The early phase of star formation : polarization properties of galactic cold cores and filaments

J.S. Carrière, 1st year Phd student

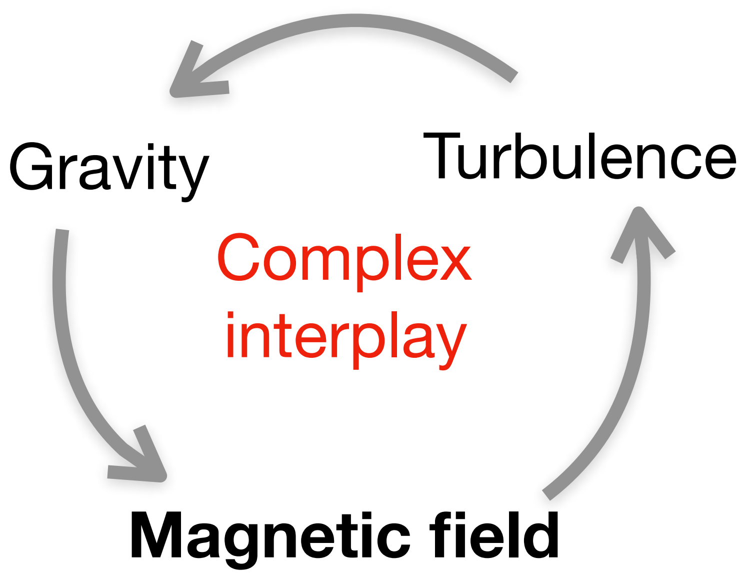
PhD advisors : *I. Ristorcelli, L. Montier, K. Ferrière*

Journée des thèses 2019, IRAP, Toulouse - 5 Juin 2019

Scientific context

The physical mechanisms regulating star formation still poorly understood.

Different processes are involved :



Which **roles** and **interplay ?**

→ **Different scales** must be probed, **molecular clouds** to **filaments**, **cold clumps** and **prestellar cores.**

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Turbulence

Complex interplay

Magnetic field

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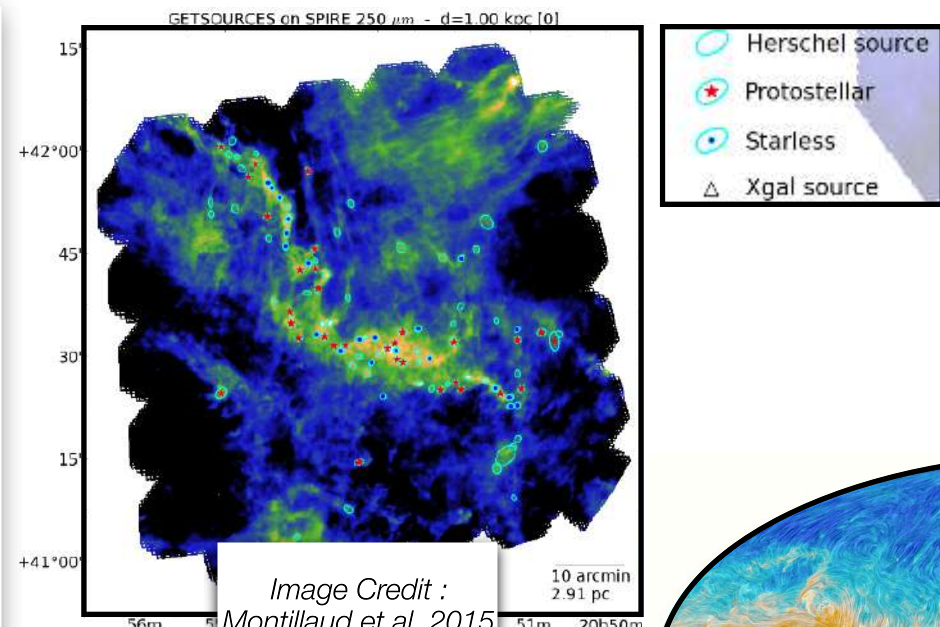
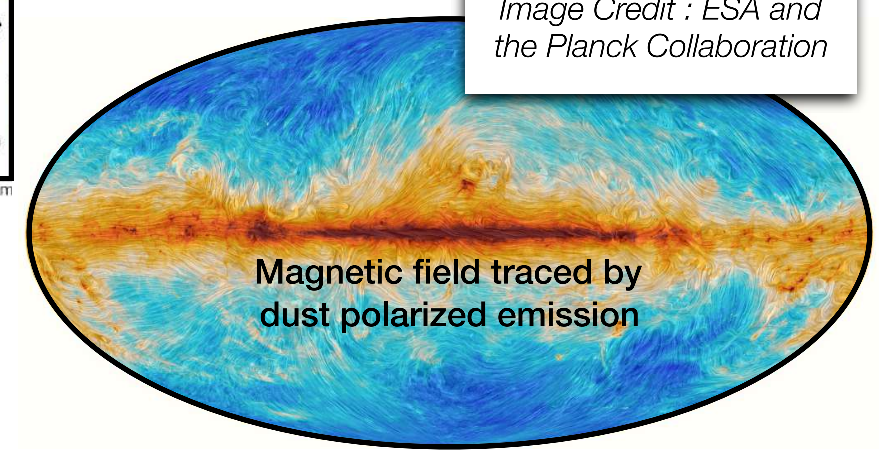


Image Credit : Montillaud et al. 2015



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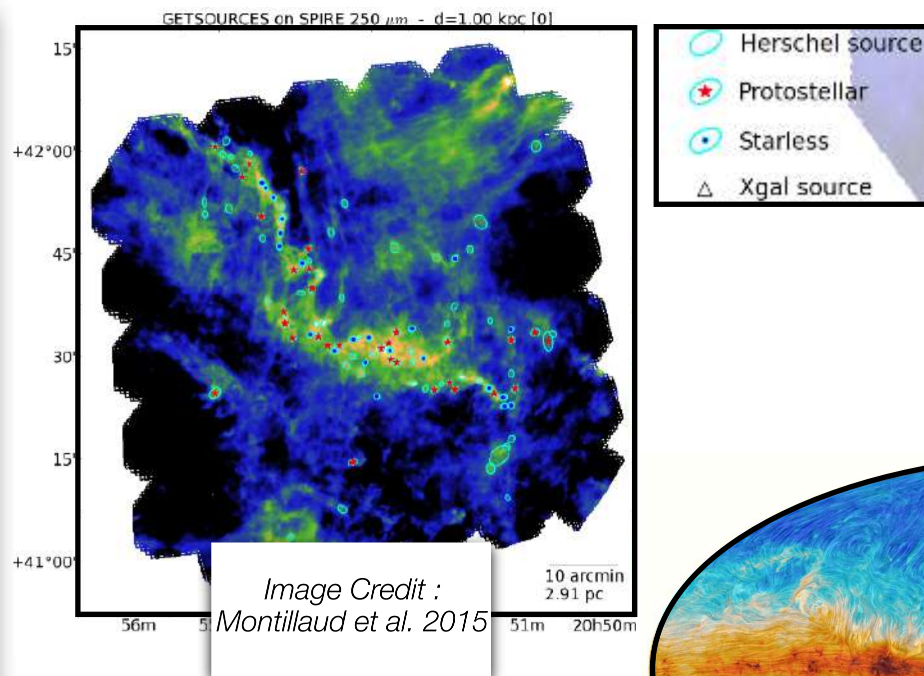

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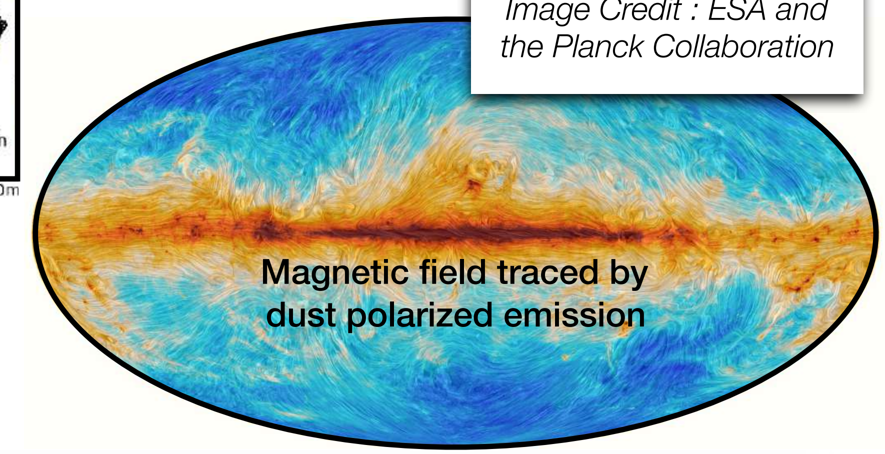

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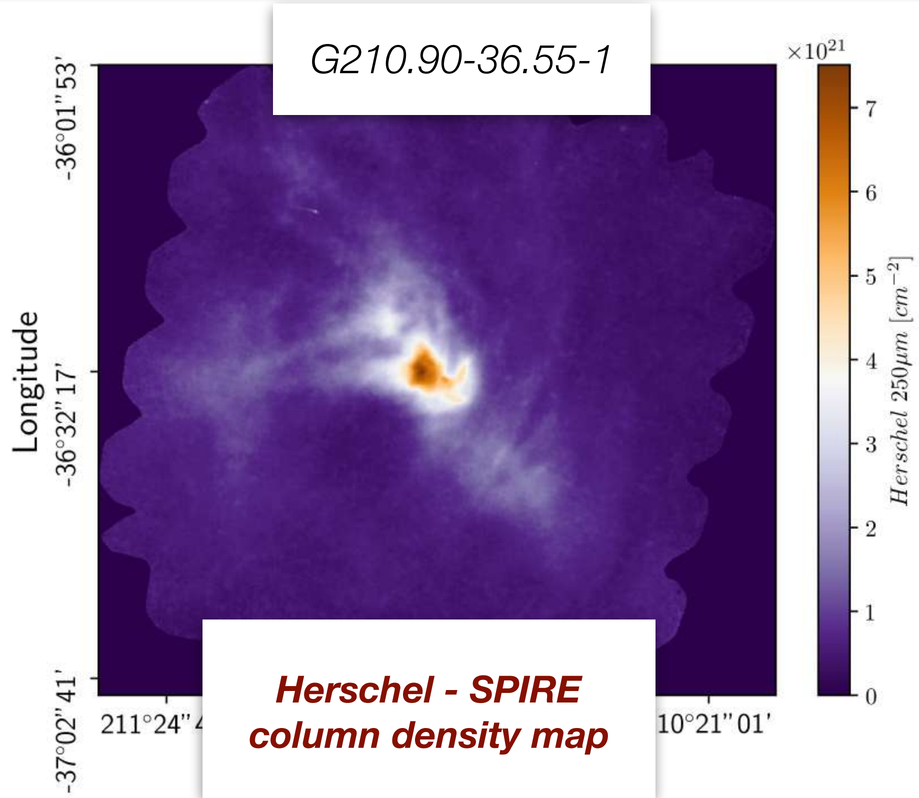
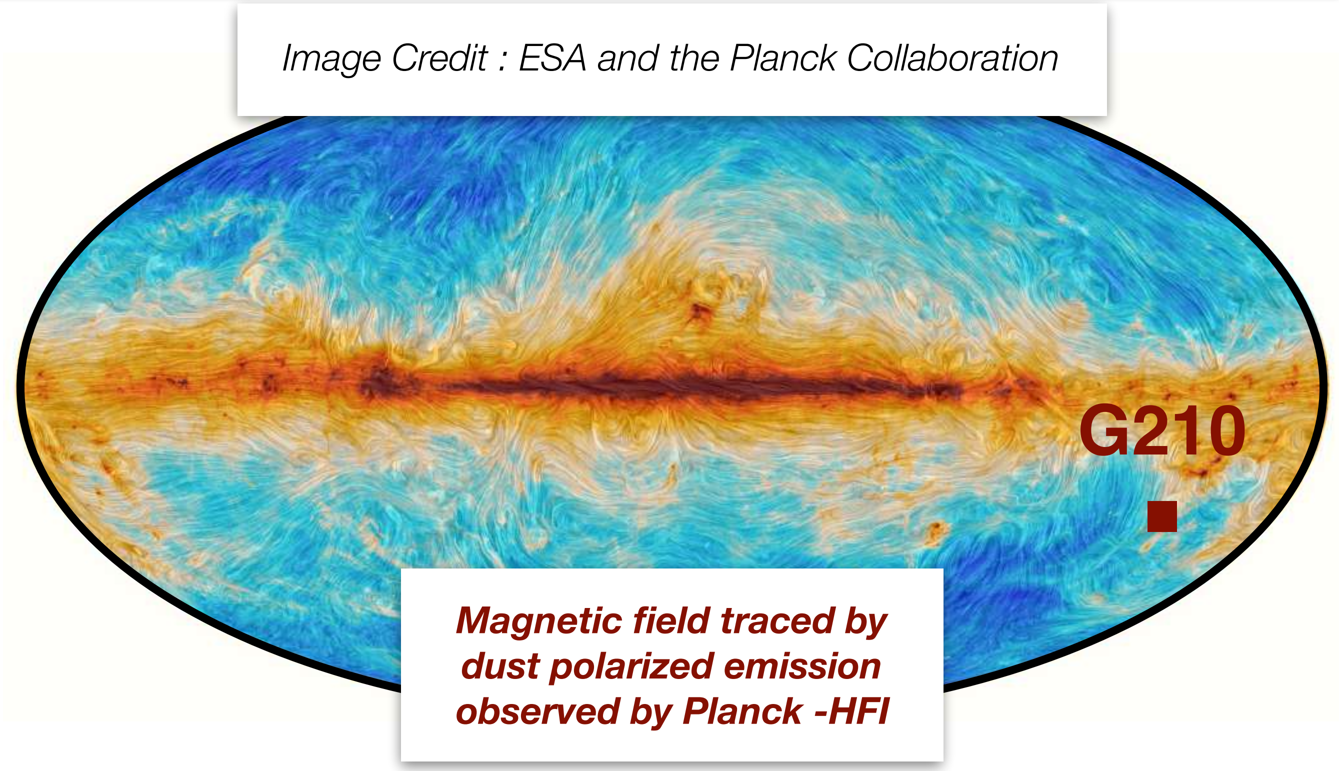
Objectives of the PhD thesis

Study the properties of the **magnetic field** toward the **cold cores** and **clumps** detected with **Planck-Herschel** and toward their **environments structures (filaments)**

Scientific context





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Scientific context

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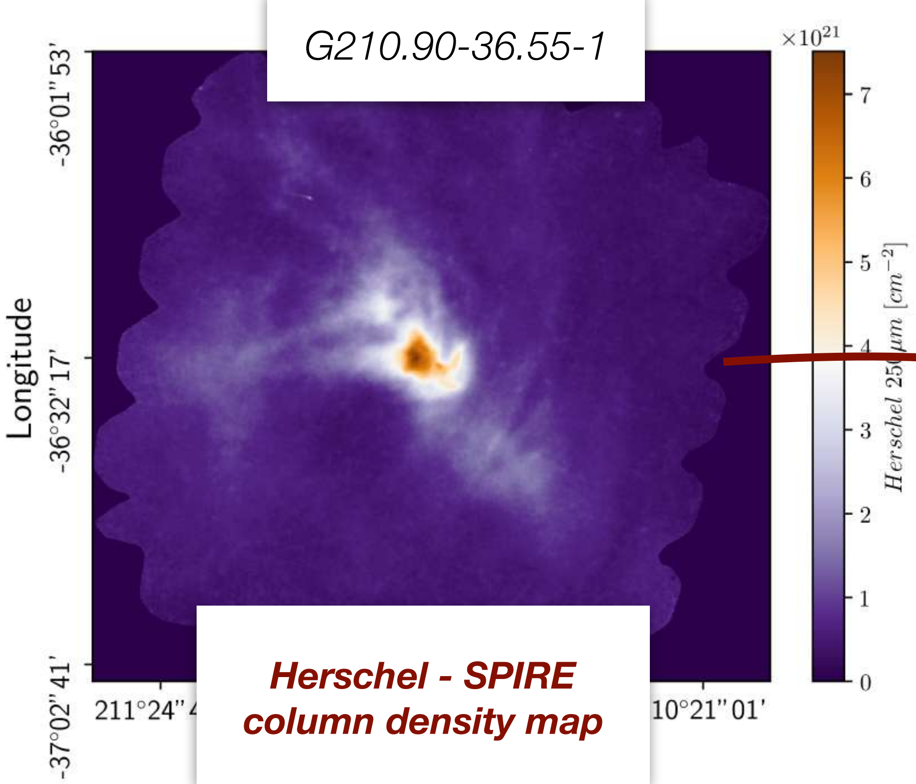
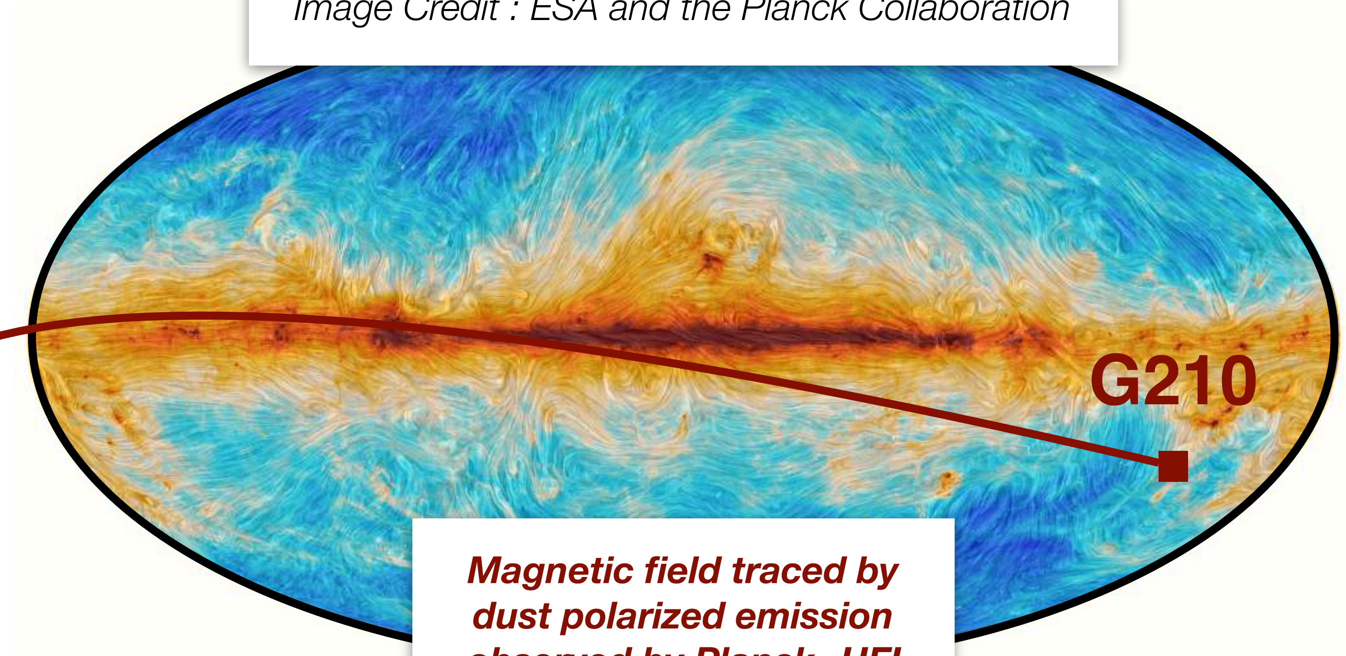


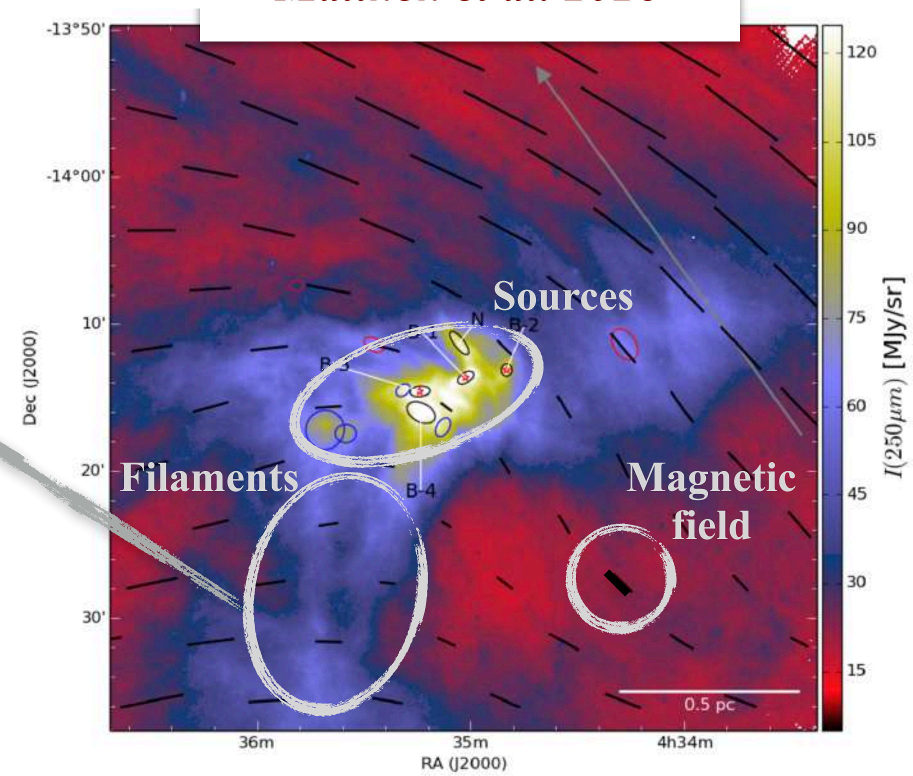
Herschel - SPIRE column density map

Image Credit : ESA and the Planck Collaboration



Magnetic field traced by dust polarized emission observed by Planck -HFI

Malinen et al. 2016



Filaments

Ubiquitous in the **diffuse ISM** and in **star-forming molecular clouds**.

Scientific context

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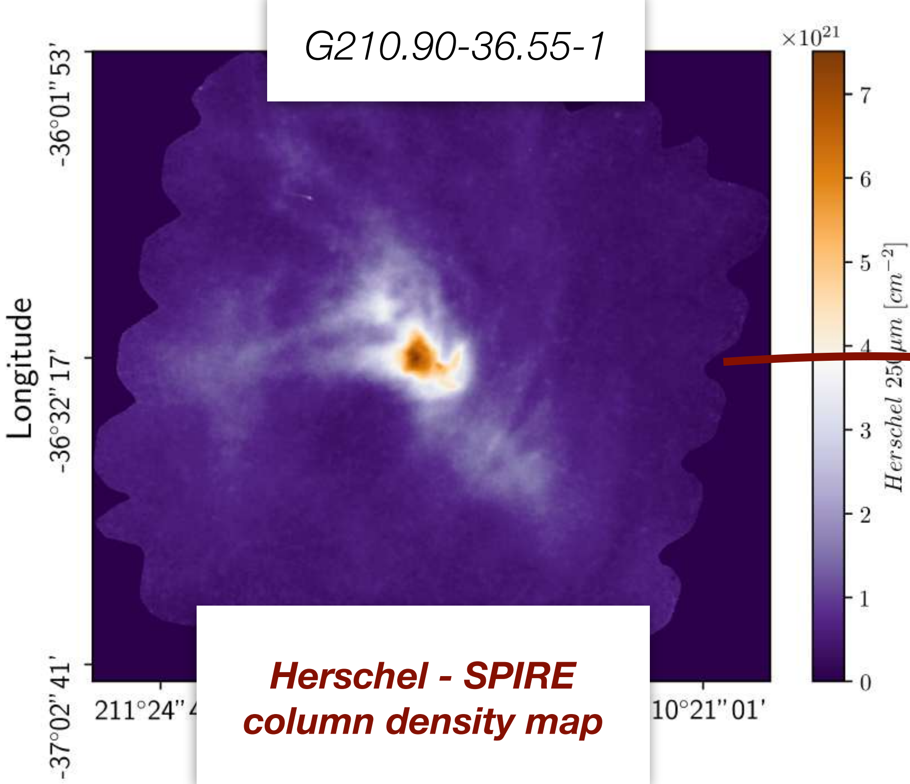

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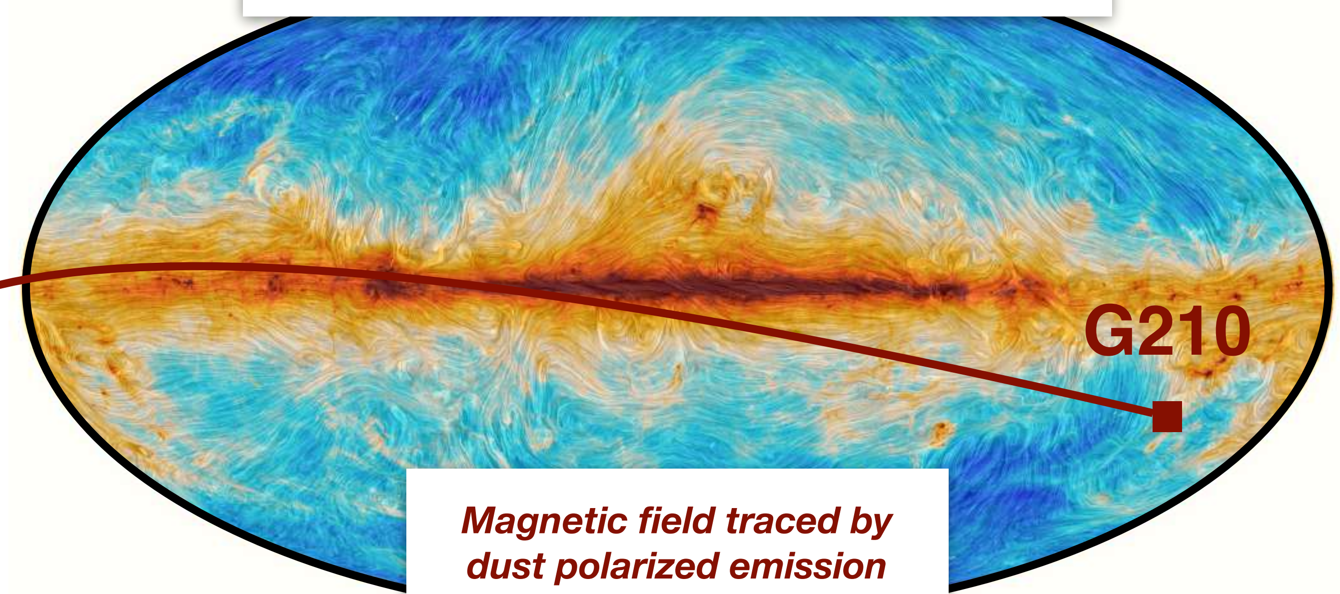

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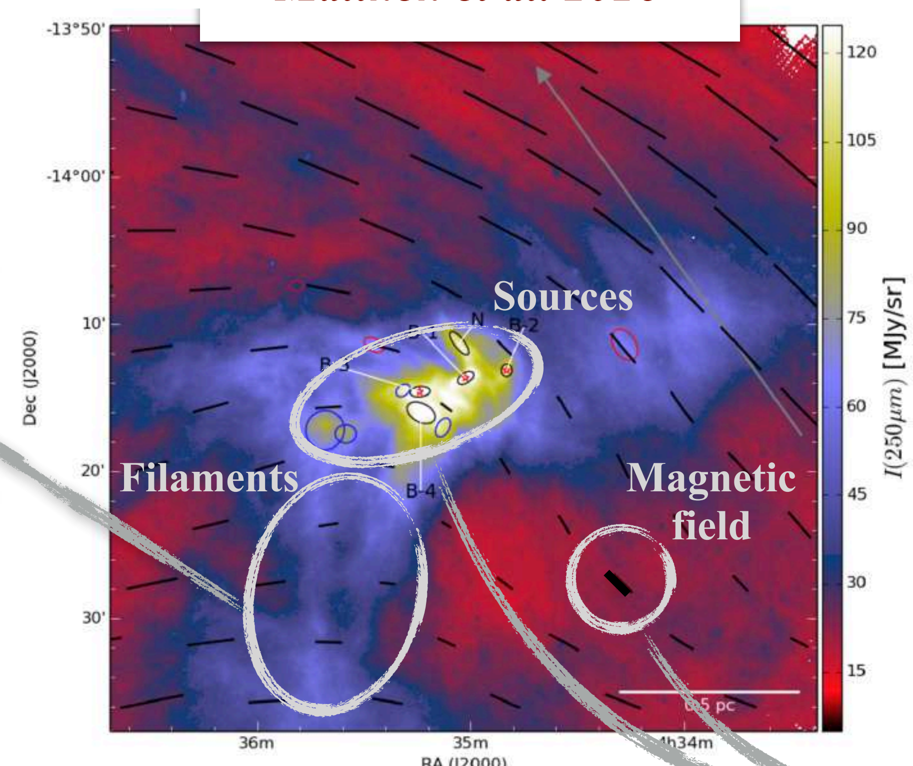

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Prestellar cores are preferentially located in the densest filaments.

Origin and **evolution of dense cores** is now **strongly connected to the filaments**.

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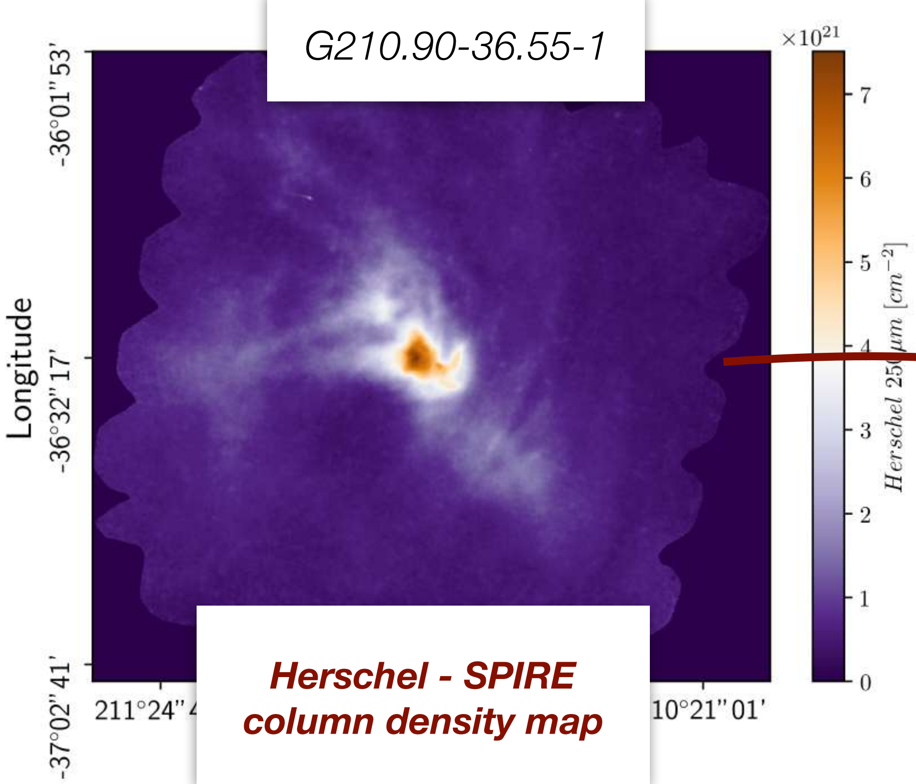

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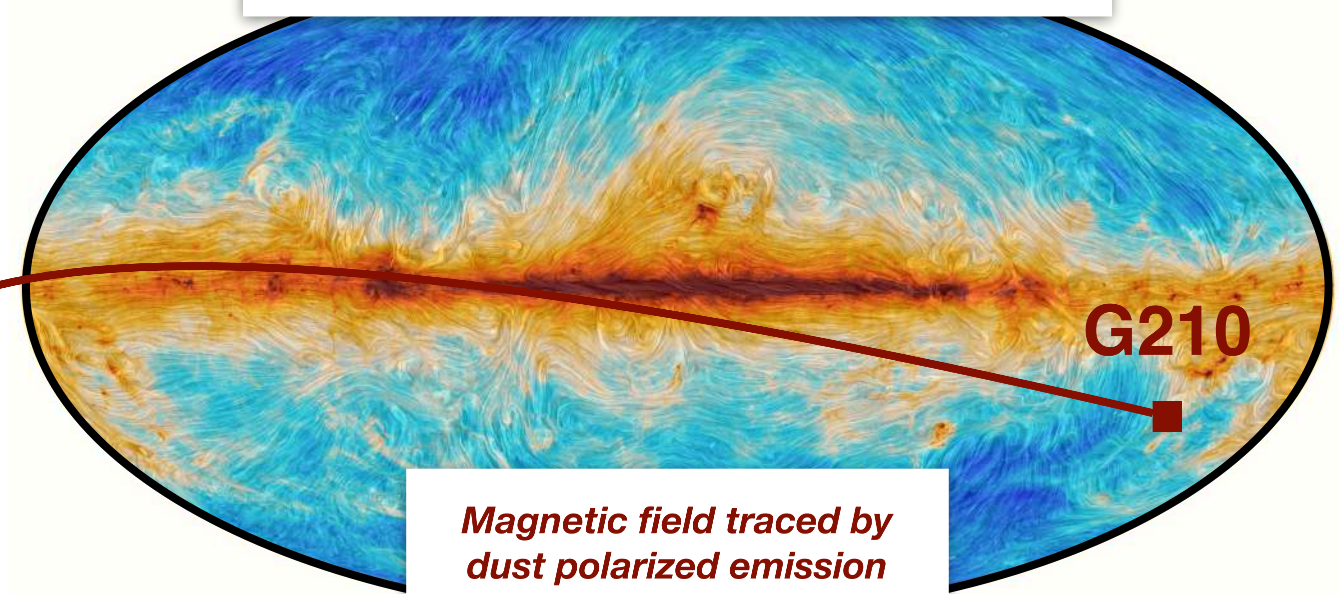

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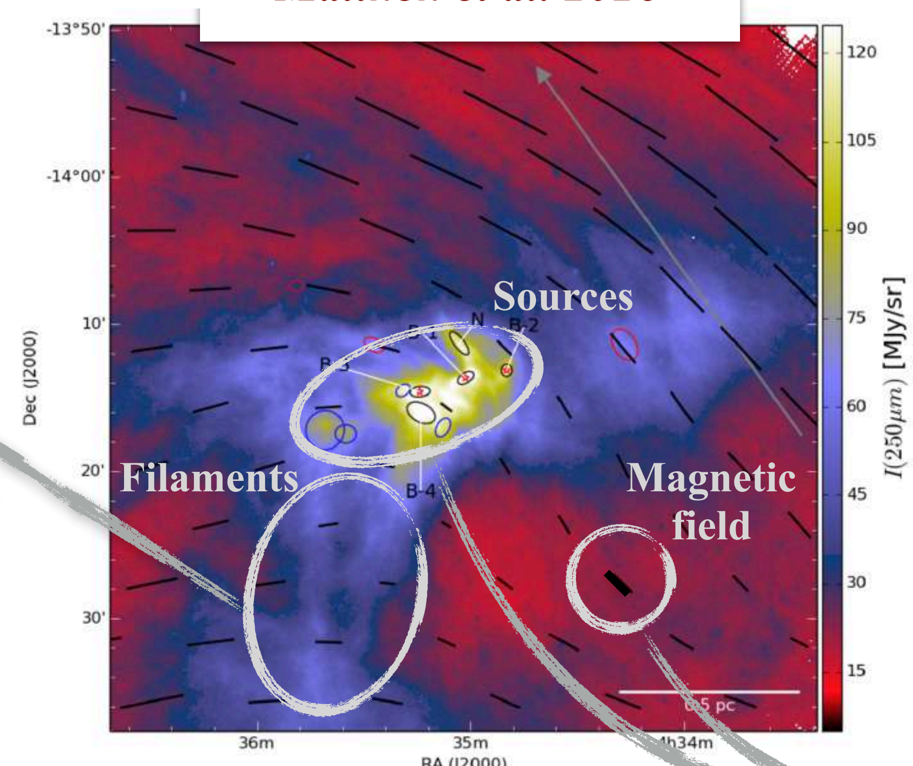

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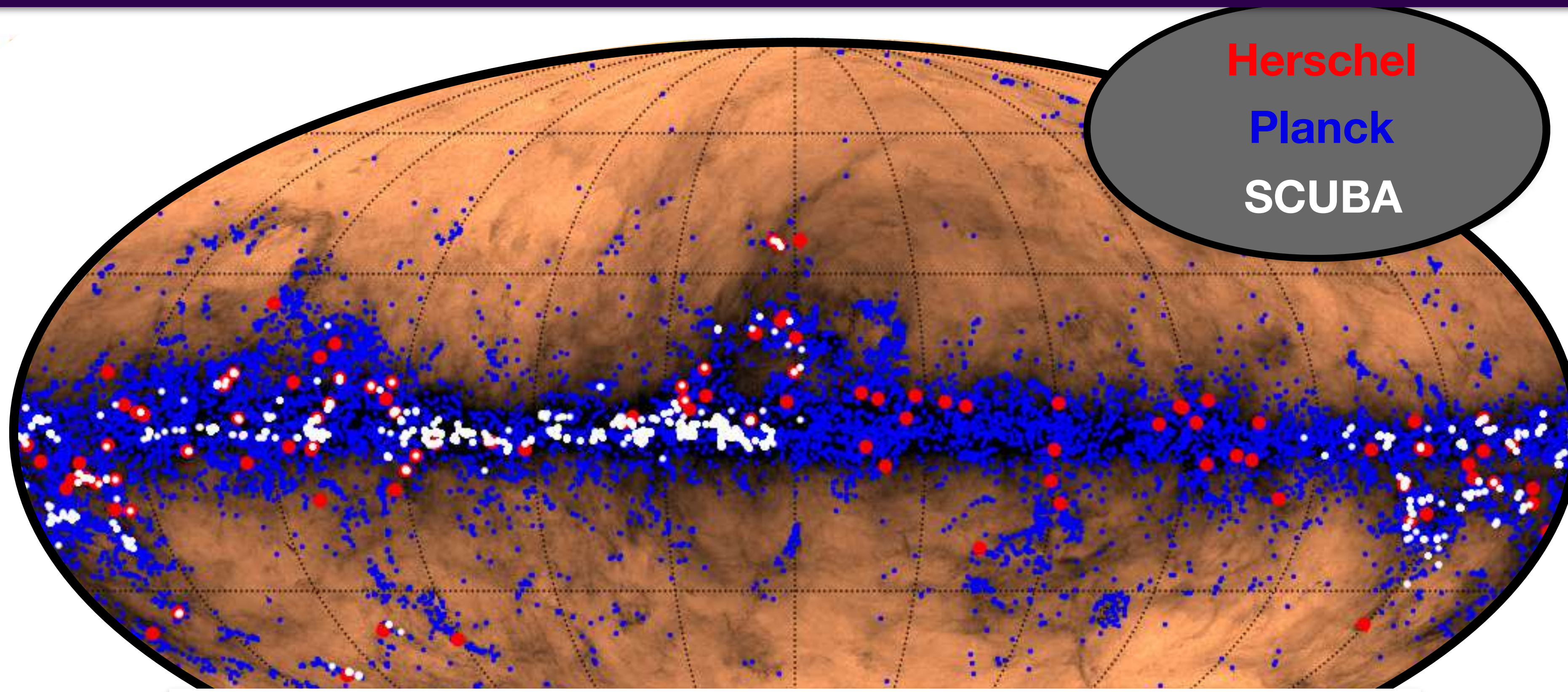
PhD 1st objectives

- **relative orientation** between the **magnetic field** and **the structures (filaments, cores)**
- Link it to **cold cores evolutionary stage on a sample of Herschel fields**.

Scientific context



Planck all-sky survey at 857GHz, with the distribution of Planck Galactic Cold Cores (PGCC) clumps and their follow-ups

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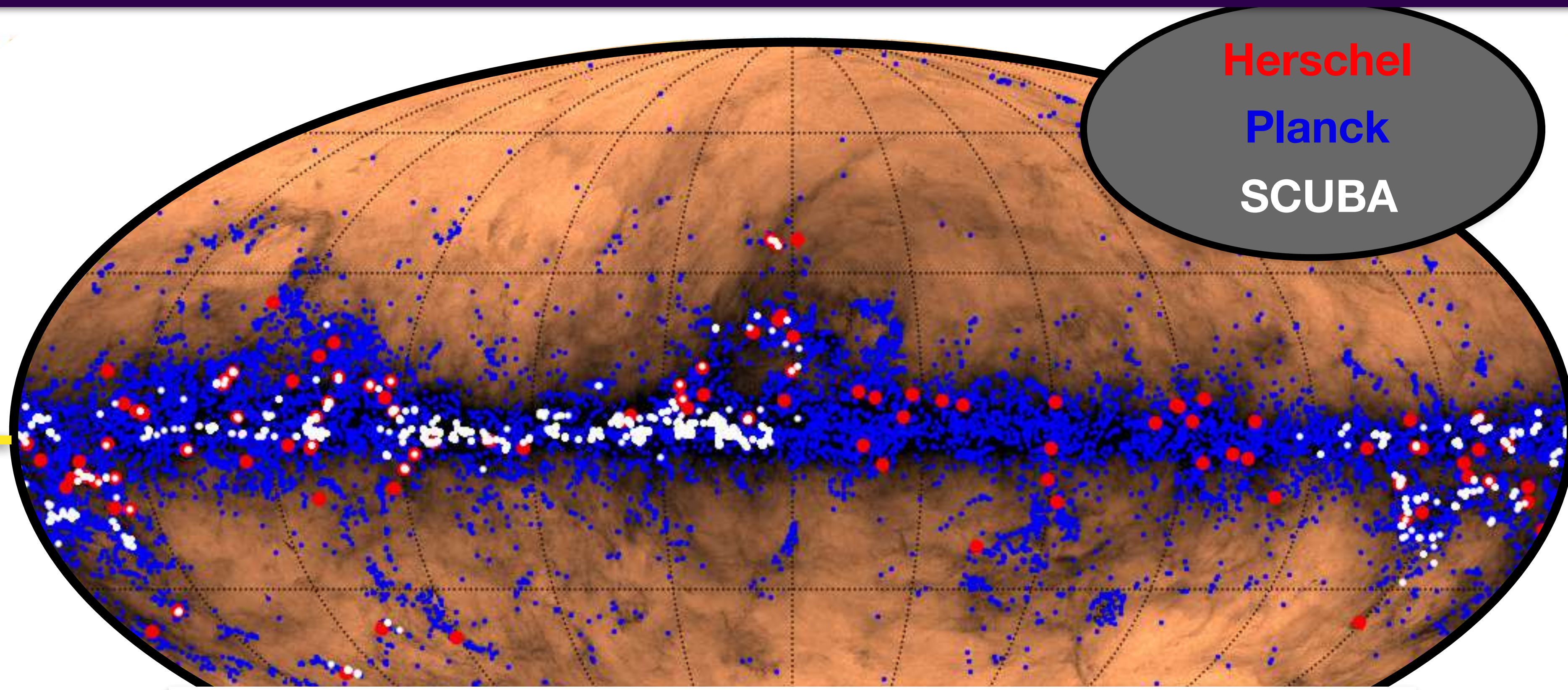

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2nd objective : Statistical analysis of **relative orientation** over **116 fields** from ***Herschel-Planck Galactic Cold Cores (Herschel-PGCC) follow-up*.**

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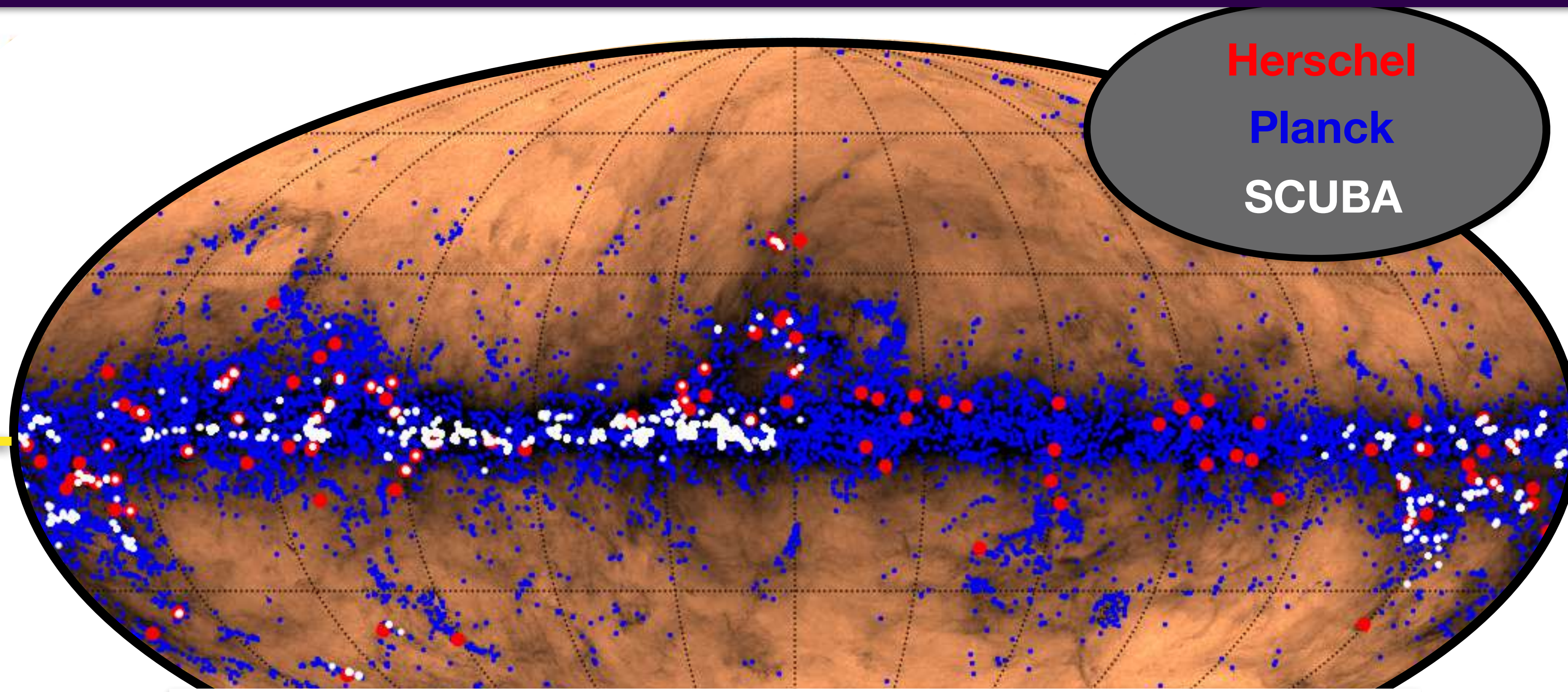

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More objectives :

Dust polarization surveys (SMA, NIKA2, SCUBA-pol, ALMA, PILOT)

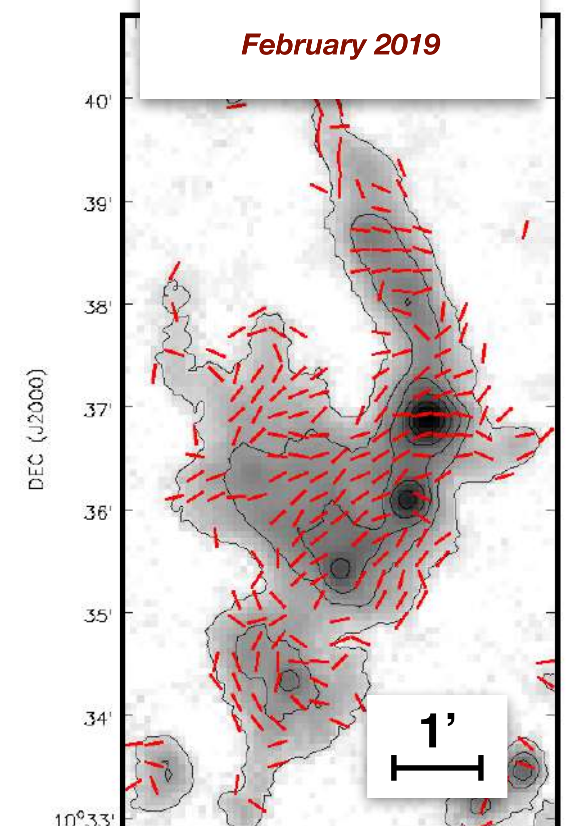
→ **Complementary angular resolutions**

→ **Large range of spatial scales (pc to mpc).**

Comparison to **numerical MHD simulations.**

Resolution : 16”
Wavelength : 850µm

February 2019



First objectives

Planck - HFI

- Dust polarization emission maps
  → Traces the B-field lines projected on the plane of sky
- Angular resolution : 7'

Herschel - SPIRE

- NH density map
- High angular resolution : 18''

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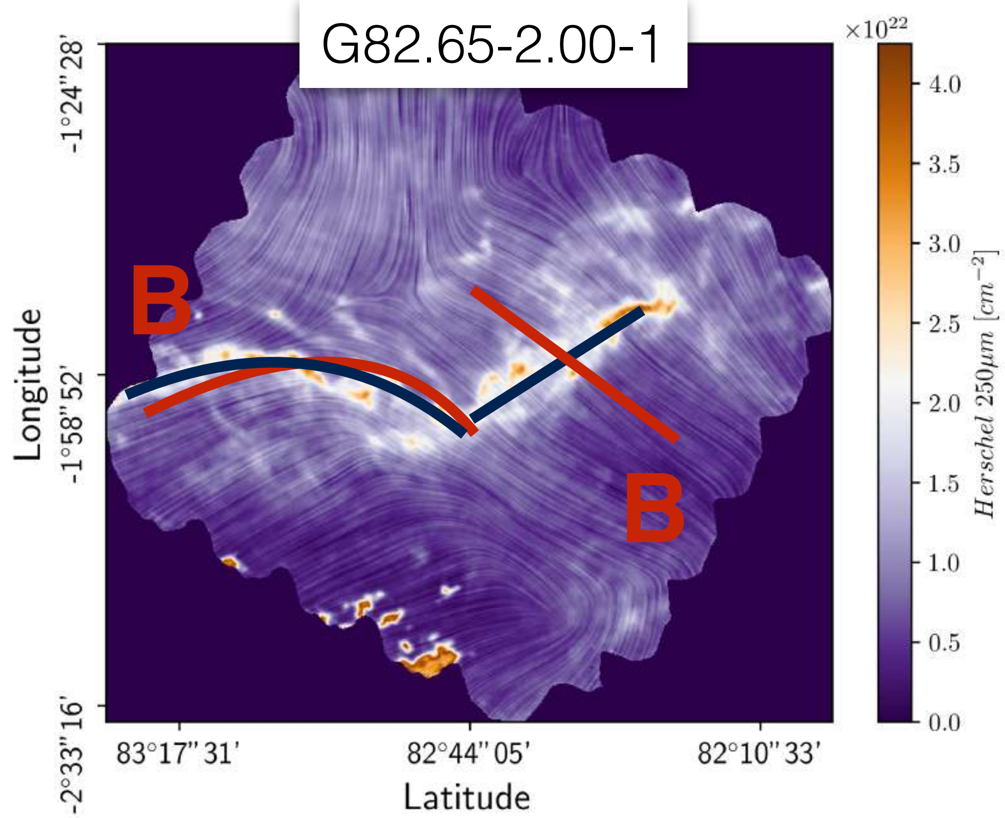

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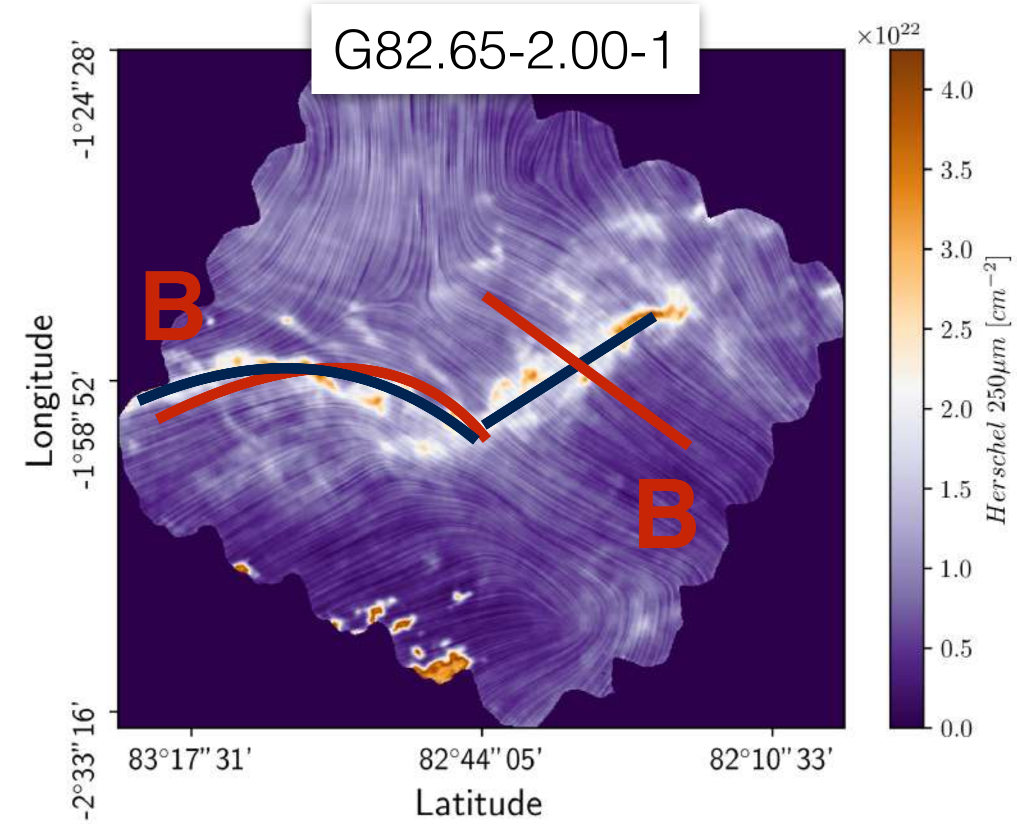


- **Statistical analysis of the relative orientation between B-fields and filamentary structures**
- **Impact of the environment properties**
- **Link with the cold cores evolutionary stage**

Methodology for filamentary extraction

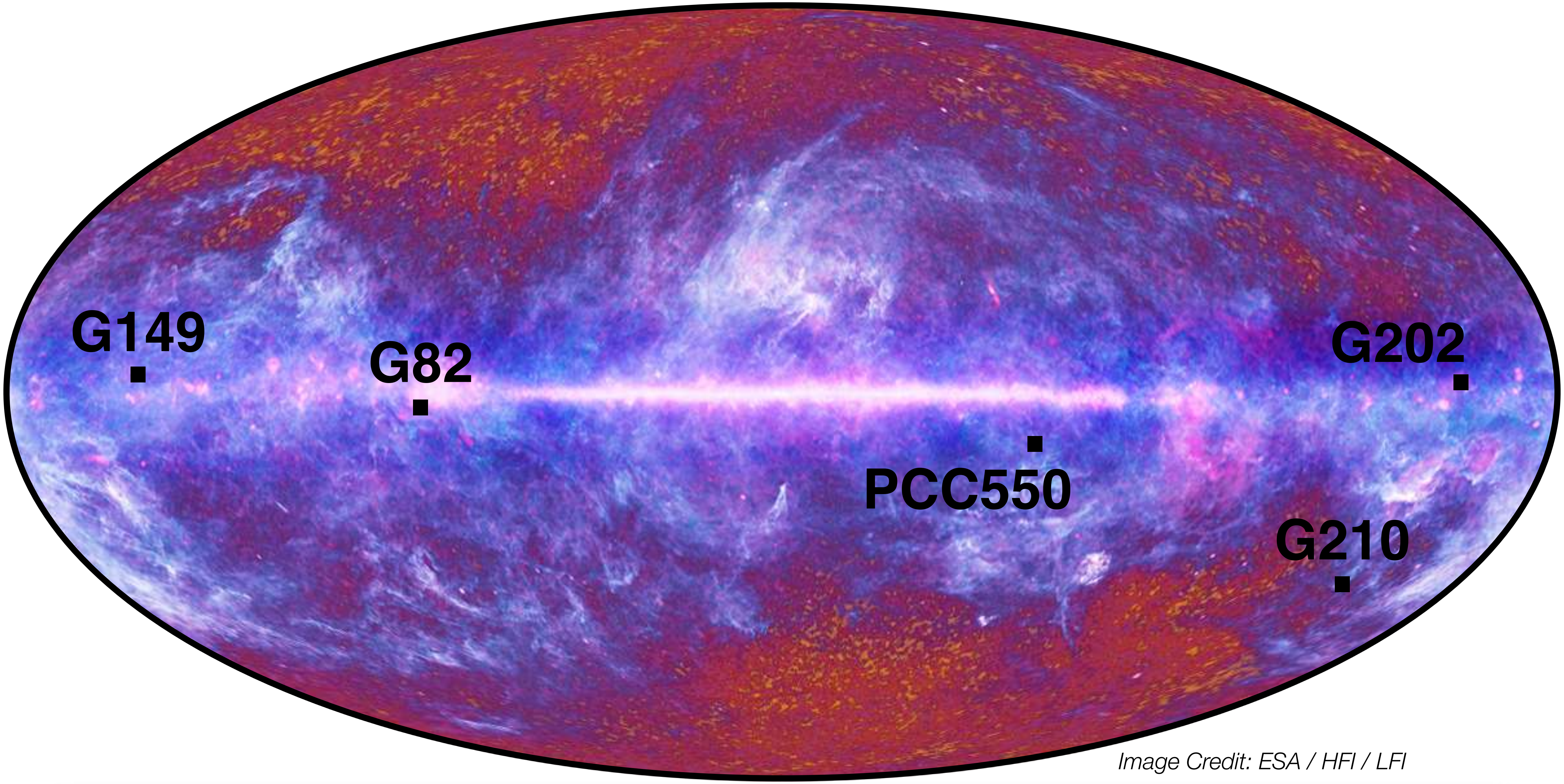
Adapted from Rolling Hough Transform (RHT) Clark et al. (2014)

Development of the **Rolling Radon Transform (RRT)**

Allows to disentangle multi scale filaments

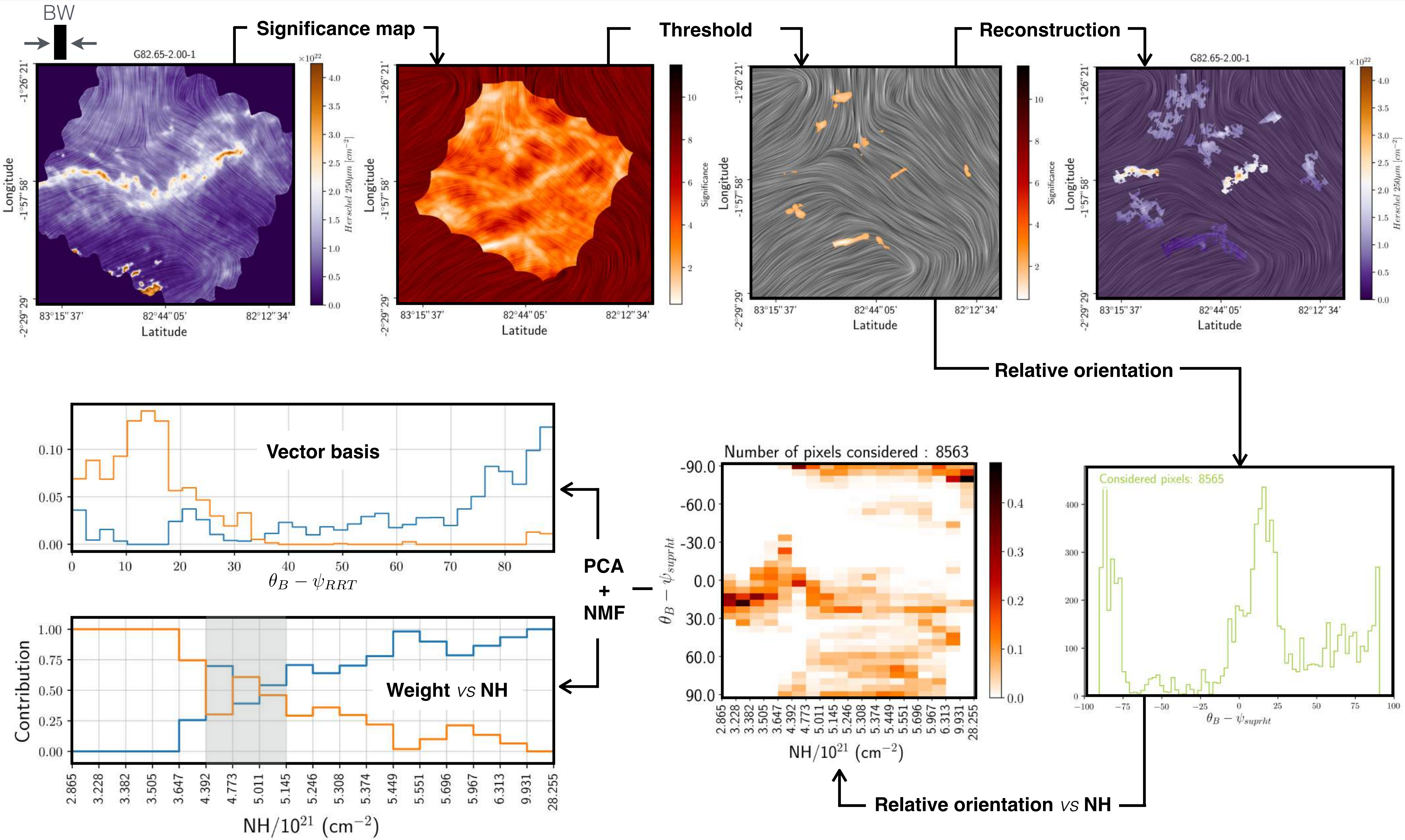
→ **Better** { Control of filaments size; Automatic definition of significance }

Preliminary results on a subsample of Herschel fields

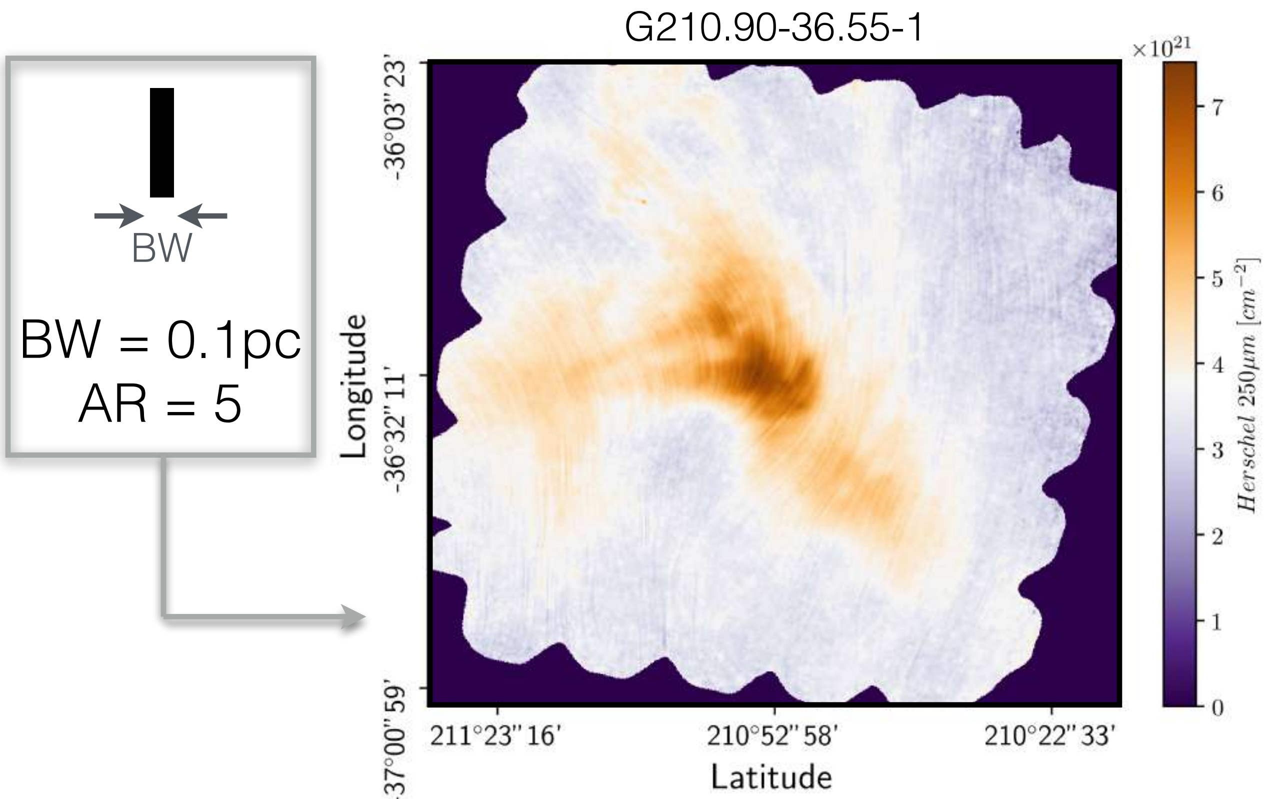


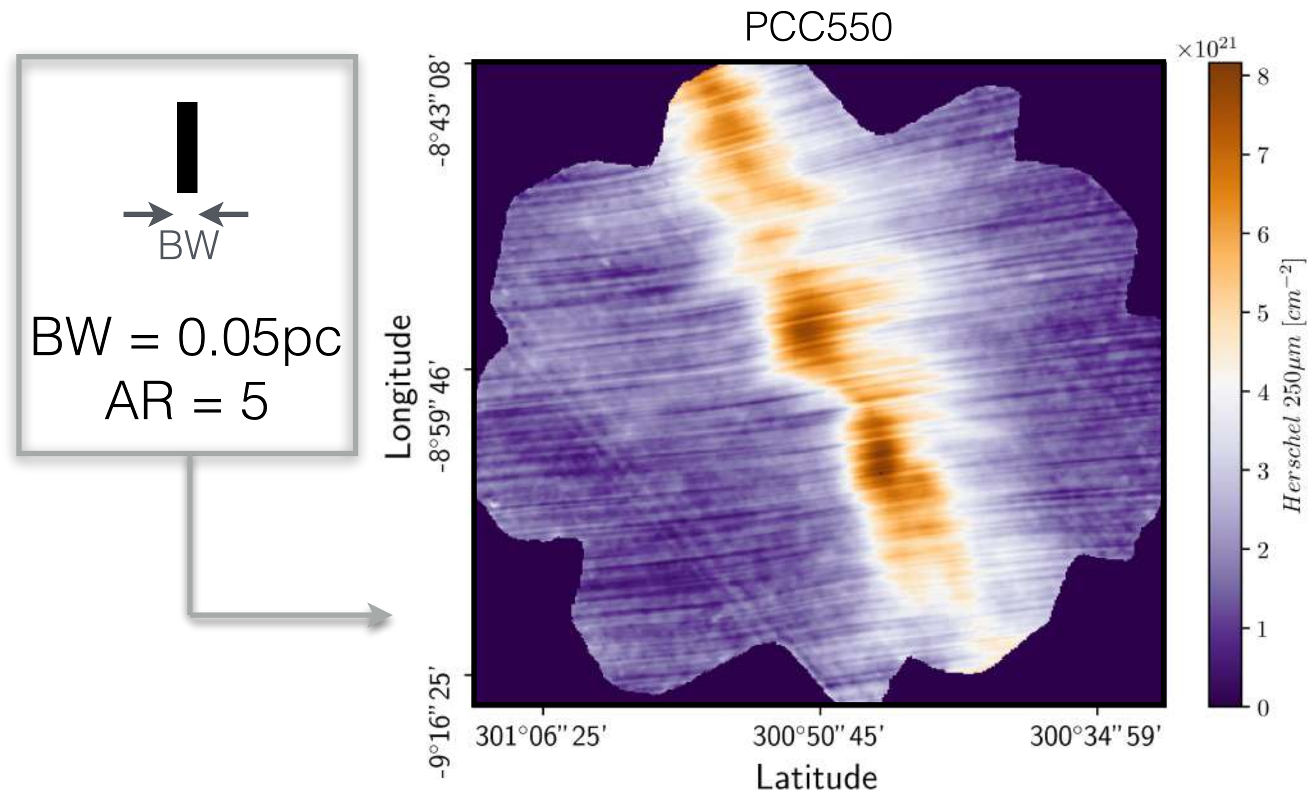
Subsample from Alina et al. 2019
Homogeneous background B-field, various environments (density) and filaments density contrast.

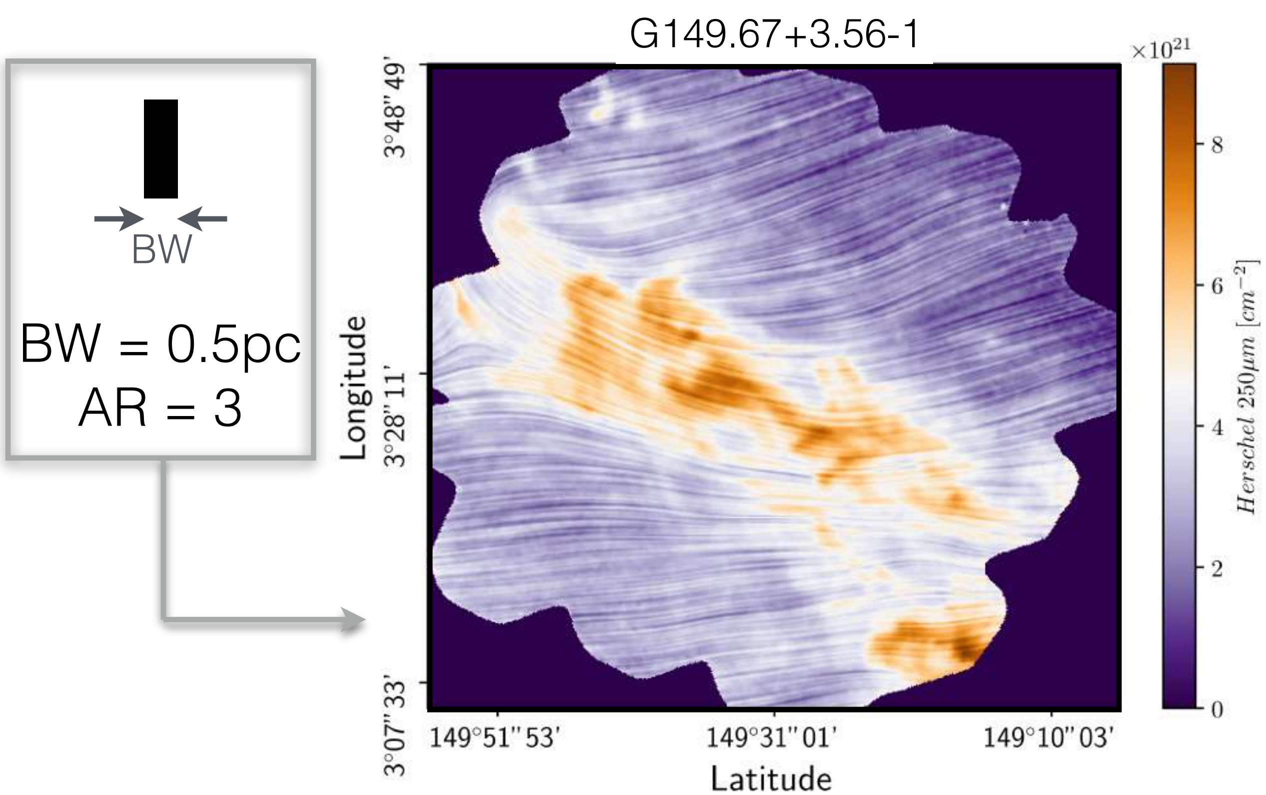
Preliminary results

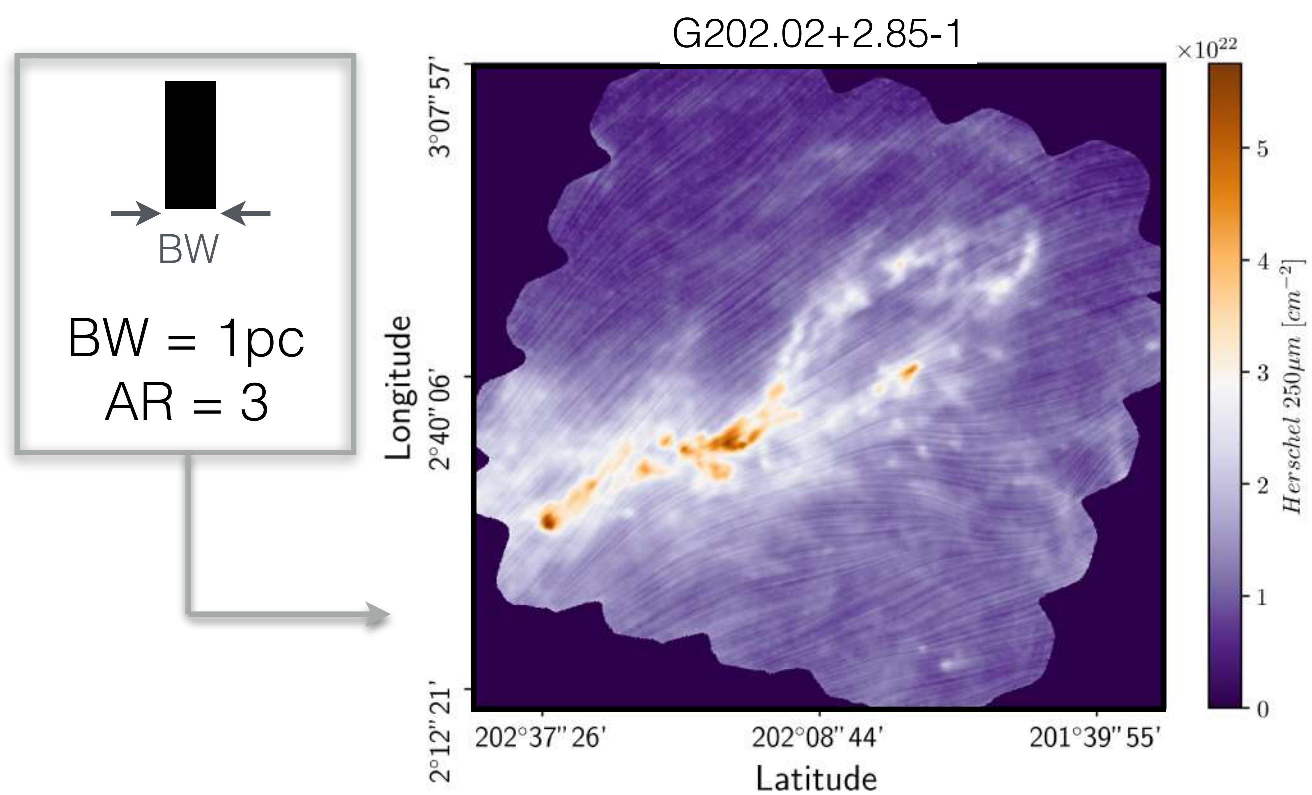


Fields sample illustration - NH maps









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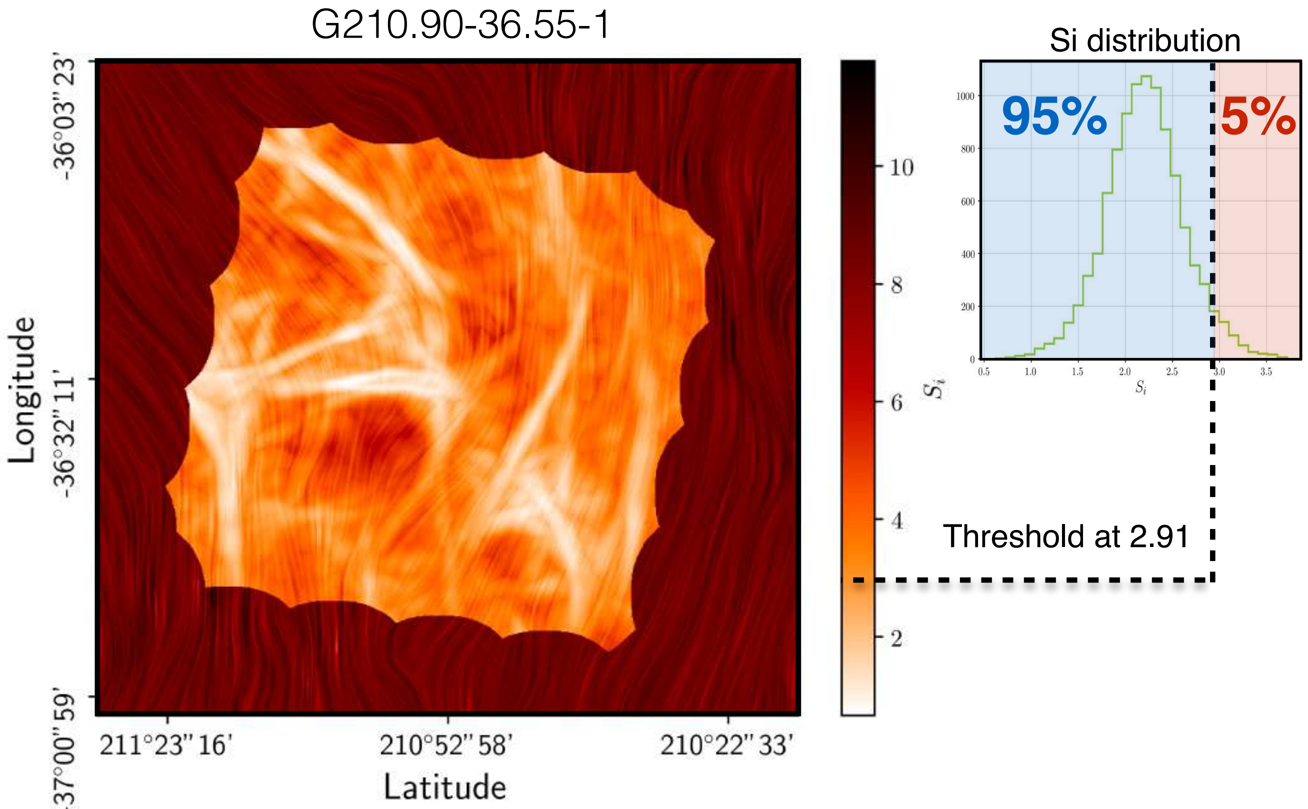
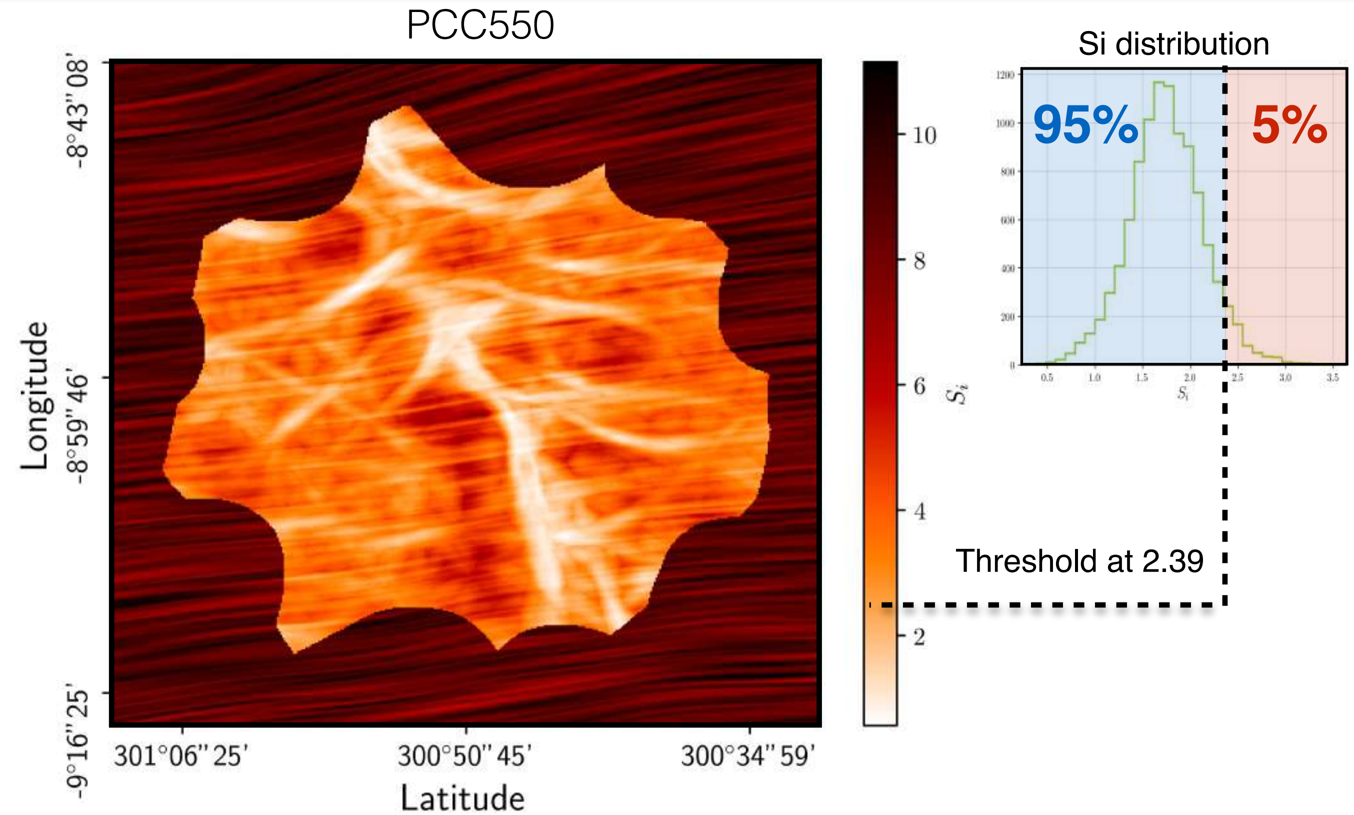
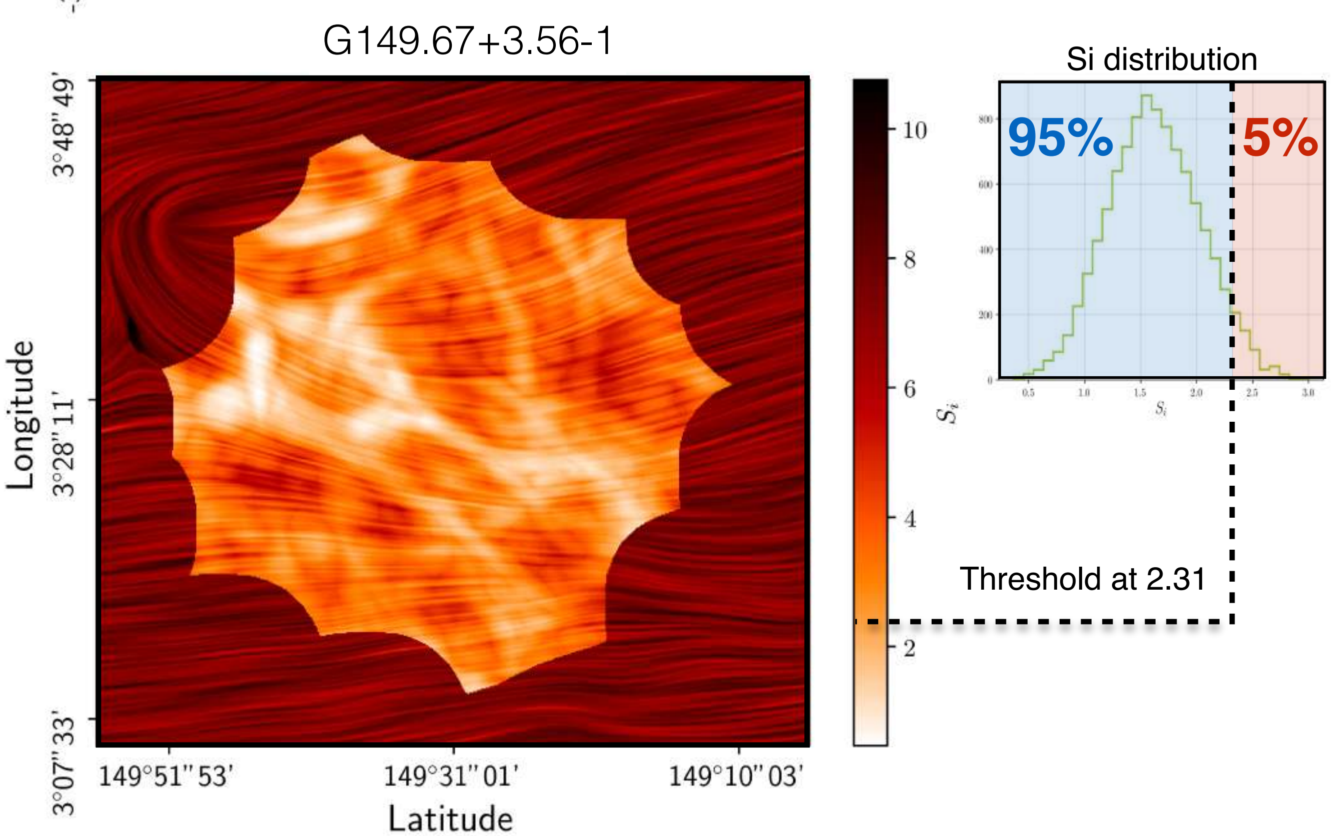
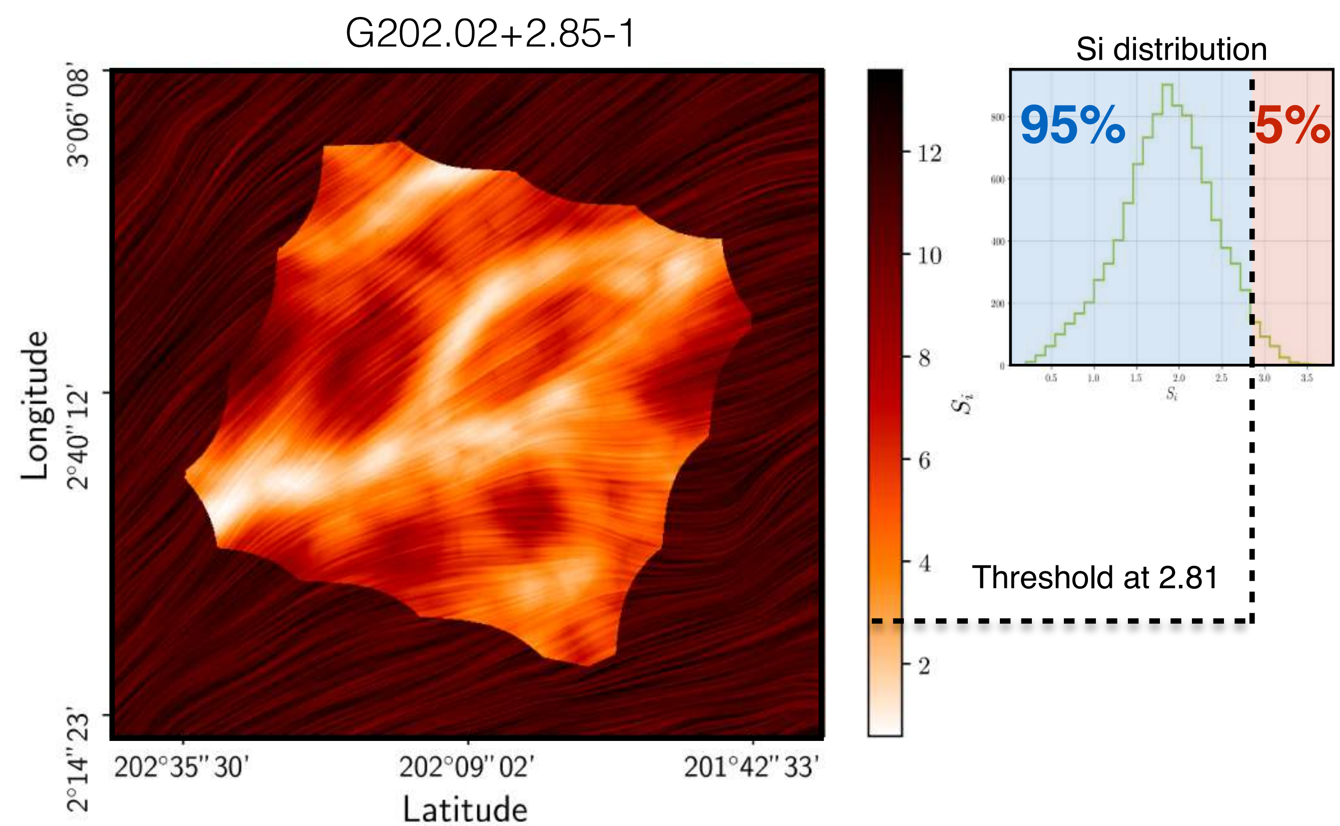
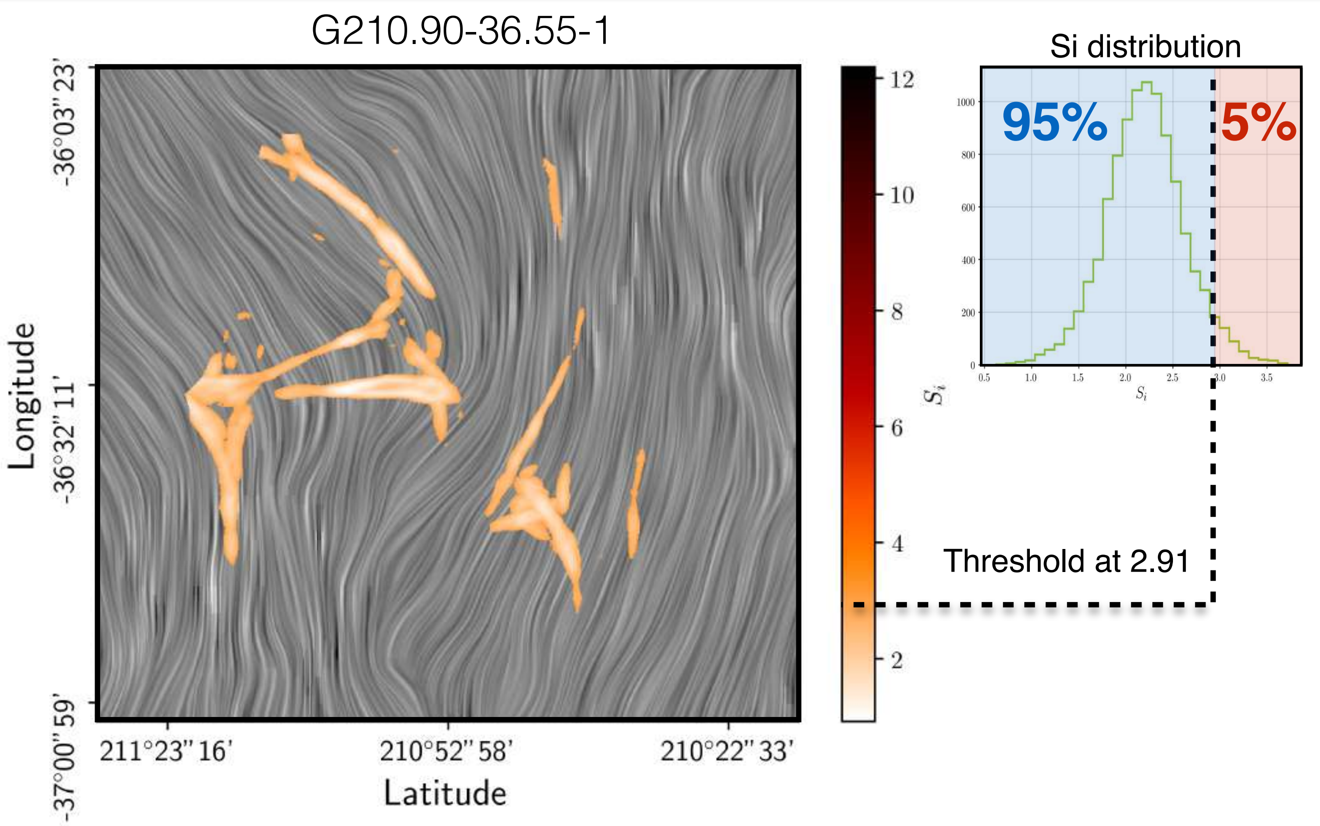


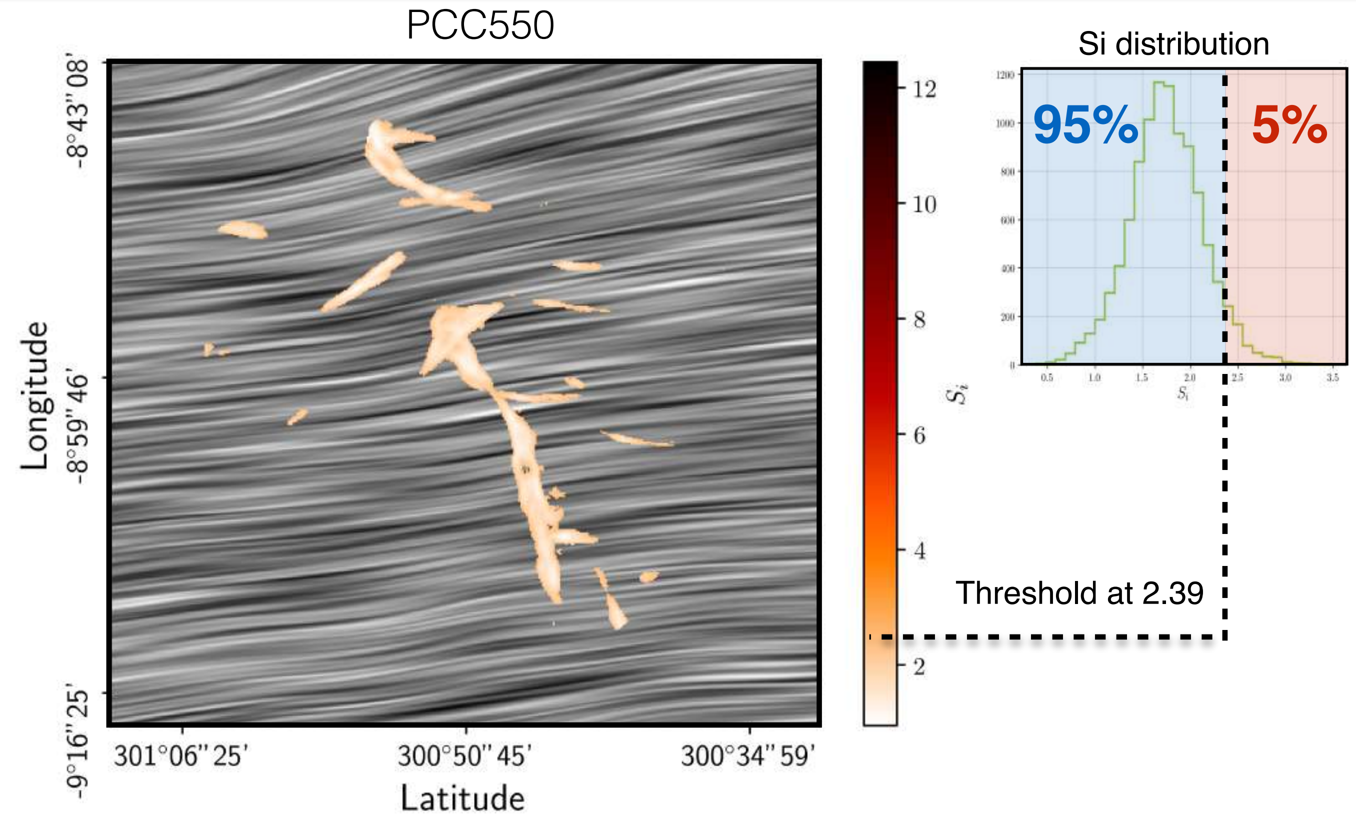


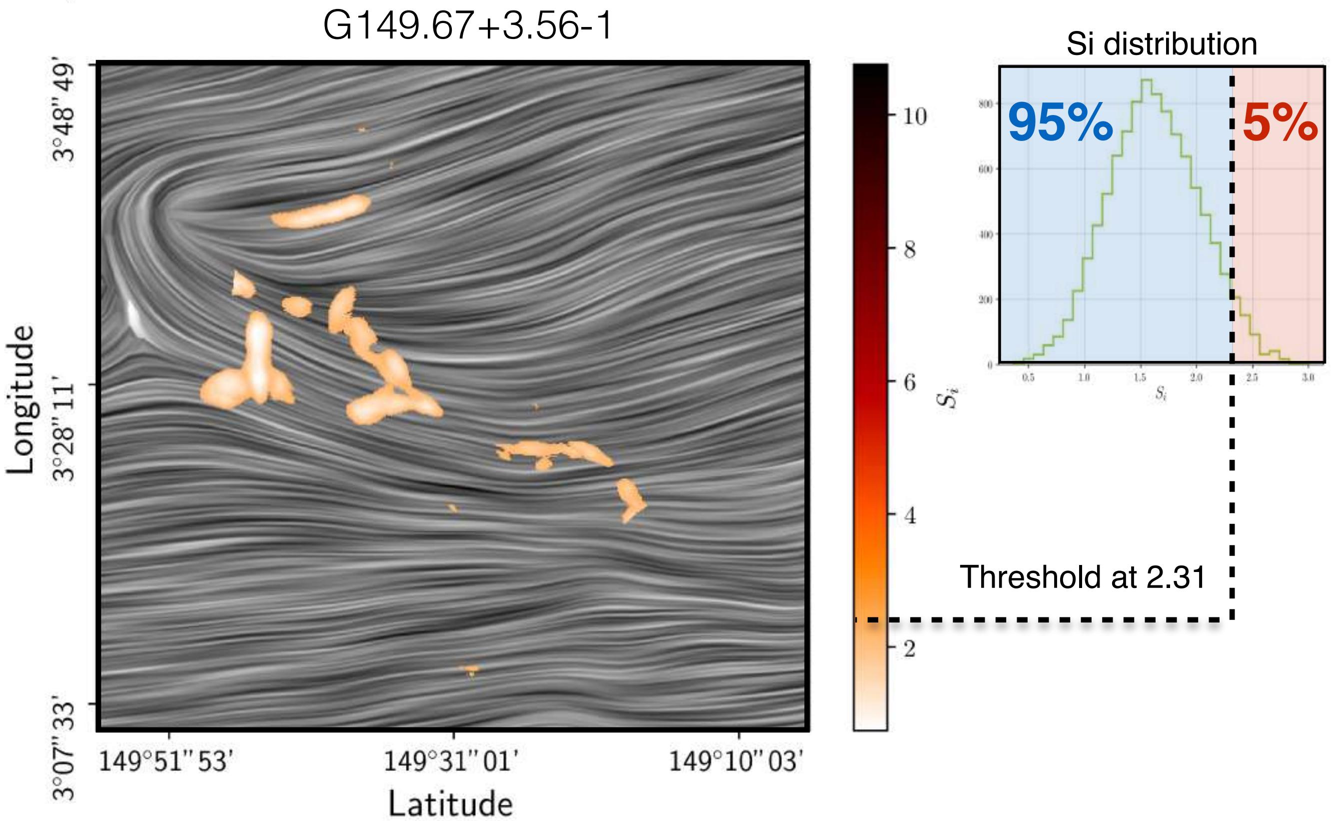


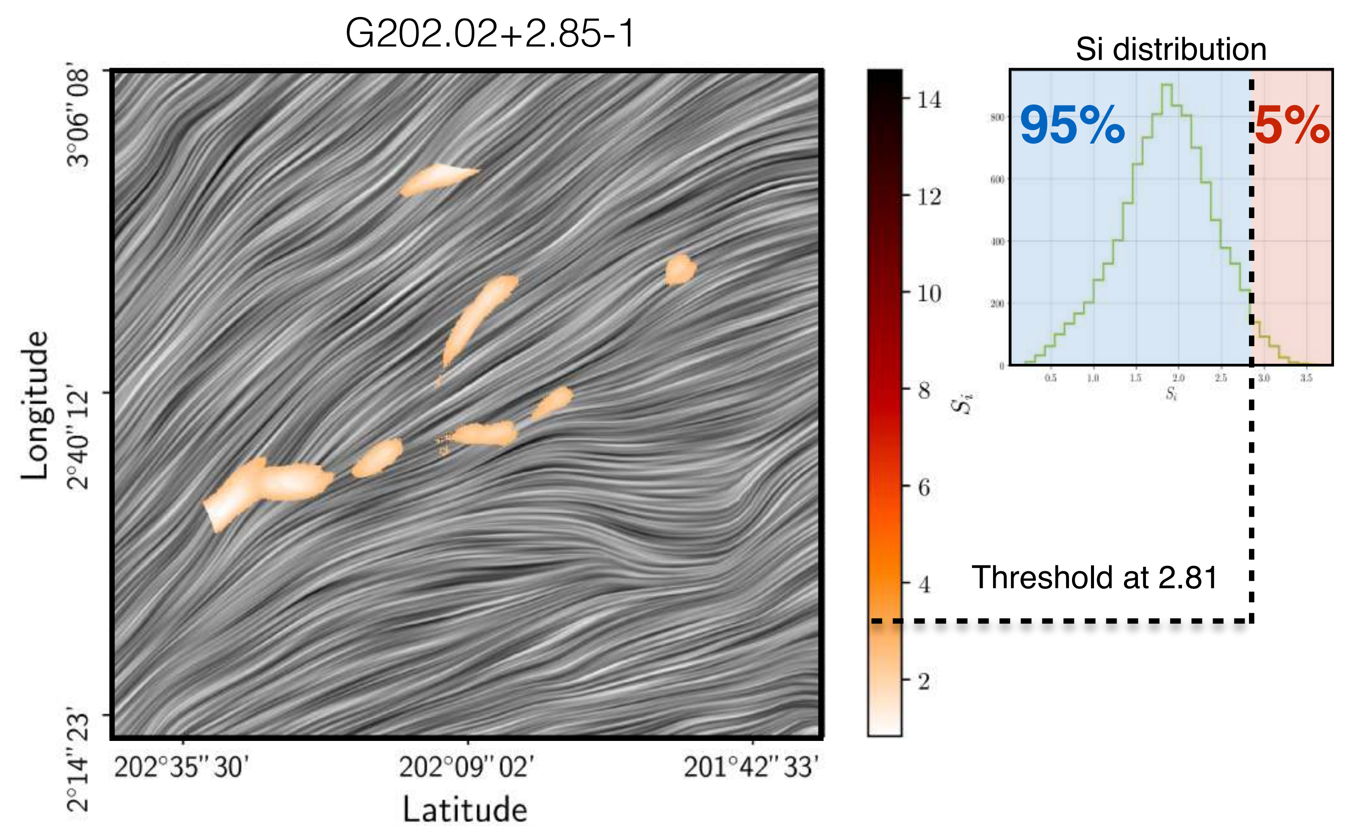


Fields sample illustration - Si maps with threshold

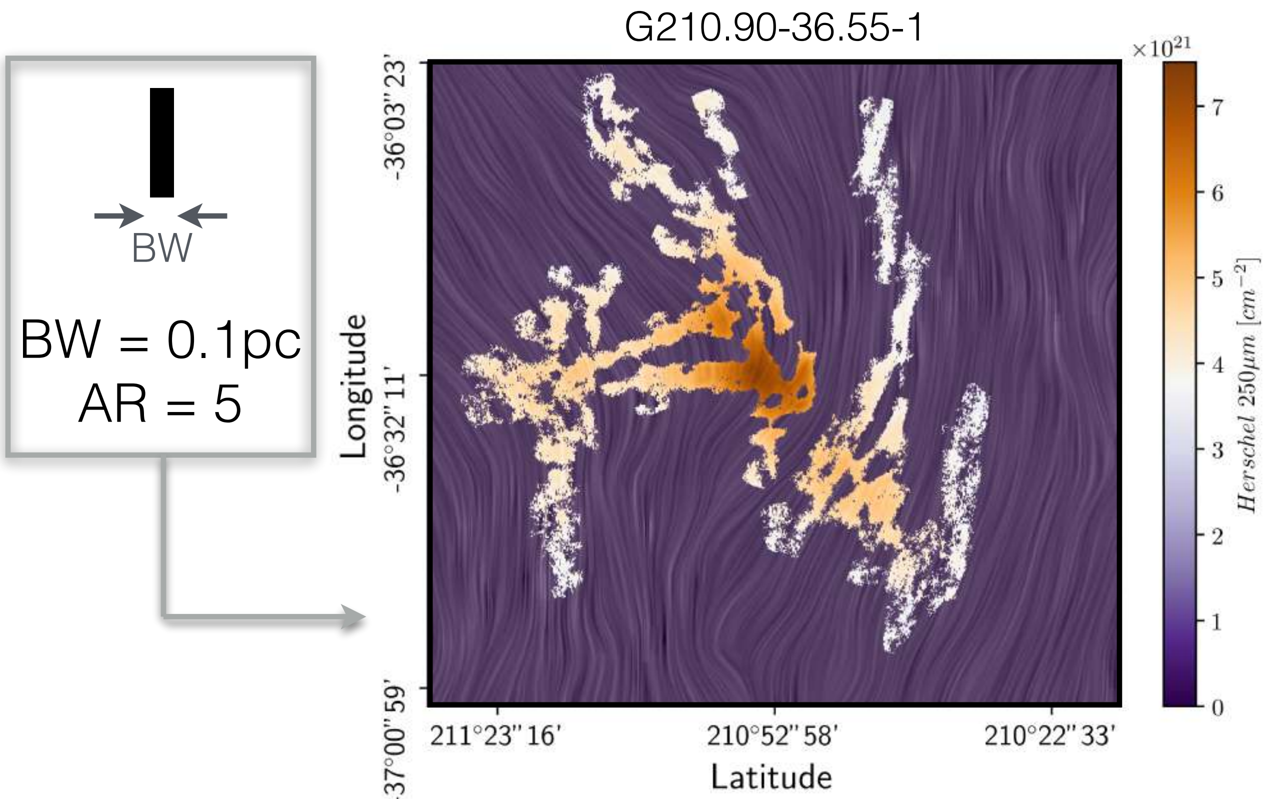


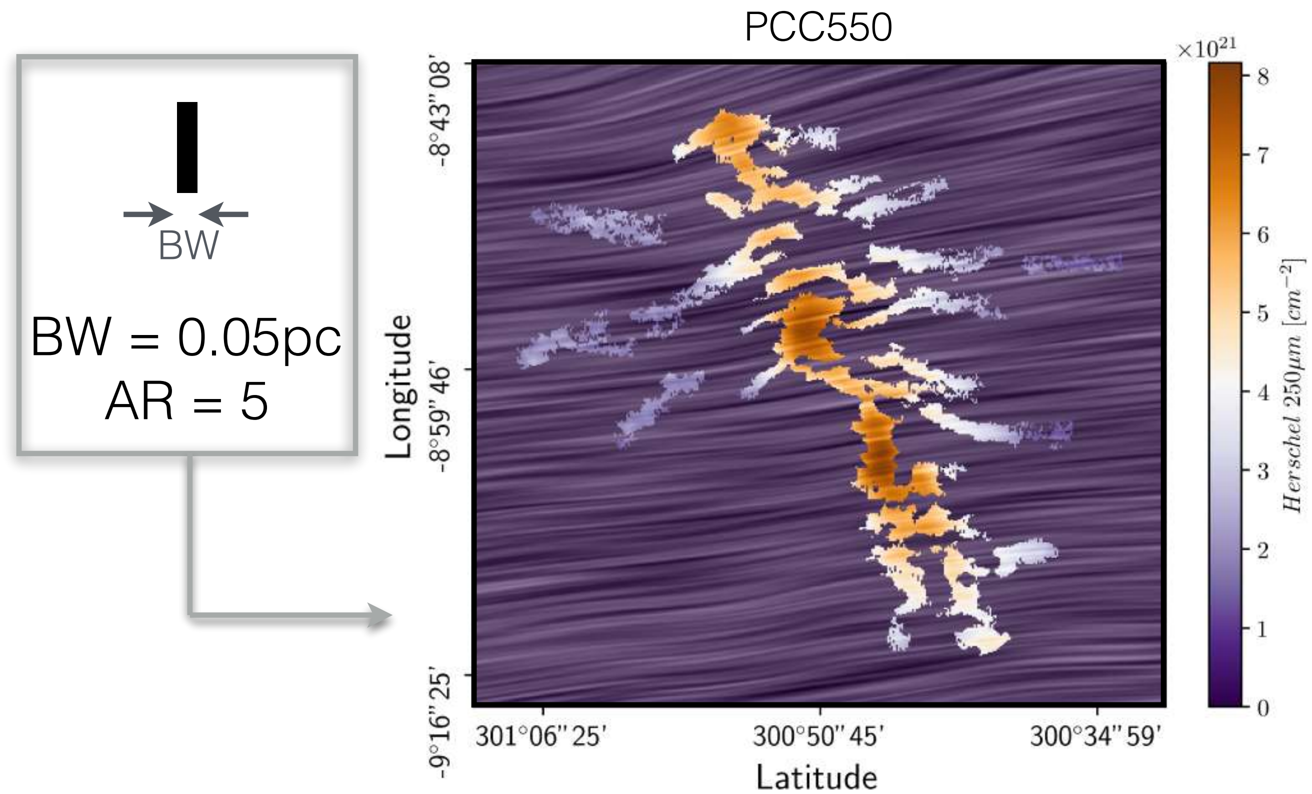


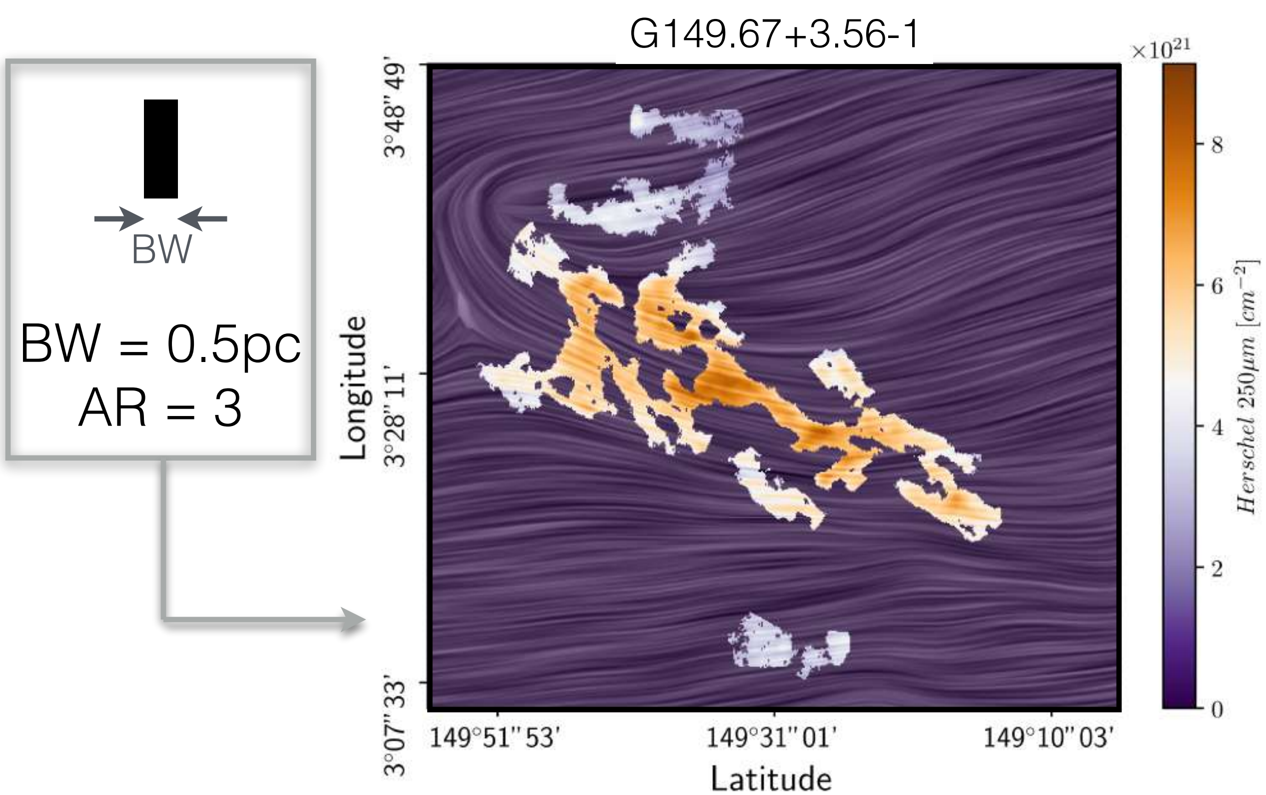


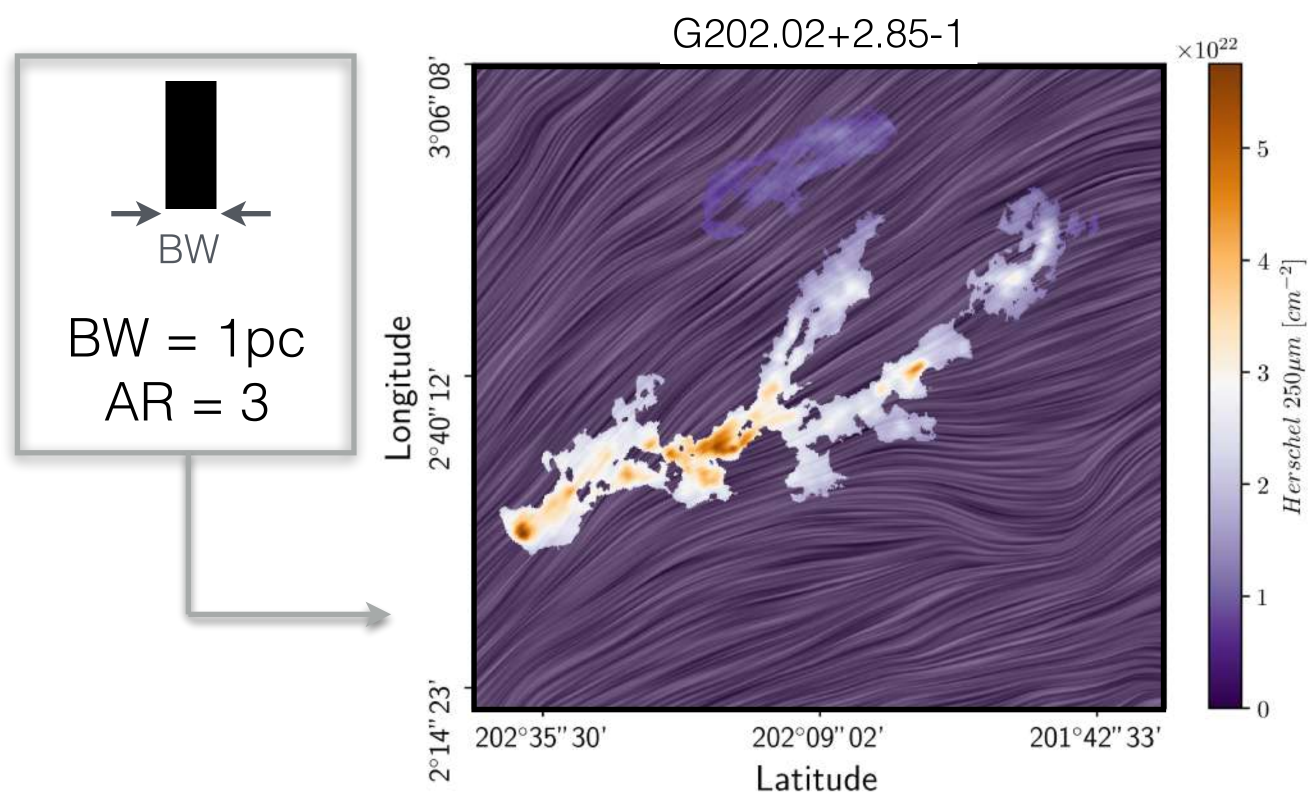


Fields sample illustration - Reconstruction on NH maps









Fields sample illustration - Relative orientation

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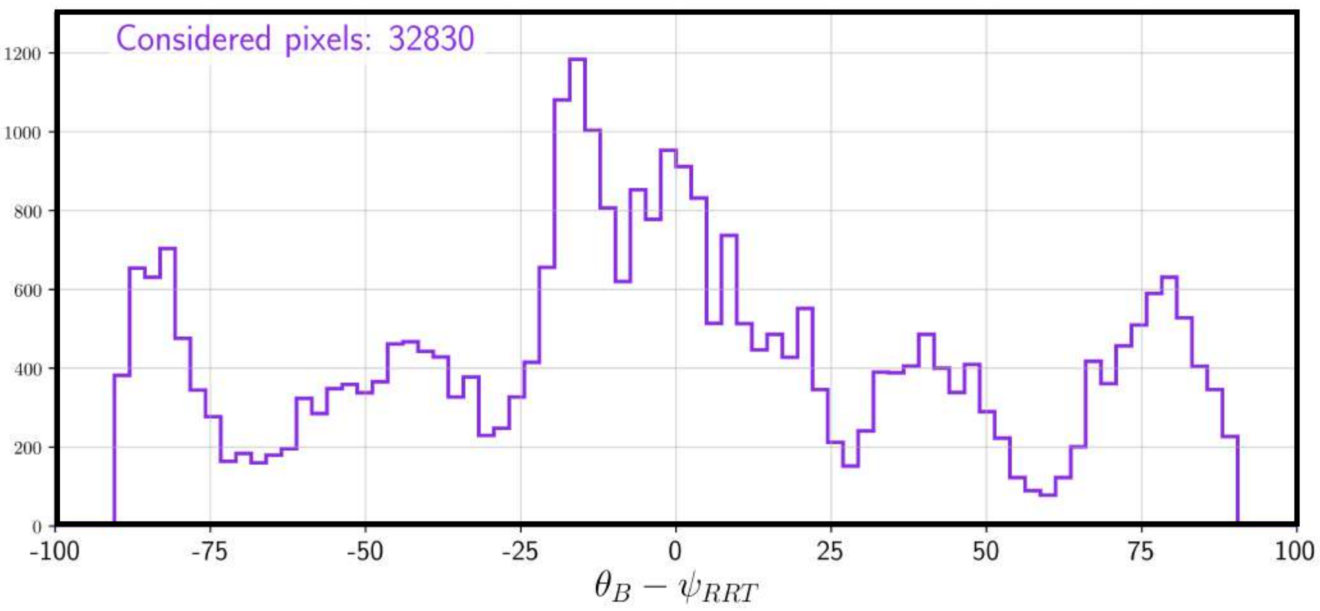
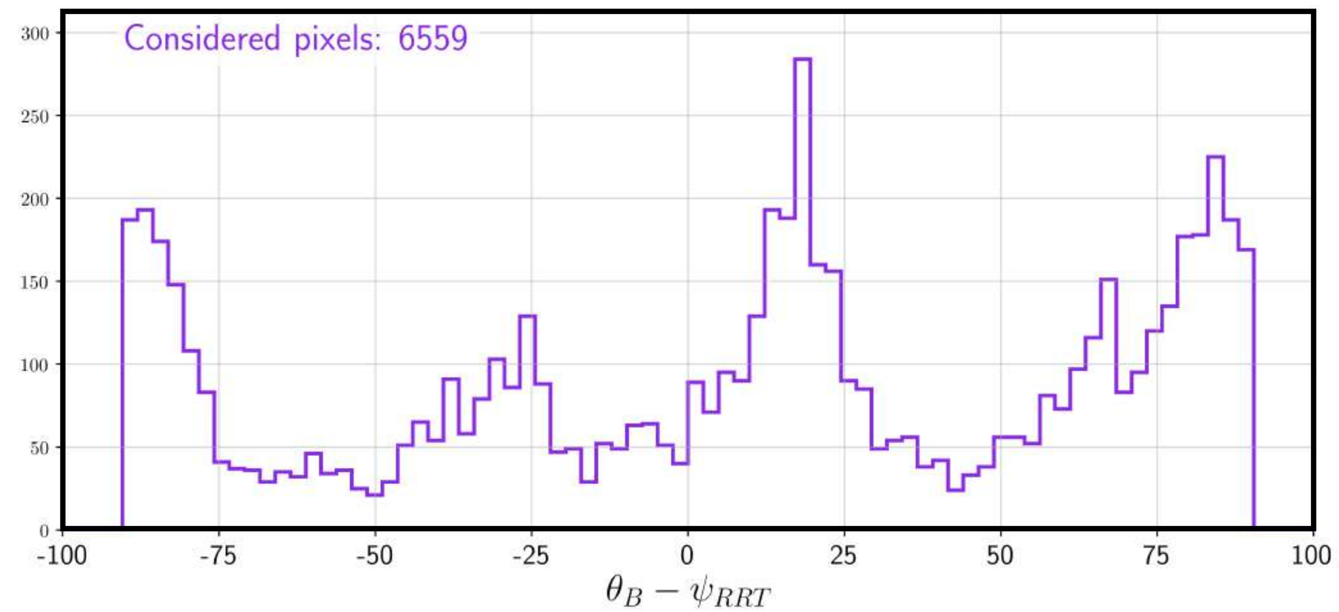
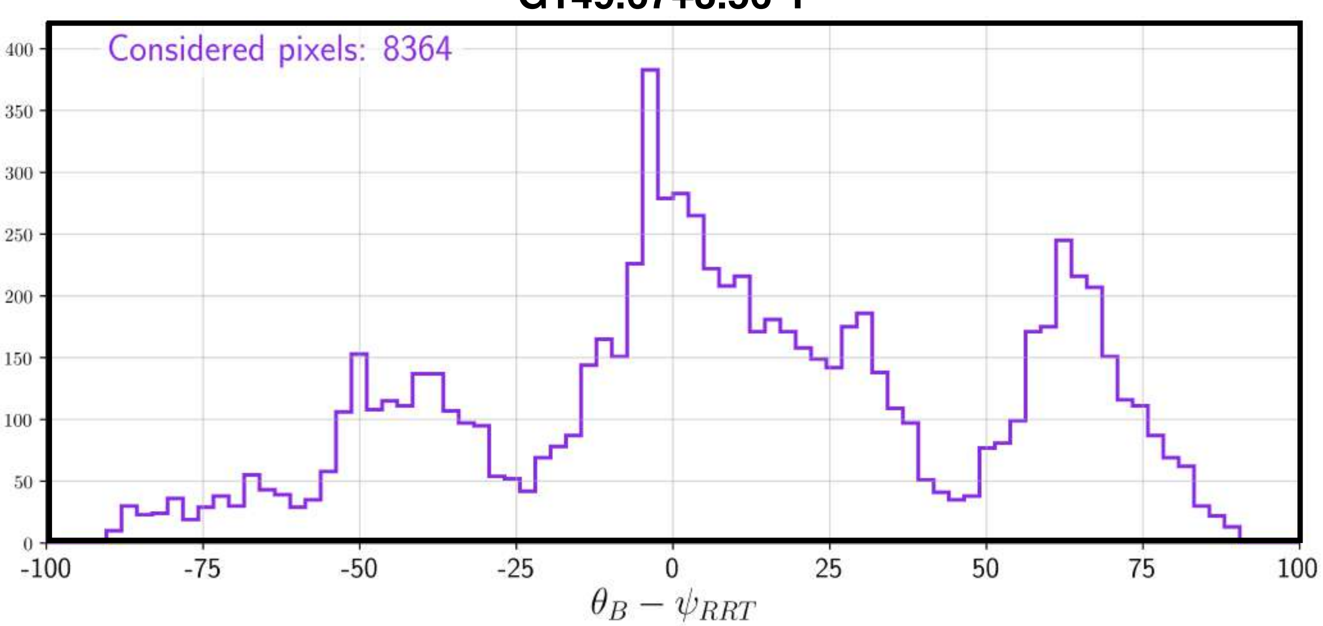


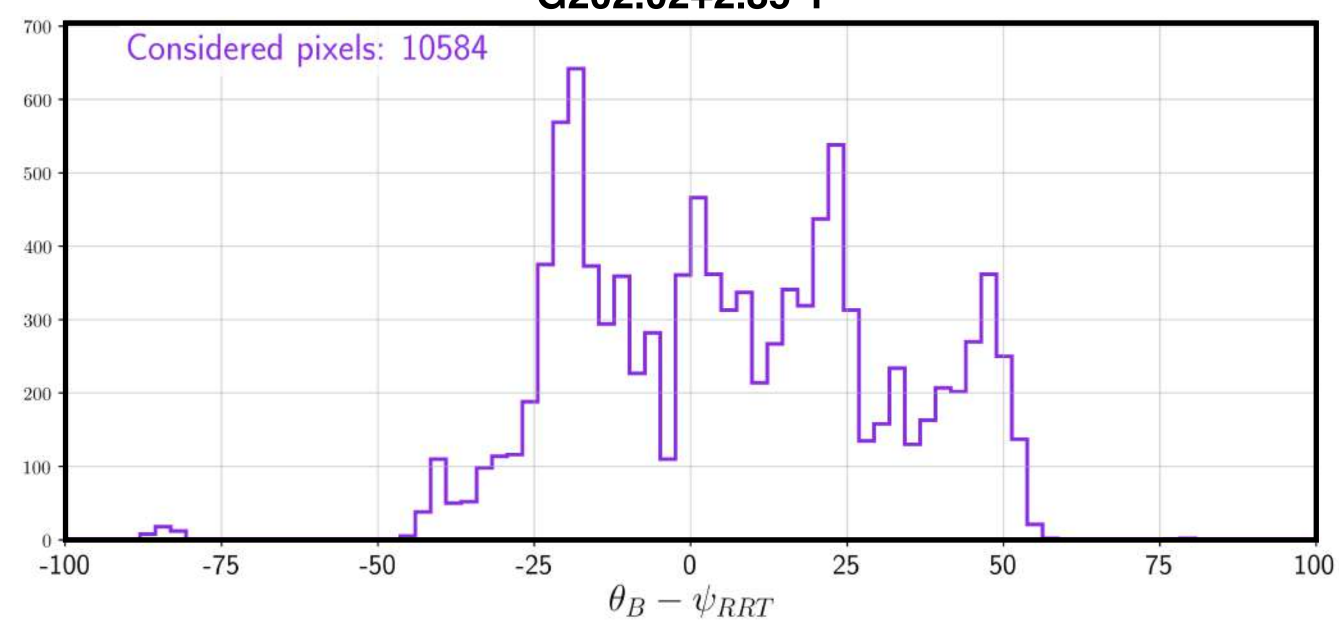
PCC550



G149.67+3.56-1



G202.02+2.85-1



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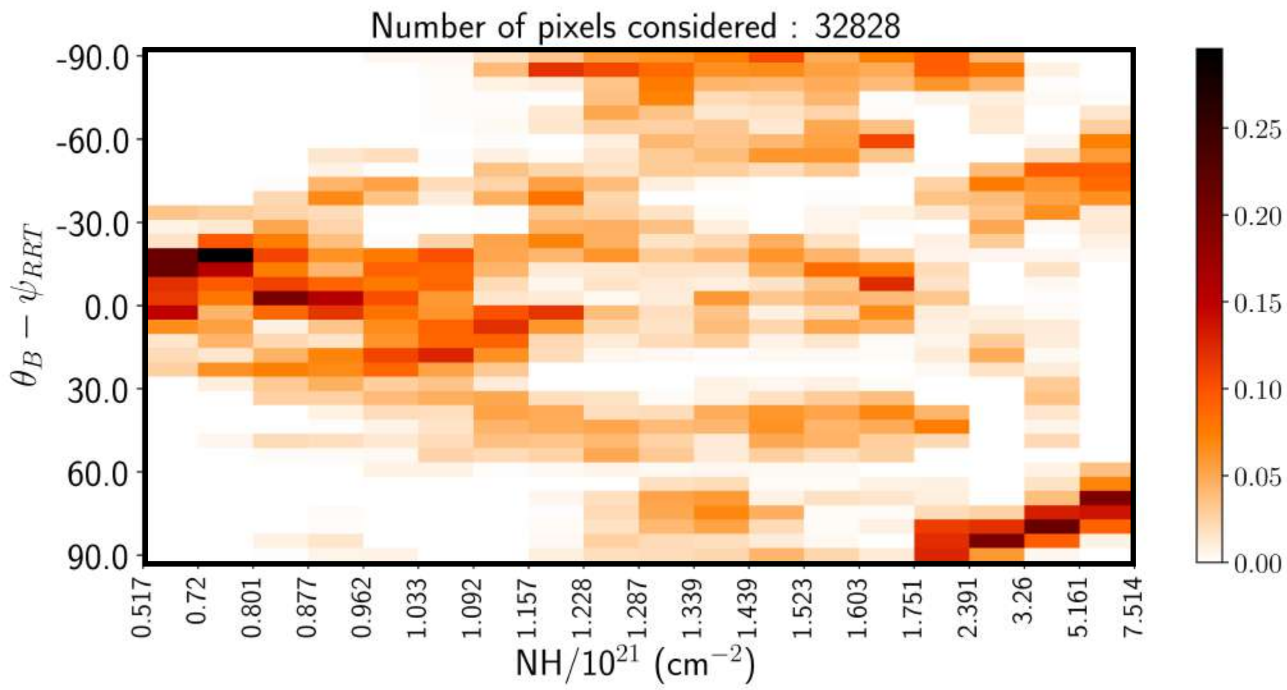

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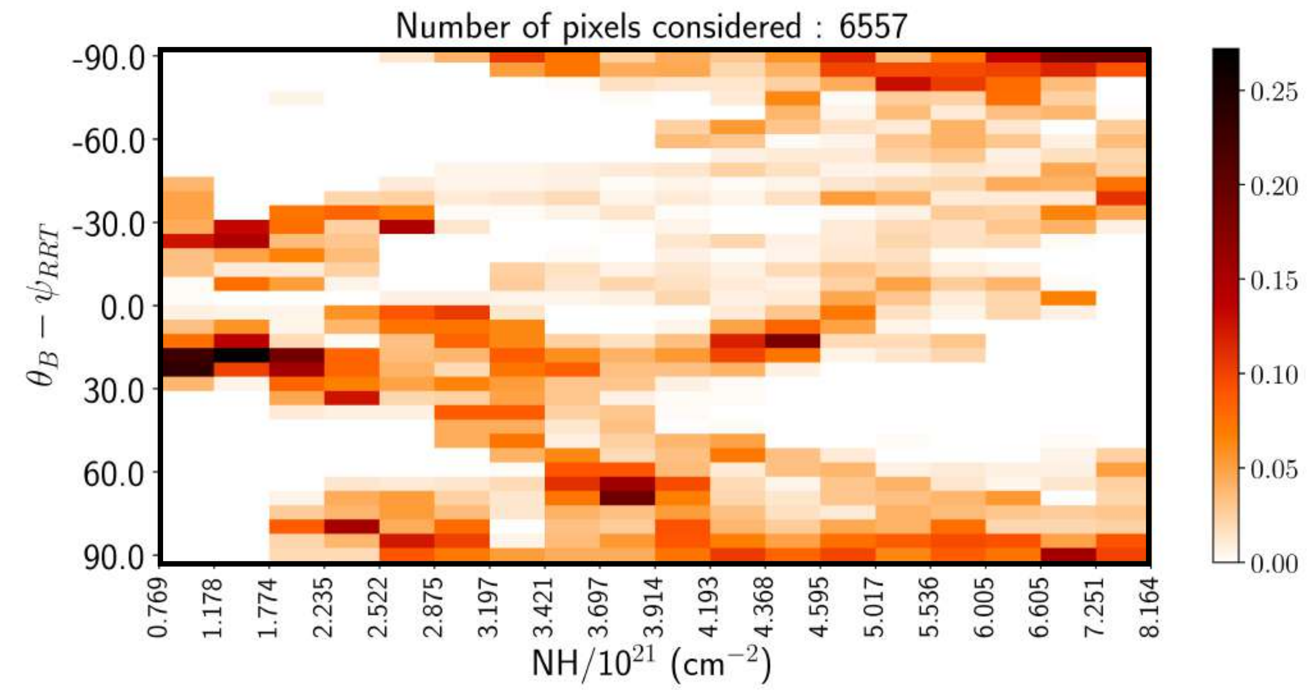

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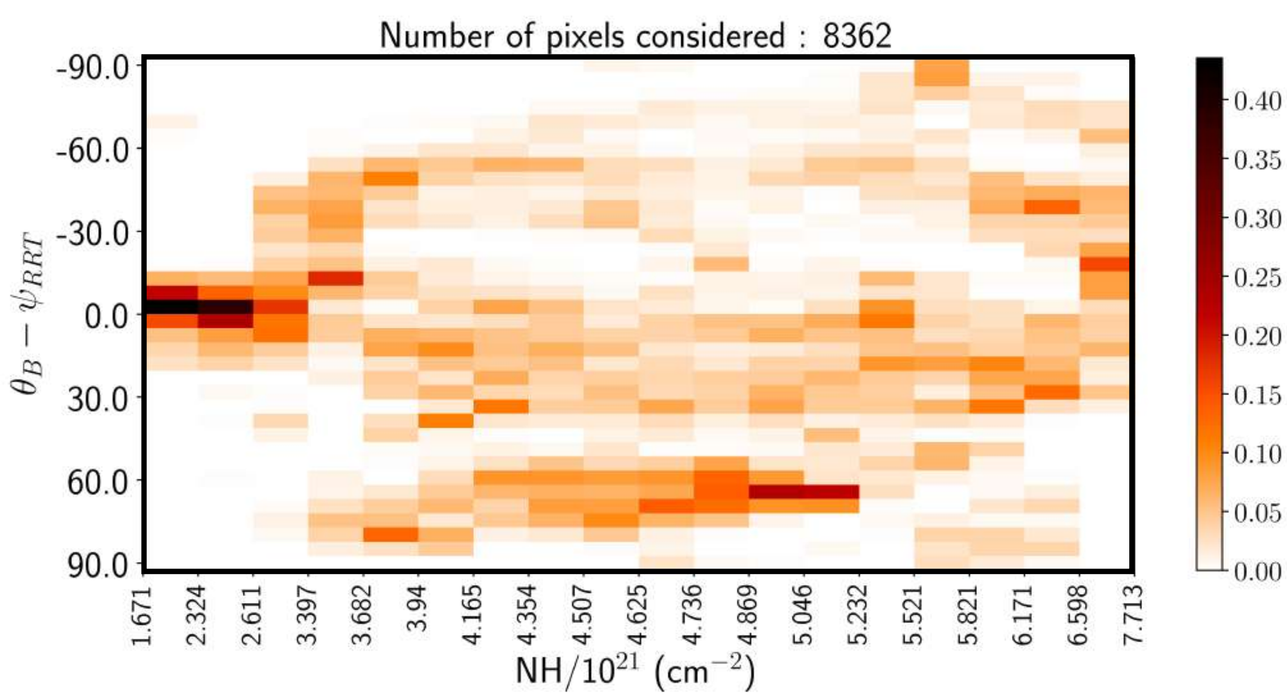

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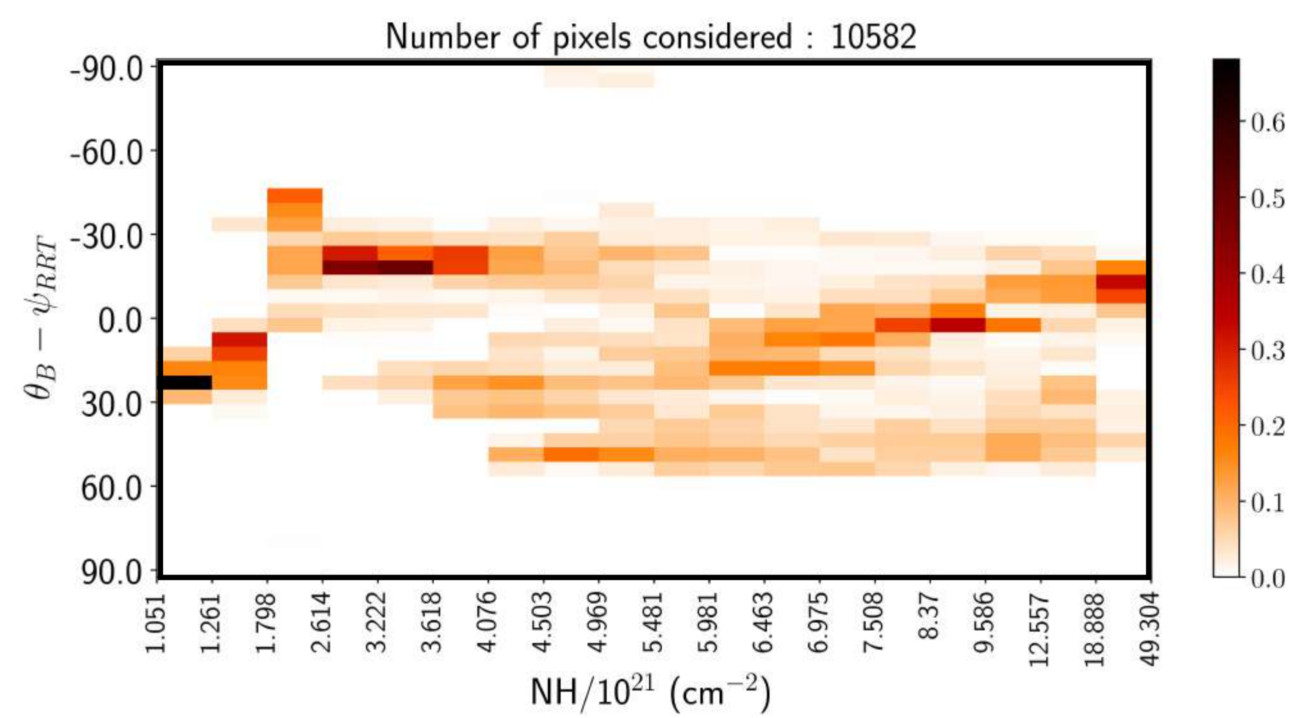
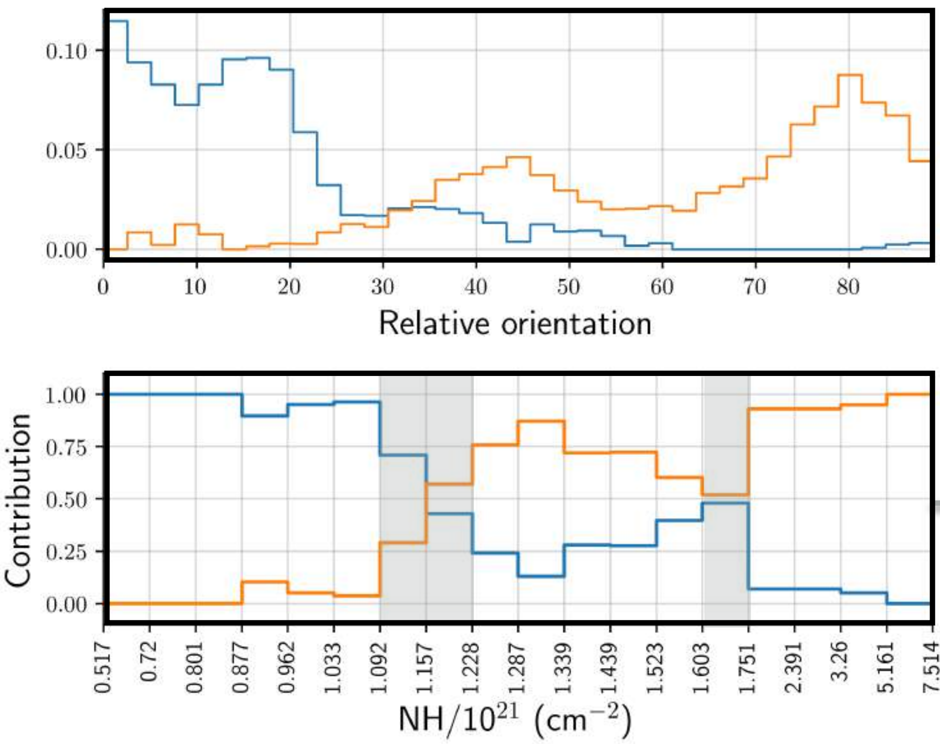


Fields sample illustration - PCA & NMF

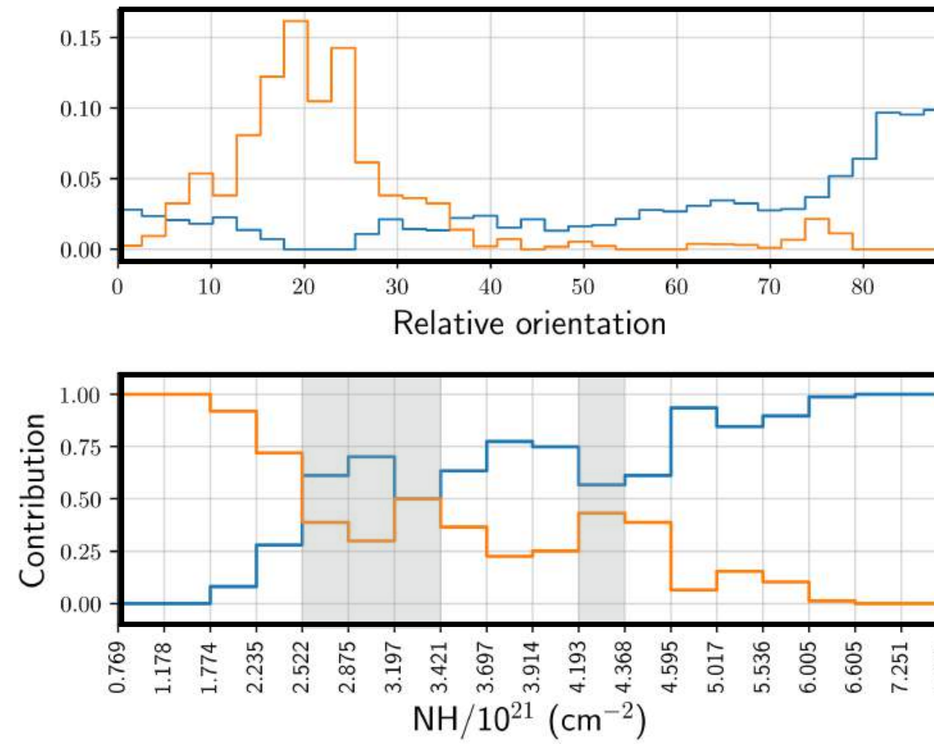
G210.90-36.55-1



Transition : NH $\sim 1.2 \times 10^{21}$ cm^{-2}

50/50 : NH $\sim 1.7 \times 10^{21}$ cm^{-2}

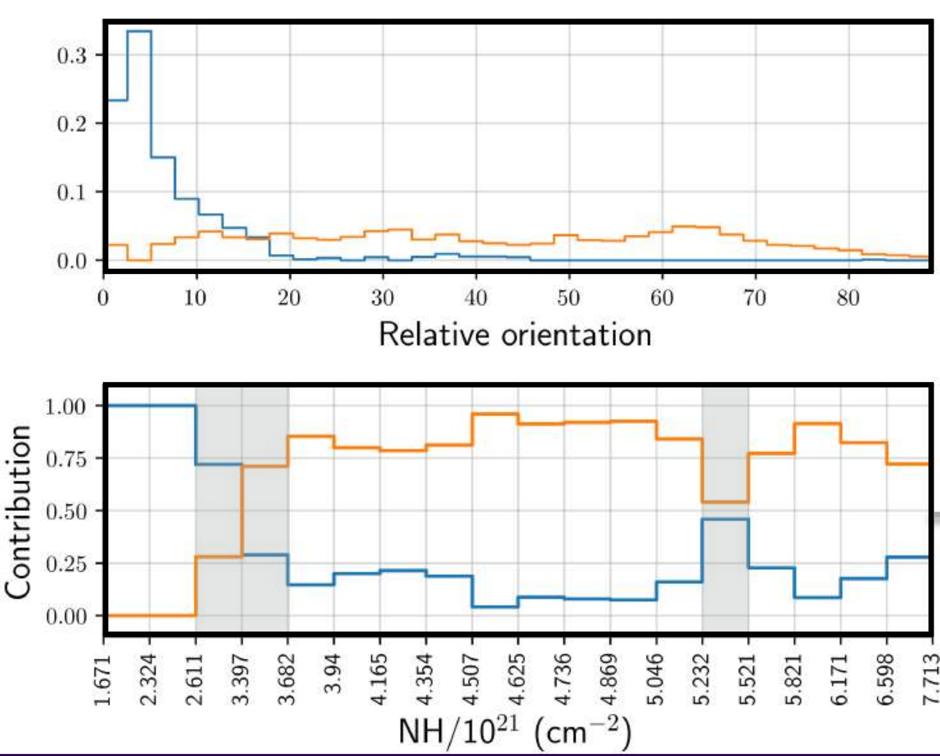
PCC550



Transition : NH $\sim 3.0 \times 10^{21}$ cm^{-2}

50/50 : NH $\sim 4.3 \times 10^{21}$ cm^{-2}

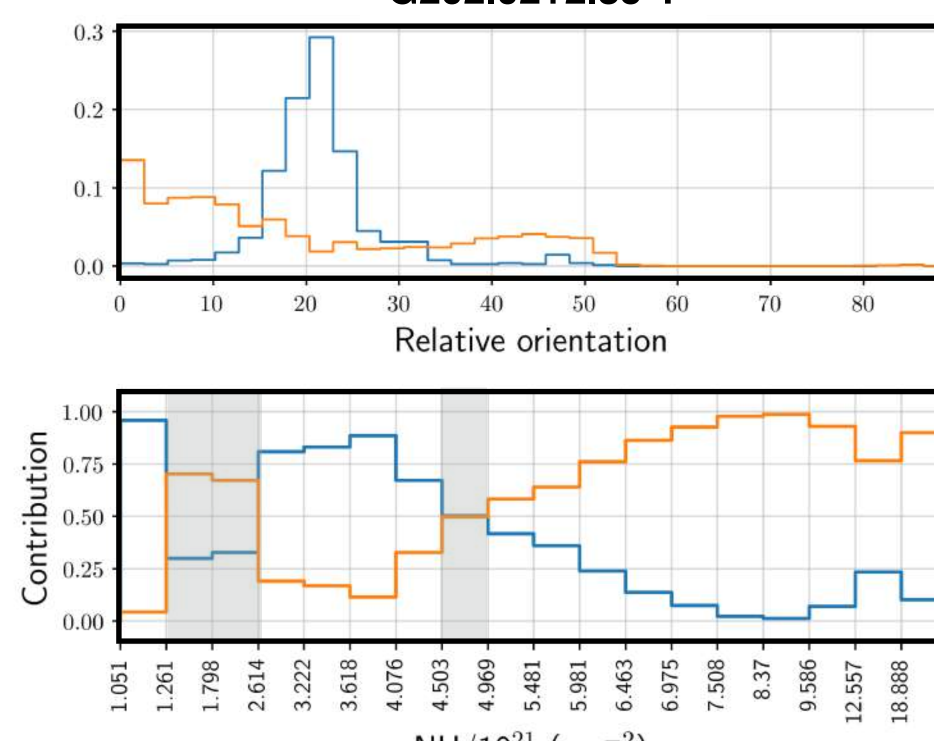
G149.67+3.56-1



Transition : NH $\sim 3.4 \times 10^{21}$ cm^{-2}

50/50 : NH $\sim 5.4 \times 10^{21}$ cm^{-2}

G202.02+2.85-1



Transition : NH $\sim 1.8 \times 10^{21}$ cm^{-2}

NH $\sim 5.0 \times 10^{21}$ cm^{-2}

Conclusion & Perspective

New method Rolling Radon Transform : **RRT**

Optimised version of RHT (Rolling Hough Transform)

Fast : < 30min / bar for one field

User friendly : Only two parameters, bar's width and length and automatic significance

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Combining Planck & Herschel is quite powerful

Including **striations features**

Bimodal orientation between B-Field & filamentary structures, dependency with the column density

→ **Carriere et al. in prep**

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Extension to all the 116 Herschel PGCC fields

Broad range of **properties / sizes / configurations**

Including **evolution stage of cores (starless, pre-stellar, proto-stellar)**

Combination with **molecular data** to get dynamics

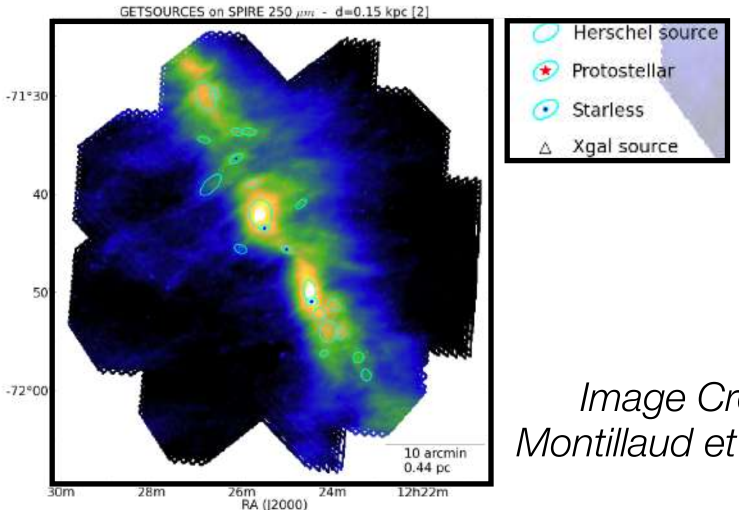
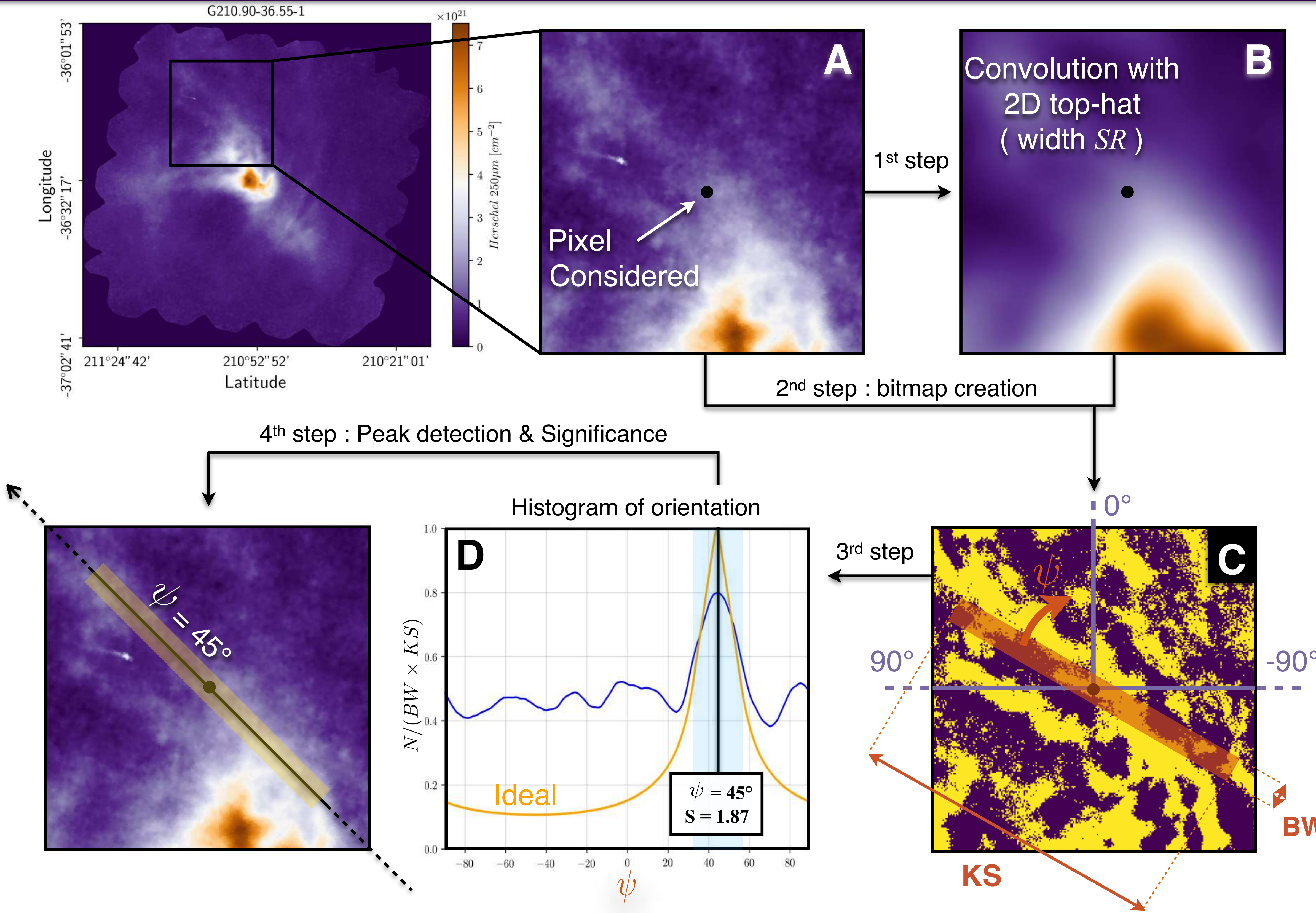
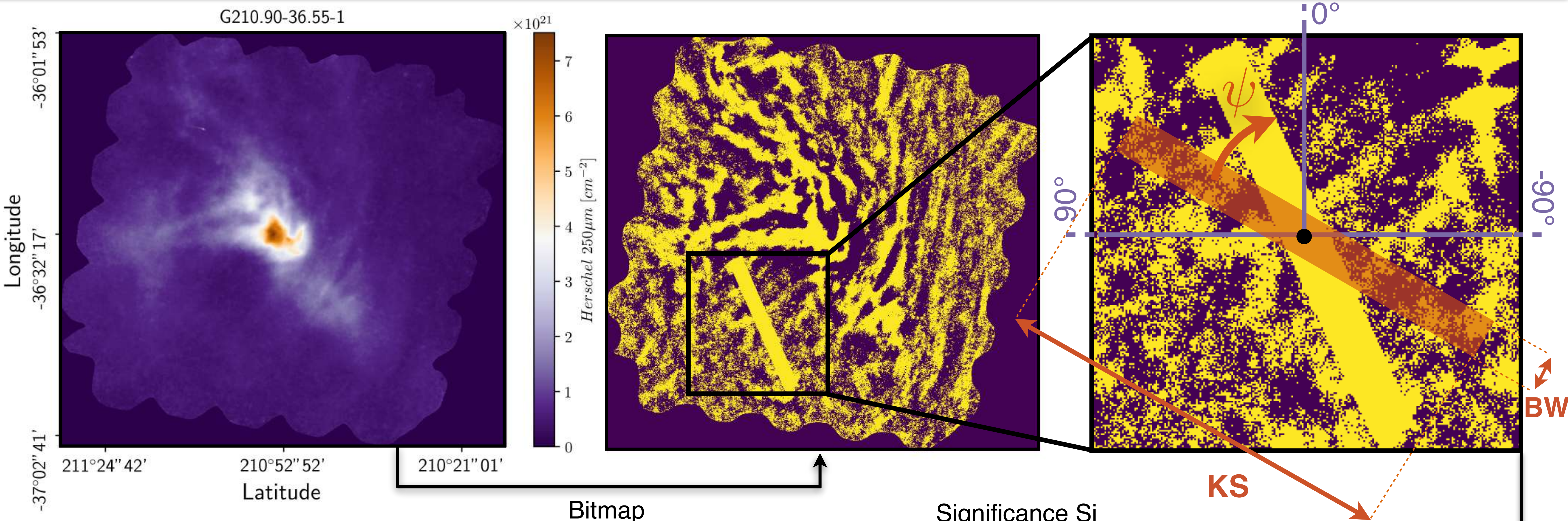


Image Credit : Montillaud et al. 2015

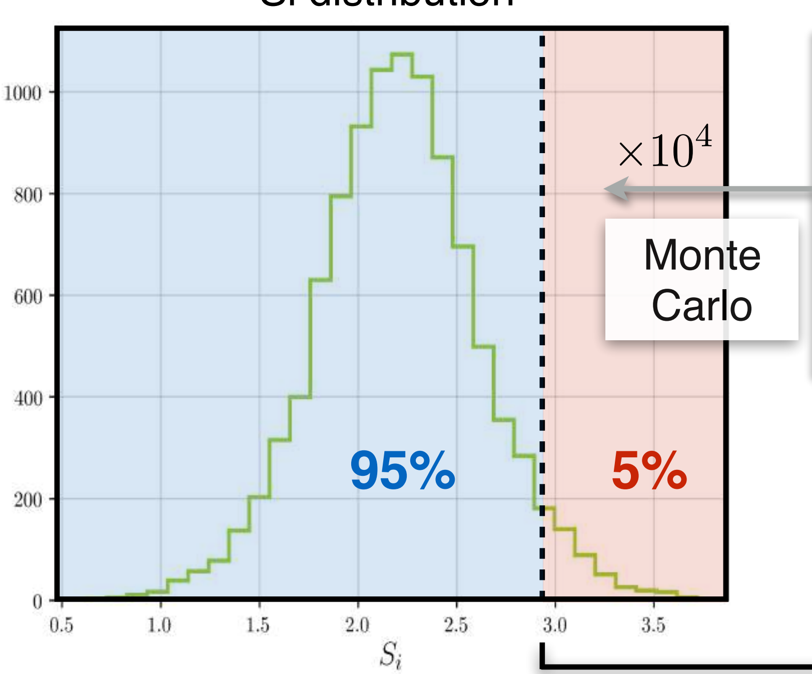
Rolling Radon Transform



Automatic determination of Significance & Threshold



Si distribution

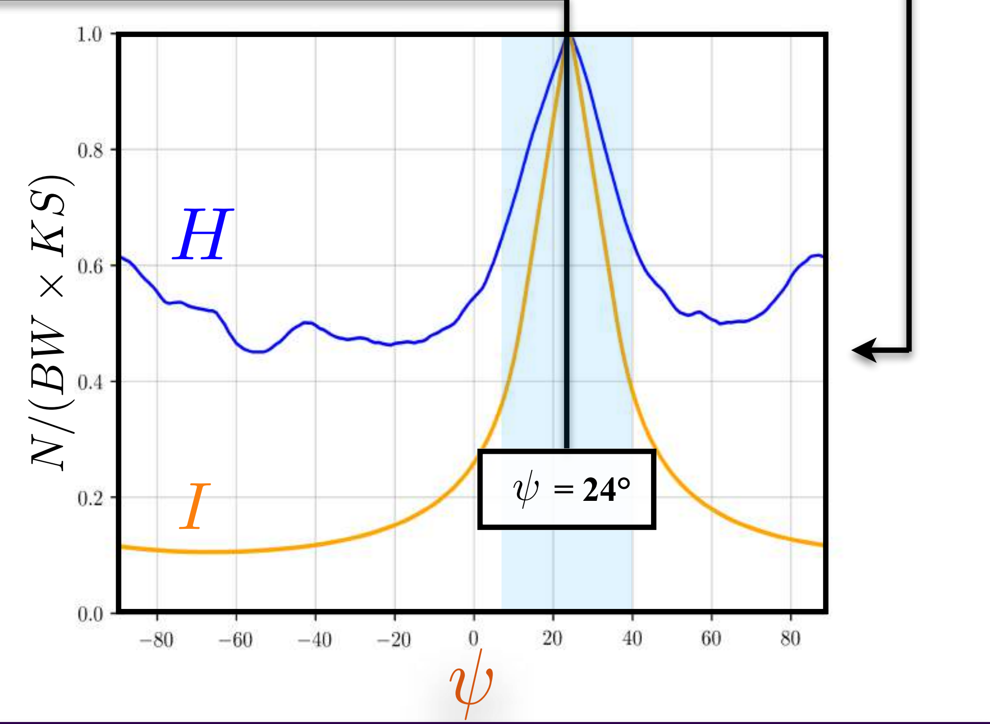


$$S_i = \sqrt{\frac{1}{P_c} \times \sum_j^{P_c} \frac{(I_j - H_j)^2}{\sigma^2}}$$

$$\sigma \Leftrightarrow \mathrm{MAD} = \mathrm{median}\left(|H - \mathrm{median}\left(H\right)|\right)$$

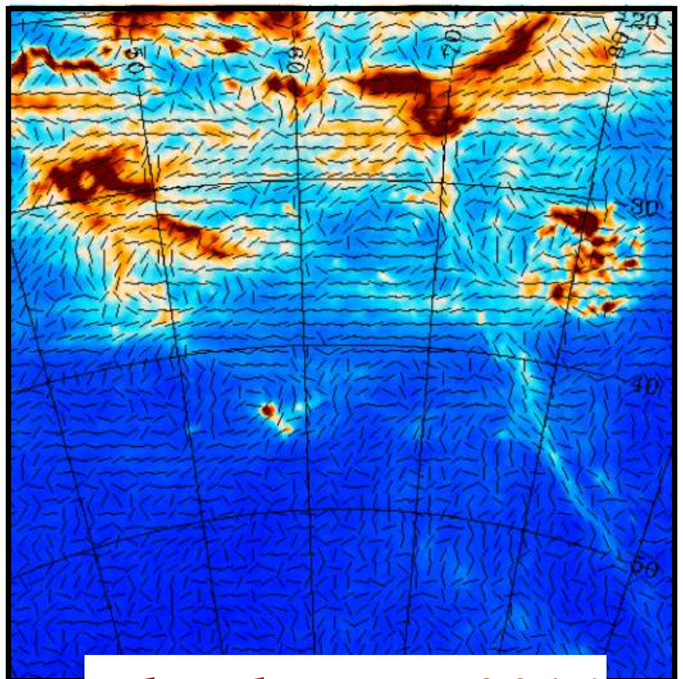
Threshold = 2.9

p-value

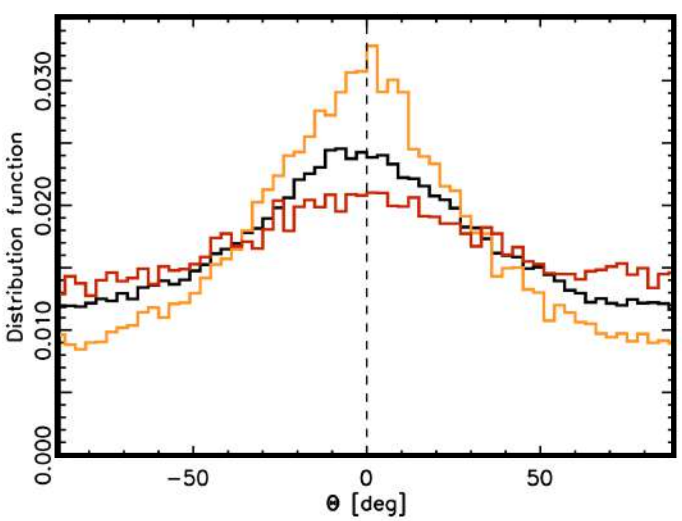


B-field interplay with filamentary structures from Planck Statistical analysis

Filaments in the Diffuse ISM

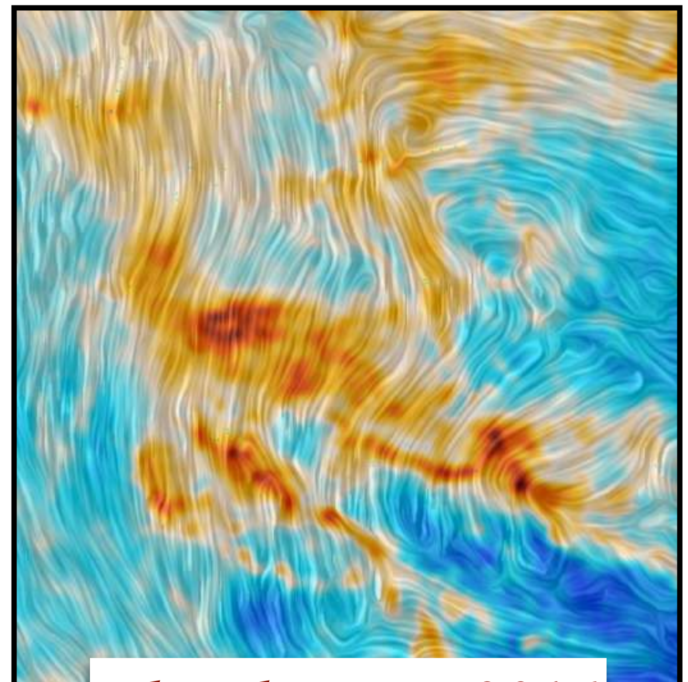


Planck XXXII 2016

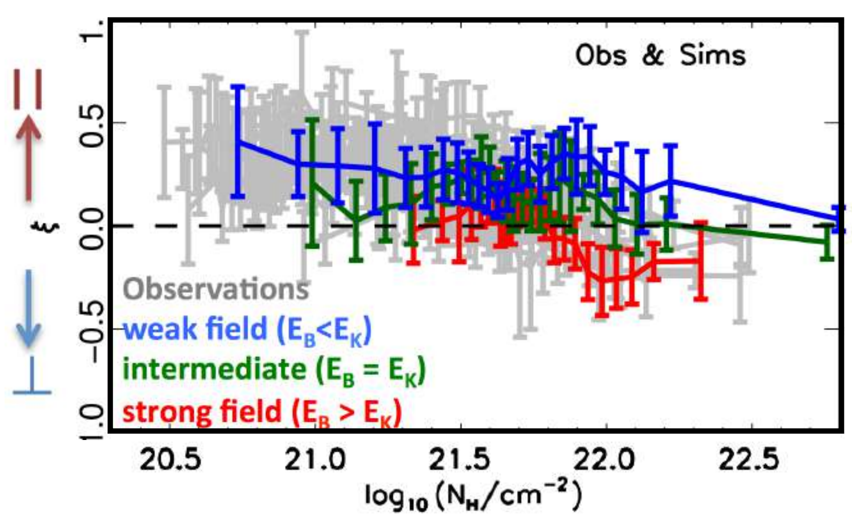


B-fields & filaments mostly aligned

Nearby Molecular complexes

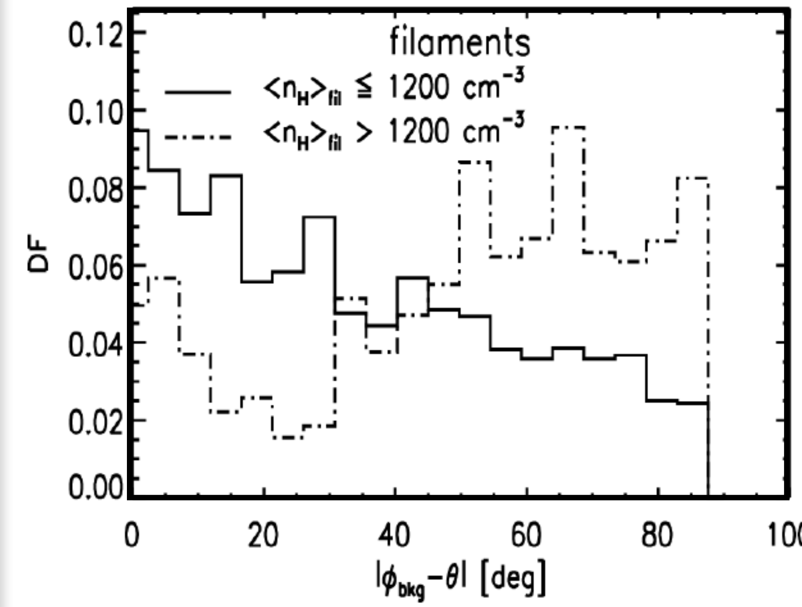


Planck XXXV 2016



NH transition between // and perp. orientations

Filaments hosting clumps

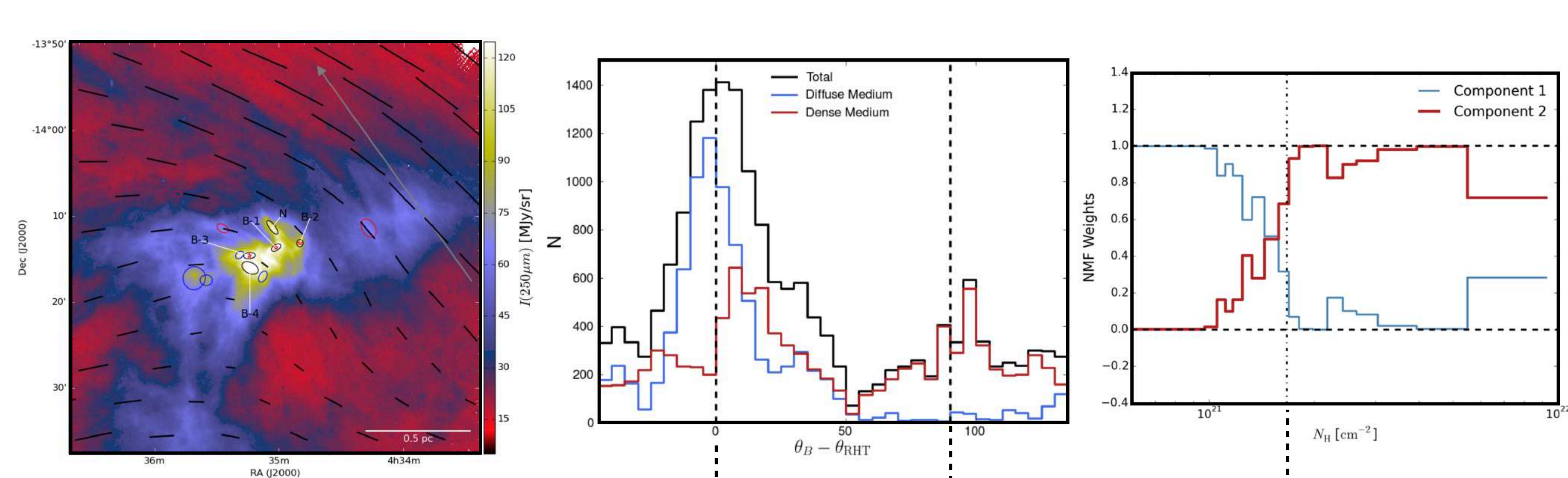


Alina et al. 2019

→ **Transition** in density nH

→ Influence of B-field in the formation and evolution of filaments and clumps

Planck-Herschel combined analysis

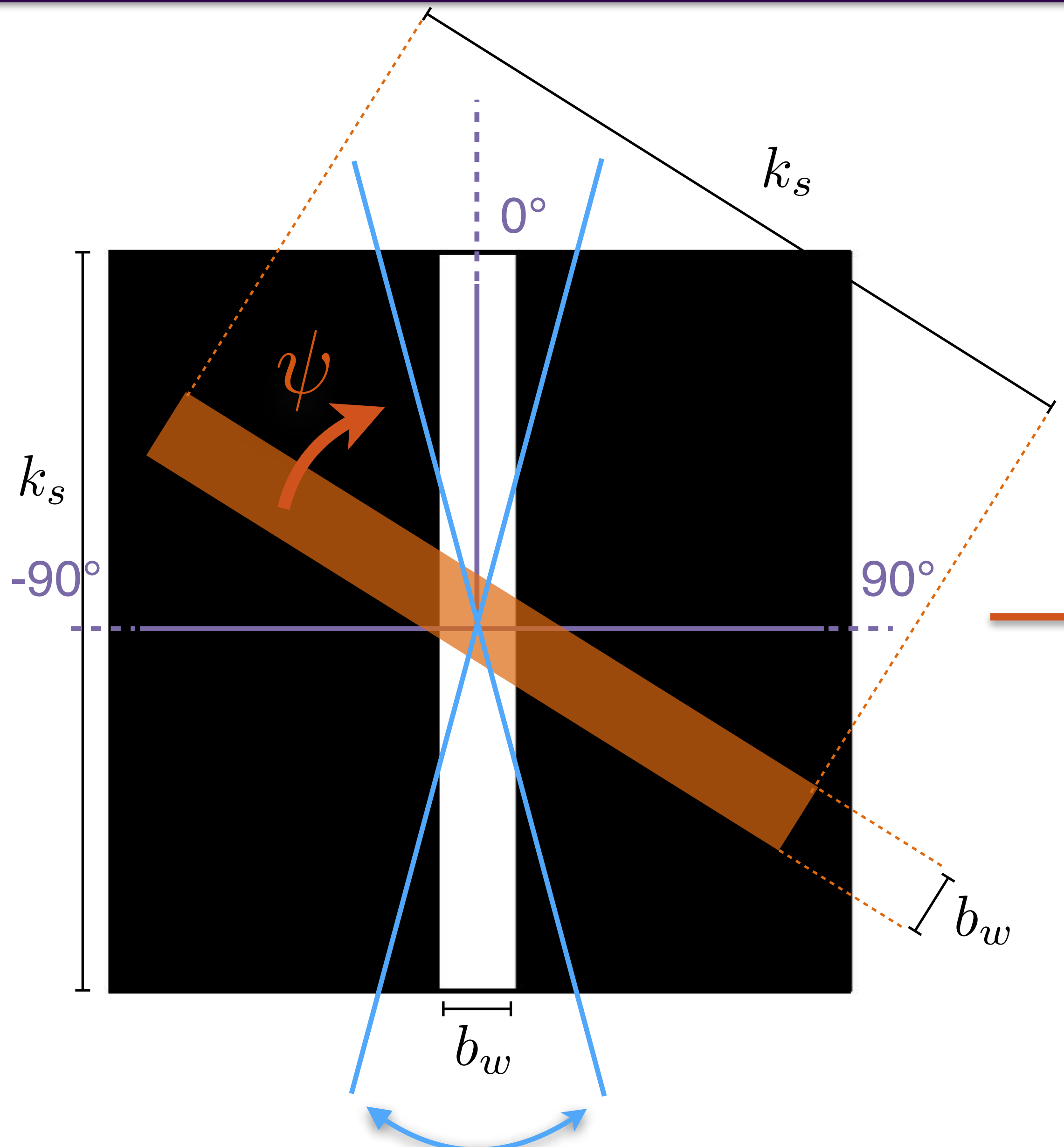


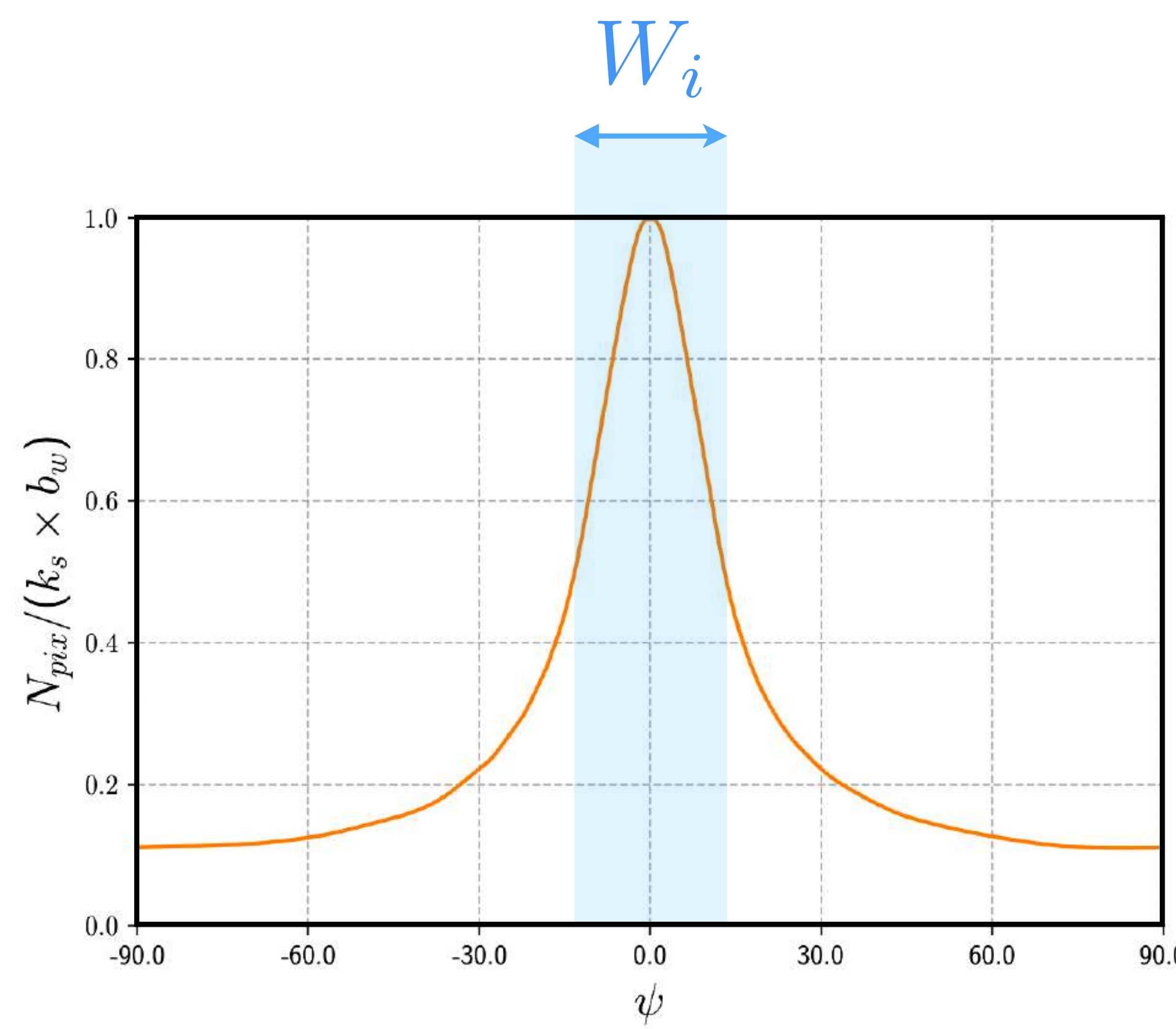
Malinen et al. 2016

Diffuse medium : Diffuse striations and B field are clearly aligned

Dense medium : Bimodal distribution of relative orientation centered at ~0° and 90°

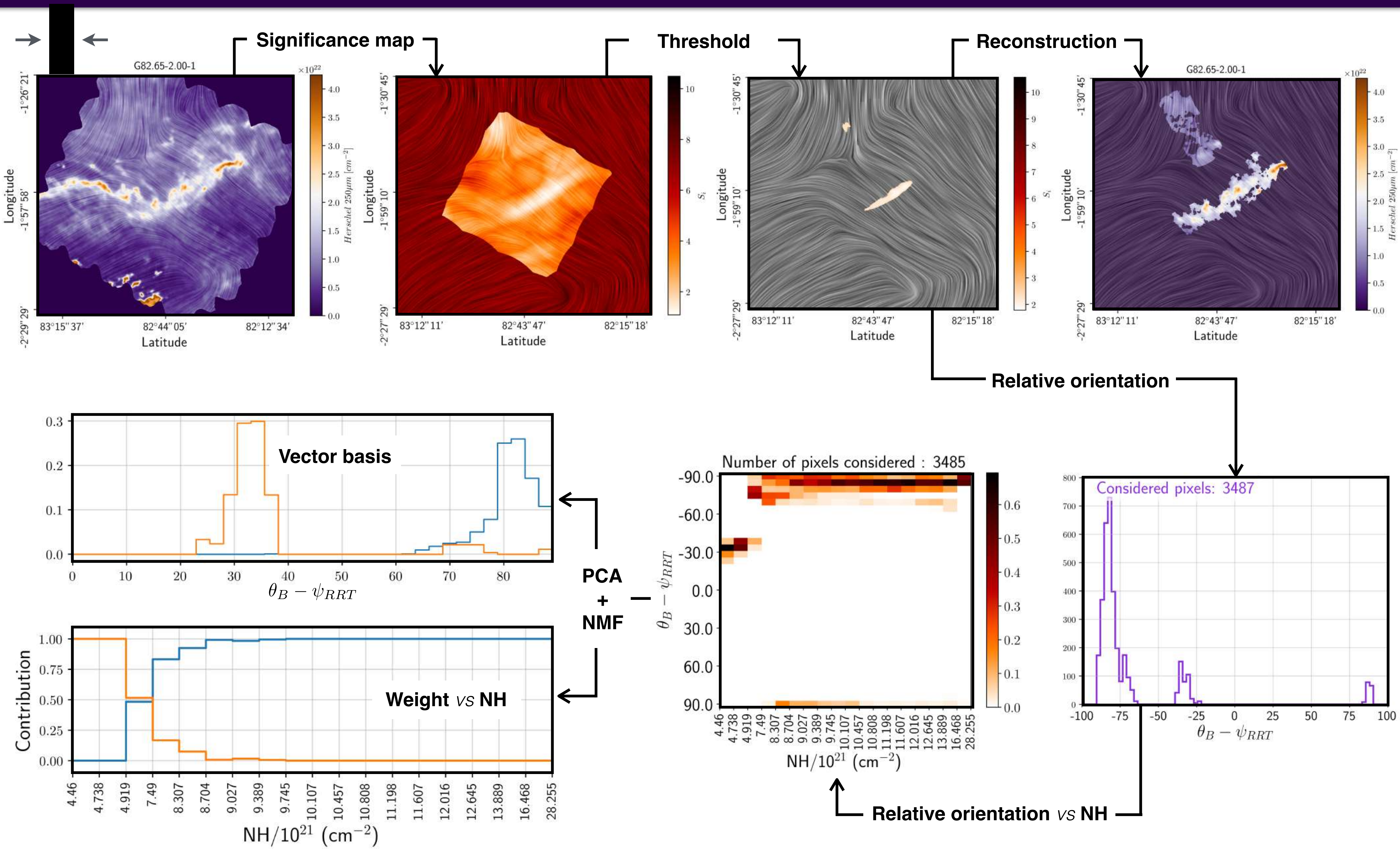
Clear **transition** from aligned to perpendicular structures with B-field at $\boldsymbol{N_{\rm H} = 1.6 \times 10^{21}}$ **cm**$^{-2}$



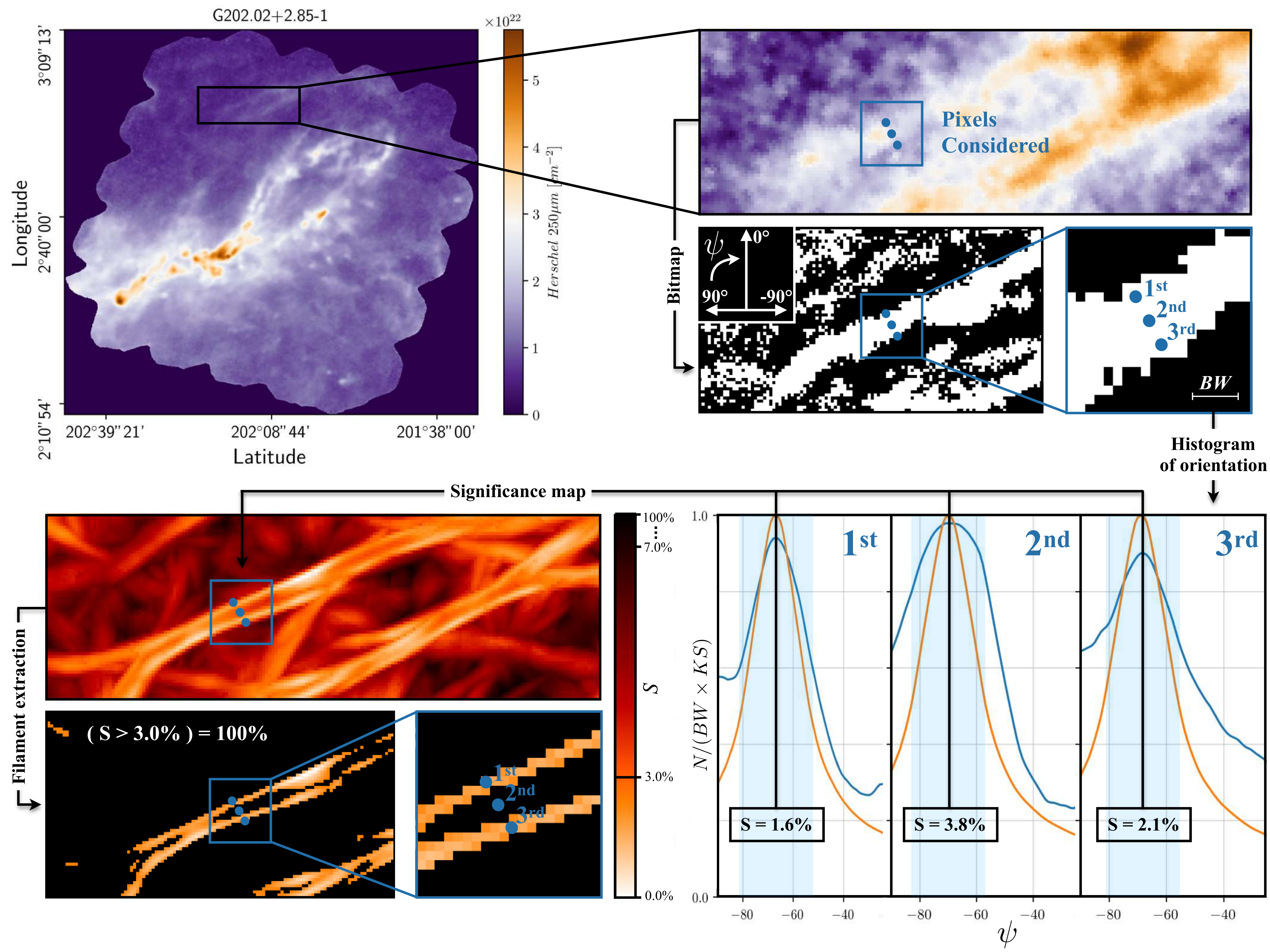


$$W_i = 4 \times arctan\left(\frac{b_w}{k_s}\right)$$

Preliminary results



 J.S. Carrière *SF2A 2019 - Nice - 14 Mai 2019*



G202.02+2.85-1
Longitude
Latitude
Herschel 250μm [cm⁻²]
Pixels Considered
Bitmap
ψ
0°
90°
-90°
1st
2nd
3rd
BW
Histogram of orientation
Significance map
Filament extraction
(S > 3.0%) = 100%
S
100%
7.0%
3.0%
0.0%
N/(BW × KS)
S = 1.6%
S = 3.8%
S = 2.1%