

The ARTS Single Scattering Database

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Outline

1. Overview
2. Specifications
3. Example results
4. Database structure
5. Summary



Overview

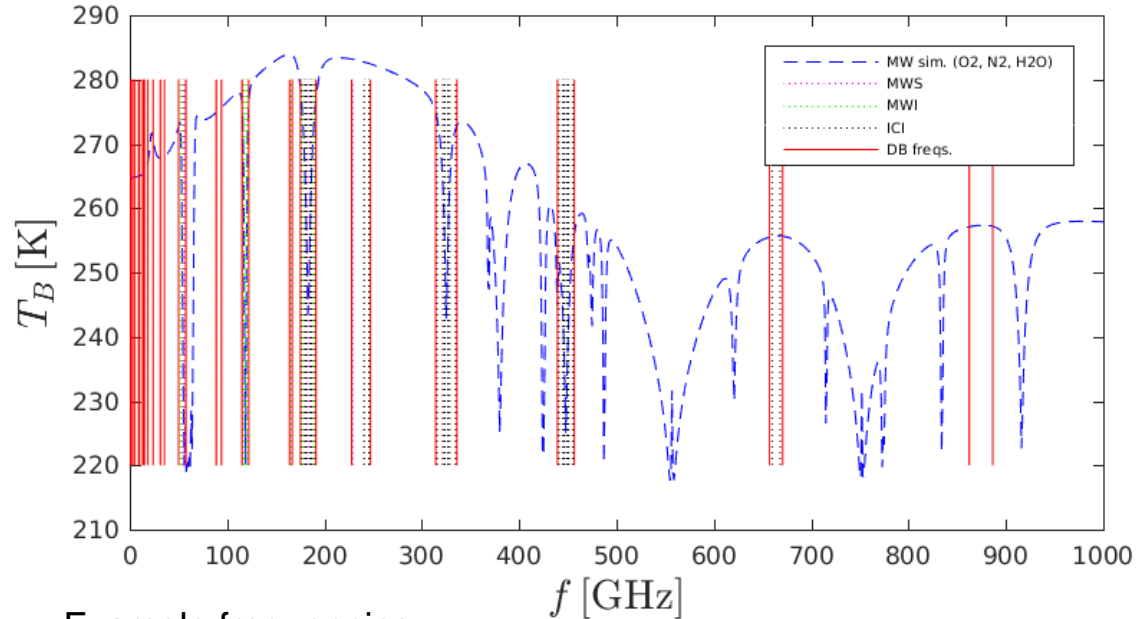
- Background
 - Passive and active applications
 - ARTS
 - EUMETSAT:
 - ICI, MWI, MWS
- Scope
 - Pristine, aggregate, melting and rimed particles
 - Frequencies: $[1, 1000]$ GHz
 - Orientations:
 - Totally random
 - Azimuthally random
- Method
 - External and “in-house” generated shape data
 - Amsterdam DDA



Specifications

Frequencies and temperatures

- 32 Frequencies:
- ICI (ISMAR), MWI, MWS.
 - (IceCube, CloudSat, EarthCare)
- 3 Temperatures:
 - 190, 230, 270 K
- Refractive index of ice:
 - Mätzler 2006



- Example frequencies:
 - 1, 31, 94, 118, 165, 175, 230, 330, 444, 664, 874 GHz....

Specifications

Habits

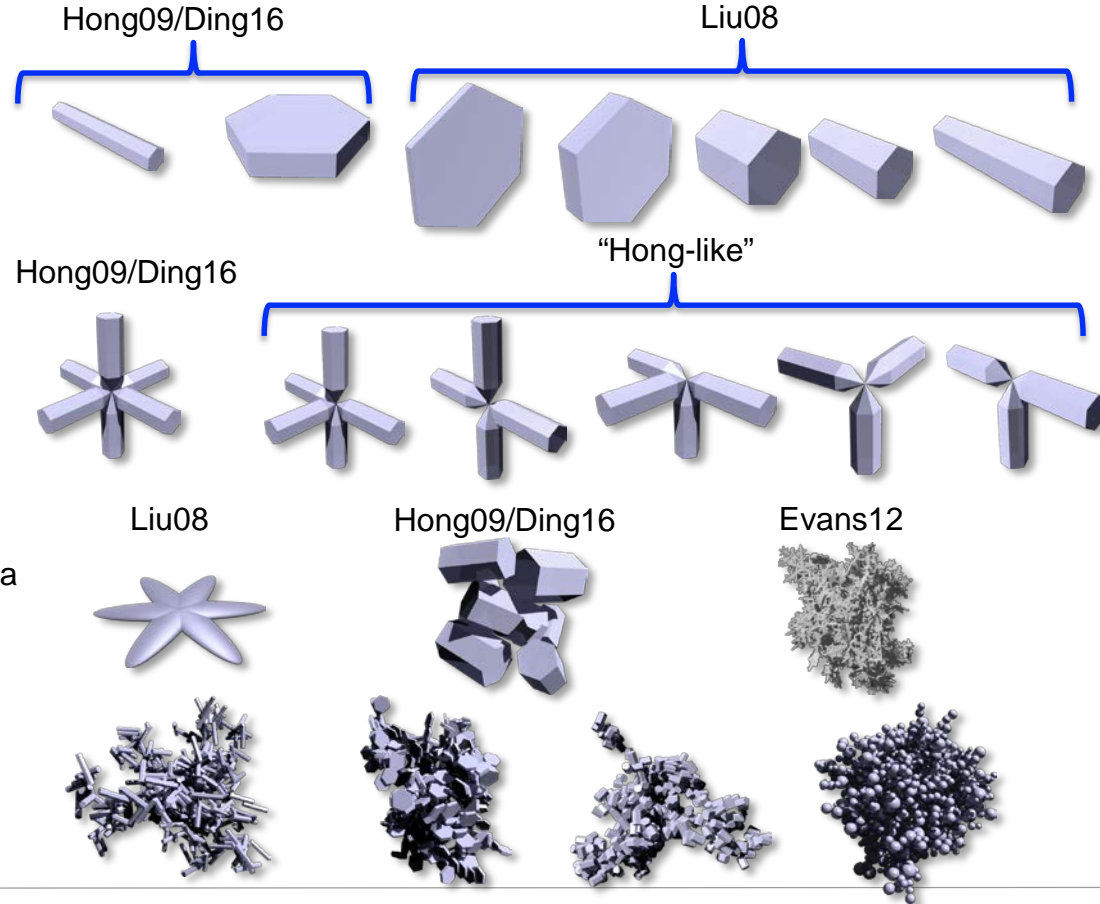
- 32 habits
- Size range:
 - $D_{max} \leq 2$ cm
 - $D_{veq} \leq 5$ mm
 - At least 35 sizes per habit.
- $m = \alpha D_{max}^{\beta}$
- Totally random orientation

columns & plates

Bullet rosettes

Misc external data

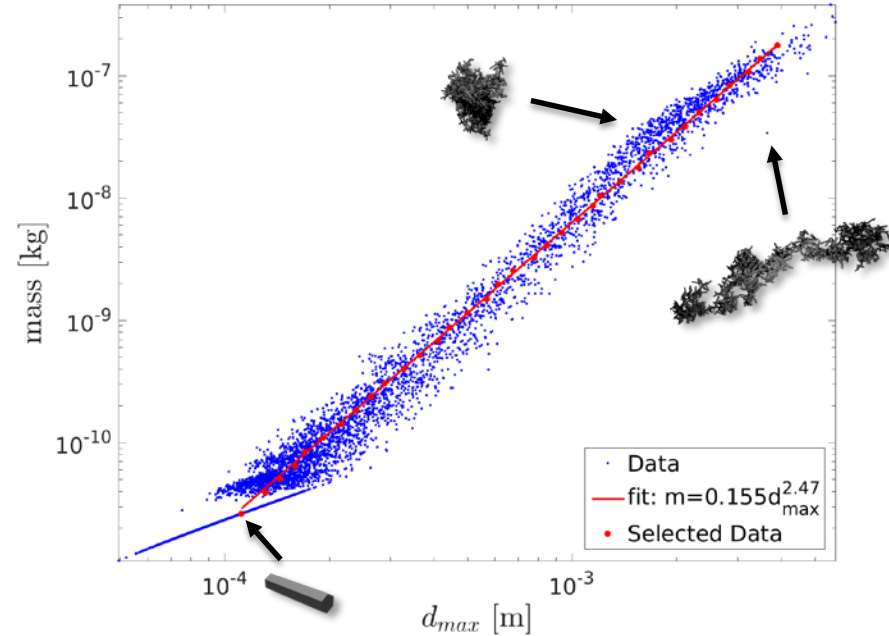
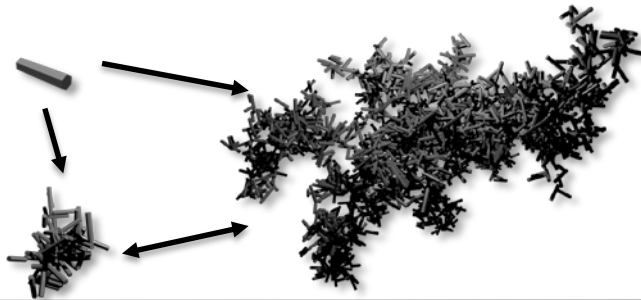
Chalmers aggregates



Specifications

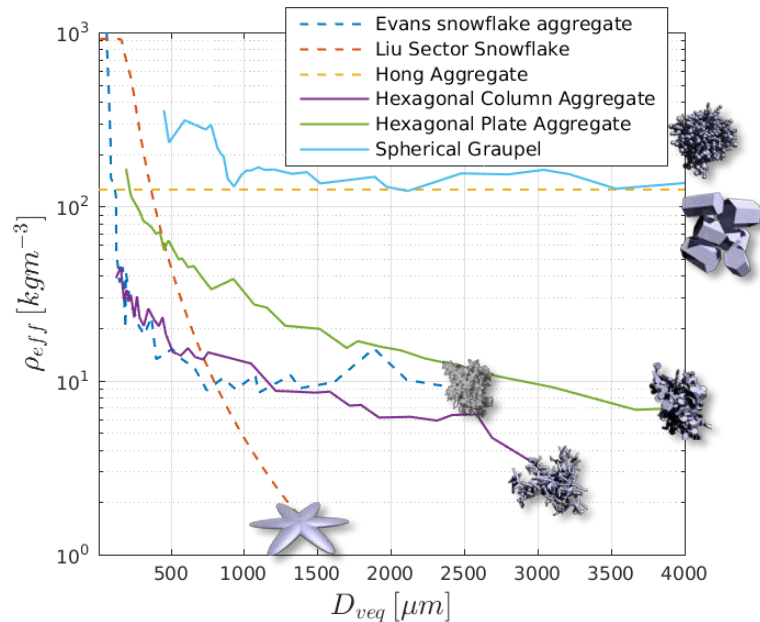
Aggregate generation

- Iterative “Stochastic collision model”
 - Up to 5,000 particles simultaneously
 - Shape of building blocks customizable.
 - Only hexagonal columns/plates considered currently.
- Particles selected along $m = \alpha D_{\max}^{\beta}$

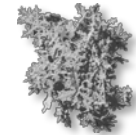


Example results

Effective density



- Evans Snow Aggregate



- Sector Snowflake



- Hong Aggregate



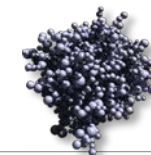
- Long Column Aggregate



- Thin Plate Aggregate

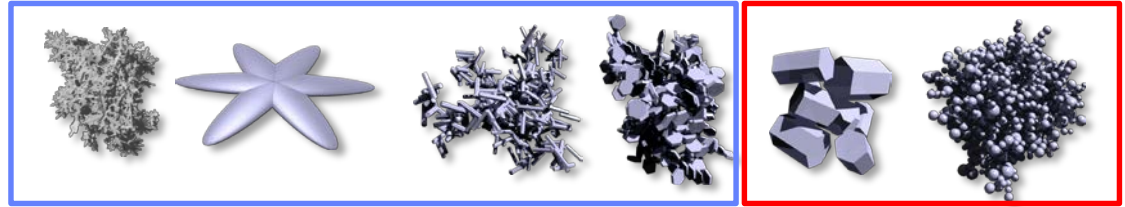


- Spherical Graupel

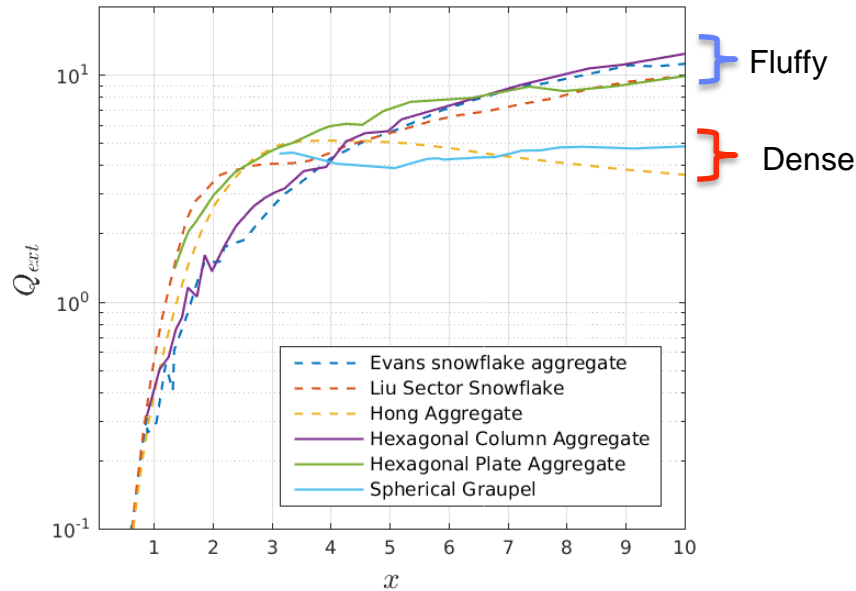


Example results

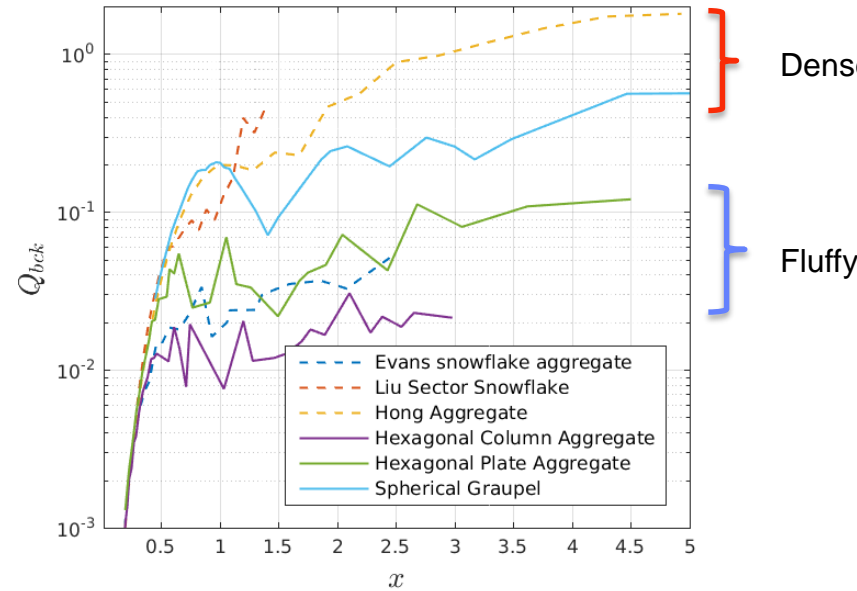
Scattering



Extinction 657.3 GHz



Back-scattering 94.1 GHz



Database structure

- Content
 - Scattering properties
 - Shape data
 - DDA settings
- Format
 - NetCDF4
 - One file for each size, frequency and temperature
- Interfaces
 - MATLAB, Python
- Availability
 - ARTS home page: <http://www.radiativetransfer.org>
 - Snowport (soon): snowport.meteo.uni-koeln.de/

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Details
Command Window
first three levels give a rough classification of each
habit. The information found in the two last levels is:
habit id: habit name          a          / b
orientations
where mass = a * Dmax*b.

Habits marked with *(x)* are still work in progress
(use with caution).

Ice
...
Aggregates
Pristine
1: EvansSnowAgg              a=2.3e-01 / b=2.41
   TotallyRandom
21: HexColAggCrystal-Dmax100m-AxisRat1.25 a=2.1e-01 / b=2.33
   TotallyRandom
17: HexColAggCrystal-Dmax100m-AxisRat1.05 a=1.4e-01 / b=2.45
   TotallyRandom
18: HexColAggCrystal-Dmax350m-AxisRat1.05 a=2.5e-01 / b=2.43
   TotallyRandom
19: HexPlaAggCrystal-Dmax100m-AxisRat1.05 a=8.1e-02 / b=2.25
   TotallyRandom
20: HexPlaAggCrystal-Dmax350m-AxisRat1.05 a=1.9e-01 / b=2.24
   TotallyRandom
8: HongAggregate              a=6.5e+01 / b=3.00
   TotallyRandom

Rimed
23: SphericalGraupel         a=1.6e+01 / b=2.72
   TotallyRandom
SingleCrystals
Pristine
(x) 5: HongBulLetRosette-3b-flat          a=2.7e-01 / b=2.44
   TotallyRandom
(x) 4: HongBulLetRosette-3b-perp         a=7.7e-01 / b=2.51
   TotallyRandom
(x) 11: HongBulLetRosette-4b-flat        a=3.5e-01 / b=2.43
   TotallyRandom
(x) 10: HongBulLetRosette-4b-perp        a=9.7e-01 / b=2.50
   TotallyRandom
(x) 2: HongBulLetRosette-5b              a=4.4e-01 / b=2.44
   TotallyRandom
(x) 6: HongBulLetRosette-6b              a=4.3e-01 / b=2.41
   TotallyRandom
7: HongColumn                          a=3.1e-02 / b=2.01
   TotallyRandom
(x) 9: HongPlate                          a=7.6e-01 / b=2.48
   TotallyRandom
(x) 24: IceSphere                          a=4.0e+02 / b=3.00
   TotallyRandom
12: LiuBlockColumn                       a=2.1e+02 / b=3.00
   TotallyRandom
14: LiuLongColumn                        a=3.4e+01 / b=3.00
   TotallyRandom
3: LiuSectorSnowflake                    a=8.1e-04 / b=1.44
   TotallyRandom
(x) 13: LiuShortColumn                    a=1.1e+02 / b=3.00
   TotallyRandom
15: LiuThickPlate                         a=1.1e+02 / b=3.00
   TotallyRandom
16: LiuThinPlate                          a=3.0e+01 / b=3.00
   TotallyRandom
    
```

Database structure

Core content

- Stored scattering data :
 - Scattering matrix (4x4)
 - Extinction matrix (4x4)
 - Absorption vector (4x1)
- Other common parameters easily derived
 - Single scattering albedo
 - Back-scattering
- Data reduction:
 - Non-zero and non-unique elements omitted.
 - Angular dependency expressed in terms of scattering angle for totally random orientation.

$$\frac{d\mathbf{I}(\nu, \hat{\mathbf{r}}, \hat{\mathbf{n}})}{ds} = -\mathbf{K}(\nu, \hat{\mathbf{r}}, \hat{\mathbf{n}})\mathbf{I}(\nu, \hat{\mathbf{r}}, \hat{\mathbf{n}}) + \mathbf{a}(\nu, \hat{\mathbf{r}}, \hat{\mathbf{n}})B(\nu, \hat{\mathbf{r}}) + \int_{4\pi} \mathbf{Z}(\nu, \hat{\mathbf{r}}, \hat{\mathbf{n}}, \hat{\mathbf{n}}')\mathbf{I}(\nu, \hat{\mathbf{r}}, \hat{\mathbf{n}}')d\hat{\mathbf{n}}'$$

- Scattering matrix

$$\mathbf{Z}(\theta_{sca}, \phi_{sca}, \theta_{inc}, \phi_{inc}) = \begin{pmatrix} Z_{11} & Z_{12} & Z_{13} & Z_{14} \\ Z_{21} & Z_{22} & Z_{23} & Z_{24} \\ Z_{31} & Z_{32} & Z_{33} & Z_{34} \\ Z_{41} & Z_{42} & Z_{43} & Z_{44} \end{pmatrix}$$

- Extinction matrix

$$\mathbf{K}(\theta_{inc}, \phi_{inc}) = \begin{pmatrix} K_{11} & K_{12} & 0 & K_{13} & 0 & K_{14} \\ K_{21} & K_{22} & 0 & K_{23} & 0 & K_{24} \\ K_{31} & -K_{23} & K_{11} & 0 & K_{34} & \\ K_{41} & -K_{24} & 0 & -K_{34} & K_{11} & K_{11} \end{pmatrix}$$

- Absorption vector

$$\mathbf{a}(\theta_{inc}, \phi_{inc}) = \begin{pmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{pmatrix}$$



Conclusion

- Current version (beta) available
 - ARTS home page: <http://www.radiativetransfer.org>
 - Snowport (soon): snowport.meteo.uni-koeln.de
- So far:
 - Totally random orientation
 - 32 habits (more on the way)
 - 32 frequencies in [1, 900] GHz
- Future:
 - Azimuthally random orientation
 - Melting particles

End

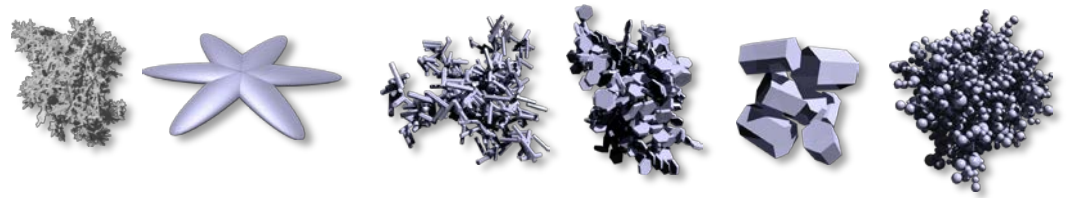
robin.ekelund@chalmers.se

- ARTS home page: <http://www.radiativetransfer.org>
- Snowport (soon): snowport.meteo.uni-koeln.de/

Backup slides

Example results

Radar triple frequencies

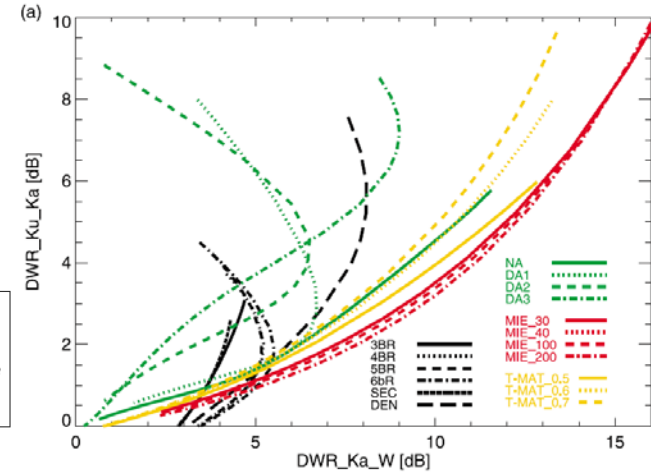
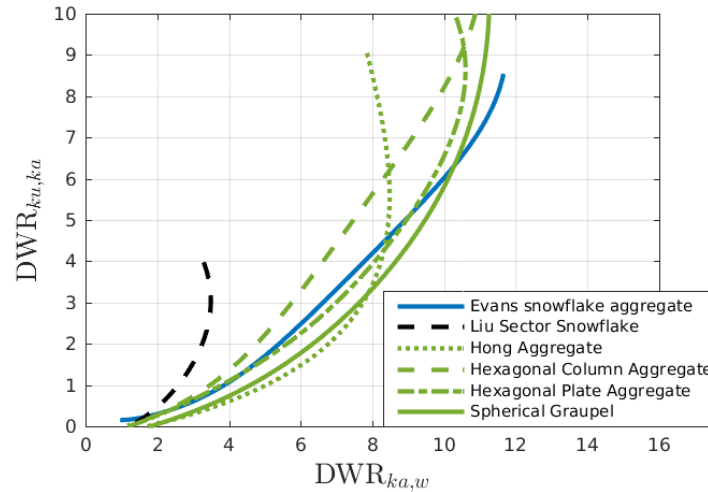


Exponential PSD

- $N = N_0 e^{-\Lambda D_{max}}$
- $\Lambda: [100, 500] m^{-1}$

Ku, Ka, W band

- 13.4, 36.5, 89.0 GHz



Kneifel et al. 2011

Overview

Parameters

- Stokes parameters formalism (radiance): $\mathbf{I} = \begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix}$
- Radiative transfer equation:

$$\frac{d\mathbf{I}(\nu, \hat{\mathbf{r}}, \hat{\mathbf{n}})}{ds} = -\mathbf{K}(\nu, \hat{\mathbf{r}}, \hat{\mathbf{n}})\mathbf{I}(\nu, \hat{\mathbf{r}}, \hat{\mathbf{n}}) - \mathbf{a}(\nu, \hat{\mathbf{r}}, \hat{\mathbf{n}})B(\nu, \hat{\mathbf{r}}) + \int_{4\pi} \mathbf{Z}(\nu, \hat{\mathbf{r}}, \hat{\mathbf{n}}, \hat{\mathbf{n}}')\mathbf{I}(\nu, \hat{\mathbf{r}}, \hat{\mathbf{n}}')d\hat{\mathbf{n}}'$$

Extinction matrix (4x4)

Absorption/emission vector (4x1)

Scattering matrix (4x4)

$$\mathbf{K}(\theta_{inc}, \phi_{inc}) = \begin{pmatrix} K_{11} & K_{12} & K_{13} & K_{14} \\ K_{12} & K_{11} & K_{23} & K_{24} \\ K_{13} & -K_{23} & K_{11} & K_{34} \\ K_{14} & -K_{24} & -K_{34} & K_{11} \end{pmatrix}$$

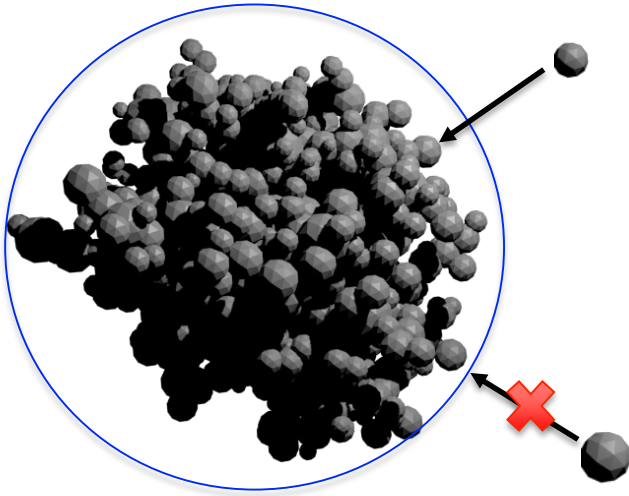
$$\mathbf{a}(\theta_{inc}, \phi_{inc}) = \begin{pmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{pmatrix}$$

$$\mathbf{Z}(\theta_{sca}, \phi_{sca}, \theta_{inc}, \phi_{inc}) = \begin{pmatrix} Z_{11} & Z_{12} & Z_{13} & Z_{14} \\ Z_{21} & Z_{22} & Z_{23} & Z_{24} \\ Z_{31} & Z_{32} & Z_{33} & Z_{34} \\ Z_{41} & Z_{42} & Z_{43} & Z_{44} \end{pmatrix}$$

Shape data

Other

- “Graupel” tool-kit
 - Rime



- Rimecraft
 - Rime
 - Melting

