

## Hierarchical Structure and Application

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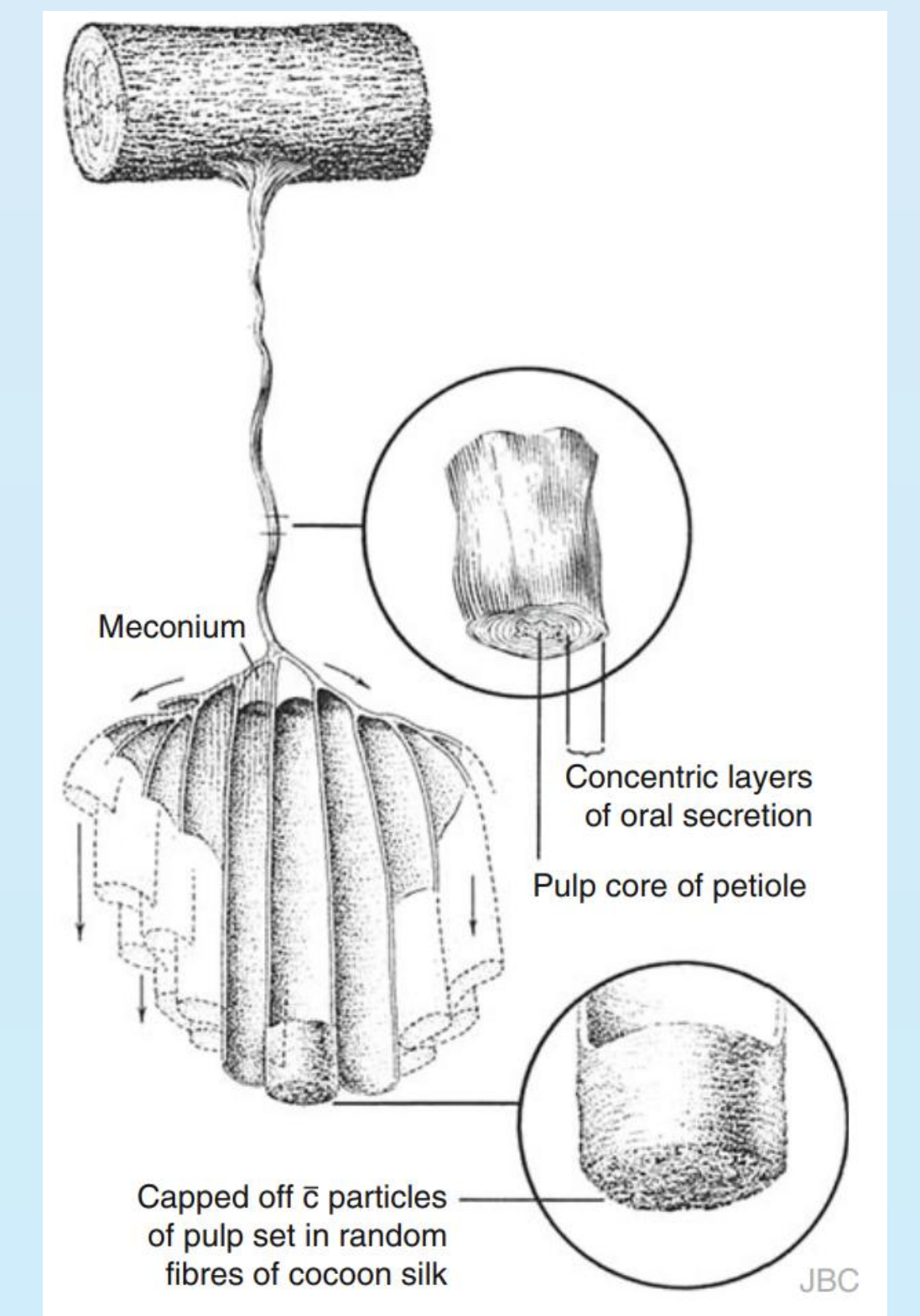


Figure 3: Diagram of *Mischocyttarus* wasp nest.  
• Nests are made from cellulose fibers that have been processed into pulp by the wasps<sup>5</sup>.  
• Stalk composed of tightly packed circular layers of cellulose fibers<sup>5</sup>.  
• Larval Cells are composed of randomized cellulose fibers<sup>5</sup>.

### Introduction:

- Biomass is organic material that comes from plants and animals and is a renewable source of energy<sup>1</sup>.
- Cellulose is a type of biomass that is most commonly present in plants to provide structure.
- Animals, like paper wasps, reuse cellulose from plant matter to build their nests<sup>5</sup>.
- Paper wasp nests are incredibly strong and durable, withstanding the harshest of weather events.
  - Stalks appear to be thick, strong, and linear, whereas the larval cell walls appear to be randomly oriented, soft, and insulated<sup>5</sup>.
- Small-angle X-ray scattering (SAXS) is a technique that involves shining an X-ray of uniform wavelength at a sample to measure how the light scatters as it travels through the sample<sup>3</sup>.
  - Can show fiber density, particle size, and orientation<sup>4</sup>.
  - If paper wasps can control the directionality and type of fiber used in their construction, then their techniques may be applied to the modern manufacturing of biomass consumer goods.

### Methods:

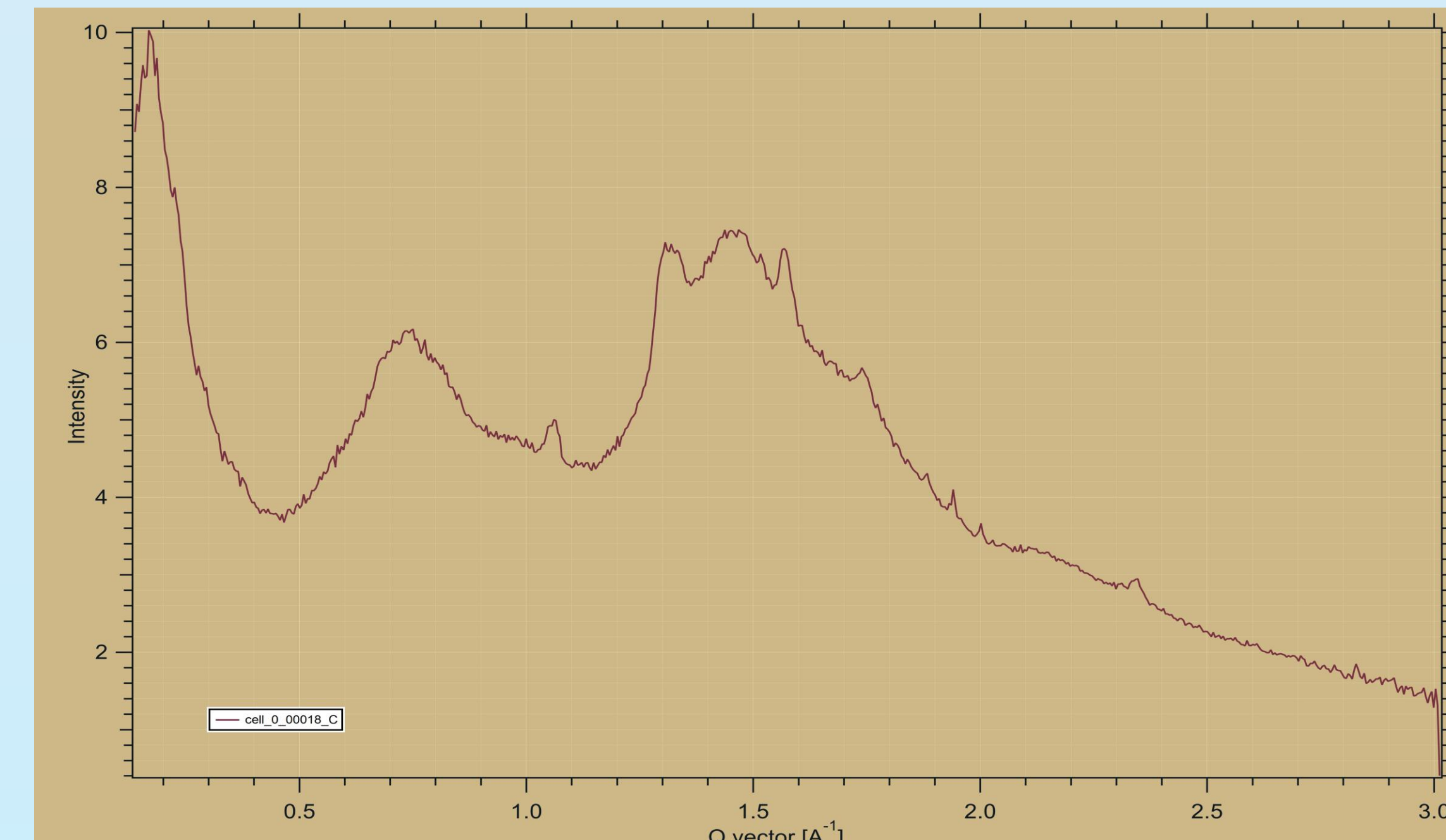
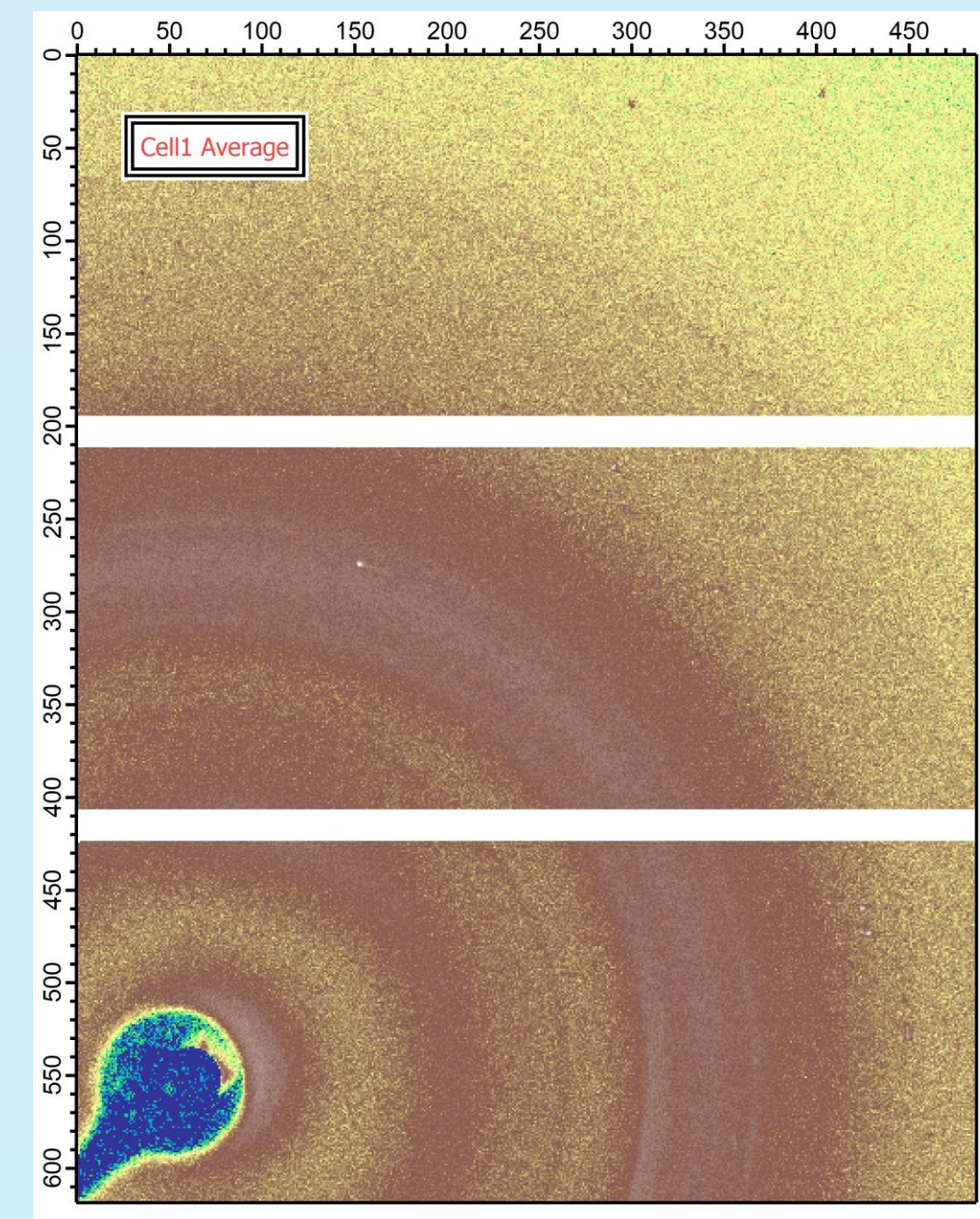
Paper wasp nest material was obtained from the FAMU Department of Entomology. Samples included:

- Two larval cell samples
- One stem/stalk sample

Samples were cut to size before undergoing Small-Angle X-Ray Scattering (SAXS)

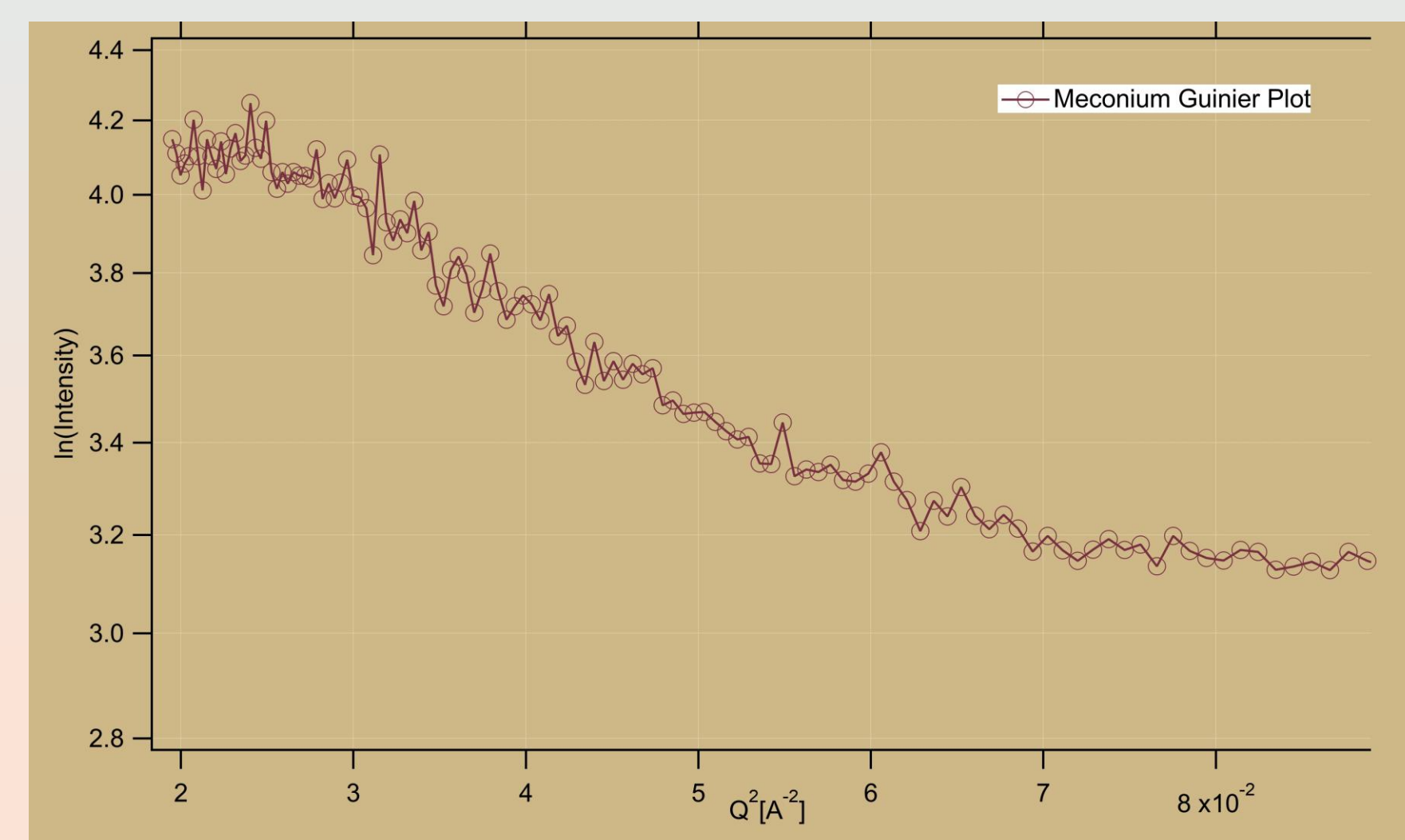
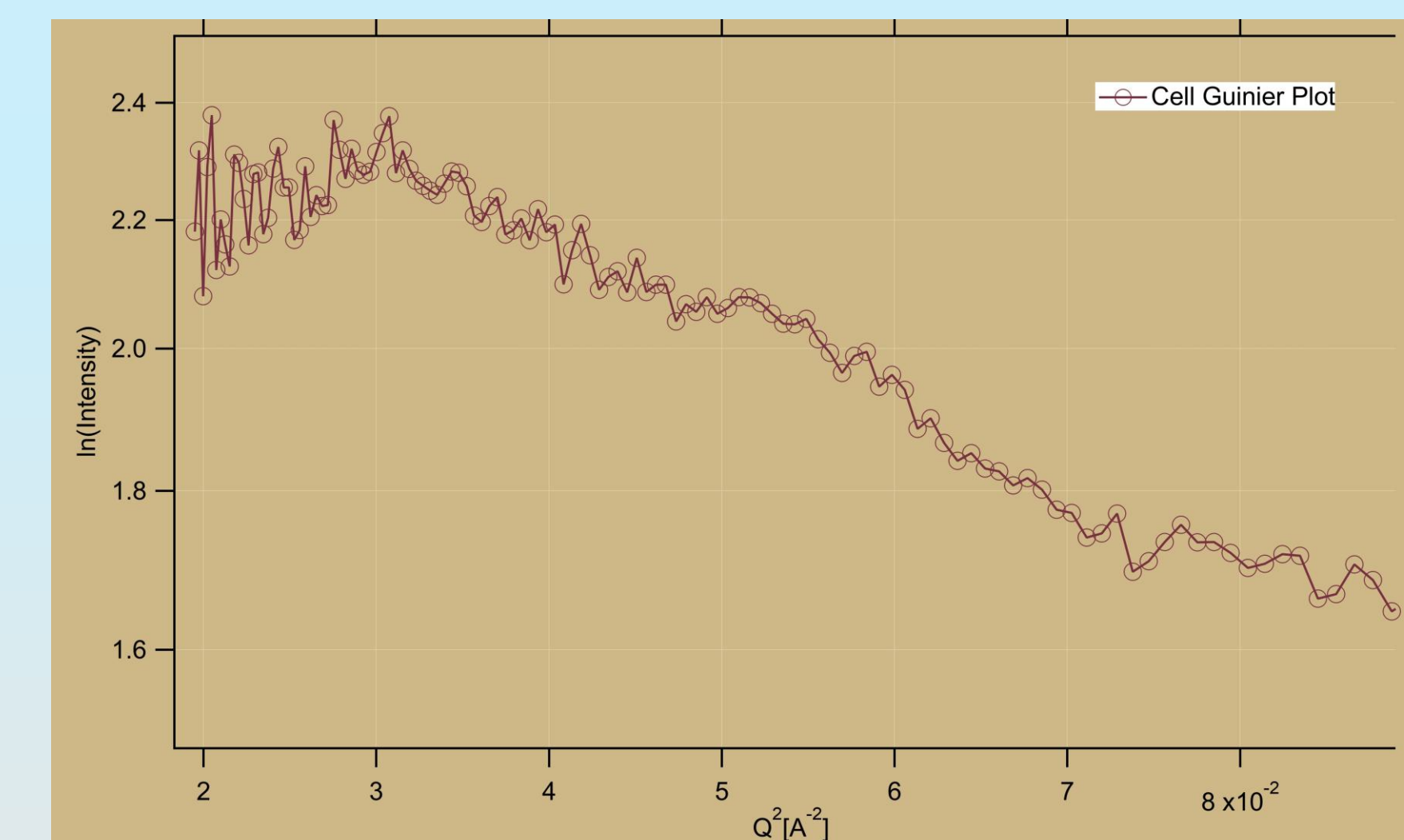
The IgorPro software with the NIKA SAXS macro was used to process all data.

- 2D diffraction fields were then transformed into a 1D graph to show fiber density, size, and orientation.
- Cu X-ray source with  $\lambda = 1.54\text{\AA}$
- Mask was made to cover blind spots from machine.
- Guinier Analysis:  $I(Q) \approx I(0) \exp \frac{-q^2 R_g^2}{3}$
- Radius of Gyration (Distance from electrons to center of particle):  $R_g \approx \sqrt{\frac{3 \ln \left( \frac{I(Q)}{I(0)} \right)}{-Q^2}}$



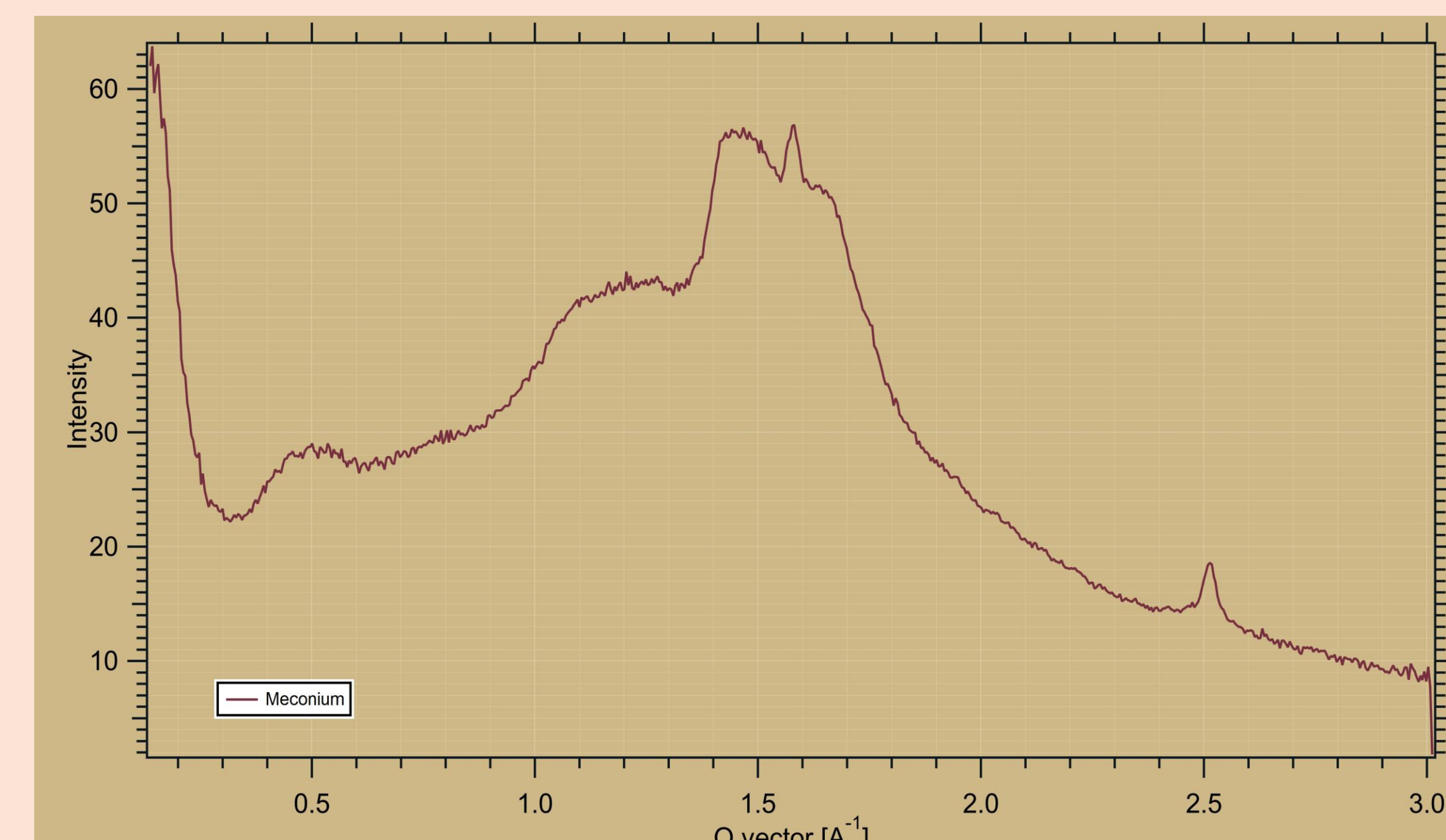
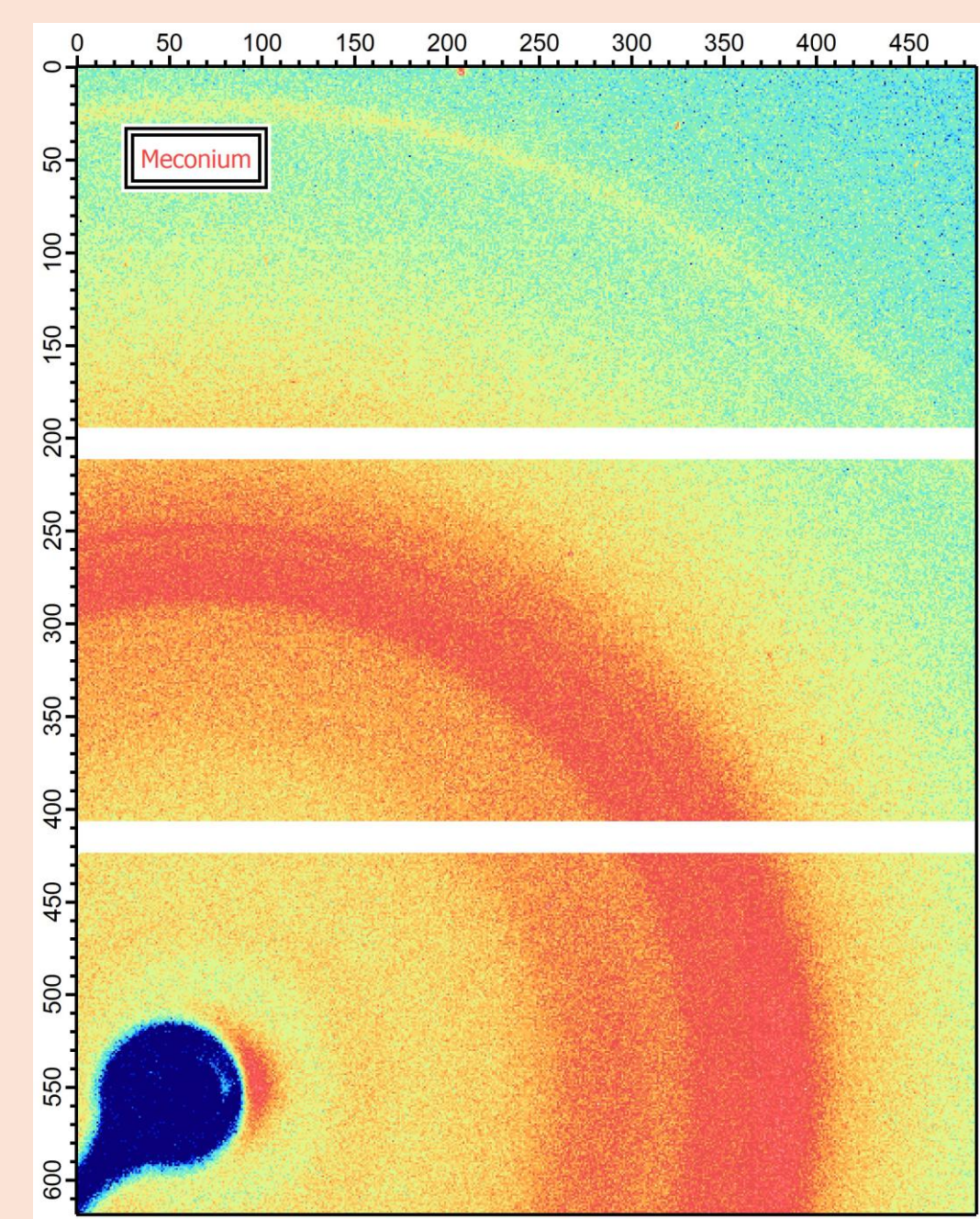
Figures 1A (Left), 1B (Top Right), and 1C (Bottom Right):

- 1A: 2D X-Ray diffraction pattern of larval cell wall.
- 1B: 1D projection of 2D field placing Intensity against the Q-Vector (Scattering Vector).
  - Lower Q-values refer to larger structural features in the sample whereas higher Q-values refer to smaller structural features<sup>4</sup>.
  - High intensity refers to a higher concentration of particles in a set size range<sup>4</sup>.
- 1C: Guinier Plot of larval cell tissue placing  $\ln(\text{Intensity})$  against the square of the Q-Vector.
  - Downward curving slope shows particle repulsion in the structure of the larval cell wall<sup>2</sup>.



Figures 2A (Bottom Left), 2B (Bottom Right), and 2C (Left)

- 2A: 2D X-Ray diffraction pattern of stalk support.
- 2B: 1D projection of 2D field placing Intensity against the Q-Vector (Scattering Vector)
  - Shows lower concentration of large structural features, and higher concentration of small structural features in comparison with Figure 1B<sup>4</sup>.
- 2C: Guinier Plot of stalk support placing  $\ln(\text{Intensity})$  against the square of the Q-Vector.
  - Upward curving slope shows particle aggregation in the stalk support structure<sup>2</sup>.



### Results:

- The 1D projection of the larval cell sample (Figure 1B) shows that the larval cells possess both a high concentration of large particles and small particles.
  - Peak  $R_g$  values: 1.4  $\text{\AA}$ , 0.61  $\text{\AA}$ , 0.51  $\text{\AA}$ , 0.50  $\text{\AA}$
- Guinier Analysis (Figure 1C) shows that these particles tend to repel each other, shown by a downward-facing curve.
- The 1D projection of the support structure sample (Figure 2B) shows that the support structure possesses a higher concentration of small particles than large particles.
  - Peak  $R_g$  values: 0.43  $\text{\AA}$ , 0.30  $\text{\AA}$
- Guinier Analysis (Figure 2C) shows that these particles tend to attract each other and aggregate, shown by an upward-facing curve.

### Discussion:

- Paper wasps appear to have control over the particle size and orientation used in different nest structures.
- Cells contain larger particles that repel each other, and stalks contain smaller particles that attract each other.
- Next steps:
  - Identify enzymes in paper wasp saliva
  - Isolate enzymes
  - Determine whether the enzymes cause ordering in cellulose pulp when isolated.

### Acknowledgements:

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### Bibliography: QR Code

