ALMA polarization observations toward the protoplanetary disks around HD 142527 and HD 163296

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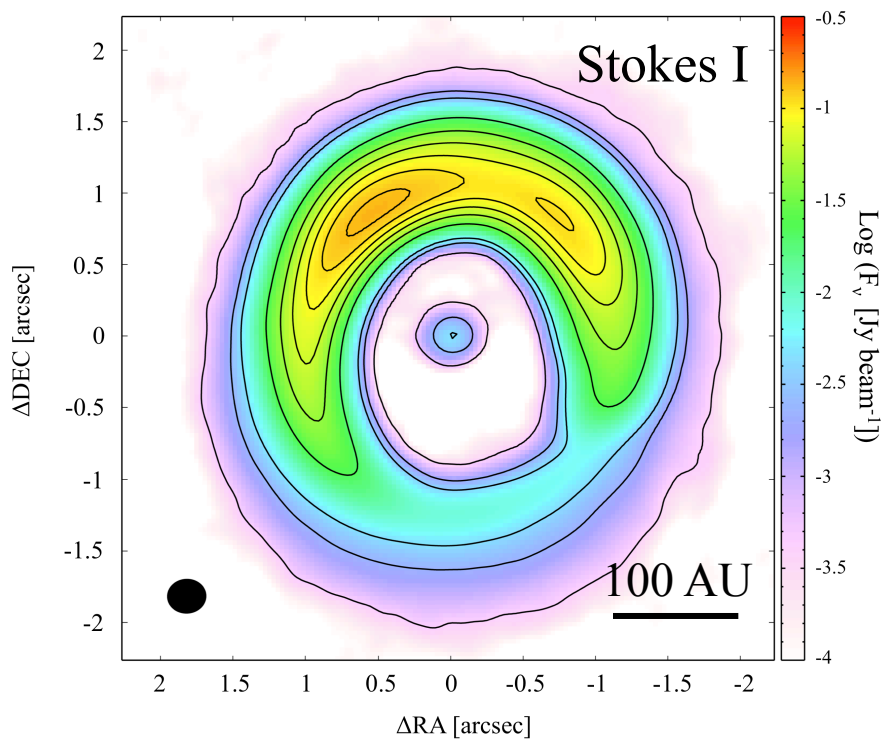
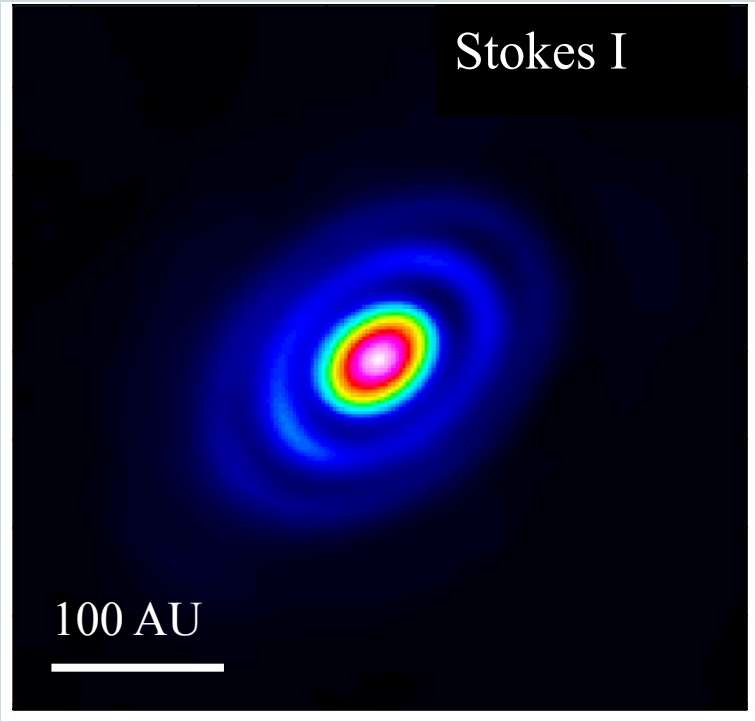
HD 142527

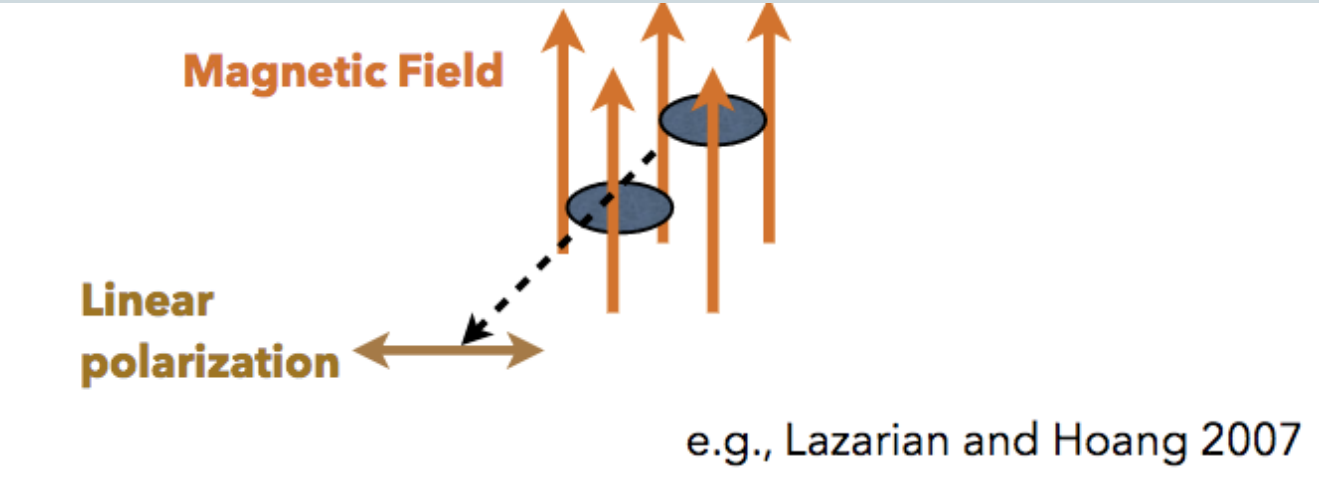


HD 163296



mechanisms of polarization in disks

- 1. alignment of dust grains with magnetic fields



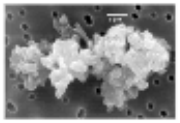
- 2. self scattering of thermal dust emission

  e.g., Kataoka et al. 2015

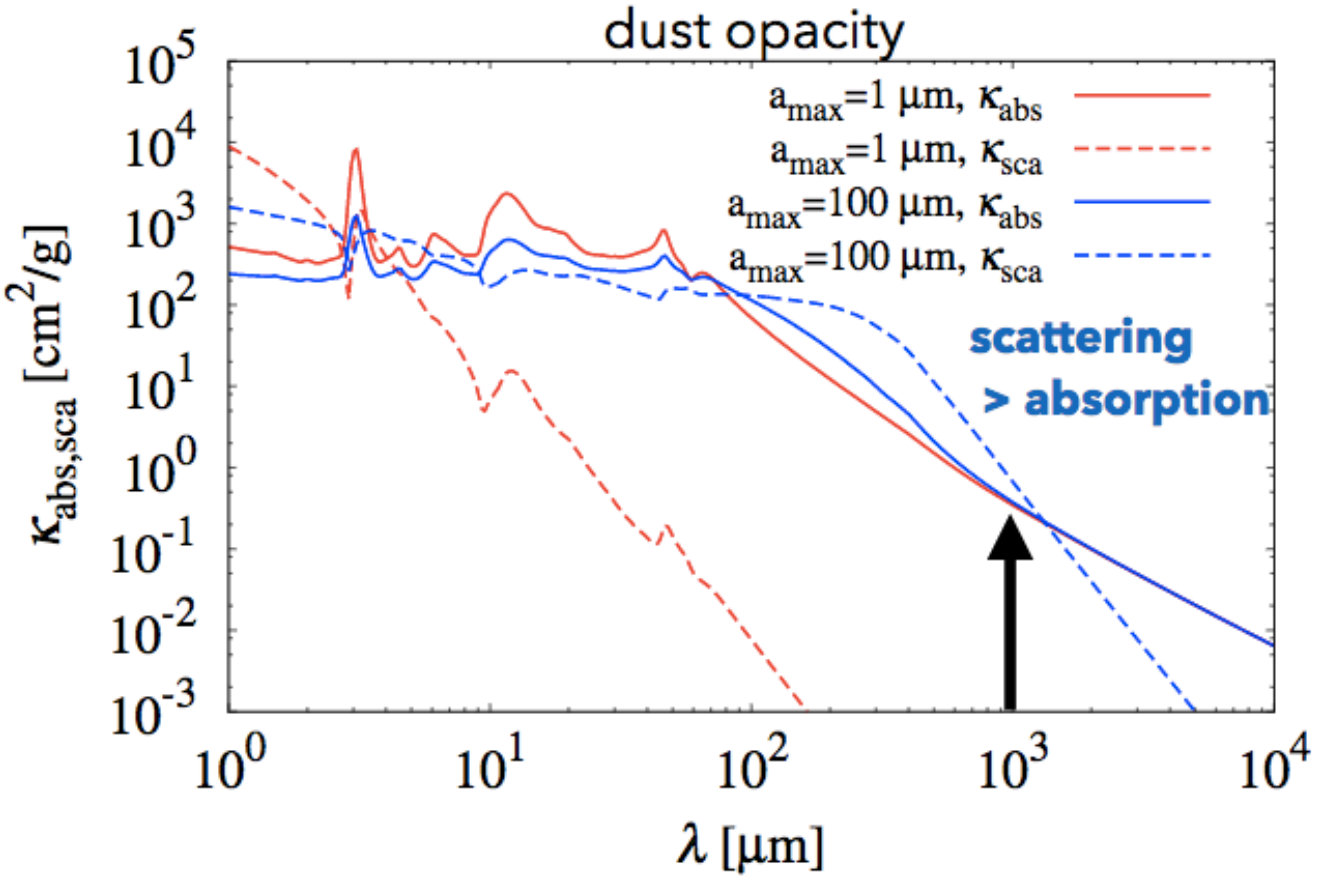
- 3. alignment of dust grains with radiation fields

  e.g., Tazaki et al. 2017

Dust is big in disks



0.1μm — 1mm — 1m — 1km — $10^{2\text{-}4}$km



Conditions of dust grains for polarization

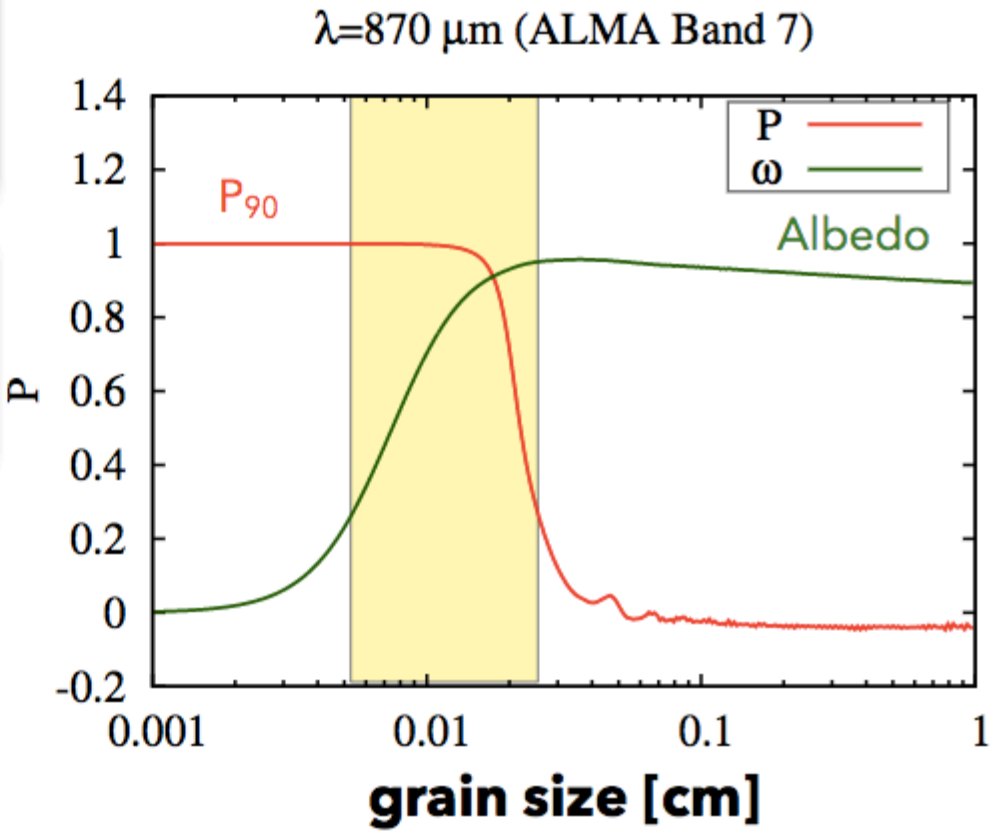
- For efficient scattering

  (grain size) >~ λ

- For efficient polarization

  (grain size) <~ λ

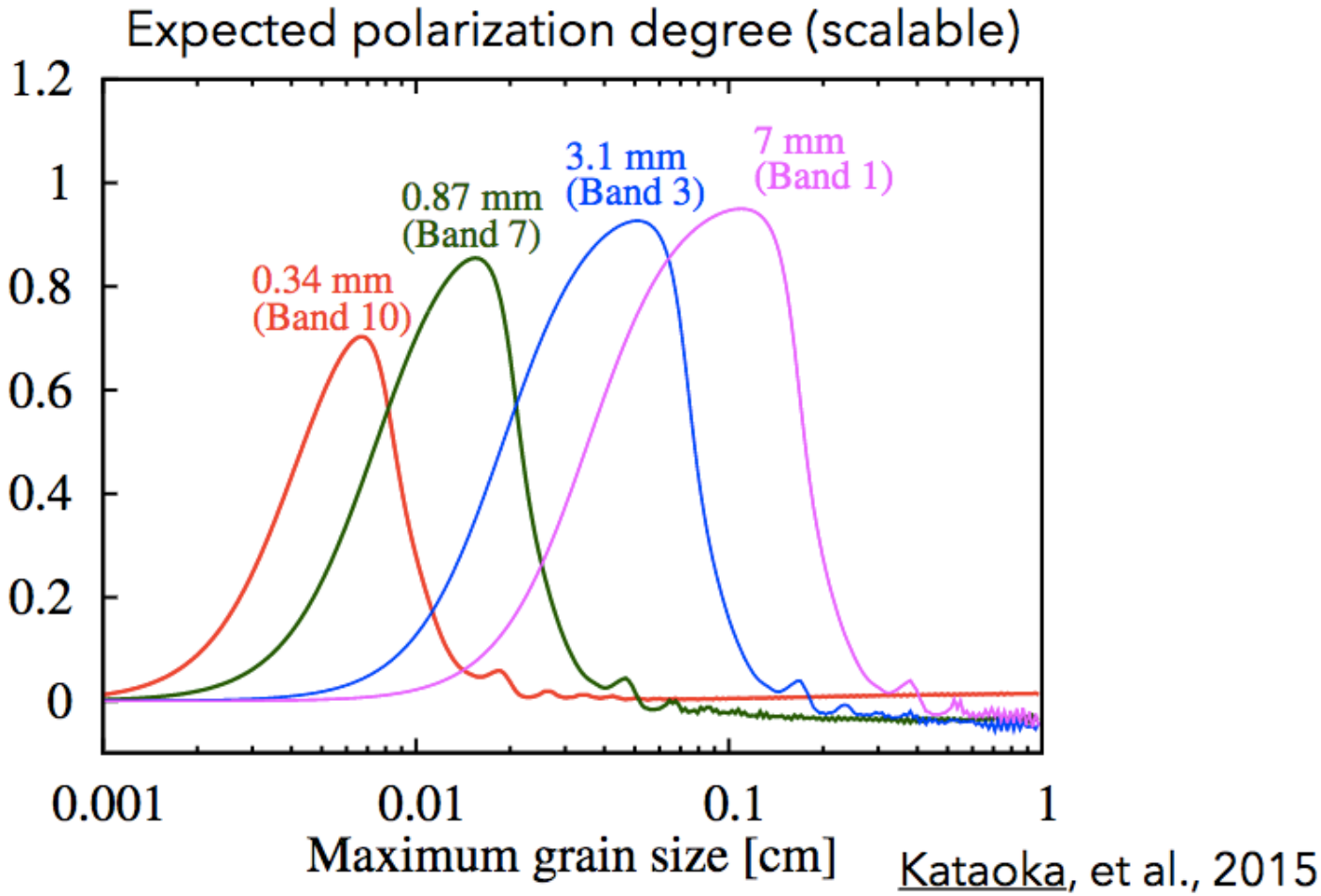
There is a grain size which contributes most to the polarized emission



If (grain size) ~ λ/2π, the polarized emission due to dust scattering is the strongest

self-scattering

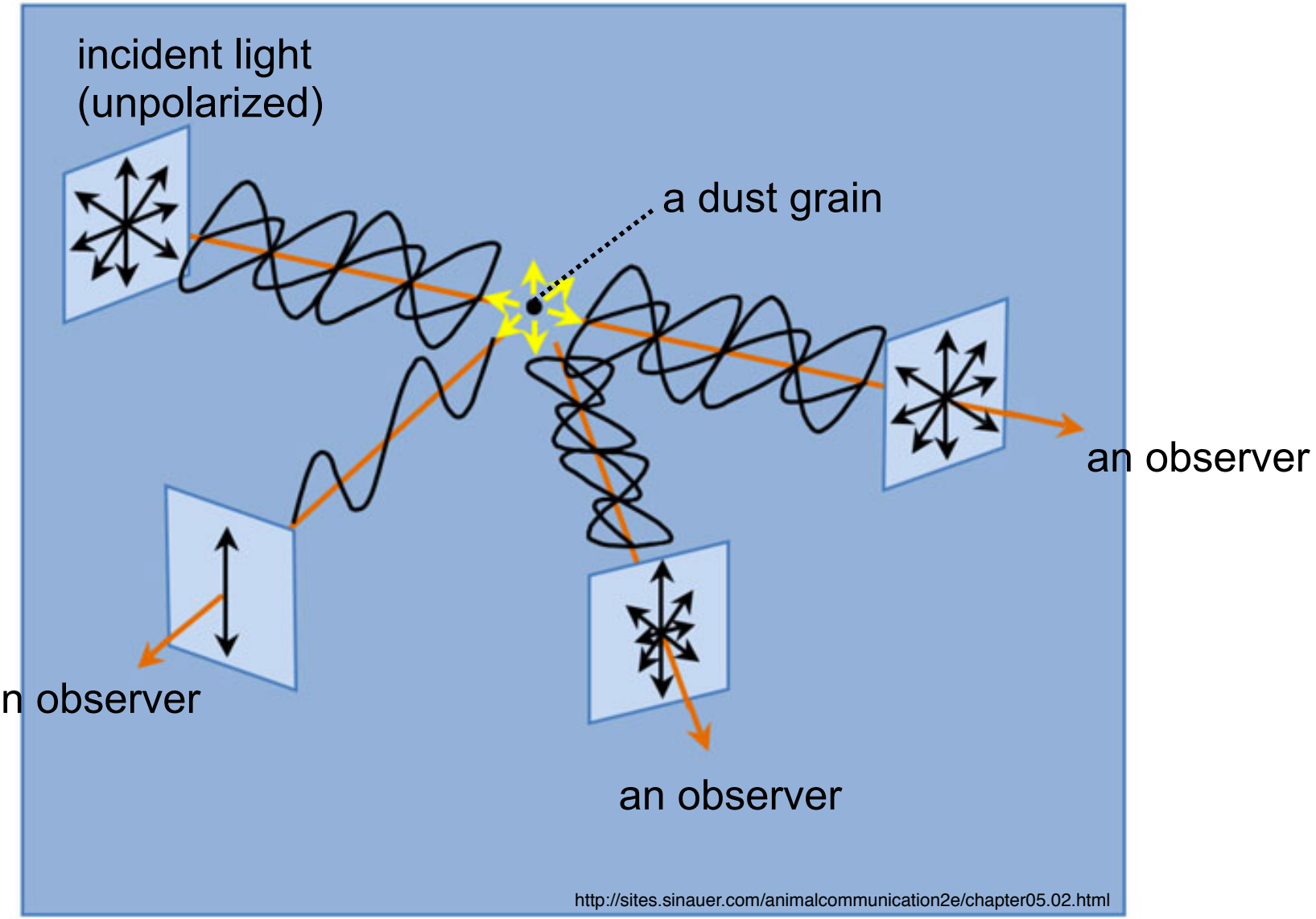
Grain size constraints by polarization



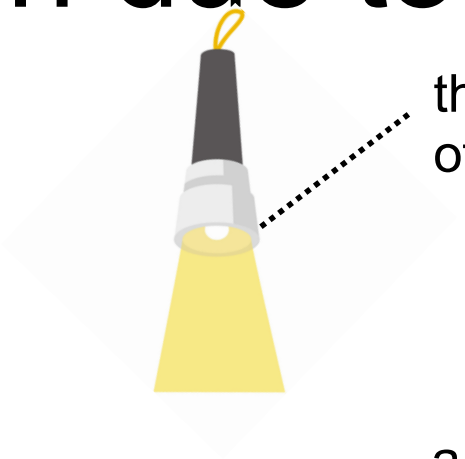
Kataoka, et al., 2015

Multi-wave polarization → constraints on the grain size

Polarization due to scattering

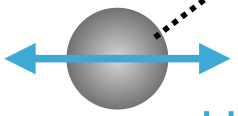


Polarization due to scattering



thermal dust emission
of other dust grains

a dust grain

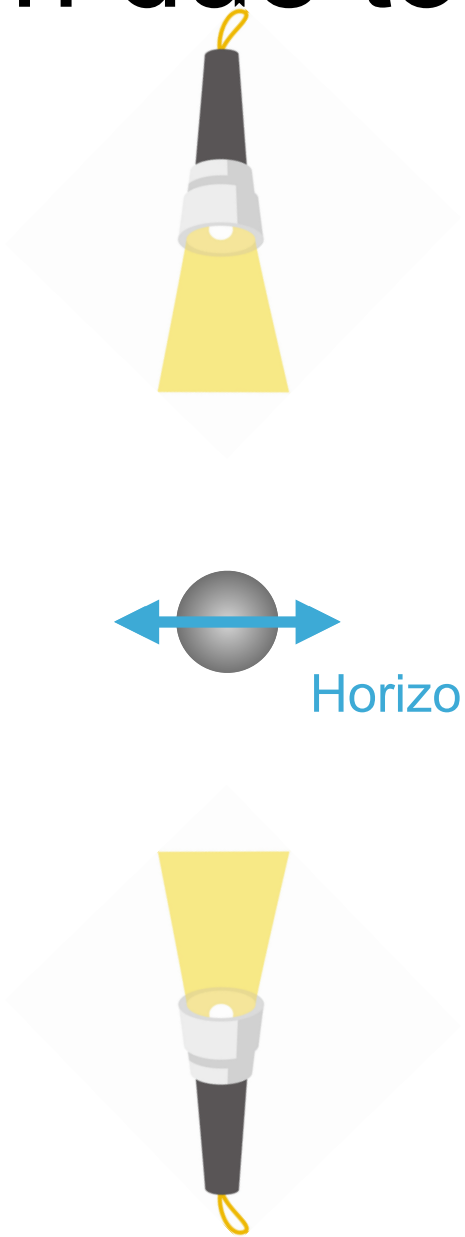


Horizontal Polarization

The observer is you.

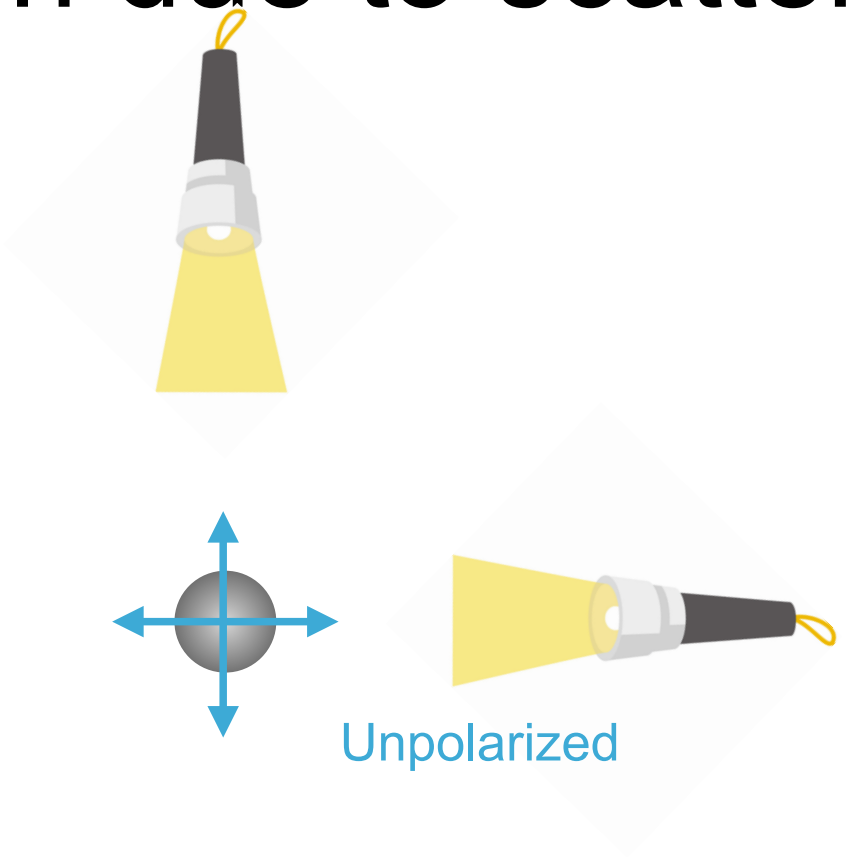
(the line of sight is perpendicular to the plane of this slide)

Polarization due to scattering

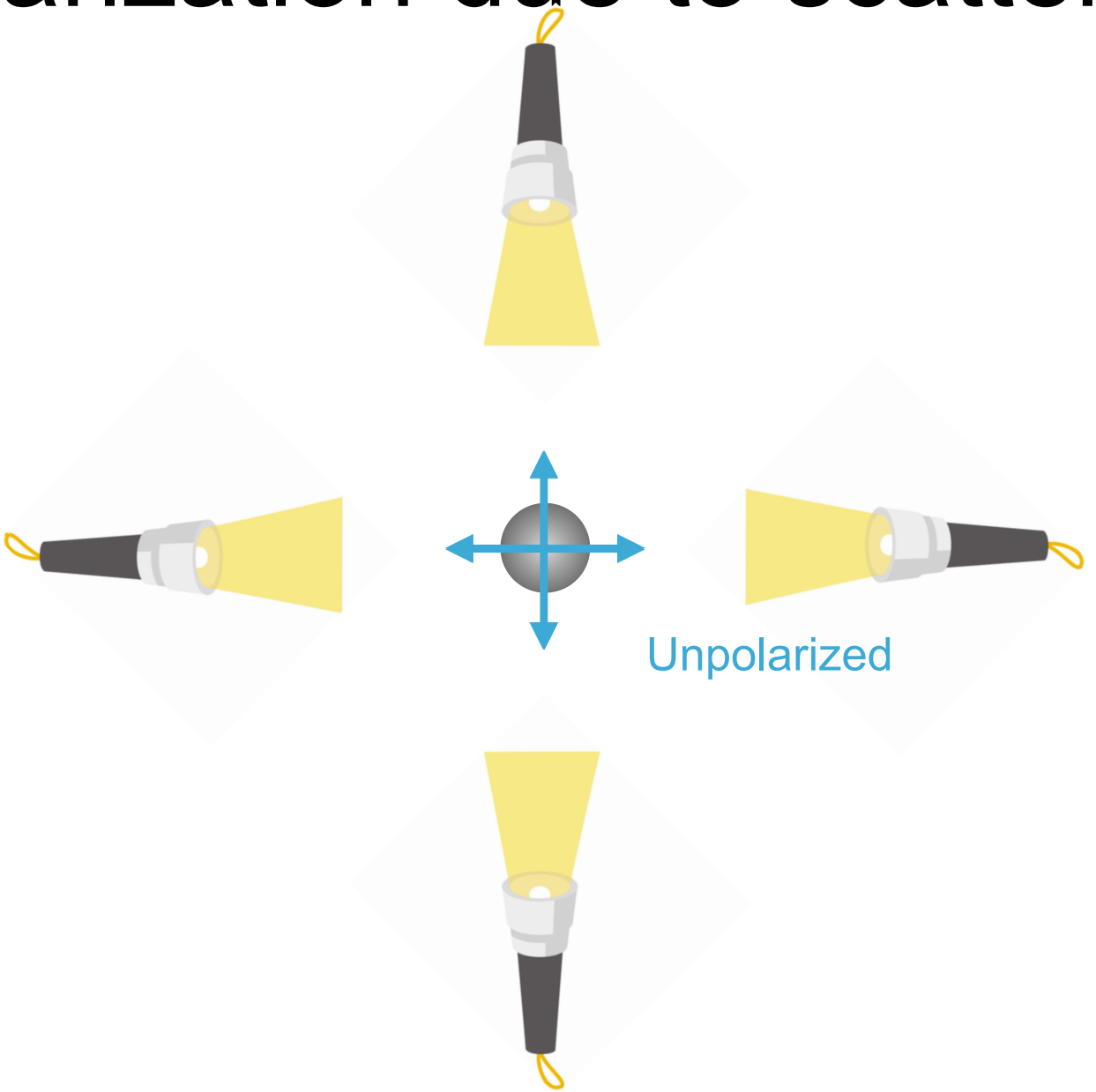


Horizontal Polarization

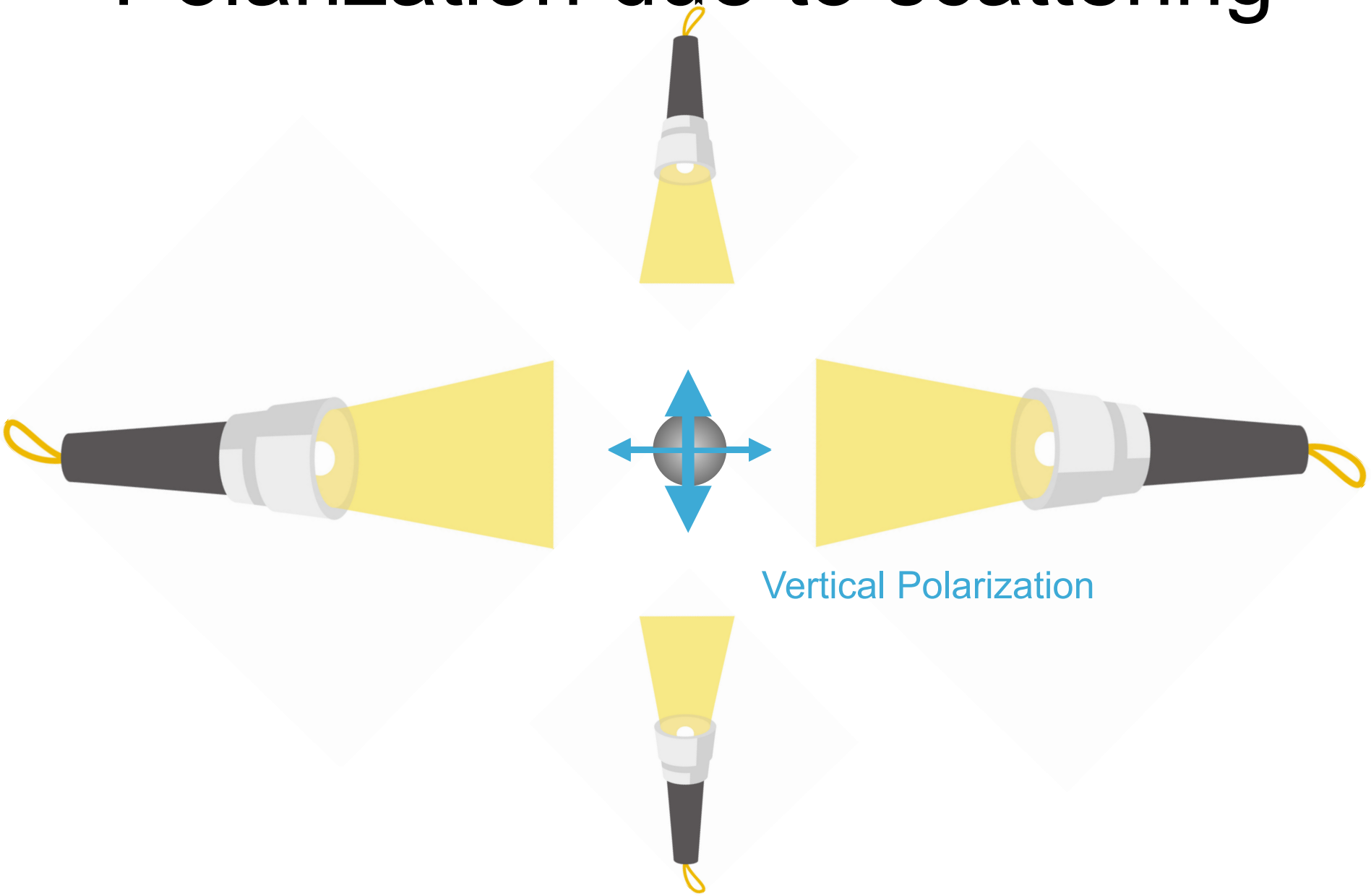
Polarization due to scattering



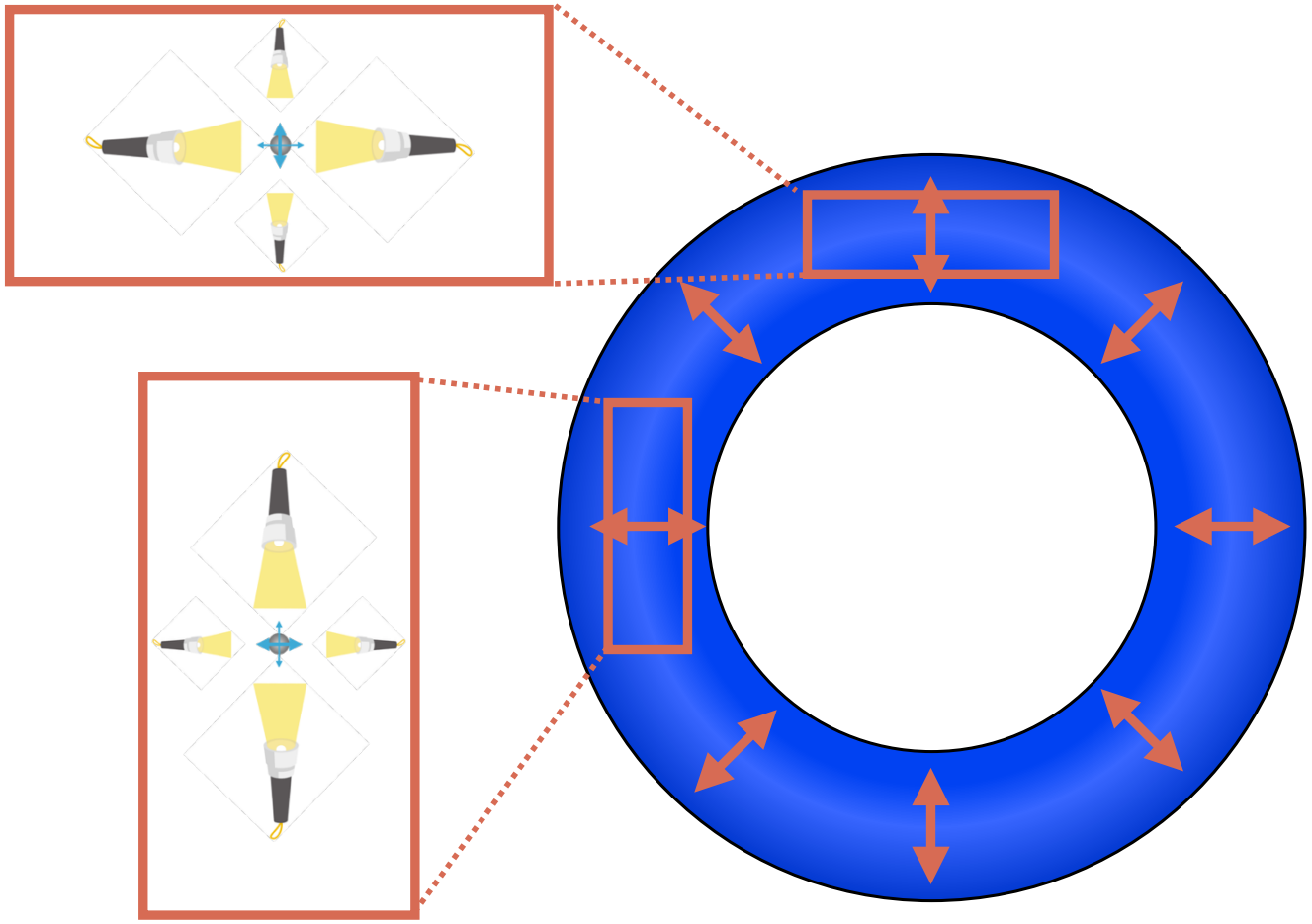
Polarization due to scattering



Polarization due to scattering

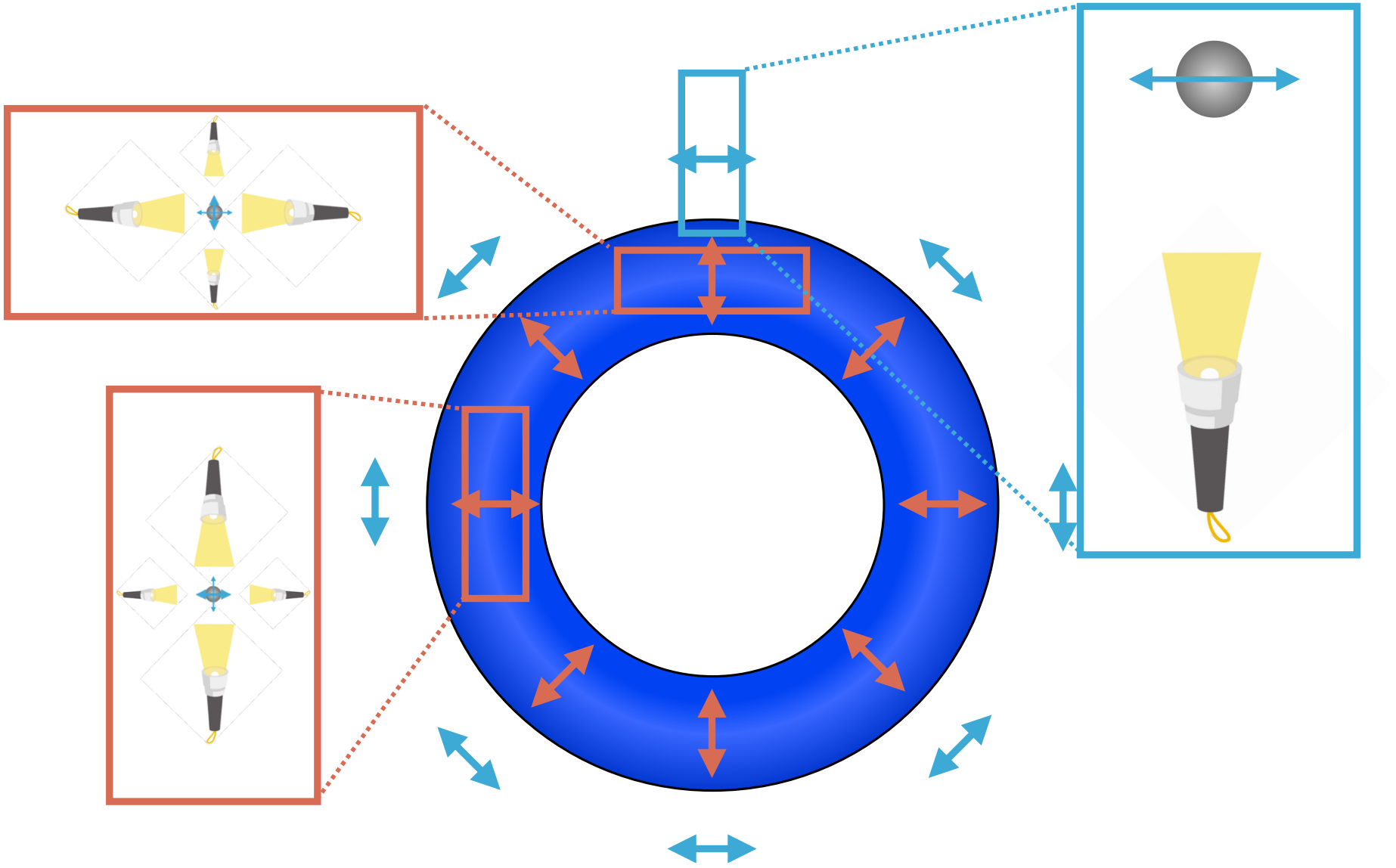


self-scattering in a protoplanetary disk



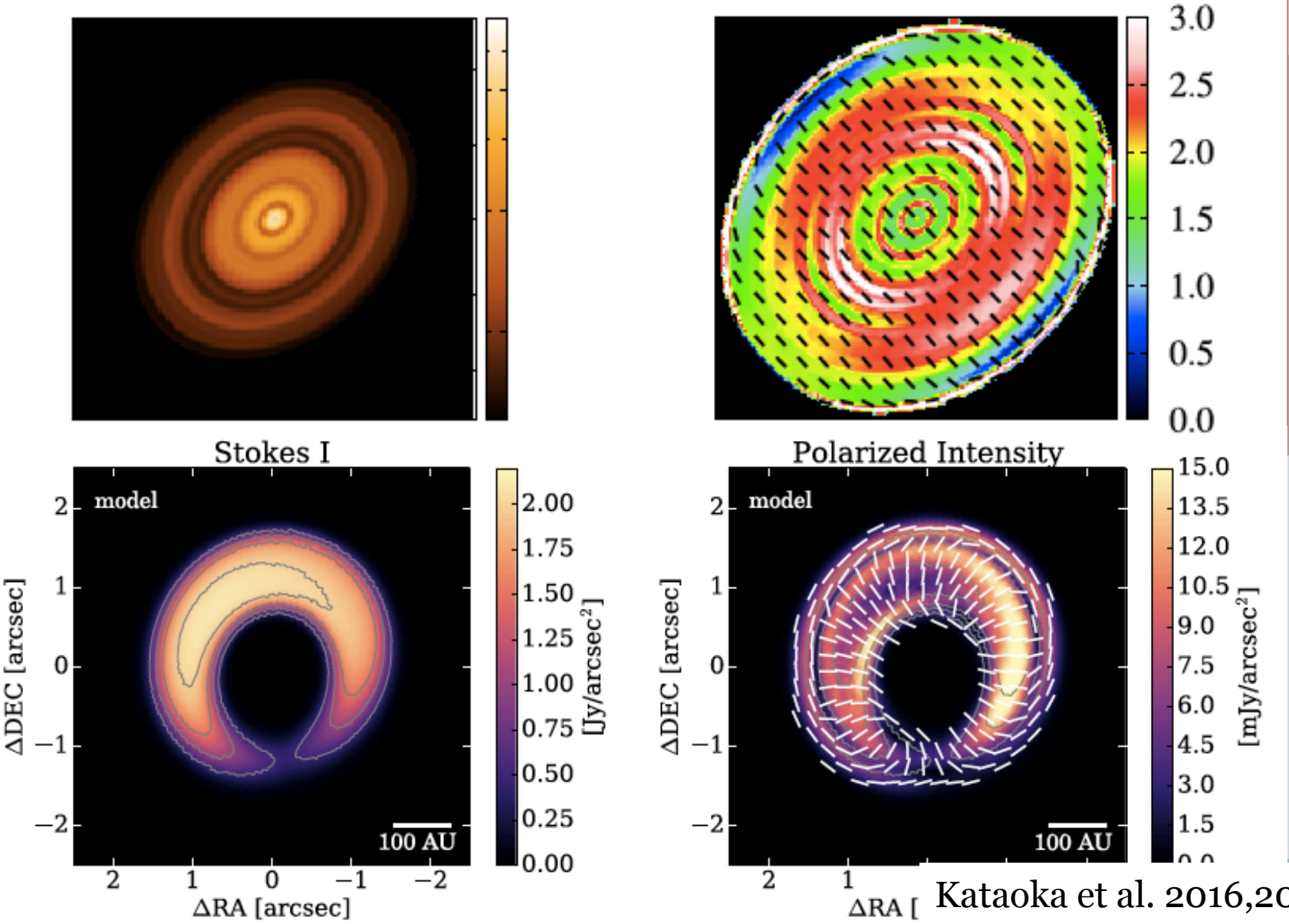
Akimasa Kataoka (Humboldt fellow, Heidelberg University)

self-scattering in a protoplanetary disk



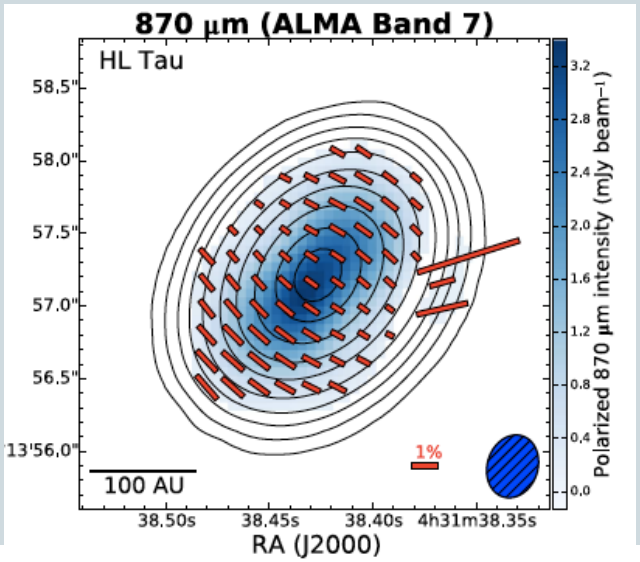
Akimasa Kataoka (Humboldt fellow, Heidelberg University)

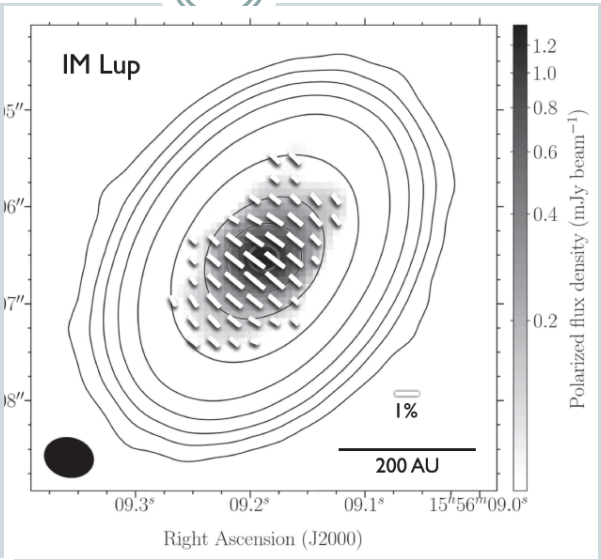
How the scattered polarization looks like ?

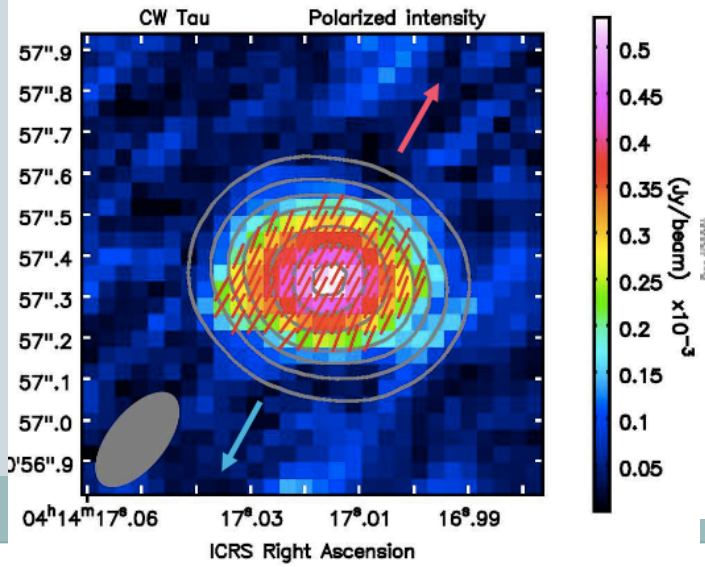


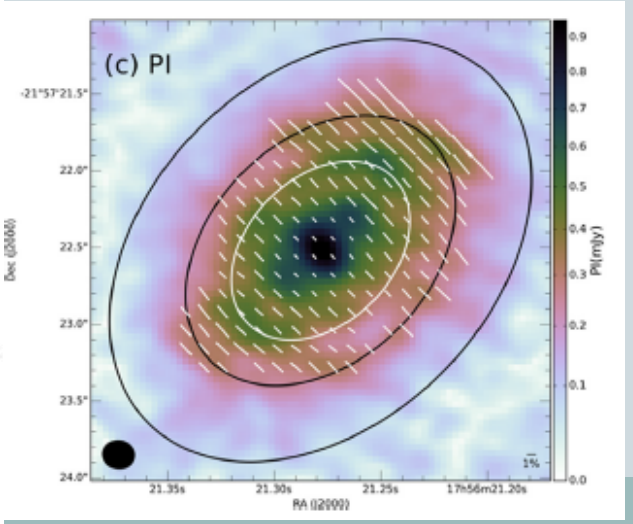
Kataoka et al. 2016,2017

Observational results of self scattering





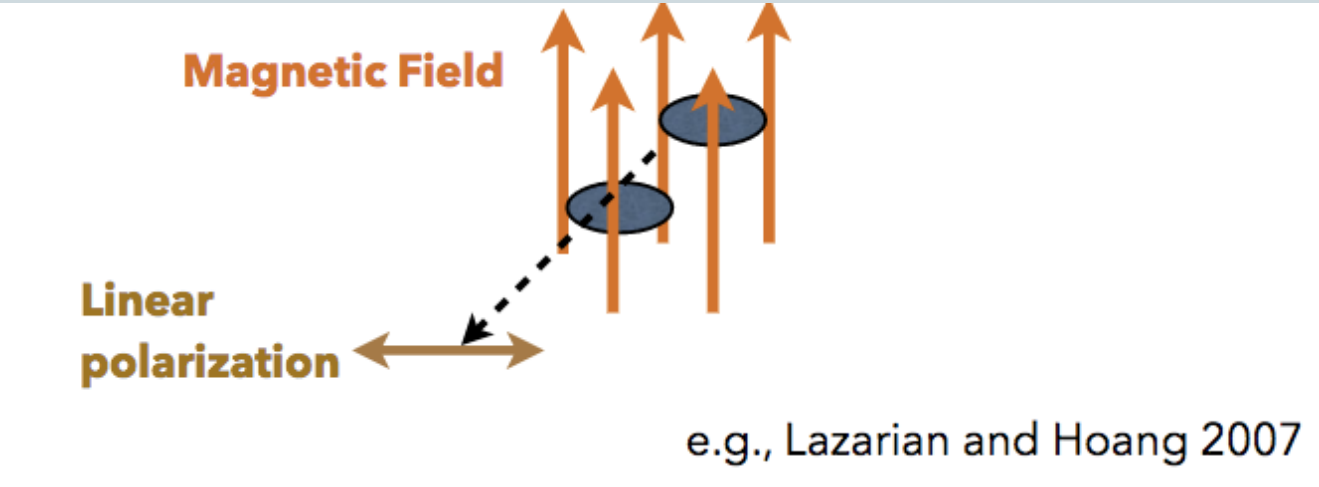




Kataoka et al. 2016,
Kataoka et al. 2017
Hull et al. 2017,
Stephens et al. 2017,
Girart et al. 2018,
Hariss et al. 2018,
Bacciotti et al. 2018,
Dent et al. 2018

mechanisms of polarization in disks

- 1. alignment of dust grains with magnetic fields



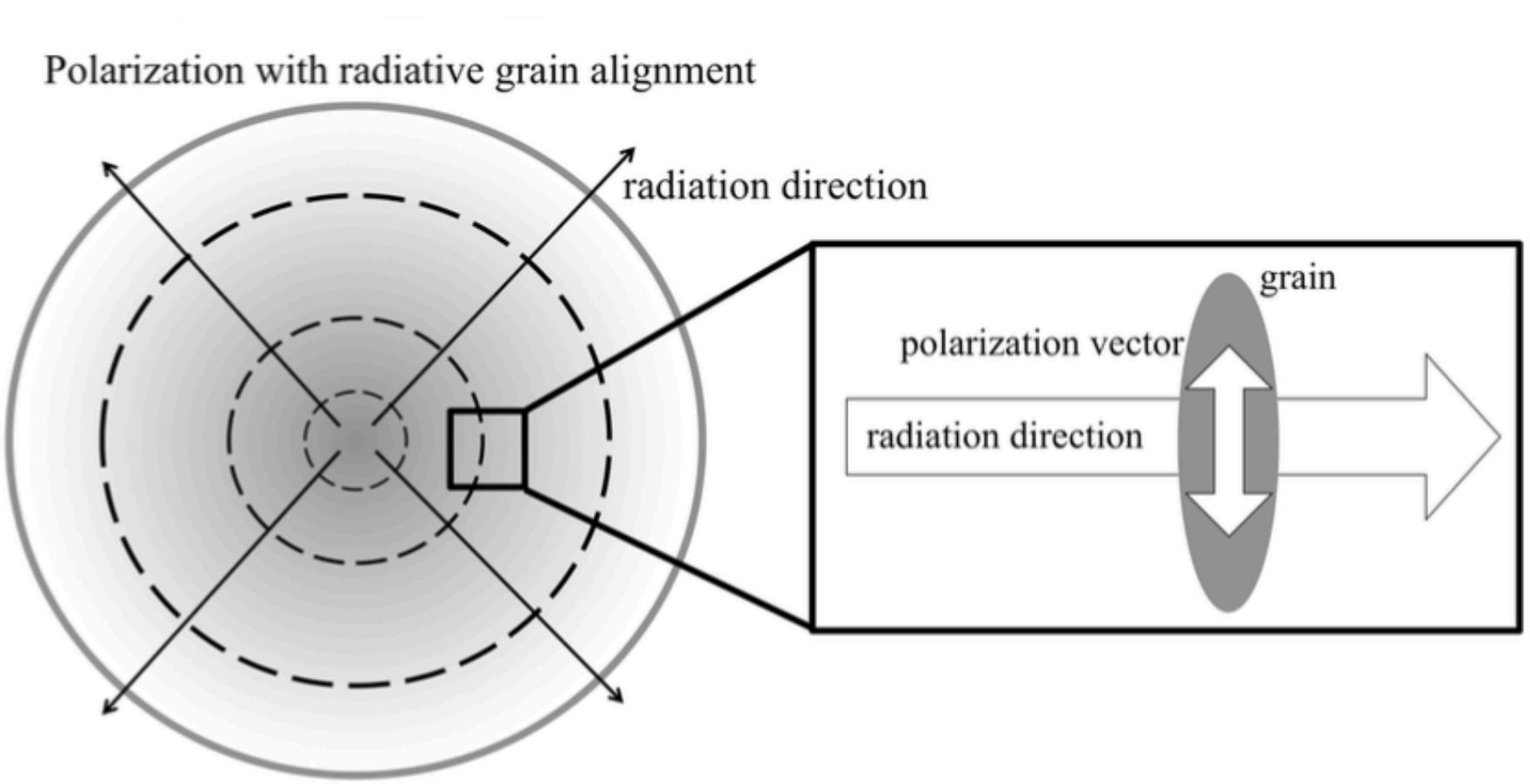
- 2. self scattering of thermal dust emission

e.g., Kataoka et al. 2015

- 3. alignment of dust grains with radiation fields

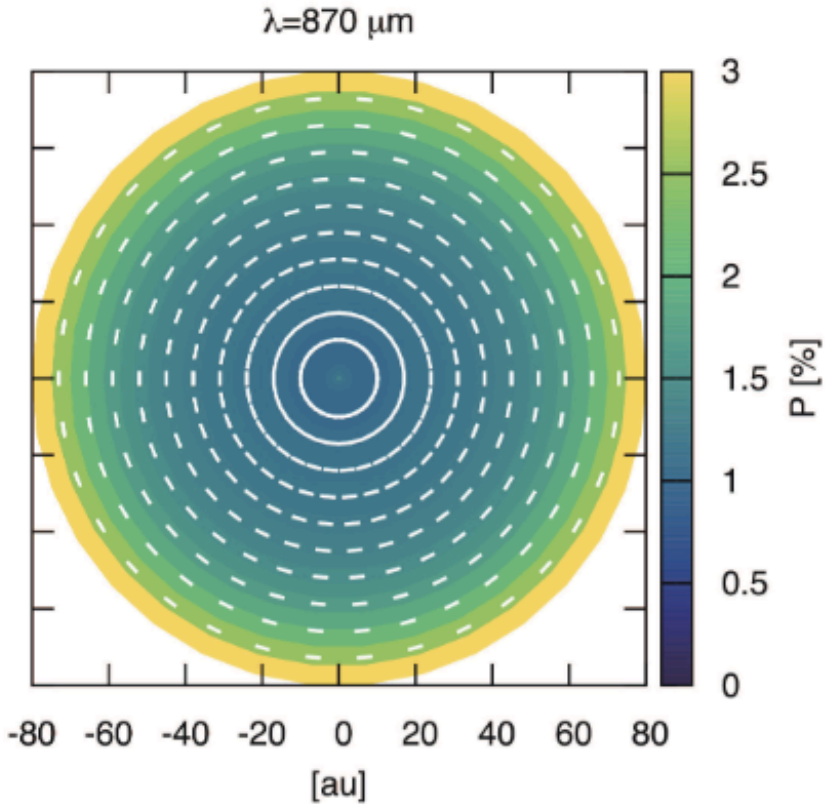
e.g., Tazaki et al. 2017

Radiative grain alignment

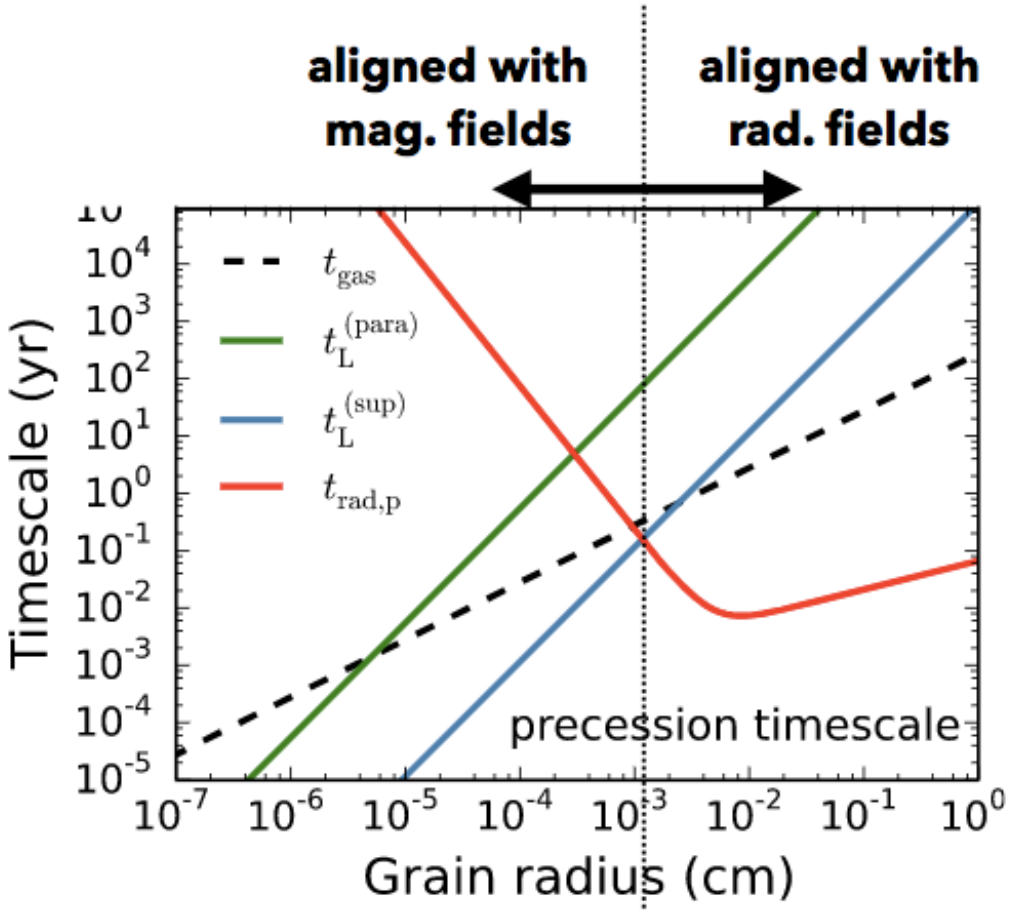


Radiative grain alignment

Tazaki et al. 2017



a ~ 10 um



ALMA polarization observations cycle 3&4

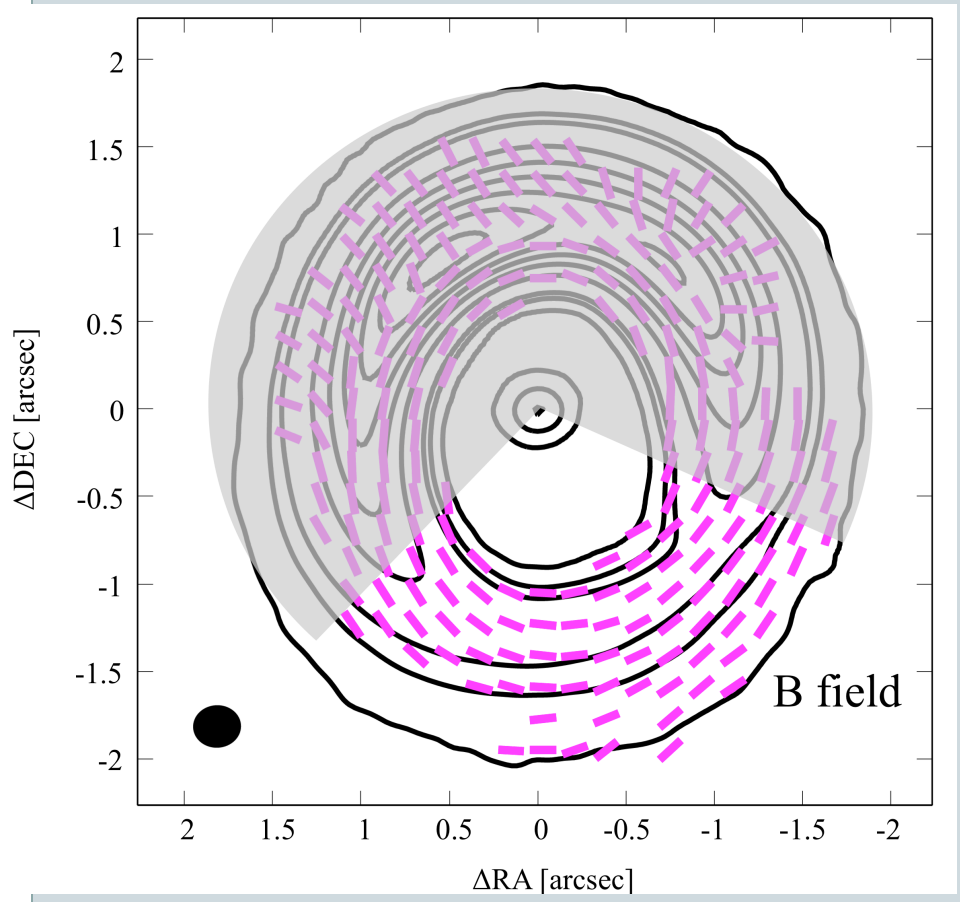
[redacted]

Band 7 (870 um)	beamsize	rms (stokes I)	rms (PI)
Cycle 3&4	0.27″ ×0.24″	43 μ Jy beam^{-1}	29 μ Jy beam^{-1}

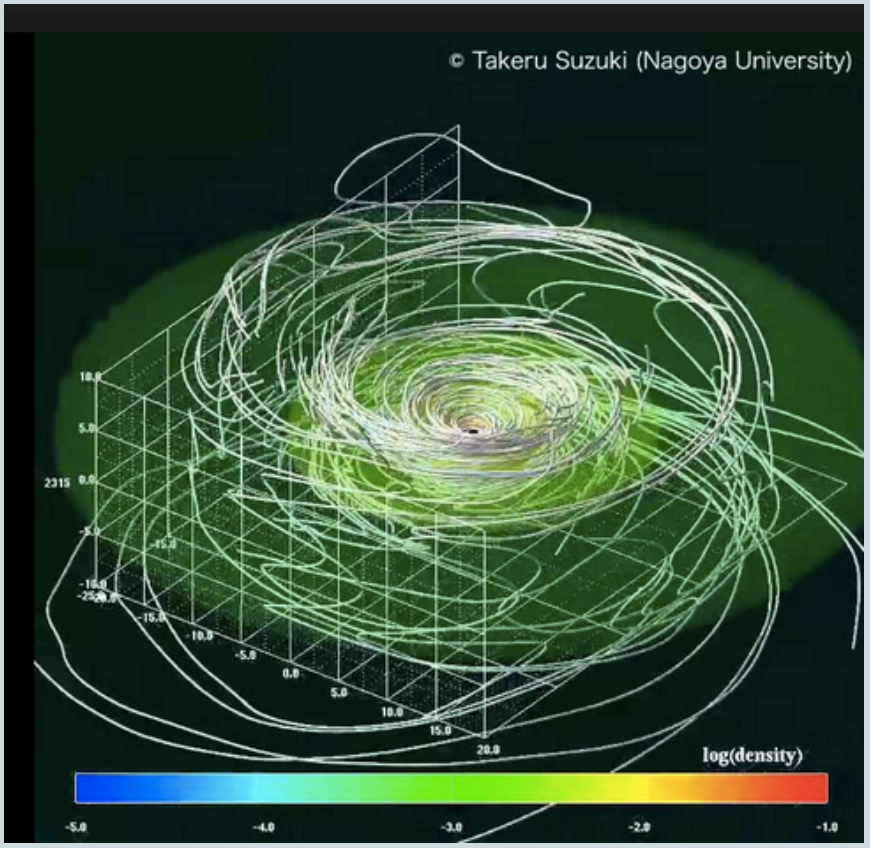
1″ ~ 156 AU
0.25″ ~ 40 AU

The toroidal magnetic fields

- We finally find the magnetic field, which is toroidal

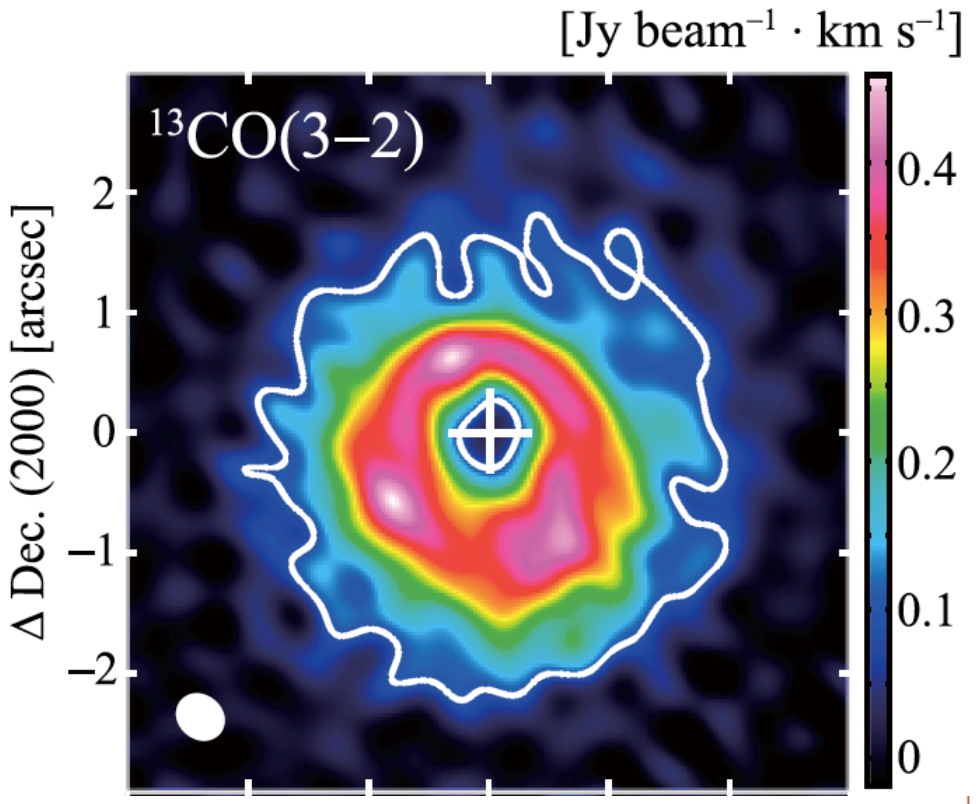


クレジット:CfCA



Dust vs Gas

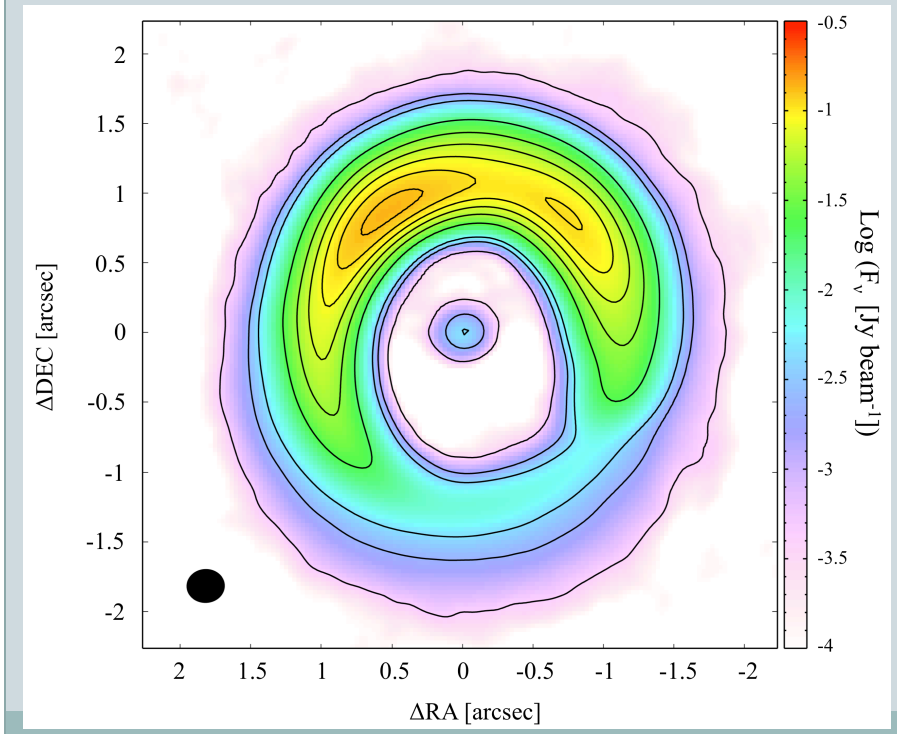
small grains are well coupled with gas, but larger grain goes to region where the pressure is high

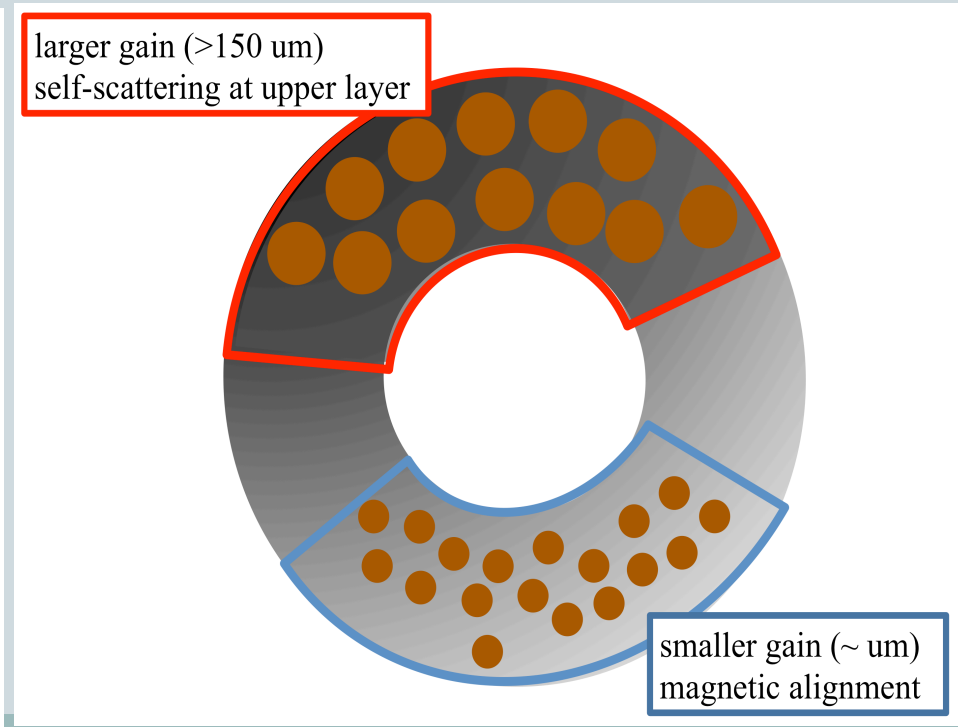


Casassus et al. 2013, Fukagawa et al. 2013, Muto et al. 2016, Boehler et al. 2017

Possible polarization of HD 142527

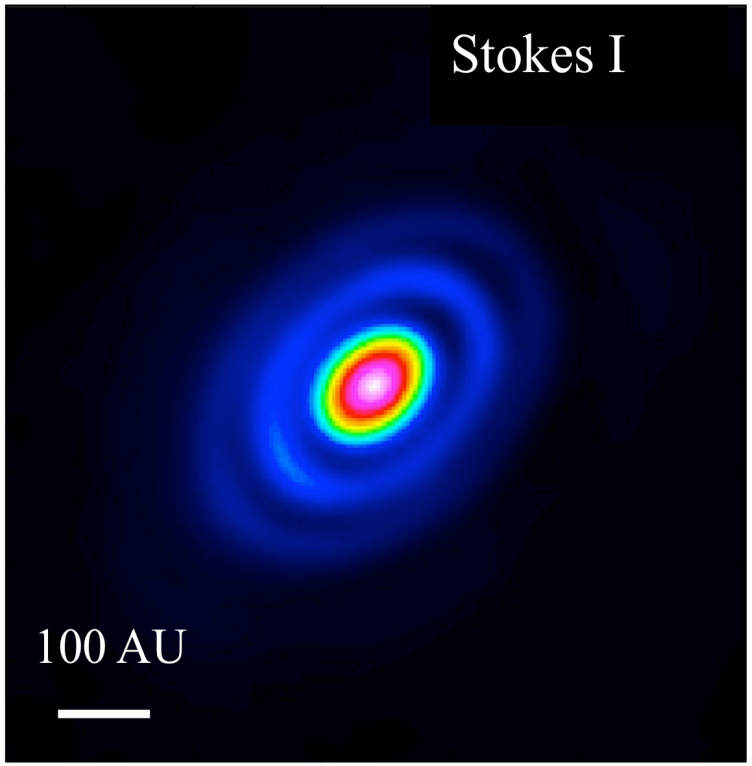
- The flip is likely to be the self-scattering
- Larger dust may be settled into the midplane
- The southern region has micron grains aligned by magnetic field
- Even 100 um size grains are trapped by gas pressure

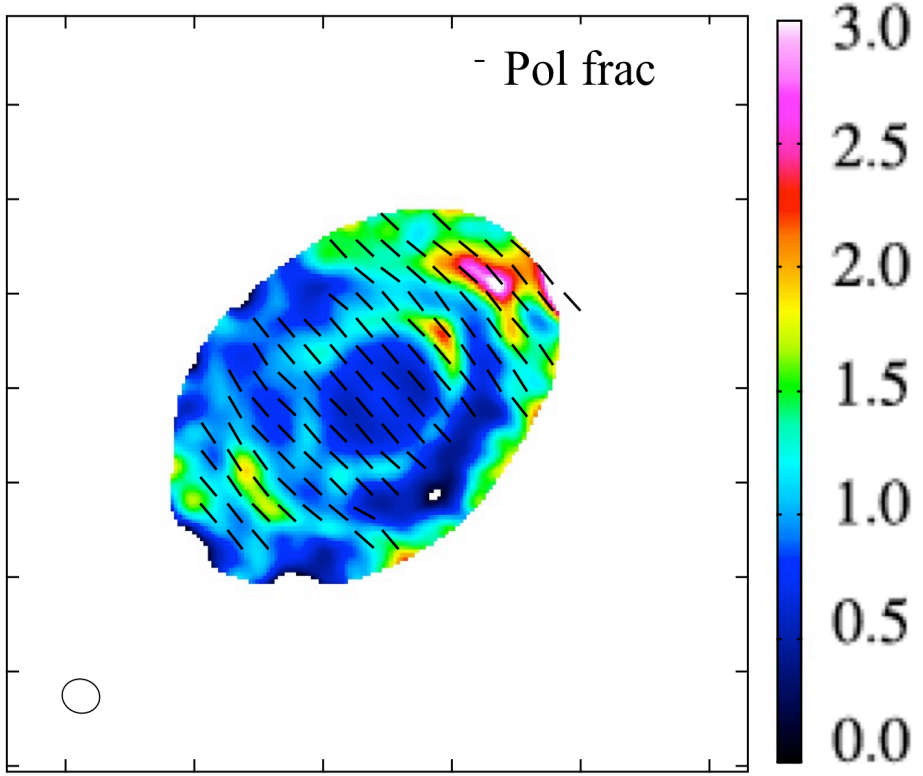




HD 163296 (data taken by Dent et al. 2018)

Observations

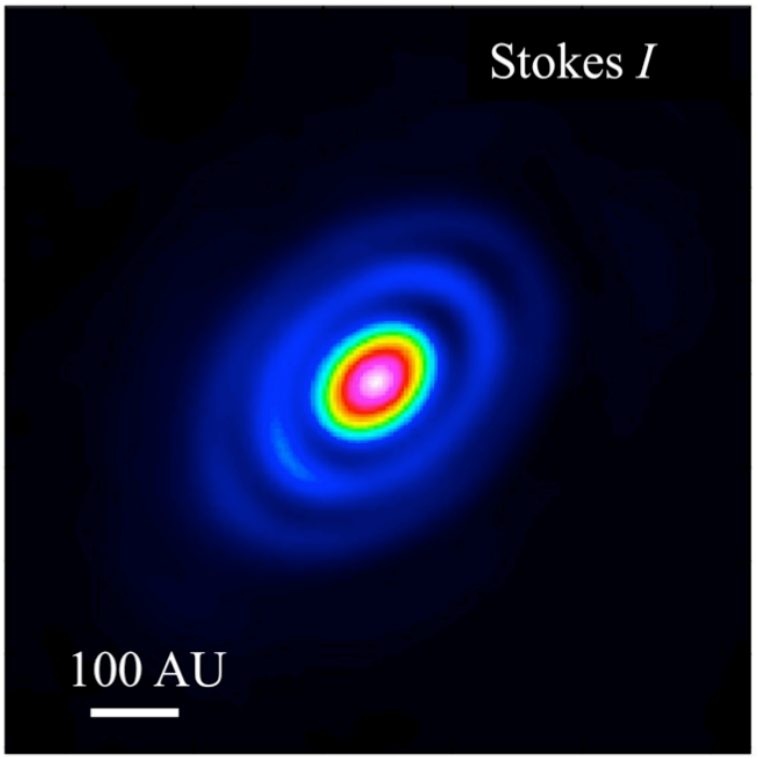


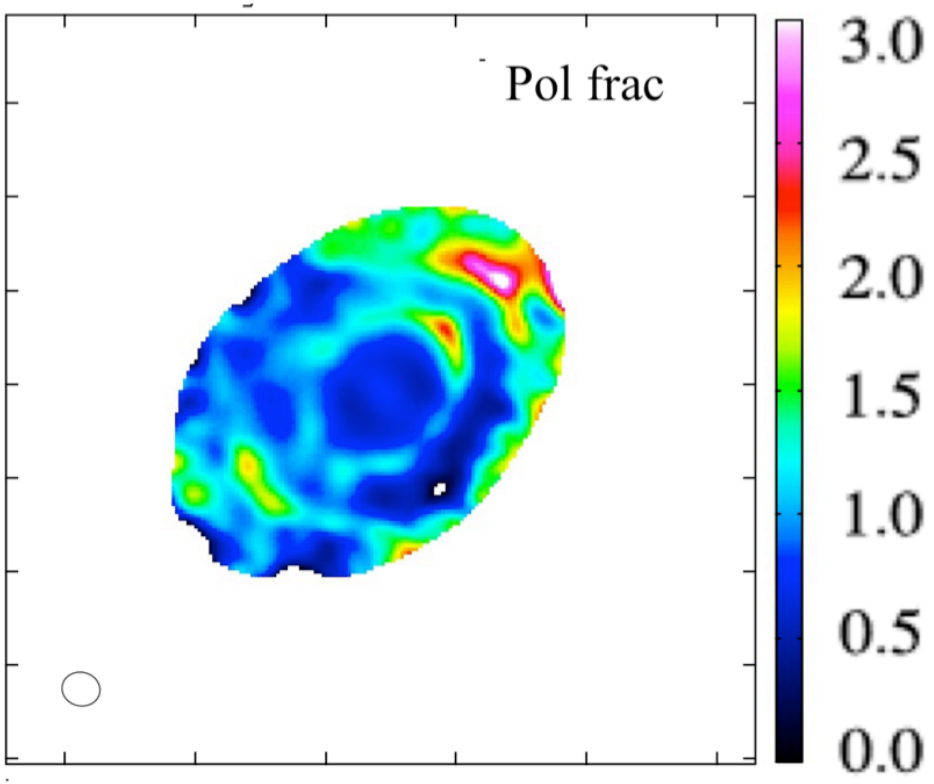


The polarization vectors are recognized along with the minor axis
→ self-scattering

HD 163296 (data taken by Dent et al. 2018)

observation

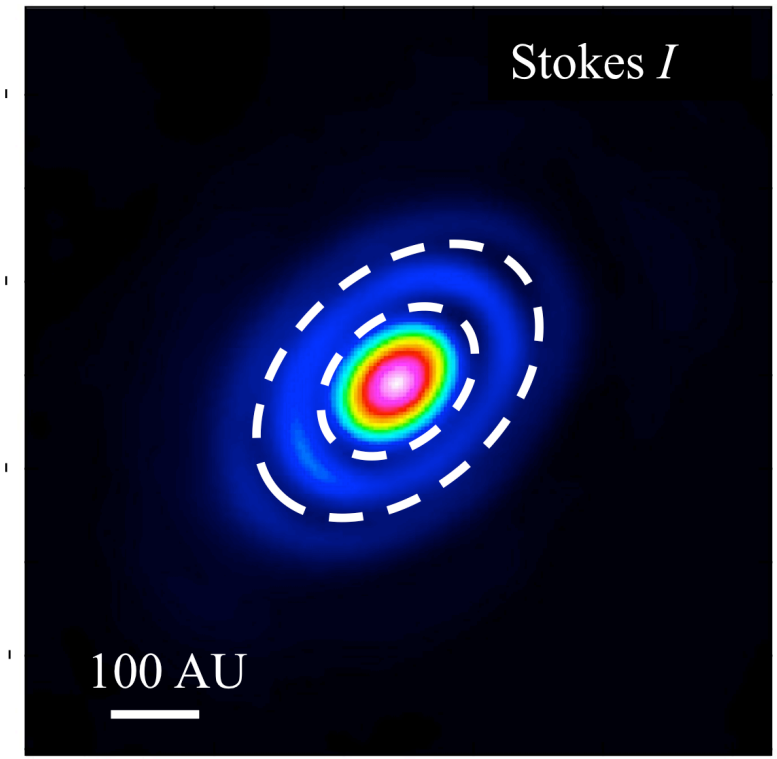


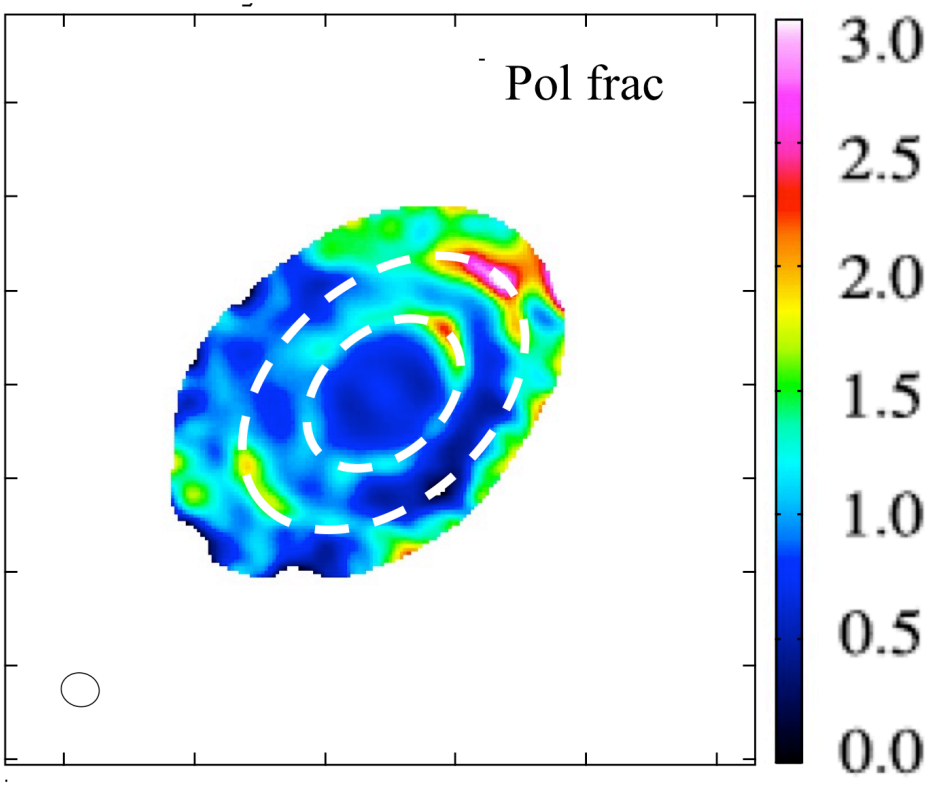


The polarization fraction becomes higher toward the gaps

HD 163296 (data taken by Dent et al. 2018)

observation



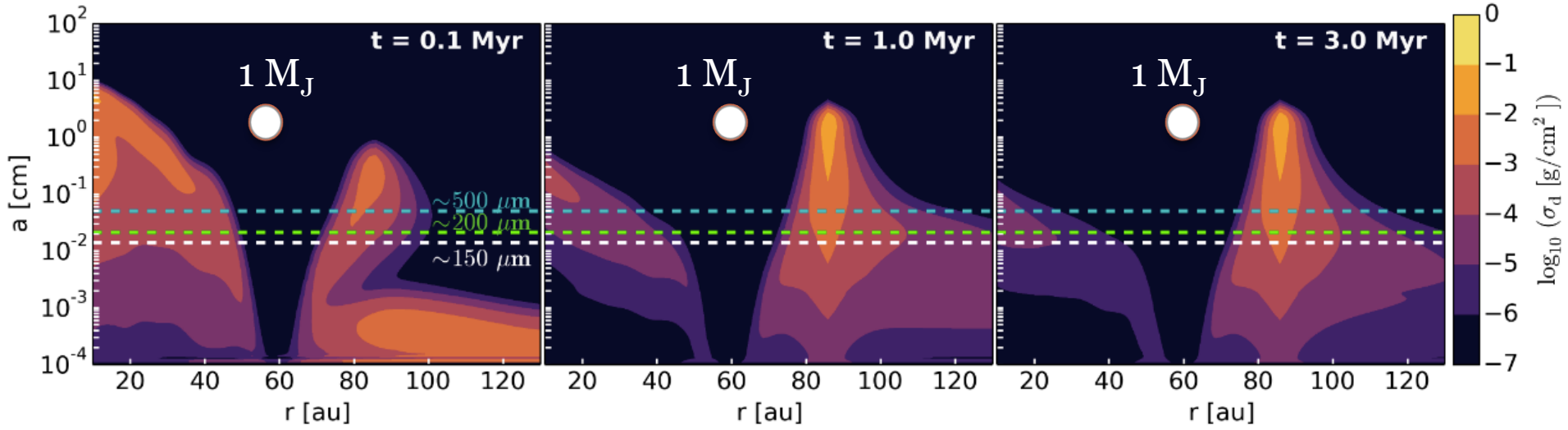


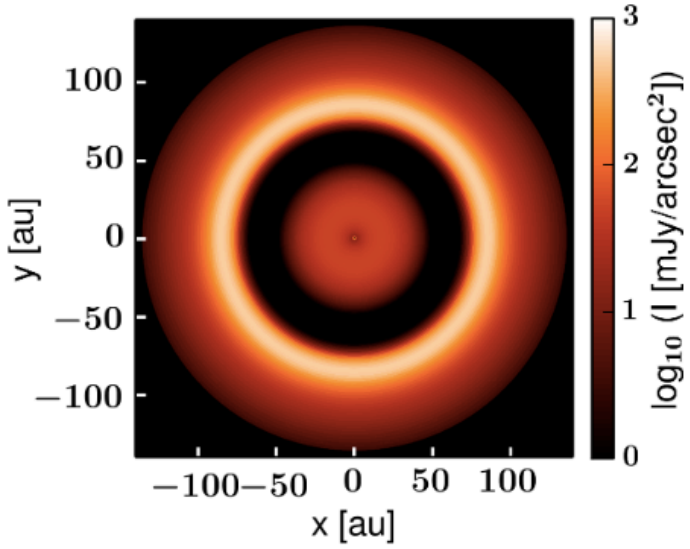
The polarization fraction becomes higher toward the gaps

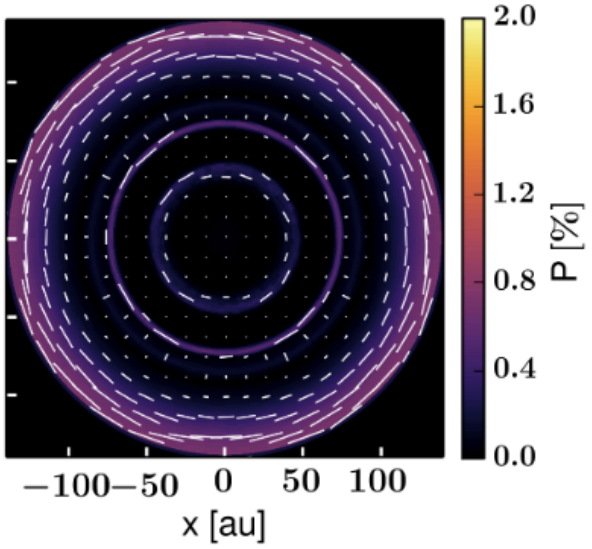
HD 163296 (data taken by Dent et al. 2018)

No evidence of dust trapping

Pohl et al. 2016

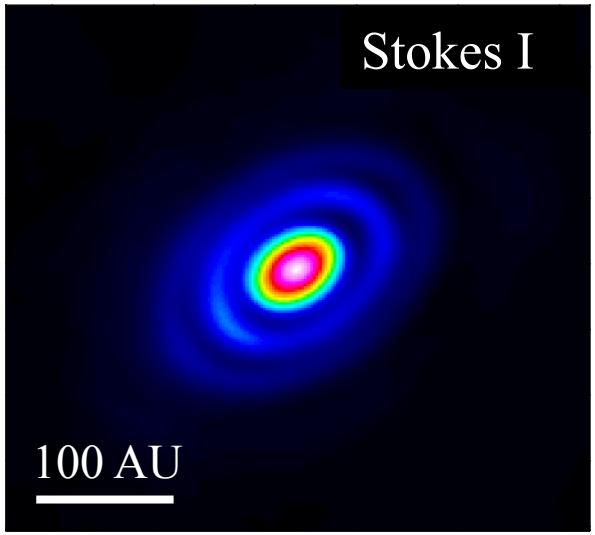


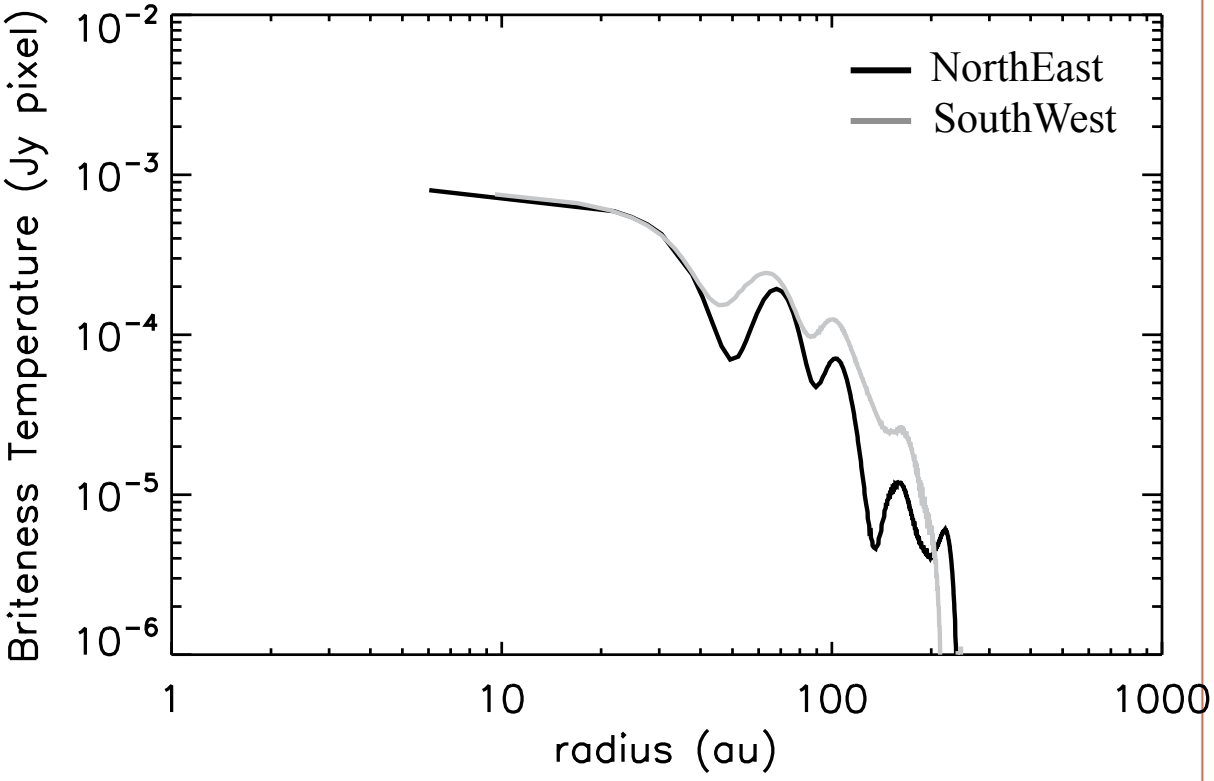




HD 163296 (data taken by Dent et al. 2018)

observation

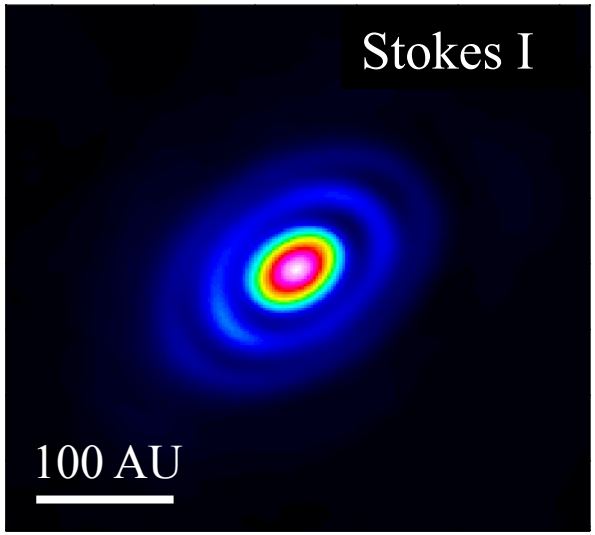


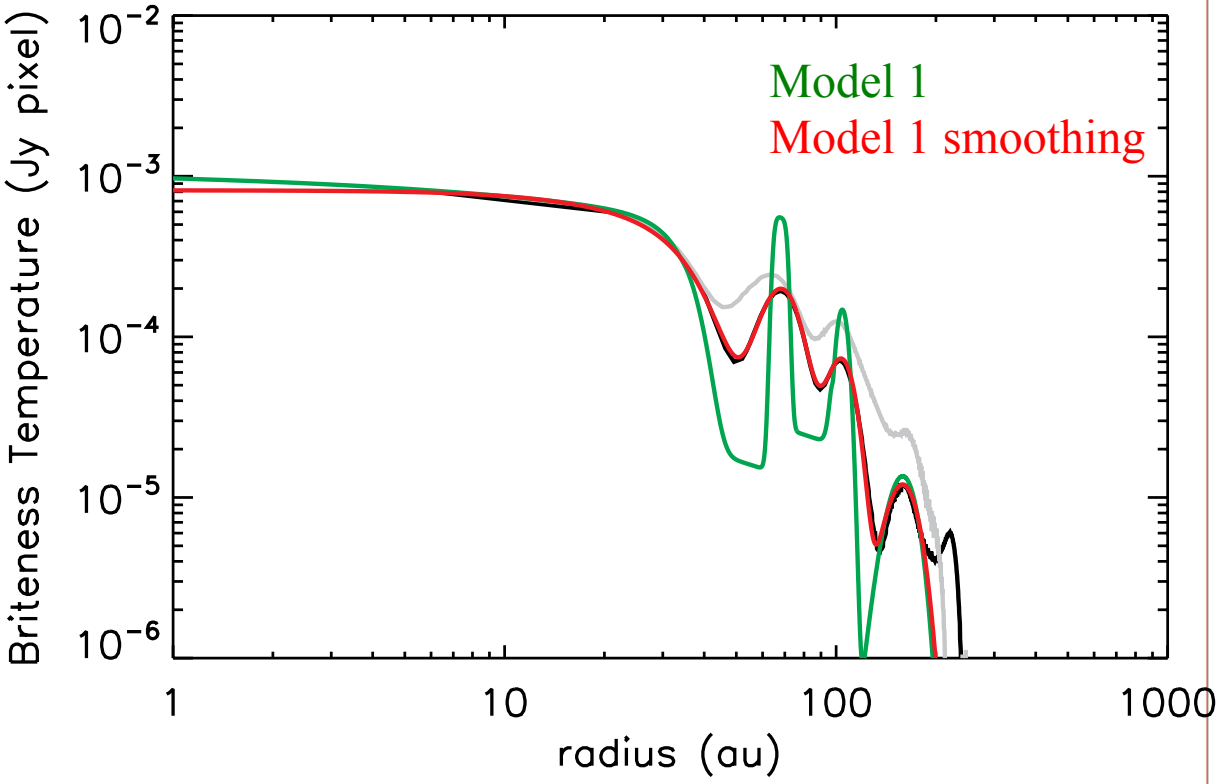


We focus on the radial profile of the NE direction to reproduce by radiative transfer modeling

HD 163296 (data taken by Dent et al. 2018)

observation



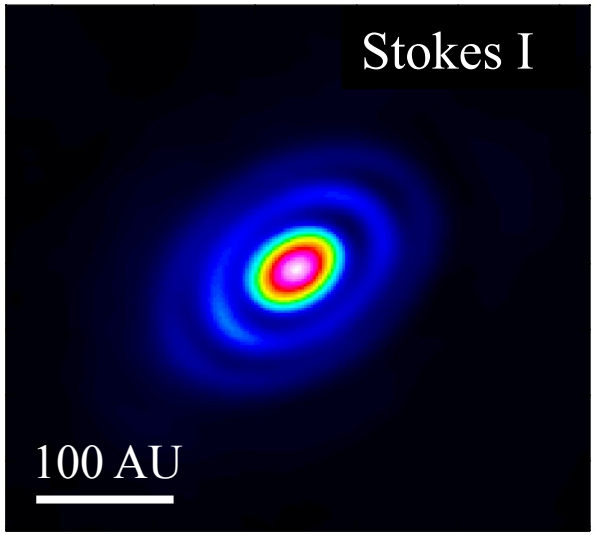


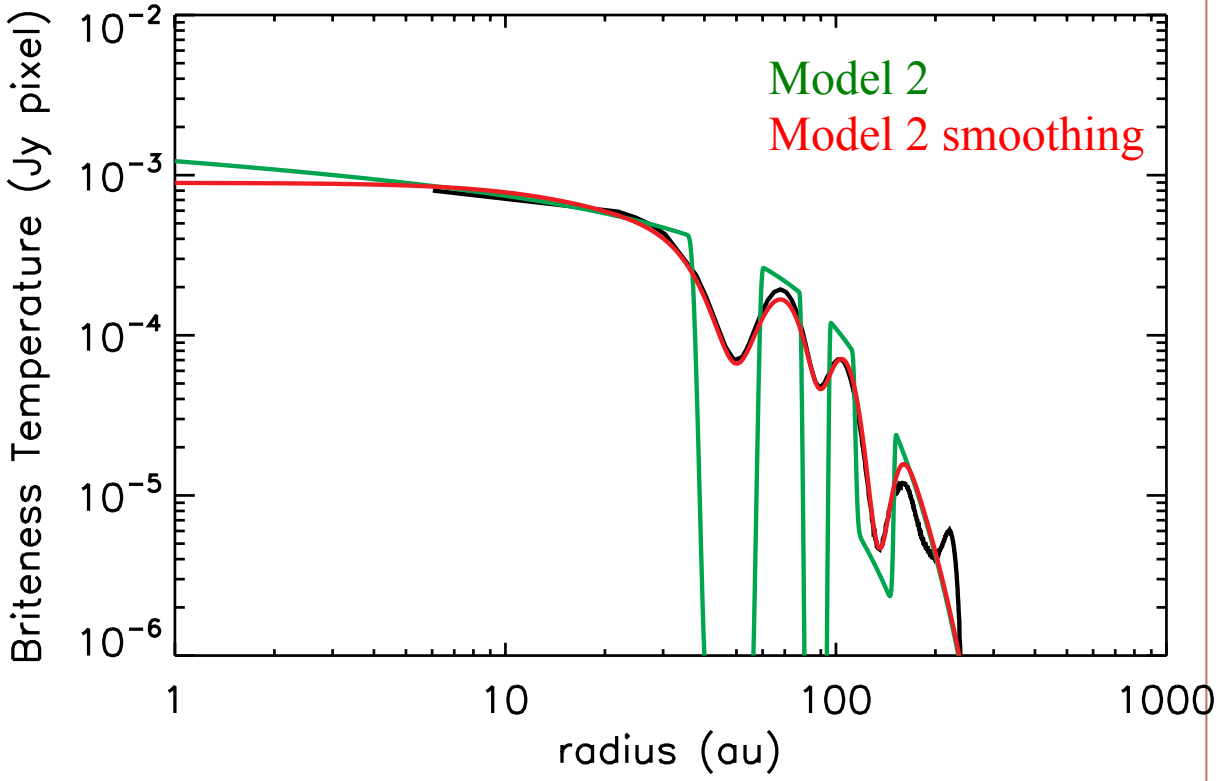
We can produce the observations by various profiles because of poor observed beam size

→ the polarization put constrain the models

HD 163296 (data taken by Dent et al. 2018)

observation





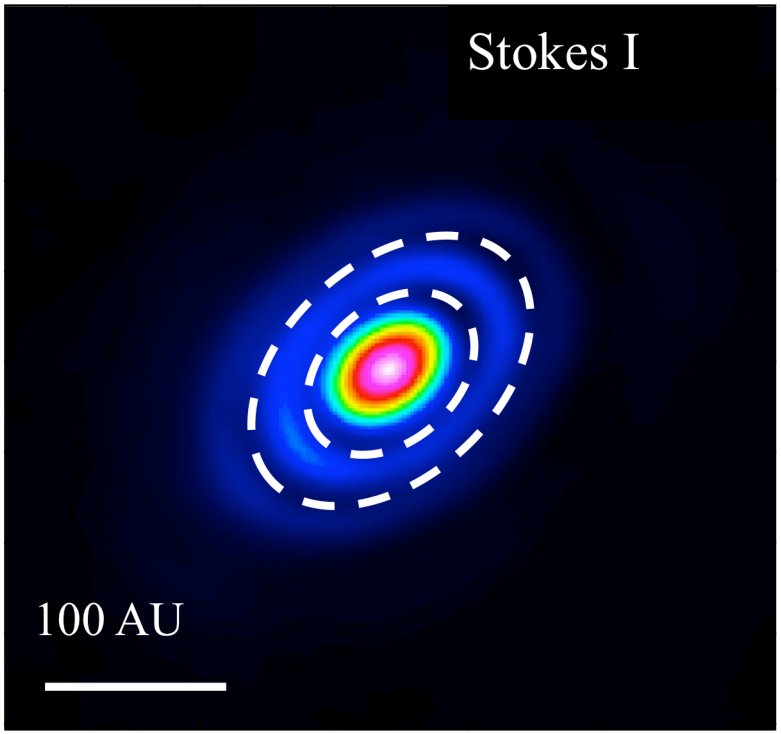
We can produce the observations by various profiles because of poor observed beam size

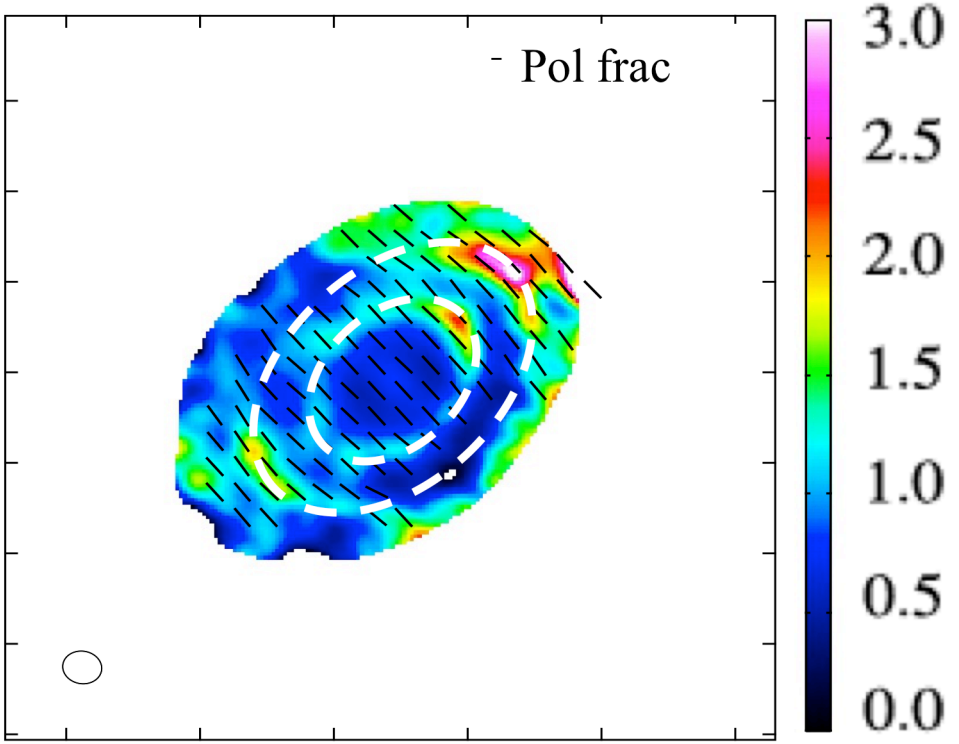
→ the polarization put constrain the models

HD 163296 (data taken by Dent et al. 2018)

Observing features

observation





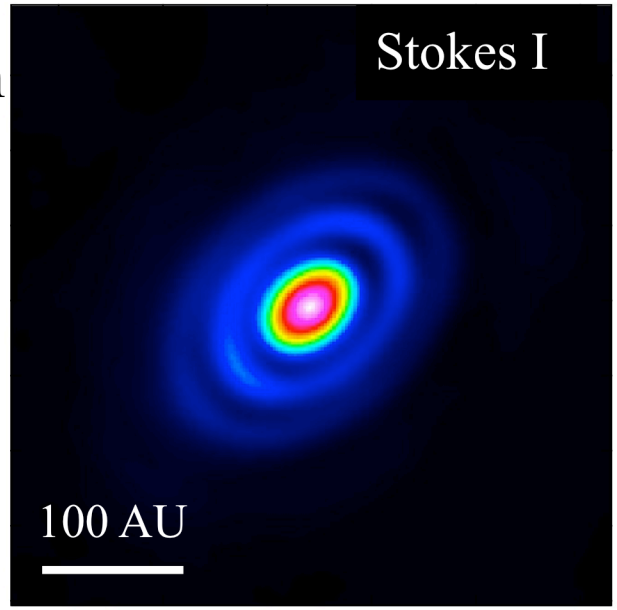
1. The pol fraction becomes higher toward the gaps
2. The pol fraction of major axis is much higher than that of minor

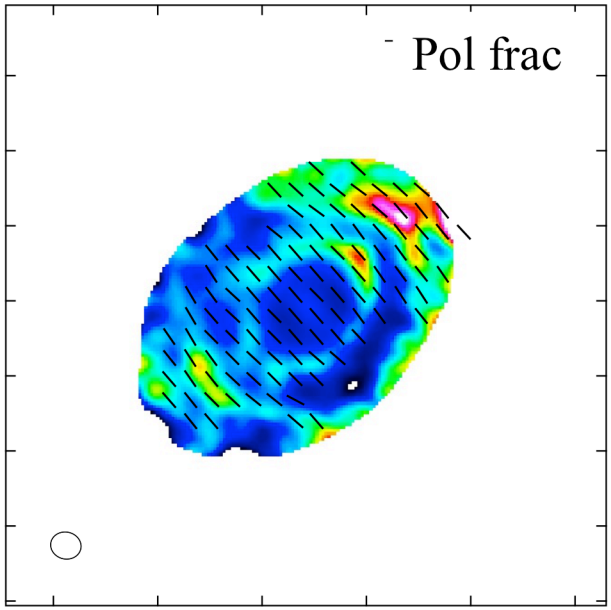
HD 163296 (data taken by Dent et al. 2018)

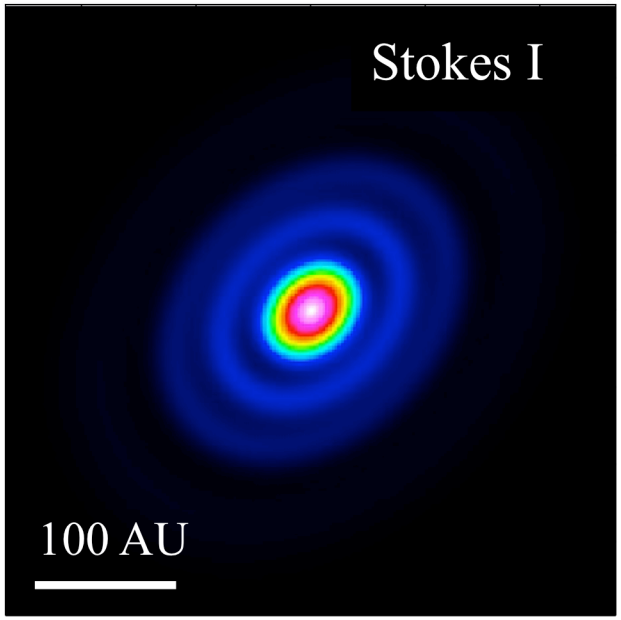
Ohashi et al. in prep

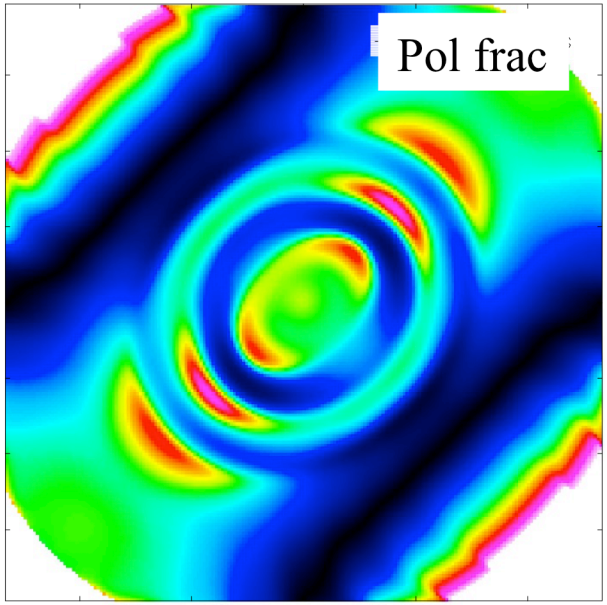
observation

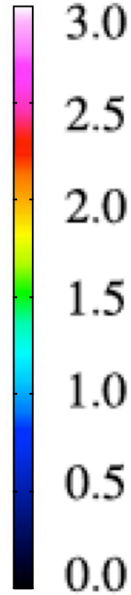
succeeded model









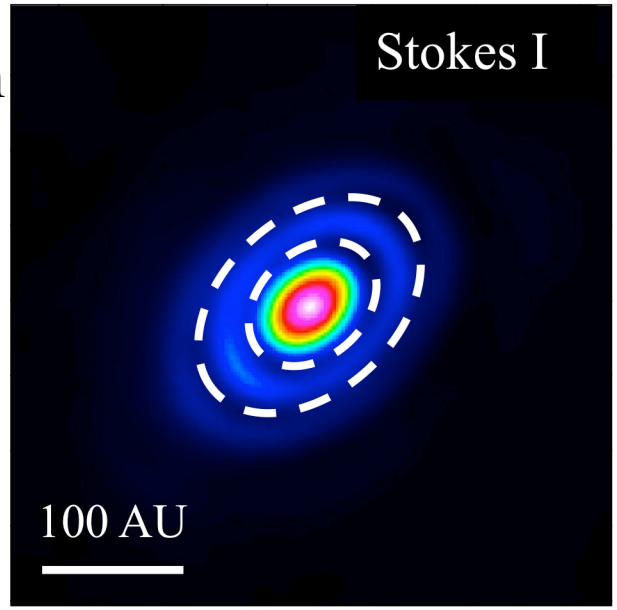


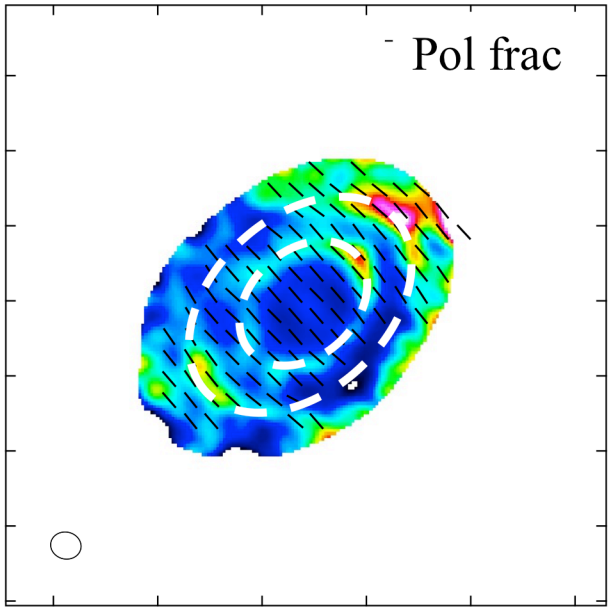
HD 163296 (data taken by Dent et al. 2018)

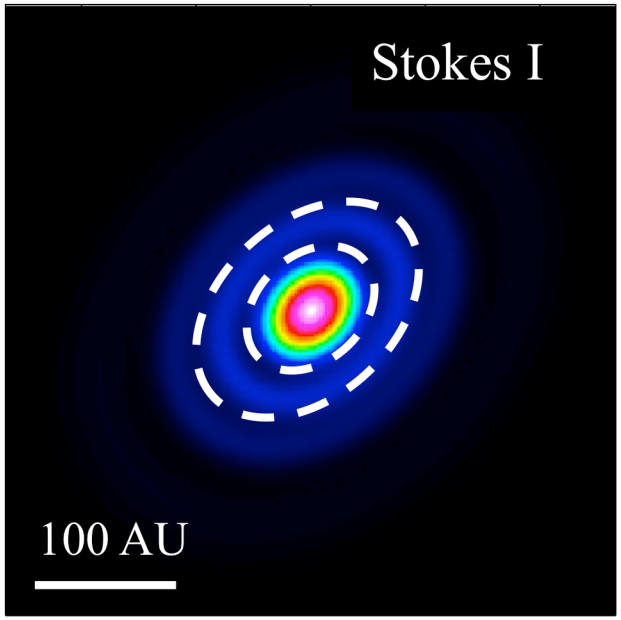
Ohashi et al. in prep

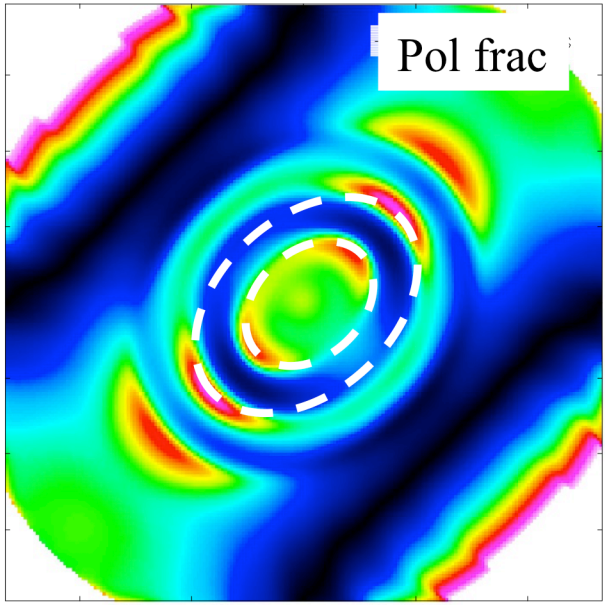
observation

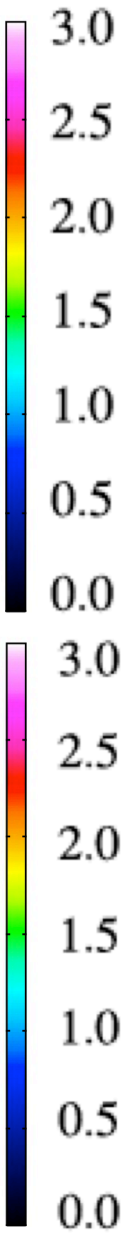
succeeded model











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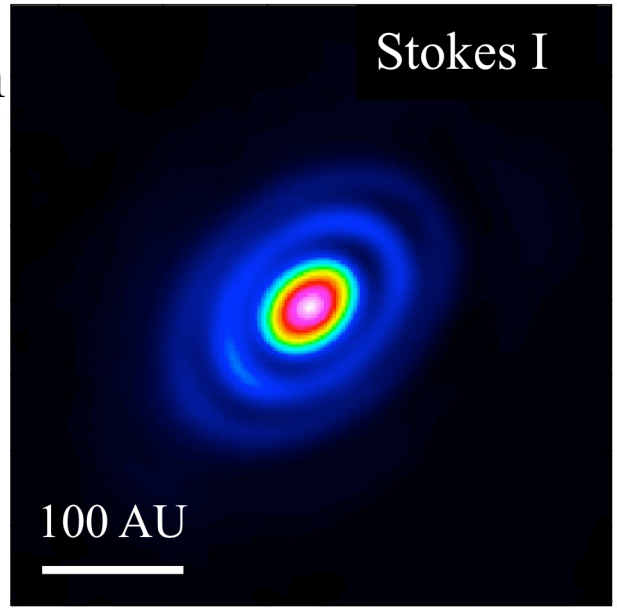

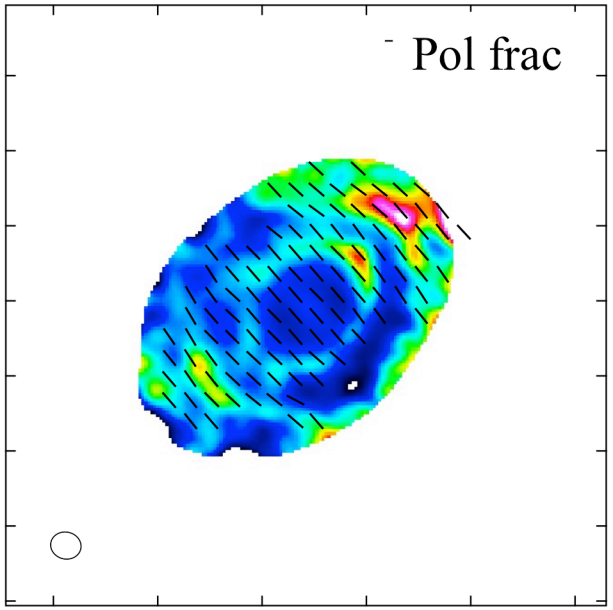

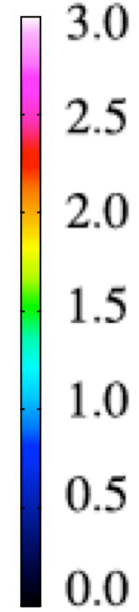

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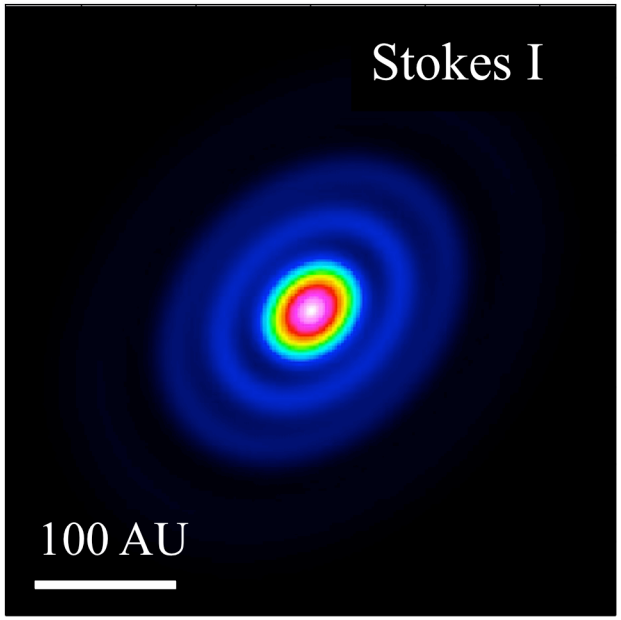
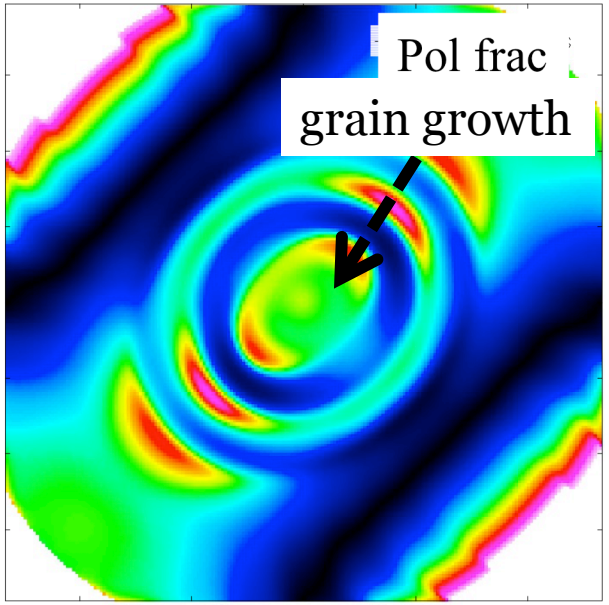
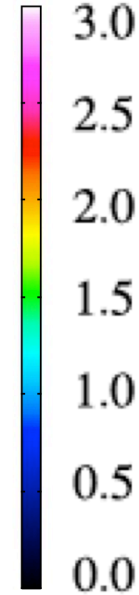






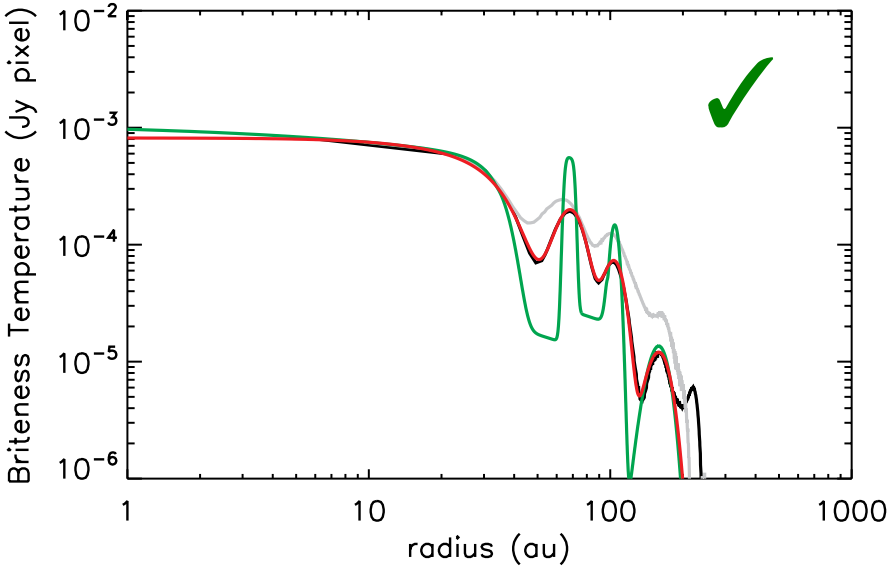
Observed features and explanation by scattering

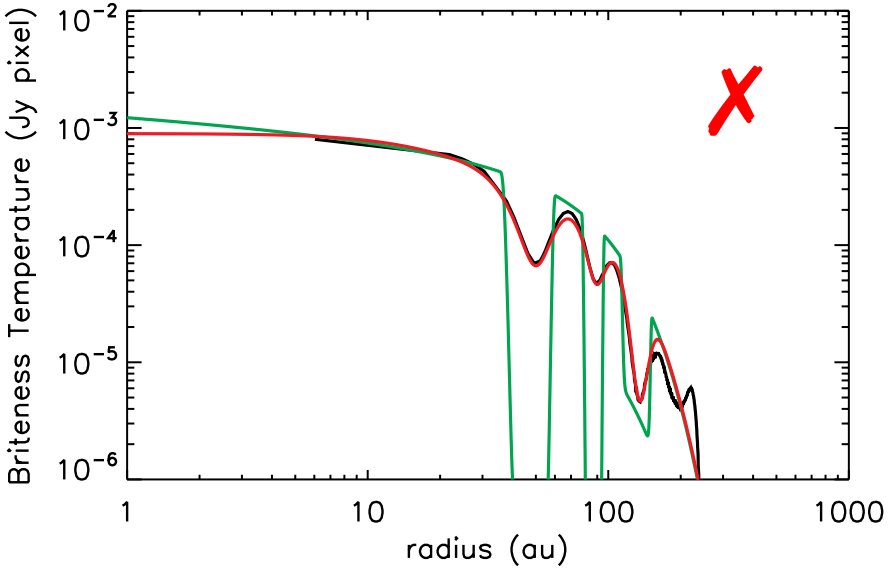
1. The pol fraction becomes higher toward the gaps

→ dust grains with ~150 um are uniformly distributed
(No differences between the gaps and rings)

→ central part has slightly larger grains (~ mm)

→ dust grains in the gaps are still needed (~ 0.1 Σ_{rings})





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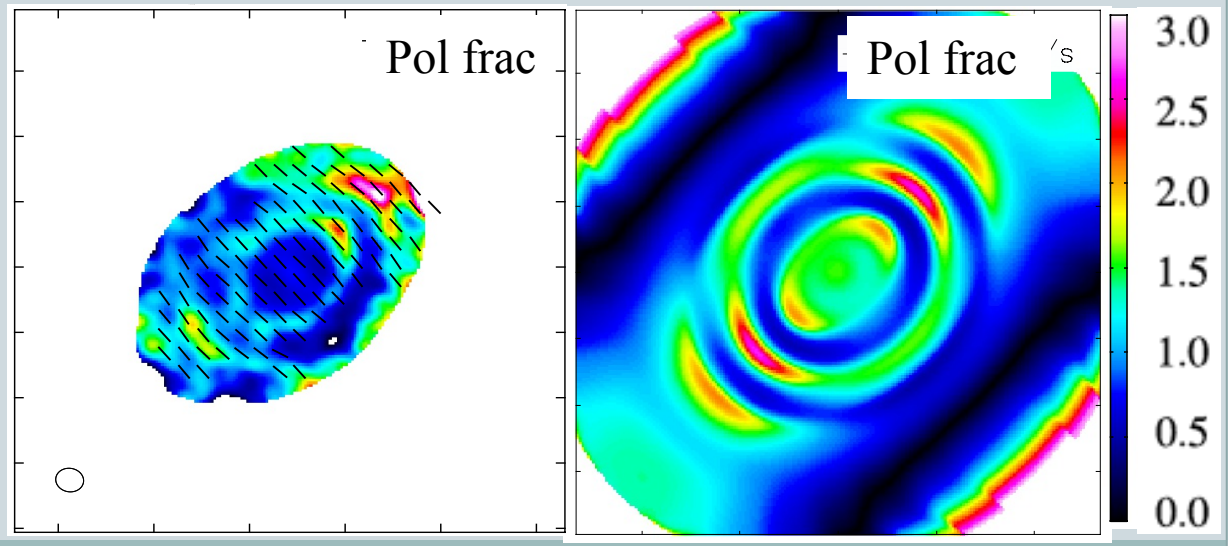
2. The pol fraction of major axis is much higher than that of minor
→ H_{dust} ~ 1/(1-3) H_{gas}



Rough estimations of St and α

$$\mathrm{St} = \frac{\pi \rho_{\mathrm{int}} a_{\mathrm{dust}}}{2\Sigma_{\mathrm{gas}}}$$

1.5 x 10^{-2} cm

~10 g cm^{-2}

~ 3x10^{-3}

$$\alpha = \frac{\dot{M}_{\mathrm{gas}}\Omega}{2\pi c_s^{\,2}\Sigma_{\mathrm{gas}}} \left| \frac{d \ln \Omega}{d \ln R} \right|^{-1}$$

~ 6x10^{-2}

at 100 au

$$H_{\mathrm{dust}} = \left(1 + \frac{\mathrm{St}}{\alpha}\frac{1 + 2\mathrm{St}}{1 + \mathrm{St}}\right)^{-1/2} H_{\mathrm{gas}},$$

Polarization model

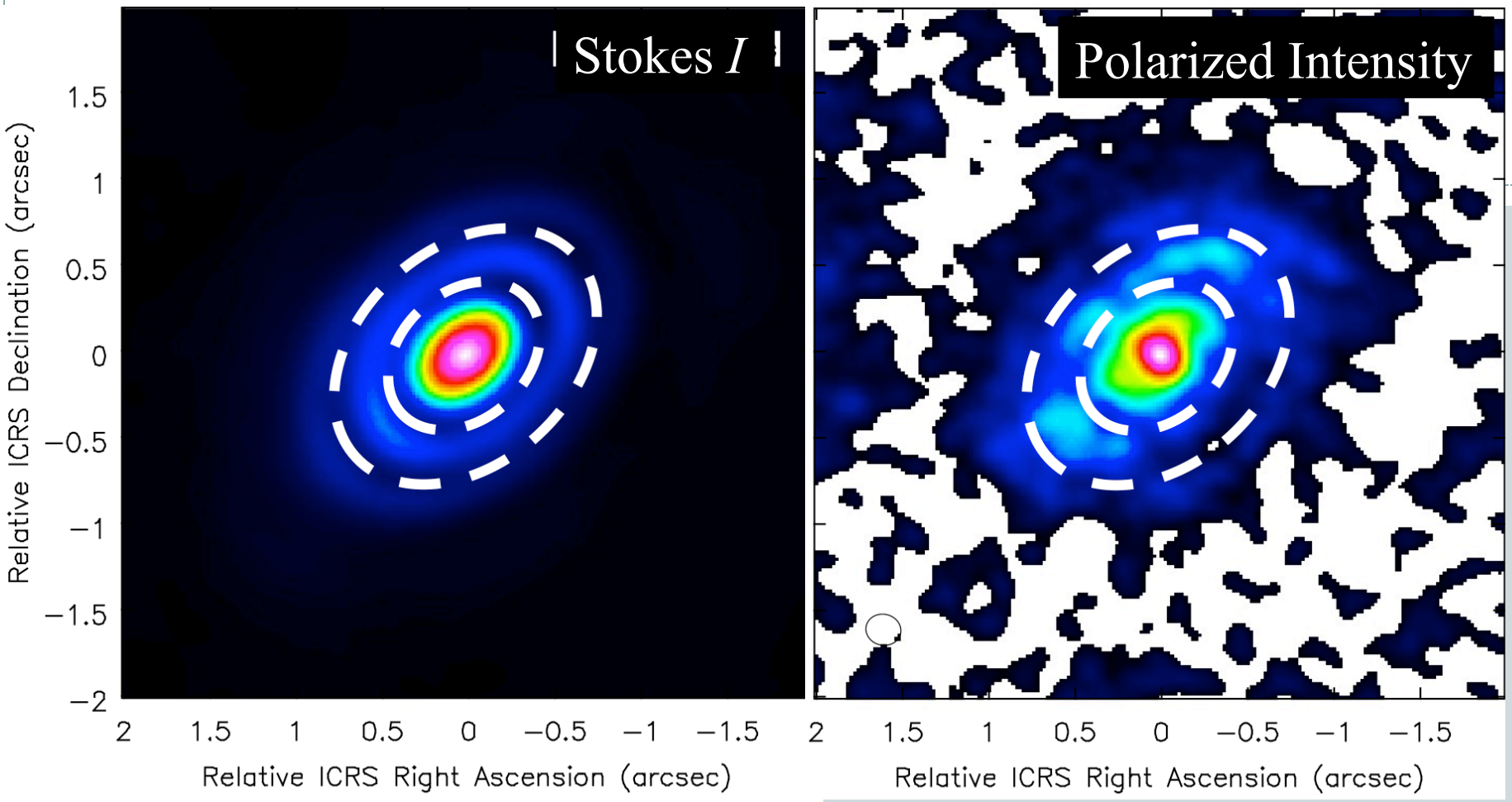
~ 1-8

$$\frac{\mathrm{St}}{\alpha}$$

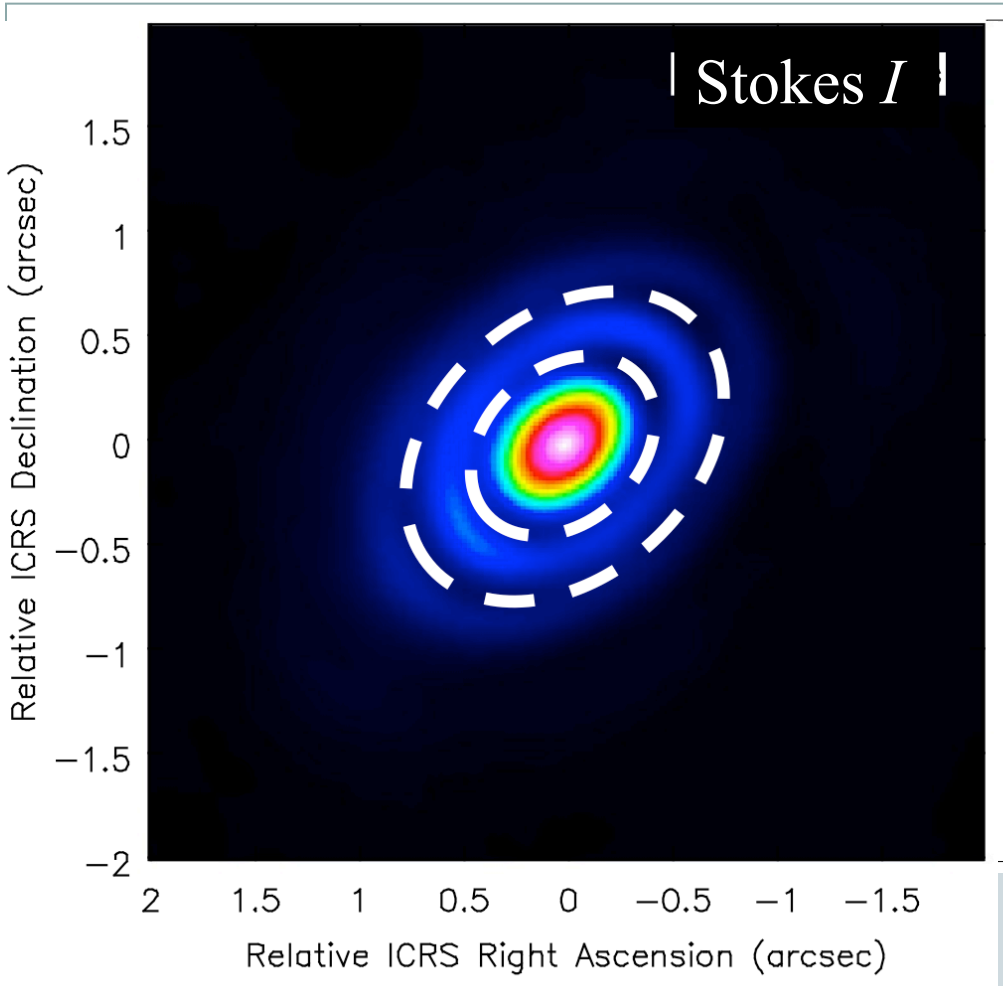
at 100 au

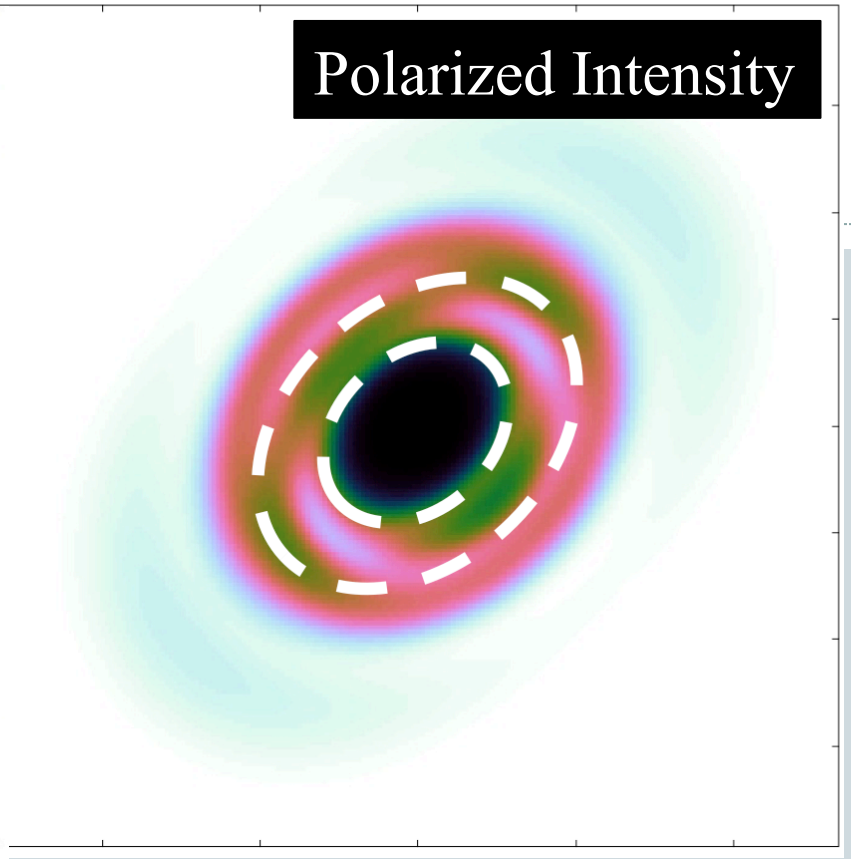
Observations

~ 0.05



リングでPolarized Intensityが受かっている
→ 150 umサイズのダストがある





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