Observational Constraints on Interstellar Grain Alignment

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Why do we care?

- Optical/NIR ISM polarization arises due to dicroic extinction by aligned, asymmetric, dust grains
  - Discovered in 1949, still not well understood!
  - FIR polarimetry from emission by aligned grains
- Polarimetry can be used to
  - Trace magnetic field structure
  - Measure field strength through Chandrasekhar-Fermi analysis
  - Grain micro-physics
- But if we don’t know which grains we are probing, we don’t know what it means!
Modern theory favors RATs

- An asymmetric grain will have a differential right-hand/left-hand helicity ("basis vector decomposition")
- The helicity of the grain "absorbs" torques from the circular polarization in an asymmetric radiation field.
- Alignment should depend (amongst other) on:
  - Radiation field strength
  - Radiation field colour (\(\lambda/a\))
- Pin-wheel torques ("quasi Purcell") might enhance the Radiative Alignment Torques alignment
How do we measure grain alignment?

- Fraction of aligned grains
  - \( p/A_v \)
  - Sensitive to l.o.s. turbulence/field topology
    - (polarization is a vector!)
- Relative alignment of different grain sizes
  - Measure \( \lambda_{\text{max}} \)
  - Requires multi-band data

\[
p(\lambda) = p_{\text{max}} e^{-\left[K \ln^2(\lambda_{\text{max}} / \lambda)\right]}
\]
When observational biases:

- Anomalous sightlines
- Near-by bright stars
- Cloud-to-cloud differences in grains size

are corrected for:

Universal relation:

\[ \lambda_{\text{max}} = (0.157 \pm 0.002) \langle R_v \rangle + (0.0252 \pm 0.004) A_{\text{V}} \]

Supports radiative grain alignment
Can be used to probe for secondary effects
Alignment is enhanced close to a bright star

- Measure the differentials of $I_{60}/I_{100}$ and $\lambda_{\text{max}}$ vs. the nominal relations as functions of $A_V$, close to HD 97300 in Chamaeleon.

Additional radiation $\Rightarrow$ additional alignment
Do pin-wheel torques contribute?

- Deep H$_2$ 1-0 S(1) imaging
- 15 sightlines with NOT/ALFOSC
- H$_2$ formation seems to enhance the alignment
- If true: Grains are not super-paramagnetic
Conclusions

A quantitative theory of grain alignment has recently been developed, based on direct radiative effects.

We have observationally shown that:

- $\lambda_{\text{max}}$ correlates with $A_V$
- Alignment enhanced close to bright star
- Alignment seems to be enhanced by H$_2$ formation

Supporting radiative alignment theory.

A 60 year old problem is being solved!