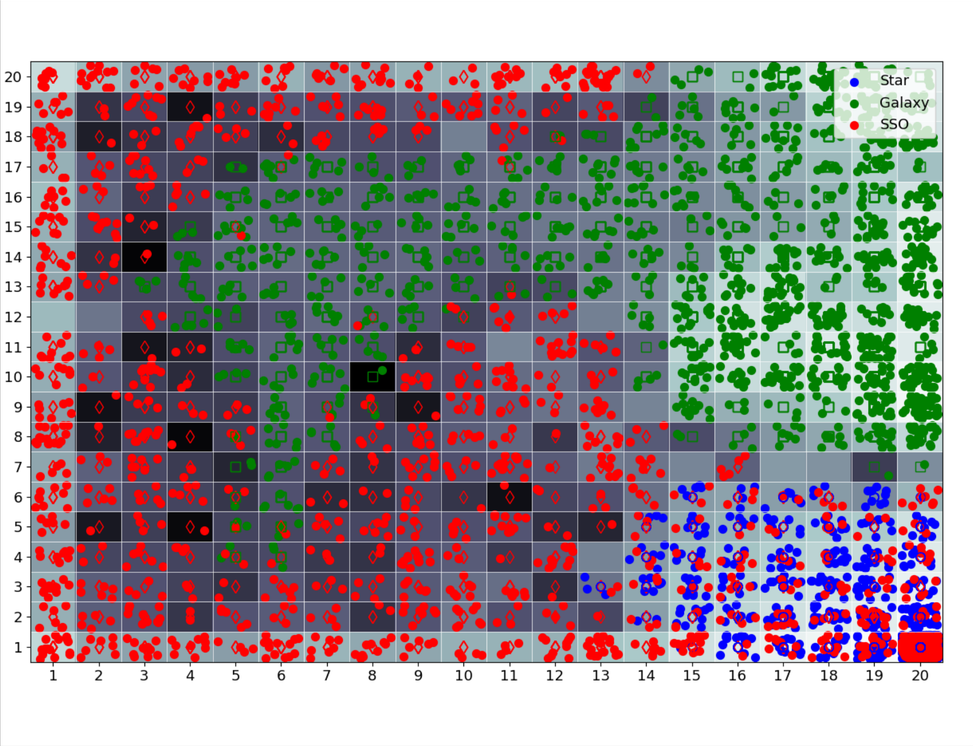


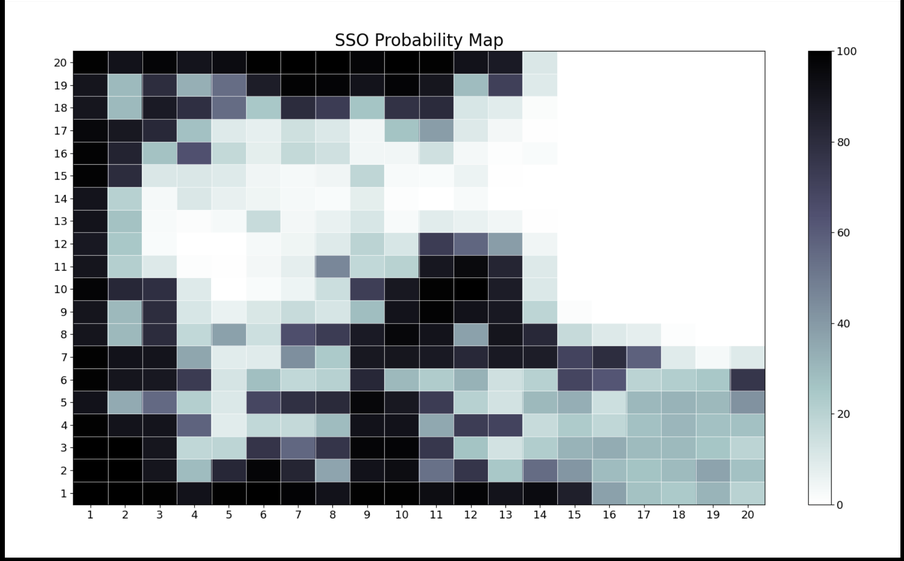


# Early-stopping SOMs as a tool to classify SSOs in space surveys

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# SOM: How Does It Work

- $Q = N\,M$ neurons organized in a rectangular lattice, with coordinates $(i, j)$ with $(i = 0, \dots, N - 1, j = 0, \dots, M - 1)$
- Each neuron associated to a reference vector $r_k$ with $K$ values and is exposed to an input vector $w_k$ coming from a training dataset with $L$ inputs
- How does a neuron win? By minimizing the Euclidean distance:

$$D^l_{\text{min}} = \min_{i,j}\left(\sqrt{\sum_{k=0}^{K-1} m^l_k\,(r^{i,j}_k - w^l_k)^2}\right)$$

- After a full epoch, iterative process by updating neuron components:

$$r'^{i,j}_k = r^{i,j}_k + \alpha\left(\frac{t}{N_e}\right) H\left(\frac{t}{N_e}, d_{win} - d\right)\left(w^l_k - r^{i,j}_k\right)$$

- The parameters $\alpha(t)$ and $\sigma(t)$ can either be linearly or exponentially decreasing with the passing epochs.

# Early stopping

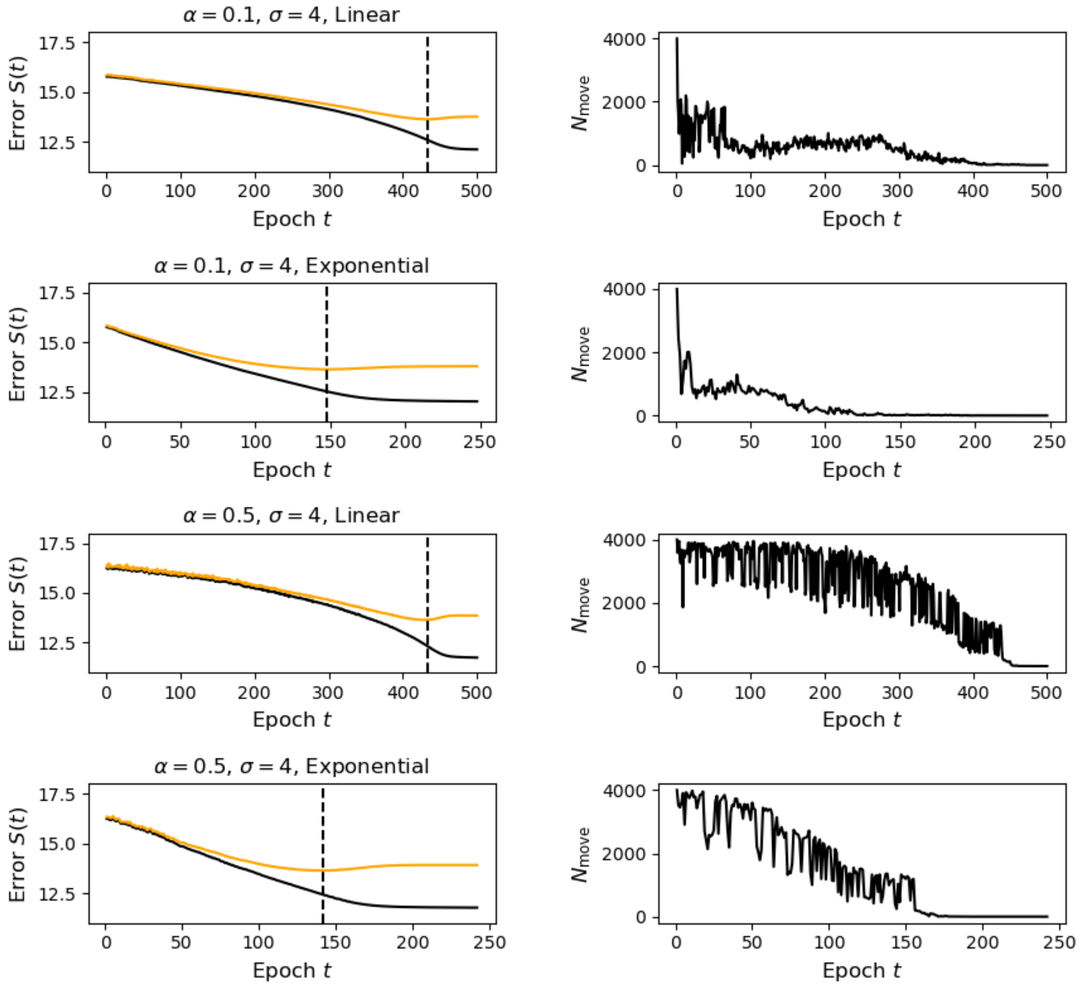
- Using $N_e$, process can be long and time (and memory!) consuming, and eventually produce over-fitting
- Solution: check performance of the SOM on an independent, randomly chosen validation dataset
- Metric:

$$S(t) = \frac{\sum_{l=0}^{L-1} D_{\min}^{l}}{L}$$

- Expected behavior: $S(t)$ will continuously decrease, $S_{val}(t)$ will reach a minimum and trend upward (overfitting!)
- By stopping the learning process before the overfitting stage, the SOM will maintain its capability to classify new data.

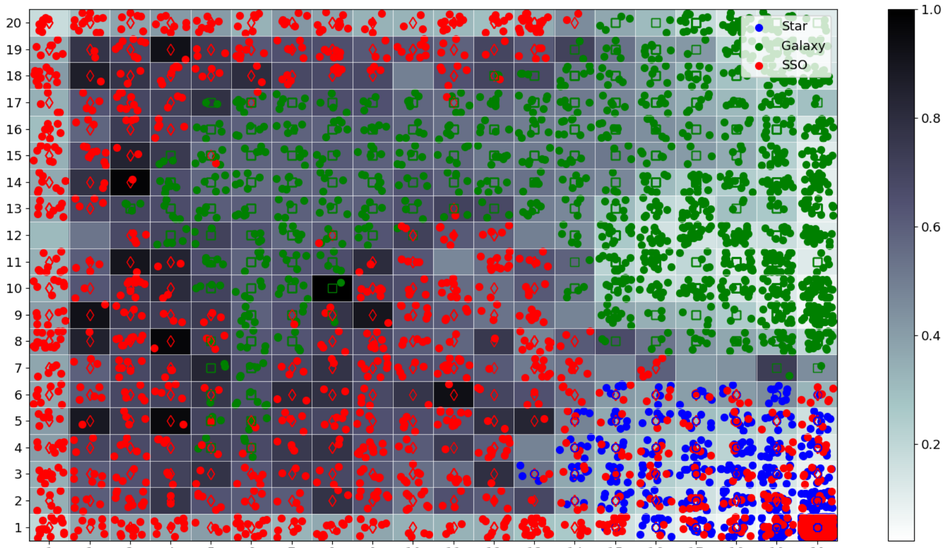
# Training the SOM

- 4000 random 101x101 images → 20x20 neurons
- Comparing errors and numbers of movements for different models and parameters:
- Results: exponential, $\alpha = 0.5$ , $\sigma = 4$

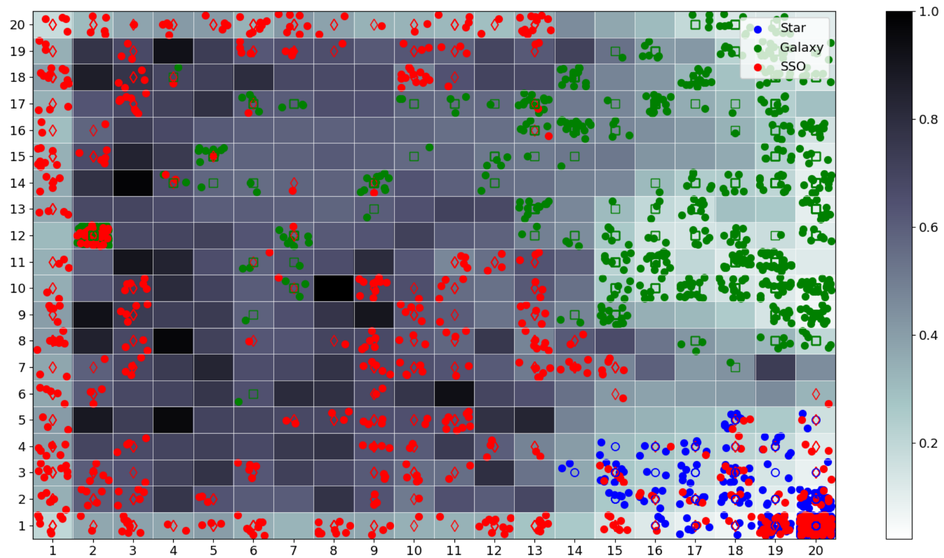


# Training the SOM

- U-matrix generated from SOM training:

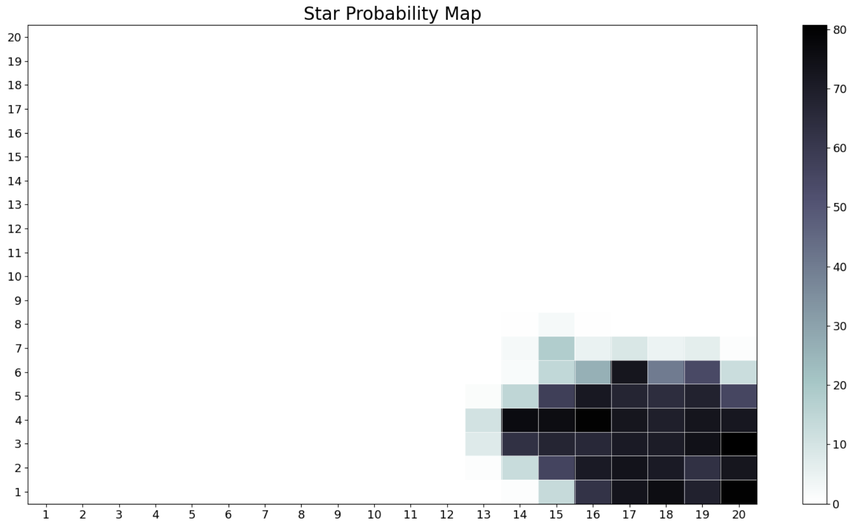


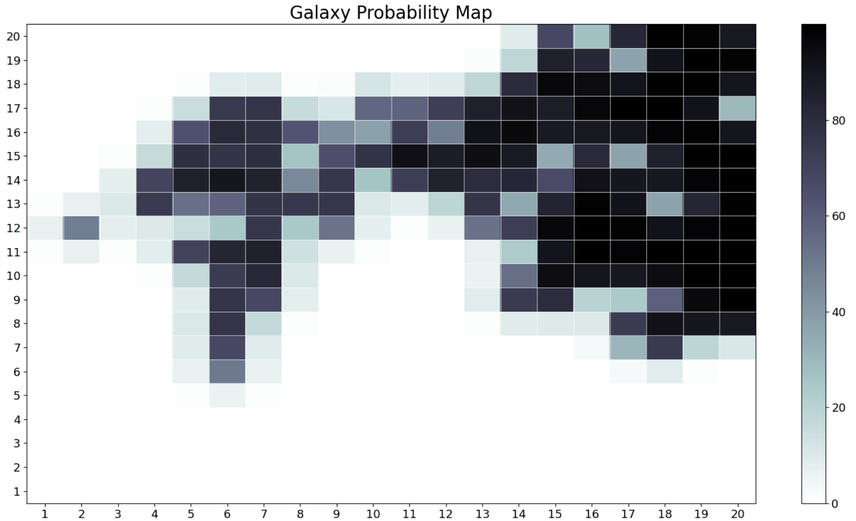

- U-matrix with 2000 images from test dataset:

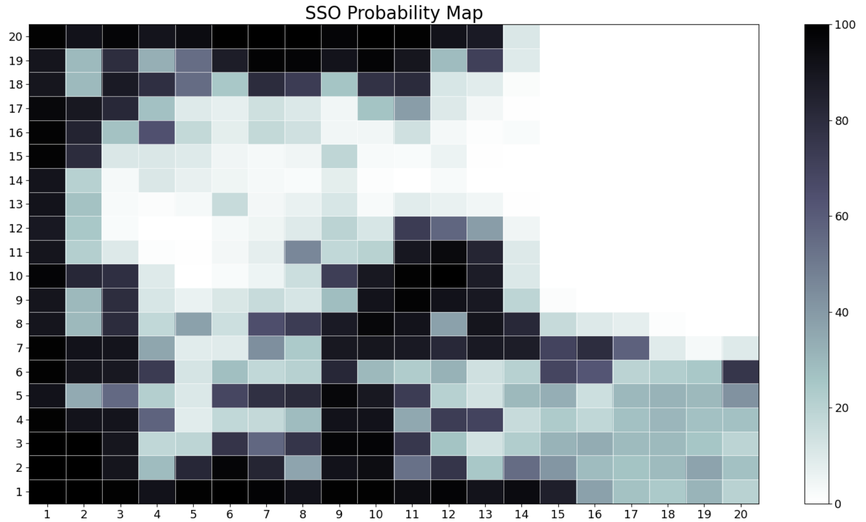


# Results

- Quality assessment with $10^4$ images, bins 0-3’’/h, 3-6’’/h, 6-10’’/h
- Purity: 11%, 100%, 100%
- Completeness: 51%, 48%, 60%



# Conclusions

- Early-stopping is a powerful technique to improve SOMs
- With proper parameters, stopping time is more than halved
- Relatively high accuracy above 1’’/h (slow moving SSOs are undistinguishable from stars!)
- Difference between simulated and authentic images: more training is needed for real survey data