

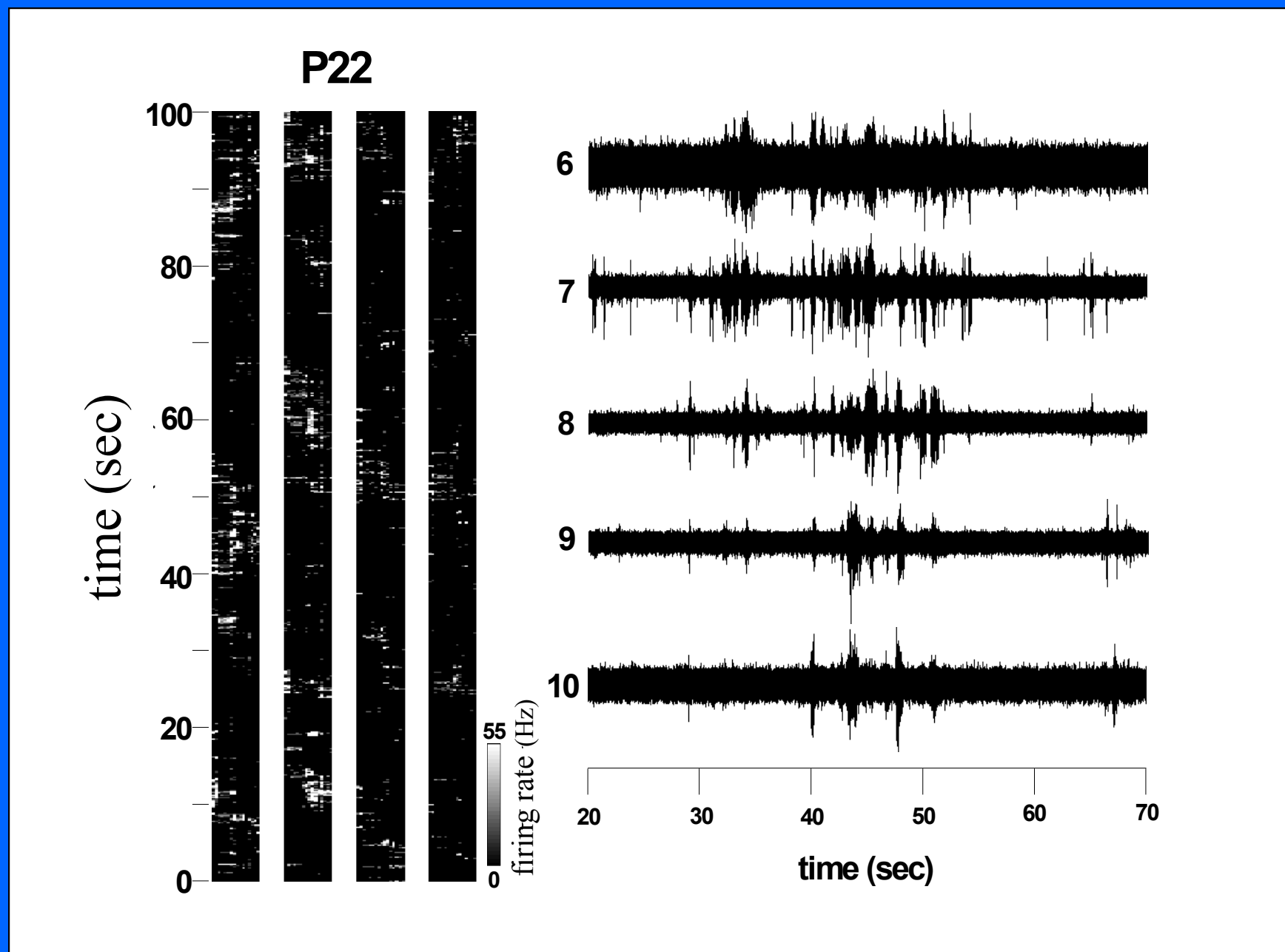
# The development of visual cortical activity in normal and lid sutured ferrets

József Fiser

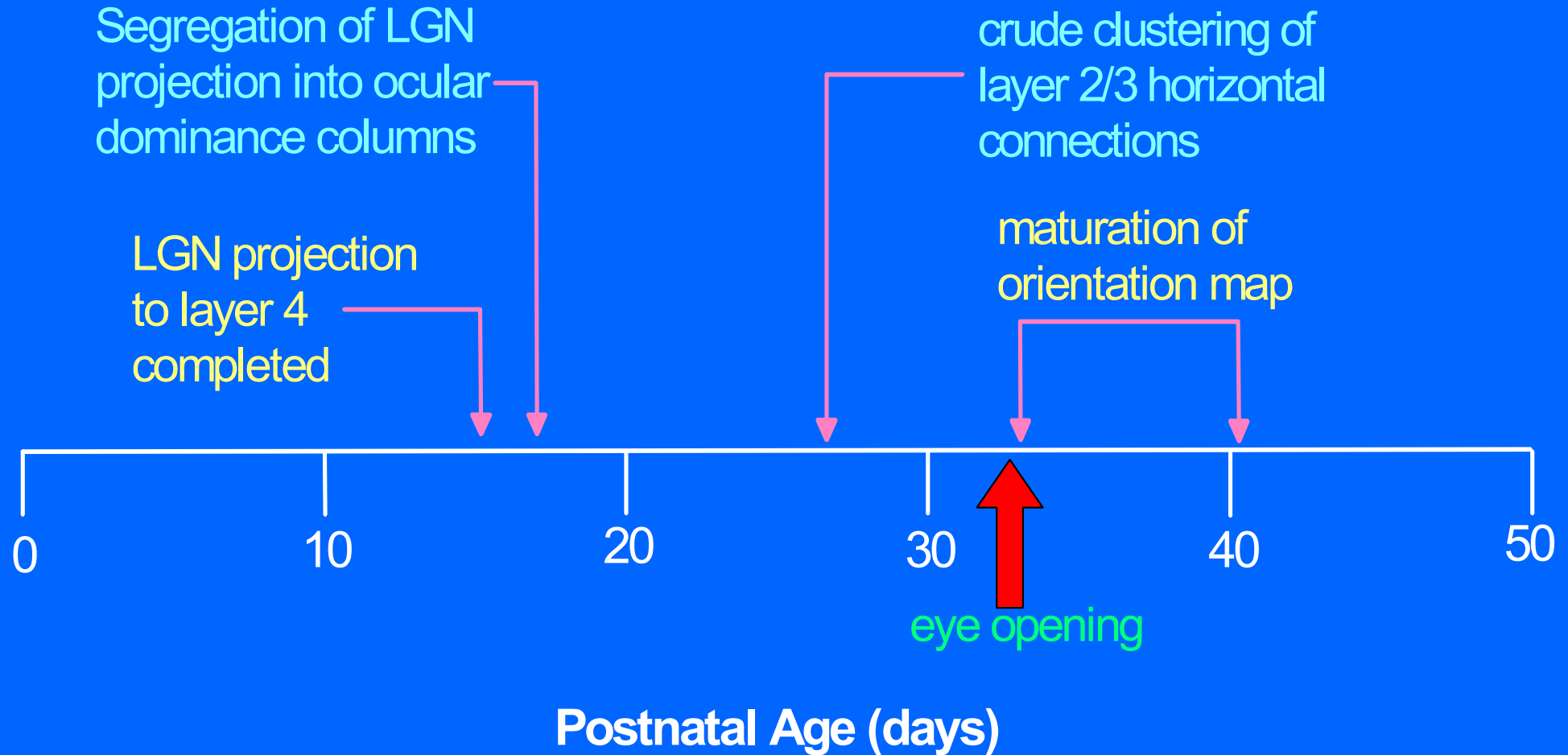
Brandeis University

Chiayu Chiu, David Wagner, Michael Weliky  
University of Rochester

# Patterned Spontaneous Activity in the Primary Visual Cortex



# Visual Cortical Development in Ferrets



# A puzzle

*Before eye opening:* patterned spontaneous activity is thought to have an important role in guiding the establishment and stabilization of developing synaptic connections in the visual system (Ocular Dominance, Orientation columns)

*After eye opening:* patterned spontaneous activity is thought to be unwanted noise

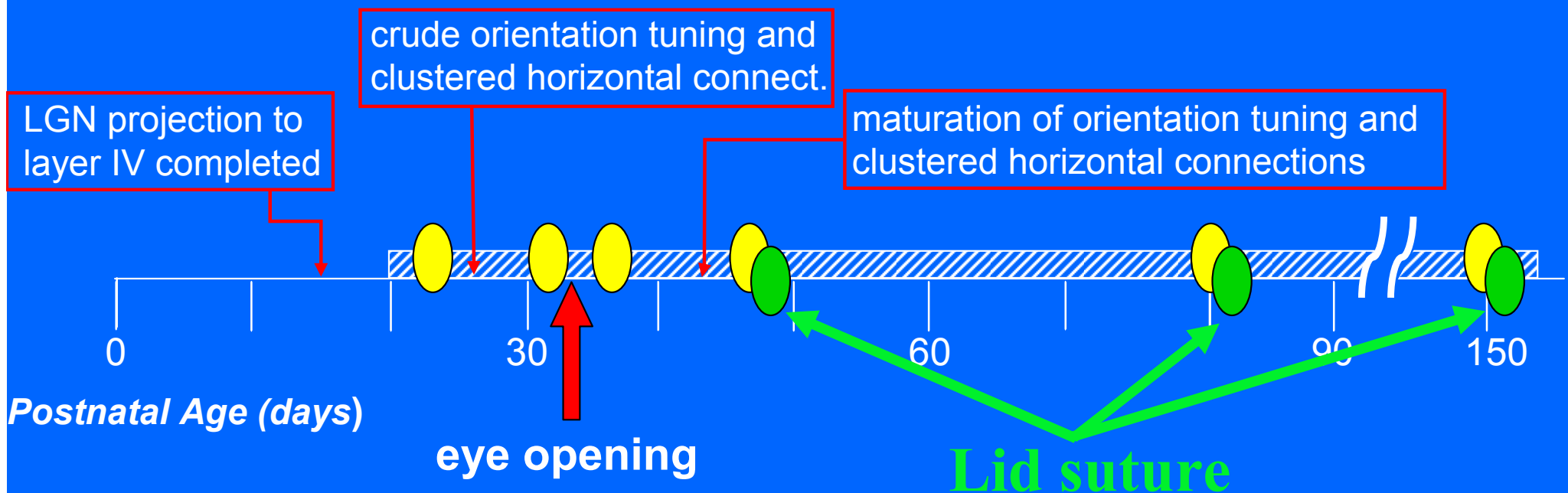
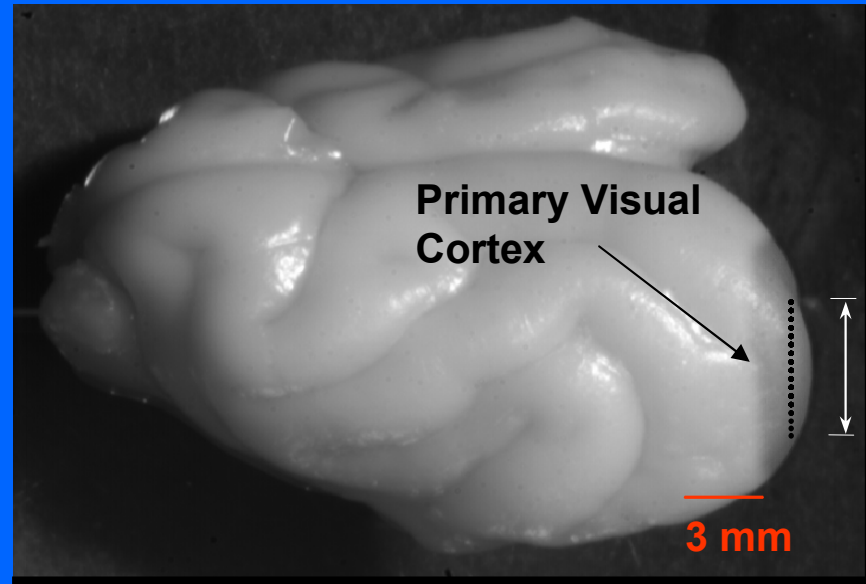
**What happens at eye opening???**

# Possible resolutions

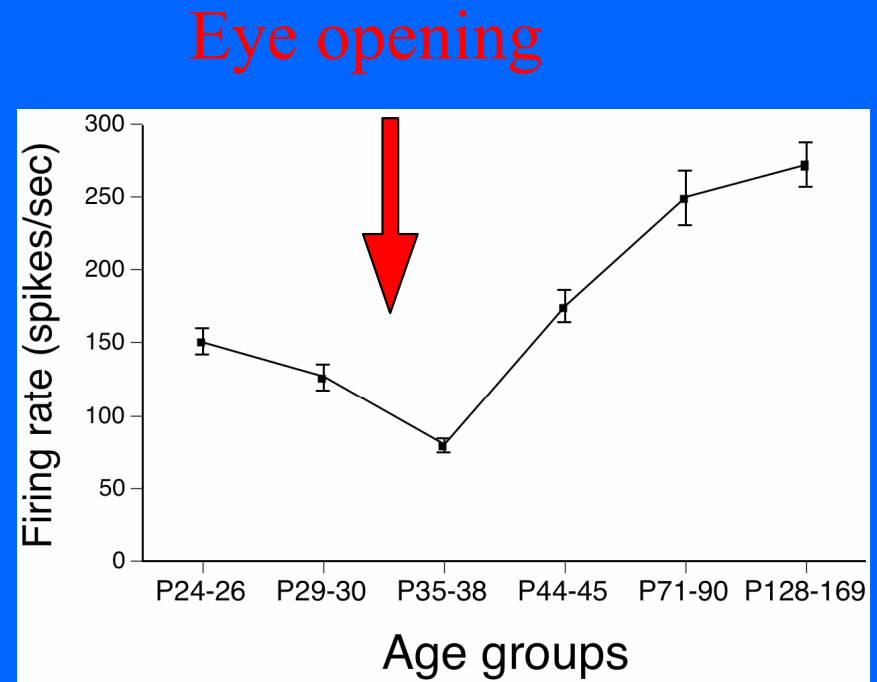
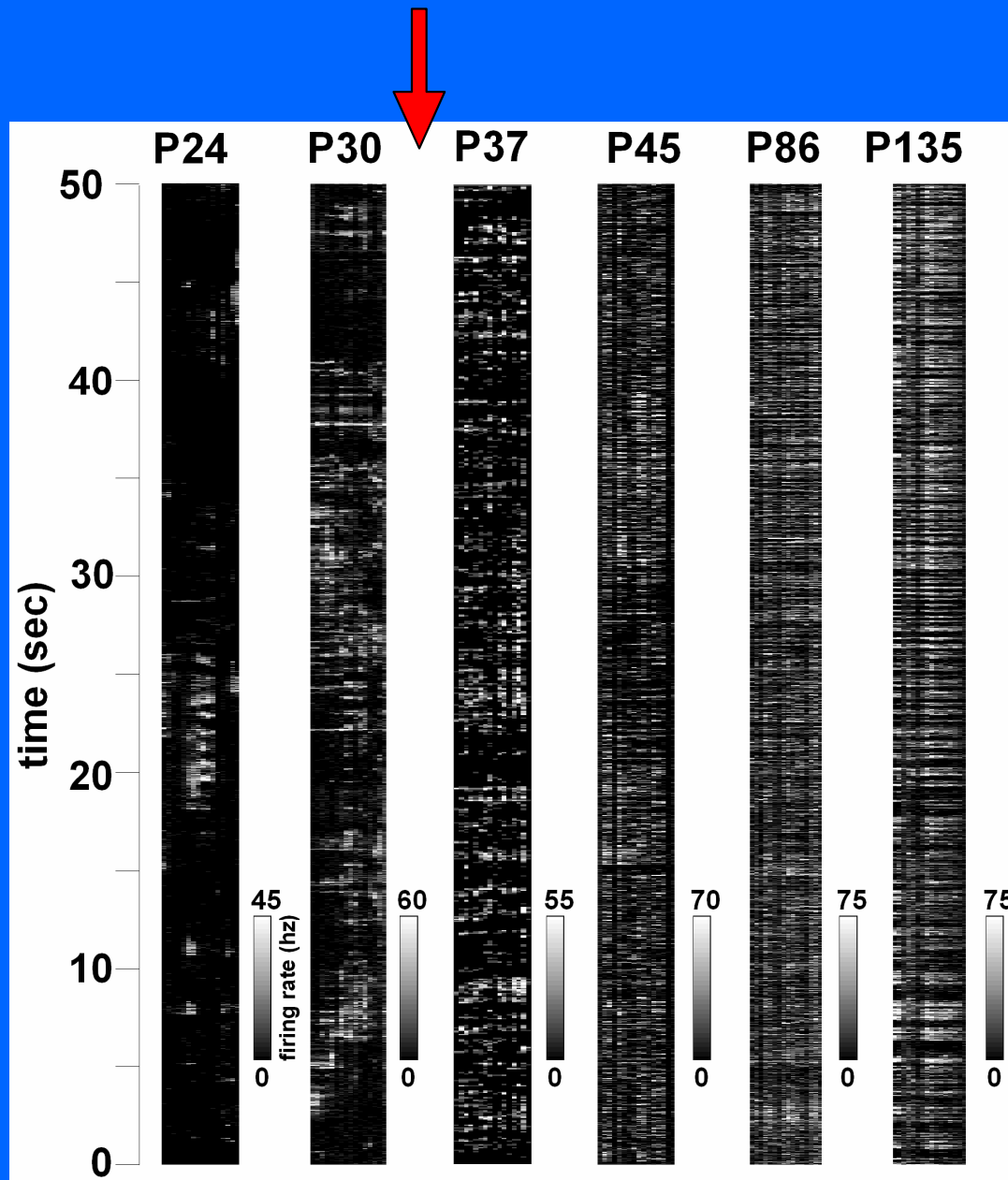
At eye opening.....

- Correlated patterns in spontaneous activity disappear (random noise)
- Magnitude of patterned spontaneous activity is negligible compared to visually driven activity
- The animal does not see anything

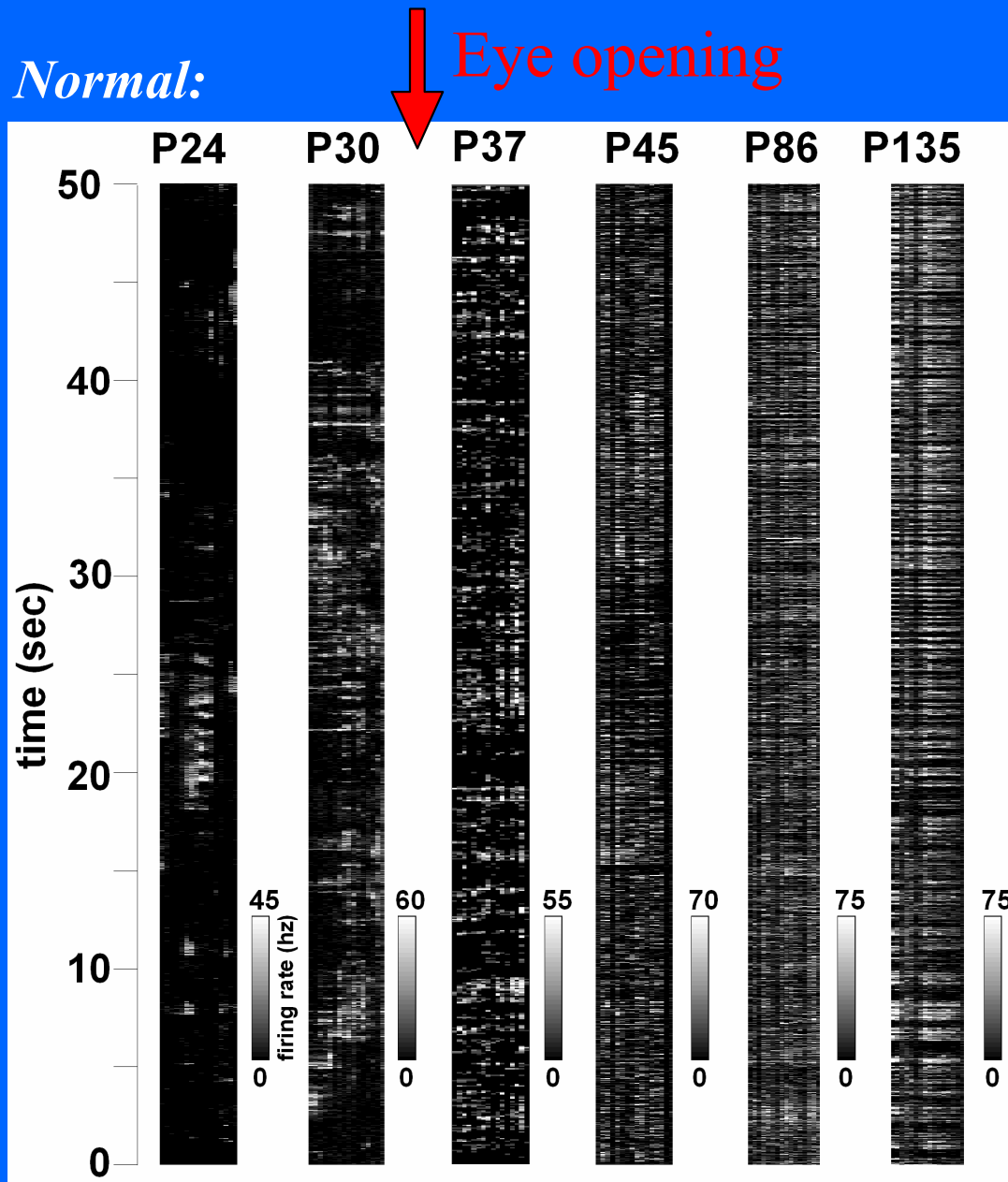
# Method: Multi-electrode recording in the primary visual cortex



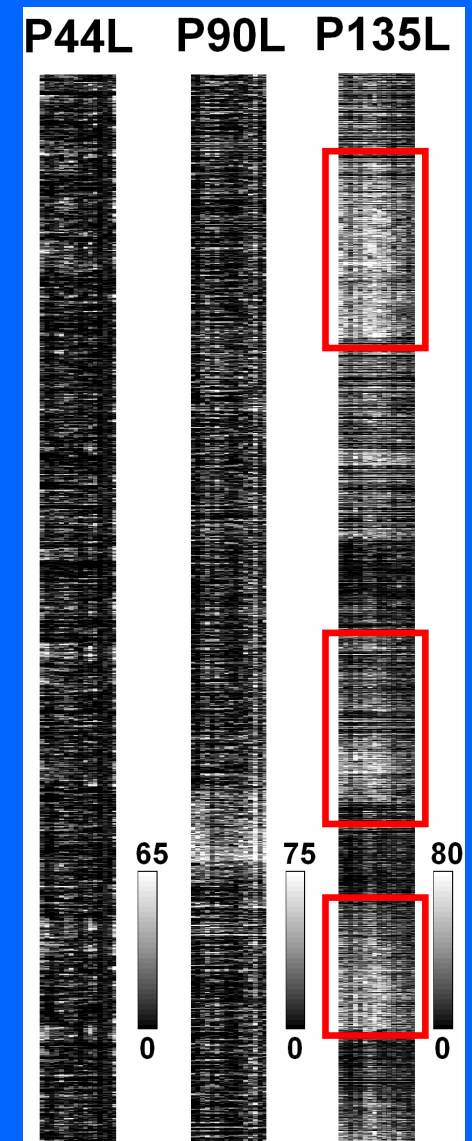
# Development of spontaneous activity



# Spontaneous activity after lid suture



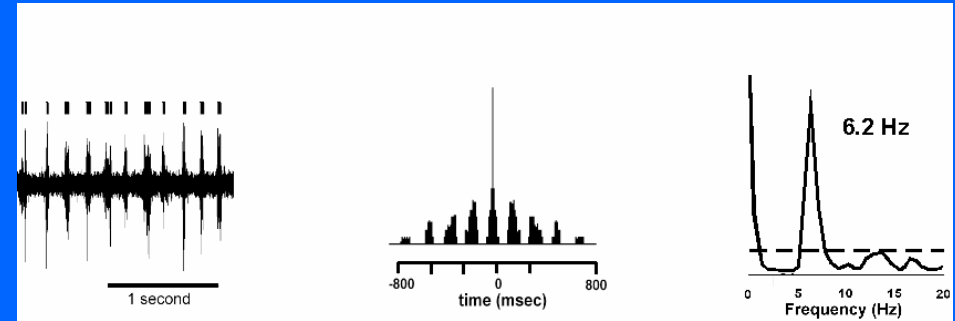
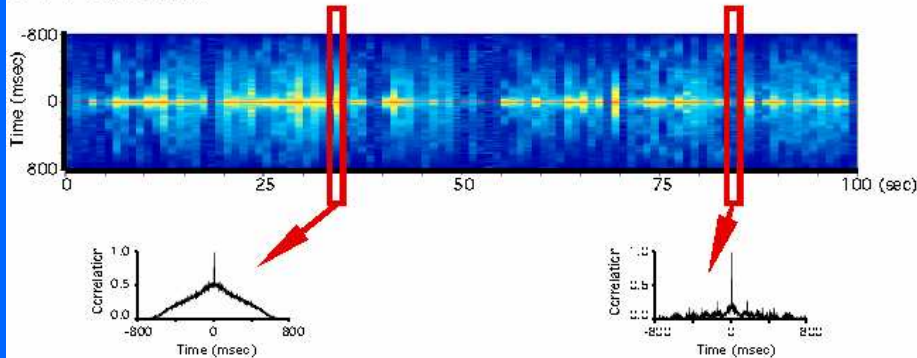
*Lid sutured:*



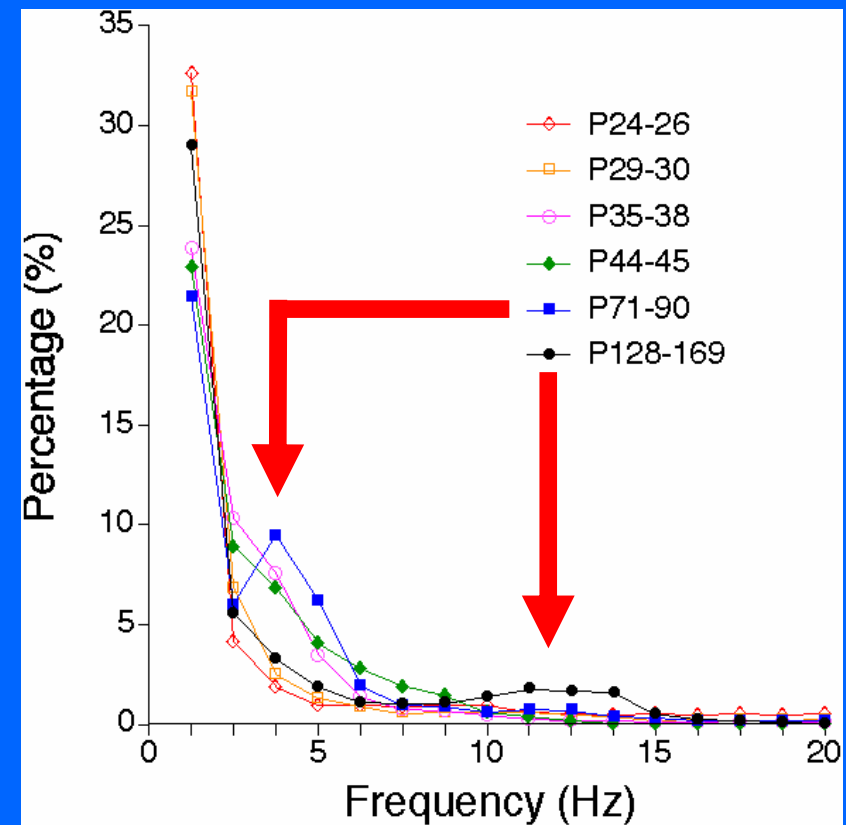
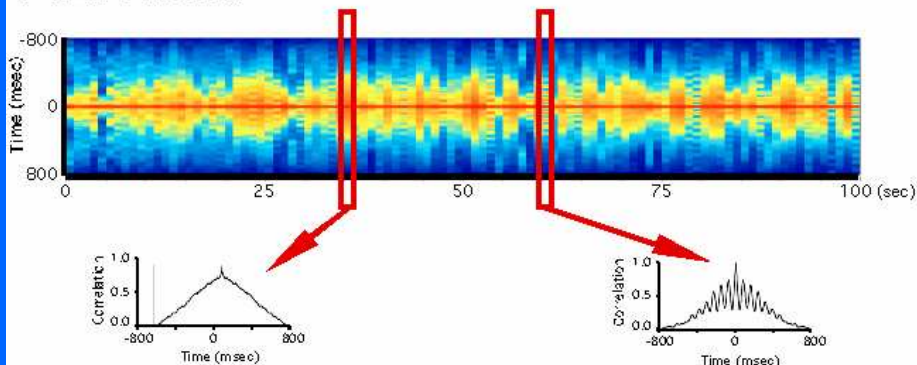


# Development of an oscillatory pattern

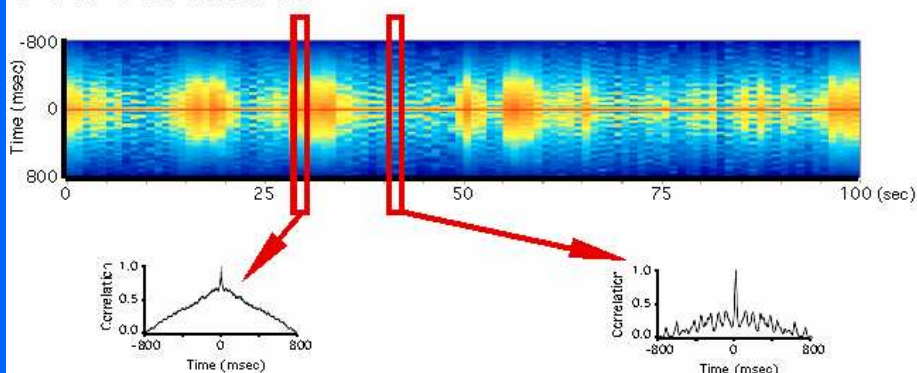
P35 Normal



P129 Normal

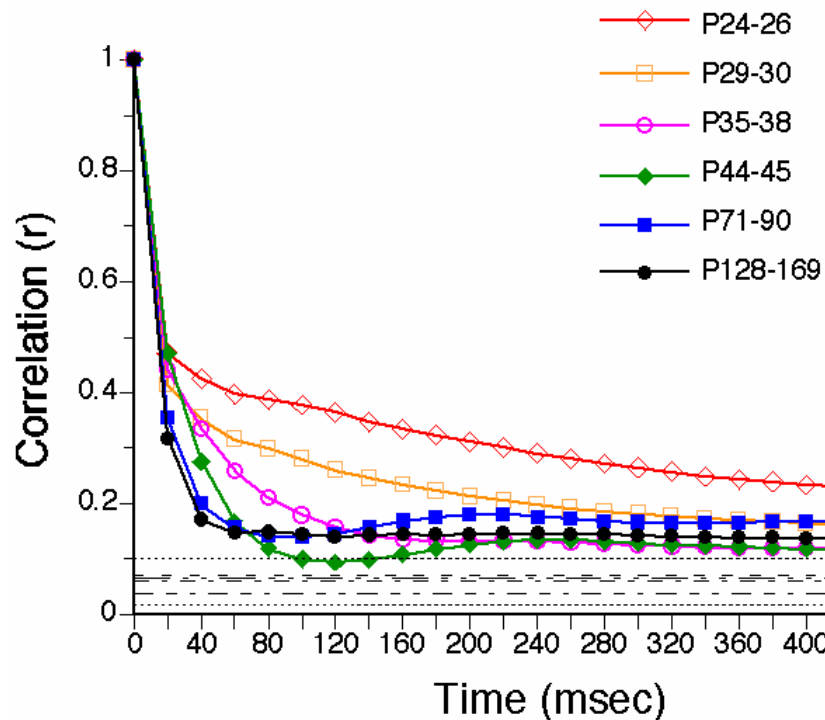


P147 Lid sutured

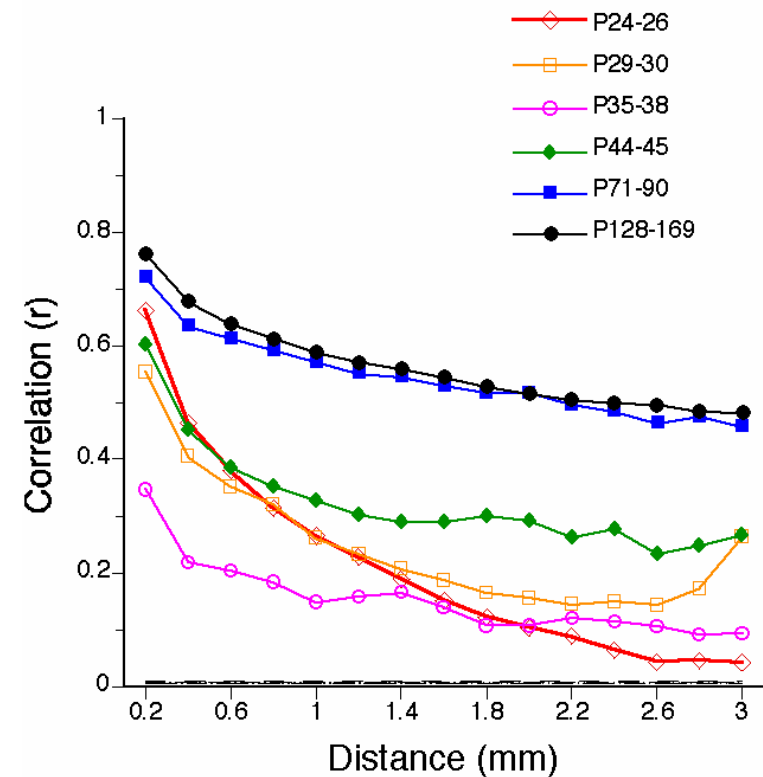


# Development of temporal and spatial correlations

## Temporal Correlations

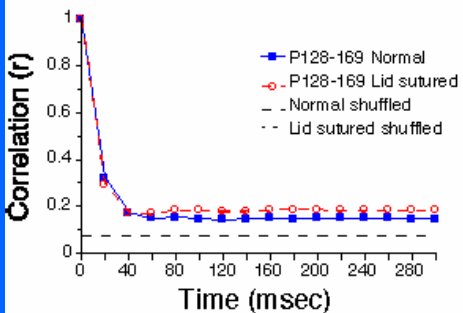
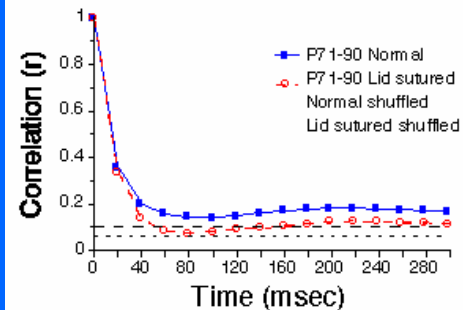
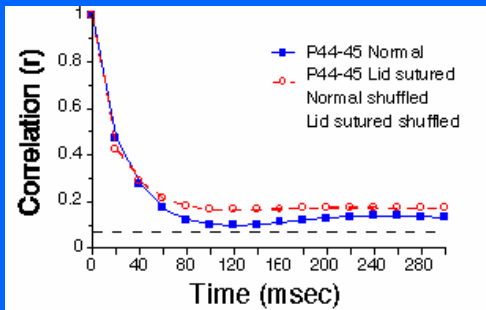


## Spatial Correlations

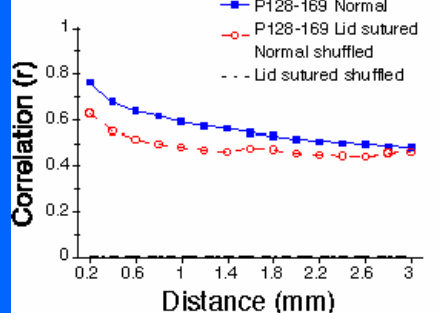
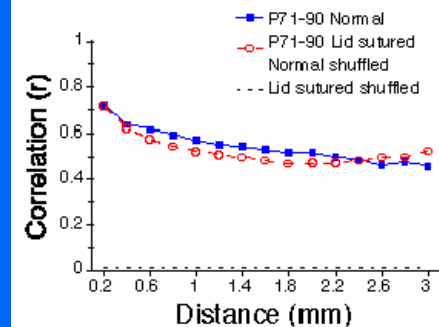
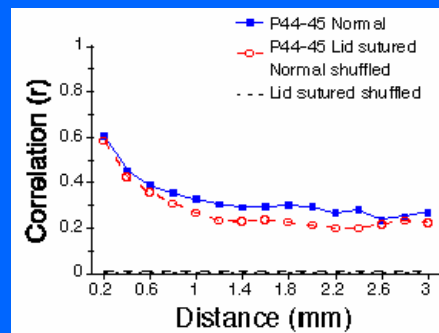


# Spatio-temporal correlations after lid suture

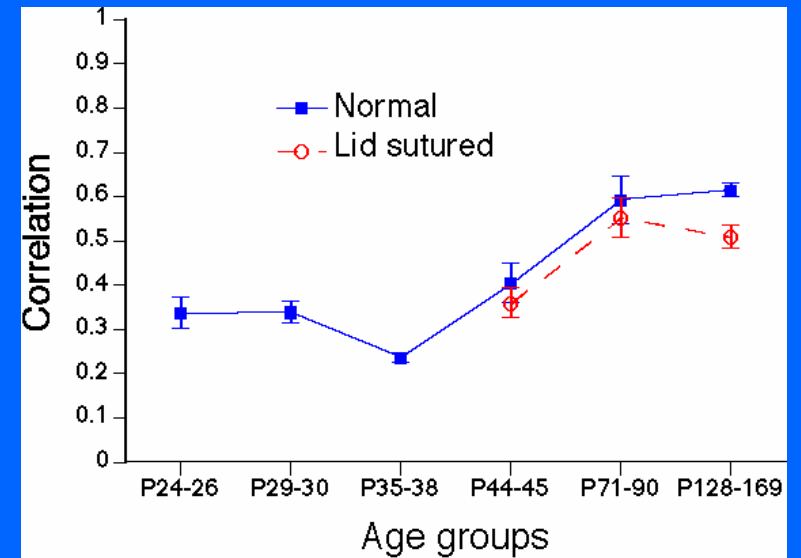
## Temporal correlations



## Spatial correlations



## Development of spatial correlations



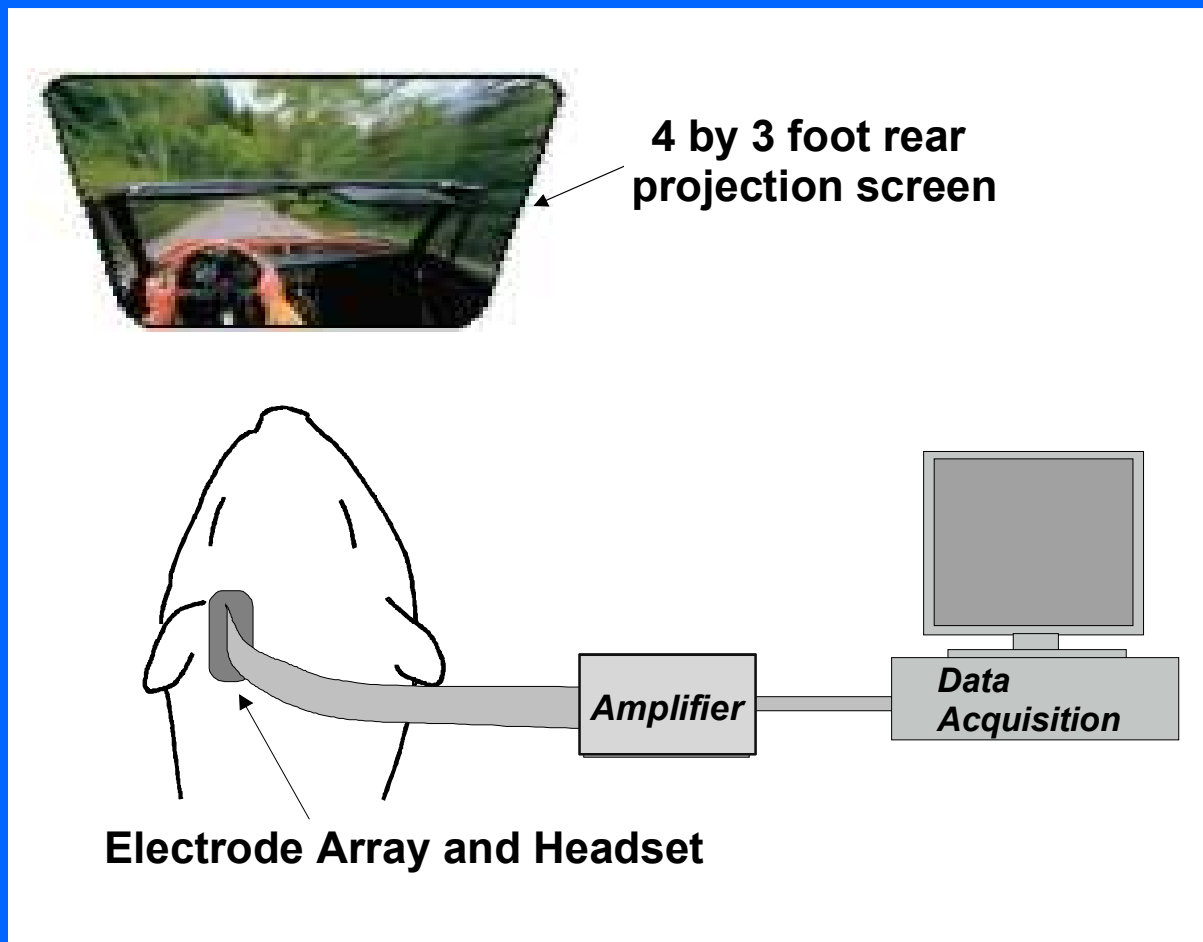
# Summary (Part I)

At eye opening.....

..correlated patterns in spontaneous activity DO NOT disappear!

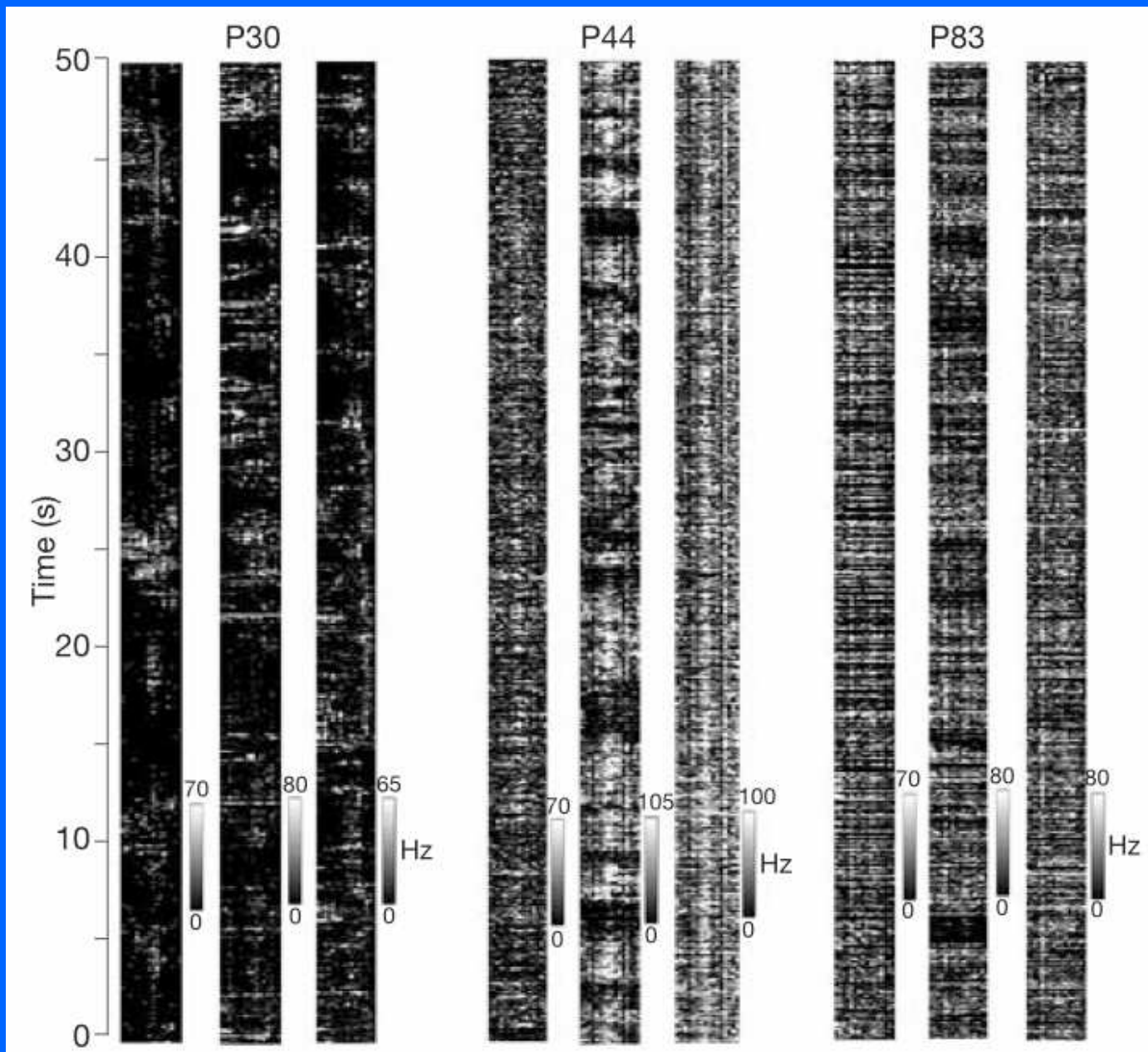
**Is the level of spontaneous activity negligible compared to visually driven activity ??**

# Visually evoked responses: Experimental setup



- Awake, head-restrained ferret
- 3 age groups (P30, P45, P90)
- Three interleaved trial types:
  - complete dark (spont.)
  - natural scene movie
  - white noise stimuli
- Compare neural activity under the different conditions

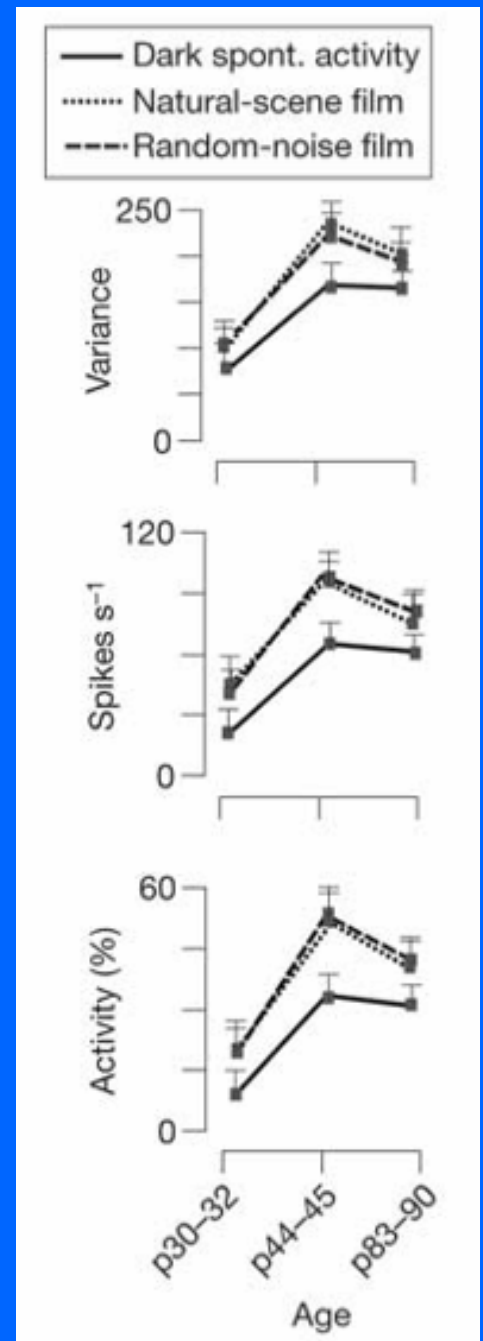
**How to make the comparison?**



Dark Noise Movie

Dark Noise Movie

Dark Noise Movie



**Level of visually driven activity only ~30% higher**

# Summary (Part II)

After eye opening.....

..correlated patterns in spontaneous activity DO NOT disappear....

..and their contribution to neural activity is NOT NEGLIGABLE compared to the visually driven component!

**EVEN IN THE ADULT ANIMAL**

**How can the animal see??**

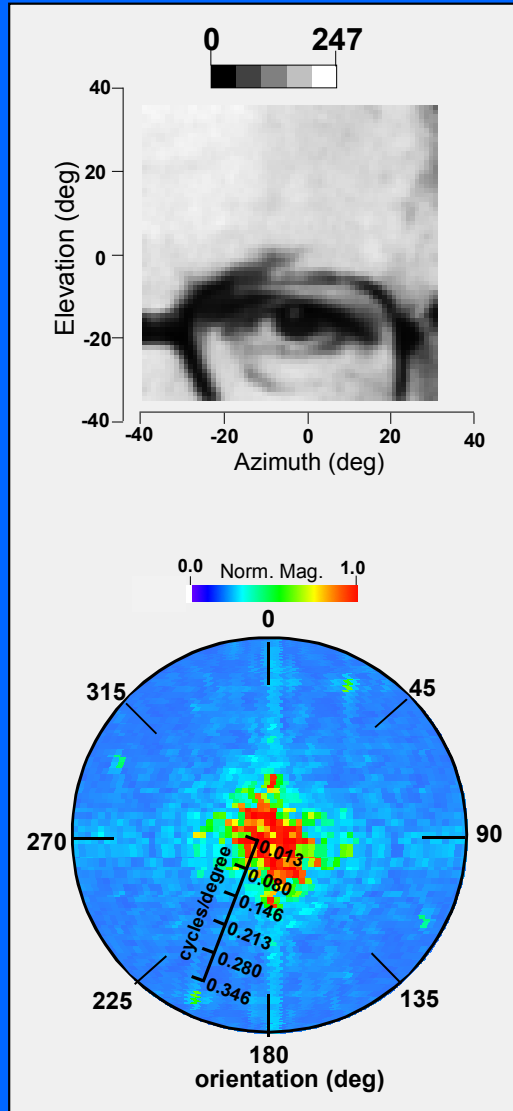
Standard answer:

Average out the correlated noise

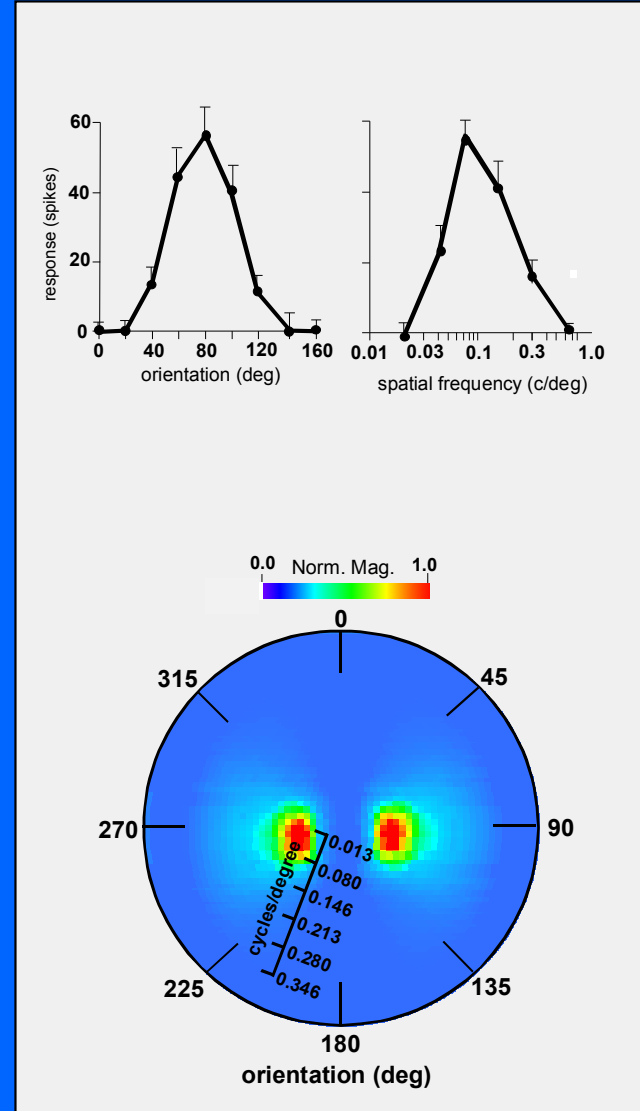
**Can we?**



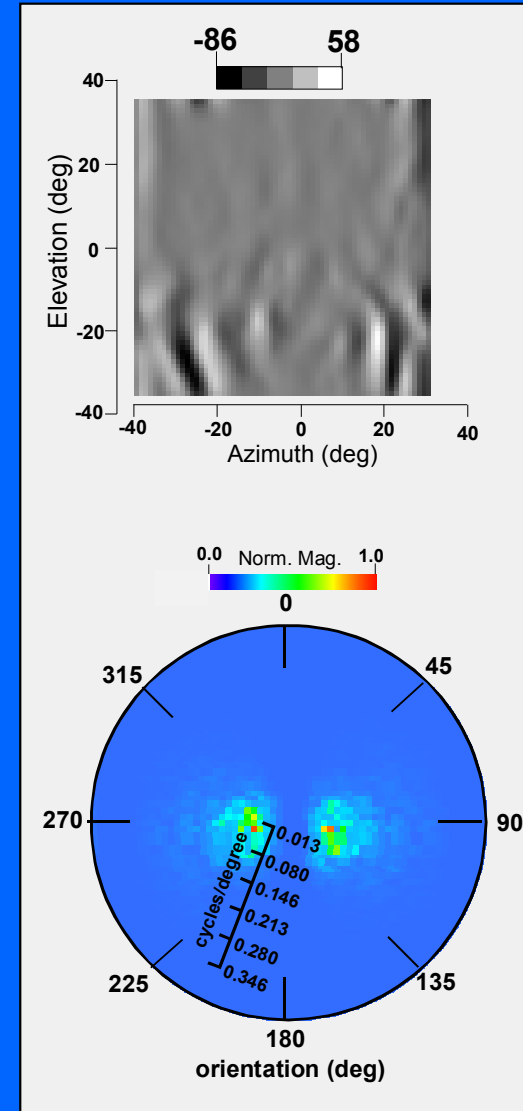
# Linear Filter Model



*Original Image*

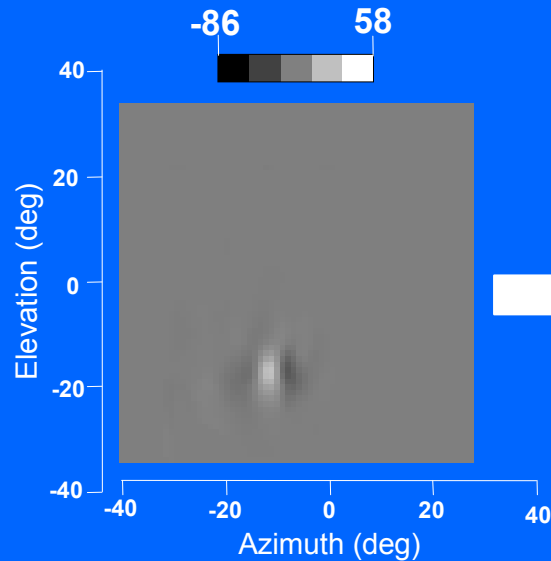


*Measured Cell Filter Properties*



*Filtered Image*

# Computing Expected Responses

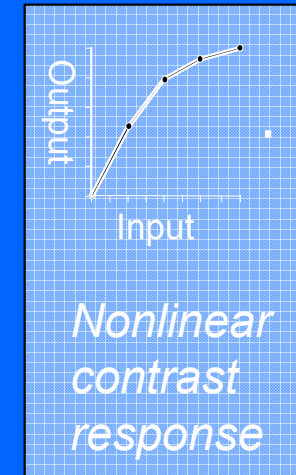


*Filtered Image*

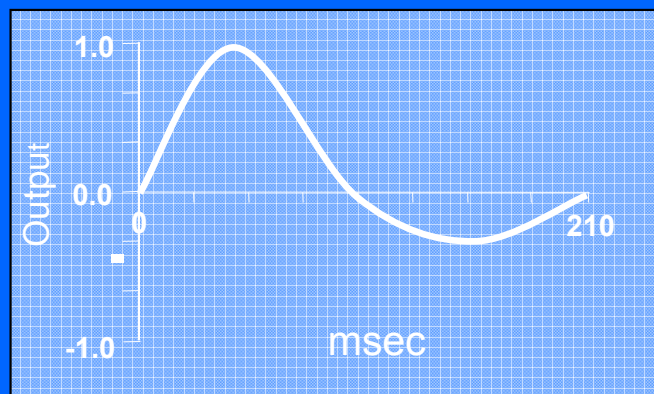
$$\text{Contrast} = \frac{(\text{max}-\text{min})}{(\text{max}+\text{min})}$$

*Michelson-contrast*

*Energy model of  
complex cells*

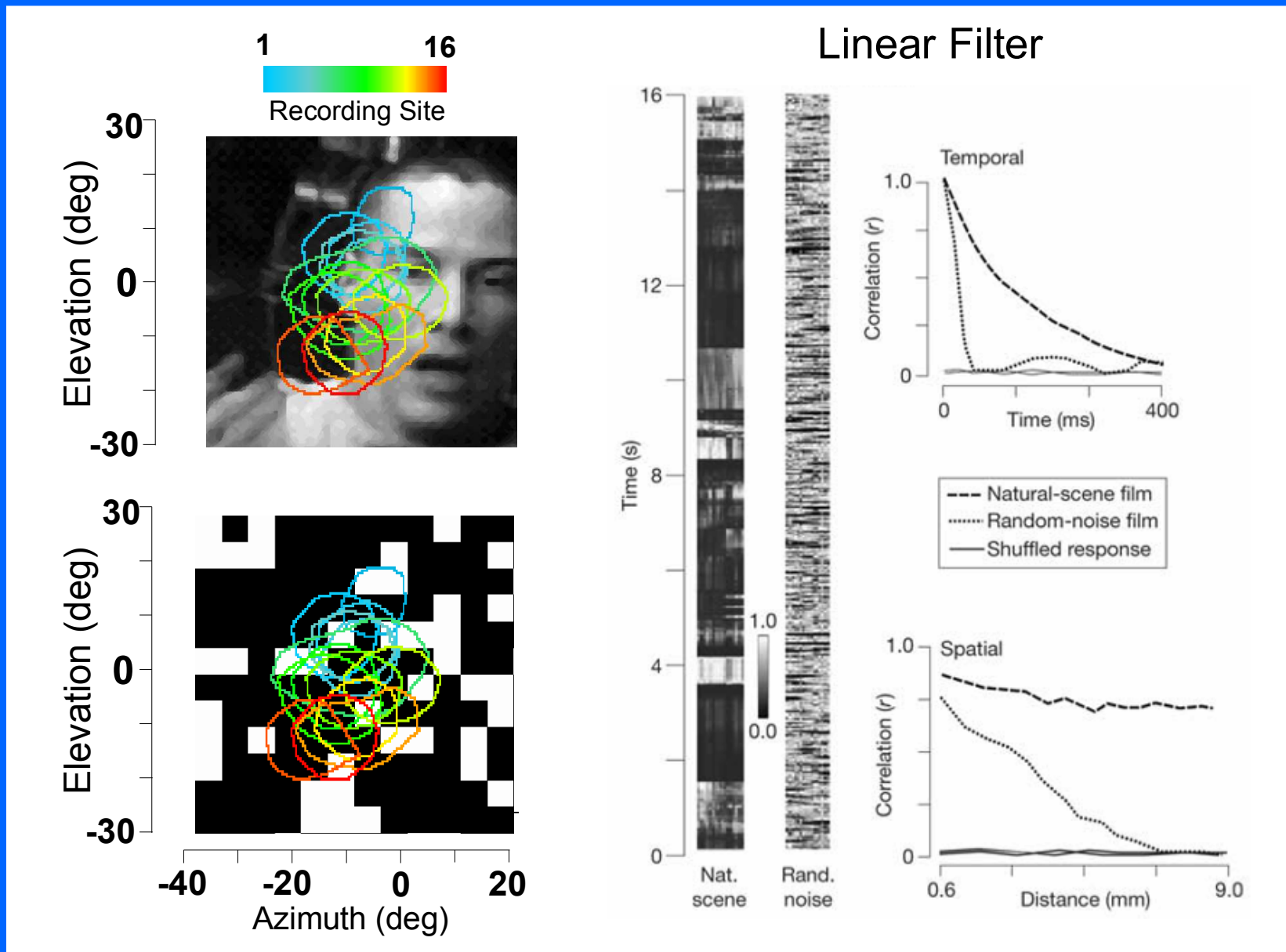


*Model output*

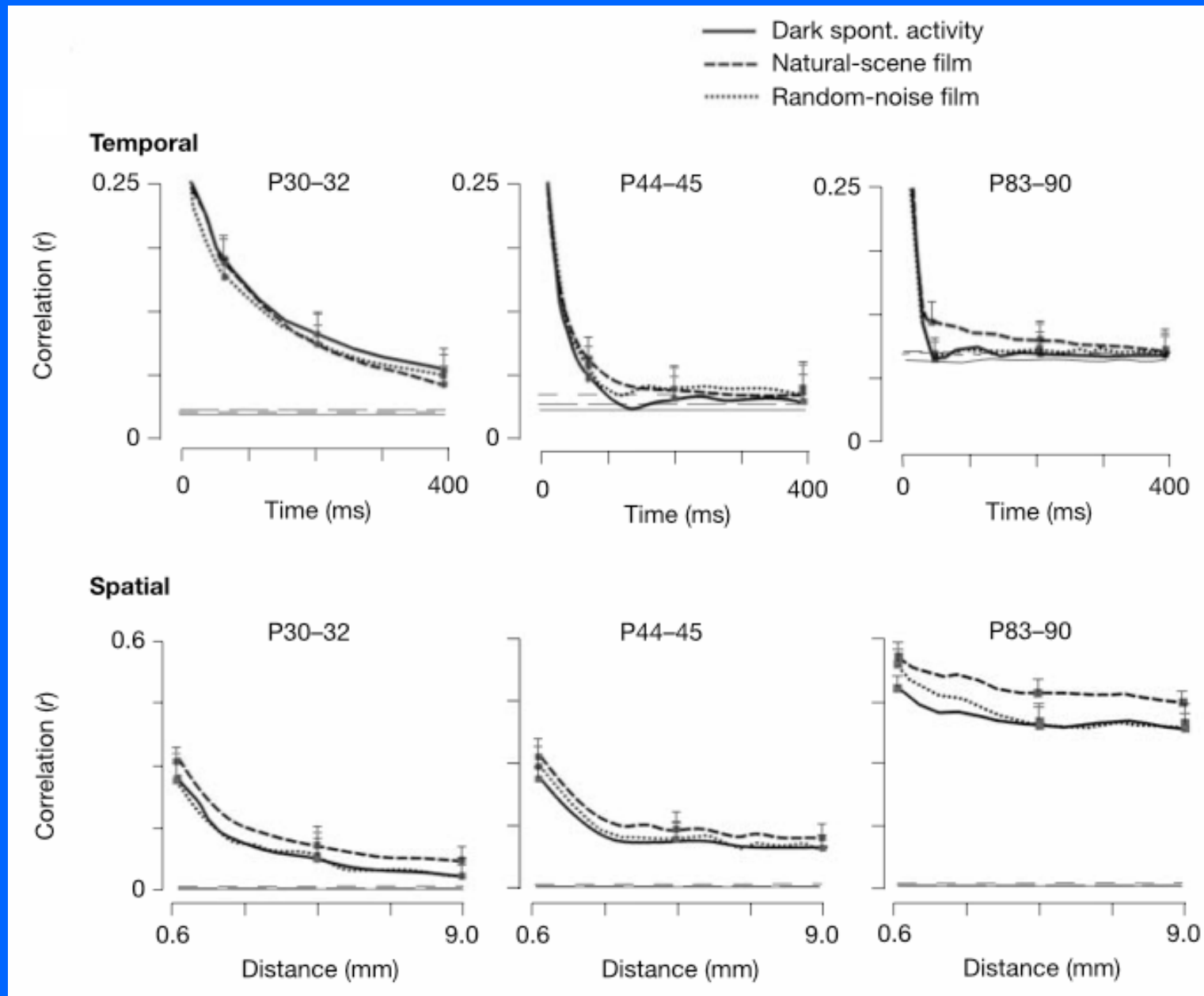


*Impulse Response (Usrey et al., 2003)*

# Expected neural statistics based on the dynamics of the visual displays



# Correlation functions under the three conditions



## Two observations

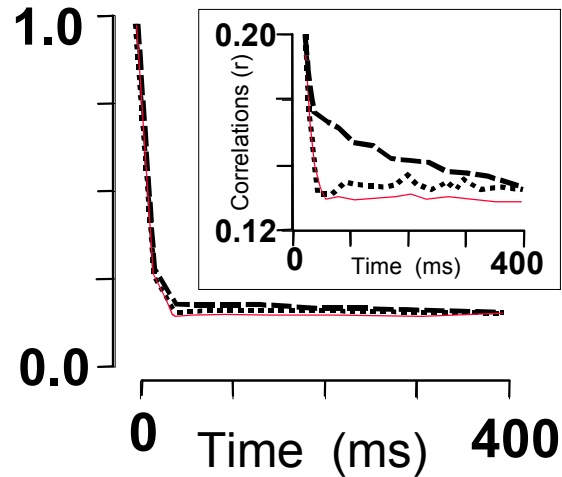
- This level of spatial correlated noise cannot be averaged out
- Spontaneous activity dominates the correlations in neural responses

Does this mean that neural firing does not reflect the structure of the input at all?

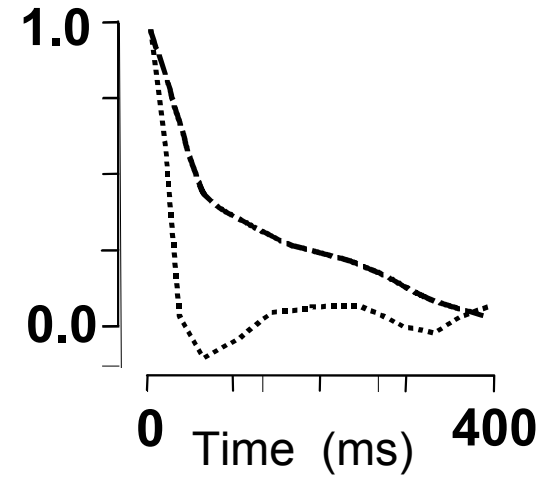
**No!**

## Temporal Correlation

*neural response P83-90*



*stimulus input*

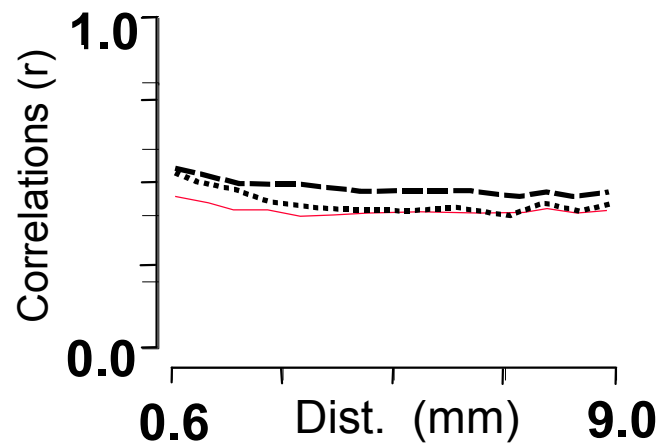


--- Natural Scene Movie  
..... White Noise Movie  
— Dark Spont. Activity

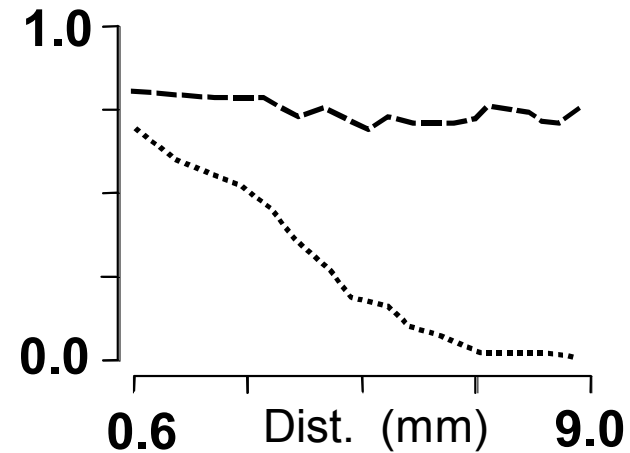
--- Natural Scene Movie  
..... White Noise Movie

## Spatial Correlation

*neural response P83-90*



*stimulus input*



0.6 Dist. (mm) 9.0

0.6 Dist. (mm) 9.0

Neural firing does reflect the structure of the input but only by a 3% modulation in the temporal and a 15% modulation in the spatial correlations.

Is this due to the spontaneous activity or just a cellular developmental or eye movement effect?

**No!**

## Conclusions

- There exist a highly structured spontaneous activity in the primary visual cortex of the awake ferret after eye opening
- The spatial and temporal structure of this activity develops with age from slow unspecific bursting to rapid synchronized firing
- Dominant aspects of this evolving structure seem to be linked to internal network dynamics rather than to visual experience, maturity of individual cells or eye movements
- Visual stimulation changes the firing rate and the second-order correlational structure of the spontaneous neural activity only modestly (albeit significantly)



# Why is this interesting at all?

It requires a completely different model of sensory coding in which:

- Neural activity is not exclusively stimulus driven
- Spontaneous activity is not noise but takes part in the coding
- Coding means not a massive change in firing rates but rather a modulating effect by sensory input on the dynamics of cell-assemblies

**Thank you!**