

# Workshop on Complex Networks and Application to Fluid Dynamics 2024

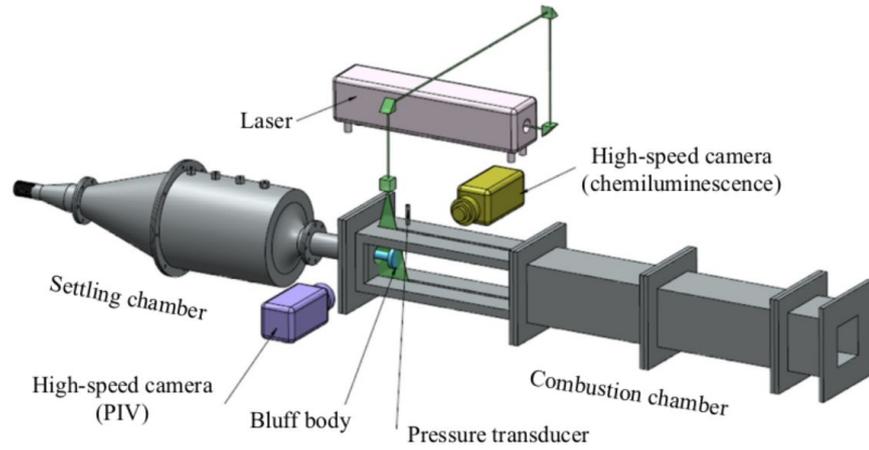
Correlating hydrodynamic and acoustic fields in a turbulent combustor through community-based dimensionality reduction of vortical networks

February 20, 2024

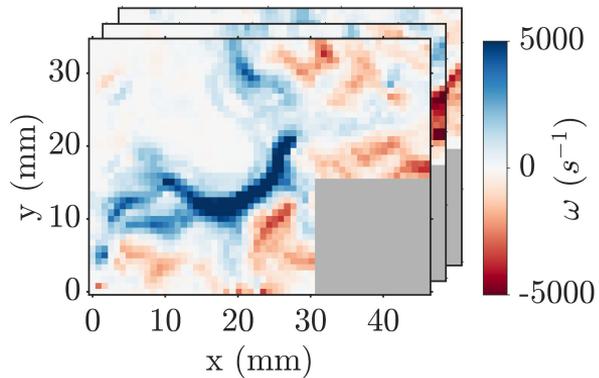
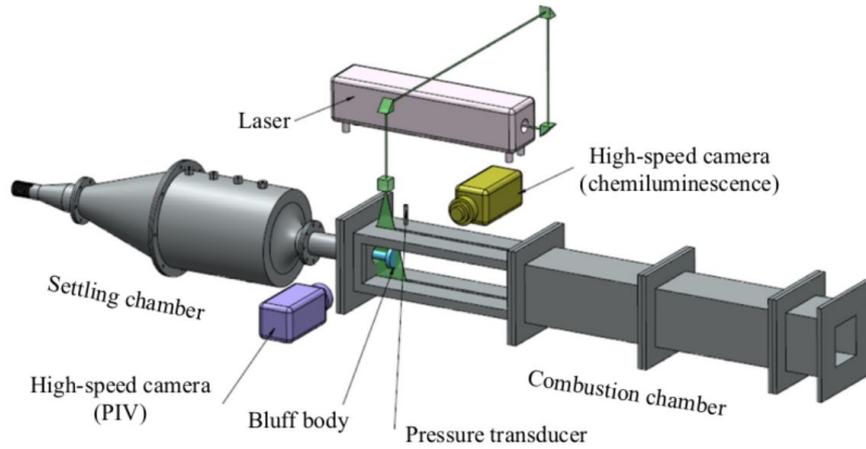
Ankit Sahay, Muralikrishnan Gopalakrishnan Meena, R. I. Sujith



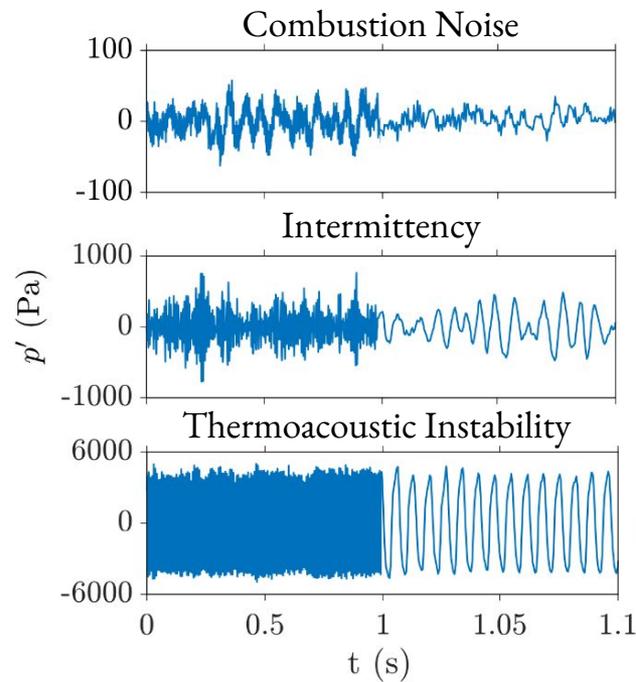
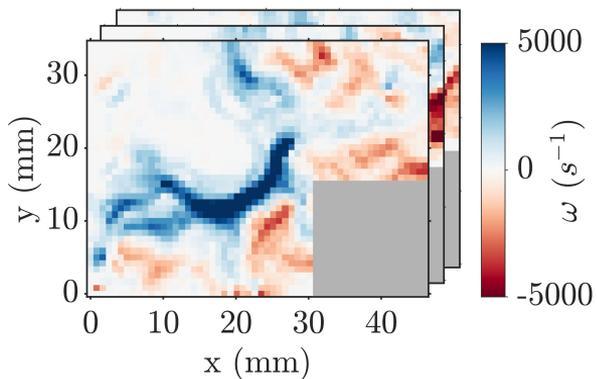
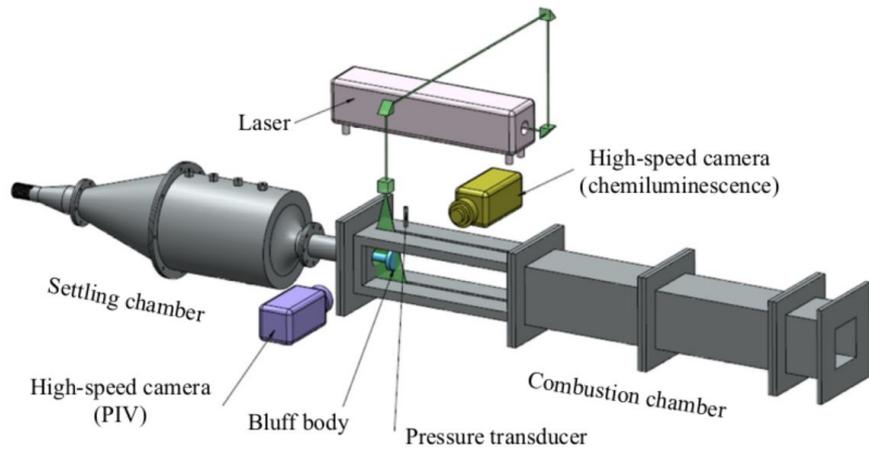
# Bluff-body stabilized turbulent combustor



# Vortical structures drive thermoacoustic instability in many combustors

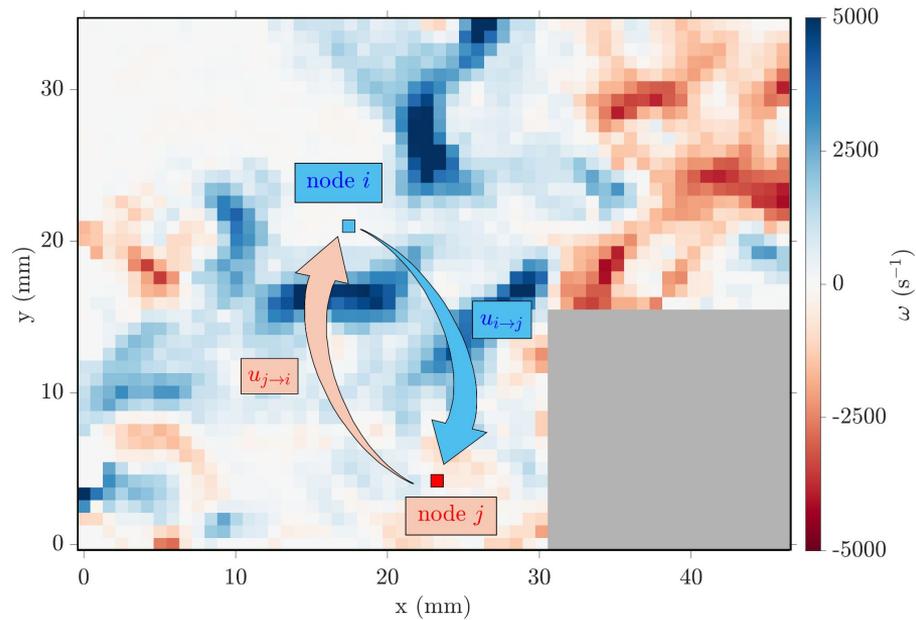


# Bluff-body stabilized turbulent combustor - states of combustion noise, intermittency, and thermoacoustic instability

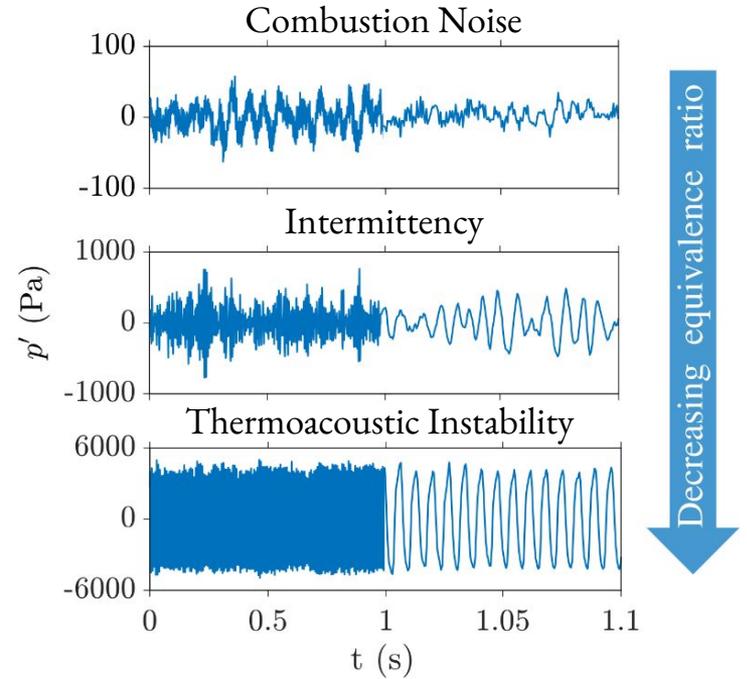


Decreasing equivalence ratio

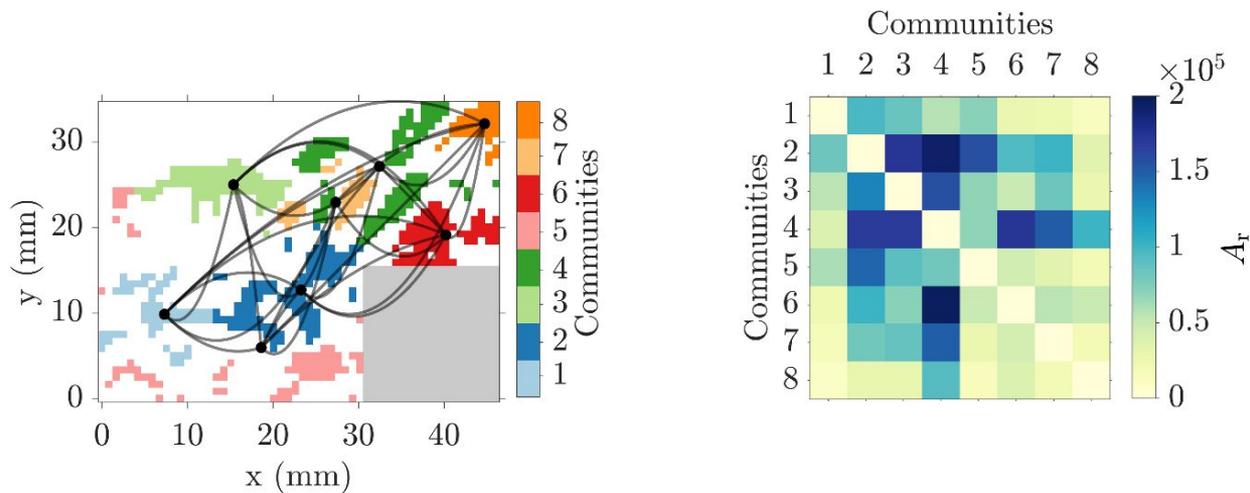
# Understand the interplay between hydrodynamic interactions and acoustic pressure oscillations



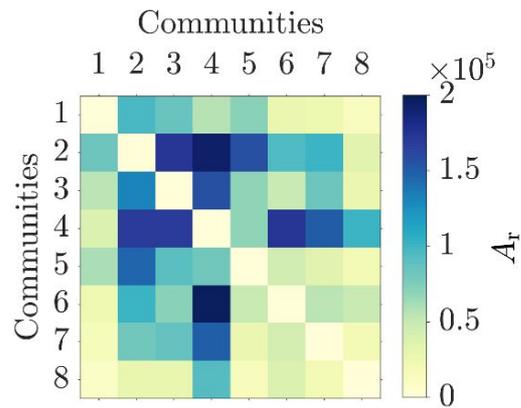
$$\mathbf{u}_{i \rightarrow j} = \frac{1}{2\pi} \int_{S_i} \frac{\boldsymbol{\omega}_i(\mathbf{r}', t) \times (\mathbf{r}_j - \mathbf{r}'_i)}{\|\mathbf{r}_j - \mathbf{r}'_i\|_2^2} dS_i$$



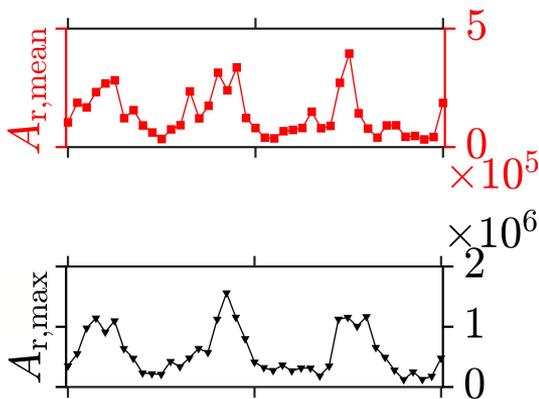
At each time instant, inter-community edge weights are used to form **inter-community reduced networks**



# Network measures considered - mean and maximum of the reduced adjacency matrix



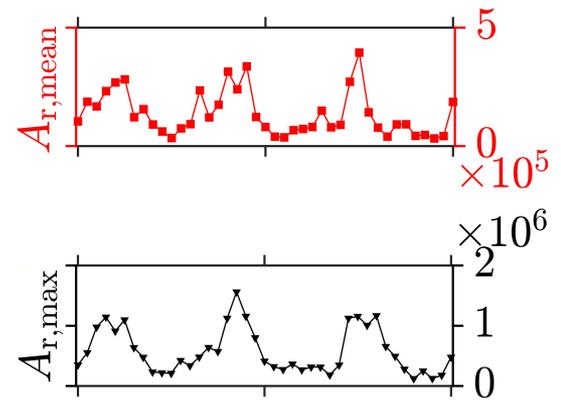
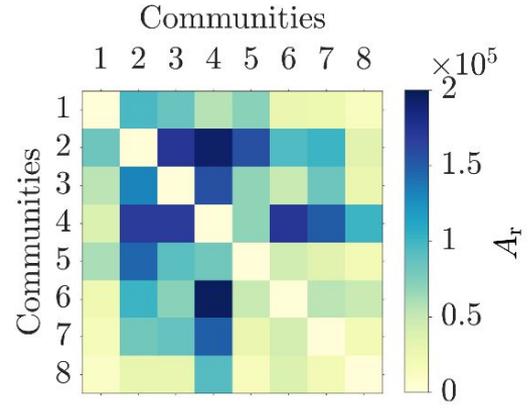
$A_r$  



Average of all  
inter-community interactions

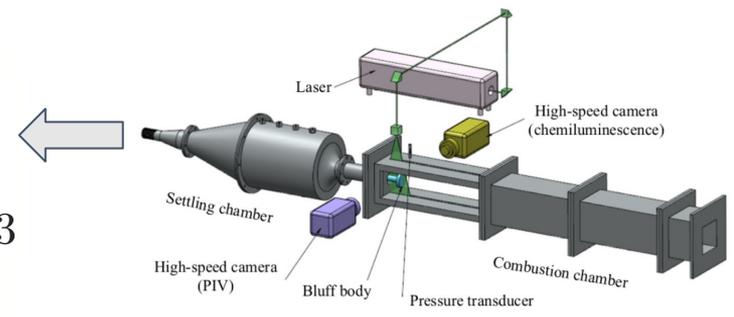
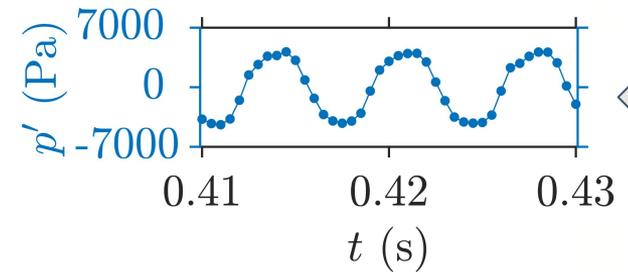
Maximum of all  
inter-community interactions

# Evaluate correlation between temporal evolution of network measures and acoustic pressure fluctuations

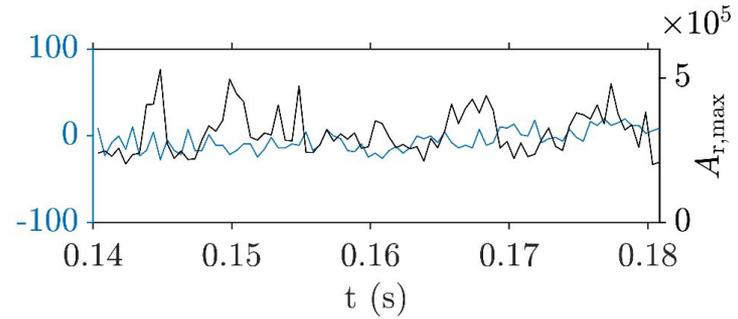
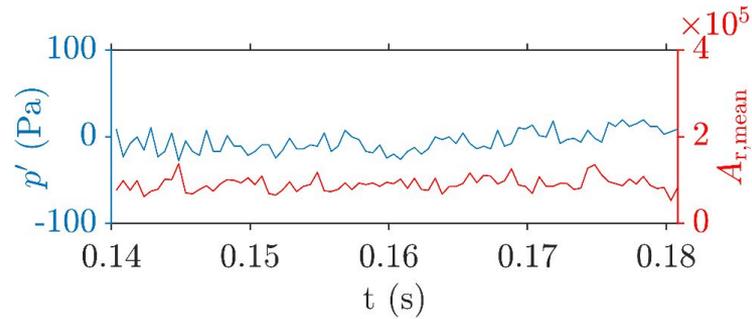


Average of all inter-community interactions

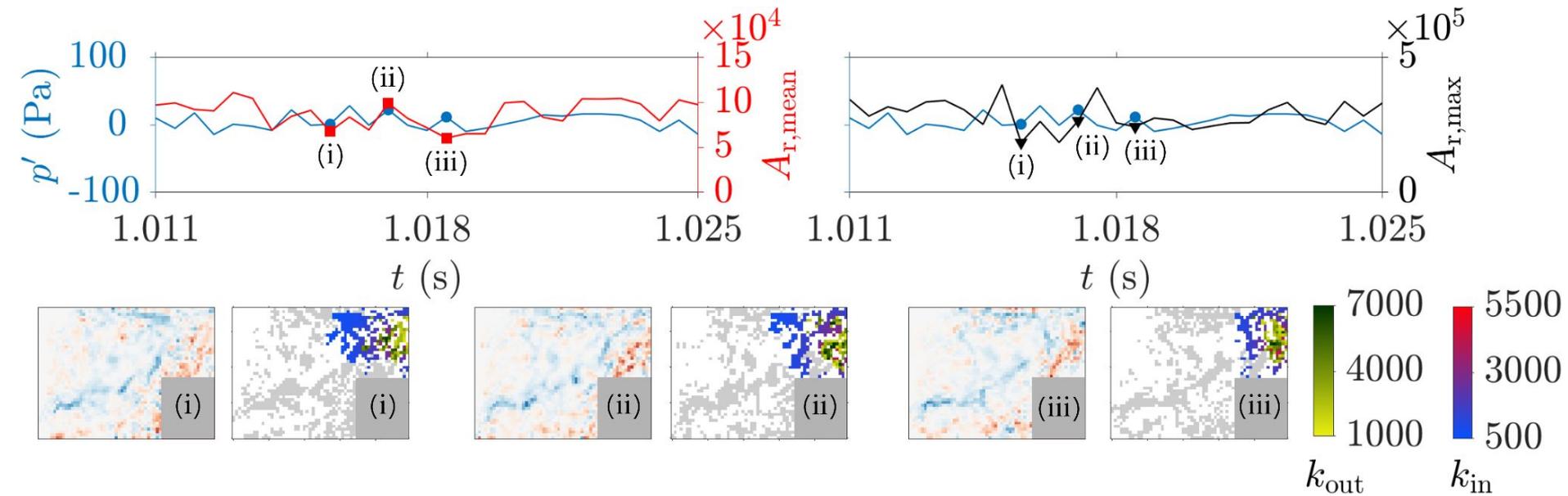
Maximum of all inter-community interactions



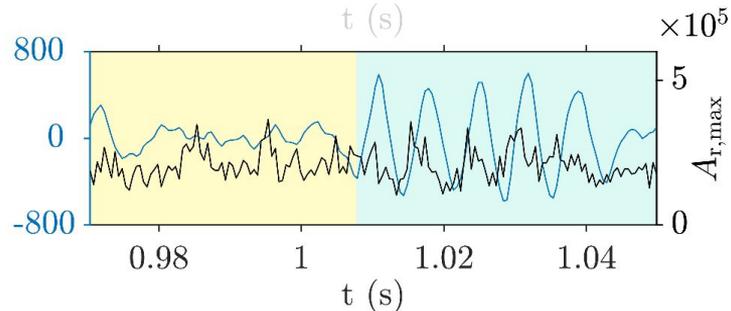
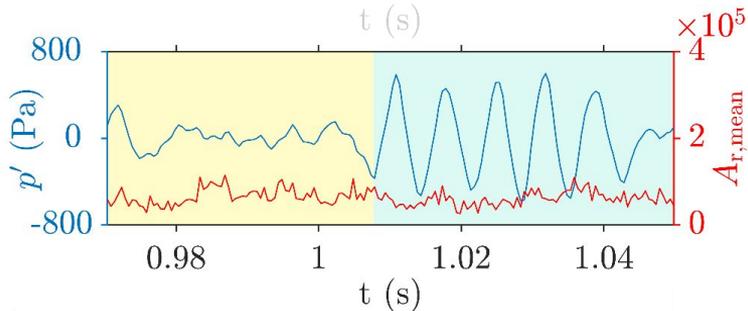
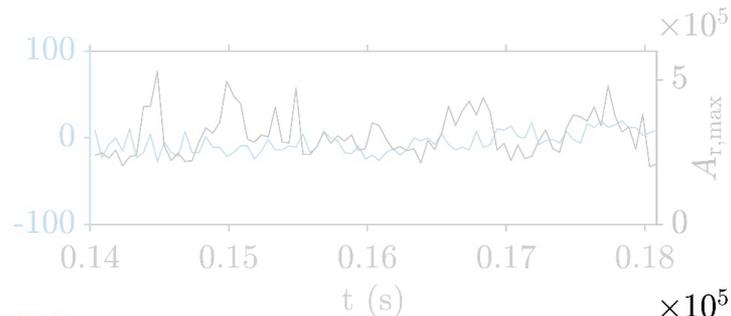
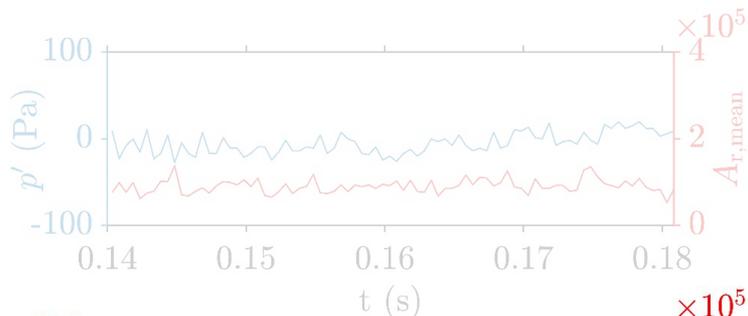
# Combustion noise - aperiodic dynamics of networks measures



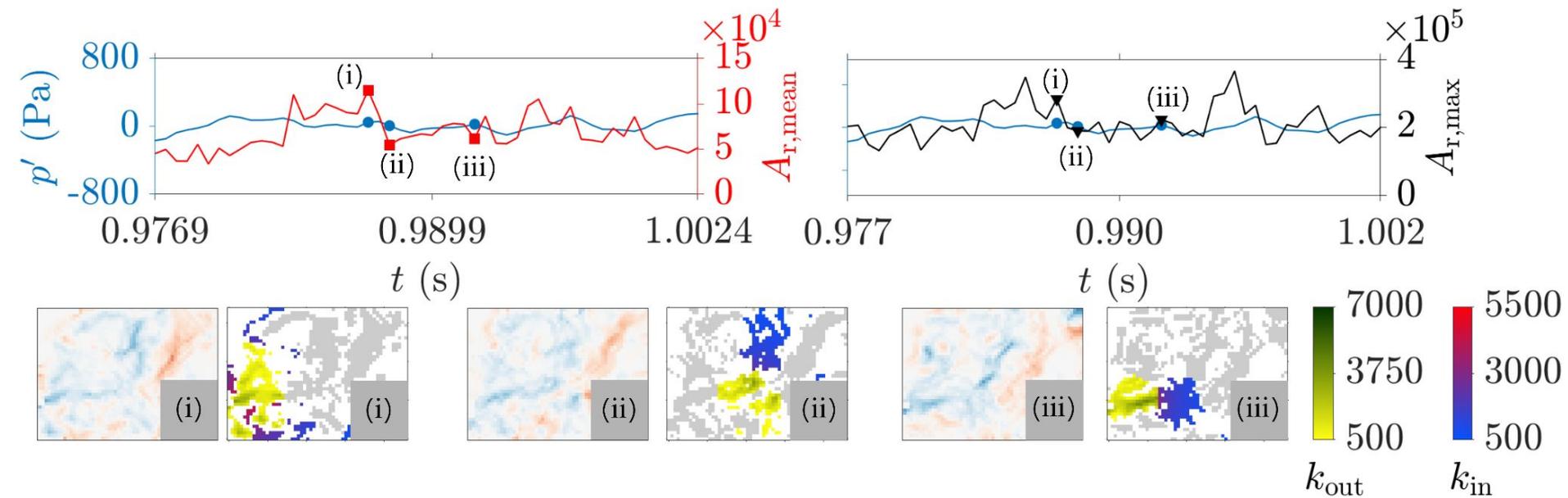
# Combustion noise - significant vortex shedding from the upstream tip of bluff body



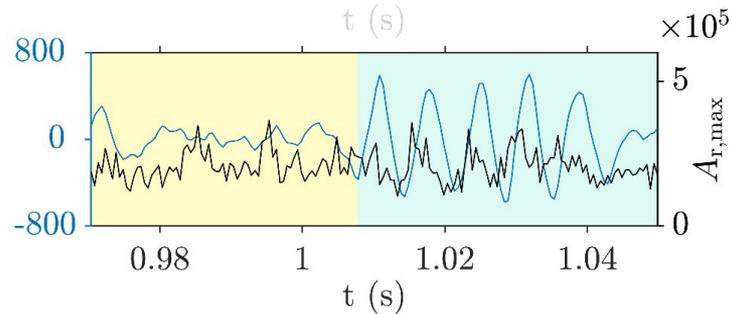
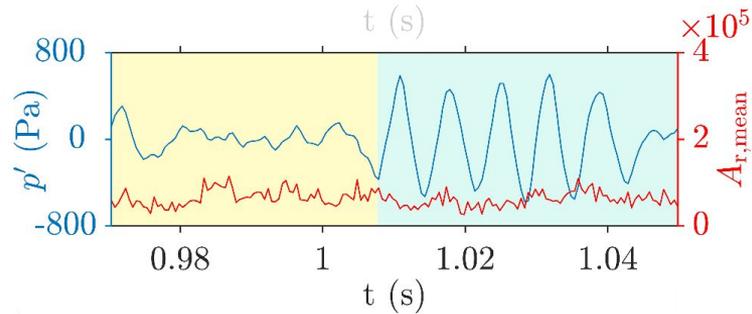
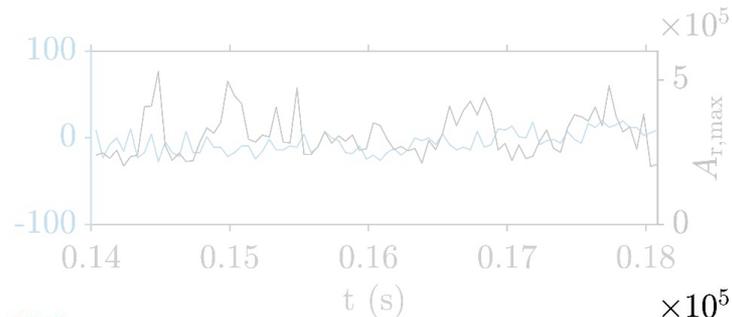
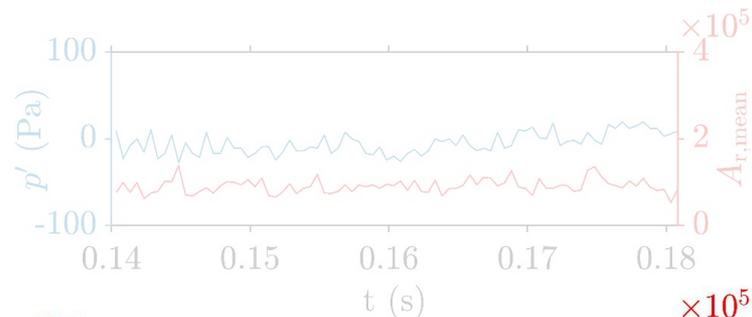
# Intermittency - network measures are aperiodic during the aperiodic epoch of intermittency



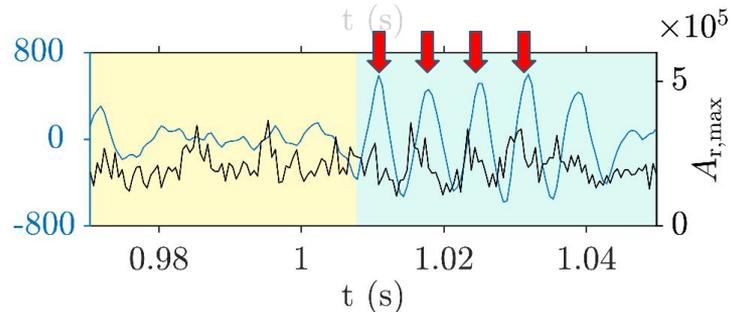
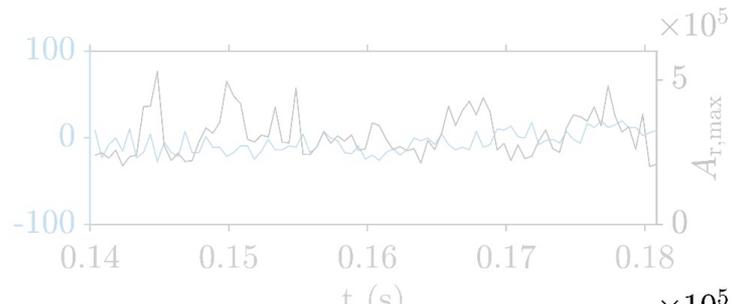
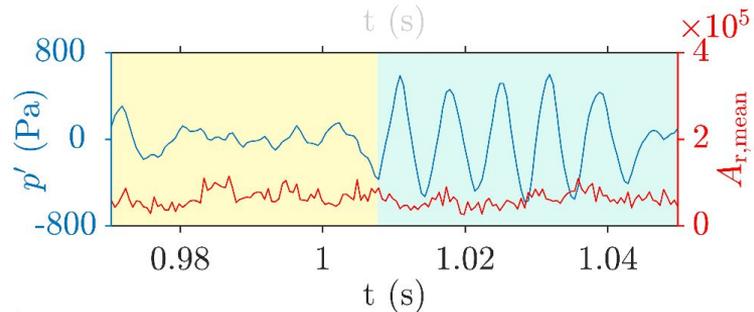
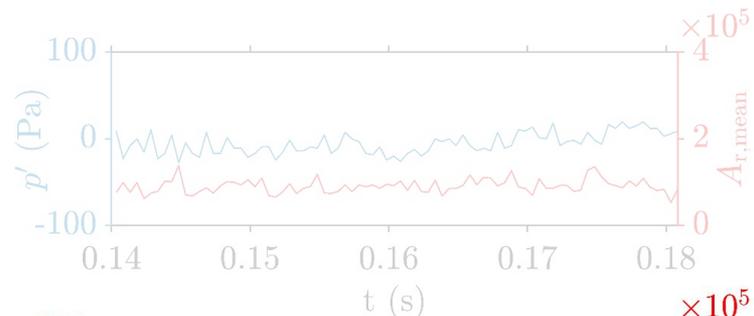
# Aperiodic epoch of intermittency - aperiodic temporal variation of network measures



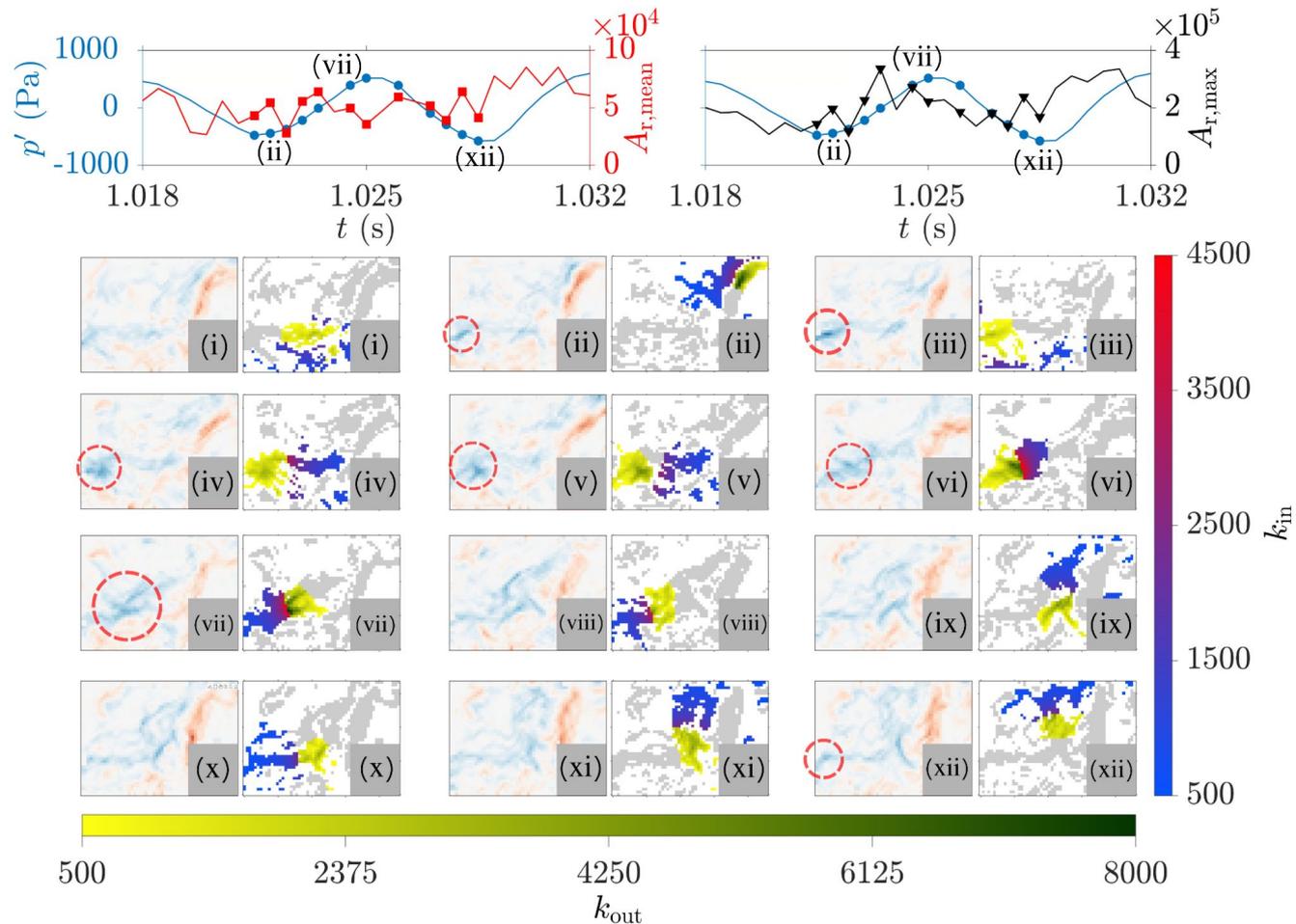
# Intermittency - taking average of inter-community interactions smears out the periodic information of the flow field



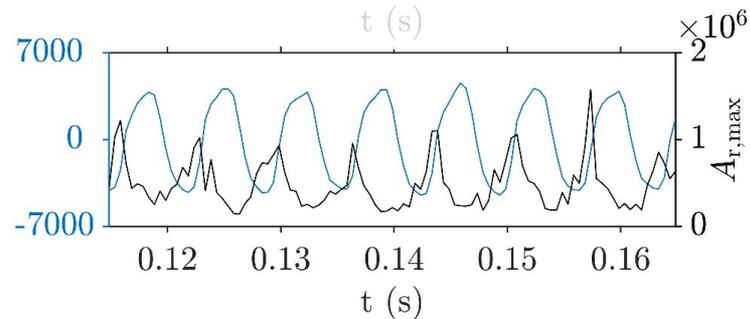
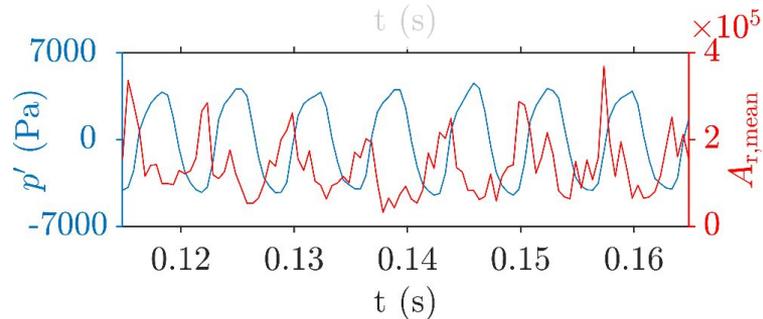
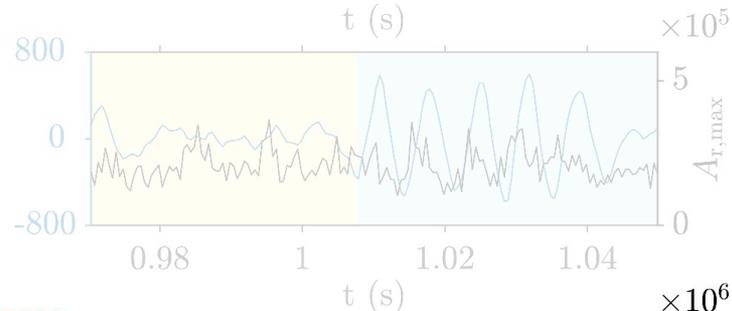
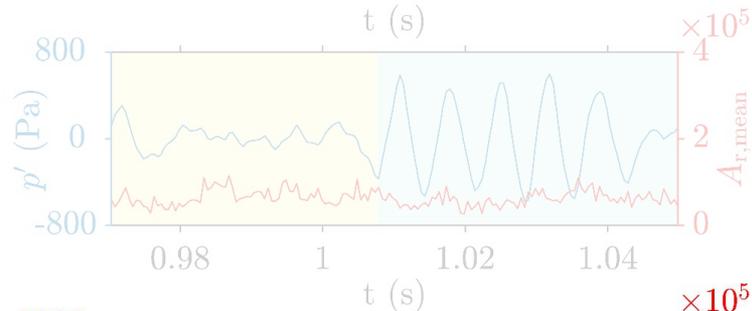
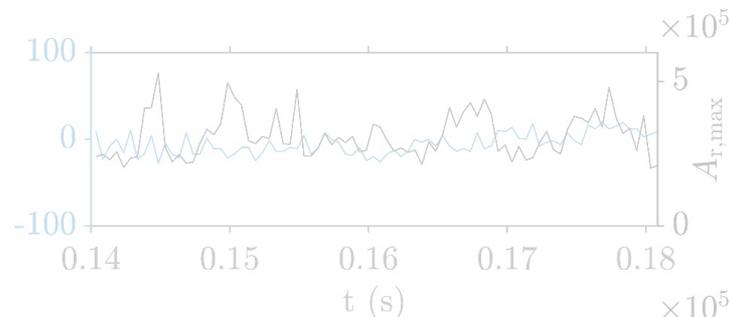
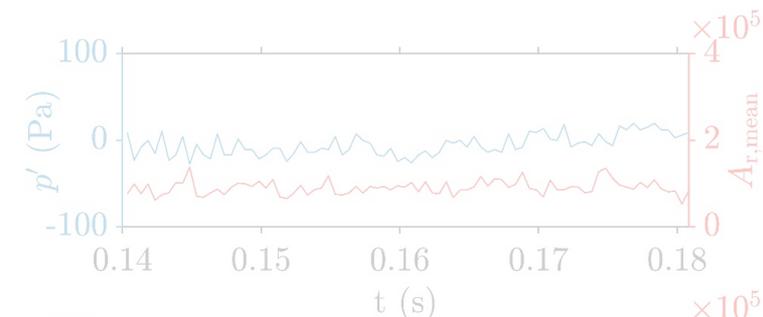
# Intermittency - maximum inter-community interactions captures the periodicity of acoustics during the periodic epoch



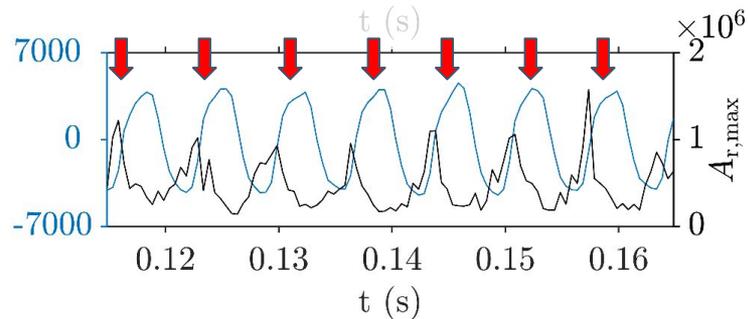
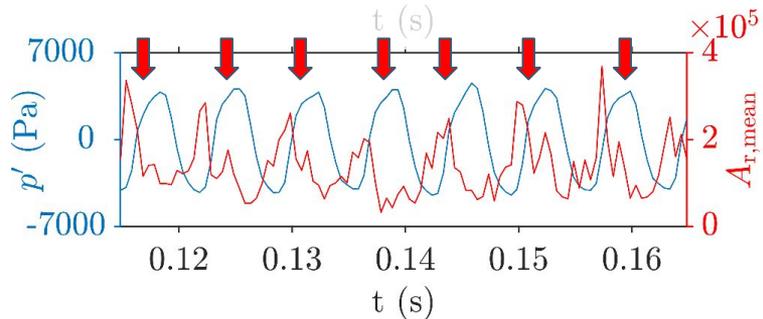
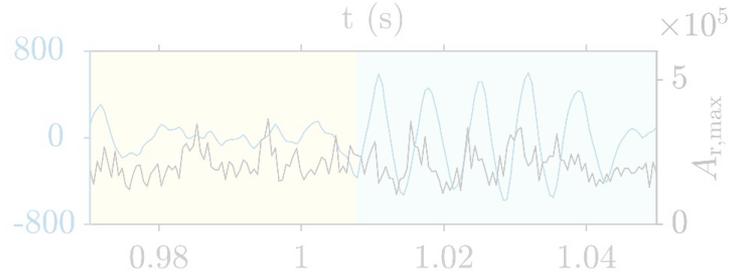
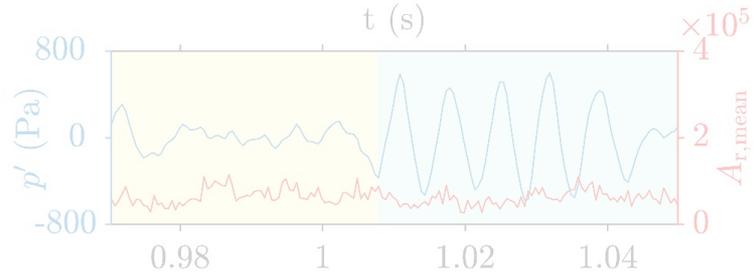
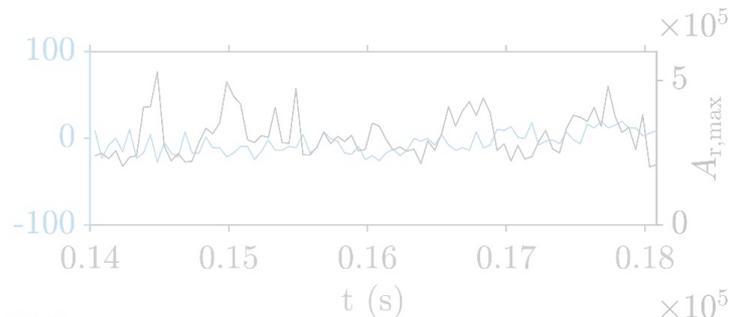
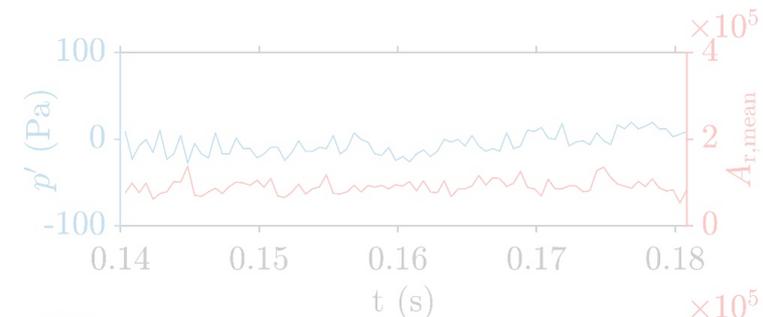
# Periodic epoch of intermittency - periodic emergence of vortices



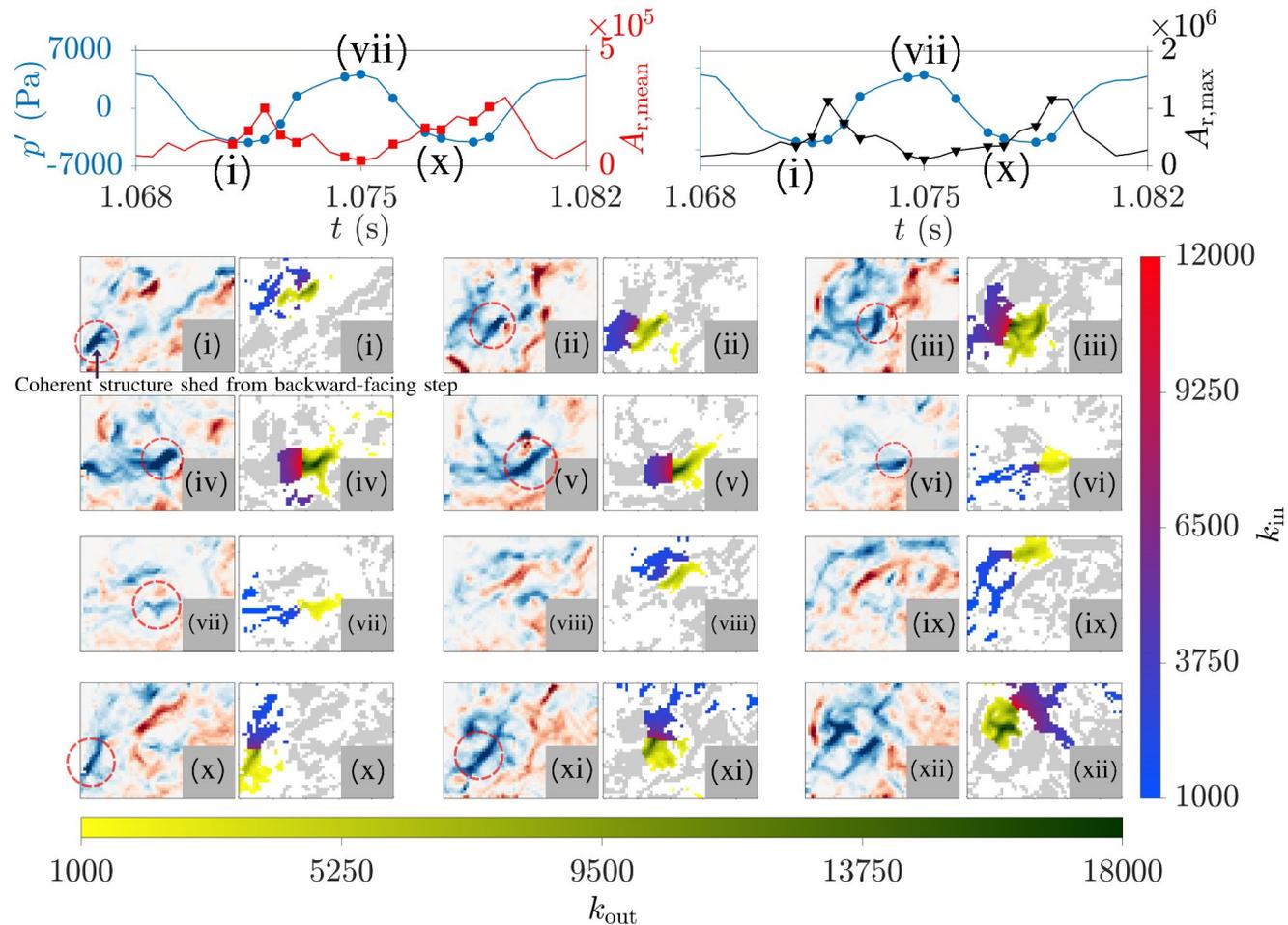
# Thermoacoustic instability - network measures are periodic



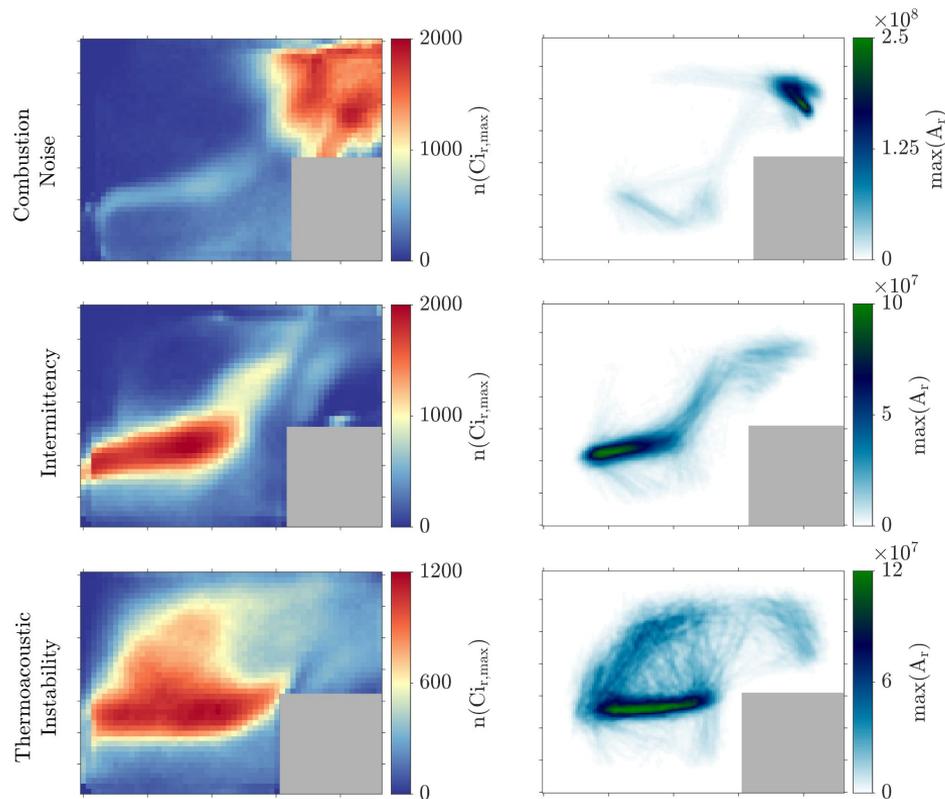
# Thermoacoustic instability - significant delayed correlation between acoustics and network measures



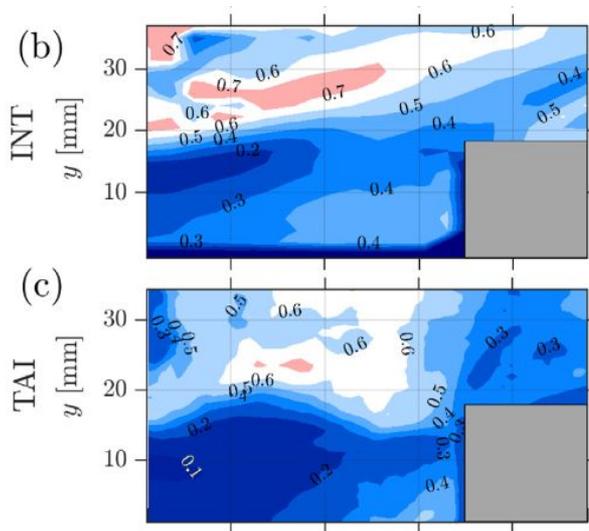
# Thermoacoustic instability - periodic dynamics of network measures



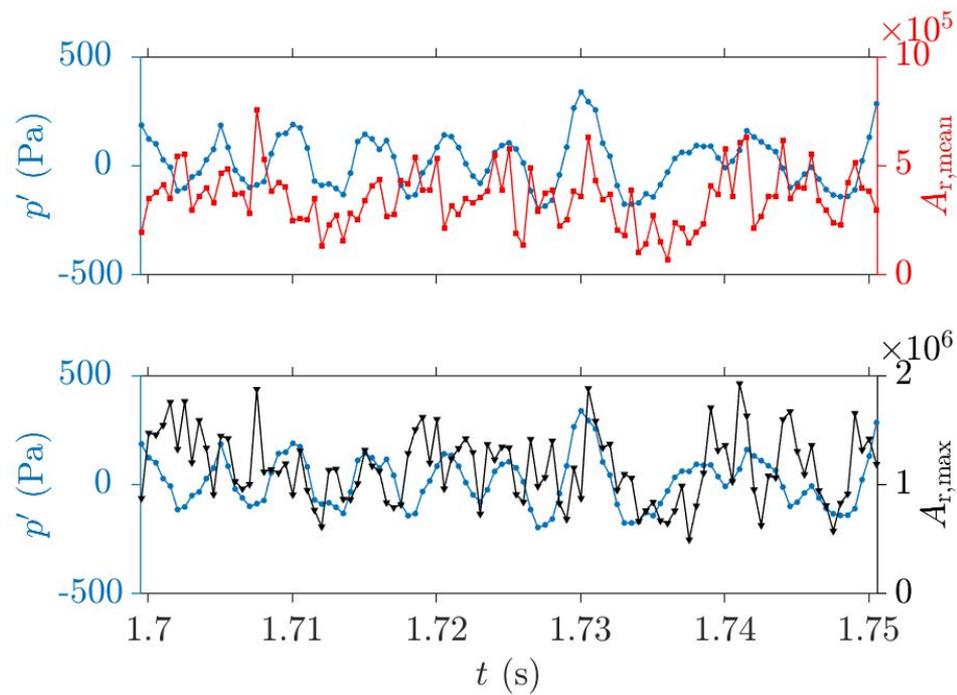
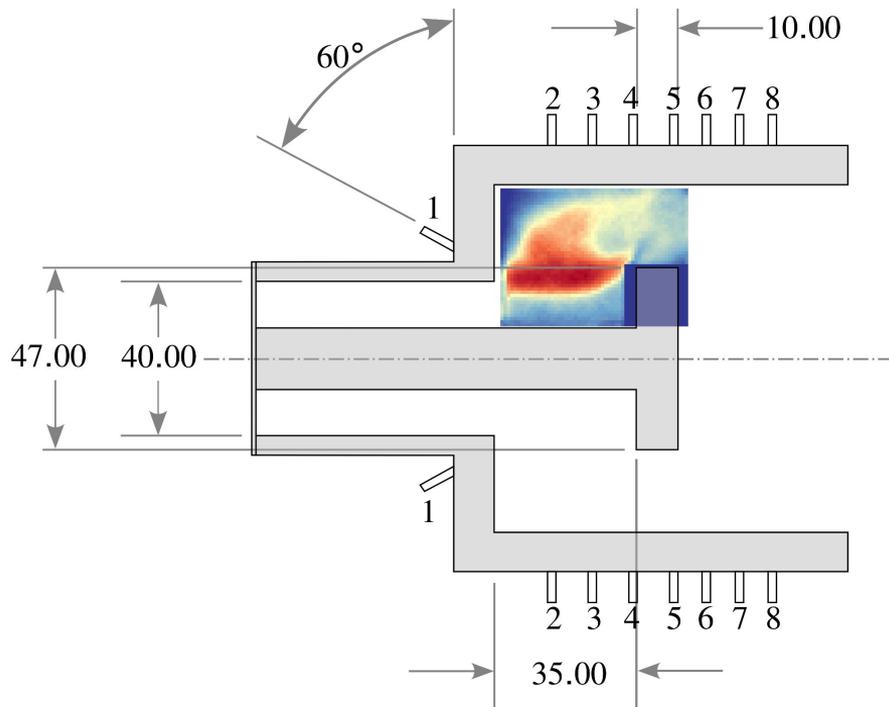
# Critical regions - probability distribution of communities with largest inter-community interactions



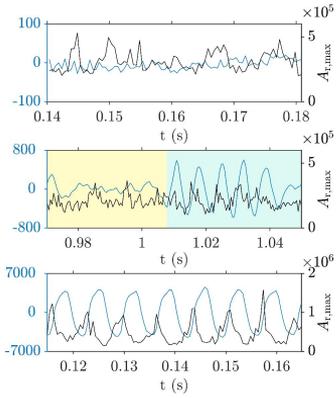
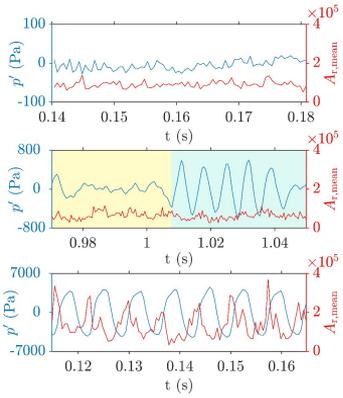
Hurst exponent (Roy et al.,  
Combust. Flame, 2021)



# Smart passive control - mitigation of thermoacoustic instability via air microjets

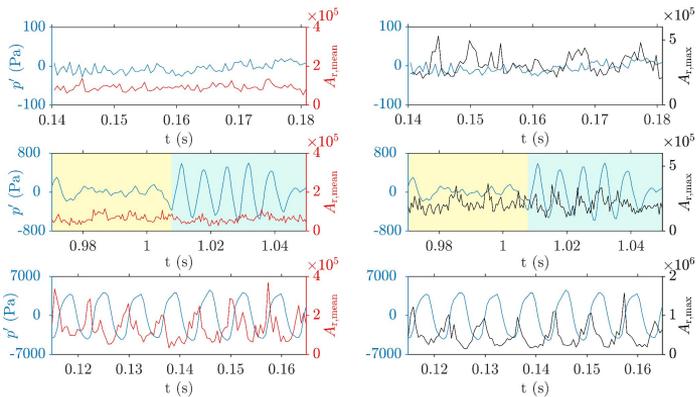


# Summary

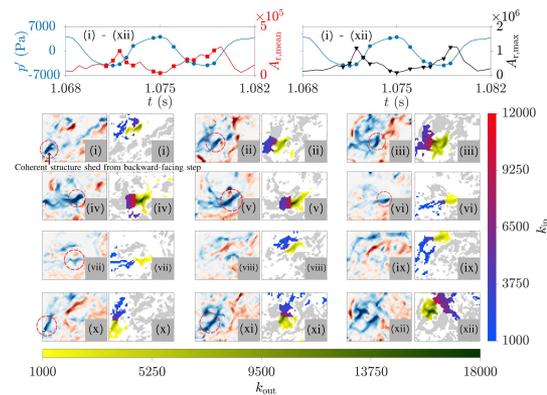


Interplay between  
vortical  
interactions and  
acoustics  
quantified via  
vortical network  
measures

# Summary

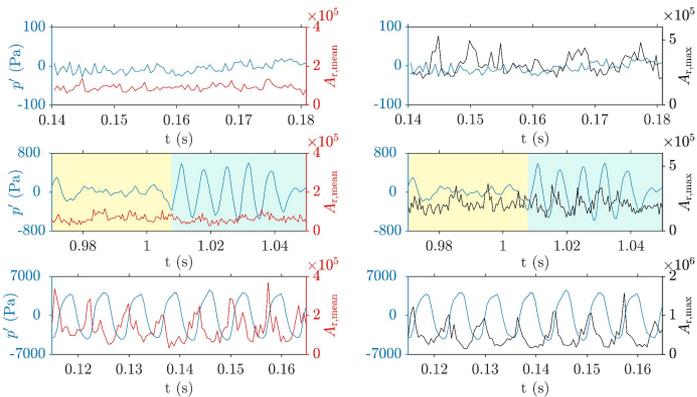


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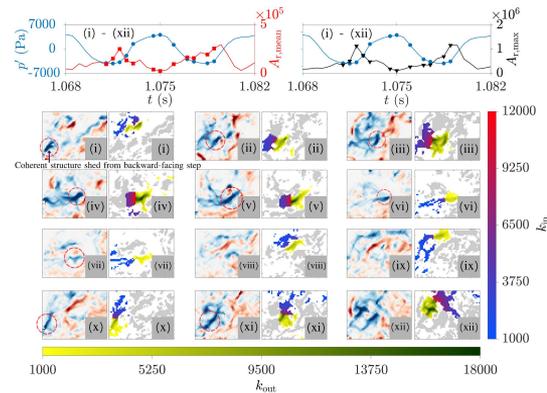


Temporal  
evolution of  
influential vortical  
communities in  
the reaction field  
of the combustor

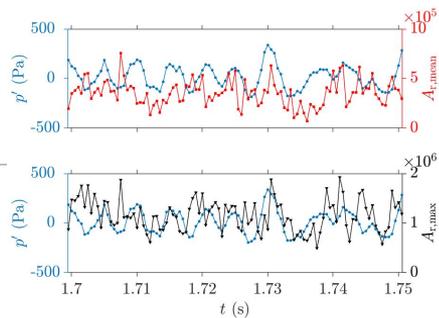
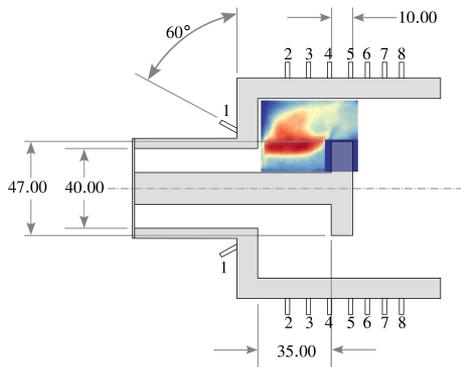
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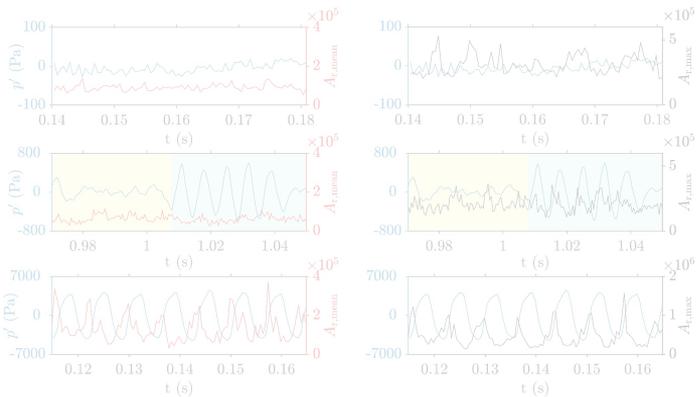


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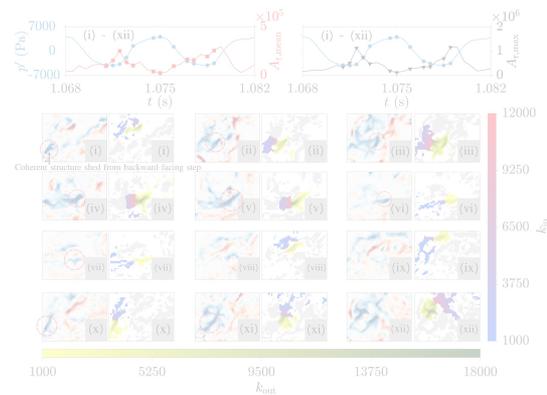


Significance toward control of thermoacoustic instability

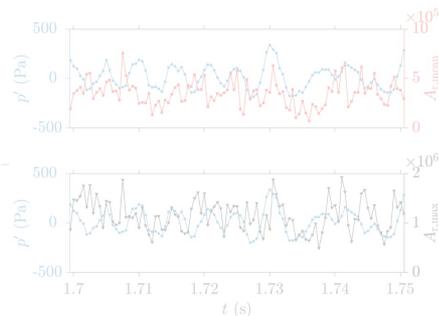
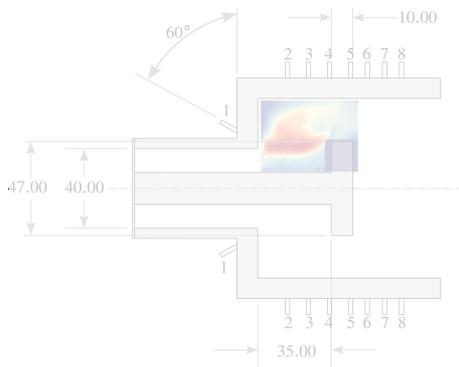
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Significance toward control of thermoacoustic instability

**Thank you**

arXiv:2311.12541

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