Soft self-assembled nanoparticles with temperature-dependent properties

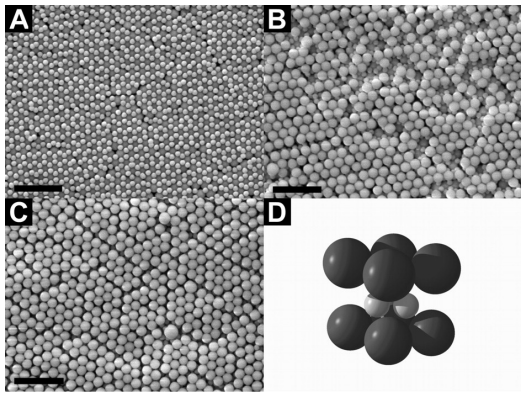
Lorenzo Rovigatti, Barbara Capone and Christos N. Likos

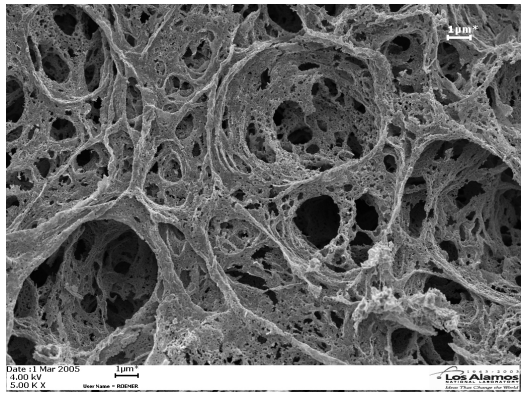
University of Vienna (Austria)

Roma
22 September 2015

Valence-limited building blocks

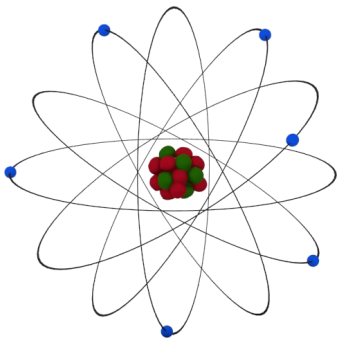
- Soft matter materials can be engineered to a high degree

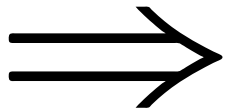


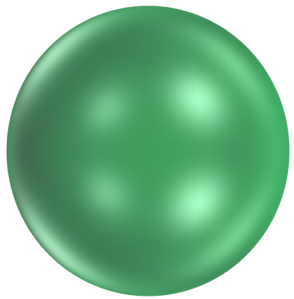


Valence-limited building blocks

- Soft matter materials can be engineered to a high degree
- Colloids can be seen as "large atoms"...





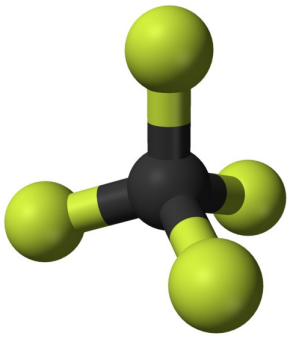


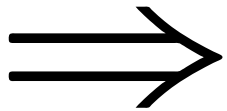
Science
AAAS

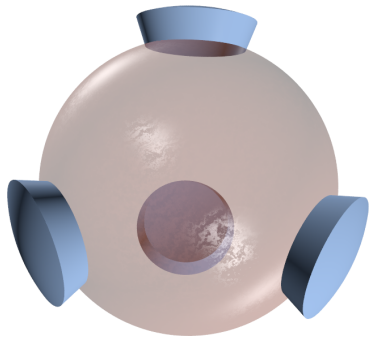
Colloids as Big Atoms
Wilson Poon
Science **304**, 830 (2004);
DOI: 10.1126/science.1097964

Valence-limited building blocks

- Soft matter materials can be engineered to a high degree
- Colloids can be seen as "large atoms"... or molecules!

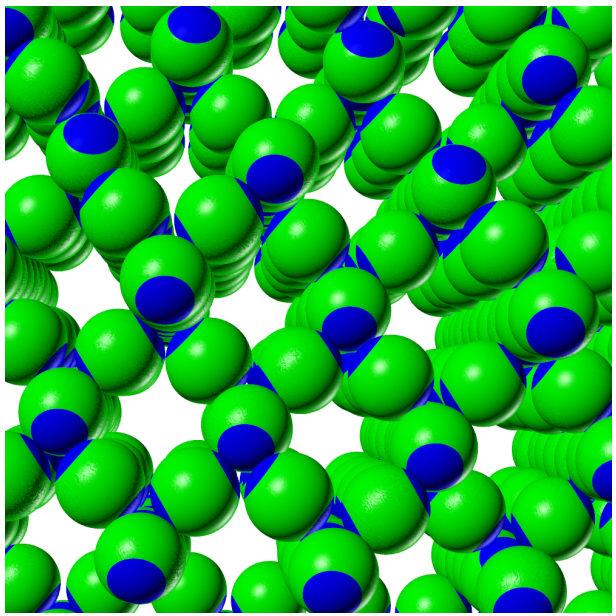


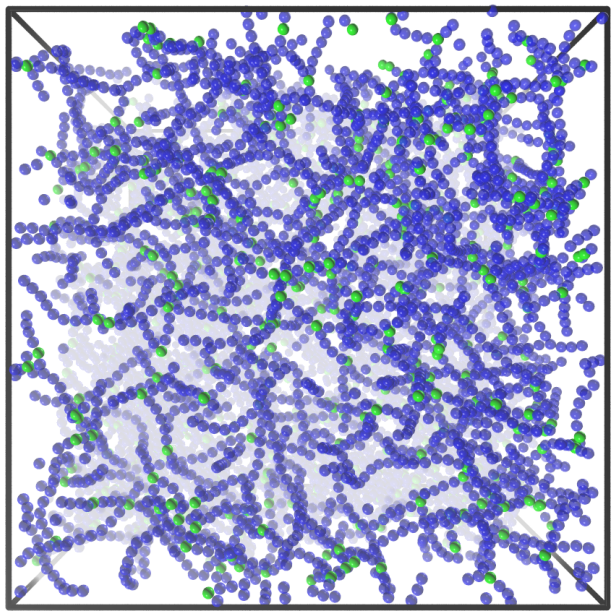




Valence-limited building blocks

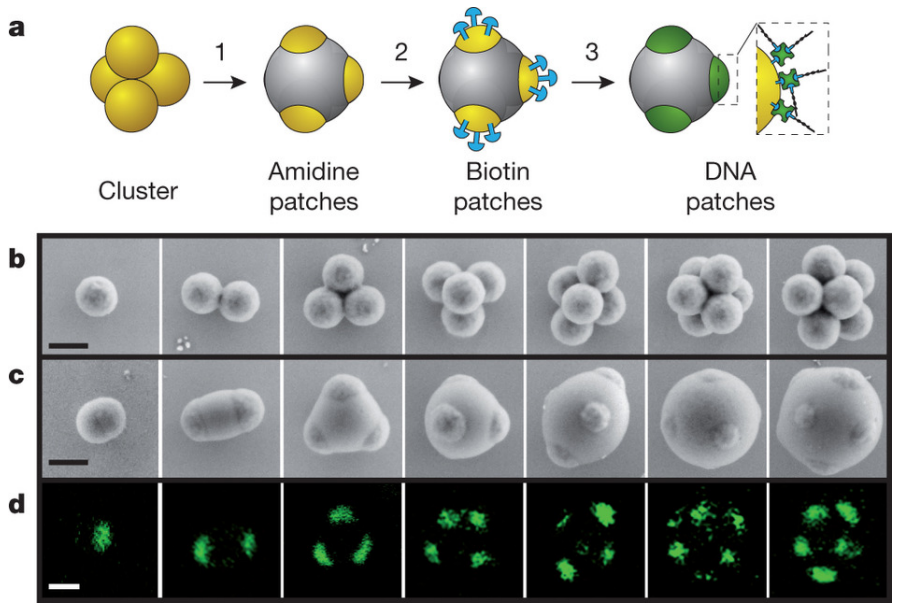
- Soft matter materials can be engineered to a high degree
- Colloids can be seen as "large atoms"... or molecules!
- Limited valence → open structures





A hierarchical self-assembly

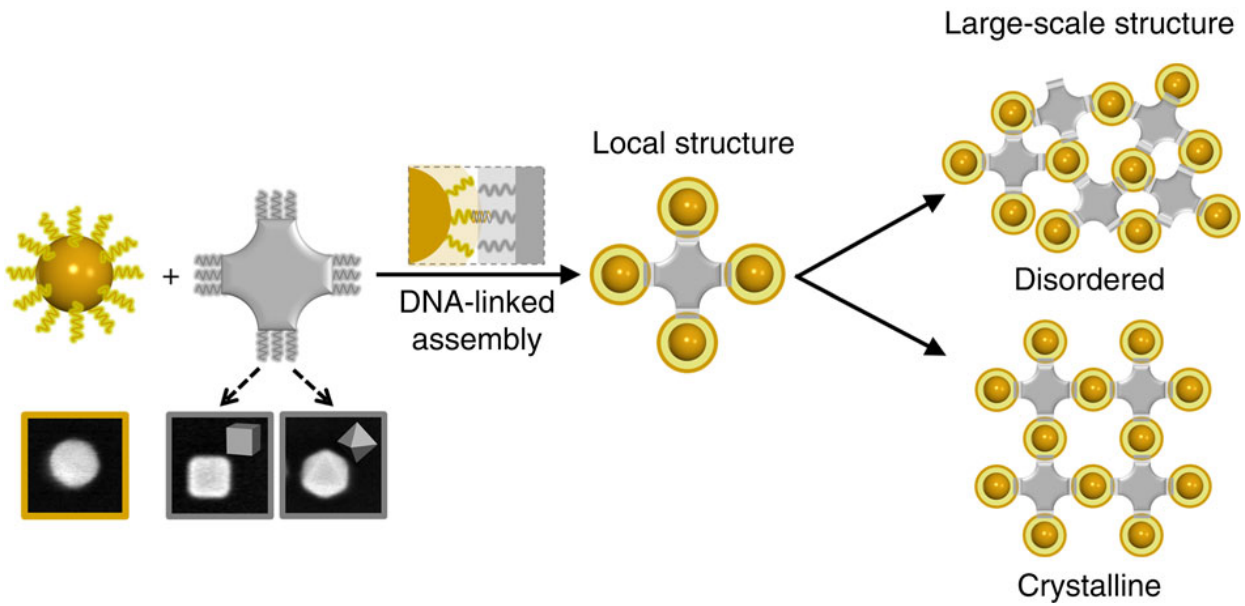
- *Hard* "patchy" colloids are difficult to synthesise



[1] Y. Wang *et al.*, *Nature* (2012)

A hierarchical self-assembly

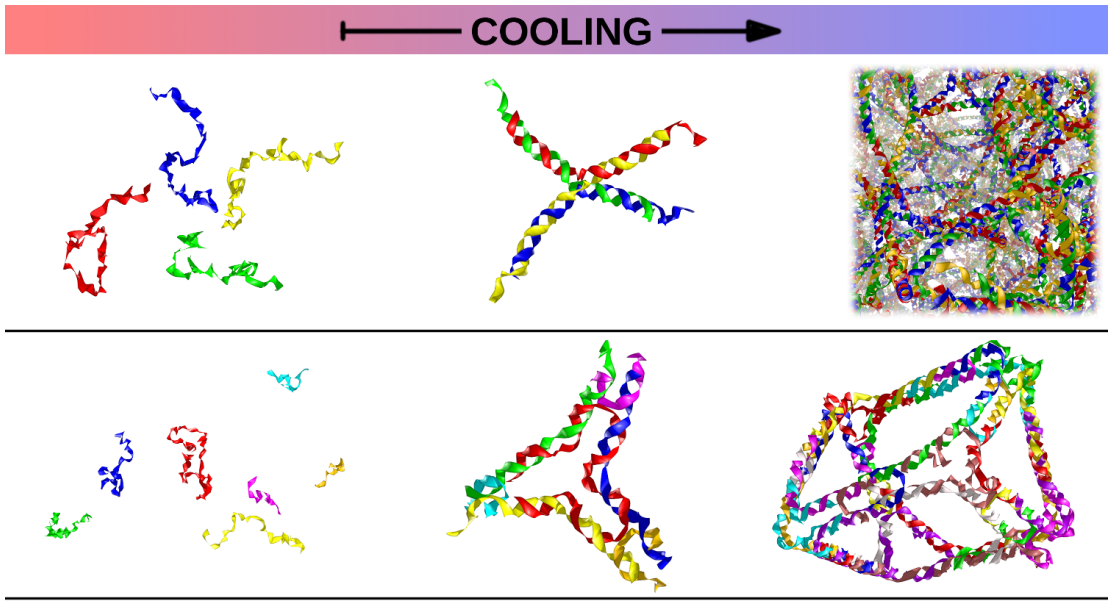
- *Hard* "patchy" colloids are difficult to synthesise



[2] F. Lu *et al.*, *Nat. Commun.* (2015)

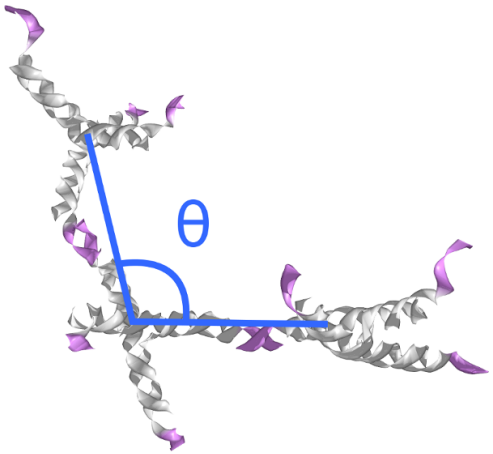
A hierarchical self-assembly

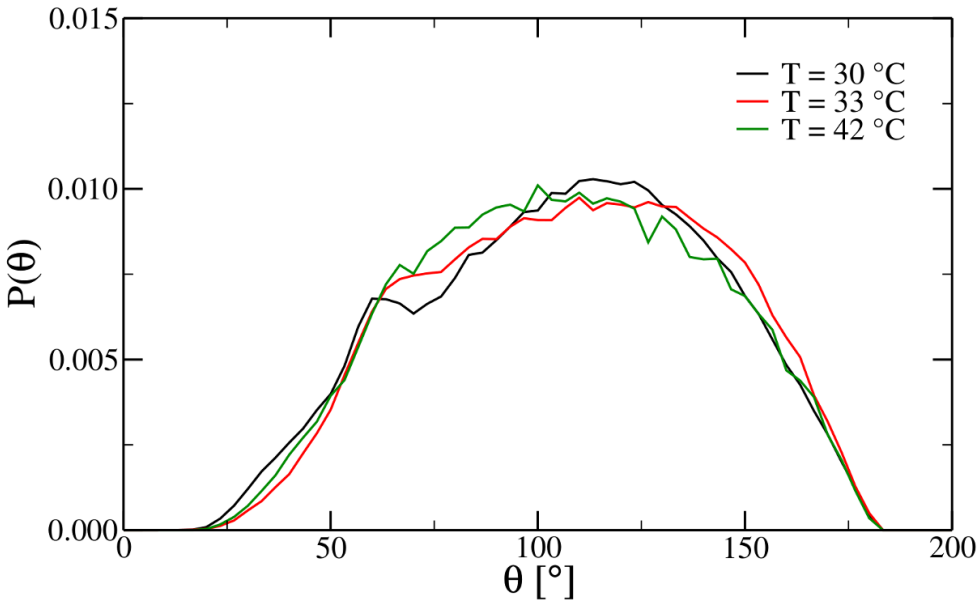
- *Hard* "patchy" colloids are difficult to synthesise
- A different approach: self-assembling (bio)polymers



A hierarchical self-assembly

- *Hard* "patchy" colloids are difficult to synthesise
- A different approach: self-assembling (bio)polymers
- New challenges (and opportunities): intrinsic *softness*



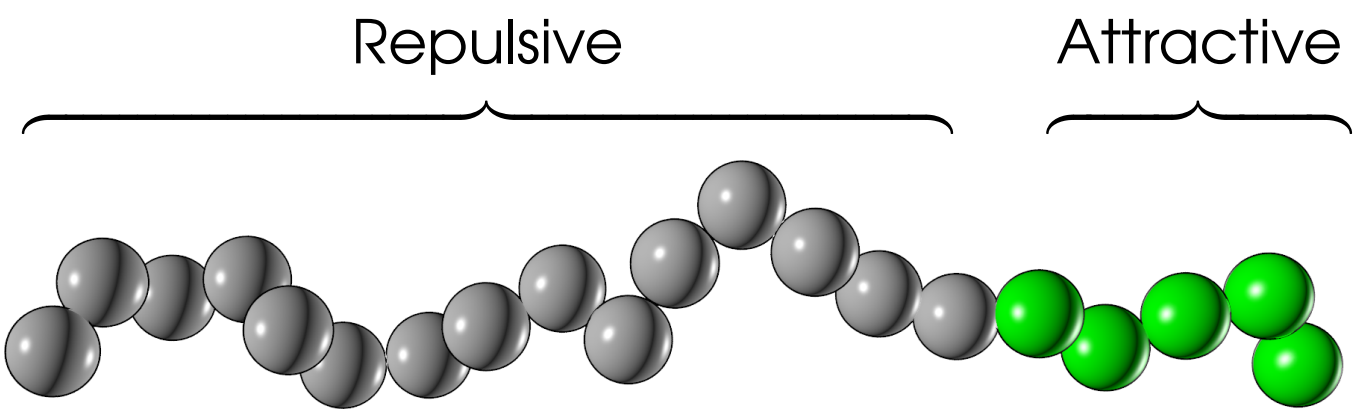


[3] LR *et al.*, *ACS Nano* (2014)

Telechelic star polymers

The recipe

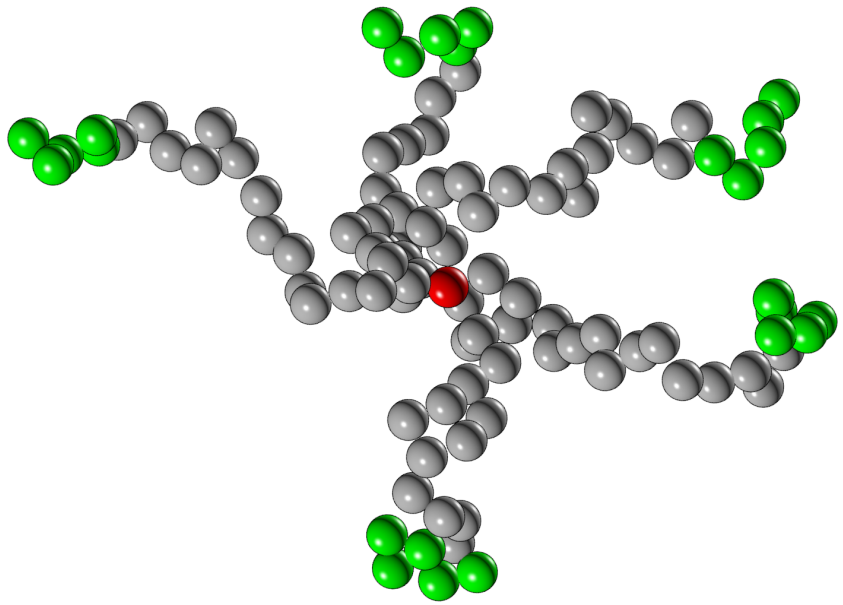
1. Take f diblock co-polymers (attractive-to-repulsive ratio α)



Telechelic star polymers

The recipe

1. Take f diblock co-polymers (attractive-to-repulsive ratio α)
2. Graft them on a central anchoring point ($R \ll R_g$)



Telechelic star polymers

The recipe

1. Take f diblock co-polymers (attractive-to-repulsive ratio α)
2. Graft them on a central anchoring point ($R \ll R_g$)

- Experimentally viable (*e.g.* with zwitterionic end groups)

[1] M. Pitsikalis *et al., J. Chem. Phys.* (1996)

[2] D. Vlassopoulos *et al., J. Chem. Phys.* (1999)

[3] D. Vlassopoulos *et al., Macromol.* (2000)

[4] X. Zhang *et al., Macromol.* (2000)

Telechelic star polymers

The recipe

1. Take f diblock co-polymers (attractive-to-repulsive ratio α)
2. Graft them on a central anchoring point ($R \ll R_g$)

- Experimentally viable (*e.g.* with zwitterionic end groups)
- Simulations show formation of ordered and disordered phases

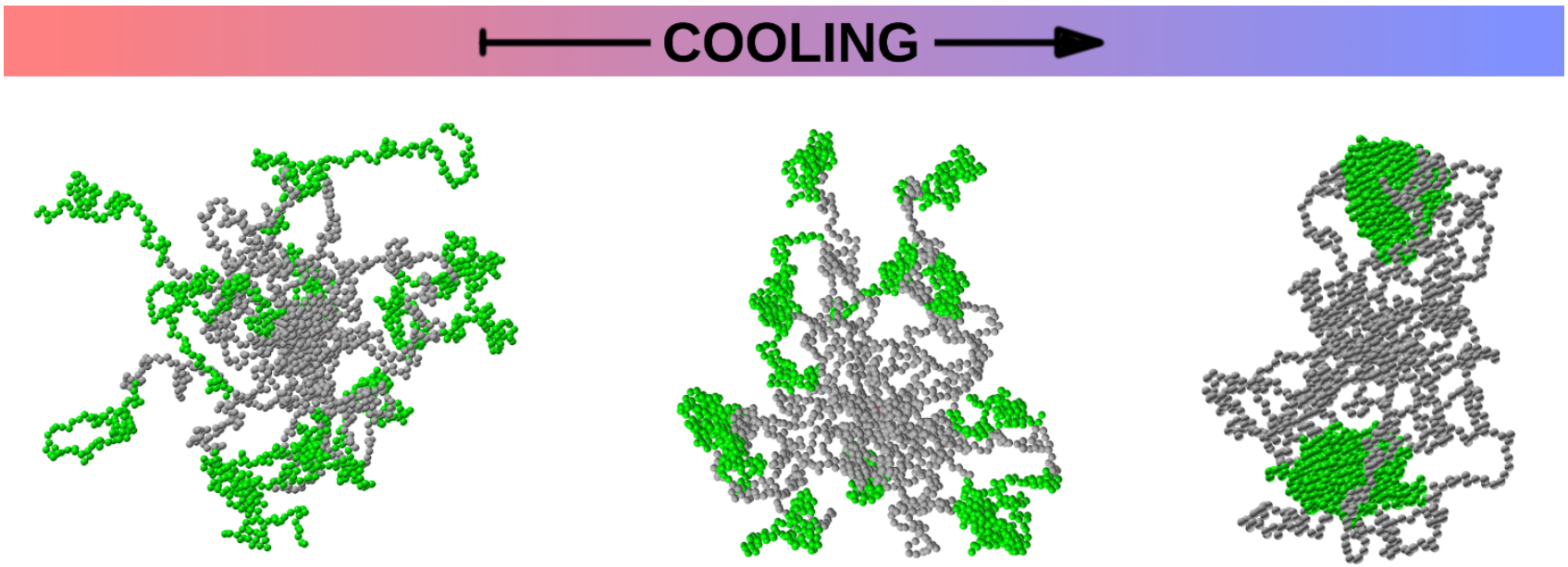
[5] F. Lo Verso *et al.*, *Phys. Rev. Lett.* (2006)

[6] B. Capone *et al.*, *Phys. Rev. Lett.* (2012)

[7] C. Koch *et al.*, *Soft Matter* (2013)

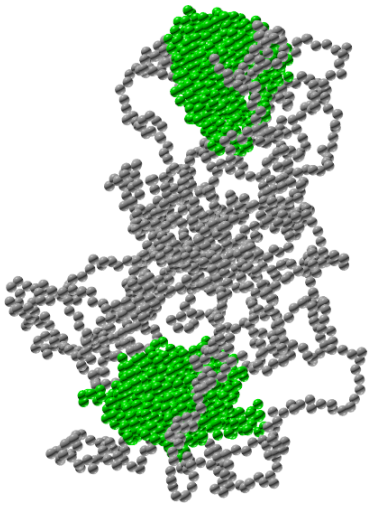
The role of the temperature

- T controls the attraction between end monomers

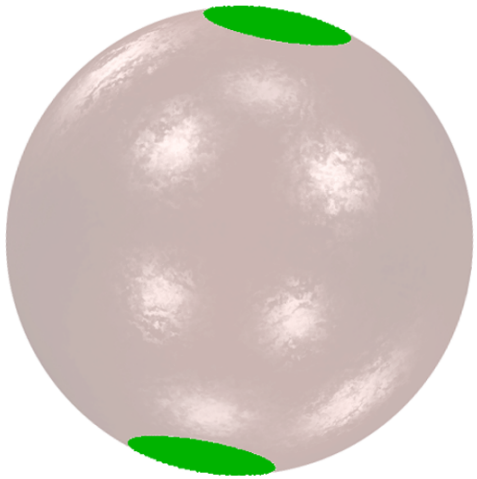


The role of the temperature

- T controls the attraction between end monomers
- At low T "patches" form

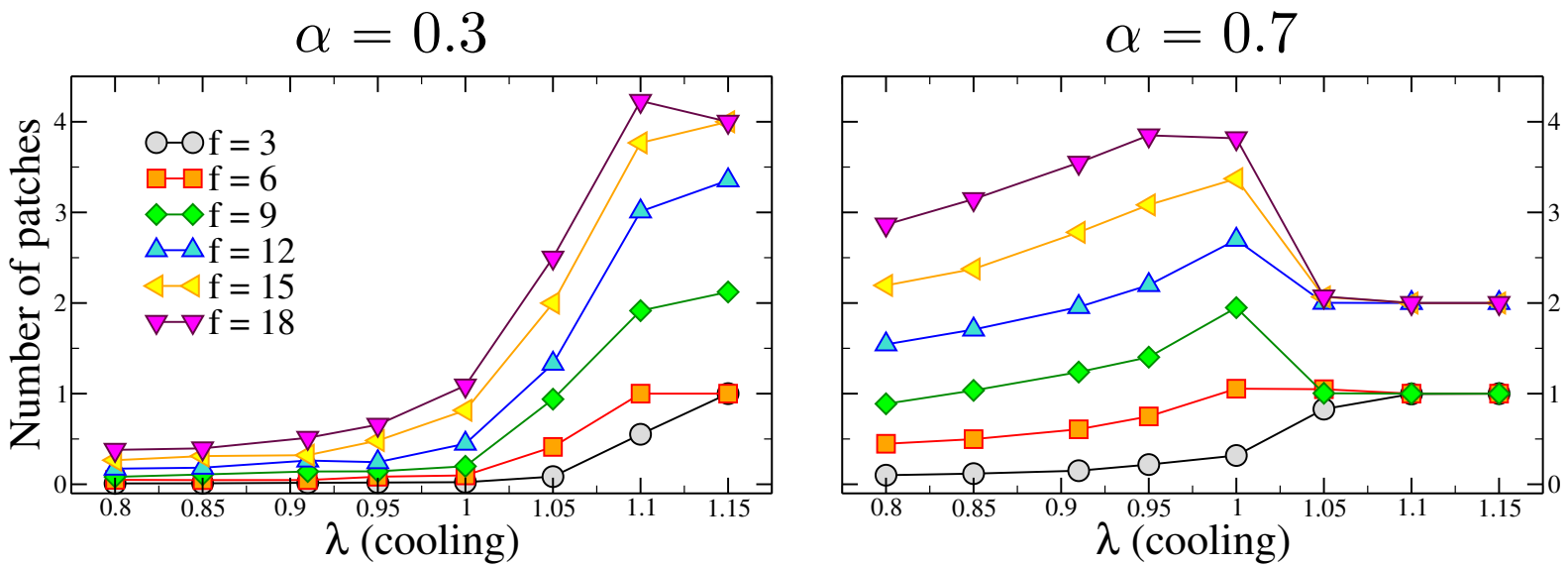


$\approx$



The role of the temperature

- T controls the attraction between end monomers
- At low T "patches" form
- Patch number and size depend on f, α and T

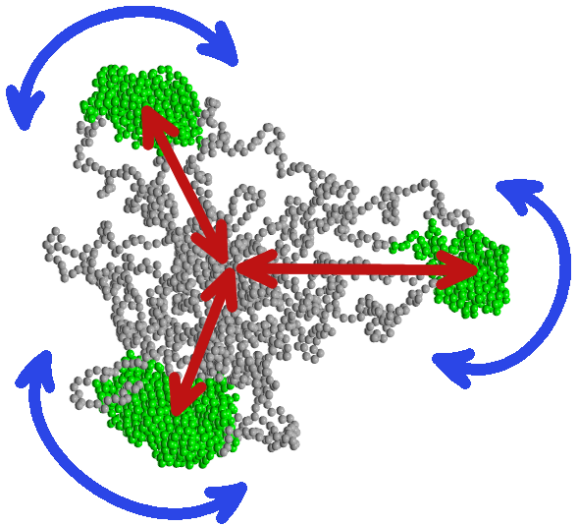


Tuning the flexibility

- TSP's are inherently floppy

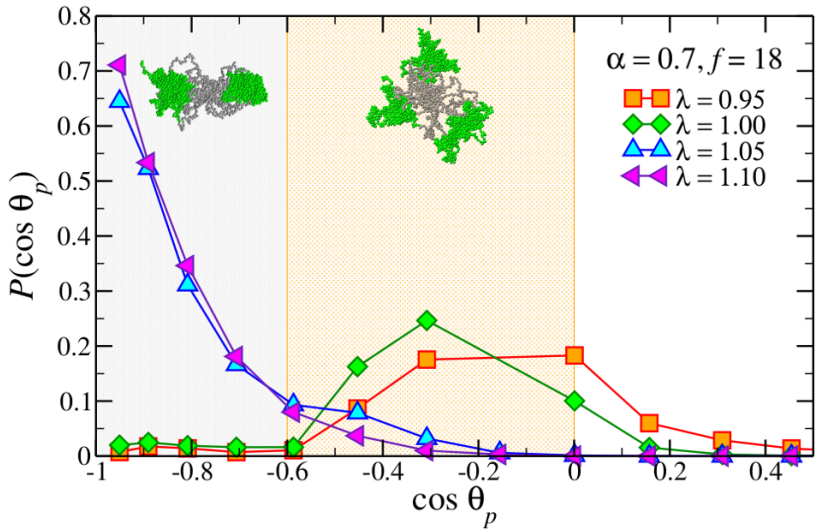
Angular flexibility

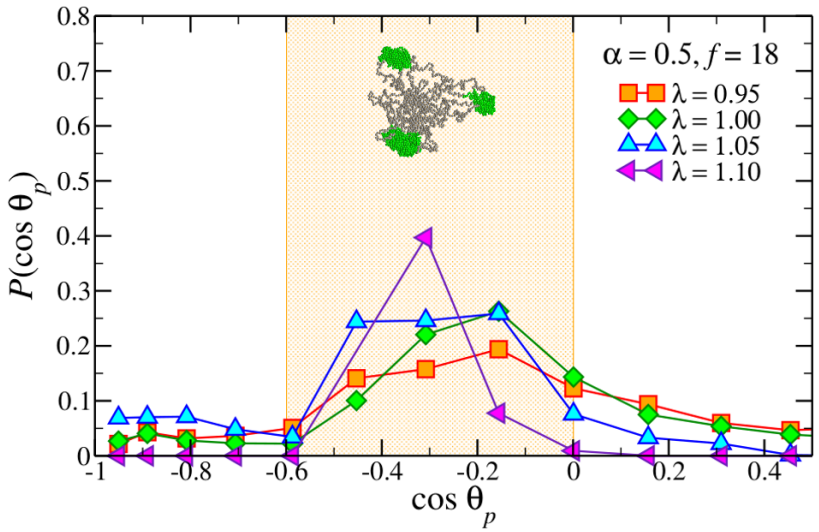
Radial flexibility



Tuning the flexibility

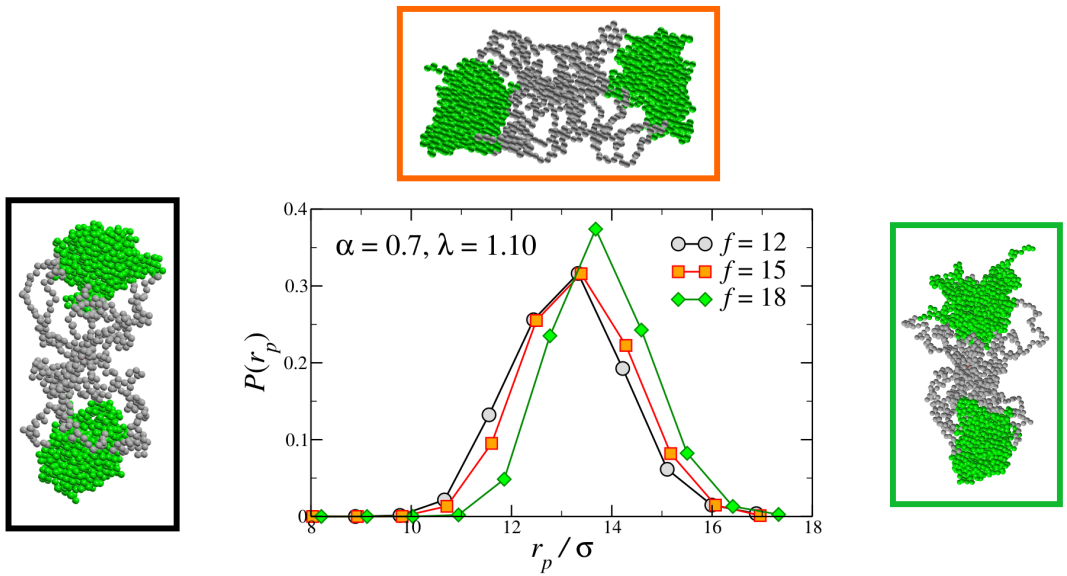
- TSP's are inherently floppy
- f, α and T control flexibility



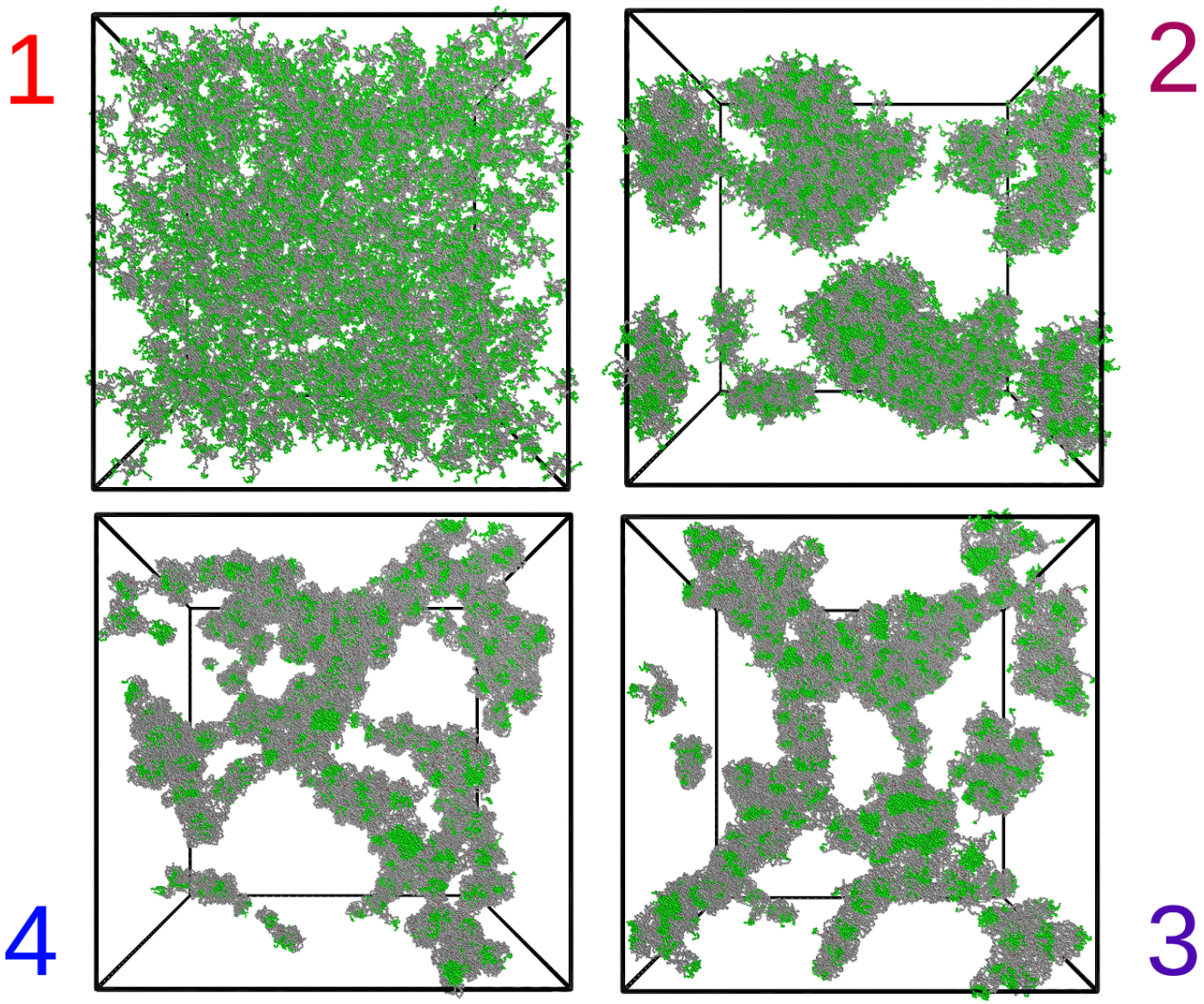


Tuning the flexibility

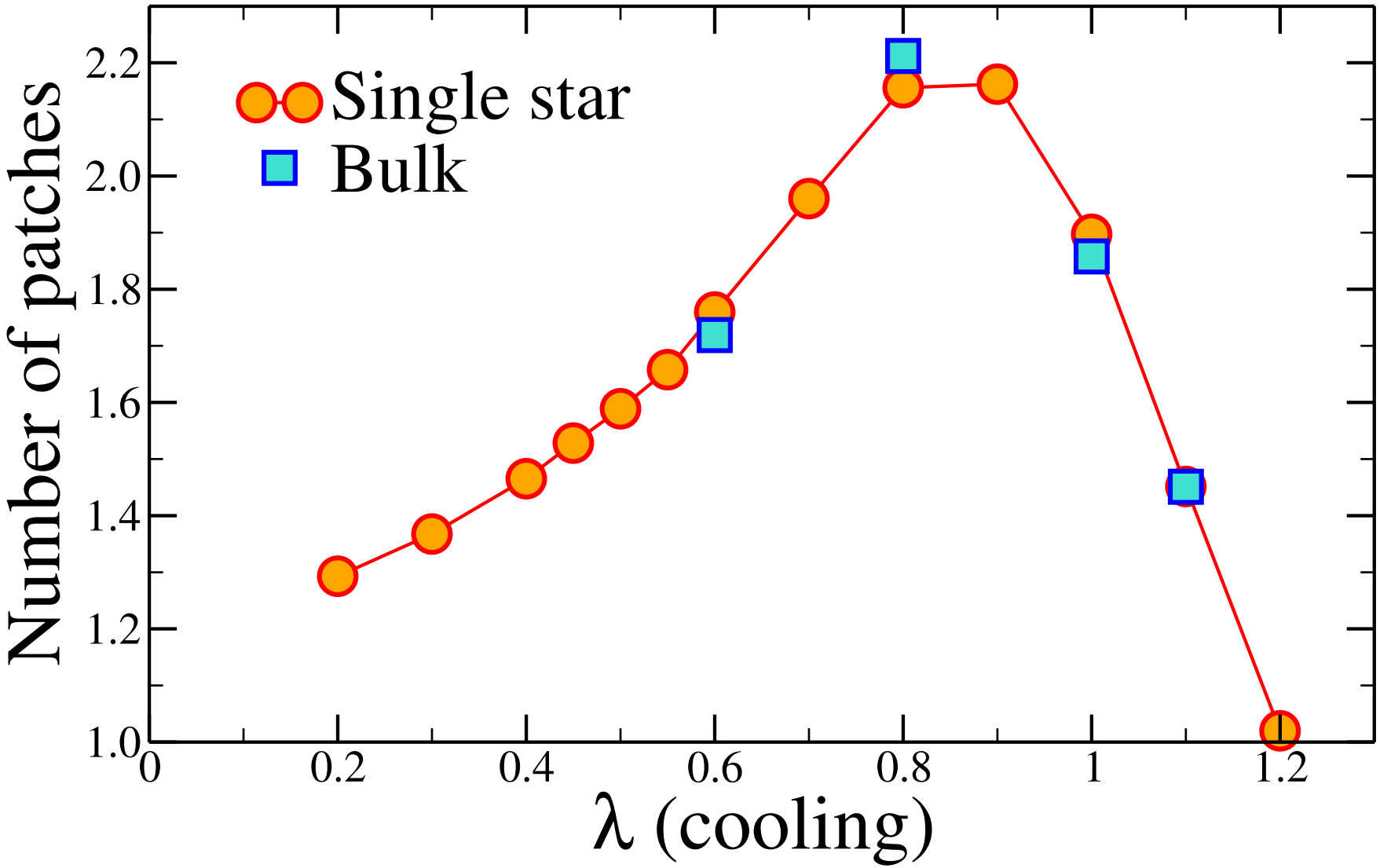
- TSP's are inherently floppy
- f, α and T control flexibility
- Same patch geometry, different flexibility → materials with similar structures, different mechanics



In the bulk



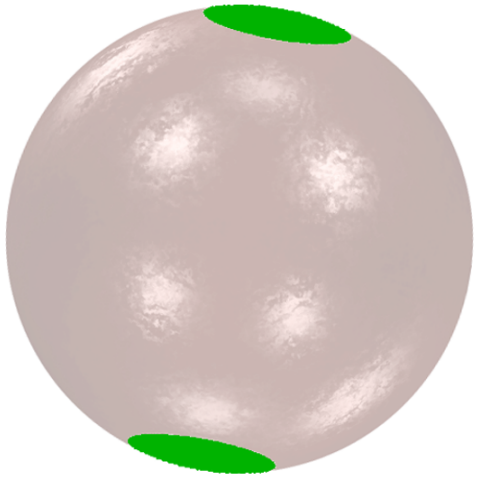
In the bulk


Single star
Bulk
Number of patches
λ (cooling)
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0
0.2
0.4
0.6
0.8
1
1.2

Outlook and conclusions

- TSP's self-assemble into soft patchy particles[1]

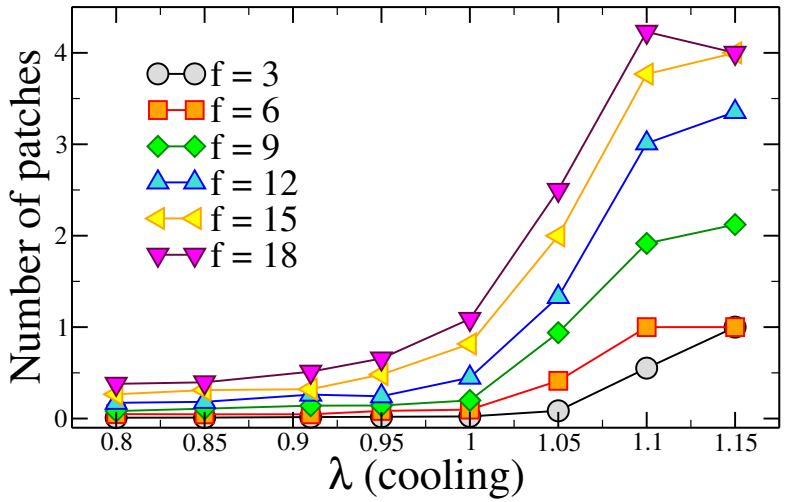
≈

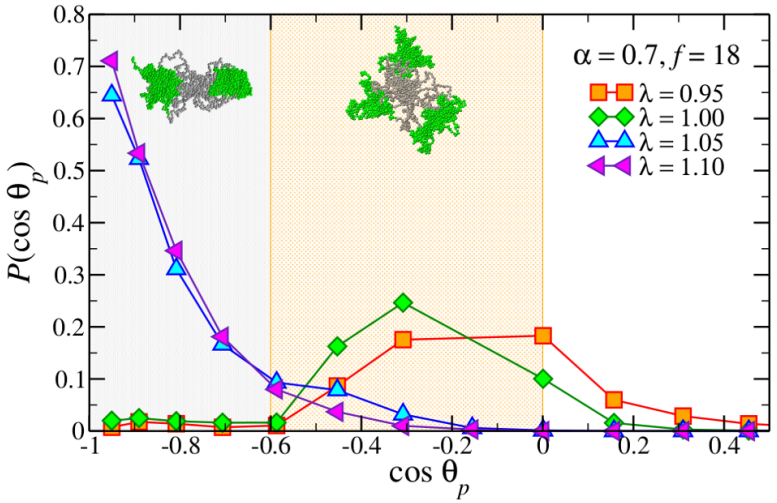


[1] LR *et al.*, *Nanoscale* (2015)

Outlook and conclusions

- TSP's self-assemble into soft patchy particles[1]
- Their self-assembly can be finely controlled

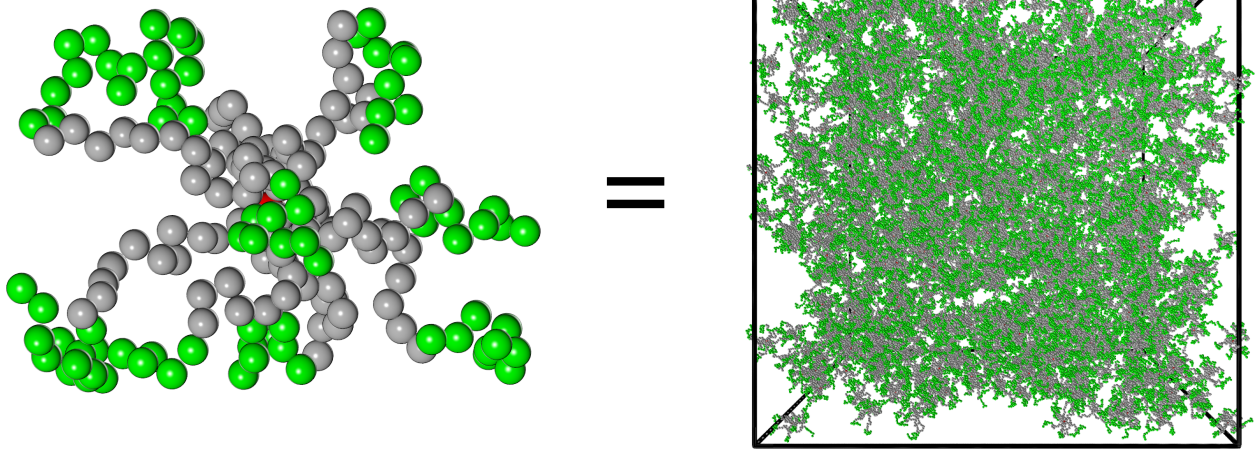




[1] LR *et al.*, *Nanoscale* (2015)

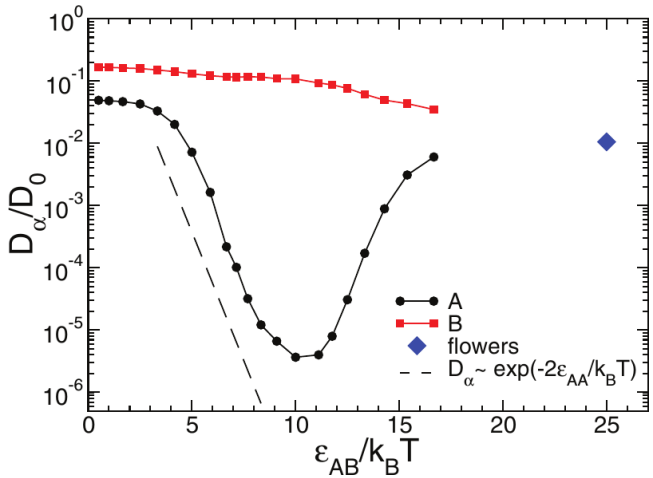
Outlook and conclusions

- TSP's self-assemble into soft patchy particles[1]
- Their self-assembly can be finely controlled
- Single-star properties are retained in the bulk



Outlook and conclusions

- TSP's self-assemble into soft patchy particles[1]
- Their self-assembly can be finely controlled
- Single-star properties are retained in the bulk
- Next step: re-entrant gels[2]



[2]S. Roldan-Vargas *et al.*, *Sci. Rep.* (2013)

Outlook and conclusions

- TSP's self-assemble into soft patchy particles[1]
- Their self-assembly can be finely controlled
- Single-star properties are retained in the bulk
- Next step: re-entrant gels[2]

Thanks for your attention!