On ‘ways to reduce uncertainties in mobile search of radioactive material out of regulatory control’

A Joint Nordic NKS-project – NKS-B AUTOMORC

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On ‘ways to reduce uncertainties in mobile search of radioactive material out of regulatory control’

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Medical Radiation Physics, Lund University, Malmö

Mobile laboratory in Sweden operated by Radiation Physics Institution, Stockholm, 1950:ies

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When do you need to perform search operations to find radiation sources ?

Accident
Dispersion of radioactive material (Satellite reentry Cosmos 954)
Lost radioactive material (Gamma radiography sources)

Theft
Stolen radioactive material (Goiania radiotherapy source, Cs-137)
Hidden radioactive material (Smuggling, contraband)

Threat
Case of pronounced threat, terrorist acts
Secure areas ahead of and during large gatherings (Royal weddings, Olympic games, Pope visit)

Various types of mobile search vehicles

SGU 4x4 L NaI(Tl)-detector inside fixed wing aircraft

SSM rented helicopter with
HPGe-spectrometer outside

DEMA 4 L NaI(Tl)-detector on vehicle rooftop

SSM 2x4 L NaI(Tl)-detector, 123 % HPGe inside vehicle

Swedish National Defence CBRN terrain vehicle

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Problems and challenges in mobile search of radiation sources

Radionuclide, activity, shielding

Is the radionuclide known? Gamma emission?
Possible activity range, MBq, GBq, TBq ?
Open or shielded or partly shielded source?

Areas to be searched

Large areas, prioritization necessary?
Open rural areas, villages, cities ?

Available search resources, vehicles, measuring equipment

Total gamma detection? Gamma spectrometry?
Fixed wing aircraft? Helicopters ?
Car-borne along roads? Terrain vehicles?
On foot with portable instrumentation ?
Knowledge level among operators?

Management, coordination, analysis,

Which units where? Coordination of search resources.
Analysis of objects found, clearance of areas
information to the concerned.

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A way to reduce the uncertainty in mobile search of radiation sources

Knowledge of physics and statistics for mobile measurements facilitates the choice of search method and setting of measuring instruments.

In a joint Nordic project, search parameters and detection limits have been studied experimentally. A theoretical model for calculation maximum detection distances has been developed. NKS-B MOMORC 2016, NKS-B AUTOMORC 2017 - 2018

Authorities in all Nordic countries have participated with their mobile detection equipment in joint experiments 2016 and 2018

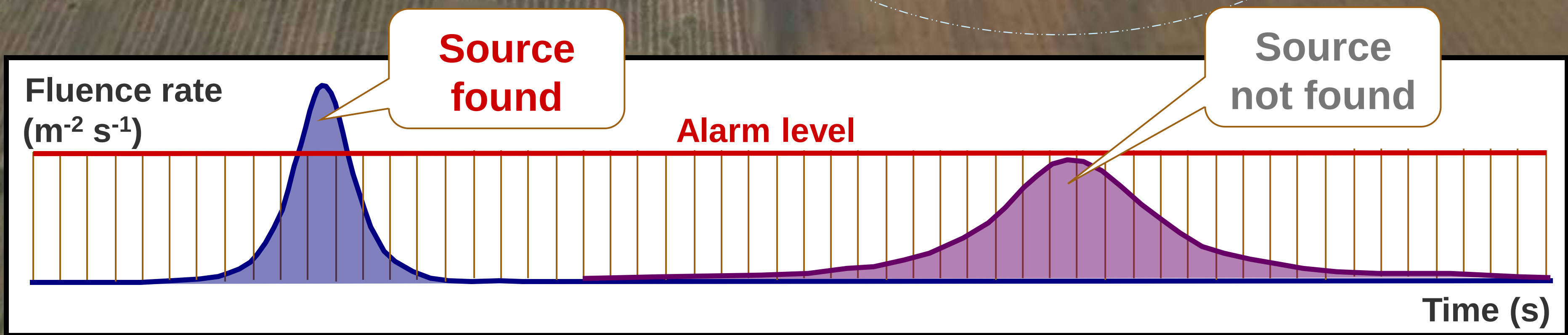
Here are some results and conclusions…

Source activity, distance and integration time

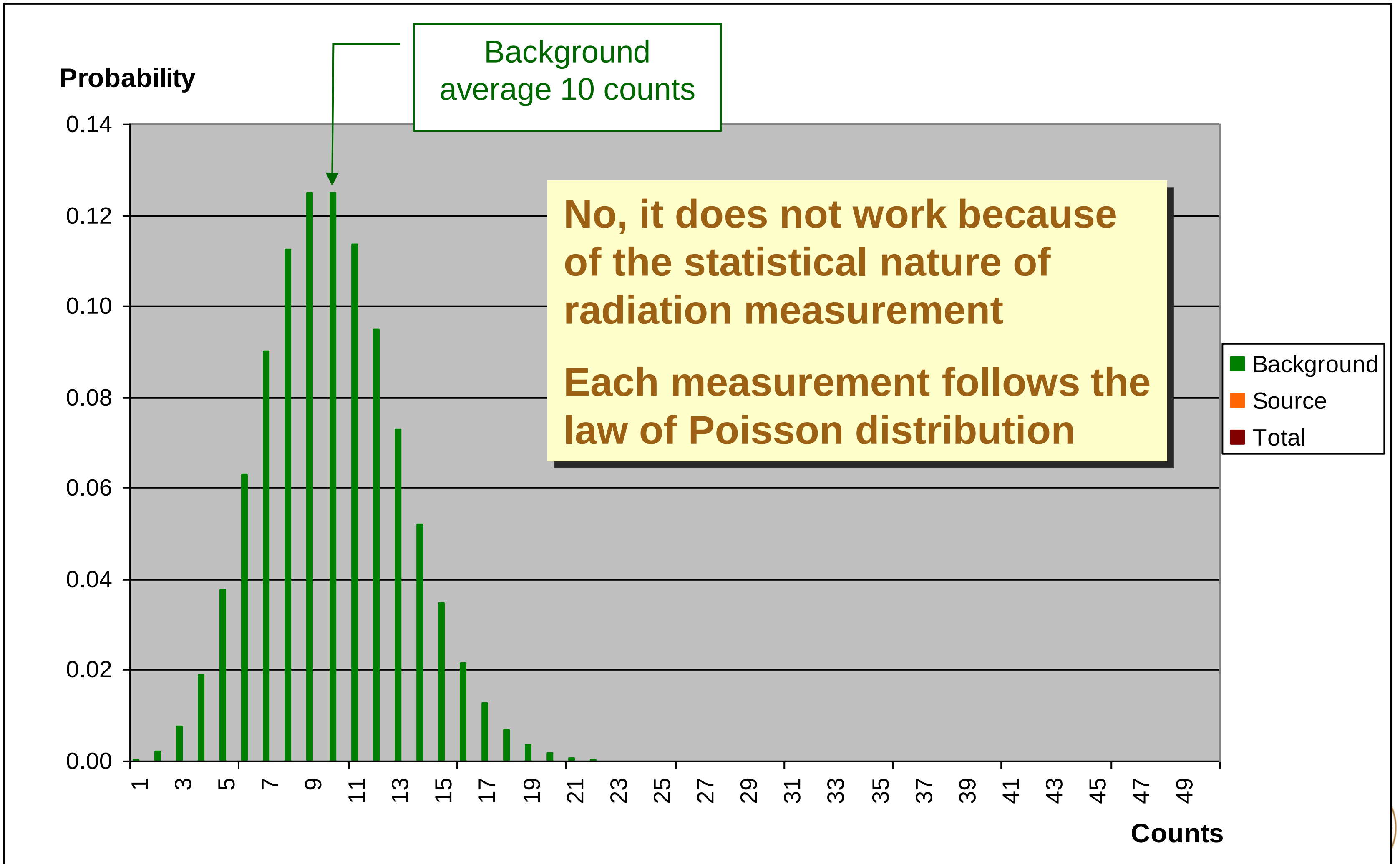
Need to use information from more than one acquisition time interval to trigger a source alarm.

Recommendation:

Use sets of different floating time intervals.



But why not just lower the alarm level?



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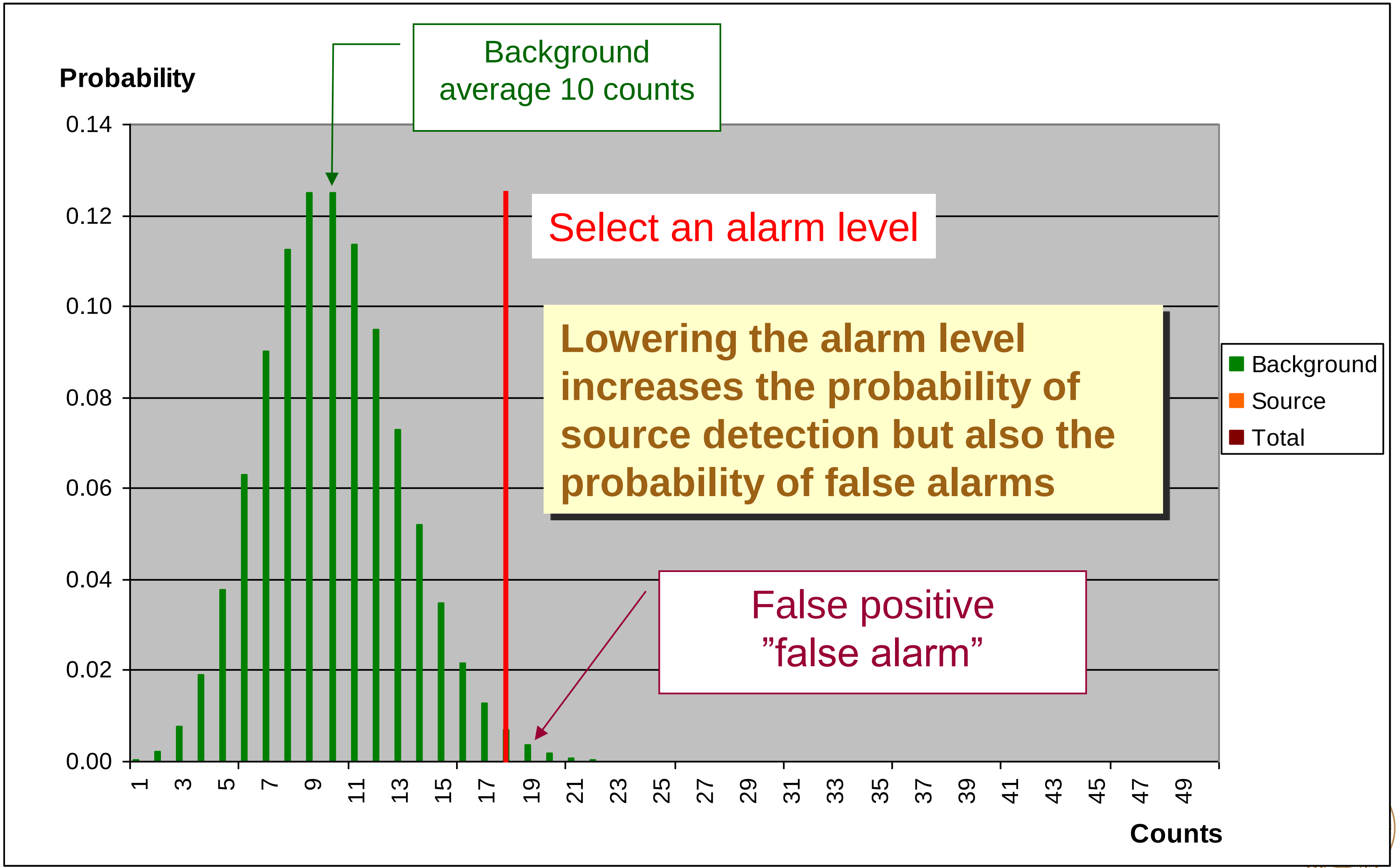
Probability distribution of counts per time interval



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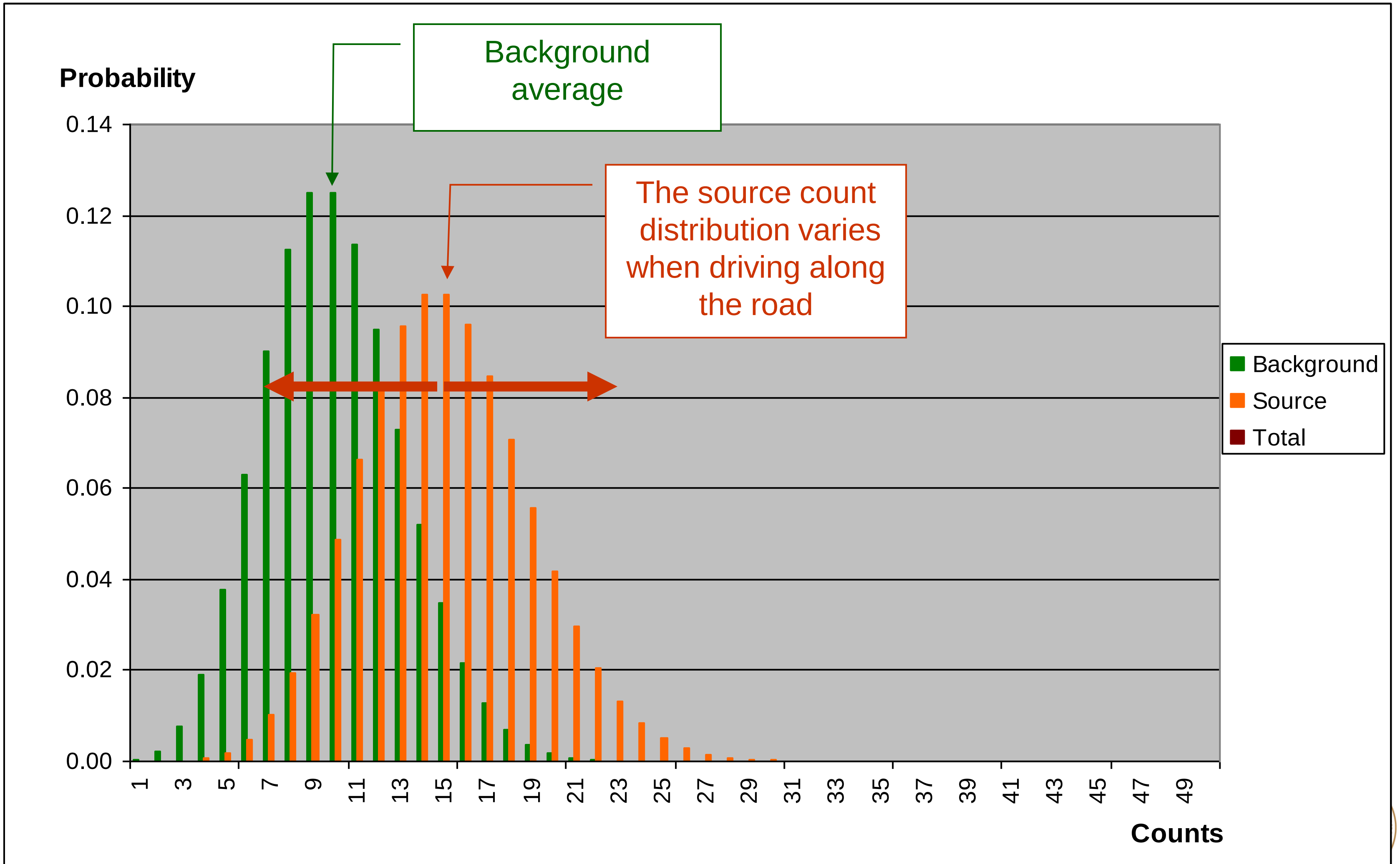
Probability distribution of counts per time interval



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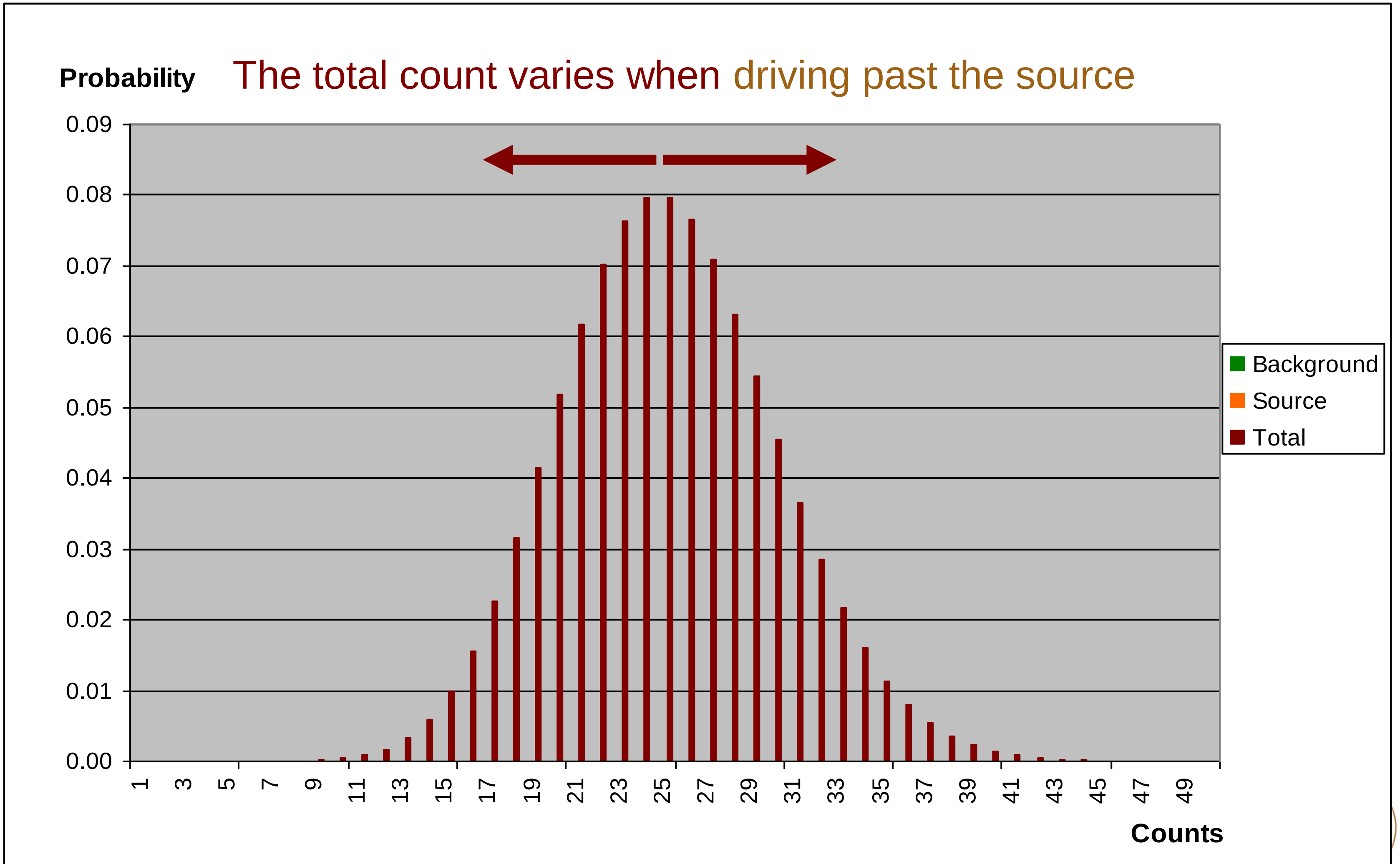
Background and source count distribution



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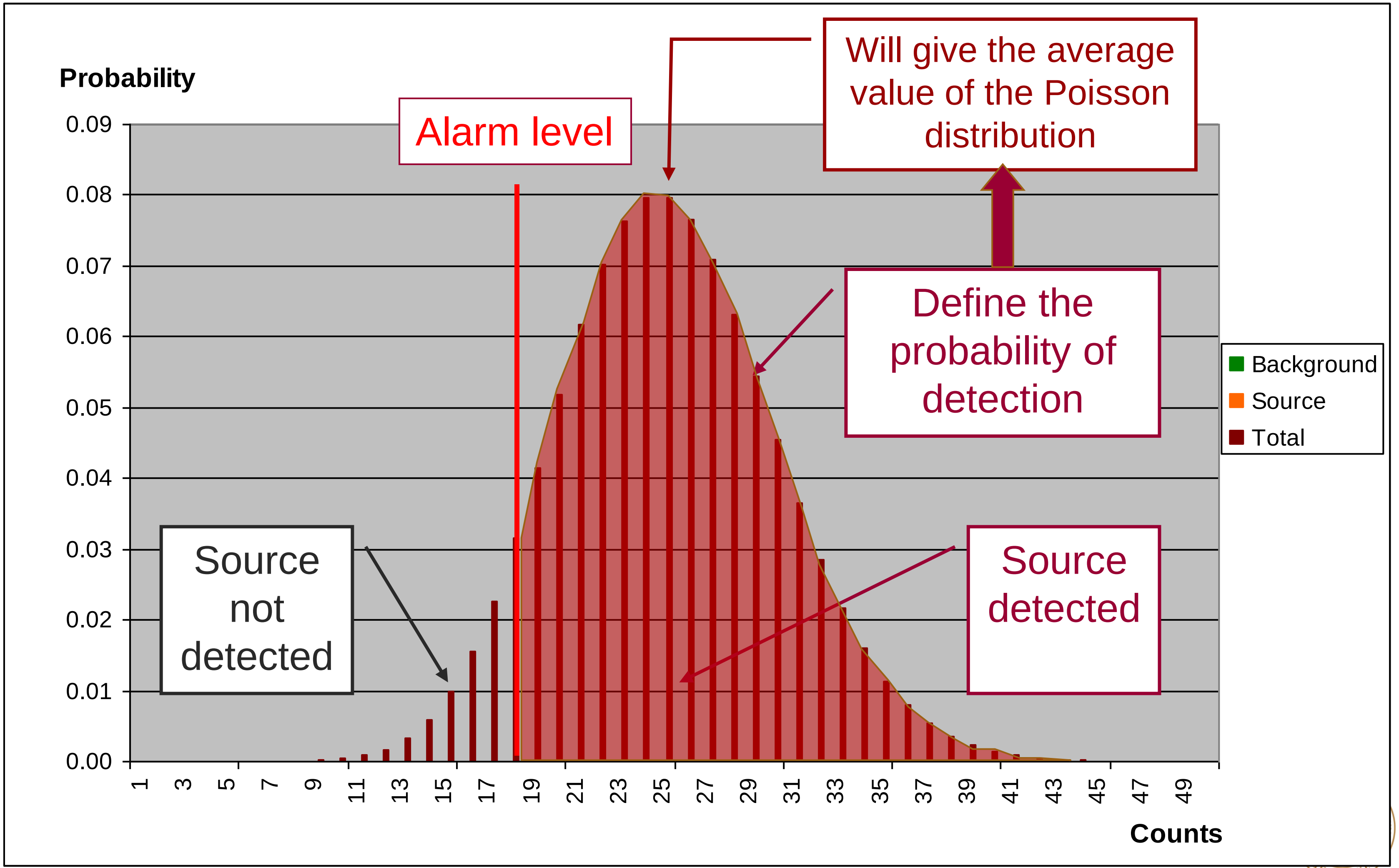
Calculation of average source count



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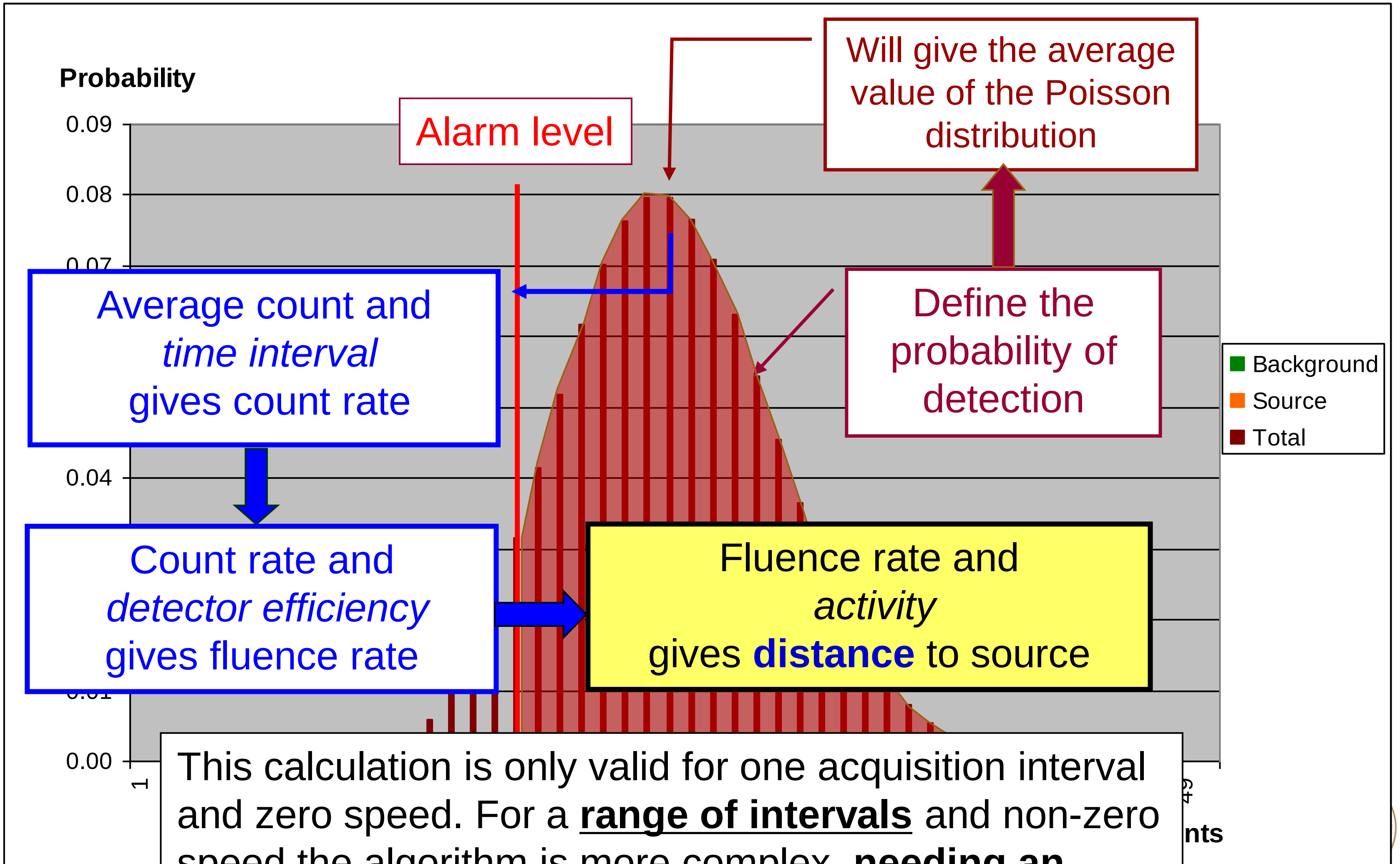
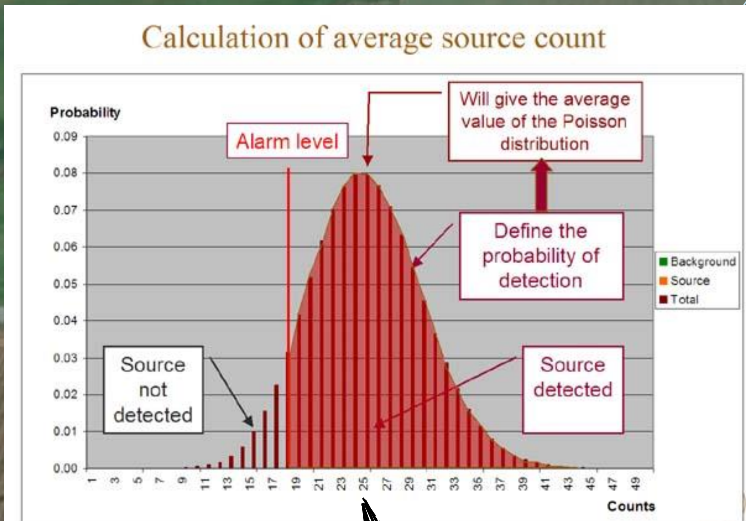
Distance calculation from distribution of counts

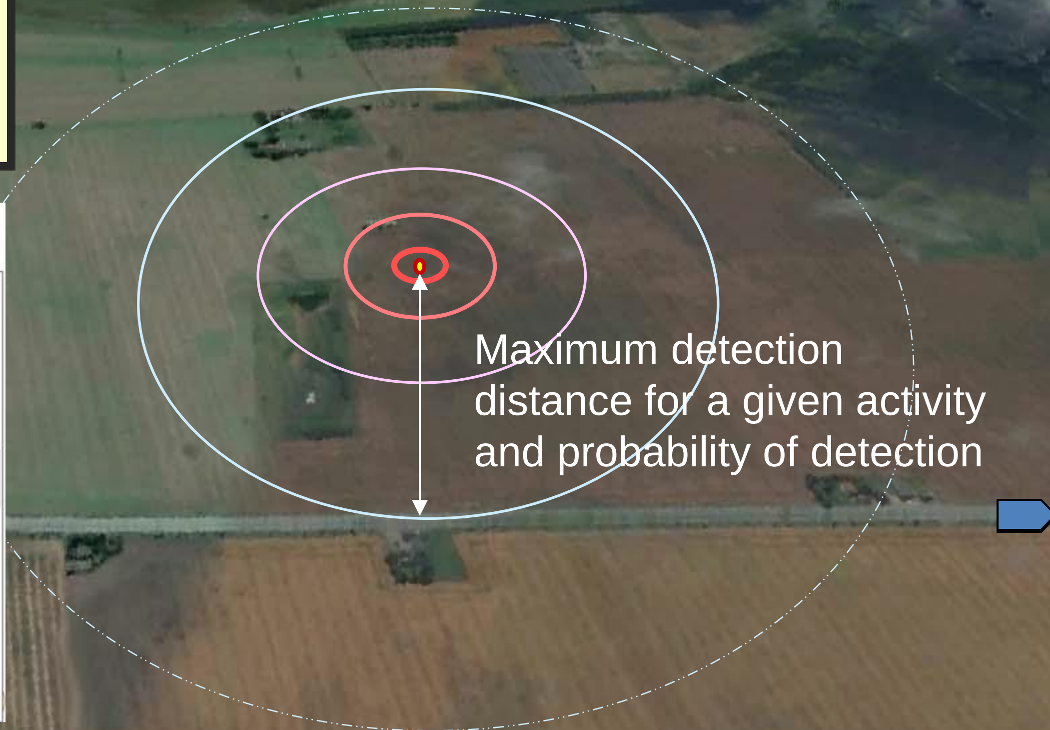


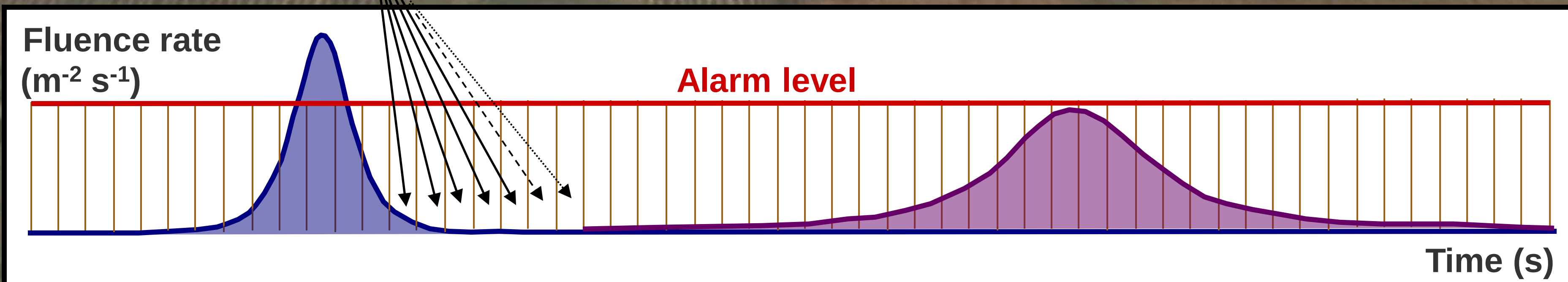
This calculation is only valid for one acquisition interval and zero speed. For a **range of intervals** and non-zero speed the algorithm is more complex, **needing an iterative solution**.

Detection distance calculation

This calculation must be made for each and every time interval. Then all calculations are combined to obtain the maximum detection distance for a given source activity

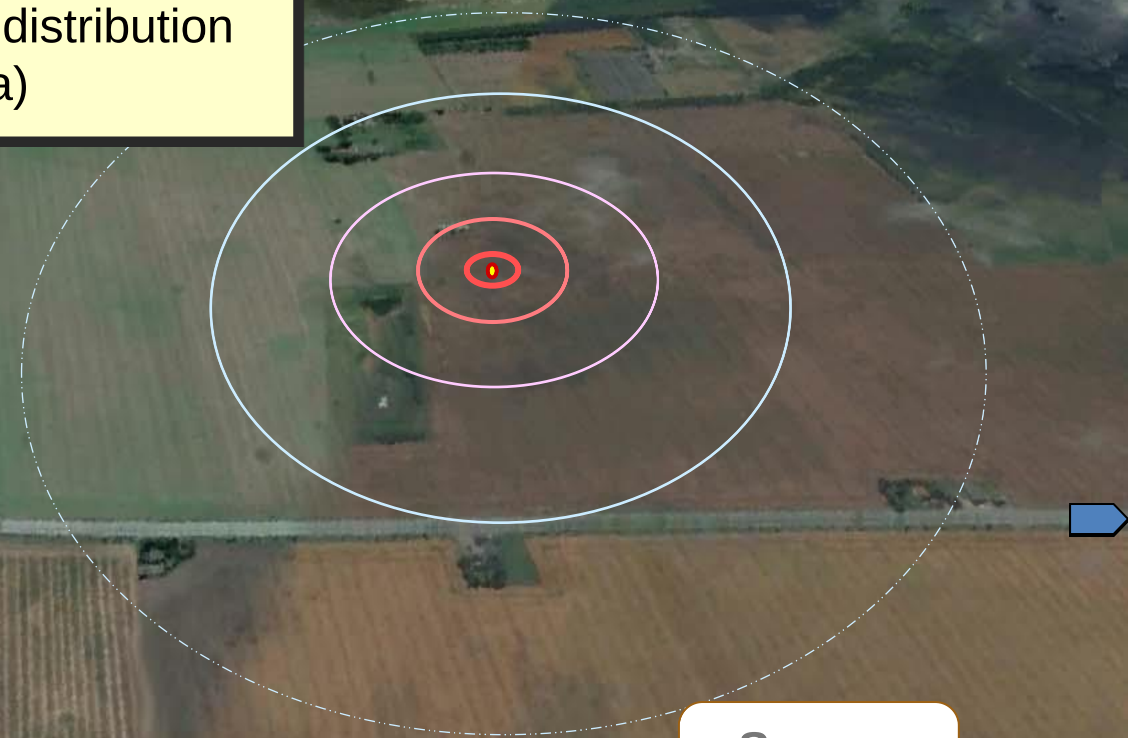


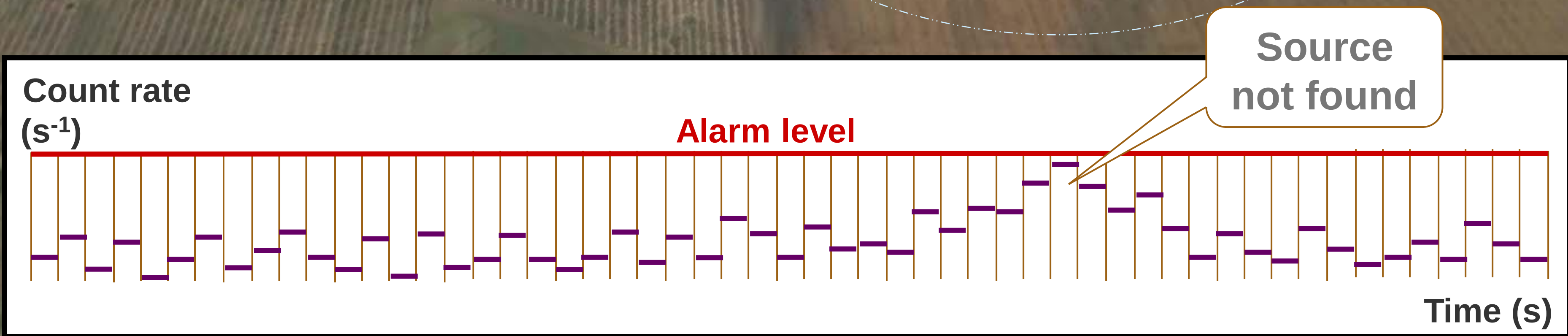




Examples of measured count rates

The count rate for each measurement in a time interval follows a Poisson distribution (the statistics of measured data)





Using varying time intervals

By using longer time intervals, the statistical variation in measurement data is damped

The alarm level can be lowered

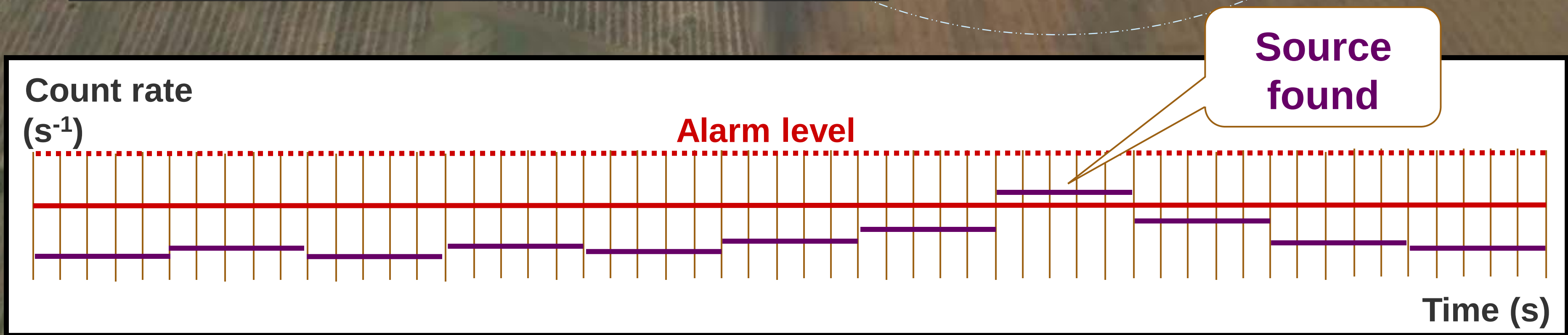
This is done to the cost of deteriorating geographical resolution.

The relation between alarm level and geographical resolution is important at high speeds, for example when using aircraft.

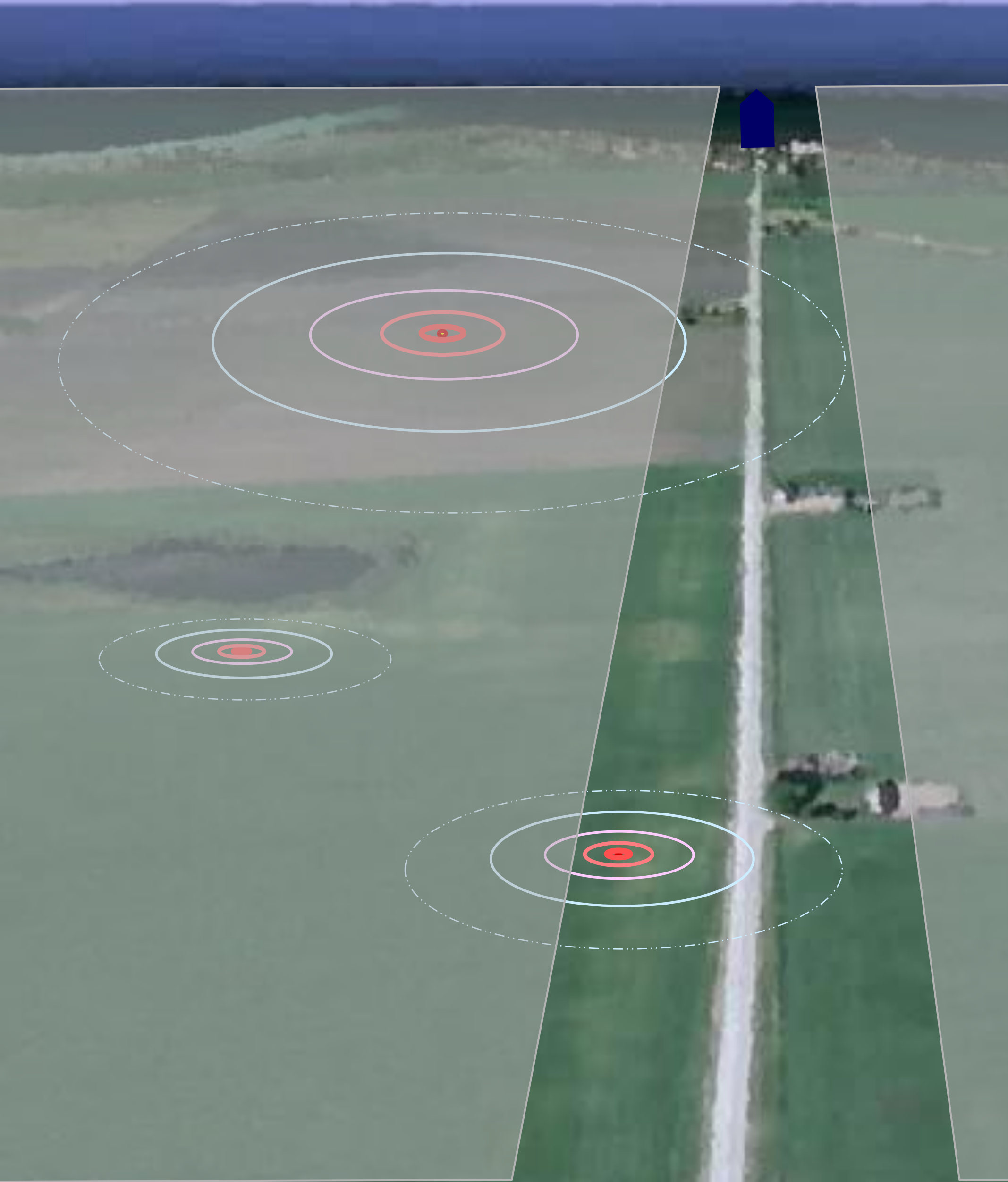
Variation in the natural background influences the selection of alarm level.

The background and the signal from a source can have different time signatures.

Possible solution:
Time signature analysis.



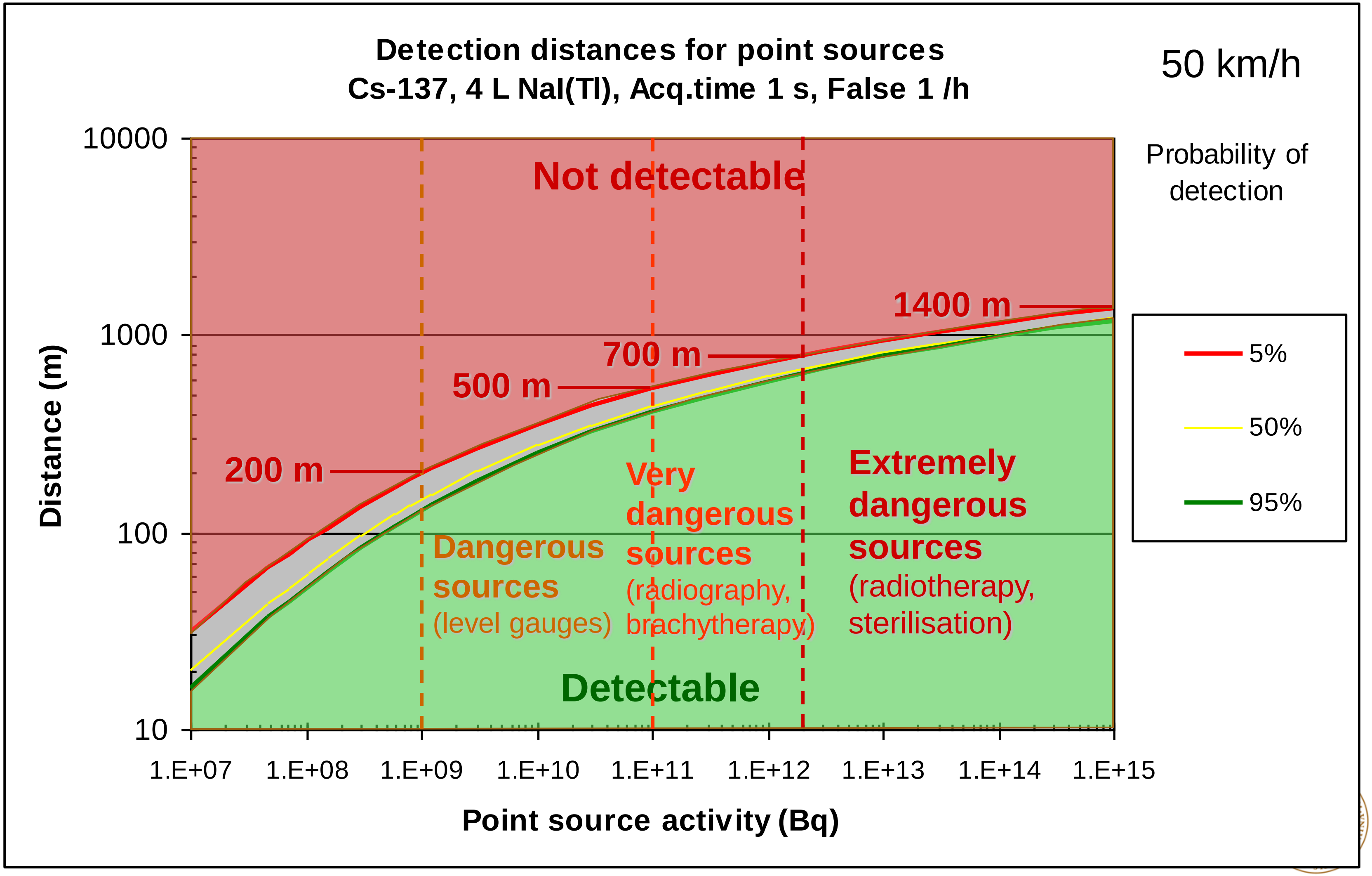
The “corridor” of detection



Mobile measurement can detect sources up to a maximum distance (a corridor) depending on:

- **Source activity**, higher widens
- **Time intervals**, increased widens, but leads to lower geographical accuracy
- **Alarm level**, lower widens, but causes more false alarms
- **Background level**, lower widens
- **Speed**, lower widens
- **Detector volume**, higher widens
- **Detector resolution**, higher widens

Detection distances depending on activity



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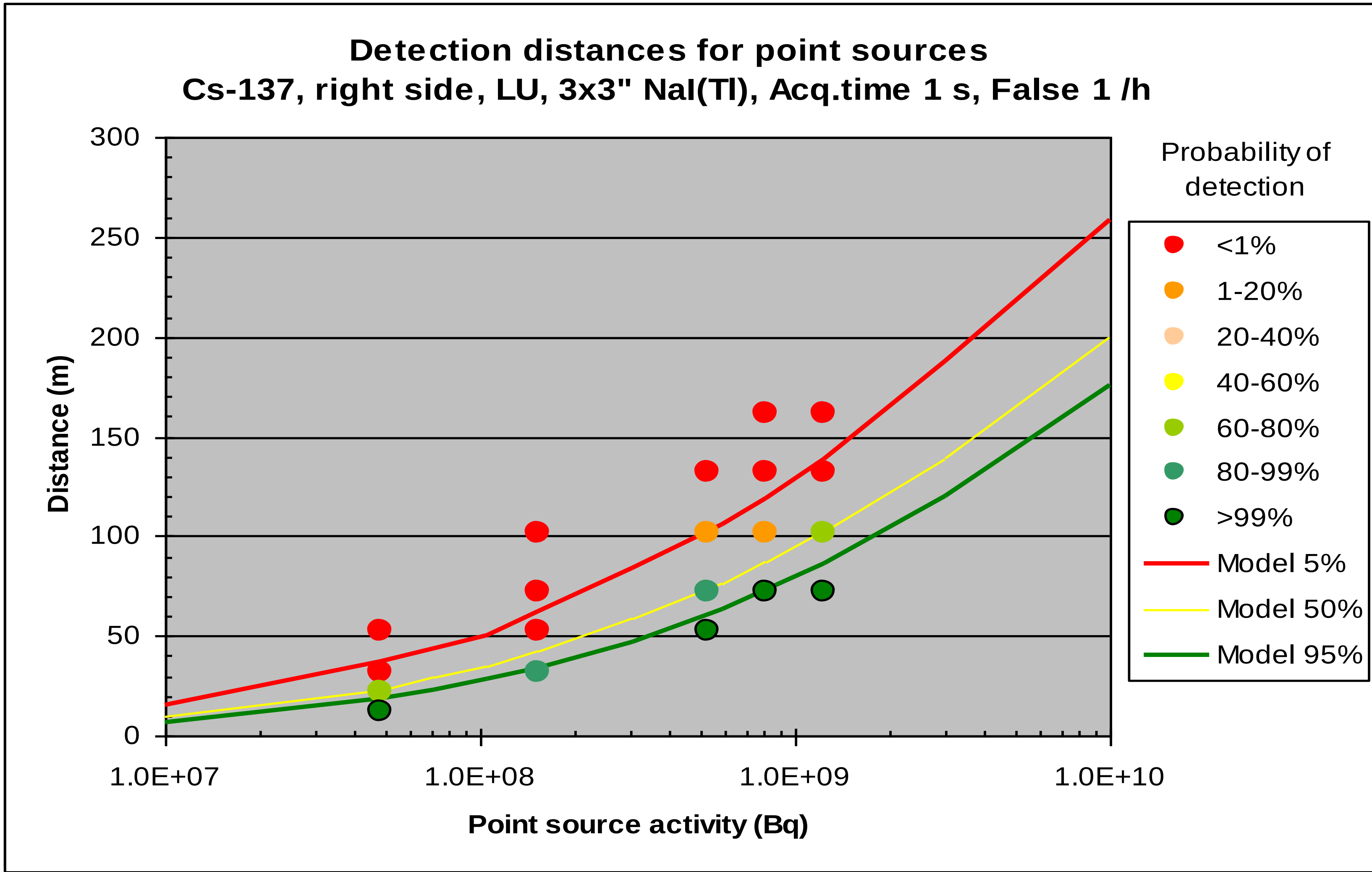
Experimental validation of the detection distance model

Joint Nordic field experiment in Barsebäck, Sweden, June 2018



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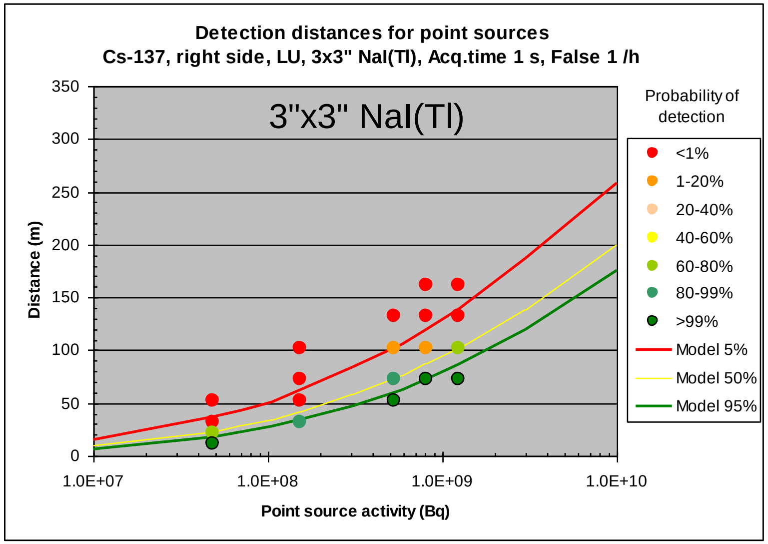
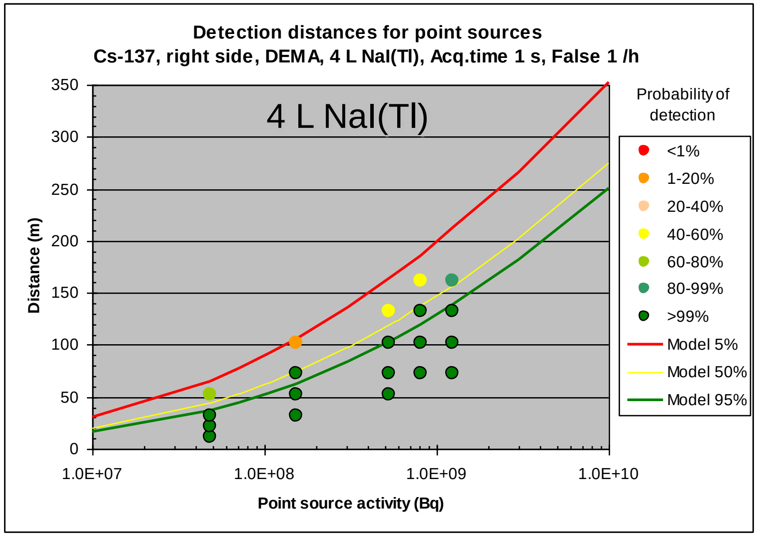
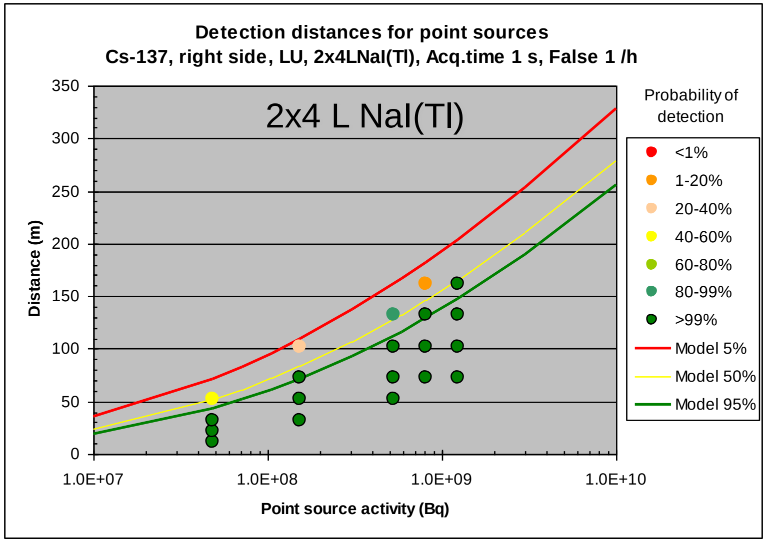
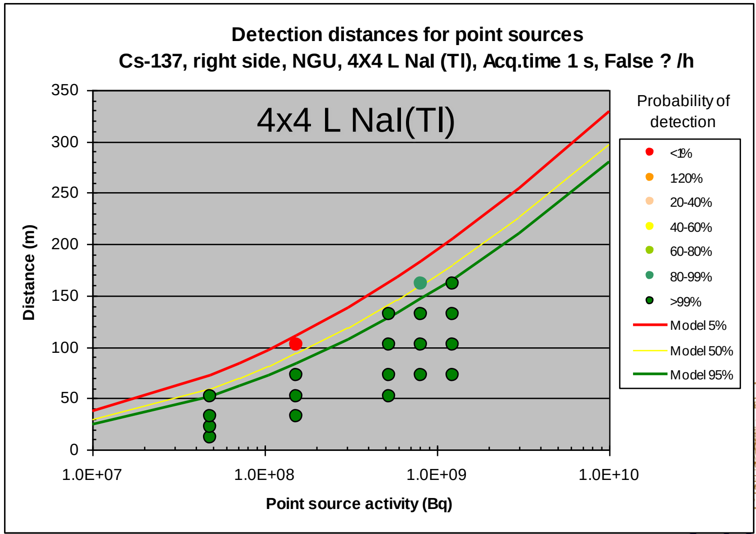
Detection distances depending on detector volumes









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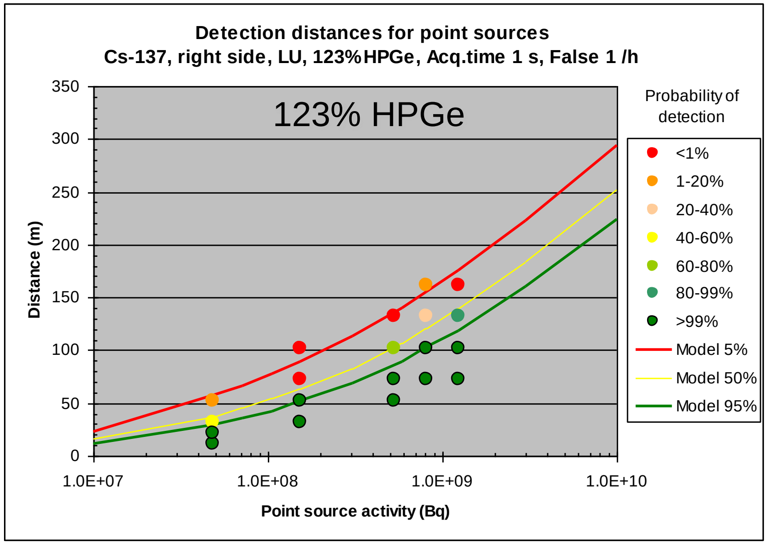
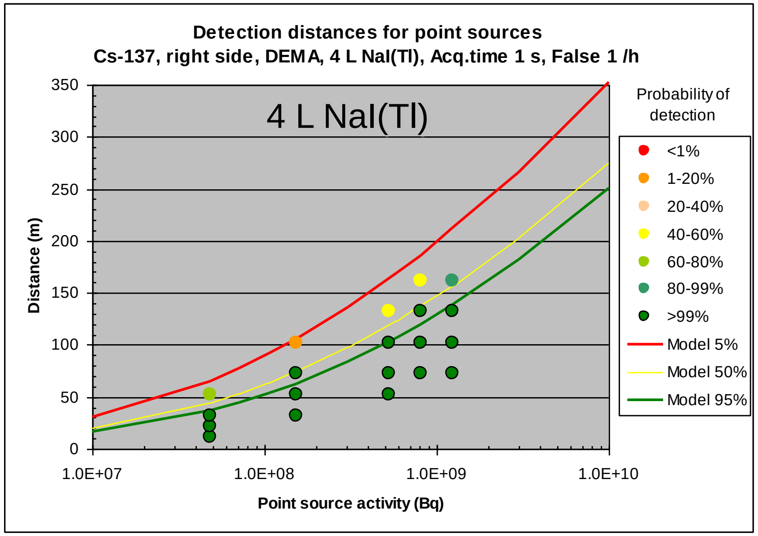
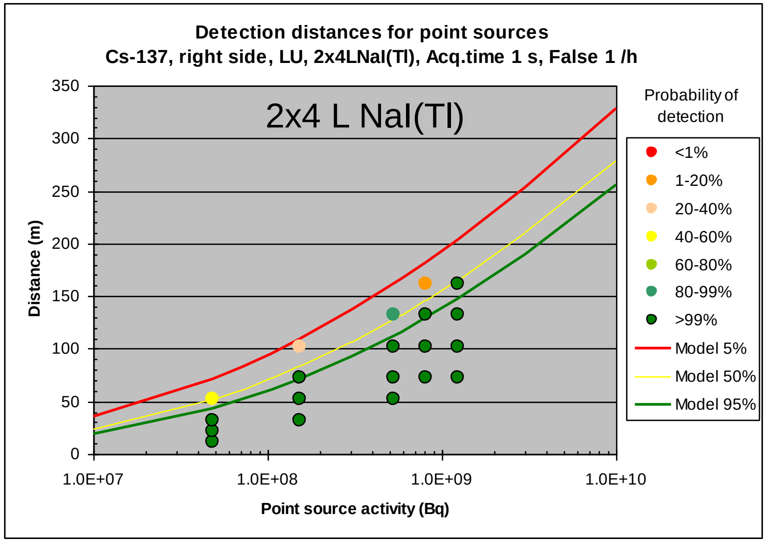
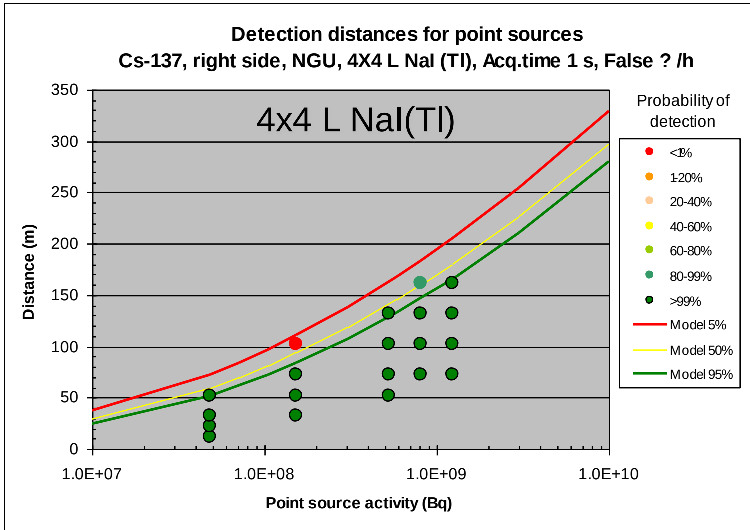
Detection distances for HPGe compared to NaI(Tl)









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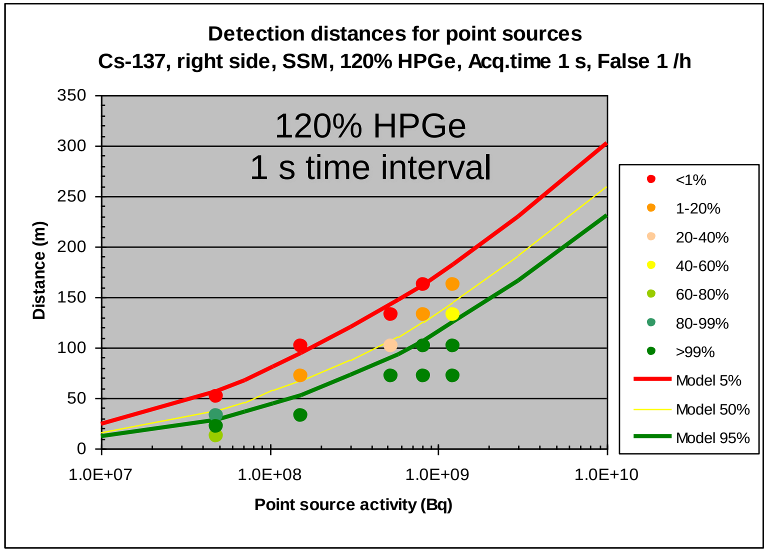
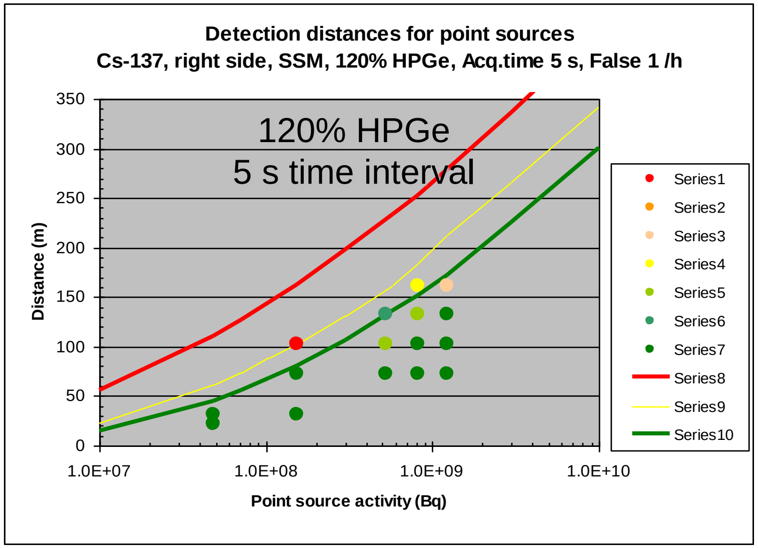
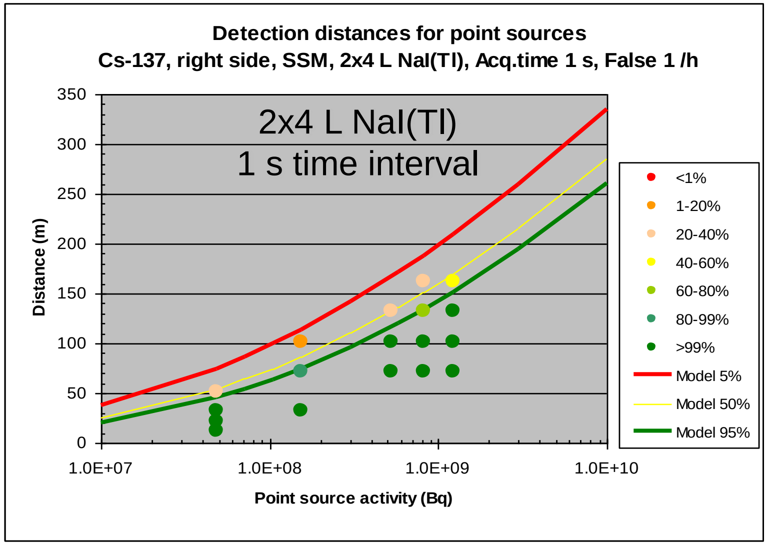
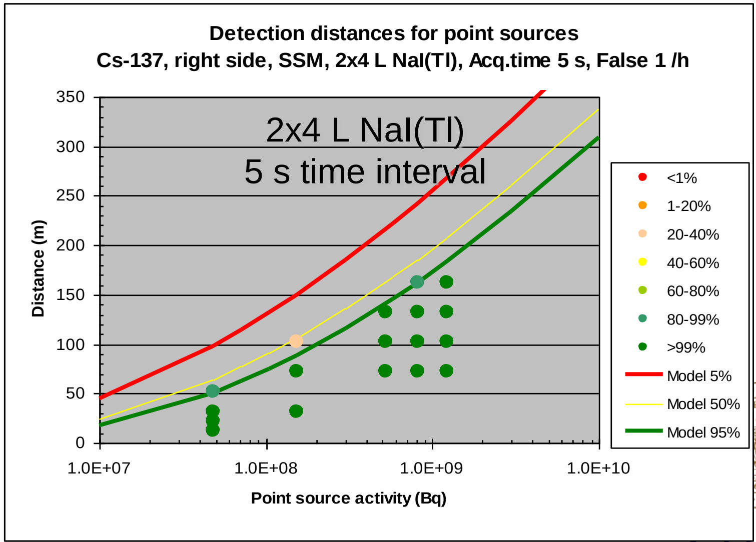
Increasing the acquisition time interval from 1 to 5 s









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Example, how to use model calculations

In a search mission, a helicopter and a fixed wing aircraft are available. Air speed is 120 and 200 km/h respectively. Lowest flying altitude is 120 m. The detector is a 4 L NaI(Tl)-spectrometer, having a shortest integration time of 1 s.

Which maximum distance between flight paths can be used if you are searching an area for an unshielded Cs-137 source with possible activity between 1 GBq and 1 TBq?

Solution from model calculation:

Activity	**1 GBq**	**10 GBq**	**100 GBq**	**1 TBq**
Helicopter	**70 m**	**420 m**	**740 m**	**1100 m**
Aircraft	**can't**	**400 m**	**710 m**	**1080 m**

With 500 m between flight paths, you can miss sources up to some tens of GBq

With 1000 m between flight paths, you can miss sources up to some hundreds of GBq

You can start searching with large distance between flight lines to find high activity sources first, then narrowing with denser flight lines in between in order to find weaker sources.

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Conclusions

Based on the physics and statistics for mobile measurements, using model calculations, the best selection of measuring equipment and search parameters such as vehicle speed and alarm level can be chosen.

By using time signature analysis the detection distances can be optimized and uncertainties in the mission reduced.

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