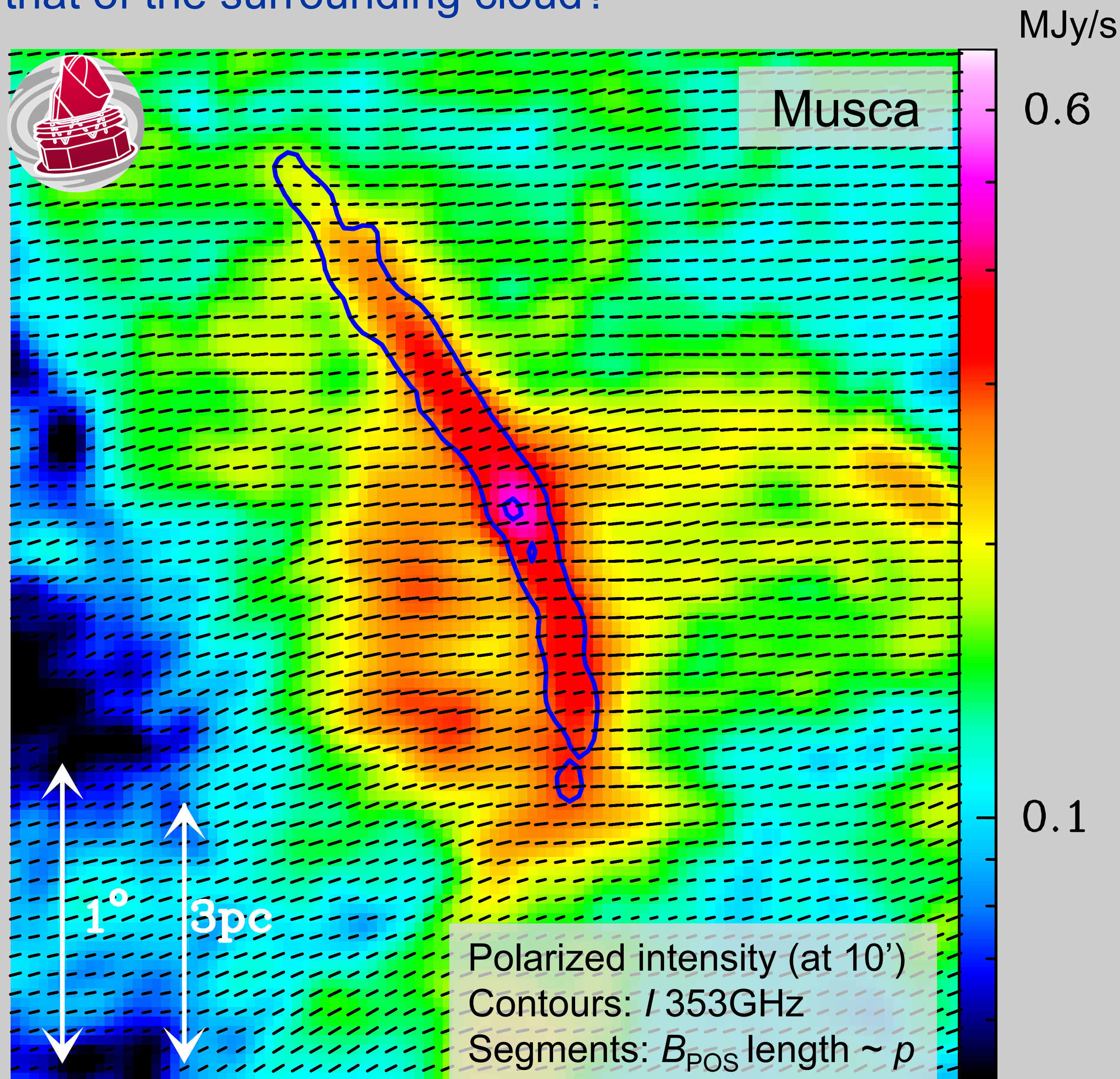


Dust emission observed towards interstellar filaments

- What is the 3D magnetic field structure of a star forming filament?
- Is it the same as that of the surrounding cloud?



Musca in absorption with starlight polarization
Pereyra & Magalhães 2004



The observed polarized emission depends on the structure of the magnetic field and the polarization efficiency of dust grains

Linear polarization results from non-spherical spinning dust grains, which precess around the local magnetic field lines (Davis & Greenstein 1951, Vaillancourt 2007)

Observed Stokes parameters

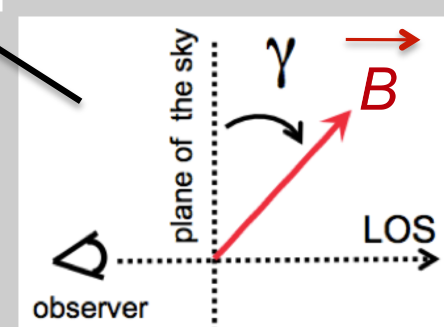
The imprint of the mean field geometry is present in *Q* and *U*, which are integrated quantities along the line of sight (LOS)

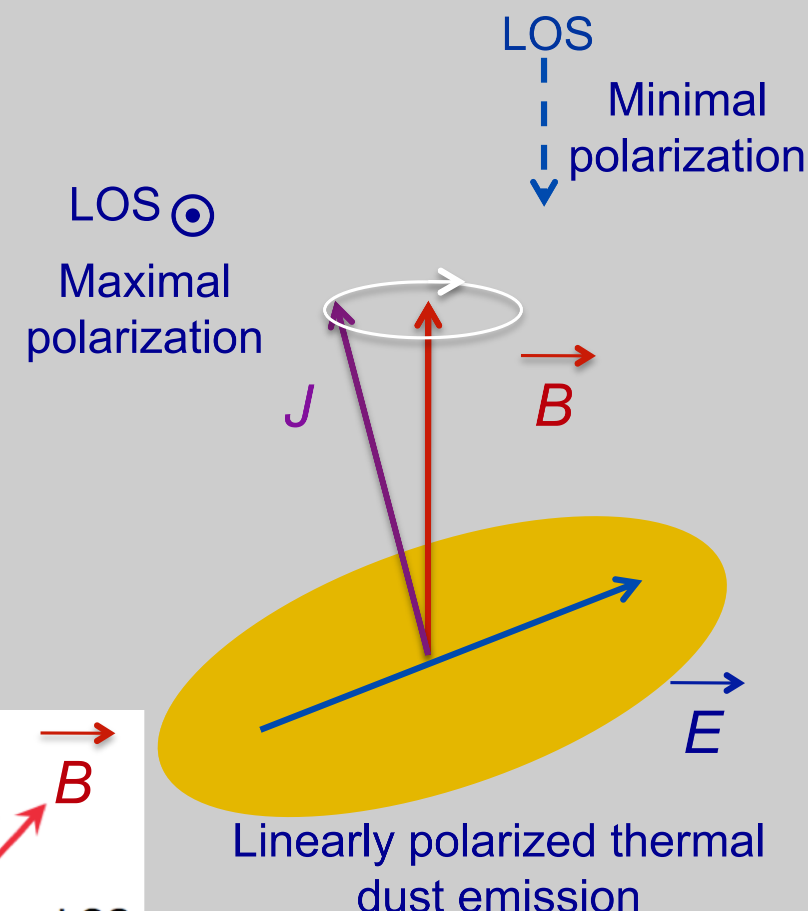
$$Q = \int p_0 \cos(2\psi) \cos^2(\gamma)\, dI$$

$$U = \int p_0 \sin(2\psi) \cos^2(\gamma)\, dI$$

Polarization fraction of dust grains

Polarization angle, + 90° orientation of B_{POS}





Modelling the Stokes parameters observed towards nearby filaments

Reconstructing the 3D magnetic field of the filament and its parent cloud, with a uniform dust polarization fraction (p_0), i.e., assuming that all of the observed polarized emission is accounted for by the field geometry

Observed Stokes parameters

The imprint of the mean field geometry is present in *Q* and *U*, which are integrated quantities along the line of sight (LOS)

$$Q = \int p_0 \cos(2\psi) \cos^2(\gamma)\, dI$$

$$U = \int p_0 \sin(2\psi) \cos^2(\gamma)\, dI$$

Degeneracy

Grain alignment

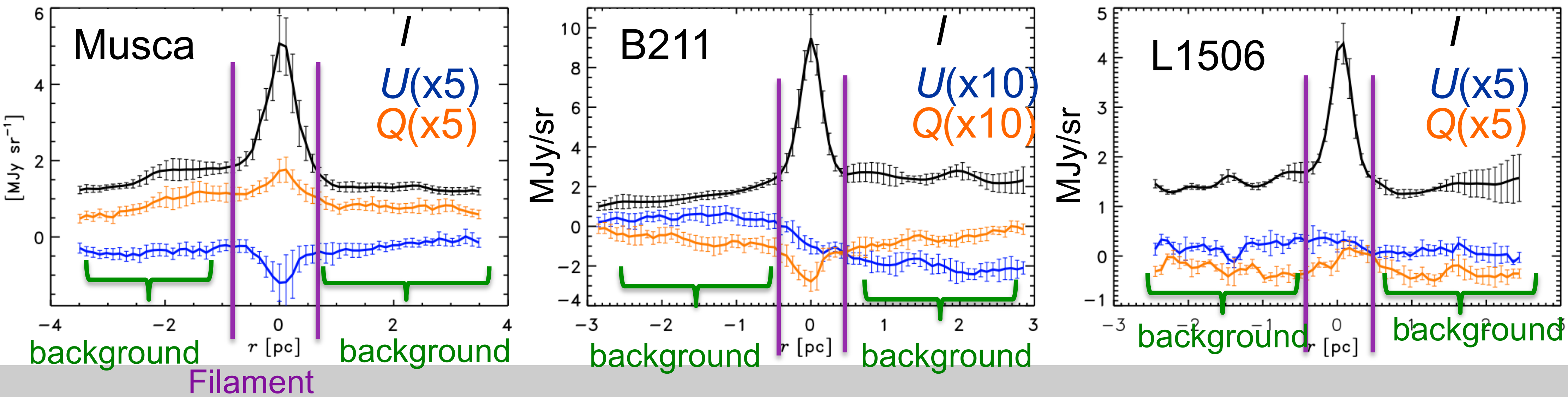
$$p_0 = p_{\max} R\, F$$

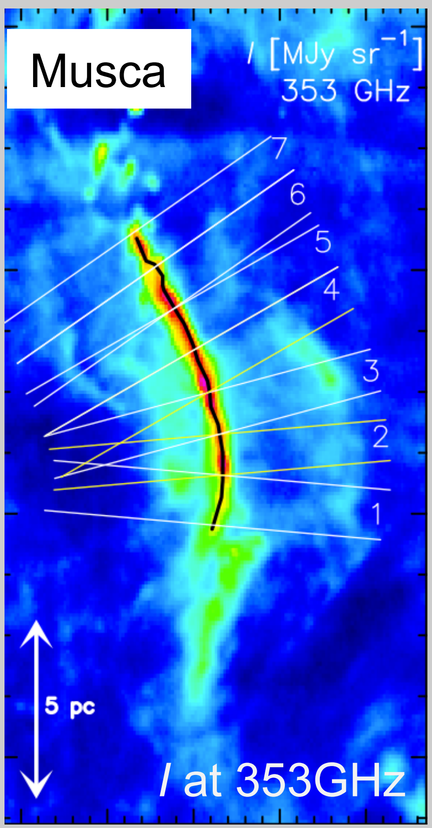
Maximum intrinsic dust polarization

Depolarization due to random *B* fields along the LOS

Lee & Draine 1985, Hildebrand 1988

Modelling the mean radial profiles of the Stokes parameters perpendicular to the filament's main axis

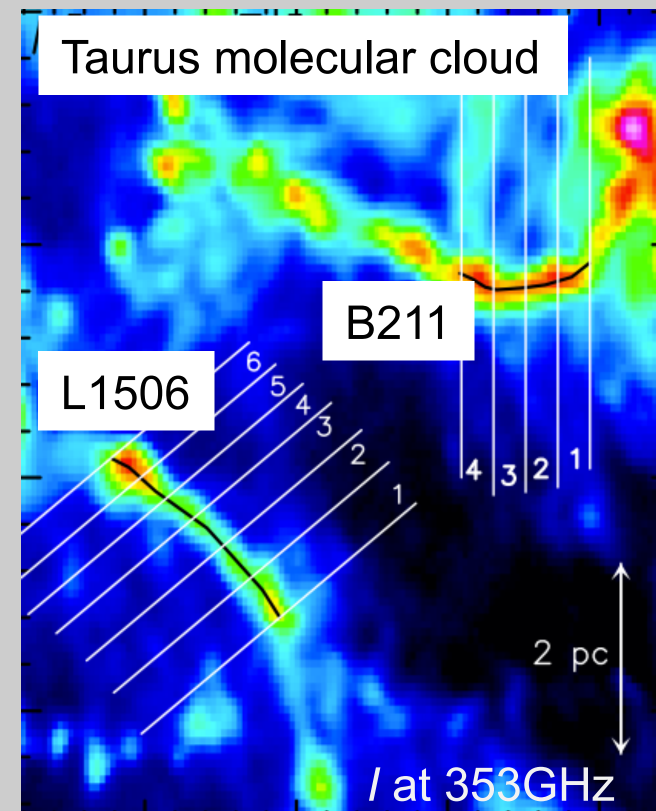




Two layer model to estimate the contribution of the filament to the total observed emission

$$I_{\rm mod} = I_{\rm bg} + I_{\rm fil}$$
$$U_{\rm mod} = U_{\rm bg} + U_{\rm fil}$$
$$Q_{\rm mod} = Q_{\rm bg} + Q_{\rm fil}$$

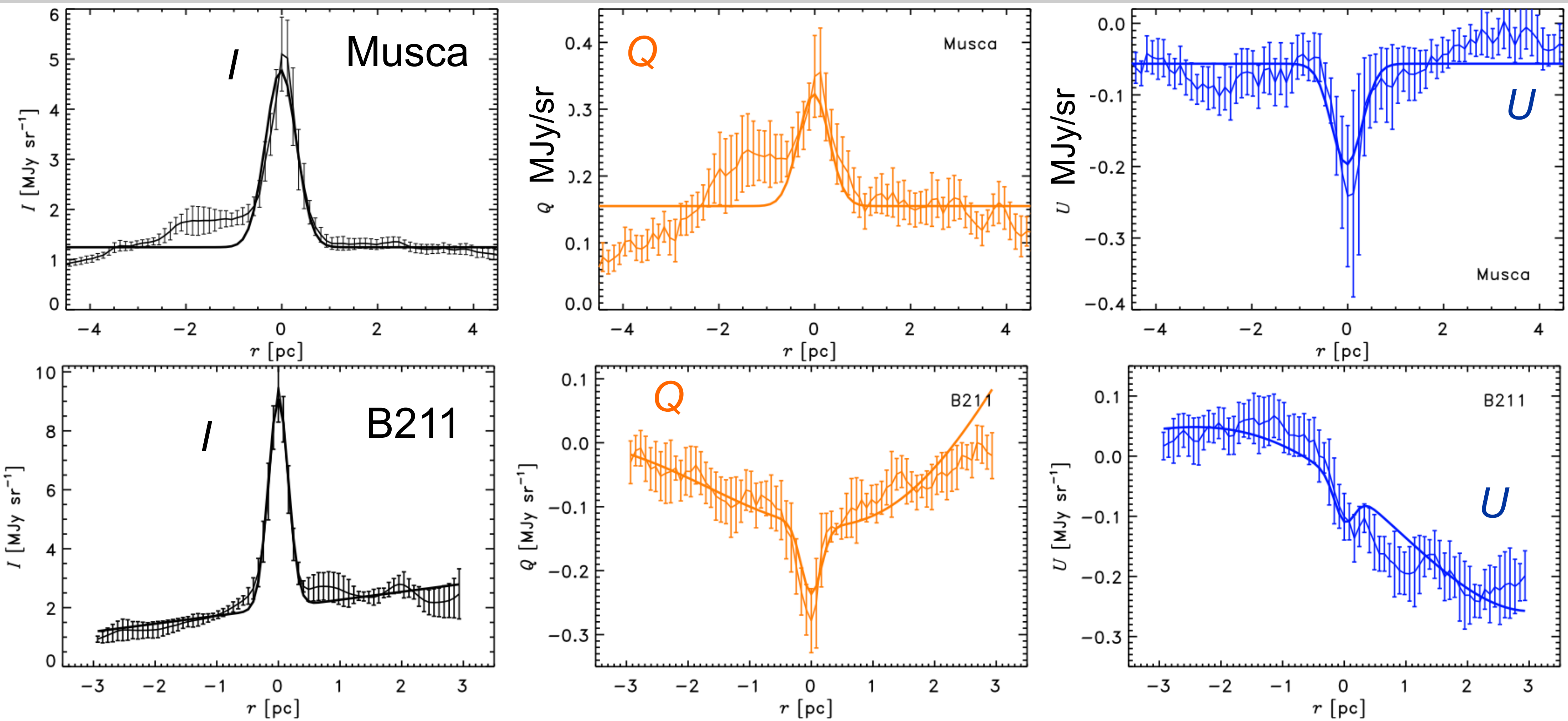
Fitting the observed *Q* and *U* profiles to derive the 3D field geometry with constant p_0



Results of the modelling

Polarization properties, at the resolution of *Planck* observations, are well modelled with a uniform field in the filament, which differs from that of its parent cloud, assuming constant dust polarization efficiency

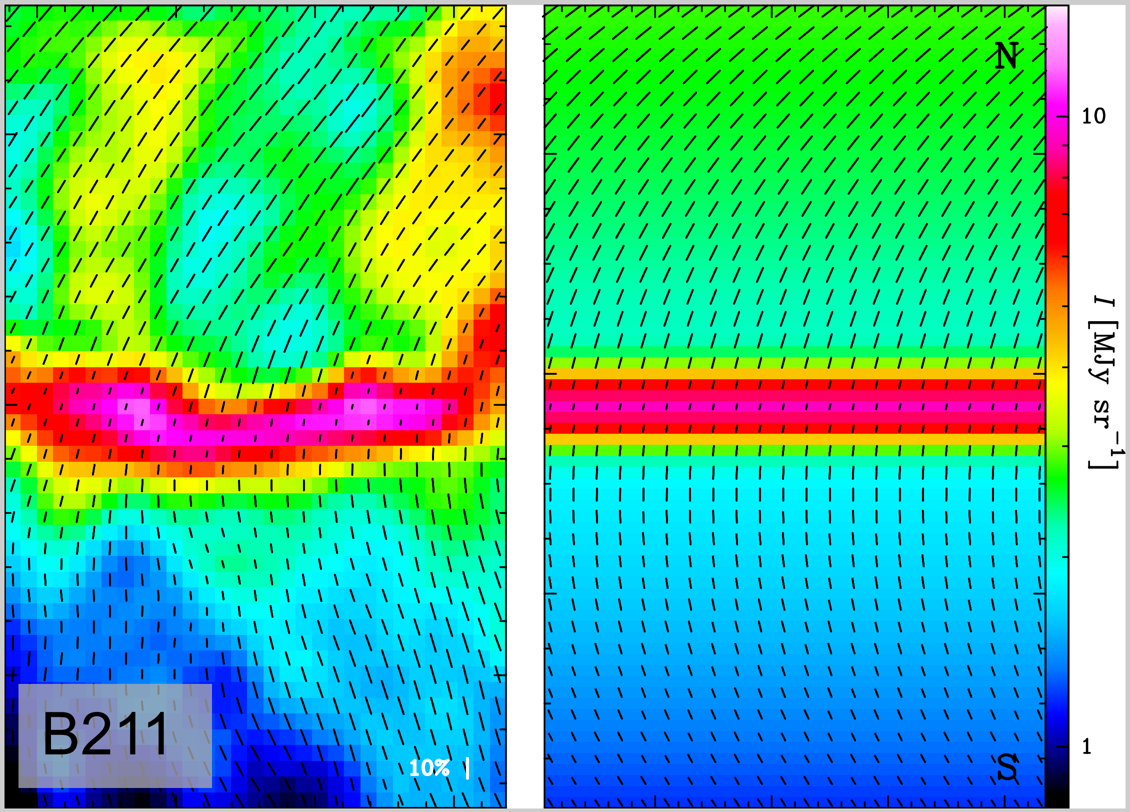
Examples of observed and modelled Stokes parameter profiles of the filaments

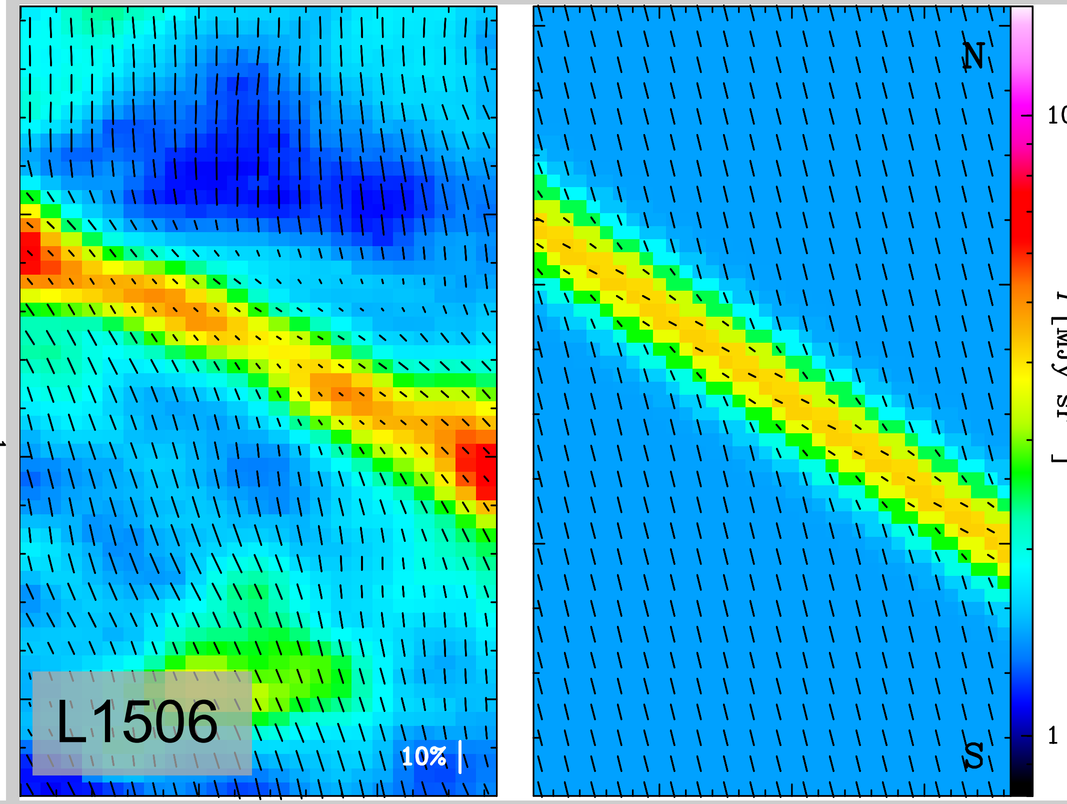


Results of the modelling

The observed polarization fraction and *B* field orientation are well reproduced

Planck Observations — Our model — *Planck* Observations — Our model

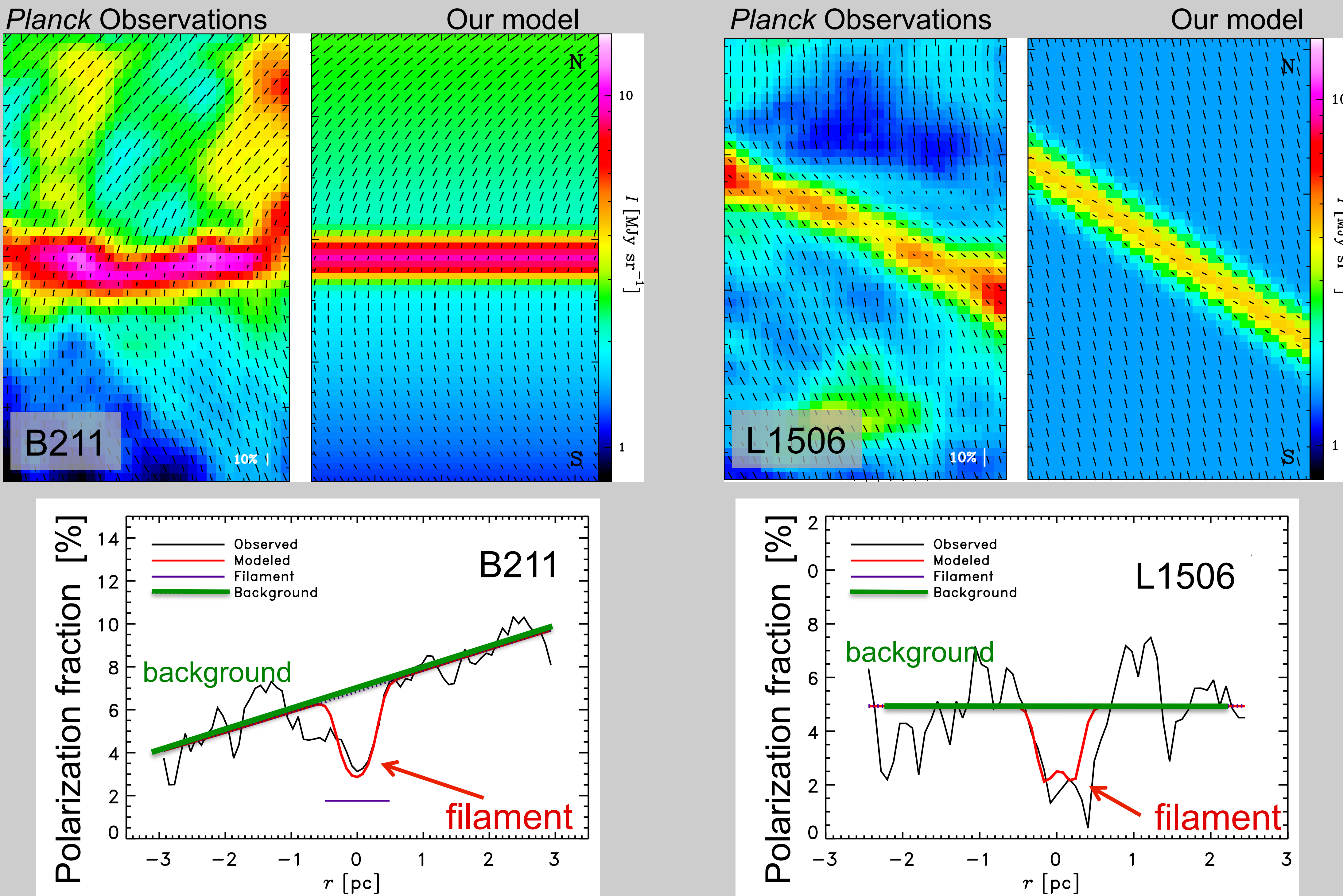




I map at 353GHz,
black segments: orientation of B_{POS},
Length of the segments ~ polarization fraction

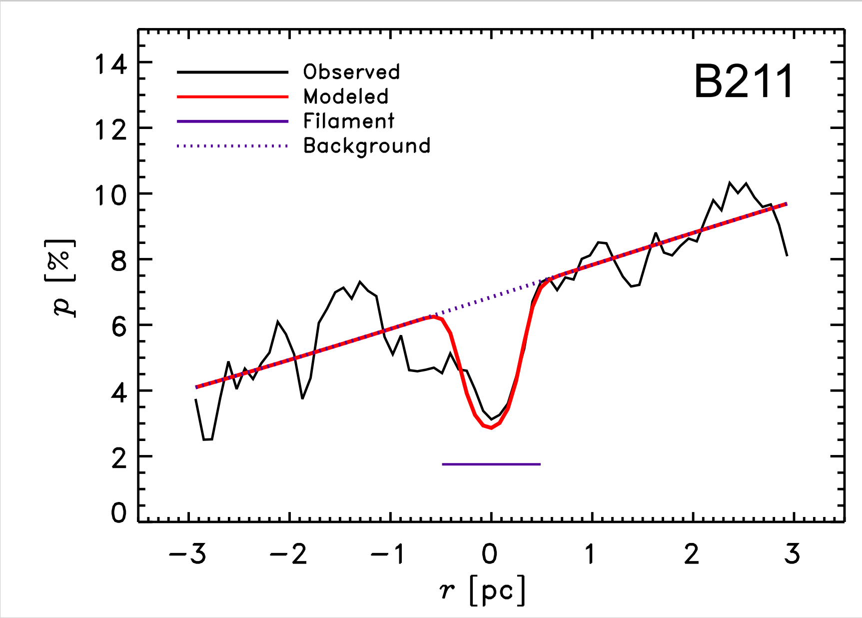
Planck intermediate results XXXIII (astro-ph1411.2271)

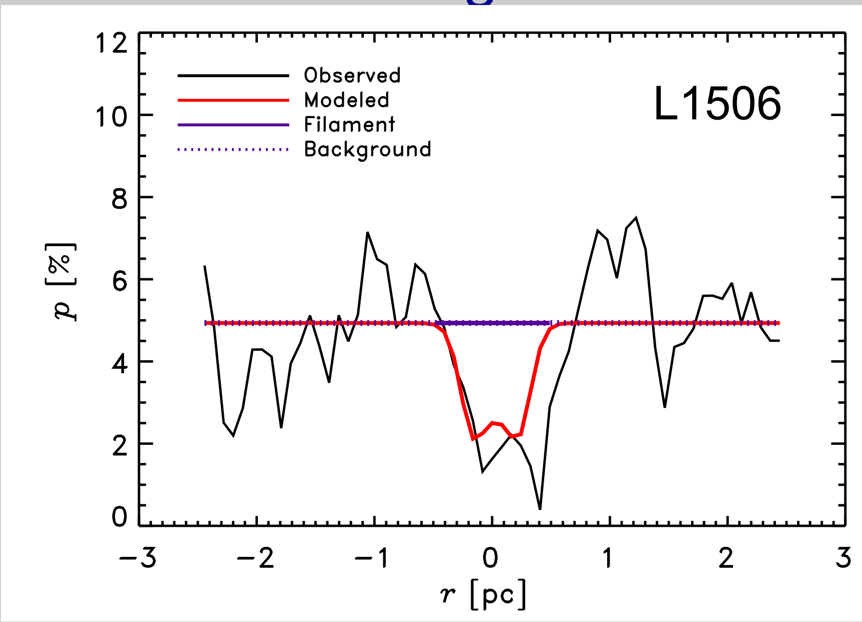
Decrease of the polarization fraction in the filaments

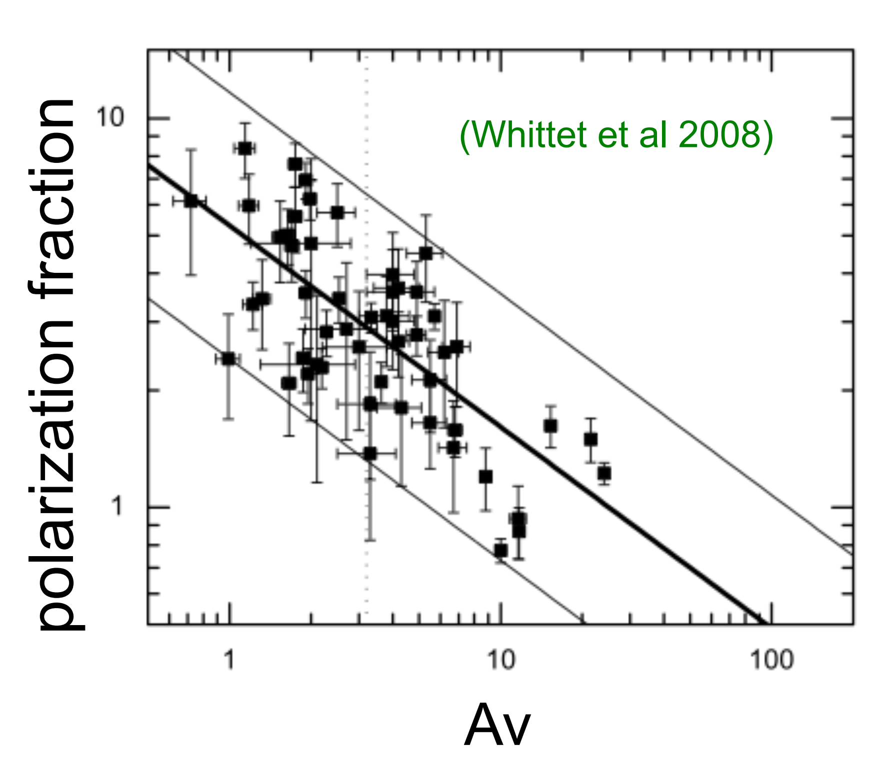


Decrease of the polarization fraction in the filaments

In our two layer model, the drop in the observed p is explained by the variation of the orientation of B between the filament and the background





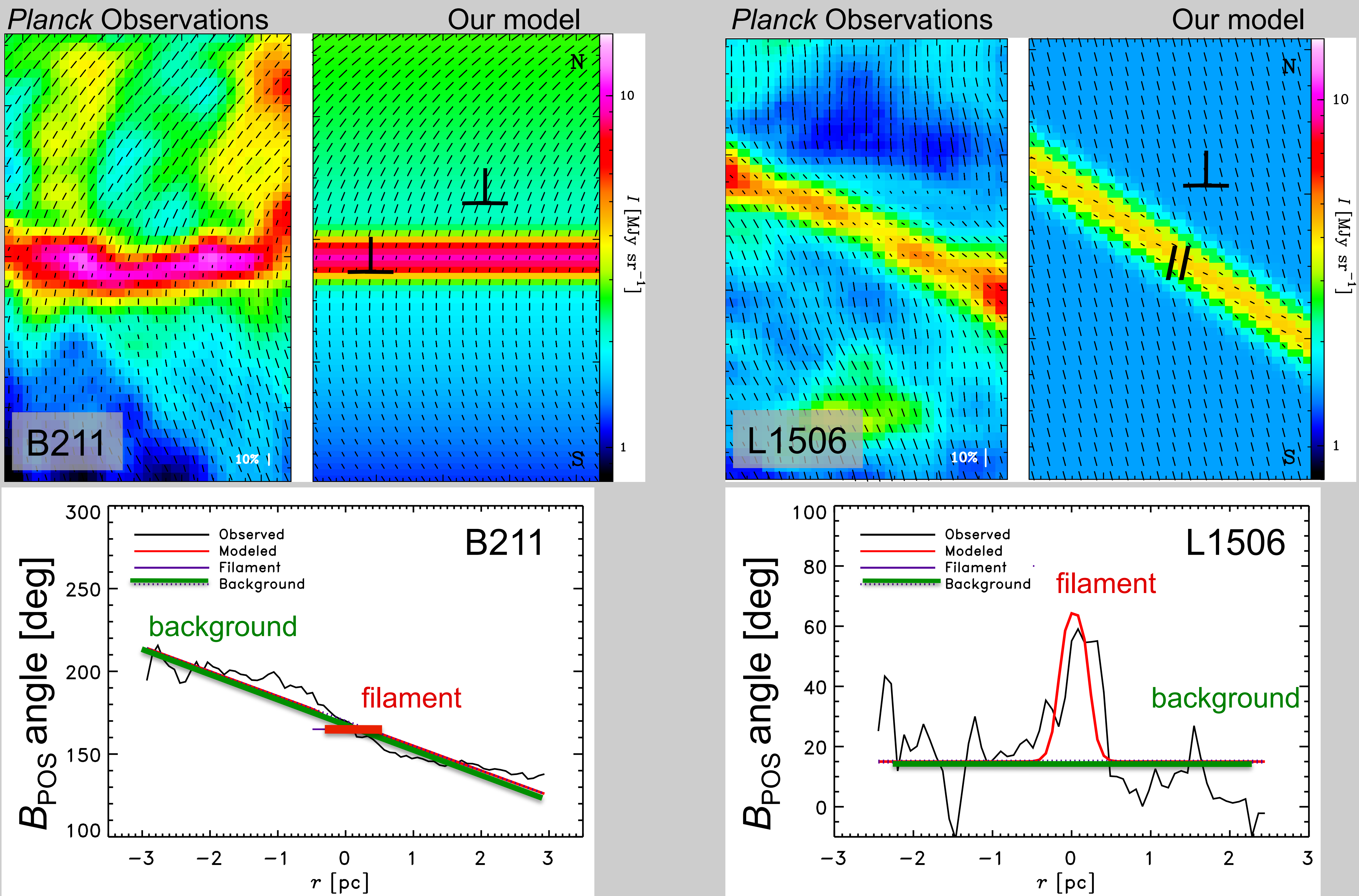


Other interpretations

Decrease of p due to loss of dust alignment in dense shielded regions
(Goodman 1992, Whittet et al 2008, Chapman et al. 2011, Alves et al. 2014, Ward-Thomson et al. 2000, Matthews & Wilson 2000)

Decrease of p due to depolarization from turbulent field along the LOS and orientation of the field
(Planck Collaboration Int. XX 2014, Falceta-Gonçalves et al. 2008, 2009)

Variation of the POS *B* field in the filaments and their background



Conclusions and perspectives

• Polarized dust emission observed towards interstellar filaments carries a signature of the magnetic field geometry

• The *B* field surrounding the filaments has an ordered mean component compatible with sub-Alfvénic/Alfvénic turbulence

• *Planck* dust polarization observations of (three) nearby filaments are well fitted with a uniform field assuming constant dust polarization fraction

→ Need to be combined with higher angular resolution observations to resolve the central parts of the filaments, where other configurations of the field and/or tangling of the field lines could also contribute to the observed polarized emission

• The modelled 3D magnetic fields of the filaments are different from that of their surrounding clouds

→ Extend the study to larger samples

→ Study the link between velocity and magnetic fields esa

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a look back to the birth of Universe

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