Model Selection for Galaxy Shapes

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Overview

1. Problem Definition
2. Model Selection Method
3. Simulation Studies

1 Problem Definition

2 Model Selection Method

3 Simulation Studies

Problem Definition

Our goal: match the images with the correct models.

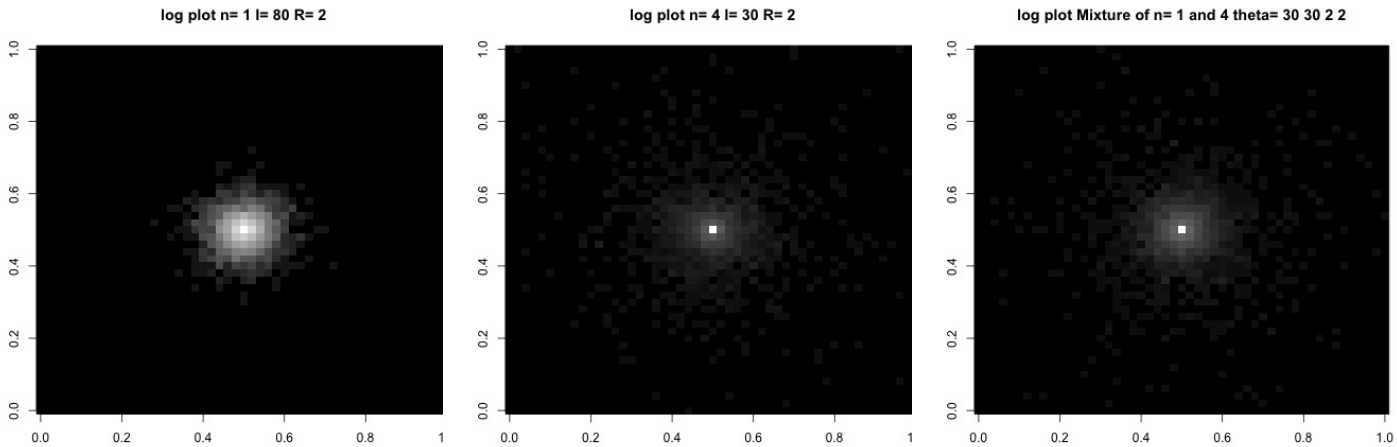

Figure: Simulated from three different models

Galaxy Shape Model–Sersic Profile

Sersic Profile is an intensity profile:

$$I(R) = I_e \exp\{-k[(\frac{R}{R_e})^{\frac{1}{n}} - 1]\}$$

where I_e is the intensity at the effective radius R_e that encloses half of the total light from the model. n is the Sersic index which controls the degree of curvature of the profile, usually ranging from $\frac{1}{2}$ to 10. k depends on n.

Models to be considered

- We assume a Poisson model to fit the image:

$$y \sim \text{Poisson}(\lambda),$$

where y is the pixel value, $\lambda = I(R)$.

- In Astronomy, a galaxy can be a mixture of two Sersic Profiles with different n:

$$I(R) = I_1 \exp\{-k_1[(\frac{R}{R_1})^{\frac{1}{n_1}} - 1]\} + I_2 \exp\{-k_2[(\frac{R}{R_2})^{\frac{1}{n_2}} - 1]\}.$$

- For the Poisson model with a mixture $I(R)$, we call it a mixture model(four parameters,I_1, I_2, R_1, and R_2.). Otherwise, we call it a single model(two parameters). Our job here is to select the "correct" model behind a given image.

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Model Selection Method

- The model selection method used here is BIC.

$$\text{BIC}(M) = k * \log(n) - 2\log(L),$$

where k is the number of parameters in the model, L is the likelihood, and n is number of observations you have. We always prefer the model with the lowest BIC.

- Why BIC? BIC is good for model selection, while AIC is good for prediction accuracy. Second reason: empirical results.

- What is the challenge? Initial values of parameters during the likelihood maximization process.

How to choose the initial values?

- Making use of the physical meanings of the parameters.
- Since R_e is the radius which encloses half of the total intensity, choose the radius R_0 which encloses half of the total intensity of the image as the initial value for R_e.
- Since I_e is the intensity on the circle with radius R_e, choose the average intensity I_0 on the circle with the radius R_0 found before as the initial value for I_e.
- How about the mixture model?

How to choose the initial values?

- For a mixture model. The outer part of the galaxy is mainly impacted by the component with smaller n, while the inner part of the galaxy is mainly impacted by the component with bigger n.

- In our study, we investigate a typical mixture model with $n_1 = 1$ and $n_2 = 4$.

$$I(R) = I_1 \exp\{-1.68[\frac{R}{R_1} - 1]\} + I_2 \exp\{-7.67[(\frac{R}{R_2})^{\frac{1}{4}} - 1]\}.$$

- One natural idea is to divide the whole galaxy into two parts. Use the inner part to fit an $n = 4$ model, the estimated I_e and R_e will be used as the initial values for I_2 and R_2. The outer part will be used to fit an $n = 1$ model, and the estimated I_e and R_e will be used as the initial values for I_1 and R_1.

How to choose the initial values?

- How to divide the whole image?
- Use the 80% quantile of the radius with non-zero pixels as the threshold between inner and outer parts.
- Why 80%? Empirical results.

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Simulation Design

The experimental designs used here was proposed by Vinay. The following tables describe the 32 designs for I_1, I_2, R_1, R_2.

I_1	I_2	R_1	R_2
30	30	2	2
30	30	5	5
30	30	10	10
30	30	50	50
30	30	5	2
30	30	10	5
30	30	50	10
30	30	50	5

I_1	I_2	R_1	R_2
30	15	2	2
30	15	5	5
30	15	10	10
30	15	50	50
30	15	5	2
30	15	10	5
30	15	50	10
30	15	50	5

Simulation Design

I_1	I_2	R_1	R_2
80	80	2	2
80	80	5	5
80	80	10	10
80	80	50	50
80	80	5	2
80	80	10	5
80	80	50	10
80	80	50	5

I_1	I_2	R_1	R_2
80	40	2	2
80	40	5	5
80	40	10	10
80	40	50	50
80	40	5	2
80	40	10	5
80	40	50	10
80	40	50	5

Simulation Studies: No PSF

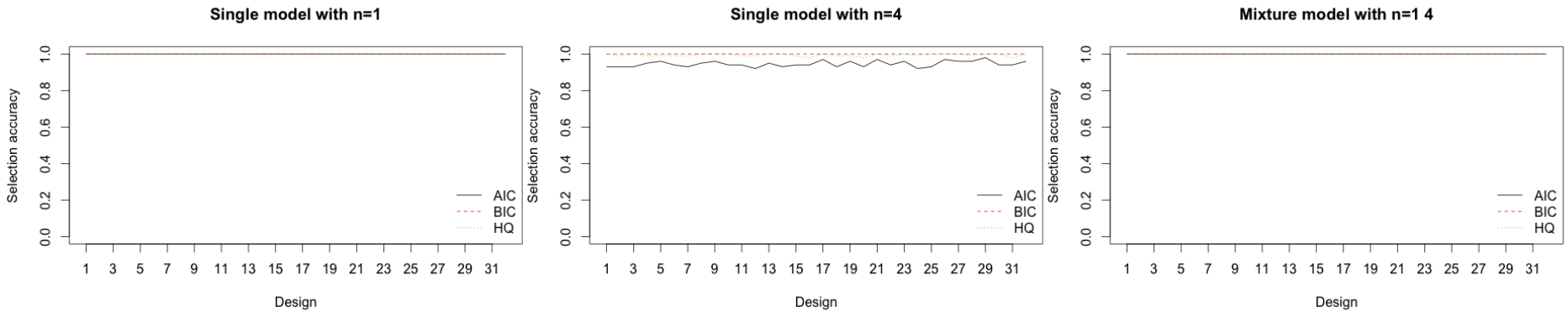

Figure: Image Size: 101*101

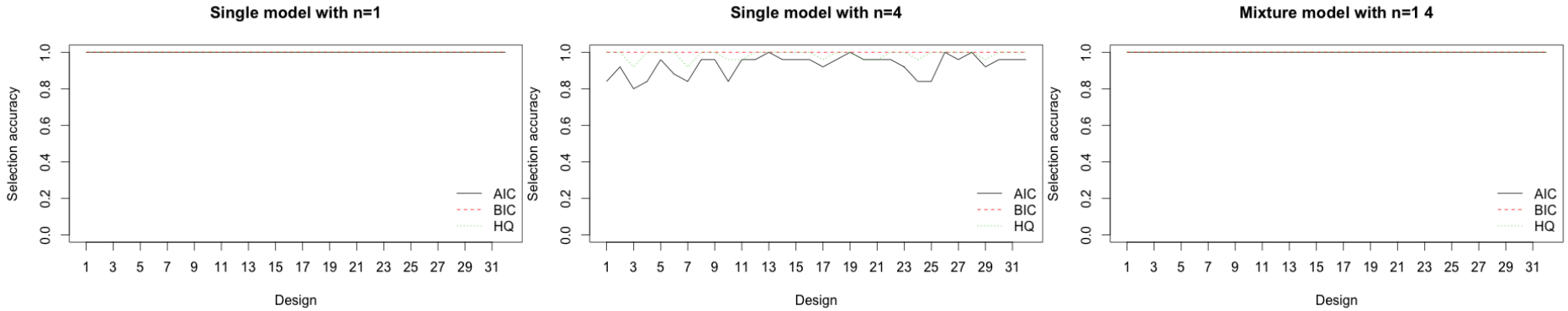

Figure: Image Size: 51*51

Simulation Studies: No PSF

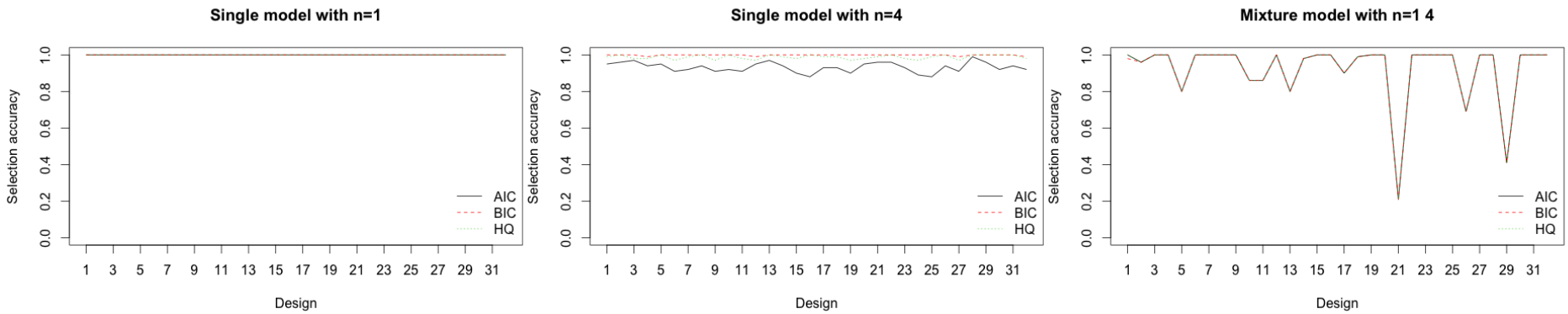

Figure: Image Size: 21*21

Simulation Studies: With Gaussian PSF, $\sigma = 0.5$

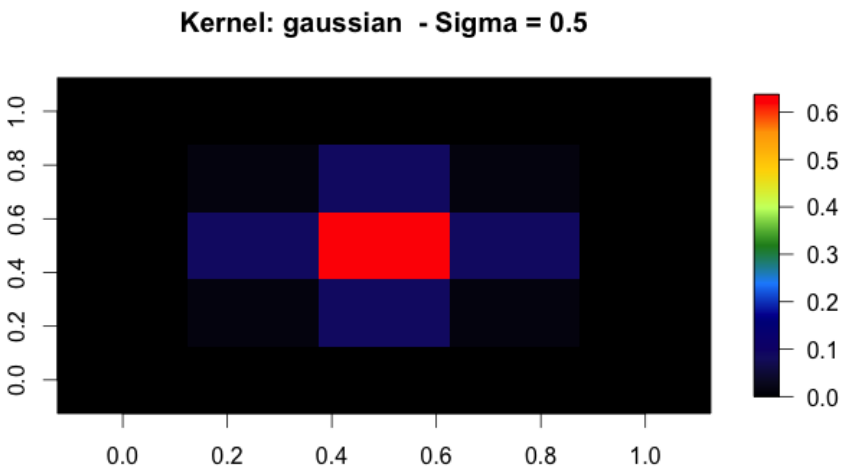

Figure: Gaussian Kernel Sigma=0.5

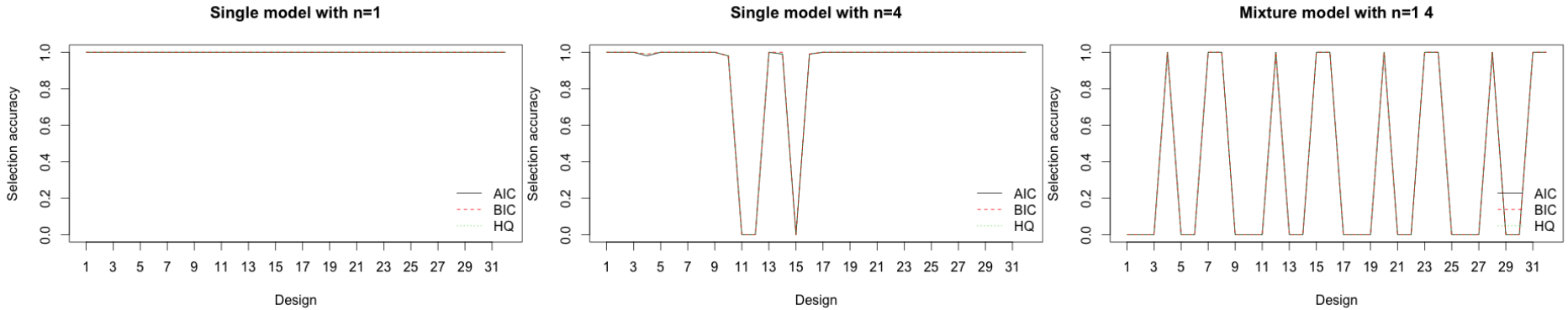

Figure: Image Size: 101*101

Simulation Studies: With Gaussian PSF, $\sigma = 0.5$

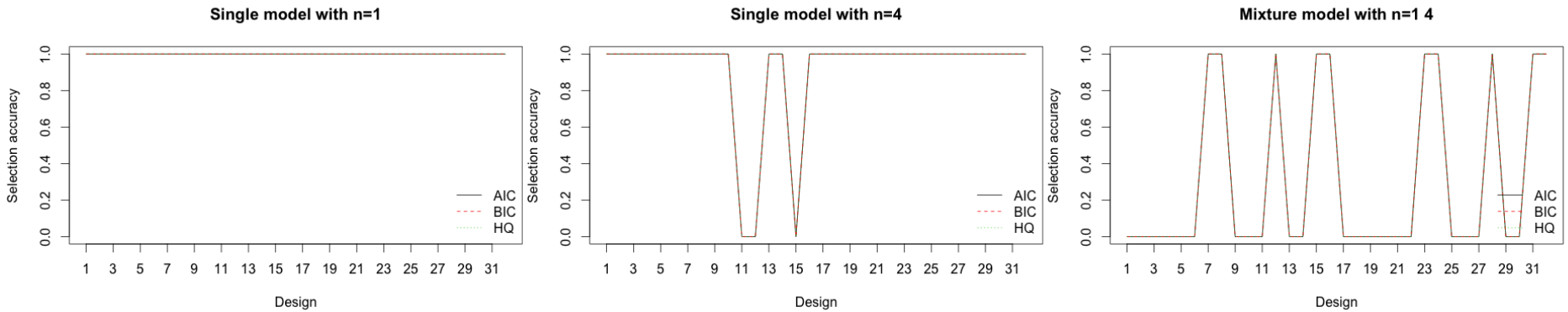

Figure: Image Size: 51*51

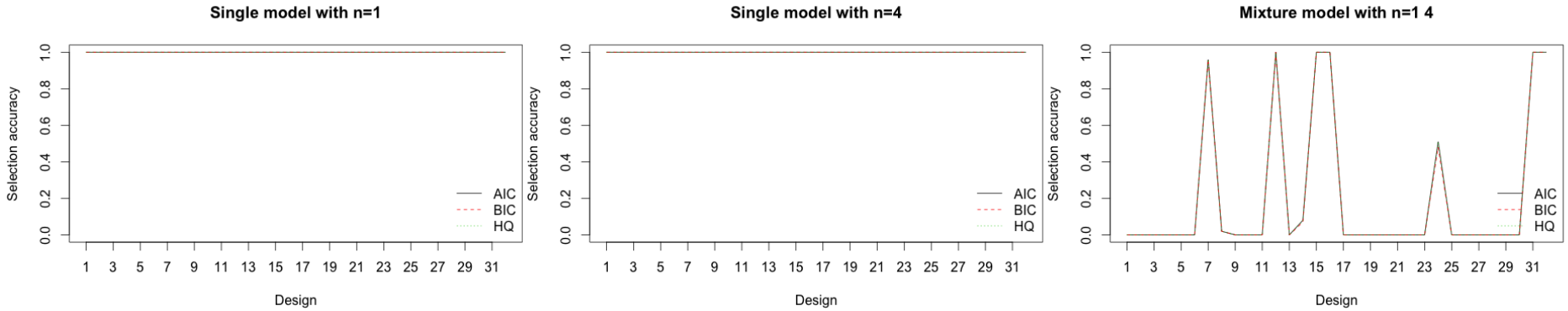

Figure: Image Size: 21*21

Some Questions

- What is the appropriate PSF to be used in simulation study?
- What is the next step?

The End