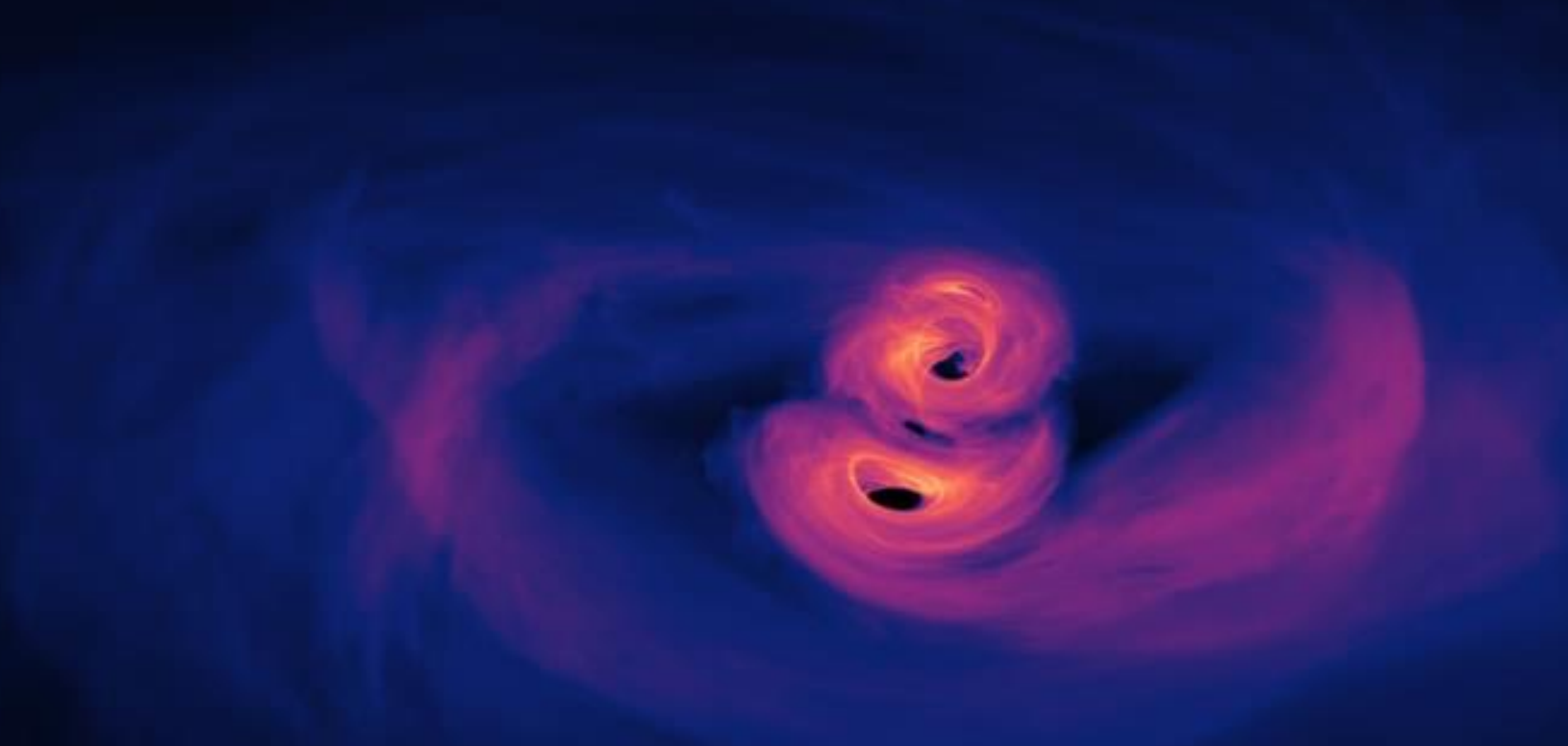


Anisotropy searches with pulsar timing arrays



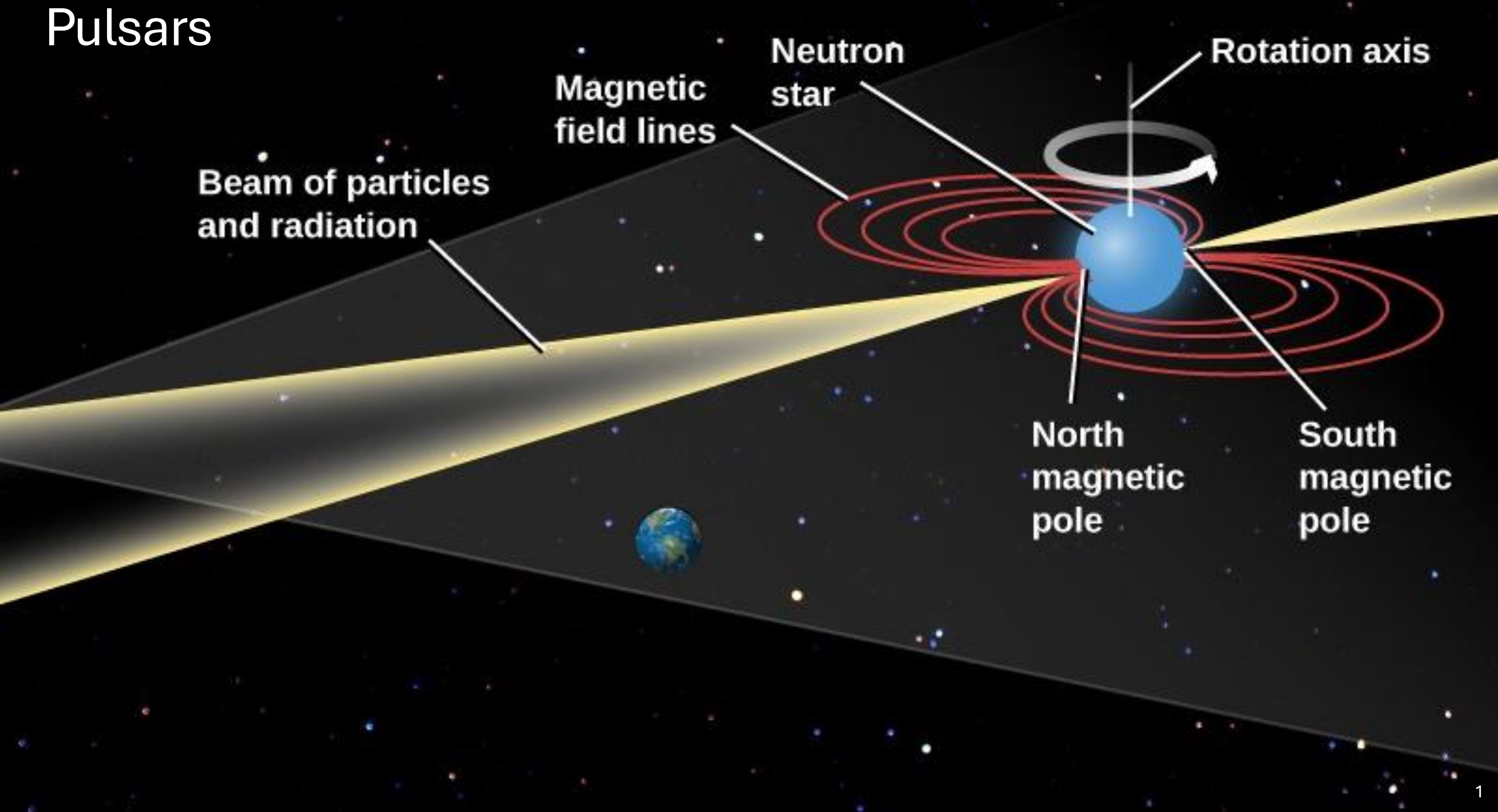
Anna-Malin Lemke

with Thomas Konstandin, Andrea Mitridate and Enrico Perboni

Cargese BSM summer school

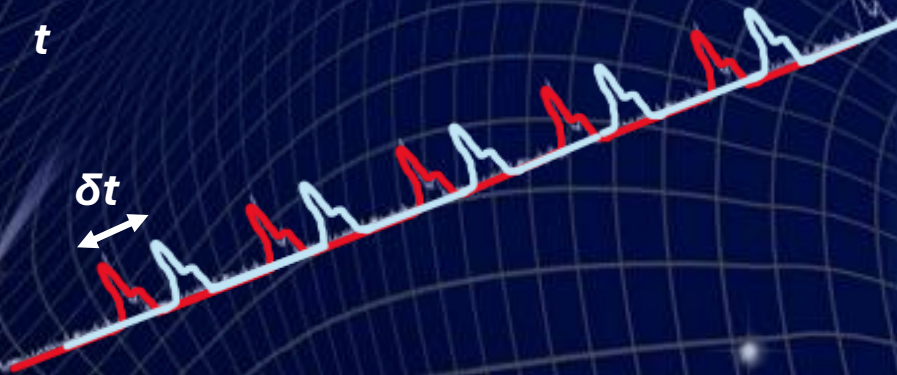
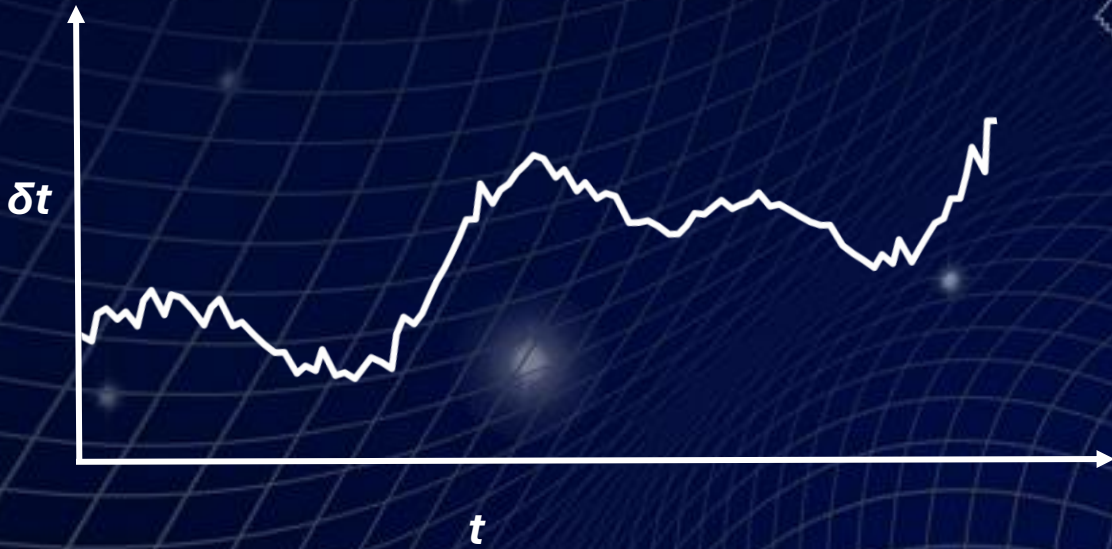


Pulsars

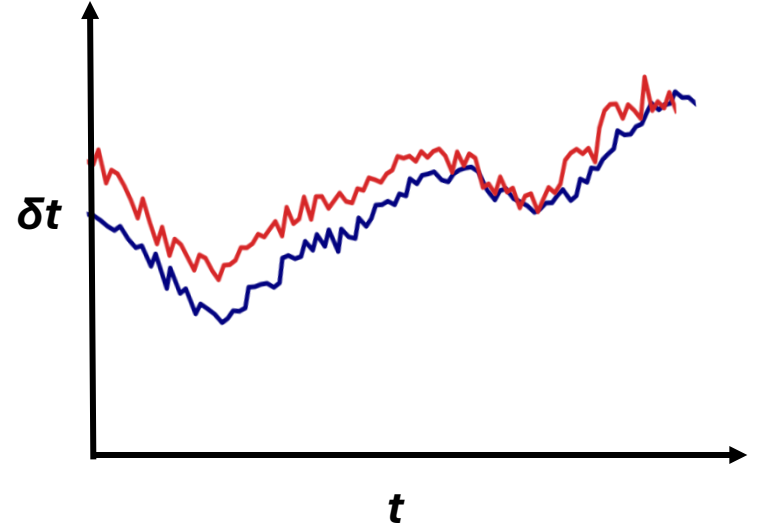
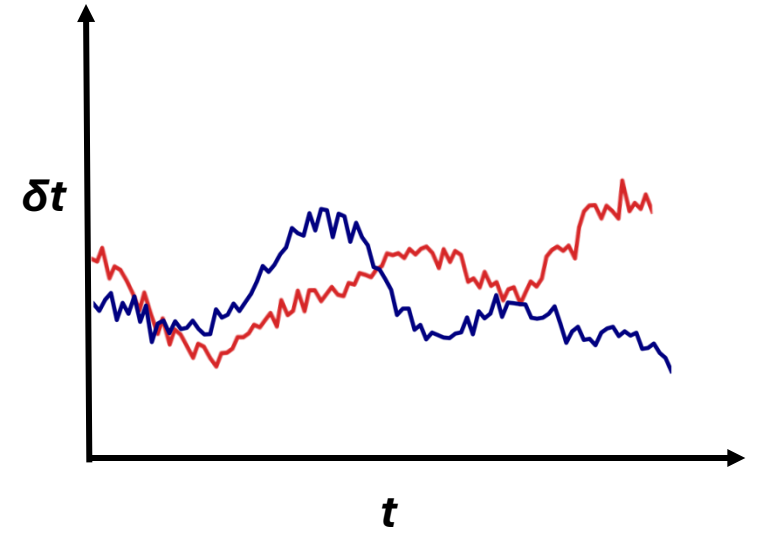
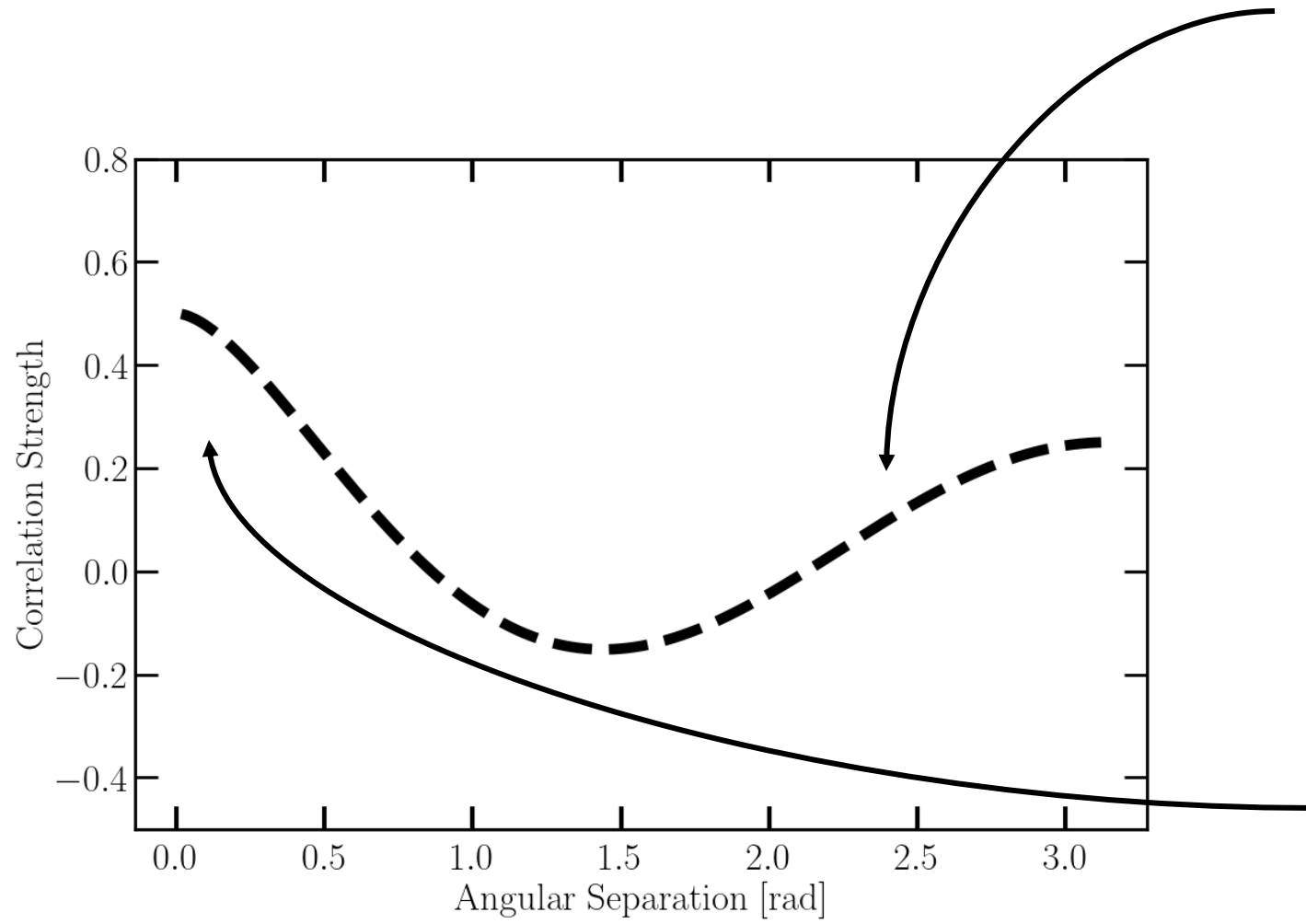


Pulsar Timing Arrays

timing residuals:



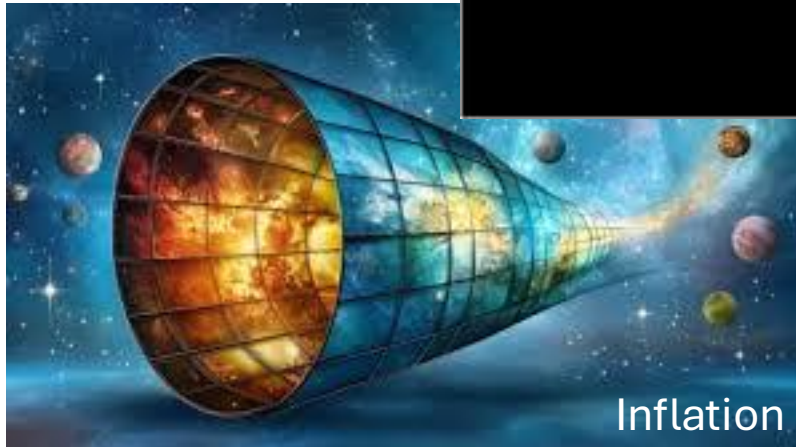
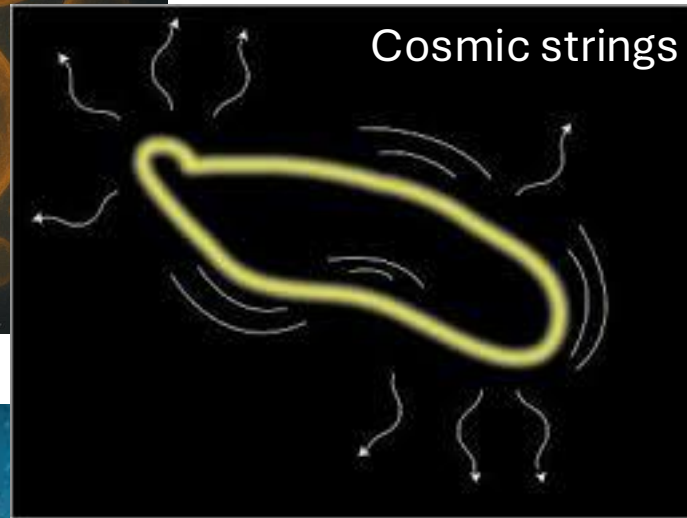
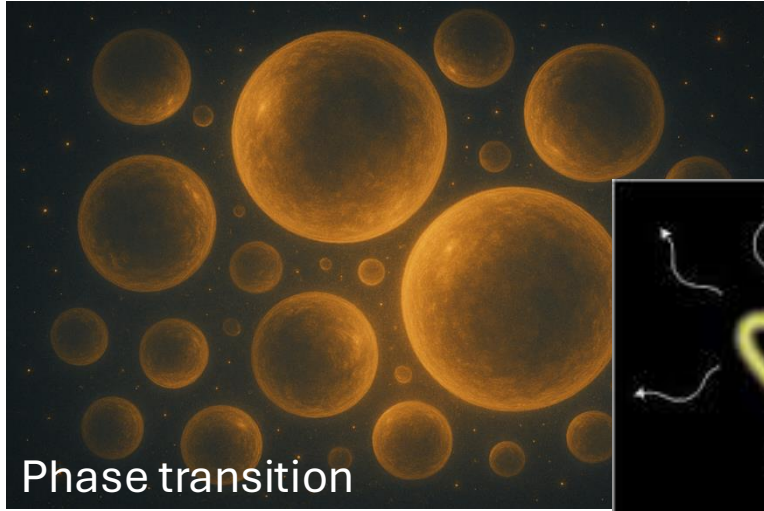
Pulsar pair correlations



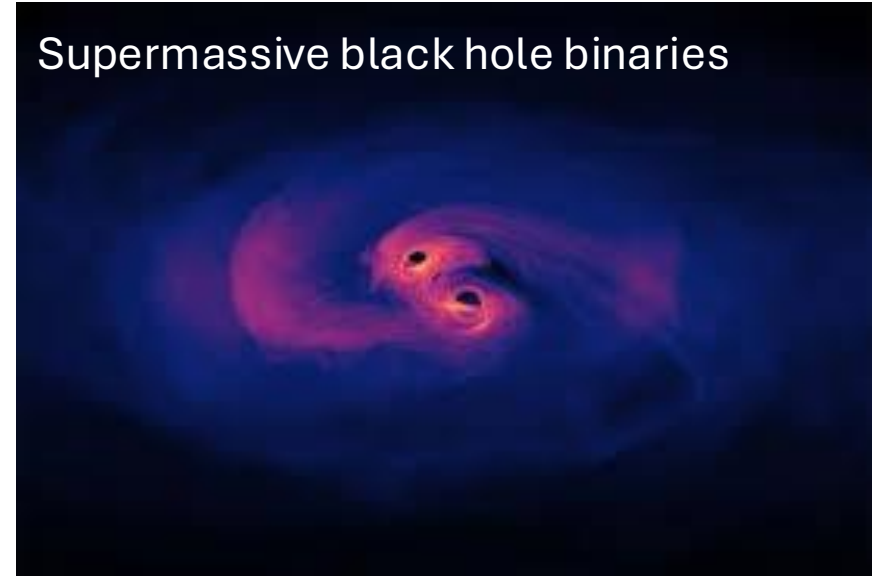
We have (evidence for) a background!



What is causing the signal?

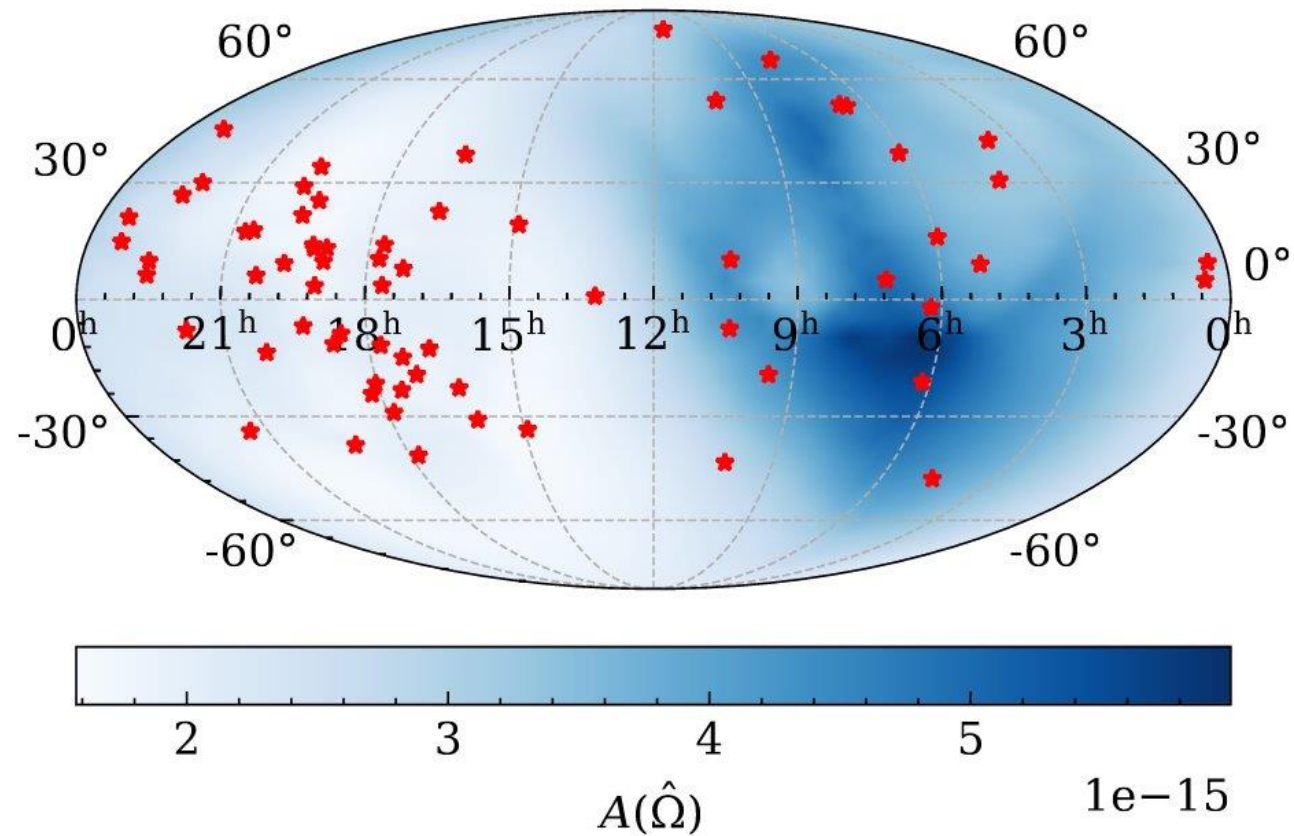


Supermassive black hole binaries



Anisotropy Searches

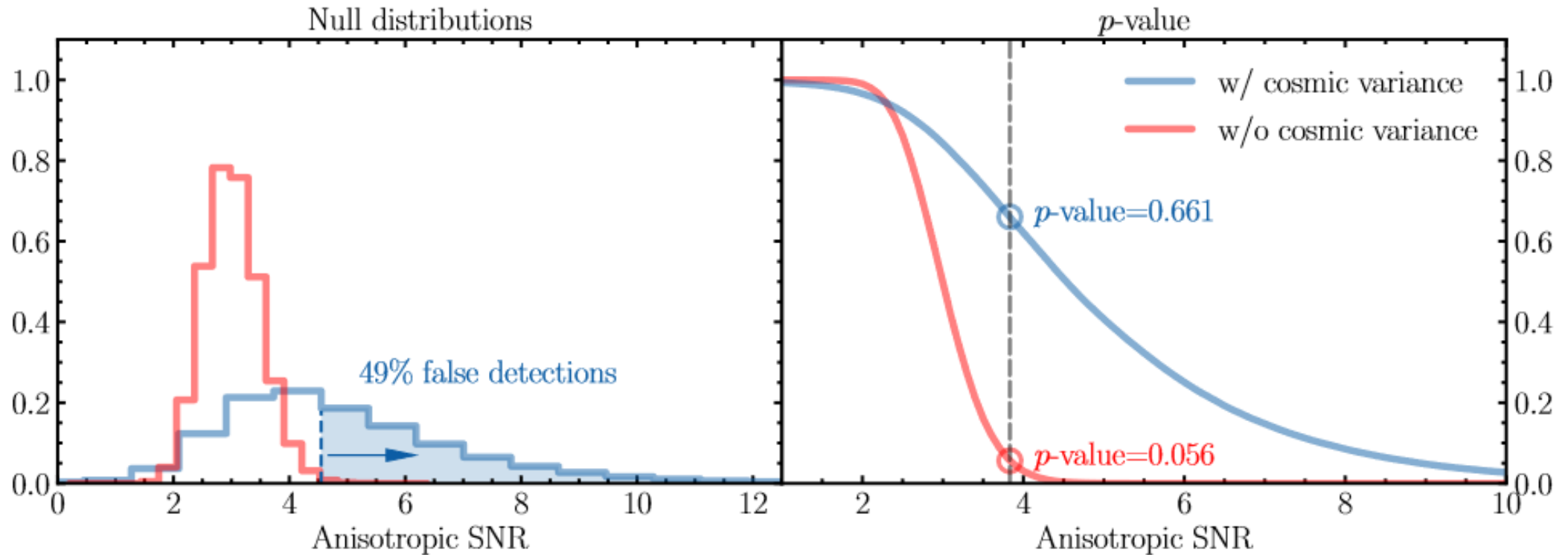
NANOGrav 15 year: Agazie et. al., 2306.16221



Right now: Null detection for anisotropies

Null distributions are important!

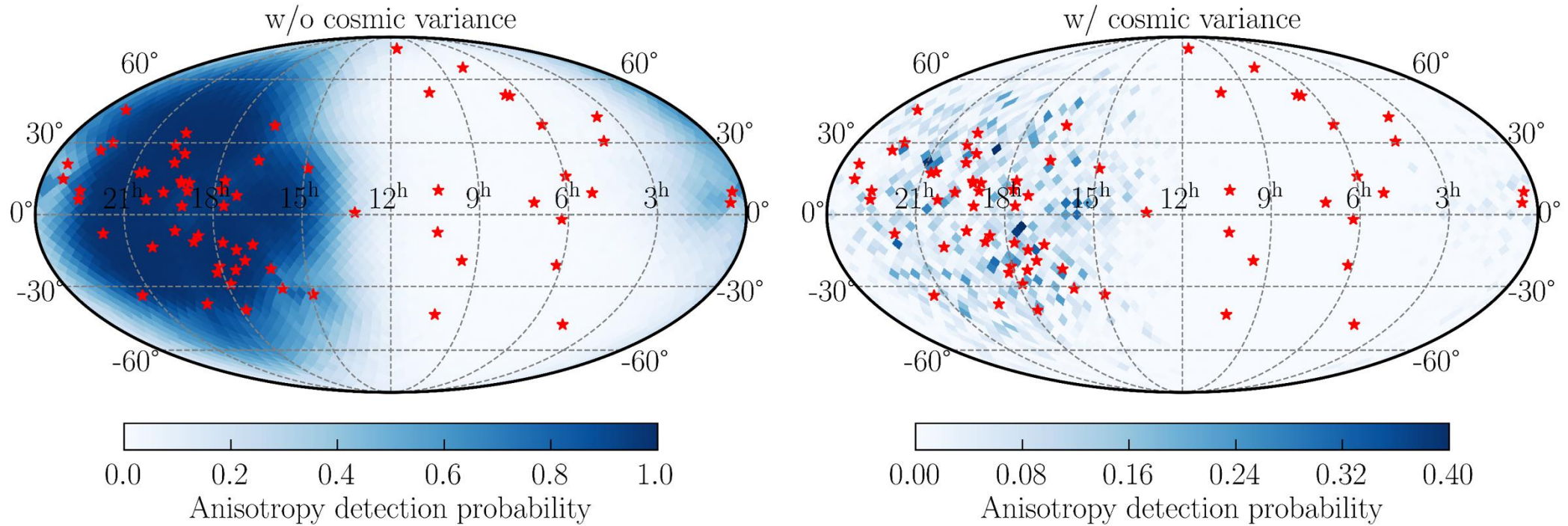
Konstandin, AL, Mitridate, Perboni: 2408.07741



Need to include interference effects between gravitational wave sources!

Detection Probabilities

Konstandin, AL, Mitridate, Perboni: 2408.07741



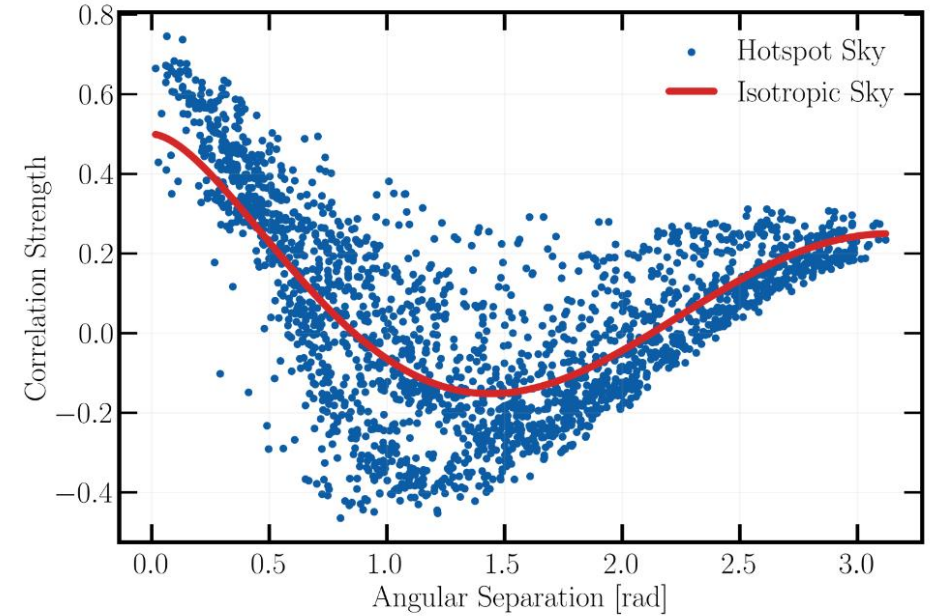
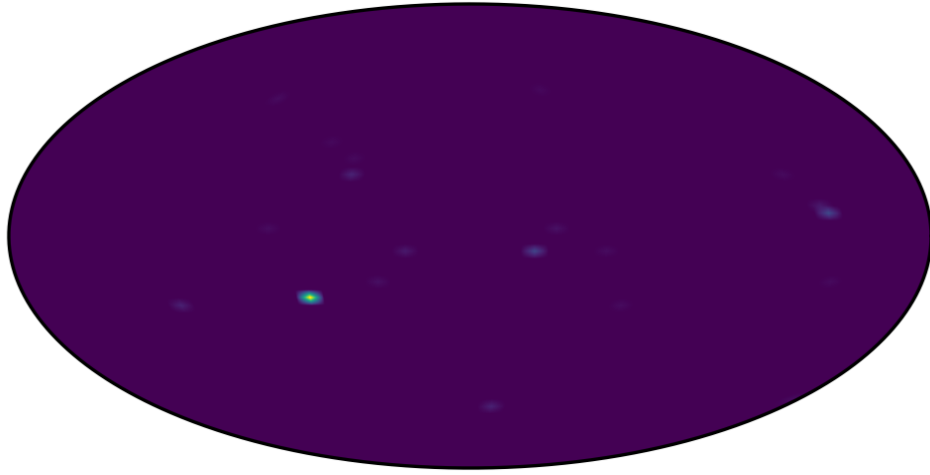
Detecting anisotropies is a lot harder than we thought

Thank you!

Questions?



SMBHB Anisotropies



$$\langle h_A^*(f, \hat{\Omega}_k) h_A(f, \hat{\Omega}_{k'}) \rangle \propto \delta_{kk'} P(\hat{\Omega}_k)$$



GW power in direction $\hat{\Omega}_k$

$$\langle \rho \rangle = \mathbf{RP}$$

$$R_{ab,k} \propto F_{a,k}^+ F_{b,k}^+ + F_{a,k}^\times F_{b,k}^\times$$



response of pulsar a to GW
from $\hat{\Omega}_k$ in +-polarization

Correlations 2.0

$$h_{kj}^A \rightarrow \text{const.}$$

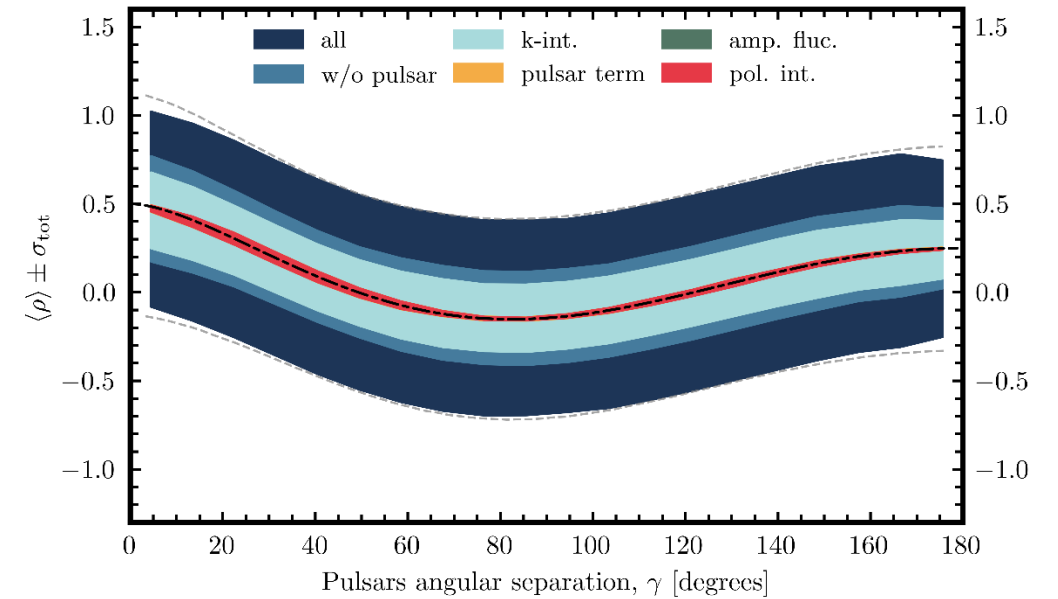
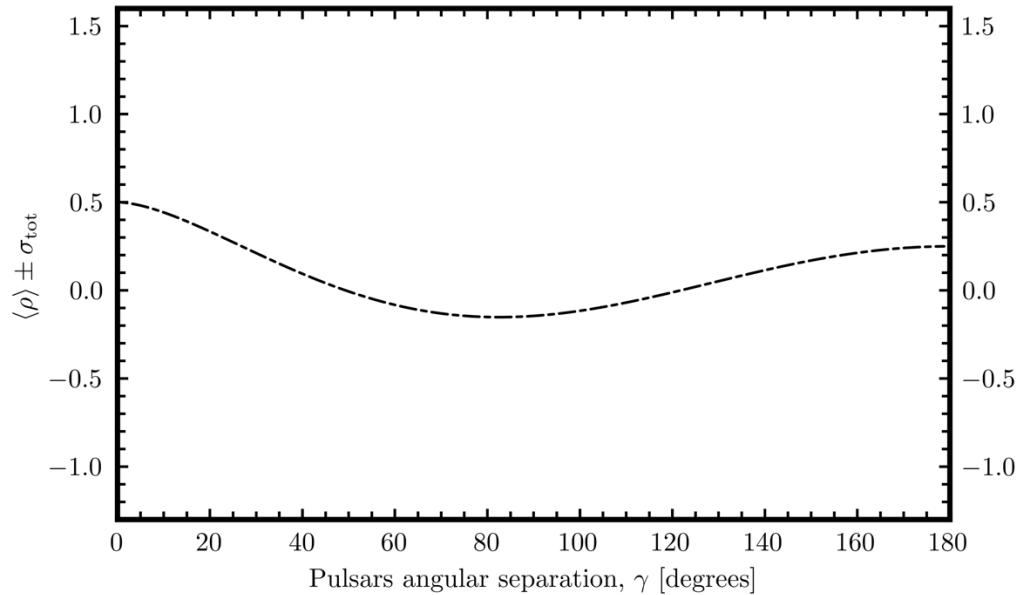


$$\left\langle h_{kj}^{*A} h_{k'j'}^{A'} \right\rangle \propto \delta_{kk'} \delta_{jj'} \delta_{AA'} H(f_j) P(\hat{\Omega}_k)$$

$$\rho \rightarrow \langle \rho \rangle = \mathbf{RP}$$



$$\rho_{ab} \propto \Sigma_{jj'} \Sigma_{kk'} \Sigma_{AA'} R_{akj}^{*A} R_{bk'j'}^{A'} h_{kj}^{*A} h_{k'j'}^{A'} \text{sinc}(\pi(j - j')) + \text{c. c.}$$



Tension with expectations?

AL, Mitridate, Gersbach: 2407.08705

Anisotropy searches on simulated data
from gravitational wave backgrounds
from black hole binaries

Null detection is fully in line with
expectations!

We can't say anything about early
universe sources yet :(

