Inspiral, Merger, Ringdown

Jolien Creighton
University of Wisconsin–Milwaukee

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MEETINGS

None of Us is as Dumb as All of Us.

NR + DA

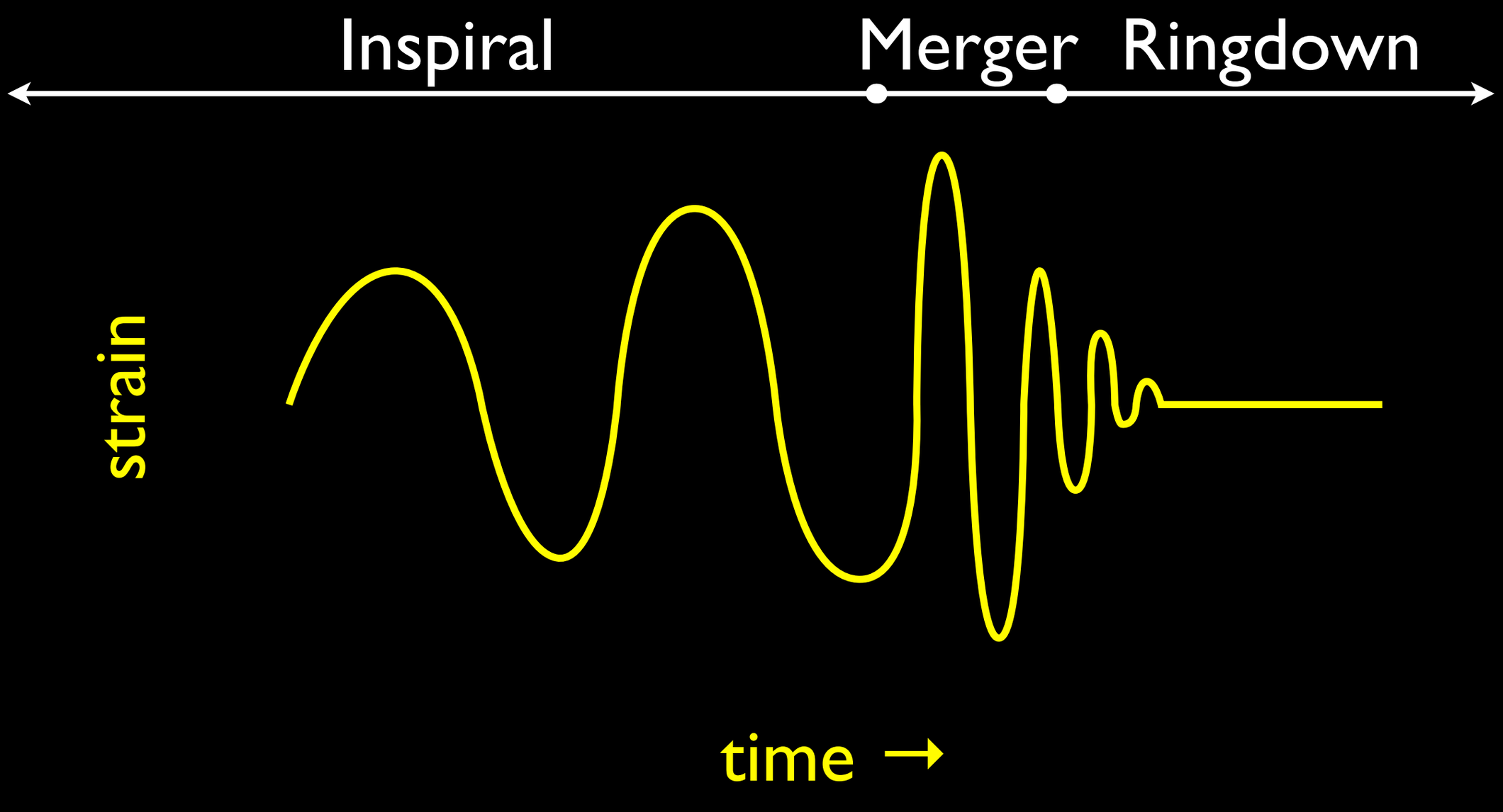
NOT EVERYONE GETS TO ~~BE AN ASTRONAUT~~ WHEN THEY GROW UP.

Quantize Gravity

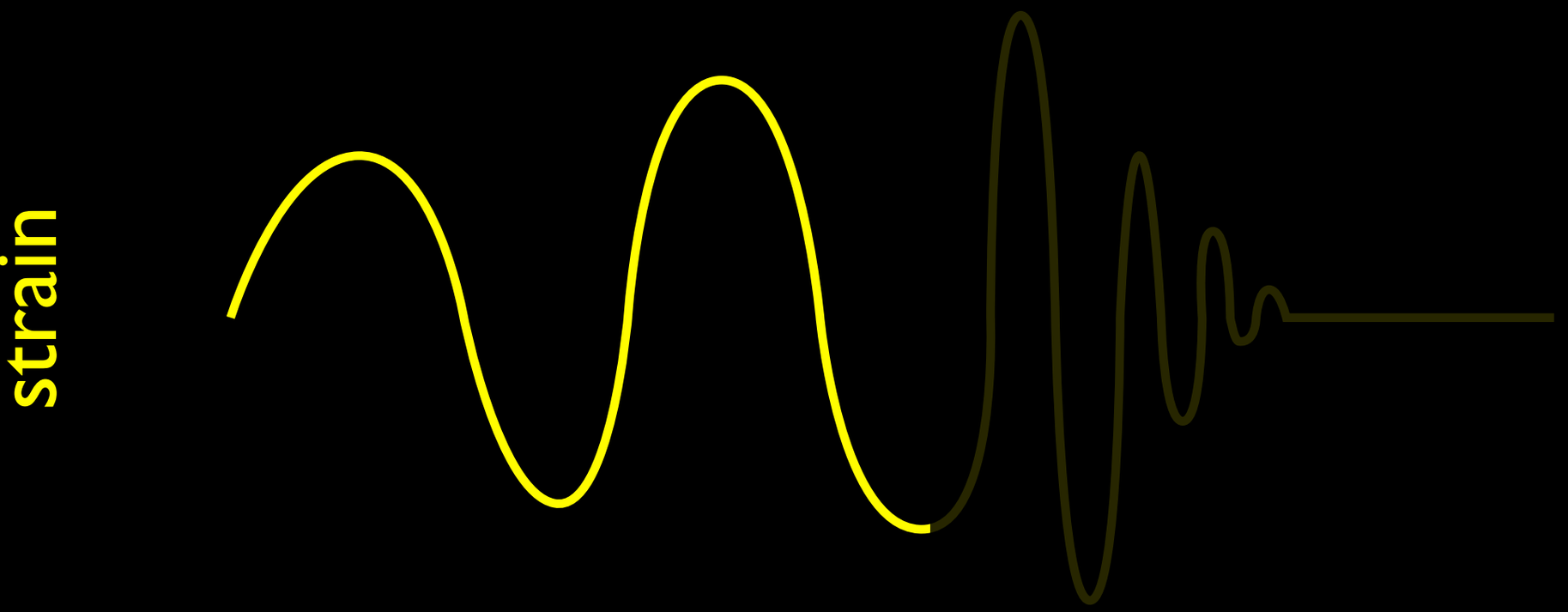
Data Analysis

Outline

- Inspiral
- Merger
- Ringdown
- Outlook


Inspiral
Merger
Ringdown
strain
time →

Inspiral



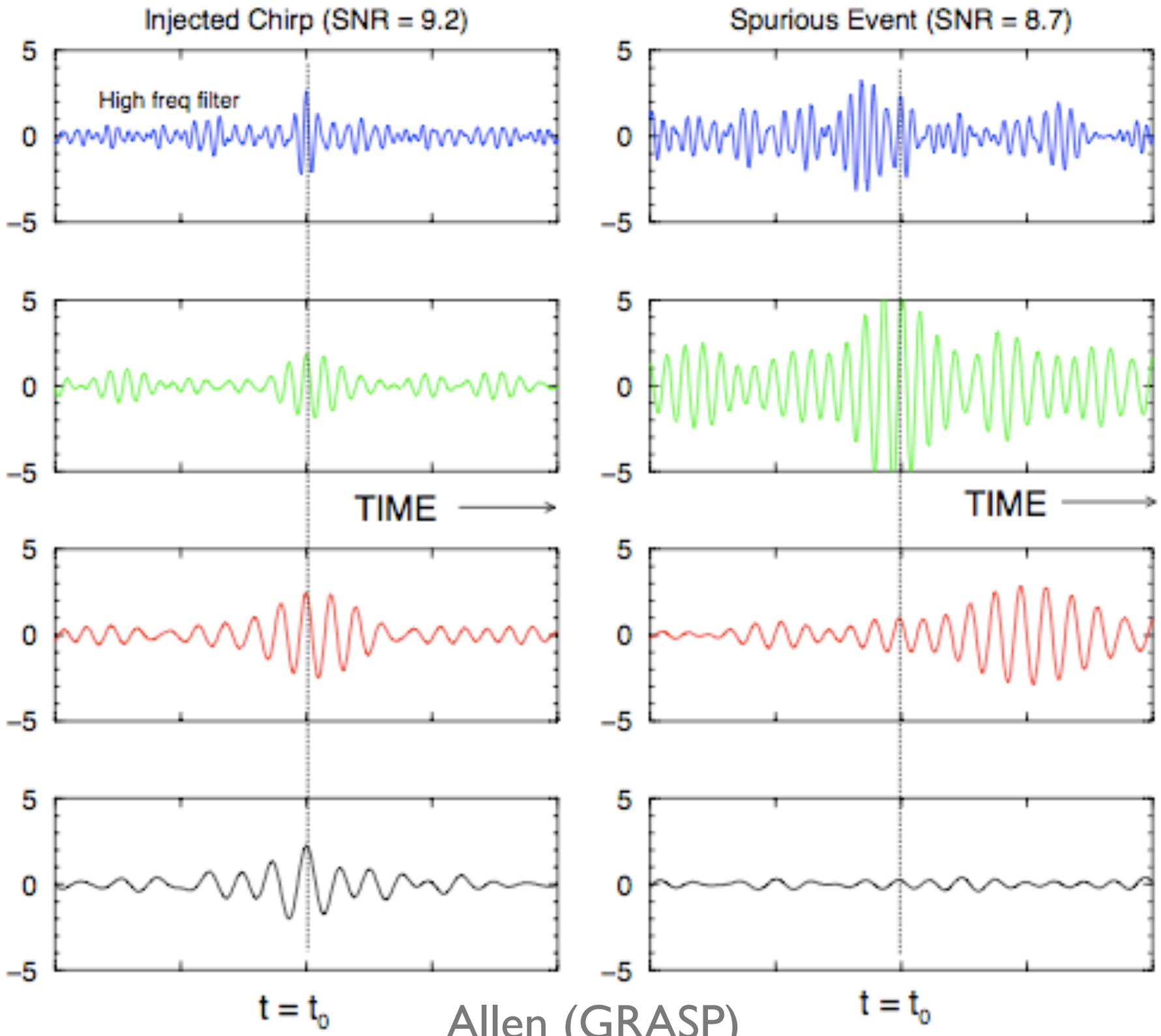
Inspiral Search

- Matched filter is optimal:
  - determines: Pr{ Inspiral | Data }
- Search over unknown params:
  { t, φ, m_1, m_2, ... }
- Search over { t, φ } is easy
- Use a bank to search over { m_1, m_2 }

Inspiral Search

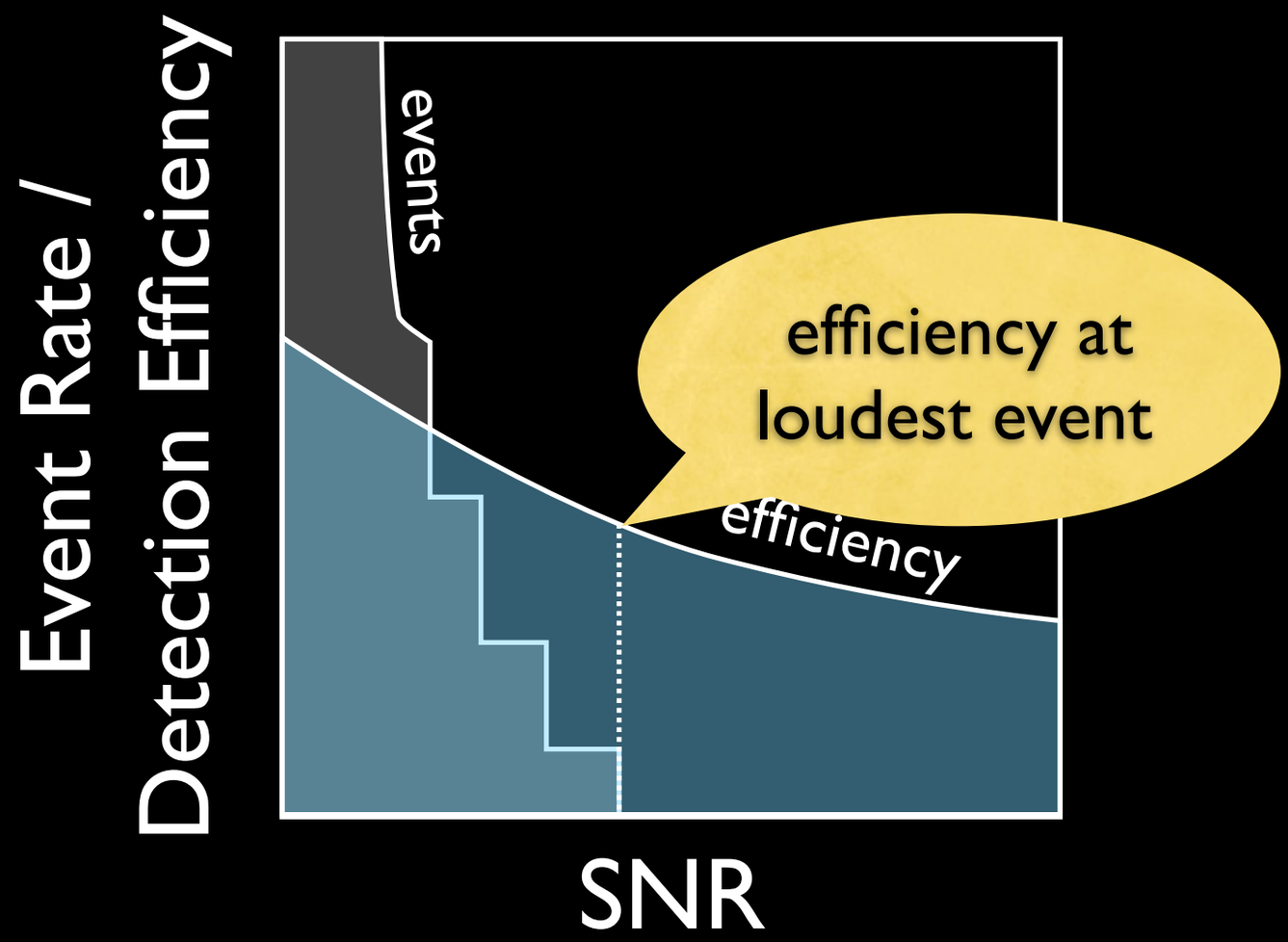
- Restricted 2 pN stationary phase templates
  - High mass?
  - Spin?
- χ^2 (chi-squared) waveform quality veto
- Upper limit depends on efficiency estimate

χ^2 Veto


Injected Chirp (SNR = 9.2)
Spurious Event (SNR = 8.7)
High freq filter
5
0
−5
TIME
t = t0

Allen (GRASP)

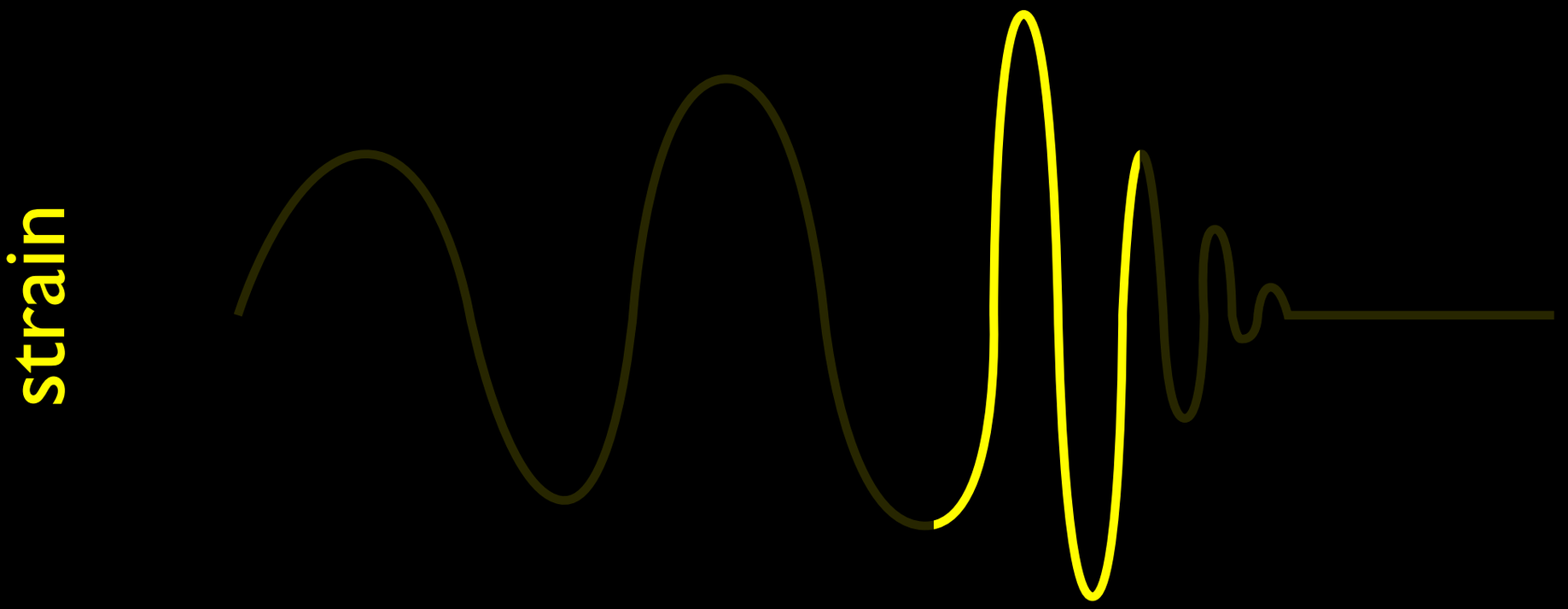
Detection Efficiency



Issues

- Does our bank cover real signals?
- Does our veto veto real signals?
- Do we correctly compute efficiency?
- Can we do better?

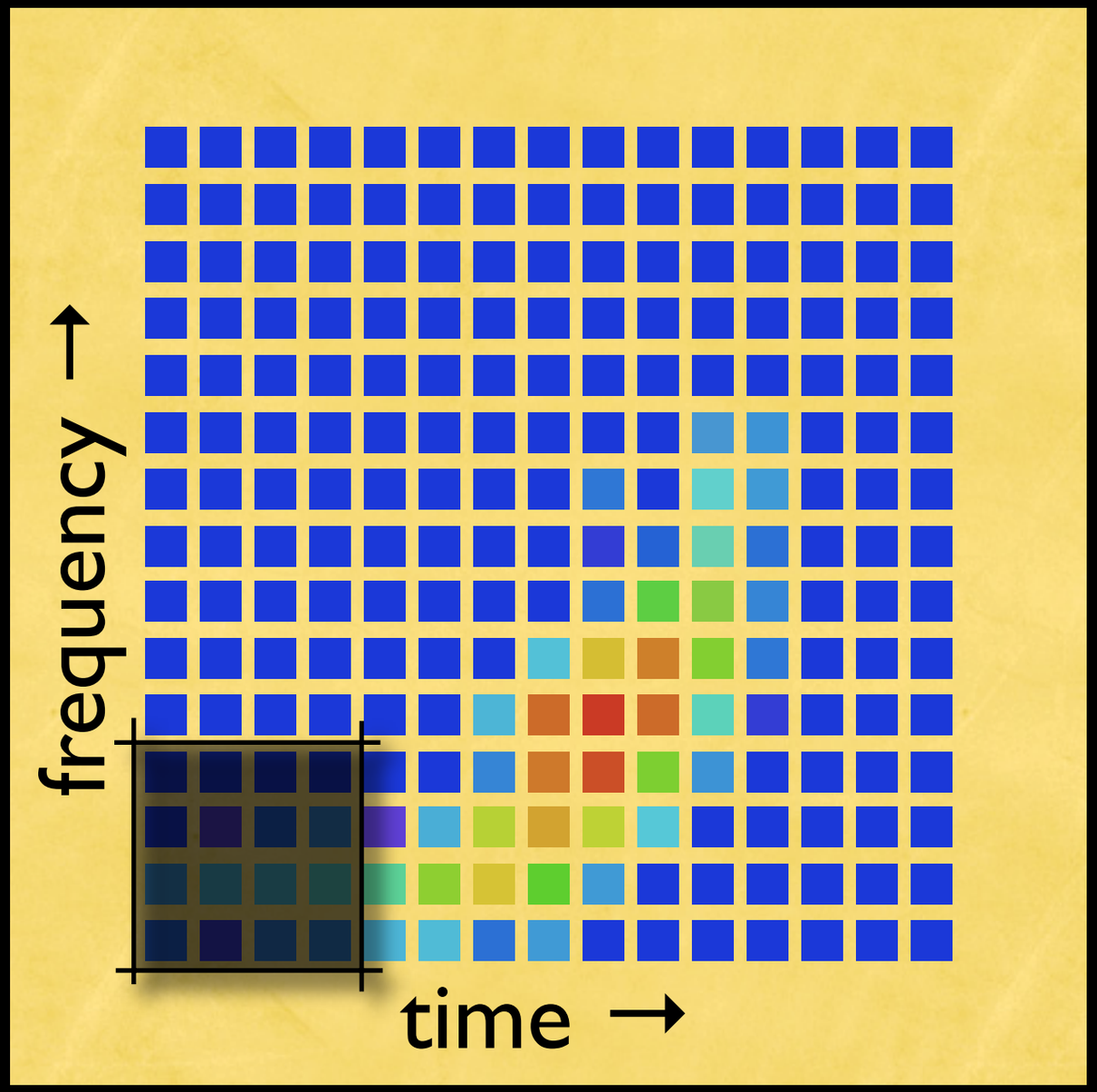
Merger



Unknown Burst Search

Unknown Burst Search

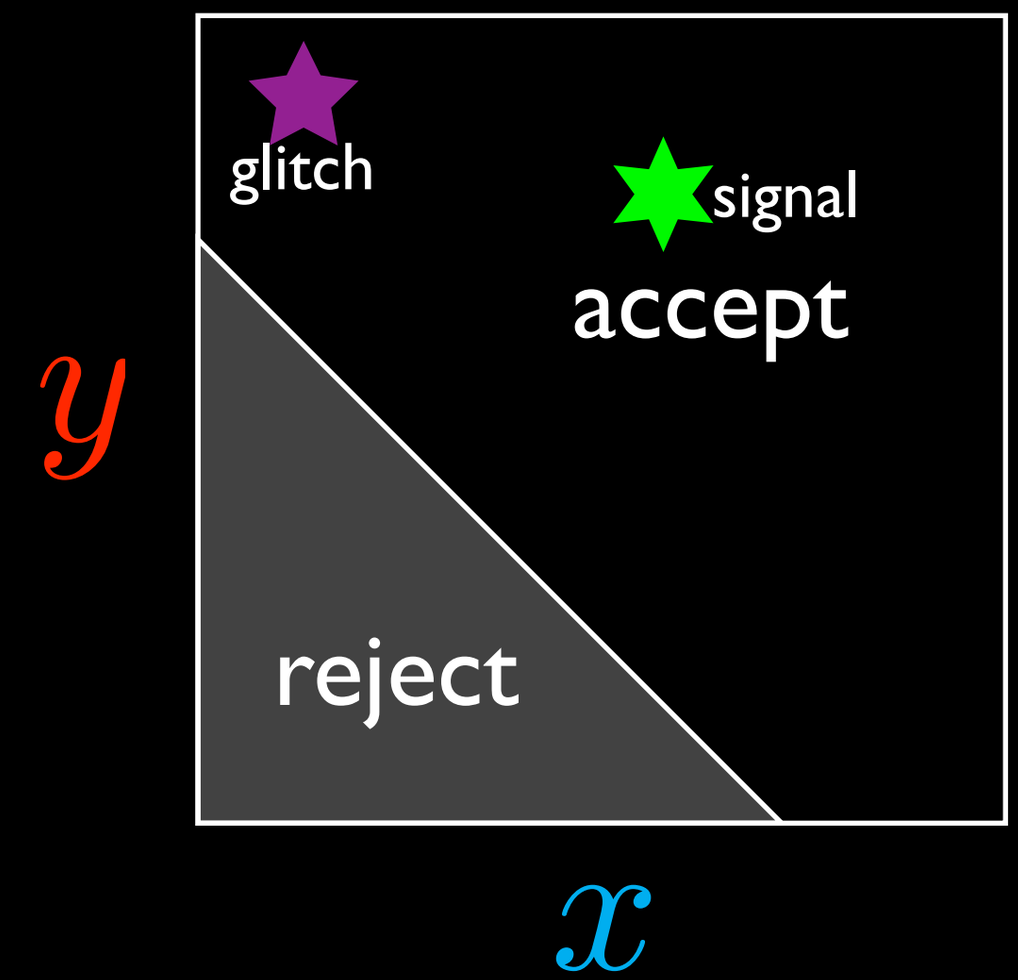
- Short burst — unknown signal shape
- Excess power marginalizes over unknown shape — optimal for known duration, band
  - Just returns power in required time interval / frequency band
- Tricky bit: how to tie into preceding signal?


frequency →
time →

Types of Power

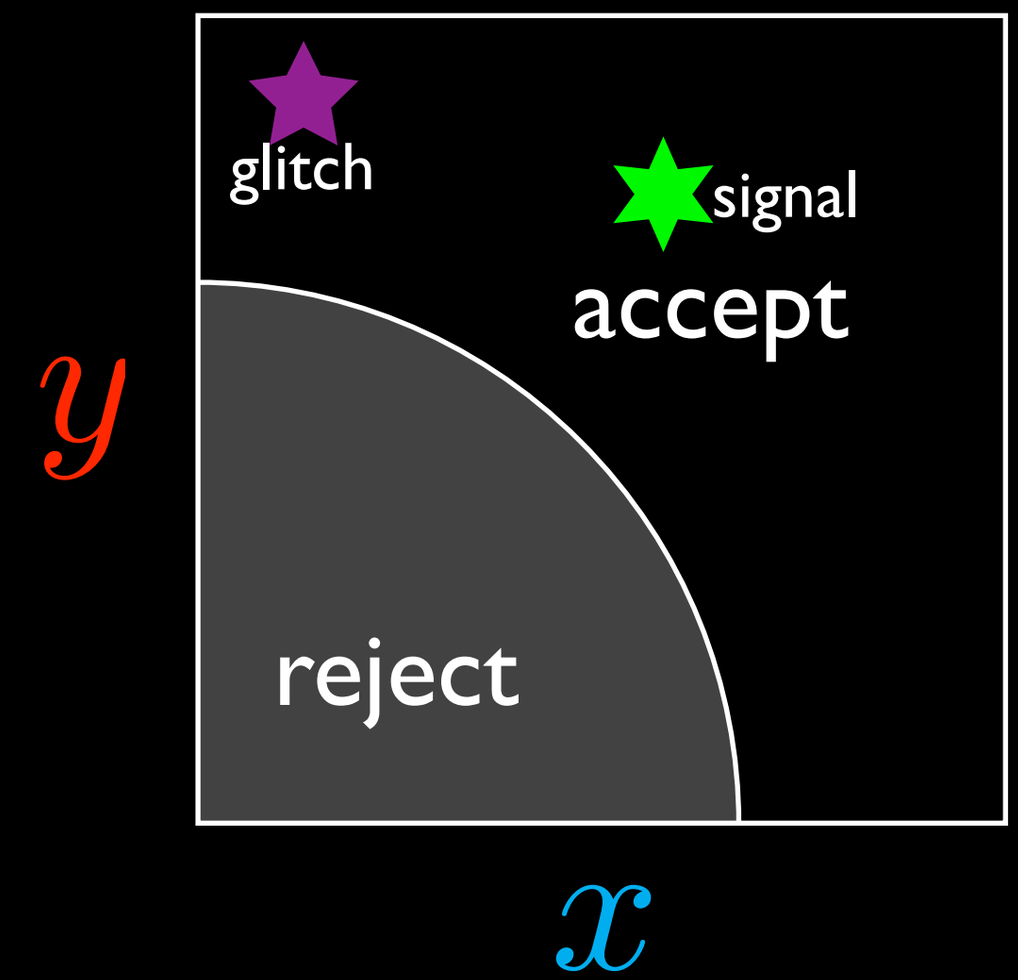
Coherent

$$(x+y)^2 = x^2 + 2xy + y^2 > \text{threshold}$$



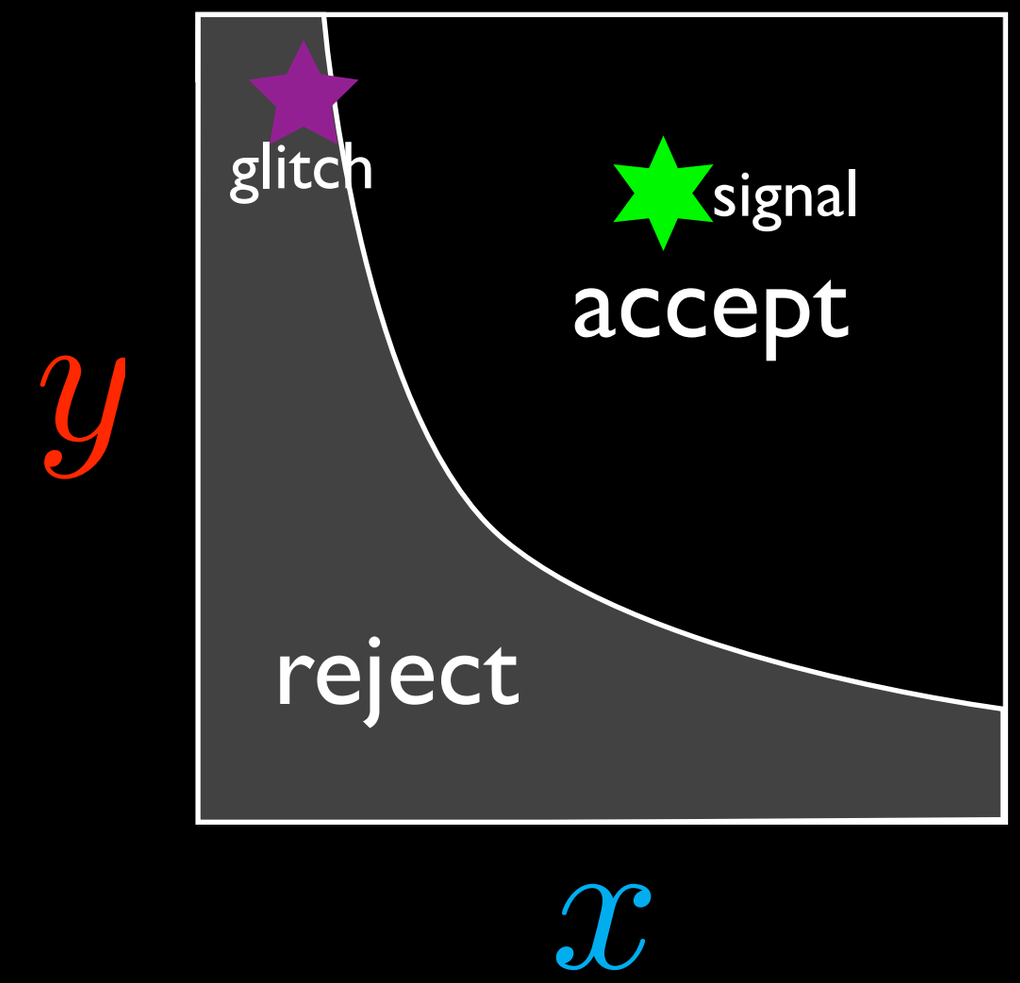
Incoherent

$$(x+y)^2 = x^2 + 2xy + y^2 > \text{threshold}$$



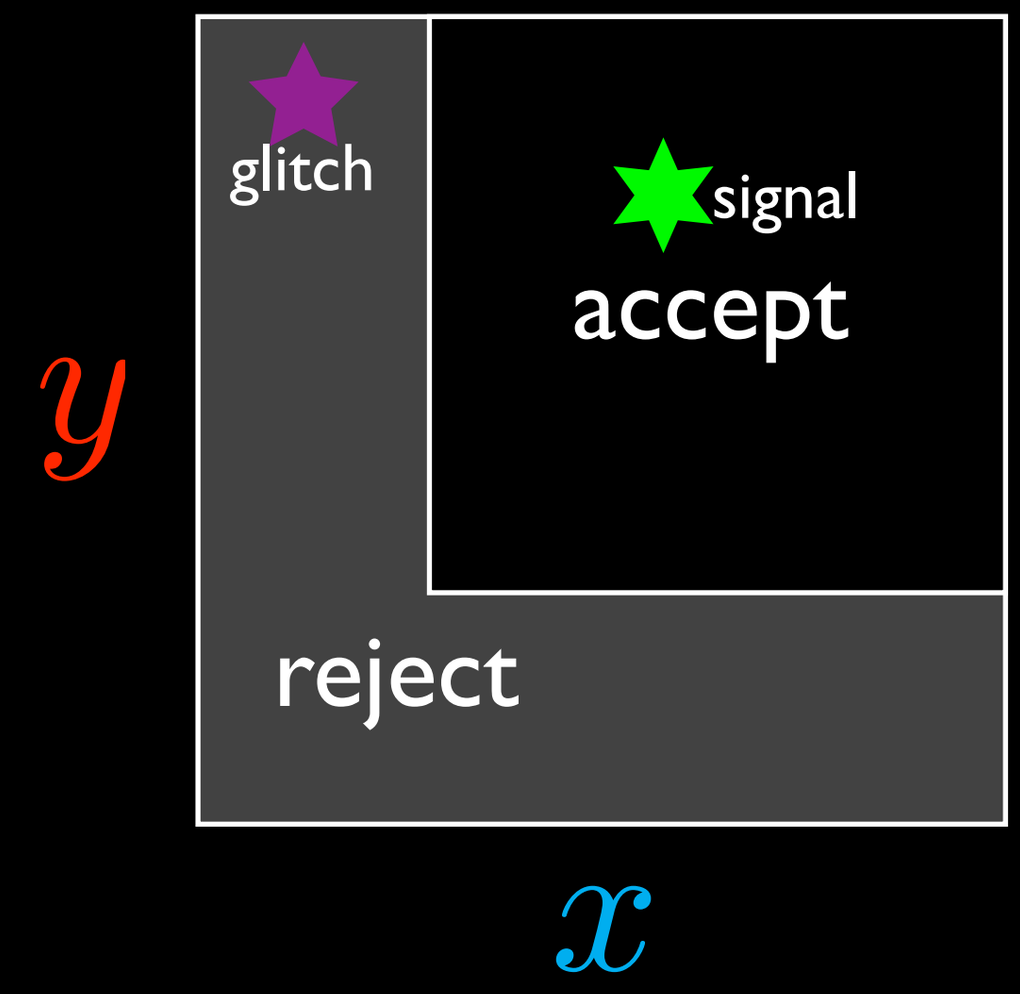
Correlated

$$(x+y)^2 = \cancel{x^2} + 2xy + \cancel{y^2} > \text{threshold}$$



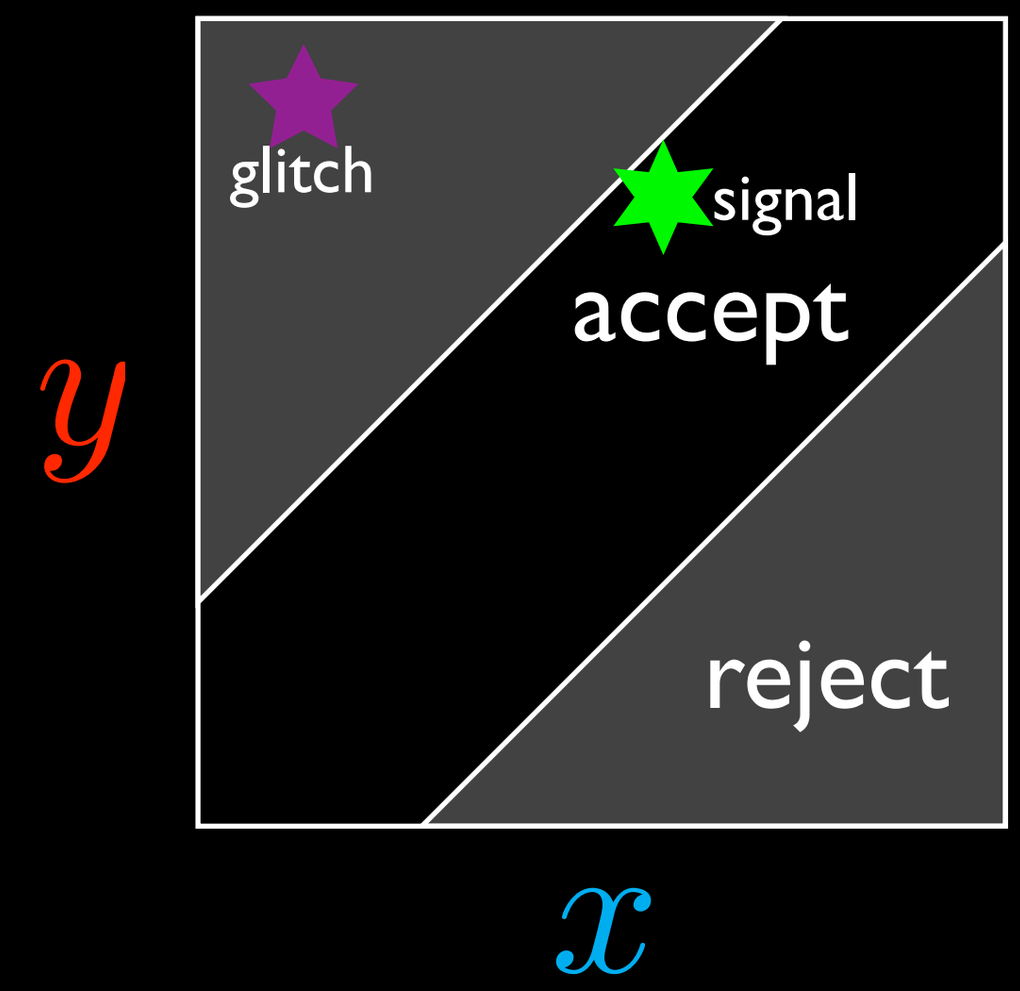
Coincidence

$$\min(x^2, y^2) > \text{threshold}$$



Null Veto

$$(x - y)^2 = x^2 - 2xy + y^2 < \text{threshold}$$



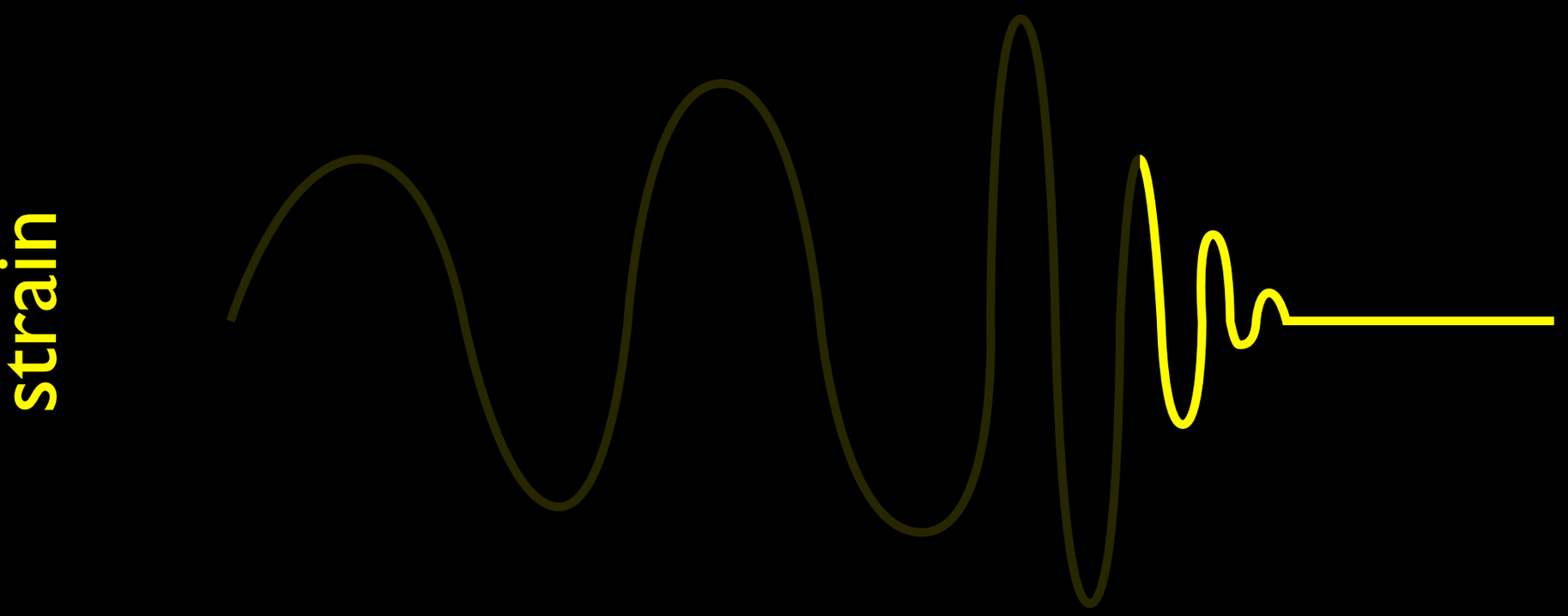
Excess Power Searches

- TFClusters (incoherent)
- WaveBurst (incoherent)
- Coherent WaveBurst (coherent)
- Corrpower (correlation)
- Q-pipeline (incoherent, null veto)
- X-pipeline (coherent)

Can We Do Better?

- More information on time-freq track
  - Better guess of duration / freq-band
    - Tie into preceding inspiral waveform
- Sidebands?

Ringdown

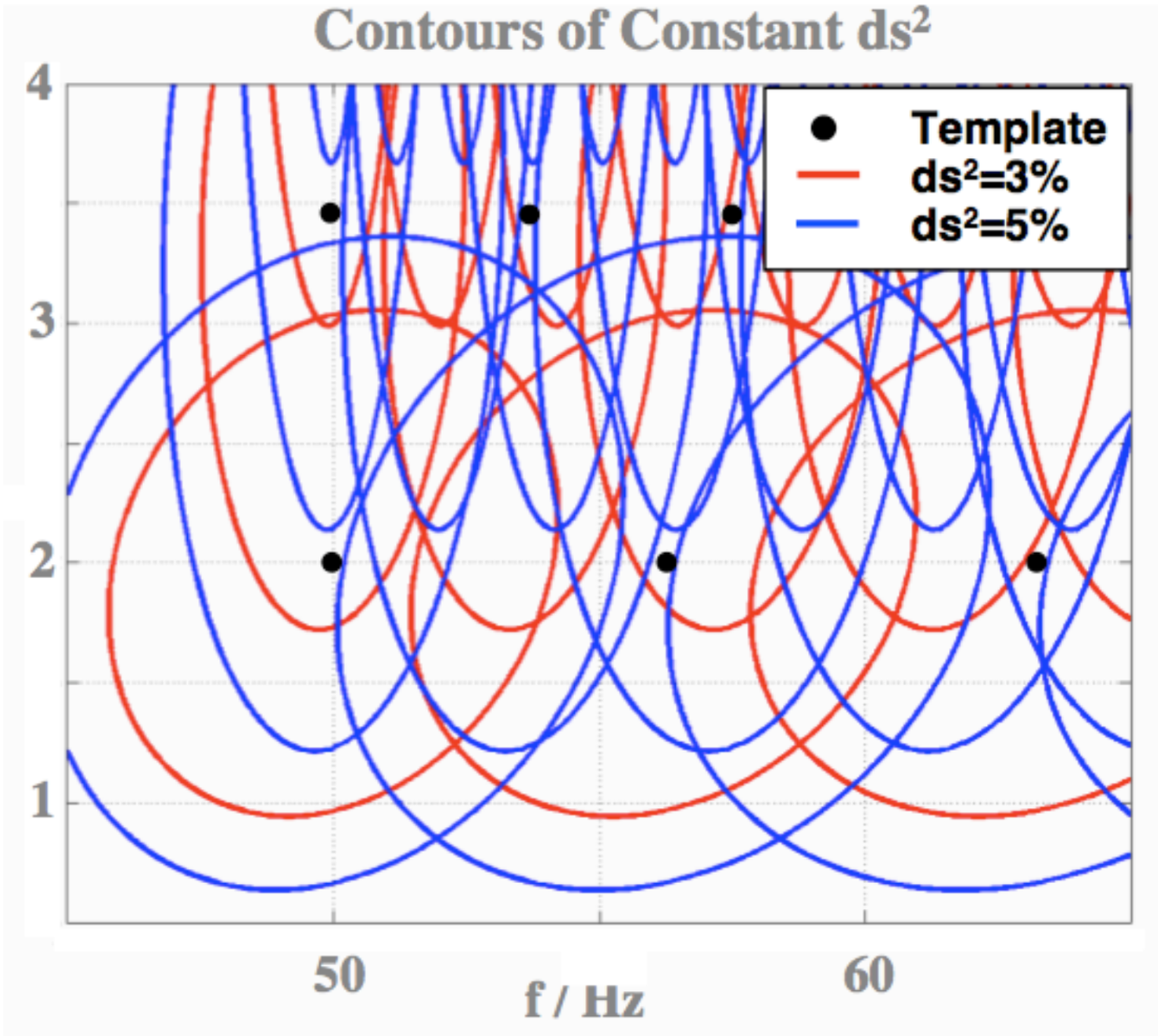


Ringdown Search

- Very simple waveform — too simple!
- Matched filter available, but perhaps not much different from Excess Power
- Basically sees whatever is at 150 Hz
- How to tie into preceding waveform?

Ringdown Morphology

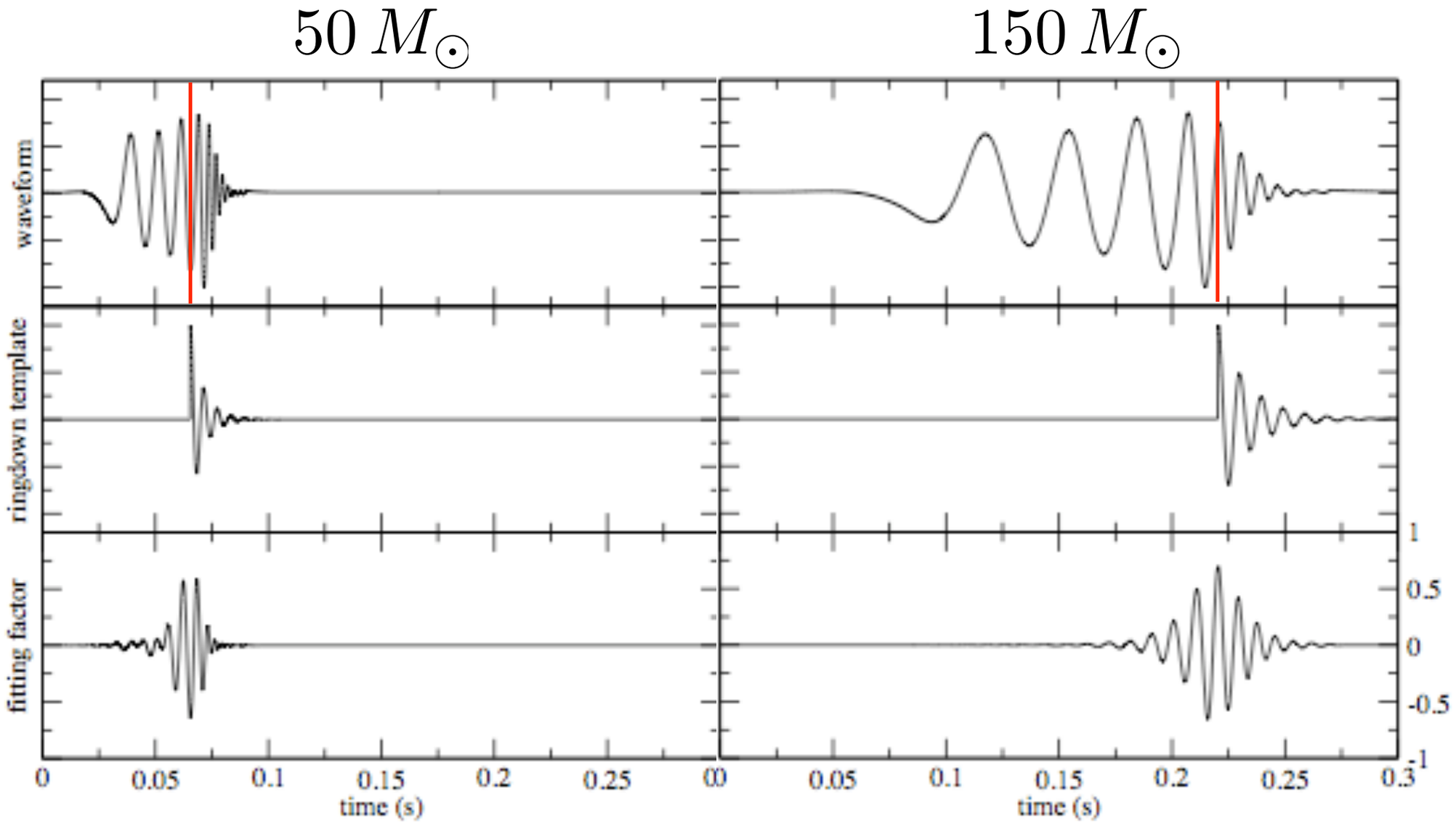
Ring Template Bank



Goggin

Binary Black Hole Coalescence Waveforms

Baumgarte, Brady, Creighton, Lehner, Pretorius, DeVoe



Outlook

LIGO Science Runs

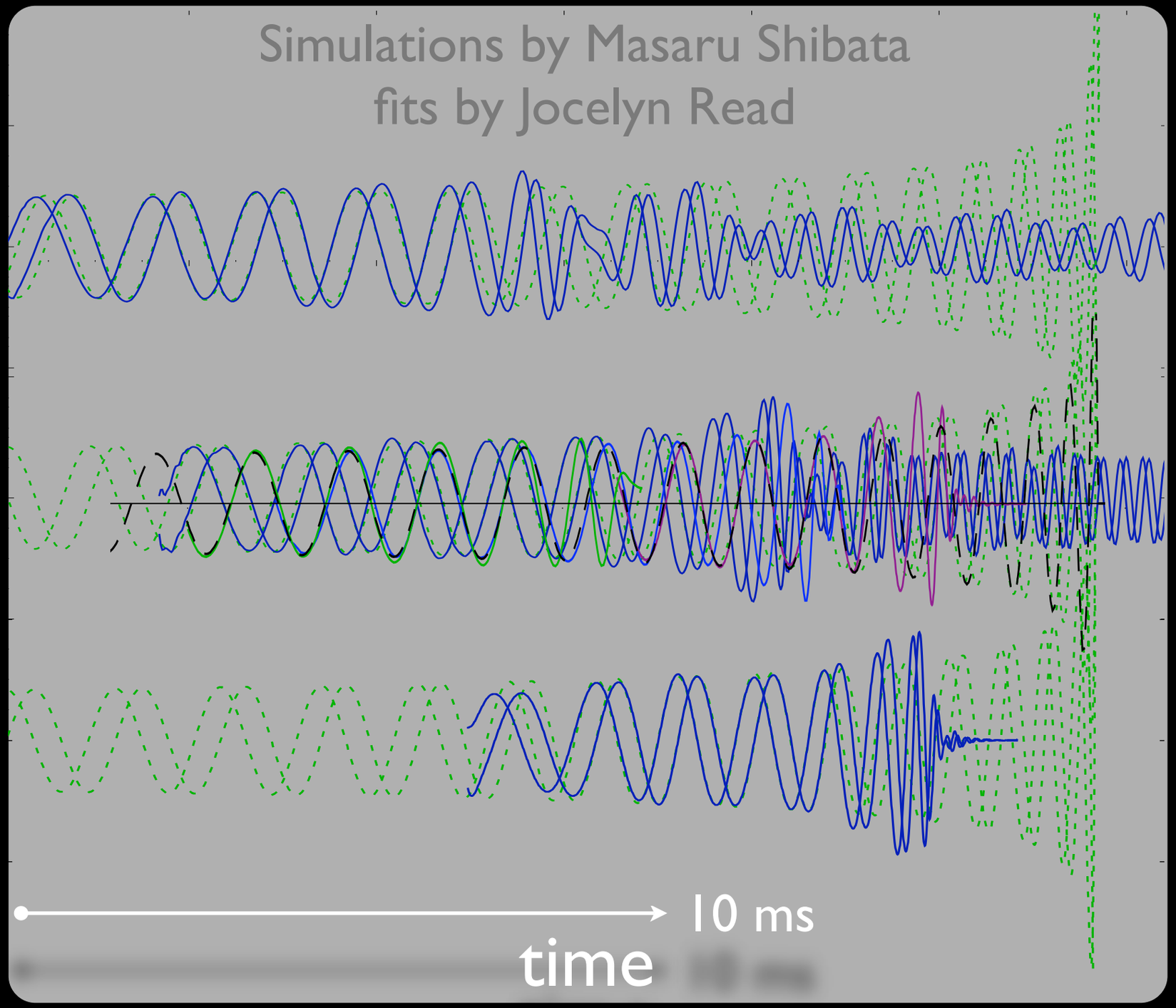
- **S1**: 23 Aug – 9 Sep 2002 First Results!
- **S2**: 14 Feb – 14 Apr 2003
- **S3**: 31 Oct 2003 – 9 Jan 2004
- **S4**: 22 Feb – 23 Mar 2005
- **S5**: Nov 2005 – 1 Oct 2007 Design Sensitivity!
- Enhanced LIGO: 2009 – 2010 Factor of 2 better
- Advanced LIGO: 2013+ Factor of 10 better

Binary Neutron Star Range

Future...

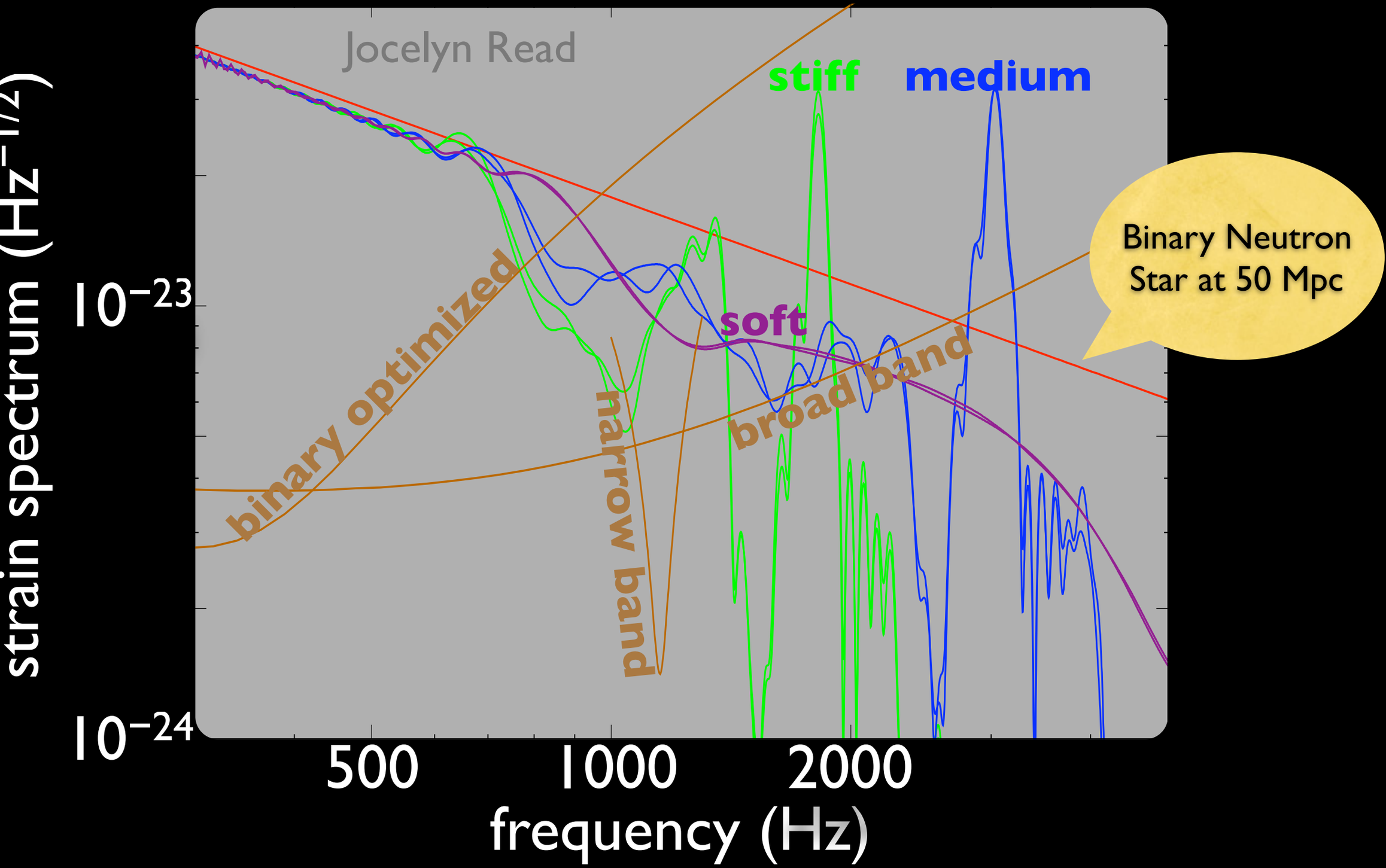
Parameter Estimation and Astrophysics

Binary Neutron Star Coalescence Waveforms



Neutron Star Equation of State

Advanced LIGO Noise Curves



Conclusions

- Present: We want waveforms to
  - Improve/validate methods, hone vetoes
  - Determine efficiencies
- Future: We need waveforms to
  - Parameter estimation, astrophysics
  - Construct template banks?


MOTIVATION
If a Pretty Poster and a Cute Saying are All it Takes to Motivate You,
You Probably have a Very Easy Job. The Kind ~~Robots~~ Will be Doing Soon.
Computers

The End

Matched Filter Inner Product

$$\langle s|h\rangle = 4\Re \int_0^\infty \frac{\tilde{s}^*(f)\tilde{h}(f)}{S_h(f)}\, df$$

Fisher Matrix

$$\Gamma^{ij} = \left\langle \frac{\partial h}{\partial \lambda_i} \middle| \frac{\partial h}{\partial \lambda_j} \right\rangle$$

Measurement Accuracy

$$(\Delta\lambda_i)_{\mathrm{rms}} = \sqrt{(\Gamma^{-1})_{ii}} \quad (\text{no sum})$$

One-Parameter Measurement Accuracy

$$(\Delta\lambda)_{\mathrm{rms}} = \frac{|\lambda_1 - \lambda_2|}{\sqrt{\langle h_1 - h_2 | h_1 - h_2 \rangle}}$$

Fitting Factor

$$\mathrm{FF} = \frac{\langle h_1 | h_2 \rangle}{\sqrt{\langle h_1 | h_1 \rangle \langle h_2 | h_2 \rangle}}$$