Physical modeling of dust polarization spectrum by RAT alignment and disruption

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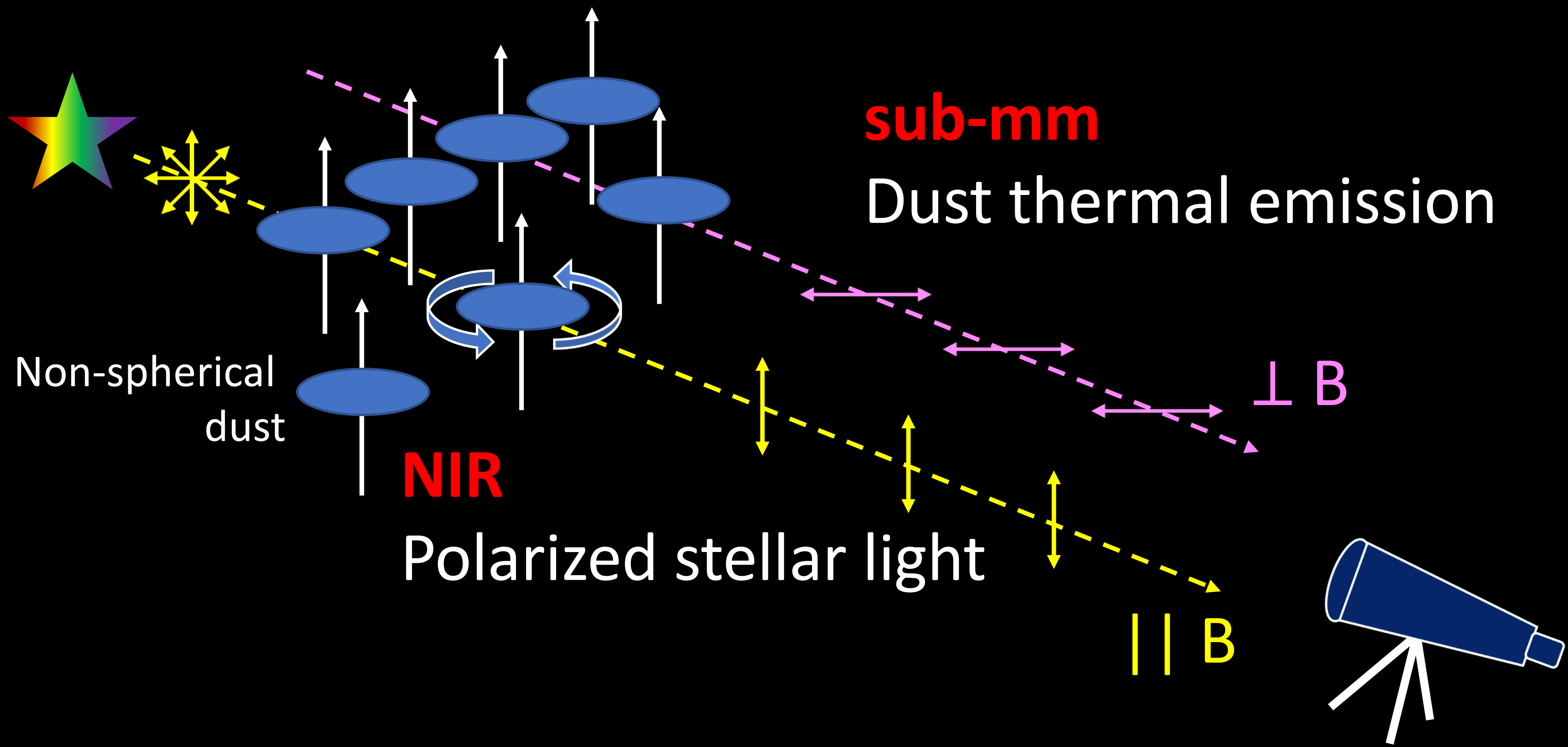
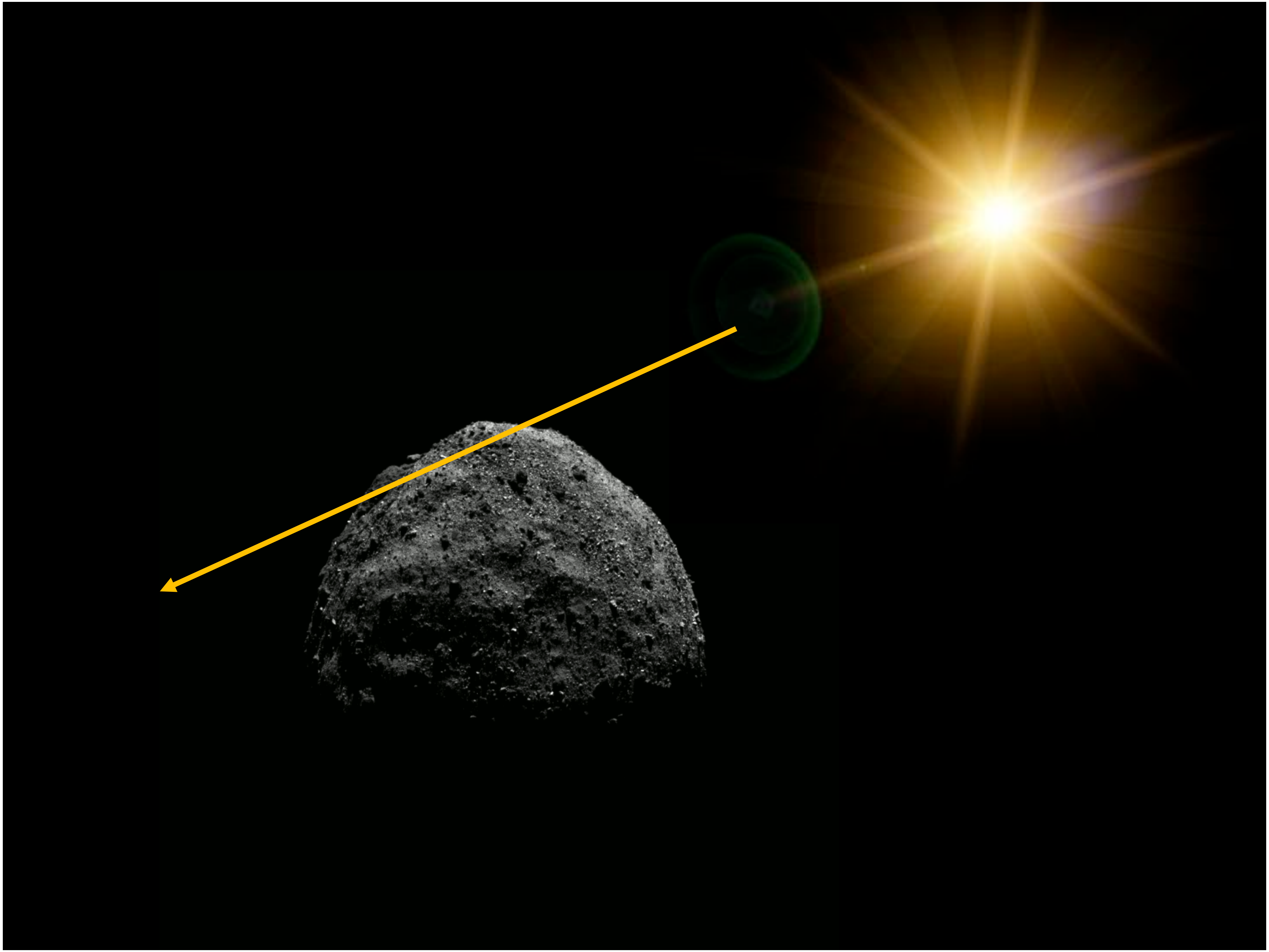
Ngan Le

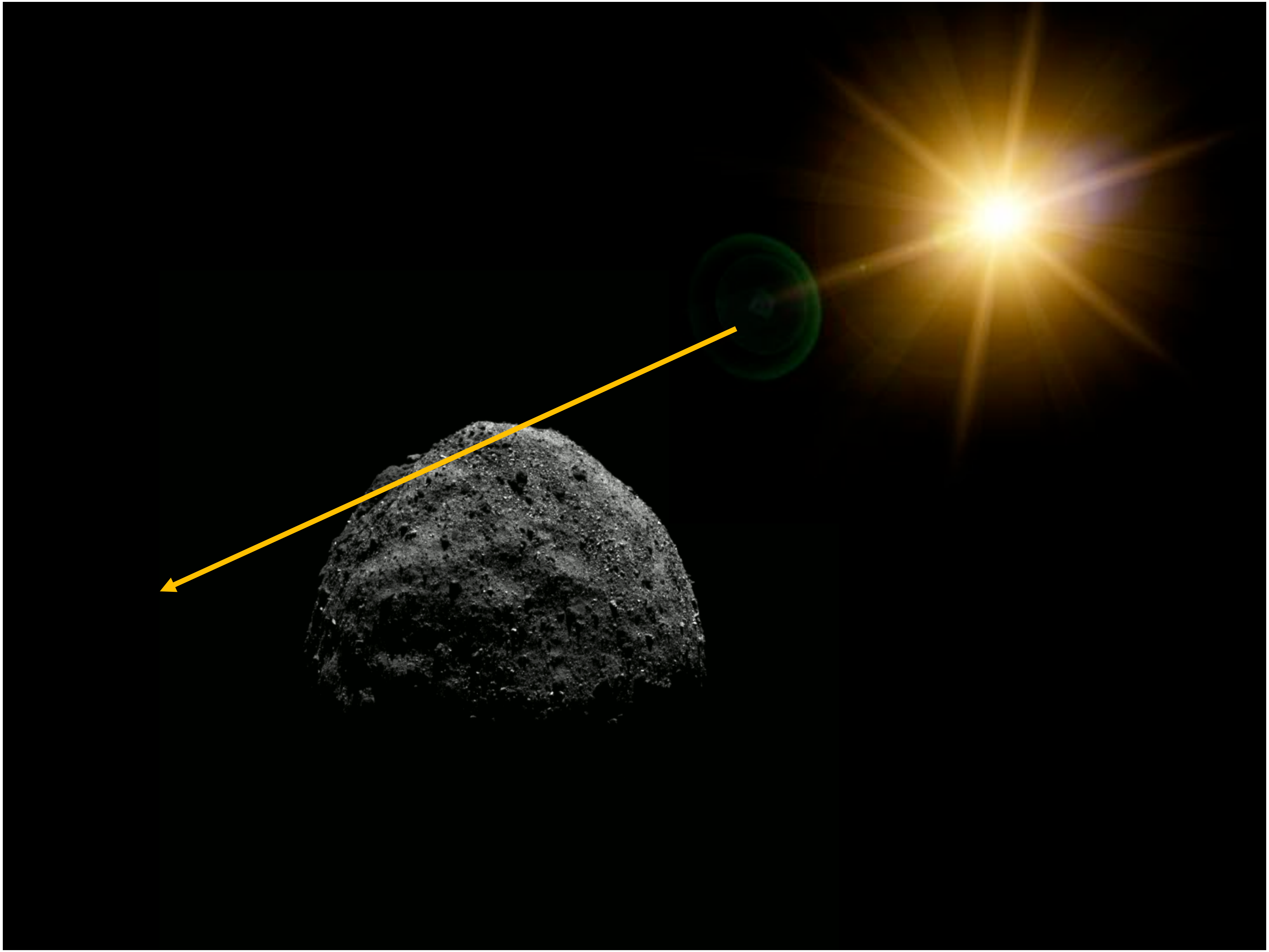
Jungyeon Cho (CNU)

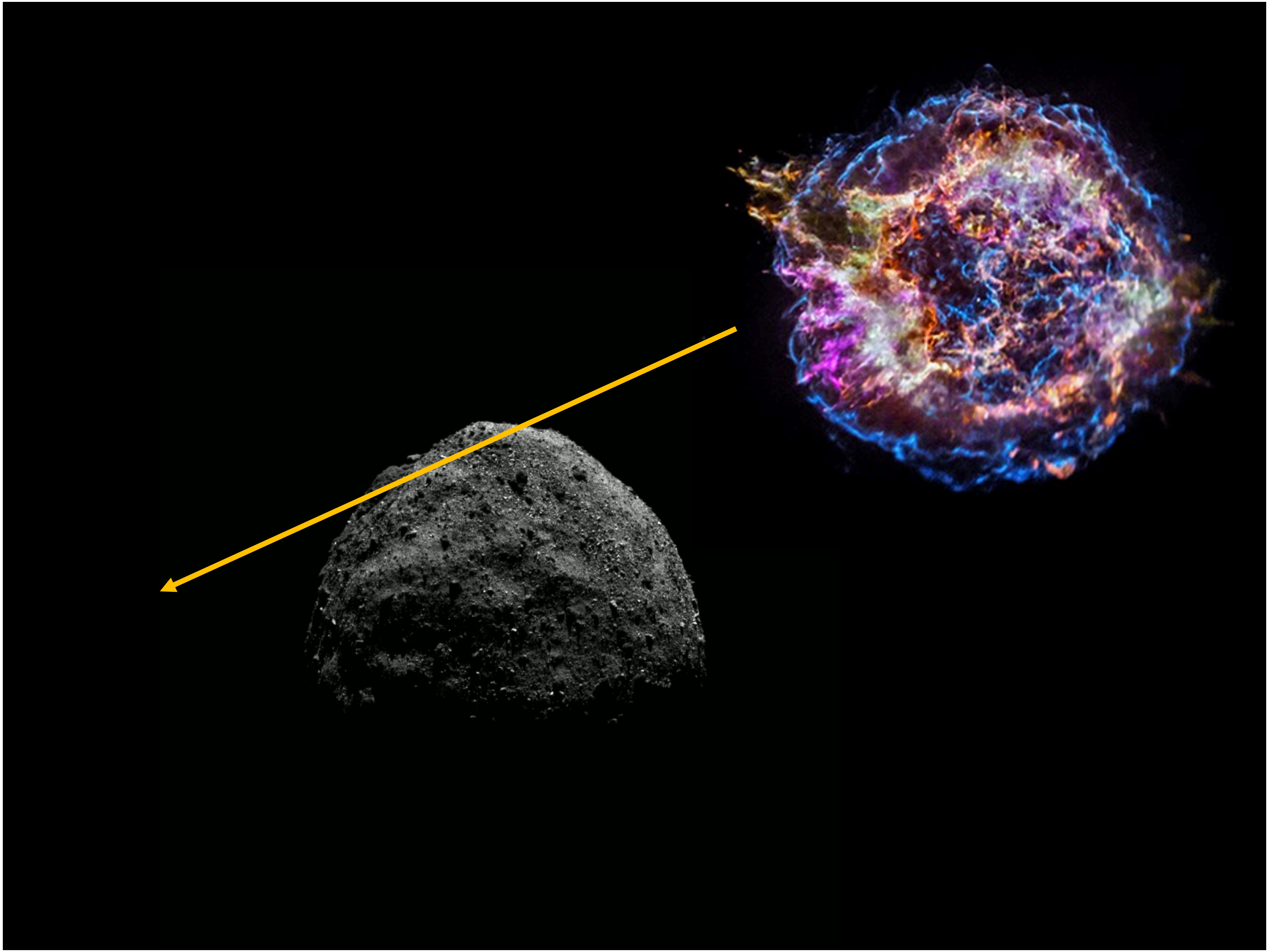
in submitted

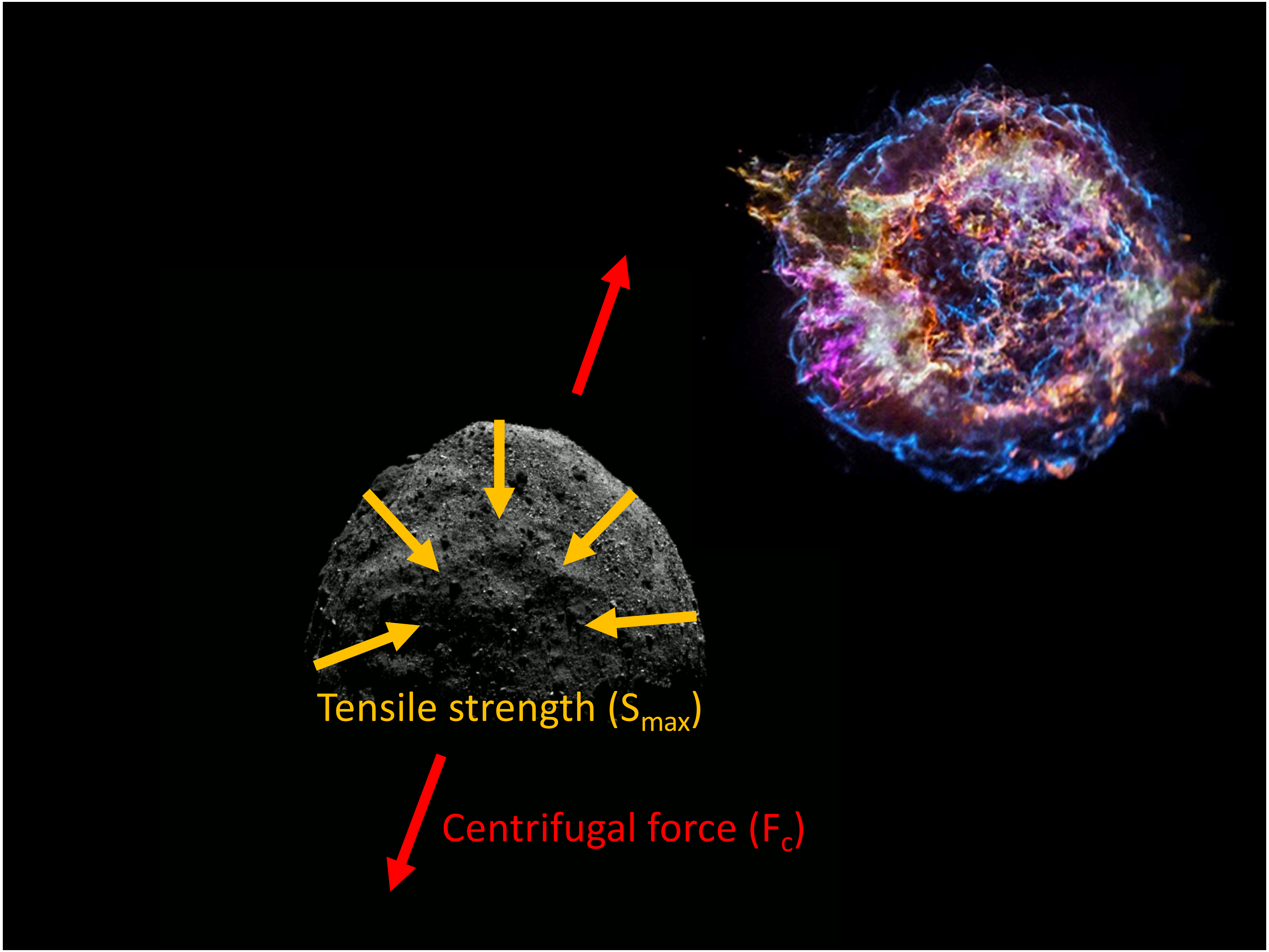
Polarization by dust

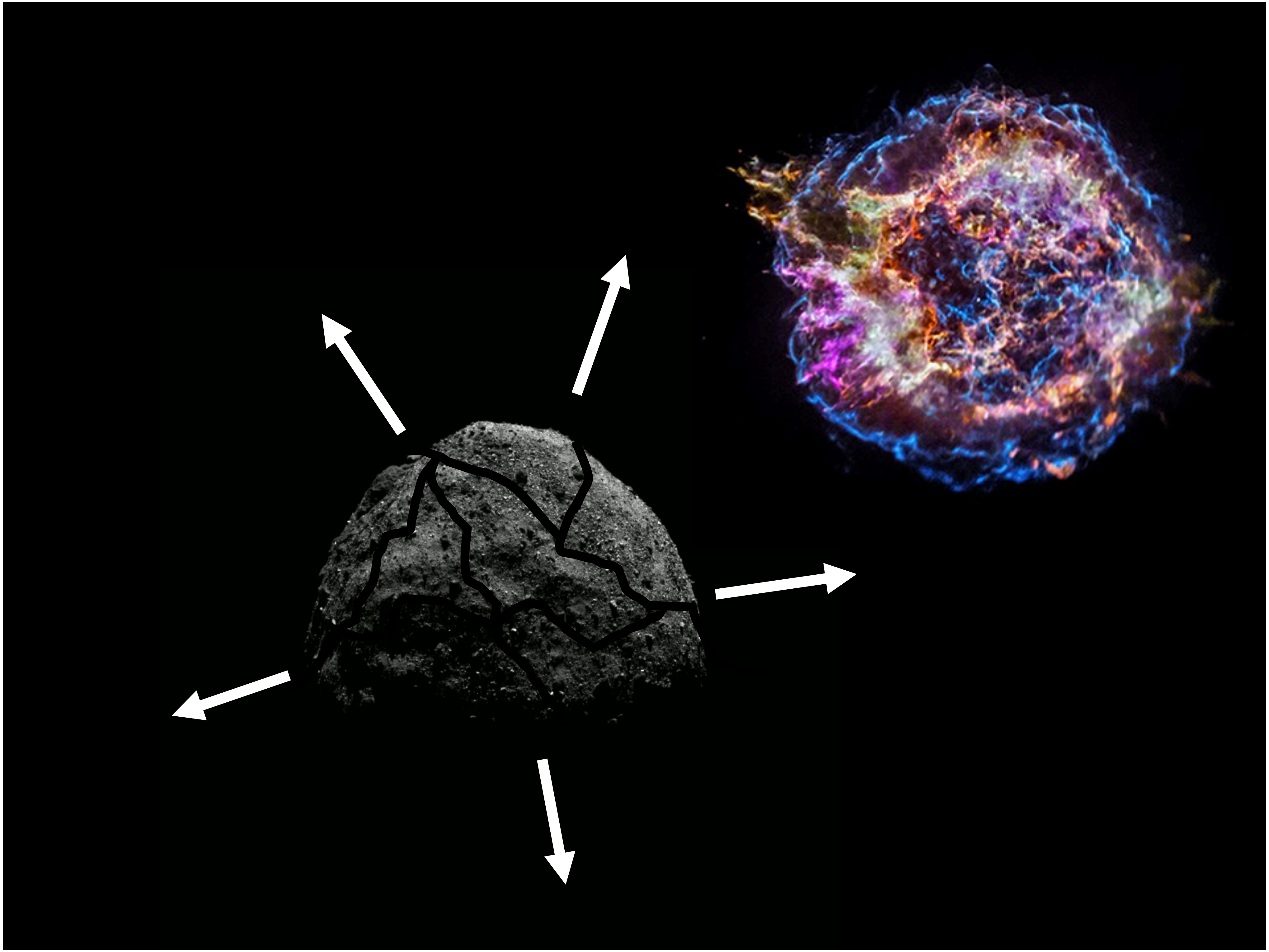




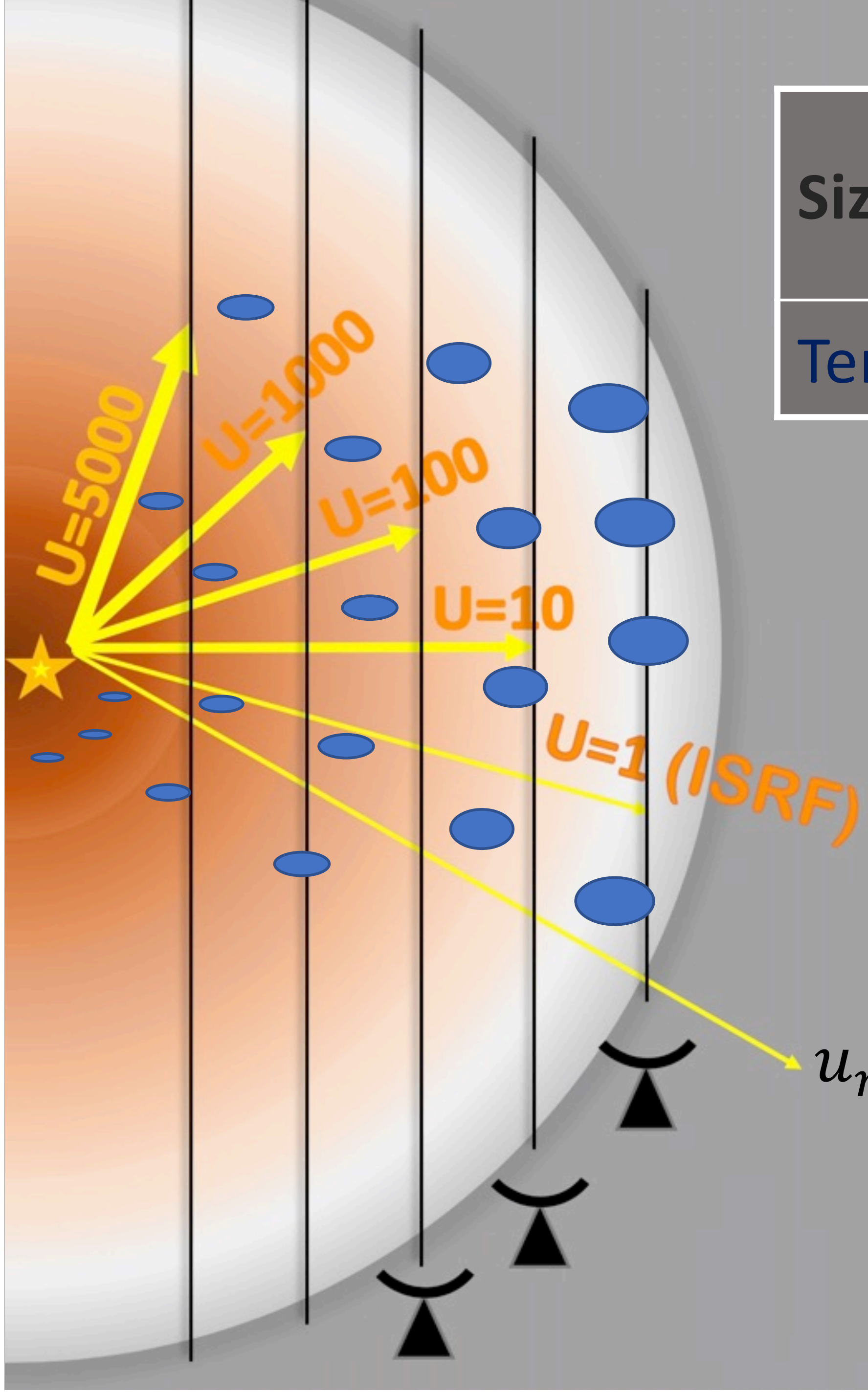





Tensile strength (S_{max})
Centrifugal force (F_c)



Diffuse media



10Å $\quad a_{disruption}$

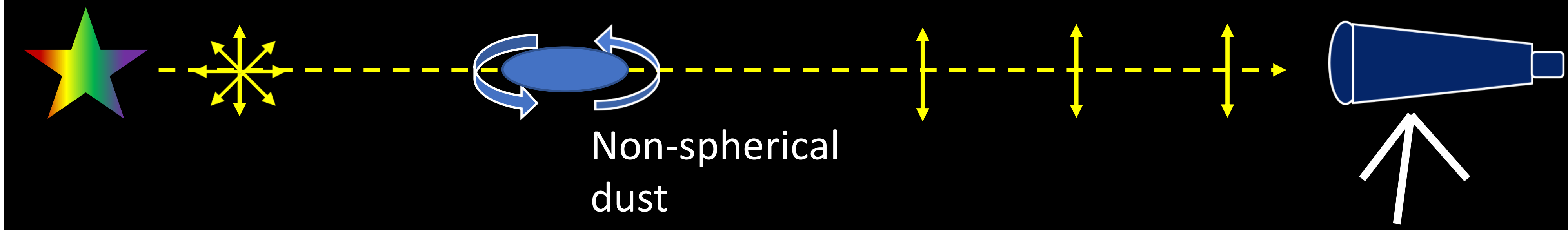
$$a_{min} \leq a \leq a_{max}$$

Size distribution	$\frac{1}{n_H}\frac{dn_j}{da} = C_j a^{-3.5}$
Tensile strength	S_{max} = 10^6 ~ 10^9 erg/cm^3

$$u_{rad} = \int u_\lambda d\lambda \longrightarrow U = u_{rad}/u_{ISRF}$$

Radiation strength

Polarized starlight



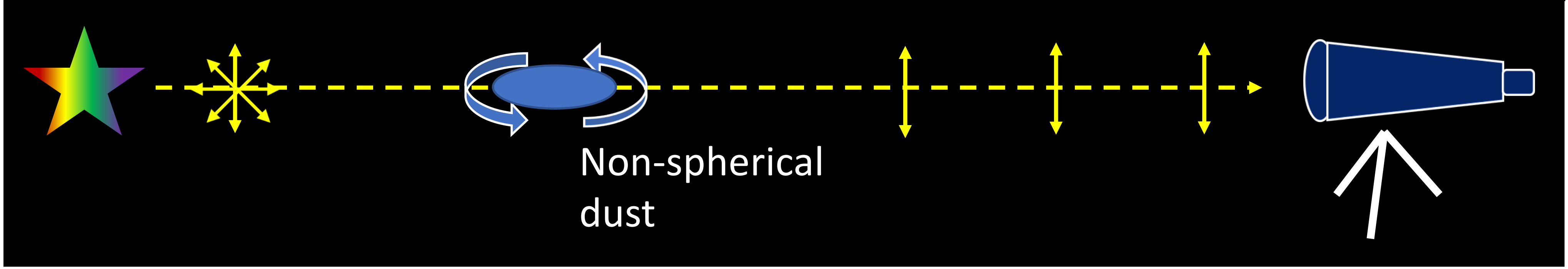
effective degree of grain alignment

$$\frac{P_\lambda}{N_H} = \int_{a_{min}}^{a_{max}} \frac{1}{2} C_{pol}^{sil}(\lambda, a) f(a) \frac{1}{n_H} \frac{dn_{sil}}{da} da$$

Cross-section

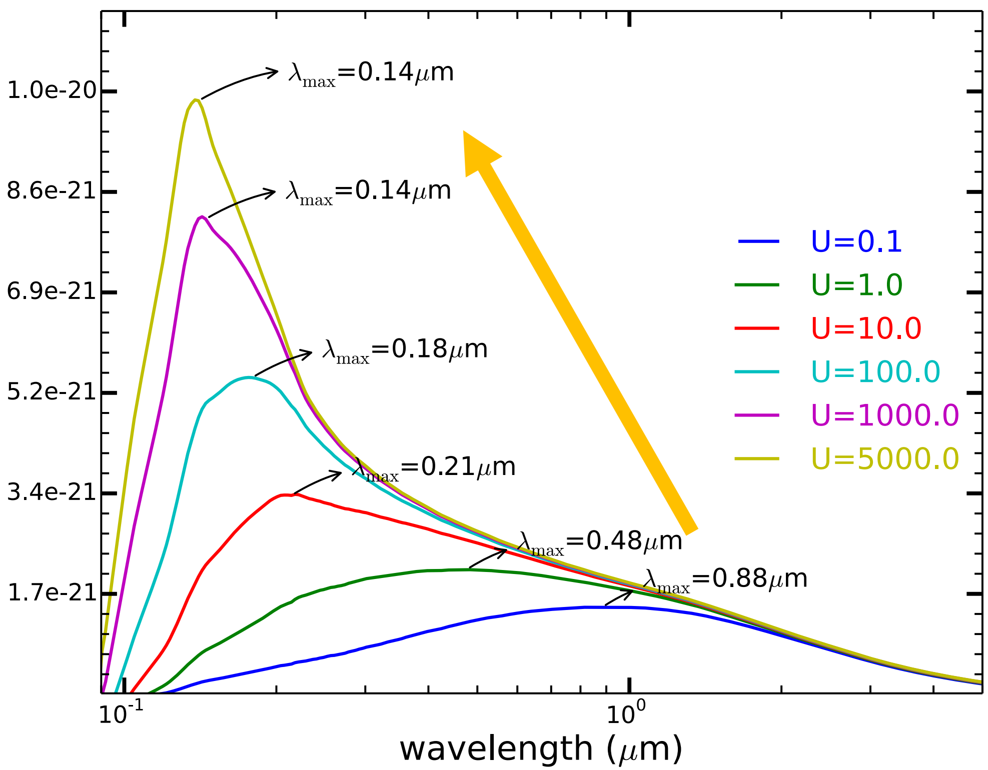
$N_H = n_H L$, L is the length of the line of sight

Polarization spectrum

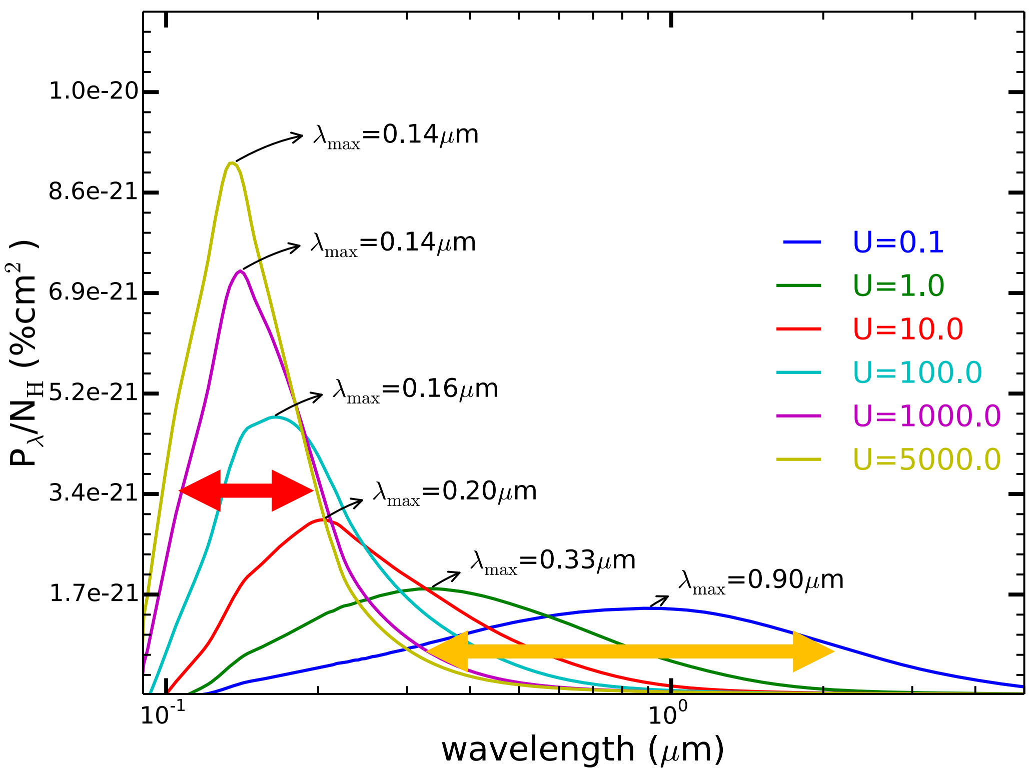


- $S_{max} = 10^7$ erg cm^{-3}

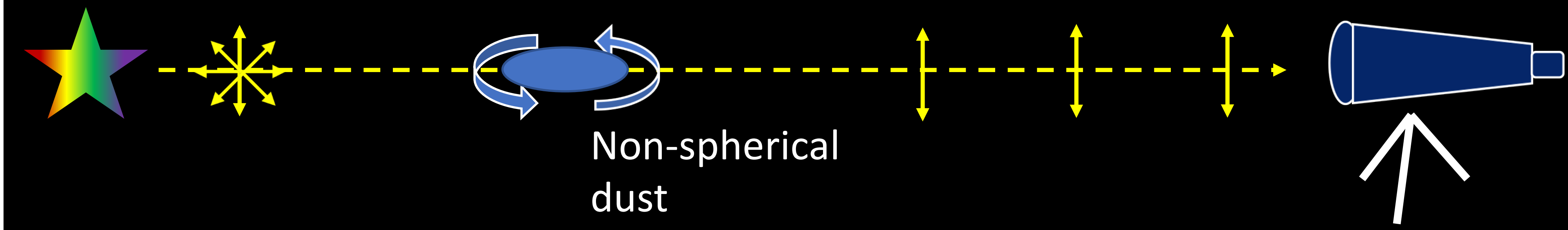
No disruption



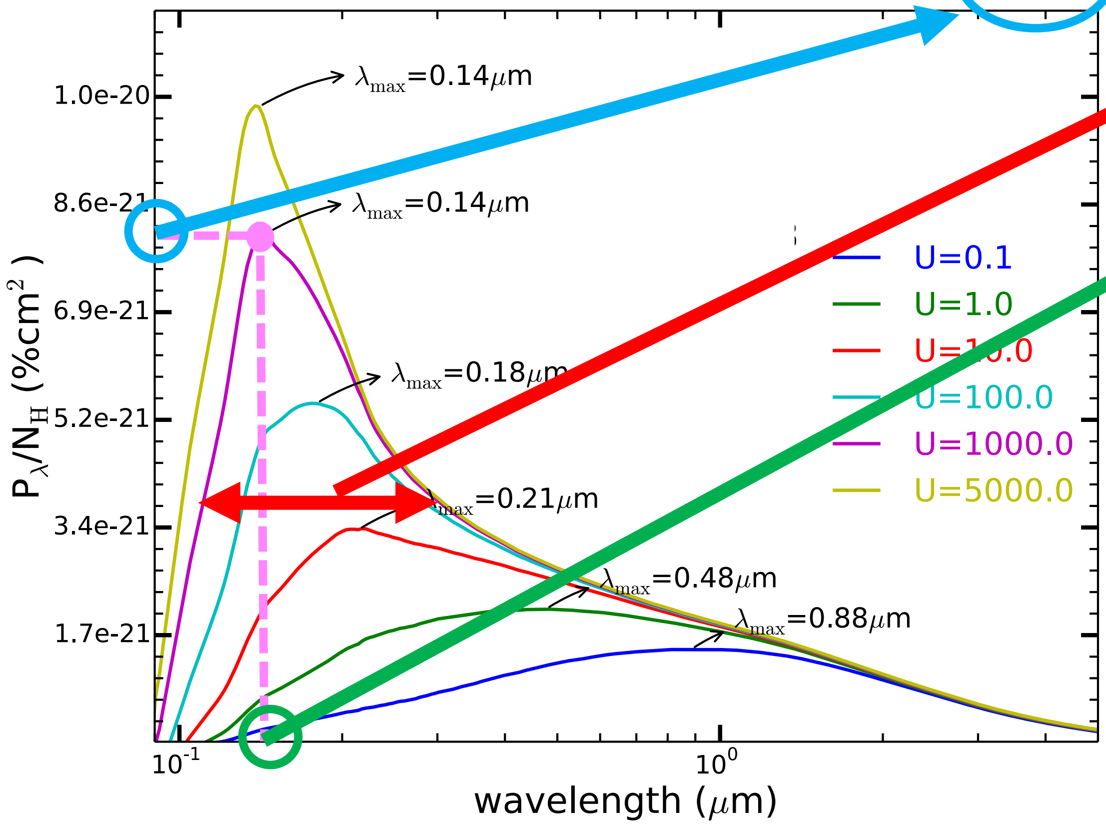
RATD



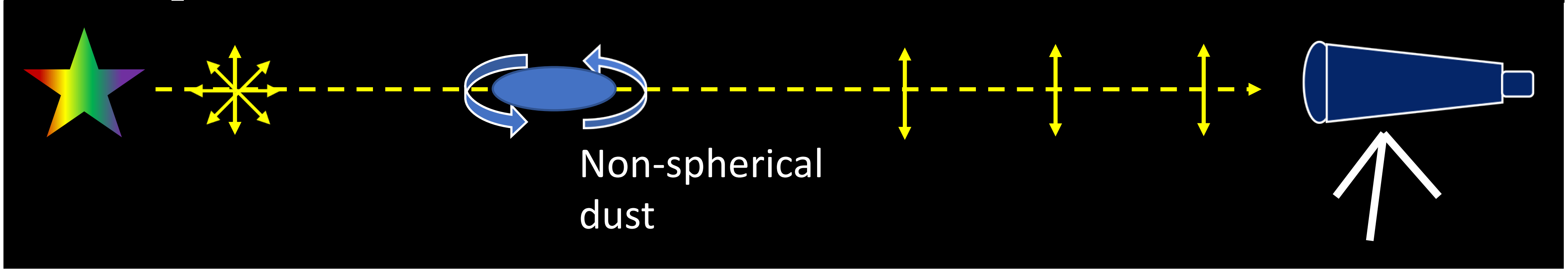
Polarization spectrum



(Serkowski law) $$P(\lambda) = P_{max} exp\left(-K\, ln^2\left(\frac{\lambda}{\lambda_{max}}\right)\right)$$

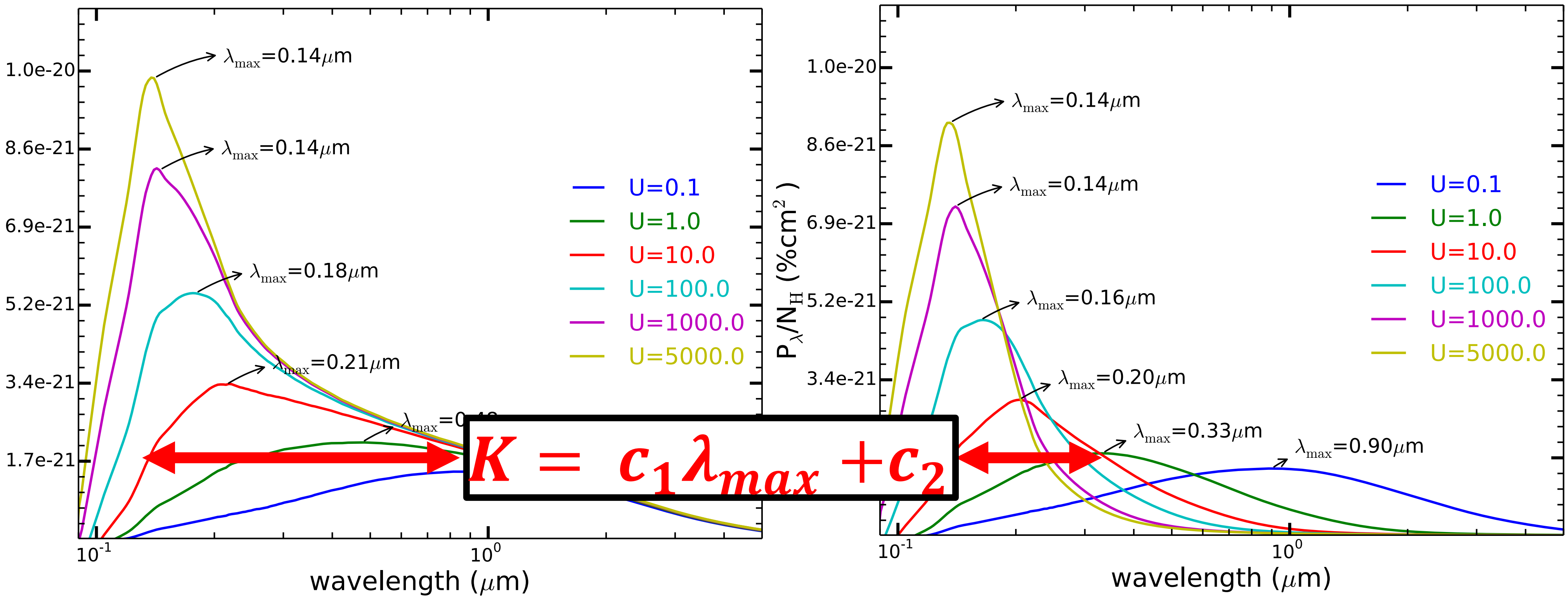


Polarization spectrum



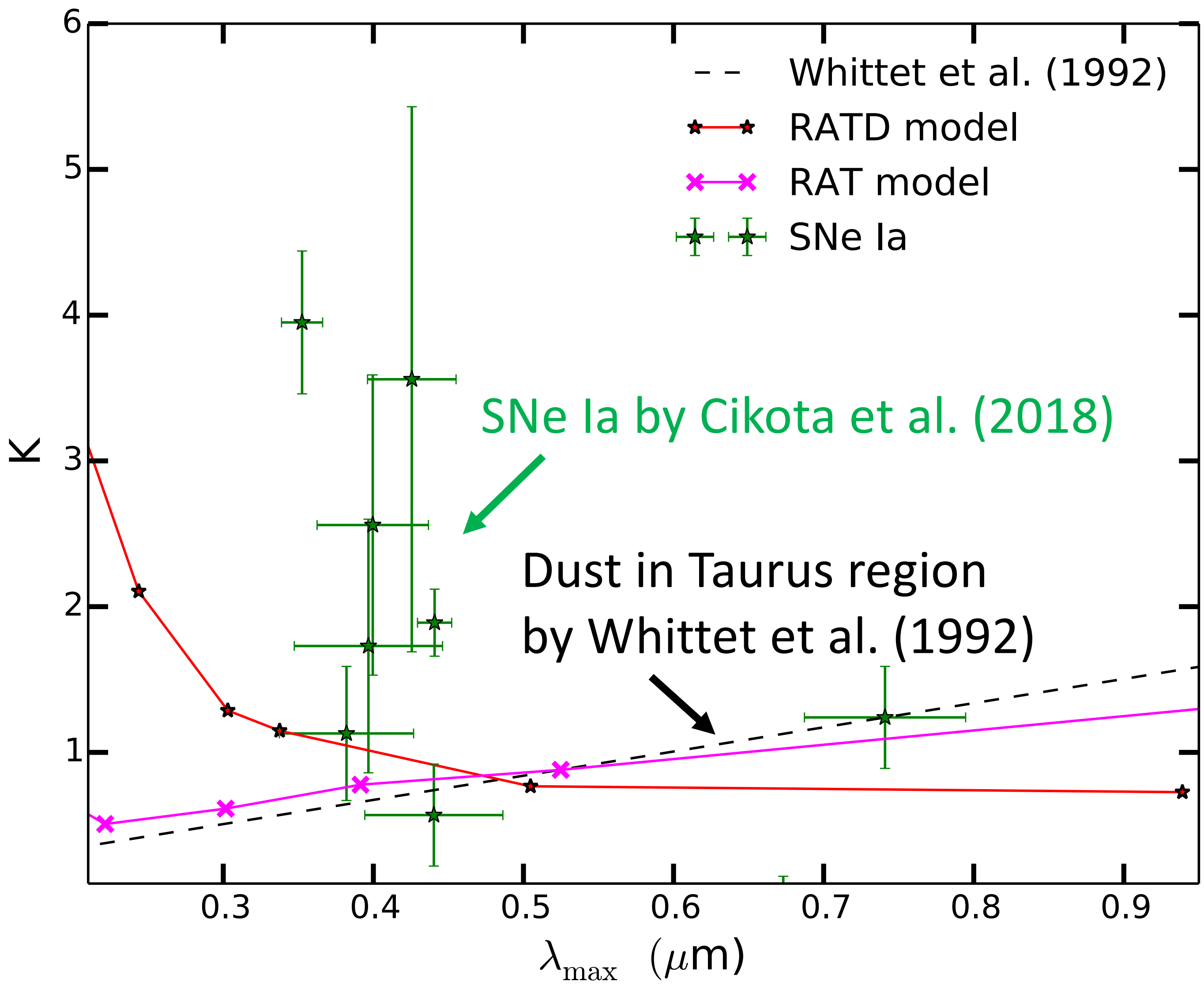
- $S_{max} = 10^7$ erg cm^{-3}

No disruption | **RATD**

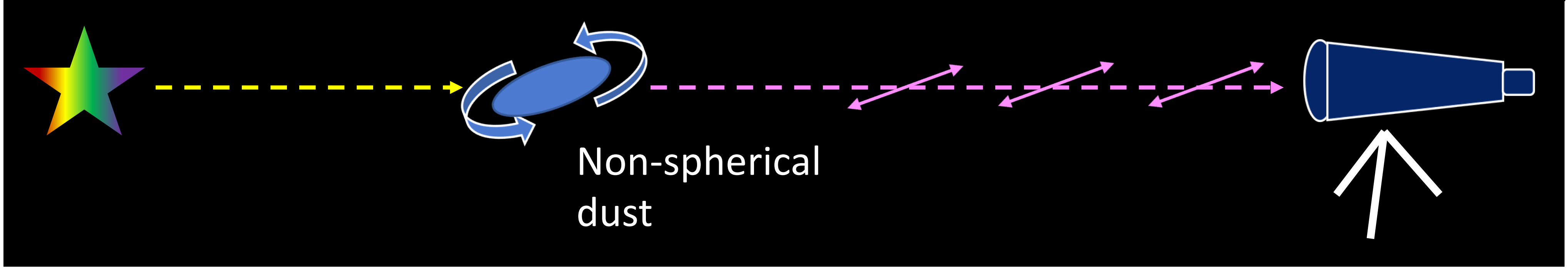


$$K = c_1\lambda_{max} + c_2$$

λ_{max} – K relation



Polarized emission



$$P(\%) = 100\times\left(\frac{I_{pol}}{I_{em}}\right)$$

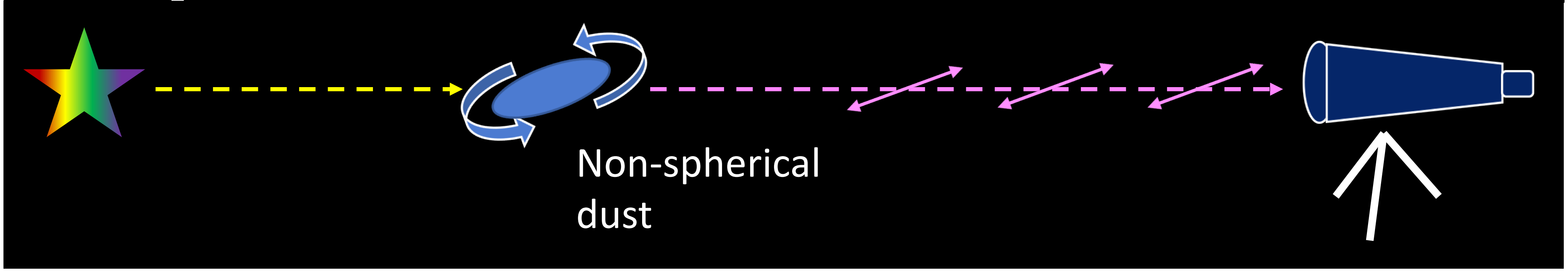
For optically thin regime,

Planck function

Total emission intensity	$\frac{I_{em}(\lambda)}{N_H} = \sum_{j=sil,car}\int_{a_{min}}^{a_{max}} Q_{ext}\pi a^2 \int dT B_\lambda(T_d)\frac{dP}{dT}\frac{1}{n_H}\frac{dn_j}{da}da$
Polarized intensity	$\frac{I_{pol}(\lambda)}{N_H} = \int_{a_{min}}^{a_{max}} f(a)Q_{pol}\pi a^2 \int dT B_\lambda(T_d)\frac{dP}{dT}\frac{1}{n_H}\frac{dn_{sil}}{da}da$

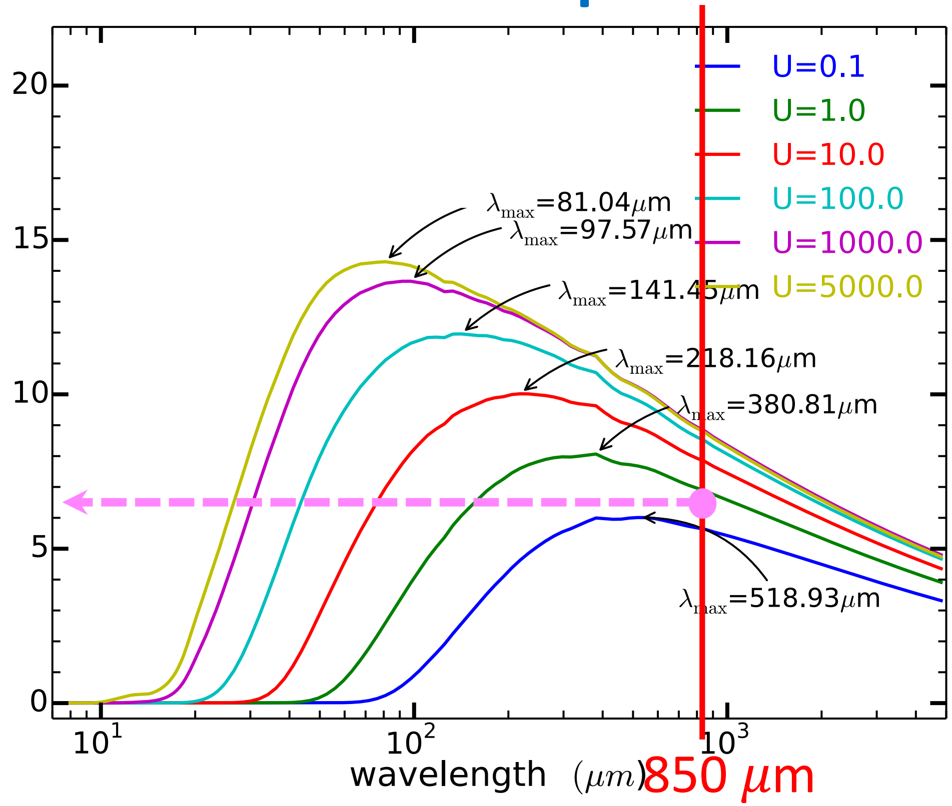
Temperature distribution function which depends on the grain size and radiation strength **U**

Polarization degree

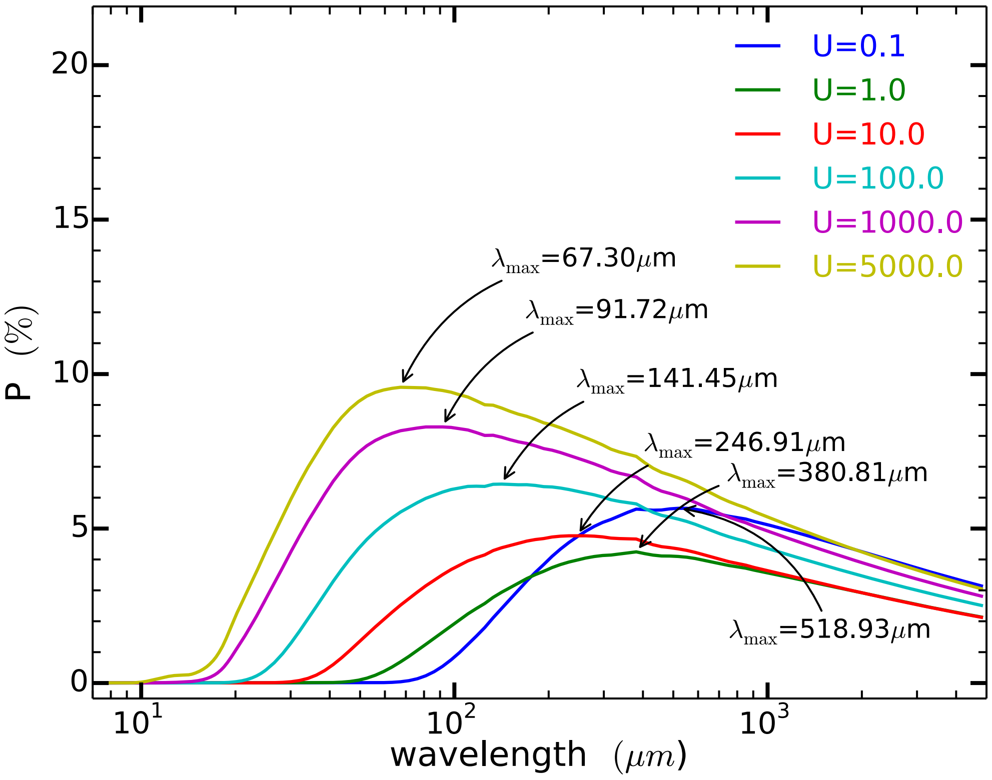


- $S_{max} = 10^7$ erg cm^{-3}

No disruption

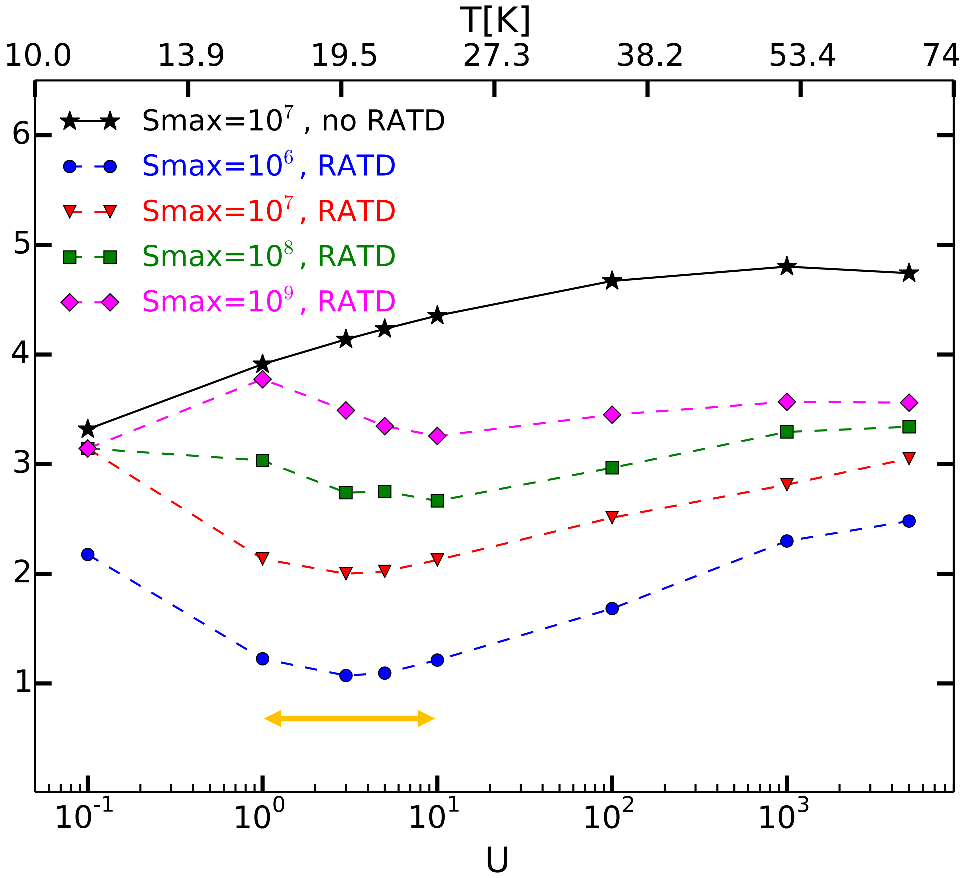


RATD

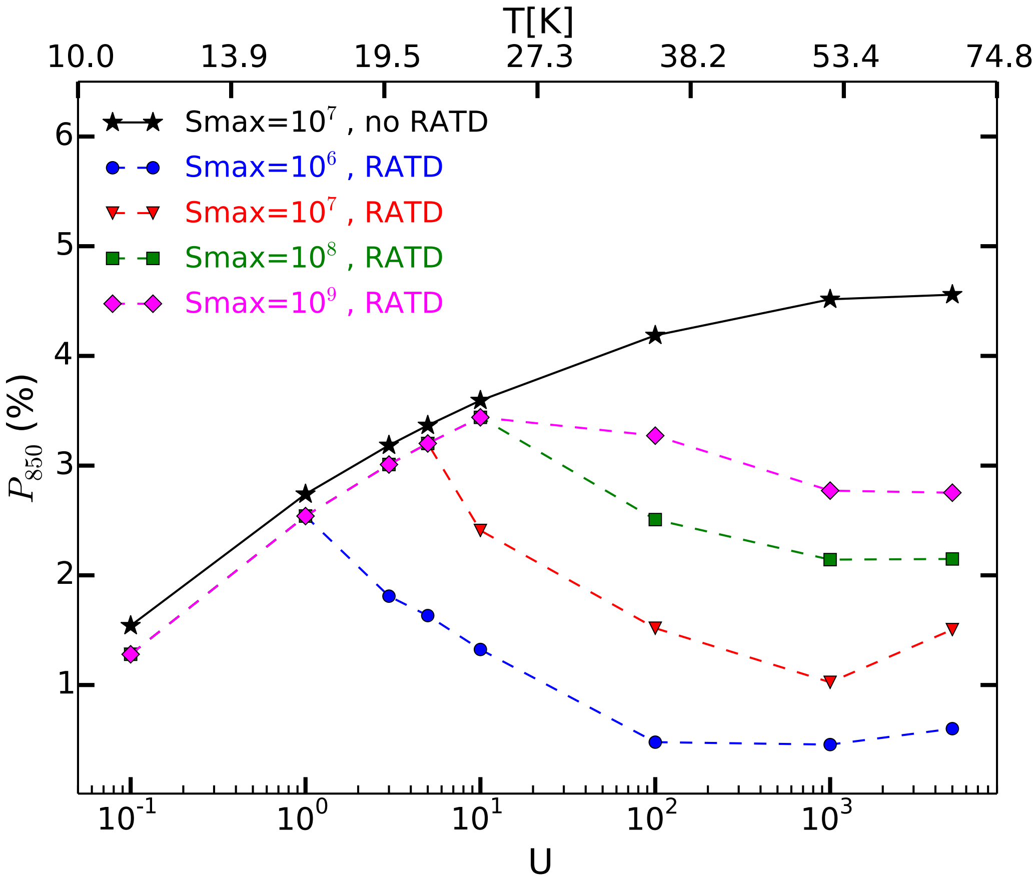


P_{850} vs U

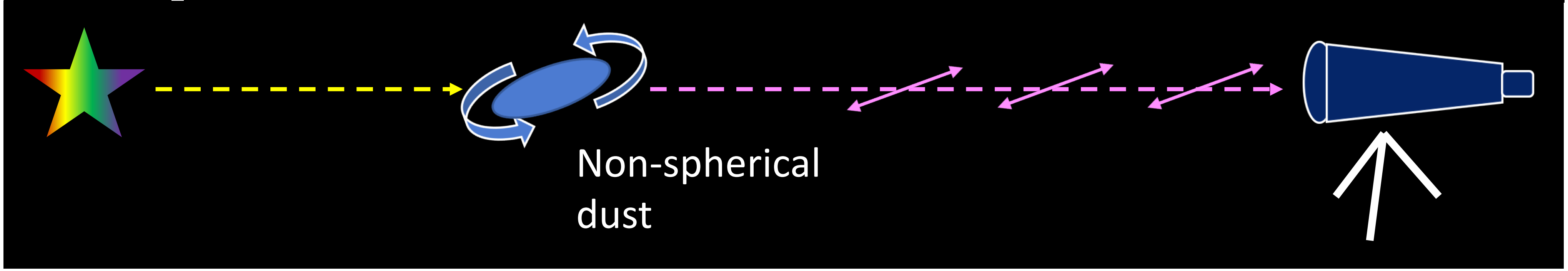
diffuse media



dense media



Polarization degree



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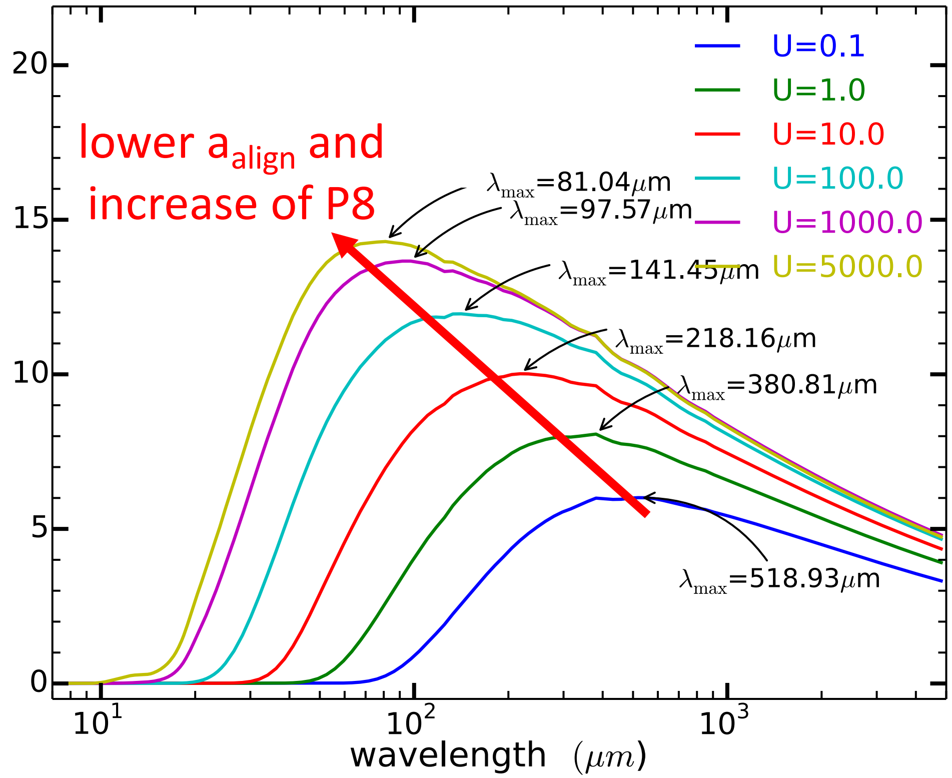
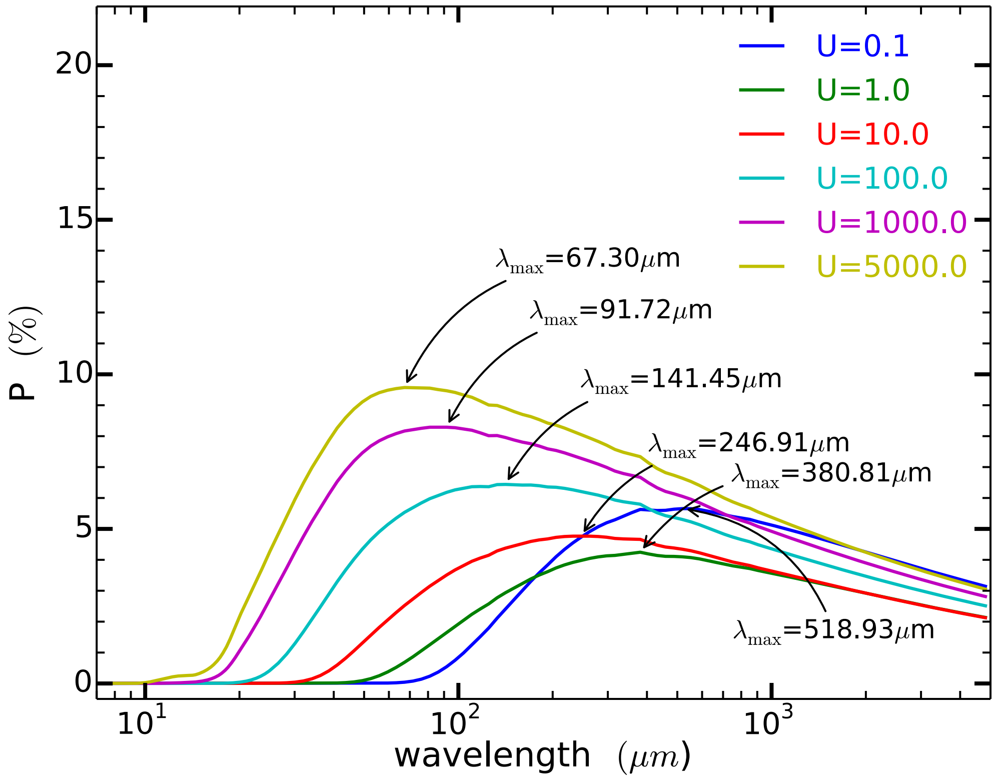
No disruption

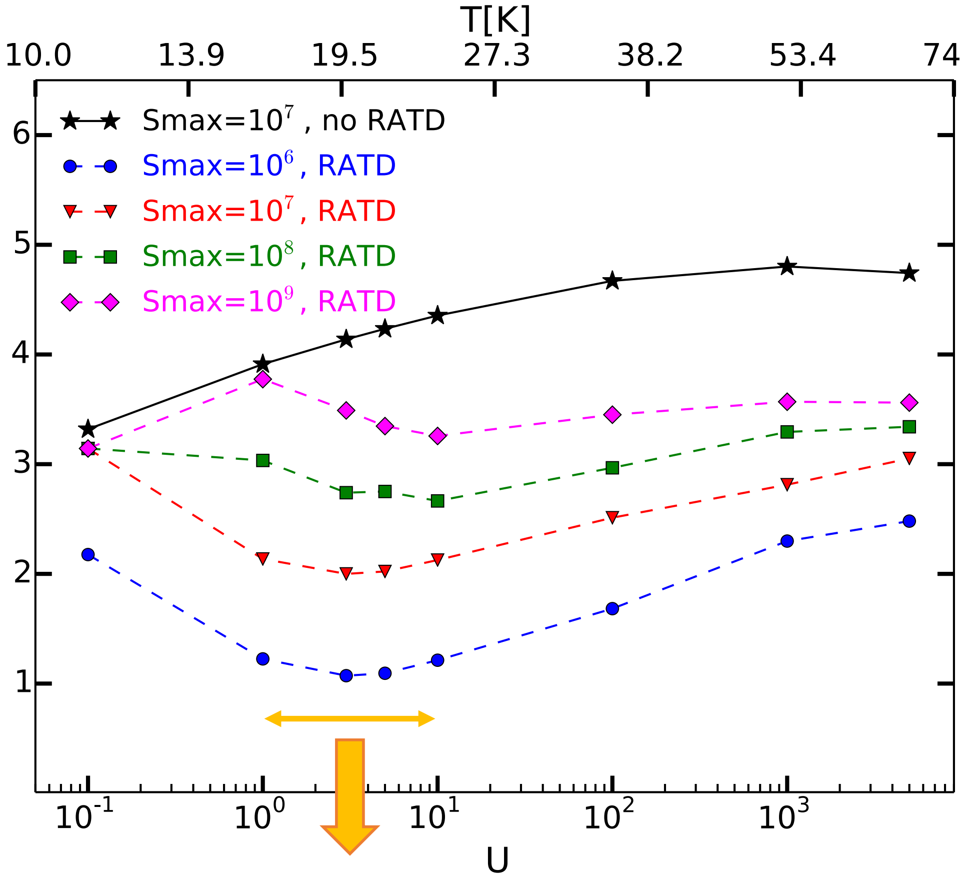


RATD



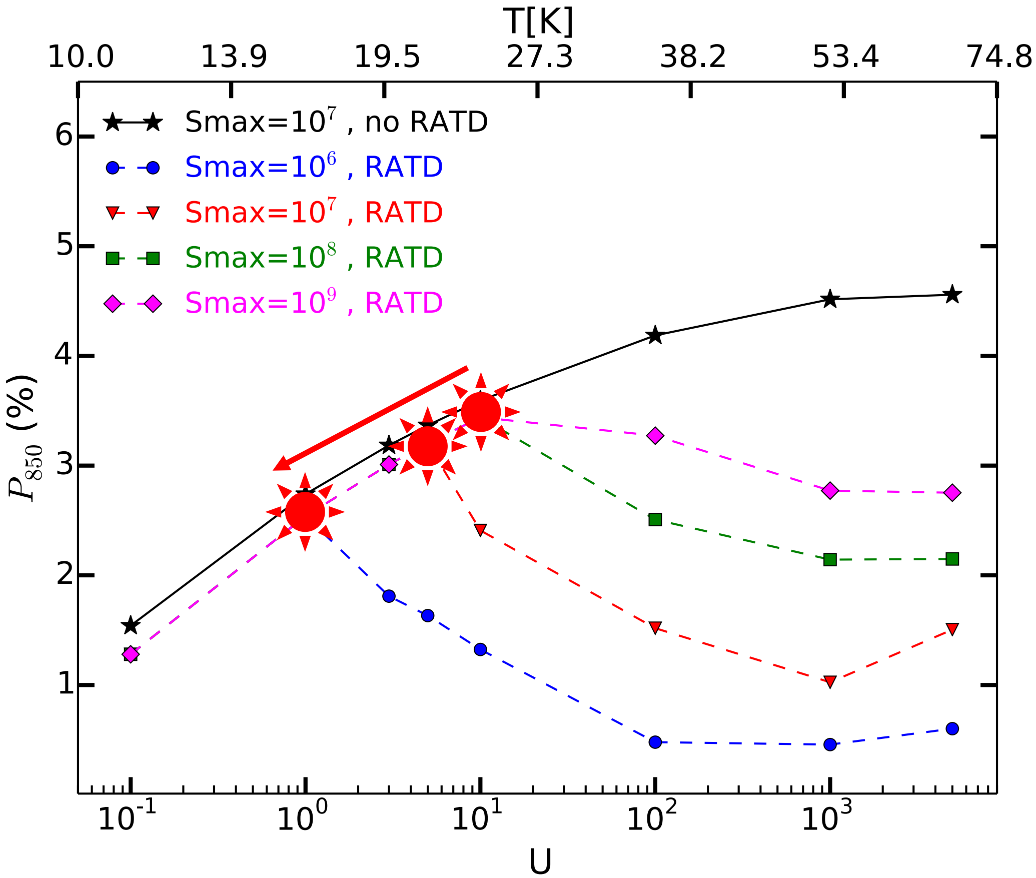
P_{850} vs U

diffuse media



compensation of the shift of polarization toward short wavelengths due to lower a_{align} and the increase of the polarization

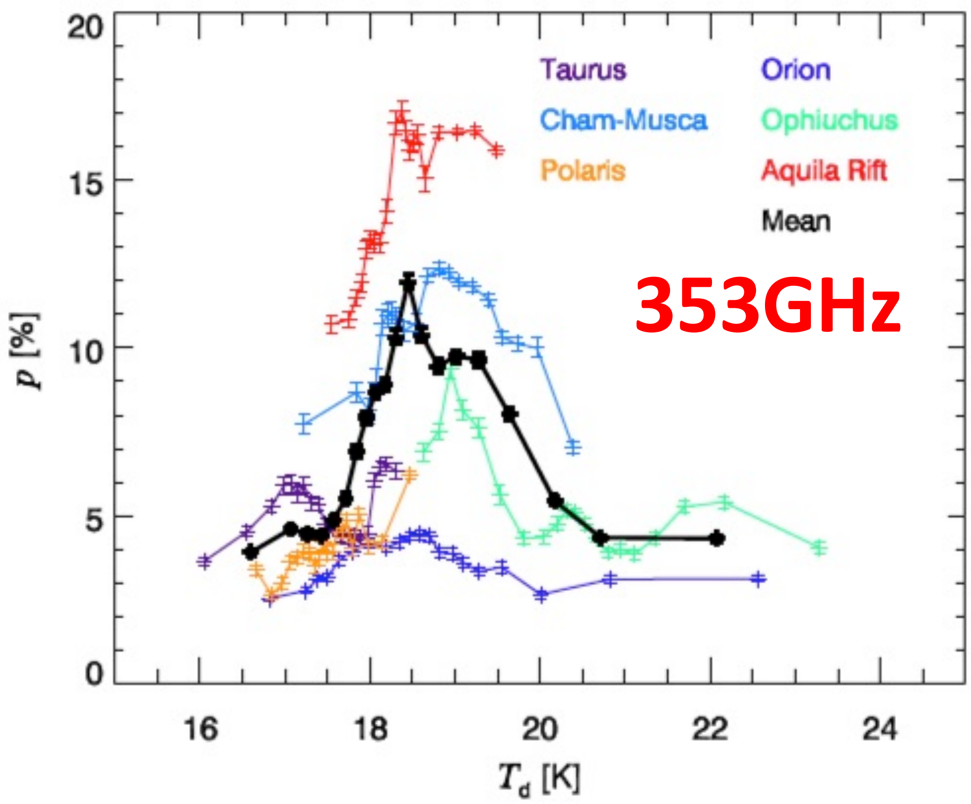
dense media



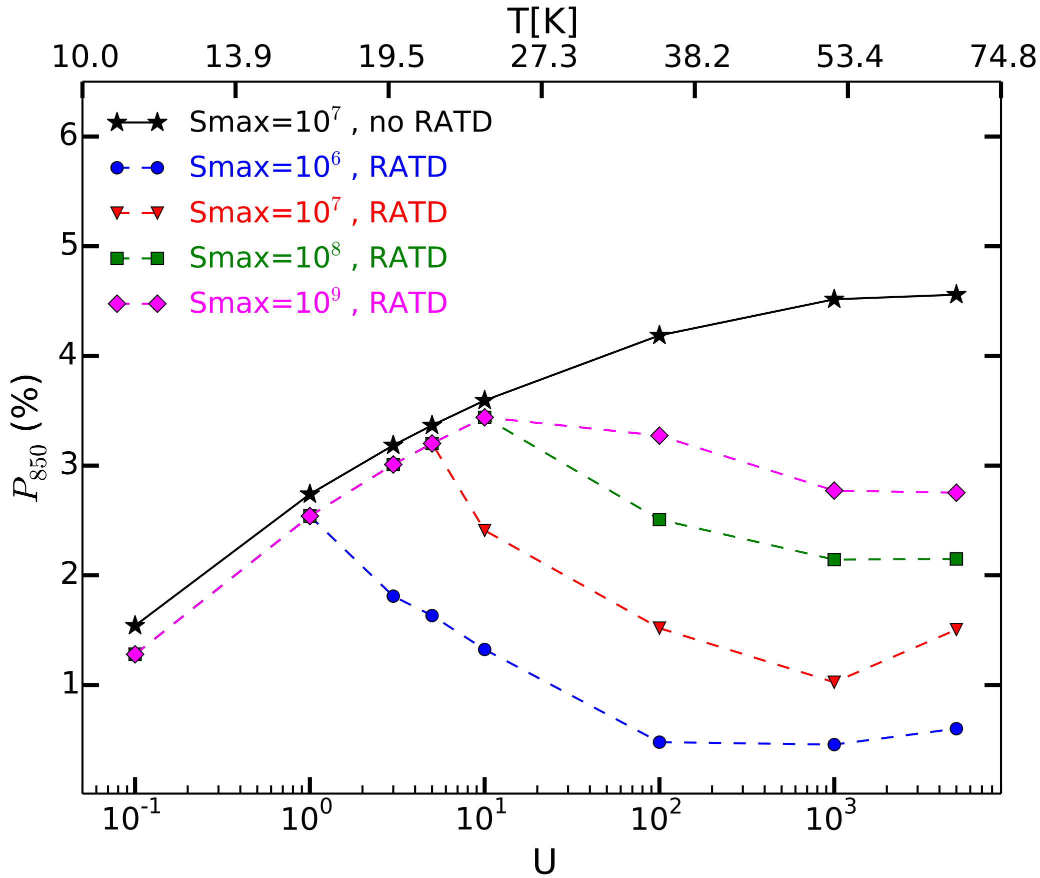
Planck data

Planck data

Planck Collaboration et al. (2018)



dense media



Summary

Using the RAT alignment and **RATD theory**, we model the polarization of starlight and polarized thermal emission by aligned grains.

1. For the diffuse medium, the **optical/NIR polarization** is reduced due to the **disruption** of large grains into **smaller ones**.
2. For **polarized thermal emission**, the $\mathbf{P_{max}}$ increases but the $\lambda_{\mathbf{max}}$ decreases with increasing **U** due to enhanced alignment of small grains ➔ SOFIA/HAWC+
3. When taking into account **RATD**, the variation of the polarization degree with **U** depends on the $\mathbf{S_{max}}$ of grain materials.
4. Comparison with Planck data (2018), interstellar grains unlikely to have a compact structure with very high $\mathbf{S_{max}}$ perhaps a **composite structure**.
5. Our models of starlight polarization for high radiation intensity with RATD find that the **K-** $\lambda_{\mathbf{max}}$ qualitatively agree with observations toward **SNe Ia**.
6. Based on our results, we suggest that an important way to test RAT theory and RATD is to observe **polarization toward star-forming regions**.

Articles
https://doi.org/10.1038/s41550-019-0763-6
nature astronomy

Rotational disruption of dust grains by radiative torques in strong radiation fields

Thiem Hoang[1,2*], Le Ngoc Tram[1,3,4], Hyeseung Lee[1] and Sang-Hyeon Ahn[1]

Massive stars, supernovae, … Jniverse. Observations usu-
ally show near- to mid-infra … oung massive star clusters.
Early-phase observations in … roperties of dust extinction
and dust polarization. The … properties is the predomi-
nance of small grains (size $a \lesssim 0.05\,\mu m$) relative to large grains ($a \gtrsim 0.1\,\mu m$) in the local environment of these strong radiation

RATD mechanism

DRAFT VERSION NOVEMBER 5, 2019
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PHYSICAL MODEL OF DUST POLARIZATION BY RADIATIVE TORQUE ALIGNMENT AND DISRUPTION AND IMPLICATIONS FOR GRAIN INTERNAL STRUCTURES

HYESEUNG LEE[1], THIEM HOANG[1,2], NGAN LE[3,4], AND JUNGYEON CHO[1,5]
[1] Korea Astronomy and Space Science Institute, Daejeon 34055, Republic of Korea; thiemhoang@kasi.re.kr

Polarization by dust with RATD

[4] Department of Space and Applications, University of Science and Technology of Hanoi, Vietnam Academy of Science and Technology, 18 Hoang Quoc Viet, Hanoi, Vietnam
and
[5] Chungnam National University, Daejeon 34134, Republic of Korea

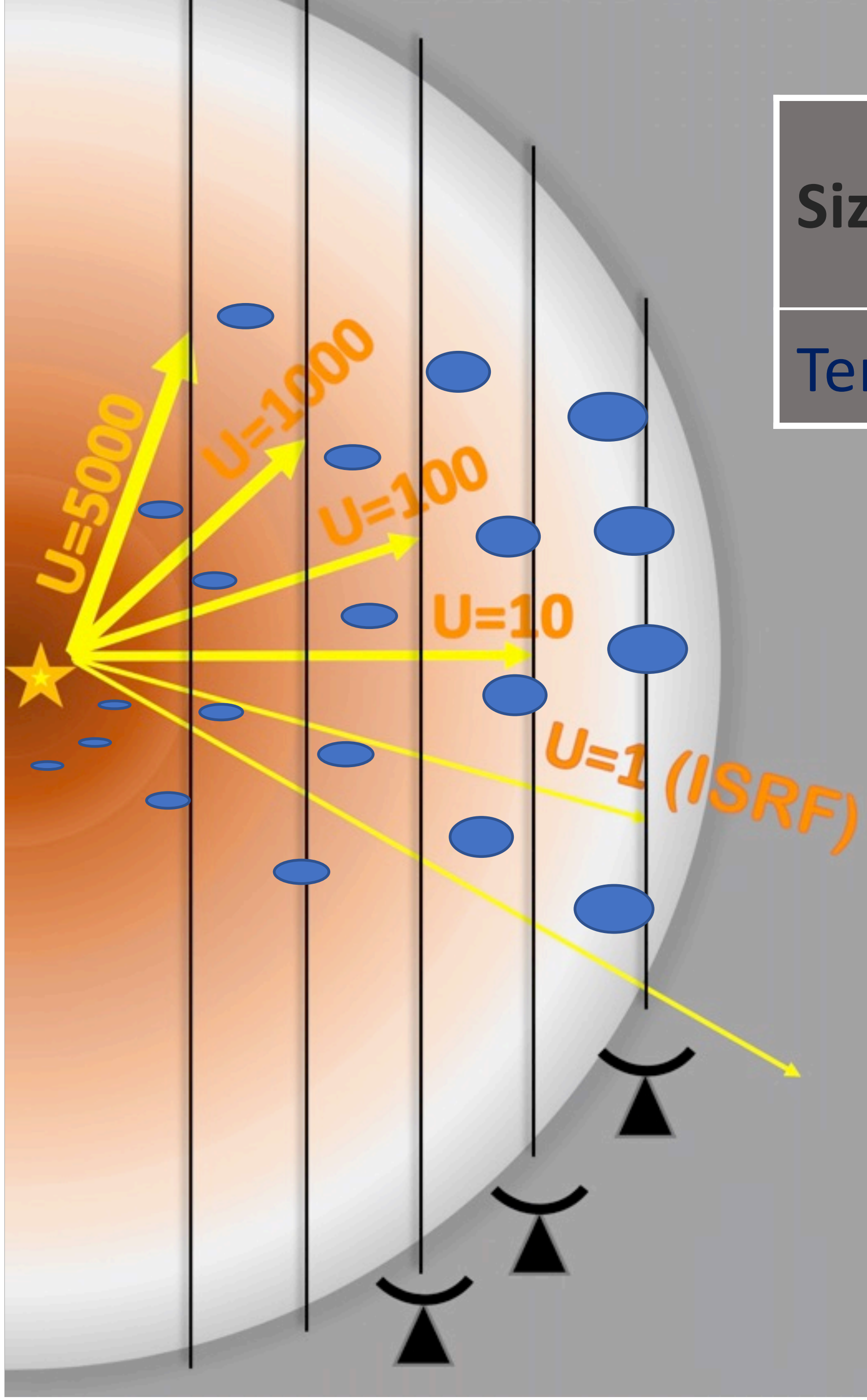
Thank you 😊

감사합니다

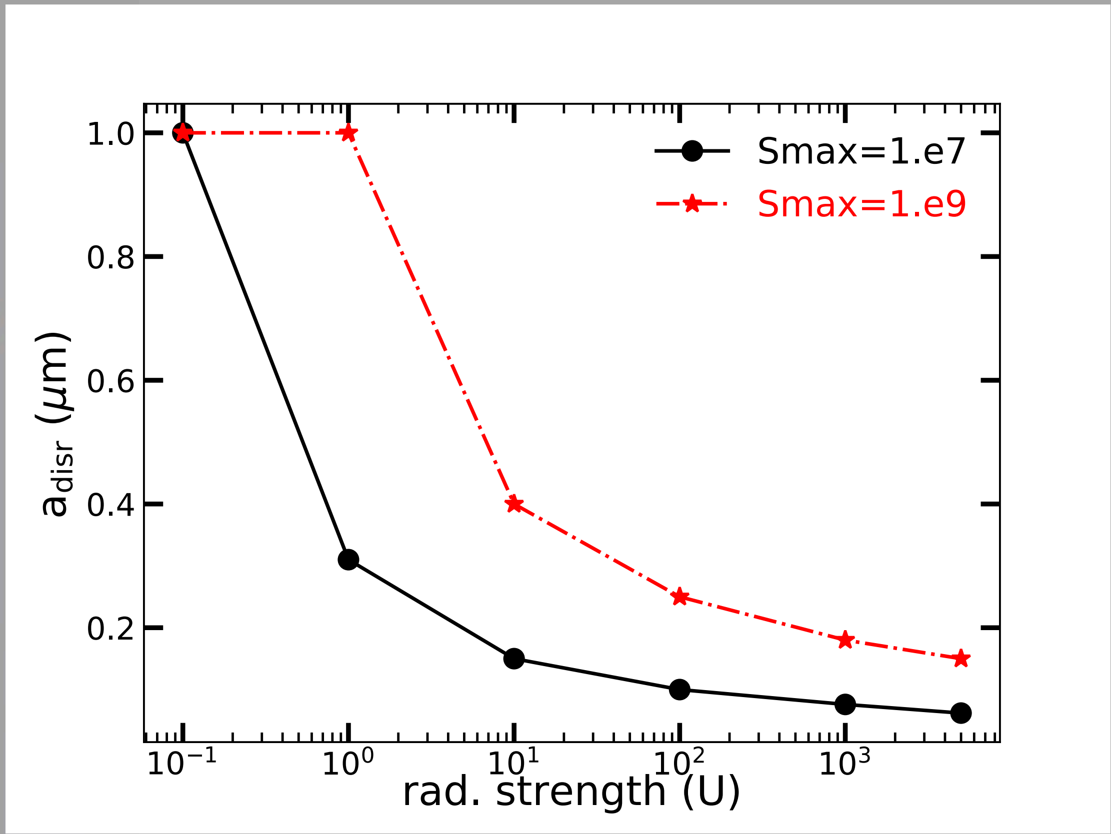
谢谢

ありがとうございました

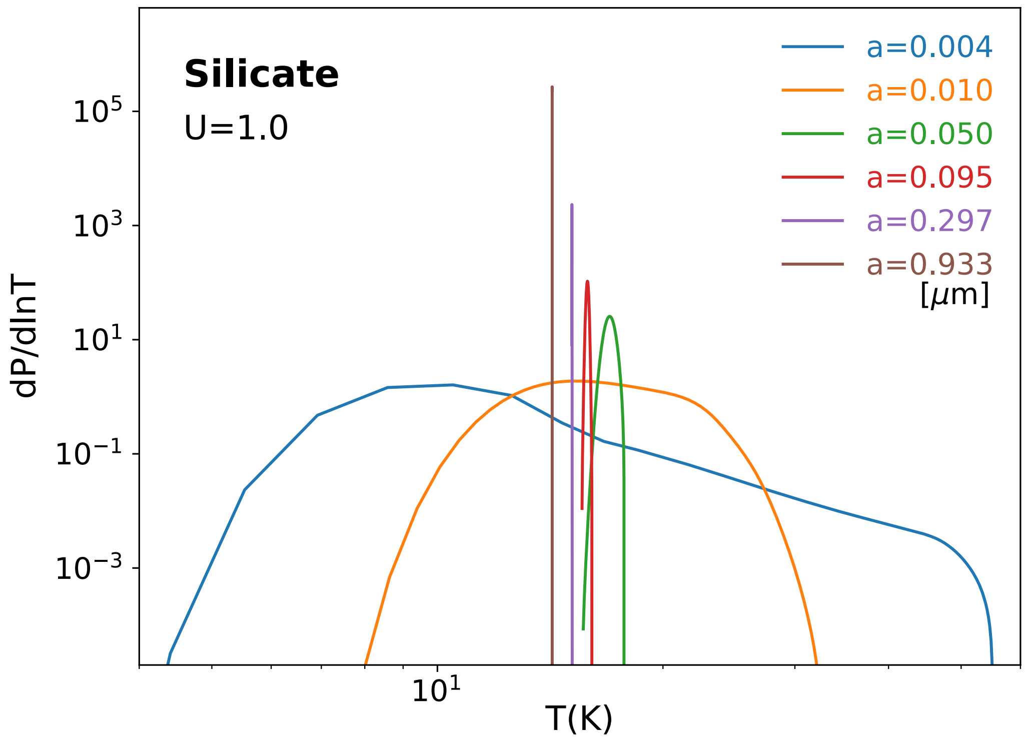
Diffuse media

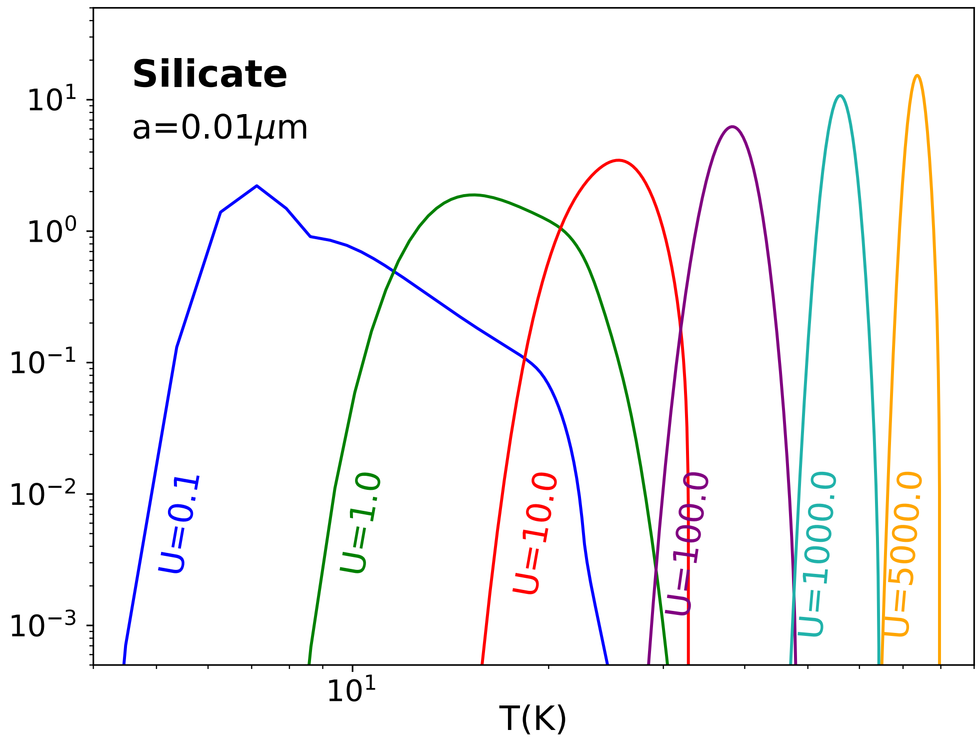


Size distribution	$\frac{1}{n_H}\frac{dn_j}{da} = C_j a^{-3.5}$
Tensile strength	S_{max} = **10^6 ~ 10^9** erg/cm^3

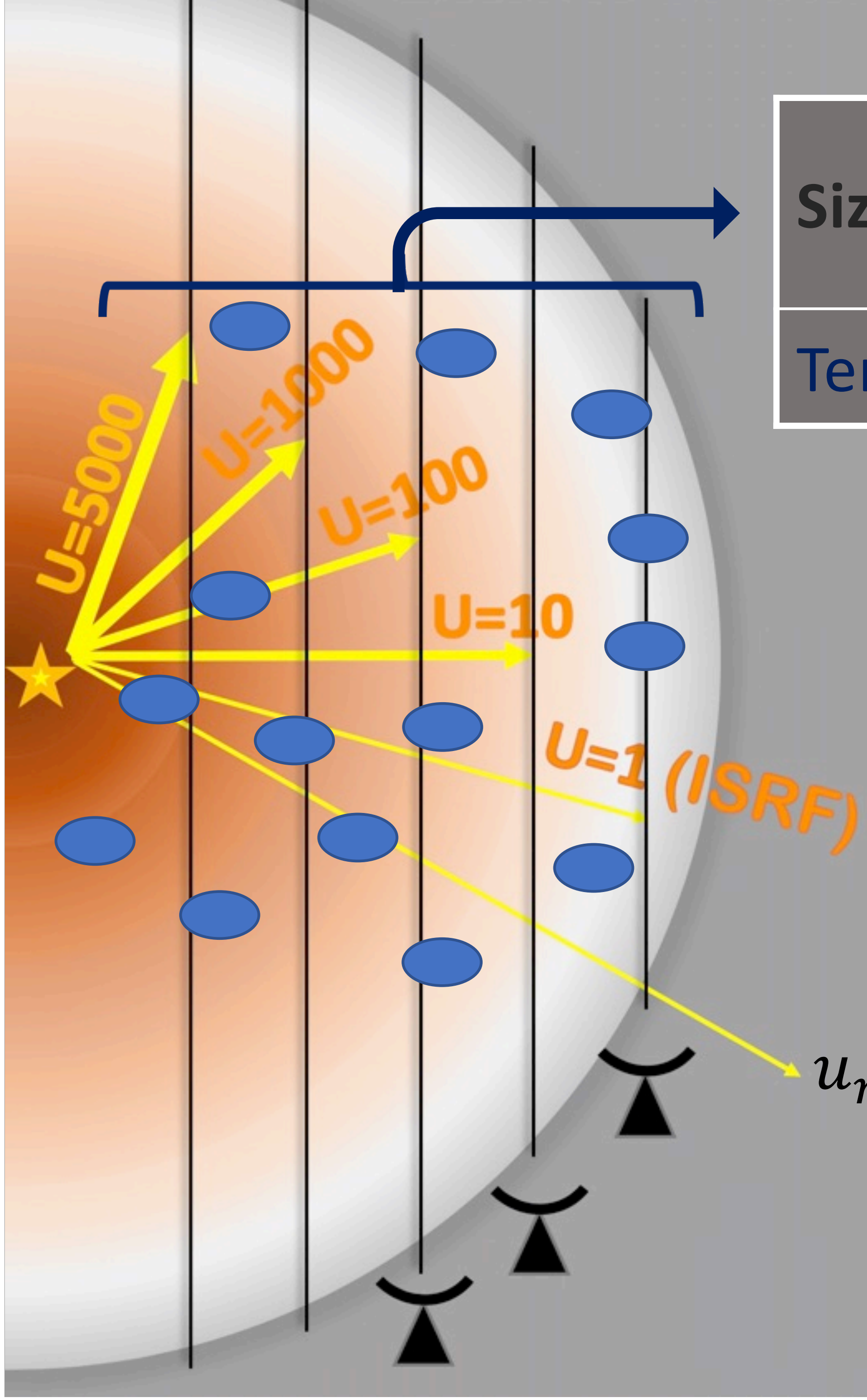


Temperature Distribution





Diffuse media



10Å → $a_{min} \leq a \leq a_{max}$ ← $a_{disruption}$

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$$u_{rad} = \int u_\lambda d\lambda \longrightarrow U = \boldsymbol{u_{rad}/u_{ISRF}}$$

Radiation strength