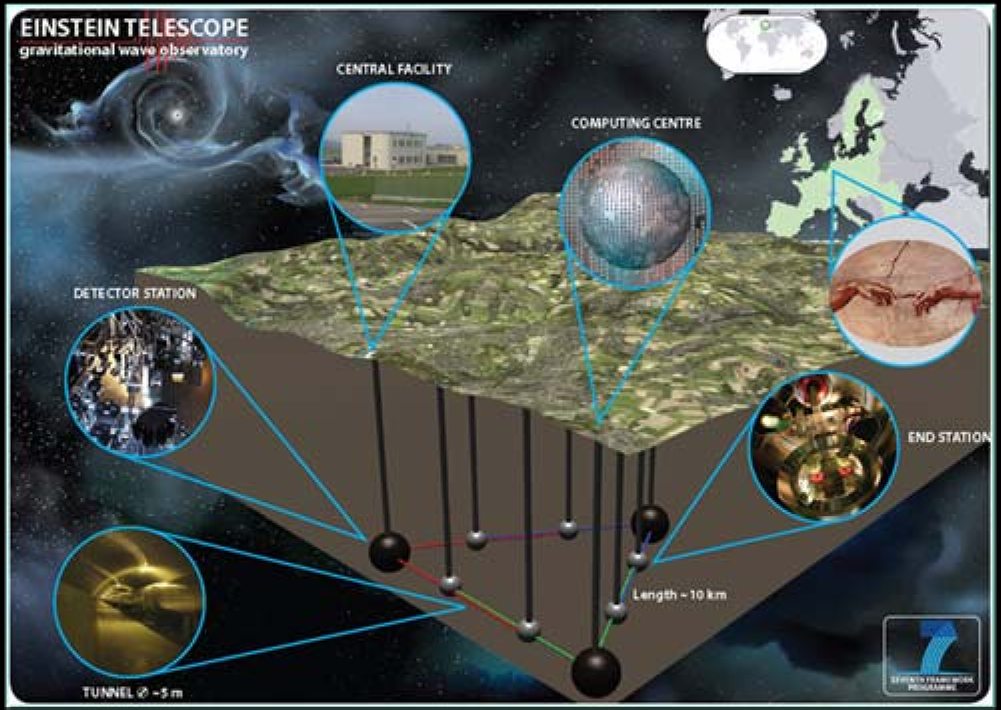
# Status of the Einstein Telescope Design Study




B.S. Sathyaprakash
Cardiff University


# What is the ET Project

- ET is a conceptual design study supported, for about 3 years (2008-2011), by the European Commission under the Framework Programme 7 (PF7)
  - EU financial support ~ 3M€
  - Aim of the project is the delivery of a conceptual design of a 3rd generation GW observatory
    - Sensitivity of the apparatus~10 better than advanced detectors

SEVENTH FRAMEWORK PROGRAMME

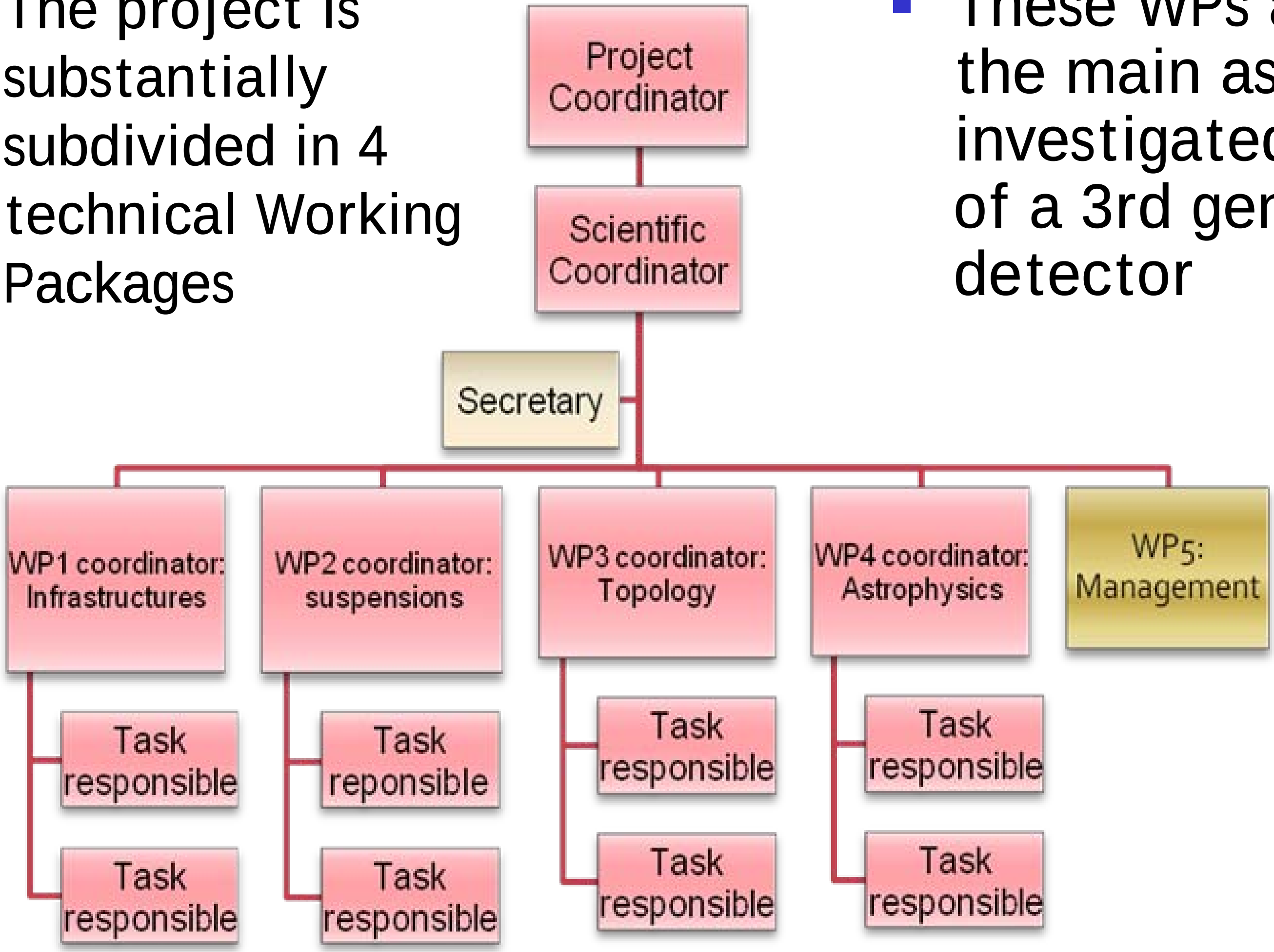

# Participants

- The proposal was presented by the major groups working in GEO600 and Virgo
- Project coordinator:
  - EGO
- Open participation via the ET Science Team

| EGO | |
|---|---|
| INFN | |
| MPG | |
| CNRS | |
| Birmingham Univ. | |
| Glasgow Univ. | |
| NIKHEF | |
| Cardiff University | |


# Project Organization

- The project is substantially subdivided in 4 technical Working Packages




- These WPs are related to the main aspects to be investigated in the design of a 3rd generation detector


# ET Working Packages

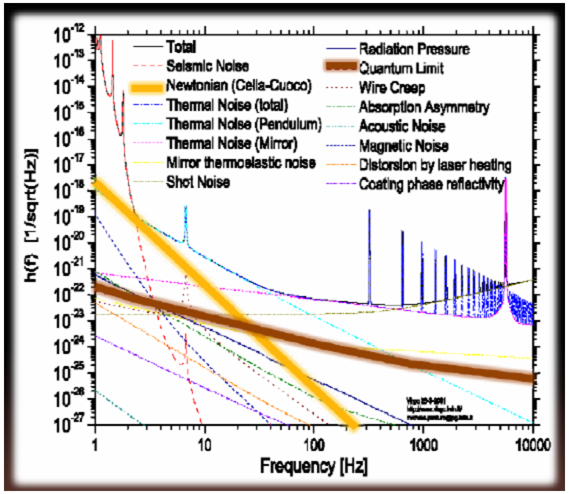
- WP1: Infrastructures - Coordinator: Jo van den Brand
  - Definition of the site requirements.
    - Low seismic activity, reduction of the Newtonian noise
    - Multi-km (~10km) arms possibilities. Costs
- WP2: Suspensions and test masses – (Fulvio Ricci)
    - 1 Hz seismic filtering, reduction of the thermal noise through cryogenics and new materials; mechanical and optical properties of new materials for the test masses
- WP3: Topology – (Andreas Freise)
  - Design of the geometry and configuration of the core ITF.
    - HP lasers, alternative ITF geometries, quantum noise reduction
- WP4: Astrophysics issues – (B.S. Sathyaprakash)
  - The goal of WP4 is to address ET science and data analysis.
    - ET potentialities, Science Case, computational costs

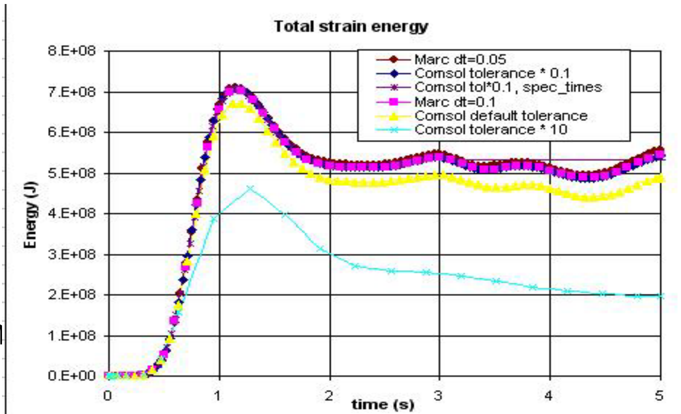
# Face to Face meetings

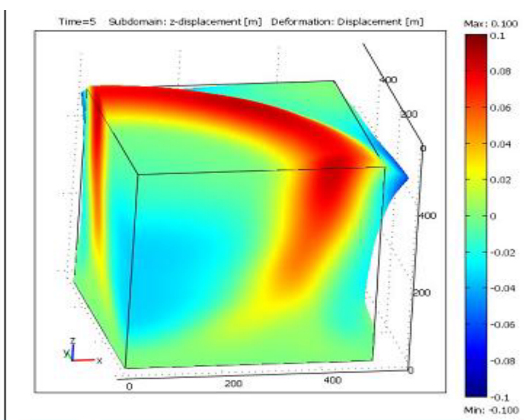
- Collaboration meeting
  - Official opening, May 2008, ELBA
  - Joint ILIAS and ET meeting, Nov 2008
- Working group meetings
  - WP1 – Feb 2009
  - WP2 – Jan 2009
  - WP3 – Feb 2009
  - WP4 – Sept 2008, Mar 2009
- Weekly telecons of the Executive Board through 2008

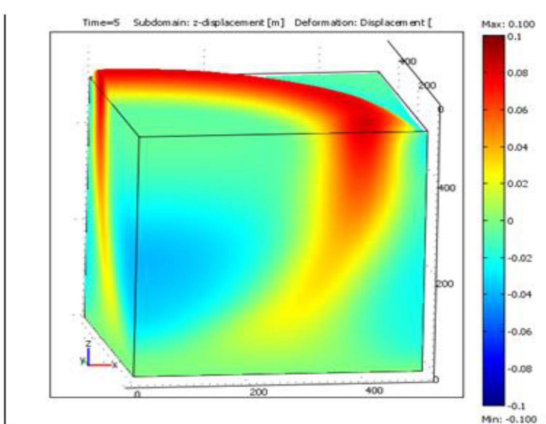
# ET WP1 – Seismic studies and simulations

- Site issues: gravity gradient noise studies
- Determine sensitivity at low frequency
  - Depth
  - Cavity size and shape
- Analytical studies –Cella, Cuoco (Pisa)
  - Depth
  - Cavity size and shape
- FEA studies –Hennes, Rabeling, Beker, van den Brand (Nikhef)
  - Realistic geology
- Subtraction procedure



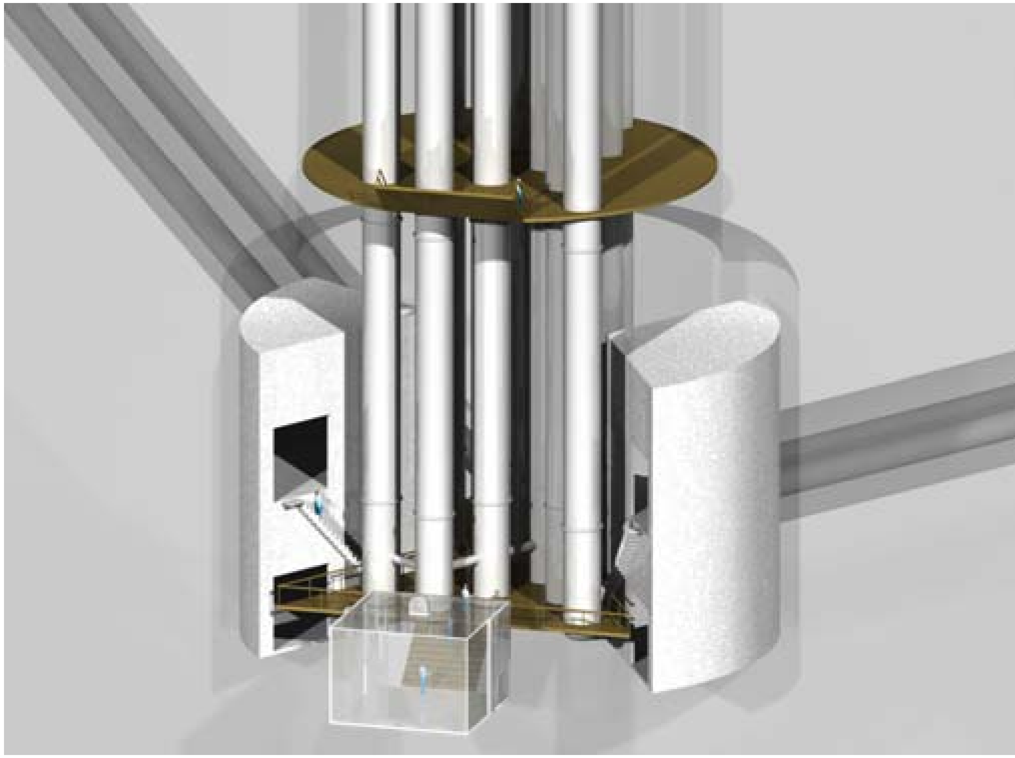



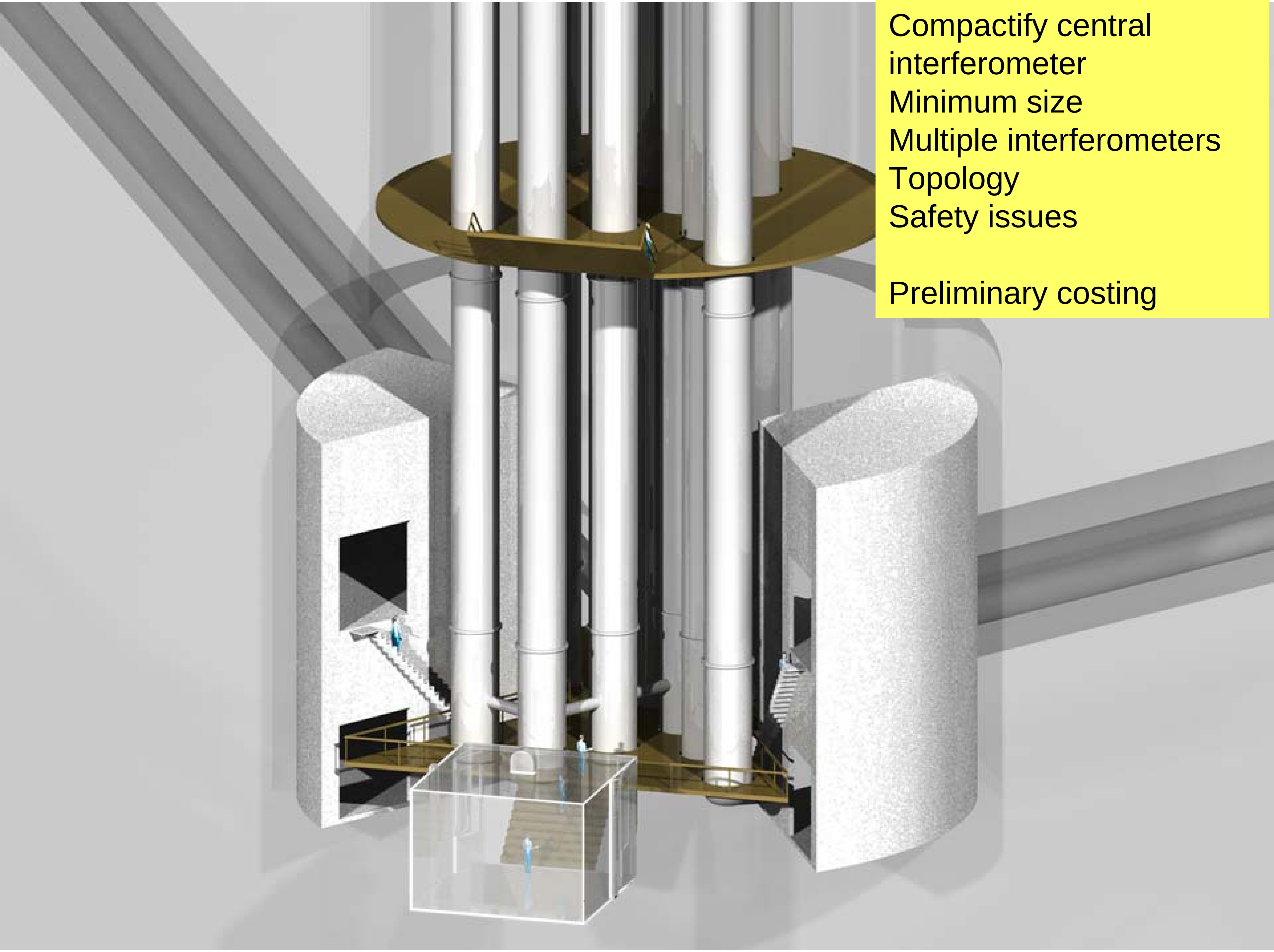
# ET WP1 – Infrastructure

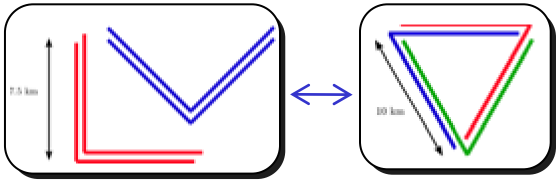
- Infrastructure
  - Tunnels, caverns, buildings
  - Vacuum, cryogenics, safety systems
  - Computing, etc.
- Big cost items
  - Collaborate with industry
    - COB
    - Saes Getters Italy
    - Demaco Netherlands
- Input from WG2 & 3
  - Topology
  - Length of superattenuators
- Experience
  - Virgo, GEO, Gran Sasso, LIGO, etc.



- Compactify central interferometer
- Minimum size
- Multiple interferometers
- Topology
- Safety issues

- Preliminary costing

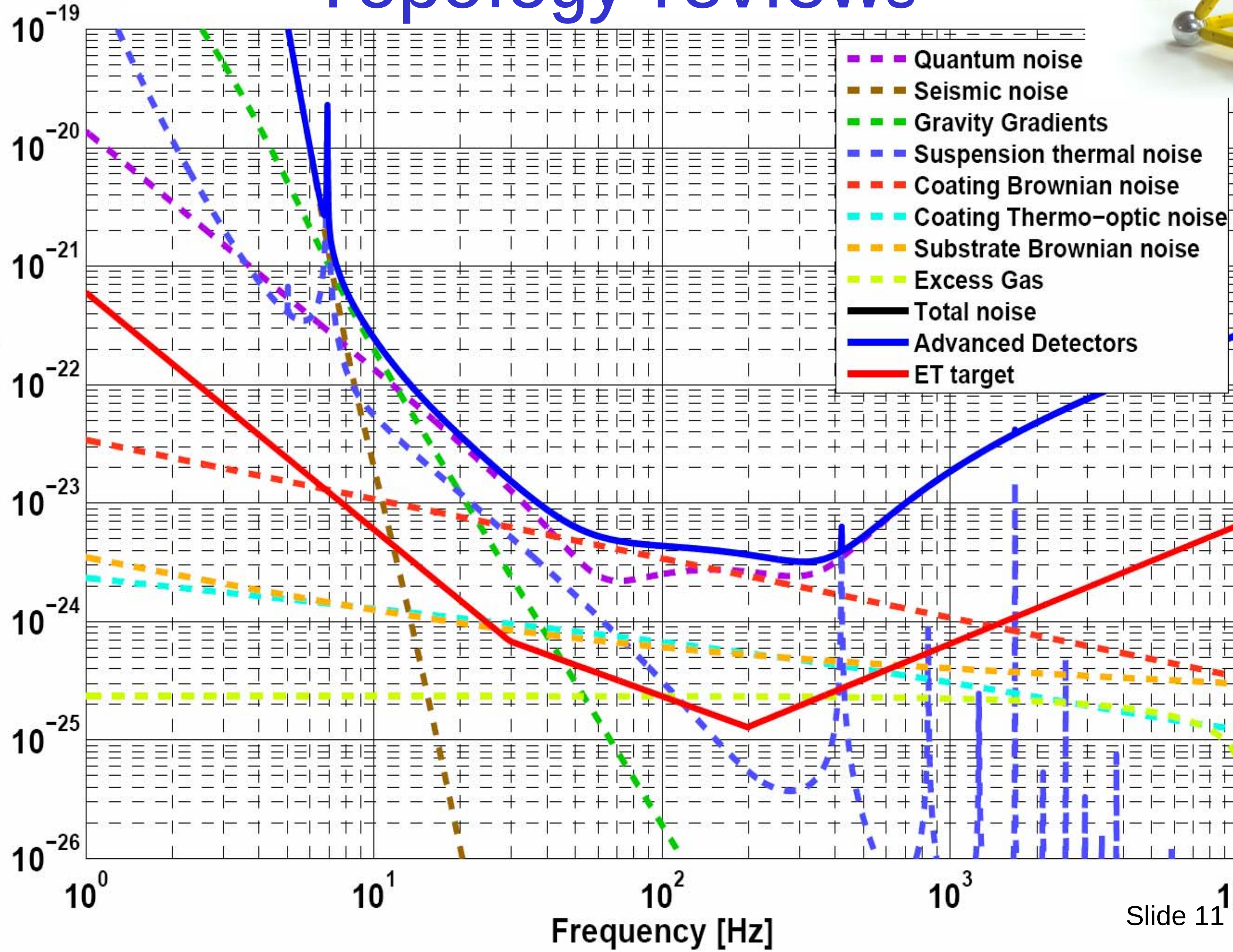




# ET WP3 Topology

- Basic Question: *For a given infrastructure cost what is the best optical layout?*
  - Geometry? Triangle, L shape,multiple sites, other ?
  - Multiple frequency bands per site?
    - High Frequency + Low frequency ITFs, tunable ITF?
  - Orientation?
  - How to incorporate the Advanced detectors to build a network?
    - Location/orientation with respect to the existing site (LIGO/Virgo)
    - To which extend could we rely on AdV+ a& AdL+ for source location?
    - What if there is or there is not an LCGT/Australian detector?
  - What is the impact of an US ET?
  - Phasing of the construction/commissioning of the ITFs?

# Topology reviews

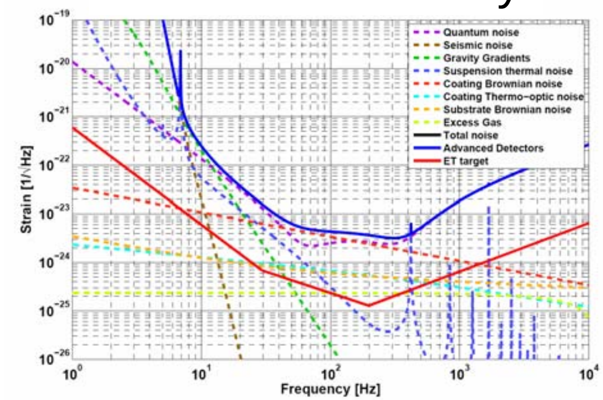



Hild et al., (2008) arXiv:0810.0604v2

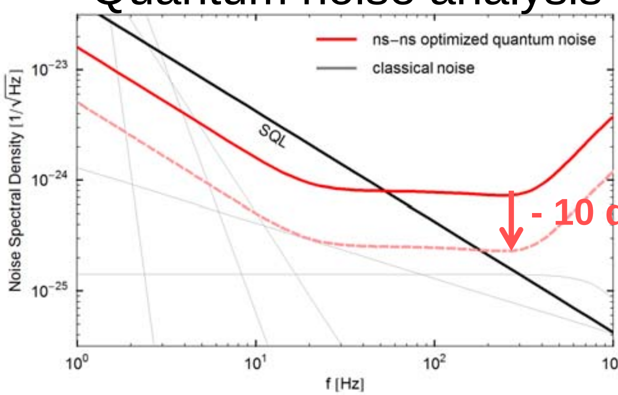
# Topology reviews

Hild et al., (2008) arXiv:0810.0604v2

Classical noise analysis




Quantum noise analysis



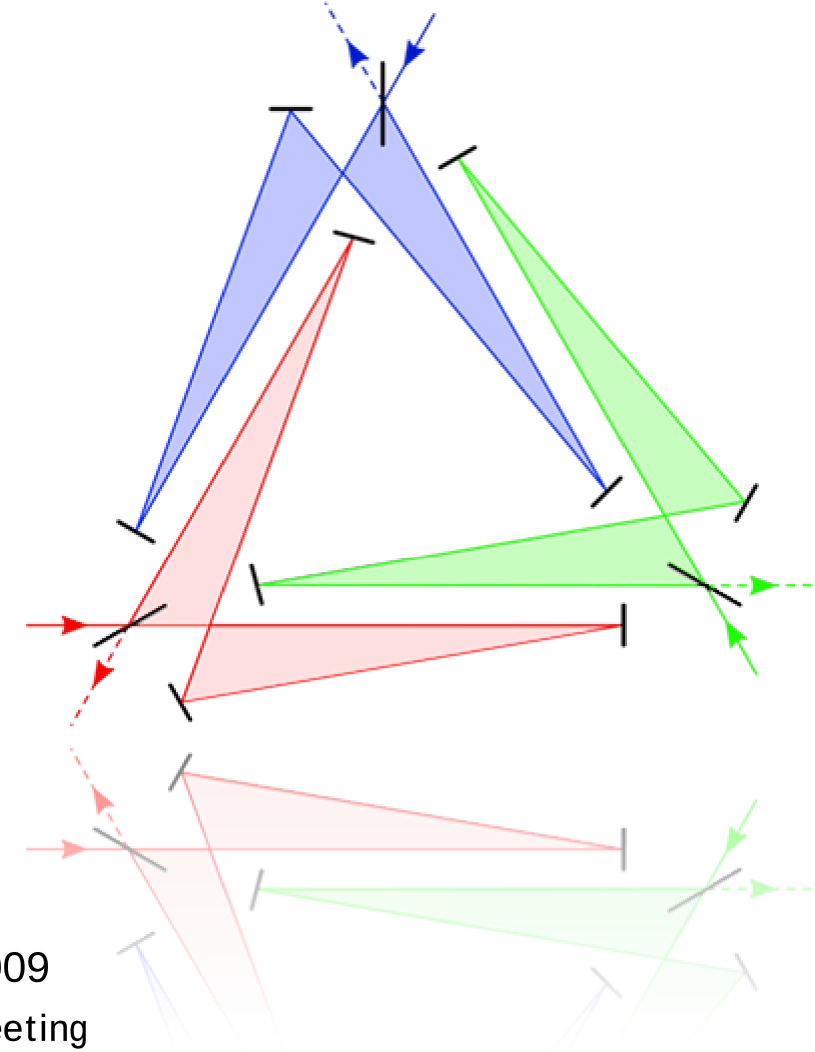

1800 Mpc

4000 Mpc

- 10 dB

H. Müller Ebhardt, WP3 ET Meeting March 2009

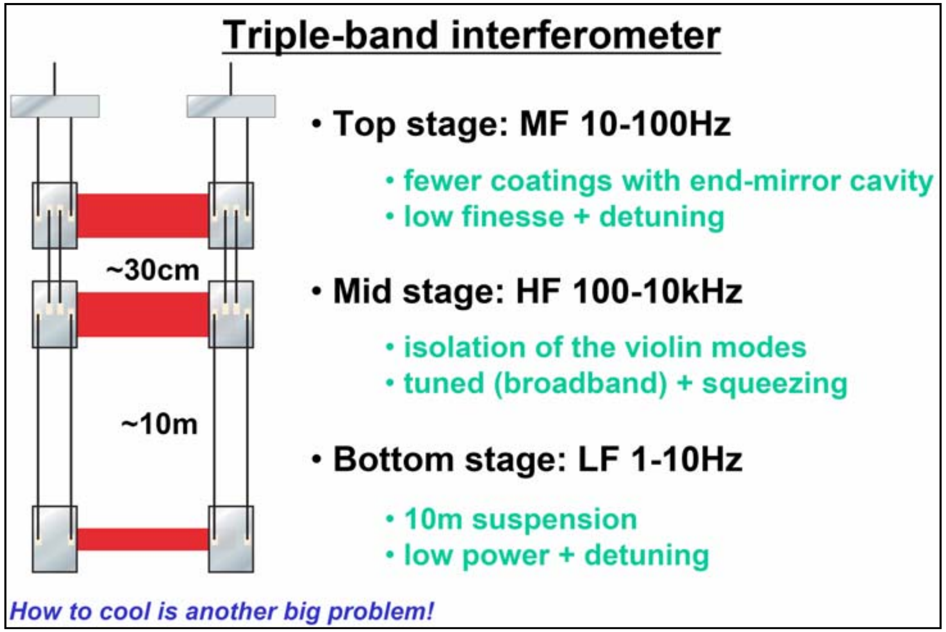
Sagnac Topology



S. Chelkowski WP3 ET Meeting March 2009

# Review of new ideas and new problems

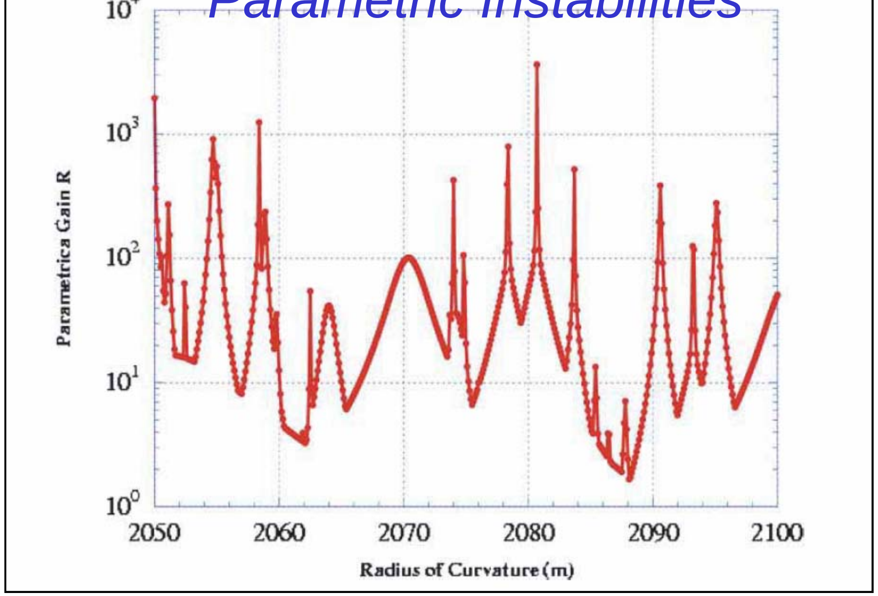
## New ideas




K. Somiya, WP3 ET Meeting March 2009

## New problems

*Parametric Instabilities*




L. Ju et al., Physics Letters A **354** (2006) 360

# ET WP4: Science Potential

Regimbau and Hughes, 2009

# Local Coalescence Rate

| authors | NS-NS ($Myr^{-1}$) | NS-BH ($Myr^{-1}$) |
|---|---|---|
| **statistics:** | | |
| Kalogera et al. (2004) | 83 (17-292) | |
| **pop. synthesis:** | | |
| Tutunov & Yungelson (1993) | 300 | 20 |
| Lipunov et al. (1997) | 30 | 2 |
| Potergies Zwart & Yungelson (1998) | 20 | 1 |
| Nelemans et al. (2001) | 20 | 4 |
| Voss & Tauris (2003) | 2 | 0.6 |
| O'Shaughnessy et al. (2005) | 7 | 1 |
| de Freitas Pacheco et al. (2006) | 17 | |
| Belczinsky et al. (2007) | 10-15 | 0.1 |
| O'Shaughnessy et al. (2008) | 30 | 3 |

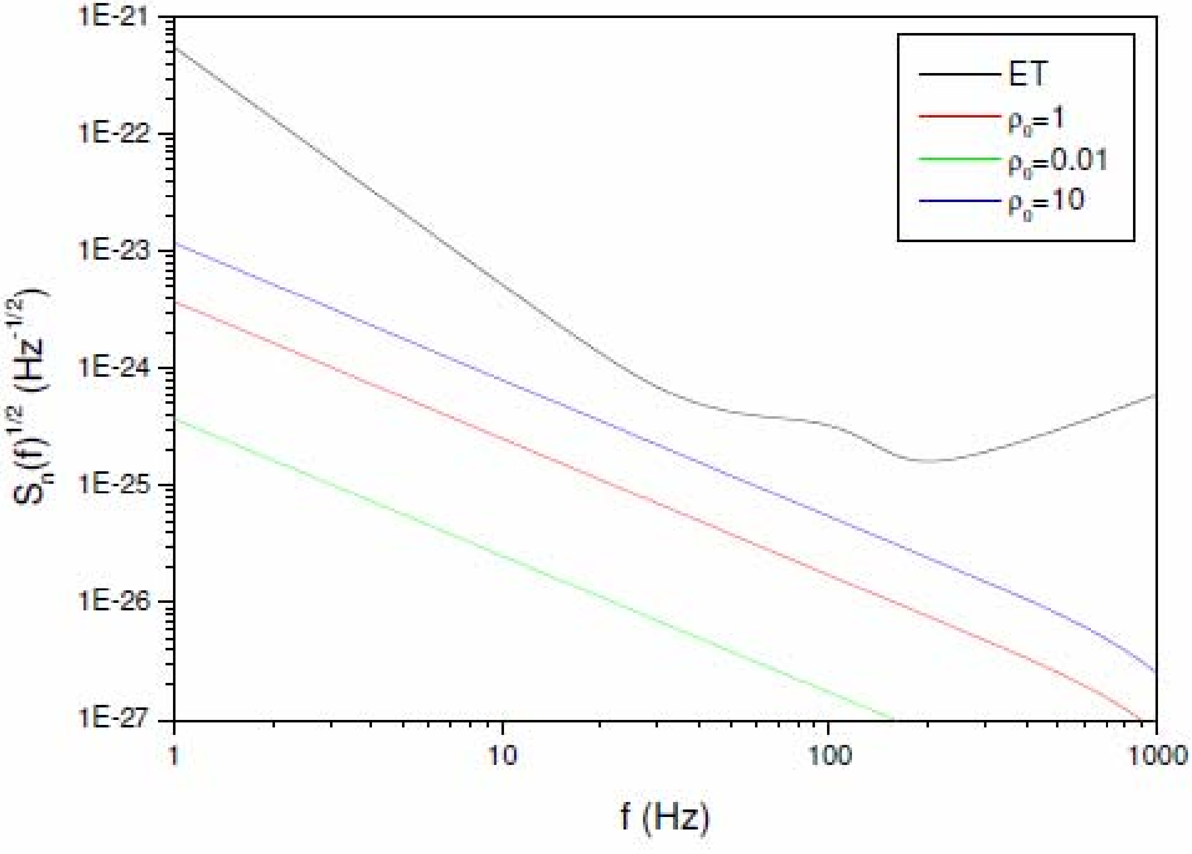
NS-NS: $\dot{\rho}_0 = 0.01 - 10\ \mathrm{Myr}^{-1}\mathrm{Mpc}^{-3}$, reference: 0.4 (pop synthesis) and 1 (statistics)

NS-BH: $\dot{\rho}_0 = 0.001 - 1\ \mathrm{Myr}^{-1}\mathrm{Mpc}^{-3}$, reference: 0.04

Regimbau and Hughes, 2009

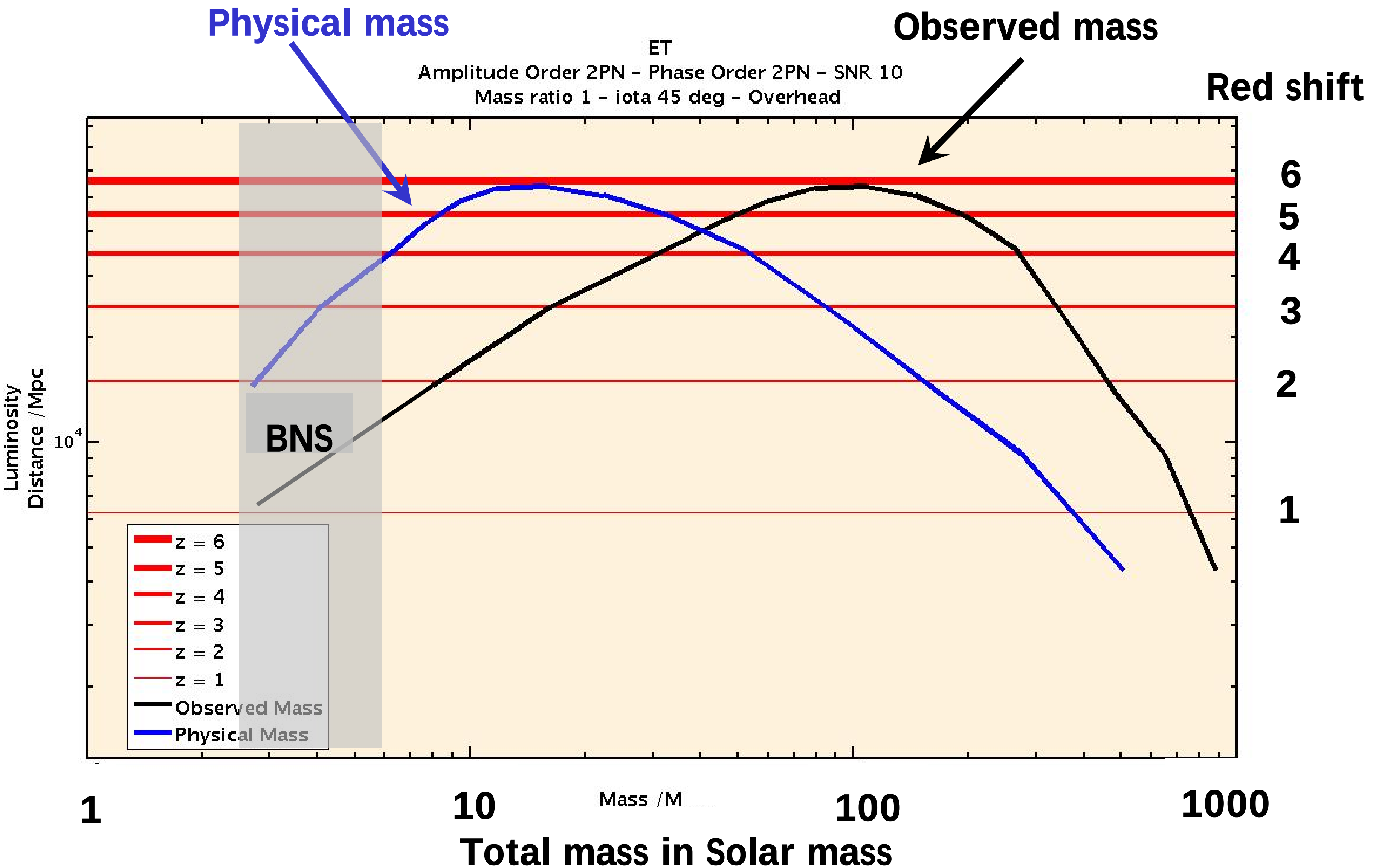
# Confusion Background NS-NS

no PN corrections, first harmonic in eccentricity



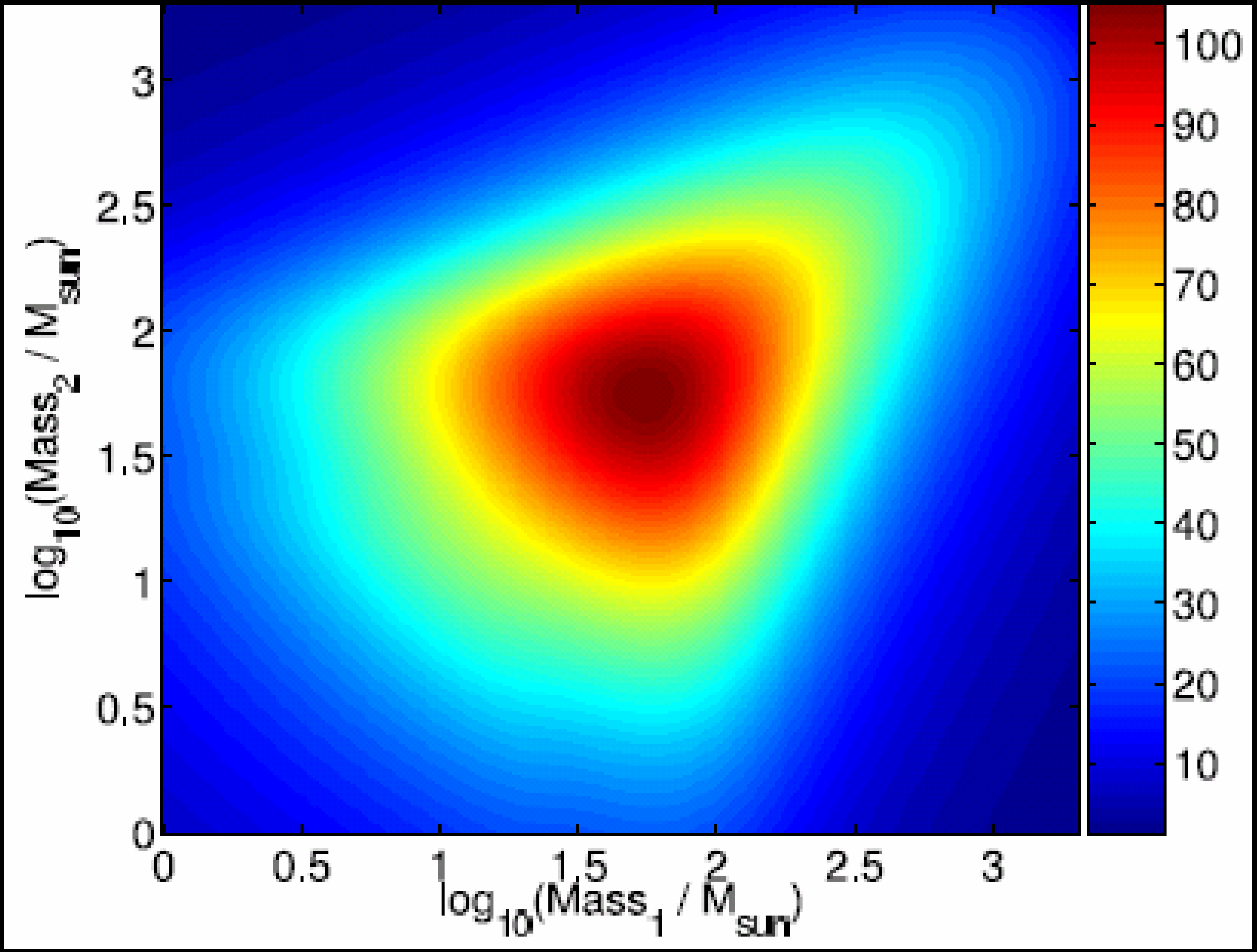
# Red shift makes a difference

Mckechan et al, 2009



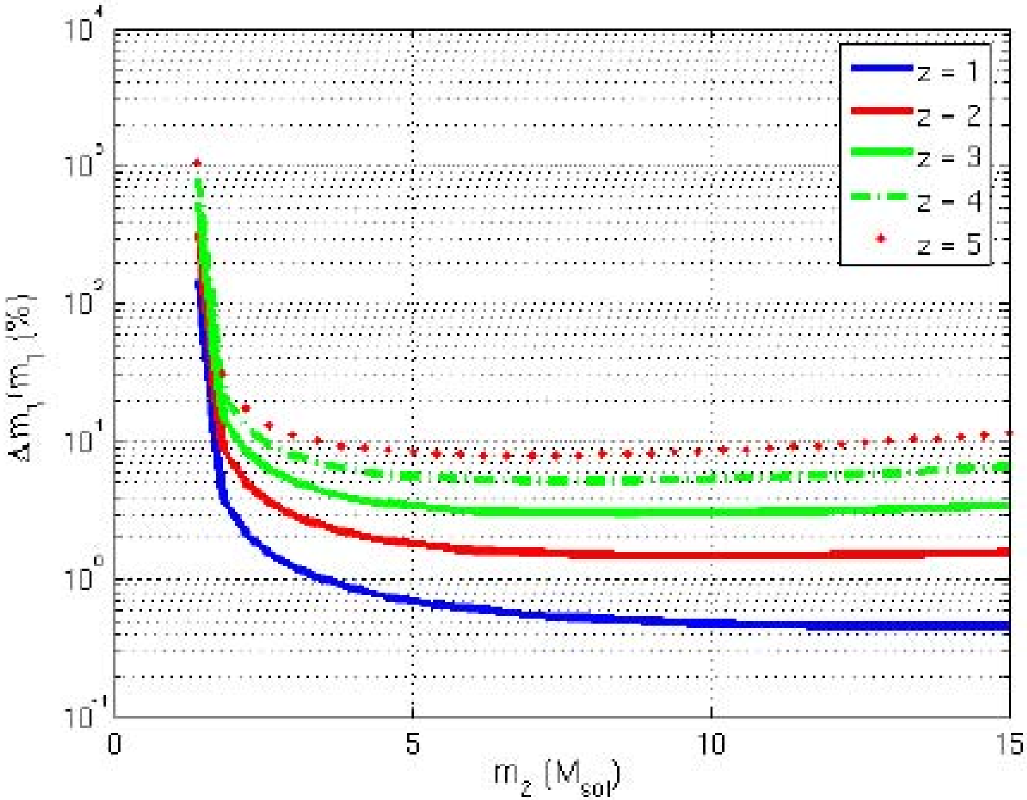
Bose et al 2009

# SNR for sources at z=0.5



# What is the mass range of neutron stars?

- Let one object in a binary be a neutron star; how well can we measure its mass as a function of the other object's mass?
- Mass measurement better than a percent out to z ~ 1
- Secondary object needs to be a black hole
- Asymmetric binaries: Can map the mass distribution out to redshift of several

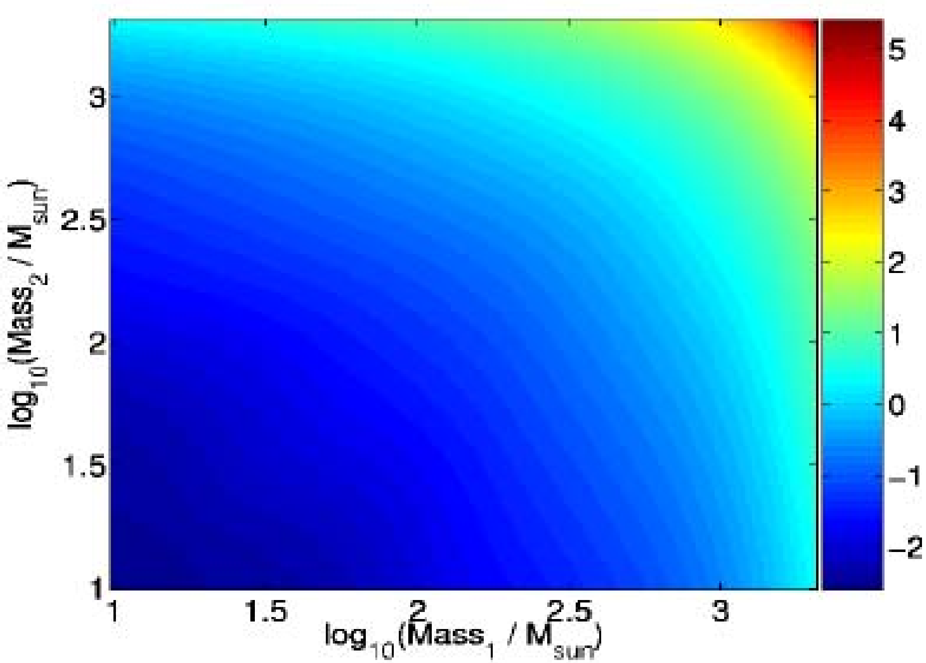



**Bose et al 2009**

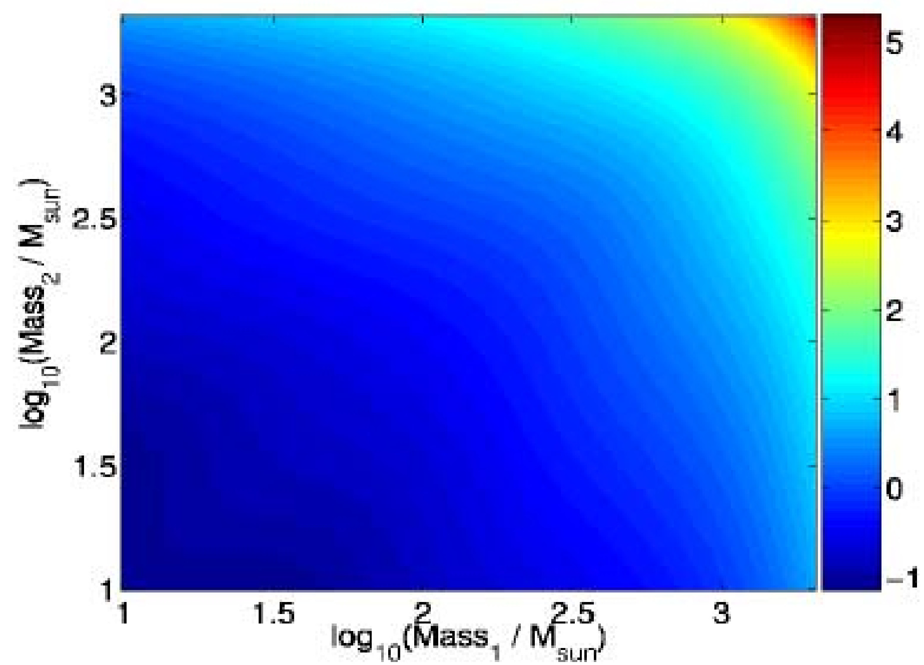
# Weighing black holes over cosmological distances

- Estimation of mass parameters at a distance of 3 Gpc

$\log_{10}$ of percentage error in chirp mass



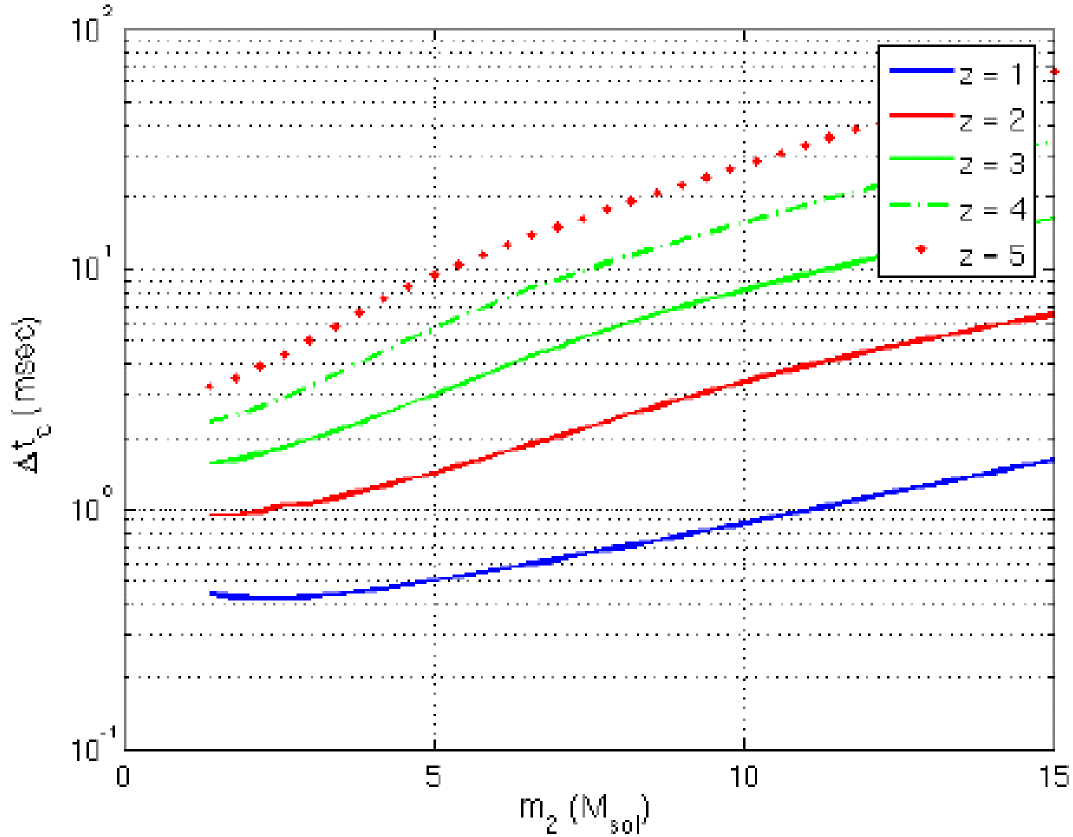

$\log_{10}$ of percentage error in $\eta$




**Bose et al 2009**

# What is the mechanism behind GRBs?

- Some short, hard GRBs could be caused by the inspiral of two neutron stars, or a neutron star and a black hole
- Beamed gamma ray emission perpendicular to the inspiral plane
- Constrain such models by:
  - Measuring the promptness of gravitational radiation compared to the gamma radiation
  - Constraining the opening angles of the beams by measuring inclination angle?




Bose et al 2009

CARDIFF UNIVERSITY

# How well can we measure cosmological parameters?

- Luminosity distance Vs. red shift has cosmological parameters $H_0$, $\Omega_M$, $\Omega_b$, $\Omega_\Lambda$, $w$, etc.

$$D_L = \frac{c(1+z)}{H_0} \int \frac{dz}{[\Omega_M (1+z)^3 + \Omega_\Lambda (1+z)^{3(1+w)}]^{1/2}}$$

- Einstein Telescope will detect 1000's of compact binary mergers for which the source can be identified (e.g. GRB) and red-shift measured.
- A fit to such observations can determine the cosmological parameters to better than a few percent.

# Exploring seeds of galaxy formation

# Computing Merger Rates

- Construct semi-analytic merger trees by following mergers of dark matter halos (e.g., Volonteri, Haardt & Madau 2003).

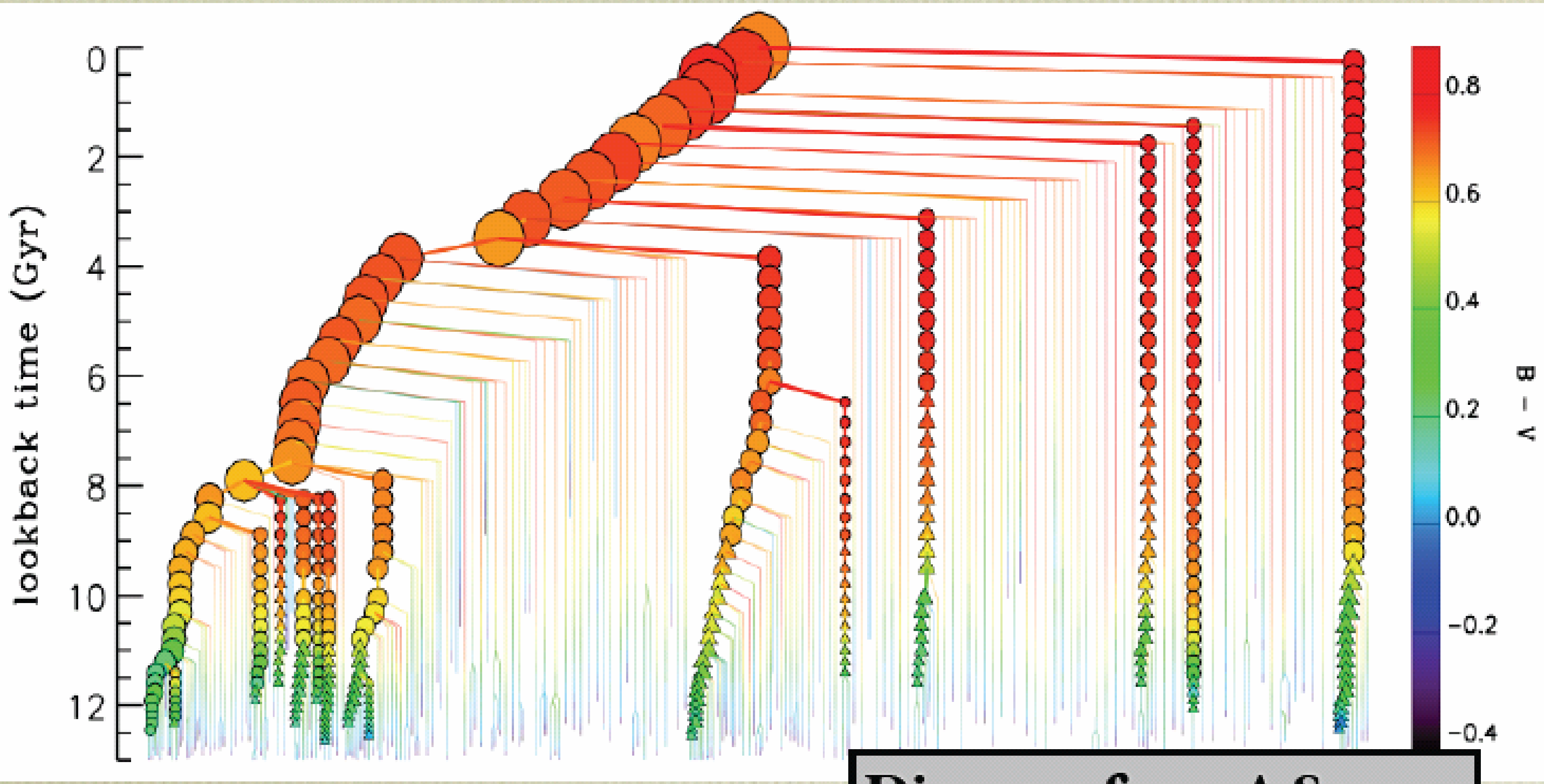
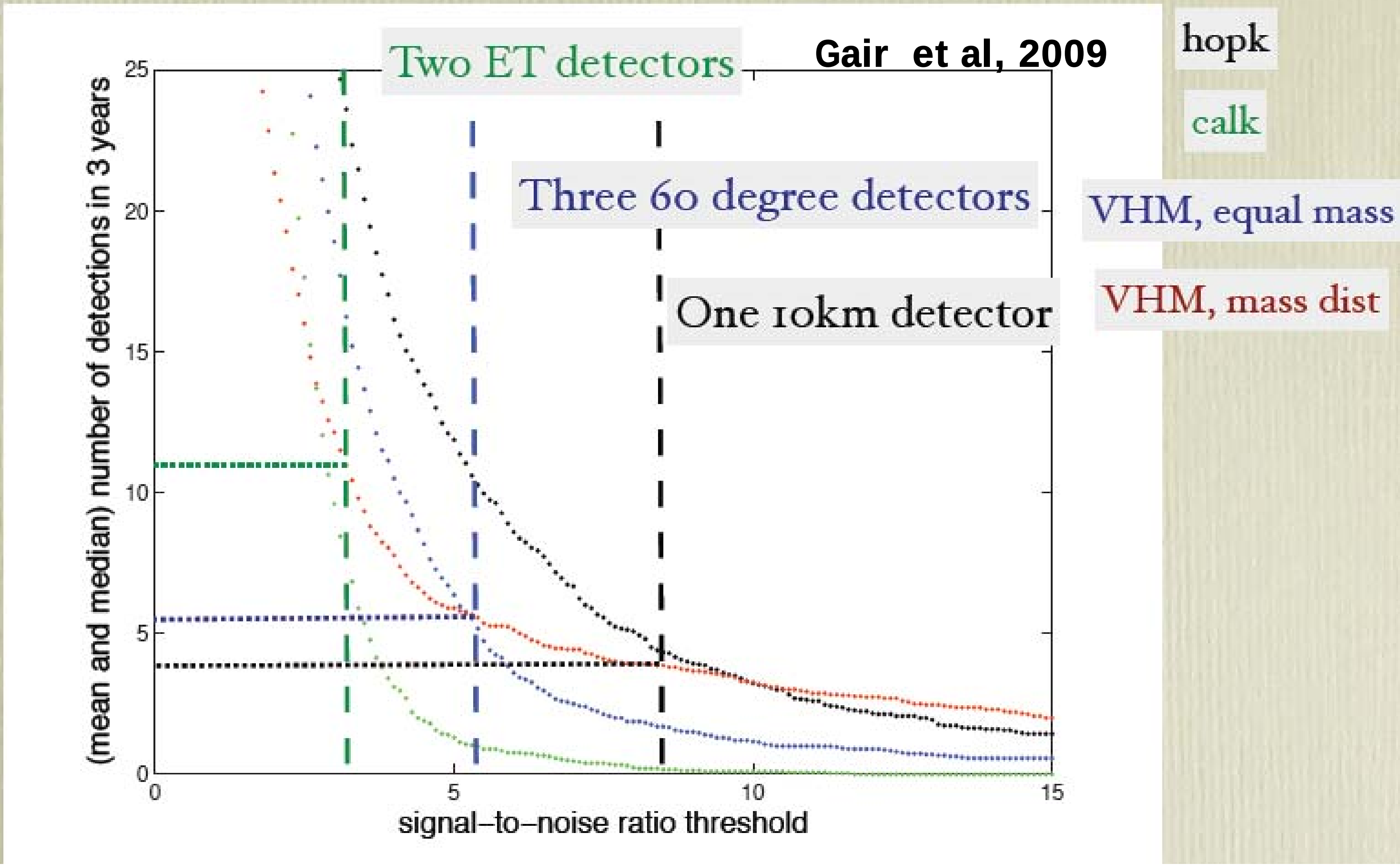



**Diagram from A Sesana**

# ET event rate



# A sample of what we might learn

Some questions we can hope to address:

- What is the mass distribution of compact objects, and how has this distribution evolved over cosmological timescales?
- In particular, what is the mass range for neutron stars?
- What is the lowest mass a black hole can have?
  (Is there an intermediate state between neutron stars and black holes?)
- What is the mechanism behind gamma ray bursts (GRBs)?
- Can we use compact binary inspiral events as standard sirens and use them to do cosmology?

# Participation in the Study

- As a member of an institution that led the FP7 proposal or via the ET Science Team.
- The ET web pages at: http://www.et-gw.eu/
- To register for WG*n* mailing list go to
  - https://mail.virgo.infn.it/mailman/listinfo/wg*n*-et.
  - WG*n* e-mail address is: WG*n*-et AT ego-gw.it
  - WG4 working area is at: https://workarea.et-gw.eu/et/WG*n*-Astrophysics
- To register for the ET Science Team go
  - https://mail.virgo.infn.it/mailman/listinfo/science-team-et
  - Science Team e-mail is: science-team-et AT ego-gw.it