LUMINESCENT NANOPARTICLES AS NANOTHERMOMETERS

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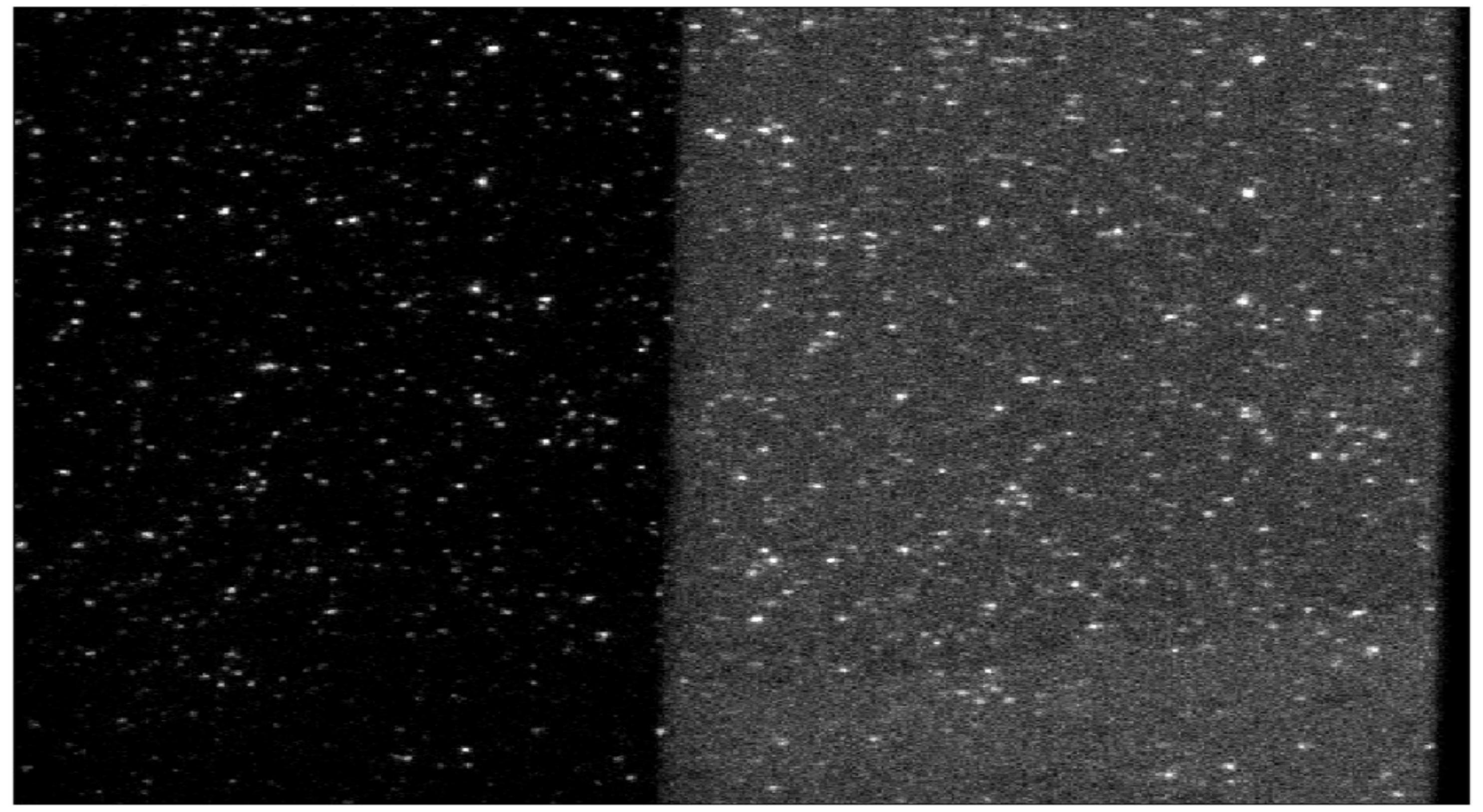
Introduction:

Thermodynamics is a field with numerous uncertainties, partly because temperature is ill-defined at the nanoscale. Temperature is often described as a state variable in terms of other macroscopic parameters, but it is also defined by the average kinetic energy of the system's particles. The goal of this project is to use fluorescent nanoparticles to measure the distribution of kinetic energy at the nanoscale which, because of Brownian motion, has been a poorly defined area for decades. Examining the spectral change (difference between energy distributions) of the particles will allow us to measure the temperature around those particles at the nanoscale!

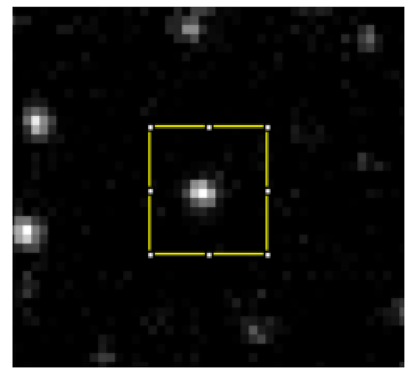
The System:

- The particles are around 50 nm in diameter, and their brightness is affected by the temperature
- The data was acquired from a movie of the particles at 35°C .
- A screenshot of the system of particles is shown below, notice that the image is split!
- Each side of the image represents a different **spectral range** (the range of light wavelengths detected by the camera)
- We can use the ratio of the brightness of a particle in each spectral range to approximate the temperature of that particle



Pesky Noise:

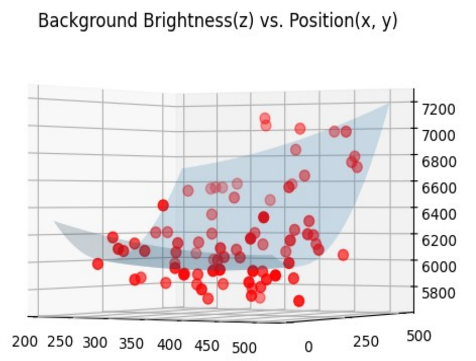
- To make sure that all brightness due to the particle is included, several boxes were made around the particle of increasing size. One 15 square pixel box looks like:



- The brightness of the particle is found when the brightness within the boxes reaches a constant as the box size increases (with the background brightness/noise subtracted)
- To accurately get the ratio of brightness values at either spectral band, it is important to ensure that the calculated brightness was only that due to the particle. That is, there is background noise (instrumental and perhaps scattering) that needs to be subtracted.

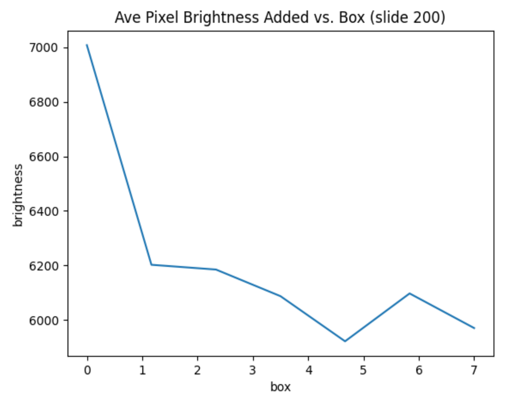
Best Fit Method

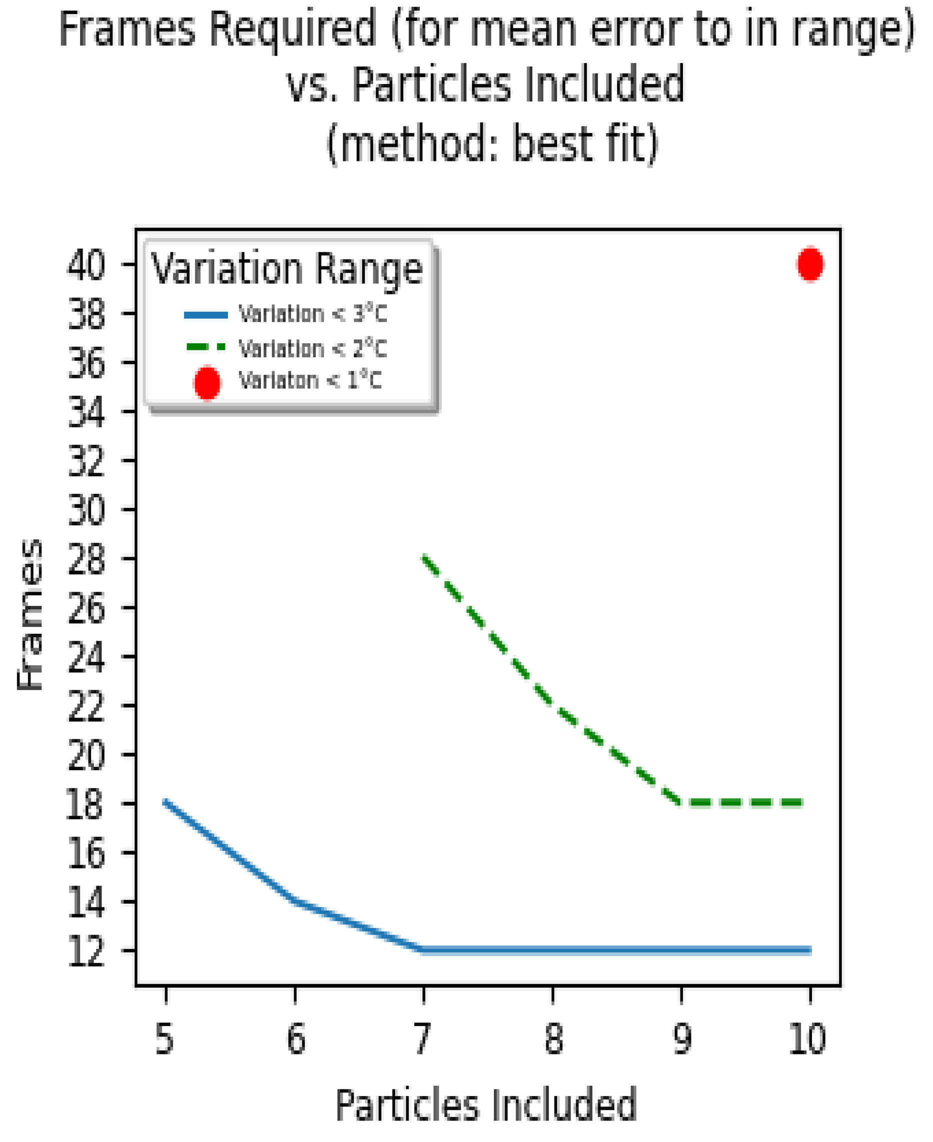
- One way to subtract the background was to collect brightness measurements at empty spaces in the image, and then construct a best fit surface to give an equation for the brightness at every point in the image. To the right is one sample best fit curve for a slide in the left spectral band.

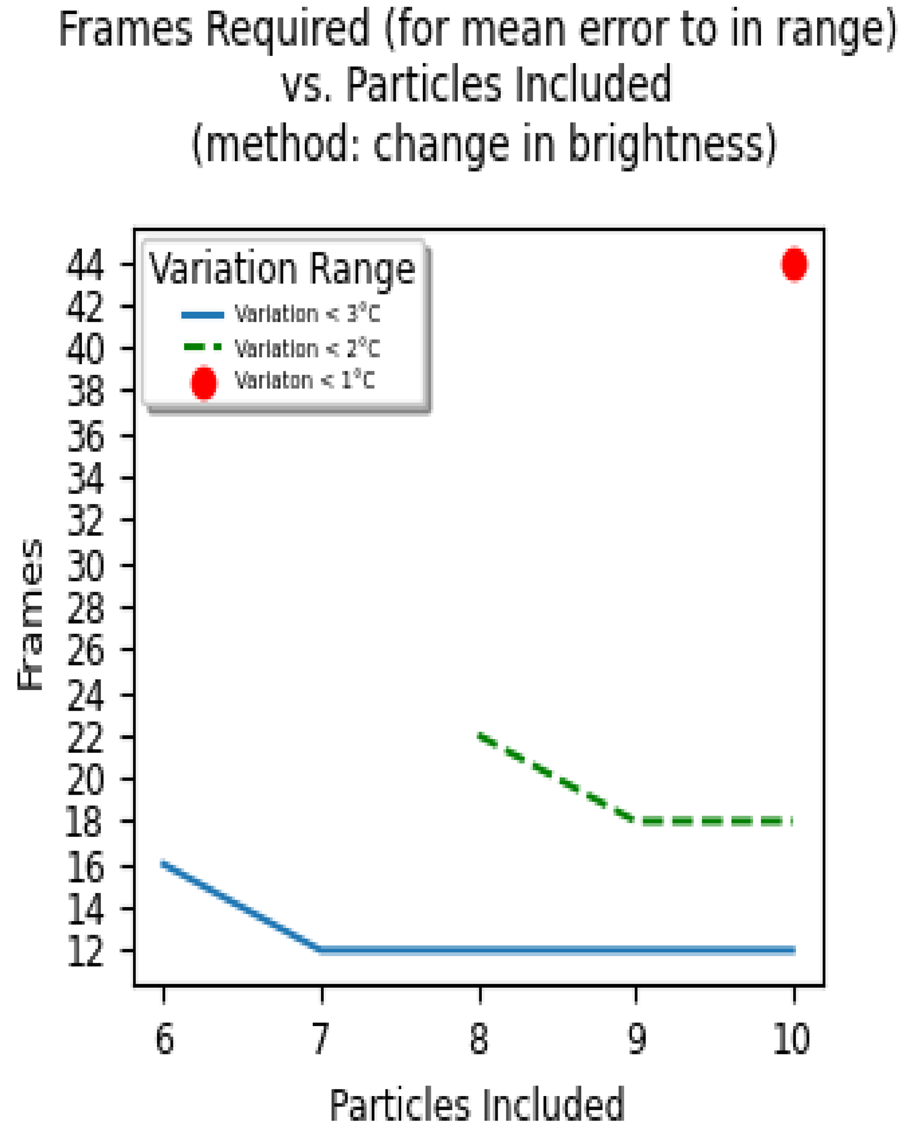


Change in Brightness Method

- The other employed strategy was to calculate the rate of change of brightness within each box for expanding size. This rate of change eventually reaches a constant, approximating the background of the particle. A sample of the change in brightness for each box size around one particle is shown to the right. Box 0 is 6 square pixels, and each box increase adds 2 pixels to the width and height. The average of the last 4 boxes was used as the brightness value.







How well do they work?

That is, how many particles and frames of each movie have to be included in the average temperature value to give the temperature of the system? The above graphs show how many frames of the movie are needed to get the average temperature value within the range specified in the legend, versus the number of particles included. Generally, more frames and more particles implies a smaller deviation from the set temperature of the system; the critical ranges are shown by the graph.

Calculating Temperature from the Ratio Values:

- Once the intensity due to the particle is found for each side, the ratio is found by dividing the intensity on the right by that on the left.
- To convert to a temperature value, some additive constant, x, needs to be determined to apply to this equation:

$$Temp = \frac{Ratio - x}{0.013}$$

- The method to attain these constants was find the average ratio for each particle through the last 200 frames, average all of these ratio values together, and then find the additive constant such that this total average ratio yields 35°C (in the above equation).