Magnetic Fields and Turbulence in the ISM & Potential OST studies

with thanks to Chat Hull and Erik Rosolowsky who lead the development of the Magnetic Fields and Turbulence Killer App

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OST Face to Face Meeting

June 14th 2017

Outline For This Talk

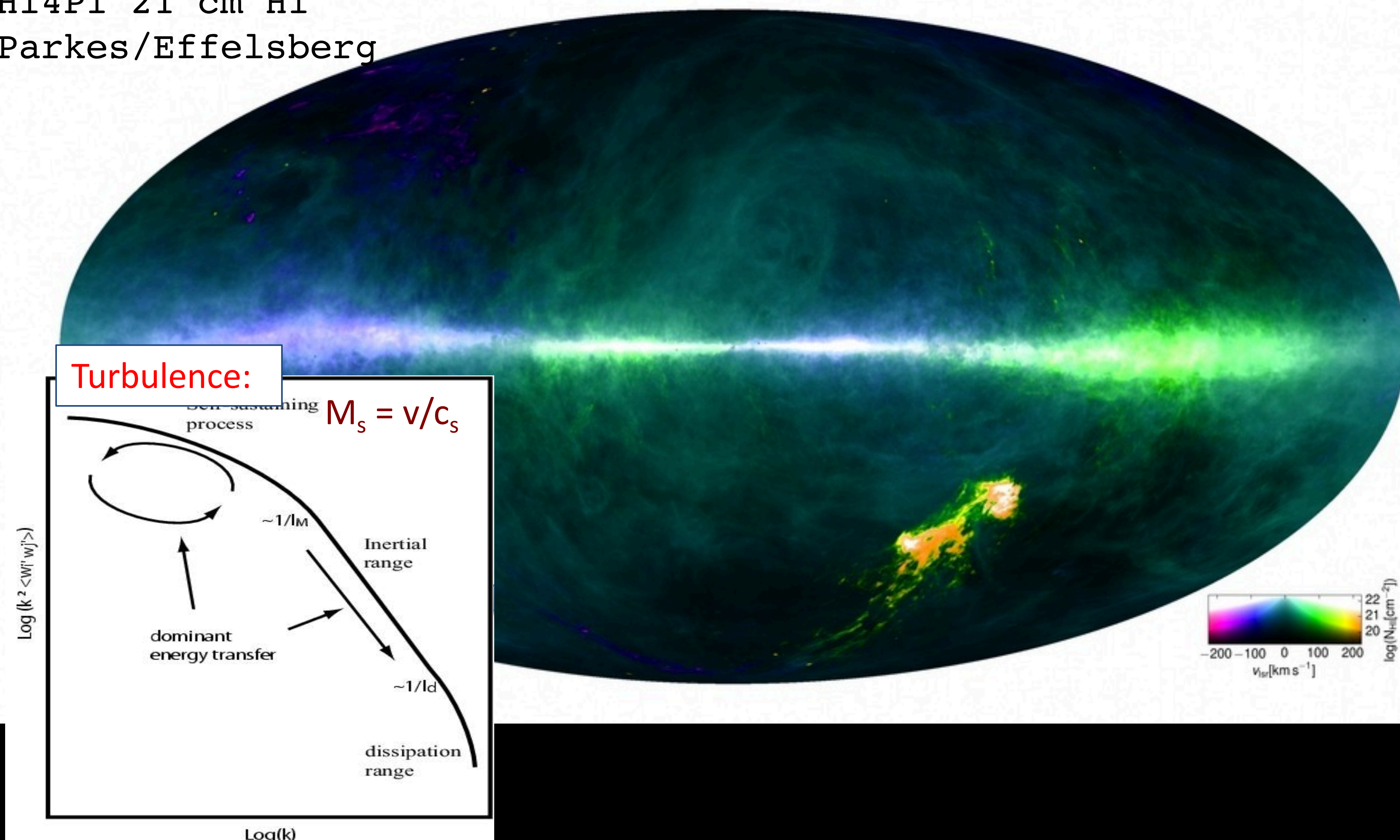
- Why is it important to study magnetic fields and turbulence?
  - What have we learned from polarimetry to date.
  - *Discussion will mostly focus on magnetic field studies.*
- Polarimetry with the OST – Far IR Polarimeter
  - OST vs other Polarimeters
  - How do the descope options affect our science?

The Goal: Understanding Gas Dynamics and Energy Transport on All Scales in the ISM

HI4PI 21 cm HI
Parkes/Effelsberg

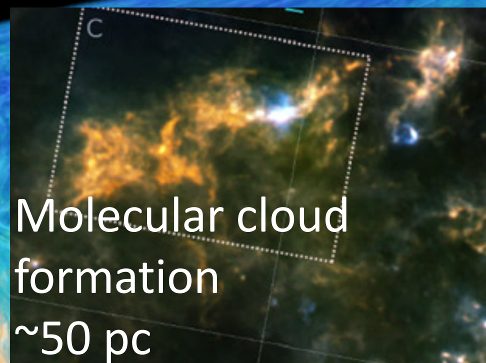
Turbulence:

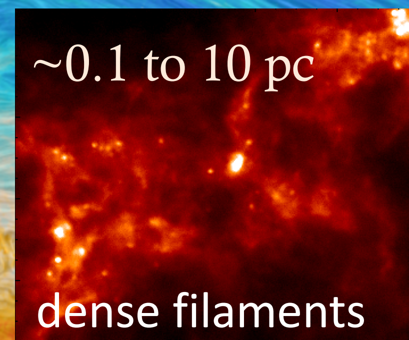
$M_s = v/c_s$

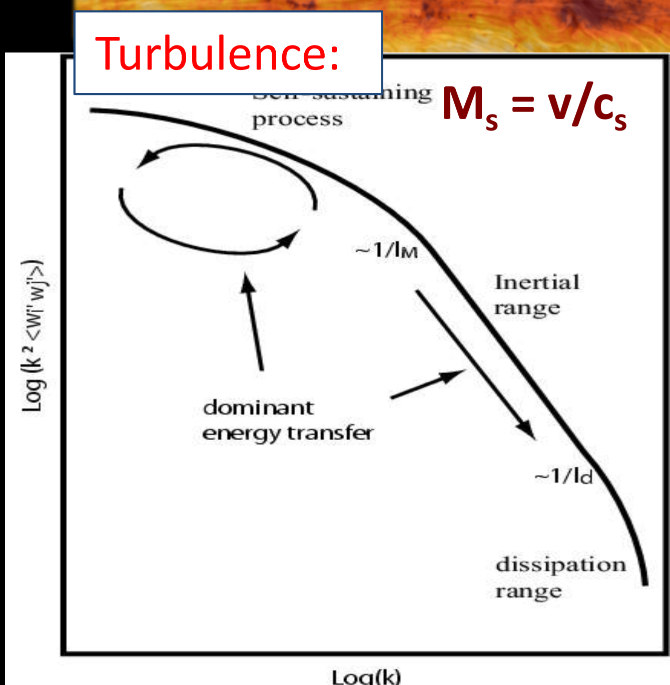


The Goal: Understanding Gas Dynamics and Energy Transport on All Scales in the ISM

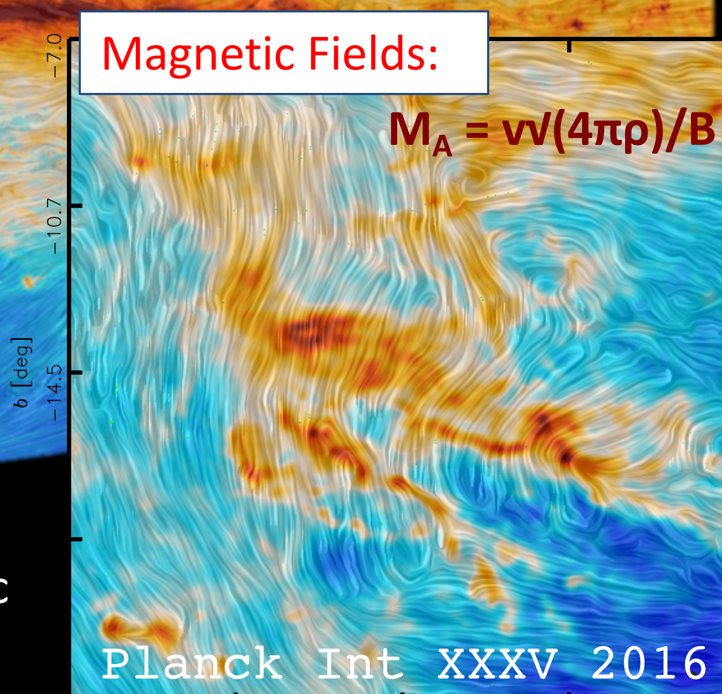
Planck Int XIX 2015



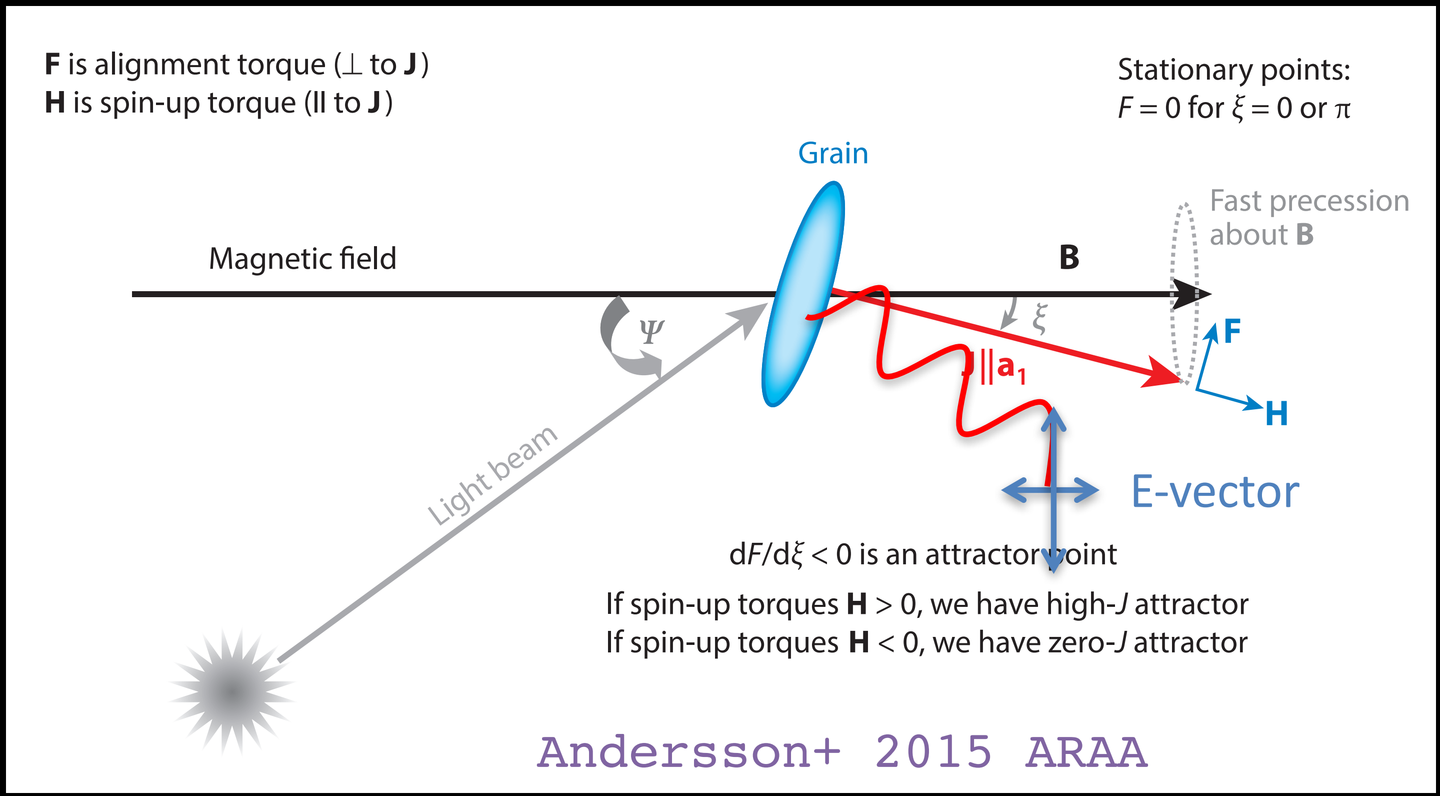




B-Fields make turbulence anisotropic
Turbulence can amply B-Field strength

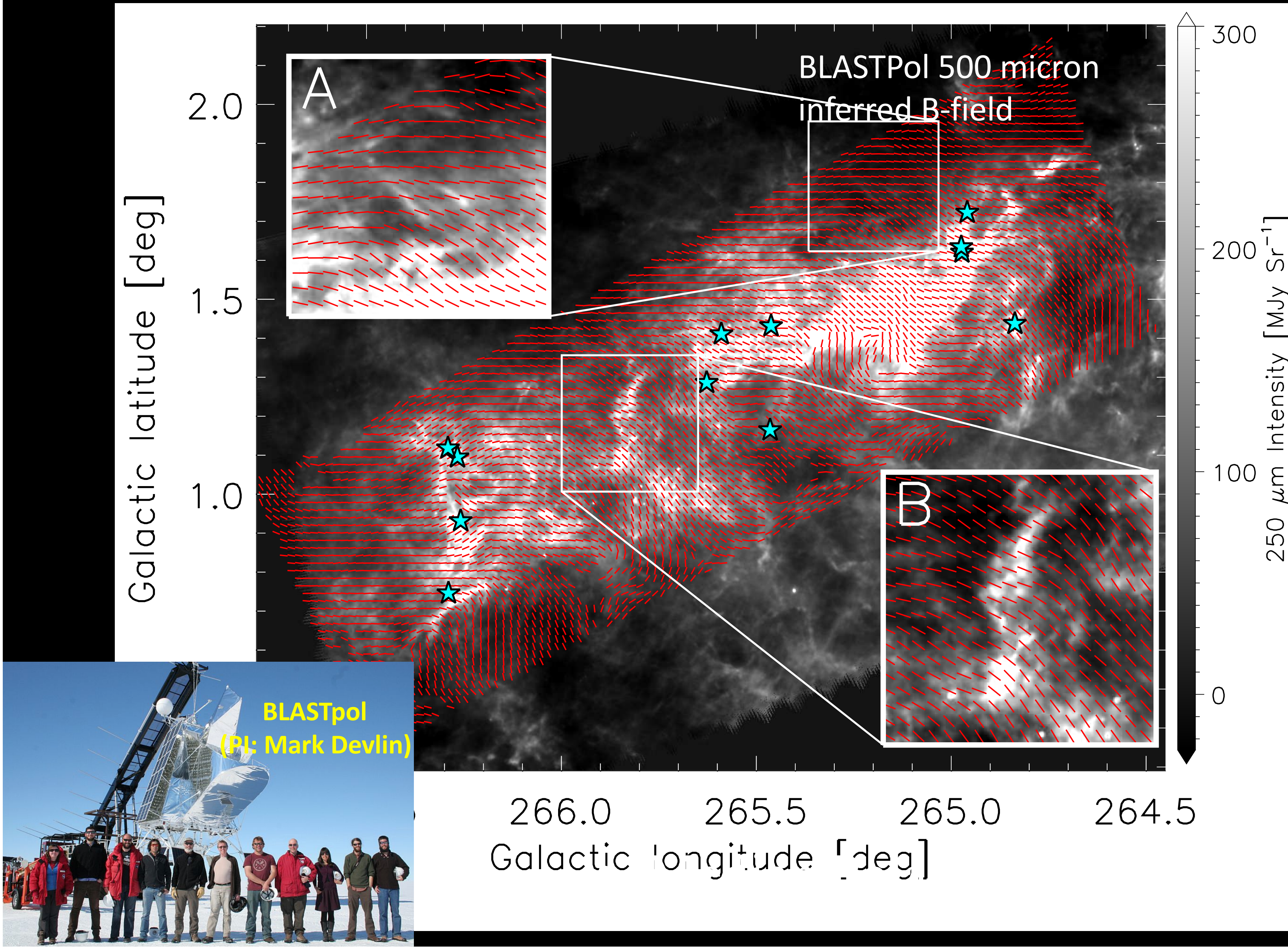


Polarized Dust Emission



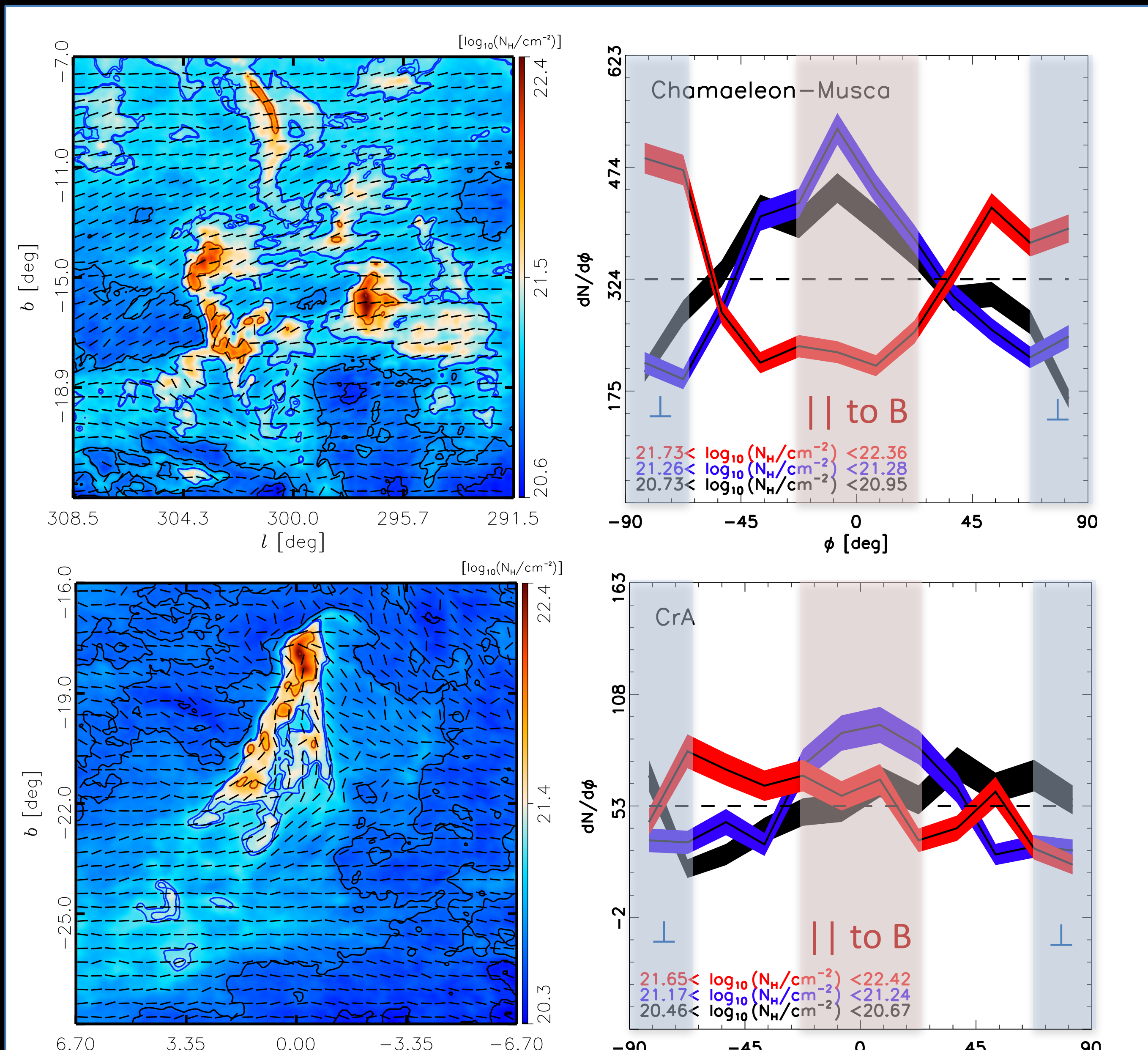
- Alignment of grains perpendicular to the magnetic field
  - most likely through radiative torques
    - Requires an anisotropic source of radiation with $\lambda < a$
- Can trace the orientation of the B_{POS}
  - (weighted by grain alignment and dust emissivity)

Magnetic Fields as traced by Polarization



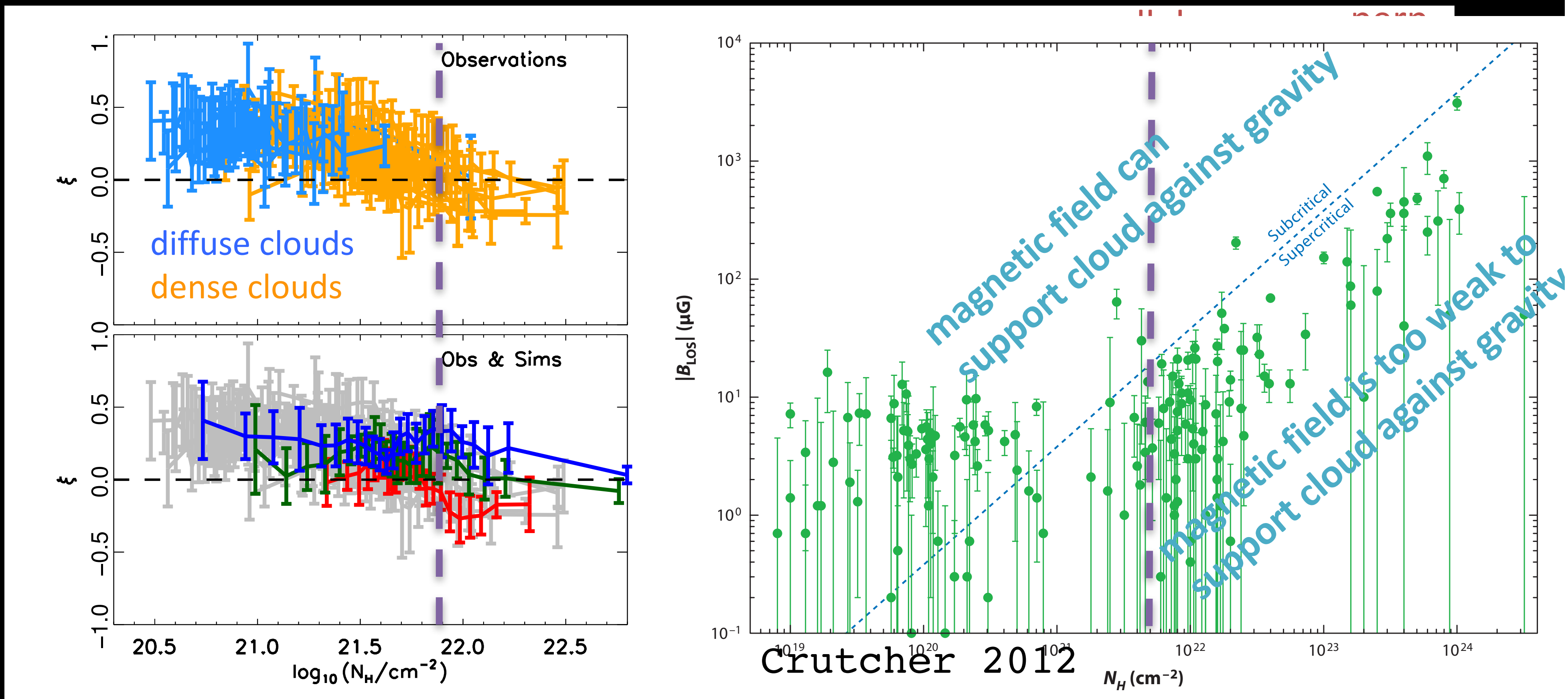
Planck: Histograms of relative orientation

Planck Int. XXXV (2016): 353 GHz, 10 MCs within 400 pc, 10' resolution (0.4-1.2 pc)



Shape Parameter vs Column Density with Planck

Planck Int. XXXV (2016): 353 GHz, 10 MCs within 400 pc, 10’ resolution (0.4-1.2 pc)



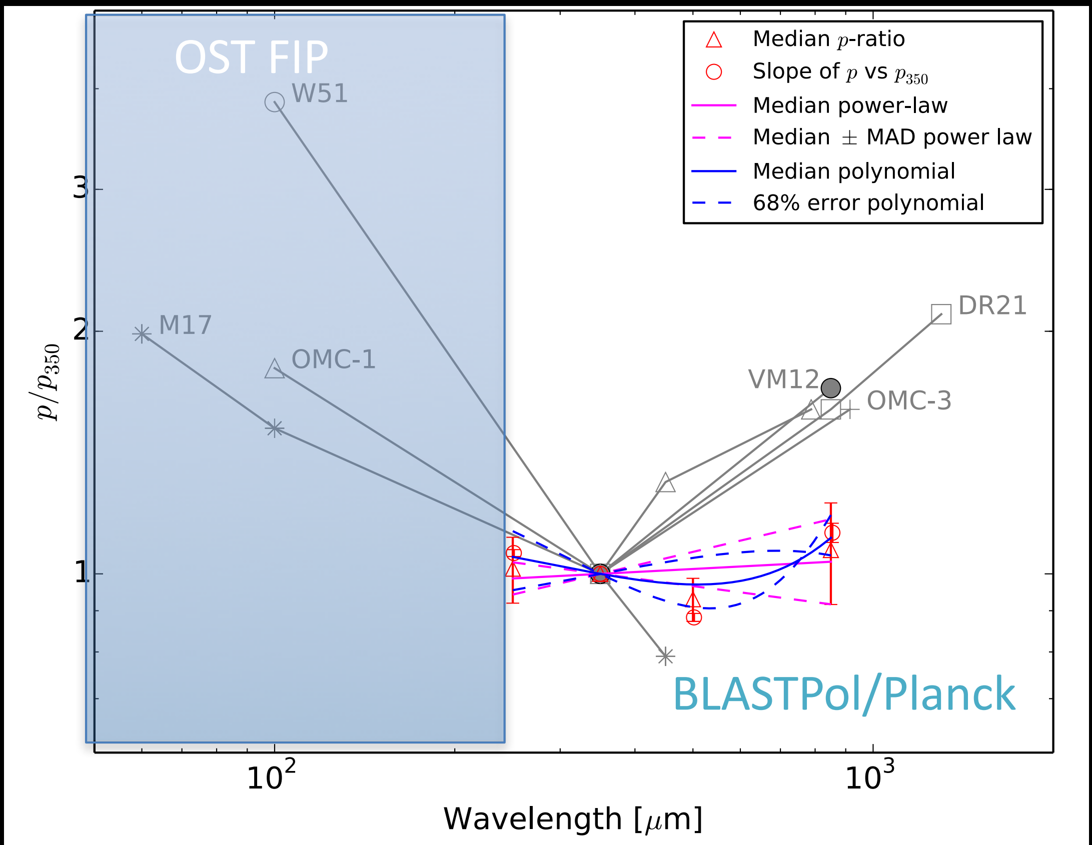
Grey (data), Colours RAMSES MHD Simulations (Soler et al. 2013):

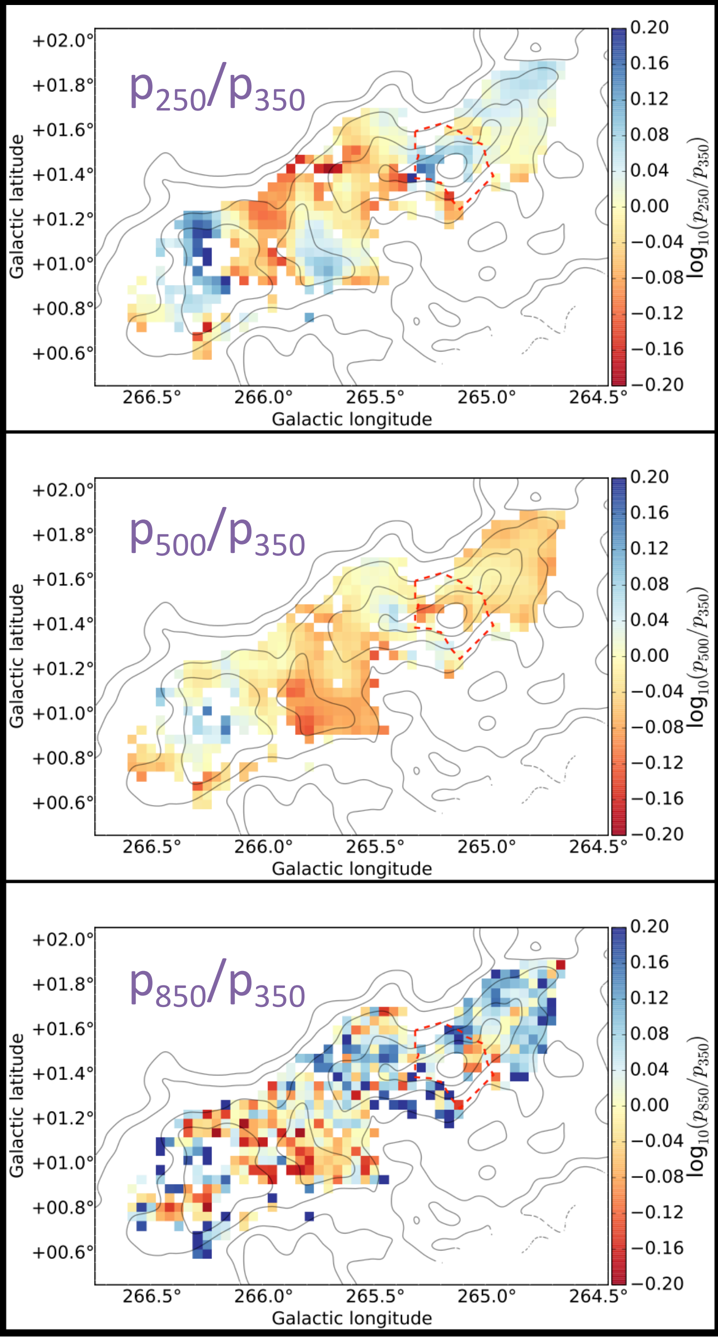
weak field (**B**= 0.35 μG)

intermediate field (trans-Alfvenic, **B**= 3.5 μG)

strong field (sub-Alfvenic, **B**= 11 μG)

Studying the Properties of Polarized Dust

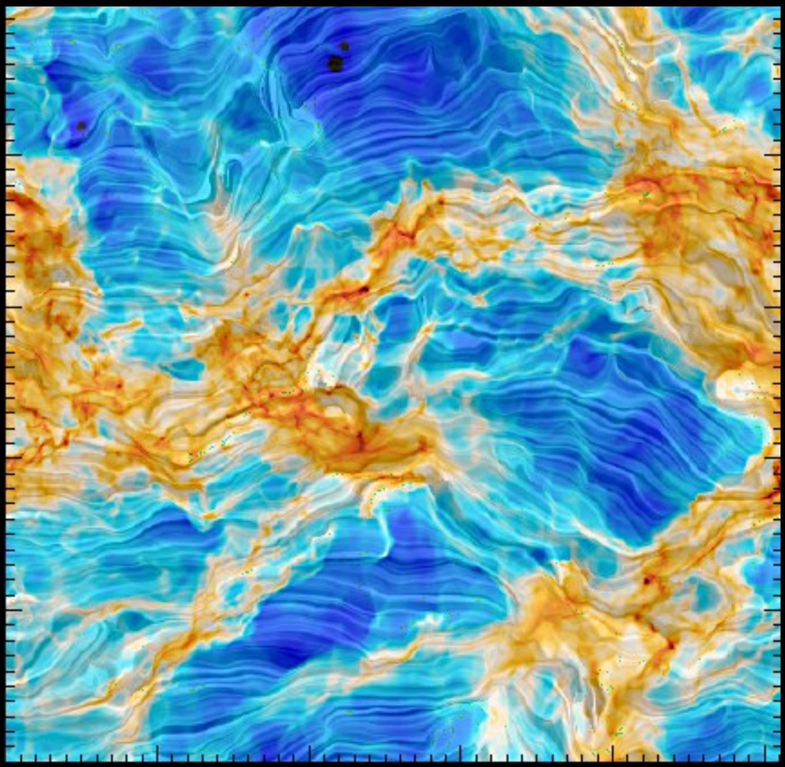




Gandilo et al. 2015

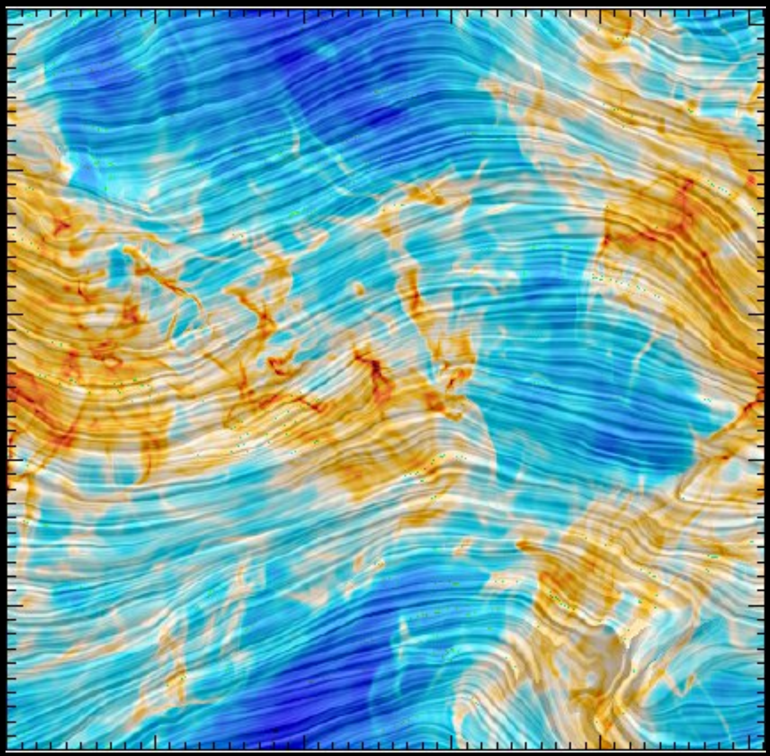
Magnetic fields in Molecular Cloud Simulations

Weak magnetic field
(**$|B_0|$=0.35μG**)



disordered B-field

Strong magnetic field
(**$|B_0|$=10.97μm**)



ordered B-field

Can be used to estimate $|B_{POS}|$ (Davis 1951, Chandrasekhar & Fermi 1953, Ostriker, Stone & Gammie 2001)

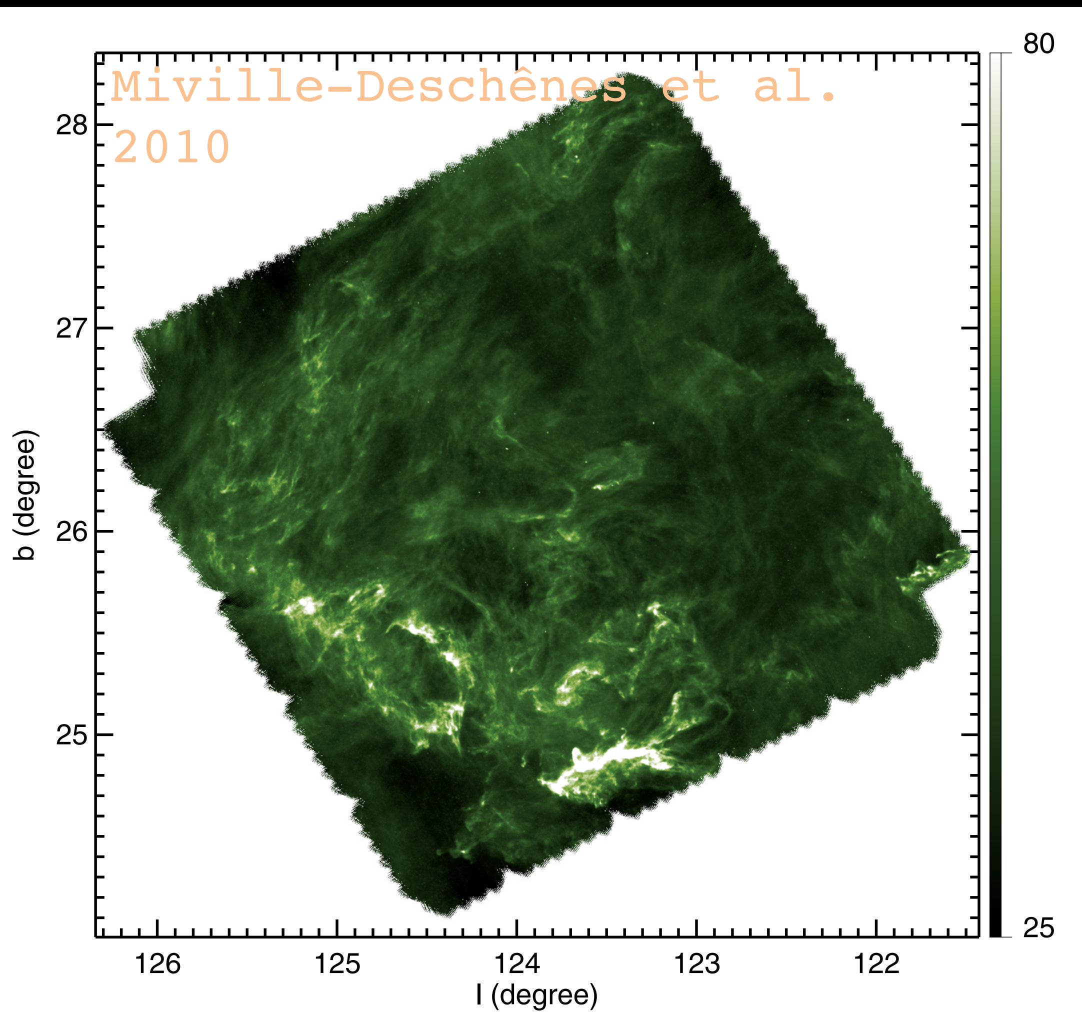
Characterize the MHD turbuence power spectrum (e.g. Houde et al. 2011)

RAMSES MHD Simulations from Soler et al. 2013

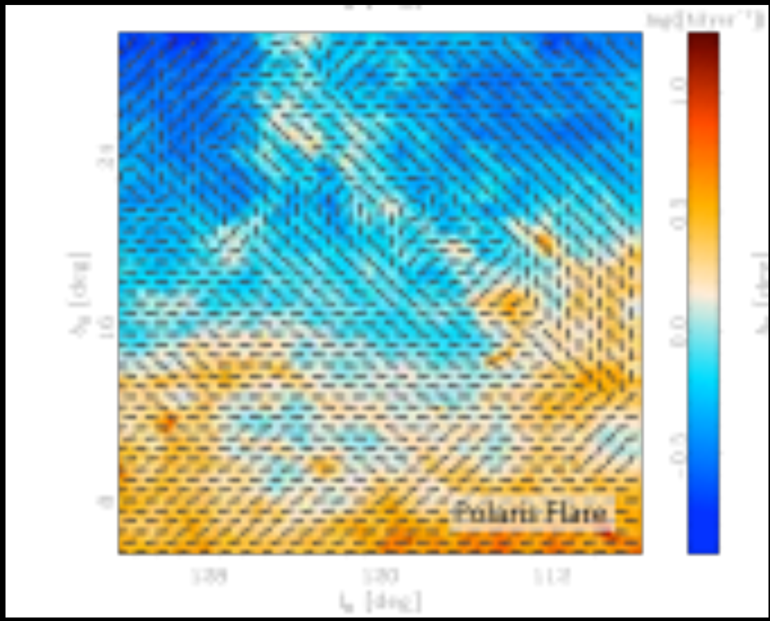
OST Polarimetry Case Study: Polaris Flare

High Latitude Cirrus Cloud, distance ~150 pc

SPIRE 250 (16'' FWHM)



Planck Int XIX 2015



Planck resolution: 10' (0.4pc) >8000, FIP beams could fit into 1 Planck beam !

In this cloud at 240 microns, FIP would probe scales from 1,000 AU to 20 pc (a factor of 4000 in spatial scale) with up to 4,000,000 independent measurements of B-direction.

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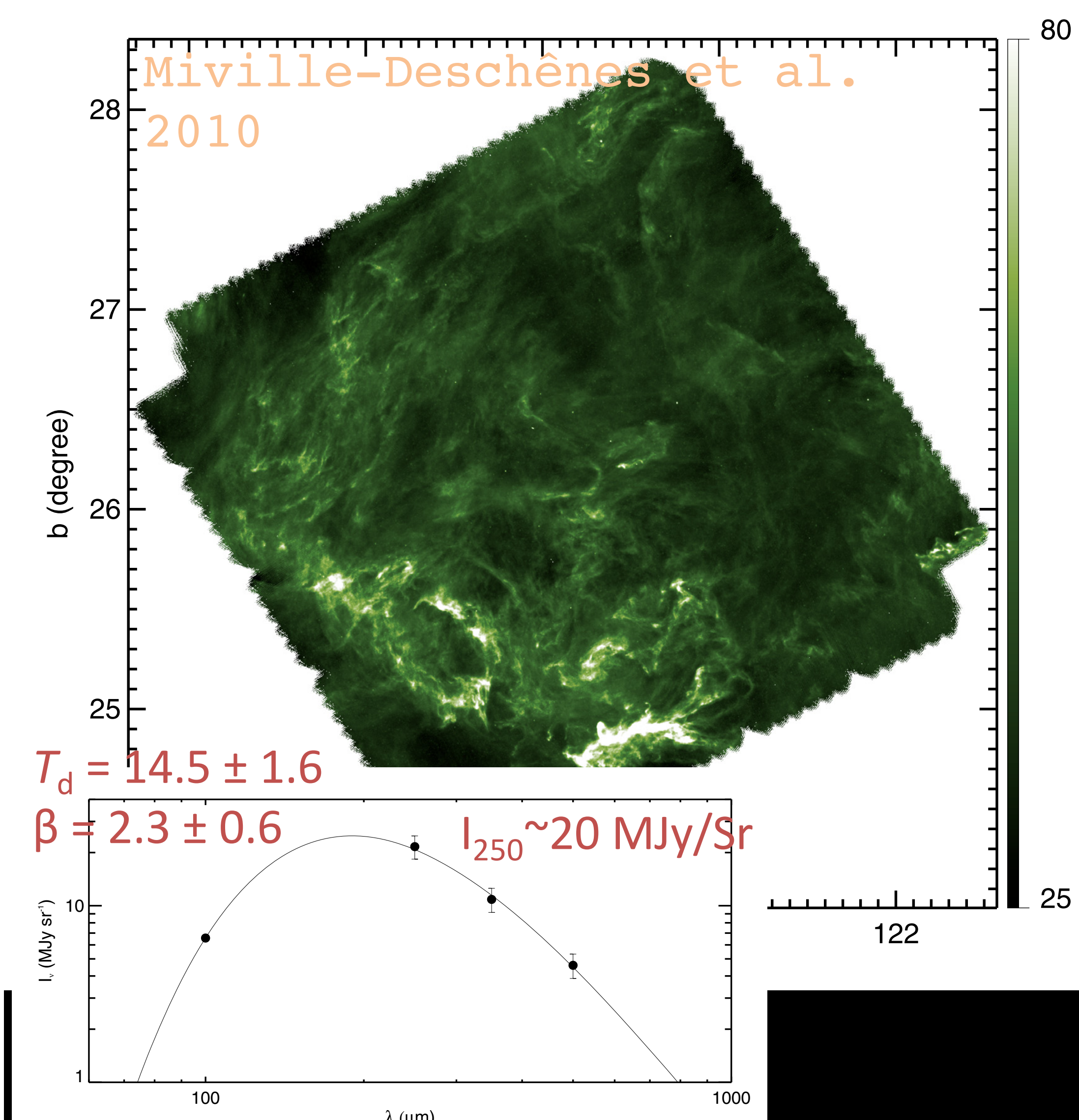
High Latitude Cirrus Cloud, distance ~150 pc

SPIRE 250 (16’’ FWHM)



OST-FIP NEFD_{250} = 0.1 MJy/Sr

(low background detectors)

Beam FWHM = 6.6”

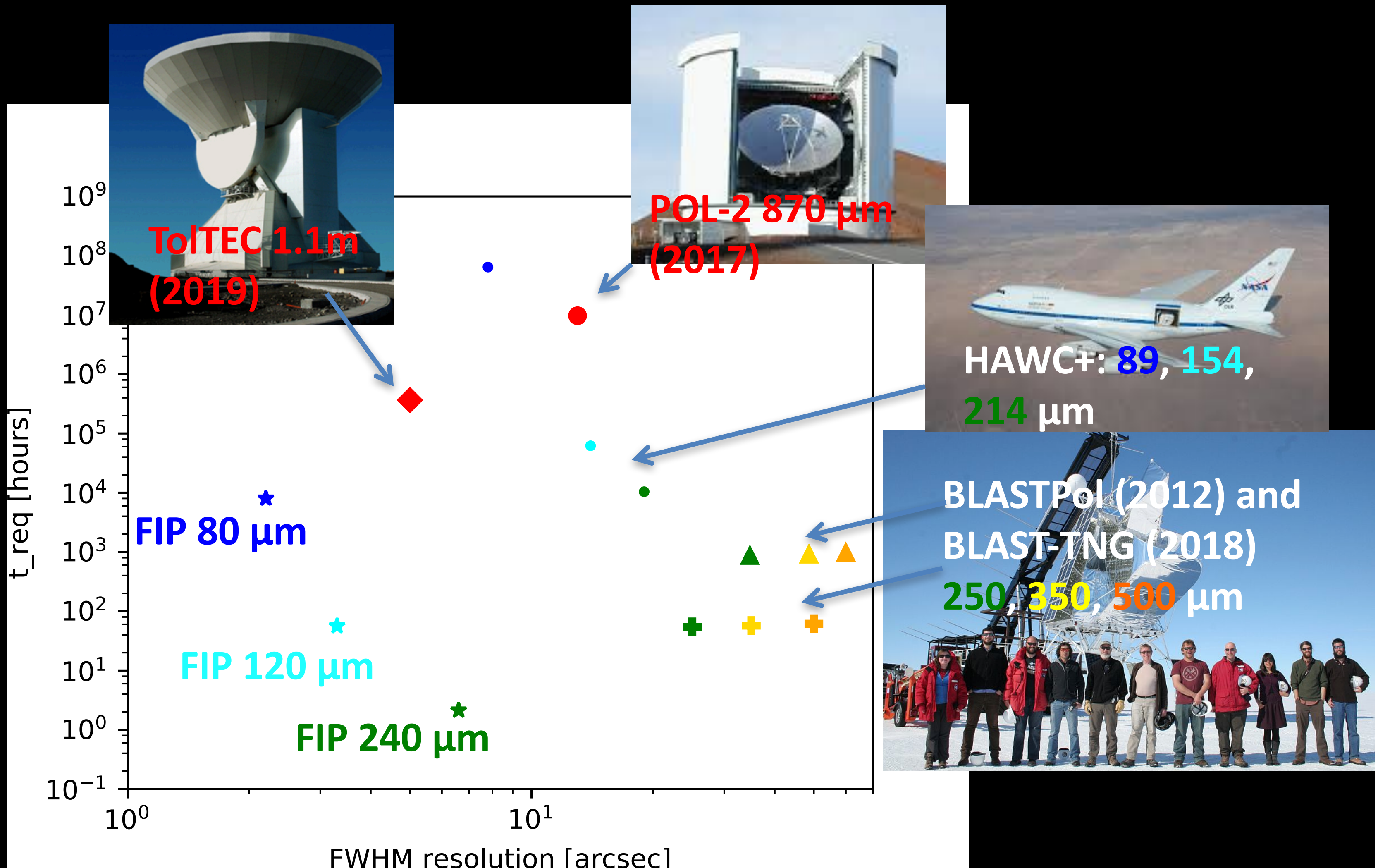
$t_{req} = (2\mathrm{xNEFD}_{250}/\sigma_P)^2\, N_{beams}$

For a 5-σ detection of 5% polarized dust

t_{req} = 33 hours

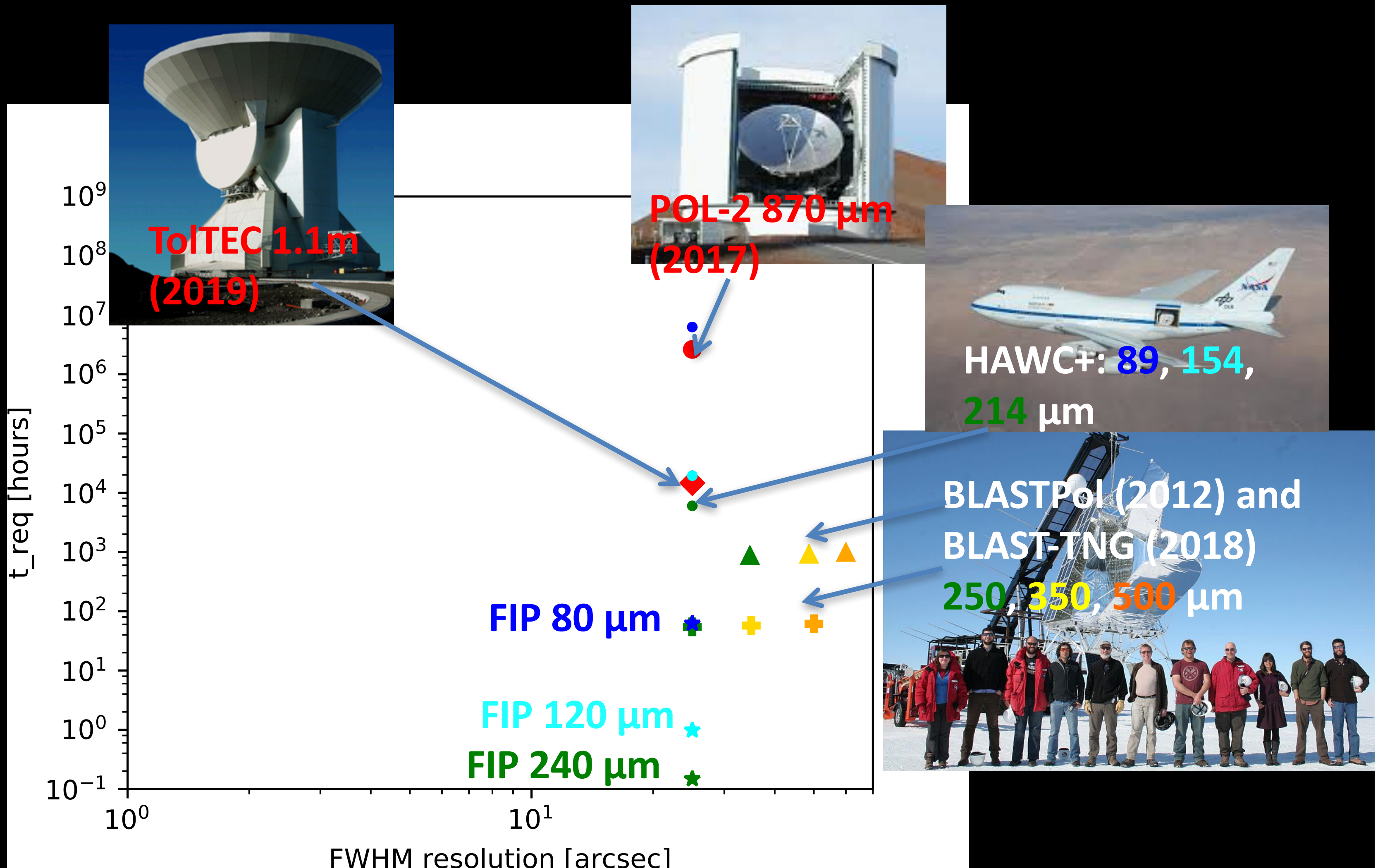
Same survey with BLAST-TNG 250 micron band at 25” resolution: 900 hours!

Time Required to map a 1 deg^2 region
20 MJy/Sr Dust @240μm with σ_p=1%



Assume β = 2, T = 16 K

Time Required to map a 1 deg^2 region 20 MJy/Sr Dust @240μm with σ_p=1%

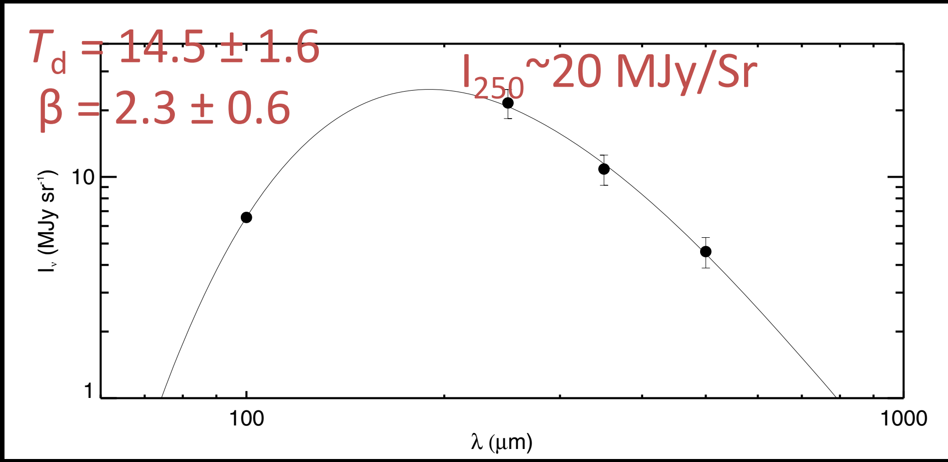


Assume β = 2, T = 16 K

FIP at 240 microns has ~400x the mapping speed of BLAST-TNG!

If the FIP had a longer wavelength band we could better study the magnetic fields in cold early stage star forming regions.

Polaris Flare SED
Miville-Deschênes 2010



Dust temperatures are not actually uniform even in clouds without star formation: dust is warmer near the cloud surface.

At 240 microns 20K dust is 6x brighter than 10K dust.

Magnetic field direction measured is weighted toward the lower density cloud regions.

At 500 microns 20K dust is only 1.6x brighter.

Descope Options:

- We would **really** not like to lose:
  - Dynamic range in instrument sensitivity.
  - Ability to recover polarization structure on large scales (up to 10 degrees).
  - The 240 micron band!

Other Descope Options

- Sensitivity:
  - 2x decrease in sensitivity would mean we could map ¼ as many clouds to the same depth OR not target as many diffuse ISM clouds.
- Resolution:
  - This limits the cloud distance (and number of clouds) for which we can get high resolution.
    - Example: For the 120 μm we can resolve the core scale (~0.03pc) out to 2kpc.
  - A moderate degradation in resolution (e.g. ~25%) wouldn't degrade our science case very much.
- Instantaneous Field of View:
  - Shouldn't affect us as long as we can recover emission on scales larger than the FOV.

Conclusions

- Polarimetry allows us to trace magnetic and turbulent energy over all ISM scales, from galactic feedback to star forming cores.
- OST will be revolutionary in terms of:
  - Ability to trace MHD turbulence over range in spatial scale and column density scales.
  - Mapping speed, which will allow OST to map hundreds of clouds.