Dust Polarization

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Layout

- Dust polarization (Extinction)
- Dust polarization (Emission)
- Dust polarization observational evidences
- Planck results on dust polarization (what can be shown)
- Instrumental considerations

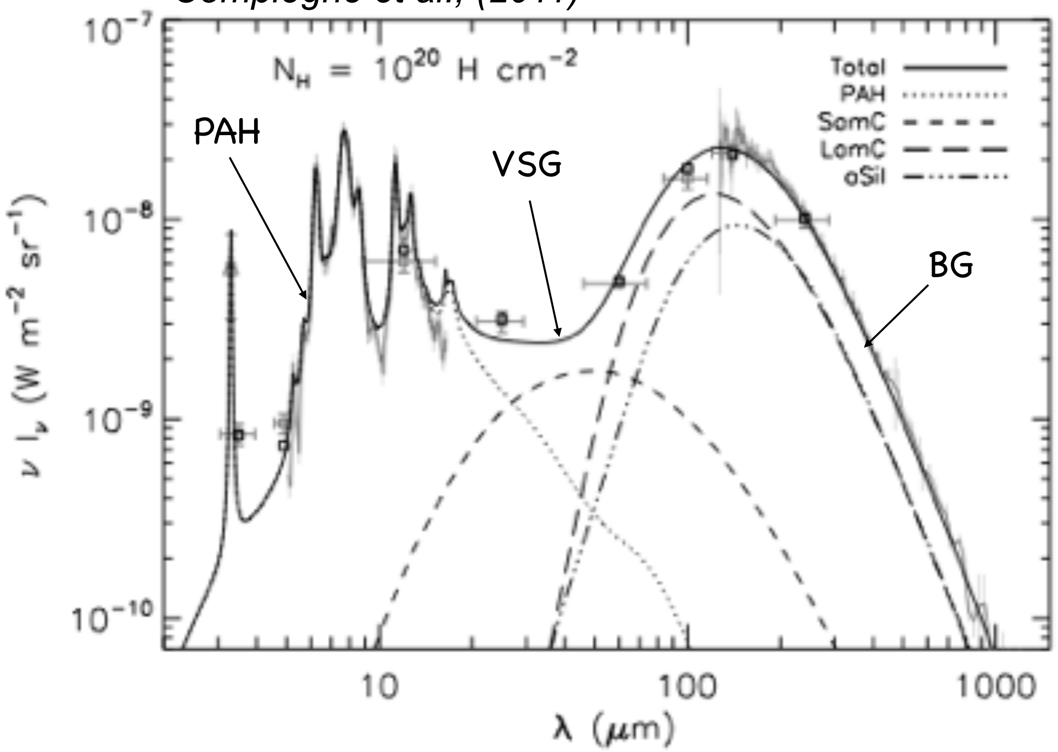
The Planck Consortium

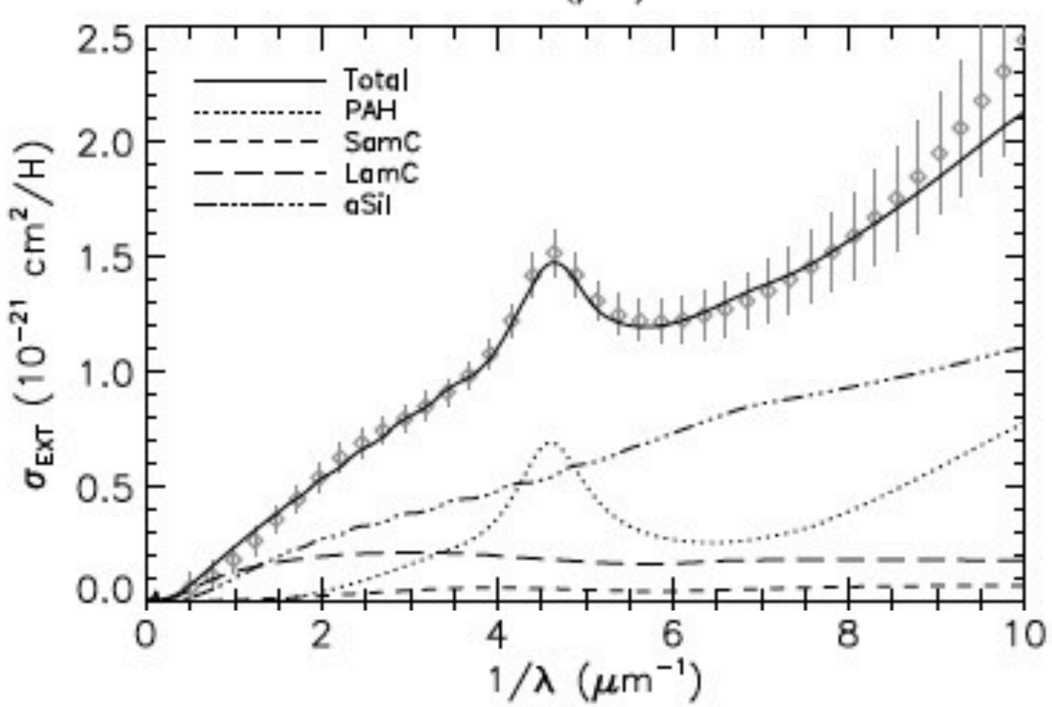
The Planck Collaboration, includes individuals from more than 50 scientific institutes in Europe, the USA and Canada

Planck is a project of the European Space Agency -- ESA -- with instruments provided by two scientific Consortia funded by ESA member states (in particular the lead countries: France and Italy) with contributions from NASA (USA), and telescope reflectors provided in a collaboration between ESA and a scientific Consortium led and funded by Denmark.

There is no single model to explain dust emission

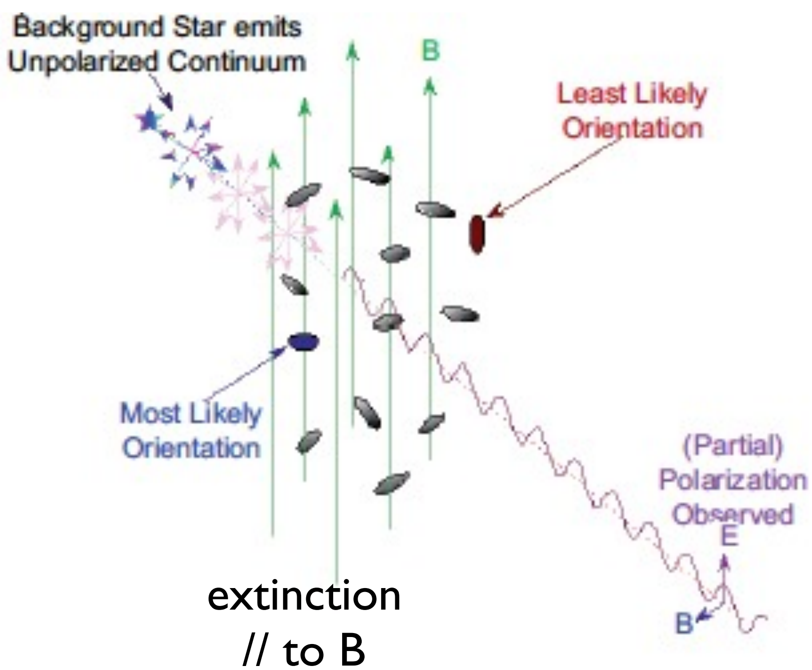
Compiegne et al., (2011)

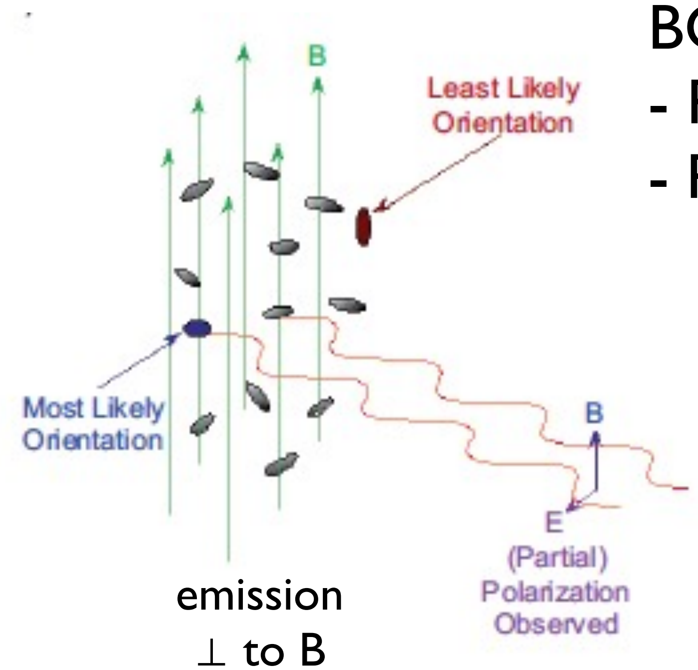




There is a consensus that NIR emission is produced by large molecules or very small dust particles (PAH)
MIR is due to intermediate size grains, which nature is uncertain

Even for Big Grains, the composition is uncertain
BG necessarily include Silicates
Silicates in BG is amorphous (from extinction)
BG also probably include Carbonaceous material (Amorphous Carbon, Graphite, ...)
It is currently unclear if these 2 components are separate or part of the same dust grains





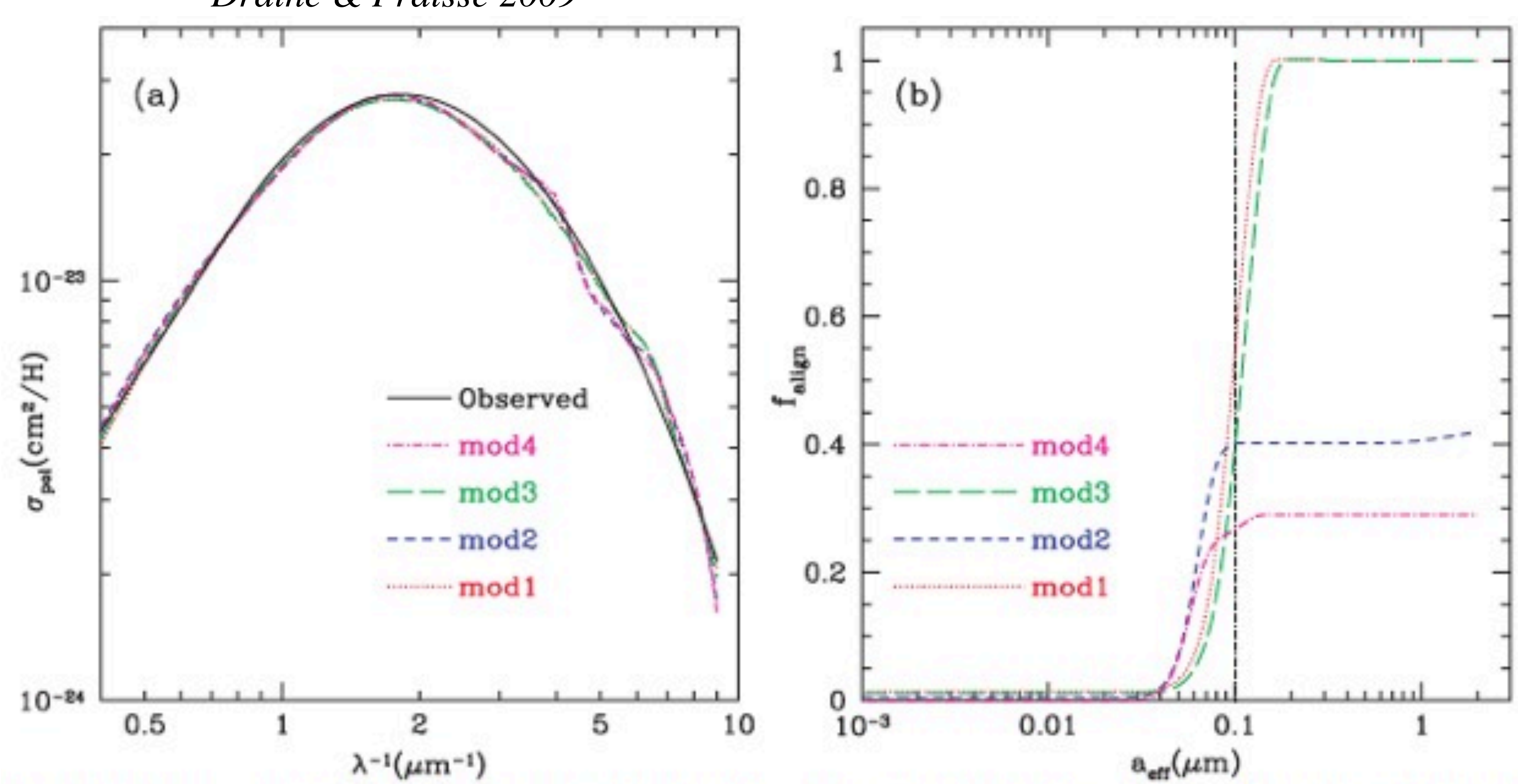
BG:
- Rotating, elongated and align partially on B
- Produce polarized emission & extinction

Possible alignment mechanisms:
- Paramagnetic relaxation alignment
- Radiative Alignment Torques

Grain disalignment by:
- Gas/grain collisions
- Plasma drag

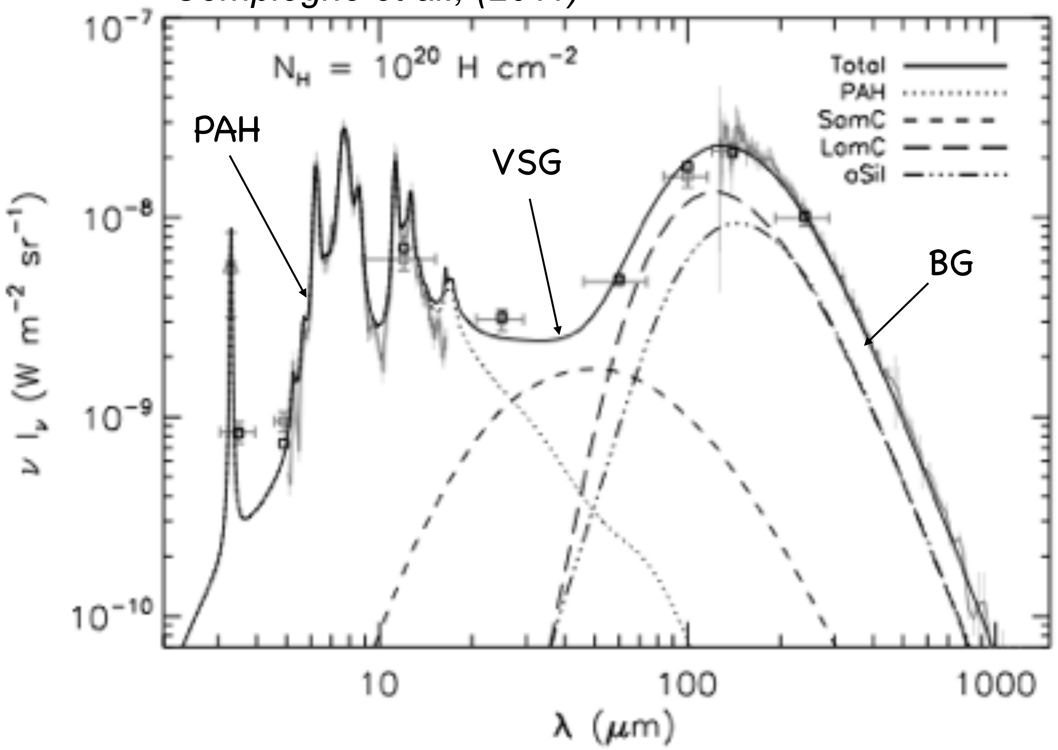
From extinction polarization:
- 2200 Å bump and FUV rise, DIBs not polarized ==> PAH & VSG: are unlikely to be aligned (too small)
- 3.4 mic feature not polarized ==> Carbonaceous BG may not align or may be spherical
- 10-20 mic feature is polarized ==> Silicate grains aligned and elongated

Draine & Fraisse 2009

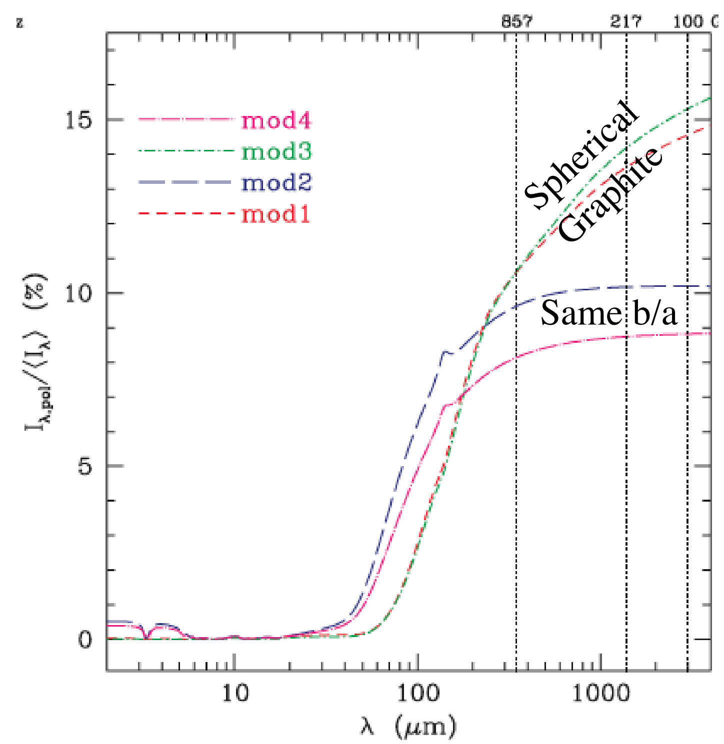


Dust Polarization

Compiegne et al., (2011)

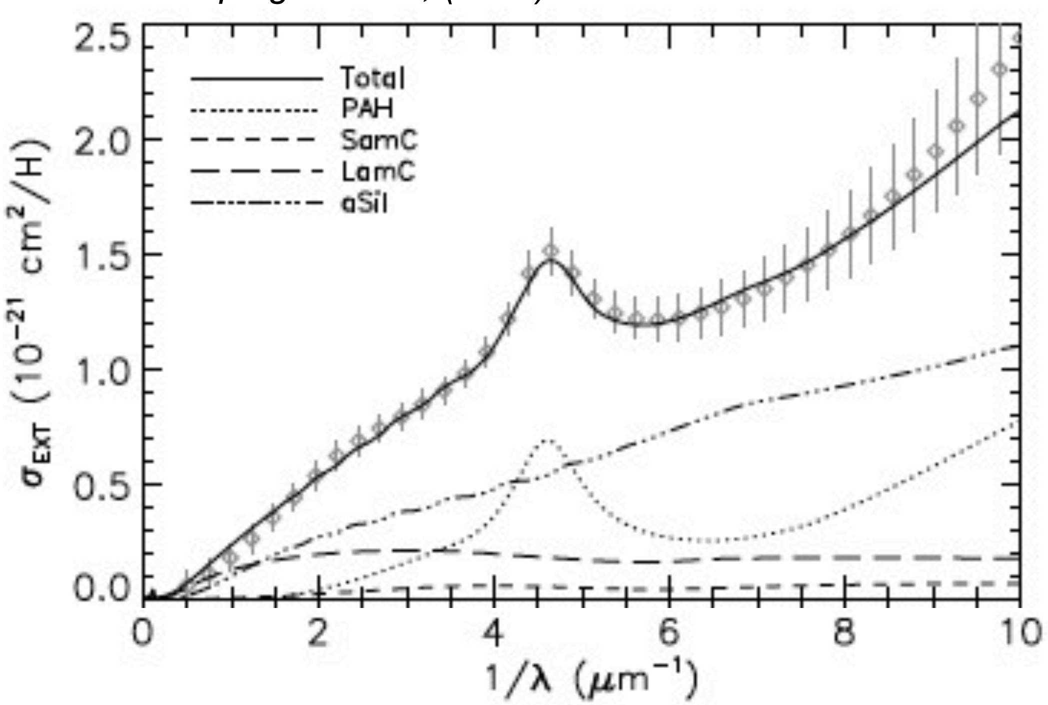


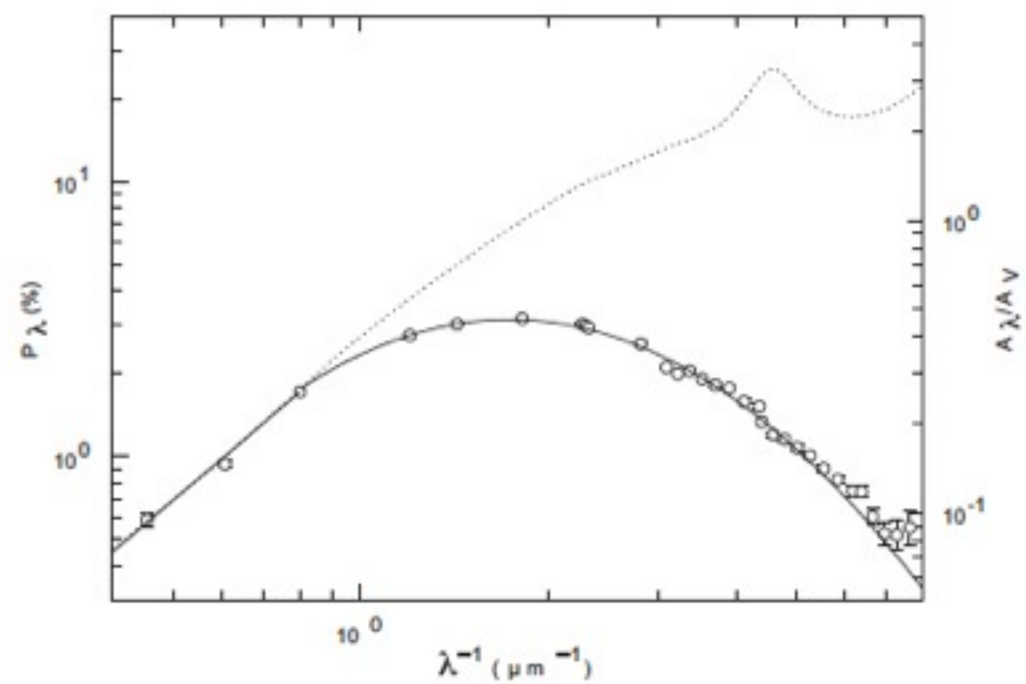
Draine & Fraisse 2009



polarization in emission is predicted ~10-15%

Compiegne et al., (2011)





Various possible models lead to different predictions in polarization

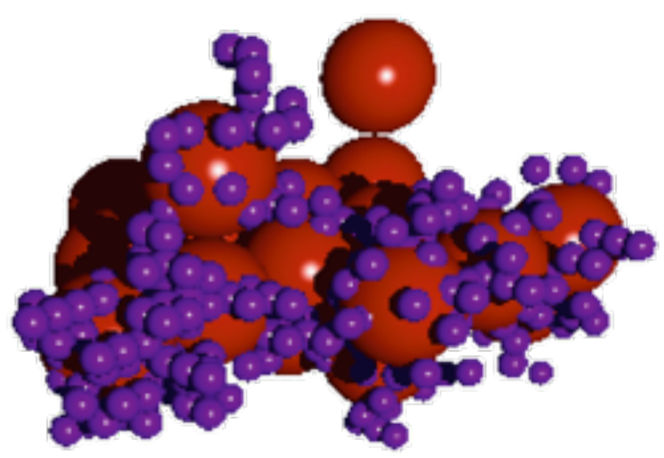
Variations of polarization fraction with frequency will help constrain dust models

Submm Emissivity Variations

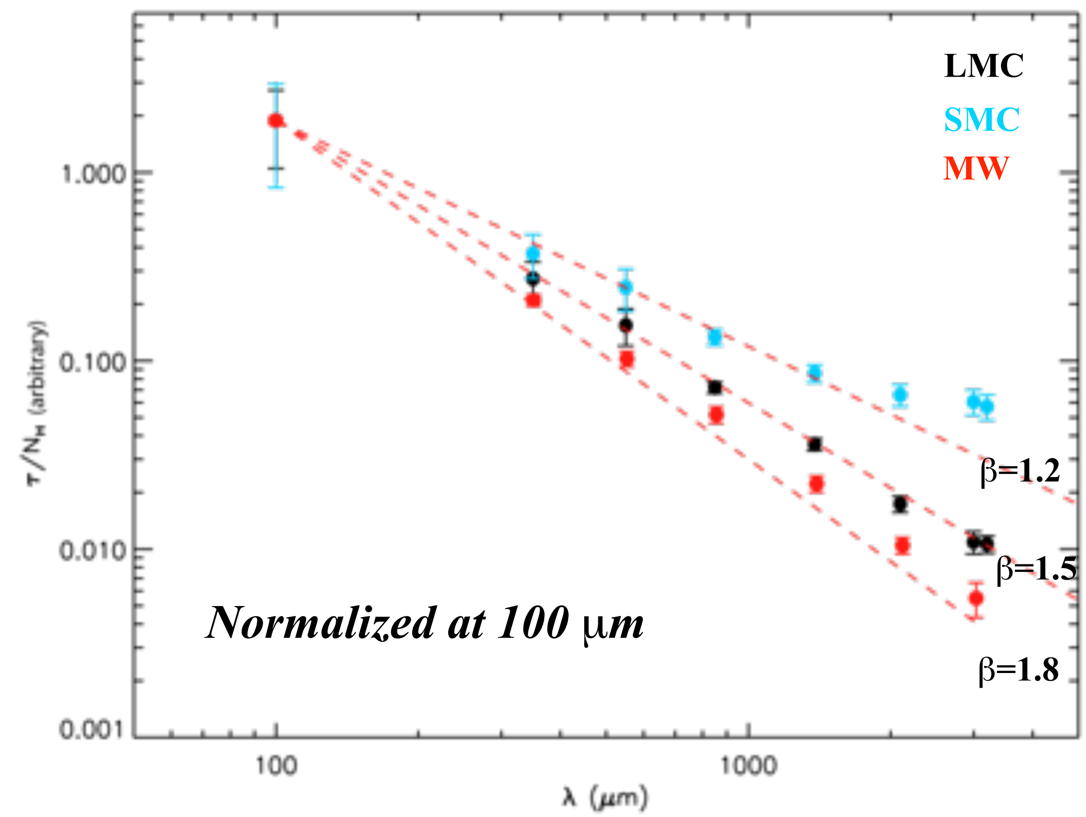
Large variations of the sub-mm emissivity are observed between the MW, the LMC and the SMC Such variations also seem to happen within the MW

The dust emissivity law seem to flatten above ~500 microns (MW, some low metalicity galaxies)
The origin is unclear and could in principle be due to:
- Existence of extremely cold dust
- Modified optical dust properties

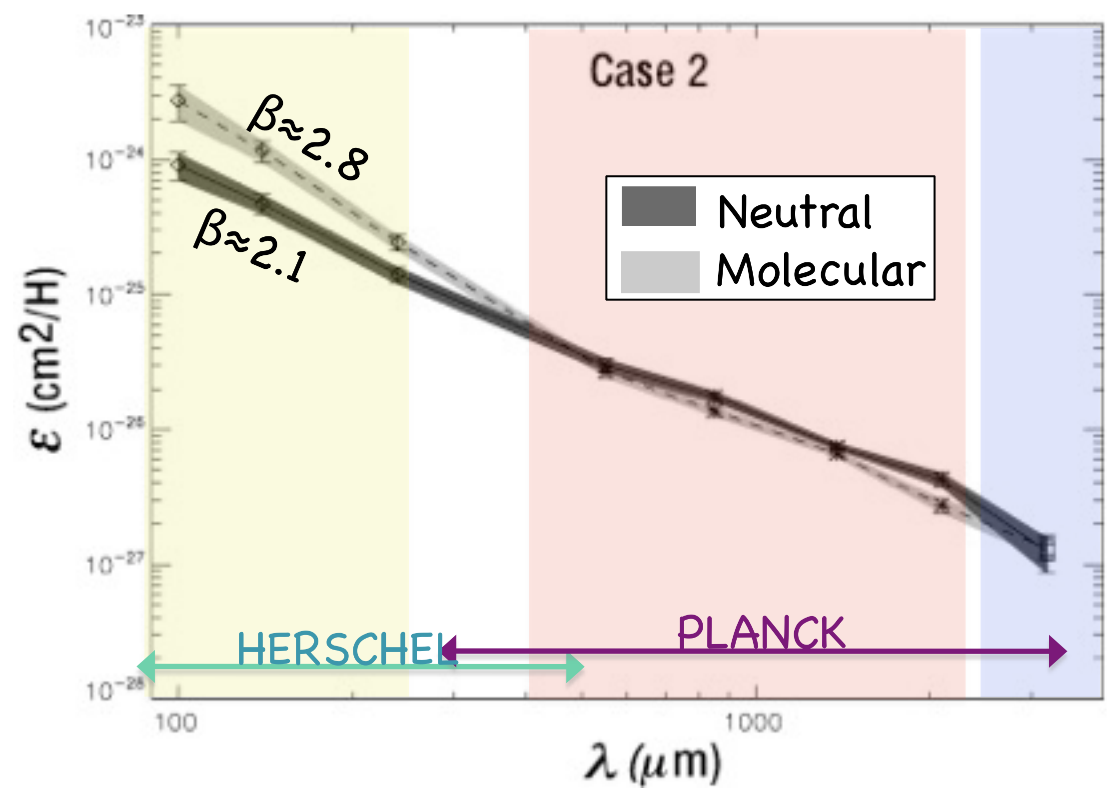
In dense regions, dust aggregates, which also changes its emissivity properties



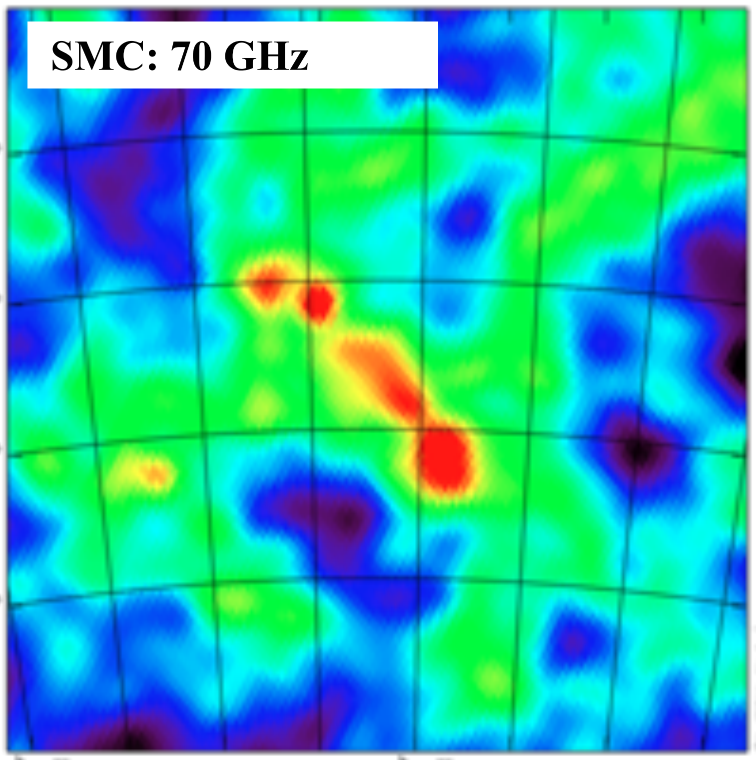
Planck Collaboration 2011, A&A 536, A17

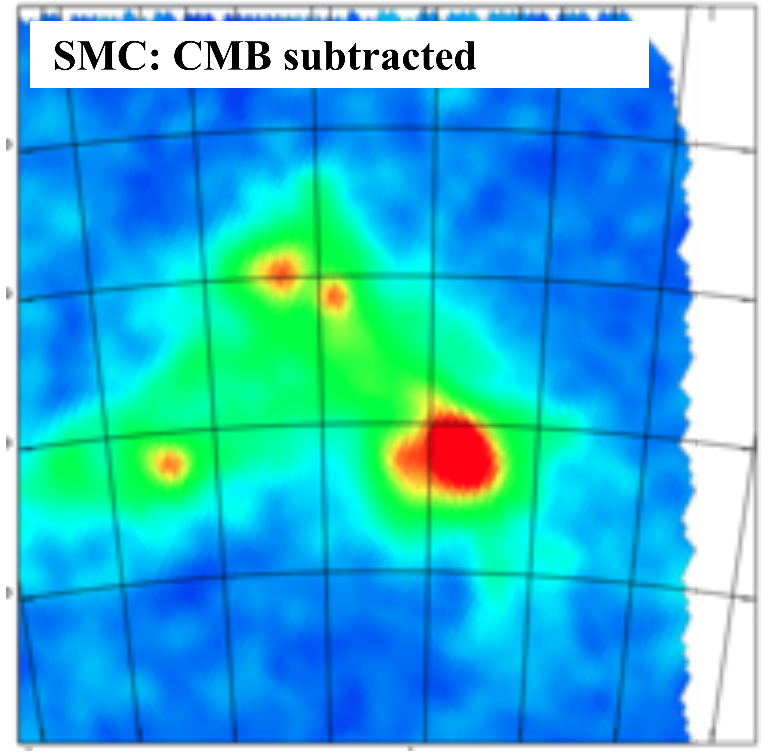


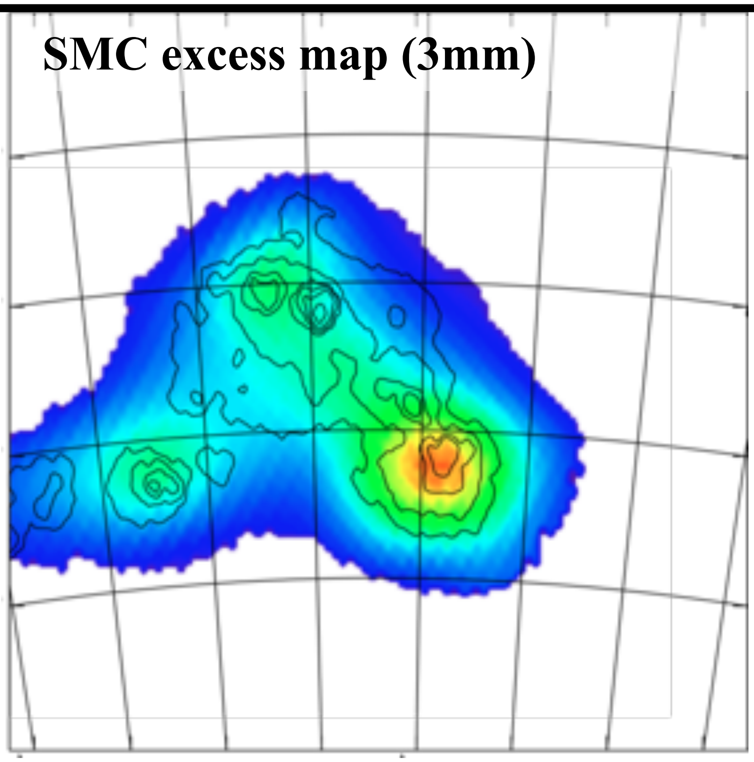
Paradis et al. 2009



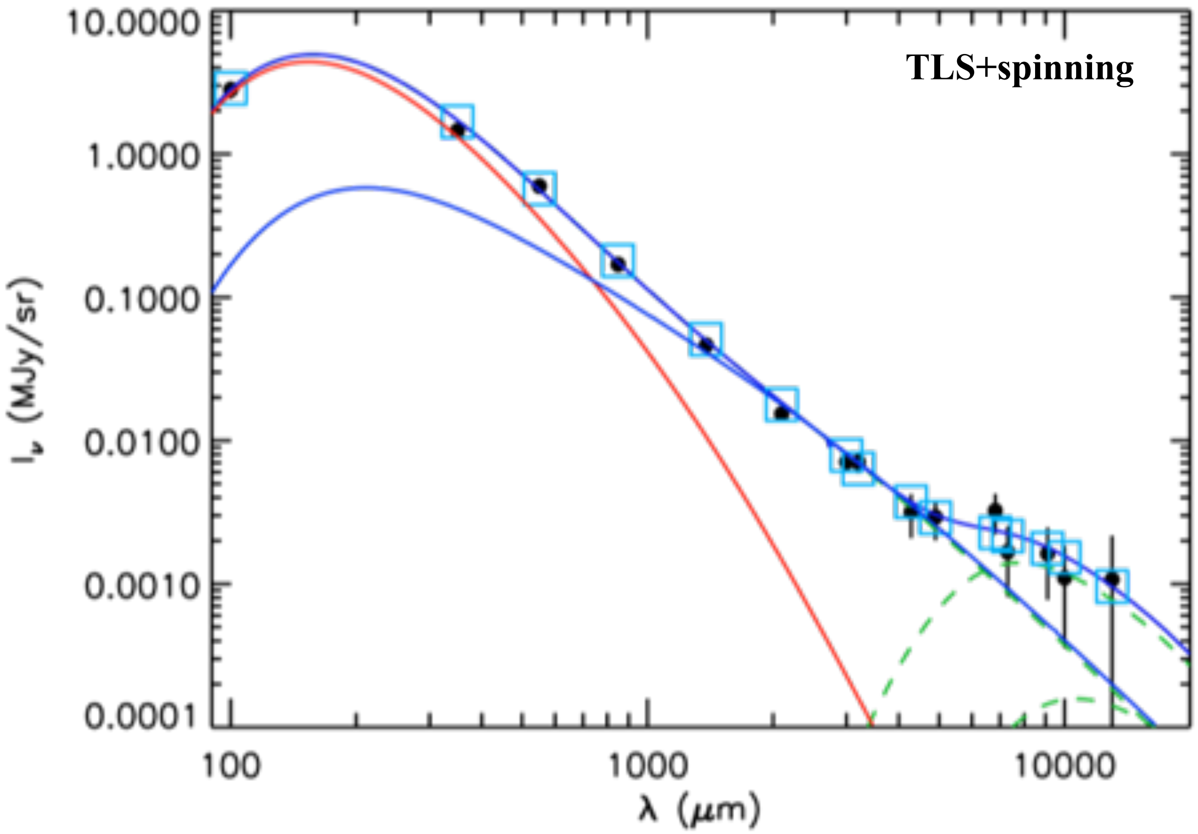
Exemple of SMC







- Free-Free contribution subtracted, extrapolated from Hα emission, assuming no extinction
- Submm excess follows the spatial distribution of thermal dust at high frequencies
- Best fit obtained for a combination of the Two-Level System (TLS) model and spinning dust
- Amorphous grains with similar parameters as MW, but more amorphous than in MW
- Spinning dust parameters compatible with PAH emission in the SMC

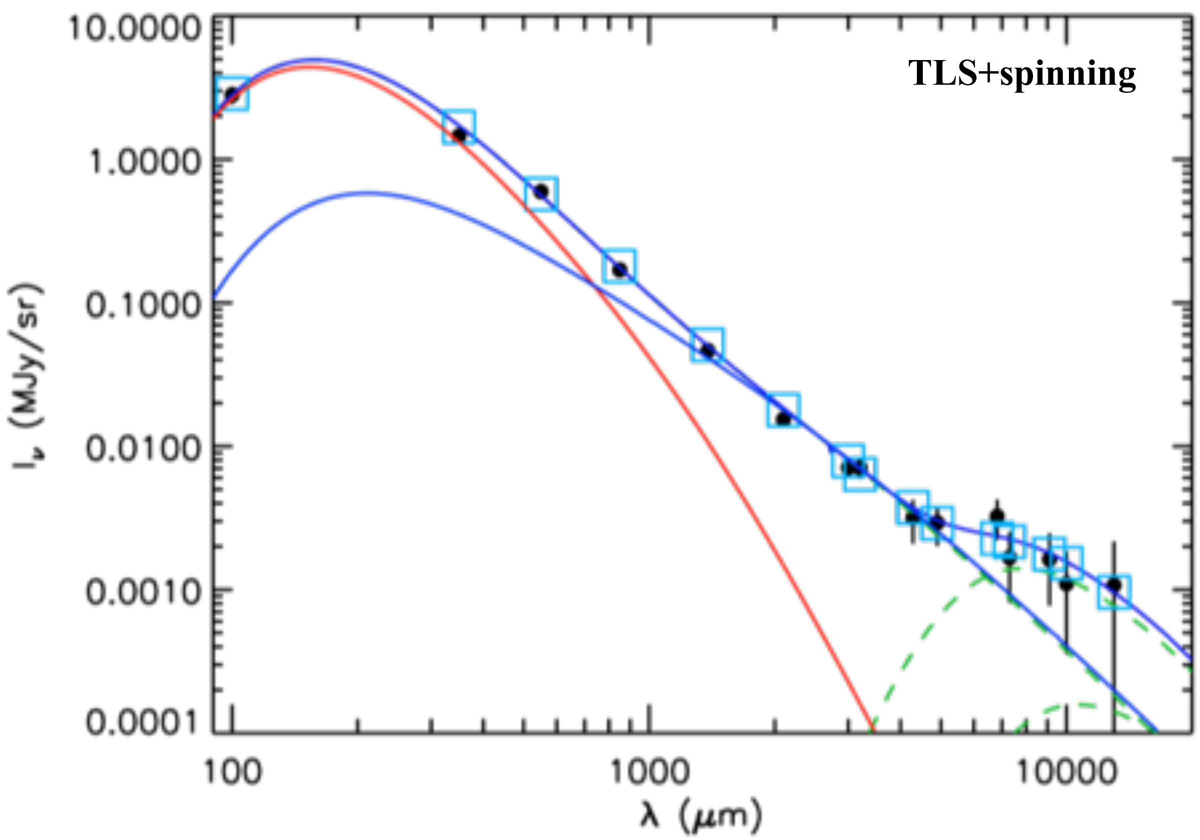


Planck Collaboration 2011, A&A 536, A17
(C. Author J.-Ph. Bernard)

planck

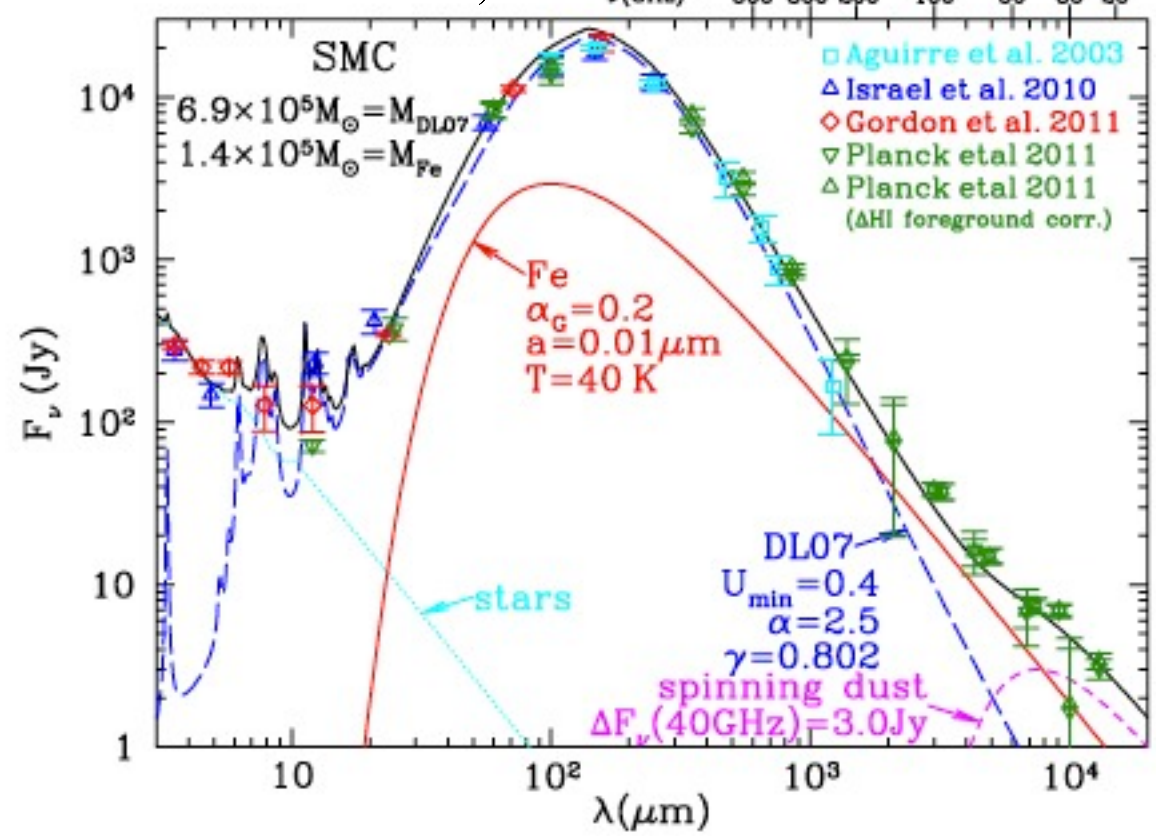
Two-Level Systems

Planck Collaboration 2011, A&A 536, A17



Magnetic nanoparticles

Draine et al. 2011, 2012



Various possible models lead to different predictions in polarization

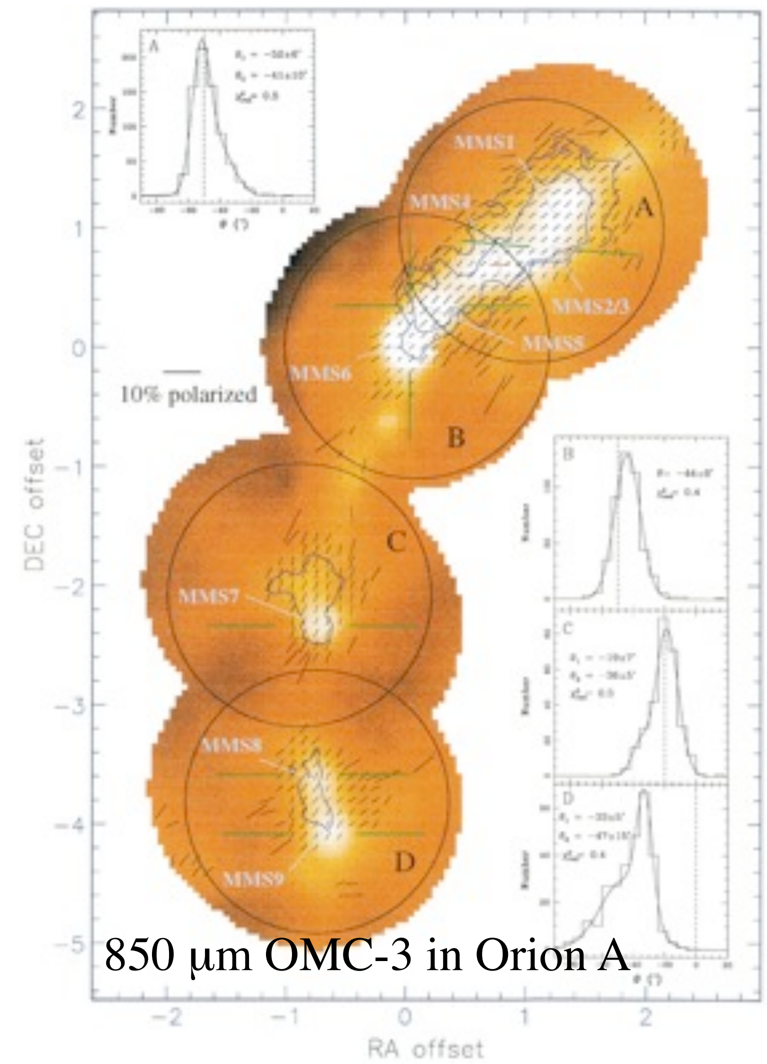
For instance :

- The TLS model would not require variations of p with frequency (same grains)
- Free-flying magnetic nanoparticle model will produce larger p at long wavelengths
- Magnetic nanoparticle inclusion in BG will produce lower p at long wavelengths

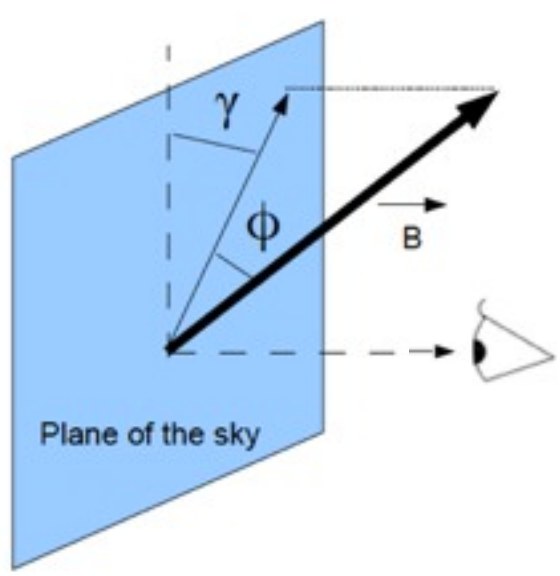
See presentation by B. Draine

Spatial variations of p

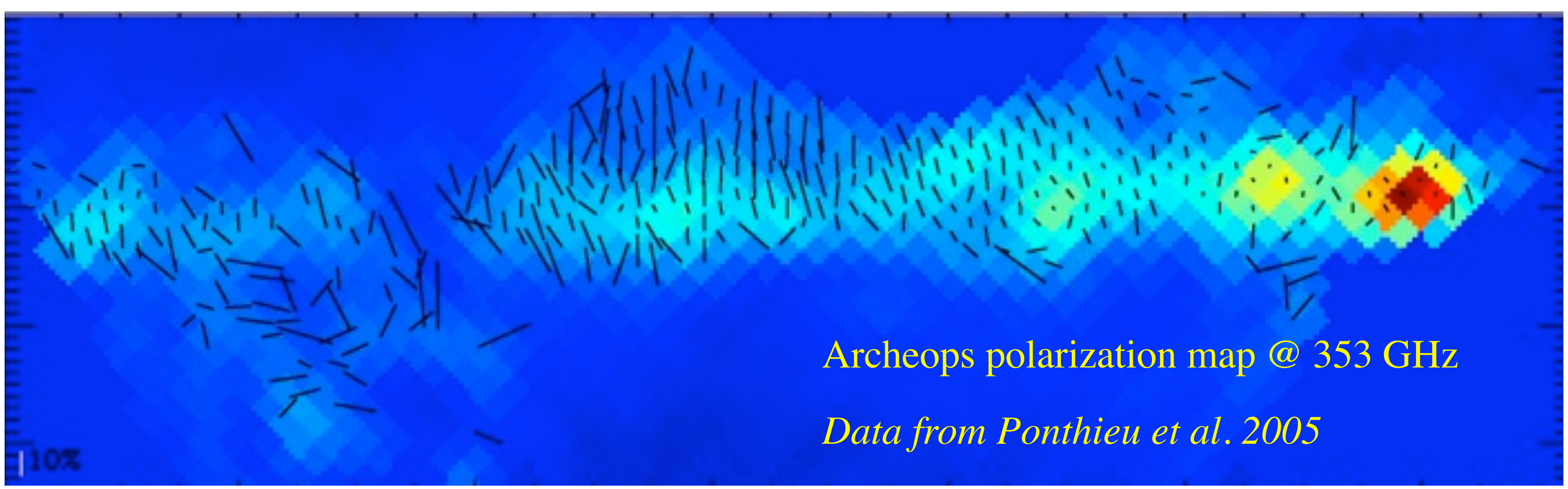
- Ground submm measurements (restricted to bright regions) indicate low values (usually a few %)
- However, Archeops claimed 10-15% in the plane (2nd Galactic Quadrant)
- p variations are difficult to analyze because:
+ affected by on-sky B field geometry
+ affected by 2nd angle
+ affected by bias (noise dependent)
- is there a single (intrinsic) true p value affected only by B structure ?



850 µm OMC-3 in Orion A



$P = \sqrt{(Q^2+U^2)} \propto \cos^2\phi$



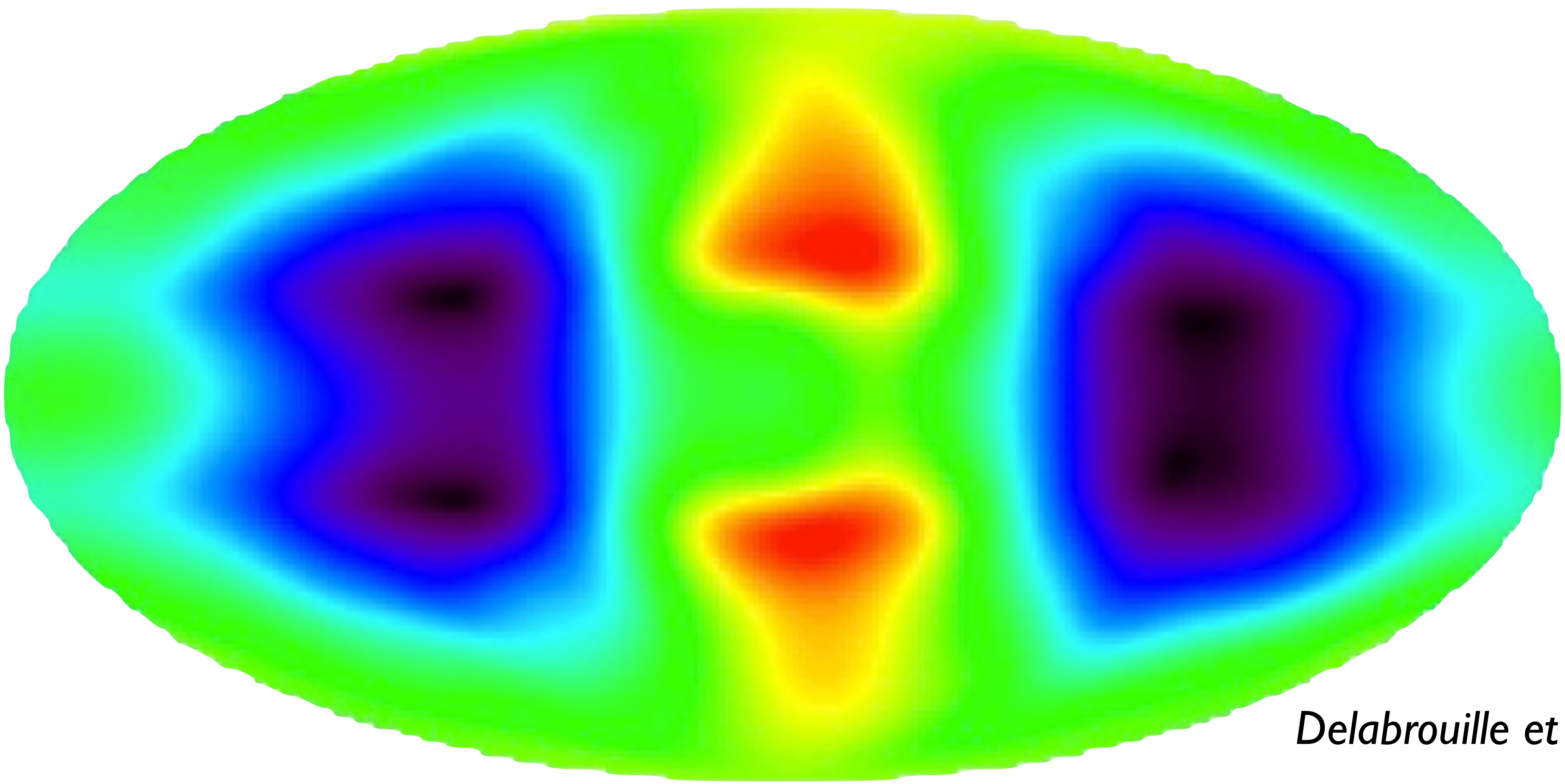
Archeops polarization map @ 353 GHz

Data from Ponthieu et al. 2005

spatial variations of p

There should be large scale variations of p due to B field structure of the MW

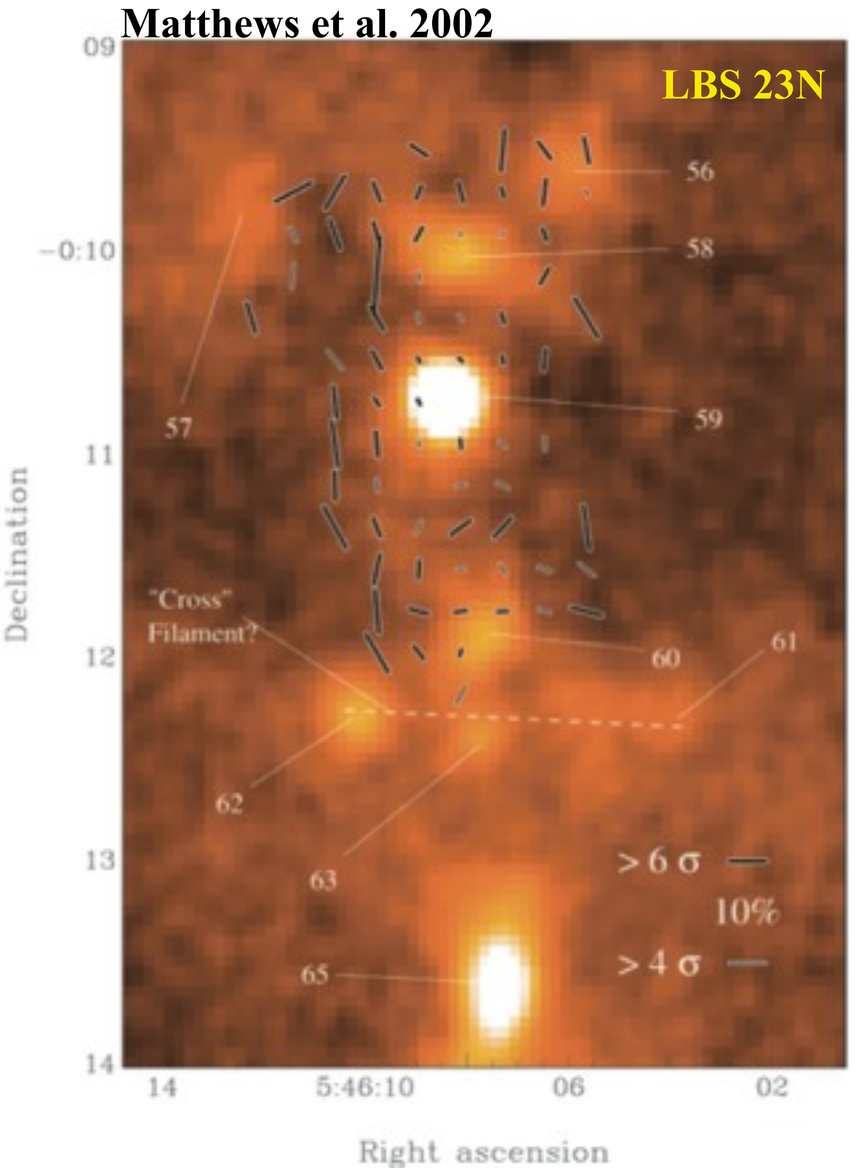
depolarization effect (G factor) as predicted by PSM
Based mainly on Synchrotron measurements

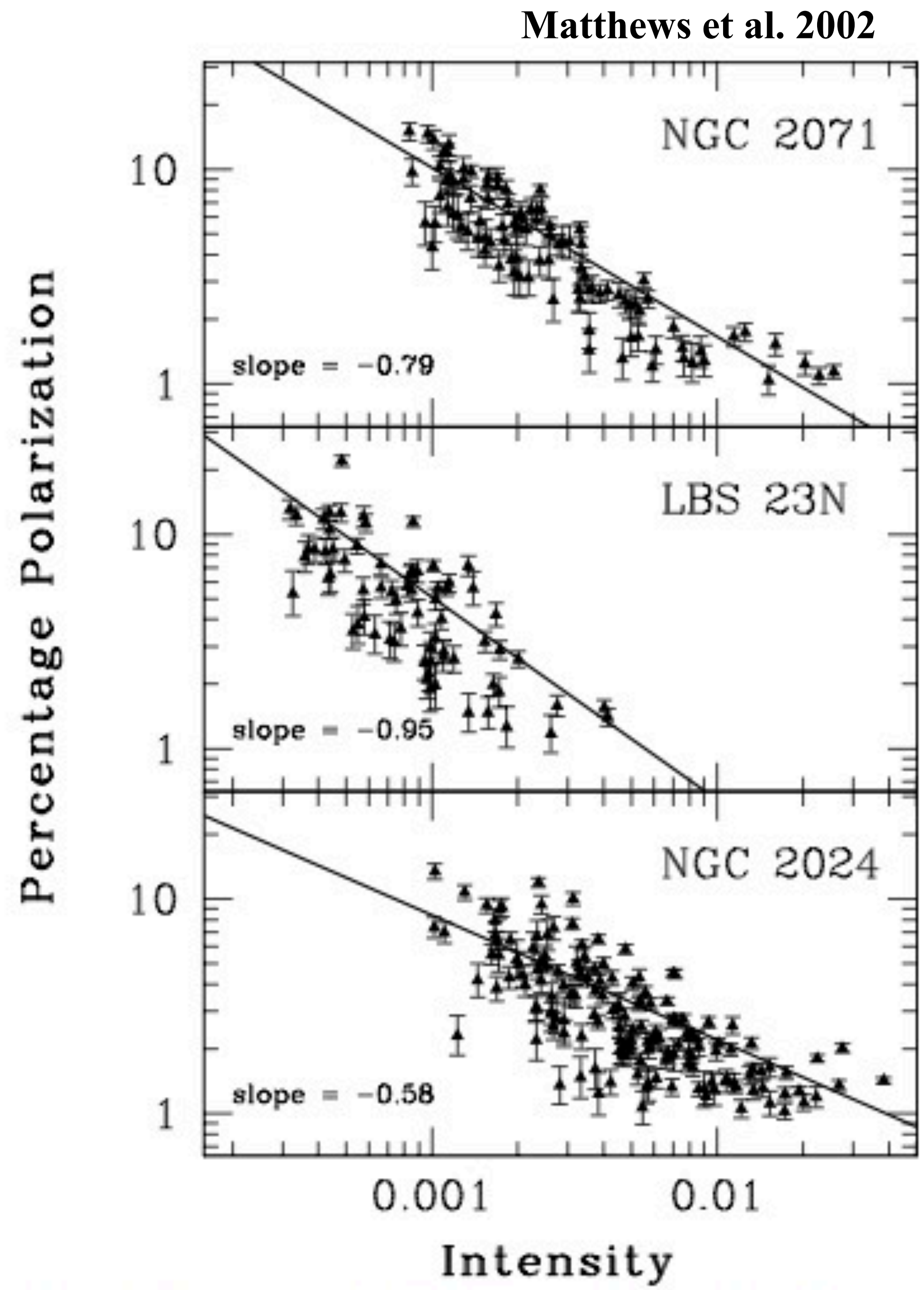


Delabrouille et al. in prep

spatial variations of p

Variation of p with intensity
Seen in most ground submm data



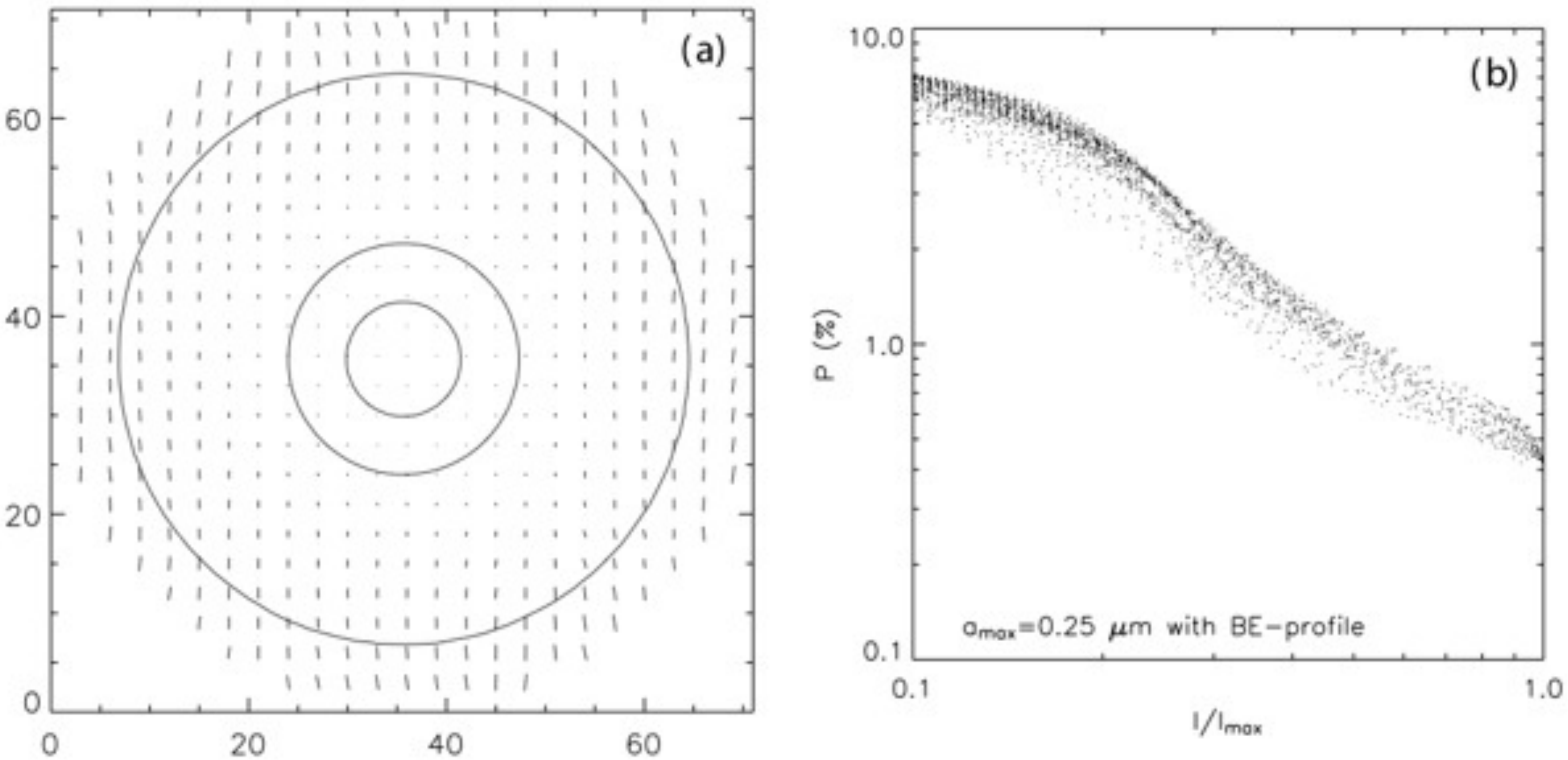


Correlation between p and tau (NH) ?
Correlation between p and T ?
Will be searched for systematically in Planck data
could help dissociate if a B effect or alignment effect

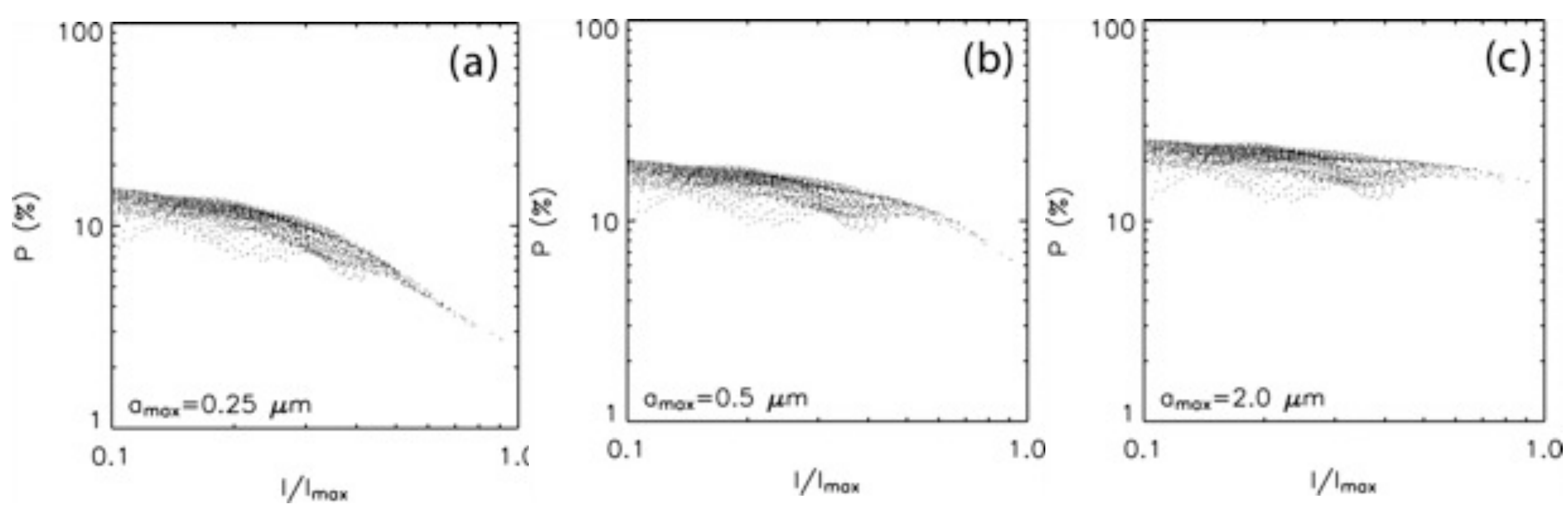
spatial variations of p

Variation of p with NH

Cho & Lazarian 2005



Cho & Lazarian 2005



Cho et Lazarian (2005)

Radiative Alignment Torques (RAT) in dense cores illuminated by external ISRF

Depolarisation as a function of depth
Also a function of grain size.

Could explain existing observations

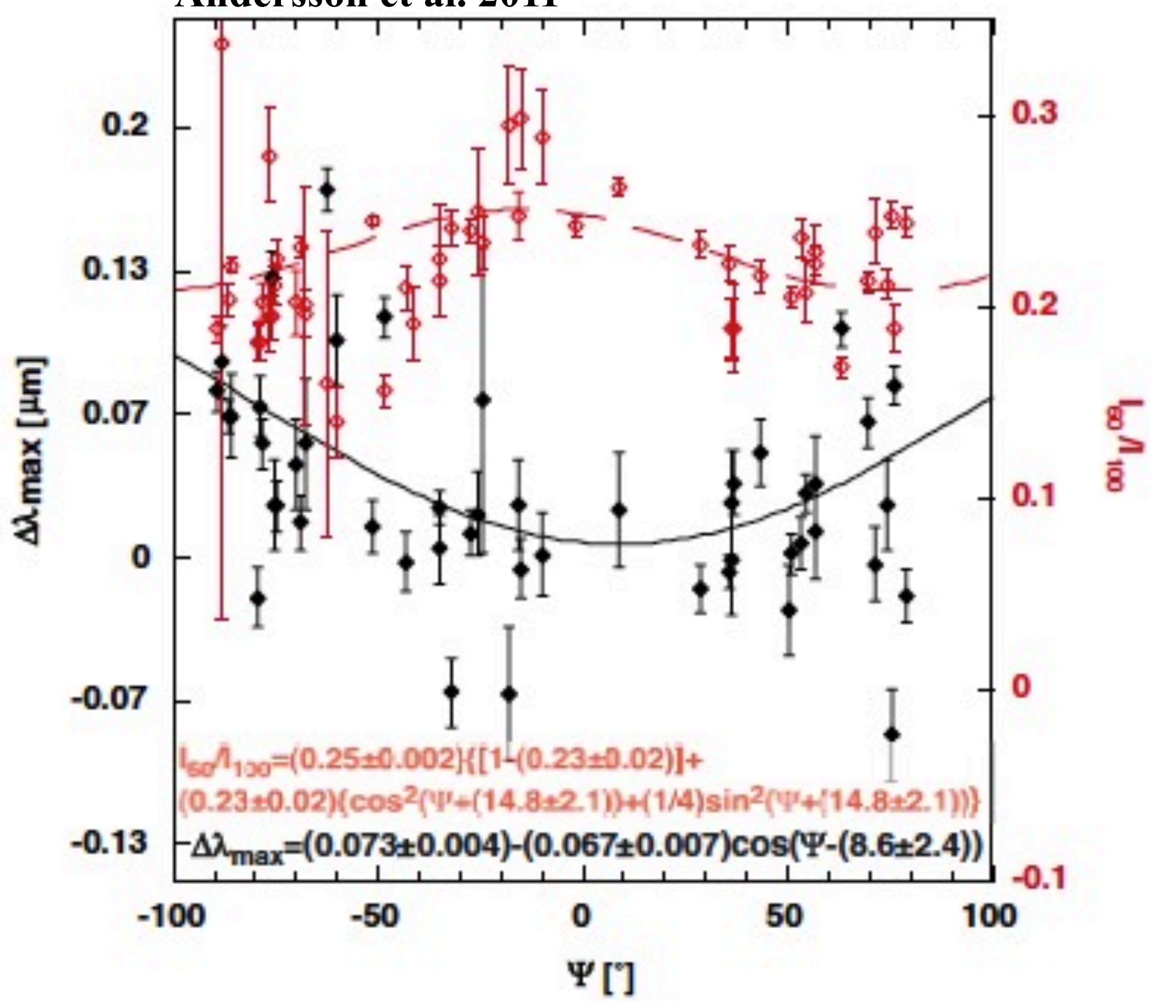
Variation of p could also be due to B field structure only
Requires comparison to MHD & rad. transfer simulations

spatial variations of p

Evidence for RATs ?

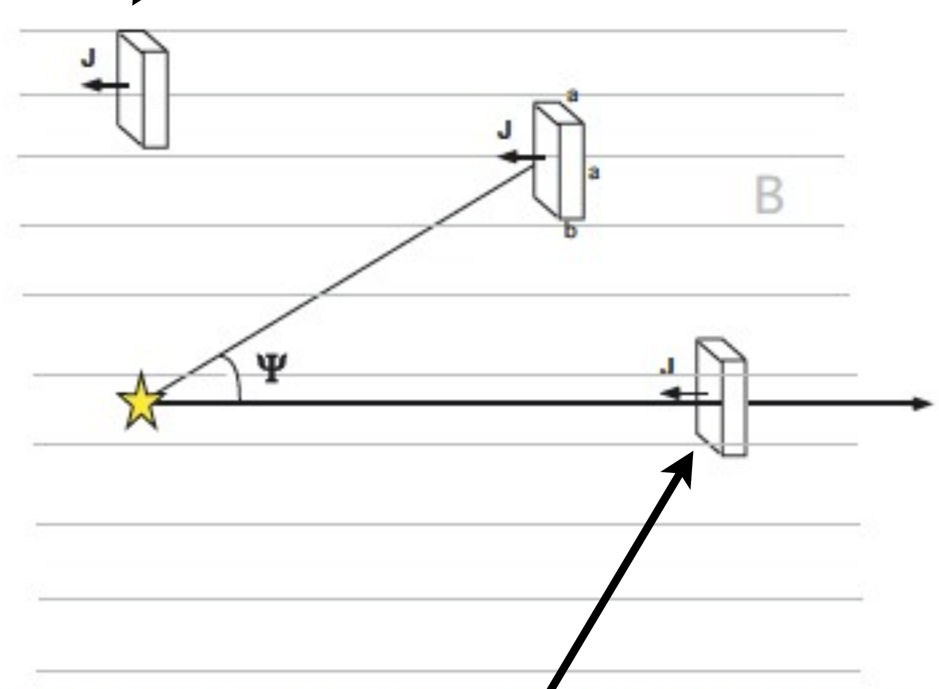
Around HD97300 (Chamaeleon I)

Andersson et al. 2011



colder & more polarized

Andersson et al. 2011



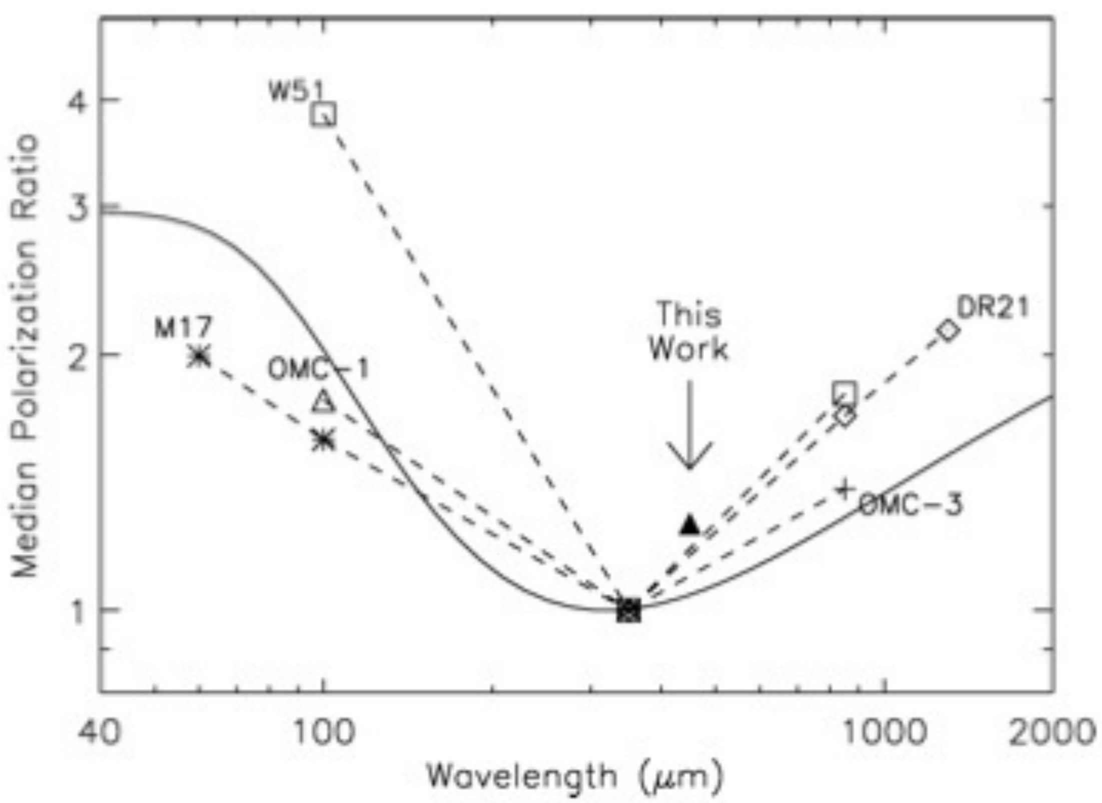
warmer & less polarized

Existing evidence in one object from Vis
Will be searched for systematically with Planck

Variations of p with Wavelength ?

This is probably the main question of interest for Polarization component separation.

Some information in the dense ISM



- Existing measurements indicate lowest p at around 250 microns
- Requires 2 T components with higher T best aligned or difference in emissivity
- This result is questionned (different instruments, objects, ...)

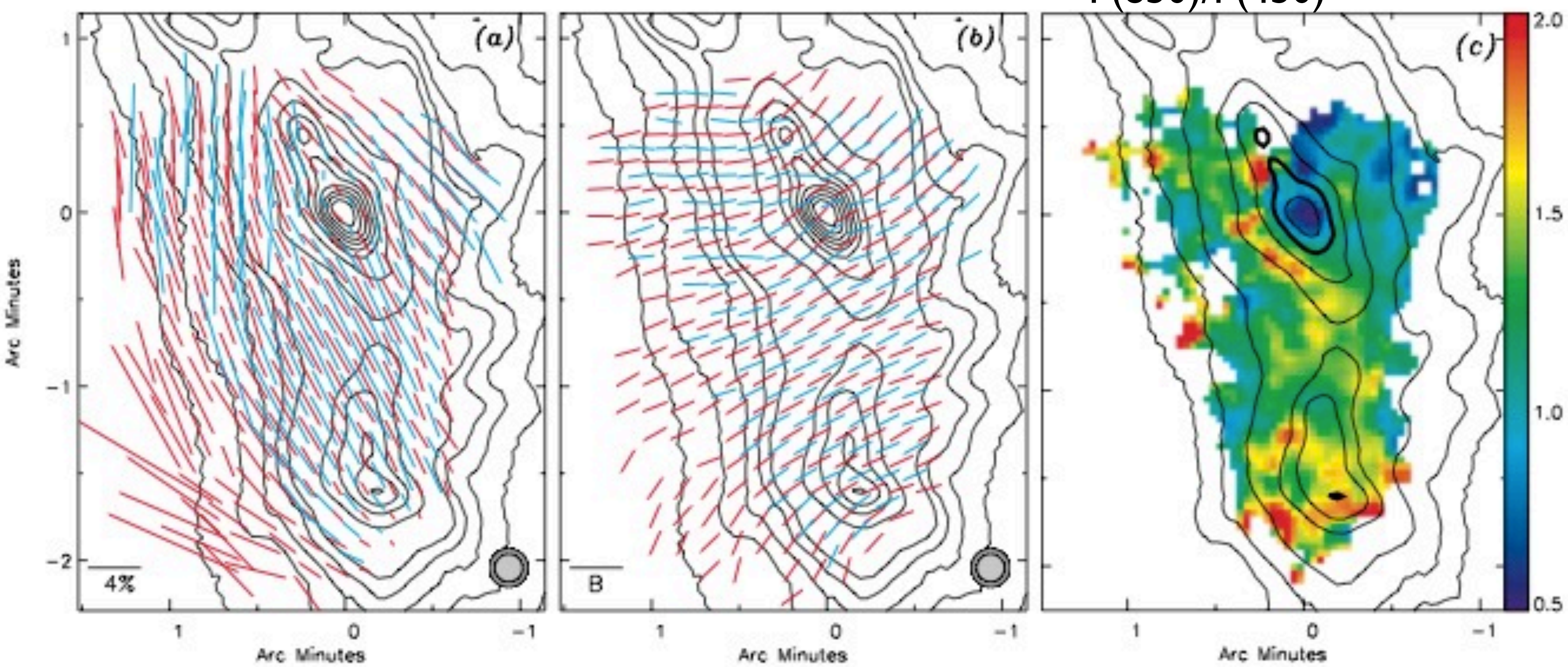
- p variations with wavelength are difficult to analyze because:
+ Affected by bias (noise dependent) which is strongly band dependent (steep dust SED)

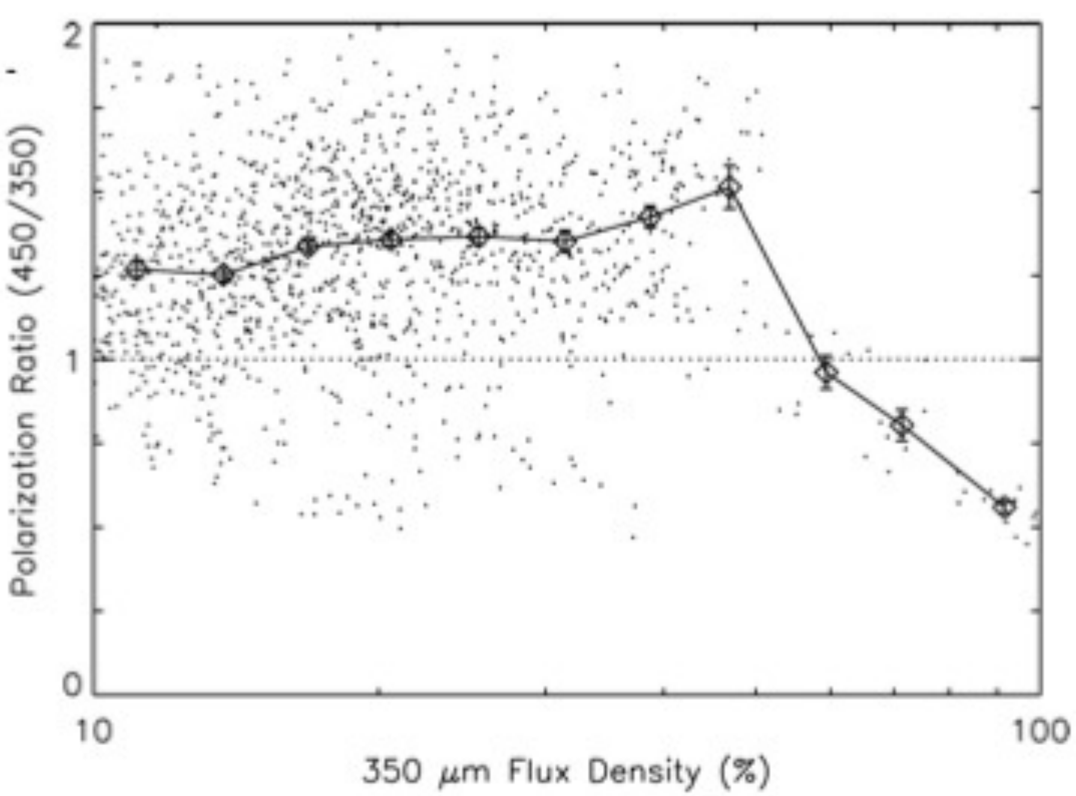
Little to no information in the diffuse ISM (Planck will do)

Variation of p(wav) with NH

From Vaillancourt 2008

P(850)/P(450)

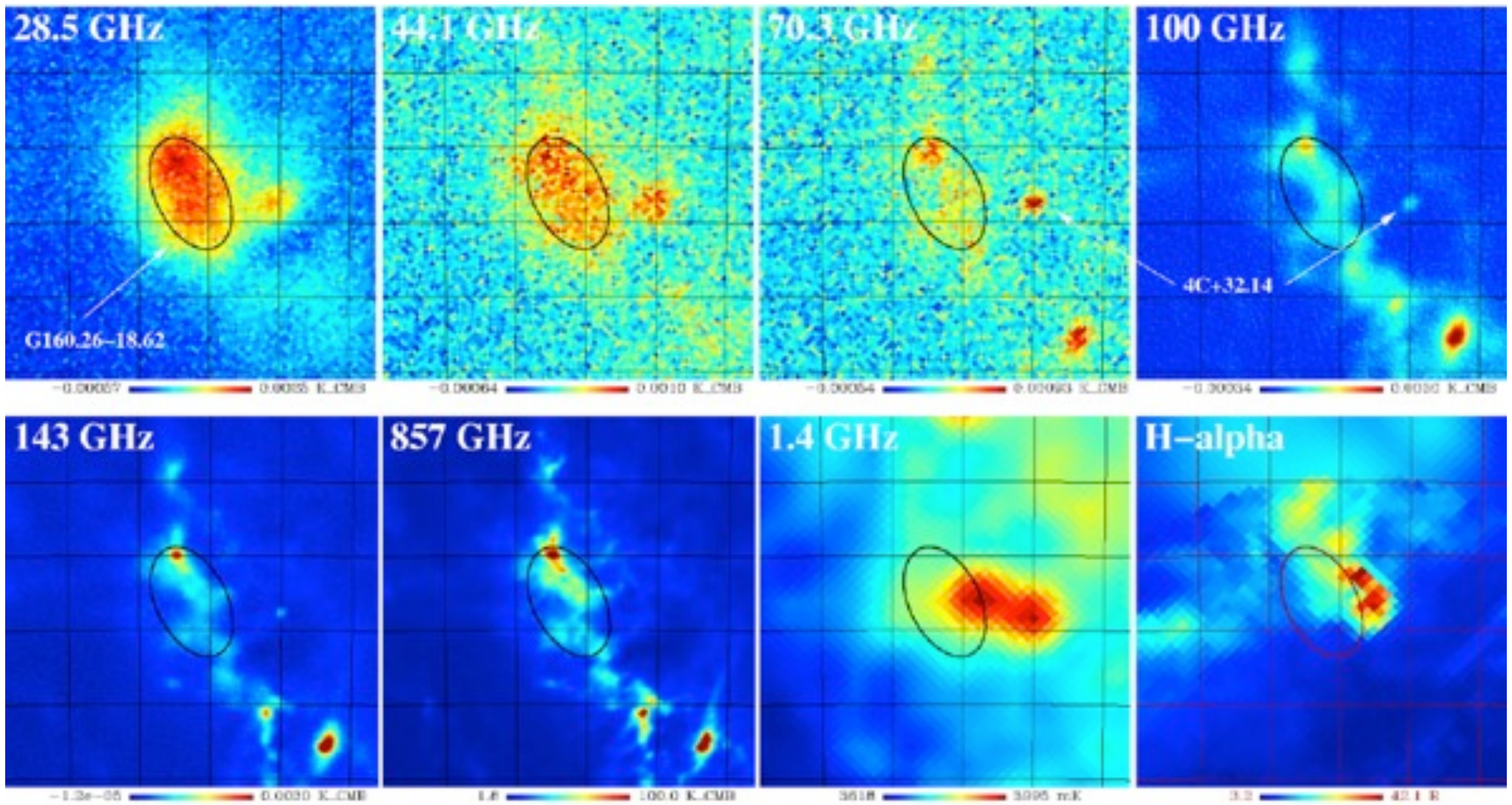




P(850)/P(450) drops at high NH in OMC-1

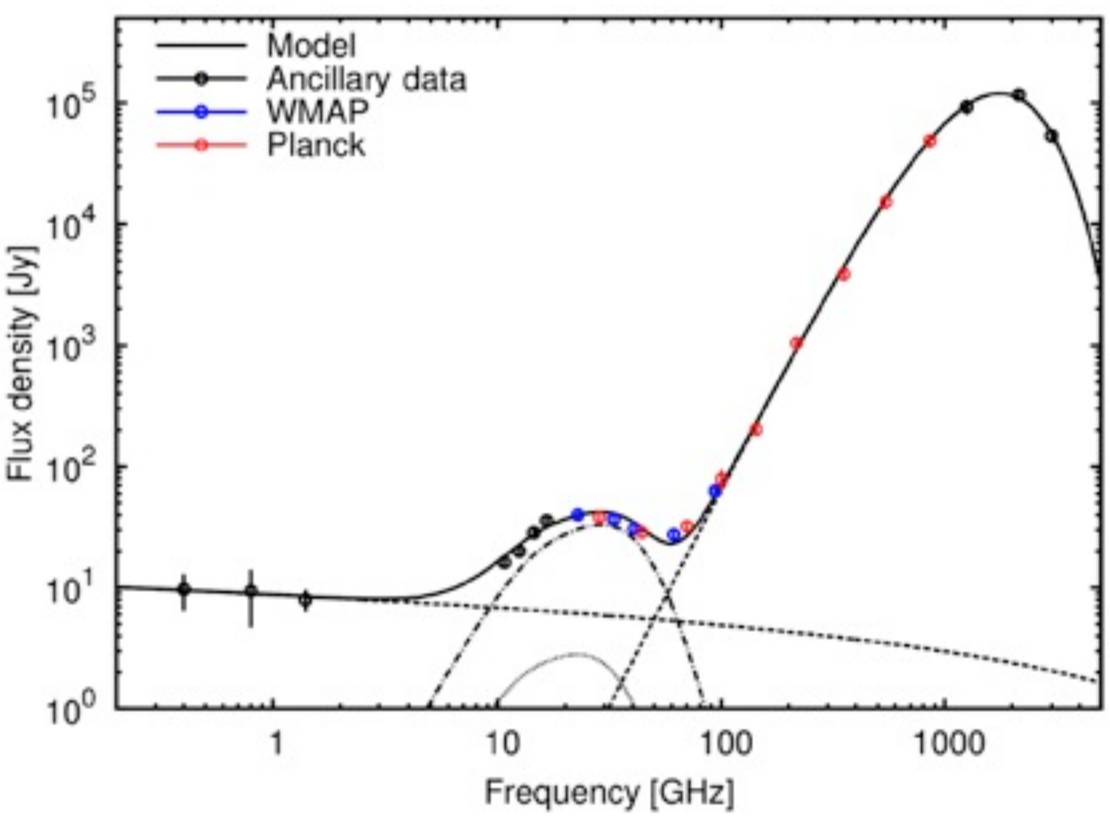
Is AME dust polarized ?

This is also important for Polarization component separation.



AME is likely Spinning dust
Therefore likely due to PAH or VSG
Therefore, should not be strongly polarized

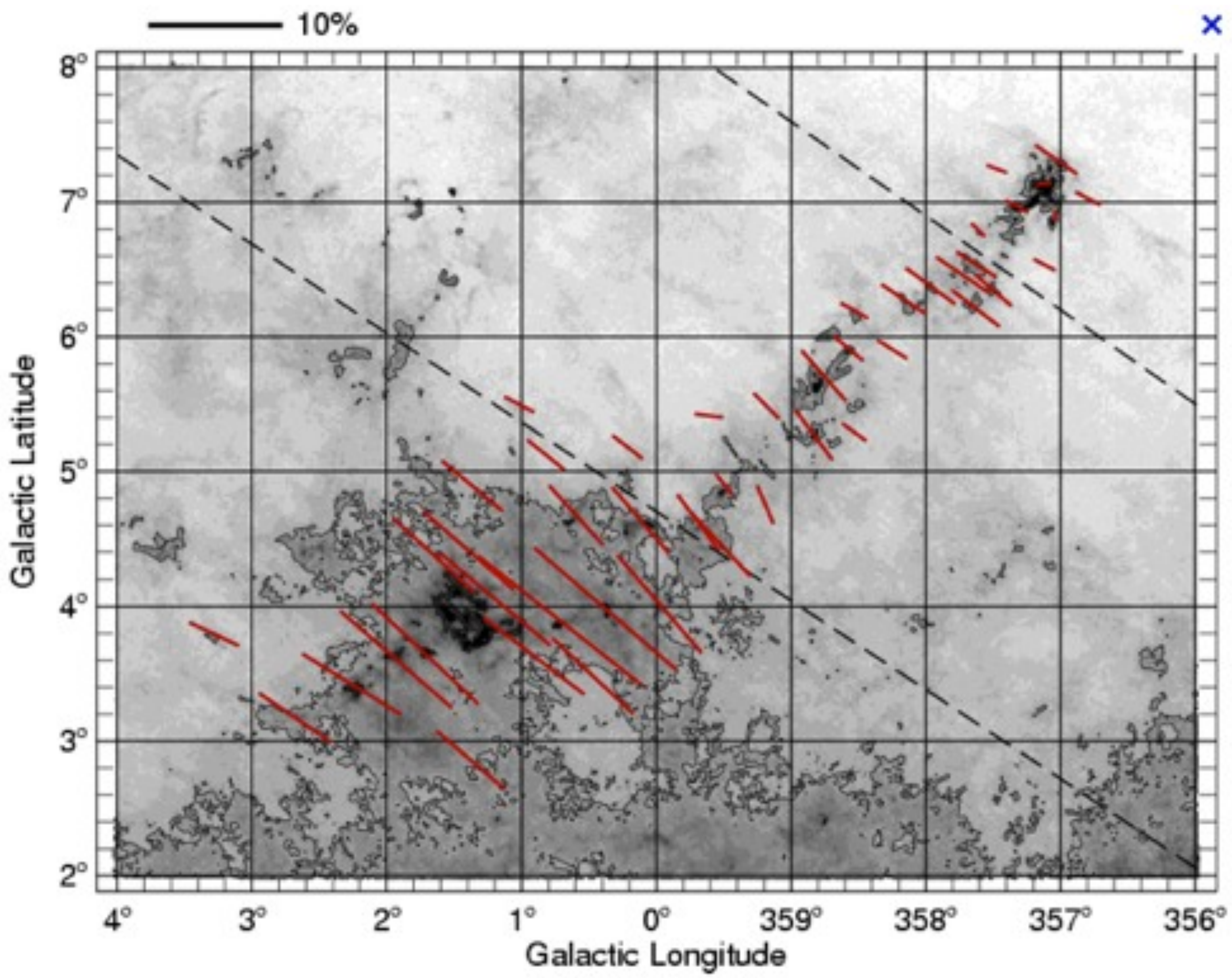
Existing measurement show p<2% (Battistelli et al., 2006; Lopez-Caraballo et al., 2011; Dickinson, Peel, & Vidal, 2011)



As Planck measures AME very well, constraints on AME polarization should be quite efficient

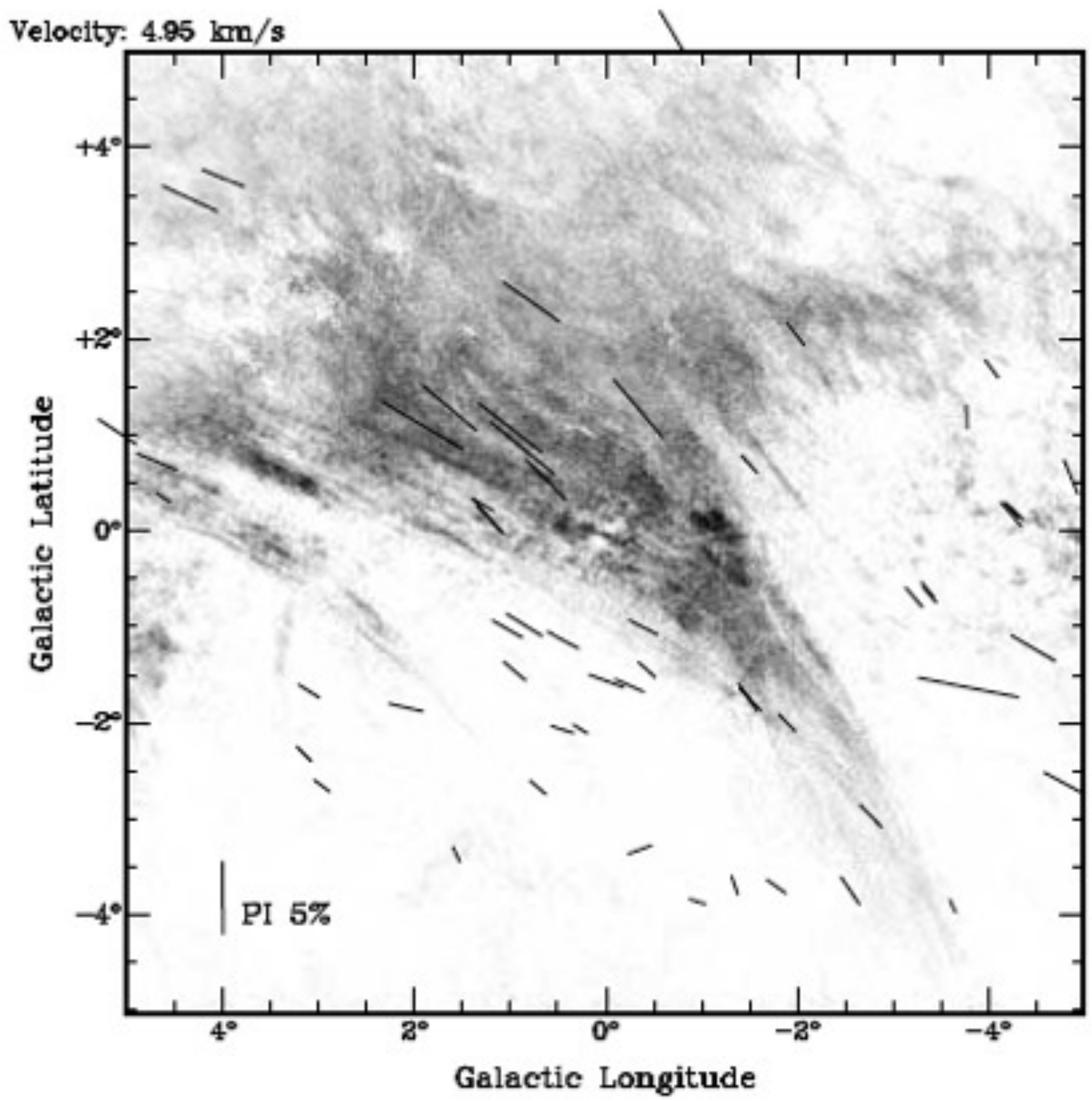
Planck Collaboration 2011, A&A 536, A20
(C. author C. Dickinson)

polar angle vs ISM filaments



Some ISM filamentary structure show apparent connection with magnetic field ...

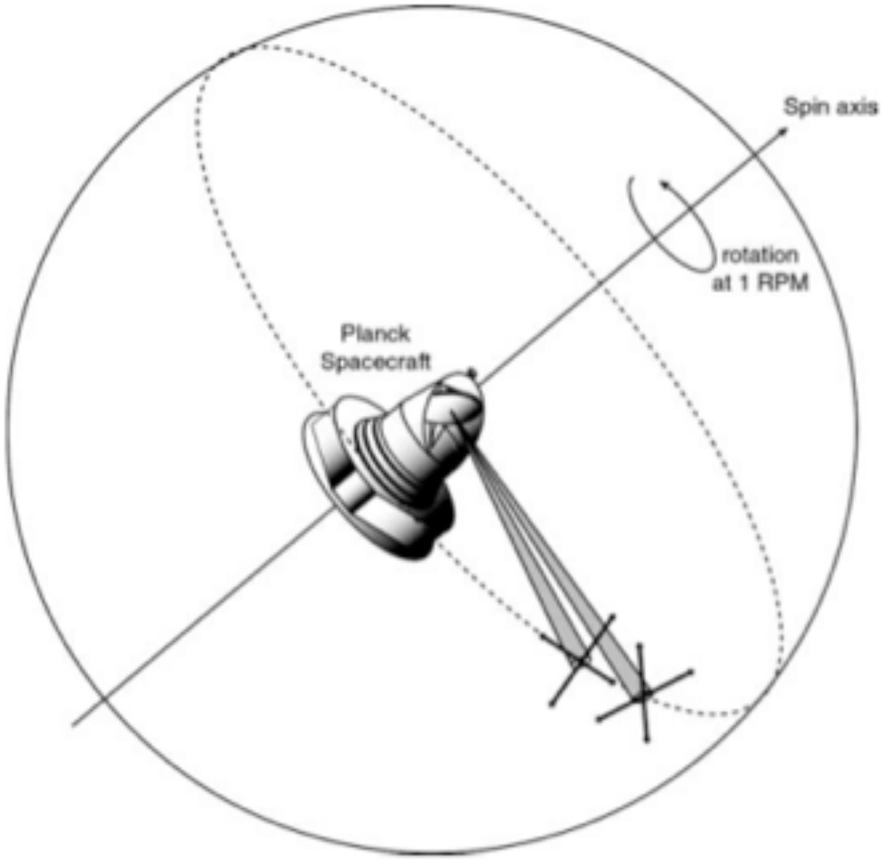
... although the two examples shown here (only a few degrees apart on the sky) give opposite filament orientation w.r.t. B field



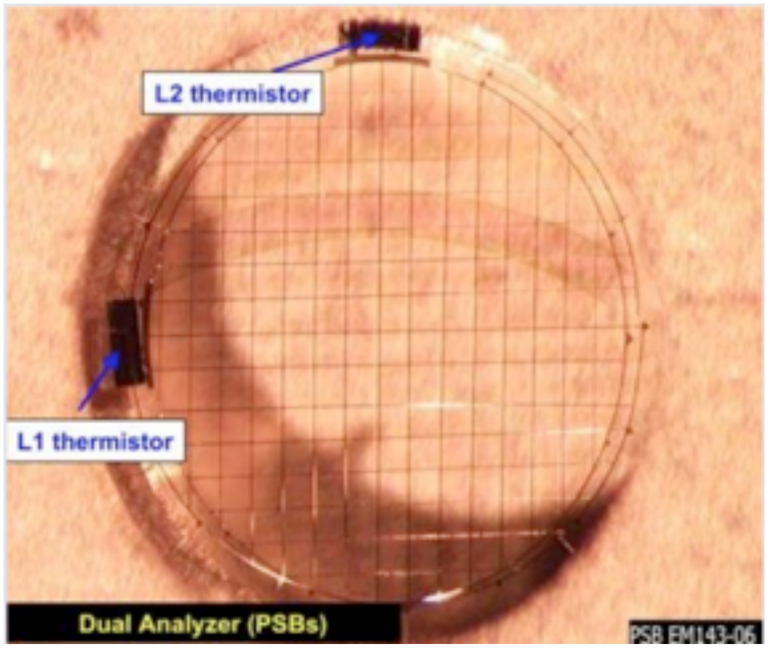
The planck data will allow to test this with much more statistics than stellar absorption measurements allow.

From data to Stokes parameters

Planck scanning the sky



Planck/HFI focal plane



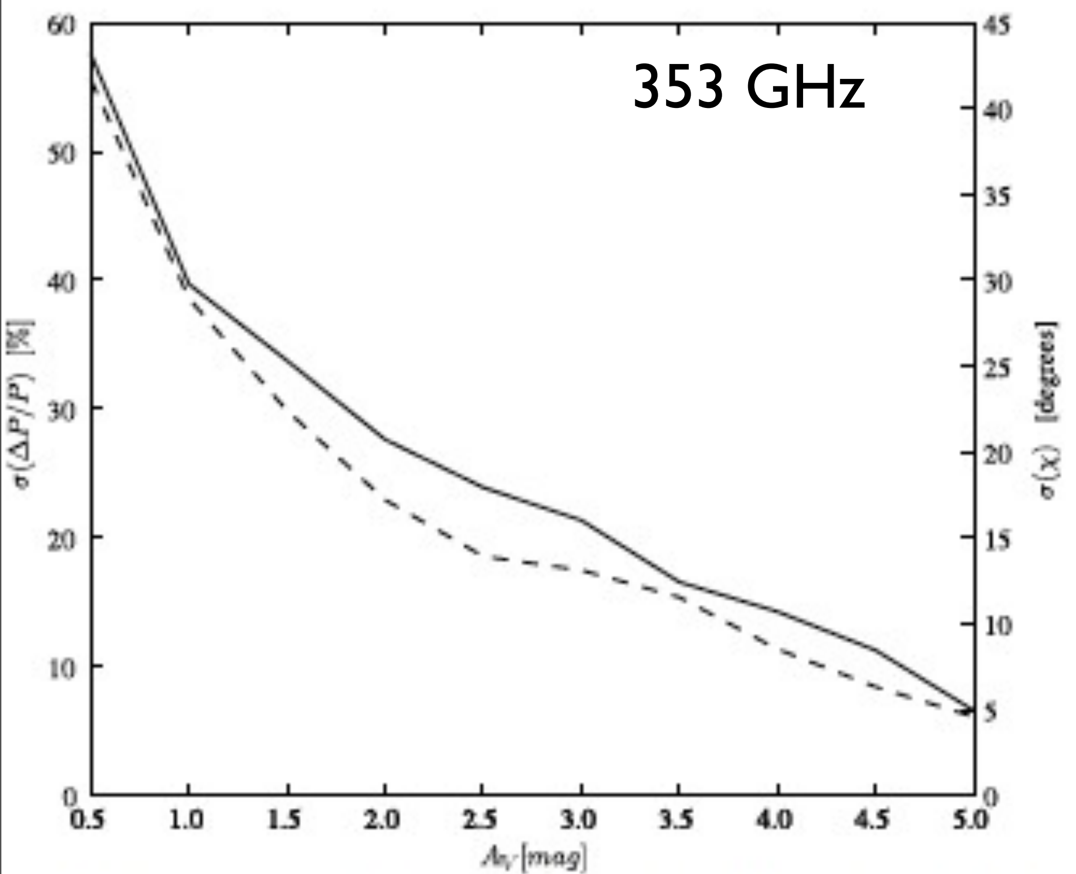
Derivation of Stokes parameters (I, Q and U) involves the combination of two pairs of PSB bolometers that observe the same sky positions within a few seconds. The polarizers of the second pair are rotated by 45° with respect to the first pair.

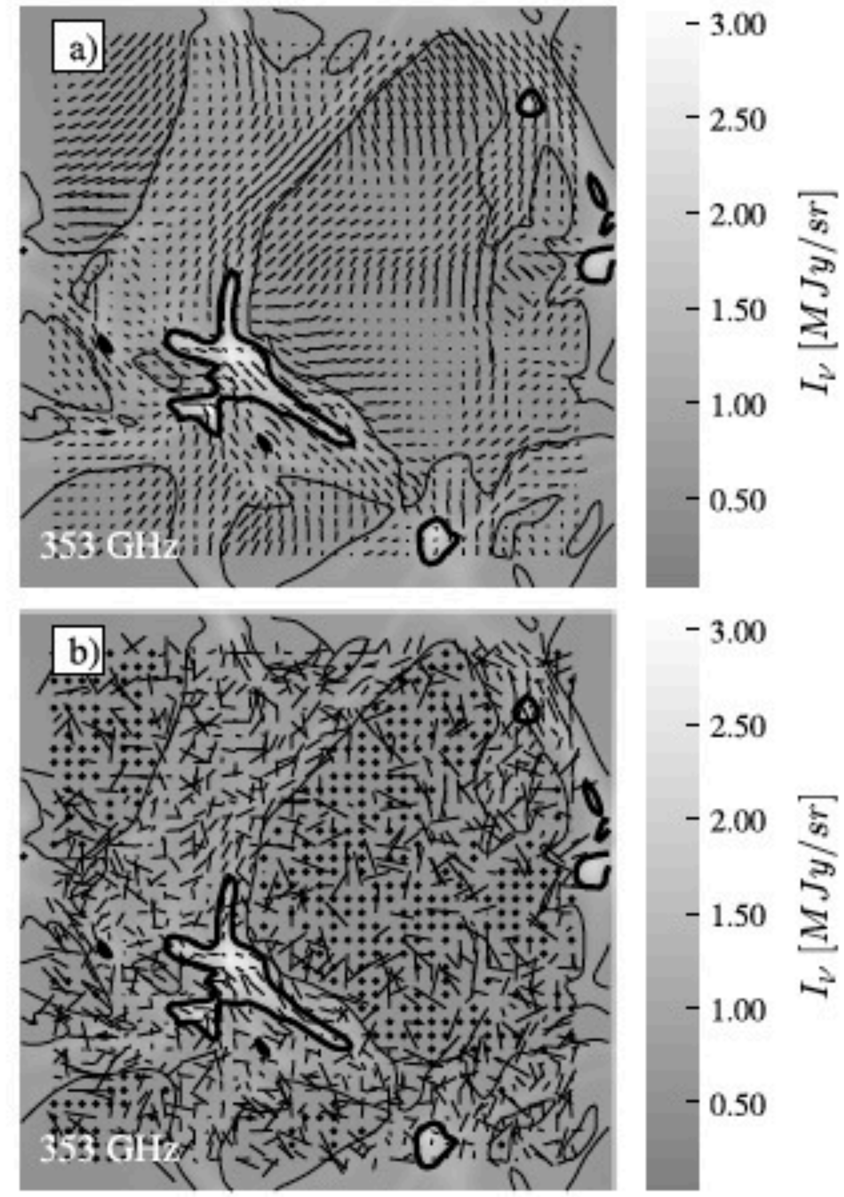
$$s_1 - s_2 = Q\ cos(2\alpha) + U\ sin(2\alpha)$$
$$s_3 - s_4 = Q\ sin(2\alpha) - U\ cos(2\alpha)$$

Multiple scans and multiple surveys provide Q and U measurements with different α orientation. Maps of Q and U and their standard deviations are inferred from the multiple measurements.

Planck Polarization Sensitivity

Pelkonen et al. 2007

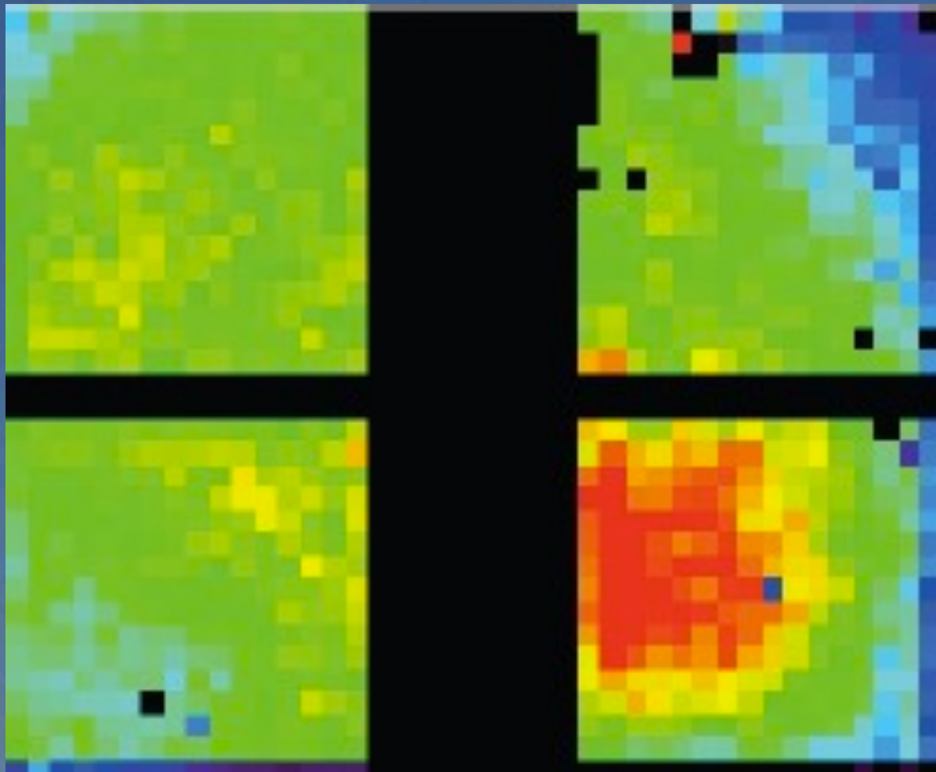




Limitations to Planck dust polar measurements ?

- Bandpass mismatch on Dust emission
- CO contribution (100, 217, 353 GHz)
- Effect of noise (and bias), in particular at low freq
- Systematic effects :
  Optical effects (FSL, beams in Q vs U, ...)
  Component separation (Dust vs CMB, Synch, free-free, AME, ...)

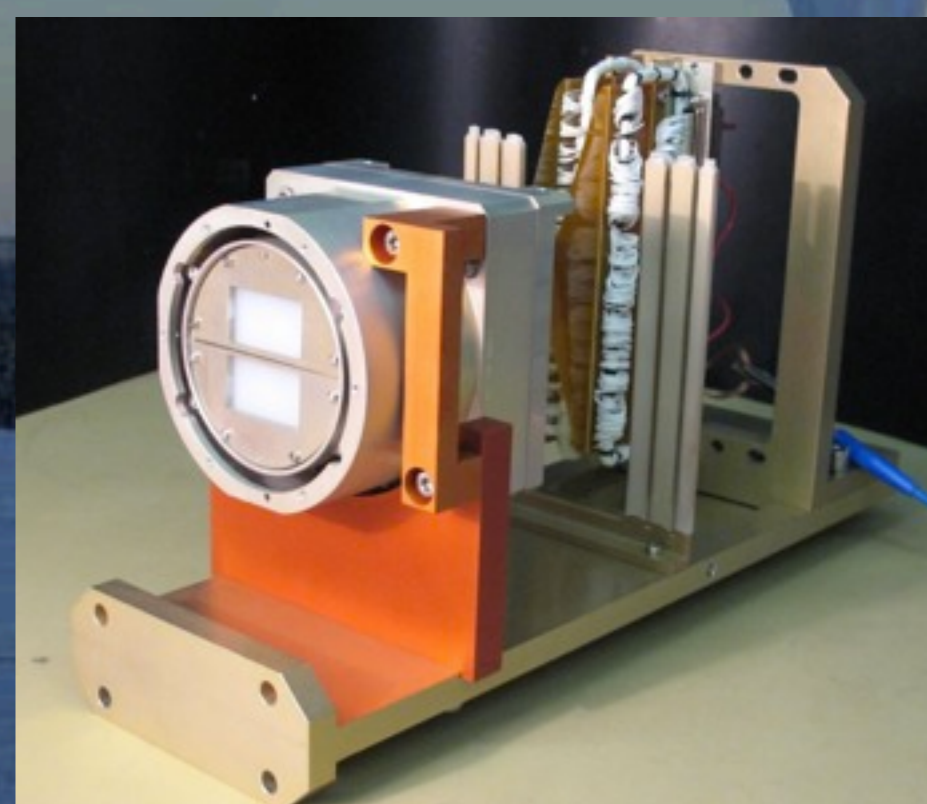
Coming soon : Pilot



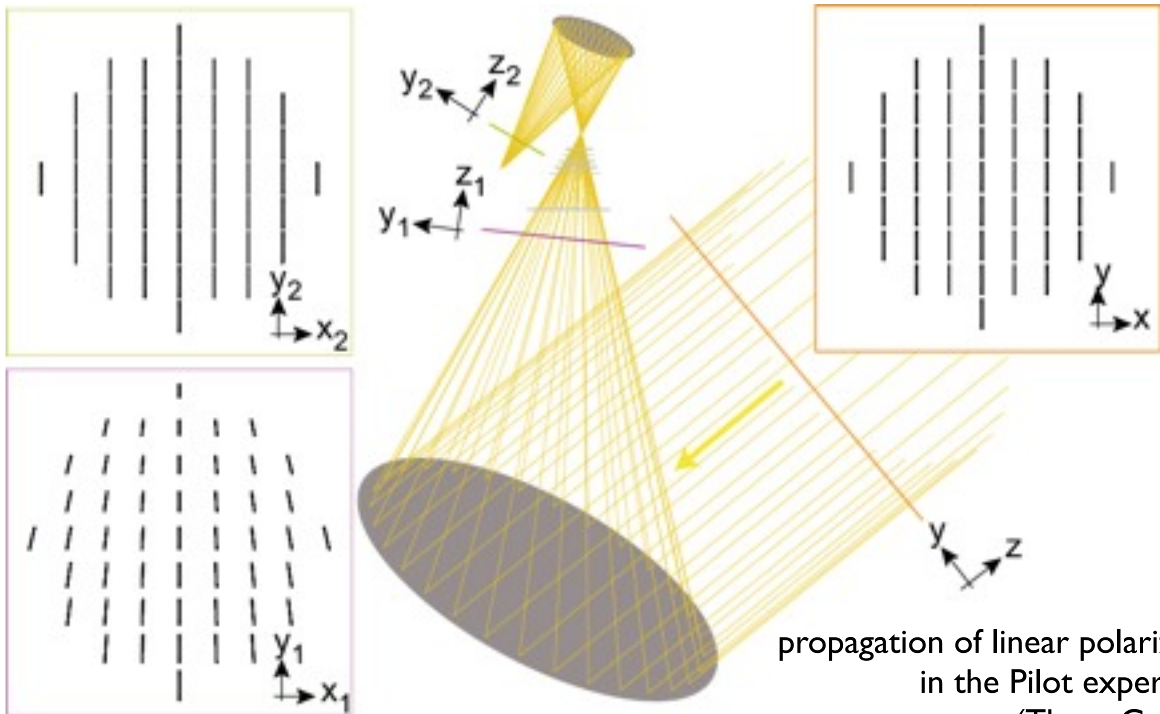
Dust emission polarization at 240 and 500 microns

First launch forseen in 2014

http://pilot.irap.omp.eu

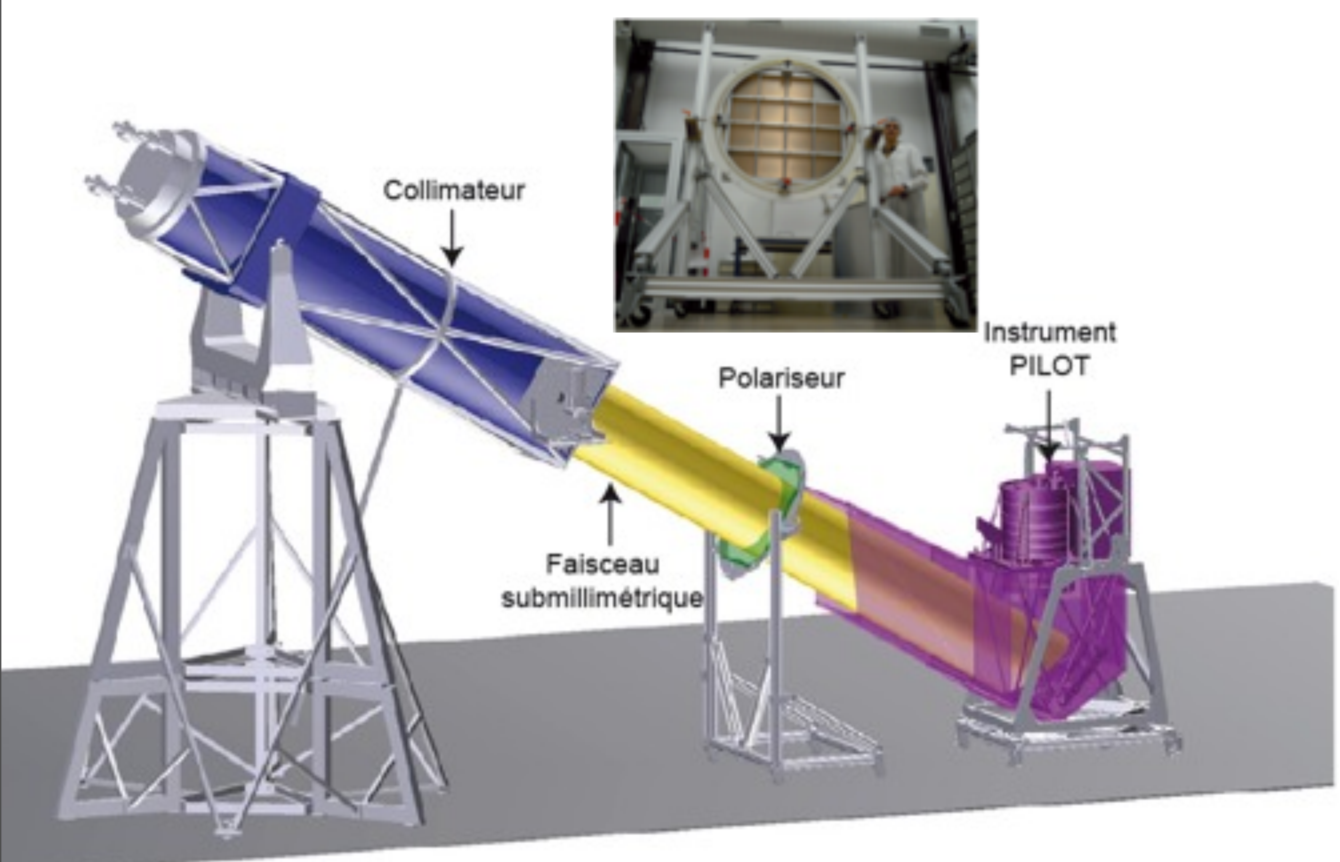


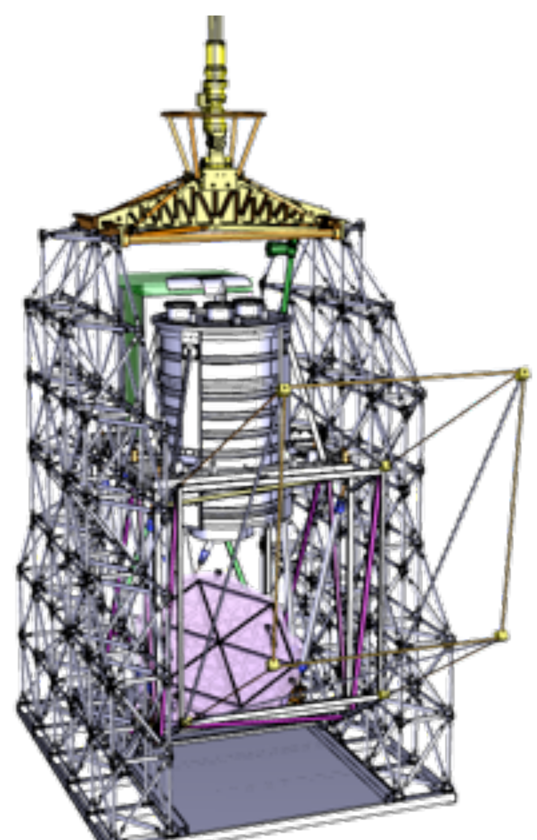
Instrumental considerations



propagation of linear polarization
in the Pilot experiment
(These C. Engel)

- The propagation of polarization modes in a given instrument is a complex problem
- Today, we have little automated tools to simulate this and run MC analysis to optimize instruments
- Several problems arise in instruments (intercalibration, band mismatch, beam mismatch, etc ...)
- Such detailed models are also needed for data analysis
- Full End-to-end tests of the instrument in polarization are needed





Dust polarization results from complex processes
Various possible models lead to different predictions in polarization
We don't really know how difficult the foreground correction will be
The main questions are :

-1 How does p varies with frequency ?
-2 How stable is this on the sky ?
-3 What is the intensity of dust polarization ?

If 1 and 2 unfavorable, good physical understanding will be needed

Planck will answer those questions

Polarization is hard to measure.
We probably miss dedicated optical software
We need very precise end-to-end instrument calibration
We miss precise natural and/or artificial calibration sources (p and angle)