# Computational light scattering

Course page for Computational light scattering — Laskennallinen valonsironta

### Advanced Course, 5 credits, PAP315, Autumn 2020, Period 1

Computational light scattering assesses elastic light scattering (electromagnetic scattering) by particles of arbitrary sizes, shapes, and optical properties. Particular attention is paid to advanced computational methods for both single and multiple scattering, that is, to methods for isolated particles and extended media of particles (cf. dust particles in cometary comae and particulate media on asteroids). Theoretical foundations are described for the physics of light scattering based on the Maxwell equations and for a number of computational methods. In single scattering, the methods include, for example, the volume integral equation, discrete-dipole approximation, T-matrix or transition matrix, and finite-difference time-domain methods. In multiple scattering, the methods are typically based on Monte Carlo ray tracing. These include far-field radiative transfer and coherent backscattering methods and their extensions incorporating full-wave interactions. Students are engaged in developing numerical methods for specific scattering problems. The development and computations take place in both laptop and supercomputing environments.

Course is held virtually in Zoom, on Mondays 10-12 and Wedsnesdays 12-14. Exercise sessions are also in Zoom, on Mondays 9-10 and Wednesdays 9-10.

Lectures by Karri Muinonen, Guangland Xu, and Antti Penttilä.

Recommended preliminary knowledge: basic courses in Physics, basic courses in Mathematics, Electrodynamics, Mathematical Methods for Physicists I & II, Scientific Computing I.

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## Information

- Information package about course details

## Lecture material

- Lecture 1a: Handouts, Lecture
- Lecture 1b: Handouts, Lecture
- Lecture 2a: Handouts, Lecture
- Lecture 2b: Handouts, Lecture
- Lecture 3a: Handouts, Lecture
- Lecture 3b: Handouts, Lecture
- Lecture 4a: Handouts, Draine, Penttilä et al., Lecture
- Lecture 4b: Handouts, Lecture
- Lecture 5a: Handouts,
- Lecture 5b: Handouts, Handouts2
- Lecture 6a: Handouts, Chang et al., Notes on inhomogeneous waves, Muinonen et al., Lecture
- Lecture 6b: Handouts, Lecture
- Lecture 7a, Handouts
- Lecture 7b, Handouts
- Lecture 8a, Handouts
- Lecture 8b, Handouts
- Lecture 9a, Handouts
- Lecture 9b, Handouts
- Lecture 10ab: Handouts
- Lecture 11a, Handouts, Muinonen et al. WRM, Muinonen et al. ApJ, Lecture
- Lecture 11b: Handouts, Lecture
- Lecture 12a: Handouts, Muinonen et al. Radio Sci., Lecture
- Lecture 12b: Handouts, Lecture
- Lecture 13a: Handouts, Penttilä et al. Icarus, Lecture
- Lecture 13b: Väisänen et al. JQSRT, Lecture
- Lecture 14a: Handouts, Lecture
- Lecture 14b: Muinonen et al A&A, Lecture

Handouts from older courses, part 1, 2, 3, 4, 5, 6 by K. Muinonen, 7, 8, 9 by J. Markkanen, 10 by J. Herranen, 11-12 by A. Penttilä, 13, 14 by K. Muinonen

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## Exercises

- Exercise 1, Answers
- Exercise 2, Answers, Hansen-Travis
- Exercise 3, AnswerP3
- Project task 1
- Exercise 4,  AnswerP12,, AnswerP3
- Exercise 5, AnswerP2
- Project task 2

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## Background material

- P. C.Y. Chang, J.G. Walker, K.I. Hopcraft. Ray tracing in absorbing media. JQSRT 96 (2005).
- Yang, P. and Liou, K.N., 1996. Finite-difference time domain method for light scattering by small ice crystals in three-dimensional space. JOSA A, 13(10), pp.2072-2085.
- Tang G, Yang P, Sun B, Panetta RL, Kattawar GW. Enhancement of the computational efficiency of the near-to-far field mapping in the finite-difference method and ray-by-ray method with the fast multi-pole plane wave expansion approach. Journal of Quantitative Spectroscopy and Radiative Transfer. 2016 Jun 1;176:70-81.
- Mishchenko's *T*-matrix code for particles in random orientation, modified to read parameters from an input file: tmd-lp.f, lpd.f, tmd.par.f. An example input file default.in, and article explaining the parameters: 98_jqsrt_60_309.pdf
- Example input file for Mackowski's MSTM code: mstm-input.inp
- Example input files for RT-CB code: rayleigh-plane.inp
- Alternative Makefile for RT-CB, copy to directory src\dsfmt under the rt-cb root folder

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## Suggested reading

- J. D. Jackson: Classical Electrodynamics
- C. F. Bohren & D. R. Huffman: Absorption and Scattering of Light by Small Particles
- M. I. Mishchenko, J. W. Hovenier & L. D. Travis: Light Scattering by Nonspherical Particles: Theory, Measurements, and Applications
- H. C. van de Hulst: Light Scattering by Small Particles

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Previous versions of this course

- Fall 2016
- Fall 2014
- Fall 2012