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The end of unexplained noise? A New Model for Noise in TESs

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As demanding applications such as x-ray spectroscopy push transition-edge sensors (TESs) to even better energy resolution, it is critical to understand all their potential noise sources. Since the early days of TESs, many groups have observed a broadband voltage noise that could not be explained by known noise mechanisms. In 2004, Ullom et al.[1] showed this unexplained noise could be suppressed using both device geometry and an applied magnetic field. However, despite more than a decade of effort, the magnitude of the unexplained noise in TESs is still not understood. Some progress was made in 2006 [2], when Irwin predicted an enhancement of the Johnson noise based on an analysis of non-linear bolometers near equilibrium. This analysis predicted that the noise level in a TES is equal to the Johnson noise due to the TES resistance at its operating point multiplied by a factor of $(1 + 2\beta_I)$. In some scenarios the (1+2β_I) term has reasonably predicted the amount of Johnson noise. In many other scenarios, especially low in the transition, and for devices with high α_I and high β_I, the $(1 + 2\beta_I)$ expression dramatically underpredicts the observed noise [3].

To resolve this mystery, we present a new noise model for TESs that takes into account their junction nature and the shape of the $R(I, T)$ surface. We present analytical expressions for the unexplained noise within the context of the RSJ and two-fluid models. We also present an expression for the unexplained noise for an arbitrary $R(I, T)$ surface. We then compare these expressions with the measured noise in different TESs and at different operating resistances. Initial testing shows good agreement between measurement and theory.

[1] Ullom, Joel N., et al., Appl. Phys. Lett., 84 (2004) 4206.

[2] Irwin, Kent D., Nucl. Instrum. Methods Phys. Res. A, 559 (2006) 718.

[3] Jethava, Nikhil, et al., AIP Conference Proceedings., 1185 (2009) 31.

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