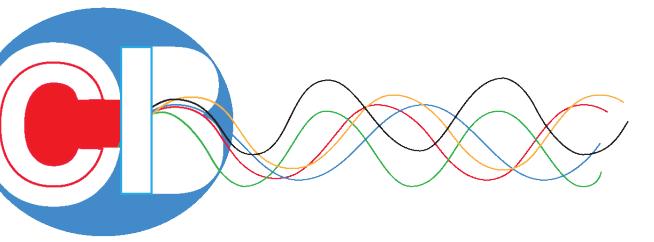


# Investigating the Role of Membrane Composition on the Stability of Decorated Nanoparticle Aggregates

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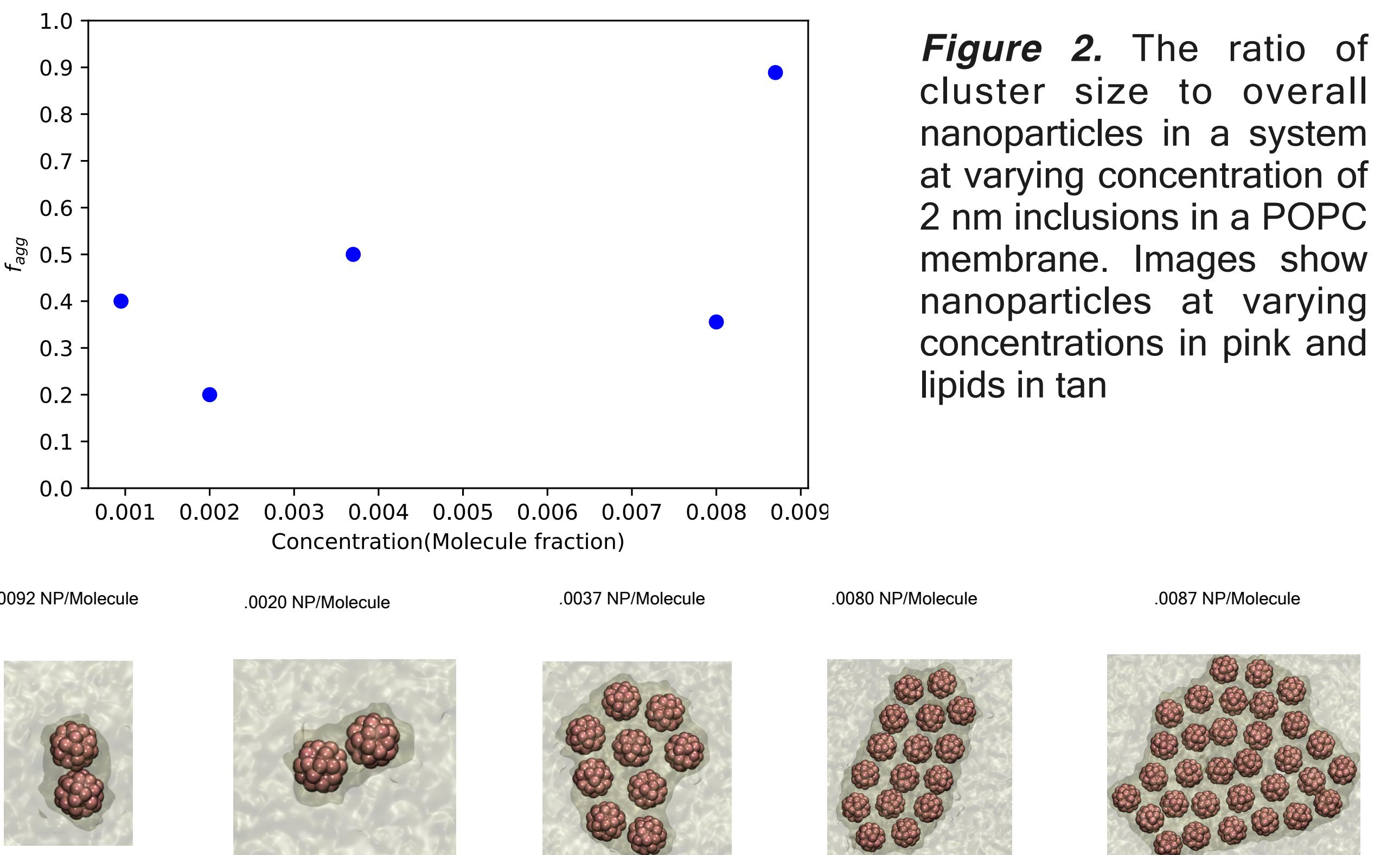
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## Abstract

Interactions between embedded nanoparticles (NP) and lipid membranes depend on various factors, including NP-NP interaction, NP-lipid interaction, and shape based membrane deformation. Using Coarse Grain Molecular Dynamics(CG-MD) via Martini, a simplified model is constructed to observe NP-membrane interactions. We use decorated, hydrophobic ligand coated nanoparticles to probe interactions which stabilize or destabilize aggregates. Aggregation is found to stabilize and destabilize with four membrane traits, nanoparticle concentration, lipid chain length, nanoparticle size and ligand chain length. Significant long-range ordering of decorated nanoparticles and the degree of membrane deformation are influenced by these four traits. NP aggregation is mediated by microscopic lipid deformation.

## Aggregation increases with concentration



## Aggregate shape changes with increase in ligand or lipid length

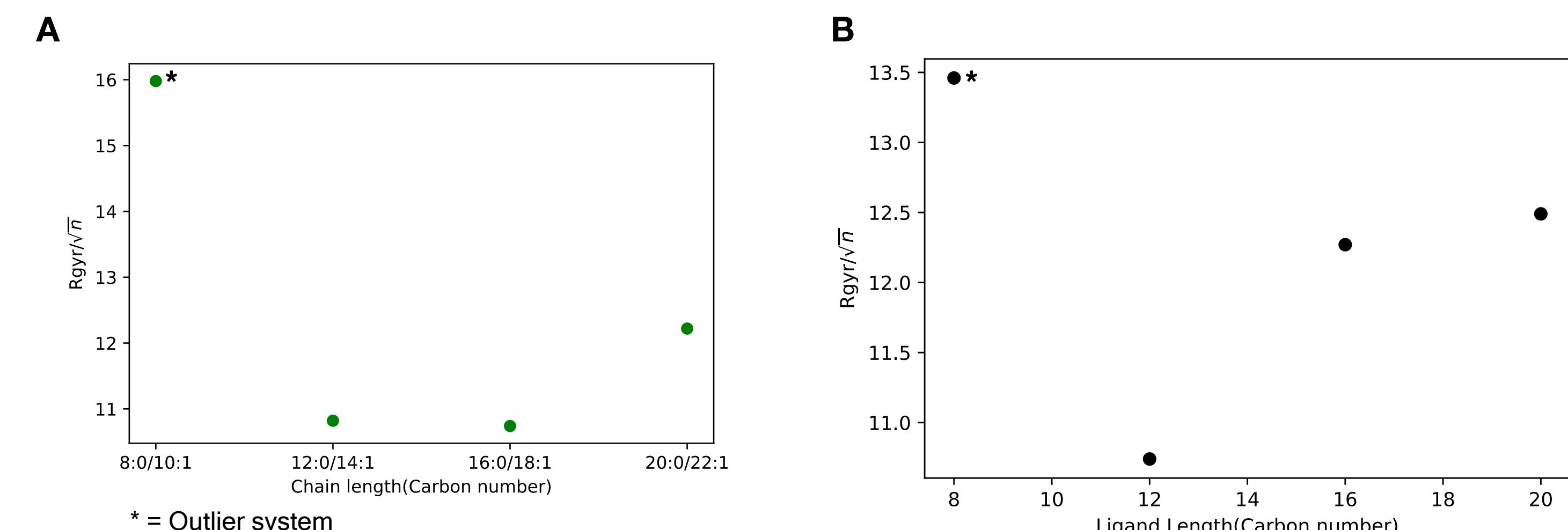


Figure 3. Shape changes in aggregates Normalized dispersion in the radius of aggregates as a function of lipid chain length (A) and ligand chain length (B). Particularly high values correspond to non-planar aggregates (A) or extended aggregates (B).

## Introduction

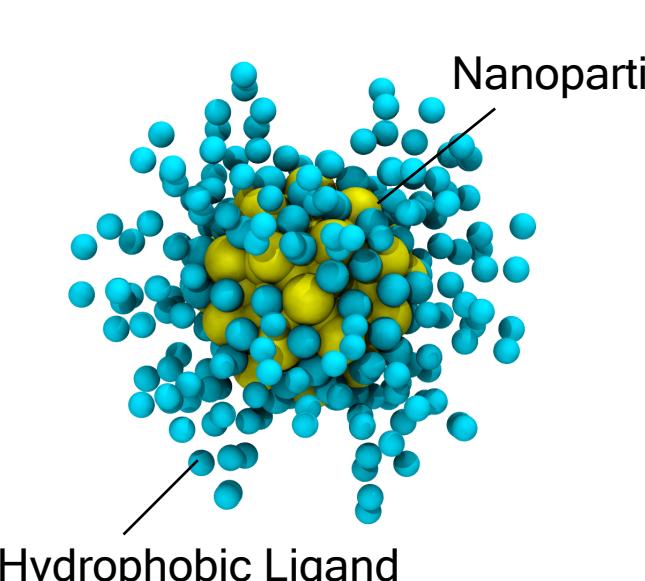


Figure 1. Visualization of a 2 nm inclusion with decorated ligands nanoparticles. NP in yellow and ligands in cyan

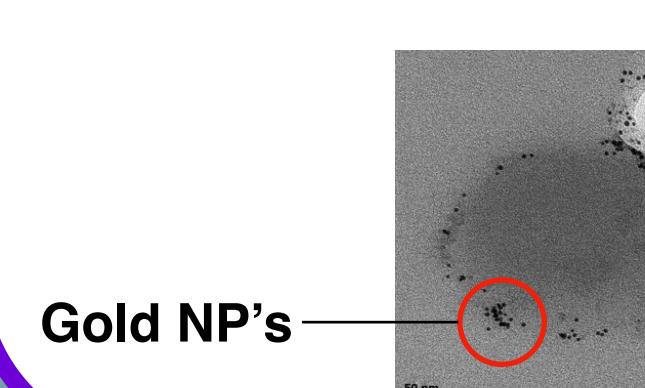
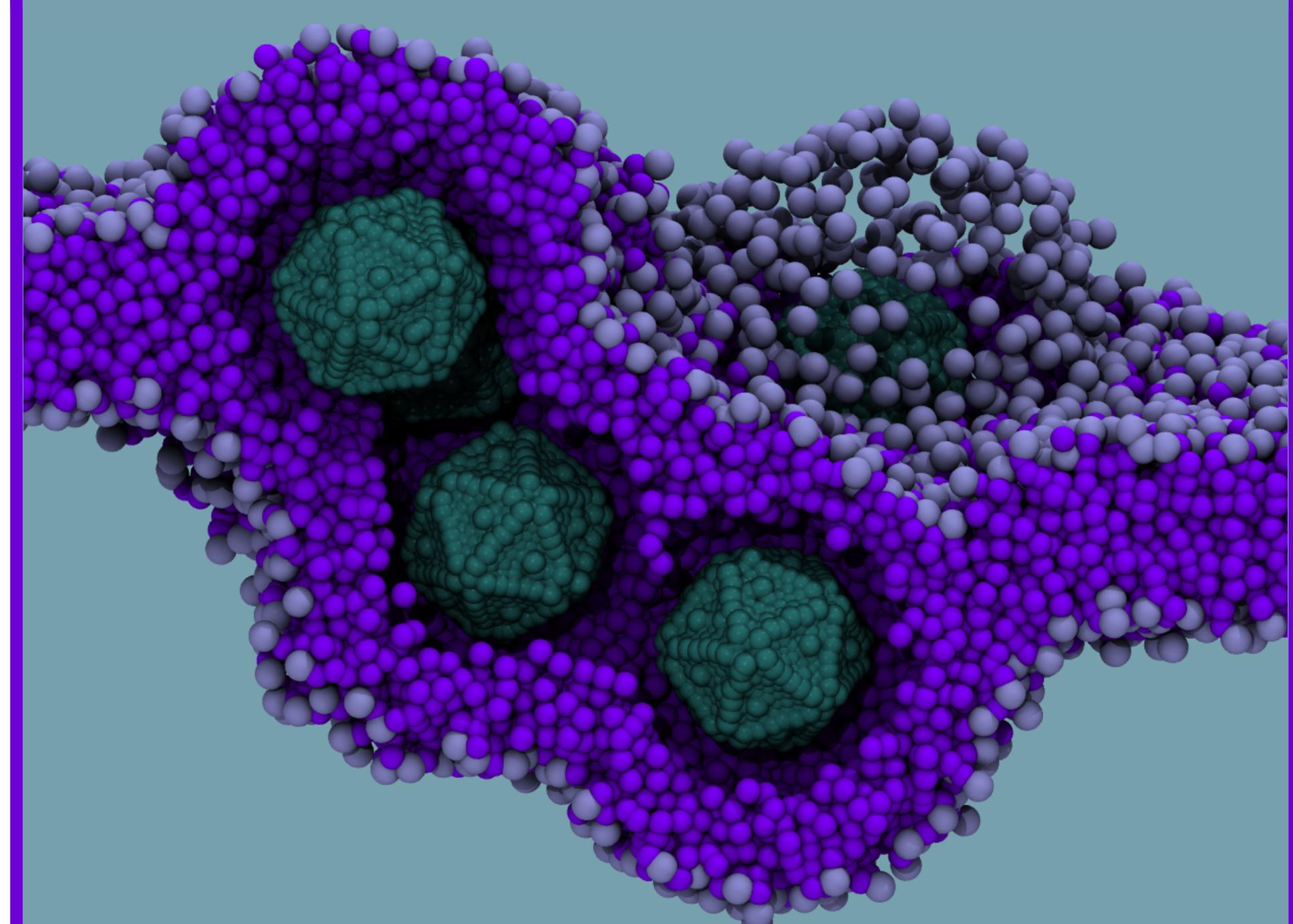


Figure 2. TEM image of liposome with clusters of gold nanoparticles (Black) [3]



## Longer ligands and lipids increase the formation of disk-shaped aggregates

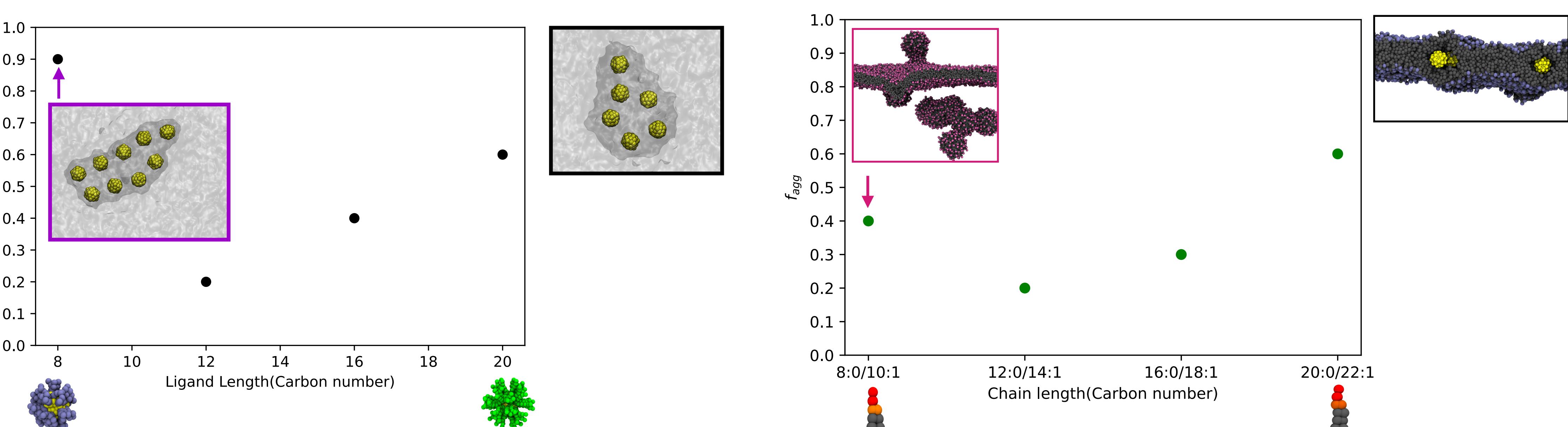


Figure 4 Fractional size of the largest aggregate as a function of ligand length (A) and lipid chain length (B). A) For disk-forming aggregates, increasing ligand length increased the fraction of available nanoparticles in the largest aggregate (green). However, the shortest ligand nanoparticles (octanethiol, purple) yielded long extended aggregates that included most available nanoparticles. B) Similarly, increasing the length of the lipid chains increased the size of the largest planar aggregate (iceblue). However, the same nanoparticles in short-chain lipids formed non-planar aggregates that were ejected from the bilayer.(pink)

## Summary

- We observed most nanoparticles pack in stable hexagonal arrays if the concentration was sufficiently high, with the following exceptions:
- Nanoparticles with short decorating ligands formed extended aggregates
- Nanoparticles were ejected from particularly thin membranes
- For a given concentration, the size of the aggregates increased with ligand length and with membrane thickness
- However, the aggregate size was relatively insensitive to overall NP size, even though larger aggregates caused visible membrane deformations
- These results suggest that disk-like aggregation is dominated by lipid chain packing disruptions, not larger scale membrane deformations

## Approach

We investigate the mechanism behind nanoparticle aggregation in decorated inclusions by testing 3 mechanisms

Macroscopic lipid Deformation

Microscopic lipid Deformation

Ligand Chain Entropy

- To test the mechanisms we ran coarse-grained molecular dynamics simulations of nanoparticle embedded membranes.
- Systems vary with NP concentration, NP size, ligand length and lipid length
- We tracked degree of aggregation and aggregation shape:

$$\# \text{ of NPs in the largest aggregate } (n)$$
$$\text{fraction in the largest aggregate } (f_{agg}) = n/n_{tot}$$

$$\text{Normalized radius of gyration: } \frac{R_{gyr}}{\sqrt{n}} = \sqrt{\frac{\sum_i (\vec{r}_i - \vec{r}_0)^2}{n}}$$

## Aggregation is insensitive to changes in nanoparticle size

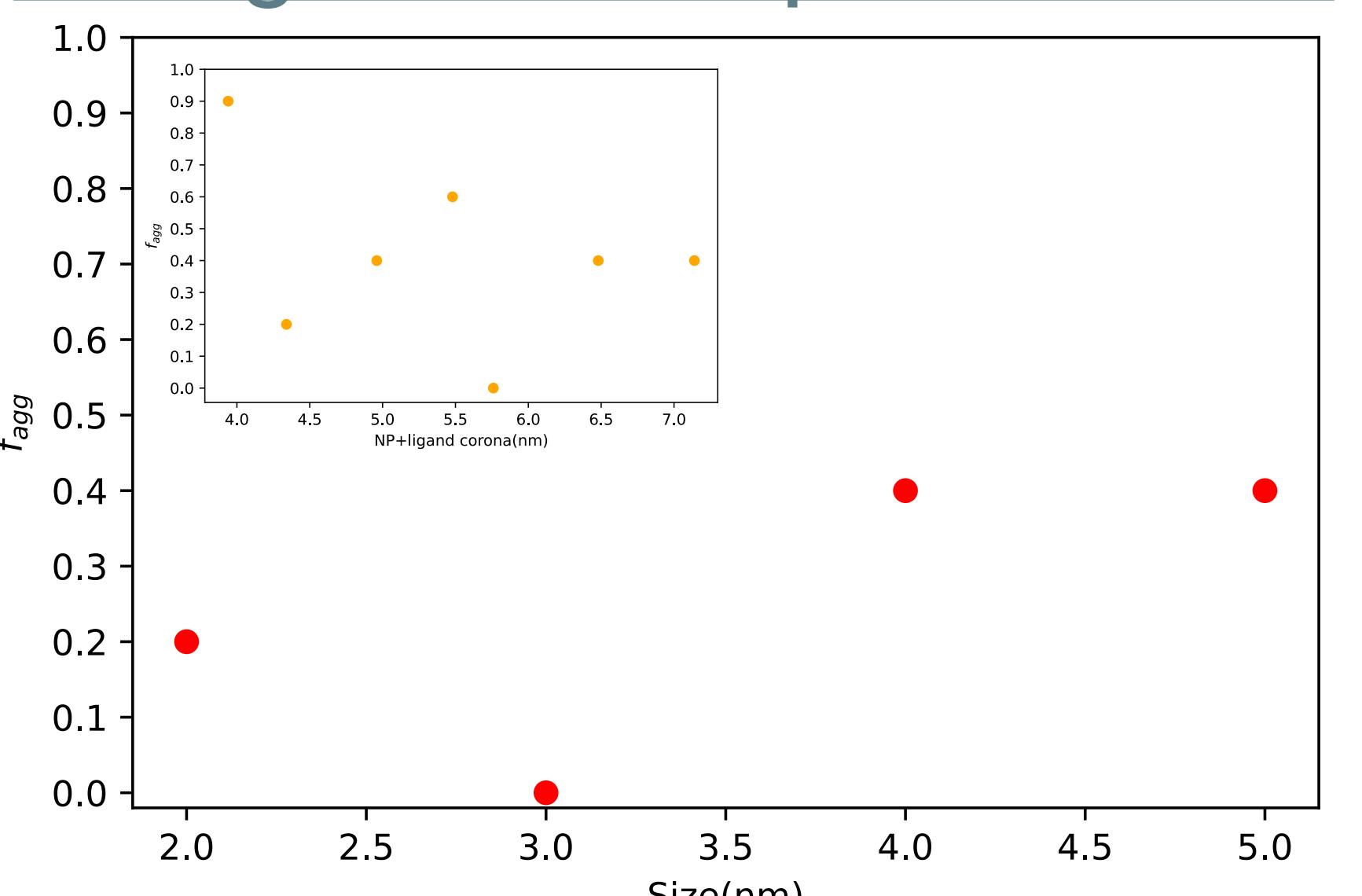


Figure 5. Ratio between the largest cluster and total np's in the system varying with np size. Inset varies with np size plus ligand corona

## References

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- [2] H.Aranda Espinoza, A.Berman, N.Dan, P.Pincus, S. Safran, Interaction between inclusions embedded in membrane, *Biophysical Journal*, Volume 71, Issue 2, 1996, Pages 648-656, ISSN 0006-3495, [https://doi.org/10.1016/S0006-3495\(96\)79265-2](https://doi.org/10.1016/S0006-3495(96)79265-2).
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