CENTER FOR BIOTECH DATA SCIENCE
CENTER FOR FOOD CHEMISTRY AND TECHNOLOGY

Developing a Segmentation Model for Microscopic Images of Microplastics Isolated from Clams

Ho-min Park | 01-10-2021 | MAES Workshop @ ICPR

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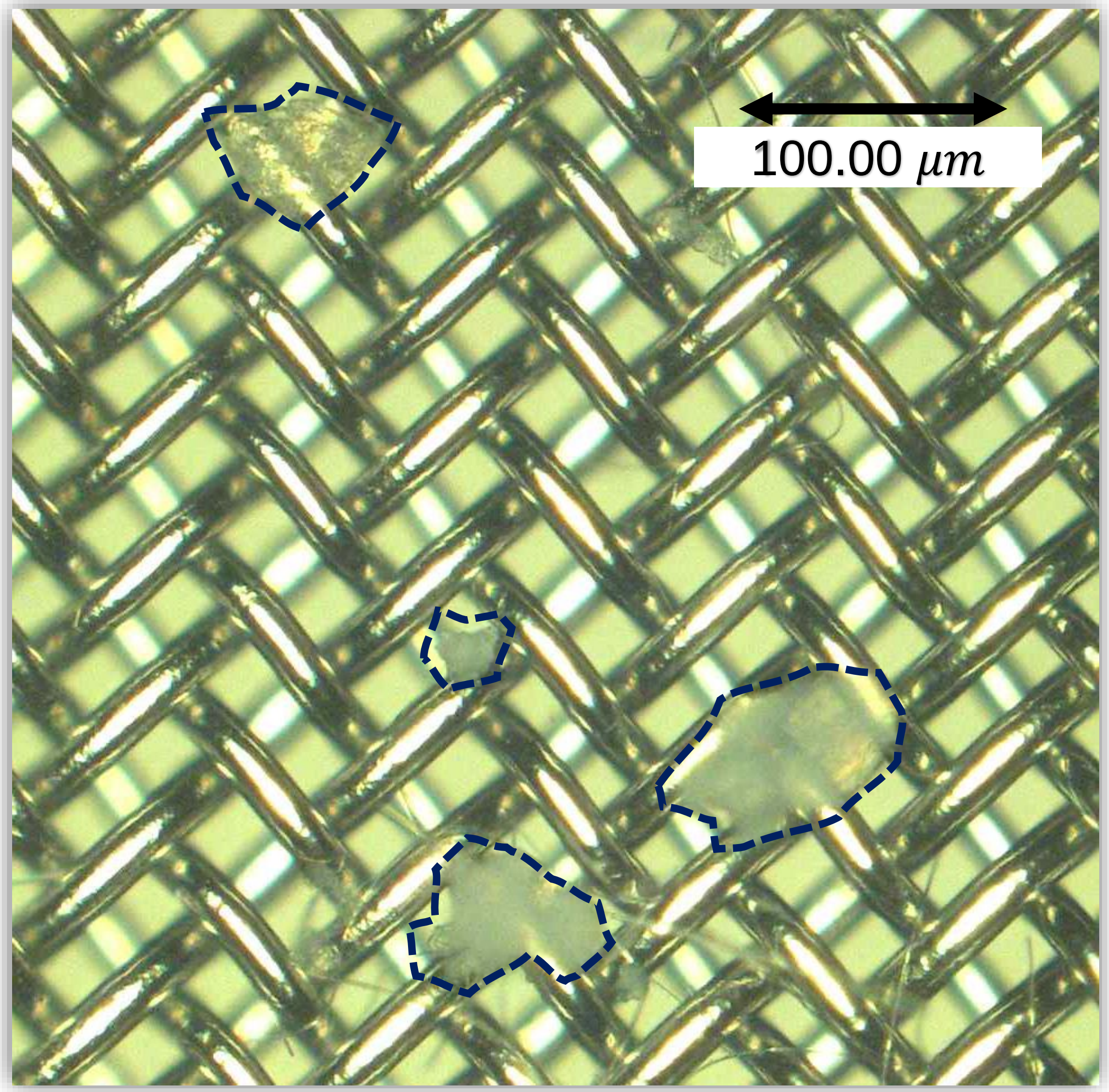
MICROPLASTIC (MP) – CHARACTERIZATION

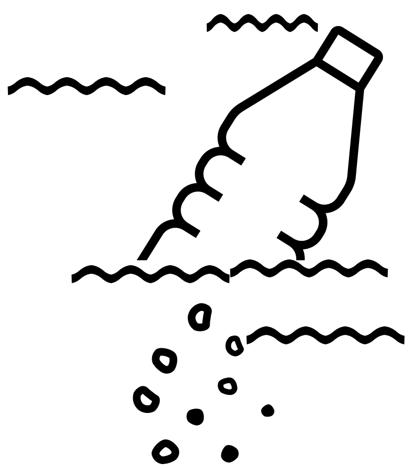


Type	Size
Macroplastic	> 5 cm
Mesoplastic	5 cm - 5 mm
Microplastic	**5 mm - 0.1 μm**
- Large MP	**5 mm - 1 mm**
- Small MP	**1 mm - 0.1 μm**
Nanoplastic	< 0.1 μm

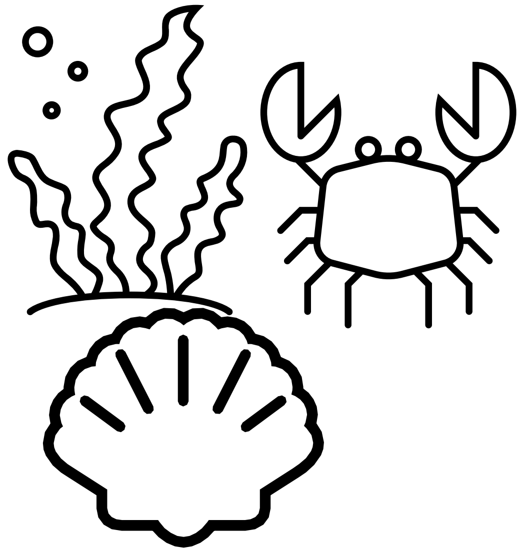
J. Li *et al.*, “Using mussel as a global bioindicator of coastal microplastic pollution,” *Environ. Pollut.*, vol. 244, pp. 522–533, 2019.
Arthur, C., Baker, J. & Bamford, H. Proceedings of the International Research Workshop on the Occurrence, Effects, and Fate of Microplastic Marine Debris. Sept 9-11, 2008. 530 (2009)

MICROPLASTIC CONCENTRATION IN FOOD

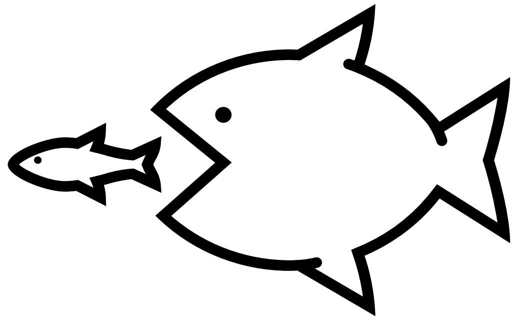
MP derived from plastics



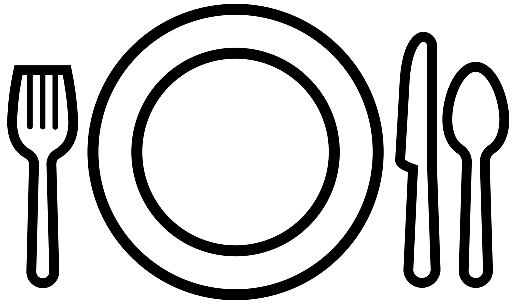
Ingestion by marine biota



Concentration by food chain



Concentration by food chain

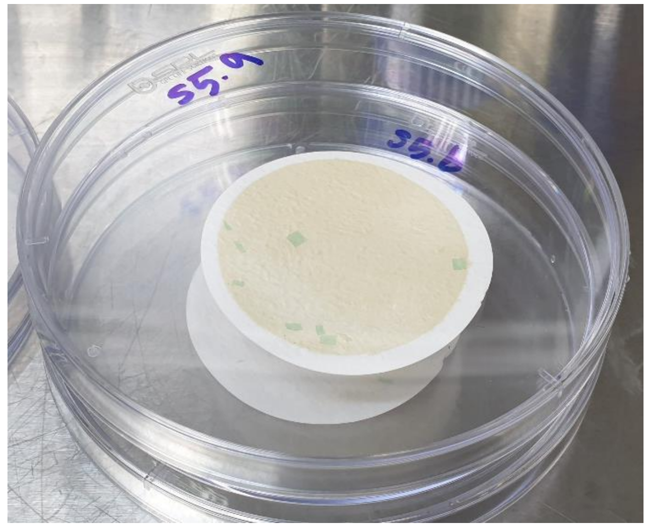


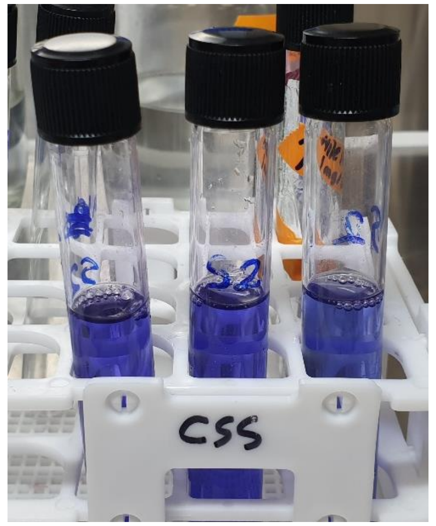
MP monitoring via Manila clams
Needs 8 phases

National Oceanic and Atmospheric Administration. Microplastic Fact sheet. Available at: https://marinedebris.noaa.gov/info/plastic.html.

WET LAB PHASE (PHASE 1 – 4)

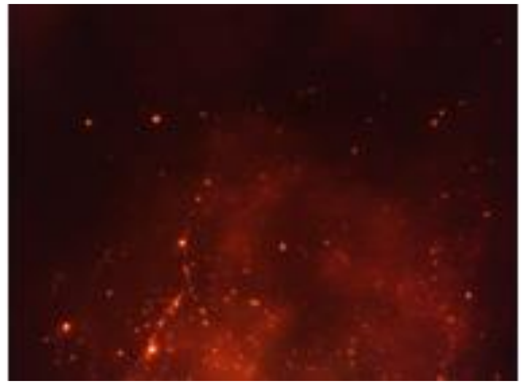
Sampling → Digestion → Filtering → Staining

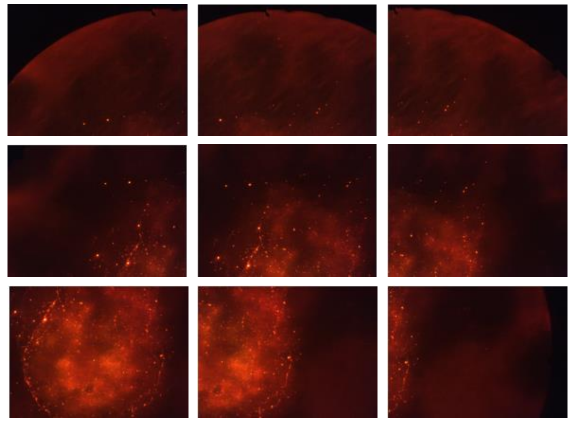


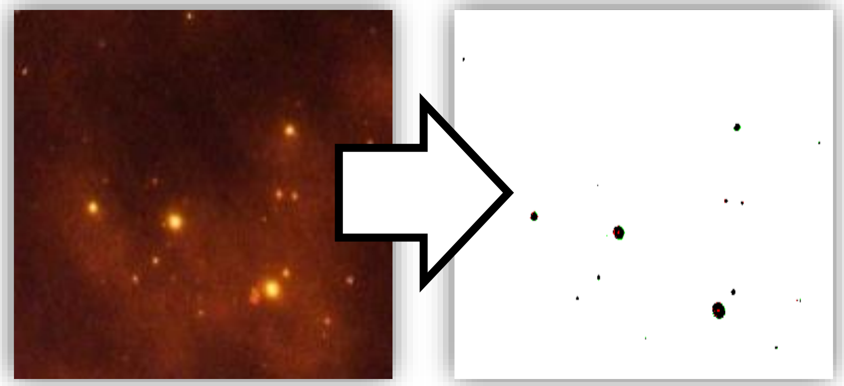


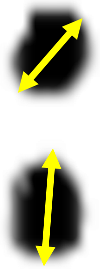
DRY LAB PHASE (PHASE 5 – 8)

Capturing → Stitching → **Binarization** → Counting and measuring



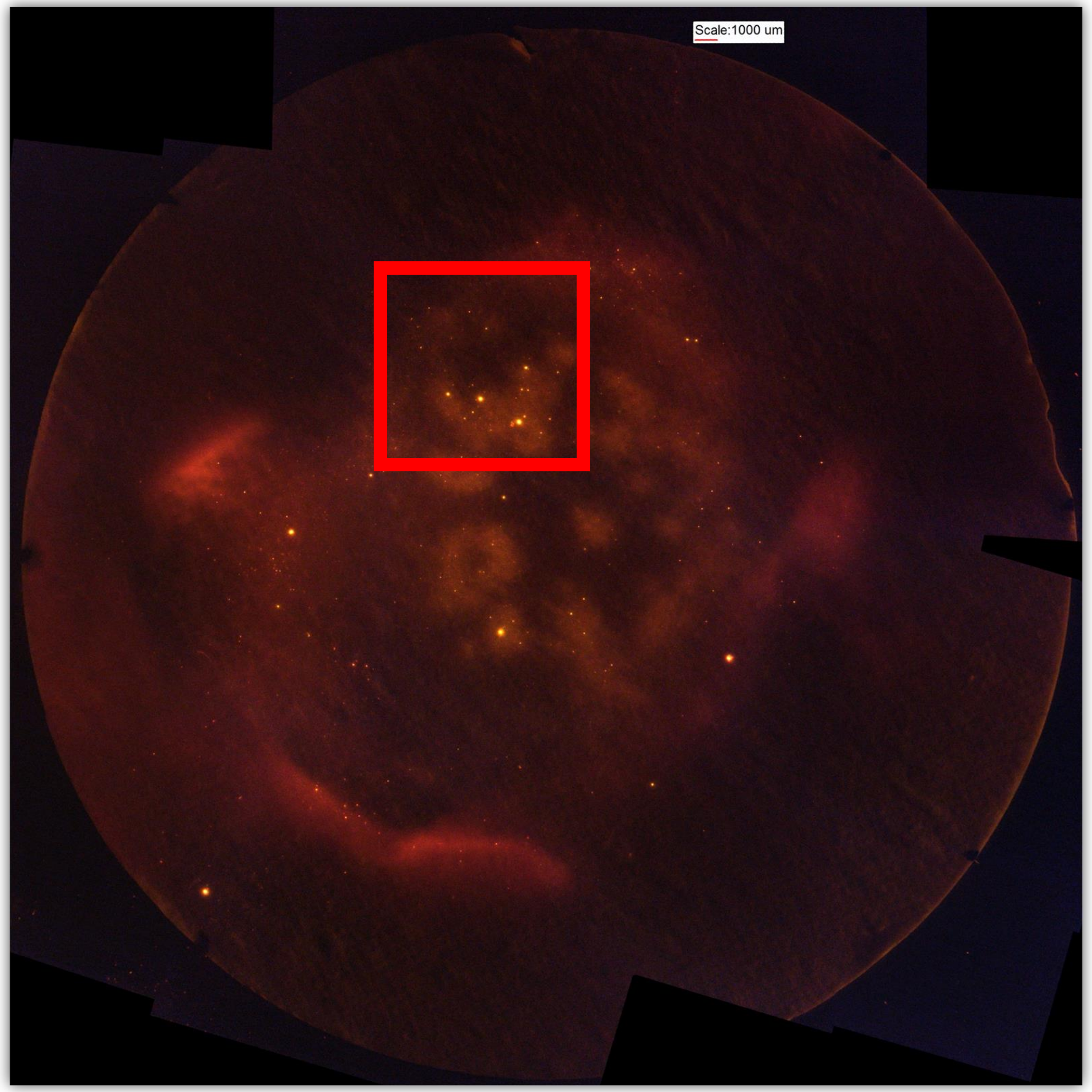




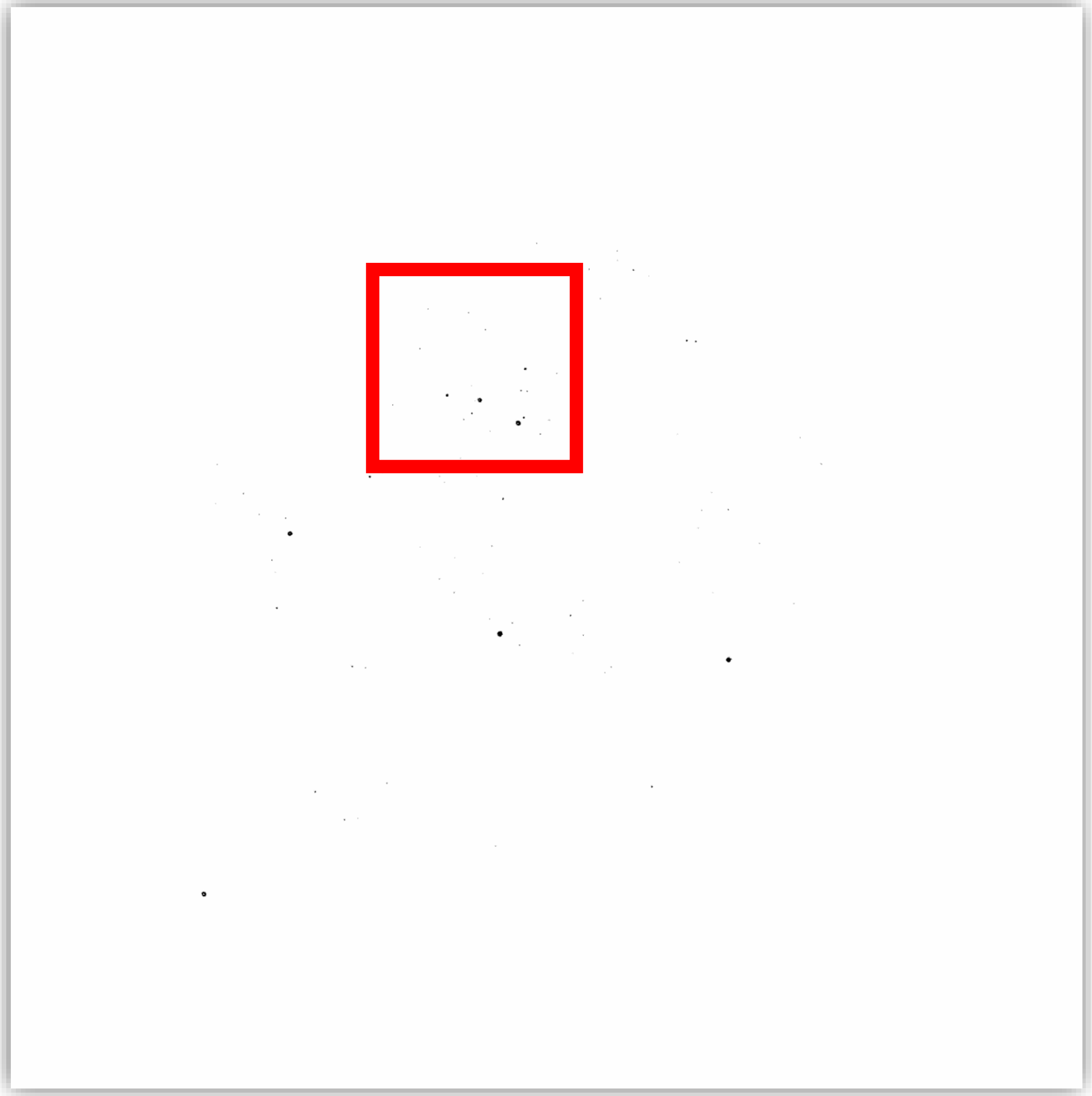


Type: particle
Size: 12μm

Type: particle
Size: 20μm

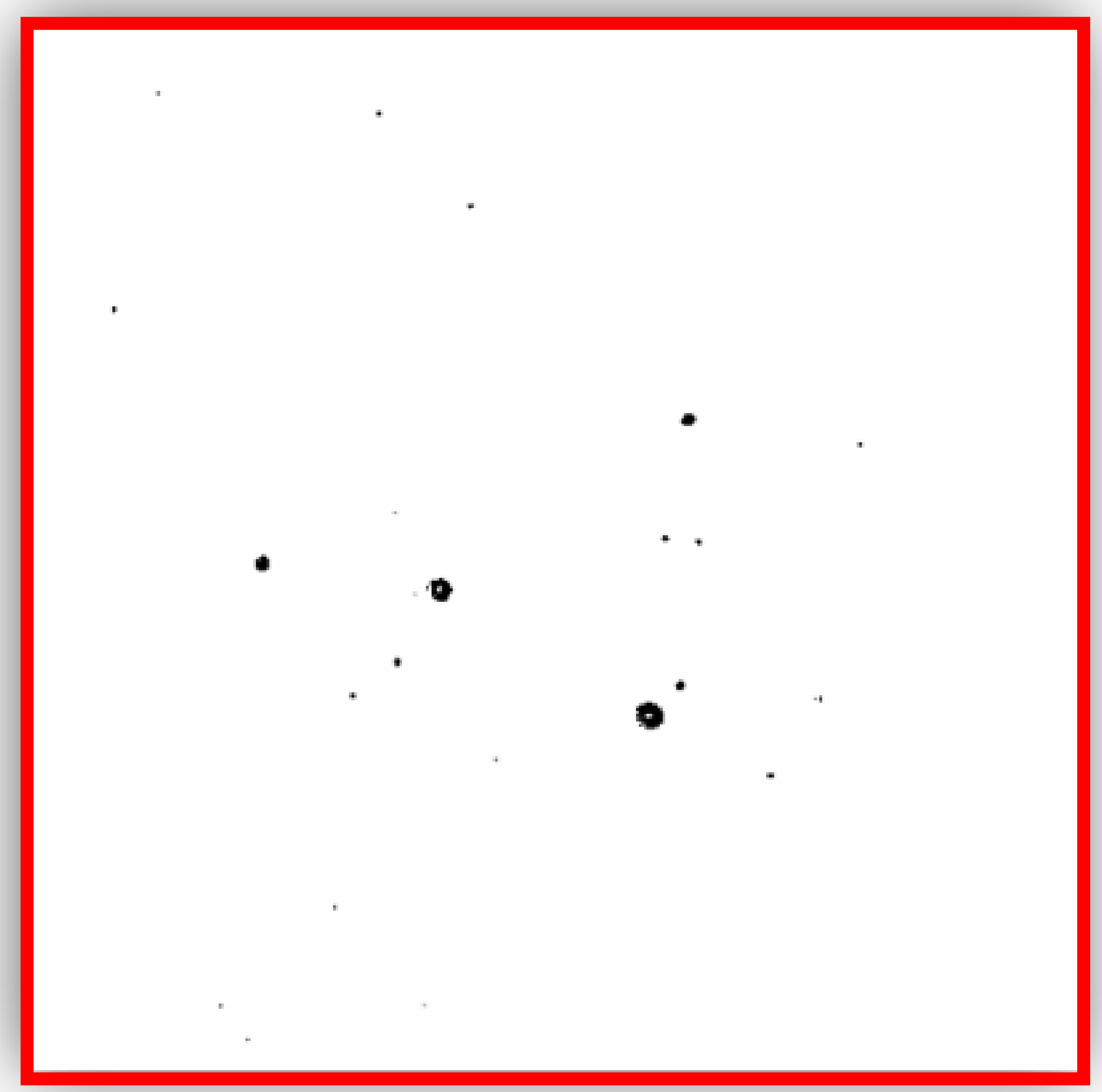


P6: High-resolution fluorescent image (stitched together)



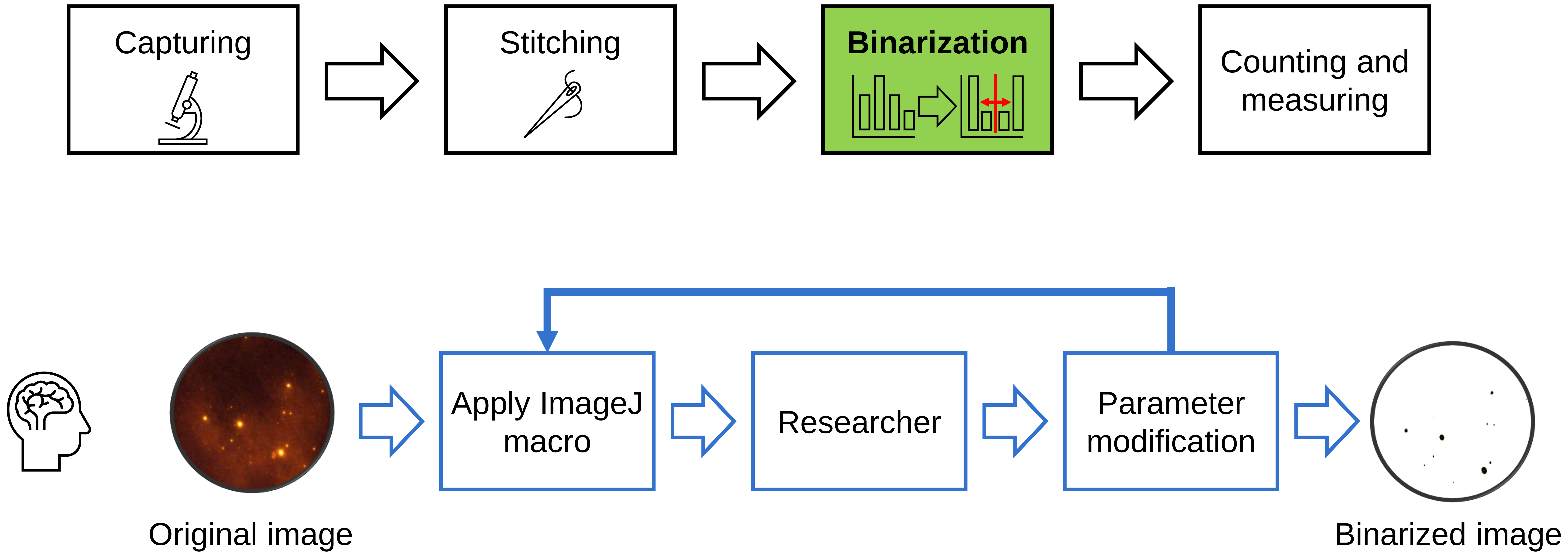
P7: Binarized image (ground truth mask)

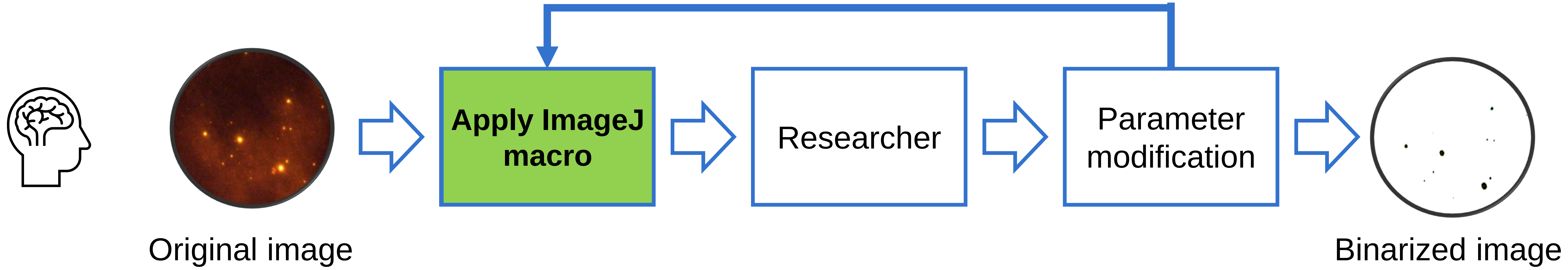
Magnified image

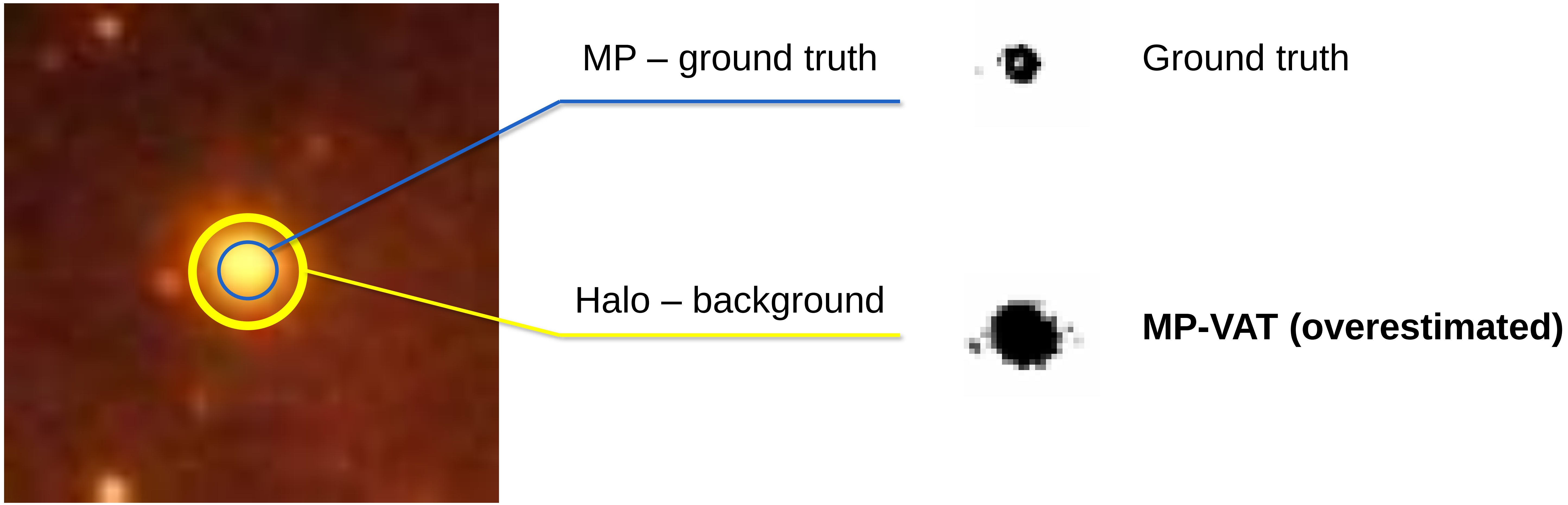


Ground truth

DRY LAB PHASE







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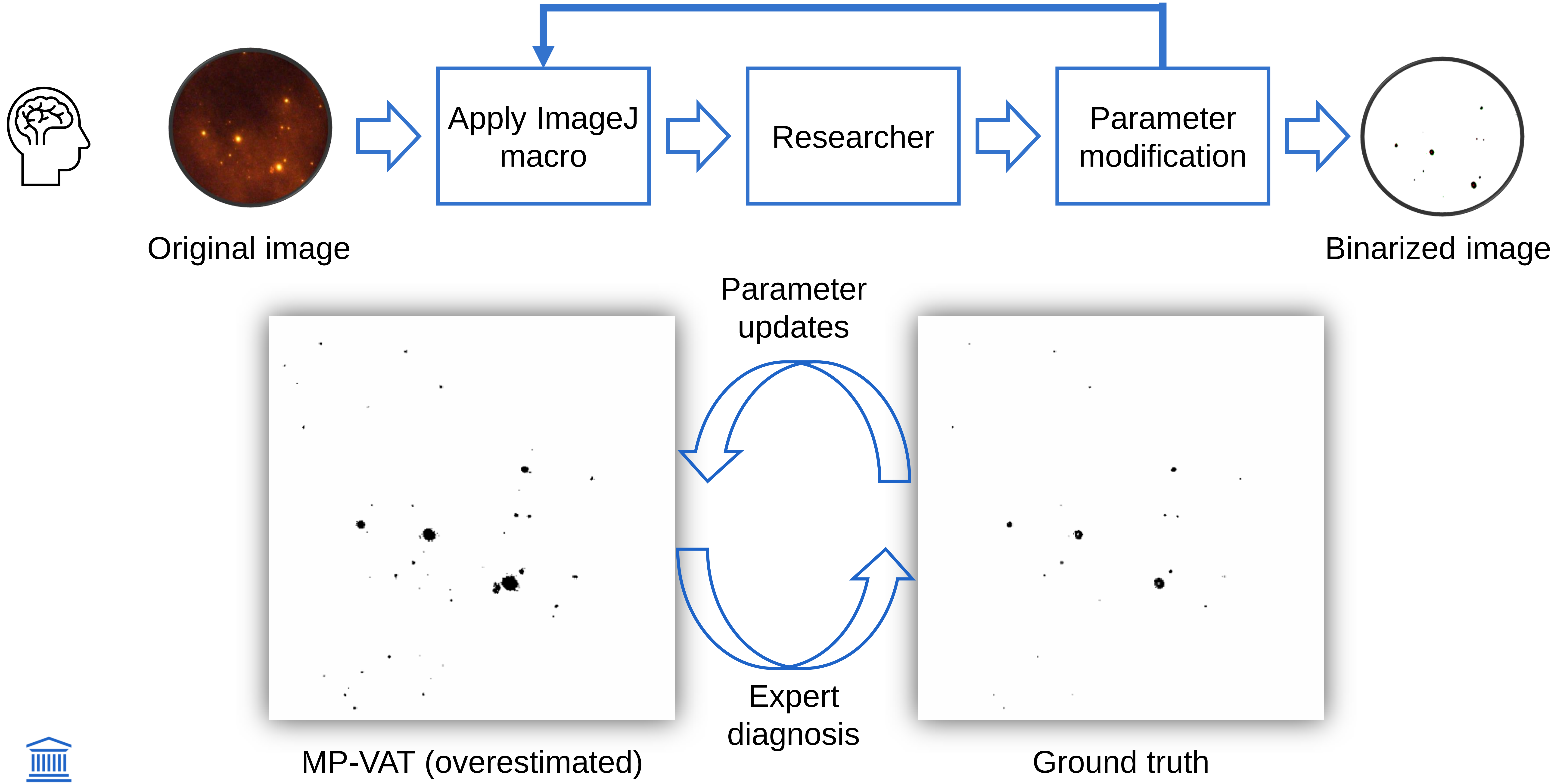
Prata, J. C., Reis, V., Matos, J. T., da Costa, J. P., Duarte, A. C., & Rocha-Santos, T. (2019). A new approach for routine quantification of microplastics using Nile Red and automated software (MP-VAT). *Science of The Total Environment*, *690*, 1277-1283.



Takes 10 – 30 min for labeling

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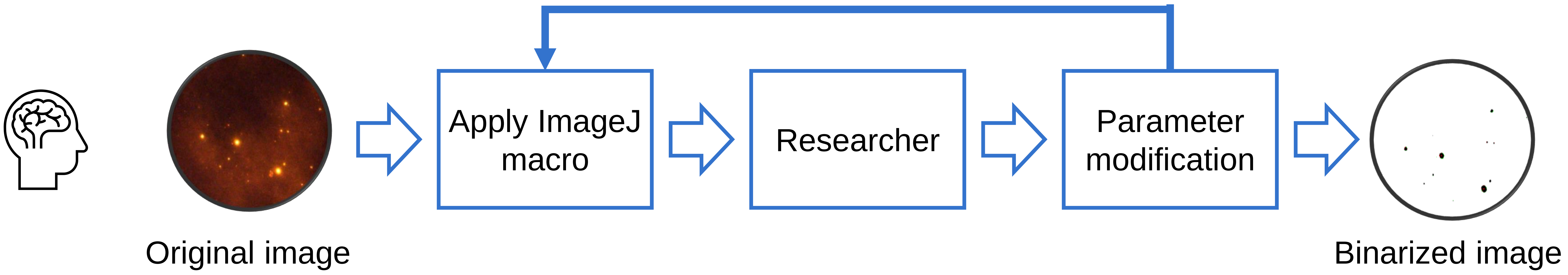
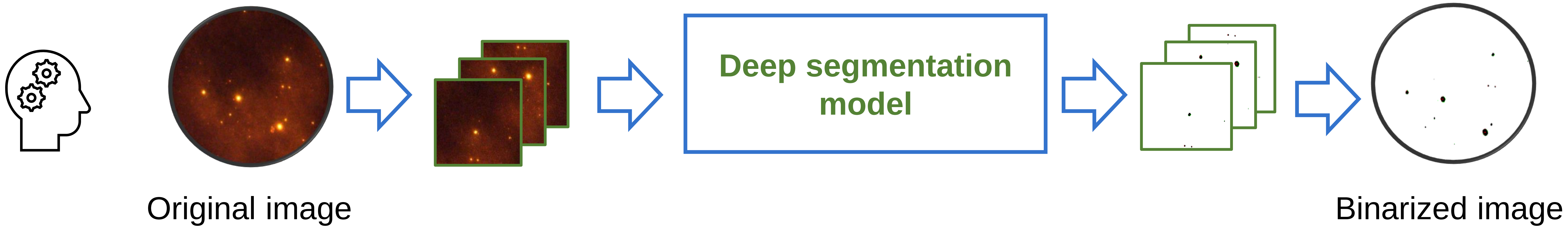
DEEP SEGMENTATION MODEL





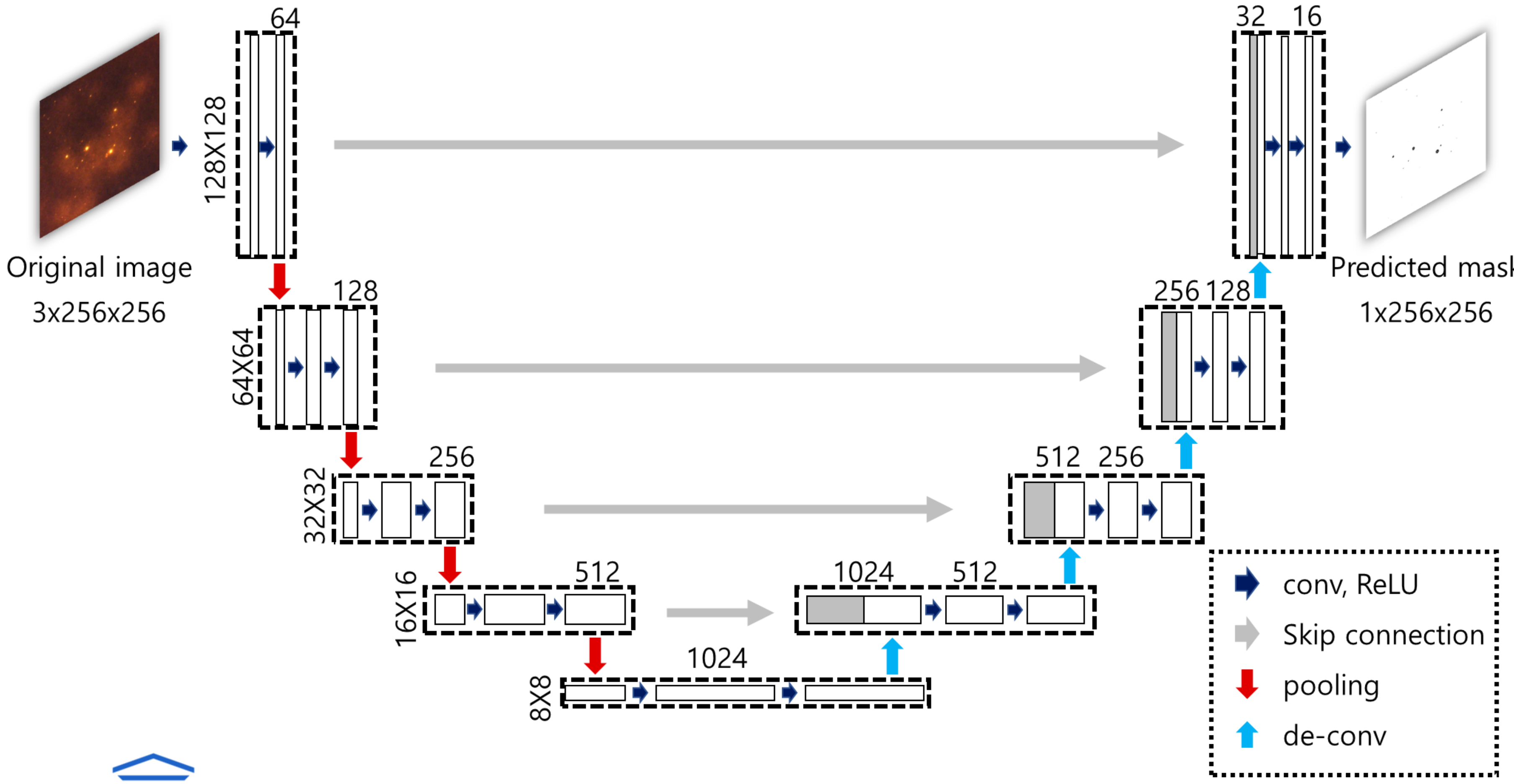
DATASET

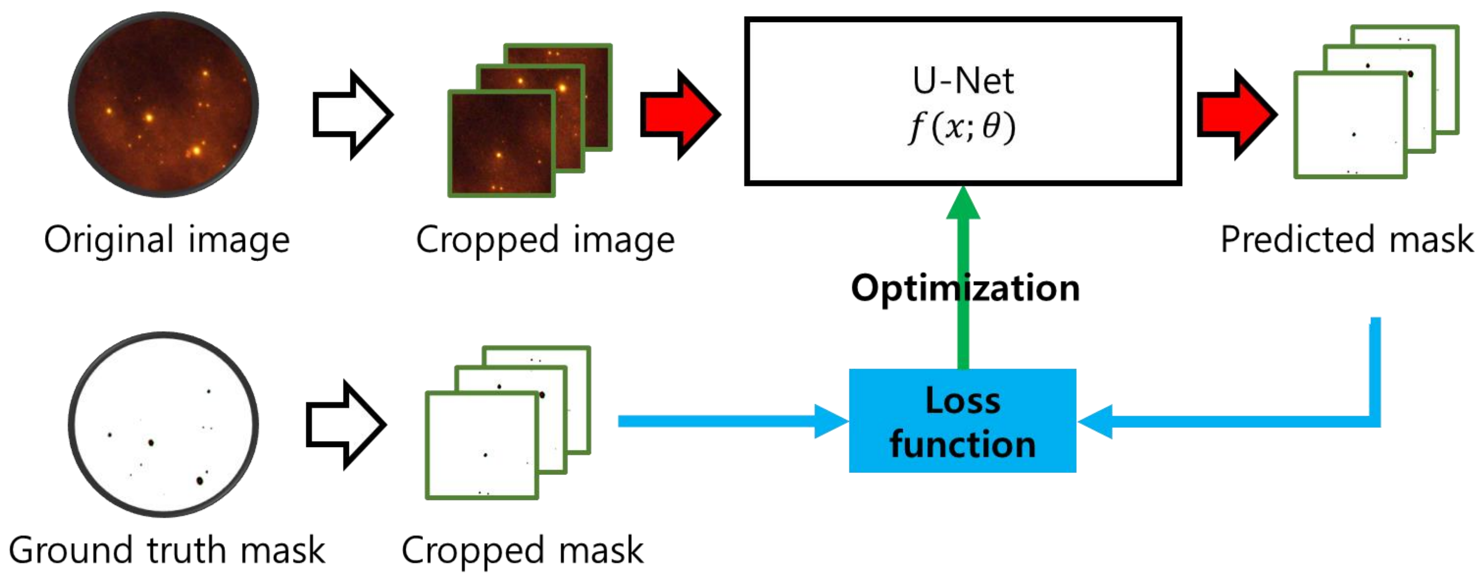
- **99 fluorescent microscopy images and corresponding masks**
  - resolution: 1280×960 – 7140×5424

- **Use of a sliding window, cropping, and random selection to generate 100,000 patches with a resolution of 256×256**
  - organized into 5 datasets of 20,000 patches
    - 4 datasets for 4-fold cross-validation
    - 1 dataset for testing

DEEP SEGMENTATION MODEL

- **Use of U-Net (pre-trained on ImageNet)**
  - initially developed for biomedical image segmentation
  - now often used in other domains





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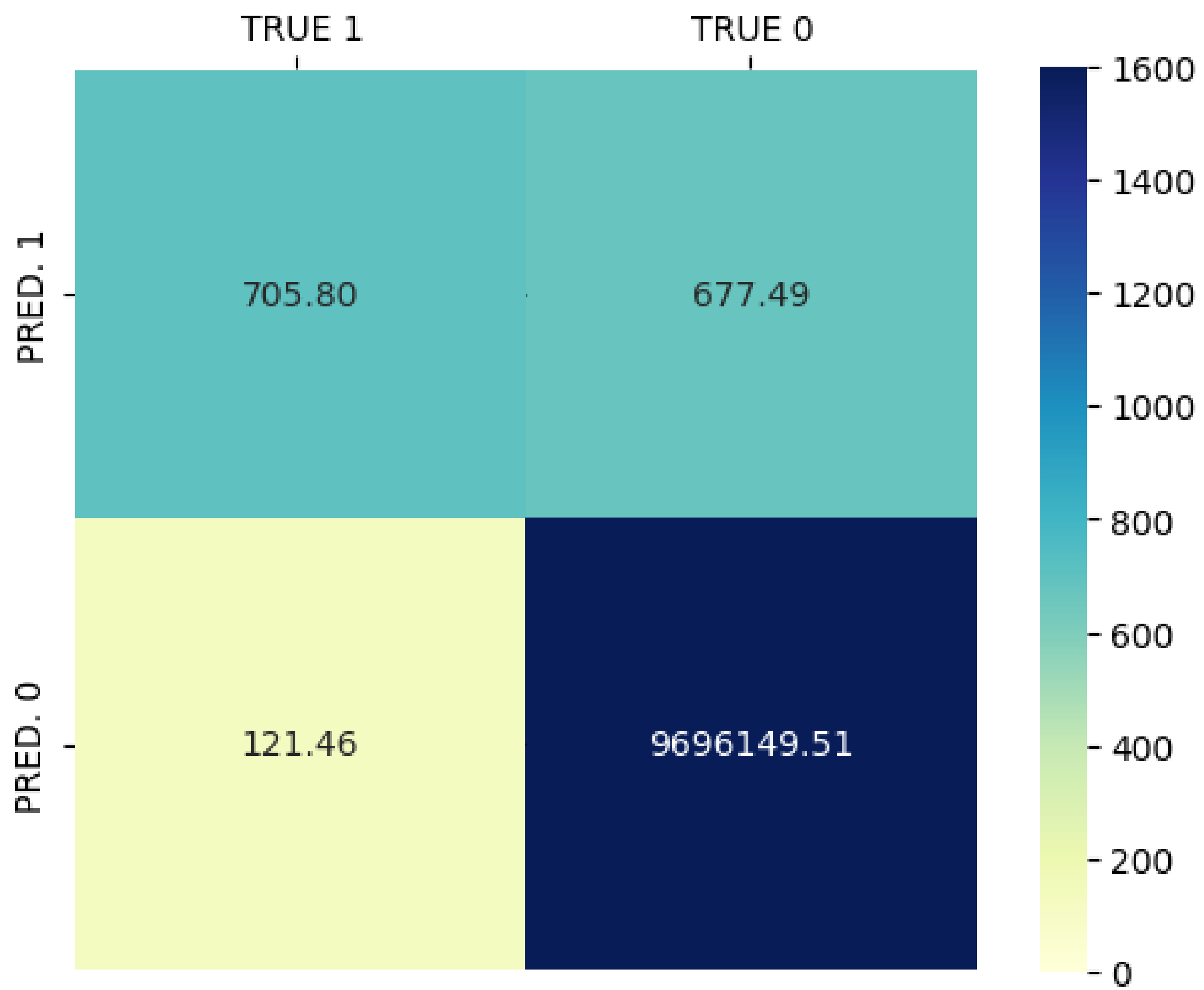
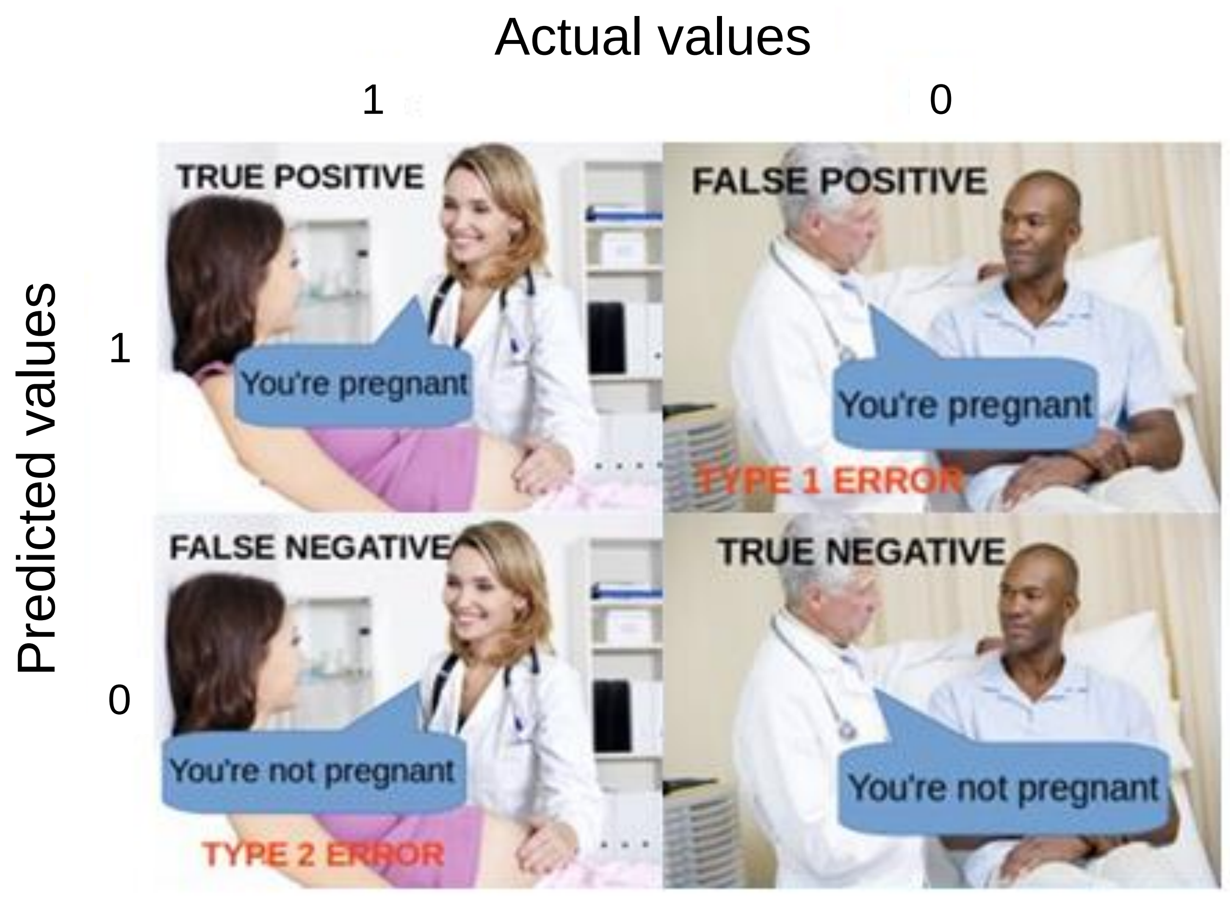
QUANTITATIVE RESULTS



TP: # of true positives
TN: # of true negatives
FP: # of false positives
FN: # of false negatives



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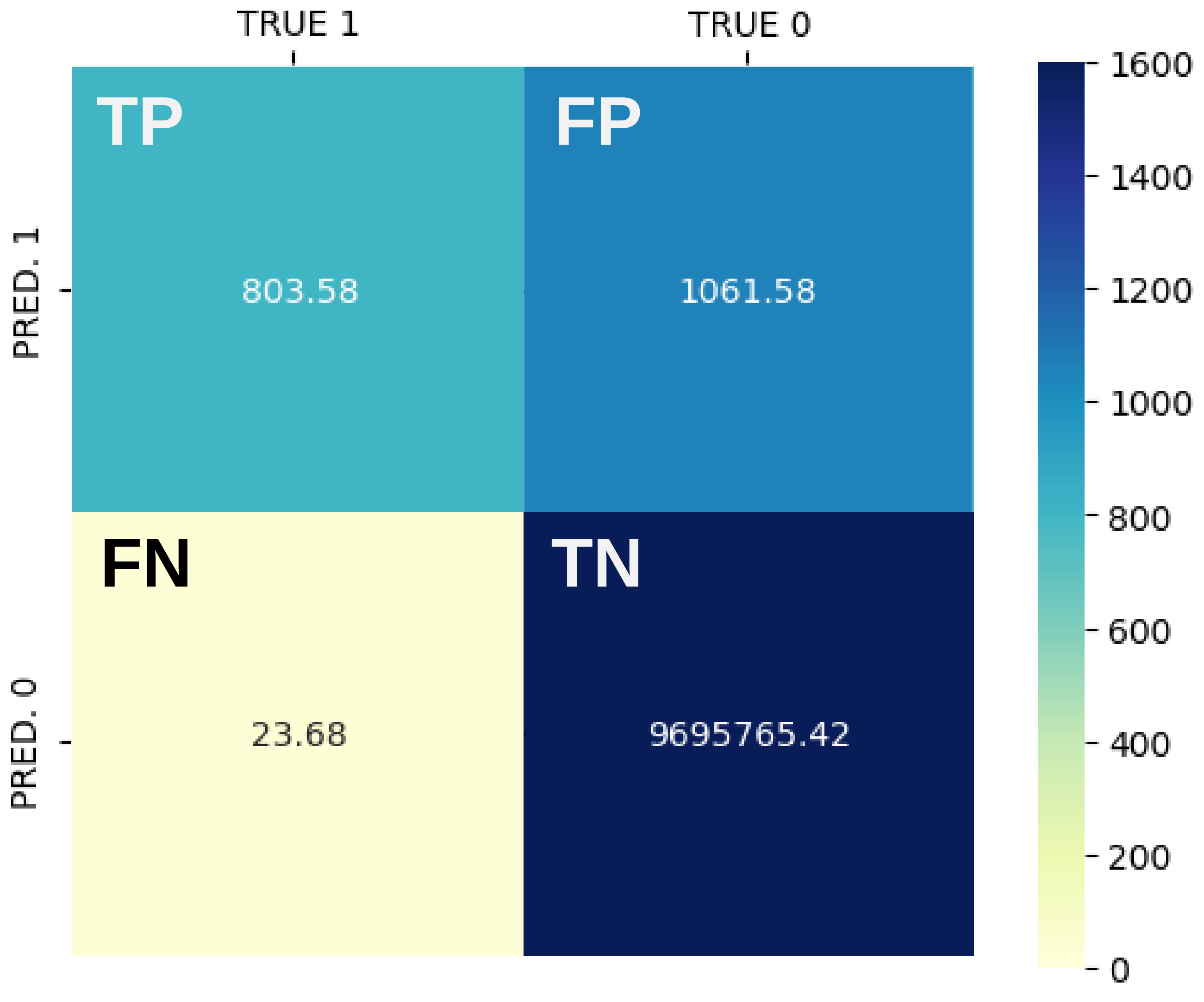
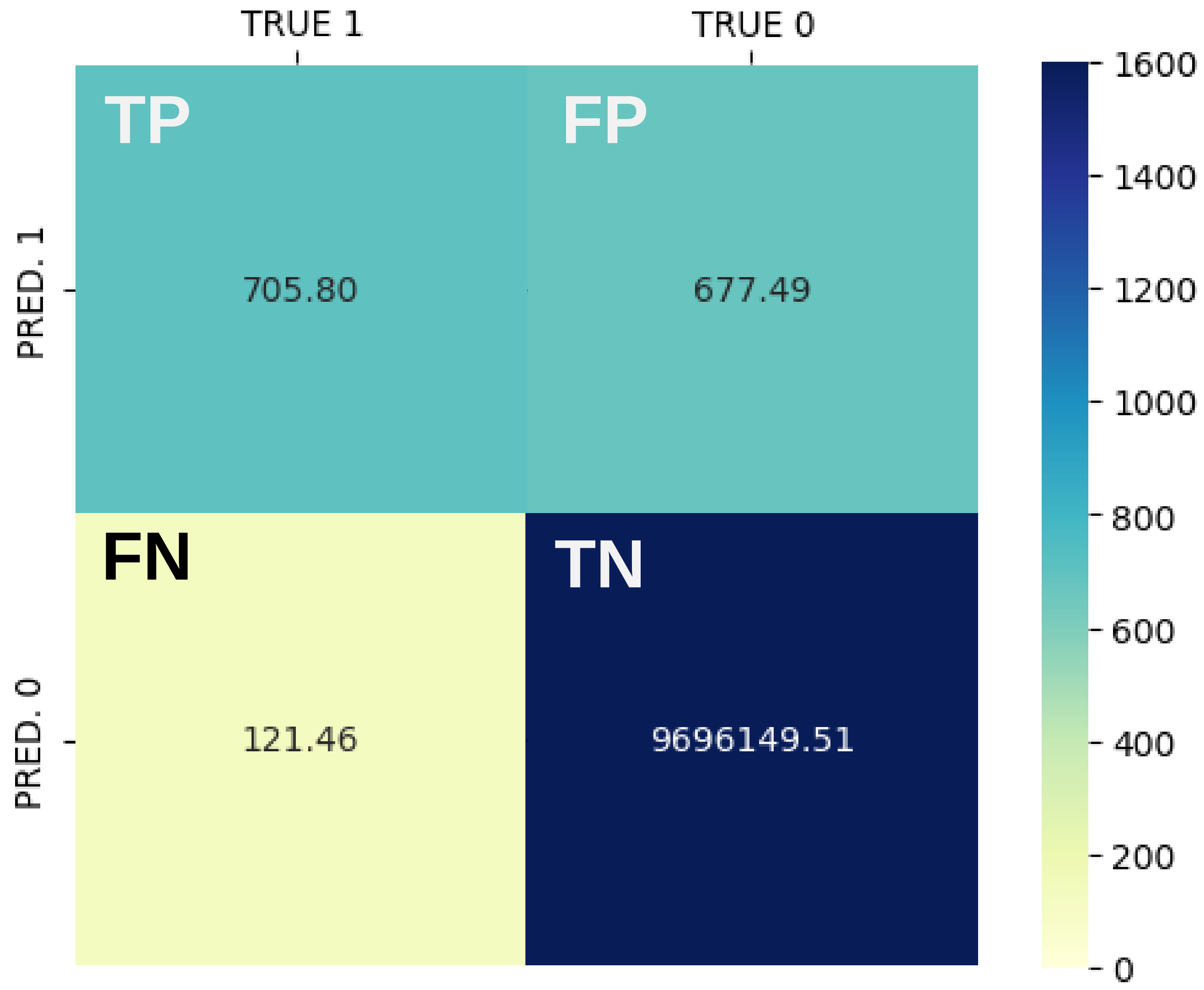
QUANTITATIVE RESULTS



MP-VAT



U-Net

(1) high number of true negatives (background pixels can be predicted well)

(2) reduced number of false positives

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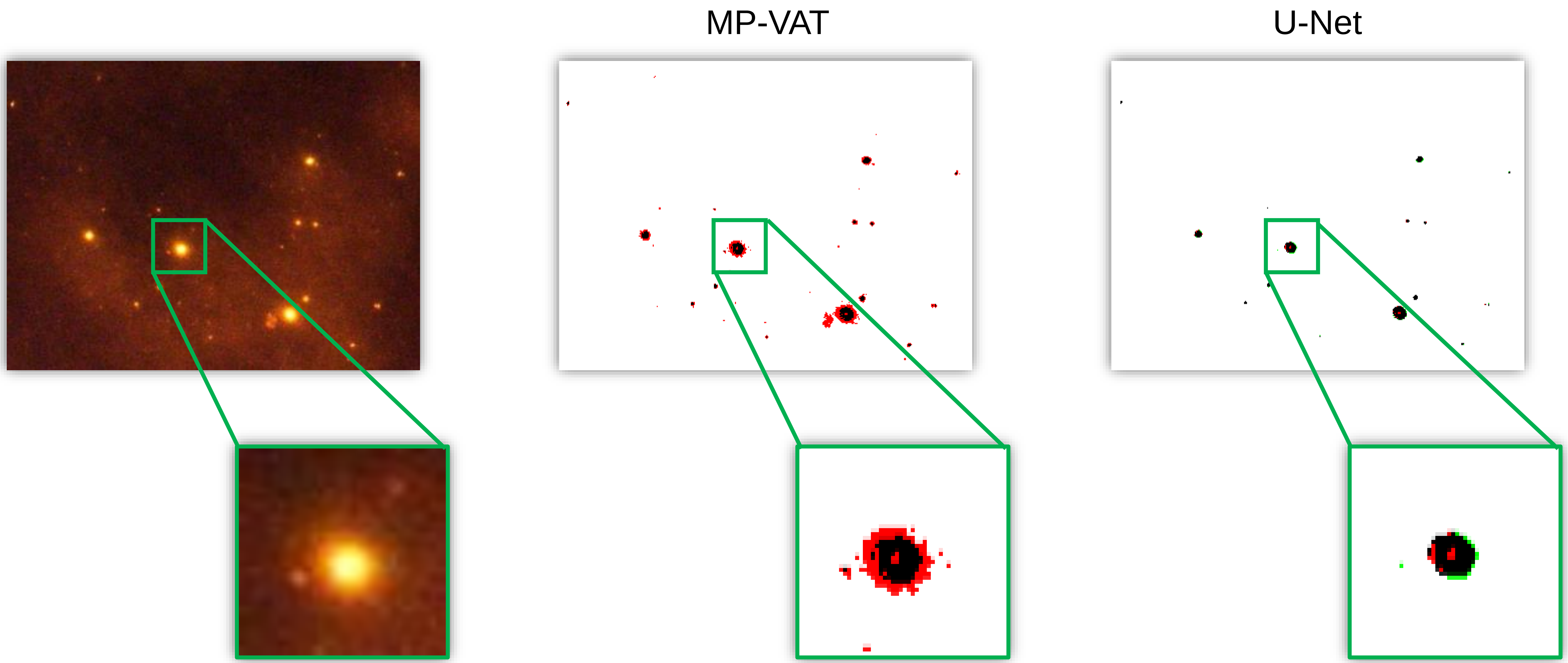
QUALITATIVE RESULTS (HALO DETECTION)



white and black pixels: correctly predicted

red pixels: false positives

green pixels: false negatives

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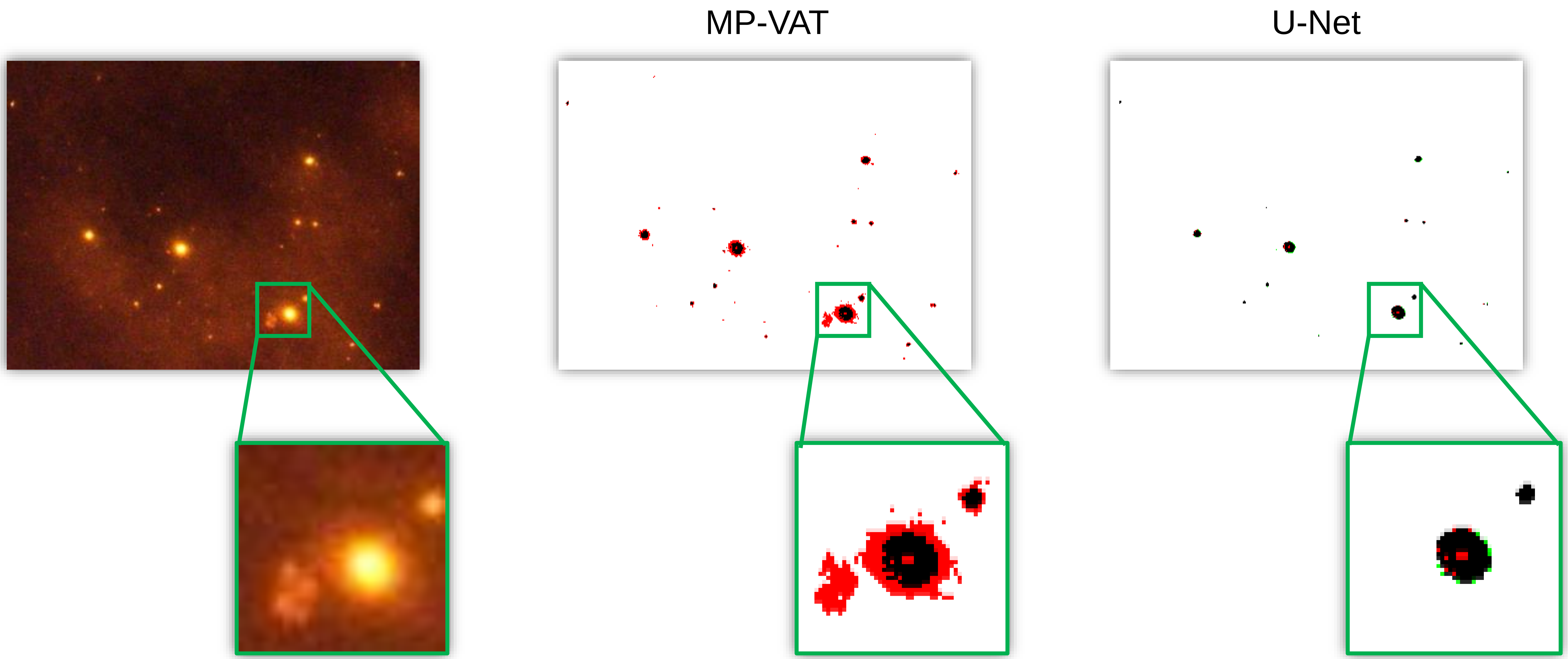
QUALITATIVE RESULTS (NOISE REMOVAL)

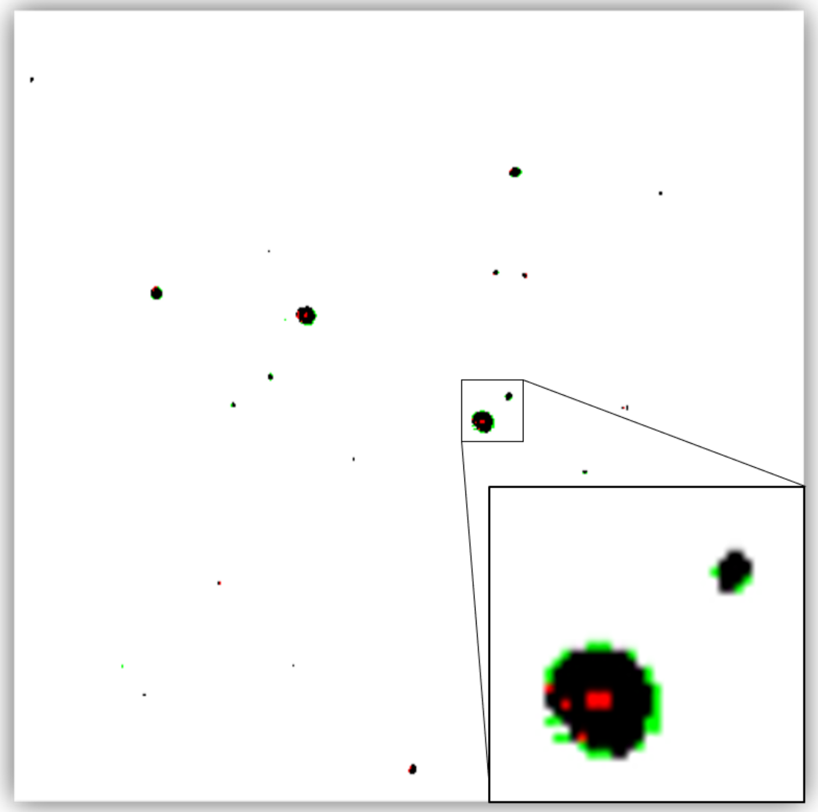


white and black pixels: correctly predicted

red pixels: false positives

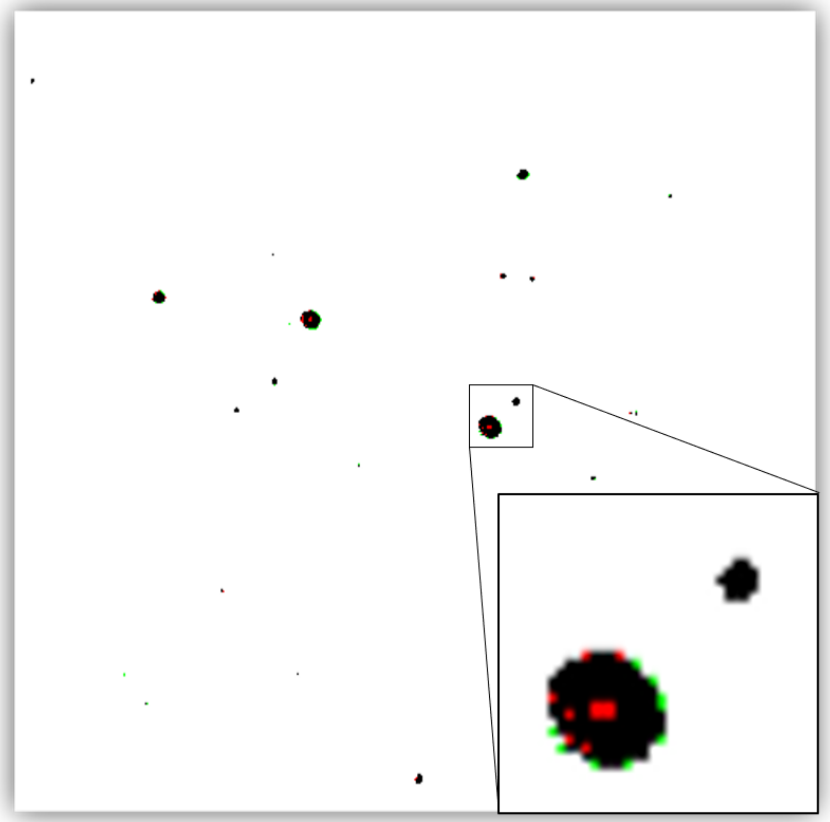
green pixels: false negatives

QUALITATIVE RESULTS (LOSS FUNCTIONS)



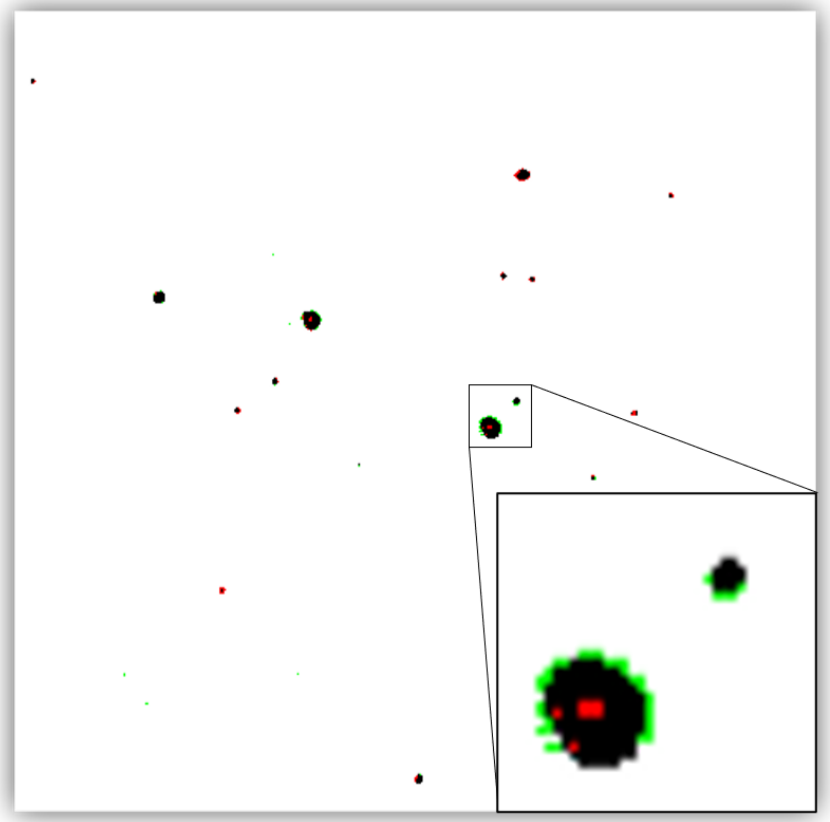
U-Net (1)

BCE with logits loss and SGD



U-Net (2)

Dice loss and Adam



U-Net (3)

BCE with dice loss and Adam

BCE: Binary cross-entropy

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SUMMARY

- **MP monitoring using marine biota** (i.e., Manila clams)

- **MP detection in microscopic images**
  - MP-VAT (manual intervention, prone to errors)
  - U-Net (deep learning, highly automated)

- **Better results in terms of false positive detection** ($F_{0.5}$, precision)

- **Alternative to already existing methods**

FUTURE WORK

- **Model improvement**
  - reduction of false positives
  - comparison to other segmentation models
  - optimization of hyperparameter values (vs. default ones)

- **Better accessibility & usefulness**
  - GUI interface or ImageJ macro
  - integration of support for counting and finding size and shape

Thank you for your attention! Any questions?

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