L △

Andreas Freise

GWADW, Elba 2016
LIGO-G1601205

Which one is better?

L

△

Cheapest way to get to a given sensitivity

Near-optimal for one site

The question should be **‘Which one is better for me?’** when writing a specific detector proposal.

UNIVERSITY OF BIRMINGHAM

Motivations Leading to △

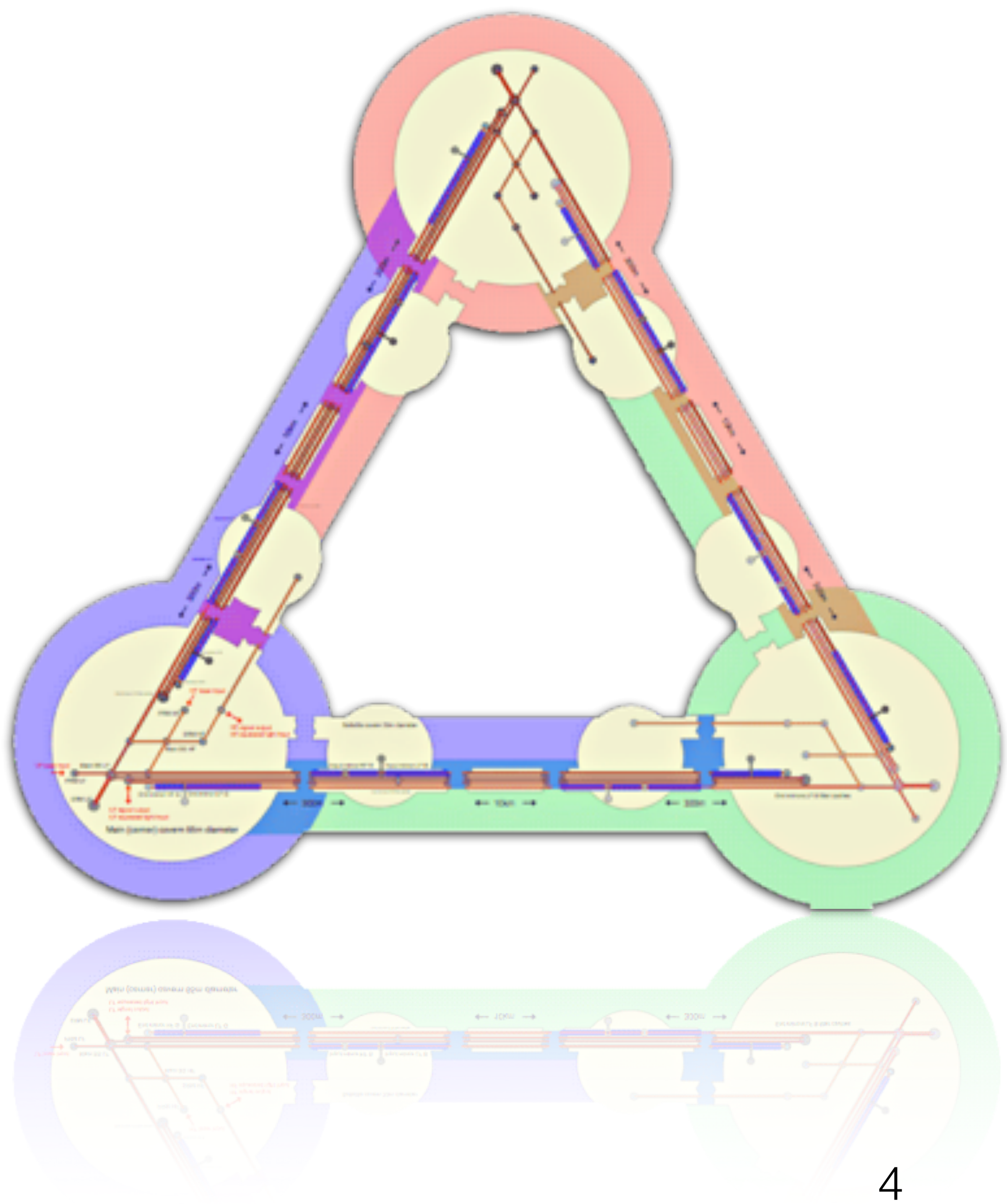
- Facility for long-term future (50 years)
- Allow for iterative installation and upgrade of instruments
- Provide 24/7 coverage of the GW-sky for a wide range of known or possible sources
- Targeting an underground site

`Triple Michelson interferometer for a third-generation gravitational wave detector'
CQG, 2009, 26, 085012 (14pp)

Example Triangle Layout

Detailed, interactive drawing:

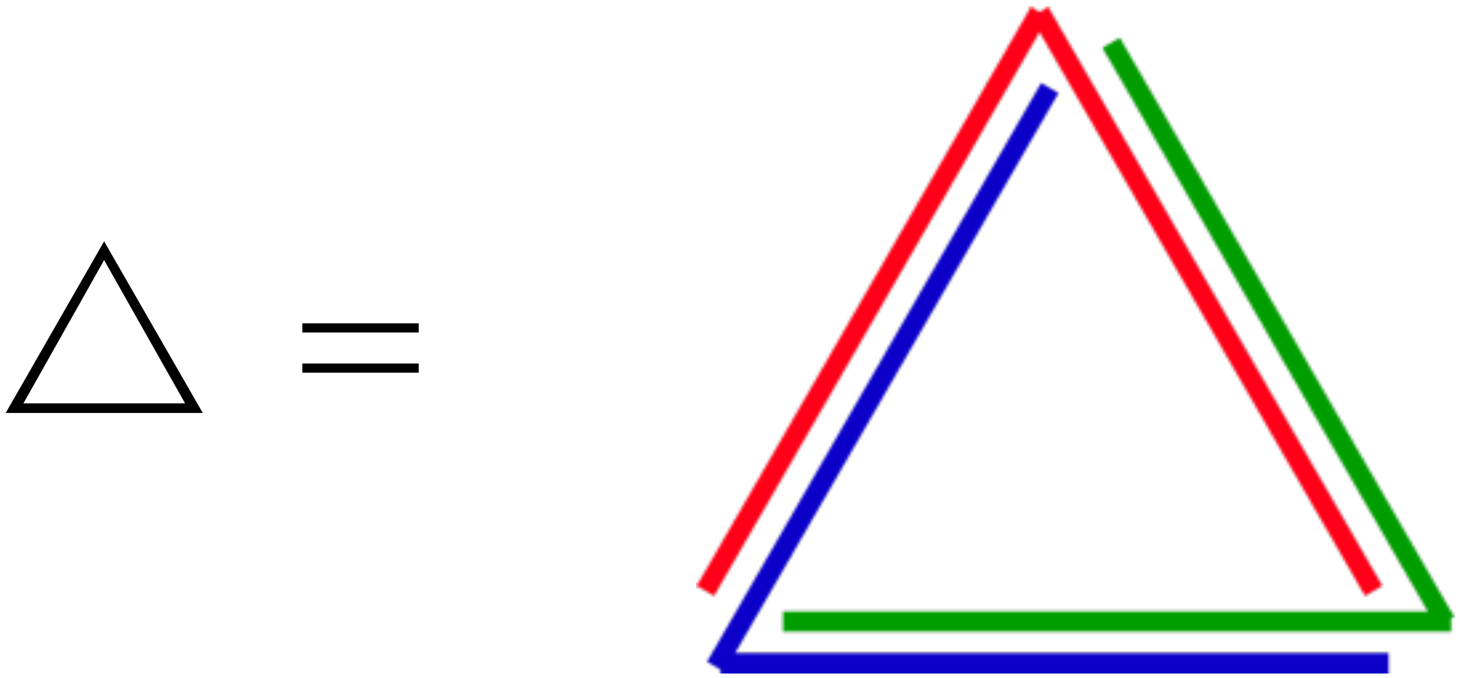
http://www.gwoptics.org/research/et/layout/



Other examples:

- LISA
- Original GEO

3 Detectors



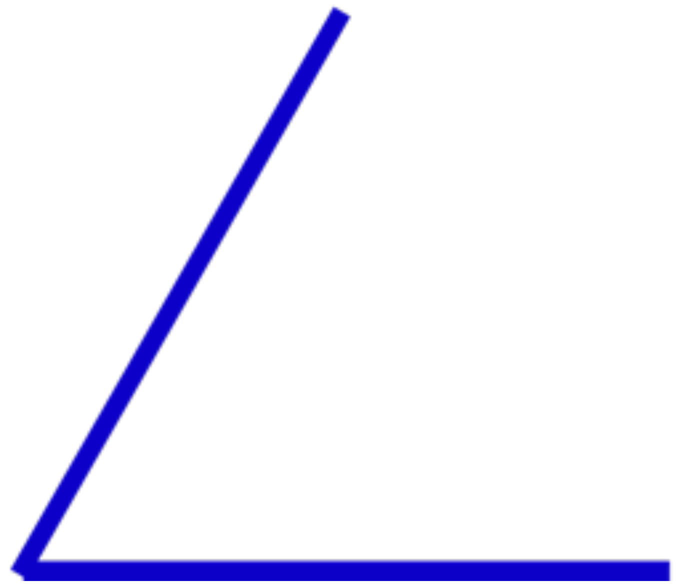
Might be confusing: current ET design has two interferometers per detectors (xylophone). But those could be replaced by **one** Michelson/speedmeter/... each. This is **not relevant** for the discussion of the triangle as a detector shape.

UNIVERSITY OF BIRMINGHAM

Simple Equations

$$h(t) = F_+(t)h_+(t) + F_\times(t)h_\times(t)$$

[P Jaranowski et al, Phys Rev D 58 1998]



Opening angle:

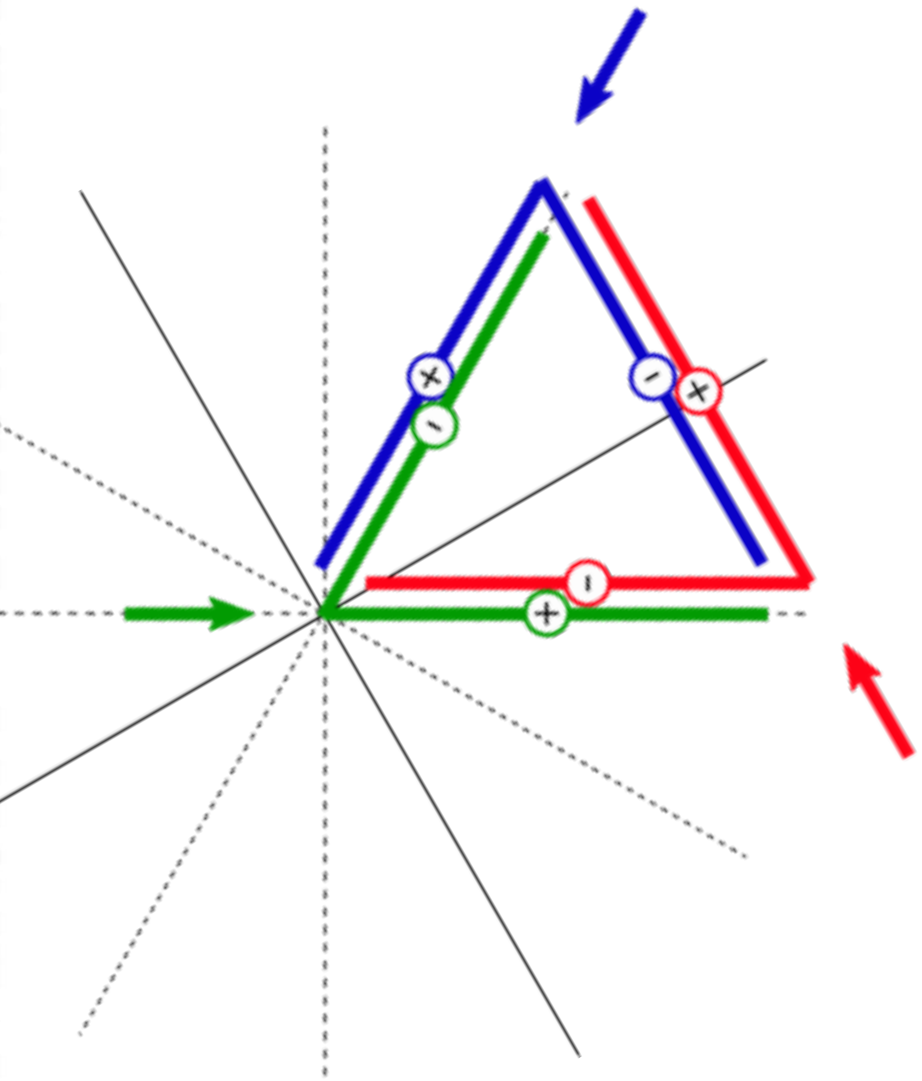
$$h(t) = \sin(\zeta) \times (\dots)$$

$$\sin(60^\circ) \;=\; \sqrt{3/4} = 0.87$$

UNIVERSITY OF BIRMINGHAM

Simple Equations

$$h(\gamma) = \sin\zeta\,[(C_1 \sin 2\gamma + C_2 \cos 2\gamma)\,h_+ + (C_3 \sin 2\gamma + C_4 \cos 2\gamma)\,h_\times]$$



Oriented at different angles the instrument measure combinations of the different polarisations. Combine signals for reconstructing signals from other orientations:

$$-h_{0^\circ} = h_{240^\circ} + h_{120^\circ}$$

$$h_{45^\circ} = \frac{1}{\sqrt{3}}\,(h_{240^\circ} - h_{120^\circ})$$

UNIVERSITY OF BIRMINGHAM

Simple Equations

Sensitivity:

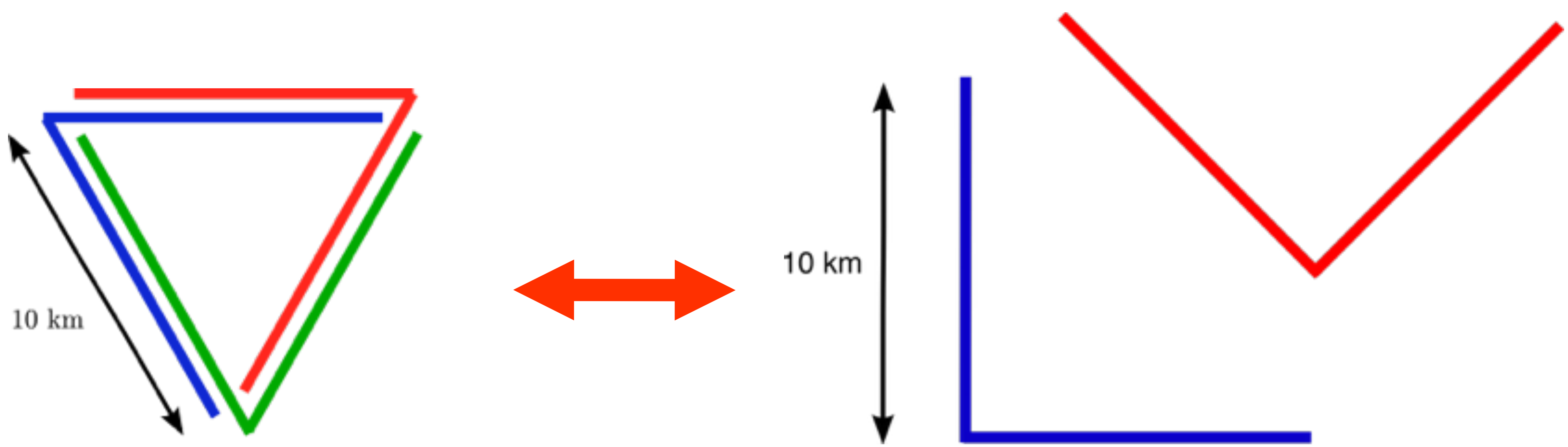
+

$$h_\Delta(0^\circ) = h(0^\circ) - h(120^\circ) - h(240^\circ) = 2h(0^\circ)$$

$$\mathrm{SNR}_{\Delta,10\,\mathrm{km}} = \frac{2}{\sqrt{3}}\sqrt{\frac{3}{4}}\mathrm{SNR}_{L,10\,\mathrm{km}} = \mathrm{SNR}_{L,10\,\mathrm{km}}$$

X

$$\mathrm{SNR}_{\Delta,10\,\mathrm{km}} = \sqrt{\frac{3}{2}}\sqrt{\frac{3}{4}}\mathrm{SNR}_{L,10\,\mathrm{km}} \approx 1.06\ \mathrm{SNR}_{L,10\,\mathrm{km}}$$

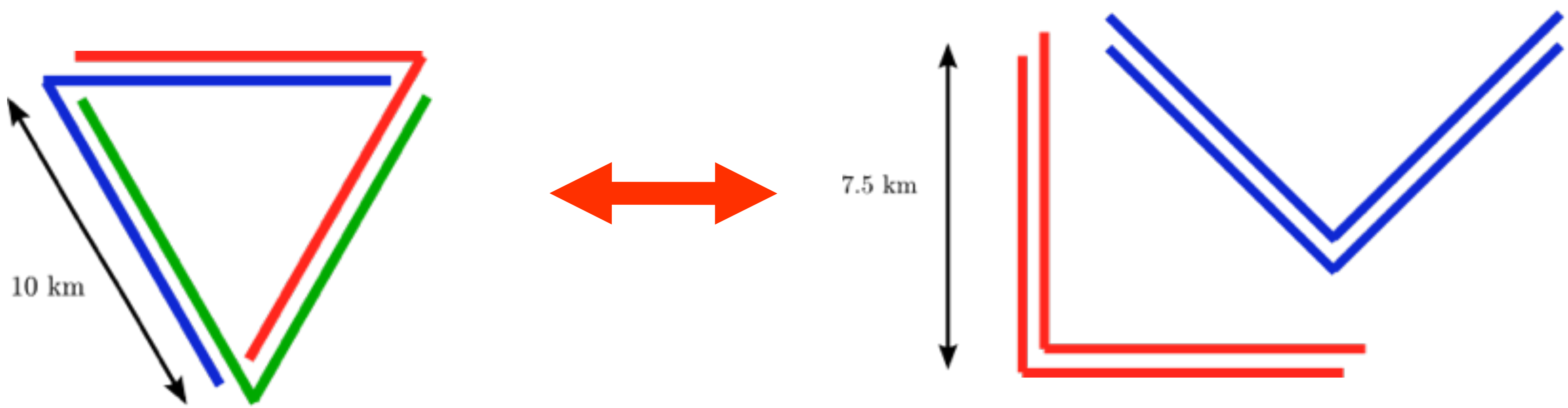


UNIVERSITY OF BIRMINGHAM

Simple Equations

Co-aligned, and both polarisation:

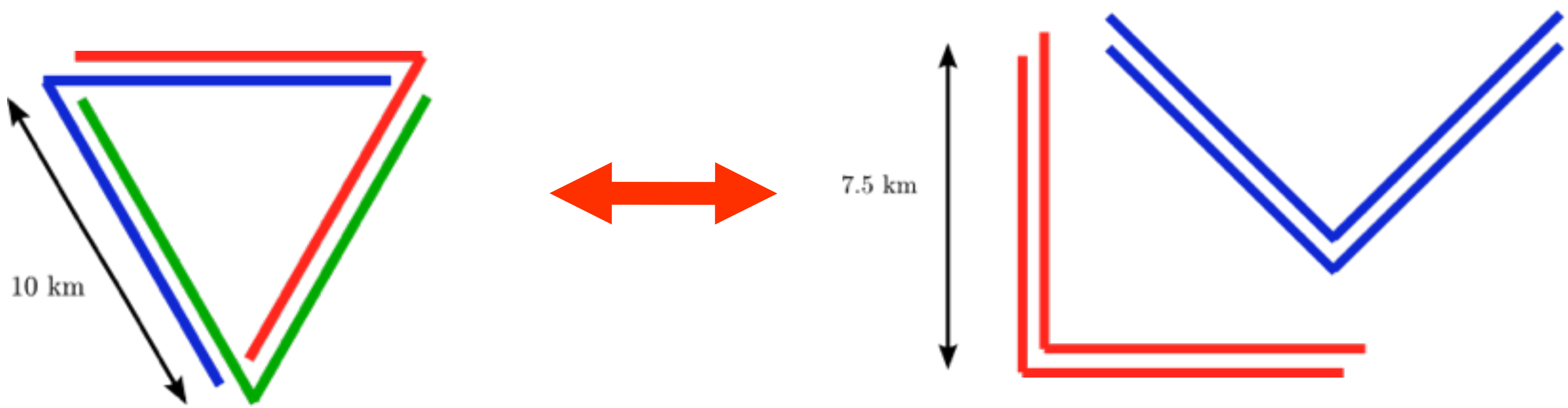
$$\mathrm{SNR}_{2L,7.5\,\mathrm{km}} = \frac{2}{\sqrt{2}}\frac{7.5}{10}\mathrm{SNR}_{L,10\,\mathrm{km}} \approx 1.06\ \mathrm{SNR}_{L,10\,\mathrm{km}}$$



Andreas Freise, GWADW 26.05.2016

Simple Equations

- Same sensitivity, same features
- 30 km `tunnel' length, 60 km beam tube length
- Triangle expected to be cheaper because of lower number of vertices



Co-located, Co-aligned

UNIVERSITY OF BIRMINGHAM

- Un-modelled incoherent signals (bursts, stochastic):
  - null-stream, can check for coherence, separating between signal and noise
  - high frequency (> ~30 Hz) require co-located detectors

Both Polarisations

UNIVERSITY OF BIRMINGHAM

- CBC: Break degeneracy between distance and inclination angle, better distance and sky location and any derived results
(can be done by a distributed network)

- Burst: different information in h_x and h_+
(at high frequency, local detectors have advantages)

Redundancy

- Build two interferometers instead of one
- Sequential installation of instruments
- Iterative upgrades of instruments while taking data
- Connecting commissioning and maintenance (maybe even R+D) at a **center** for gravitational wave research
- Retention and development of knowledge and experts on site long term

Detector Networks

- Network of three L-shaped detectors:
  - locate them at large distances
  - mis-align them for detection of both polarisations
- 3G detector in a heterogenous network:
  - Longer L or shorter △?
  - Science case still evolving

Lanky et al: `Detecting gravitational-wave memory with LIGO: implications of GW150914', https://arxiv.org/abs/1605.01415

Costs

- Cost will be the key factor for what type of network and what type of detector we build
- However early cost estimates have large error bars (steel prize, tunnel digging)
- More detailed design studies are needed to trade-off detector concepts

Summary

- △ is a near-optimal single-site detector
- It includes co-aligned detectors for both polarisations
- It is **one possible option** for a 3G detector design in a future network
- Expect changing opinions with more details on science case and cost emerge soon

UNIVERSITY OF BIRMINGHAM