

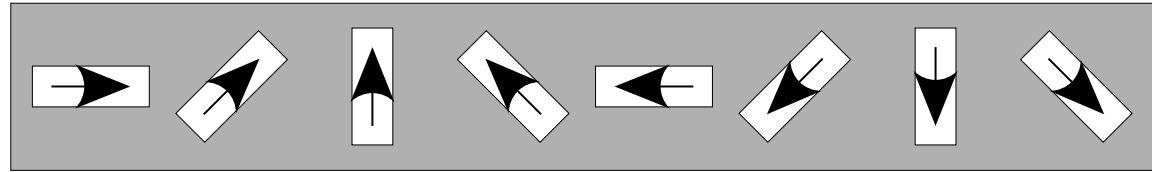
Correlated noise and the retina's population code for direction

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Greg Schwartz
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University of Washington

DS cell responses are noisy

Stimulus



trial 1

Cell-attached
spike rasters

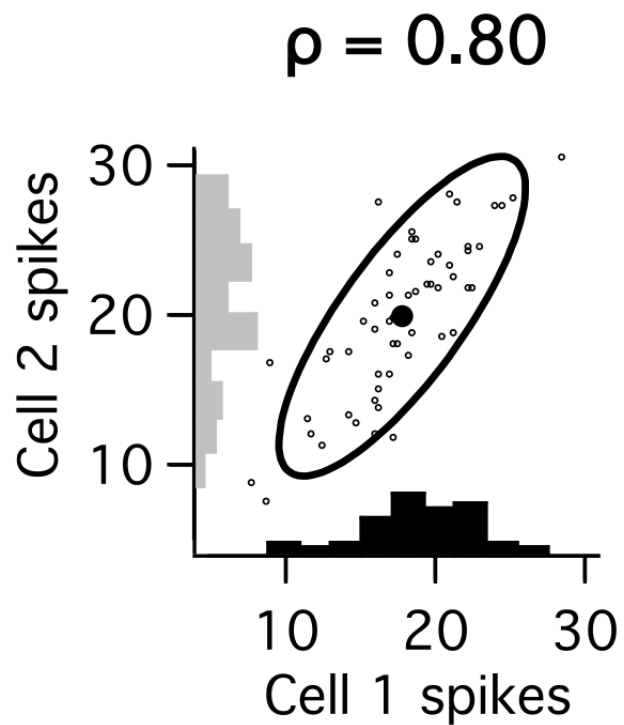
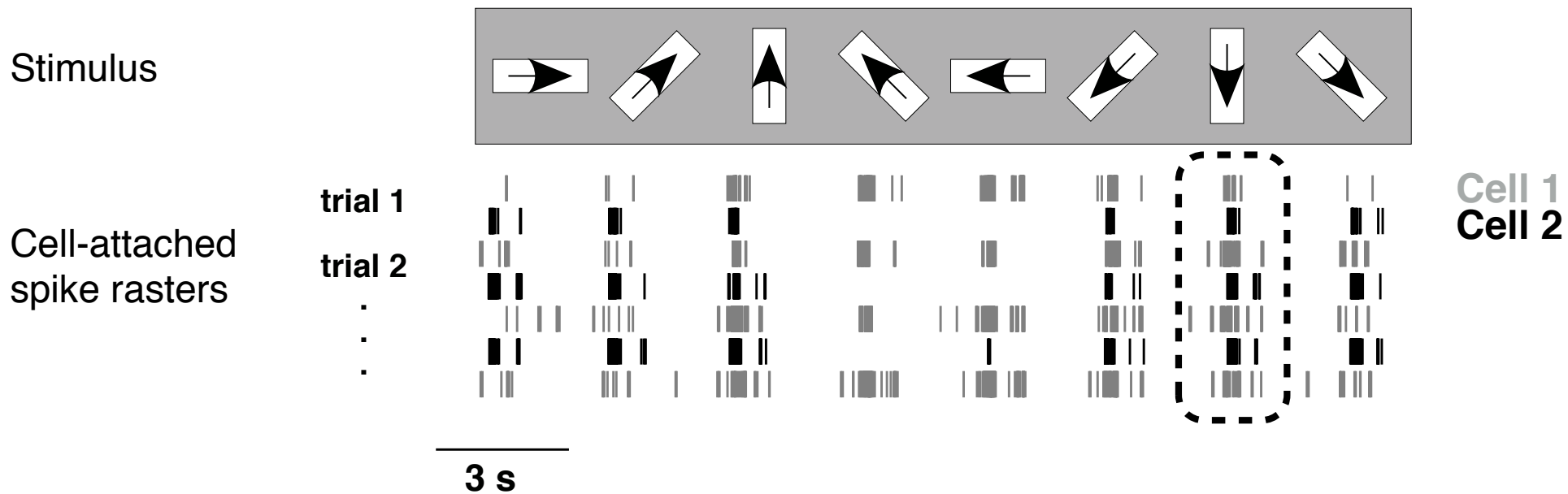
ON-OFF DS cells



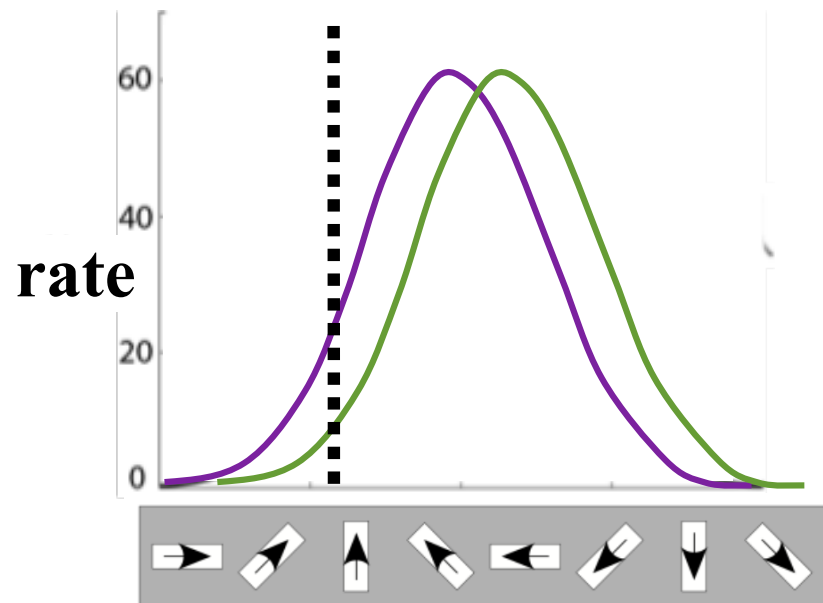
Cell 1

3 s

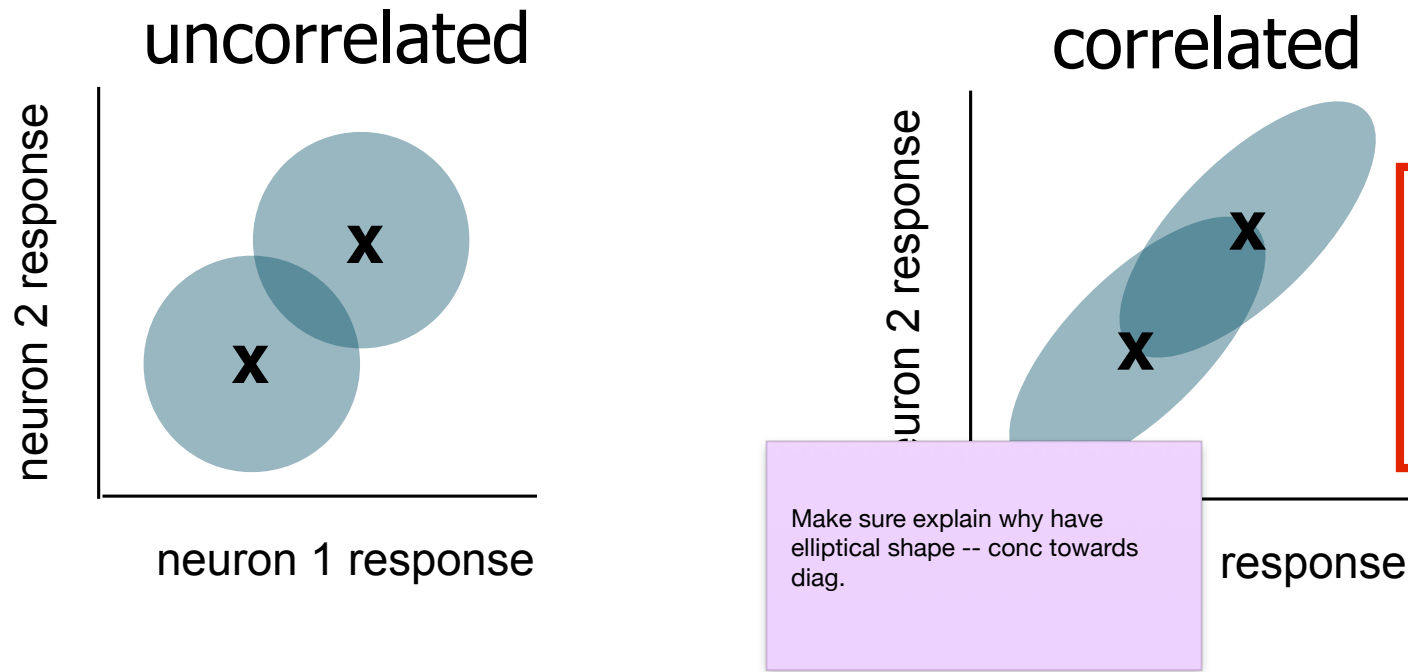
DS cell responses are noisy + noise is correlated from cell to cell



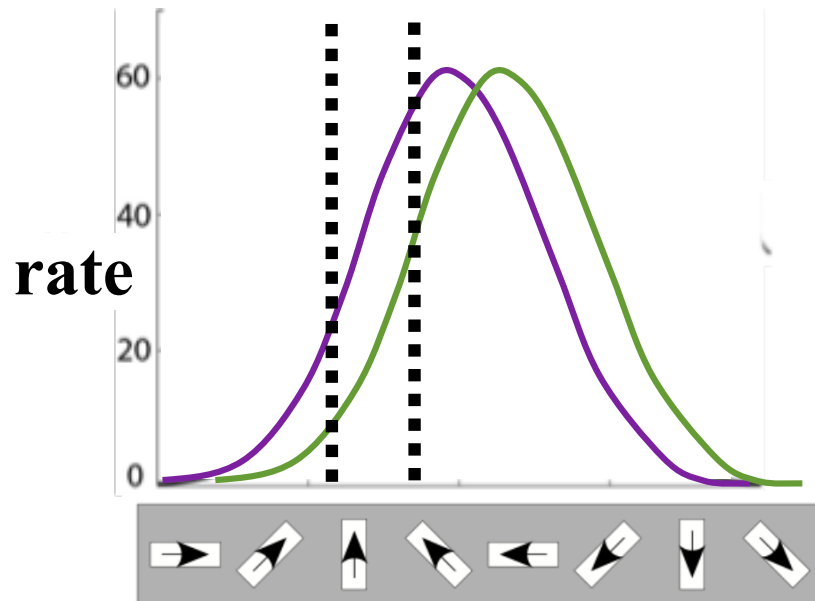
How does correlated noise impact sensory coding?



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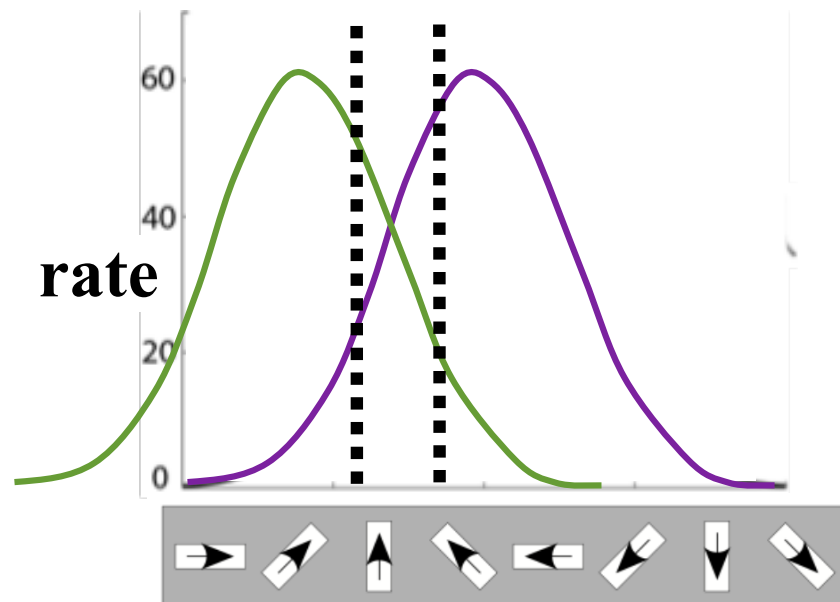
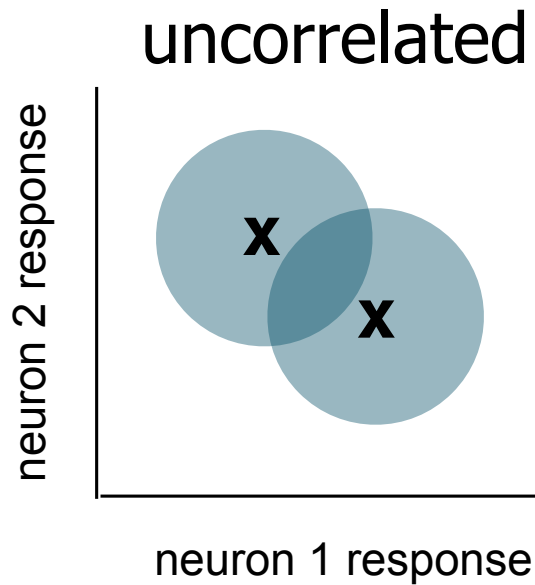


Correlation can **degrade** signal encoding.



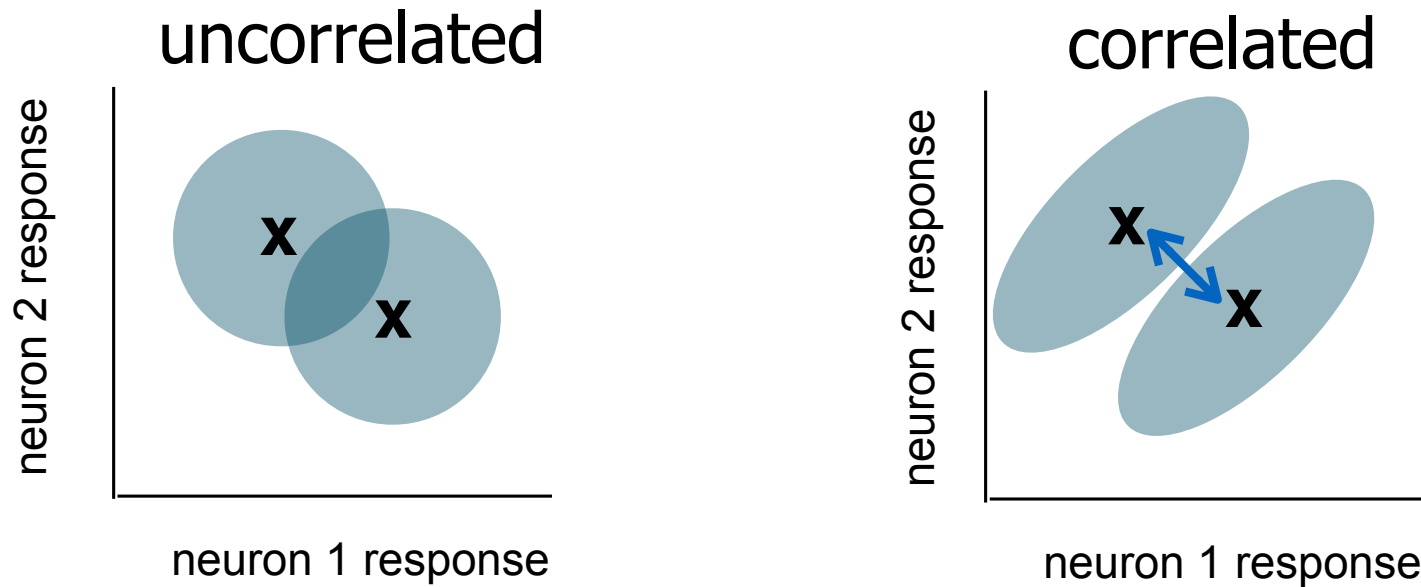
Zohary et al '94
Abbott+Dayan '99
Sompolinsky et al. '01,
Panzeri + Peterson '01,
Averbeck et al., *Nat Rev Nsci* '06

How does correlated noise impact sensory coding?



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How does correlated noise impact sensory coding?



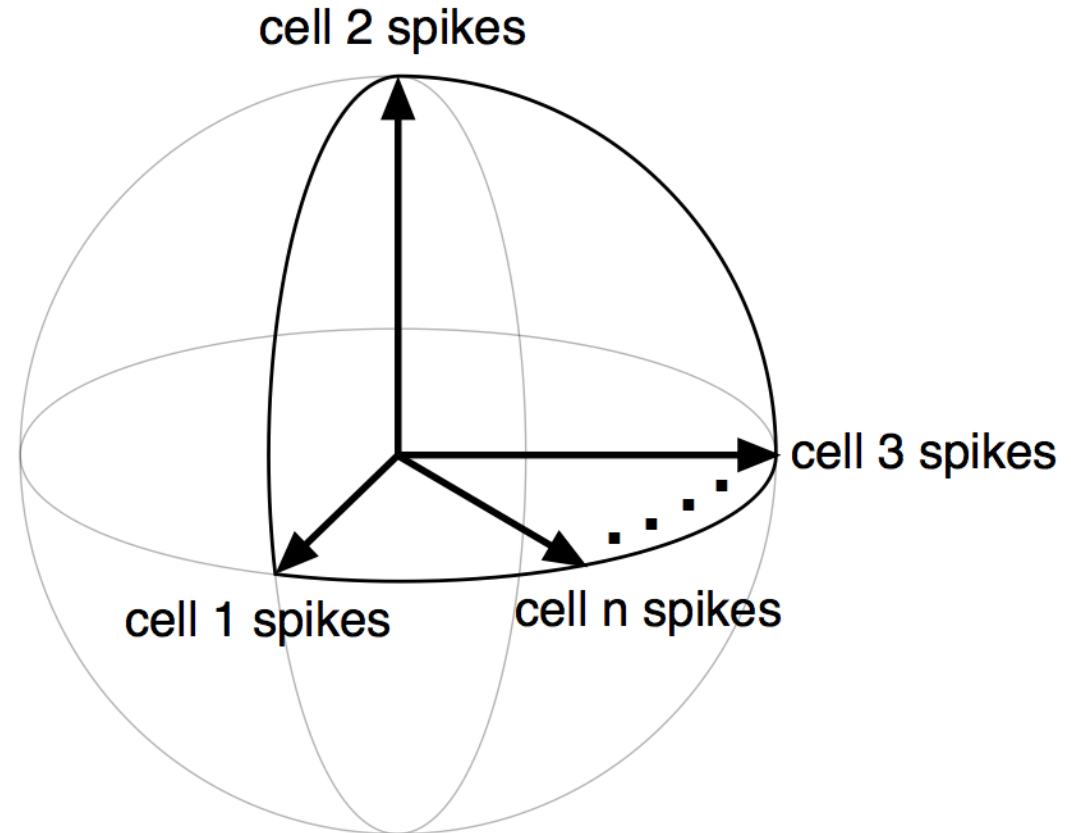
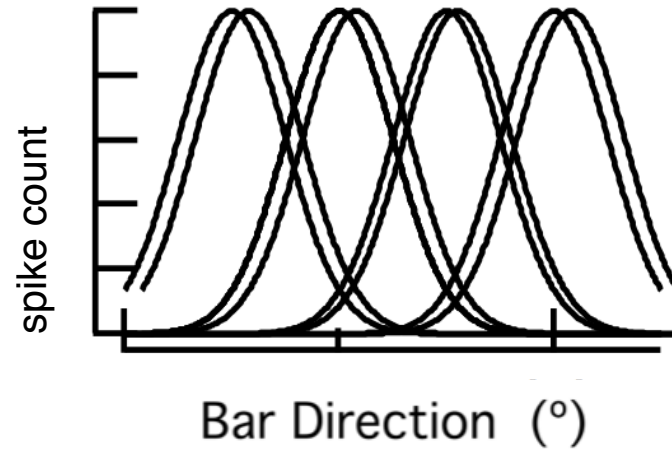
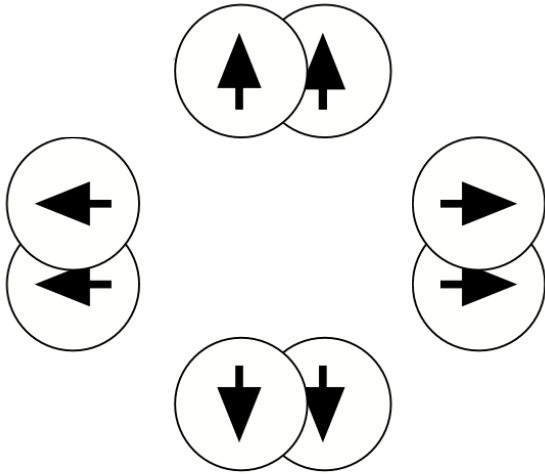
Correlation can **enhance** signal encoding.

Varied effects:
Depends on **signal direction**
vs. **noise direction.**

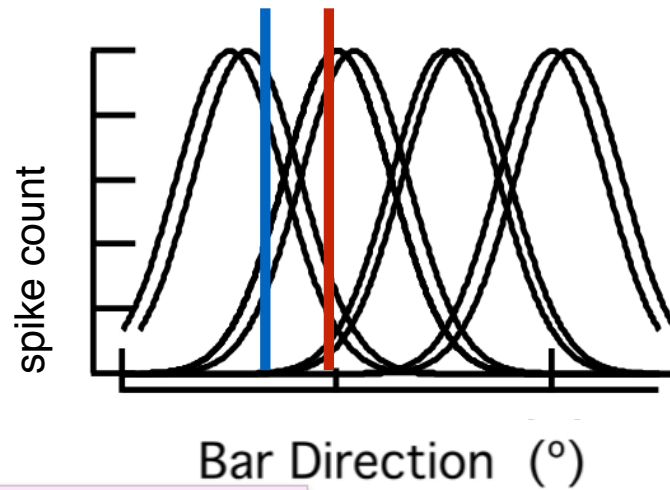
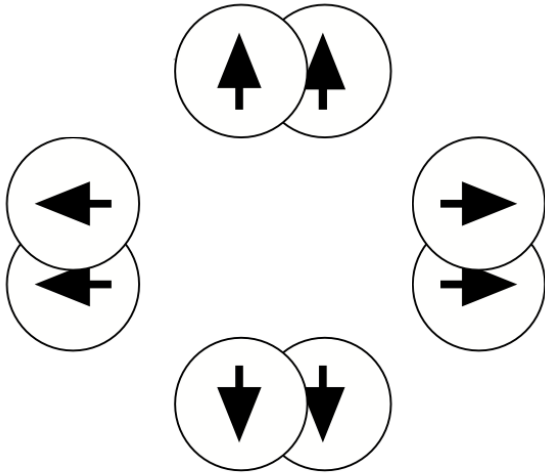
**What happens in DS cell circuit,
and why?**

Zohary et al '94
Abbott+Dayan '99
Sompolinsky et al. '01,
Panzeri + Peterson '01,
Averbeck et al., *Nat Rev Nsci* '06
Shamir et al '06
Josic et al '09
Ecker et al '11
da Silveira and Berry, '13
Hu et al '14

Population view of DS cell responses - (idealized!)

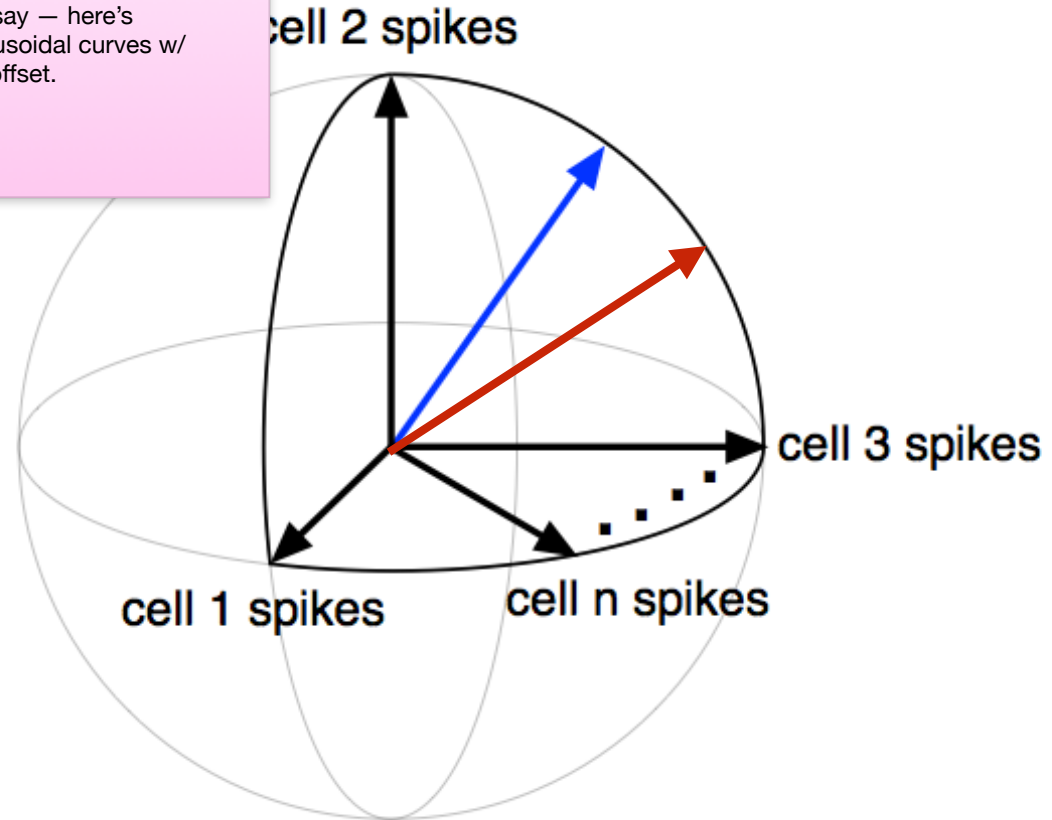


Population view of DS cell responses - (idealized!)

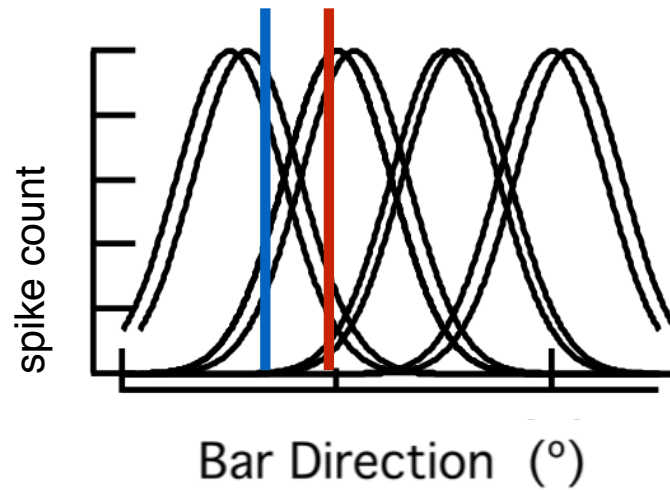
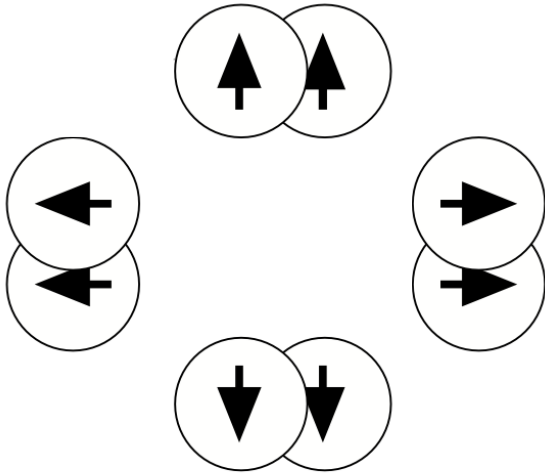


Wait to explain idealization until show red arrow. Then, say — here's idealization ... sinusoidal curves w/ same amplitude, offset.

Signal direction: tangent to
Noise direction:



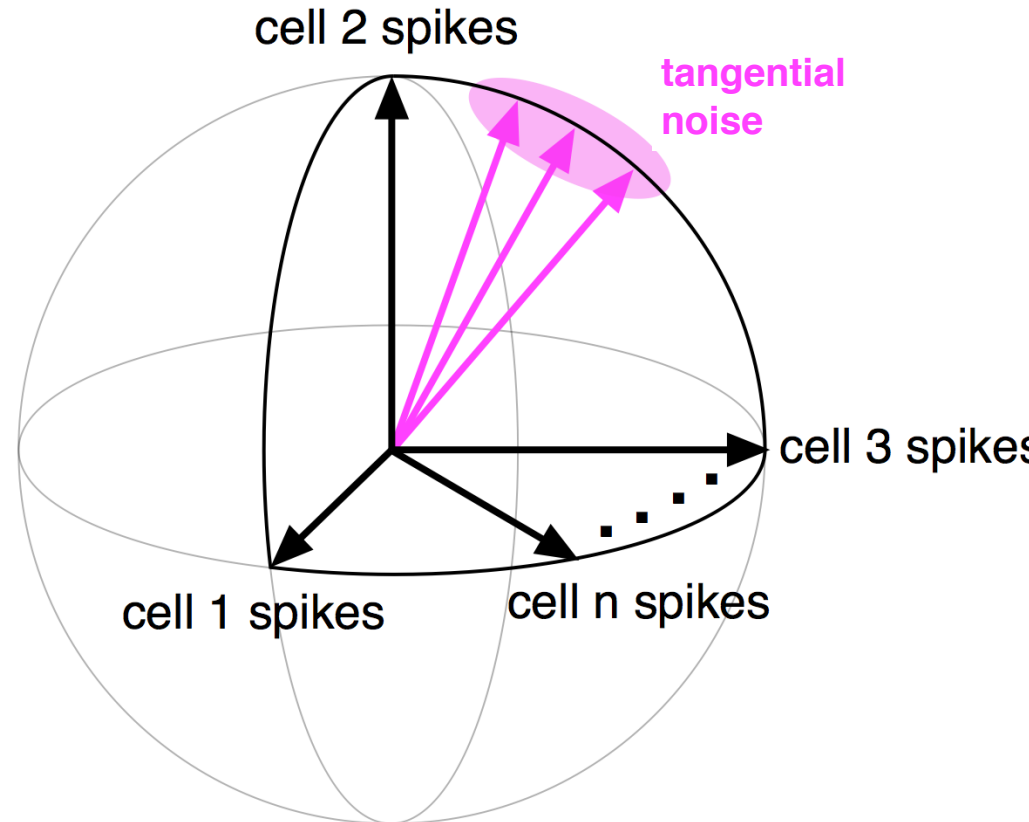
Population view of DS cell responses - (idealized!)



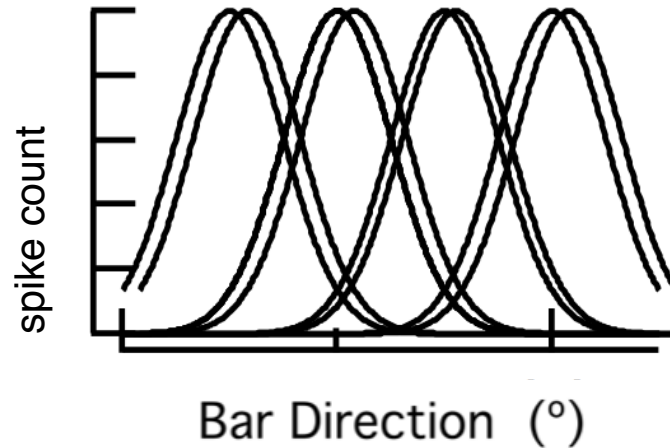
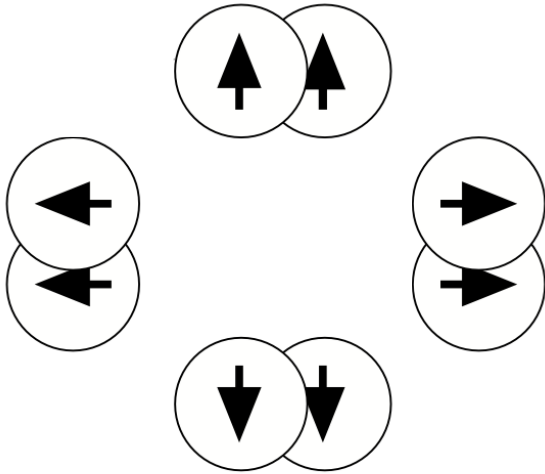
Signal direction: tangent to sphere

Noise direction:

tangential degrades coding



Population view of DS cell responses - (idealized!)



Signal direction: tangent to

Noise direction:

tangential degrades c

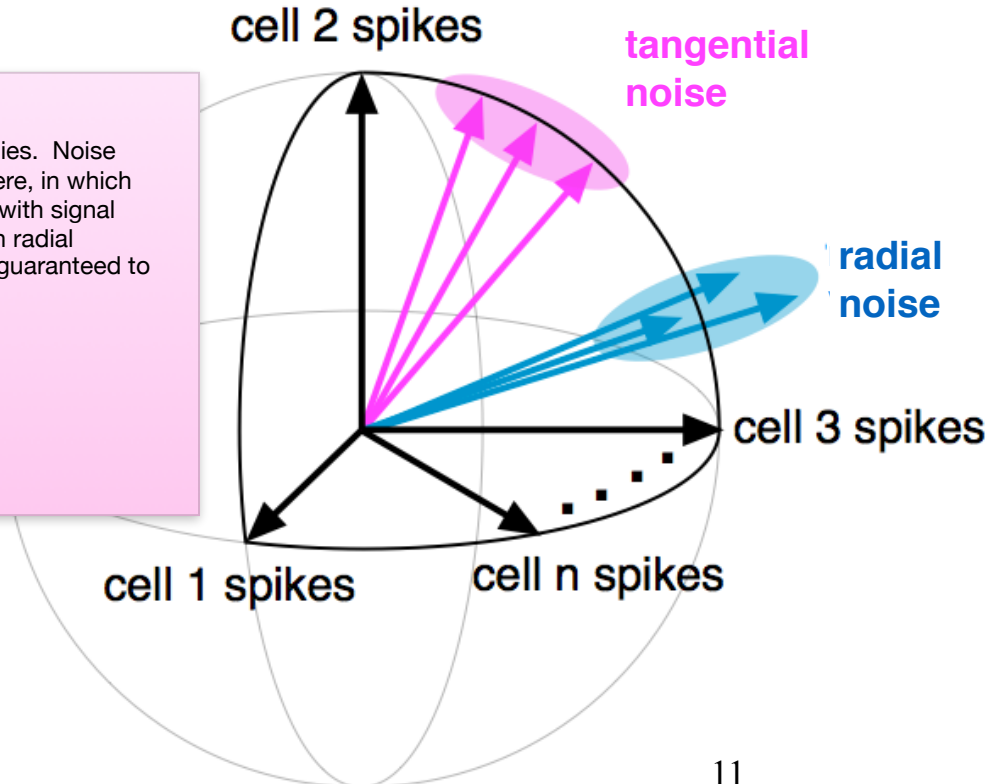
radial enhances codir

Which case occurs?

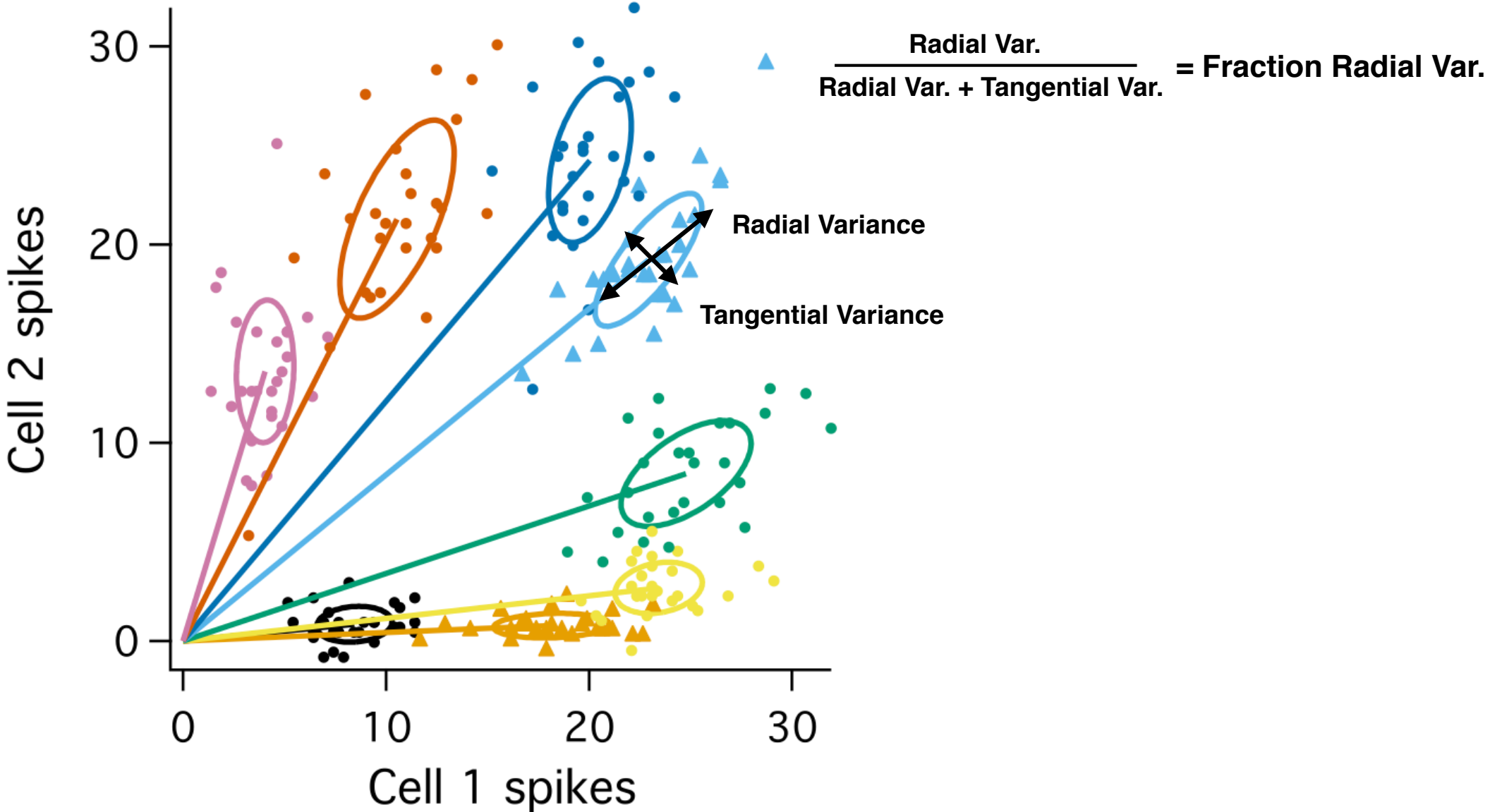
Measure from cell pairs

Model cell population

SAY ... are two possibilities. Noise could be tangent to sphere, in which case it COULD interfere with signal direction. Or, could be in radial direction, in which case guaranteed to be out of way.



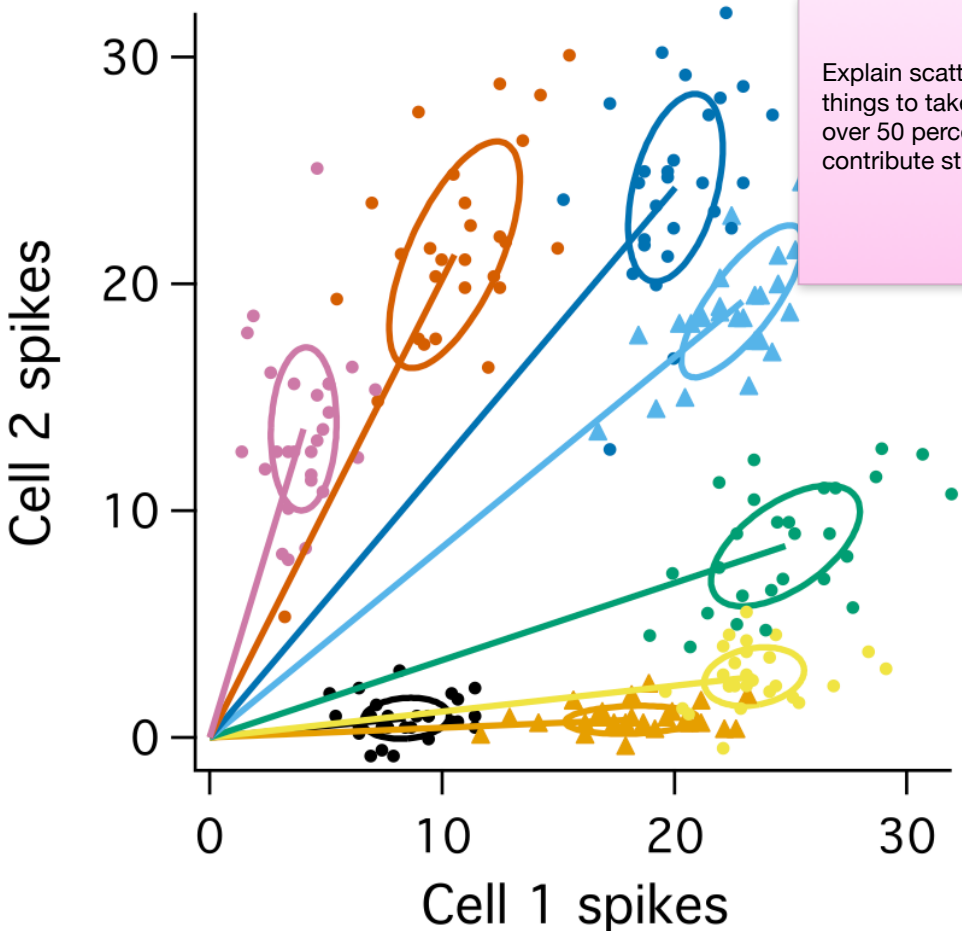
Response noise in DS cell pairs



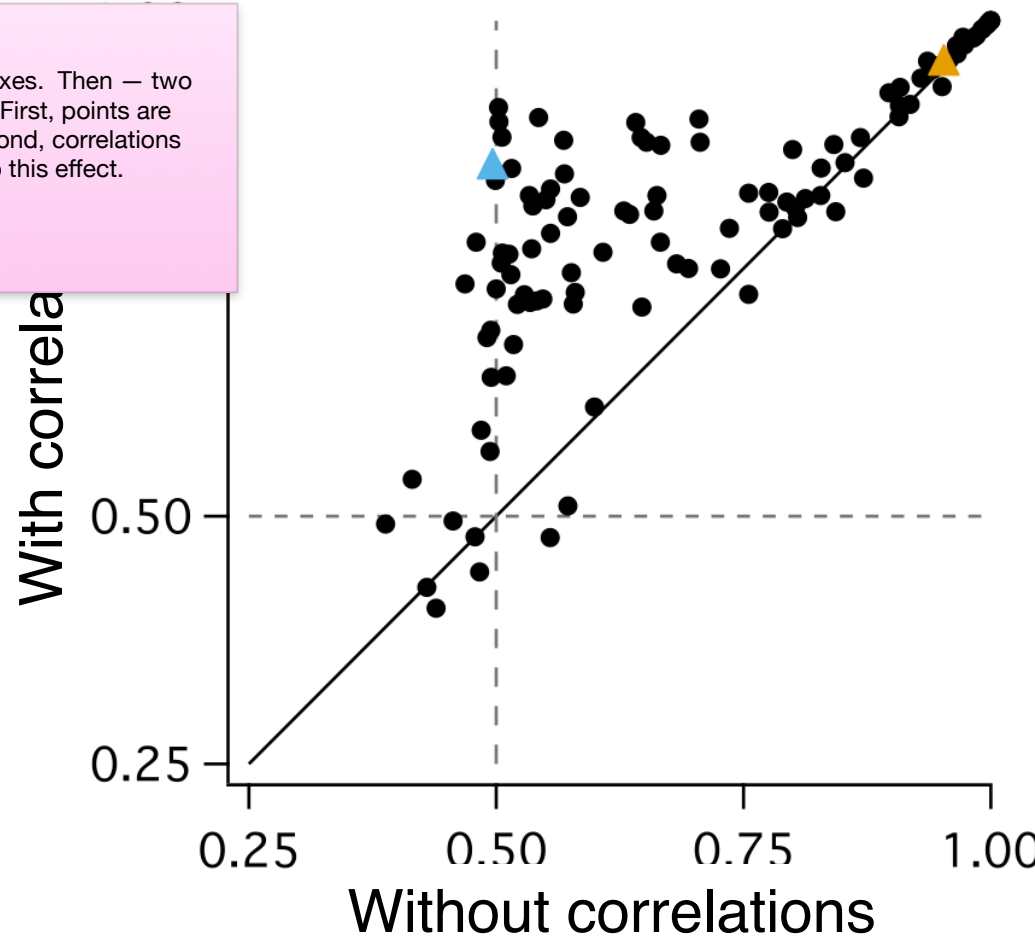
Response noise in DS cell pairs ... is largely radial.

What are the underlying circuit mechanisms?

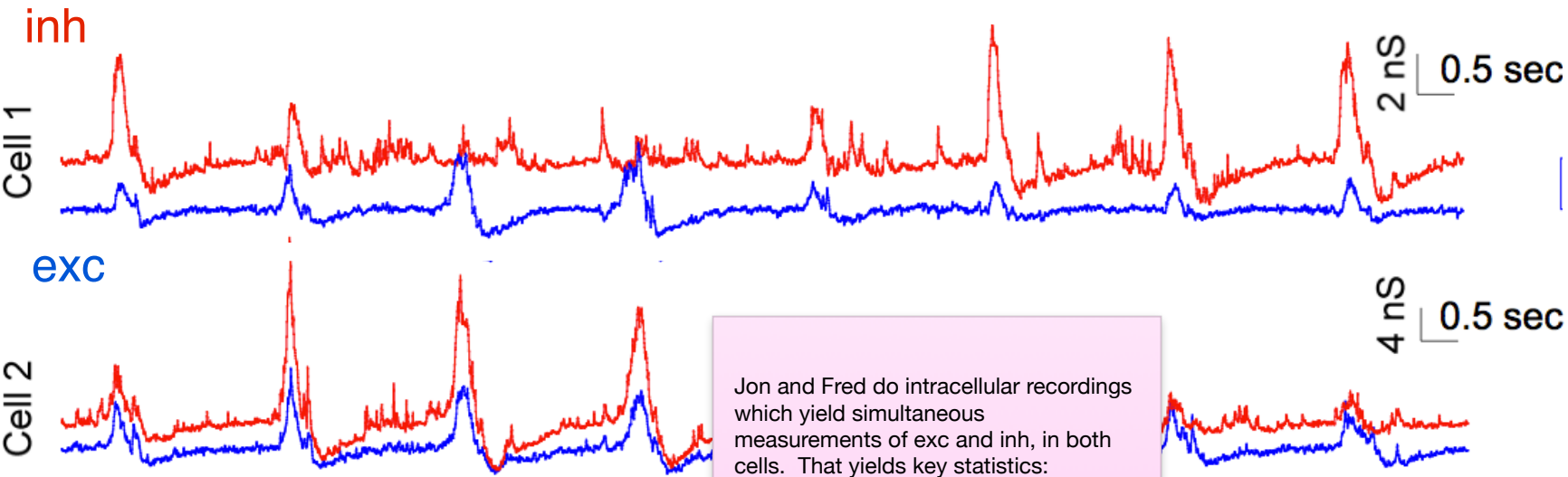
$$\frac{\text{Radial Var.}}{\text{Radial Var.} + \text{Tangential Var.}} = \text{Fraction Radial Var.}$$



Explain scatter plot axes. Then — two things to take away. First, points are over 50 percent. Second, correlations contribute strongly to this effect.

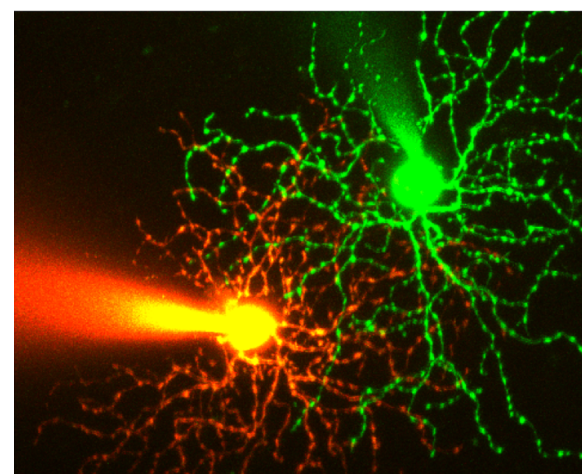


Paired alternating voltage clamp experiments: conductance correlations

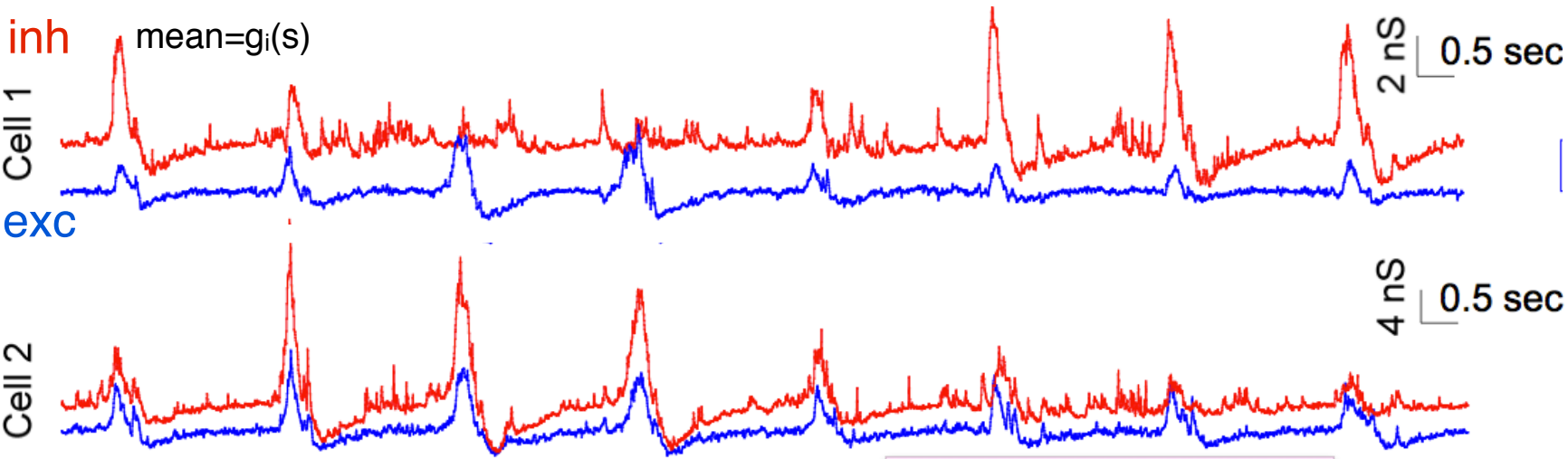


Jon and Fred do intracellular recordings which yield simultaneous measurements of exc and inh, in both cells. That yields key statistics: covariance among all possible conductances within and between cells, and how these depend on stim. This leads to following model

cf. Cafaro and Rieke '11

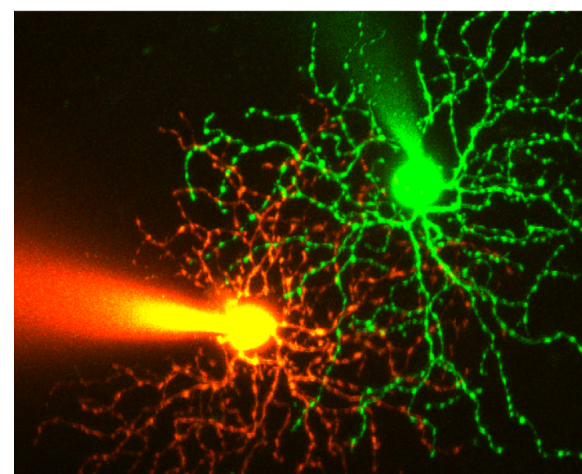
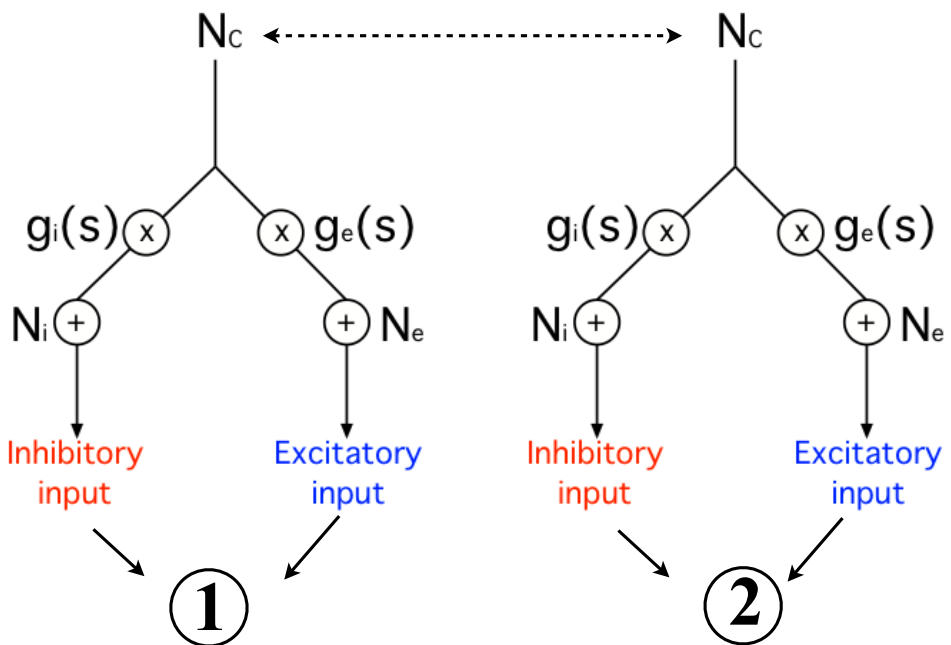


Paired alternating voltage clamp experiments: conductance correlations

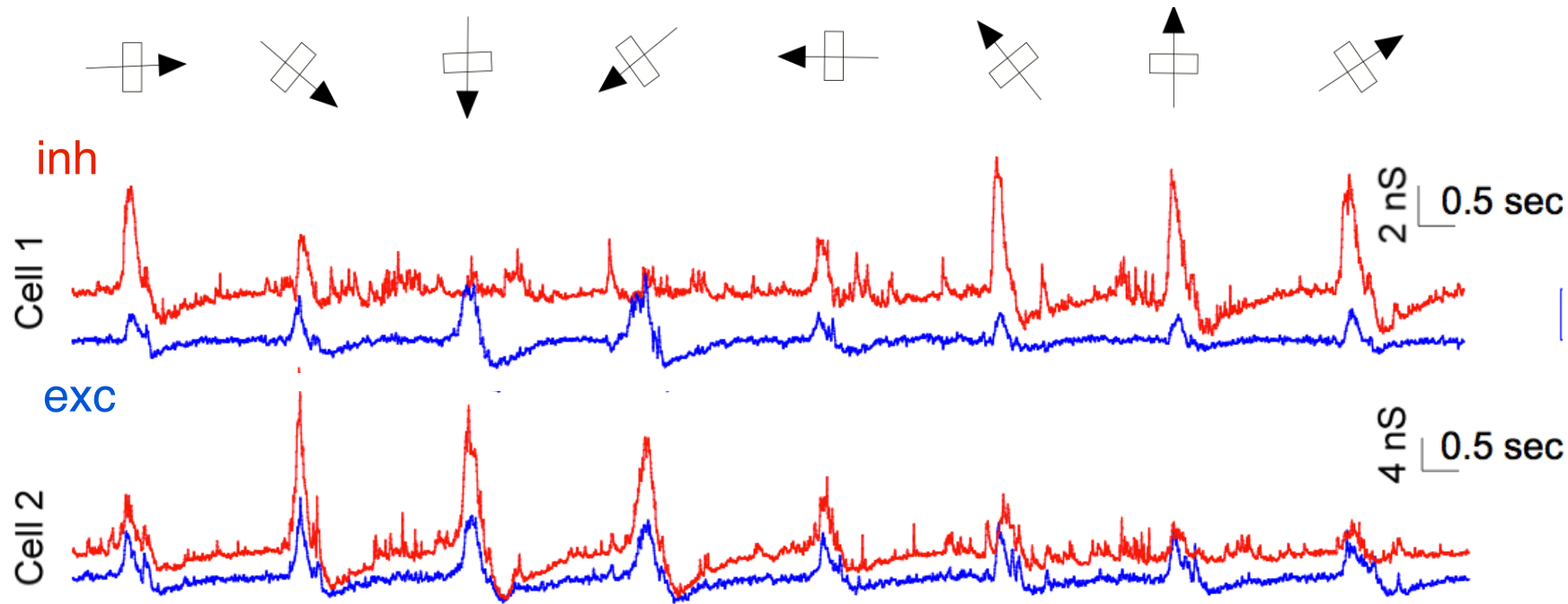


Conductance correlations and input model

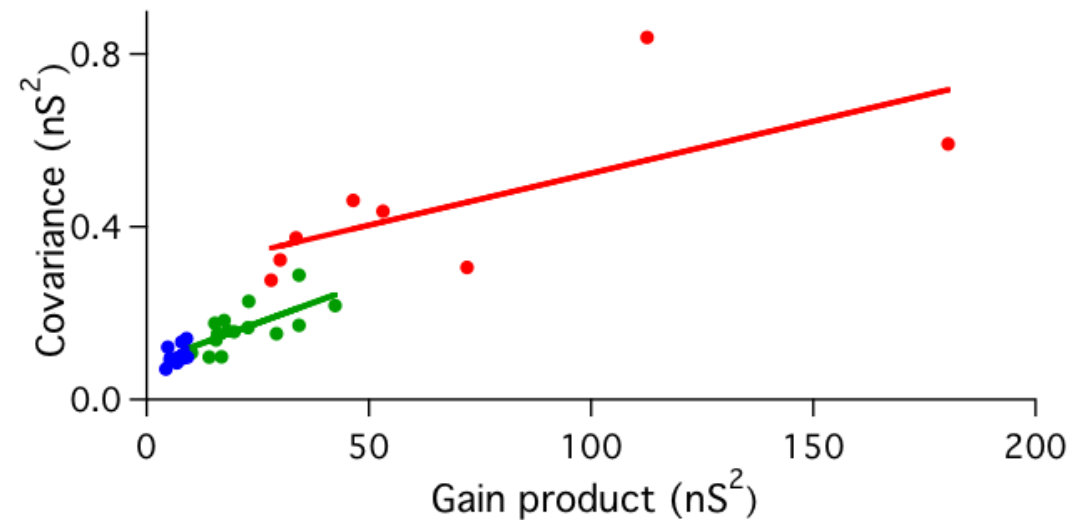
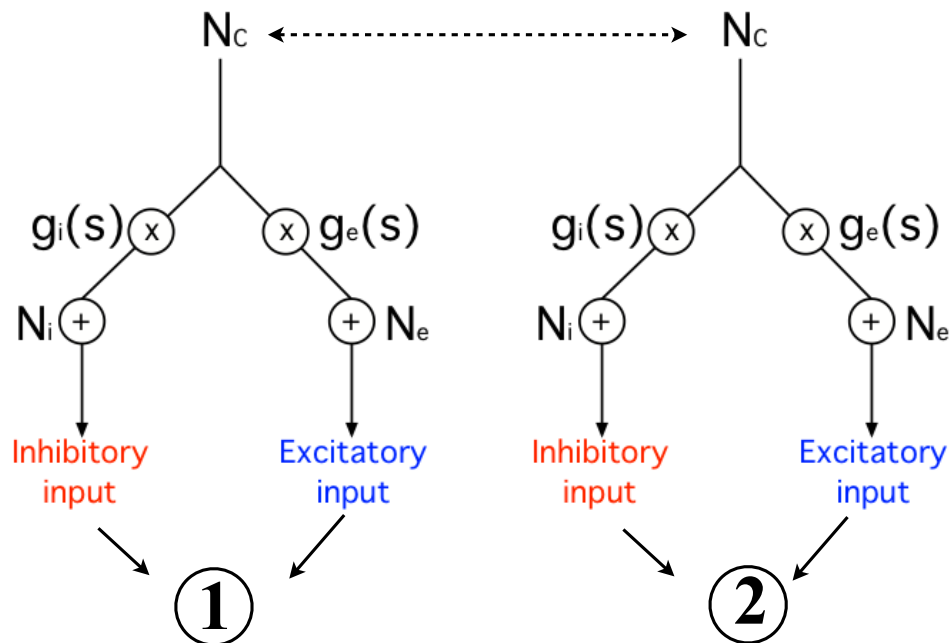
Common noise source diverges to enter exc and inh pathways for each cell. Along way, multiplied by stim-dependent gain. And, that gain is set by the mean response (as for exp nonlin).



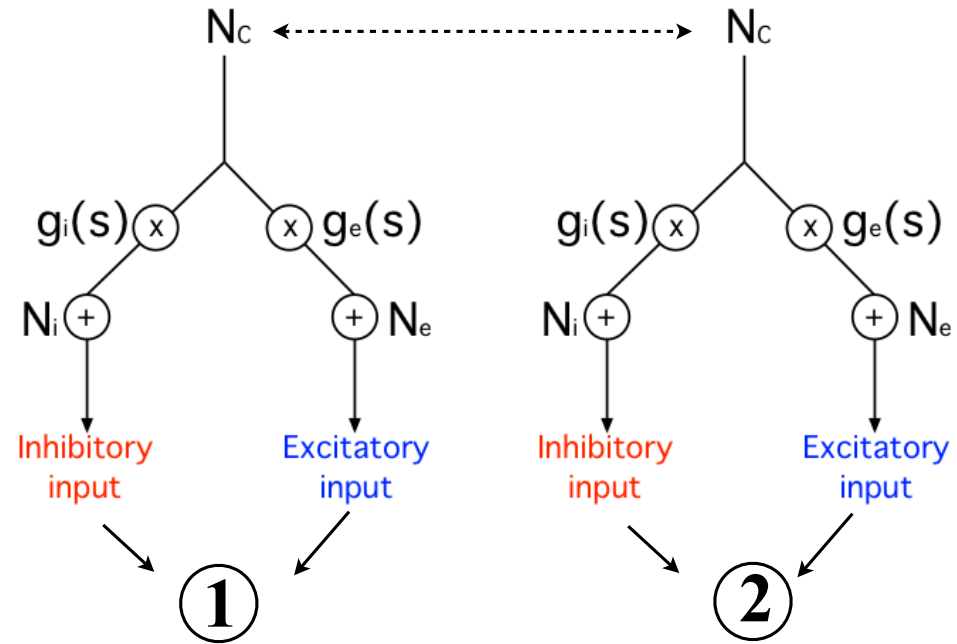
Paired alternating voltage clamp experiments: conductance correlations



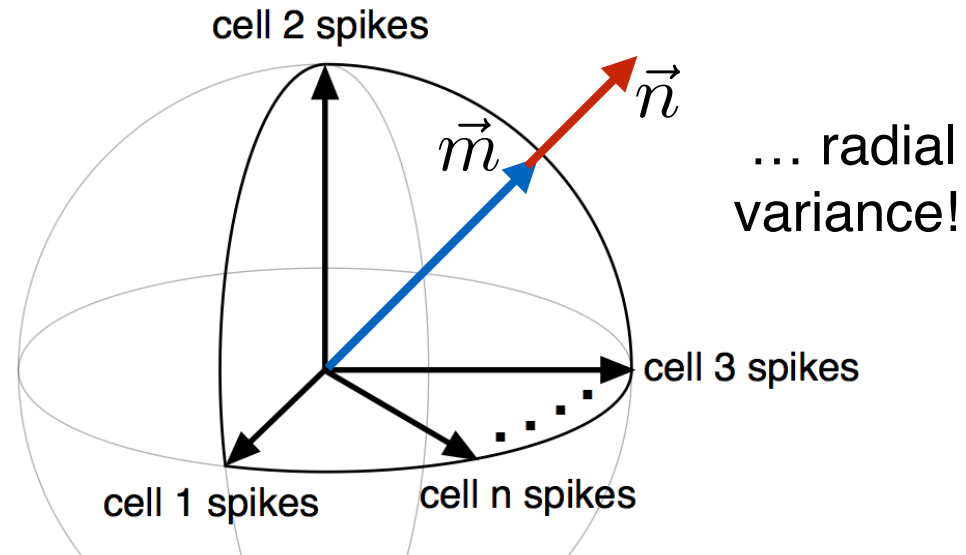
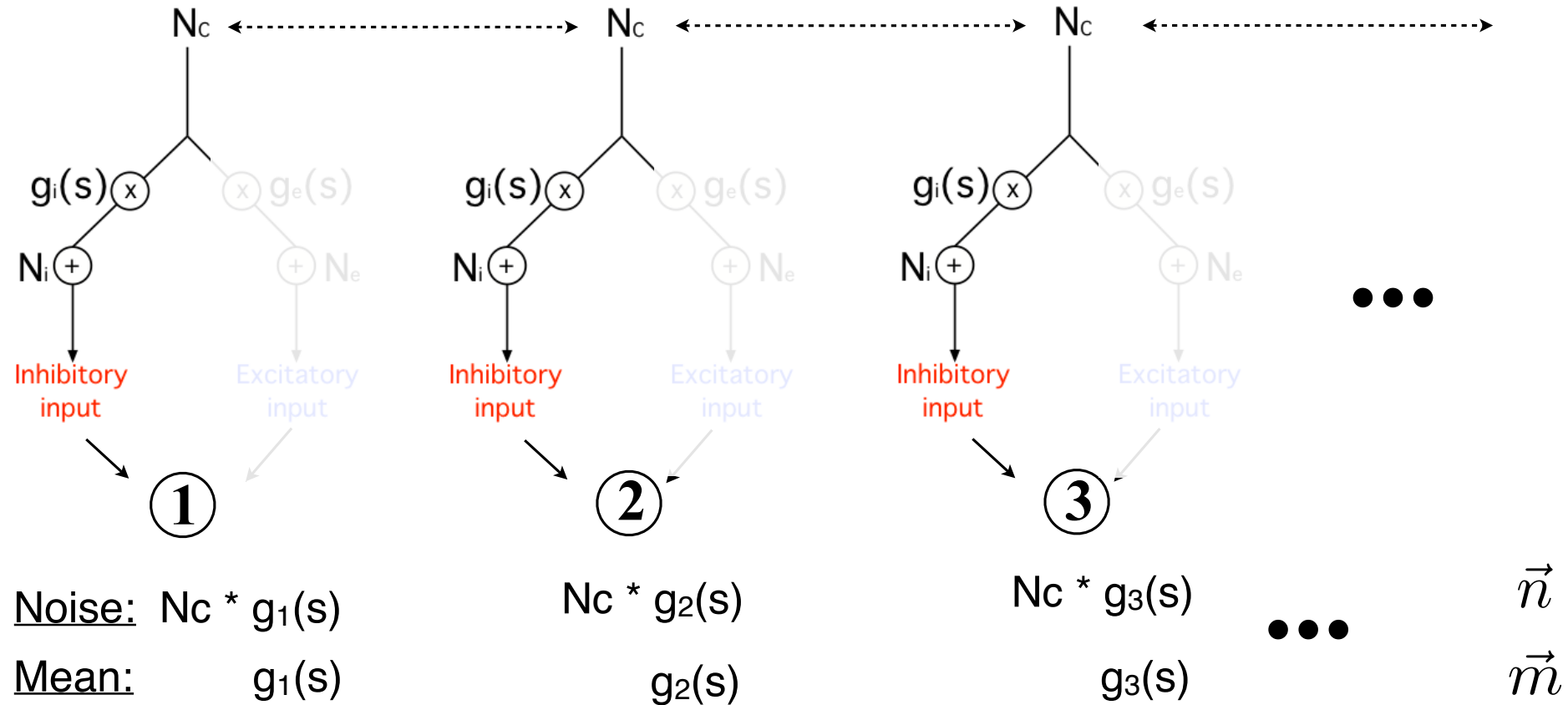
Conductance correlations suggest common input model



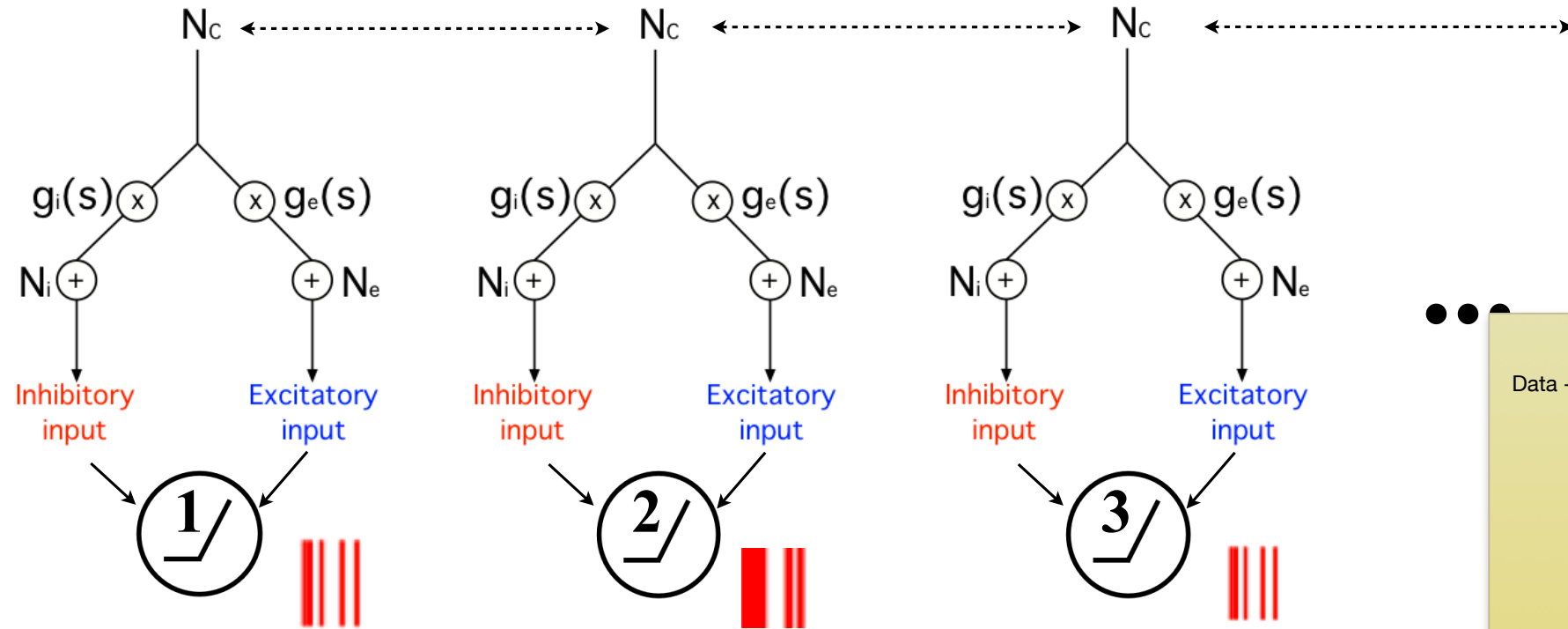
Common input model produces radial variance



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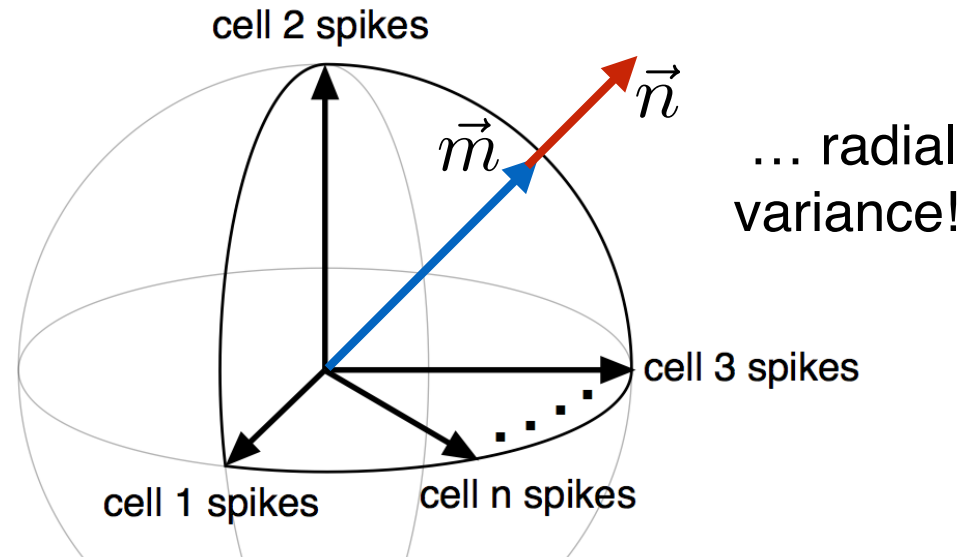
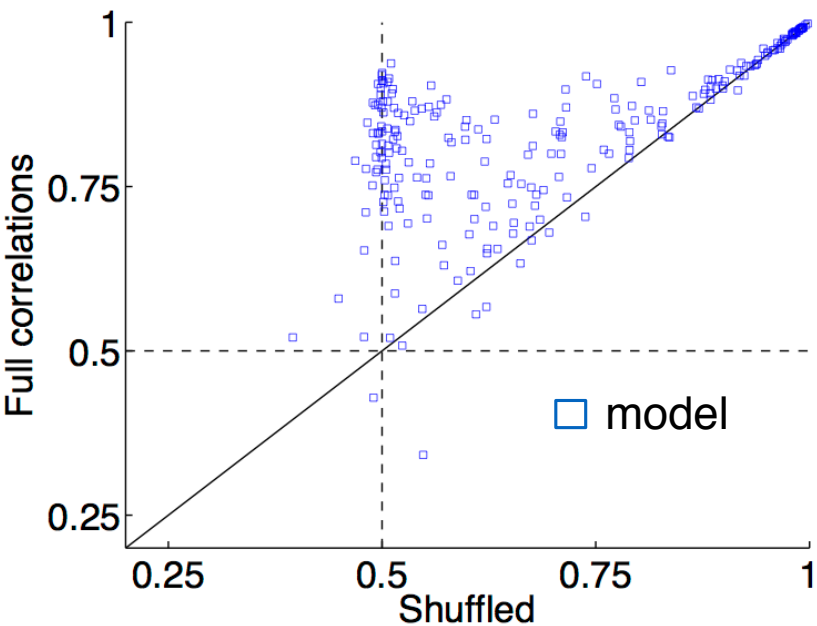


Common input model produces radial variance

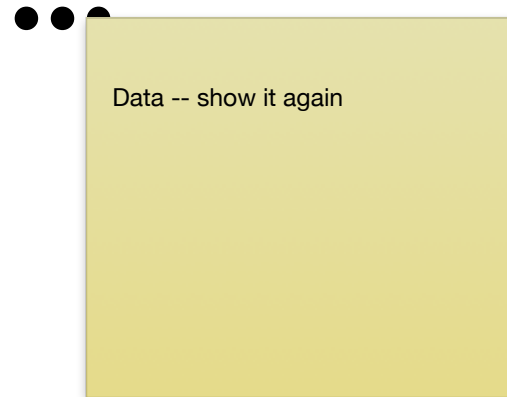
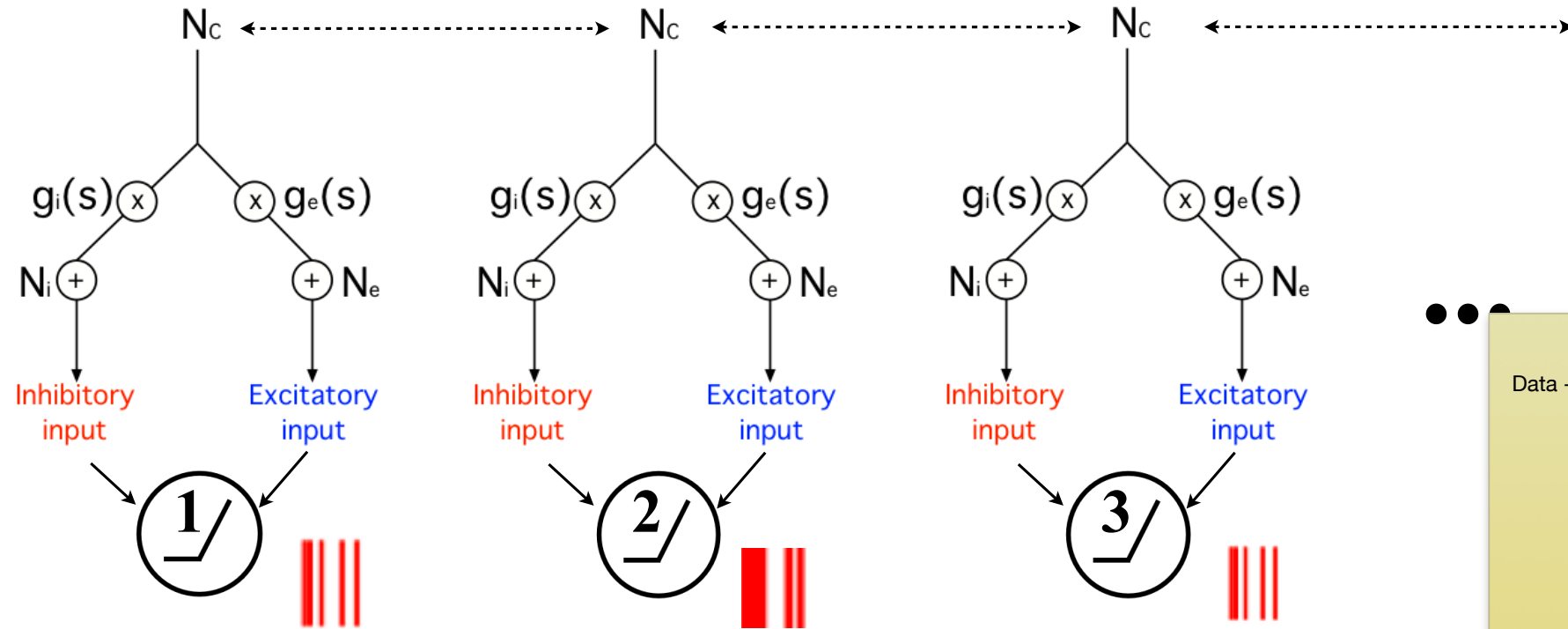


Spike outputs preserve radial variance

Fraction radial variance

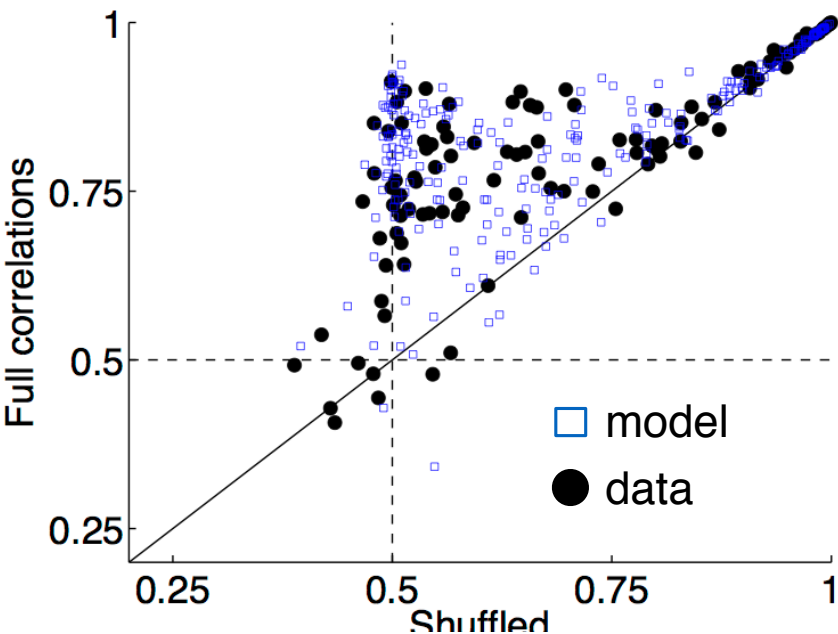


Common input model produces radial variance

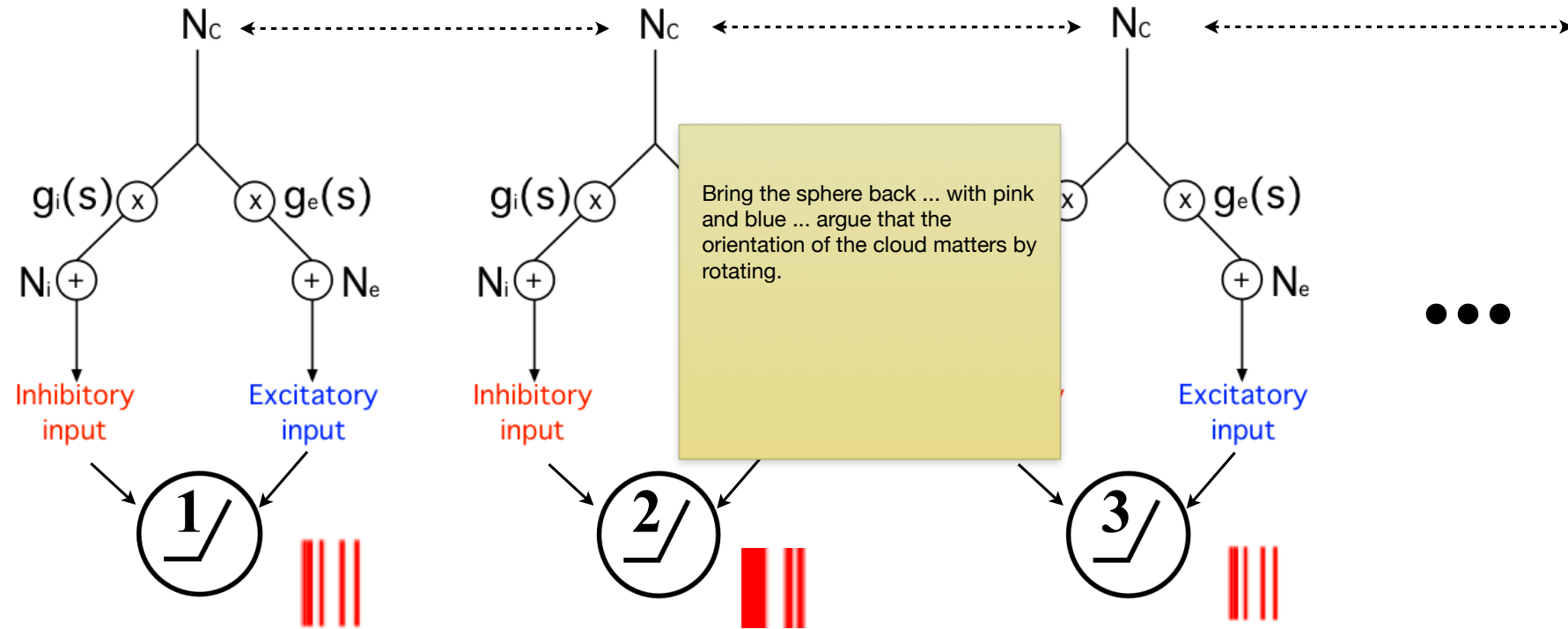


Spike outputs preserve radial variance

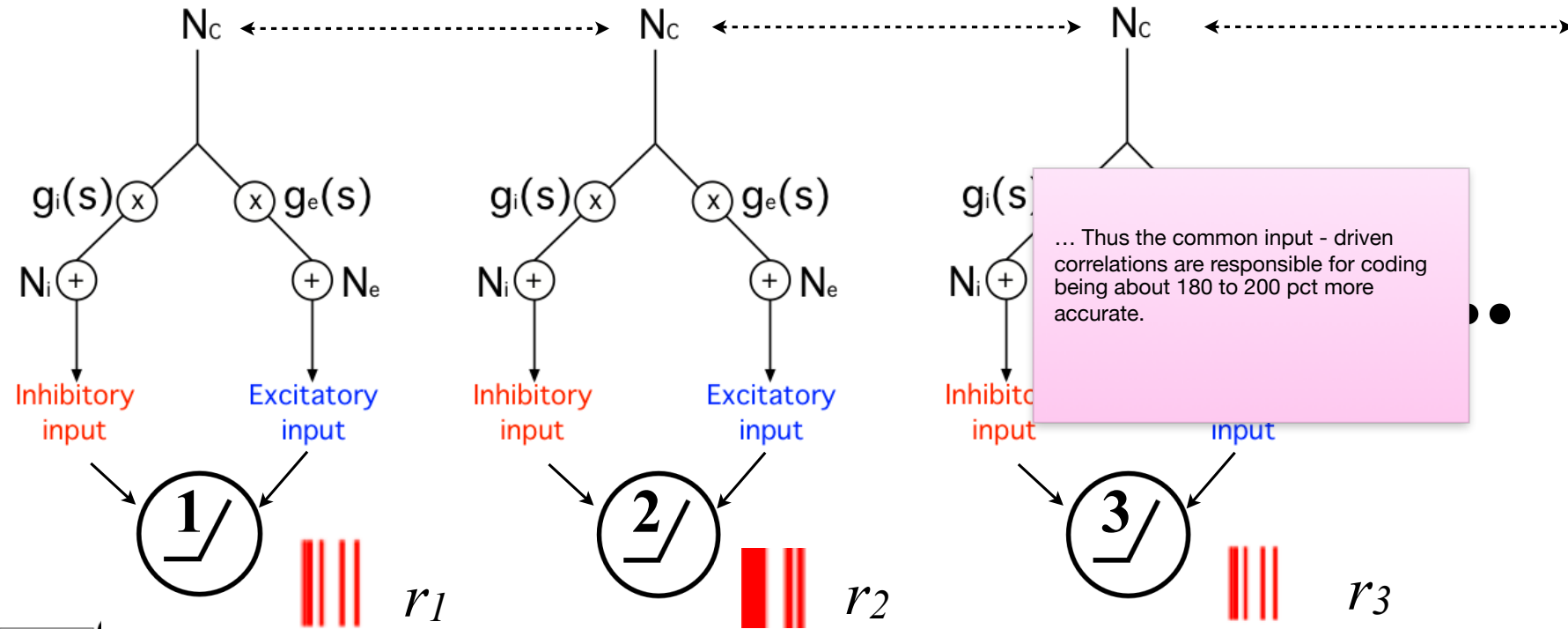
Fraction radial variance



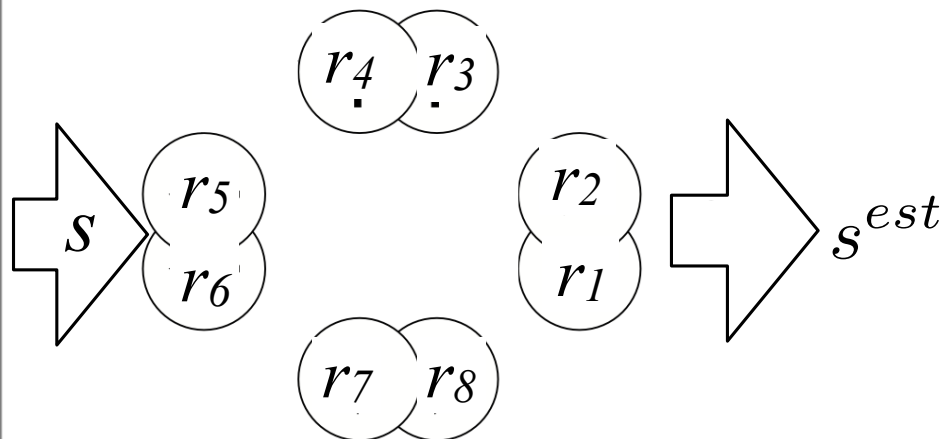
Common input model produces radial variance...



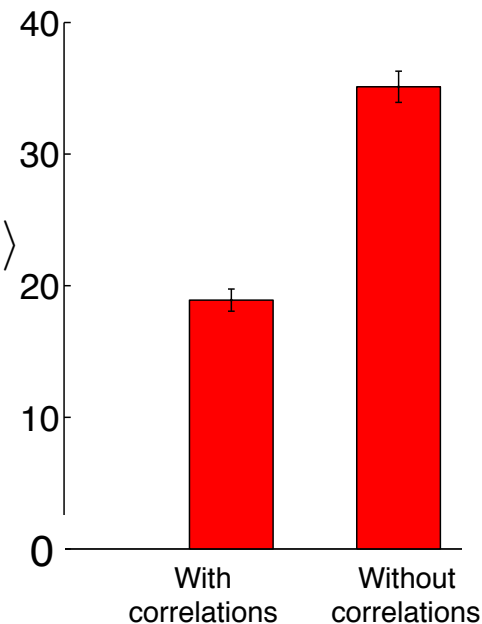
Common input model produces radial variance...



... that ~doubles coding precision



$$\text{Coding error } \langle (s - s^{est})^2 \rangle \text{ (deg}^2\text{)}$$

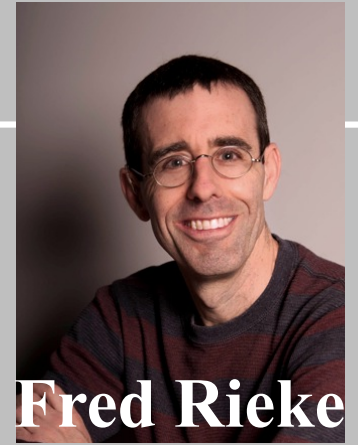


Caveat: enough heterogeneity?

Summary

- **ON-OFF direction selective RGCs give noisy, correlated spike responses**
- **Intracellular recordings suggest a *common input* circuit model**
- **This circuit model**
 - **orients noise in *radial* direction**
 - **separates noise from signal, improving coding accuracy**

Thank you...



Fred Rieke

BURROUGHS-WELLCOME FUND

SIMONS FOUNDATION

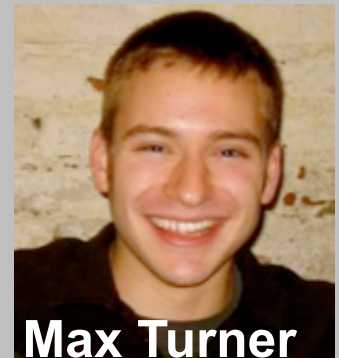
NSF -- Math Biol., Robust Intelligence, Statistics

Teragrid / XSEDE

HHMI



Jon Cafaro



Max Turner



Joel Zylberberg