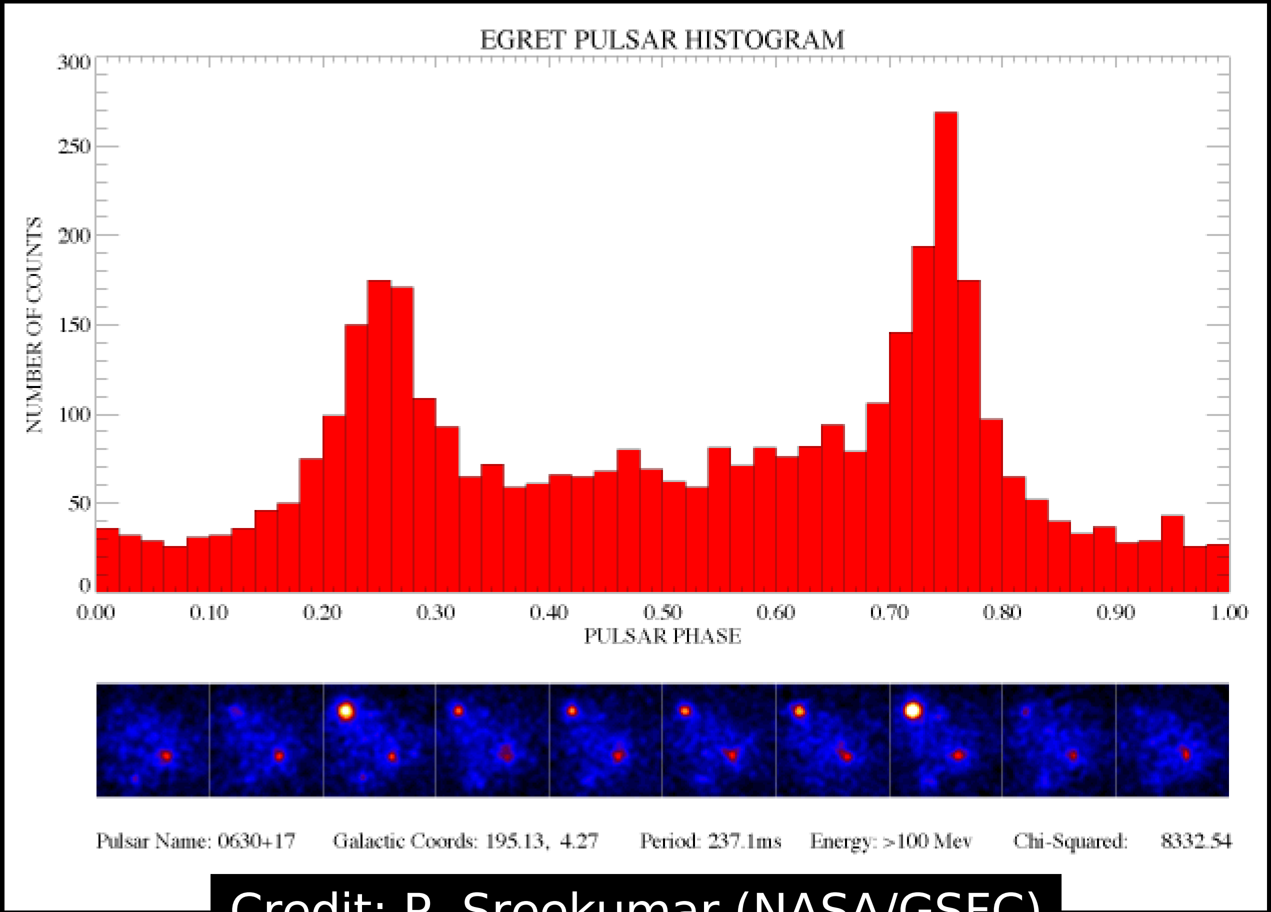
Finding (or not) New Gamma-Ray Pulsars with GLAST

Scott Ransom
NRAO



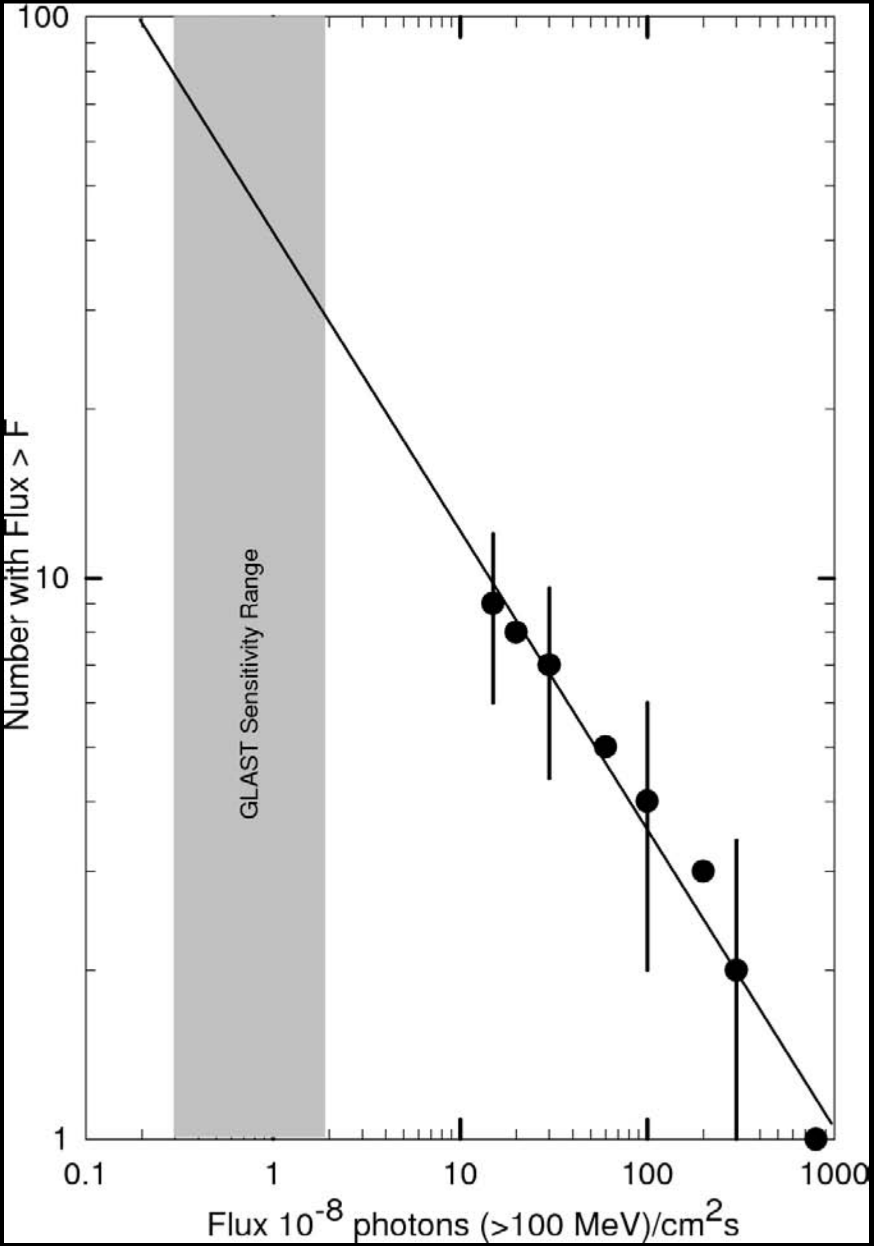
Credit: P. Sreekumar (NASA/GSFC)

Why pulsars with GLAST?

- EGRET saw pulsed emission from 7+ pulsars
- All but one (Geminga) are radio pulsars
- Usually young and energetic
- Pulsars are used as tools:
  - Strong-field gravitation tests
  - Equation of state of matter at supra-nuclear densities
  - Plasma astrophysics
- Yet we still don't understand the emission mechanism(s)!

Gamma-ray Pulsar Properties

- Non-variable
- Flat-ish spectra (power-law indices <2)
- Spectral breaks above 1 GeV
- Complex pulse profiles
- All found without using EGRET!
- Likely many more



See review by David Thompson (astro-ph/0312272)

High Energy PSR Search Basics

- Several techniques:
  - Sinusoidal: Fourier techniques are optimal
  - Complex profiles:
    - Fourier techniques with harmonic summing
    - Epoch folding with significance test
- For optimal sensitivity, collect source events and maintain phase coherence for as long as possible -- this is hard
- Can use incoherent techniques with a loss of sensitivity

Phase Coherent Techniques

- Discussed by many groups. Good published discussion for EGRET data by Chandler et al., 2001, ApJ, 556, 59
- Highly sensitive, but many problems:
  - Low count rates demand long integrations
  - Long integrations mean searching over f-dot
  - Young pulsars have timing noise and glitches
  - As integration times increase, so do the computations and the numbers of trials
- Crab, Vela, and Geminga (at least) can be identified blindly in EGRET data

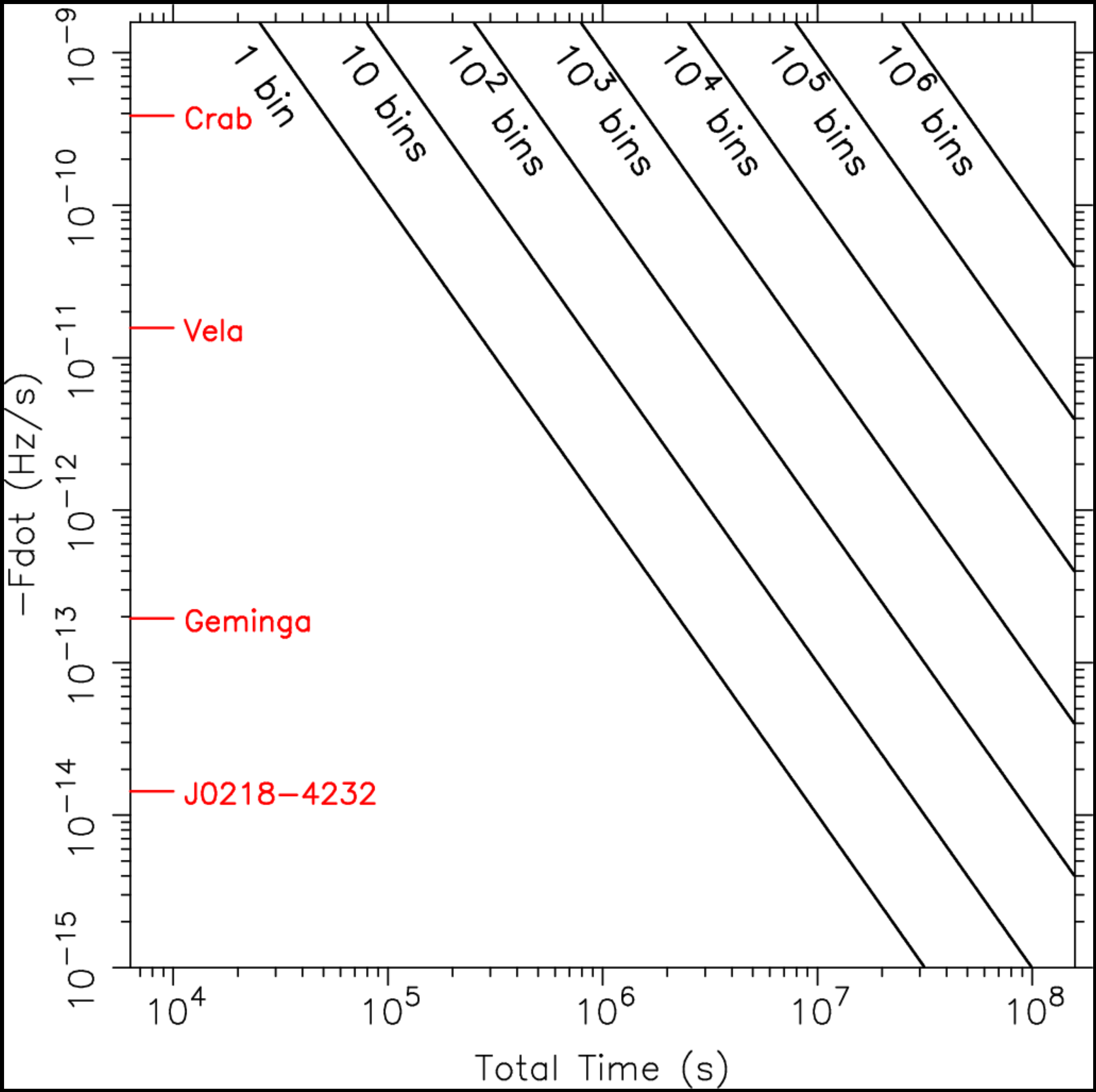
Scaling Relations

- N_b,N_s,N_t = bakground, source, and total events
- T_{view} = time from first event to last
- α = shape factor (0.4-0.9 for known PSRs)
- "Power": $$P \sim 1 + \alpha \frac{N_s^2}{N_t}$$
- # of Trials: $$N_{\rm trials} \sim f_{\rm max} |\dot{f}_{\rm max}| T^3$$
- Significance: $$\propto e^{-P} N_{\rm trials}$$

Frequency Derivatives

Coherent searches with T_{view} > 1 day will need to account for fdot

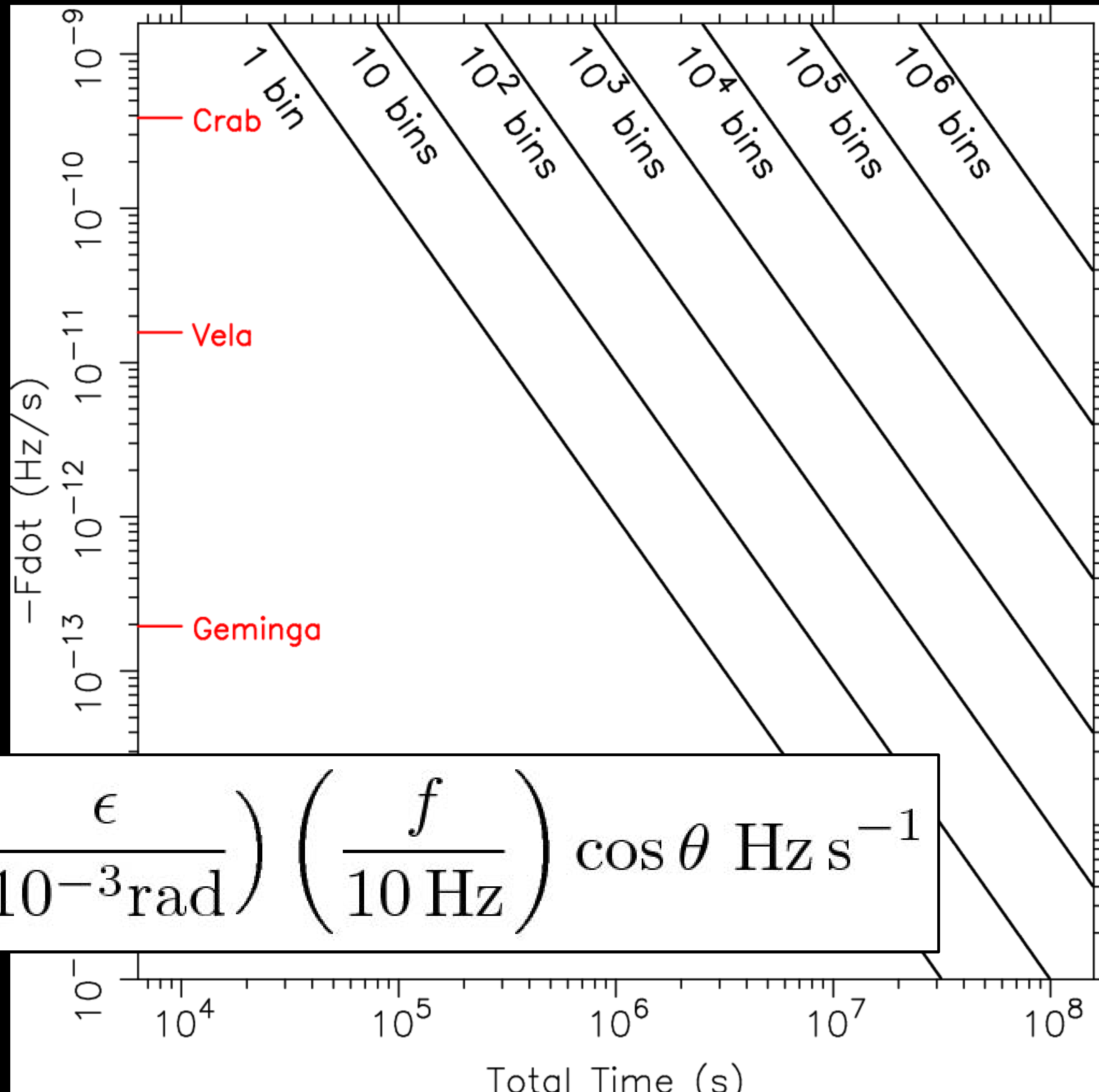
Note: 1 "bin" is $1/T_{view}$ in Hz



Frequency Derivatives

Position errors can cause a Doppler-induced fdot

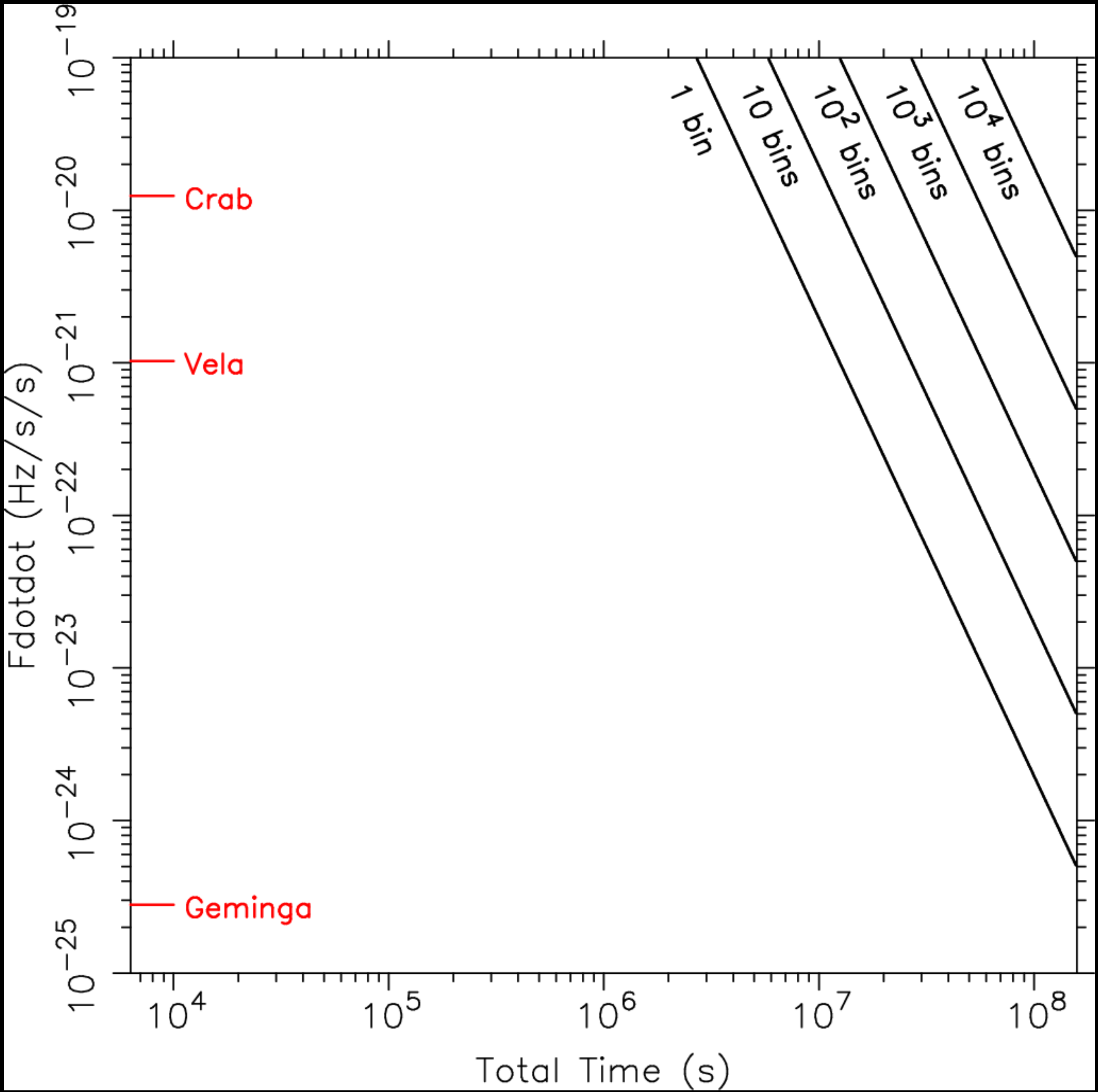
(Chandler et al. 2001)



$$\delta \dot{f} \sim 2 \times 10^{-13} \left(\frac{\epsilon}{10^{-3}\mathrm{rad}} \right) \left(\frac{f}{10\,\mathrm{Hz}} \right) \cos\theta \ \mathrm{Hz\,s^{-1}}$$

Frequency 2nd Derivs

Coherent searches with T_{view} > 1-2 months will need to account for freq 2nd derivs



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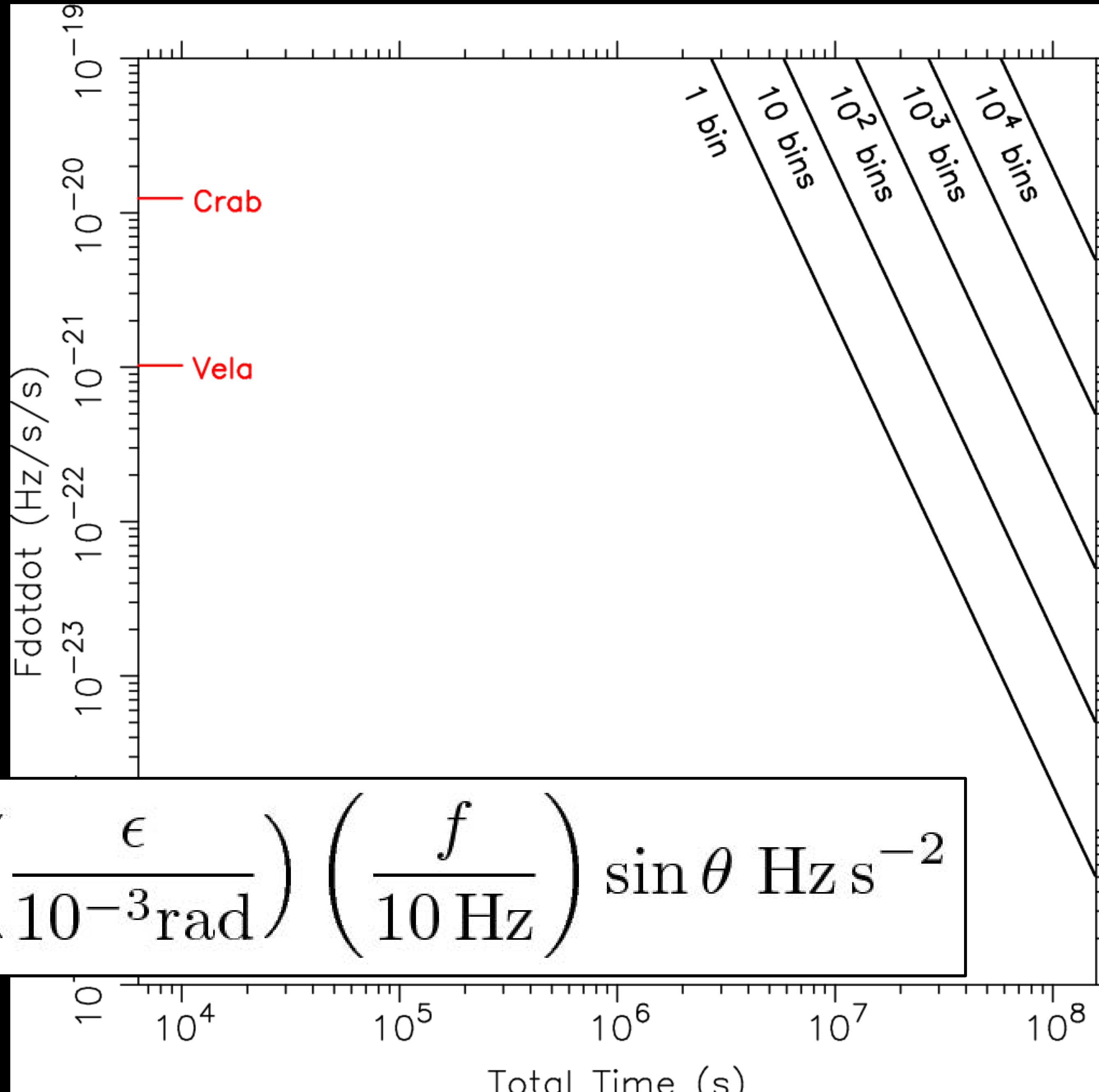


$$\delta \ddot{f} \sim 4 \times 10^{-20} \left(\frac{\epsilon}{10^{-3}\mathrm{rad}} \right) \left(\frac{f}{10\,\mathrm{Hz}} \right) \sin\theta \ \mathrm{Hz\,s^{-2}}$$

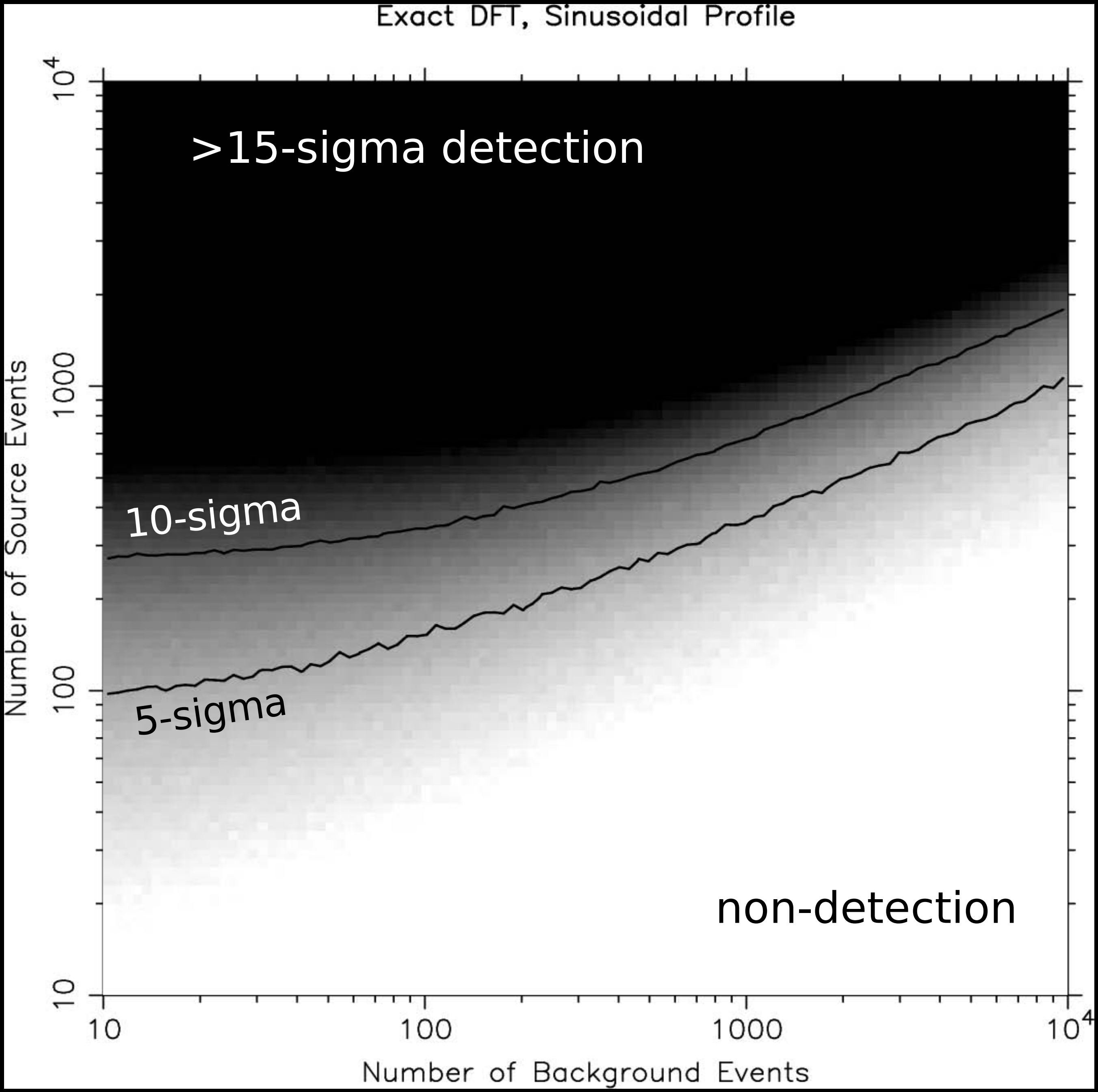
Sinusoidal Pulse

Most conservative

Valid for any T_{view}

All calculations are at 95% confidence-limit

Does not account for trials!



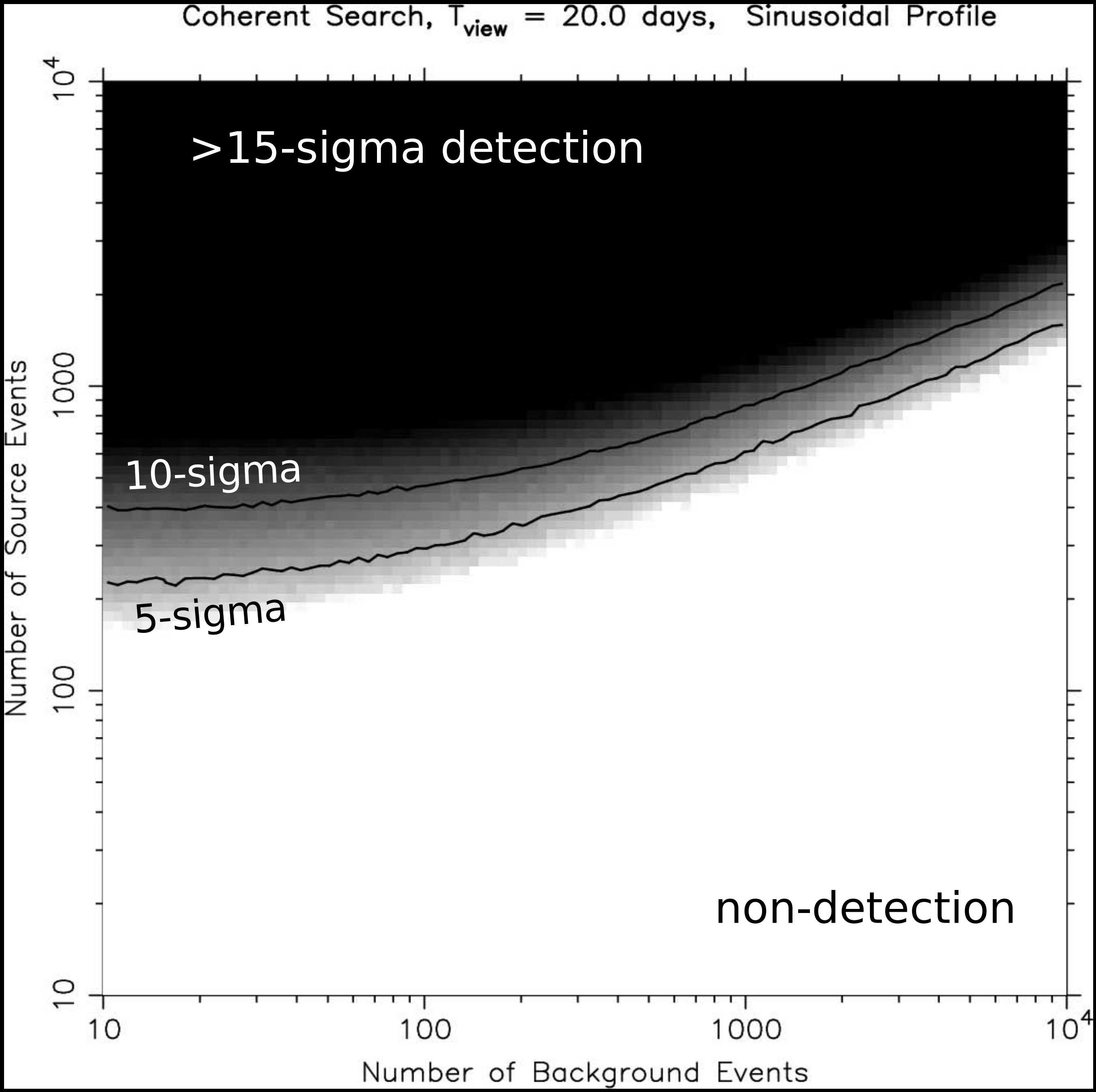
Sinusoidal Pulse

T_{view} = 20 days

Majority of pulsars are unaffected by 2nd freq deriv or position error

~10^{12} trials!

This would be a reasonable request for a GLAST pointing



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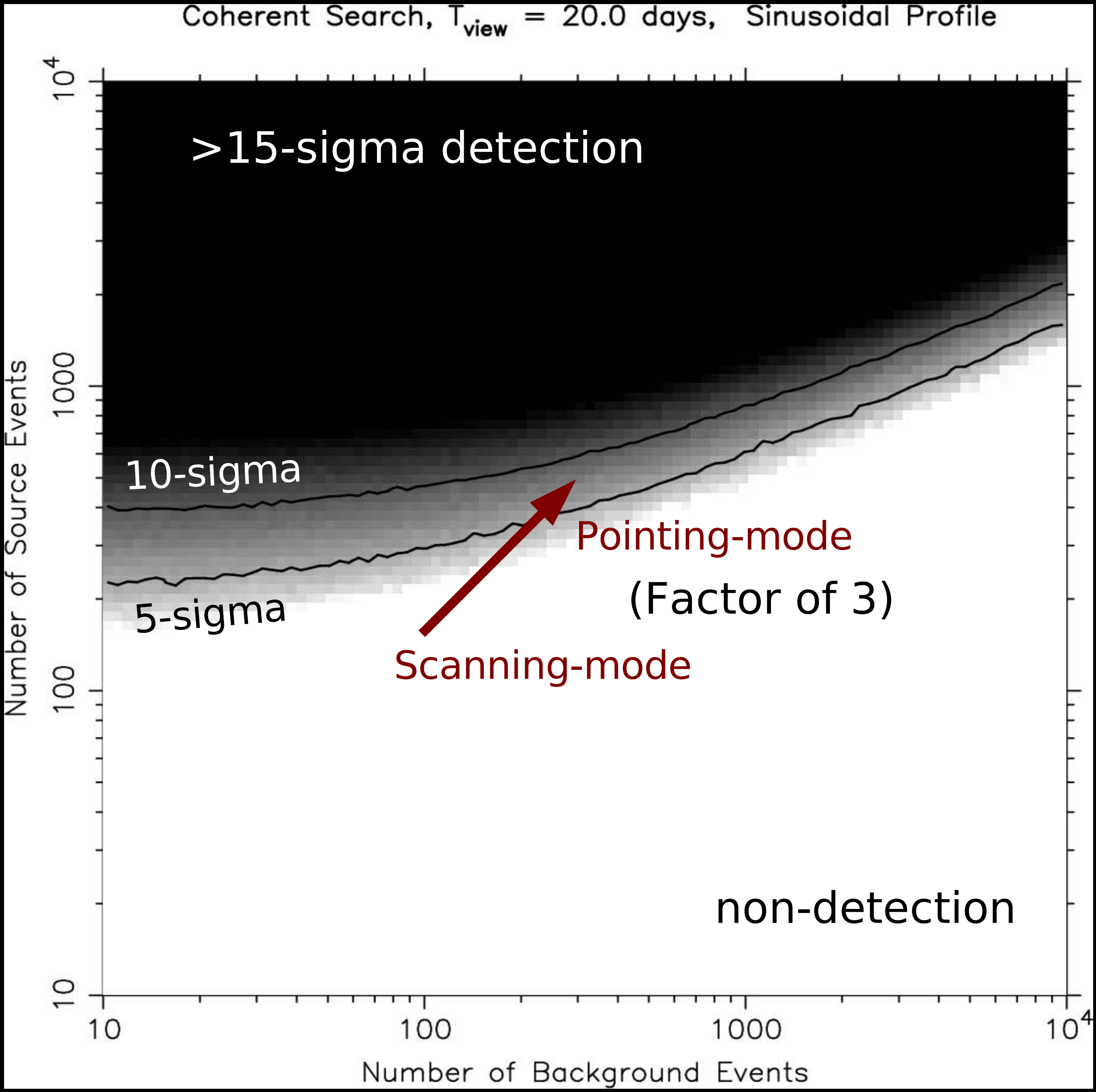

15% FWHM Gaussian

Probably a bit optimistic

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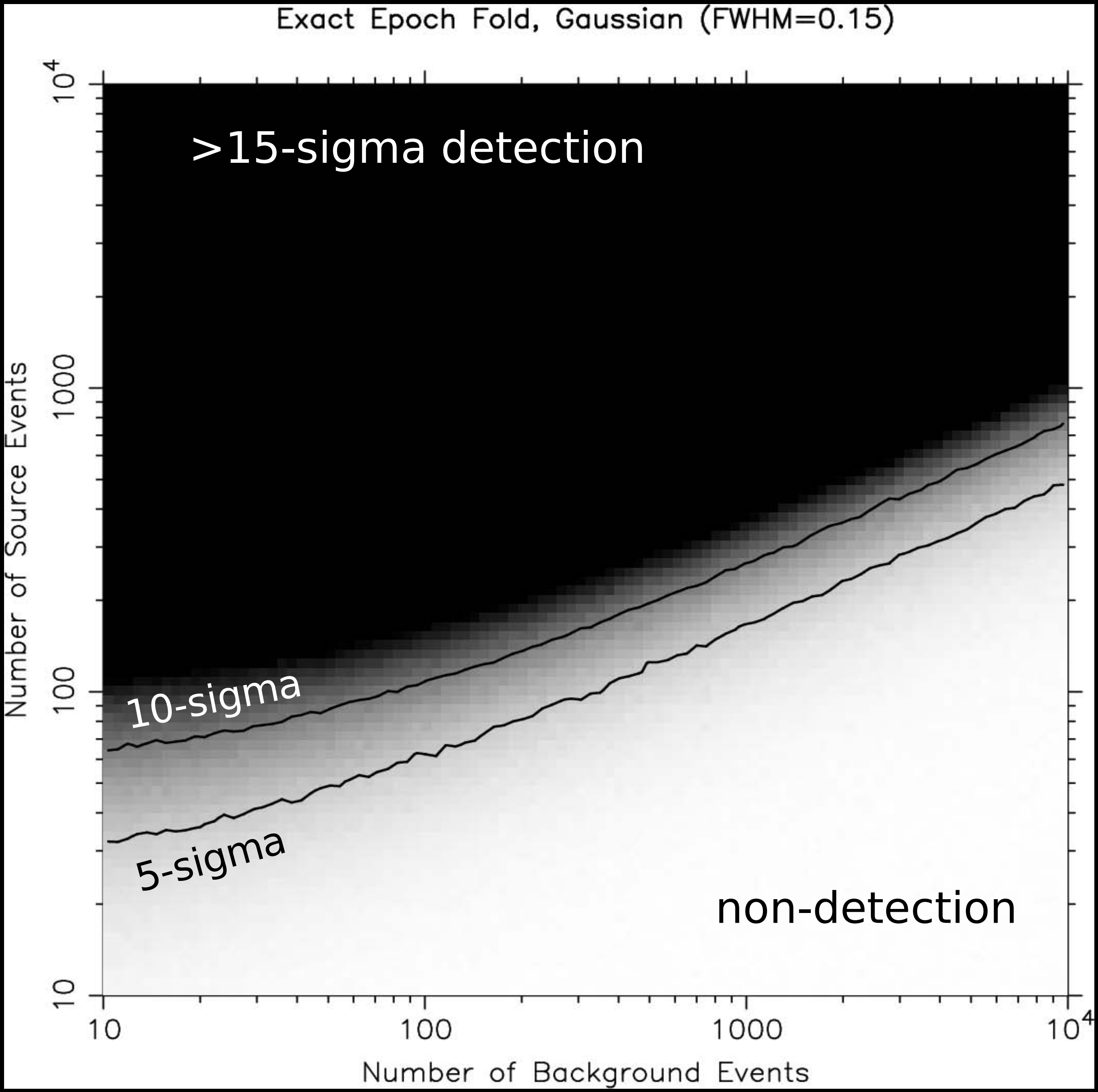

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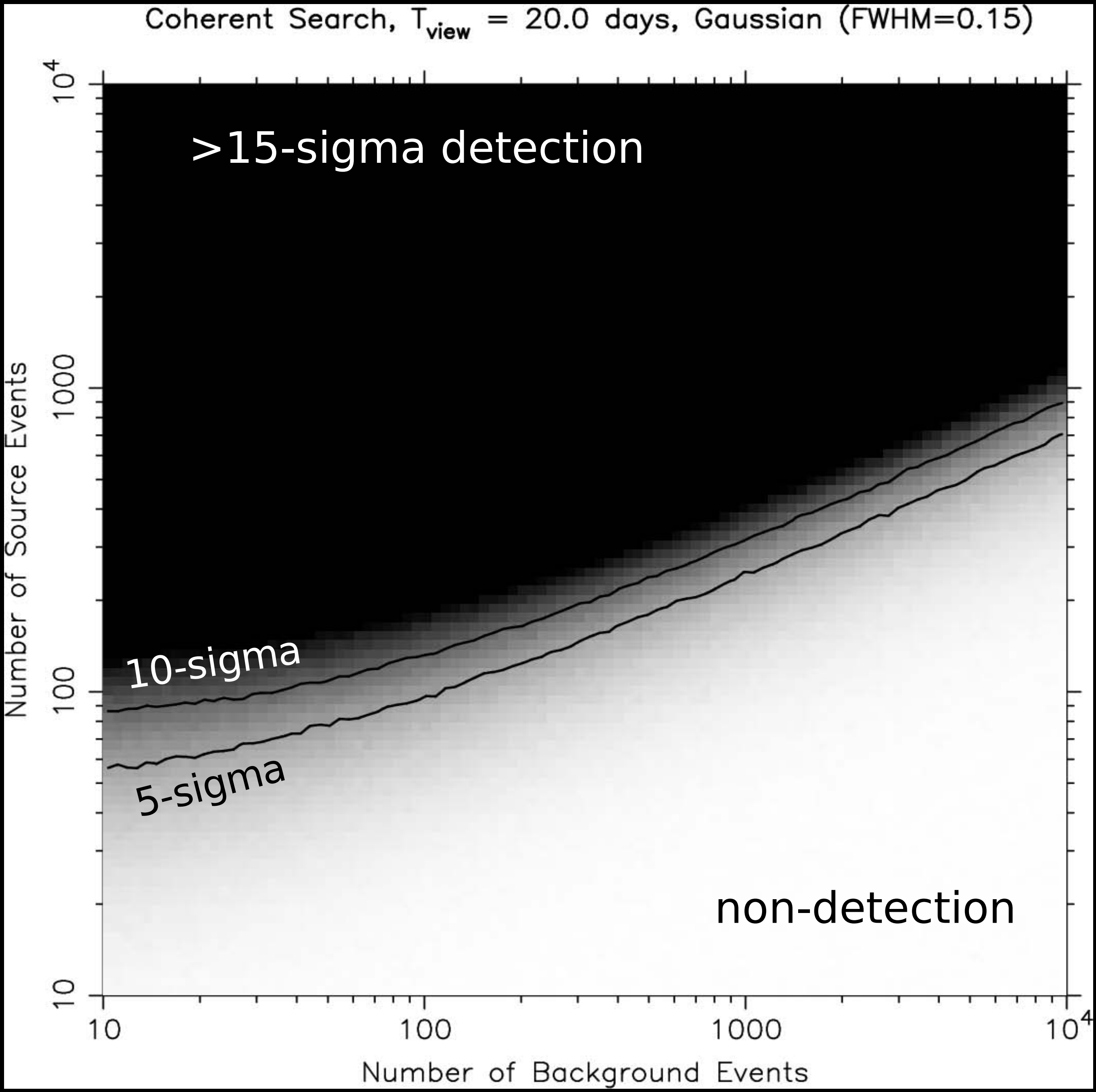

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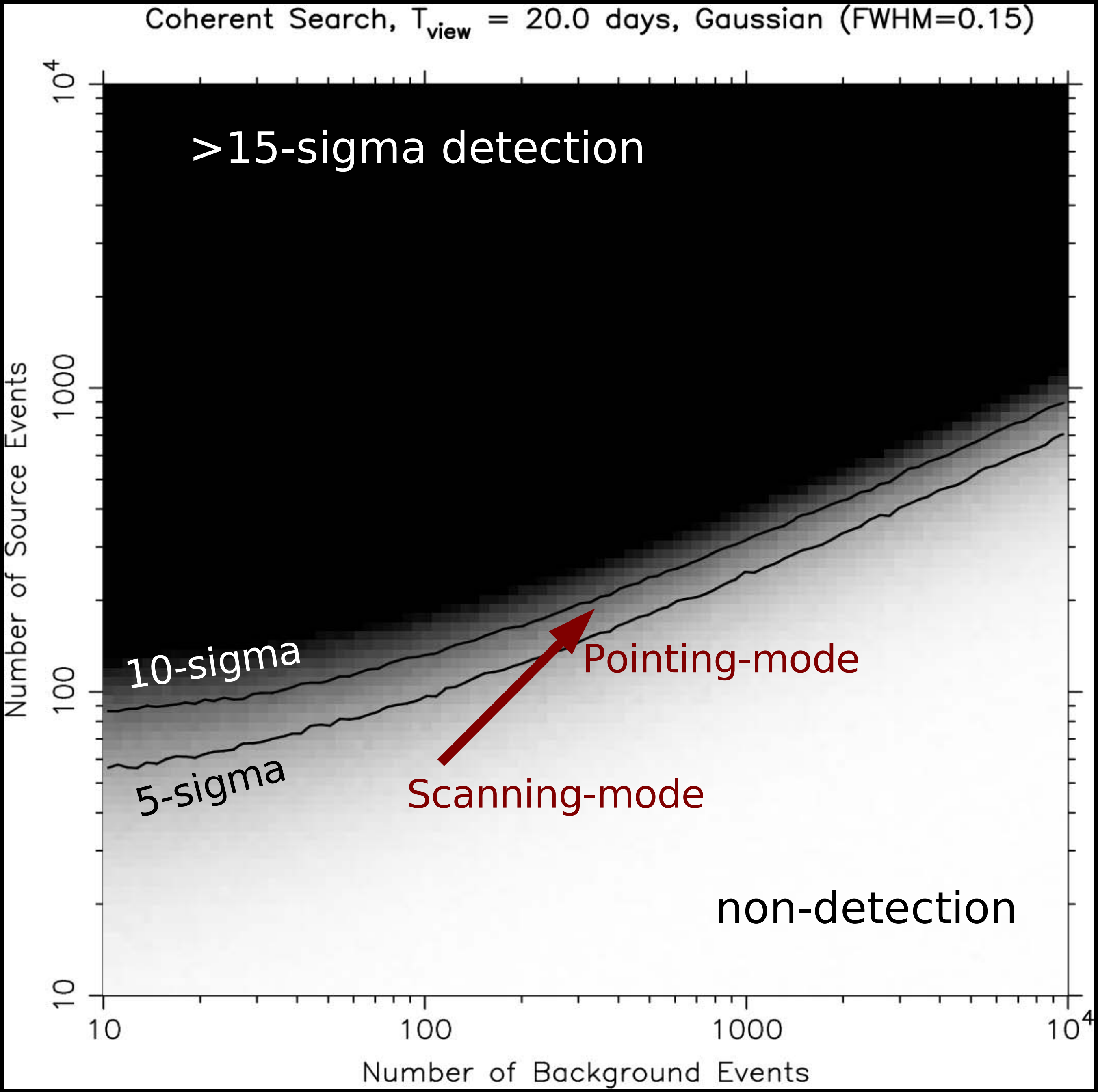


Incoherent Search Techniques

- Break T_{view} into segments of duration T_{win}
- Optimally:
  - T_{win} is as large as possible for sensitivity
  - T_{win} is small enough to remove fdot effects
- Perform a coherent analysis on each segment, then add the segments
- Computations faster, sensitivity suffers
- New "time-differencing technique" by Atwood, Ziegler, Johnson, & Baughman 2006, ApJ, 652, L49 is promising

Time-Difference Method

(Atwood et al '06)

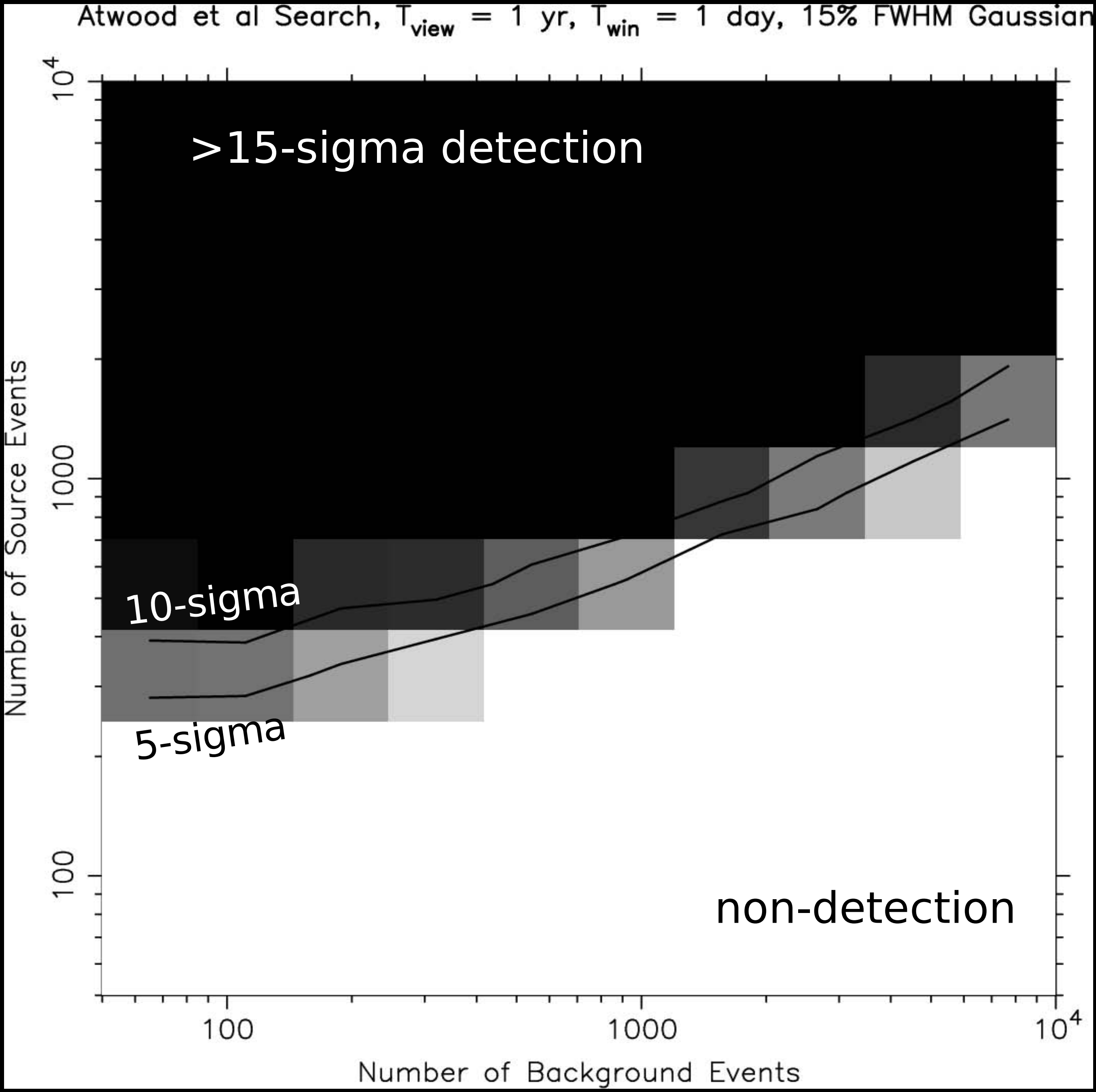
FWHM=15% Gaussian

T_{view} = 1 yr

T_{win} = 1 day

~10^{10} trials

Note: very preliminary MC!



Summary

- GLAST will likely find several to 10s of new gamma-ray pulsars via blind searches:
  - Coherent searches:
    - Useful when T_{view} < 1-2 months
    - Sensitivity: 4×10^{-8} to 4×10^{-7} phot/cm^2/s (>100Mev)
    - Significantly improved sensitivity when pointing instead of slewing ~2×10^{-8} phot/cm^2/s (>100Mev)
  - Incoherent searches:
    - Allow analyses on workstation-size computers
    - Atwood et al method will allow (at some level) analysis of events over long durations (1+ years)
    - Sensitivities maybe as low as ~$1\text{-}2\times10^{-8}$ phot/cm^2/s