Construction of aerosol and ice particle scattering database for advanced remote sensing algorithms

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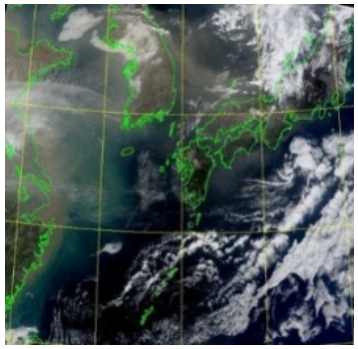
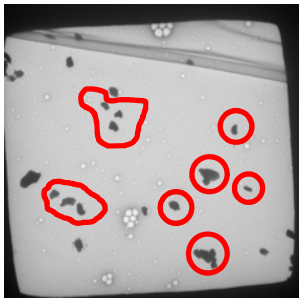
(CI) K. Adachi, K. Masuda, Y. Mano

Meteorological Research Institute

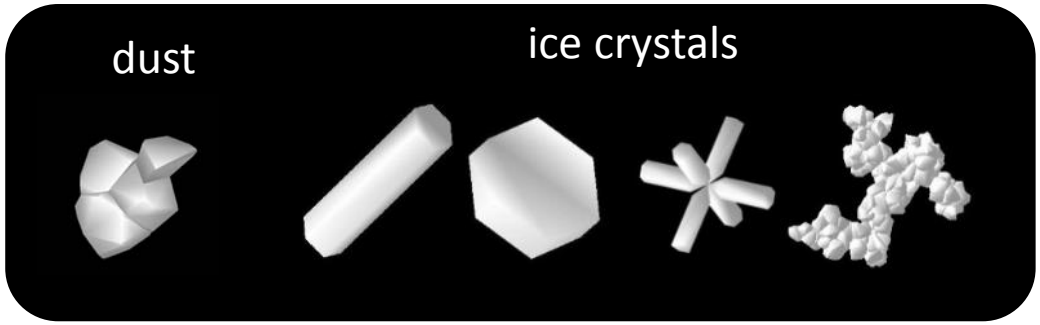
Concept of particle scattering database

clouds and aerosols





particle models

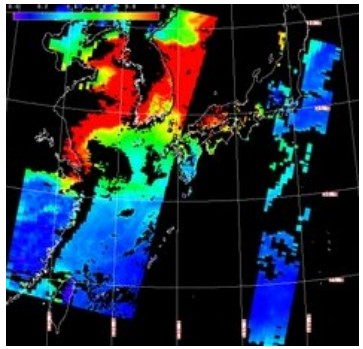


calculation of single scattering properties

Database for GCOM-C1/SGLI channels and for other remote sensing measurements (e.g. Himawari)

particle selection improvement

retrieval results

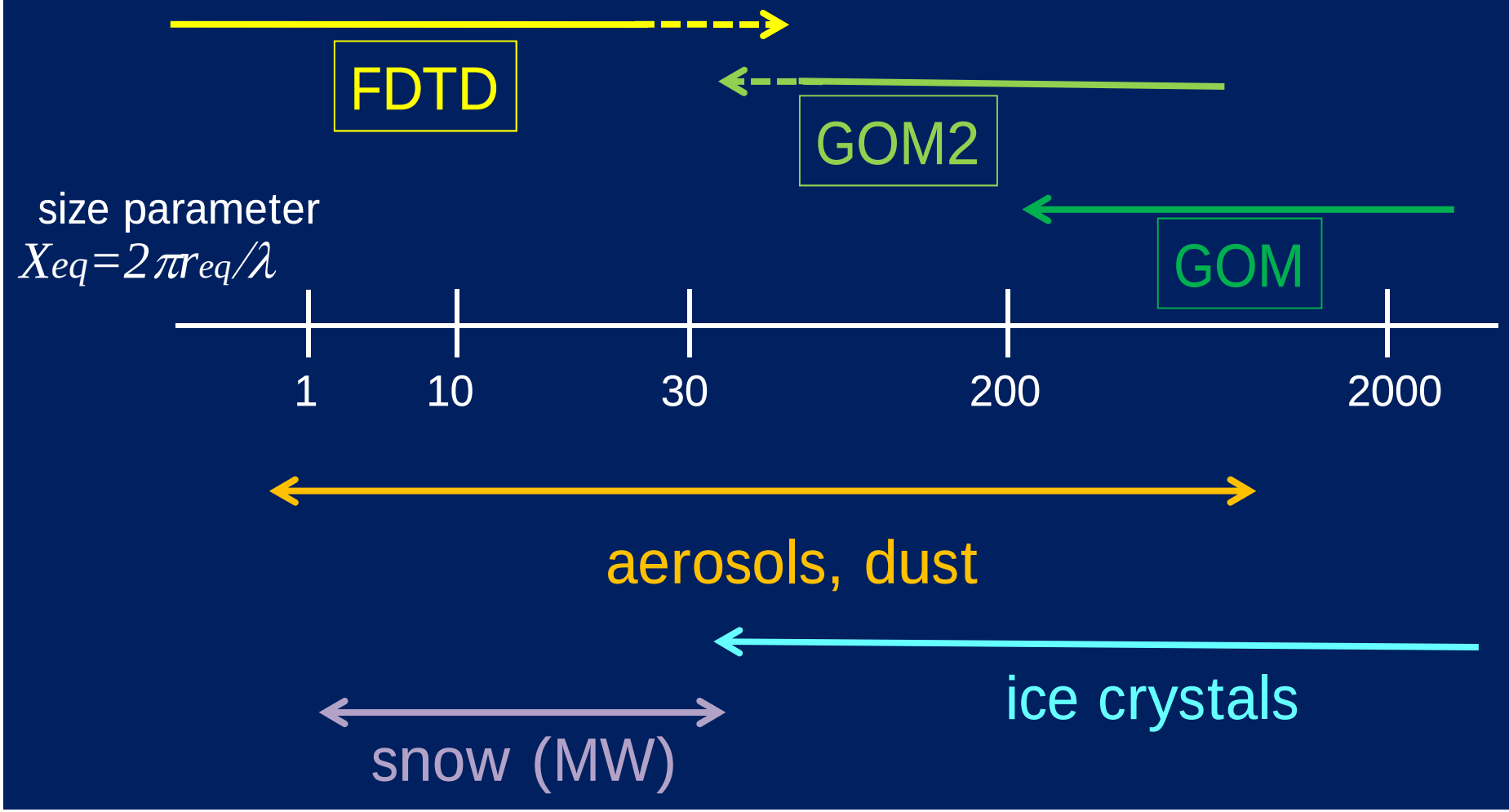


RT code

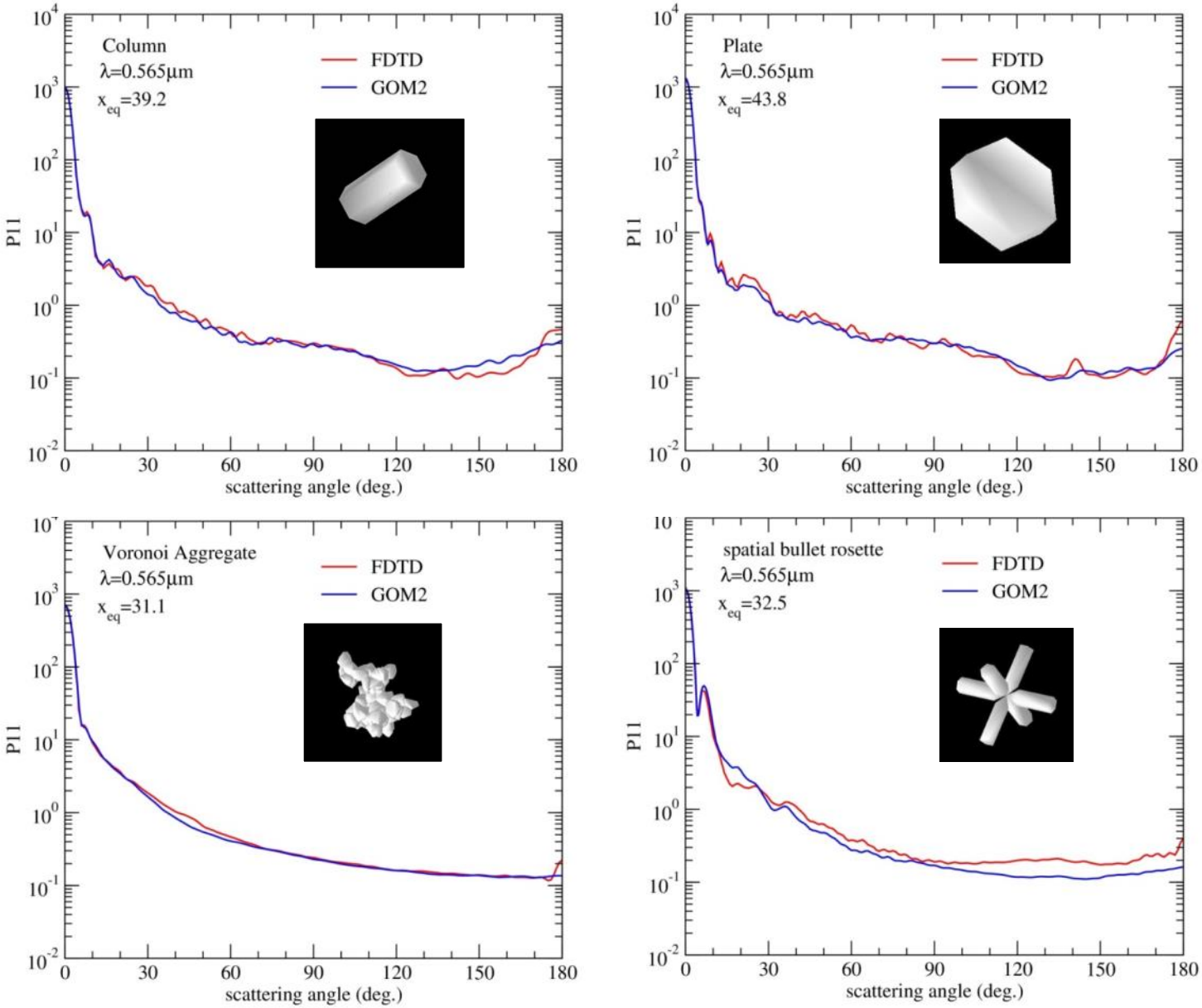
e.g. Rstar

Light scattering calculations

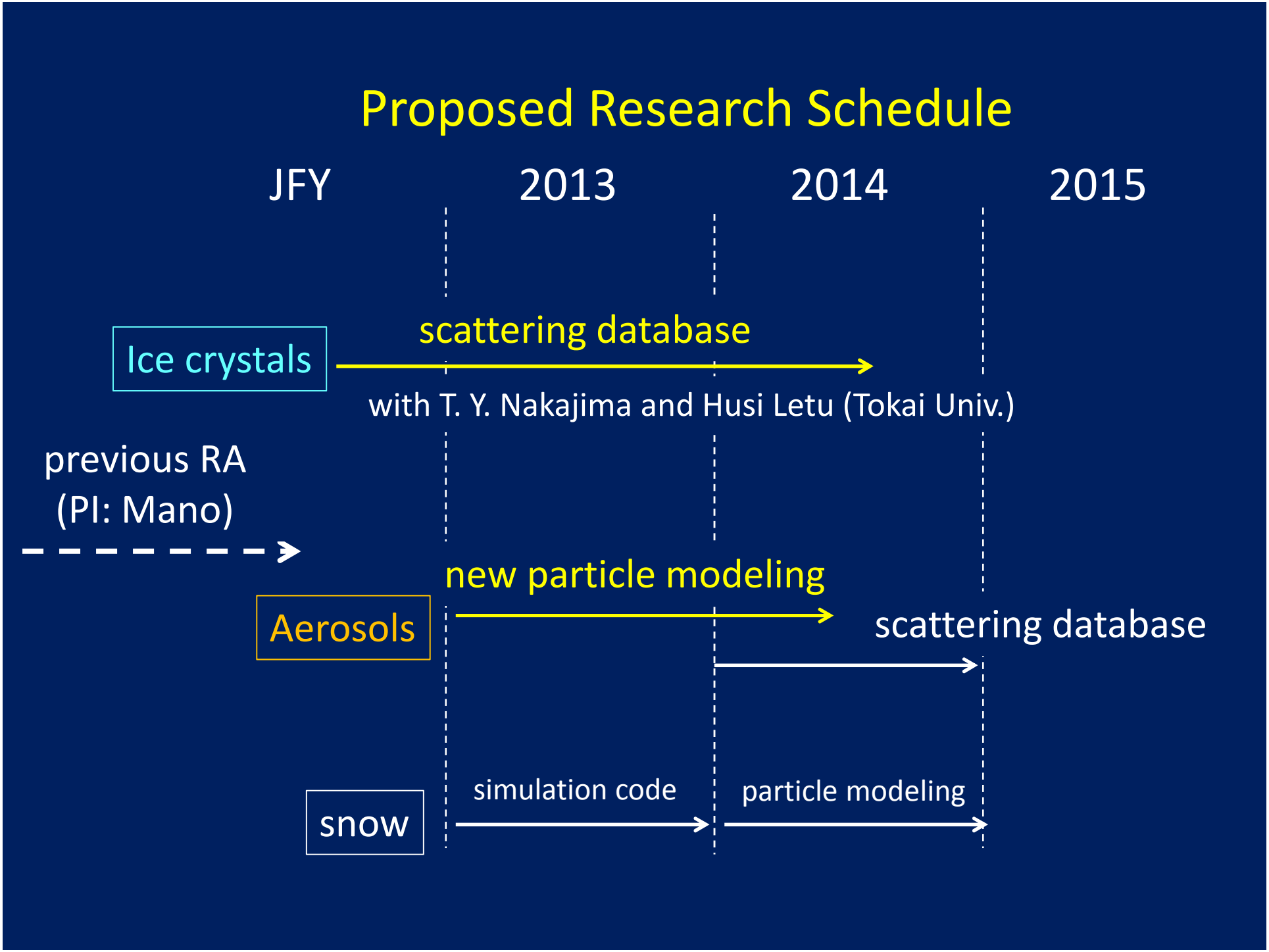
for non-spherical, irregularly shaped particles



FDTD vs GOM2 at transition size parameter $\lambda = 0.565\,\mu m$

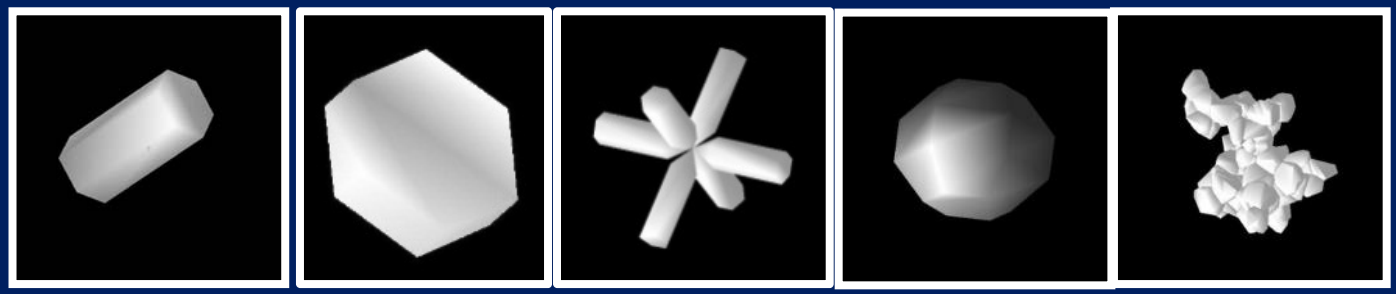


Proposed Research Schedule



Ice crystals

✓ Column, Plate, Bullet Rosette, Droxtal, Voronoi aggregate

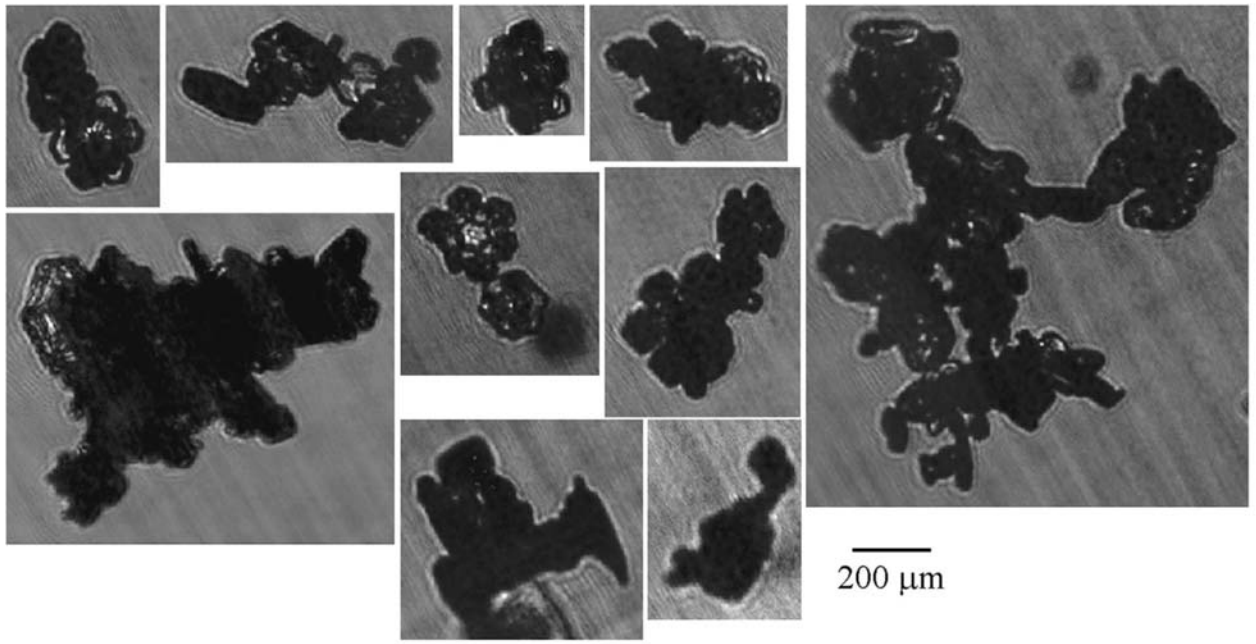


Shape definition

✓ Yang and Liou (2000) for regular shape particles

✓ Ishimoto et al. (2012) for irregular shaped particles

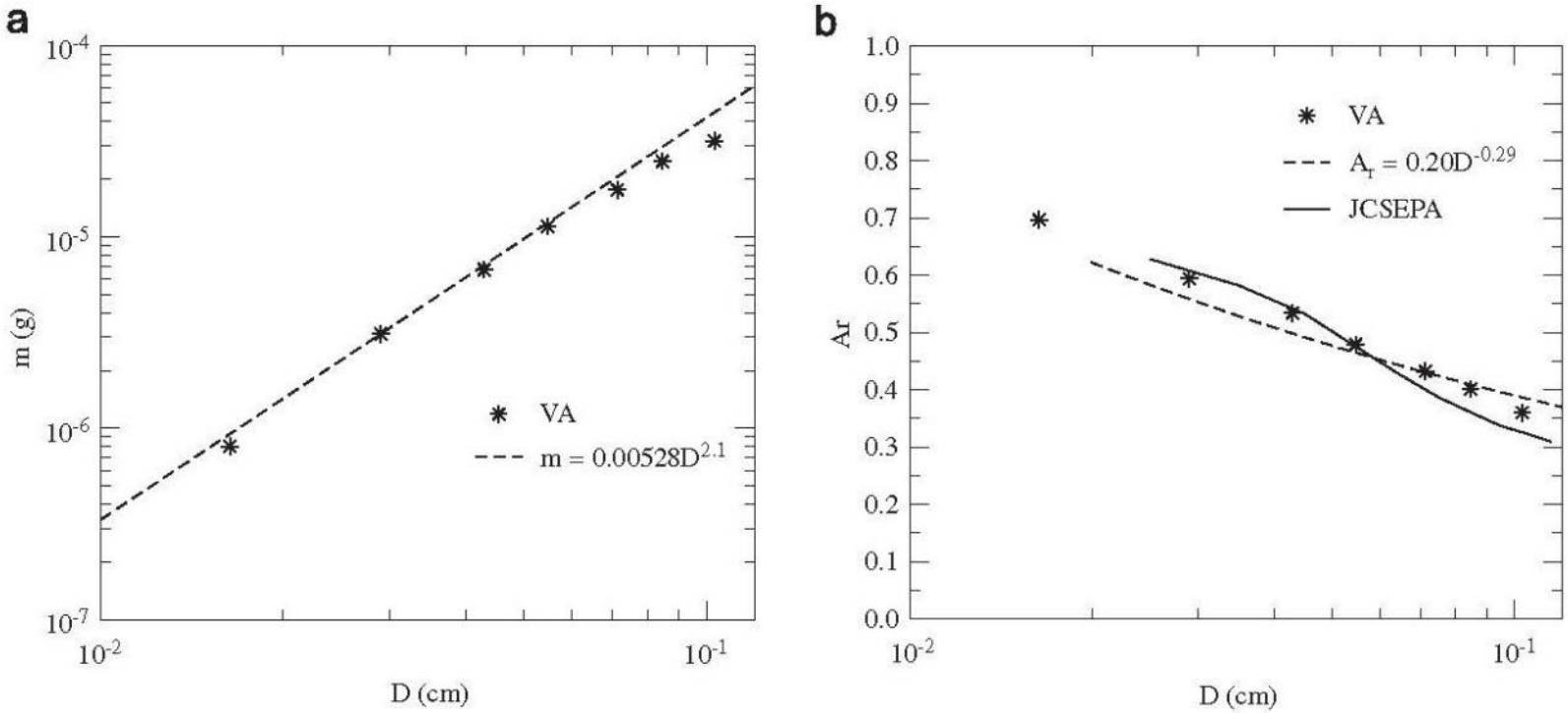
Irregularly shaped particles in convective cirrus



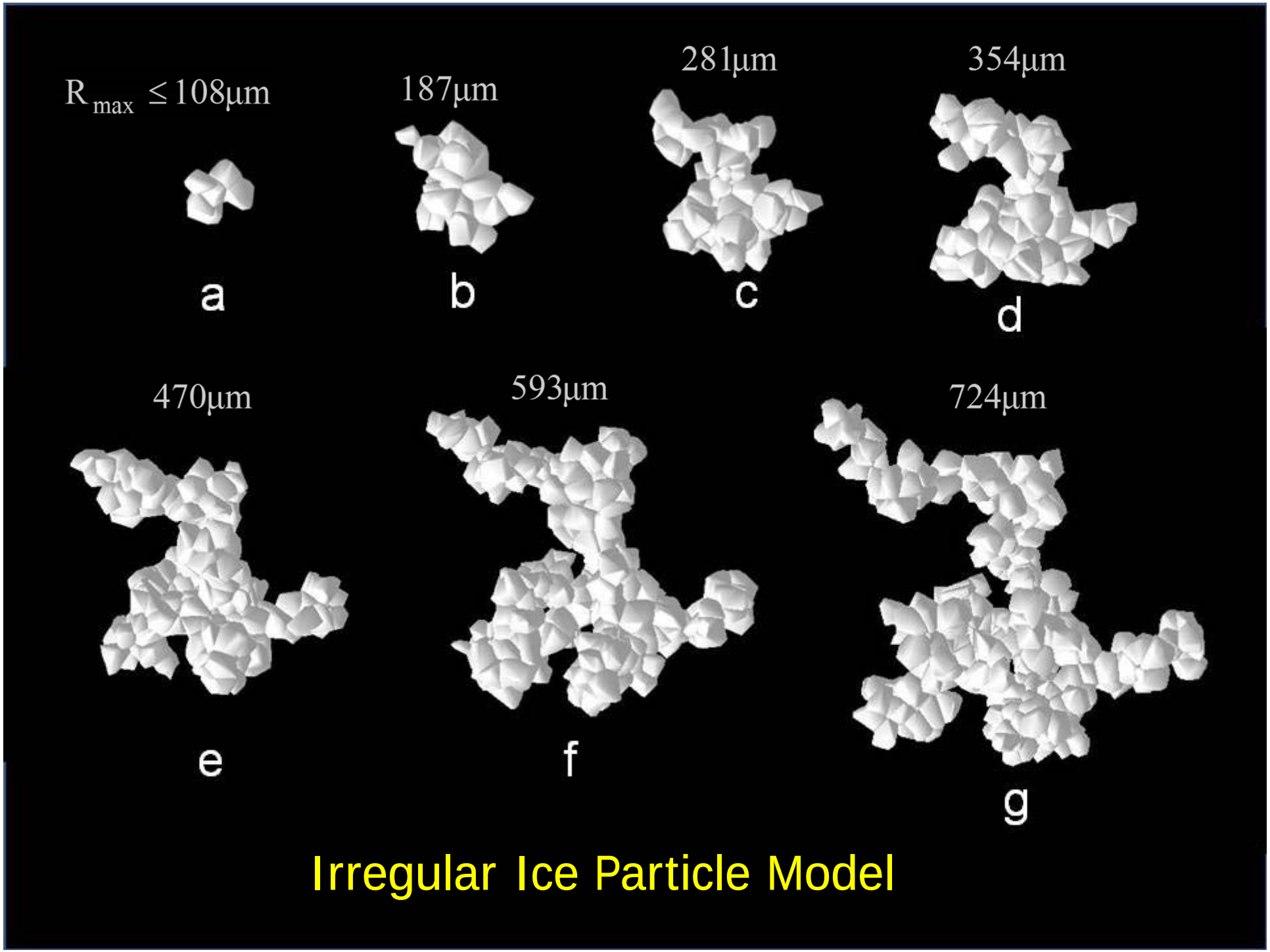
Schmitt and Heymsfield (2010)

size - mass

size - area ratio

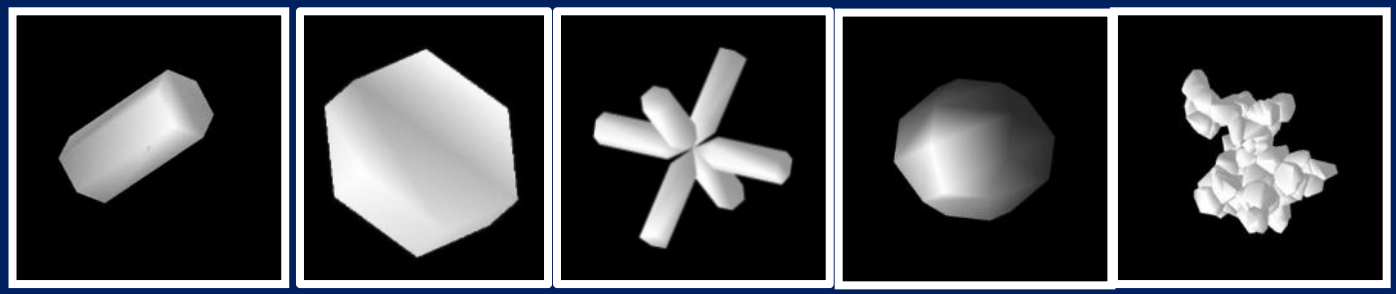


Ishimoto et al. (2012)


$R_{max} \leq 108\mu m$
187μm
281μm
354μm
a
b
c
d
470μm
593μm
724μm
e
f
g
Irregular Ice Particle Model

Ice crystals

✓ Column, Plate, Bullet Rosette, Droxtal, Voronoi aggregate



Shape definition

✓ Yang and Liou (2000) for regular shape particles

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VN6 VN7/8 VN10/11/P2 SW1 SW2

当体積 / 球半径Re	WL 波長 0.5500	0.5650	0.5800	0.6590	0.6740	0.6860	0.8530	0.8650	0.8830	1.0350	1.0500	1.0650	1.3650	1.3800	1.3950
0.700	7.997	7.784	7.583	6.674	6.526	6.411	5.156	5.085	4.981	4.249	4.189	4.130	3.222	3.187	3.153
1.000	11.424	11.121	10.833	9.534	9.322	9.159	7.366	7.264	7.116	6.071	5.984	5.900	4.603	4.553	4.504
1.300	14.851	14.457	14.083	12.395	12.119	11.907	9.576	9.443	9.250	7.892	7.779	7.670	5.984	5.919	5.855
1.900	21.706	21.129	20.583	18.115	17.712	17.402	13.995	13.801	13.520	11.534	11.370	11.209	8.746	8.651	8.558
2.600	29.702	28.914	28.166	24.790	24.238	23.814	19.152	18.886	18.501	15.784	15.558	15.339	11.968	11.838	11.711
3.500	39.984	38.922	37.916	33.370	32.628	32.057	25.781	25.423	24.905	21.247	20.944	20.649	16.111	15.936	15.764
4.900	55.977	54.491	53.082	46.719	45.679	44.880	36.093	35.593	34.867	29.746	29.322	28.909	22.555	22.310	22.070
6.900	78.825	76.733	74.748	65.788	64.323	63.198	50.825	50.120	49.099	41.888	41.290	40.708	31.761	31.416	31.078
9.500	108.528	105.646	102.914	90.577	88.561	87.012	69.977	69.006	67.599	57.672	56.848	56.047	43.729	43.254	42.789
13.200	150.796	146.793	142.997	125.854	123.053	120.901	97.231	95.882	93.928	80.133	78.989	77.876	60.760	60.100	59.454
18.200	207.916	202.396	197.162	173.527	169.665	166.697	134.061	132.201	129.506	110.487	108.909	107.375	83.776	82.865	81.974
25.300	289.027	281.353	274.077	241.221	235.853	231.727	186.359	183.774	180.028	153.589	151.395	149.263	116.458	115.192	113.953
35.100	400.981	390.336	380.241	334.658	327.210	321.487	258.546	254.959	249.762	213.082	210.038	207.080	161.568	159.811	158.093
47.300	540.354	5307.901	5170.628	4550.780	4449.502	4371.668	3515.785	3467.011	3396.336	2897.550	2856.157	2815.929	2197.043	2173.163	2149.795
60.600	692.293	673.913	656.485	577.786	564.927	555.045	446.379	440.186	431.213	367.885	362.630	357.522	278.946	275.914	272.947
77.100	880.788	857.405	835.230	735.104	718.744	706.171	567.917	560.039	548.622	468.052	461.365	454.867	354.896	351.039	347.264
97.500	1113.837	1084.266	1056.225	929.606	908.918	893.018	718.184	708.220	693.783	591.894	583.439	575.221	448.799	443.921	439.147
122.800	1402.864	1365.620	1330.302	1170.827	1144.770	1124.745	904.543	891.994	873.811	745.483	734.833	724.484	565.257	559.112	553.100
154.000	1759.292	1712.585	1668.294	1468.301	1435.624	1410.511	1134.362	1118.625	1095.822	934.889	921.534	908.554	708.872	701.167	693.628
192.700	2201.400	2142.955	2087.534	1837.283	1796.394	1764.971	1419.425	1399.734	1371.200	1169.826	1153.114	1136.873	887.011	877.369	867.935
242.300	2768.029	2694.541	2624.855	2310.191	2258.777	2219.265	1784.778	1760.018	1724.140	1470.933	1449.920	1429.498	1115.323	1103.200	1091.337
308.400	3523.153	3429.618	3340.921	2940.416	2874.977	2824.686	2271.670	2240.155	2194.490	1872.207	1845.461	1819.469	1419.586	1404.155	1389.057

size

当体積 / 球半径Re	1.4800	1.6300	1.7800	2.1730	2.2100	2.2480	3.7000	10.2450	10.8000	11.3550	11.4450	12.0000	12.5550
0.700	2.972	2.698	2.471	2.024	1.990	1.957	1.189	0.429	0.407	0.387	0.384	0.367	0.350
1.000	4.245	3.855	3.530	2.891	2.843	2.795	1.698	0.613	0.582	0.553	0.549	0.524	0.500
1.300	5.519	5.011	4.589	3.759	3.696	3.634	2.208	0.797	0.756	0.719	0.714	0.681	0.651
1.900	8.066	7.324	6.707	5.494	5.402	5.311	3.227	1.165	1.105	1.051	1.043	0.995	0.951
2.600	11.038	10.022	9.178	7.518	7.392	7.267	4.415	1.595	1.513	1.439	1.427	1.361	1.301
3.500	14.859	13.492	12.355	10.120	9.951	9.783	5.944	2.147	2.036	1.937	1.921	1.833	1.752
4.900	20.802	18.888	17.296	14.168	13.931	13.696	8.321	3.005	2.851	2.711	2.690	2.566	2.452
6.900	29.293	26.598	24.356	19.951	19.617	19.286	11.717	4.232	4.014	3.818	3.788	3.613	3.453
9.500	40.331	36.620	33.534	27.469	27.009	26.553	16.133	5.826	5.527	5.257	5.215	4.974	4.754
13.200	56.039	50.882	46.594	38.168	37.529	36.894	22.416	8.095	7.679	7.304	7.247	6.912	6.606
18.200	77.266	70.156	64.244	52.625	51.744	50.869	30.906	11.162	10.588	10.071	9.992	9.529	9.108
25.300	107.409	97.524	89.306	73.154	71.930	70.714	42.963	15.516	14.719	14.000	13.889	13.247	12.661
35.100	149.013	135.300	123.899	101.491	99.792	98.105	59.605	21.527	20.420	19.422	19.270	18.378	17.566
47.300	2026.327	1839.855	1684.811	1380.103	1356.997	1334.059	810.531	292.725	277.682	264.110	262.033	249.914	238.866
60.600	257.271	233.596	213.911	175.224	172.290	169.378	102.908	37.166	35.256	33.532	33.269	31.730	30.327
77.100	327.320	297.199	272.154	222.933	219.201	215.495	130.928	47.285	44.855	42.663	42.327	40.369	38.585
97.500	413.926	375.835	344.163	281.919	277.199	272.514	165.570	59.796	56.723	53.951	53.526	51.051	48.794
122.800	521.335	473.359	433.469	355.074	349.129	343.227	208.534	75.312	71.442	67.950	67.416	64.298	61.456
154.000	653.791	593.626	543.601	445.288	437.833	430.432	261.516	94.447	89.594	85.214	84.544	80.634	77.070
192.700	818.068	742.804	680.208	557.188	547.860	538.599	327.235	118.182	112.108	106.629	105.790	100.897	96.437
242.300	1028.659	933.997	855.290	700.606	688.876	677.231	411.464	148.601	140.964	134.074	133.020	126.868	121.260
308.400	1309.280	1188.794	1088.615	891.732	876.803	861.981	523.712	189.140	179.420	170.650	169.308	161.478	154.340

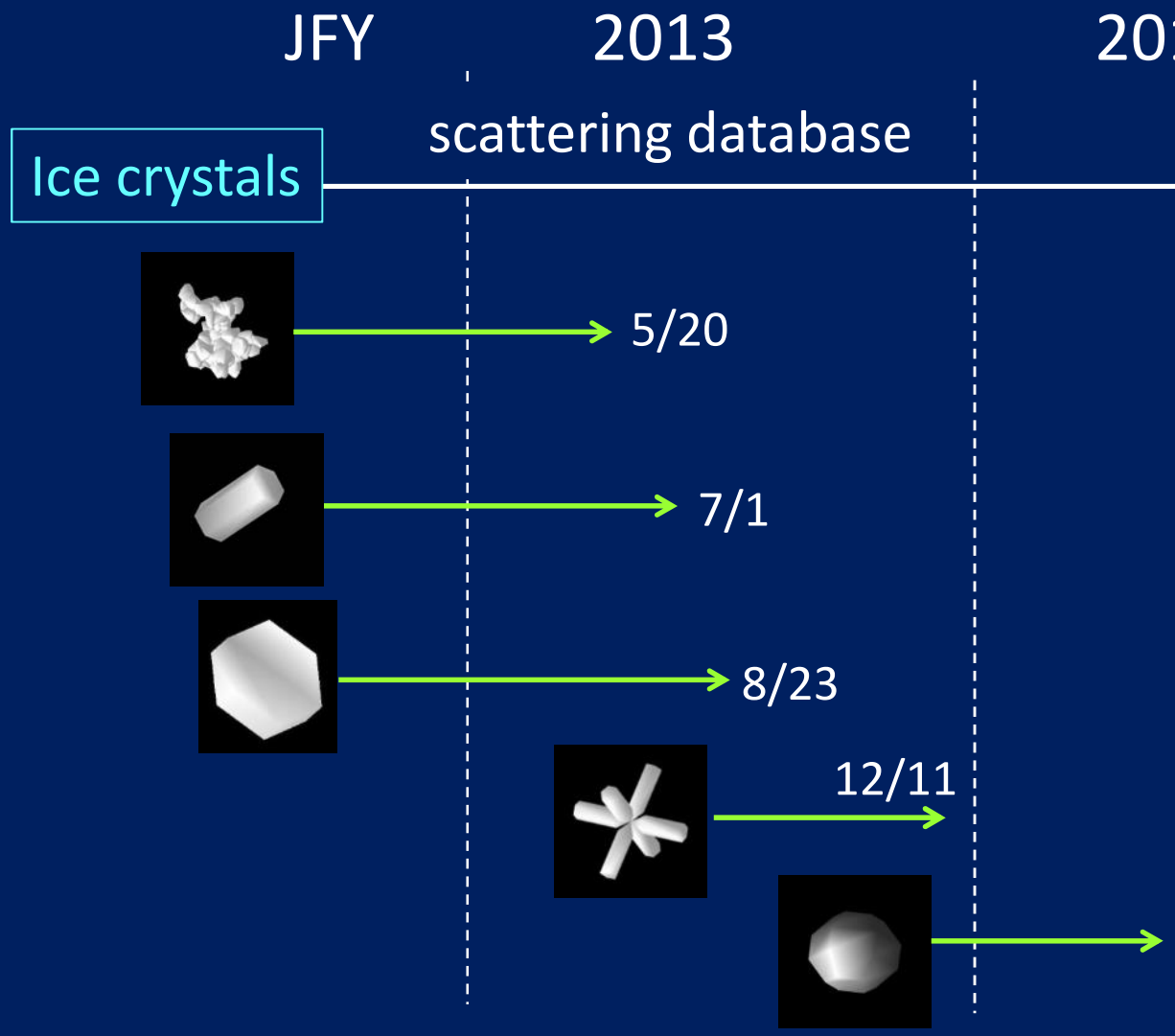
size

SW3 SW4 T1 T2

Bluck test	: GOM2
Blue test	: FDTD

planned by
Husi Letu
T. Y. Nakajima
(Tokai Univ.)

Progress of scattering database for ice crystals

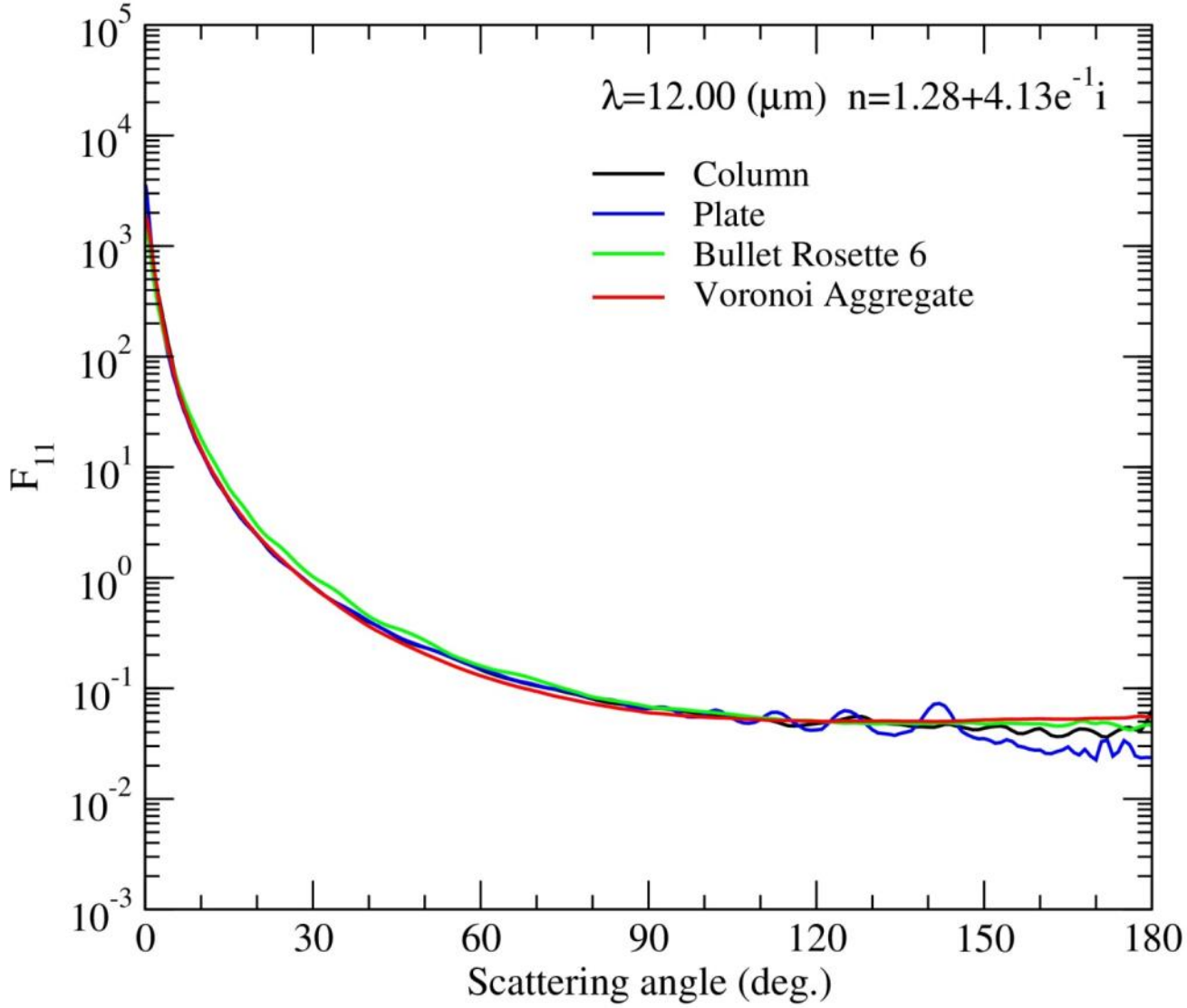


calculations have been done as scheduled

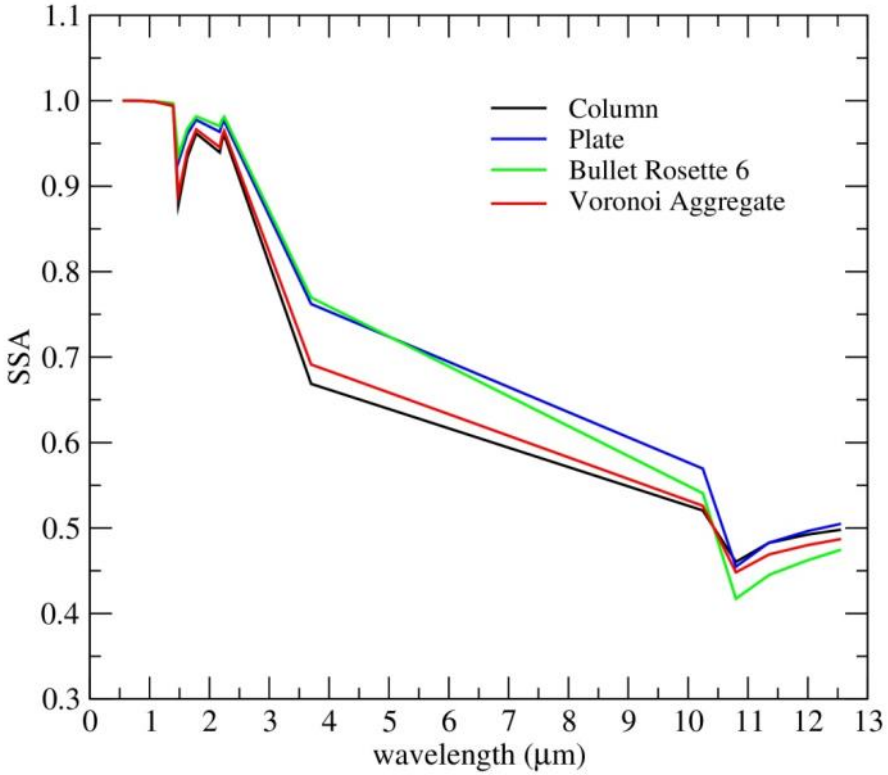
size averaged phase function $N(D) = N_0 D^{\alpha} \exp(-\beta D)$

$\alpha = -1.0$

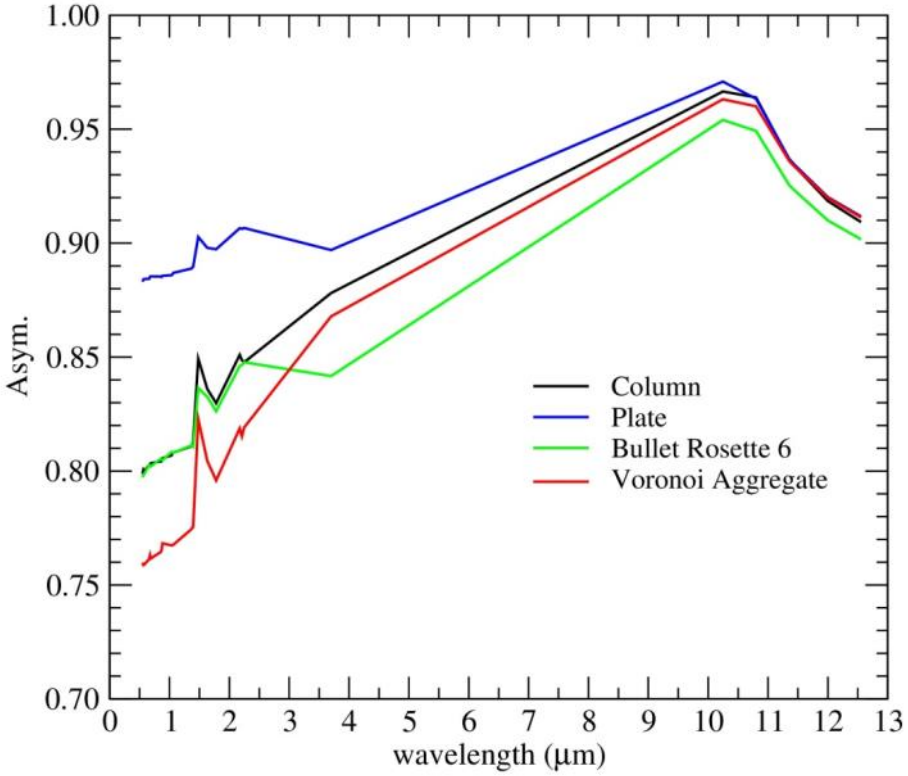
$\beta = 0.00463$

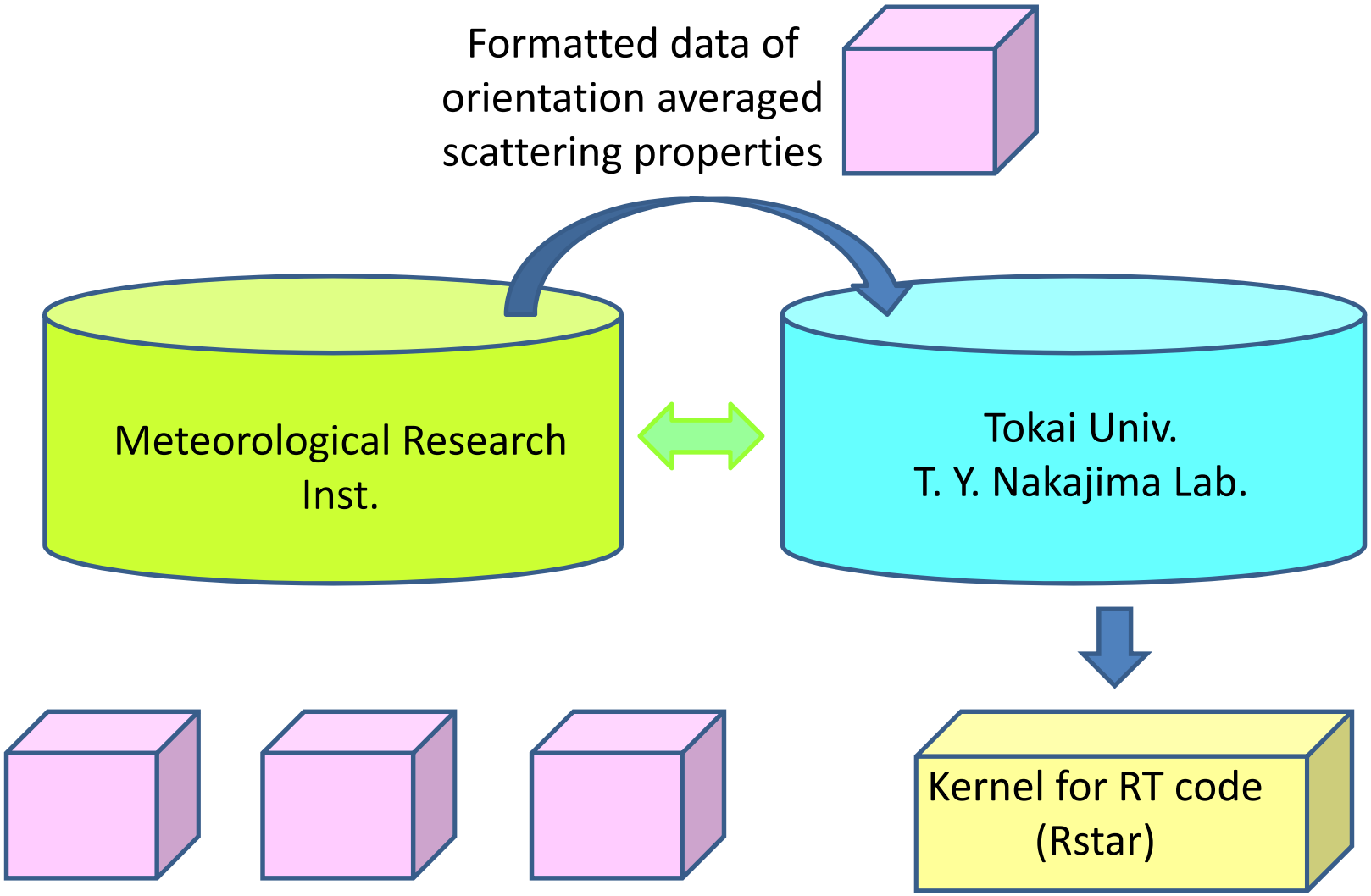


single scattering albedo



asymmetry factor




Formatted data of
orientation averaged
scattering properties
Meteorological Research
Inst.
Tokai Univ.
T. Y. Nakajima Lab.
Kernel for RT code
(Rstar)
package can be provided
for every researcher

Mineral dust model

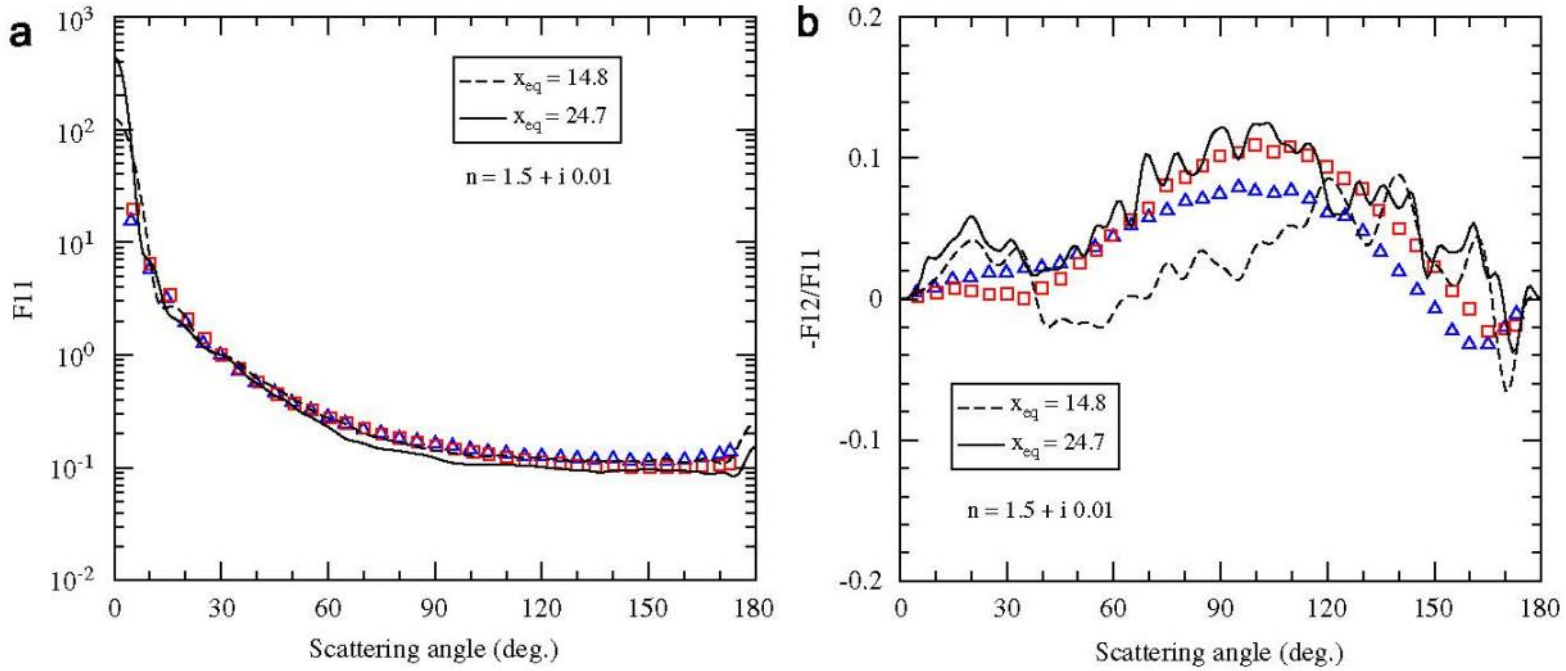
Current shape model

- Voronoi aggregate (4 elements)

A shape model is determined by comparisons of roundness parameters between sampled dust particles and originated Voronoi aggregates (Ishimoto et al. 2010).

$N = n + i\,k \quad 3(n) \times 5(k) = 15$ sets refractive indices

- installed in Rstar6b RT code as an optional choice of mineral dust model



Typical scattering properties for irregular dust particles have been well simulated by current dust model.

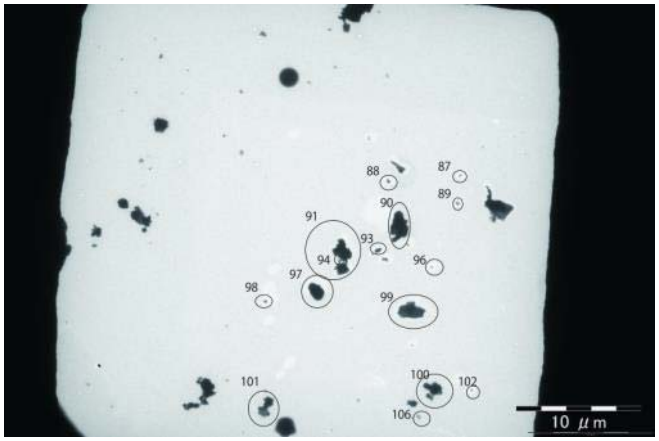
Only one shape model had been proposed because of a small number of samples (18) that identified as dust particle.

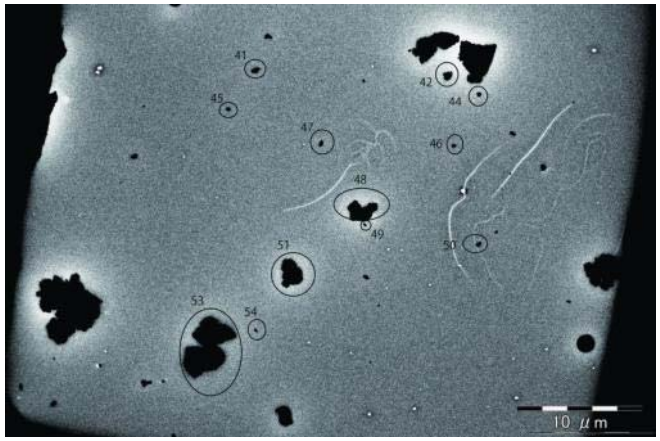
New dust samples

by K. Adachi (CI)

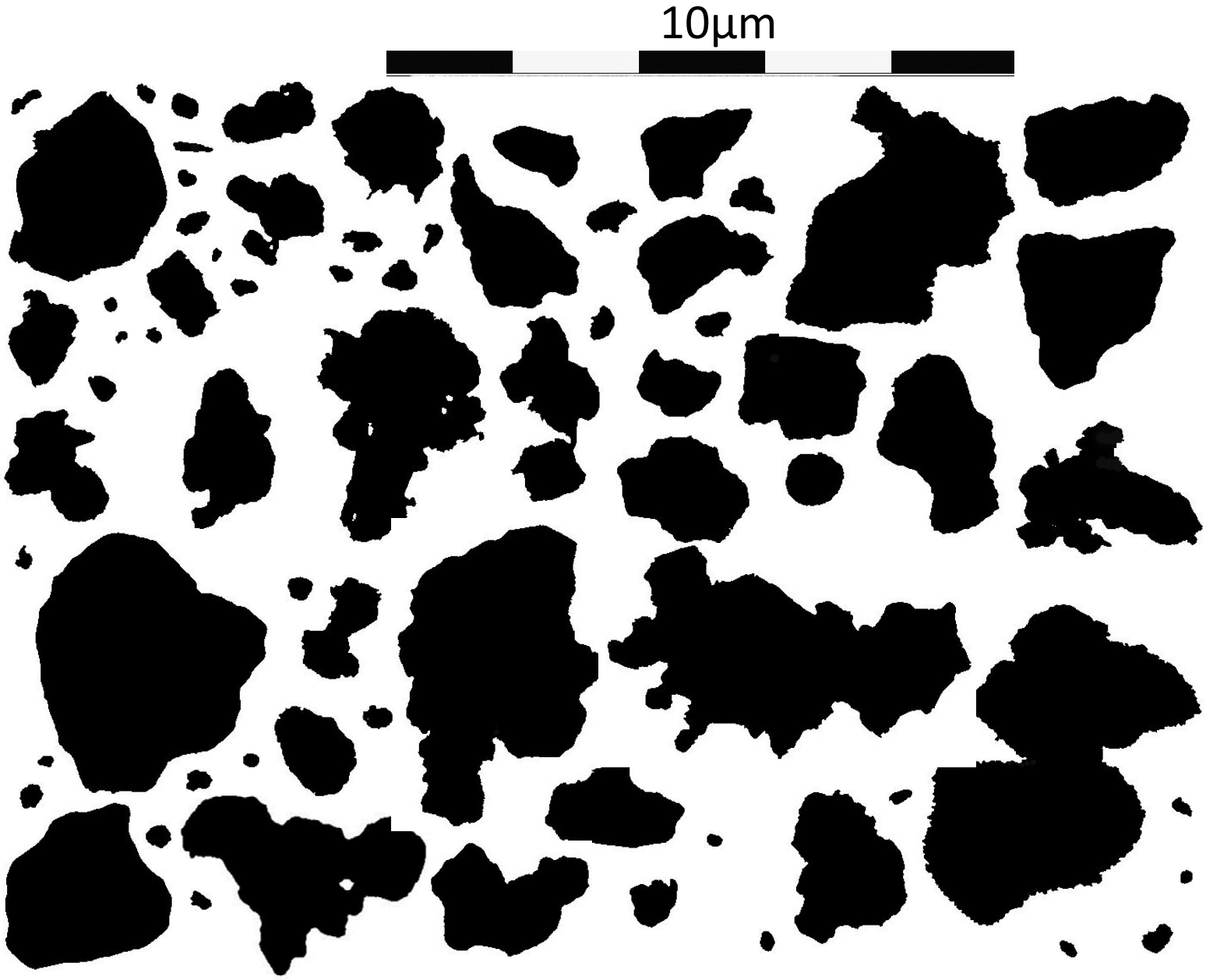
Local dust event on 10 Mar 2013

Sampled local dust (determined by STEM/EDX analysis)



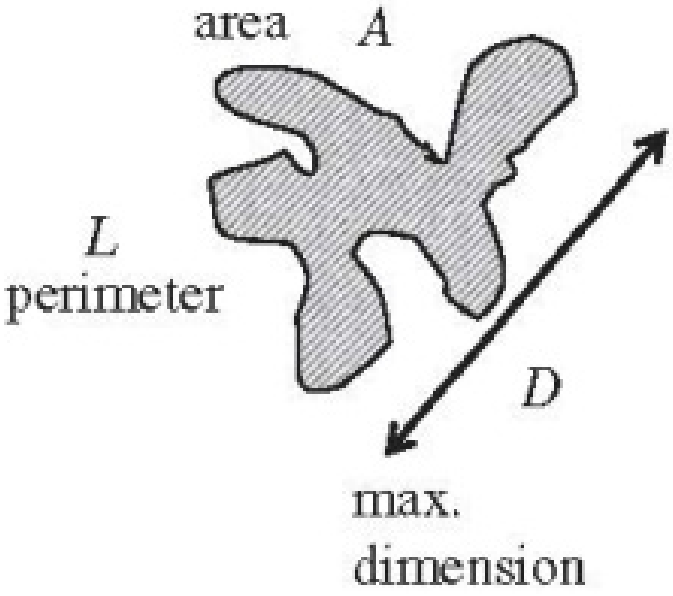


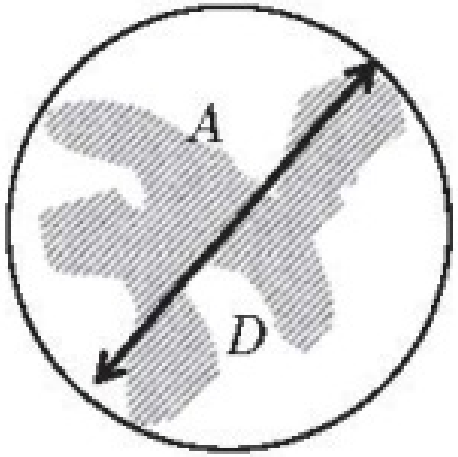
STEM: Scanning Transmission Electron Microscope
EDX: Energy Dispersive X-ray Spectroscopy



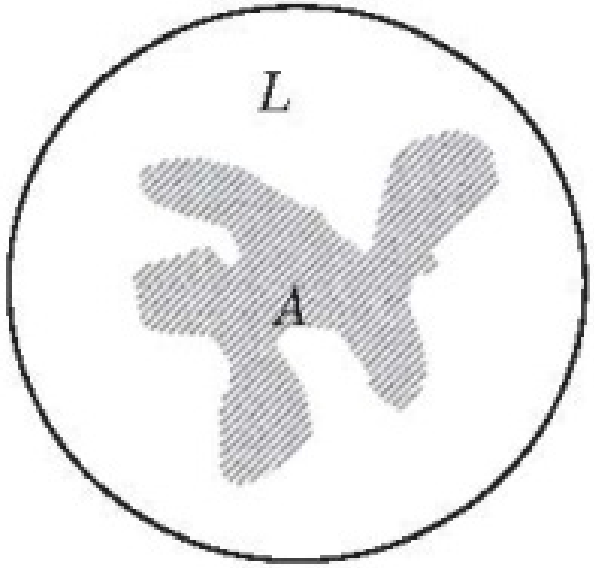
75 dust samples for shape analysis

Roundness parameters (α, β)

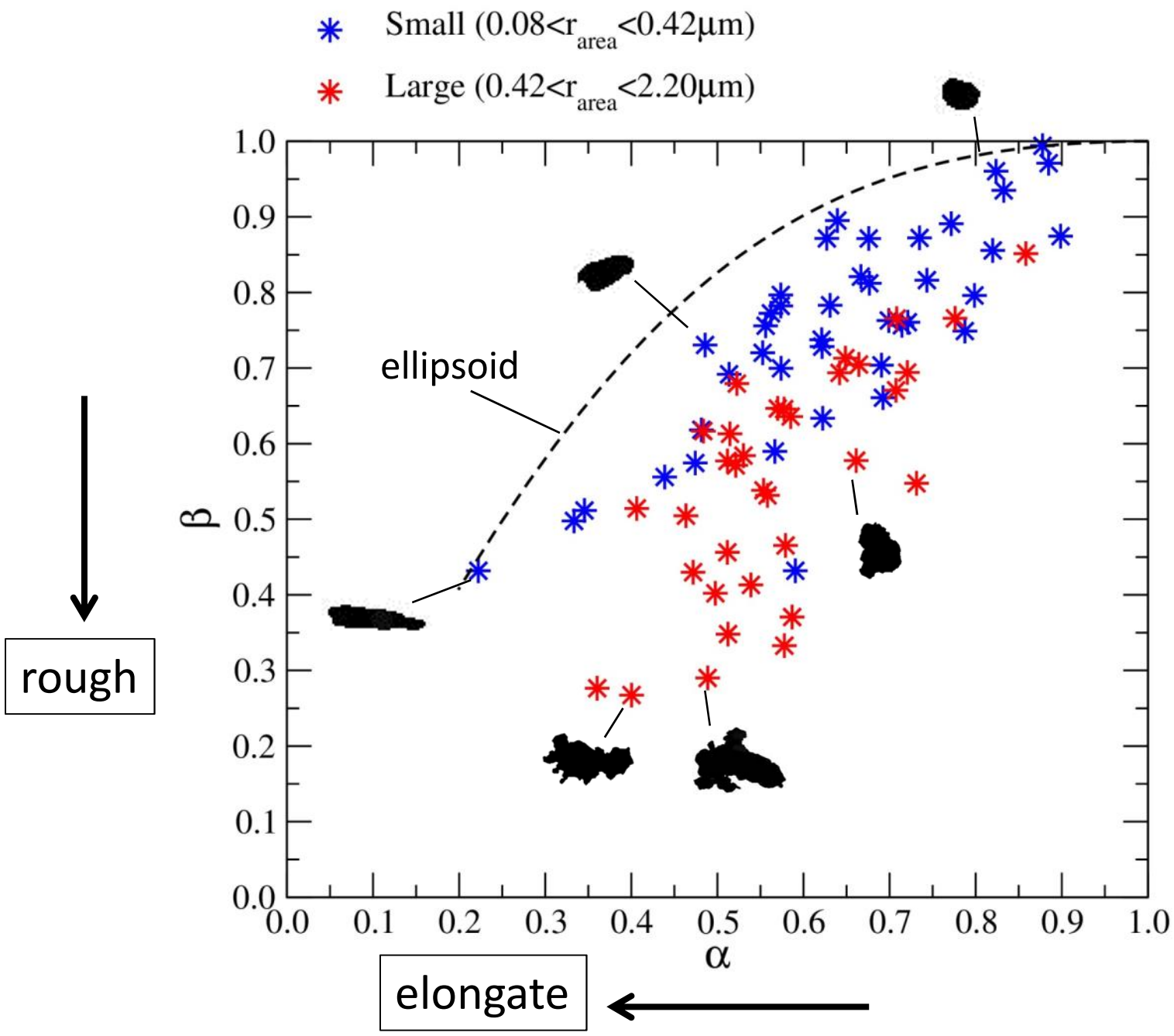




$$\alpha \equiv \frac{4A}{\pi D^2}$$

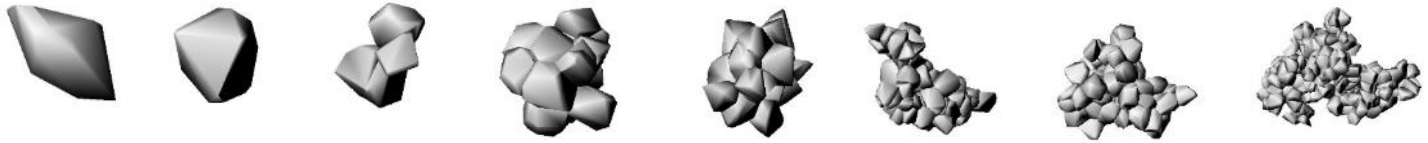


$$\beta \equiv \frac{4\pi A}{L^2}$$


Small (0.08<r_area<0.42μm)
Large (0.42<r_area<2.20μm)
ellipsoid
β
α
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
rough
elongate

Determination of the dust shape model

- We assume that the shape models can simulate the (α, β) distribution of the sampled particles.
- Prepare many shape models



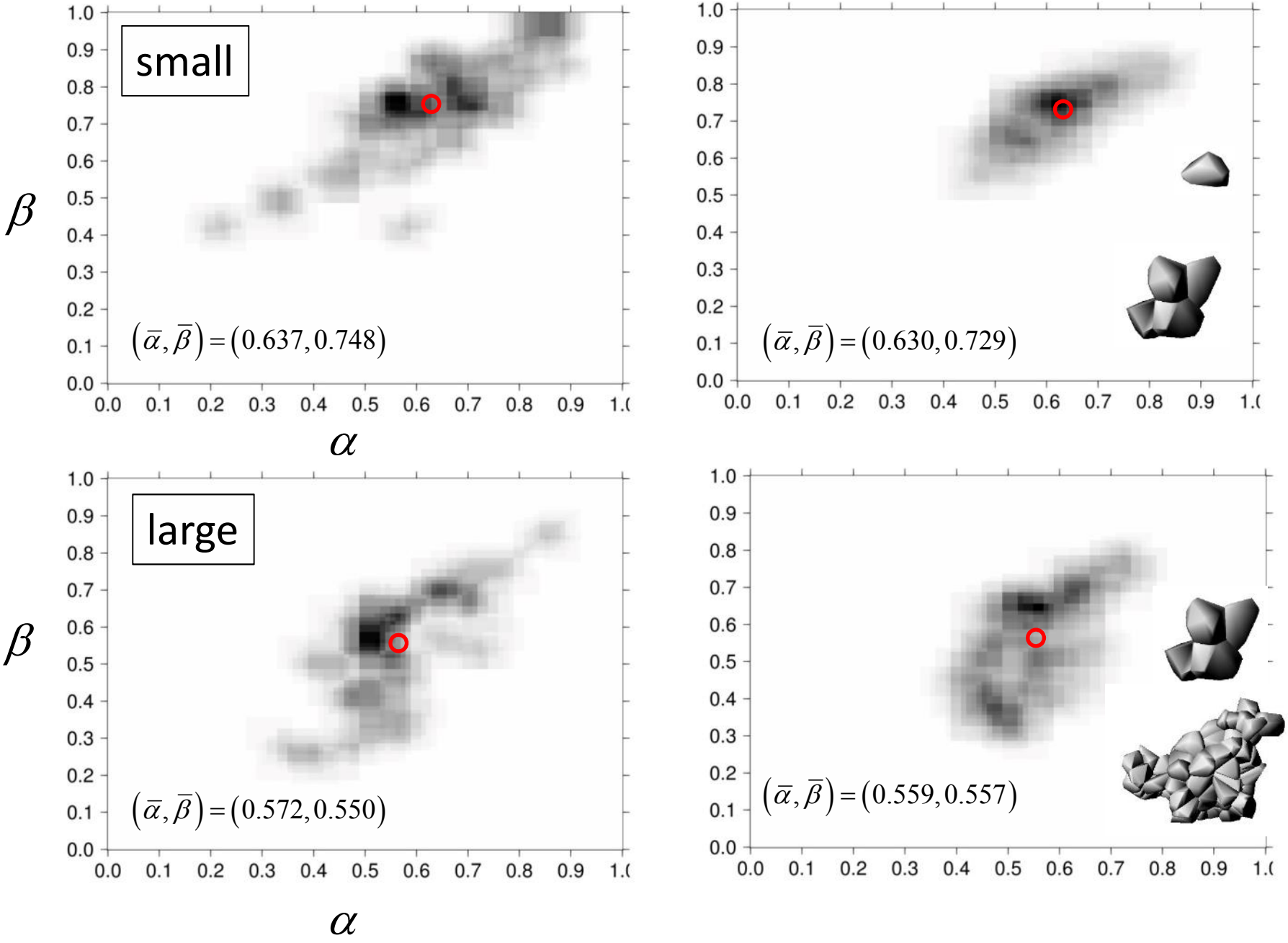
~ 2,000 Vornoi type particles

- Calculate (α, β) distribution of each modeled particle in its random orientation

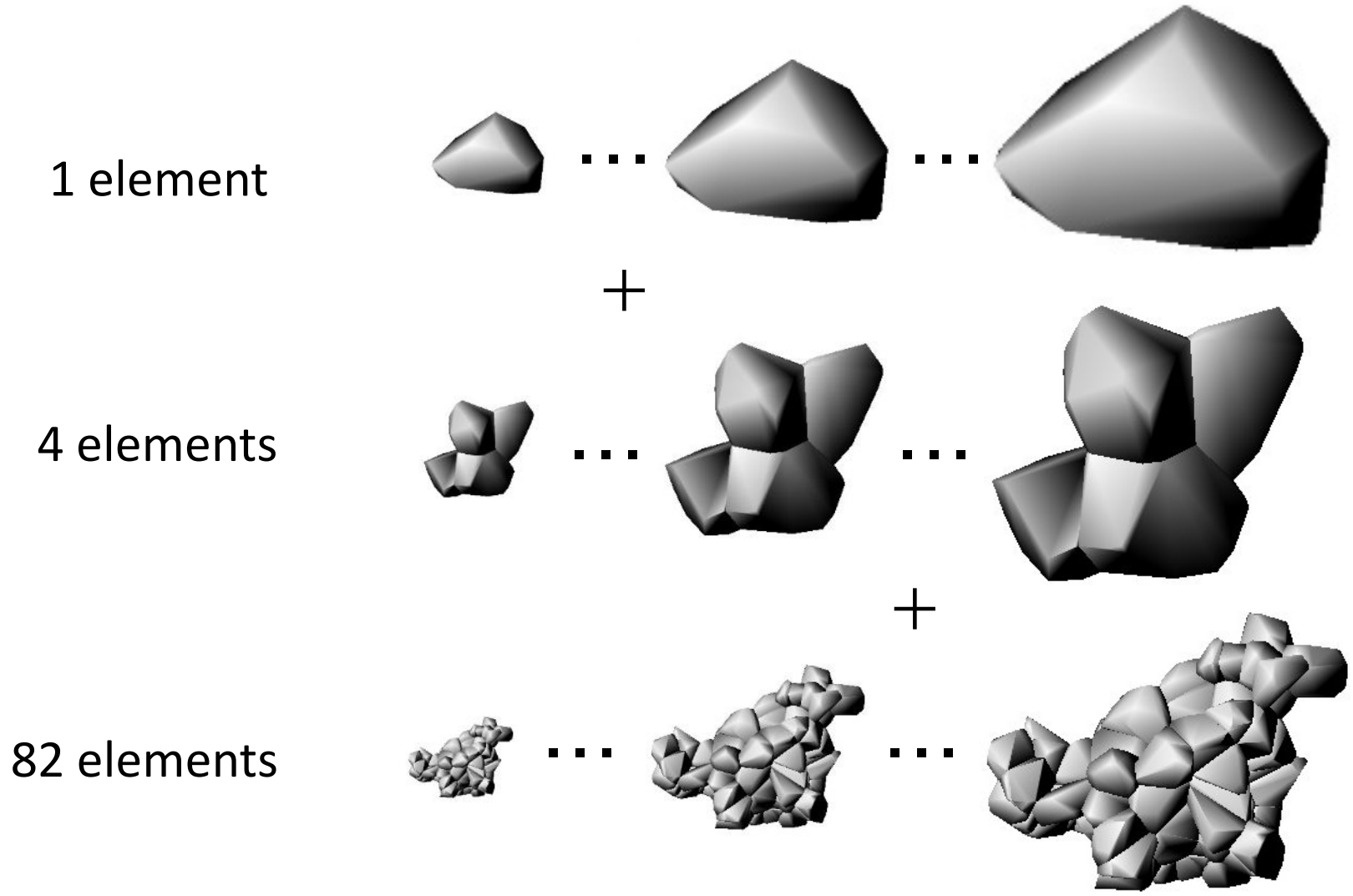
- Least square analysis for the (α, β) distribution between sampled dust particles and modeled particles

Dust samples

Shape models (random ori.)

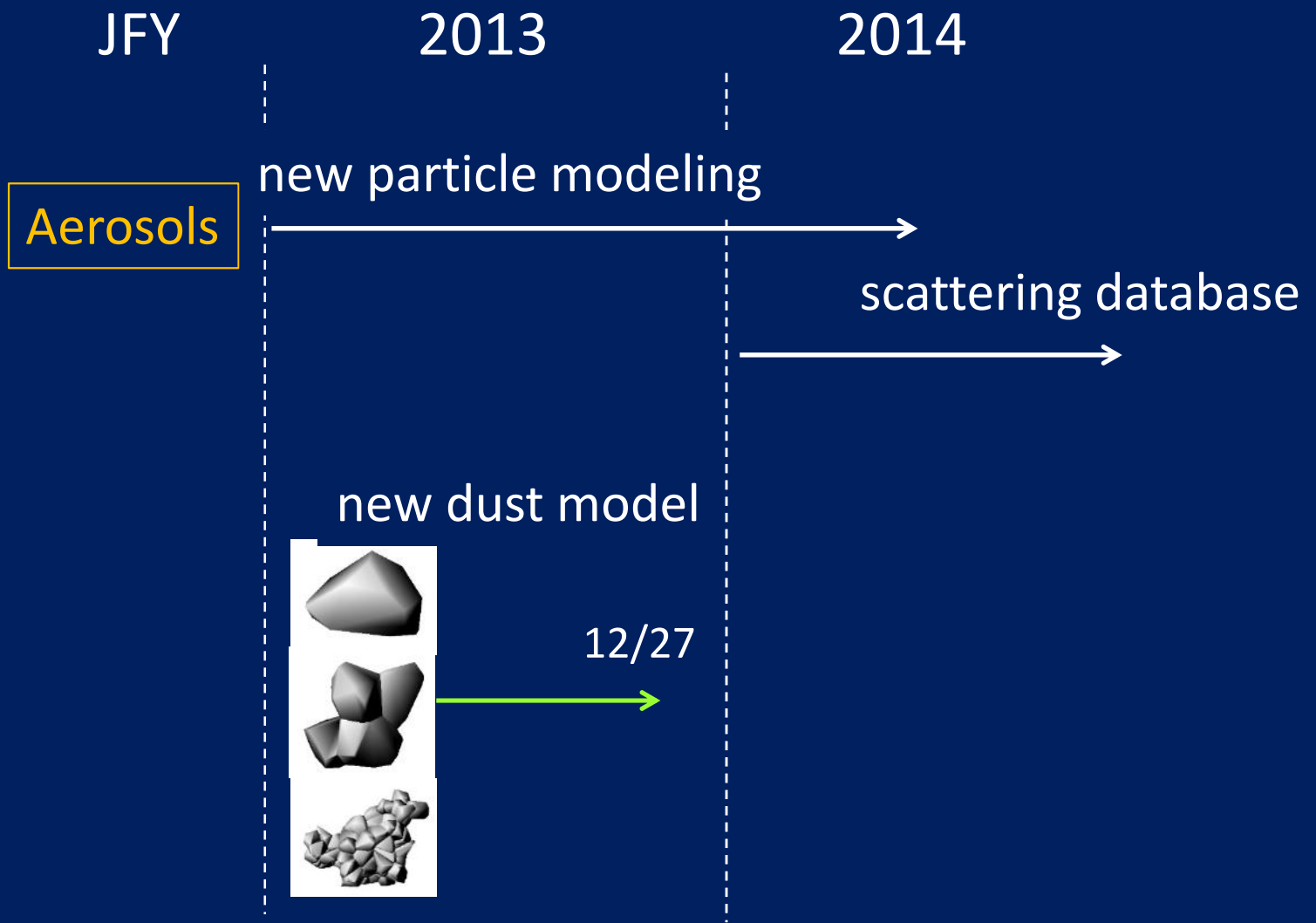


New dust shape models for light scattering database



Estimated calculation time is about 1 year.

Progress of scattering database for aerosols



light scattering calculations can be started as scheduled

Summary

- The database of light scattering properties has been originated for 4 types of ice crystals (column, plate, bullet rosette, aggregate). The planned calculations for ice crystals will be finished in this year.

- New shape models of dust particles, in which the size dependence of the shape complexity is taken into account, has been proposed. We will start the calculations for their light scattering properties in this year.