

# Learning where to look: A foveated visuomotor control model

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# Outline

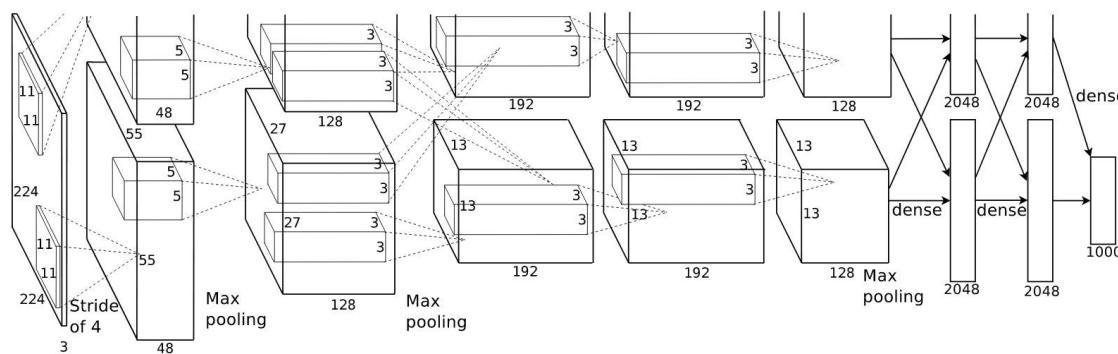
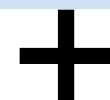
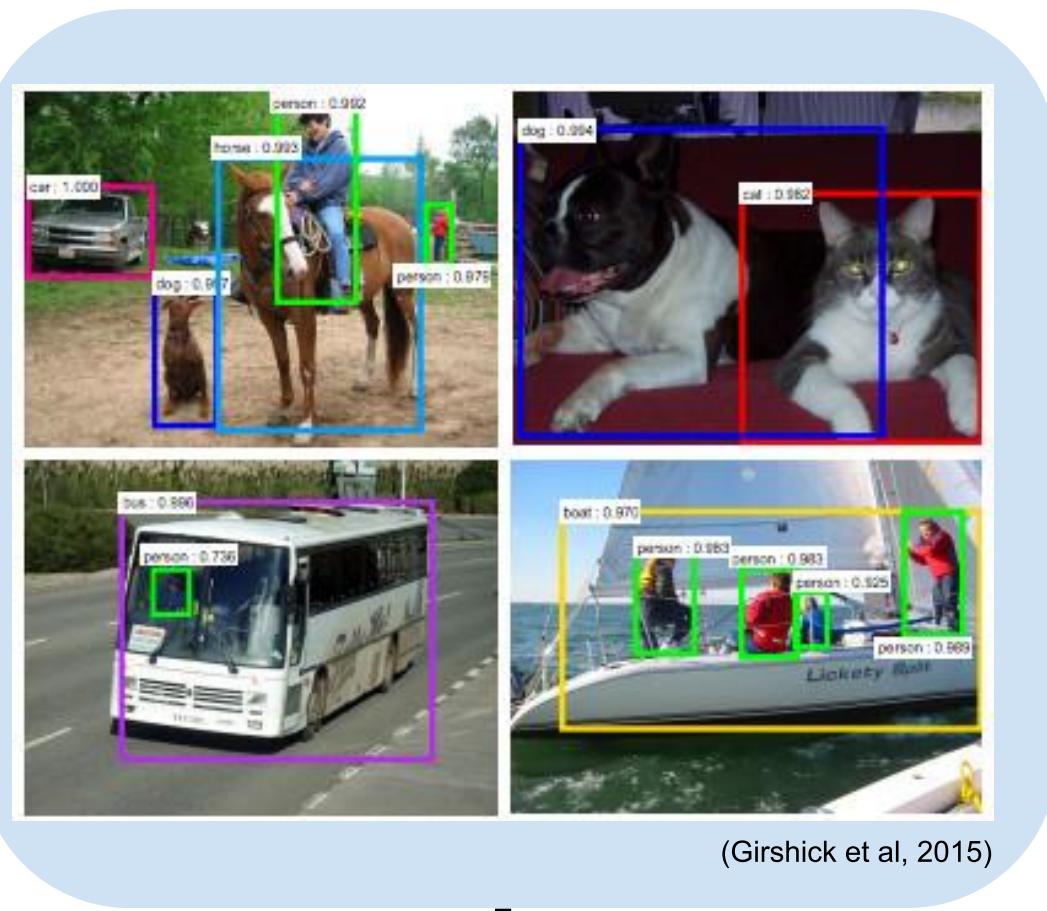
1. Motivation
2. Methods
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# Computer vision

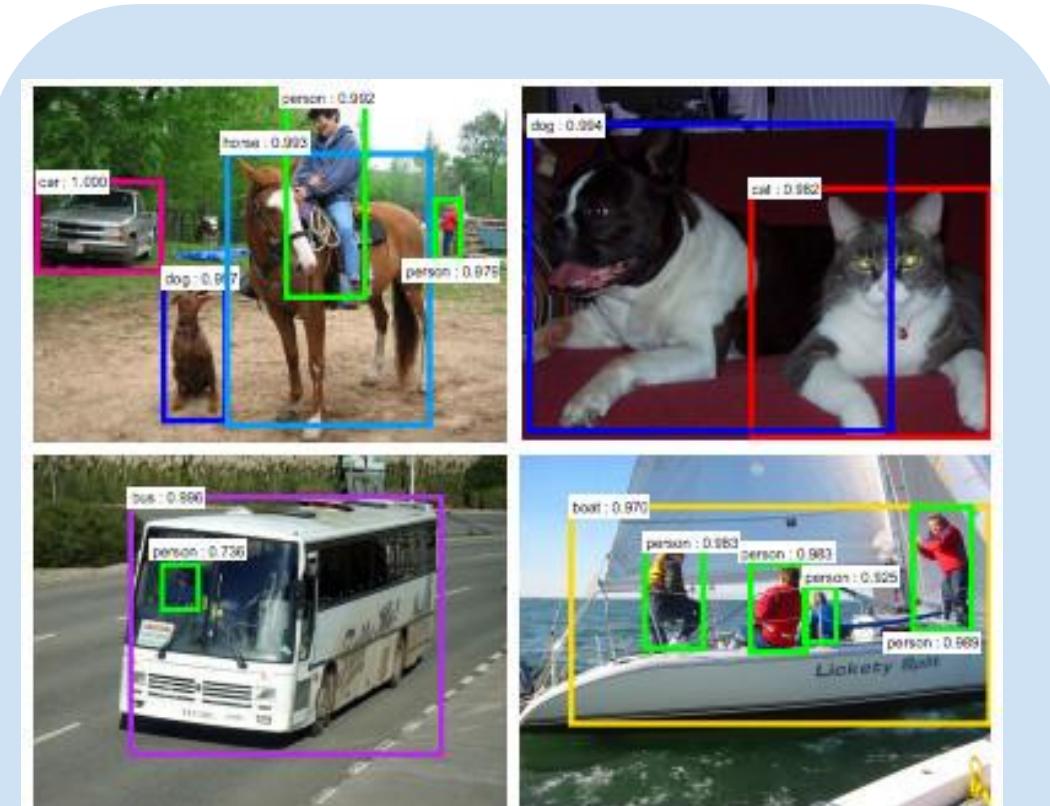
## COMPUTER VISION



(Hinton et al, 2012)

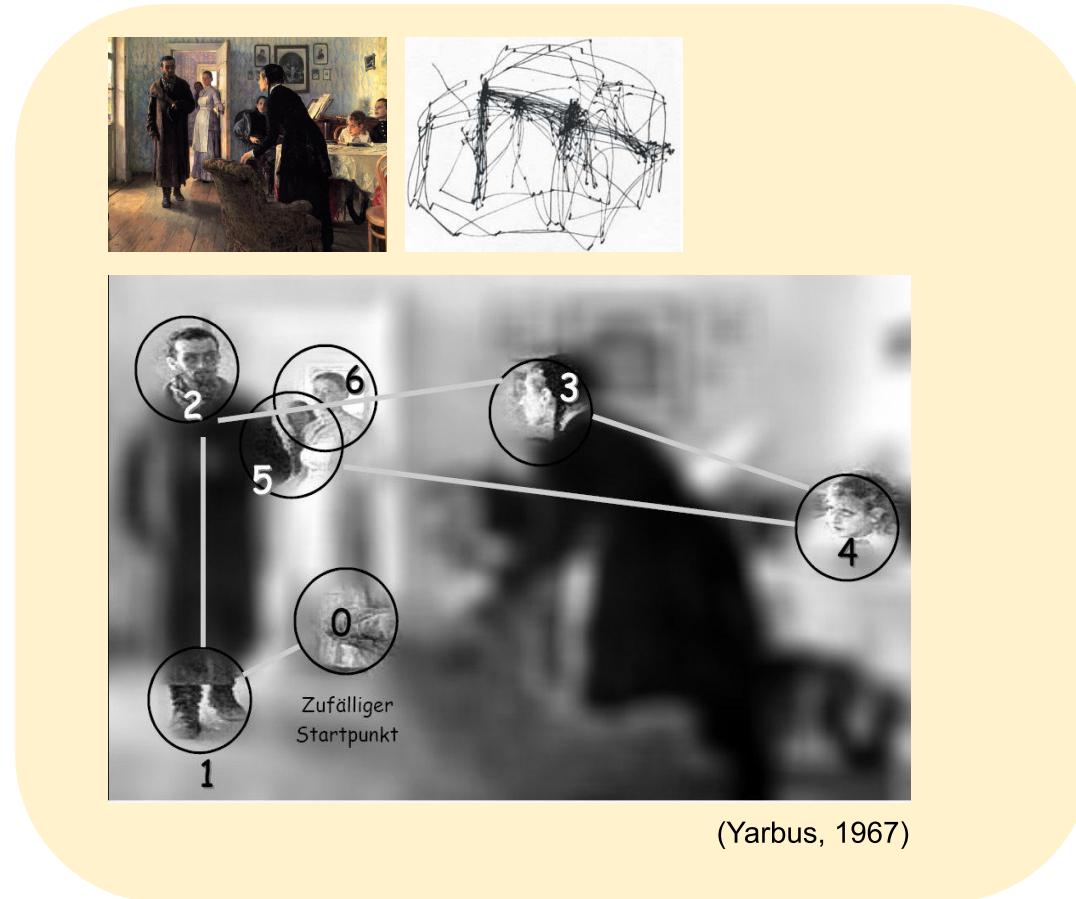
# Human vision

COMPUTER VISION

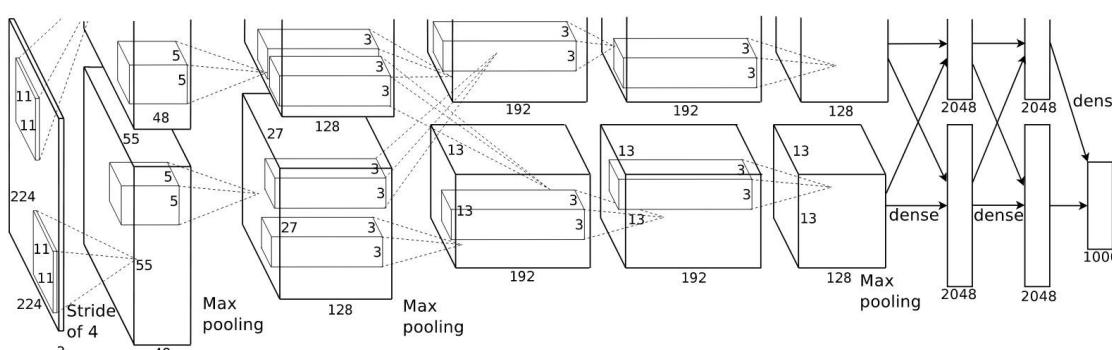
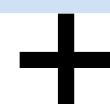


(Girshick et al, 2015)

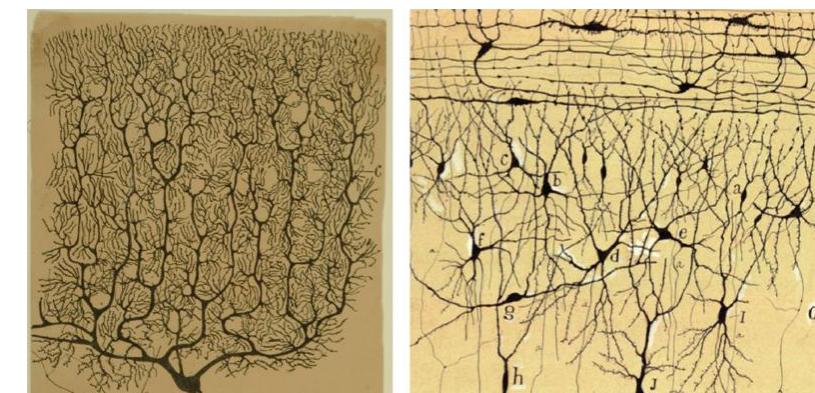
HUMAN VISION



(Yarbus, 1967)



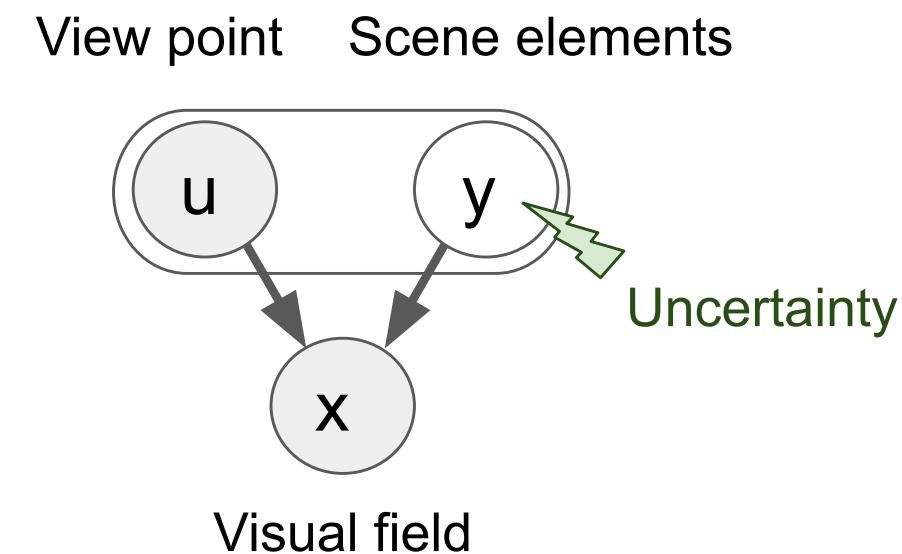
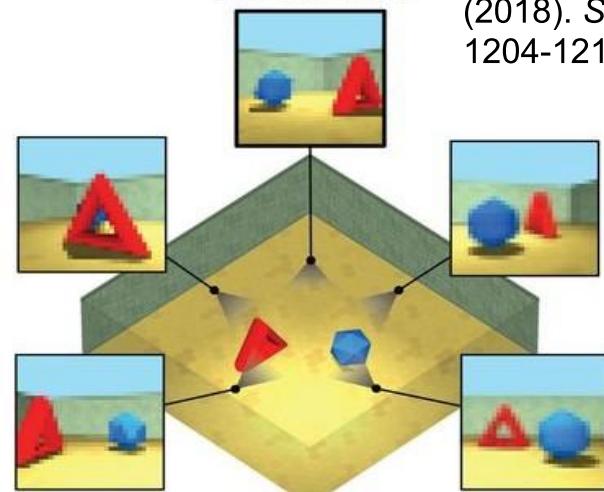
(Hinton et al, 2012)



(Cajal, 1888)

# Statistical Viewpoint

Eslami, S. A., Rezende, et al.  
(2018). *Science*, 360(6394),  
1204-1210.



# Attention vs. Scene Understanding

Bayesian surprise  
(Information Gain)

(Itti & Baldi, 2009)

$$E_y [\log P(Y|x, u) - \log P(Y)]$$

B O T T O M - U P

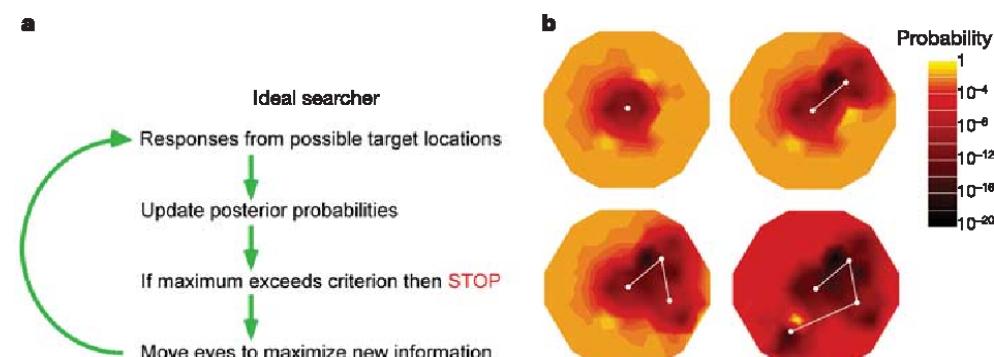
Visual attention  
Saliency Maps



Itti and Koch (2000)  
Kümmerer et al (2015)

T O P - D O W N

Active Inference  
Recurrent Attention



Najemnik, J., & Geisler, W. S. (2005)  
Butko & Movellan (2010)  
Fu et al (2017)

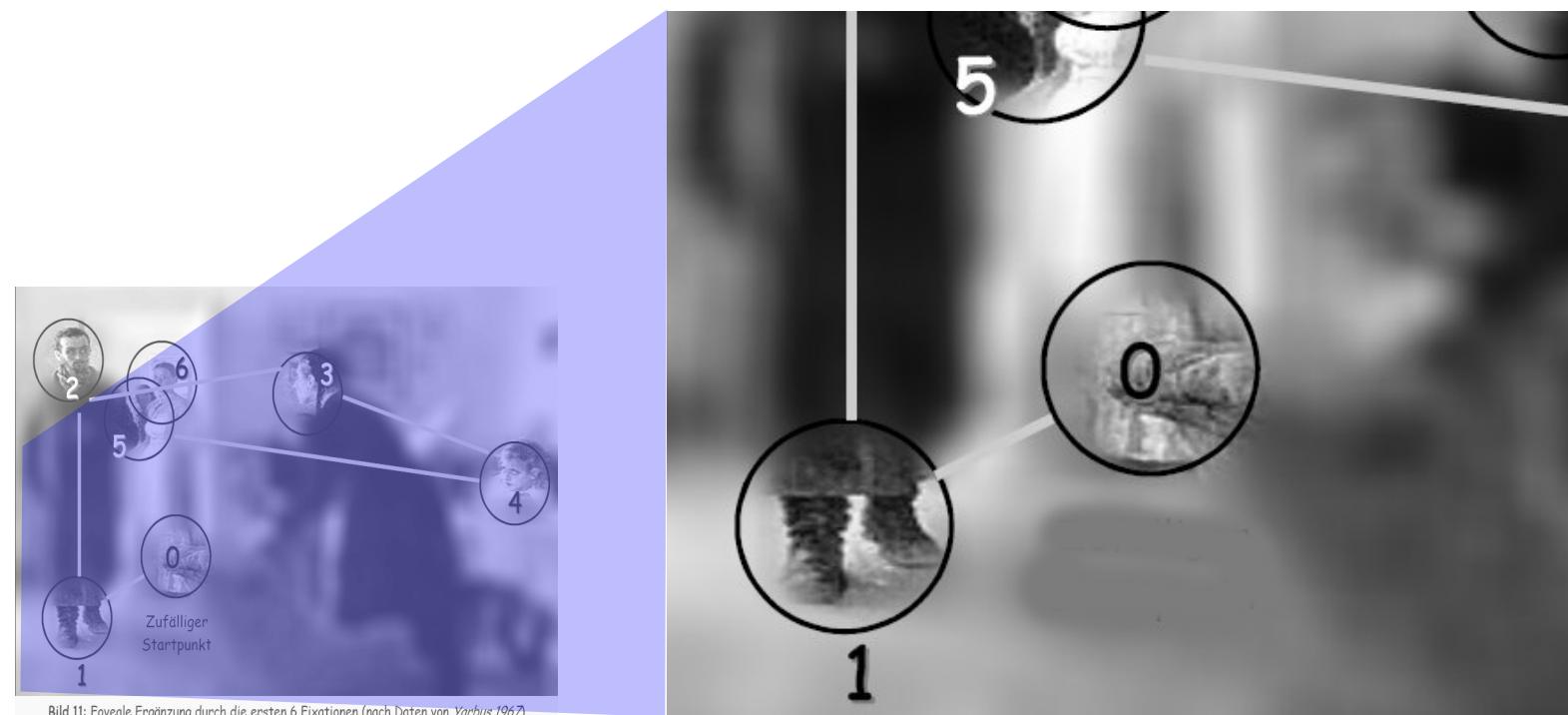
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# Principles for central and peripheric vision

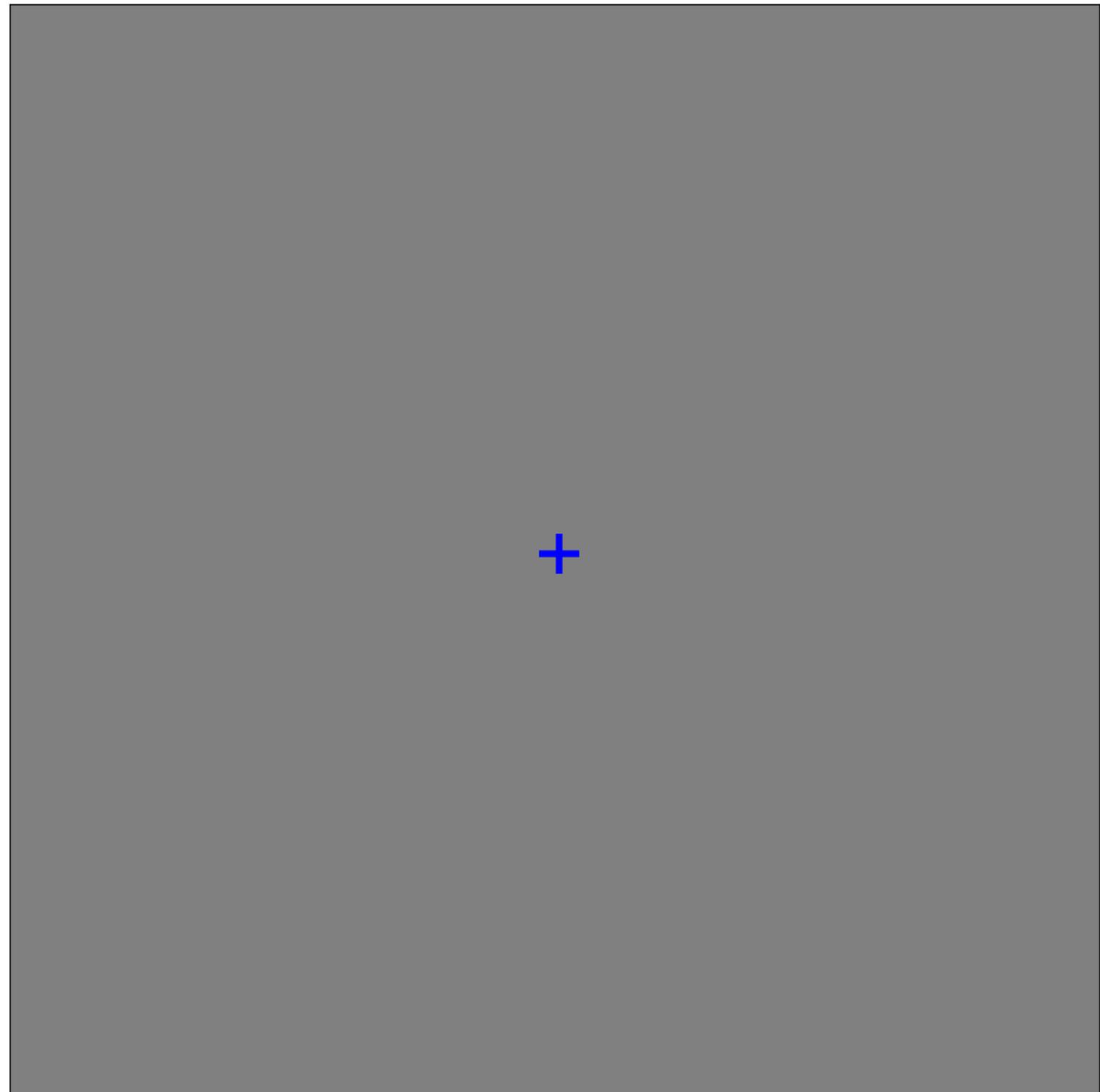


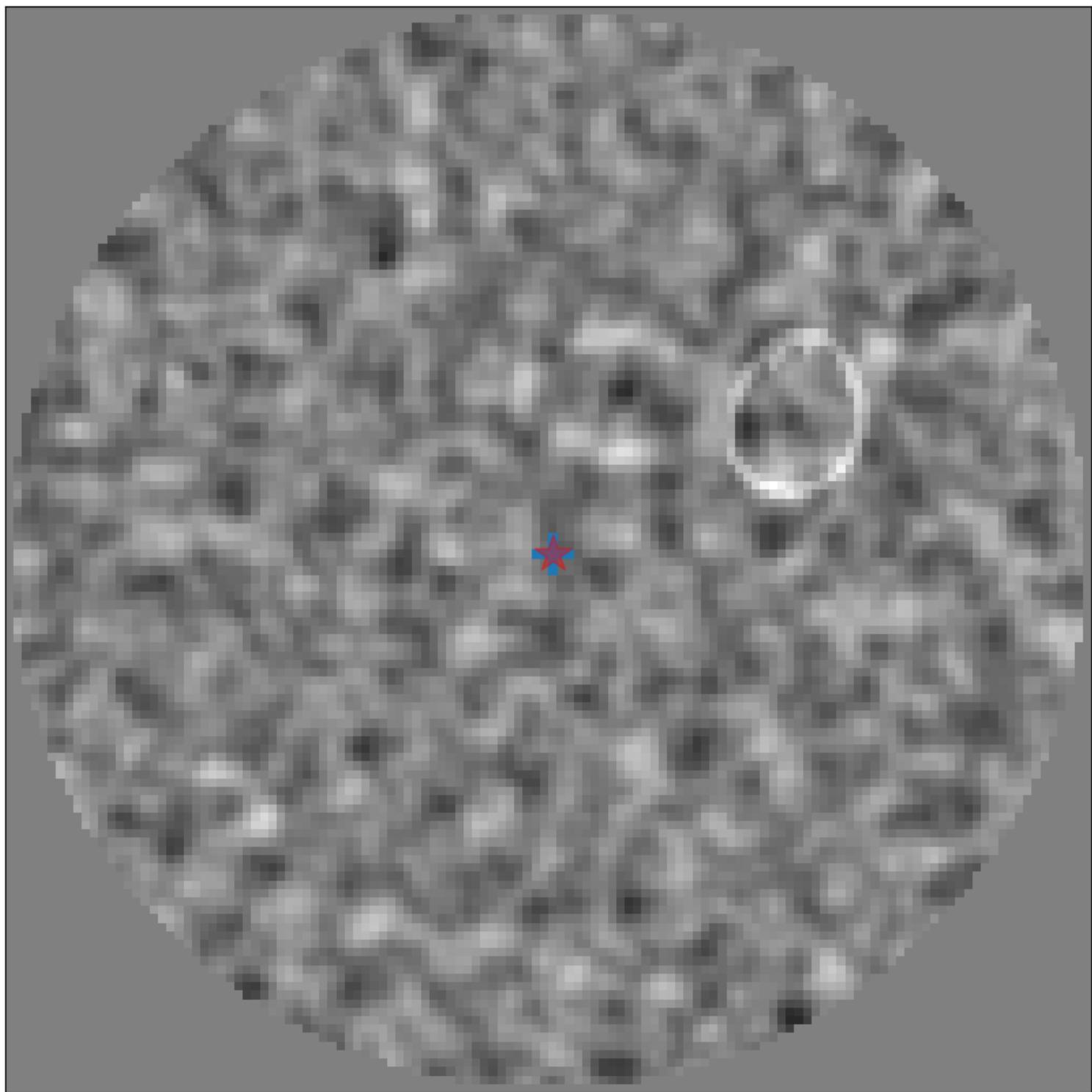
Information Gain :

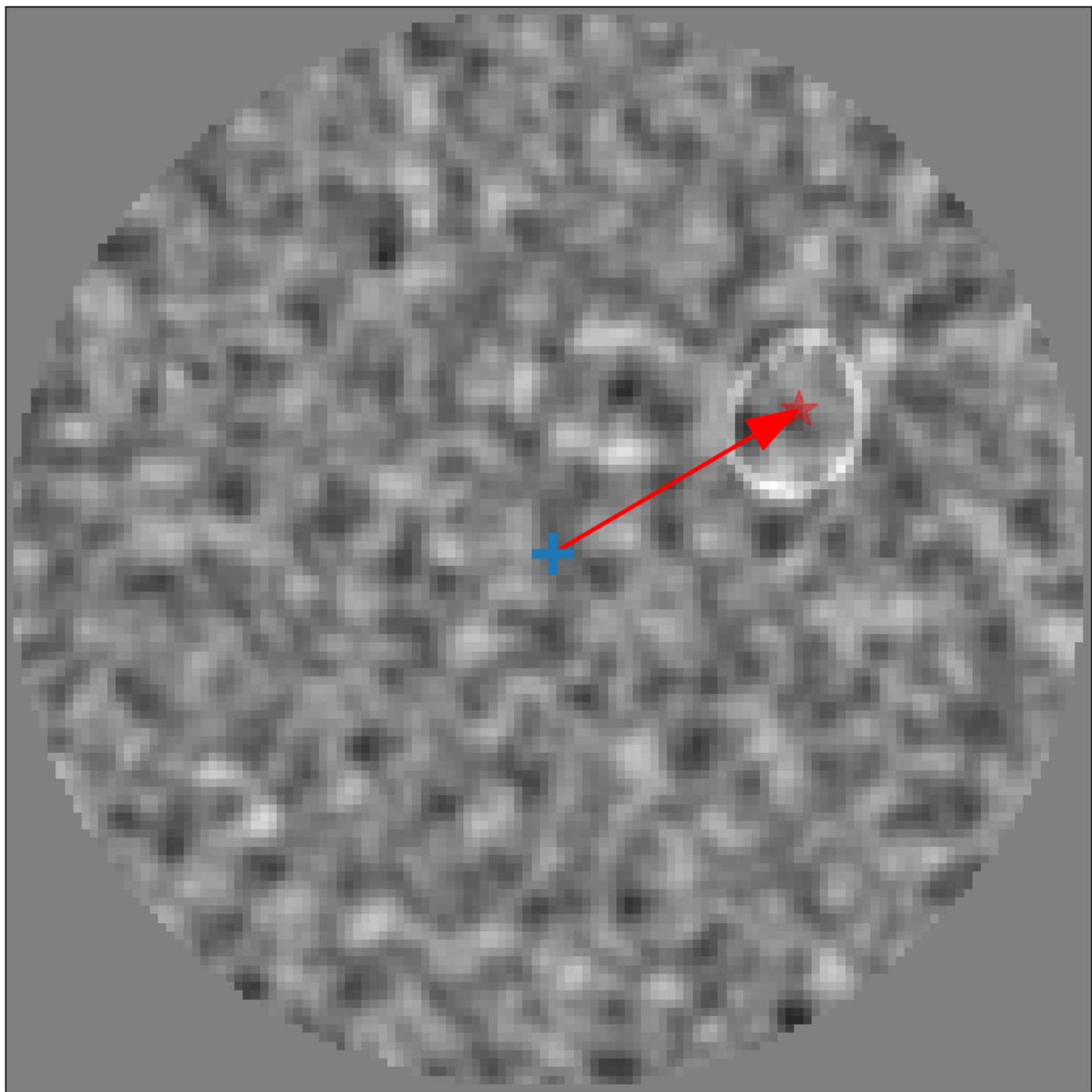
$$E_y [\log P(Y|x, u) - \log P(Y)]$$

Peripheral processing

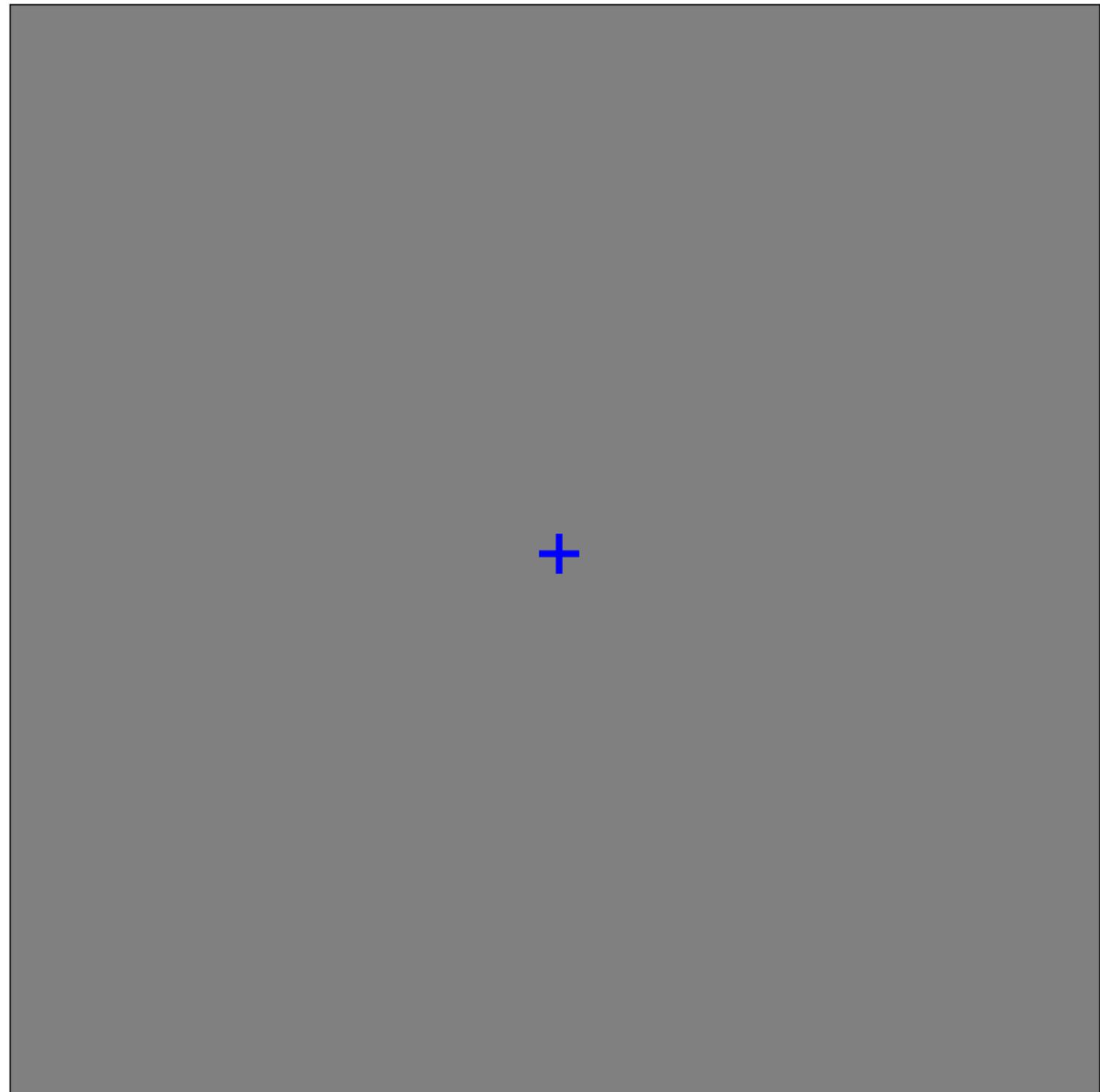
Central processing

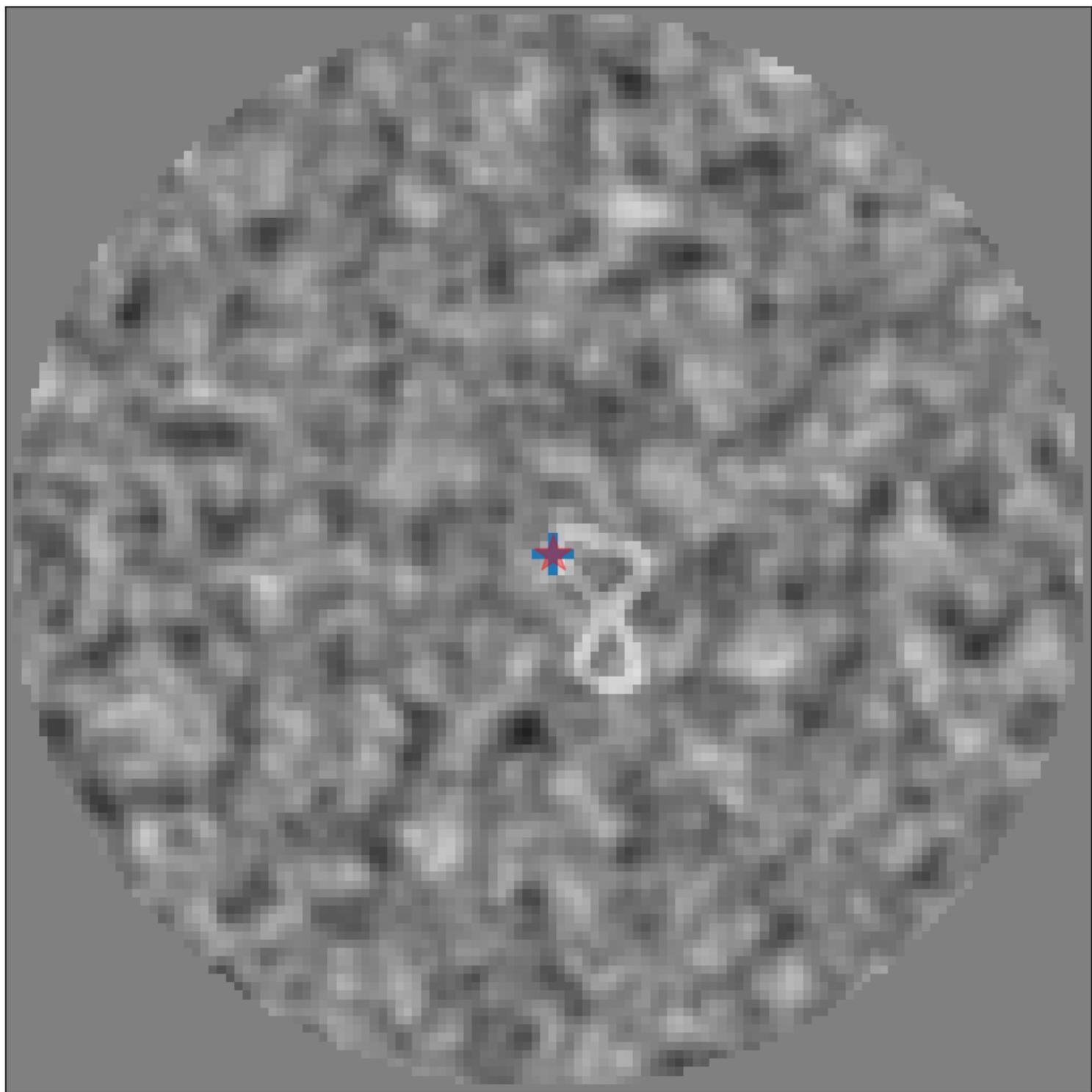


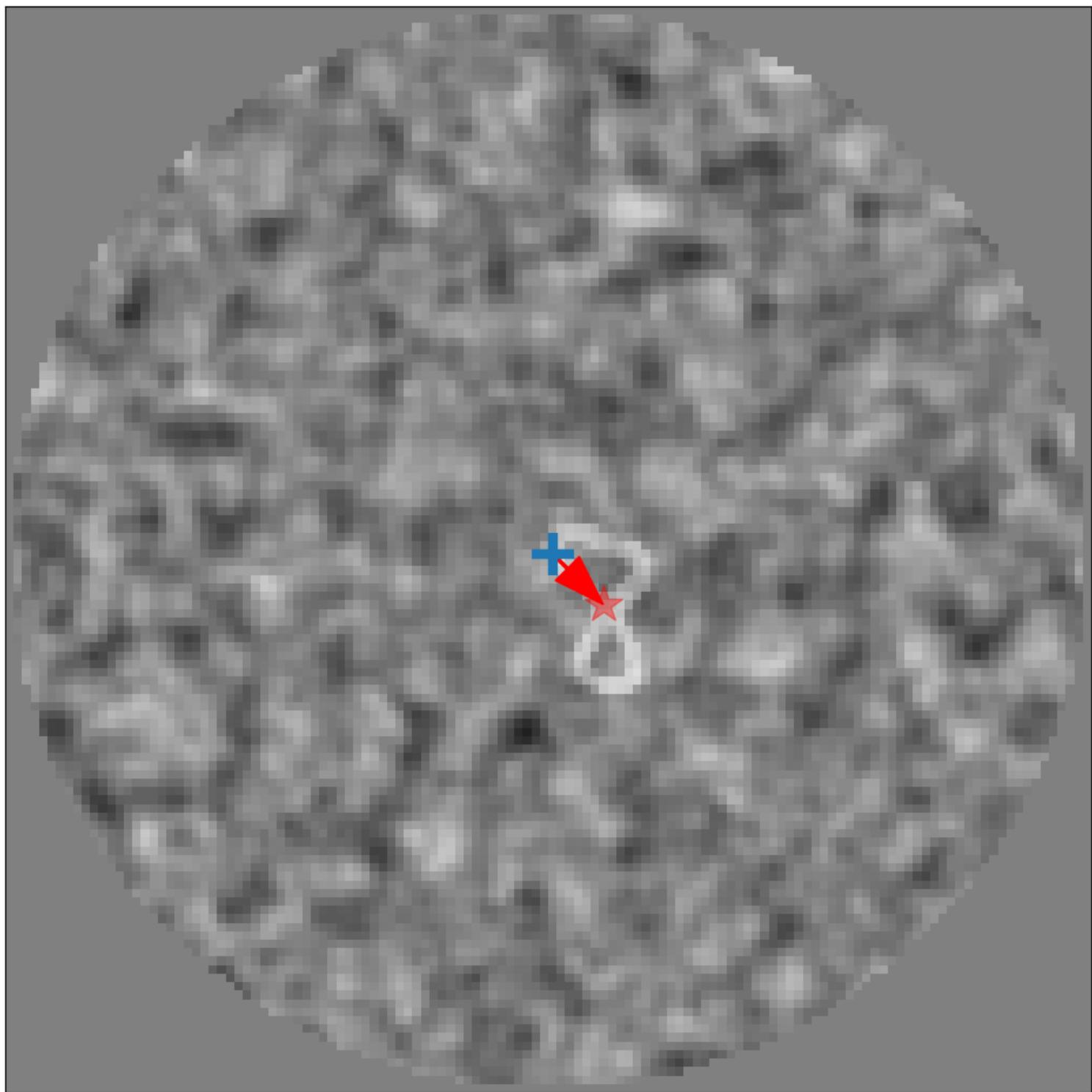




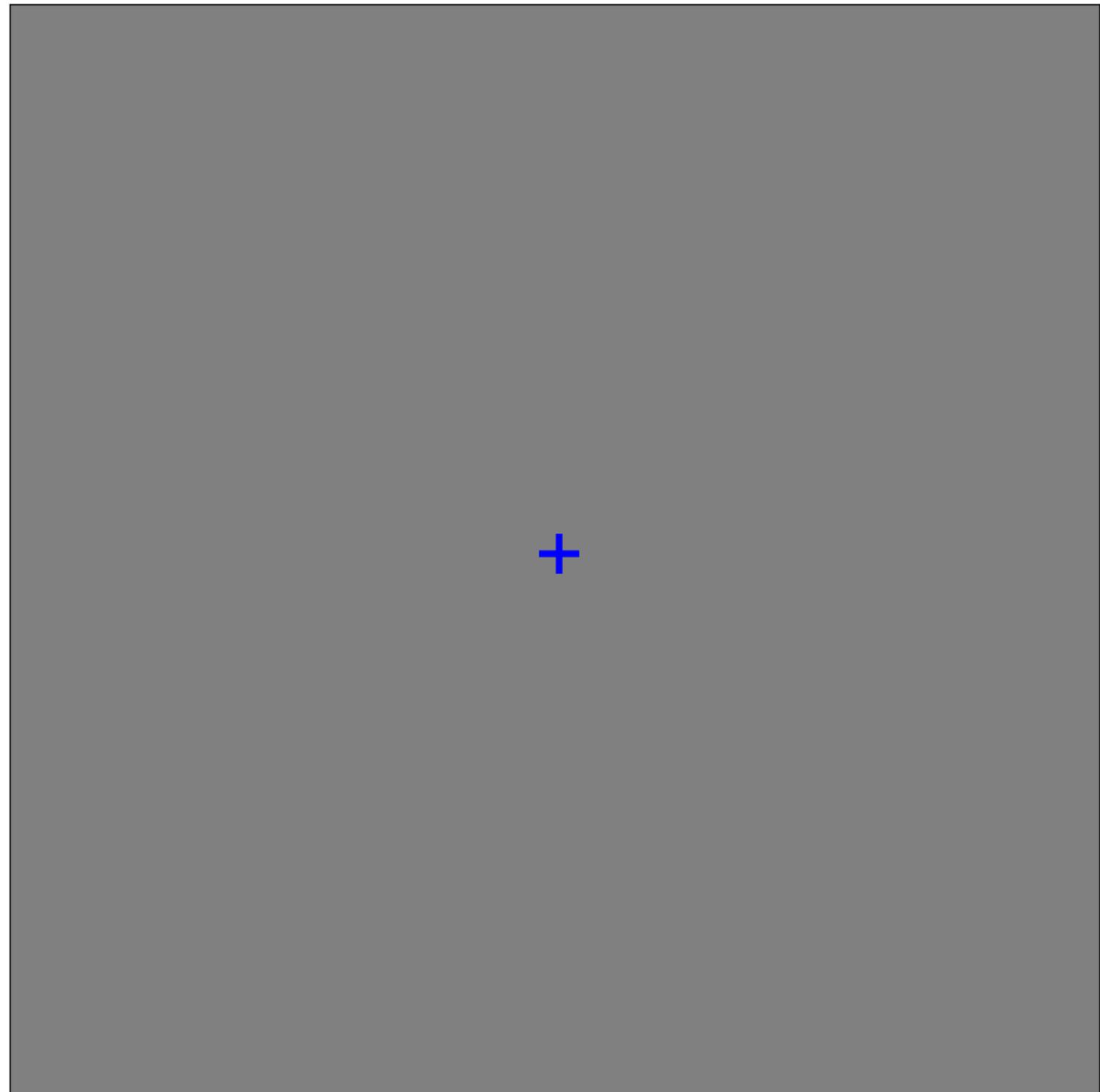
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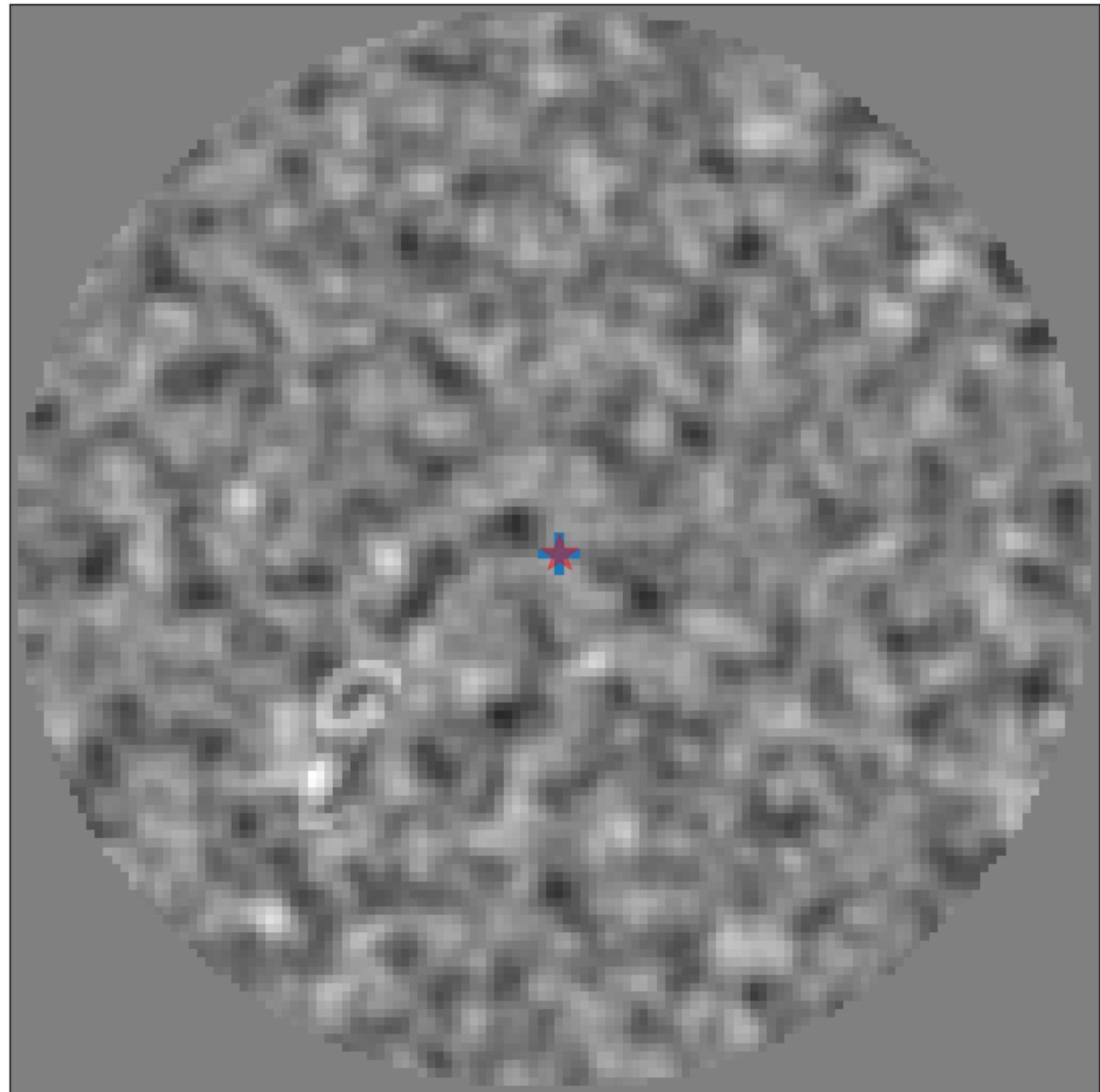


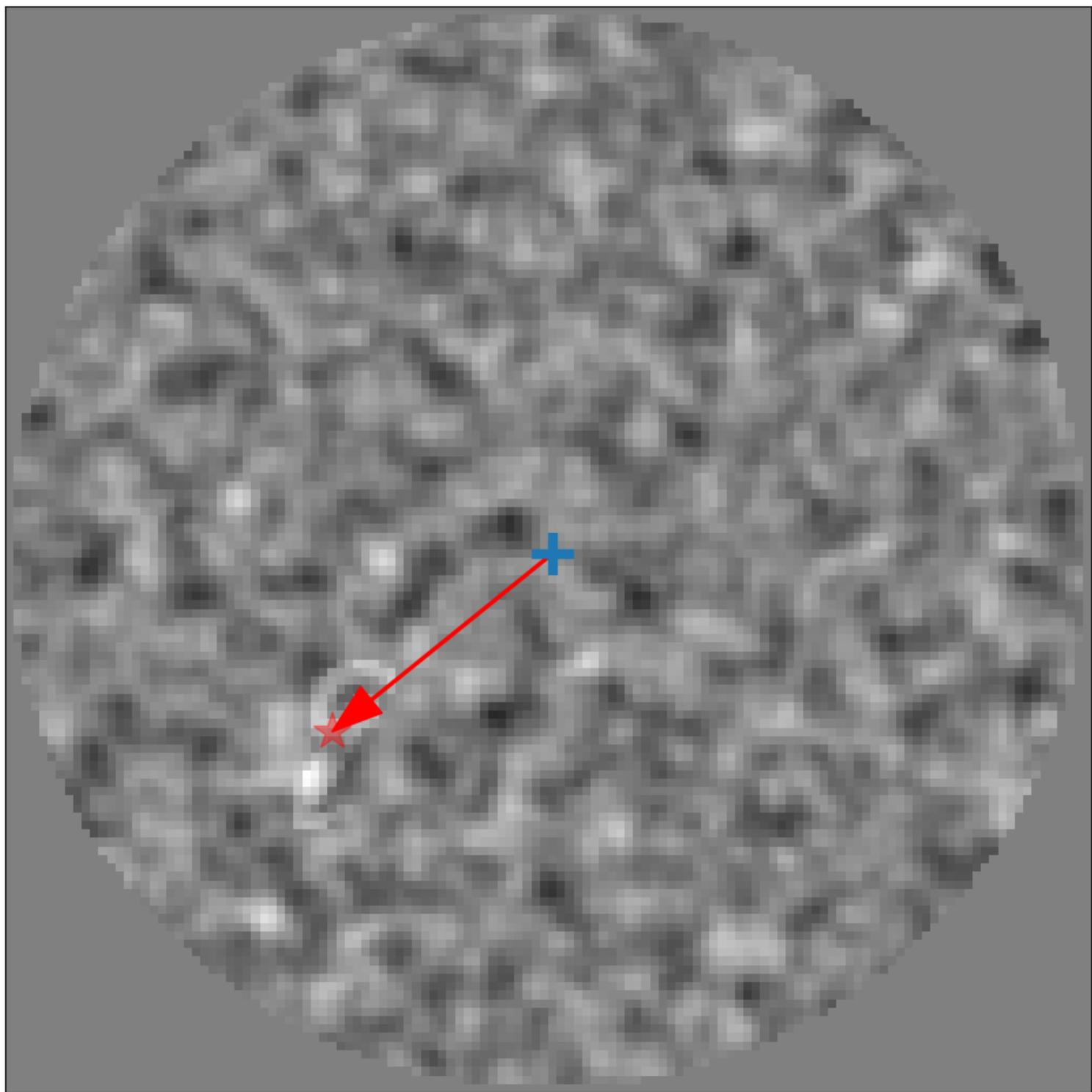




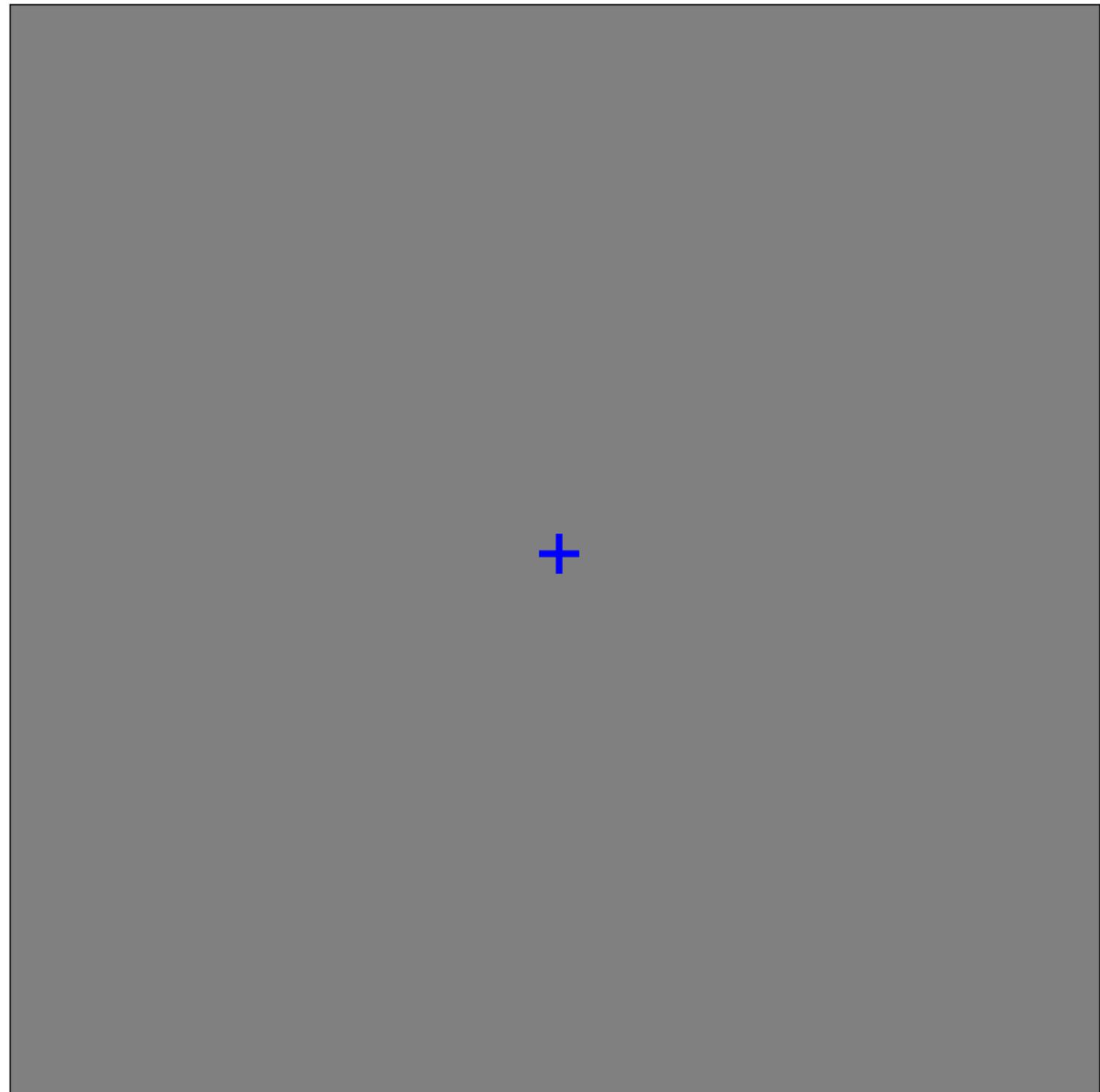
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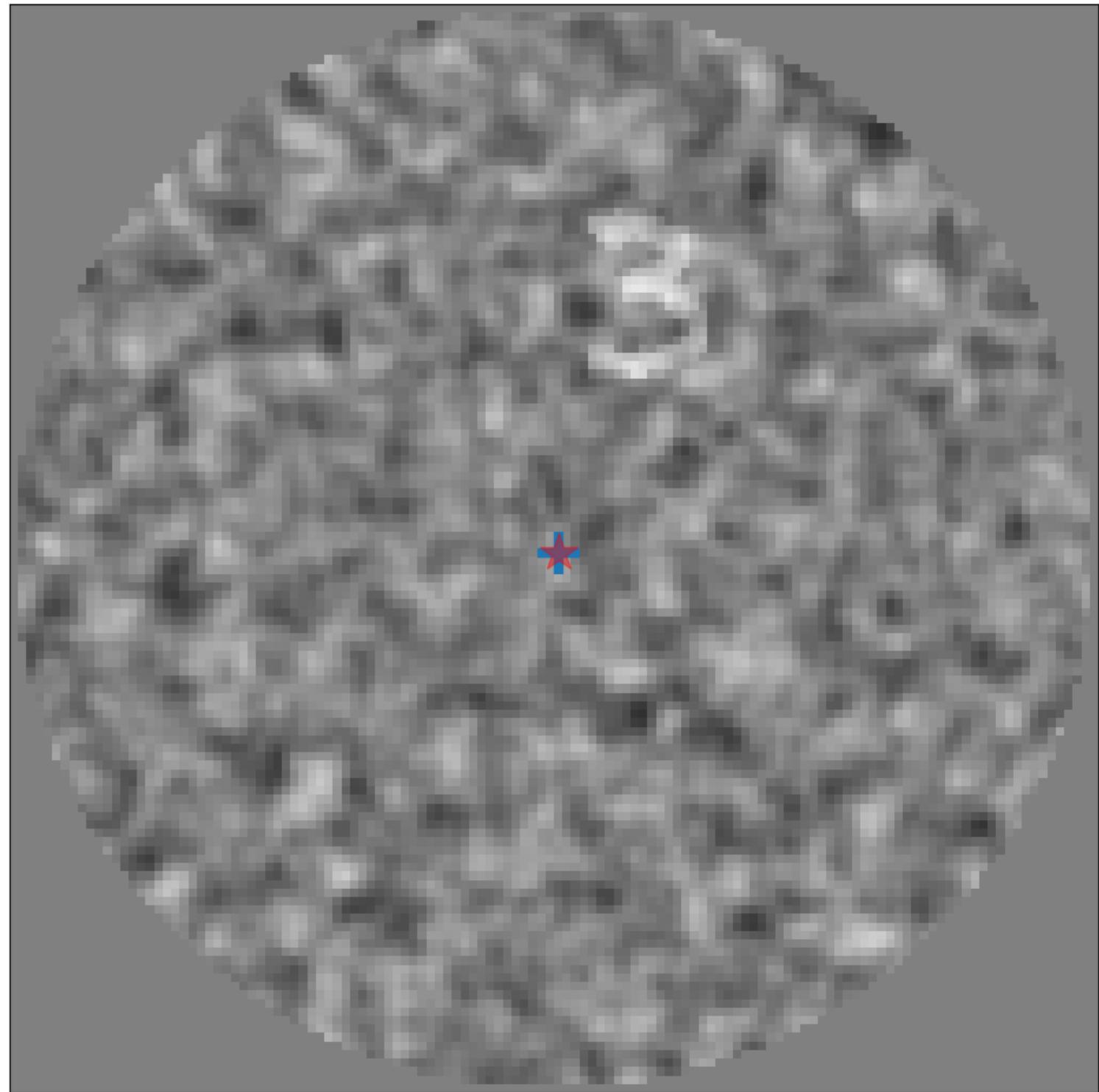


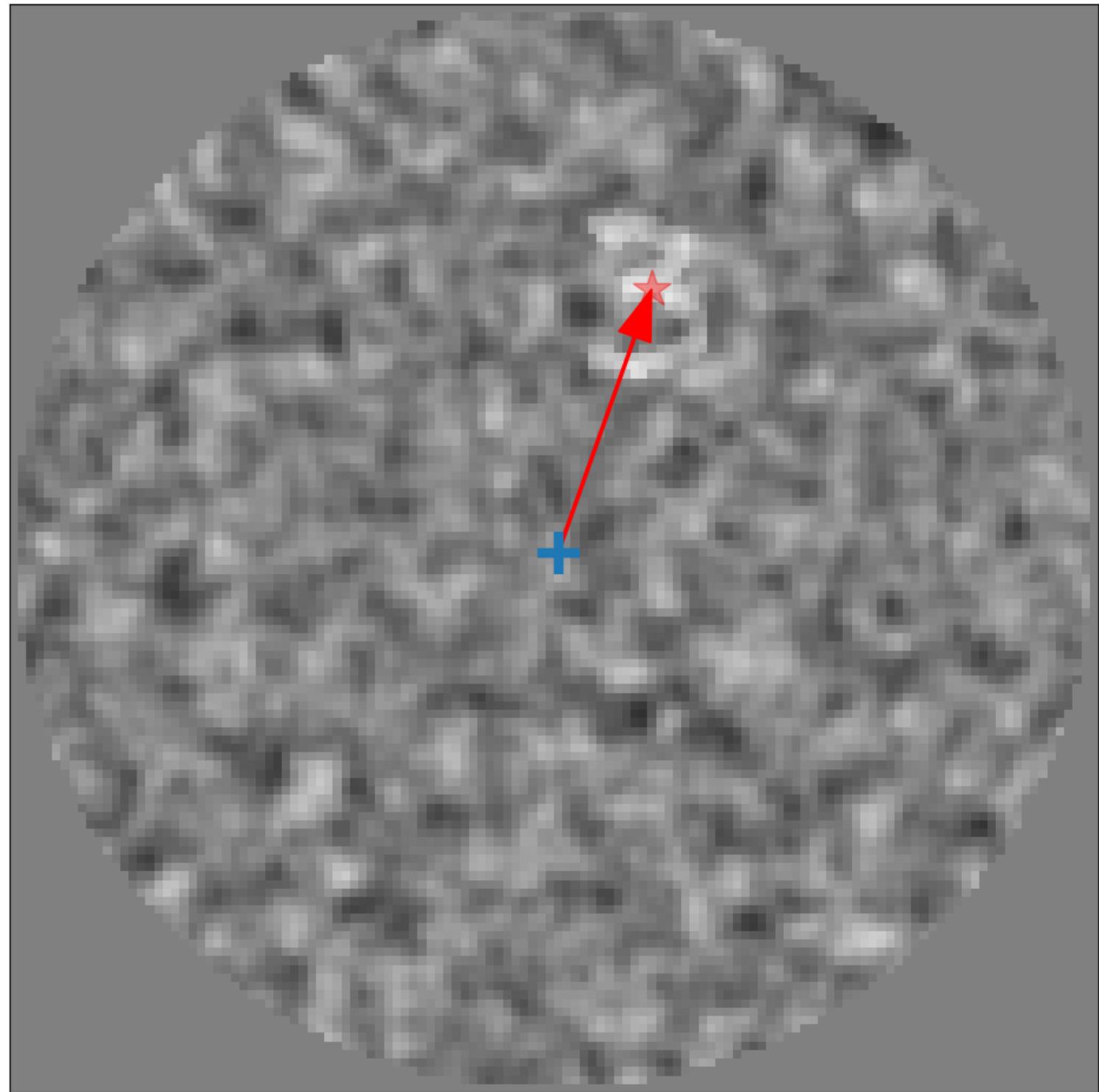




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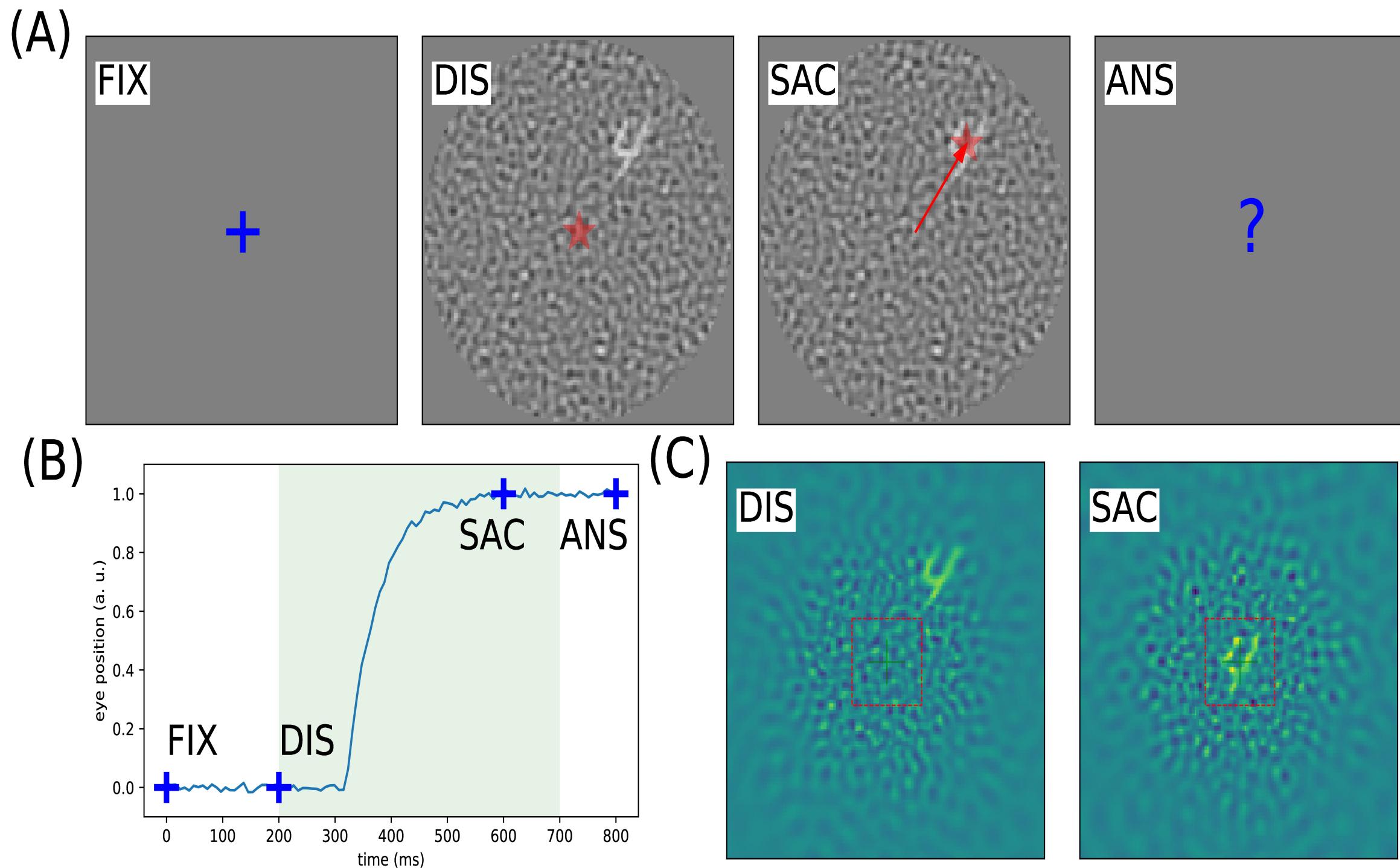




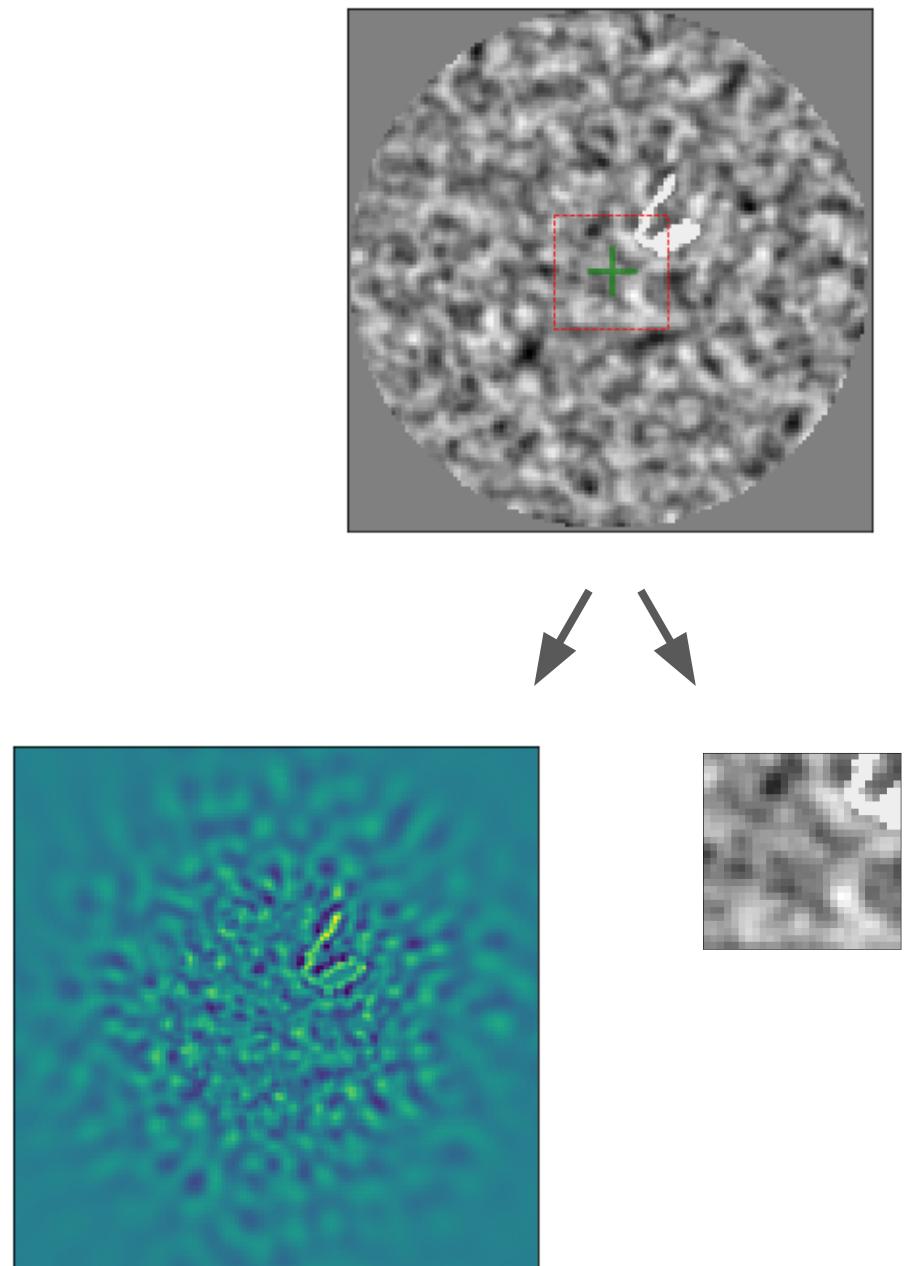


?

# Methods - "Experimental" setup



# Methods: What/Where separation



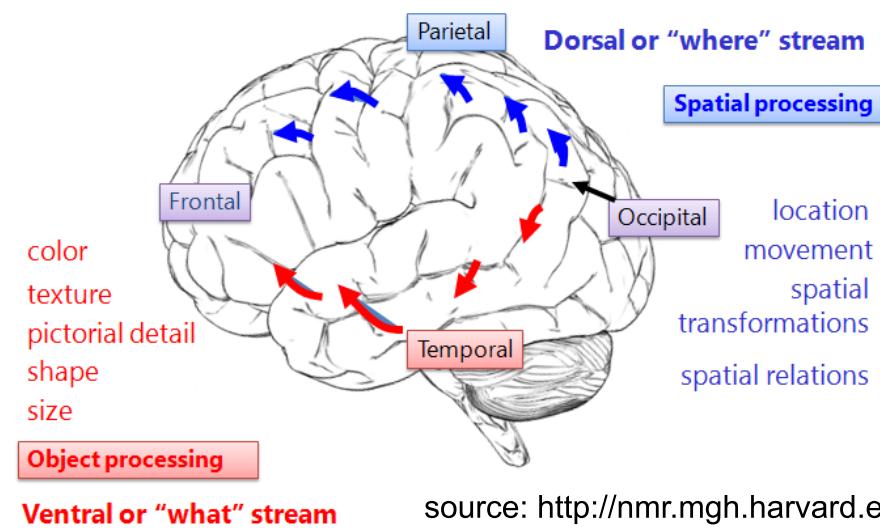
Approximate Information Gain :

$$E_y [\log P(Y|x, u) - \log P(Y)] \approx \log P(\hat{y}|x, u) - \log P(\hat{y})$$

Future Central  
Accuracy  
(after saccade)

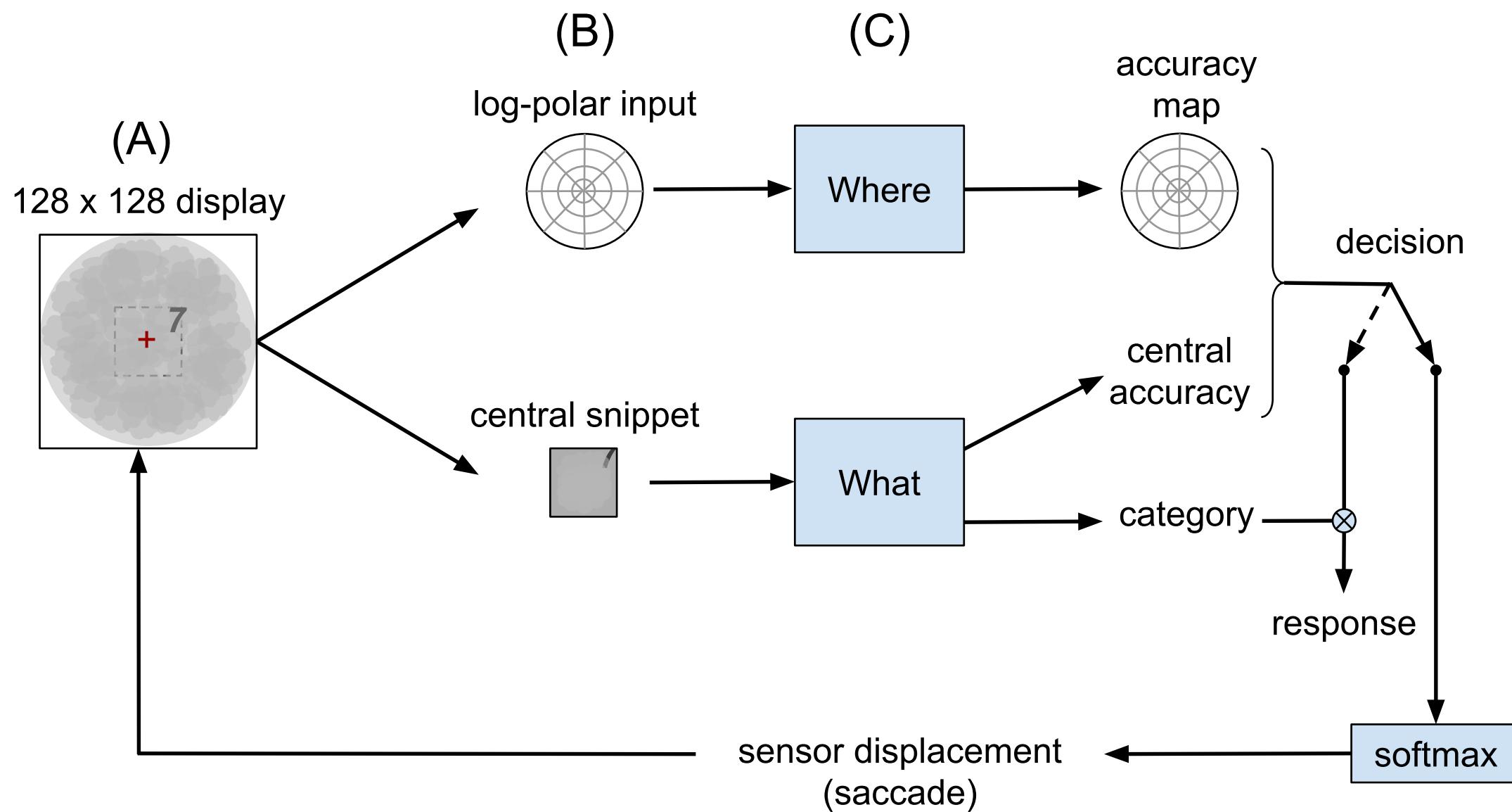
Central Accuracy

What/where pathways in visual processing  
Mishkin, M., Ungerleider, L. G., & Macko, K. A. (1983).

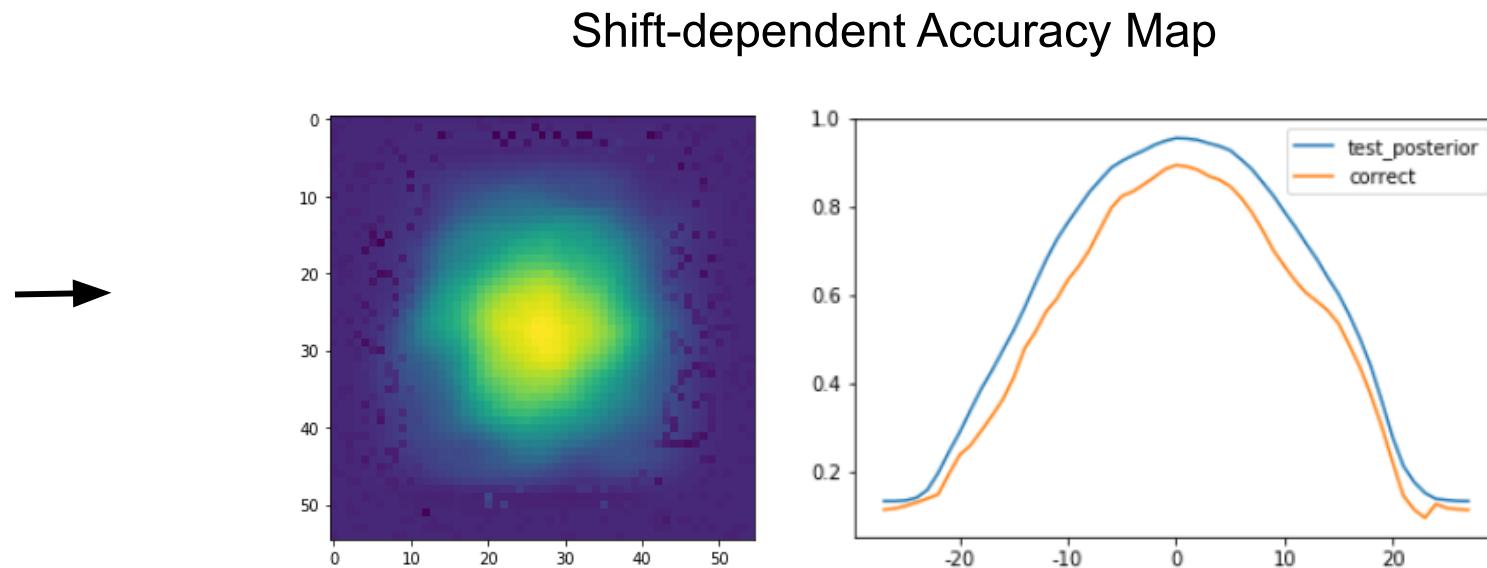
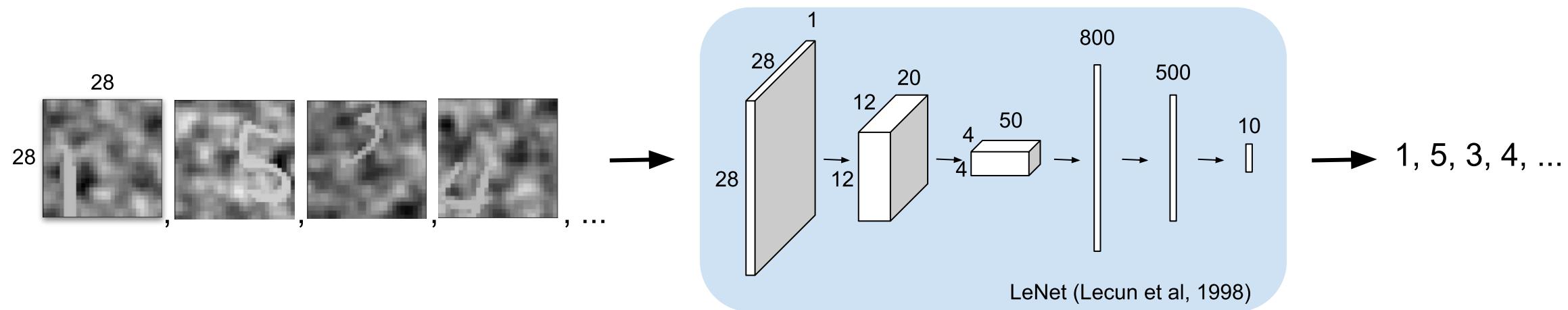


source: <http://nmr.mgh.harvard.edu>

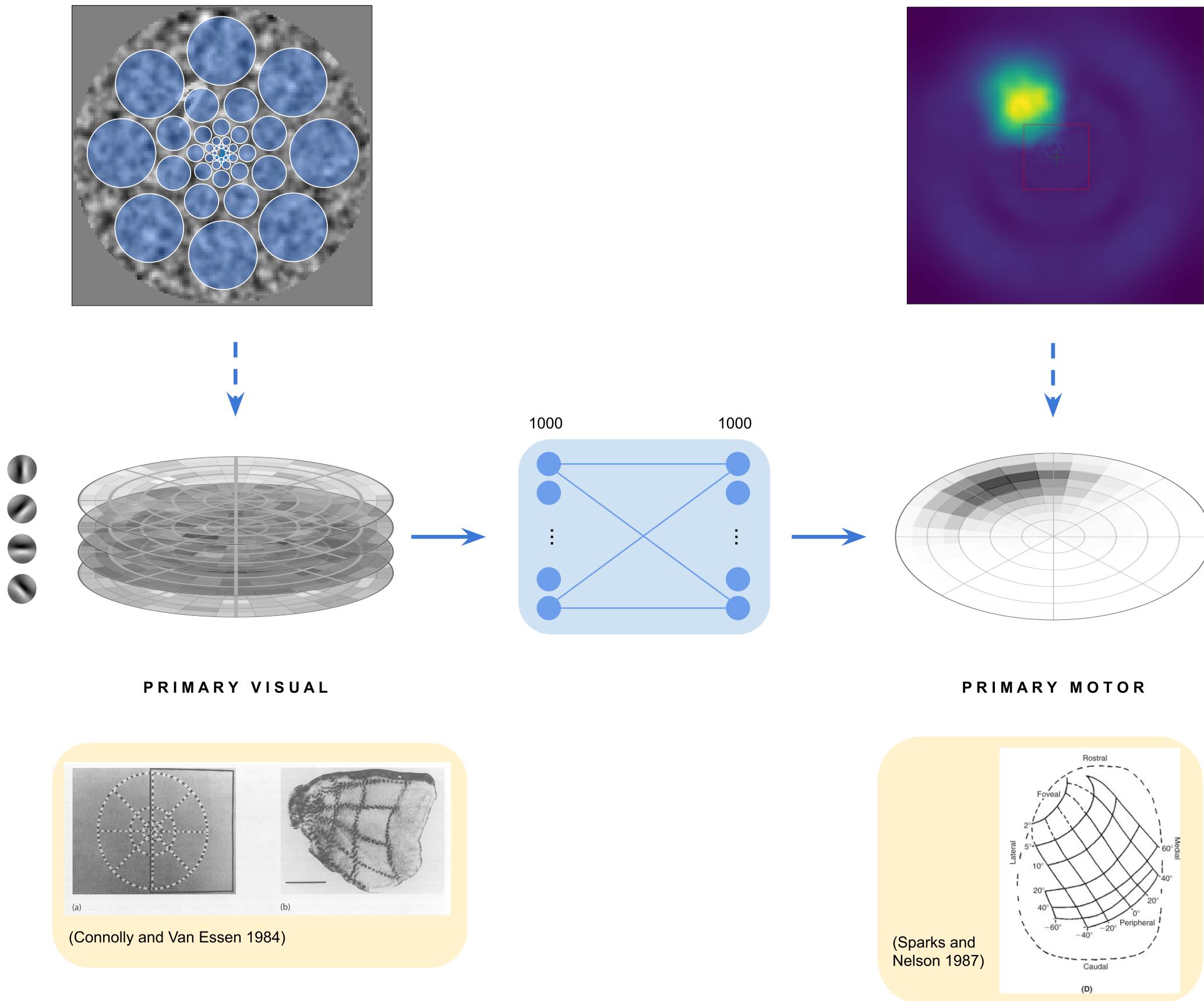
# Methods: Computational Graph



# Methods: What



# Methods: Where



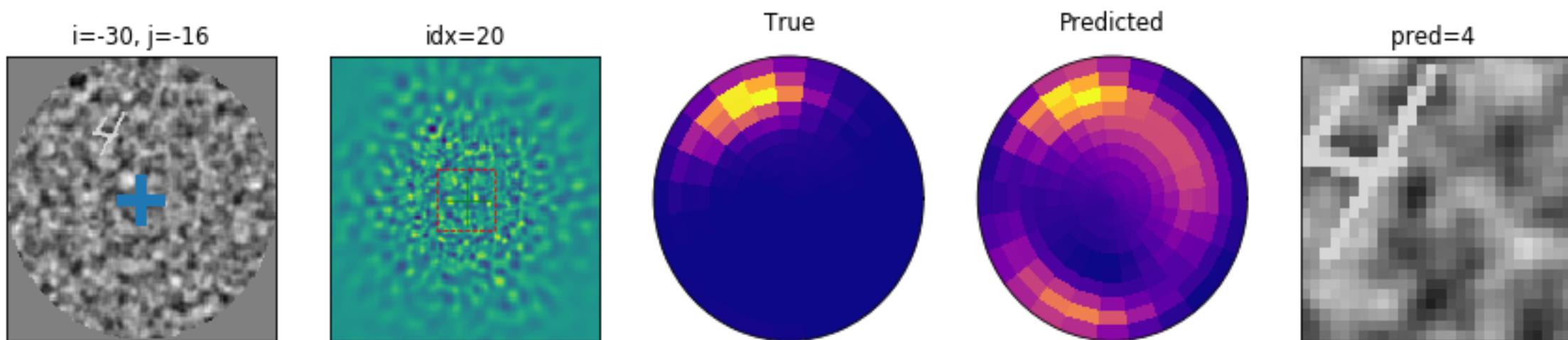
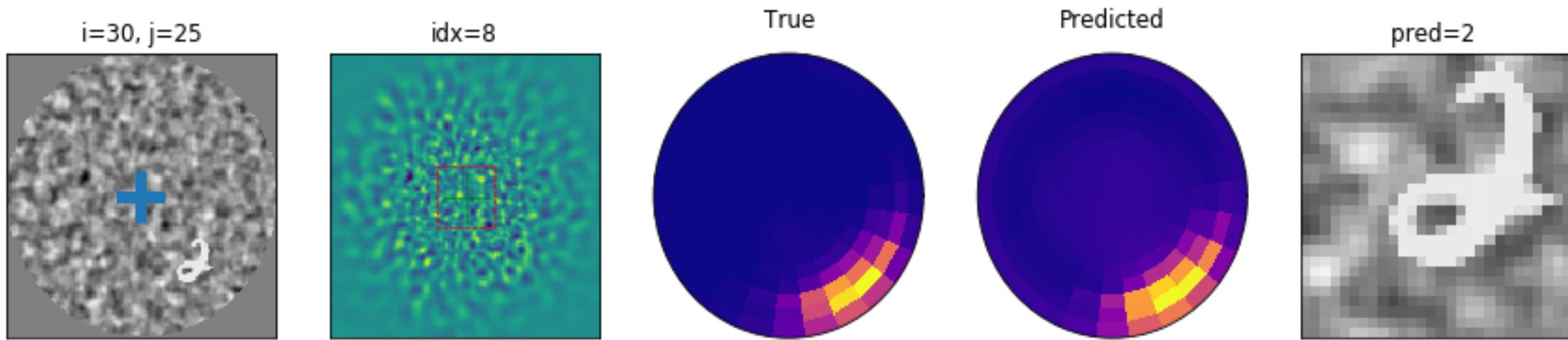
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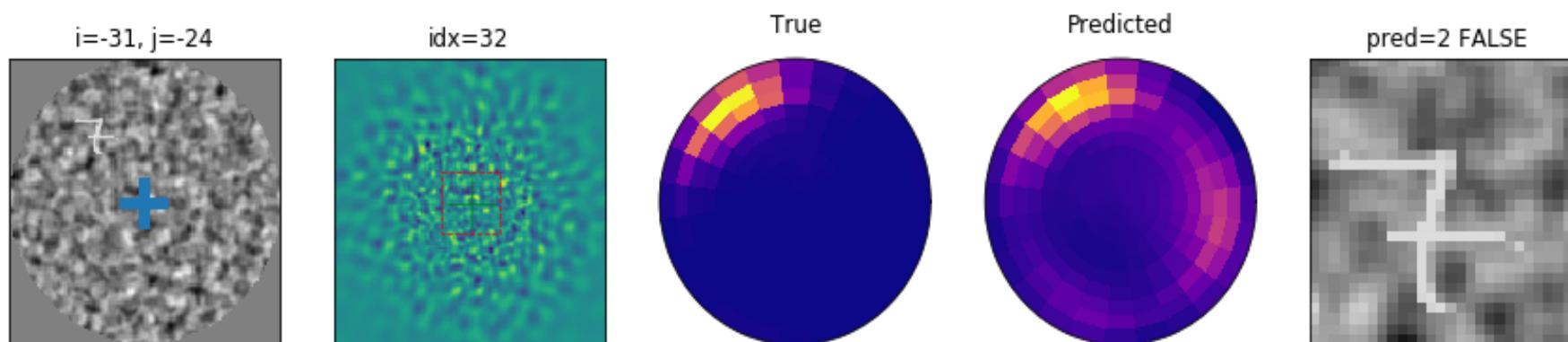
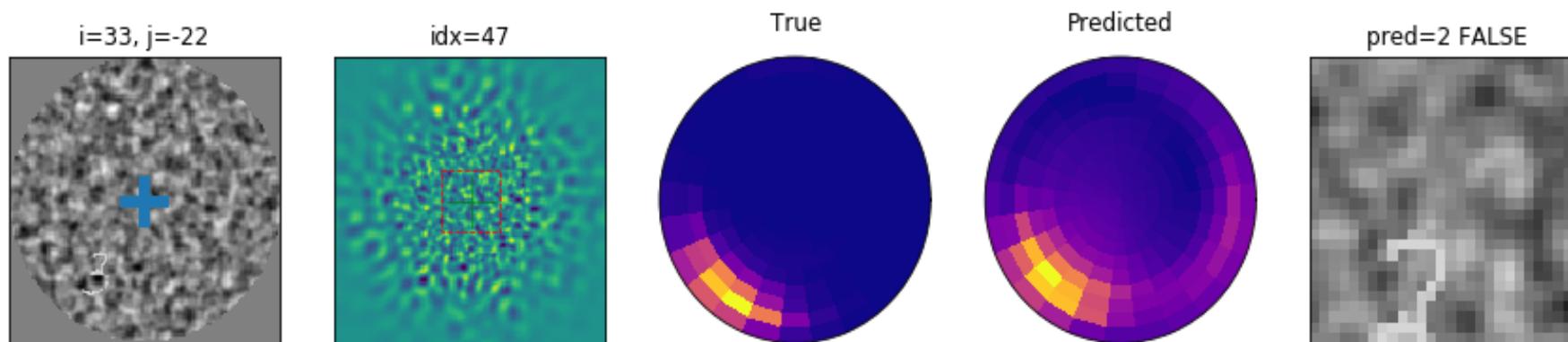
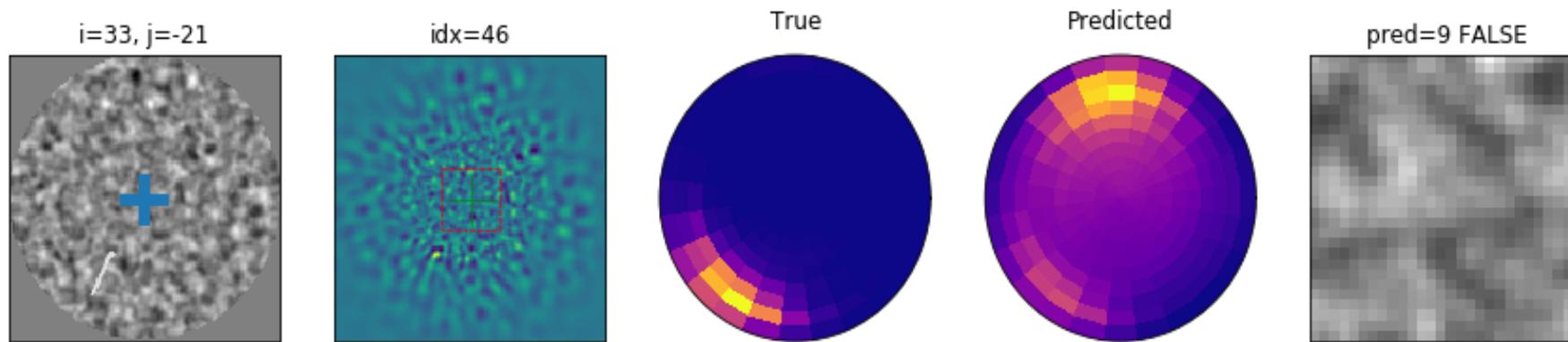
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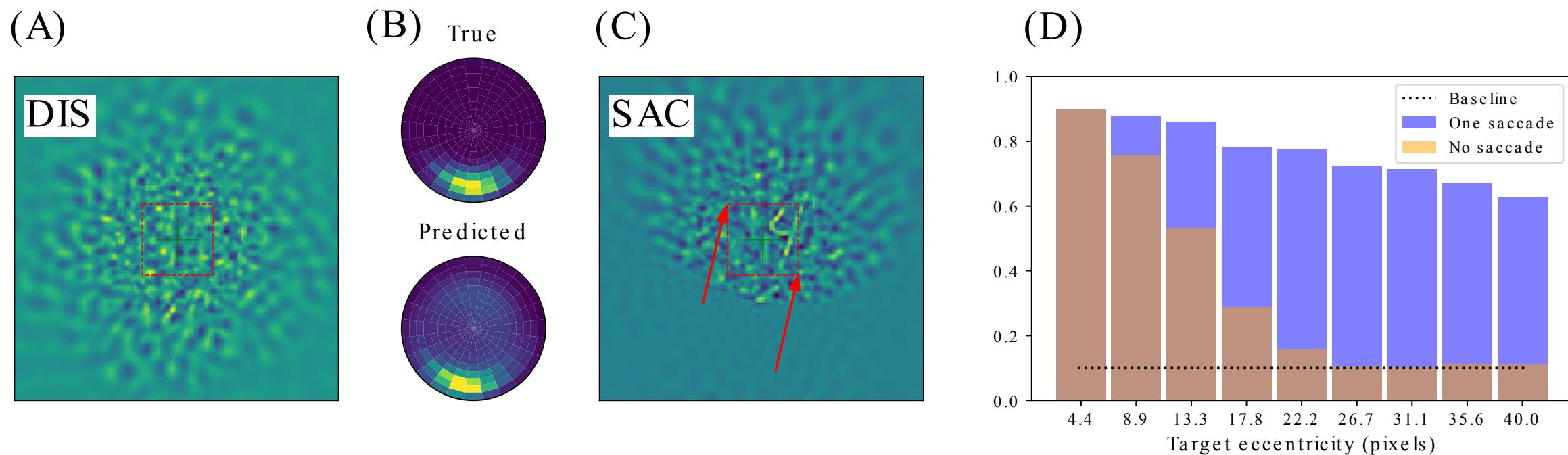
# Results: success



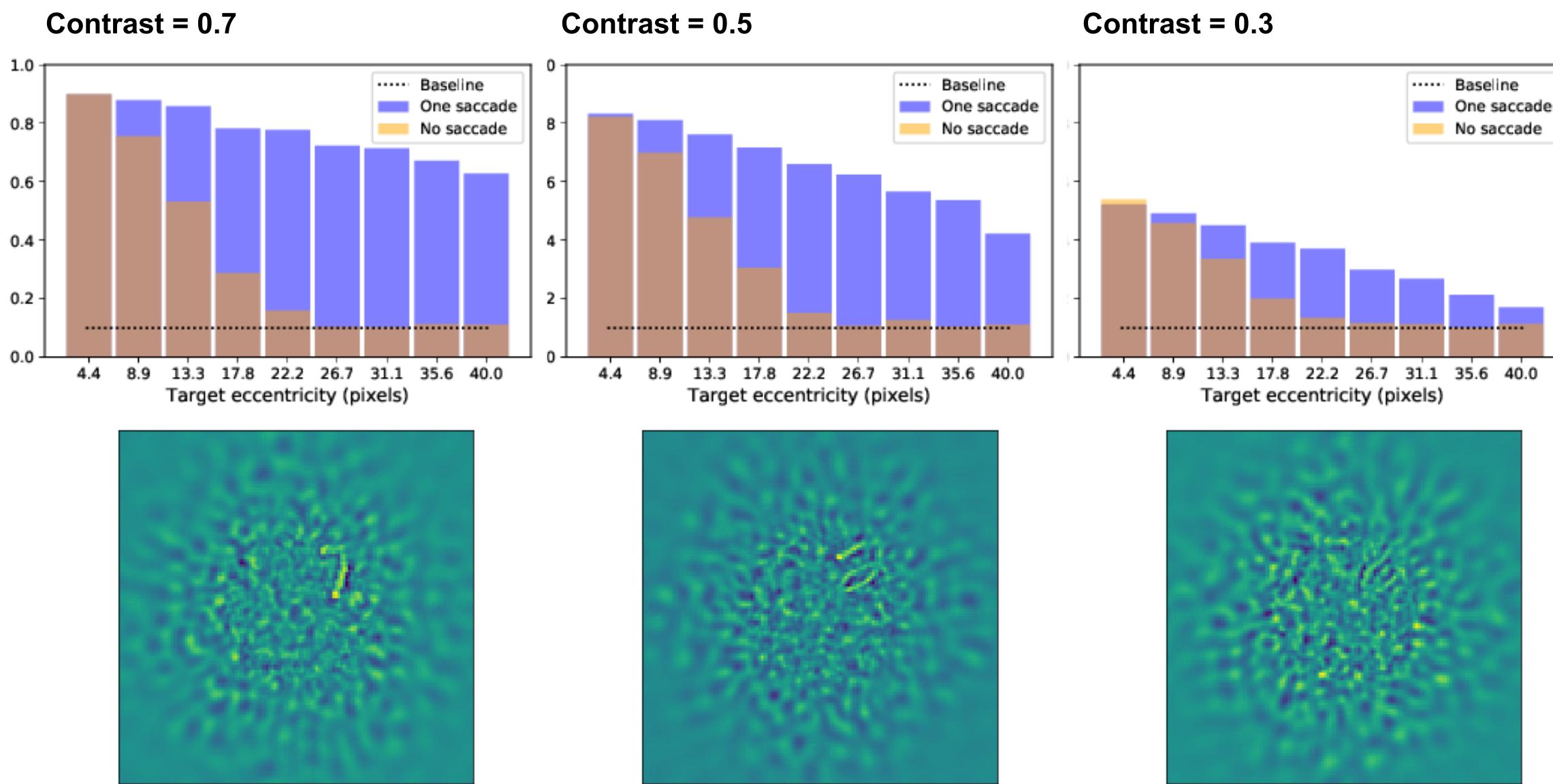
# Results: failure



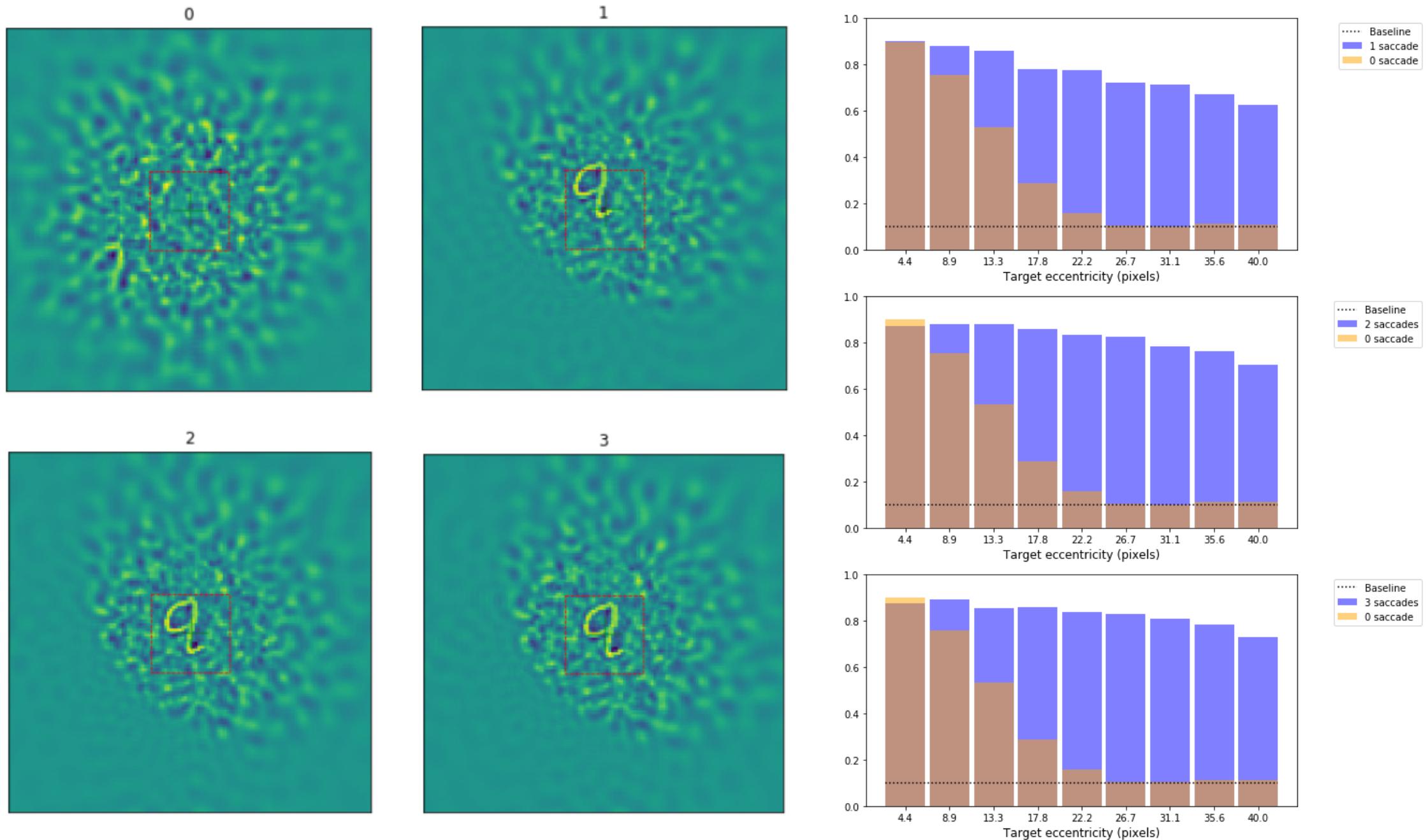
# Results: one saccade



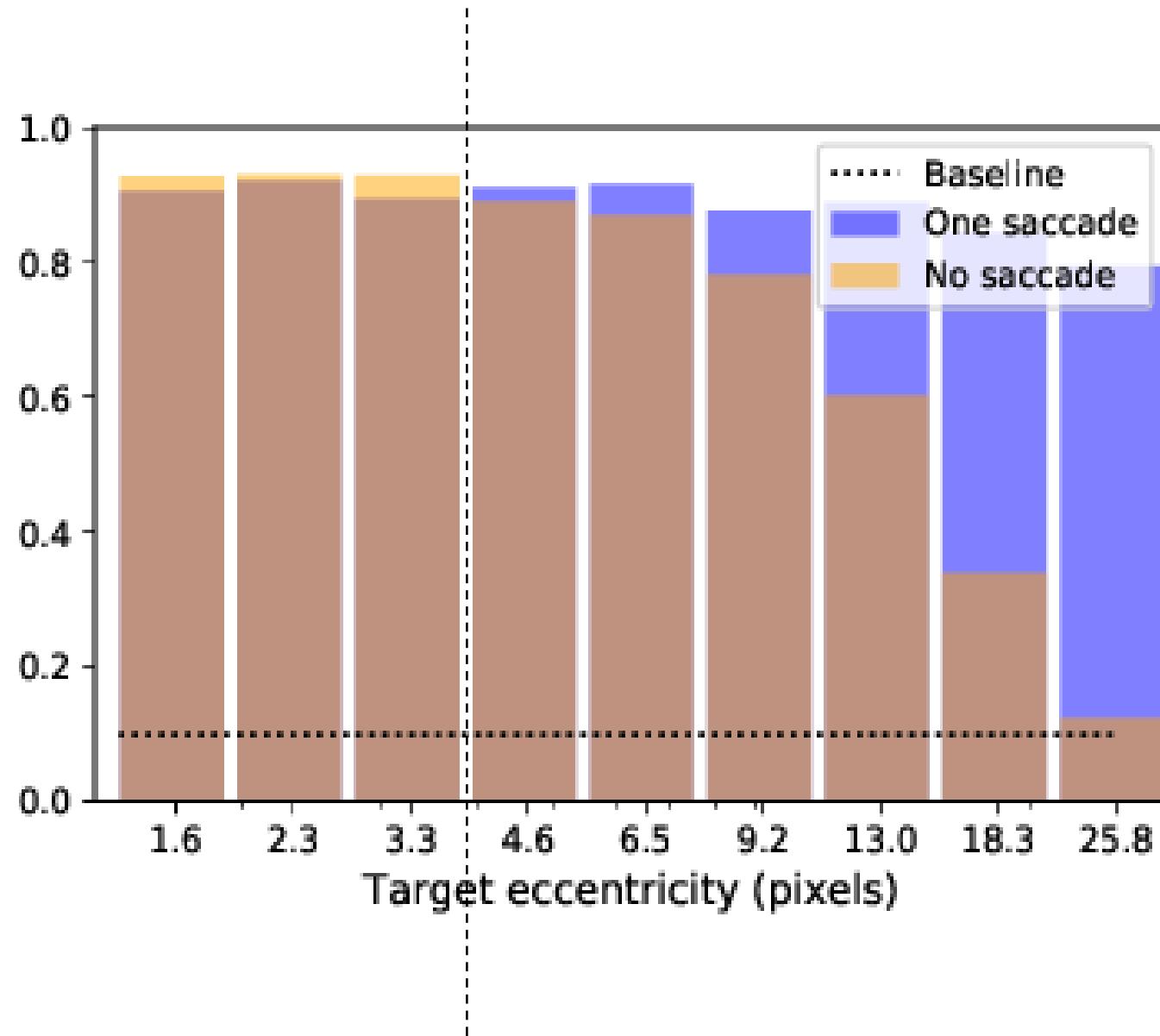
# Results: role of contrast



# Results: more saccades



# IG-based selection of action



DECISION BOUNDARY

$$\log P(\hat{y}|x, u) - \log P(\hat{y})$$

Future Central  
Accuracy  
(after saccade)

Central Accuracy

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# Main results:

- A new interpretation of Information Gain in visuo-motor action selection :
  - Center-surround interpretation
  - An effective decoding scheme with strong bandwidth reduction
  - Information-gain based selection of action (saccade/pursuit)
- A sub-linear object detection for image processing:
  - A full log-polar processing pathway (from early vision toward action selection)
  - Sequential info gain converges to zero: in practice 2-3 saccades are enough
  - Ready for up-scaling
- Object identity-based monitoring of action
  - Dorsal = "actor" (where to look next?)
  - Ventral = "critic" (for what to see?)

# Limits and Open questions

- Importance of centering objects:
  - Central object referential
  - log polar scale/rotation invariance
  - (feedback) prediction
- Information Gain-based décision :
  - Sequential info gain converges to zero: in practice 2-3 saccades are enough
  - Pursuit vs. saccade.
  - Maximizing info gain on multiple targets/ddls.
    - Overt/covert attention
    - Inhibition of return

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<https://laurentperrinet.github.io/talk/2019-07-15-cns>