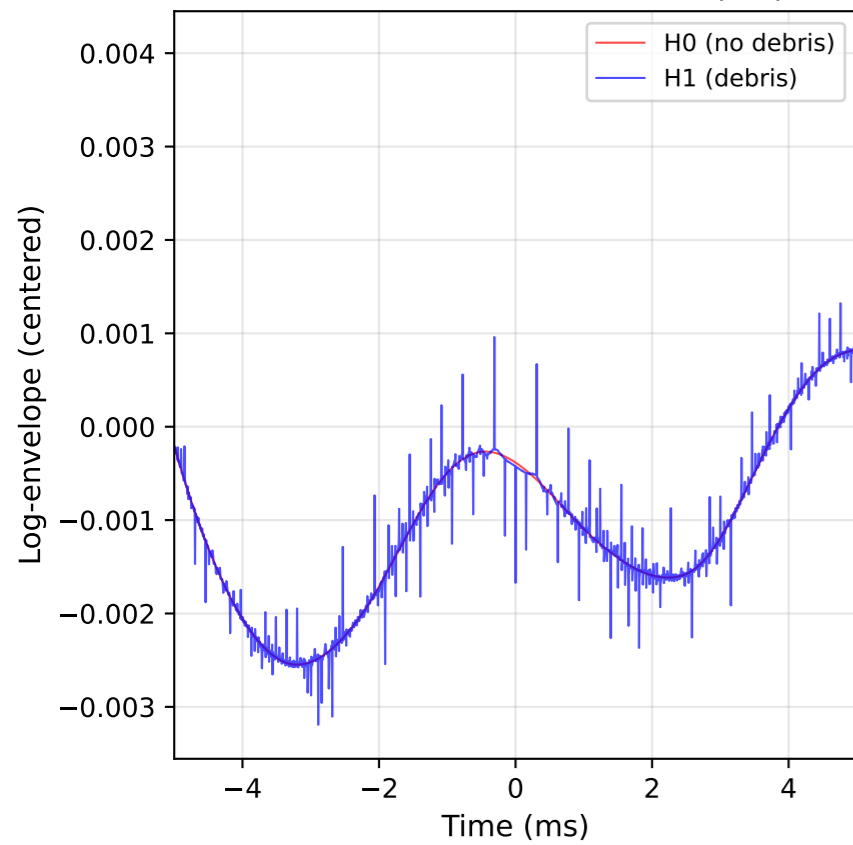
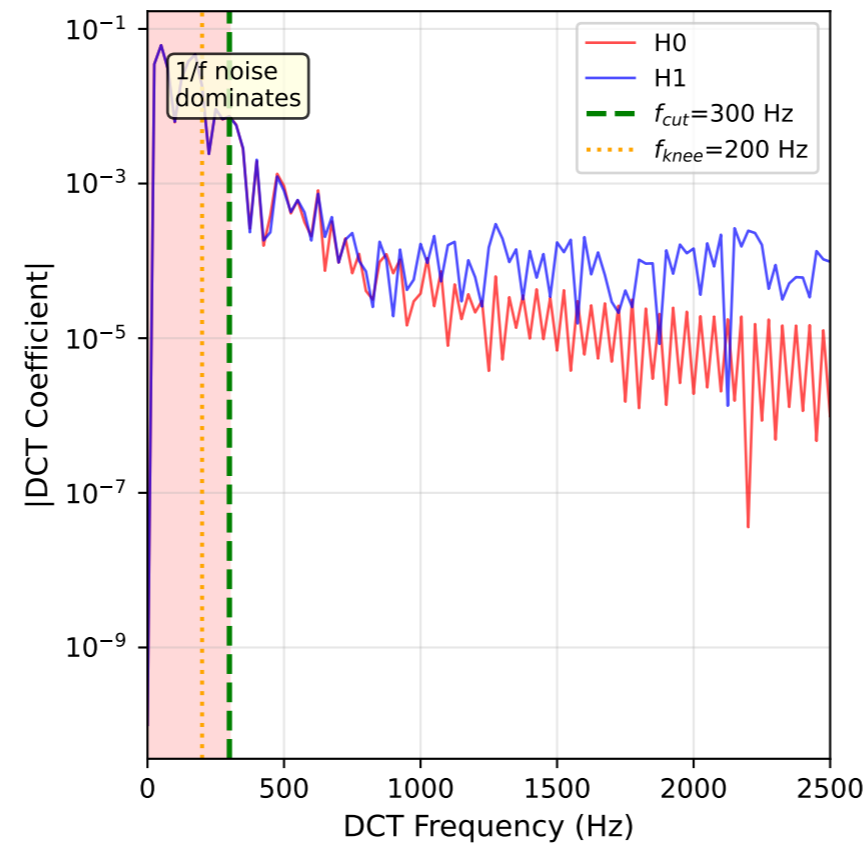
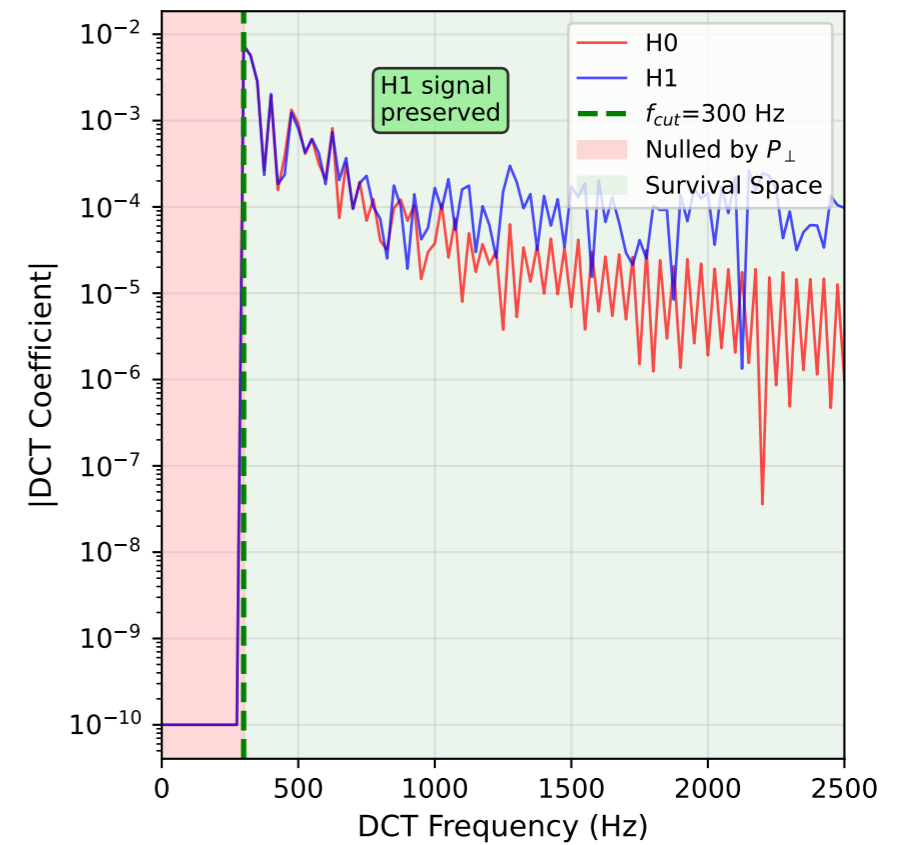
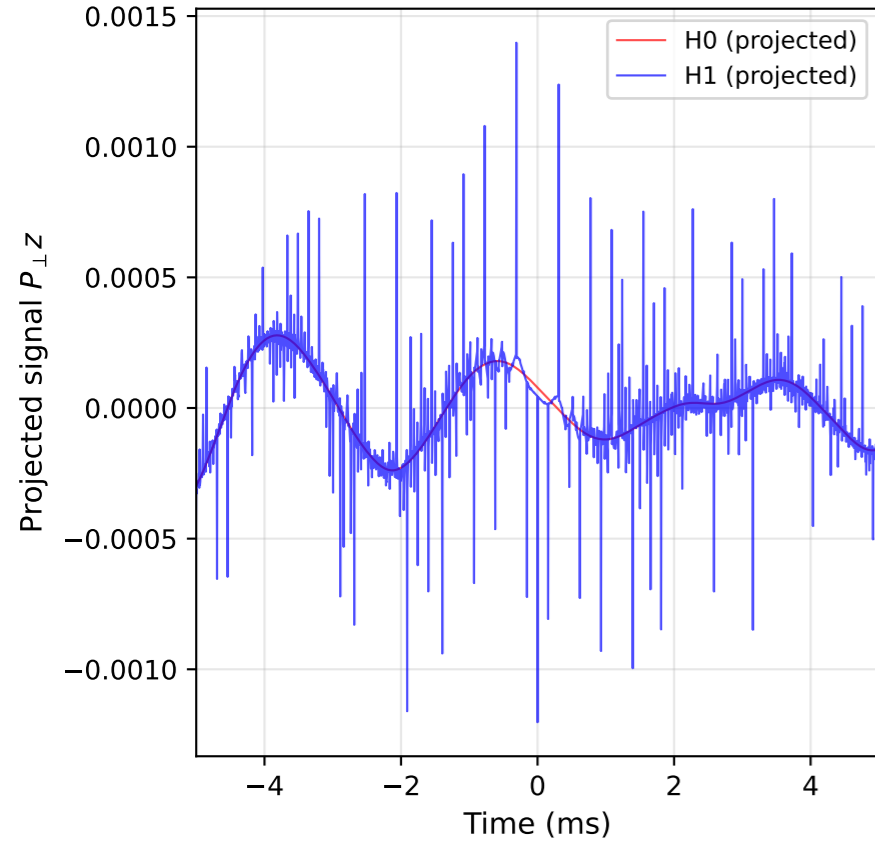
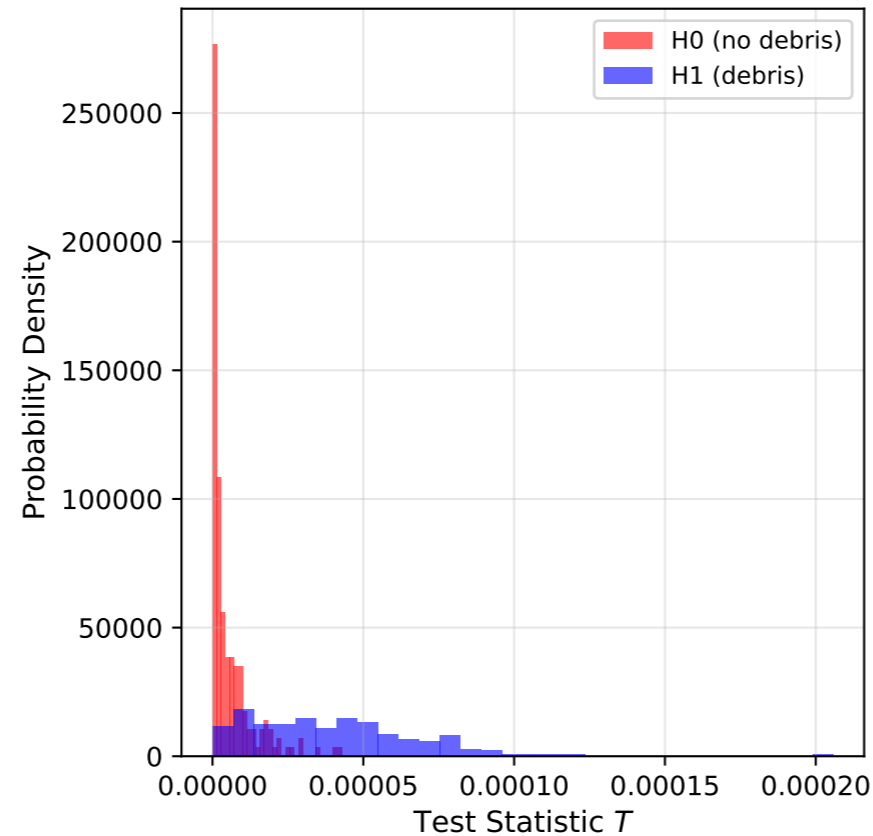


(a) Log-Envelope Signal $z(t) = \ln|r(t)|$ (b) DCT Spectrum Before P_{\perp} Projection(c) DCT Spectrum After P_{\perp} Projection

(d) After Projection: 1/f Noise Removed



(e) Detection Statistics (AUC=0.920)



(f) Design Summary

SURVIVAL SPACE DESIGN

Physical Parameters:

- Fresnel radius: $r_F = \sqrt{\lambda \cdot L_{eff}} = 4.47$ m
- Crossing time: $T_{cross} = 2r_F/v_{rel} \approx 0.60$ ms
- Signal bandwidth: $f_{max} \approx 1/T_{cross} \approx 1677$ Hz

1/f Jitter Noise:

- Knee frequency: $f_{knee} = 200$ Hz
- Power spectrum: $S_j(f) \propto 1/f^\alpha$ for $f < f_{knee}$

Design Choice: $f_{cut} = 300$ Hz

- 1.5 \times margin above $f_{knee} \rightarrow$ noise rejection
- 0.18 \times of $f_{max} \rightarrow$ signal preservation
- Energy retention: $\eta > 99\%$ for all v_{rel}

Key Result:

Projection P_{\perp} removes $>90\%$ of 1/f noise while preserving $>99\%$ of debris signal energy.