

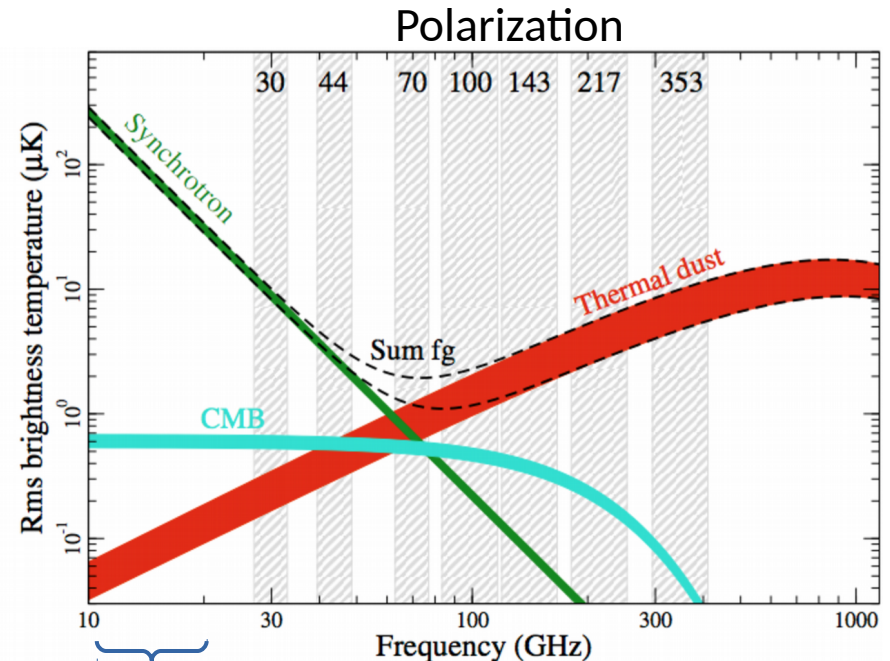
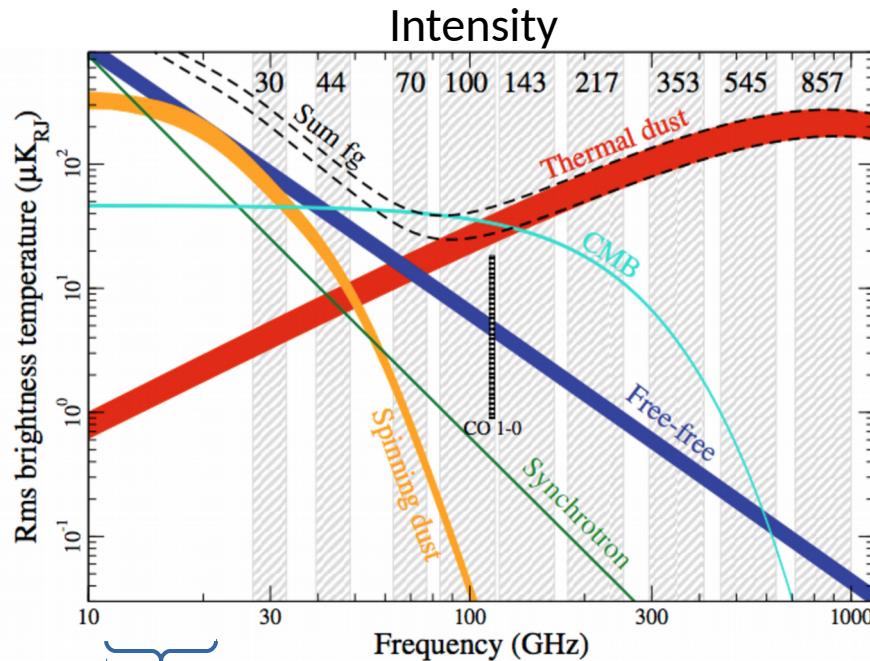
QUESO2017 — Garching, Germany

Extreme-scale Alignments of Quasar Optical Polarizations And Galactic Dust Contamination

Vincent Pelgrims
LPSC, Grenoble, France



Galactic foregrounds:



QUIJOTE frequency bands

'Ultimate' characterization of the CMB Foregrounds at radio to sub-mm wavelengths

Add low frequency data to break degeneracies among components

Provide the community with tools and up-to-date models

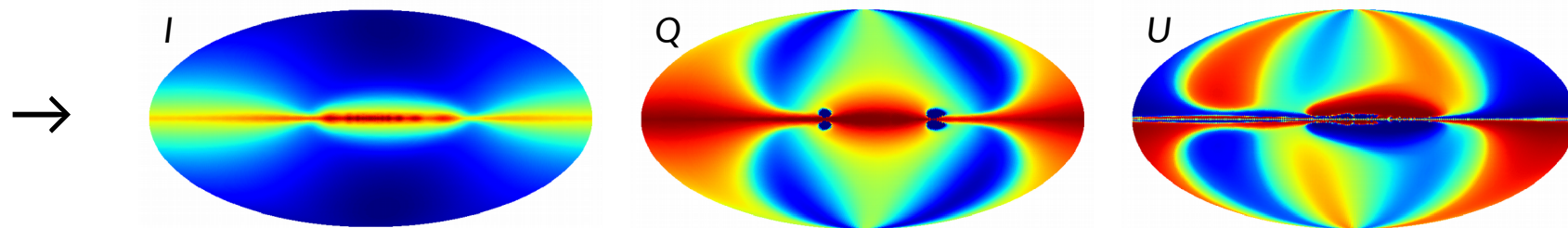
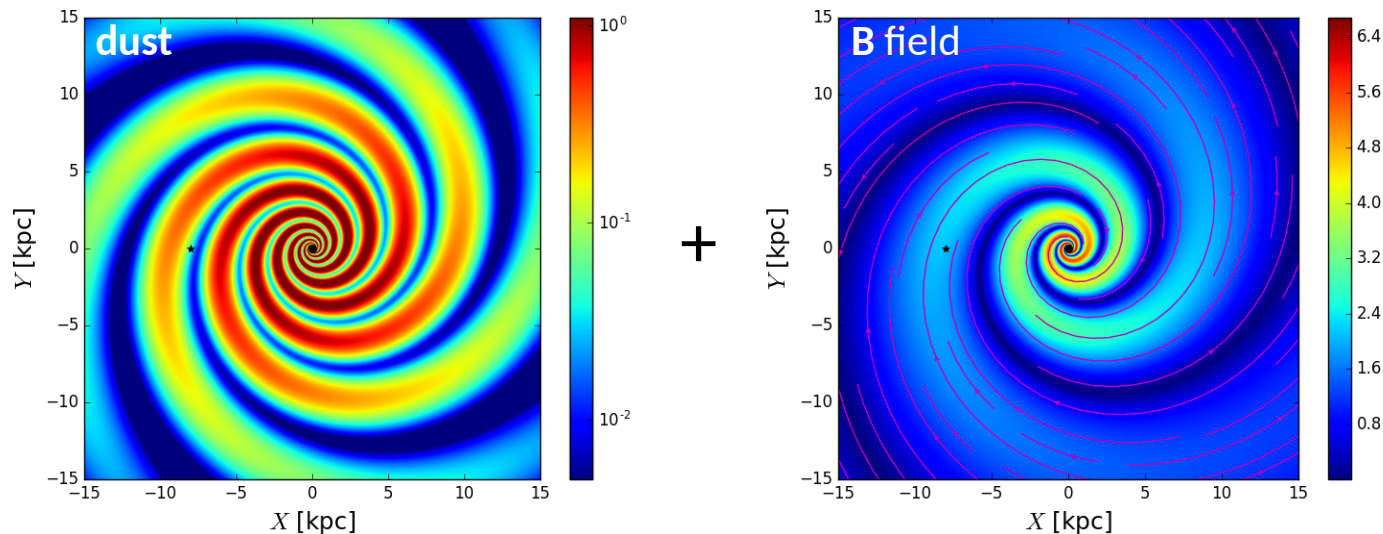
Forecasting limitations of component separation algorithms for the future CMB probes

...

Provide the best **three-dimensional regular Galactic Magnetic field** ← my duty

Galactic foregrounds & three-dimensional regular Galactic Magnetic field:

- Synchrotron and thermal dust diffuse emissions:
Stokes I , Q and U theoretically depend on the integration along the line of sight of a clever mixture of \mathbf{B} field and of density distribution of relativistic electron and dust grains
- *In principle*, 3d modeling of those should enable one to constrain the models, especially \mathbf{B}



Python suite of codes is being released *on the tiptoe*. Have a look there: <http://www.radioforegrounds.eu/pages/software.php>

Extreme-scale alignments of quasars optical polarization vectors

[Hutsemékers et al. 1998, 2005]

Anomaly:

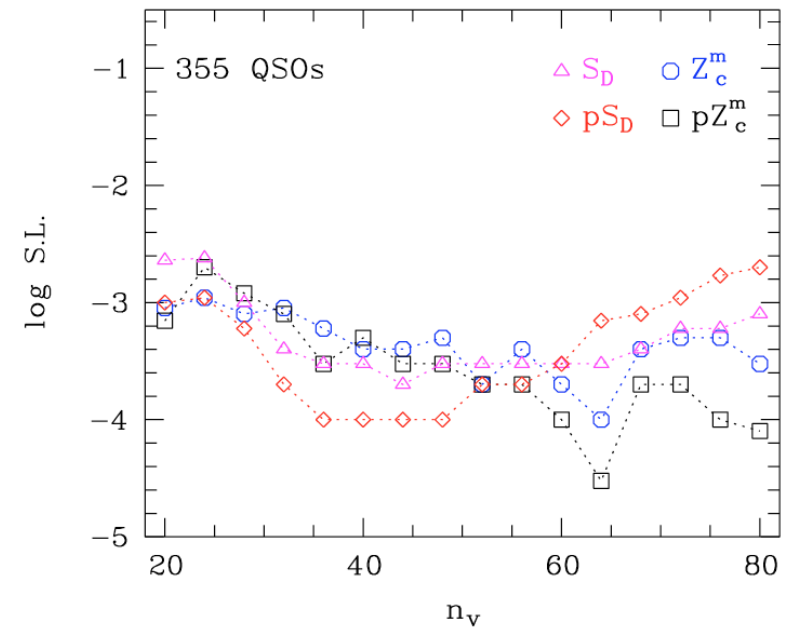
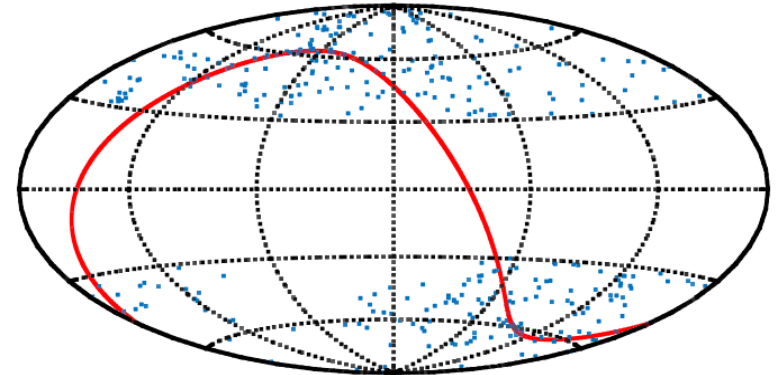
“Optical polarization vectors from quasars appear to be significantly correlated through scales larger than Giga-parsec. No correlation between objects is expected at that scale.”

Current sample:

355 quasars with $|b_{\text{gal}}| \geq 30^\circ$; $p_{\text{lin}} \geq 0.6\%$ and $\sigma_\psi \leq 14^\circ$ to ensure ‘reliable’ polarization measurements. (to be upgraded soon)

Main features of the alignments:

- significant at 3 – 4 σ compared to expected randomness, even using dedicated statistical test implementing LEE
- stronger in Gpc-scale regions/along a cosmic axis
- apparent redshift dependence of the preferred ‘pointing direction’



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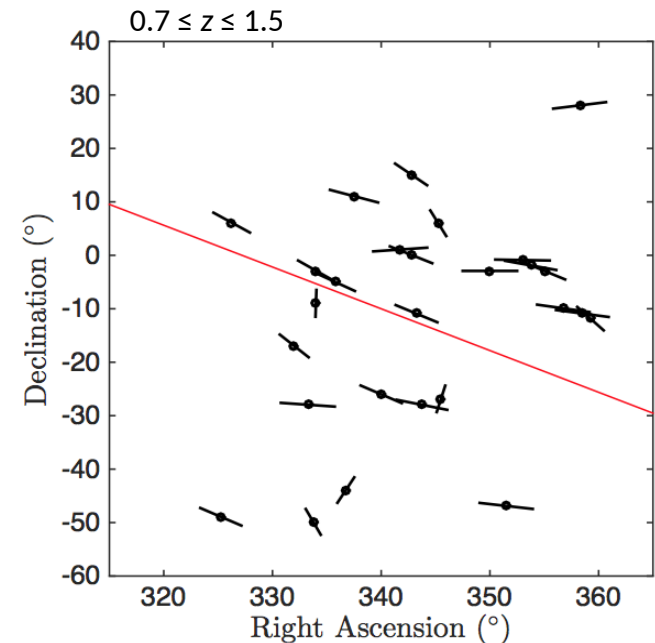
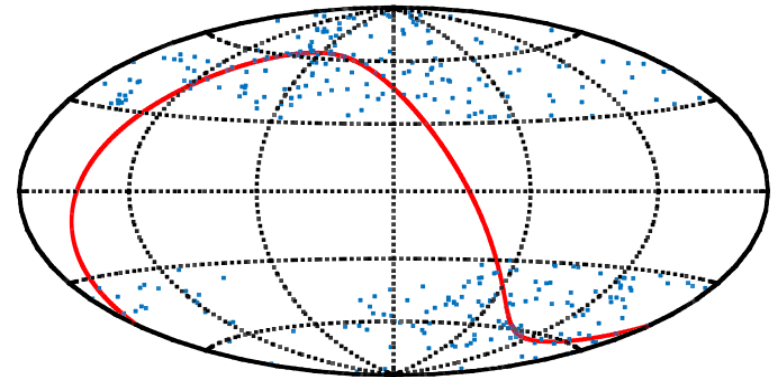
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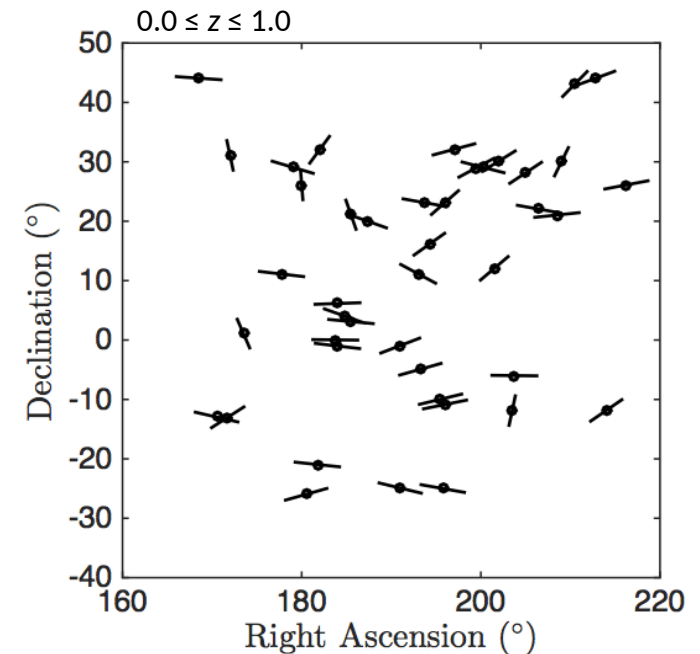
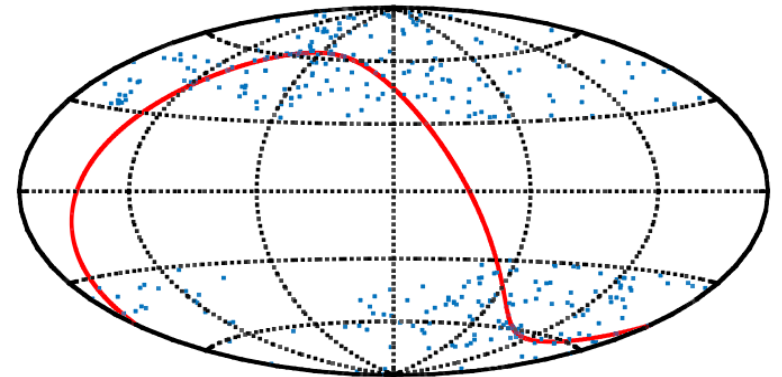
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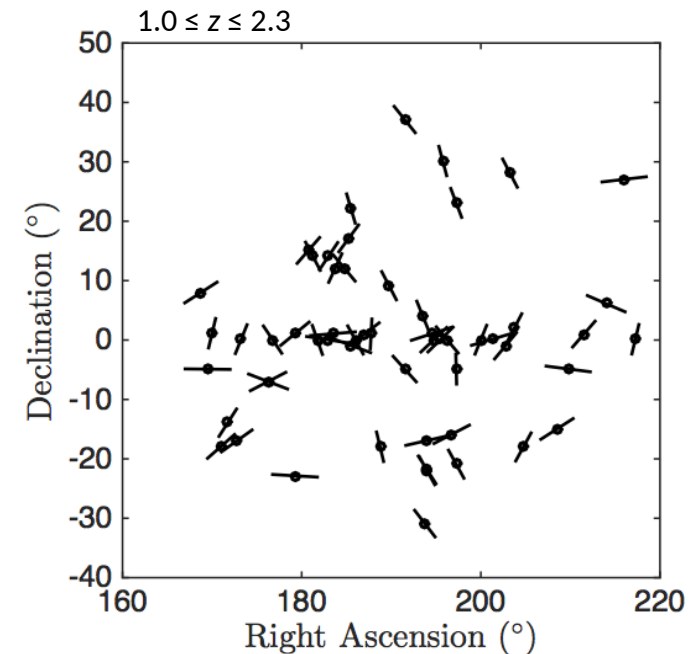
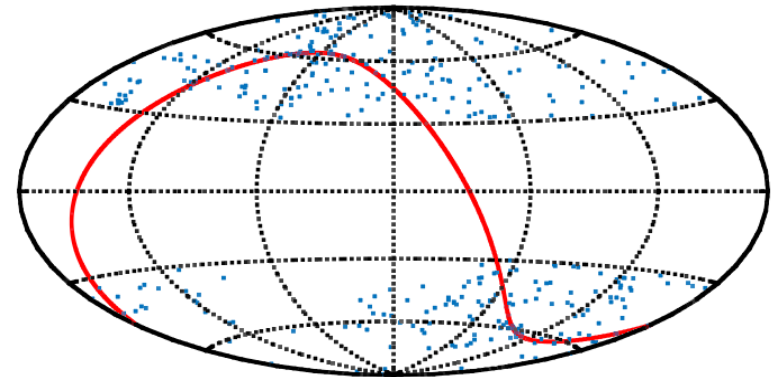
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Extreme-scale alignments of quasars optical polarization vectors

[Hutsemékers et al. 1998, 2005]

Anomaly:

“Optical polarization vectors from quasars appear to be significantly correlated through scales larger than Giga-parsec. No correlation between objects is expected at that scale.”

Proposed explanations: [not exhaustive list, quite long!]

- Cosmic strings / Cosmic loops
- Cosmological scale magnetic field
- Bi-refringence of the Universe
- Axion-like Dark Matter particle
- Anisotropic cosmological expansion
- ...

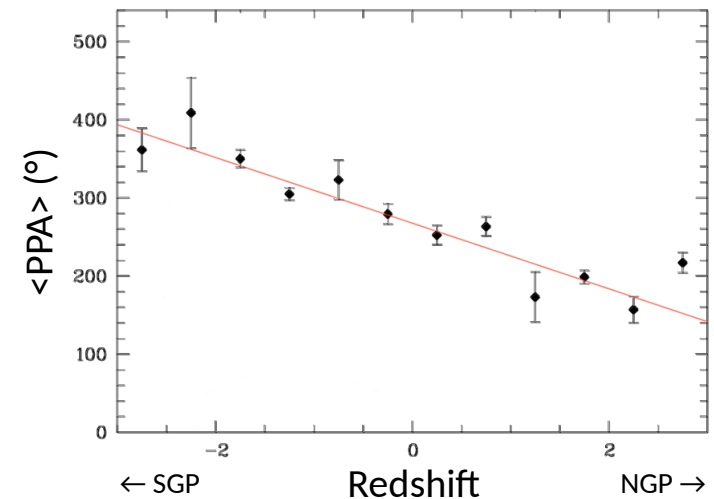
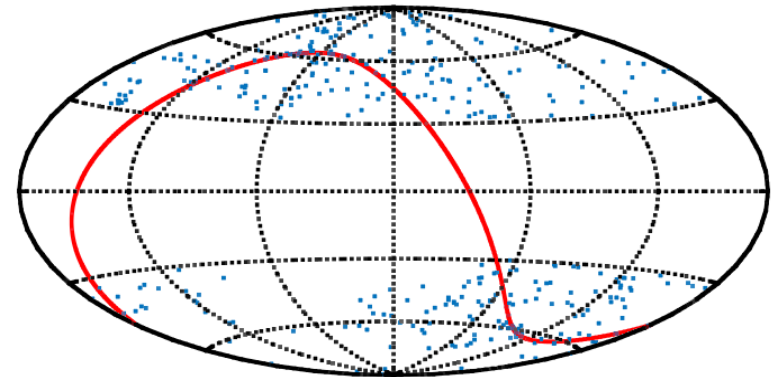
Still, no satisfying explanation

- Dust contamination in our Galaxy?
[naivest way to explain large-scale correlation]

[Hutsemékers et al. 1998,2001,2005] → NO!

- Redshift dependence of alignment direction
- Quality criteria:
 $|b_{\text{gal}}| \geq 30^\circ$; $p_{\text{lin}} \geq 0.6\%$ and $\sigma_\psi \leq 14^\circ$

BUT... ISM contamination estimate from starlight polarization measurement!

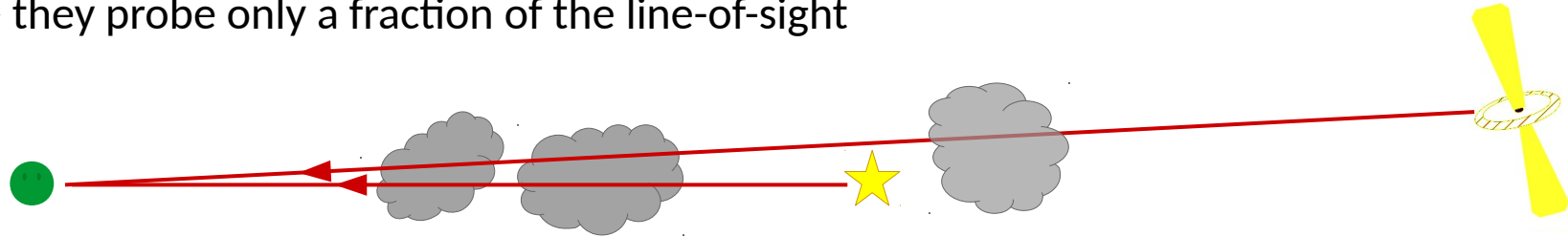


Extreme-scale alignments of quasars optical polarization vectors

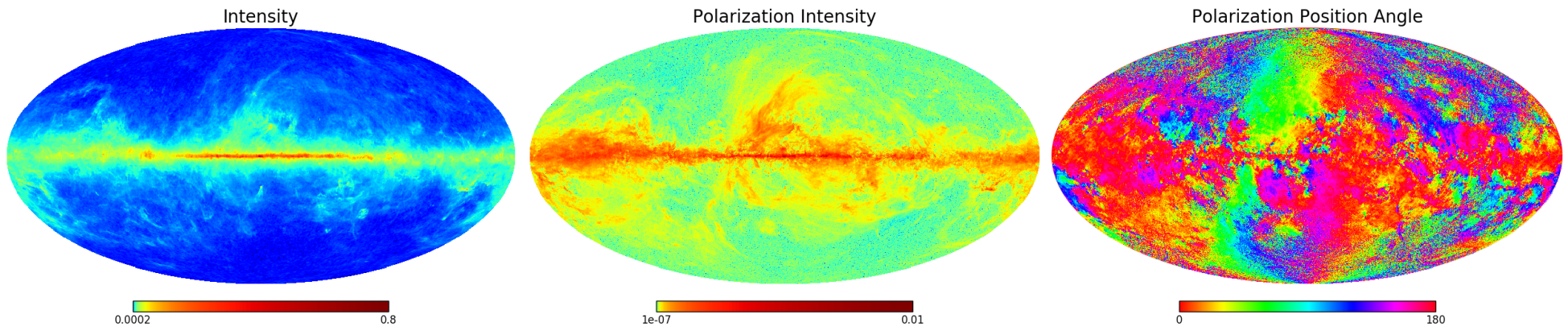
[Pelgrims 2017]

Foreground contamination by Galactic dust:

- ISM polarizability inferred by starlight is an under-estimation of the possible contamination
→ they probe only a fraction of the line-of-sight



- ISM polarizability can now be inferred from polarized Galactic dust emission directly, thanks to *Planck* 353-GHz polarization channel!
→ the whole line-of-sight through the Galaxy and above is integrated



!!! Large-scale features extend to high Galactic latitude

Extreme-scale alignments of quasars optical polarization vectors Gauging the Galactic dust contamination with Planck data

Motivation:

Verify the 'reliability' of quasar optical polarizations with respect to dust contamination, accounting for the whole line-of-sight

Results:

Cosmological-scale coherent orientations of quasar optical polarization vectors in the *Planck* era Surviving to Galactic dust contamination scenario

V. Pelgrims¹

[[astro-ph: arXiv:1709.10271](https://arxiv.org/abs/1709.10271)], *submitted to A&A*

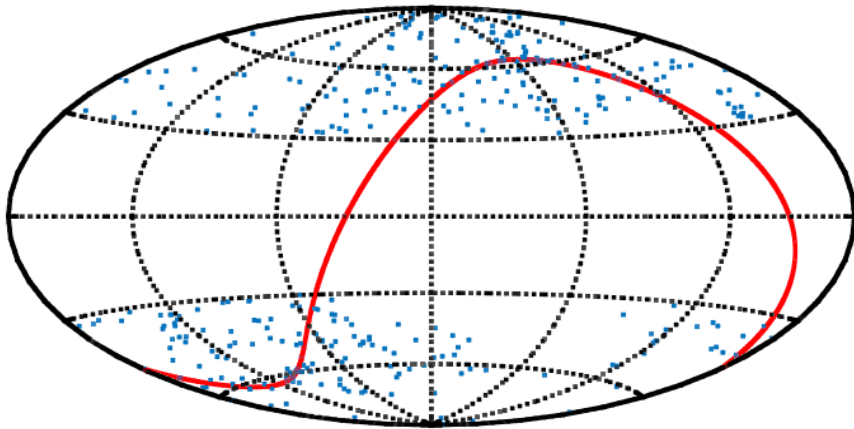
Extreme-scale alignments of quasars optical polarization vectors Gauging the Galactic dust contamination with Planck data

[Pelgrims 2017]

Looking for correlation:

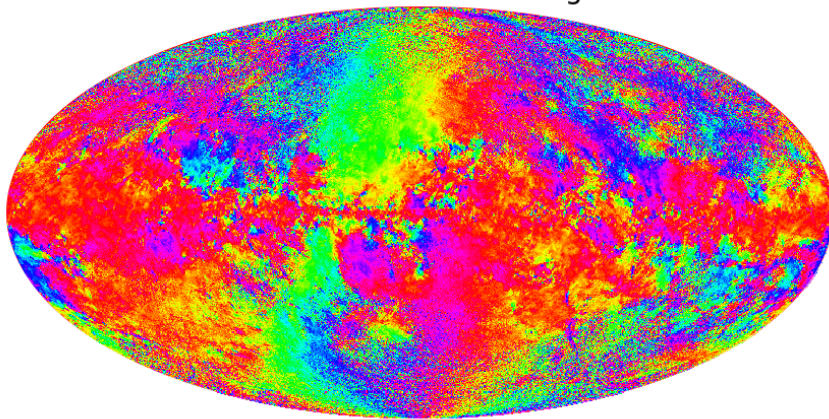
A position-angle approach

Quasar sky distribution

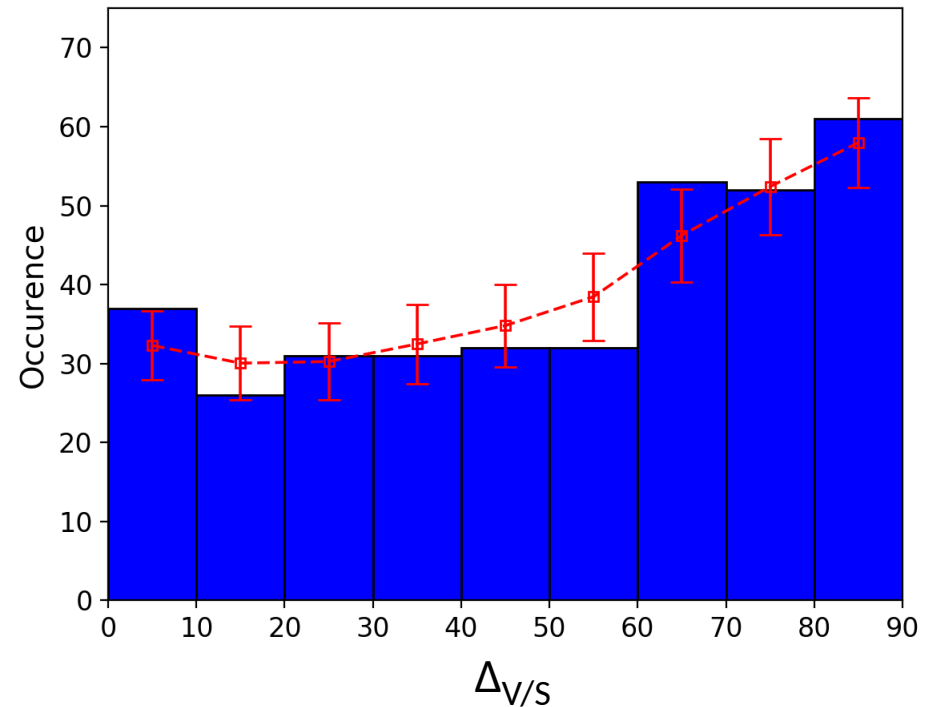


Planck map smoothed with 15' kernel

Polarization Position Angle



Relative Angle between quasar
and dust polarization vectors



Strong deviation from uniformity: $> 4\sigma$
→ correlated PPAs
→ measurable contamination

Extreme-scale alignments of quasars optical polarization vectors

Gauging the Galactic dust contamination with Planck data

[Pelgrims 2017]

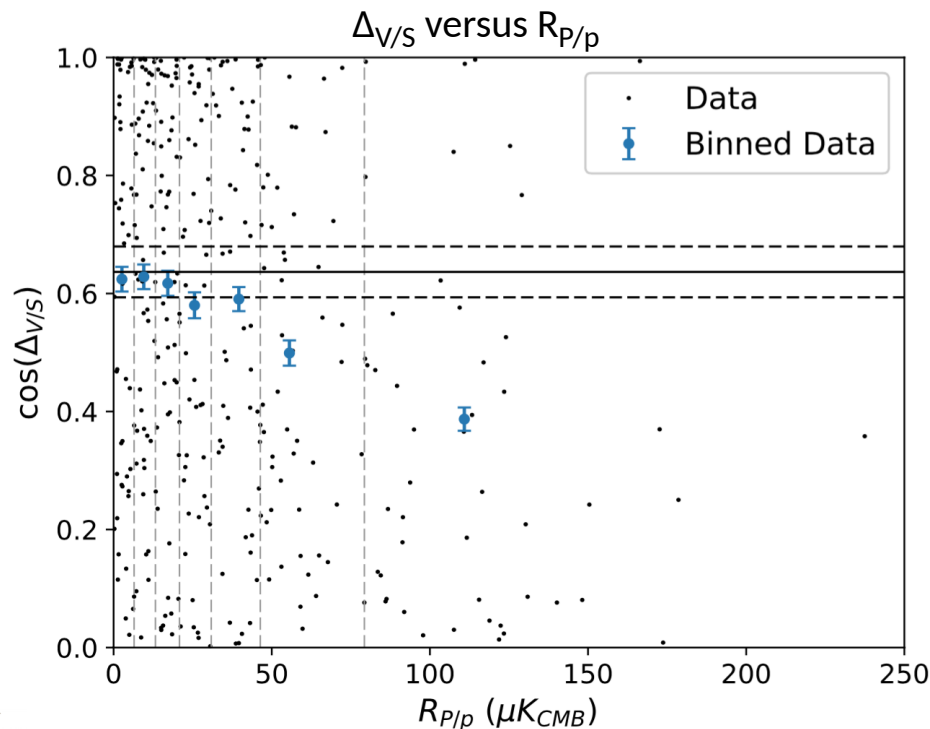
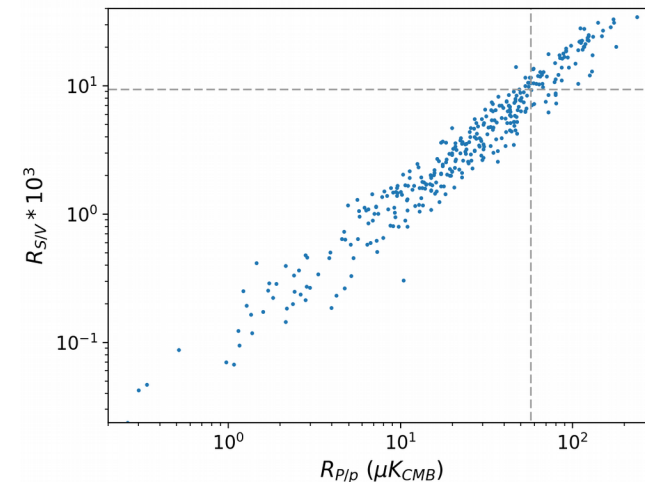
Investigating the correlation:

Use polarization ratios

$$R_{P/p} = \frac{P_{dust}}{p_{quasar}}$$

$$R_{S/V} = \frac{P_{dust}/I_{dust}}{p_{quasar}/\tau_{quasar}}$$

Large if contamination is likely to occur



- Correlation between $\Delta_{V/S}$ and $R_{P/p}$ detected at more than 4 sigma [Spearman + reshuffling]
- Corroborate contamination scenario
- !!! show that the contamination is detected ONLY for a fraction of the sample !!!

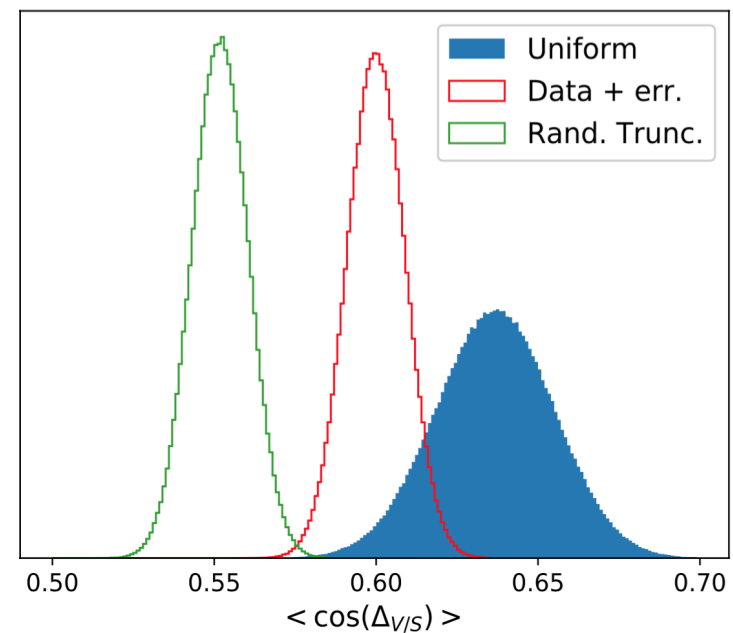
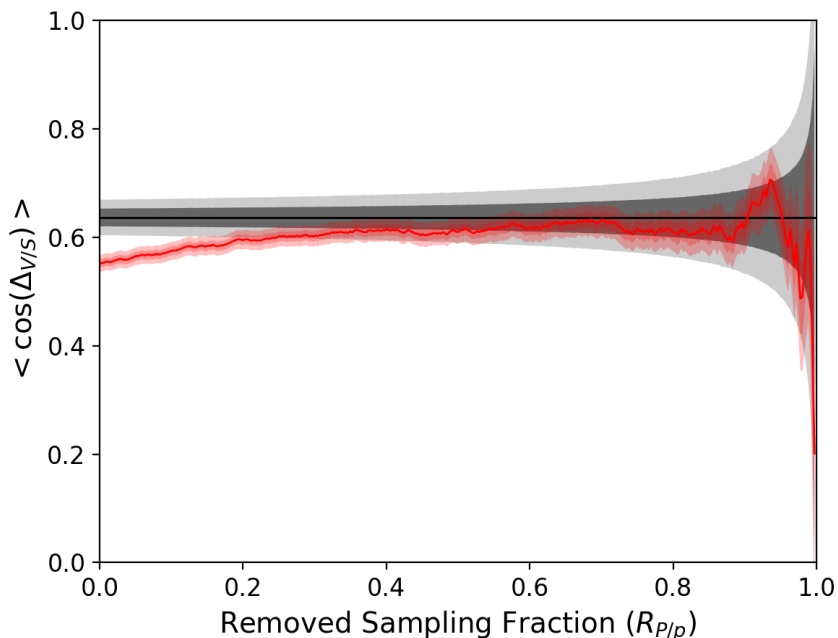
Extreme-scale alignments of quasars optical polarization vectors

Gauging the Galactic dust contamination with Planck data

[Pelgrims 2017]

Towards unbiased quasar sample:

- The contamination likely involve only a fraction of the sample.
- Truncation of the sample lead to a 'clean' quasar optical polarization sample, i.e. such that the correlation with dust disappears



Removing 20 – 30 % of the sample appear to be sufficient to have a quasar polarization sample clean enough from the dust.

Extreme-scale alignments of quasars optical polarization vectors

Surviving to Galactic dust contamination scenario

[Pelgrims 2017]

Results:

- Remaining dust contamination in the original quasar sample contamination possibly previously missed by field star inquiries
- Introduction of a new quality criteria using dust polarized emission takes into account the dust contribution along the whole line-of-sight
- 70 – 80 % of the optical quasar polarization sample used to study the extreme-scale alignment is SAVED from dust contamination dust contribution should be very small (undetected but there!)
- The new quality criteria select *almost* homogeneously the sources in the parameter space $(RA, dec, z, p_{\text{quasar}}, b_{\text{gal}}, l_{\text{gal}})$
 - the extreme-scale alignments of the quasar optical polarization cannot be accounted for by Galactic dust
 - phenomenological details of the alignments might be slightly modified [this has to be tested in future works, but waiting more data]

Extreme-scale alignments of quasars optical polarization vectors

Surviving to Galactic dust contamination scenario

Results:

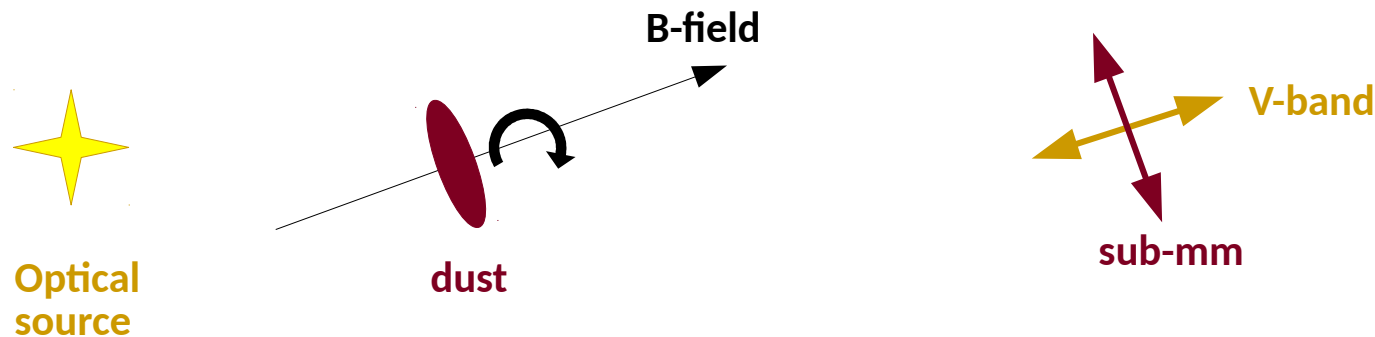
- Remaining dust contamination in the original quasar sample
- Introduction of a new quality criteria using dust polarized emission
- 70 – 80 % of the optical quasar polarization sample used to study the extreme-scale alignment is SAVED from dust contamination
- The new quality criteria select *almost* homogeneously the sources in the parameter space (RA, dec, z, p_{quasar} , b_{gal} , l_{gal})
 - the extreme-scale alignments of the quasar optical polarization cannot be accounted for by Galactic dust
 - the phenomenology of the alignments might be slightly modify
- That study also shows that comparing the optical polarization of astrophysical objects with dust polarization as recorded by Planck is feasible at *high* Galactic latitudes, and seems to make sense
 - Comparison with V-band starlight might lead to constraints on the 3-dimensional mapping of:
 - three dimensional dust distribution in our Galaxy
 - constraints on three-dimensional Galactic magnetic field

- Thank you -

Extreme-scale alignments of quasars optical polarization vectors

Foreground contamination by Galactic dust: a scenario

- Dust polarization arises from thermal emission of aspherical dust grains that align with Galactic magnetic field lines
- Optical light of a background source undergoes an anisotropic absorption by the same dust grains (depolarization)
 - production of an effective optical polarization
- induces starlight optical polarization (assumed to be zero for 'normal' stars)
- adds to the intrinsic optical polarization of quasars: *contamination*



**Polarization in absorption (optical) and emission (sub-mm)
are expected to be perpendicular by construction**

Extreme-scale alignments of quasars optical polarization vectors

Surviving to Galactic dust contamination scenario

References:

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- Planck Coll. Int. Res. XXI, 2015, A&A 576, A106
- Planck Coll. Int. Res. XXII 2015, A&A 576, A107
- RADIOFOREGROUNDS project <http://www.radioforegrounds.eu/>