Possibility of a new level of space debris identification and tracking by MKIDs

Initial simulation results-Incident photons at the Earth

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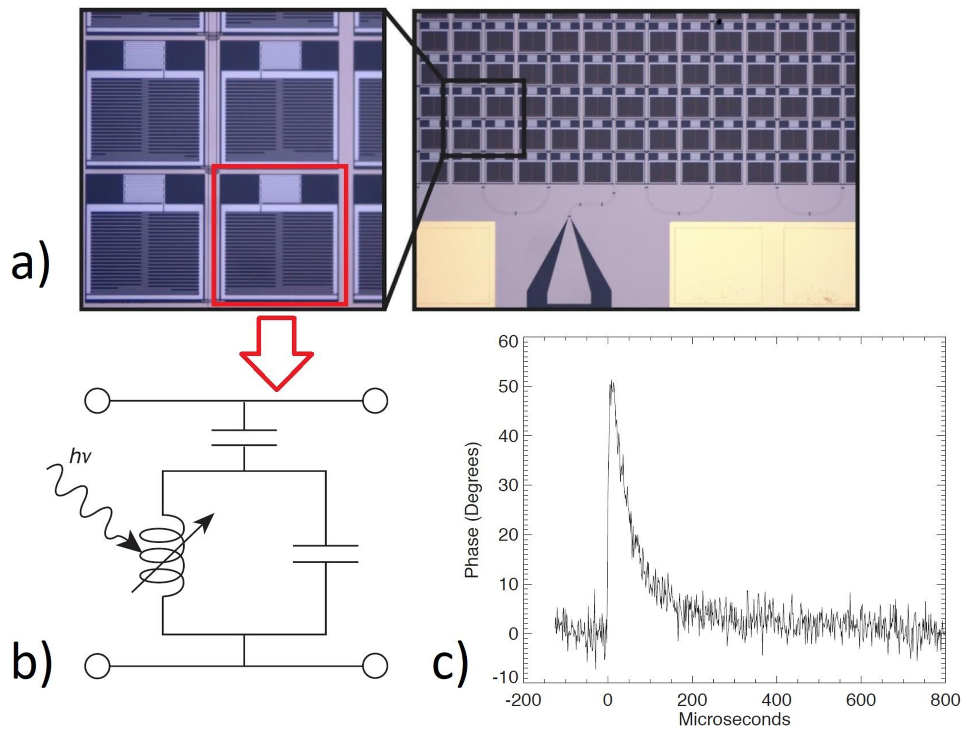
What are MKIDs?

A single photon spectrally resolving detector.

- MKIDs (Microwave Kinetic Inductance Detectors) are the most powerful photon detectors on the pixel-by-pixel basis [1].
- Each pixel in an MKID array is a tuned superconducting LCR circuit.
- They measure the incidence of a single photon by the changes on the surface impedance of a superconductor through the kinetic inductance effect [2].

Figure 1.*



*images courtesy of B. Mazin

a) Photo of an MKID array and zoomed in pixels.
b) Equivalent circuit for an MKID pixel
c) A pulse produce by a single photon incident on an MKID pixel

Question: Can an MKID array offer unprecedented detectability of space debris

Modelling the MKIDs spectral response and output signal

The MKIDs output can be defined as the intensity of the photon counts:

$$I_N(\lambda) = \sum_{\substack{\lambda_0=\lambda_i \\ \sigma_0=\sigma_i}}^{\substack{\sigma_0=\sigma_n \\ \lambda_0=\lambda_n}} f(\lambda|\lambda_0,\sigma_0).N(\lambda_0)$$

σ_0 : standard deviation in the output signal based on the MKIDs resolution.

$N(\lambda_0)$: number of detected photons in each wavelength.

$f(\lambda|\lambda_0,\sigma_0)$: function which describes the MKIDs response to each wavelength across the spectrum in terms of a Probability Density Function.

Modelling of the space debris signal

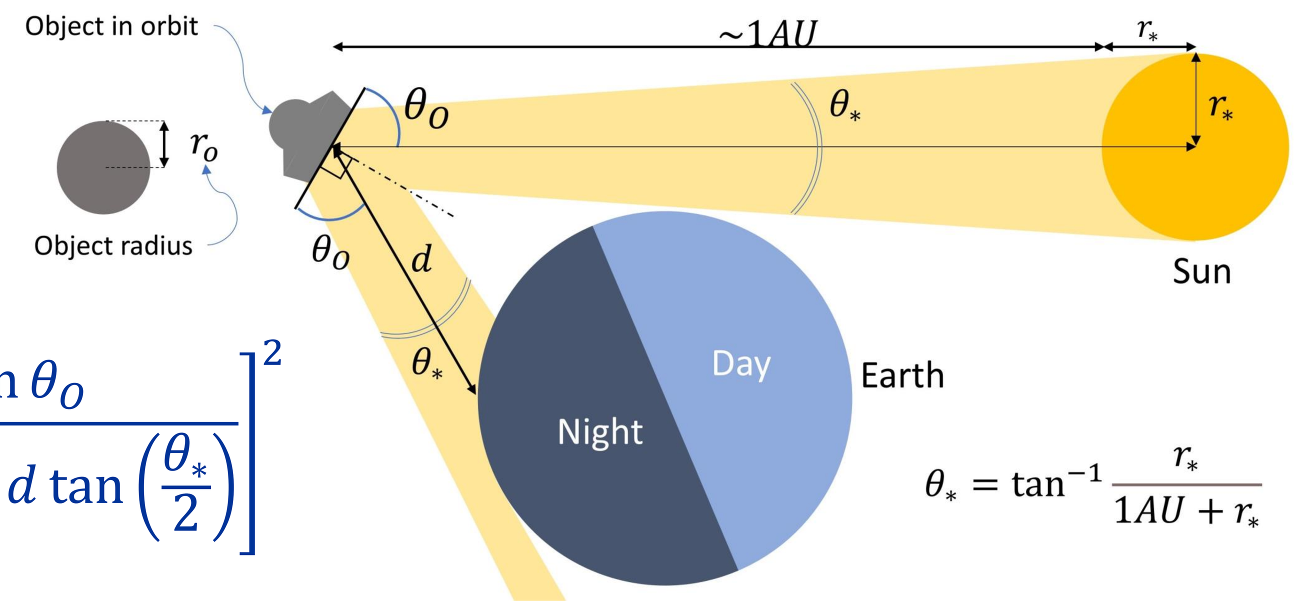
The received signal can be defined as the intensity of the photon flux:

$$I_s = I_* f(d, r_o, \theta_O).F_a$$

I_* is the intensity of the sunlight as it hits the object.

F_a is the attenuation factor which is a combination of all the other elements that might affect the signal. This is considered as 1 in the initial modelling and simulation presented here.

Figure 2.



$$f(d, r_o, \theta_O) = \left[\frac{r_o \sin\theta_O}{r_o \sin\theta_O + d \tan\left(\frac{\theta_*}{2}\right)}\right]^2$$

Notice: the detectable angle for a ground- based system is 45° to 90°.

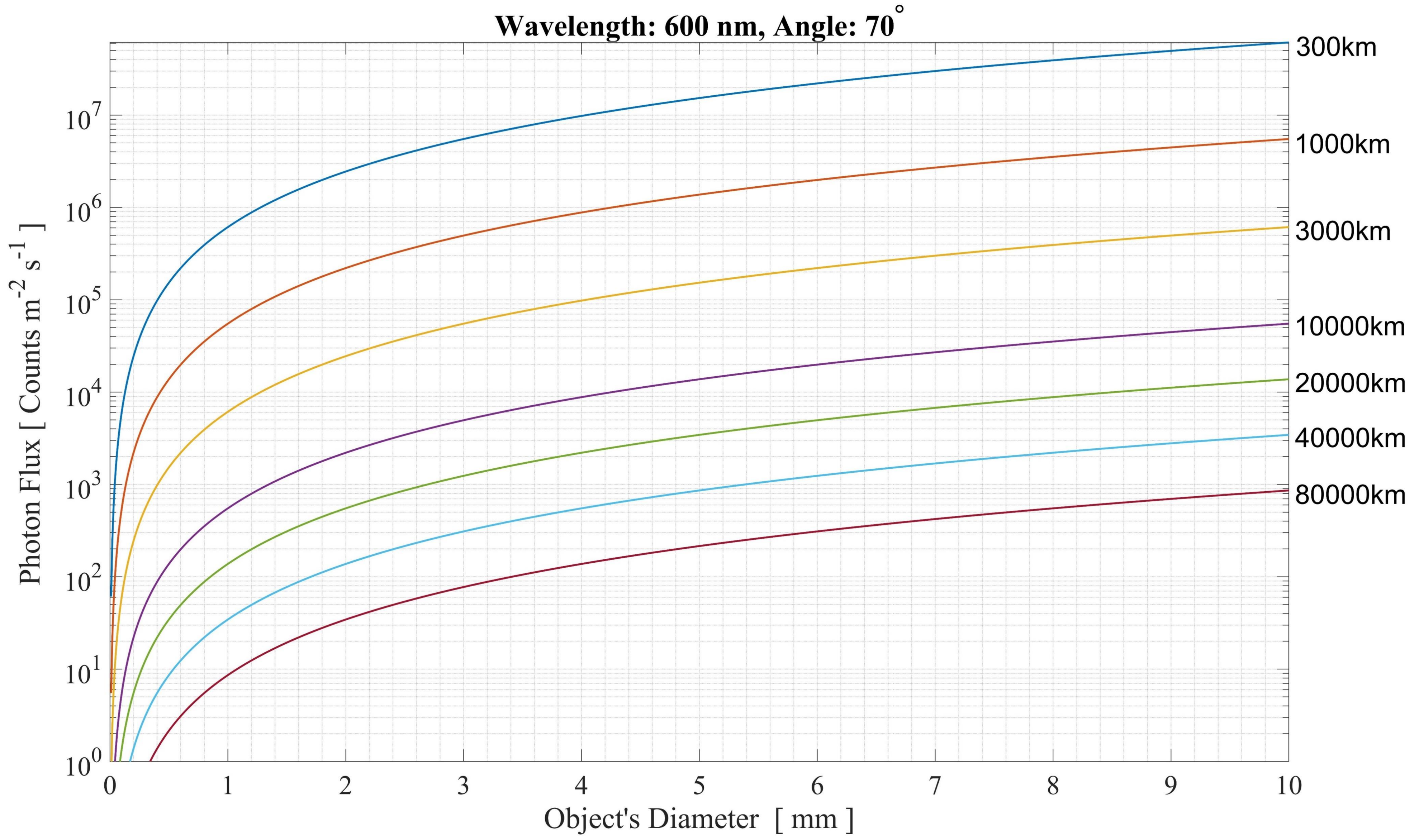


Figure 3. Photon counts (incident on the Earth surface) at the wavelength of 600 nm for objects with sizes up to 1cm at multiple altitudes with a Sun angle of 70°.

Initial simulation results - Incident photons at the Earth

(assuming 100% reflectivity & no atmospheric attenuation)

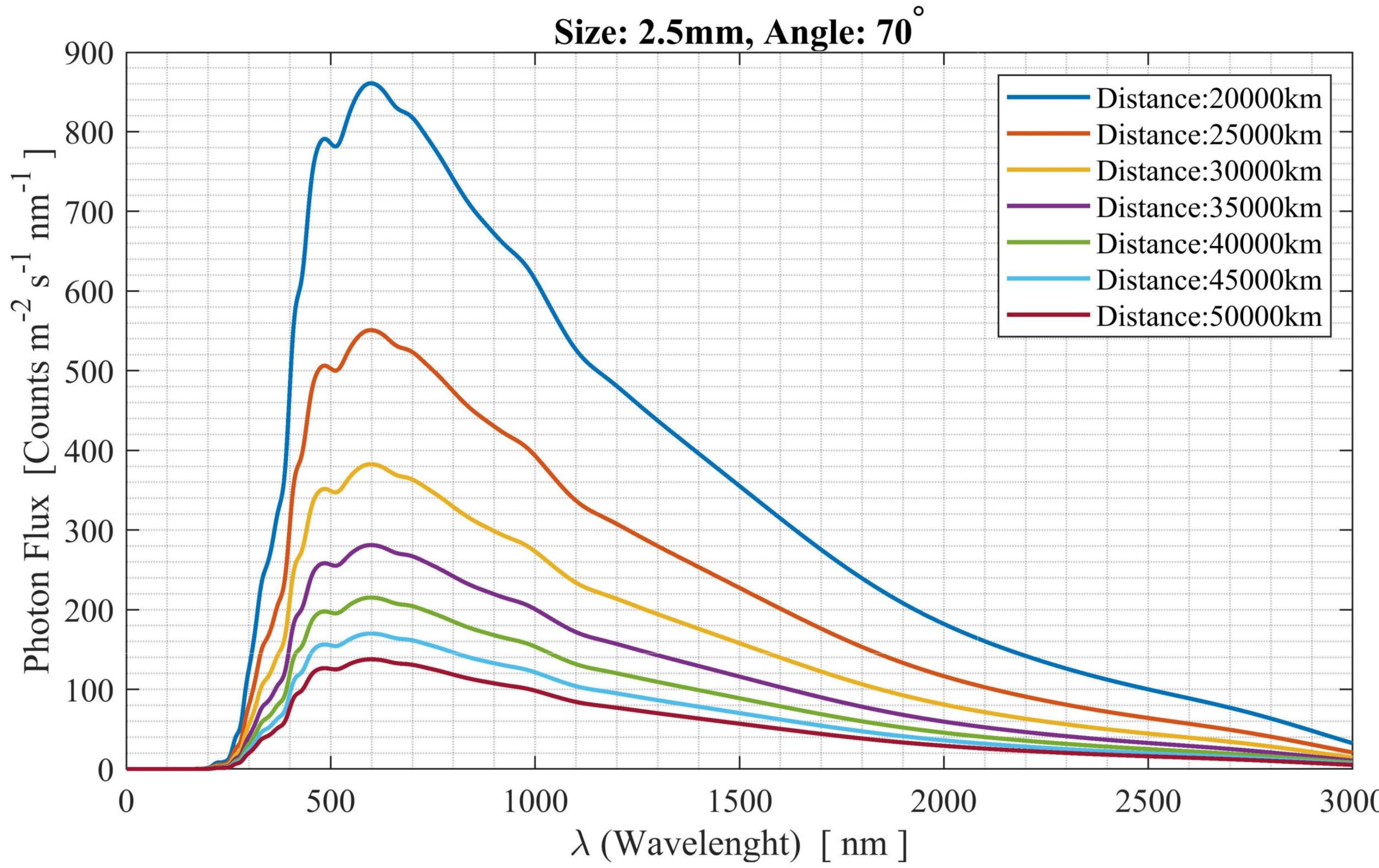


Figure 4. An example of a simulated MKID output for space debris signals, based on the initial model for an ideal situation.

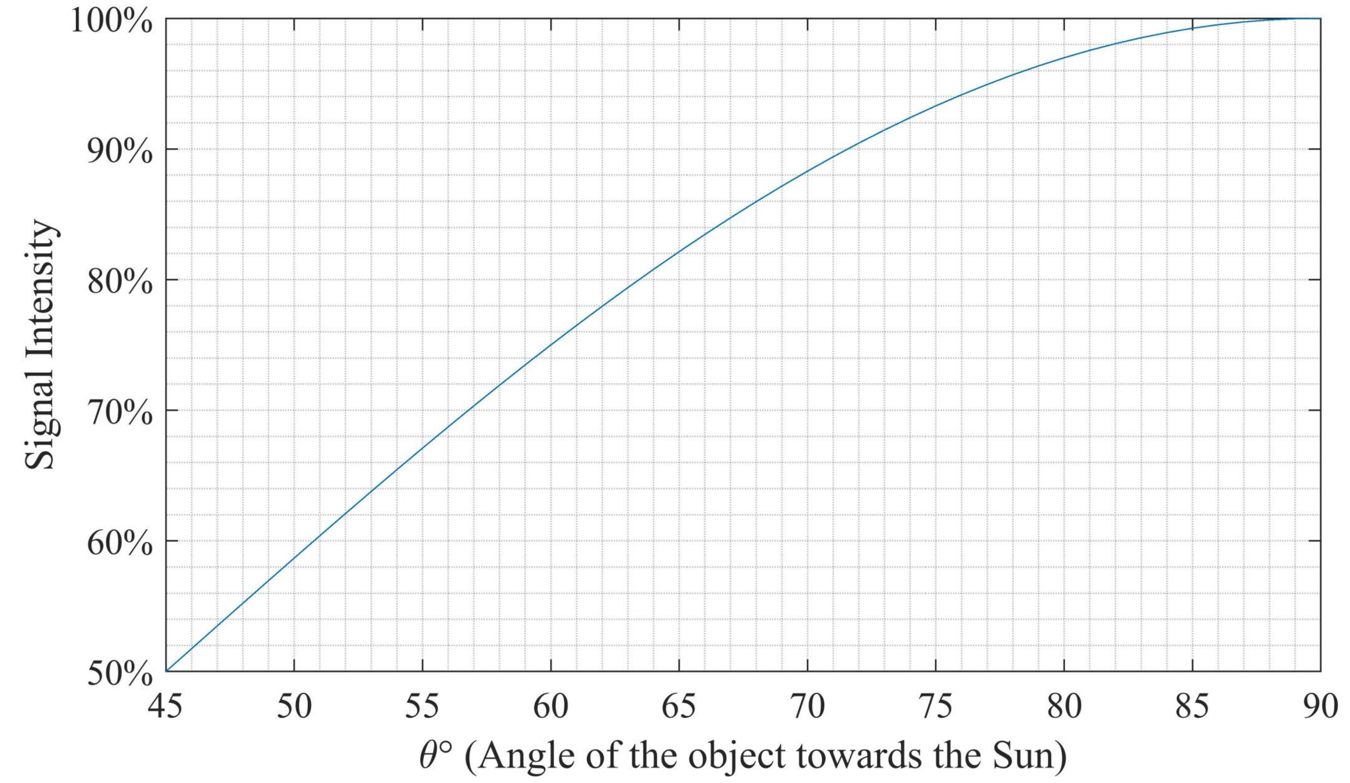


Figure 5. The variation of the intensity of the received signal from a piece of debris based on its angle towards the Sun.

Next phase of project

Improving the model by the inclusion of

- Atmospheric attenuation
- Sky photon background
- Spectral reflectivity of debris materials

References

1. Mazin, B. A., 2018. KRAKENS: a general purpose MKID integral field spectrograph for the Keck I telescope. Austin, Texas, United States, SPIE.
2. Mazin, B. A., 2004. Microwave Kinetic Inductance Detectors. Pasadena, California: California Institute of Technology.