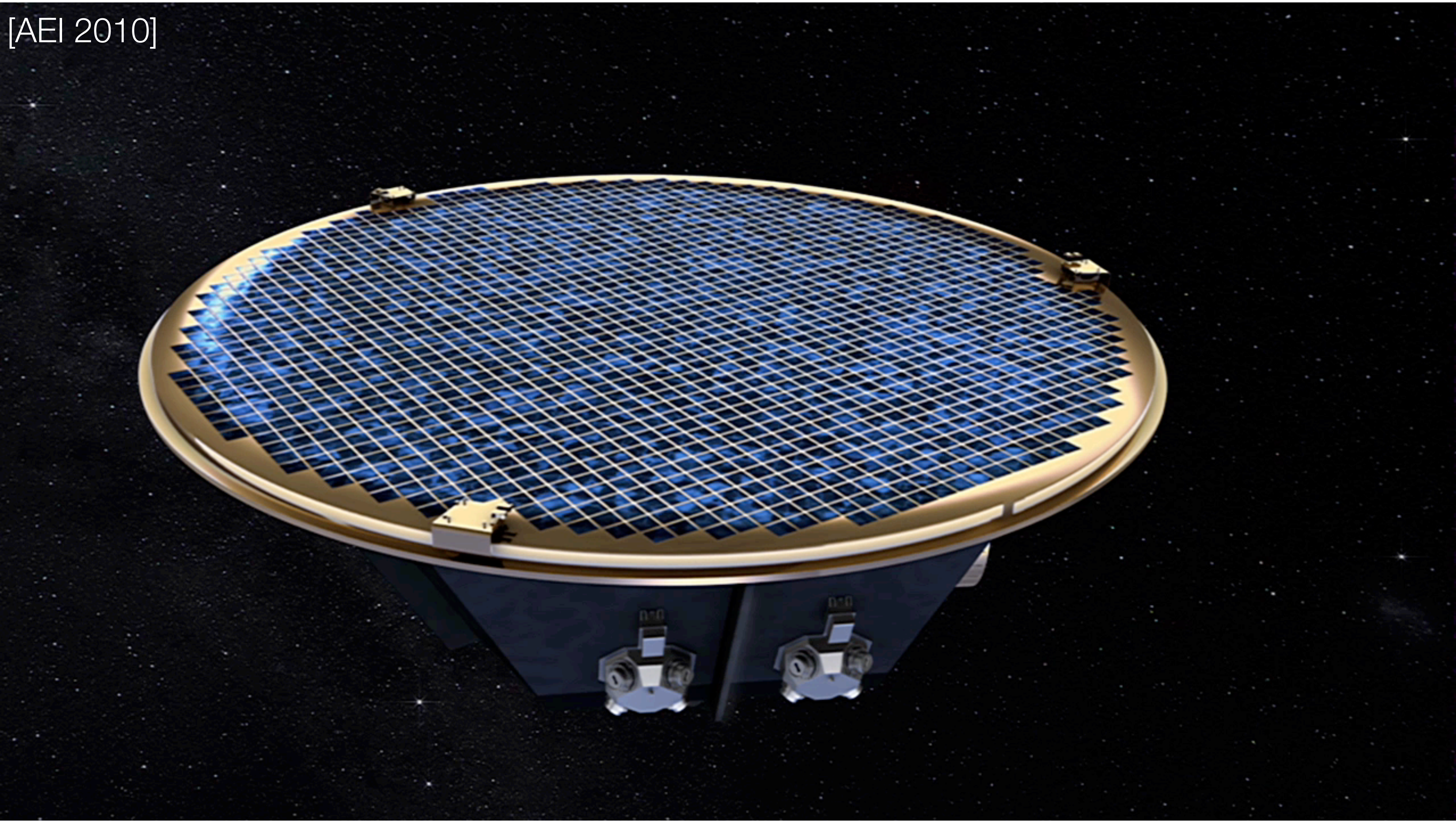


LISA science: the next ten years

Michele Vallisneri
Jet Propulsion Laboratory

- LISA gets third priority among large space projects, after WFIRST and the Explorer program.
- "A gravity-wave observatory that would open an entirely new window in the universe [...] its recommendation and prioritization reflect its compelling science case and technical readiness."
- A new start is possible in 2015 (after LISA Pathfinder's success and the European decision) for launch in 2025.

Pathfinder

WFIRST

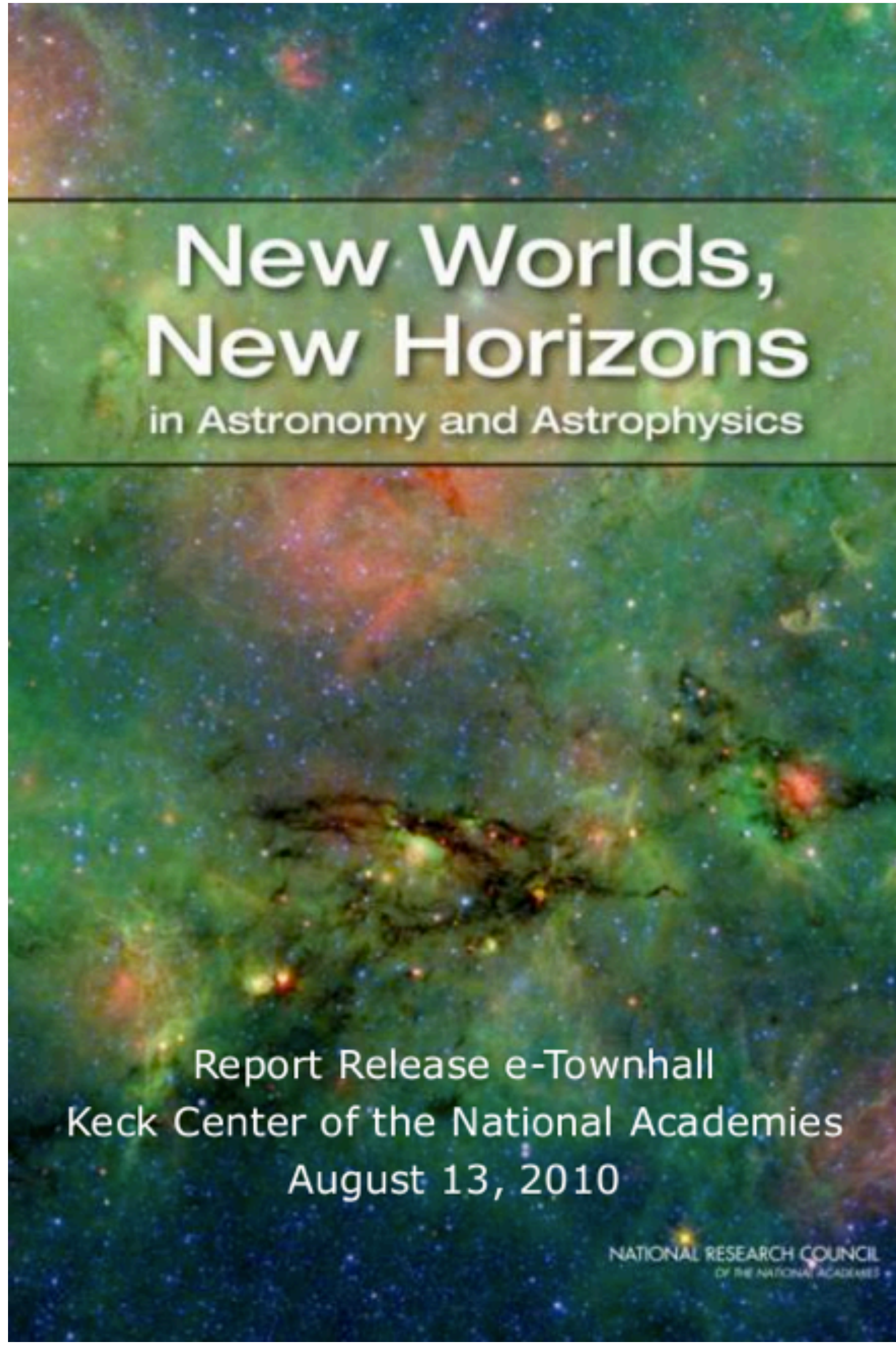
JWST

Euclid

Cosmic Visions

Laplace

IXO



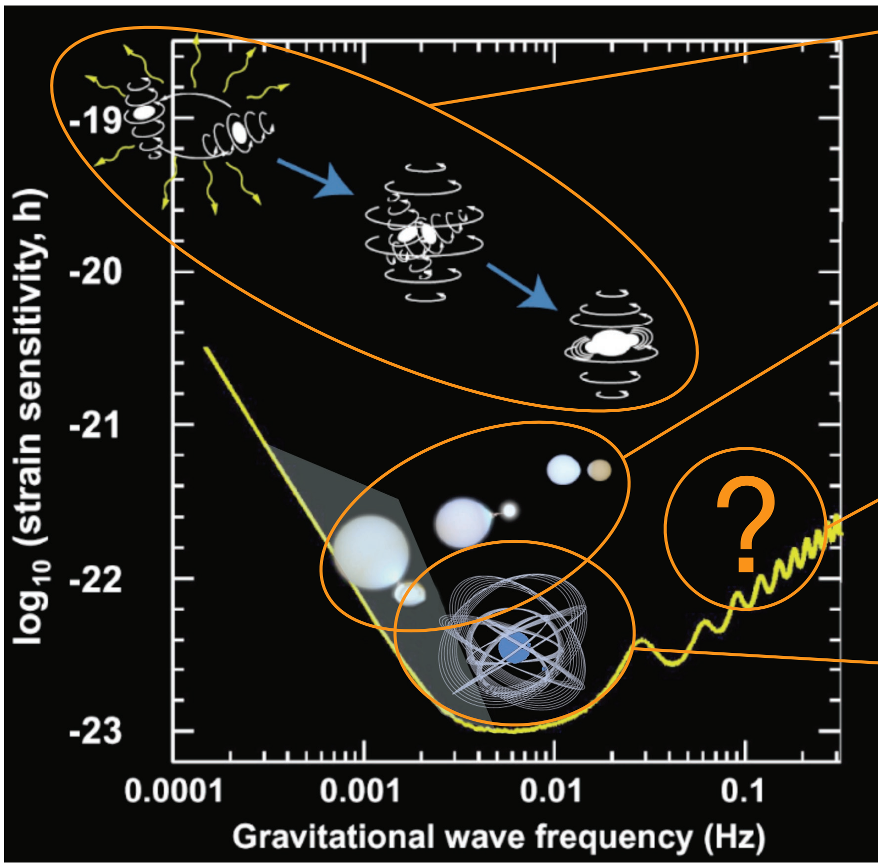
2025?

So what do we do for the next ten years?

- Enjoy the centennial and the GW detection era
- Continue advocating LISA's unique science case
- Really, there's lot of work to do

Remember:

- LISA will detect and characterize many thousands of individual GW sources, as well as the diffuse background from millions more



MBH mergers

- study the coevolution of galaxies and MBHs
- measure accurate distances of high-*z* objects
- test GR in the nonlinear regime

Galactic binaries

- study the astrophysics of binary stellar evolution, including the common envelope phase

bursts and stochastic backgrounds

- look for new physics from the early Universe and string theory

extreme–mass-ratio inspirals (EMRIs)

- study MBHs and their environment in the dense nuclei of galaxies
- map BH spacetimes and test cosmic censorship

So what do we do for the next ten years?

- Enjoy the centennial and the GW detection era
- Continue advocating LISA's unique science case
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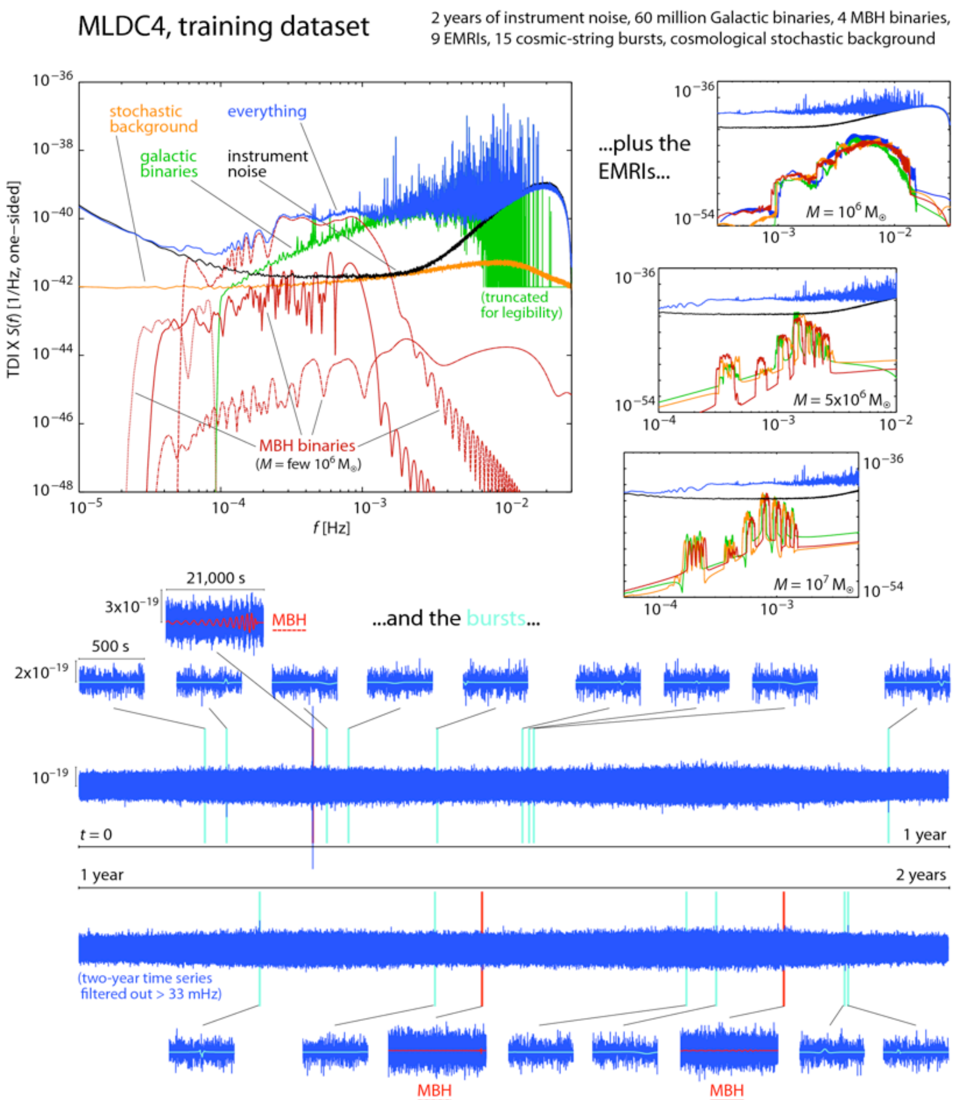
- The Mock LISA data challenges have demonstrated the detection and parameter characterization of signals of known shape with moderate SNR

Indeed, the MLDCs have been a great platform to encourage LISA data-analysis development in friendly competition



- Four challenges completed since 2006, one in progress
- 70 participants, 25 institutions
- 30+ publications
- Demonstrated the detection and parameter estimation of all major LISA source classes
- Bank filtering, time–frequency, MCMC, genetic algorithms, nested sampling, ...
- lisatools.googlecode.com
- Now tackling global-fit problem; next, realistic data

Now however we need a platform to encourage collaboration, and to ensure the reuse and preservation of our work

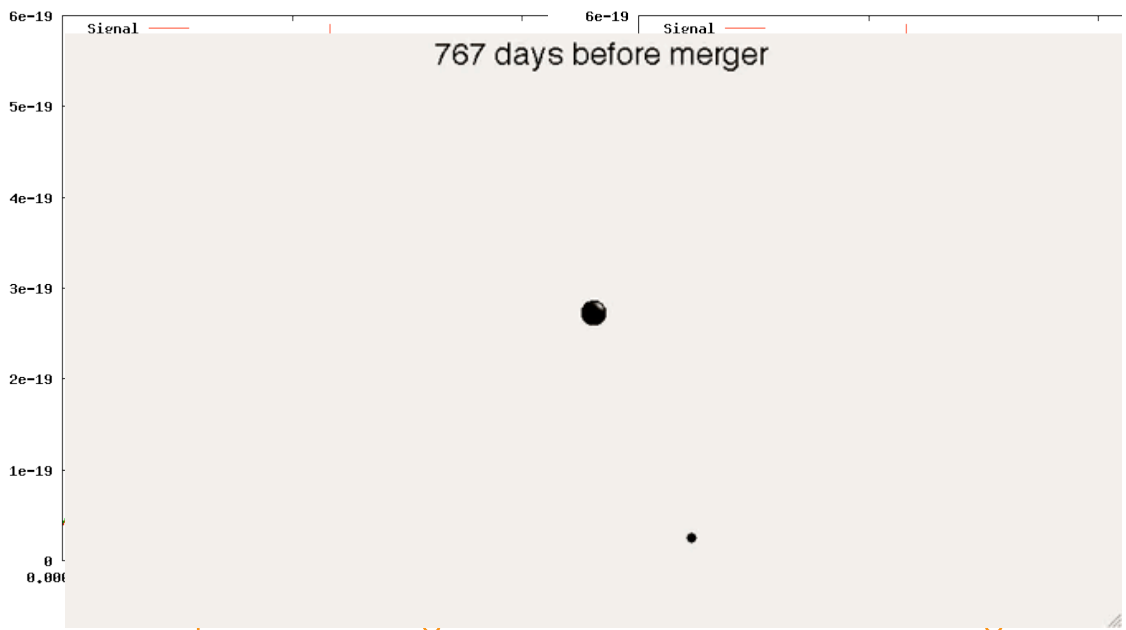
- No single group has the expertise necessary to master all the different sources in global-fit problems, and the investment of time and effort needed from new participants has become prohibitive
- We should spend our time figuring out and improving what really works rather than repeatedly programming the same routines
- The investment of time and effort needed from new participants has become prohibitive

So we're working together to build lisasolve.googlecode.com

- An open-source collection of LISA data-analysis codes (libraries and analyses, with granular credit)
- A platform for collaboration on MLDCs and broader investigations
- A forum for outreach to computational astronomers

So what else do we do for the next ten years?

Theory Challenge 1: accurate and efficient MBH-binary templates
Theory Challenge 2: accurate and efficient EMRI templates
Theory Challenge 3: work out the probabilistic representation and querying of the LISA source "catalog"
Theory Challenge 4: understand how LISA can test GR



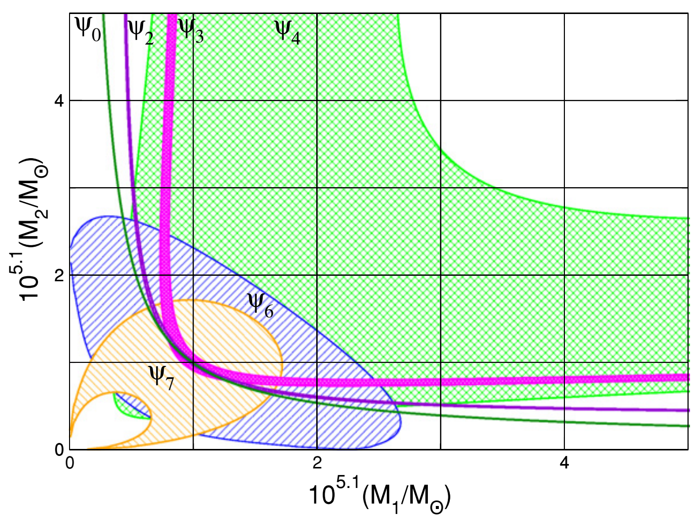
[Crowder 2007]

Testing GR with LISA—we really have to figure it out yet!

- Standard tests of GR are based on Will et al.'s "standard model" (equivalence principle + metric theories + parametrized post-Newtonian), which leaves little room for detecting non-standard radiation
- No simple principled framework exists for radiative systems or systems containing strong internal fields. So we must consider individual alternative theories (but the Hulse-Taylor pulsar already killed the best ones!)
- It will be hard to distinguish non-GR from non-BHs from (un)known astrophysics

$$\left\langle \frac{\partial h}{\partial \lambda_{\text{physical}}} \middle| \frac{\partial h}{\partial \lambda_{\text{non-GR}}} \right\rangle \simeq 0$$

- Conversely, the matched-filtering dilemma suggests that truly different gravity may go completely undetected
- Null tests, such as PN-coefficient consistency, are conceptually most robust



Naïve and sentimental tests of GR consistency

In order of difficulty and un-likelihood:

- If we divide the waveform in segments, do individual SNRs pass a χ^2 test?
- Is there a coherent residual?
- What about the source parameters determined from each segment—are they consistent (within estimated errors) with the parameters determined from the entire waveform?
- Is the shape of the likelihood surface consistent with what's expected for this waveform family?
- Is the Bayesian evidence (or just the SNR) consistent with what's expected for a source with the inferred parameters?

- But we have to mind: instrument systematics, environmental effects (tidal fields, attractors, strong lensing, thick disks), data-analysis artifacts

From astro-gr@Paris: “smoking guns” of non-standard gravity

Starting with the most unlikely

- No LISA detections
  (But we’ll have to convince everybody that LISA is working correctly.)
- Anti-chirps
  (Wow.)
- Wrong GW polarizations
  (They would have to be huge.)
- Chaotic orbits
  (Would we see them at all?)
- Missed EM/GW coincidence
  (Is there a clean scenario?)
- No BH horizon
  (Distinguishable from region with chaotic dynamics?)

What can LISA contribute to the GW community (before launch)?

- Experience with parameter estimation and optimization in large parameter spaces (MCMC, genetic algorithms, &c.)
- An increasing focus on the inverse problem for astrophysical populations
- A dedication to serving a community of astronomical “users”
- A commitment to open science and the early, full release of data

As for our launch date:
I don’t expect (but hope!) to be surprised