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## ► To cite this version:

Sébastien Brisard, Camille Chateau, Pierre Levitz. From projections to small-angle scattering: Artifacts induced by polychromatic cone-beams. 5th International Conference on Tomography of Materials and Structures (ICTMS 2022), Jun 2022, Grenoble, France. hal-03745847

**HAL Id: hal-03745847**

**<https://enpc.hal.science/hal-03745847>**

Submitted on 4 Aug 2022

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# From projections to small-angle scattering : Artifacts induced by polychromatic cone-beams

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## Context and objectives

Small-angle scattering (SAS - X-ray, neutron) is a technique for the investigation of the structure of disordered materials at the 1nm - 100nm scale. It delivers, in Fourier space, the two-point correlations of the electron density within the material.

For isotropic materials, the SAS pattern  $I(q)$  depends on the norm  $q$  of the wave-vector only, and the covariance function  $\gamma(r)$  depends on the norm  $r$  of the lag-vector only.

$$I(q) \propto \int_0^{+\infty} 4\pi r^2 \text{sinc}(qr) \gamma(r) dr$$

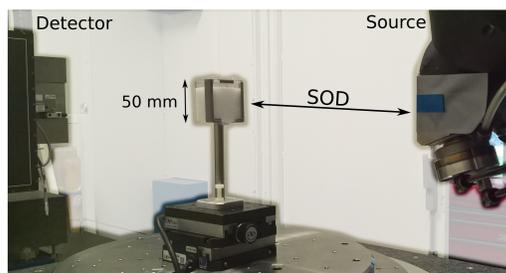
- ▶ The sample preparation is kept to a minimum.
- ▶ The 3d structural information [ $\gamma(r)$ ] is limited, but quantitative: volume fraction, specific surface area, particle-size distribution...
- ▶ Applications from biology [1] to geomaterials [2-3].

A technique was proposed to simulate the SAS pattern of a material from a **single X-ray radiography** [4], which:

- ▶ bridges the length scales explored by SAS and by microtomography,
- ▶ opens the door to time-resolved, quantitative experiments,
- ▶ was successfully used in various applications [3, 5, 6].

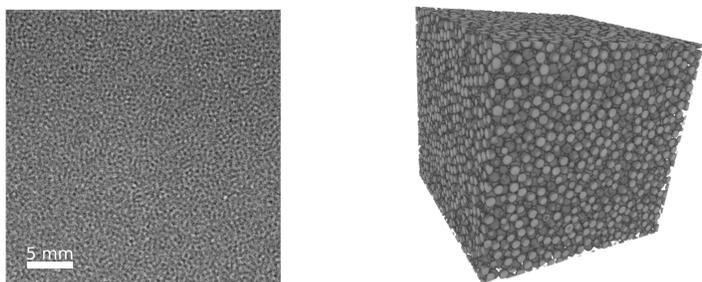
However, it is mathematically correct (and fully validated) for parallel beams only. In order to **extend this technique to cone-beam geometries**, our goal in this project is to quantify the distortions induced by non paraxial rays.

## Materials and Methods



Polystyrene beads were placed in a plastic container. Projections were acquired on a laboratory tomograph (RX Solutions) under various source-to-object distance (SOD) and a long source-to-detector distance.

For reference, a full tomography scan was also acquired (voxel-size 30 $\mu$ m).

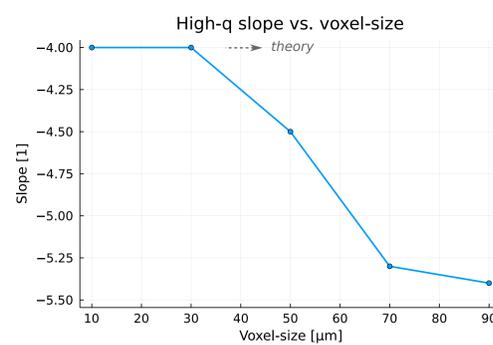
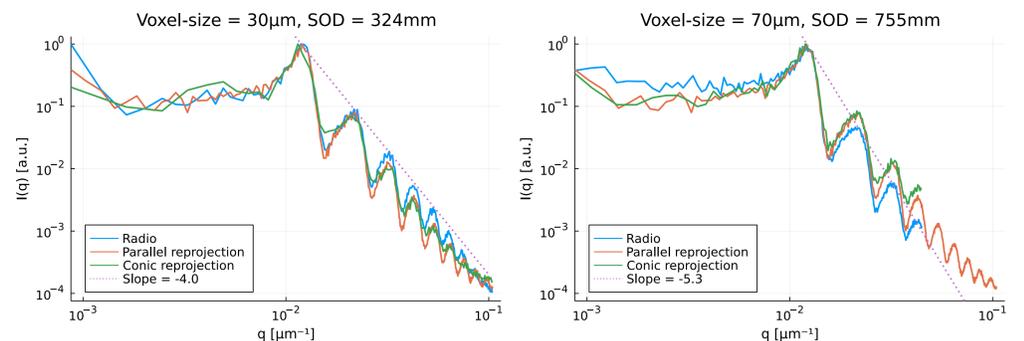


The SAS spectra were computed from the projections  $P$  (log of radios) at each SOD.

$$I(q_x, q_y, q_z = 0) = \left| \hat{P}(q_x, q_y) \right|^2$$

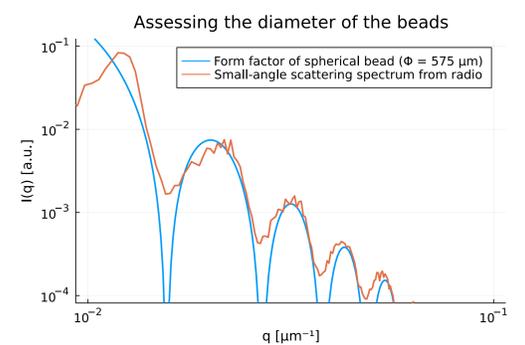
The SAS spectra were also computed from the **parallel reprojection** and **conic reprojection** of the 3D reconstructed + thresholded volume. Both reprojections are monochromatic.

## Results



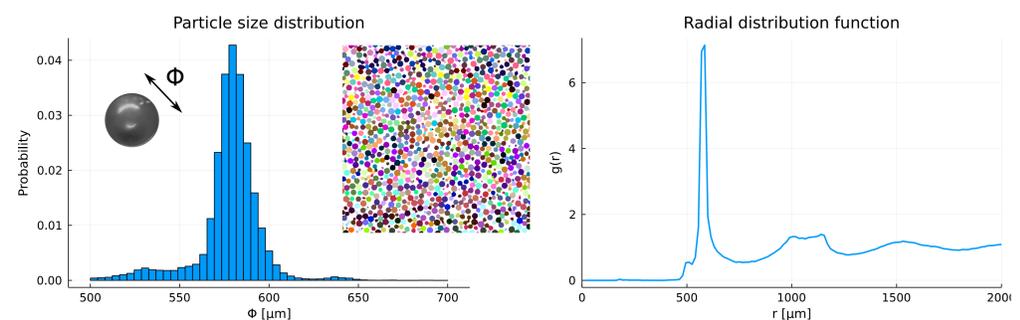
Maximizing the source-to-object distance minimizes the distortions induced by the conic geometry. Our results therefore suggest that there is at least one more source of distortions.

Comparison of **radio** and **conic reprojection** shows that beam-hardening cannot be neglected.



Despite these distortions, the proposed method is **quantitative**. We were able to measure the average radius of the spherical beads from one single radio.

The resulting value was confirmed by a more costly analysis of the 3D reconstructed volume (PSD + RDF [8]).



## Perspectives

- ▶ New experimental setup, with a more controlled sample (dimensions, ...)
- ▶ Quantification of other descriptors: volume fraction, specific surface area ...
- ▶ Analytical model of geometric, noise-induced and beam-hardening distortions → deconvolution
- ▶ Extension to  $N > 2$  phases: vary source kV and/or use photon-counting, dual energy, XC-Thor sensor from DirectConversion
- ▶ "Sub-pixel" accuracy?

## References

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