# Searching for Gravitational Wave Repeaters

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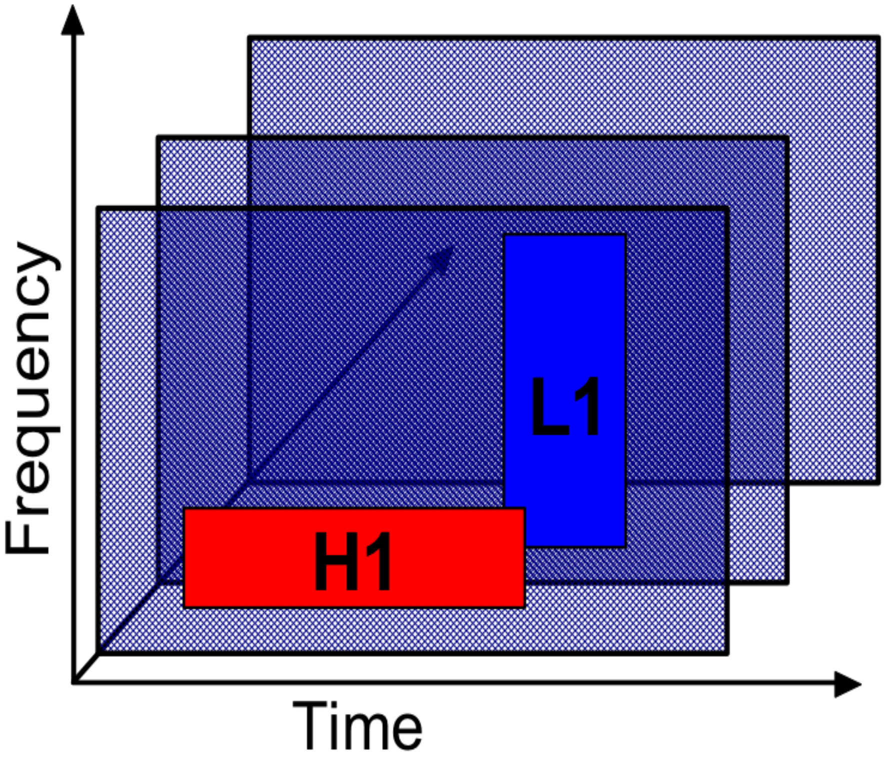
# Project Overview

- Search Aim
  - Target potential burst signals coming from the same location in the sky (gravitational wave repeaters)

- Strategy
  - Test method on 6 months of simulated data with noise characteristic similar to the 4-km LIGO detectors (L1 and H1)
  - Add simulated signals from a single source location to noise

- Search Method
  - From initial trigger lists for each detector find coincidences
  - For each coincident trigger, compute the time difference between arrival time at L1 & H1
  - Establish the ring of source locations for the event
  - Find locations where many rings cross

# Finding Coincident Triggers & Time Differences



Criteria for Coincidence

1. Triggers must be separated by less than 10 ms in time (baseline light travel time)

2. Triggers must overlap in frequency

3. Triggers must have similar Q (Quality factor) values

Parameter Cuts

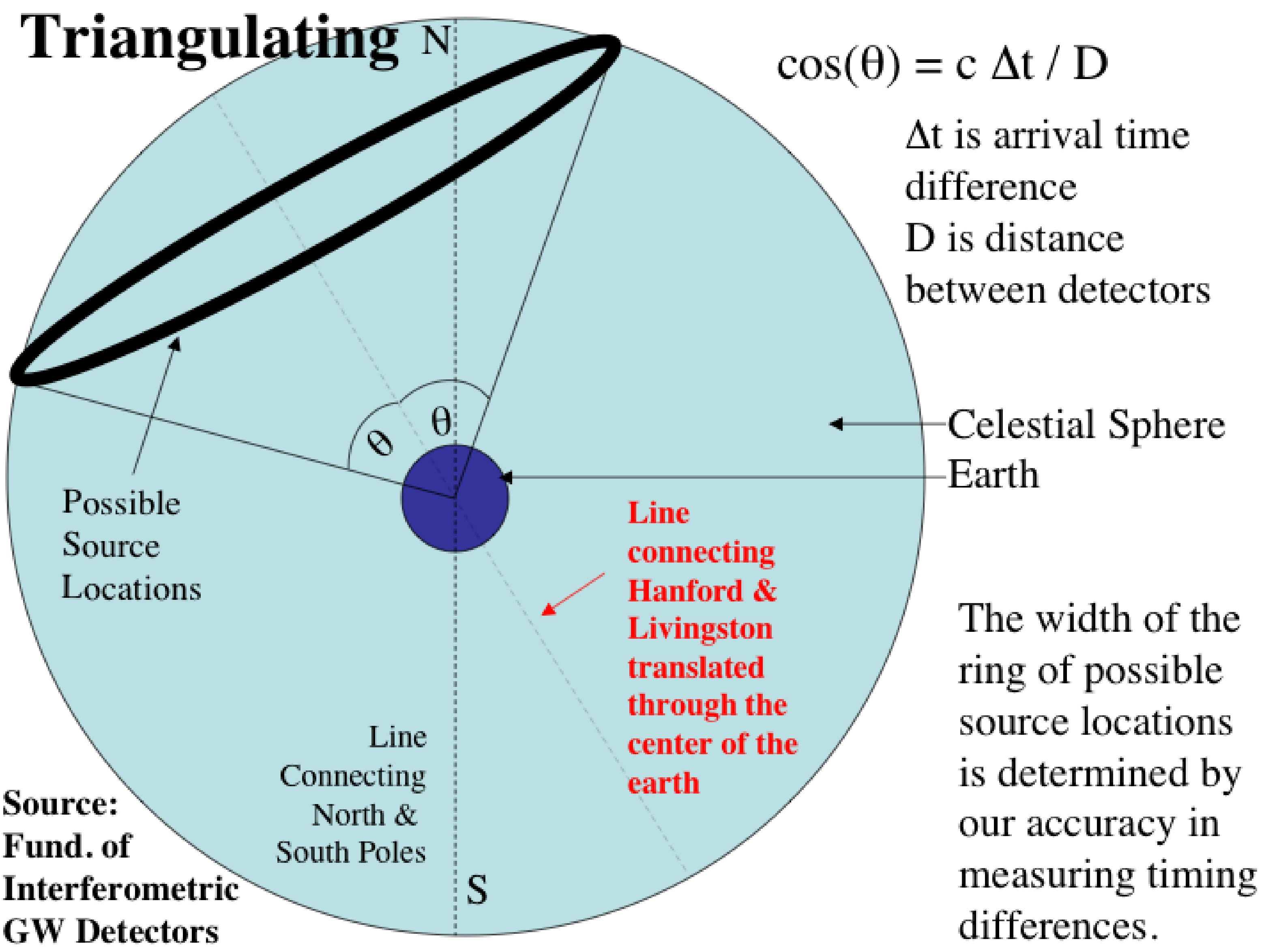
4. Reject any events below pre-determined significance level

5. Reject any event for which the error on the time difference (calculated below) is greater than a pre-determined threshold

Finding the Time Difference

- We go back to the original data at the trigger time and calculate the mutual information between L1 & H1 data streams for different time shifts.
- The time shift that maximizes this quantity is the arrival time difference
- The width of our fit around this maximum is the error on the arrival time difference (usually <1 ms to 1 ms, depends greatly on frequency content)

# Plotting Rings



**Triangulating**

$\cos(\theta) = c\,\Delta t / D$

$\Delta t$ is arrival time difference

D is distance between detectors

Celestial Sphere

Earth

Possible Source Locations

**Line connecting Hanford & Livingston translated through the center of the earth**

Line Connecting North & South Poles

The width of the ring of possible source locations is determined by our accuracy in measuring timing differences.

**Source: Fund. of Interferometric GW Detectors**

# Evaluation of Search Sensitivity

- Determine how many repeats are needed over a 6 month period for a gravitational wave repeater to be statistically significant compared to noise

- We create two pools of events $\{t, \Delta t, \delta(\Delta t)\}$
  - Background
  - Simulated signals (of different types of various strengths)
    - Comparable strength background events occur 1-4 times per day

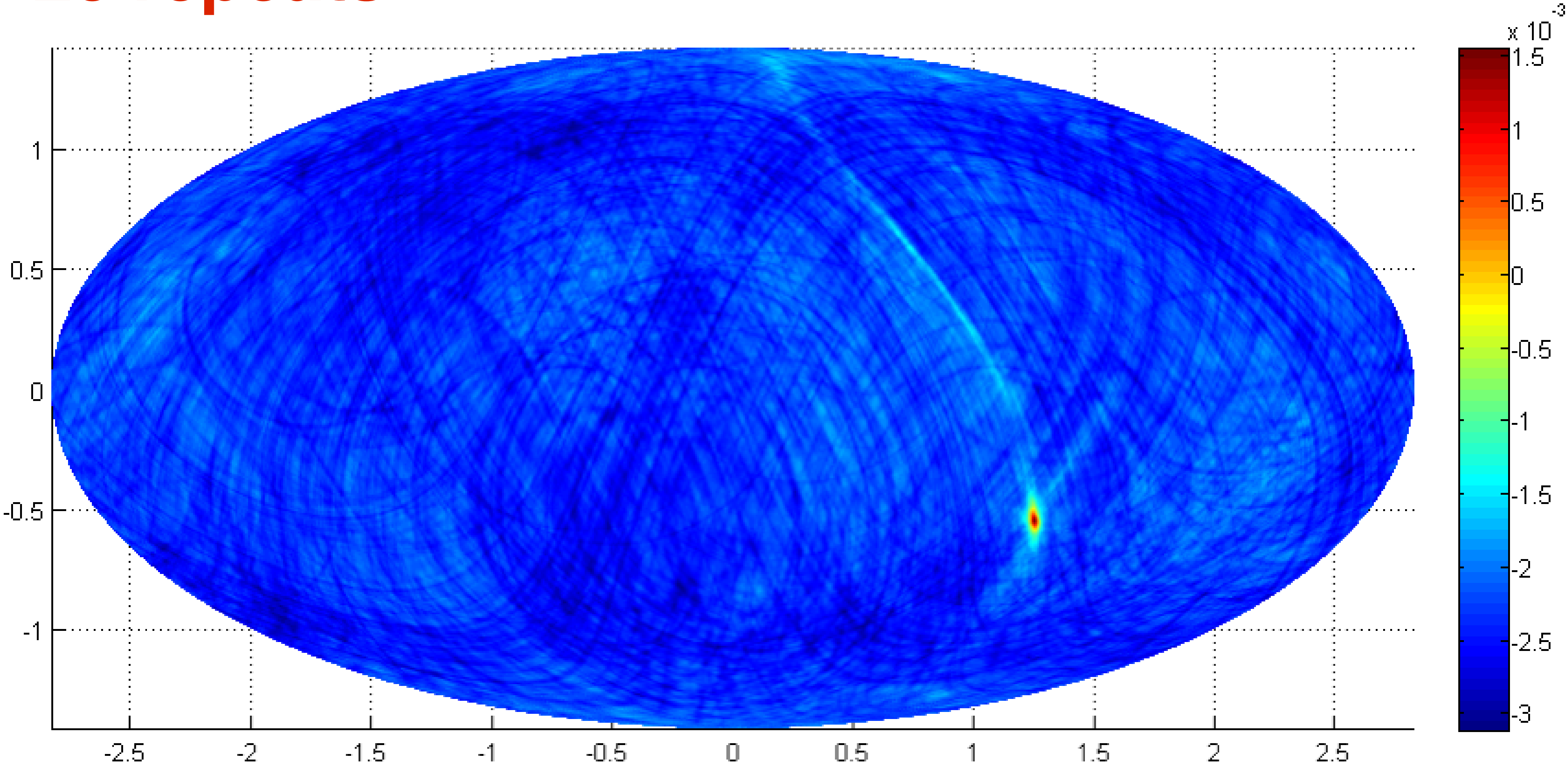
- We characterize the background occupancy number distribution for each sky pixel by plotting 6 months worth of background events on the sky (drawn randomly from the background event pool) and repeating many times to obtain statistics for each sky pixel

- 6 months of background + small # of signals occupancy number distribution

- Use pixel statistics to establish confidence limits
  - Determine an upper bound for each pixel of the background distribution
    - 99.9% of time the pixel occupancy number is smaller than this value
  - Determine a lower bound for each pixel of the signal+background distribution
    - 90% of the time the pixel occupancy number is larger than this value

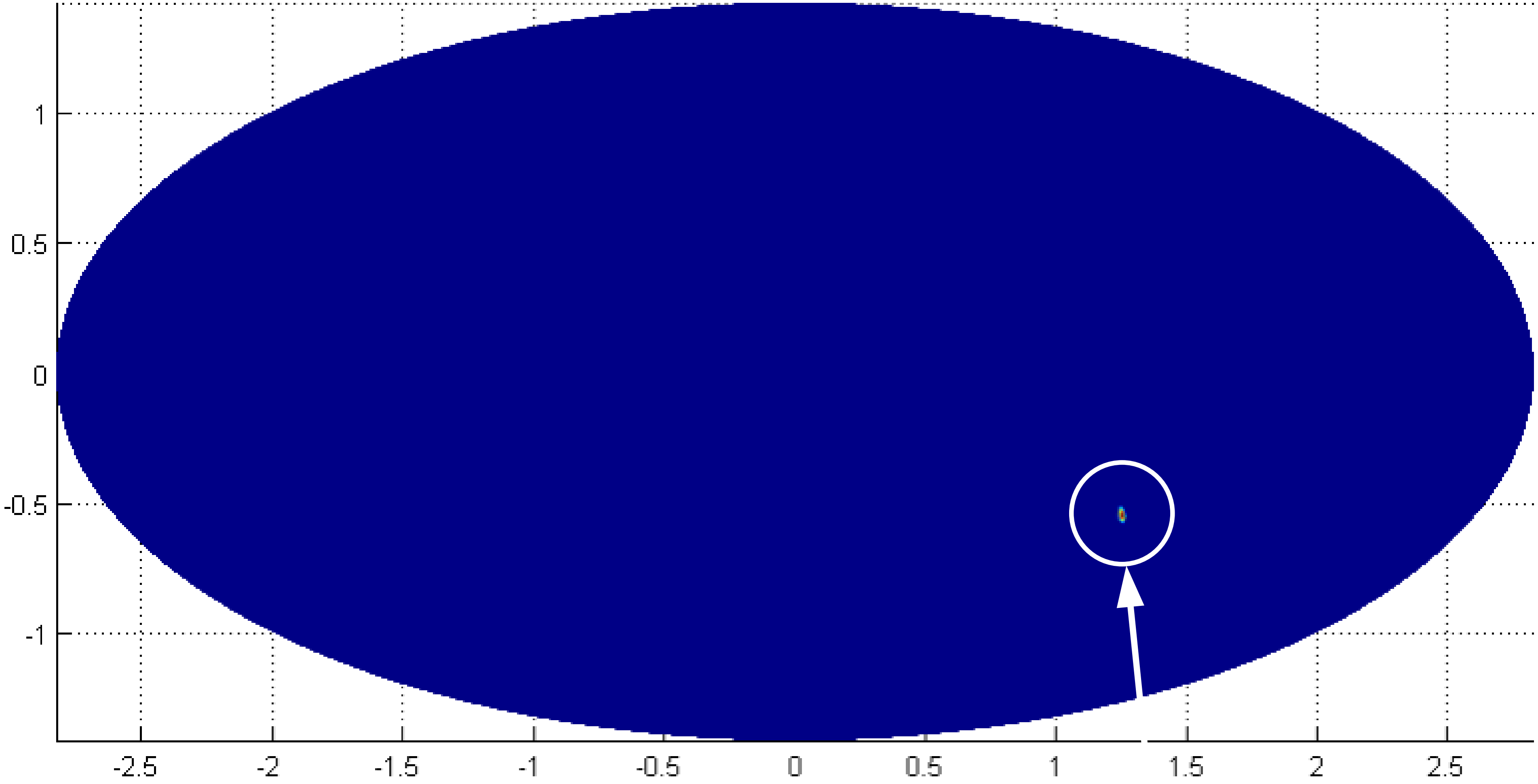
# Galactic Center Injection Example

## 20 repeats



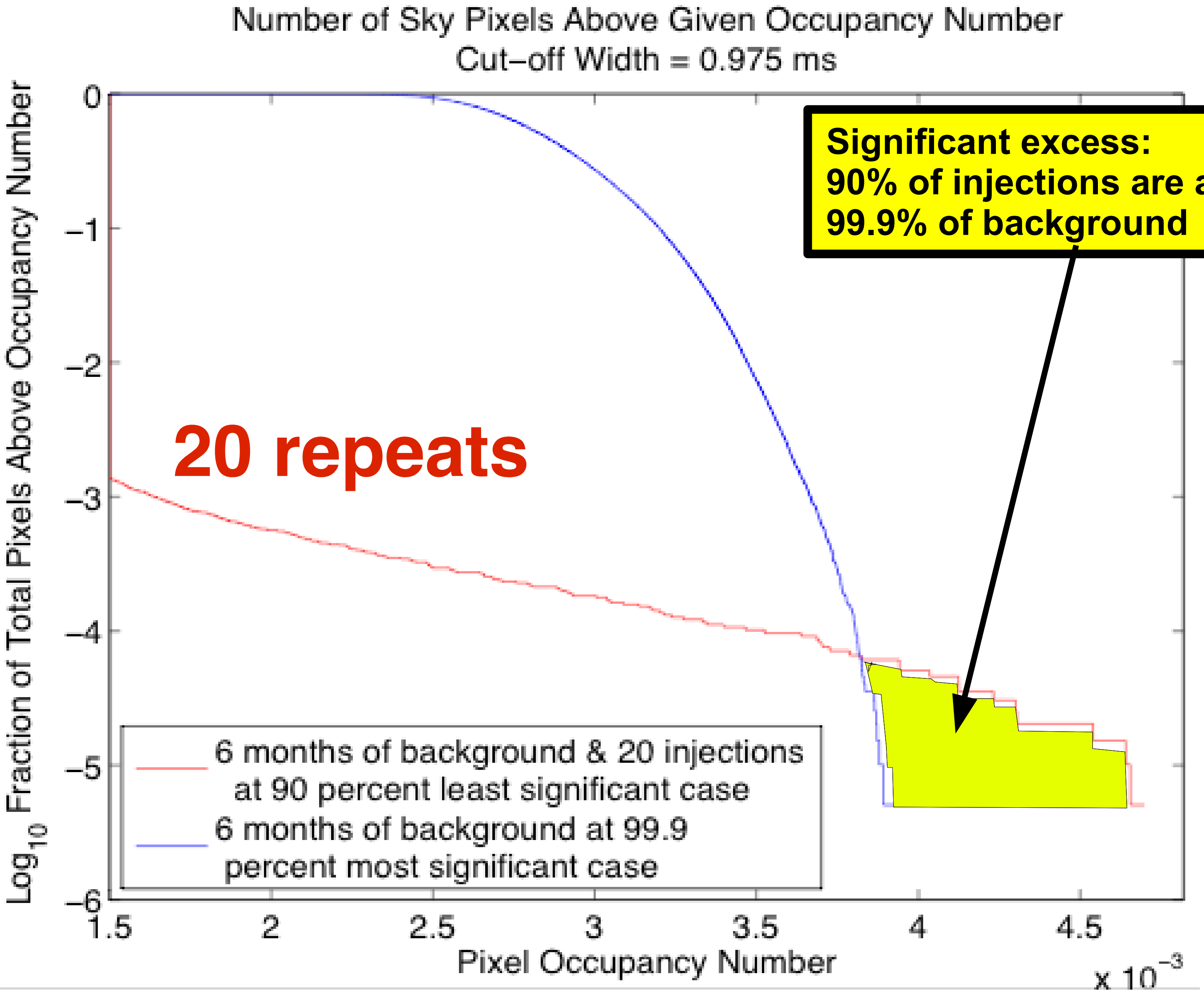
Lower bound on injection+background
MINUS
Upper bound on background

# Plotting only the Excess



The galactic center –
our simulated signal
source location

# Evaluation of Search Method



**Significant excess: 90% of injections are above 99.9% of background**

**20 repeats**

Injections:
-1-ms Gaussian pulses
-Supernova A1 waveforms
-Q15, f=235 Sine-Gaussian
-Q15, f=820 Sine-Gaussian