AI in Astrophysics: Applying Artificial Intelligence and Deep Learning to Astronomical Research

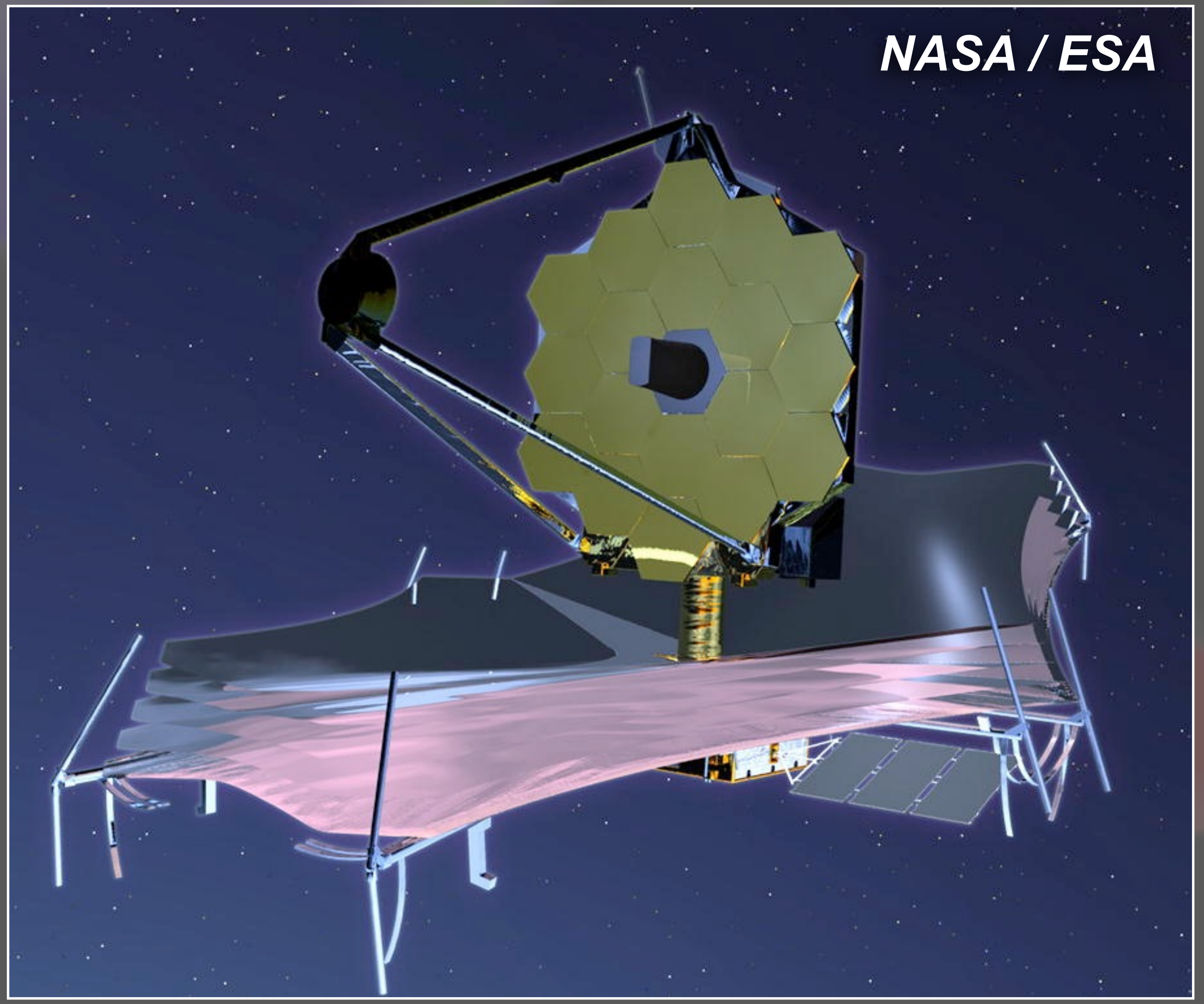
Brant Robertson
Maureen and John Hendricks Visiting Professor
Institute for Advanced Study, Princeton, NJ
Associate Professor, University of California Santa Cruz
Department of Astronomy and Astrophysics

Ryan Hausen
University of California Santa Cruz
Department of Computer Science

NVIDIA GTC 2019

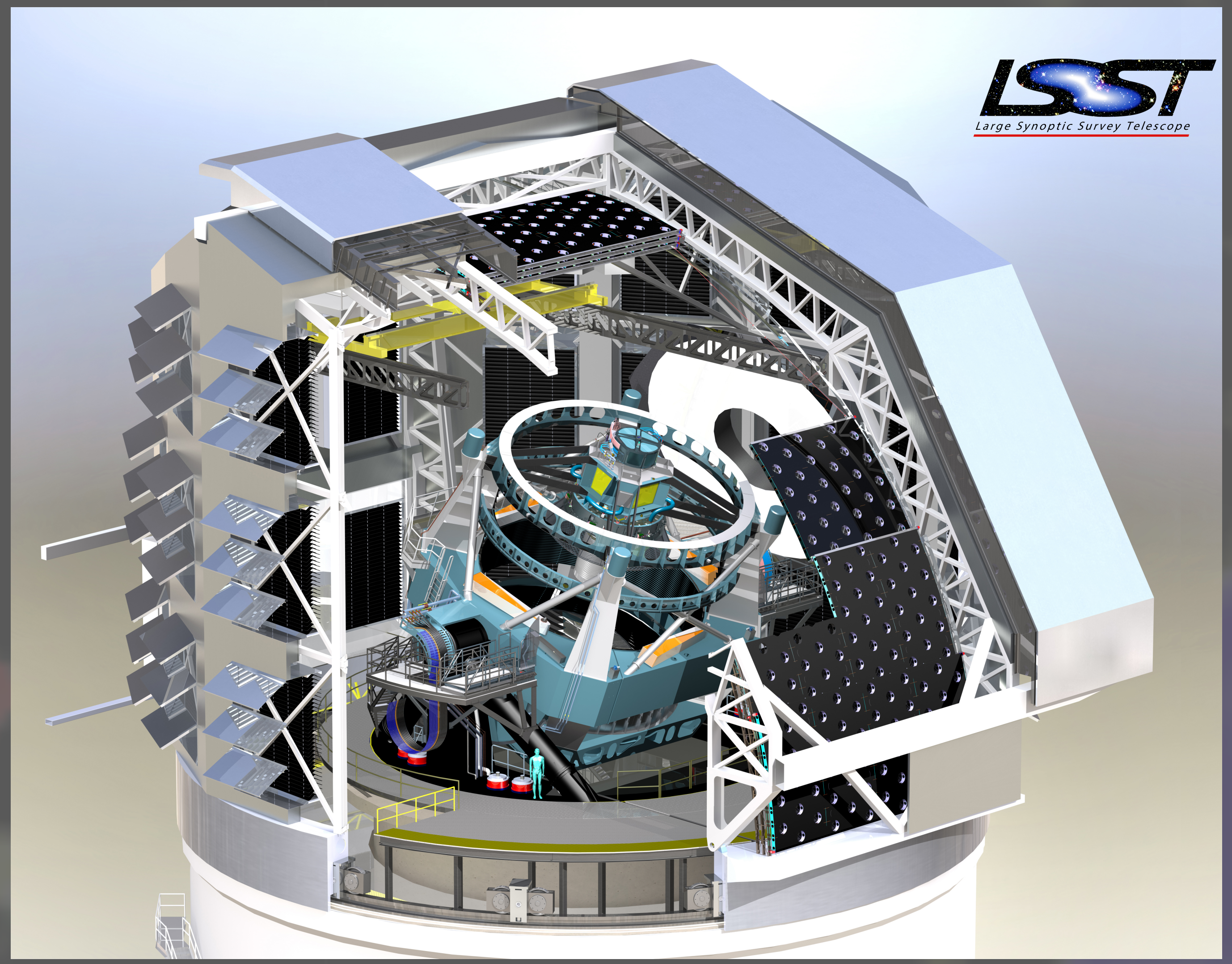
Astronomy is on the cusp of a data revolution

James Webb Space Telescope



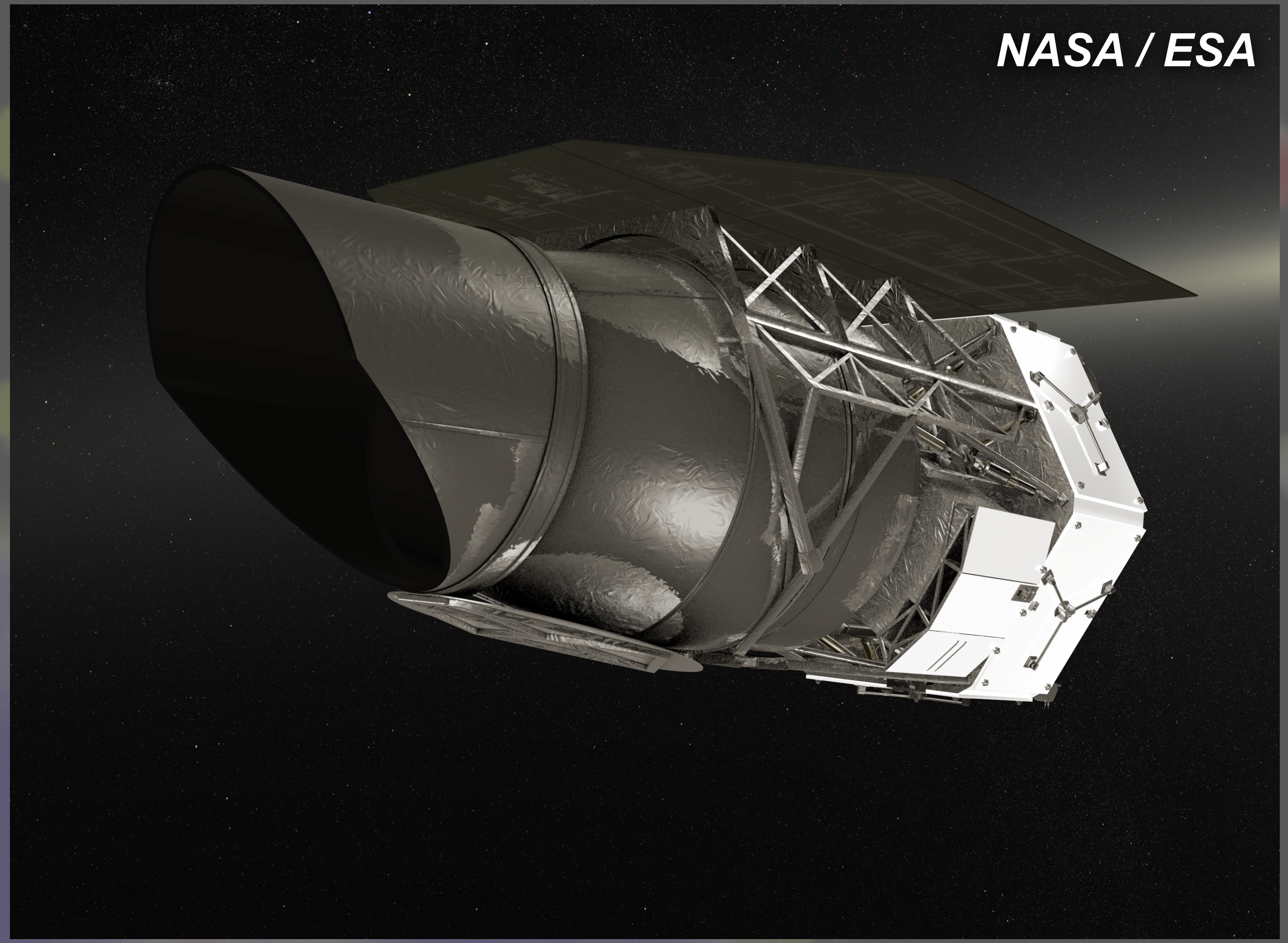
Launch expected 2021

Large Synoptic Survey Telescope



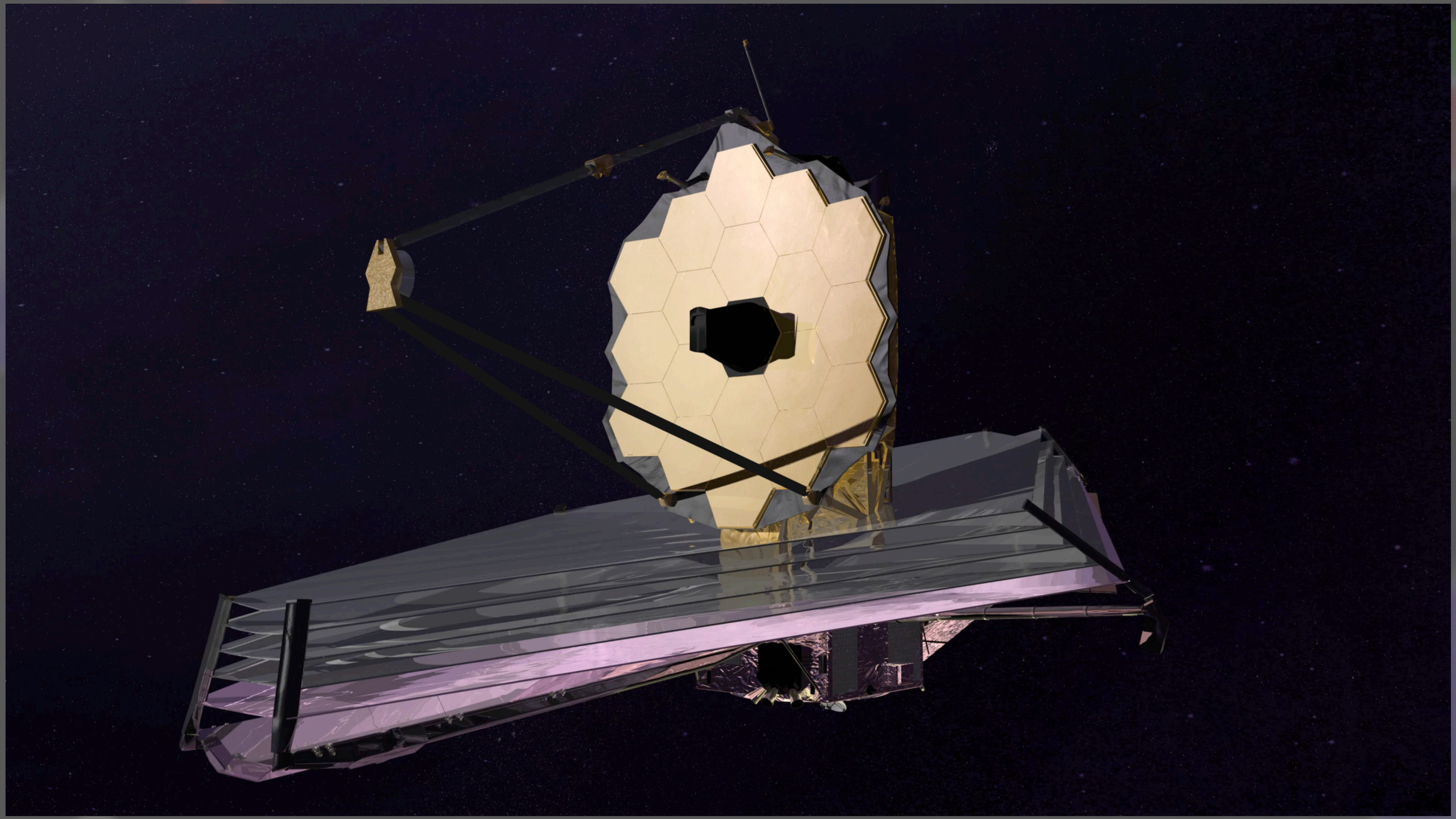
Science operations 2023

Wide Field Infrared Survey Telescope

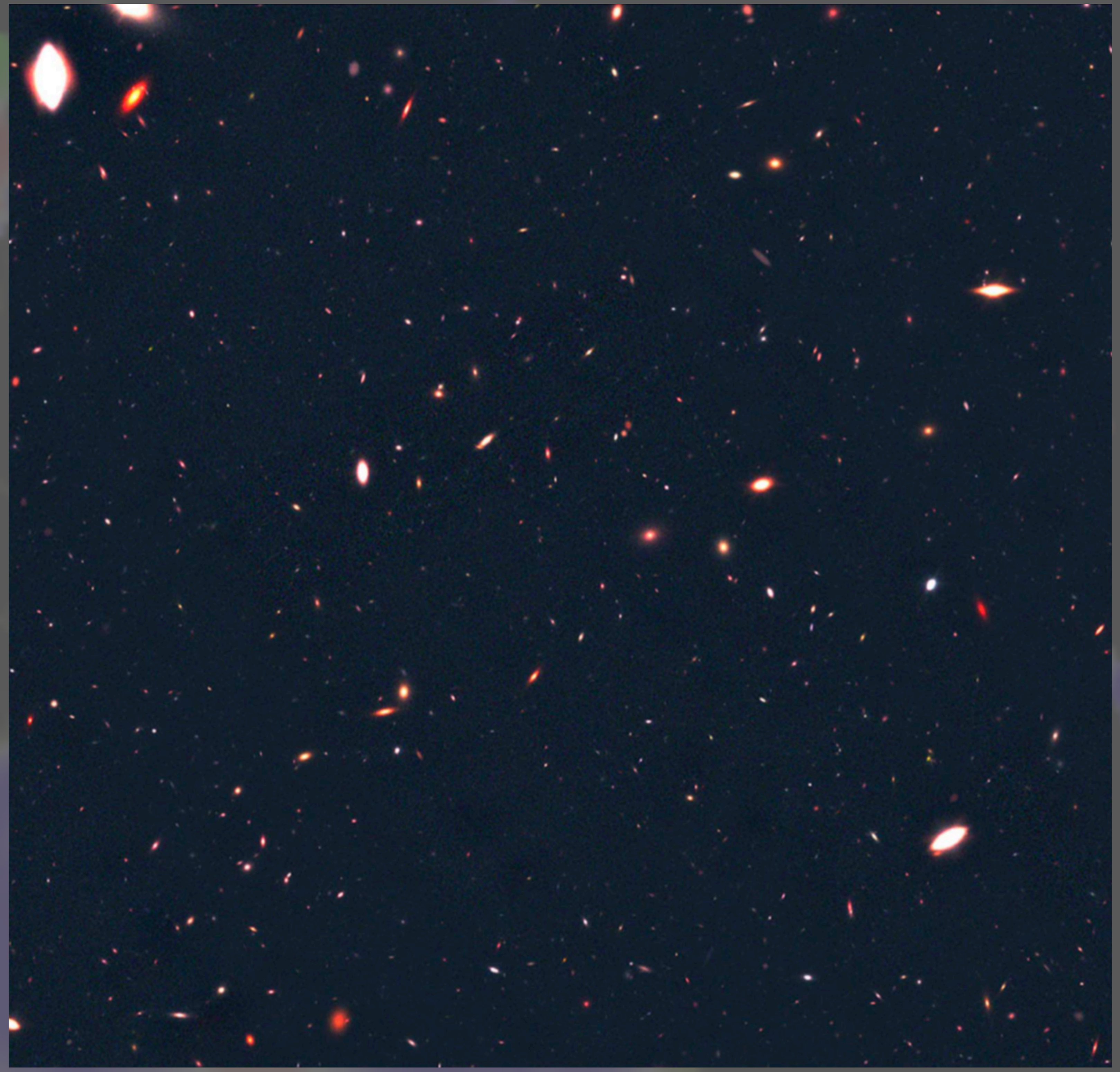


Launch expected ~2025

James Webb Space Telescope

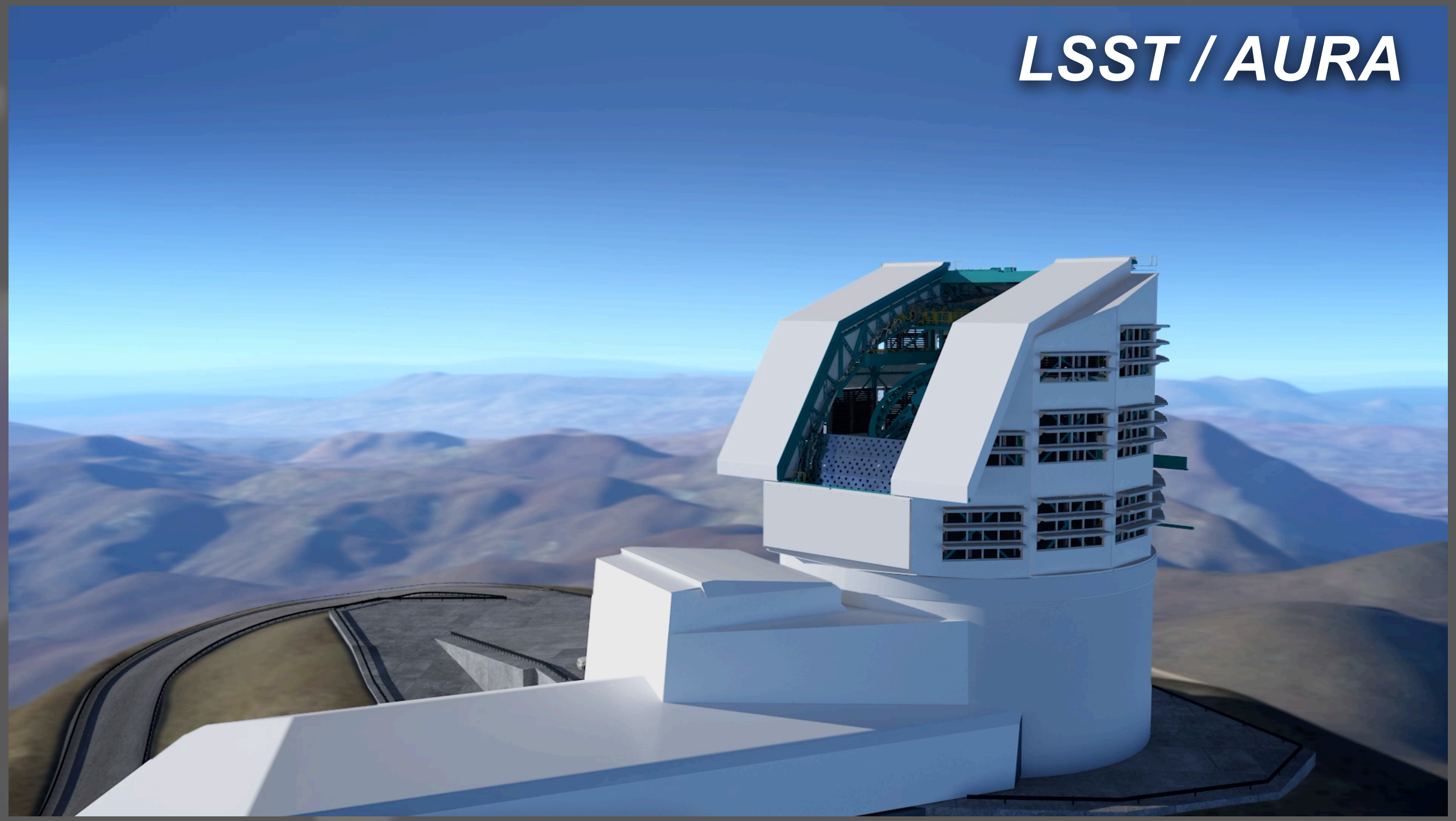


JWST Observatory
(NASA/ESA)



Simulated JWST Data
(Williams et al. 2018)

Large Synoptic Survey Telescope



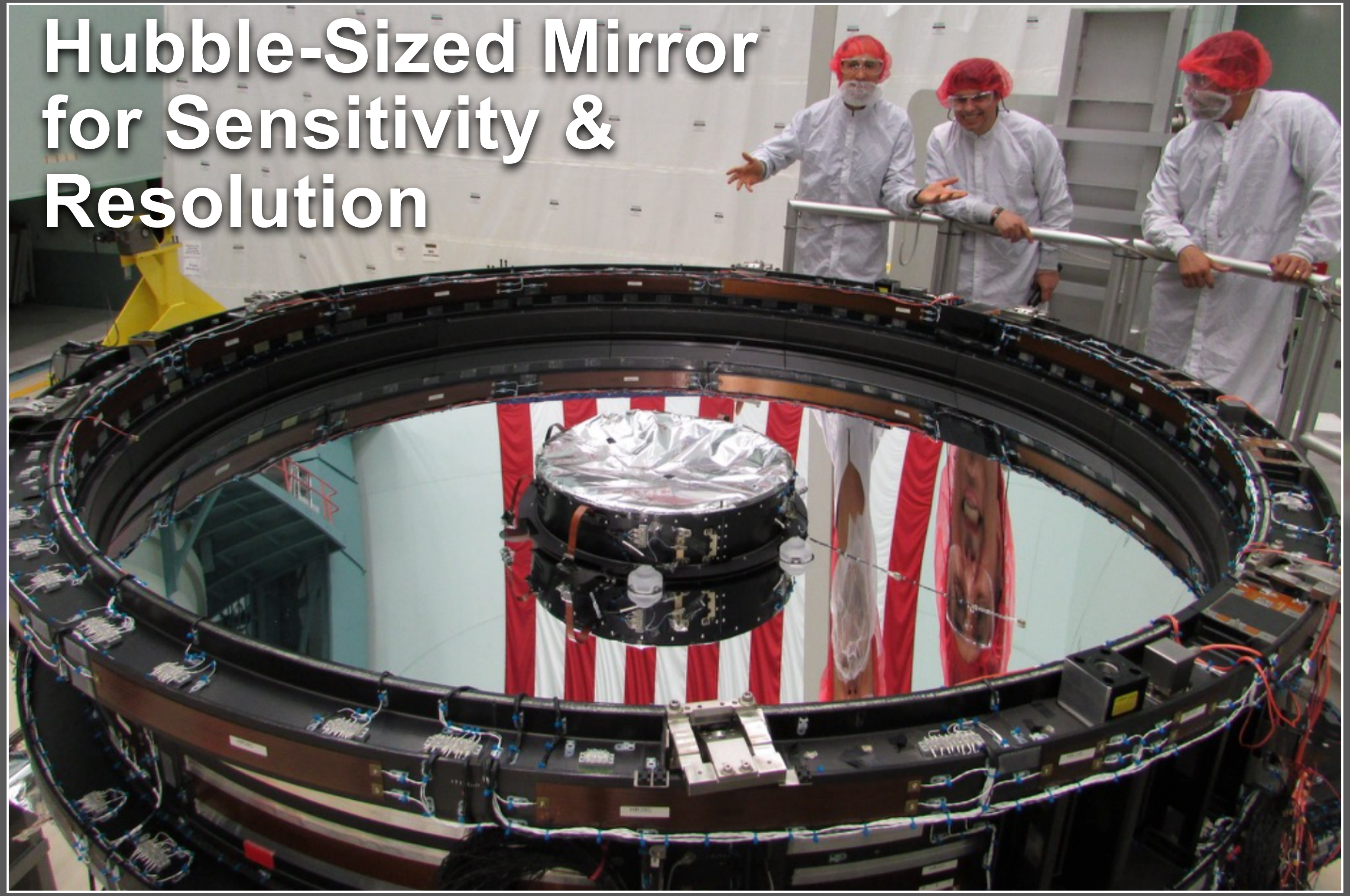
LSST Observatory

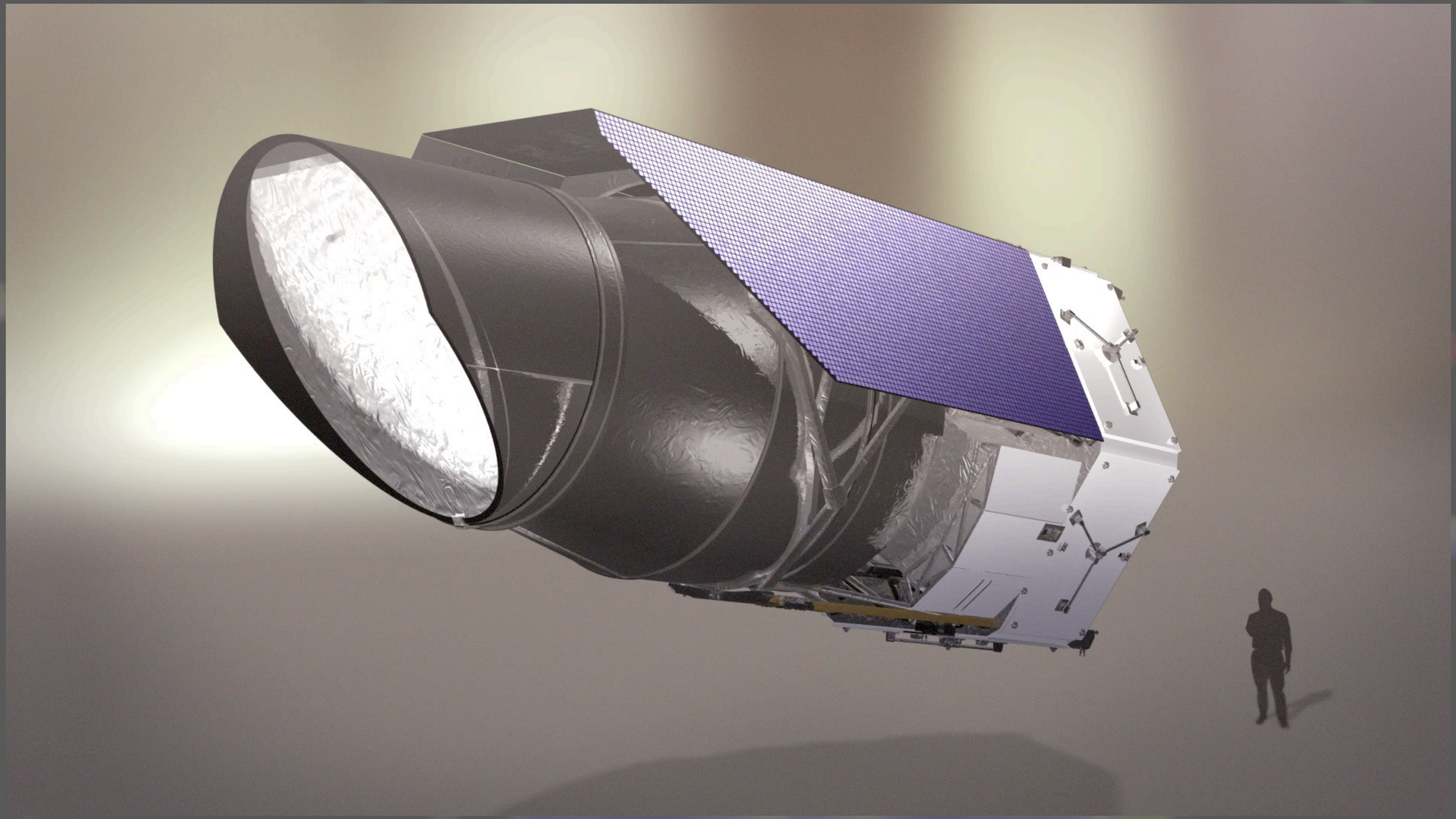
LSST Camera Lens

LSST All-Hands Meeting 2012

LSST Camera Mount

Wide Field Infrared Survey Telescope





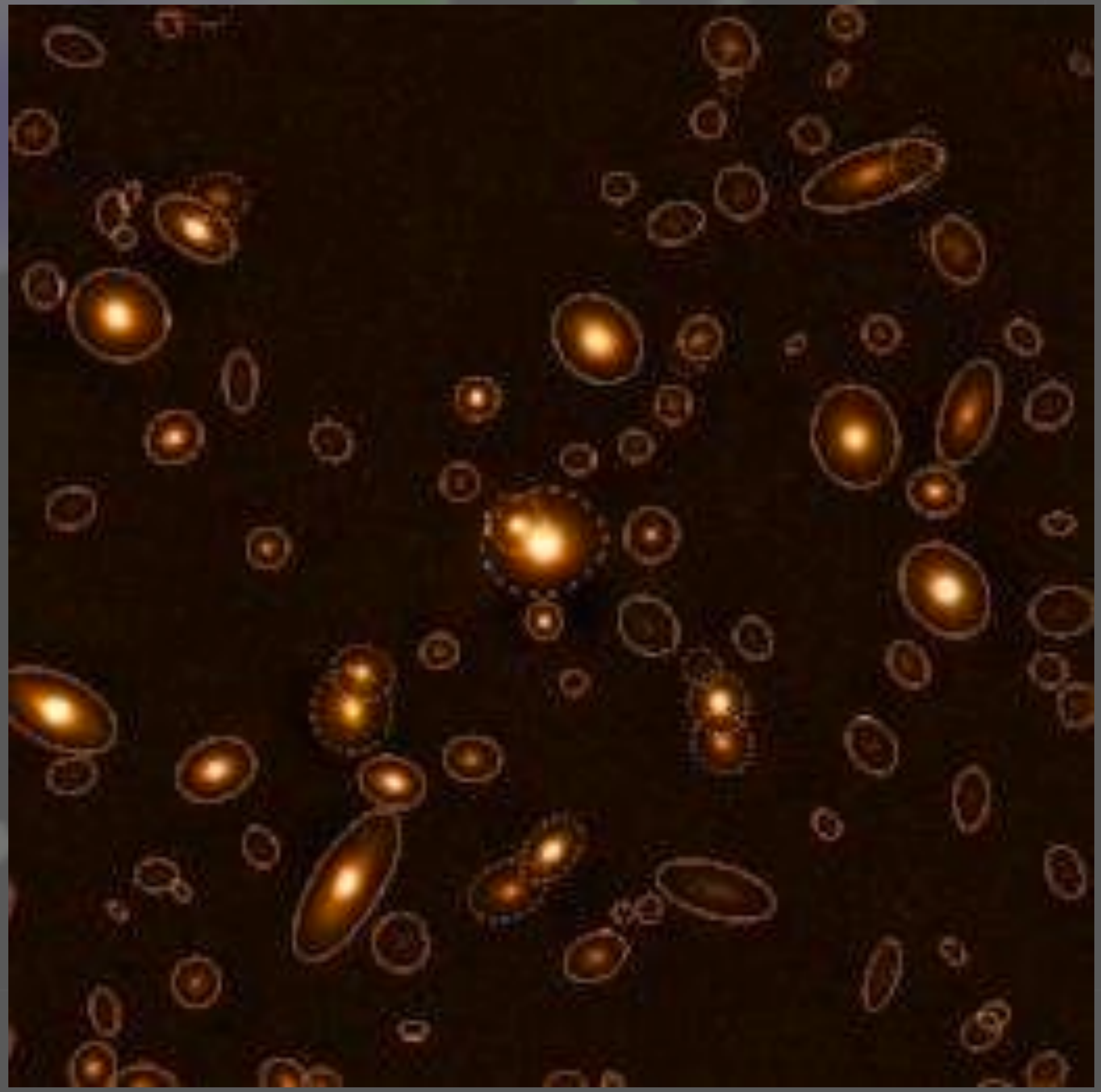
WFIRST Observatory (NASA/ESA)

Astronomical Data are Richly Complex

(STScI/NASA/ESA)

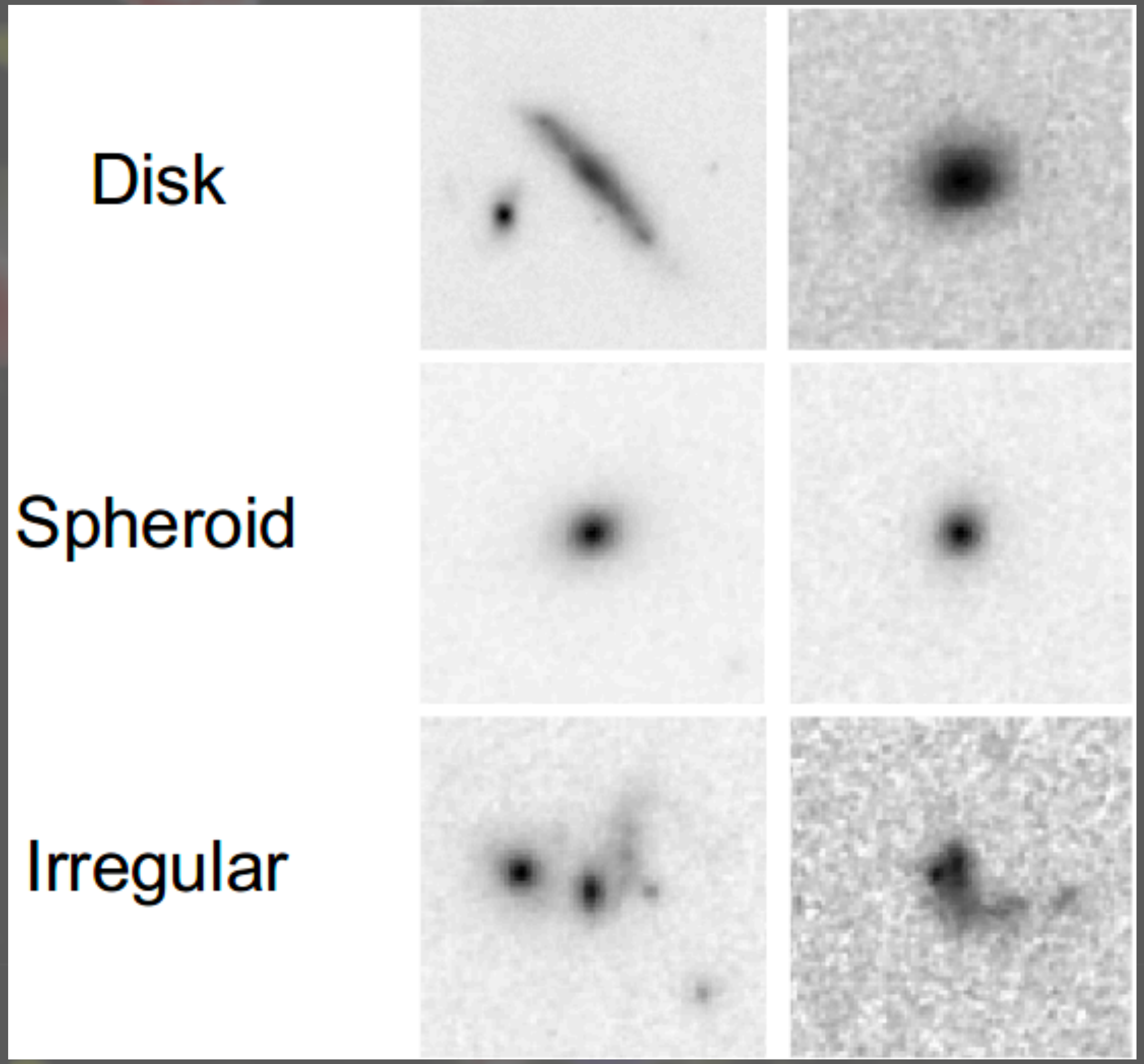
Tasks in Astronomical Imaging

Source Segmentation (Where)



http://astroa.physics.metu.edu.tr/MANUALS/sextractor

Source Classification (What)



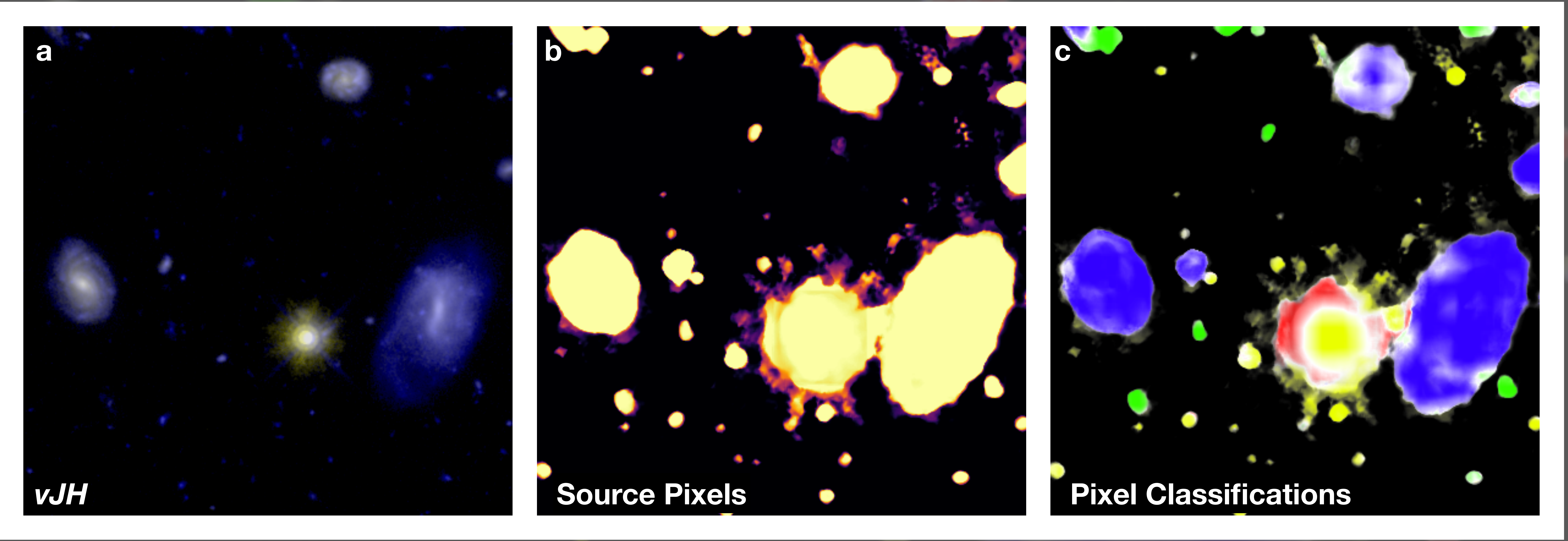
Kartaltepe et al., ApJS, 221, 11 (2015)

Tasks in Astronomical Imaging

Semantic Segmentation (Where and What)

Cityscapes Dataset

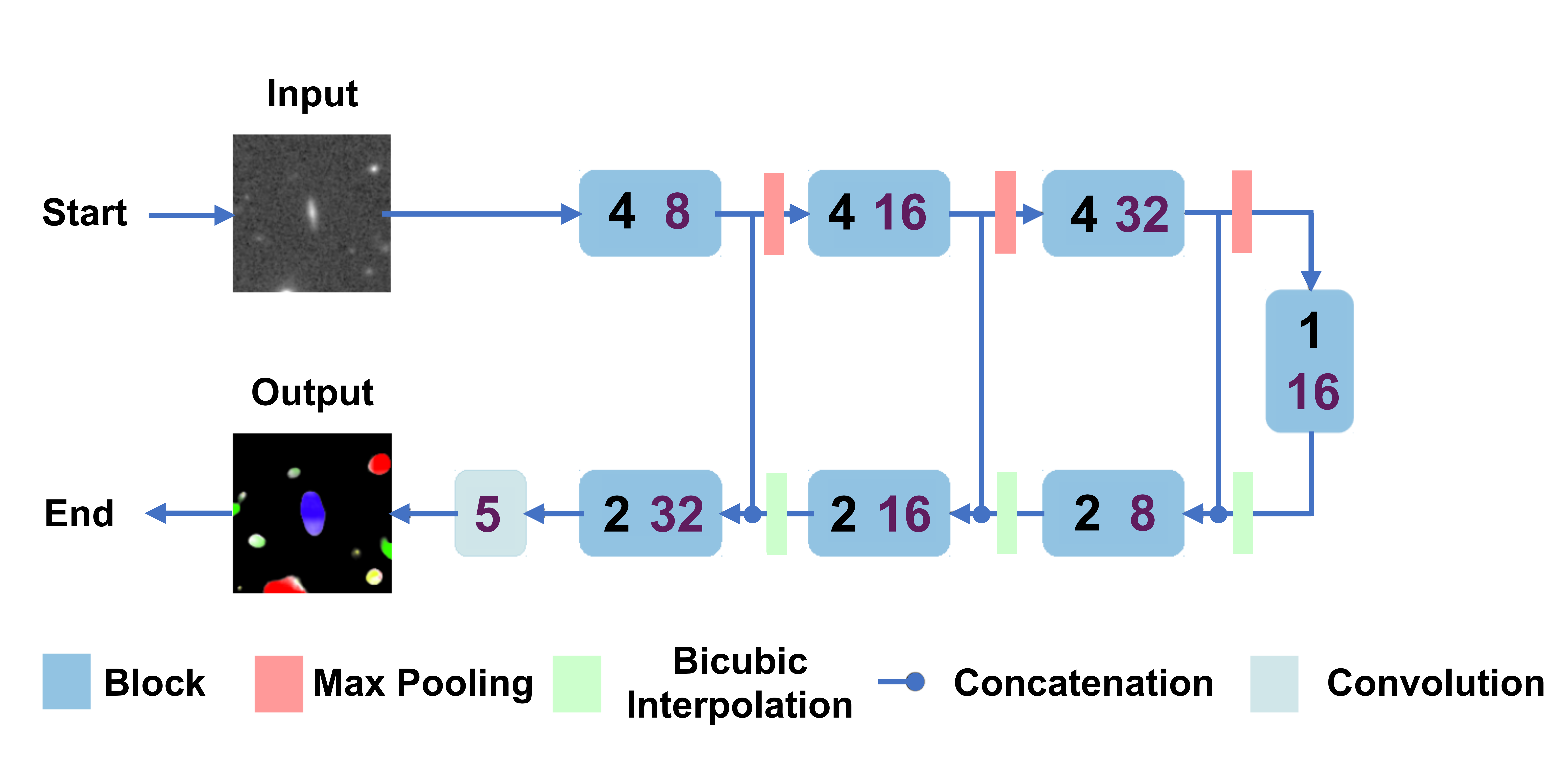
Introducing "Morpheus": Pixel-level semantic segmentation for astronomical datasets



Astronomical Data *Object Detection* *Semantic Segmentation*

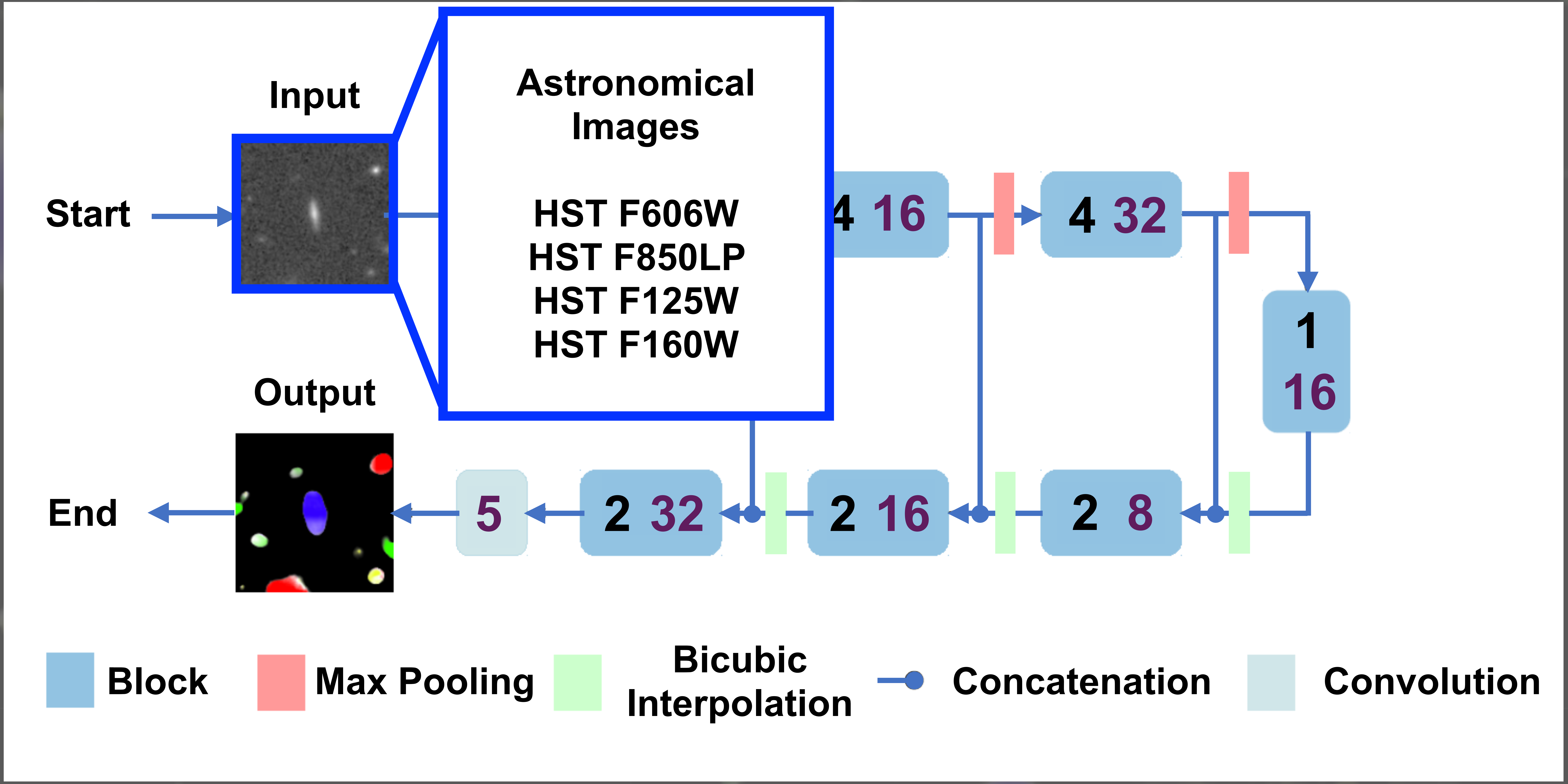
Hausen & Robertson (in prep)

Morpheus Model Architecture



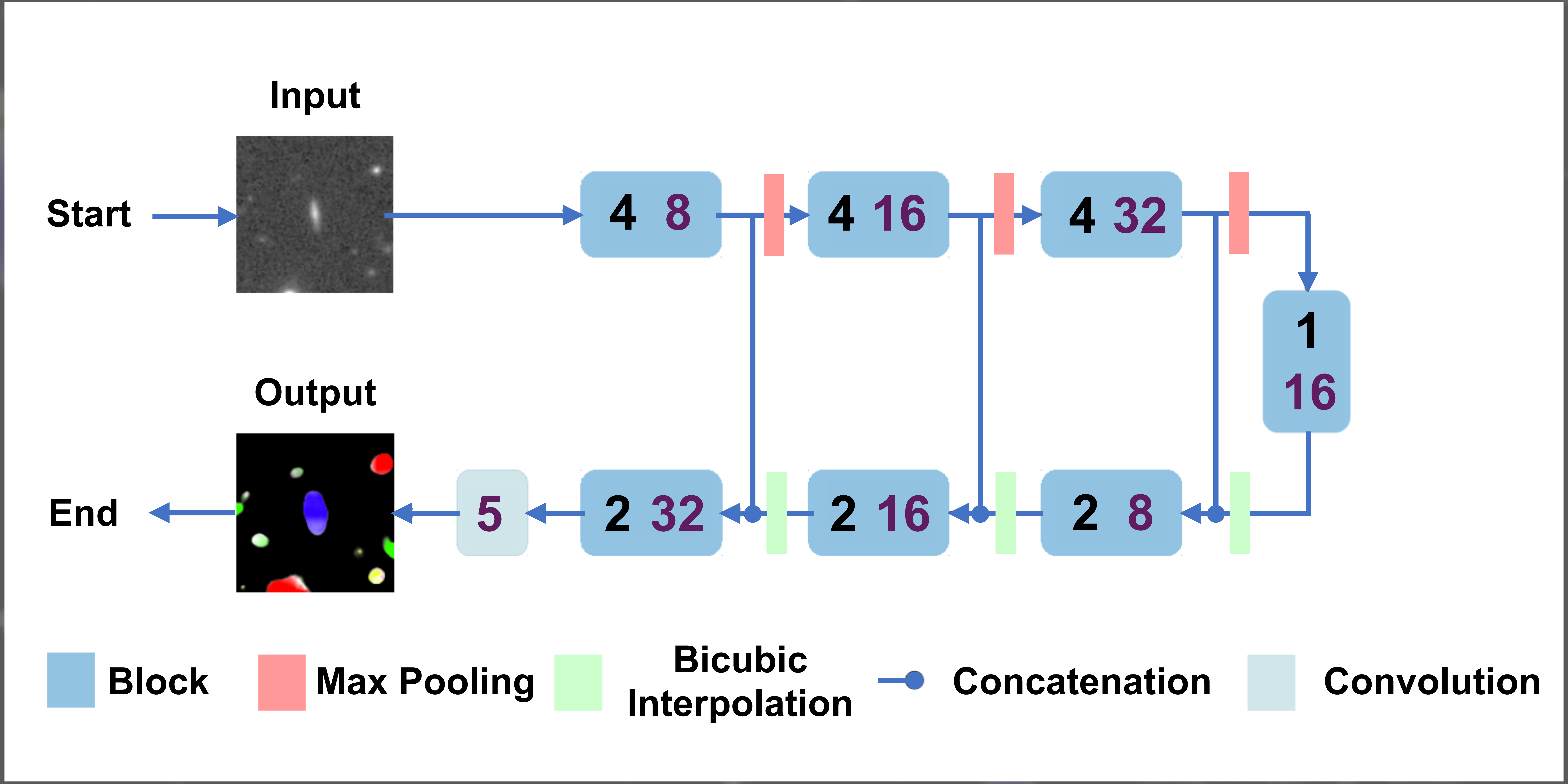
Hausen & Robertson (in prep)

Morpheus Model Input



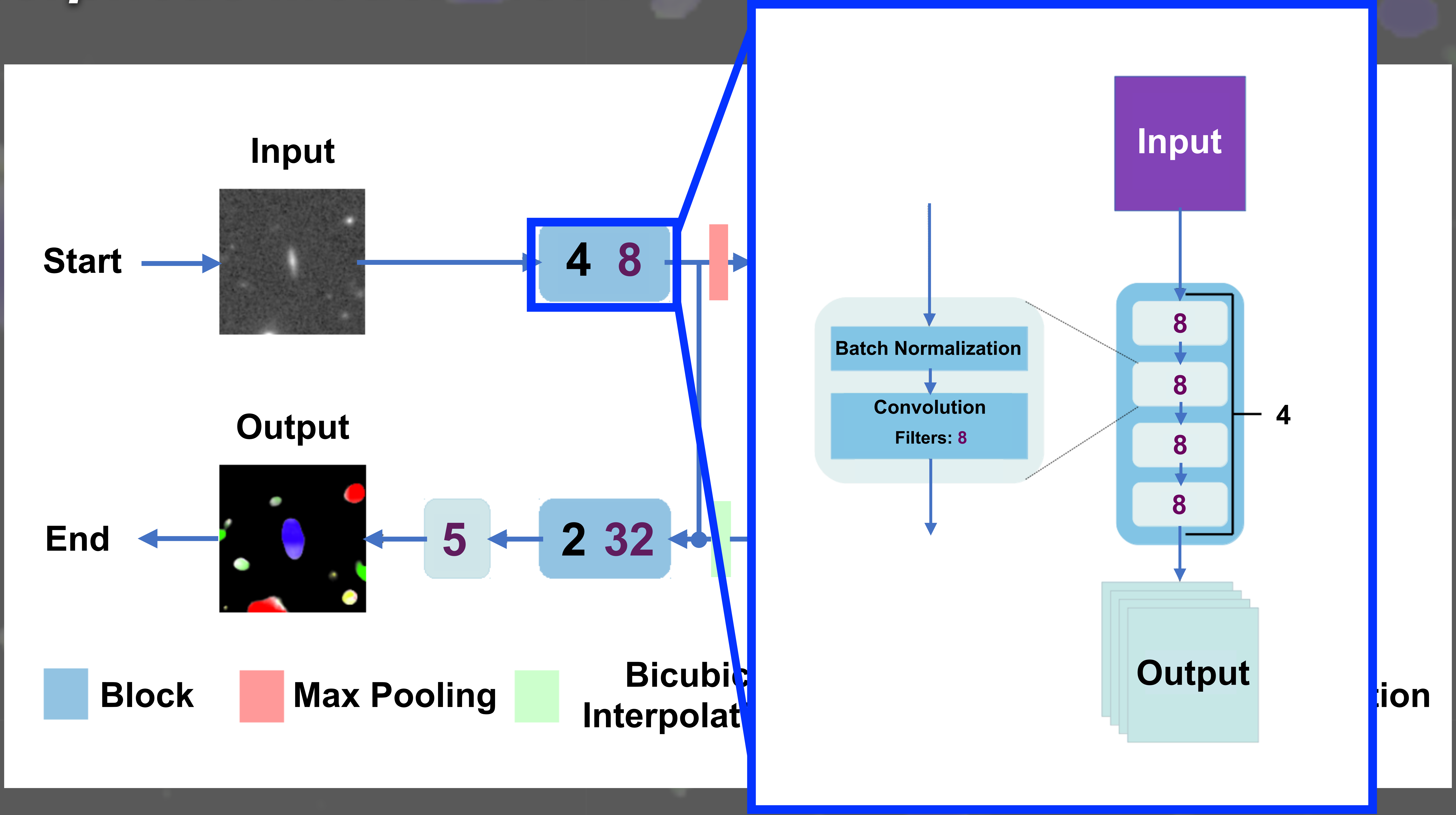
Hausen & Robertson (in prep)

Morpheus Model Architecture



Hausen & Robertson (in prep)

Morpheus Model Block

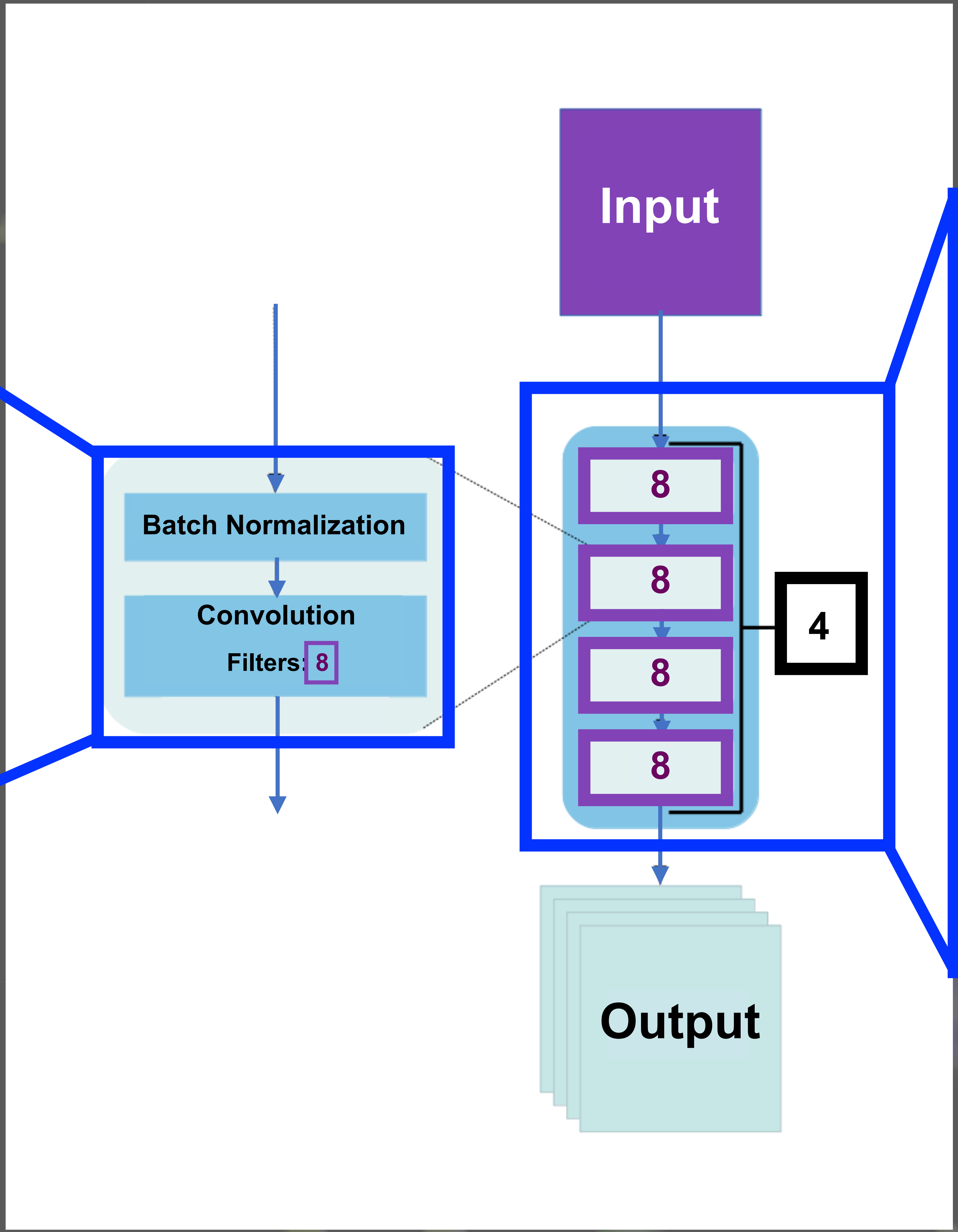


Hausen & Robertson (in prep)

Morpheus Model Block

Block Operations:

- Batch Normalization
- Convolutional Layer
  - Zero pad input
  - ReLU Activation



Block:

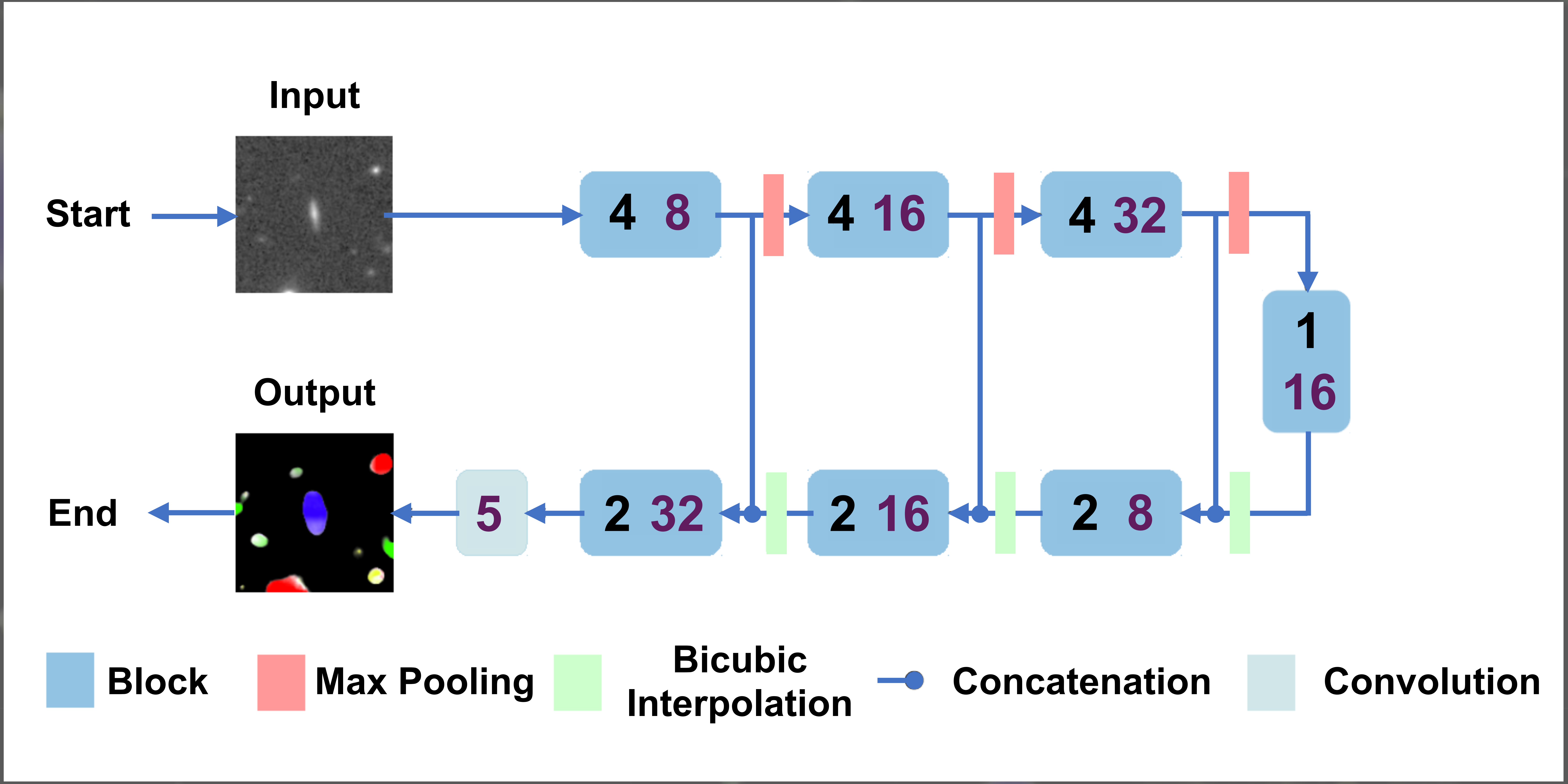
- A logical grouping of image operations
- Parameterized by two values:

# of block operations

# of feature maps

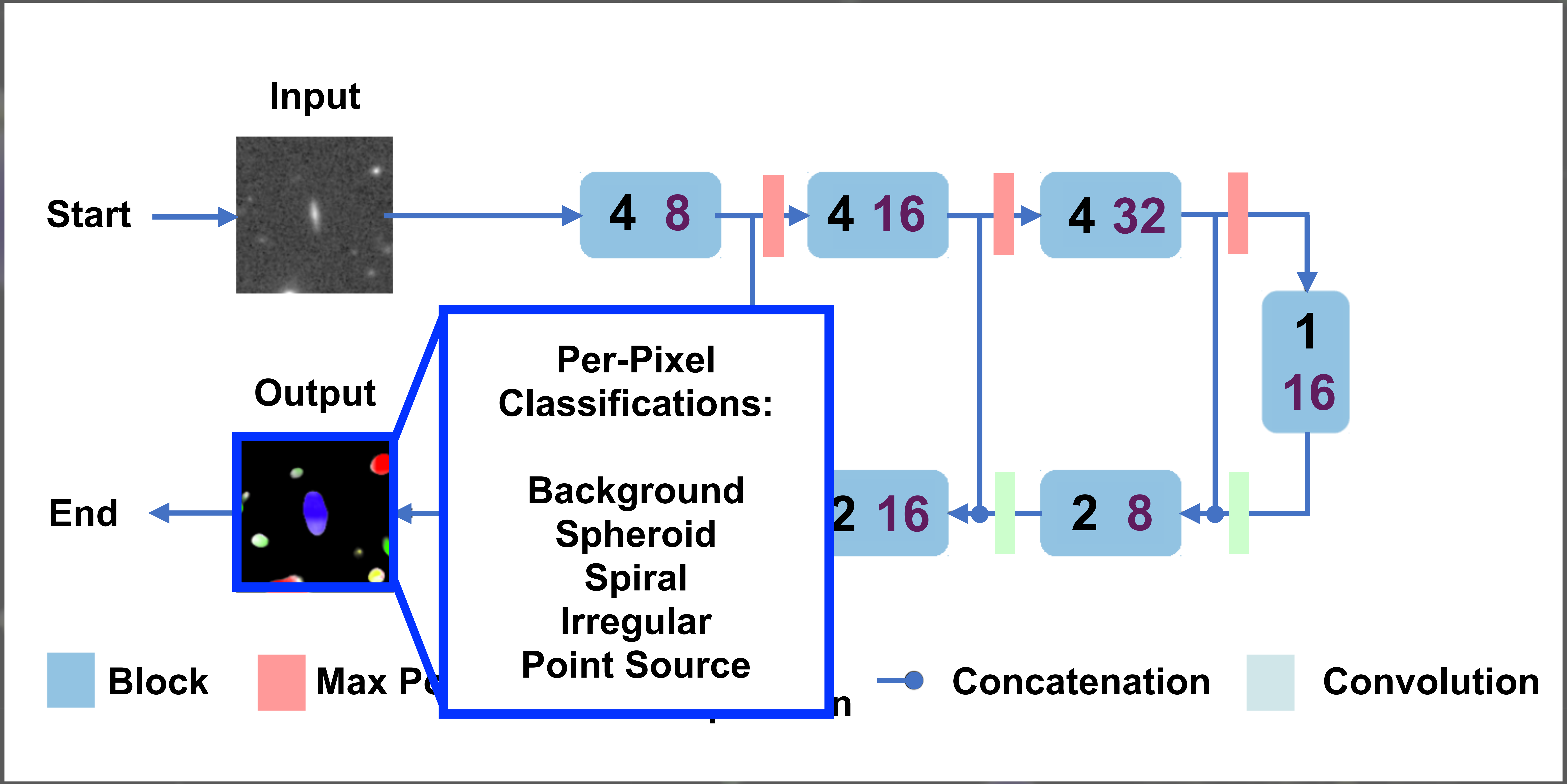
Hausen & Robertson (in prep)

Morpheus Model Architecture



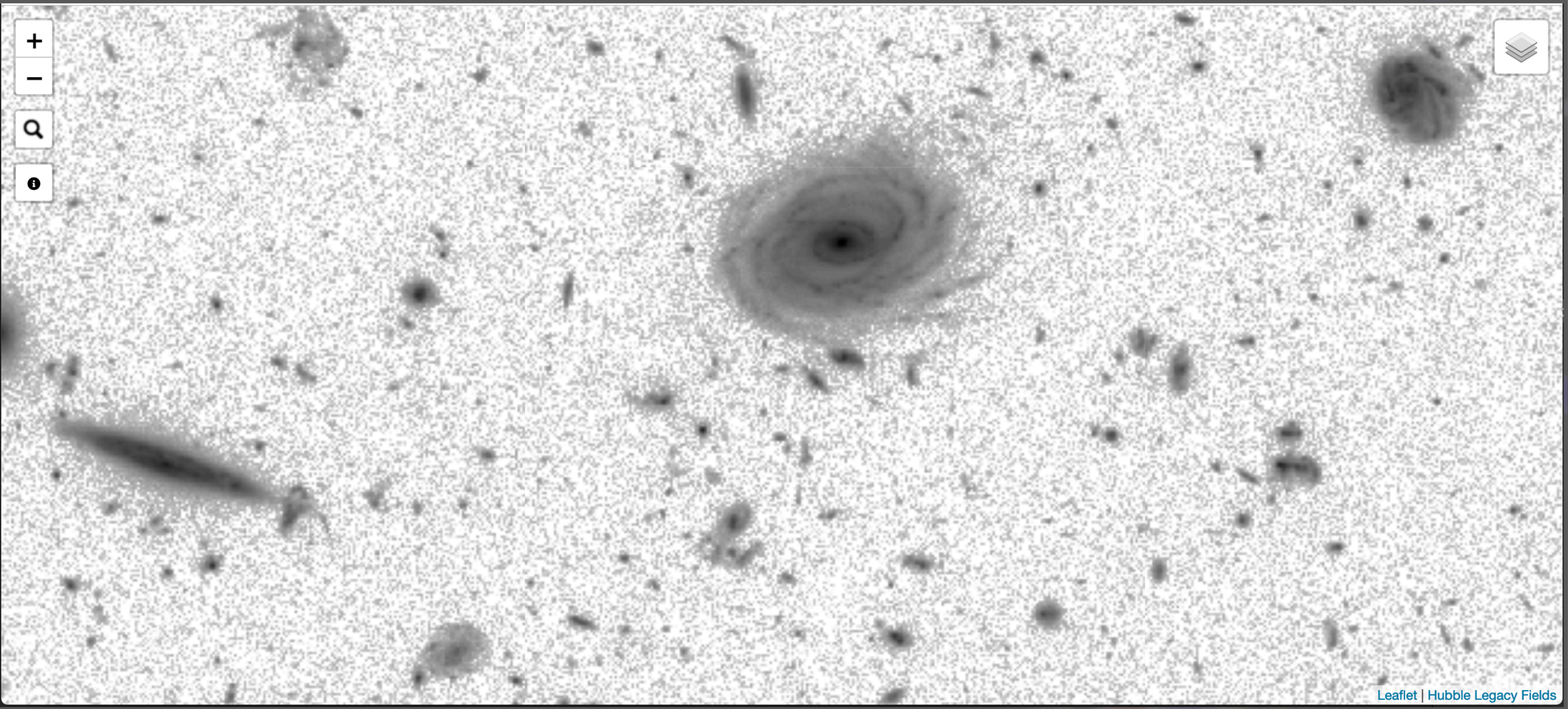
Hausen & Robertson (in prep)

Morpheus Model Architecture

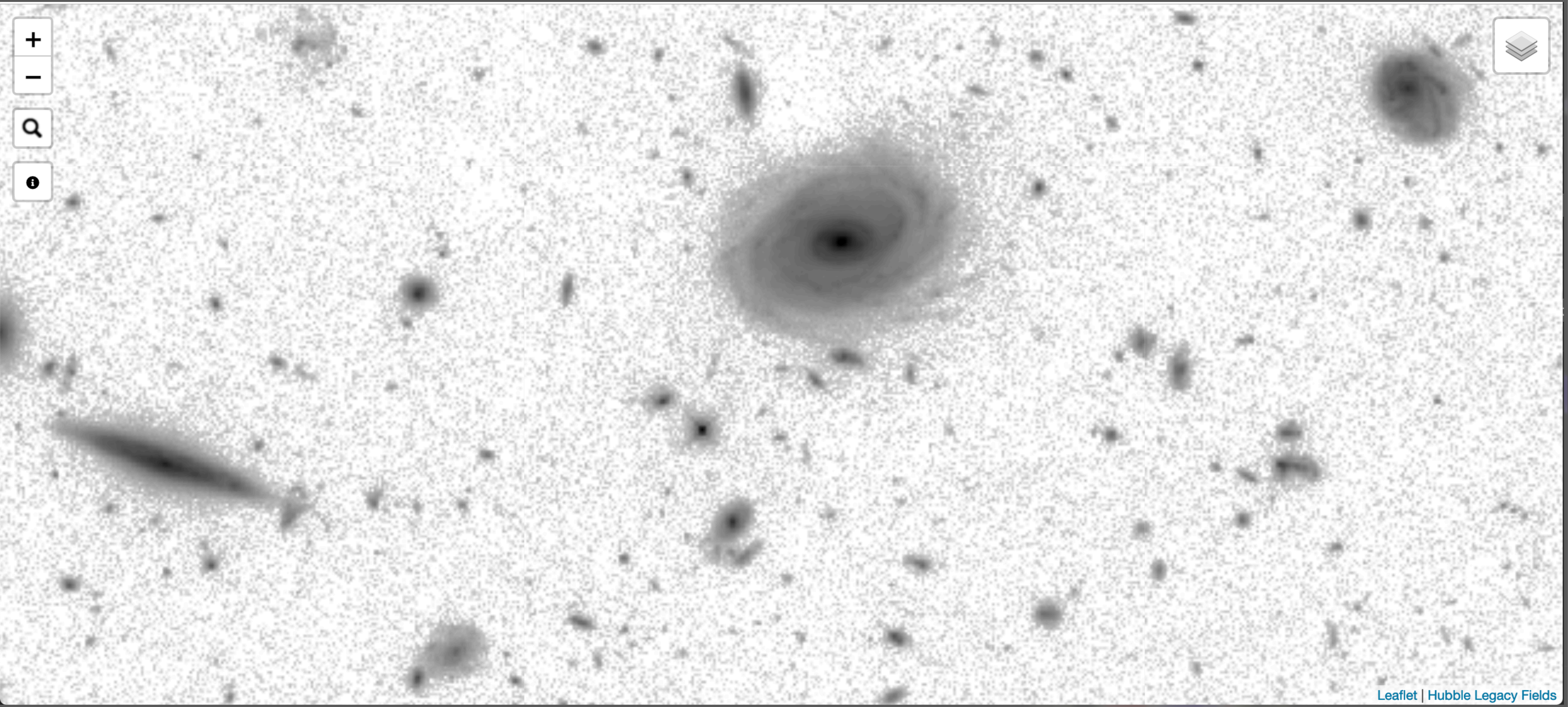


Hausen & Robertson (in prep)

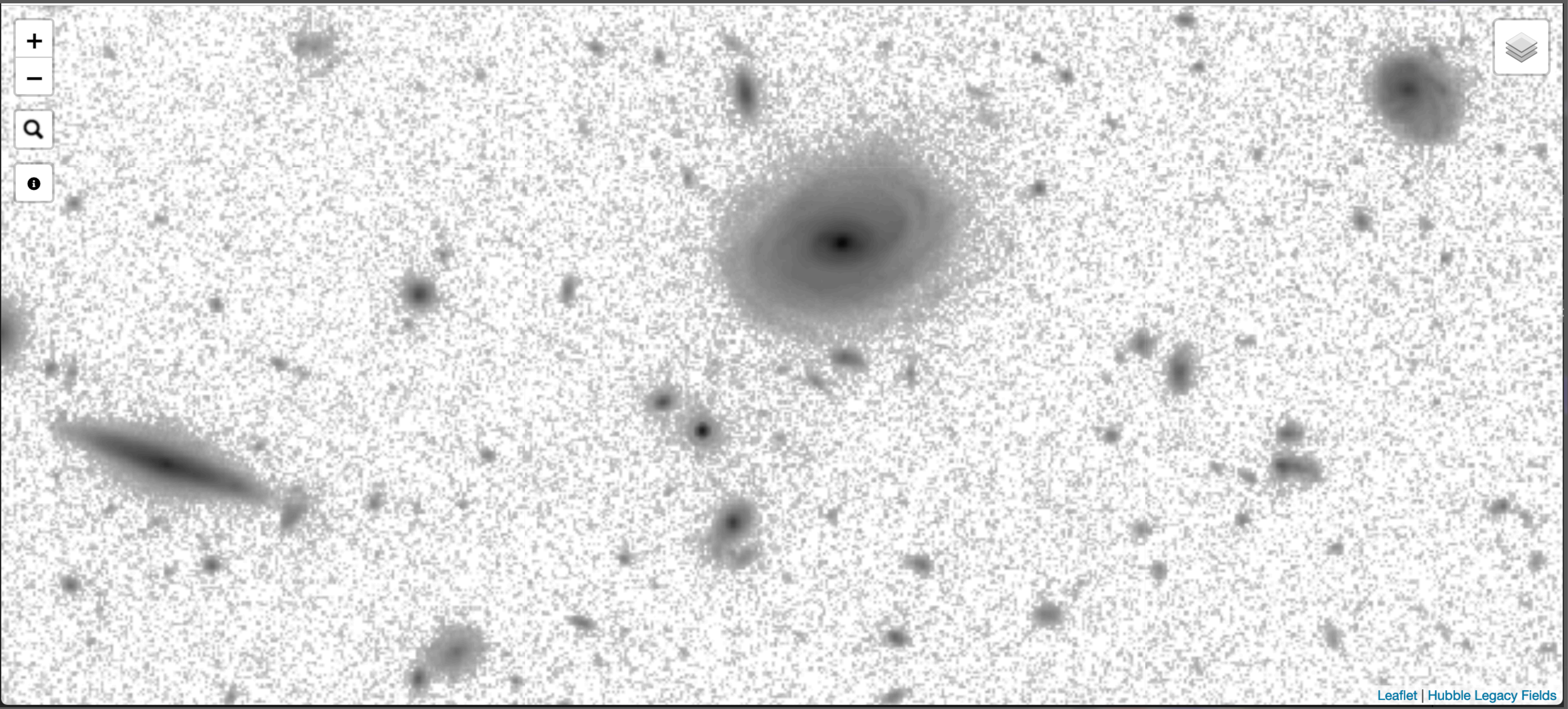
Hubble Space Telescope 0.65 micron Image



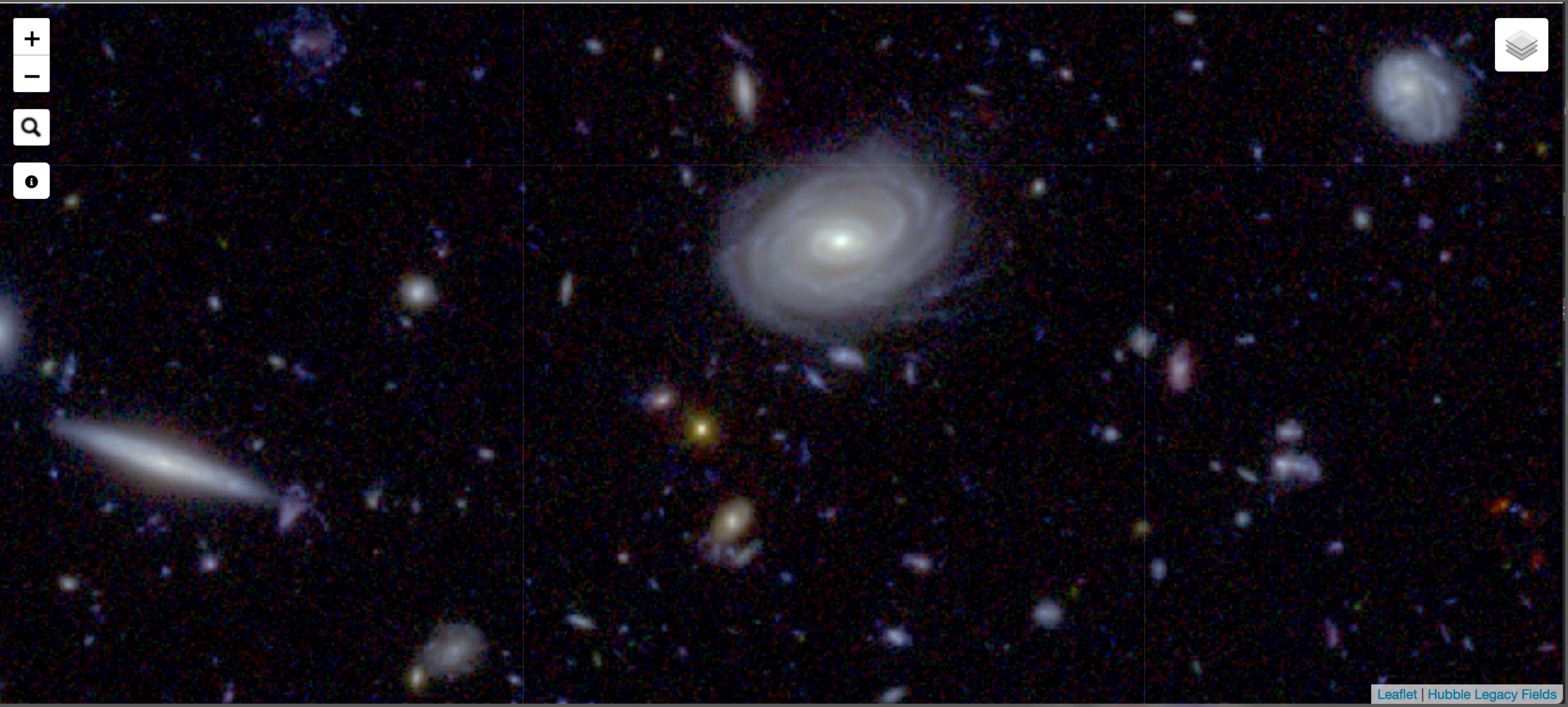
Hubble Space Telescope 0.9 micron Image



Hubble Space Telescope 1.25 micron Image



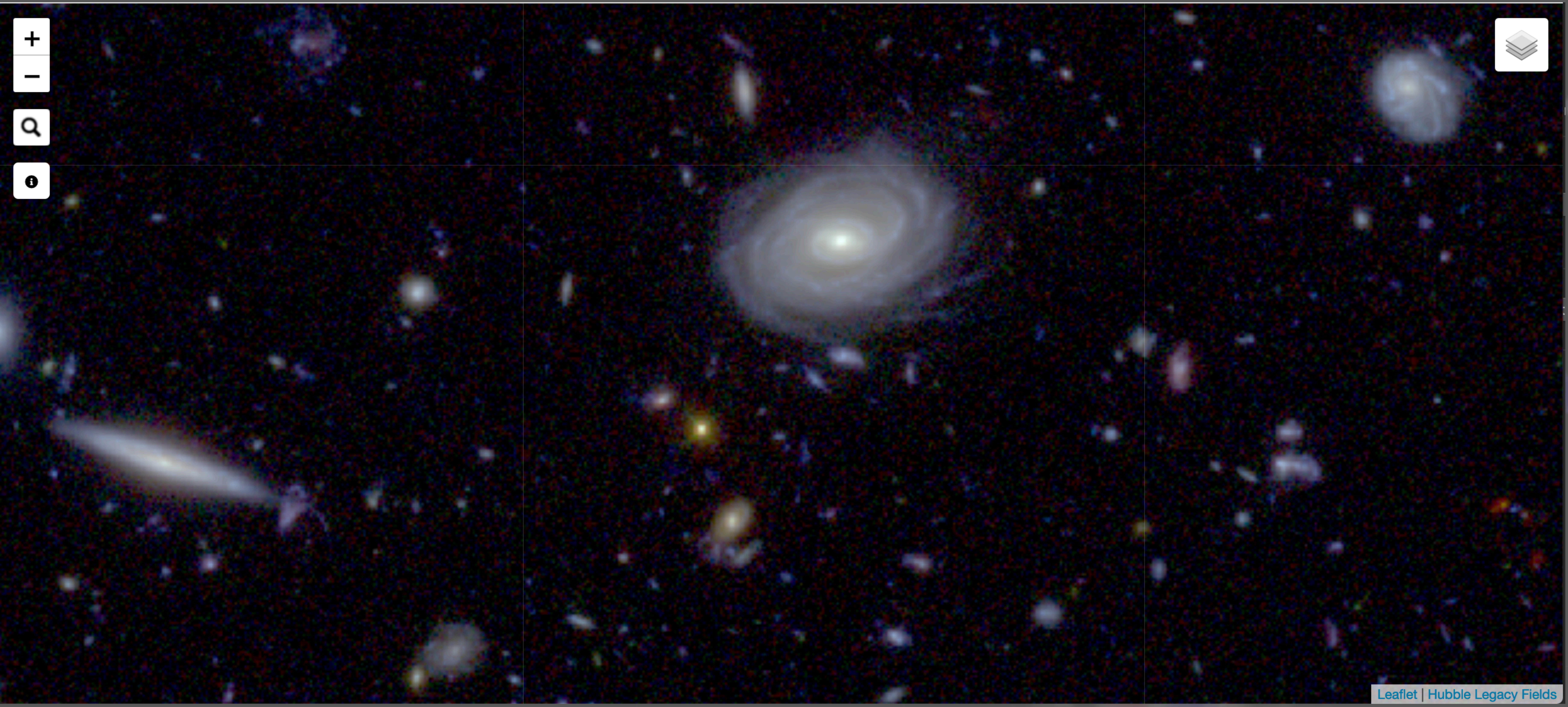
RGB Image of HST Data



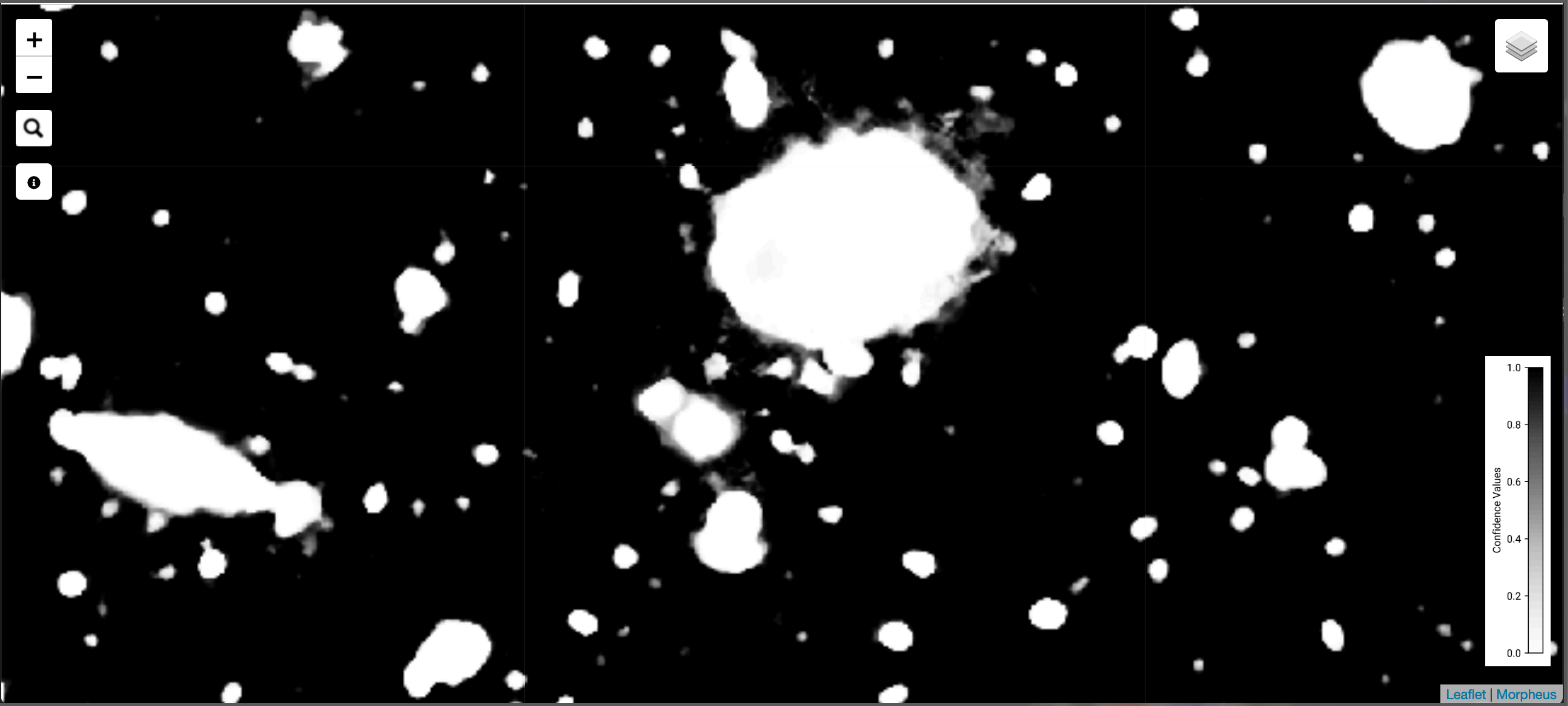
Morpheus Model Flow

Hausen & Robertson (in prep)

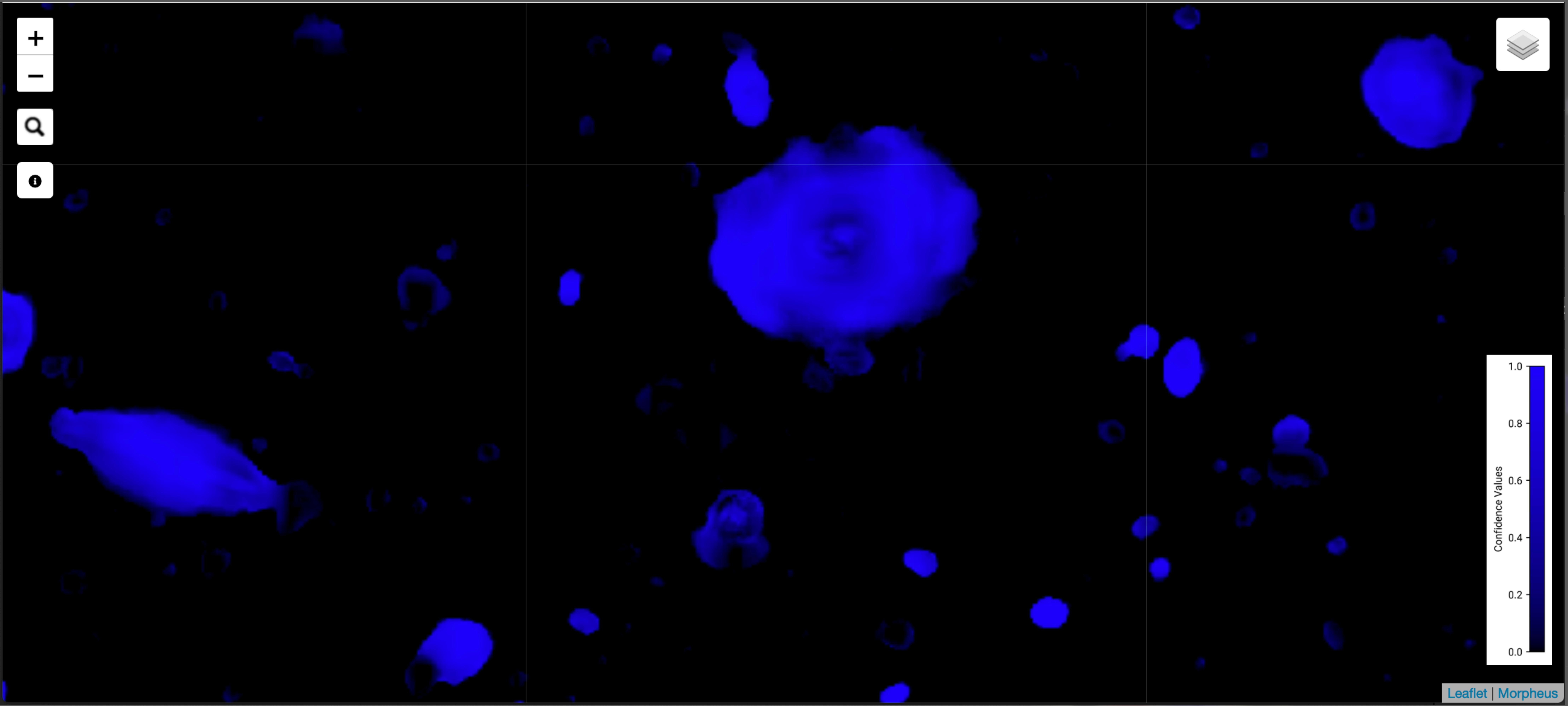
RGB Image of HST Data



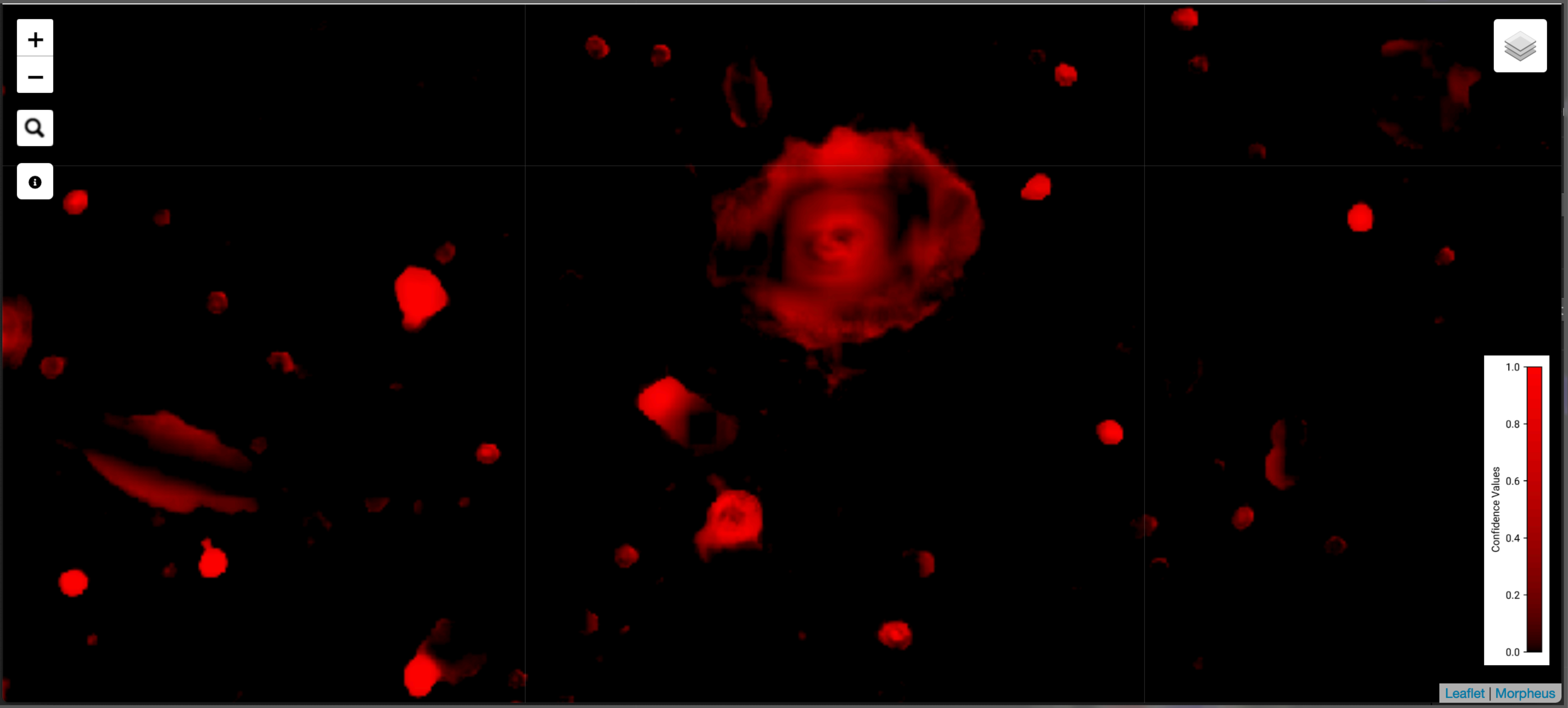
Morpheus “Background”



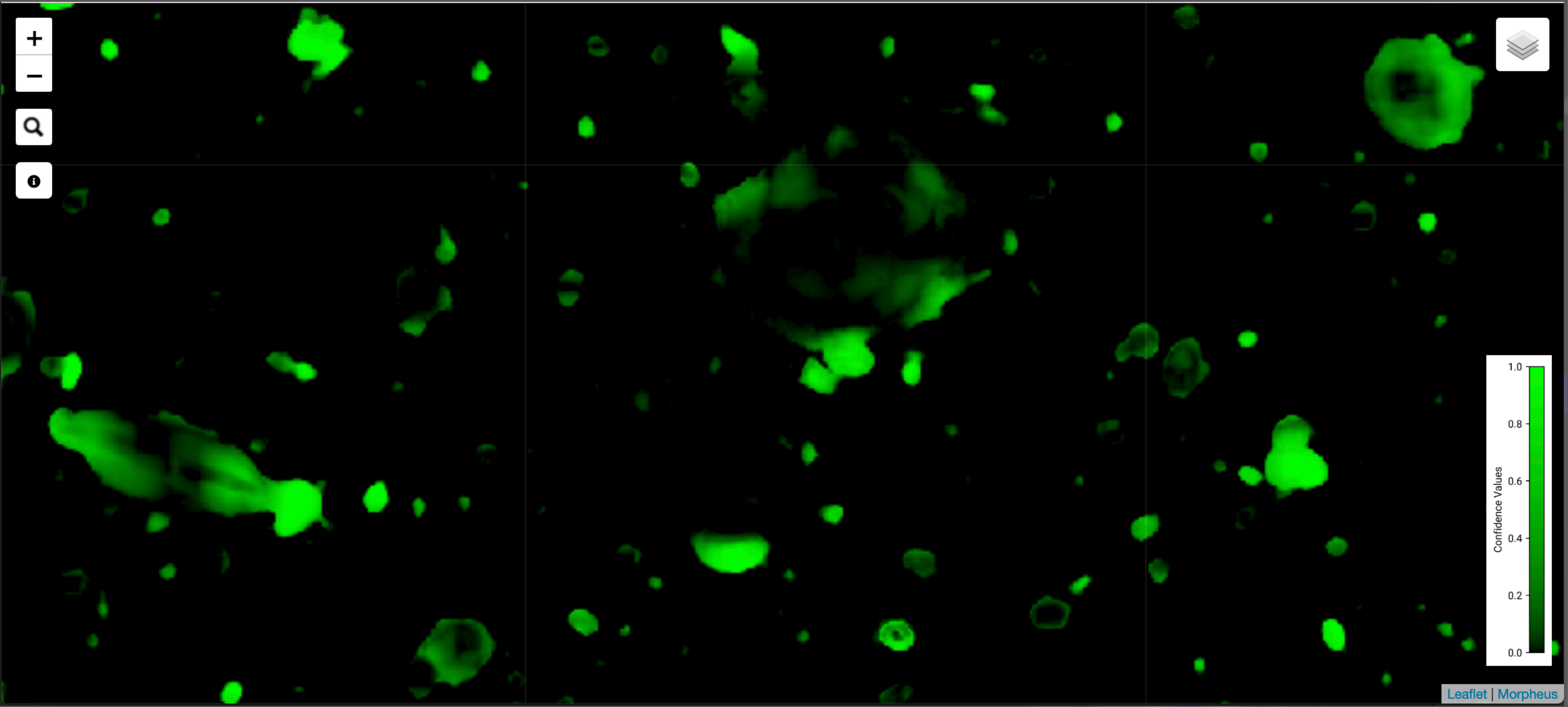
Morpheus "Disk Galaxy" Pixels



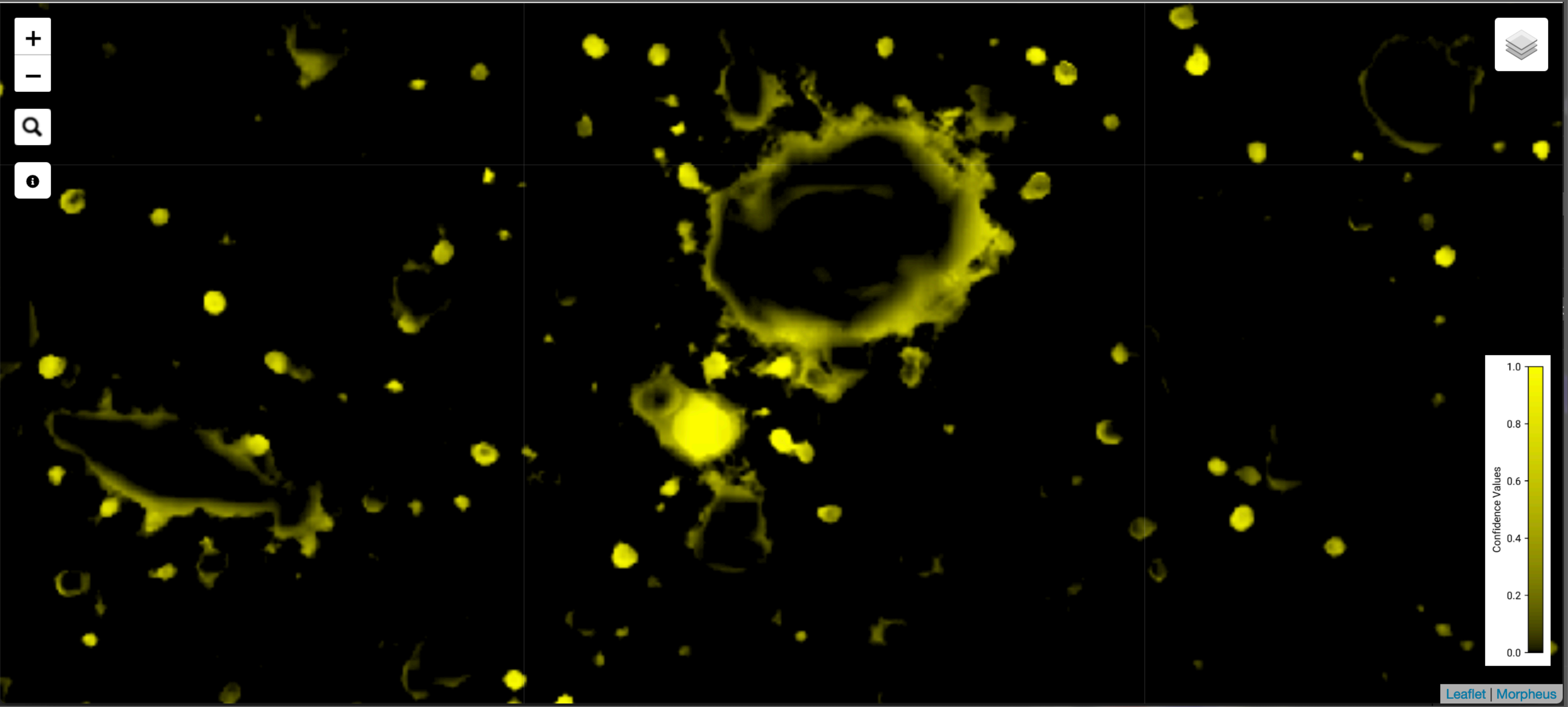
Morpheus "Spheroidal Galaxy" Pixels



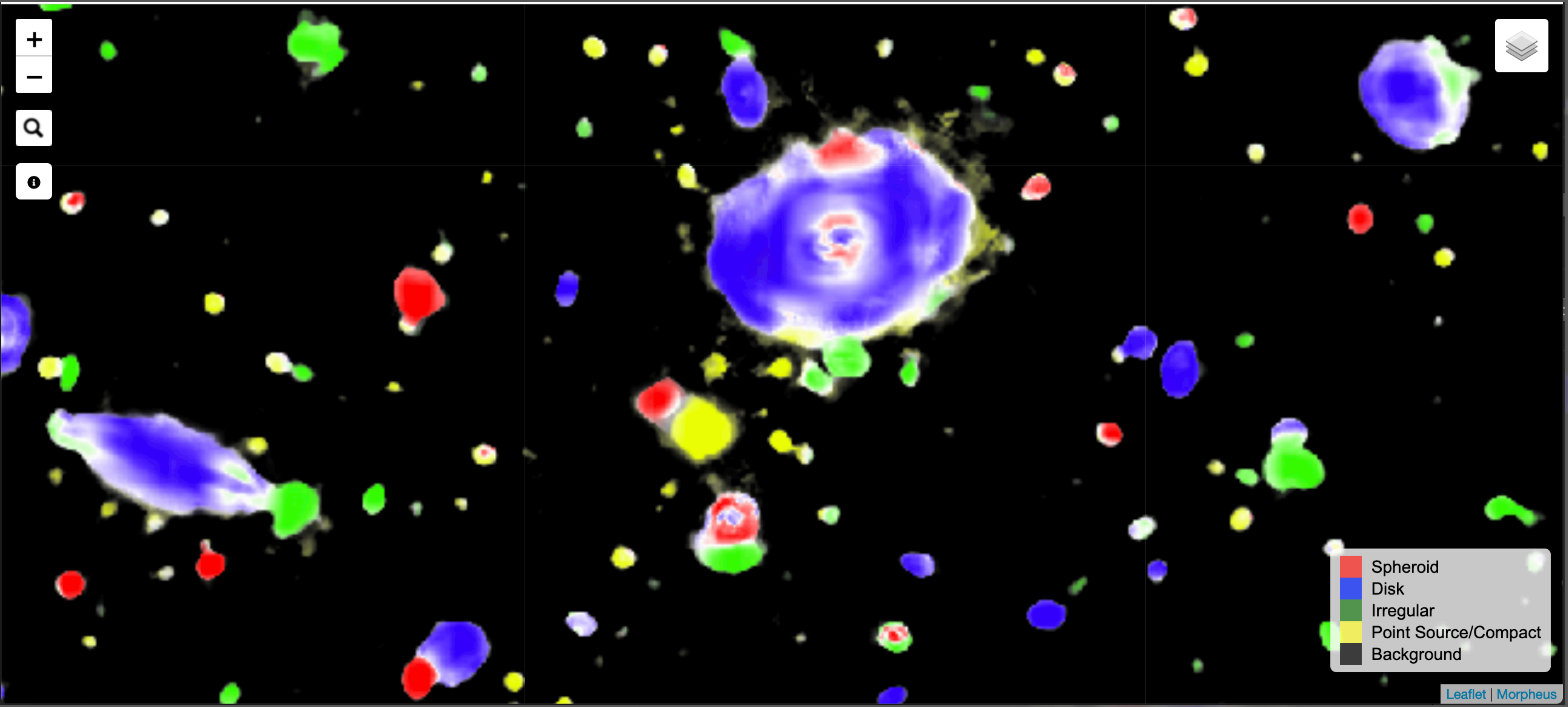
Morpheus “Irregular Galaxy” Pixels



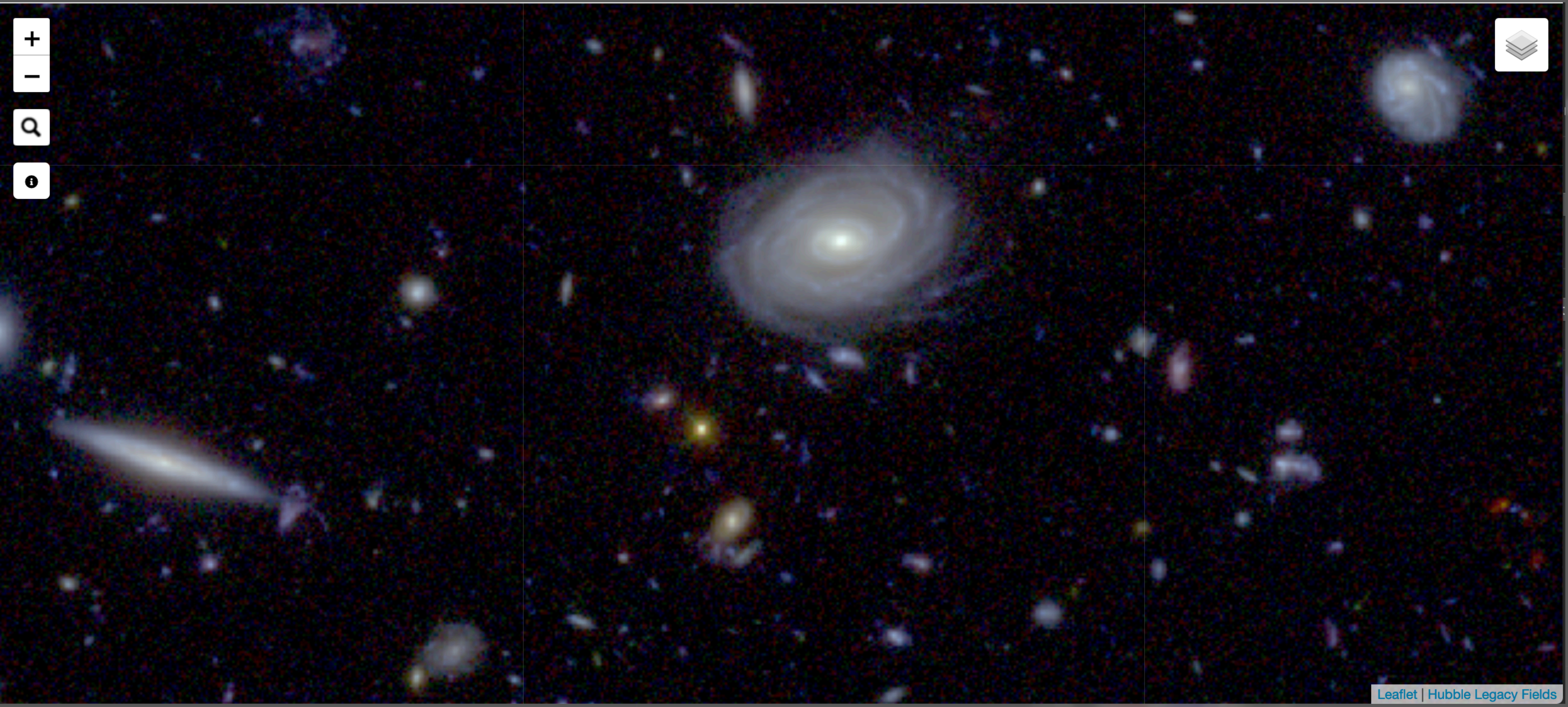
Morpheus "Point Source" Pixels



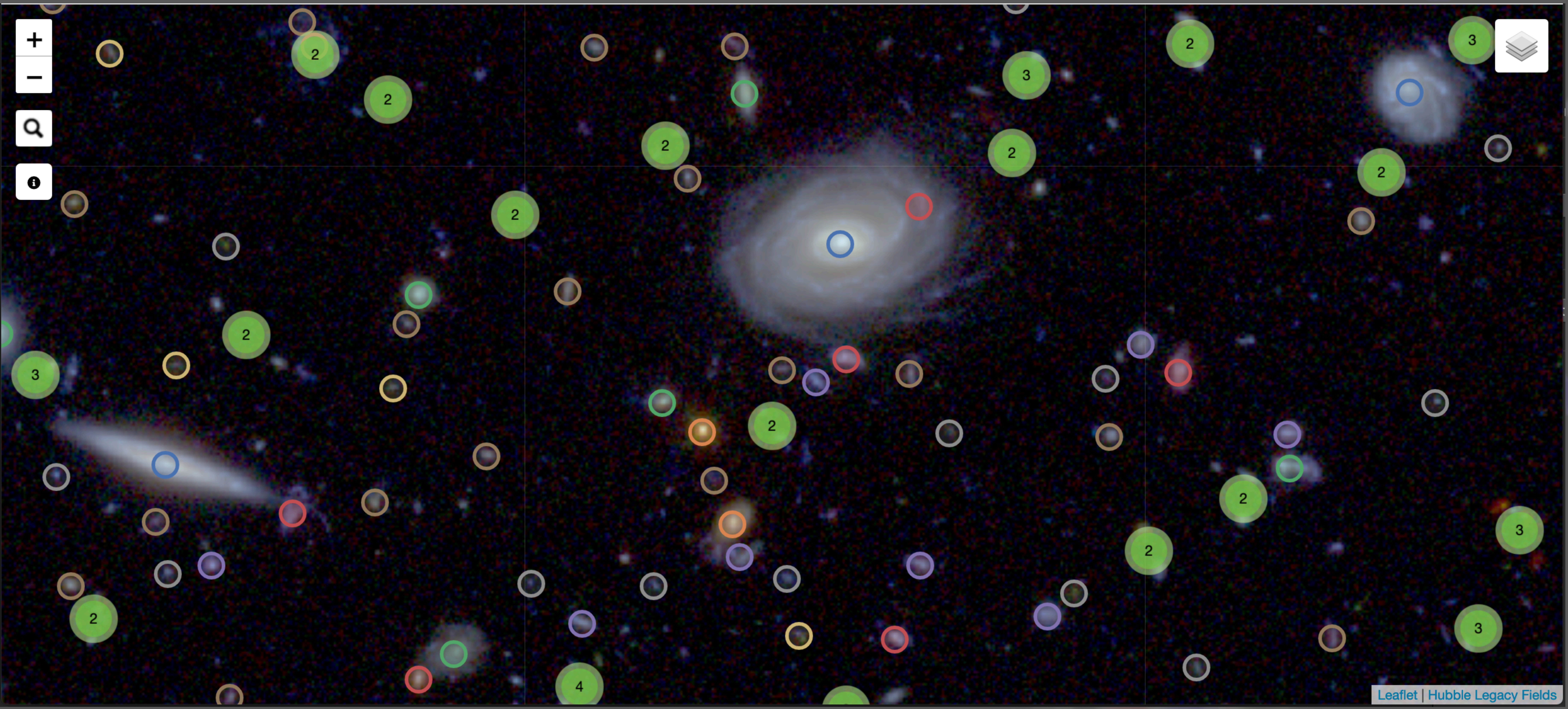
Morpheus “Morphological Color” Image



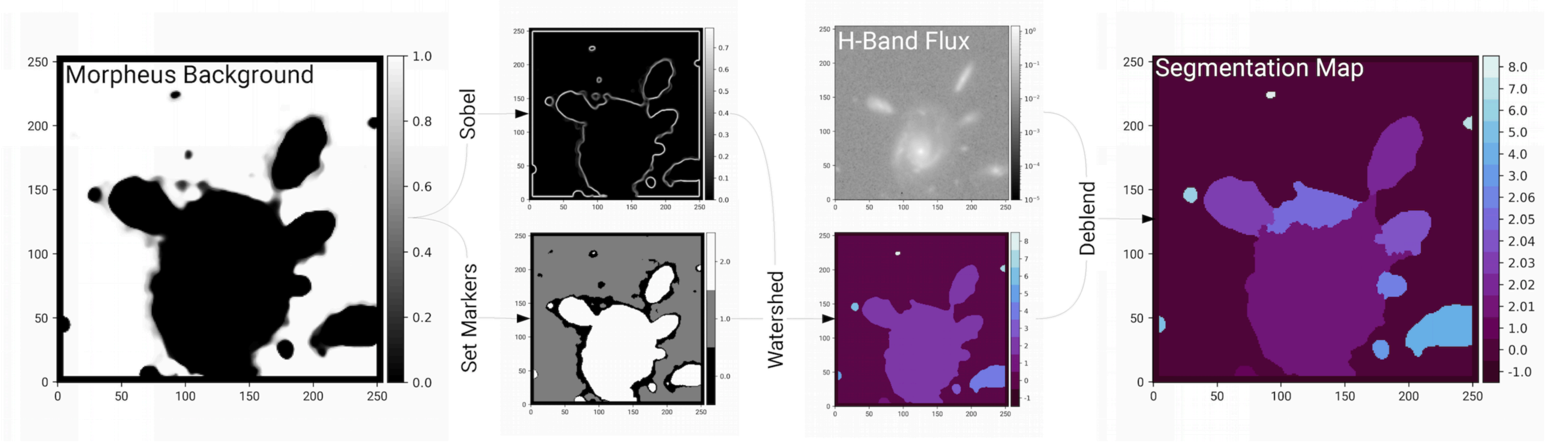
RGB Image of HST Data



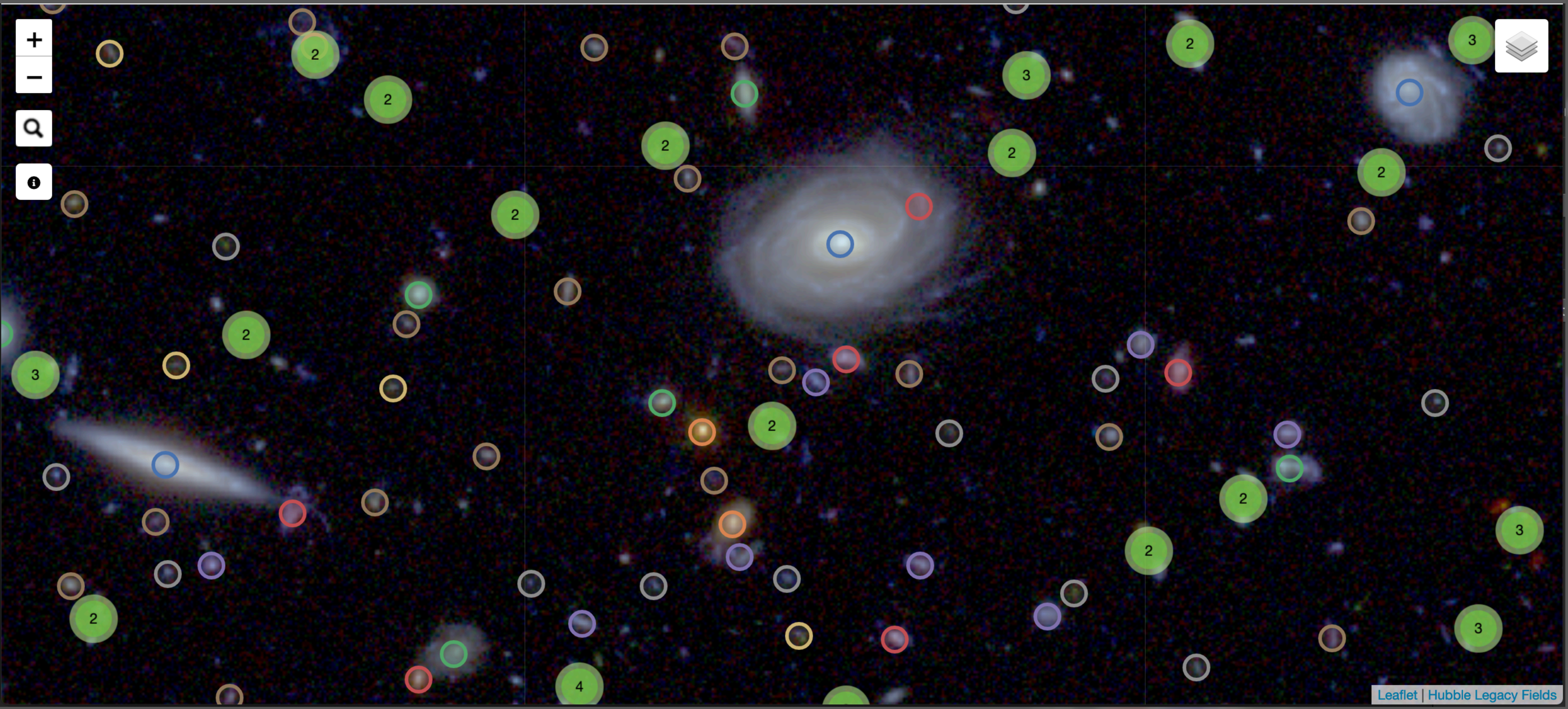
Known Astronomical Objects



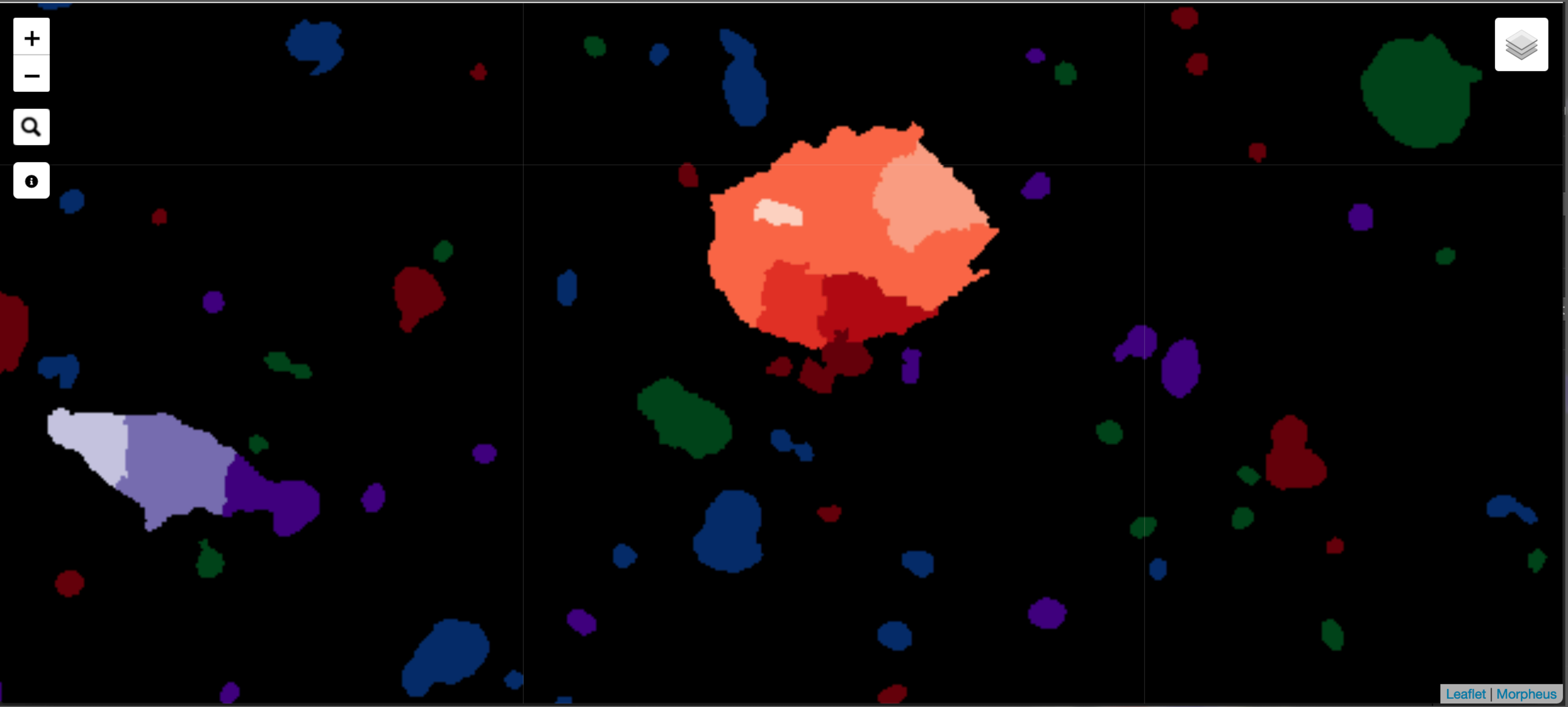
Morpheus: Deblending Algorithm



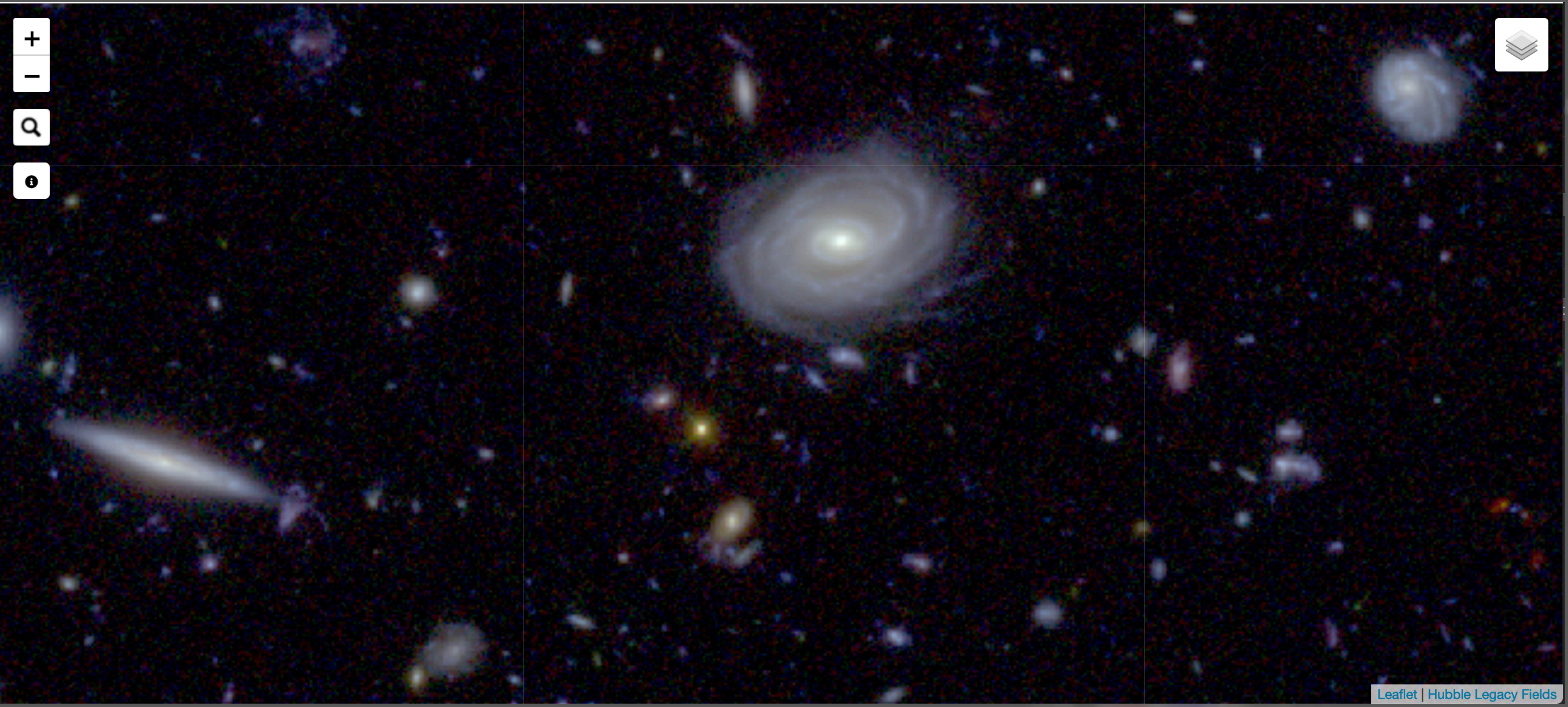
Known Astronomical Objects



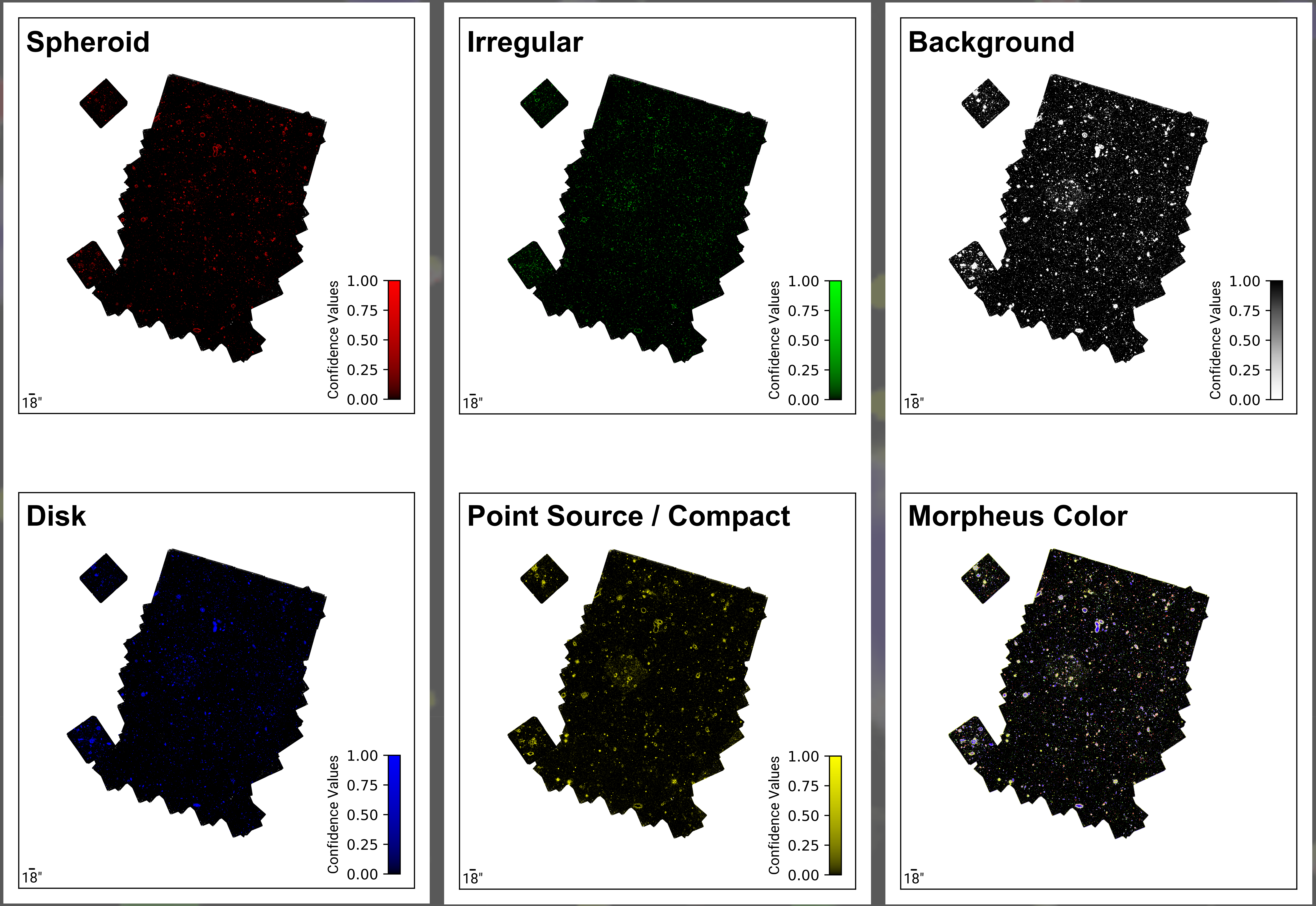
Morpheus Segmentation



RGB Image of HST Data



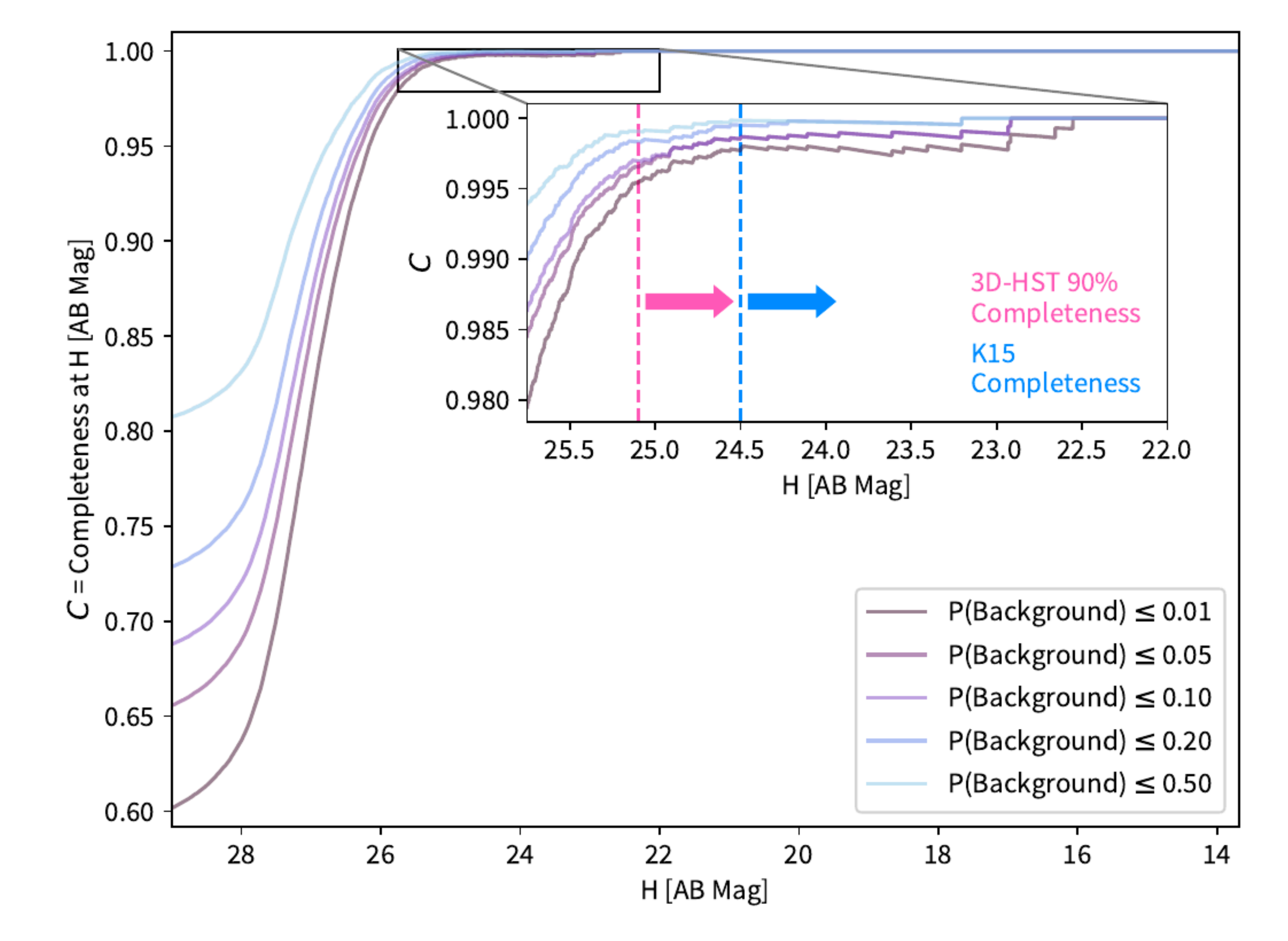
Morpheus Classification of HST GOODS-S/CANDELS



NVIDIA GTC 2019

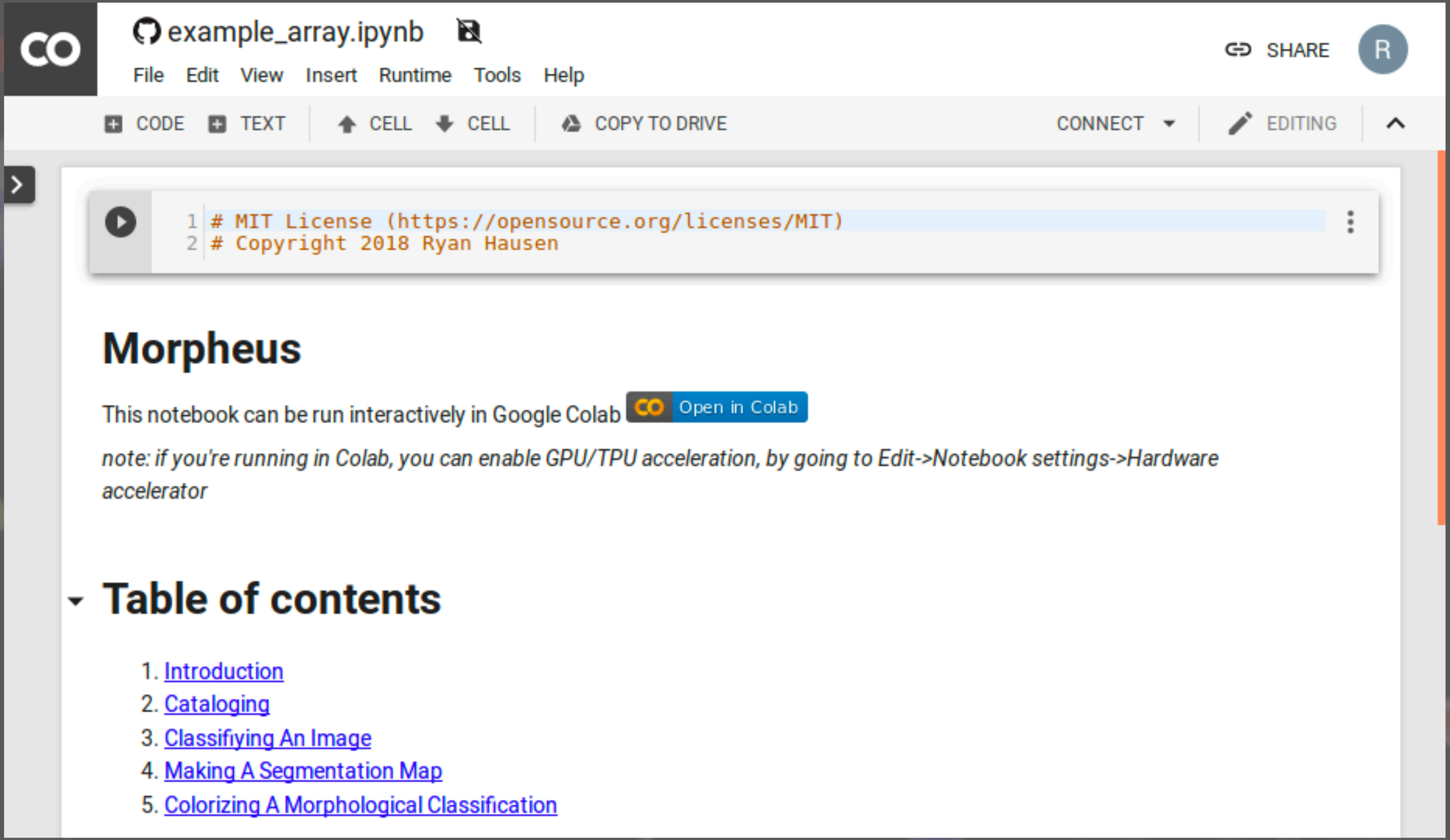
100,000,000 pixels!

Morpheus: Completeness of 3DHST Sources



Morpheus is highly complete, and to fainter flux levels than the training sample's completeness limit.

Try Morpheus on Google Colab



https://bit.ly/2ue3lf5


Morpheus: Leaflet Demo

Morpheus: Conclusion

- Deep Learning model for pixel-level morphological classification of astronomical datasets.
- Provides a Deep Learning framework for analyzing astronomical datasets.
- Give it a try:
  - Code: https://github.com/morpheus-project/morpheus
  - PyPI: https://pypi.org/project/morpheus-astro
  - Docker: https://hub.docker.com/morpheusastro/morpheus
  - Leaflet Viz: https://users.soe.ucsc.edu/~ryanhausen

Thanks!