The origin of dust polarization in the Orion Bar

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SOFIA Teletalk
July Wednesday 26th 2023

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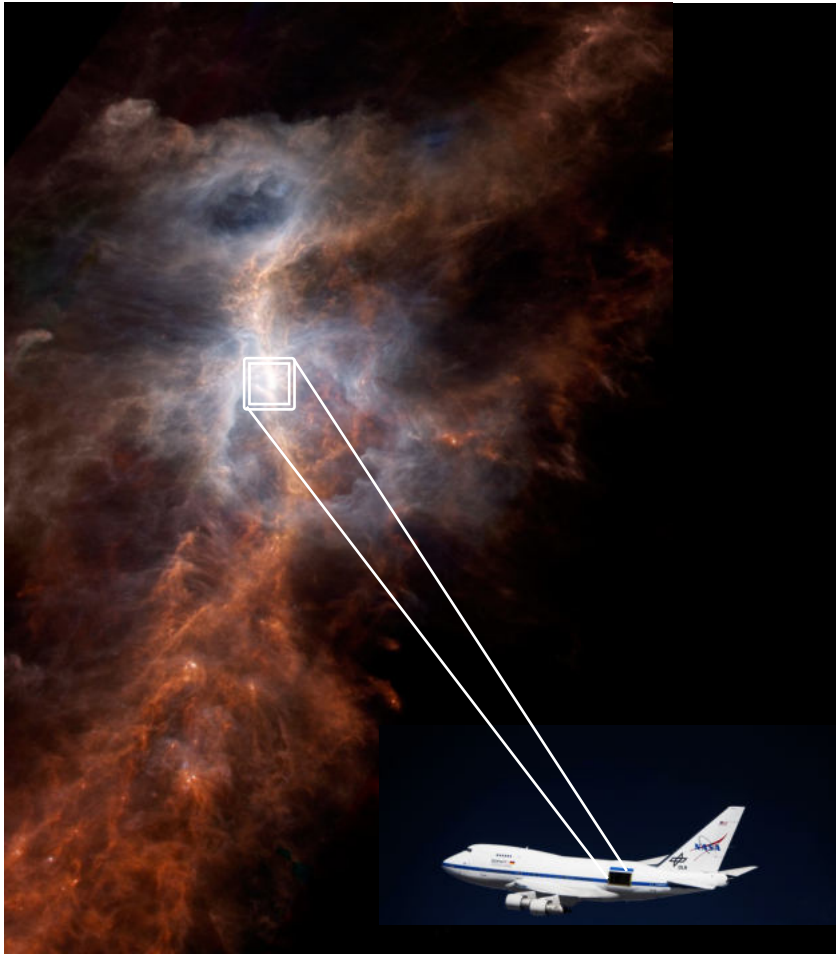
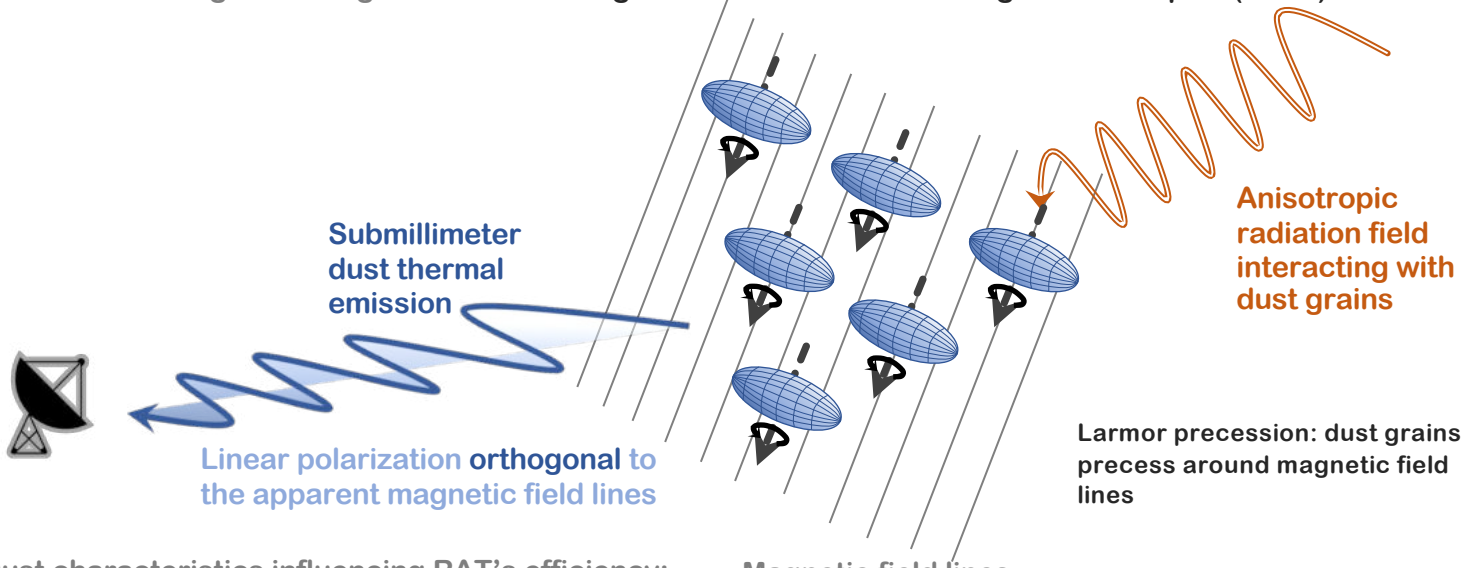


Credit: ESA/Herschel

Dust polarization and grain alignment

What **grain alignment mechanisms**?

- **B-RATs** : alignment of grains with the **magnetic field** via **Radiative Alignment Torques (RATs)**



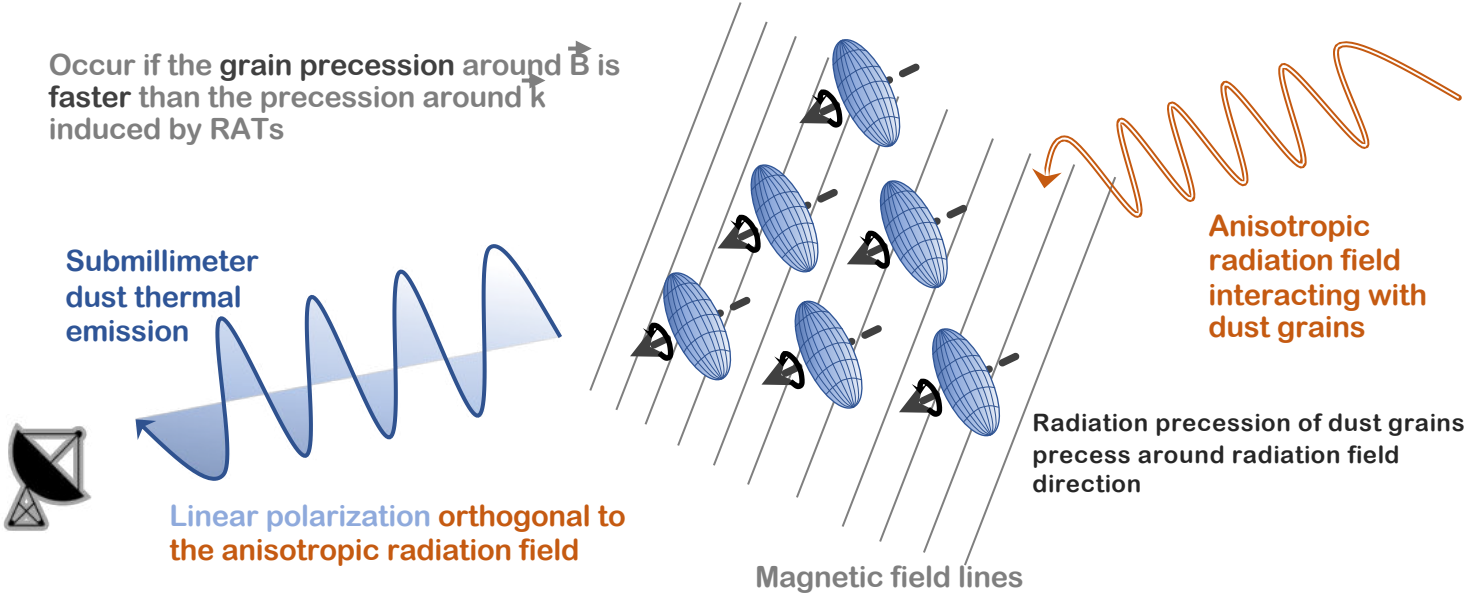
Dust characteristics influencing RAT's efficiency:

- Size
- Shape
- Composition

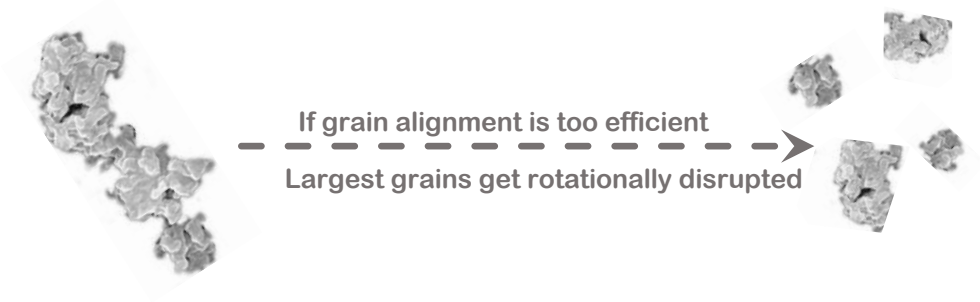
Dust polarization and grain alignment

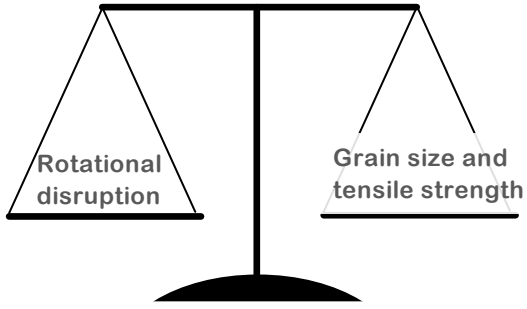
What **grain alignment mechanisms?**

- B-RATs : alignment of grains with the magnetic field via Radiative Alignment Torques (RATs)
- **k-RATs : alignment of grains with the radiation field via Radiative Alignment Torques (RATs)**

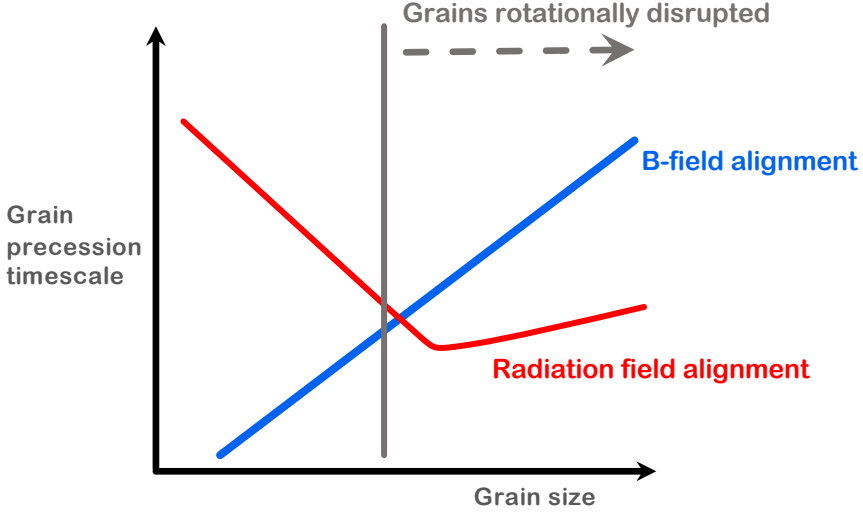


Processes acting on aligned dust grains





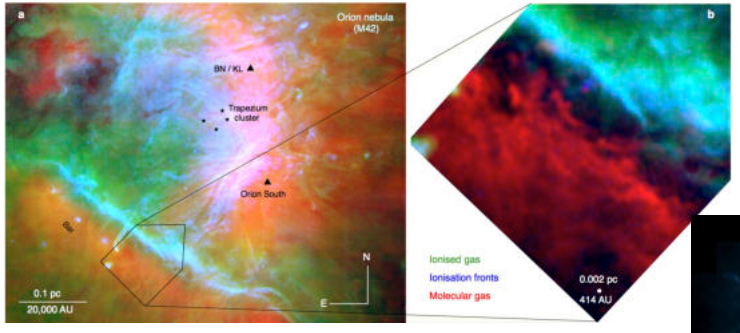
RATD mechanism, see Hoang+2019



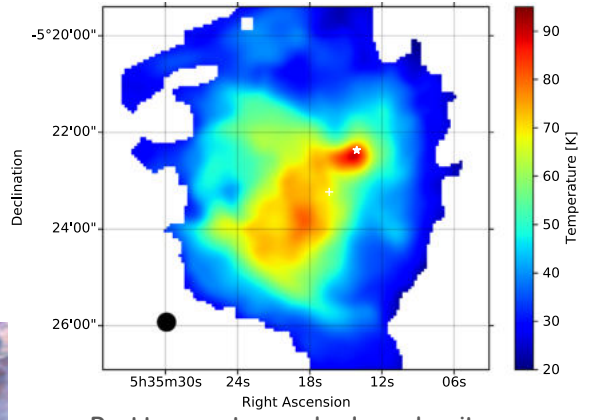
- Large grains in supra-thermal rotation can be eligible to rotational disruption depending on their tensile strength.
- Radiative precession becomes dominant over magnetic field precession for larges grains rotating at thermal velocities.

Aligned dust grains in the Orion Bar

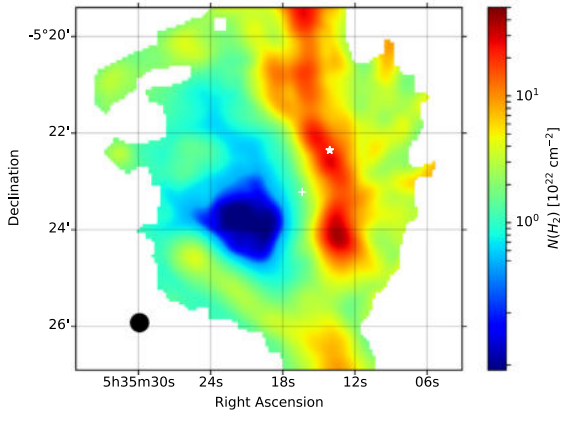
- Do magnetic fields play a role in regulating the evolution of PDRs?
- Do we trace the magnetic field via with dust polarization in such irradiated regions?



Goicoechea + 2016

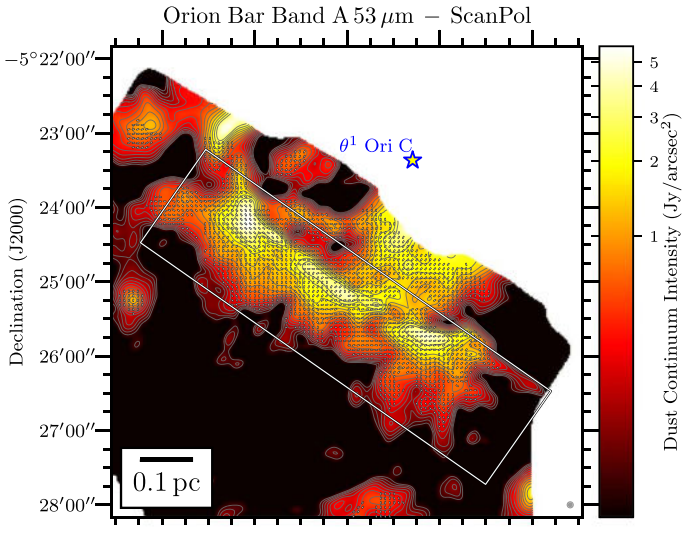


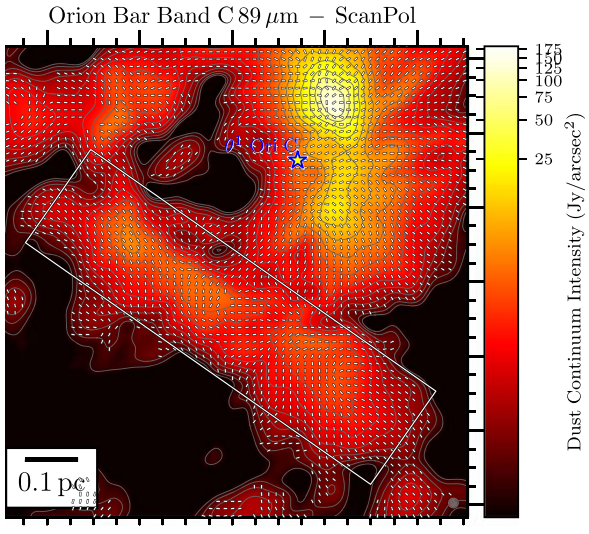
Dust temperature and column density map from SED fitting (Chuss + 2019)

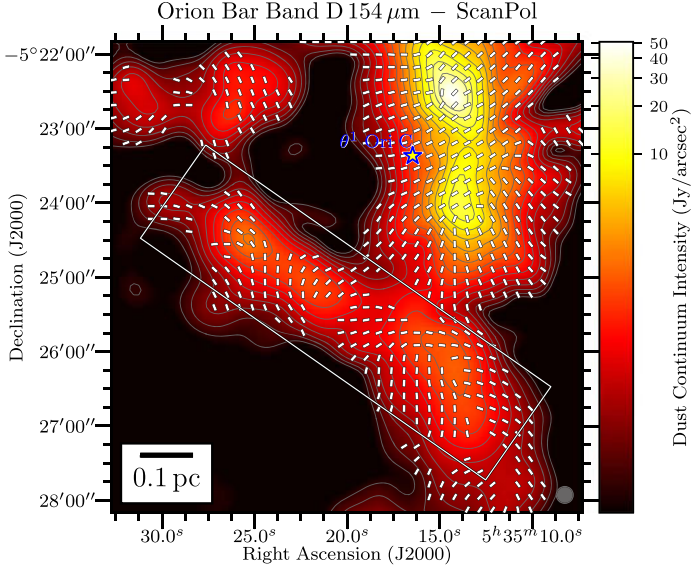


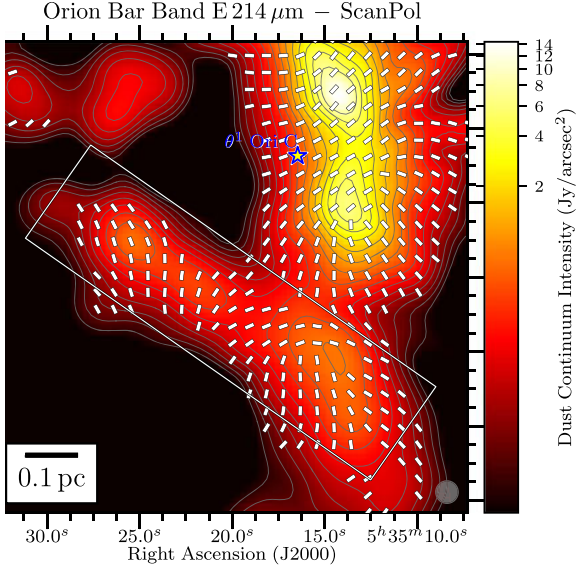
➢ The example of the Orion Bar

Aligned dust grains in the Orion Bar



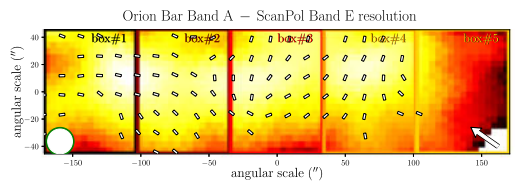


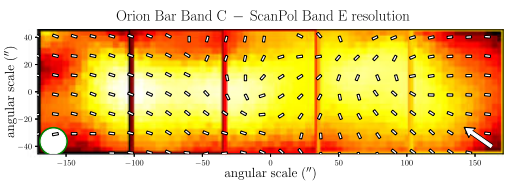


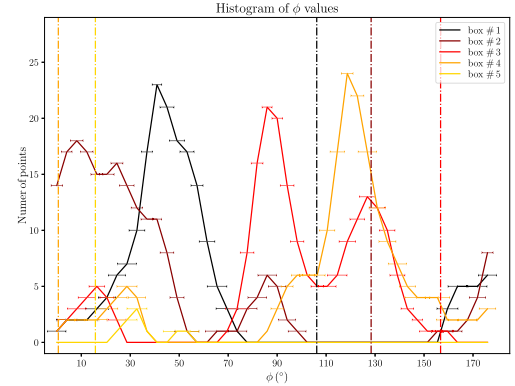


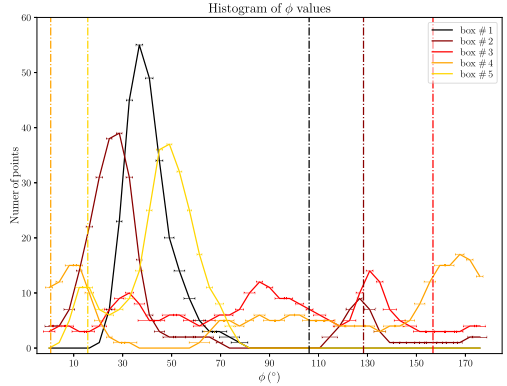
SOFIA HAWC+ Scan-Pol dust polarization observations at 53, 89, 154, and 214 μm

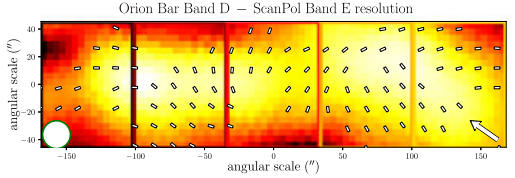
Le Gouellec + 2023

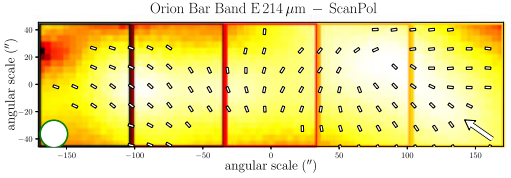


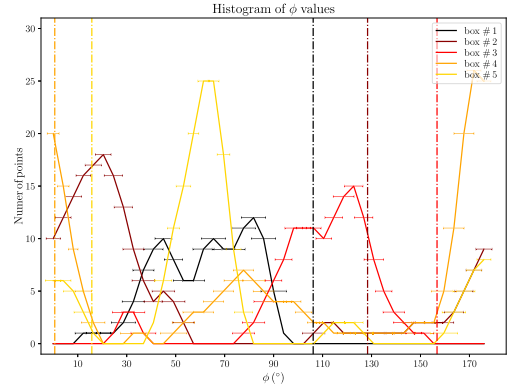


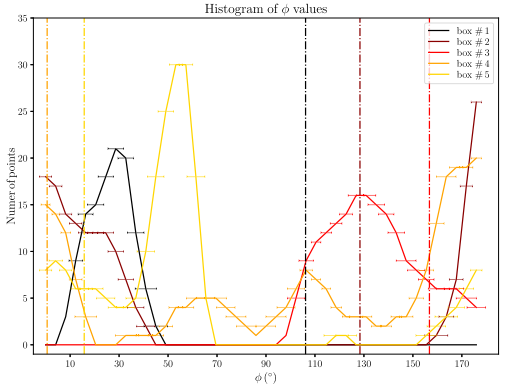












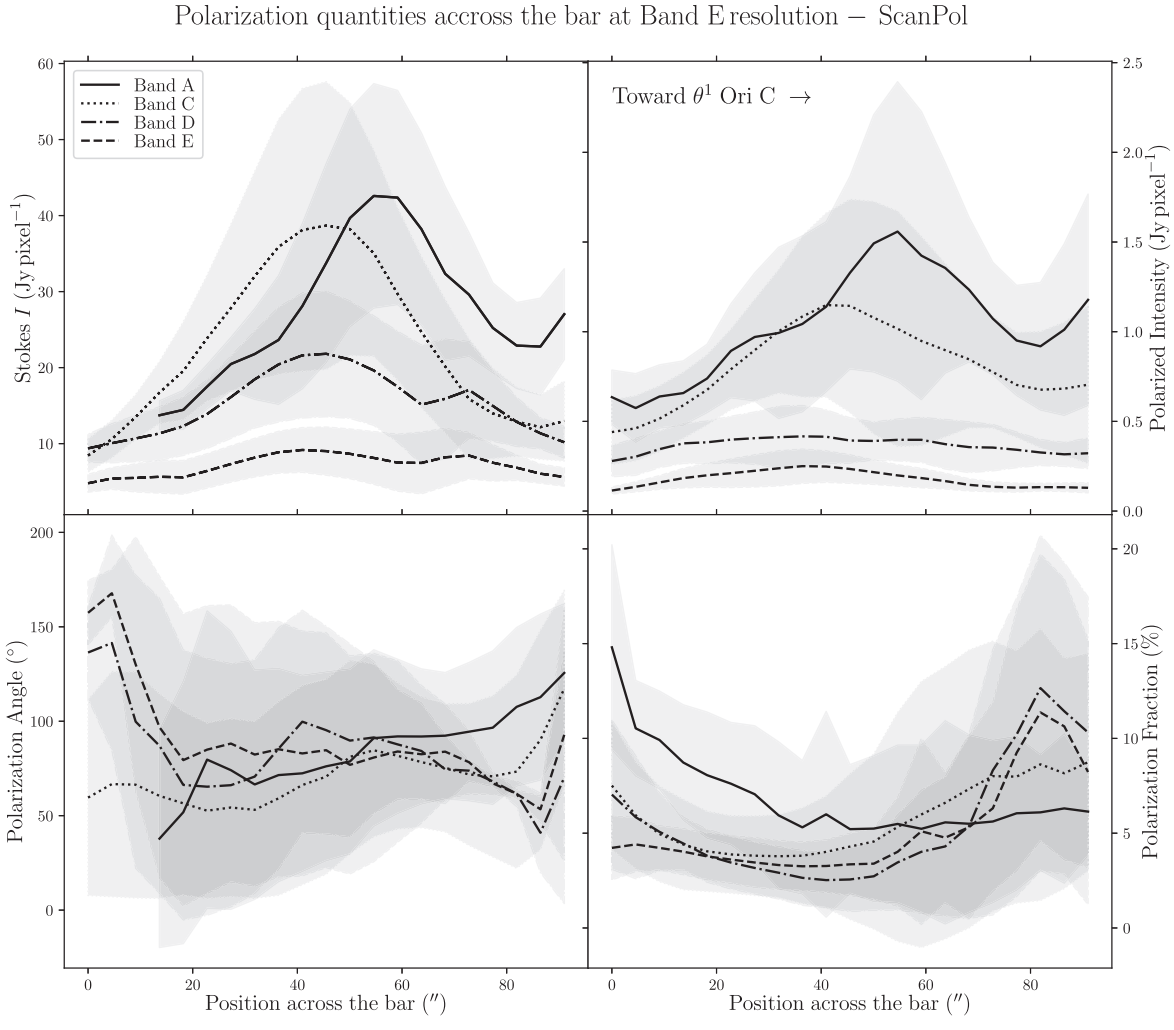
Aligned dust grains in the Orion Bar

We find :

- **No variations** of polarization angles change across wavelengths within ~20°
- Polarization angles change are **not** consistent with grains being aligned the radiation field from the Trapezium cluster

➢ Grains in supra-thermal rotation aligned with the magnetic field are dominating the FIR polarization.

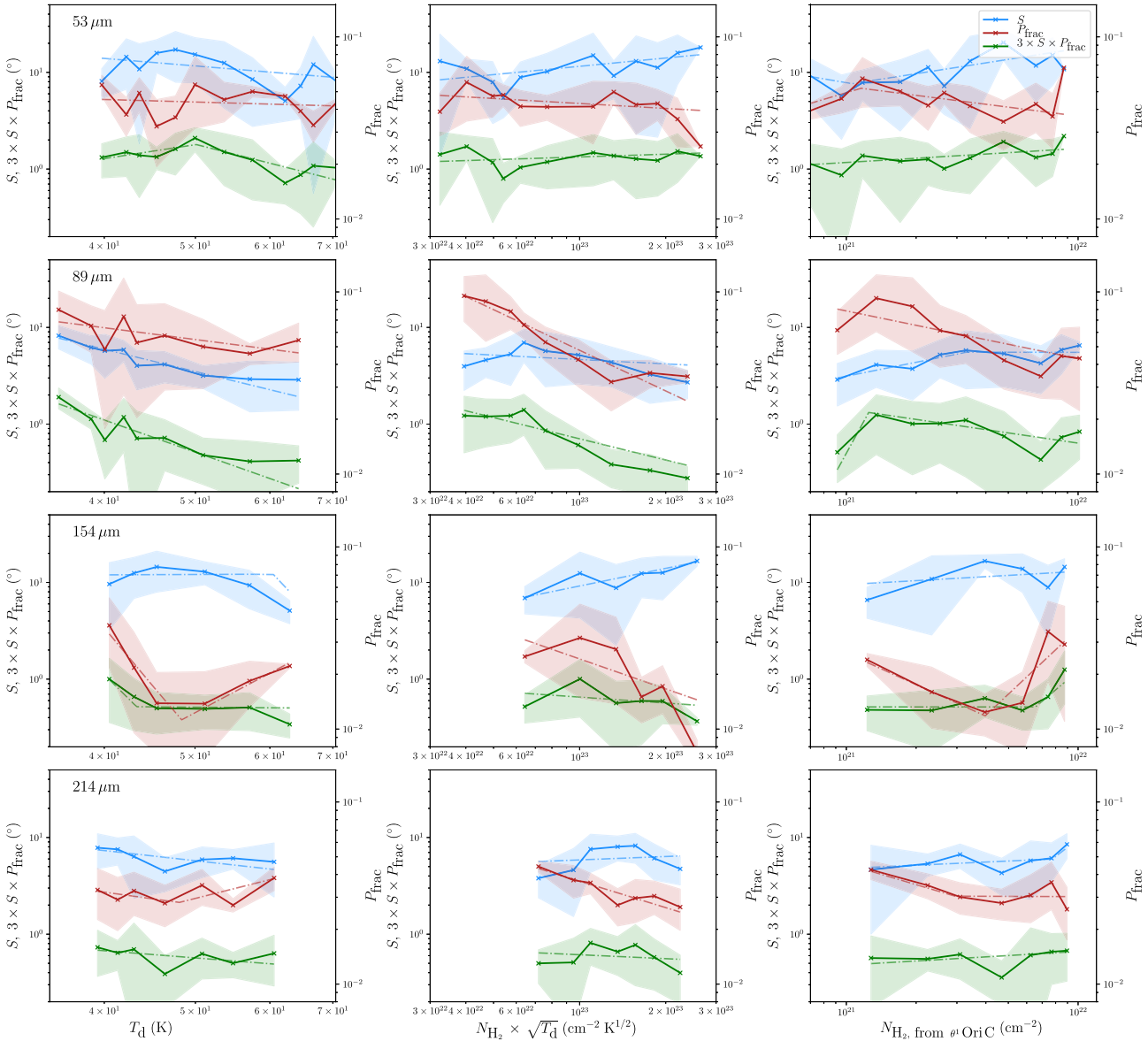
Aligned dust grains in the Orion Bar



See the different profiles for the Band A dataset compared to Band C, D, and E.

Clearly tracing a hotter dust component in Band A.

Band A potentially also suffer from systematics.



Comparing grain alignment efficiency with RAT's theory

Using P_{frac} x S as a proxy for grain alignment efficiency

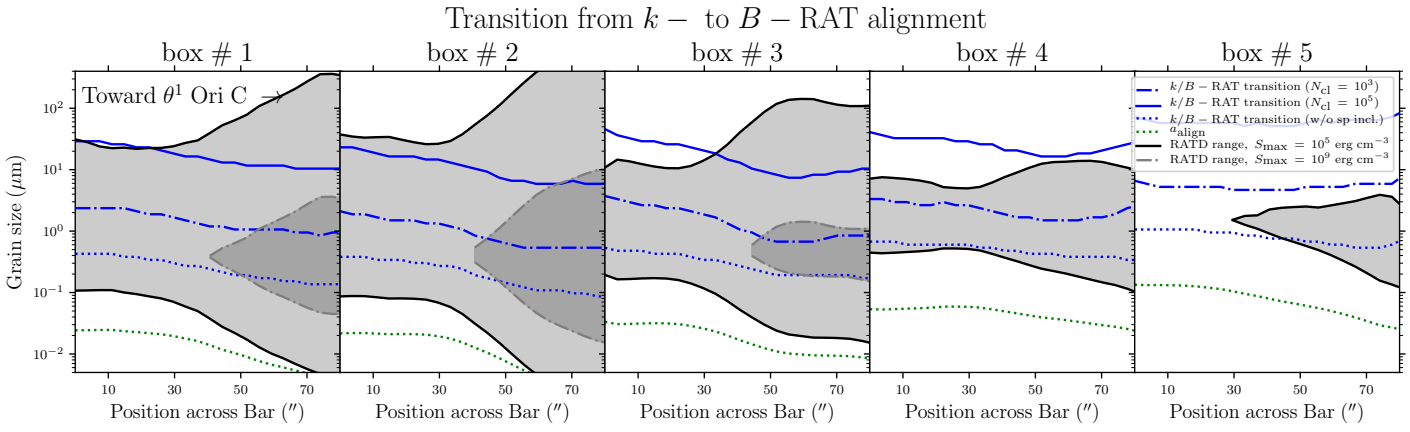
Dust temperature as a proxy for irradiation field strength

N_{H2} x $(T_d)^{1/2}$ as a proxy for gas randomization

$N_{H2\ from\ Trapezium}$ as a proxy for the reddening

- Observations are not consistent with RAT theory without invoking dust grain evolution

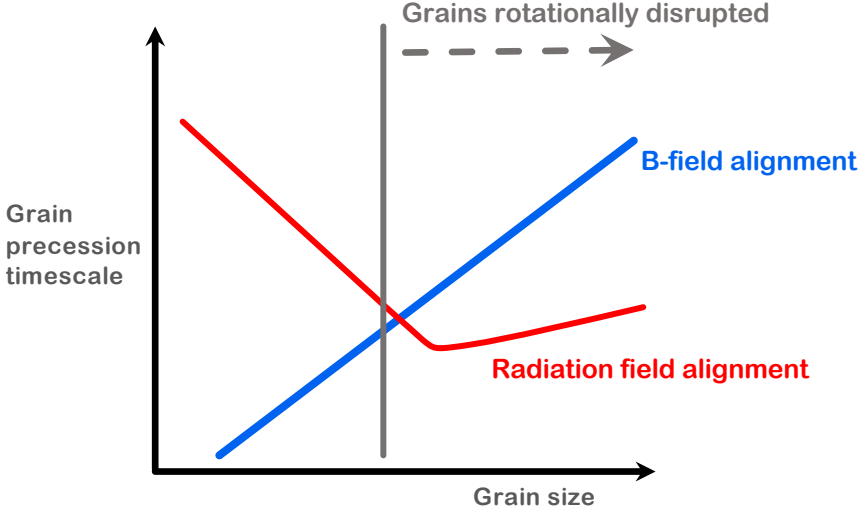
Modeling of aligned dust grains in the Orion Bar



Above: radiative alignment

Below: magnetic alignment

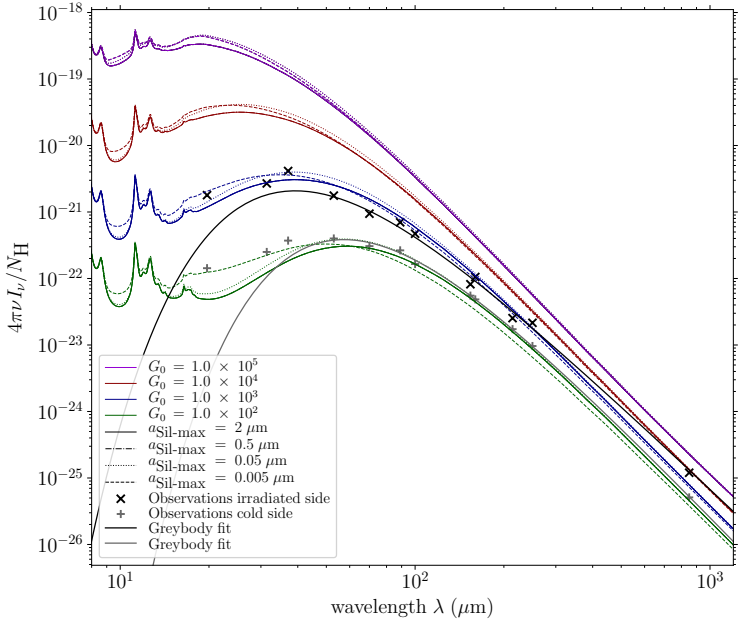
Gray area: grain disruption

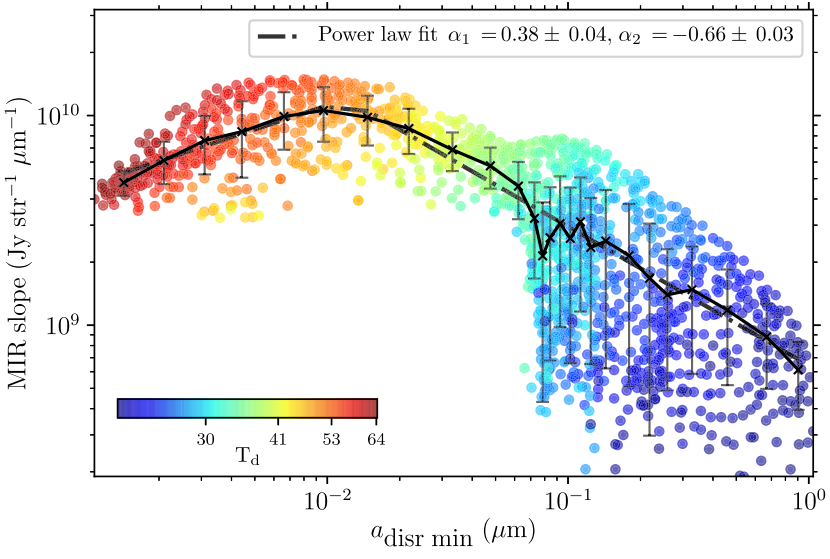


Only large grains are eligible to *k*-RATs.

- These large grains don't dominate the FIR dust polarization emission
- There are big enough to be disrupted by RATD if grains are efficiently aligned.

Dust grain evolution across the Bar ?



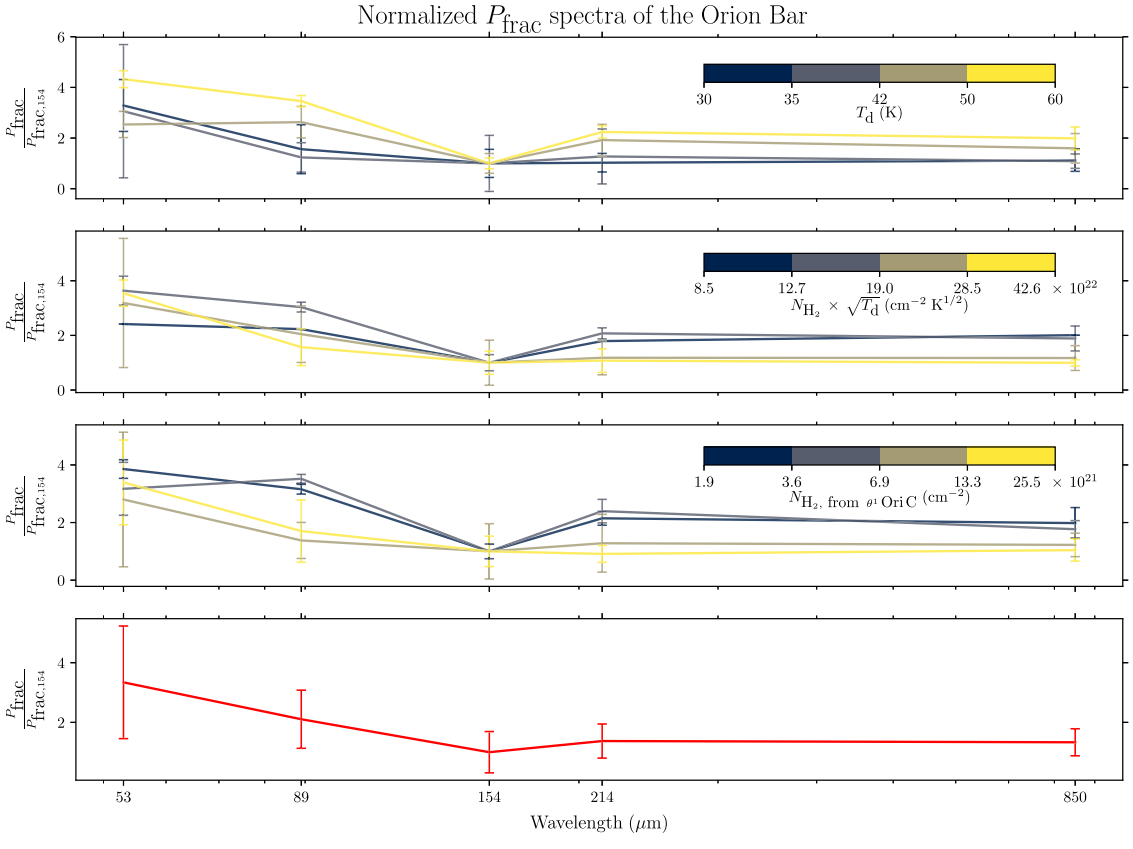


Can we constrain the rotational disruption of aligned grains (i.e., silicates) in the bar ?

Insights from the MIR SED

MIR slope as a tracer of large grain depletion ?

Dust grain evolution across the Bar ?



FIR to submillimeter polarization fraction spectra: synergy between SOFIA HAWC+ and JCMT POL2.

Spatially resolved modeling of such spectra would be valuable to constrain the evolution of the large grains across PDRs.

Can mechanical alignment contribute?

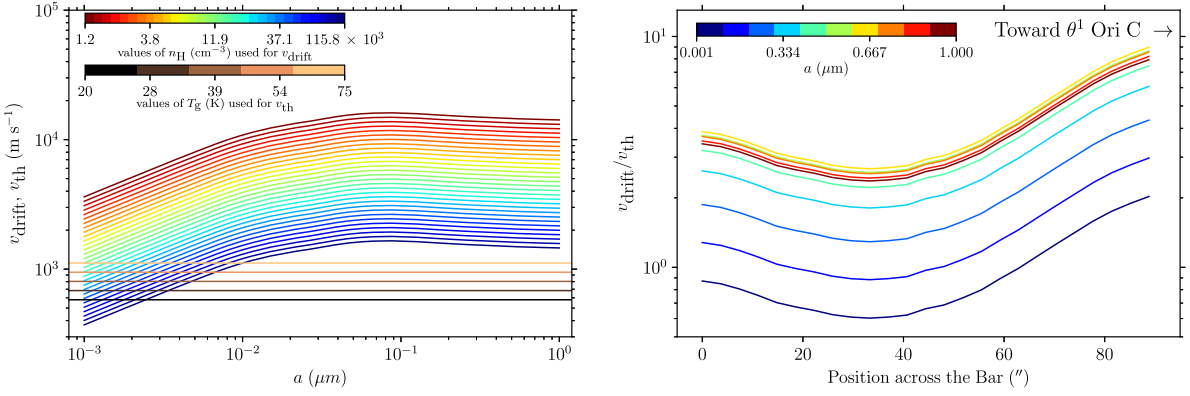


Figure 16. Gas–dust drift and thermal velocities derived with the environmental conditions of the Orion Bar. Left panel: the gas–dust drift (thermal) velocities are shown with rainbow colors (tints of orange) for a range of gas volume density (gas temperature) values encountered in the Orion Bar. We estimate the gas–dust drift using the Equation (19) of Schirmer et al. (2022). Right panel: evolution of gas–dust drift to thermal velocity ratio as a function of the position across the Orion Bar (we used the map of $n_{\rm H}$ and T_d we derived from Chuss et al. (2019)) for several grain sizes, indicated by the different colors.

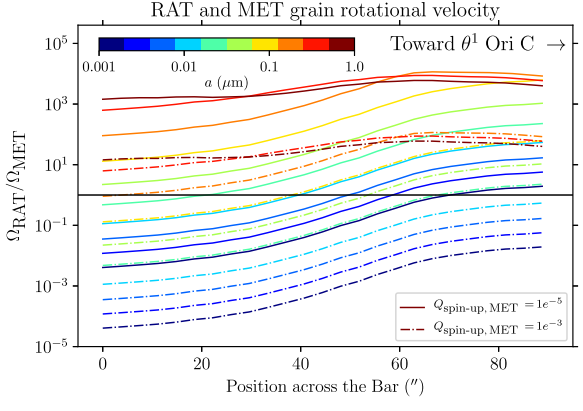
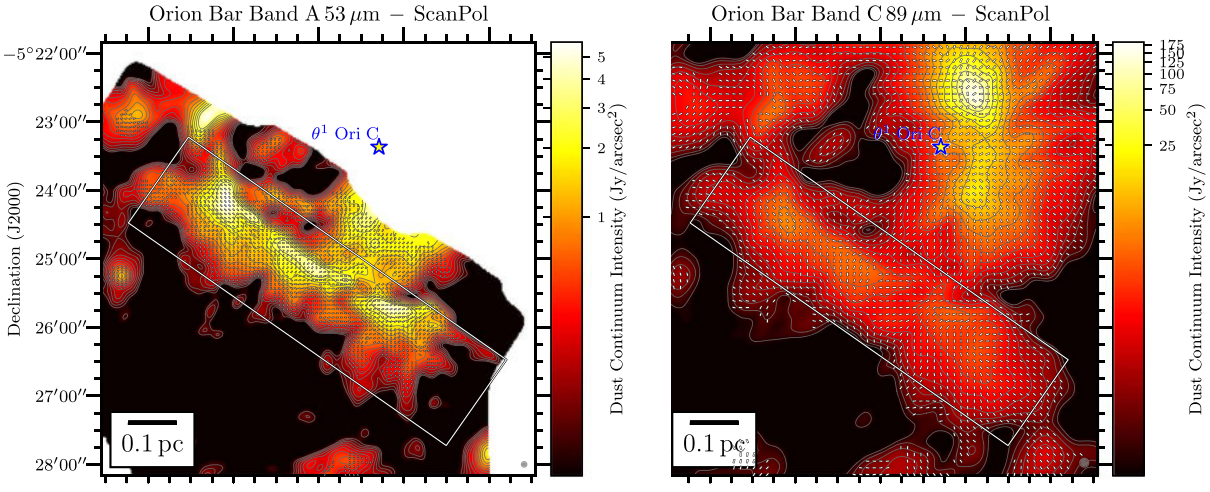


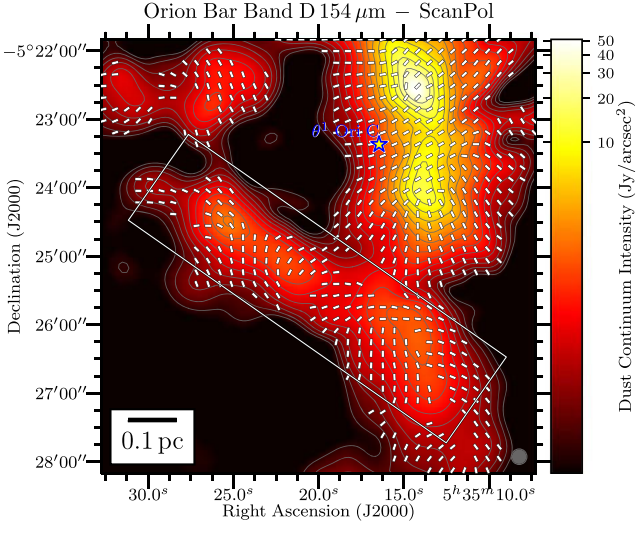
Figure 17. Evolution of grain rotational velocity ratio $\Omega_{\rm RAT}/\Omega_{\rm MET}$ as a function of the position across the Orion Bar. The color of the lines correspond to different grain sizes. Solid (dotted–dashed) lines correspond to grain rotational velocity ratio calculated for a MET spin-up efficiency of $Q_{\rm spin-up,\,MET} = 10^{-5}$ (10^{-3}). The horizontal black line denotes the location where $\Omega_{\rm RAT} = \Omega_{\rm MET}$.

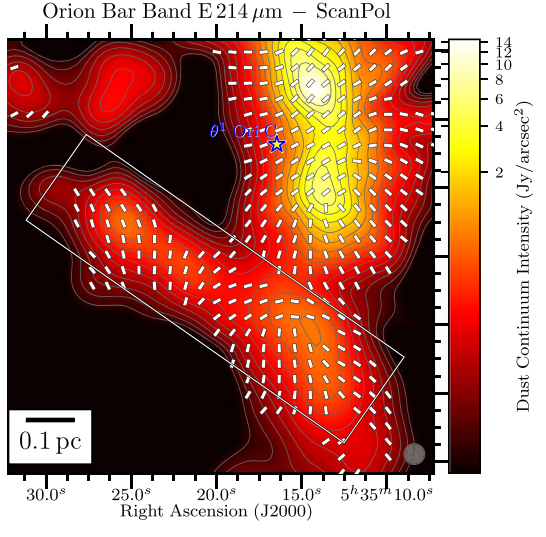
Gas randomization would limit the drift of small grains once within the dense cloud.

- **Mechanical alignment is not likely to be dominant in the Orion Bar PDR.**

Summary: origin of dust polarization in the Orion Bar







Orion Bar PDR

- No transition of polarization angle as a function of wavelength
- Grains are not predominantly aligned with the radiation field.

➢ Grains in supra-thermal rotation aligned with the magnetic field are dominating the FIR polarization.

- Maximum grain size of aligned grains could be governed by rotational disruption depending on their tensile strength. This can be an active factor of dust grain evolution across the Orion Bar PDR.