# Parameter estimation of binary black holes

P. Ajith / AEI Hannover
(“work in progress” in collaboration with Sukanta Bose and others)

# Motivation and outline

- **Background** Great progress in NR. The inspiral-merger-ring down stages can be coherently searched over using a single template family. Improved sensitivity and parameter estimation (?).

- **Aim** To characterise the errors in the parameter estimation of non-spinning BBHs.

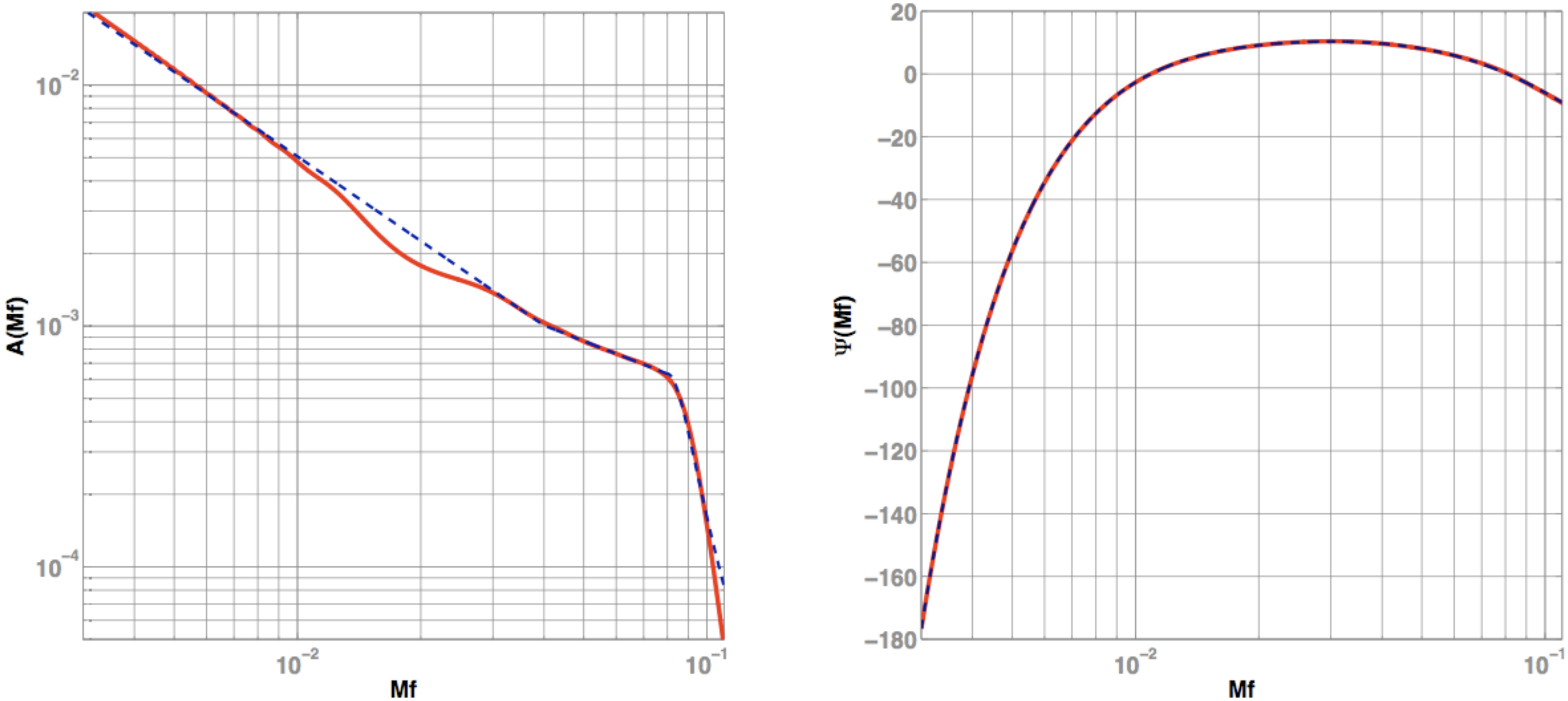
- **Motivation** Accurate estimation of parameters is important for GW astronomy

  - **Question of particular interest: BBH 'standard sirens'** How well can we constrain the values of cosmological parameters (e.g., EOS of dark energy) using Adv. LIGO-Virgo network?

  - **Interesting (plausible) scenario** Merger of two stellar clusters each hosting an IMBH. (Amaro-Seoane & Freitag, 2006)

- **Plan** Estimate the errors using Fisher matrix formalism. Corroborate with Mote-Carlo simulations.

# Binary black-hole (phenomenological) waveforms




Phenomenological waveforms having high overlaps with the 'hybrid waveforms'

$$u(f) \equiv A_{\text{eff}}(f)\, e^{\mathrm{i}\Psi_{\text{eff}}(f)},$$

$$A_{\text{eff}}(f) \equiv C \begin{cases} (f/f_{\text{merg}})^{-7/6} & \text{if } f < f_{\text{merg}} \\ (f/f_{\text{merg}})^{-2/3} & \text{if } f_{\text{merg}} \le f < f_{\text{ring}} \\ w\,\mathcal{L}(f, f_{\text{ring}}, \sigma) & \text{if } f_{\text{ring}} \le f < f_{\text{cut}}, \end{cases}$$

$$\Psi_{\text{eff}}(f) \equiv 2\pi f t_0 + \varphi_0 + \frac{1}{\eta} \sum_{k=0}^{7} (x_k\,\eta^2 + y_k\,\eta + z_k)\,(\pi M f)^{(k-5)/3}$$

# Fisher matrix & Monte-Carlo simulations

Covariance matrix

**Fisher matrix**

Error in estimating the parameter *a*

$$\Gamma_{ab} = \langle \partial_a u(f), \partial_b u(f) \rangle = (C^{-1})_{ab}$$

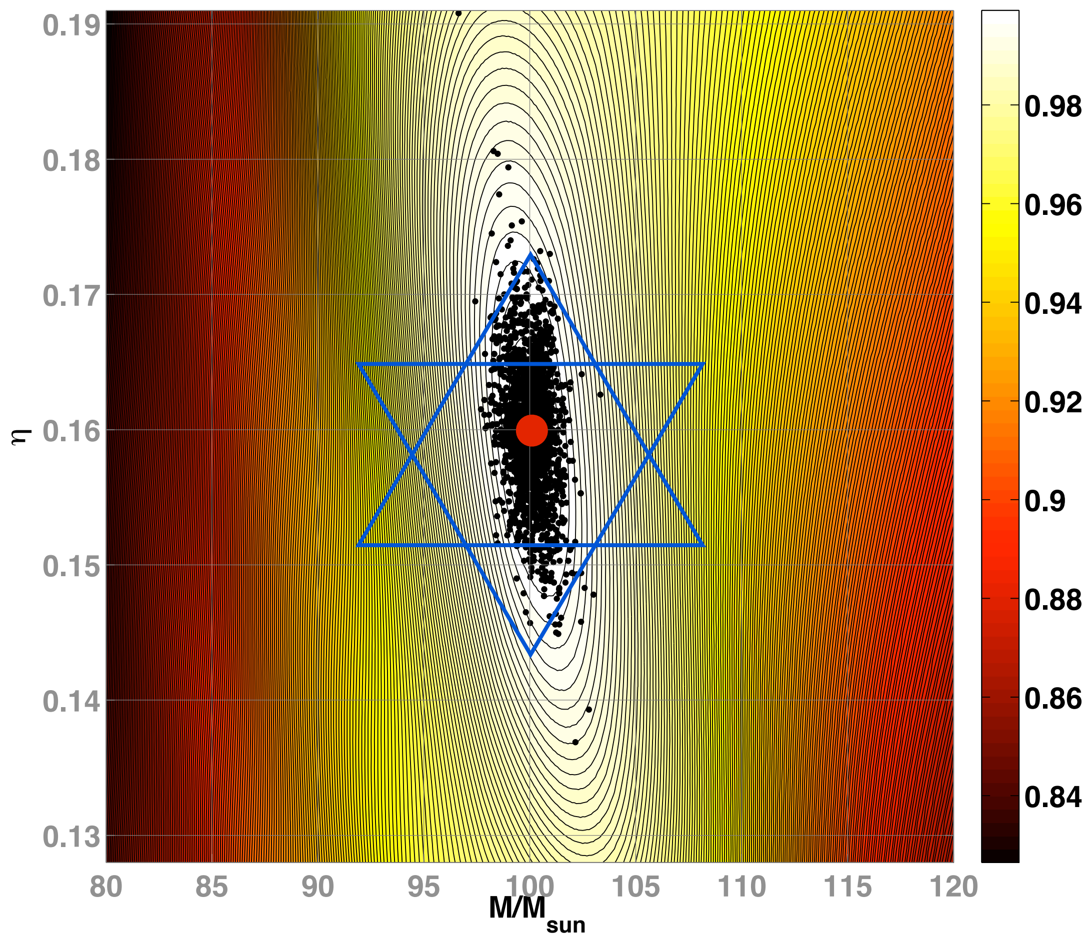
$$\sigma_a = \sqrt{C_{aa}}$$

PROBLEMS Fisher matrix can be ill conditioned. Hard to invert.

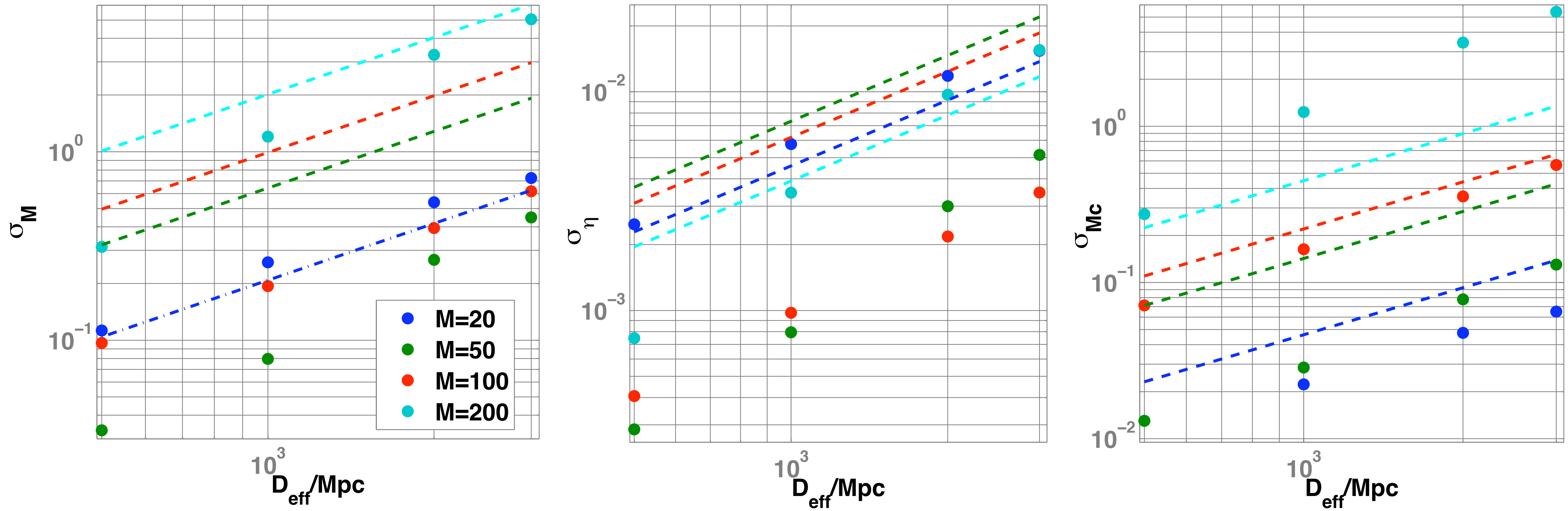
**Monte-Carlo simulations**

Generate signal + coloured noise. Search using the same family of templates. Maximise the SNR over M and eta using the 'amoeba' simplex algorithm.

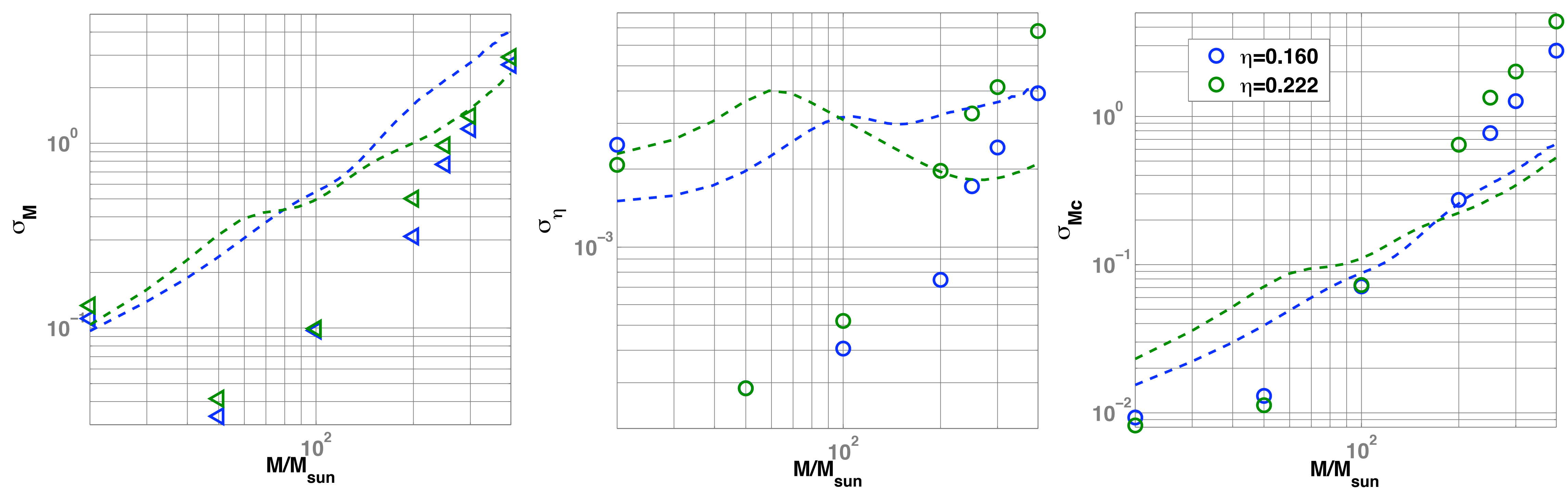
PROBLEMS Results are significantly dependent on the choice of initial simplex. Thus, start the maximisation using many of (~20) different simplexes, and choose the best among them.



# Some preliminary results (oops!)




Errors against the effective distance (top); against the total mass (bottom)



# Future/ongoing work

- The current template waveforms are based on the l=2, m=2 mode of the numerical (hybrid) waveforms.
- Systematic errors due to neglecting the higher modes. E.g., the l=2, m=2 spherical harmonics weighting functions can be zero at certain directions (in the wave frame). All the contributions come from higher modes. The template will try to fit the signal, giving completely wrong set of parameters.
- How good is the source localisation using a network of detectors? Can we associate an EM counterpart with a binary merger? Plausible scenario: merger of stellar clusters. Can we do Cosmology using Advanced LIGO-VIrgo network?