Title: General Relativity on Trial: Gravitational Waves and the Parameterized Post-Einstenian Framework

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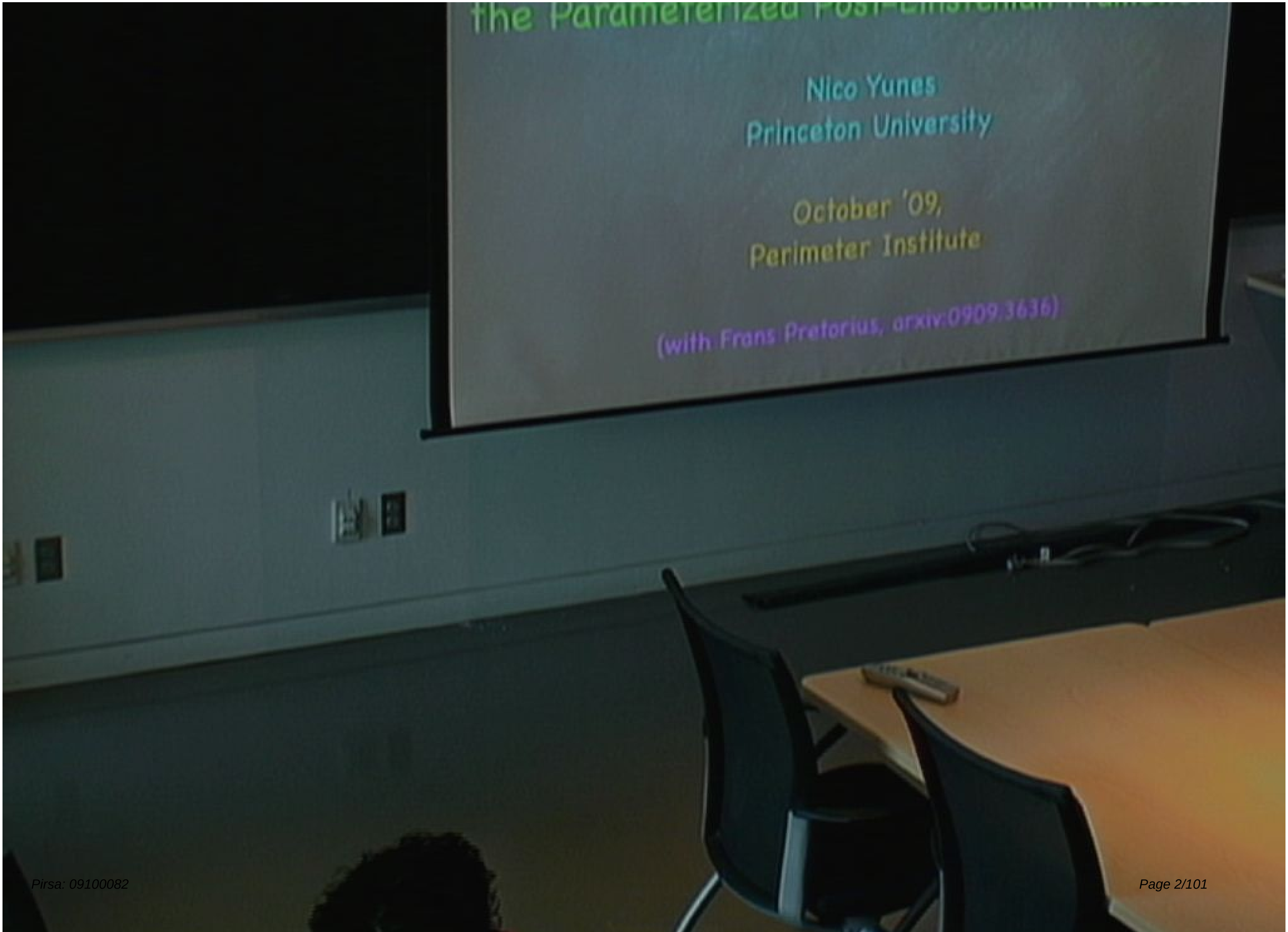
Abstract: With the imminent detection of gravitational waves by ground-based interferometers, such as LIGO, VIRGO and TAMA, pulsar timing observations, and proposed space-borne detectors, such as LISA, we must ask ourselves: how much do we trust general relativity? The confirmation of general relativity through Solar System experiments and binary pulsar observations has proved its validity in the weak-field, where velocities are small and gravity is weak, but no such tests exist in the strong, dynamical regime, precisely the regime of most interest to gravitational wave observations. Unfortunately, because of their inherent feebleness, the extraction of gravitational waves from detector noise relies heavily on the technique of matched filtering, where one constructs waveform filters or templates to clean the data. Currently, all such waveforms are constructed with the implicit assumption that general relativity is correct both in the weak and strong, dynamical regimes. Such an assumption constitutes a fundamental bias that will introduce a systematic error in the detection and parameter estimation of signals, and in turn can lead to a mischaracterization of the universe through incorrect inferences about source event rates and populations. In this talk, I will define this bias, explain its possible consequences and propose a remedy through a new scheme: the parameterized post-Einsteinian framework. In this framework one enhances waveforms via the inclusion of post-Einsteinian parameters that both interpolate between general relativity and well-motivated alternative theories, but also extrapolate to unknown theories, following sound theoretical principles, such as consistency with conservation laws and symmetries. The parametrized post-Einsteinian framework should allow matched filtered data to select a specific set of post-Einsteinian parameters without {\emph{a priori}} assuming the validity of the former, thus allowing the data to either verify general relativity or point to possible dynamical strong-field deviations.


Nico Yunes
Princeton University
October '09,
Perimeter Institute
(with Frans Pretorius, arxiv:0909.3636)

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Cosmological Tests: Well...we need dark energy and dark matter...but otherwise we are doing great! (WMAP, SN)

(see eg. C. M. Will Liv. Rev.)

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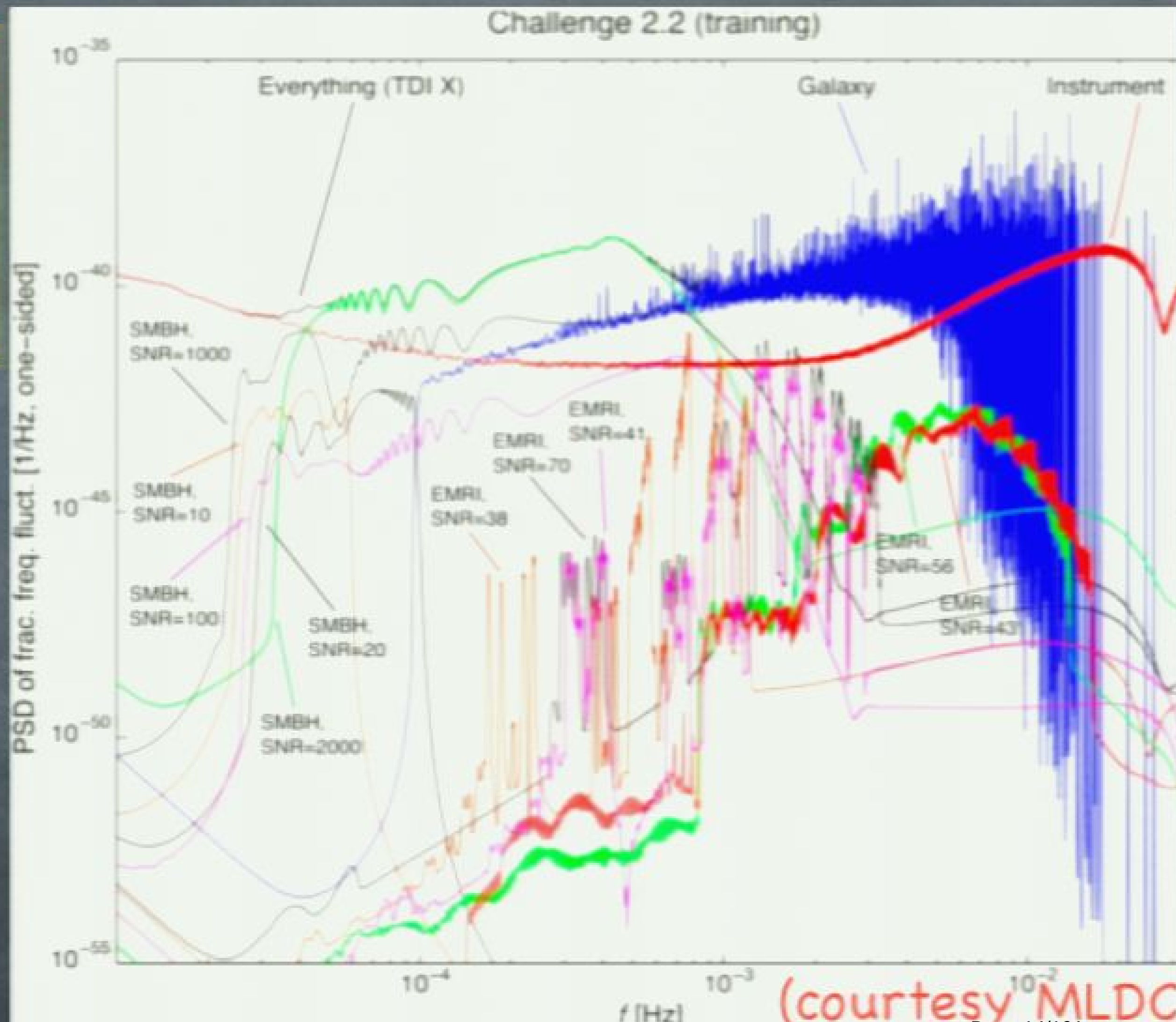

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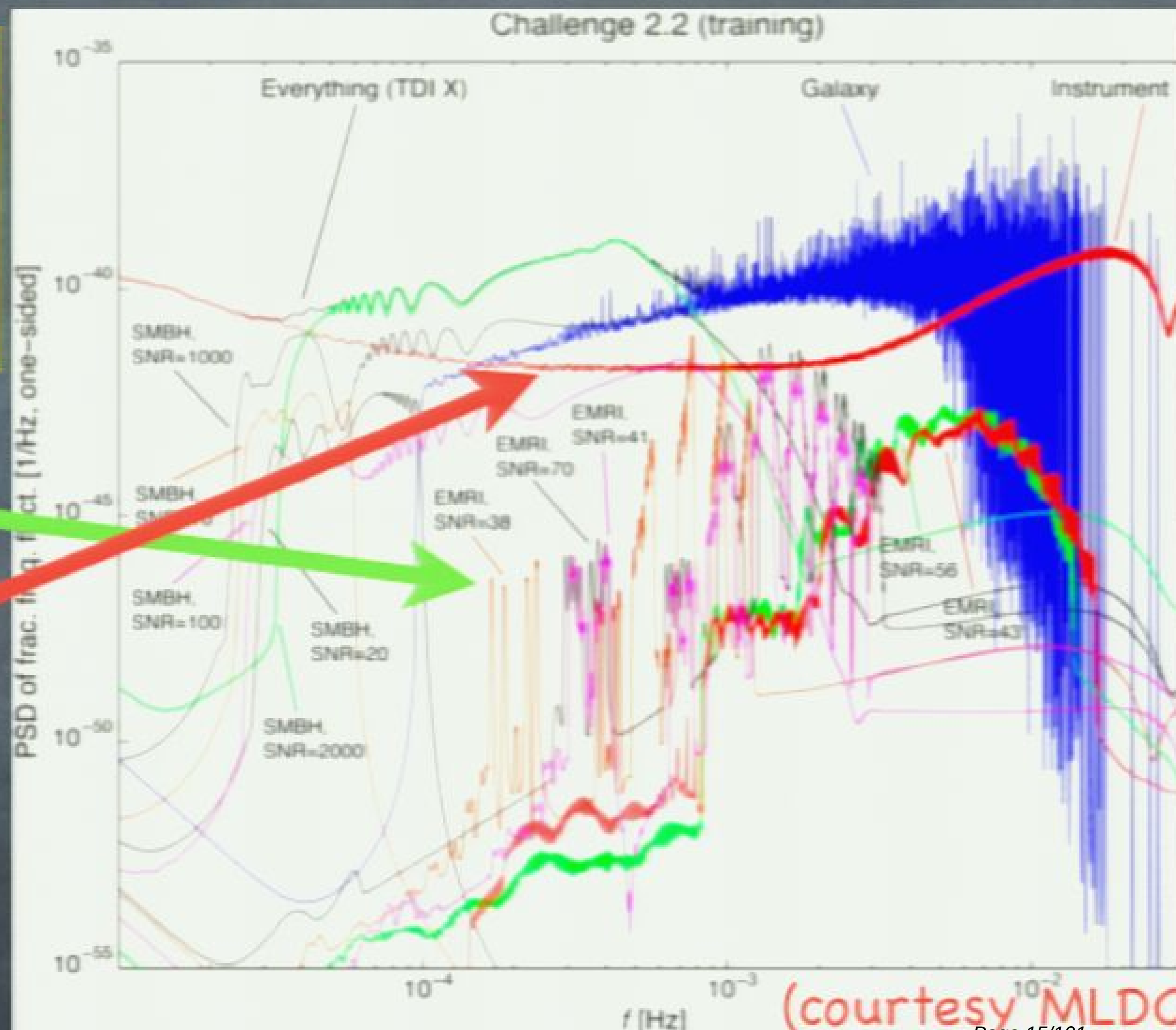
A lot of sources buried well under the noise curve



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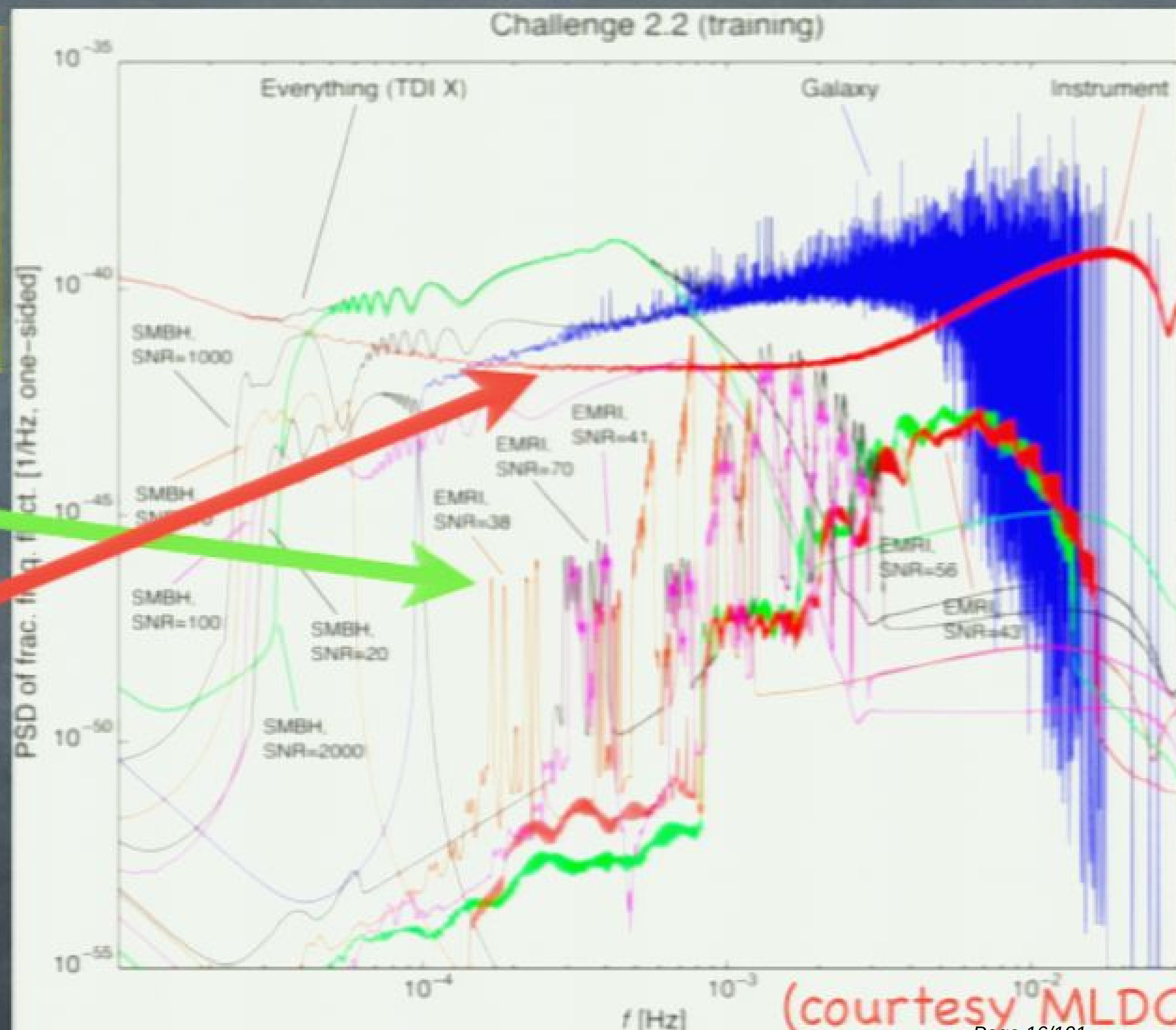

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(Maximize cross-correlation between a template and data as a function of sys. par.)

Matched filtering allows you to extract signals

So what if we use the wrong filters?

Wrong filters could:

1) Filter out wild observations.
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Quant. Grav: How can we test GR if we assume GR?

Road Map

I. A brief review of gravitational wave astrophysics

II. Alternative Theories? Who Ordered That ?!

III. Fundamental Bias and the ppE framework

Ia. What are Gravitational Waves?

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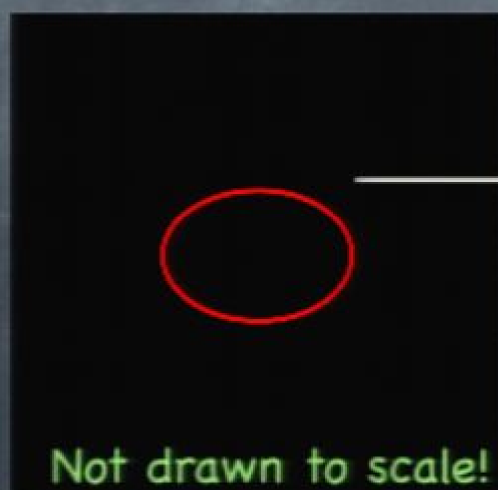
Given a ring of test-particles, the plus polarization induces:



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So for example, let's shoot Lee with a GW gun face on...

Not drawn to scale!

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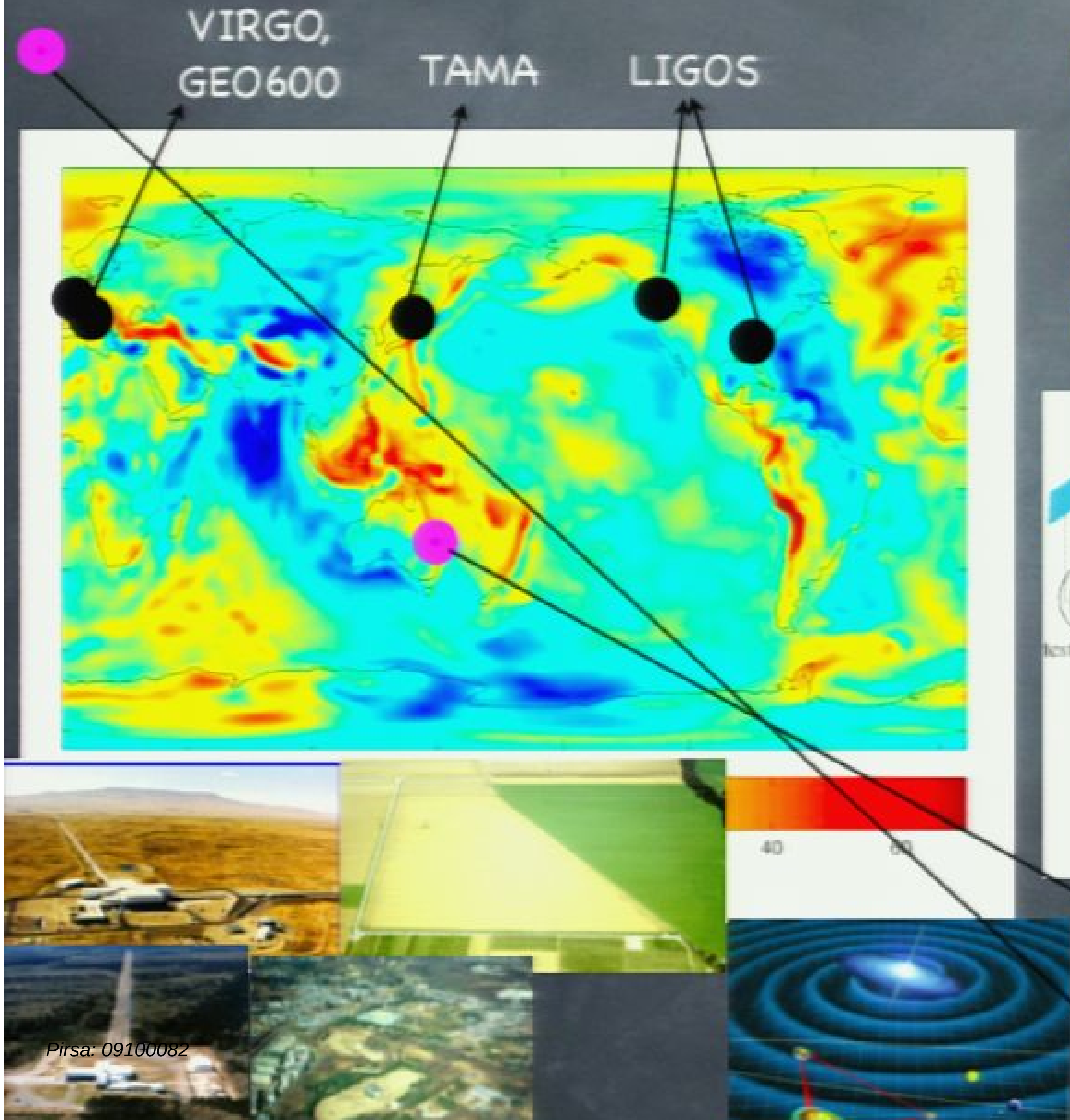
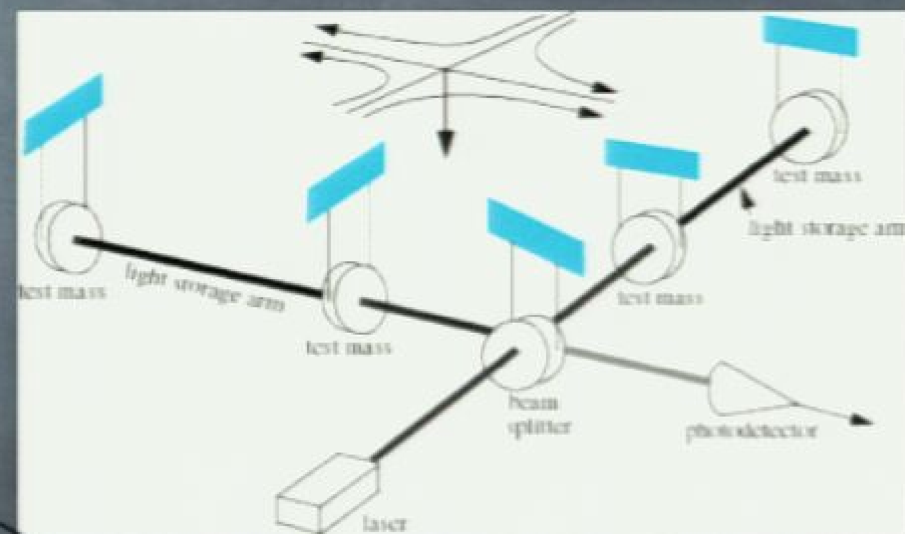
Ib. How do the detectors work?



Bounce light off mirrors and look for interference pattern when the light recombines.



Ic. How does the Analysis Work?

$$\boxed{\rho^2 \sim \int \frac{\tilde{d}(f)\tilde{h}(f;\lambda^\mu)}{S_n(f)}df}$$

Matched Filtering: Maximize the signal-to-noise ratio over all template parameters λ^μ

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A Minimal (?) Set of Criteria:

1. Weak-Field Consistency (existence and stability of physical solutions, satisfaction of precision tests).
2. Strong-Field Inconsistency (deviations only where experiments cannot currently rule out modifications)
3. Metric theory (gravity is curved spacetime, controlled by metric tensor that is WEP consistent).

IIb. What theories satisfy that ?!

Some examples include:

(i) Scalar-Tensor theories: Promote Newton's constant to a scalar field, $G \to \phi(x^\mu)$ and give it dynamics. Passes weak-field tests for non-dynamical coupling. Spontaneous scalarization can lead to strong deviation in NS inspirals and mergers.

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(ii) Chern-Simons Modified Gravity: Enhance the action with the Pontryagin density $\phi(x^\mu) R \wedge R$. Passes weak-field tests. It could lead to strong-field deviations (parity violation?).

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(iii) Gauss-Bonnet Modified Gravity: Enhance the action with the Gauss-Bonnet term $\phi(x^\mu)(a_1 R^2 + a_2 R_{\mu\nu} R^{\mu\nu} + a_3 R_{\mu\nu\delta\gamma} R^{\mu\nu\delta\gamma})$

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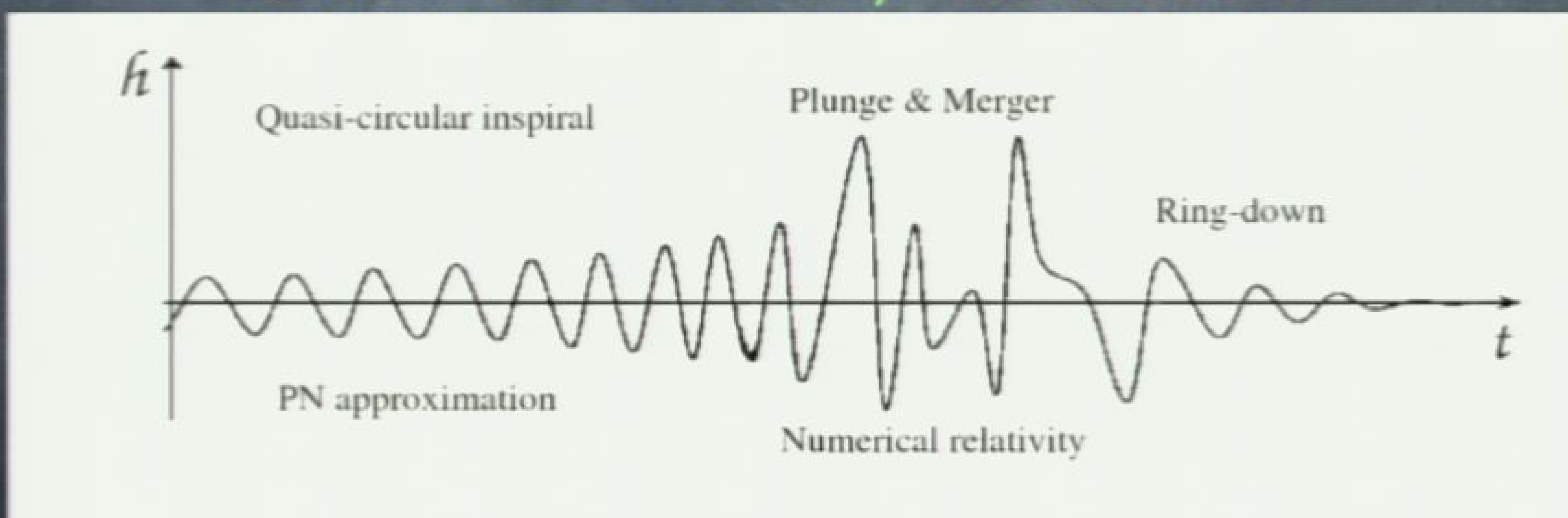

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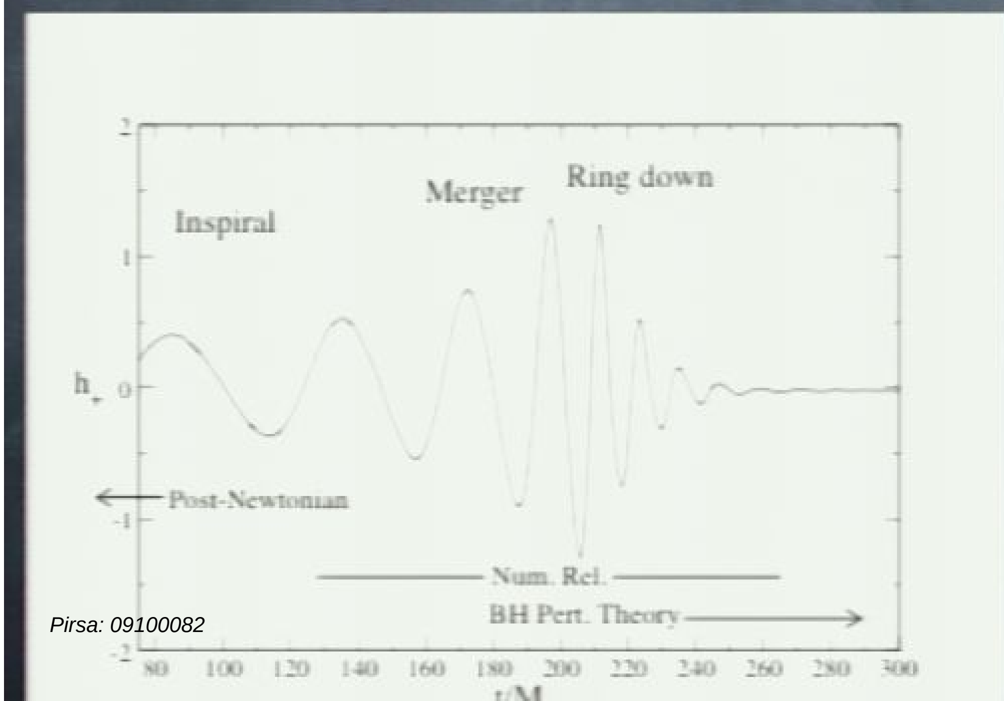

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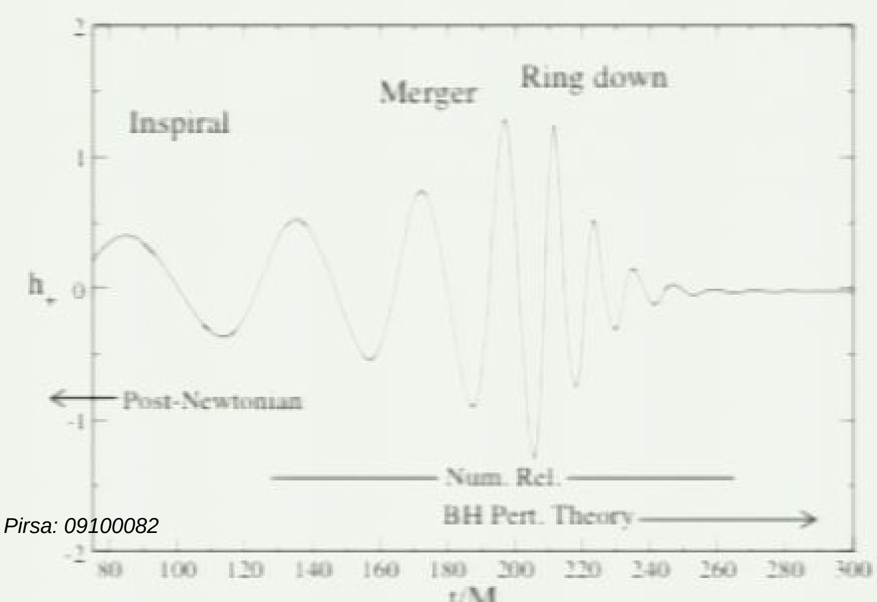

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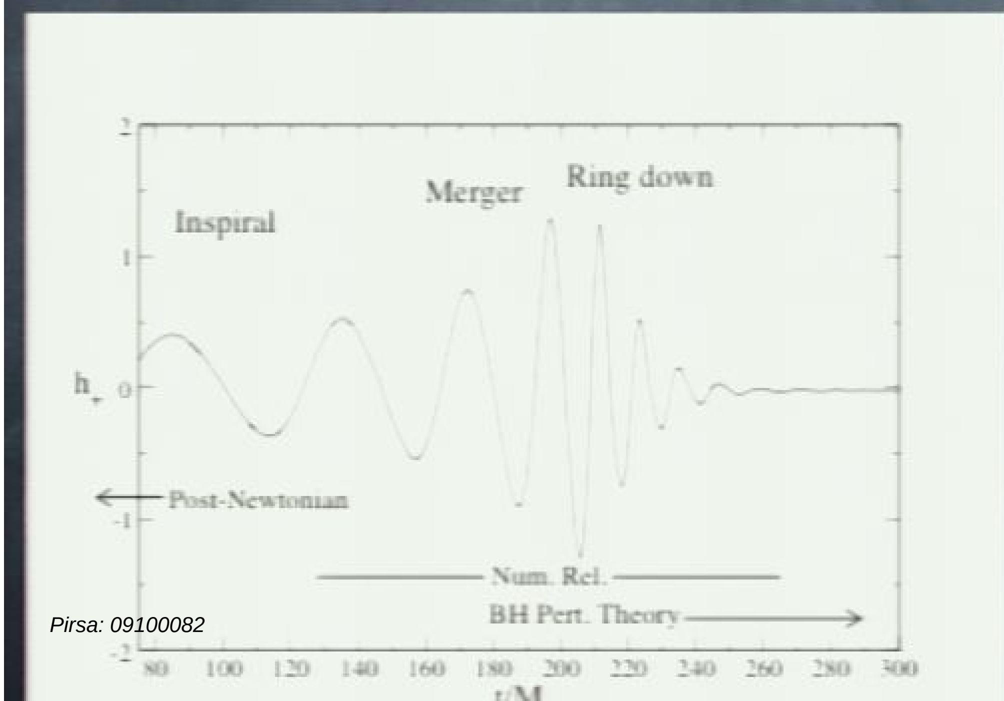

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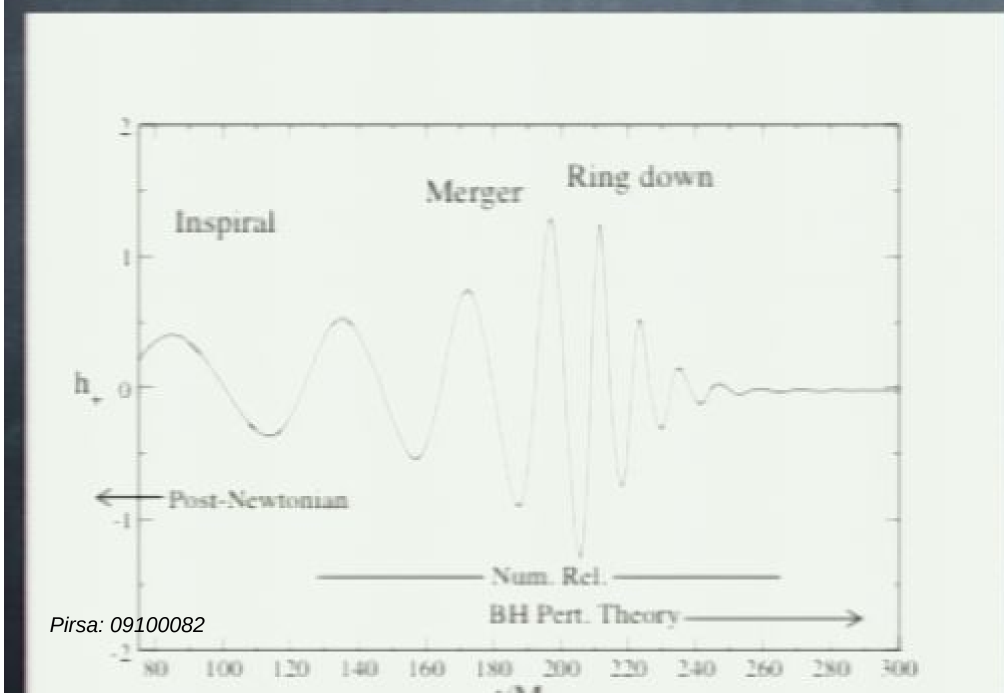

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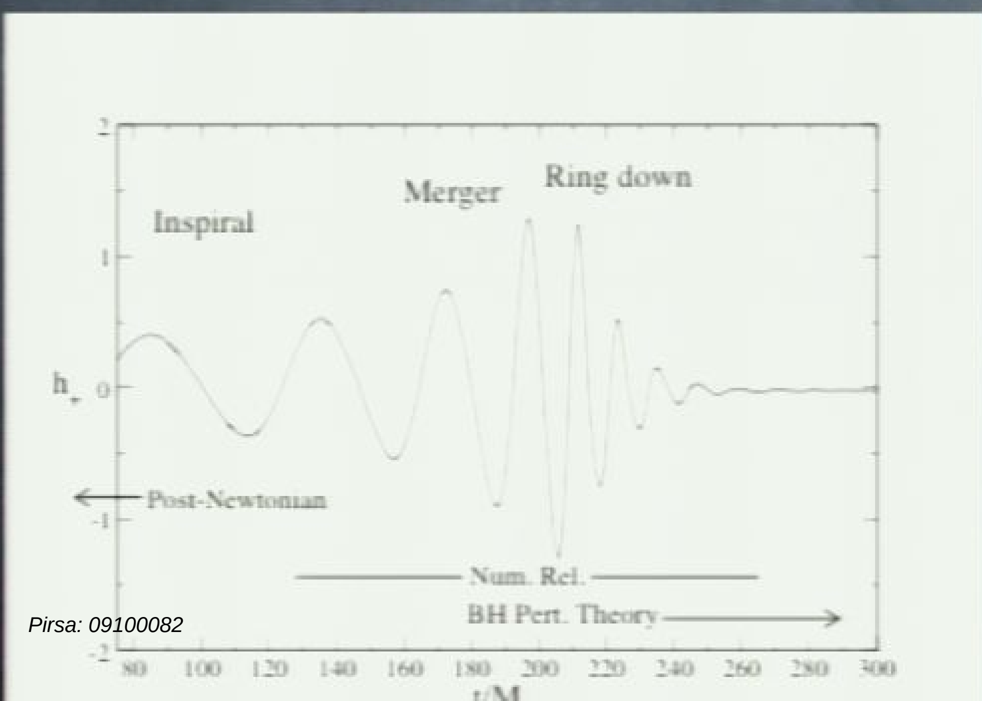

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A Lorentzian is the FT of a exponentially damped sinusoid

IId. How can the observable be modified?

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(in the inspiral phase)

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Finder
File
Edit
View
Go
Window
Help
Thu 2:53 PM
(59%)
NO NAME
Einstein-3
PI-
psswd.tex
statEinstei
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