Refractive index for speckles mask

SM, 15/1/2020

Intro

- Our case:
  - big particles: $x = ka \ll 1$ where a radius of particle, $\mathrm{k} = \frac{2\pi}{\lambda}$ Low refractive index: $\delta \ll 1$ where $\mathrm{n} = 1 - \delta + i\beta$
- This is the so-called ‘anomalous diffraction‘ case. Scattering is result of:
  - Reflection and refraction of light inside the particle (negligible)
  - Diffraction from particle shape (dominant)
- Purpose is to calculate the scattering efficiency as a function of the refractive index. All equations are taken from Van de Hulst, “Light scattering by small particles”

Extinction and scattering function (single particle)

- **Extinction** is the optical power removed from transmitted by scattering and absorption. In our case:

$$Q_{ext} \cong \frac{1}{2}\rho^2$$

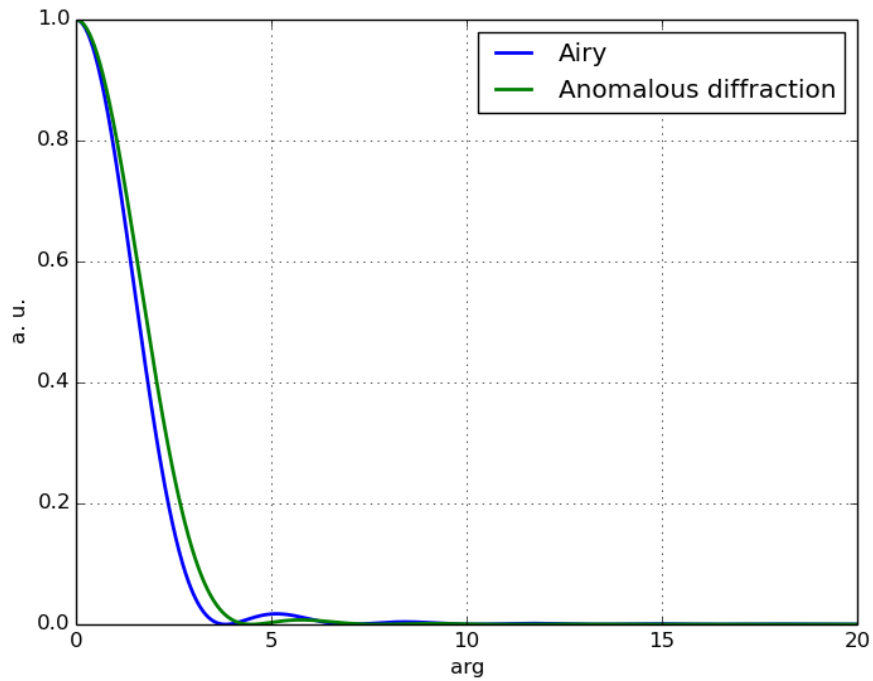
Where $\rho = 2x\delta$. ρ is the max variation of optical path ("ray" crossing the centre of the particle). Under the assumption that absorption is negligible ($\delta \gg \beta$) this is entirely due to scattering.

- **Scattering function**. Our case is at the border between the anomalous diffraction case (very big particles) and the Rayleigh-Gans approximation (very low δ). In this case the scattering field amplitude is

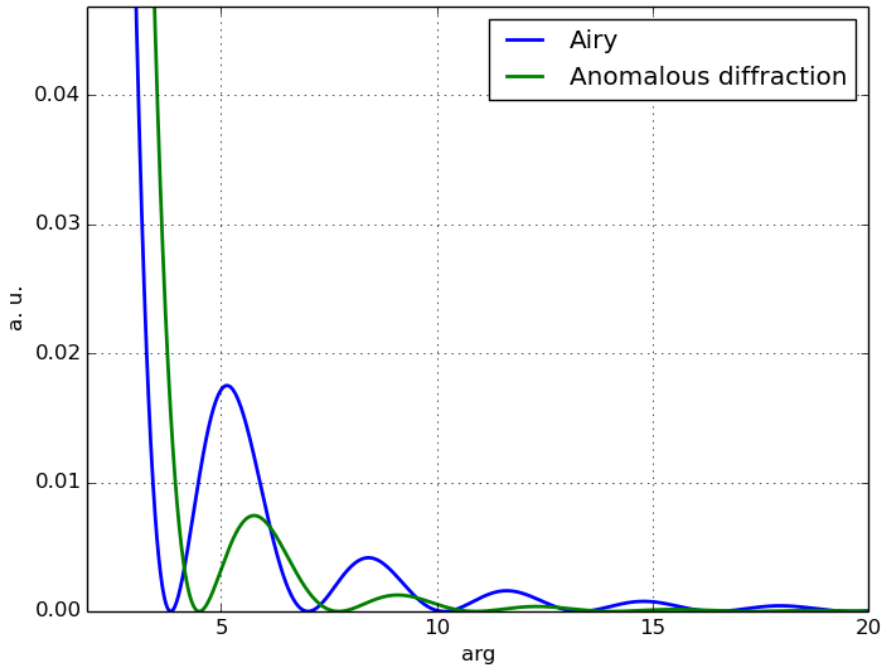
$$S(\theta) = i\rho k^2 a^2 \left(\frac{\pi}{2z^3}\right)^{1/2} J_{3/2}(z)$$

Where $z = \theta x = \theta k a$ That is <u>linearly</u> proportional to $\rho = 2x\delta$.

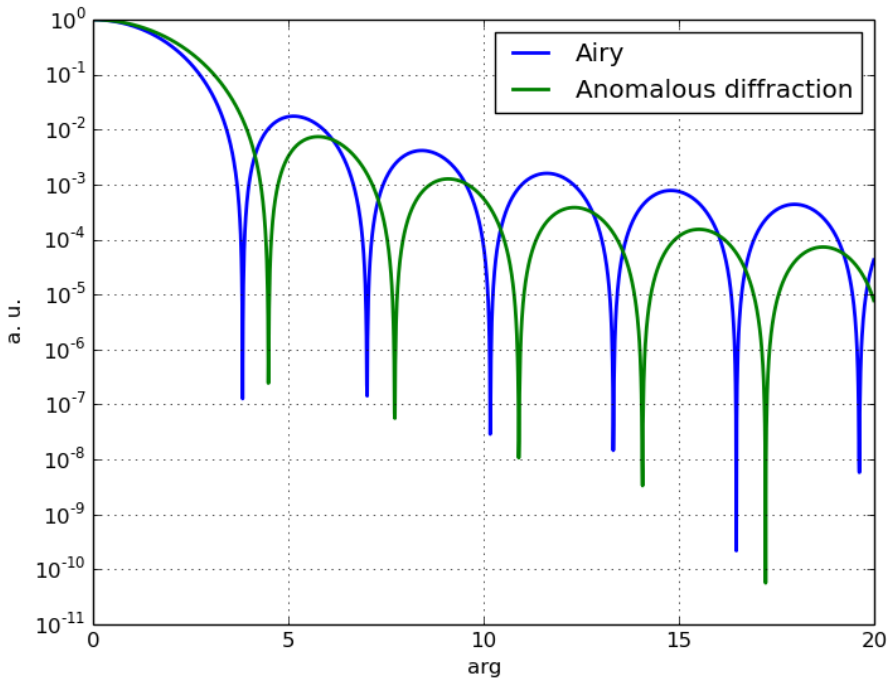
Comparison with pure diffraction



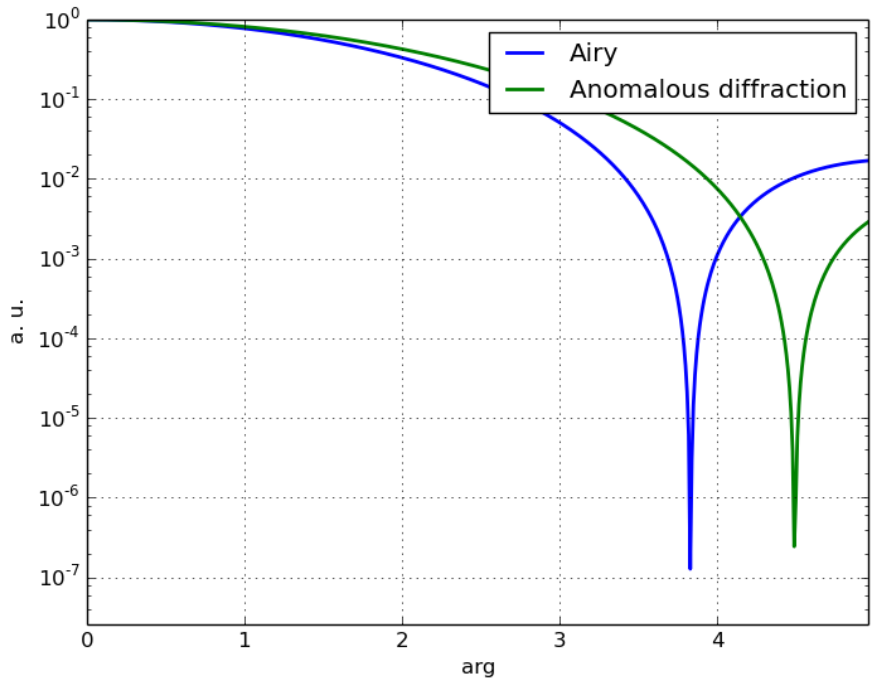
Comparison with pure diffraction



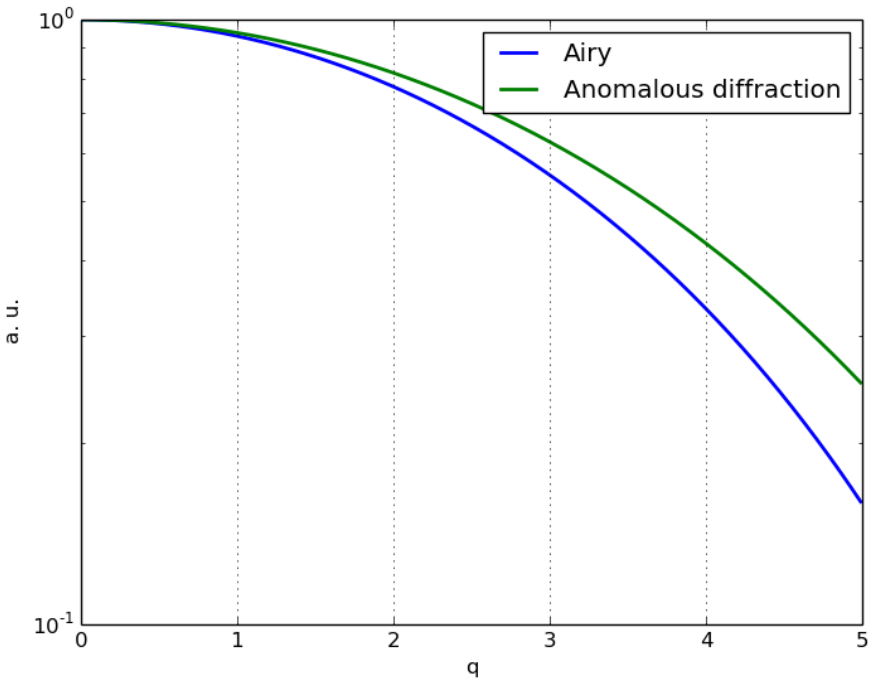
Comparison with pure diffraction



Comparison with pure diffraction



Comparison with pure diffraction



Mask vs particles

- Exploiting Babinet' s principle, a spherical particle of radius a and refractive index δ is equivalent to (except sign of field amplitude) a hole of same radius in slab of refractive index δ.
- For N particles, scattering amplitudes (and extinction) add linearly ($S_{tot}(\theta) = NS(\theta)$). In the case of a mask, amplitude proportional to the number of holes per unit surface

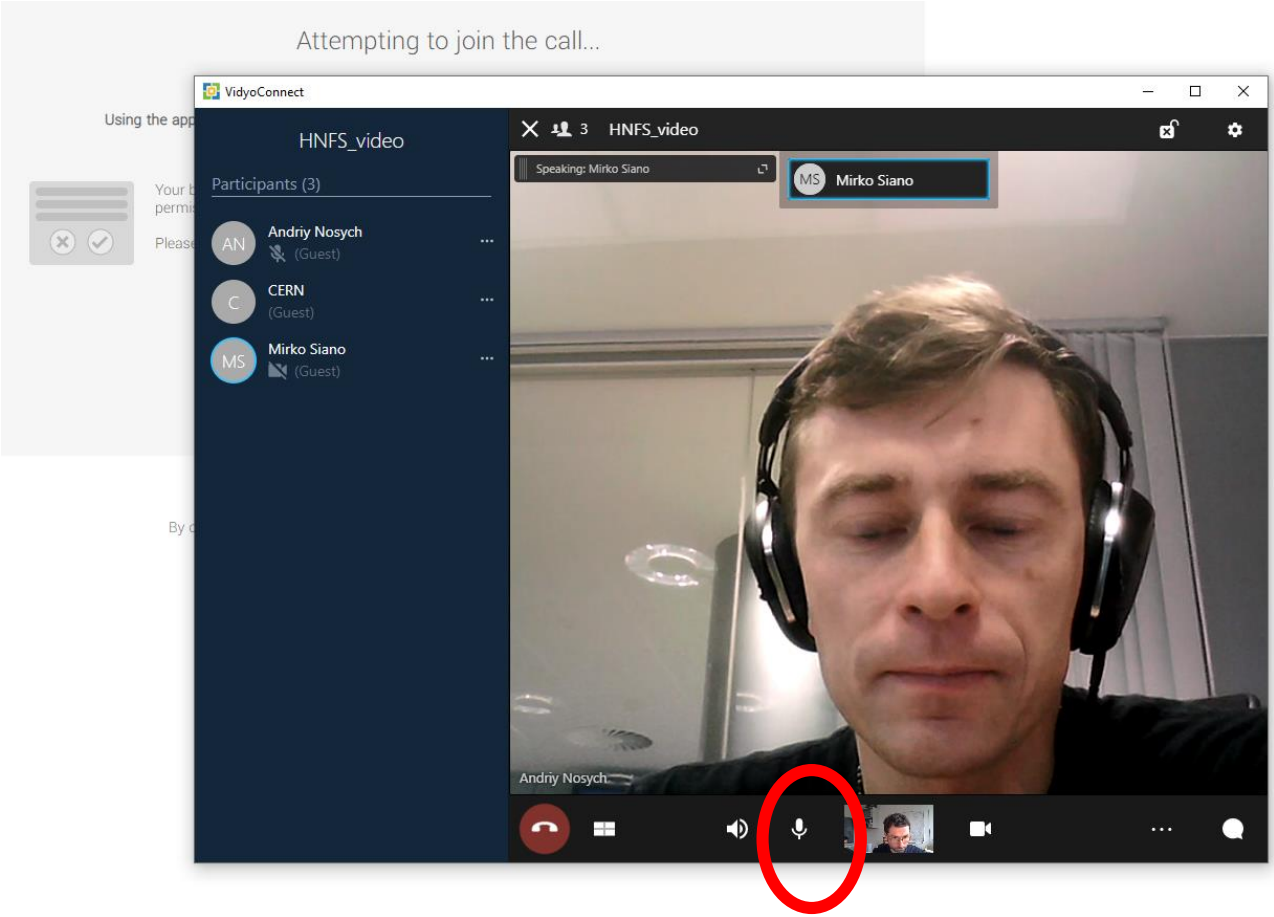
In order to maximize the extinction (=scattering), the mask should have a maximum of $\rho = 2kd\delta$, where d is the thickness. That is:

<u>max thickness, max δ and max N</u>

A few numbers

material	δ @ 12 keV	ρ	N
500nm SiO2 particles	3.18E-06	4.8E-02	Order 1E06 (200x200 um2)
Water	1.6E-06	N/A	N/A
Si, 10 um	3.39E-06	2.1	Order 1E03
Au, 10 um	1.79E-05	10.9	
Air	? I assume 0 (n=1)	N/A	N/A

- Increase of signal per scatterer (x40 increase with 500 nm holes in 10 um Si slab). For $|S(\theta)|^2$?
- However, surface density of scatterers WAY lower for mask. As a result, overall signal might be lower for mask. This can be compensated by increase of exposure time (static pattern).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Participants (3)
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Andriy Nosych
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3
HNFS_video
Speaking: Mirko Siano
MS
Mirko Siano
Andriy Nosych