GW-SAG Status and Plans

Guido Mueller
University of Florida

AAS Meeting

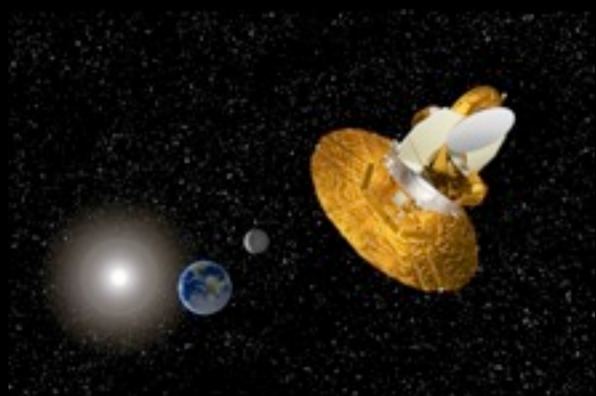
Long Beach 2013

GW-SAG

- GWs around the world:
  - Non-space based detectors
- Summarize GW Study in US
  - Presentation on Monday
- eLISA
- NASA plans/path forward
- Role and Organization of GW-SAG

GW-Detection schemes/Detectors

Inflation Probe



Polarization in
u-Wave Background

Source:
Density Fluctuations
Gravitational Waves

Pulsar Timing

IPTA

Sources:
Background from
MBH-binaries

Reach critical
sensitivity: 2016

LISA

Sources:
SMBH mergers
EMRIs
Galactic binaries

Guaranteed signals
Largest SNR
Most Science

LIGO

LIGO, VIRGO,
KAGRA, GEO
Sources:
NS/BH mergers
Supernovae
Pulsars, ...

Reach critical
sensitivity: 2016

-18 -15 -9 -6 -5 -1 1 4

f [log Hz]

GWs around the world

- Advanced LIGO

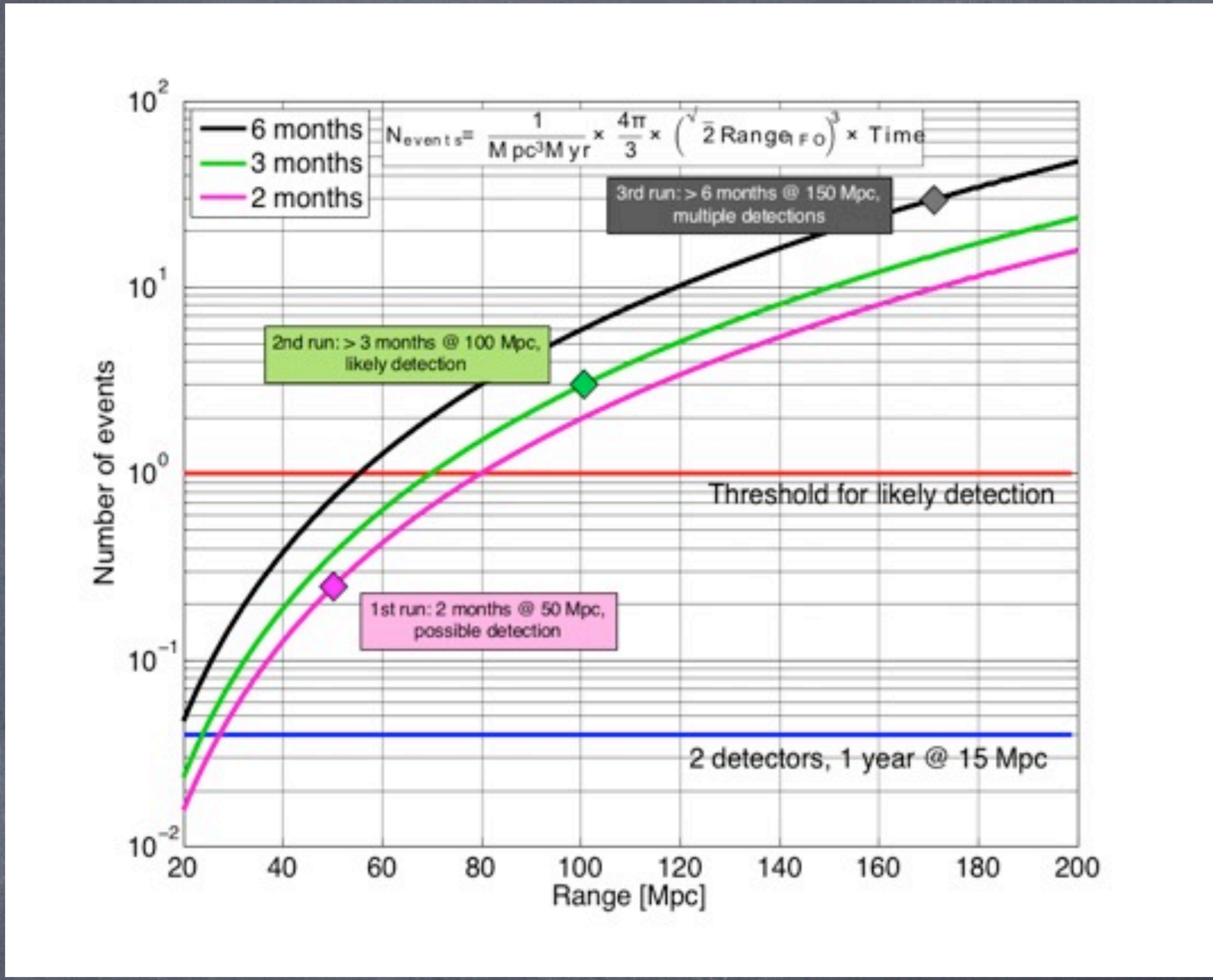
Construction on schedule, science operation expected to begin 2015

- ~95% of hardware built, installation ~55% complete[1]
- At least one of almost all kinds of hardware installed, tested, functioning

[1] LIGO-PAC Meeting Nov. 2012

GWs around the world

- Advanced LIGO/VIRGO
  - will likely detect GWs from NS and solar mass BH mergers this decade!
- KAGRA (Japan)
  - working on a cryogenic underground detector
- GEO
  - currently in Astrowatch
  - later: HF-GEO, focus on high frequency signals
- LIGO-India
  - Approval expected early 2013
  - Planned to reach aLIGO sensitivity in 2021

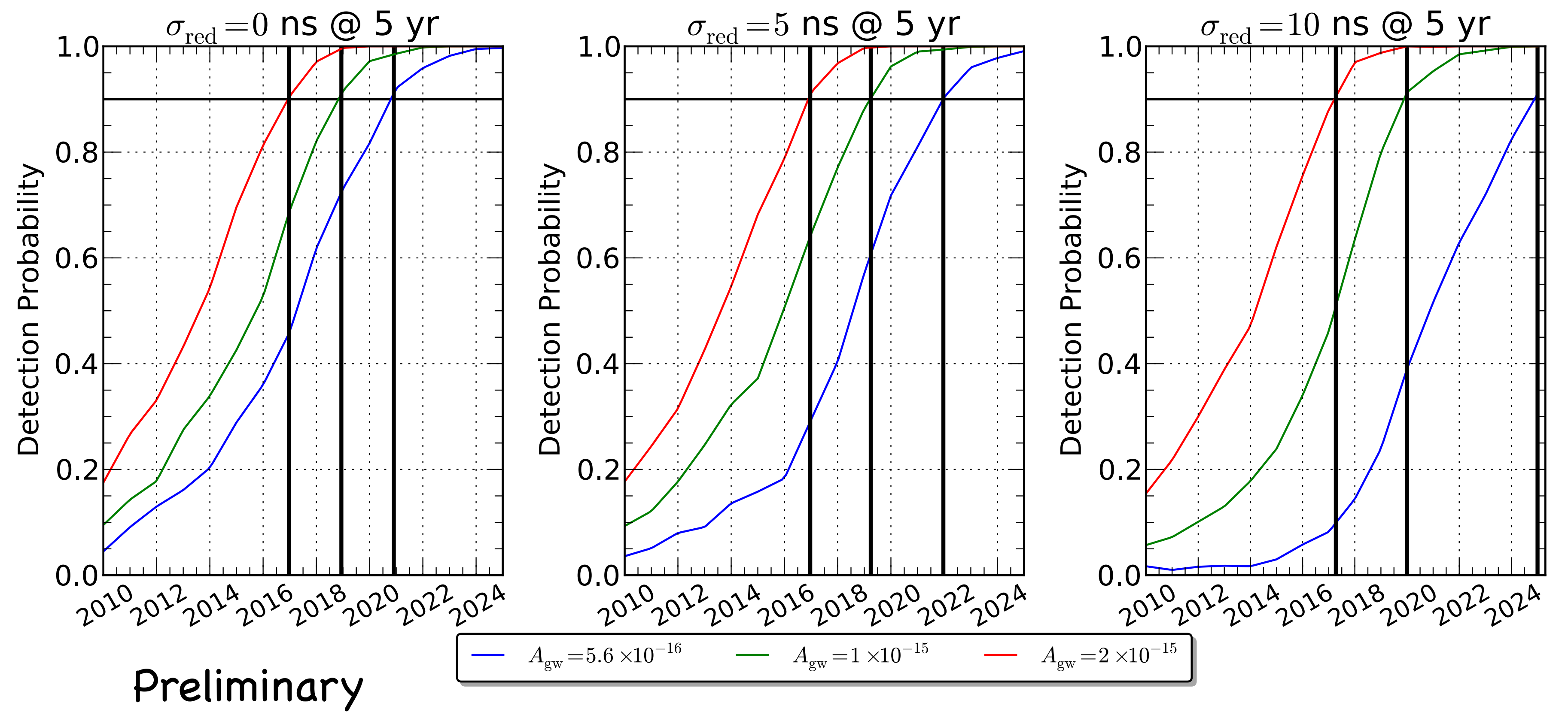


Summary:
Major progress towards first detections of GWs from low mass binaries and other potential high frequency sources

Pulsar Timing

- International Pulsar Timing Array
  - NanoGrav
  - EPTA (Europe)
  - Parkes Pulsar Timing Array
- Looking for GWs from massive black hole binaries long before the merger
- Current best estimate
  - Detection of stochastic GWs likely between 2016 and 2024

Intrinsic spin noise



Credit: Justin Ellis and Xavier Siemens for the NANOGrav Collaboration

GW-Detection schemes/Detectors

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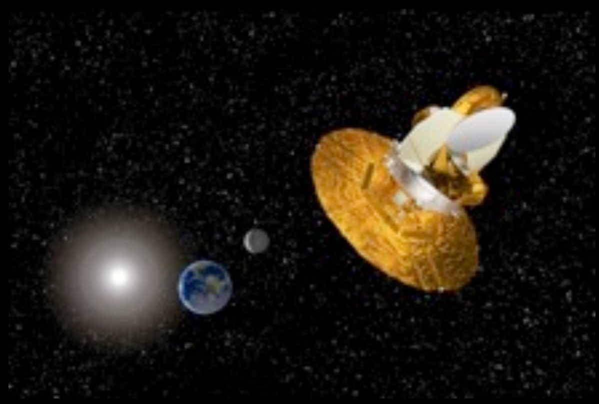

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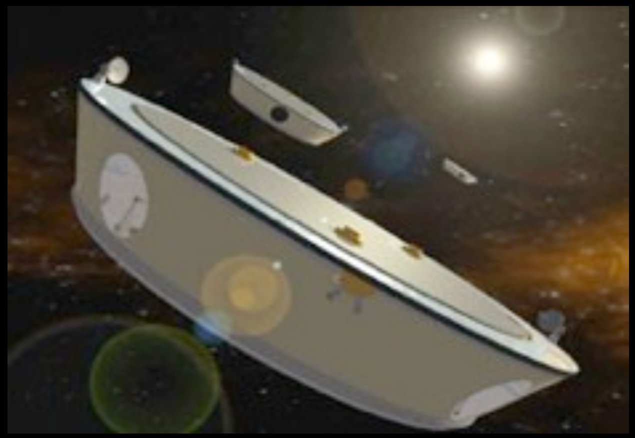

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f [log Hz]

GW Study

Goals

- Mission concepts at lower cost points
- Explore how architectural choices affect science, risk and cost
- Identify key enabling technologies

General findings (short version)

- Can get some science done at reduced cost
- Eliminating a measurement arm reduces costs modestly, reduces science and increases mission risk.
- Scientific performance decreases far more rapidly than cost.
- No new technology magically appeared that reduces the cost significantly!
- Cost will be >$1B

3 S/C cost money!

Science Performance	SGO High	SGO Mid	LAGRANGE/ McKenzie	OMEGA Option 1	OMEGA Option 2
Massive Black Hole Binaries					
Total detected	108–220	41–52	37–45	21–32	21–32
Detected at $z \geq 10$	3–57	1–4	1–5	1–6	1–6
Both mass errors ≤ 1%	67–171	18–42	8–25	11–26	11–26
One spin error ≤ 1%	49–130	11–27	3–11	7–18	7–18
Both spin errors ≤ 1%	1–17	<1	0	<1	<1
Distance error ≤ 3%	81–108	12–22	2–6	10–17	10–17
Sky location ≤ 1 deg^2	71–112	14–21	2–4	15–18	15–18
Sky location ≤ 0.1 deg^2	22–51	4–8	≤ 1	5–8	5–8
Total EMRIs detected†	800	~35	~20	~15	~15
WD binaries detected (resolved)	4×10^4	7×10^3	5×10^3	5×10^3	5×10^3
WD binaries with 3D location	8×10^3	8×10^2	3×10^2	1.5×10^2	1.5×10^2
Stochastic Background Sensitivity (rel. to LISA)	1.0	0.2	0.15*	0.25	0.25
Top Team X Risk	Moderate‡	Low	Moderate	Moderate	High
Top Team X + Core Team Risk	Moderate‡	Low	High	High	High
Team X Cost Estimate (FY 12$)	2.1B	1.9B	1.6B	1.4B	1.2B

† Based on median rate; estimates for EMRI rates vary by as much as an order of magnitude in each direction.
* Two-arm instruments such as LAGRANGE/McKenzie lack the "GW null" channel that can be used to distinguish between stochastic backgrounds & instrumental noise, making such measurements more challenging.
‡ The moderate risk for SGO High comes about from the thruster development necessary to demonstrate the required lifetime for 5 years of science operations.

Summary: LISA-like mission promises most science with lowest risk and cost

The final study report can be downloaded from:
http://pcos.gsfc.nasa.gov/studies/gravitational-wave-mission.php

eLISA

- evolved LISA
  - European group prepares proposal for ESAs L2/L3-call
    - Call expected after SPC meeting in February

Figure 1, The eLISA gravitational wave observatory concept: Three spacecraft in orbit around the Sun, each containing two Gravitational Reference Sensors, linked by a laser interferometer.

- Rules of call still evolving
  - Might be similar to L1
- Boundary conditions for L1:
  - ESA led
  - about 1B€ cost cap
  - International partners:
    - not mission critical
    - improve science
    - < 20% of total cost

eLISA

- eLISA
  - 2-arm mission
  - Drift away orbit
  - 2 year science operation

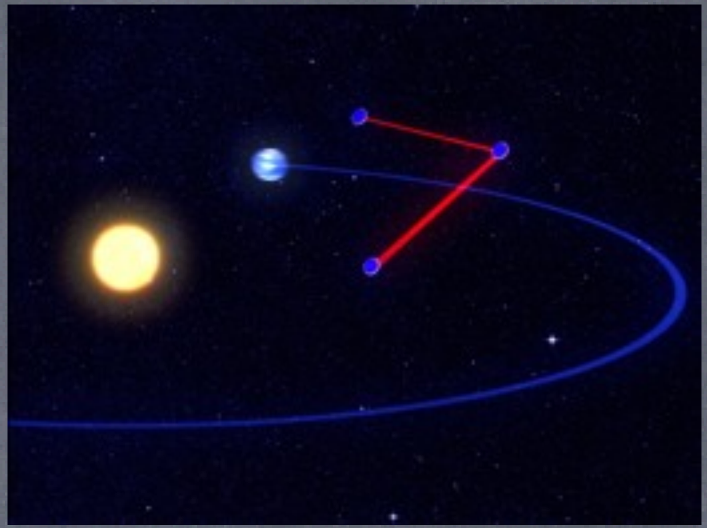

Figure 1, The eLISA gravitational wave observatory concept: Three spacecraft in orbit around the Sun, each containing two Gravitational Reference Sensors, linked by a laser interferometer.

- Roadmap for LISA (from eLISA Consortium)
  - Preselection of LISA for L2 in 2013/14
  - Confirmation after successful LISA Pathfinder (Launch 2015)
  - Fixing technology gaps not covered in LPF (2013-2015)
  - Build EQM[1] of complex payload (2016-2020)
  - Start industrial implementation in 2020
  - Launch in 2028

[1]Engineering Qualification Model

NASA Implementation Plan

LISA/LISA-like GW mission:

- Candidate large mission next decade
- Candidate for international partnership (eLISA)
- Technology Development over the next years

GWSAG and eLISA: Discussions with NASA and eLISA Consortium:

- What could NASA contribute?
  - 3rd arm, lifetime, more laser power, ...
    - Everything on board is mission critical
  - How to prioritize technology development (Monday session)

When would we need to join?

Does the EQM freezes the technologies and suppliers?

NASA Implementation Plan

LISA/LISA-like GW mission:

- Candidate large mission next decade
- Candidate for international partnership (eLISA)
-

Best way forward will depend on L2-call: ESA-Conditions for an international partner?

GW … n:

-
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Organization of GW-SAG

Organization of GW-SAG:

- Advocacy/Outreach: Scott Hughes
- Science: Neil Cornish
- Organization and Technology: Guido Mueller (Chair)

Organization of GW-SAG

Advocacy/Outreach: Scott Hughes et al.

- Organize presence at meetings
  - Poster session at AAS
  - Session at HEAD with European guest speakers
  - APS Meeting:
    - Joint GGR-DAP session on multimessenger astronomy
    - Focus session of Gravitational wave missions in space
- Plans for Articles for newsletters (LIGO Magazine, ...)
- Follow up on LISA-related scientific papers
- Online Blog
  - http://gravitytalking.wordpress.com/
- ...

Organization of GW-SAG

Science: Neil Cornish et al.

- Science capabilities of LISA-like missions
  - Detection rates
  - Parameter estimation
    - Masses, spins, sky localizations, ...
- Science case for white papers/yellow books/proposals
- Science WGs (match eLISA Science WGs)
  - Ultra Compact Binaries (Shane Larson)
  - Massive Black Holes (Emanuele Berti)
  - Extreme Mass Ratio Inspirals (Scott Hughes)
  - Testing Fundamental Physics (Nicolas Yunes)
  - Cosmology (Daniel Holz)
  - Data Analysis and Mock LISA Data Challenges (Michele Vallisneri)

Currently unfunded work ...

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Open to the public!

Contact us!

Currently unfunded work ...

Organization of GW-SAG

Organization and Technology: Guido Mueller et al.

- Close Collaboration with the former LISA Team
  - led by Robin 'Tuck' Stebbins at GSFC
  - Support writing of Technology Development Plan
- In Contact with Paul Hertz and others
  - Discuss current options and future opportunities
    - eLISA, LTP
- Interact with eLISA Consortium
  - Direct contact with eLISA leadership
  - 1st eLISA meeting in October 2012 in Paris
  - 'Science of measurement' WG meeting January 28-29 in Hannover

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The best path forward is not obvious!

But we keep on going!

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what keeps us going?

what keeps us going?

Fantastic
Science

what keeps us going?

GW Detection by LIGO and IPTA

Fantastic Science

what keeps us going?

GW Detection by LIGO and IPTA

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Pathfinder Success

what keeps us going?

GW Detection by LIGO and IPTA

Fantastic Science

Low Risk ratings

Pathfinder Success

what keeps us going?

GW Detection by LIGO and IPTA

Fantastic Science

LISA will come soon

Low Risk ratings

Pathfinder Success

BACK UP

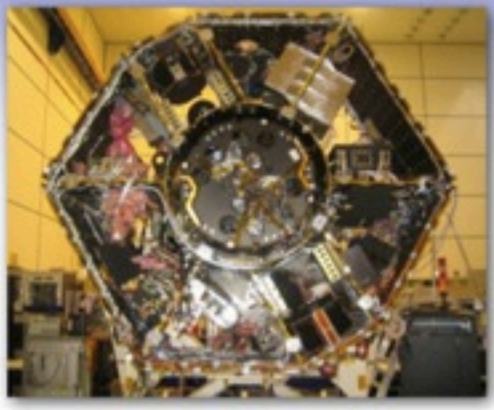
LISA Pathfinder:

- Paul McNamara reported early November in GWSAG telecon

LISA Pathfinder

Status [1]

- Spacecraft integration has been put on hold awaiting delivery of the payload and cold gas thrusters
  - Payload delivery: May 2014
  - Cold gas thruster delivery: Dec 2013
- Spacecraft environmental testing (1st Phase) complete
  - Magnetic test
  - Separation shock
  - Vibration
  - Thermal vacuum



hfinder

LISA Pathfinder

Status [2]

- The payload is on the critical path
  - Critical path item is the inertial sensor heads
- Project is in hibernation
  - Hibernation expected to last until end 2013
- System level performance surpasses requirements on every level
- Launch scheduled for Jan 2015

lisa pathfinder

Friday, 2 November 12

Launch: January 2015