Space Debris

Identification & Tracking by Microwave Kinetic Inductance Detectors (MKIDs)

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Background & Definition

Human putting objects in orbit for over 60 years (over 90% of them are space debris).

Any man-made object in orbit (about the Earth) which no longer functions or serves a useful purpose:

- Spent rocket stages and boosters
- Non-functional/dead satellites
- Lost equipment
- Fragments from disintegrations, erosion & collisions

Refers as

ESA: Space Debris

NASA: Orbital Debris

General Public: Space Junk, Space Waste

Population & Distribution

Monthly Number of Catalogued Objects in Earth Orbit by Object Type. This graph displays a summary of all objects in Earth orbit officially catalogued by the U.S. Space Surveillance Network. “Fragmentation debris” includes satellite breakup debris and anomalous event debris, while “mission-related debris” includes all objects dispensed, separated, or released as part of the planned mission.

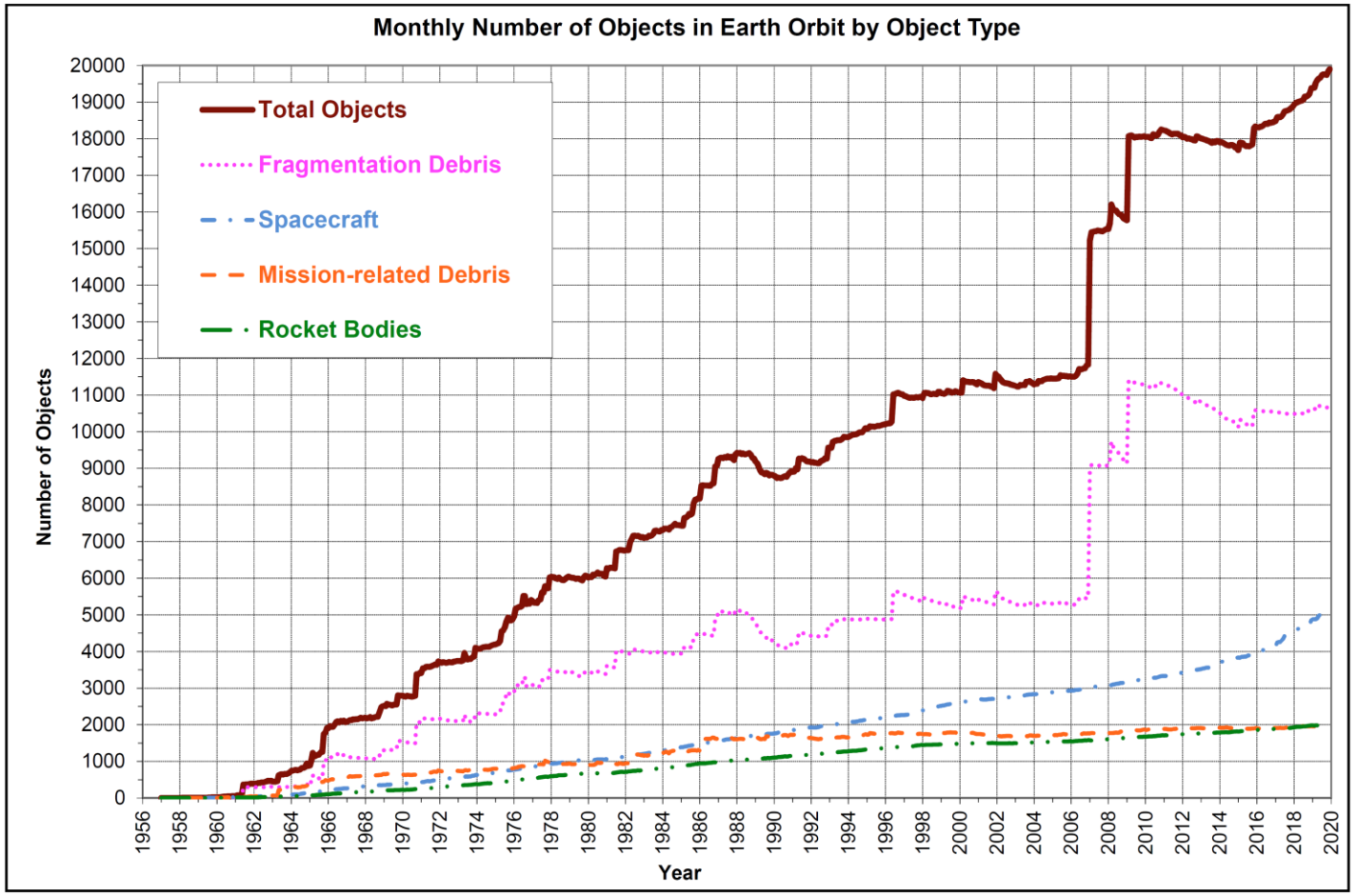


Image: NASA, February 2020. Standard Practices. Orbital Debris Quarterly News, 24(1), p. 4.

Population & Distribution

We need better tools for detecting, identifying, tracking, and cataloguing the objects of smaller sizes (< 10cm) and higher altitudes (e.g. GEO)

Number of debris estimated by statistical models to be in orbit (ESA, 2021).

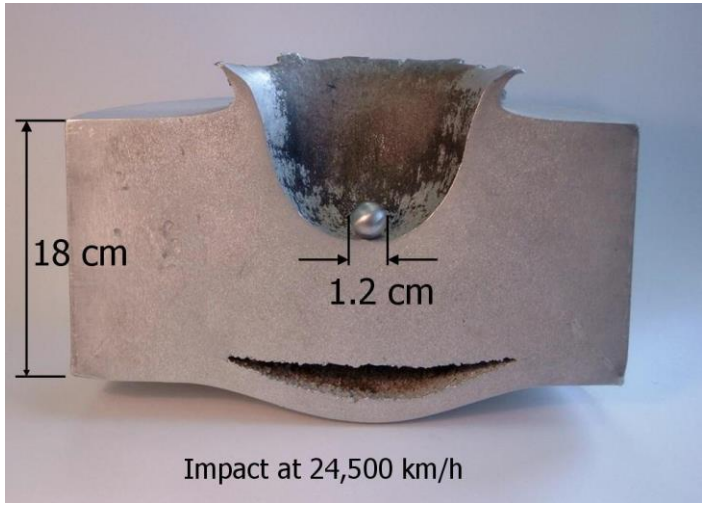
- **34 000** objects greater than 10 cm
- **900 000** objects from greater than 1 cm to 10 cm
- **128 million** objects from greater than 1 mm to 1cm

The Importance of Monitoring Space Debris

- Space is recognised by the UK Government as critical national infrastructure.

- There are considerable amount of debris that are too small to monitor but too large enough to shield satellites against.

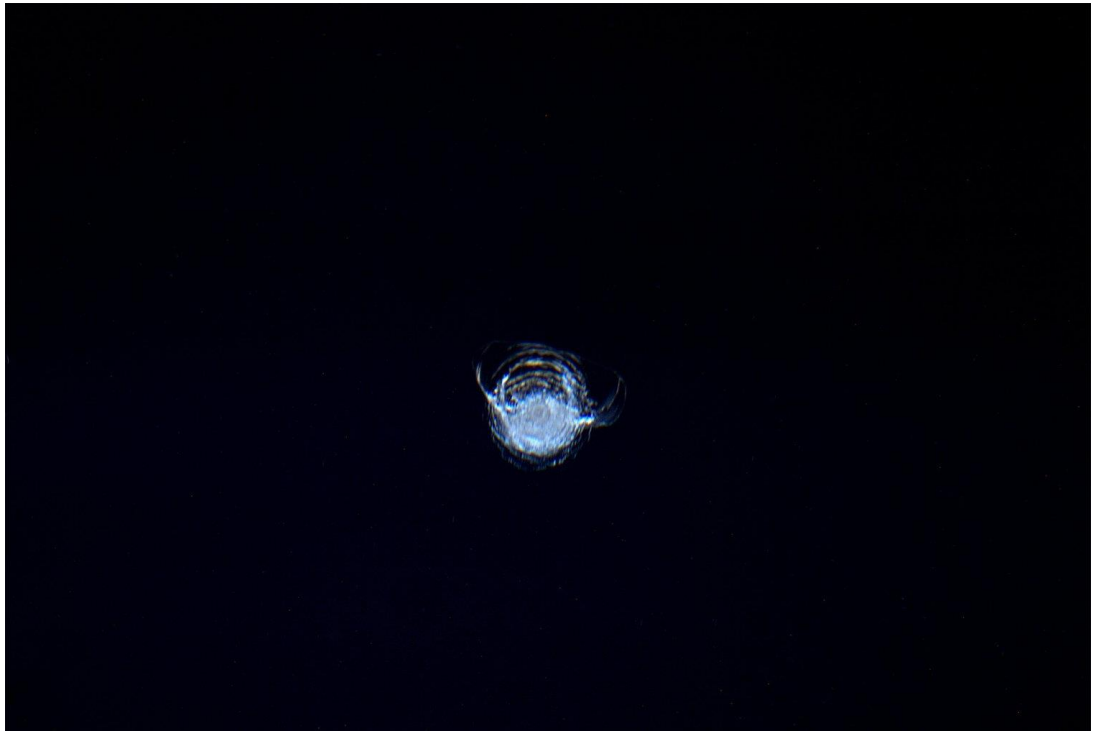
- Average impact speed of piece of Space Debris is 10 km/s !! Posing threat to:
  - Functional satellites (international space station, communication satellites, GPS satellites, …)
  - Can prevent the use of valuable orbits in the future.



A Hypervelocity impact test done by the ESA. Showing how much damage could be caused by even small particles of space debris the block is solid aluminium.

The Importance of Monitoring Space Debris

ESA astronaut Tim Peake took this photo from inside Cupola (ISS) in April 2016, showing a 7 mm-diameter circular chip gouged out by the impact from a tiny piece of space debris, possibly a paint flake or small metal fragment no bigger than a few thousandth of a millimetre across. Image Credit: ESA



The Importance of Monitoring Space Debris

We need better tools for detecting and cataloguing Space Debris !

Microwave Kinetic Inductance Detectors (MKIDs)

A single photon spectrally resolving detector.

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 measuring the **changes on the surface impedance of a superconductor** through the kinetic inductance effect [2].

Single photon sensitivity

High temporal response (~ microseconds)

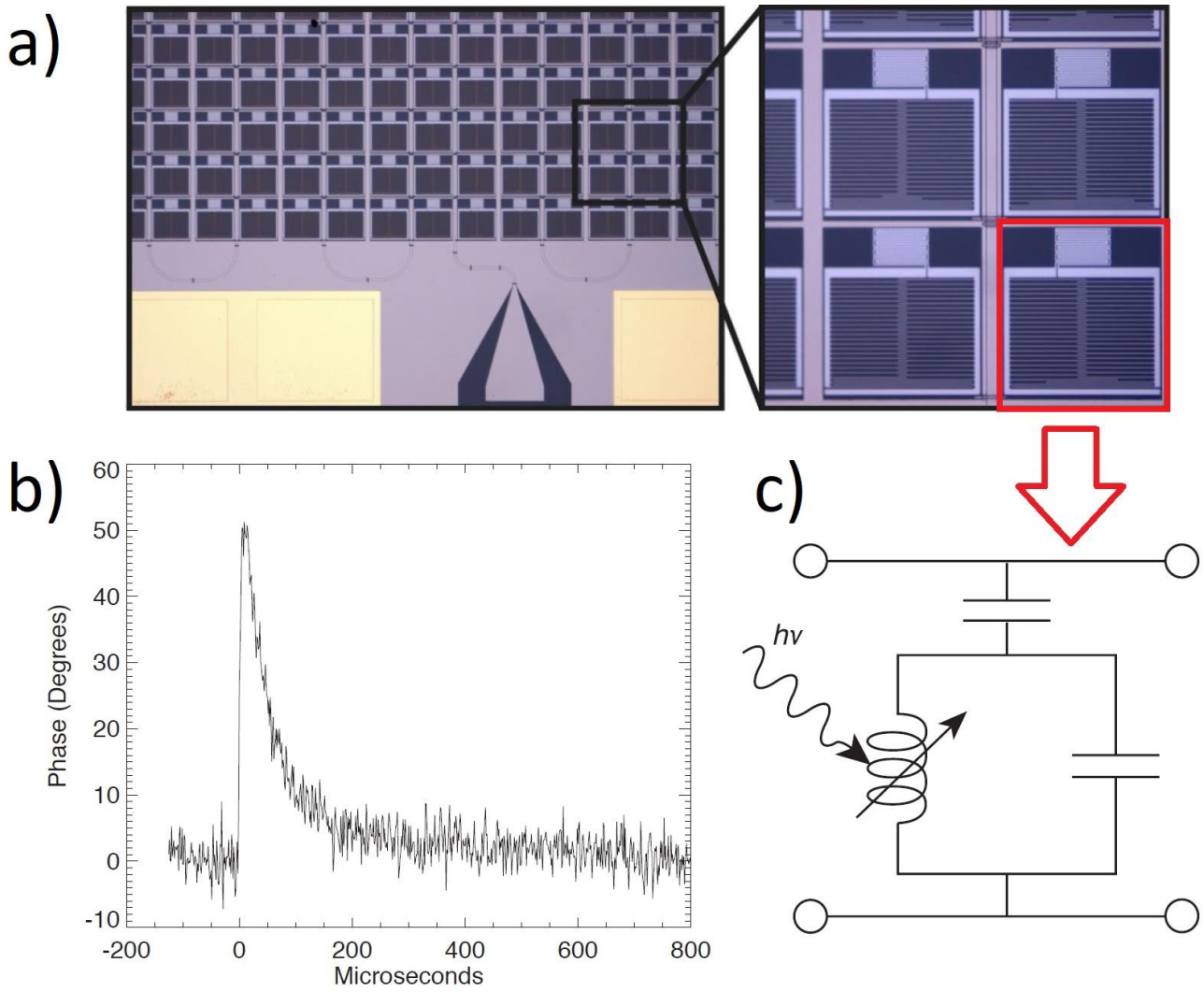
Operating temperature ~ 100 millikelvins

Using **FDM** (Frequency Division Multiplexing) arrays of many **thousands of pixel**s can be read out through **a single feedline**.

a) An MKID array and zoomed in pixels.

b) Equivalent circuit for an MKID pixel

c) A pulse produce by an MKID



Images courtesy of B. Mazin

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.

Modelling the Space Debris Signal

Ideal round object with 100% reflectivity (mirror)

The intensity of the received signal can be defined ask:

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

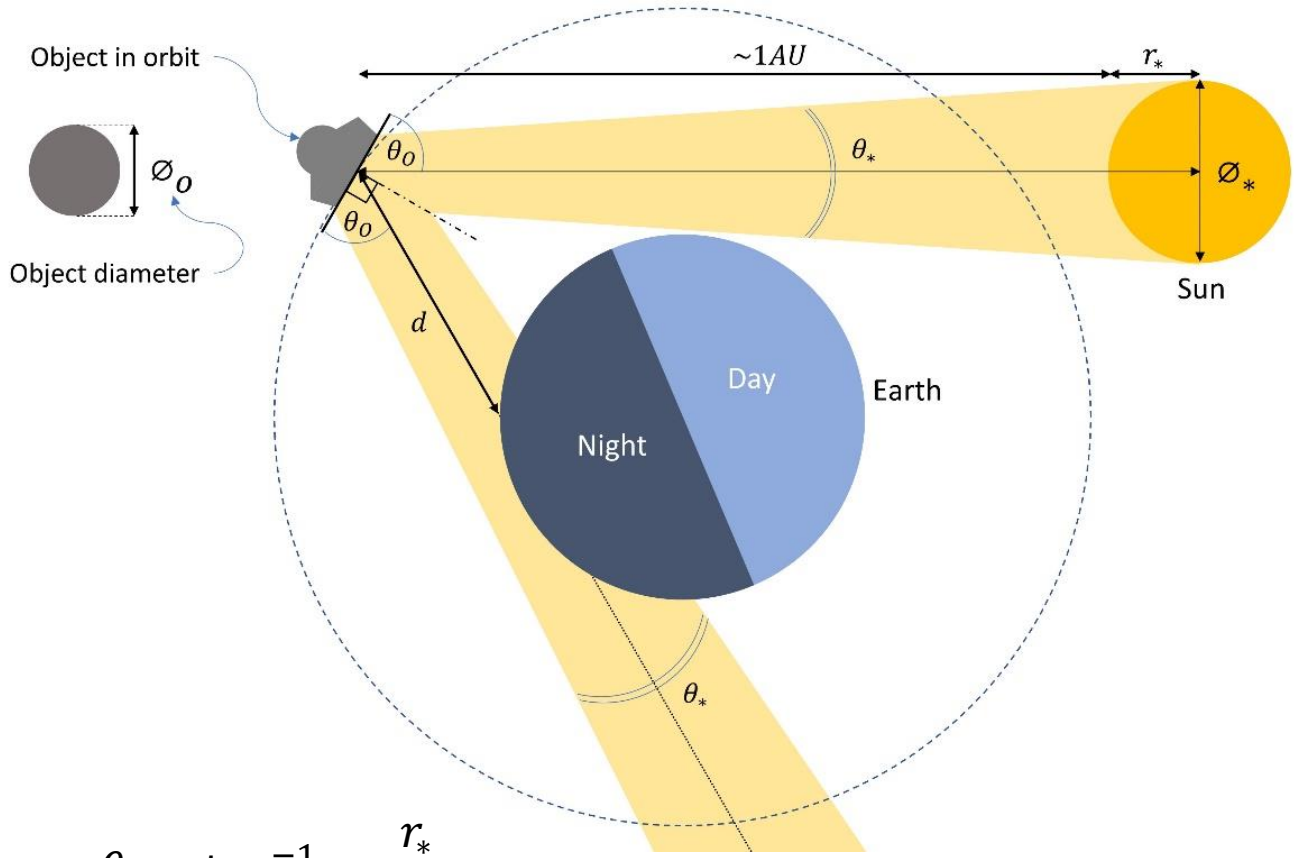
I_* is the intensity of the sunlight as it hits the object.

$f(d, r_o, \theta_O)$ is a function based on the object distance, object radius and angle of the object towards the sunlight, describing their effect on the intensity of the signal.

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

F_a is the attenuation factor (a combination of all the other elements that might affect the signal).

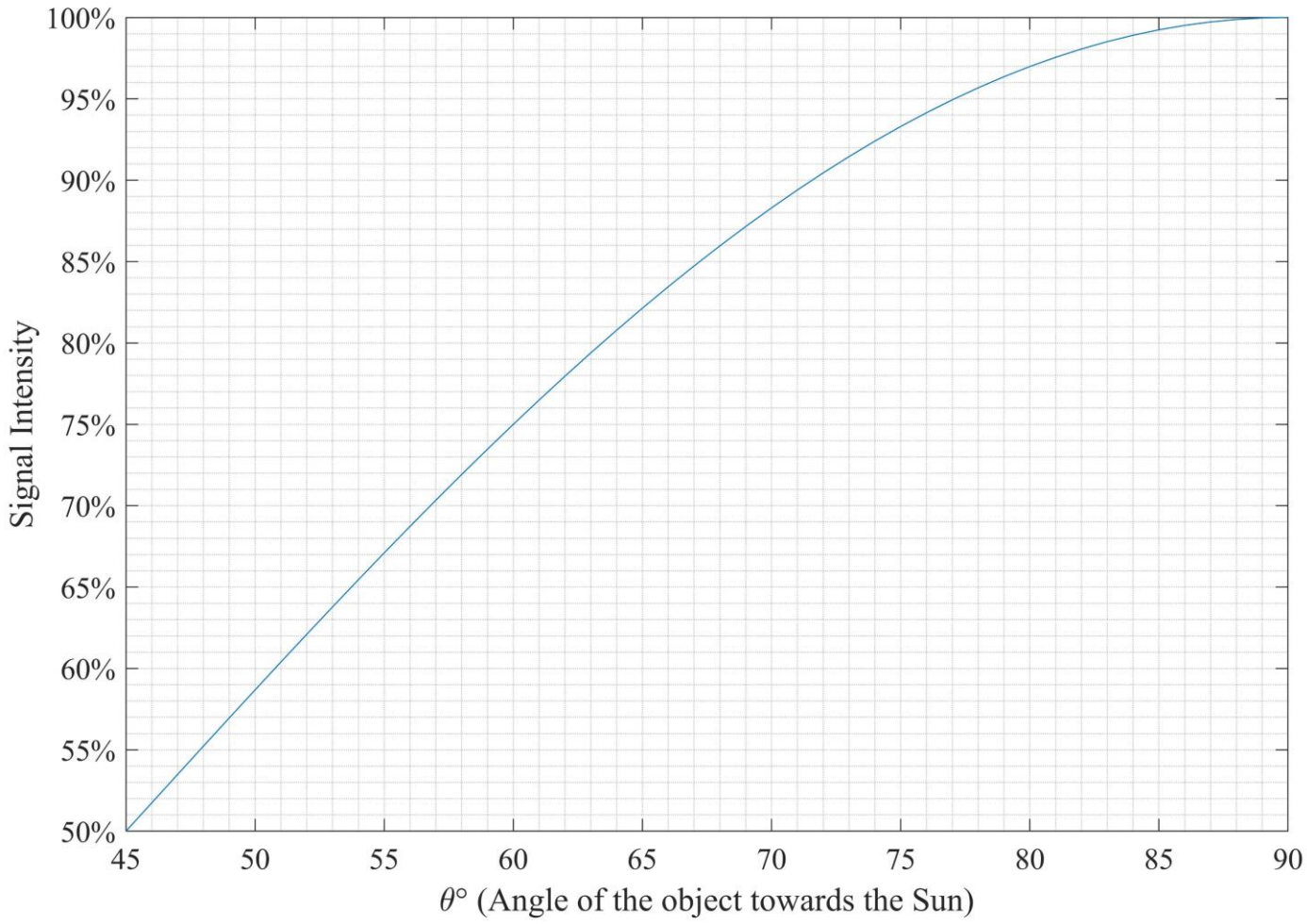
* F_a considered as 1 in the initial analysis.



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

Initial Simulation Results

Detecting Incident photons at a ground-based observatory
(assuming 100% reflectivity & no atmospheric attenuation)



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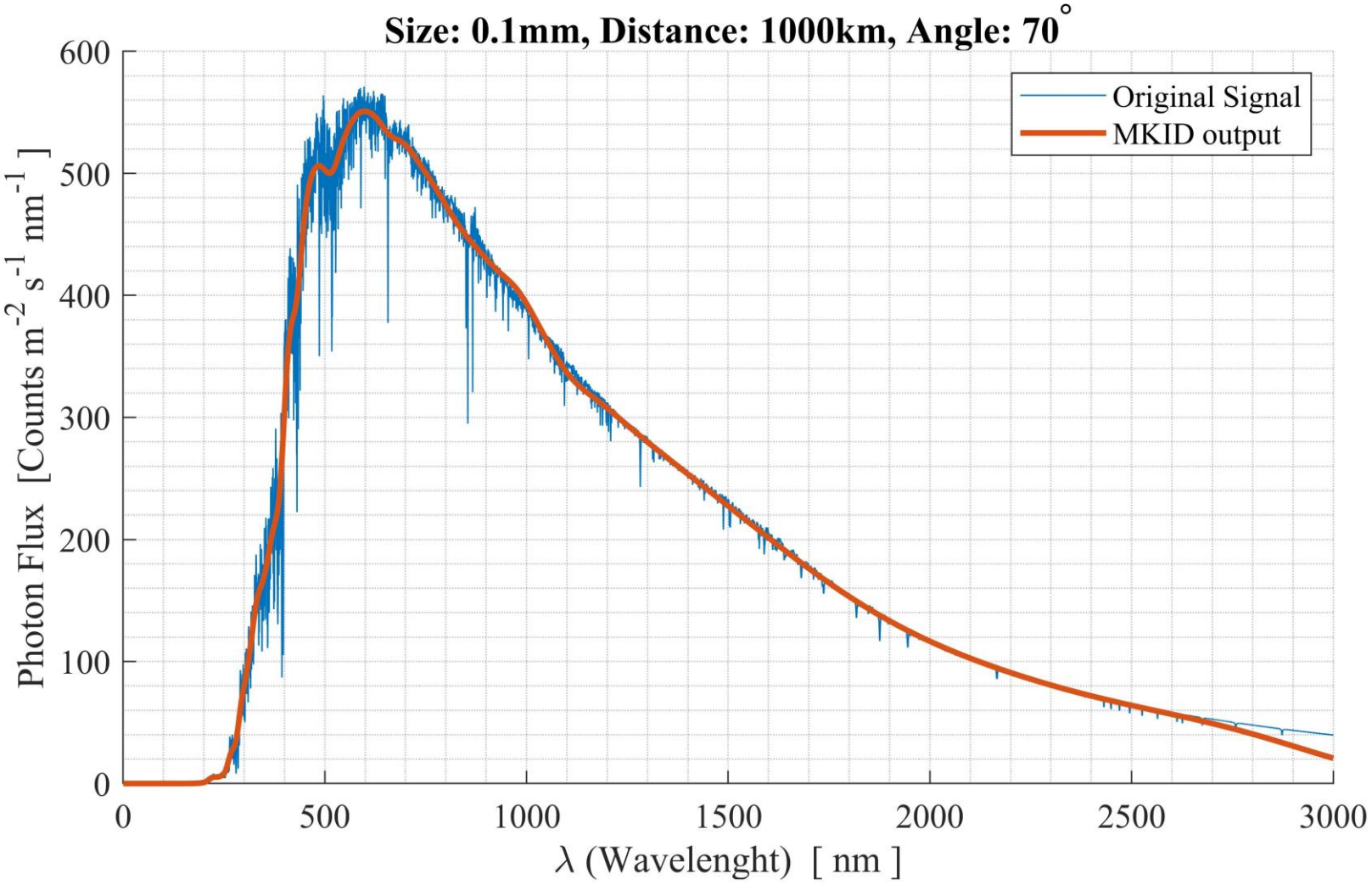

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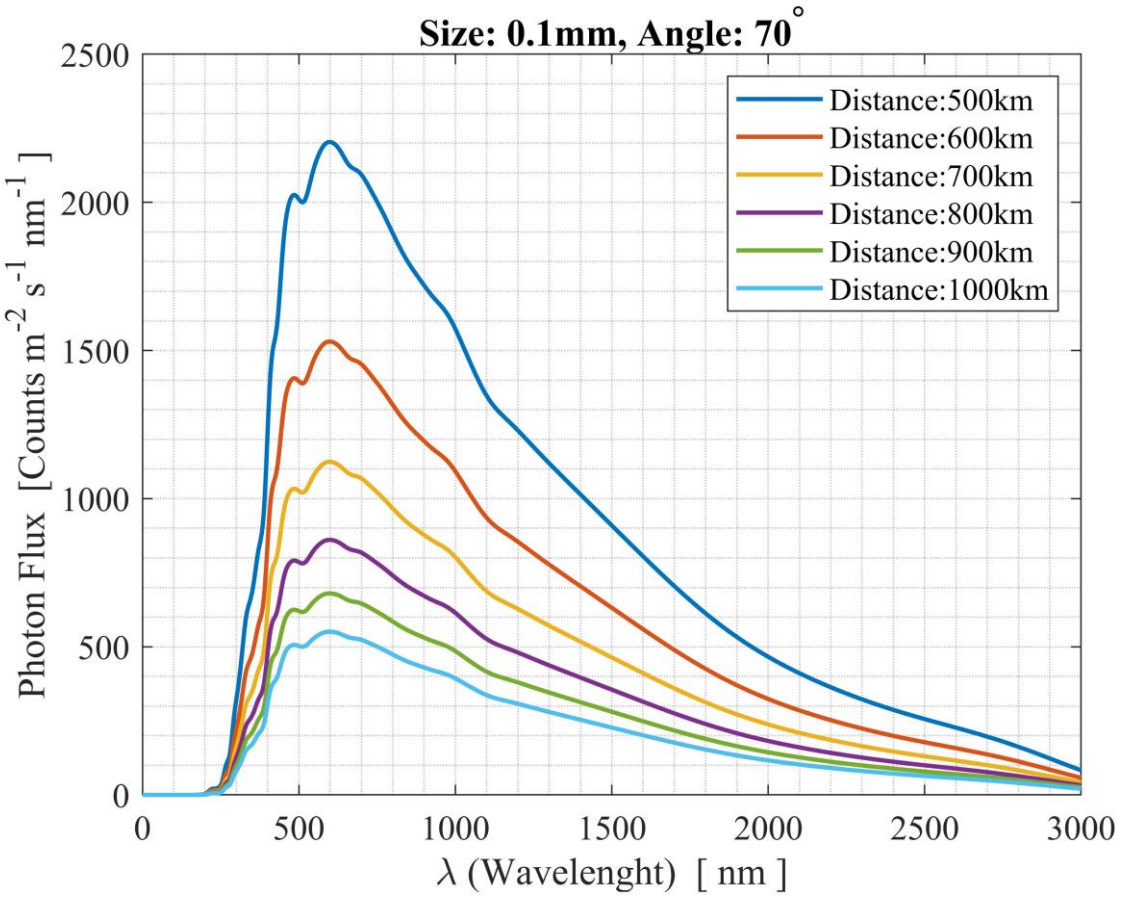

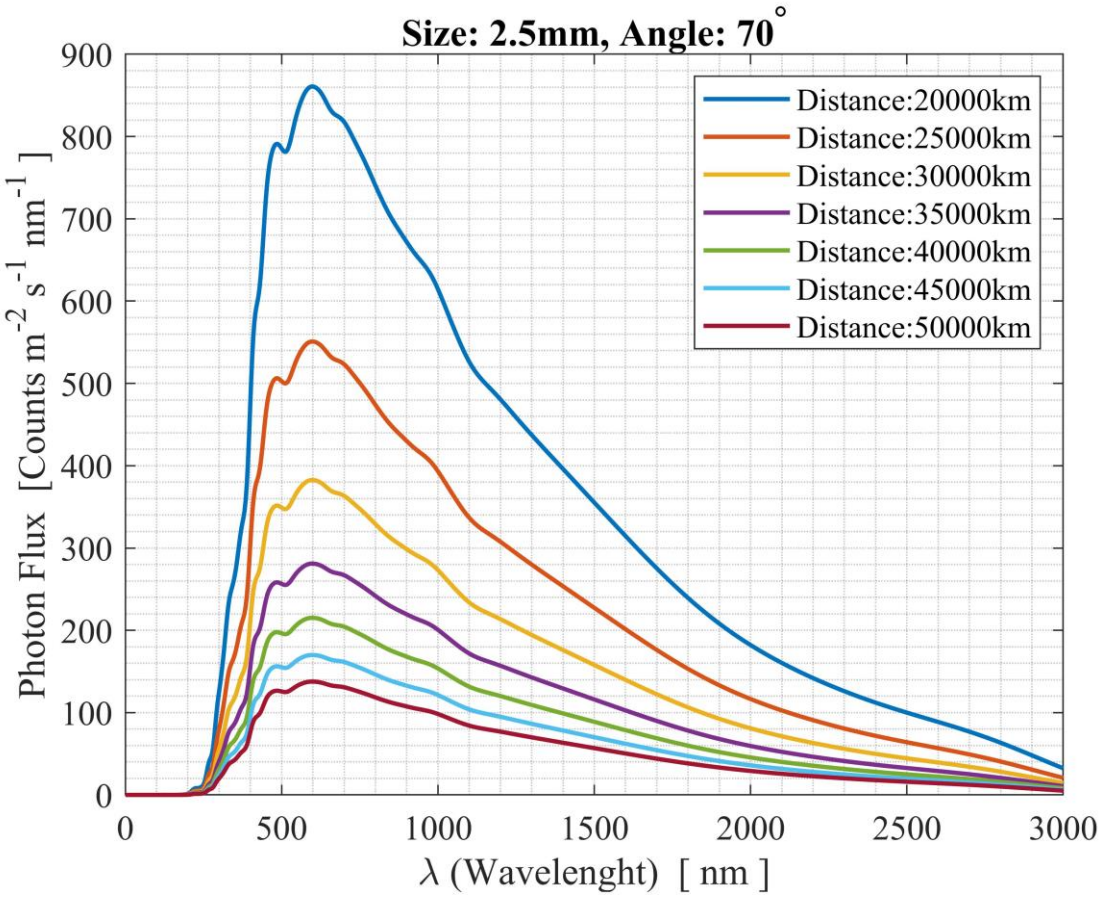

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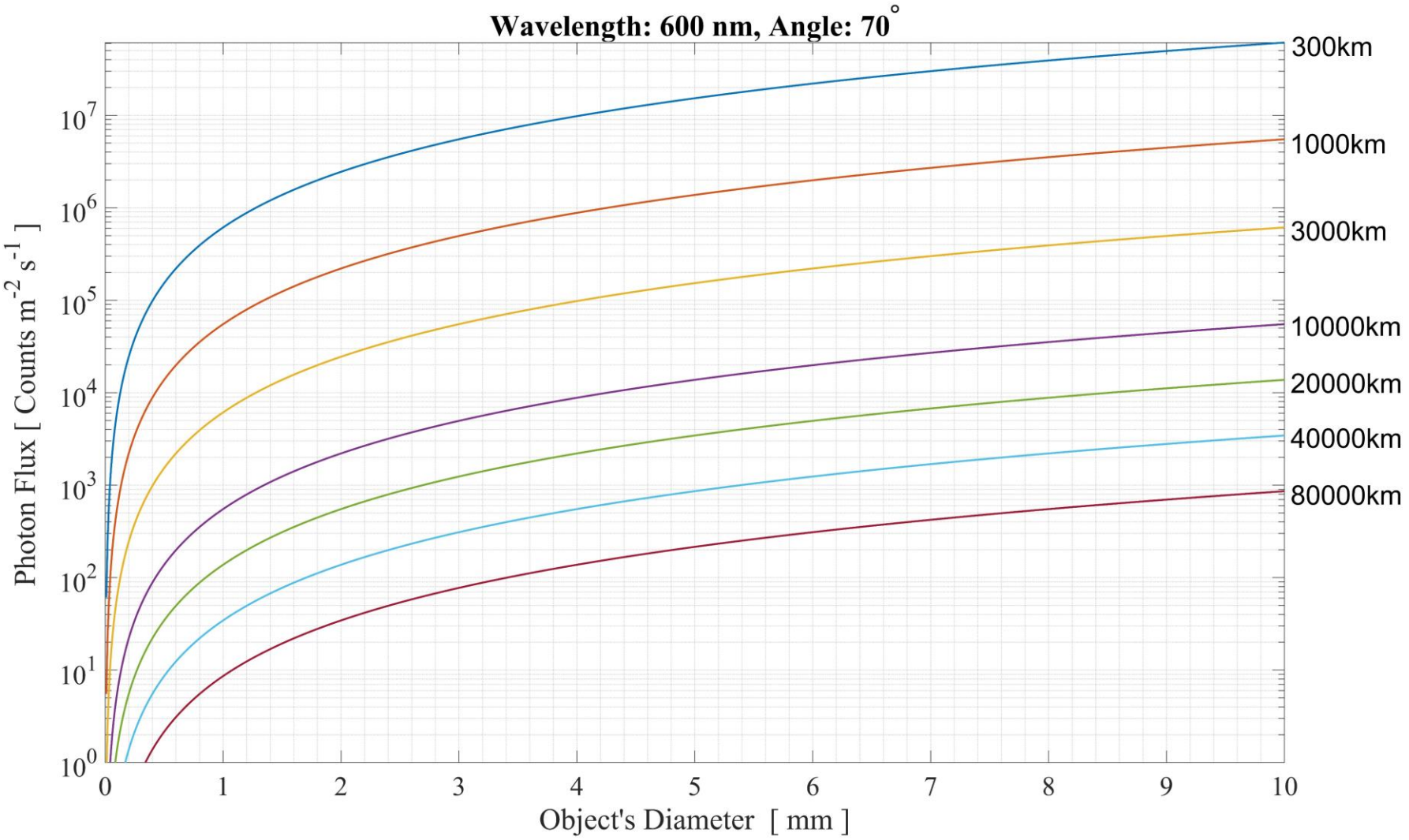

Future Work

F_a considered as 1 in the initial analysis. $I_s = I_* f(d, r_o, \theta_O).F_a$

Next phase of project include adding more variable to the model by the inclusion of

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

Also, investigating the identification of the debris based on unique characteristics of debris such as spectral features and spin velocity.

Thank you!

Any question?