

# Possibility of a new level of space debris identification and tracking by MKIDs (Microwave Kinetic Inductance Detectors )



## MSSL

### Mullard Space Science Laboratory

Saeed Vahedikamal

Potential use of Microwave Kinetic Inductance Detectors (MKIDs) in space debris identification and tracking

Prof Ian Hepburn

Possible application of hyperspectral imaging to space debris identification and tracking (at 17:15)

Based in the Surrey Hills near Dorking



# Objectives for using MKIDs?

- **Detecting objects of smaller sizes (less than 10Cm)**
- **Detecting objects in higher orbits (GEO)**
- **Cataloguing objects using their unique spectral features (hyper spectroscopy)**

## What are MKIDs?

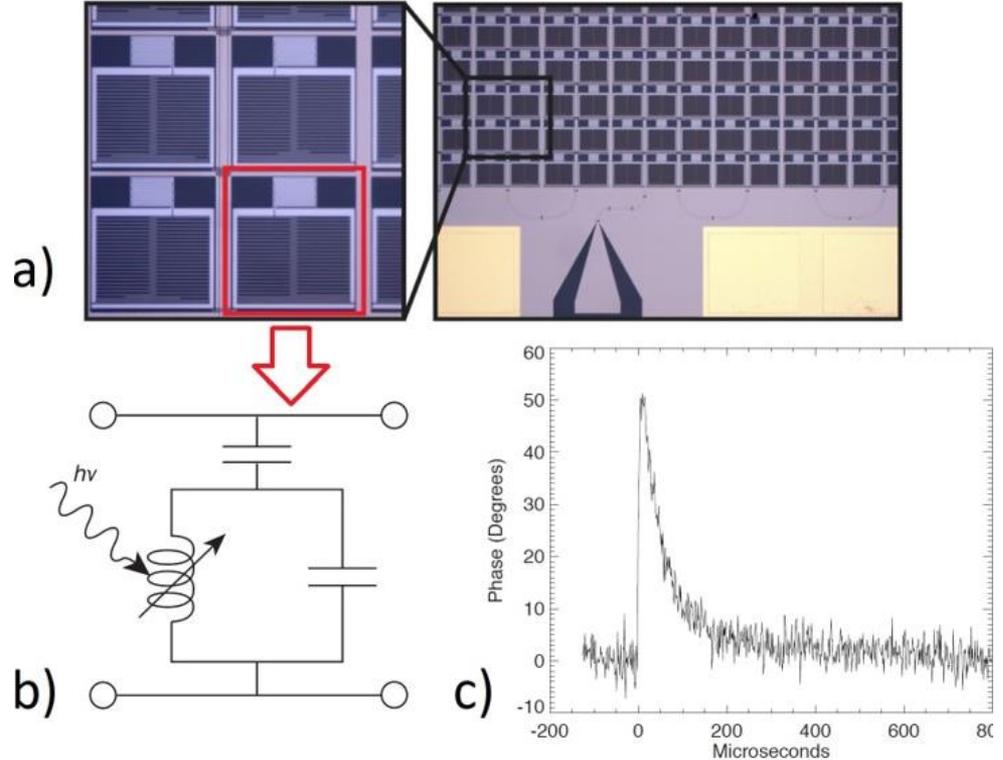
**A single photon spectrally resolving detector.**

- **MKIDs (Microwave Kinetic Inductance Detectors) are the most powerful photon detectors on the pixel-by-pixel basis.**
- **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.**

# What are MKIDs?

## Principles of Operation

- 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



## Modelling the MKIDs spectral response and output signal

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

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

$\sigma_0$ : 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 (An Ideal Scenario)

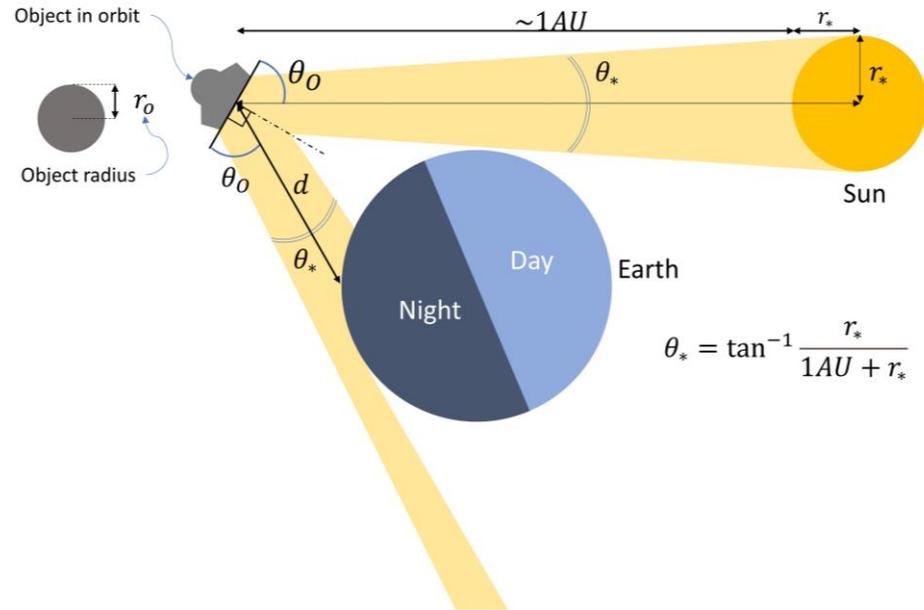
The received signal can be defined as the intensity of the photon flux:

$$I_s = I_* f(d, r_o, \theta_o) \cdot F_a$$

$I_*$  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.

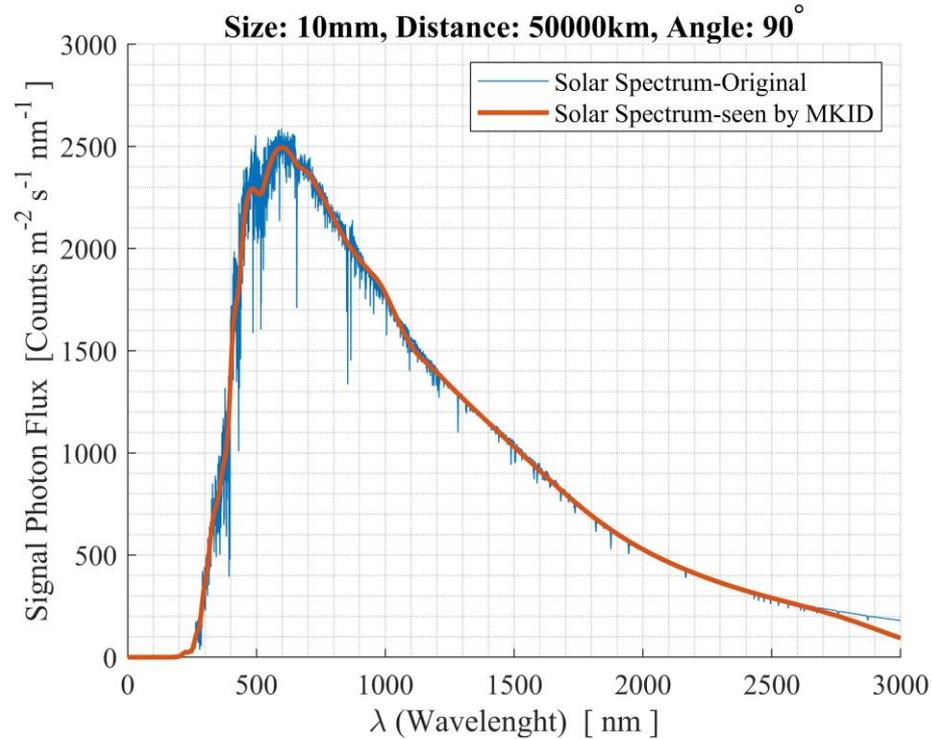
$$f(d, r_o, \theta_o) = \left[ \frac{r_o \sin \theta_o}{r_o \sin \theta_o + d \tan \left( \frac{\theta_*}{2} \right)} \right]^2$$



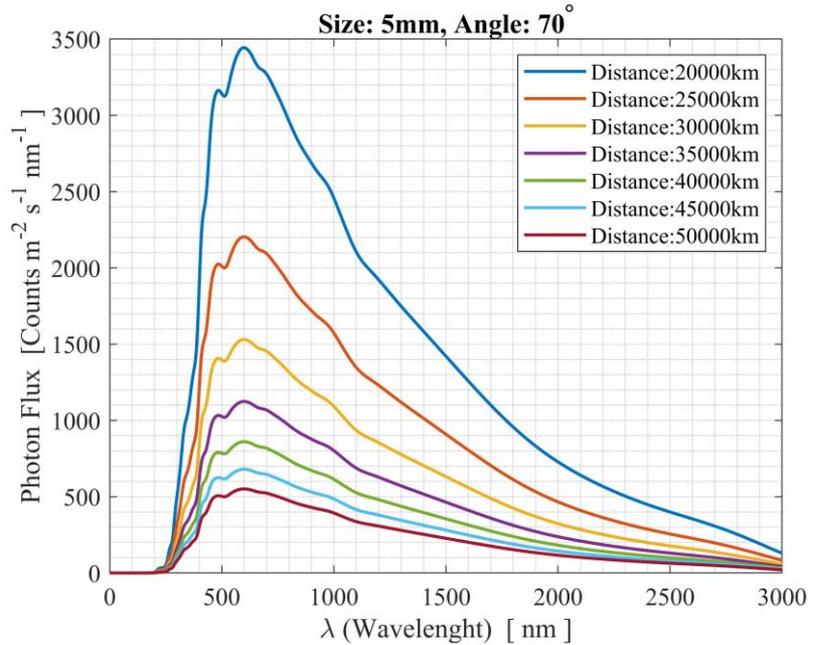
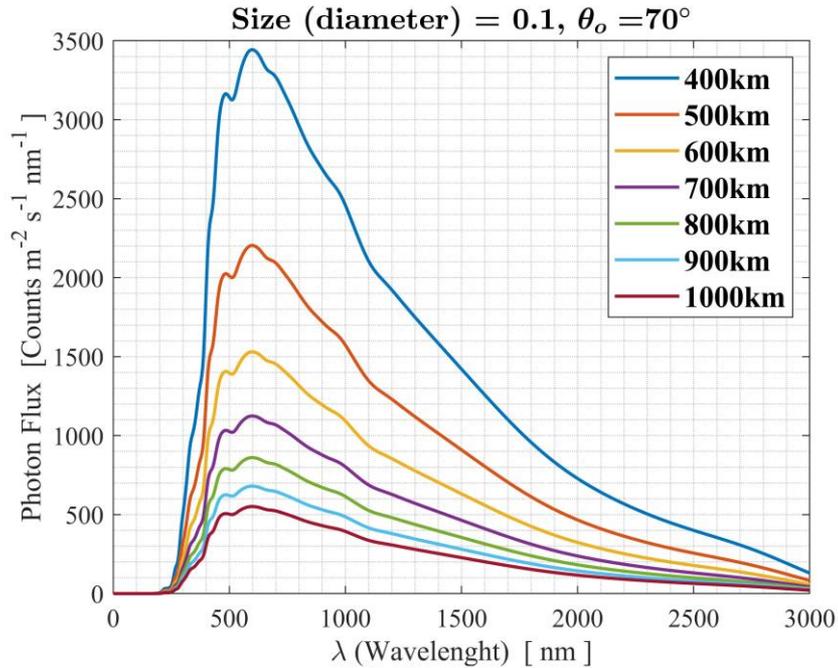
$$\theta_* = \tan^{-1} \frac{r_*}{1AU + r_*}$$

\* The detectable angle for a ground-based system is considered 45° to 90°.

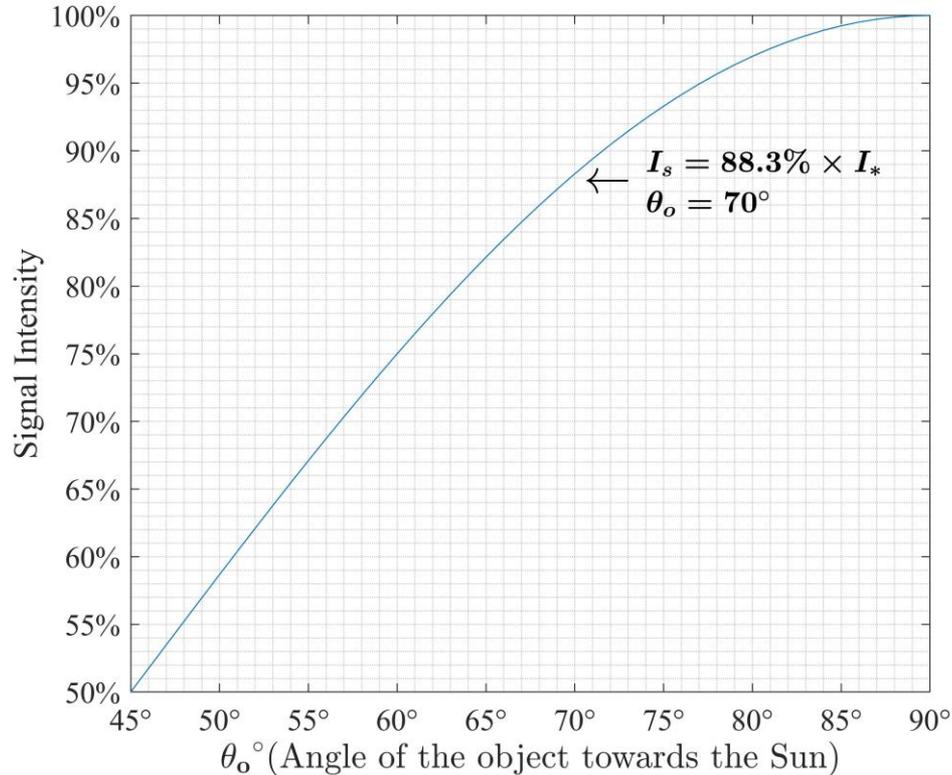
## Initial simulation results – MKID response to Solar Spectrum



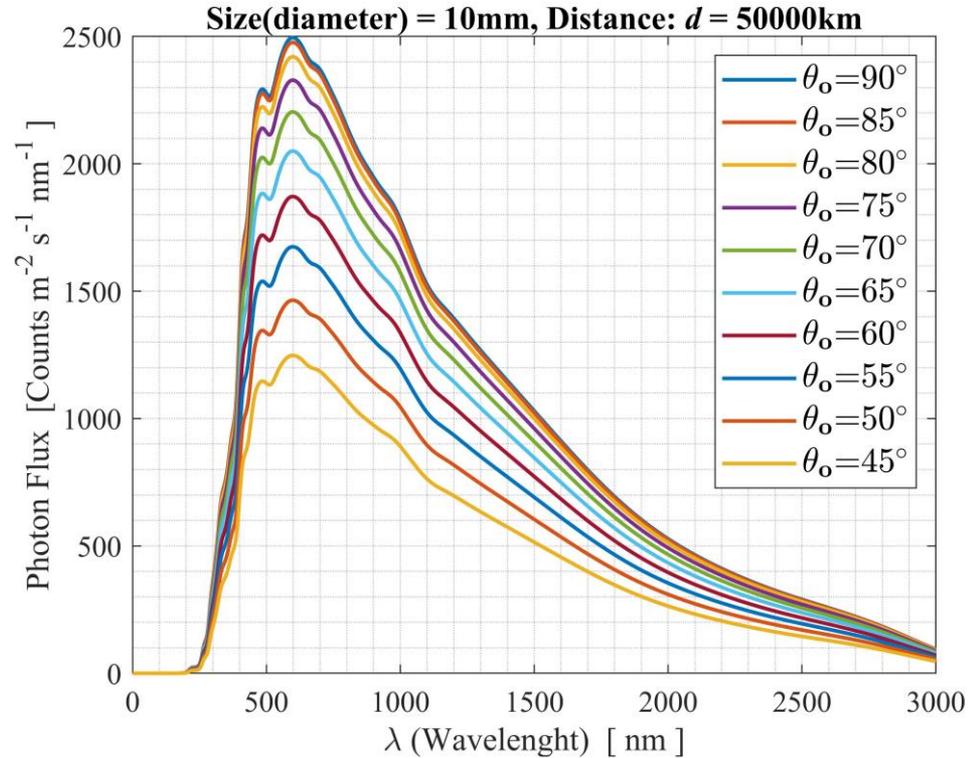
## Initial simulation results - Incident photons at the Earth



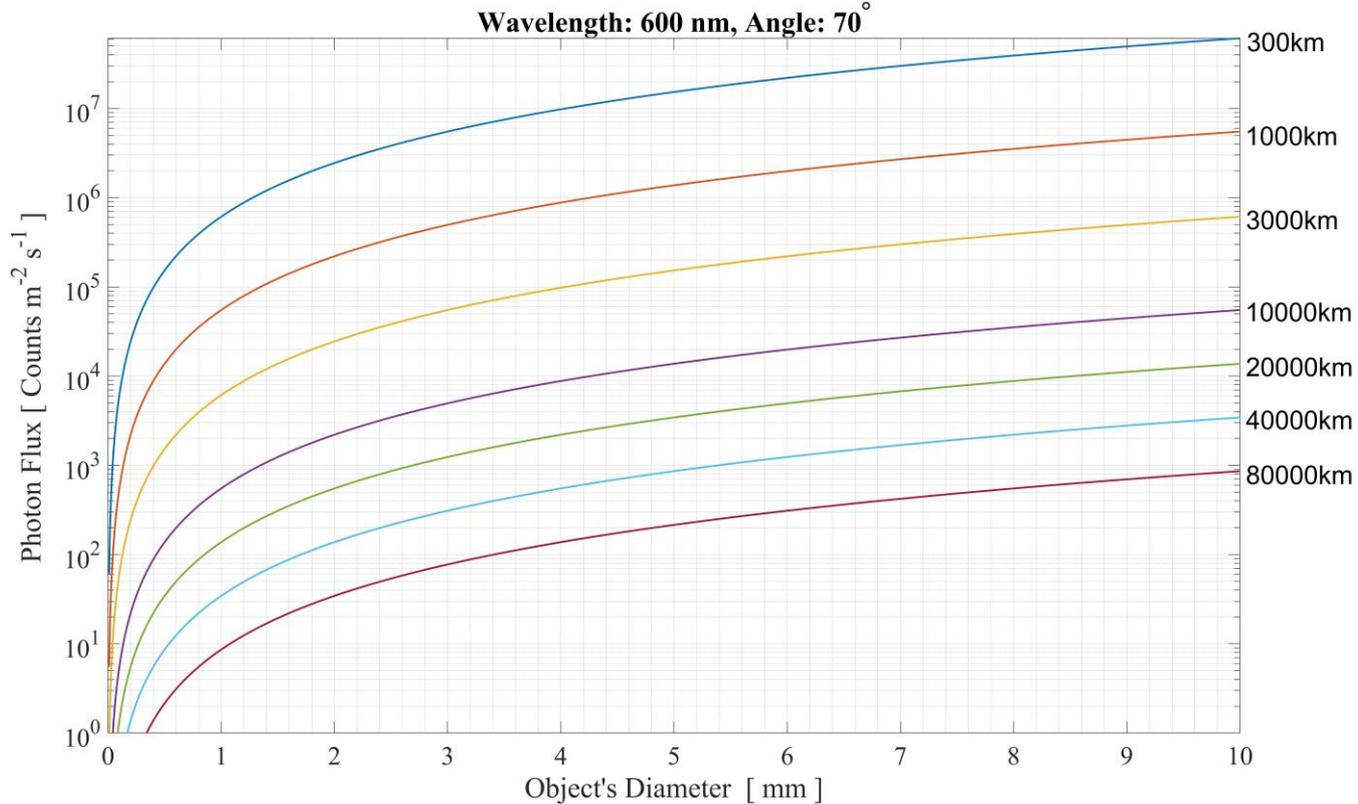
## Initial simulation results - Incident photons at the Earth



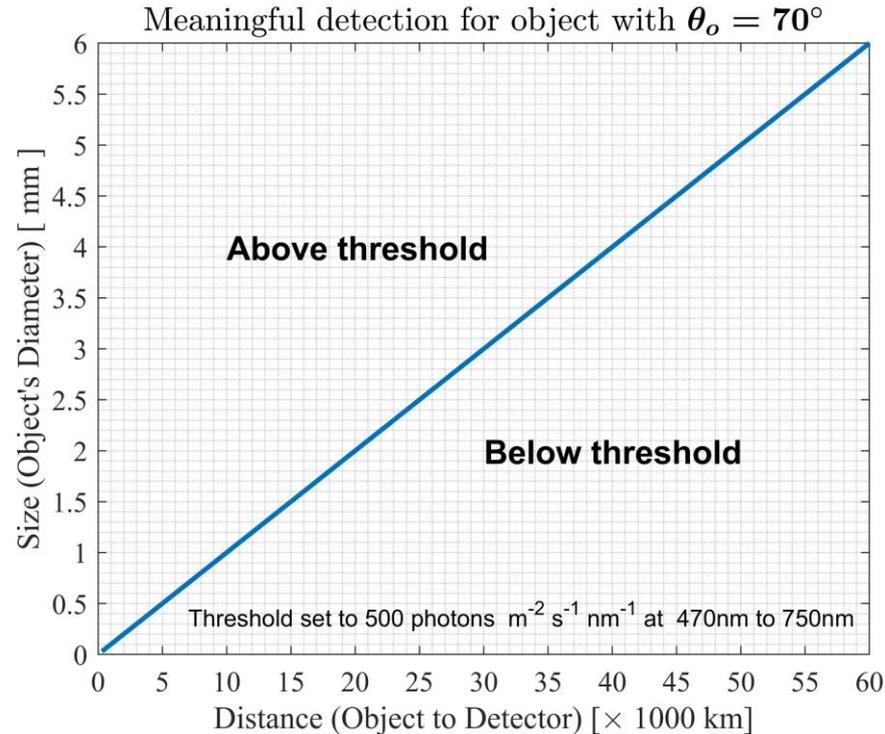
## Initial simulation results - Incident photons at the Earth



## Initial simulation results - Incident photons at the Earth



## Initial simulation results - Incident photons at the Earth



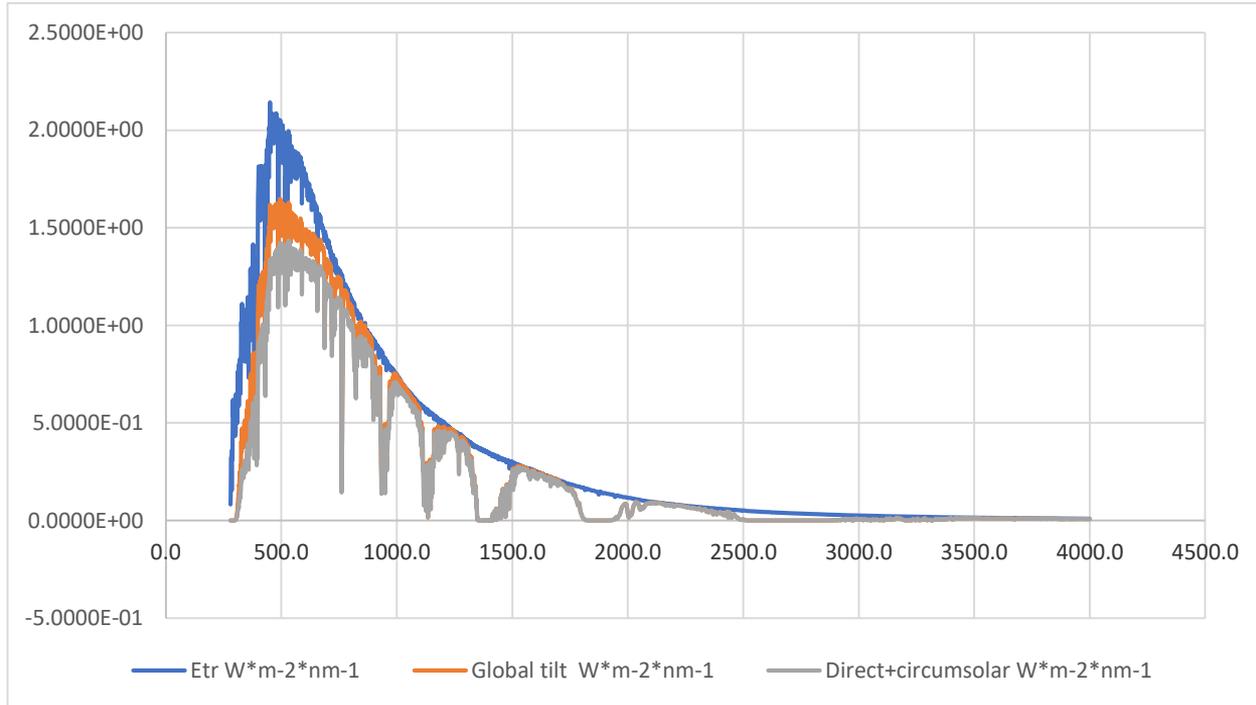
# Completing the model (ongoing work)

## Considering the effect of

- **Airmass**
- **Sky Background**
- **Stellar Background**

## Assessing the pixel saturation in the detector

# Airmass



# Sky Background

At sites with no artificial light contamination,

The main sky brightness contribution came from atoms and molecules emission ( $O_2$ ,  $O$ ,  $OH$ ,  $Na$ ) at high altitudes (90 ~ 300 km) by means of excitation by UV radiation. This is known as airglow, contributing with about a 65% to the sky brightness.

Others contributions to the sky brightness are the Zodiacal light (light dispersed by interplanetary dust) with a contribution of ~27%, and diffuse light from stars which is dispersed into the atmosphere (which contributes with ~7%)

Light pollution (Artificial light) degrades the quality of the night sky, increasing its brightness.

## Sky Background



15 second exposure 50 % illuminated moon  
(behind camera)



15 second exposure no moon in sky

## Stellar Background

Stellar background down to  
magnitude 12

3 ° field of view



**We are considering**

**An ideal location for a ground-based observation**

**Space based observation (Possibly in GEO)**

**Thank you**