Constraining dust parameters through observations of eccentric debris disks

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Introduction

Dust-replenishing planetesimals in the parent belt of debris disks orbit their host star and continuously supply the disk with fine dust through their mutual collisions. We aim to understand effects of different collisional parameters, e.g., the eccentricities of the planetesimals, dynamical excitation, and the material strength, on the observational appearance of eccentric debris disks, e.g., the spectral energy distribution (SED), and spatially resolved images.

Collisional physics in debris disk

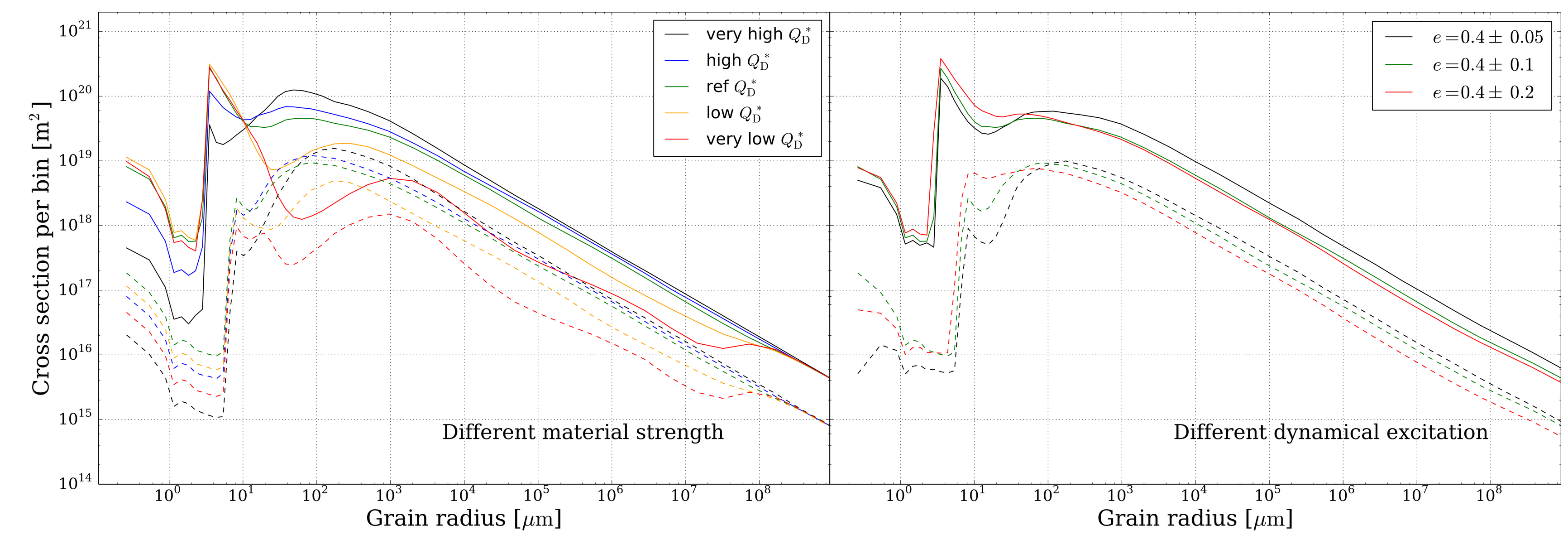
Critical energy for fragmentation (Benz & Asphaug 1999; Löhne et al 2017):

$$Q_D^* = \left[Q_s\left(\frac{s_{ij}}{1\mathrm{m}}\right)^{-0.37} + Q_g\left(\frac{s_{ij}}{1\mathrm{km}}\right)^{1.38}\right]\left(\frac{v_{\mathrm{imp}}}{3\mathrm{km/s}}\right)^{0.5} + \frac{3G(m_i+m_j)}{5s_{ij}} \qquad (1)$$

The quantity Q_s is relevant for describing shock disruption in the strength regime, while Q_g is the corresponding specific energy in the gravity regime, both scaled by the impact velocity v_{imp}. The equivalent radii of the spheres, s_i and s_j, with $s_{ij} \equiv (s_i^3 + s_j^3)^{1/3}$ as the combined volume of the colliders. Reference value of $Q_s = Q_g = 5 \times 10^2$ J/kg.

Selected model parameters: Eccentricities (e_b = 0.0 to 0.4), dynamical excitation (Δe_b = ± 0.05 to 0.2), material strengths (Q_s by $Q_s = \alpha \times$ reference value of Q_s, with α = 25, 5, 1, 1/5, and 1/25). Fomalhaut-like A3V star (1.92 $M_\odot$, 16.6 $L_\odot$ and 8590 K, Mamajek 2012).

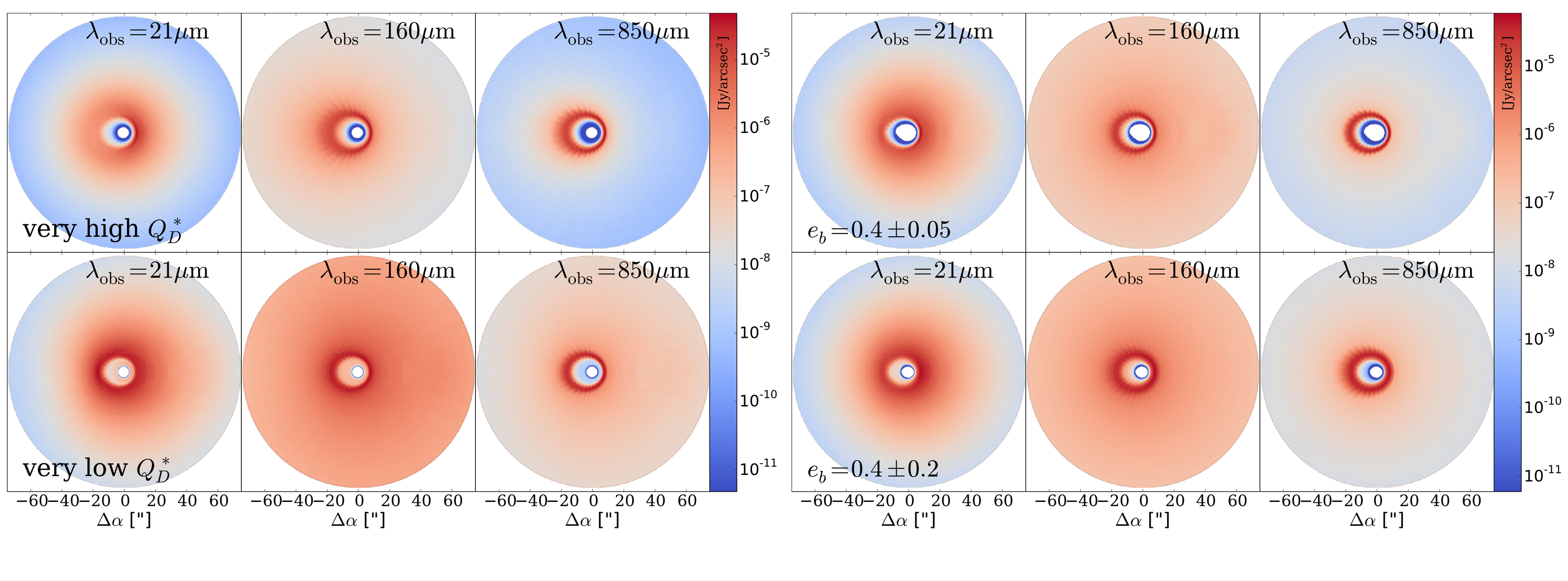
Grain size distribution

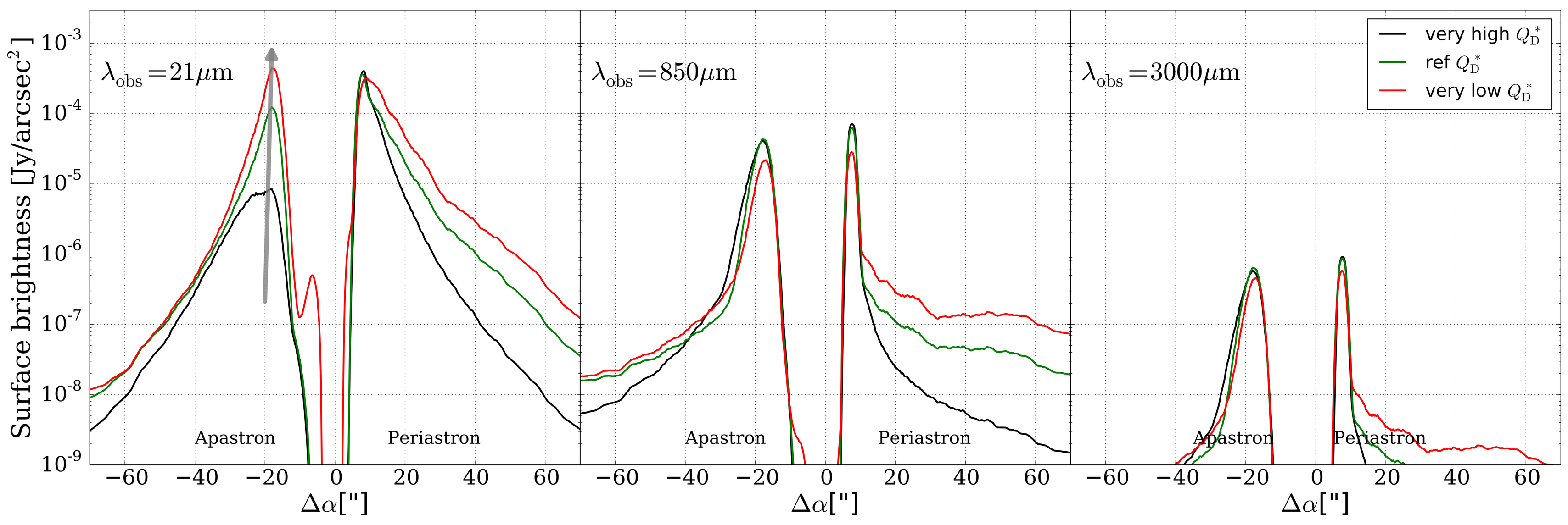


① The wavy pattern of the grain size distribution becomes deeper and broader for low material strengths (apocenter with solid lines/pericenter with dashed lines).

② For the low-excitation case (lower values of Δe_b), the depletion of small grains is even more pronounced.

Pericenter Glow → Apocenter Glow

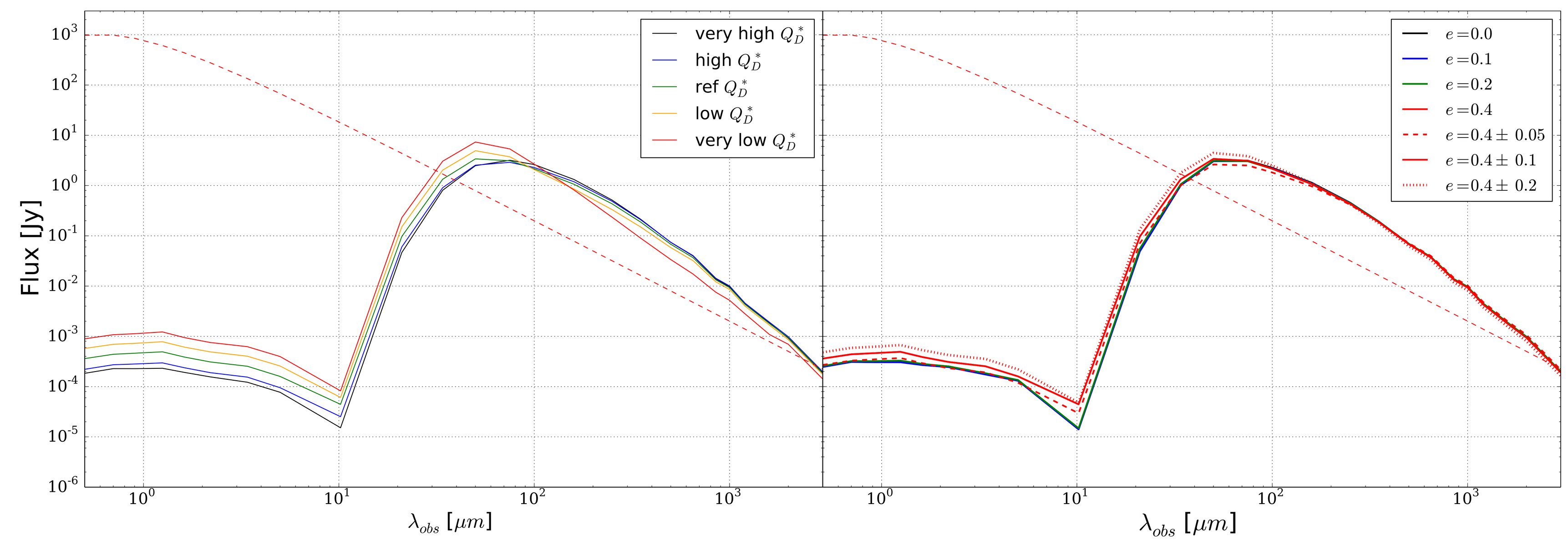




① Increase of destructive collisions (e.g., decrease of the material strength) leads to a transition from **"pericenter glow"** to **"apocenter glow"**.

② For very low material strengths, the **"pericenter glow"** phenomenon is reduced and eventually even replaced by the opposite effect, the **"apocenter glow"** in the near-infrared/mid-infrared wavelength range.

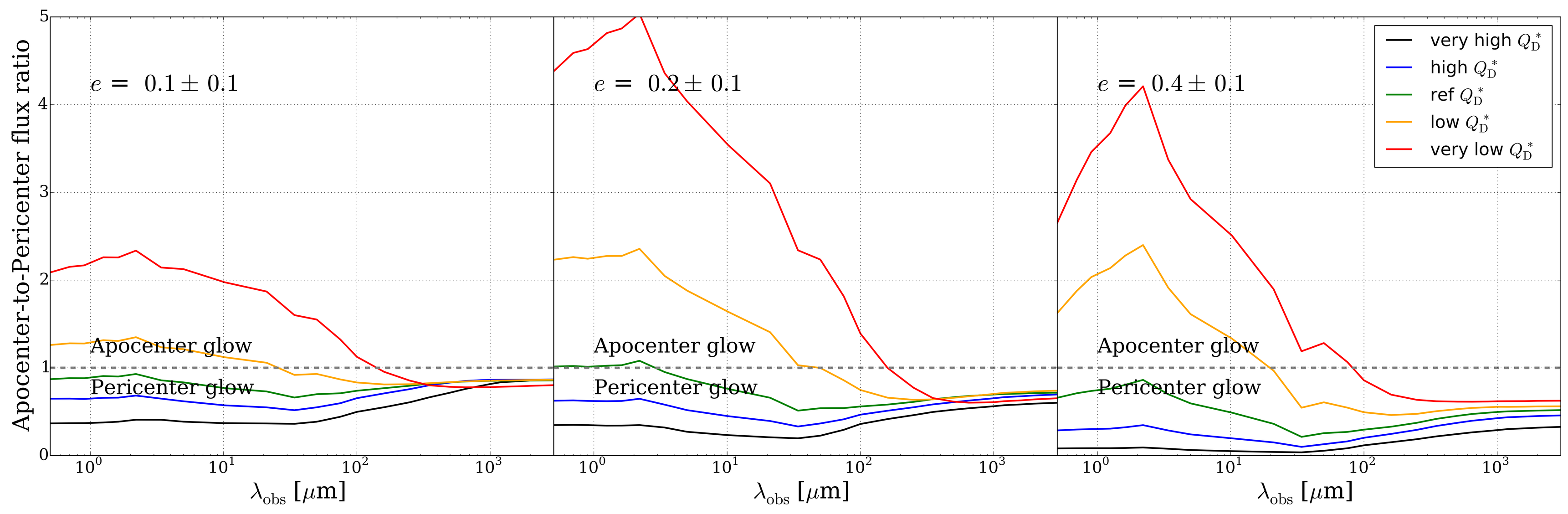
Spectral energy distribution (SED)



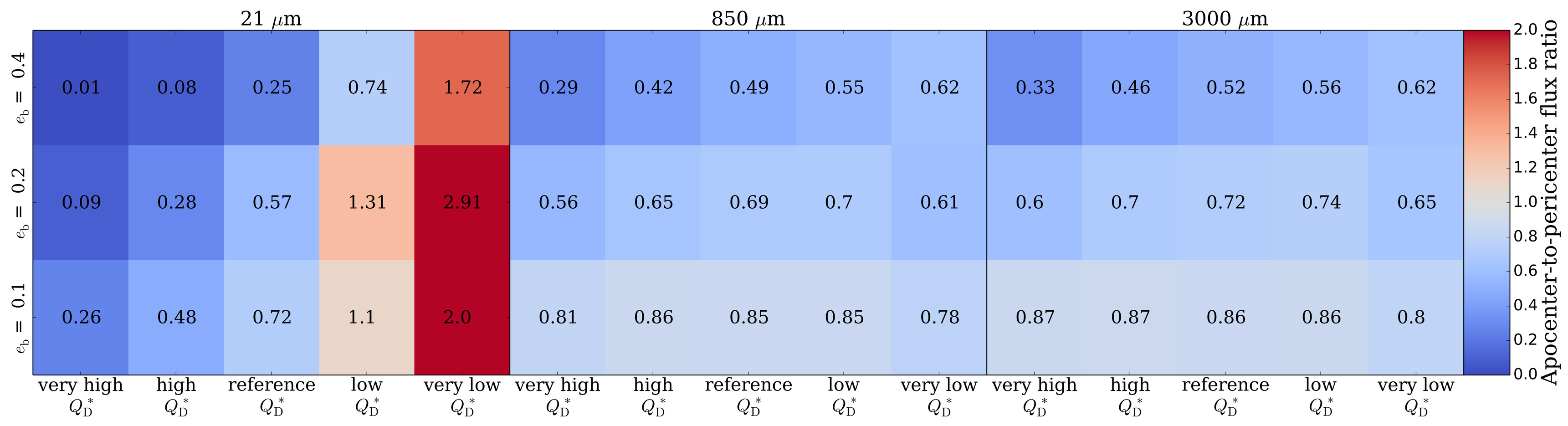
① Higher eccentricities and an increasing level of dynamical excitation increase mutual collisional velocities. The disk appears brighter in regions where this effect is strongest.

② The deeper and broader wavy pattern of the grain size distribution for low material strengths results in the slope of the SED in this range becomes flatter.

Apocenter-to-Pericenter flux ratio



Due to different size distribution resulting from different collisional evolutions, apocenter-to-pericenter flux ratio is the wavelength-dependent.



The wavelength-dependent apocenter-to-pericenter flux ratio for selected values of the eccentricity e_b and material strength Q_D^* (The number in each box indicates the apocenter-to-pericenter flux ratio).

Conclusions

① Increase of destructive collisions (e.g., higher e_b, higher dynamical excitation Δe_b, or lower material strengths Q_D^*) results in a higher production rate of smaller particles that reduce the surface brightness differences between periastron and apastron.

② Within the considered parameter space, the impact of material strengths Q_D^* is stronger than that of the dynamical excitation Δe_b in the belt eccentricity.

③ Deriving unique constraints for the impact of considered collisional parameters on the SED is hardly possible.

Reference and acknowledgements

Kim, M., Wolf, S., Löhne, T., Kirchschlager, F., & Krivov, A. V. 2018, Submitted to A&A
Löhne, T., Krivov, A. V., Kirchschlager, F., Sende, J. A., & Wolf, S. 2017, A&A, 605, A7

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The author of this poster is around and happy to answer any question!