Making big things look small: Blur combined with other depth cues affects perceived size and distance

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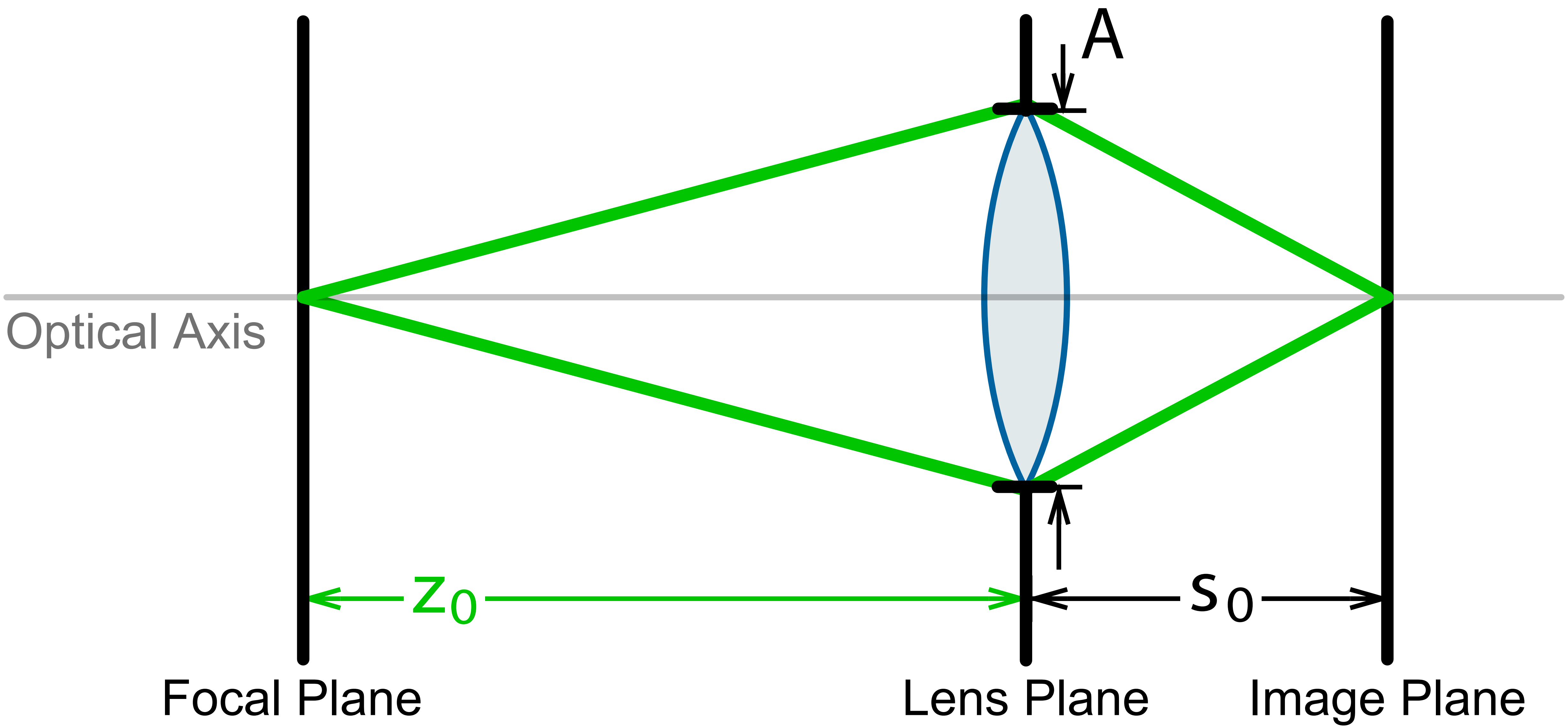
Blur as a depth cue: Previous findings

- Blur is a weak cue to depth
  - Other depth cues, such as disparity, are much stronger (Mather 2000)
  - Blur only useful to reveal the depth ordering of surfaces that occlude each other (Marshall et al. (1996) and Mather (1996))

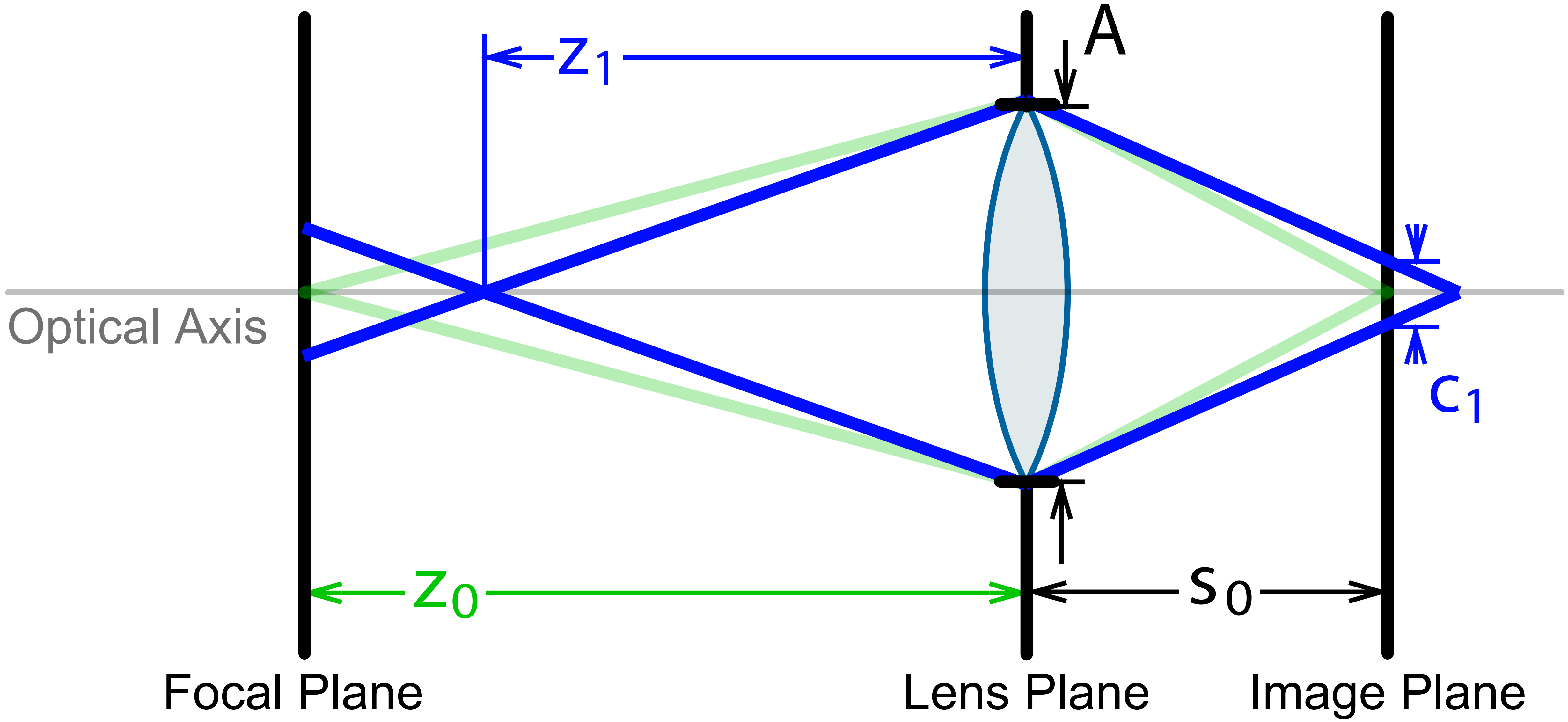
Revisiting blur as a cue



Important terms:

Focal (absolute) distance: z_0

Revisiting blur as a cue



Important terms:

Focal (absolute) distance: z_0

Relative distance: $d = z_1/z_0$

Blur magnitude: c_1

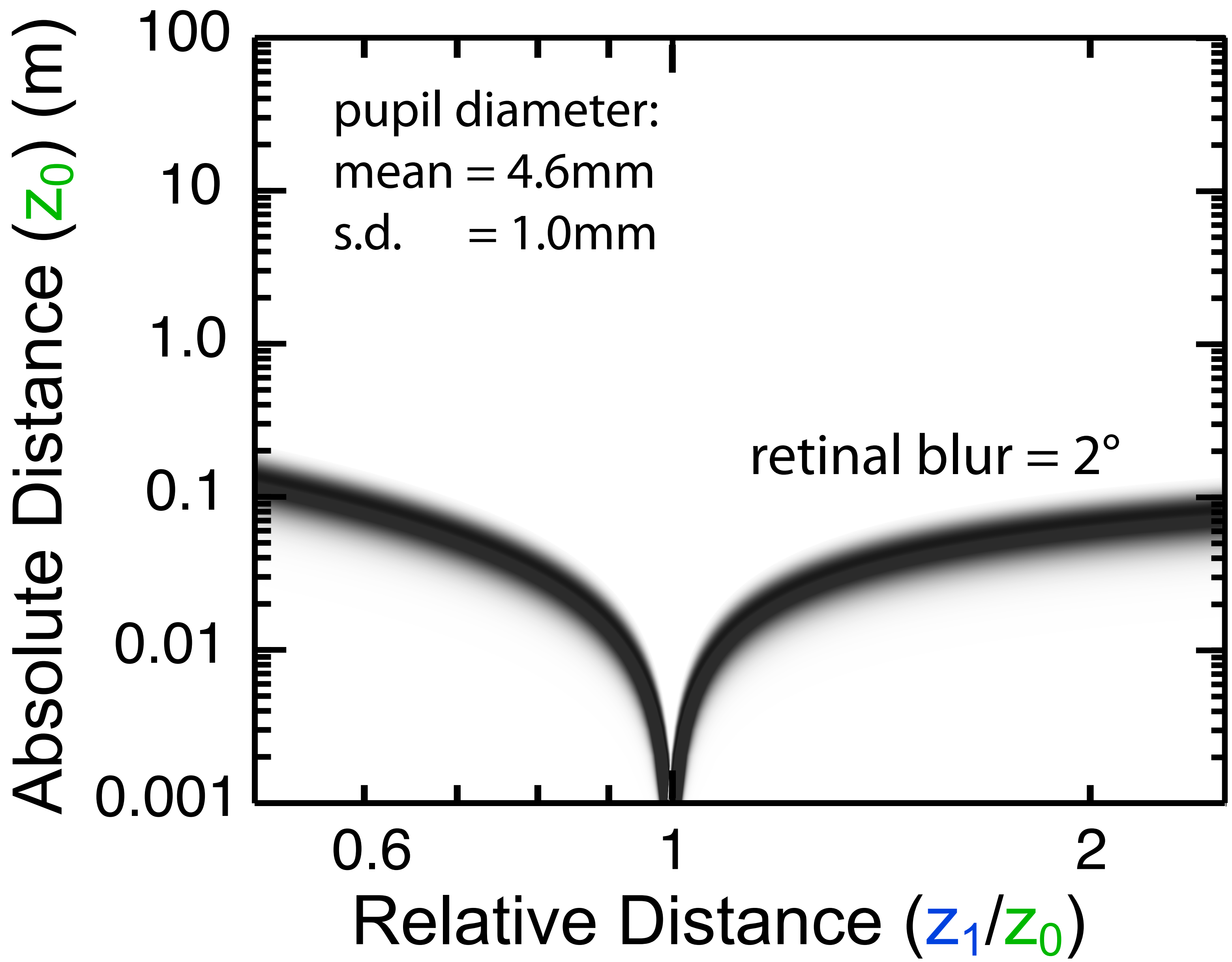
$$c_1 = \left| A \left(\frac{s_0}{z_0} \right) \left(1 - \frac{1}{d} \right) \right|$$

Information from blur

Information from blur

Information from blur

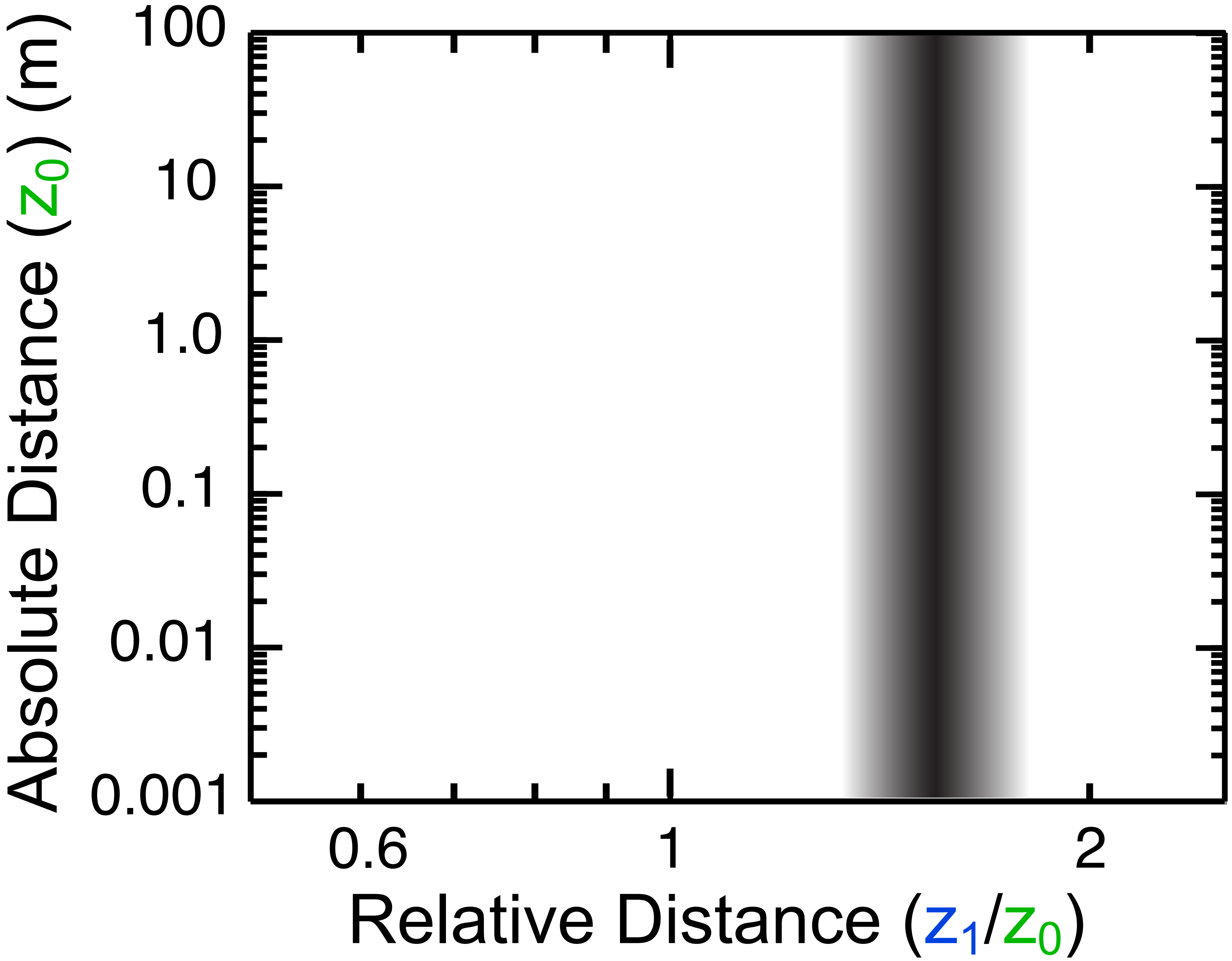
- Blur alone could correspond to any combination of relative distance and focal distance



Pupil data from Spring and Stiles (1948)

Other information

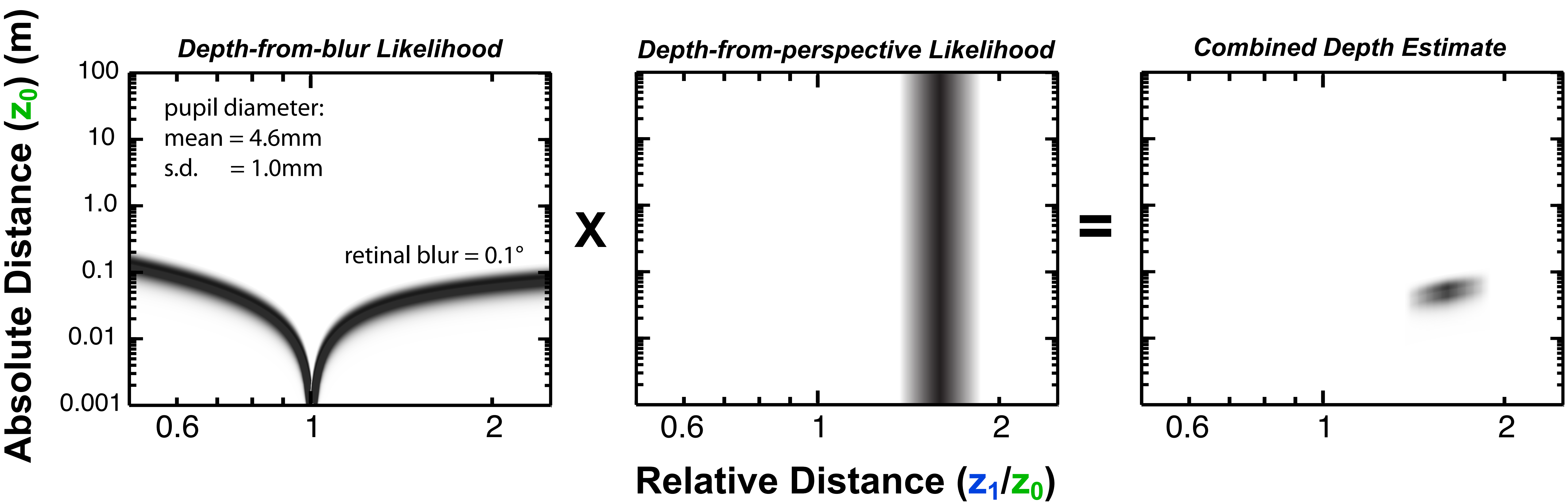
- Perspective information can estimate the relative distance to the building



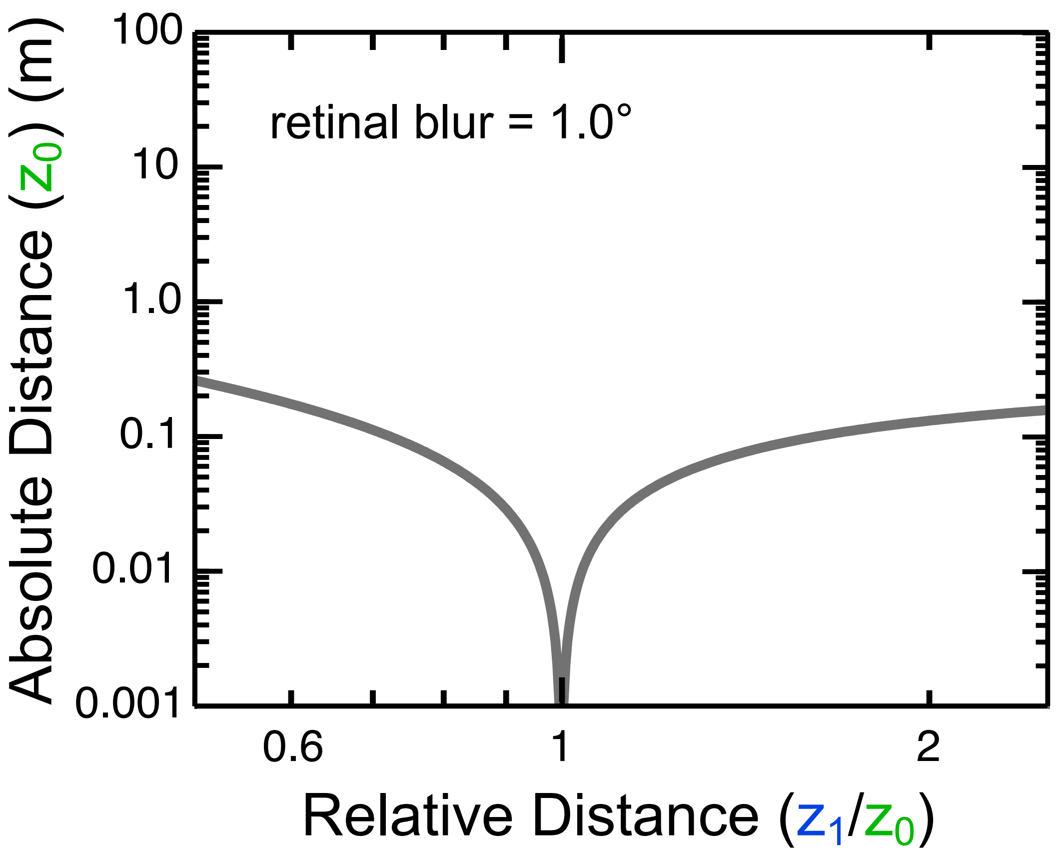
Pupil data from Spring and Stiles (1948)

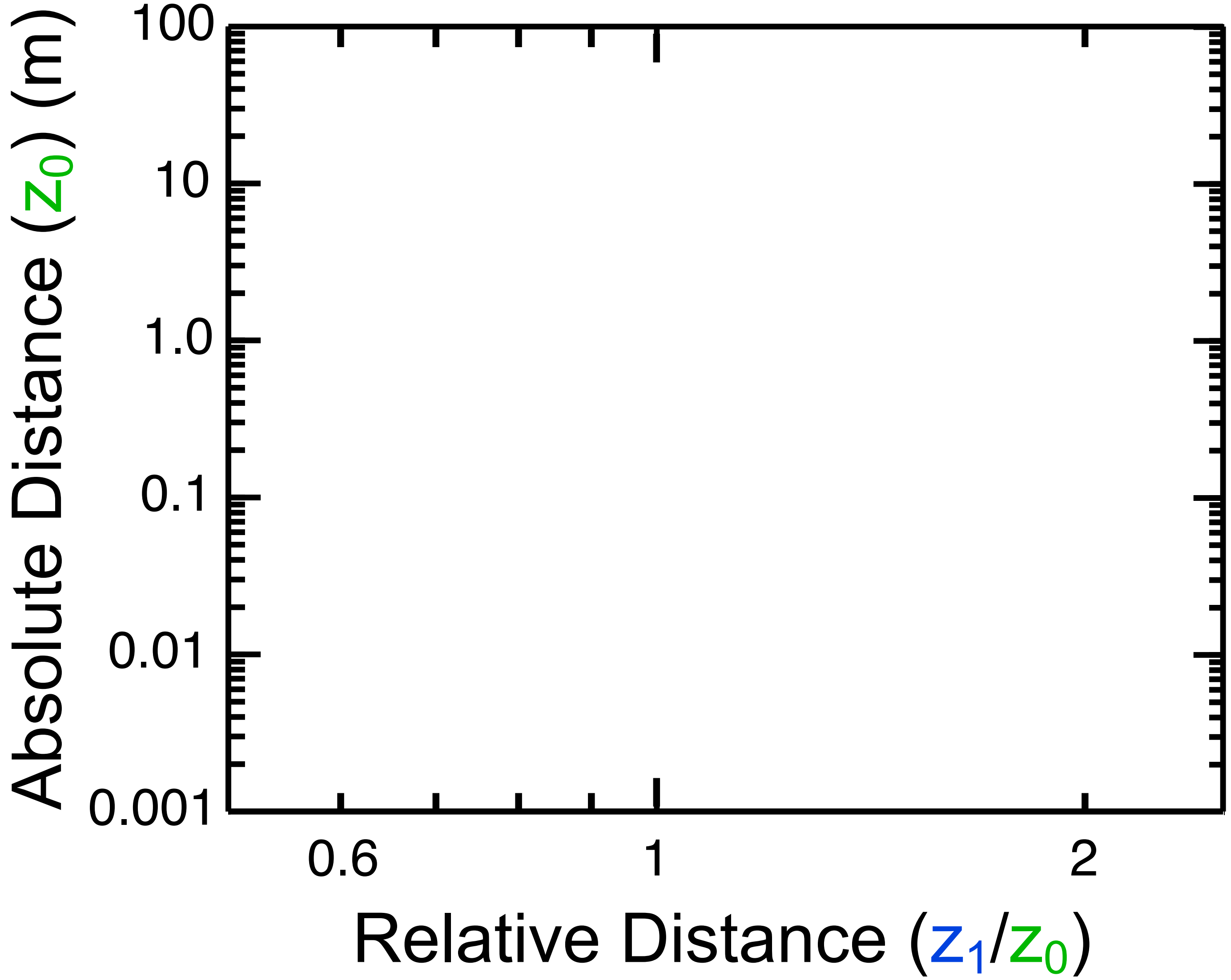
Model

- Combined with relative depth information, blur can act as a cue to absolute distance
- Bayesian approach:



Recovering absolute distance





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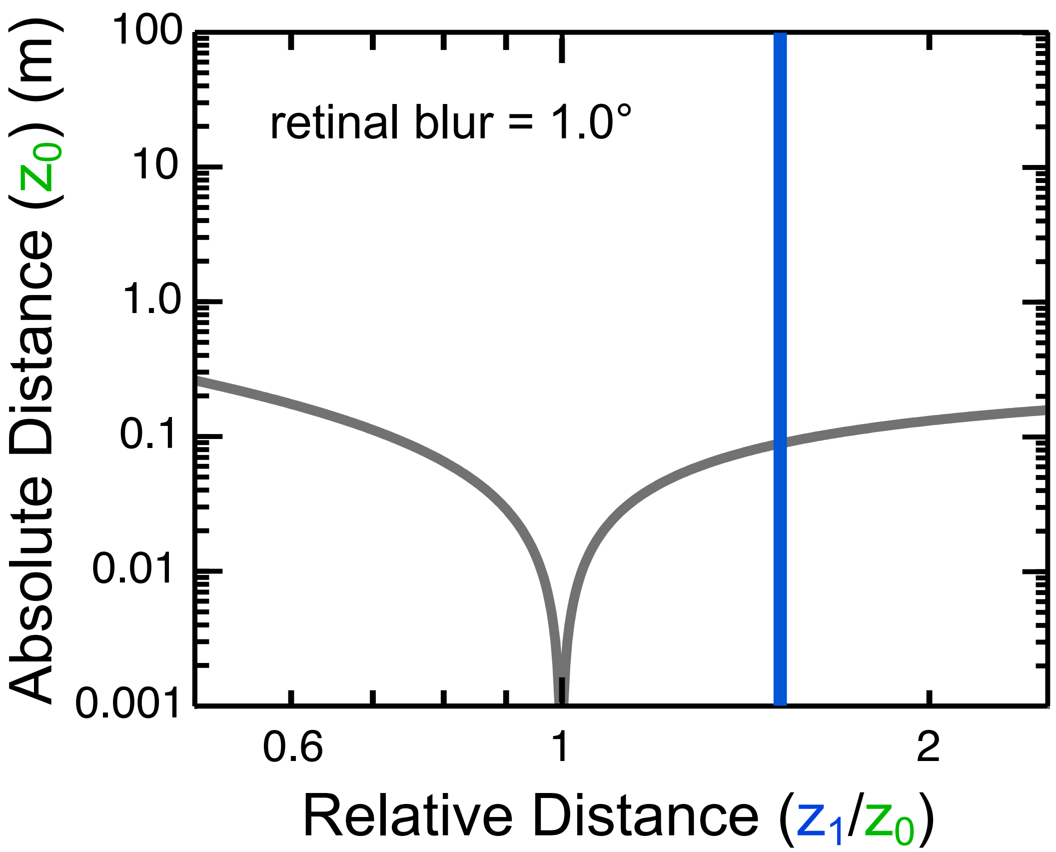

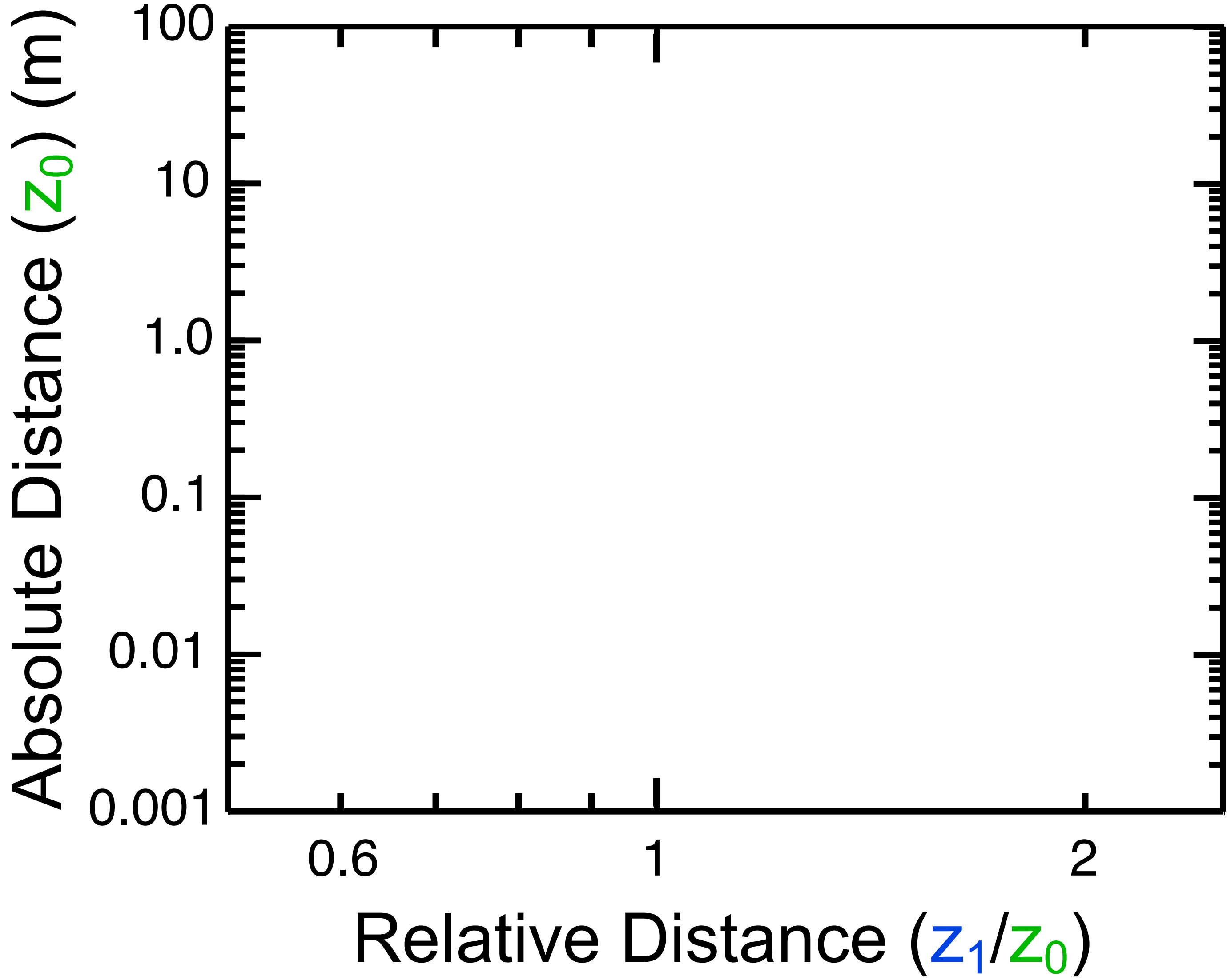

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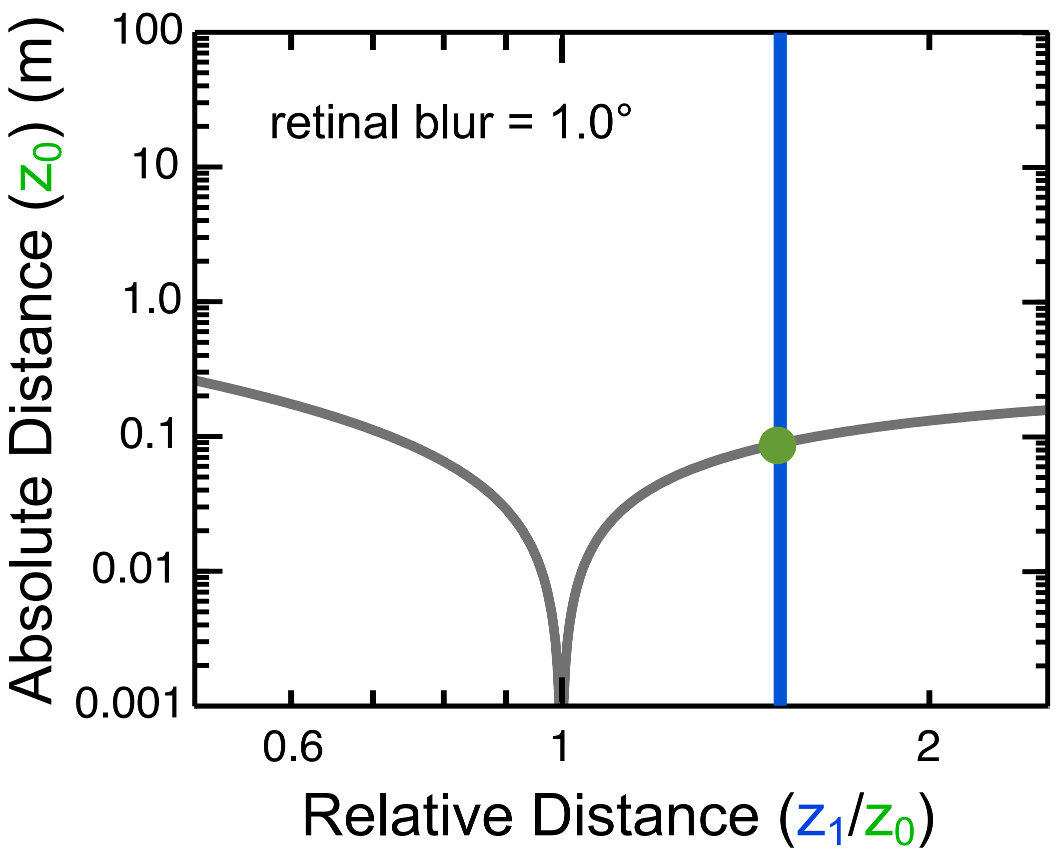

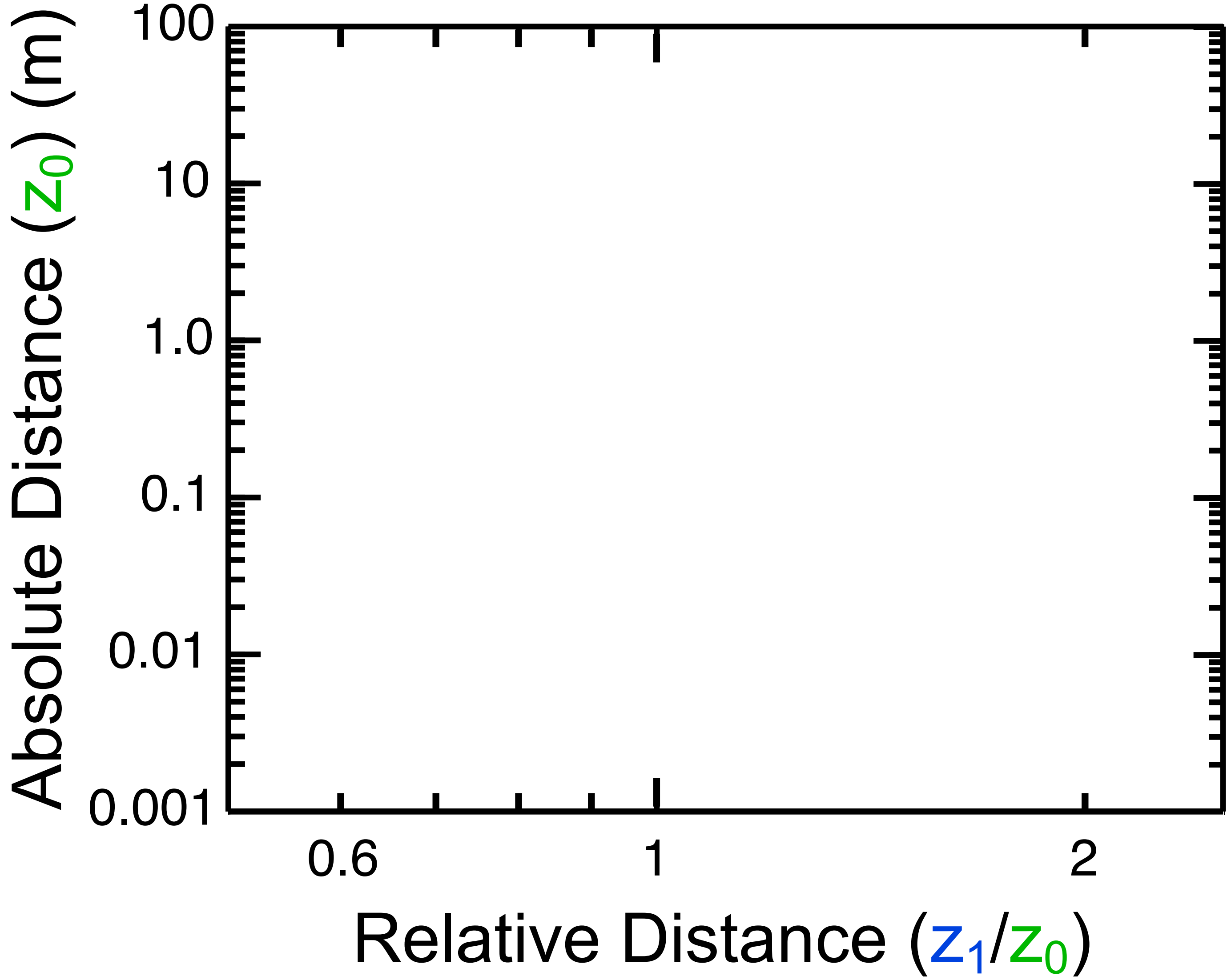

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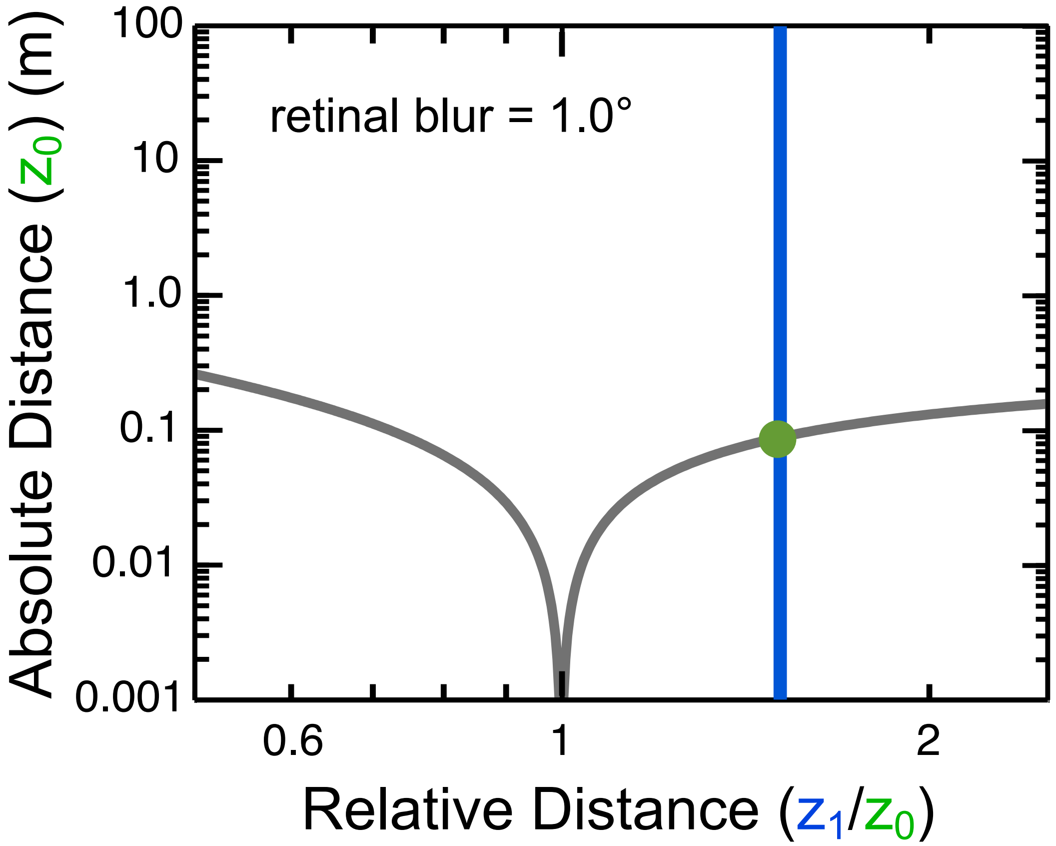

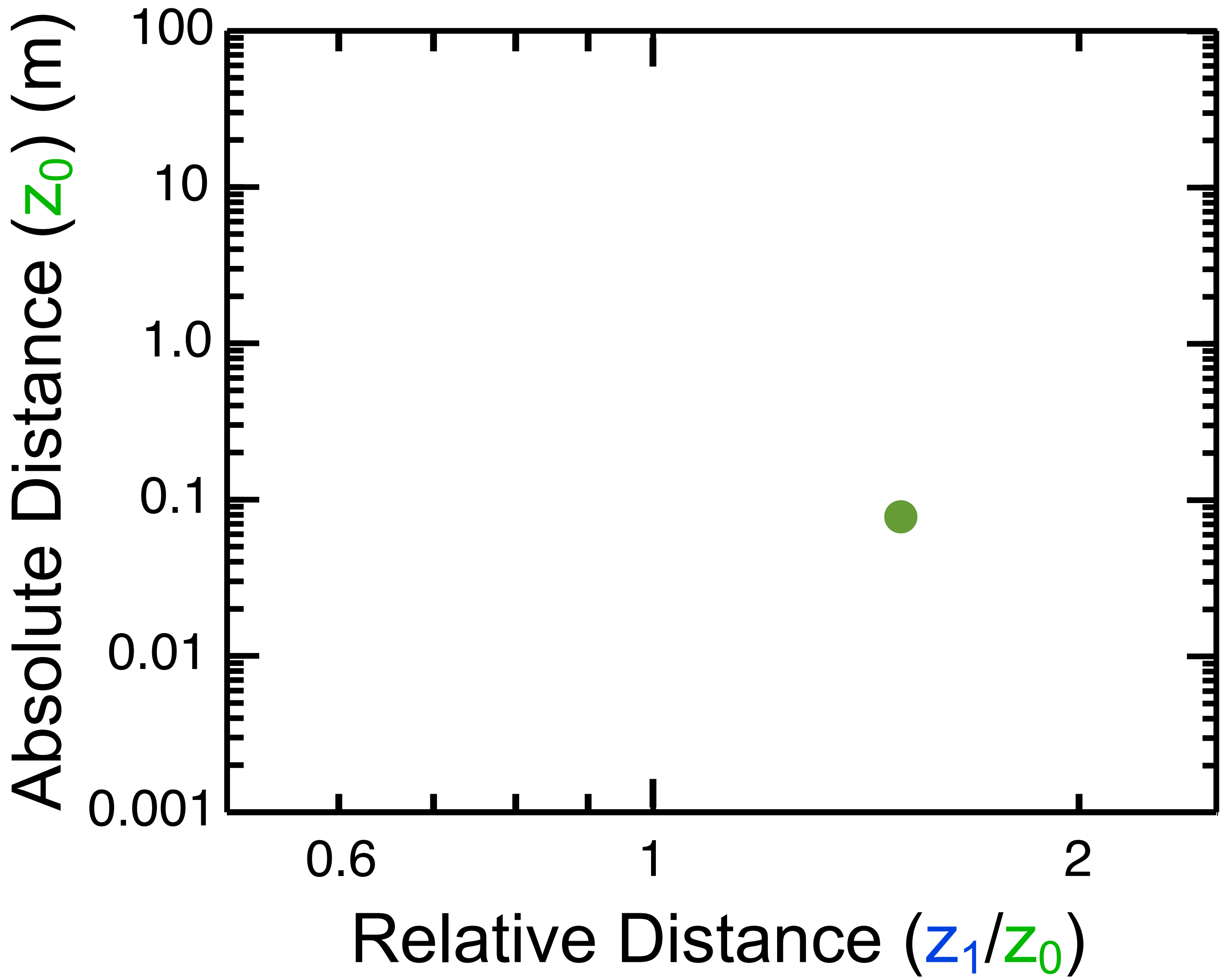

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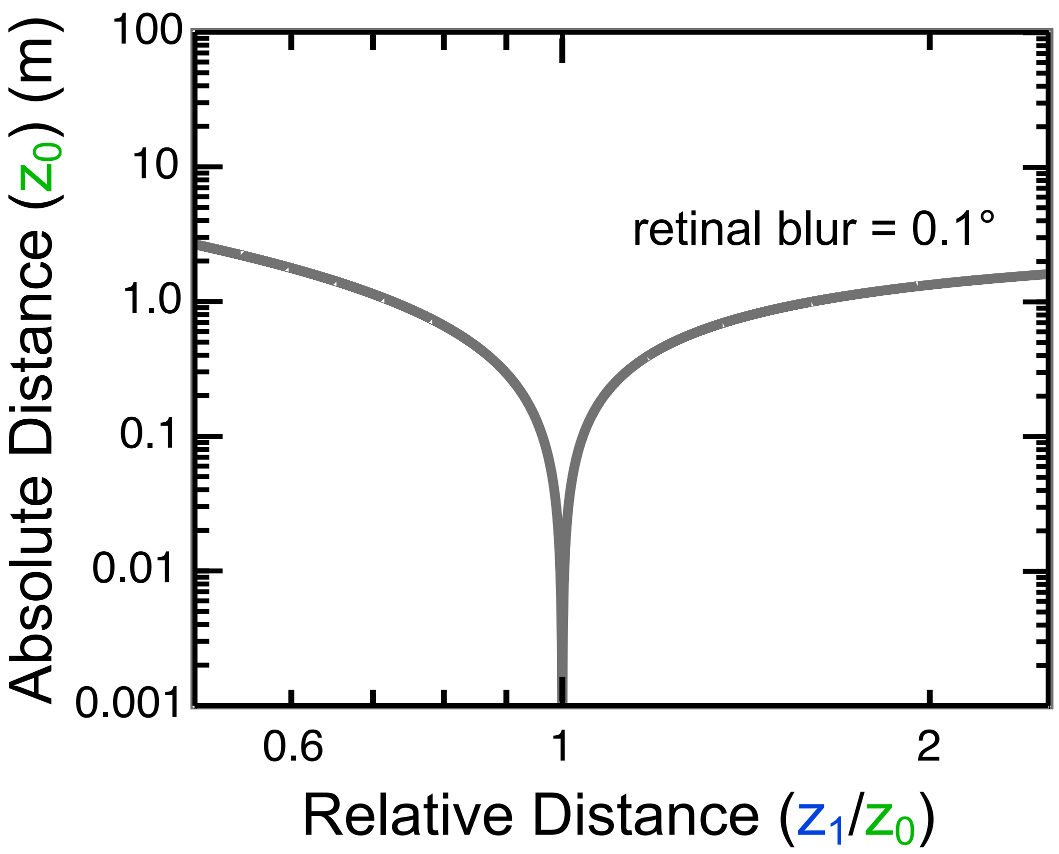

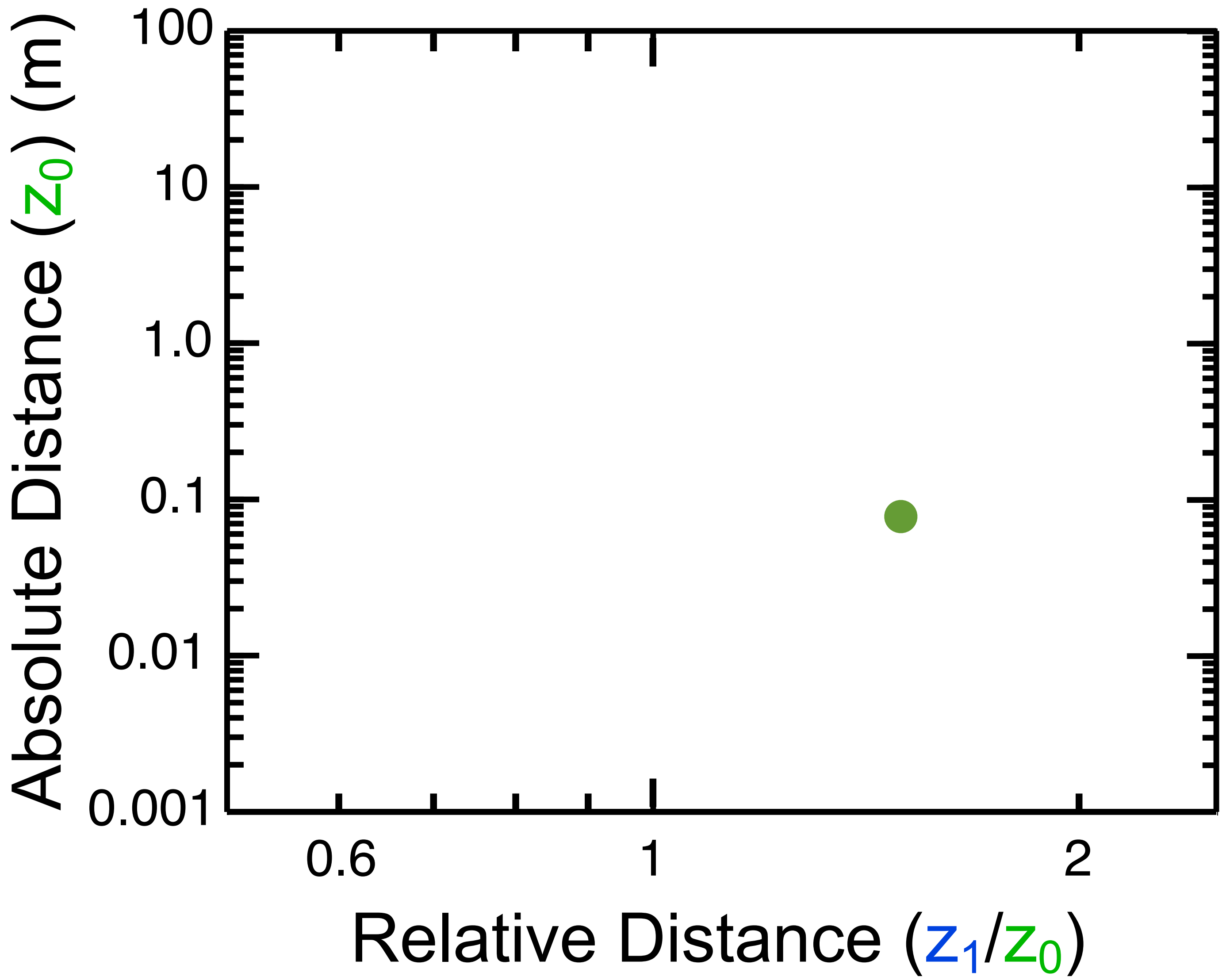

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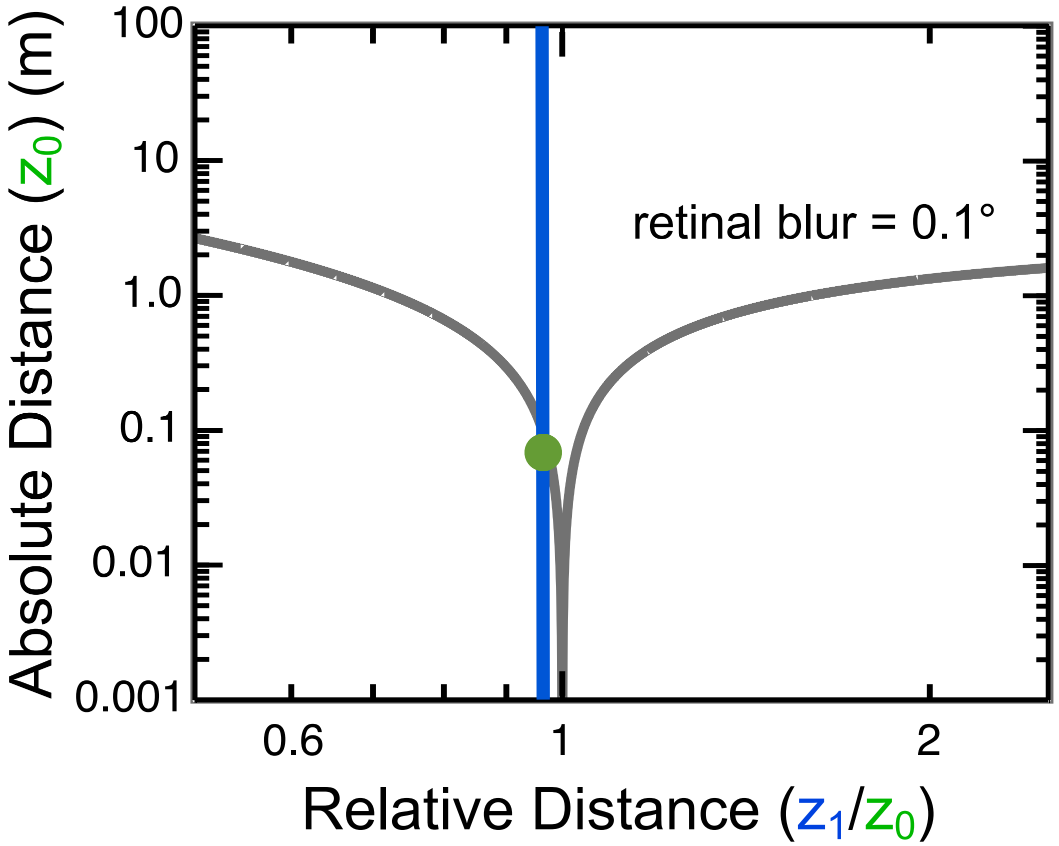

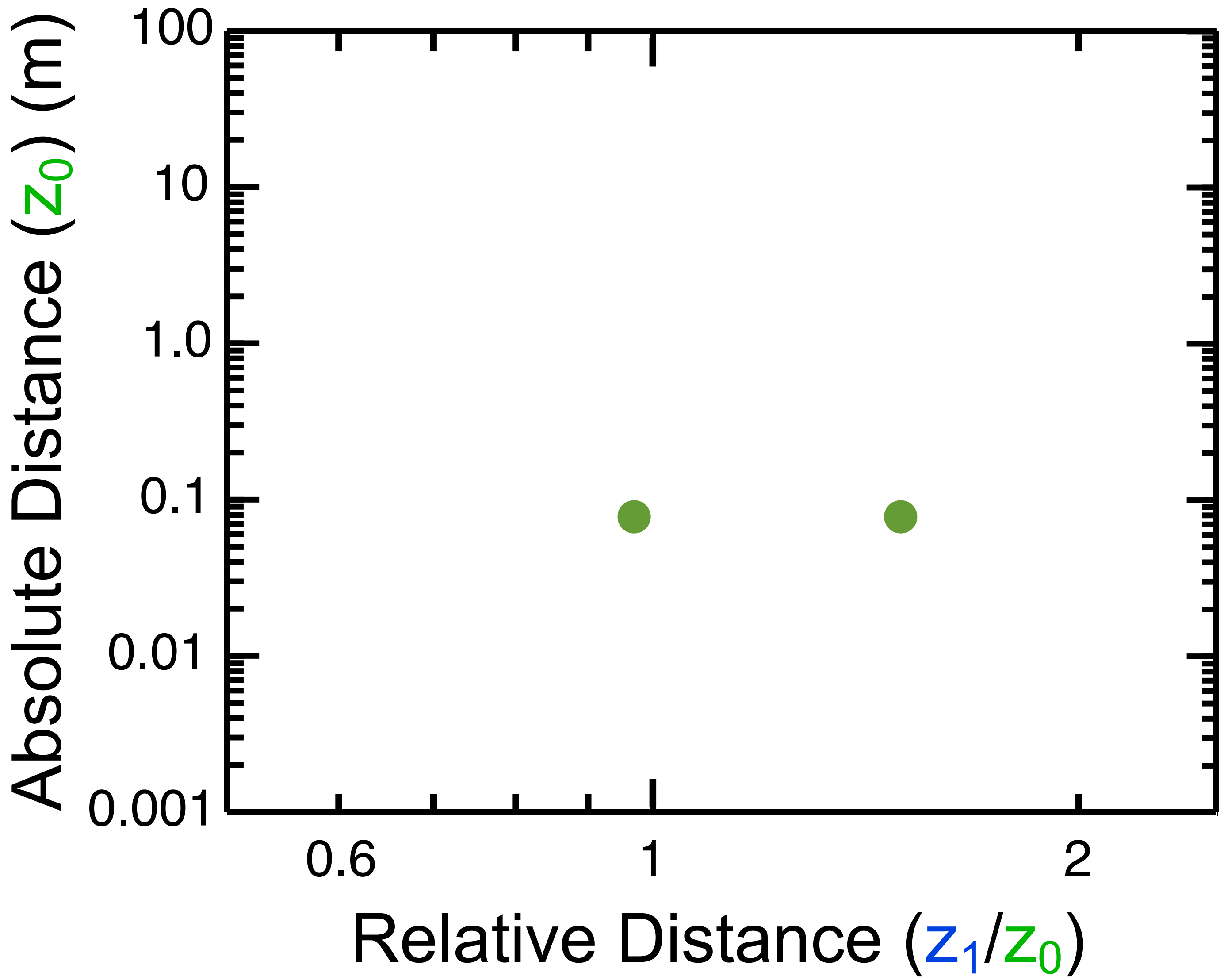

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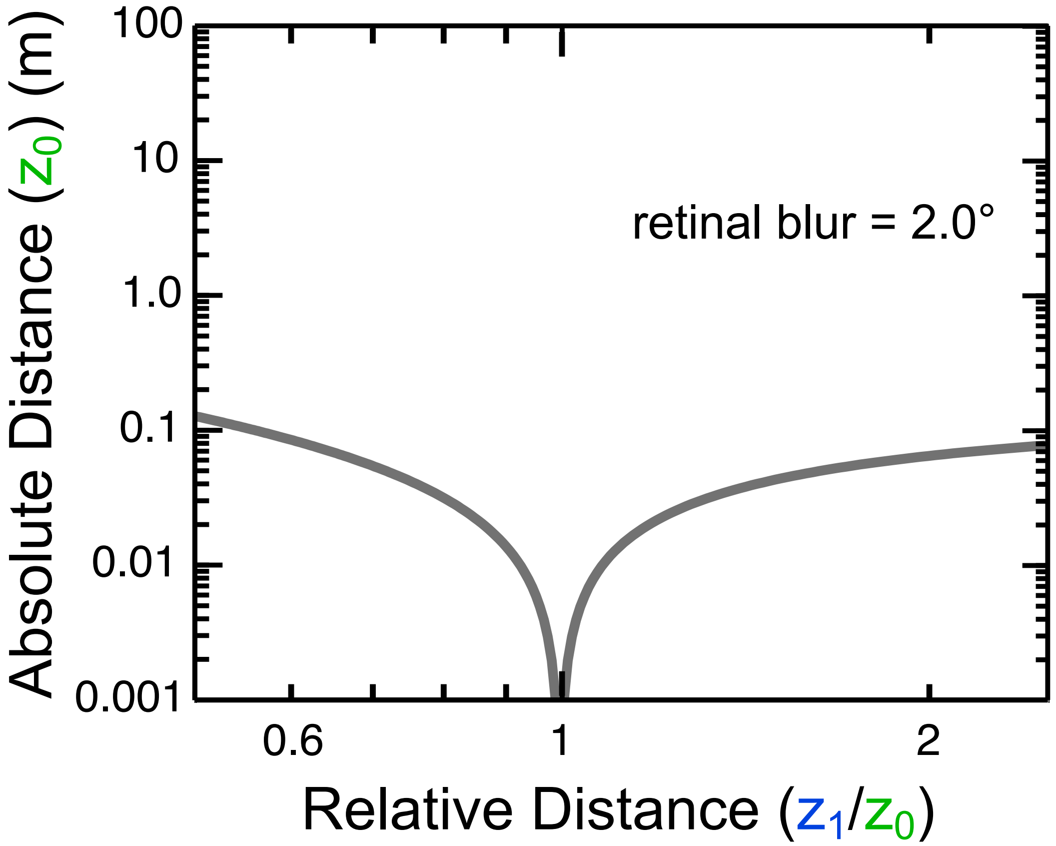

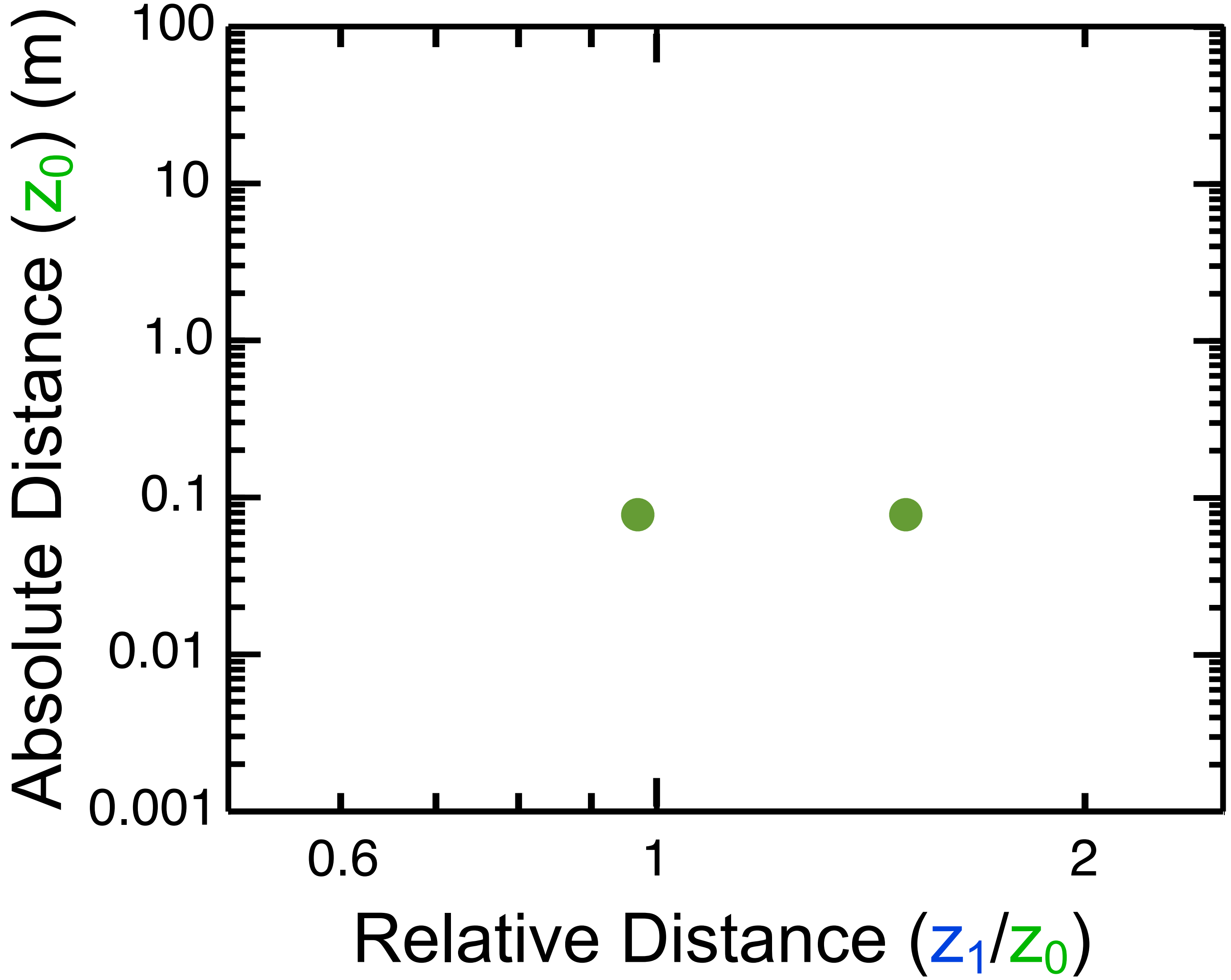

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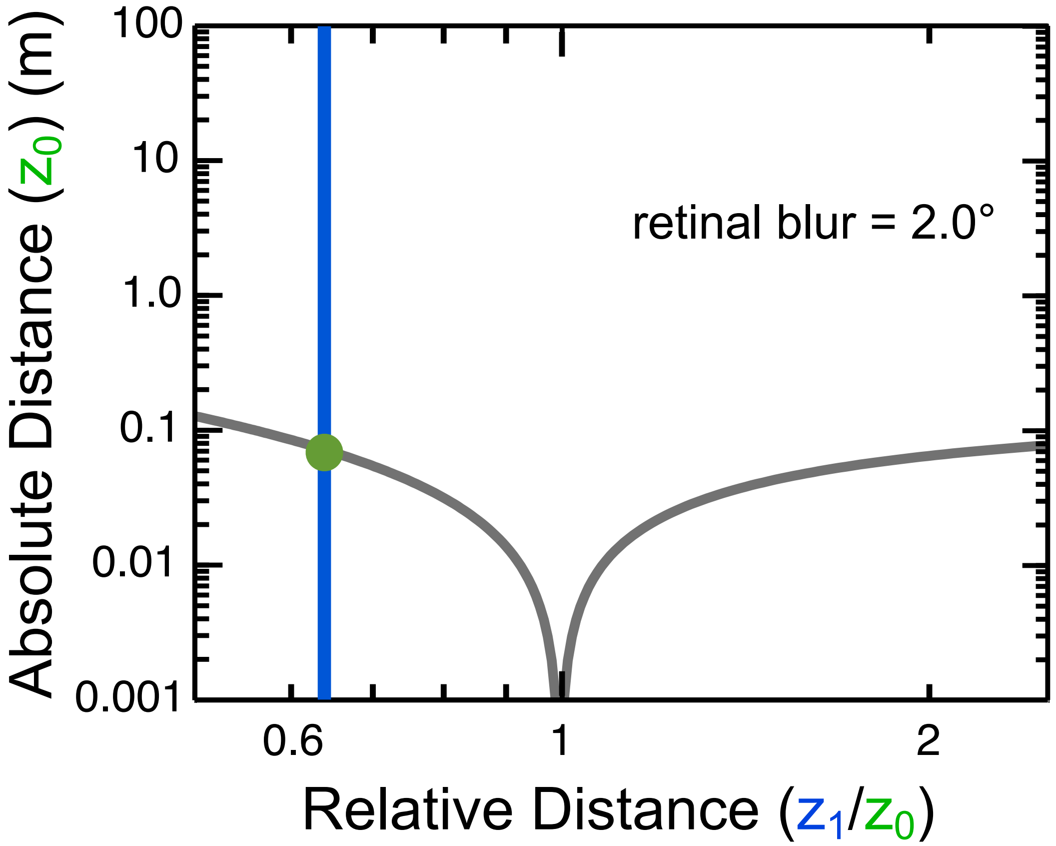
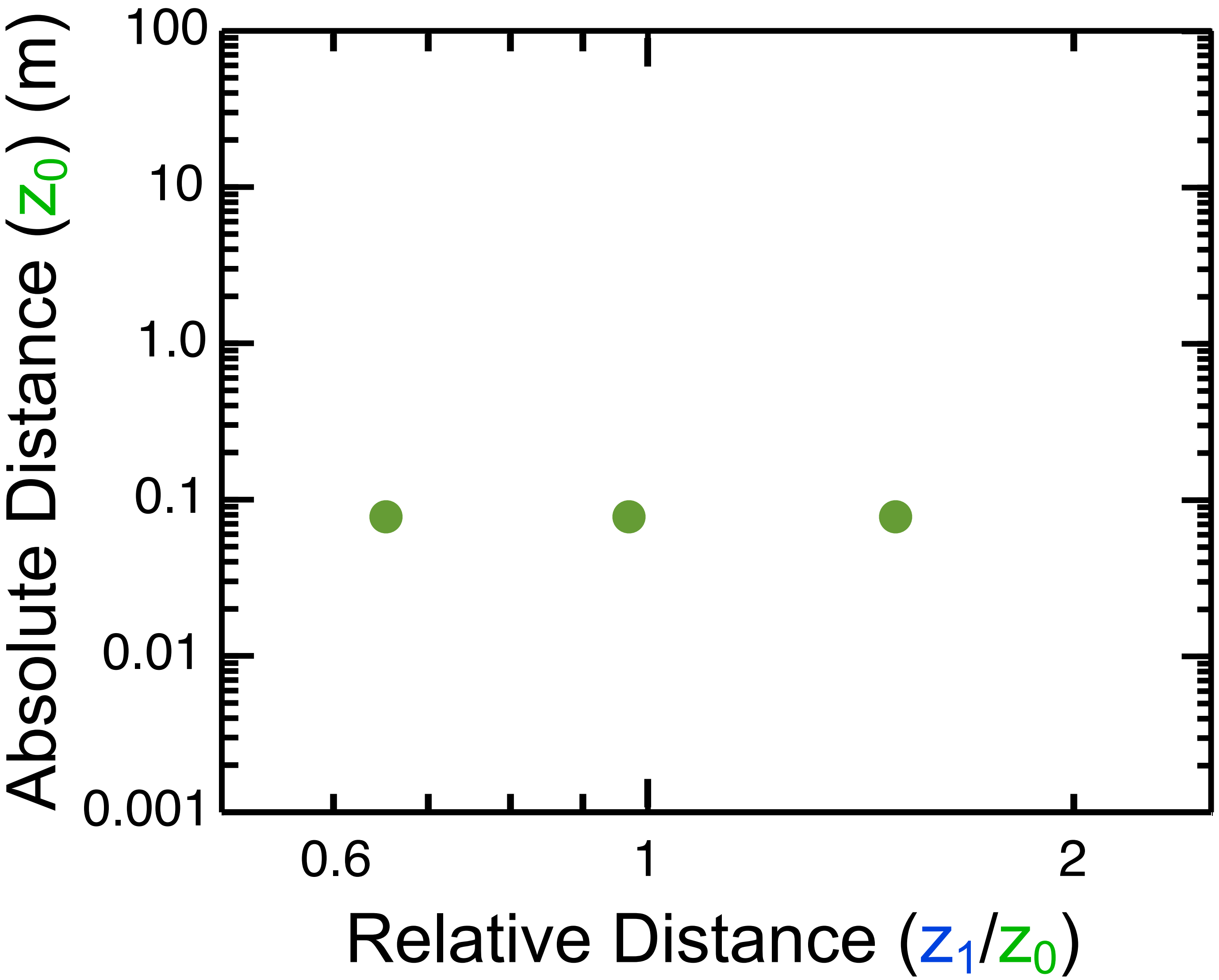
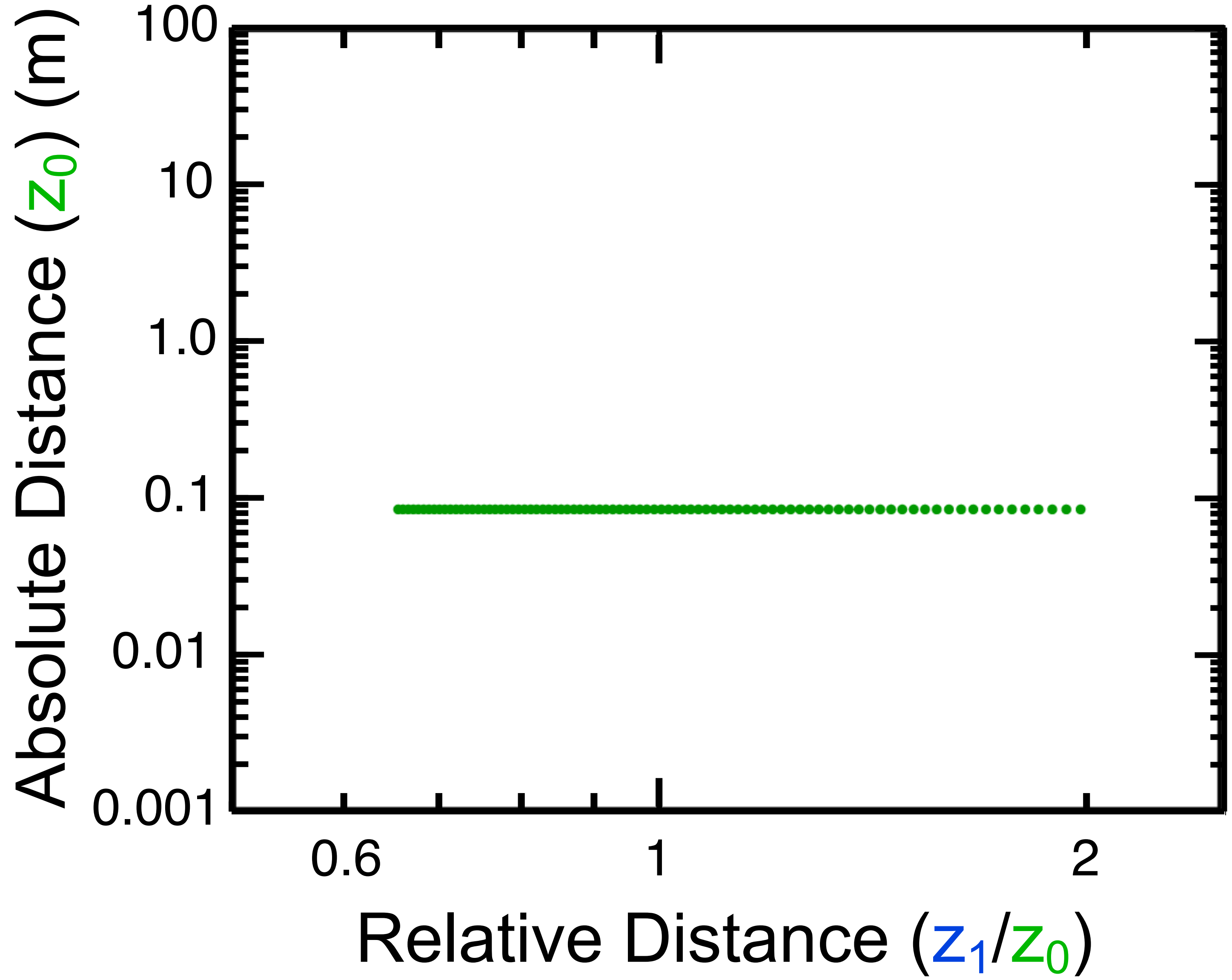




Recovering absolute distance



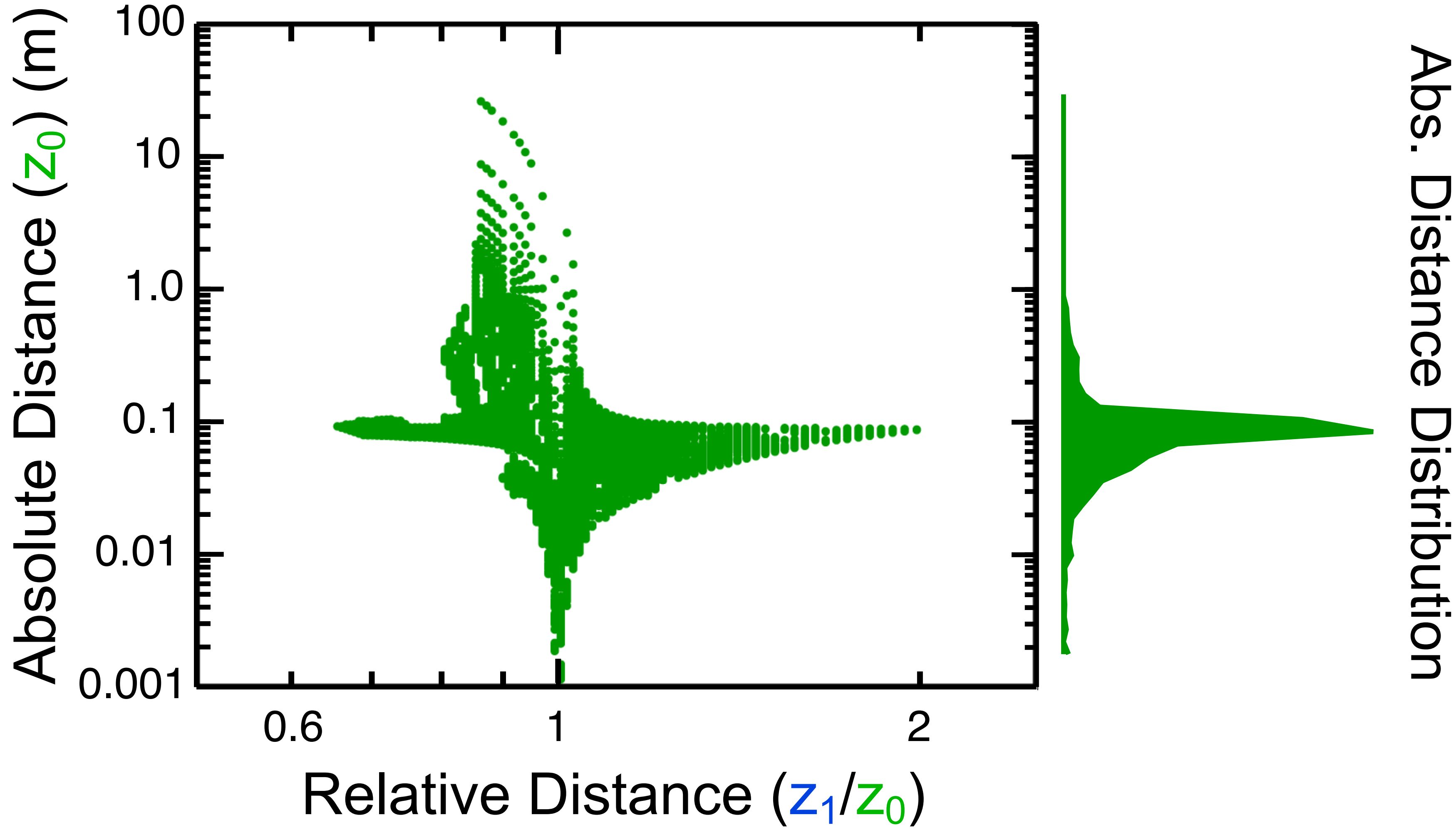
- Predicted perceived distance: 8cm

Inaccurate blur

Consistent blur

Aligned blur gradient

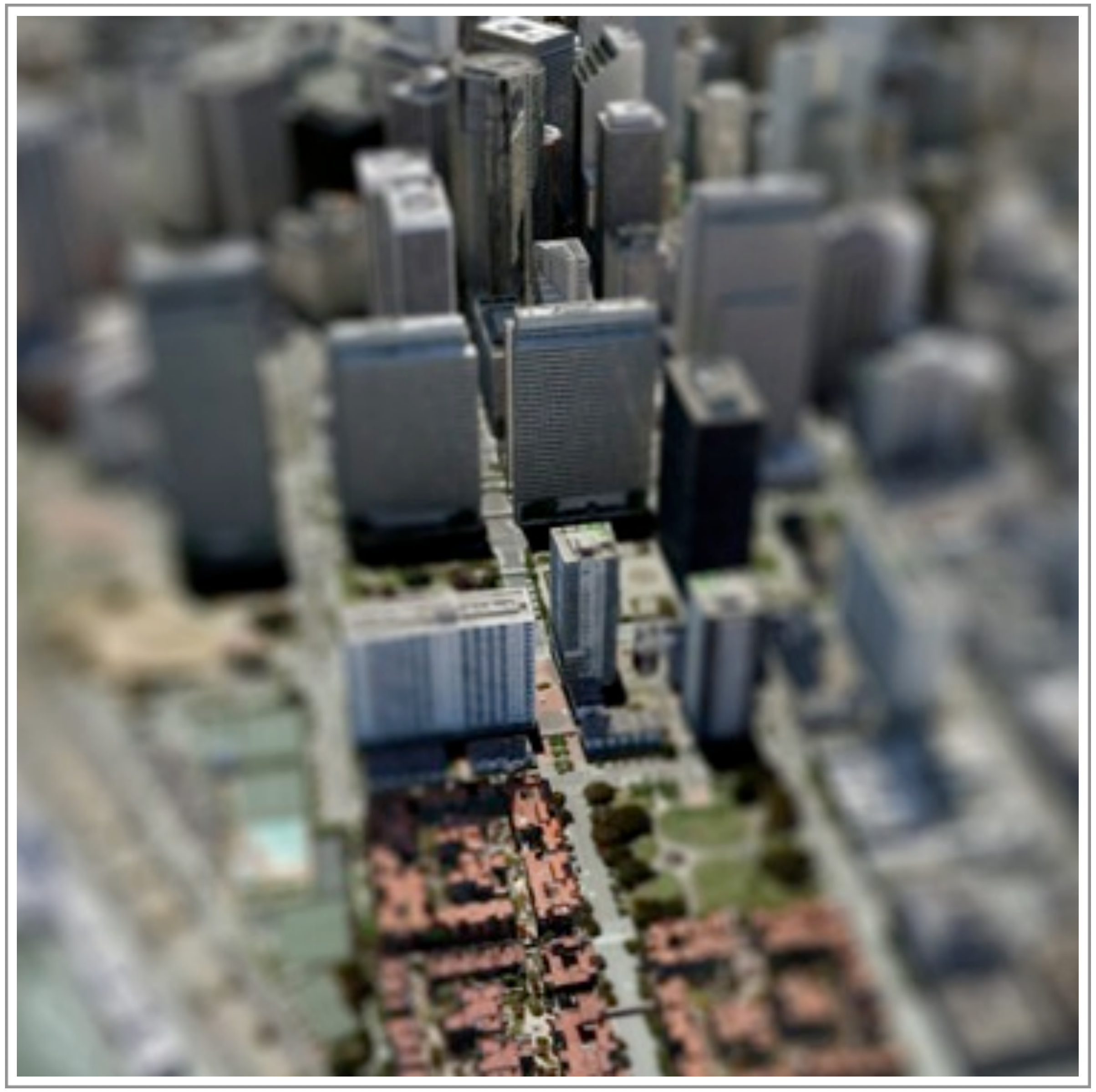
Aligned blur gradient



- Predicted perceived distance: ~10cm
  - Expect weaker influence of blur due to variance

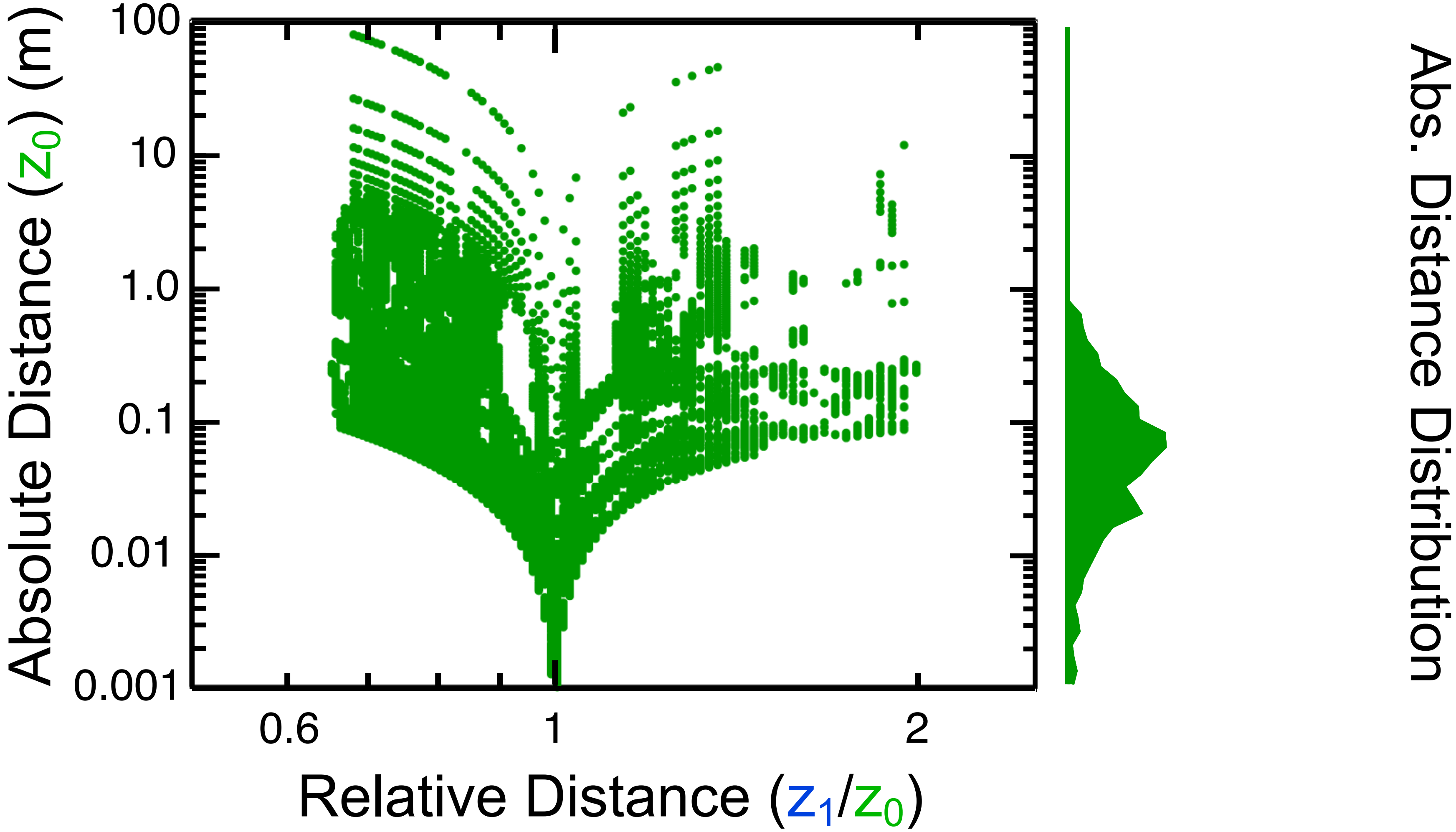
Inaccurate blur

Consistent blur



Unaligned blur gradient

Unaligned blur gradient

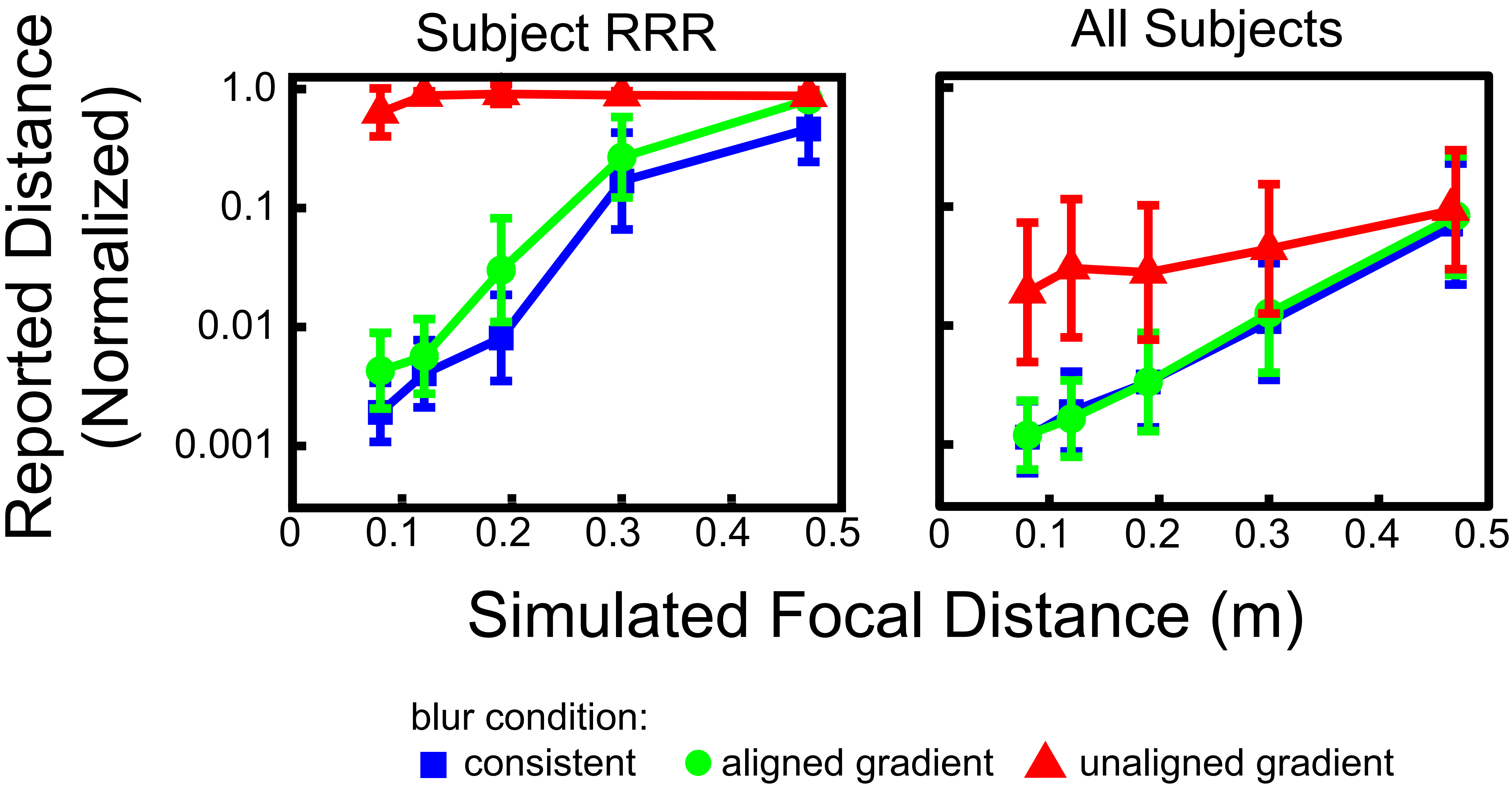


- Predicted perceived distance: ambiguous
  - Expect weakest miniaturization effect, if any

Experiment

- 7 sample scenes from GoogleEarth
- Each scene rendered sharply and with consistent, aligned gradient, and unaligned gradient blur
- 5 blur magnitudes
- Subjects viewed each image monocularly for 3.0sec, then reported the distance from a marked building in the center of the image to the camera that produced the image
- Each image repeated 7 times (randomly interleaved)

Results



Subject RRR
All Subjects
Reported Distance (Normalized)
1.0
0.1
0.01
0.001
0
0.1
0.2
0.3
0.4
0.5
Simulated Focal Distance (m)
blur condition:
consistent
aligned gradient
unaligned gradient

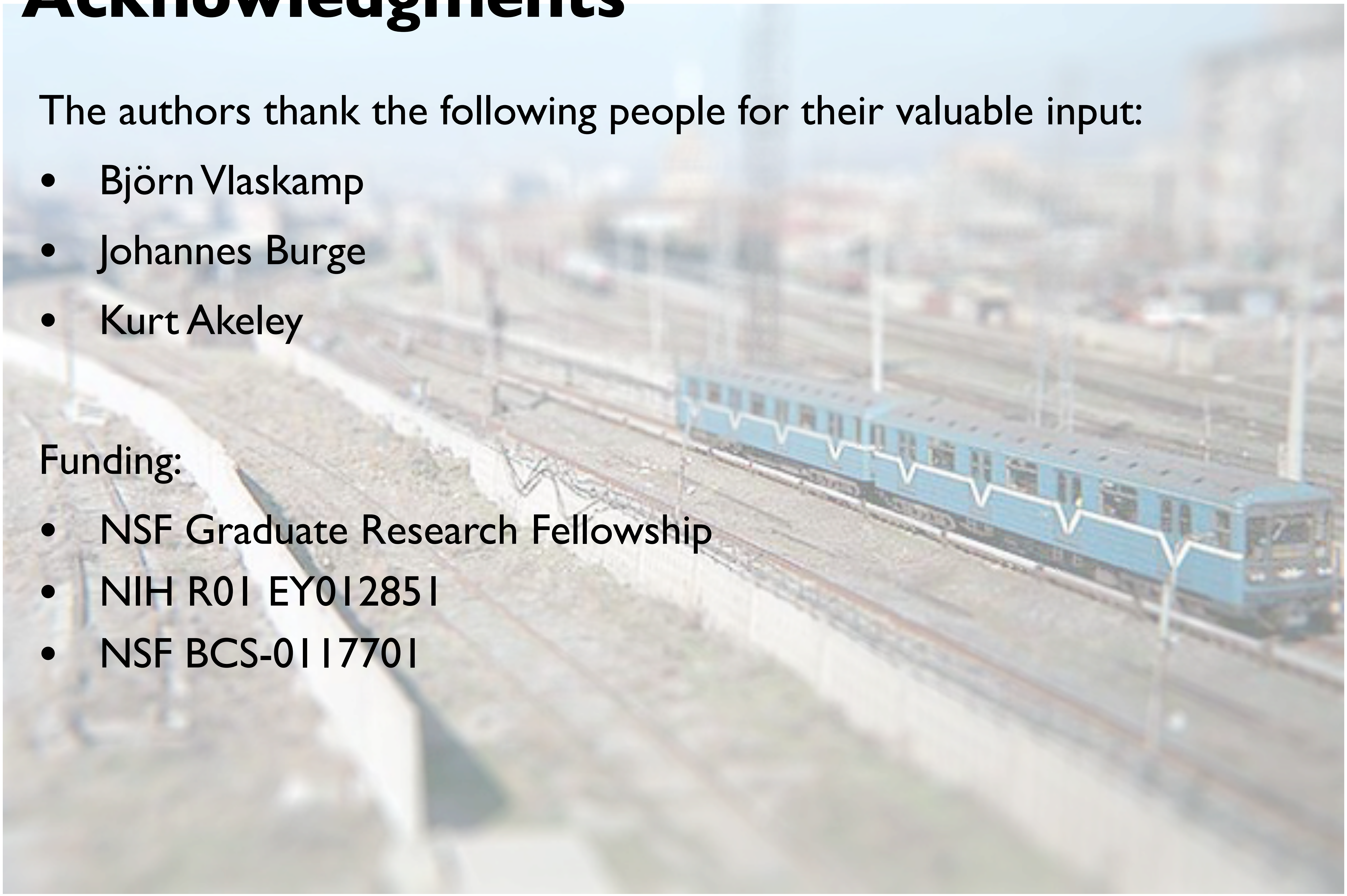
Discussion

- Previously, blur considered a weak depth cue

Discussion

- Previously, blur considered a weak depth cue
- Blur can act as a strong cue to absolute distance and size
    - Must be combined with other depth cues
    - Explains the perceptual basis of the tilt-shift effect
    - Also predicts previous findings in vision science literature

Acknowledgments



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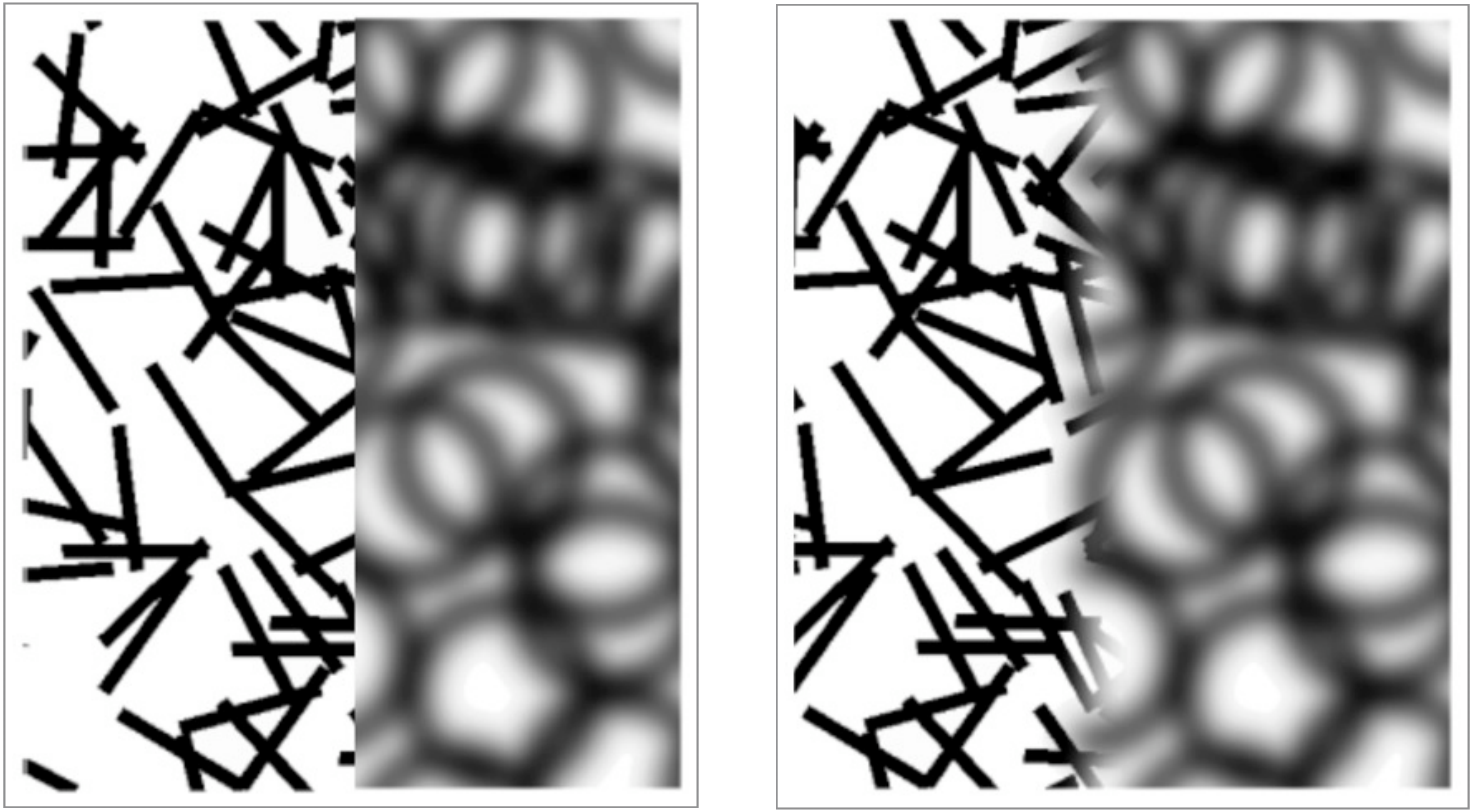
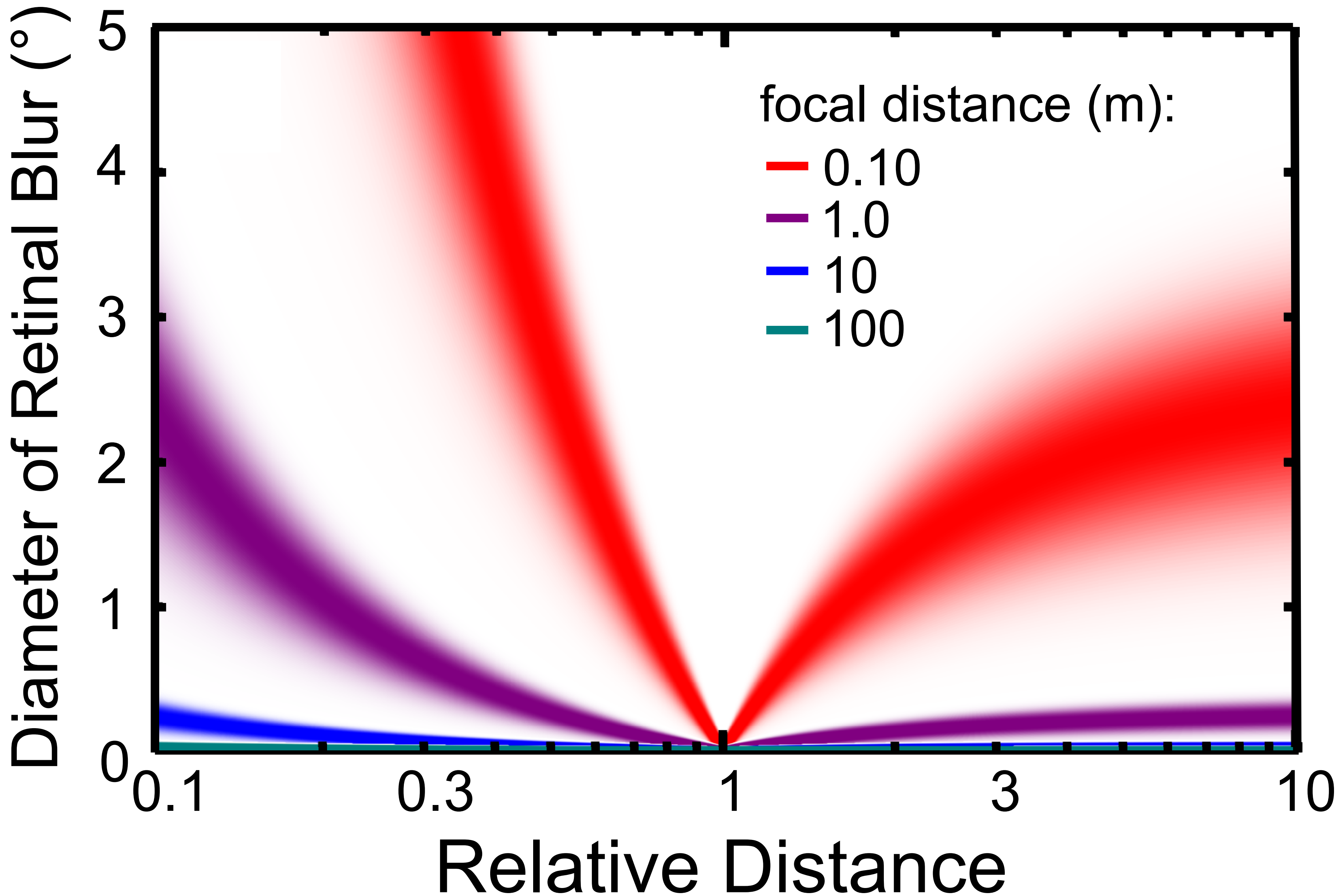
Blur as a depth cue: Previous results

- Blur is a weak, ordinal cue to depth
  - Blur can reveal the depth ordering of surfaces that occlude each other (Marshall et al. (1996) and Mather (1996))

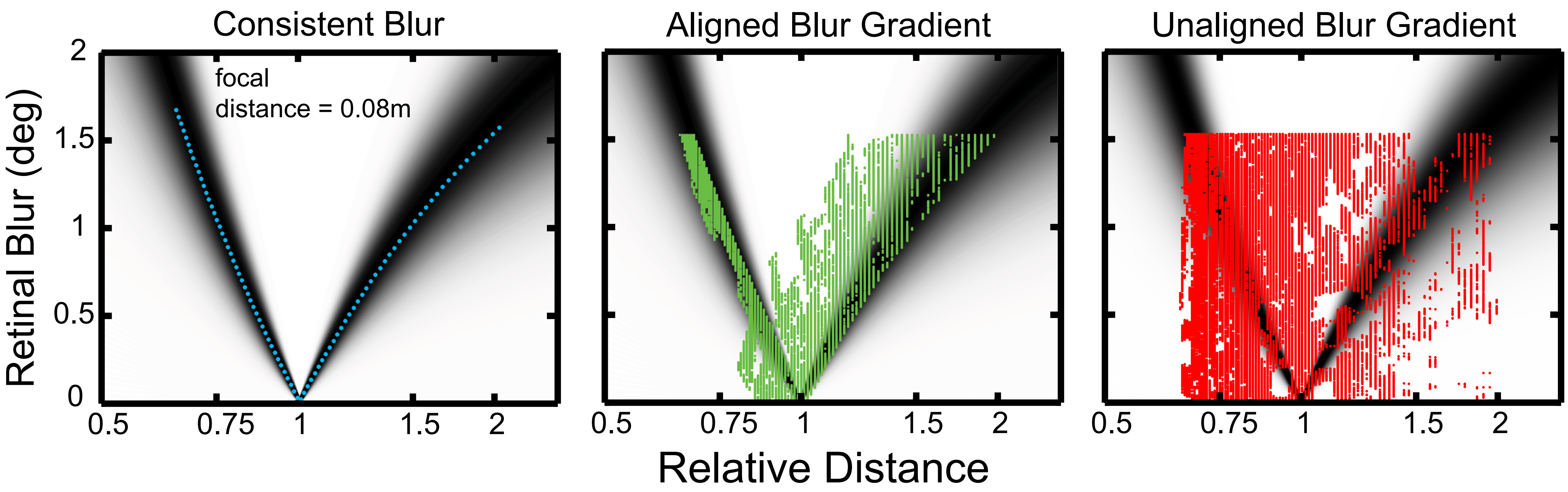


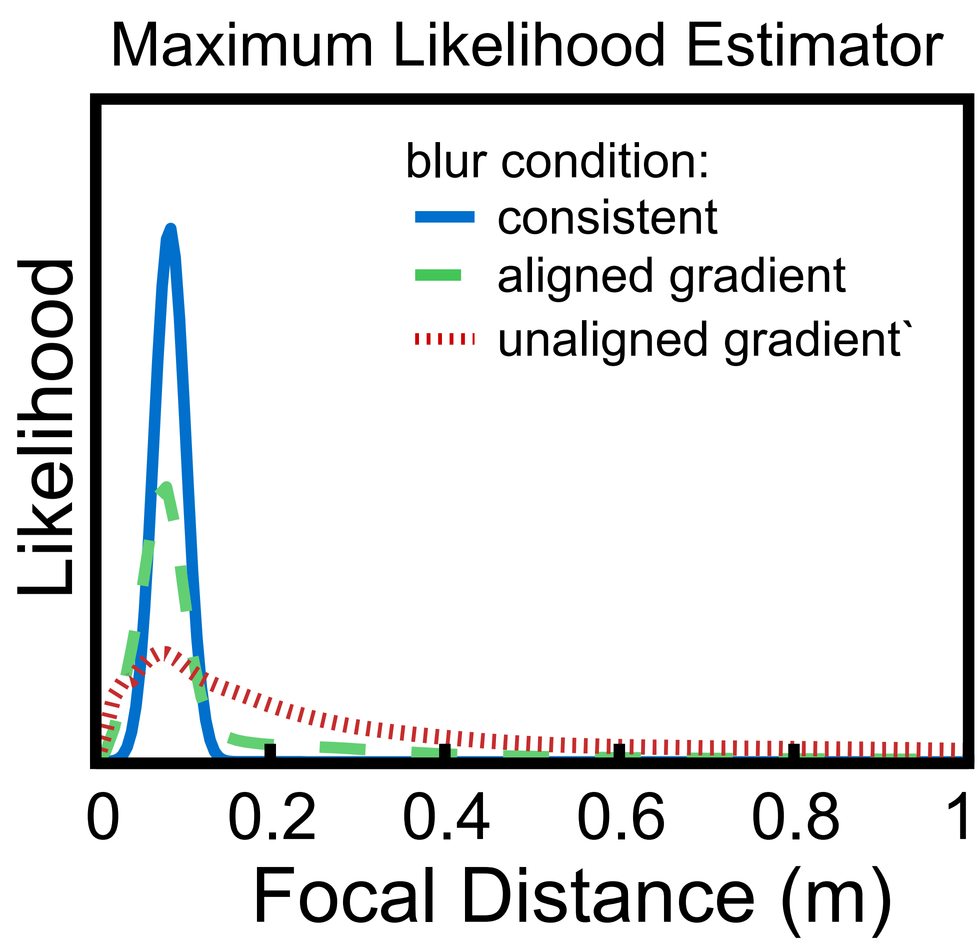
Theory

- Matching-task interpretation



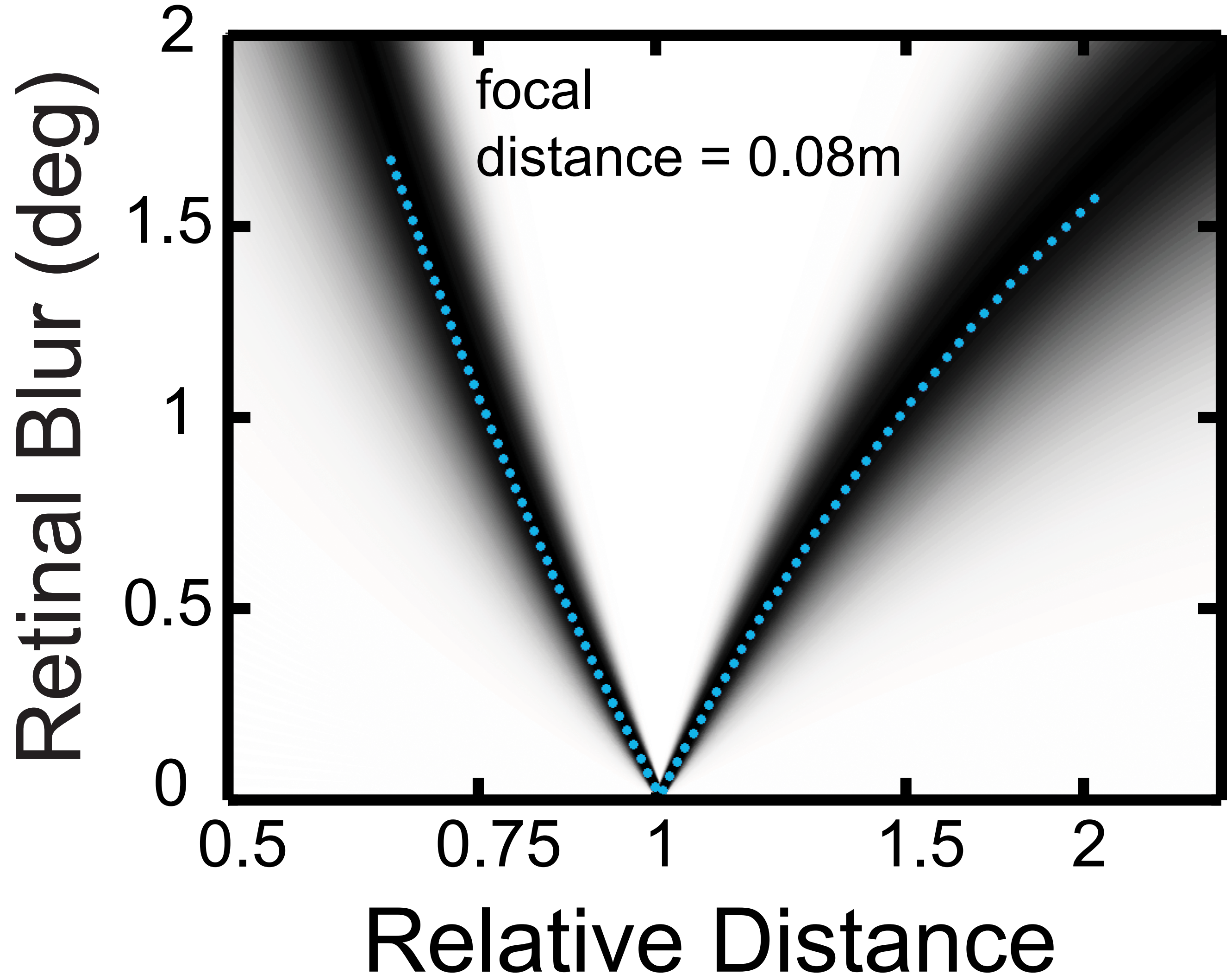
Likelihood estimates





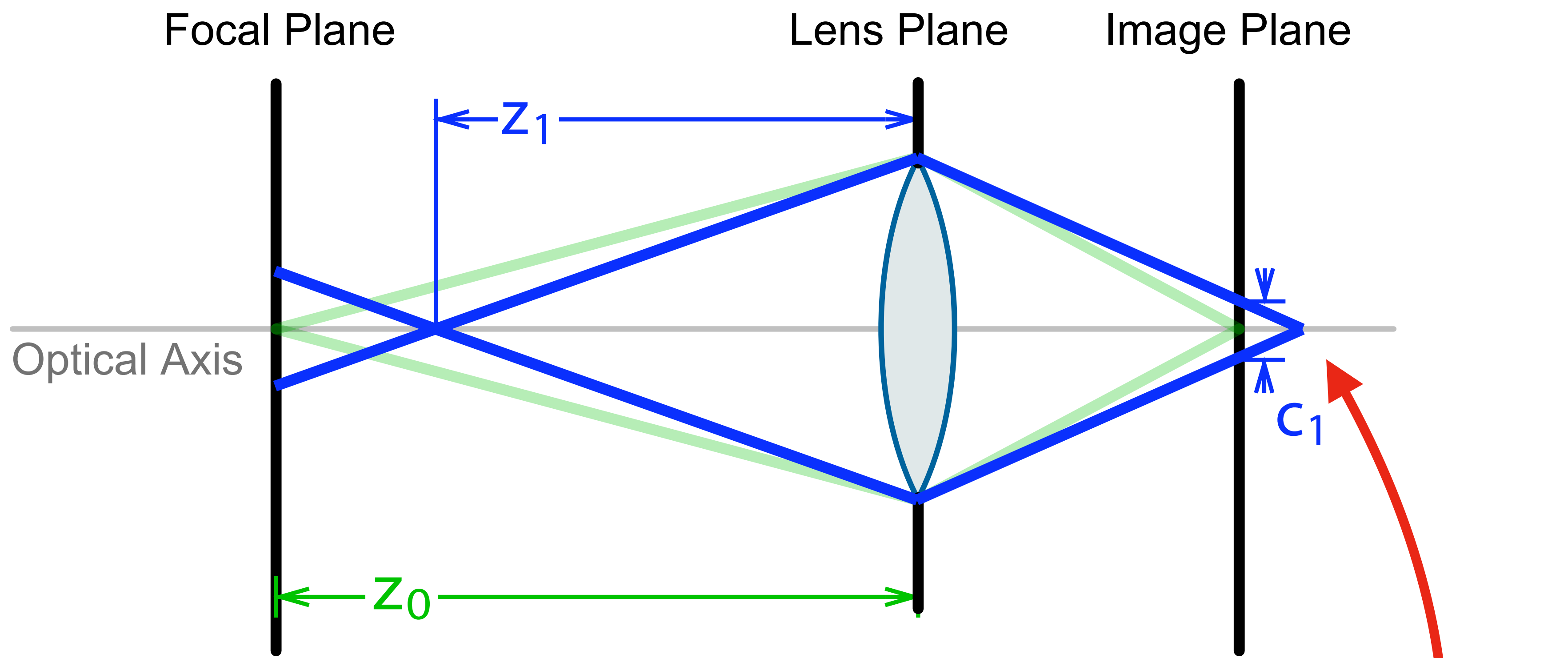
- Peaks indicate estimated focal depth
- Variance reflects reliability of estimate
- Unreliable cues are given less weight by the visual system
  - Unaligned gradients should have a small affect on perceived distance and scale

Consistent Blur

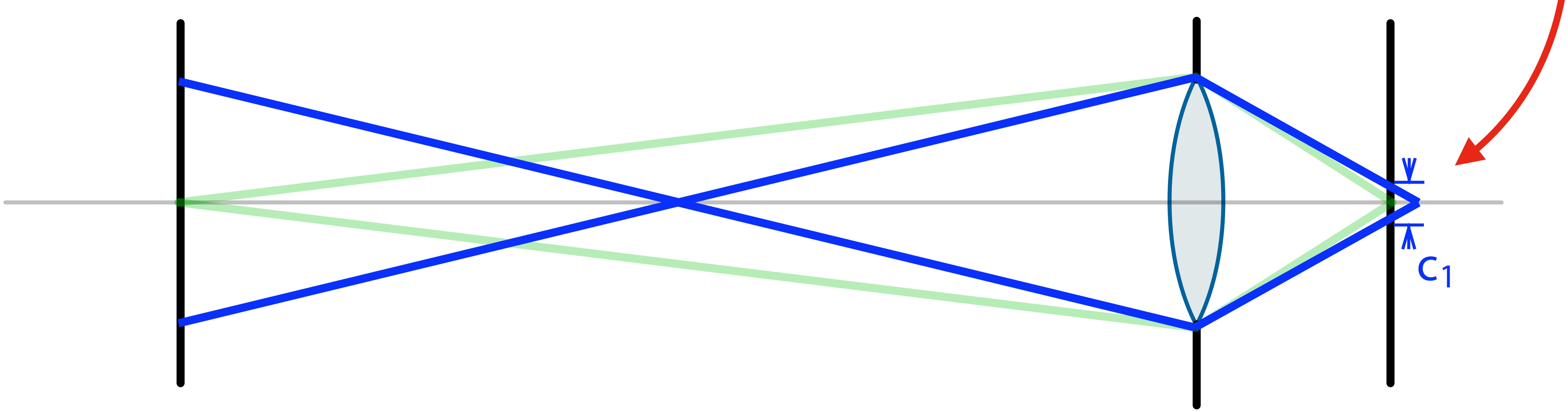


- Sampled points perfectly match curve

Information from blur



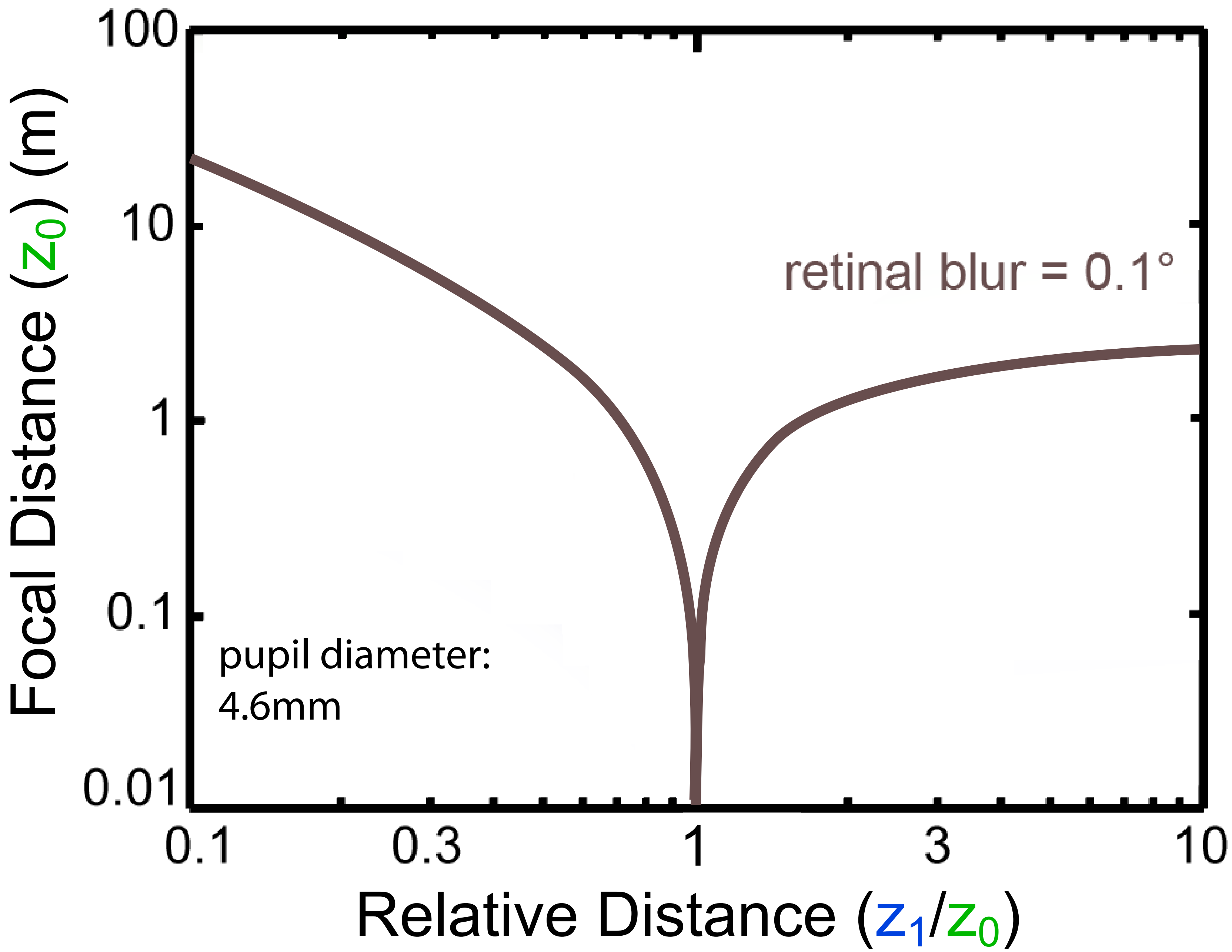
$z_o = 0.9\text{m}, \ (z_1/z_o) = 0.75$



$z_o = 2.3\text{m}, \ (z_1/z_o) = 0.50$

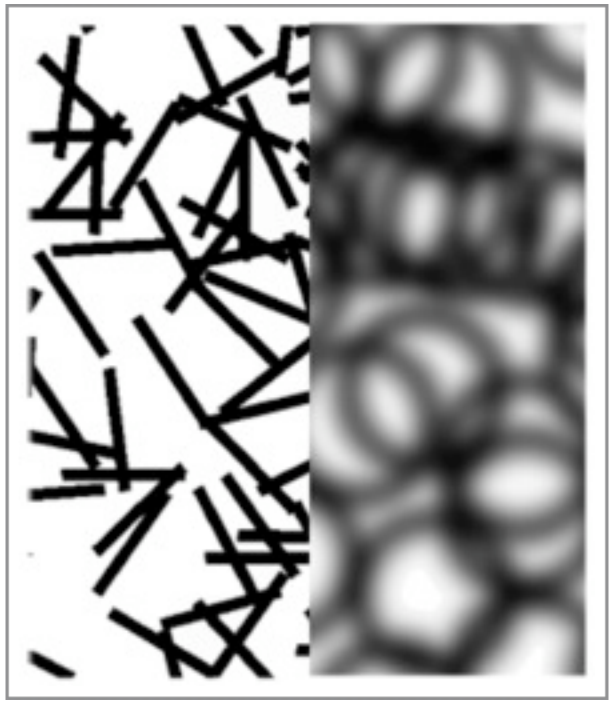
Information from blur

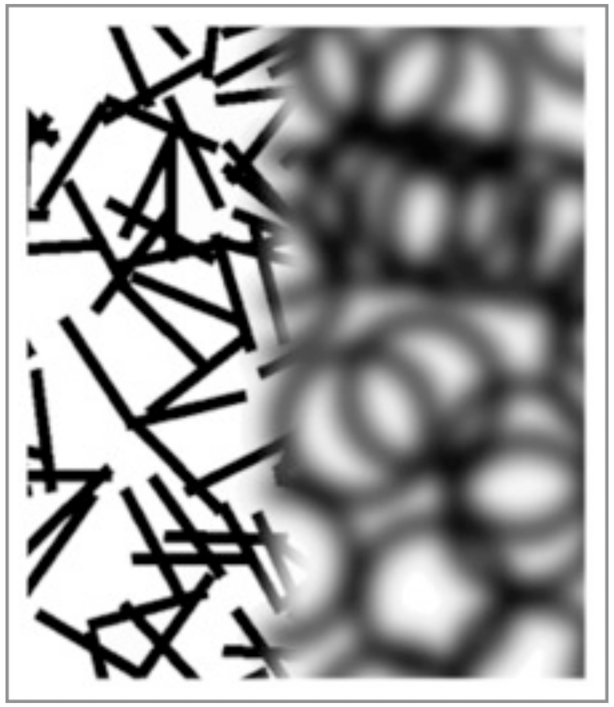
Blur alone could correspond to any combination of relative distance and focal distance

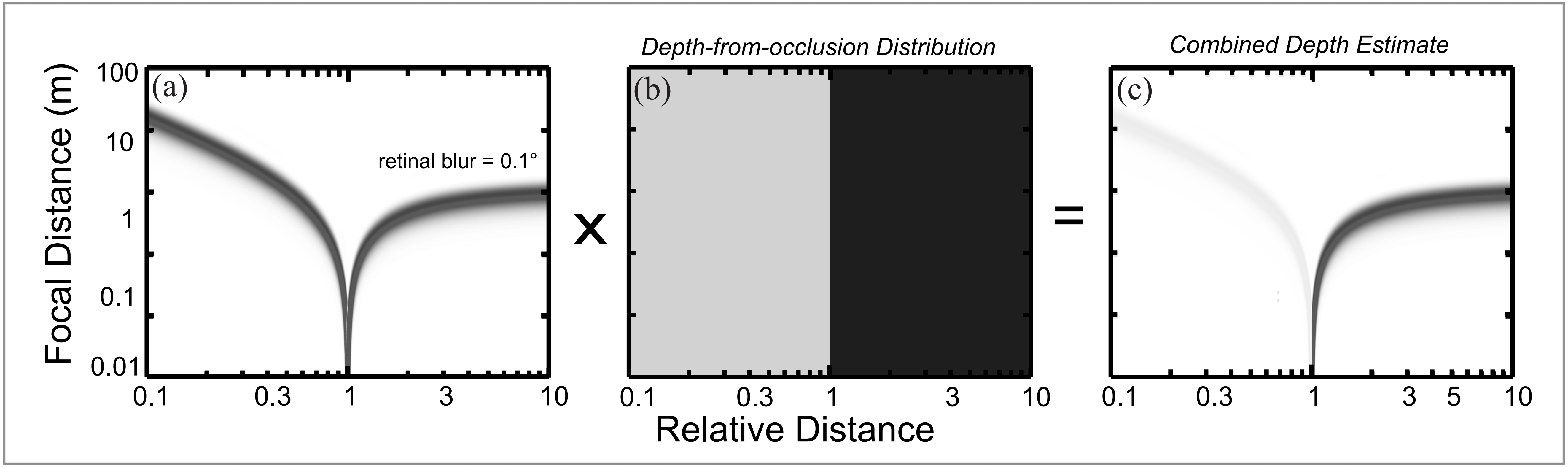


Theory applied to previous studies

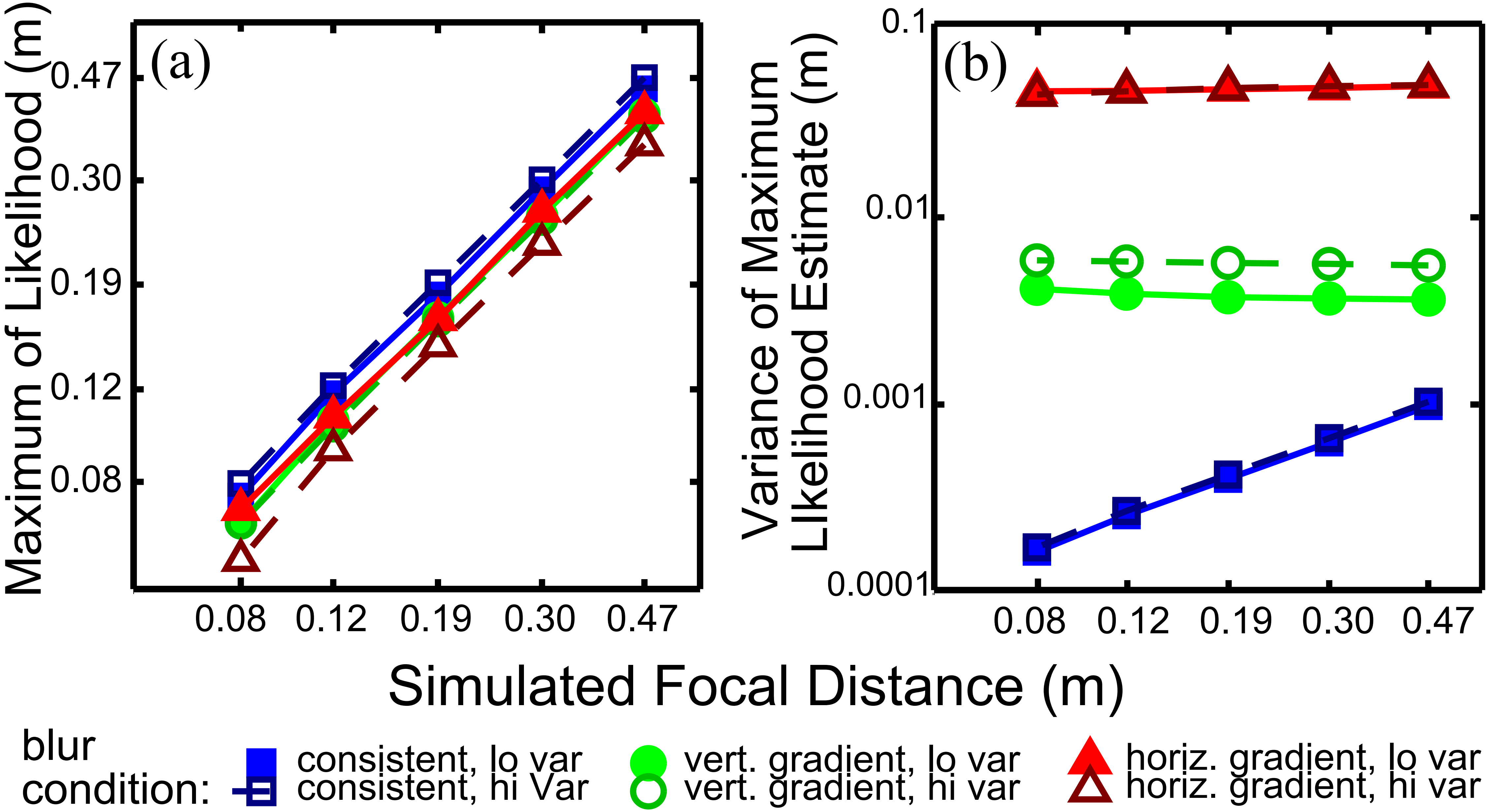
- Explains results by Marshall et al. (1996) and Mather (1996)







Predictions



- Consistent blur most reliable, followed by vertical and horizontal gradients
- Vertical gradients more reliable for low depth variation

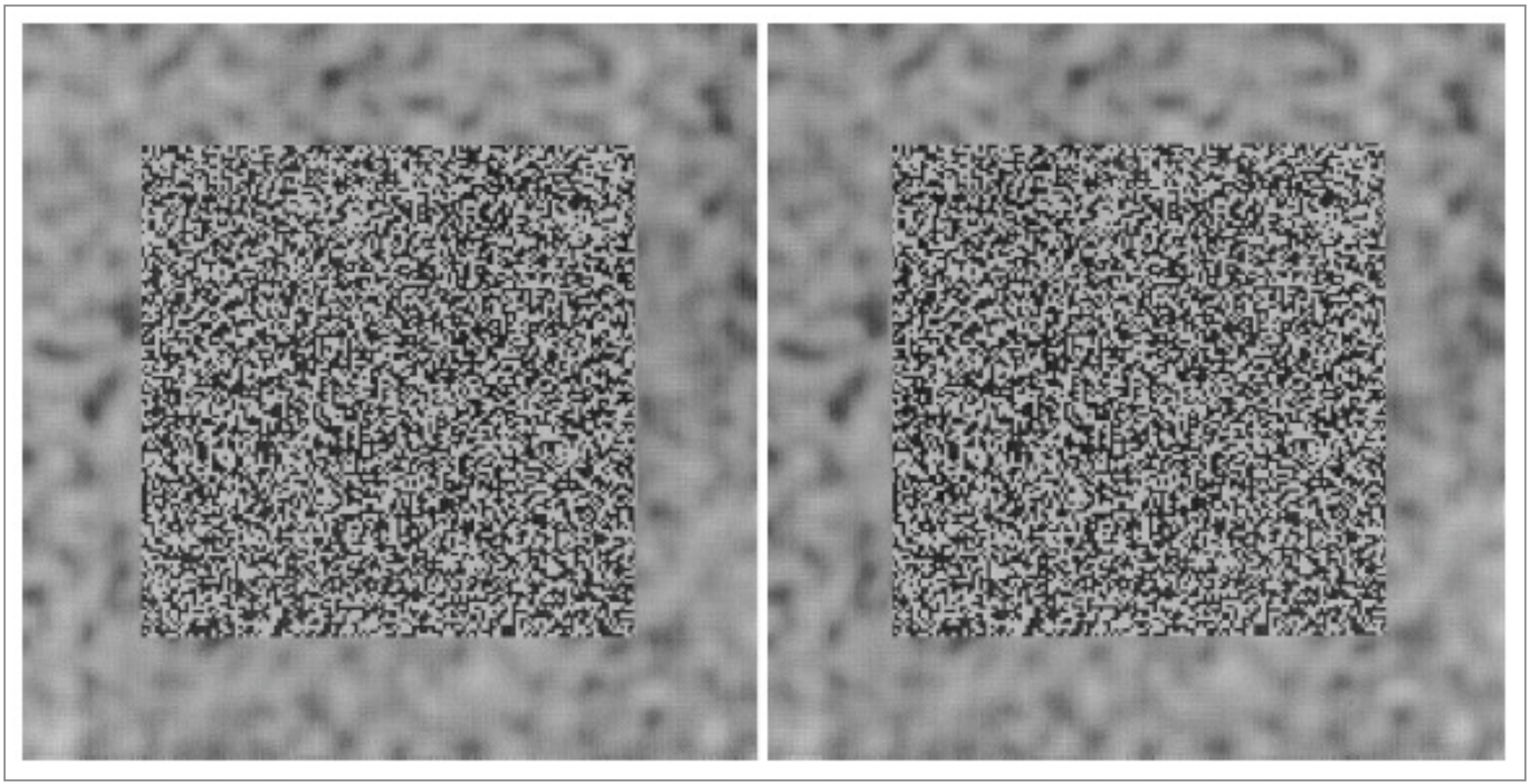
Blur in Photography

Blur in cinema

- Small apertures and long exposures minimize blur
- Result: Scale models appear life-sized

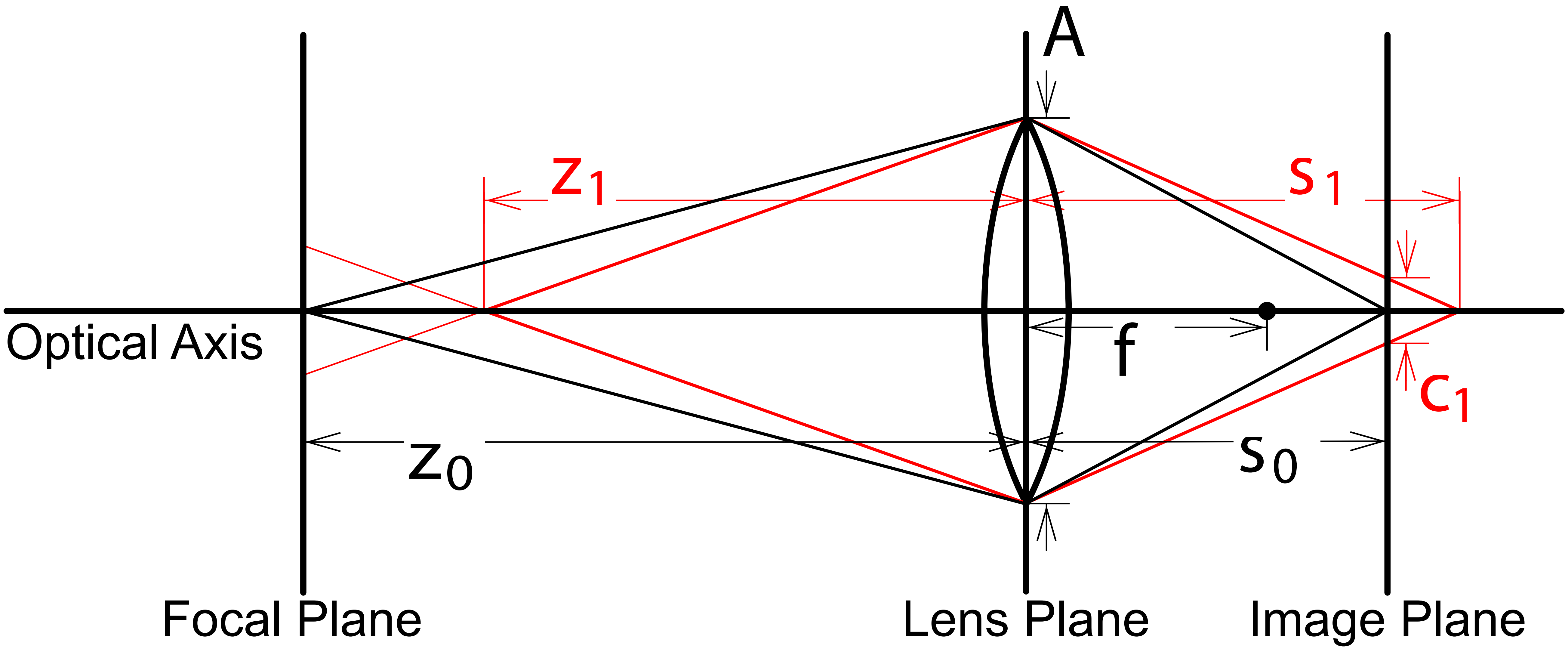
Blur as a depth cue

- Compare strengths of disparity and blur as depth cues
- With disparity present, blur had little effect on percept, unless it was greatly exaggerated
- Conclusion: Blur provides coarse, qualitative information



Mather et al. (2000)

Revisiting blur as a cue



Important terms:

Focal distance: z_0

Relative distance: $d = z_1/z_0$

Blur magnitude: c_1 (deg)

$$c_1 = \left| A \left(\frac{s_0}{z_0} \right) \left(1 - \frac{1}{d} \right) \right|$$