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New Ice Cloud Optical Parameterization for COSMO

Ulrich Blahak (DWD), Harel Muskatel (IMS), Pavel Khain (IMS)

COSMO GM September 2015

Outline

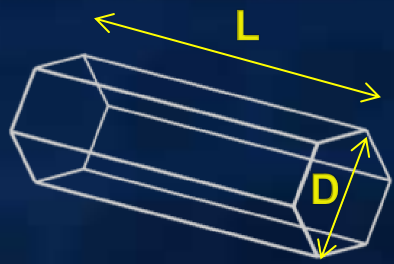
- Visible bands: using geometric ray tracing calculations for randomly oriented hexagonal ice particles (Fu 2007)
- IR bands: using weighted average of Mie-scattering, ADT, GOM & FDTD methods (Fu et. al 1998)
- The aspect ratio - AR is identified as key parameter to determine asymmetry factor g (instead of D_{ge})
- Suitable also for complicated ice particles such as bullet rosettes, aggregates with rough surfaces, and fractal crystals
- Extended particles size range- [5 μm- 300μm] by using 7000 size Modified Gamma Distributions (MGDs)

Definition of AR and D_{ge}

$$AR \equiv \frac{\int_{L_{min}}^{L_{max}} (\frac{D}{L}) A_c N(L) dL}{\int_{L_{min}}^{L_{max}} A_c N(L) dL} \qquad D_{ge} \equiv \frac{\int_{L_{min}}^{L_{max}} D^2 \cdot L \cdot N(L) dL}{\int_{L_{min}}^{L_{max}} (D \cdot L + \frac{\sqrt{3}}{4} D^2) N(L) dL} = 2R_e$$

Projected area: $A_c = \frac{3}{4}\left(\frac{\sqrt{3}}{4} D^2 + LD\right) = \frac{surface\ area}{4}$

Particle size Distribution: $N(L) = N_0 L^{\mu} e^{-\lambda L^{\delta}}$



Moments: $M_i = \int L^i N(L) dL = \frac{N_0}{\delta} \cdot \frac{\Gamma\left(\frac{\mu+i+1}{\delta}\right)}{\lambda^{\left(\frac{\mu+i+1}{\delta}\right)}}$

Mass-size relation: $m = a_g L^{b_g}$

$$\bar{x} = \frac{\int mN(L)dL}{\int N(L)dL} = \frac{IWC}{N_{ice}}$$

$$AR(a_g, b_g, \mu, \bar{x}) = \frac{d_1 \bar{x}^{d_2} + d_3 \bar{x}^{d_4}}{d_5 \bar{x}^{d_6} + d_7 \bar{x}^{d_8}} \qquad D_{ge}(a, b, \mu, \bar{x}) = \frac{1}{c_1 \bar{x}^{c_2} + c_3 \bar{x}^{c_4}}$$

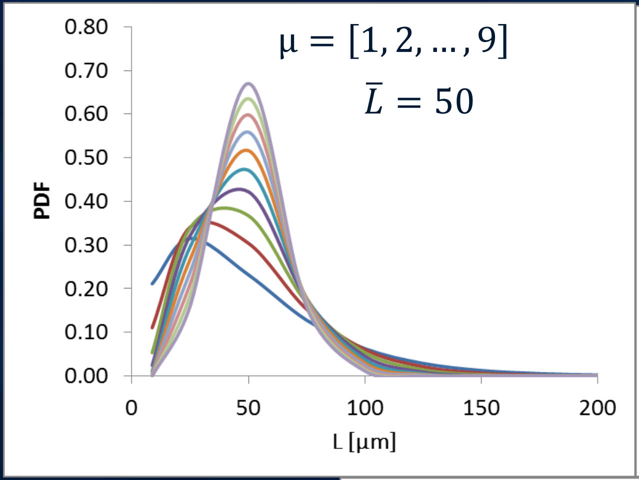
Generalized Gamma Distribution

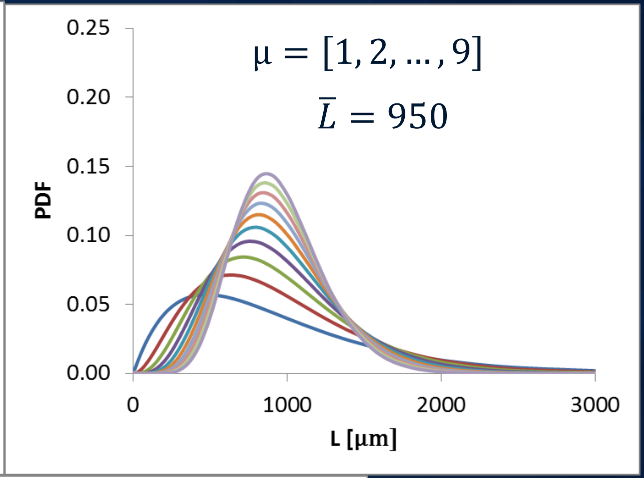
$$N(L) = N_0 L^{\mu} e^{-\lambda L^{\delta}}$$

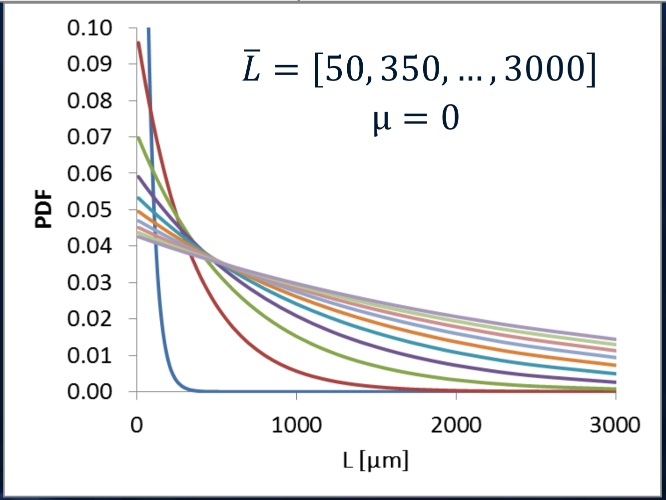
$$\mu = [0, 1, \dots, 14]\,,\ \bar{L} = \frac{\mu+1}{\lambda} = [5\mu m, 3000\ \mu m],\ \delta = 1$$

total of 7000 distributions

Examples:







β'_{ext} as function of *Generalized effective size* D_{ge}

$$\beta'_{ext} = \frac{\beta_{ext}}{IWC}$$

Spectral Averaging:

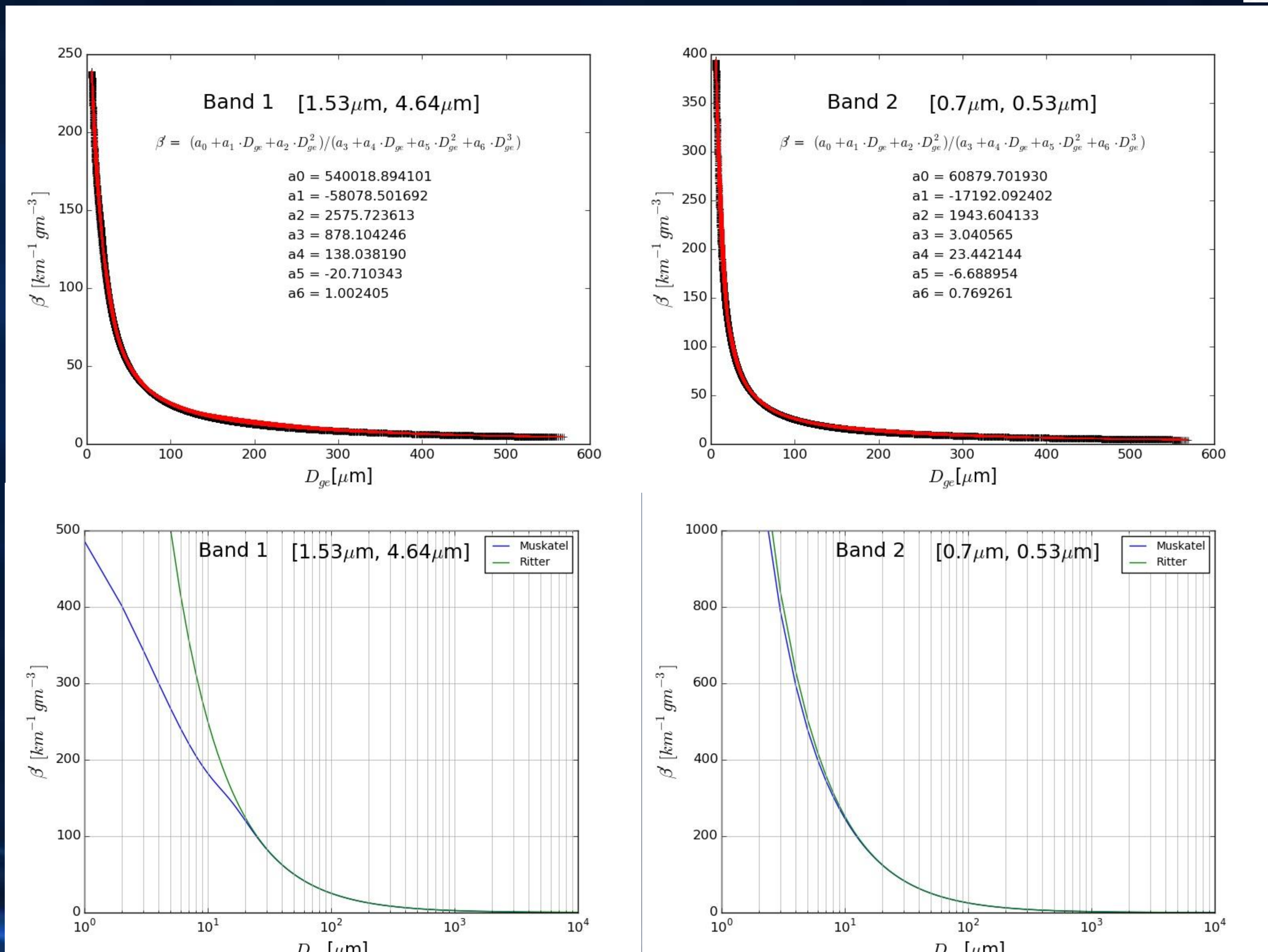
$$\mathcal{R}(\rho_c) = \begin{cases} \frac{2}{\rho_{c,max}} - \frac{2}{\rho_{c,max}}\rho_c & if \quad 0 \le \rho_c \le \rho_{c,max} \\ 0 & else \end{cases}$$

$$Z(\Delta z) = \begin{cases} \frac{1}{\Delta z_{max}} - \frac{1}{\Delta z_{min}} & if \quad \Delta z_{min} \le \Delta z \le \Delta z_{max} \\ 0 & else \end{cases}$$

$$\overline{\beta'_{ext}}^{\lambda}(D_{ge}, \rho_c, \Delta z) = -\frac{1}{\rho_c \Delta z} \ln\left[\frac{\int_{\lambda_{min}}^{\lambda_{max}} S(\lambda) e^{(-\beta'_{ext}\rho_c\Delta z)} d\lambda}{\int_{\lambda_{min}}^{\lambda_{max}} S(\lambda)\, d\lambda}\right]$$

$$\overline{\overline{\overline{\beta'_{ext}}}}^{\lambda,\rho_c,\Delta z}(D_{ge}) = \frac{\iint \overline{\beta'_{ext}}^{\lambda}(D_{ge}, \rho_c, \Delta z)\, \mathcal{R}(\rho_c) Z(\Delta z) d\rho_c d\Delta z}{\iint \mathcal{R}(\rho_c) Z(\Delta z) d\rho_c d\Delta z}$$

Fitting $\beta'_{ext}(D_{ge})$



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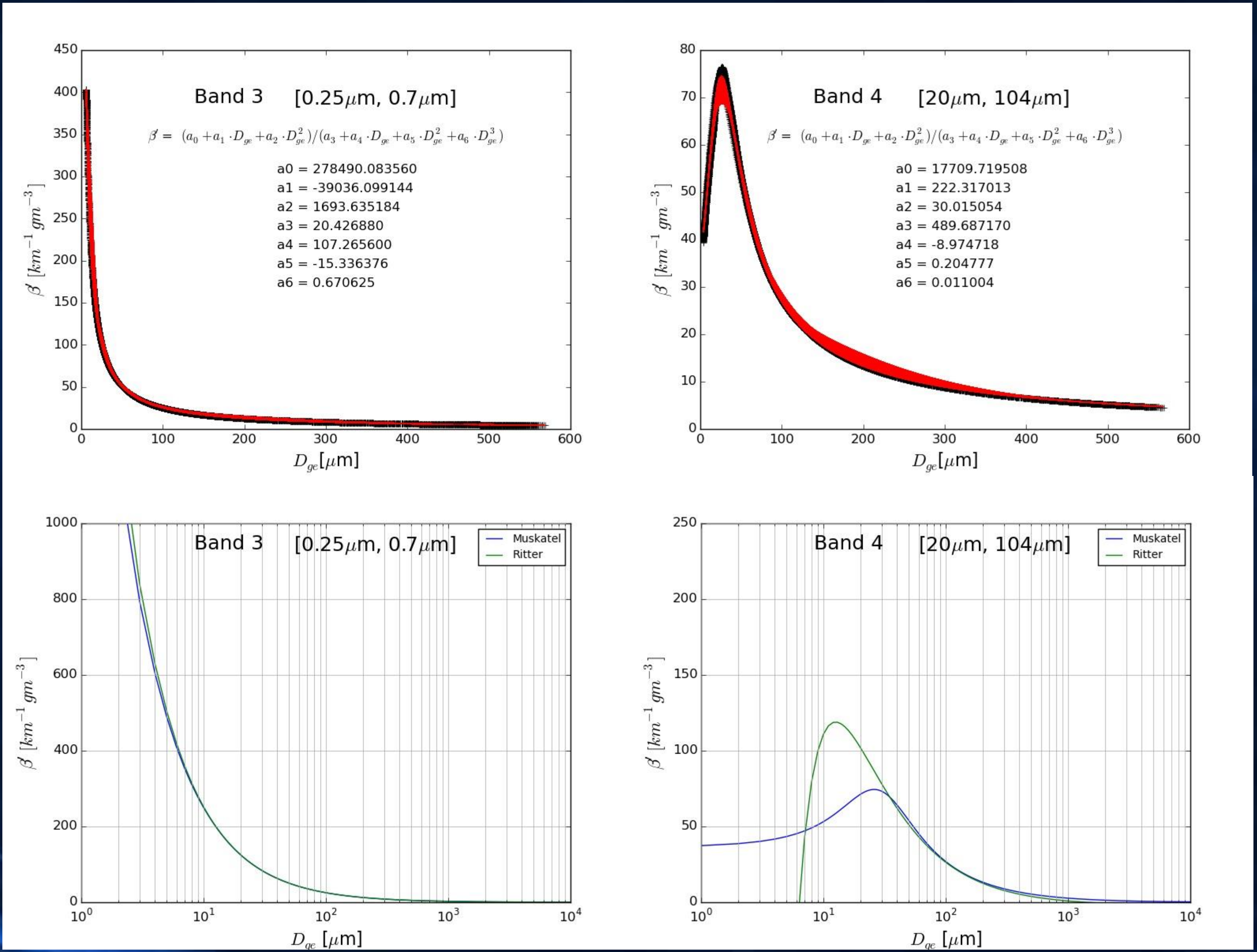

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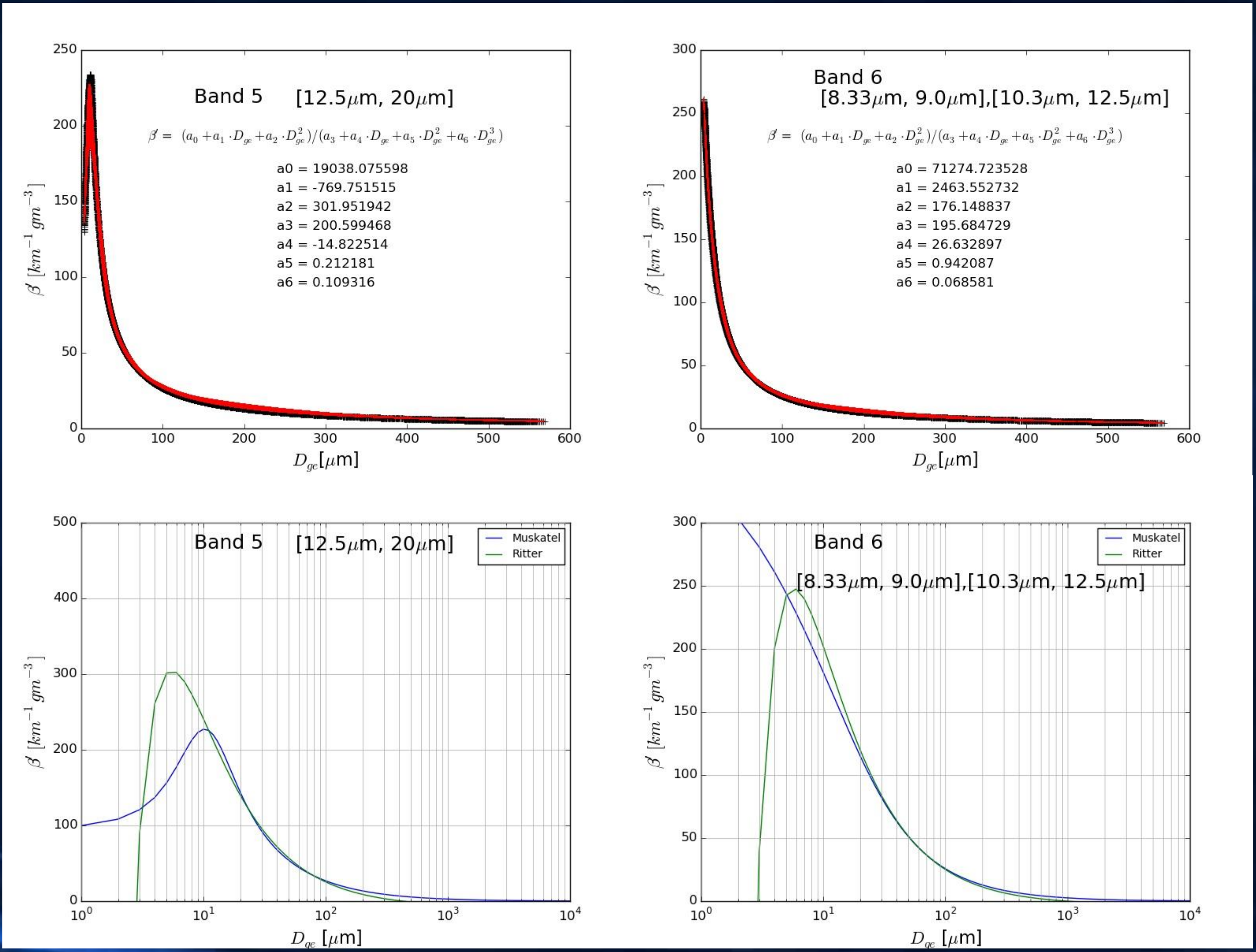
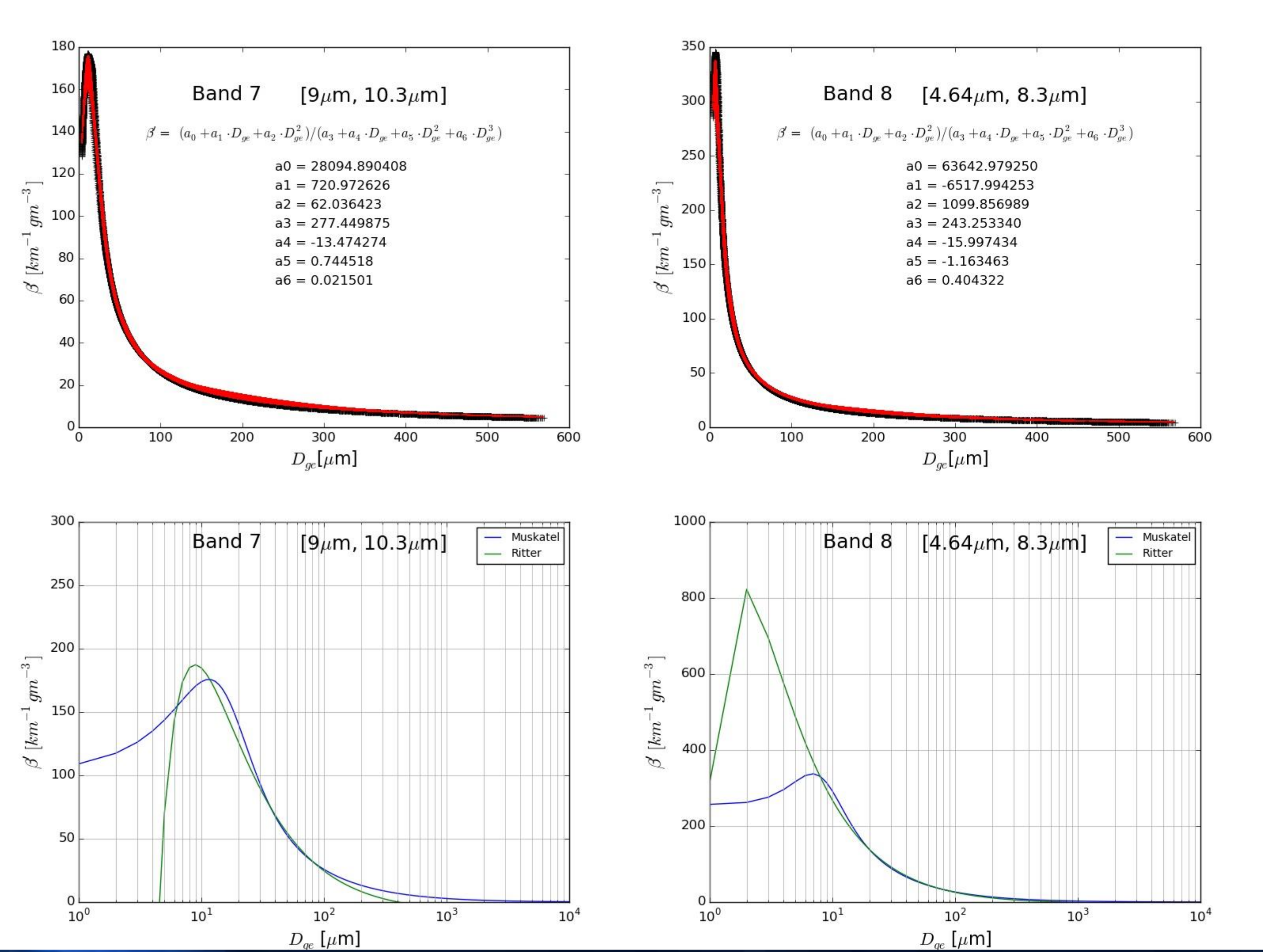
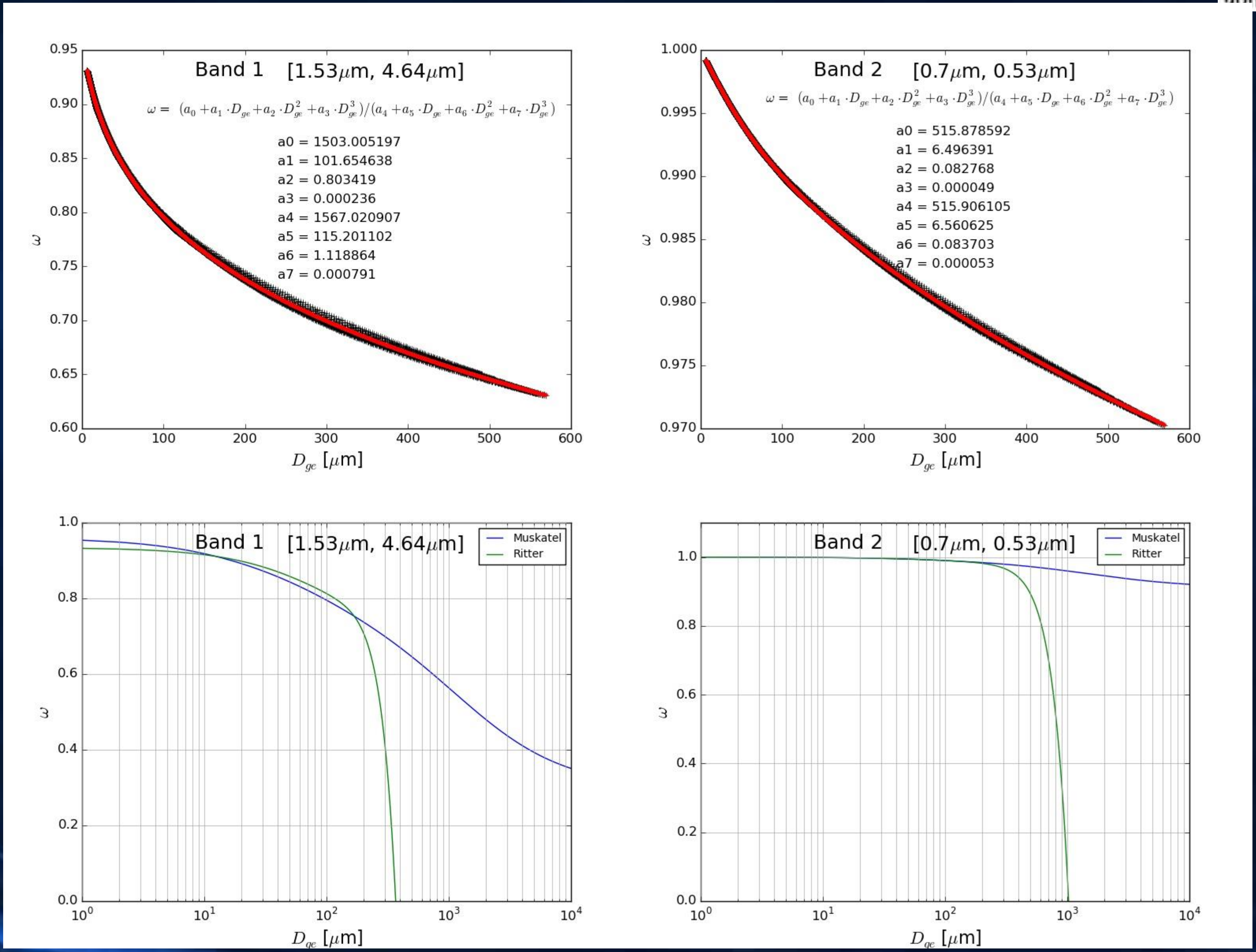


Fitting $\beta'_{ext}\,(D_{ge})$



Fitting Single Sca. Albedo $\omega(D_{ge})$



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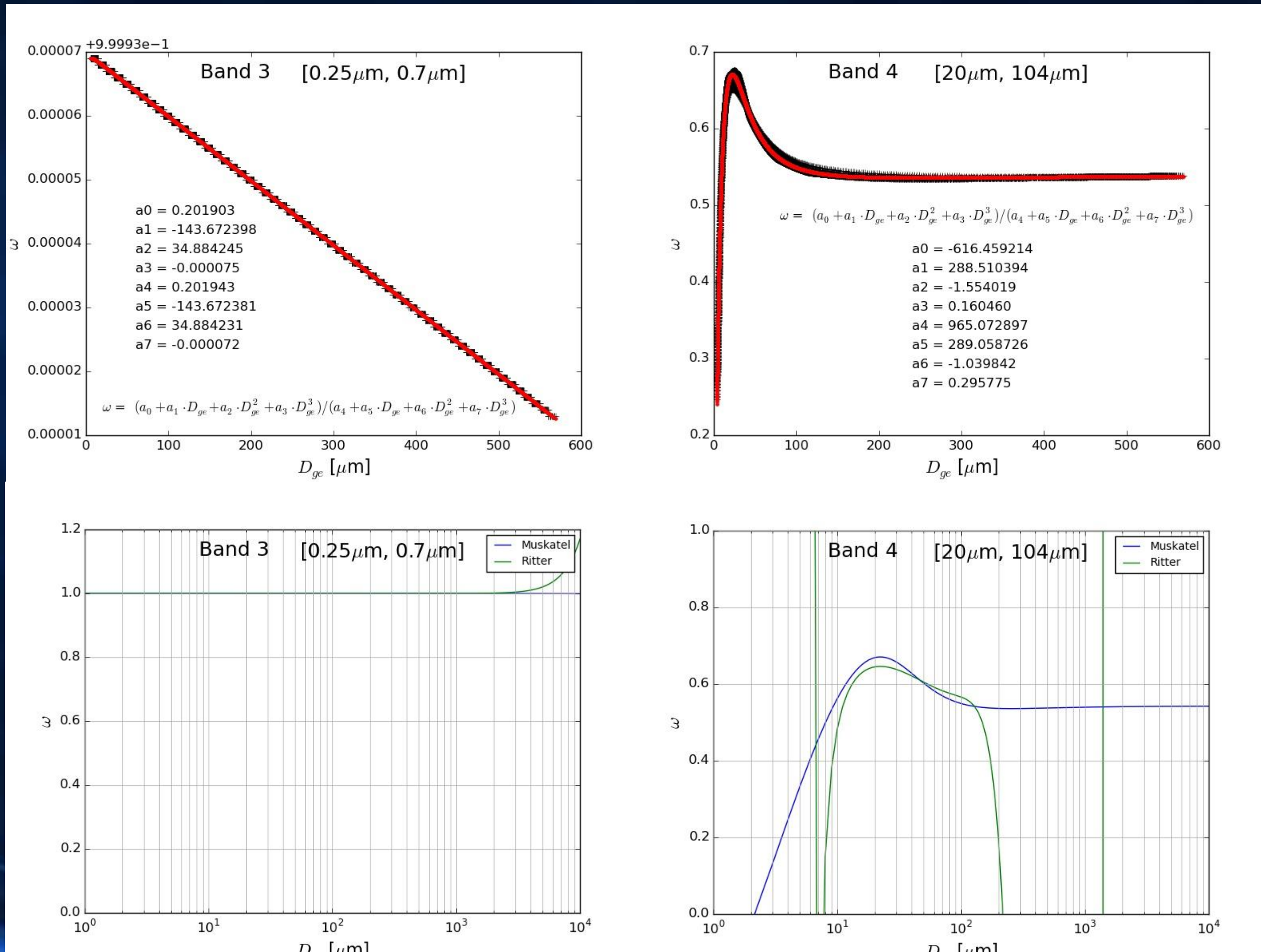

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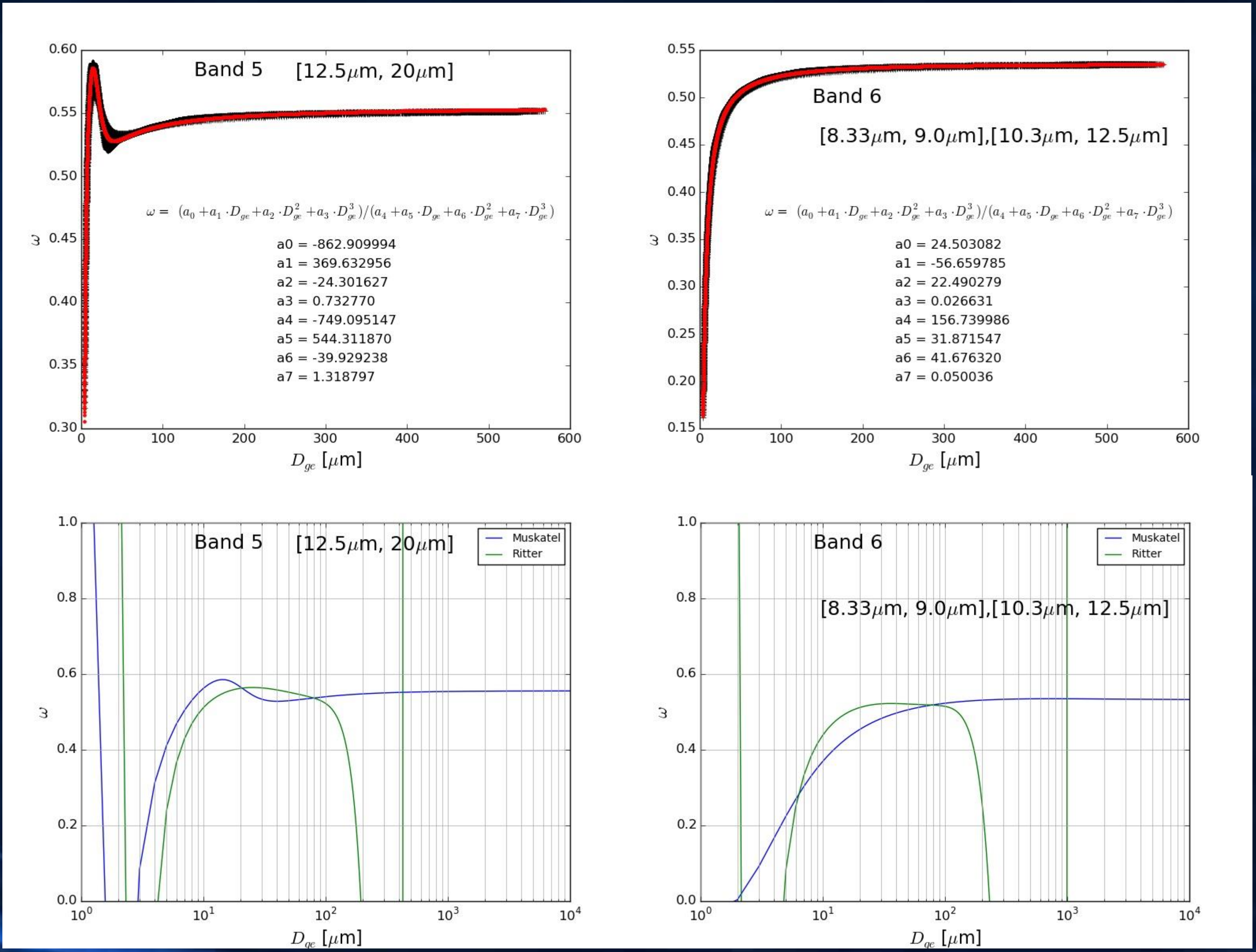

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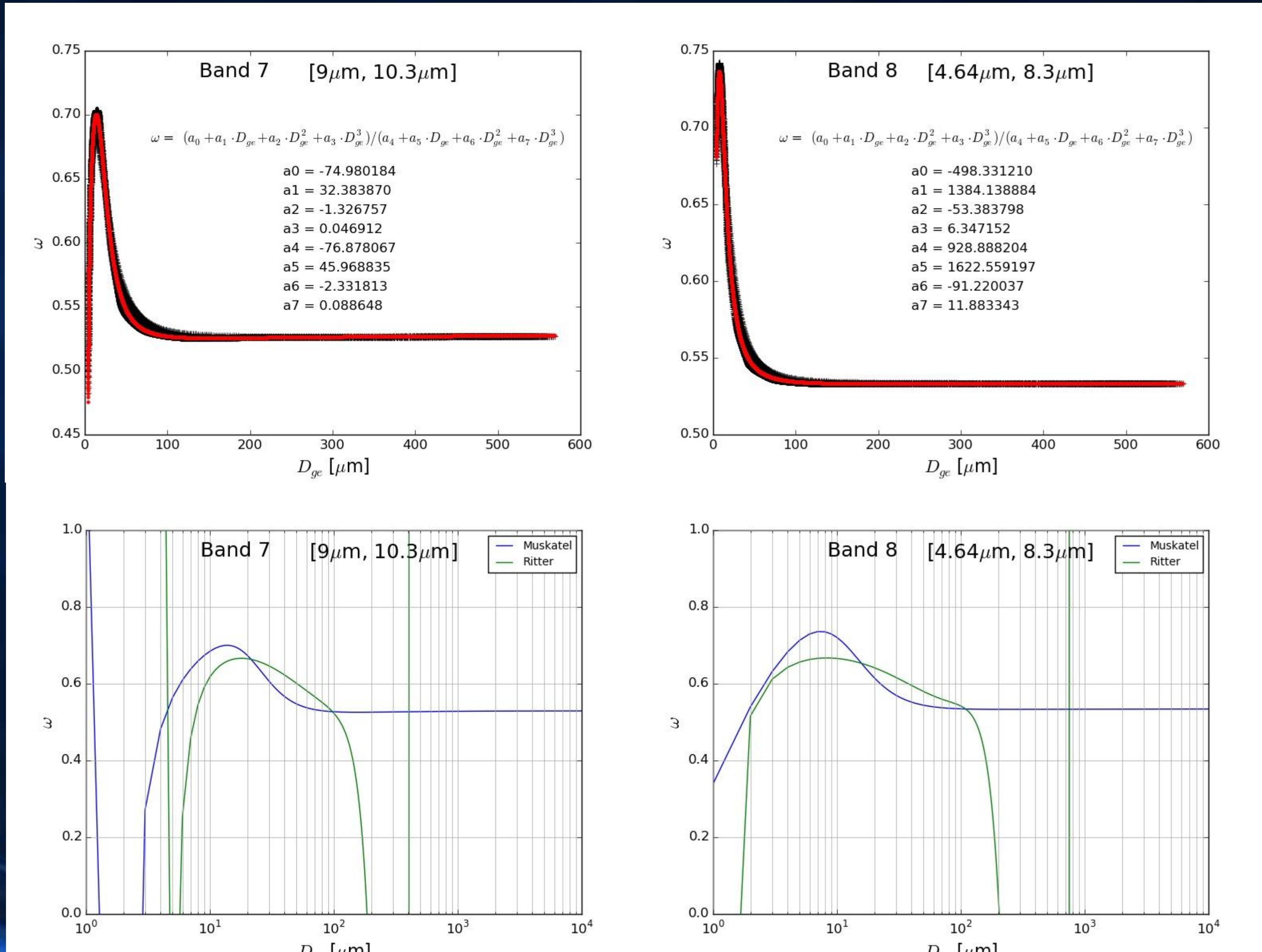
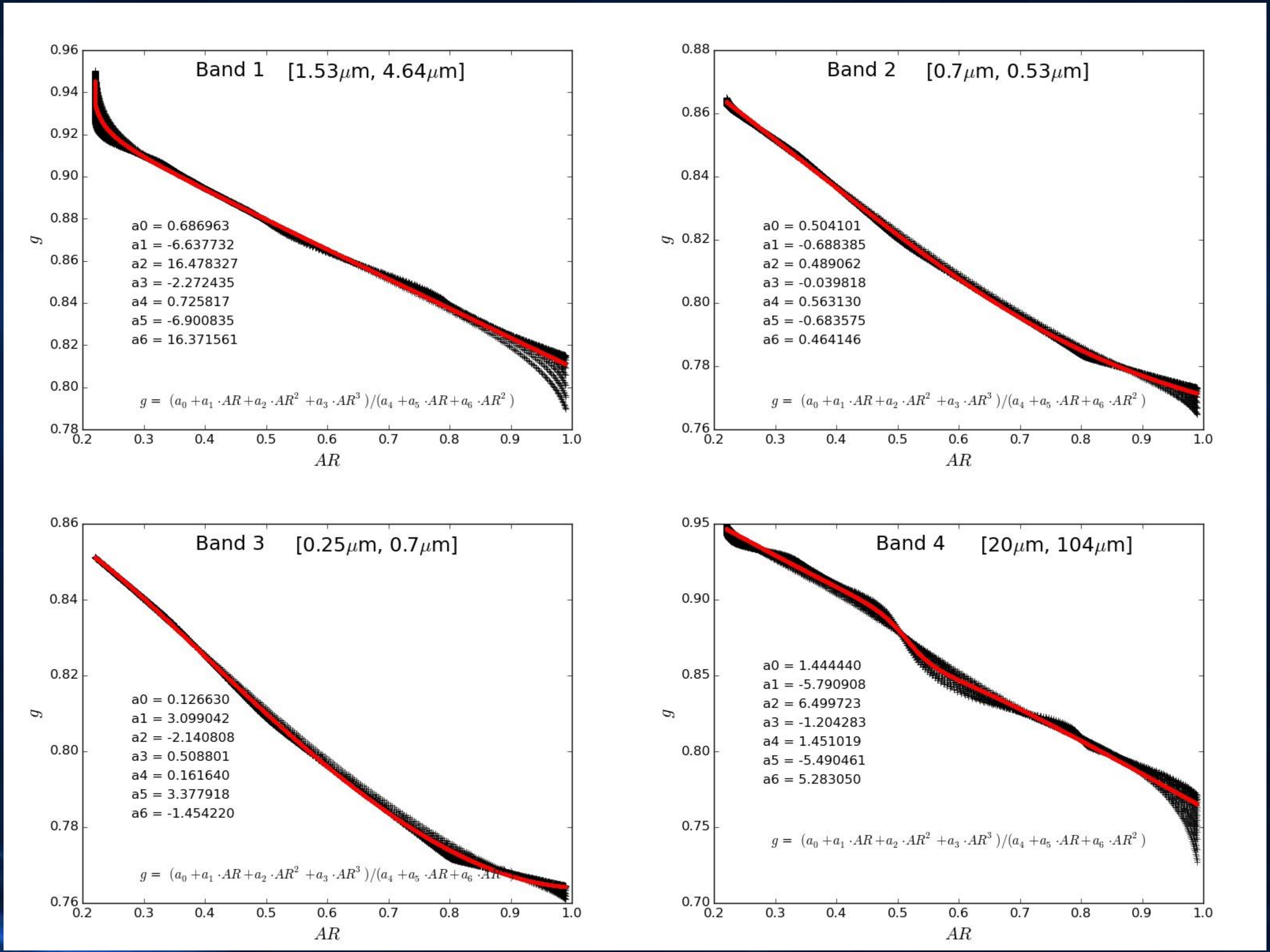


Fitting asymmetry factor for smooth surfaces g_s(AR)



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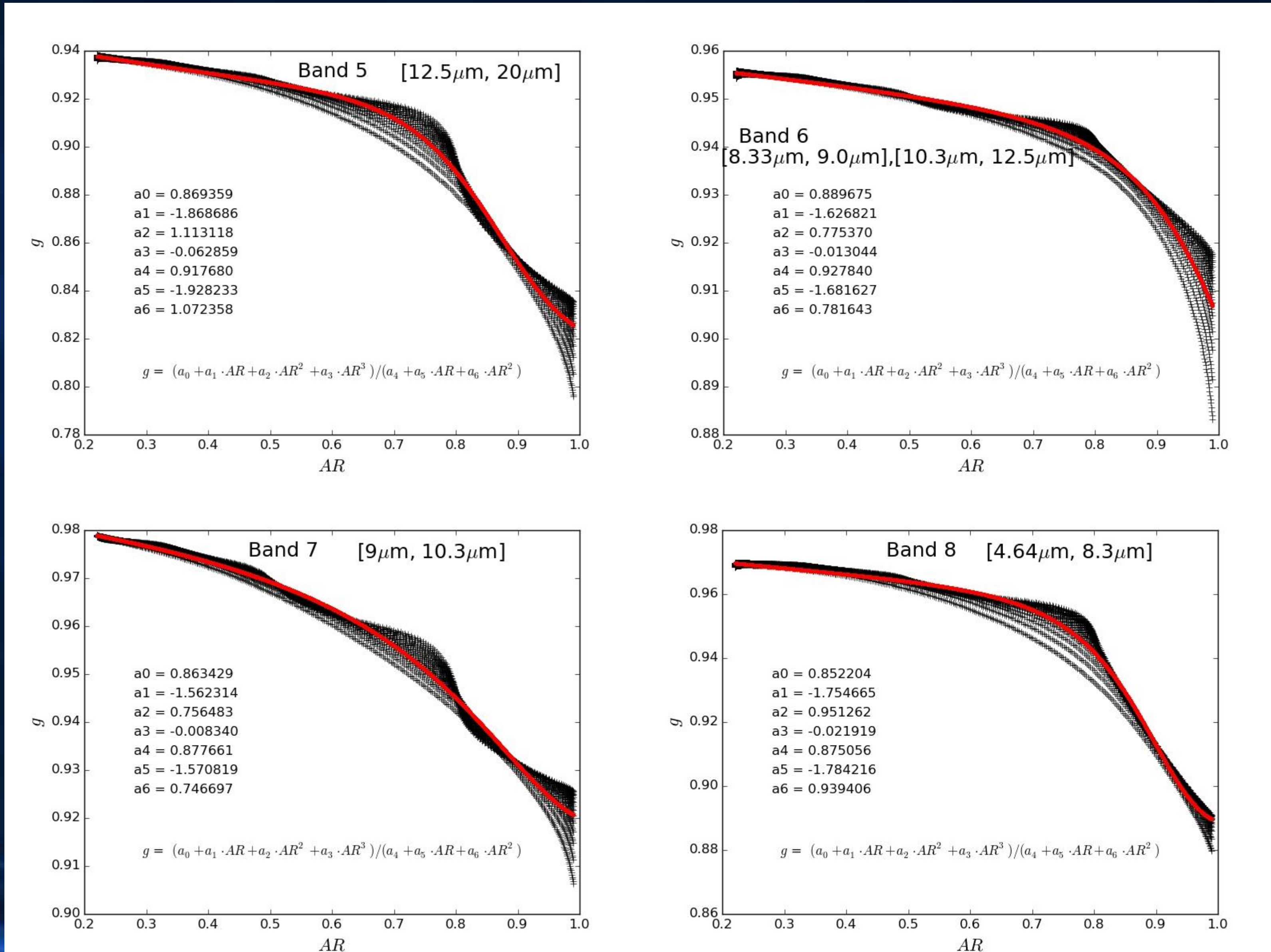
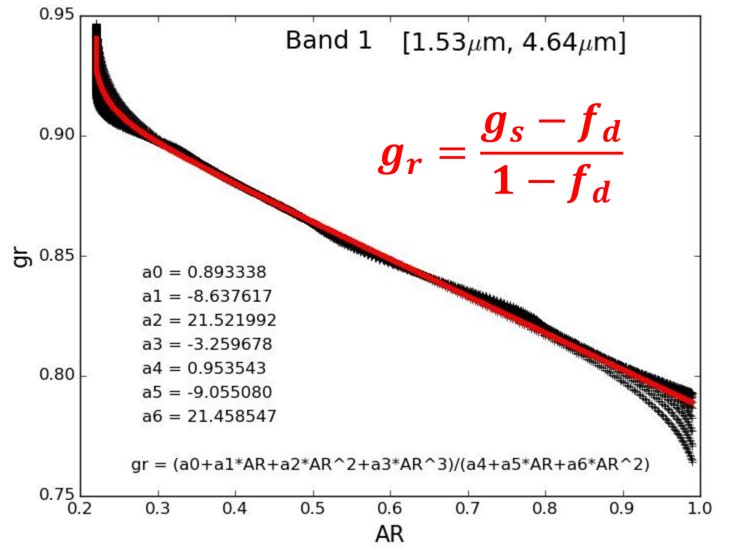
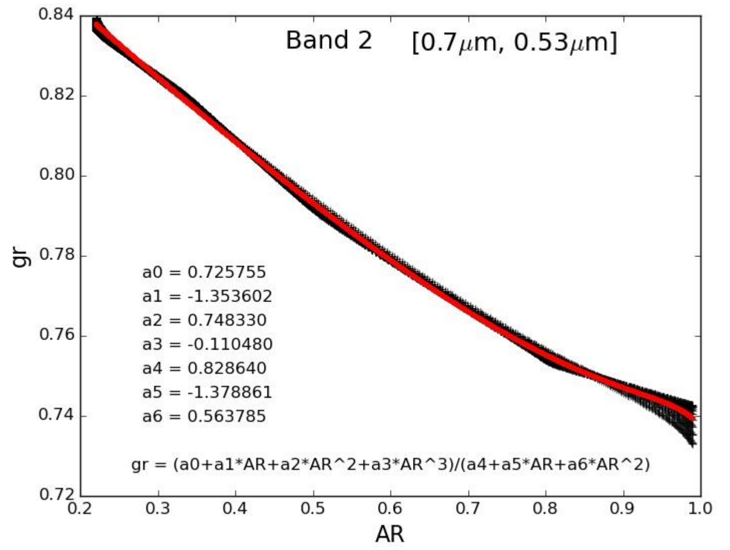
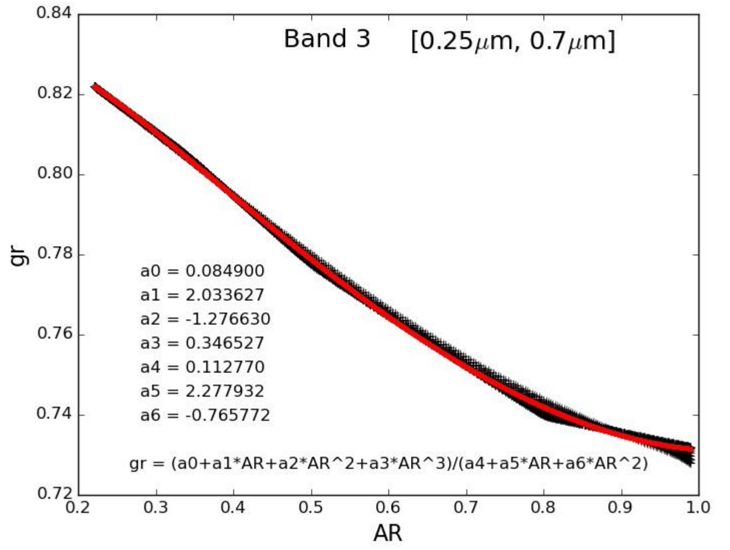


Fitting asymmetry factor for rough surfaces g_r(AR)





(For IR bands we take g)



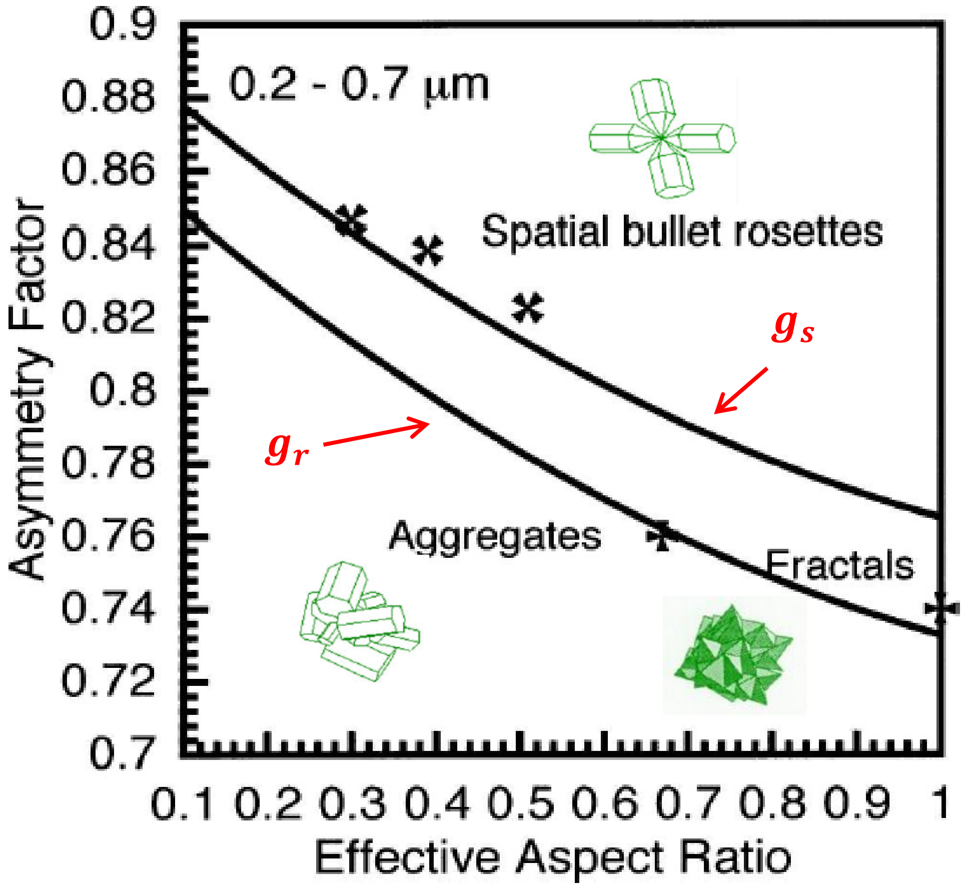
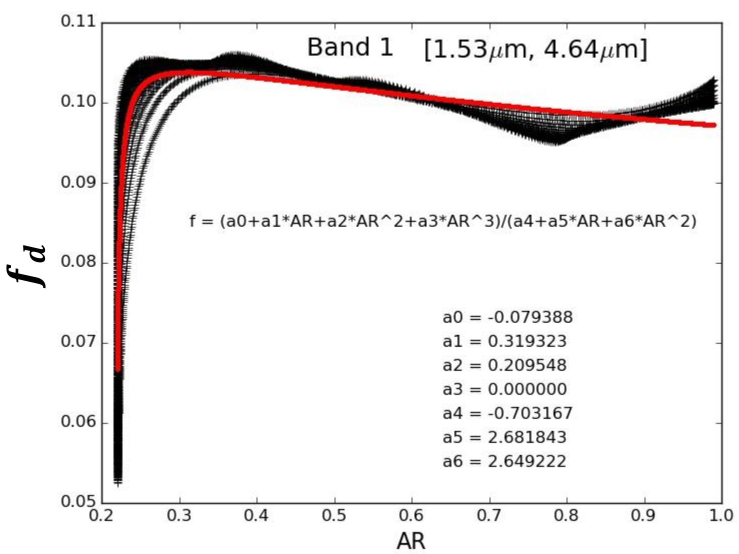
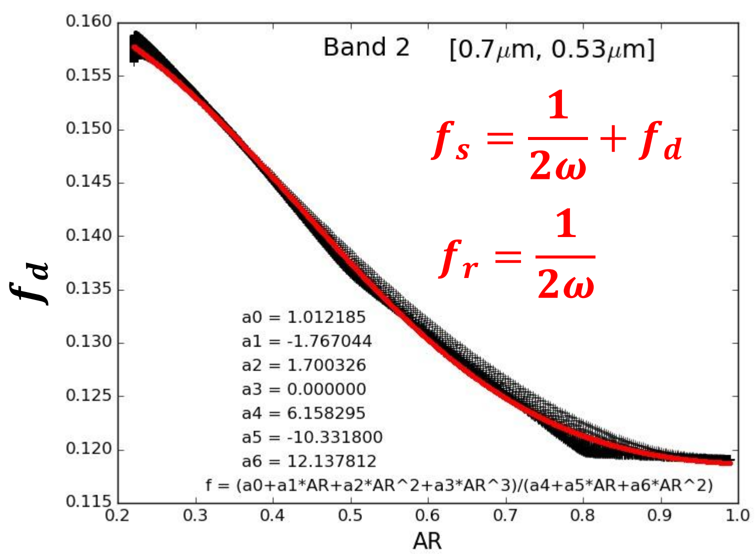


FIG. 7. Comparison of asymmetry factors based on the parameterization with those of spatial bullet rosettes with smooth surfaces, aggregates with rough surfaces, and fractal ice crystals in the visible.

Fu Q., J. Atm. Sci. V. 64, 4140-4150 (2007)

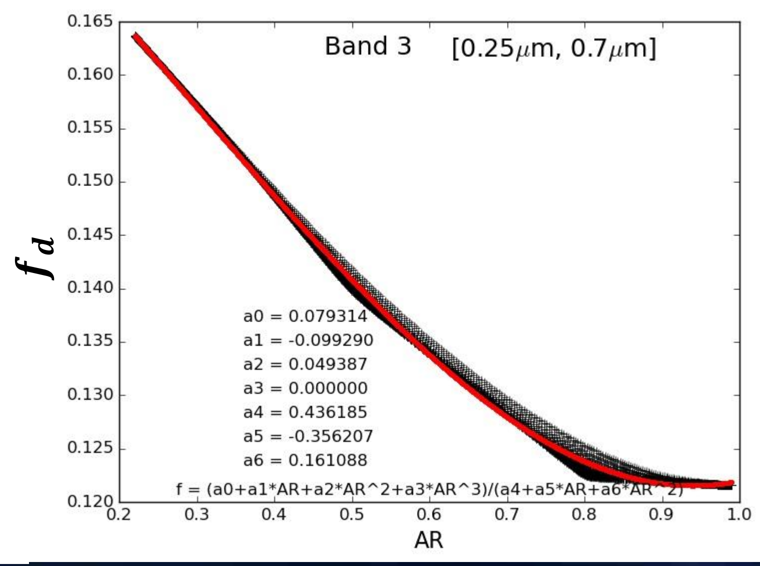
Fitting delta transmission fraction $f_d(AR)$





$$f_s = \frac{1}{2\omega} + f_d$$

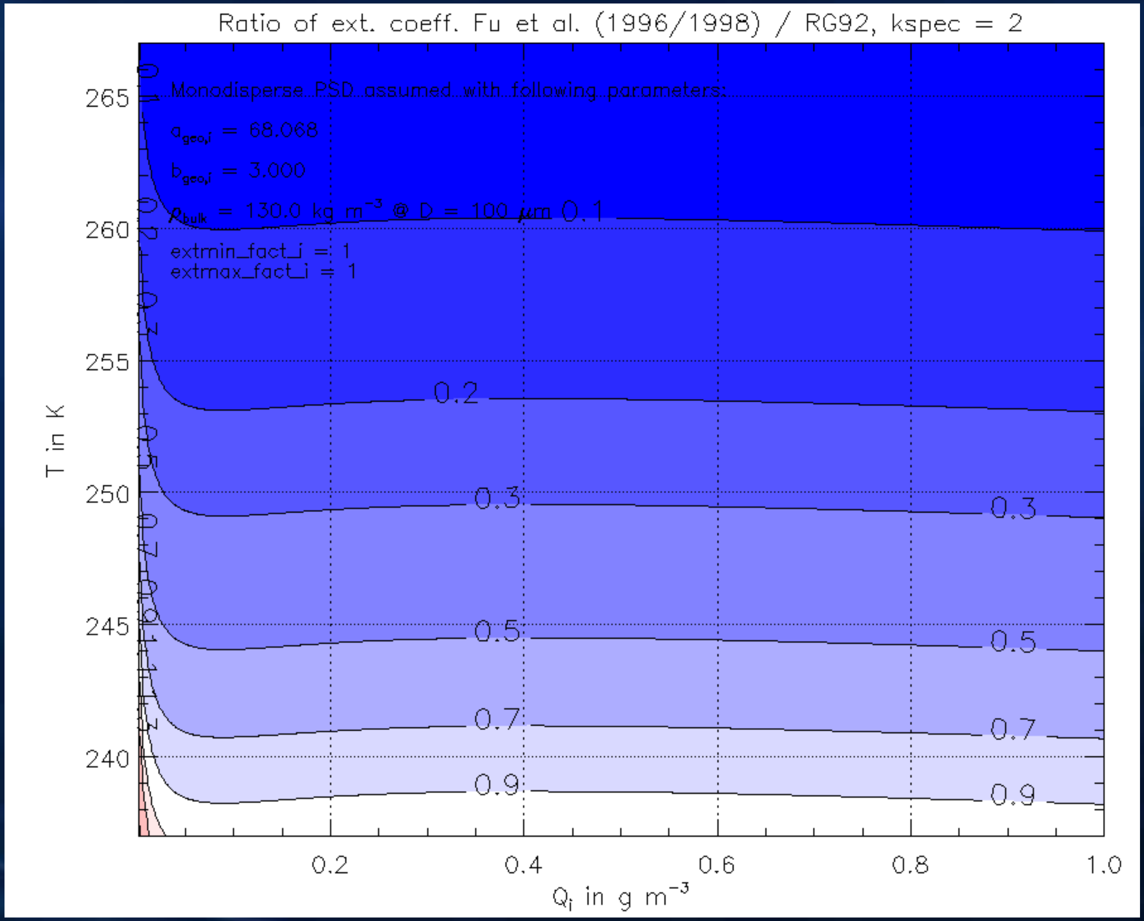
$$f_r = \frac{1}{2\omega}$$



Comparison to current RG92 (cloud ice)

If grid scale qi > 0: from cloud microphysics:

$$f(D) = \text{monodispers}$$
$$N_i(T) = a \exp(b(T_3 - T))$$
$$q_i \text{ prognostic}$$
$$m_i = 130\, D^3 \text{ (SI-units)}$$



Spectral interval „2“
(visible range)

β_{ext} ratio new fits / RG92

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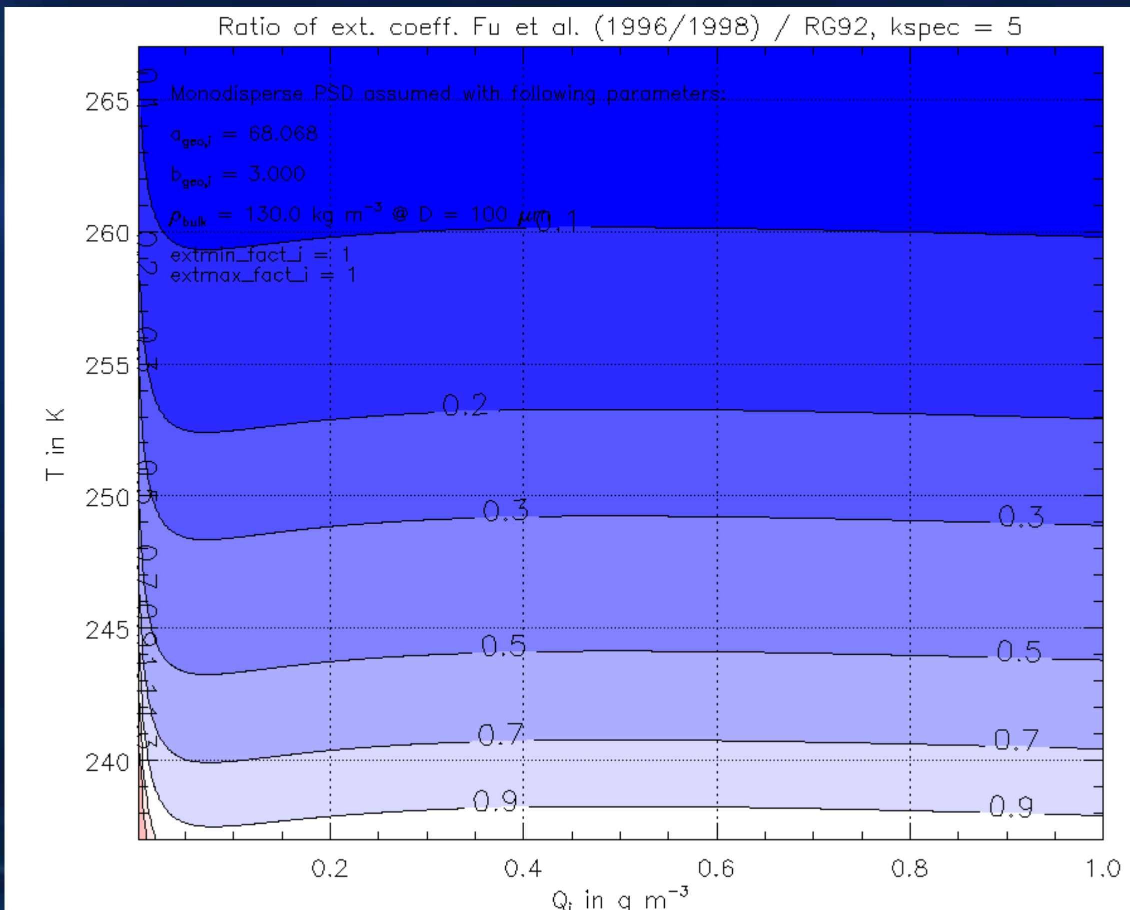
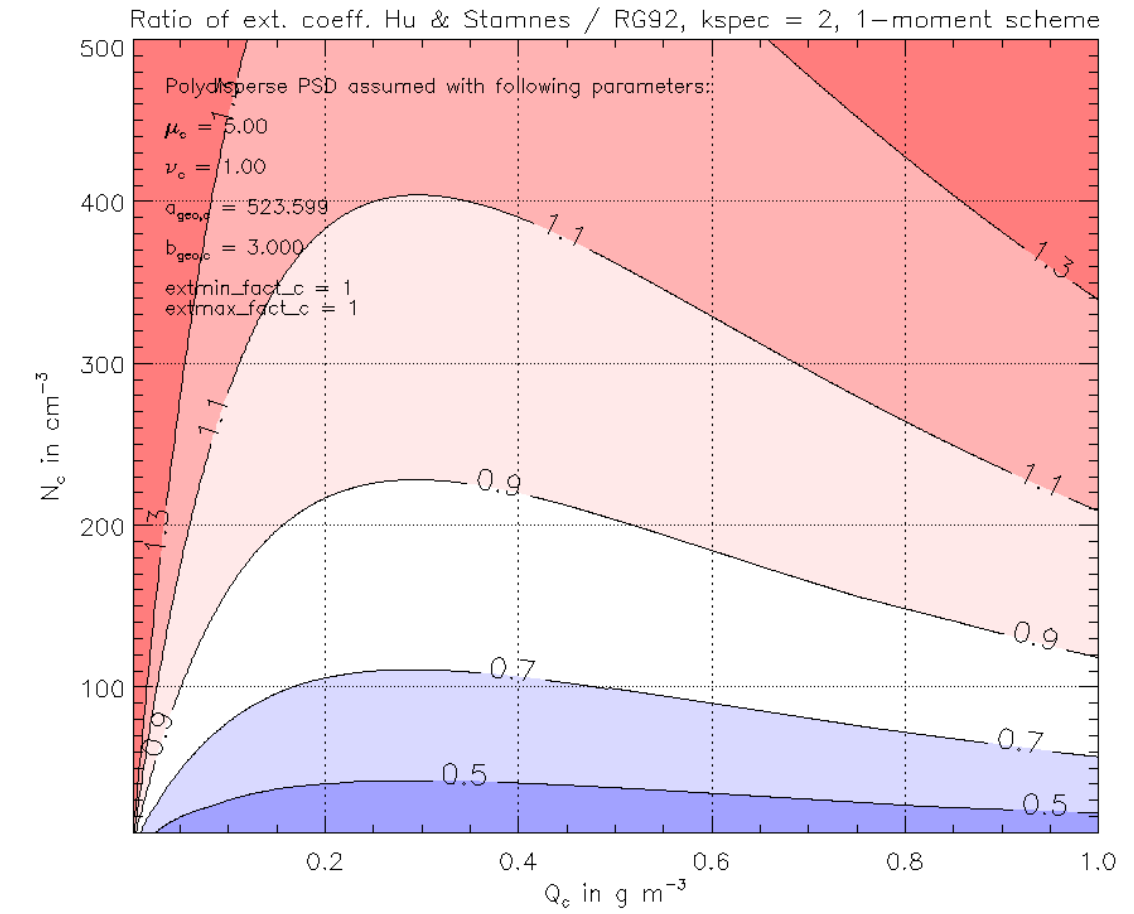


Spectral interval „5“
(IR range)

β_{ext} ratio new fits / RG92

Comparison to current RG92 (droplets)

if gridscale qc > 0:



from cloud microphysics:

$$f(D) = N_0 D^{\mu} e^{-\lambda D}$$

$\mu = 5.0$

$N_c = \texttt{cloud\_num}$

q_c prognostic

Spectral interval „2“ (visible range)

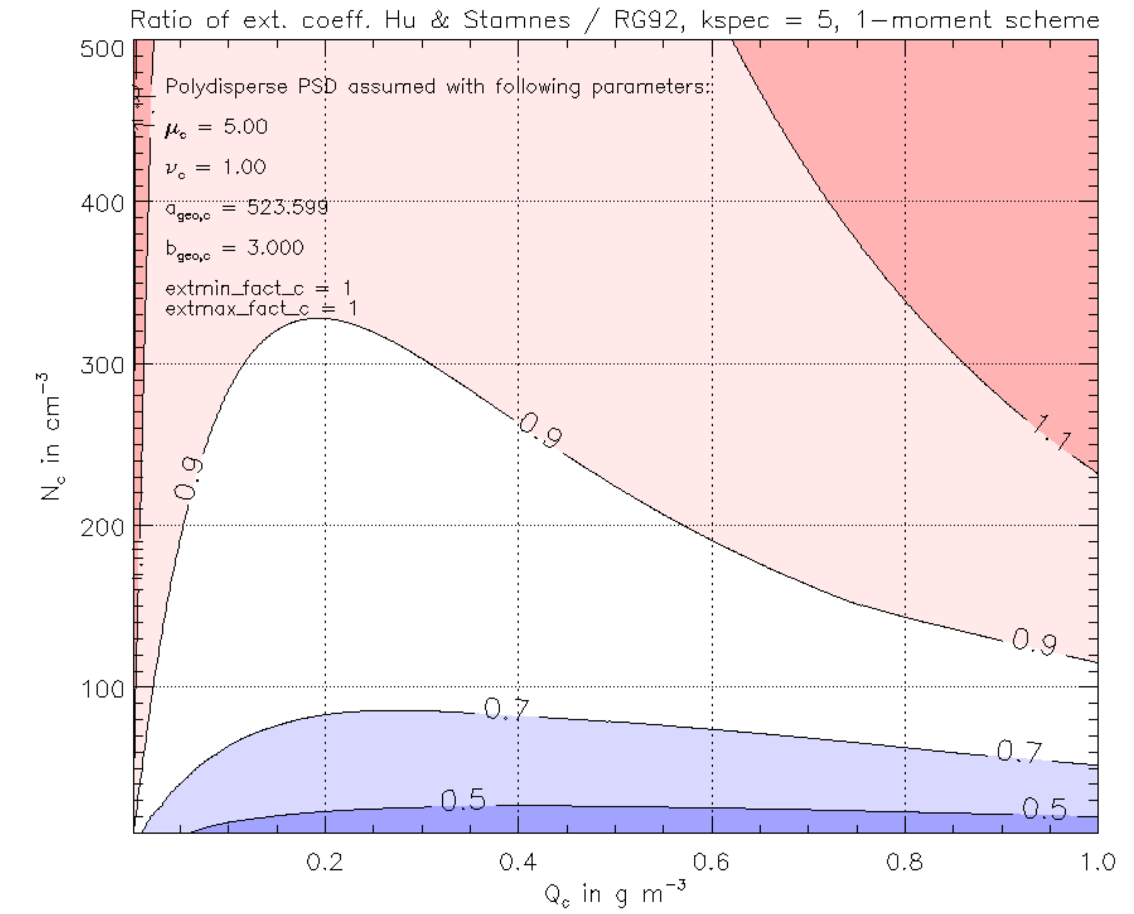
β_{ext} ratio own fits / RG92

Comparison to current RG92 (droplets)

if gridscale qc > 0:

from cloud microphysics:

$$f(D) = N_0 D^{\mu} e^{-\lambda D}$$
$$\mu = 5.0$$
$$N_c = \texttt{cloud\_num}$$
q_c prognostic



Spectral interval „5“ (IR range)

β_{ext} ratio own fits / RG92

The End