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Posterior contraction under misspecification and heteroskedasticity in non-linear inverse problems

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In many practical and numerical inverse problems, the exact data log-likelihood is not fully accessible, motivating the use of surrogate likelihoods. We study heteroscedastic statistical nonparametric nonlinear inverse problems and establish posterior contraction results when inference is based on a surrogate log-likelihood constructed from proxy error variances and an approximate forward map. Under general assumptions on the approximation quality, we show that the resulting surrogate posterior is statistically reliable and contracts at rates comparable to those of the exact posterior. The analysis leverages consistency properties of the maximum a posteriori (MAP) estimator to effectively handle heteroscedastic noise and to control the impact of likelihood approximation errors. We apply the framework to PDE-constrained regression problems for a reaction–diffusion equation and the two-dimensional Navier–Stokes equations. In the latter case, we consider misspecified viscosity and forcing terms as well as Oseen-type linearization models, highlighting relevance for numerical analysis applications.

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