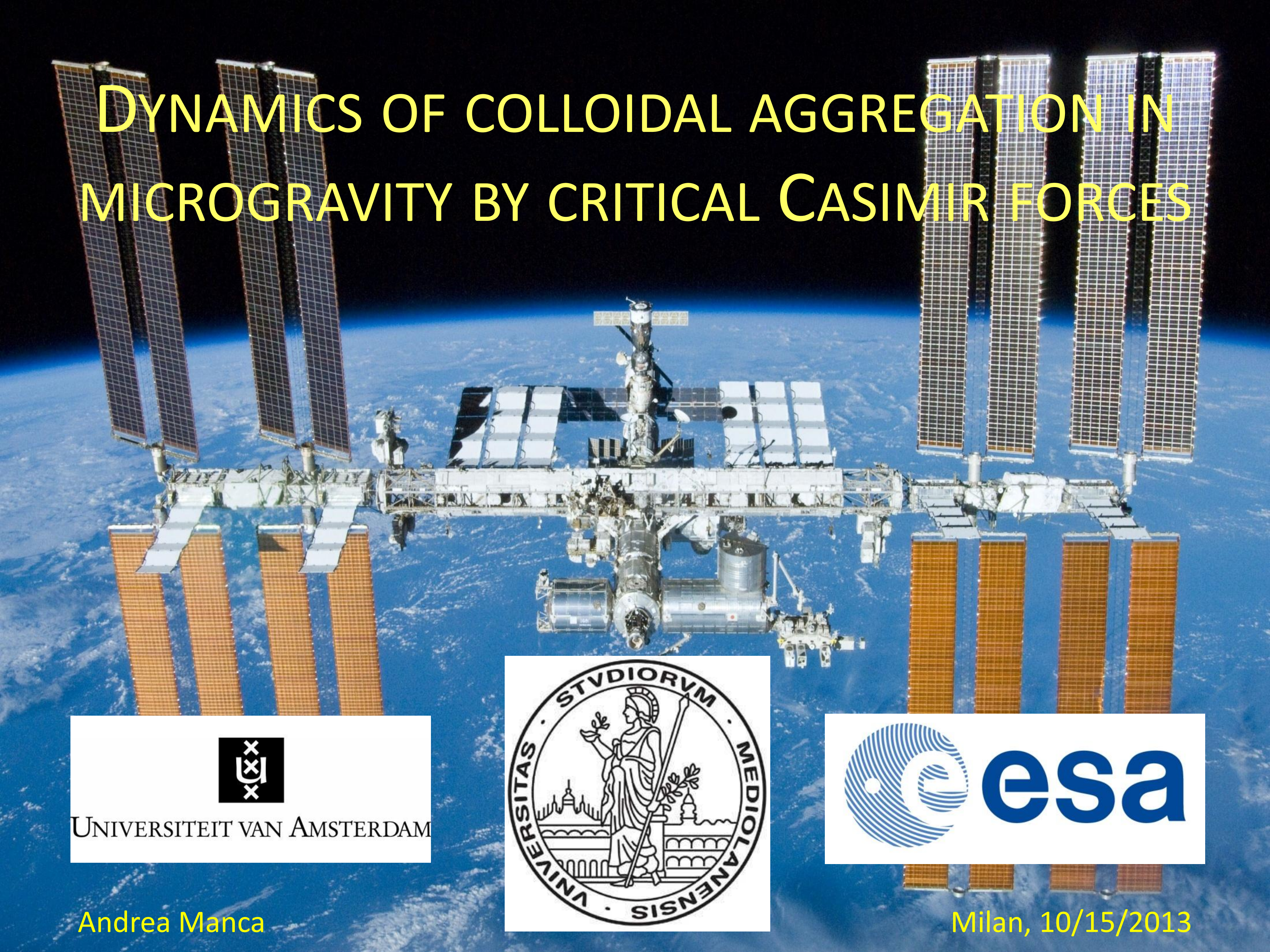
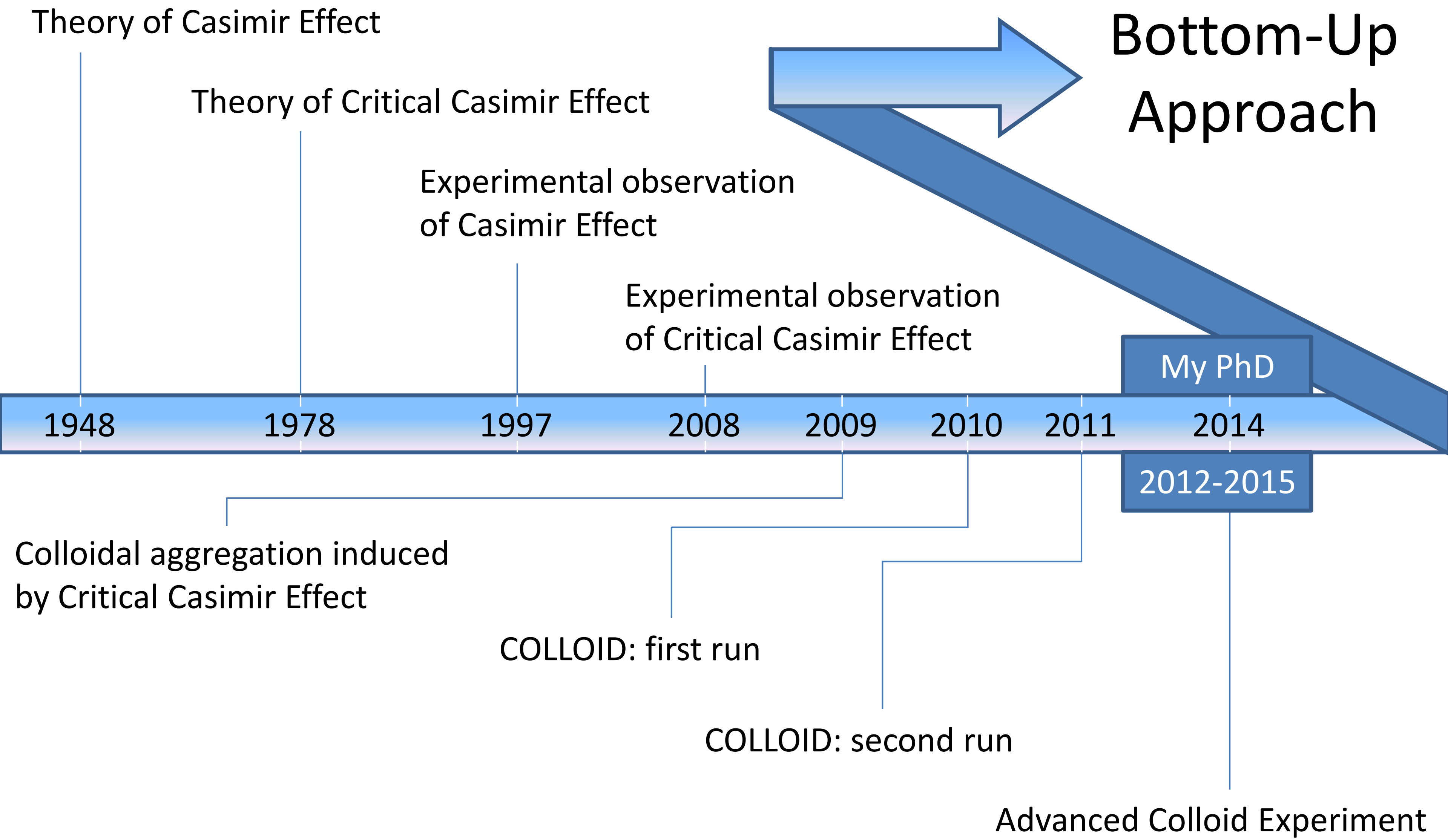
DYNAMICS OF COLLOIDAL AGGREGATION IN MICROGRAVITY BY CRITICAL CASIMIR FORCES



Andrea Manca

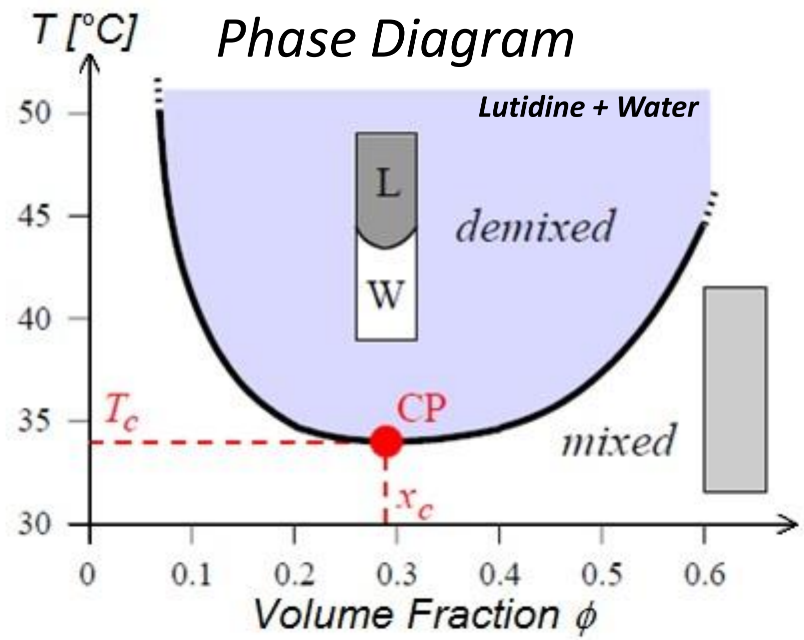
Milan, 10/15/2013

Timeline



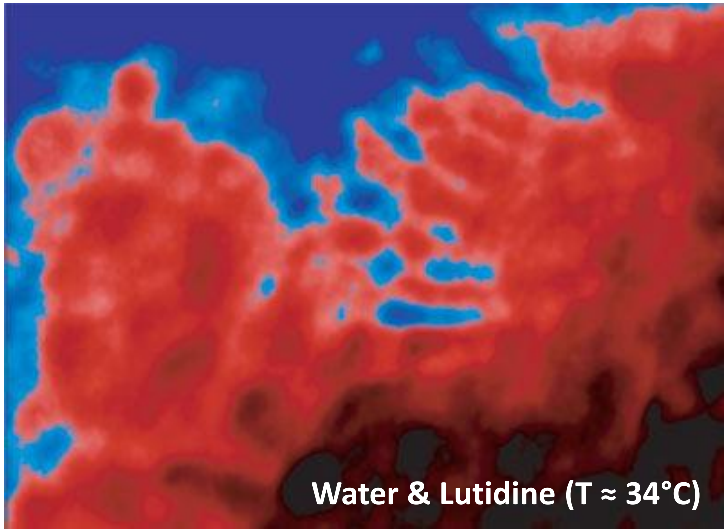
Theory of Casimir Effect
Theory of Critical Casimir Effect
Experimental observation of Casimir Effect
Experimental observation of Critical Casimir Effect
Bottom-Up Approach
My PhD
1948
1978
1997
2008
2009
2010
2011
2014
2012-2015
Colloidal aggregation induced by Critical Casimir Effect
COLLOID: first run
COLLOID: second run
Advanced Colloid Experiment

Critical Casimir Effect



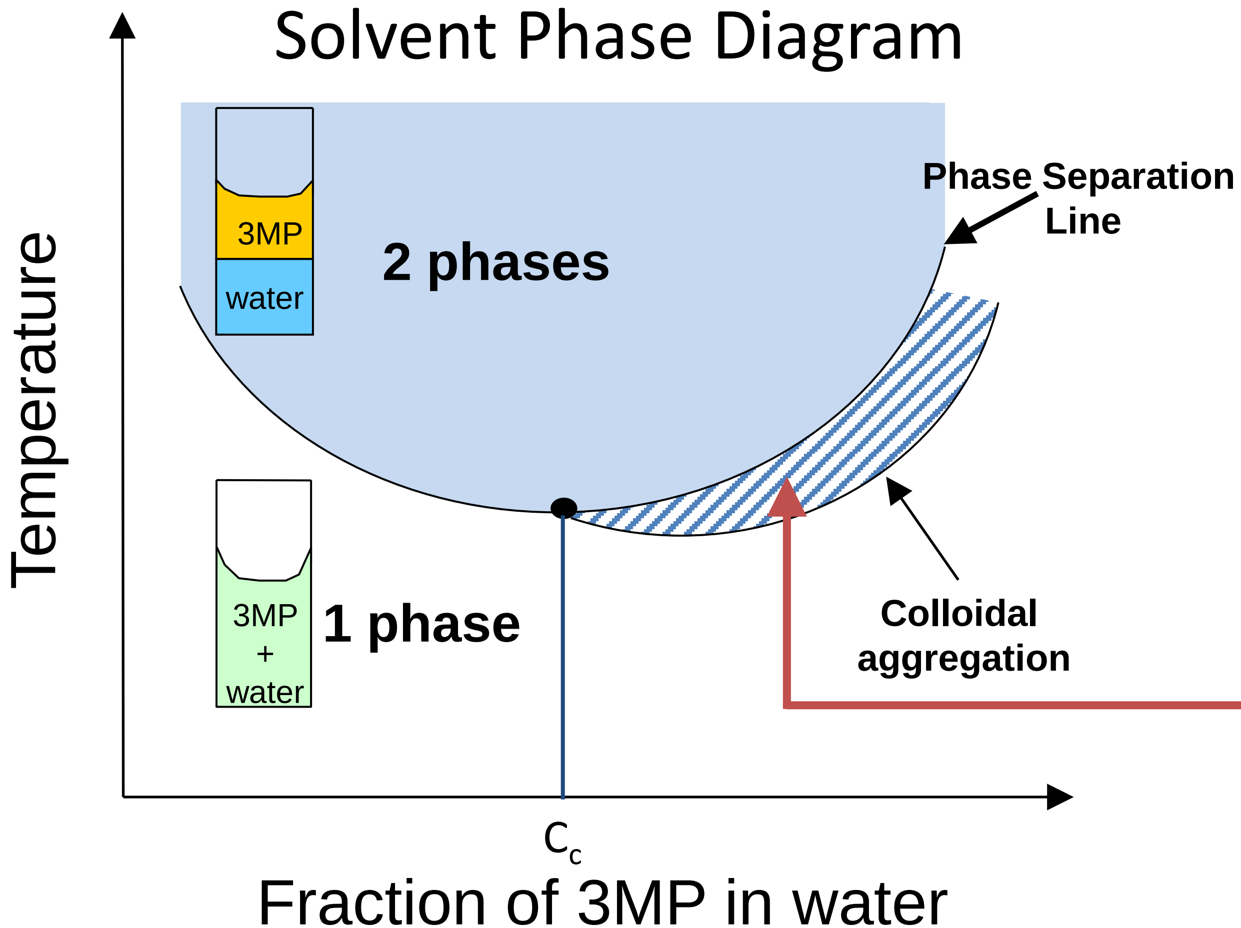
$$\xi \approx \xi_0 \left| 1 - \frac{T}{T_c} \right|^{-0.63}$$

$$\frac{F}{A} = \frac{k_B T}{L^3} \Theta(L/\xi)$$



C. HERTLEIN *et Al*, *Nature* **451**, 136-137 (2008)

Analyzed Sample



- Water
- 3-methyl Pyridine
- NaCl
- SiO_2 Spheres *0.2 μm* in radius

$C_0 = 37.5\%$

$T_{agg} = 46.2°C$

D. BONN *et Al*, *Phys. Rev. Lett.* **103**, 156101 (2009)

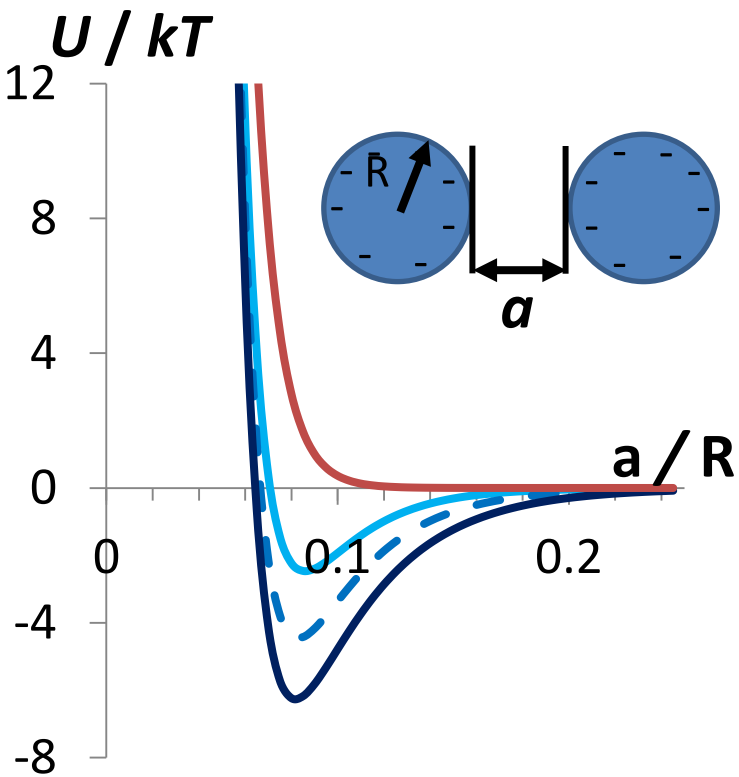
Interaction Potential

$$V(r) = V_{el} + V_{VdW} + V_{Casimir}$$

Index Matching

$$V_{el}(a) \propto \lambda_d^2 e^{-a/\lambda_d}$$

$$V_{Casimir}(a) \propto -\frac{1}{\xi} e^{-a/\xi}$$



D. BONN *et Al*, *Phys. Rev. Lett.* **103**, 156101 (2009)

Interaction Potential

$$V(r) = V_{el} + \cancel{V_{VdW}} + V_{Casimir}$$

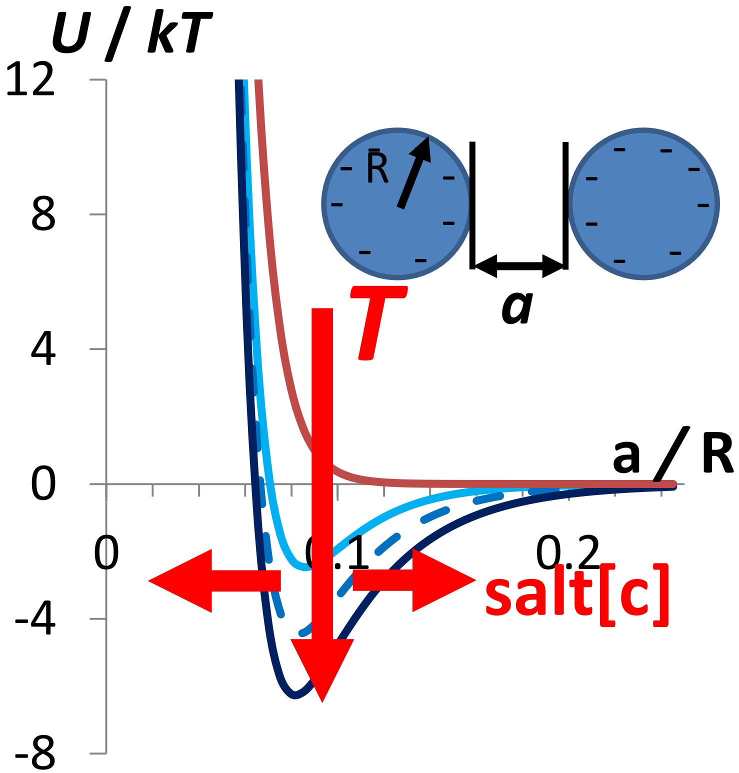
Index Matching

$$V_{el}(a) \propto \lambda_d^2 e^{-a/\lambda_d}$$

Salt Concentration

$$V_{Casimir}(a) \propto -\frac{1}{\xi} e^{-a/\xi}$$

Temperature



D. BONN *et Al*, *Phys. Rev. Lett.* **103**, 156101 (2009)

Fractals


Snowflake
Cauliflower
SCALE INVARIANCE
Leaf Venation
Lightning

Fractal Aggregates

$$M(R_g) \propto R_g^{d_f}$$

DLCA

Diffusion Limited Cluster Aggregation

$$R_g(t) \propto t^{1/d_f}$$

RLCA

Reaction Limited Cluster Aggregation

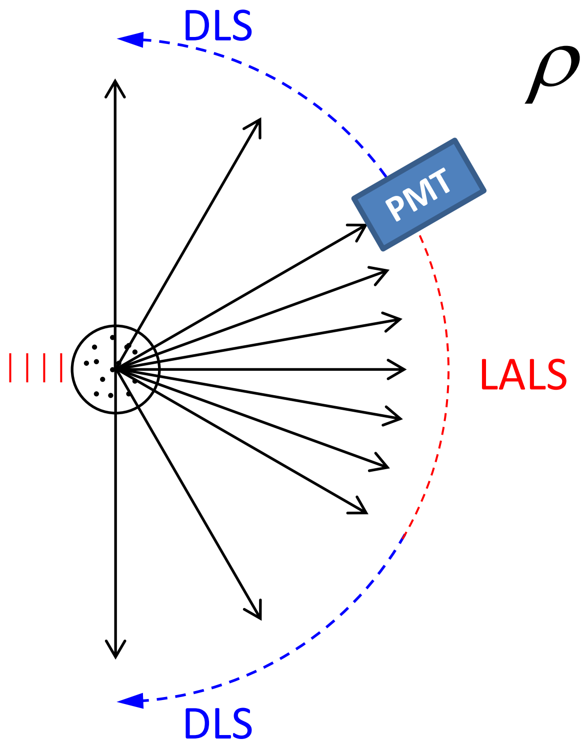
$$R_g(t) \propto e^{\alpha t}$$

$$\rho(R_g) = R_g^{d_f - 3} \cdot f_c(R_g, R_c)$$

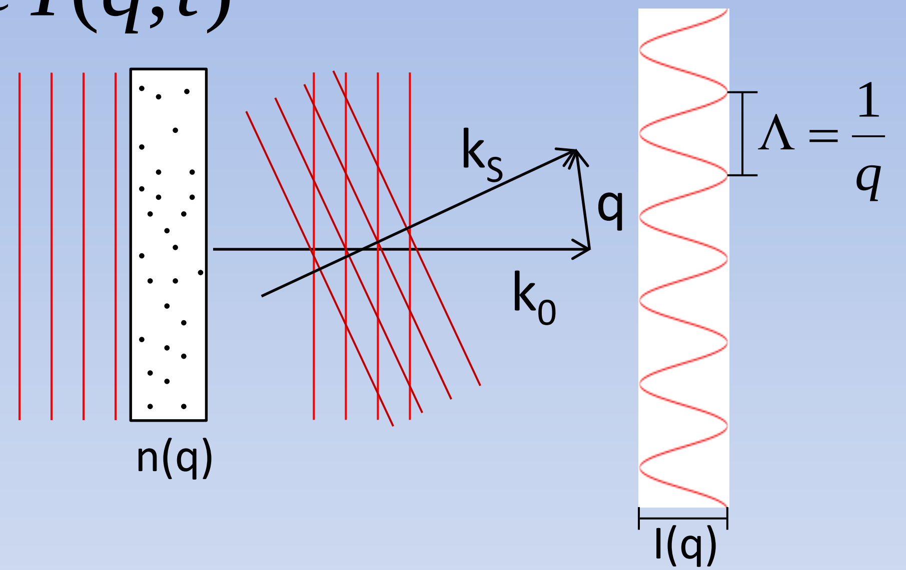
Scattering Techniques

Low Angle Light Scattering
Dynamic Light Scattering

Near Field Scattering
In-Line Holography



$$\rho(\vec{q},t) \propto I(\vec{q},t)$$



$$I(r,t) = I_0(r) + \mathrm{Re}\left\{E_0(r)E_S^*(r,t)\right\}$$

LALS → $I(q,t)$

DLS → $D = \frac{k_B T}{6\pi\eta R}$

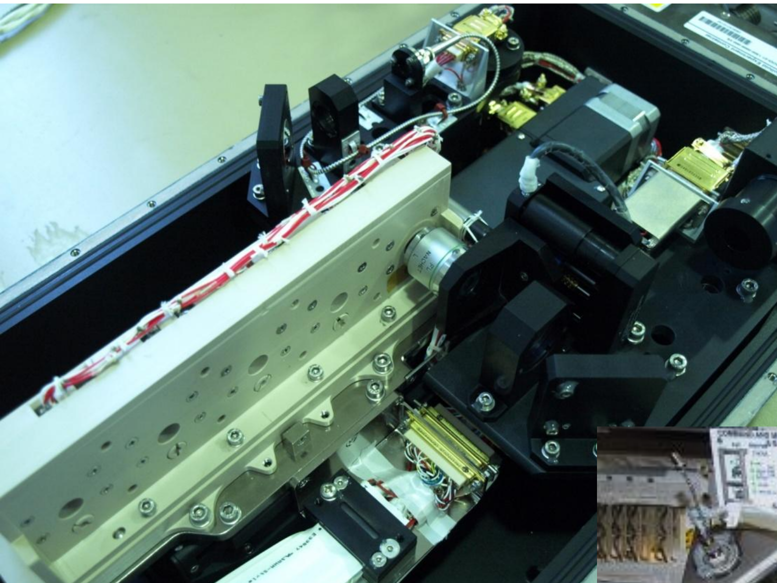
→ $I(q,t)$

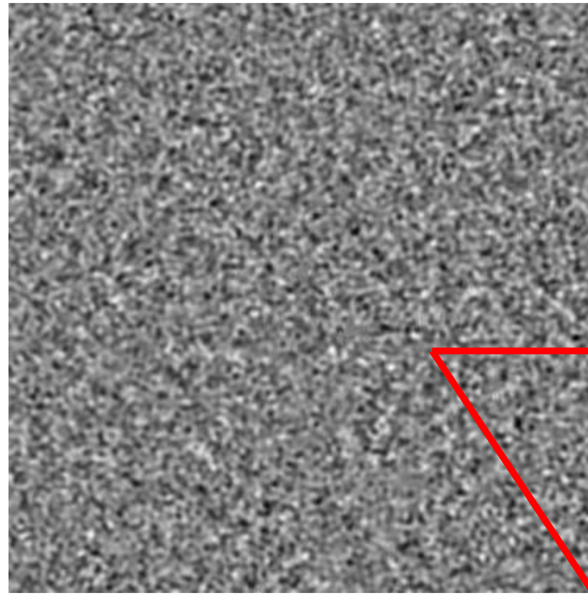
→ $D = \frac{k_B T}{6\pi\eta R}$

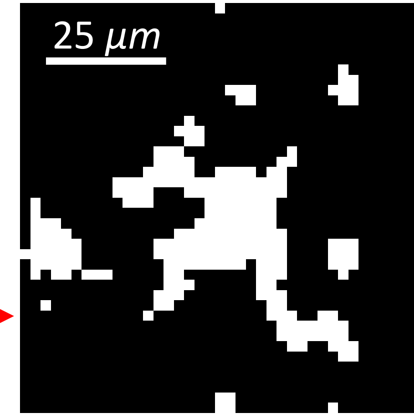
COLLOID

September-October 2010

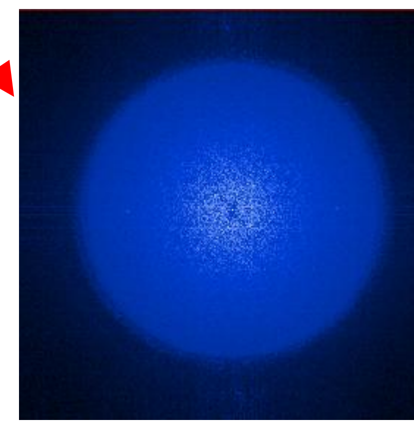
October-November 2011







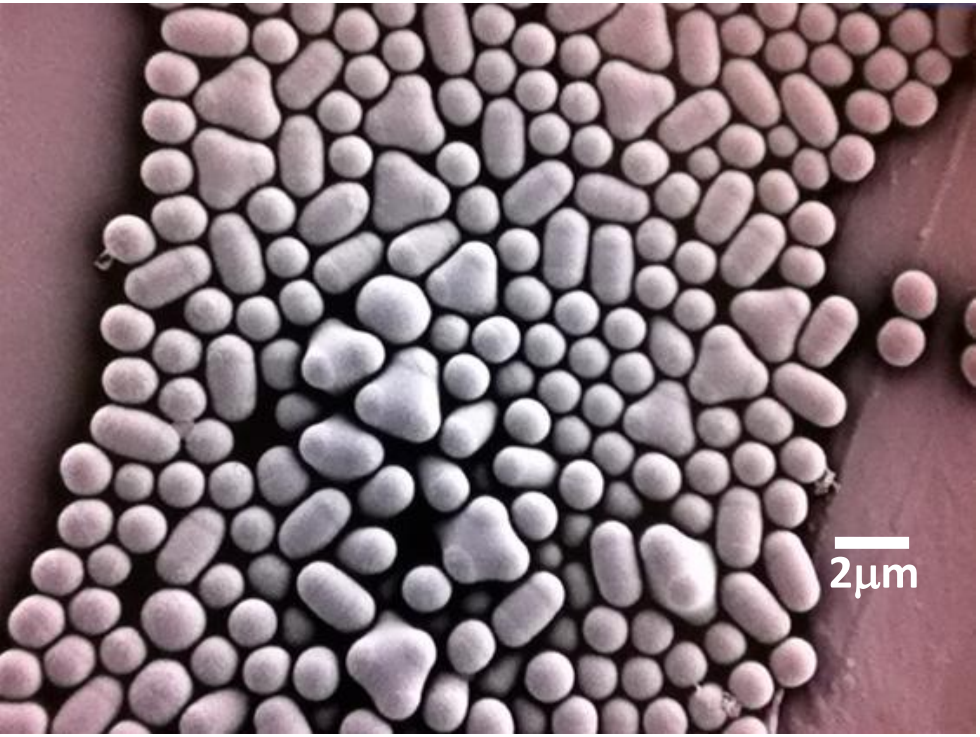
Holographic reconstruction



Static Form Factor

Laser: *935 nm* (IR)
Sample: Water, 3-methyl Pyridine, NaCl, SiO_2 Spheres *0.2 μm* in radius.
Objective: *20x*, NA 0.25
CCD: 1024x1024, *6.6 μm*

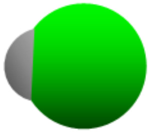
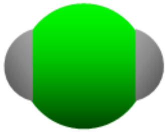
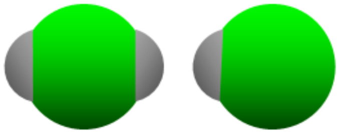
Advanced Colloid Experiment



2014: ACE at ISS

- Microscopy
? Near field Scattering
? Holographic reconstruction

Hydrophobic
Hydrophilic

Mono Patch	Di-Patch	Mixtures	Tetra-Patch
			
Colloidal Micelles	Colloidal Polymers	Molecules, Superstructures	Diamond structure

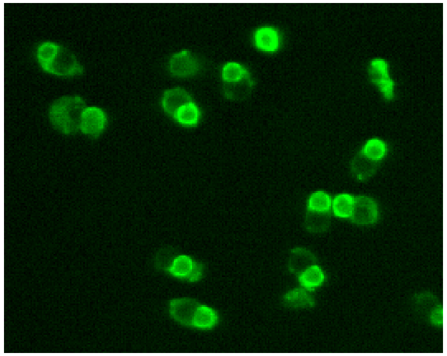
Advanced Colloid Experiment

Ground Based Measurements

Near Field Scattering:
Statics and Dynamics

In-Line Holography

Confocal Microscopy



Summary and Perspectives

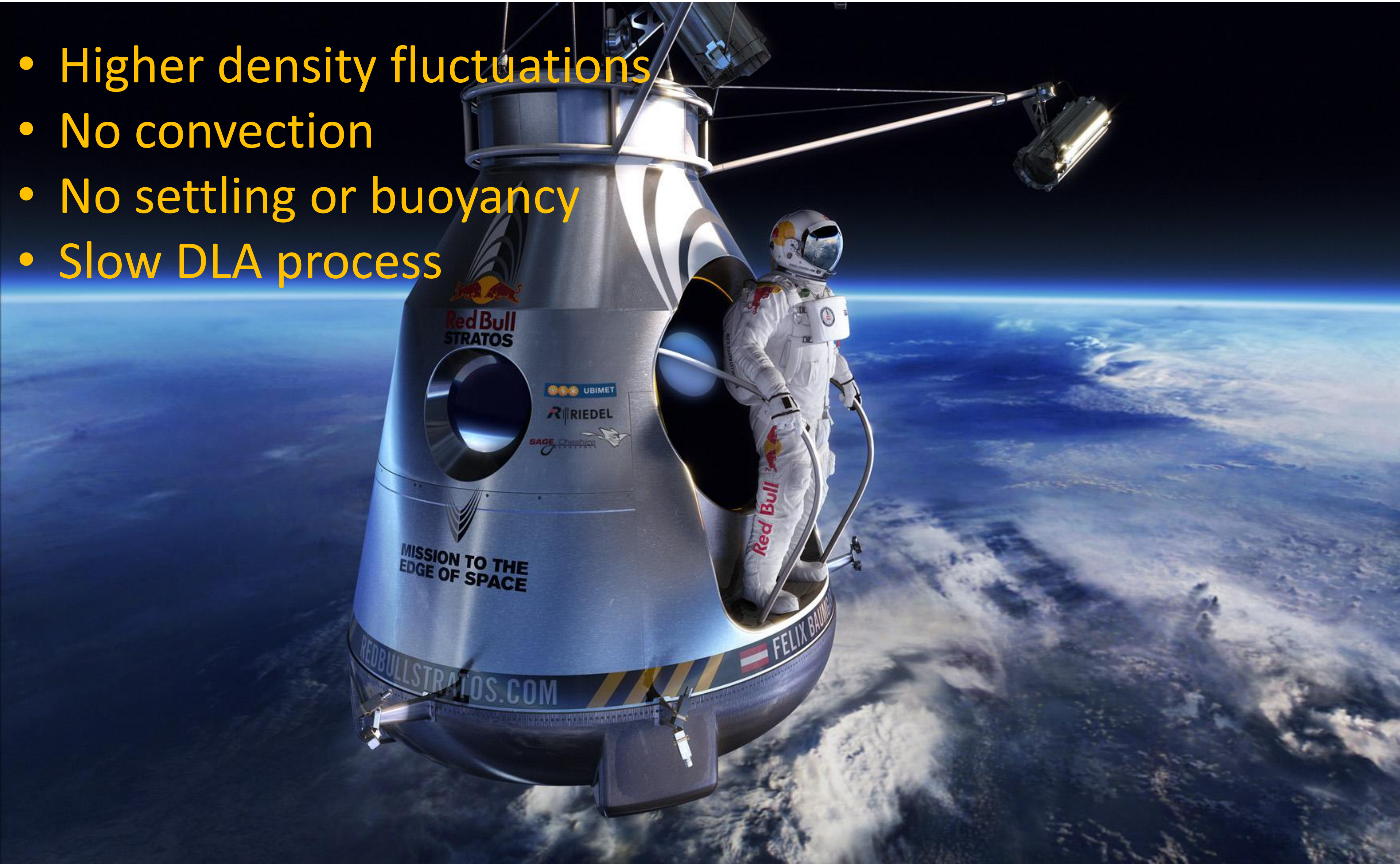
COLLOID:

- *Evidence of T-dependent interaction*
- *Information on the Internal Structure*
- *Analysis of COLLOID 2*

ACE:

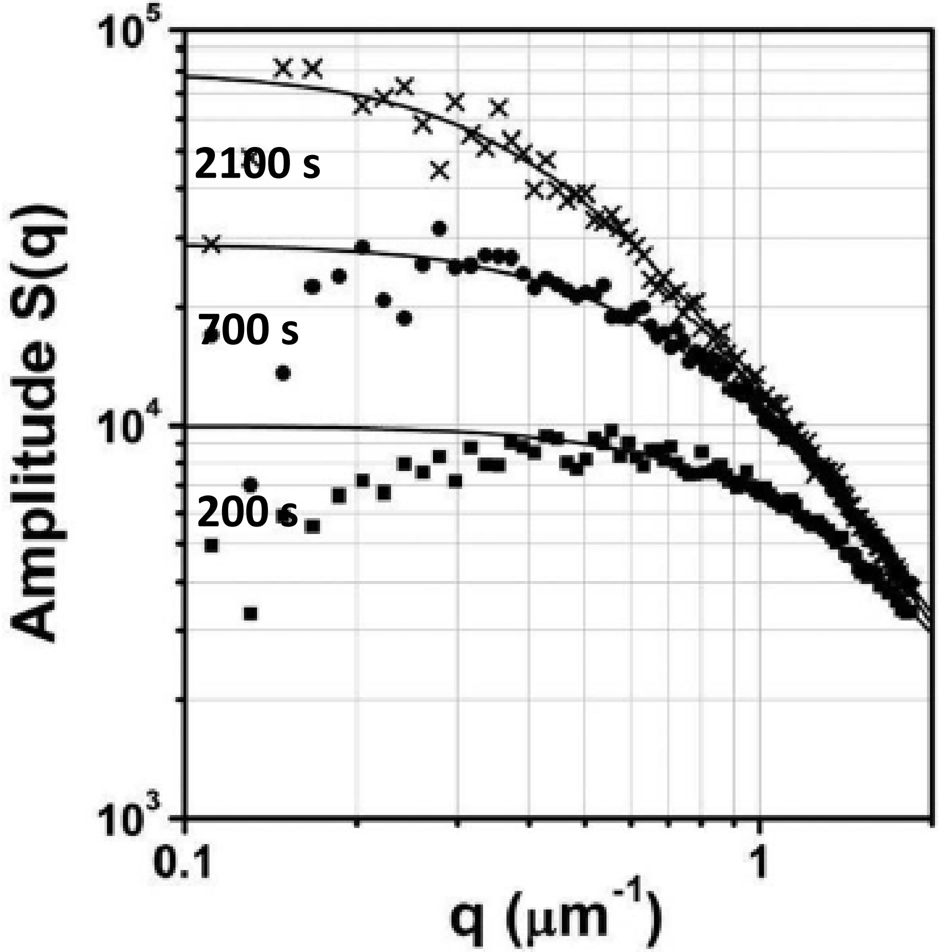
- On Ground: characterization of single particles and aggregates
- On ISS: study of the aggregation processes and of the aggregate structure in perfect DLA conditions

Why in Microgravity?



- Higher density fluctuations
- No convection
- No settling or buoyancy
- Slow DLA process

Static Form Factor



Fisher-Burford

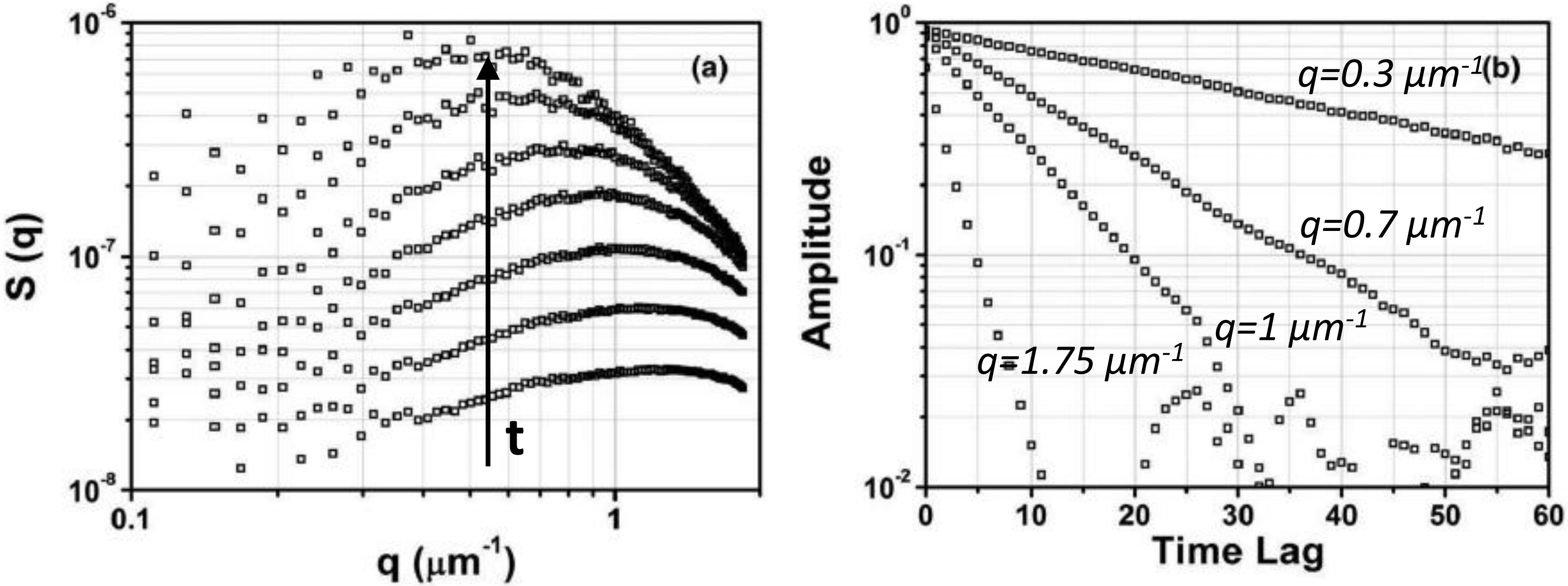
$$S(q) = \frac{I(q=0)}{\left[1 + \frac{2(qR_g)^2}{3d_f}\right]^{d_f/2}}$$

S. J. VEEN *et Al*, *Phys. Rev. Lett.* **109**, 248302 (2012)

Dynamic Light Scattering

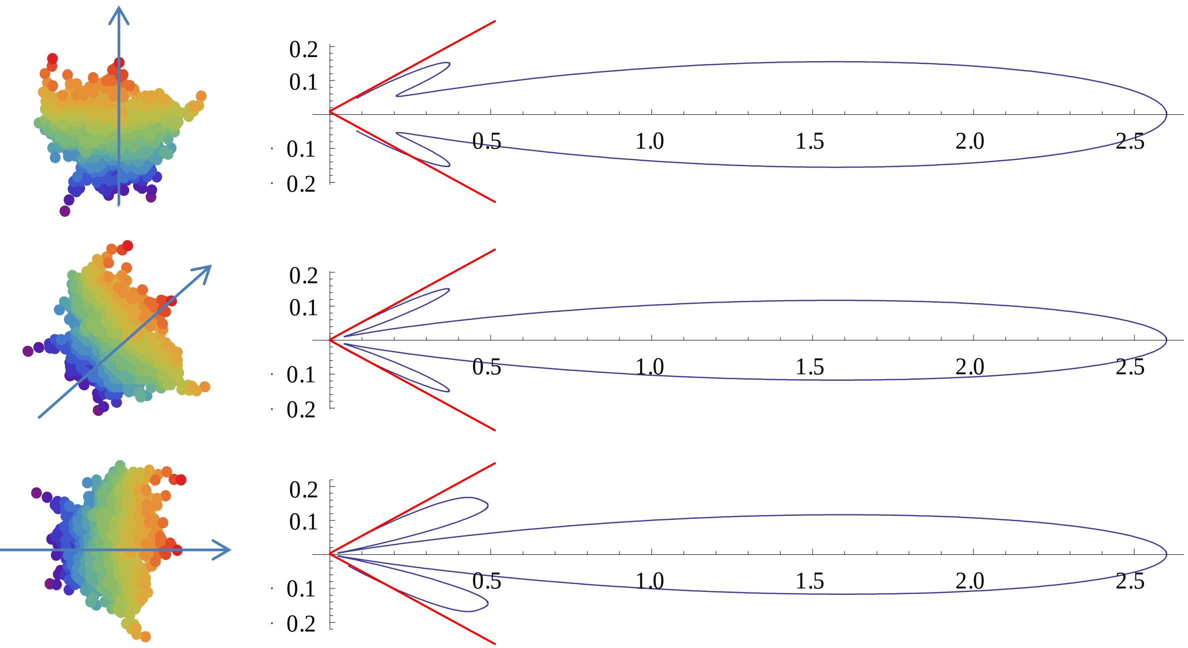
$$\frac{d\rho(\vec{q},t)}{dt} = -Dq^2\rho(\vec{q},t) \qquad \rho(\vec{q},t) \propto I(\vec{q},t)$$

$$\langle E(t)E(t+\tau)\rangle = Ae^{-Dq^2\tau} + B$$



Dynamic Light Scattering Results

$$\left\langle E(t)E(t+\tau)\right\rangle = Ae^{-D_{eff}(q)q^2\tau} + B$$

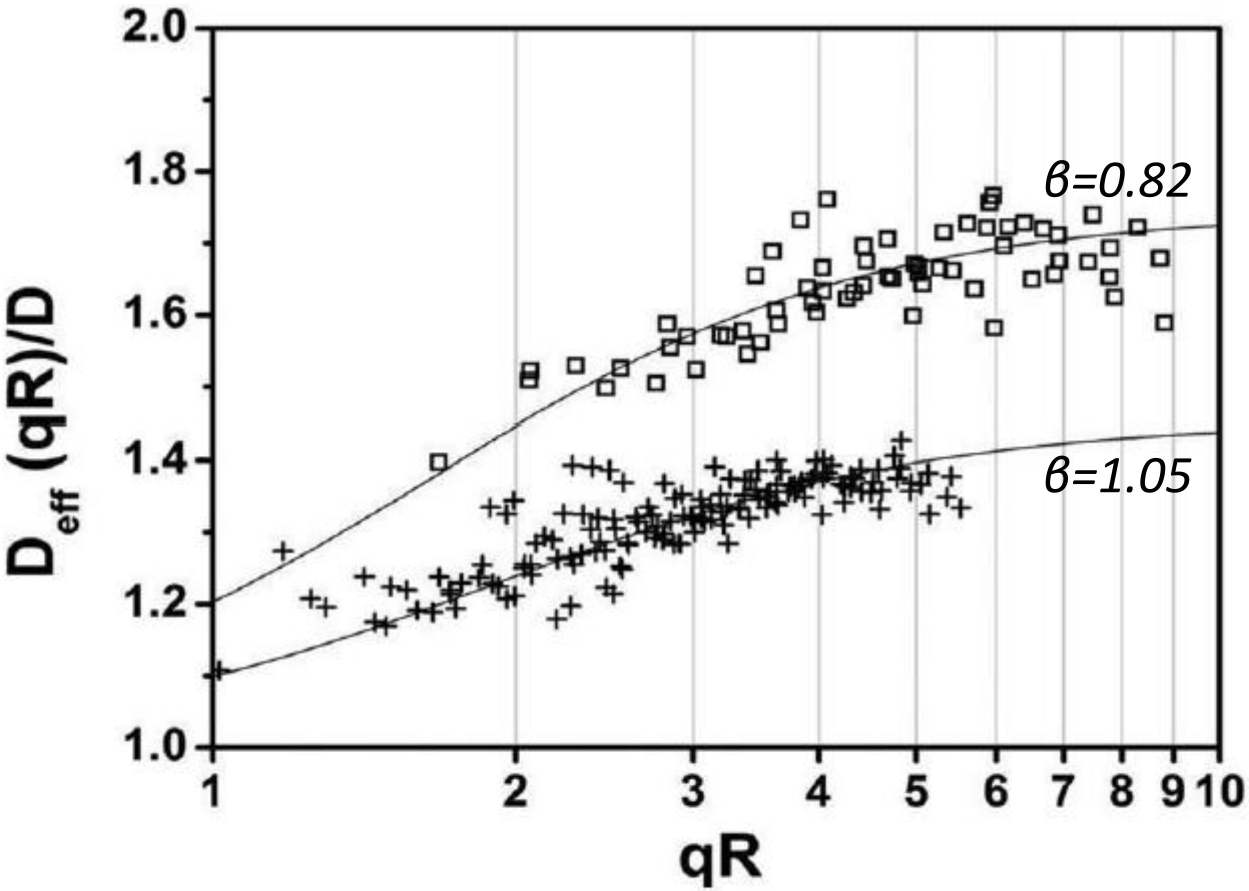


$$D_{eff}(q) = D + \alpha(q)D_{Rot}$$

$$\frac{D_{eff}(q)}{D} = 1 + \frac{1}{2\beta^2}\left[1 - \frac{3d_f}{3d_f + 2(qR_g)^2}\right]$$

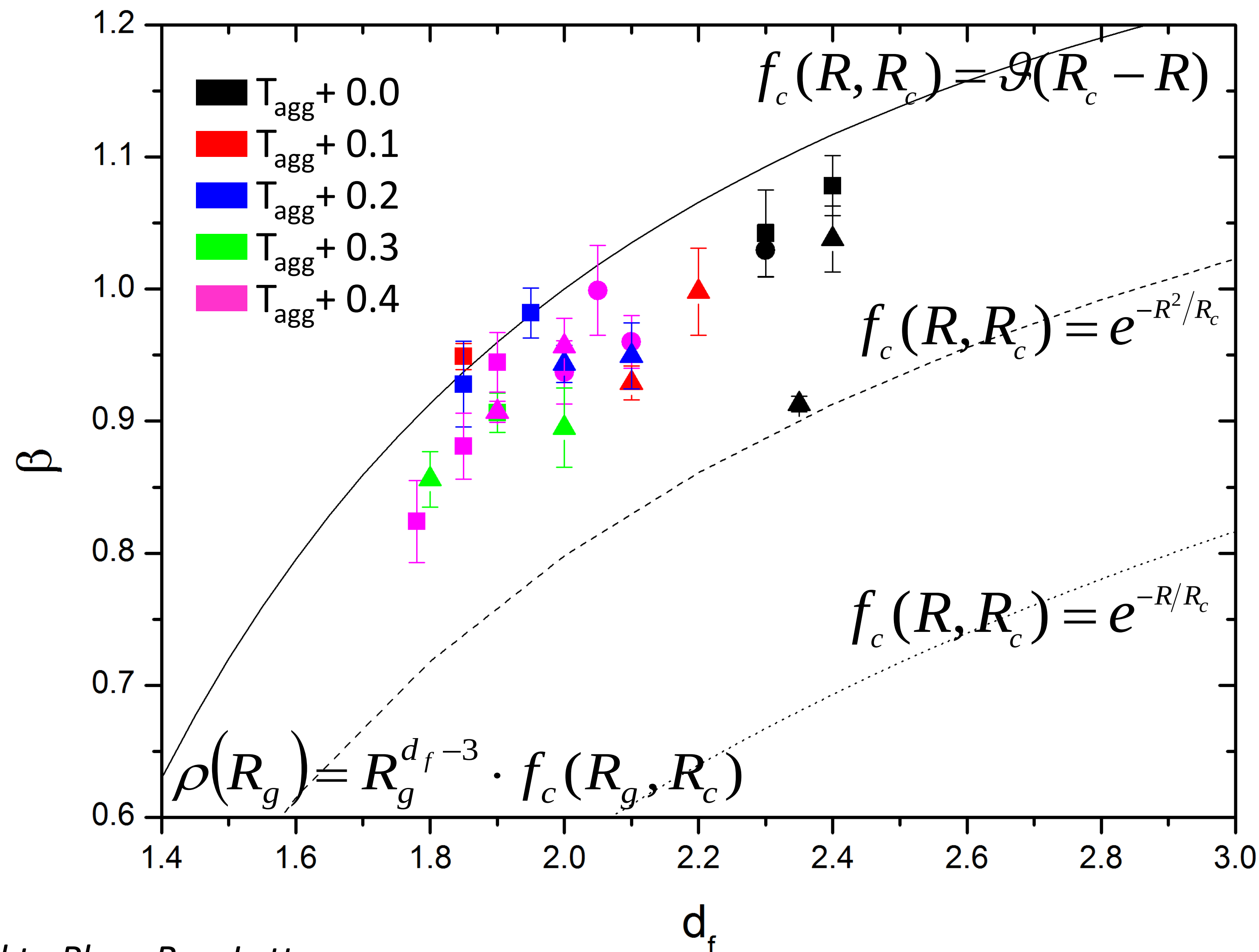
M. Y. LIN *et Al*, *Phys Rev A* **41**, 2005 (1990)
M. LATTUADA *et Al*, *Langmuir* **20**, 5630 (2004)

Dynamic Light Scattering Results



$$\frac{D_{eff}}{D} = 1 + \frac{1}{2\beta^2}\left[1 - \frac{3d_f}{3d_f + 2(qR_g)^2}\right]$$

Structure of the Aggregates



Submitted to Phys. Rev. Lett.