Sky Localization of Gravitational Wave Signals Using Time of Arrival

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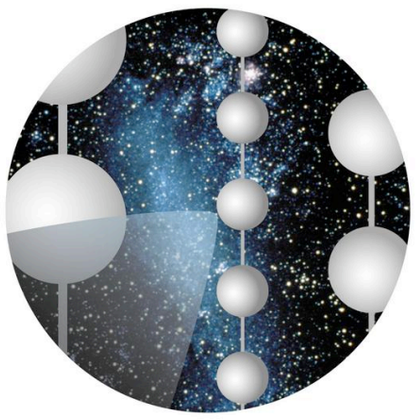


Motivation:

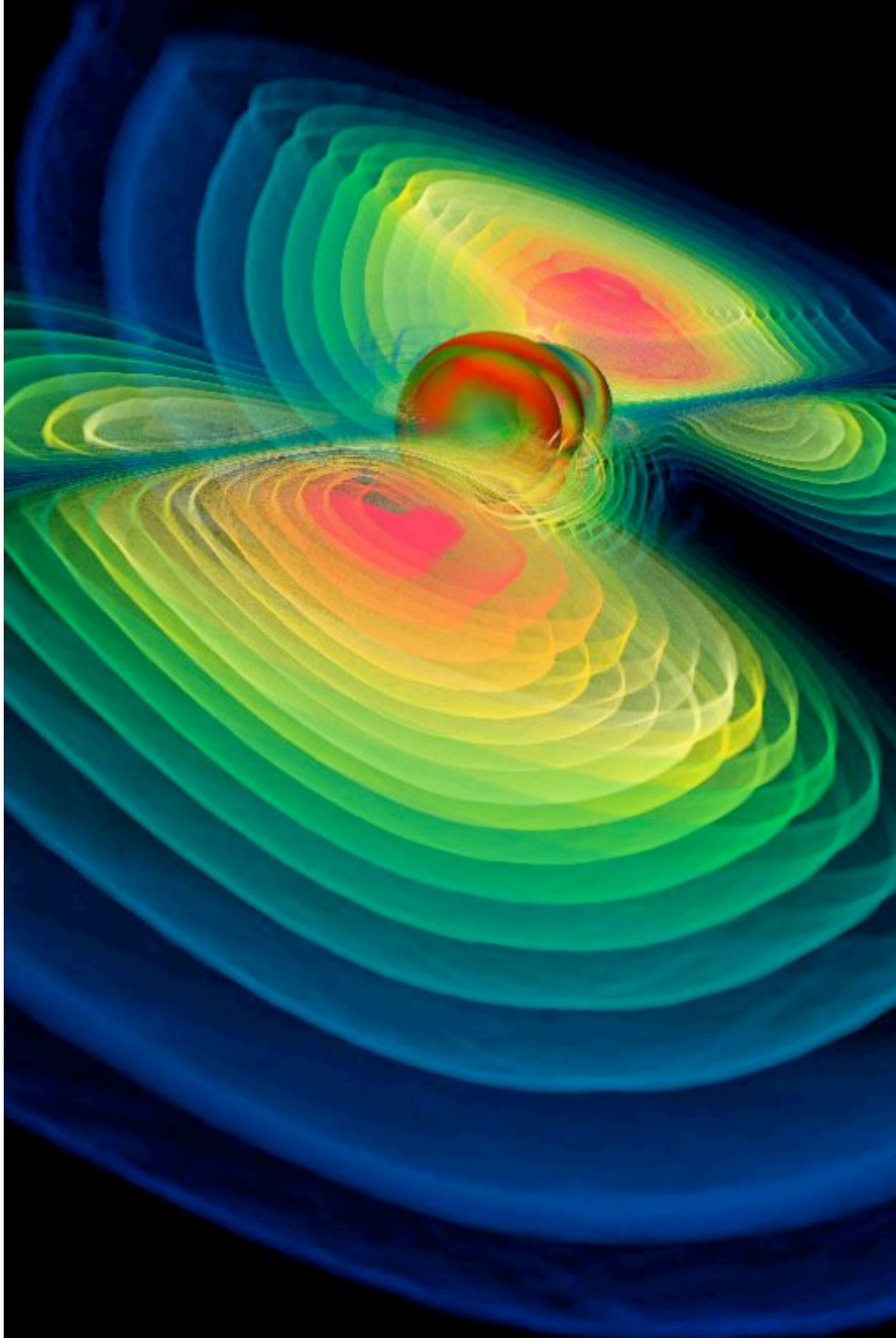
Gravitational Waves have an important role to play in the era of multi-messenger astronomy.

Basic Method:

Use triangulation to locate the source on the sky

Inspiral Sources

- 1657 injections
- 2PN Waveforms
- Uniformly distributed from 1-15 $M_\odot$
- Logarithmically distributed in distance
- Gaussian noise in H1, L1, V1 at design sensitivity (Larne Pekowsky and Shourov Chatterji)



Enhancement: A Virgo Idea

Problem:

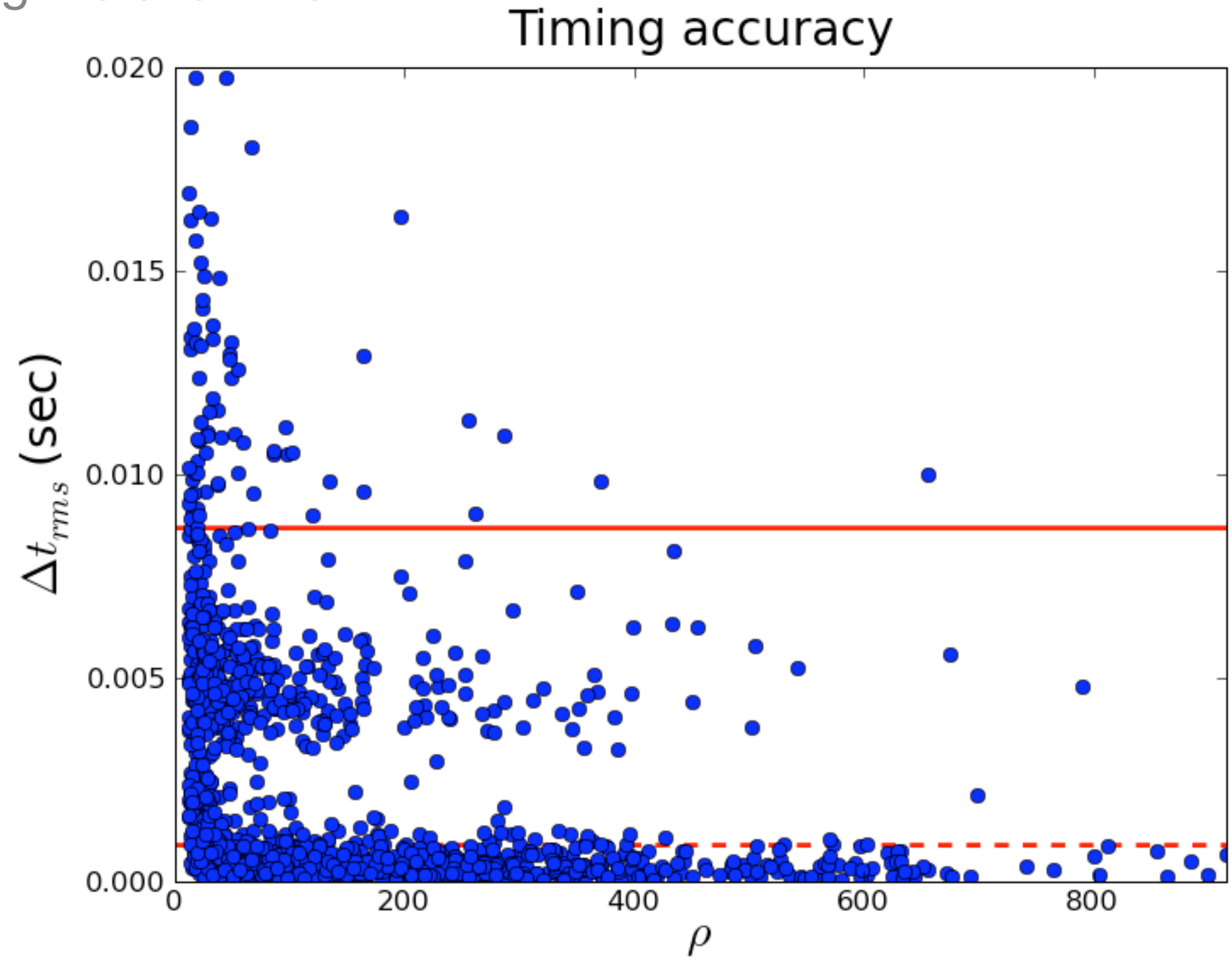
- SNR does not accumulate uniformly across the frequency band of the detector.
- Phase difference does accumulate uniformly across the frequency band.

Solution:

Measure the time the signal crosses some reference frequency in the high SNR region of the frequency band, NOT the end time.
[F Acernese et al 2007 Class. Quantum Grav. 24 S617]

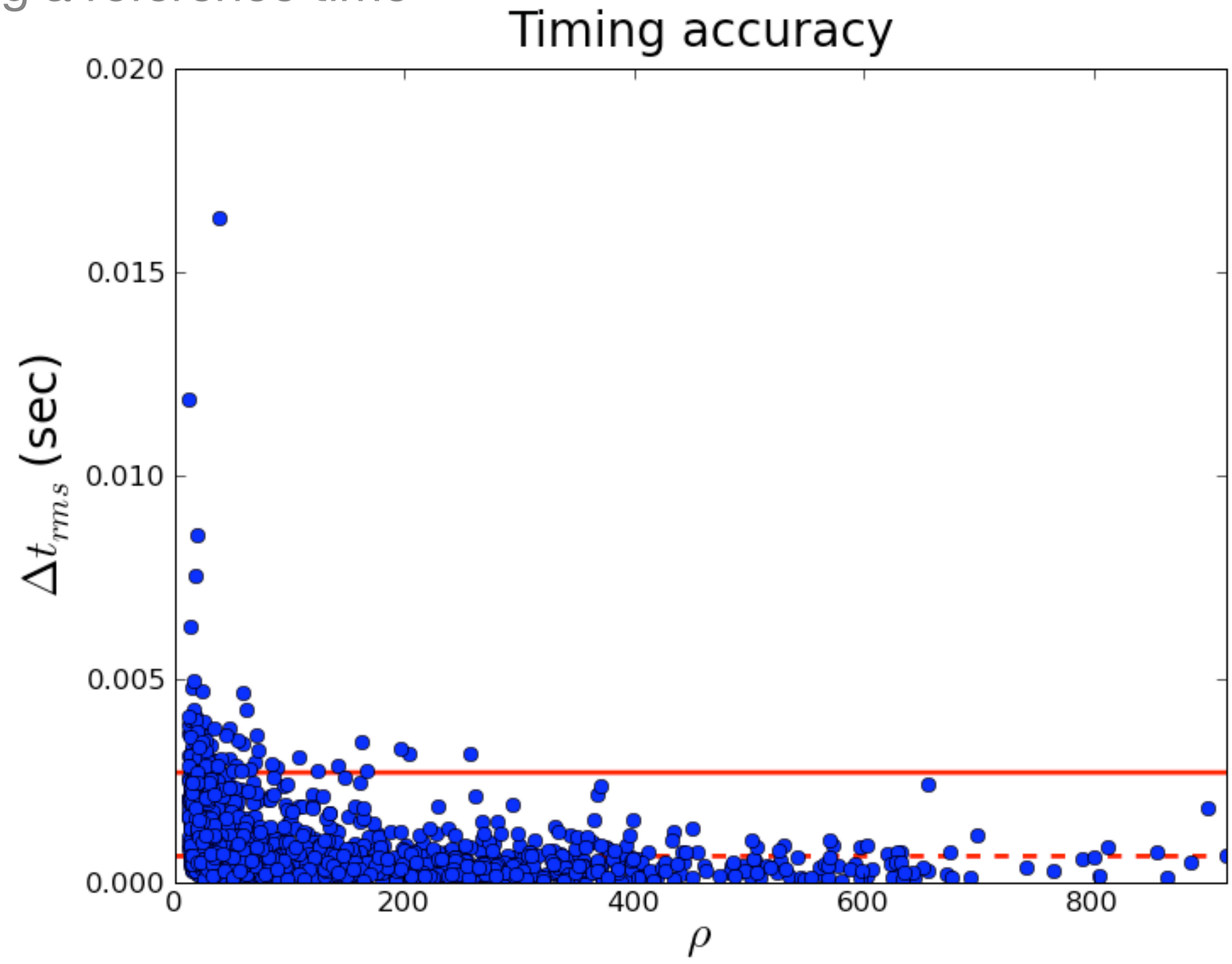
Comparison of Timing Accuracy

Using the end time



Comparison of Timing Accuracy

Using a reference time



Enhancement: Use Effective Distance

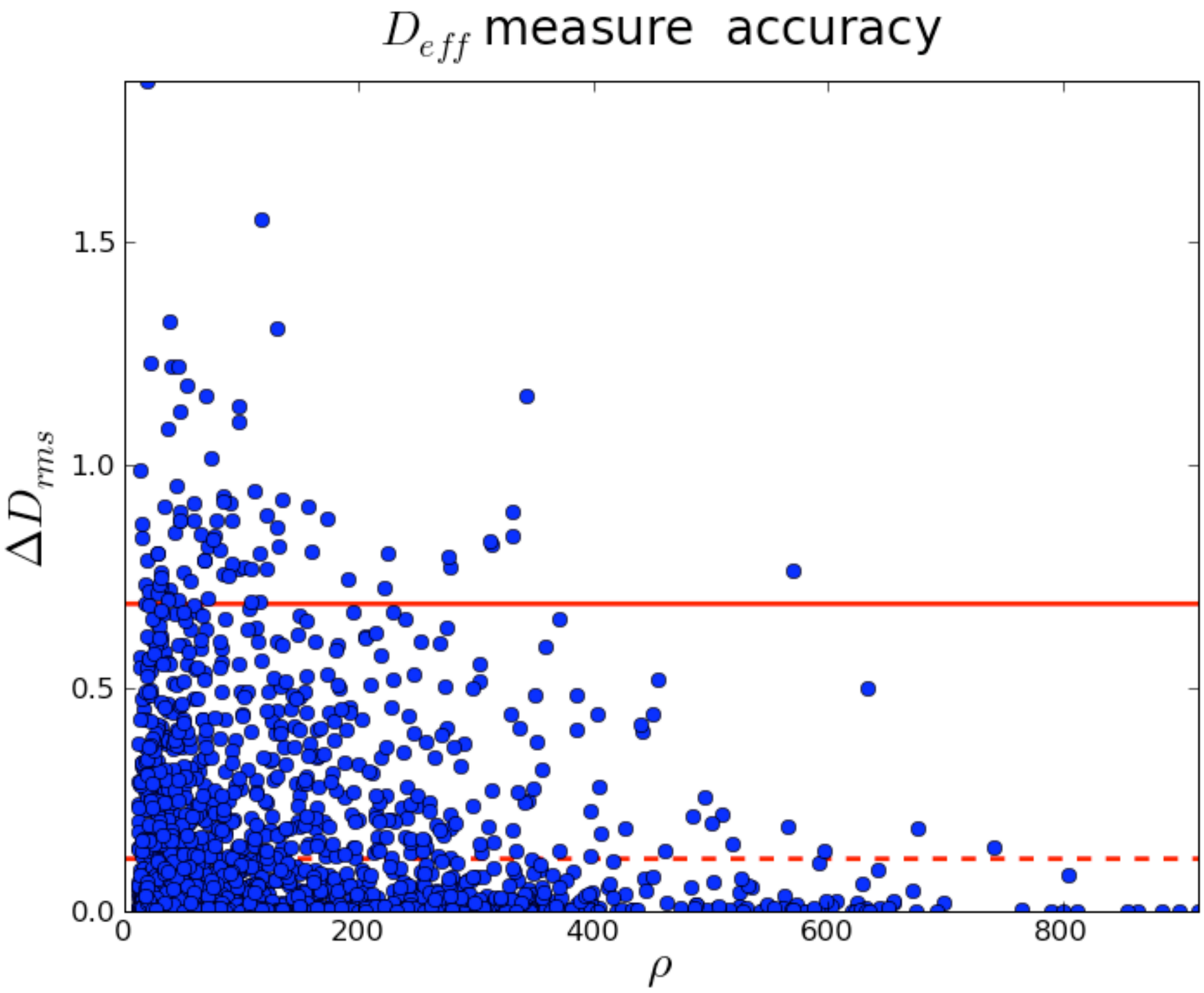
Specifically, consider:

$$\Delta(D^2_{\rm eff}) = \frac{D^2_{\rm A} - D^2_{\rm B}}{D^2_{\rm A} + D^2_{\rm B}} - \frac{\tilde{D}^2_{\rm A}(\theta,\phi) - \tilde{D}^2_{\rm B}(\theta,\phi)}{\tilde{D}^2_{\rm A}(\theta,\phi) + \tilde{D}^2_{\rm B}(\theta,\phi)}$$

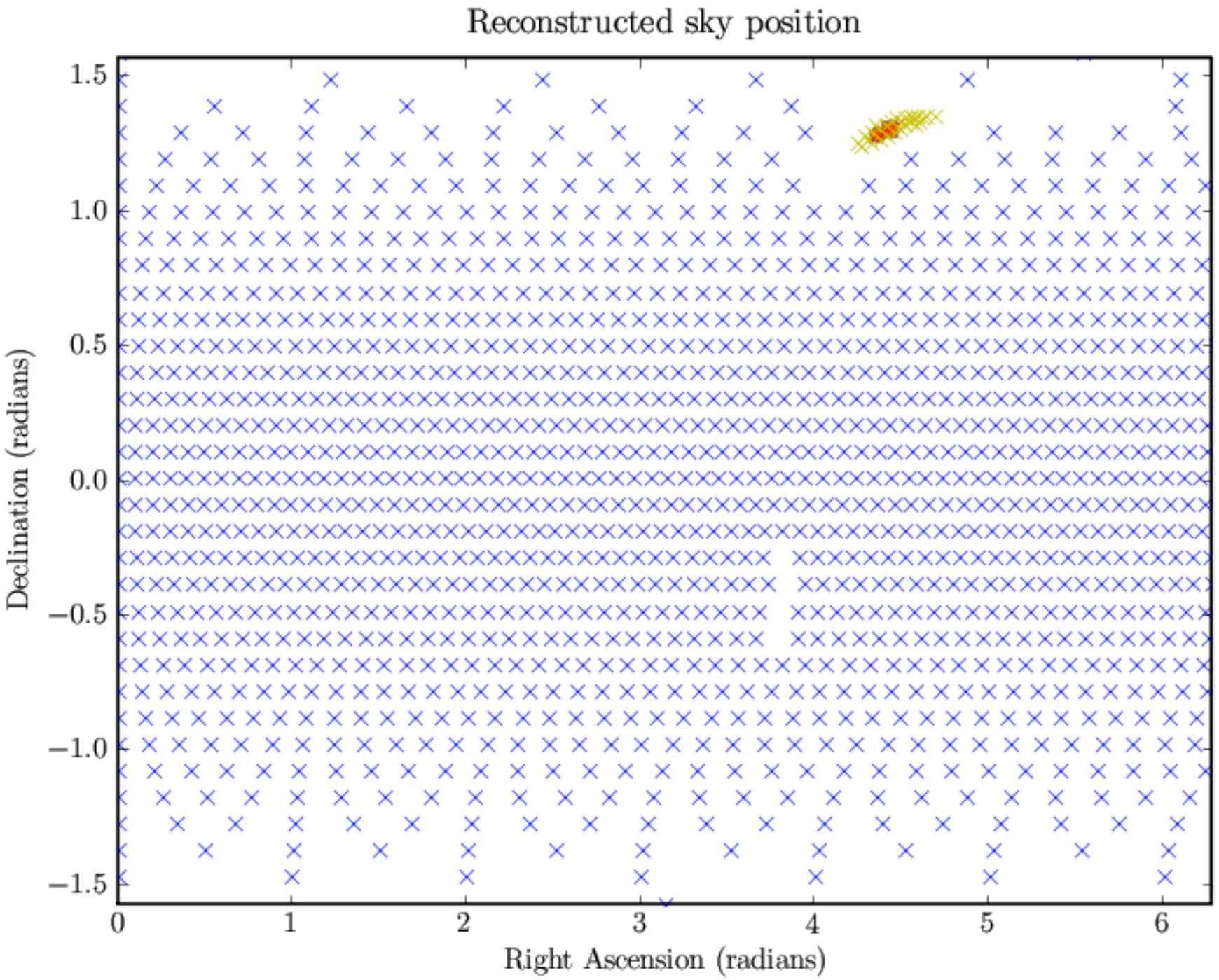
Where:

$$\tilde{D}^2(\theta,\phi) \propto \frac{1}{F^2_+(\theta,\phi,\psi=0) + F^2_\times(\theta,\phi,\psi=0)}$$

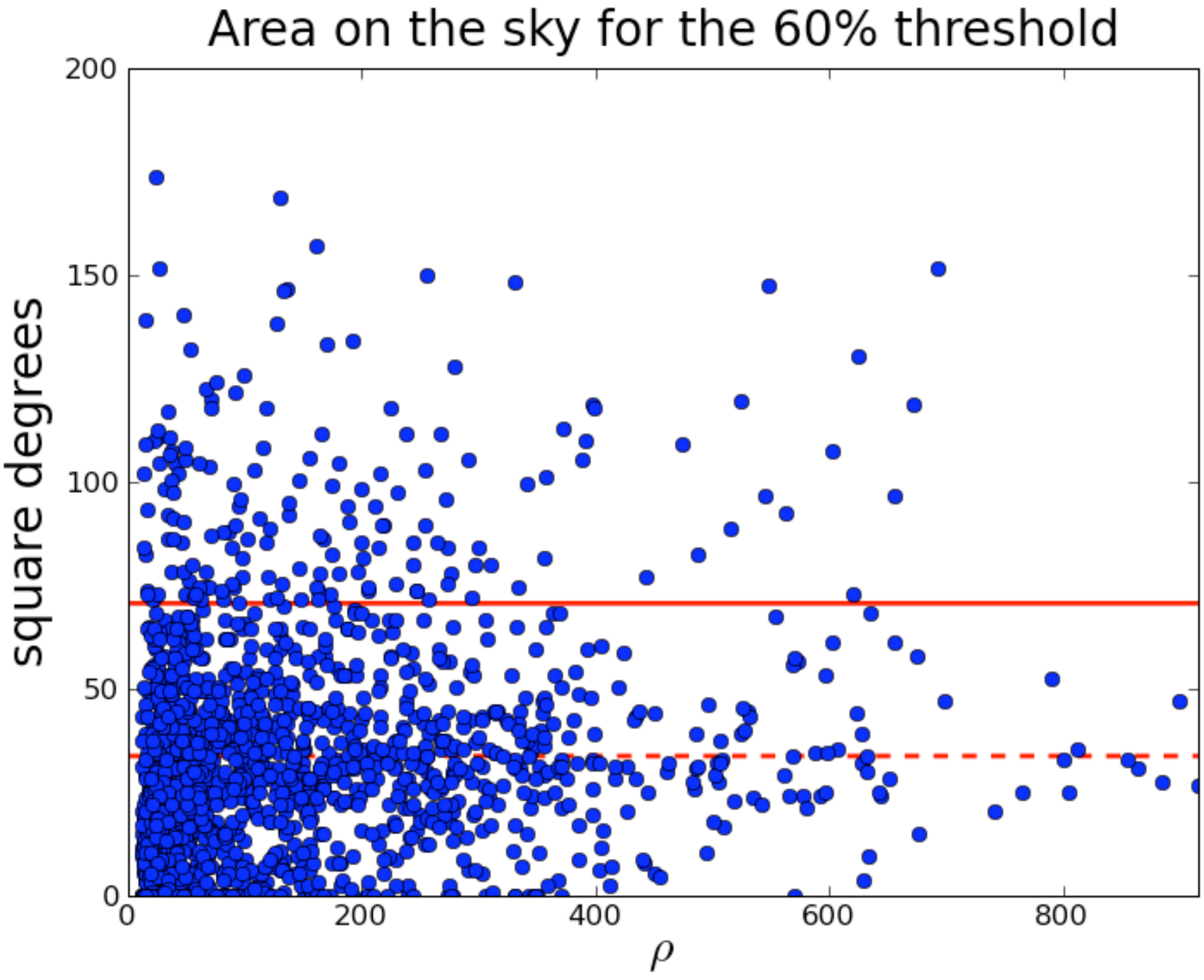
Accuracy of Effective Distance Measure



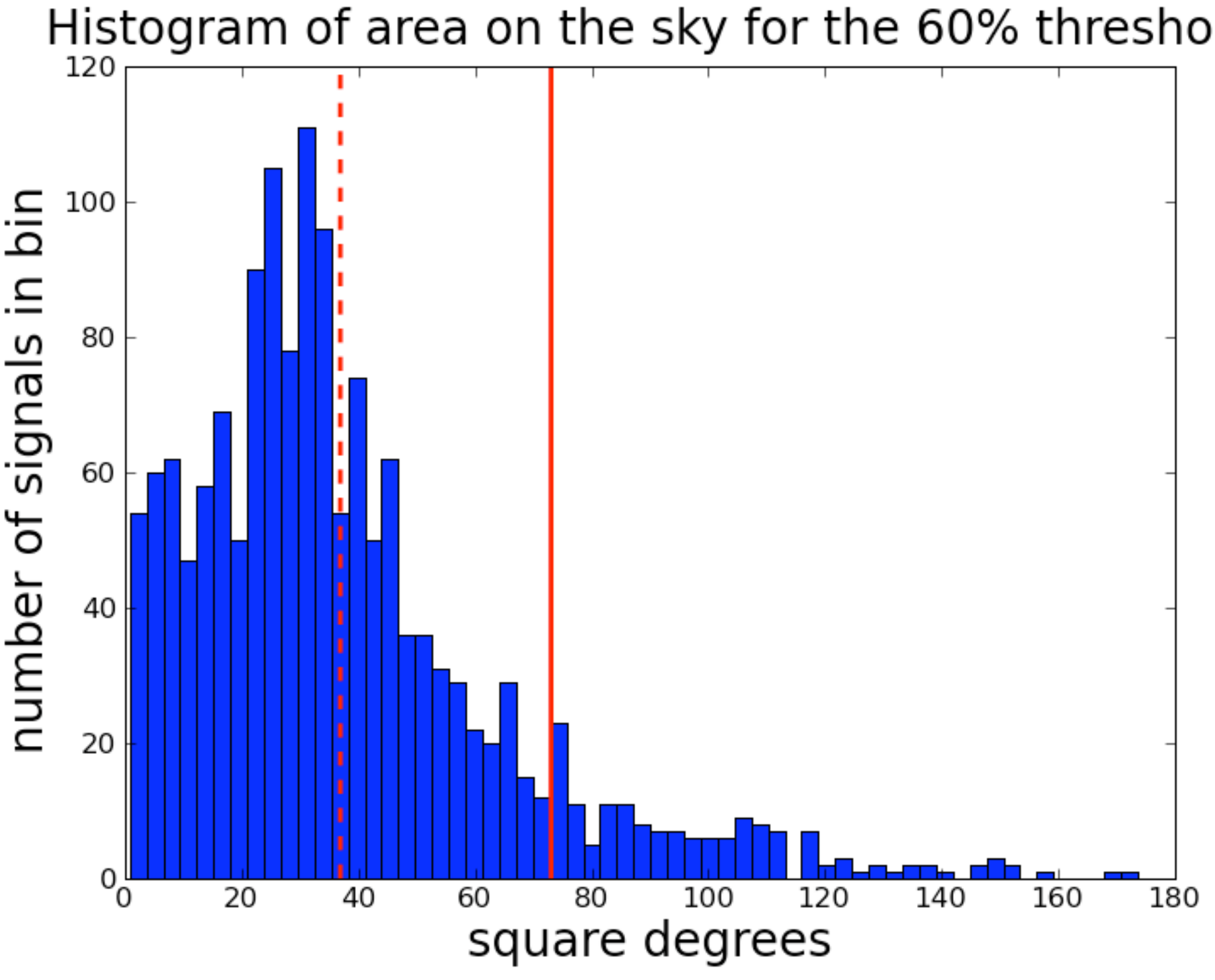
Results: Skymaps



Results: Localization



Results: Localization



Enhancement: Use A Galaxy Catalog

Kopparapu, Hanna, Kalogera, O'Shaughnessy, González, Brady & Fairhurst (2008 ApJ 675 1459)

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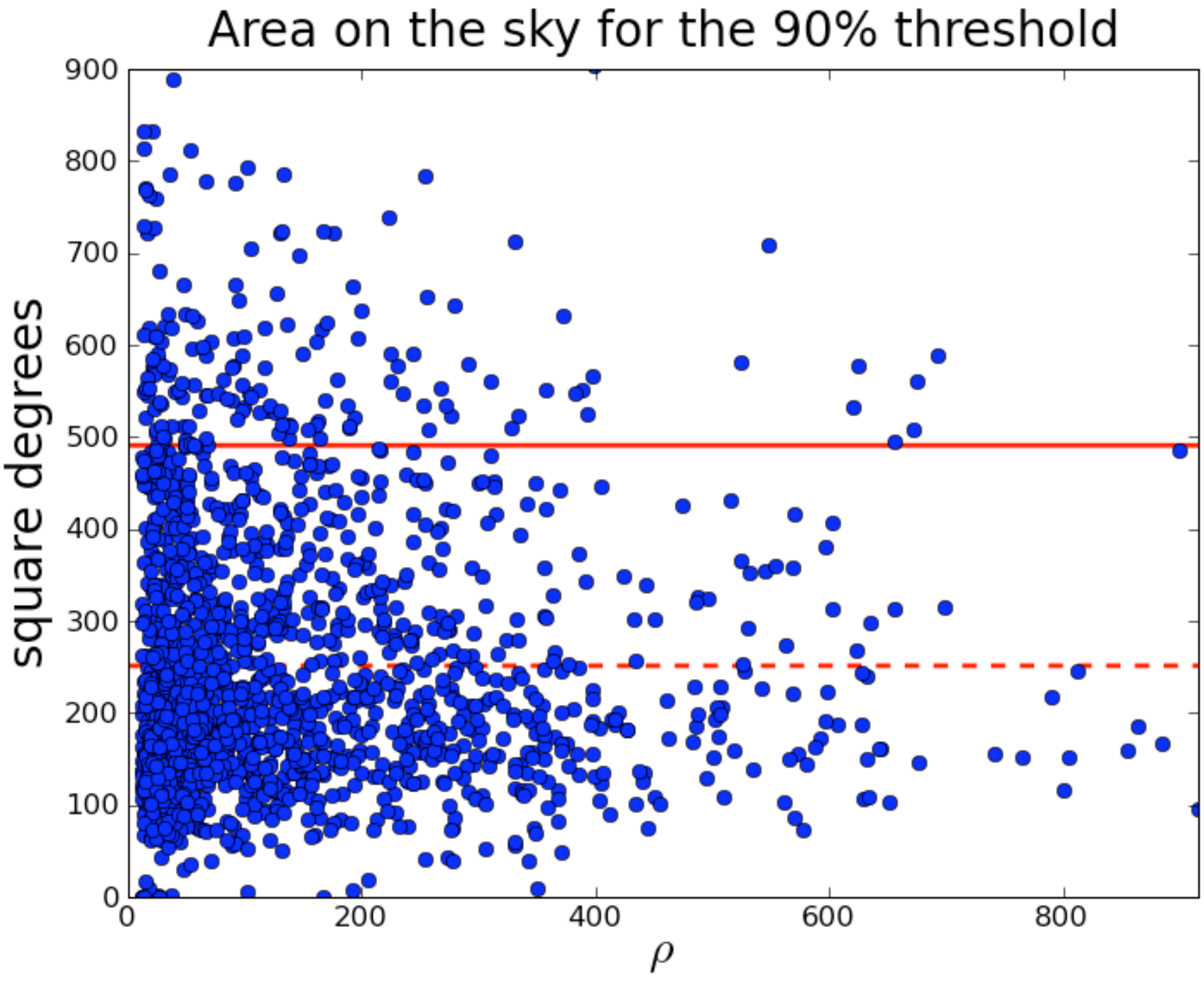
What's Next?

- More statistics
- Focus on low SNR
- Compare with other methods
- More detailed studies with the galaxy catalog

Results: Localization



Results: Localization