Sky-position reconstruction abilities for different ET geometries and layouts

Alexander Dietz
Benoit Mours

Outline

- Overview
- Technical details
- Preliminary results
  - SNR based simulations/calculations
  - Timedelay based simulations/calculations
- Outlook

Overview

- Investigate the ability of two different ET geometries to reconstruct the sky position
- Methods used:
  - **Timedelay** of the signal between the sites
  - Different responses (i.e. different **SNR**)

Networks

- Four ET geometries, each with the *ET-B* noise:
  - "Triangle": Single triangular instrument at Cascina only. L=10km
  - "GV": Two L-shaped instruments at Hanover and Cascina, the Hanover instrument ~45^{o} rotated. L=7.5 km
  - "DV": Two L-shaped instruments at Cascina site and DUSEL mine, L=7.5 km
  - "EU-US": Two triangular instrument, same location as "DV". Length=10 km

Technical I

- Using self-made code: pyET.py
  - Can choose noise curve (LIGO-I, advanced, ETB,ETC)
  - Can define any detector with any arm directions
  - Can create a 'network' of detectors
  - Calculates the SNR of a signal (VIR-027A-09):

$$\rho = 1.56 \times 10^{-19} \left(\frac{\mathcal{M}}{M_\odot}\right)^{5/6} \left(\frac{Mpc}{r}\right) f_{geo} \sqrt{\int_{f_{low}}^{f_{ISCO}} \frac{f^{-7/3}}{S_h(f)} df}$$

  - And the time delay for a given source

Technical II

- Signal parameters:
  - Masses: 1.4/10/100 Solar masses
  - distances: 10/100/200 Mpc
- SNR value depends only on
  - low cutoff frequency (LIGO-I: 40, adv: 10, ET: 3 [Hz])
  - sky position
  - source orientation (*for now: optimal orientation*)

Determine the sky area

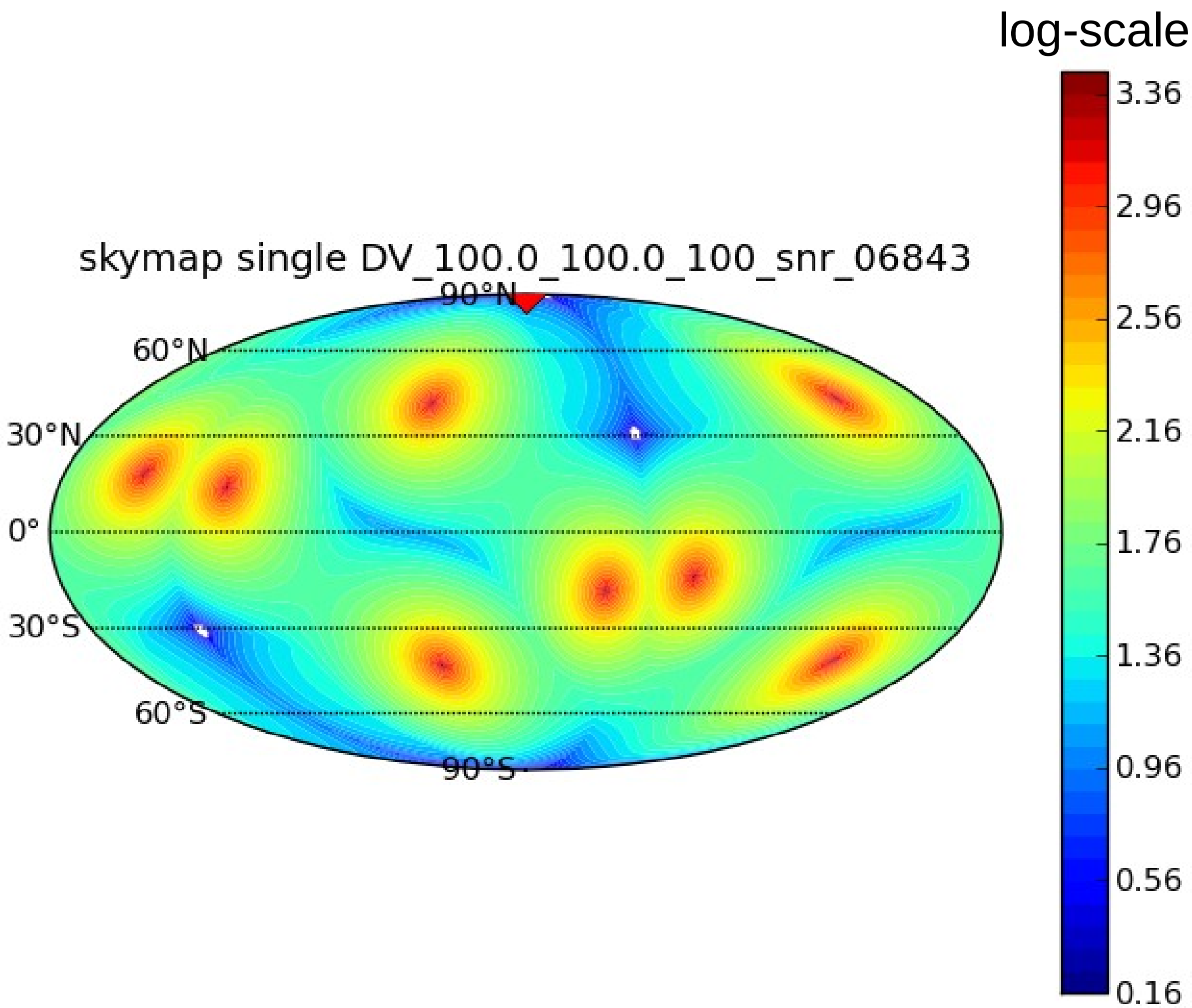
- Using dump scanning technique:
  - Place sources over entire sky with $\Delta\alpha=5^o$ (or randomly). Compute the SNRs and end-times.
  - Scan whole sky with $\Delta\alpha=2^o$ and see if that point yield the correct SNRs and end-times, within error.
  - In that case (or if below some limit): Make a more precise sub-scan with smaller steps
  - Sum the sky area of each point satisfying the condition

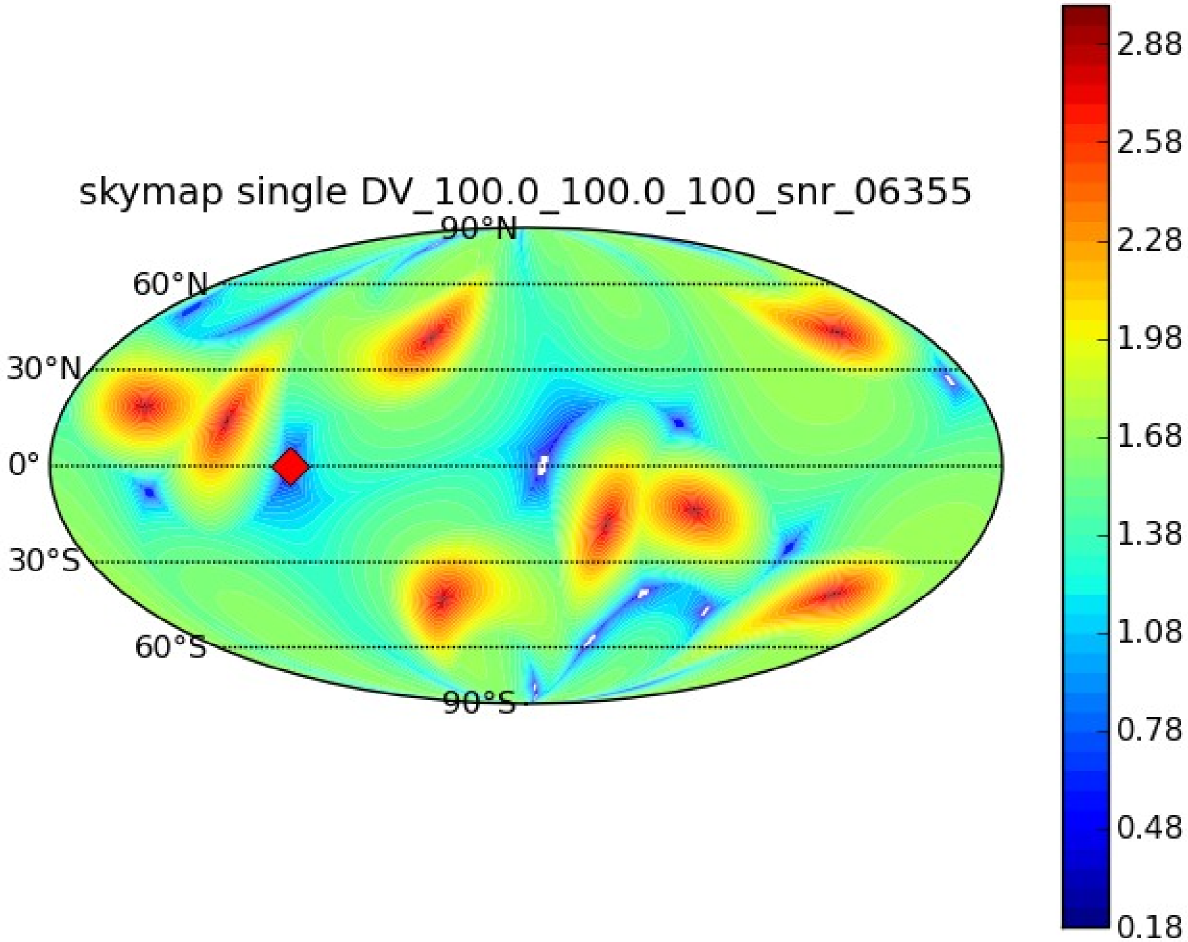
Next three skymap examples

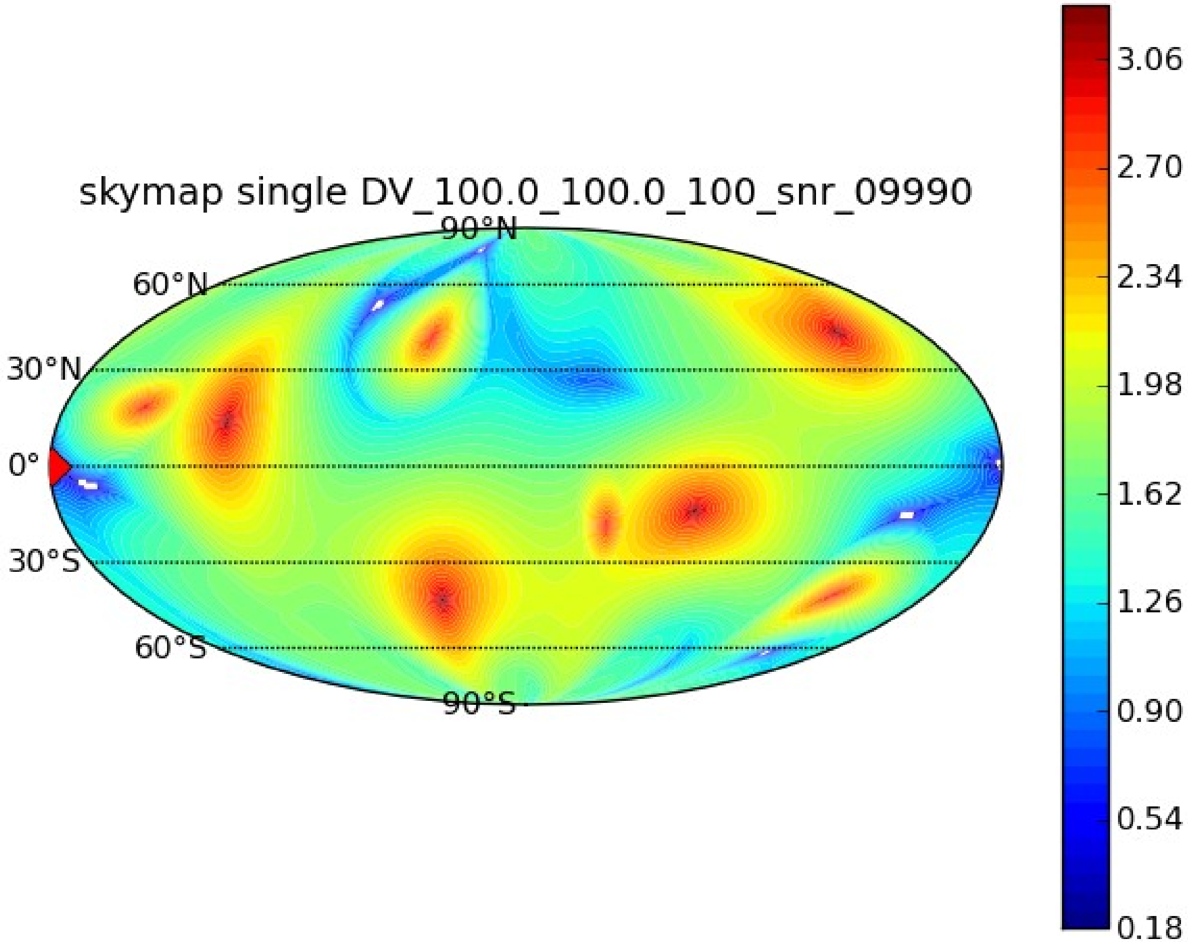
- Simulation by **SNR**
  - **Error** on SNR: 1+1%*SNR

Intrinsic error
Calibration error

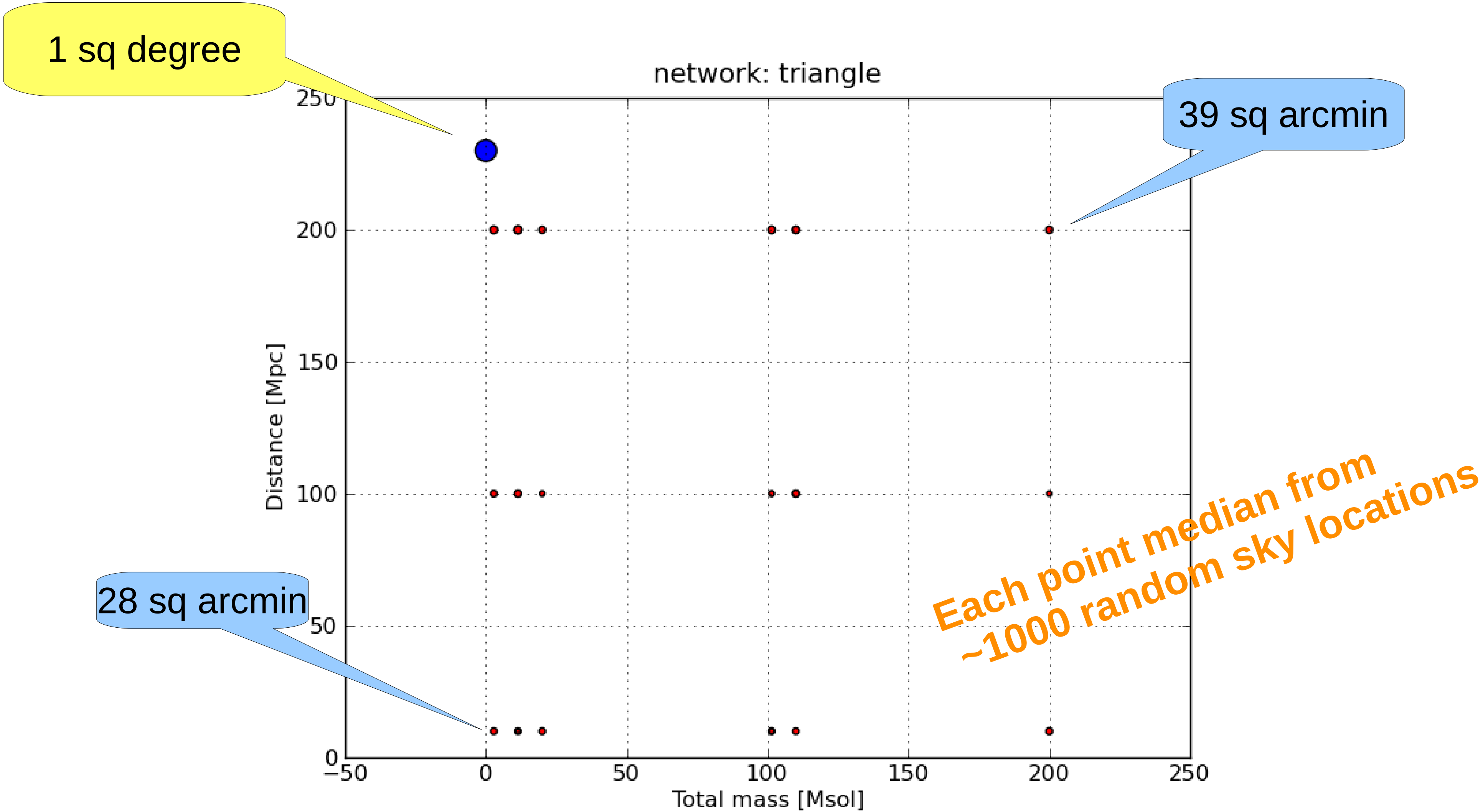
- m1 = m2 = 100 Solarmasses
- Distance: 100 Mpc
- Zero inclination
- Network: **DV** (Two L's at Virgo and Dusel)
- Source position at three positions (ra/dec):
  - 0.0/0.0 pi/2,0.0 0.0/pi/2


log-scale
skymap single DV_100.0_100.0_100_snr_06843
90°N
60°N
30°N
0°
30°S
60°S
90°S
3.36
2.96
2.56
2.16
1.76
1.36
0.96
0.56
0.16

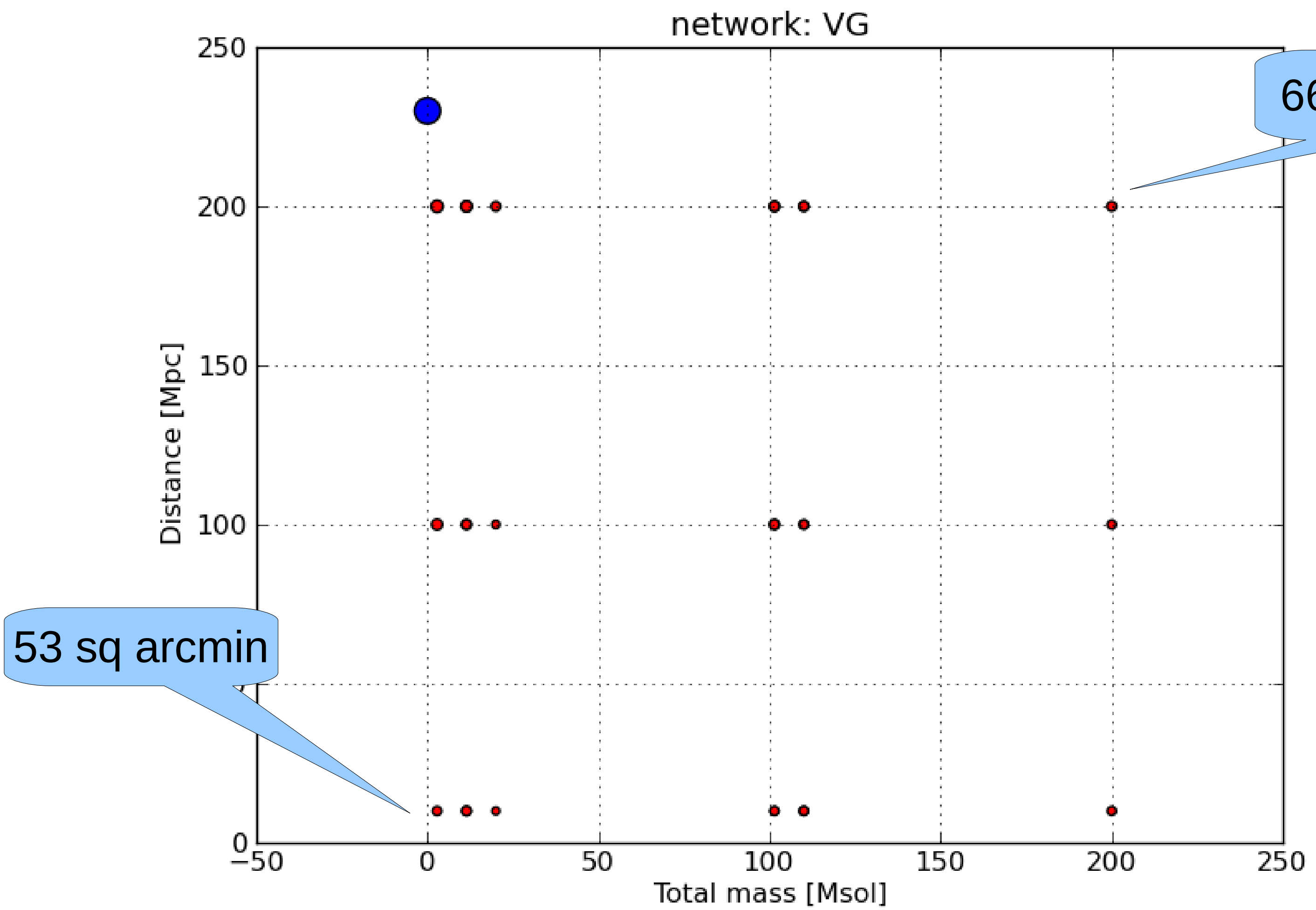

skymap single DV_100.0_100.0_100_snr_06355
90°N
60°N
30°N
0°
30°S
60°S
90°S
2.88
2.58
2.28
1.98
1.68
1.38
1.08
0.78
0.48
0.18


skymap single DV_100.0_100.0_100_snr_09990
90°N
60°N
30°N
0°
30°S
60°S
90°S
3.06
2.70
2.34
1.98
1.62
1.26
0.90
0.54
0.18

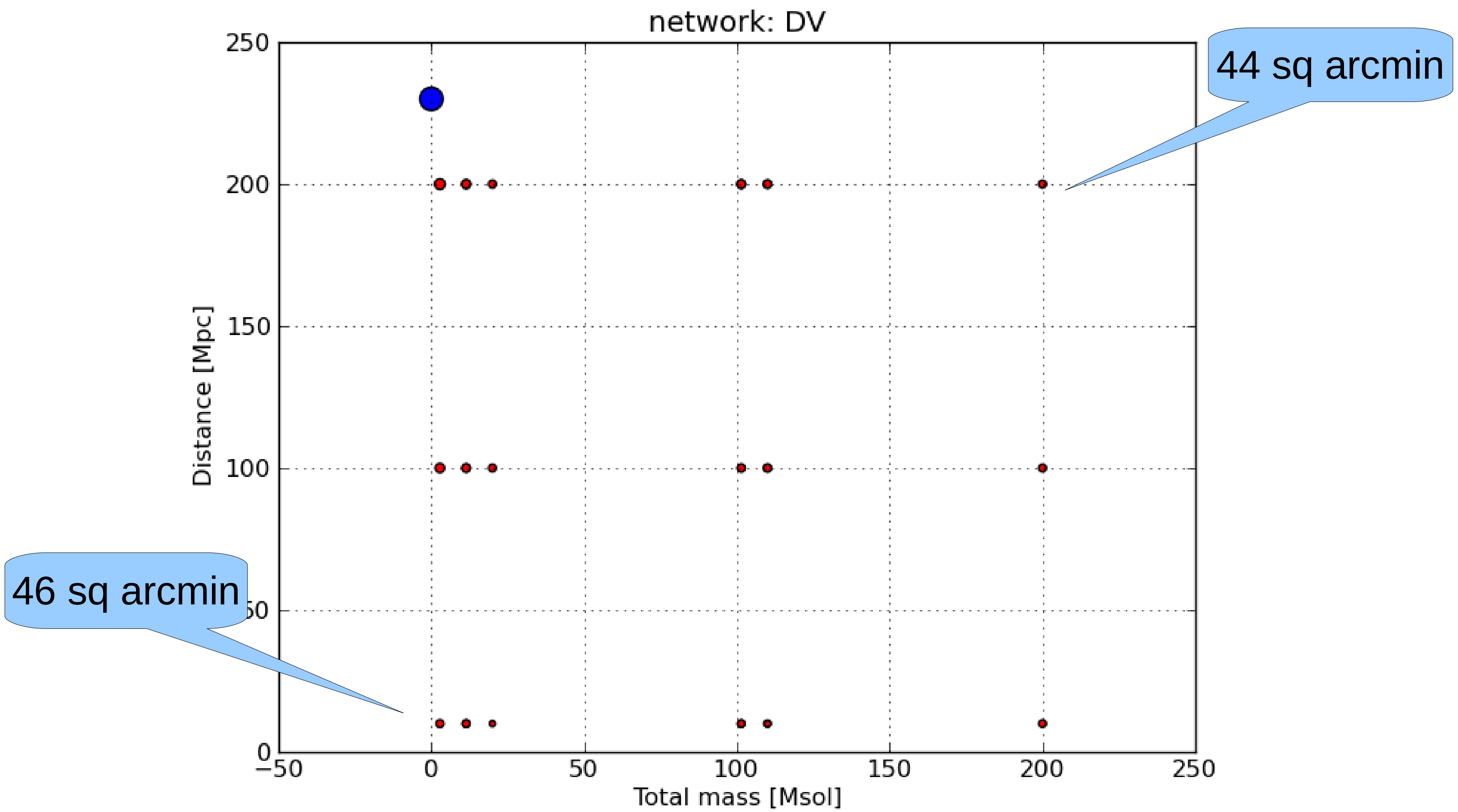
SNR based localization: Triangle



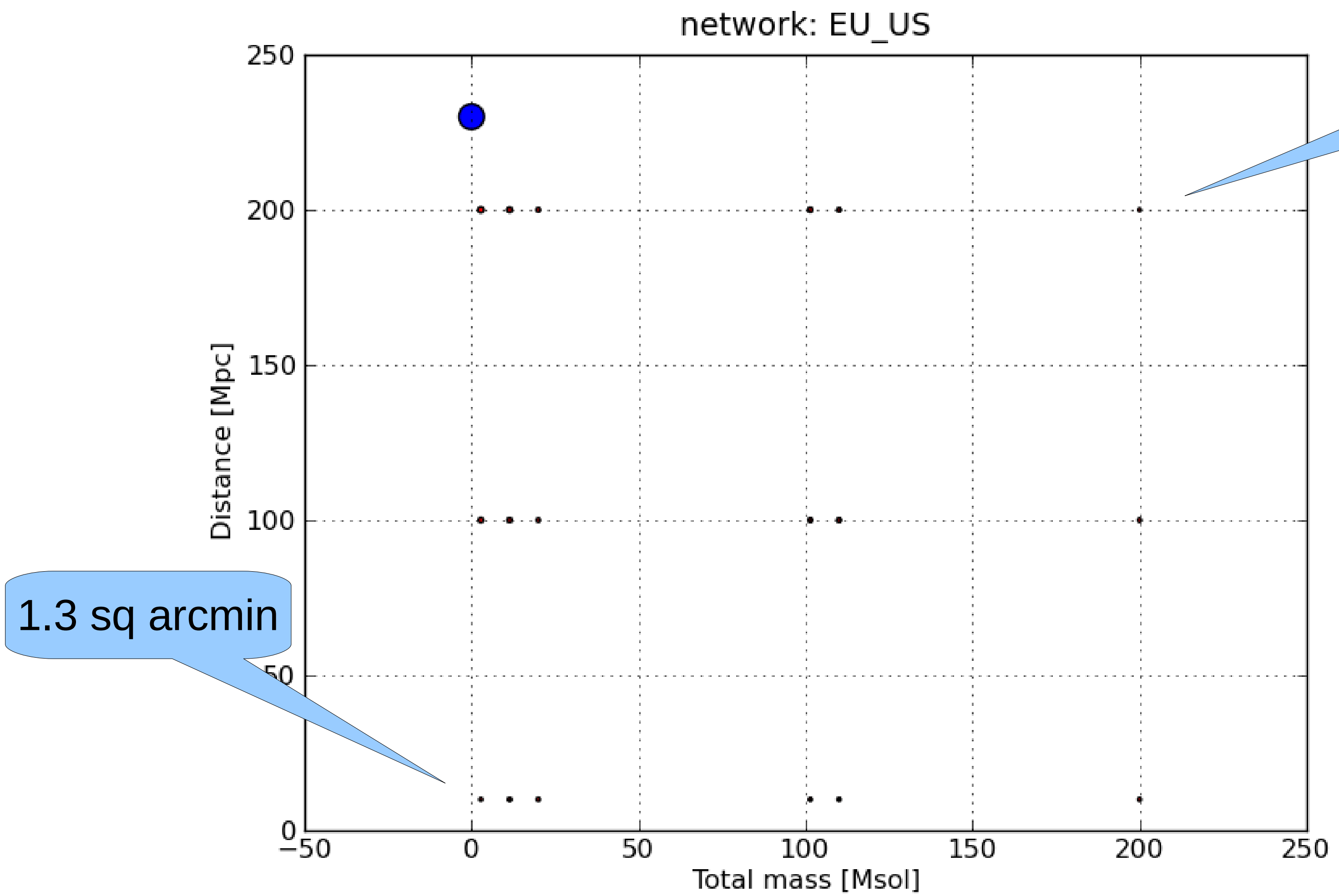
SNR based localization: VG



SNR based localization: DV



SNR based localization: EU_US

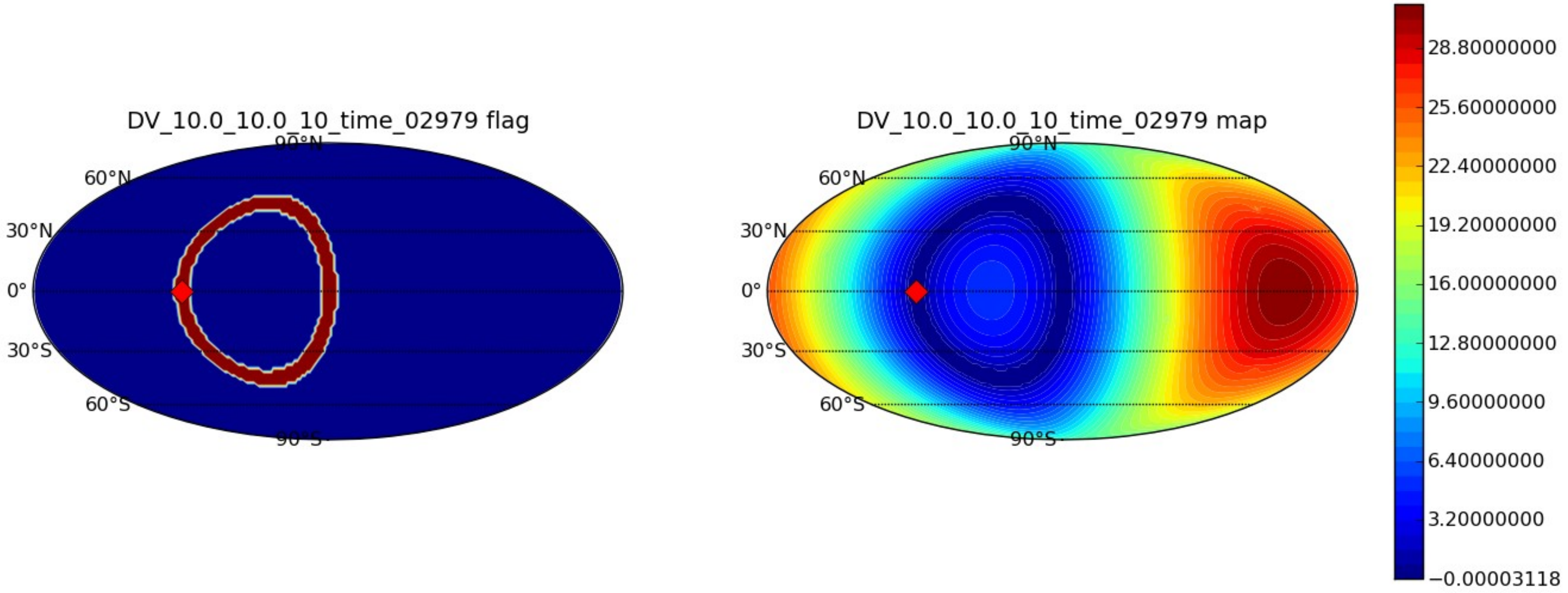


Time delay calculation

- Calculate the time-delay for the anticipated source location
- Calculate the timing error, depending on
  - frequency moments (Fairhurst, 0908.2356), depending on
    - the SNR and its error
- Check if the time-delay is within error range

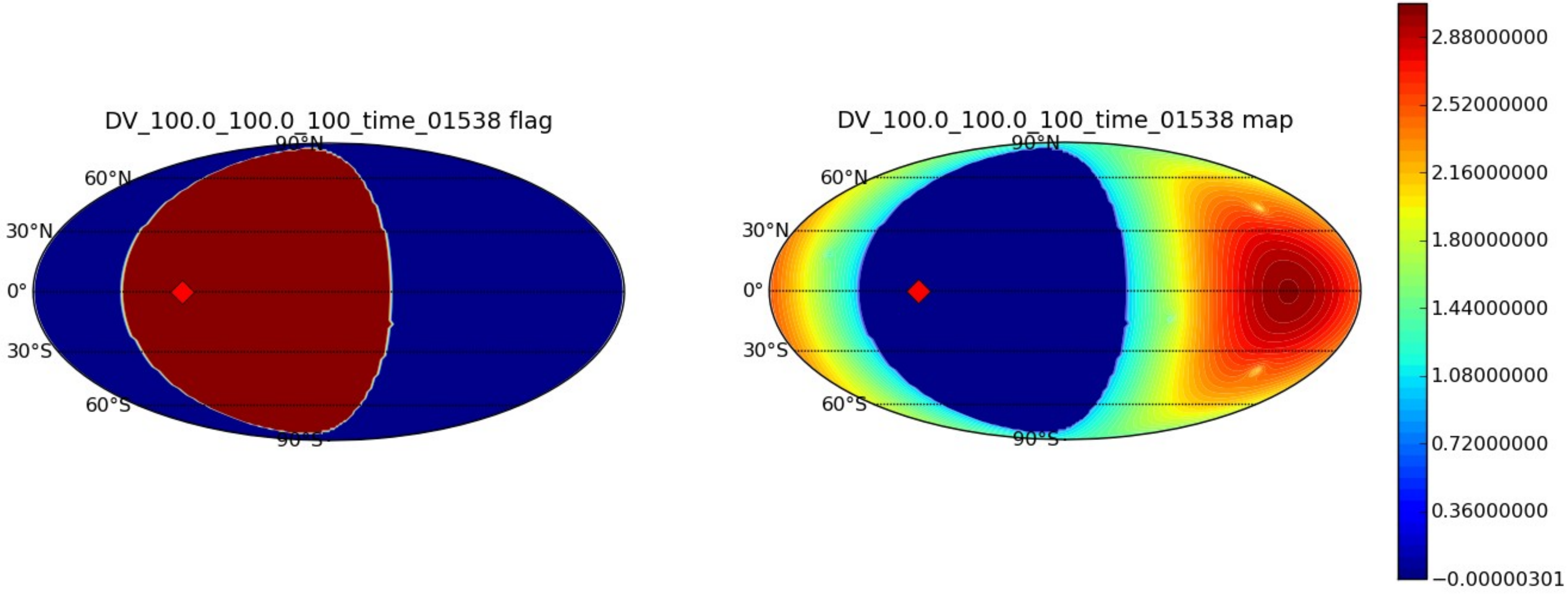
Example: time difference

- 10/10 Solarmasses at 10 Mpc



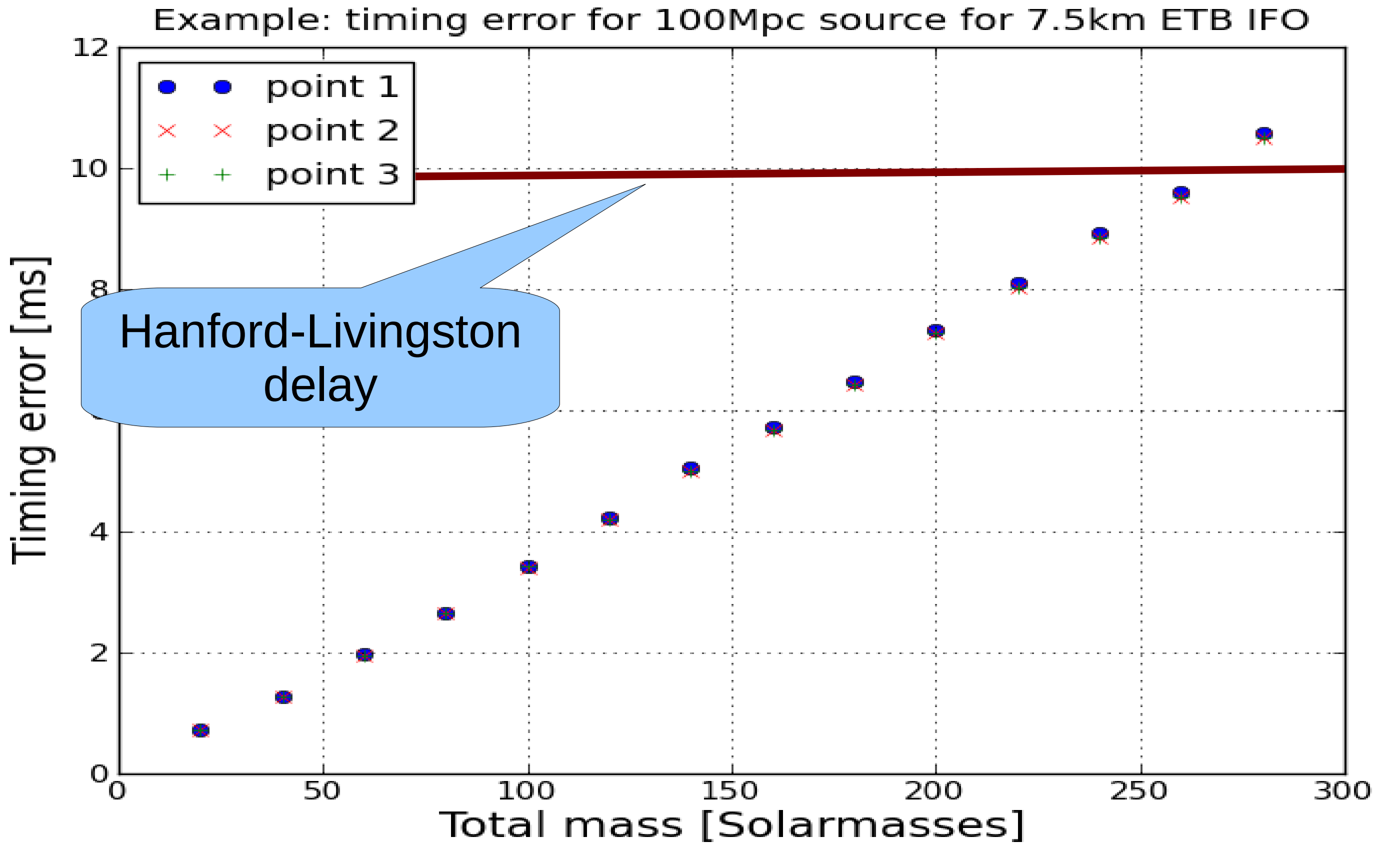
Example: time difference

- 100/100 Solarmasses at 100 Mpc



Timing error for single IFO

- Each point on a different location
- Nice linear scaling, independent of location



Outlook

- *Verify the code and algorithms*
- Implement **more sophisticated methods**
  - Each IFO describes annuli on sky
  - Compute these annuli, rotate them to proper IFO location
  - Intersect annuli, calculate area more precise
- Look at **computations** instead of simulations
- Use SNR **and** Timedelay information
- Compare with **ET-C noise curve** (i.e. Xylophone)
- Investigate for arbitrary **inclination/polarization**
- Rotation of earth? (20 minutes for 10/10 source for f=3 Hz)