Planning ET-MDC

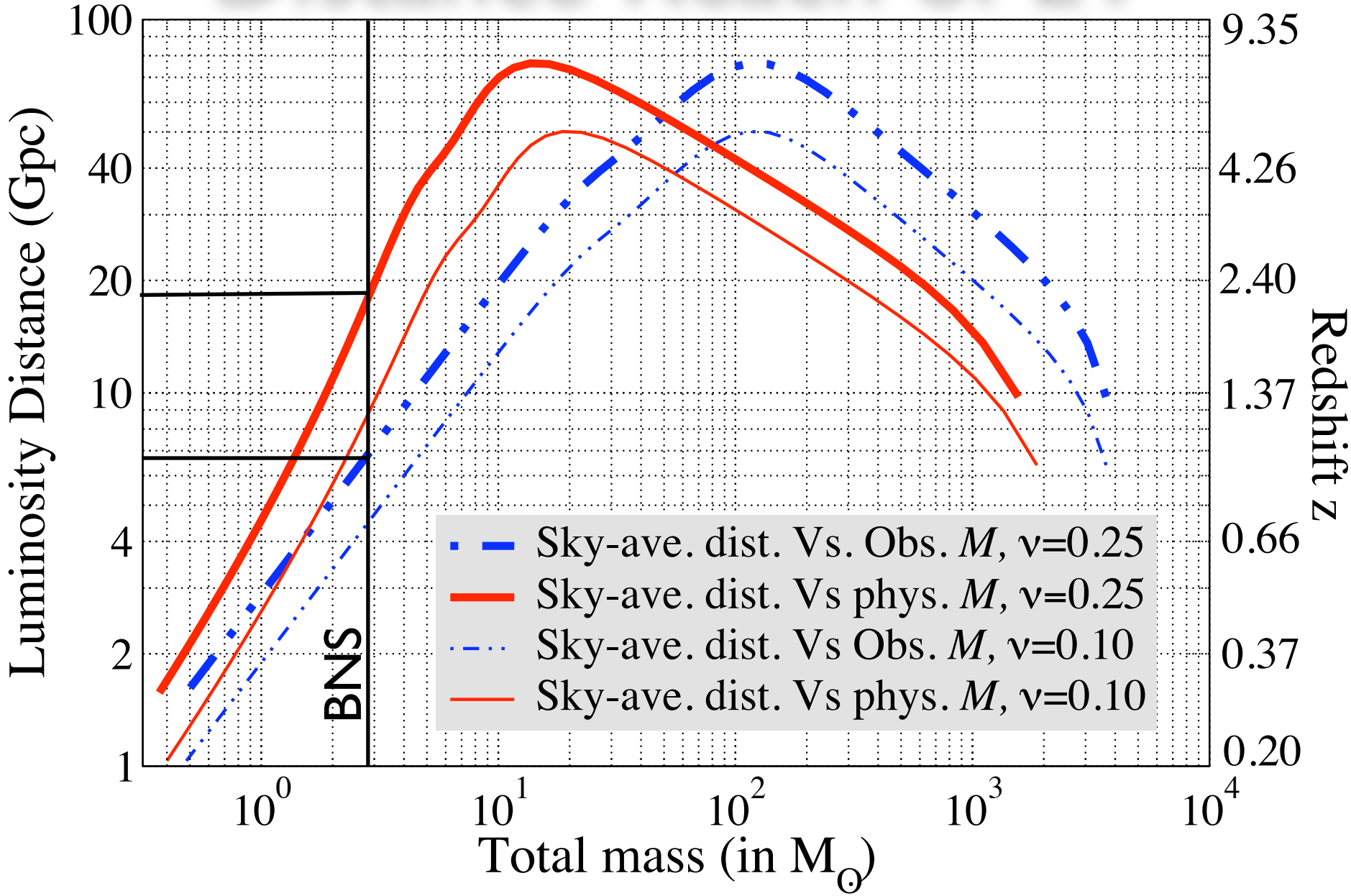
B.S. Sathyaprakash

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

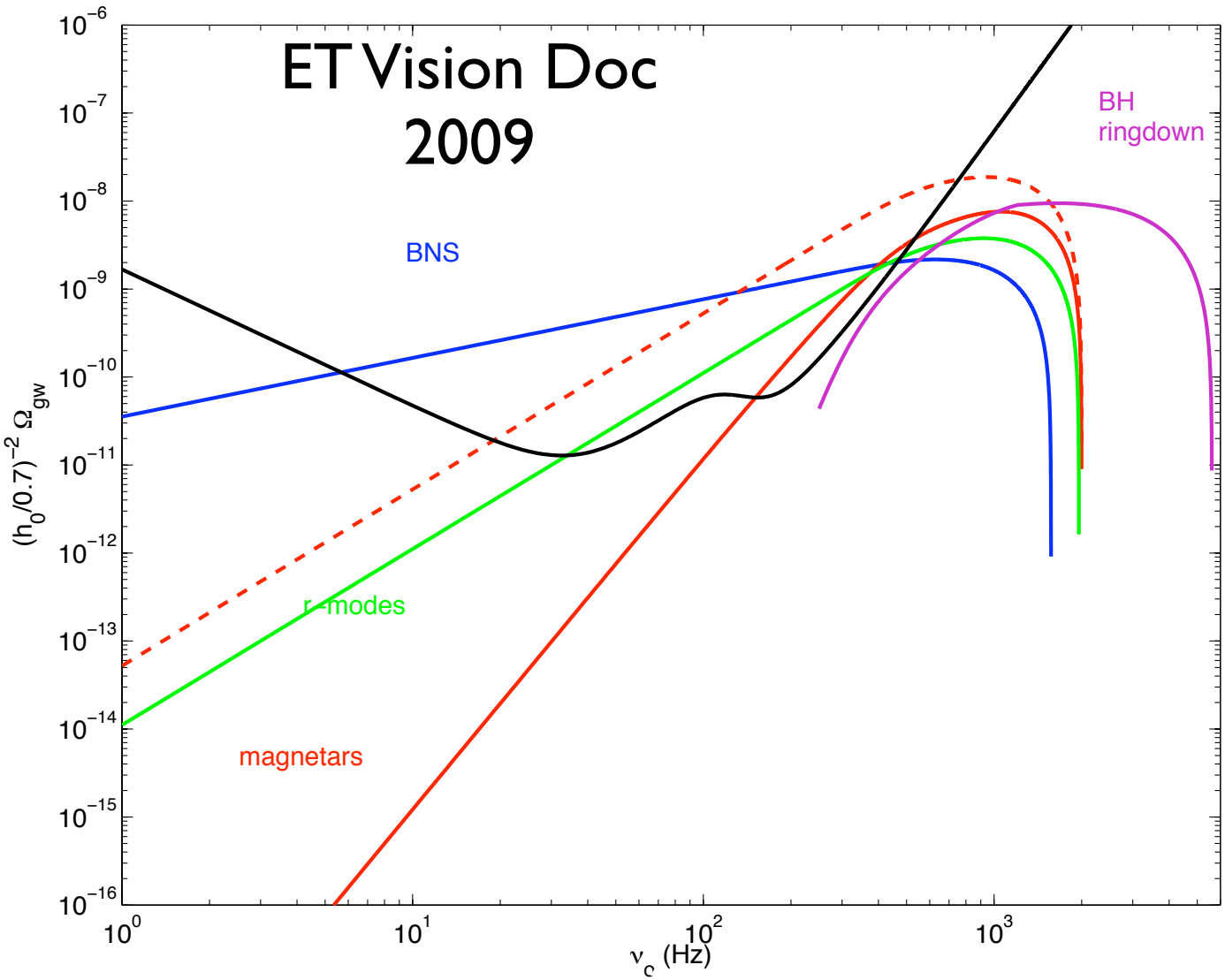
Why ET-MDC?

- ET will be a "signal-dominated" detector
  - Expected event rate from BNS mergers alone will be about one every 30 seconds; similar rate for BBH, NS-BH
  - Large (10^4) duty cycle (ratio of the duration of events in band to the interval between successive events)
  - Large number of overlapping sources
- What fraction of foreground sources can ET really discriminate?
- Identify computational and data analysis challenges
  - Inspiral signals could be in band for periods up to a day - data sets of order $N \sim 10^9$, millions of templates

Distance Reach of ET



Astrophysical Backgrounds



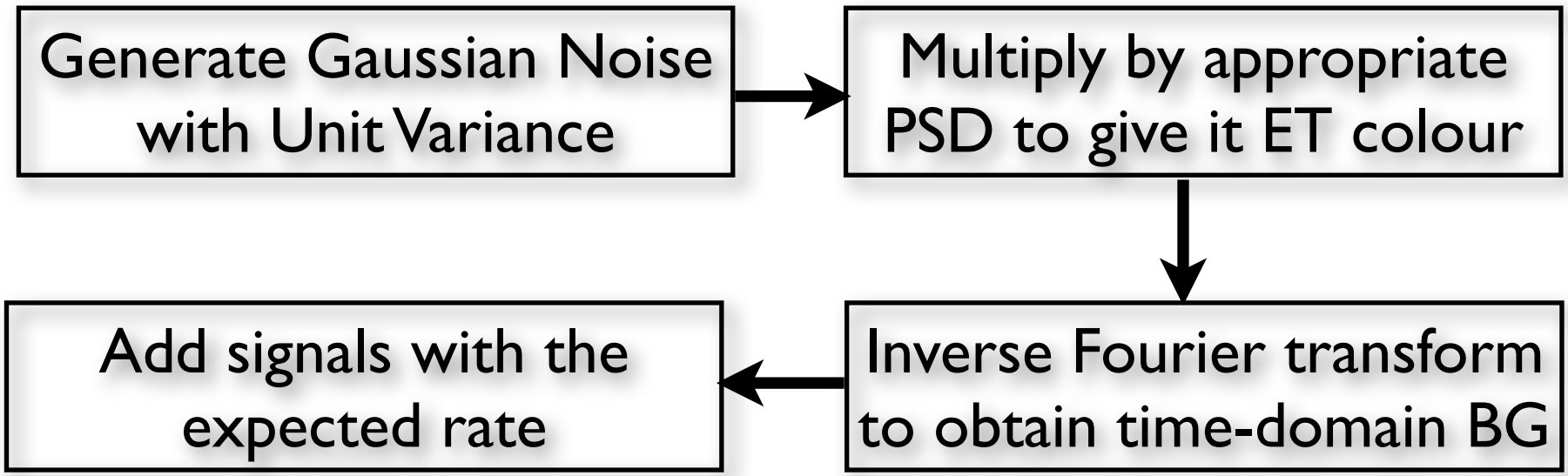
Transients in ET

- Supernovae
  - ET could detect SNe at 3-10 Mpc depending on the mechanism underlying the collapse and explosion
  - How easy is to detect SNe in ET in the presence of a confusion background?
- Magnetars
  - Occasional flares: rich in science impact
  - Normal modes of the core, crustal modes, could produce a b/g
- Neutron star mergers
  - Merger signal currently not well understood
  - A lot of physics: NS EoS, high spin frequencies, general relativistic magnetohydrodynamics

Where are we with Mock Data

- Signal-only data sets are currently available on coma2.astro.cf.ac.uk (Tania)
  - See Tania's talk for details on how these data sets were produced
  - Frame files, each 1000 seconds long,
  - Three data sets corresponding to the three ET detectors at the same site
- Time-domain Gaussian and stationary background (Sathya)
  - Can only add noise to about a day's worth of data
  - These data sets should soon be available

Simulating the Background



- An inefficient process as one cannot produce very large data sets maintaining continuity
- Analysis pipeline requires chunks that are typically 2048 s long

Analysis Codes

- IHOPE hacked to analyze ET data (Craig)
  - No automated graphs at the moment
- Can perform all the steps of the current LV analysis:
  - First stage inspiral, coincidence with three ET detectors, second state inspiral and Chi-square test, second stage inspiral
  - Likely to encounter very large number of coincidences
- Estimation of the background and PSD unreliable
  - The current pipeline for estimating the background is not reliable as it assumes a noise-dominated detector
    - Time-slides are not an accurate way of estimating background in a signal-dominated detector
  - PSD estimation has to be done better (how do LISA folks address this question?)

Where do we need help

- Production of signal+noise data sets that are a year, or at least a month, long in duration
  - New ideas needed
- Estimation of PSD
  - Can get away by using design sensitivity curve
  - Would be good to have an algorithm that can compute PSD from the data
- Estimation of the background
  - A real challenge: How does one compute accidentals and assign significance to events?

Other Signal Types

- The full parameter space of compact binary coalescences
- Occasional transients from SNe, neutron star normal modes
- Continuous waves
- Stochastic background
- Should form a concrete plan on how to go about the MDC
  - Three MDCs over the next 18 months
  - First MDC: Only BNS plus Gaussian noise, one day's worth of data
    - Data Release in January 2010, Results by April 2010
  - Second MDC should contain a month's worth of data from the full CBC parameter space
    - Data Release in June 2010, Results by October 2010
  - Third MDC should contain a month's worth of data plus transients
    - Data release in November 2010, results by April 2011

ET Trade Studies

B.S. Sathyaprakash

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

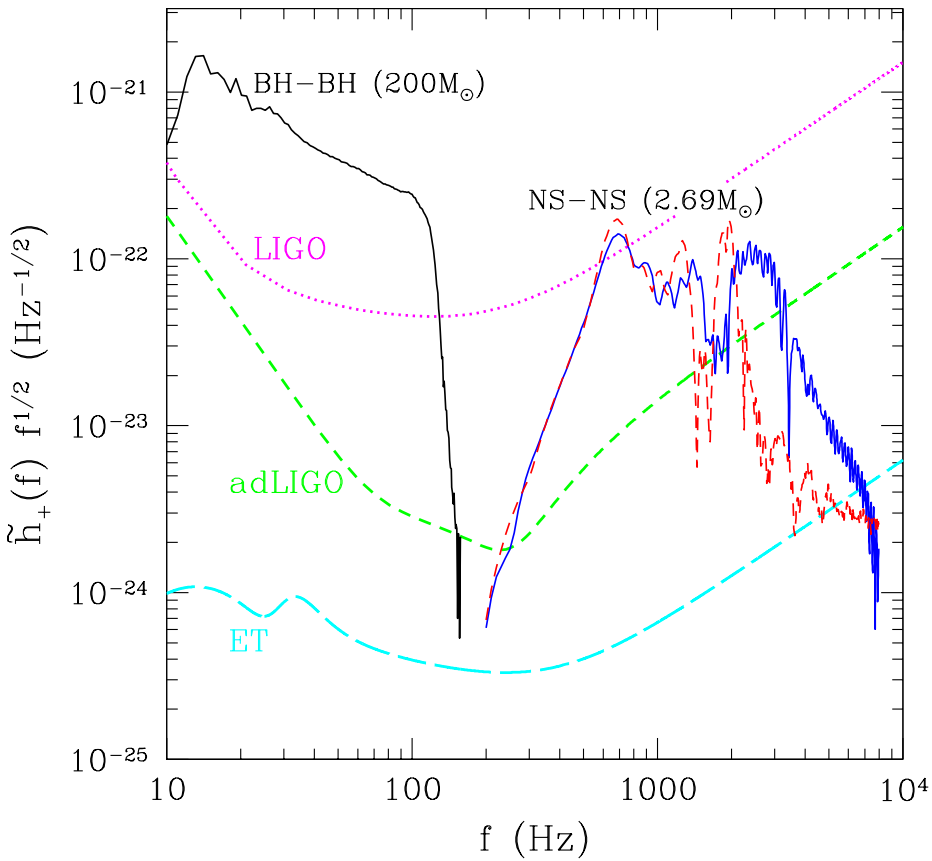
Vision Document

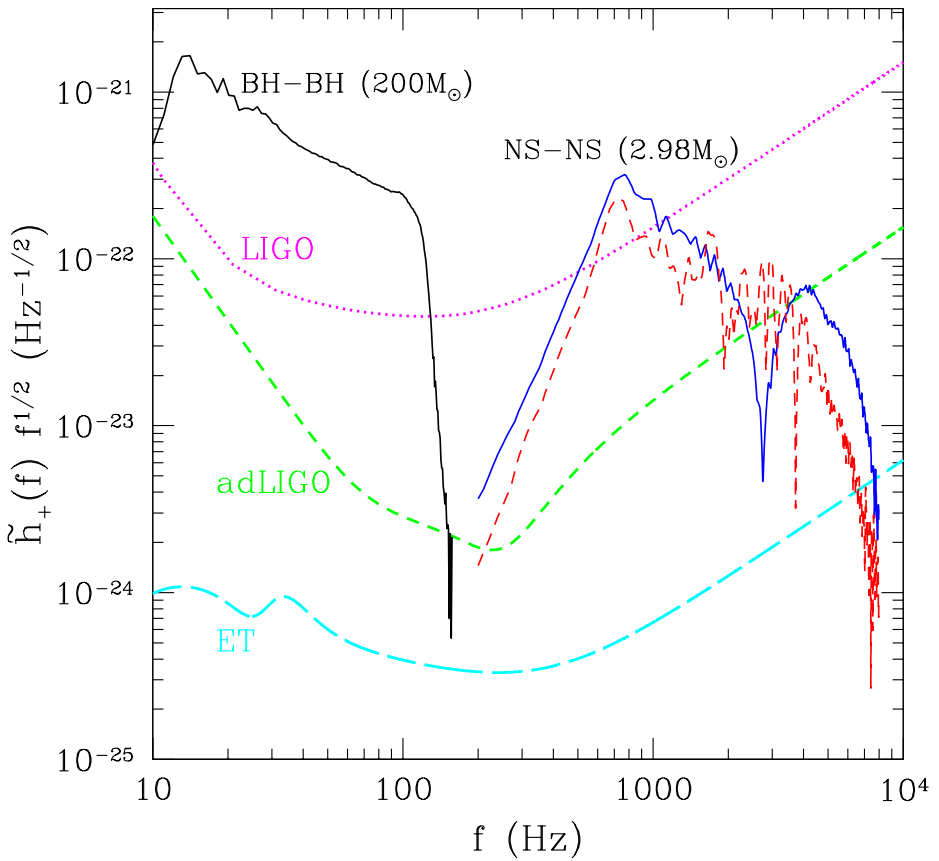
- Some 74 pages long
  - Executive summary (1 page)
  - Science Requirements (3 pages)
  - Sources (20 pages)
- Four science Sections
  - Fundamental Physics (9 pages)
  - Astrophysics (15 pages)
  - Cosmology (6 pages)
  - Data Analysis and Computational Challenges (6 pages)
- An Appendix on ET sensitivity curve (5 pages)
- More than 200 references (7 pages)

Summary of ET Science

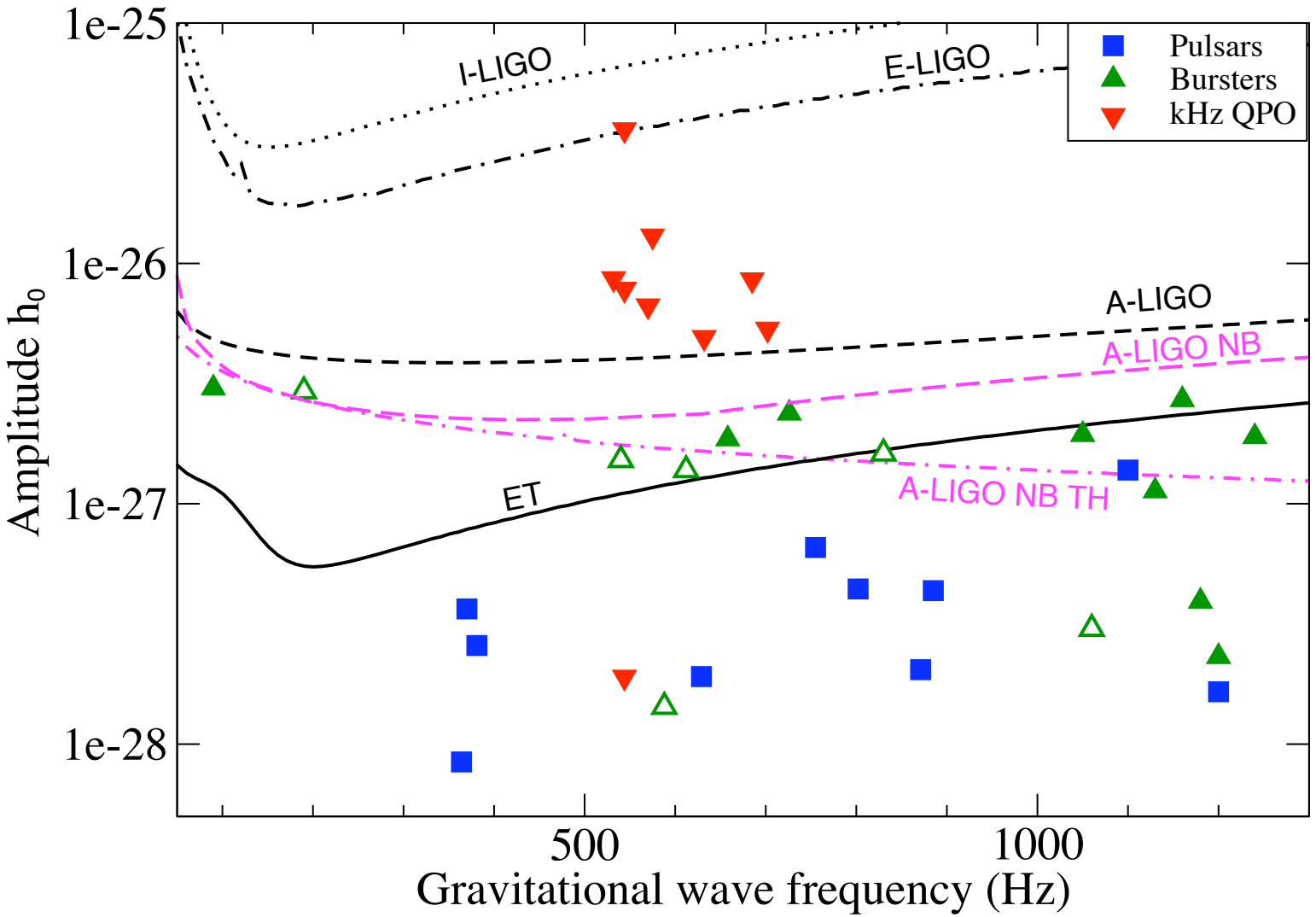
- Fundamental physics
  - Wave generation formula beyond the quadrupole approx.
  - Polarization states of GW,
  - Upper limits on graviton and neutrino masses
  - EoS of super-dense nuclear matter and of dark energy
  - Black hole no-hair theorem, naked singularities,
  - Signature of string theory
- Astrophysics
  - GRB progenitors, mass function of NS, history of star formation rate, NS normal modes (glitching pulsars, flaring magnetars), NS equation-of-state from mergers
- Cosmology
  - Cosmological parameters, seed black holes, intermediate-mass black holes,

Double Neutron Star Mergers

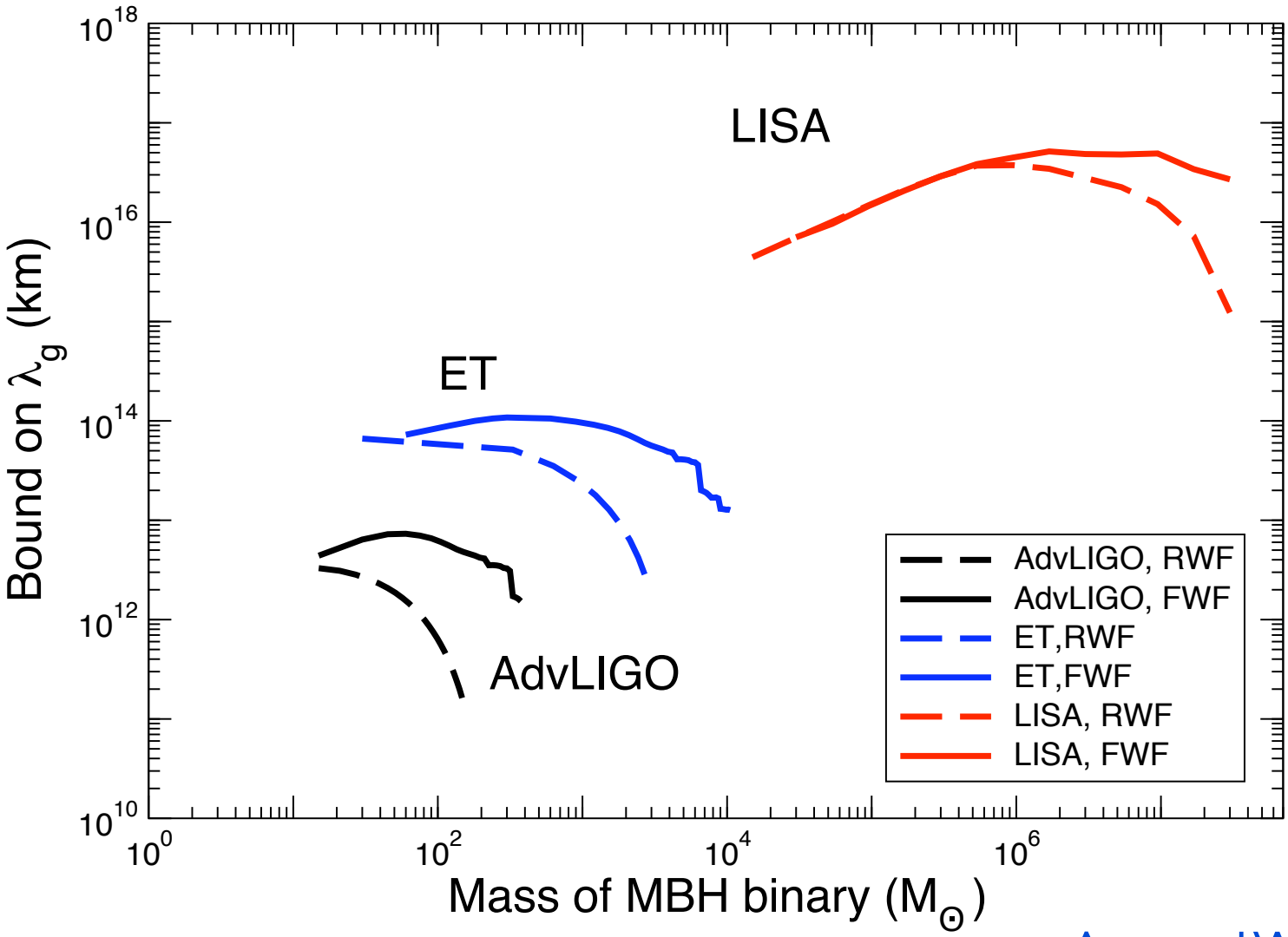




Accreting Neutron Stars



Bounds on Graviton Mass



Arun and Will (2009)

WG4 tasks

Future of the Vision Document

- Many interesting problems in fundamental physics, astrophysics and cosmology
  - However, we need more quantitative evaluation of the science ET can do
- The document lacks clarity on prioritization of science and what theoretical progress is necessary to take advantage of ET
- Should probably aim at producing a glossy, shorter version that could be used for outreach and lobbying?
  - Exploring the Extremes of Physics with ET

Open but easy problems

- A systematic and well-document study of the angular resolution of ET for BNS, BBH, NSBH
- A systematic study of the error in luminosity distance with red-shift
- The number of galaxies within the error box of ET on the sky
- Trade studies with different ET designs
  - A single site triangle versus multiple site L-shaped detectors
- Can ET operate usefully in coincidence with advanced detectors? What about BBO/DECIGO?

Science with BBH mergers

- ET should be able to see thousands of BBH mergers at z~1 with an SNR of 100 or more
- Within z~5-8, ET should detect millions of these sources
- Challenges:
  - Can we disentangle these sources from everything else
  - Not looked at the science potential of such a large number of events
- Obvious things to do
  - Mass function of black hole binaries, star formation rate, strong field tests of GR
  - How well can we determine cosmological parameters statistically?

Multi-messengers and ET

- What optical, radio, x-ray, gamma-ray, neutrino telescopes/detectors will be operating on the 2025 time scale that are capable of good sky-coverage
- If we want to follow-up ET BNS/BBH coalescences what sort of optical telescopes would we need, how many of them to cover the entire globe, etc.
  - Create a database of "small" (3 m class) telescopes around the world
  - Record all the necessary information about every potential telescope that could be useful for us

Large scale structure

- From a large sample of measurements of the Hubble parameter it should be possible to deduce large-scale anisotropy
  - Dipole anisotropy can be measured to an accuracy of fraction of a percent
  - Residuals can be used to test anisotropic Bianchi Type I models

Sensitivity to Stochastic Background

- Can ET's sensitivity to SBG improved beyond the standard cross-correlation-based values
- Can one construct "noise-only" channels from ET's three detectors?
- How well can we subtract the noise to improve sensitivity to SBG?
- What lessons have been learned from H1-H2 common noise?

Trade Studies

- Possible Sensitivity Curves
  - Cost (a very rough estimate based on UG/Cryogenics/ Multiple Lasers/Subtraction of GG, etc.)
    - Low, Medium, High
  - Technological Readiness Level (TRL)
    - Low, Medium High
- The goal of these markers is not that we have use it outside the project but to give us an indication of how worth is it doing from the point of view of Science
- It also sets the stage for future work

Trade Studies

- Figure of Merit for each source type and science case
  - Distance reach as a function of total mass for CBC
  - Upper limit on SNe burst energy at 3 Mpc
  - Upper limit on NS glitch energy at 10 kpc
  - Upper limit on NS ellipticity at 3 kpc (10% of all galactic NS)
- Above FOMs might turn out to be inadequate if confusion background is too strong
- MDC - a valuable tool for a realistic assessment of ET science
  - E.g., how accurately can one measure the dark energy EoS with the observation of BNS in coincidence with GRBs?

Science FOMs: Difficult

- What is our current theoretical knowledge and what needs to be done on the time-scale of ET?
- How easy is to extract and measure the required parameters in "real" data?
  - Could we use test LV data sets artificially scaled in sensitivity and bandwidth for use in ET MDC?
- Limitations imposed by data analysis algorithms and computational resources

Trade Study Table - Source

Sensitivity curve	BNS	BBH	NS-BH	SNe	NS glitches	CW	Stochastic background
ET-A Cost, TRL							
ET-B Cost, TRL							
ET-C Cost, TRL							
ET-D Cost, TRL							

Trade Study Table - Science

Sensitivity curve	DE EOS	NS EOS	GRB progenitors	SNe models	BNS mergers	Strong field tests of gravity	Cosmology H, W, w
ET-A Cost, TRL							
ET-B Cost, TRL							
ET-C Cost, TRL							
ET-D Cost, TRL							